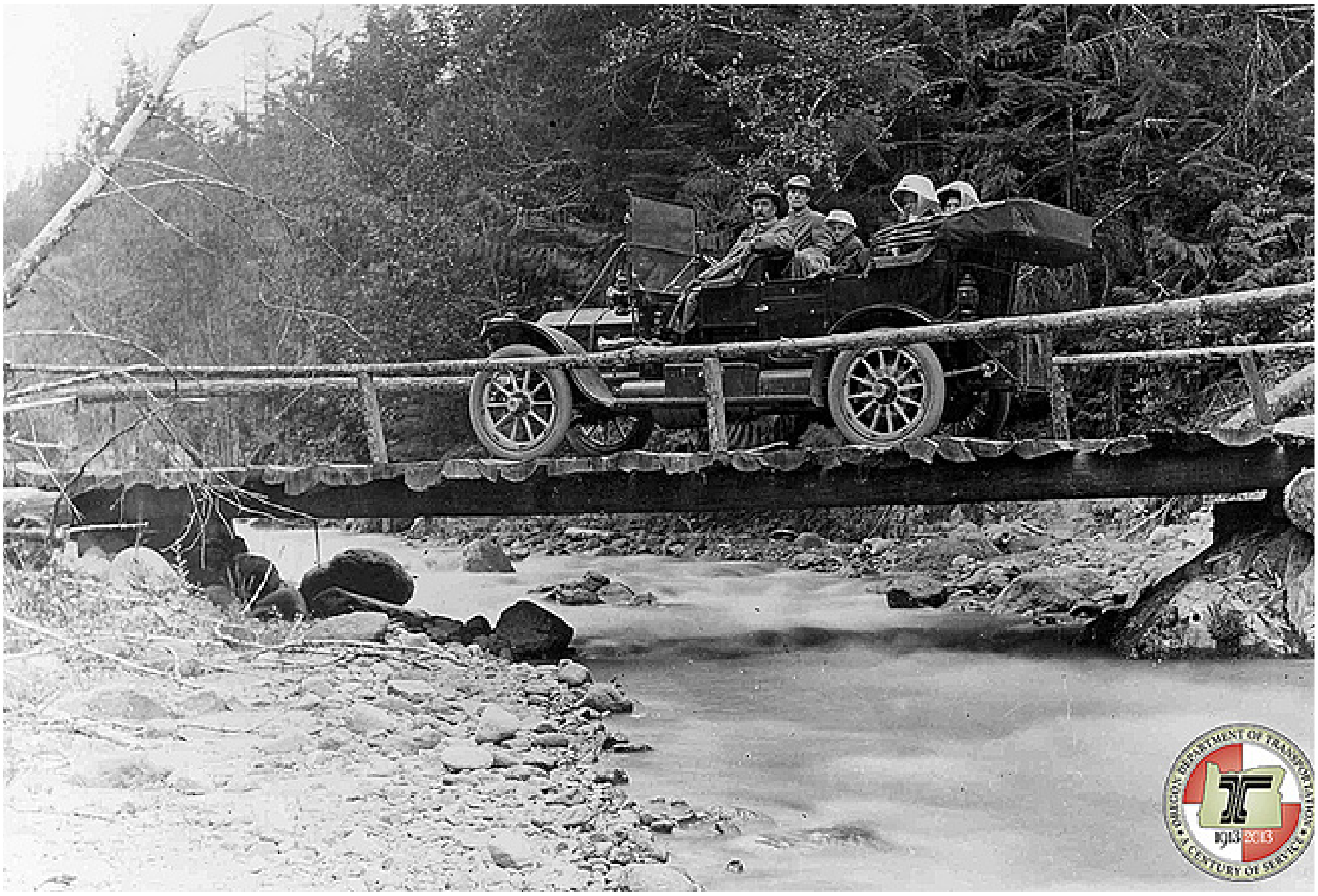
ODOT LRFR Manual



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Oregon Department of Transportation

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SECTION 1: GENERAL OVERVIEW

1.1 Purpose of Load Rating and the Manual

The primary function of the Oregon Department of Transportation is to provide safe and uninterrupted traffic flow over the highways and bridges in Oregon. Protecting the significant investment in the bridge portion of the state's infrastructure is second only to the safety of traffic and the bridges themselves. Knowledge of the capacity of each bridge to carry loads is critical for each function. A Load Rating that reflects the current condition of each bridge provides a valuable tool that is used in identifying the need for load posting or bridge strengthening and in making overweight-vehicle permit decisions. Load Ratings are also used in the bridge management system to prioritize bridge repairs and replacements.

The procedures stated in this document, *ODOT LRFR Load Rating Manual*, are to provide a methodology that will result in consistent and reproducible Load Rating inputs and deliverables. Also hereinafter referred to as *this Manual or ODOT LRFR Manual*, this document was developed using the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Bridge Evaluation 2nd Edition*, hereinafter referred to as the *"MBE Manual*" or simply "MBE" for article references. The *MBE Manual* frequently refers to the AASHTO *LRFD Bridge Design Specifications*, hereinafter referred to as "*AASHTO LRFD Specifications*" or simply "AASHTO LRFD". The *MBE Manual* is consistent with the *AASHTO LRFD Specifications* in using a reliability-based limit states philosophy, but it extends the provisions of LRFD to the areas of Load Rating, posting, and overweight permit checking.

In the 2013 Interim Revisions of the MBE, the National Live Load Factors have been re-calibrated and are now very similar to the Oregon Specific Live Load Factors that are used for ODOT owned bridges. As a result, all bridges in Oregon (regardless of the owner) will be rated following the ODOT LRFR Load Rating Procedures. ODOT bridges will use the Oregon Specific Live Load Factors and all other bridges will use the re-calibrated National Live Load Factors. If a specific structure type is not currently covered in the ODOT LRFR Manual, contact ODOT's Senior Load Rating Engineer (Jon Rooper) at (503)-986-3357 or at Jonathan.W.ROOPER@odot.state.or.us.

1.2 Organization of the Manual

This Manual is designed to provide the load rater with a well-organized source of information that is necessary to accomplish a Load Rating. This version was specifically created for a particular combination of bridge types and materials. This should allow the rater to easily find the information needed, without having to sift through information that is not applicable to the rating in progress.

This manual is divided into these main areas:

Section 1: General Overview
The "General Overview" covers basic information on the Load Rating process, the standards and manuals that are used in Load Rating, and the limit states for each Load Rating method. The assembly of supporting documents, location of critical members, loads considered, and analysis programs available, are all found in this portion.

Section 2: Load Rating Reinforced Concrete Deck Girder Bridges
All information specific to Reinforced Concrete Deck Girder bridges will be included in Section 2.

Section 3: Load Rating Reinforced Concrete Box Girder Bridges
All information specific to Reinforced Concrete Box Girder bridges will be included in Section 3.

Section 4: Load Rating Reinforced Concrete Slab Bridges
All information specific to Reinforced Concrete Slab Bridges will be included in Section 4.

Section 5: Load Rating Prestress Concrete Girder Bridges
All information specific to Prestress Concrete Girder Bridges will be included in Section 5.

Section 6: Load Rating Post-Tensioned Box Girder Bridges
All information specific to Post-Tensioned Box Girder Bridges will be included in Section 6.

Section 7: Load Rating Straight Steel I-Girder Bridges
All information specific to Straight Steel I-Girder bridges will be included in Section 7.

Section 8: Load Rating Timber Girder Bridges
All information specific to Timber Girder Bridges will be included in Section 8.

Section 9: Load Rating Steel Truss Bridges
All information specific to primary members of Steel Truss Bridges will be included in Section 9. Does not include the analysis for gusset plates or splice plates.

Section 10: Load Rating Arch Bridges
All information specific to Concrete Arch Bridges and Steel Arch Bridges will be included in Section 10.

Section 11: Load Rating Steel Box Girder Bridges
All information specific to Steel Box Girder Bridges will be included in Section 11.

Section 12: Load Rating Decks
This section is being reserved for the future addition of this topic. All information specific to load rating a deck will eventually be included in Section 12.

Section 13: Load Rating Reinforced Concrete Culverts
This section is being reserved for the future addition of this topic. All information specific to load rating Reinforced Concrete Culverts will eventually be included in Section 13.

Section 14: Load Rating Metal Culverts
All information specific to Metal Culverts will be included in Section 14.

Section 15: Load Rating Concrete Bridges without Existing Plans
All information specific to Concrete Bridges without Existing will be included in Section 15.

Section 16: Load Rating New Bridges Using AASHTOWare BrDR
This section is being reserved for the future addition of this topic. All information specific to load rating a new bridge designed with LRFD using AASHTOWare BrDR software will eventually be included in Section 16.

Section 17: Load Rating Gusset Plates
This section is being reserved for the future addition of this topic. All information specific to load rating gusset plates will eventually be included in Section 17.

Section 18: Load Rating Pin and Hanger Connections
All information specific to Pin and Hanger Connections will be included in Section 18.

Section 19: Load Rating Crossbeams
All information specific to Crossbeams will be included in Section 19.

Section 20: Load Rating Summary Workbook (Excel)
This section covers the features of the Load Rating Summary Workbook and includes instructions on obtaining rating factors from BRASS and Crossbeam Analysis.

Section 21: Deliverables
This section gives instruction on the preparation of the Load Rating Report and Electronic copies.

Section 22: ODOT Quality Control & Quality Assurance
This section provides specific procedures to ensure competent engineering for this type of Bridge Work.

Section 23: Bridge Load Restrictions
This section outlines the processes and procedures for implementing a load posting or load restriction for a given bridge.

Supporting Materials: The latest versions are always available on the ODOT FTP Server at ftp://ftp.odot.state.or.us/Bridge/LoadRating/LRFR/

Examples

Examples of Load Ratings are provided for several different bridge types. These can be used to better understand the concepts that are covered in this manual and the specifications and references that apply. The examples also show a complete picture of how the individual lines of code are used to describe a real bridge. Perhaps the best use of the example section is using an example as a "template" to build the files for the current Load Rating. This must be done with caution since there can be subtle differences between bridges that look very similar. The files that were built from templates will have to be reviewed very thoroughly to ensure that they accurately describe the bridge that is being rated.

Tools

This section is a collection of useful information that is presented in tables, diagrams, lists and small applications. Much of this information currently resides in several different reference files. These include tables such as the FIPS **(**Federal Information Processing Standards**)** Codes, standard rail weights and the BRASS truck and section libraries. The trucks that are rated are shown in the Truck Configuration Diagrams in Article 1.5.1.

1.3 References and Terminology

1.3.1 Specifications

There are two main publications that are used for reference when performing a Load Rating. The primary references are the latest editions with the latest interim revisions of the publications listed below.

1. AASHTO ***The Manual for Bridge Evaluation, Third Edition*** (2018), hereinafter referred to as the "*MBE Manual*". Chapter 6, "Load Rating", is used to generate Rating Factors at critical sections and the Inventory Rating and the Operating Rating for each bridge. The Inventory and Operating Ratings are generated by each state and reported to FHWA so analysis can be done on the National Bridge Inventory (NBI). These NBI ratings are used for NBI reporting purposes only, and are not intended to be used for load restriction purposes nor compared to ODOT's Load Resistance Factor Rating (LRFR) for Legal and Permit vehicles.

2. AASHTO ***LRFD Bridge Design Specifications,*** Customary U.S. Units, Eighth Edition (November 2017), hereinafter referred to as the "*AASHTO LRFD Specifications*"**.** The *AASHTO LRFD Specifications* are the source for how highway bridges are designed in the United States. This reference has a section dedicated to each material that is used in bridge construction. It also shows the standard loadings that are used in the NBI ratings and how wheel loads are distributed. Where the *MBE Manual* is silent, the AASHTO LRFD Specifications shall govern.

1.3.2 System of Units

Use the English System of units for all Load Rating inputs and deliverables.

1.3.3 Definitions

AASHTO – American Association of State Highway and Transportation Officials.

As-Built Plans (As Constructed) – Plans that show the state of the bridge at the end of construction.

ACWS – Asphalt Concrete Wearing Surface

Available Load Capacity – A live load that can utilize a bridge repeatedly over the duration of a specified inspection cycle.

BDS – Bridge Data System, a document retrieval system used by the ODOT Bridge Section.

Bent and Span numbering conventions – The numbering convention for Bents and Spans that is used on the inspection report may not match the numbering convention shown in the as-built plan sheets. When this discrepancy is determined, follow the plan numbering convention and document the conversion in the scoping file.

Beta – See Reliability Index.

Bias – The ratio of the mean to nominal value of a random variable.

Bonus Weight – A term referring to ODOT MCTD rules that allow permit truck configurations to have 48-kip tandem axles under certain limited conditions under Weight Table 5.

BRASS-GIRDER(LRFD)™ – A girder analysis program that employs a finite element methods, developed and maintained by Wyoming D.O.T., used for Load Rating the girder members of Oregon's bridges. In this manual, "BRASS-GIRDER(LRFD)" and "BRASS" are use interchangeably to refer to the program.

Bridge (NBI Bridge) – A structure including supports erected over a depression or an obstruction such as water, highway, or railway, and having a track or passage-way for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between centers of bearing of abutments or spring lines of arches.

Bridge Management System (BMS) – A system designed to optimize the use of available resources for inspection, maintenance, rehabilitation, and replacement of bridges.

Bridge Name - For state bridges, use the Bridge Name from the ODOT Bridge Log, which is available on the Bridge Section web pages at https://www.oregon.gov/ODOT/Bridge/Documents/brlog.pdf.
For non-state bridges use the name after "Structure" at the top of the most recent Bridge Inspection Report. This should follow the naming convention "This over That" for grade separations, and "Water Body, Highway" for water crossings (which is the convention used in the Bridge Log).

Calibration – A process of adjusting the parameters in a new standard to achieve approximately the same reliability as exists in a current standard or specification or to achieve a target reliability index.

Coefficient of Variation – The ratio of the standard deviation to the mean of a random variable.

Condition Rating – The result of the assessment of the functional capability and the physical condition of bridge components by considering the extent of deterioration and other defects.

Crossbeam (Bent Cap) – A transverse beam supporting longitudinal girders at a bent (pier or abutment).

Distribution Factor – The fraction of a vehicle lane supported by a girder.

Failure – A condition where a limit state is reached or exceeded. This may or may not involve collapse or other catastrophic occurrences.

FHWA – Federal Highway Administration, U.S. Department of Transportation.

Inventory Level Rating - Generally represents the load that can use the structure on a continuing basis, but reflects the existing bridge and material conditions with regard to deterioration and loss of section.

LFD – Load Factor Design

Limit State – A condition beyond which the bridge component ceases to satisfy the criteria for which it was designed.

Load Effect – The response (axial force, shear force, bending moment, torque) in a member or an element due to the loading.

Load Factor – A load multiplier accounting for the variability of loads, the lack of accuracy in analysis, and the probability of simultaneous occurrence of different loads.

Load Rating – The determination of the live load carrying capacity of an existing bridge.

Load Rating File Set – The complete collection of documentation, preliminary, analysis and summary files that make up the Load Rating, stored in a bridge-numbered folder.

Load Rating Report – The printed, stamped, bound and labeled calculation book (hard copy) for the Load Rating.

Load Rating Team – The Load Rating specialist group that is part of the Bridge Program Unit in the ODOT Bridge Engineering Section.

LRFD – Load and Resistance Factor Design

LRFR – Load and Resistance Factor Rating

MCTD – ODOT's Motor Carrier Transportation Division, a division of ODOT.

National Bridge Inventory (NBI) – The aggregation of structure inventory and appraisal data collected to fulfill the requirements of the National Bridge Inspection Standards.

National Bridge Inspection Standards (NBIS) – Federal regulations establishing requirements for inspection procedures, frequency of inspections, qualifications of personnel, inspection reports, and preparation and maintenance of bridge inventory records. The NBIS apply to all structures defined as bridges located on or over all public roads.

Nominal Resistance – Resistance of a component or connection to load effects, based on its geometry, permissible stresses, or specified strength of materials. Also referred to as *Unfactored Resistance.*

Operating Level Rating – The absolute maximum load that the structure can be subjected to, for limited passages of the load.

Posting – Signing a bridge for load restriction.

RCBG – Reinforced Concrete Box Girder

RCDG – Reinforced Concrete Deck Girder

Reliability Index (Beta) – A computed quantity defining the relative safety of a structural element or structure expressed as the number of standard deviations that the mean of the margin of safety falls on the safe side.

Resistance Factor – A resistance multiplier accounting for the variability of material properties, structural dimensions and workmanship, and the uncertainty in the prediction of resistance.

RF – *Rating Factor*. The ratio of the available load capacity to the load produced by the vehicle that was considered.

Service Limit State – Limit state relating to stress, deformation, and cracking.

Serviceability Limit State – Collective term for service and fatigue limits.

Scoping Load Rating – A Load Rating performed according to the *ODOT LRFR Interim Scoping Load Rating Guidelines* for purposes of project scoping and decision support, not for posting or load restriction purposes.

Specialized Hauling Vehicles (SHVs) – Short but heavy vehicles that meet the provisions of Federal Bridge Formula B but induce load effects greater than the AASHTO Legal Vehicles, especially on short spans. These trucks are designated “SU4” through “SU7”.

Strength Limit State – Safety limit state relating to strength and stability.

Structure Inventory and Appraisal Sheet (SI&A) – A summary sheet of bridge data required by NBIS.

Super Load – Any load that exceeds the limits of Weight Tables 4 and 5 and therefore must be evaluated by Bridge Engineering.

Target Reliability – A desired level of reliability (safety) in a proposed evaluation.

Weight Tables – Rules used by MCTD Transportation Permit Unit to determine classification of a truck configuration and its eligibility for permits.

1.4 Load Rating Basics

The capability of a bridge to carry loads is determined through the Load Rating process. The primary result of this process is the calculation a Rating Factor (RF) at controlling locations for each loading situation considered. A Rating Factor is simply the ratio of the available load capacity to the load produced by the vehicle that was considered. The Rating Factor is always associated with a particular live load, and is a useful tool for support of bridge program decisions and management of load restrictions. Expressed mathematically, the Rating Factor is:

$$RF = \frac{\text{Available Load Capacity}}{\text{Load of Vehicle Considered}}$$

The Rating Factor should normally be greater than 1.0 at all locations. The amount of the Rating Factor greater than 1.0 is a measure of the residual load carrying capacity that is not being used in this loading situation. In order to calculate the Rating Factors for a bridge, it is necessary to analyze numerous locations of each load-carrying member. The Rating Factor for the weakest section of a member is used as the Rating Factor for the bridge under the loading considered. Since most bridges contain numerous members and are used by many different vehicles, there will be a large number of Rating Factors calculated for each bridge.

1.4.1 Equations and Factors

1.4.1.1 LRFR Equation

Load and Resistance Factor Rating (LRFR) of a bridge accounts for both the physical condition and the loadings. The Load and Resistance Factors recognize uncertainties in making judgments on strength, analysis, and loading. The basic rating equation (MBE 6A.4.2.1-1) is shown as:

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_p)(P)}{(\gamma_L)(LL + IM)}$$

In the LRFR Rating Factor equation:

RF = Rating Factor
C = Capacity
R_n = Nominal member resistance (as inspected)
DC = Dead load effect due to structural components and attachments
DW = Dead load effects due to wearing surface and utilities
P = Permanent loads other than dead loads (secondary prestressing effects, etc.)
LL = Live load effect of the Rating Vehicle
IM = Dynamic load allowance
γ_{DC} = LRFD load factor for structural components and attachments
γ_{DW} = LRFD load factor for wearing surfaces and utilities
γ_p = LRFD load factor for permanent loads other than dead loads
γ_L = Evaluation live load factor for the Rating Vehicle

For Strength Limit States:

$$C = \phi_c \ \phi_s \ \phi \ R_n$$

where

ϕ_c = Condition Factor
ϕ_s = System Factor
ϕ = AASHTO LRFD Resistance Factor

and where the following lower limit shall apply:

$$\phi_c \ \phi_s \geq 0.85$$

Notes:

DW - Where ACWS exists, for the DW (dead load of wearing surface) calculation, add 1 inch to the measured thickness to account for variability, unless the thickness has been obtained from averaging multiple core samples.

Multiple Lanes – The “multiple presence” effect of vehicles in lanes adjacent to the rating vehicle is normally taken into account in the various calibrated live load factors in MBE 6A.4.4.2.3a-1. However, in crossbeam analysis where the member supports multiple lanes of traffic and the load rating is for Permit Vehicles, the Rating Factor equation will be modified to apply only to the rated Permit Vehicle. The “residual capacity” in the numerator must be further reduced by the effect of a Legal Type 3S2 vehicle in each adjacent lane, as follows:

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_{p})(P) - (\gamma_{L3S2})\,\Sigma\,(LL_{3S2} + IM)}{(\gamma_{L})(LL + IM)}$$

where

$\Sigma(LL_{3S2})$ = live load effect of Legal Type 3S2 vehicles on all lanes adjacent to the lane containing the load rated Permit Vehicle

γ_{L3S2} = live load factor for the Legal 3S2 vehicle

1.4.1.2 Limit States and Load Factors

Adaptation of MBE Table 6A.4.2.2-1

Bridge Type	Limit State	Dead Load	Dead Load	Design Load MBE 6A.4.3.2.2 Inventory	Design Load MBE 6A.4.3.2.2 Operating	Legal Load MBE 6A.4.4	Permit Load MBE 6A.4.5
		γ_{DC}	γ_{DW}	γ_L	γ_L	γ_L	γ_L
Reinforced Concrete	Strength I	1.25	1.50[a]	1.75	1.35	Tables 6A.4.4.2.3a-1 and 6A.4.4.2.3b-1	-
	Strength II	1.25	1.50[a]	-	-	-	Table 6A.4.5.4.2a-1
Prestressed Concrete	Strength I	1.25	1.50[a]	1.75	1.35	Tables 6A.4.4.2.3a-1 and 6A.4.4.2.3b-1	-
	Strength II	1.25	1.50[a]	-	-	-	Table 6A.4.5.4.2a-1
	Service III	1.00	1.00	0.80	-	1.00[b]	-
Steel	Strength I	1.25	1.50[a]	1.75	1.35	Tables 6A.4.4.2.3a-1 and 6A.4.4.2.3b-1	-
	Strength II	1.25	1.50[a]	-	-	-	Table 6A.4.5.4.2a-1
	Service II	1.00	1.00	1.30	1.00	1.30	1.00[c]
Wood	Strength I	1.25	1.50[a]	1.75	1.35	Tables 6A.4.4.2.3a-1 and 6A.4.4.2.3b-1	-
	Strength II	1.25	1.50[a]	-	-	-	Table 6A.4.5.4.2a-1

Notes:

[a] Load factor for DW at the Strength Limit state may be taken as 1.25 where the thickness has been field measured. The normal ACWS thickness on ODOT Bridge Inspection Reports is assumed to be field measured unless known to be otherwise, so γ_{DW} will normally be taken as 1.25.

[b] Service III for legal loads of prestressed concrete is optional. Thus, the ODOT load rating summary sheet will automatically ratio the dead load and live factors between the Strength I and Service III Limit States for the design load and will then only import from BRASS the Service III rating factors for the HL93 design vehicle when a Service III rating factor is below 1.10.

[c] Service II for permit loads of steel members is optional. Since Service II is required for design and legal loads, permit loads will be evaluated as well. The ODOT load rating summary sheet will automatically ratio the dead load and live factors between the Strength I, Strength II and Service III Limit States for all of the loads and will then only import from BRASS the Service II rating factors for when a Service II rating factor is below 1.10.

The basic definition of the Load Rating Factor can be expressed in more specific terms as:

$$RF = \frac{\text{Capacity} - \text{Dead Load}}{\text{Live Load + Impact}}$$

There are uncertainties in each term on the right side of the above equation. For example, the capacity of a bridge can decrease over time as the condition of the bridge deteriorates. The dead load is not exact since the materials used to build the bridge do not exactly match the materials that are tested in the lab, and the actual dimensions of each load carrying member may vary from the plans. The live load may vary significantly due to unknown overweight vehicles, or to an increase in traffic volume. Impact forces vary due to condition of the wearing surface, uneven approaches that can “launch” vehicles onto the bridge, and the speed at which the vehicles travel.

1.4.1.3 Condition Factor ϕ_c:

The condition factor provides a reduction to account for increased uncertainty in the resistance of deteriorated members and the likely increased future deterioration of these members during the period between inspection cycles.

MBE T 6A.4.2.3-1

Structural Condition of Member	ϕ_c
Good or Satisfactory	1.00
Fair	0.95
Poor	0.85

If condition information is collected and recorded in the form of NBI condition ratings only, then the following approximate conversion may be applied in selecting ϕ_c.

MBE T C6A.4.2.3-1

Superstructure Condition Rating (NBI Item 59) or Substructure Condition Rating (NBI Item 60) whichever is applicable	Equivalent Member Structural Condition
6 or higher	Good or satisfactory
5	Fair
4 or lower	Poor

Notes:
For crossbeams supporting longitudinal members, in MBE Table C6A.4.2.3-1, the applicable Condition Rating is the Substructure (NBI Item 60).

For a newly designed bridge that replaces an existing bridge – A load rating can be performed prior to the first bridge inspection with the following assumptions:

- Deck, Superstructure and Substructure (NBI Items 58, 58 and 60) Condition Ratings are all 8.
- Pontis Elements 325 (Traffic Impact Assessment) and 326 (Wearing Surface) are both 100% in Pontis Condition State 1.
- ADT (NBI Item 29) and Truck Percentage (NBI Item 109) are the same as the bridge being replaced.

For a newly designed bridge that does *not* replace an existing bridge, the same assumptions can be made except a load rating cannot be performed until the ADTT and Truck Percentage on the new structure has been rationally estimated.

Epoxy Crack Injection – ODOT's position is that epoxy injection should not be considered as a permanent structural repair. Therefore, the condition rating (and corresponding ϕ_c) of members will not be adjusted as a result of epoxy injection.

1.4.1.4 System Factor ϕ_s:

System factors are multipliers applied to the nominal resistance to reflect the level of redundancy of the complete superstructure system. MBE Table 6A.4.2.4-1 does not specifically cover crossbeams, and for use in Mathcad it is convenient to distinguish between the ϕ_s values for flexure and shear. Therefore the following System Factor table will be used:

ODOT modification of MBE Table 6A.4.2.4-1

Structure Type	System Factor for Flexure ϕ_{sf}	System Factor for Shear ϕ_{sv}
Two Girders with Welded Members	0.85	1.00
Two Girders with Riveted Members	0.90	1.00
Two Girder Concrete Bridges	0.95	1.00
Post-Tensioned Box Girder Bridge with 2 or more Stems (Webs)	1.00	1.00
Steel Box Girder Bridge with 2 Webs	0.95	1.00
Steel Box Girder Bridge with 3 or more Webs	1.00	1.00
Three-Girder Bridges with Girder Spacing ≤ 6 ft.	0.85	1.00
Four-Girder Bridges with Girder Spacing ≤ 4 ft.	0.95	1.00
All Other Girder and Slab Bridges	1.00	1.00
Crossbeams supported by 1 or 2 columns	0.90	1.00
Crossbeams supported by 3 columns	0.95	1.00
Crossbeams supported by 4 or more columns	1.00	1.00
Timber Stringers	1.00	1.00

Use 1.0 for system factor when considering bearing in steel girders.

1.4.1.5 AASHTO LRFD Resistance Factor ϕ:

(From AASHTO LRFD 5.5.4.2, 6.5.4.2, and 8.5.2.2)

Stress Type	ϕ
Flexure and Tension of Reinforced Concrete	0.90
Shear of Normal Weight Concrete	0.90
Flexure and Tension of Prestress Concrete	1.00
For compression in strut-and-tie models	0.70
For tension in strut-and-tie models : reinforced concrete	0.90
For tension in strut-and-tie models : prestressed concrete	1.00
Flexure and Shear of Steel Members	1.00
Flexure of Timber Members	0.85
Shear of Timber Members	0.75

1.4.1.6 AASHTO LRFD Distribution Factors (Lever Rule):

BRASS calculates the distribution factors based on the tables in AASHTO LRFD sections 4.6.2.2.2 and 4.6.2.2.3. If the structure doesn't meet the range of applicability, the lever rule is applied. For LRFR, ODOT is allowing a modification to when and how the lever rule is applied. If the BRASS defaults produce acceptable values, no modification to the procedure is required.

The empirical equations, found in the tables of AASHTO LRFD sections 4.6.2.2.2 and 4.6.2.2.3, are based on bridge geometry; including beam length, deck thickness, number of beams, girder spacing, etc. The range of applicability for several variables includes maximum and minimum values. Having an allowable range can result in a structures distribution factors being calculated with the more conservative lever rule, even when the bridges geometry facilitates better live load distribution. Consider the calculation of the live load distribution for moment in an interior beam for a type "d" cross section. The empirical distribution factor equation for one lane loaded is as follows:

$$DF = \left(1.75 + \frac{S}{3.6}\right)\left(\frac{1}{L}\right)^{0.35}\left(\frac{1}{N_c}\right)^{0.45}$$ (AASHTO LRFD T 4.6.2.2.2b-1)

Because L, span of beam, is in the denominator of the equation any increase in L results in a decrease in the distribution factor. This is reasonable since the longer span length should result in greater load sharing. However, at 240ft the empirical equation is no longer valid, because of the range of applicability, and the more conservative lever rule is applied. It seems to be overly conservative to penalize a structure in these types of circumstances. Therefore, the following may be considered when using the tables in AASHTO LRFD sections 4.6.2.2.2 and 4.6.2.2.3:

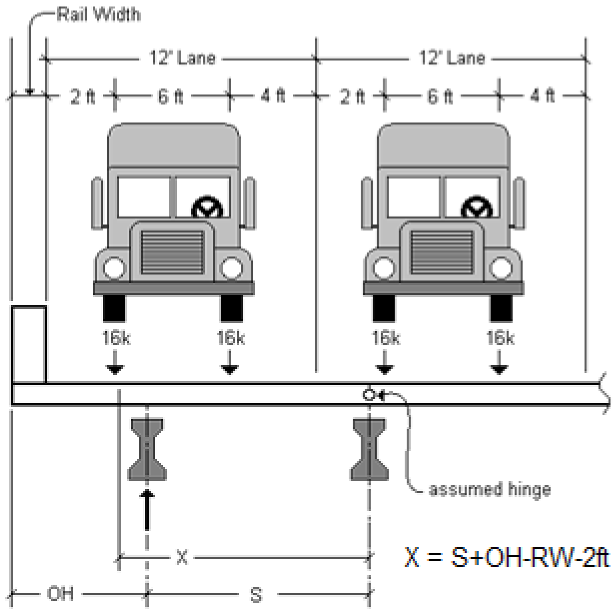
- Variable in the Denominator: If the actual value is greater than the maximum permitted, use the maximum permitted value for calculating the distribution factor.
- Variable in the Numerator: If the actual value is less than the minimum permitted, use the minimum permitted value for calculating the distribution factor.

If the lever rule is going to be used, ODOT will allow a modification to how the trucks are placed. The AASHTO LRFD manual defines a twelve foot travel lane with a ten foot design lane placed within this travel lane. MBE defines a six foot distance between the wheels of a truck and a distance between adjacent wheel lines of passing trucks of a minimum of four feet. This definition allows for a wheel line spacing, for exterior girder analysis, of two feet from barrier, six feet for axle, four feet to adjacent vehicle. Using the AASHTO LRFD live load placement for an exterior girder would result in two feet from barrier, six feet for axle, and six feet to the adjacent truck. This is because the ten foot design lane must reside within the twelve foot travel lane. BRASS defaults to the AASHTO LRFD definition of travel lanes when performing the lever rule.

In the event that the distribution factors require manual calculation, this manual used to allow users to follow a simplified vehicle spacing shown in NCHRP Report 592. Using the simplified spacing and resulting equations from NCHRP Report 592 was deemed to be too conservative for most cases since the adjacent vehicle spacing was always set to four feet and the lane widths were set to ten feet. Thus, users may refer to the diagrams and equations shown on the next two pages for computing the Lever Rule Distribution Factors that follow the AASHTO LRFD definition of travel lanes.

For single lane cases, make sure to multiply the result of the lever rule by the multiple presence factor of 1.2. When manually calculating the distribution factors, show the appropriate lever rule equations used in the load rating preliminary file. If there is an error in the calculation of Distribution Factors by BRASS, notify the ODOT load Rating Unit of the problem.

LEVER RULE EXTERIOR BEAM



For X < 6:

One Lane = $\frac{16}{32}\left(\frac{X}{S}\right)$

For 6 ≤ X < 12:

One Lane = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}\right)$

For 12 ≤ X < 18:

One Lane = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}\right)$

For 18 ≤ X < 24:

One Lane = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}\right)$

For 24 ≤ X < 30:

One Lane = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}\right)$

Three Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}+\frac{X-24}{S}\right)$

For 30 ≤ X < 36:

One Lane = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}\right)$

Three Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}+\frac{X-24}{S}+\frac{X-30}{S}\right)$

For 36 ≤ X < 42:

One Lane = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}\right)$

Three Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}+\frac{X-24}{S}+\frac{X-30}{S}\right)$

Four Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}+\frac{X-24}{S}+\frac{X-30}{S}+\frac{X-36}{S}\right)$

For 42 ≤ X ≤ 48:

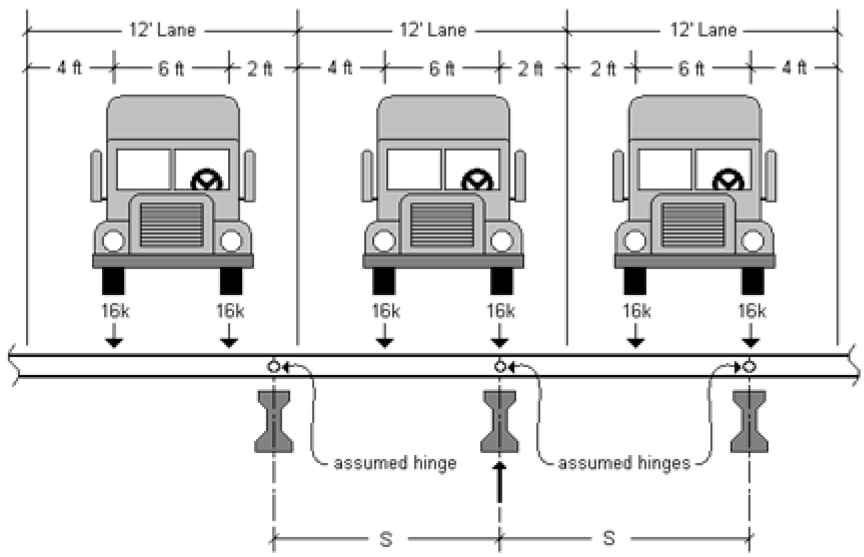
One Lane = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}\right)$

Three Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}+\frac{X-24}{S}+\frac{X-30}{S}\right)$

Four Lanes = $\frac{16}{32}\left(\frac{X}{S}+\frac{X-6}{S}+\frac{X-12}{S}+\frac{X-18}{S}+\frac{X-24}{S}+\frac{X-30}{S}+\frac{X-36}{S}+\frac{X-42}{S}\right)$

LEVER RULE INTERIOR BEAM



For S < 4:

One Lane = $\frac{16}{32}$

For 4 ≤ S < 6:

One Lane = $\frac{16}{32}$

Two Lanes = $\frac{16}{32}\left(1+\frac{S-4}{S}\right)$

For 6 ≤ S < 10:

One Lane = $\frac{16}{32}\left(1+\frac{S-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}\right)$

For 10 ≤ S < 12:

One Lane = $\frac{16}{32}\left(1+\frac{S-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}\right)$

For 12 ≤ S < 16:

One Lane = $\frac{16}{32}\left(1+\frac{S-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}\right)$

Three Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}+\frac{S-12}{S}\right)$

For 16 ≤ S < 18:

One Lane = $\frac{16}{32}\left(1+\frac{S-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}\right)$

Three Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}+\frac{S-12}{S}\right)$

Four Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}+\frac{S-12}{S}+\frac{S-16}{S}\right)$

For 18 ≤ S < 22:

One Lane = $\frac{16}{32}\left(1+\frac{S-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}\right)$

Three Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}+\frac{S-12}{S}+\frac{S-18}{S}\right)$

Four Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}+\frac{S-12}{S}+\frac{S-18}{S}+\frac{S-16}{S}\right)$

For 22 ≤ S ≤ 24:

One Lane = $\frac{16}{32}\left(1+\frac{S-6}{S}\right)$

Two Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}\right)$

Three Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}+\frac{S-12}{S}+\frac{S-18}{S}\right)$

Four Lanes = $\frac{16}{32}\left(1+\frac{S-6}{S}+\frac{S-4}{S}+\frac{S-10}{S}+\frac{S-12}{S}+\frac{S-18}{S}+\frac{S-16}{S}+\frac{S-22}{S}\right)$

1.4.1.7 Application of Live Loads:

When calculating the number of lanes for use in analysis, follow MBE 6A.2.3.2. The number of lanes used for analysis, and the number of lanes actually delineated are not necessarily the same. PER MBE 6A.2.3.2 if the travel way width is at least 18ft, it shall be analyzed with two travel lanes.

1.4.1.8 Design Live Load Factors γ_L:

Adaptation of MBE Table 6A4.3.2.2-1

Evaluation Level	Live Load Factor γ_L
Inventory	1.75
Operating	1.35

1.4.1.9 Generalized Live Load Factors for Legal Loads γ_L on State-Owned Bridges:

Table 1.4.1.9 (Adaptation of MBE Table 6A.4.4.2.3a-1)

	Live Load Factor γ_L by ADTT[a] (one direction)[b]			
Traffic Volume (one direction)	Unknown	≥ 5000	= 1500	≤ 500
Live Load Factor γ_L	1.40	1.40	1.35	1.30

Notes (MBE Table 6A.4.4.2.3a-1):
[a] Interpolate the live load factor by ADTT values. Live load factors from this table should not be used when advanced methods of analysis are employed.

[b] If there are two directions of traffic, use only half of the structure ADTT (use one direction) to determine the live load factors.

These live load factors are applicable to the Specialized Hauling Vehicles (SHVs).
The Excel application **LL_Factors_State.XLS** implements this table.

These live load factors are to only be used with the live load distribution factors that are computed following LRFD Article 4.6.2.2 (Beam Slab Bridges) of the AASHTO LRFD Bridge Design Specifications. If a refined analysis model is used, then the national live load factors as described in Article 1.4.1.10 should be used. The Excel application **LL_Factors_Refined_2013.xlsm** implements the national live load factors for refined load rating analysis.

The Oregon-specific live load factors presented in this table and in Article 1.4.1.11 are the result of an extensive calibration study based on weigh-in-motion data, conducted under the provisions of MBE commentary Article C6A.4.4.2.3. See *ODOT LRFR Policy Report: Live Load Factors for Use in Load and Resistance Factor Rating (LRFR) of Oregon's State-Owned Bridges* for details.

1.4.1.10 Generalized Live Load Factors for Legal Loads γ_L on Local Agency Bridges:

Table 1.4.1.10 (Adaptation of MBE Table 6A.4.4.2.3a-1)

Traffic Volume[a] (one direction)[b]	Live Load Factor γ_L
Unknown	1.45
ADTT ≥ 5000	1.45
ADTT ≤ 1000	1.30

Notes (Table 1.4.1.10):

[a] Interpolate the live load factor by ADTT values.
[b] If there are two directions of traffic, use only half of the structure ADTT (use one direction) to determine the live load factors.

These live load factors are applicable to the Specialized Hauling Vehicles (SHVs).
The Excel application **LL_Factors_Local_2013.xlsm** implements this table.

1.4.1.11 Generalized Live Load Factors for Emergency Vehicles γ_L :

Load ratings (or rating factors) should be determined for the FAST Act Emergency Vehicle configurations i.e., Types EV2 and EV3, at the operating or legal load rating level. Use a live load factor of 1.30 in the load rating of these vehicles.

1.4.1.12 Generalized Live Load Factors for Permit Loads γ_L on State-Owned Bridges:

Because ODOT's Motor Carrier Transportation Division (MCTD) issues Single Trip Permits in such large numbers on a routine basis without a specific structural review, they are treated the same as "Routine or Annual" in this table. Use Table 1.4.1.11A only where multiple-lane Distribution Factors are used.

Table 1.4.1.11A (Adaptation of upper portion of MBE Table 6A.4.5.4.2a-1) for ODOT Routine Permits

Permit Type	Frequency	Loading Condition	DF[a]	Permit Vehicle	Live Load Factor γ_L by ADTT[b] (one direction)[c]			
					Unknown	≥ 5000	= 1500	≤ 500
Continuous Trip (Annual)	Unlimited Crossings	Mix w/traffic (other vehicles may be on the bridge)	2 or more lanes	CTP-2A	1.35	1.35	1.35	1.25
				CTP-2B	1.35	1.35	1.35	1.25
				CTP-3	1.45	1.45	1.40	1.30
Single Trip	Route-Specific Limited Crossings	Mix w/traffic (other vehicles may be on the bridge)	2 or more lanes	STP-3	1.25	1.25	1.20	1.10
				STP-4A	1.40	1.40	1.35	1.25
				STP-4B	1.00	1.00	1.00	1.00
				STP-4C	1.10	1.10	1.05	1.00
				STP-4D	1.05	1.05	1.05	1.00
				STP-4E	1.00	1.00	1.00	1.00
				STP-5BW	1.00	1.00	1.00	1.00

Use Table 1.4.1.11B whenever one-lane Distribution Factors are used. Note: ODOT assumes the multiple-lane loading to always control over the single-lane loading, so this table would only be used in (1) the exceptional case where single-lane loading is shown to govern over multiple-lane loading, or (2) in the "Super-Load" case where the loading is known to be single-lane.

Table 1.4.1.11B (Adaptation of lower portion of MBE Table 6A.4.5.4.2a-1) for ODOT "Super-load" Permits

Permit Type	Frequency	Loading Condition	DF[a]	Permit Vehicle	Live Load Factor γ_L by ADTT[b] (one direction)[c]			
					Unknown	≥ 5000	= 1000	≤ 100
Special or Limited Crossings (Super-Loads)	Single-Trip	Escorted w/no other vehicles on the bridge	One Lane	Specific	1.15	1.15	1.15	1.15
	Single-Trip	Mix w/traffic (other vehicles may be on the bridge)	One Lane	Specific	1.50	1.50	1.40	1.35

Notes: (Tables 1.4.1.11A and 1.4.1.11B)

[a] DF = LRFD live load distribution factor. To mitigate the effects of the Oregon-specific live load factor calibration, ODOT has decided, for state-owned bridges, when a one-lane Distribution Factor controls for an exterior girder, the built-in Multiple Presence Factor for one lane (1.2) should *not* be divided out of the Distribution Factor (this approach is conservative). However, for escorted super-load permit reviews (done only by ODOT personnel), where the national MBE live load factor of 1.15 applies and a one-lane Distribution Factor controls, ODOT *will* divide out the Multiple Presence Factor to be consistent with the national MBE code. These adjustments will be accomplished in the

coding of the Summary Spreadsheet

[b] Interpolate the live load factor by ADTT values. Live load factors from this table should not be used when advanced methods of analysis are employed.

[c] If there are two directions of traffic, use only half of the structure ADTT (use one direction) to determine the live load factors.

The Excel application **LL_Factors_State.XLS** implements this table. Because Oregon MCTD issues Single Trip Permits in such large numbers on a routine basis without a specific structural review, **LL_Factors_State.XLS** is programmed to treat them the same as "Routine or Annual" in the live load factor tables. This means live load factors will vary according to ADTT. Use Table 1.4.1.11B (for "Special or Limited Crossings") only when doing a review analysis for a specific permit vehicle.

These live load factors are to only be used with the live load distribution factors that are computed following LRFD Article 4.6.2.2 (Beam Slab Bridges) of the AASHTO LRFD Bridge Design Specifications. If a refined analysis model is used, then the national live load factors as described in Article 1.4.1.12 should be used. The Excel application **LL_Factors_Refined_2013.xlsm** implements the national live load factors for refined load rating analysis.

1.4.1.13 Generalized Live Load Factors for Permit Loads γ_L on Local Agency Bridges:

Table 1.4.1.12 Adaptation of MBE Table 6A.4.5.4.2a-1

Permit Type	Frequency	Loading Condition	DF[a]	ADTT (one direction)[c]	Live Load Factor γ_L by Permit Weight Ratio[b]		
					GVW / AL ≤ 2.0 (kip/ft)	2.0 < GVW/AL < 3.0 (kip/ft)	GVW / AL ≥ 3.0 (kip/ft)
Routine or annual	Unlimited Crossings	Mix w/traffic (other vehicles may be on the bridge)	Two or more Lanes	> 5000	1.40	1.35	1.30
				= 1000	1.35	1.25	1.20
				< 100	1.30	1.20	1.15
					All Weights		
Special or Limited Crossings (Super-Loads"	Single-Trip	Escorted with no other vehicles on the bridge	One Lane	N/A	1.10		
	Single-Trip	Mix with traffic (other vehicles may be on the bridge)	One Lane	All ADTTs	1.20		
	Multiple-Trips (less than 100 crossings)	Mix with traffic (other vehicles may be on the bridge)	One Lane	All ADTTs	1.40		

Notes:

[a] DF = LRFD live load distribution factor. For Local Agency bridges, when one-lane distribution factor is used, the built-in multiple presence factor for one lane (1.2) should be divided out of the distribution factor.

[b] Permit Weight Ratio = GVW / AL; GVW = Gross Vehicle Weight; AL = Front axle to rear axle length; Use only axle weights on the bridge.

[c] If there are two directions of traffic, use only half of the structure ADTT (use one direction) to determine the live load factors.

Use an effective bridge length to determine axle weights on the bridge. For continuous span bridges, use the longest two consecutive spans. For simple span bridges, use the longest simple span. For bridges with a combination of continuous spans with joints at the bents, use the longer of (a) the longest two adjacent continuous spans or (b) the longest simple span length. This will be slightly conservative for some portions of the bridge compared to using the entire bridge length, but not excessively so.

The Excel application, **LL_Factors_Local_2013.xlsm**, implements this table. Because Oregon MCTD issues Single Trip Permits in such large numbers on a routine basis without a specific structural review, LL_Factors_Local.XLS is programmed to treat them the same as “Routine or Annual” in the live load factor tables. This means live load factors will vary according to ADTT, weight, and effective bridge length. Use the lower portion of MBE Table 6A.4.5.4.2a-1 (for “Special or Limited Crossings”) only when doing a review analysis for a specific permit vehicle.

1.4.1.14 Dynamic Load Allowance IM:

Increase the static effects of the truck loads for strength limit states to account for the dynamic effects due to moving vehicles.

For Design Vehicles, regardless of the riding surface condition or the span length, always use 33% for the dynamic load allowance (IM).

Per AASHTO LRFD C3.6.2.1, field tests indicate that in the majority of highway bridges, the dynamic component of the response does not exceed 25 percent of the static response to vehicles. Therefore, for legal and permit vehicles, a maximum dynamic load allowance (IM) of 25% will be used.

For Legal and Permit Vehicles, longitudinal members having spans greater than 40 ft. with less severe approach and deck surface conditions, the dynamic load allowance (IM) may be decreased as given in MBE Table C6A.4.4.3-1. Because the load effects due to impact are dependent on span length and support continuity, in addition to riding surface, any decrease in impact factor is also subject to the following:

- Multi-Span Bridges Continuous for Live Load: If a span length is 40ft or less; do not reduce the impact factor in any span. Because BRASS-GIRDER(LRFD) does not allow definition of separate dynamic load allowance (impact factors) for each span, as a general rule use 25% for the whole bridge. If Rating Factors are < 1.0 using this somewhat conservative assumption, the ODOT Bridge Load Rating Unit may authorize an alternative analysis with multiple BRASS runs to apply different dynamic load allowances in each span. No alternative analysis is acceptable without written approval of the ODOT Bridge Load Rating Unit.
- Simple Spans: Reduction is permitted within any span whose length is greater than 40 ft in length. When multi-span structures are simply supported for live load, it is permissible to have different impact factors for different spans. Use the reduced impact factor in the spans longer than 40 ft, and do not reduce the impact factor in the spans with lengths equal to or less than 40 ft.

MBE Table C6A.4.4.3-1 (as Modified by ODOT)

Riding Surface Condition	**IM**
Condition State 1 for Element # 999. Smooth riding surface at approaches, bridge deck, and expansion joints, with no noticeable bumps.	10%
Condition State 2 for Element # 999. Moderate surface deviations or depressions causing minor bumps.	20%
Condition State 3 for Element # 999. A rough ride, with significant to severe bumps, or the perception that trucks are being “launched” at the approach to the bridge.	25%

Note:
The *Oregon Coding Guide* condition state language for the Roadway Impact (Pontis Element 999) has been modified to reflect the *MBE Manual* provisions.

1.4.1.15 Loads Not Needing Consideration

1. **Pedestrian Live Loads: *PL* -** Pedestrian loads on sidewalks need not be considered simultaneously with vehicular loads when load rating a bridge, unless the Engineer has reason to expect that significant pedestrian loading will coincide with maximum vehicular loading (MBE 6A.2.3.4). If pedestrian live load is used, further guidance can be found in AASHTO LRFD Design Article 3.6.1.6.

2. **Wind Loads: *WL and WS*** – Wind loads need not be considered unless special circumstances justify otherwise.

3. **Temperature Effects**: ***TG and TU*** – Temperature effects need not be considered in calculating Load Ratings for non-segmental bridge components that have been provided with well-distributed steel reinforcement to control thermal cracking.

4. **Earthquake Effect *: EQ*** – Earthquake effects need not be considered in calculating Load Ratings.

5. **Creep and Shrinkage *: CR and SH*** - Creep and shrinkage effects do not need to be considered in calculating Load Ratings where there is well-distributed reinforcement to control cracking in non-segmental, non-prestressed components.

1.4.2 Concrete

Use the specific concrete strength values f'_c given on the plans whenever available.

When compressive strength of concrete, f'_c, is not given but a “class” of concrete is designated on the plans, use the following:

ODOT Construction Specifications on Concrete Classes

	Compressive Strengths				Maximum Aggregate Sizes			
Year of Specifications	Class A (psi.)	Class B (psi.)	Class C (psi.)	Class AA (psi.)	Class A (inches)	Class B (inches)	Class C (inches)	Class AA (inches)
1916	2000				1 1/2	2 1/2	2 1/2	
1922					1 1/4	2 1/4	2 1/4	
1929	2200	1700	1500		2	3	3	
1932	2200	1700	1500		2	2 1/2	3	
1939	3000	2200	1500		2 1/2	2 1/2	3	
1940	3000	2200	1500		2	2	2 1/2	
1946	3000	2200	1500		2	2	2 1/2	
1949	3300	2200	1500		1 1/2	2	2 1/2	
1954	3300	2200	1500		1 1/2	2	2 1/2	
1964	3300	2200		5000	1 1/2	2		3/4
1970	2500 - 5500	2200		5000 - 6000	1 1/2	2		1

(Blank cells indicate unknown data)

Construction Year	Before 1932	1932 and later
Class “D”	f'_c = 2800 psi	f'_c = 2800 psi

The BRASS default is to use 0.75 inches for the maximum aggregate size. The crossbeam section of this manual indicates to use 0.75 inches unless the plans indicate otherwise. The topic of modifying the maximum aggregate sizes came up during the load rating of a crossbeam where the SU7 legal vehicle resulted in a rating factor of 0.63 with 0.75” aggregate. The plans clearly indicate “Class A” concrete and the bridge was built in 1965, which correlated to 1.5” maximum aggregate size according to the Standard Specifications. Using the larger maximum aggregate size of 1.5" resulted in the rating factor for the SU7 vehicle being increased from 0.63 to 0.91, which reduced the severity of the load restriction. This really matters if the minimum stirrup spacing check in LRFD isn't met.

When compressive strength of concrete, f'_c, is unknown and no concrete "class" designation is given on the plans, and the concrete is in satisfactory condition, f'_c, for reinforced concrete superstructure members may be taken as given in MBE Table 6A.5.2.1-1 by considering the date of construction.

MBE Table 6A.5.2.1-1

Year of Construction	Compressive Strength, f'_c, ksi
Prior to 1959	2.5
1959 and later	3.0

1.4.3 Reinforcing Steel

Yield strengths for reinforcing steels are specified in MBE Table 6A.5.2.2-1. Yield strengths of unknown reinforcing steel may be estimated by considering the date of construction.

Table 1.4.3 (Adaptation of MBE Table 6A.5.2.2-1)

Type of Reinforcing Steel	Yield Strength, f_y, ksi
Unknown steel constructed prior to 1954	33.0
Structural Grade	36.0
Billet or intermediate grade, Grade 40, and unknown steel constructed during or after 1954	40.0
Rail or Hard Grade, Grade 50	50.0
Grade 60	60.0
Unknown steel constructed after 1984	60.0

1.4.4 Prestressing Steel

Where the tensile strength of the prestressing strand is unknown, the values specified in MBE Table 6A.5.2.3-1 based on the date of construction may be used. Stress-relieved strands should be assumed when strand type is unknown.

MBE Table 6A.5.2.3-1

Year of Construction	Tensile Strength, f_{pu}, ksi
Prior to 1963	232.0
1963 and later	250.0

In the absence of a well-defined yield stress for prestressing steels, the following values of f_{py} are defined:

MBE Table 6A.5.4.2.2b-1

Type of Tendon	f_{py}, ksi
Low-Relaxation Strand	0.9 f_{pu}
Stress-Relieved Strand and Type 1 High-Strength Bar	0.85 f_{pu}
Type 2 High-Strength Bar	0.80 f_{pu}

Based on documents and information provided by ODOT's technical experts, it appears that ODOT changed from stress-relieved strands to low-relaxation strands in 1984. About that time there was a new set of standard drawings issued for slabs, box beams and girders. For projects let at or near the change, one should confirm whether or not these standard drawings were used. If an earlier standard was used, they probably used stress-relieved strand. Below is the list of standards that were issued at that time:

Dwg. # 38630 – Oct. 1983 – Box Beams
Dwg. # 39488 – Date not shown (likely between Oct. '83 and May '84) – Bulb-I Girders
Dwg. # 39489 – Date not shown (likely between Oct. '83 and May '84) – Bulb-T Girders
Dwg. # 39527 – June 1984 – 12" Slabs
Dwg. # 39528 – June 1984 – 15" Slabs
Dwg. # 39529 – June 1984 – 18" Slabs
Dwg. # 39530 – May 1984 – 21" Slabs
Dwg. # 39531 – May 1984 – 26" Slabs

Properties and design strengths of Prestressing Steel from Table 2.11-1 of the "PCI Bridge Design Manual" are shown on the next page:

Seven-Wire Low-Relaxation Strand Grade 270 (f'_s = 270 ksi)

Nominal Diameter (in.)	3/8	7/16	1/2	½ Special	9/16	0.6
Nominal Area (A_s, in.^{2})	0.085	0.115	0.153	0.167	0.192	0.217
Nominal Weight (plf)	0.29	0.39	0.52	0.53	0.65	0.74
Minimum Tensile Strength (kip)	23.0	31.0	41.3	45.1	51.8	58.6
Minimum Yield Strength (kip)	20.7	27.9	37.2	40.6	46.6	52.7
0.70 $f'_s A_s$ (kip)	16.1	21.7	28.9	31.6	36.3	41.0
0.75 $f'_s A_s$ (kip)	17.2	23.3	31.0	33.8	38.9	44.0
0.80 $f'_s A_s$ (kip)	18.4	24.8	33.0	36.1	41.4	46.9

Seven-Wire Low-Relaxation Strand Grade 250 (f'_s = 250 ksi)

Nominal Diameter (in.)	3/8	7/16	1/2	0.6
Nominal Area (A_s, in.^{2})	0.080	0.108	0.144	0.216
Nominal Weight (plf)	0.27	0.37	0.49	0.74
Minimum Tensile Strength (kip)	20.0	27.0	36.0	54.0
Minimum Yield Strength (kip)	18.0	24.3	32.4	48.6
0.70 $f'_s A_s$ (kip)	14.0	18.9	25.2	37.8
0.75 $f'_s A_s$ (kip)	15.0	20.3	27.0	40.5
0.80 $f'_s A_s$ (kip)	16.0	21.6	28.8	43.2

Deformed Prestressing Bars Grade 150 (f'_s = 150 ksi)

Nominal Diameter (in.)	5/8	1	1-1/4	1-3/8
Nominal Area (A_s, in.^{2})	0.28	0.85	1.25	1.58
Nominal Weight (plf)	0.98	3.01	4.39	5.56
Minimum Tensile Strength (kip)	42.0	127.5	187.5	237.0
Minimum Yield Strength (kip)	33.6	102.0	150.0	189.6
0.70 $f'_s A_s$ (kip)	29.4	89.3	131.3	165.9
0.75 $f'_s A_s$ (kip)	31.5	95.6	140.6	177.8
0.80 $f'_s A_s$ (kip)	33.6	102.0	150.0	189.6

Use a Modulus of Elasticity of 28,500 ksi for all Prestressing Steel.

1.4.5 Structural Steel

The minimum yield strengths of unknown structural steels are specified in MBE Table 6A.6.2.1-1, which may be assumed based on the year of construction.

Table 1.4.5 (Adaptation of MBE Table 6A.6.2.1-1)

Year of Construction	Minimum Yield Strength, F_y, ksi	Minimum Tensile Strength, F_u , ksi
Prior to 1905	26	52
1905 to 1936	30	60
1936 to 1963	33	66
After 1963	36	66

1.4.6 Steel Pins

The minimum yield strengths of unknown steel pins are specified in MBE Table 6A.6.2.2-1, which may be assumed based on the year of construction.

Table 1.4.6 (Adaptation of MBE Table 6A.6.2.2-1)

Year of Construction	Minimum Yield Strength, F_y, ksi
Prior to 1905	25.5
1905 to 1936	30
1936 to 1963	33
After 1963	36

1.4.7 Timber Bridge Materials

The reference design values for existing timber bridge components in satisfactory condition may be taken as given in LRFD Design Articles 8.4.1.1.4 and 8.4.1.2.3 and adjusted for actual conditions of use in accordance with LRFD Design Article 8.4.4. To obtain values for species and grades not included in the LRFD articles, a direct conversion of Allowable Stress Design Values in the National Design Specification for Wood Construction, 2005 Edition may be performed.

Use the design values listed for the West Coast Lumber Inspection Bureau (WCLIB) grading rules. The timber grade of existing stringers and caps can be estimated by using the following guidelines:

Grade	Maximum slope of grain in middle 1/3 of span length	Maximum knot size on narrow face and edge of wide face in middle 1/3 of span length	Maximum knot size at ends and along centerline of wide face
Select Structural	1” in 15”	1/4 width	1/4 height
No. 1	1” in 10”	1/3 width	1/3 height

The majority of timber bridges do not have plans, and material properties need to be assumed. The following properties may be used, unless there is cause to assume otherwise.

Reference Design Values for Visually Graded Sawn Lumber (AASHTO Table 8.4.1.1.4-1)

Species	Size	F_{bo} (ksi)	F_{vo} (ksi)	F_{cpo} (ksi)	E_o (ksi)
Douglas Fir	Beams and stringers	1.60	0.17	0.625	1600

Reference Design Values for Structural Glulam (AASHTO Table 8.4.1.2.3-1)

Species	Combination Symbol	F_{bo} (ksi)	F_{vo} (ksi)	F_{cpo} (ksi)	E_o (ksi)
Douglas Fir	24F-V4	2.40	0.265	0.650	1800

Reference Design Values for Visually Graded Dimension Lumber (AASHTO Table 8.4.1.1.4-1)

Species	Size	F_{bo} (ksi)	F_{vo} (ksi)	F_{cpo} (ksi)	E_o (ksi)
Douglas Fir	Width greater than or equal to 2in.	1.50	0.18	0.625	1900

1) Typically used in timber slab bridges.

1.4.8 Wearing Surface Materials

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Add 1" to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples.

Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½" to the design thickness of PPC overlays to account for construction variations and uncertainty.

For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all wearing surface dead loads (stage 2 dead loads) equally among all girders.

1.5 Process Basics

1.5.1 Standard Load Rating Trucks

The MBE Specification makes clear distinctions between Design Load Rating, Legal Load Rating and Permit Load Rating. Because information at all these load levels is useful for load restrictions and general bridge asset management, ODOT will disregard the flow chart in MBE Appendix A6A, and will require concurrent performance of all types of Load Ratings. ODOT will also subdivide Permit Load Rating into Continuous Trip Permit (CTP) Load Rating and Single Trip Permit (STP) Load Rating.

1.5.1.1 Design Live Load

The LRFD design live load is designated HL-93 and consists of various combinations of the Design Truck, Design Tandem and Design Lane Loads. The HL-93 loading is rated to provide a design check (see how the design compares to current design requirements) and provide structure inventory and appraisal data for reporting to the NBI. The configurations are shown in MBE Appendix C6A.

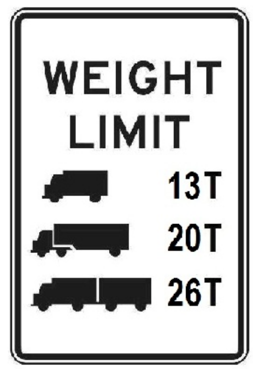
1.5.1.2 ODOT Legal Trucks

ODOT makes Legal Load posting decisions based on a set of legal trucks plus the Legal Truck and Lane combinations specified in the MBE Manual. Note that the Oregon Legal Type 3S2 vehicle is different (heavier) than the 3S2 vehicle in the MBE Manual. Refer to MBE Appendix D6A, figures D6A-4 and D6A-5, for required Lane-Type Legal Load Combinations. The "Lane-Type Legal Load Model" (Type 3-3 at 75% + Legal Lane Load of 0.2 klf) is not used as long as spans are < 200 ft.

Just a note regarding the "Lane-Type Legal Load Models":

> There is no need to manually modify or scale the load factors to obtain the 75% application of the legal vehicle in BRASS. Based on the "Live Load Type" that is entered in the third parameter of the LOAD-LIVE-DEFINITION (12-4.3) command, BRASS is programmed to only use 75% of the vehicle for these load combinations. This can be verified by searching for the "LIVE LOAD COMBINATIONS SUMMARY" in the BRASS output for the _T file (see Section 1.5.5.2 for the definition of the _T file).

The AASHTO legal vehicles, designated as Type 3, Type 3S2, and Type 3-3 are sufficiently representative of routine average truck configurations in use today, and are used as vehicle models for load rating. When a load rating shows that a bridge does not have sufficient capacity for any one of these standard legal vehicles, the bridge must be posted for load. When a bridge needs to be posted for less than legal loads, Oregon uses a single weight-limit sign or a three-vehicle combination sign that conforms to FHWA's *Manual on Uniform Traffic Control Devices* (MUTCD). The silhouettes on the three-vehicle combination sign represent the three standard legal vehicles described below.



Note that the signs shown above do not include weight limits for the Specialized Hauling Vehicles (SHV's), which are described in Section 1.5.1.3. Oregon has developed a new load posting sign that will eventually replace the sign with the silhouettes of the three standard legal vehicles shown above. Refer to the end of Section 1.5.1.3 of this manual for the description of the new load posting signs for the standard legal vehicles, which will also include load posting for the SHVs.

The 2017 Oregon Legislative Session passed House Bill 2462 into law, which allows commercial trucks that use natural gas as a fuel source to increase their allowed Gross Vehicle Weight by 2,000 LBS to compensate for the weight of the tanks and engine hardware needed to use the cleaner fuel source. ODOT's Motor Carrier Division has stated that natural gas is not a viable fuel source for long haul trucking operations. Therefore, ODOT has modified the load rating models for only the Type 3 legal vehicle and the Specialized Hauling Vehicles (SHVs) by adding 2,000 LBS to the steer axles. As a result, we now have an Oregon specific load rating vehicle model for the Type 3 and SHVs.

OREGON LEGAL LOADS - Load Rating LRFR

Revised April 26, 2018

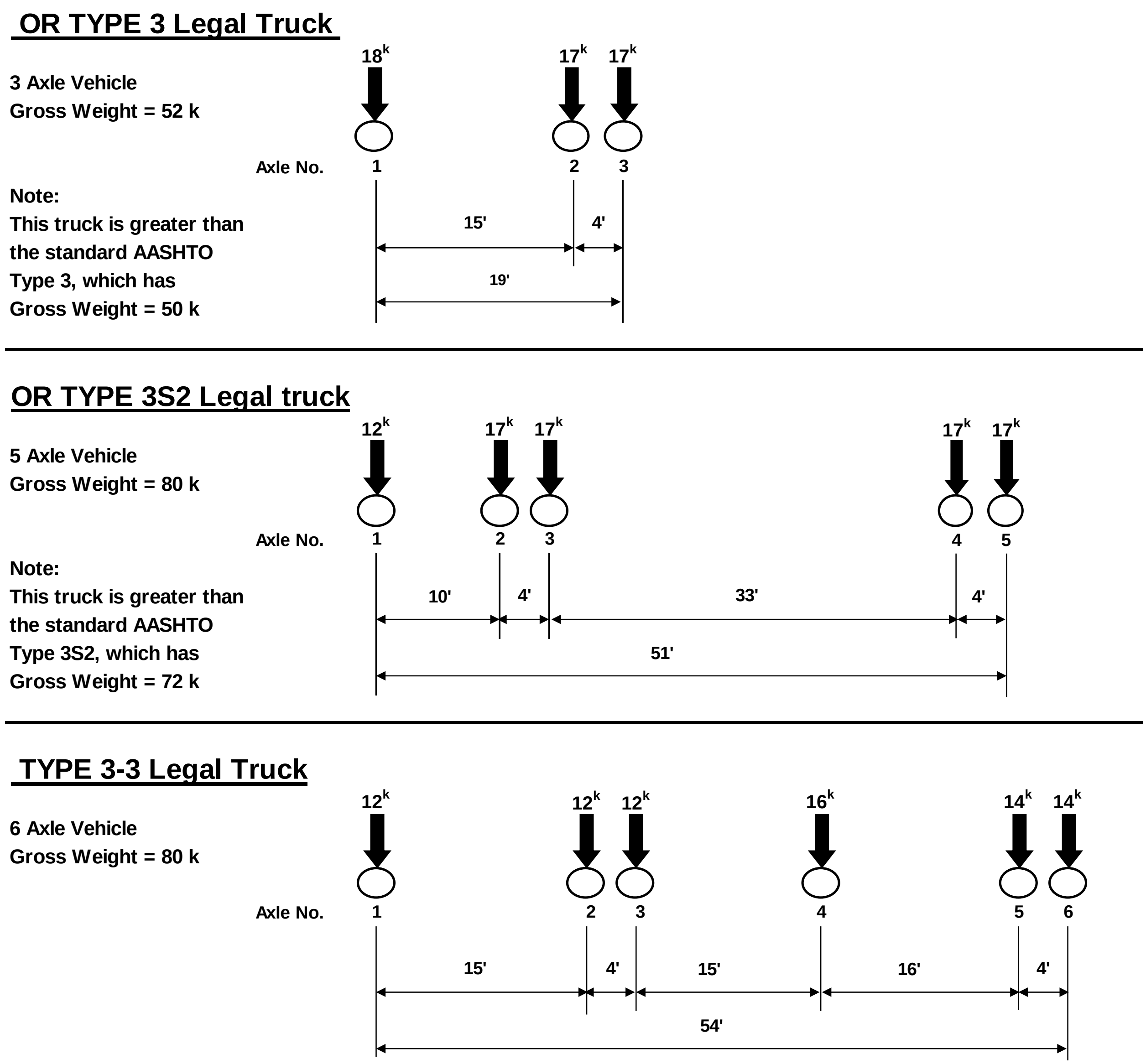


Figure 1.5.1.2A

1.5.1.3 Specialized Hauling Vehicles (SHVs)

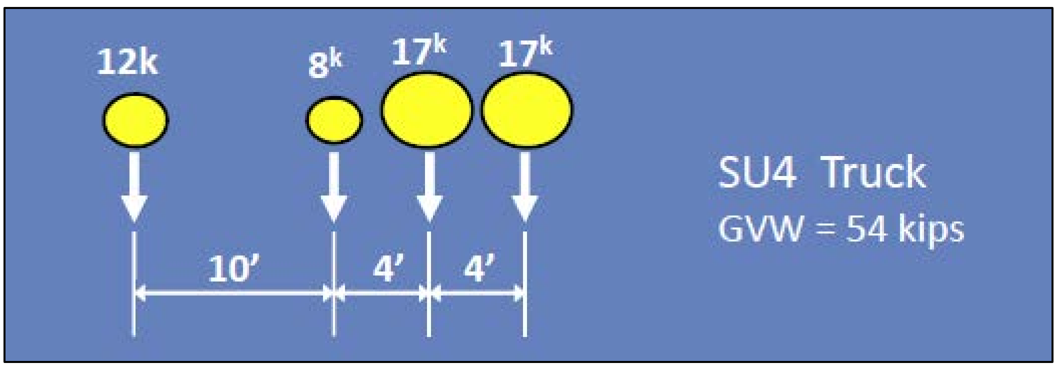
Specialized Hauling Vehicles (SHVs) are legal vehicles with legal axle weights that meet the Federal Bridge Formula (Formula B) equation for maximum axle group weight and represent short wheel based vehicles with multiple drop axles (such as modern concrete and dump trucks). These vehicles are commonly used in the construction, waste management, bulk cargo and commodities hauling industries. These vehicles consist of moveable axles that raise or lower as needed for weight, and result in higher loads concentrated over shorter distance.

Since the 1975 adoption of the American Association of State Highway and Transportation Officials (AASHTO) family of three legal loads, the trucking industry has introduced specialized single-unit trucks with closely spaced multipleaxles that make it possible for these short-wheelbase trucks to carry the maximum load of up to 80,000 lbs and still meet the "Formula B" equation. The AASHTO family of three legal loads selected at the time to closely match the Formula B in the short, medium, and long truck length ranges do not represent these newer axle configurations. These SHV trucks cause force effects in bridges that exceed the stresses induced by the Type 3, Type 3S2, or Type 3-3 legal vehicles by over 50 percent in certain cases. The shorter bridge spans are most sensitive to the newer SHV axle configurations.

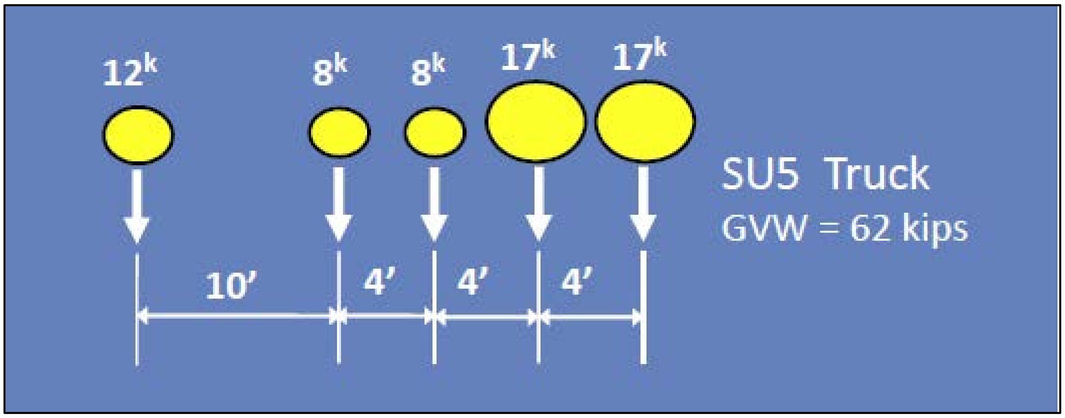
The Federal Highway Administration (FHWA) sent a memo to all states on November 15, 2013 requiring every state to post bridges for SHVs that do not pass a load rating analysis for these vehicles, in addition to the current standard legal vehicles.

Four Specialized Hauling Vehicle models were adopted by AASHTO in 2005 to represent new trucks that comply with Formula B and meet all Federal weight regulations.

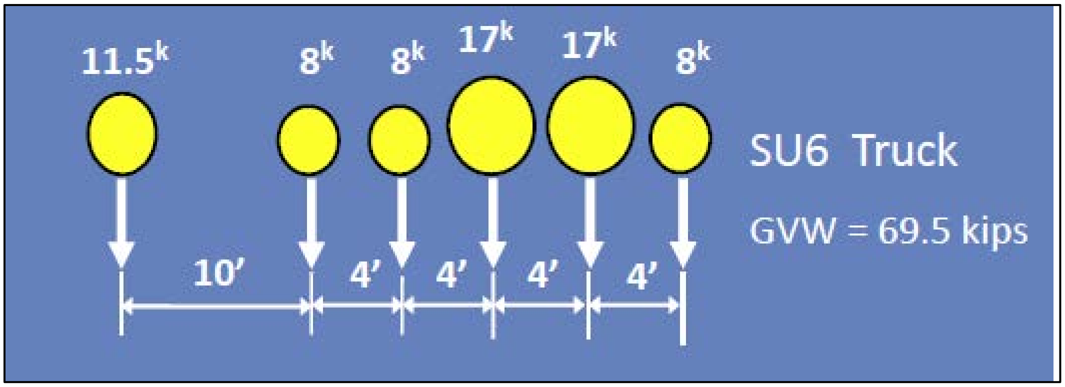
The first National SHV model is the SU4, which is a four axle vehicle with a gross vehicle weight of 54,000 LBS (27 tons).

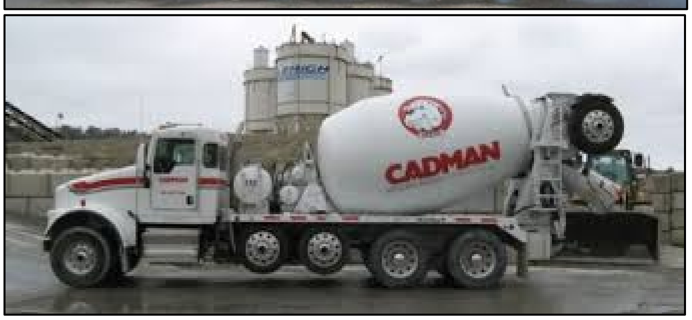


The second National SHV model is the SU5, which a five axle vehicle with a gross vehicle weight of 62,000 LBS (31 tons).

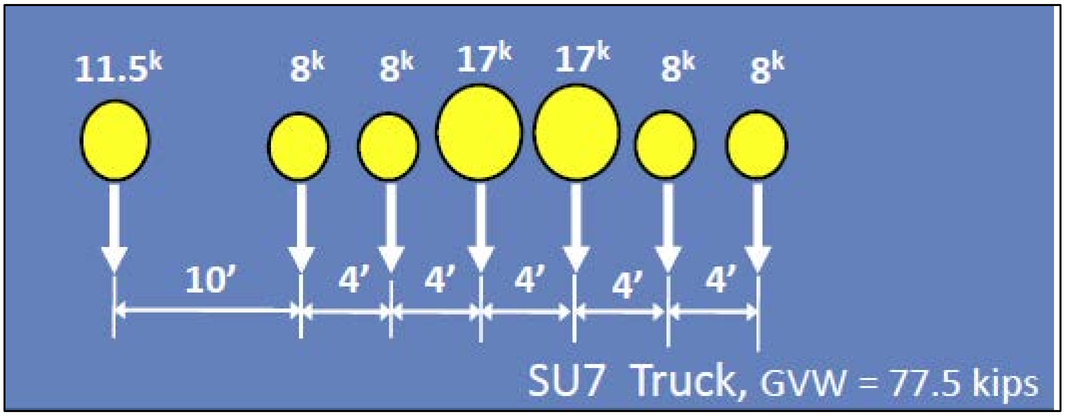


The third National SHV model is the SU6, which is a six axle vehicle with a gross vehicle weight of 69,500 LBS (34.75 tons).



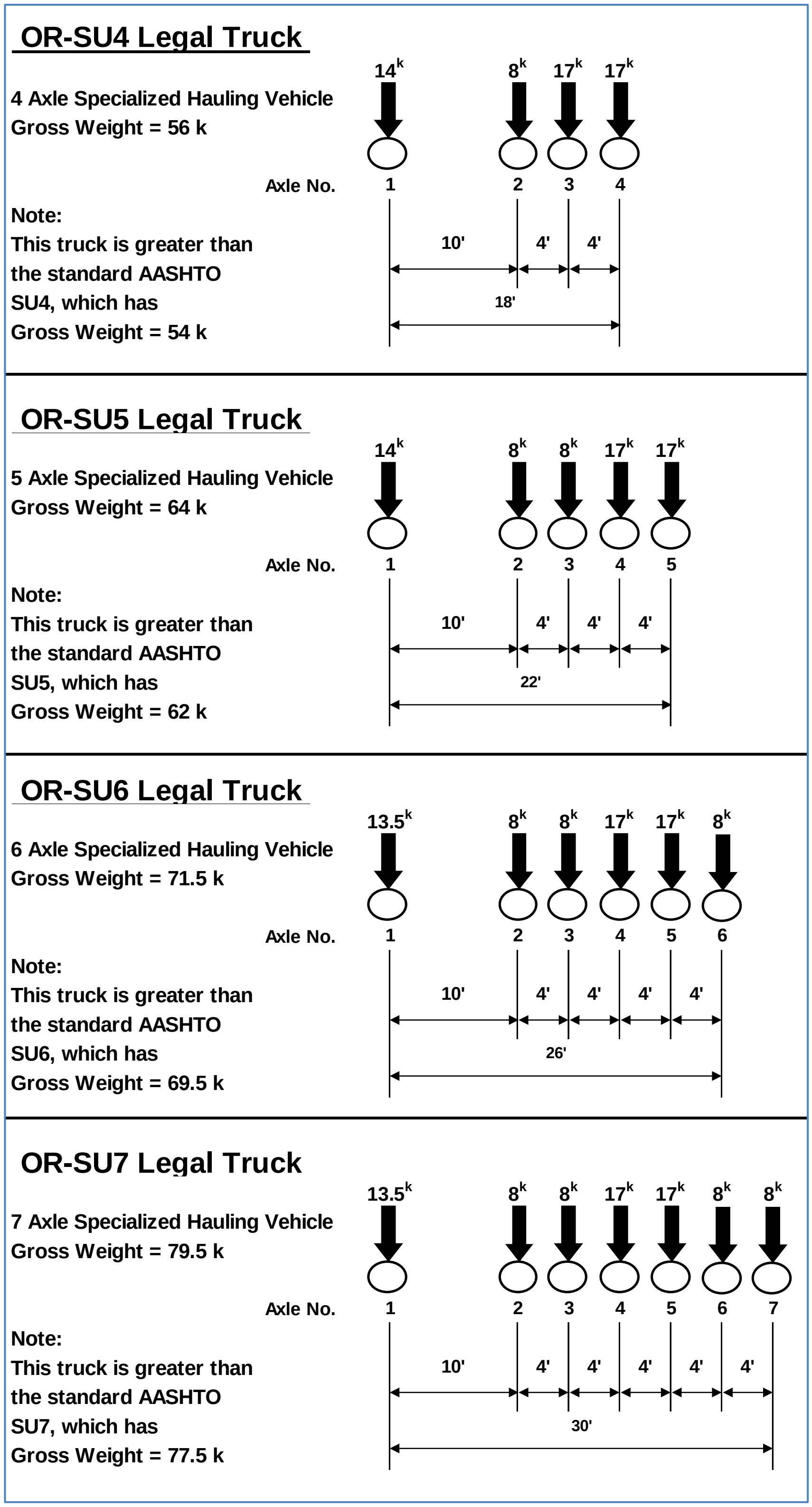


The fourth National SHV model is the SU7, which is a seven axle vehicle with a gross vehicle weight of 77,500 LBS (38.75 tons).



The effect of these 4 vehicles, designated SU4 (4 axles) through SU7 (7 axles), is upper-bounded by the introduction of a single 80-kip Notional Rating Load (NRL). Because this notional load has variable axle spacing, at this time it cannot be accommodated in BRASS without re-coding. Just as it is ODOT's policy to rate for specific Legal, CTP and STP vehicles even when a bridge is adequate for the HL-93 notional loading, in a similar manner ODOT will require rating for each of the specific SHVs (SU4 through SU7), regardless of the results that might be obtained by rating with the NRL.

As stated in Section 1.5.1.2, the 2017 Oregon Legislative Session passed House Bill 2462 into law, which allows commercial trucks that use natural gas as a fuel source to increase their allowed Gross Vehicle Weight by 2,000 LBS to compensate for the weight of the tanks and engine hardware needed to use the cleaner fuel source. ODOT's Motor Carrier Division has stated that natural gas is not a viable fuel source for long haul trucking operations. Therefore, ODOT has modified the load rating models for only the Type 3 legal vehicle and the Specialized Hauling Vehicles (SHVs) by adding 2,000 LBS to the steer axles. As a result, we now have an Oregon specific load rating vehicle model for the Type 3 and SHVs (the new Oregon SHV models are shown here to the right)..

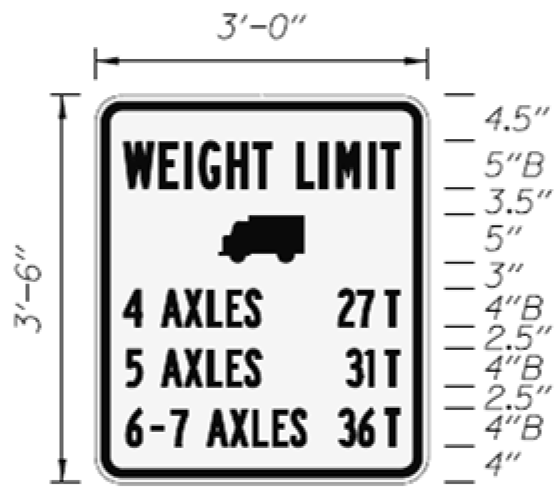


When a load rating shows that a bridge does not have sufficient capacity for any one of the four Specialized Hauling Vehicle models, the bridge must be posted for load. Posting signs must conform to the *Manual on Uniform Traffic Control Devices* (MUTCD). The MUTCD only has one sign (R12-5) that has silhouettes of trucks for load posting; which are for the three standard legal vehicles. The MUTCD does not allow any other silhouettes of trucks to be used on signs, so there will be no new silhouettes depicting the SHVs on a posting sign. Plus, there is a safety issue of having truck drivers attempting to count the number of axles depicted on a sign while travelling at highway speeds.

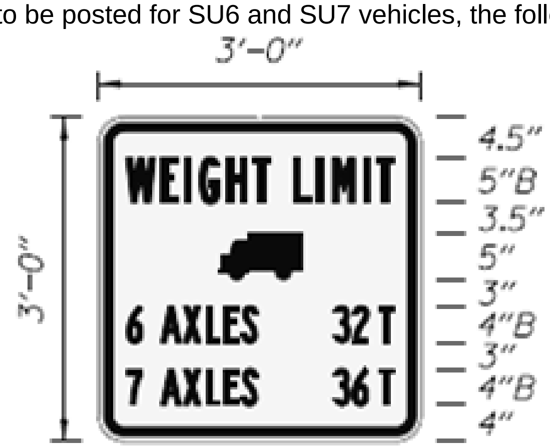
The MUTCD does allow the language on posting signs to be modified to account for the posting of

Specialized Hauling Vehicles. It is up to each state to determine the language to be used on the posting signs for SHVs. ODOT worked with the freight industry, Motor Carrier Enforcement, and local agencies to establish signs for the load posting for SHVs in Oregon. ODOT has designed new posting signs that will be used under different scenarios when a bridge requires posting for the standard legal vehicles and/or SHVs.

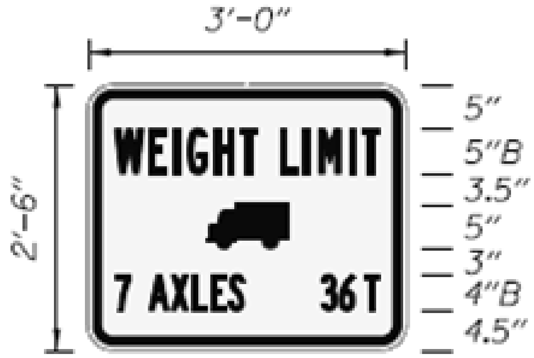
The first posting sign has three variations that can be used when the bridge has sufficient capacity for the three standard legal vehicles, but needs to be load posted for one or more of the legal 4-7 axle Specialized Hauling Vehicles. Since SHV trucks can cause force effects in bridges that exceed the stresses induced by the Type 3, Type 3S2, or Type 3-3 legal vehicles by over 50 percent in certain cases, there is a possibility that a bridge has sufficient capacity for legal axle weights and 80,000 LBS GVW for routine commercial traffic, but does not have sufficient capacity for the different SHV configurations. Instead of penalizing all trucks from using the bridge, the following posting signs were developed to restrict single unit vehicles to a lower gross vehicle weight. The posted weight for each single unit vehicle will be determined on a case-by-case basis for the safe load capacity of the bridge. When a bridge needs to be posted for SU4 or SU5 vehicles (which will also require the SU6 and SU7 vehicles to be posted), but the standard legal vehicles do not need to be posted, the following sign will be used:



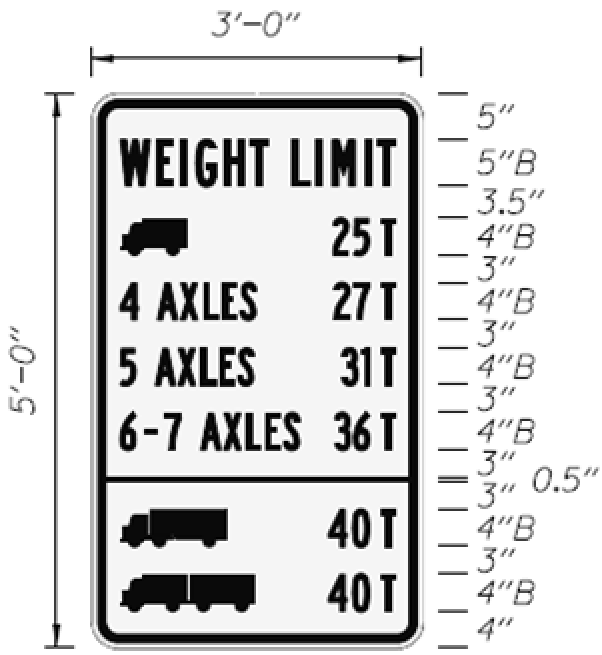
When a bridge only needs to be posted for SU6 and SU7 vehicles, the following sign will be used:



When a bridge only needs to be posted for the SU7 vehicle, the following sign will be used:



When a bridge needs to be posted for the standard legal loads, which will also require load posting for the SHVs, the following sign will be used:



These new posting signs are now included as an update to the ODOT Sign Policy and Guidelines for the State Highway System, which is now available on the ODOT Traffic-Roadway Section Sign Policy Information website:

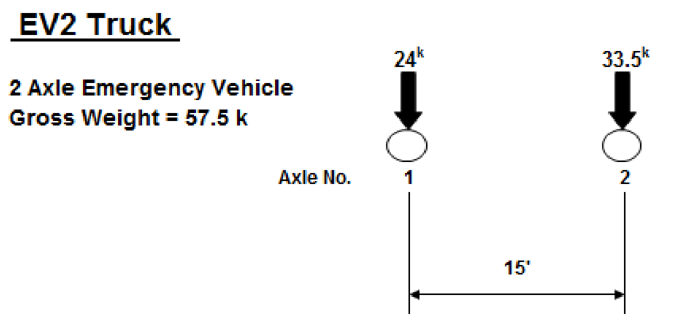
https://www.oregon.gov/ODOT/Engineering/Pages/Sign-Policy.aspx

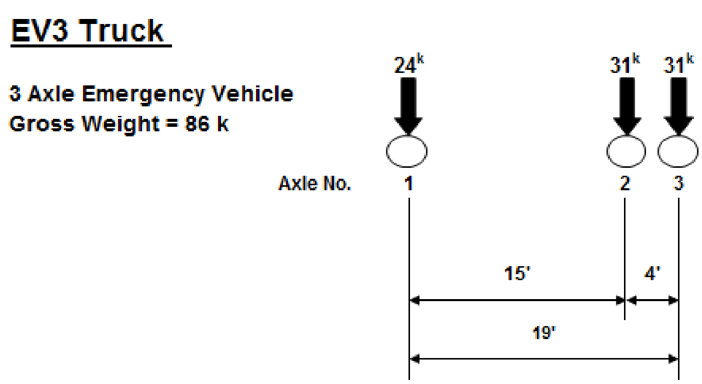
1.5.1.4 FAST Act Emergency Vehicles (EVs)

On November 3, 2016, the Federal Highway Administration sent Memorandum HIBS-1 to all state DOTs requiring that all bridges on the Interstate System and within reasonable access to the Interstate System be load rated and, if necessary, posted for the two new emergency vehicle configurations (EVs) that were developed in response to the revised weight limits for some vehicles resulting from the Fixing America's Surface Transportation Act (FAST Act). ODOT's implementation plan is to include the EV analysis for all LRFR load ratings. For bridges that are not on an Interstate System or within Reasonable Access, the EV ratings will be for information only.

Oregon Administrative Rule 737-073-0066 states that Reasonable Access is allowed up to and including one mile on highways intersecting National Network Highways, except where specifically prohibited.

Emergency vehicles are typically operated by fire departments and are primarily equipped for firefighting, but are also used to respond to and mitigate other hazardous situations in an emergency. These vehicles may not meet Federal Bridge Formula B. They can create higher load effects compared to the AASHTO legal loads (i.e., Types 3, 3S2, 3-3, and SU4 to SU7) which are currently included in the AASHTO Manual for Bridge Evaluation (MBE). The Federal Highway Administration (FHWA) has determined that, for the purpose of load rating, two emergency vehicle configurations produce load effects in typical bridges that envelop the effects resulting from the family of typical emergency vehicles that is covered by the FAST Act:





Load ratings (or rating factors) should be determined for these emergency vehicle configurations i.e., Types EV2 and EV3, at the operating or legal load rating level in accordance with the methods specified in the AASHTO MBE with two exceptions:

1. Multiple presence: If necessary, when combined with other unrestricted legal loads for rating

purposes, the emergency vehicle needs only to be considered in a single lane of one direction of a bridge.

2. Live load factor: A live load factor of 1.3 may be utilized in the Load and Resistance Factor Rating (LRFR) or Load Factor Rating (LFR) method.

ODOT's Bridge Engineering Section is working with ODOT's Motor Carrier Division to determine if using posting signs or a permitting system is the best course for restricting Emergency Vehicles. ODOT is also inquiring with AASHTO T-18 to see what is being done on a National level with the Emergency Vehicle posting signs. ODOT anticipates having either a posting or restriction process for EVs in place by January 1, 2019.

1.5.1.5 ODOT Continuous Trip Permit (CTP) Trucks

The designations for ODOT Permit Vehicles contain indicators of the type of permit - Continuous Trip Permit (CTP) or Single Trip Permit (STP), and the number of the MTCD Weight Table it represents. For example, "Type CTP-2A" indicates a Continuous Trip Permit vehicle that conforms to Weight Table 2.

OREGON CONTINUOUS TRIP PERMIT (CTP) LOADS - Load Rating LRFR

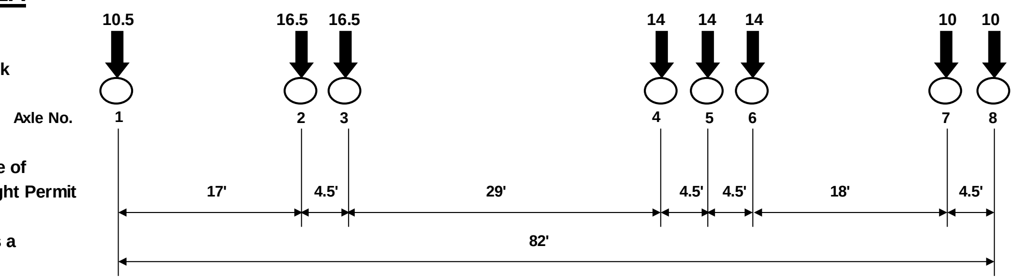
Revised May 12, 2006

Indicated concentrated loads are axle loads in kips

Type OR-CTP-2A

8 Axle Vehicle
Gross Weight = 105.5 k

Representative Sample of Annual Extended Weight Permit Weight Table 2
MCTD refers to this as a "Canadian Mule Train"
(This load was not used in Tier-1)

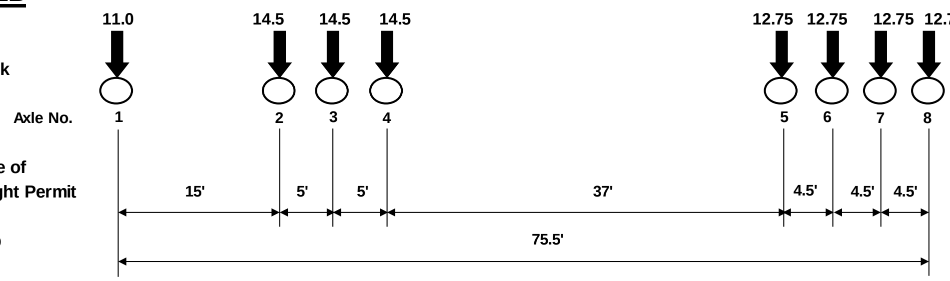


Type OR-CTP-2B

8 Axle Vehicle
Gross Weight = 105.5 k

Representative Sample of Annual Extended Weight Permit Weight Table 2
Maximum 4-axle group

(This load was not used in Tier-1)

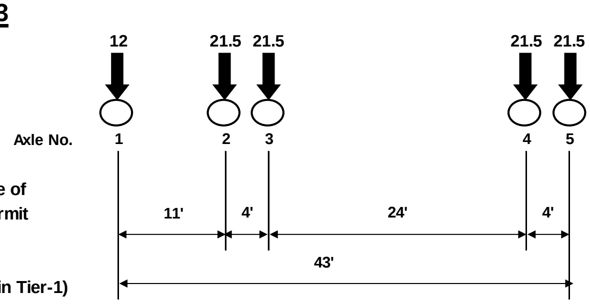


Type OR-CTP-3

5 Axle Vehicle
Gross Weight = 98 k

Representative Sample of Annual Heavy Haul Permit Weight Table 3

(Similar to "Permit-1" in Tier-1)



Note:
"Extended Weight" is a term that refers to trucks with axles or tandems the same as Legal Loads (20 k single-axle, 34 k tandem) but have a maximum GVW of 105.5 k. These are found in Weight Table 2. Examples of these include log trucks and milk tank trucks.

Figure 1.5.1.4

1.5.1.6 ODOT Single Trip Permit (STP) Trucks

The designations for ODOT Permit Vehicles contain indicators of the type of permit (CTP or STP) and the number MTCD Weight Table it represents. For example, “Type STP-4A” indicates this is a Single Trip Permit vehicle that conforms to Weight Table 4.

OREGON SINGLE-TRIP PERMIT (STP) LOADS - Load Rating LRFR

Revised May 12, 2006

Indicated concentrated loads are axle loads in kips

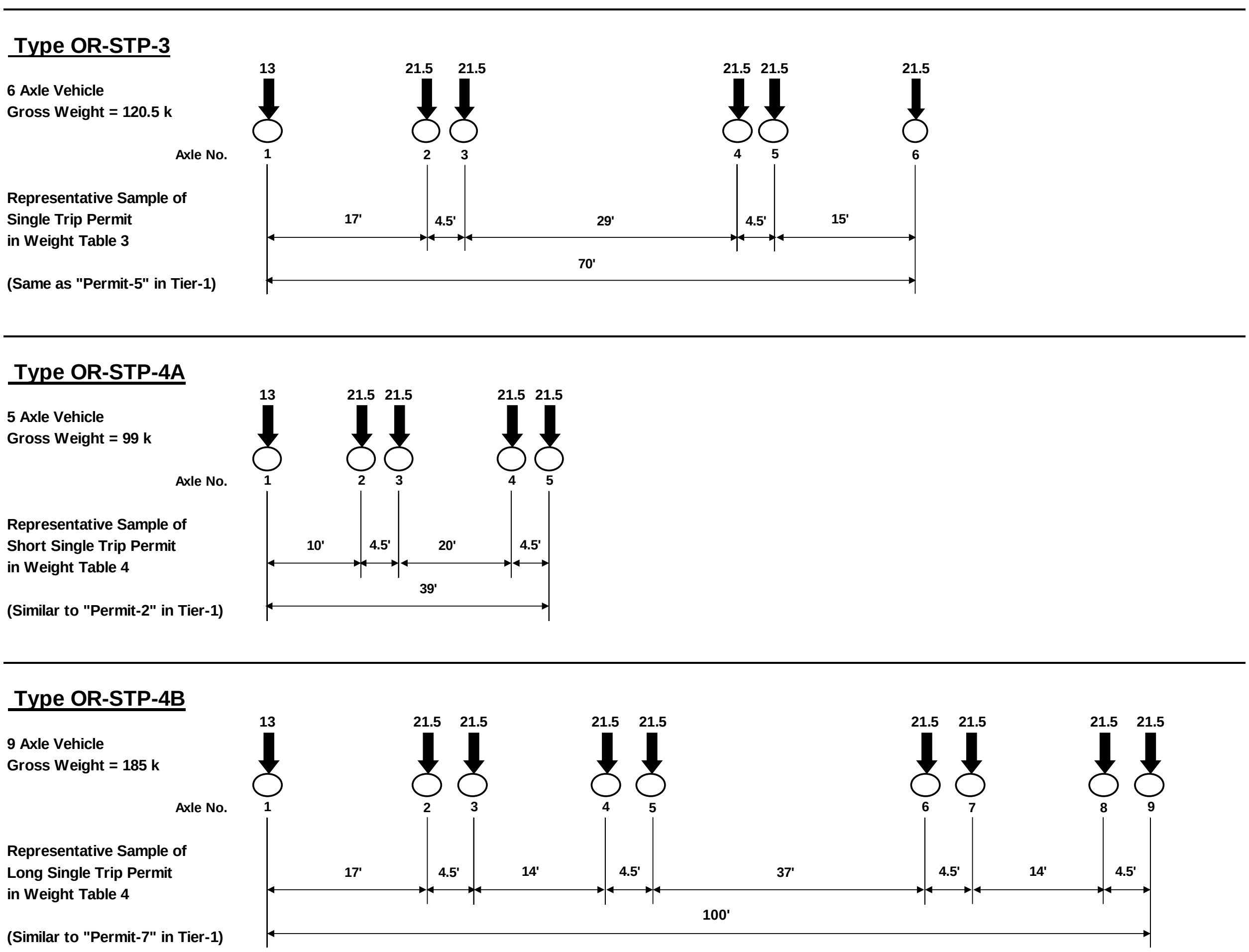


Figure 1.5.1.5A

1.5.1.6 ODOT Single Trip Permit (STP) Trucks (continued)

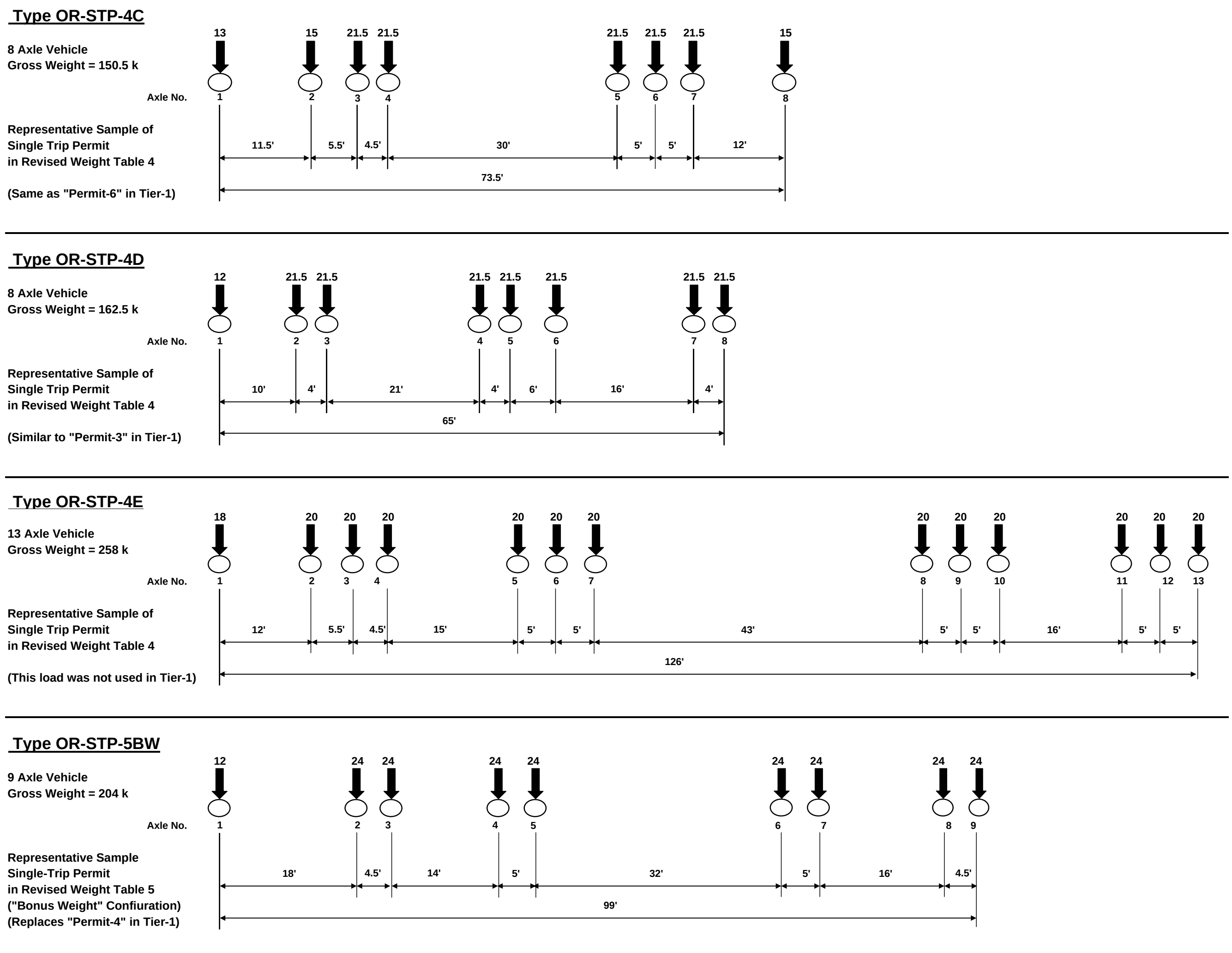


Figure 1.5.1.5B

1.5.2 Members to be Rated

Not every member in a bridge needs to be load rated. Load rating is recommended for only interior and exterior girders and crossbeams of RCDG bridges. Decks will not be load rated in this version of the Manual. Substructure members such as columns and footings are not routinely checked for load capacity.

1.5.3 Typical Critical Member Locations

Based on cracked bridge research at OSU*, Rating Factors should be investigated at the following groups of locations for RC Deck Girders, Prestressed Precast Concrete Members (girders, slabs, and

* Assessment Methodology for Diagonally Cracked Reinforced Concrete Deck Girders, SPR 350 (SR 500-091) published by ODOT Research Unit (October 2004)

boxes), and Post-Tensioned Concrete Members :

(1) Maximum Moment Locations (for both positive and negative moments; when applicable)
(2) Critical Shear Section Points (d_v from the support face at each end of each span)
(3) Flexural Bar Cutoff Points
(4) Girder Geometry Change Points
(5) Stirrup Spacing Change Points
(5) Locations of Significant Shear Cracks that are not related to one of the above conditions

To clarify the Load Rating process for future users, calculations of Rating Factor locations shall always be grouped in this way and presented in this order. Until further cracked bridge research indicates otherwise, the same section location criteria and procedure will be applied to crossbeams.

For steel girders and stringers, Rating Factors should be investigated at the following groups of locations:

(1) Maximum Moment Locations (for both positive and negative moments; when applicable)
(2) Critical Shear Section Points
(3) Bearing at support locations (performed when bearing stiffeners are defined in BRASS)
(4) Girder Geometry Change Points
    a. Moment should be checked at every location where the top or bottom flanges change (thickness, width, or material strength)
    b. Shear should be checked at every location where the web changes (thickness or material strength)
    c. Shear and moment should be checked at every location where the web depth changes

1.5.4 Analysis Tools

The majority of ODOT bridges are deck girder and box girder construction. Standard analysis tools have been chosen and developed to maximize efficiency and applicability to ODOT's bridge inventory while maintaining sound engineering practices.

To facilitate future revisions of Load Ratings by different parties and to avoid version compatibility problems, the ODOT Load Rating Team will specify the acceptable version(s) of software to be used.

Use of analysis software or versions other than those listed below is prohibited without the consent of the Load Rating Team.

1.5.4.1 BRASS

BRASS (**B**ridge **R**ating and **A**nalysis of **S**tructural **S**ystems) is a family of programs developed and maintained in the public domain by the Wyoming Department of Transportation. BRASS-GIRDER™ (Version 7.5), (also referred to herein as "BRASS"BRASS-GIRDER(LRFD)) is the primary program for Load Rating the majority of ODOT bridges. BRASS-GIRDER is different from the previous BRASS-GIRDER(LRFD) program in that it no longer uses text file inputs, but instead utilizes a Graphical User Interface (GUI) with data saved in xml file format. Instead of developing new procedures to populate the GUI of BRASS-GIRDER, this manual will continue to give instructions on how to create the text input file for BRASS-GIRDER(LRFD). Once the file is ready for analysis, the user will run the text input file through the BRASS-GIRDER translator that will create the xml input file used to populate the new GUI. From there the user will be able to run the analysis within BRASS-GIRDER.

BRASS-GIRDER and BRASS-GIRDER(LRFD) both utilize a finite element method of analysis and follow the current AASHTO LRFD specifications. It computes moments, shears, axial forces, deflections, and rotations caused by dead loads, live loads, settlements and temperature change.

These actions are utilized by various subroutines to rate user-specified sections of the deck or girder. It is capable of rating steel, timber and concrete deck and box girder bridges, but is currently not applicable to transverse crossbeams or floor beams in the above structure types. It is not capable of analyzing and rating truss, arch, cable stayed, and suspension bridges.

Web link:
http://www.dot.state.wy.us/home/engineering_technical_programs/bridge/brass/brass_suite_pricing/brass_girder.html

To provide as much consistency as possible across various structure types, and to allow for future nonstandard permit load investigations in a short timeframe, ODOT Bridge Section will require the use of the BRASS-GIRDER program for Load Rating of the following bridge types:

Steel girders and stringers (both composite and non-composite) in girder and truss bridges
Reinforced concrete deck girders
Reinforced concrete box girder bridges
Reinforced concrete slab bridges
Reinforced concrete rigid frames
Precast prestressed concrete girders (pre-tensioned)
Precast prestressed concrete slabs (referred to in AASHTO Art. 3.23.4.1 as multi-beam decks)

A sample BRASS-GIRDER(LRFD) input file (**INTGIR.DAT**) for a similar structure will normally be used as a starting point to develop the input file for the bridge being rated.

1.5.4.2 Mathcad

Mathcad™ from PTC (Parametric Technology Corporation, formerly Mathsoft™), is used for creating Preliminary Files for girders, slabs, crossbeams, etc. Mathcad lets you work with mathematical expressions using standard math notation - but with the added ability to recalculate, view, present, and publish with ease.

A sample Mathcad Preliminary File (**INTGIR.XMCD**) for a similar structure will normally be used as a starting point to develop the Preliminary File for the bridge being rated.

ODOT Load Rating Preliminary Files should be created in either version 15 or Prime 2.0. A previous version of Mathcad is acceptable but must be independently checked for compatibility with version 15.

Notes: To eliminate the wavy lines (spelling error warnings) on Mathcad printouts, from the menu go to Tools/Preferences, click on the “Warnings” Tab and uncheck the “Show Warnings…” box. Use the same general Mathcad format as the ODOT load rating examples. Do not incorporate colored backgrounds or text, arrays, advanced programming techniques, auto-solvers or other advanced features beyond what is found in the examples. The intent is to have Mathcad files that are readily understandable and usable by future load raters without the need to learn the advanced features of Mathcad.

Web link: https://www.ptc.com/en/products/mathcad/

1.5.4.3 Excel

Microsoft™ Excel is used for several calculation tools supporting the Preliminary Files, for Crossbeam Load Rating Analysis files, and for the Load Rating Summary Workbook. ODOT currently uses the Microsoft™ Office 2010 Program suite. Thus, these tools must be saved as Macro-Enabled Workbooks in Microsoft™ Excel 2010.

Several tools have been developed to provide consistent input and aid in the Load Rating process:

LR_Trucks_Annotated_Tier2.XLS (Shows all ODOT Legal, Continuous Trip Permit, and Single Trip Permit vehicles that will be rated. There is also a matrix available with details on the Weight Tables and other important considerations.)

Bar_Ld.XLS (Shows top bar and bottom bar development lengths for both 40 ksi and 60 ksi rebars)

LL_Factors_State.XLS (A file to determine the live load factors for Legal, Continuous Trip Permit, and Single Trip Permit vehicles. This file implements the Oregon-specific LRFR live load factors and is only applicable to State-owned bridges.)

LL_Factors_Local_2013.xlsm (A file to determine the live load factors for Legal, Continuous Trip Permit, and Single Trip Permit vehicles. This file implements the LRFR live load factors in the national code that were revised in 2013 and is only applicable to Local-Agency-owned bridges.)

LL_Factors_Refined_2013.xlsm (A file to determine the live load factors for Legal, Continuous Trip Permit, and Single Trip Permit vehicles. This file implements the LRFR live load factors in the national code that were revised in 2013 and is only applicable to refined analysis models of a bridge where the LRFD distribution factor equations or Lever Rule for girder line analysis were not used.)

dv_Calculator.XLS (Worksheet used to calculate effective shear depth d_v, used for determination of the critical section for shear.)

RAILDL.XLS (A summary of current and past standard rail dead loads tabulated according to their Standard Drawing Number.)

TOC.XLS (A sample file that will be modified to become the Table of Contents that will be placed in the completed Load Rating.)

LR.xltm (A template for the Load Rating Summary Workbook where the Rating Factors for each analysis point are recorded. The first and second controlling members are listed on the first page, and all Rating Factors less than 1.0 are shown in bold print.)

XB_RC.XLT (A template for the file that is used to input the design and loading conditions for reinforced concrete crossbeams. This file is to be saved as a Crossbeam Analysis Data File.)

XB_S.XLT (A template for the file that is used to input the design and loading conditions for steel crossbeams. This file is to be saved as a Crossbeam Analysis Data File.)

XB_T.XLT (A template for the file that is used to input the design and loading conditions for timber crossbeams. This file is to be saved as a Crossbeam Analysis Data File.)

XB_MAIN.XLS (The Crossbeam Analysis Program used with XB_RC.XLT, XB_S.XLT, and XB_T.XLT to determine the Rating Factors for crossbeams.)

1.5.4.4 Word

Microsoft Word (2010) is used only to create the label for the Load Rating Report cover. Therefore, all Microsoft Word files should be saved as the Word 2010 (*.docx) format.

Label.docx (A sample Microsoft Word file that will be modified with bridge-specific information to create the label for cover of the Load Rating Report)

1.5.4.5 Internet Explorer

Microsoft Internet Explorer used to be used only to save the Bridge Inspection Report and SI&A Sheet when these documents are called up on the ODOT Bridge Inspection web pages. However, it has been discovered that these file types can become corrupted and will not open after being saved for long periods of time as newer versions of Internet Explorer cannot read the coding in the older saved files. For this reason, it is preferred the Bridge Inspection Report and SIA sheets get printed/saved as an Adobe Printable Document Format (pdf).

1.5.4.6 Notepad++

Notepad++ is a free, open-source, plain-text editor and source code editor for use with Microsoft Windows. It supports tabbed editing, which allows working with multiple open files in a single window.

Microsoft Word and other word processors should not be used for BRASS input files as they introduce hidden formatting characters that are likely to render the files unusable by BRASS.

Those who expect to do a significant amount of ODOT Load Rating work are advised to associate the file extensions **.**DAT, **.**OUT, **.**DST, **.**EFF, **.**RFS, **.**ERR and **.**RPT with their text editor so these text files can be launched directly by double-clicking on the filename in a file management program.

1.5.4.7 WordPad

The Microsoft WordPad application, normally furnished with the Windows operating system in the “Accessories” folder, can be used for the same purposes as Notepad++. Because it supports a few different file formats, make sure that only the “Text Document” file type is used.

1.5.4.8 Adobe Portable Document Format

Invented by Adobe Systems and perfected over the years, Adobe Portable Document Format (PDF) lets you capture and view robust information—from any application, on any computer system—and share it with anyone around the world. Adobe PDF files look exactly like original documents and preserve source file information — text, drawings, 3D, full-color graphics, photos, and even business logic — regardless of the application used to create them.

Any hand and/or computer generated drawings or sketches that are used to compute or clarify the dimensions or geometry of the load rated members shall be submitted as part of the electronic file set in Adobe Portable Document Format (PDF).

Adobe Portable Document Format (PDF) can be used to save the Bridge Inspection Report and SI&A Sheet when these documents are called up on the ODOT Bridge Inspection web pages. This applies to bridges Load Rated within ODOT, or where these files are provided to an external Load Rater.

BIRnnnnnn.PDF (Current Bridge Inspection Report for Bridge Number nnnnnn. Usually this file includes the Structure Inventory and Appraisal Sheet).

SIAnnnnnn.PDF (Current NBI Structure Inventory and Appraisal Sheet for Bridge Number nnnnnn). Only create and save this file if for some reason the SI&A sheet was not saved with the Bridge Inspection Report.

1.5.4.9 MicroStation

MicroStation is a suite of CAD software products for 2- and 3-dimensional design and drafting, developed and sold by Bentley Systems. The latest versions of the software are released solely for

Microsoft Windows operating systems. Its native format is the DGN (DesiGN file) format.

ODOT's only CAD platform is MicroStation. Therefore any CAD drawings or sketches that are used to compute or clarify the dimensions or geometry of the load rated members shall be submitted as part of the electronic file set in not only the Adobe Portable Document Format (PDF), but also in the MicroStation design file (DGN) format. This will allow those reviewers who have access to MicroStation to be able to open the CAD file and physically measure and verify the dimensions as they are drawn.

1.5.4.10 ODOT Concrete Bridge Generator

Created by ODOT, the ODOT Concrete Bridge Generator (CBG) is a stand-alone windows software package that is a pre-BRASS processor for Cast-In-Place concrete bridge girder sections. Once the user enters basic bridge information, concrete section geometry, span configuration geometry, and the longitudinal reinforcement within the form fields, the program will generate the first half of the BRASS code. The program will also generate the BRASS code for the bar cut-off shear points that the user will paste into the appropriate locations in the BRASS input file.

The CBG is solely for the Microsoft Windows operating system and utilizes the Microsoft .NET Framework. The program's native format is the CBG (Concrete Bridge Generator) file format.

1.5.4.11 ODOT BRASS Moment Analyzer

Created by ODOT, the ODOT BRASS Moment Analyzer is a stand-alone windows software package that will evaluate the BRASS output files after an initial BRASS run and determine if the maximum positive moment locations for the live loads differ from the dead load locations. If so, the program will then analyze the differences in the locations and then provide a range of recommended positive moment locations (at 20th points) along with the BRASS commands for these new flexural analysis locations that can be copied and pasted into the BRASS input files. The program will create a text file, with the modified name of _MOMENT_INITIAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

After the final BRASS run, the BRASS Moment Analyzer can be used to once again evaluate the BRASS output files. This time, the software will check and report if the maximum combined moment for every vehicle at each analysis point is negative, positive, or contains both negative and positive values. The program will allow the user to print a summary report which they can refer to when selecting the type of moment during the BRASS import of the moment locations on the Load Rating Summary sheet. The program will create a text file, with the modified name of _MOMENT_FINAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

Do not include the BRASS Moment Analyzer output in the printed Load Rating Calc. Book. We only request that the .TXT files that it produces be included with the electronic files for the load rating.

The intent is to only use the BRASS Moment Analyzer for continuous bridges with adjacent span lengths that vary more than 30%.
The ODOT BRASS Moment Analyzer is solely for the Microsoft Windows operating system and utilizes the Microsoft .NET Framework.

1.5.4.12 Midas Civil

Midas Civil is a general finite element analysis software. At this time, post-tensioned box girder analysis is not adequately supported by BRASS GIRDER LRFD, thus Midas Civil has been selected to analyze load effects for these bridges. Midas Civil is also used in ODOT's load rating procedures to model the load effects of arch bridges, steel truss bridges, bridges with complex geometry, and to perform grillage analysis in order to refine distribution factors for bridges rating out low. Detailed output is not required to be included in the Load Rating Calculation Book. The electronic file does need to be submitted with the electronic deliverables.

1.5.5 File Naming Conventions

1.5.5.1 Path Name

To allow for future archiving and retrieval, always store the complete Load Rating File Set for each bridge in a folder named with the 5- or 6-character NBI Bridge Number. For State-owned bridges this normally means a 5-digit numeric (padded with leading zeros as necessary) sometimes followed by 1 alphabetic character if part of the Bridge Number. The first 6 characters are to be identical to the first 6 characters of the 15-character structure number that appears in the National Bridge Inventory (Item 8 on the SI&A sheet). Do not insert a leading zero in front of a 5-digit Bridge Number.

1.5.5.2 File Name Root:

Generally, for the file root name (or prefix, the portion before the period) use a meaningful (not arbitrary) file name, preferably 8 or less characters, containing no spaces (the underscore character is acceptable, a comma is not).

For BRASS files, identify the girder type (interior or exterior, or girder labeling letters as indicated on the plans, such as GIR_A, GIR_B, etc.).
This leaves up to 6 characters at the beginning of the name for the girder description.

For crossbeam Preliminary and Analysis files, use “XB_BentXX” where XX is the bent number.

For the Load Rating Summary Workbook, use "LRnnnnnn" where nnnnnn is the unique 5- or 6-digit Bridge Number. (Do not insert a leading zero in front of a 5-digit Bridge Number).

1.5.5.3 File Name Extension:

The following will be the only acceptable file extensions and file formats in the Load Rating File Set:

.DAT BRASS Input file, a pure ASCII text file readable by any ASCII text editor
.OUT BRASS Output file, a pure ASCII text file readable by any ASCII text editor with large file capacity. Note: Always use the same file root name as the BRASS input file.
.DST BRASS Distribution Factor file a pure ASCII text file readable by any ASCII text editor

.EFF BRASS Effective Flange Width Calculation Output file, a pure ASCII text file readable by any ASCII text editor. With the 2008 revisions to the AASTO LRFD code, the effective flange width calculations were changed to simply equate to the adjacent girder spacing. Thus, there is no need to have BRASS calculate the effective flange widths.
.ERR BRASS Error Message File (the less you see these, the better).
.BLB BRASS Library File, a reference file use by BRASS-GIRDER(LRFD) for storing truck definitions or section properties, prior to the release of BRASS-GIRDER(LRFD) 2.0.0.
.BLS BRASS Section Library File, a reference file use by BRASS-GIRDER(LRFD) Version 2.0.0 or later for storing section properties. Not compatible with releases of BRASS-GIRDER(LRFD) prior to 2.0.0.
.BLV BRASS Vehicle Library File, a reference file use by BRASS-GIRDER(LRFD) Version 2.0.0 or later for storing truck definitions. Not compatible with releases of BRASS-GIRDER(LRFD) prior to 2.0.0.
.DOC Microsoft Word (97-2003) file, used for cover label and optionally for supporting documentation
.docx Microsoft Word (2010) file, used for cover label and optionally for supporting documentation
.xmcd Mathcad file used for the Preliminary File which provides input for girder or slab analysis using BRASS or crossbeam analysis using the ODOT Crossbeam Load Rating Software

.XLS	Microsoft Excel (97-2003) spreadsheet file, used for the Load Rating Summary Workbook, Table of Contents, the ODOT Crossbeam Load Rating Software, the Crack Map Report and various calculation tools supporting the Preliminary File
.xlsm	Microsoft Excel (2010) macro-enabled spreadsheet file, used for the Load Rating Summary Workbook, Table of Contents, the ODOT Crossbeam Load Rating Software, the Crack Map Report and various calculation tools supporting the Preliminary File
.HTM	Hypertext Markup Language file, optionally used to contain the Inspection Report and SI&A Sheet
.TIF	Tagged Image File Format used for scanned bridge construction drawings
.PDF	Adobe Portable Document Format, an acceptable format for bridge drawings, hand sketches, CAD drawings, inspection reports and SI&A Sheets.
.DGN	MicroStation design file format, used for CAD drawings or sketches that are used to compute or clarify the dimensions or geometry of the load rated members.
.CBG	ODOT Concrete Bridge Generator (CBG) file, used to save the data entered within the ODOT Concrete Bridge Generator program.
.pnh	ODOT LRFR Pin and Hanger (PNH) file, used to save the data entered within the ODOT LRFR Pin and Hanger program that load rates pin & hanger connections as well as beam hinges.
.XML	BRASS XML format input file used to populate the BRASS-GIRDER GUI interface. This file is created when a BRASS-GIRDER(LRFD) file is ran through the BRASS Translator tool that is a part of BRASS-GIRDER.
.PDF	Portable Document Format file, since a pdf will maintain the original fonts, images, graphics as well as the exact layout of the file, some prefer to use this format for saving and printing the bridge inspection reports or printing groupings of bridge plans,

Files with different extensions (for different purposes) share the same root name indicating the member. For example, an interior girder could have a Preliminary File **INTGIR.xmcd**, a BRASS Input File **INTGIR.DAT**, a BRASS Output File **INTGIR.OUT**, a BRASS Distribution Factor file **INTGIR.DST,** and a BRASS Effective Flange Width Calculation file **INTGIR.EFF**.

Contact the ODOT Load Rating Team immediately if there are any questions or if conditions arise that appear to warrant a departure from this file naming convention.

For an illustration of the file naming conventions, see the sample Load Rating File Set in Article 12.2.

1.5.6 Work Flow

1.5.6.1 Assembly and Review of Support Documents

As a minimum, Load Rating requires the reference materials, the necessary software programs and software seed files, the as-constructed Contract Plans (including widening and other modifications), most recent Inspection Report and the SI&A (Structure Inventory & Appraisal) sheet. Inspection Reports and SI&A sheets can be obtained from the ODOT Intranet, and must be provided to load raters who do not have access to the ODOT Intranet. The Inspection and SI&A reports provide essential information for the determination of several parameters and factors involved in the LRFR process.

Additionally, other supporting documents are sometimes available that may contribute to the LRFR parameters and the overall engineering judgment concerning the load carrying capacity of the bridge. These include photos, correspondence and sketches from the Maintenance File, crack maps or descriptions, crack monitoring information, other recent Inspection Reports (especially if the frequency is less than 24 months), and special inspection reports such as cross-channel profiles, scour and fracture-critical reports. These additional inspection documents are also available on the ODOT Intranet. All relevant supporting documentation should be included with the Load Rating Report.

1.5.6.1.1 Assemble General Reference Materials

AASHTO LRFD Bridge Design Specifications, Customary U.S. Units, Eighth Edition (November 2017).

AASHTO The Manual for Bridge Evaluation Second Edition (2010) with 2016 interim revisions

LR_Trucks_Annotated_Tier2.XLS (This shows all ODOT Legal, Continuous Trip Permit, and Single Trip Permit vehicles that will be rated. There is also a matrix available with details on the weight table and other important considerations. This is a reference file that should *not* be included as part of the Load Rating File Set.)

This document, *ODOT LRFR Load Rating Manual.* (Shows procedures and has reference materials needed to accomplish Load Rating.)

1.5.6.1.2 Have the Necessary Tools Available

BAR_Ld.XLS (To calculate bar development length, top bar and bottom bar calculations for both 40 ksi and 60 ksi rebars. This is a reference file that should *not* be included as part of the Load Rating File Set).

LL_Factors_State.XLS (A file to determine the live load factors for Legal, Continuous Trip Permit, and Single Trip Permit vehicles. This file implements the Oregon-specific LRFR live load factors and is only applicable to State-owned bridges.)

LL_Factors_Local_2013.xlsm (A file to determine the live load factors for Legal, Continuous Trip Permit, and Single Trip Permit vehicles. This file implements the LRFR live load factors in the national code that were revised in 2013 and is only applicable to Local-Agency-owned bridges.)

LL_Factors_Refined_2013.xlsm (A file to determine the live load factors for Legal, Continuous Trip Permit, and Single Trip Permit vehicles. This file implements the LRFR live load factors in the national code that were revised in 2013 and is only applicable to refined analysis models of a bridge where the LRFD distribution factor equations or Lever Rule for girder line analysis were not used.)

dv_Calculator.XLS (Worksheet used to calculate effective shear depth d_v, used for determination of the critical section for shear.)

LR.XLT (Template for the Load Rating Summary Workbook where the Rating Factors for each analysis point are recorded and the first and second controlling members are identified.

XB_RC.XLT (Part of the ODOT Crossbeam Load Rating Software - the template that becomes the Crossbeam Analysis Data File.)

XB_MAIN.XLS (Part of the ODOT Crossbeam Load Rating Software – the Crossbeam Analysis Program used with XB_RC.XLT to determine the Rating Factors for reinforced concrete crossbeams. This file should *not* be included as part of the Load Rating File Set).
TOC.XLS (Sample that will be modified to become the Table of Contents that will be placed in the completed Load Rating).

Label.DOC (Sample that will be modified to label the cover of the completed Load Rating)

ODOT Concrete Bridge Generator (a pre-BRASS processor for Cast-In-Place concrete bridge girder sections that will generate portions of the BRASS input file).

Timber_Decay.xmcd (The Mathcad file used to calculate the adjusted reference values when timber members have decay.)

1.5.6.1.3 Collect Bridge Specific Materials

Current Inspection Report

Current Structure Inventory and Appraisal (SI&A) sheet

Current crack map (if available)

All Bridge Drawings (original construction, widening, overlays, rail retrofits, etc.)

Sample Mathcad Preliminary File for a similar structure (e.g. INTGIR.xmcd)

Sample BRASS-GIRDER(LRFD) input file for a similar structure (e.g. INTGIR.DAT)

1.5.6.1.4 Review Bridge Specific Materials

Taking time to examine the total materials available will help the rater to find the current condition and configuration of the structure, and potentially save many hours when "surprises" are found in the middle of the Load Rating process.

- Inspection Report

  Note that many inspection reports are excellent, each part building upon the other parts. However, some reports may have incomplete sections so it is critical to review the condition states, NBI ratings, remarks, and maintenance recommendations.

  AC Depth – This will be used to calculate the dead load of the wearing surface. Add 1" to the value given on the inspection report to account for unmeasured variations. The only exception will be when the remarks section indicates multiple core samples have been taken.

  Deck Element – Make sure that this is consistent with AC depth. Also, in some cases this may be the only indication that the bridge has a structural overlay. If there has been a structural overlay and there are no detailed drawings showing the depth of the overlay, assume 0.25" of deck wear/surface preparation and a 1.5" thick structural overlay. The net effect will be a 1.25" thicker deck. If element 513, Rigid Wearing Surface, is in condition state 3 or worse, or if there are inspector's remarks about significant delamination, consider the overlay as being non-structural. In this situation, the overlay just adds to the dead load, not structural depth. (Do not decrease girder or crossbeam height by ¼" for a non-structural overlay, since any increase in accuracy will be more than offset by the potential for errors). If the overlay is in good condition (no significant delaminations), and it consists of Portland Cement Concrete (PCC), Latex-Modified Concrete (LMC), or Micro-silica Concrete (Silica Fume Concrete), it will be counted as being structural and will increase the thickness of the deck and the cover for the top reinforcing bars. Overlays of AC or of Polyester Polymer Concrete (PPC) shall be considered non-structural (adding dead load only). Some designs may have specified a certain thickness of concrete as "Sacrificial wearing" on the plans, but if the additional thickness is still there and is sound, it is then still contributing to the capacity of the section. And thus, the sacrificial wearing thickness of the concrete should be considered as part of the structural cross-section of the member.

  Remarks – Look for concrete cracking, repairs to load carrying elements, and any notes that may help to describe the condition of the bridge.

Maintenance Recommendations - Look for repairs that have been completed, and conditions that need to be corrected.

- Concrete Crack Map

In the late 90's and early 2000s, bridge inspectors were providing concrete crack maps as part of their bridge inspections. However, sometime around 2010, it was decided that crack maps were no longer required as part of the bridge inspection. If a crack map exists, go ahead and include it as part of the load rating. This document will give detailed crack information of the structure. If there are significant shear cracks (>0.040") these locations will need to be analyzed. Note that many times only one girder line is mapped, and only one crossbeam is mapped. Look for notes in the crack map that show the element mapped is typical of other elements. Also, cross reference the inspection report to see the extent of cracking for girders and crossbeams. Note that with LRFR, there are many sections already analyzed, so chances are high that there is already an analysis point sufficiently close to the location of significant shear cracks.

- Structure Inventory and Appraisal

Note item 102, direction of traffic. If there are two directions of traffic, only half of the ADTT (one direction) will be used to determine the live load factors. This is because the probability of trucks in the passing lane is much higher than trucks traveling in opposite directions being on the bridge at the same time. Also note item 29 (Average Daily Traffic), item 30 (Year of ADT), and item 109 (Average Daily Truck Traffic) (Percent).

If the percentage of trucks in the traffic population is not available then use the following assumed values: for urban areas use 15% of the ADT for ADTT, and for rural areas use 25% of the ADT for ADTT.

- Drawings

Be sure that you have a complete set of drawings for the structure you will be rating. This includes widening, repairs, overlays, rail retrofits, and protective screening. If the bridge was widened, make sure to have drawings for the original structure. If the structure has a twin carrying traffic in the opposite direction, make sure that the Bridge Number on the drawings is actually for the bridge that is being rated. In some cases alpha suffixes were changed once the twin structure was built. In general, the NBI and the Bridge Log should be considered the reliable sources for the correct bridge number, not the contract plans.

In the case of bridges using standard drawings, especially for precast prestressed slabs or girders, compare the date of the standard drawing to the dates of the other drawings for the bridge. The available scanned standard drawing file *may* be scanned from a version that is later than the drawing actually used to build the bridge. Generally only the final version of a standard drawing was scanned and linked into BDS. This situation can sometimes result in the use of the wrong material strength or geometry in the load rating. If the final date on the scanned standard drawing is *later* than the other bridge drawings, it will be necessary to search through archives of older, superseded versions of standard drawings to find the version of the same standard drawing with the appropriate date. Users can search for date-stamped **.**PDF files of the most appropriate available version of superseded standard drawings on the ODOT FTP site (ftp://ftp.odot.state.or.us/Bridge/LoadRating/SupersededStandardDrawings/). If there does not appear to be a version of a standard drawing that precedes the date of the bridge plans, contact the ODOT Load Rating Unit to determine and provide the appropriate standard drawing(s).

1.5.7 Non-Typical Superstructure and Substructure Types

When load rating a superstructure or substructure type that is beyond the capabilities of BRASS or ODOT Crossbeam software, the Engineer performing the load rating is responsible for determining the load rating procedure. Here are a few issues to consider when developing the procedure:

1) **Can BRASS-GIRDER(LRFD) be forced to work using work-arounds?** An example would be performing a LFR load rating that has girder lengths greater than 200 ft. BRASS-GIRDER(STD) does not have the capability to perform the Lane Load case required in AASHTO (75% of Type 3-3 truck in combination with a 200 lb/ft uniform load), but BRASS-GIRDER(LRFD) *does* have the capability and can be forced to perform the load analysis. You may not want to use BRASS-GIRDER(LRFD) to determine the rating factors, since the capacity calculations have changed since AASHTO Standard Specification. A BRASS work-around is the preferred solution by ODOT since permit reviews can easily be performed.

2) **Can the ODOT Crossbeam software be forced to work?** An example would be load rating a non-Reinforced Concrete, non-Steel or non-Timber crossbeam. This can be performed in several situations by manually entering the section capacity or load influence ordinates into the ODOT Crossbeam software and then using the software to determine rating factors.

3) **Do the owner and ODOT have the software available to them to perform additional analysis of the structure?** This is required to perform permit reviews and assess the load capacity of the structure in the event of a change of condition.

4) **Can the number of programs used be minimized?** An example of using too many programs would be using QConBridge to determine HL93 loading and SAP 2000 to determine loading for legal and permit vehicles.

5) **Is additional analysis software really required?** In some instances when dealing with secondary force effects, the existing software may not be able to analyze those effects. If the effect of the additional force affects would result less than 3% change in the rating factors, you may want to consider ignoring them. An example would be when you have unequal length columns at a bent. Although it is possible that the forces are higher in certain sections of the crossbeam than those currently provided by the analysis, the Engineer should take into consideration that the entire analysis procedure is conservative from the live load factors, to how the loads are applied to the crossbeam. If you lack the confidence to make this sort of judgment, you may request permission from the ODOT Load Rating Unit to use a Finite Element Model, perform a complete 3D analysis, and potentially include all the force effects.

6) **Is the solution simple enough and is it documented well enough for other engineers to make future modifications?**

Software ODOT supports:

BRASS-GIRDER BRASS-GIRDER(LRFD) MIDAS Civil PSBeam	Response 2000 Excel Mathcad ODOT Concrete Bridge Generator ODOT's BRASS Moment Analyzer ODOT LRFR Pin and Hanger

The acceptable software version(s) change frequently and should be determined in consultation with the ODOT Load Rating Unit.

If you have any question contact ODOT Load Rating Section.

1.6 Improving Low Rating Factors

When a load rating analysis results in rating factors less than 1.0 for legal loads, the specific members that are rating out low will need to be repaired/strengthened, or the bridge will have to be posted for reduced truck loads. Likewise, if a bridge rates out low for permit vehicles, those members rating out low will have to be repaired/strengthened or the permit vehicles will be restricted from using the bridge. The engineering costs during the load rating analysis to improve low rating factors is relatively cheap compared to the construction costs to strengthen/repair a bridge or to the economic costs of load posting/restricting a bridge.

This section will list simple and complex refinements that can be used to improve low rating factors for a given bridge. If a bridge results in low rating factors after performing the initial load rating following the prescribed procedures outlined in this manual, the expectation is that the load rater at a minimum will apply the simple refinements listed within this section to attempt to improve the load rating. If these simple refinements do not get the rating factors above 1.0, then contact the ODOT Load Rating Unit to determine if the complex refinements listed within this section should be conducted.

Simple refinements are as follows:

- Round the rating factors of 0.95 and greater to 1.0, as long as no other refinements are used. If the engineer follows the general procedures in this manual for a common structure type, and no refined calculations for distribution factors and/or capacities are used in the calculation of the rating factors, the rating factors of 0.95 and greater can simply be manually rounded up to 1.0 where they occur on pages two and above in the load rating summary sheet. ODOT does not recommend rounding the rating factor values on page one of the load rating summary sheet because they might get overwritten by the actual rating factors if the “Refresh” button is pressed at the bottom of the load rating summary sheet. For primary truss members, arches, and other unusual geometry or structure types, please check with the ODOT Load Rating Unit to verify if this rounding procedure will apply for the given bridge.

- When the low rating factors occur for trusses, two-girder bridges, arches, exterior girder lines, and crossbeams, the Live Load distribution may be computed by placing the truck loads within the existing striped lanes of the bridge. As per MBE 6A.2.3.2, the transverse positioning of the truck should include placing the wheel load anywhere within the lane, including on the lane stripe.

- When the low rating factors occur for legal and permit vehicles where the full 33% dynamic impact was used, a reduced dynamic impact of 25% may be used for legal and permit vehicles instead (see Section 1.4.1.13). As per AASHTO LRFD Commentary C3.6.2.1, field tests indicate that in the majority of highway bridges, the dynamic component of the response does not exceed 25 percent of the static response to vehicles. The 33% that is used in design was a product of 4/3 and the basic 25% to compensate for the lane loading not being increased by the dynamic load allowance.

- Verify if a deficiency or section-loss can be accounted for in the capacity computations at a specific location in the bridge or member, instead of applying the condition factor globally to the entire bridge. If this is the case, then account for the section loss at the specific location (cross-section) and use a condition factor of 1.0, or only apply the condition factor for the particular location or member(s) that the inspection report specifies is deficient.

- For concrete members, include temperature/skin reinforcing steel that is further away from the tension face of the member.

- For concrete members, include compression steel for increased ductility.

Complex refinements are as follows:

- Refine Live Load Distribution Factors using a grillage model.

- Use actual material properties in the load rating analysis, which requires a minimum of 3 samples (concrete cores or steel coupons) of the bridge materials to be taken from the existing structure and tested in a materials lab. Material testing shall be conducted in accordance with the requirements of Section 5 of the AASHTO Manual for Bridge Evaluation (MBE) Third Edition. For concrete members, the material strength resulting from material testing shall be calculated in accordance with section 6A.5.2.1 of the MBE. For steel members, the material strength resulting from material testing shall be calculated in accordance with section 6A.6.2.1 of the MBE.

- For concrete members with low rating factors for shear, use actual concurrent forces from live loads instead of the maximum envelope forces that BRASS-GIRDER uses to compute the shear capacity.

- Use alternate/refined analysis to compute member capacities, such as strain compatibility, alternate shear capacity calculations for concrete from LRFD Appendix B5 (Tables), Response 2000, or Strut-and-Tie Analysis.

- Perform load testing on the bridge to calibrate actual live load distributions, determine actual dynamic impact, verify composite action up to a given load, or proof test the bridge to establish a target live load capacity.

1.7 When to Update an Existing Load Rating

The basic rule is that anytime a bridge has a change in capacity, condition, and/or dead load, the load rating should be updated to reflect the current state of the bridge. In order to manage the bridge program, ODOT has established a “Load Rating Threshold Criteria” that gives direction as to when a load rating needs to be updated when the condition of a bridge has digressed significantly from the conditions as to when the load rating was performed. The Load Rating Threshold Criteria is as follows:

- NBI Condition Rating Changes – Deck (58), Superstructure (59), Substructure (60)

Load Rating Factor	Load Rating Condition	Current Condition Rating
< 1.5	4 to 9	3 or less
$\geq$ 1.5	any	2 or less

Note: If the bridge is closed, posted, has temporary shoring, or there is a detour structure in place, there is no need to update the load rating. Only update the load rating for bridges that are open to traffic and where there are concerns that the condition has changed and the issues have not been addressed already.

- Increases in Dead Load on the Bridge

Load Rating Factor	Increase in Dead Load
< 1.3	Any Increase in AC Wearing Surface Thickness, Any PPC Overlay Thickness, or Any Structural Overlay Thickness
$\geq$ 1.3	Increase AC Wearing Surface Thickness of more than 2”, PPC Overlay Thickness of more than 1.5”, or Structural Overlay Thickness of more than 1.5”.
$\leq$ 1.3	Bridge Rail changed from post and rail to concrete barrier

- Change in the Traffic Impact

Load Rating Factor	Load Rating Condition Rating	Current Condition State Rating
$\leq$ 1.1	4 to 9 or CS1 or CS2	CS3

Note: Prior to the establishment of Element 999, all load ratings were based on the worse rating recorded for the “Approach Roadway Condition” or the “Wearing Surface Condition”. The cross-walk conversion factors are as follows:

- 6 to 9 - - - - - - CS1
- 4 to 5 - - - - - - CS2
- 3 or less - - - - CS3

- Changes in Temporary Repair Designation
    - Adequacy or Condition of Temporary Shoring is questionable.
    - Temporary Shoring is changed to Permanent Repairs --- NBI Items 103 and 41.
    - Permanent Repairs are determined to be Temporary --- NBI Items 103 and 41.

1.8 Tasks to Update an Existing LRFR Load Rating

For a typical concrete girder bridge that an engineer has not worked on the original LRFR load rating on, they will have to perform the following tasks for each rated member in order to take ownership and update the rating:

- Perform a cursory review of the MathCAD preliminary files to verify that there are no mistakes and to see if any special analysis or considerations had to be done for the rating of those members.
    - Download a copy of the latest Bridge Inspection Report to see if any of the conditions of changed since the previous load rating.
    - Modify condition factors if different from previous load rating
    - Update the ADTT computations based on recent BIR data and update Live Load Factors using current Live Load Factor spreadsheet.
    - Update dead load computations to account for new construction dead loads.
    - Document any details where bridge strengthening occurred so that they can be included in BRASS analysis.
    - Review analysis locations to verify that they are correct and other critical points are not missing.

- Review Concrete Bridge Generator input data to verify it is correct.
    - Include any changes to geometry, and/or longitudinal reinforcing details resulting from any strengthening projects.
    - Generate BRASS input from latest version of CBG to capture bug fixes and changes in design code.

- Review BRASS input files to verify there are no mistakes.
    - Combine older “N” and “T” input files into a single BRASS file that has all of the current load rating vehicles (if not done already).
    - Replace/include the BRASS input data from the latest version of the CBG tool
    - Update all factors and dead loads that were revised in the Mathcad preliminary file.
    - If any strengthening occurred or will occur, update the BRASS input file to account for the new details.
    - Include any new/corrected analysis points.
    - Re-run the BRASS analysis and import into the latest/current version of the load rating summary sheet. Do not re-use original load rating summary sheet.

- Review Crossbeam MathCAD preliminary file
    - Modify condition factors if different from previous load rating
    - Document any details where bridge crossbeam strengthening occurred so that they can be included in crossbeam analysis.
    - Review analysis locations to verify that they are correct and other critical points are not missing.
    - Update dead loads and live loads from BRASS output.

- Create a new crossbeam load rating analysis file. Do not reuse the original crossbeam file since the latest includes bug fixes and latest LRFD and load rating requirements.
    - Most of the data can be copied and pasted from the original crossbeam file, except where the data has been updated/modified as listed in the crossbeam preliminary file above.
    - Review the unchanged input data to verify that they are correct.
    - Re-run the crossbeam Main influence line analysis to verify the vehicle/lane placement is correct.
    - Copy and paste the results to the new load rating summary sheet.

- After all of the primary members have been load rated and included in the new load rating summary sheet, create a new load rating calc book that is stamped/sealed by the engineer that is now the Engineer of Record for the updated load rating
    - Include current load rating files that may have not been included in the original load rating, such as the load rating scoping sheet.
    - Only include the files/outputs from this updated rating, not the original load rating files that are no longer being used in the current rating.
        - Use the latest bridge inspection report, not the original
        - Don’t forget to include all plan sheets
        - CBG file input from latest version of the CBG tool.
        - The updated/new files listed in the bullets above.

The tasks above seems like a lot of effort, but should still be significantly less than doing the load rating from scratch. Other bridge types will require similar effort, but the engineer will have to review and modify the different software tools that were used for the bridge type being modified.

1.9 When to Rerate a Load Posted Bridge for SHVs

Bridges that have a single ton load posting for 15 tons or less do not need to be re-rated for SHVs as long as all of the following conditions are satisfied:

- The bridge has a valid load rating determined by one of the AASHTO recognized load rating methods;
- The load rating of the bridge is consistent with the current structural and loading conditions, and AASHTO Routine Commercial Traffic Legal Loads, i.e. Type 3, 3S2 and 3-3 vehicles have been rated for the bridge; and
- The safe posting load shown on the posting sign does not exceed the operating rating of the AASHTO Type 3 vehicle.

These directives are supported by the following two documents:

- FHWA letter approval (HAD.2-OR) that is dated April 21, 2015 and is provided in APPENDIX I of this manual.
- ODOT’s parametric study report, *Load Comparison for Posted Bridges,* that is provided in APPENDIX J of this manual.

SECTION 2: LOAD RATING REINFORCED CONCRETE DECK GIRDER BRIDGES

2.0 Scoping of Structure

Create a scoping file (nnnnnn_scope.xls) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended affect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0 then, there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

2.1 Decide What Girders to Analyze

Due to the effects of all the various LRFD Distribution Factor provisions, it is difficult to predict which girder will control the load rating. Therefore a separate preliminary file and BRASS input will be required for both the interior and exterior girder. In the Load Rating Summary Workbook file, importing the rating factors from both girders is required (be sure to do a “Refresh” after the second import) because it is not uncommon for different girders to control for different loads.

2.2 Preliminary Files for Girders (Mathcad)

For reinforced concrete deck girder bridges, the preliminary file name and extension (Mathcad) for interior girders is INTGIR.xmcd. The preliminary file name and extension for exterior girders is EXTGIR.xmcd. If there are more unique girders of each type, the file names should differentiate between them with some additional identifier (e.g. INTGIR_ORIG.xmcd and INTGIR_WIDEN.xmcd).

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied factors with parentheses.

2.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description ("Spans" field) from the Bridge Log is adequate for this purpose.

Note: the Mathcad regions at the top in the right margin (outside the printable area) are there for 2 purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

2.2.2 Resistance Factors

Document the decisions regarding all 3 Resistance Factors, with references to the appropriate MBE tables.

BRASS-GIRDER(LRFD) provides input for the MBE Condition Factor ϕ_c (MBE 6A.4.2.3) and System Factor ϕ_s (MBE 6A.4.2.4). However, the ODOT Load Rating Summary Sheet and the ODOT Crossbeam Load Rating Software always require and display the product of all the resistance factors as a single ϕ factor. Therefore, the product of all these resistance factors must always be obtained.

Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure:
$\Phi_f = \phi\ [\max(\phi_c\phi_{sf}, 0.85)]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Shear:
$\Phi_v = \phi\ [\max(\phi_c\phi_{sv}, 0.85)]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).

Generally Φ_f and Φ_v will be the same for redundant members such as girders and will be different for non-redundant members such as single-span and 2-span crossbeams.

2.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into BRASS. The Load Rating Summary Workbook **(LR.XLT)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and effective bridge length. Note that effective bridge length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which live load factor application is used, ADTT is specified as "one direction". Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the live load factor application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the live load factor application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the "LRFR Strength I & II" table from the live load factor application, and in Mathcad use Edit / Paste Special. In the "Paste Special" dialog box choose the "Paste" button, highlight "Bitmap" in the "As" list, and click the "OK" button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to MBE 6A.4.4.3.

2.2.4 Material Properties

Enter the material properties within the appropriate fields of the ODOT Concrete Bridge Generator (CBG) program, and the elastic modulus E_c and modular ratio n will be calculated. The CBG program uses AASHTO LRFD Equation 5.4.2.4-1 to determine the elastic modulus of concrete, assuming K_1=1.0. Document any assumptions made about the material properties if they are not given on the bridge plans within the Mathcad preliminary file.

2.2.5 Bridge Average Geometry

Calculate the physical edge-to-edge width of the concrete slab and the roadway width of the bridge. If the width of the slab or roadway changes over the length of the bridge, calculate the average roadway width per span. Enter the skew angle of the bridge. These values are entered in BRASS to calculate the Distribution Factors.

2.2.6 Shear Reinforcement Layout

Use an embedded Excel spreadsheet within Mathcad to calculate the ranges and span fractions for the shear reinforcement layout for each span as indicated below. Double-clicking on an embedded spreadsheet activates Excel, and its toolbars and functionality become available. An existing embedded Excel spreadsheet can be copied, pasted in another location and modified to do similar calculations for another span. Determine the shear reinforcement bar size(s) and area(s) that are present in each span that will contain analysis sections. Then for each span that contains analysis sections, working consecutively from the left end of the span to the right, populate the yellow fields in the following table in the preliminary file. Where there is an approximate "plus-or-minus" stirrup spacing given near the middle of a span, it is necessary to calculate this "remnant spacing" in Mathcad in order to complete the shear reinforcement layout accurately enough to code it in BRASS.

Span # :	1		Span Length :	68	ft	
Section	Spaces	Spacing (in.)	Start (in.)	Range (in.)	End (in.)	Span Fraction
1	7	4	3.00	28	31.00	0.004
2	4	11	31.00	44	75.00	0.038
3	51	13	75.00	659	734.00	0.092
4	4	11	734.00	44	778.00	0.900
5	8	4	778.00	32	810.00	0.953

2.2.7 Component Dead Loads (DC)

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the Preliminary (**.**xmcd) File as they will appear in the BRASS Input (**.**DAT) File. Use AASHTO LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c. For dead load calculations, use w_c+0.005 kcf to account for the reinforcement, in accordance with AASHTO LRFD Commentary C3.5.1.

Show calculations for the girder dimensions.

Consider diaphragm point loads to be part of component load DC. Include any diaphragms/end beams at the end of the girder over the support, as they will be utilized when applying the girder dead load reactions to crossbeams.

Where standard rail drawings occur, wherever possible use the rail dead loads tabulated in Appendix H - ODOT Standard Rail Weights, found in file **RAILDL.XLS**. Provide detailed calculations for the dead load of any rail not found in this summary.

For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all rail, curb and sidewalk dead loads (stage 2 dead loads) equally among all girders.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16" diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to need to be included in the load rating.

For load rating, we want to consider a utility as a "non-structural attachment" and keep it listed under DC for dead loads. The main reason for this is if a load rater ever comes across a situation where they have to load rate a bridge where they are uncertain of the wearing surface thickness. In that situation they are required to use a DW gamma of 1.50. That way they would only be penalizing the load of the wearing surface, not the utilities, for the uncertainty.

2.2.8 Wearing Surface Dead Loads (DW)

Always separate wearing surface dead load (DW) from the component (DC) dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes, and (c) it facilitates input for the Crossbeam Load Rating Software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Show calculations for wearing surface dead load distributed equally to all the girders. Add 1” to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½” to the design thickness of PPC overlays to account for construction variations and uncertainty.

For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all wearing surface dead loads (stage 2 dead loads) equally among all girders.

2.2.9 Live Loads (LL)

Simply list the four classes of rating loads to be analyzed. (See articles 1.5.1.1 through 1.5.1.4).

Normally live load distribution factors are calculated in BRASS, but in the rare case where they must be calculated manually, the complete calculations should be provided with thorough documentation in this section of the preliminary file. Distribution factors will need to be calculated manually in the case of widened bridges or half-viaducts where the deck was not made continuous between the original and widening structures, or between the viaduct structure and the adjacent pavement. Where there is no barrier to the wheel load at the edge of deck, because of the assumed 20” wide wheel footprint, a full concentrated wheel load can be placed no closer than 10” from the edge of deck.

2.2.10 Analysis Sections

Determine the spans to be investigated. These should be any span that is unique and is not repeated due to symmetry or due to repetition of a span between joints.

Within each span, check for symmetry of sections, reinforcement and loads, and do not identify any analysis points that are structurally symmetrical with analysis points already defined. Defining analysis points that are structurally symmetrical has the potential effect of corrupting the Load Rating Summary Sheet. Because the “Refresh” module is looking for the lowest Rating Factors, defining a symmetrical point causes it to identify the most critical rating location twice, thus preventing it from identifying the second most critical analysis point. The second controlling point is useful information in evaluating potential repairs for the bridge.

List the analysis sections for flexure. These are normally the positive moments in each unique span and the negative moments over each unique support.

There will be a large number of analysis sections for shear. For each unique span, subdivide the calculations of analysis sections into the categories (up to 5) given in article 1.5.3. Summarize the underlined headings that will begin each section of calculations. An example of this summary follows:

<u>Span 1 Critical Shear Section Points</u>
<u>Span 1 Flexural Bar Cutoff Points</u>
<u>Span 1 Girder Geometry Change Points</u>
<u>Span 1 Stirrup Spacing Change Points</u>
<u>Span 1 Large Crack Location Points</u>

<u>Span 2 Critical Shear Section Points</u>
<u>Span 2 Flexural Bar Cutoff Points</u>
<u>Span 2 Girder Geometry Change Points</u>
<u>Span 2 Stirrup Spacing Change Points</u>
<u>Span 2 Large Crack Location Points</u>

Then repeat each header, one by one, and under each header provide the calculations necessary to determine or document the location of each shear investigation point in that category. Thus there will be up to 5 separate calculation sections for each span. In any calculation section, if any particular point duplicates a previously calculated point or is within 1 ft of a previously calculated point, the new point may be omitted. In this case, explain the omission by indicating which previously identified point already covers the current one. This gives priority to critical sections and bar cutoff points when near-duplicates are encountered.

- Critical Shear Section Points

  According to AASHTO LRFD 5.7.3.2, critical section locations shall be taken at shear depth d_v from face of support. Use the shear depth calculation tool **dv_Calculator.XLS** to determine the shear depth d_v Use the original file of **dv_Calculator.XLS** as a “seed file” to be copied, used and saved within the bridge-specific Load Rating File Set.

  In previous versions of BRASS (LRFD) the skew correction factor was applied to the first segment only. Because of this it was important to not code any nodes within the critical section. Starting with BRASS (LRFD) v2.0.3, the software now applies the skew correction factor across the entire span. For shear the skew factor will be applied at the support and will decrease linearly to unity at midspan. With this update, section changes (node points) can now be defined within the critical section.

  In constant-depth girders, calculate the input parameters for **dv_Calculator.XLS** and determine shear depth d_v. Note: The input parameter “fy tension reinf.” refers to the fy of the longitudinal steel, not the stirrups. For longitudinal girders, it is sufficiently accurate and slightly conservative to ignore the compression flange and input the section as rectangular. This will cause d_v to be slightly smaller (an inch or so), which means the critical section will be slightly closer to the support, which is where the shear is slightly larger (conservative). Then calculation from the face of support is straightforward. In haunched girders, insert an appropriate diagram identifying the calculation variables, and the corresponding calculations, from the Mathcad source files provided. For linear, parabolic and circular haunches, these files are **LINEAR.xmcd**, **PARABOL.xmcd** and **CIRCULAR.xmcd**, respectively. Update the imported Mathcad calculations for the specific dimensions of the haunch. Then determine a preliminary depth of the critical section h_p, conservatively assuming a section h_{max} from the support face. Having determined h_p from the Mathcad procedure, use the shear depth calculation tool **dv_Calculator.XLS** to determine the shear depth d_v and calculate the critical section at d_v from the support face.

  Do this for each critical section location (each end of each unique span). When all critical sections have been located, save this bridge-specific copy of **dv_Calculator.XLS** in the Load Rating File Set.

- Flexural Bar Cutoff Points

  Normally the purpose for flexural bar cutoff points is to check shear due to research results that indicate flexural bar cutoffs are a likely starting point for shear cracks. However, if the Inspection Report indicates flexural cracking in negative moment areas (transverse deck cracking over interior supports), the top flexural bar cutoff points should also be checked for moment. Any moment checks at bar cutoff points should be listed within the calculation group for this type of shear analysis section. (These flexural checks should not be grouped with the other flexural analysis points because BRASS cannot be coded to check the same analysis point twice).

  Prior to the 2008 Revisions of the AASHTO LRFD code, when evaluating shear capacity, AASHTO LRFD Article 5.7.3.4.2, General Procedure for Modified Compression Field Theory (MCFT) shear capacity evaluation required that all of the development length of the longitudinal reinforcement be ignored. Therefore, BRASS was configured so that the longitudinal bars are considered to be fully developed. To accomplish the intention of the LRFD code, node points between girder elements (BRASS sections) were located a development length l_d back along the bar from the actual bar cutoff point. However, points of interest (sections to be evaluated for shear) were at the actual bar cutoff point, assuming this is the most conservative and likely point where a crack might develop. By this method, for the longitudinal strain (ε_x) calculation, A_s had always excluded the bars being terminated.

Since the 2008 Revisions of the AASHTO LRFD code, Article 5.7.3.4.2, now requires that the partially developed areas of the longitudinal reinforcement be included within the calculation of the shear capacity. Unfortunately BRASS is not directly configured to calculate the partial development of each bar entered, but it is capable of linearly interpolating the reinforcement area between node points (BRASS sections). This will require two BRASS sections for each bar cutoff point, one for the physical end of the bar and one at the point of full development.

With the number of geometry cross-section changes and overlapping bar cutoff points, the ODOT Concrete Bridge Generator (CBG) program was developed to aid in the creation of the BRASS input file by determining the required number of BRASS sections and computing the bar cutoff points. The CBG program will create the BRASS input file data for the BRASS sections, span layout, and generate the BRASS analysis points for the bar cutoffs.

In the MCFT General Procedure evaluation (AASHTO LRFD 5.7.3.4.2), A_s is defined as the area of non-prestressed steel "on the flexural tension side of the member." Including tension-side temperature steel in A_s would only cause a small percentage decrease in the strain ε_x, and have an even smaller effect on increasing the nominal shear resistance V_n. Therefore including temperature steel will be considered an unnecessary increase in complexity under normal circumstances.

Print a copy of the reference tool **BAR_Ld.XLS** (used to calculate bar development length, top bar and bottom bar calculations for both 40 ksi and 60 ksi rebars). In accordance with AASHTO LRFD 5.10.8.2.1a, the minimum l_d is 12", except for standard hooked bars which can have a minimum l_{dh} of 6". In accordance with AASHTO LRFD 5.10.8.2.1b, note that there are two columns for "TOP" "STRAIGHT" bars in the file, one that includes the 1.4 factor for top bars with >12" of concrete below them, and the other for top bars with ≤ 12" of concrete below them. Note the 1.4 factor does not apply to top bars in slabs <14" thick. To increase accuracy in using this tool, consider highlighting the rows that show the reinforcement used and then cross out the columns for the concrete strength that will not be used.

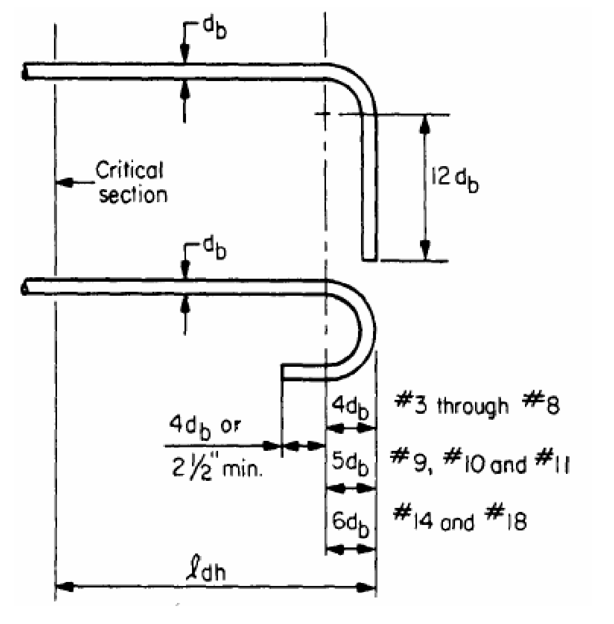


Figure C5.11.2.4-1 Hooked-Bar Details for Development of Standard Hooks (*ACI*).

For bars that have a 90° or 180° standard hook (as illustrated in the figure to the right), the reference tool **BAR_Ld.XLS** has the development length l_{dh} for each bar computed in accordance with AASHTO LRFD 5.10.8.2.4a. One thing to note is that for some bar sizes with a f_y = 40 ksi, the development length of the standard hooked bar is larger than that of the straight bar of equal size. It is ODOT's policy to use the straight bar development length when the hooked bar development length is greater for a given bar size and strength.

In all cases, for purposes of l_d calculation, in this tool we consider square bars to have the same l_d as the round bar of equivalent area. The assumption is made that the lack of deformations on a square bar is offset by its greater bonding surface area compared to the equivalent round bar.

In the rare case of railroad rails used as concrete reinforcing, to determine the development length, determine the area and perimeter of the rail, assume a yield stress fy = 50 ksi, and use a bond stress f_b of 0.100 ksi For example, a 55-lbs/yard rail with A_s=5.33 in^2 and perimeter p=18.24 in would have tensile capacity $T = A_s f_y = (5.33\ in^2)(50\ k/in^2) = 266.5\ k$ and development length $l_d = T/(f_b p) = (266.5\ k)/(0.100\ k/in^2)(18.24\ in) = 146.1\ in$.

- Girder Geometry Change Points

  Show calculations locating any abrupt change in girder cross section, such as the beginnings or ends of haunches, web tapers, or partial bottom flanges.

- Stirrup Spacing Change Points

  These locations are taken from the stirrups schedule spreadsheet embedded in the Preliminary File and adjusted by one stirrup space toward the direction with the greater spacing. The analysis location is moved for two reasons. At a stirrup spacing change location, a shear crack would propagate across both stirrup spaces. BRASS doesn't interpolate the shear capacity to the left and right of an analysis point. Therefore, moving the analysis point by one stirrup space moves the analysis location away from the transition area. Also, it was originally assumed that BRASS would calculate the capacity to the left and right of a section change and use the weaker section when calculating rating factors. However, it doesn't appear that BRASS performs this check. Rather BRASS uses the stirrup spacing from the schedule right at the point that was coded. Moving the analysis point toward the larger stirrup spacing ensures that the larger stirrup spacing (lesser capacity) is used when calculating the rating factor.

  Indicate which stirrup spacing change points in the girder are farther from the support than the critical shear point and not within the middle 1/3 of a non-cantilever span. There are several reasons for ignoring shear in the middle 1/3:
  - The shear loading is relatively low within the middle third of the span.
  - We have not observed significant shear cracking/failures within the middle third of the span.
  - In utilizing the Modified Compression Field Theory (MCFT) for shear in LRFR, we have found that the stirrup spacing near the midspan of older bridges will often cause the girder to fail the "Minimum Transverse Reinforcement" check within the AASHTO LRFD code. When this check fails, the user is forced to use AASHTO LRFD Equation 5.7.3.4.2-2 to calculate Beta. This equation will yield higher Beta values, which will significantly reduce the shear capacity at the location.

  In crossbeams, where a single large stirrup space coincides with the location of longitudinal girders framing into the side(s) of the crossbeam, the stirrup spacing change can be ignored.

- Large Crack Location Points

  Show calculations locating any section that has a shear crack > 0.040" wide or shows evidence of being a working shear crack regardless of crack width.

  For crack locations that are inside the critical shear location near a simple support, use AASHTO LRFD 5.7.3.4.1 – Simplified Procedure for Non-prestressed Sections. This is due to the Modified Compression Field Theory (MCFT) not providing accurate results for areas with high shear and low moment, basically near a simple support. This section of the AASHTO LRFD code sets beta and theta to 2.0 and 45 degrees, which in turn makes the expressions for shear strength become essentially identical to those traditionally used in LFD for evaluating shear resistance.

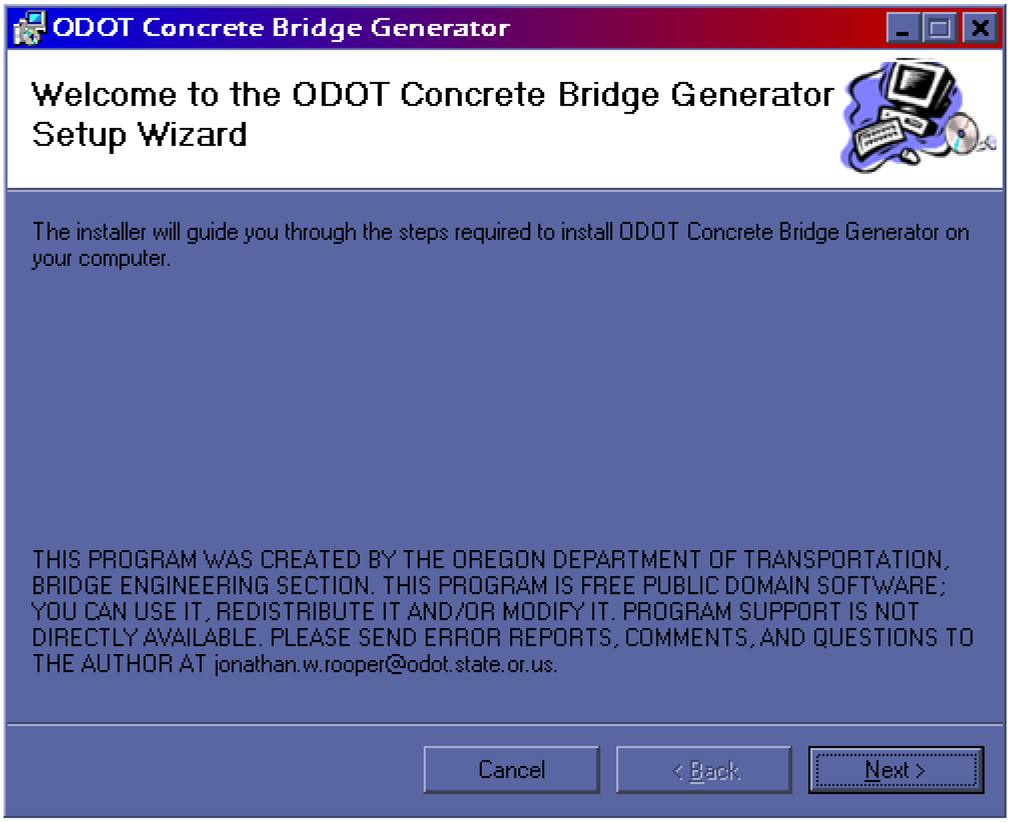
2.3 ODOT Concrete Bridge Generator (CBG)

The ODOT Concrete Bridge Generator (CBG) was created by the Oregon Department of Transportation, Bridge Engineering Section. The CBG is a stand-alone windows software package that is a pre-BRASS processor for Cast-In-Place concrete bridge girder sections. Once the user enters basic bridge information, concrete section geometry, span configuration geometry, and the longitudinal reinforcement within the form fields, the program will generate the first half of the BRASS code. The program will also generate the BRASS code for the bar cut-off shear points that the user will paste into the appropriate locations in the BRASS input file. The program is not set up to define rigid frame structures; it is only configured to define a beam analysis in BRASS.

The CBG is solely for the Microsoft Windows operating system and utilizes the Microsoft .NET Framework. The program's native format is the CBG (Concrete Bridge Generator) file format. The CBG is free public domain software; meaning that users are free to use it, redistribute it, and/or modify it. The current version of the CBG is version 1.0.13.

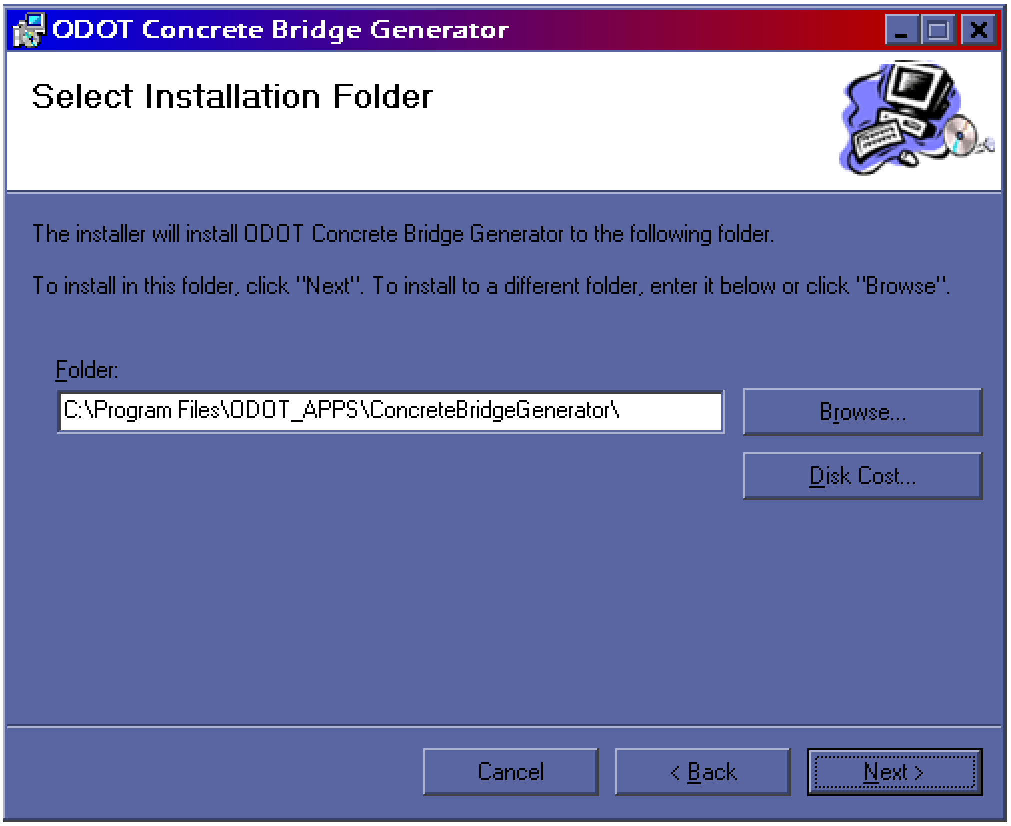
2.3.1 CBG Installation

Previous versions of this program need to be uninstalled through the Windows Control Panel interface prior to installing a newer version. To install the ODOT Concrete Bridge Generator, run the Windows Installer Package titled, "ODOT_Concrete_Bridge_Generator.msi". This will launch the Setup Wizard and pause at the Welcome dialog for the Wizard. Select the "Next" button to continue.



The next dialog will ask the user to select an installation folder to install the Concrete Bridge Generator to. The default location is, "C:\Program Files\ODOT_APPS\ConcreteBridgeGenerator\". If the default location is satisfactory or after the preferred folder location has been specified, select the

"Next" button to continue.



The next dialog will ask the user to confirm the installation before it begins. Click the "Next" button to begin the installation.

A dialog with a progress bar will be shown during the installation. This part of the process can take anywhere from a few seconds to a few minutes depending on if the wizard needs to download and install an update to the Microsoft .NET framework to the computer.

The installation will place a shortcut for the program on the users desktop as well as under the Start Menu > All Programs > ODOT Load Rating. When the installation is complete, click the "Close" button to end the Wizard.

2.3.2 CBG - Overview

When first starting a session of the CBG software, a dialog window explaining the terms of use for the software will be displayed. If the user selects the "DECLINE" button, the session will end and the software will not launch. If the user selects the "I ACCEPT" button, the session will continue and the software will launch.

At the top left of the program there are five buttons associated with icons that are titled "New", "Open", "Save", "Report", and "Exit". The "New" button will erase all of the data entered in the form fields and start over with a blank form. The "Open" button will populate the form fields from a saved *.cbg file that was created from using the "Save" button from a previous session. The "Save" button will save the data entered in the form fields in a *.cbg file. The program will incorporate the values entered within the "Bridge Number" and "Member Being Load Rated" form fields in the file name during the save process. The "Report" button will display a print preview of a report that reflects the data entered in the various form fields of the program. The "Exit" button will exit and close the current session of the program.

At the top right of the program there are three buttons that are titled "Show Cross-Section Matrix", "Generate BRASS File Input", and "Generate Bar Cutoff Points for Shear Analysis". The functions of these buttons will be explained later.

In the top section of the program form is where the user specifies the basic information of the bridge. These form fields are set to only accept the maximum number of characters that the BRASS-GIRDER(LRFD) commands using the data will allow. Form fields with white backgrounds require user input, while the form fields with grey backgrounds will automatically fill in values based on the user input within other fields. The different fields within this top section are the Bridge Name, Bridge Number, Load Rater's Name, Highway/Route Name, Mile Point, the Load Rating Date, the name of the Member Being Rated, and the File Name associated with the saved data entered on the forms.

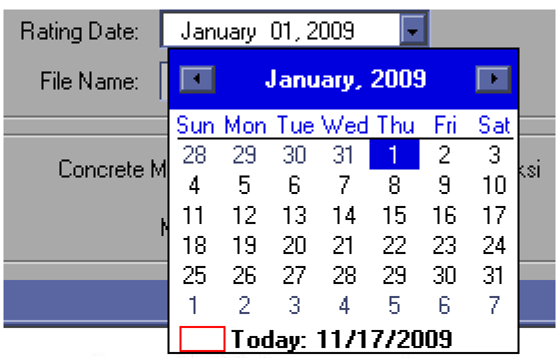
In the next section, the user inputs the concrete strength and longitudinal reinforcement yield stress. The program will then compute the concrete unit weight, the concrete modulus of elasticity, the reinforcement modulus of elasticity, and the modular ratio.

The bottom section of the program is divided into four tabs, which are used to define the cross-section geometry, span configuration/layout, and the longitudinal reinforcement. The tabs are named "Span Configuration", "Concrete Dimensions", "Concrete Section Assignment", and "Reinforcement". The functions of these tabs will be explained later.

2.3.3 CBG – General Bridge & Load Rating Info

In the "Bridge Name" form field, up to 60 characters may be used to enter the bridge name. The user has up to 15 characters to enter the bridge number in the "Bridge Number" form field, which typically only uses 5 to 6 characters. In the "Load Rater" form field, up to 60 characters may be used to enter the name of the engineer that is running the program. The user has up to 60 characters to enter the route name where the bridge is located in the "Route Name" form field. In the "Mile Point" form field, enter the milepost where the bridge is located.

In the "Rating Date" form field, the user can type in the numeric date for the month, day, and year. Or the user can select the drop down calendar view and select the day within the appropriate month and year. Instead of scrolling through the different months within the calendar view, the user can simply select red box that is titled "Today" at the bottom of the calendar view to select the current date.



In the "Member Being Load Rated" form field, use the drop down list to select what type of member that the current BRASS analysis will be for. The choices are: IntGir for a RCDG interior girder, ExtGir for a RCDG exterior girder, RCBG for a reinforced concrete box girder, RCSlab for a reinforced concrete slab, and EDGSTP for a reinforced concrete slab edge strip analysis.

The "File Name" form field will be automatically filled in when the user saves the data on the forms using the "Save" button. The program will incorporate the bridge number and the member being rated into the file name. For example, if the bridge number was 12345 and the member being rated was set to IntGir, the default file name would be set to "12345_IntGir.cbg". If the user is going to be performing multiple interior girder analysis for the same bridge, for example girders A through D, then during the save process the user can manually type the beam letter within the file name. Thus, if the analysis was for girder "A", the file name would be "12345_IntGirA.cbg".

2.3.4 CBG – Material Properties

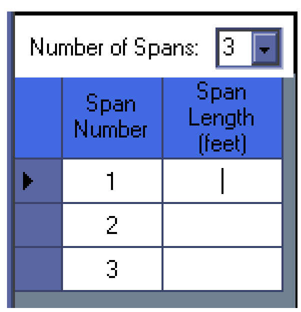
For the material properties area of the form, all that needs to be entered is the concrete strength (f'c) in ksi and the longitudinal reinforcement yield stress (f_y) in ksi. The program will then calculate and display the concrete unit weight in kips per cubic feet, the concrete Modulus of Elasticity (E_c) in ksi, the longitudinal reinforcement Modulus of Elasticity (E_s) in ksi, and the Modular Ratio (n) of the two materials.

2.3.5 CBG – Span Configuration Tab

The span configuration tab is where the user identifies the number of spans that will be modeled in the current BRASS analysis, the lengths of each span, the vertical profile of each span, and which spans are copies of previously defined spans.

It is recommended that the first thing that be defined is the number of spans that will be analyzed in the current BRASS run. Several other form fields within the tab pages refer to the number of spans and the defined span lengths when computing data and populating lists for the user to choose from. The user is able to later specify a greater number of spans without much affect to data that may already be entered on the other tab forms. However, once the user specifies a number of spans that is less than what is currently specified, most of the data that may have been already entered on the other tab forms will be erased.

The Concrete Bridge Generator is configured to make BRASS perform a beam analysis, instead of a frame analysis. For a beam analysis, BRASS is limited to a maximum of 13 spans. Thus, the CBG is limited to a maximum of 13 spans. One the left side of the Span Configuration Tab, the user can either directly type in the number of spans or they can use the drop down list and choose the number. The form field for specifying the span lengths below the number of spans selection will dynamically resize to the number of spans that are defined. Once the number of spans has been defined, the next step is to enter the length of each span in feet.



Once the number of spans and span lengths are defined, the vertical profile of each span needs to be defined. This is done by defining segments of the span where the vertical profile changes or control points occur. In the main form table on the Span Configuration Tab, the first column is the only one that is white and active and is used to identify the span that is being defined. Once the span has been identified, the second and third columns turn white and are active. These two columns are check box cells. The first is used to identify if the user is defining the vertical profile for a span segment, and the second is used to identify if the span is going to be a copy of another defined span.

If the “Define Span Segment” cell is checked, the “Span Copy” cell becomes inactive and the following seven cells to the right become active. These cells have the following column headings:

Web Variation Indicator – A code indicator used by BRASS to indicate what type of vertical profile change that is taking place along the segment length.

Web Variation – provides a graphical representation of the type of vertical profile change that is taking place along the segment length.

Left End Web Depth (inches) – Where the user specifies the depth of the web at the left end of the span segment.

Right End Web Depth (inches) – Where the user specifies the depth of the web at the right end of the span segment.

Length of Span Segment (feet) – Where the user specifies the length of the span segment being defined.

Starting Point from Left End of Span (feet) – The software calculates the starting location based on the span length and the length of the previously defined span segment. If the current segment is the first one being defined for the span, the starting point will be zero feet.

Ending Point from the Left End of Span (feet) – The software calculates the ending location based on the start point and the user specified segment length. If the ending point exceeds the span length, and error message in the cell will be given. If the ending point is less than the span length, a new row for the span will begin being defined with the start point being equal to the current ending point.

Within the Web Variation Indicator cell, the user can choose the following values for the vertical profile change:

L = Linear Web Depth Variation – The depth of the web varies linearly for the segment. If the web depth is constant, the user would choose this option and then specify the left and right web depths to be the same.

P- = Parabolic Concave Down Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the smaller web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used.

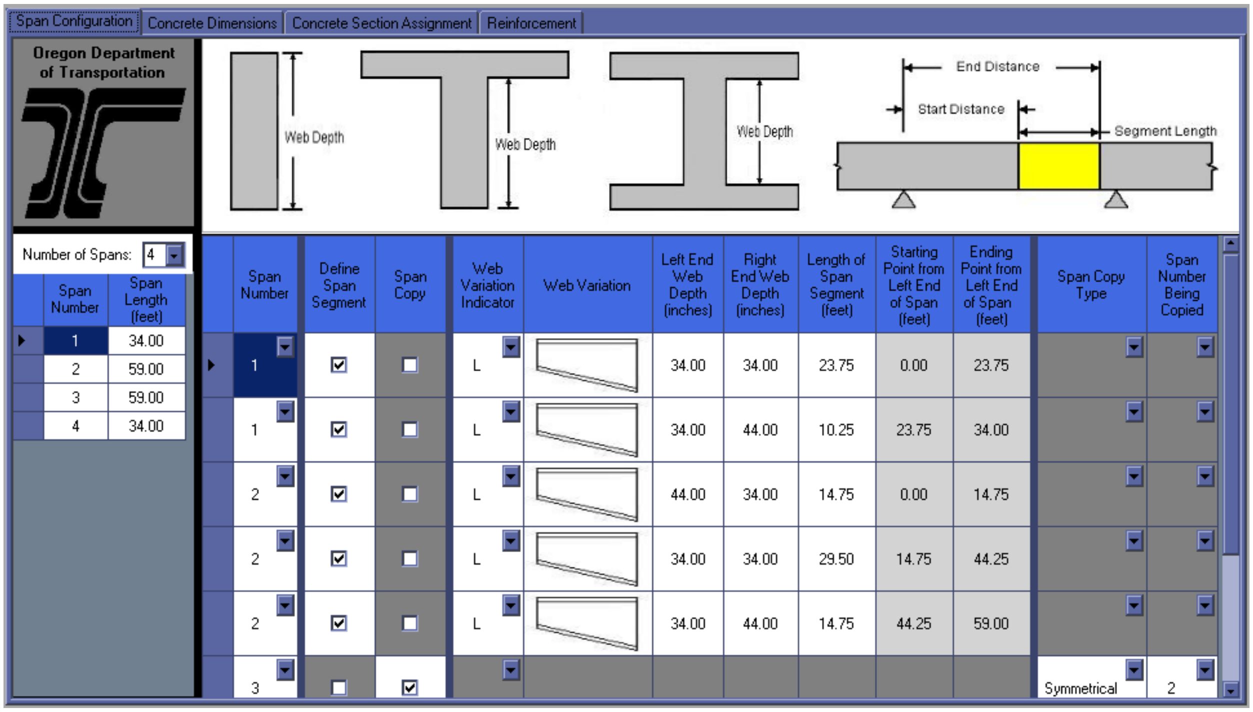
P+ = Parabolic Concave Up Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the larger web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used.

E- = Elliptical Concave Down Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the smaller web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used. Zero vertical slope at the end with the larger web depth is also enforced.

E+ = Elliptical Concave Up Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the larger web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used. Zero vertical slope at the end with the smaller web depth is also enforced.

The Web Variation cell will display a graphic of the variation indicator selected to assist the user in understanding how the different profiles may appear. Holding the mouse over this cell will call a tooltip window to appear giving the same description of the associated Web Variation Indicator as in the previous paragraph. Due to the amount of text written on the tooltip, the time allotted for the tooltip window is a little long and the user may end up having several tooltip windows appear on their screen as they move the mouse across the cell. Simply clicking the mouse in a different cell will force all of the tooltip windows to disappear.

If the “Span Copy” cell is selected, then the “Define Span Segment” cell becomes inactive and all of the cells related to defining the span segment remain inactive. The last two cells to the far right of the table will become active. They are the “Span Copy Type” and the “Span Number Being Copied” cells. In the Span Copy Type cell, the user can select if the copy is going to be identical or symmetrical. The user then can choose the span number that will be copied for the current span. If the span number being copied has a different span length than the current span, an error message will be displayed in the cell.

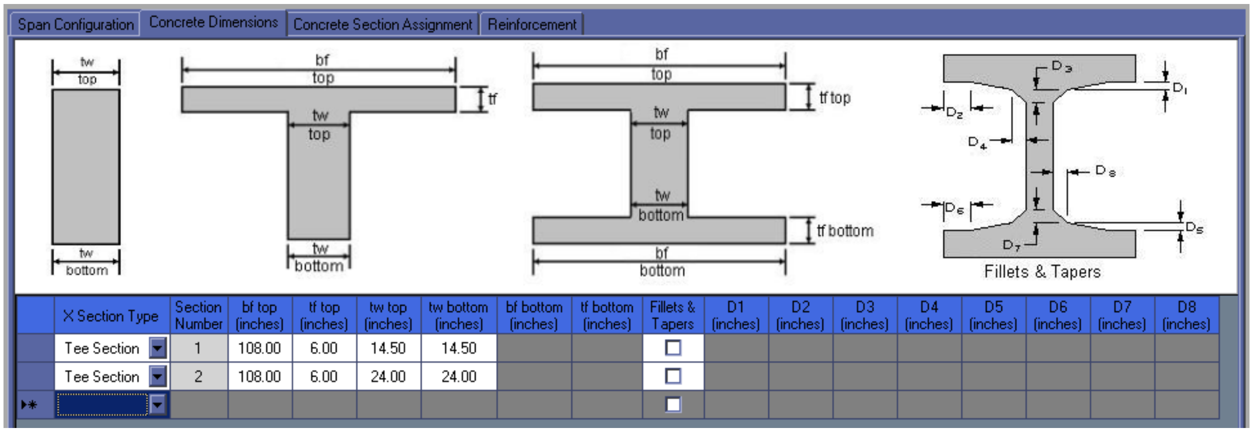


2.3.6 CBG – Concrete Dimensions Tab

The concrete dimensions tab is where the user defines the actual concrete cross-sections of the girder. Originally, only the first cell in the table is active. This cell is titled “X Section Type”, and the user is able to choose from a Rectangular Section, a Tee Section, and an I-Section. The rectangular section is typically used to define the slab strip for a Cast-In-Place (CIP) slab section. The Tee Section is typically used to define RCDG sections. And the I-Section is typically used to define CIP Box Girder Sections.

When defining a concrete section, the program will assign a section number in the second cell. The cells in columns three through eight will become active based on the type of X Section that the user has selected. These cells are used to define the top flange width, top flange thickness, the web thickness at the top, the web thickness at the bottom, the bottom flange width, and the bottom flange thickness.

If the concrete section has fillets and/or tapers between the flanges and webs, the user can check the box in the 9th column titled “Fillets & Tapers”. This will activate the cells in the last eight columns where the user can define the taper and fillet dimensions. These dimensions are illustrated in the diagram and have been given the designations D1 through D8. The user can use the illustration to see what the dimension is referring to, and holding the mouse over the column headings and the actual cells will cause a tooltip window to appear that gives a brief description as to what the dimension is referring to.



2.3.7 CBG – Concrete Section Assignment Tab

The Concrete Section Assignment Tab is divided into three sections. The first section is for Concrete Section Assignments, where the user assigns the defined concrete sections to each span. The second section is for the Support Conditions, where the user defines the horizontal, vertical, and rotational fixity at each support location. The third section is for Hinge Locations, where the user can define hinge locations that may be present in the structure.

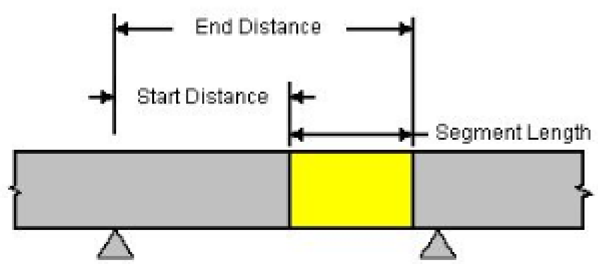
For each span that has span segments defined under the Span Configuration Tab, concrete sections will need to be assigned under the Concrete Section Assignments Tab. In the first cell, the user will specify/choose which span that they are going to assign concrete sections to. The second cell is where the user specifies are chooses the starting Concrete Section Number, which refers to the section numbers that were assigned under the Concrete Dimensions Tab. The third cell is where the program automatically determines where the start point of the span segment is located from the left end of the span. The fourth cell is where the user specifies the length of the span segment in feet. The fifth cell is where the program automatically calculates and reports the Ending point of the span segment from the left end of the span. If the ending point is longer/beyond the span length, then an error message will be displayed in the cell. The last cell is for the user to specify the ending concrete section number.

If this is the first cross section assignment for the span, the start point will be at zero feet. Then if the span segment length plus the start point location is less than the defined span length, a new row will be started and the start point will be equal to the ending point of the previous definition. This will continue until the ending point is equal to the span length.

By default, the Ending Concrete Section Number will automatically set to the same value as the Starting Concrete Section Number. This is for segments that have the same cross section over their length. For segments that have the concrete tapering/transitioning between two cross sections over the segment length, the user would specify a different section number for the ending point. For an abrupt change in cross section, the user would have the starting and ending concrete sections numbers the same for the segment, and then start the next segment with a different concrete section number than the previous definition.

Span Configuration | Concrete Dimensions | Concrete Section Assignment | Reinforce

Concrete Section Assignments



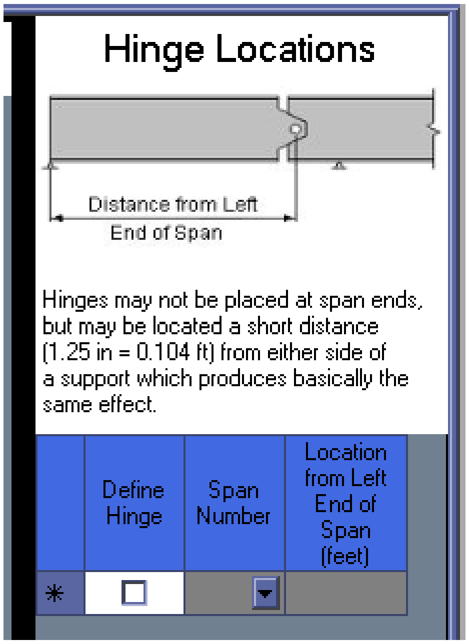
	Span Number	Starting Concrete Section Number	Starting Point from Left End of Span (feet)	Length of Span Segment (feet)	Ending Point from Left End of Span (feet)	Ending Concrete Section Number
▶	1	1	0.00	23.75	23.75	1
	1	1	23.75	10.25	34.00	2
	2	2	0.00	14.75	14.75	1
	2	1	14.75	29.50	44.25	1
	2	1	44.25	14.75	59.00	2
*						

The Support Conditions table will automatically be resized for the appropriate number of supports based on the number of spans defined under the Span Configuration Tab. For each support, the user must choose if the condition is Free or Restrained for the Horizontal, Vertical, and Rotational supports.

Support Conditions

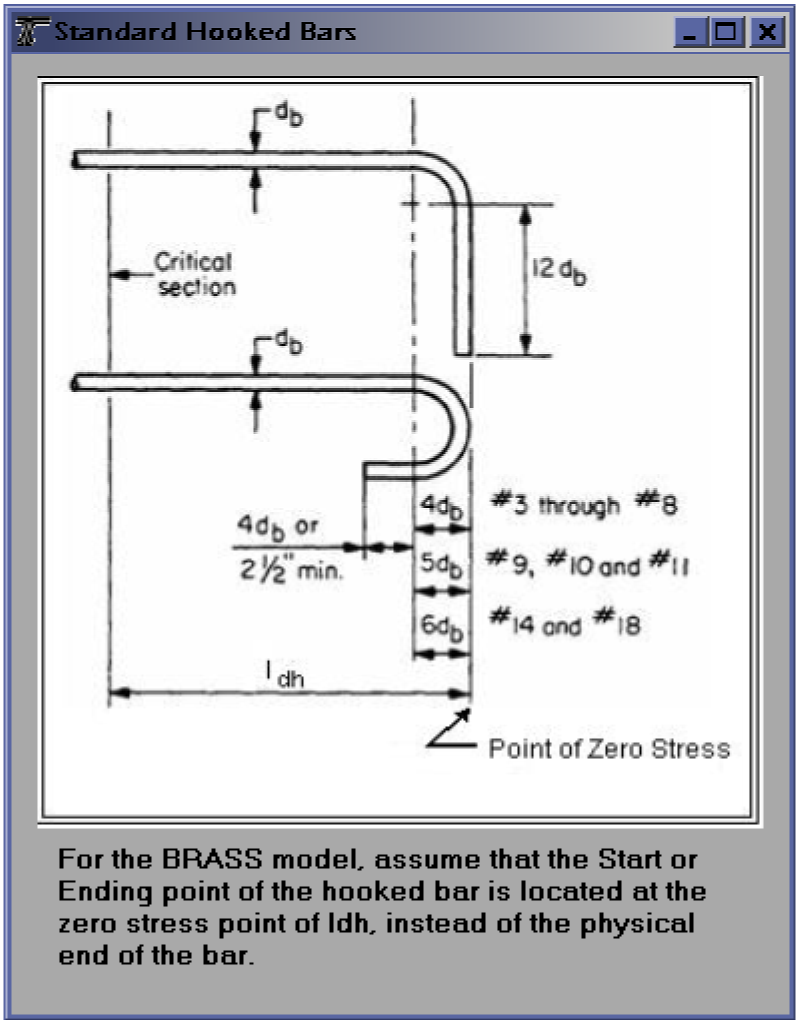
Support Number	Horizontal Support	Vertical Support	Rotational Support
1	Restrained	Restrained	Free
	Span 1		
2	Free	Restrained	Free
	Span 2		
3	Free	Restrained	Free
	Span 3		
4	Free	Restrained	Free
	Span 4		
5	Free	Restrained	Free

Since not all bridges have hinges, the Hinge Location table is inactive by default. To define a hinge within a span, the user must first select the check box under the 'Define Hinge" column in the Hinge Locations table. Doing so will make the next two cells active, which are where the user would specify which span and the location in feet from the left end of the span where the hinge exists. The BRASS manual states that hinges may not be placed at span ends, but may be located a short distance (1.25 inches) from either side of a support which produces basically the same effect.



2.3.8 CBG – Reinforcement Tab

The Reinforcement Tab is where the user defines the longitudinal reinforcement for each span that has span segments defined under the Span Configuration Tab. To aid the user, at the top of the section there are illustrations showing the reference points of how the bar locations are measured in respect to the cross section and span. There are also two buttons located in upper right hand portion of the section. The first button is titled, “LRFD Bar Development Lengths”, and will display a new window with an image of the development length table from the tool BAR_Ld.XLS. The second button is titled, “Hooked Bar Diagram”, and will display the LRFD hooked bar illustrations for standard hooks. The purpose of this illustration is to inform the user that for the BRASS model, the end point of the bar should be defined as the point of zero stress instead of the physical end of the hooked bar.



The reinforcement table can be populated in any order that the user desires. Some prefer to define all of the bottom bars first and then go back and define all of the top bars. Others prefer to define both top and bottom bars working from left to right. As long as all of the bars are eventually defined, there is no difference in the results of how/when they are defined on the table.

The first cell of the Reinforcement table is where the user specifies the rebar row. Rows one through three are reserved for bottom (positive moment) bars, and rows four and five are reserved for top (negative moment) bars. The user can either type just the number of the row or select it from the drop down list.

The second cell is where the user specifies the number of bars in the current bar group.

The third cell is where the user specifies the bar size. The user can either select the bar size from the drop down list, or they can just type in the number of the bar size. Notice that the display/format of the bar sizes changes when any cell in this column has focus. The fraction bar sizes change to decimal and the "#" sign in front of normal round bars disappears. When the focus is moved to a different column in the table, the display/format changes back. That way, if typing in the number for a bar one can simply type the number for the round bar size or the decimal equivalent of the square bar size. For example for a 1-1/8 in sq bar the user can simply type 1.125, or for a #8 round bar one can simply type 8.

The fourth cell is where the vertical distance, in inches, from either the bottom or the top of the girder is defined. For bars that reside in rows one through three, the vertical distance is measured from the bottom of the girder. For bars residing in rows four and five, the vertical distance is measured from the top of the girder.

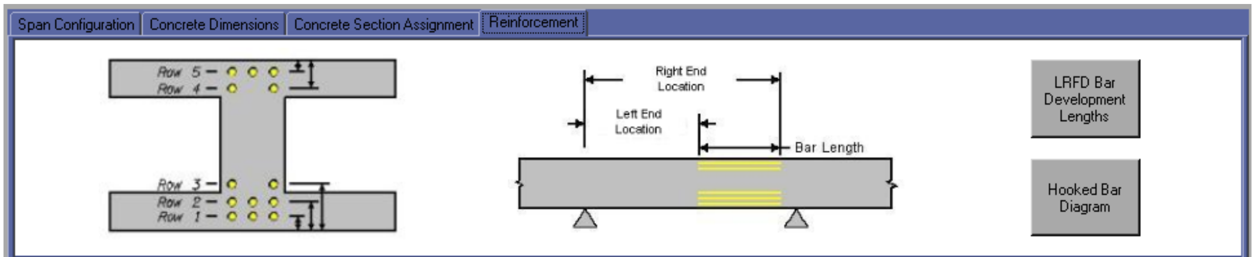
The fifth cell is used to identify the span number where the left end of the bar is located. The sixth cell is used to specify the location, in feet, where the left end of the bar is located from the left end of the span. For straight bars, it would be the physical end of the bar location. For hooked bars, it would be the location at the zero stress point of the hooked bar development length.

The seventh cell is used to specify the development length, in inches, of the left end of the bar. The eighth cell is used to specify the overall bar length in feet. The ninth cell is used to specify the development length, in inches, of the right end of the bar. By default, the program will automatically use the value for the right end development length that was entered for the development length at the left end of the bar. For cases where one end of the bar contains a hook, the user can change the right development length to a different value by simply typing the new value into the cell.

For structures that have a bent bar that transition to a different depth in the member, the user can simply specify a zero development length at the location where the bend occurs. The length of the bar should be specified for the horizontal portion of the bar only at a given elevation, not the portion that is bent and changing elevation or exists at a different elevation in the member. When a zero development length is encountered, the program will assume that the bar is bent and will not specify a bar cutoff analysis point since the bar is fully developed through the transition area. If the user still wishes to have the program generate a bar cutoff analysis point at this location, they must enter some other value, other than zero, for the development length of the bar.

Some of the older bridges occasionally have the deck reinforcing exposed. ACI318, Article 12.2.3.2, states that for bars with a cover of d_b or less or with a clear spacing of $2d_b$ or less that the basic development length (obtained from the LRFD code) be multiplied by 2.0. Therefore, if the inspection report or photos indicate that the deck reinforcement is exposed, double the development length of the deck reinforcement.

The last two cells at the right of the table are where the program automatically calculates and displays the span number that the right end of the bar resides in and the location from the left end of that span, in feet, that the right end of the bar resides.



	Row	Number of Bars	Bar Size	Vertical Distance (in)	Left End Span Number	Left End Location (ft)	Left End Development Length (in)	Bar Length (ft)	Right End Development Length (in)	Right End Location (ft)	Right End Span Number
1	1	2.00	1-1/8in sq	2.56	1	0.00	26.60	26.00	35.00	26.00	1
2	1	1.00	1-1/8in sq	2.56	1	0.50	35.00	24.00	35.00	24.50	1
3	2	2.00	1-1/8in sq	4.56	1	2.50	35.00	20.00	35.00	22.50	1
4	1	2.00	1-1/4in sq	2.63	1	22.00	42.90	27.00	42.90	15.00	2
5	1	2.00	1-1/2in sq	2.75	2	10.00	59.50	37.00	59.50	47.00	2
6	1	1.00	1-1/2in sq	2.75	2	11.50	59.50	34.00	59.50	45.50	2
7	2	2.00	1-1/2in sq	4.75	2	15.00	59.50	28.00	59.50	43.00	2
8	1	2.00	1-1/4in sq	2.63	2	42.50	42.90	33.00	42.90	16.50	3
9	5	2.00	#8	2.00	1	0.00	20.90	14.00	21.70	14.00	1
10	5	2.00	1-1/4in sq	2.13	1	10.00	42.90	42.00	42.90	18.00	2
11	5	2.00	1-1/4in sq	2.13	1	14.00	42.90	34.00	42.90	14.00	2
12	5	2.00	1-1/4in sq	2.13	1	19.00	42.90	24.00	42.90	9.00	2
13	5	2.00	1-1/4in sq	2.13	1	25.00	42.90	15.00	42.90	6.00	2

2.3.9 CBG – Show Cross Section Matrix Button

Once the user has completed entering the data in the various tables and form fields, it is recommended to save the data before continuing just in case the program encounters an unexpected error or bug and closes the CBG. It is then recommended to select the "Show Cross-Section Matrix" button, which will open a new window containing a spreadsheet or matrix of the concrete dimensions and longitudinal reinforcement that will be used to define the spans in BRASS. The Concrete Section Matrix is just a tool for the load rater to see and verify how the bridge is being modeled based on the data that was entered.

The first column lists the span fraction at each section point. The second column lists the span number. And the third column lists the actual location of the of the section point in feet. Columns four through 18 lists the concrete dimensions as they are illustrated on the Concrete Dimensions tab of the main form.

Cells that have white backgrounds are actual control points that were specified on either the Concrete Section Assignment tab or on the Reinforcement tab. The cells with a light grey background are intermediate points that were linearly interpolated between the control points with white backgrounds. Span fraction cells that have a light green background are cells that are made up of two or more control points that were combined into one analysis point. Making the mouse hover over the green cell will cause a tooltip window to display the reason why the cells are combined.

Concrete Section Matrix

	Span Fraction	Span Number	Location	X-Section Number	bf top	tf top	tw top	tw bottom	bf bottom	tf bottom	D1	D2	D3	D4	D5	D6	D7	D8
1	100.00	1	0.00	1	108.00	6.00	14.50	14.50										
2	100.15	1	0.50	-	108.00	6.00	14.50	14.50										
3	100.41	1	1.40	-	108.00	6.00	14.50	14.50										
4	100.51	1	1.74	-	108.00	6.00	14.50	14.50										
5	100.65	1	2.22	-	108.00	6.00	14.50	14.50										
6	100.74	1	2.50	-	108.00	6.00	14.50	14.50										
7	101.01	1	3.42	-	108.00	6.00	14.50	14.50										
8	101.59	1	5.42	-	108.00	6.00	14.50	14.50										
9	102.94	1	10.00	-	108.00	6.00	14.50	14.50										
10	103.59	1	12.19	-	108.00	6.00	14.50	14.50										
11	103.99	1	13.58	-	108.00	6.00	14.50	14.50										
12	104.12	1	14.00	-	108.00	6.00	14.50	14.50										
13	105.17	1	17.58	-	108.00	6.00	14.50	14.50										
14	105.59	1	19.00	-	108.00	6.00	14.50	14.50										
15	105.76	1	19.58	-	108.00	6.00	14.50	14.50										
16	106.35	1	21.58	-	108.00	6.00	14.50	14.50										
17	106.47	1	22.00	-	108.00	6.00	14.50	14.50										
18	106.62	1	22.50	-	108.00	6.00	14.50	14.50										
19	106.79	1	23.08	-	108.00	6.00	14.50	14.50										
20	106.99	1	23.75	1	108.00	6.00	14.50	14.50										
21	107.21	1	24.50	-	108.00	6.00	15.19	15.19										
22	107.35	1	25.00	-	108.00	6.00	15.64	15.64										
23	107.52	1	25.58	-	108.00	6.00	16.17	16.17										
24	107.65	1	26.00	-	108.00	6.00	16.58	16.58										
25	108.41	1	28.58	-	108.00	6.00	18.98	18.98										
26	110.00	1	34.00	2	108.00	6.00	24.00	24.00										
27	200.00	2	0.00	2	108.00	6.00	24.00	24.00										

The columns beyond column 18 are used to show the longitudinal bars that were defined under the Reinforcement Tab. Each bar group consists of four columns that list the rebar row number, the number of bars, the bar size, and the vertical distance in the girder were the bars are located. Each bar group will have four control points, one at each physical end of the bar and one at each point of full bar development. As with the concrete sections, all points that fall between the rebar control points will be linearly interpolated.

The first rebar group shown in the matrix is defined by the first row in the Reinforcement Tab Table, the second group is defined by the second row in the table and so on. Knowing how the bars are defined and represented in the matrix and in the table will allow the load rater to verify how the reinforcement is being modeled.

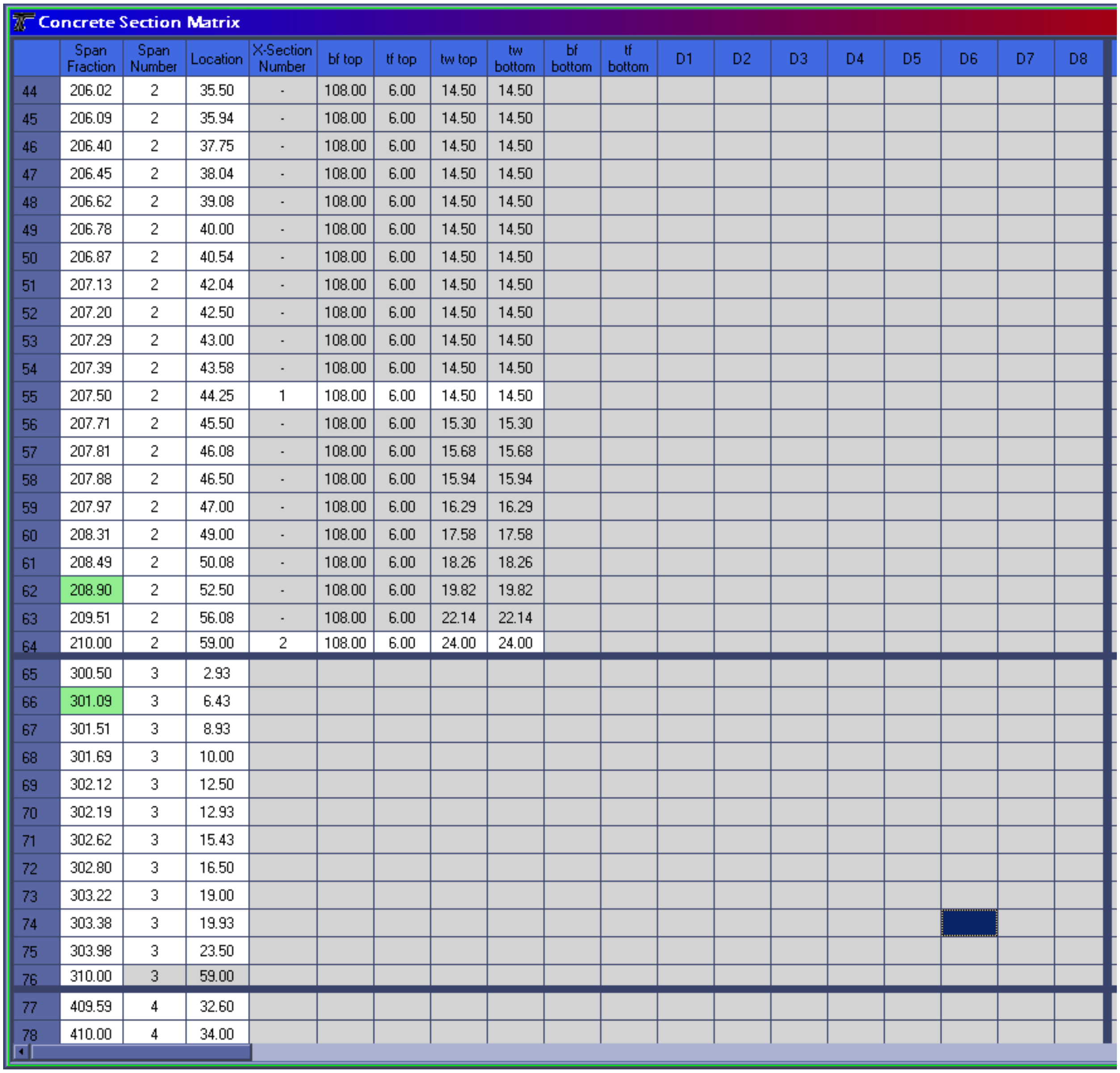
Concrete Section Matrix

					Row 1 on Reinforcement Table				Row 2 on Reinforcement Table				Row 3 on Reinforcement Table				Row 4 on Reinforcement Table			
	Span Fraction	Span Number	Location	D8	Row #	num bars	bar size	vert dist	Row #	num bars	bar size	vert dist	Row #	num bars	bar size	vert dist	Row #	num bars	bar size	vert dist
1	100.00	1	0.00		1	0.00	1-1/8i...	2.56												
2	100.15	1	0.50		1	0.45	1-1/8i...	2.56	1	0.00	1-1/8i...	2.56								
3	100.41	1	1.40		1	1.26	1-1/8i...	2.56	1	0.31	1-1/8i...	2.56								
4	100.51	1	1.74		1	1.57	1-1/8i...	2.56	1	0.43	1-1/8i...	2.56								
5	100.65	1	2.22		1	2.00	1-1/8i...	2.56	1	0.59	1-1/8i...	2.56								
6	100.74	1	2.50		1	2.00	1-1/8i...	2.56	1	0.69	1-1/8i...	2.56	2	0.00	1-1/8i...	4.56				
7	101.01	1	3.42		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	0.63	1-1/8i...	4.56				
8	101.59	1	5.42		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
9	102.94	1	10.00		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
10	103.59	1	12.19		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
11	103.99	1	13.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
12	104.12	1	14.00		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
13	105.17	1	17.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
14	105.59	1	19.00		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
15	105.76	1	19.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
16	106.35	1	21.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	0.63	1-1/8i...	4.56				
17	106.47	1	22.00		1	2.00	1-1/8i...	2.56	1	0.86	1-1/8i...	2.56	2	0.34	1-1/8i...	4.56	1	0.00	1-1/4i...	2.63
18	106.62	1	22.50		1	2.00	1-1/8i...	2.56	1	0.69	1-1/8i...	2.56	2	0.00	1-1/8i...	4.56	1	0.28	1-1/4i...	2.63
19	106.79	1	23.08		1	2.00	1-1/8i...	2.56	1	0.49	1-1/8i...	2.56					1	0.60	1-1/4i...	2.63
20	106.99	1	23.75		1	1.54	1-1/8i...	2.56	1	0.26	1-1/8i...	2.56					1	0.98	1-1/4i...	2.63
21	107.21	1	24.50		1	1.03	1-1/8i...	2.56	1	0.00	1-1/8i...	2.56					1	1.40	1-1/4i...	2.63
22	107.35	1	25.00		1	0.69	1-1/8i...	2.56									1	1.68	1-1/4i...	2.63
23	107.52	1	25.58		1	0.29	1-1/8i...	2.56									1	2.00	1-1/4i...	2.63
24	107.65	1	26.00		1	0.00	1-1/8i...	2.56									1	2.00	1-1/4i...	2.63
25	108.41	1	28.58														1	2.00	1-1/4i...	2.63
26	110.00	1	34.00														1	2.00	1-1/4i...	2.63
27	200.00	2	0.00														1	2.00	1-1/4i...	2.63

For reinforcement that reside on the same row in the matrix, if the rebar row number, bar size, and vertical distance are the same, then the number of bars will be added together when the program creates the BRASS cross-sections. For example, in the above matrix screenshot, in row three of the matrix the first two rebar groups have the same rebar row number, bar size, and vertical distance. Thus, when the program creates BRASS cross-section number three, it will generate 1.57 - #10 bars in row 1 at a vertical distance of 2.56 inches.

Each numbered row in the matrix that has concrete dimensions showing will end up having the same BRASS cross-section number. Thus, matrix row one will end up being BRASS cross-section number one, matrix row two will end up being BRASS cross-section number two and so on.

The user is to define the starting and ending points for every bar that exists within each unique span. This will often result with bars ending in other spans that are defined as copies of a previous unique span. The program will only generate BRASS cross-sections for the matrix rows that have concrete dimensions displayed. For example, in the following screenshot of the matrix, the program will only generate 64 BRASS cross-sections. This is because the matrix rows 65 and above do not have concrete dimensions shown. This is because the user had indicated on the Span Configuration Tab that spans three and four are to be copies of spans one and two. Spans three and four show control points in the matrix for the ending locations of rebar that started in spans one and two.



Concrete Section Matrix

	Span Fraction	Span Number	Location	X-Section Number	bf top	tf top	tw top	tw bottom	bf bottom	tf bottom	D1	D2	D3	D4	D5	D6	D7	D8
44	206.02	2	35.50	-	108.00	6.00	14.50	14.50										
45	206.09	2	35.94	-	108.00	6.00	14.50	14.50										
46	206.40	2	37.75	-	108.00	6.00	14.50	14.50										
47	206.45	2	38.04	-	108.00	6.00	14.50	14.50										
48	206.62	2	39.08	-	108.00	6.00	14.50	14.50										
49	206.78	2	40.00	-	108.00	6.00	14.50	14.50										
50	206.87	2	40.54	-	108.00	6.00	14.50	14.50										
51	207.13	2	42.04	-	108.00	6.00	14.50	14.50										
52	207.20	2	42.50	-	108.00	6.00	14.50	14.50										
53	207.29	2	43.00	-	108.00	6.00	14.50	14.50										
54	207.39	2	43.58	-	108.00	6.00	14.50	14.50										
55	207.50	2	44.25	1	108.00	6.00	14.50	14.50										
56	207.71	2	45.50	-	108.00	6.00	15.30	15.30										
57	207.81	2	46.08	-	108.00	6.00	15.68	15.68										
58	207.88	2	46.50	-	108.00	6.00	15.94	15.94										
59	207.97	2	47.00	-	108.00	6.00	16.29	16.29										
60	208.31	2	49.00	-	108.00	6.00	17.58	17.58										
61	208.49	2	50.08	-	108.00	6.00	18.26	18.26										
62	208.90	2	52.50	-	108.00	6.00	19.82	19.82										
63	209.51	2	56.08	-	108.00	6.00	22.14	22.14										
64	210.00	2	59.00	2	108.00	6.00	24.00	24.00										
65	300.50	3	2.93															
66	301.09	3	6.43															
67	301.51	3	8.93															
68	301.69	3	10.00															
69	302.12	3	12.50															
70	302.19	3	12.93															
71	302.62	3	15.43															
72	302.80	3	16.50															
73	303.22	3	19.00															
74	303.38	3	19.93															
75	303.98	3	23.50															
76	310.00	3	59.00															
77	409.59	4	32.60															
78	410.00	4	34.00															

2.3.10 CBG – Generate Brass File Inputs

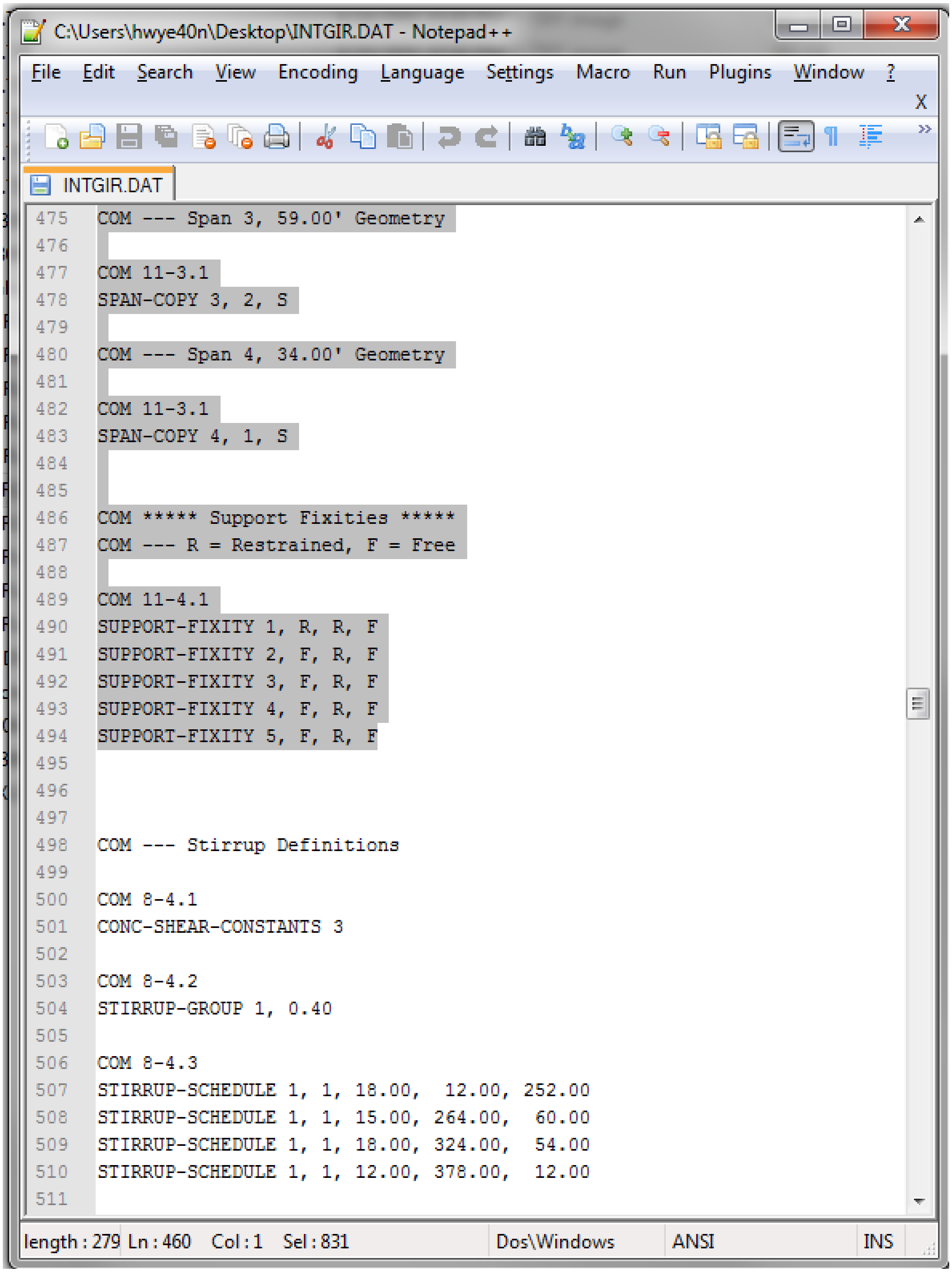
Selecting the “Generate BRASS File Input” button will display a text window that contains all of the needed BRASS-GIRDER(LRFD) input commands from the very beginning of the file up to the point where the user defines the stirrup definitions. When the window appears, all of the text is already selected, therefore all the user has to do is right click in the window and select the “Copy” command.

BRASS-GIRDER(LRFD) Command Input (*.DAT)

Copy and Paste the below text into the BRASS-GIRDER(LRFD) Input File

```
COM 2-1.3
BRIDGE-NAME 07806, Hwy 35 over Hwy 1

COM 2-1.5
ROUTE 76.65, Hwy35 (Coos Bay - Roseburg Highway)

COM 2-1.6
TITLE File IntGir.DAT  Interior Girder
TITLE Rating for Design, Legal, CTP, & STP Loads

COM 2-1.1
AGENCY Oregon DOT

COM 2-1.2
ENGINEER S Burgess T Kinney

COM
COM  ***** LRFR Load Rating, Strength Limit State *****
COM

COM 4-1.1
ANALYSIS B, 1, RAT, T, Y

COM 4-1.2
POINT-OF-INTEREST U

COM 2-1.4
UNITS US

COM 5-1.1
OUTPUT 4, Y, , , 1, , , , , , , , , ,

COM 5-7.3
OUTPUT-EFF-WIDTH N

COM BRASS (LRFD) INPUT ADJUSTMENT TYPE 1:
COM For LRFR specify the Strength Limit States
COM and ignore Service & Fatigue Limits
COM Design & Legal Loads = Strength-I
COM Permit Loads = Strength-II
COM (refer to 4-5.1, Fig. 2) and
COM specify shear checks for all load types.

COM 4-5.1, 4-5.2
MAP-LIMIT-STATE ST, 1, I, Y, N
MAP-LIMIT-STATE ST, 2, N, N, Y
MAP-SPEC-CHECK ST, 1, D, SHR, Y
```

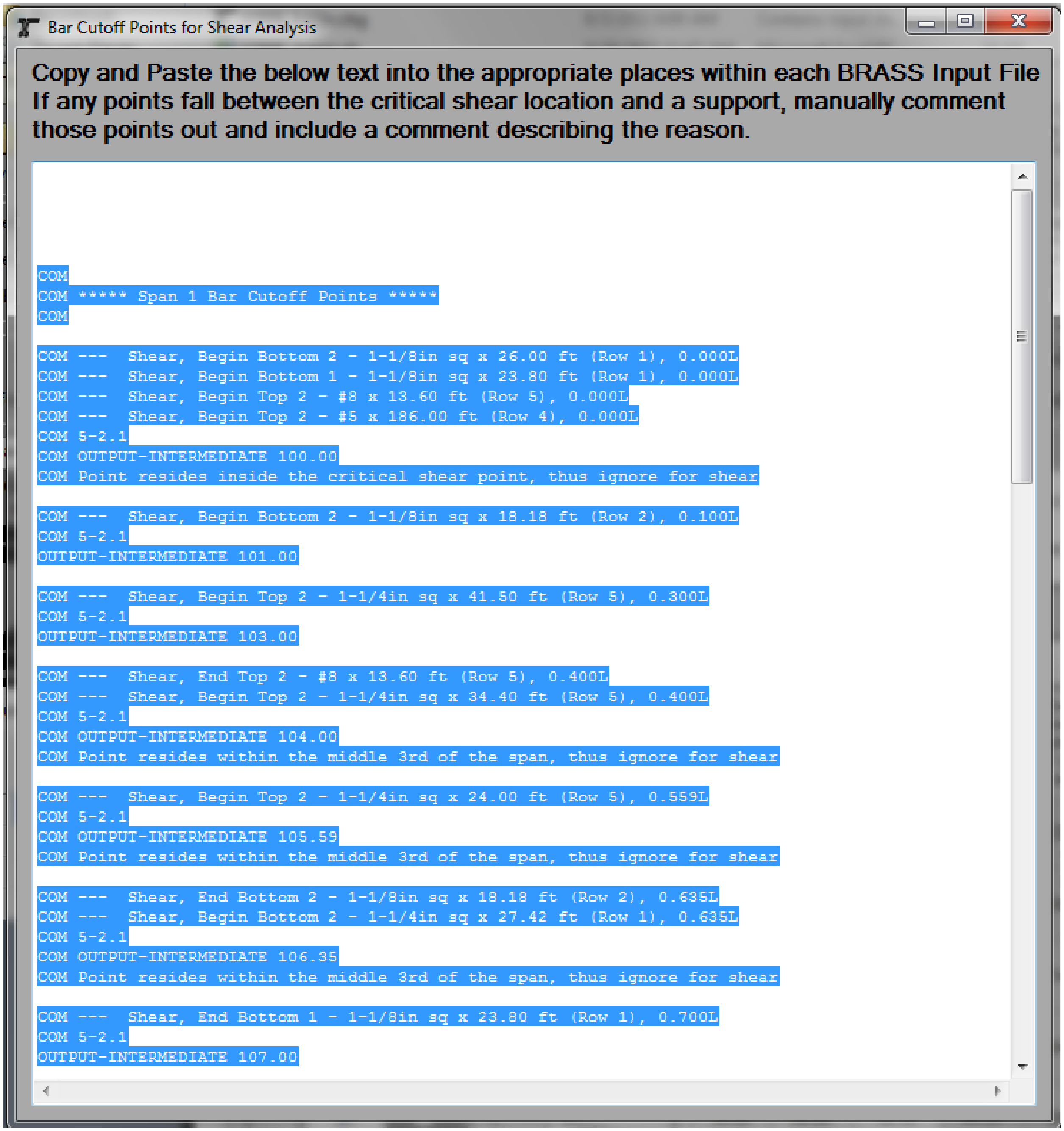
Then in the appropriate input file template, the user selects all of the text from the very beginning of the file up to just before the comment line that states, “Stirrup Definitions”. Then selecting the “Paste” command will replace all of the selected text commands with those that were just copied from the CBG.




```
COM --- Span 3, 59.00' Geometry

COM 11-3.1
SPAN-COPY 3, 2, S

COM --- Span 4, 34.00' Geometry

COM 11-3.1
SPAN-COPY 4, 1, S


COM ***** Support Fixities *****
COM --- R = Restrained, F = Free

COM 11-4.1
SUPPORT-FIXITY 1, R, R, F
SUPPORT-FIXITY 2, F, R, F
SUPPORT-FIXITY 3, F, R, F
SUPPORT-FIXITY 4, F, R, F
SUPPORT-FIXITY 5, F, R, F



COM --- Stirrup Definitions

COM 8-4.1
CONC-SHEAR-CONSTANTS 3

COM 8-4.2
STIRRUP-GROUP 1, 0.40

COM 8-4.3
STIRRUP-SCHEDULE 1, 1, 18.00,  12.00, 252.00
STIRRUP-SCHEDULE 1, 1, 15.00, 264.00,  60.00
STIRRUP-SCHEDULE 1, 1, 18.00, 324.00,  54.00
STIRRUP-SCHEDULE 1, 1, 12.00, 378.00,  12.00

```

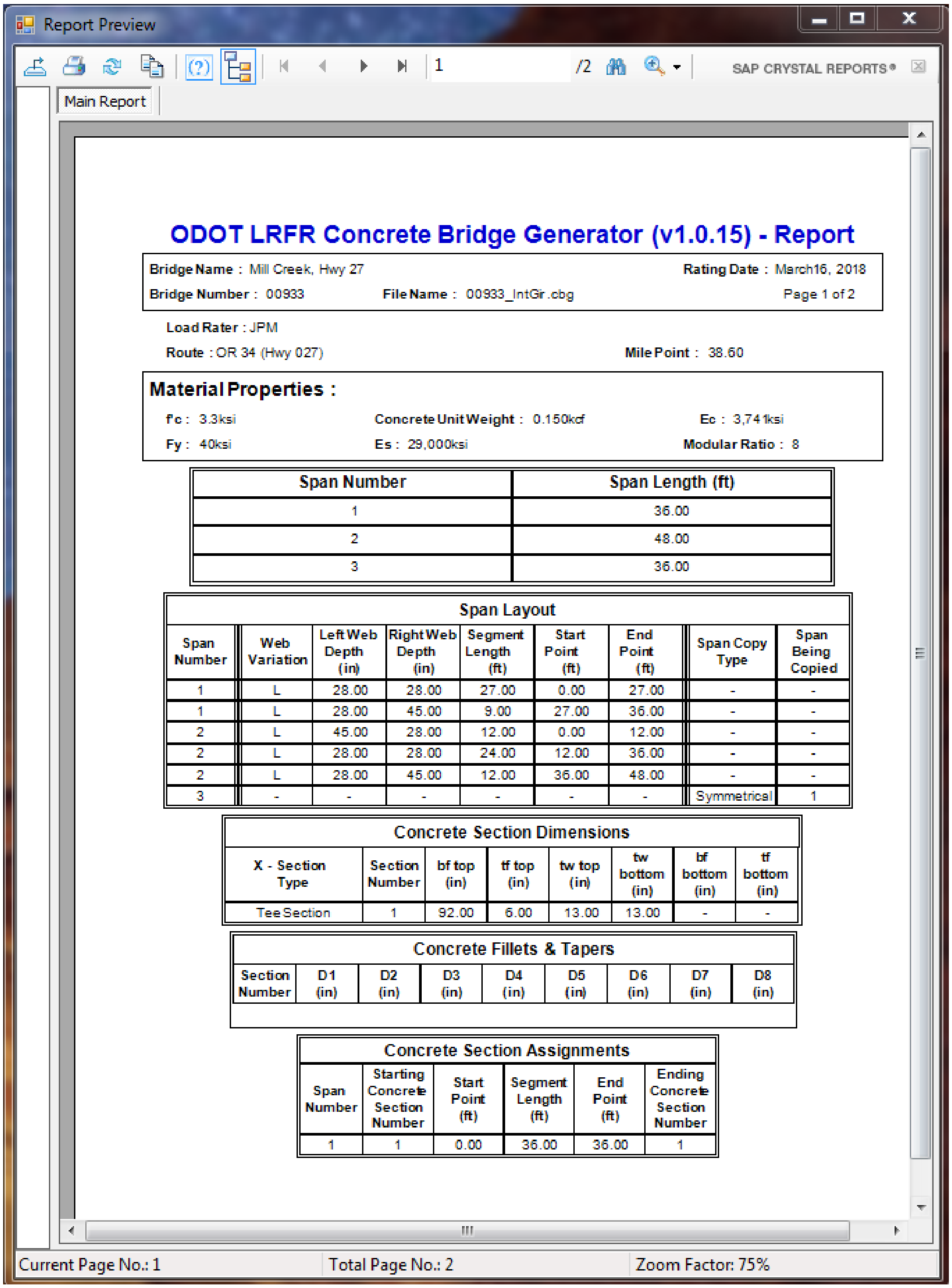
2.3.11 CBG – Generate Bar Cutoff Points for Shear Analysis

Selecting the "Generate Bar Cutoff Points for Shear Analysis" button will display a text window that contains all of the needed BRASS input shear commands for the bar cutoff points. When the window appears, all of the text for all of the commands for the different spans is already selected. The user needs to select and copy the group of commands for only one span at a time, and then paste them within the appropriate spot in each BRASS input file. Comment out any analysis points that are within the critical shear section.



2.3.12 CBG – Report

Once all of the data has been entered, verified with the matrix and the various BRASS commands have been copied and pasted in the BRASS input files, the user should save the data into a *.cbg file that will be included in the electronic file set. Then the user should select the "Report" button, which will display a print preview of a report that reflects the data entered in the various form fields of the program. Selecting the button that has the printer icon at the top of the print preview will print a hard copy of the report, which should be included in the printed calc book for the load rating.



ODOT LRFR Concrete Bridge Generator (v1.0.15) - Report

Bridge Name : Mill Creek, Hwy 27 — Rating Date : March16, 2018
Bridge Number : 00933 — File Name : 00933_IntGr.cbg — Page 1 of 2

Load Rater : JPM
Route : OR 34 (Hwy 027) — Mile Point : 38.60

Material Properties :

f'c : 3.3ksi — Concrete Unit Weight : 0.150kcf — Ec : 3,741ksi
Fy : 40ksi — Es : 29,000ksi — Modular Ratio : 8

Span Number	Span Length (ft)
1	36.00
2	48.00
3	36.00

Span Layout

Span Number	Web Variation	Left Web Depth (in)	Right Web Depth (in)	Segment Length (ft)	Start Point (ft)	End Point (ft)	Span Copy Type	Span Being Copied
1	L	28.00	28.00	27.00	0.00	27.00	-	-
1	L	28.00	45.00	9.00	27.00	36.00	-	-
2	L	45.00	28.00	12.00	0.00	12.00	-	-
2	L	28.00	28.00	24.00	12.00	36.00	-	-
2	L	28.00	45.00	12.00	36.00	48.00	-	-
3	-	-	-	-	-	-	Symmetrical	1

Concrete Section Dimensions

X - Section Type	Section Number	bf top (in)	tf top (in)	tw top (in)	tw bottom (in)	bf bottom (in)	tf bottom (in)
Tee Section	1	92.00	6.00	13.00	13.00	-	-

Concrete Fillets & Tapers

Section Number	D1 (in)	D2 (in)	D3 (in)	D4 (in)	D5 (in)	D6 (in)	D7 (in)	D8 (in)

Concrete Section Assignments

Span Number	Starting Concrete Section Number	Start Point (ft)	Segment Length (ft)	End Point (ft)	Ending Concrete Section Number
1	1	0.00	36.00	36.00	1

2.3.13 CBG – Known Issues

All known errors with the CBG have been corrected.

2.4 Analysis of Girders

BRASS-GIRDER will be used to load rate the concrete girders. BRASS-GIRDER is different from the previous BRASS-GIRDER(LRFD) program in that it no longer uses text file inputs, but instead utilizes a Graphical User Interface (GUI) with data saved in xml file format. Instead of developing new procedures and a new CBG program to populate the GUI of BRASS-GIRDER, this manual will continue to give instructions on how to create the text input file for BRASS-GIRDER(LRFD). Once the file is ready for analysis, the user will run the text input file through the BRASS-GIRDER translator that will create the xml input file used to populate the new GUI. From there the user will be able to run the analysis within BRASS-GIRDER.

BRASS has increased the live load definition limit from 20 to 100 per file. In the past, since ODOT requires more than 20 vehicles to be analyzed in every LRFR load rating, two nearly identical BRASS input files were used to cover all of the different vehicles. Since the transition from using BRASS-GIRDER(LRFD) to using BRASS-GIRDER for the analysis, ODOT has modified all of its tools to only use a single BRASS file with all of the rating vehicles included. Therefore, ODOT will no longer require the two separate nearly identical BRASS "_N" and "_T" files.

2.4.1 BRASS Input File Conventions

Use the heavily commented sample files provided as templates to be copied to a new bridge-number-specific folder (with a new filename if appropriate) and then modified for the actual Load Ratings. Separate input files will be required for each structure type in any bridge with a combination of structure types, and for interior and exterior girders due to the variability of live load distribution factors in LRFR.

- General conventions

  Use the full length of each command name except the COMMENT (3-1.1) command shall be only COM.

  Precede each command or logical group of similar commands (except for the COMMENT command) with a comment referring to the Article number in the BRASS-GIRDER(LRFD) Command Manual. For example, precede an ANALYSIS (4-1.1) command with a comment command thus:

  ```
  COM 4-1.1
  ANALYSIS F, 1, RAT, T, Y
  ```

  Generally, leave in all comments found in the template (unless they become totally irrelevant to a particular input file), modifying them and adding more comments as required to fit the specific conditions of the rating. Use comments liberally with the expectation that someone unfamiliar with the BRASS-GIRDER(LRFD) program and unfamiliar with the bridge will need to read the data file and fully understand it.

  Leave parameters blank (spaces between commas) where they are irrelevant to the specific structure. Although trailing commas can be omitted where all parameters to the right are to be blank, it is recommended to clarify your intentions by showing the blank parameters separated by commas. However, avoid leaving blank parameters such as material strengths where default values would apply. Enter the default values to make the dataset more meaningful to a future user.

Show in-line calculations (what the BRASS-GIRDER(LRFD) Manual calls in-line arithmetic) within a parameter (between commas) to convert units from feet to inches where the command parameter requires inches. Similarly, show in-line calculations to show how you determined the vertical dimensions to locate flexural bars. However, note that BRASS has the following limitations on in-line calculations: It cannot handle parentheses within in-line calculations, and it cannot correctly handle more than one multiplication or division operator in any one term, i.e. use no more than one multiplication or division between plus and minus signs. Other than these in-line calculations, the best place to put calculations is in the Preliminary File rather than in the BRASS comments.

Whenever a BRASS-GIRDER(LRFD) input file contains a series of occurrences of the same command, vertically aligning the same command parameters for clarity is encouraged. This practice simplifies the process of changing values of parameters when cloning an old BRASS file for use in a new bridge. Inserting spaces as required to accomplish this is harmless. However, do not use tab characters to accomplish this. They are misinterpreted by BRASS-(LRFD) as the next parameter, and are likely to cause fatal errors.

- Input File Sections

To make it easier for a subsequent user to find their way around the Input File, separate the BRASS input file into logical sections (large groups of commands) by using spaced comments as indicated in the sample files. Typically, an input file for an RCDG will be divided into the following sections:

```
COM
COM  ***** LRFR Load Rating, Strength Limit State *****
COM

COM
COM  ***** Material Properties *****
COM

COM
COM  ***** Section Geometry *****
COM

COM
COM  ***** Span Length and Section Information *****
COM

COM
COM  ***** Dead Loads *****
COM

COM
COM  ***** Live Loads *****
COM

COM
COM  ***** Distribution Factors *****
COM

COM
COM  ***** Resistance Factors *****
COM

COM
```

```
COM   ***** Critical Flexural Sections *****
COM

COM
COM  ***** Shear Points of Interest *****
COM
```

With similar comment sets, subdivide the "Shear Points of Interest" section into subsections for each category of investigated section for each unique span. (See the sample input files).

- Specific conventions

Several of these conventions and commands will be automatically created by the CBG program. They are listed within this section to provide background and understanding as to what ODOT is requiring within the BRASS-GIRDER(LRFD) input files.

At the beginning of every input file, use the BRIDGE-NAME (2-1.3) command to provide the 5- or 6-character NBI Bridge Number, followed by the Bridge Name. Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Next, use the ROUTE (2-1.5) command to provide the mile point and signed Route Number where applicable (always required for State-owned bridges). Note the signed Route Number is not the same as the ODOT internal (maintenance) Highway Number.

Use 2 lines of the TITLE (2-1.6) command. Use the first TITLE line to provide the file name and describe which girder(s) this file applies to. Use the second TITLE line to provide the purpose or work grouping of the Load Rating.

Use the AGENCY (2-1.1) command to identify the Load Rating as being performed according to ODOT standards. This command should always be the same:

```
COM 2-1.1
AGENCY Oregon DOT
```

Use the ENGINEER (2-1.2) command to indicate the load rater.

Use the UNITS (2-1.4) command to force BRASS to always use US (English) units for both input and output. BRASS normally defaults to US units, but it has been found that when referenced dimensions get large, BRASS will automatically assume the large dimensions are in millimeters and will convert the units when it calculates the resistance of the member. Using the UNITS command will not allow BRASS to arbitrarily convert the units during an analysis.

```
COM 2-1.4
UNITS US
```

Use the ANALYSIS (4-1.1) command to provide BRASS with parameters needed to do a rating analysis. The "continuous beam model" is the preferred choice ("B" in parameter 1) as long as there is no need to include columns in the analysis and the bridge has ≤ 13 spans. Parameter 5 needs to be coded as Y, for yes, to interpolate reinforcing steel from the left cross section to the right cross section. This will allow BRASS to account for partially developed reinforcing steel per AASHTO LRFD 5.7.3.4.2. Except for a rigid frame analysis (with columns) that would require the "frame type model" ("F" in parameter 1), this command would normally be the same:

```
COM 4-1.1
ANALYSIS B, 1, RAT, T, Y,
```

Use the POINT-OF-INTEREST (4-1.2) command to set BRASS to generate user-defined points of interest from subsequent OUTPUT-INTERMEDIATE (5-2.1) commands.

```
COM 4-1.2
POINT-OF-INTEREST U
```

Leaving the 2nd parameter (Specification Check Output) blank causes BRASS to default to refrain from generating a large additional output (**.**OUT) file for each point of interest, information that is not normally needed. Use of “Y” for parameter 2 to turn on this additional output may be justified at sections where there is a need to account for partially developed bars. If these additional **.**OUT files are generated, they do not need to be printed in the Load Rating Report.

Use the OUTPUT (5-1.1) command to control the wide variety of output options. Unless there is a problem that requires more detailed intermediate output for investigation, this command should always the same:

```
COM 5-1.1
OUTPUT 4, Y, , , 1, , , , , , , , , ,
```

Beginning with BRASS-Girder(LRFD) v.1.6.1, the effective top flange width is calculated and applied to the section properties automatically. Use the OUTPUT-EFF-WIDTH (5-7.3) command to direct BRASS to not output its effective flange width calculations. This command should always be the same:

```
COM 5-7.3
OUTPUT-EFF-WIDTH N
```

Code all BRASS models in the same direction as the girder elevation appears on the plans, i.e. from left to right on the plans, regardless of mile point direction.

In the “Material Properties” section, use the CONC-MATERIALS (8-1.1) command to provide the material properties consistent with the notes on the bridge plans. Although there are exceptions, a typical RCDG structure from the 1950’s or early 1960’s would have the following properties command:

```
COM 8-1.1
CONC-MATERIALS 0.15, 3.3, 40.0, 40.0, 9, , , 170.0, , ,
```

In the “Material Properties” section, use the DECK-MATL-PROPERTIES (6-4.1) command to assure that the default wearing surface weight (parameter 3) is set to 0. Without this command, BRASS would generate its own DW load, which we want to define explicitly in the “dead loads” section.

```
COM This command is required to assure default deck Wearing
Surface Weight
COM (parameter 3) is 0 so BRASS does not generate a DW load on
its own
COM 6-4.1
DECK-MATL-PROPERTIES , , 0.0
```

If the material properties of the top flange differ from those in the web and bottom flange of the girder, use the CONC-MATERIAL-FLANGE (8-1.2) command to define the properties for the concrete in the top flange of a concrete girder. The following is an example of this command:

```
COM 8-1.2
COM Deck slab concrete strength differs from girder concrete.
CONC-MATERIAL-FLANGE 4.0, 8
```

In the “Section Geometry” section, define each section numbered sequentially, preceded by a comment identifying it with characteristics from the plans. Use the CONC-TEE-SECTION (8-2.3) or the CONC-I-SECTION (8-2.4) if applicable, to define the cross-section section dimensions (except for depth). Note the parameters for these commands changed beginning with BRASS-GIRDER(LRFD) v.1.6.1.

BRASS version 2.0.3 has been updated to include the 2008 revision of the 4^{th} Edition LRFD Code. With this update it is no longer necessary to calculate the effective flange width of composite slabs in the preliminary file. The second parameter of COMPOSITE-SLAB command may be left blank to allow BRASS to calculate the effective width.

Use as many CONC-REBAR (8-2.8) commands as required to define all the layers of longitudinal reinforcement that are present. For negative moment sections, it is important to include all longitudinal bars present within the effective top flange width. The following is an example of the series of commands to define one section:

```
COM --- Sect 1, Pos. Moment, Span 1, 2#11 + 4#10 bot, 2#5 top

COM 8-2.3, 8-2.8
CONC-TEE-SECTION 1, 92.00, 6.00, 13.00, ,
CONC-REBAR 1, 1,  2, 11,  2.00+1.25/2
CONC-REBAR 1, 1,  1, 10,  2.00+1.125/2
CONC-REBAR 1, 2,  3, 10,  2.00+1.25+3.00+1.125/2
CONC-REBAR 1, 5,  2,  5,  2.00+0.625/2
```

Some of the older bridges occasionally have the deck reinforcing exposed. ACI318, Article 12.2.3.2, states that for bars with a cover of d_b or less or with a clear spacing of $2d_b$ or less that the basic development length (obtained from the LRFD code) be multiplied by 2.0. Therefore, if the inspection report or photos indicate that the deck reinforcement is exposed, double the development length of the deck reinforcement.

In the “Span Lengths and Section Information” section, define each span beginning with the appropriate command from Chapter 11 of the *BRASS-GIRDER(LRFD) Command Manual* that describes the profile (depth variation) along the span. Follow this command with a sequence of SPAN-SECTION (11-2.1) commands to assign the previously defined sections to cumulative ranges from the left end of the span. The following is an example of the series of commands to define one span:

```
COM --- Span 1, 36' Geometry

COM 11-1.3, 11-2.1
SPAN-UNIF-HAUNCH 1, 36.0*12, R, 28.00, 27.0*12, 45.00,
SPAN-SECTION 1,  1, 12.88*12
SPAN-SECTION 1,  2, 14.08*12
SPAN-SECTION 1,  3, 18.13*12
SPAN-SECTION 1,  4, 21.08*12
SPAN-SECTION 1,  5, 24.13*12
SPAN-SECTION 1,  6, 26.08*12
SPAN-SECTION 1,  7, 27.29*12
SPAN-SECTION 1,  8, 34.08*12
SPAN-SECTION 1,  9, 36.00*12
```

Use the SPAN-HINGE (11-5.1) command if necessary to define the location of any hinge within the span. If the structure has an expansion joint over a support, approximate this condition by placing a hinge close to, but not at, the support. BRASS-GIRDER(LRFD) does not allow the use of a hinge at a support, and recommends that it be located a distance of 1.2" from the support. If BRASS gives anomalous moment results, or it unexpectedly places the hinge farther out in the span than you expect, the solution is to relocate the hinge farther than 1.2" from the support, increasing in small increments until the reported moments behave as expected. (Sometimes increasing the offset by hundredths of a foot can make all the difference!).

Use the SUPPORT-FIXITY (11-4.1) command to define the boundary conditions of each span, for example:

```
COM --- Support Fixities

COM 11-4.1
SUPPORT-FIXITY 1, R, R, F
SUPPORT-FIXITY 2, F, R, F
SUPPORT-FIXITY 3, F, R, F
SUPPORT-FIXITY 4, F, R, F
```

Use a sequence of commands from Chapter 8 of the *BRASS-GIRDER(LRFD) Command Manual* to facilitate obtaining Rating Factors at shear points of interest without defining the stirrup area and spacing at each point. Use the CONC-SHEAR-CONSTANTS (8-4.1) to choose which AASHTO LRFD procedure to apply for shear capacity calculations. Use the STIRRUP-GROUP (8-4.2) command to define each group of stirrups that has a unique geometry. Then use a series of STIRRUP-SCHEDULE (8-4.3) commands to assign stirrup groups and define stirrup spacing along each span. The following is an example of the series of commands to define the stirrups for one span:

```
COM 8-4.1
CONC-SHEAR-CONSTANTS 3

COM 8-4.2
STIRRUP-GROUP 1, 0.40

COM 8-4.3
STIRRUP-SCHEDULE 1, 1, 10.00,  15.00,  30.00
STIRRUP-SCHEDULE 1, 1, 13.88,  45.00, 235.96
STIRRUP-SCHEDULE 1, 1,  8.00, 280.96, 136.00
```

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the BRASS-GIRDER(LRFD) Input (**.**DAT) file as they were calculated in the Preliminary (**.xmcd**) File. Diaphragm point loads should be considered part of component load DC.

Because BRASS calculates girder dead load (self-weight) using the input section dimensions and treats it separately from other dead loads, group the rest of the structure dead loads under the first occurrence of the of the LOAD-DEAD-DESCR (12-1.2) command, using the description (parameter 4) "Other Structure dead loads". Beginning with BRASS-GIRDER(LRFD) Version 1.6.1, BRASS correctly calculates the girder self-weight regardless of what portion of the top flange is effective. There is no longer a need to account for ineffective top flange weight separately in the "Other Structure dead loads" group. This group will normally include the LOAD-DEAD-POINT (12-1.4) commands for the dead load of the diaphragms. Include loads for diaphragms directly over the supports. While they will not have any effect on the girder analysis, they will be used to calculate dead load reactions used in the crossbeam analysis. Precede each group of LOAD-DEAD-UNIFORM and LOAD-DEAD-POINT commands with an additional identifying comment describing the load. An example of this first (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 1, DC, 1, Other Structure Dead Loads

COM  Diaphragms 1.783 k at midspan points, spans 1,3
COM  Diaphragms 1.783 k at quarter points, span 2

COM 12-1.4
LOAD-DEAD-POINT 1, 1, , 1.783, 18.0*12
LOAD-DEAD-POINT 1, 2, , 1.783, 12.0*12
LOAD-DEAD-POINT 1, 2, , 1.783, 24.0*12
LOAD-DEAD-POINT 1, 2, , 1.783, 36.0*12
LOAD-DEAD-POINT 1, 3, , 1.783, 18.0*12
```

Group the remaining component dead loads (DC) (excluding wearing surface dead loads) in the next LOAD-DEAD-DESCR (12-1.2) command using the description (parameter 4) "Superimposed dead loads". This group should include LOAD-DEAD_UNIFORM (12-1.3) commands as needed to account for all superimposed (Stage-2) dead loads except the wearing surface. Precede each group of LOAD-DEAD-UNIFORM commands with an additional identifying comment describing the load. An example of this 2nd (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 2, DC, 1, Superimposed Dead Loads

COM  Each rail = 0.422 k/ft (Std. Dwg. 10734)
COM  Distributed equally to all 4 girders, w = 0.211 k/ft

COM 12-1.3
LOAD-DEAD-UNIFORM 2, 1, 0.0*12, 0.211/12, 36.0*12, 0.211/12
LOAD-DEAD-UNIFORM 2, 2, 0.0*12, 0.211/12, 48.0*12, 0.211/12
LOAD-DEAD-UNIFORM 2, 3, 0.0*12, 0.211/12, 36.0*12, 0.211/12
```

To facilitate future re-ratings with different wearing surface loads, always apply the wearing surface dead load under its own LOAD-DEAD-DESCR (12-1.2) command separate from all other uniform superimposed dead loads. Precede each LOAD-DEAD-UNIFORM command with an additional identifying comment describing the load. An example of this 3rd (DW) dead load group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 3, DW, 1, Wearing Surface Dead Load
COM  2.5" + 1" ACWS
COM  Distributed equally to all 4 girders, w = 0.284 k/ft

COM 12-1.3
LOAD-DEAD-UNIFORM 3, 1, 0.0*12, 0.284/12, 36.0*12, 0.284/12
LOAD-DEAD-UNIFORM 3, 2, 0.0*12, 0.284/12, 48.0*12, 0.284/12
LOAD-DEAD-UNIFORM 3, 3, 0.0*12, 0.284/12, 36.0*12, 0.284/12
```

Use the BRASS Input Adjustments #1 thru #3 explained below to code the live load requirements.

To assure that BRASS calculates girder Distribution Factors (number of lanes) according to AASHTO LRFD 4.6.2.2, the following BRASS-GIRDER(LRFD) commands are required:

- Specify number of girders & spacing with the DECK-GEOMETRY (6-1.1) command. Note that the left and right cantilevers (parameters 4 and 5) are the distances from centerline of exterior girder to edge of *deck*.
- If girder spacing is variable, use the DECK-VSPACING (6-1.2) to define the spacing that differs from the uniform spacing specified in the DECK-GEOMETRY command.
- Specify the girder of interest (interior or exterior, using girder numbers starting at the left edge) using the DIST-CONTROL-GIRDER (4-3.1) command.
- Specify number of lanes and skew using the DIST-CONTROL-LL (4-3.3) command.
- Specify the edges of the roadway (which limits the extreme transverse wheel positions) by using the DECK-TRAVEL-WAY (6-3.3) command.

Do not calculate Distribution factors manually (in the Mathcad Preliminary File) unless absolutely necessary. However, if Distribution Factors in AASHTO LRFD 4.6.2.2 are calculated manually, note that we interpret the definition of d_e in AASHTO LRFD 4.3 as "distance from the *centerline* of the exterior web to the interior edge of curb or traffic barrier."

Use the BRASS Input Adjustment #4 explained below to code the Resistance Factors.

Use the BRASS Input Adjustment #5 explained below to obtain detailed output regarding the Distribution Factors.

To obtain Rating Factors for flexure points of interest, use OUTPUT-INTERMEDIATE (5-2.1) commands grouped in the same order and groupings as the analysis points were calculated in the Preliminary File.

To obtain Rating Factors for shear points of interest, use OUTPUT-INTERMEDIATE (5-2.1) commands grouped in the same order and groupings as the analysis points were calculated in the Preliminary File. In the "Bar Cutoff Points" subsection of the "Critical Shear Sections" portion of the BRASS code, normally these commands are copied from the window that is displayed when selecting the "Generate Bar Cutoff Points for Shear Analysis" button in the CBG program. Within each span, make sure that none of the analysis points duplicate each other (have identical span fractions), and delete one of each duplicate pair. Precede each OUTPUT-INTERMEDIATE command with a comment (usually text taken from the Preliminary File) explaining which type of force is being investigated (Positive Moment, Negative Moment or Shear), the span number and nearby bent number, and the span fraction. The use of the OUTPUT-INTERMEDIATE command along with the Stirrup Schedule feature of BRASS, eliminates the need to determine stirrup area and spacing specifically at every shear point of interest.

Note: Section 8-3.1 of the *BRASS-GIRDER(LRFD) Command Manual* implies that omitting the CONC-SHEAR command would mean that parameter 2, the Shear Indicator, would default to 2, so the program would use the Simplified Method for shear. However the previous use of the CONC-SHEAR-CONSTANTS (8-4.1) command in the stirrup definition sequence overrides this default and forces the AASHTO General Method for shear (MCFT) to be used.

Normally shear need not be evaluated within d_v of the face of a simple support nor in the middle 1/3 of a span. However, the presence of significant shear cracking (> 0.040" wide) in the region within d_v of the support face may warrant a shear investigation in this region. In such an investigation, since the MCFT approach is less conservative in this "zone of confusion" near a simple support, shear capacity should be evaluated using the AASHTO Simplified Procedure in AASHTO LRFD 5.7.3.4.1. This is accomplished in BRASS by using the CONC-SHEAR (8.3-1) command and setting the Shear Indicator (2nd parameter) to 2.

However, in the case of checking the shear inside the d_v point near a continuous support, MCFT works very well since that location has high (negative) moment and shear. Thus, there would be no reason to change the shear command for these special analysis points.

2.4.2 BRASS Input Adjustments

Because BRASS-GIRDER(LRFD) was designed primarily for AASHTO LRFD analyses and was created before the *MBE Manual* was published, a number of standard BRASS Input Adjustments are necessary. Fortunately the program is flexible enough to allow an accurate solution with work-arounds (BRASS Input Adjustments). These adjustments will normally apply to every Input File, at least until BRASS-GIRDER(LRFD) is changed. See the sample input files for proper placement of these adjustments.

- BRASS-GIRDER(LRFD) Input Adjustment Type 1:

Use the MAP-LIMIT-STATE (4-5.1) and MAP-SPEC-CHECK (4-5.2) commands to force BRASS to check flexure and shear for only the limit states required by MBE. These limit states are different than the BRASS-GIRDER(LRFD) defaults. Thus it is necessary to force BRASS to check flexure and shear for Strength-I for Design and Legal loads, and for Strength-II for Permit Loads: For Design Loads (Strength-I Limit State), these commands also force BRASS to use γ_L = 1.75 (Inventory Level). (The Operating Level γ_L = 1.35 Rating Factors will automatically be derived from the Inventory Rating Factors in the Load Rating Summary Workbook by multiplying by the γ_L ratio). Use the following sequence of commands, which will normally not change:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 1:
COM  For LRFR specify the required Strength Limit States
COM  and ignore Service I & Fatigue Limits
COM  Design & Legal Loads - Strength-I
COM  Permit Loads - Strength-II
COM  (refer to 4-5.1 command, Fig. 2) and
COM  specify shear checks for all load types

COM 4-5.1, 4-5.2
MAP-LIMIT-STATE ST, 1, I, Y, N
MAP-LIMIT-STATE ST, 2, N, N, Y
MAP-SPEC-CHECK ST, 1, D, SHR, Y
MAP-SPEC-CHECK ST, 1, L, SHR, Y
MAP-SPEC-CHECK ST, 2, P, SHR, Y
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 2:

Use the FACTORS-LOAD-DL command (13-1.2) to force BRASS to use the MBE dead load factors, which are different than the AASHTO LRFD factors used by default. MBE Table 6A.4.2.2-1 requires constant dead load factors γ_{DC} and γ_{DW}, and the footnote allows γ_{DW} to be 1.25 when wearing surface thickness is field-measured, which is normally the case. Therefore, these commands are always required. Since the command only covers one limit state level at a time, use one for Strength-I and one for Strength-II:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,

COM 13-1.2
```

```
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 3:

  Using the BRASS-GIRDER(LRFD) LOAD-LIVE-CONTROL (12-4.1) command to apply the default Design and Legal Load sets would have 3 undesirable consequences:
  (a) BRASS would apply the Fatigue Design Load that is not needed for RCDG structures, generating unwanted output
  (b) BRASS would default to listing the Design Load outputs *after* all the other loads, potentially causing confusion in transferring loads to the ODOT Load Rating Summary Workbook
  (c) BRASS would apply the AASHTO 3S2 Legal Load which is lighter than the Oregon Legal 3S2 load.

  Therefore, use the LOAD-LIVE-DEFINITION (12-4.3) commands to define each Design and Legal Load separately, and use the LOAD-LIVE-CONTROL (12-4.1) command to define only parameter 1 (direction control, normally "B" for traffic in both directions) and parameter 7 (wheel advancement denominator, normally 100), as follows:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 3:
COM  All live loads will be entered individually
COM  Design Loads entered as live load definitions  1 thru  4
COM  Legal  Loads entered as live load definitions  5 thru  9
COM  Permit Loads entered as live load definitions 10 thru 19

COM 12-4.1
LOAD-LIVE-CONTROL B, , , , , , 100
```

  In structures with short spans, especially short cantilevers, BRASS may "crash" because the span is divided into live load advancement increments that are too small. If this occurs and you have a small span, try decreasing parameter 7 to the largest number for which BRASS will work, often 50 or sometimes even less.

  Further, because MBE Table 6A.4.2.2.1 requires a different live load factor γ_L for each truck, ADTT and truck weight combination, and BRASS-GIRDER(LRFD) does not provide for a separate live load factor for each truck, more BRASS Input Adjustments are required to define truck specific live load factors.

  Use the optional FACTORS-LOAD-LL command (13-1.3) such that the universal "gamma LL (Design)" (parameter 3), "gamma LL (Legal)" (parameter 4) and "gamma LL (Permit)" (parameter 5) are all forced to 1.0. Since this command only covers one limit state level at a time, two commands are always required (one for Strength-I and one for Strength-II):

```
COM  Use the FACTORS-LOAD-LL command to force
COM  universal gamma-LL to 1.0 for Legal & Permit Loads

COM 13-1.3
FACTORS-LOAD-LL ST, 1, 1.0, 1.0, 1.0
FACTORS-LOAD-LL ST, 2, 1.0, 1.0, 1.0
```

  With the universal live load factors set to 1.0, truck specific live load factors can be defined using the BRASS command 13-1.6, FACTORS-LOAD-LL-LS. Previous version of BRASS (LRFD) did not accommodate individual truck live load factors. Thus, a work around was developed where the live load factors were input as scale factors. With BRASS v 2.0.3 the FACTORS-LOAD-LL-LS command has been added to resolve this limitation. Live load factors shall be input using this new command. Parameter 6 of command 12-4.3, scale factor, will be reserve for its original purpose. With this update the LR summary sheet will no longer modify the rating factors reported in the BRASS output file.

In the FACTORS-LOAD-LL-LS (13-1.6) commands for each load, enter the specific live load Factor γ_L (from **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable). This command can be copied and pasted from the BRASS tab of LL_Factors_State.XLS.

Thus the complete live load definition command set for input files is as follows:

```
COM  Define each Design and Legal live load separately and
COM  apply the truck specific live load factor (instead
COM  of defining them in the LOAD-LIVE-CONTROL command)
COM  There are 3 reasons...
COM  (a) to prevent BRASS from applying the Fatigue Design
Load
COM      that is not needed for RCDG structures
COM  (b) to force BRASS to list the Design Loads outputs in
the
COM      same order as ODOT's Load Rating Summary Workbook
COM  (c) to allow use of the Oregon 3S2 Legal Load rather than
COM      the AASHTO 3S2 Design Load

COM Do NOT code the truck specific live load factor in
COM Parameter 6.

COM 12-4.3
LOAD-LIVE-DEFINITION  1, HL-93-TRUCK , DTK, D, ,
LOAD-LIVE-DEFINITION  2, HL-93-TANDEM, DTM, D, ,
LOAD-LIVE-DEFINITION  3, HL-93-TRKTRA, TKT, D, ,
LOAD-LIVE-DEFINITION  4, HL-93-LANE  , DLN, D, ,

LOAD-LIVE-DEFINITION  5, OR-LEG3     , TRK, L, ,
LOAD-LIVE-DEFINITION  6, ORLEG3S2    , TRK, L, ,
LOAD-LIVE-DEFINITION  7, ORLEG3-3    , TRK, L, ,
LOAD-LIVE-DEFINITION  8, ORLEG3-3    , LGT, L, ,
LOAD-LIVE-DEFINITION  9, LEGAL-LANE  , LLN, L, ,

LOAD-LIVE-DEFINITION 10, OR-SU4      , TRK, L, ,
LOAD-LIVE-DEFINITION 11, OR-SU5      , TRK, L, ,
LOAD-LIVE-DEFINITION 12, OR-SU6      , TRK, L, ,
LOAD-LIVE-DEFINITION 13, OR-SU7      , TRK, L, ,

LOAD-LIVE-DEFINITION 14, EV2         , TRK, L, , , ONE
LOAD-LIVE-DEFINITION 15, EV3         , TRK, L, , , ONE

LOAD-LIVE-DEFINITION 16, OR-CTP-2A   , TRK, P, ,
LOAD-LIVE-DEFINITION 17, OR-CTP-2B   , TRK, P, ,
LOAD-LIVE-DEFINITION 18, OR-CTP-3    , TRK, P, ,

LOAD-LIVE-DEFINITION 19, OR-STP-3    , TRK, P, ,
LOAD-LIVE-DEFINITION 20, OR-STP-4A   , TRK, P, ,
LOAD-LIVE-DEFINITION 21, OR-STP-4B   , TRK, P, ,
LOAD-LIVE-DEFINITION 22, OR-STP-4C   , TRK, P, ,
LOAD-LIVE-DEFINITION 23, OR-STP-4D   , TRK, P, ,
LOAD-LIVE-DEFINITION 24, OR-STP-4E   , TRK, P, ,
LOAD-LIVE-DEFINITION 25, OR-STP-5BW  , TRK, P, ,
```

```
COM  Use for spans > 200 ft only...
COM LOAD-LIVE-DEFINITION 24, ORLEG3-3     , LTK, L, ,

COM Truck Specific Live Load Factors


COM 13-1.6
FACTORS-LOAD-LL-LS 1, ST, 1, 1.75
FACTORS-LOAD-LL-LS 2, ST, 1, 1.75
FACTORS-LOAD-LL-LS 3, ST, 1, 1.75
FACTORS-LOAD-LL-LS 4, ST, 1, 1.75

FACTORS-LOAD-LL-LS 5, ST, 1, 1.30
FACTORS-LOAD-LL-LS 6, ST, 1, 1.30
FACTORS-LOAD-LL-LS 7, ST, 1, 1.30
FACTORS-LOAD-LL-LS 8, ST, 1, 1.30
FACTORS-LOAD-LL-LS 9, ST, 1, 1.30

FACTORS-LOAD-LL-LS 10, ST, 1, 1.30
FACTORS-LOAD-LL-LS 11, ST, 1, 1.30
FACTORS-LOAD-LL-LS 12, ST, 1, 1.30
FACTORS-LOAD-LL-LS 13, ST, 1, 1.30

FACTORS-LOAD-LL-LS 14, ST, 1, 1.30
FACTORS-LOAD-LL-LS 15, ST, 1, 1.30

FACTORS-LOAD-LL-LS 16, ST, 2, 1.25
FACTORS-LOAD-LL-LS 17, ST, 2, 1.25
FACTORS-LOAD-LL-LS 18, ST, 2, 1.30

FACTORS-LOAD-LL-LS 19, ST, 2, 1.10
FACTORS-LOAD-LL-LS 20, ST, 2, 1.25
FACTORS-LOAD-LL-LS 21, ST, 2, 1.00
FACTORS-LOAD-LL-LS 22, ST, 2, 1.00
FACTORS-LOAD-LL-LS 23, ST, 2, 1.00
FACTORS-LOAD-LL-LS 24, ST, 2, 1.00
FACTORS-LOAD-LL-LS 25, ST, 2, 1.00

COM Use for spans > 200 ft only...
COM Replace parameter 3 with the legal live load value.
COM FACTORS-LOAD-LL-LS 24, ST, 1.30
```

The Oregon Legal Load designations listed in this example are applicable to BRASS-GIRDER(LRFD) Version 2.0.0 and later. BRASS-GIRDER(LRFD) runs for versions prior to v2.0.0 used the legal load designations OLEG3, OLEG3S2 & OLEG3-3.

Special note: For one-lane (escorted) special permit reviews and true single-lane bridges (roadway width < 20 ft), it is necessary to enter "ONE" for parameter 7 in the LOAD-LIVE-DEFINITION (12-4.3) command. It is not clear in the BRASS Command Manual, but this parameter is needed to force BRASS to apply only a single-lane loading with the appropriate single-lane Distribution Factors.

- BRASS-GIRDER(LRFD) Input Adjustment Type 4:

While performing an analysis on a prestressed girder, it was found that the FACTORS-

RESIST-RC and FACTOR-RESIST-PS commands cannot be used simultaneously. Since phi is often different for flexure in prestressed elements and reinforced concrete elements, a different approach is required. Using the FACTORS-RESIST-MOD command to modify phi-s and FACTORS-RESIST-COND command to modify phi-c. BRASS will properly calculate the final phi values for flexure, flexure/tension (RC), and shear. This adjustment would allow both prestress bridges and reinforced concrete bridges to use the same set of BRASS commands.

Use FACTORS-RESIST-MOD (13-2.4) command, entering FL to designate for flexure in parameter 2 and the appropriate System Factor ϕ_s for Flexure in parameter 3. Repeat the command entering SH to designate for shear in parameter 2 and the System Factor ϕ_s for shear in parameter 3. Use FACTORS-RESIST-COND (13-2.5) command, entering the condition factor ϕ_c in parameter 2. Thus the complete phi factor command set is as follows:

```
COM BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 4:
COM  Use the FACTORS-RESIST-MOD command to modify phi-s
COM  Use the FACTORS-RESIST-COND command to modify phi-c
COM  BRASS automatically calculates base phi for flexure,
COM  flexure/tension (RC), and shear

COM 13-2.4
FACTORS-RESIST-MOD ST, FL, phi-s
FACTORS-RESIST-MOD ST, SH, phi-s

COM 13-2.5
FACTORS-RESIST-COND  ST, phi-c
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 5:

  To facilitate crossbeam calculations and to clarify what BRASS is doing regarding live load Distribution Factors, always include the following lines in the BRASS input file at the end of the “Distribution Factors” section:

```
COM  Request output of LL Distribution Factor computations
OUTPUT-DIST-LL Y, Y
```

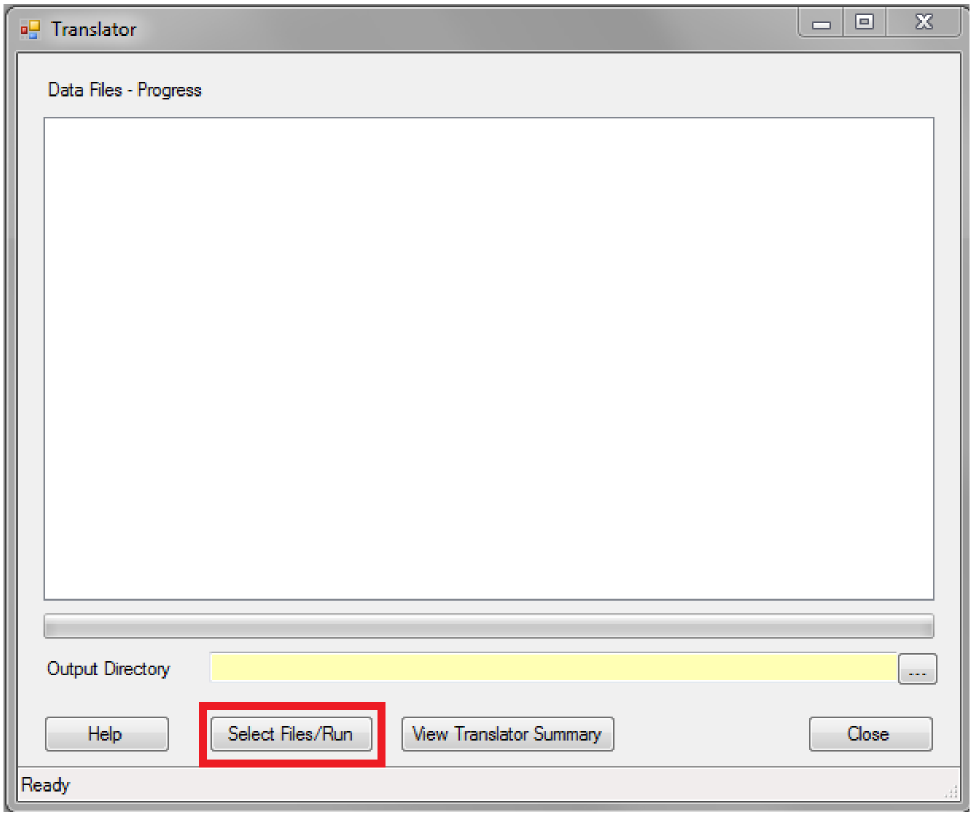
2.4.3 Running BRASS

Open the BRASS-GIRDER GUI interface. Because it is more efficient to use BRASS-GIRDER(LRFD) Input Files generated from previous ones, the GUI interface will not be used to generate input files.

The BRASS-GIRDER(LRFD) input file must first be translated into a BRASS-GIRDER xml file that will then populate the GUI interface in BRASS-GIRDER. The steps for translating and running the input files in BRASS-GIRDER are as follows:

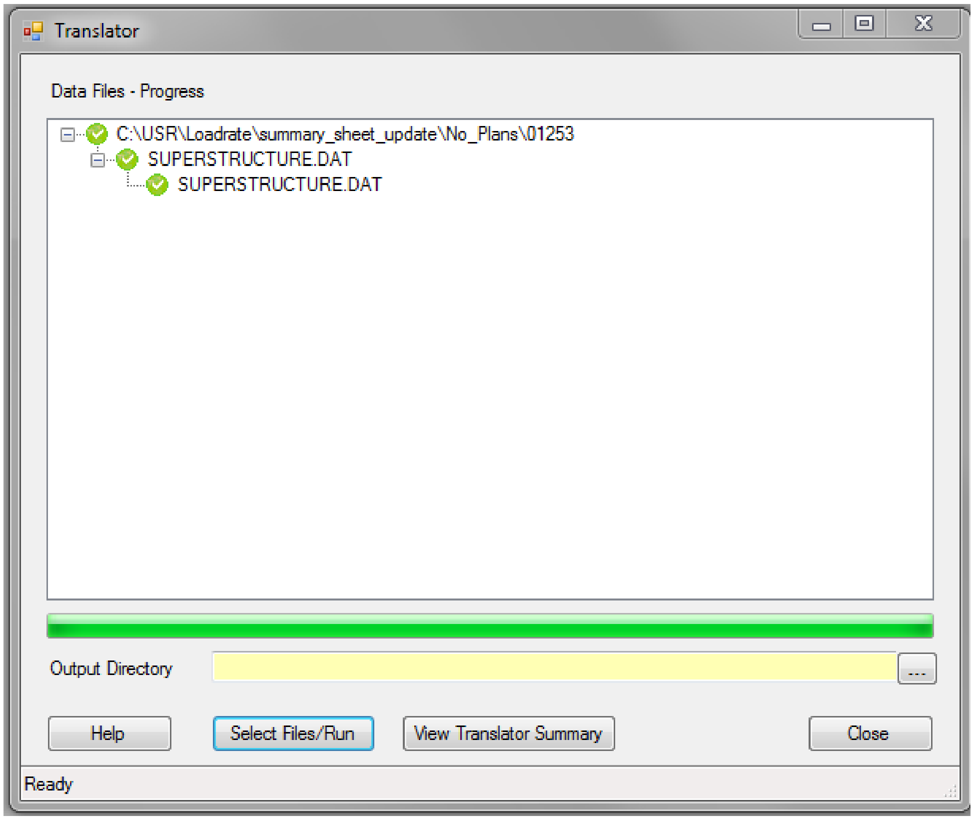
1. Start the BRASS-GIRDER program. From the “File” menu, hover your mouse pointer over “Translate (DAT to XML)”. Select the option for “BRASS-GIRDER(LRFD)”.

2. The Translator window will then open on your screen. Click on the button that says “Select File/Run”, as shown in the red outlined box in the following figure.



3. In the next window that appears, navigate to the location where the BRASS-GIRDER(LRFD) input file that you wish to run is stored, and select that file. Click on the “Open” button at the bottom right of this window.

4. The Translator window will then open back up and the selected file will run through the translation. If there are any errors detected during the translation, a red “X” will be displayed next to the file name in the window and an error file will be generated. Refer to the error file to decipher what is causing the error during translation. Once corrected, follow these steps again to translate the file. If successful, a green check will appear next to the file name as shown in the following figure:



5. Click the “Close” button at the bottom right of the Translator window. Within BRASS-GIRDER, select “Open” under the File menu. Select the BRASS XML file that was just created from the Translator program. Click on the “Open” button at the bottom right of this window.

6. BRASS-GIRDER will then load the model into the GUI. Under the “Execute” menu, select “Analysis Engine” to run the analysis. Or you can simply click on the green traffic light icon on the toolbar.

7. Verify that the output directory is the same as where the input files are located, and then click the “OK” button. A black DOS window will appear showing program progress. Depending on your system speed and memory and the complexity of the structure, the execution process may take a few seconds or several minutes. Upon completion of the analysis, a text output file will be generated within the same directory. You can now use a text editor to open and view the BRASS output.

When making changes or corrections to BRASS files, ODOT prefers that all changes be made within the BRASS-GIRDER(LRFD) input file so that it becomes the master document for the BRASS model. Reviewing this text input file will be quicker and more efficient than trying to navigate the GUI to verify that the bridge is being modelled correctly. Thus, any time the text input file is modified, the above steps will have to be repeated to translate the text input file into a BRASS XML file before the analysis is re-ran in BRASS-GIRDER.

2.4.4 BRASS Errors

If an error file is generated (same prefix, .ERR extension), open this file with your text editor and try to interpret what BRASS is telling you. The vast majority of error messages will point you to a straightforward typographical error or omission in your input. At the beginning of your experience with BRASS, do not expect a successful execution until one or more typographical errors have been

corrected.

When executing BRASS-GIRDER, if you get an error message regarding zeros in the stiffness matrix, look at the ANALYSIS (4-1.1) command, parameter 1, and check to see if you are running a Frame type model on a structure with more than 6 spans. In such cases the Beam type model (the recommended default) is required (with a maximum of 13 spans).

When executing BRASS-GIRDER, you may get an error message stating, "*The effective web width (b_v) cannot be zero. This causes a divide-by-zero error in the compression field computations.*" This most likely means that you have selected points that are too close to another defined point of interest within your BRASS input file. A general rule is not to have points closer than six inches from one another. Verify in your input file that you have correctly entered the web width parameter while defining your BRASS sections. Also check in the "Span Length and Section Information" portion of the input file to see that the ranges of the elements are not too close to each other.

A rare error can sometimes occur in executing BRASS-GIRDER where the processing of the analysis takes a considerable amount of time, and then produces a very large output file (around 600 megabytes) along with an error file. The program will report an "Interpolation Error". This occurs on files that have a BRASS span of 99.99 ft and was attempting to increment each truck across the span at 100 increments (as specified in the LOAD-LIVE-CONTROL command). We found that one of two simple workarounds can correct the error: 1) round the BRASS spans from 99.99 ft to 100.00 ft, or 2) increase the live load increment from 100 to 105 in the LOAD-LIVE-CONTROL command. The second method is the preferred option as it only requires a correction in one command, whereas adjusting the span lengths would have required doing it for multiple spans for the bridge that experienced this error.

When executing BRASS-GIRDER, if you get an unexpected termination of the program while attempting to run a file, check the BRASS error file (*.err) to see if it states that, "Standard Vehicle: OLEG3S2 is not presently stored in the standard vehicle library file." This usually means that the user did not update the names of the Legal Vehicle in the BRASS input file. In the early part of 2009, ODOT made a small revision to the vehicle library so that both the old Tier 1 and LRFR rating methodologies would use the same legal vehicles for their analysis. As a result, ODOT changed the names of the legal vehicles. To correct the error, make the following changes to the names of the legal vehicles in the BRASS input file:

Original Vehicle Names	Previous Vehicle Name	Current Vehicle Name
OLEG3	ORLEG3	OR-LEG3
OLEG3S2	ORLEG3S2	ORLEG3S2
OLEG3-3	ORLEG3-3	ORLEG3-3
SU4	SU4	OR-SU4
SU5	SU5	OR-SU5
SU6	SU6	OR-SU6
SU7	SU7	OR-SU7

2.4.5 BRASS Output Files

BRASS-GIRDER(LRFD) has been known to "run perfectly" and still produce completely wrong results. Although a successful run may indicate a lack of errors, it is prudent to search the main output (**.**OUT) file for the words "error" and "warning" to check out the seriousness of the problem, and to do a "reality check" on the Rating Factors. Unexpected Rating Factor results often indicate an error in the BRASS coding.

We recommend that, at the very least, load raters routinely employ the following two BRASS verification measures:

(1) Do a reasonability check on the section properties. This is why we routinely code “Y” in parameter 2 of the OUTPUT (5-1.1) command, to provide a list of girder properties at each node point. (Search the Output File for “Calculated Properties” in each span). It is not uncommon to make errors in the concrete section definitions, the SPAN-UNIF-HAUNCH (11-1.3) command or the SPAN-SECTION (11-2.1) commands that can result in a girder profile that is quite different than the one you expected.

(2) Do a reasonability check on the distribution of shears and moments across the structure. This is especially critical if you have an expansion joint within the structure that you have modeled by coding a hinge near one of the internal supports. Check if you are getting nearly-zero moments at the support next to the hinge. (It can’t be truly zero because of the offset of the hinge from the support, but the moment value should be quite low). There have been cases where, due to numerical instabilities in the analysis process, unreasonably high moments were present at the support. The solution is usually to increase the offset of the hinge from the support in small increments until the reported moments behave as expected (sometimes increasing the offset by hundredths of a foot can make all the difference!).

If you really have doubts about what BRASS is giving you, be aware that you can use additional commands in the OUTPUT- group (BRASS-GIRDER(LRFD) Manual, Chapter 5 to generate additional output that may facilitate your detective work. Use caution – the size of this output can be daunting.

When reading the BRASS Output File, in the Rating Factor Summary sections for Legal Loads, it may be difficult to distinguish between the live load Combo cases because two of them are identified as “ORLEG3-3”. In these cases, it is possible to distinguish them by looking for the 3-letter BRASS live load Type codes in parentheses. These codes are defined for parameter 3 of the LOAD-LIVE-DEFINITION command (12-4.3). Thus there will be separate Rating Factor Results for ORLEG3-3 (TRK) which is the Type 3-3 truck by itself, and ORLEG3-3 (LGT) which is the Type 3-3 two-truck train plus Legal Lane load.

2.4.6 Longitudinal Tension Check

Prior to BRASS-GIRDER(LRFD) version 2.0.1, the results of the longitudinal reinforcement tension check (LRFD 5.7.3.5) were not found in the basic output files, but could only be found by performing a detailed analysis of a specific point. The longitudinal tension check is done to ensure that there is sufficient longitudinal reinforcement to resist the tension forces caused by flexure and shear.

With the release of BRASS-GIRDER(LRFD) version 2.0.1, the program now calculates a rating factor for the longitudinal tension check using the worst case of the maximum tension forces developed due to maximum shear and concurrent moment, minimum shear and concurrent moment, maximum moment and concurrent shear, and minimum moment and concurrent shear.
Since the longitudinal tension check rating factor is being computed for every analysis point, and the ODOT Load Rating Summary sheet only has a limited number of columns to report rating factors, the summary sheet has been programmed to only report the longitudinal tension rating factors for a given analysis point only if a rating factor for one of the trucks is lower than 1.1.

Detailed Discussion:

Section 5.7.3.5 of the AASHTO LRFD Bridge Design Specifications has the equation that is used by designers to ensure that there is sufficient longitudinal reinforcement to resist tension forces caused by both shear and flexure. If this equation is not satisfied, the designer simply adds the necessary reinforcement so that the equation is satisfied.

The Manual for Bridge Evaluation (MBE) is based on the AASHTO Bridge Design Specifications. The software ODOT uses for LRFR ratings is BRASS-GIRDER(LRFD). Prior to version 2.0.1, this software performed the tension check as part of the rating, but the basic output (usually several hundred of pages per bridge) did not indicate if the bridge had locations where the tension check failed. The information on the results of the tension check could only be found by examining the additional output that is provided when detailed analysis of a specific point was requested.

While satisfying the tension check is needed to have an accurate model when using Modified Compression Field Theory (MCFT) to calculate shear capacity, there is no guidance in the MBE manual for the load rater to use when the tension check fails. This has been brought to the attention of a primary developer of the LRFR code, Bala Sivakumar, PE, who acknowledged that the current code does not fully address this issue. Christopher Higgins, PhD, PE, from Oregon State University, who lead the effort to test full scale beams has emphasized that the tension check is fundamental to the use of MCFT. The concern of providing the results of the tension check in the basic output has been communicated to the developers of the BRASS software.

There were two areas that needed to be addressed before the load rater could be sure that the tension check had failed. First, all of the reinforcement must be accounted for. Since the ODOT ratings originally counted the reinforcement only when it was fully developed, there may have been a significant amount of partially developed reinforcement available to resist tension forces. Prior to the development of the ODOT Concrete Bridge Generator (CBG), a simple bridge would take several weeks for a load rater to go through all of the detailed output and add up all of the partially developed reinforcement. While many of the points that originally failed the tension check will pass for the lighter loads, the heavier permit loads can still result in a failed condition. Even if all of the points were to pass the tension check, the weeks of analysis would have been inefficient and resulted in a product that was complicated to the point that a secondary check would have been difficult. With the development of the CBG, the partially developed bars are now accounted for in the BRASS model, and thus this first issue is resolved.

The second area that needed to be addressed was the nature of the loading. For a given load, there will be a maximum moment force, and a maximum shear force. For analysis, BRASS-GIRDER(LRFD) uses these maximum values. The actual loading caused by a moving load does result in a point experiencing the maximum force values, but not at the same time. By treating the maximum values as being concurrent, the BRASS analysis of the tension check would be somewhat conservative at some locations.

There are differences between the design of new bridges and the rating of current bridges. MBE section 6A.1.3 states that “Design may adopt a conservative reliability index and impose checks to ensure serviceability and durability without incurring a major cost impact. In rating, the added cost of overly conservative evaluation standards can be prohibitive as load restrictions, rehabilitation, and replacement become increasingly necessary.”

With the release of BRASS-GIRDER(LRFD) version 2.0.1, the program now calculates a rating factor for the longitudinal tension check using the worst case of the maximum tension forces developed due to maximum shear and concurrent moment, minimum shear and concurrent moment, maximum moment and concurrent shear, and minimum moment and concurrent shear. Thus, this second issue has been addressed.

The developers of the MBE code acknowledged that while LRFD does incorporate state-of-the-art design, analysis methods, and loading, that almost all existing bridges were designed using the older AASHTO Standard Specifications for Highway Bridges. Section 6A.1.4 states “Where the behavior of a member under traffic is not consistent with that predicted by the governing specifications, as evidenced by a lack of visible signs of distress or excessive deformation or cases where there is evidence of distress even though the specification does not predict such distress, deviation from the governing specifications based upon the known behavior of the member under traffic may be used and shall be fully documented”.

The 1950’s bridges were designed using Working Stress. Once the stresses of the concrete exceed its ability to resist tension, cracking occurs. This initial cracking takes place at a comparatively low level of loading. The bridge is designed to see “service loads” where the forces in the reinforcement are kept well below the yield point. The bridges that Oregon State University instrumented showed that the reinforcement was being operated well below the yield point. During full scale beam tests to failure, the reinforcement was yielding, but at much higher loads than in-service bridges experience, and with much greater distress.

Even though ODOT and BRASS have found a way to perform the tension check for load rating, this is still an issue to be solved on a national scale. Based on the guidance from the MBE code, and the lack of distress noted in the vast majority of bridge inspections, Oregon bridges are not being operated anywhere near the level that would cause yielding of the reinforcement as indicated by the failure of the tension check. For those few bridges that do show excessive deterioration, the current MBE code is sufficient that the known behavior of the member shall be used and be fully documented. Bridges with deterioration consistent with yielding of reinforcement would not be considered for “no work” regardless of the results of the tension check. Calculations for repairs should be done in accordance with the AASHTO LRFD code and therefore the longitudinal reinforcing should always pass the tension check after the repairs are complete.

2.4.7 BRASS/LRFD Issues Regarding Minimum Transverse Reinforcement

BRASS-GIRDER(LRFD) prior to version 1.6.4 had an error in the use of the AASHTO LRFD 4th Edition (prior to the 2008 Revision) Table 5.8.3.4.2-2 (now Table B5.2-2 in LRFD Eighth Edition), Values of θ and β for Sections with less than minimum transverse reinforcement. It appears that only the top row of the table was used, yielding higher values of β and lower values of θ than should have been used. The result of this was that sections with less than minimum transverse reinforcement were assigned higher rating factors than they should have been.

A comparison of shear rating factors was accomplished using BRASS-GIRDER(LRFD) versions 1.6.5 and 1.6.2. For the three bridges selected, locations outside of horizontally tapered webs had adequate transverse reinforcement, and the shear ratings were unaffected by the corrections to how the table was used for less than minimum transverse reinforcement. However, some sections inside horizontally tapered webs do have less than the minimum transverse reinforcement. These sections experienced a significant drop in rating factors.

The bridge designers in the 1950’s sometimes used an increased concrete cross section to resist shear forces near interior bents. The very technique that gained shear capacity using the AASHTO LRFD Design Specifications now causes the section to have less than minimum transverse reinforcement. The extra concrete the 1950’s designers used to increase shear capacity has the unintended consequence of placing a section with good reinforcement details into a design code table that was never intended to be used for design.

Prior to the 2008 Revisions of LRFD Article 5.7.3.4.2 (General Procedure for Determining Shear Resistance in Concrete Beams) beta and theta were determined by an iterative procedure (which is now in LRFD Appendix B5):

- For sections with minimum transverse reinforcement – For an applied load, an assumed value of theta is initially used to calculate the longitudinal strain in the web at $0.5d_v$. The shear stress ratio is computed for the section. Using Table B5.2-1, the longitudinal strain and shear stress ratio are used to determine a new value of theta and beta. This new value of theta is used to calculate a new longitudinal strain, which is then used in Table B5.2-1 to compute a new theta and beta. The process continues until theta is solved. The final values of theta and beta are then used in computing the shear resistance of the concrete section.

- For sections with less than minimum transverse reinforcement – the procedure is similar to that above. The only differences being are that the longitudinal strain is calculated at the location in the web subject to the highest longitudinal tensile strain, and instead of using the shear stress ratio with the longitudinal strain in Table B5.2-1 to determine a new theta and beta, the crack spacing parameter is used with the longitudinal strain in Table B5.2-2.

- When calculating the longitudinal strain for a section, longitudinal bars on the flexural tension side of the member that were not fully developed were to be ignored.

In LRFD Article 5.7.3.4.2, beta and theta are determined by direct solution using algebraic equations:

- The strain in non-prestressed longitudinal tension reinforcement is directly computed for a given load. This strain is used directly in the equations to compute theta and beta.

- The value of theta is the same regardless if the section has less than or contains at least the minimum transverse reinforcement. Thus, there is only one direct solution for theta.

- There is one equation for beta for sections containing at least the minimum transverse reinforcement. There is a different equation for beta for sections with less than minimum transverse reinforcement, which is similar to the first but has an added component containing the crack spacing parameter.

- In calculating A_s, the area of bars terminated less than their development length from the section under consideration should be reduced in proportion to their lack of full development (instead of ignored).

In most cases, the new direct solution equations are producing higher capacities for sections that have less than minimum transverse reinforcement. The main reason is that theta no longer is penalized, which results in shallower crack angles allowing for more stirrups within the member to contribute to the shear resistance.

Unfortunately, the old iterative method is still a valid option in the LRFD code, as the 2008 Revisions have placed the old Article 5.8.3.4.2 language in Appendix B5. BRASS Girder (LRFD) Version 2.0.3 has been updated to include the 2008 revisions of the AASHTO LRFD code. The algebraic equations are now used to calculate shear capacity.

2.4.8 Continuous Multi-Spanned Bridges with Varied Span Lengths

We were made aware of an issue that occurs with continuous multi-span bridges, when the adjacent span lengths vary by a considerable amount. It was noticed that the maximum positive moment sections were being evaluated at odd locations (0.1L for an end span and 0.4L for an interior span). This was a result of our original practice of basing these locations off of the dead load maximum moment locations and not the factored combined (dead load and live load) maximums. The maximum dead load moment location shifts were due to the uplift in short spans caused by the dead load of an adjacent long span.

To compensate for the uplift effects of dead load on the adjacent short spans, we will now use the maximum and minimum Load Factors stipulated in AASHTO LRFD Table 3.4.1-2. As a result, we have modified the BRASS Input Adjustment Type 2 commands in the BRASS input files to the following:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,
```

COM 13-1.2
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65

The heavier vehicles will produce a maximum positive moment location closer towards the midspan, while the lighter vehicles will produce a maximum positive moment location away from midspan towards the maximum moment location of the dead load. Therefore, in order to capture the maximum positive moment for the entire suite of vehicles that we use in load rating, we may have to establish a range of points where the different vehicles will produce their maximum positive moment.

In order to facilitate this procedure, we have developed a new application (BRASS Moment Analyzer) that will evaluate the BRASS output files after an initial BRASS run and determine if the maximum positive moment locations for the live loads differ from the dead load locations. If so, the program will then analyze the differences in the locations and then provide a range of recommended positive moment locations (at 20th points) along with the BRASS commands for these new flexural analysis locations that can be copied and pasted into the BRASS input files. The program will create a text file, with the modified name of _MOMENT_INITIAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

After the final BRASS run, the BRASS Moment Analyzer can be used to once again evaluate the BRASS output files. This time, the software will check and report if the maximum combined moment for every vehicle at each analysis point is negative, positive, or contains both negative and positive values. The program will allow the user to print a summary report which they can refer to when selecting the type of moment during the BRASS import of the moment locations on the Load Rating Summary sheet. The program will create a text file, with the modified name of _MOMENT_FINAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

Do not include the BRASS Moment Analyzer output in the printed Load Rating Calc. Book. We only request that the .TXT files that it produces be included with the electronic files for the load rating.

The intent is to only use the BRASS Moment Analyzer for continuous bridges with adjacent span lengths that vary more than 30%.

2.5 Exterior Girder Analysis

Use the interior girder files as a starting point for creating the exterior girder files. Most of the interior girder file will still apply for the exterior girder analysis. Because the interior file is used as a starting point, it is suggested to not begin the exterior girder analysis until throughout checking of the interior files have been completed. Any mistakes found in the interior file would likely also be mistakes in the exterior file.

2.5.1 Generating an Exterior Girder Preliminary File from an Interior Girder File

For the typical un-widened RCDG structure where the exterior girder design is the same as the interior girder, the task of generating an exterior girder preliminary file from the corresponding interior girder preliminary file generally consists on the following steps:

(1) Make a copy of **INTGIR.xmcd** and rename it **EXTGIR.xmcd**.
(2) Change the title (first header).
(3) Eliminate all the calculation sections above “Component dead loads (DC)”.
and replace them with the statement “All factors and material properties are the same as for the interior girders (see **INTGIR.xmcd**)”.
(4) Revise the calculations for actual flange width for girder dead load (over-hang width combined with half the adjacent girder spacing).
(5) Revise the calculations for dead load of the diaphragms.

(6) Revise the calculations for liveload distribution factors (if, for some reason, the live load distribution factors are being manually calculated).
(7) Eliminate all the calculation sections after “Wearing Surface dead loads (DW)” and append the statement “All live loads, Girder Geometry & Analysis Sections are the same as for the interior girder (see **INTGIR.xmcd**)”.

2.5.2 Generating an Exterior Girder CBG File from an Interior Girder File

For the typical un-widened RCDG structure where the exterior girder design is the same as the interior girder, task of generating an exterior girder CBG file from the corresponding interior girder CBG file generally consists of the following steps:

(1) With the completed IntGir CBG file opened in the CBG program, change the “Member Being Load Rated” field from IntGir to ExtGir.
(2) Under the “Concrete Dimensions” Tab, revise the value of the top flange width for each cross-section to the value that was computed in the Exterior Girder Preliminary File.
(3) Save the CBG data file.

2.5.3 Generating an Exterior Girder BRASS Input File from an Interior Girder File

For the typical un-widened RCDG structure where the exterior girder design is the same as the interior girder, the task of generating an exterior girder BRASS input file from the corresponding interior girder BRASS input file generally consists on the following steps:

(1) Copy **INTGIR.DAT** to **EXTGIR.DAT**
(2) From the ExtGir CBG file, copy the BRASS commands that are displayed from selecting the “Generate BRASS File Input” button and paste them over the commands from the beginning of the BRASS Input file up to the point of the stirrup definitions.
(3) Change the dead loads due to diaphragms
(4) Change the girder of interest, i.e. parameter 1 of the DIST-CONTROL-GIRDER command (4-3.1) from 2 to 1

SECTION 3: LOAD RATING REINFORCED CONCRETE BOX GIRDER BRIDGES

3.0 Scoping of Structure

Create a scoping file (nnnnnn_scope.xls) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended affect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

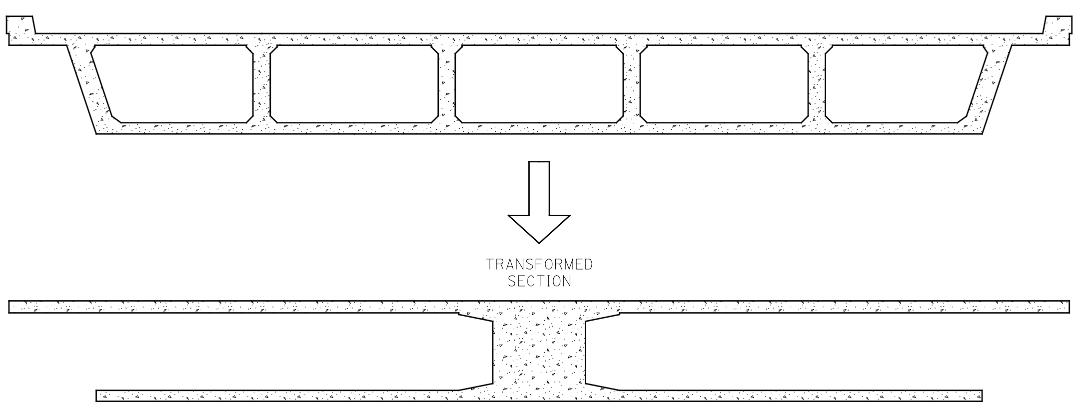
Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0 then, there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

3.1 ODOT's Chosen Method for Box Girder Analysis

AASHTO LRFD Article 4.6.2.2.1 states that cast-in-place multicell concrete box girder bridge types may be designed as whole-width structures. Such cross-sections shall be designed for the live load Distribution Factors in Articles 4.6.2.2.2 and 4.6.2.2.3 for interior girders, multiplied by the number of girders, i.e., webs. For a concrete box girder section having vertical or angled webs, it can be converted to an equivalent I-shaped section by combining the webs into a single web. Then this section may be analyzed as a single I-shaped concrete section. The following figure illustrates the conversion.



The other method that is allowed by the AASHTO LRFD code is to treat each girder web as a regular I-beam, using the web spacing as its flange width. For exterior webs, the bottom flange width will be half of the cell width. Such cross-sections are designed for the live load distribution factors in Articles 4.6.2.2.2 and 4.6.2.2.3 for interior and exterior girders. This would require separate analysis for interior and exterior webs. Plus, if the individual webs (stems) were analyzed as individual I-Girders, the exterior girder lines would often control for positive moment since they have smaller flange widths and less flexural reinforcement to contribute to their capacity.

Since the cross-section is very stiff and the webs of a concrete box girder bridge do not act independently, ODOT chose to use the first method of analysis of converting the entire cross-section into an equivalent I-shaped section.

3.2 Preliminary Files for Girders (Mathcad)

For reinforced concrete box girder bridges, the preliminary file name and extension (Mathcad) is BOXGIR.xmcd.

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied terms with parentheses.

3.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description (“Spans” field) from the Bridge Log is adequate for this purpose.

Note: the Mathcad regions at the top in the right margin (outside the printable area) are there for 2 purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

3.2.2 Resistance Factors

Document the decisions regarding all 3 Resistance Factors, with references to the appropriate MBE tables.

BRASS-GIRDER(LRFD) provides input for the MBE Condition Factor ϕ_c (MBE 6A.4.2.3) and System Factor ϕ_s (MBE 6A.4.2.4). However, the ODOT Load Rating Summary Sheet and the ODOT Crossbeam Load Rating Software always require and display the product of all the resistance factors as a single ϕ factor. Therefore, the product of all these resistance factors must always be obtained.

Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure:
$\Phi_f = \phi\,[\max(\phi_c\phi_{sf}, 0.85)]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Shear:
$\Phi_v = \phi [\max (\phi_c\phi_{sv} , 0.85)]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).

Generally Φ_f and Φ_v will be the same for redundant members such as girders and will be different for non-redundant members such as single-span and 2-span crossbeams.

3.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into BRASS. The Load Rating Summary Workbook **(LR.XLT)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and Effective Bridge Length. Note that Effective Bridge Length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which Live Load Factor Application is used, ADTT is specified as “one direction”. Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the Live Load Factor Application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the Live Load Factor Application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the “LRFR Strength I & II” table from the live load factor application, and in Mathcad use Edit / Paste Special. In the “Paste Special” dialog box choose the “Paste” button, highlight “Bitmap” in the “As” list, and click the “OK” button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to MBE 6A.4.4.3.

3.2.4 Material Properties

Enter the material properties within the appropriate fields of the ODOT Concrete Bridge Generator (CBG) program, and the elastic modulus E_c and modular ratio n will be calculated. The CBG program uses AASHTO LRFD Equation 5.4.2.4-1 to determine the elastic modulus of concrete, assuming K_1=1.0. Document any assumptions made about the material properties if they are not given on the bridge plans within the Mathcad preliminary file.

3.2.5 Bridge Average Geometry

Calculate the physical edge-to-edge width of the concrete slab and the roadway width of the bridge. If the width of the slab or roadway changes over the length of the bridge, calculate the average roadway width per span. Enter the skew angle of the bridge. These values are entered in BRASS to calculate the Distribution Factors.

3.2.6 Shear Reinforcement Layout

Use an embedded Excel spreadsheet within Mathcad to calculate the ranges and span fractions for the shear reinforcement layout for each span as indicated below. Double-clicking on an embedded spreadsheet activates Excel, and its toolbars and functionality become available. An existing embedded Excel spreadsheet can be copied, pasted in another location and modified to do similar calculations for another span. Determine the shear reinforcement bar size(s) and area(s) that are present in each span that will contain analysis sections. Then for each span that contains analysis sections, working consecutively from the left end of the span to the right, populate the yellow fields in the following table in the preliminary file. Where there is an approximate "plus-or-minus" stirrup spacing given near the middle of a span, it is necessary to calculate this "remnant spacing" in Mathcad in order to complete the shear reinforcement layout accurately enough to code it in BRASS.

Span # :	1		Span Length :	68	ft	
Section	Spaces	Spacing (in.)	Start (in.)	Range (in.)	End (in.)	Span Fraction
1	7	4	3.00	28	31.00	0.004
2	4	11	31.00	44	75.00	0.038
3	51	13	75.00	659	734.00	0.092
4	4	11	734.00	44	778.00	0.900
5	8	4	778.00	32	810.00	0.953

3.2.7 Component Dead Loads (DC)

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the Preliminary (**.xmcd**) File as they will appear in the BRASS Input (**.**DAT) File. Use AASHTO LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c. For dead load calculations, use w_c+0.005 kcf to account for the reinforcement, in accordance with AASHTO LRFD Commentary C3.5.1.

Show calculations for the transformed girder dimensions.

Consider diaphragm point loads to be part of component load DC. Include any diaphragms/end beams at the end of the girder over the support, as they will be utilized when applying the girder dead load reactions to crossbeams.

Where standard rail drawings occur, wherever possible use the rail dead loads tabulated in Appendix H - ODOT Standard Rail Weights, found in file **RAILDL.XLS**. Provide detailed calculations for the dead load of any rail not found in this summary.

Assume adequate lateral distribution of loads and apply the sum of all rail, curb and sidewalk dead loads (stage 2 dead loads) directly to the converted I-girder being analyzed.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16" diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to need to be included in the load rating.

For load rating, we want to consider a utility as a "non-structural attachment" and keep it listed under DC for dead loads. The main reason for this is if a load rater ever comes across a situation where they have to load rate a bridge where they are uncertain of the wearing surface thickness. In that situation they are required to use a DW gamma of 1.50. That way they would only be penalizing the load of the wearing surface, not the utilities, for the uncertainty.

3.2.8 Wearing Surface Dead Loads (DW)

Always separate wearing surface dead load (DW) from the component (DC) dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes, and (c) it facilitates input for the Crossbeam Load Rating Software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Show calculations for wearing surface dead load and apply directly to the converted I-girder being analyzed. Add 1" to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½" to the design thickness of PPC overlays to account for construction variations and uncertainty.

3.2.9 Live Loads (LL)

Simply list the four classes of rating loads to be analyzed. (See Articles 1.5.1.1 through 1.5.1.4).

Normally live load distribution factors are calculated in BRASS, but in the rare case where they must be calculated manually, the complete calculations should be provided with thorough documentation in this section of the preliminary file. Distribution factors will need to be calculated manually in the case of widened bridges or half-viaducts where the deck was not made continuous between the original and widening structures, or between the viaduct structure and the adjacent pavement. Where there is no barrier to the wheel load at the edge of deck, because of the assumed 20" wide wheel footprint, a full concentrated wheel load can be placed no closer than 10" from the edge of deck.

3.2.9.1 Distribution Factors

ODOT chose to follow AASHTO LRFD Article 4.6.2.2.1, which states that cast-in-place multicell concrete box girder bridge types may be designed as whole-width structures. Such cross-sections shall be designed for the live load distribution factors in Articles 4.6.2.2.2 and 4.6.2.2.3 for interior girders, multiplied by the number of girders, i.e., webs. This should be documented in the preliminary file. This will be accomplished by using the scaling parameter in BRASS, see article 3.4.2 of this manual.

3.2.10 Analysis Sections

Determine the spans to be investigated. These should be any span that is unique and is not repeated due to symmetry or due to repetition of a span between joints.

Within each span, check for symmetry of sections, reinforcement and loads, and do not identify any analysis points that are structurally symmetrical with analysis points already defined. Defining analysis points that are structurally symmetrical has the potential effect of corrupting the Load Rating Summary Sheet. Because the “Refresh” module is looking for the lowest Rating Factors, defining a symmetrical point causes it to identify the most critical rating location twice, thus preventing it from identifying the second most critical analysis point. The second controlling point is useful information in evaluating potential repairs for the bridge.

List the analysis sections for flexure. These are normally the positive moments in each unique span and the negative moments over each unique support.

There will be a large number of analysis sections for shear. For each unique span, subdivide the calculations of analysis sections into the categories (up to 5) given in Article 1.5.3. Summarize the underlined headings that will begin each section of calculations. An example of this summary follows:

<u>Span 1 Critical Shear Section Points</u>

<u>Span 1 Flexural Bar Cutoff Points</u>

<u>Span 1 Girder Geometry Change Points</u>

<u>Span 1 Stirrup Spacing Change Points</u>

<u>Span 1 Large Crack Location Points</u>

<u>Span 2 Critical Shear Section Points</u>

<u>Span 2 Flexural Bar Cutoff Points</u>

<u>Span 2 Girder Geometry Change Points</u>

<u>Span 2 Stirrup Spacing Change Points</u>

<u>Span 2 Large Crack Location Points</u>

Then repeat each header, one by one, and under each header provide the calculations necessary to determine or document the location of each shear investigation point in that category. Thus there will be up to 5 separate calculation sections for each span. In any calculation section, if any particular point duplicates a previously calculated point or is within 1 ft of a previously calculated point, the new point may be omitted. In this case, explain the omission by indicating which previously identified point already covers the current one. This gives priority to critical sections and bar cutoff points when near-duplicates are encountered.

- Critical Shear Section Points

  According to AASHTO LRFD 5.7.3.2, critical section locations shall be taken at shear depth d_v from face of support. Use the shear depth calculation tool **dv_Calculator.XLS** to determine the shear depth d_v Use the original file of **dv_Calculator.XLS** as a “seed file” to be copied, used and saved within the bridge-specific Load Rating File Set.

  In previous versions of BRASS (LRFD) the skew correction factor was applied to the first segment only. Because of this it was important to not code any nodes within the critical section. BRASS (LRFD) v2.0.3 now applies the skew correction factor across the entire span. For shear the skew factor will be applied at the support and will decrease linearly to unity at midspan. With this update, section changes (node points) can now be defined within the critical section.
  .
  In constant-depth girders, calculate the input parameters for **dv_Calculator.XLS** and determine shear depth d_v. Note: The input parameter “fy tension reinf.” refers to the fy of the longitudinal steel, not the stirrups. For longitudinal girders, it is sufficiently accurate and slightly conservative to ignore the compression flange and input the section as rectangular. This will cause d_v to be slightly smaller (an inch or so), which means the critical section will be slightly closer to the

support, which is where the shear is slightly larger (conservative). Then calculation from the face of support is straightforward. In haunched girders, insert an appropriate diagram identifying the calculation variables, and the corresponding calculations, from the Mathcad source files provided. For linear, parabolic and circular haunches, these files are **LINEAR.xmcd**, **PARABOL.xmcd** and **CIRCULAR.xmcd**, respectively. Update the imported Mathcad calculations for the specific dimensions of the haunch. Then determine a preliminary depth of the critical section h_p, conservatively assuming a section h_{max} from the support face. Having determined h_p from the Mathcad procedure, use the shear depth calculation tool **dv_Calculator.XLS** to determine the shear depth d_v and calculate the critical section at d_v from the support face.

Do this for each critical section location (each end of each unique span). When all critical sections have been located, save this bridge-specific copy of **dv_Calculator.XLS** in the Load Rating File Set.

- Flexural Bar Cutoff Points

Normally the purpose for flexural bar cutoff points is to check shear due to research results that indicate flexural bar cutoffs are a likely starting point for shear cracks. However, if the Inspection Report indicates flexural cracking in negative moment areas (transverse deck cracking over interior supports), the top flexural bar cutoff points should also be checked for moment. Any moment checks at bar cutoff points should be listed within the calculation group for this type of shear analysis section. (These flexural checks should not be grouped with the other flexural analysis points because BRASS cannot be coded to check the same analysis point twice).

Prior to the 2008 Revisions of the AASHTO LRFD code, when evaluating shear capacity, AASHTO LRFD Article 5.7.3.4.2, General Procedure for Modified Compression Field Theory (MCFT) shear capacity evaluation required that all of the development length of the longitudinal reinforcement be ignored. Therefore, BRASS was configured so that the longitudinal bars are considered to be fully developed. To accomplish the intention of the LRFD code, node points between girder elements (BRASS sections) were located a development length l_d back along the bar from the actual bar cutoff point. However, points of interest (sections to be evaluated for shear) were at the actual bar cutoff point, assuming this is the most conservative and likely point where a crack might develop. By this method, for the longitudinal strain (ε_x) calculation, A_s had always excluded the bars being terminated.

Since the 2008 Revisions of the AASHTO LRFD code, Article 5.7.3.4.2, now requires that the partially developed areas of the longitudinal reinforcement be included within the calculation of the shear capacity. Unfortunately BRASS is not directly configured to calculate the partial development of each bar entered, but it is capable of linearly interpolating the reinforcement area between node points (BRASS sections). This will require two BRASS sections for each bar cutoff point, one for the physical end of the bar and one at the point of full development.

With the number of geometry cross-section changes and overlapping bar cutoff points, the ODOT Concrete Bridge Generator (CBG) program was developed to aid in the creation of the BRASS input file by determining the required number of BRASS sections and computing the bar cutoff points. The CBG program will create the BRASS input file data for the BRASS sections, span layout, and generate the BRASS analysis points for the bar cutoffs.

In the MCFT General Procedure evaluation (AASHTO LRFD 5.7.3.4.2), A_s is defined as the area of non-prestressed steel "on the flexural tension side of the member." Including tension-side temperature steel in A_s would only cause a small percentage decrease in the strain ε_x, and have an even smaller effect on increasing the nominal shear resistance V_n. Therefore including temperature steel will be considered an unnecessary increase in complexity under normal circumstances.

Print a copy of the reference tool **BAR_Ld.XLS** (used to calculate bar development length, top bar and bottom bar calculations for both 40 ksi and 60 ksi rebars). In accordance with AASHTO LRFD 5.10.8.2.1a, the minimum L_d is 12", except for standard hooked bars which can have a minimum l_{dh} of 6". In accordance with AASHTO LRFD 5.10.8.2.1b, note that there are two columns for "TOP" "STRAIGHT" bars in the file, one that includes the 1.4 factor for top bars with >12" of concrete below them, and the other for top bars with ≤ 12" of concrete below them. Note the 1.4 factor does not apply to top bars in slabs <14" thick. To increase accuracy in using this tool, consider highlighting the rows that show the reinforcement used and then cross out the columns for the concrete strength that will not be used.

For bars that have a 90^o or 180^o standard hook (as illustrated in the figure to the right), the reference tool **BAR_Ld.XLS** has the development length l_{dh} for each bar computed in accordance with AASHTO LRFD 5.10.8.2.4a. One thing to note is that for some bar sizes with a f_y = 40 ksi, the development length of the standard hooked bar is larger than that of the straight bar of equal size. It is ODOT's policy to use the straight bar development length when the hooked bar development length is greater for a given bar size and strength.

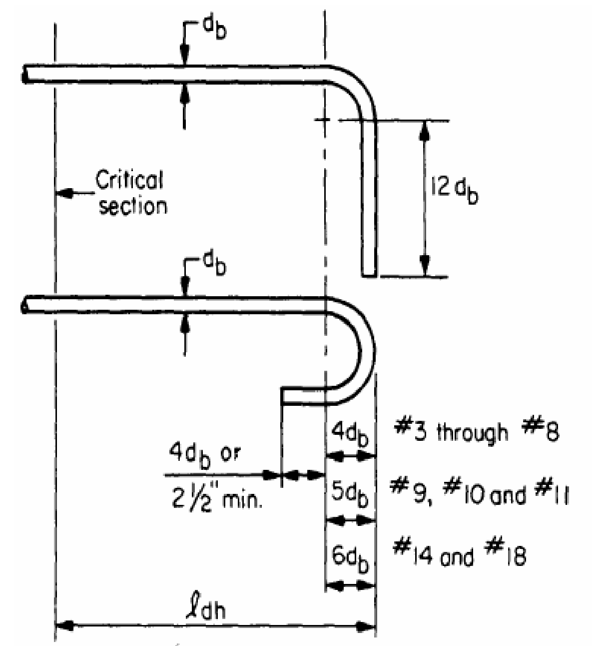


Figure C5.11.2.4-1 Hooked-Bar Details for Development of Standard Hooks (*ACI*).

In all cases, for purposes of l_d calculation, in this tool we consider square bars to have the same l_d as the round bar of equivalent area. The assumption is made that the lack of deformations on a square bar is offset by its greater bonding surface area compared to the equivalent round bar.

In the rare case of railroad rails used as concrete reinforcing, to determine the development length, determine the area and perimeter of the rail, assume a yield stress fy = 50 ksi, and use a bond stress f_b of 0.100 ksi For example, a 55-lbs/yard rail with A_s=5.33 in^2 and perimeter p=18.24 in would have tensile capacity T = $A_s f_y$ = (5.33 in^2)(50 k/in^2) = 266.5 k and development length l_d = T/(f_bp) = (266.5 k)/(0.100 k/in^2)(18.24 in) = 146.1 in.

- Girder Geometry Change Points

  Show calculations locating any abrupt change in girder cross section, such as the beginnings or ends of haunches, web tapers, or partial bottom flanges.

- Stirrup Spacing Change Points

  These locations are taken from the stirrups schedule spreadsheet embedded in the Preliminary File and adjusted by one stirrup space toward the direction with the greater spacing. The analysis location is moved for two reasons. At a stirrup spacing change location, a shear crack would propagate across both stirrup spaces. BRASS doesn't interpolate the shear capacity to the left and right of an analysis point. Therefore, moving the analysis point by one stirrup space moves the analysis location away from the transition area providing a more realistic analysis. Also, It was originally assumed that BRASS would calculate the capacity to the left and right of a section change and use the weaker section when calculating rating factors. However, it doesn't appear that BRASS performs this check. Rather BRASS uses the stirrup spacing from the schedule right at the point that was coded. Moving the analysis point toward the larger stirrup spacing ensures that the larger stirrup spacing (lesser capacity) is used when calculating the rating factor.

Indicate which stirrup spacing change points in the girder are farther from the support than the critical shear point and not within the middle 1/3 of a non-cantilever span. There are several reasons for ignoring shear in the middle 1/3:

- The shear loading is relatively low within the middle third of the span.
- We have not observed significant shear cracking/failures within the middle third of the span.
- In utilizing the Modified Compression Field Theory (MCFT) for shear in LRFR, we have found that the stirrup spacing near the midspan of older bridges will often cause the girder to fail the "Minimum Transverse Reinforcement" check within the AASHTO LRFD code. When this check fails, the user is forced to use AASHTO LRFD Equation 5.7.3.4.2-2 to calculate Beta. This equation will yield higher Beta values, which will significantly reduces the shear capacity at the location.

In crossbeams, where a single large stirrup space coincides with the location of longitudinal girders framing into the side(s) of the crossbeam, the stirrup spacing change can be ignored.

- Large Crack Location Points

  Show calculations locating any section that has a shear crack > 0.040" wide or shows evidence of being a working shear crack regardless of crack width.

  For crack locations that are inside the critical shear location near a simple support, use AASHTO LRFD 5.7.3.4.1 – Simplified Procedure for Non-prestressed Sections. This is due to the Modified Compression Field Theory (MCFT) not providing accurate results for areas with high shear and low moment, basically near a simple support. This section of the LRFD code sets beta and theta to 2.0 and 45 degrees, which in turn makes the expressions for shear strength become essentially identical to those traditionally used in LFD for evaluating shear resistance.

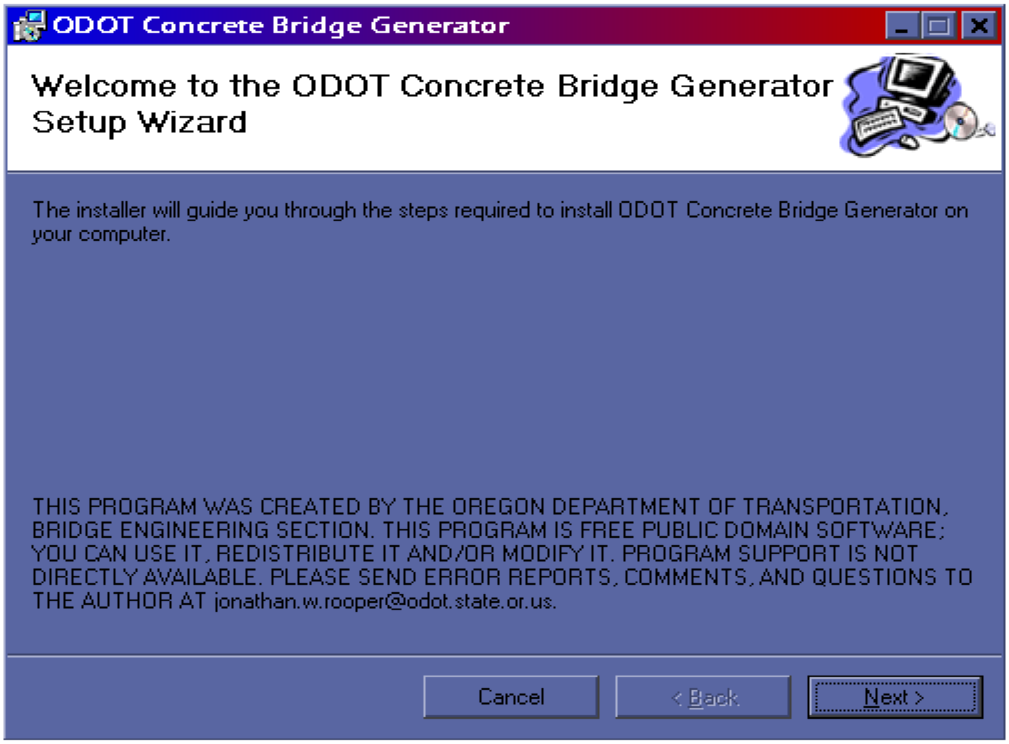
3.3 ODOT Concrete Bridge Generator (CBG)

The ODOT Concrete Bridge Generator (CBG) was created by the Oregon Department of Transportation, Bridge Engineering Section. The CBG is a stand alone windows software package that is a pre-BRASS processor for Cast-In-Place concrete bridge girder sections. Once the user enters basic bridge information, concrete section geometry, span configuration geometry, and the longitudinal reinforcement within the form fields, the program will generate the first half of the BRASS code. The program will also generate the BRASS code for the bar cut-off shear points that the user will paste into the appropriate locations in the BRASS input file. The program is not set up to define rigid frame structures; it is only configured to define a beam analysis in BRASS.

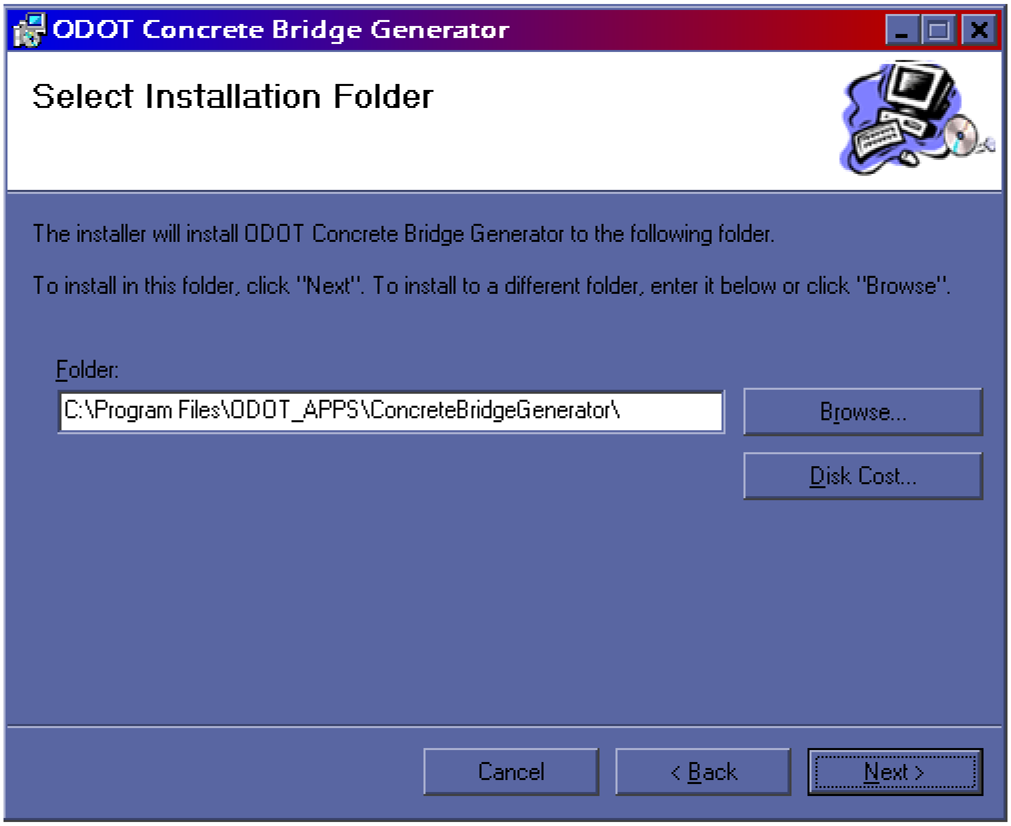
The CBG is solely for the Microsoft Windows operating system and utilizes the Microsoft .NET Framework. The program's native format is the CBG (Concrete Bridge Generator) file format. The CBG is free public domain software; meaning that users are free to use it, redistribute it, and/or modify it. The current version of the CBG is version 1.0.13.

3.3.1 CBG Installation

Previous versions of this program need to be uninstalled through the Windows Control Panel interface prior to installing a newer version. To install the ODOT Concrete Bridge Generator, run the Windows Installer Package titled, "ODOT_Concrete_Bridge_Generator.msi". This will launch the Setup Wizard and pause at the Welcome dialog for the Wizard. Select the "Next" button to continue.



The next dialog will ask the user to select an installation folder to install the Concrete Bridge Generator to. The default location is, “C:\Program Files\ODOT_APPS\ConcreteBridgeGenerator\”. If the default location is satisfactory or after the preferred folder location has been specified, select the “Next” button to continue.



The next dialog will ask the user to confirm the installation before it begins. Click the “Next” button to begin the installation.

A dialog with a progress bar will be shown during the installation. This part of the process can take anywhere from a few seconds to a few minutes depending on if the wizard needs to download and install an update to the Microsoft .NET framework to the computer.

The installation will place a shortcut for the program on the users desktop as well as under the Start Menu > All Programs > ODOT Load Rating. When the installation is complete, click the “Close” button to end the Wizard.

3.3.2 CBG - Overview

When first starting a session of the CBG software, a dialog window explaining the terms of use for the software will be displayed. If the user selects the “DECLINE” button, the session will end and the software will not launch. If the user selects the “I ACCEPT” button, the session will continue and the software will launch.

At the top left of the program there are five buttons associated with icons that are titled “New”, “Open”, “Save”, “Report”, and “Exit”. The “New” button will erase all of the data entered in the form fields and start over with a blank form. The “Open” button will populate the form fields from a saved *.cbg file that was created from using the “Save” button from a previous session. The “Save” button will save the data entered in the form fields in a *.cbg file. The program will incorporate the values entered within the “Bridge Number” and “Member Being Load Rated” form fields in the file name during the save process. The “Report” button will display a print preview of a report that reflects the data entered in the various form fields of the program. The “Exit” button will exit and close the current session of the program.

At the top right of the program there are three buttons that are titled “Show Cross-Section Matrix”, “Generate BRASS File Input”, and “Generate Bar Cutoff Points for Shear Analysis”. The functions of these buttons will be explained later.

In the top section of the program form is where the user specifies the basic information of the bridge. These form fields are set to only accept the maximum number of characters that the BRASS-GIRDER(LRFD) commands using the data will allow. Form fields with white backgrounds require user input, while the form fields with grey backgrounds will automatically fill in values based on the user input within other fields. The different fields within this top section are the Bridge Name, Bridge Number, Load Rater’s Name, Highway/Route Name, Mile Point, the Load Rating Date, the name of the Member Being Rated, and the File Name associated with the saved data entered on the forms.

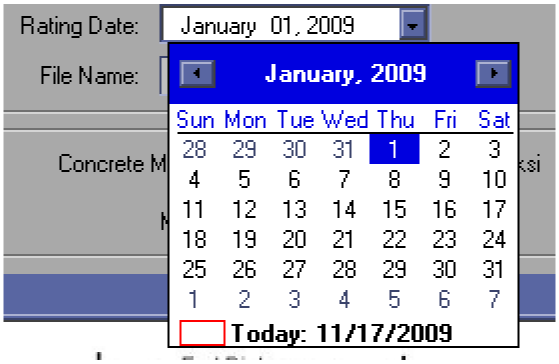
In the next section, the user inputs the concrete strength and longitudinal reinforcement yield stress. The program will then compute the concrete unit weight, the concrete modulus of elasticity, the reinforcement modulus of elasticity, and the modular ratio.

The bottom section of the program is divided into four tabs, which are used to define the cross-section geometry, span configuration/layout, and the longitudinal reinforcement. The tabs are named “Span Configuration”, “Concrete Dimensions”, “Concrete Section Assignment”, and “Reinforcement”. The functions of these tabs will be explained later.

3.3.3 CBG – General Bridge & Load Rating Info

In the “Bridge Name” form field, up to 60 characters may be used to enter the bridge name. The user has up to 15 characters to enter the bridge number in the “Bridge Number” form field, which typically only uses 5 to 6 characters. In the “Load Rater” form field, up to 60 characters may be used to enter the name of the engineer that is running the program. The user has up to 60 characters to enter the route name where the bridge is located in the “Route Name” form field. In the “Mile Point” form field, enter the milepost where the bridge is located.

In the “Rating Date” form field, the user can type in the numeric date for the month, day, and year. Or the user can select the drop down calendar view and select the day within the appropriate month and year. Instead of scrolling through the different months within the calendar view, the user can simply select red box that is titled “Today” at the bottom of the calendar view to select the current date.



In the “Member Being Load Rated” form field, use the drop down list to select what type of member that the current BRASS analysis will be for. The choices are: IntGir for a RCDG interior girder, ExtGir for a RCDG exterior girder, RCBG for a reinforced concrete box girder, RCSlab for a reinforced concrete slab, and EDGSTP for a reinforced concrete slab edge strip analysis.

The “File Name” form field will be automatically filled in when the user saves the data on the forms using the “Save” button. The program will incorporate the bridge number and the member being rated into the file name. For example, if the bridge number was 12345 and the member being rated was set to IntGir, the default file name would be set to “12345_IntGir.cbg”. If the user is going to be performing multiple interior girder analysis for the same bridge, for example girders A through D, then during the save process the user can manually type the beam letter within the file name. Thus, if the analysis was for girder “A”, the file name would be “12345_IntGirA.cbg”.

3.3.4 CBG – Material Properties

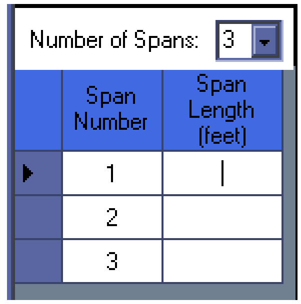
For the material properties area of the form, all that needs to be entered is the concrete strength (f’c) in ksi and the longitudinal reinforcement yield stress (f_y) in ksi. The program will then calculate and display the concrete unit weight in kips per cubic feet, the concrete Modulus of Elasticity (E_c) in ksi, the longitudinal reinforcement Modulus of Elasticity (E_s) in ksi, and the Modular Ratio (n) of the two materials.

3.3.5 CBG – Span Configuration Tab

The span configuration tab is where the user identifies the number of spans that will be modeled in the current BRASS analysis, the lengths of each span, the vertical profile of each span, and which spans are copies of previously defined spans.

It is recommended that the first thing that be defined is the number of spans that will be analyzed in the current BRASS run. Several other form fields within the tab pages refer to the number of spans and the defined span lengths when computing data and populating lists for the user to choose from. The user is able to later specify a greater number of spans without much affect to data that may already be entered on the other tab forms. However, once the user specifies a number of spans that is less than what is currently specified, most of the data that may have been already entered on the other tab forms will be erased.

The Concrete Bridge Generator is configured to make BRASS perform a beam analysis, instead of a frame analysis. For a beam analysis, BRASS is limited to a maximum of 13 spans. Thus, the CBG is limited to a maximum of 13 spans. One the left side of the Span Configuration Tab, the user can either directly type in the number of spans or they can use the drop down list and choose the number. The form field for specifying the span lengths below the number of spans selection will dynamically resize to the number of spans that are defined. Once the number of spans has been defined, the next step is to enter the length of each span in feet.



Once the number of spans and span lengths are defined, the vertical profile of each span needs to be defined. This is done by defining segments of the span where the vertical profile changes or control points occur. In the main form table on the Span Configuration Tab, the first column is the only one that is white and active and is used to identify the span that is being defined. Once the span has been identified, the second and third columns turn white and are active. These two columns are check box cells. The first is used to identify if the user is defining the vertical profile for a span segment, and the second is used to identify if the span is going to be a copy of another defined span.

If the “Define Span Segment” cell is checked, the “Span Copy” cell becomes inactive and the following seven cells to the right become active. These cells have the following column headings:

Web Variation Indicator – A code indicator used by BRASS to indicate what type of vertical profile change that is taking place along the segment length.

Web Variation – provides a graphical representation of the type of vertical profile change that is taking place along the segment length.

Left End Web Depth (inches) – Where the user specifies the depth of the web at the left end of the span segment.

Right End Web Depth (inches) – Where the user specifies the depth of the web at the right end of the span segment.

Length of Span Segment (feet) – Where the user specifies the length of the span segment being defined.

Starting Point from Left End of Span (feet) – The software calculates the starting location based on the span length and the length of the previously defined span segment. If the current segment is the first one being defined for the span, the starting point will be zero feet.

Ending Point from the Left End of Span (feet) – The software calculates the ending location based on the start point and the user specified segment length. If the ending point exceeds the span length, and error message in the cell will be given. If the ending point is less than the span length, a new row for the span will begin being defined with the start point being equal to the current ending point.

Within the Web Variation Indicator cell, the user can choose the following values for the vertical profile change:

L = Linear Web Depth Variation – The depth of the web varies linearly for the segment. If the web depth is constant, the user would choose this option and then specify the left and right web depths to be the same.

P- = Parabolic Concave Down Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the smaller web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used.

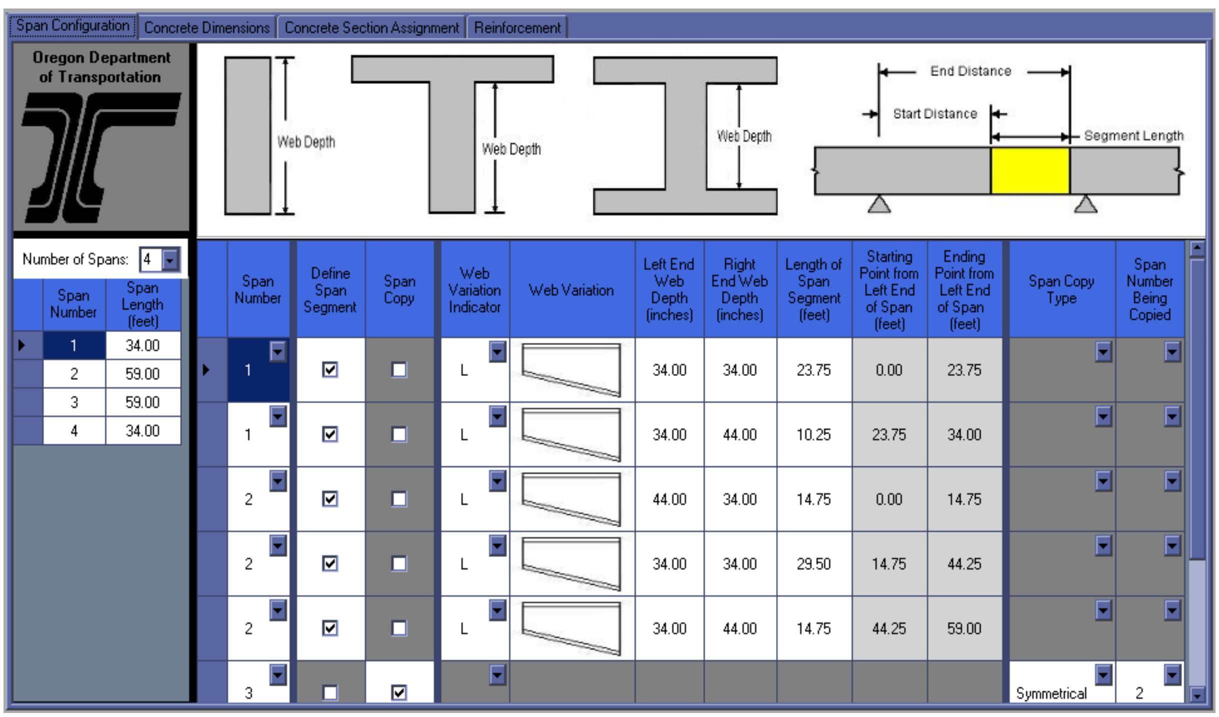
P+ = Parabolic Concave Up Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the larger web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used.

E- = Elliptical Concave Down Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the smaller web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used. Zero vertical slope at the end with the larger web depth is also enforced.

E+ = Elliptical Concave Up Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the larger web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used. Zero vertical slope at the end with the smaller web depth is also enforced.

The Web Variation cell will display a graphic of the variation indicator selected to assist the user in understanding how the different profiles may appear. Holding the mouse over this cell will call a tooltip window to appear giving the same description of the associated Web Variation Indicator as in the previous paragraph. Due to the amount of text written on the tooltip, the time allotted for the tooltip window is a little long and the user may end up having several tooltip windows appear on their screen as they move the mouse across the cell. Simply clicking the mouse in a different cell will force all of the tooltip windows to disappear.

If the “Span Copy” cell is selected, then the “Define Span Segment” cell becomes inactive and all of the cells related to defining the span segment remain inactive. The last two cells to the far right of the table will become active. They are the “Span Copy Type” and the “Span Number Being Copied” cells. In the Span Copy Type cell, the user can select if the copy is going to be identical or symmetrical. The user then can choose the span number that will be copied for the current span. If the span number being copied has a different span length than the current span, an error message will be displayed in the cell.

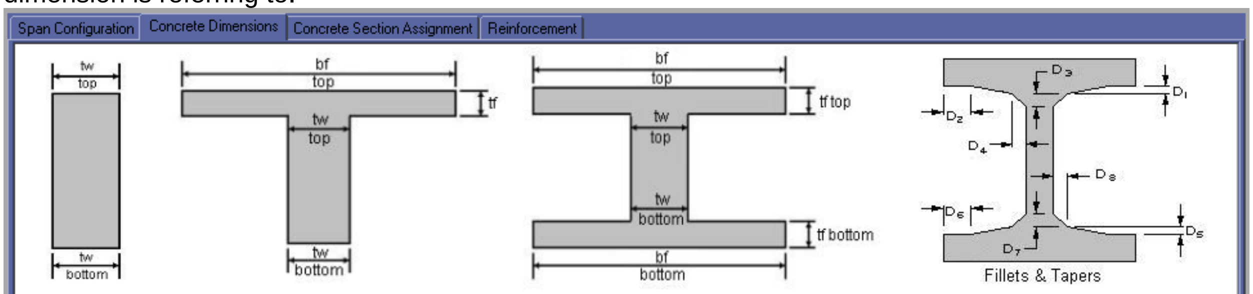


3.3.6 CBG – Concrete Dimensions Tab

The concrete dimensions tab is where the user defines the actual concrete cross-sections of the girder. Originally, only the first cell in the table is active. This cell is titled “X Section Type”, and the user is able to choose from a Rectangular Section, a Tee Section, and an I-Section. The rectangular section is typically used to define the slab strip for a Cast-In-Place (CIP) slab section. The Tee Section is typically used to define RCDG sections. And the I-Section is typically used to define CIP Box Girder Sections.

When defining a concrete section, the program will assign a section number in the second cell. The cells in columns three through eight will become active based on the type of X Section that the user has selected. These cells are used to define the top flange width, top flange thickness, the web thickness at the top, the web thickness at the bottom, the bottom flange width, and the bottom flange thickness.

If the concrete section has fillets and/or tapers between the flanges and webs, the user can check the box in the 9th column titled “Fillets & Tapers”. This will activate the cells in the last eight columns where the user can define the taper and fillet dimensions. These dimensions are illustrated in the diagram and have been given the designations D1 through D8. The user can use the illustration to see what the dimension is referring to, and holding the mouse over the column headings and the actual cells will cause a tooltip window to appear that gives a brief description as to what the dimension is referring to.



	X Section Type	Section Number	bf top (inches)	tf top (inches)	tw top (inches)	tw bottom (inches)	bf bottom (inches)	tf bottom (inches)	Fillets & Tapers	D1 (inches)	D2 (inches)	D3 (inches)	D4 (inches)	D5 (inches)	D6 (inches)	D7 (inches)	D8 (inches)
	Tee Section	1	108.00	6.00	14.50	14.50			☐								
	Tee Section	2	108.00	6.00	24.00	24.00			☐								
▸*									☐								

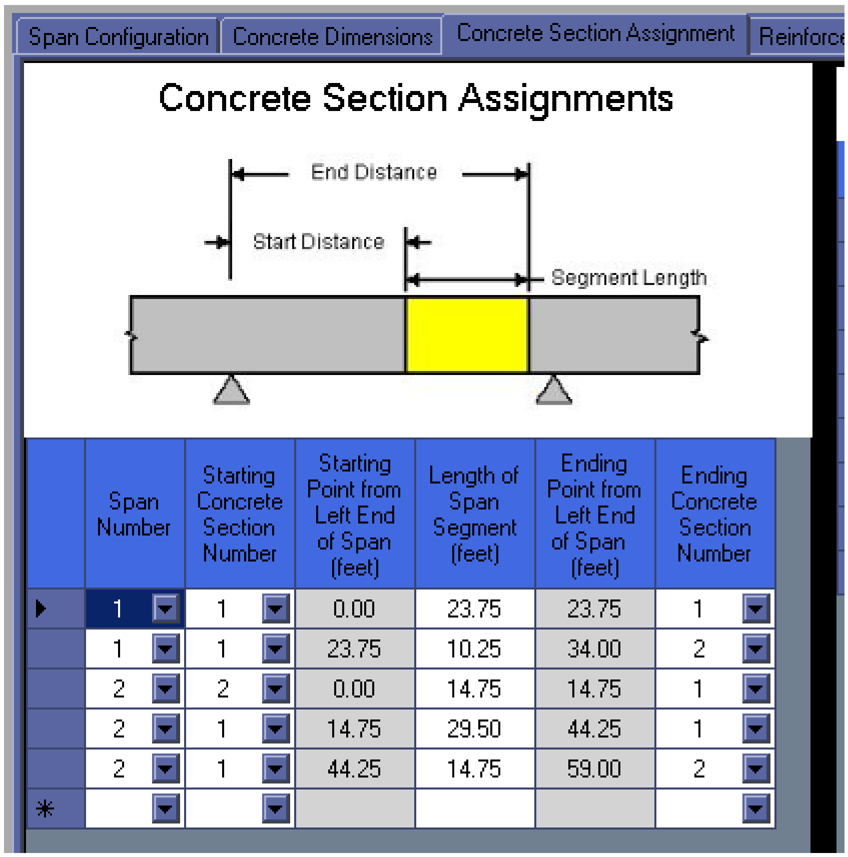
3.3.7 CBG – Concrete Section Assignment Tab

The Concrete Section Assignment Tab is divided into three sections. The first section is for Concrete Section Assignments, where the user assigns the defined concrete sections to each span. The second section is for the Support Conditions, where the user defines the horizontal, vertical, and rotational fixity at each support location. The third section is for Hinge Locations, where the user can define hinge locations that may be present in the structure.

For each span that has span segments defined under the Span Configuration Tab, concrete sections will need to be assigned under the Concrete Section Assignments Tab. In the first cell, the user will specify/choose which span that they are going to assign concrete sections to. The second cell is where the user specifies are chooses the starting Concrete Section Number, which refers to the section numbers that were assigned under the Concrete Dimensions Tab. The third cell is where the program automatically determines where the start point of the span segment is located from the left end of the span. The fourth cell is where the user specifies the length of the span segment in feet. The fifth cell is where the program automatically calculates and reports the Ending point of the span segment from the left end of the span. If the ending point is longer/beyond the span length, then an error message will be displayed in the cell. The last cell is for the user to specify the ending concrete section number.

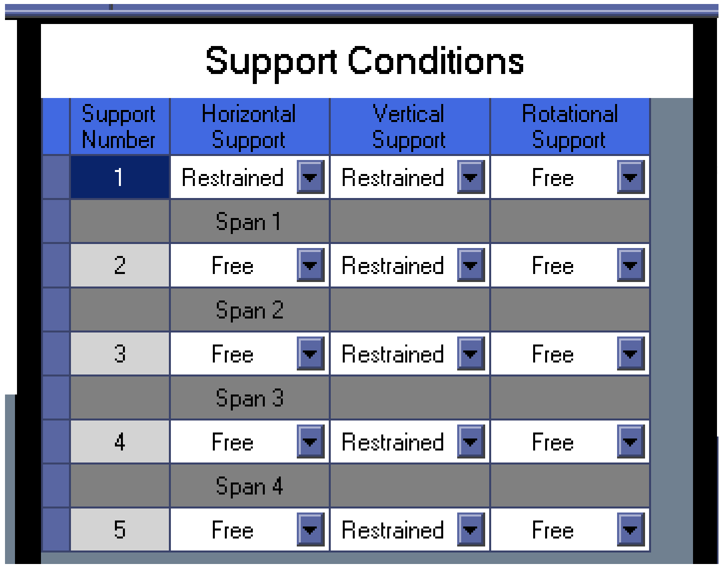
If this is the first cross section assignment for the span, the start point will be at zero feet. Then if the span segment length plus the start point location is less than the defined span length, a new row will be started and the start point will be equal to the ending point of the previous definition. This will continue until the ending point is equal to the span length.

By default, the Ending Concrete Section Number will automatically set to the same value as the Starting Concrete Section Number. This is for segments that have the same cross section over their length. For segments that have the concrete tapering/transitioning between two cross sections over the segment length, the user would specify a different section number for the ending point. For an abrupt change in cross section, the user would have the starting and ending concrete sections numbers the same for the segment, and then start the next segment with a different concrete section number than the previous definition.

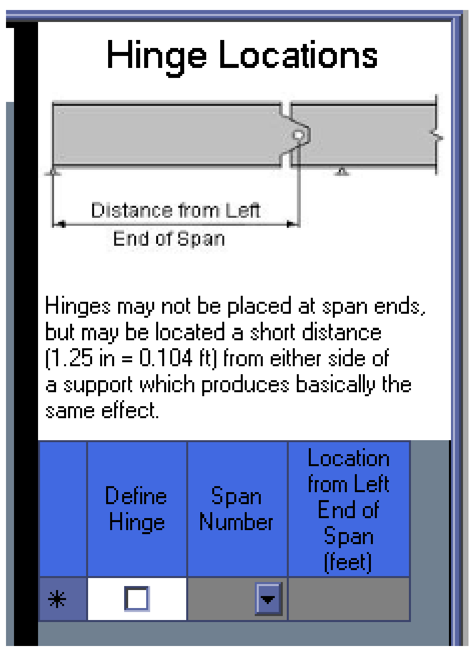


Span Number	Starting Concrete Section Number	Starting Point from Left End of Span (feet)	Length of Span Segment (feet)	Ending Point from Left End of Span (feet)	Ending Concrete Section Number
1	1	0.00	23.75	23.75	1
1	1	23.75	10.25	34.00	2
2	2	0.00	14.75	14.75	1
2	1	14.75	29.50	44.25	1
2	1	44.25	14.75	59.00	2

The Support Conditions table will automatically be resized for the appropriate number of supports based on the number of spans defined under the Span Configuration Tab. For each support, the user must choose if the condition is Free or Restrained for the Horizontal, Vertical, and Rotational supports.

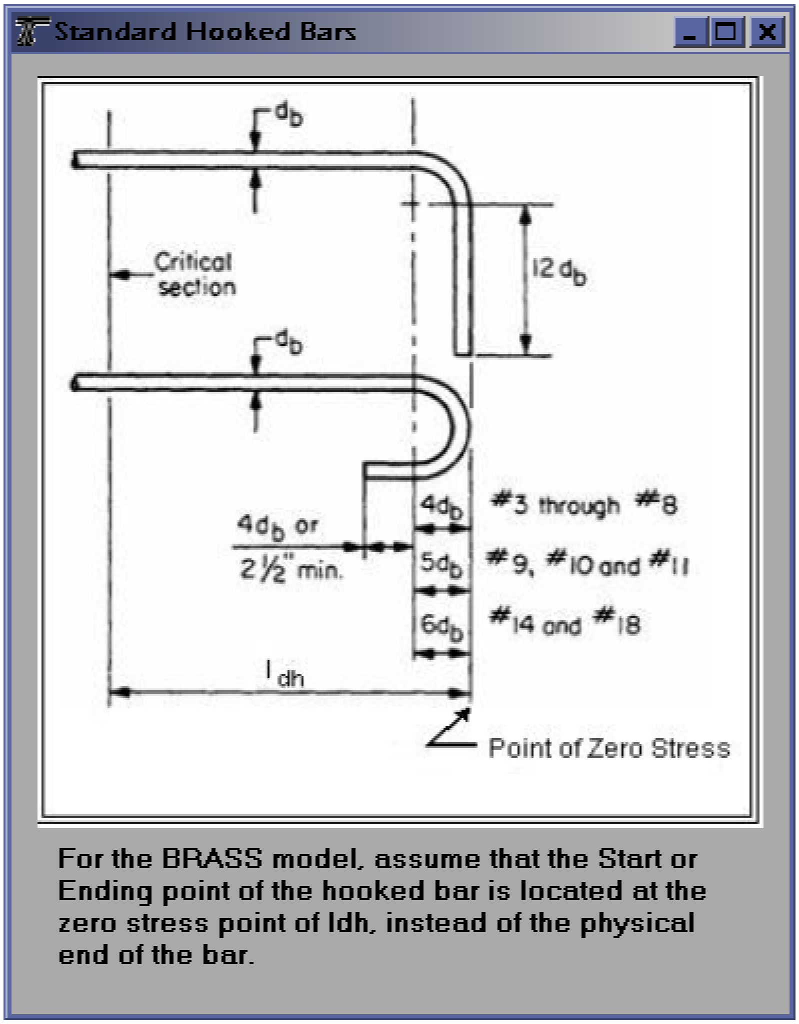


Since not all bridges have hinges, the Hinge Location table is inactive by default. To define a hinge within a span, the user must first select the check box under the 'Define Hinge" column in the Hinge Locations table. Doing so will make the next two cells active, which are where the user would specify which span and the location in feet from the left end of the span where the hinge exists. The BRASS manual states that hinges may not be placed at span ends, but may be located a short distance (1.25 inches) from either side of a support which produces basically the same effect.



3.3.8 CBG – Reinforcement Tab

The Reinforcement Tab is where the user defines the longitudinal reinforcement for each span that has span segments defined under the Span Configuration Tab. To aid the user, at the top of the section there are illustrations showing the reference points of how the bar locations are measured in respect to the cross section and span. There are also two buttons located in upper right hand portion of the section. The first button is titled, "LRFD Bar Development Lengths", and will display a new window with an image of the development length table from the tool BAR_Ld.XLS. The second button is titled, “Hooked Bar Diagram”, and will display the LRFD hooked bar illustrations for standard hooks. The purpose of this illustration is to inform the user that for the BRASS model, the end point of the bar should be defined as the point of zero stress instead of the physical end of the hooked bar.



The reinforcement table can be populated in any order that the user desires. Some prefer to define all of the bottom bars first and then go back and define all of the top bars. Others prefer to define both top and bottom bars working from left to right. As long as all of the bars are eventually defined, there is no difference in the results of how/when they are defined on the table.

The first cell of the Reinforcement table is where the user specifies the rebar row. Rows one through three are reserved for bottom (positive moment) bars, and rows four and five are reserved for top (negative moment) bars. The user can either type just the number of the row or select it from the drop down list.

The second cell is where the user specifies the number of bars in the current bar group.

The third cell is where the user specifies the bar size. The user can either select the bar size from the drop down list, or they can just type in the number of the bar size. Notice that the display/format of the bar sizes changes when any cell in this column has focus. The fraction bar sizes change to decimal and the “#” sign in front of normal round bars disappears. When the focus is moved to a different column in the table, the display/format changes back. That way, if typing in the number for a bar one can simply type the number for the round bar size or the decimal equivalent of the square bar size. For example for a 1-1/8 in sq bar the user can simply type 1.125, or for a #8 round bar one can simply type 8.

The fourth cell is where the vertical distance, in inches, from either the bottom or the top of the girder is defined. For bars that reside in rows one through three, the vertical distance is measured from the bottom of the girder. For bars residing in rows four and five, the vertical distance is measured from the top of the girder.

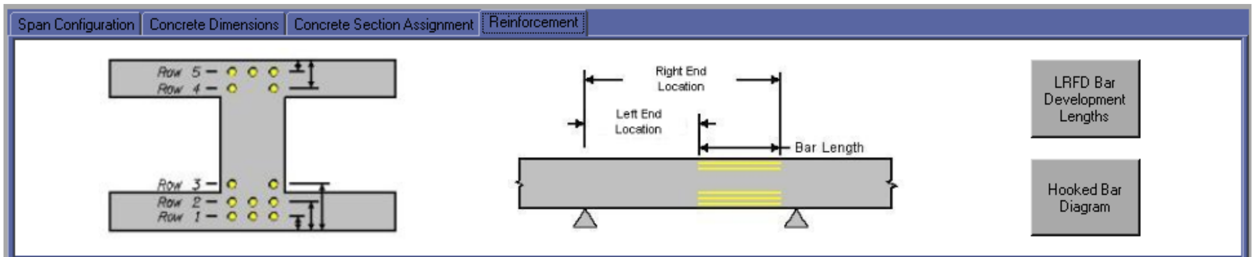
The fifth cell is used to identify the span number where the left end of the bar is located. The sixth cell is used to specify the location, in feet, where the left end of the bar is located from the left end of the span. For straight bars, it would be the physical end of the bar location. For hooked bars, it would be the location at the zero stress point of the hooked bar development length.

The seventh cell is used to specify the development length, in inches, of the left end of the bar. The eighth cell is used to specify the overall bar length in feet. The ninth cell is used to specify the development length, in inches, of the right end of the bar. By default, the program will automatically use the value for the right end development length that was entered for the development length at the left end of the bar. For cases where one end of the bar contains a hook, the user can change the right development length to a different value by simply typing the new value into the cell.

For structures that have a bent bar that transitions to a different depth in the member, the user can simply specify a zero development length at the location where the bend occurs. The length of the bar should be specified for the horizontal portion of the bar only at a given elevation, not the portion that is bent and changing elevation or exists at a different elevation in the member. When a zero development length is encountered, the program will assume that the bar is bent and will not specify a bar cutoff analysis point since the bar is fully developed through the transition area. If the user still wishes to have the program generate a bar cutoff analysis point at this location, they must enter some other value, other than zero, for the development length of the bar.

Some of the older bridges occasionally have the deck reinforcing exposed. ACI318, Article 12.2.3.2, states that for bars with a cover of d_b or less or with a clear spacing of $2d_b$ or less that the basic development length (obtained from the LRFD code) be multiplied by 2.0. Therefore, if the inspection report or photos indicate that the deck reinforcement is exposed, double the development length of the deck reinforcement.

The last two cells at the right of the table are where the program automatically calculates and displays the span number that the right end of the bar resides in and the location from the left end of that span, in feet, that the right end of the bar resides.



	Row	Number of Bars	Bar Size	Vertical Distance (in)	Left End Span Number	Left End Location (ft)	Left End Development Length (in)	Bar Length (ft)	Right End Development Length (in)	Right End Location (ft)	Right End Span Number
1	1	2.00	1-1/8in sq	2.56	1	0.00	26.60	26.00	35.00	26.00	1
2	1	1.00	1-1/8in sq	2.56	1	0.50	35.00	24.00	35.00	24.50	1
3	2	2.00	1-1/8in sq	4.56	1	2.50	35.00	20.00	35.00	22.50	1
4	1	2.00	1-1/4in sq	2.63	1	22.00	42.90	27.00	42.90	15.00	2
5	1	2.00	1-1/2in sq	2.75	2	10.00	59.50	37.00	59.50	47.00	2
6	1	1.00	1-1/2in sq	2.75	2	11.50	59.50	34.00	59.50	45.50	2
7	2	2.00	1-1/2in sq	4.75	2	15.00	59.50	28.00	59.50	43.00	2
8	1	2.00	1-1/4in sq	2.63	2	42.50	42.90	33.00	42.90	16.50	3
9	5	2.00	#8	2.00	1	0.00	20.90	14.00	21.70	14.00	1
10	5	2.00	1-1/4in sq	2.13	1	10.00	42.90	42.00	42.90	18.00	2
11	5	2.00	1-1/4in sq	2.13	1	14.00	42.90	34.00	42.90	14.00	2
12	5	2.00	1-1/4in sq	2.13	1	19.00	42.90	24.00	42.90	9.00	2
13	5	2.00	1-1/4in sq	2.13	1	25.00	42.90	15.00	42.90	6.00	2

3.3.9 CBG – Show Cross Section Matrix Button

Once the user has completed entering the data in the various tables and form fields, it is recommended to save the data before continuing just in case the program encounters an unexpected error or bug and closes the CBG. It is then recommended to select the "Show Cross-Section Matrix" button, which will open a new window containing a spreadsheet or matrix of the concrete dimensions and longitudinal reinforcement that will be used to define the spans in BRASS. The Concrete Section Matrix is just a tool for the load rater to see and verify how the bridge is being modeled based on the data that was entered.

The first column lists the span fraction at each section point. The second column lists the span number. And the third column lists the actual location of the of the section point in feet. Columns four through 18 lists the concrete dimensions as they are illustrated on the Concrete Dimensions tab of the main form.

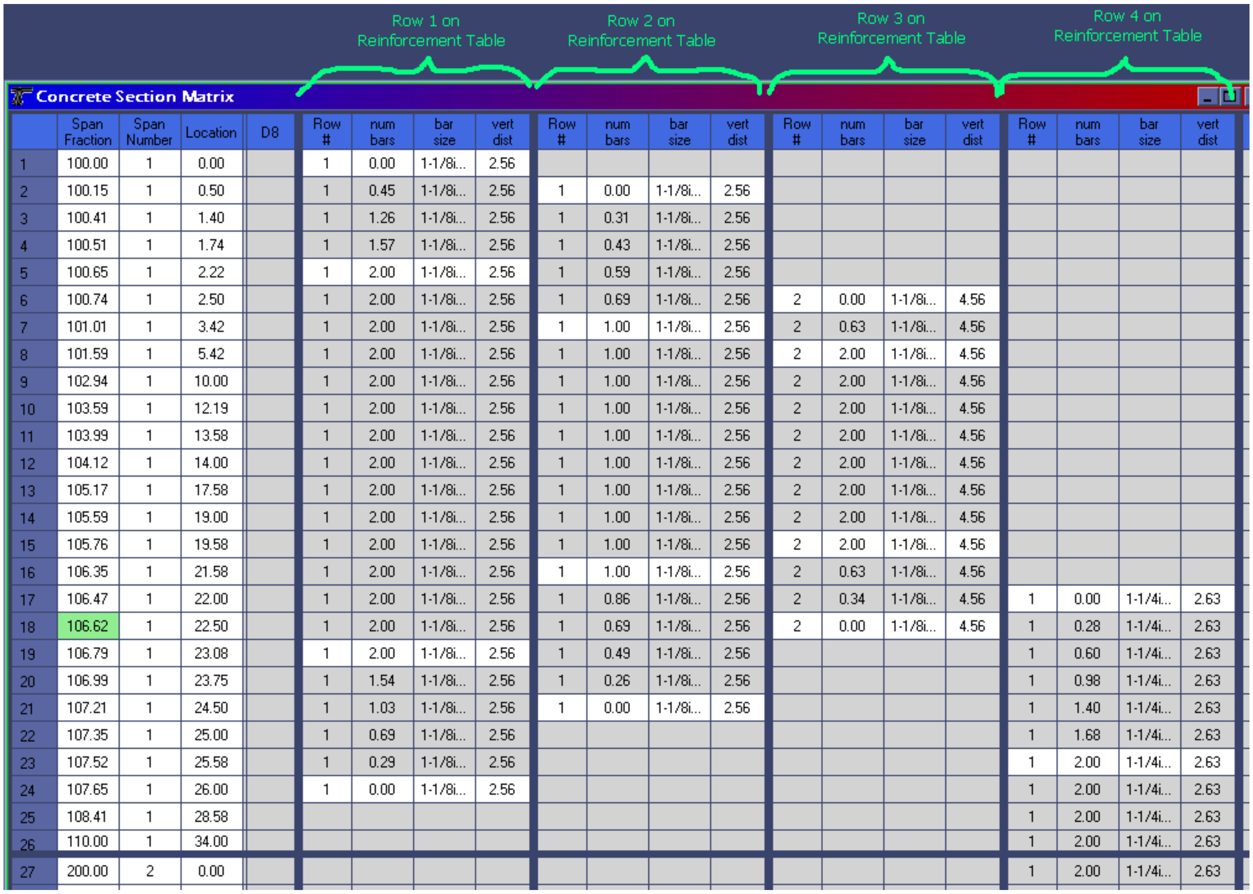
Cells that have white backgrounds are actual control points that were specified on either the Concrete Section Assignment tab or on the Reinforcement tab. The cells with a light grey background are intermediate points that were linearly interpolated between the control points with white backgrounds. Span fraction cells that have a light green background are cells that are made up of two or more control points that were combined into one analysis point. Making the mouse hover over the green cell will cause a tooltip window to display the reason why the cells are combined.

Concrete Section Matrix

	Span Fraction	Span Number	Location	X-Section Number	bf top	tf top	tw top	tw bottom	bf bottom	tf bottom	D1	D2	D3	D4	D5	D6	D7	D8
1	100.00	1	0.00	1	108.00	6.00	14.50	14.50										
2	100.15	1	0.50	-	108.00	6.00	14.50	14.50										
3	100.41	1	1.40	-	108.00	6.00	14.50	14.50										
4	100.51	1	1.74	-	108.00	6.00	14.50	14.50										
5	100.65	1	2.22	-	108.00	6.00	14.50	14.50										
6	100.74	1	2.50	-	108.00	6.00	14.50	14.50										
7	101.01	1	3.42	-	108.00	6.00	14.50	14.50										
8	101.59	1	5.42	-	108.00	6.00	14.50	14.50										
9	102.94	1	10.00	-	108.00	6.00	14.50	14.50										
10	103.59	1	12.19	-	108.00	6.00	14.50	14.50										
11	103.99	1	13.58	-	108.00	6.00	14.50	14.50										
12	104.12	1	14.00	-	108.00	6.00	14.50	14.50										
13	105.17	1	17.58	-	108.00	6.00	14.50	14.50										
14	105.59	1	19.00	-	108.00	6.00	14.50	14.50										
15	105.76	1	19.58	-	108.00	6.00	14.50	14.50										
16	106.35	1	21.58	-	108.00	6.00	14.50	14.50										
17	106.47	1	22.00	-	108.00	6.00	14.50	14.50										
18	106.62	1	22.50	-	108.00	6.00	14.50	14.50										
19	106.79	1	23.08	-	108.00	6.00	14.50	14.50										
20	106.99	1	23.75	1	108.00	6.00	14.50	14.50										
21	107.21	1	24.50	-	108.00	6.00	15.19	15.19										
22	107.35	1	25.00	-	108.00	6.00	15.64	15.64										
23	107.52	1	25.58	-	108.00	6.00	16.17	16.17										
24	107.65	1	26.00	-	108.00	6.00	16.58	16.58										
25	108.41	1	28.58	-	108.00	6.00	18.98	18.98										
26	110.00	1	34.00	2	108.00	6.00	24.00	24.00										
27	200.00	2	0.00	2	108.00	6.00	24.00	24.00										

The columns beyond column 18 are used to show the longitudinal bars that were defined under the Reinforcement Tab. Each bar group consists of four columns that list the rebar row number, the number of bars, the bar size, and the vertical distance in the girder were the bars are located. Each bar group will have four control points, one at each physical end of the bar and one at each point of full bar development. As with the concrete sections, all points that fall between the rebar control points will be linearly interpolated.

The first rebar group shown in the matrix is defined by the first row in the Reinforcement Tab Table, the second group is defined by the second row in the table and so on. Knowing how the bars are defined and represented in the matrix and in the table will allow the load rater to verify how the reinforcement is being modeled.



	Span Fraction	Span Number	Location	D8	Row #	num bars	bar size	vert dist	Row #	num bars	bar size	vert dist	Row #	num bars	bar size	vert dist	Row #	num bars	bar size	vert dist
1	100.00	1	0.00		1	0.00	1-1/8i...	2.56												
2	100.15	1	0.50		1	0.45	1-1/8i...	2.56	1	0.00	1-1/8i...	2.56								
3	100.41	1	1.40		1	1.26	1-1/8i...	2.56	1	0.31	1-1/8i...	2.56								
4	100.51	1	1.74		1	1.57	1-1/8i...	2.56	1	0.43	1-1/8i...	2.56								
5	100.65	1	2.22		1	2.00	1-1/8i...	2.56	1	0.59	1-1/8i...	2.56								
6	100.74	1	2.50		1	2.00	1-1/8i...	2.56	1	0.69	1-1/8i...	2.56	2	0.00	1-1/8i...	4.56				
7	101.01	1	3.42		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	0.63	1-1/8i...	4.56				
8	101.59	1	5.42		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
9	102.94	1	10.00		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
10	103.59	1	12.19		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
11	103.99	1	13.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
12	104.12	1	14.00		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
13	105.17	1	17.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
14	105.59	1	19.00		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
15	105.76	1	19.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
16	106.35	1	21.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	0.63	1-1/8i...	4.56				
17	106.47	1	22.00		1	2.00	1-1/8i...	2.56	1	0.86	1-1/8i...	2.56	2	0.34	1-1/8i...	4.56	1	0.00	1-1/4i...	2.63
18	106.62	1	22.50		1	2.00	1-1/8i...	2.56	1	0.69	1-1/8i...	2.56	2	0.00	1-1/8i...	4.56	1	0.28	1-1/4i...	2.63
19	106.79	1	23.08		1	2.00	1-1/8i...	2.56	1	0.49	1-1/8i...	2.56					1	0.60	1-1/4i...	2.63
20	106.99	1	23.75		1	1.54	1-1/8i...	2.56	1	0.26	1-1/8i...	2.56					1	0.98	1-1/4i...	2.63
21	107.21	1	24.50		1	1.03	1-1/8i...	2.56	1	0.00	1-1/8i...	2.56					1	1.40	1-1/4i...	2.63
22	107.35	1	25.00		1	0.69	1-1/8i...	2.56									1	1.68	1-1/4i...	2.63
23	107.52	1	25.58		1	0.29	1-1/8i...	2.56									1	2.00	1-1/4i...	2.63
24	107.65	1	26.00		1	0.00	1-1/8i...	2.56									1	2.00	1-1/4i...	2.63
25	108.41	1	28.58														1	2.00	1-1/4i...	2.63
26	110.00	1	34.00														1	2.00	1-1/4i...	2.63
27	200.00	2	0.00														1	2.00	1-1/4i...	2.63

For reinforcement that reside on the same row in the matrix, if the rebar row number, bar size, and vertical distance are the same, then the number of bars will be added together when the program creates the BRASS cross-sections. For example, in the above matrix screenshot, in row three of the matrix the first two rebar groups have the same rebar row number, bar size, and vertical distance. Thus, when the program creates BRASS cross-section number three, it will generate 1.57 - #10 bars in row 1 at a vertical distance of 2.56 inches.

Each numbered row in the matrix that has concrete dimensions showing will end up having the same BRASS cross-section number. Thus, matrix row one will end up being BRASS cross-section number one, matrix row two will end up being BRASS cross-section number two and so on.

The user is to define the starting and ending points for every bar that exists within each unique span. This will often result with bars ending in other spans that are defined as copies of a previous unique span. The program will only generate BRASS cross-sections for the matrix rows that have concrete dimensions displayed. For example, in the following screenshot of the matrix, the program will only generate 64 BRASS cross-sections. This is because the matrix rows 65 and above do not have concrete dimensions shown. This is because the user had indicated on the Span Configuration Tab that spans three and four are to be copies of spans one and two. Spans three and four show control points in the matrix for the ending locations of rebar that started in spans one and two.

Concrete Section Matrix

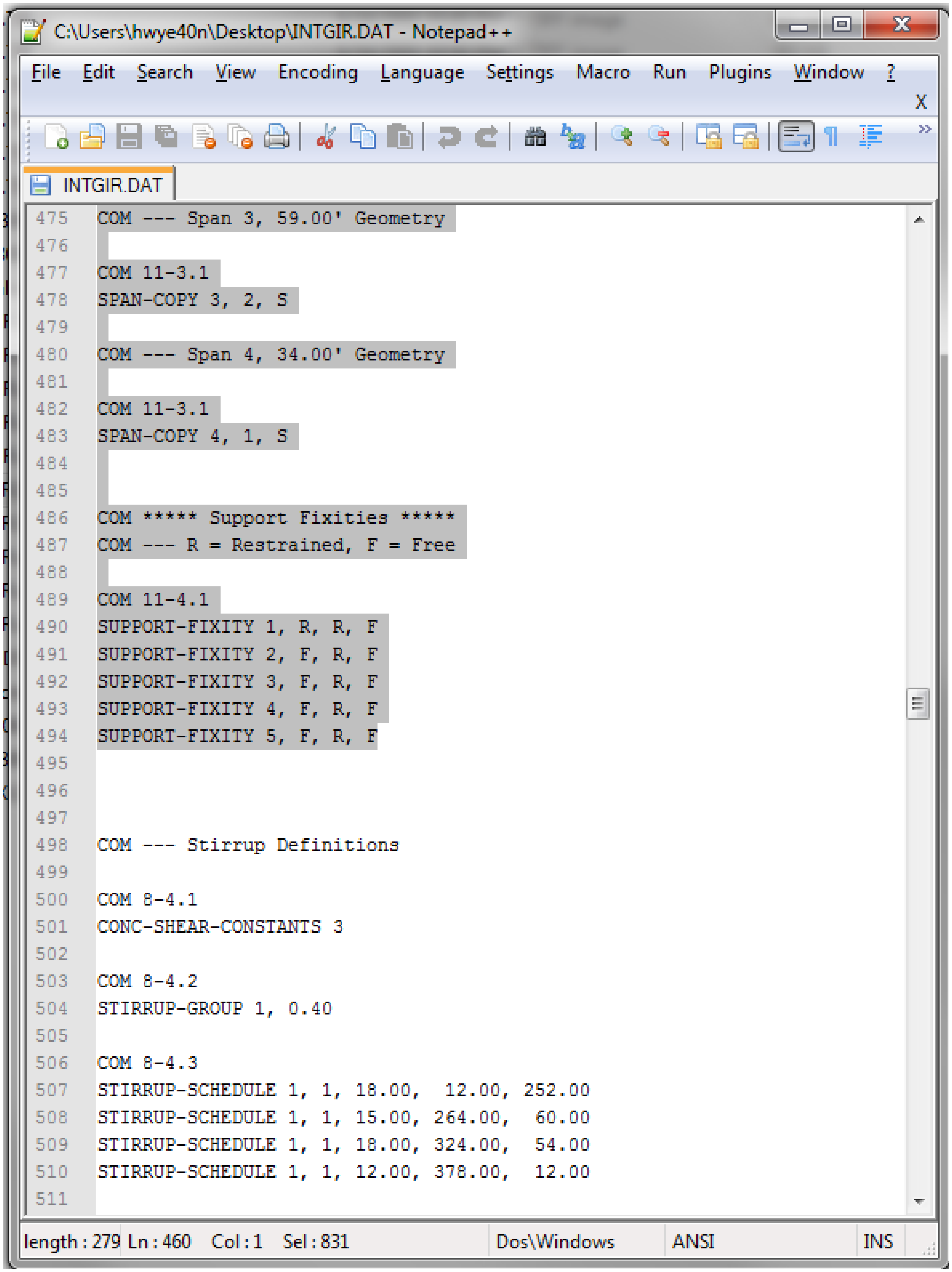
	Span Fraction	Span Number	Location	X-Section Number	bf top	tf top	tw top	tw bottom	bf bottom	tf bottom	D1	D2	D3	D4	D5	D6	D7	D8
44	206.02	2	35.50	-	108.00	6.00	14.50	14.50										
45	206.09	2	35.94	-	108.00	6.00	14.50	14.50										
46	206.40	2	37.75	-	108.00	6.00	14.50	14.50										
47	206.45	2	38.04	-	108.00	6.00	14.50	14.50										
48	206.62	2	39.08	-	108.00	6.00	14.50	14.50										
49	206.78	2	40.00	-	108.00	6.00	14.50	14.50										
50	206.87	2	40.54	-	108.00	6.00	14.50	14.50										
51	207.13	2	42.04	-	108.00	6.00	14.50	14.50										
52	207.20	2	42.50	-	108.00	6.00	14.50	14.50										
53	207.29	2	43.00	-	108.00	6.00	14.50	14.50										
54	207.39	2	43.58	-	108.00	6.00	14.50	14.50										
55	207.50	2	44.25	1	108.00	6.00	14.50	14.50										
56	207.71	2	45.50	-	108.00	6.00	15.30	15.30										
57	207.81	2	46.08	-	108.00	6.00	15.68	15.68										
58	207.88	2	46.50	-	108.00	6.00	15.94	15.94										
59	207.97	2	47.00	-	108.00	6.00	16.29	16.29										
60	208.31	2	49.00	-	108.00	6.00	17.58	17.58										
61	208.49	2	50.08	-	108.00	6.00	18.26	18.26										
62	208.90	2	52.50	-	108.00	6.00	19.82	19.82										
63	209.51	2	56.08	-	108.00	6.00	22.14	22.14										
64	210.00	2	59.00	2	108.00	6.00	24.00	24.00										
65	300.50	3	2.93															
66	301.09	3	6.43															
67	301.51	3	8.93															
68	301.69	3	10.00															
69	302.12	3	12.50															
70	302.19	3	12.93															
71	302.62	3	15.43															
72	302.80	3	16.50															
73	303.22	3	19.00															
74	303.38	3	19.93															
75	303.98	3	23.50															
76	310.00	3	59.00															
77	409.59	4	32.60															
78	410.00	4	34.00															

3.3.10 CBG – Generate Brass File Inputs

Selecting the “Generate BRASS File Input” button will display a text window that contains all of the needed BRASS-GIRDER(LRFD) input commands from the very beginning of the file up to the point where the user defines the stirrup definitions. When the window appears, all of the text is already selected, therefore all the user has to do is right click in the window and select the “Copy” command.

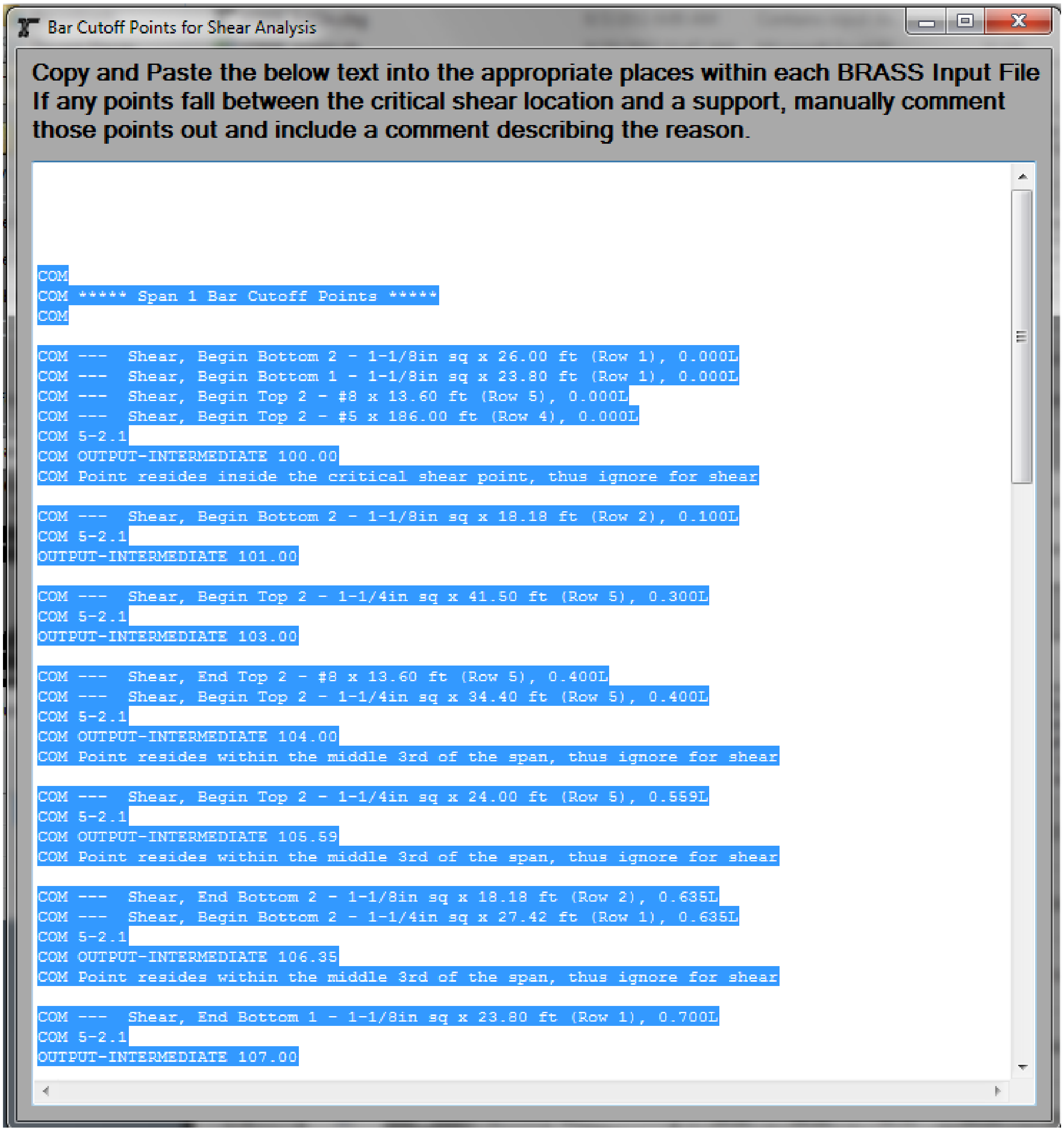

```
COM 2-1.3
BRIDGE-NAME 07806, Hwy 35 over Hwy 1

COM 2-1.5
ROUTE 76.65, Hwy35 (Coos Bay - Roseburg Highway)

COM 2-1.6
TITLE File IntGir.DAT  Interior Girder
TITLE Rating for Design, Legal, CTP, & STP Loads

COM 2-1.1
AGENCY Oregon DOT

COM 2-1.2
ENGINEER S Burgess T Kinney

COM
COM  ***** LRFR Load Rating, Strength Limit State *****
COM

COM 4-1.1
ANALYSIS B, 1, RAT, T, Y

COM 4-1.2
POINT-OF-INTEREST U

COM 2-1.4
UNITS US

COM 5-1.1
OUTPUT 4, Y, , , 1, , , , , , , , , ,

COM 5-7.3
OUTPUT-EFF-WIDTH N

COM BRASS (LRFD) INPUT ADJUSTMENT TYPE 1:
COM For LRFR specify the Strength Limit States
COM and ignore Service & Fatigue Limits
COM Design & Legal Loads = Strength-I
COM Permit Loads = Strength-II
COM (refer to 4-5.1, Fig. 2) and
COM specify shear checks for all load types.

COM 4-5.1, 4-5.2
MAP-LIMIT-STATE ST, 1, I, Y, N
MAP-LIMIT-STATE ST, 2, N, N, Y
MAP-SPEC-CHECK ST, 1, D, SHR, Y
```

Then in the appropriate input file template, the user selects all of the text from the very beginning of the file up to just before the comment line that states, “Stirrup Definitions”. Then selecting the “Paste” command will replace all of the selected text commands with those that were just copied from the CBG.



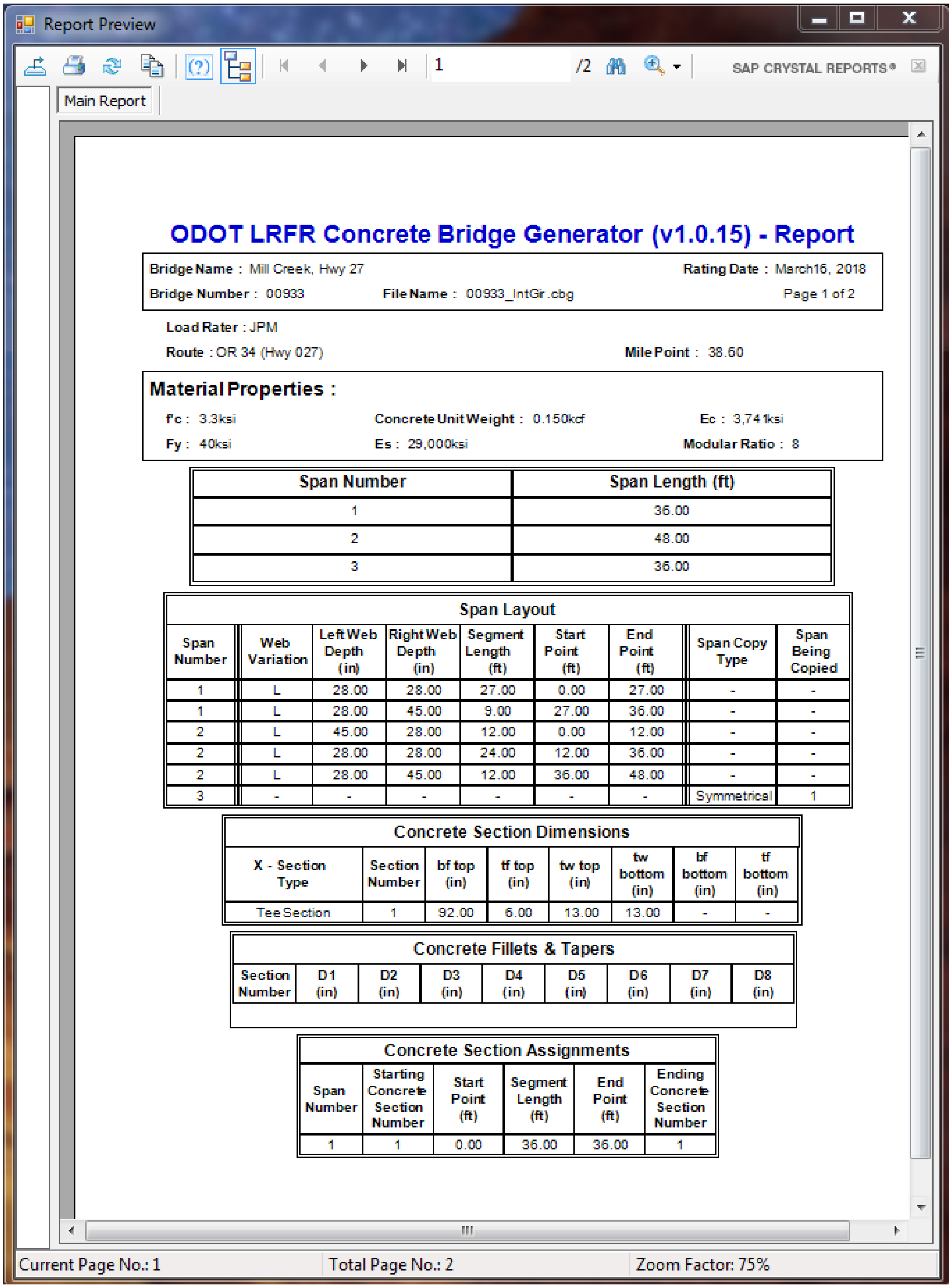
3.3.11 CBG – Generate Bar Cutoff Points for Shear Analysis

Selecting the “Generate Bar Cutoff Points for Shear Analysis” button will display a text window that contains all of the needed BRASS input shear commands for the bar cutoff points. When the window appears, all of the text for all of the commands for the different spans is already selected. The user needs to select and copy the group of commands for only one span at a time, and then paste them within the appropriate spot in each BRASS input file. Comment out any analysis points that are within the critical shear section.



3.3.12 CBG – Report

Once all of the data has been entered, verified with the matrix and the various BRASS commands have been copied and pasted in the BRASS input files, the user should save the data into a *.cbg file that will be included in the electronic file set. Then the user should select the "Report" button, which will display a print preview of a report that reflects the data entered in the various form fields of the program. Selecting the button that has the printer icon at the top of the print preview will print a hard copy of the report, which should be included in the printed calc book for the load rating.



Report Preview

Main Report

1 /2 SAP CRYSTAL REPORTS®

ODOT LRFR Concrete Bridge Generator (v1.0.15) - Report

Bridge Name : Mill Creek, Hwy 27 **Rating Date :** March16, 2018

Bridge Number : 00933 **File Name :** 00933_IntGr.cbg Page 1 of 2

Load Rater : JPM

Route : OR 34 (Hwy 027) **Mile Point :** 38.60

Material Properties :

f'c : 3.3ksi **Concrete Unit Weight :** 0.150kcf **Ec :** 3,741ksi

Fy : 40ksi **Es :** 29,000ksi **Modular Ratio :** 8

Span Number	Span Length (ft)
1	36.00
2	48.00
3	36.00

Span Layout

Span Number	Web Variation	Left Web Depth (in)	Right Web Depth (in)	Segment Length (ft)	Start Point (ft)	End Point (ft)	Span Copy Type	Span Being Copied
1	L	28.00	28.00	27.00	0.00	27.00	-	-
1	L	28.00	45.00	9.00	27.00	36.00	-	-
2	L	45.00	28.00	12.00	0.00	12.00	-	-
2	L	28.00	28.00	24.00	12.00	36.00	-	-
2	L	28.00	45.00	12.00	36.00	48.00	-	-
3	-	-	-	-	-	-	Symmetrical	1

Concrete Section Dimensions

X - Section Type	Section Number	bf top (in)	tf top (in)	tw top (in)	tw bottom (in)	bf bottom (in)	tf bottom (in)
Tee Section	1	92.00	6.00	13.00	13.00	-	-

Concrete Fillets & Tapers

Section Number	D1 (in)	D2 (in)	D3 (in)	D4 (in)	D5 (in)	D6 (in)	D7 (in)	D8 (in)

Concrete Section Assignments

Span Number	Starting Concrete Section Number	Start Point (ft)	Segment Length (ft)	End Point (ft)	Ending Concrete Section Number
1	1	0.00	36.00	36.00	1

Current Page No.: 1 Total Page No.: 2 Zoom Factor: 75%

3.3.13 CBG – Known Issues

All known errors with the CBG have been corrected.

3.4 Analysis of Girders

BRASS-GIRDER will be used to load rate the concrete girders. BRASS-GIRDER is different from the previous BRASS-GIRDER(LRFD) program in that it no longer uses text file inputs, but instead utilizes a Graphical User Interface (GUI) with data saved in xml file format. Instead of developing new procedures and a new CBG program to populate the GUI of BRASS-GIRDER, this manual will continue to give instructions on how to create the text input file for BRASS-GIRDER(LRFD). Once the file is ready for analysis, the user will run the text input file through the BRASS-GIRDER translator that will create the xml input file used to populate the new GUI. From there the user will be able to run the analysis within BRASS-GIRDER.

BRASS has increased the live load definition limit from 20 to 100 per file. In the past, since ODOT requires more than 20 vehicles to be analyzed in every LRFR load rating, two nearly identical BRASS input files were used to cover all of the different vehicles. Since the transition from using BRASS-GIRDER(LRFD) to using BRASS-GIRDER for the analysis, ODOT has modified all of its tools to only use a single BRASS file with all of the rating vehicles included. Therefore, ODOT will no longer require the two separate nearly identical BRASS "_N" and "_T" files.

3.4.1 BRASS Input File Conventions

Use the heavily commented sample files provided as templates to be copied to a new bridge-number-specific folder (with a new filename if appropriate) and then modified for the actual Load Ratings. Separate input files will be required for each structure type in any bridge with a combination of structure types, and for interior and exterior girders due to the variability of live load distribution factors in LRFR.

- General conventions

Use the full length of each command name except the COMMENT (3-1.1) command shall be only COM.

Precede each command or logical group of similar commands (except for the COMMENT command) with a comment referring to the Article number in the BRASS-GIRDER(LRFD) Command Manual. For example, precede an ANALYSIS (4-1.1) command with a comment command thus:

```
COM 4-1.1
ANALYSIS B, 1, RAT, T, Y
```

Generally, leave in all comments found in the template (unless they become totally irrelevant to a particular input file), modifying them and adding more comments as required to fit the specific conditions of the rating. Use comments liberally with the expectation that someone unfamiliar with the BRASS-GIRDER(LRFD) program and unfamiliar with the bridge will need to read the data file and fully understand it.

Leave parameters blank (spaces between commas) where they are irrelevant to the specific structure. Although trailing commas can be omitted where all parameters to the right are to be blank, it is recommended to clarify your intentions by showing the blank parameters separated by commas. However, avoid leaving blank parameters such as material strengths where default values would apply. Enter the default values to make the dataset more meaningful to a future user.

Show in-line calculations within a parameter (between commas) to convert units from feet to inches where the command parameter requires inches. Similarly, show in-line calculations to show how you determined vertical dimensions to locate flexural bars. Never use parentheses in in-line calculations. Other than these in-line calculations, the best place to put calculations is in the Preliminary File rather than in the BRASS comments.

Whenever a BRASS-GIRDER(LRFD) input file contains a series of occurrences of the same command, vertically aligning the same command parameters for clarity is encouraged. This practice simplifies the process of changing values of parameters when cloning an old BRASS file for use in a new bridge. Inserting spaces as required to accomplish this is harmless. However, do not use tab characters to accomplish this. They are misinterpreted by BRASS-(LRFD) as the next parameter, and are likely to cause fatal errors.

- Input File Sections

To make it easier for a subsequent user to find their way around the Input File, separate the BRASS input file into logical sections (large groups of commands) by using spaced comments as indicated in the sample files. Typically, an input file for an RCDG will be divided into the following sections:

```
COM
COM  ***** LRFR Load Rating, Strength Limit State *****
COM

COM
COM  ***** Material Properties *****
COM

COM
COM  ***** Section Geometry *****
COM

COM
COM  ***** Span Length and Section Information *****
COM

COM
COM  ***** Dead Loads *****
COM

COM
COM  ***** Live Loads *****
COM

COM
COM  ***** Distribution Factors *****
COM

COM
COM  ***** Resistance Factors *****
COM

COM
COM   ***** Critical Flexural Sections *****
COM


COM
COM  ***** Shear Points of Interest *****
COM
```

With similar comment sets, subdivide the “Shear Points of Interest” section into subsections for each category of investigated section for each unique span. (See the sample input files).

- Specific conventions

Several of these conventions and commands will be automatically created by the CBG program. They are listed within this section to provide background and understanding as to what ODOT is requiring within the BRASS input files.

At the beginning of every input file, use the BRIDGE-NAME (2-1.3) command to provide the 5- or 6-character NBI Bridge Number, followed by the Bridge Name. Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Next, use the ROUTE (2-1.5) command to provide the mile point and signed Route Number where applicable (always required for State-owned bridges). Note the signed Route Number is not the same as the ODOT internal (maintenance) Highway Number.

Use 2 lines of the TITLE (2-1.6) command. Use the first TITLE line to provide the file name and describe which girder(s) this file applies to. Use the second TITLE line to provide the purpose or work grouping of the Load Rating.

Use the AGENCY (2-1.1) command to identify the Load Rating as being performed according to ODOT standards. This command should always be the same:

```
COM 2-1.1
AGENCY Oregon DOT
```

Use the ENGINEER (2-1.2) command to indicate the load rater.

Use the UNITS (2-1.4) command to force BRASS to always use US (English) units for both input and output. BRASS normally defaults to US units, but it has been found that when referenced dimensions get large, BRASS will automatically assume the large dimensions are in millimeters and will convert the units when it calculates the resistance of the member. Using the UNITS command will not allow BRASS to arbitrarily convert the units during an analysis.

```
COM 2-1.4
UNITS US
```

Use the ANALYSIS (4-1.1) command to provide BRASS with parameters needed to do a rating analysis. The “continuous beam model” is the preferred choice (“B” in parameter 1) as long as there is no need to include columns in the analysis and the bridge has ≤ 13 spans. Parameter 5 needs to be coded as Y, for yes, to interpolate reinforcing steel from the left cross section to the right cross section. This will allow BRASS to account for partially developed reinforcing steel per AASHTO LRFD 5.7.3.4.2. Except for a rigid frame analysis (with columns) that would require the “frame type model” (“F” in parameter 1), this command would normally be the same:

```
COM 4-1.1
ANALYSIS B, 1, RAT, T, Y
```

Use the POINT-OF-INTEREST (4-1.2) command to set BRASS to generate user-defined points of interest from subsequent OUTPUT-INTERMEDIATE (5-2.1) commands.

```
COM 4-1.2
POINT-OF-INTEREST U
```

Leaving the 2nd parameter (Specification Check Output) blank causes BRASS to default to refrain from generating a large additional output (.OUT) file for each point of interest, information that is not normally needed. Use of "Y" for parameter 2 to turn on this additional output may be justified at sections where there is a need to account for partially developed bars. If these additional .OUT files are generated, they do not need to be printed in the Load Rating Report.

Use the OUTPUT (5-1.1) command to control the wide variety of output options. Unless there is a problem that requires more detailed intermediate output for investigation, this command should always the same:

```
COM 5-1.1
OUTPUT 4, Y, , , 1, , , , , , , , ,
```

Beginning with BRASS-GIRDER(LRFD) v.1.6.1, the effective top flange width is calculated and applied to the section properties automatically. Use the OUTPUT-EFF-WIDTH (5-7.3) command to direct BRASS to not output its effective flange width calculations. This command should always be the same:

```
COM 5-7.3
OUTPUT-EFF-WIDTH N
```

Code all BRASS models in the same direction as the girder elevation appears on the plans, i.e. from left to right on the plans, regardless of mile point direction.

In the "Material Properties" section, use the CONC-MATERIALS (8-1.1) command to provide the material properties consistent with the notes on the bridge plans. Although there are exceptions, a typical RCDG structure from the 1950's or early 1960's would have the following properties command:

```
COM 8-1.1
CONC-MATERIALS 0.15, 3.3, 40.0, 40.0, 9, , , 170.0, , ,
```

In the "Material Properties" section, use the DECK-MATL-PROPERTIES (6-4.1) command to assure that the default wearing surface weight (parameter 3) is set to 0. Without this command, BRASS would generate its own DW load, which we want to define explicitly in the "dead loads" section.

```
COM This command is required to assure default deck Wearing
Surface Weight
COM (parameter 3) is 0 so BRASS does not generate a DW load on
its own
COM 6-4.1
DECK-MATL-PROPERTIES , , 0.0
```

If the material properties of the top flange differ from those in the web and bottom flange of the girder, use the CONC-MATERIAL-FLANGE (8-1.2) command to define the properties for the concrete in the top flange of a concrete girder. The following is an example of this command:

```
COM 8-1.2
COM Deck slab concrete strength differs from girder concrete.
CONC-MATERIAL-FLANGE 4.0, 8
```

In the "Section Geometry" section, define each section numbered sequentially, preceded by a comment identifying it with characteristics from the plans. Use the CONC-TEE-SECTION (8-2.3) or the CONC-I-SECTION (8-2.4) if applicable, to define the cross-section section dimensions (except for depth). Note the parameters for these commands changed beginning with BRASS-GIRDER(LRFD) v.1.6.1.

BRASS version 2.0.3 has been updated to include the 2008 revision of the 4^{th} Edition LRFD Code. With this update it is no longer necessary to calculate the effective flange width of composite slabs in the preliminary file. The second parameter of COMPOSITE-SLAB command may be left blank to allow BRASS to calculate the effective width.

Use as many CONC-REBAR (8-2.8) commands as required to define all the layers of longitudinal reinforcement that are present. For negative moment sections, it is important to include all longitudinal bars present within the effective top flange width. The following is an example of the series of commands to define one section:

```
COM --- Section 1, Span 1, 16#10 + 16#9 bot, 86#5 top
COM 8-2.4, 8-2.7, 8-2.8
CONC-I-SECTION 1, 511.00, 7.50, 69.00, , 409.00, 6.00
CONC-FILLETS 1, 0, 0, 5.0, 16.0, 0, 0, 4.0, 16.0
CONC-REBAR 1, 1, 16, 10,  1.50+0.625+1.27/2
CONC-REBAR 1, 1, 16,  9,  1.50+0.625+1.128/2
CONC-REBAR 1, 4, 44,  5,  7.50-1.0-0.625-0.625/2
CONC-REBAR 1, 5, 42,  5,  1.50+0.625+0.625/2
```

Some of the older bridges occasionally have the deck reinforcing exposed. ACI318, Article 12.2.3.2, states that for bars with a cover of d_b or less or with a clear spacing of $2d_b$ or less that the basic development length (obtained from the AASHTO LRFD code) be multiplied by 2.0. Therefore, if the inspection report or photos indicate that the deck reinforcement is exposed, double the development length of the deck reinforcement.

In the "Span Lengths and Section Information" section, define each span beginning with the appropriate command from Chapter 11 of the *BRASS-GIRDER(LRFD) Command Manual* that describes the profile (depth variation) along the span. Follow this command with a sequence of SPAN-SECTION (11-2.1) commands to assign the previously defined sections to cumulative ranges from the left end of the span. The following is an example of the series of commands to define one span:

```
COM --- Span 1, 36' Geometry

COM 11-1.3, 11-2.1
SPAN-UNIF-HAUNCH 1, 36.0*12, R, 28.00, 27.0*12, 45.00,
SPAN-SECTION 1,  1, 12.88*12
SPAN-SECTION 1,  2, 14.08*12
SPAN-SECTION 1,  3, 18.13*12
SPAN-SECTION 1,  4, 21.08*12
SPAN-SECTION 1,  5, 24.13*12
SPAN-SECTION 1,  6, 26.08*12
SPAN-SECTION 1,  7, 27.29*12
SPAN-SECTION 1,  8, 34.08*12
SPAN-SECTION 1,  9, 36.00*12
```

Use the SPAN-HINGE (11-5.1) command if necessary to define the location of any hinge within the span. If the structure has an expansion joint over a support, approximate this condition by placing a hinge close to, but not at, the support. BRASS-GIRDER(LRFD) does not allow the use of a hinge at a support, and recommends that it be located a distance of 1.2" from the support. If BRASS gives anomalous moment results, or it unexpectedly places the hinge farther out in the span than you expect, the solution is to relocate the hinge farther than 1.2" from the support, increasing in small increments until the reported moments behave as expected. (Sometimes increasing the offset by hundredths of a foot can make all the difference!).

Use the SUPPORT-FIXITY (11-4.1) command to define the boundary conditions of each span, for example:

```
COM --- Support Fixities

COM 11-4.1
SUPPORT-FIXITY 1, R, R, F
SUPPORT-FIXITY 2, F, R, F
SUPPORT-FIXITY 3, F, R, F
SUPPORT-FIXITY 4, F, R, F
```

Use a sequence of commands from Chapter 8 of the *BRASS-GIRDER(LRFD) Command Manual* to facilitate obtaining Rating Factors at shear points of interest without defining the stirrup area and spacing at each point. Use the CONC-SHEAR-CONSTANTS (8-4.1) to choose which AASHTO procedure to apply for shear capacity calculations. Entering 3 for parameter 1 assures that the AASHTO General Procedure (MCFT) is always used, overriding the default method from other commands. Use the STIRRUP-GROUP (8-4.2) command to define each group of stirrups that has a unique geometry. Then use a series of STIRRUP-SCHEDULE (8-4.3) commands to assign stirrup groups and define stirrup spacings along each span. The following is an example of the series of commands to define the stirrups for one span:

```
COM 8-4.1
CONC-SHEAR-CONSTANTS 3

COM 8-4.2
STIRRUP-GROUP 1, 0.40

COM 8-4.3
STIRRUP-SCHEDULE 1, 1, 10.00,  15.00,  30.00
STIRRUP-SCHEDULE 1, 1, 13.88,  45.00, 235.96
STIRRUP-SCHEDULE 1, 1,  8.00, 280.96, 136.00
```

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the BRASS Input (**.**DAT) file as they were calculated in the Preliminary (**.xmcd**) File. Diaphragm point loads should be considered part of component load DC.

Because BRASS calculates girder dead load (self-weight) using the input section dimensions and treats it separately from other dead loads, group the rest of the structure dead loads under the first occurrence of the of the LOAD-DEAD-DESCR (12-1.2) command, using the description (parameter 4) "Other Structure dead loads". Beginning with BRASS-GIRDER(LRFD) Version 1.6.1, BRASS correctly calculates the girder self-weight regardless of what portion of the top flange is effective. There is no longer a need to account for ineffective top flange weight separately in the "Other Structure dead loads" group. This group will normally include the LOAD-DEAD-POINT (12-1.4) commands for the dead load of the diaphragms. Include loads for diaphragms directly over the supports. While they will not have any effect on the girder analysis, they will be used to calculate dead load reactions used in the crossbeam analysis. Precede each group of LOAD-DEAD-UNIFORM and LOAD-DEAD-POINT commands with an additional identifying comment describing the load. An example of this first (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 1, DC, 1, Other Structure Dead Loads

COM  Diaphragms 1.783 k at midspan points, spans 1,3
COM  Diaphragms 1.783 k at quarter points, span 2

COM 12-1.4
LOAD-DEAD-POINT 1, 1, , 1.783, 18.0*12
LOAD-DEAD-POINT 1, 2, , 1.783, 12.0*12
LOAD-DEAD-POINT 1, 2, , 1.783, 24.0*12
LOAD-DEAD-POINT 1, 2, , 1.783, 36.0*12
LOAD-DEAD-POINT 1, 3, , 1.783, 18.0*12
```

Group the remaining component dead loads (DC) (excluding wearing surface dead loads) in the next LOAD-DEAD-DESCR (12-1.2) command using the description (parameter 4) “Superimposed dead loads”. This group should include LOAD-DEAD_UNIFORM (12-1.3) commands as needed to account for all superimposed (Stage-2) dead loads except the wearing surface. Precede each group of LOAD-DEAD-UNIFORM commands with an additional identifying comment describing the load. An example of this 2nd (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 2, DC, 1, Superimposed dead loads

COM  Each rail = 0.210 k/ft (Std. Dwg. 22701)
COM  Applied directly to transformed girder, w = 0.420 k/ft

COM 12-1.3
LOAD-DEAD-UNIFORM 2, 1, 0.0*12, 0.420/12, 50.0*12, 0.420/12
LOAD-DEAD-UNIFORM 2, 2, 0.0*12, 0.420/12, 108.0*12, 0.420/12
LOAD-DEAD-UNIFORM 2, 3, 0.0*12, 0.420/12, 70.0*12, 0.420/12
```

To facilitate future re-ratings with different wearing surface loads, always apply the wearing surface dead load under its own LOAD-DEAD-DESCR (12-1.2) command separate from all other uniform superimposed dead loads. Precede each LOAD-DEAD-UNIFORM command with an additional identifying comment describing the load. An example of this 3rd (DW) dead load group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 3, DW, 1, Wearing Surface Dead Load
COM  2.5" + 1" ACWS
COM  Applied directly to transformed girder, w = 1.136 k/ft

COM 12-1.3
LOAD-DEAD-UNIFORM 3, 1, 0.0*12, 1.136/12, 36.0*12, 1.136/12
LOAD-DEAD-UNIFORM 3, 2, 0.0*12, 1.136/12, 48.0*12, 1.136/12
LOAD-DEAD-UNIFORM 3, 3, 0.0*12, 1.136/12, 36.0*12, 1.136/12
```

Use the BRASS Input Adjustments #1 thru #3 explained below to code the live load requirements.

To assure that BRASS calculates girder Distribution Factors (number of lanes) according to AASHTO LRFD 4.6.2.2, the following BRASS-GIRDER(LRFD) commands are required:

- Specify number of girders (webs) & spacing with the DECK-GEOMETRY (6-1.1) command. Note that the left and right cantilevers (parameters 4 and 5) are the distances from centerline of exterior web to edge of *deck*.
- If girder (web) spacing is variable, use the DECK-VSPACING (6-1.2) to define

the spacing that differs from the uniform spacing specified in the DECK-GEOMETRY command.

- Specify the girder (web) of interest (since we are modeling as the whole width approach, call out an interior web using girder numbers starting at the left edge) using the DIST-CONTROL-GIRDER (4-3.1) command.
- Specify number of lanes and skew using the DIST-CONTROL-LL (4-3.3) command.
- Specify the edges of the roadway (which limits the extreme transverse wheel positions) by using the DECK-TRAVEL-WAY (6-3.3) command.

Also note that in order for BRASS to correctly compute the live load forces for the whole width approach, the live load factor that is inserted as the scale factor (sixth parameter) of the LOAD-LIVE-DEFINITION (12-4.3) command needs to be set equal to the number of webs in the box girder bridge.

Do not calculate Distribution factors manually (in the Mathcad Preliminary File) unless absolutely necessary. However, if Distribution Factors in AASHTO LRFD 4.6.2.2 are calculated manually, note that we interpret the definition of d_e in AASHTO LRFD 4.3 as "distance from the *centerline* of the exterior web to the interior edge of curb or traffic barrier."

Use the BRASS Input Adjustment #4 explained below to code the Resistance Factors.

Use the BRASS Input Adjustment #5 explained below to obtain detailed output regarding the Distribution Factors.

To obtain Rating Factors for points of interest, use OUTPUT-INTERMEDIATE (5-2.1) commands grouped in the same order and groupings as the analysis points were calculated in the Preliminary File. In the "Bar Cutoff Points" subsection of the "Critical Shear Sections" portion of the BRASS code, normally these commands are copied from the window that is displayed when selecting the "Generate Bar Cutoff Points for Shear Analysis" button in the CBG program. Within each span, make sure that none of the analysis points duplicate each other (have identical span fractions), and delete one of each duplicate pair. Precede each OUTPUT-INTERMEDIATE command with a comment (usually text taken from the Preliminary File) explaining which type of force is being investigated (Positive Moment, Negative Moment or Shear), the span number and nearby bent number, and the span fraction. The use of the OUTPUT-INTERMEDIATE command, along with the Stirrup Schedule feature of BRASS, eliminates the need to determine stirrup area and spacing specifically at every shear point of interest.

Note: Section 8-3.1 of the *BRASS-GIRDER(LRFD) Command Manual* implies that omitting the CONC-SHEAR command would mean that parameter 2, the Shear Indicator, would default to 2, so the program would use the Simplified Method for shear. However the previous use of the CONC-SHEAR-CONSTANTS (8-4.1) command in the stirrup definition sequence overrides this default and forces the AASHTO General Method for shear (MCFT) to be used.

Normally shear need not be evaluated within d_v of the face of a simple support nor in the middle 1/3 of a span. However, the presence of significant shear cracking (> 0.040" wide) in the region within d_v of the support face may warrant a shear investigation in this region. In such an investigation, since the MCFT approach is less conservative in this "zone of confusion" near a simple support, shear capacity should be evaluated using the Simplified Procedure in AASHTO LRFD 5.7.3.4.1. This is accomplished in BRASS by using the CONC-SHEAR (8.3-1) command and setting the Shear Indicator (2nd parameter) to 2. However, in the case of checking the shear inside the d_v point near a continuous support, MCFT works very well since that location has high (negative) moment and shear. Thus, there would be no reason to change the shear command for these special analysis points.

3.4.2 BRASS Input Adjustments

Because BRASS-GIRDER(LRFD) was designed primarily for LRFD analyses and was created before the *MBE Manual* was published, a number of standard BRASS Input Adjustments are necessary. Fortunately the program is flexible enough to allow an accurate solution with work-arounds (BRASS Input Adjustments). These adjustments will normally apply to every Input File, at least until BRASS-GIRDER(LRFD) is changed. See the sample input files for proper placement of these adjustments.

- BRASS-GIRDER(LRFD) Input Adjustment Type 1:

  Use the MAP-LIMIT-STATE (4-5.1) and MAP-SPEC-CHECK (4-5.2) commands to force BRASS to check flexure and shear for only the limit states required by MBE. These limit states are different than the BRASS-GIRDER(LRFD) defaults. Thus it is necessary to force BRASS to check flexure and shear for Strength-I for Design and Legal loads, and for Strength-II for Permit Loads: For Design Loads (Strength-I Limit State), these commands also force BRASS to use γ_L = 1.75 (Inventory Level). (The Operating Level γ_L = 1.35 Rating Factors will automatically be derived from the Inventory Rating Factors in the Load Rating Summary Workbook by multiplying by the γ_L ratio). Use the following sequence of commands, which will normally not change:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 1:
COM  For LRFR specify the required Strength Limit States
COM  and ignore Service & Fatigue Limits
COM  Design & Legal Loads - Strength-I
COM  Permit Loads - Strength-II
COM  (refer to 4-5.1 command, Fig. 2) and
COM  specify shear checks for all load types

COM 4-5.1, 4-5.2
MAP-LIMIT-STATE ST, 1, I, Y, N
MAP-LIMIT-STATE ST, 2, N, N, Y
MAP-SPEC-CHECK ST, 1, D, SHR, Y
MAP-SPEC-CHECK ST, 1, L, SHR, Y
MAP-SPEC-CHECK ST, 2, P, SHR, Y
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 2:

  Use the FACTORS-LOAD-DL command (13-1.2) to force BRASS to use the MBE dead load factors, which are different than the AASHTO LRFD factors used by default. MBE Table 6A.4.2.2-1 requires constant dead load factors γ_{DC} and γ_{DW}, and the footnote allows γ_{DW} to be 1.25 when wearing surface thickness is field-measured, which is normally the case. Therefore, these commands are always required. Since the command only covers one limit state level at a time, use one for Strength-I and one for Strength-II:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,

COM 13-1.2
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 3:

Using the BRASS-GIRDER(LRFD) LOAD-LIVE-CONTROL (12-4.1) command to apply the default Design and Legal Load sets would have 3 undesirable consequences:
(a) BRASS would apply the Fatigue Design Load that is not needed for RCBG structures, generating unwanted output
(b) BRASS would default to listing the Design Load outputs *after* all the other loads, potentially causing confusion in transferring loads to the ODOT Load Rating Summary Workbook
(c) BRASS would apply the AASHTO 3S2 Legal Load which is lighter than the Oregon Legal 3S2 load.

Therefore, use the LOAD-LIVE-DEFINITION (12-4.3) commands to define each Design and Legal Load separately, and use the LOAD-LIVE-CONTROL (12-4.1) command to define only parameter 1 (direction control, normally “B” for traffic in both directions) and parameter 7 (wheel advancement denominator, normally 100), as follows:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 3:
COM  All live loads will be entered individually
COM  Design Loads entered as live load definitions  1 thru  4
COM  Legal  Loads entered as live load definitions  5 thru  9
COM  Permit Loads entered as live load definitions 10 thru 19

COM 12-4.1
LOAD-LIVE-CONTROL B, , , , , , 100
```

In structures with short spans, especially short cantilevers, BRASS may “crash” because the span is divided into liveload advancement increments that are too small. If this occurs and you have a small span, try decreasing parameter 7 to the largest number for which BRASS will work, often 50 or sometimes even less.

Further, because MBE Table 6A.4.2.2.1 requires a different live load factor γ_L for each truck, ADTT and truck weight combination, and BRASS-GIRDER(LRFD) does not provide for a separate live load factor for each truck, more BRASS Input Adjustments are required to define truck specific live load factors.

Use the optional FACTORS-LOAD-LL command (13-1.3) such that the universal “gamma LL (Design)” (parameter 3), “gamma LL (Legal)” (parameter 4) and “gamma LL (Permit)” (parameter 5) are all forced to 1.0. Since this command only covers one limit state level at a time, two commands are always required (one for Strength-I and one for Strength-II):

```
COM  Use the FACTORS-LOAD-LL command to force
COM  universal gamma-LL to 1.0 for Legal & Permit Loads

COM 13-1.3
FACTORS-LOAD-LL ST, 1, 1.0, 1.0, 1.0
FACTORS-LOAD-LL ST, 2, 1.0, 1.0, 1.0
```

With the universal live load factors set to 1.0, truck specific live load factors can be defined using the BRASS command 13-1.6, FACTORS-LOAD-LL-LS. Previous version of BRASS (LRFD) did not accommodate individual truck live load factors. Thus, a work around was developed where the live load factors were input as scale factors. With BRASS v 2.0.3 the FACTORS-LOAD-LL-LS command has been added to resolve this limitation. Live load factors shall be input using this new command. Parameter 6 of command 12-4.3, scale factor, will be reserve for its original purpose. With this update the LR summary sheet will no longer modify the rating factors reported in the BRASS output file.

In the FACTORS-LOAD-LL-LS (13-1.6) commands for each load, enter the specific live load Factor γ_L (from **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable). This command can be copied and pasted from the BRASS tab of LL_Factors_State.XLS.

Thus the complete live load definition command set for input files is as follows:

```
COM  Define each Design and Legal live load separately and
COM  apply the truck specific live load factor (instead
COM  of defining them in the LOAD-LIVE-CONTROL command)
COM  There are 3 reasons...
COM  (a) to prevent BRASS from applying the Fatigue Design Load
COM      that is not needed for RCDG structures
COM  (b) to force BRASS to list the Design Loads outputs in the
COM      same order as ODOT's Load Rating Summary Workbook
COM  (c) to allow use of the Oregon 3S2 Legal Load rather than
COM      the AASHTO 3S2 Design Load

COM Do NOT code the truck specific live load factor in
COM Parameter 6.

COM 12-4.3
LOAD-LIVE-DEFINITION  1, HL-93-TRUCK , DTK, D, ,
LOAD-LIVE-DEFINITION  2, HL-93-TANDEM, DTM, D, ,
LOAD-LIVE-DEFINITION  3, HL-93-TRKTRA, TKT, D, ,
LOAD-LIVE-DEFINITION  4, HL-93-LANE  , DLN, D, ,

LOAD-LIVE-DEFINITION  5, OR-LEG3     , TRK, L, ,
LOAD-LIVE-DEFINITION  6, ORLEG3S2    , TRK, L, ,
LOAD-LIVE-DEFINITION  7, ORLEG3-3    , TRK, L, ,
LOAD-LIVE-DEFINITION  8, ORLEG3-3    , LGT, L, ,
LOAD-LIVE-DEFINITION  9, LEGAL-LANE  , LLN, L, ,

LOAD-LIVE-DEFINITION 10, OR-SU4      , TRK, L, ,
LOAD-LIVE-DEFINITION 11, OR-SU5      , TRK, L, ,
LOAD-LIVE-DEFINITION 12, OR-SU6      , TRK, L, ,
LOAD-LIVE-DEFINITION 13, OR-SU7      , TRK, L, ,

LOAD-LIVE-DEFINITION 14, EV2         , TRK, L, , , ONE
LOAD-LIVE-DEFINITION 15, EV3         , TRK, L, , , ONE

LOAD-LIVE-DEFINITION 16, OR-CTP-2A   , TRK, P, ,
LOAD-LIVE-DEFINITION 17, OR-CTP-2B   , TRK, P, ,
LOAD-LIVE-DEFINITION 18, OR-CTP-3    , TRK, P, ,

LOAD-LIVE-DEFINITION 19, OR-STP-3    , TRK, P, ,
LOAD-LIVE-DEFINITION 20, OR-STP-4A   , TRK, P, ,
LOAD-LIVE-DEFINITION 21, OR-STP-4B   , TRK, P, ,
LOAD-LIVE-DEFINITION 22, OR-STP-4C   , TRK, P, ,
LOAD-LIVE-DEFINITION 23, OR-STP-4D   , TRK, P, ,
LOAD-LIVE-DEFINITION 24, OR-STP-4E   , TRK, P, ,
LOAD-LIVE-DEFINITION 25, OR-STP-5BW  , TRK, P, ,


COM  Use for spans > 200 ft only...
COM LOAD-LIVE-DEFINITION 24, ORLEG3-3     , LTK, L, ,
```

```
COM Truck Specific Live Load Factors


COM 13-1.6
FACTORS-LOAD-LL-LS 1, ST, 1, 1.75
FACTORS-LOAD-LL-LS 2, ST, 1, 1.75
FACTORS-LOAD-LL-LS 3, ST, 1, 1.75
FACTORS-LOAD-LL-LS 4, ST, 1, 1.75

FACTORS-LOAD-LL-LS 5, ST, 1, 1.30
FACTORS-LOAD-LL-LS 6, ST, 1, 1.30
FACTORS-LOAD-LL-LS 7, ST, 1, 1.30
FACTORS-LOAD-LL-LS 8, ST, 1, 1.30
FACTORS-LOAD-LL-LS 9, ST, 1, 1.30

FACTORS-LOAD-LL-LS 10, ST, 1, 1.30
FACTORS-LOAD-LL-LS 11, ST, 1, 1.30
FACTORS-LOAD-LL-LS 12, ST, 1, 1.30
FACTORS-LOAD-LL-LS 13, ST, 1, 1.30

FACTORS-LOAD-LL-LS 14, ST, 1, 1.30
FACTORS-LOAD-LL-LS 15, ST, 1, 1.30

FACTORS-LOAD-LL-LS 16, ST, 2, 1.25
FACTORS-LOAD-LL-LS 17, ST, 2, 1.25
FACTORS-LOAD-LL-LS 18, ST, 2, 1.30

FACTORS-LOAD-LL-LS 19, ST, 2, 1.10
FACTORS-LOAD-LL-LS 20, ST, 2, 1.25
FACTORS-LOAD-LL-LS 21, ST, 2, 1.00
FACTORS-LOAD-LL-LS 22, ST, 2, 1.00
FACTORS-LOAD-LL-LS 23, ST, 2, 1.00
FACTORS-LOAD-LL-LS 24, ST, 2, 1.00
FACTORS-LOAD-LL-LS 25, ST, 2, 1.00

COM Use for spans > 200 ft only...
COM Replace parameter 3 with the legal live load value.
COM FACTORS-LOAD-LL-LS 24, ST, 1.30
```

The Oregon Legal Load designations listed in this example are applicable to BRASS-GIRDER(LRFD) Version 2.0.0 and later. BRASS-GIRDER(LRFD) runs for versions prior to v2.0.0 used the legal load designations OLEG3, OLEG3S2 & OLEG3-3.

Special note: For one-lane (escorted) special permit reviews and true single-lane bridges (roadway width < 20 ft), it is necessary to enter “ONE” for parameter 7 in the LOAD-LIVE-DEFINITION (12-4.3) command. It is not clear in the BRASS Command Manual, but this parameter is needed to force BRASS to apply only a single-lane loading with the appropriate single-lane Distribution Factors.

- BRASS-GIRDER(LRFD) Input Adjustment Type 4:

While performing an analysis on a prestressed girder, it was found that the FACTORS-RESIST-RC and FACTOR-RESIST-PS commands cannot be used simultaneously. Since phi is often different for flexure in prestressed elements and reinforced concrete elements, a different approach is required. Using the FACTORS-RESIST-MOD command to modify phi-s and FACTORS-RESIST-COND command to modify phi-c, BRASS will properly calculate the final phi values for flexure, flexure/tension (RC), and shear. This adjustment would allow both prestress bridges and reinforced concrete bridges to use the same set of BRASS commands.

Use the FACTORS-RESIST-MOD (13-2.4) command, entering FL to designate for flexure in parameter 2 and the appropriate System Factor ϕ_s for Flexure in parameter 3. Repeat the command entering SH to designate for shear in parameter 2 and the System Factor ϕ_s for shear in parameter 3. Use FACTORS-RESIST-COND (13-2.5) command, entering the condition factor ϕ_c in parameter 2. Thus the complete phi factor command set is as follows:

```
COM BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 4:
COM  Use the FACTORS-RESIST-MOD command to modify phi-s
COM  Use the FACTORS-RESIST-COND command to modify phi-c
COM  BRASS automatically calculates base phi for flexure,
COM  flexure/tension (RC), and shear

COM 13-2.4
FACTORS-RESIST-MOD ST, FL, phi-s
FACTORS-RESIST-MOD ST, SH, phi-s

COM 13-2.5
FACTORS-RESIST-COND  ST, phi-c
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 5:

To facilitate crossbeam calculations and to clarify what BRASS is doing regarding live load Distribution Factors, always include the following lines in the BRASS input file at the end of the “Distribution Factors” section:

```
COM  Request output of LL Distribution Factor computations
OUTPUT-DIST-LL Y, Y
```

Technically this input adjustment is not needed in the case of box girders because the Distribution Factors are calculated and input manually, and no .DST file is generated by BRASS-GIRDER(LRFD). It was left in the file in the interest of maintaining consistency among the input files for various bridges.

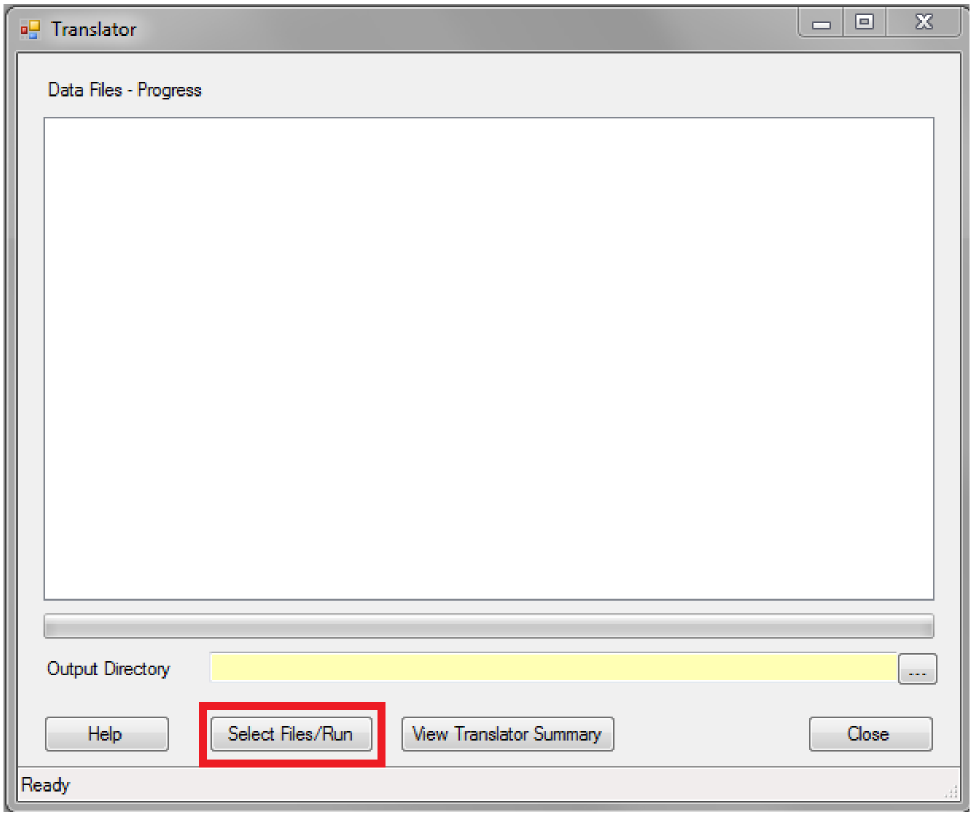
3.4.3 Running BRASS

Open the BRASS-GIRDER GUI interface. Because it is more efficient to use BRASS-GIRDER(LRFD) Input Files generated from previous ones, the GUI interface will not be used to generate input files.

The BRASS-GIRDER(LRFD) input file must first be translated into a BRASS-GIRDER xml file that will then populate the GUI interface in BRASS-GIRDER. The steps for translating and running the input files in BRASS-GIRDER is as follows:

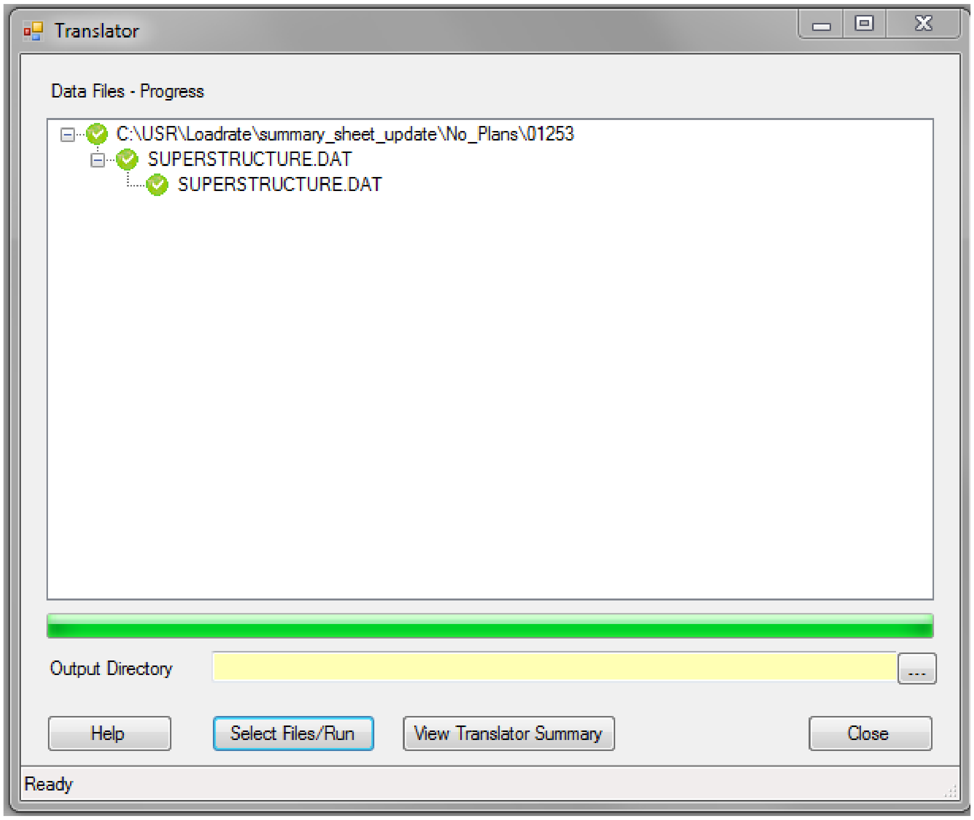
1. Start the BRASS-GIRDER program. From the “File” menu, hover your mouse pointer over “Translate (DAT to XML)”. Select the option for “BRASS-GIRDER(LRFD)”.

2. The Translator window will then open on your screen. Click on the button that says “Select File/Run”, as shown in the red outlined box in the following figure.



3. In the next window that appears, navigate to the location where the BRASS-GIRDER(LRFD) input file that you wish to run is stored, and select that file. Click on the “Open” button at the bottom right of this window.

4. The Translator window will then open back up and the selected file will run through the translation. If there are any errors detected during the translation, a red “X” will be displayed next to the file name in the window and an error file will be generated. Refer to the error file to decipher what is causing the error during translation. Once corrected, follow these steps again to translate the file. If successful, a green check will appear next to the file name as shown in the following figure:



5. Click the “Close” button at the bottom right of the Translator window. Within BRASS-GIRDER, select “Open” under the File menu. Select the BRASS XML file that was just created from the Translator program. Click on the “Open” button at the bottom right of this window.

6. BRASS-GIRDER will then load the model into the GUI. Under the “Execute” menu, select “Analysis Engine” to run the analysis. Or you can simply click on the green traffic light icon on the toolbar.

7. Verify that the output directory is the same as where the input files are located, and then click the “OK” button. A black DOS window will appear showing program progress. Depending on your system speed and memory and the complexity of the structure, the execution process may take a few seconds or several minutes. Upon completion of the analysis, a text output file will be generated within the same directory. You can now use a text editor to open and view the BRASS output.

When making changes or corrections to BRASS files, ODOT prefers that all changes be made within the BRASS-GIRDER(LRFD) input file so that it becomes the master document for the BRASS model. Reviewing this text input file will be quicker and more efficient than trying to navigate the GUI to verify that the bridge is being modelled correctly. Thus, any time the text input file is modified, the above steps will have to be repeated to translate the text input file into a BRASS XML file before the analysis is re-ran in BRASS-GIRDER.

3.4.4 BRASS Errors

If an error file is generated (same prefix, **.**ERR extension), open this file with your text editor and try to interpret what BRASS is telling you. The vast majority of error messages will point you to a straightforward typographical error or omission in your input. At the beginning of your experience with BRASS, do not expect a successful execution until one or more typographical errors have been

corrected.

When executing BRASS-GIRDER, if you get an error message regarding zeros in the stiffness matrix, look at the ANALYSIS (4-1.1) command, parameter 1, and check to see if you are running a Frame type model on a structure with more than 6 spans. In such cases the Beam type model (the recommended default) is required (with a maximum of 13 spans).

When executing BRASS-GIRDER, you may get an error message stating, "*The effective web width (b_v) cannot be zero. This causes a divide-by-zero error in the compression field computations.*" This most likely means that you have selected points that are too close to another defined point of interest within your BRASS input file. A general rule is not to have points closer than six inches from one another. Verify in your input file that you have correctly entered the web width parameter while defining your BRASS sections. Also check in the "Span Length and Section Information" portion of the input file to see that the ranges of the elements are not too close to each other.

A rare error can sometimes occur in executing BRASS-GIRDER where the processing of the analysis takes a considerable amount of time, and then produces a very large output file (around 600 megabytes) along with an error file. The program will report an "Interpolation Error". This occurs on files that have a BRASS span of 99.99 ft and was attempting to increment each truck across the span at 100 increments (as specified in the LOAD-LIVE-CONTROL command). We found that one of two simple workarounds can correct the error: 1) round the BRASS spans from 99.99 ft to 100.00 ft, or 2) increase the live load increment from 100 to 105 in the LOAD-LIVE-CONTROL command. The second method is the preferred option as it only requires a correction in one command, where as adjusting the span lengths would have required doing it for multiple spans for the bridge that experienced this error.

When executing BRASS-GIRDER, if you get an unexpected termination of the program while attempting to run a file, check the BRASS error file (*.err) to see if it states that, "Standard Vehicle: OLEG3S2 is not presently stored in the standard vehicle library file." This usually means that the user did not update the names of the Legal Vehicle in the BRASS input file. In the early part of 2009, ODOT made a small revision to the vehicle library so that both the old Tier 1 and LRFR rating methodologies would use the same legal vehicles for their analysis. As a result, ODOT changed the names of the legal vehicles. To correct the error, make the following changes to the names of the legal vehicles in the BRASS input file:

Original Vehicle Names	Previous Vehicle Name	Current Vehicle Name
OLEG3	ORLEG3	OR-LEG3
OLEG3S2	ORLEG3S2	ORLEG3S2
OLEG3-3	ORLEG3-3	ORLEG3-3
SU4	SU4	OR-SU4
SU5	SU5	OR-SU5
SU6	SU6	OR-SU6
SU7	SU7	OR-SU7

3.4.5 BRASS Output Files

BRASS-GIRDER(LRFD) has been known to "run perfectly" and still produce completely wrong results. Although a successful run may indicate a lack of errors, it is prudent to search the main output (**.**OUT) file for the words "error" and "warning" to check out the seriousness of the problem, and to do a "reality check" on the Rating Factors. Unexpected Rating Factor results often indicate an error in the BRASS coding.

We recommend that, at the very least, load raters routinely employ the following two BRASS verification measures:

(1) Do a reasonability check on the section properties. This is why we routinely code "Y" in

parameter 2 of the OUTPUT (5-1.1) command, to provide a list of girder properties at each node point. (Search the Output File for "Calculated Properties" in each span). It is not uncommon to make errors in the concrete section definitions, the SPAN-UNIF-HAUNCH (11-1.3) command or the SPAN-SECTION (11-2.1) commands that can result in a girder profile that is quite different than the one you expected.

(2) Do a reasonability check on the distribution of shears and moments across the structure. This is especially critical if you have an expansion joint within the structure that you have modeled by coding a hinge near one of the internal supports. Check if you are getting nearly-zero moments at the support next to the hinge. (It can't be truly zero because of the offset of the hinge from the support, but the moment value should be quite low). There have been cases where, due to numerical instabilities in the analysis process, unreasonably high moments were present at the support. The solution is usually to increase the offset of the hinge from the support in small increments until the reported moments behave as expected (sometimes increasing the offset by hundredths of a foot can make all the difference!).

If you really have doubts about what BRASS is giving you, be aware that you can use additional commands in the OUTPUT- group (BRASS-GIRDER(LRFD) Manual, Chapter 5 to generate additional output that may facilitate your detective work. Use caution – the size of this output can be daunting.

When reading the BRASS Output File, in the Rating Factor Summary sections for Legal Loads, it may be difficult to distinguish between the live load Combo cases because two of them are identified as "ORLEG3-3". In these cases, it is possible to distinguish them by looking for the 3-letter BRASS live load Type codes in parentheses. These codes are defined for parameter 3 of the LOAD-LIVE-DEFINITION command (12-4.3). Thus there will be separate Rating Factor Results for ORLEG3-3 (TRK) which is the Type 3-3 truck by itself, and ORLEG3-3 (LGT) which is the Type 3-3 two-truck train plus Legal Lane load.

3.4.6 Longitudinal Tension Check

Prior to BRASS-GIRDER(LRFD) version 2.0.1, the results of the longitudinal reinforcement tension check (LRFD 5.7.3.5) were not found in the basic output files, but could only be found by performing a detailed analysis of a specific point. The longitudinal tension check is done to ensure that there is sufficient longitudinal reinforcement to resist the tension forces caused by flexure and shear.

With the release of BRASS-GIRDER(LRFD) version 2.0.1, the program now calculates a rating factor for the longitudinal tension check using the worst case of the maximum tension forces developed due to maximum shear and concurrent moment, minimum shear and concurrent moment, maximum moment and concurrent shear, and minimum moment and concurrent shear.
Since the longitudinal tension check rating factor is being computed for every analysis point, and the ODOT Load Rating Summary sheet only has a limited number of columns to report rating factors, the summary sheet has been programmed to only report the longitudinal tension rating factors for a given analysis point only if a rating factor for one of the trucks is lower than 1.1.

Detailed Discussion:

Section 5.7.3.5 of the AASHTO LRFD Bridge Design Specifications has the equation that is used by designers to ensure that there is sufficient longitudinal reinforcement to resist tension forces caused by both shear and flexure. If this equation is not satisfied, the designer simply adds the necessary reinforcement so that the equation is satisfied.

The Manual for Bridge Evaluation (MBE) is based on the AASHTO Bridge Design Specifications. The software ODOT uses for LRFR ratings is BRASS-GIRDER(LRFD). Prior to version 2.0.1, this software performed the tension check as part of the rating, but the basic output (usually several hundreds of pages per bridge) did not indicate if the bridge had locations where the tension check failed. The information on the results of the tension check could only be found by examining the additional output that is provided when detailed analysis of a specific point was requested.

While satisfying the tension check is needed to have an accurate model when using Modified Compression Field Theory (MCFT) to calculate shear capacity, there is no guidance in the MBE manual for the load rater to use when the tension check fails. This has been brought to the attention of a primary developer of the MBE code, Bala Sivakumar, PE, who acknowledged that the current code does not fully address this issue. Christopher Higgins, PhD, PE, from Oregon State University, who lead the effort to test full scale beams has emphasized that the tension check is fundamental to the use of MCFT. The concern of providing the results of the tension check in the basic output has been communicated to the developers of the BRASS software.

There were two areas that needed to be addressed before the load rater could be sure that the tension check had failed. First, all of the reinforcement must be accounted for. Since the ODOT ratings originally counted the reinforcement only when it was fully developed, there may have been a significant amount of partially developed reinforcement available to resist tension forces. Prior to the development of the ODOT Concrete Bridge Generator (CBG), a simple bridge would take several weeks for a load rater to go through all of the detailed output and add up all of the partially developed reinforcement. While many of the points that originally failed the tension check will pass for the lighter loads, the heavier permit loads can still result in a failed condition. Even if all of the points were to pass the tension check, the weeks of analysis would have been inefficient and resulted in a product that was complicated to the point that a secondary check would have been difficult. With the development of the CBG, the partially developed bars are now accounted for in the BRASS model, and thus this first issue is resolved.

The second area that needed to be addressed was the nature of the loading. For a given load, there will be a maximum moment force, and a maximum shear force. For analysis, BRASS-GIRDER(LRFD) uses these maximum values. The actual loading caused by a moving load does result in a point experiencing the maximum force values, but not at the same time. By treating the maximum values as being concurrent, the BRASS analysis of the tension check would be somewhat conservative at some locations.

There are differences between the design of new bridges and the rating of current bridges. MBE section 6A.1.3 states that “Design may adopt a conservative reliability index and impose checks to ensure serviceability and durability without incurring a major cost impact. In rating, the added cost of overly conservative evaluation standards can be prohibitive as load restrictions, rehabilitation, and replacement become increasingly necessary.”

With the release of BRASS-GIRDER(LRFD) version 2.0.1, the program now calculates a rating factor for the longitudinal tension check using the worst case of the maximum tension forces developed due to maximum shear and concurrent moment, minimum shear and concurrent moment, maximum moment and concurrent shear, and minimum moment and concurrent shear. Thus, this second issue has been addressed.

The developers of the MBE code acknowledged that while LRFD does incorporate state-of-the-art design, analysis methods, and loading, that almost all existing bridges were designed using the older AASHTO Standard Specifications for Highway Bridges. Section 6A.1.4 states “Where the behavior of a member under traffic is not consistent with that predicted by the governing specifications, as evidenced by a lack of visible signs of distress or excessive deformation or cases where there is evidence of distress even though the specification does not predict such distress, deviation from the governing specifications based upon the known behavior of the member under traffic may be used and shall be fully documented”.

The 1950’s bridges were designed using Working Stress. Once the stresses of the concrete exceed its ability to resist tension, cracking occurs. This initial cracking takes place at a comparatively low level of loading. The bridge is designed to see “service loads” where the forces in the reinforcement are kept well below the yield point. The bridges that Oregon State University instrumented showed that the reinforcement was being operated well below the yield point. During full scale beam tests to failure, the reinforcement was yielding, but at much higher loads than in-service bridges experience, and with much greater distress.

Even though ODOT and BRASS have found a way to perform the tension check for load rating, this is still an issue to be solved on a national scale. Based on the guidance from the MBE code, and the lack of distress noted in the vast majority of bridge inspections, Oregon bridges are not being operated anywhere near the level that would cause yielding of the reinforcement as indicated by the failure of the tension check. For those few bridges that do show excessive deterioration, the current MBE code is sufficient that the known behavior of the member shall be used and be fully documented. Bridges with deterioration consistent with yielding of reinforcement would not be considered for “no work” regardless of the results of the tension check. Calculations for repairs should be done in accordance with the AASHTO LRFD code and therefore the longitudinal reinforcing should always pass the tension check after the repairs are complete.

3.4.7 BRASS/LRFD Issues Regarding Minimum Transverse Reinforcement

BRASS-GIRDER(LRFD) prior to version 1.6.4 had an error in the use of the LRFD 4th Edition (prior to the 2008 Revision) Table 5.8.3.4.2-2 (now Table B5.2-2 in LRFD Eighth Edition), Values of θ and β for Sections with less than minimum transverse reinforcement. It appears that only the top row of the table was used, yielding higher values of β and lower values of θ than should have been used. The result of this was that sections with less than minimum transverse reinforcement were assigned higher rating factors than they should have been.

A comparison of shear rating factors was accomplished using BRASS-GIRDER(LRFD) versions 1.6.5 and 1.6.2. For the three bridges selected, locations outside of horizontally tapered webs had adequate transverse reinforcement, and the shear ratings were unaffected by the corrections to how the table was used for less than minimum transverse reinforcement. However, some sections inside horizontally tapered webs do have less than the minimum transverse reinforcement. These sections experienced a significant drop in rating factors.

The bridge designers in the 1950’s sometimes used an increased concrete cross section to resist shear forces near interior bents. The very technique that gained shear capacity using the AASHTO Guide Specifications now causes the section to have less than minimum transverse reinforcement. The extra concrete the 1950’s designers used to increase shear capacity has the unintended consequence of placing a section with good reinforcement details into a design code table that was never intended to be used for design.

Prior to the 2008 Revisions of LRFD Article 5.7.3.4.2 (General Procedure for Determining Shear Resistance in Concrete Beams) beta and theta were determined by an iterative procedure (which is now in LRFD Appendix B5):

1) For sections with minimum transverse reinforcement – For an applied load, an assumed value of theta is initially used to calculate the longitudinal strain in the web at $0.5d_v$. The shear stress ratio is computed for the section. Using Table B5.2-1, the longitudinal strain and shear stress ratio are used to determine a new value of theta and beta. This new value of theta is used to calculate a new longitudinal strain, which is then used in Table B5.2-1 to compute a new theta and beta. The process continues until theta is solved. The final values of theta and beta are then used in computing the shear resistance of the concrete section.

2) For sections with less than minimum transverse reinforcement – the procedure is similar to that above. The only differences being are that the longitudinal strain is calculated at the

location in the web subject to the highest longitudinal tensile strain, and instead of using the shear stress ratio with the longitudinal strain in Table B5.2-1 to determine a new theta and beta, the crack spacing parameter is used with the longitudinal strain in Table B5.2-2.

3) When calculating the longitudinal strain for a section, longitudinal bars on the flexural tension side of the member that were not fully developed were to be ignored.

In AASHTO LRFD Article 5.7.3.4.2, beta and theta are determined by direct solution using algebraic equations:

1) The strain in non-prestressed longitudinal tension reinforcement is directly computed for a given load. This strain is used directly in the equations to compute theta and beta.

2) The value of theta is the same regardless if the section has less than or contains at least the minimum transverse reinforcement. Thus, there is only one direct solution for theta.

3) There is one equation for beta for sections containing at least the minimum transverse reinforcement. There is a different equation for beta for sections with less than minimum transverse reinforcement, which is similar to the first but has an added component containing the crack spacing parameter.

4) In calculating A_s, the area of bars terminated less than their development length from the section under consideration should be reduced in proportion to their lack of full development (instead of ignored).

In most cases, the new direct solution equations in the 2008 Revisions are producing higher capacities for sections that have less than minimum transverse reinforcement. The main reason is that theta no longer is penalized, which results in shallower crack angles allowing for more stirrups within the member to contribute to the shear resistance.

Unfortunately, the old iterative method is still a valid option in the LRFD code, as the 2008 Revisions have placed the old Article 5.7.3.4.2 language in Appendix B5. BRASS Girder (LRFD) Version 2.0.3 has been updated to include the 2008 revisions of the AASHTO LRFD code. The algebraic equations are now used to calculate shear capacity.

3.4.8 Continuous Multi-Spanned Bridges with Varied Span Lengths

We were made aware of an issue that occurs with continuous multi-span bridges, when the adjacent span lengths vary by a considerable amount. It was noticed that the maximum positive moment sections were being evaluated at odd locations (0.1L for an end span and 0.4L for an interior span). This was a result of our original practice of basing these locations off of the dead load maximum moment locations and not the factored combined (dead load and live load) maximums. The maximum dead load moment location shifts were due to the uplift in short spans caused by the dead load of an adjacent long span.

To compensate for the uplift effects of dead load on the adjacent short spans, we will now use the maximum and minimum Load Factors stipulated in AASHTO LRFD Table 3.4.1-2. As a result, we have modified the BRASS Input Adjustment Type 2 commands in the BRASS input files to the following:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,
```

COM 13-1.2
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65

The heavier vehicles will produce a maximum positive moment location closer towards the midspan, while the lighter vehicles will produce a maximum positive moment location away from midspan towards the maximum moment location of the dead load. Therefore, in order to capture the maximum positive moment for the entire suite of vehicles that we use in load rating, we may have to establish a range of points where the different vehicles will produce their maximum positive moment.

In order to facilitate this procedure, we have developed a new application (BRASS Moment Analyzer) that will evaluate the BRASS output files after an initial BRASS run and determine if the maximum positive moment locations for the live loads differ from the dead load locations. If so, the program will then analyze the differences in the locations and then provide a range of recommended positive moment locations (at 20th points) along with the BRASS commands for these new flexural analysis locations that can be copied and pasted into the BRASS input files. The program will create a text file, with the modified name of _MOMENT_INITIAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

After the final BRASS run, the BRASS Moment Analyzer can be used to once again evaluate the BRASS output files. This time, the software will check and report if the maximum combined moment for every vehicle at each analysis point is negative, positive, or contains both negative and positive values. The program will allow the user to print a summary report which they can refer to when selecting the type of moment during the BRASS import of the moment locations on the Load Rating Summary sheet. The program will create a text file, with the modified name of _MOMENT_FINAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

Do not include the BRASS Moment Analyzer output in the printed Load Rating Calc. Book. We only request that the .TXT files that it produces be included with the electronic files for the load rating.

The intent is to only use the BRASS Moment Analyzer for continuous bridges with adjacent span lengths that vary more than 30%.

SECTION 4: LOAD RATING REINFORCED CONCRETE SLAB BRIDGES

This section applies to cast-in-place reinforced concrete slabs spanning longitudinally. For precast, prestressed slab bridges, refer to Section 5

4.0 Scoping of Structure

Create a scoping file (nnnnnn_scope.xls) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended affect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0 then, there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

4.1 Decide What Girders to Analyze

Due to the effects of all the various LRFD Distribution Factor provisions, it is difficult to predict which girder will control the load rating. Therefore a separate preliminary file and BRASS input will be required for both the interior and exterior slab. In the Load Rating Summary Workbook file, importing the rating factors from both girders is required (be sure to do a “Refresh” after the second import) because it is not uncommon for different girders to control for different loads.

4.2 Preliminary Files for RC Slabs (Mathcad)

Computations for interior strip widths and widths are both made in a single preliminary file for RC Slab Bridges and are used to check the BRASS Distribution Factor calculations. The file name and extension for this file is: RCSLAB.xmcd.

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied terms with parentheses.

4.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description ("Spans" field) from the Bridge Log is adequate for this purpose.

Note: the Mathcad regions at the top in the right margin (outside the printable area) are there for 2 purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

4.2.2 Resistance Factors

Document the decisions regarding all 3 Resistance Factors, with references to the appropriate MBE tables.

BRASS-GIRDER(LRFD) provides input for the MBE Condition Factor ϕ_c (MBE 6A.4.2.3) and System Factor ϕ_s (MBE 6A.4.2.4). However, the ODOT Load Rating Summary Sheet and the ODOT Crossbeam Load Rating Software always require and display the product of all the resistance factors as a single ϕ factor. Therefore, the product of all these resistance factors must always be obtained.

Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure:
$\Phi_f = \phi\,[\,\max(\phi_c\phi_{sf}\,,\,0.85)\,]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).

4.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into BRASS. The Load Rating Summary Workbook **(LR.XLT)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and Effective Bridge Length. Note that Effective Bridge Length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which live load factor Application is used in ODOT LRFR Tables 1.4.1.9 and 1.4.1.11A, ADTT is specified as "one direction". Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item

109). For bridges with two-way traffic, the ADTT entered into the live load factor Application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the live load factor Application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the Load Rating File Set. To avoid errors in the Preliminary File, copy the “LRFR Strength I & II” table from the live load factor Application, and in Mathcad use Edit / Paste Special. In the “Paste Special” dialog box choose the “Paste” button, highlight “Bitmap” in the “As” list, and click the “OK” button. This will insert an image of the live load factor Application into the Mathcad Preliminary File. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is not recommended due to the idiosyncrasies of the live load factor Application. Because you are pasting an inert bitmap, if any subsequent changes in live load Factor input were to occur, the pasted object should be deleted from the Preliminary File, the corrections should be done in the live load factor Application and copied and pasted again into the Preliminary File as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to ODOT LRFR 1.4.1.13.

4.2.4 Material Properties

Enter the material properties within the appropriate fields of the ODOT Concrete Bridge Generator (CBG) program, and the elastic modulus E_c and modular ratio n will be calculated. The CBG program uses LRFD Equation 5.4.2.4-1 to determine the elastic modulus of concrete, assuming $K_1=1.0$. Document any assumptions made about the material properties if they are not given on the Bridge Plans within the MathCAD preliminary file.

4.2.5 Bridge Average Geometry

Calculate the physical edge-to-edge width of the concrete slab and the roadway width of the bridge. If the width of the slab or roadway changes over the length of the bridge, calculate the average roadway width per span. Calculate the distance from the edge of the slab to the inside face of barrier. Enter the slab strip width that will be analyzed in BRASS. This will normally be 12 inches unless there is a voided slab present in the bridge, and then it is the center-to-center spacing of the voids. Enter the skew angle of the bridge. These values are entered in BRASS to calculate the Distribution Factors per slab strip.

4.2.5.1 Equivalent Strip Width for Slab Type Bridges (LRFD 4.6.2.3)

Since cast-in-place slab bridges do not have adjacent girders to share the live load, the slab is divided into equivalent strip widths that are analyzed to support single lane loads and multiple lane loads. BRASS calculates the equivalent strip widths per AASHTO LRFD 4.6.2.3, for an interior strip, and AASHTO LRFD 4.6.2.1.4b for an edge strip. Live load distribution factors are calculated by dividing the cross section width by the equivalent strip width. BRASS v2.0.3 calculates these widths and applies the skew correction factors correctly. The equivalent strip width must still be calculated in the preliminary file in order to determine the percent of design lane load to apply to the longitudinal edge strip.

4.2.5.2 Longitudinal Edge Strip (LRFD 4.6.2.1.4)

The edge of a slab bridge is converted into an edge strip that supports one line of wheels plus a tributary portion of the design lane load (LRFD 4.6.2.1.4b). Calculate the edge strip along with a tributary portion of the lane load for the span. Tributary portion of lane load is calculated by dividing the longitudinal edge strip by 10ft. Using a 10ft lane is consistent with the lane width used for load rating. Although BRASS now correctly calculates the edge strip distribution factor, and applies the skew correction factor correctly, the edge strip width must still be calculated in the Preliminary file. The strip width must be known in order to calculate the tributary portion of the design lane load.

Since an edge strip analysis file is simple to create from the interior strip width in an RC Slab Preliminary File, and slab bridges often have special edge reinforcement or an edge beam to account for, always perform a separate edge strip analysis for every slab bridge. Calculate the edge strip width and tributary portion of lane loading for each span in a slab bridge. If an edge beam is present, model the edge strip as the edge beam with a flange consisting of the effective portion of the slab. Include all edge beam bars and those slab bars present in the edge strip width. Interior strip widths are commonly modeled with a 12" wide slab, which is representative of the total interior equivalent strip width. Modeling a 12" wide exterior strip may not adequately represent the total equivalent strip width because of the varying reinforcement in the outside edge. When analyzing an edge strip, model a wide enough section to be representative of the overall equivalent edge strip.

4.2.6 Shear Reinforcement Layout

Concrete slabs and slab bridges designed in conformance with AASHTO Specifications may be considered satisfactory for shear (LRFD 5.12.2.1). Therefore, do not document shear reinforcement information in the preliminary file. Also, do not input shear reinforcement for BRASS analysis.

4.2.7 Component Dead Loads (DC)

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the Preliminary (**.xmcd**) File as they will appear in the BRASS Input (**.**DAT) File. Use LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c. For dead load calculations, use w_c+0.005 kcf to account for the reinforcement, in accordance with LRFD Commentary C3.5.1.

Where standard rail drawings occur, wherever possible use the rail dead loads tabulated in Appendix H - ODOT Standard Rail Weights, found in file **RAILDL.XLS**. Provide detailed calculations for the dead load of any rail not found in this summary.

For slab bridges, distribute the sum of all rail, curb and sidewalk dead loads (stage 2 dead loads) equally across the edge-to-edge slab width and multiply it by the slab strip width that is being analyzed for each span to obtain a unit load per length of slab strip width.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16" diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to need to be included in the load rating.

4.2.8 Wearing Surface Dead Loads (DW)

Always separate Wearing Surface dead load (DW) from the component (DC) dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes, and (c) it facilitates input for the Crossbeam Load Rating Software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). For each span, show calculations for Wearing Surface (DW) dead load distributed equally across the edge-to-edge slab width and multiply it by the slab strip width to obtain a unit load per length of slab strip width. Add 1" to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½" to the design thickness of PPC overlays to account for construction variations and uncertainty.

4.2.9 Live Loads (LL)

Simply list the four classes of rating loads to be analyzed. (See articles 1.5.1.1 through 1.5.1.4).

4.2.10 Analysis Sections

Determine the spans to be investigated. These should be any span that is unique and is not repeated due to symmetry or due to repetition of a span between joints.

Within each span, check for symmetry of sections, reinforcement and loads, and do not identify any analysis points that are structurally symmetrical with analysis points already defined. Defining analysis points that are structurally symmetrical has the potential effect of corrupting the Load Rating Summary Sheet. Because the “Refresh” module is looking for the lowest Rating Factors, defining a symmetrical point causes it to identify the most critical rating location twice, thus preventing it from identifying the second most critical analysis point. The second controlling point is useful information in evaluating potential repairs for the bridge.

List the analysis sections for flexure. These are normally the positive moments in each unique span and the negative moments over each unique support.

Calculate the number of longitudinal tension bars per slab strip width for each analysis point. This is done by dividing the slab strip width by the longitudinal tension bar spacing.

For an edge strip analysis, calculate the number of longitudinal tension bars per slab strip width for each analysis point. This is usually the same as the interior strip analysis, except that some bridges have additional bars or different reinforcement details for the edge of the slab.

Concrete slabs and slab bridges designed in conformance with AASHTO Specifications may be considered satisfactory for shear (AASHTO LRFD 5.12.2.1).

With the number of geometry cross-section changes and overlapping bar cutoff points that made the shear analysis complicated for other CIP concrete structure types, the ODOT Concrete Bridge Generator (CBG) program was developed to aid in the creation of the BRASS input file by determining the required number of BRASS sections and computing the bar cutoff points. Even though there is no shear analysis required for CIP slabs, the CBG program will facilitate the creation of the BRASS input file data for the BRASS sections, span layout.

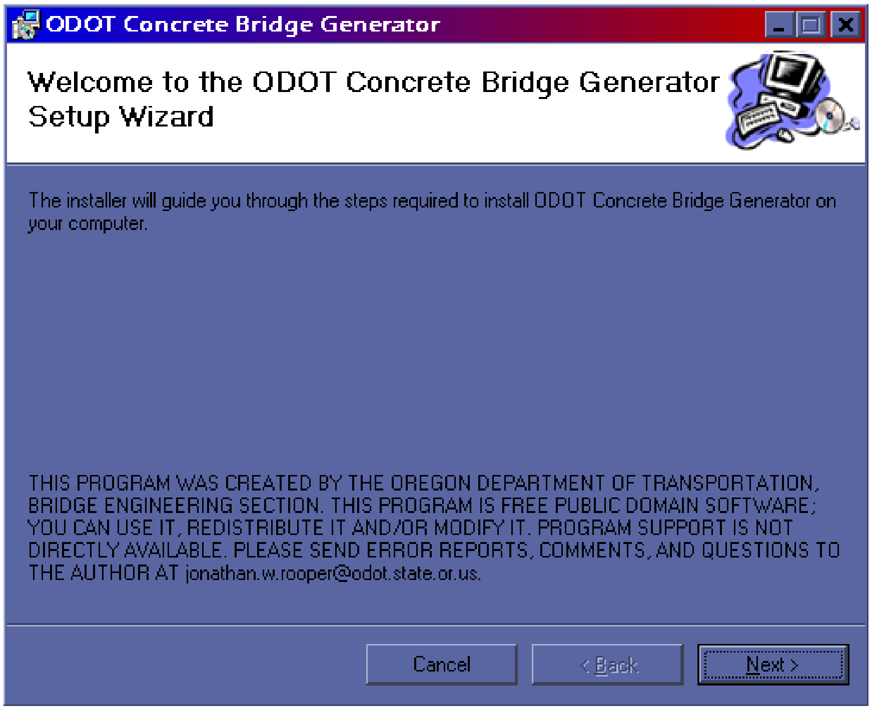
4.3 ODOT Concrete Bridge Generator (CBG)

The ODOT Concrete Bridge Generator (CBG) was created by the Oregon Department of Transportation, Bridge Engineering Section. The CBG is a stand alone windows software package that is a pre-BRASS processor for Cast-In-Place concrete bridge girder sections. Once the user enters basic bridge information, concrete section geometry, span configuration geometry, and the longitudinal reinforcement within the form fields, the program will generate the first half of the BRASS code. The program will also generate the BRASS code for the bar cut-off shear points that the user will paste into the appropriate locations in the BRASS input file. The program is not set up to define rigid frame structures; it is only configured to define a beam analysis in BRASS.

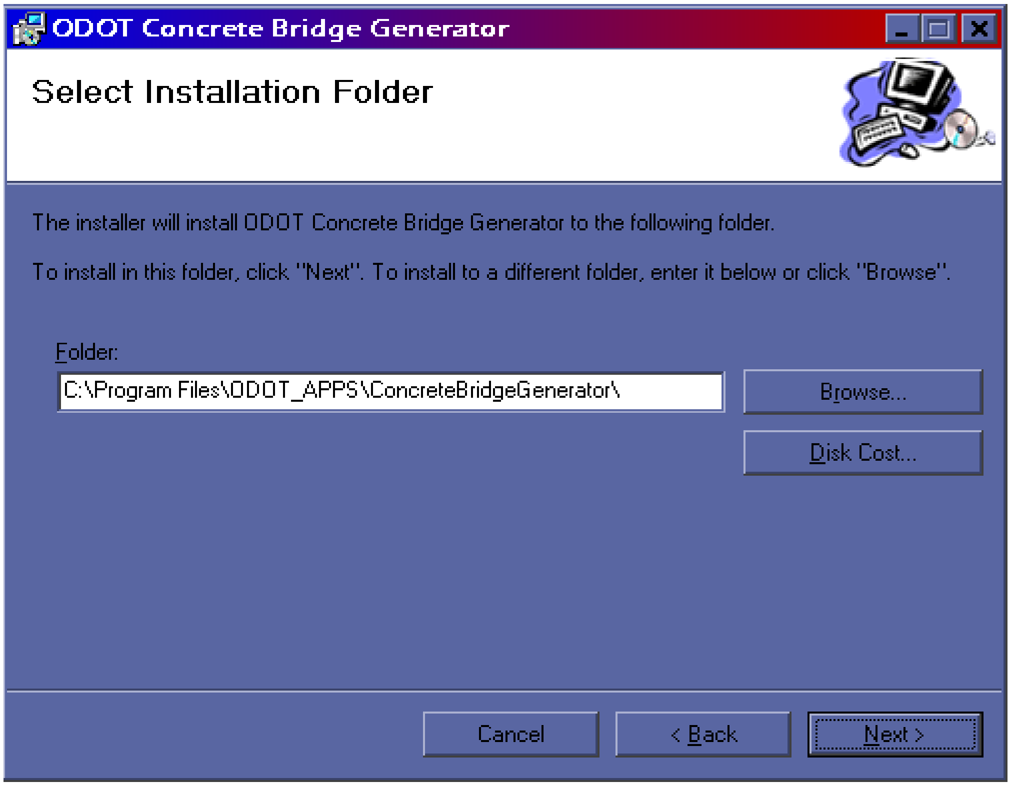
The CBG is solely for the Microsoft Windows operating system and utilizes the Microsoft .NET Framework. The program’s native format is the CBG (Concrete Bridge Generator) file format. The CBG is free public domain software; meaning that users are free to use it, redistribute it, and/or modify it. The current version of the CBG is version 1.0.10.

4.3.1 CBG Installation

Previous versions of this program need to be uninstalled through the Windows Control Panel interface prior to installing a newer version. To install the ODOT Concrete Bridge Generator, run the Windows Installer Package titled, “ODOT_Concrete_Bridge_Generator.msi”. This will launch the Setup Wizard and pause at the Welcome dialog for the Wizard. Select the “Next” button to continue.



The next dialog will ask the user to select an installation folder to install the Concrete Bridge Generator to. The default location is, “C:\Program Files\ODOT_APPS\ConcreteBridgeGenerator\”. If the default location is satisfactory or after the preferred folder location has been specified, select the “Next” button to continue.



The next dialog will ask the user to confirm the installation before it begins. Click the “Next” button to begin the installation.

A dialog with a progress bar will be shown during the installation. This part of the process can take anywhere from a few seconds to a few minutes depending on if the wizard needs to download and install an update to the Microsoft .NET framework to the computer.

The installation will place a shortcut for the program on the users desktop as well as under the Start Menu > All Programs > ODOT Load Rating. When the installation is complete, click the “Close” button to end the Wizard.

4.3.2 CBG - Overview

When first starting a session of the CBG software, a dialog window explaining the terms of use for the software will be displayed. If the user selects the “DECLINE” button, the session will end and the software will not launch. If the user selects the “I ACCEPT” button, the session will continue and the software will launch.

At the top left of the program there are five buttons associated with icons that are titled “New”, “Open”, “Save”, “Report”, and “Exit”. The “New” button will erase all of the data entered in the form fields and start over with a blank form. The “Open” button will populate the form fields from a saved *.cbg file that was created from using the “Save” button from a previous session. The “Save” button will save the data entered in the form fields in a *.cbg file. The program will incorporate the values entered within the “Bridge Number” and “Member Being Load Rated” form fields in the file name during the save process. The “Report” button will display a print preview of a report that reflects the data entered in the various form fields of the program. The “Exit” button will exit and close the current session of the program.

At the top right of the program there are three buttons that are titled “Show Cross-Section Matrix”, “Generate BRASS File Input”, and “Generate Bar Cutoff Points for Shear Analysis”. The functions of these buttons will be explained later.

In the top section of the program form is where the user specifies the basic information of the bridge. These form fields are set to only accept the maximum number of characters that the BRASS commands using the data will allow. Form fields with white backgrounds require user input, while the form fields with grey backgrounds will automatically fill in values based on the user input within other fields. The different fields within this top section are the Bridge Name, Bridge Number, Load Rater's Name, Highway/Route Name, Mile Point, the Load Rating Date, the name of the Member Being Rated, and the File Name associated with the saved data entered on the forms.

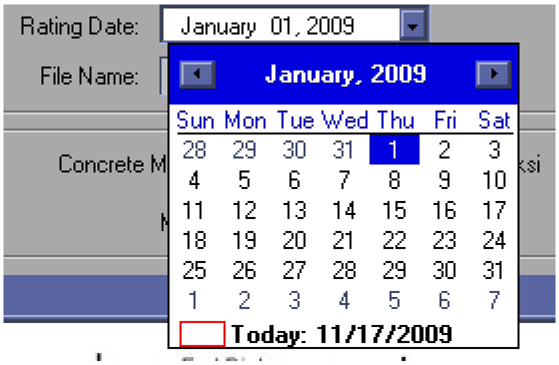
In the next section, the user inputs the concrete strength and longitudinal reinforcement yield stress. The program will then compute the concrete unit weight, the concrete modulus of elasticity, the reinforcement modulus of elasticity, and the modular ratio.

The bottom section of the program is divided into four tabs, which are used to define the cross-section geometry, span configuration/layout, and the longitudinal reinforcement. The tabs are named "Span Configuration", "Concrete Dimensions", "Concrete Section Assignment", and "Reinforcement". The functions of these tabs will be explained later.

4.3.3 CBG – General Bridge & Load Rating Info

In the "Bridge Name" form field, up to 60 characters may be used to enter the bridge name. The user has up to 15 characters to enter the bridge number in the "Bridge Number" form field, which typically only uses 5 to 6 characters. In the "Load Rater" form field, up to 60 characters may be used to enter the name of the engineer that is running the program. The user has up to 60 characters to enter the route name where the bridge is located in the "Route Name" form field. In the "Mile Point" form field, enter the milepost where the bridge is located.

In the "Rating Date" form field, the user can type in the numeric date for the month, day, and year. Or the user can select the drop down calendar view and select the day within the appropriate month and year. Instead of scrolling through the different months within the calendar view, the user can simply select red box that is titled "Today" at the bottom of the calendar view to select the current date.



In the "Member Being Load Rated" form field, use the drop down list to select what type of member that the current BRASS analysis will be for. The choices are: IntGir for a RCDG interior girder, ExtGir for a RCDG exterior girder, RCBG for a reinforced concrete box girder, RCSlab for a reinforced concrete slab, and EDGSTP for a reinforced concrete slab edge strip analysis.

The "File Name" form field will be automatically filled in when the user saves the data on the forms using the "Save" button. The program will incorporate the bridge number and the member being rated into the file name. For example, if the bridge number was 12345 and the member being rated was set to IntGir, the default file name would be set to "12345_IntGir.cbg". If the user is going to be performing multiple interior girder analysis for the same bridge, for example girders A through D, then during the save process the user can manually type the beam letter within the file name. Thus, if the analysis was for girder “A”, the file name would be “12345_IntGirA.cbg”.

4.3.4 CBG – Material Properties

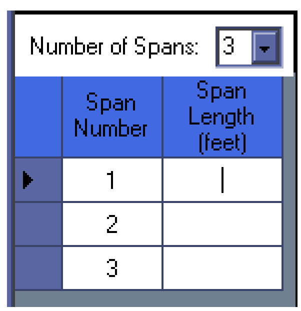
For the material properties area of the form, all that needs to be entered is the concrete strength (f’c) in ksi and the longitudinal reinforcement yield stress (f_y) in ksi. The program will then calculate and display the concrete unit weight in kips per cubic feet, the concrete Modulus of Elasticity (E_c) in ksi, the longitudinal reinforcement Modulus of Elasticity (E_s) in ksi, and the Modular Ratio (n) of the two materials.

4.3.5 CBG – Span Configuration Tab

The span configuration tab is where the user identifies the number of spans that will be modeled in the current BRASS analysis, the lengths of each span, the vertical profile of each span, and which spans are copies of previously defined spans.

It is recommended that the first thing that be defined is the number of spans that will be analyzed in the current BRASS run. Several other form fields within the tab pages refer to the number of spans and the defined span lengths when computing data and populating lists for the user to choose from. The user is able to later specify a greater number of spans without much affect to data that may already be entered on the other tab forms. However, once the user specifies a number of spans that is less than what is currently specified, most of the data that may have been already entered on the other tab forms will be erased.

The Concrete Bridge Generator is configured to make BRASS perform a beam analysis, instead of a frame analysis. For a beam analysis, BRASS is limited to a maximum of 13 spans. Thus, the CBG is limited to a maximum of 13 spans. One the left side of the Span Configuration Tab, the user can either directly type in the number of spans or they can use the drop down list and choose the number. The form field for specifying the span lengths below the number of spans selection will dynamically resize to the number of spans that are defined. Once the number of spans has been defined, the next step is to enter the length of each span in feet.



Once the number of spans and span lengths are defined, the vertical profile of each span needs to be defined. This is done by defining segments of the span where the vertical profile changes or control points occur. In the main form table on the Span Configuration Tab, the first column is the only one that is white and active and is used to identify the span that is being defined. Once the span has been identified, the second and third columns turn white and are active. These two columns are check box cells. The first is used to identify if the user is defining the vertical profile for a span segment, and the second is used to identify if the span is going to be a copy of another defined span.

If the “Define Span Segment” cell is checked, the “Span Copy” cell becomes inactive and the following seven cells to the right become active. These cells have the following column headings:

Web Variation Indicator – A code indicator used by BRASS to indicate what type of vertical profile change that is taking place along the segment length.

Web Variation – provides a graphical representation of the type of vertical profile change that is taking place along the segment length.

Left End Web Depth (inches) – Where the user specifies the depth of the web at the left end of the span segment.

Right End Web Depth (inches) – Where the user specifies the depth of the web at the right end of the span segment.

Length of Span Segment (feet) – Where the user specifies the length of the span segment being defined.

Starting Point from Left End of Span (feet) – The software calculates the starting location based on the span length and the length of the previously defined span segment. If the current segment is the first one being defined for the span, the starting point will be zero feet.

Ending Point from the Left End of Span (feet) – The software calculates the ending location based on the start point and the user specified segment length. If the ending point exceeds the span length, and error message in the cell will be given. If the ending point is less than the span length, a new row for the span will begin being defined with the start point being equal to the current ending point.

Within the Web Variation Indicator cell, the user can choose the following values for the vertical profile change:

L = Linear Web Depth Variation – The depth of the web varies linearly for the segment. If the web depth is constant, the user would choose this option and then specify the left and right web depths to be the same.

P- = Parabolic Concave Down Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the smaller web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used.

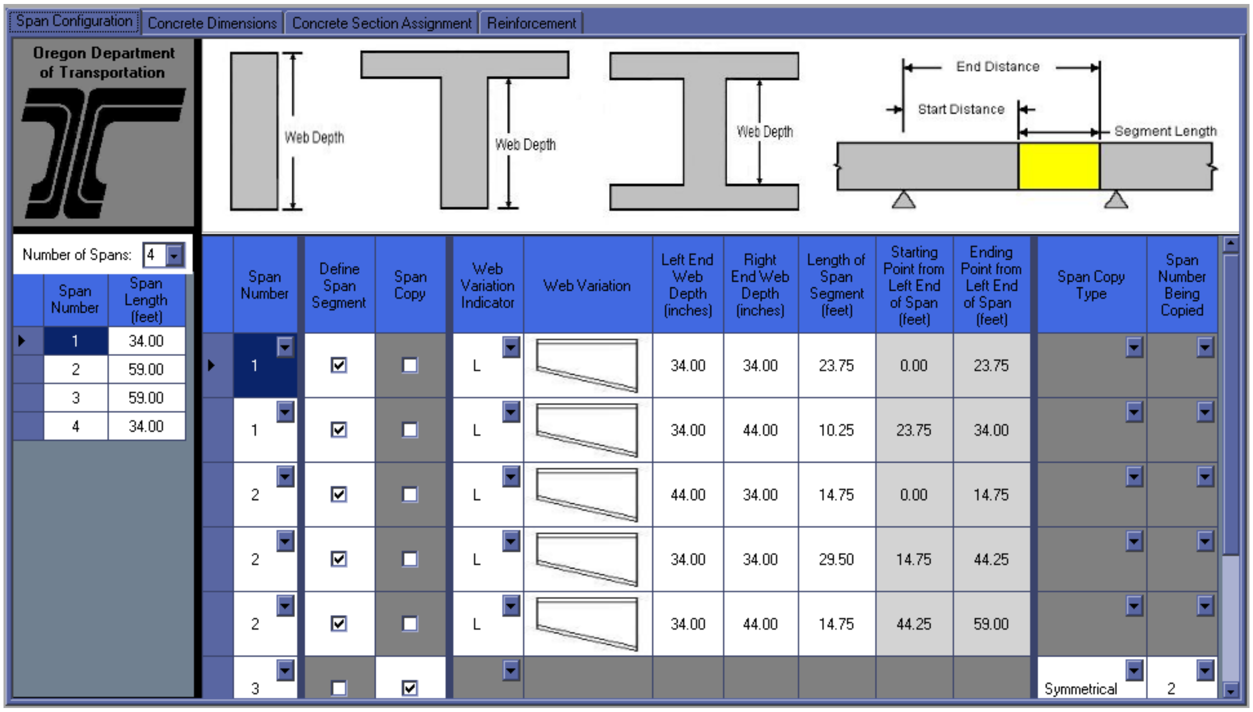
P+ = Parabolic Concave Up Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the larger web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used.

E- = Elliptical Concave Down Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the smaller web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used. Zero vertical slope at the end with the larger web depth is also enforced.

E+ = Elliptical Concave Up Web Depth Variation – The web is varied such that the horizontal slope at the segment end with the larger web depth is equal to the slope of an adjacent linear segment. If no linear adjacent segment is present, zero horizontal slope is used. Zero vertical slope at the end with the smaller web depth is also enforced.

The Web Variation cell will display a graphic of the variation indicator selected to assist the user in understanding how the different profiles may appear. Holding the mouse over this cell will call a tooltip window to appear giving the same description of the associated Web Variation Indicator as in the previous paragraph. Due to the amount of text written on the tooltip, the time allotted for the tooltip window is a little long and the user may end up having several tooltip windows appear on their screen as they move the mouse across the cell. Simply clicking the mouse in a different cell will force all of the tooltip windows to disappear.

If the "Span Copy" cell is selected, then the "Define Span Segment" cell becomes inactive and all of the cells related to defining the span segment remain inactive. The last two cells to the far right of the table will become active. They are the "Span Copy Type" and the "Span Number Being Copied" cells. In the Span Copy Type cell, the user can select if the copy is going to be identical or symmetrical. The user then can choose the span number that will be copied for the current span. If the span number being copied has a different span length than the current span, an error message will be displayed in the cell.

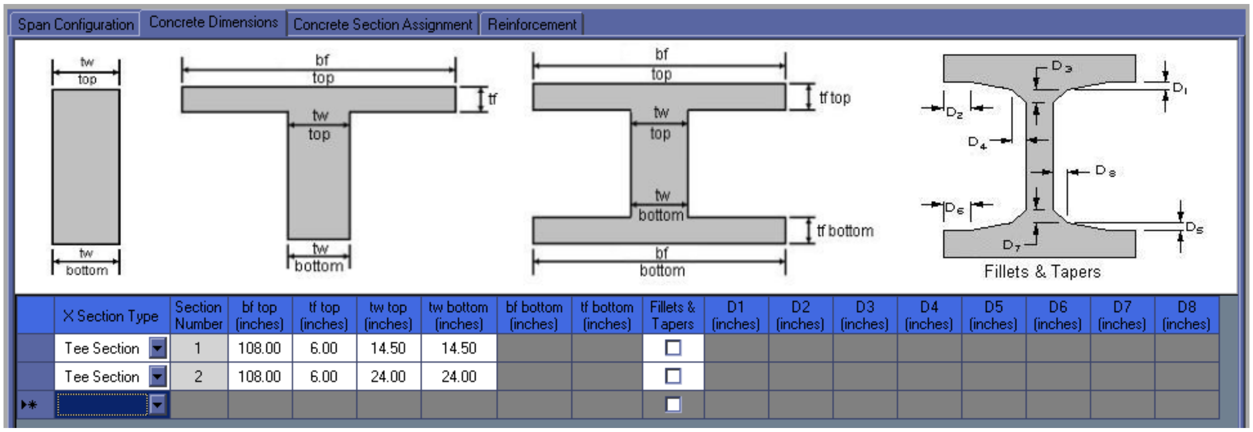


4.3.6 CBG – Concrete Dimensions Tab

The concrete dimensions tab is where the user defines the actual concrete cross-sections of the girder. Originally, only the first cell in the table is active. This cell is titled "X Section Type", and the user is able to choose from a Rectangular Section, a Tee Section, and an I-Section. The rectangular section is typically used to define the slab strip for a Cast-In-Place (CIP) slab section. The Tee Section is typically used to define RCDG sections. And the I-Section is typically used to define CIP Box Girder Sections.

When defining a concrete section, the program will assign a section number in the second cell. The cells in columns three through eight will become active based on the type of X Section that the user has selected. These cells are used to define the top flange width, top flange thickness, the web thickness at the top, the web thickness at the bottom, the bottom flange width, and the bottom flange thickness.

If the concrete section has fillets and/or tapers between the flanges and webs, the user can check the box in the 9th column titled "Fillets & Tapers". This will activate the cells in the last eight columns where the user can define the taper and fillet dimensions. These dimensions are illustrated in the diagram and have been given the designations D1 through D8. The user can use the illustration to see what the dimension is referring to, and holding the mouse over the column headings and the actual cells will cause a tooltip window to appear that gives a brief description as to what the dimension is referring to.



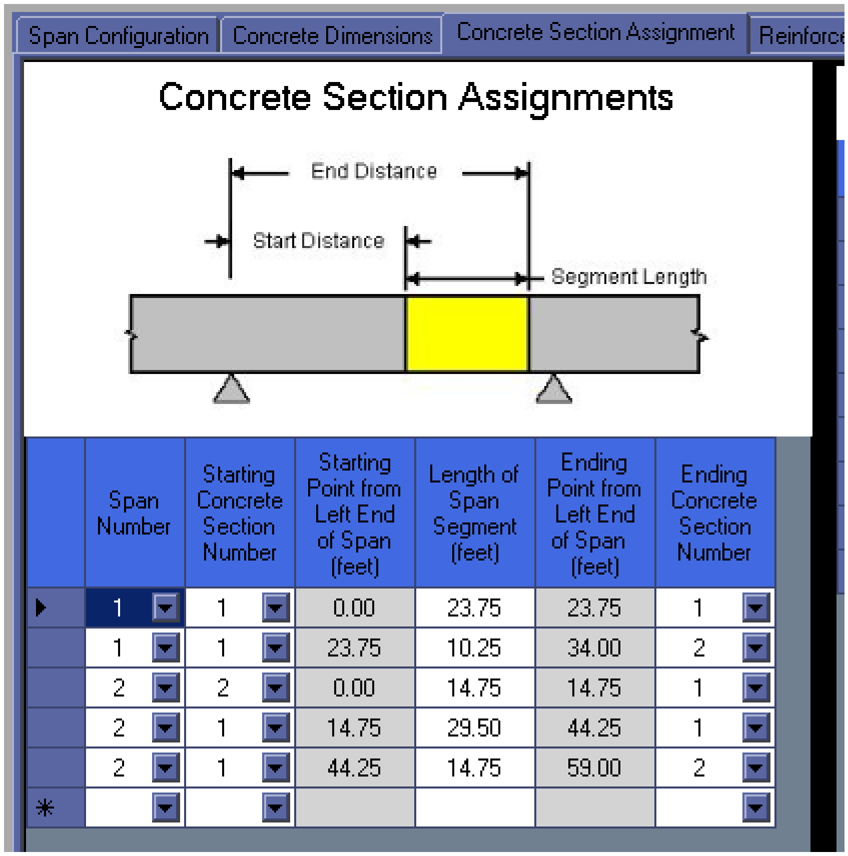
4.3.7 CBG – Concrete Section Assignment Tab

The Concrete Section Assignment Tab is divided into three sections. The first section is for Concrete Section Assignments, where the user assigns the defined concrete sections to each span. The second section is for the Support Conditions, where the user defines the horizontal, vertical, and rotational fixity at each support location. The third section is for Hinge Locations, where the user can define hinge locations that may be present in the structure.

For each span that has span segments defined under the Span Configuration Tab, concrete sections will need to be assigned under the Concrete Section Assignments Tab. In the first cell, the user will specify/choose which span that they are going to assign concrete sections to. The second cell is where the user specifies are chooses the starting Concrete Section Number, which refers to the section numbers that were assigned under the Concrete Dimensions Tab. The third cell is where the program automatically determines where the start point of the span segment is located from the left end of the span. The fourth cell is where the user specifies the length of the span segment in feet. The fifth cell is where the program automatically calculates and reports the Ending point of the span segment from the left end of the span. If the ending point is longer/beyond the span length, then an error message will be displayed in the cell. The last cell is for the user to specify the ending concrete section number.

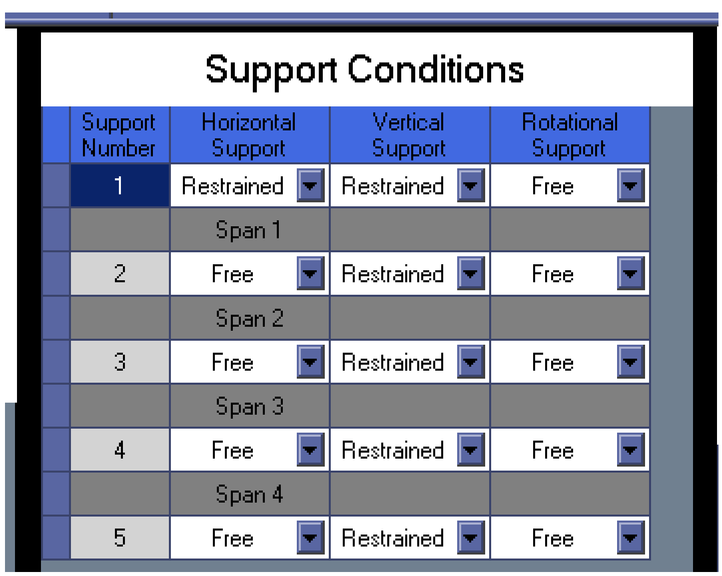
If this is the first cross section assignment for the span, the start point will be at zero feet. Then if the span segment length plus the start point location is less than the defined span length, a new row will be started and the start point will be equal to the ending point of the previous definition. This will continue until the ending point is equal to the span length.

By default, the Ending Concrete Section Number will automatically set to the same value as the Starting Concrete Section Number. This is for segments that have the same cross section over their length. For segments that have the concrete tapering/transitioning between two cross sections over the segment length, the user would specify a different section number for the ending point. For an abrupt change in cross section, the user would have the starting and ending concrete sections numbers the same for the segment, and then start the next segment with a different concrete section number than the previous definition.



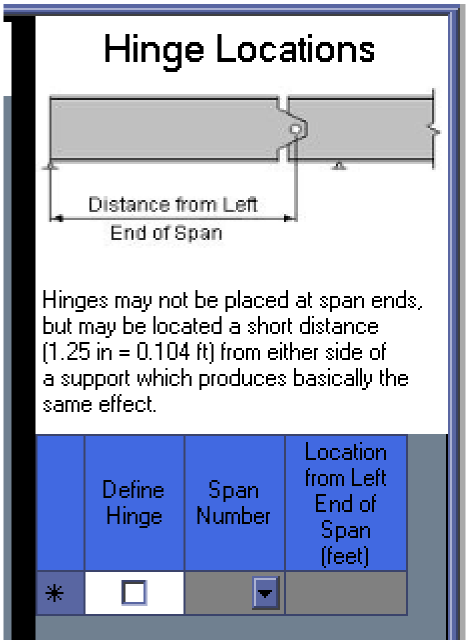
	Span Number	Starting Concrete Section Number	Starting Point from Left End of Span (feet)	Length of Span Segment (feet)	Ending Point from Left End of Span (feet)	Ending Concrete Section Number
▶	1	1	0.00	23.75	23.75	1
	1	1	23.75	10.25	34.00	2
	2	2	0.00	14.75	14.75	1
	2	1	14.75	29.50	44.25	1
	2	1	44.25	14.75	59.00	2
*						

The Support Conditions table will automatically be resized for the appropriate number of supports based on the number of spans defined under the Span Configuration Tab. For each support, the user must choose if the condition is Free or Restrained for the Horizontal, Vertical, and Rotational supports.



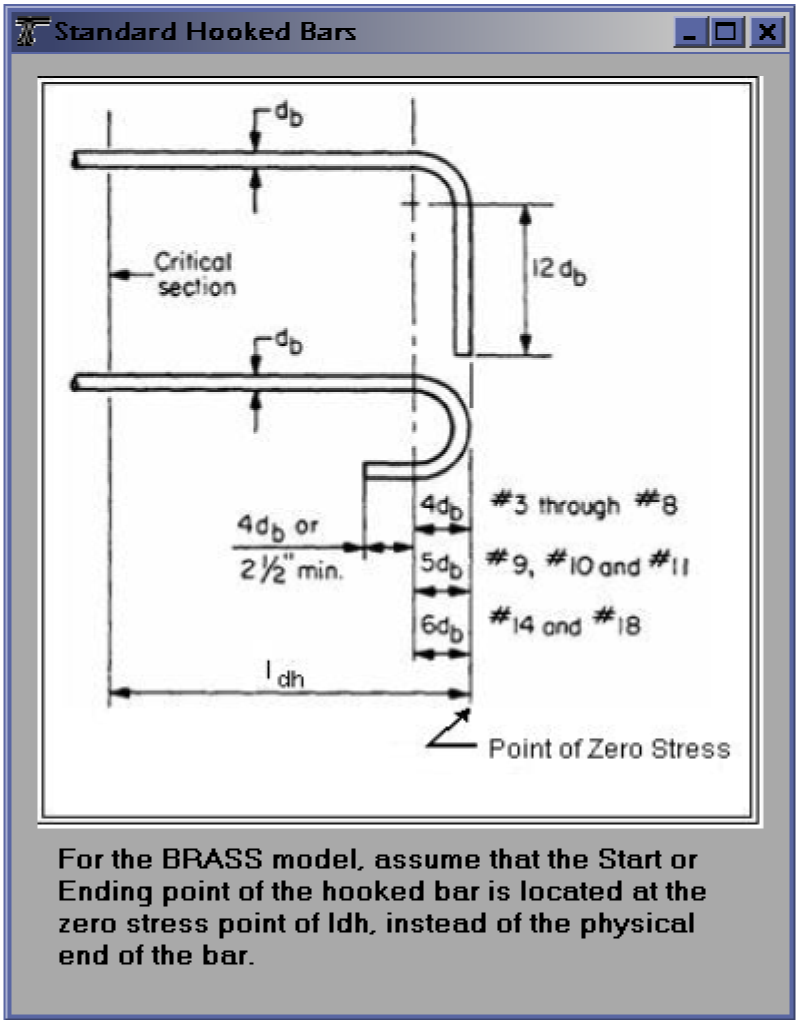
Support Number	Horizontal Support	Vertical Support	Rotational Support
1	Restrained	Restrained	Free
	Span 1		
2	Free	Restrained	Free
	Span 2		
3	Free	Restrained	Free
	Span 3		
4	Free	Restrained	Free
	Span 4		
5	Free	Restrained	Free

Since not all bridges have hinges, the Hinge Location table is inactive by default. To define a hinge within a span, the user must first select the check box under the ‘Define Hinge” column in the Hinge Locations table. Doing so will make the next two cells active, which are where the user would specify which span and the location in feet from the left end of the span where the hinge exists. The BRASS manual states that hinges may not be placed at span ends, but may be located a short distance (1.25 inches) from either side of a support which produces basically the same effect.



4.3.8 CBG – Reinforcement Tab

The Reinforcement Tab is where the user defines the longitudinal reinforcement for each span that has span segments defined under the Span Configuration Tab. To aid the user, at the top of the section there are illustrations showing the reference points of how the bar locations are measured in respect to the cross section and span. There are also two buttons located in upper right hand portion of the section. The first button is titled, “LRFD Bar Development Lengths”, and will display a new window with an image of the development length table from the tool BAR_Ld.XLS. The second button is titled, “Hooked Bar Diagram”, and will display the LRFD hooked bar illustrations for standard hooks. The purpose of this illustration is to inform the user that for the BRASS model, the end point of the bar should be defined as the point of zero stress instead of the physical end of the hooked bar.



The reinforcement table can be populated in any order that the user desires. Some prefer to define all of the bottom bars first and then go back and define all of the top bars. Others prefer to define both top and bottom bars working from left to right. As long as all of the bars are eventually defined, there is no difference in the results of how/when they are defined on the table.

The first cell of the Reinforcement table is where the user specifies the rebar row. Rows one through three are reserved for bottom (positive moment) bars, and rows four and five are reserved for top (negative moment) bars. The user can either type just the number of the row or select it from the drop down list.

The second cell is where the user specifies the number of bars in the current bar group.

The third cell is where the user specifies the bar size. The user can either select the bar size from the drop down list, or they can just type in the number of the bar size. Notice that the display/format of the bar sizes changes when any cell in this column has focus. The fraction bar sizes change to decimal and the "#" sign in front of normal round bars disappears. When the focus is moved to a different column in the table, the display/format changes back. That way, if typing in the number for a bar one can simply type the number for the round bar size or the decimal equivalent of the square bar size. For example for a 1-1/8 in sq bar the user can simply type 1.125, or for a #8 round bar one can simply type 8.

The fourth cell is where the vertical distance, in inches, from either the bottom or the top of the girder is defined. For bars that reside in rows one through three, the vertical distance is measured from the bottom of the girder. For bars residing in rows four and five, the vertical distance is measured from the top of the girder.

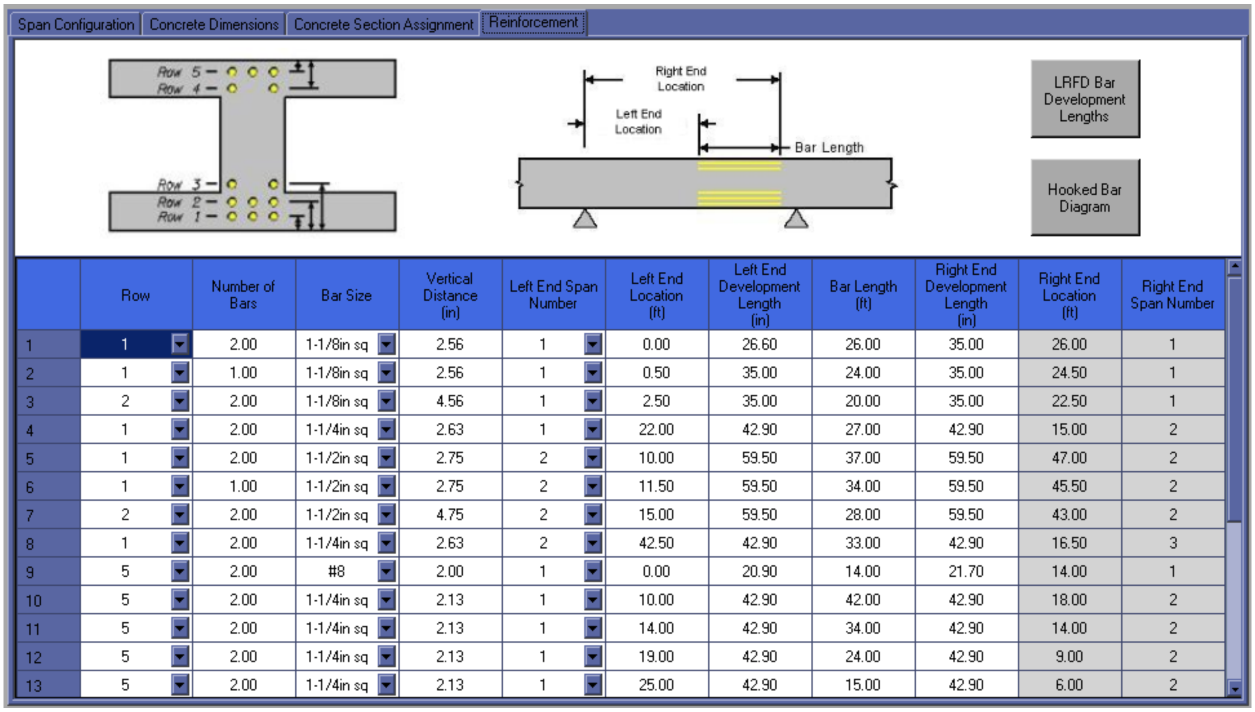
The fifth cell is used to identify the span number where the left end of the bar is located. The sixth cell is used to specify the location, in feet, where the left end of the bar is located from the left end of the span. For straight bars, it would be the physical end of the bar location. For hooked bars, it would be the location at the zero stress point of the hooked bar development length.

The seventh cell is used to specify the development length, in inches, of the left end of the bar. The eighth cell is used to specify the overall bar length in feet. The ninth cell is used to specify the development length, in inches, of the right end of the bar. By default, the program will automatically use the value for the right end development length that was entered for the development length at the left end of the bar. For cases where one end of the bar contains a hook, the user can change the right development length to a different value by simply typing the new value into the cell.

For structures that have a bent bar that transition to a different depth in the member, the user can simply specify a zero development length at the location where the bend occurs. The length of the bar should be specified for the horizontal portion of the bar only at a given elevation, not the portion that is bent and changing elevation or exists at a different elevation in the member. When a zero development length is encountered, the program will assume that the bar is bent and will not specify a bar cutoff analysis point since the bar is fully developed through the transition area. If the user still wishes to have the program generate a bar cutoff analysis point at this location, they must enter some other value, other than zero, for the development length of the bar.

Some of the older bridges occasionally have the deck reinforcing exposed. ACI318, Article 12.2.3.2, states that for bars with a cover of d_b or less or with a clear spacing of $2d_b$ or less that the basic development length (obtained from the LRFD code) be multiplied by 2.0. Therefore, if the inspection report or photos indicate that the deck reinforcement is exposed, double the development length of the deck reinforcement.

The last two cells at the right of the table are where the program automatically calculates and displays the span number that the right end of the bar resides in and the location from the left end of that span, in feet, that the right end of the bar resides.



	Row	Number of Bars	Bar Size	Vertical Distance (in)	Left End Span Number	Left End Location (ft)	Left End Development Length (in)	Bar Length (ft)	Right End Development Length (in)	Right End Location (ft)	Right End Span Number
1	1	2.00	1-1/8in sq	2.56	1	0.00	26.60	26.00	35.00	26.00	1
2	1	1.00	1-1/8in sq	2.56	1	0.50	35.00	24.00	35.00	24.50	1
3	2	2.00	1-1/8in sq	4.56	1	2.50	35.00	20.00	35.00	22.50	1
4	1	2.00	1-1/4in sq	2.63	1	22.00	42.90	27.00	42.90	15.00	2
5	1	2.00	1-1/2in sq	2.75	2	10.00	59.50	37.00	59.50	47.00	2
6	1	1.00	1-1/2in sq	2.75	2	11.50	59.50	34.00	59.50	45.50	2
7	2	2.00	1-1/2in sq	4.75	2	15.00	59.50	28.00	59.50	43.00	2
8	1	2.00	1-1/4in sq	2.63	2	42.50	42.90	33.00	42.90	16.50	3
9	5	2.00	#8	2.00	1	0.00	20.90	14.00	21.70	14.00	1
10	5	2.00	1-1/4in sq	2.13	1	10.00	42.90	42.00	42.90	18.00	2
11	5	2.00	1-1/4in sq	2.13	1	14.00	42.90	34.00	42.90	14.00	2
12	5	2.00	1-1/4in sq	2.13	1	19.00	42.90	24.00	42.90	9.00	2
13	5	2.00	1-1/4in sq	2.13	1	25.00	42.90	15.00	42.90	6.00	2

4.3.9 CBG – Show Cross Section Matrix Button

Once the user has completed entering the data in the various tables and form fields, it is recommended to save the data before continuing just in case the program encounters an unexpected error or bug and closes the CBG. It is then recommended to select the “Show Cross-Section Matrix” button, which will open a new window containing a spreadsheet or matrix of the concrete dimensions and longitudinal reinforcement that will be used to define the spans in BRASS. The Concrete Section Matrix is just a tool for the load rater to see and verify how the bridge is being modeled based on the data that was entered.

The first column lists the span fraction at each section point. The second column lists the span number. And the third column lists the actual location of the of the section point in feet. Columns four through 18 lists the concrete dimensions as they are illustrated on the Concrete Dimensions tab of the main form.

Cells that have white backgrounds are actual control points that were specified on either the Concrete Section Assignment tab or on the Reinforcement tab. The cells with a light grey background are intermediate points that were linearly interpolated between the control points with white backgrounds. Span fraction cells that have a light green background are cells that are made up of two or more control points that were combined into one analysis point. Making the mouse hover over the green cell will cause a tooltip window to display the reason why the cells are combined.

Concrete Section Matrix

	Span Fraction	Span Number	Location	X-Section Number	bf top	tf top	tw top	tw bottom	bf bottom	tf bottom	D1	D2	D3	D4	D5	D6	D7	D8
1	100.00	1	0.00	1	108.00	6.00	14.50	14.50										
2	100.15	1	0.50	-	108.00	6.00	14.50	14.50										
3	100.41	1	1.40	-	108.00	6.00	14.50	14.50										
4	100.51	1	1.74	-	108.00	6.00	14.50	14.50										
5	100.65	1	2.22	-	108.00	6.00	14.50	14.50										
6	100.74	1	2.50	-	108.00	6.00	14.50	14.50										
7	101.01	1	3.42	-	108.00	6.00	14.50	14.50										
8	101.59	1	5.42	-	108.00	6.00	14.50	14.50										
9	102.94	1	10.00	-	108.00	6.00	14.50	14.50										
10	103.59	1	12.19	-	108.00	6.00	14.50	14.50										
11	103.99	1	13.58	-	108.00	6.00	14.50	14.50										
12	104.12	1	14.00	-	108.00	6.00	14.50	14.50										
13	105.17	1	17.58	-	108.00	6.00	14.50	14.50										
14	105.59	1	19.00	-	108.00	6.00	14.50	14.50										
15	105.76	1	19.58	-	108.00	6.00	14.50	14.50										
16	106.35	1	21.58	-	108.00	6.00	14.50	14.50										
17	106.47	1	22.00	-	108.00	6.00	14.50	14.50										
18	106.62	1	22.50	-	108.00	6.00	14.50	14.50										
19	106.79	1	23.08	-	108.00	6.00	14.50	14.50										
20	106.99	1	23.75	1	108.00	6.00	14.50	14.50										
21	107.21	1	24.50	-	108.00	6.00	15.19	15.19										
22	107.35	1	25.00	-	108.00	6.00	15.64	15.64										
23	107.52	1	25.58	-	108.00	6.00	16.17	16.17										
24	107.65	1	26.00	-	108.00	6.00	16.58	16.58										
25	108.41	1	28.58	-	108.00	6.00	18.98	18.98										
26	110.00	1	34.00	2	108.00	6.00	24.00	24.00										
27	200.00	2	0.00	2	108.00	6.00	24.00	24.00										

The columns beyond column 18 are used to show the longitudinal bars that were defined under the Reinforcement Tab. Each bar group consists of four columns that list the rebar row number, the number of bars, the bar size, and the vertical distance in the girder were the bars are located. Each bar group will have four control points, one at each physical end of the bar and one at each point of full bar development. As with the concrete sections, all points that fall between the rebar control points will be linearly interpolated.

The first rebar group shown in the matrix is defined by the first row in the Reinforcement Tab Table, the second group is defined by the second row in the table and so on. Knowing how the bars are defined and represented in the matrix and in the table will allow the load rater to verify how the reinforcement is being modeled.

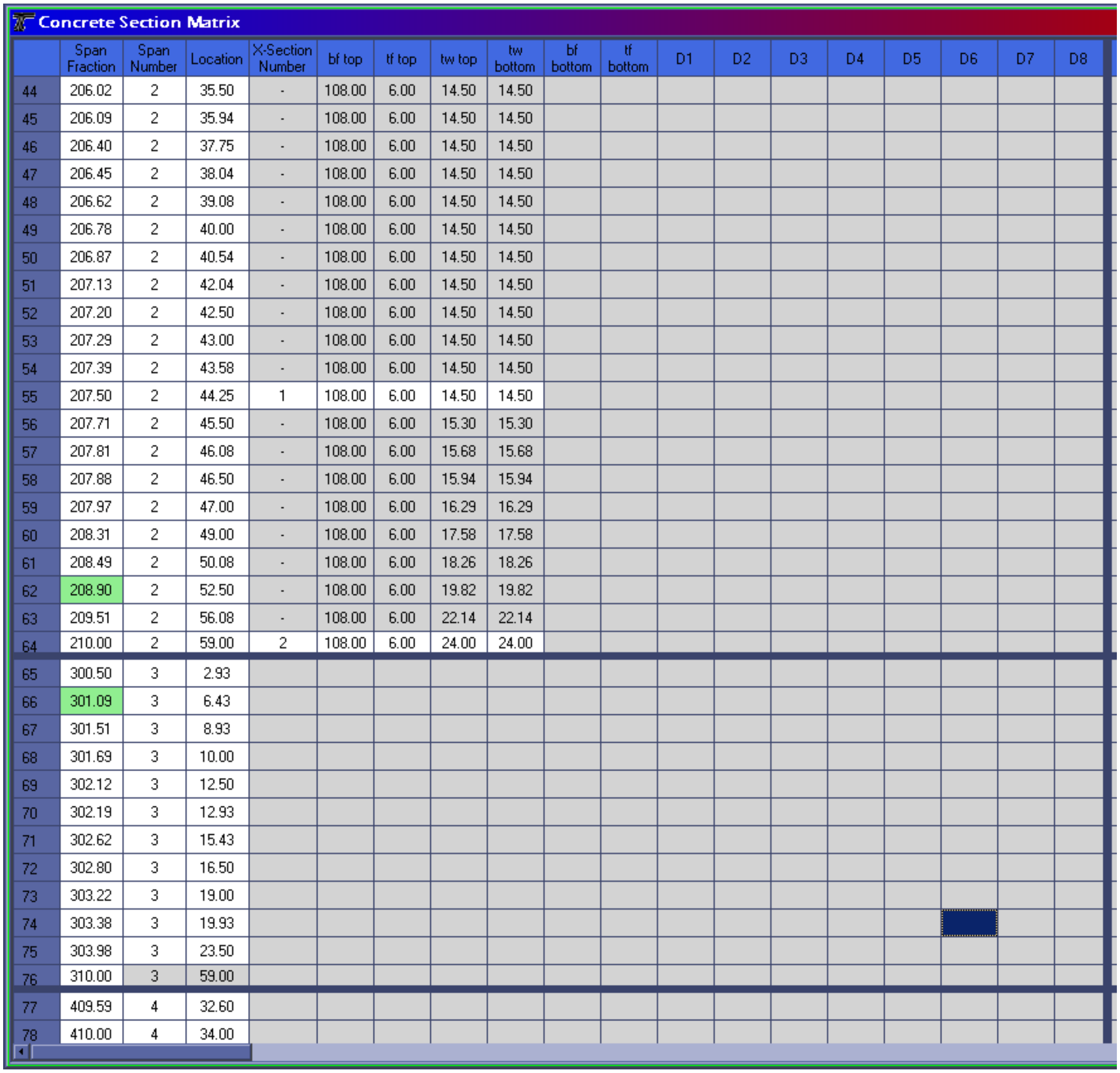
Concrete Section Matrix

					Row 1 on Reinforcement Table				Row 2 on Reinforcement Table				Row 3 on Reinforcement Table				Row 4 on Reinforcement Table			
	Span Fraction	Span Number	Location	D8	Row #	num bars	bar size	vert dist	Row #	num bars	bar size	vert dist	Row #	num bars	bar size	vert dist	Row #	num bars	bar size	vert dist
1	100.00	1	0.00		1	0.00	1-1/8i...	2.56												
2	100.15	1	0.50		1	0.45	1-1/8i...	2.56	1	0.00	1-1/8i...	2.56								
3	100.41	1	1.40		1	1.26	1-1/8i...	2.56	1	0.31	1-1/8i...	2.56								
4	100.51	1	1.74		1	1.57	1-1/8i...	2.56	1	0.43	1-1/8i...	2.56								
5	100.65	1	2.22		1	2.00	1-1/8i...	2.56	1	0.59	1-1/8i...	2.56								
6	100.74	1	2.50		1	2.00	1-1/8i...	2.56	1	0.69	1-1/8i...	2.56	2	0.00	1-1/8i...	4.56				
7	101.01	1	3.42		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	0.63	1-1/8i...	4.56				
8	101.59	1	5.42		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
9	102.94	1	10.00		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
10	103.59	1	12.19		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
11	103.99	1	13.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
12	104.12	1	14.00		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
13	105.17	1	17.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
14	105.59	1	19.00		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
15	105.76	1	19.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	2.00	1-1/8i...	4.56				
16	106.35	1	21.58		1	2.00	1-1/8i...	2.56	1	1.00	1-1/8i...	2.56	2	0.63	1-1/8i...	4.56				
17	106.47	1	22.00		1	2.00	1-1/8i...	2.56	1	0.86	1-1/8i...	2.56	2	0.34	1-1/8i...	4.56	1	0.00	1-1/4i...	2.63
18	106.62	1	22.50		1	2.00	1-1/8i...	2.56	1	0.69	1-1/8i...	2.56	2	0.00	1-1/8i...	4.56	1	0.28	1-1/4i...	2.63
19	106.79	1	23.08		1	2.00	1-1/8i...	2.56	1	0.49	1-1/8i...	2.56					1	0.60	1-1/4i...	2.63
20	106.99	1	23.75		1	1.54	1-1/8i...	2.56	1	0.26	1-1/8i...	2.56					1	0.98	1-1/4i...	2.63
21	107.21	1	24.50		1	1.03	1-1/8i...	2.56	1	0.00	1-1/8i...	2.56					1	1.40	1-1/4i...	2.63
22	107.35	1	25.00		1	0.69	1-1/8i...	2.56									1	1.68	1-1/4i...	2.63
23	107.52	1	25.58		1	0.29	1-1/8i...	2.56									1	2.00	1-1/4i...	2.63
24	107.65	1	26.00		1	0.00	1-1/8i...	2.56									1	2.00	1-1/4i...	2.63
25	108.41	1	28.58														1	2.00	1-1/4i...	2.63
26	110.00	1	34.00														1	2.00	1-1/4i...	2.63
27	200.00	2	0.00														1	2.00	1-1/4i...	2.63

For reinforcement that reside on the same row in the matrix, if the rebar row number, bar size, and vertical distance are the same, then the number of bars will be added together when the program creates the BRASS cross-sections. For example, in the above matrix screenshot, in row three of the matrix the first two rebar groups have the same rebar row number, bar size, and vertical distance. Thus, when the program creates BRASS cross-section number three, it will generate 1.57 - #10 bars in row 1 at a vertical distance of 2.56 inches.

Each numbered row in the matrix that has concrete dimensions showing will end up having the same BRASS cross-section number. Thus, matrix row one will end up being BRASS cross-section number one, matrix row two will end up being BRASS cross-section number two and so on.

The user is to define the starting and ending points for every bar that exists within each unique span. This will often result with bars ending in other spans that are defined as copies of a previous unique span. The program will only generate BRASS cross-sections for the matrix rows that have concrete dimensions displayed. For example, in the following screenshot of the matrix, the program will only generate 64 BRASS cross-sections. This is because the matrix rows 65 and above do not have concrete dimensions shown. This is because the user had indicated on the Span Configuration Tab that spans three and four are to be copies of spans one and two. Spans three and four show control points in the matrix for the ending locations of rebar that started in spans one and two.



Concrete Section Matrix

	Span Fraction	Span Number	Location	X-Section Number	bf top	tf top	tw top	tw bottom	bf bottom	tf bottom	D1	D2	D3	D4	D5	D6	D7	D8
44	206.02	2	35.50	-	108.00	6.00	14.50	14.50										
45	206.09	2	35.94	-	108.00	6.00	14.50	14.50										
46	206.40	2	37.75	-	108.00	6.00	14.50	14.50										
47	206.45	2	38.04	-	108.00	6.00	14.50	14.50										
48	206.62	2	39.08	-	108.00	6.00	14.50	14.50										
49	206.78	2	40.00	-	108.00	6.00	14.50	14.50										
50	206.87	2	40.54	-	108.00	6.00	14.50	14.50										
51	207.13	2	42.04	-	108.00	6.00	14.50	14.50										
52	207.20	2	42.50	-	108.00	6.00	14.50	14.50										
53	207.29	2	43.00	-	108.00	6.00	14.50	14.50										
54	207.39	2	43.58	-	108.00	6.00	14.50	14.50										
55	207.50	2	44.25	1	108.00	6.00	14.50	14.50										
56	207.71	2	45.50	-	108.00	6.00	15.30	15.30										
57	207.81	2	46.08	-	108.00	6.00	15.68	15.68										
58	207.88	2	46.50	-	108.00	6.00	15.94	15.94										
59	207.97	2	47.00	-	108.00	6.00	16.29	16.29										
60	208.31	2	49.00	-	108.00	6.00	17.58	17.58										
61	208.49	2	50.08	-	108.00	6.00	18.26	18.26										
62	208.90	2	52.50	-	108.00	6.00	19.82	19.82										
63	209.51	2	56.08	-	108.00	6.00	22.14	22.14										
64	210.00	2	59.00	2	108.00	6.00	24.00	24.00										
65	300.50	3	2.93															
66	301.09	3	6.43															
67	301.51	3	8.93															
68	301.69	3	10.00															
69	302.12	3	12.50															
70	302.19	3	12.93															
71	302.62	3	15.43															
72	302.80	3	16.50															
73	303.22	3	19.00															
74	303.38	3	19.93															
75	303.98	3	23.50															
76	310.00	3	59.00															
77	409.59	4	32.60															
78	410.00	4	34.00															

4.3.10 CBG – Generate Brass File Inputs

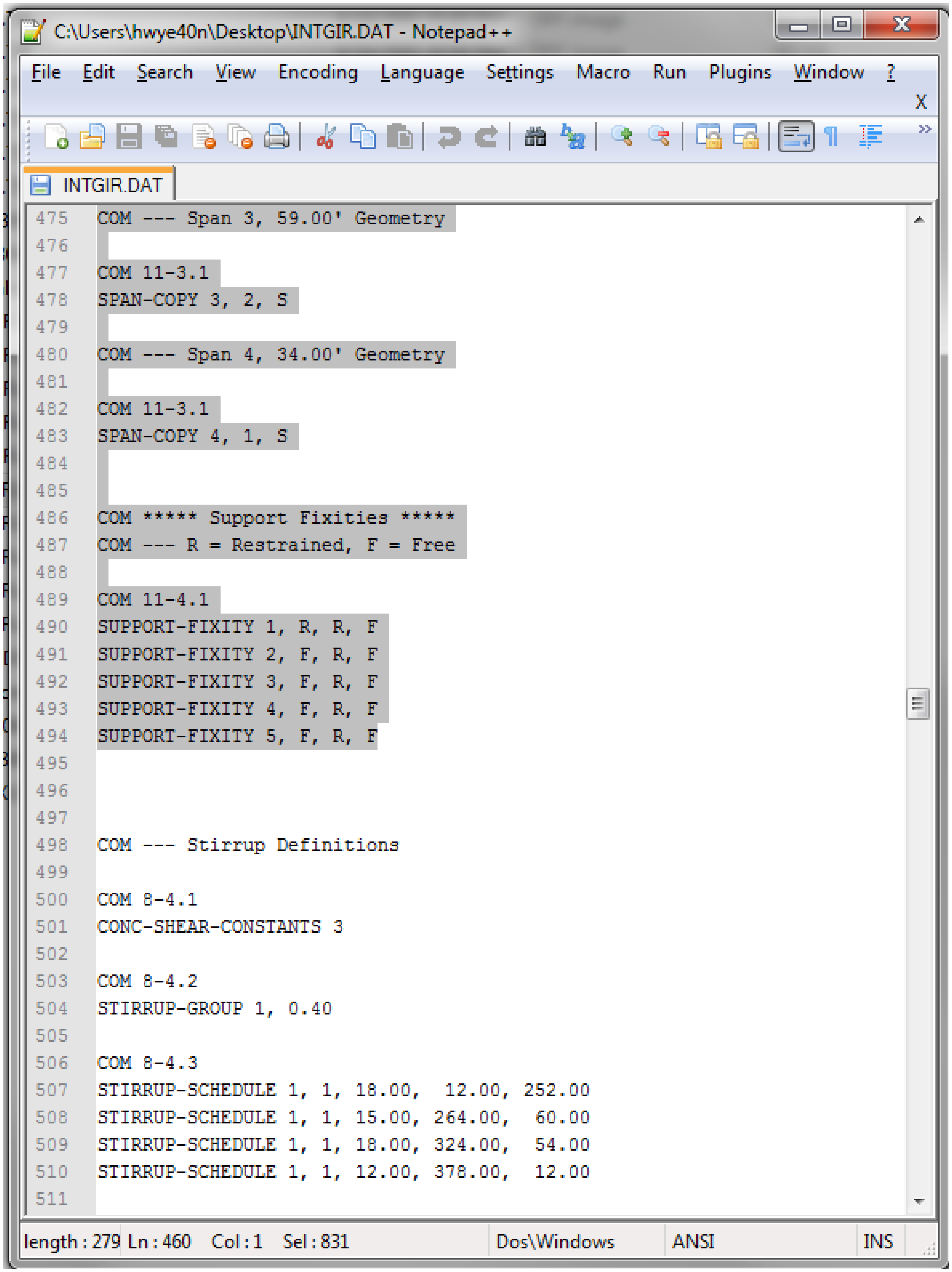
Selecting the “Generate BRASS File Input” button will display a text window that contains all of the needed BRASS input commands from the very beginning of the file up to the point where the user defines the stirrup definitions. When the window appears, all of the text is already selected, therefore all the user has to do is right click in the window and select the “Copy” command.

BRASS-GIRDER(LRFD) Command Input (*.DAT)

Copy and Paste the below text into the BRASS-GIRDER(LRFD) Input File

```
COM 2-1.3
BRIDGE-NAME 07806, Hwy 35 over Hwy 1

COM 2-1.5
ROUTE 76.65, Hwy35 (Coos Bay - Roseburg Highway)

COM 2-1.6
TITLE File IntGir.DAT  Interior Girder
TITLE Rating for Design, Legal, CTP, & STP Loads

COM 2-1.1
AGENCY Oregon DOT

COM 2-1.2
ENGINEER S Burgess T Kinney

COM
COM  ***** LRFR Load Rating, Strength Limit State *****
COM

COM 4-1.1
ANALYSIS B, 1, RAT, T, Y

COM 4-1.2
POINT-OF-INTEREST U

COM 2-1.4
UNITS US

COM 5-1.1
OUTPUT 4, Y, , , 1, , , , , , , , , ,

COM 5-7.3
OUTPUT-EFF-WIDTH N

COM BRASS (LRFD) INPUT ADJUSTMENT TYPE 1:
COM For LRFR specify the Strength Limit States
COM and ignore Service & Fatigue Limits
COM Design & Legal Loads = Strength-I
COM Permit Loads = Strength-II
COM (refer to 4-5.1, Fig. 2) and
COM specify shear checks for all load types.

COM 4-5.1, 4-5.2
MAP-LIMIT-STATE ST, 1, I, Y, N
MAP-LIMIT-STATE ST, 2, N, N, Y
MAP-SPEC-CHECK ST, 1, D, SHR, Y
```

Then in the appropriate input file template, the user selects all of the text from the very beginning of the file up to just before the comment line that states, “dead loads”. Then selecting the “Paste” command will replace all of the selected text commands with those that were just copied from the CBG.




```
COM --- Span 3, 59.00' Geometry

COM 11-3.1
SPAN-COPY 3, 2, S

COM --- Span 4, 34.00' Geometry

COM 11-3.1
SPAN-COPY 4, 1, S


COM ***** Support Fixities *****
COM --- R = Restrained, F = Free

COM 11-4.1
SUPPORT-FIXITY 1, R, R, F
SUPPORT-FIXITY 2, F, R, F
SUPPORT-FIXITY 3, F, R, F
SUPPORT-FIXITY 4, F, R, F
SUPPORT-FIXITY 5, F, R, F



COM --- Stirrup Definitions

COM 8-4.1
CONC-SHEAR-CONSTANTS 3

COM 8-4.2
STIRRUP-GROUP 1, 0.40

COM 8-4.3
STIRRUP-SCHEDULE 1, 1, 18.00,  12.00, 252.00
STIRRUP-SCHEDULE 1, 1, 15.00, 264.00,  60.00
STIRRUP-SCHEDULE 1, 1, 18.00, 324.00,  54.00
STIRRUP-SCHEDULE 1, 1, 12.00, 378.00,  12.00
```

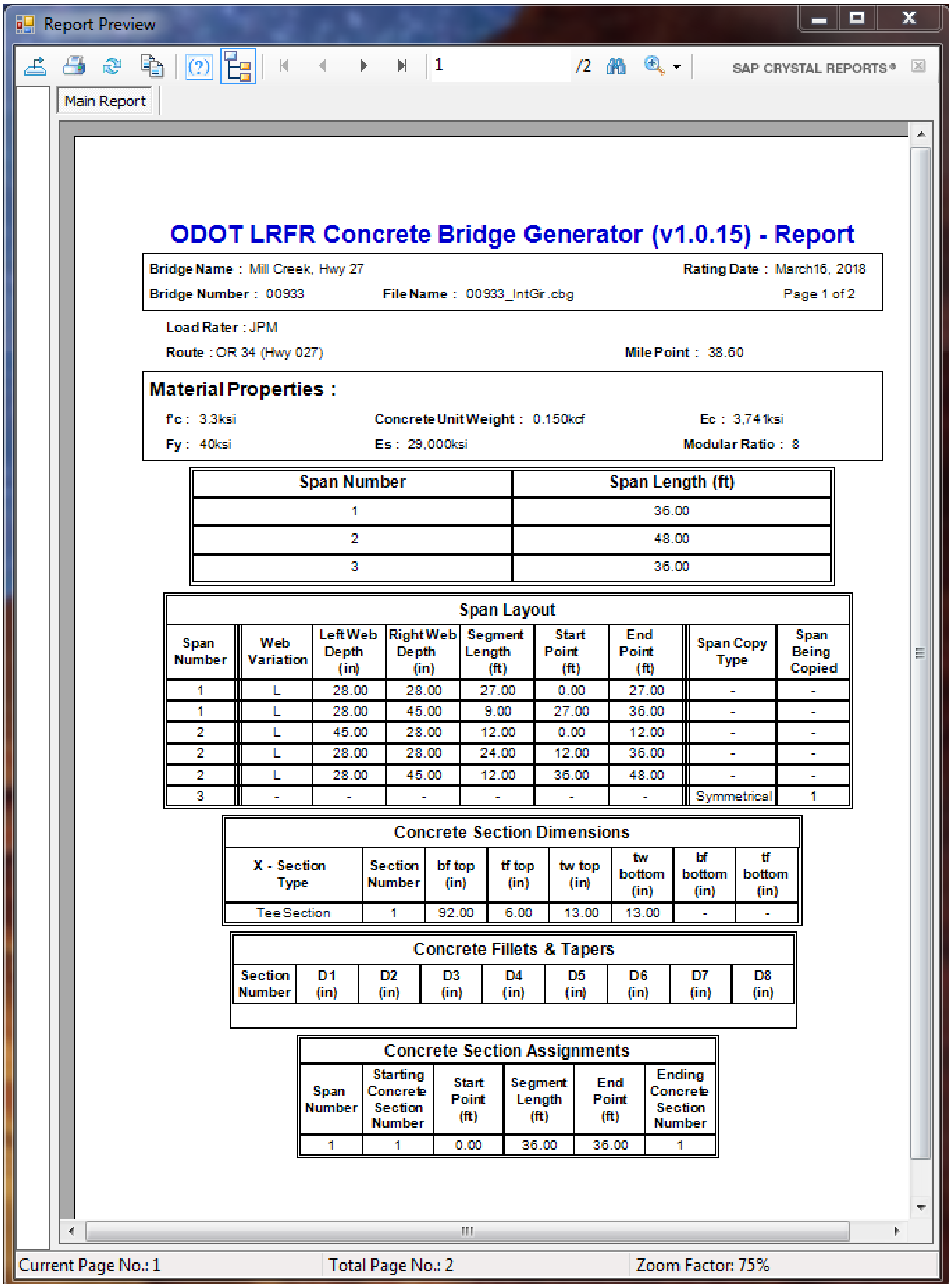
4.3.11 CBG – Generate Bar Cutoff Points for Shear Analysis

Selecting the “Generate Bar Cutoff Points for Shear Analysis” button will display a text window that contains all of the needed BRASS input shear commands for the bar cutoff points. Since shear analysis is not required for CIP Slabs, this button can be ignored.

For other structure types, the user would select the button. When the window appears, all of the text for all of the commands for the different spans is already selected. The user would select and copy the group of commands for only one span at a time, and then paste them within the appropriate spot in each BRASS input file. Again, since this is not required for slab structures, this step can be ignored.

4.3.12 CBG – Report

Once all of the data has been entered, verified with the matrix and the various BRASS commands have been copied and pasted in the BRASS input files, the user should save the data into a *.cbg file that will be included in the electronic file set. Then the user should select the "Report" button, which will display a print preview of a report that reflects the data entered in the various form fields of the program. Selecting the button that has the printer icon at the top of the print preview will print a hard copy of the report, which should be included in the printed calc book for the load rating.



ODOT LRFR Concrete Bridge Generator (v1.0.15) - Report

Bridge Name : Mill Creek, Hwy 27 **Rating Date :** March16, 2018
Bridge Number : 00933 **File Name :** 00933_IntGir.cbg Page 1 of 2

Load Rater : JPM
Route : OR 34 (Hwy 027) **Mile Point :** 38.60

Material Properties :
f'c : 3.3ksi **Concrete Unit Weight :** 0.150kcf **Ec :** 3,741ksi
Fy : 40ksi **Es :** 29,000ksi **Modular Ratio :** 8

Span Number	Span Length (ft)
1	36.00
2	48.00
3	36.00

Span Layout

Span Number	Web Variation	Left Web Depth (in)	Right Web Depth (in)	Segment Length (ft)	Start Point (ft)	End Point (ft)	Span Copy Type	Span Being Copied
1	L	28.00	28.00	27.00	0.00	27.00	-	-
1	L	28.00	45.00	9.00	27.00	36.00	-	-
2	L	45.00	28.00	12.00	0.00	12.00	-	-
2	L	28.00	28.00	24.00	12.00	36.00	-	-
2	L	28.00	45.00	12.00	36.00	48.00	-	-
3	-	-	-	-	-	-	Symmetrical	1

Concrete Section Dimensions

X - Section Type	Section Number	bf top (in)	tf top (in)	tw top (in)	tw bottom (in)	bf bottom (in)	tf bottom (in)
Tee Section	1	92.00	6.00	13.00	13.00	-	-

Concrete Fillets & Tapers

Section Number	D1 (in)	D2 (in)	D3 (in)	D4 (in)	D5 (in)	D6 (in)	D7 (in)	D8 (in)

Concrete Section Assignments

Span Number	Starting Concrete Section Number	Start Point (ft)	Segment Length (ft)	End Point (ft)	Ending Concrete Section Number
1	1	0.00	36.00	36.00	1

4.3.13 CBG – Known Issues

All known errors with the CBG have been corrected.

4.4 Analysis of Slab Strips

BRASS-GIRDER will be used to load rate the concrete girders. BRASS-GIRDER is different from the previous BRASS-GIRDER(LRFD) program in that it no longer uses text file inputs, but instead utilizes a Graphical User Interface (GUI) with data saved in xml file format. Instead of developing new procedures and a new CBG program to populate the GUI of BRASS-GIRDER, this manual will continue to give instructions on how to create the text input file for BRASS-GIRDER(LRFD). Once the file is ready for analysis, the user will run the text input file through the BRASS-GIRDER translator that will create the xml input file used to populate the new GUI. From there the user will be able to run the analysis within BRASS-GIRDER.

BRASS has increased the live load definition limit from 20 to 100 per file. In the past, since ODOT requires more than 20 vehicles to be analyzed in every LRFR load rating, two nearly identical BRASS input files were used to cover all of the different vehicles. Since the transition from using BRASS-GIRDER(LRFD) to using BRASS-GIRDER for the analysis, ODOT has modified all of its tools to only use a single BRASS file with all of the rating vehicles included. Therefore, ODOT will no longer require the two separate nearly identical BRASS "_N" and "_T" files.

4.4.1 BRASS Input File Conventions

Use the heavily commented sample files provided as templates to be copied to a new bridge-number-specific folder (with a new filename if appropriate) and then modified for the actual Load Ratings. Separate input files will be required for each structure type in any bridge with a combination of structure types, and for interior strip width and edge strip width.

- General conventions

  Use the full length of each command name except the COMMENT (3-1.1) command shall be only COM.

  Precede each command or logical group of similar commands (except for the COMMENT command) with a comment referring to the Article number in the BRASS-GIRDER(LRFD) Command Manual. For example, precede an ANALYSIS (4-1.1) command with a comment command thus:

  ```
  COM 4-1.1
  ANALYSIS F, 1, RAT, T, Y
  ```

  Generally, leave in all comments found in the template (unless they become totally irrelevant to a particular input file), modifying them and adding more comments as required to fit the specific conditions of the rating. Use comments liberally with the expectation that someone unfamiliar with the BRASS-GIRDER(LRFD) program and unfamiliar with the bridge will need to read the data file and fully understand it.

  Leave parameters blank (spaces between commas) where they are irrelevant to the specific structure. Although trailing commas can be omitted where all parameters to the right are to be blank, it is recommended to clarify your intentions by showing the blank parameters separated by commas. However, avoid leaving blank parameters such as material strengths where default values would apply. Enter the default values to make the dataset more meaningful to a future user.

  Show in-line calculations within a parameter (between commas) to convert units from feet to inches where the command parameter requires inches. Similarly, show in-line calculations to show how you determined vertical dimensions to locate flexural bars. Never use parentheses in in-line calculations. Other than these in-line calculations, the best place to put calculations is in the Preliminary File rather than in the BRASS comments.

  Whenever a BRASS-GIRDER(LRFD) input file contains a series of occurrences of the same command, vertically aligning the same command parameters for clarity is encouraged. This practice simplifies the process of changing values of parameters when cloning an old BRASS file for use in a new bridge. Inserting spaces as required to accomplish this is harmless. However, do not use tab characters to accomplish this. They are misinterpreted by BRASS-(LRFD) as the next parameter, and are likely to cause fatal errors.

- Input File Sections

To make it easier for a subsequent user to find their way around the Input File, separate the BRASS input file into logical sections (large groups of commands) by using spaced comments as indicated in the sample files. Typically, an input file for an RC Slab will be divided into the following sections:

```
COM
COM  ***** LRFR Load Rating, Strength Limit State *****
COM

COM
COM  ***** Material Properties *****
COM

COM
COM  ***** Section Geometry *****
COM

COM
COM  ***** Span Length and Section Information *****
COM

COM
COM  ***** Dead Loads *****
COM

COM
COM  ***** Dive Loads *****
COM

COM
COM  ***** Distribution Factors *****
COM

COM
COM  ***** Resistance Factors *****
COM

COM
COM   ***** Critical Flexural Sections *****
COM
```

- Specific conventions

Several of these conventions and commands will be automatically created by the CBG program. They are listed within this section to provide background and understanding as to what ODOT is requiring within the BRASS-GIRDER(LRFD) input files.

At the beginning of every input file, use the BRIDGE-NAME (2-1.3) command to provide the 5- or 6-character NBI Bridge Number, followed by the Bridge Name. Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Next, use the ROUTE (2-1.5) command to provide the mile point and signed Route Number where applicable (always required for State-owned bridges). Note the signed Route Number is not the same as the ODOT internal (maintenance) Highway Number.

Use 2 lines of the TITLE (2-1.6) command. Use the first TITLE line to provide the file name and describe which girder(s) this file applies to. Use the second TITLE line to provide the purpose or work grouping of the Load Rating.

Use the AGENCY (2-1.1) command to identify the Load Rating as being performed according to ODOT standards. This command should always be the same:

```
COM 2-1.1
AGENCY Oregon DOT
```

Use the ENGINEER (2-1.2) command to indicate the load rater.

Use the UNITS (2-1.4) command to force BRASS to always use US (English) units for both input and output. BRASS normally defaults to US units, but it has been found that when referenced dimensions get large, BRASS will automatically assume the large dimensions are in millimeters and will convert the units when it calculates the resistance of the member. Using the UNITS command will not allow BRASS to arbitrarily convert the units during an analysis.

```
COM 2-1.4
UNITS US
```

Use the ANALYSIS (4-1.1) command to provide BRASS with parameters needed to do a rating analysis. The “continuous beam model” is the preferred choice (“B” in parameter 1) as long as there is no need to include columns in the analysis and the bridge has ≤ 13 spans. Parameter 5 needs to be coded as Y, for yes, to interpolate reinforcing steel from the left cross section to the right cross section. This will allow BRASS to account for partially developed reinforcing steel per AASHTO LRFD 5.7.3.4.2. Except for a rigid frame analysis (with columns) that would require the “frame type model” (“F” in parameter 1), this command would normally be the same:

```
COM 4-1.1
ANALYSIS B, 1, RAT, T, Y
```

Use the OUTPUT (5-1.1) command to control the wide variety of output options. Unless there is a problem that requires more detailed intermediate output for investigation, this command should always the same:

```
COM 5-1.1
OUTPUT 4, Y, , , 1, , , , , , , , , ,
```

Beginning with BRASS-GIRDER(LRFD) v.1.6.1, the effective top flange width is calculated and applied to the section properties automatically. Use the OUTPUT-EFF-WIDTH (5-7.3) command to direct BRASS to not output its effective flange width calculations. This command should always be the same:

```
COM 5-7.3
OUTPUT-EFF-WIDTH N
```

Code all BRASS models in the same direction as the bridge elevation appears on the plans, i.e. from left to right on the plans, regardless of mile point direction.

In the “Material Properties” section, use the CONC-MATERIALS (8-1.1) command to provide the material properties consistent with the notes on the bridge plans. Although there are exceptions, a typical RC Slab structure from the 1950’s or early 1960’s would have the following properties command:

```
COM 8-1.1
CONC-MATERIALS 0.15, 3.3, 40.0, 40.0, 9, , , 170.0, , ,
```

In the “Material Properties” section, use the DECK-MATL-PROPERTIES (6-4.1) command to assure that the default wearing surface weight (parameter 3) is set to 0. Without this command, BRASS would generate its own DW load, which we want to define explicitly in the “dead loads” section.

```
COM This command is required to assure default deck Wearing
Surface Weight
COM (parameter 3) is 0 so BRASS does not generate a DW load on
its own
COM 6-4.1
DECK-MATL-PROPERTIES , , 0.0
```

In the “Section Geometry” section, define each section numbered sequentially, preceded by a comment identifying it with characteristics from the plans. For solid slabs, use the CONC-RECT-SECTION (8-2.2) to define the cross-section width using the slab strip width. Use as many CONC-REBAR (8-2.8) commands as required to define all the layers of longitudinal reinforcement that are present on the tension side of the slab strip. The following is an example of the series of commands to define one solid slab strip:

```
COM --- Section 1, Pos. Moment, Span 1, 3#10 bot
COM 8-2.2, 8-2.8
CONC-RECT-SECTION 1, 12,
CONC-REBAR 1, 1, 2.000, 10, 1.5+1.27/2
```

For voided slabs, use the CONC-VOIDED-SLAB (8-2.6) command to define the cross-section. Use as many CONC-REBAR (8-2.8) commands as required to define all the layers of longitudinal reinforcement that are present on the tension side of the slab strip. BRASS will convert the voided slab into an equivalent I-Section as follows: The top and bottom flange widths are set to the center-to-center void spacing (which is why we set the slab strip width to equal the void spacing, so that the Distribution Factors compute correctly). The top and bottom flange thicknesses are set from the appropriate face of the slab to the nearest edge of the void. The web thickness is set to the center-to-center void spacing minus twice the void radius. The circular portion remaining is converted to equivalent equal leg fillets. See the BRASS Technical Manual for details. The following is an example of the series of commands to define one voided slab strip:

```
COM --- Section 1, Pos. Moment, Span 1, 3#10 bot
COM 8-2.6, 8-2.8
CONC-VOIDED-SLAB 1, 12.0, 12.0, 4.5, 1.5
CONC-REBAR 1, 1, 3.000, 10, 1.5+1.27/2
```

Some of the older bridges occasionally have the deck reinforcing exposed. ACI318, Article 12.2.3.2, states that for bars with a cover of d_b or less or with a clear spacing of $2d_b$ or less that the basic development length (obtained from the LRFD code) be multiplied by 2.0. Therefore, if the inspection report or photos indicate that the deck reinforcement is exposed, double the development length of the deck reinforcement.

In the “Span Lengths and Section Information” section, define each span beginning with the appropriate command from Chapter 11 of the *BRASS-GIRDER(LRFD) Command Manual* that describes the profile (depth variation) along the span. Follow this command with a sequence of SPAN-SECTION (11-2.1) commands to assign the previously defined sections to cumulative ranges from the left end of the span. Since there are very few analysis points that we are checking, the spans can be defined by the one or two sections that represent the points being checked. The following is an example of the series of commands to define a three span RC Slab bridge:

```
COM --- Span 1, 36' Geometry
COM 11-1.3, 11-2.1
SPAN-UNIF-HAUNCH 1, 36.0*12, R, 16.00, 24*12, 24.00,
SPAN-SECTION 1,  1, 36*12


COM --- Span 2, 48' Geometry
COM 11-1.3, 11-2.1
SPAN-UNIF-HAUNCH 2, 48.0*12, B, 24.00, 12.0*12, 16.00, 36.0*12,24.00
SPAN-SECTION 2,  2, 12.0*12
SPAN-SECTION 2,  3, 36.0*12
SPAN-SECTION 2,  2, 48.0*12

COM --- Span 3, 36' Geometry
COM 11-3.1
SPAN-COPY 3, 1, S
```

Use the SPAN-HINGE (11-5.1) command if necessary to define the location of any hinge within the span. If the structure has an expansion joint over a support, approximate this condition by placing a hinge close to, but not at, the support. BRASS-GIRDER(LRFD) does not allow the use of a hinge at a support, and recommends that it be located a distance of 1.2” from the support. If BRASS gives anomalous moment results, or it unexpectedly places the hinge farther out in the span than you expect, the solution is to relocate the hinge farther than 1.2” from the support, increasing in small increments until the reported moments behave as expected. (Sometimes increasing the offset by hundredths of a foot can make all the difference!).

Use the SUPPORT-FIXITY (11-4.1) command to define the boundary conditions of each span, for example:

```
COM --- Support Fixities

COM 11-4.1
SUPPORT-FIXITY 1, R, R, F
SUPPORT-FIXITY 2, F, R, F
SUPPORT-FIXITY 3, F, R, F
SUPPORT-FIXITY 4, F, R, F
```

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the BRASS Input (**.**DAT) file as they were calculated in the Preliminary (**.xmcd**) File.

Because BRASS calculates girder dead load (self-weight) using the input section dimensions and treats it separately from other dead loads, group the rest of the structure dead loads (DC) (excluding wearing surface dead loads) under the first occurrence of the of the LOAD-DEAD-DESCR (12-1.2) command, using the description (parameter 4) “Superimposed dead loads”. This group should include LOAD-DEAD_UNIFORM (12-1.3) commands as needed to account for all superimposed (Stage-2) dead loads except the wearing surface. Precede each group of LOAD-DEAD-UNIFORM commands with an additional identifying comment describing the load. An example of this (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 1, DC, 1, Superimposed Dead Loads

COM  Each rail = 0.209 k/ft (Dwg. 23610)
COM  Distributed evenly across slab strip width,
COM Spans 1 - 3, w = 0.009 k/ft

COM 12-1.3
LOAD-DEAD-UNIFORM 1, 1, 0.0*12, 0.009/12, 36.0*12, 0.009/12
LOAD-DEAD-UNIFORM 1, 2, 0.0*12, 0.009/12, 48.0*12, 0.009/12
LOAD-DEAD-UNIFORM 1, 3, 0.0*12, 0.009/12, 36.0*12, 0.009/12
```

To facilitate future re-ratings with different wearing surface loads, always apply the wearing surface dead load under its own LOAD-DEAD-DESCR (12-1.2) command separate from all other uniform superimposed dead loads. Precede each LOAD-DEAD-UNIFORM command with an additional identifying comment describing the load. An example of this (DW) dead load group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 2, DW, 1, Wearing Surface Dead Load
COM  4" + 1" ACWS
COM  Distributed evenly across the slab strip width,
COM Spans 1 - 3, w = 0.063 k/ft

COM 12-1.3
LOAD-DEAD-UNIFORM 2, 1, 0.0*12, 0.063/12, 36.0*12, 0.063/12
LOAD-DEAD-UNIFORM 2, 2, 0.0*12, 0.063/12, 48.0*12, 0.063/12
LOAD-DEAD-UNIFORM 2, 3, 0.0*12, 0.063/12, 36.0*12, 0.063/12
```

Use the BRASS Input Adjustments #1 thru #3 explained below to code the live load requirements.

To assure that BRASS calculates slab width Distribution Factors (number of lanes) according to LRFD 4.6.2.1.4, the following BRASS-GIRDER(LRFD) commands are required:

- Specify the bridge width (out-to-out width of the slab) and distance from edge of slab to inside face of barrier using the DECK-GEOMETRY-SLAB (6-1.3) command.
- Specify the edges of the roadway (which limits the extreme transverse wheel positions) by using the DECK-TRAVEL-WAY (6-3.3) command.
- Specify if an Interior Strip Width Analysis or an Edge Strip Width Analysis is to be performed using the DIST-CONTROL-SLAB (4-3.1.1) command.
- To assure that BRASS-GIRDER(LRFD) distributes the dead loads uniformly to the slab strip width, use the DIST-CONTROL-DL (4-3.2) command with all the parameters blank.
- Specify the bridge type and skew using the DIST-CONTROL-LL (4-3.3) command.
- Specify the edges of the roadway (which limits the extreme transverse wheel positions) by using the DECK-TRAVEL-WAY (6-3.3) command.

Use the BRASS Input Adjustment #4 explained below to code the Resistance Factors.

To obtain Rating Factors for flexure points of interest, use OUTPUT-INTERMEDIATE (5-2.1) commands grouped in the same order as the analysis points were calculated in the

Preliminary File.

4.4.2 BRASS Input Adjustments

Because BRASS-GIRDER(LRFD) was designed primarily for LRFD analyses and was created before the *MBE Manual* was published, a number of standard BRASS Input Adjustments are necessary. Fortunately the program is flexible enough to allow an accurate solution with work-arounds (BRASS Input Adjustments). These adjustments will normally apply to every Input File, at least until BRASS-GIRDER(LRFD) is changed. See the sample input files for proper placement of these adjustments.

- BRASS-GIRDER(LRFD) Input Adjustment Type 1:

Use the MAP-LIMIT-STATE (4-5.1) and MAP-SPEC-CHECK (4-5.2) commands to force BRASS to check flexure and shear for only the limit states required by MBE. These limit states are different than the BRASS-GIRDER(LRFD) defaults. Thus it is necessary to force BRASS to check flexure and shear for Strength-I for Design and Legal loads, and for Strength-II for Permit Loads: For Design Loads (Strength-I Limit State), these commands also force BRASS to use γ_L = 1.75 (Inventory Level). (The Operating Level γ_L = 1.35 Rating Factors will automatically be derived from the Inventory Rating Factors in the Load Rating Summary Workbook by multiplying by the γ_L ratio). Use the following sequence of commands, which will normally not change:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 1:
COM  For LRFR specify the required Strength Limit States
COM  and ignore Service & Fatigue Limits
COM  Design & Legal Loads - Strength-I
COM  Permit Loads - Strength-II
COM  (refer to 4-5.1 command, Fig. 2) and
COM  specify shear checks for all load types

COM 4-5.1, 4-5.2
MAP-LIMIT-STATE ST, 1, I, Y, N
MAP-LIMIT-STATE ST, 2, N, N, Y
MAP-SPEC-CHECK ST, 1, D, SHR, Y
MAP-SPEC-CHECK ST, 1, L, SHR, Y
MAP-SPEC-CHECK ST, 2, P, SHR, Y
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 2:

Use the FACTORS-LOAD-DL command (13-1.2) to force BRASS to use the MBE dead load factors, which are different than the LRFD factors used by default. MBE T 6A.4.2.2-1 requires constant dead load factors γ_{DC} and γ_{DW}, and the footnote allows γ_{DW} to be 1.25 when wearing surface thickness is field-measured, which is normally the case. Therefore, these commands are always required. Since the command only covers one limit state level at a time, use one for Strength-I and one for Strength-II:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,

COM 13-1.2
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 3:

  Using the BRASS-GIRDER(LRFD) LOAD-LIVE-CONTROL (12-4.1) command to apply the default Design and Legal Load sets would have 3 undesirable consequences:

  (a) BRASS would apply the Fatigue Design Load that is not needed for RC Slab structures, generating unwanted output
  (b) BRASS would default to listing the Design Load outputs *after* all the other loads, potentially causing confusion in transferring loads to the ODOT Load Rating Summary Workbook
  (c) BRASS would apply the AASHTO 3S2 Legal Load which is lighter than the Oregon Legal 3S2 load.

  Therefore, use the LOAD-LIVE-DEFINITION (12-4.3) commands to define each Design and Legal Load separately, and use the LOAD-LIVE-CONTROL (12-4.1) command to define only parameter 1 (direction control, normally "B" for traffic in both directions) and parameter 7 (wheel advancement denominator, normally 100), as follows:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 3:
COM  All live loads will be entered individually
COM  Design Loads entered as live load definitions  1 thru  4
COM  Legal  Loads entered as live load definitions  5 thru  9
COM  Permit Loads entered as live load definitions 10 thru 19

COM 12-4.1
LOAD-LIVE-CONTROL B, , , , , , 100
```

  In structures with short spans, especially short cantilevers, BRASS may "crash" because the span is divided into liveload advancement increments that are too small. If this occurs and you have a small span, try decreasing parameter 7 to the largest number for which BRASS will work, often 50 or sometimes even less.

  Further, because ODOT LRFR Tables 1.4.1.9 and 1.4.1.11A requires a different live load factor γ_L for each truck, ADTT and truck weight combination, and BRASS-GIRDER(LRFD) does not provide for a separate live load factor for each truck, more BRASS Input Adjustments are required to define truck specific live load factors.

  Use the optional FACTORS-LOAD-LL command (13-1.3) such that the universal "gamma LL (Design)" (parameter 3), "gamma LL (Legal)" (parameter 4) and "gamma LL (Permit)" (parameter 5) are all forced to 1.0. Since this command only covers one limit state level at a time, two commands are always required (one for Strength-I and one for Strength-II):

```
COM  Use the FACTORS-LOAD-LL command to force
COM  universal gamma-LL to 1.0 for Legal & Permit Loads

COM 13-1.3
FACTORS-LOAD-LL ST, 1, 1.0, 1.0, 1.0
FACTORS-LOAD-LL ST, 2, 1.0, 1.0, 1.0
```

  With the universal live load factors set to 1.0, truck specific live load factors can be defined using the BRASS command 13-1.6, FACTORS-LOAD-LL-LS. Previous version of BRASS (LRFD) did not accommodate individual truck live load factors. Thus, a work around was developed where the live load factors were input as scale factors. With BRASS v 2.0.3 the FACTORS-LOAD-LL-LS command has been added to resolve this limitation. Live load factors shall be input using this new command. Parameter 6 of command 12-4.3, scale factor, will be reserve for its original purpose. With this update the LR summary sheet will no longer modify the rating factors reported in the BRASS output file.

In the FACTORS-LOAD-LL-LS (13-1.6) commands for each load, enter the specific live load Factor γ_L (from **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable). This command can be copied and pasted from the BRASS tab of LL_Factors_State.XLS.

Thus the complete live load definition command set for input files is as follows:

```
COM  Define each Design and Legal live load separately and
COM  apply the truck specific live load factor (instead
COM  of defining them in the LOAD-LIVE-CONTROL command)
COM  There are 3 reasons...
COM  (a) to prevent BRASS from applying the Fatigue Design Load
COM      that is not needed for RCDG structures
COM  (b) to force BRASS to list the Design Loads outputs in the
COM      same order as ODOT's Load Rating Summary Workbook
COM  (c) to allow use of the Oregon 3S2 Legal Load rather than
COM      the AASHTO 3S2 Design Load

COM Do NOT code the truck specific live load factor in
COM Parameter 6.

COM 12-4.3
LOAD-LIVE-DEFINITION  1, HL-93-TRUCK , DTK, D, ,
LOAD-LIVE-DEFINITION  2, HL-93-TANDEM, DTM, D, ,
LOAD-LIVE-DEFINITION  3, HL-93-TRKTRA, TKT, D, ,
LOAD-LIVE-DEFINITION  4, HL-93-LANE  , DLN, D, ,

LOAD-LIVE-DEFINITION  5, OR-LEG3     , TRK, L, ,
LOAD-LIVE-DEFINITION  6, ORLEG3S2    , TRK, L, ,
LOAD-LIVE-DEFINITION  7, ORLEG3-3    , TRK, L, ,
LOAD-LIVE-DEFINITION  8, ORLEG3-3    , LGT, L, ,
LOAD-LIVE-DEFINITION  9, LEGAL-LANE  , LLN, L, ,

LOAD-LIVE-DEFINITION 10, OR-SU4      , TRK, L, ,
LOAD-LIVE-DEFINITION 11, OR-SU5      , TRK, L, ,
LOAD-LIVE-DEFINITION 12, OR-SU6      , TRK, L, ,
LOAD-LIVE-DEFINITION 13, OR-SU7      , TRK, L, ,

LOAD-LIVE-DEFINITION 14, EV2         , TRK, L, , , ONE
LOAD-LIVE-DEFINITION 15, EV3         , TRK, L, , , ONE

LOAD-LIVE-DEFINITION 16, OR-CTP-2A   , TRK, P, ,
LOAD-LIVE-DEFINITION 17, OR-CTP-2B   , TRK, P, ,
LOAD-LIVE-DEFINITION 18, OR-CTP-3    , TRK, P, ,

LOAD-LIVE-DEFINITION 19, OR-STP-3    , TRK, P, ,
LOAD-LIVE-DEFINITION 20, OR-STP-4A   , TRK, P, ,
LOAD-LIVE-DEFINITION 21, OR-STP-4B   , TRK, P, ,
LOAD-LIVE-DEFINITION 22, OR-STP-4C   , TRK, P, ,
LOAD-LIVE-DEFINITION 23, OR-STP-4D   , TRK, P, ,
LOAD-LIVE-DEFINITION 24, OR-STP-4E   , TRK, P, ,
LOAD-LIVE-DEFINITION 25, OR-STP-5BW  , TRK, P, ,


COM  Use for spans > 200 ft only...
COM LOAD-LIVE-DEFINITION 24, ORLEG3-3     , LTK, L, ,
```

```
COM Truck Specific Live Load Factors


COM 13-1.6
FACTORS-LOAD-LL-LS 1, ST, 1, 1.75
FACTORS-LOAD-LL-LS 2, ST, 1, 1.75
FACTORS-LOAD-LL-LS 3, ST, 1, 1.75
FACTORS-LOAD-LL-LS 4, ST, 1, 1.75

FACTORS-LOAD-LL-LS 5, ST, 1, 1.30
FACTORS-LOAD-LL-LS 6, ST, 1, 1.30
FACTORS-LOAD-LL-LS 7, ST, 1, 1.30
FACTORS-LOAD-LL-LS 8, ST, 1, 1.30
FACTORS-LOAD-LL-LS 9, ST, 1, 1.30

FACTORS-LOAD-LL-LS 10, ST, 1, 1.30
FACTORS-LOAD-LL-LS 11, ST, 1, 1.30
FACTORS-LOAD-LL-LS 12, ST, 1, 1.30
FACTORS-LOAD-LL-LS 13, ST, 1, 1.30

FACTORS-LOAD-LL-LS 14, ST, 1, 1.30
FACTORS-LOAD-LL-LS 15, ST, 1, 1.30

FACTORS-LOAD-LL-LS 16, ST, 2, 1.25
FACTORS-LOAD-LL-LS 17, ST, 2, 1.25
FACTORS-LOAD-LL-LS 18, ST, 2, 1.30

FACTORS-LOAD-LL-LS 19, ST, 2, 1.10
FACTORS-LOAD-LL-LS 20, ST, 2, 1.25
FACTORS-LOAD-LL-LS 21, ST, 2, 1.00
FACTORS-LOAD-LL-LS 22, ST, 2, 1.00
FACTORS-LOAD-LL-LS 23, ST, 2, 1.00
FACTORS-LOAD-LL-LS 24, ST, 2, 1.00
FACTORS-LOAD-LL-LS 25, ST, 2, 1.00

COM Use for spans > 200 ft only...
COM Replace parameter 3 with the legal live load value.
COM FACTORS-LOAD-LL-LS 24, ST, 1.30
```

The Oregon Legal Load designations listed in this example are applicable to BRASS-GIRDER(LRFD) Version 2.0.0 and later. BRASS-GIRDER(LRFD) runs for versions prior to v2.0.0 used the legal load designations OLEG3, OLEG3S2 & OLEG3-3.

Special note: For one-lane (escorted) special permit reviews and true single-lane bridges (roadway width < 20 ft), it is necessary to enter “ONE” for parameter 7 in the LOAD-LIVE-DEFINITION (12-4.3) command. It is not clear in the BRASS Command Manual, but this parameter is needed to force BRASS to apply only a single-lane loading with the appropriate single-lane Distribution Factors.

- BRASS-GIRDER(LRFD) Input Adjustment Type 4:

While performing an analysis on a prestressed girder, it was found that the FACTORS-RESIST-RC and FACTOR-RESIST-PS commands cannot be used simultaneously. Since phi is often different for flexure in prestressed elements and reinforced concrete elements, a different approach was required. Using the FACTORS-RESIST-MOD command to modify phi-s and FACTORS-RESIST-COND command to modify phi-c, BRASS will properly calculate the final phi values for flexure, flexure/tension (RC), and shear. This adjustment would allow both prestress bridges and reinforced concrete bridges to use the same BRASS commands.

Use FACTORS-RESIST-MOD (13-2.4) command, entering FL to designate for flexure in parameter 2 and the System Factor for Flexure in parameter 3. Repeat the command entering SH to designate for shear in parameter 2 and the System Factor for shear in parameter 3. Use FACTORS-RESIST-COND (13-2.5) command, entering the condition factor in parameter 2. Thus the complete phi factor command set is as follows:

```
COM BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 4:
COM  Use the FACTORS-RESIST-MOD command to modify phi-s
COM  Use the FACTORS-RESIST-COND command to modify phi-c
COM  BRASS automatically calculates base phi for flexure,
COM  flexure/tension (RC), and shear

COM 13-2.4
FACTORS-RESIST-MOD ST, FL, 1.0
FACTORS-RESIST-MOD ST, SH, 1.0

COM 13-2.5
FACTORS-RESIST-COND  ST, 0.95
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 5:

  To facilitate crossbeam calculations and to clarify what BRASS is doing regarding liveload Distribution Factors, always include the following lines in the BRASS input file at the end of the “Distribution Factors” section:

```
COM  Request output of LL Distribution Factor computations
OUTPUT-DIST-LL Y, Y
```

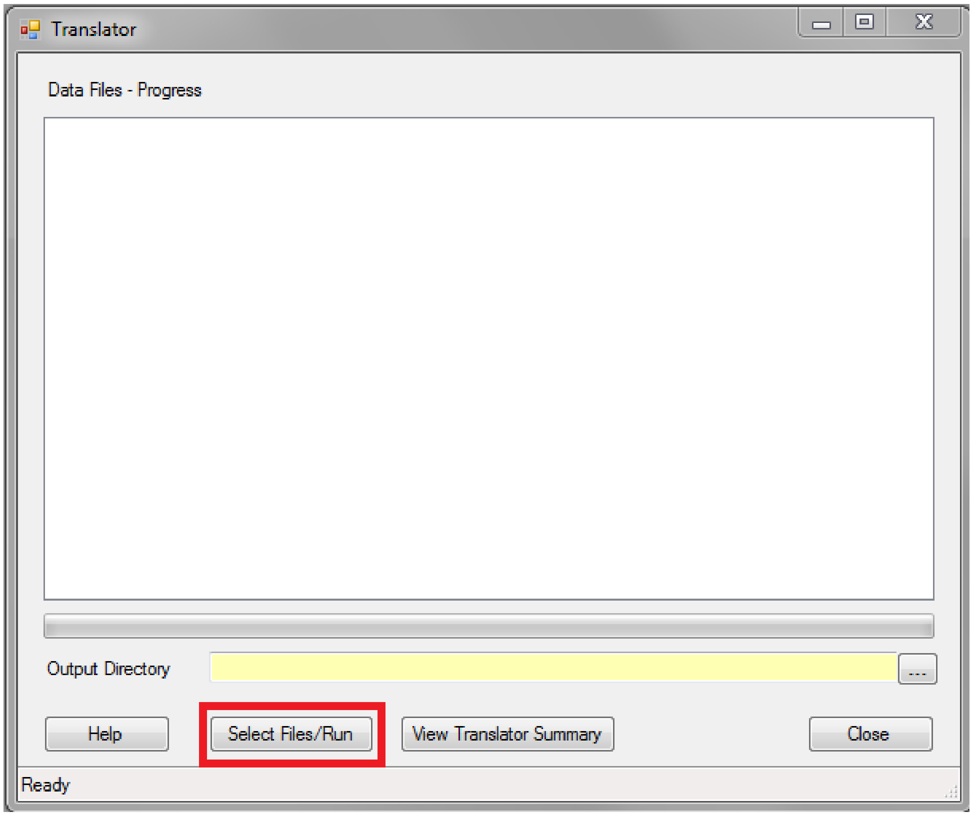
4.4.3 Running BRASS

Open the BRASS-GIRDER GUI interface. Because it is more efficient to use BRASS-GIRDER(LRFD) Input Files generated from previous ones, the GUI interface will not be used to generate input files.

The BRASS-GIRDER(LRFD) input file must first be translated into a BRASS-GIRDER xml file that will then populate the GUI interface in BRASS-GIRDER. The steps for translating and running the input files in BRASS-GIRDER is as follows:

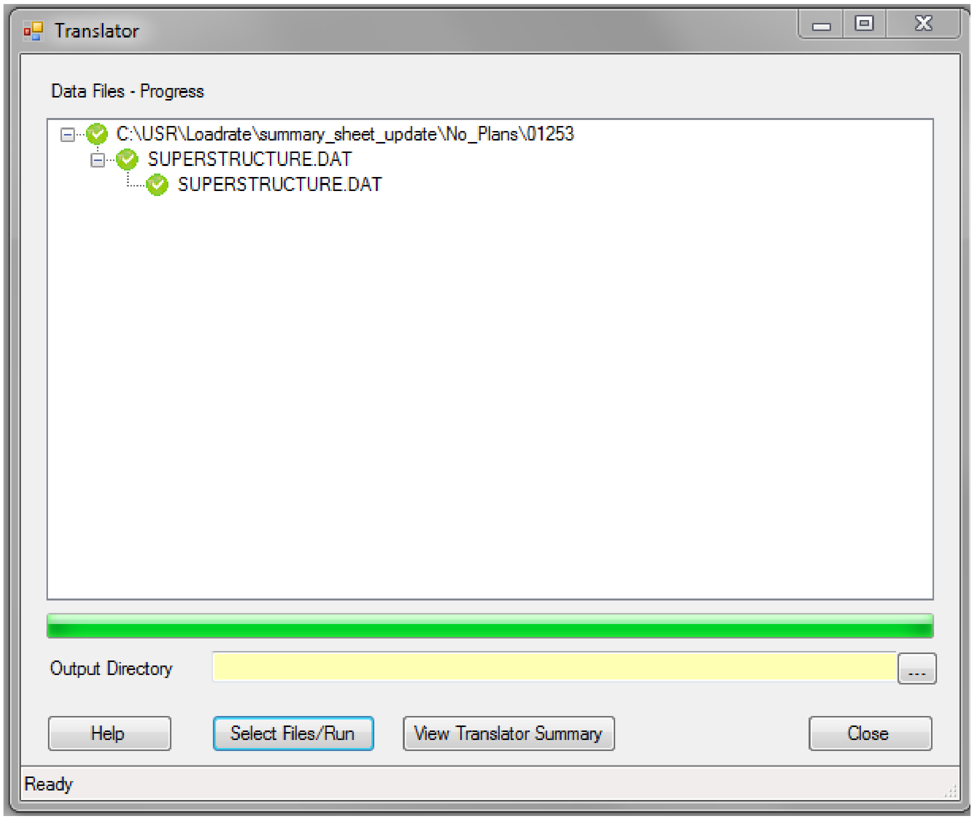
1. Start the BRASS-GIRDER program. From the “File” menu, hover your mouse pointer over “Translate (DAT to XML)”. Select the option for “BRASS-GIRDER(LRFD)”.

2. The Translator window will then open on your screen. Click on the button that says “Select File/Run”, as shown in the red outlined box in the following figure.



3. In the next window that appears, navigate to the location where the BRASS-GIRDER(LRFD) input file that you wish to run is stored, and select that file. Click on the “Open” button at the bottom right of this window.

4. The Translator window will then open back up and the selected file will run through the translation. If there are any errors detected during the translation, a red “X” will be displayed next to the file name in the window and an error file will be generated. Refer to the error file to decipher what is causing the error during translation. Once corrected, follow these steps again to translate the file. If successful, a green check will appear next to the file name as shown in the following figure:



5. Click the “Close” button at the bottom right of the Translator window. Within BRASS-GIRDER, select “Open” under the File menu. Select the BRASS XML file that was just created from the Translator program. Click on the “Open” button at the bottom right of this window.

6. BRASS-GIRDER will then load the model into the GUI. Under the “Execute” menu, select “Analysis Engine” to run the analysis. Or you can simply click on the green traffic light icon on the toolbar.

7. Verify that the output directory is the same as where the input files are located, and then click the “OK” button. A black DOS window will appear showing program progress. Depending on your system speed and memory and the complexity of the structure, the execution process may take a few seconds or several minutes. Upon completion of the analysis, a text output file will be generated within the same directory. You can now use a text editor to open and view the BRASS output.

When making changes or corrections to BRASS files, ODOT prefers that all changes be made within the BRASS-GIRDER(LRFD) input file so that it becomes the master document for the BRASS model. Reviewing this text input file will be quicker and more efficient than trying to navigate the GUI to verify that the bridge is being modelled correctly. Thus, any time the text input file is modified, the above steps will have to be repeated to translate the text input file into a BRASS XML file before the analysis is re-ran in BRASS-GIRDER.

4.4.4 BRASS Errors

If an error file is generated (same prefix, **.**ERR extension), open this file with your text editor and try to interpret what BRASS is telling you. The vast majority of error messages will point you to a straightforward typographical error or omission in your input. At the beginning of your experience with BRASS, do not expect a successful execution until one or more typographical errors have been

corrected.

When executing BRASS-GIRDER, if you get an error message regarding zeros in the stiffness matrix, look at the ANALYSIS (4-1.1) command, parameter 1, and check to see if you are running a Frame type model on a structure with more than 6 spans. In such cases the Beam type model (the recommended default) is required (with a maximum of 13 spans).

When executing BRASS-GIRDER, you may get an error message stating, "*The effective web width (b_v) cannot be zero. This causes a divide-by-zero error in the compression field computations.*" This most likely means that you have selected points that are too close to another defined point of interest within your BRASS input file. A general rule is not to have points closer than six inches from one another. Verify in your input file that you have correctly entered the web width parameter while defining your BRASS sections. Also check in the "Span Length and Section Information" portion of the input file to see that the ranges of the elements are not too close to each other.

A rare error can sometimes occur in executing BRASS-GIRDER where the processing of the analysis takes a considerable amount of time, and then produces a very large output file (around 600 megabytes) along with an error file. The program will report an "Interpolation Error". This occurs on files that have a BRASS span of 99.99 ft and was attempting to increment each truck across the span at 100 increments (as specified in the LOAD-LIVE-CONTROL command). We found that one of two simple workarounds can correct the error: 1) round the BRASS spans from 99.99 ft to 100.00 ft, or 2) increase the live load increment from 100 to 105 in the LOAD-LIVE-CONTROL command. The second method is the preferred option as it only requires a correction in one command, whereas adjusting the span lengths would have required doing it for multiple spans for the bridge that experienced this error.

When executing BRASS-GIRDER, if you get an unexpected termination of the program while attempting to run a file, check the BRASS error file (*.err) to see if it states that, "Standard Vehicle: OLEG3S2 is not presently stored in the standard vehicle library file." This usually means that the user did not update the names of the Legal Vehicle in the BRASS input file. In the early part of 2009, ODOT made a small revision to the vehicle library so that both the old Tier 1 and LRFR rating methodologies would use the same legal vehicles for their analysis. As a result, ODOT changed the names of the legal vehicles. To correct the error, make the following changes to the names of the legal vehicles in the BRASS input file:

Original Vehicle Names	Previous Vehicle Name	Current Vehicle Name
OLEG3	ORLEG3	OR-LEG3
OLEG3S2	ORLEG3S2	ORLEG3S2
OLEG3-3	ORLEG3-3	ORLEG3-3
SU4	SU4	OR-SU4
SU5	SU5	OR-SU5
SU6	SU6	OR-SU6
SU7	SU7	OR-SU7

4.4.5 BRASS Output Files

BRASS-GIRDER(LRFD) has been known to "run perfectly" and still produce completely wrong results. Although a successful run may indicate a lack of errors, it is prudent to search the main output (**.**OUT) file for the words "error" and "warning" to check out the seriousness of the problem, and to do a "reality check" on the Rating Factors. Unexpected Rating Factor results often indicate an error in the BRASS coding.

We recommend that, at the very least, load raters routinely employ the following two BRASS verification measures:

(1) Do a reasonability check on the section properties. This is why we routinely code "Y" in

parameter 2 of the OUTPUT (5-1.1) command, to provide a list of girder properties at each node point. (Search the Output File for "Calculated Properties" in each span). It is not uncommon to make errors in the concrete section definitions, the SPAN-UNIF-HAUNCH (11-1.3) command or the SPAN-SECTION (11-2.1) commands that can result in a girder profile that is quite different than the one you expected.

(2) Do a reasonability check on the distribution of shears and moments across the structure. This is especially critical if you have an expansion joint within the structure that you have modeled by coding a hinge near one of the internal supports. Check if you are getting nearly-zero moments at the support next to the hinge. (It can't be truly zero because of the offset of the hinge from the support, but the moment value should be quite low). There have been cases where, due to numerical instabilities in the analysis process, unreasonably high moments were present at the support. The solution is usually to increase the offset of the hinge from the support in small increments until the reported moments behave as expected (sometimes increasing the offset by hundredths of a foot can make all the difference!).

If you really have doubts about what BRASS is giving you, be aware that you can use additional commands in the OUTPUT- group (BRASS-GIRDER(LRFD) Manual, Chapter 5 to generate additional output that may facilitate your detective work. Use caution – the size of this output can be daunting.

When reading the BRASS Output File, in the Rating Factor Summary sections for Legal Loads, it may be difficult to distinguish between the live load Combo cases because two of them are identified as "ORLEG3-3". In these cases, it is possible to distinguish them by looking for the 3-letter BRASS live load Type codes in parentheses. These codes are defined for parameter 3 of the LOAD-LIVE-DEFINITION command (12-4.3). Thus there will be separate Rating Factor Results for ORLEG3-3 (TRK) which is the Type 3-3 truck by itself, and ORLEG3-3 (LGT) which is the Type 3-3 two-truck train plus Legal Lane load.

4.4.6 Longitudinal Tension Check

Prior to BRASS-GIRDER(LRFD) version 2.0.1, the results of the longitudinal reinforcement tension check (LRFD 5.7.3.5) were not found in the basic output files, but could only be found by performing a detailed analysis of a specific point. The longitudinal tension check is done to ensure that there is sufficient longitudinal reinforcement to resist the tension forces caused by flexure and shear.

With the release of BRASS-GIRDER(LRFD) version 2.0.1, the program now calculates a rating factor for the longitudinal tension check using the worst case of the maximum tension forces developed due to maximum shear and concurrent moment, minimum shear and concurrent moment, maximum moment and concurrent shear, and minimum moment and concurrent shear.
Since the longitudinal tension check rating factor is being computed for every analysis point, and the ODOT Load Rating Summary sheet only has a limited number of columns to report rating factors, the summary sheet has been programmed to only report the longitudinal tension rating factors for a given analysis point only if a rating factor for one of the trucks is lower than 1.1.

Detailed Discussion:

Section 5.7.3.5 of the AASHTO LRFD Bridge Design Specifications has the equation that is used by designers to ensure that there is sufficient longitudinal reinforcement to resist tension forces caused by both shear and flexure. If this equation is not satisfied, the designer simply adds the necessary reinforcement so that the equation is satisfied.

The Manual for Bridge Evaluation (MBE) is based on the AASHTO Bridge Design Specifications. The software ODOT uses for LRFR ratings is BRASS-GIRDER(LRFD). Prior to version 2.0.1, this software performed the tension check as part of the rating, but the basic output (usually several hundred of pages per bridge) did not indicate if the bridge had locations where the tension check failed. The information on the results of the tension check could only be found by examining the additional output that is provided when detailed analysis of a specific point was requested.

While satisfying the tension check is needed to have an accurate model when using Modified Compression Field Theory (MCFT) to calculate shear capacity, there is no guidance in the MBE manual for the load rater to use when the tension check fails. This has been brought to the attention of a primary developer of the LRFR code, Bala Sivakumar, PE, who acknowledged that the current code does not fully address this issue. Christopher Higgins, PhD, PE, from Oregon State University, who lead the effort to test full scale beams has emphasized that the tension check is fundamental to the use of MCFT. The concern of providing the results of the tension check in the basic output has been communicated to the developers of the BRASS software.

There were two areas that needed to be addressed before the load rater could be sure that the tension check had failed. First, all of the reinforcement must be accounted for. Since the ODOT ratings originally counted the reinforcement only when it was fully developed, there may have been a significant amount of partially developed reinforcement available to resist tension forces. Prior to the development of the ODOT Concrete Bridge Generator (CBG), a simple bridge would take several weeks for a load rater to go through all of the detailed output and add up all of the partially developed reinforcement. While many of the points that originally failed the tension check will pass for the lighter loads, the heavier permit loads can still result in a failed condition. Even if all of the points were to pass the tension check, the weeks of analysis would have been inefficient and resulted in a product that was complicated to the point that a secondary check would have been difficult. With the development of the CBG, the partially developed bars are now accounted for in the BRASS model, and thus this first issue is resolved.

The second area that needed to be addressed was the nature of the loading. For a given load, there will be a maximum moment force, and a maximum shear force. For analysis, BRASS-GIRDER(LRFD) uses these maximum values. The actual loading caused by a moving load does result in a point experiencing the maximum force values, but not at the same time. By treating the maximum values as being concurrent, the BRASS analysis of the tension check would be somewhat conservative at some locations.

There are differences between the design of new bridges and the rating of current bridges. MBE section 6A.1.3 states that “Design may adopt a conservative reliability index and impose checks to ensure serviceability and durability without incurring a major cost impact. In rating, the added cost of overly conservative evaluation standards can be prohibitive as load restrictions, rehabilitation, and replacement become increasingly necessary.”

With the release of BRASS-GIRDER(LRFD) version 2.0.1, the program now calculates a rating factor for the longitudinal tension check using the worst case of the maximum tension forces developed due to maximum shear and concurrent moment, minimum shear and concurrent moment, maximum moment and concurrent shear, and minimum moment and concurrent shear. Thus, this second issue has been addressed.

The developers of the MBE code acknowledged that while LRFD does incorporate state-of-the-art design, analysis methods, and loading, that almost all existing bridges were designed using the older AASHTO Standard Specifications for Highway Bridges. Section 6A.1.4 states “Where the behavior of a member under traffic is not consistent with that predicted by the governing specifications, as evidenced by a lack of visible signs of distress or excessive deformation or cases where there is evidence of distress even though the specification does not predict such distress, deviation from the governing specifications based upon the known behavior of the member under traffic may be used and shall be fully documented”.

The 1950’s bridges were designed using Working Stress. Once the stresses of the concrete exceed its ability to resist tension, cracking occurs. This initial cracking takes place at a comparatively low level of loading. The bridge is designed to see “service loads” where the forces in the reinforcement are kept well below the yield point. The bridges that Oregon State University instrumented showed that the reinforcement was being operated well below the yield point. During full scale beam tests to failure, the reinforcement was yielding, but at much higher loads than in-service bridges experience, and with much greater distress.

Even though ODOT and BRASS have found a way to perform the tension check for load rating, this is still an issue to be solved on a national scale. Based on the guidance from the LRFR code, and the lack of distress noted in the vast majority of bridge inspections, Oregon bridges are not being operated anywhere near the level that would cause yielding of the reinforcement as indicated by the failure of the tension check. For those few bridges that do show excessive deterioration, the current LRFR code is sufficient that the known behavior of the member shall be used and be fully documented. Bridges with deterioration consistent with yielding of reinforcement would not be considered for “no work” regardless of the results of the tension check. Calculations for repairs should be done in accordance with the LRFD code and therefore the longitudinal reinforcing should always pass the tension check after the repairs are complete.

4.4.7 BRASS/LRFD Issues Regarding Minimum Transverse Reinforcement

BRASS-GIRDER(LRFD) prior to version 1.6.4 had an error in the use of the AASHTO LRFD 4th Edition (prior to the 2008 Revision) Table 5.8.3.4.2-2 (now Table B5.2-2 in LRFD Eighth Edition), Values of θ and β for Sections with less than minimum transverse reinforcement. It appears that only the top row of the table was used, yielding higher values of β and lower values of θ than should have been used. The result of this was that sections with less than minimum transverse reinforcement were assigned higher rating factors than they should have been.

A comparison of shear rating factors was accomplished using BRASS-GIRDER(LRFD) versions 1.6.5 and 1.6.2. For the three bridges selected, locations outside of horizontally tapered webs had adequate transverse reinforcement, and the shear ratings were unaffected by the corrections to how the table was used for less than minimum transverse reinforcement. However, some sections inside horizontally tapered webs do have less than the minimum transverse reinforcement. These sections experienced a significant drop in rating factors.

The bridge designers in the 1950’s sometimes used an increased concrete cross section to resist shear forces near interior bents. The very technique that gained shear capacity using the AASHTO LRFD Design Specifications now causes the section to have less than minimum transverse reinforcement. The extra concrete the 1950’s designers used to increase shear capacity has the unintended consequence of placing a section with good reinforcement details into a design code table that was never intended to be used for design.

Prior to the 2008 Revisions of LRFD Article 5.7.3.4.2 (General Procedure for Determining Shear Resistance in Concrete Beams) beta and theta were determined by an iterative procedure (which is now in LRFD Appendix B5):

- For sections with minimum transverse reinforcement – For an applied load, an assumed value of theta is initially used to calculate the longitudinal strain in the web at $0.5d_v$. The shear stress ratio is computed for the section. Using Table B5.2-1, the longitudinal strain and shear stress ratio are used to determine a new value of theta and beta. This new value of theta is used to calculate a new longitudinal strain, which is then used in Table B5.2-1 to compute a new theta and beta. The process continues until theta is solved. The final values of theta and beta are then used in computing the shear resistance of the concrete section.

- For sections with less than minimum transverse reinforcement – the procedure is similar to that above. The only differences being are that the longitudinal strain is calculated at the location in the web subject to the highest longitudinal tensile strain, and instead of using the shear stress ratio with the longitudinal strain in Table B5.2-1 to determine a new theta and beta, the crack spacing parameter is used with the longitudinal strain in Table B5.2-2.

- When calculating the longitudinal strain for a section, longitudinal bars on the flexural tension side of the member that were not fully developed were to be ignored.

In LRFD Article 5.7.3.4.2, beta and theta are determined by direct solution using algebraic equations:

- The strain in non-prestressed longitudinal tension reinforcement is directly computed for a given load. This strain is used directly in the equations to compute theta and beta.

- The value of theta is the same regardless if the section has less than or contains at least the minimum transverse reinforcement. Thus, there is only one direct solution for theta.

- There is one equation for beta for sections containing at least the minimum transverse reinforcement. There is a different equation for beta for sections with less than minimum transverse reinforcement, which is similar to the first but has an added component containing the crack spacing parameter.

- In calculating A_s, the area of bars terminated less than their development length from the section under consideration should be reduced in proportion to their lack of full development (instead of ignored).

In most cases, the new direct solution equations in the 2008 Revisions are producing higher capacities for sections that have less than minimum transverse reinforcement. The main reason is that theta no longer is penalized, which results in shallower crack angles allowing for more stirrups within the member to contribute to the shear resistance.

Unfortunately, the old iterative method is still a valid option in the LRFD code, as the 2008 Revisions have placed the old Article 5.7.3.4.2 language in Appendix B5. BRASS Girder (LRFD) Version 2.0.3 has been updated to include the 2008 revisions of the AASHTO LRFD code. The algebraic equations are now used to calculate shear capacity.

4.4.8 Continuous Multi-Spanned Bridges with Varied Span Lengths

We were made aware of an issue that occurs with continuous multi-span bridges, when the adjacent span lengths vary by a considerable amount. It was noticed that the maximum positive moment sections were being evaluated at odd locations (0.1L for an end span and 0.4L for an interior span). This was a result of our original practice of basing these locations off of the dead load maximum moment locations and not the factored combined (dead load and live load) maximums. The maximum dead load moment location shifts were due to the uplift in short spans caused by the dead load of an adjacent long span.

To compensate for the uplift effects of dead load on the adjacent short spans, we will now use the maximum and minimum Load Factors stipulated in AASHTO LRFD Table 3.4.1-2. As a result, we have modified the BRASS Input Adjustment Type 2 commands in the BRASS input files to the following:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,

COM 13-1.2
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65
```

The heavier vehicles will produce a maximum positive moment location closer towards the midspan, while the lighter vehicles will produce a maximum positive moment location away from midspan towards the maximum moment location of the dead load. Therefore, in order to capture the maximum positive moment for the entire suite of vehicles that we use in load rating, we may have to establish a range of points where the different vehicles will produce their maximum positive moment.

In order to facilitate this procedure, we have developed a new application (BRASS Moment Analyzer) that will evaluate the BRASS output files after an initial BRASS run and determine if the maximum positive moment locations for the live loads differ from the dead load locations. If so, the program will then analyze the differences in the locations and then provide a range of recommended positive moment locations (at 20th points) along with the BRASS commands for these new flexural analysis locations that can be copied and pasted into the BRASS input files. The program will create a text file, with the modified name of _MOMENT_INITIAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

After the final BRASS run, the BRASS Moment Analyzer can be used to once again evaluate the BRASS output files. This time, the software will check and report if the maximum combined moment for every vehicle at each analysis point is negative, positive, or contains both negative and positive values. The program will allow the user to print a summary report which they can refer to when selecting the type of moment during the BRASS import of the moment locations on the Load Rating Summary sheet. The program will create a text file, with the modified name of _MOMENT_FINAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

Do not include the BRASS Moment Analyzer output in the printed Load Rating Calc. Book. We only request that the .TXT files that it produces be included with the electronic files for the load rating.

The intent is to only use the BRASS Moment Analyzer for continuous bridges with adjacent span lengths that vary more than 30%.

4.5 Edge Strip Analysis

Use the interior slab files as a starting point for creating the edge strip files. Most of the interior strip file will still apply for the edge strip analysis. Because the interior file is used as a starting point, it is suggested to not begin the exterior girder analysis until throughout checking of the interior files have been completed. Any mistakes found in the interior file would likely also be mistakes in the exterior file.

4.5.1 Generating an Exterior Strip Preliminary File from an Interior Strip File

It is not necessary to create separate preliminary files for interior and exterior strips. Typically the only variation between interior and edge strips is in how the distribution factors are calculated. Therefore, include any edge strip calculations within the interior slab preliminary file.

It is common for the edge strip to have different reinforcement details than the interior strips. In these cases it may be advantageous to analyze a wider edge strip than the common 12 inches. The maximum allowable edge strip width is the minimum width calculated per AASHTO LRFD 4.6.2.1.4.

4.5.2 Generating an Edge Strip CBG File from an Interior Strip CBG File

For the typical un-widened RC Slab structure where the exterior strip design is similar to the interior strip, the task of generating an edge strip CBG file from the corresponding interior strip CBG file generally consists of the following steps:

(1) With the completed IntGir CBG file opened in the CBG program, change the “Member Being Load Rated” field from RCSlab to EDGSTP.
(2) Under the “Concrete Dimensions” Tab, revise the value of the slab width for each cross-section to the value that was computed in the RC Slab Preliminary File. Note: the slab width will only change if the edge strip needs to be analyzed as a wider section due to different edge strip reinforcement.
(3) Update any reinforcement details that changed from the interior slab. The edge strip commonly has different longitudinal mild reinforcement.
(4) Save the CBG data file.

4.5.3 Generating an Edge Strip BRASS Input File from an RC Slab File

The task of generating an Edge Strip BRASS input file from the corresponding RC Slab (interior strip) BRASS input file generally consists on the following steps:

(1) Copy **RCSLAB.DAT** to **EDGSTP.DAT**.
(2) From the EDGSTP CBG file, copy the BRASS commands that are displayed from selecting the “Generate BRASS File Input” button and paste them over the commands from the beginning of the EDGSTP.DAT file up to the point of the dead loads definitions..
(3) Per AASHTO LRFD 4.6.2.1.4b, Edge beams shall be assumed to support one line of wheels and, where appropriate, a tributary portion of the design lane loads. BRASS-GIRDER will automatically reduce the truck live load to one line of wheels when an edge-strip analysis is performed. However, thelane live loads need to be manually reduced by a tributary portion. These calculations are performed in the preliminary file under Edge Strip Distribution Factors Summary. The maximum of the single and multiple lane edge strip width is divided by 10 ft to determine the tributary portion. This fraction is input in parameter 6 of BRASS command 12-4.3 for the lane load.

For the EDGSTP.DAT file:

```
COM Do NOT code the truck specific live load factor in
COM Parameter 6.

COM FOR EDGE STRIPS
COM The lane load must be reduced by the tributary portion.
COM Code the tributary fraction calculated in the preliminary
COM file (RCSLAB.XMCD) in parameter 6 for all lane loads.

COM 12-4.3
LOAD-LIVE-DEFINITION  1, HL-93-TRUCK , DTK, D, ,
LOAD-LIVE-DEFINITION  2, HL-93-TANDEM, DTM, D, ,
LOAD-LIVE-DEFINITION  3, HL-93-TRKTRA, TKT, D, ,
LOAD-LIVE-DEFINITION  4, HL-93-LANE  , DLN, D, , 0.6

LOAD-LIVE-DEFINITION  5, ORLEG3      , TRK, L, ,
LOAD-LIVE-DEFINITION  6, ORLEG3S2    , TRK, L, ,
LOAD-LIVE-DEFINITION  7, ORLEG3-3    , TRK, L, ,
LOAD-LIVE-DEFINITION  8, ORLEG3-3    , LGT, L, ,
LOAD-LIVE-DEFINITION  9, LEGAL-LANE  , LLN, L, , 0.6

LOAD-LIVE-DEFINITION 10, SU4         , TRK, L, ,
LOAD-LIVE-DEFINITION 11, SU5         , TRK, L, ,
LOAD-LIVE-DEFINITION 12, SU6         , TRK, L, ,
LOAD-LIVE-DEFINITION 13, SU7         , TRK, L, ,

LOAD-LIVE-DEFINITION 14, OR-CTP-2A   , TRK, P, ,
```

```
LOAD-LIVE-DEFINITION 15, OR-CTP-2B   , TRK, P, ,
LOAD-LIVE-DEFINITION 16, OR-CTP-3    , TRK, P, ,

LOAD-LIVE-DEFINITION 17, OR-STP-3    , TRK, P, ,
LOAD-LIVE-DEFINITION 18, OR-STP-4A   , TRK, P, ,
LOAD-LIVE-DEFINITION 19, OR-STP-4B   , TRK, P, ,
LOAD-LIVE-DEFINITION 20, OR-STP-4C   , TRK, P, ,
LOAD-LIVE-DEFINITION 21, OR-STP-4D   , TRK, P, ,
LOAD-LIVE-DEFINITION 22, OR-STP-4E   , TRK, P, ,
LOAD-LIVE-DEFINITION 23, OR-STP-5BW  , TRK, P, ,

COM  Use for spans > 200 ft only...
COM LOAD-LIVE-DEFINITION 24, ORLEG3-3     , LTK, L, ,
COM Truck Specific Live Load Factors

COM 13-1.6
FACTORS-LOAD-LL-LS 1, ST, 1, 1.75
FACTORS-LOAD-LL-LS 2, ST, 1, 1.75
FACTORS-LOAD-LL-LS 3, ST, 1, 1.75
FACTORS-LOAD-LL-LS 4, ST, 1, 1.75

FACTORS-LOAD-LL-LS 5, ST, 1, 1.36
FACTORS-LOAD-LL-LS 6, ST, 1, 1.36
FACTORS-LOAD-LL-LS 7, ST, 1, 1.36
FACTORS-LOAD-LL-LS 8, ST, 1, 1.36
FACTORS-LOAD-LL-LS 9, ST, 1, 1.36

FACTORS-LOAD-LL-LS 10, ST, 1, 1.36
FACTORS-LOAD-LL-LS 11, ST, 1, 1.36
FACTORS-LOAD-LL-LS 12, ST, 1, 1.36
FACTORS-LOAD-LL-LS 13, ST, 1, 1.36

FACTORS-LOAD-LL-LS 14, ST, 2, 1.35
FACTORS-LOAD-LL-LS 15, ST, 2, 1.35
FACTORS-LOAD-LL-LS 16, ST, 2, 1.41

FACTORS-LOAD-LL-LS 17, ST, 2, 1.21
FACTORS-LOAD-LL-LS 18, ST, 2, 1.36
FACTORS-LOAD-LL-LS 19, ST, 2, 1.00
FACTORS-LOAD-LL-LS 20, ST, 2, 1.06
FACTORS-LOAD-LL-LS 21, ST, 2, 1.05
FACTORS-LOAD-LL-LS 22, ST, 2, 1.00
FACTORS-LOAD-LL-LS 23, ST, 2, 1.00


COM Use for spans > 200 ft only...
COM Replace parameter 3 with the legal live load value.
COM FACTORS-LOAD-LL-LS 24, ST, 1.30
```

Special note: For one-lane (escorted) special permit reviews and true single-lane bridges (roadway width < 20 ft), it is necessary to enter "ONE" for parameter 7 in the LOAD-LIVE-DEFINITION (12-4.3) command. It is not clear in the BRASS Command Manual, but this parameter is needed to force BRASS to apply only a single-lane loading with the appropriate single-lane Distribution Factors.

(4) Change the first parameter of the DIST-CONTROL-SLAB (4-3.1.1) command from an "I" to an "E".

SECTION 5: LOAD RATING PRESTRESS CONCRETE GIRDER BRIDGES

This section applies to most precast prestressed concrete sections, such as Prestressed Bulb-I and Bulb-T Girders, Prestressed Slab Girders, and Prestressed Box Girders. Post-tensioned members are covered in Section 6.

5.0 Scoping of Structure

Create a scoping file (nnnnnn_scope.xls) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended affect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0 then, there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

5.1 Decide What Girders to Analyze

Due to the effects of all the various LRFD Distribution Factor provisions, it is difficult to predict which girder will control the load rating. Therefore a separate preliminary file and BRASS input will be required for both the interior and exterior girder. In the Load Rating Summary Workbook file, importing the rating factors from both girders is required (be sure to do a “Refresh” after the second import) because it is not uncommon for different girders to control for different loads.

In the case of a prestressed slab or box girder bridge with a sidewalk or rail and curb that covers half or more of a 4-foot exterior girder width, or 1 foot or more of a 3-foot exterior girder width, the exterior girder does not need to be analyzed. This is due to the distribution factors becoming zero for the exterior girder in this situation.

Due to BRASS Girder(LRFD)’s inability to analyze multiple non-continuous spans (BRASS will treat multiple prestress spans simply supported for dead load and continuous for liveload), a separate BRASS analysis will be needed for each unique non-continuous prestress span.

5.2 Preliminary Files for Girders (Mathcad)

For prestressed concrete girder bridges, the preliminary file name and extension (Mathcad) for interior girders is typically PSINT.xmcd. The preliminary file name and extension for exterior girders is typically PSEXT.xmcd.

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied terms with parentheses.

5.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description ("Spans" field) from the Bridge Log is adequate for this purpose.

Note: the Mathcad regions at the top in the right margin (outside the printable area) are there for 2 purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

5.2.2 Resistance Factors

Document the decisions regarding all 3 Resistance Factors, with references to the appropriate MBE tables.

BRASS-GIRDER(LRFD) provides input for the MBE Condition Factor ϕ_c (MBE 6A.4.2.3) and System Factor ϕ_s (MBE 6A.4.2.4). However, the ODOT Load Rating Summary Sheet and the ODOT Crossbeam Load Rating Software always require and display the product of all the resistance factors as a single ϕ factor. Therefore, the product of all these resistance factors must always be obtained.

Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure in RC Members:
$\Phi_f = \phi$ [max ($\phi_c\phi_{sf}$, 0.85)]
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Flexure in PS Members:
$\Phi_f = \phi$ [max ($\phi_c\phi_{sf}$, 0.85)]
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Shear:
$\Phi_v = \phi\ [\ \max\ (\phi_c\phi_{sv}\ , 0.85)\ ]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).

Generally Φ_f and Φ_v will be the same for redundant members such as girders and will be different for non-redundant members such as single-span and 2-span crossbeams.

5.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into BRASS. The Load Rating Summary Workbook **(LR.XLT)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and effective bridge length. Note that effective bridge length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which Live Load Factor Application is used, ADTT is specified as “one direction”. Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the Live Load Factor Application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the Live Load Factor Application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the “LRFR Strength I & II” table from the live load factor application, and in Mathcad use Edit / Paste Special. In the “Paste Special” dialog box choose the “Paste” button, highlight “Bitmap” in the “As” list, and click the “OK” button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to MBE 6A.4.4.3.

5.2.4 Material Properties

Enter the material properties and calculate elastic modulus for reinforced concrete (E_c) and prestressed concrete (E_{psc}). Then compute the modular ratio for concrete materials (n), prestress materials (n_{psc}), and composite materials (n_c). Use AASHTO LRFD Equation 5.4.2.4-1 to determine the elastic modulus of concrete, assuming K_1=1.0. Document assumptions made about the material properties if they are not given on the Bridge Plans.

Precast prestress reinforced concrete shall use a minimum unit weight of 0.155 kcf. This minimum is based on recommendations from the precast industry. AASHTO LRFD T3.5.1-1 has a formula used to calculate the density of concrete based on compressive strength. If the 28 day compressive strength is greater than 10.0 ksi use AASHTO LRFD T3.5.1-1 to compute the density.

5.2.5 Bridge Average Geometry

Calculate the physical edge-to-edge width of the concrete slab and the roadway width of the bridge. If the width of the slab or roadway changes over the length of the bridge, calculate the average roadway width per span. Enter the skew angle of the bridge. These values are entered in BRASS to calculate the Distribution Factors.

5.2.5.1 Span Layout

Typically, precast girders are longer than the supported span length. BRASS optionally allows the beam overhang to be specified, so end effects are more accurately modeled. When the beam overhang is specified, debonding, transfer, and development lengths may be specified without having to perform any adjustments. The user is required to specify the length of each span to be used for analysis. These span lengths are used for every stage of construction during a BRASS analysis. For most bridges, use the distance between centerlines of the bearings as the BRASS span length; not the span length designated on the plans which runs from the center to center of each bent.

However, there is an exemption to the above rule. There are designs that required the girders to bear on temporary supports during construction, which were located a specified distance before the end of the girder. Then the closure pour and deck placement encased the ends of the girders within the bent and the temporary supports were later removed, thus making the center of bearing located at the center of the bent (beyond the end of the prestressed girder).

Multi-span prestressed bridges can be either simply supported for both dead load and live load, or be simple for dead load and made continuous for live load. BRASS is not capable of modeling multiple prestressed spans that are simply supported for both dead load and live load. Each unique span will require its own BRASS run, and a BRASS reaction run will be required to obtain the live load reactions for interior crossbeams.

For multi-span bridges having pretensioned simple spans made continuous for live load, continuity may be obtained through composite action using non-prestress reinforcement or by post-tensioning additional strands. The interior supports for these structures are double bearing piers and BRASS does not consider the gap (diaphragm) between the ends of the adjacent girders.

For girders to be modeled as continuous over a support, all of the following conditions must be met:

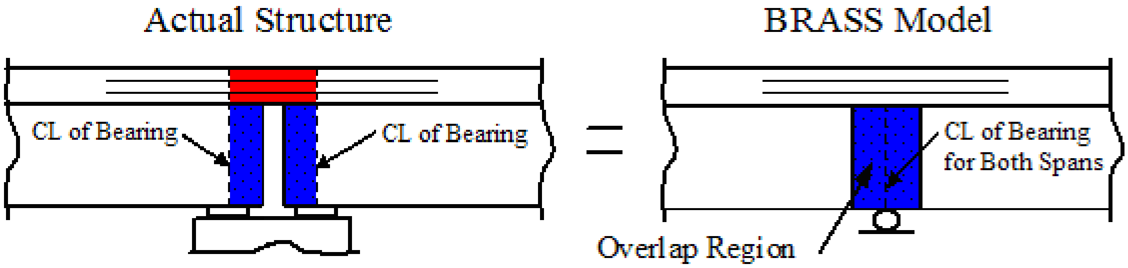
1. The addition of negative moment reinforcement in the deck spanning over the support.
2. A concrete closure pour (plug) in between the end of the girders at the support to transfer the negative moment compression block from one span to the other.
3. The girders must line up from one span to the other.

Otherwise, model the spans as simply supported.

For some bridges, the above conditions 1 and 2 may be satisfied to show that the intent was for the spans to act continuous over the support. But, when the girders do not line up, we are relying on the stiffness of the bent to transfer the compression block from one span to the other. Thus, the bent is acting similar to a spring. Without performing a finite element model of the bent to determine how stiff it is, we have no idea of the force values to enter in the SUPPORT-SPRINGS command (11-4.2) for

BRASS. Since we know that the behavior of the bridge is going to be in between continuous and simply supported, it is more conservative (and easier) to model the spans as simply supported.

Most bridge plans list the span lengths from the center of bent to center of bent. To model the bridge in BRASS (from center of bearing to center of bearing), the portions of the bridge that extend beyond the center of the support will be ignored in the BRASS model as illustrated by the blue and red shaded areas in the following figure.



The red section represents the deck and rail area that will be ignored and not modeled in the BRASS model. The blue section represents the girder overhang area that will not be modeled in BRASS for dead load, but will be accounted for by using the PS-BEAM-OVERHANG (9-2.3) command to specify the beam overhang beyond the ends of the span or past the centerline of bearing. The white area in between the blue areas will be either an empty void (as in the case for simply supported spans, and thus will have a separate BRASS model per each unique span) or will contain concrete from a closure pour (plug). The PS-BEAM-OVERHANG command provides additional distance to accommodate transfer, development, and/or debond length for the prestressing strands, but will not add dead load for the additional girder length or concrete material beyond the centerline of bearing.

In order to accurately model the prestressed girders, the harp points will need to be converted from their locations along the girder to their locations along the BRASS spans. This can be done by using the following table in the preliminary file.

Span Layout: (double left click table to enter input, yellow fields require input)

Span #	Span Length (ft)	Girder Length (ft)	Overhang Left (in)	Overhang Right (in)	Span Length (in.)	Left harp point along beam (ft)	Right harp point along beam (ft)	Left harp point along beam (ft) (Brass Input)	Right harp point along beam (ft) (Brass Input)
1	68.000	68.500	6.500	-0.500	816.000	30.917	30.917	30.375	37.041
2	68.000	67.917	-0.500	-0.501	816.000	30.625	30.625	30.667	37.333
3	68.000	67.917	-0.500	-0.501	816.000	30.625	30.625	30.667	37.333
4	68.000	67.917	-0.500	-0.501	816.000	30.625	30.625	30.667	37.333
5	68.000	68.500	-0.500	6.500	816.000	30.917	30.917	30.959	37.625

Double left clicking on the table will allow Mathcad to enter the Excel interface. Once there, the table should be adjusted for the number of spans present on the bridge. Enter the length of each span (distance between centerlines of the supports as shown on the plans). Enter the actual length of the girders for each span as shown on the beam schedule in the plans.

Next, enter the overhang of the girders for the left side of each span. The value is measured from center of bent to end of beam. A positive value indicates the girder extends longer than the center of bent, and a negative value indicates the girder terminates short of the center of bent. The table will then automatically calculate the overhang on the right end of the span.

Next, enter the left harp point location measured from the actual left end of the girder concrete. Then enter the right harp point location measured from the actual right end of the girder concrete. The left and right harp points in reference to the BRASS span length (center-to-center of bents) are then computed.

5.2.6 Shear Reinforcement Layout

Use an embedded Excel spreadsheet within Mathcad to calculate the ranges and span fractions for the shear reinforcement layout for each span as indicated below. Double-clicking on an embedded spreadsheet activates Excel, and its toolbars and functionality become available. An existing embedded Excel spreadsheet can be copied, pasted in another location and modified to do similar calculations for another span. Determine the shear reinforcement bar size(s) and area(s) that are present in each span that will contain analysis sections. Then for each span that contains analysis sections, working consecutively from the left end of the span to the right, populate the yellow fields in the following table in the preliminary file. Where there is an approximate "plus-or-minus" stirrup spacing given near the middle of a span, it is necessary to calculate this "remnant spacing" in Mathcad in order to complete the shear reinforcement layout accurately enough to code it in BRASS.

Span # :	1		Span Length :	68	ft	
Section	Spaces	Spacing (in.)	Start (in.)	Range (in.)	End (in.)	Span Fraction
1	7	4	3.00	28	31.00	0.004
2	4	11	31.00	44	75.00	0.038
3	25	13	75.00	325	400.00	0.092
4	1	9	400.00	9	409.00	0.490
5	25	13	409.00	325	734.00	0.501
6	4	11	734.00	44	778.00	0.900
7	8	4	778.00	32	810.00	0.953

5.2.7 Component Dead Loads (DC)

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the Preliminary (**.xmcd**) File as they will appear in the BRASS Input (**.**DAT) File. Use AASHTO LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c. For dead load calculations, use w_c+0.005 kcf to account for the reinforcement, in accordance with AASHTO LRFD Commentary C3.5.1.

Consider diaphragm point loads to be part of component load DC. Include any diaphragms/end beams at the end of the girder over the support, as they will be utilized when applying the girder dead load reactions to crossbeams.

For Prestressed Slabs and Boxes, include the diaphragm loads at the tie rod locations.

When a composite deck is to be defined in BRASS, the uniform dead load of the deck per girder will need to be computed and applied as part of the component load DC.

Where standard rail drawings occur, wherever possible use the rail dead loads tabulated in Appendix H - ODOT Standard Rail Weights, found in file **RAILDL.XLS**. Provide detailed calculations for the dead load of any rail not found in this summary.

For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all rail, curb and sidewalk dead loads (stage 2 dead loads) equally among all girders.

Account for the additional dead load of the End-Block over the length of the End-Block near the end of the girder. This will be for the additional concrete area outside of the area contained within the cross-section being modeled in BRASS.

Add a point load at the center of bearing to account for the dead load of the rails, deck, and girder that extend beyond the center of bearing (the blue and red shaded areas illustrated in Article 5.2.5.1). Even though these loads will have no impact to the load rating of the girder, they will be utilized when applying the girder dead load reactions to crossbeams.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16” diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to need to be included in the load rating.

5.2.8 Wearing Surface Dead Loads (DW)

Always separate wearing surface dead load (DW) from the component (DC) dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes, and (c) it facilitates input for the Crossbeam Load Rating Software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Show calculations for wearing surface dead load distributed equally to all the girders. Add 1” to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½” to the design thickness of PPC overlays to account for construction variations and uncertainty.

For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all wearing surface dead loads (stage 2 dead loads) equally among all girders.

Add a point load at the center of bearing to account for the dead load of the wearing surface that extends beyond the center of bearing (the red shaded area illustrated in Article 5.2.5). Even though this load will have no impact to the load rating of the girder, it will be utilized when applying the girder dead load reactions to crossbeams.

5.2.9 Live Loads (LL)

Simply list the four classes of rating loads to be analyzed. (See Articles 1.5.1.1 through 1.5.1.4).

5.2.10 Analysis Sections

Determine the spans to be investigated. These should be any span that is unique and is not repeated due to symmetry or due to repetition of a span between joints.

Within each span, check for symmetry of sections, reinforcement and loads, and do not identify any analysis points that are structurally symmetrical with analysis points already defined. Defining analysis points that are structurally symmetrical has the potential effect of corrupting the Load Rating Summary Sheet. Because the “Refresh” module is looking for the lowest Rating Factors, defining a symmetrical point causes it to identify the most critical rating location twice, thus preventing it from identifying the second most critical analysis point. The second controlling point is useful information in evaluating potential repairs for the bridge.

The commentary of MBE Article C6A.5.8 states that for prestressed concrete, multiple locations (preferably at 0.05 points) need to be checked for shear. The location where shear is highest may not be critical because the corresponding moment may be quite low. Typically, locations near the 0.25 point could be critical because of relatively high levels of both shear and moment.

Therefore, to follow the recommendation of the MBE code for prestressed concrete, check shear at all points (including 0.05 points) between the critical shear section locations.

The maximum positive moment location is at the mid-span for simple spans, and can vary between 0.4L to 0.6 L for continuous spans. For prestressed girders with harped strands, the harp location is usually located at 0.4L to 0.45L. Due to the possibility that flexural capacity decreases faster than the positive moment demand, check the harp locations for moment. Thus, for prestressed concrete both shear and moment will be checked for the 0.05 points from 0.4L to mid-span in simple spans and from 0.4L to 0.6L for continuous spans.

For continuous spans, there is no need to check shear at the supports since the closure pour is not considered part of the prestressed girder. Therefore, only check negative moment over each unique support for continuous spans.

Besides the locations listed above, there are a number of additional analysis sections for shear. For each unique span, subdivide the calculations of analysis sections into the categories (up to 5) given in article 1.5.3. Summarize the underlined headings that will begin each section of calculations. An example of this summary follows:

<u>Span 1 Critical Shear Section Points</u>
<u>Span 1 0.05 Location Points</u>
<u>Span 1 Stirrup Spacing Change Points</u>
<u>Span 1 Large Crack Location Points</u>

<u>Span 2 Negative Moment Section</u>
<u>Span 2 Critical Shear Section Points</u>
<u>Span 2 0.05 Location Points</u>
<u>Span 2 Stirrup Spacing Change Points</u>
<u>Span 2 Large Crack Location Points</u>

<u>etc</u>.

Then repeat each header, one by one, and under each header provide the calculations necessary to determine or document the location of each shear investigation point in that category. Thus there will be up to 5 separate calculation sections for each span. In any calculation section, if any particular point duplicates a previously calculated point or is within 1 ft of a previously calculated point, the new point may be omitted. In this case, explain the omission by indicating which previously identified point already covers the current one. This gives priority to critical sections and bar cutoff points when near-duplicates are encountered.

Note that the Microsoft Excel templates have been added which will generate BRASS commands for these shear analysis points. Copy as required and paste into the BRASS preliminary input file.

- Critical Shear Section Points

  According to AASHTO LRFD Article 5.7.3.2, critical shear section locations shall be taken at shear depth d_v from face of support. AASHTO LRFD Article 5.7.2.8 states that the effective shear depth (d_v) is taken as the distance, measured perpendicular to the neutral axis, between the resultants of the tensile and compressive forces due to flexure; it need not be taken to be less than the greater of $0.9d_e$ or $0.72h$ (in.). Thus, for flexural members the distance between the resultants of the tensile and compressive forces due to flexure can be determined as:

$$d_v = \frac{M_n}{A_s f_y + A_{ps} f_{ps}}$$ (AASHTO LRFD C5.7.2.8-1)

For prestressed members with harped strands, the calculation of the moment capacity at given distance from the support in the above equation becomes complicated and would require an iterative approach. To simplify the approach, the critical section at d_v shall be calculated as 0.*72* h (in.) from the support face. Do this for each critical section location (each end of each unique span).

In the event that the above equation produced a higher d_v, 0.72h will be more conservative as it is located closer to the support thus resulting in higher shear location that is being analyzed. Likewise, if $0.90d_e$ is greater than 0.72h, using 0.72h will be located closer to the support thus resulting in higher shear location that is being analyzed. In the event that 0.72h is greater than the above equation or $0.90d_e$, then 0.72h will be in compliance with AASHTO LRFD Article 5.7.2.8.

In previous versions of BRASS (LRFD) the skew correction factor was applied to the first segment only. Because of this it was important to not code any nodes within the critical section. BRASS (LRFD) v2.0.3 now applies the skew correction factor across the entire span. For shear the skew factor will be applied at the support and will decrease linearly to unity at midspan. With this update, section changes (node points) can now be defined within the critical section.

- Flexural Bar Cutoff Points

For prestressed girder bridges, normally flexural bar cutoffs occur in the composite deck. Since the critical shear points, 0.05 location points, and stirrup spacing change points are already being checked for shear throughout the length of the girder, the bar cutoff points will not need to be checked for shear.

If the Inspection Report indicates flexural cracking in the negative moment areas (transverse deck cracking over interior supports), the flexural bar cutoff points shall be checked for negative moment.

For most concrete bridge types the most tedious portion of LRFR ratings is to locate the bar cutoff points and identify nodes and unique sections for BRASS input. However, for single span or simply supported prestressed concrete bridges there will usually be no bar cutoffs. And for prestressed concrete bridges that are made continuous for live load, all of the bar cutoffs occur within the deck slab, resulting in a smaller number of unique sections.

In the early days of ODOT LRFR load ratings, **BarCutoffs.XLS** was the tool that was used to organize the unique sections for each span. In the case of prestressed girders continuous for live load, the tool was just used to organize the sections that needed to be defined, not to identify shear analysis points.

If there were no bar cutoffs present in the span, one was simply able to insert a note in the preliminary file stating such, instead of including the BarCutoffs.XLS file stating the same thing.

Unlike reinforced concrete sections, the development lengths for bar cutoffs do not need to be coded for capacity analysis. For mild reinforced structures, the **ODOT Concrete Bridge Generator (CBG)** software has been developed to aid in the process of coding mild reinforcement development lengths. Without the aid of the ODOT CBG software this task would be tedious. Because prestressed concrete only has a few bar cutoff analysis points, the decision to include the partially developed reinforcement will be left to the Load Rating Engineer. If an analysis section falls within a development length, then this partial reinforcement may be coded to increase the sections capacity.

The **BAR_Ld.XLS** tool is used to calculate bar development length, top bar and bottom bar calculations for both 40 ksi and 60 ksi rebars. In accordance with AASHTO LRFD 5.10.8.2.1a, the minimum L_d is 12”, except for standard hooked bars which can have a minimum l_{dh} of 6”. In accordance with AASHTO LRFD 5.10.8.2.1b, note that there are two columns for “TOP” “STRAIGHT” bars in the file, one that includes the 1.4 factor are for top bars with >12” of concrete below them, and the other for top bars with ≤ 12” of concrete below them. Note the 1.4 factor does not apply to top bars in slabs <14” thick.
For bars that have a 90^o or 180^o standard hook (as illustrated in the figure below), the reference tool **BAR_Ld.XLS** has the development length l_{dh} for each bar computed in accordance with LRFD 5.10.8.2.4a. One thing to note is that for some bar sizes with a f_y = 40 ksi, the development length of the standard hooked bar is larger than that of the straight bar of equal size. It is ODOT’s policy to use the straight bar development length when the hooked bar development length is greater for a given bar size and strength.

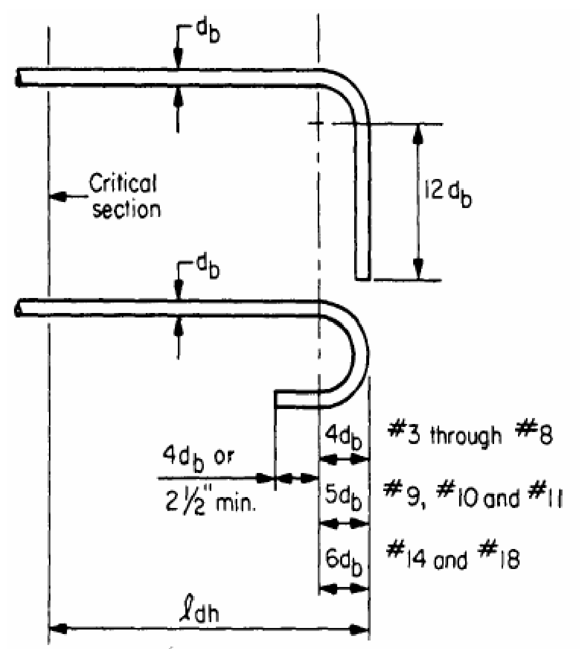


Figure C5.11.2.4-1 Hooked-Bar Details for Development of Standard Hooks (*ACI*).

In all cases, for purposes of l_d calculation, in this tool we consider square bars to have the same l_d as the round bar of equivalent area. The assumption is made that the lack of deformations on a square bar is offset by its greater bonding surface area compared to the equivalent round bar.

- Girder Geometry Change Points

Show calculations locating any abrupt change in girder cross section, such as the beginnings or ends of haunches, web tapers, or partial bottom flanges. An exception is made for end blocks on prestressed girders, which are ignored. This is because most or all of the end block would not be checked for shear as it is within d_v of the support, end blocks are no longer considered necessary and have eliminated from standard prestressed girder sections, and they are ignored in all the standard section definitions in the BRASS section library file SECTIONS.LBY.

- Stirrup Spacing Change Points

  These locations are taken from the stirrups schedule spreadsheet embedded in the Preliminary File and adjusted by one stirrup space toward the direction with the greater spacing. The analysis location is moved for two reasons. At a stirrup spacing change location, a shear crack would propagate across both stirrup spaces. BRASS doesn't interpolate the shear capacity to the left and right of an analysis point. Therefore, moving the analysis point by one stirrup space moves the analysis location away from the transition area providing a more realistic analysis. Also, It was originally assumed that BRASS would calculate the capacity to the left and right of a section change and use the weaker section when calculating rating factors. However, it doesn't appear that BRASS performs this check. Rather BRASS uses the stirrup spacing from the schedule right at the point that was coded. Moving the analysis point toward the larger stirrup spacing ensures that the larger stirrup spacing (lesser capacity) is used when calculating the rating factor.

  Indicate which stirrup spacing change points in the girder are farther from the support than the critical shear point.

- Debonded Strand Points

  The debonded strand locations need to be checked for shear only when the number of debonded strands at a section exceeds the limits specified in AASHTO LRFD 5.9.4.3.3.

5.3 ODOT Concrete Bridge Generator (CBG)

The ODOT Concrete Bridge Generator is not currently configured to assist with the generation of prestressed BRASS code.

5.4 Analysis of Girders

BRASS-GIRDER will be used to load rate the concrete girders. BRASS-GIRDER is different from the previous BRASS-GIRDER(LRFD) program in that it no longer uses text file inputs, but instead utilizes a Graphical User Interface (GUI) with data saved in xml file format. Instead of developing new procedures and a new CBG program to populate the GUI of BRASS-GIRDER, this manual will continue to give instructions on how to create the text input file for BRASS-GIRDER(LRFD). Once the file is ready for analysis, the user will run the text input file through the BRASS-GIRDER translator that will create the xml input file used to populate the new GUI. From there the user will be able to run the analysis within BRASS-GIRDER.

BRASS has increased the live load definition limit from 20 to 100 per file. In the past, since ODOT requires more than 20 vehicles to be analyzed in every LRFR load rating, two nearly identical BRASS input files were used to cover all of the different vehicles. Since the transition from using BRASS-GIRDER(LRFD) to using BRASS-GIRDER for the analysis, ODOT has modified all of its tools to only use a single BRASS file with all of the rating vehicles included. Therefore, ODOT will no longer require the two separate nearly identical BRASS "_N" and "_T" files.

5.4.1 BRASS Input File Conventions

Use the heavily commented sample files provided as templates to be copied to a new bridge-number-specific folder (with a new filename if appropriate) and then modified for the actual Load Ratings. Separate input files will be required for each structure type in any bridge with a combination of structure types, and for interior and exterior girders due to the variability of live load distribution factors in LRFR.

- General conventions

  Use the full length of each command name except the COMMENT (3-1.1) command shall be only COM.

  Precede each command or logical group of similar commands (except for the COMMENT command) with a comment referring to the Article number in the BRASS-GIRDER(LRFD) Command Manual. For example, precede an ANALYSIS (4-1.1) command with a comment command thus:

  ```
  COM 4-1.1
  ANALYSIS B, 2, RAT, T, N
  ```

  Generally, leave in all comments found in the template (unless they become totally irrelevant to a particular input file), modifying them and adding more comments as required to fit the specific conditions of the rating. Use comments liberally with the expectation that someone unfamiliar with the BRASS-GIRDER(LRFD) program and unfamiliar with the bridge will need to read the data file and fully understand it.

  Leave parameters blank (spaces between commas) where they are irrelevant to the specific structure. Although trailing commas can be omitted where all parameters to the right are to be blank, it is recommended to clarify your intentions by showing the blank parameters separated by commas. However, avoid leaving blank parameters such as material strengths where default values would apply. Enter the default values to make the dataset more meaningful to a future user.

  Show in-line calculations within a parameter (between commas) to convert units from feet to inches where the command parameter requires inches. Similarly, show in-line calculations to show how you determined vertical dimensions to locate flexural bars. Never use parentheses in in-line calculations. Other than these in-line calculations, the best place to put calculations is in the Preliminary File rather than in the BRASS comments.

  Whenever a BRASS-GIRDER(LRFD) input file contains a series of occurrences of the same command, vertically aligning the same command parameters for clarity is encouraged. This practice simplifies the process of changing values of parameters when cloning an old BRASS file for use in a new bridge. Inserting spaces as required to accomplish this is harmless. However, do not use tab characters to accomplish this. They are misinterpreted by BRASS-(LRFD) as the next parameter, and are likely to cause fatal errors.

- Input File Sections

  To make it easier for a subsequent user to find their way around the Input File, separate the BRASS input file into logical sections (large groups of commands) by using spaced comments as indicated in the sample files. Typically, an input file for a prestressed girder will be divided into the following sections:

  ```
  COM
  COM  ***** LRFR Load Rating, Strength Limit State *****
  COM

  COM
  COM  ***** Material Properties *****
  COM

  COM
  ```

```
COM  ***** Section Geometry *****
COM

COM
COM  ***** Span Length and Section Information *****
COM

COM
COM  ***** Dead Loads *****
COM

COM
COM  ***** Live Loads *****
COM

COM
COM  ***** Distribution Factors *****
COM

COM
COM  ***** Resistance Factors *****
COM

COM
COM  ***** Analysis Sections *****
COM
```

With similar comment sets, subdivide the "Analysis Sections" section into subsections for each category of investigated section for each unique span. (See the sample input files).

- Specific conventions

At the beginning of every input file, use the BRIDGE-NAME (2-1.3) command to provide the 5- or 6-character NBI Bridge Number, followed by the Bridge Name. Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Next, use the ROUTE (2-1.5) command to provide the mile point and signed Route Number where applicable (always required for State-owned bridges). Note the signed Route Number is not the same as the ODOT internal (maintenance) Highway Number.

Use 2 lines of the TITLE (2-1.6) command. Use the first TITLE line to provide the file name and describe which girder(s) this file applies to. Use the second TITLE line to provide the purpose or work grouping of the Load Rating.

Use the AGENCY (2-1.1) command to identify the Load Rating as being performed according to ODOT standards. This command should always be the same:

```
COM 2-1.1
AGENCY Oregon DOT
```

Use the ENGINEER (2-1.2) command to indicate the load rater.

Use the UNITS (2-1.4) command to force BRASS to always use US (English) units for both input and output. BRASS normally defaults to US units, but it has been found that when referenced dimensions get large, BRASS will automatically assume the large dimensions are in millimeters and will convert the units when it calculates the resistance of the member. Using the UNITS command will not allow BRASS to arbitrarily convert the units during an analysis.

```
COM 2-1.4
UNITS US
```

Use the ANALYSIS (4-1.1) command to provide BRASS with parameters needed to do a rating analysis. The “continuous beam model” is the preferred choice (“B” in parameter 1) as long as there is no need to include columns in the analysis and the bridge has ≤ 13 spans. Rigid frame analysis (with columns) will require the “frame type model” (“F” in parameter 1).

For composite structures, two stages of loading will need to be specified by placing a “2” in the second parameter. This will result in all dead loads being applied to the non-composite structure in stage one and then all live loads are applied to the composite structure in stage two. For prestressed girder structures that are composed of simple spans for dead load and made continuous for live load using mild steel reinforcement, BRASS uses two stages of construction. This process will be described later under prestress definitions portion of the input file. Parameter 5 will be coded as N, for no, to prevent BRASS from interpolating mild steel reinforcement from the left to right cross sections. Partial development is not currently being considered for prestressed concrete analysis. For typical composite prestressed girder bridges this command would normally be the same:

```
COM 4-1.1
ANALYSIS B, 2, RAT, T, N
```

Use the POINT-OF-INTEREST (4-1.2) command to set BRASS to generate user-defined points of interest from subsequent OUTPUT-INTERMEDIATE (5-2.1) commands.

```
COM 4-1.2
POINT-OF-INTEREST U
```

Leaving the 2nd parameter (Specification Check Output) blank causes BRASS to default to refrain from generating a large additional output (**.**OUT) file for each point of interest, information that is not normally needed. Use of “Y” for parameter 2 to turn on this additional output may be justified at sections where there is a need to account for partially developed bars. If these additional **.**OUT files are generated, they do not need to be printed in the Load Rating Report.

Use the OUTPUT (5-1.1) command to control the wide variety of output options. Unless there is a problem that requires more detailed intermediate output for investigation, this command should always the same:

```
COM 5-1.1
OUTPUT 4, Y, , , 1, , , , , , , , ,
```

Beginning with BRASS-GIRDER(LRFD) v.1.6.1, the effective top flange width is calculated and applied to the section properties automatically. Use the OUTPUT-EFF-WIDTH (5-7.3) command to direct BRASS to not output its effective flange width calculations. This command should always be the same:

```
COM 5-7.3
OUTPUT-EFF-WIDTH N
```

Use the OUTPUT-PRESTRESS (5-7.1) command to control output for prestress load balancing, losses, and other prestress computations. This command should always be the same:

```
COM 5-7.1
OUTPUT-PRESTRESS Y, Y, Y, Y, Y
```

Code all BRASS models in the same direction as the girder elevation appears on the plans, i.e. from left to right on the plans, regardless of mile point direction.

In the “Material Properties” section, use the CONC-MATERIALS (8-1.1), PRESTRESS-MATERIALS (9-1.1), and COMPOSITE-MATERIALS (10-1.1) commands to provide the material properties consistent with the notes on the bridge plans. Be aware that the concrete strength that is entered under the CONC-MATERIALS command is the final concrete strength of the prestressed girder. Likewise, the modular ratio that is entered under the CONC-MATERIALS command is the ratio of mild reinforcement to the prestressed concrete. The properties that are entered under the PRESTRESS-MATERIALS command are primarily for design code checks and loss calculations for the girder **at time of release/transfer**. The second parameter of the PRESTRESS-MATERIALS command is used to transform the prestressing steel and calculate a moment of inertia for the service condition. The value of the input for this parameter is the ratio of the modulus of elasticity of the prestressing steel to the modulus of elasticity of the girder concrete, E_{ps}/E_c. Although there are exceptions, a typical prestressed concrete deck girder structure will have the following properties commands:

```
COM 8-1.1
CONC-MATERIALS      0.155, 6.0, 40.0, 40.0, 6,

COM 9-1.1
PRESTRESS-MATERIALS 6.0, 5.778, 70.0, , ,

COM 10-1.1
COMPOSITE-MATERIALS 3.3, 40.0, 9, , , ,
```

In the “Material Properties” section, use the DECK-MATL-PROPERTIES (6-4.1) command to assure that the default wearing surface weight (parameter 3) is set to 0. Without this command, BRASS would generate its own DW load, which we want to define explicitly in the “dead loads” section.

```
COM This command is required to assure default deck Wearing
Surface Weight
COM (parameter 3) is 0 so BRASS does not generate a DW load on
its own
COM 6-4.1
DECK-MATL-PROPERTIES , , 0.0
```

Often times for continuous prestressed spans, there are different final concrete strengths specified for the girders in different spans. Since BRASS only allows one concrete strength to be specified for the entire BRASS run, it is ODOT’s practice to use the lowest concrete strength that is specified for the series of continuous spans. If the rating factors for the higher strength spans are greater than 1.0 while using the lower strength concrete, then nothing more needs to be done. If there are rating factors in the higher strength spans less than 1.0 while using the lower strength concrete, then additional BRASS runs will be required using a different concrete strength for each run. In each BRASS run, only import the rating factors for the analysis points that fall within the span that the correct concrete strength was specified.

For prestressed slabs and boxes, BRASS is only capable of modeling the girder as an equivalent I-shaped cross section, instead of a hollow/voided rectangular section. Thus, the volume-to-surface ratios are internally computed in BRASS based on the I-shaped cross section. For girders converted to I-shapes, the volume of the section is computed correctly, however, the surface area is not. Since the webs of the voided rectangular section are combined into one for the equivalent I-shaped section, the inside surface of the actual webs is not considered. Parameter 4 of the PRESTRESS-MATERIALS command allows the user to adjust the percentage of the V/S ratio to compensate for this converted cross section condition.

AASHTO LRFD Article 5.4.2.3.2 states that for poorly vented enclosed cells, only 50 percent of the interior perimeter should be used in calculating the surface area. Following this code requirement will then produce a V/S ratio for the actual slab or box girder that is greater than the V/S ratio for the equivalent I-shaped section. BRASS has been updated to allow values greater than 100% to be entered.

Although it is ODOT design practice to conservatively limit prestressed girder tension to 0.0948√f'c in ksi (equivalent to 3√f'c in psi) for non-severe corrosion conditions under service loads, for load rating purposes we will adhere to the less conservative stress limits in the AASHTO LRFD code. This approach is supported by these reasons:

- The Inventory Rating for Design Loads is used only for NBI reporting, that is for national comparison purposes.
- This limit is for load rating evaluation, not the more conservative design purpose of the tension limits in the ODOT BDDM.
- The use of 0.19√f'c will result in the Service III Limit (crack control) governing less often than would the more stringent ODOT tension limits.

Because BRASS-GIRDER(LRFD) defaults to 0.0948√f'c ksi for all tensile stress limits, it is necessary to explicitly specify the LRFD tension limits for each span. The following commands accomplish this, where xxx and yyy are the values of 0.19√f'c in ksi (equivalent to 6√f'c in psi), for the girder and girder top flange (not the composite deck acting as an effective flange), respectively. For severe corrosive environments (on the Oregon Coast), use the value of 0.0948√f'c in ksi.

```
COM ------ CONCRETE STRESS LIMITS
COM Required to force 0.19*sqrt(f'c)
COM 9-8.1, 9-8.2
CONC-STLIM-GROUP 1, , , , , xxx, , , , , , yyy
CONC-STLIM-SCHEDULE 1,1
CONC-STLIM-SCHEDULE 2,1
CONC-STLIM-SCHEDULE 3,1
```

In the "Section Geometry" section, define each section numbered sequentially, preceded by a comment identifying it with characteristics from the plans. Use the CONC-I-SECTION (8-2.4) and CONC-FILLETS (8-2.7) to define the cross-section dimensions (except for depth). Note the parameters for these commands changed beginning with BRASS-GIRDER(LRFD) v.1.6.1. Use COMPOSITE-SLAB (10-2.1) command to define the composite deck thickness, and as many COMPOSITE-REBAR (10-2.2) commands as required to define all the layers of longitudinal reinforcement that are present in the effective flange width of the deck. For negative moment sections, it is important to include all longitudinal bars present within the effective top flange width.

Some of the older bridges occasionally have the deck reinforcing exposed. ACI318, Article 12.2.3.2, states that for bars with a cover of d_b or less or with a clear spacing of $2d_b$ or less that the basic development length (obtained from the LRFD code) be multiplied by 2.0. Therefore, if the inspection report or photos indicate that the deck reinforcement is exposed, double the development length of the deck reinforcement.

BRASS version 2.0.3 has been updated to included the 2008 revision of the 4th Edition LRFD Code. With this update it is no longer necessary to calculate the effective flange width of composite slabs in the preliminary file. The second parameter of COMPOSITE-SLAB command may be left blank to allow BRASS to calculate the effective width.

The following is an example of the series of commands to define one section:

```
COM --- Section 2, Negative Moment
COM 8-2.4, 8-2.7, 10-2.1, 10-2.2
CONC-I-SECTION 2, 12.0, 6.0, 6.0, 6.0, 18.0, 6.0
CONC-FILLETS 2, 0.0, 0.0, 3.0, 3.0, 0.0, 0.0, 6.0, 6.0
COMPOSITE-SLAB 2, 84.00, 7.5
COMPOSITE-REBAR 2, T , 5, 10, 2.25+0.625+0.5*1.27
```

For standard concrete girder types that are stored in the BRASS girder section library (BRASS-Sections.BLS), one can use the CONC-STD-SECTION (8-2.1) command to define the cross-section. The following is an example of the series of commands to define one standard section:

```
COM --- Section 1, Positive Moment
COM Standard section for AASHTO-III beams is used.
COM 8-2.1, 10-2.1, 10-2.2
CONC-STD-SECTION 1, AASHTO-III
COMPOSITE-SLAB 1, 84.00, 7.0
COMPOSITE-REBAR 1, B , 10, 5, 1.0+1.0+0.625+0.5*0.625
COMPOSITE-REBAR 1, T , 5, 10, 1.0+7.0-1.5-0.625-0.5*0.50
```

In the “Span Lengths and Section Information” section, define each span beginning with the appropriate command from Chapter 11 of the *BRASS-GIRDER(LRFD) Command Manual* that describes the profile (depth variation) along the span. Follow this command with a sequence of SPAN-SECTION (11-2.1) commands to assign the previously defined sections to cumulative ranges from the left end of the span. The following is an example of the series of commands to define one span:

```
COM --- Span 1, 59' Span Length Geometry

COM 11-1.2, 11-2.1
SPAN-LINEAR 1, 59.0*12, 36.0
SPAN-SECTION 1,  1, 44.65*12
SPAN-SECTION 1,  2, 50.65*12
SPAN-SECTION 1,  3, 59.0*12
```

When the CONC-STD-SECTION (8-2.1) command is used to define the cross-sections, the SPAN-STD-XSECT (11-1.1) command is required to define the span or spans that the standard cross-sections are used. The following is an example of the series of commands to define one span:

```
COM --- Span 1, 59' Span Length Geometry

COM 11-1.1, 11-2.1
SPAN-STD-XSECT 1, 59.0*12
SPAN-SECTION 1,  1, 44.65*12
SPAN-SECTION 1,  2, 50.65*12
SPAN-SECTION 1,  3, 59.0*12
```

Normally the SPAN-HINGE (11-5.1) command is used to define the location of any hinge within the span. If the structure has an expansion joint over a support, this condition is approximated by placing a hinge close to, but not at, the support. BRASS-GIRDER(LRFD) does not allow the use of a hinge at a support, and recommends that it be located a distance of 1.2” from the support. Unfortunately, the current version of BRASS-GIRDER(LRFD) (version 1.6.5) removes any hinges in the bridge during the second stage of loading. **The end result is that any non-continuous spans will require their own BRASS analysis.**

Use the SUPPORT-FIXITY (11-4.1) command to define the boundary conditions of each span, for example:

```
COM --- Support Fixities

COM 11-4.1
SUPPORT-FIXITY 1, R, R, F
SUPPORT-FIXITY 2, F, R, F
SUPPORT-FIXITY 3, F, R, F
SUPPORT-FIXITY 4, F, R, F
```

Use the PRESTRESS-CONTINUITY (9-2.1) command to describe the continuity of the prestress concrete structure. In the first parameter enter “SC” for simple or continuous spans only (this would lead one to believe that the SPAN-HINGE command should work), enter “CA” for simple spans made continuous by composite action and non-prestressed reinforcement, or enter “AP” for pretensioned simple spans made continuous by post-tensioning additional strands.

For prestressed girder structures that are composed of simple spans for dead load and made continuous for live load using mild steel reinforcement, BRASS uses two stages of construction. In stage one, BRASS places a hinge at the support nodes. Then the stage one dead loads and prestress loads are applied to the non-composite simple spans. Initial losses are considered in assigning the prestress loads. For stage two, BRASS removes the support node hinges, thereby making the structure continuous. Then the stage two loads are applied to the composite continuous structure. These include superimposed dead loads, shrinkage loads, and live loads. Prestress losses are applied to the continuous structure as loads in the opposite direction of the original prestress forces. For simple spans made continuous for live loads with mild reinforcement, code parameter 4 of command 9-2.1 with “Y”. This will ignore beam stresses at interior supports. The following is an example of the command to describe the continuity of a prestressed structure:

```
COM --- Prestress Definitions

COM 9-2.1
PRESTRESS-CONTINUITY CA, , , Y
```

Since the distance between the centerlines of bearing are being used as the BRASS span length, use the PS-BEAM-OVERHANG (9-2.3) command to specify the beam overhang beyond the ends of the span or past the centerline of bearing. This command provides additional distance to accommodate transfer, development, and/or debond length. This command can only modify the girder properties for when the end of the girder is past the center of bearing (typically at the ends of the bridge), and can not compensate for when the girder terminates prior to the end of the span (at interior bents). For this reason, the overhang is set at zero at interior supports. The following is an example of the overhangs for a three-span prestressed girder bridge:

```
COM 9-2.3
PS-BEAM-OVERHANG 1, 6.5, 0.0
PS-BEAM-OVERHANG 2, 0.0, 0.0
PS-BEAM-OVERHANG 3, 0.0, 6.5
```

Note: This command is not applicable to girder ends that stop short of the centerline of bent. It cannot handle negative numbers in parameters 2 and 3, so in these cases enter 0.0.

Use the STRAND-MATL-PRETEN (9-3.1) command to define the pretensioned prestressing strands in the girder. Using the properties listed under Article 1.4.4 of this manual, enter the strand area, type of strand, and strand diameter for each unique prestressing strand.

The following is an example of this command line:

```
COM 9-3.1
STRAND-MATL-PRETEN 1, 0.153, SR, , , , , , , , 0.5
```

Use a sequence of commands from Chapter 9 of the *BRASS-GIRDER(LRFD) Command Manual* to define the strand profiles for each span being modeled. Use the STRAND-GENERAL (9-6.1) command to define the general properties and number of strand in a particular row. For every STRAND-GENERAL command, a corresponding STRAND-STRAIGHT (9-6.2), STRAND-HARPED (9-6.3), STRAND-PARABOLIC (9-6.4), STRAND-PARA-CONT (9-6.5), or STRAND-PARA-EXT (9-6.6) command must be entered. The two most commonly used are the STRAND-STRAIGHT and STRAND-HARPED commands.

Define all straight strands together working from the bottom row and up. Straight strands in the top of the girder shall NOT to be included in the BRASS model. These strands are usually used to help with transfer and transportation stresses. Per AASHTO LRFD Article 5.7.3.4.2 only the area of prestressing that is on the flexural tension side of the member is used to calculate the shear capacity. BRASS (LRFD) ignores these strands when determining the area of strand, but then includes them when calculating d_e. Shear capacity is in part dependent on d_e, thus including the top strands will incorrectly affect the shear capacity calculated by BRASS.

Define the deflected strand rows, again working from the lowest row (consecutively numbered after the straight strand rows) and up. After all strand rows are defined, use the STRAND-DEBOND (9-6.7) command to define any strands that are debonded. If some of the strands in a single row have different debond lengths, a separate strand row (at the same depth in the girder) will have to be defined to separate the strands that require the different debonding. The following is an example of the series of commands to define the strand profiles for one span:

```
COM --- Strand Profiles

COM Straight Strand
COM 9-6.1, 9-6.2
STRAND-GENERAL  1, 1, 1, 2, 1
STRAND-STRAIGHT 1, 1, 34.0, N, 0, 0.0,
STRAND-GENERAL  1, 2, 1, 4, 1
STRAND-STRAIGHT 1, 2, 34.0, N, 0, 0.0,
STRAND-GENERAL  1, 3, 1, 6, 1
STRAND-STRAIGHT 1, 3, 32.0, N, 0, 0.0,
STRAND-GENERAL  1, 4, 1, 4, 1
STRAND-STRAIGHT 1, 4, 30.0, N, 0, 0.0,
STRAND-GENERAL  1, 5, 1, 2, 1
STRAND-STRAIGHT 1, 5, 28.0, N, 0, 0.0,

COM Harp points at 0.439(span length)
COM Subtract 6.5" for length of girder past bearing
COM 9-6.1, 9-6.3
STRAND-GENERAL 1, 6, 1,  2, 1
STRAND-HARPED  1, 6, 8.0, 27.0, 8.0, 25.0625*12, 32.0625*12,
3, 2.0, 2.0

COM Debond Straight Strand
COM Add 4.0" for distance between ctr-of-bent and end of
girder
```

```
COM 9-6.7
STRAND-DEBOND 1, 1, , 2, 0.0,  4.0*12+4
STRAND-DEBOND 1, 2, , 4, 0.0, 12.0*12+4
STRAND-DEBOND 1, 3, , 4, 0.0,  8.0*12+4
```

For spans that have the same strand profiles as another span that has been previously defined, the STRAND-COPY (9-6.9) command can be used. This command will copy the straight and deflected strand properties, and the debonded strand definitions.

Some bridge plans do not define the strand layout within the girders of each span, but instead give a profile of the Center of Gravity of Strands (C.G.S). Sometimes there is an allowable range in the profile of the C.G.S. near the ends of the girder. In these cases, bundle all of the strands at the C.G.S. locations in the beam. If there is no direction on the plan sheets on how the strands are harped (parabolic vs linear), it is conservative to assume that they are linearly harped with the hold down locations at 0.4L from each end of the girder. When the plans show a range for the C.G.S. near the end of the girder, it will be more conservative for shear to use the lower elevation of the range.

Use the LOSS-AASHTO-PRETEN (9-3.1.2) command to have the prestress losses calculated by AASHTO 5.9.5. Use the PRESTRESS-TIME (9-2.2) command to enter the curing time, the time that continuity is made and the time that various analyses are performed. Use the PSLOAD-SHRINK-STRAIN (9-9.2) command to have BRASS compute the differential shrinkage strain between the deck and the girder. If the curing method is not stated on the plans, use the BRASS default of moist cure. The typical commands for prestress losses and differential shrinkage are as follows:

```
COM --- Prestress Losses

COM 9-3.1.2
LOSS-AASHTO-PRETEN 1, 1, , , , , , 2

COM --- Differential Shrinkage Load

COM 9-2.2, 9-9.2
PRESTRESS-TIME 1, 30, 30, 75, 75, 30, 45, 60
PSLOAD-SHRINK-STRAIN B
```

Use a sequence of commands from Chapter 8 of the *BRASS-GIRDER(LRFD) Command Manual* to facilitate obtaining Rating Factors at shear points of interest without defining the stirrup area and spacing at each point. Use the CONC-SHEAR-CONSTANTS (8-4.1) to choose which AASHTO procedure to apply for shear capacity calculations. Use the STIRRUP-GROUP (8-4.2) command to define each groups of stirrups that has a unique geometry. Then use a series of STIRRUP-SCHEDULE (8-4.3) commands to assign stirrup groups and define stirrup spaces along each span. The following is an example of the series of commands to define the stirrups for one span:

```
COM 8-4.1
CONC-SHEAR-CONSTANTS 3

COM 8-4.2
STIRRUP-GROUP 1, 0.40

COM 8-4.3
STIRRUP-SCHEDULE 1, 1, 10.00,  15.00,  30.00
STIRRUP-SCHEDULE 1, 1, 13.88,  45.00, 235.96
STIRRUP-SCHEDULE 1, 1,  8.00, 280.96, 136.00
```

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the BRASS Input (**.**DAT) file as they were calculated in the Preliminary (**.xmcd**) File. Diaphragm point loads should be considered part of component load DC.

Because BRASS calculates girder dead load (self-weight) using the input section dimensions and treats it separately from other dead loads, group the rest of the structure dead loads under the first occurrence of the of the LOAD-DEAD-DESCR (12-1.2) command, using the description (parameter 4) "Other Structure dead loads". Beginning with BRASS-GIRDER(LRFD) Version 1.6.1, BRASS correctly calculates the girder self-weight regardless of what portion of the top flange is effective. There is no longer a need to account for ineffective top flange weight separately in the "Other Structure dead loads" group. This group will normally include the LOAD-DEAD-POINT (12-1.4) commands for the dead load of the diaphragms. Include loads for diaphragms directly over the supports. While they will not have any effect on the girder analysis, they will be used to calculate dead load reactions used in the crossbeam analysis. Precede each group of LOAD-DEAD-UNIFORM and LOAD-DEAD-POINT commands with an additional identifying comment describing the load. An example of this first (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 1, DC, 1, Other Structure dead loads

COM  Diaphragms 1.783 k at midspan points, spans 1,3
COM  Diaphragms 1.783 k at quarter points, span 2

COM 12-1.4
LOAD-DEAD-POINT 1, 1, , 1.783, 18.0*12
LOAD-DEAD-POINT 1, 2, , 1.783, 12.0*12
LOAD-DEAD-POINT 1, 2, , 1.783, 24.0*12
LOAD-DEAD-POINT 1, 2, , 1.783, 36.0*12
LOAD-DEAD-POINT 1, 3, , 1.783, 18.0*12
```

Group the next component dead loads (DC) for buildup between the top of girder and the bottom of deck, and for the composite deck weight per girder to be included in the first loading stage. An example of this 2nd (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 2, DC, 1, Buildup and Deck

COM  Buildup per girder, w = 0.075 k/ft at ends & 0.0 k.ft at
midspan
COM 12-1.3
LOAD-DEAD-UNIFORM 2, 1,  0.000*12, 0.075/12, 55.275*12, 0.000/12
LOAD-DEAD-UNIFORM 2, 1, 55.275*12, 0.000/12, 110.55*12, 0.075/12
LOAD-DEAD-UNIFORM 2, 2,  0.000*12, 0.075/12, 55.275*12, 0.000/12
LOAD-DEAD-UNIFORM 2, 2, 55.275*12, 0.000/12, 110.55*12, 0.075/12
LOAD-DEAD-UNIFORM 2, 3,  0.000*12, 0.075/12, 55.275*12, 0.000/12
LOAD-DEAD-UNIFORM 2, 3, 55.275*12, 0.000/12, 110.55*12, 0.075/12
LOAD-DEAD-UNIFORM 2, 4,  0.000*12, 0.075/12, 55.275*12, 0.000/12
LOAD-DEAD-UNIFORM 2, 4, 55.275*12, 0.000/12, 110.55*12, 0.075/12

COM  Deck weight per girder, w = 0.300 k/ft
COM 12-1.3
LOAD-DEAD-UNIFORM 2, 1, 0.0*12, 0.300/12, 110.55*12, 0.300/12
LOAD-DEAD-UNIFORM 2, 2, 0.0*12, 0.300/12, 110.55*12, 0.300/12
LOAD-DEAD-UNIFORM 2, 3, 0.0*12, 0.300/12, 110.55*12, 0.300/12
LOAD-DEAD-UNIFORM 2, 4, 0.0*12, 0.300/12, 110.55*12, 0.300/12
```

Group the remaining component dead loads (DC) (excluding wearing surface dead loads) in the next LOAD-DEAD-DESCR (12-1.2) command using the description (parameter 4) “Superimposed dead loads”. This group should include LOAD-DEAD_UNIFORM (12-1.3) commands as needed to account for all superimposed (Stage-2) dead loads except the wearing surface. Precede each group of LOAD-DEAD-UNIFORM commands with an additional identifying comment describing the load. An example of this 3rd (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 3, DC, 2, Superimposed dead loads (Rails)

COM Rail dead load per girder = 0.099 k/ft
COM 12-1.3
LOAD-DEAD-UNIFORM 3, 1, 0.0*12, 0.099/12, 59.0*12, 0.099/12
LOAD-DEAD-UNIFORM 3, 2, 0.0*12, 0.099/12, 65.0*12, 0.099/12
LOAD-DEAD-UNIFORM 3, 3, 0.0*12, 0.099/12, 59.0*12, 0.099/12
```

In a situation where a prestressed deck girder bridge has an AC wearing surface, and to facilitate future re-ratings with different wearing surface loads, always apply the wearing surface dead load under its own LOAD-DEAD-DESCR (12-1.2) command separate from all other uniform superimposed dead loads. Precede each LOAD-DEAD-UNIFORM command with an additional identifying comment describing the load. An example of this 4th (DW) dead load group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 4, DW, 2, Wearing Surface Dead Load
COM  2.5" + 1" ACWS
COM  Distributed equally to all 4 girders, w = 0.284 k/ft

COM 12-1.3
LOAD-DEAD-UNIFORM 4, 1, 0.0*12, 0.284/12, 36.0*12, 0.284/12
LOAD-DEAD-UNIFORM 4, 2, 0.0*12, 0.284/12, 48.0*12, 0.284/12
LOAD-DEAD-UNIFORM 4, 3, 0.0*12, 0.284/12, 36.0*12, 0.284/12
```

Use the BRASS Input Adjustments #1 thru #3 explained below to code the live load requirements.

To assure that BRASS calculates girder Distribution Factors (number of lanes) according to AASHTO LRFD 4.6.2.2, the following BRASS-GIRDER(LRFD) commands are required:

- Specify number of girders & spacing with the DECK-GEOMETRY (6-1.1) command. Note that the left and right cantilevers (parameters 4 and 5) are the distances from centerline of exterior girder to c of *deck*.
- If girder spacings are variable, use the DECK-VSPACING (6-1.2) to define the spacings that differ from the uniform spacing specified in the DECK-GEOMETRY command.
- Specify the girder of interest (interior or exterior, using girder numbers starting at the left edge) using the DIST-CONTROL-GIRDER (4-3.1) command.
- Specify the cross-section code, number of lanes, and skew using the DIST-CONTROL-LL (4-3.3) command. Normally it is our assumption that adjacent precast slabs or boxes in Oregon are tied together transversely (usually with tensioned rods) enough to consider them to act as a unit, so the Cross Section Code (parameter 1) should be “g1”. If the bridge inspector’s notes specifically indicate the slabs are not acting together, then parameter 1 should be “g2”.
- If the structure being analyzed consists of precast slab girders or precast box

girders, enter the St. Venant Torsional Constant (J) for each span using the DIST-CONTROL-LL-SPAN (4-3.3.1) command so that the Distribution Factors are correctly calculated for both interior and exterior girders. The Torsional Constant is usually listed on the Standard Drawing for the girder section. If the Torsional Constant is not provided on the drawings, show the calculations in the preliminary file or using the Section Property Calculator (SPC) tool of the MIDAS Civil software is permitted. If the SPC tool is utilized, paste a screen shot of the computed values in the preliminary file and include the *.SPC file as part of the electronic load rating file set. If the Torsional Constant is *not* manually entered, BRASS will use the "J" value that it computes for the equivalent I-shaped section, which has a different value than the box or slab that is intended for the distribution factors.

- Specify the edges of the roadway (which limits the extreme transverse wheel positions) by using the DECK-TRAVEL-WAY (6-3.3) command.

When an exterior slab or box girder has a sidewalk that covers half or more of the slab or box width, the exterior girder will not need to be analyzed. This is due to the Lever Rule giving a distribution factor of zero for this configuration. It is recommended to include a notation in the interior girder preliminary file explaining this so that it is clear that the exterior girder is purposely ignored instead of accidentally overlooked.

If Distribution Factors in LRFD 4.6.2.2 are calculated manually, note that we interpret the definition of d_e in LRFD 4.3 as "distance from the *centerline* of the exterior web to the interior edge of curb or traffic barrier."

Use the BRASS Input Adjustment #4 explained below to code the Resistance Factors.

Use the BRASS Input Adjustment #5 explained below to obtain detailed output regarding the Distribution Factors.

To obtain Rating Factors for all points of interest, use OUTPUT-INTERMEDIATE (5-2.1) commands grouped in the same order and groupings as the analysis points were calculated in the Preliminary File. In the "Bar Cutoff Points" subsection of the "Critical Shear Sections" portion of the BRASS code, normally these commands are copied from the "Analysis Points" worksheet of **BarCutoffs.XLS**. Within each span, make sure that none of the analysis points duplicate each other (have identical span fractions), and delete one of each duplicate pair. Precede each OUTPUT-INTERMEDIATE command with a comment (usually text taken from the Preliminary File) explaining the span number and nearby bent number, and the span fraction. The use of the OUTPUT-INTERMEDIATE command, along with the Stirrup Schedule feature of BRASS, eliminates the need to determine stirrup area and spacing specifically at every shear point of interest.

Note: Section 8-3.1 of the *BRASS-GIRDER(LRFD) Command Manual* implies that omitting the CONC-SHEAR command would mean that parameter 2, the Shear Indicator, would default to 2, so the program would use the Simplified Method for shear. However the previous use of the CONC-SHEAR-CONSTANTS (8-4.1) command in the stirrup definition sequence overrides this default and forces the AASHTO General Method for shear (MCFT) to be used.

Normally shear need not be evaluated within d_v of the face of a support. However, the presence of significant shear cracking (> 0.040" wide) in the region within d_v of the support face may warrant a shear investigation in this region. In such an investigation, since the MCFT approach is less conservative in this "zone of confusion", shear capacity should be evaluated using the Simplified Procedure in LRFD 5.7.3.4.1. This is accomplished in BRASS by using the CONC-SHEAR (8.3-1) command and setting the Shear Indicator (2nd parameter) to 2.

5.4.2 BRASS Input Adjustments

Because BRASS-GIRDER(LRFD) was designed primarily for LRFD analyses and was created before the *LRFR Manual* was published, a number of standard BRASS Input Adjustments are necessary. Fortunately the program is flexible enough to allow an accurate solution with work-arounds (BRASS Input Adjustments). These adjustments will normally apply to every Input File, at least until BRASS-GIRDER(LRFD) is changed. See the sample input files for proper placement of these adjustments.

- BRASS-GIRDER(LRFD) Input Adjustment Type 1:

  Use the MAP-LIMIT-STATE (4-5.1) and MAP-SPEC-CHECK (4-5.2) commands to force BRASS to check flexure and shear for only the limit states required by LRFR. These limit states are different than the BRASS-GIRDER(LRFD) defaults. Thus it is necessary to force BRASS to check flexure and shear for Strength-I for Design and Legal loads, and for Strength-II for Permit Loads: For Design Loads (Strength-I Limit State), these commands also force BRASS to use γ_L = 1.75 (Inventory Level). (The Operating Level γ_L = 1.35 Rating Factors will automatically be derived from the Inventory Rating Factors in the Load Rating Summary Workbook by multiplying by the γ_L ratio). For prestressed members (only), use an additional MAP-LIMIT-STATE command to check the Service III Limit State for Design Loads at the Inventory Rating level. Use the following sequence of commands, which will normally not change:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 1(Prestressed):
COM  For LRFR specify the required Strength Limit States
COM  and ignore Service & Fatigue Limits
COM  Design & Legal Loads - Strength-I
COM  Permit Loads - Strength-II
COM  Design Loads – Service-III
COM  (refer to 4-5.1 command, Fig. 3) and
COM  specify shear checks for all load types

COM 4-5.1, 4-5.2
MAP-LIMIT-STATE ST, 1, I, Y, N
MAP-LIMIT-STATE ST, 2, N, N, Y
MAP-LIMIT-STATE SE, 3, I, N, N
MAP-SPEC-CHECK ST, 1, D, SHR, Y
MAP-SPEC-CHECK ST, 1, L, SHR, Y
MAP-SPEC-CHECK ST, 2, P, SHR, Y
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 2:

  Use the FACTORS-LOAD-DL command (13-1.2) to force BRASS to use the LRFR dead load factors, which are different than the LRFD factors used by default. MBE T 6A.4.2.2-1 requires constant dead load factors γ_{DC} and γ_{DW}, and the footnote allows γ_{DW} to be 1.25 when wearing surface thickness is field-measured, which is normally the case. Therefore, these commands are always required. Since the command only covers one limit state level at a time, use one for Strength-I and one for Strength-II:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,
COM  and a constant 1.0 for all Service III dead loads

COM 13-1.2
```

```
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL SE, 3, 1.00, 1.00, 1.00, 1.00
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 3:

Using the BRASS-GIRDER(LRFD) LOAD-LIVE-CONTROL (12-4.1) command to apply the default Design and Legal Load sets would have 3 undesirable consequences:
(a) BRASS would apply the Fatigue Design Load that is not needed for PS Girder structures, generating unwanted output
(b) BRASS would default to listing the Design Load outputs *after* all the other loads, potentially causing confusion in transferring loads to the ODOT Load Rating Summary Workbook
(c) BRASS would apply the AASHTO 3S2 Legal Load which is lighter than the Oregon Legal 3S2 load.

Therefore, use the LOAD-LIVE-DEFINITION (12-4.3) commands to define each Design and Legal Load separately, and use the LOAD-LIVE-CONTROL (12-4.1) command to define only parameter 1 (direction control, normally “B” for traffic in both directions) and parameter 7 (wheel advancement denominator, normally 100), as follows:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 3:
COM  All live loads will be entered individually
COM  Design Loads entered as live load definitions  1 thru  4
COM  Legal  Loads entered as live load definitions  5 thru  9
COM  Permit Loads entered as live load definitions 10 thru 19

COM 12-4.1
LOAD-LIVE-CONTROL B, , , , , , 100
```

In structures with short spans, especially short cantilevers, BRASS may “crash” because the span is divided into live load advancement increments that are too small. If this occurs and you have a small span, try decreasing parameter 7 to the largest number for which BRASS will work, often 50 or sometimes even less.

Further, because ODOT LRFR Tables 1.4.1.9 and 1.4.1.11A requires a different live load factor γ_L for each truck, ADTT and truck weight combination, and BRASS-GIRDER(LRFD) does not provide for separate live load factors for each truck, more BRASS Input adjustments are required to define separate live load factors.

For Strength Limit States, use the optional FACTORS-LOAD-LL command (13-1.3) such that the universal “gamma LL (Design)” (parameter 3), “gamma LL (Legal)” (parameter 4) and “gamma LL (Permit)” (parameter 5) are all forced to 1.0. Since this command only covers one limit state level at a time, 2 commands are always required (one for Strength-I, and one for Strength-II)

For Service Limit States, use the option FACTORS-LOAD-LL command (13-1.3) such that the universal “gamma LL (Design)” (parameter 3) is forced to the values shown in MBE Table 6A.4.2.2-1. For service III this would be 0.80, and is only checked for the design vehicle.

```
COM  Use the FACTORS-LOAD-LL command to force
COM  universal gamma-LL to 1.0 for Strength Limit States
COM  and 0.80 for Service III

COM 13-1.3
FACTORS-LOAD-LL ST, 1,  1.0, 1.0, 1.0
```

```
FACTORS-LOAD-LL ST, 2,  1.0, 1.0, 1.0
FACTORS-LOAD-LL SE, 3, 0.80, 1.0, 1.0
```

With the universal live load factors set to 1.0, truck specific live load factors can be defined using the BRASS command 13-1.6, FACTORS-LOAD-LL-LS. Previous version of BRASS (LRFD) did not accommodate individual truck live load factors. Thus, a work around was developed where the live load factors were input as scale factors. With BRASS v 2.0.3 the FACTORS-LOAD-LL-LS command has been added to resolve this limitation. Live load factors shall be input using this new command. Parameter 6 of command 12-4.3, scale factor, will be reserve for its original purpose. With this update the LR summary sheet will no longer modify the rating factors reported in the BRASS output file.

In the FACTORS-LOAD-LL-LS (13-1.6) commands for each load, enter the specific live load Factor γ_L (from **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable). This command can be copied and pasted from the BRASS tab of LL_Factors_State.XLS.

Thus the complete live load definition command set for input files is as follows:

```
COM  Define each Design and Legal live load separately and
COM  apply the truck specific live load factor (instead
COM  of defining them in the LOAD-LIVE-CONTROL command)
COM  There are 3 reasons...
COM  (a) to prevent BRASS from applying the Fatigue Design Load
COM      that is not needed for RCDG structures
COM  (b) to force BRASS to list the Design Loads outputs in the
COM      same order as ODOT's Load Rating Summary Workbook
COM  (c) to allow use of the Oregon 3S2 Legal Load rather than
COM      the AASHTO 3S2 Design Load

COM Do NOT code the truck specific live load factor in
COM Parameter 6.

COM 12-4.3
LOAD-LIVE-DEFINITION  1, HL-93-TRUCK , DTK, D, ,
LOAD-LIVE-DEFINITION  2, HL-93-TANDEM, DTM, D, ,
LOAD-LIVE-DEFINITION  3, HL-93-TRKTRA, TKT, D, ,
LOAD-LIVE-DEFINITION  4, HL-93-LANE  , DLN, D, ,

LOAD-LIVE-DEFINITION  5, OR-LEG3     , TRK, L, ,
LOAD-LIVE-DEFINITION  6, ORLEG3S2    , TRK, L, ,
LOAD-LIVE-DEFINITION  7, ORLEG3-3    , TRK, L, ,
LOAD-LIVE-DEFINITION  8, ORLEG3-3    , LGT, L, ,
LOAD-LIVE-DEFINITION  9, LEGAL-LANE  , LLN, L, ,

LOAD-LIVE-DEFINITION 10, OR-SU4      , TRK, L, ,
LOAD-LIVE-DEFINITION 11, OR-SU5      , TRK, L, ,
LOAD-LIVE-DEFINITION 12, OR-SU6      , TRK, L, ,
LOAD-LIVE-DEFINITION 13, OR-SU7      , TRK, L, ,

LOAD-LIVE-DEFINITION 14, EV2         , TRK, L, , , ONE
LOAD-LIVE-DEFINITION 15, EV3         , TRK, L, , , ONE

LOAD-LIVE-DEFINITION 16, OR-CTP-2A   , TRK, P, ,
LOAD-LIVE-DEFINITION 17, OR-CTP-2B   , TRK, P, ,
LOAD-LIVE-DEFINITION 18, OR-CTP-3    , TRK, P, ,

LOAD-LIVE-DEFINITION 19, OR-STP-3    , TRK, P, ,
```

```
LOAD-LIVE-DEFINITION 20, OR-STP-4A   , TRK, P, ,
LOAD-LIVE-DEFINITION 21, OR-STP-4B   , TRK, P, ,
LOAD-LIVE-DEFINITION 22, OR-STP-4C   , TRK, P, ,
LOAD-LIVE-DEFINITION 23, OR-STP-4D   , TRK, P, ,
LOAD-LIVE-DEFINITION 24, OR-STP-4E   , TRK, P, ,
LOAD-LIVE-DEFINITION 25, OR-STP-5BW  , TRK, P, ,


COM  Use for spans > 200 ft only...
COM LOAD-LIVE-DEFINITION 24, ORLEG3-3     , LTK, L, ,

COM Truck Specific Live Load Factors


COM 13-1.6
FACTORS-LOAD-LL-LS 1, ST, 1, 1.75
FACTORS-LOAD-LL-LS 2, ST, 1, 1.75
FACTORS-LOAD-LL-LS 3, ST, 1, 1.75
FACTORS-LOAD-LL-LS 4, ST, 1, 1.75

FACTORS-LOAD-LL-LS 5, ST, 1, 1.30
FACTORS-LOAD-LL-LS 6, ST, 1, 1.30
FACTORS-LOAD-LL-LS 7, ST, 1, 1.30
FACTORS-LOAD-LL-LS 8, ST, 1, 1.30
FACTORS-LOAD-LL-LS 9, ST, 1, 1.30

FACTORS-LOAD-LL-LS 10, ST, 1, 1.30
FACTORS-LOAD-LL-LS 11, ST, 1, 1.30
FACTORS-LOAD-LL-LS 12, ST, 1, 1.30
FACTORS-LOAD-LL-LS 13, ST, 1, 1.30

FACTORS-LOAD-LL-LS 14, ST, 1, 1.30
FACTORS-LOAD-LL-LS 15, ST, 1, 1.30

FACTORS-LOAD-LL-LS 16, ST, 2, 1.25
FACTORS-LOAD-LL-LS 17, ST, 2, 1.25
FACTORS-LOAD-LL-LS 18, ST, 2, 1.30

FACTORS-LOAD-LL-LS 19, ST, 2, 1.10
FACTORS-LOAD-LL-LS 20, ST, 2, 1.25
FACTORS-LOAD-LL-LS 21, ST, 2, 1.00
FACTORS-LOAD-LL-LS 22, ST, 2, 1.00
FACTORS-LOAD-LL-LS 23, ST, 2, 1.00
FACTORS-LOAD-LL-LS 24, ST, 2, 1.00
FACTORS-LOAD-LL-LS 25, ST, 2, 1.00

COM Use for spans > 200 ft only...
COM Replace parameter 3 with the legal live load value.
COM FACTORS-LOAD-LL-LS 24, ST, 1.30
```

The Oregon Legal Load designations listed in this example are applicable to BRASS-GIRDER(LRFD) Version 2.0.0 and later. BRASS-GIRDER(LRFD) runs for versions prior to v2.0.0 used the legal load designations OLEG3, OLEG3S2 & OLEG3-3.

Special note: For one-lane (escorted) special permit reviews and true single-lane bridges (roadway width < 20 ft), it is necessary to enter “ONE” for parameter 7 in the LOAD-LIVE-DEFINITION (12-4.3) command. It is not clear in the BRASS Command Manual, but this parameter is needed to force BRASS to apply only a single-lane loading with the appropriate single-lane Distribution Factors.

- BRASS-GIRDER(LRFD) Input Adjustment Type 4:

  While performing an analysis on a prestressed girder, it was found that the FACTORS-RESIST-RC and FACTOR-RESIST-PS commands cannot be used simultaneously. Since phi is often different for flexure in prestressed elements and reinforced concrete elements, a different approach is required. Using the FACTORS-RESIST-MOD command to modify phi-s and FACTORS-RESIST-COND command to modify phi-c. BRASS will properly calculate the final phi values for flexure, flexure/tension (RC), and shear. This adjustment would allow both prestress bridges and reinforced concrete bridges to use the same set of BRASS commands.

  Use FACTORS-RESIST-MOD (13-2.4) command, entering FL to designate for flexure in parameter 2 and the appropriate System Factor ϕ_s for Flexure in parameter 3. Repeat the command entering SH to designate for shear in parameter 2 and the System Factor ϕ_s for shear in parameter 3. Use FACTORS-RESIST-COND (13-2.5) command, entering the condition factor ϕ_c in parameter 2. Thus the complete phi factor command set is as follows:

```
COM BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 4:
COM  Use the FACTORS-RESIST-MOD command to modify phi-s
COM  Use the FACTORS-RESIST-COND command to modify phi-c
COM  BRASS automatically calculates base phi for flexure,
COM  flexure/tension (RC), and shear

COM 13-2.4
FACTORS-RESIST-MOD ST, FL, phi-s
FACTORS-RESIST-MOD ST, SH, phi-s

COM 13-2.5
FACTORS-RESIST-COND  ST, phi-c
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 5:

  To facilitate crossbeam calculations and to clarify what BRASS is doing regarding live load Distribution Factors, always include the following lines in the BRASS input file at the end of the “Distribution Factors” section:

```
COM  Request output of LL Distribution Factor computations
OUTPUT-DIST-LL Y, Y
```

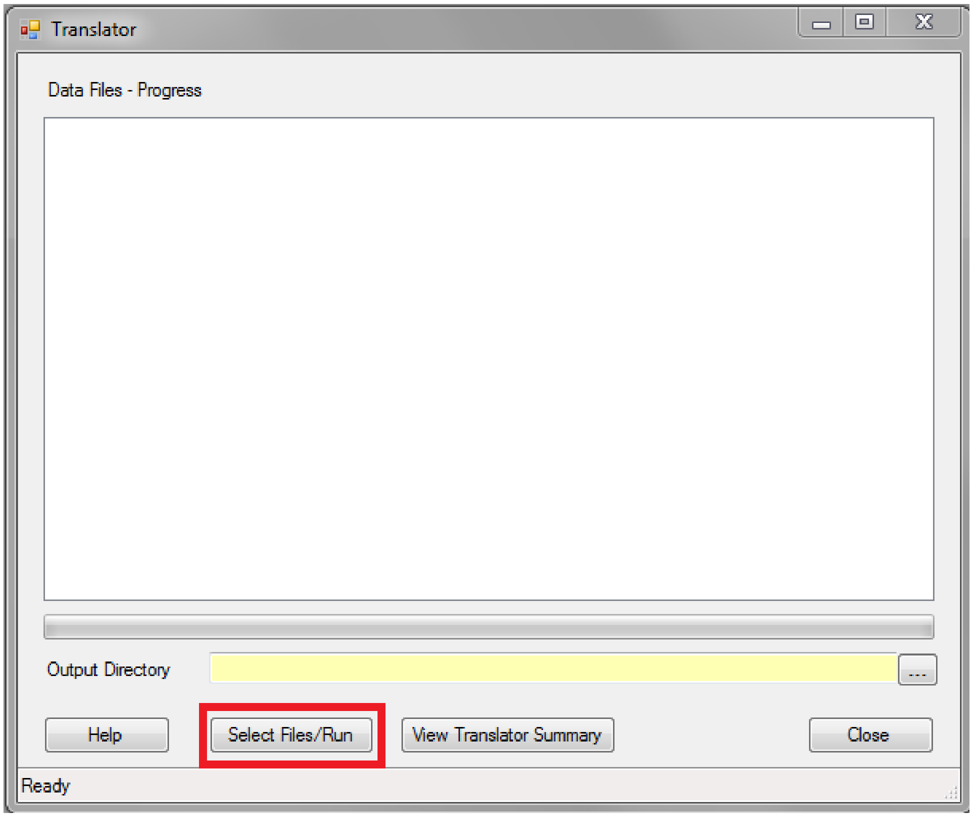
5.4.3 Running BRASS

Open the BRASS-GIRDER GUI interface. Because it is more efficient to use BRASS-GIRDER(LRFD) Input Files generated from previous ones, the GUI interface will not be used to generate input files.

The BRASS-GIRDER(LRFD) input file must first be translated into a BRASS-GIRDER xml file that will then populate the GUI interface in BRASS-GIRDER. The steps for translating and running the input files in BRASS-GIRDER is as follows:

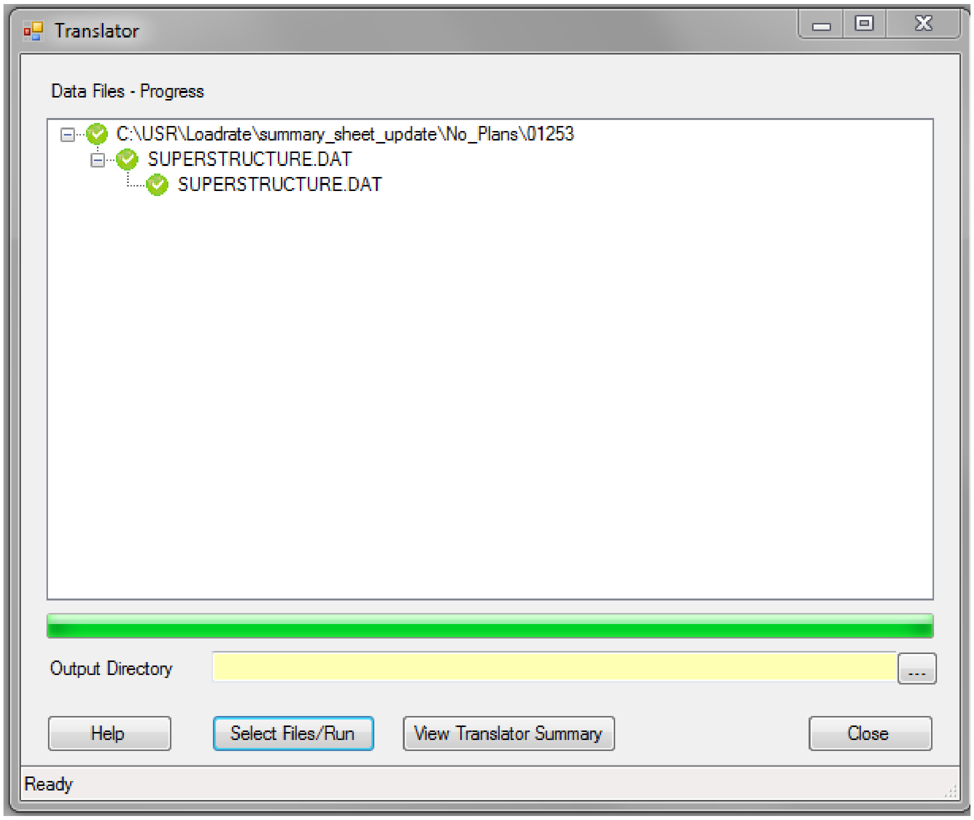
1. Start the BRASS-GIRDER program. From the “File” menu, hover your mouse pointer over “Translate (DAT to XML)”. Select the option for “BRASS-GIRDER(LRFD)”.

2. The Translator window will then open on your screen. Click on the button that says “Select File/Run”, as shown in the red outlined box in the following figure.



3. In the next window that appears, navigate to the location where the BRASS-GIRDER(LRFD) input file that you wish to run is stored, and select that file. Click on the "Open" button at the bottom right of this window.

4. The Translator window will then open back up and the selected file will run through the translation. If there are any errors detected during the translation, a red "X" will be displayed next to the file name in the window and an error file will be generated. Refer to the error file to decipher what is causing the error during translation. Once corrected, follow these steps again to translate the file. If successful, a green check will appear next to the file name as shown in the following figure:



5. Click the "Close" button at the bottom right of the Translator window. Within BRASS-GIRDER, select "Open" under the File menu. Select the BRASS XML file that was just created from the Translator program. Click on the "Open" button at the bottom right of this window.

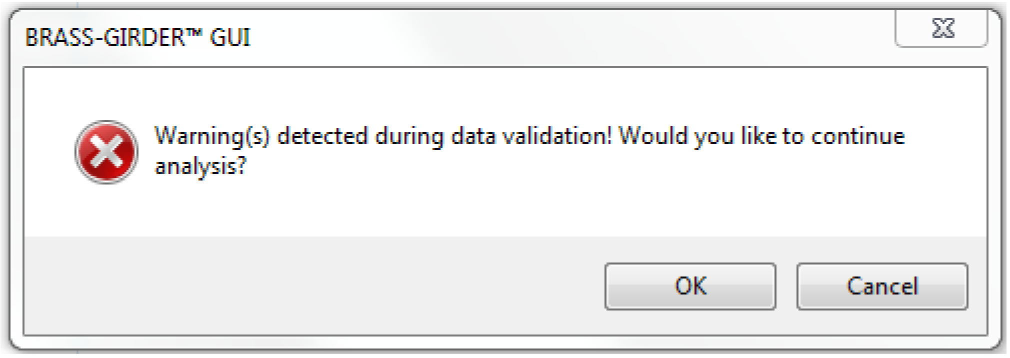
6. BRASS-GIRDER will then load the model into the GUI. Under the "Execute" menu, select "Analysis Engine" to run the analysis. Or you can simply click on the green traffic light icon on the toolbar.

7. Verify that the output directory is the same as where the input files are located, and then click the "OK" button. A black DOS window will appear showing program progress. Depending on your system speed and memory and the complexity of the structure, the execution process may take a few seconds or several minutes. Upon completion of the analysis, a text output file will be generated within the same directory. You can now use a text editor to open and view the BRASS output.

When making changes or corrections to BRASS files, ODOT prefers that all changes be made within the BRASS-GIRDER(LRFD) input file so that it becomes the master document for the BRASS model. Reviewing this text input file will be quicker and more efficient than trying to navigate the GUI to verify that the bridge is being modelled correctly. Thus, any time the text input file is modified, the above steps will have to be repeated to translate the text input file into a BRASS XML file before the analysis is re-ran in BRASS-GIRDER.

5.4.3.1 BRASS Warning Message

Recently, while attempting to run BRASS-GIRDER, the following warning message window has been popping up:



After selecting the "OK" button, BRASS-Girder will continue running through the analysis. When it is finished, a message window will appear within the program that states, " Load Factors (LRFD) – Service III live load factor incompatible with refined AASHTO loss method." The message window also provides the following solution, " Change the Service III live load factor to 1.0 per AASHTO LRFD Table 3.4.1-4."

This warning message is being produced as a result to a change that was made in the AASHTO LRFD 2016 Revisions where a new table was added in Section 3 (LRFD Table 3.4.1-4) that states to use a live load factor of 1.0 when using the refined estimate of time-dependant losses as specified in LRFD Article 5.9.3.4 to take advantage of the elastinc gain.

ODOT has made the decision to ignore the elastic gain for the design and load rating of bridges in Oregon. Therefore, ignore this warning message when it occurs and continue to use the refined analysis with the 0.8 live load factor for Service III.

5.4.4 BRASS Errors

If an error file is generated (same prefix, **.**ERR extension), open this file with your text editor and try to interpret what BRASS is telling you. The vast majority of error messages will point you to a straightforward typographical error or omission in your input. At the beginning of your experience with BRASS, do not expect a successful execution until one or more typographical errors have been corrected.

When executing BRASS-GIRDER, if you get an error message regarding zeros in the stiffness matrix, look at the ANALYSIS (4-1.1) command, parameter 1, and check to see if you are running a Frame type model on a structure with more than 6 spans. In such cases the Beam type model (the recommended default) is required (with a maximum of 13 spans).

When executing BRASS-GIRDER, you may get an error message stating, "*The effective web width (b_v) cannot be zero. This causes a divide-by-zero error in the compression field computations.*" This most likely means that you have selected points that are too close to another defined point of interest within your BRASS input file. A general rule is not to have points closer than six inches from one another. Verify in your input file that you have correctly entered the web width parameter while defining your BRASS sections. Also check in the "Span Length and Section Information" portion of the input file to see that the ranges of the elements are not too close to each other.

A rare error can sometimes occur in executing BRASS-GIRDER where the processing of the analysis takes a considerable amount of time, and then produces a very large output file (around 600 megabytes) along with an error file. The program will report an "Interpolation Error". This occurs on files that have a BRASS span of 99.99 ft and was attempting to increment each truck across the span at 100 increments (as specified in the LOAD-LIVE-CONTROL command). We found that one of two simple workarounds can correct the error: 1) round the BRASS spans from 99.99 ft to 100.00 ft, or 2) increase the live load increment from 100 to 105 in the LOAD-LIVE-CONTROL command. The second method is the preferred option as it only requires a correction in one command, whereas adjusting the span lengths would have required doing it for multiple spans for the bridge that experienced this error.

When executing BRASS-GIRDER, if you get an unexpected termination of the program while attempting to run a file, check the BRASS error file (*.err) to see if it states that, "Standard Vehicle: OLEG3S2 is not presently stored in the standard vehicle library file." This usually means that the user did not update the names of the Legal Vehicle in the BRASS input file. In the early part of 2009, ODOT made a small revision to the vehicle library so that both the old Tier 1 and LRFR rating methodologies would use the same legal vehicles for their analysis. As a result, ODOT changed the names of the legal vehicles. To correct the error, make the following changes to the names of the legal vehicles in the BRASS input file:

Original Vehicle Names	Previous Vehicle Name	Current Vehicle Name
OLEG3	ORLEG3	OR-LEG3
OLEG3S2	ORLEG3S2	ORLEG3S2
OLEG3-3	ORLEG3-3	ORLEG3-3
SU4	SU4	OR-SU4
SU5	SU5	OR-SU5
SU6	SU6	OR-SU6
SU7	SU7	OR-SU7

5.4.5 BRASS Output Files

BRASS-GIRDER(LRFD) has been known to "run perfectly" and still produce completely wrong results. Although a successful run may indicate a lack of errors, it is prudent to search the main output (**.**OUT) file for the words "error" and "warning" to check out the seriousness of the problem, and to do a "reality check" on the Rating Factors. Unexpected Rating Factor results often indicate an error in the BRASS coding.

We recommend that, at the very least, load raters routinely employ the following two BRASS verification measures:

(1) Do a reasonability check on the section properties. This is why we routinely code "Y" in parameter 2 of the OUTPUT (5-1.1) command, to provide a list of girder properties at each node point. (Search the Output File for "Calculated Properties" in each span). It is not uncommon to make errors in the concrete section definitions, the SPAN-UNIF-HAUNCH (11-1.3) command or the SPAN-SECTION (11-2.1) commands that can result in a girder profile that is quite different than the one you expected.

(2) Do a reasonability check on the distribution of shears and moments across the structure. This is especially critical if you have an expansion joint within the structure that you have modeled by coding a hinge near one of the internal supports. Check if you are getting nearly-zero moments at the support next to the hinge. (It can't be truly zero because of the offset of the hinge from the support, but the moment value should be quite low). There have been cases where, due to numerical instabilities in the analysis process, unreasonably high moments were present at the support. The solution is usually to increase the offset of the hinge from the support in small increments until the reported moments behave as expected (sometimes increasing the offset by hundredths of a foot can make all the difference!).

If you really have doubts about what BRASS is giving you, be aware that you can use additional commands in the OUTPUT- group (BRASS-GIRDER(LRFD) Manual, Chapter 5 to generate additional output that may facilitate your detective work. Use caution – the size of this output can be daunting.

When reading the BRASS Output File, in the Rating Factor Summary sections for Legal Loads, it may be difficult to distinguish between the live load Combo cases because two of them are identified as

"ORLEG3-3". In these cases, it is possible to distinguish them by looking for the 3-letter BRASS live load Type codes in parentheses. These codes are defined for parameter 3 of the LOAD-LIVE-DEFINITION command (12-4.3). Thus there will be separate Rating Factor Results for ORLEG3-3 (TRK) which is the Type 3-3 truck by itself, and ORLEG3-3 (LGT) which is the Type 3-3 two-truck train plus Legal Lane load.

5.4.6 Longitudinal Tension Check

Prior to BRASS-GIRDER(LRFD) version 2.0.1, the results of the longitudinal reinforcement tension check (LRFD 5.7.3.5) were not found in the basic output files, but could only be found by performing a detailed analysis of a specific point. The longitudinal tension check is done to ensure that there is sufficient longitudinal reinforcement to resist the tension forces caused by flexure and shear.

With the release of BRASS-GIRDER(LRFD) version 2.0.1, the program now calculates a rating factor for the longitudinal tension check using the worst case of the maximum tension forces developed due to maximum shear and concurrent moment, minimum shear and concurrent moment, maximum moment and concurrent shear, and minimum moment and concurrent shear.
Since the longitudinal tension check rating factor is being computed for every analysis point, and the ODOT Load Rating Summary sheet only has a limited number of columns to report rating factors, the summary sheet has been programmed to only report the longitudinal tension rating factors for a given analysis point only if a rating factor for one of the trucks is lower than 1.1.

Detailed Discussion:

Section 5.8.3.5 of the AASHTO LRFD Bridge Design Specifications has the equation that is used by designers to ensure that there is sufficient longitudinal reinforcement to resist tension forces caused by both shear and flexure. If this equation is not satisfied, the designer simply adds the necessary reinforcement so that the equation is satisfied.

The Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) for highway bridges is based on the AASHTO Bridge Design Specifications. The software ODOT uses for LRFR ratings is BRASS-GIRDER(LRFD). Prior to version 2.0.1, this software performed the tension check as part of the rating, but the basic output (usually several hundred of pages per bridge) did not indicate if the bridge had locations where the tension check failed. The information on the results of the tension check could only be found by examining the additional output that is provided when detailed analysis of a specific point was requested.

While satisfying the tension check is needed to have an accurate model when using Modified Compression Field Theory (MCFT) to calculate shear capacity, there is no guidance in the LRFR manual for the load rater to use when the tension check fails. This has been brought to the attention of a primary developer of the LRFR code, Bala Sivakumar, PE, who acknowledged that the current code does not fully address this issue. Christopher Higgins, PhD, PE, from Oregon State University, who lead the effort to test full scale beams has emphasized that the tension check is fundamental to the use of MCFT. The concern of providing the results of the tension check in the basic output has been communicated to the developers of the BRASS software.

There were two areas that needed to be addressed before the load rater could be sure that the tension check had failed. First, all of the reinforcement must be accounted for. Since the ODOT ratings originally counted the reinforcement only when it was fully developed, there may have been a significant amount of partially developed reinforcement available to resist tension forces. Prior to the development of the ODOT Concrete Bridge Generator (CBG), a simple bridge would take several weeks for a load rater to go through all of the detailed output and add up all of the partially developed reinforcement. While many of the points that originally failed the tension check will pass for the lighter loads, the heavier permit loads can still result in a failed condition. Even if all of the points were to pass the tension check, the weeks of analysis would have been inefficient and resulted in a product that was complicated to the point that a secondary check would have been difficult. With the development of the CBG, the partially developed bars are now accounted for in the BRASS model, and thus this first issue is resolved.

The second area that needed to be addressed was the nature of the loading. For a given load, there will be a maximum moment force, and a maximum shear force. For analysis, BRASS-GIRDER(LRFD) uses these maximum values. The actual loading caused by a moving load does result in a point experiencing the maximum force values, but not at the same time. By treating the maximum values as being concurrent, the BRASS analysis of the tension check would be somewhat conservative at some locations.

There are differences between the design of new bridges and the rating of current bridges. Section 6.1.3 states that “Design may adopt a conservative reliability index and impose checks to ensure serviceability and durability without incurring a major cost impact. In rating, the added cost of overly conservative evaluation standards can be prohibitive as load restrictions, rehabilitation, and replacement become increasingly necessary.”

With the release of BRASS-GIRDER(LRFD) version 2.0.1, the program now calculates a rating factor for the longitudinal tension check using the worst case of the maximum tension forces developed due to maximum shear and concurrent moment, minimum shear and concurrent moment, maximum moment and concurrent shear, and minimum moment and concurrent shear. Thus, this second issue has been addressed.

The developers of the MBE code acknowledged that while LRFD does incorporate state-of-the-art design, analysis methods, and loading, that almost all existing bridges were designed using the older AASHTO Standard Specifications for Highway Bridges. Section 6A.1.4 states “Where the behavior of a member under traffic is not consistent with that predicted by the governing specifications, as evidenced by a lack of visible signs of distress or excessive deformation or cases where there is evidence of distress even though the specification does not predict such distress, deviation from the governing specifications based upon the known behavior of the member under traffic may be used and shall be fully documented”.

The 1950’s bridges were designed using Working Stress. Once the stresses of the concrete exceed its ability to resist tension, cracking occurs. This initial cracking takes place at a comparatively low level of loading. The bridge is designed to see “service loads” where the forces in the reinforcement are kept well below the yield point. The bridges that Oregon State University instrumented showed that the reinforcement was being operated well below the yield point. During full scale beam tests to failure, the reinforcement was yielding, but at much higher loads than in-service bridges experience, and with much greater distress.

Even though ODOT and BRASS have found a way to perform the tension check for load rating, this is still an issue to be solved on a national scale. Based on the guidance from the LRFR code, and the lack of distress noted in the vast majority of bridge inspections, Oregon bridges are not being operated anywhere near the level that would cause yielding of the reinforcement as indicated by the failure of the tension check. For those few bridges that do show excessive deterioration, the current LRFR code is sufficient that the known behavior of the member shall be used and be fully documented. Bridges with deterioration consistent with yielding of reinforcement would not be considered for “no work” regardless of the results of the tension check. Calculations for repairs should be done in accordance with the LRFD code and therefore the longitudinal reinforcing should always pass the tension check after the repairs are complete.

5.4.7 BRASS/LRFD Issues Regarding Minimum Transverse Reinforcement

BRASS-GIRDER(LRFD) prior to version 1.6.4 had an error in the use of the AASHTO LRFD 4th Edition (prior to the 2008 Revision) Table 5.8.3.4.2-2 (now Table B5.2-2 in LRFD Eighth Edition), Values of θ and β for Sections with less than minimum transverse reinforcement. It appears that only the top row of the table was used, yielding higher values of β and lower values of θ than should have been used. The result of this was that sections with less than minimum transverse reinforcement were assigned higher rating factors than they should have been.

A comparison of shear rating factors was accomplished using BRASS-GIRDER(LRFD) versions 1.6.5 and 1.6.2. For the three bridges selected, locations outside of horizontally tapered webs had adequate transverse reinforcement, and the shear ratings were unaffected by the corrections to how the table was used for less than minimum transverse reinforcement. However, some sections inside horizontally tapered webs do have less than the minimum transverse reinforcement. These sections experienced a significant drop in rating factors.

The bridge designers in the 1950’s sometimes used an increased concrete cross section to resist shear forces near interior bents. The very technique that gained shear capacity using the AASHTO LRFD Design Specifications now causes the section to have less than minimum transverse reinforcement. The extra concrete the 1950’s designers used to increase shear capacity has the unintended consequence of placing a section with good reinforcement details into a design code table that was never intended to be used for design.

Prior to the 2008 Revisions of LRFD Article 5.7.3.4.2 (General Procedure for Determining Shear Resistance in Concrete Beams) beta and theta were determined by an iterative procedure (which is now in LRFD Appendix B5):

- For sections with minimum transverse reinforcement – For an applied load, an assumed value of theta is initially used to calculate the longitudinal strain in the web at $0.5d_v$. The shear stress ratio is computed for the section. Using Table B5.2-1, the longitudinal strain and shear stress ratio are used to determine a new value of theta and beta. This new value of theta is used to calculate a new longitudinal strain, which is then used in Table B5.2-1 to compute a new theta and beta. The process continues until theta is solved. The final values of theta and beta are then used in computing the shear resistance of the concrete section.

- For sections with less than minimum transverse reinforcement – the procedure is similar to that above. The only differences being are that the longitudinal strain is calculated at the location in the web subject to the highest longitudinal tensile strain, and instead of using the shear stress ratio with the longitudinal strain in Table B5.2-1 to determine a new theta and beta, the crack spacing parameter is used with the longitudinal strain in Table B5.2-2.

- When calculating the longitudinal strain for a section, longitudinal bars on the flexural tension side of the member that were not fully developed were to be ignored.

In LRFD Article 5.7.3.4.2, beta and theta are determined by direct solution using algebraic equations:

- The strain in non-prestressed longitudinal tension reinforcement is directly computed for a given load. This strain is used directly in the equations to compute theta and beta.

- The value of theta is the same regardless if the section has less than or contains at least the minimum transverse reinforcement. Thus, there is only one direct solution for theta.

- There is one equation for beta for sections containing at least the minimum transverse reinforcement. There is a different equation for beta for sections with less than minimum transverse reinforcement, which is similar to the first but has an added component containing the crack spacing parameter.

- In calculating A_s, the area of bars terminated less than their development length from the section under consideration should be reduced in proportion to their lack of full development (instead of ignored).

In most cases, the new direct solution equations in the 2008 Revisions are producing higher capacities for sections that have less than minimum transverse reinforcement. The main reason is that theta no longer is penalized, which results in shallower crack angles allowing for more stirrups within the member to contribute to the shear resistance.

Unfortunately, the old iterative method is still a valid option in the LRFD code, as the 2008 Revisions have placed the old Article 5.7.3.4.2 language in Appendix B5. BRASS Girder (LRFD) Version 2.0.3 has been updated to include the 2008 revisions of the AASHTO LRFD code. The algebraic equations are now used to calculate shear capacity.

5.4.8 Continuous Multi-Spanned Bridges with Varied Span Lengths

We were made aware of an issue that occurs with continuous multi-span bridges, when the adjacent span lengths vary by a considerable amount. It was noticed that the maximum positive moment sections were being evaluated at odd locations (0.1L for an end span and 0.4L for an interior span). This was a result of our original practice of basing these locations off of the dead load maximum moment locations and not the factored combined (dead load and live load) maximums. The maximum dead load moment location shifts were due to the uplift in short spans caused by the dead load of an adjacent long span.

To compensate for the uplift effects of dead load on the adjacent short spans, we will now use the maximum and minimum Load Factors stipulated in AASHTO LRFD Table 3.4.1-2. As a result, we have modified the BRASS Input Adjustment Type 2 commands in the BRASS input files to the following:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,
COM  and a constant 1.0 to dead loads for Service III

COM 13-1.2
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL SE, 3, 1.00, 1.00, 1.00, 1.00
```

The heavier vehicles will produce a maximum positive moment location closer towards the midspan, while the lighter vehicles will produce a maximum positive moment location away from midspan towards the maximum moment location of the dead load. Therefore, in order to capture the maximum positive moment for the entire suite of vehicles that we use in load rating, we may have to establish a range of points where the different vehicles will produce their maximum positive moment.

In order to facilitate this procedure, we have developed a new application (BRASS Moment Analyzer) that will evaluate the BRASS output files after an initial BRASS run and determine if the maximum positive moment locations for the live loads differ from the dead load locations. If so, the program will then analyze the differences in the locations and then provide a range of recommended positive moment locations (at 20th points) along with the BRASS commands for these new flexural analysis locations that can be copied and pasted into the BRASS input files. The program will create a text file, with the modified name of _MOMENT_INITIAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

After the final BRASS run, the BRASS Moment Analyzer can be used to once again evaluate the BRASS output files. This time, the software will check and report if the maximum combined moment for every vehicle at each analysis point is negative, positive, or contains both negative and positive values. The program will allow the user to print a summary report which they can refer to when selecting the type of moment during the BRASS import of the moment locations on the Load Rating Summary sheet. The program will create a text file, with the modified name of _MOMENT_FINAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

Do not include the BRASS Moment Analyzer output in the printed Load Rating Calc. Book. We only request that the .TXT files that it produces be included with the electronic files for the load rating.

The intent is to only use the BRASS Moment Analyzer for continuous bridges with adjacent span lengths that vary more than 30%.

5.4.9 Special Procedure for Prestressed Girder Bridges of Multiple Simple Spans

BRASS-GIRDER(LRFD) is unable to model a sequence of simple prestressed girder spans without imposing continuity. This inadequacy was judged by WYDOT to be not a “bug” but rather a future “enhancement”, subject to future budget limitations and the prioritization strategies of the nationwide BRASS Users Group. There is no certainty regarding when or if this correction will ever be made.

Therefore, for the foreseeable future, ODOT finds it necessary to do the following work-around procedure:

A. Create a separate BRASS input file for each unique combination of simple span and girder spacing.

B. Create an overall “reaction run” for the whole structure substituting equivalent non-prestressed girders and applying all the rating vehicles, in order to get the correct liveload reactions at the interior bents. The reactions from this run, along with the appropriate Distribution Factors, can be input directly into the crossbeam software.

The best practice is to generate the Reaction Run input file from a source input file from the first simple-span in the sequence. Generally, to generate a Reaction Run input file from the first simple-span input file, follow these steps:

1. Copy the interior prestressed girder input file from the first span in the sequence, naming the copy appropriately (for example: REACT.DAT)
2. In the TITLE (2-1.6) command, change the file name and description to identify this as the reaction run.
3. Delete the PRESTRESS-MATERIALS (9-1.1) command and its related comment (the reaction run can have no prestressed materials).
4. In the “Section Geometry” section of the file, insert additional CONC-STD-SECTION (8-2.1), COMPOSITE-SLAB (10-2.1) and COMPOSITE-REBAR (10-2.2) commands as necessary to identify all girder sections used in the bridge. (A bridge consisting of all the same standard section would not need additional commands here).
5. In the “Span Length and Section information” section, insert additional SPAN-STD-XSECT (11-1.1), SPAN-SECTION (11-2.1), SPAN-COPY (11-3.1) and SPAN-HINGE (11-5.1) commands (with new span numbers) as necessary to define each of the spans in the bridge. To approximate simple spans, the SPAN-HINGE command is necessary near (but not at) the support at the right end, except for the last span in the sequence. Spans that are defined with the SPAN-COPY command still need to have a separate SPAN-HINGE command.
6. After the span definitions, insert additional SUPPORT-FIXITY (11-4.1) commands for each support in the bridge. All supports would have “R” (for “Restrained”) in the Y-direction, and only one support (usually at the left end of the structure) would be restrained in the X-direction.
7. Delete all commands and associated comments related to prestress definitions, strands, losses, and shrinkage loads.
8. In each of the dead load groups, insert additional LOAD-DEAD-UNIFORM (12-1.3) and

LOAD-DEAD-POINT (12-1.4) commands as necessary to apply the dead loads to all spans of the bridge.

9. Delete all OUTPUT-INTERMEDIATE (5-2.1) commands relating to points of interest. With this run, we are interested only in liveload reactions, not in rating factors at points of interest (which would be wrong in any case due to substitution of non-prestressed girders).

5.5 Exterior Girder Analysis

Use the interior girder files as a starting point for creating the exterior girder files. Most of the interior girder file will still apply for the exterior girder analysis. Because the interior file is used as a starting point, it is suggested to not begin the exterior girder analysis until throughout checking of the interior files have been completed. Any mistakes found in the interior file would likely also be mistakes in the exterior file.

5.5. 1 Generating an Exterior Girder Preliminary File from an Interior Girder File

For the typical un-widened prestressed girder structure where the exterior girder design is the same as the interior girder, the task of generating an exterior girder preliminary file from the corresponding interior girder preliminary file generally consists on the following steps:

(1) Make a copy of **PSINT.xmcd** and rename it **PSEXT.xmcd**.
(2) Change the title (first header).
(3) Eliminate all the calculation sections above “Component dead loads (DC)”. and replace them with the statement “All factors and material properties are the same as for the interior girders (see **PSINT.xmcd**)”.
(4) Revise the calculations for actual flange width for girder dead load (over-hang width combined with half the adjacent girder spacing).
(5) Revise the calculations for dead load of the diaphragms.
(6) Revise the calculations for liveload distribution factors (if, for some reason, the live load distribution factors are being manually calculated).
(7) Eliminate all the calculation sections after “Wearing Surface dead loads (DW)” and append the statement “All live loads, Girder Geometry & Analysis Sections are the same as for the interior girder (see **PSINT.xmcd**)”.

In cases where the exterior girder design is different than the interior girder, the task of generating an exterior girder preliminary file is similar to the creation of the interior girder preliminary file.

In the case of a prestressed slab or box girder bridge with a sidewalk or rail and curb that covers half or more of the exterior girder width, the exterior girder does not need to be analyzed. This is due to the distribution factors becoming zero for the exterior girder in this situation.

5.5.2 Generating an Exterior Girder BRASS Input File from an Interior Girder File

For the typical un-widened Prestressed Concrete Deck Girder structure where the exterior girder design is the same as the interior girder, the task of generating an exterior girder BRASS input file from the corresponding interior girder BRASS input file generally consists on the following steps:

(1) Copy **PSINT.DAT** to **PSEXT.DAT**
(2) Change the title
(3) Change the dead loads due to diaphragms
(4) Change the girder of interest, i.e. parameter 1 of the DIST-CONTROL-GIRDER command (4-3.1) from 2 to 1

SECTION 6: LOAD RATING POST-TENSIONED BOX GIRDER BRIDGES

This section covers post-tensioned box girder bridges that can be designed as single-spine beams with straight segments (AASHTO LRFD 4.6.1.2.3). Segmental post-tensioned box girder bridges are not covered in this chapter. Precast girders that are spliced to form one simply supported span are not considered segmental per AASHTO LRFD 5.12.3.4.1, and can therefore be analyzed following the procedures listed below. Reference the commentary in AASHTO LRFD section 5.12.3.4.1 for a discussion of the difference between spliced and segmental construction.

6.0 Scoping of Structure

Create a scoping file (nnnnnn_scope.xls) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended affect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0 then, there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

6.1 Whole-Width Approach

Torsionally stiff cross-sections, such as cast-in-place multicell concrete box girders, can be designed using the whole-width approach (AASHTO LRFD 4.6.2.2). ODOT chose to use this method of analysis for cast-in-place multicell concrete box girders since the cross-section is very stiff and the webs do not act independently.

Often the exterior stem walls are not the same height as the interior stems, resulting in an apparent exterior stem diminished capacity. Because the sections are torsionally stiff, all of the girders resist applied loads regardless of placement location. The whole-width approach accounts for the sections ability to distribute loads amongst all the girders.

Prestressing strand information is commonly provided by the designer through one profile at the CG of all the strands. Because the exterior girders are not always full depth, an assumed strand profile for the exterior and interior girders would have to be calculated to perform a single girder analysis. Calculating a unique profile for the exterior and interior girder requires several assumptions and complicates the load rating. Using the whole width approach allows all of the strands to be input at the design prestress CG profile, thus simplifying the load rating procedure.

Precast prestressed concrete boxes that are spliced and then post-tensioned (spread boxes) can not be analyzed using the whole width approach; instead individual girder lines must be analyzed. Aside from analyzing individual girders, the procedure for analyzing the spread boxes is the same as analyzing the cast-in-place post-tensioned box girders. Although individual girder lines must be analyzed, this type of construction typically will have the same design for an interior and exterior girder line. Therefore, the only difference between the interior and exterior analysis will usually be the live load distribution factors.

Spread boxes are commonly constructed with the following procedure; place the precast tubs on temporary supports, pour closures to make precast units continuous, pour composite deck, post tension the entire superstructure, and then remove temporary supports. The methodology outlined in this chapter does not account for the difference in construction methods of spread boxes and cast-in-place box girders. Ignoring the construction staging has little effect on strength I rating factors, but will introduce slight error in service III rating factors. This error is minor in most cases. See section 6.6.17 for a more in-depth discussion of service III rating factors and construction staging.

6.2 Preliminary Files for Girders (Mathcad)

For post-tensioned box girders, the preliminary (Mathcad) file name and extension for bridge #nnnnn is typically nnnnn_PTBOX.xmcd.

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied terms with parentheses.

6.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater, date (2nd line left), File Name, and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description ("Spans" field) from the Bridge Log is adequate for this purpose.

Note: The Mathcad regions in the top right margin (outside the printable area) are there for two purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

6.2.2 Resistance Factors

Document the decisions regarding all 3 Resistance Factors, with references to the appropriate MBE tables.

Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure in RC Members:
$\Phi_f = \phi\ [\ \max(\phi_c\phi_{sf}\ ,\ 0.85)\ ]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Flexure in PS Members:
$\Phi_f = \phi\ [\ \max\ (\phi_c\phi_{sf}\ , 0.85)\ ]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Shear:
$\Phi_v = \phi\ [\ \max\ (\phi_c\phi_{sv}\ , 0.85)\ ]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2)
and ϕ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).

Generally Φ_f and Φ_v will be the same for redundant members such as girders and will be different for non-redundant members such as single-span and 2-span crossbeams.

6.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into nnnnnn_PTGirder.xls. The Load Rating Summary Workbook **(LR.XLT)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and effective bridge length. Note that effective bridge length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which Live Load Factor Application is used, ADTT is specified as “one direction”. Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the Live Load Factor Application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the Live Load Factor Application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the “LRFR Strength I & II” table from the live load factor application, and in Mathcad use Edit / Paste Special. In the “Paste Special” dialog box choose the “Paste” button, highlight “Bitmap” in the “As” list, and click the “OK” button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to MBE 6A.4.4.3.

6.2.4 Distribution Factors

nnnnn_PTGirder.xls is used to calculate the distribution factors. Per AASHTO LRFD 4.6.2.2 the live load distribution factors for an interior web are multiplied by the total number of webs when the whole-width approach is used. When spread boxes are being analyzed, both interior and exterior girder line (one tub equals one girder line) distribution factors will need to be calculated. Multiplying the number of webs by the live load distribution factor is done internally by the spreadsheet. Section 6.5.4 covers this process in detail.

6.2.5 Material Properties

Enter the material properties and calculate the elastic modulus for reinforced concrete (E_c) and prestressed concrete (E_{psc}). Then compute the modular ratio for concrete materials (n_c). Use AASHTO LRFD Equation 5.4.2.4-1 to determine the elastic modulus of concrete, assuming K_1=1.0. Document assumptions made about the material properties if they are not given on the Bridge Plans. When the deck and girder concrete are not of the same strength, the concrete modular ratio will be used to transform the deck concrete into equivalent girder concrete.

6.2.6 Bridge Average Geometry

Calculate the distance from centerline of the exterior stem to face of curb, d_e. Calculate the stem spacing and enter the values within the Mathcad preliminary file. Nnnnn_PTGirder.xls doesn't allow for variable stem spacing's within a cross section, thus calculate and record the maximum spacing. If the maximum girder spacing varies across the length of the span (flared webs) then the spacing at left support and right support shall be calculated. Nnnnn_PTGirder.xls will automatically linearly vary this spacing across the span. Document the skew angle at the left and right support. When calculating distribution factors nnnnn_PTGirder.xls will automatically use the left, right, or average skew angle depending on what distribution factor is calculated.

6.2.6.1 Span Layout

Typically post-tensioned box girders extend a short distance beyond the CL of bearing. Because the stressing strands are anchored at the end of the box girder, they do not have a development length like precast prestressed girders. If the strand layout is defined from CL of bearing, then neglecting the overhang does not significantly affect the rating factors and will therefore not be included. When the strand layout is provided from the face of the end beam then it is typically easier to simply include the end beam in the analysis. Span lengths will still always be defined from CL bearing to CL bearing. If the cross-beam warrants an analysis, the dead load from this overhang shall be included as a point load.

6.2.6.2 Section Properties

The GeometryCalcs tab in nnnnn_PTGirder.xls is predominately used to calculate the geometry at various cross sections. In this portion of the preliminary file, provide a brief description and show these calculations.

Each unique cross section change location is drawn in Microstation and imported into Midas for analysis. Midas is capable of linearly, or parabolically, tapering between unique sections about the y and z axis. This means that only section change locations need to be drafted.

In addition to the section change locations, the excel spread sheet is used to calculate capacities and rating factors, nnnnn_PTGirder.xls, requires the calculation of additional section dimensions. Using the GeometryCalcs tab calculate b_v, H, deck thickness, equivalent deck width, bottom flange thickness, and bottom flange width.

If the girder and beam concrete compressive strengths differ a transformed deck width is calculated in nnnnn_PTGirder.xls. The load rater is not required to perform this calculation.

Calculate the minimum web width and duct diameter. The minimum web width is measured parallel to the neutral axis per AASHTO LRFD 5.7.2.8 and is reduced due to the presence of ducts. Reduce the web width by ¼ of the grouted duct diameter. If the plans do not specify the duct diameter then it may be calculated as 40% of the minimum web width per AASHTO LRFD 5.4.6.2.

Calculate the volume to surface ratio for use in the Midas analysis. Per AASHTO LRFD 5.4.2.3.2, for poorly ventilated interior box girders only half of the interior perimeter is used. Take measurements of the cross sectional area and perimeter from the MicroStation file BRnnnnn.dgn.

Include nodes at 1/20 points across the entire structure, which will be used in the Midas analysis. Otherwise having large element lengths on the symmetric side of the structure may produce analysis errors. The section geometry does not need to be calculated for the symmetric nodes.

Multi-span bridges that are continuous for live loads will also need to have the support conditions accurately modeled. This includes modeling columns that are integral with the superstructure. Although rating factors will not typically be calculated for columns, they are included because they impact the superstructures stiffness.

6.2.7 Reinforcement Layout

In this section show all calculations necessary to determine the location of reinforcement that will be used for capacity calculations. It is particularly important when calculating the nominal moment capacity to include the mild steel reinforcement. Although the mild reinforcement does little to the Mn value, it does have an impact when determining if the section is tension controlled and will thus have an impact on φ_f.

6.2.7.1 Flexural Reinforcement

Show any necessary calculations for determining the flexural reinforcement. Calculate y_c, the distance from bottom of girder to centroid of the row being defined. If calculations are necessary to determine the location of bars or development lengths, they are to be shown here.

6.2.7.2 Shear Reinforcement

Use an embedded Excel spreadsheet within Mathcad to calculate the ranges and span fractions for the shear reinforcement layout for each span as indicated below. Double-clicking on an embedded spreadsheet activates Excel, and its toolbars and functionality become available. An existing embedded Excel spreadsheet can be copied, pasted in another location and modified to do similar calculations for another span. For each span that contains analysis sections, working consecutively from the left end of the span to the right, populate the yellow fields in the following table in the preliminary file. The “Remnant” stirrup space no longer needs to be calculated. Simply input the spacing and the total range that is represented by that spacing.

Shear reinforcement bar size and spacing shall but determined from the plan sheets. When the whole width approach is used, the sum of all shear reinforcement at a section will be used. Typically this will be the area of shear reinforcement for an interior stem multiplied by the total number of stems. If the exterior stem has a different stirrup schedule than the interior stems, use the spacing of the interior stem with an equivalent total shear reinforcement area.

Span # :	1	Length (ft):	180.00		
Begin (in)	Spacing (in)	Range (in)	End (in)	# Legs	Stirrup Size
20	6	216	236	22	#5
236	18	1688	1924	22	#5
1924	6	216	2140	22	#5

6.2.8 Prestressing Properties

Designers commonly provide a few parameters for prestressing strand and leave some flexibility to the post-tensioning contractor on the distribution, size, and sequence of stressing. Typically, a total prestress CG profile, final midspan prestressing force, anchor set, friction factor, wobble coefficient, assumed time dependent losses, and area of prestressing strand are provided on the bridge plans. In the Preliminary (.xmcd) file, under the section titled Prestressing Properties, document all strand properties and calculate the number of prestressing strands to achieve the design requirements.

Unless otherwise stated, assume 1/2in diameter 7-wire strand. This is the most common strand type used within the state. Document the type of strand, stress relieved or low relaxation and any other assumptions under the Prestress Properties heading.

Unless otherwise specified, assume an equivalent anchor set of 5/8in.

Provide any necessary calculations to determine the beginning and ending locations of prestressed or post-tensioning strands. For Midas to correctly output prestressing strand information, a node point must occur at the beginning and ending location of all prestressing strand.

Annual relative humidity is determined per AASHTO LRFD Figure 5.4.2.3.3-1. Interpolation between curves is not necessary, rather select the lower value.

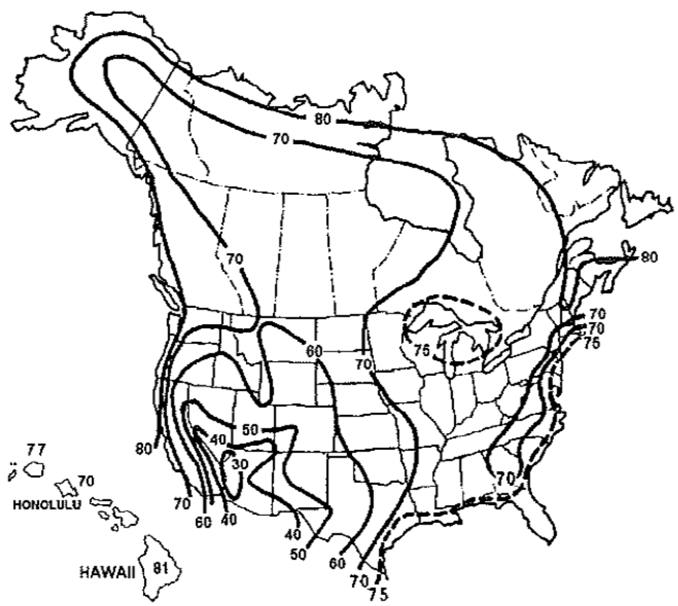


Figure 5.4.2.3.3-1 Annual Average Ambient Relative Humidity in Percent.

6.2.8.1 Number of Strands, and Initial Jacking Stress

If the designer provided an equation in the bridge plans that shows how the area of prestressing strands is calculated, then use the provided equation. No iteration is required. The equation is commonly provided under stressing details and is of the following form:

$$AS = \frac{Pj}{0.75 f_s^{'}}$$

Where: Pj is the initial force before anchor set at a specific jacking location.
$f`_s$ is the minimum ultimate strength

If the designer did not provide an equation to calculate the total prestressing area then it will have to be calculated from the information provided. Using the final midspan force and the allowable final stresses an iterative procedure can be used to determine the approximate number of strands. This procedure is outlined below. The example load rating for BR09648 can also be referenced.

> Midas Civil can be used to determine the number of strands and the initial jacking stress. This has to be an iterative approach because the number of strands, initial jacking stress, final maximum allowable stress, and final minimum midspan force are inter-dependent. If a maximum allowable final stress is not specified by the plan sheets, then $0.80(f_{py})$ shall be used per AASHTO LRFD Table 5.9.2.2.
>
> Begin by assuming the maximum allowable jacking stress was used. Calculate the number of strands required using the maximum allowable stress at midspan. Input these values into the Midas model and run the analysis.
>
> Check the results to see if iteration is required. The output can be found under; Results => Results Tables => Tendon =>Tendon Approximate Loss. Final tendon stresses are calculated using the assumed time dependent losses (provided in the plans) plus Immediate Losses calculated by Midas. These results will be used to calculate the inputs for the next iteration.
>
> If the final calculated stress is greater than the allowable stress, at any point along the span, decrease the jacking stress by a value equal to the difference of the calculated and the allowable stress. This will decrease the stress along the entire tendon such that the maximum final stress is less than the maximum allowable stress.
>
> Calculate the final midspan force by multiplying the final midspan stress by the strand area. Compare this force to the per plan minimum final midspan force. If the calculated value is below the required value then more prestressing strand needs to be specified.
>
> For the second iteration, the number of prestressing strands can be calculated by dividing the required midspan force by the calculated force per strand. The calculated force per strand is the strand area multiplied by the midspan tendon stress calculated in the previous iteration.
>
> Continue the iteration process until the calculated final midspan force is above the specified minimum and the calculated maximum final strand stress is below the specified maximum. This should not take more than a few iterations.
>
> Note: The final midspan force calculated in this section is not the same force used in capacity calculations. This section uses an assumed time dependent stress loss value, usually 25 ksi. Capacity calculation use calculated time dependent stress losses. Midas performs a refined time dependent stress loss analysis.

6.2.9 Component Dead Loads (DC)

To avoid confusion, dead loads should be grouped under the headings DC and DW in the Preliminary File (**.xmcd**) and entered in the Midas model as separate load cases. Use AASHTO LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c. For dead load calculations, use w_c+0.005 kcf to account for the reinforcement, in accordance with AASHTO LRFD Commentary C3.5.1. Precast reinforced concrete shall use a minimum weight of 0.155 kcf. This minimum is based on recommendations from the precast industry.

Consider diaphragm point loads to be part of component load DC. Include any diaphragms/end beams at the end of the girder over the support, as they will be utilized when applying the girder dead load reactions to crossbeams.

Where standard rail drawings occur, use the rail dead loads tabulated in Appendix H - ODOT Standard Rail Weights, found in file **RAILDL.XLS**. Provide detailed calculations for the dead load of any rail not found in this summary.

For all concrete box girder bridges, assume adequate lateral distribution of loads and distribute the sum of all rail, curb and sidewalk dead loads equally among all girders.

Add a point load at the center of bearing to account for the dead load of the rails, deck, and girder that extend beyond the center of bearing. Even though these loads will have no impact to the load rating of the girder, they will be utilized when applying the girder dead load reactions to crossbeams.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16” diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to be included in the load rating.

6.2.10 Wearing Surface Dead Loads (DW)

Always separate wearing surface dead load (DW) from the component (DC) dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes and (c) it facilitates input for the crossbeam load rating software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Show calculations for wearing surface dead load distributed equally to all the girders. Add 1” to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½” to the design thickness of PPC overlays to account for construction variations and uncertainty.

For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all wearing surface dead loads (stage 2 dead loads) equally among all girders.

Add a point load at the center of bearing to account for the dead load of the wearing surface that extends beyond the center of bearing (the red shaded area illustrated in Article 5.2.5), if a crossbeam analysis is warranted. Even though this load will have no impact to the load rating of the girder, it will be utilized when applying the girder dead load reactions to crossbeams.

6.2.11 Live Loads (LL)

List the four classes of rating loads to be analyzed. (See Articles 1.5.1.1 through 1.5.1.4).

6.2.12 Analysis Sections

Determine the spans to be investigated. These should be any span that is unique and is not repeated due to symmetry or due to repetition of a span between joints. If the post-tensioning strands are stressed from one end only, friction losses will cause an unsymmetrical stress profile. An unsymmetrical strand stress profile does warrant analysis of the entire section, even if the structure is otherwise geometrically symmetrical.

Within each span, check for symmetry of sections, reinforcement and loads, and do not identify any analysis points that are structurally symmetrical with analysis points already defined. Defining analysis points that are structurally symmetrical has the potential effect of corrupting the Load Rating Summary Sheet. Because the "Refresh" module is looking for the lowest Rating Factors, defining a symmetrical point causes it to identify the most critical rating location twice, thus preventing it from identifying the second most critical analysis point. The second controlling point is useful information in evaluating potential repairs for the bridge.

The commentary of MBE Article C6A.5.8 states that for prestressed concrete, multiple locations (preferably at 0.05 points) need to be checked for shear. The location where shear is highest may not be critical because the corresponding moment may be quite low. Typically, locations near the 0.25 point could be critical because of relatively high levels of both shear and moment. Therefore, to follow the recommendation of the LRFR code for prestressed concrete, check shear at all points (including 0.05 points) between the critical shear section locations.

The maximum positive moment location is at the mid-span for simple spans. However, post-tensioned box girders typically either have parabolic tendon profiles and/or parabolic cross section profiles. Because of the changing cross section it is difficult to determine the controlling flexure location. For positive moment, both moment and shear shall be checked at 0.05 points from 0.25L to 0.50L for simple spans, and from 0.25L to 0.75L for continuous spans. For negative moment locations, both moment and shear shall be checked at 0.05 points from 0.80L of the previous span to 0.20L of the next span; excluding shear checks inside the critical shear points from the support.

Besides the locations listed above, there are a number of additional analysis sections for shear. For each unique span, subdivide the calculations of analysis sections into the categories (up to 5) given in article 1.5.3. Summarize the underlined headings that will begin each section of calculations. An example of this summary follows:

Span 1 Critical Shear Section Points
Span 1 0.05 Location Points
Span 1 Stirrup Spacing Change Points
Span 1 Girder Geometry Change Points
Span 1 Large Crack Location Points

Span 2 Negative Moment Section
Span 2 Critical Shear Section Points
Span 2 0.05 Location Points
Span 2 Stirrup Spacing Change Points
Span 2 Girder Geometry Change Points
Span 2 Large Crack Location Points

etc.

Then repeat each header, one by one, and under each header provide the calculations necessary to determine or document the location of each shear investigation point in that category. Thus there will be up to 5 separate calculation sections for each span. If any particular point duplicates a previously calculated point or is within 1 ft of a previously calculated point, the new point may be omitted. In this case, explain the omission by indicating which previously identified point already covers the current one. This gives priority to critical sections and bar cutoff points when near-duplicates are encountered.

- Critical Shear Section Points

  According to AASHTO LRFD Article 5.7.3.2, critical shear section locations shall be taken at shear depth d_v from face of support. AASHTO LRFD Article 5.7.2.8 states that the effective shear depth (d_v) is taken as the distance, measured perpendicular to the neutral axis, between the resultants of the tensile and compressive forces due to flexure; it need not be taken to be less than the greater of $0.9d_e$ or $0.72h$. Thus, for flexural members the distance between the resultants of the tensile and compressive forces due to flexure can be determined as:

$$d_v = \frac{M_n}{A_s f_y + A_{ps} f_{ps}}$$ (AASHTO LRFD C5.7.2.8-1)

For prestressed members with parabolic strands, the calculation of the moment capacity at a given distance from the support in the above equation becomes complicated and would require an iterative approach. To simplify the approach, the critical section at d_v shall be calculated as 0.*72* h (in.) from the support face. Do this for each critical section location (each end of each unique span).

In the event that the above equation produced a higher d_v, 0.72h will be more conservative as it is located closer to the support thus resulting in higher shear location that is being analyzed. Likewise, if $0.90d_e$ is greater than 0.72h, using 0.72h will be located closer to the support thus resulting in higher shear location that is being analyzed. In the event that 0.72h is greater than the above equation or $0.90d_e$, then 0.72h will be in compliance with LRFD Article 5.7.2.8.

- Flexural Bar Cutoff Points

  Flexural bar cutoff analysis is not required. The flexural moment capacity is primarily developed by the prestressing tendons. Therefore, it is not necessary to evaluate mild reinforcement bar cutoff locations for post-tensioned box girders.

- Girder Geometry Change Points

  Show calculations locating any abrupt change in girder cross section, such as the beginnings or ends of haunches, web tapers, or partial bottom flanges.

- Stirrup Spacing Change Points

  These locations are taken from the stirrups schedule spreadsheet embedded in the Preliminary File and adjusted by one stirrup space toward the direction with the greater spacing. At a stirrup spacing change location, a shear crack would propagate across both stirrup spaces. The analysis doesn’t interpolate the shear capacity to the left and right of an analysis point. Therefore, moving the analysis point by one stirrup space moves the analysis location away from the transition area providing a more realistic analysis.

  Indicate which stirrup spacing change points in the girder are farther from the support than the critical shear point.

- Debonded Strand Points

  The debonded strand locations need to be checked for shear only when the number of debonded strands at a section exceeds the limits specified in AASHTO LRFD 5.9.4.3.3.

6.3 Cross Section Geometry

Calculate the section properties at each unique section change location. A combination of MicroStation and the Midas Sectional Property Calculator tool is used.

Node points will be created for the ends of spans (CL Bearing), girder geometry change points, and all analysis points. Only the section change locations will have a cross section defined. The tapered section group command within Midas is used to taper between sections.

Columns can typically be modeled using the cross section feature in Midas. Therefore, it is not necessary to draft a column cross section in MicroStation.

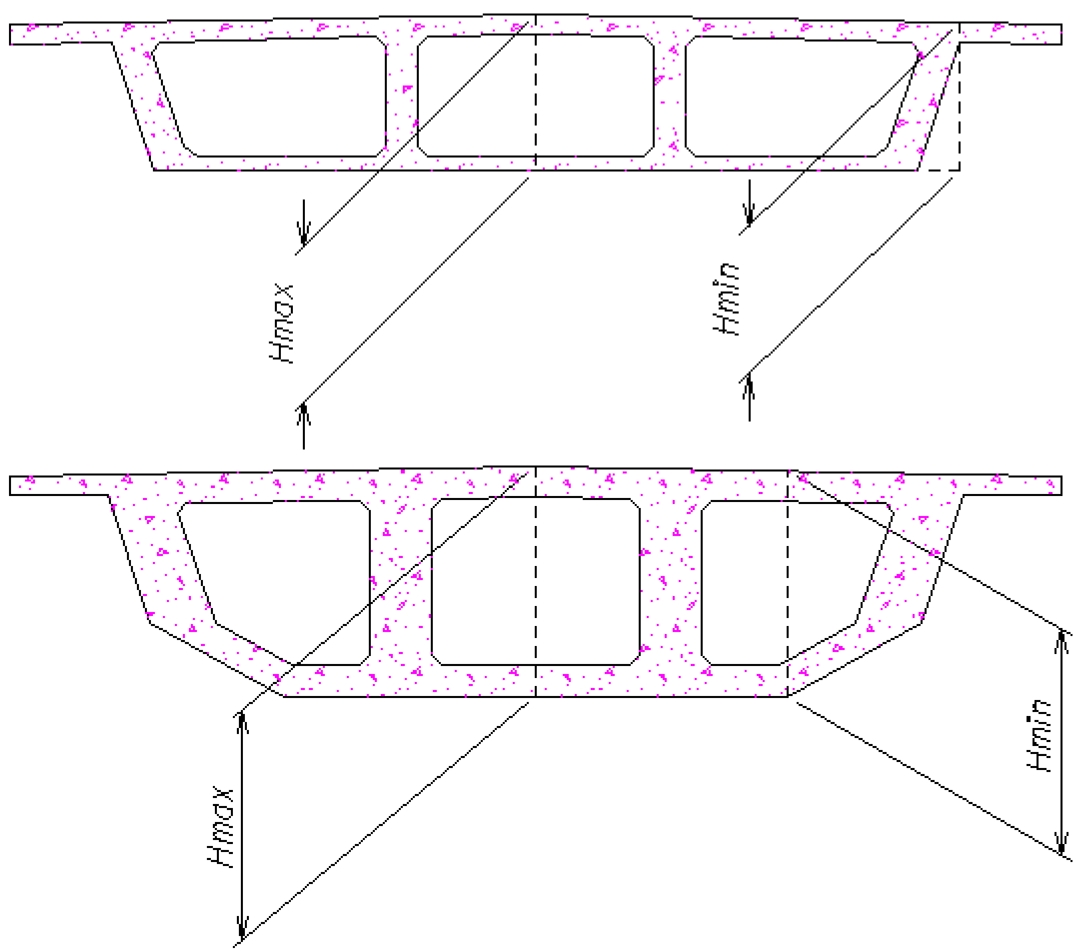
6.3.1 Geometry Calculations

Use the GeometryCalcs tab in the nnnnn_PTGirder.xls spreadsheet to document all calculated section dimensions. This sheet is useful as a guide when referencing locations, to nodes, to cross section numbers, to element locations.

MIDAS output is referenced to either node points or elements. Use this sheet to reference each section location with the Midas node point and element location.

If the box girder height varies parabolically, write an equation for the parabola so the height can be calculated at each node point. Stem wall, top and bottom flange thicknesses commonly vary near bent locations; the actual width of each shall be calculated at each node point.

Calculate an equivalent cross section height for use in Midas and nnnnn_PTGirder.XLS. This height will be the average height of the full depth box section accounting for the differences due to roadway crown. The new average height cross-section will be modeled with no crown or roadway super elevation (flanges will be flat). The figures below illustrate where the maximum and minimum heights will typically be used to calculate the average cross section height.



When all stem walls are full depth the effective shear width b_v is the sum of all stem wall widths, measured in a plane horizontal to the neutral axis, reduced by ¼ of the duct diameters for grouted tendons and ½ the diameters for ungrouted tendons, per AASHTO LRFD 5.7.2.8. For cross sections with shallow exterior stem walls, the effective shear width will be determined by summing the area of each stem (still reduce the width for the presence of ducts), and dividing by the average height. The average height is calculated as shown above; do not include the shallow exterior stem walls when determining the average height.

When the deck overhang thickness varies or is different from the rest of the deck, an equivalent deck width can be calculated. Only one deck (top flange) thickness can be input for capacity calculations. Therefore, one deck thickness will be used but the top flange effective width will be varied to account for the different overhang thickness. Use the interior deck thickness for the entire top flange, but vary the effective width to account for any varying overhang. The result should be an equivalent top flange with the same cross sectional area as that shown on the plans, with a uniform thickness, and a varying width. The small change in the top flange centroid can usually be neglected.

If the top flange concrete has a different compressive strength than the girder concrete, only use the girder compressive strengths in the Midas analysis. The nnnnn_PTGirder.xls sections allow for separate compressive strengths to be entered, so the capacity calculations will be performed correctly. Coding a single material in the Midas analysis allows for the section to be input without the composite commands. Use a transformed top flange width to account for the difference in section stiffness. The transformed top flange width is calculated automatically using the equivalent top flange width and concrete strengths defined in the GeometryCalcs tab of nnnnn_PTGirder.xls. Note that using a transformed width simplifies the analysis but will create an error in the overall dead load. Apply a uniform dead load that accounts for the difference in the equivalent top flange and the transformed top flange. If the deck is of a lower strength than the girders, then this load will be in the opposite direction of gravity.

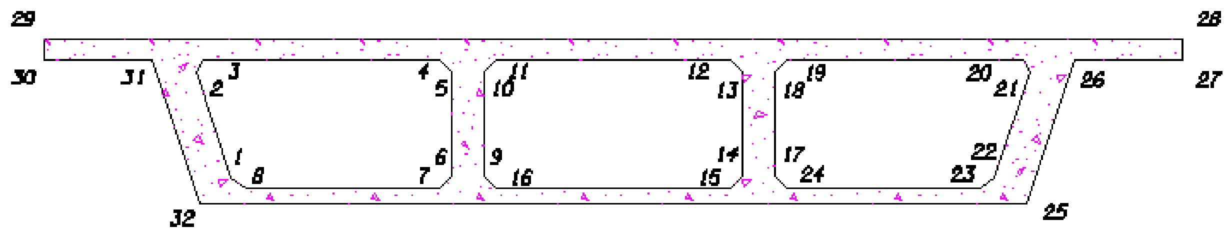
Capacity calculations of columns are not necessary unless the column is being load rated. Therefore, do not include column cross sections in the GeometryCalcs tab.

6.3.2 MicroStation Cross Sections

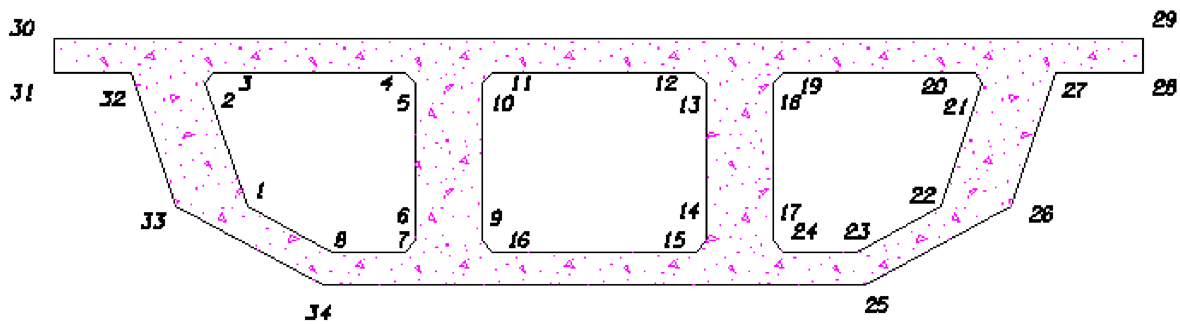
Before beginning work in MicroStation review the list of node points in the GeometryCalcs tab. Reviewing this for completeness can save significant time later. Each cross section will be drawn in MicroStation and then exported to the Midas Sectional Property Calculator. Only section change locations have to be defined here. It is acceptable to use AutoCAD to generate the cross sections.

Midas is capable of tapering from one section to the next. However, for this taper to work correctly each cross section must have the same number of joints. Because of this, a little up front planning is necessary. Determine the cross section that will have the most joints and begin here.

The figures below show a cross section near mid-span and another near the interior support. Each cross section is using an average height, thus the flanges are flat with the roadway crown not being modeled. The cross section near mid-span has only 32 joints, where the one near the interior support has 34 joints. In order to have Midas correctly taper the cross sections between each other, the cross section near midspan will have to have a couple of its straight line segments broken into smaller segments so that the number of joints match with the cross section near the interior support.



near mid-span



near interior support

Use good drafting techniques when drawing this first section. Make sure all intersecting lines are trimmed and match up correctly. Do not have any overlapping line segments. Draw in all chamfers. Most structures are symmetric about the CL of the section; take advantage by drawing half the section and then make a mirrored copy about the vertical axis. This first section will be the template for all other sections, so take the time to check it for accuracy.

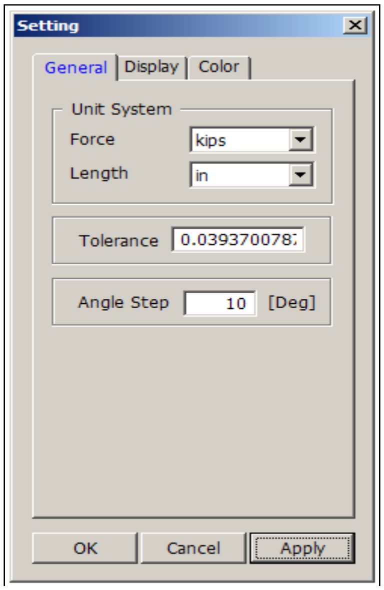
Copy and paste the first cross section to use as a starting point for the next section. Alter the section to match the new cross section dimensions. If a joint is eliminated, place a dummy joint in the new cross section. A dummy joint can be made by breaking a line segment into two line segments at approximately the location where the joint is removed. All of the sections must have the same number of joints for Midas to properly taper from one section to the next.

Continue this process until a cross section exists for each node in the span. Place the cross sections so that they are in sequential order from the first to last. Copy all of the sections and paste them adjacent to the original sections. One set of sections shall have the appropriate dimensioning shown on the drawing along with a section number label. The other set of sections will have no dimensioning or labels. Copy the non-labeled sections into a new file titled Sections and save as a .DXF.

6.3.3 Sectional Property Calculator

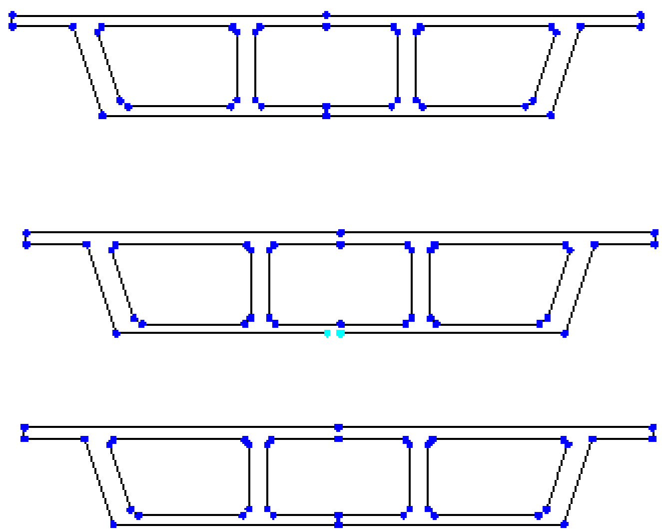
The Midas Sectional Property Calculator tool is used to convert the MicroStation Sections.dxf file into a Sections.sec (Section Export File). Once created the Sections.sec file is used by Midas to define the section properties.

Open Midas and under the tools menu open up the Sectional Property Calculator (SPC). Once open change the force to kips, the length to inches, click Apply and then okay. Apply must be clicked for the tolerance to be recalculated as shown below.

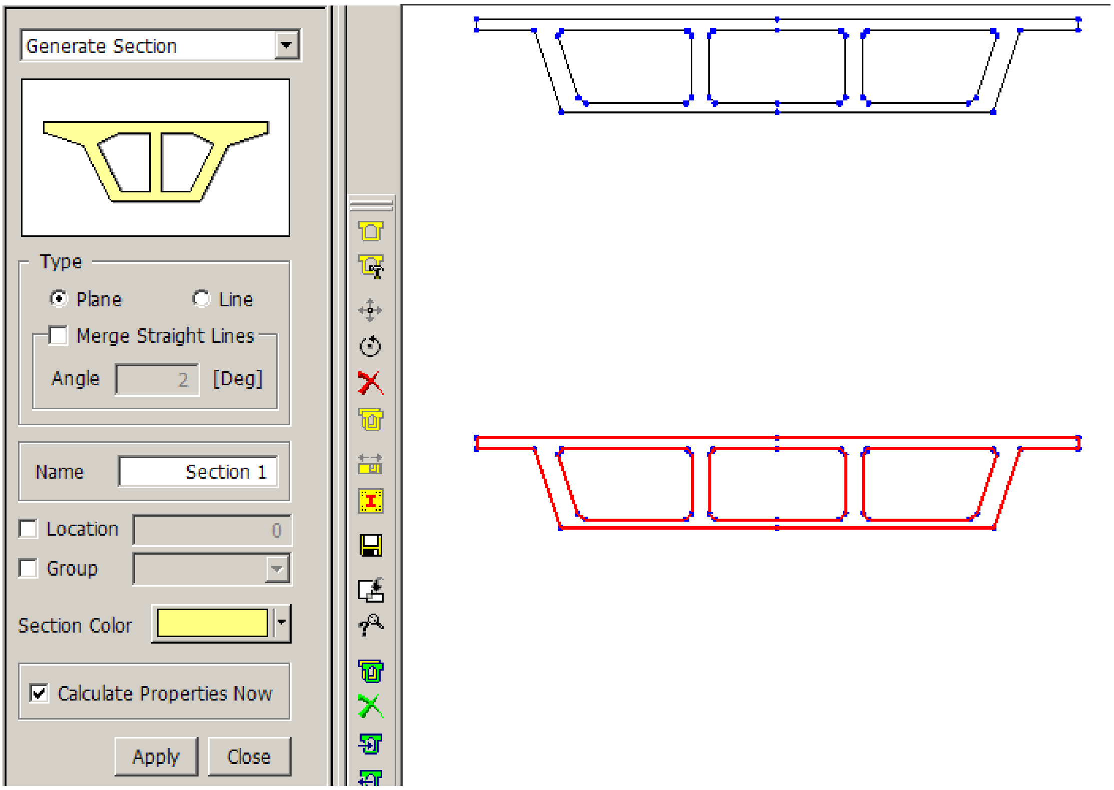


Import the Sections.dxf file created in MicroStation. Go to File => Import => AutoCAD DXF. Browse to the file location and open. The SPC will pop up a window either stating "It will take a very long time for checking the entire curves", or it will pop up "Check the intersection and/or duplication of the imported DXF model data?" If the later occurs, select No. Selecting yes would remove any dummy nodes that were intentionally created while drawing the section in MicroStation.

The imported sections will look similar to those shown below. Check that the node points are all dark blue and have the same number of nodes from one section to the next. If there is an error, the SPC software will display a light blue color at the node, as shown in the middle cross section below.



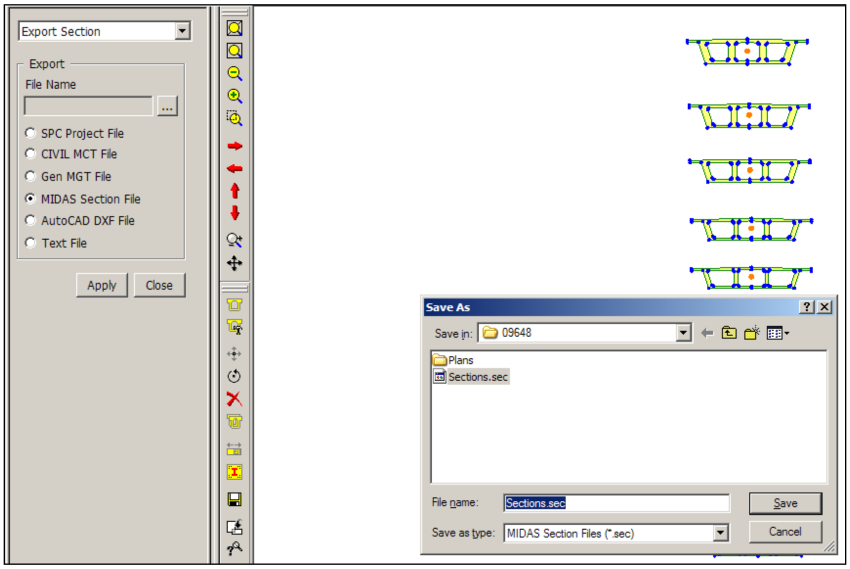
Using the Generate Sections tab (Shown below), generate and calculate the properties for each section. Highlight the cross section with the mouse. Select Plane for Type. Uncheck the Merge Straight Lines (this would remove any dummy joints). Name the section and check the calculate properties now box. Click Apply. See below for a graphic of this setup.



Continue generating sections until all cross sections have been completed.

NOTE: If an error regarding mesh size is reported, close the program and restart by importing the .dxf file. Create all of the sections as shown above, but do NOT select calculate properties now. Once all of the sections are generated, go to the top menu Property => Calculate Section Property. Refine the mesh density as required. Select all of the sections and then click apply. This may take several minutes depending on the number of sections and the mesh size.

On the left tree menu, under Section, select Export. Select Midas Section for the file type and name the file Sections. Highlight all of the sections and click apply. This will create the Sections.sec file that will be imported into Midas.



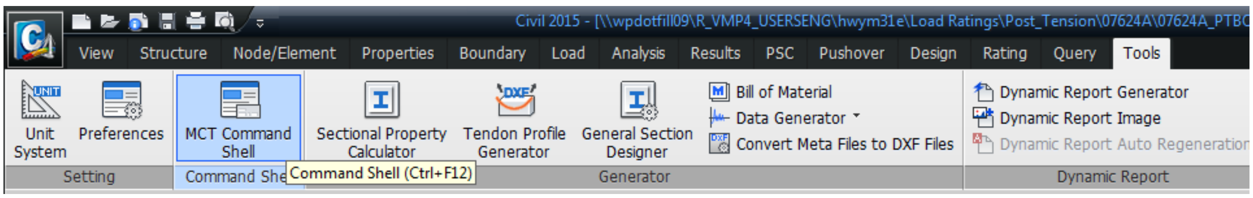
6.4 Midas Civil

Midas Civil is not used to calculate capacity or rating factors. Rather it is utilized to determine various load effects. Capacity and rating factors are calculated in nnnnn_PTGirder.XLS. Midas Civil is a powerful finite element analysis software. The below procedure may be valid on previous versions. If a previous version is used, check the input and output for consistency with this chapter.

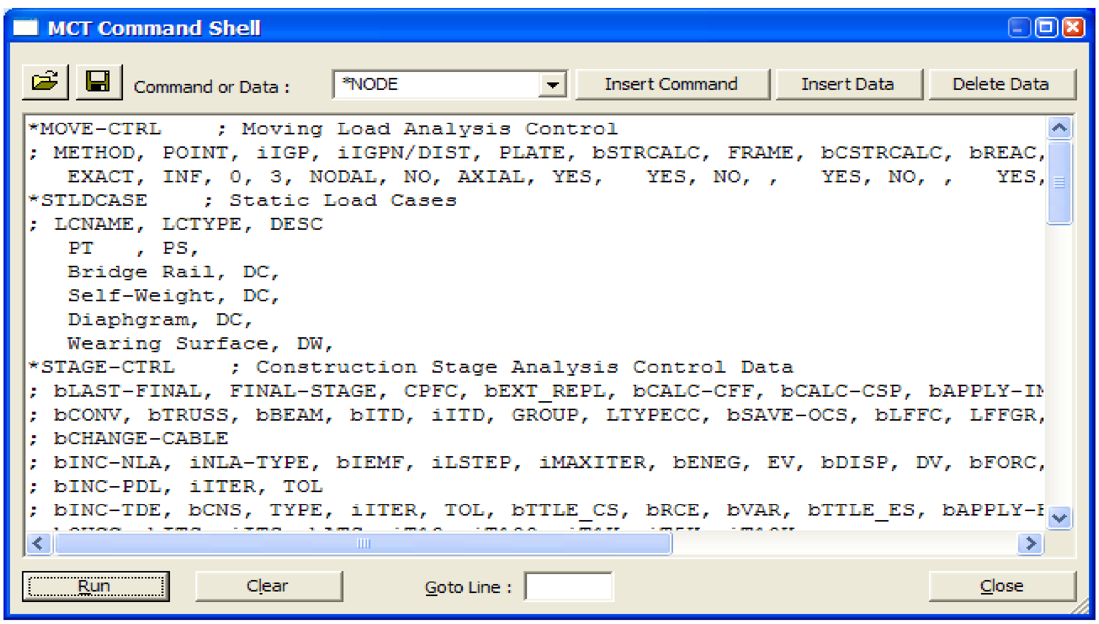
6.4.1 Midas Template

Create a new Midas model and save it with the name nnnnn_PTBOX.mcb.

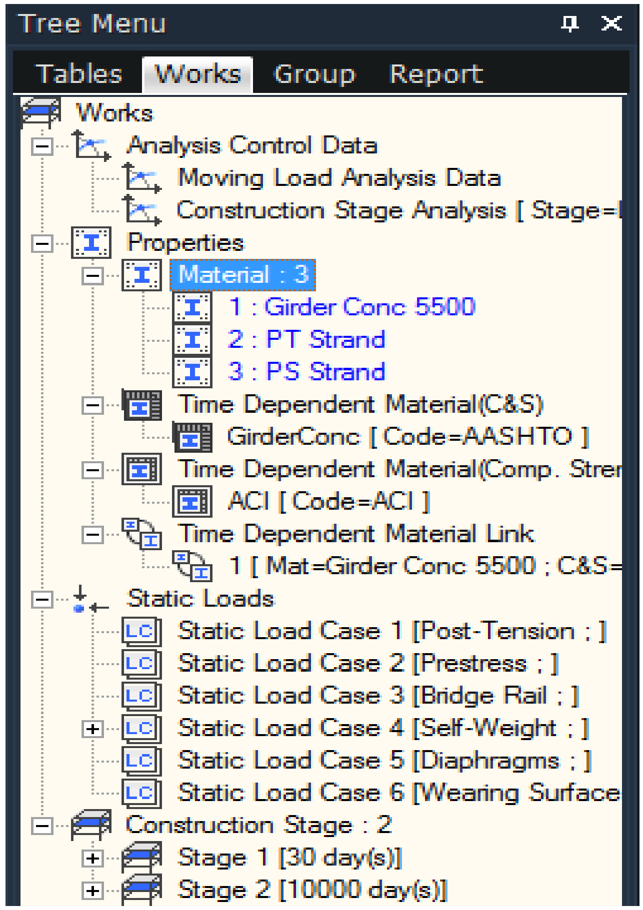
In the top menu, go to Tools > MCT Command Shell.



Within the MCT Command Shell, click the open file icon. Open the mct file named "LR_Midas_PT_Data.mct", which will populate the MCT Command Shell window with data. At the bottom left of the MCT Command Shell window click on the "Run" button. Then click on the "Close" button at the bottom right of the MCT Command Shell window.

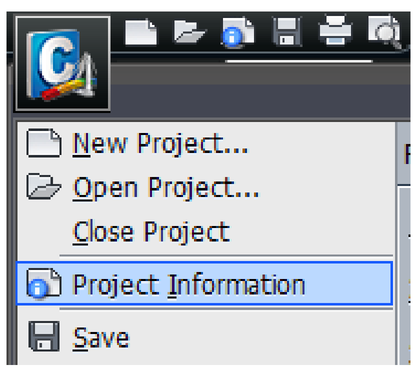


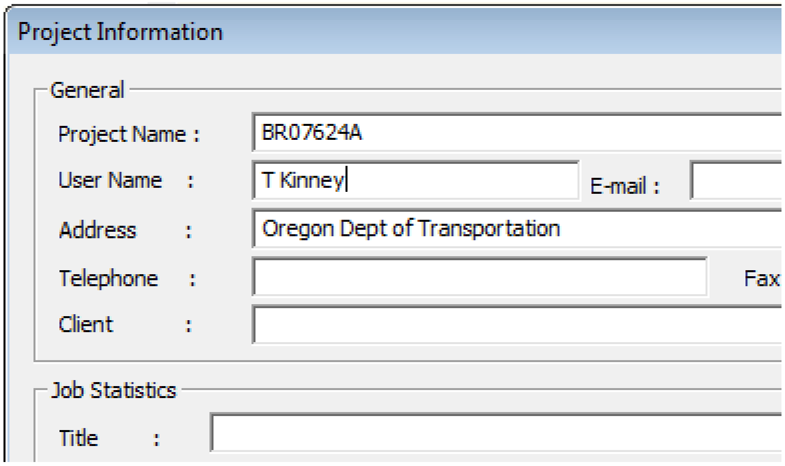
Within the Works Tree Menu there will now be Analysis Control Data, Properties, and Static Loads defined for the model.



6.4.2 Project Information

Update the project information with the bridge number, engineer's name, and company performing the load rating. In the top menu go to Midas Icon (Top Left) => Project Information.





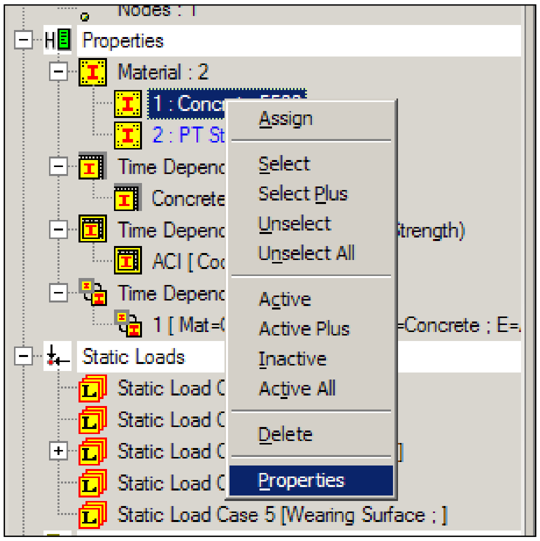
6.4.3 Properties

Using the tree menu verify the material properties and make adjustments as necessary. Make sure the input units are correct.

6.4.4.1 Materials

One concrete, one PT strand, and one PS strand material property is predefined. Update these materials as required. If additional materials need to be assigned go to the top menu under Properties => Material Properties and select Add. The deck, stem walls, and bottom slab are typically the same concrete strength; regardless the Midas model will assume one concrete strength for the entire superstructure. Any variation in girder and deck concrete strength is accounted for by using a transformed deck width. Mild steel reinforcement doesn't need to be defined in Midas. Mild reinforcement will be directly entered into the nnnnn_PTGirder.xls spreadsheet.

In the tree menu right click on "Concrete 5500", and then left click on "properties".

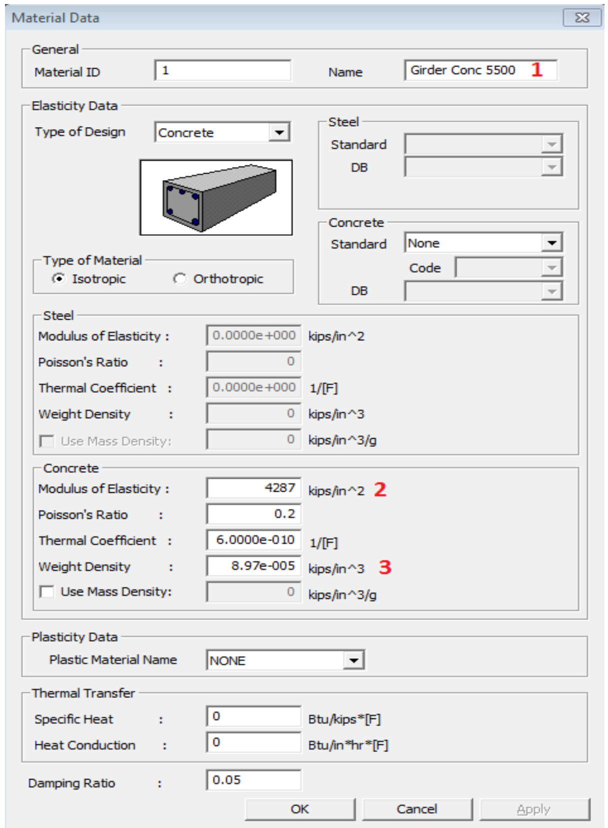


Update the following:

1) Name.

2) Modulus of Elasticity.

3) Weight Density. Select OK.

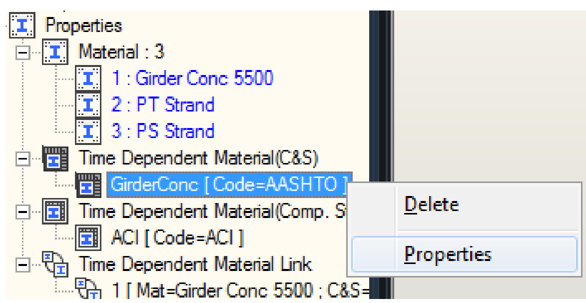


PT and PS Strand material properties should remain unchanged. Note the unit weight is set to 0.0 kips/in^3 because the unit weight of the concrete includes reinforcement.

6.4.4.2 Time Dependent Material (C&S)

Update the properties used to calculate creep and shrinkage.

Right click on Concrete (Code=AASHTO) and left click on properties.



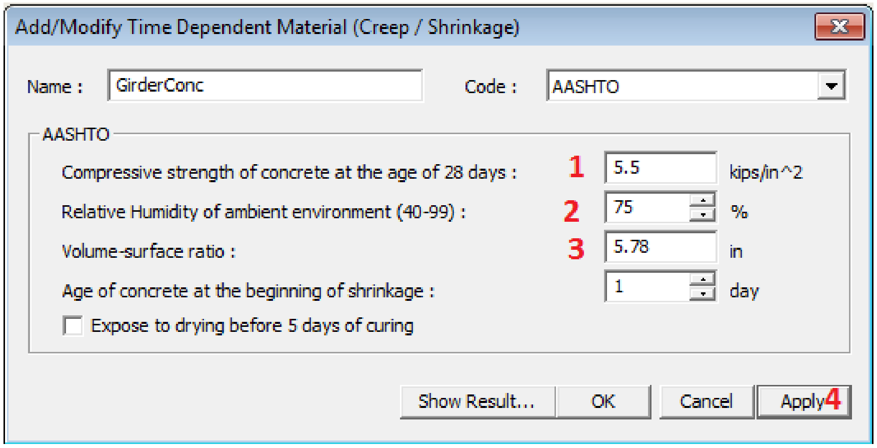
Update the following:

1) Concrete Compressive Strength.

2) Relative Humidity (PER AASHTO LRFD FIGURE 5.4.2.3.3-1).

3) Volume-surface ratio.

4) Click on Apply.



6.4.4.3 Time Dependent Material (Comp. Strength)

Update the concrete parameters used to calculate the time dependent compressive concrete strength.

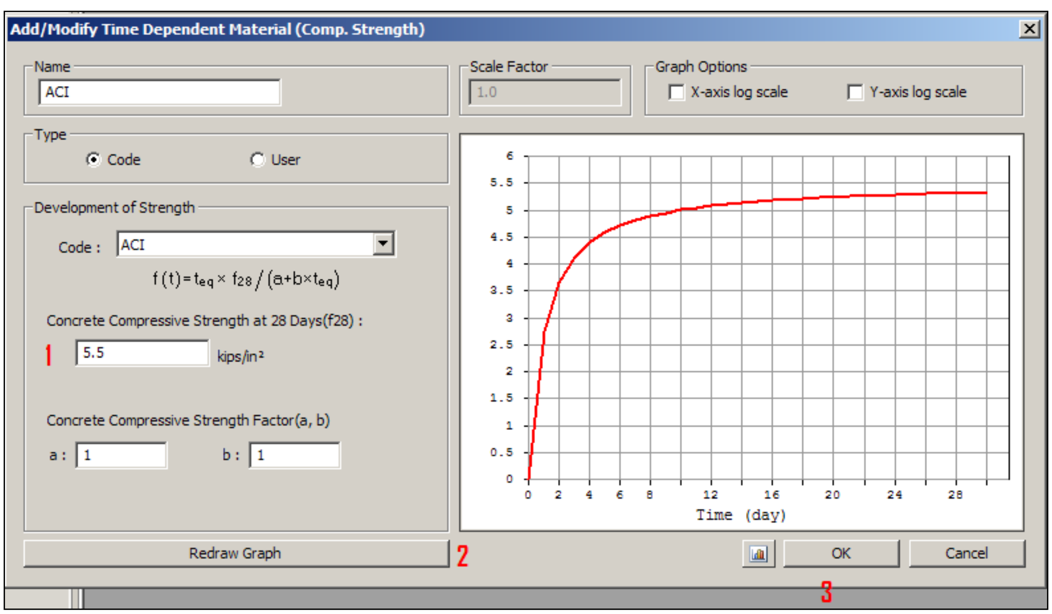
Right click on ACI [Code=ACI] and then left click on properties.

Update the following:

1) Concrete Compressive Strength.

2) Click Redraw Graph.

3) Click OK.



6.4.4.4 Time Dependent Material Link

Unless additional materials were defined, this section should remain unchanged. The Time Dependent Material Link assigns defined materials to time dependent properties. Note: prestress steel time dependent properties are defined in a different section.

Right click on 1 [Mat=Girder Conc 5500 ; C&S=Concrete ; E=ACI and then left click on properties.

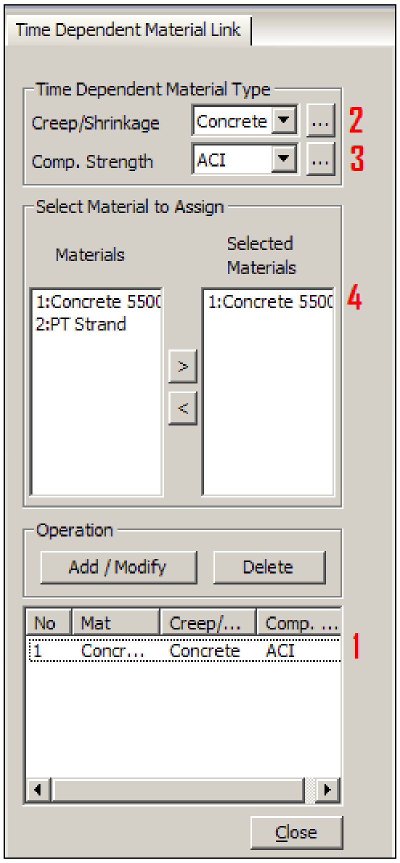
Check/Update the following:

1) Click on No 1 Concrete.

2) Creep/Shrinkage is Concrete.

3) Compressive Strength is per ACI.

4) Selected material is Concrete. If all is ok then click close, if not update to the correct parameter and then click Add/Modify, then close.

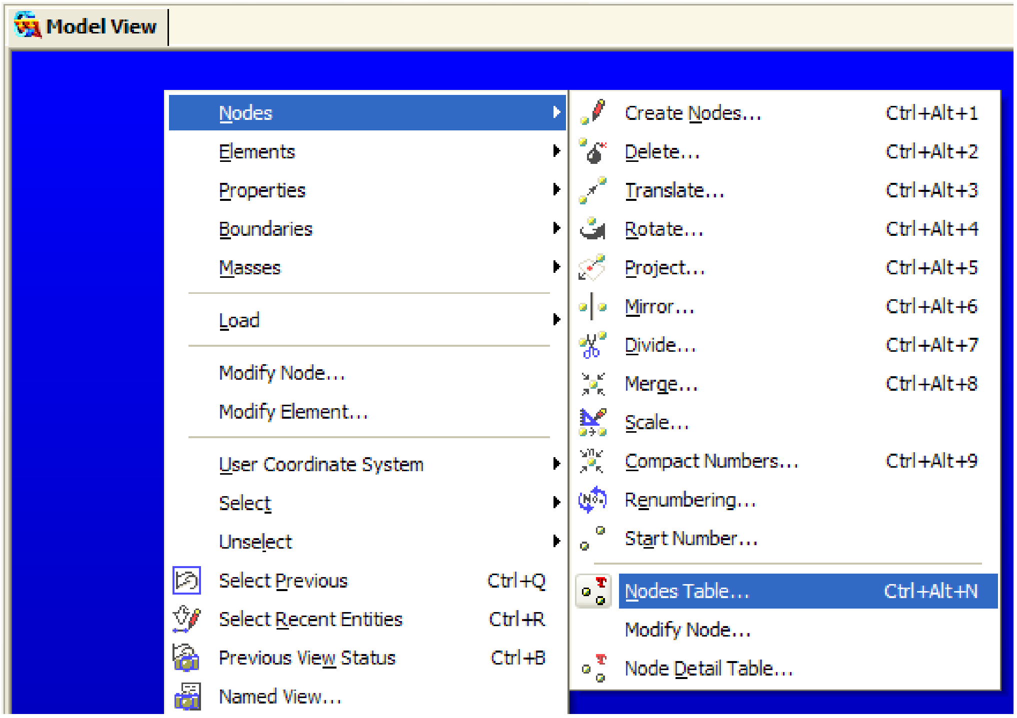


6.4.5 Sections

Cross sections have been defined, and section properties have been calculated for each cross section. These will be imported and tapered as applicable. It is beneficial to print the highlighted GeometryCalcs.xls spreadsheet to use as a reference. The sheet references nodes, to sections, to distances.

6.4.5.1 Nodes

Within the Model View window, right click anywhere and select Nodes > Nodes Table…



Node locations can either be manually typed into the X column or copy and pasted from the GeometryCalcs tab in nnnnn_PTGirder.xls spreadsheet.

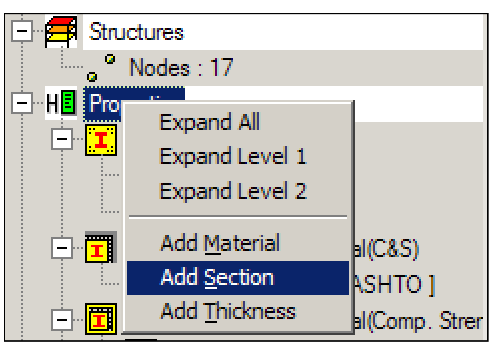
Model View | **Nodes**

Node	X(in)	Y(in)	Z(in)
1	-15.700000	0.000000	0.000000
2	0.000000	0.000000	0.000000
3	29.000000	0.000000	0.000000
4	80.840000	0.000000	0.000000
5	159.000000	0.000000	0.000000
6	173.000000	0.000000	0.000000
7	270.000000	0.000000	0.000000
8	360.000000	0.000000	0.000000
9	413.004000	0.000000	0.000000
10	450.000000	0.000000	0.000000
11	540.000000	0.000000	0.000000
12	630.000000	0.000000	0.000000
13	720.000000	0.000000	0.000000
14	810.000000	0.000000	0.000000
15	900.000000	0.000000	0.000000
16	990.000000	0.000000	0.000000
17	1080.000000	0.000000	0.000000
18	1170.000000	0.000000	0.000000
19	1260.000000	0.000000	0.000000
20	1350.000000	0.000000	0.000000
21	1387.000000	0.000000	0.000000
22	1440.000000	0.000000	0.000000
23	1530.000000	0.000000	0.000000
24	1627.000000	0.000000	0.000000
25	1710.000000	0.000000	0.000000
26	1771.000000	0.000000	0.000000
27	1800.000000	0.000000	0.000000
28	1815.700000	0.000000	0.000000

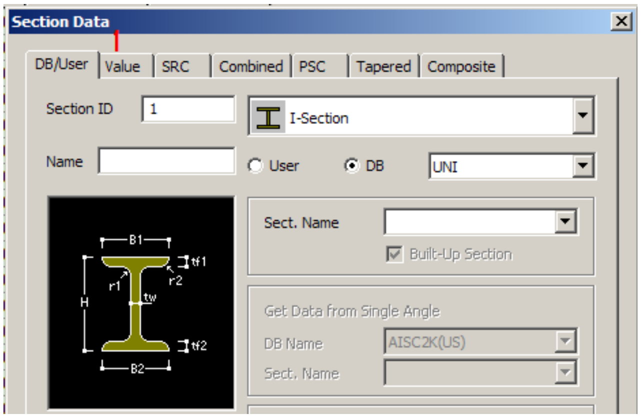
For Multi-span continuous structures; include a node at the top and bottom of any columns that are integral with the superstructure. The top node of the column doesn't have to be a node on the superstructure. Instead, detail the column to the bottom of the girder, or crossbeam and use a rigid link to connect the superstructure to the substructure.

6.4.5.2 Importing Sections

In the Tree Menu, select Properties and right click, then left click on Add Section.



Section Data field will pop up. Click on the Value tab (1).



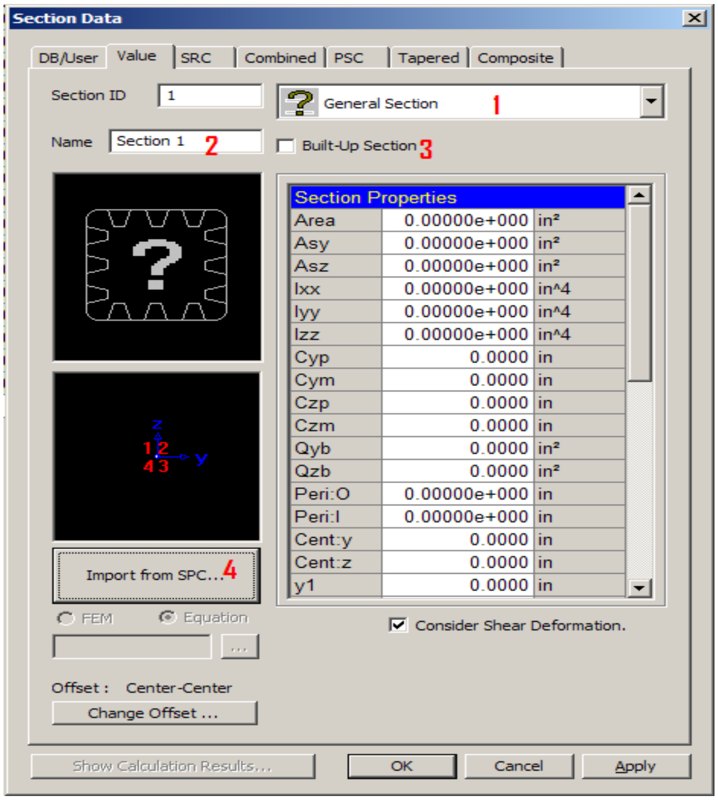
Within the Value tab Change the following:

1) Select General Section.

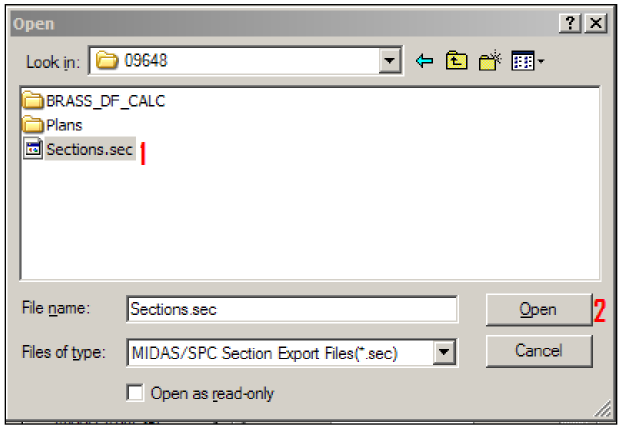
2) Name the section appropriately.

3) uncheck the Built-Up Section box.

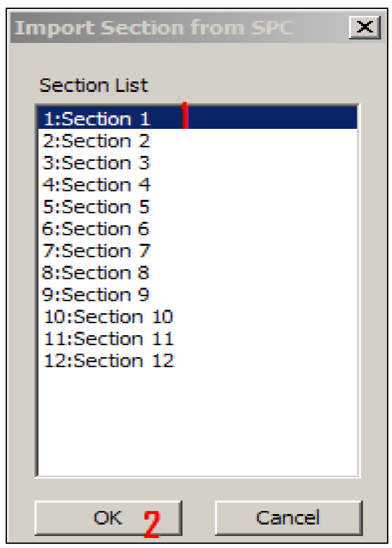
4) click on Import from SPC…



When Import from SPC is selected a new box pops open. Midas is searching for the .sec file created during section 6.3.3. Browse to this file, select it (1) and click Open (2).



Select the appropriate section (1), and click OK (2). This will populate the Sections Properties field with the values calculated by the Sectional Property Calculator.



Update the following;

1) Uncheck the Consider Shear Deformation box.

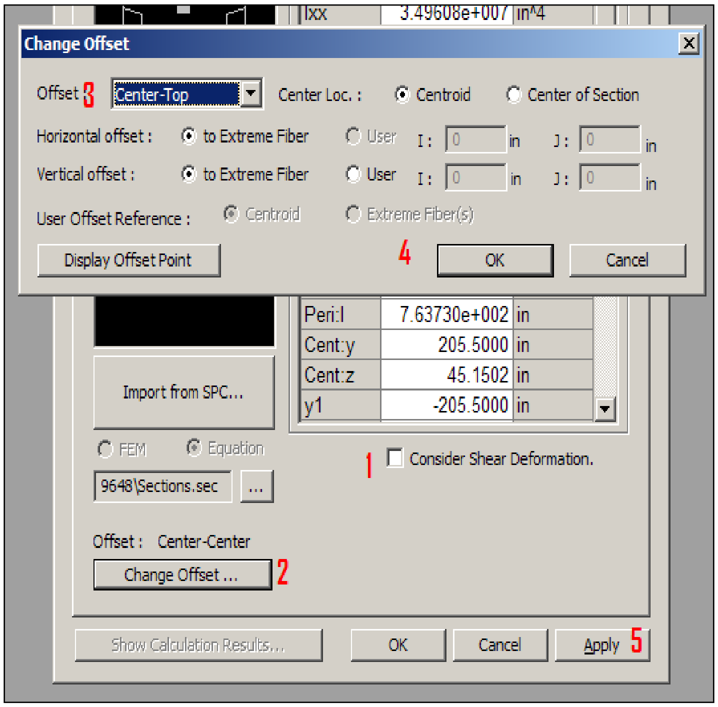
2) Click on Change Offset.

3) From the drop down box change offset to “Center-Top”.

> Note: Using “Center-Top” as the offset will introduce some longitudinal loads in the model. The difference between the centroid of the section and the top of the member will act as a lever arm for gravity loads and will be reported in the model as an axial load. The greater the member height and member curvature the larger the axial load. These forces are balanced internally and are not reported as longitudinal (Fx) reactions. Typically these forces are insignificant when compared to the moment and shear forces. Defining the sections at “Center-Center” would eliminate this axial load effect, but would significantly complicate defining prestressing strand profiles.

4) Click OK.

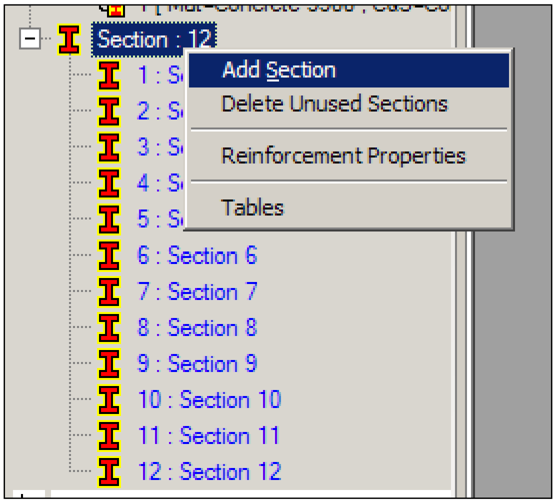
5) Click Apply.



Clicking Apply defines the cross section and brings up the next section. Continue the above steps until all of the cross sections are assigned. Each time properties are imported from SPC the offset defaults back to center-center and must be changed prior to clicking apply.

6.4.5.3 Tapered Sections

In the Tree Menu under Properties => Section, right click on Section and then left click on Add.



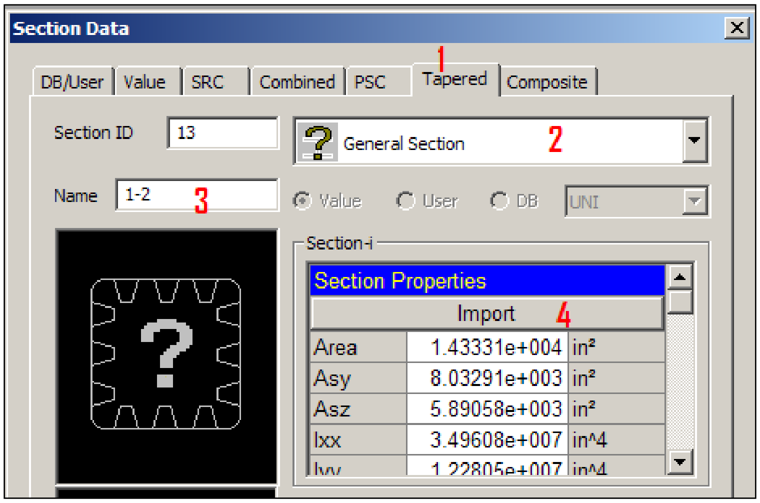
Update the Following:

1) Click on Tapered Tab.

2) Select General Section.

3) Name the sections (i.e. 1-2 reads, section 1 tapered to section 2).

4) Click on Import to assign the first section (end i).

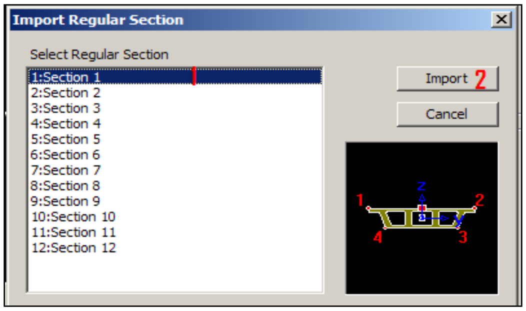


Clicking Import brings up a list of the defined cross sections.

1) Select the cross section that corresponds to the (i) end of the element being defined.

2) Click Import.

Repeat for the j end cross section.



Update the following:

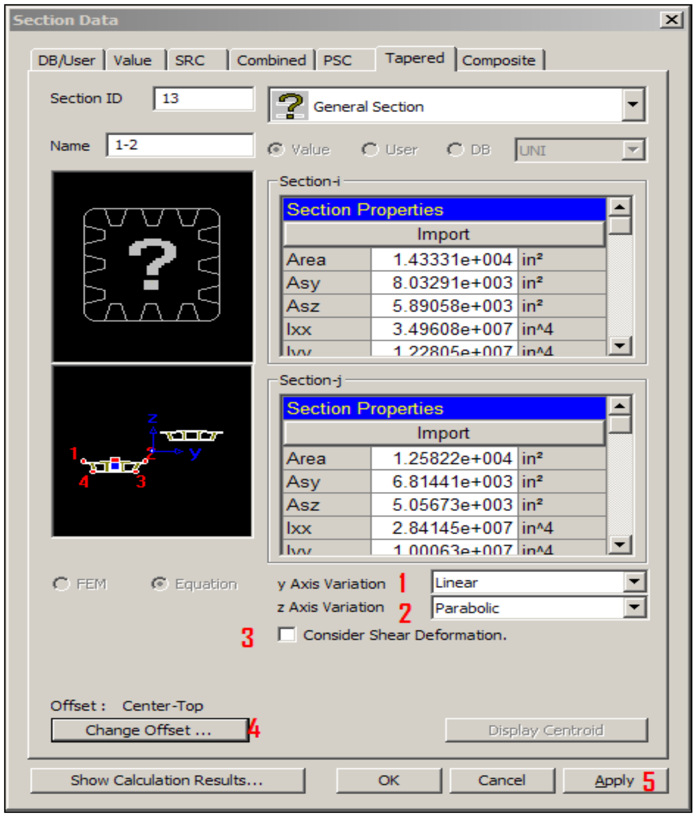
1) Select the appropriate variation for the y-axis. The y-axis tends to vary linearly.

2) Select the appropriate variation for the z-axis. The z-axis tends to vary parabolically.

3) Uncheck the Consider Shear Deformation box.

4) Change Offset to Center-top.

5) Click Apply.

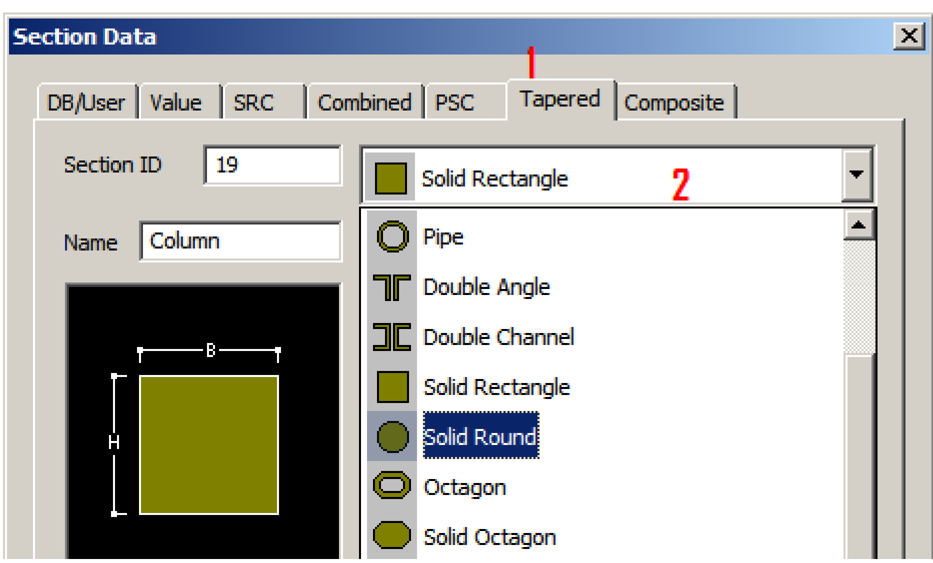


Repeat until all cross section variations have been defined. Use the SectionGeometry.xls sheet to help with which cross sections taper together. For example the tapered cross sections could be; 1-2, 2-3, 3-4, 4-5, 5-6, 6-7, 7-8, 8-9, 9-10, 10-11, 11-12, 12-10, 10-5, and 5-1.

Define the column cross section if this is a multi-span continuous bridge. Typically these cross sections aren't imported, but are instead defined in Midas. In the top menu go to Model => Properties => Section. Then click Add.

1) Use the appropriate tab for the column being defined. Typically this will be tapered.

2) Select the basic shape of the column. Solid Rectangle or Solid Round will cover the majority of columns.



3) Input the dimensions at the i end of the element.

4) Input the dimensions at the j end of the element.

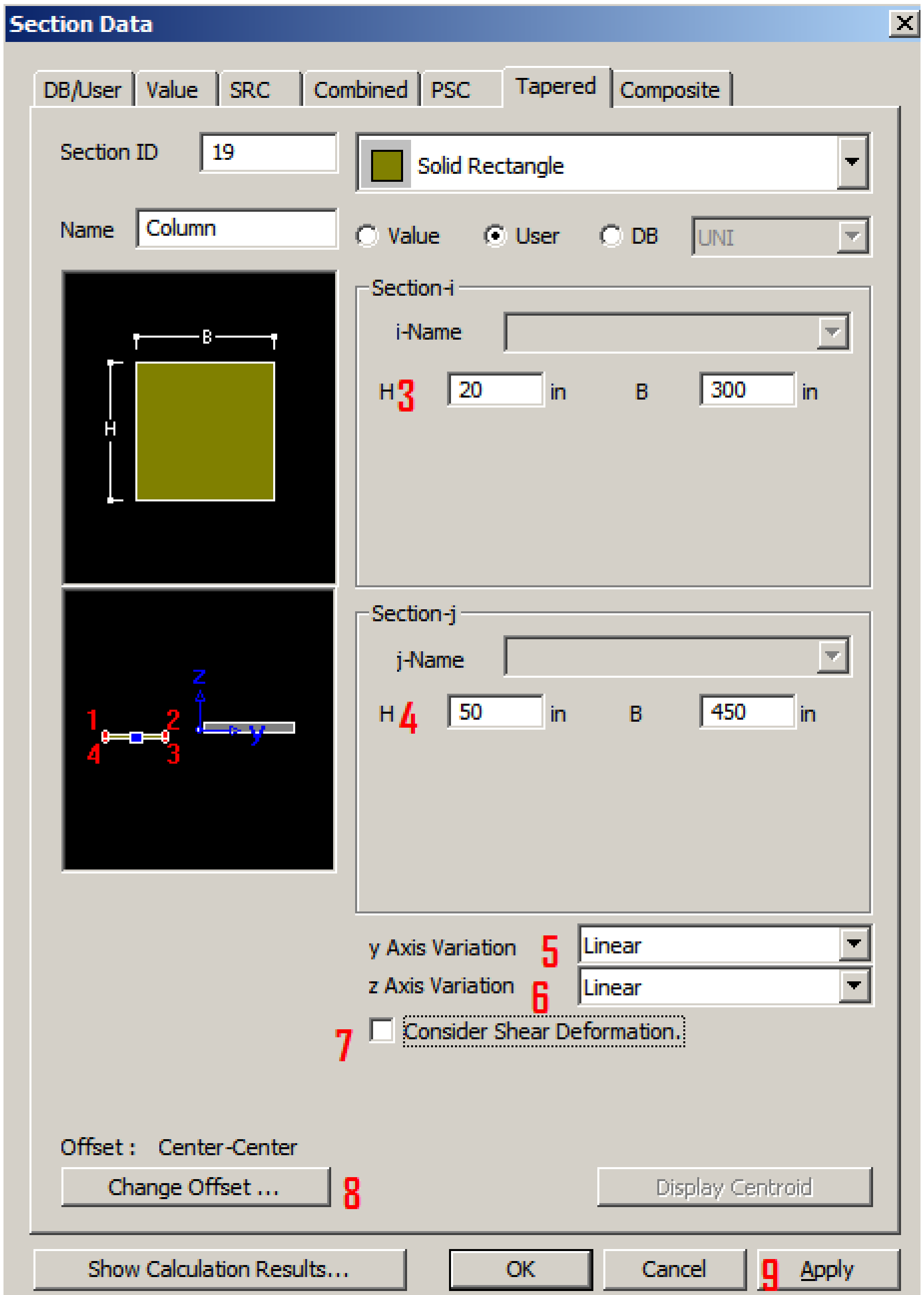
5) Select the appropriate y-axis variation.

6) Select the appropriate z-axis variation.

7) Uncheck the consider shear deformation.

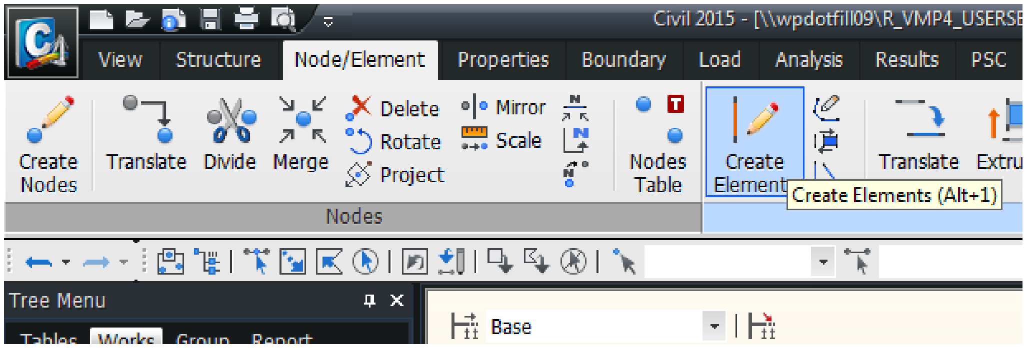
8) Select the appropriate offset. Center-Center is a common default.

9) Select Apply.



6.4.6 Elements

Under the top menu, go to Node/Element => Create Elements.



Make sure to save the file prior to proceeding with creating elements. If the number of joints, per cross section, on end (i) does not match the number on end (j), the model will crash and any unsaved data may be lost.

Select Hidden View (quick command Cntrl + h). This view will give a good graphical representation of the cross sections and will aid in checking the model.

Due to software limitations it is important to align the local axes of the elements in the superstructure. When defining the model all the elements should be defined from the left to the right, resulting in each element having the (i) end at the left node and the (j) end at the right node. It is acceptable to switch this convention and define all of the elements from right to left. It is NOT acceptable to define some elements from left to right and others from right to left in the same model.

Update the Following:

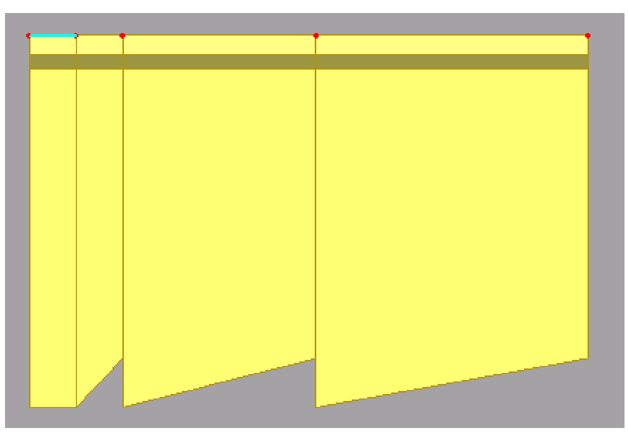
1) Select Create Elements.

2) Select General beam/Tapered beam.

3) Select the Concrete Material defined previously.

4) Select the appropriate cross section.

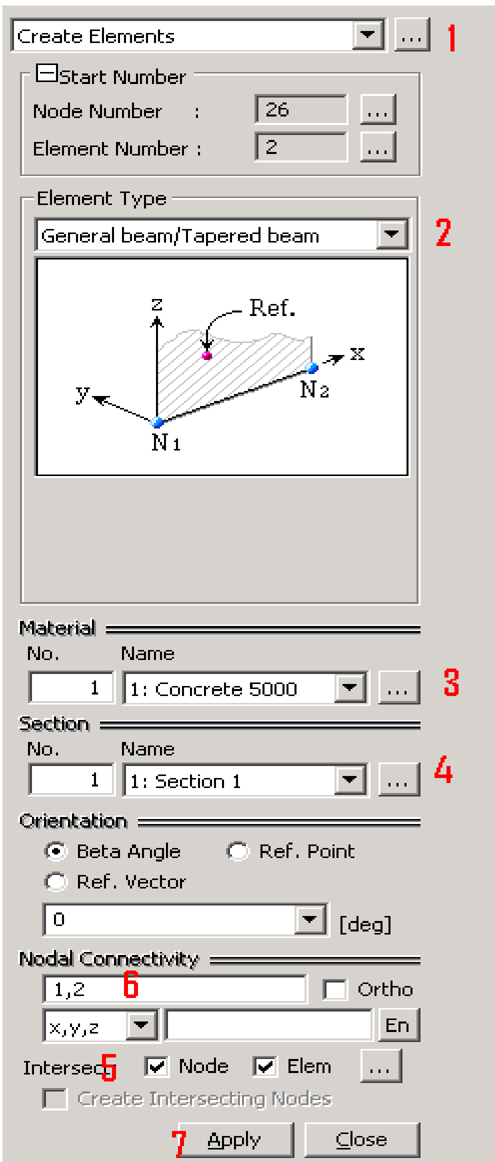
5) Select Intersect Node and Element. When tapered sections are used to define an element and the element is defined across several nodes, the model will have a saw tooth appearance. This is because as the element intersects nodes in the model, it will create additional elements each with the same section for the “I” end and the same section for the “J” end. For example, if the “I” end is section 1 and the “J” end is section 2 and the element begins at node 2 and goes to node 5. As seen below, a saw tooth appearance is created as the element intersects node 3 and 4. This is corrected later using the tapered section group command.

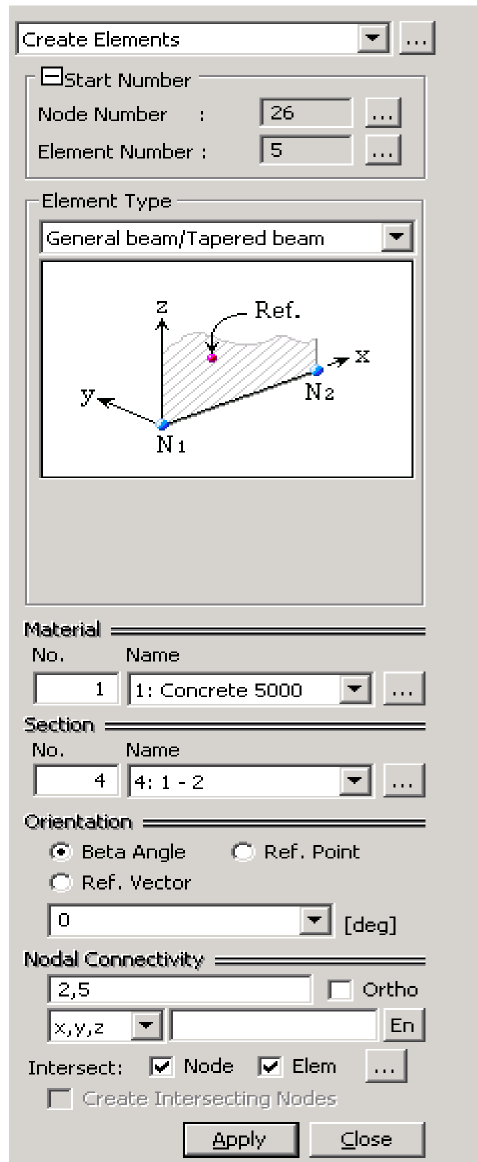


6) Type in the beginning and ending node for the specified element.

7) Click Apply.

The figure on the left shows the above steps for defining the element that has section 1 defined at both the (i) and (j) end. The figure on the right shows the input for a tapered element, from node 2 to 5, that has cross section 1 defined at end (i) and section 2 at end (j).





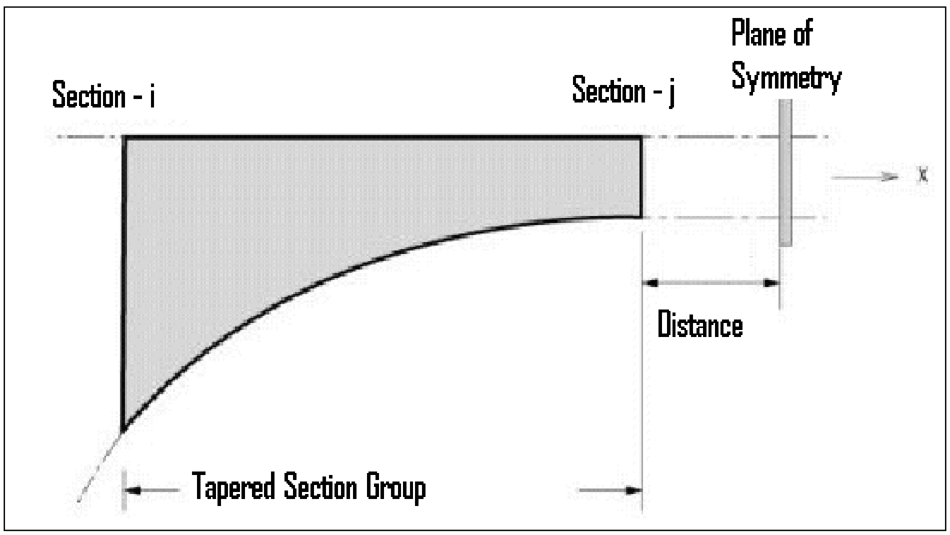
Continue until all of the elements have been created. Use the GeometryCalcs to reference nodes to the appropriate cross sections.

For multi-span structures, define the column element.

6.4.7.1 Tapered Section Group

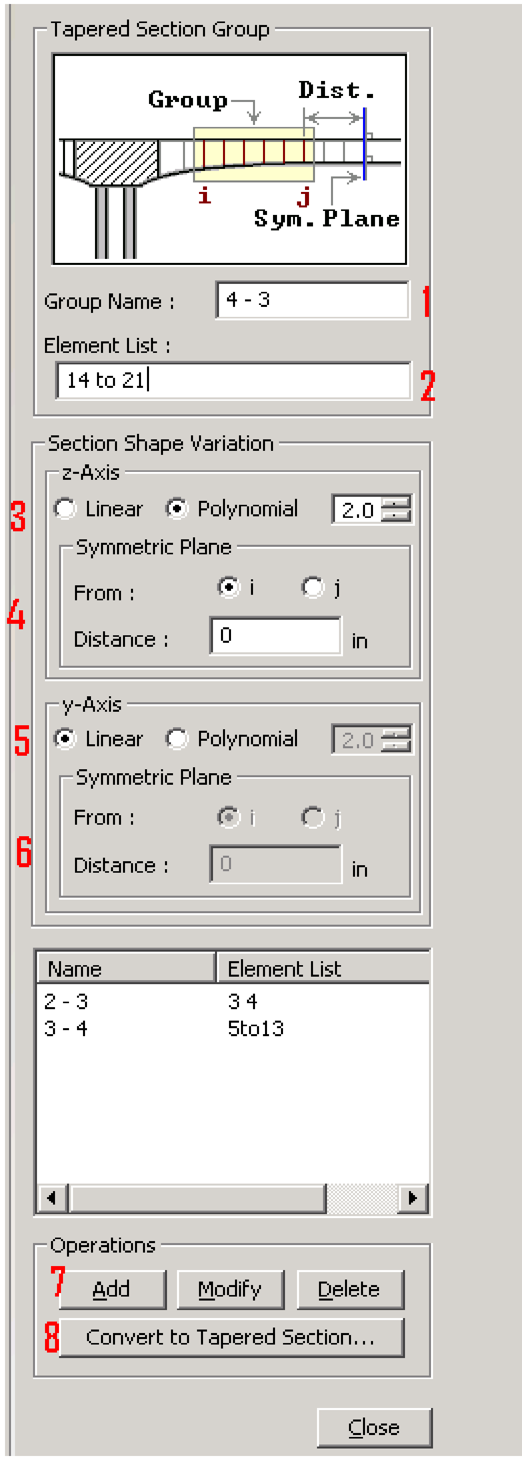
In the top menu go to Properties => Tapered Section Group. This command is used to taper a section across several elements. Both the y and z axis can be tapered independently and can be tapered as linear, or polynomial.

1) Name tapered section group. An example; "1 – 2" for a group that tapers from section 1 at the i end of the leftmost element to section 2 at the j end of the rightmost element.
2) List all of the elements that are included in the group.
3) Select z-axis variation. For most parabolic structures select a second order polynomial.
4) If a polynomial is selected, the distance to the symmetric plane must be defined. The symmetric plane is the location that the polynomial has zero slope (Commonly midspan). If the tapered section group extends to the plane of symmetry then the distance is zero. See below diagram.

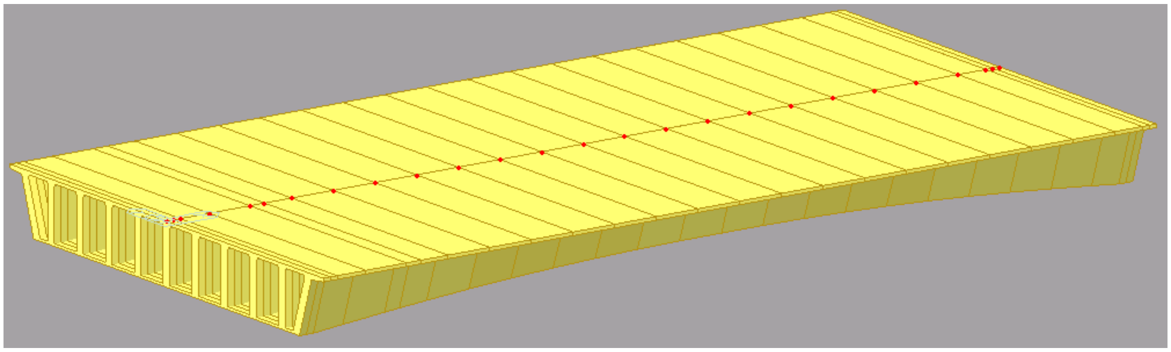


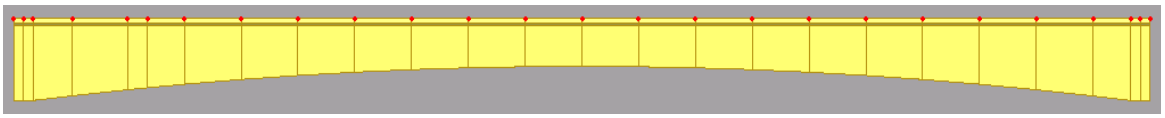
Note: Midas will vary all z-axis dimensions parabolically between sections. If the deck varies linearly and the overall structure depth varies parabolically some error will be introduced as the deck is varied parabolically. This error in dead load is generally small.

5) Select y-axis variation. This variation is typically linear but can also be defined parabolically.
6) If a polynomial is selected, the distance to the symmetric plane must be defined.
7) Click add to create the tapered section group. The next tapered section can now be defined.
8) Do NOT click on "Convert to Tapered Section…" button. This will replace the tapered section group with generated sections at each node point. Although the analysis will not be altered, using this feature makes checking a model for accuracy more difficult. It is easier to check a few sections for accuracy and the parameters of a tapered section group then to check a section at each node point.



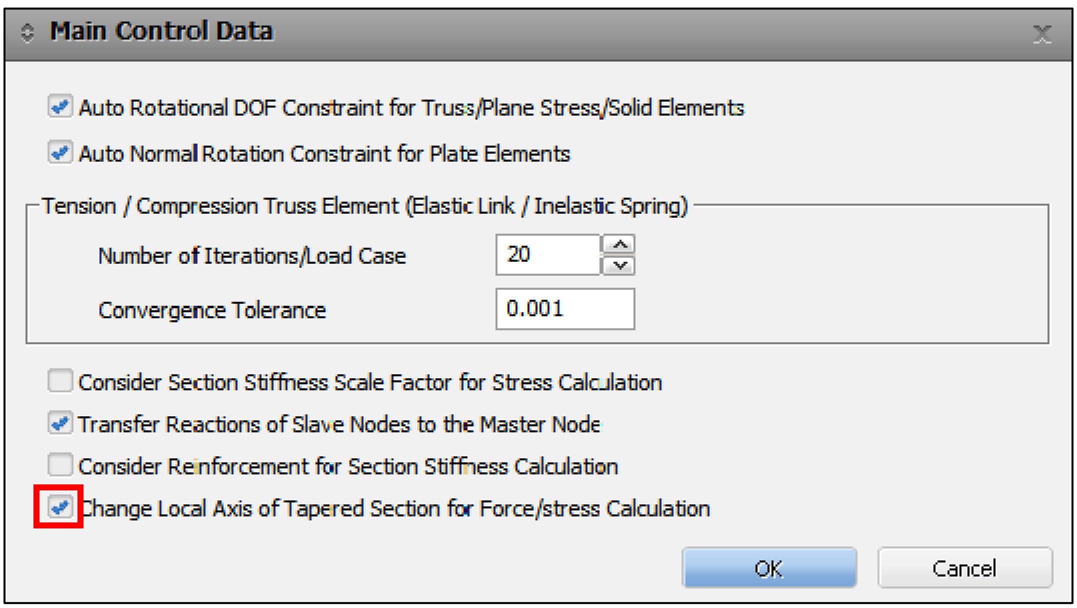
When done, a smooth three dimensional structure should be displayed. This provides a good opportunity to check that the cross sections are input and assigned correctly. The model should be smooth without jumps from one section to the next. See below for a parabolic example.





6.4.7.2 Change Local Axis for Force/Stress Calculations

Midas will default to calculating all force effects along the axis of the elements centroid. Tapered elements have a centroidal axis that is not perpendicular to the direction of gravity. Because of the inclined centroidal axis, axial force effects will incorrectly interact with shear effects. In Midas Civil 2013 version 1.2 a new feature has been added to correct this interaction. In the top menu go to Analysis => Main Control Data and check the "Change Local Axis of Tapered Section for Force/stress Calculations" box. This will force the software to calculate axial force effects perpendicular to the direction of gravity.



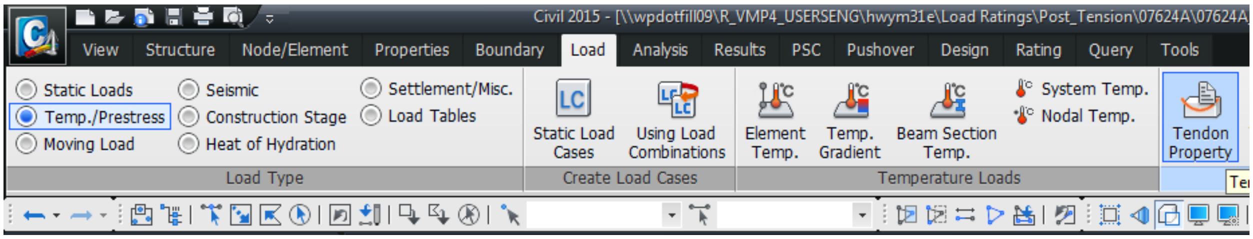
6.4.8 Prestress and Post-Tensioning

Midas provides flexibility in how post tensioning is defined. The example shows a case where half of the strands are stressed from the left end, while the other half are stressed from the right end. No strands are tensioned from both ends. There are groups pre-defined as PT Right, PT Left, PT Both and PS Sections.

Although the display is showing a 3D model, the analysis is really a 2D beam line analysis. Thus, it is not necessary to code the PT Strands at the actual location (without shop drawings these locations are unknown anyways). All of the prestressing will be coded along CL of the structure and will follow the CG profile provided in the plans. It is important to break out the strands that are tensioned from Left, Right, or Both ends.

6.4.8.1 Tendon Property

In the top menu, select Load => Temp./Prestress => Tendon Property and then click Add.



Update the following:

1) Tendon Name (Identify which end the tendon is stressed from).

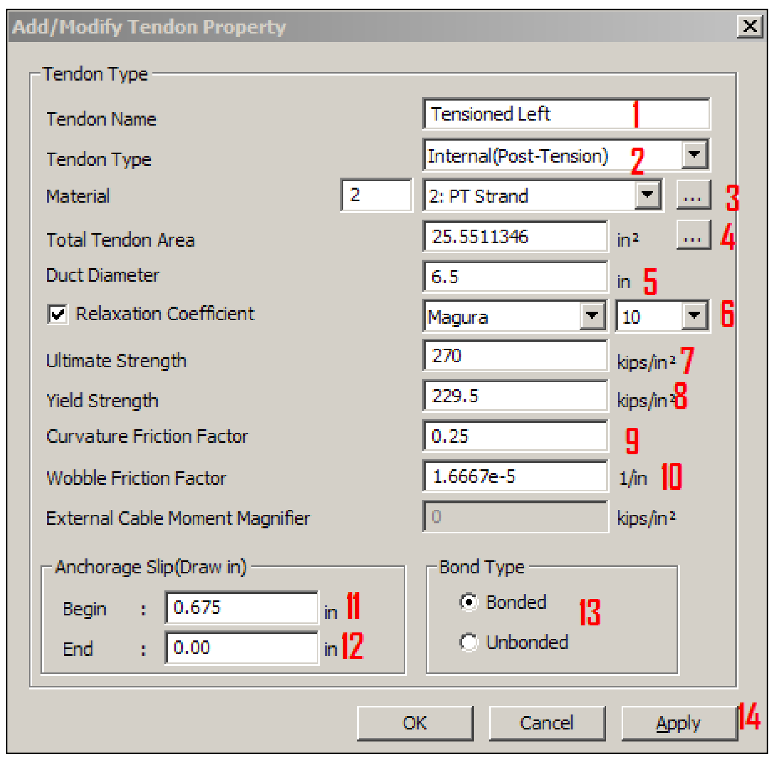
2) Select Internal (Post-Tension) or Internal (Pre-Tensioned) for Tendon Type.

3) Select PT or PS Strand for Material.

4) Total strand area for this tendon group. Reference the number of strands per duct calculation in PTBox.xmcd. The "…" box to the right of this cell brings up a field that will assist with calculating the area of all the strands. This value will be iterated later to determine the actual number of strands per duct.

5) The duct diameter is arbitrary with the exception that the duct area must be larger than the Total Tendon Area (Calculated in step 4). Back calculate the duct diameter based on an area larger than the total strand area.

    Note: When Internal (Pre-Tension) tendon type is selected the duct diameter field changes to strand diameter. This equivalent strand diameter is automatically calculated from the tendon area entered in step 4.



6) Select Magura for the relaxation analysis type, and select the appropriate coefficient; 10 for stress relieved and 45 for low relaxation strand.

7) Input the Ultimate Strength.

8) Yield Strength.

9) Curvature Friction factor. (PT Only)

10) Wobble Friction Factor. This value is commonly provided without units. If k = 0.0002 is reported, this value has units of (1/ft) and should be converted to (1/in). (PT Only)
11) Input the appropriate left end anchor set value. If the strand is tensioned from the right only input 0.0in. (PT Only)
12) Input the appropriate right end anchor set value. If the strand is tensioned from the left end only, input 0.0in. (PT Only)
13) Select Bonded or Unbonded for tendon Bond Type. (PT Only)
14) Click Apply.

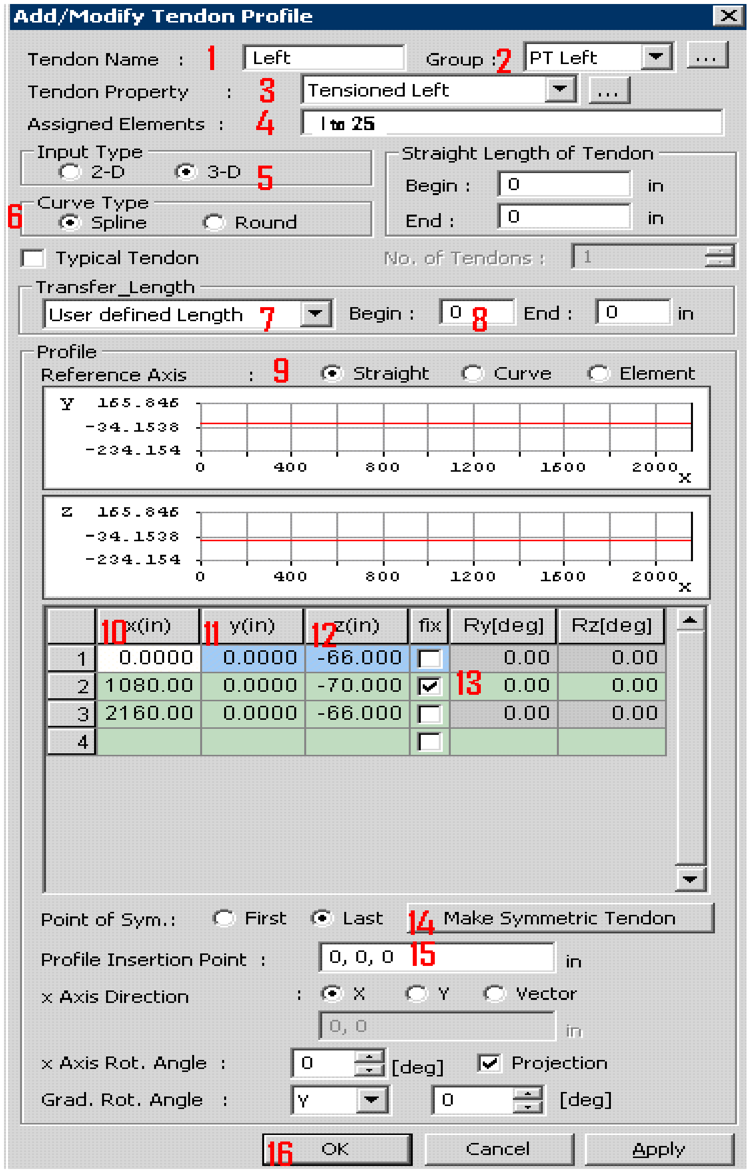
Continue until all tendon groups are entered; Left, Right, and Both.

6.4.8.2 Tendon Profile

From the top menu go to Load => Temp./Prestress => Tendon Profile.

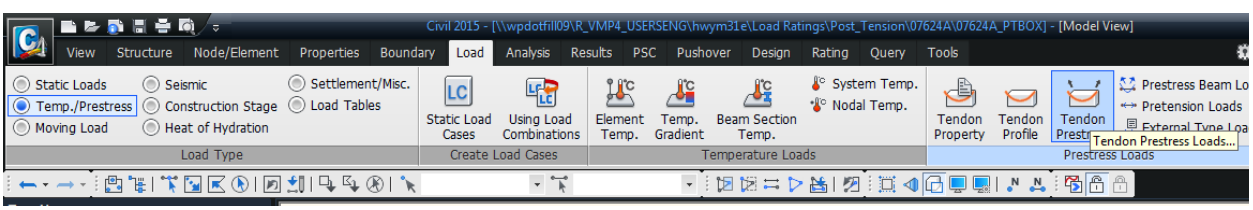
Tendon Profile location will not necessarily be within a stem wall. Because this is a 2D beam analysis (NOT 3-D) no lateral eccentricity will be built into the tendons. For ease of input, a 3D input type will be selected but the y-coordinate will always have a value of 0.0in.

1) Name the tendon. The name should identify which end the tendon is stressed from.
2) Select one of the predefined Groups; Left, Right, or Both.
3) Select the appropriate Tendon Property; Left, Right, or Both.
4) Assign all of the elements. This can be done in several ways. One way is to, in the model view use the mouse to select all elements. Elements can also be manually input by typing “1 to n”. Where n = the last element number.
5) Select 3D for input type.
6) Select Spline curve type.
7) Select user defined Length for Transfer length.
8) Set the user defined transfer lengths to zero. Transfer lengths are accounted for in nnnnn_PTGirder.xls
9) Selected Straight for Reference Axis. This makes it easy to defined the profiles from (0,0,0)
10) Enter the control points for the tendon profile. For a simple span these are typically at each bent CL and at midspan. The x-coordinate is the location along the span measured from the profile insertion point (step 15). Control points are at the ends and inflection points of a parabolic segment.
11) For a 2D analysis the y-coordinate will always be 0.0in.
12) The cross sections were imported based on a center-top offset. These cross sections are drawn flat with an average height. The design tendon profile is assumed to apply to this average height section.
13) Check the fixed box at the location where the slope of the parabola is known. For a simple span bridge with a parabolic tendon profile, symmetrical about midspan, the slope at midspan is zero. Check the fixed box at this location and enter 0 degrees for the rotation.
14) Once coordinates are entered up to and including the point of symmetry the “Make Symmetric Tendon” button can be selected to complete the rest of the input.
15) Select the location of insertion. Typically this will be (0,0,0)
16) Select apply and then OK. Continue until all tendon profiles are defined.



6.4.8.3 Tendon Prestress Loads

Under the top menu, go to Load => Temp./Prestress => Tendon Prestress Loads…



1) Select PT or PS for Load Case Name.

2) Select Post-Tension for Load Group Name.

3) Click on the Tendon of Interest.

4) Use the Arrows to Select the Tendon of interest (move it from the left to the right column).

5) Displays the currently selected Tendon.

6) Select Stress.

7) 1st Jacking can be set to either Begin (Left end Stressed), End (For right end stressed) or Both (both ends stressed).

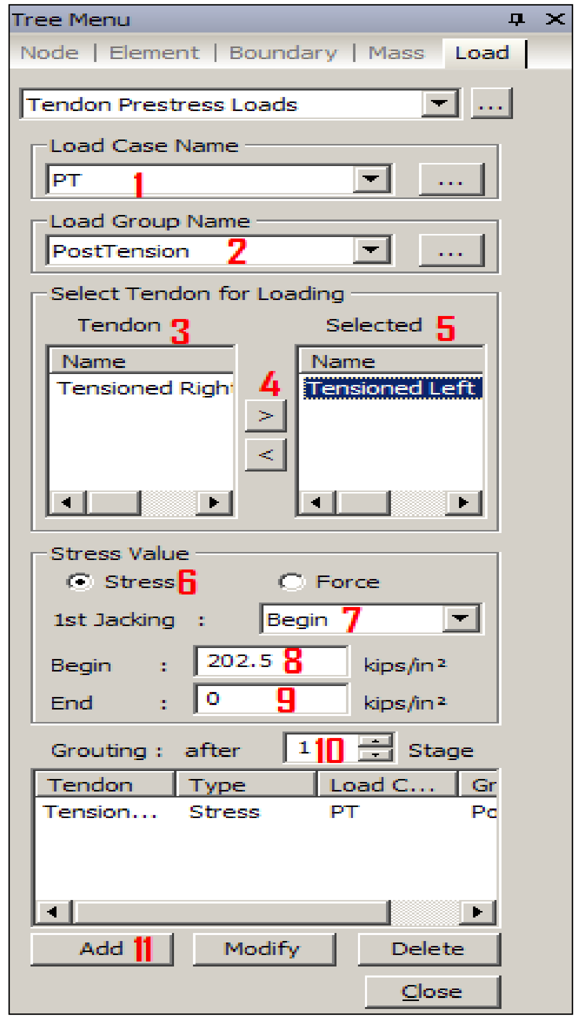
8) For left and both ends stressed conditions, enter the initial jacking stress calculated in the PTBOX.xmcd file. For right end stressed only leave blank.

9) For right and both ends stressed conditions, enter the initial jacking stress calculated in the PTBOX.xmcd file. For left end stressed only leave blank.

10) Specify which stage the tendons are grouted. Unless specified otherwise, assume tendons are grouted after stage 1.

11) Click Add.

Continue until all tendon loads have been defined.

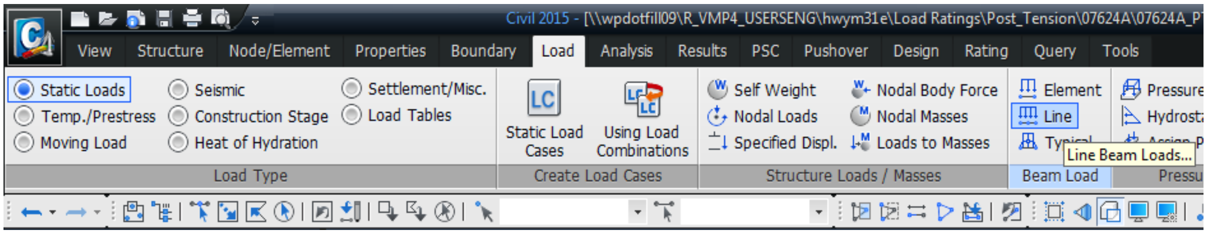


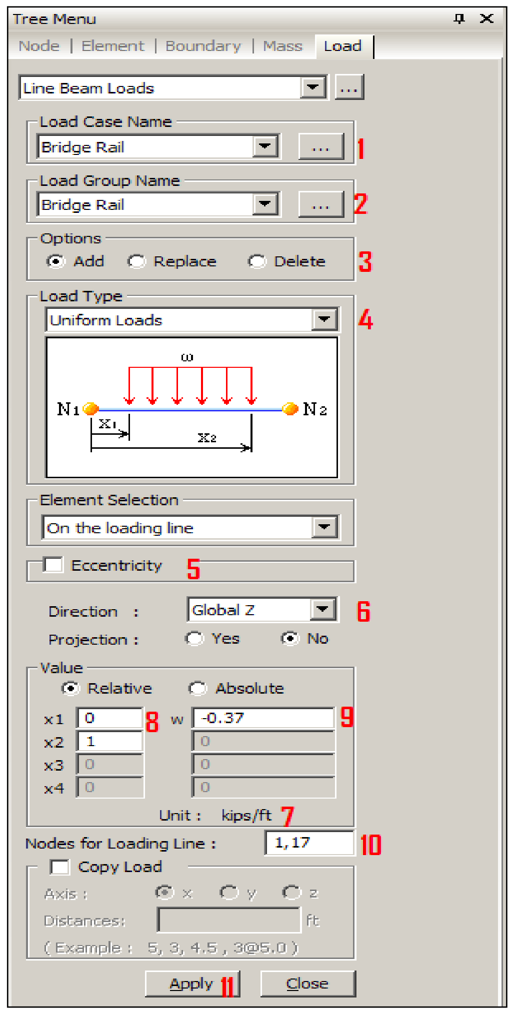
6.4.9 Static Loads

Six static load cases are predefined; Post-Tensioned, Prestressed, Bridge Rail, Self-Weight, Diaphragm, and Wearing Surface. Not all of these predefined load cases have to be used for every bridge. Additional load cases can be defined as necessary.

6.4.9.1 Distributed Loads

Under the top menu go to Load =>Static Loads => Line.

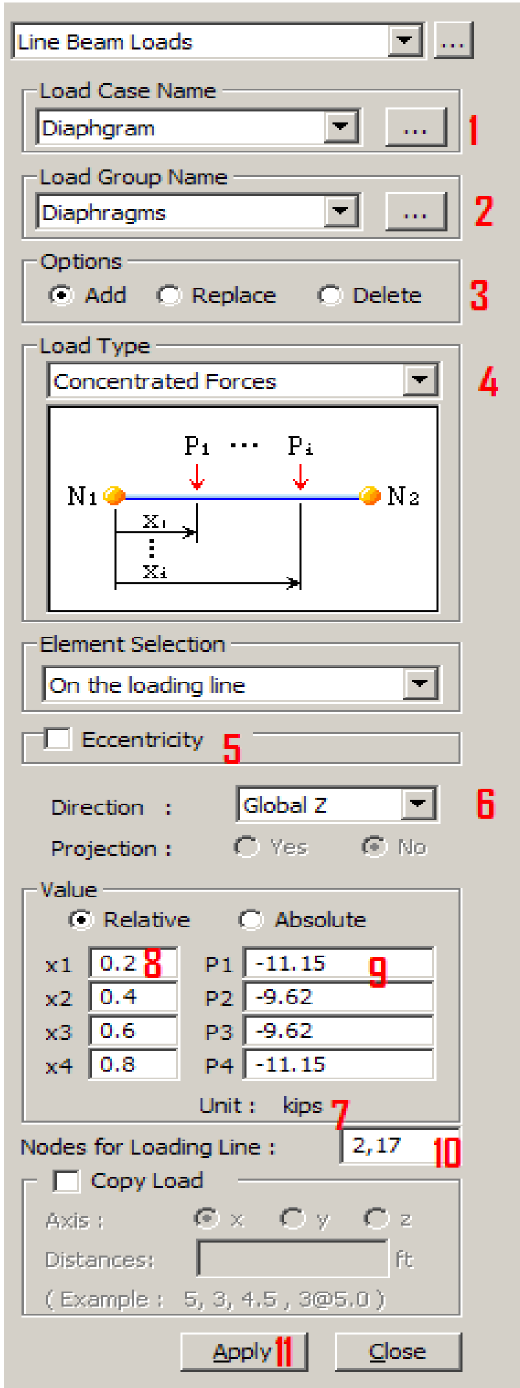




1) Select the appropriate Load Case Name.
2) Select the appropriate Load Group Name.
3) Select if this load is to be added to others, replace, or deleted. Typically Added is selected.
4) Select loading type.
5) Uncheck the Eccentricity box.
6) Gravity loads are applied in the global Z direction.
7) Check the Input units.
8) Input the location of the loads being defined. Location is input as a span fraction. For uniform loads input the range.
9) Input the magnitude of the load. Negative is in the downward sense.
10) Input the first and last node separated by a comma. This allows for distance to be input as a span fraction in step 8.
11) Click Apply.

6.4.9.2 Point Loads

1) Select the appropriate Load Case Name.
2) Select the appropriate Load Group Name.
3) Select if this load is to be added to others, replace, or deleted.
4) Select loading type.
5) Uncheck the Eccentricity box.
6) Gravity loads are applied in the global Z direction.
7) Check the Input units.
8) Input the location of the loads being defined. Location is input as a span fraction.
9) Input the magnitude of the load. Negative is in the downward sense.
10) Input the nodes at CL of bent separated by a comma. This allows for distance to be input as a span fraction in step 8. In this example the first and last nodes are actually 12 inches past CL of bent. Thus, nodes 2 and 17 are selected for loading line.
11) Click Apply.

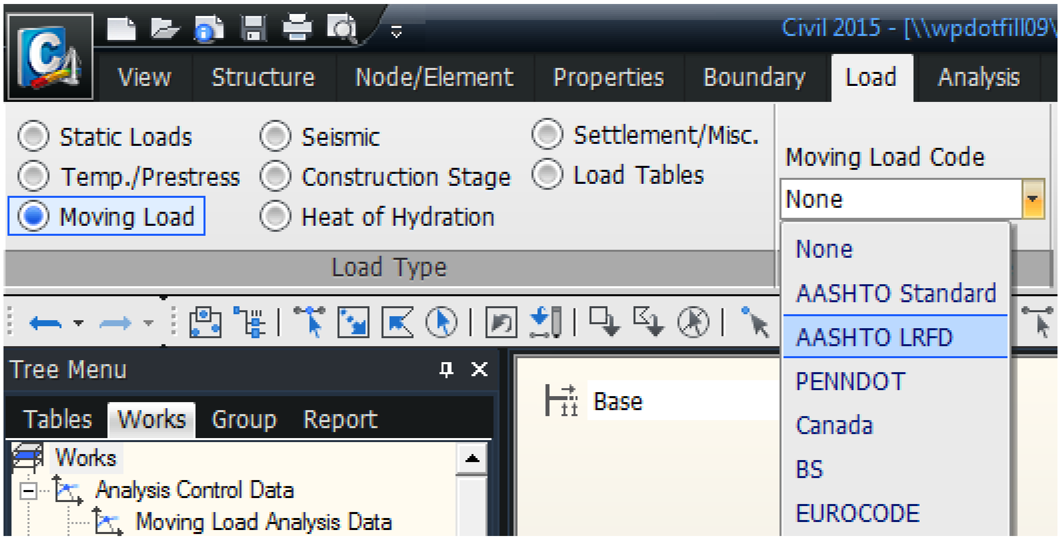


Continue until all static loads are defined.

6.4.9.3 Live Loads

Design, Legal, STP, and CTP trucks are defined in the MCT template file. In addition to the vehicles one vehicle class is defined. The HL93 vehicle class includes the HL-93 Tandem and HL-93 Truck. These trucks and class do not need to be altered. Impact factor for design vehicles are included in the truck definition. Legal and permitted impact factors are applied in the PTBOX_xls file.

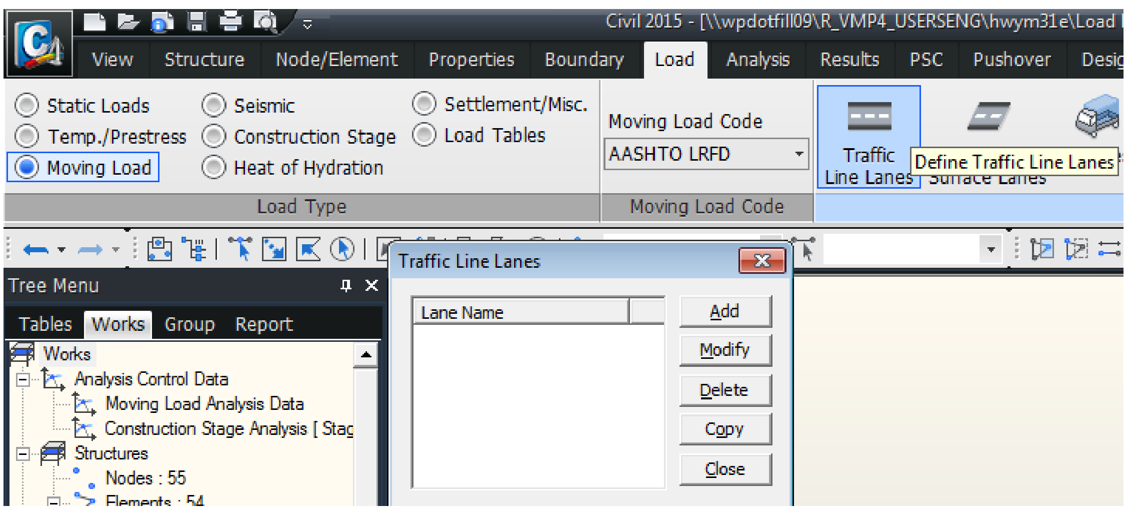
Define the moving load code for analysis. In the top menu go to Load => Toggle Moving Load => Select “AASHTO LRFD” in the drop down for Moving Load Code.



6.4.9.4 Traffic Line Lane

Only one traffic lane, defined along CL of structure needs to be assigned. The live load distribution factors account for the presence of multiple lanes.

Under the top menu go to Loads => Toggle Moving Load => Traffic Line Lanes. Then Click Add.



1) Name the traffic line lane “Lane”. The moving load cases that will be imported later require that the lane name is “Lane”. Otherwise, an error will be reported when the moving load cases are imported into the file.

2) Set eccentricity to 0.0ft

3) Set Wheel Spacing to 6.0ft.

4) Select Lane Element for Vehicular Load Distribution.

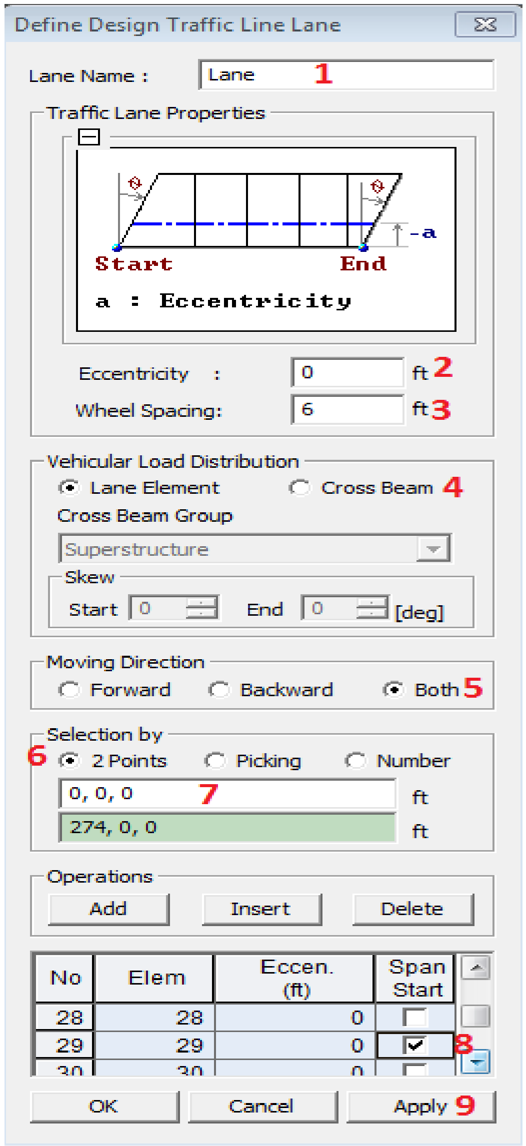
5) Select Both for Moving Direction.

6) Selection by 2 Points.

7) In the model view pick the two points that will define the traffic lane, typically the first and last node. This should populate the table showing the selected elements and the eccentricity.

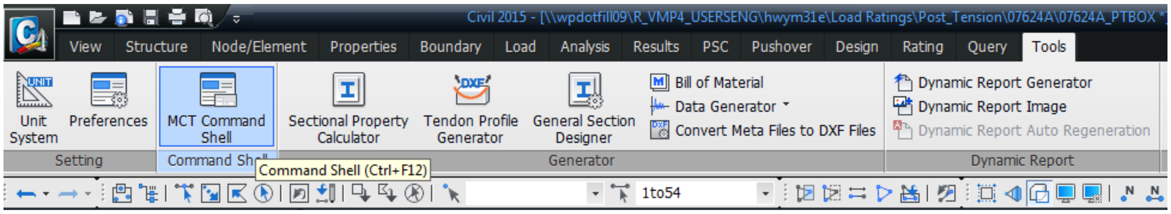
8) For multiple span bridges; check the “Span Start” box for the first element in each span.

9) Click Apply.

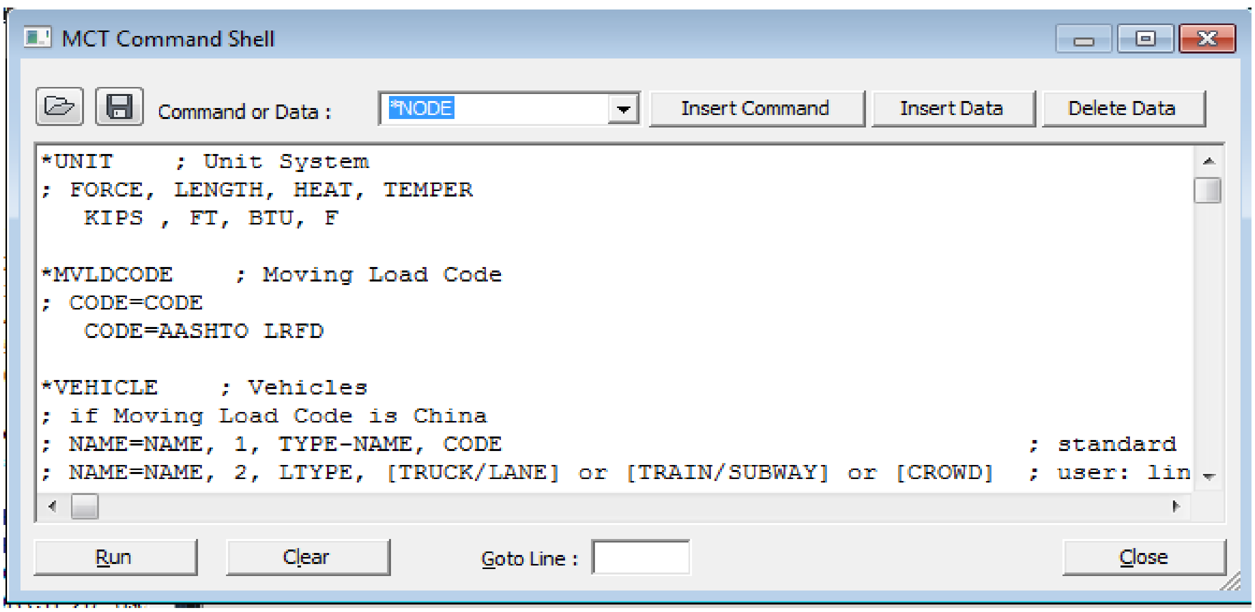


6.4.9.5 Vehicles and Moving Load Cases

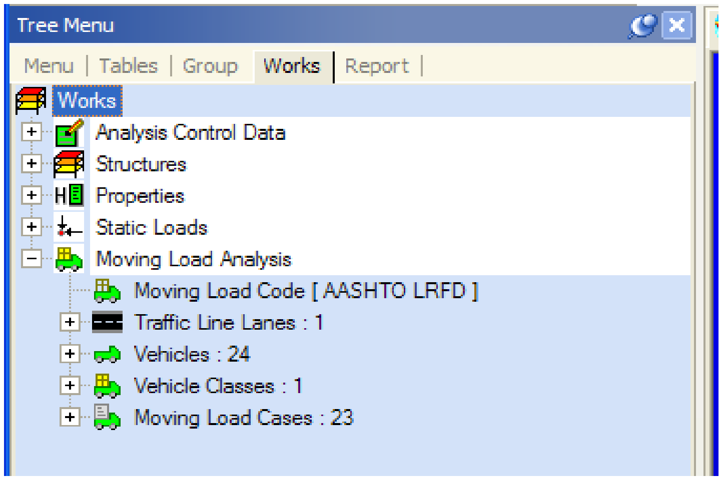
The vehicle definitions and moving load cases are already defined in a MCT command file that can be imported after the lane line has been defined in the Midas model. In the top menu, go to Tools > MCT Command Shell.



Within the MCT Command Shell, click the open file icon. Open the mct file named “LR_Midas_Vehicles.mct”, which will populate the MCT Command Shell window with data. At the bottom left of the MCT Command Shell window click on the “Run” button. Then click on the “Close” button at the bottom right of the MCT Command Shell window.

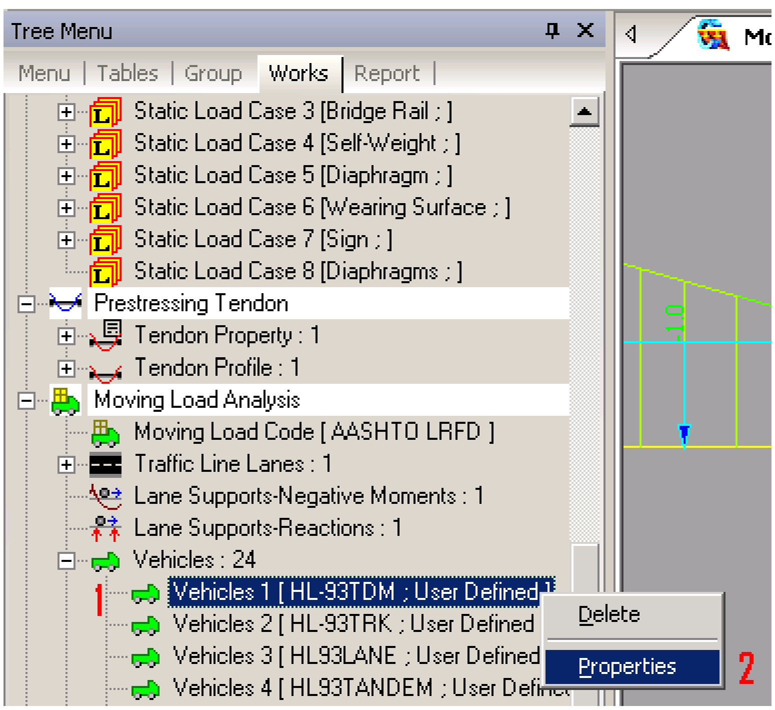


Within the Works Tree Menu there will now be 26 different vehicles, one vehicle class, and 25 different Moving Load Cases defined for the model. This command shell also contains code to populate the dynamic report tables (See section 6.4.16)



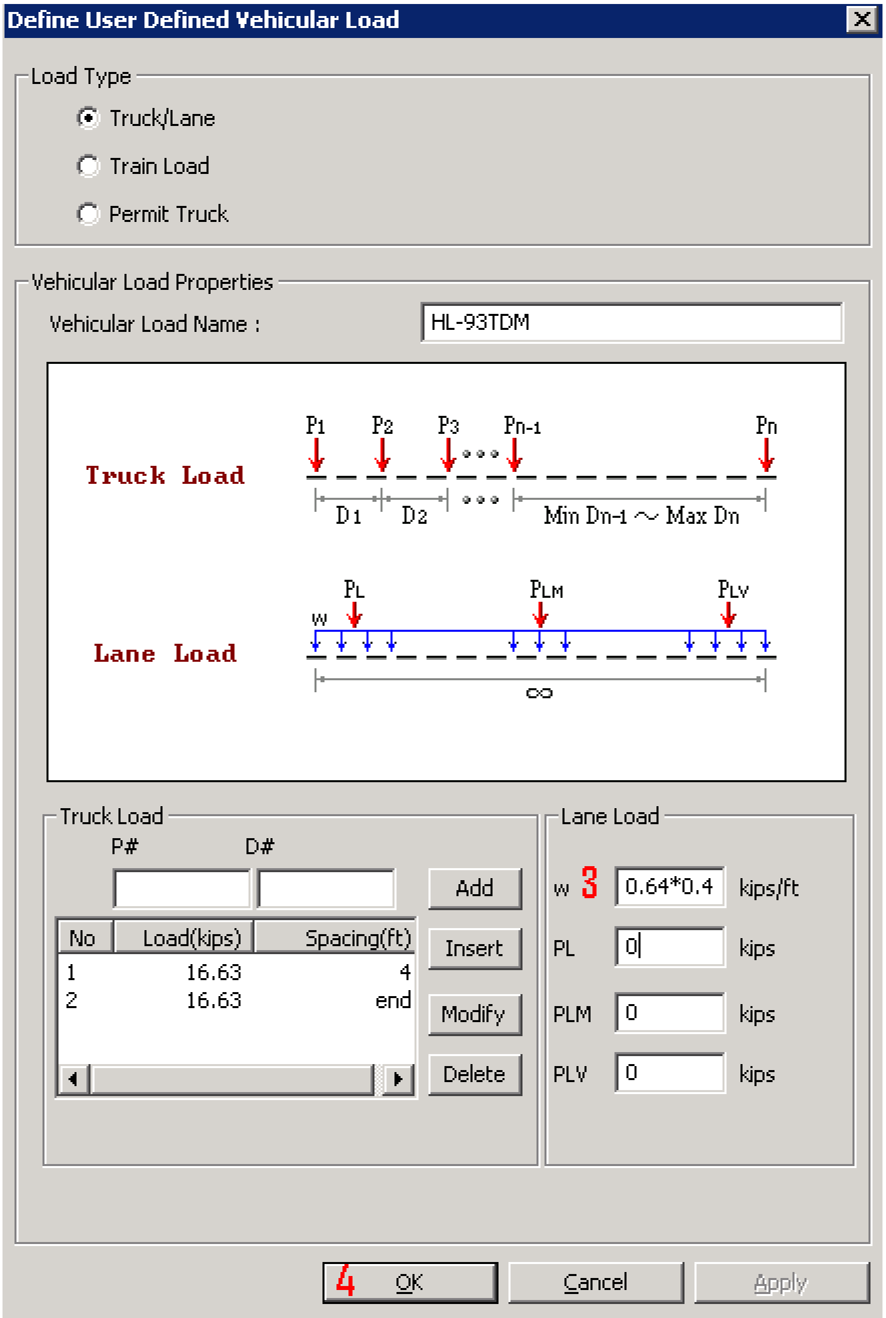
When performing an exterior edge strip analysis only one line of wheels and, a tributary portion of the lane load shall be applied to the edge strip, per AASHTO LRFD 4.6.2.1.4b. A command shell has been created to populate the trucks with the reduced axle loads. Use the mct file named LR_Midas_Vehicles_Edge_Strip.mct. Running LR_Midas_Vehicles_Edge_Strip.mct will populate the design, legal, single trip, and continuous trip permit vehicles with one wheel line (half the axle weights). **The lane loads must still be manually adjusted.** Use the fraction of the lane load that was calculated in the preliminary file to modify the lane loads as follows.

1) In the Works Tree go into the newly populated Vehicles section. Right click on the HL-93TDM vehicle.
2) Right click on Properties.



3) Reduce the design lane load by the fraction of the tributary lane width over the design lane width. Midas allows for in cell calculations. In this example the design lane load (0.64klf) is reduced by the tributary fraction of 0.40.
4) Click OK.

Note: The tandem axle weights are reduced to 16.63 kips. This value includes the 33 percent design impact value. The original axle weight is 25 kips, divided by two is 12.5 kips. Multiplied by (1+0.33) equals 16.63 kips. User defined vehicles are used to recreate the HL-93 load combination, which doesn't have input for adjusting the percent impact.



5) Repeat steps 1-4 for the following vehicles; HL-93 TDM, HL-93TRK, HL93LANE*, HL93TANDEM*, HL93 TRUCK*, and ORLEGLN.

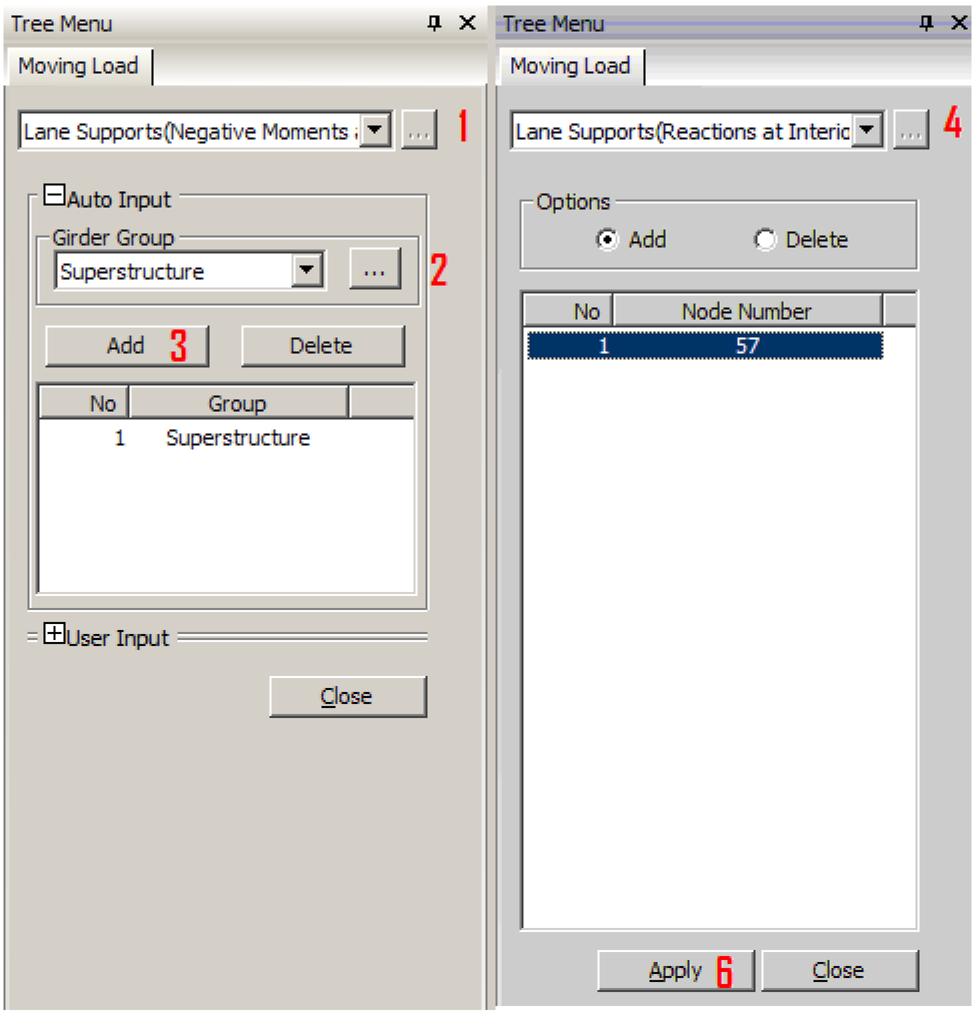
* Indicates that load is used for crossbeam analysis only.

6.4.9.6 Lane Supports (Spans Continuous for Live Loads)

When performing a multi-span analysis that is continuous for live loads, the lane support negative moment, and lane supports reactions at interior piers must be activated. This feature will automatically perform the pattern loading, per AASHTO LRFD, to determine the maximum negative moment and reaction at interior supports.

Under the top menu go to Load => Toggle Moving Load => Lane Support – Negative. Moment.

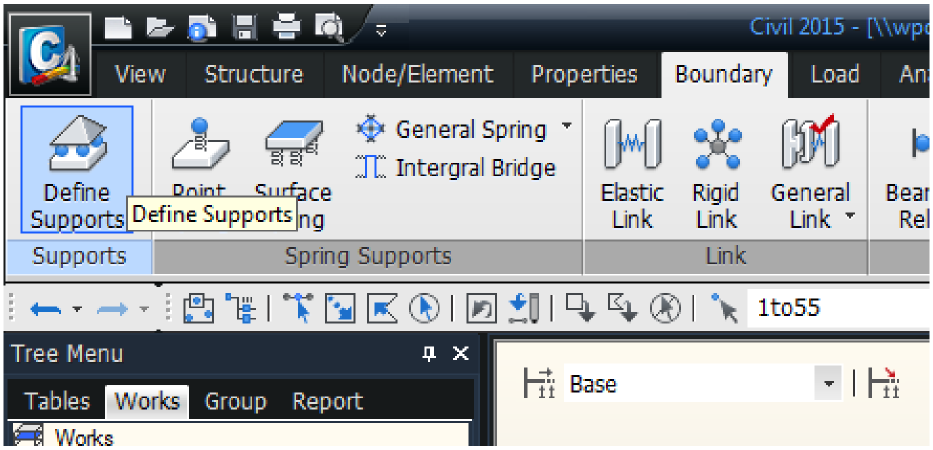
1) Select Lane Supports (Negative Moments at Interior Piers)
2) Select the structure group that includes the girders. See Section 6.4.11 for additional information on structure groups.
3) Select Add.
4) Select Lane Supports (Reactions at Interior Piers)
5) In the Model View, select the interior nodes where maximum reactions are sought. A support must be defined at this location (Base of interior columns).
6) Select Add.



6.4.10 Boundary Conditions

Two boundary groups are predefined; Pinned, and Roller. Use these groups when defining the supports. These groups will be used during the construction staging analysis.

Under the top menu go to Boundary => Define Supports



1) Select the desired Boundary Group; fixed, pinned or roller.

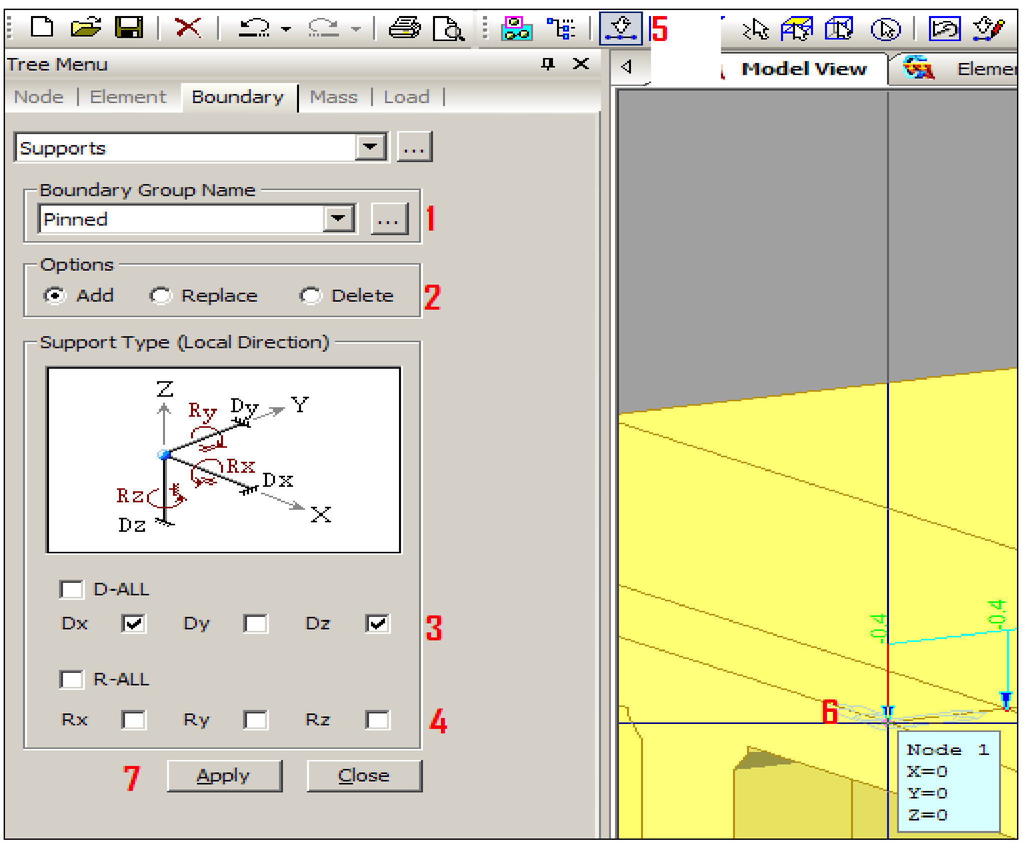
2) Select if this support is being added, replaced, or deleted from a node.

3) Select the translation restrained degrees of freedom. For pinned restrain Dx and Dz, for Roller restrain Dz only.

4) Select the rotational restrained degrees of freedom.

5/6) Select the node that the support will be assigned to. This can be done in various ways. One option is to use the "Select Single" in the tool bar (Cntrl + Shift + S). Then click on the node point that the boundary will be assigned. When selected the node should change to a pink color.

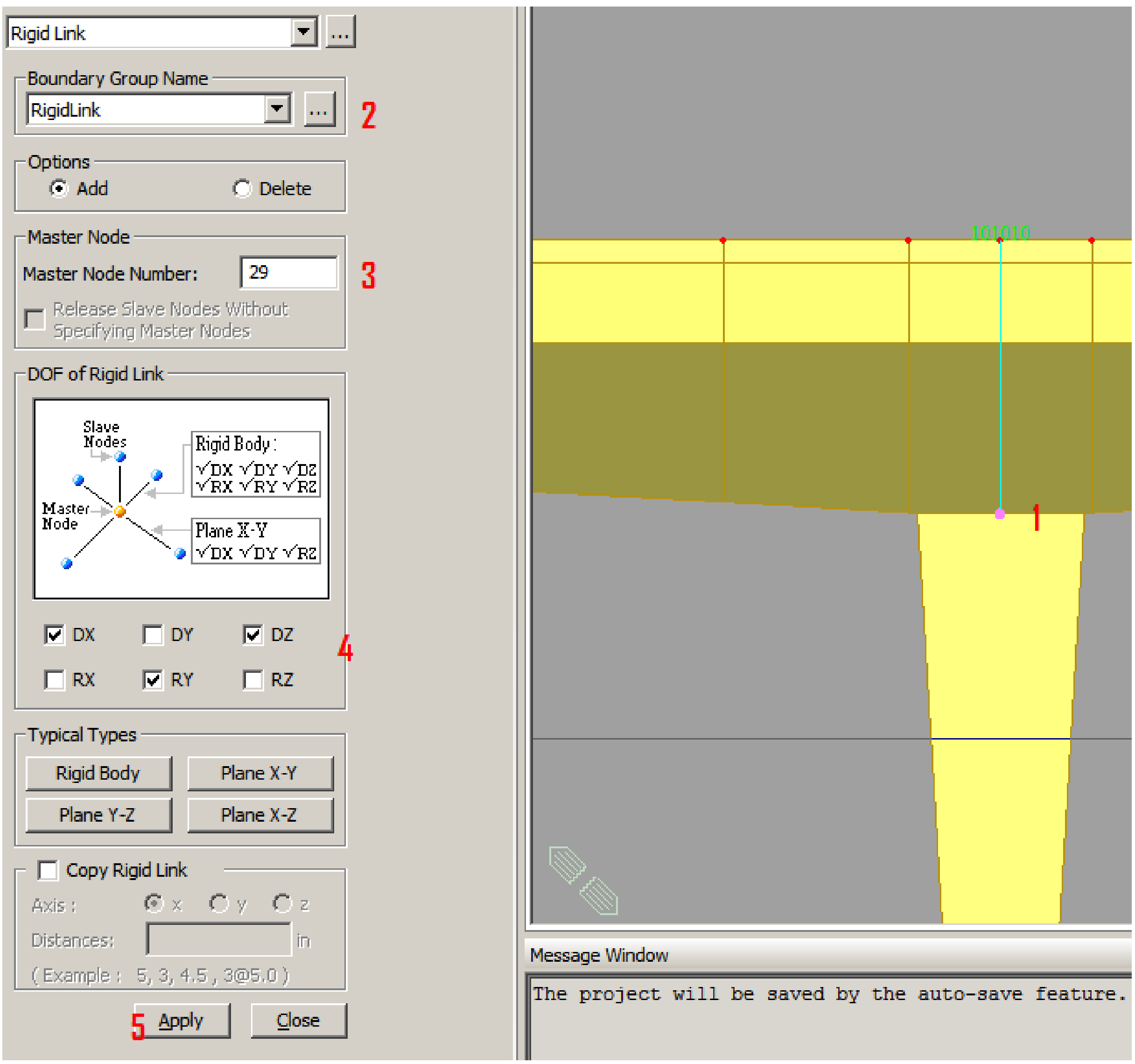
7) Click Apply.



Continue until all boundaries are defined.

When columns have been defined, a rigid link will be defined to connect the superstructure to the substructure. In the top menu go to Boundary => Rigid Link

1) In the model view window select the node that will be the slave node (Top of Column).
2) Select the appropriate boundary group (RigidLink).
3) Specify the master node (Superstructure Node corresponding to CL of Bent). The specified rotations and displacements of this node will be imposed on the slave node.
4) For a 2-D model the rigid link only needs to translate DX, DZ, and RY from the master node to the slave node.
5) Select apply.



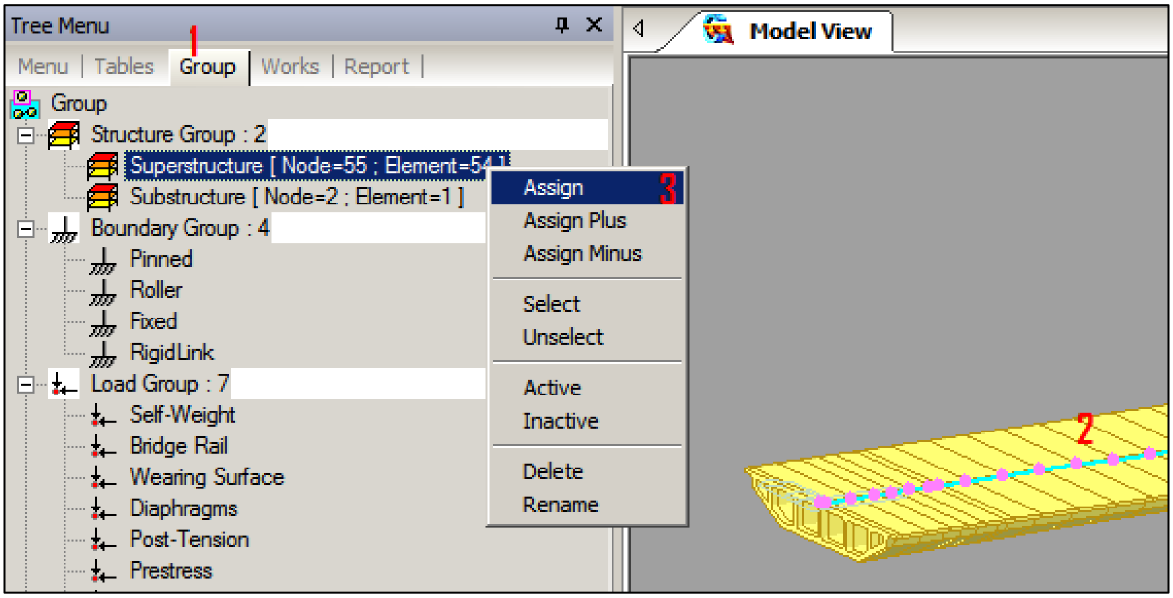
6.4.11 Structure Group

Structure groups are used to activate (or deactivate) elements in the construction staging. Load effects are pulled from the construction stage analysis. For the analysis to perform correctly, all nodes and elements must be assigned to a structure group. Superstructure and substructure groups are defined by default. For a simple span analysis, it isn't necessary to assign any elements or nodes to the substructure group because the substructure isn't included in the model. Bridges with complex construction staging, may require more structure groups than the two predefined.

1) In the Tree Menu, Select the Group tab.

2) Select all of the nodes and elements that will be assigned to the structure group. There are several ways to accomplish this. To select all the nodes and elements the Midas quick command for select all is (Cntrl + Shift + A). Individual elements and nodes can be selected with the Select Single command (Cntrl + Shift + S). Once selected the nodes and elements will appear highlighted in the Model View.

3) Right click on the desired structure group and then left click on Assign.



6.4.12 Construction Stage Analysis

In the Tree Menu review the inputs for Construction Stage Analysis. The construction staging will generally be set up to activate the entire structure, boundaries, Prestressing, Post-Tensioning, and DC loads in Stage 1. Wearing surface loads are activated in Stage 2. For elements or loads to be activated, they must be assigned to a Group (see step 6.4.11). Adjust the boundaries, elements, and loads as necessary to reasonably estimate the structures construction sequence and current configuration.

In the top menu go to Load => Toggle Construction Stage => Define C.S.

1) Name the construction stage.

2) Define the duration of the construction stage.

3) Additional steps within the construction stage can be defined. These steps allow the application of loads at times other than the beginning and end of a stage. If loads are applied at the beginning or end of the stage then additional steps are not necessary. The default has a step created at day 2. This step is so that post-tensioning strands can be applied after prestressing strands are activated. Midas will include the additional elastic shortening losses in the prestressing strands due to post-tensioning.

4) Click Add to define additional steps.

5) If several steps need to be created in one stage, then the auto generate function can be used.

6) Select the Group that will be activated or deactivated within this stage. Structure groups are

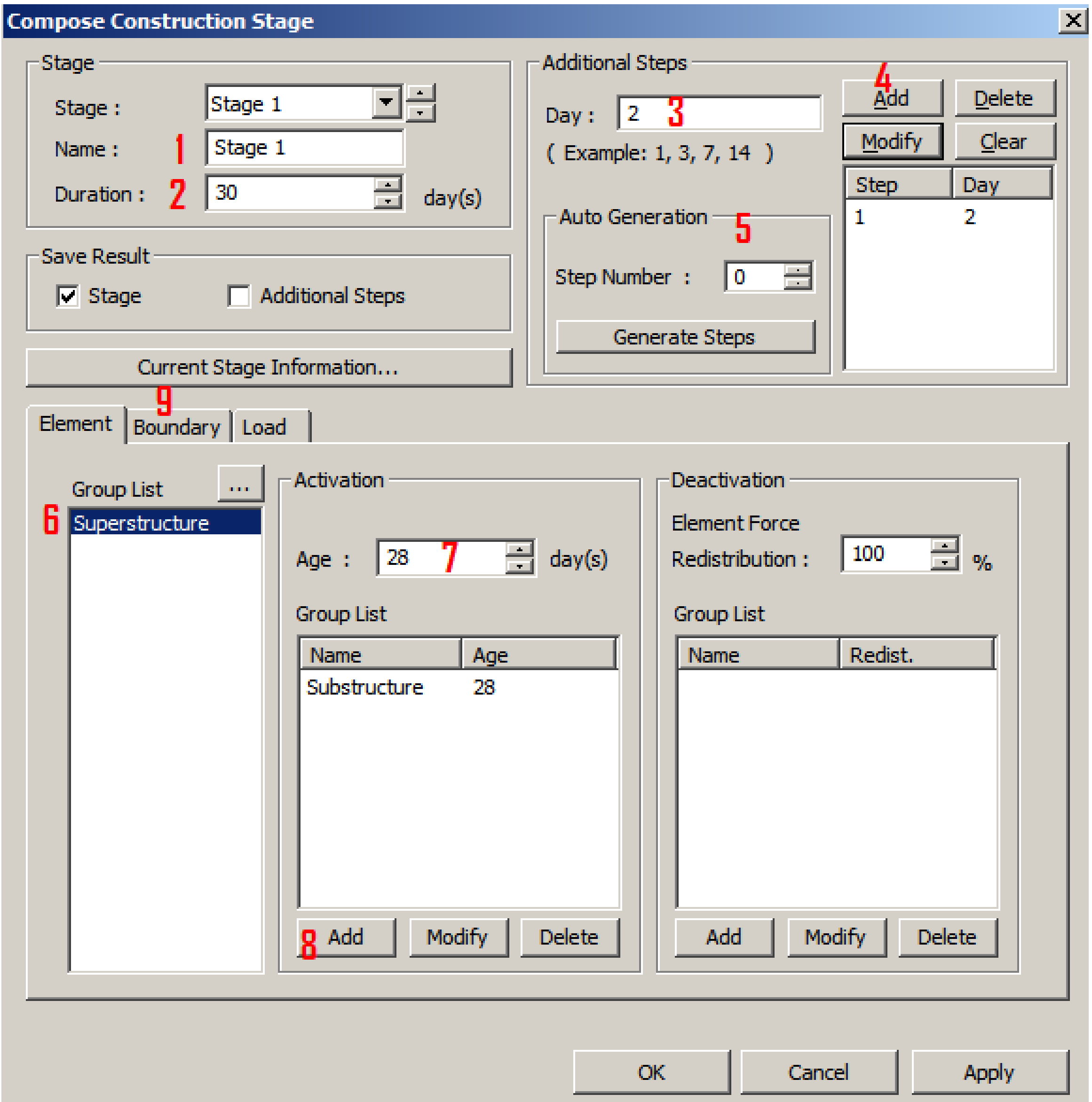
activated or deactivated at the beginning of the construction stage.

7) Define the age of the element when it is activated. ODOT will allow the default value of 28 days to be used for the activation of all elements. Without specific knowledge of the construction schedule it is impossible to know the exact construction staging. Using 28 days assumes that the elements have reached the design strength before being loaded.

8) Click Add to place the group into the activation column.

Continue until all desired groups are activated. The default is to activate the Substructure and Superstructure at 28 day strength.

9) Select the Boundary tab to define permanent and temporary supports.



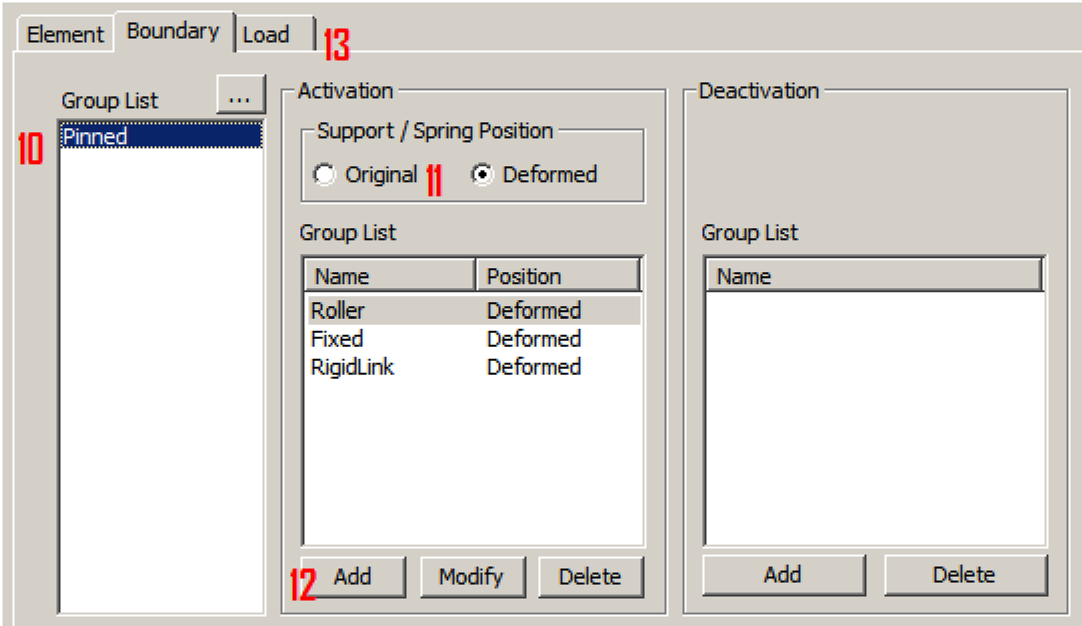
Boundaries are either activated or deactivated at the beginning of the construction stage.

10) Select the Boundary Group to be activated or deactivated.

11) Select deformed or original. Deformed is the default selection.

12) Select Add.

13) Select the Load Tab.



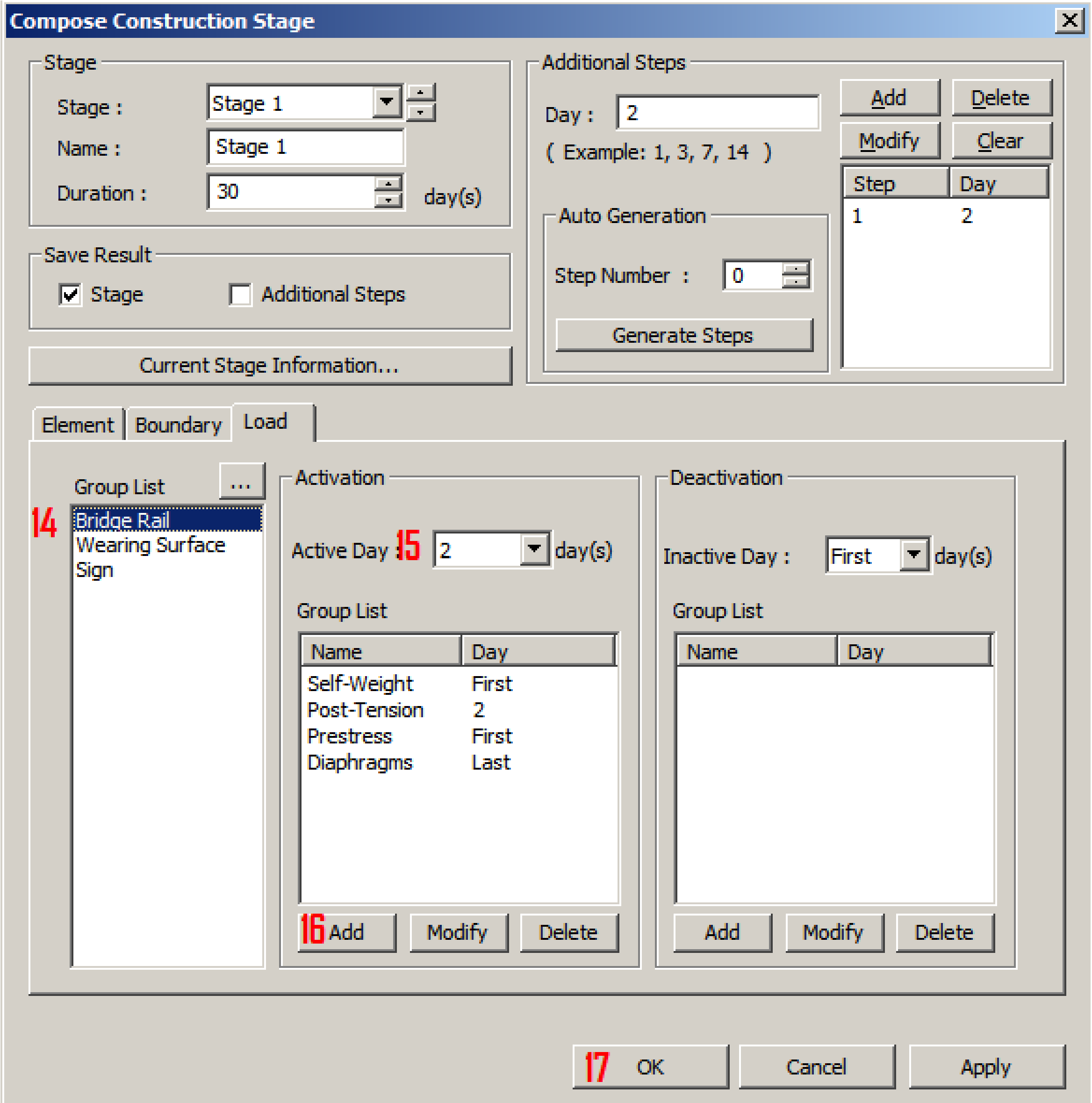
14) Select the Load Group to be activated or deactivated in this stage. Unlike boundary groups and load groups, these can be activated on the first day, last day, or at any defined step.

15) Select if this load is activated or deactivated on the first day, last day, or at a defined step in this stage.

16) Click Add

17) Click Ok.

Continue above steps until the structure is defined. The last stage should have a 10,000 day duration. The reason for the long stage is to perform time dependent prestress loss calculations.



6.4.13 Perform Midas Analysis and Review Results

Perform the analysis by going in the top menu to Analysis => Perform Analysis.

6.4.13.1 Load Combinations

Four load combinations need to be defined for the post analysis spreadsheet nnnnn_PTGirder.XLS. The four combinations are DC, DW, PT and Service III. These combinations are automatically generated by the truck command shell. If no new load cases were defined during the model construction, modification isn't necessary. All of the following load factors will be 1.0 because load factors are applied in PTGirder.xls.

In the top menu go to Results => Load Combinations.

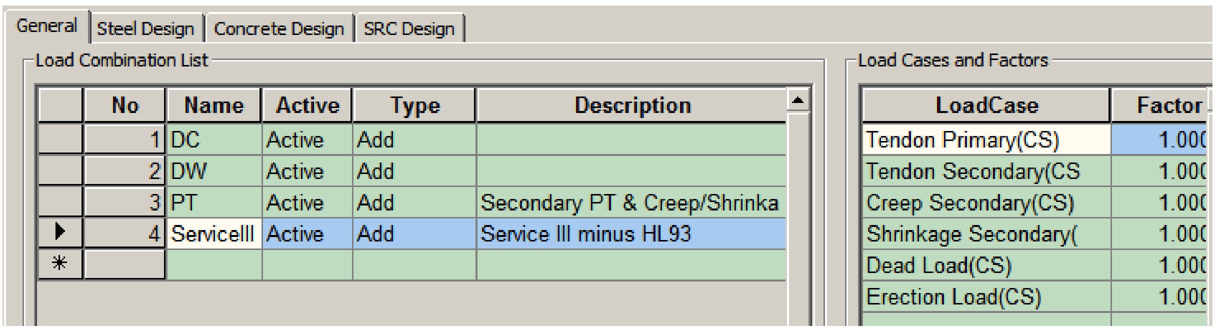
1) Under DC, make sure the Bridge Rail, Self-Weight, Diaphragm and any additional DC load cases are selected. Do not select construction stage load cases (CS). Construction stage analysis will lump the DW and DC loads. Since DC and DW have different load factors, the Dead Load (CS)

load case should **not** be selected here.

2) Under DW, make sure the Wearing Surface Load case is defined.

3) Under PT, select the Tendon Secondary (CS), Creep Secondary (CS), and Shrinkage Secondary (CS) load cases. Note that these loads are from the construction stage analysis.

4) ServiceIII does **NOT** include the HL93 load effects. Select Tendon Primary(CS), Tendon Secondary(CS), Creep Secondary(CS), Shrinkage Secondary(CS), Dead Load(CS), and Erection Load(CS). All of these loads are selected from the construction stage analysis. The ServiceIII load combination will be combined with the HL-93 load effect to calculate service III rating factors in PTGirder.xls.



6.4.13.2 Review Results

Review the results for accuracy. Reactions, Deformations, Forces, and Stress are readily output by going to the top menu under Results => Forces => Beam Forces/Moments. This will bring up a Tree Menu where Reactions, Deformations, Forces and Stresses can be viewed. Change the Load Cases/Combinations until all are verified.

6.4.14 Calculate the Number of Prestressing Strands

If prestressing area was not provided in the plans, then return to the preliminary file and iterate to determine the minimum number of prestressing strands. If the prestressing strand area was provide, this step may be skipped.

Return to the Mathcad preliminary file to calculate the number of prestressing strands required for analysis. In creating the model the number of strands used was based on an assumed time dependent prestress loss value without including any immediate stress losses. During construction the post tensioning supplier likely used this assumed value for time dependent losses and added the calculated immediate losses to determine the number of strands and initial jacking stress. Perform the iterations as required to obtain the required minimum midspan force while keeping the maximum tendon stress below the allowable maximum.

6.4.15 Dynamic Report Creator

The Dynamic Report Creator is used to generate a word document that contains the Midas model inputs. User Defined Tables were loaded with the Vehicles command shell (See step 6.4.9.5).

In the top menu go to Tools => Dynamic Report Generator.

Select New Document and click OK. This will open a new tab titled Report Editor and will open up a blank word document.

1) Right Click on Header & Footer in the tree menu, and then left click on properties.

2) Project Name, User Name, Address (Company), and File name should already be selected; If not

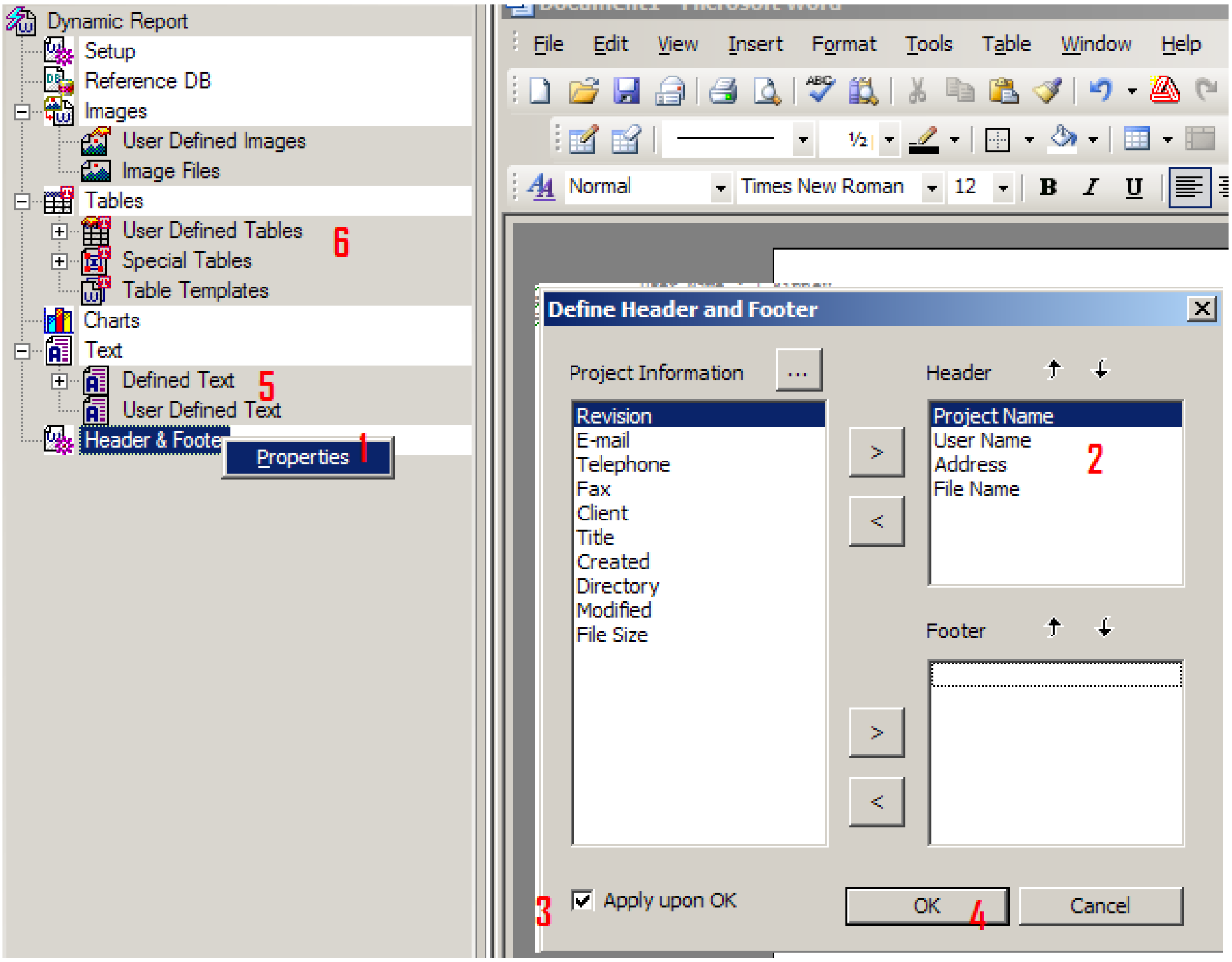
select these.

3) Select Apply upon OK.

4) Click OK.

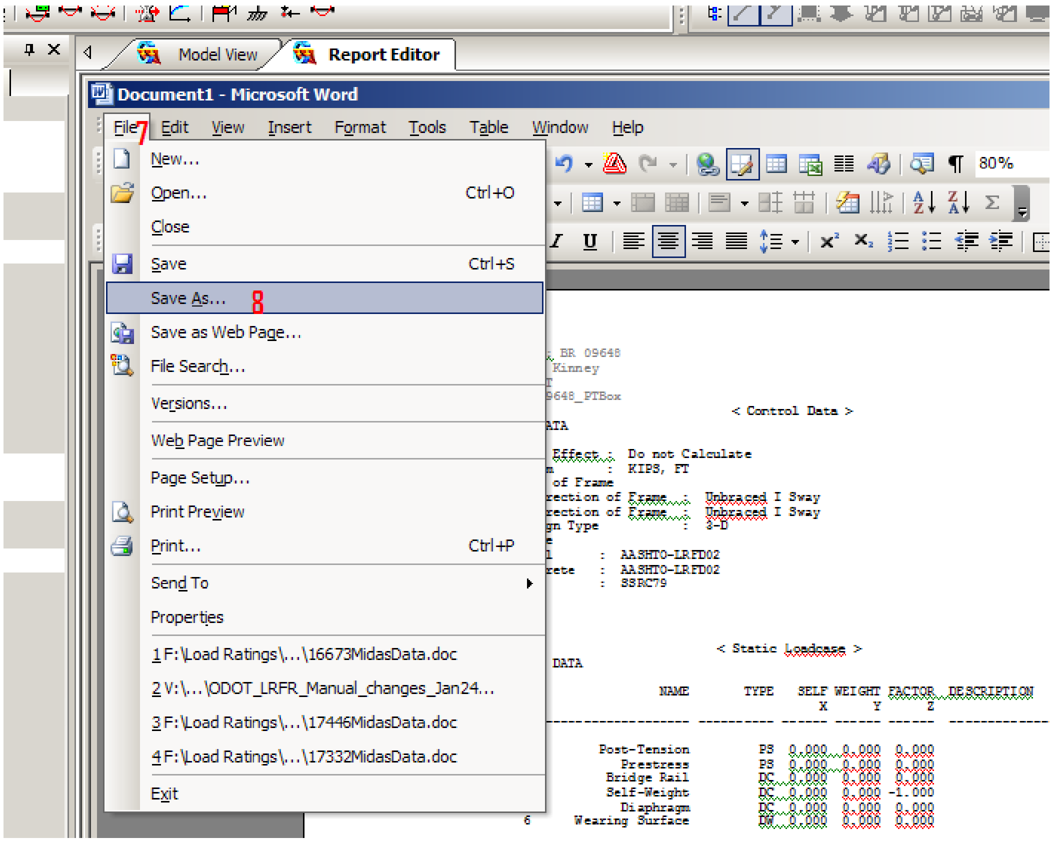
5) Right Click on Defined Text and then left click on Insert to Report.

6) Right Click on User Defined Tables and then left click on Insert to Report.



7) Click on the File menu in the Word Document.

8) Click on Save As. Name the file NNNNNMidasData.doc and save to load rating file. This report will be printed to be included in the calculation book.



6.5 Capacity and RF Worksheet (Nnnnn_PTGirder.XLS)

Nnnnn_PTGirder.XLS is an excel spreadsheet developed to calculate capacities and rating factors. Distribution factors and load effects are imported from BRASS GIRDER LRFD and Midas Civil. Some inputs have macros written to automate the process while other information is manually entered. Where buttons have been provided to perform a task, use the button. Buttons have been provided to not only aid the user, but to also assign cell ranges.

nnnnn_PTGirder.XLS is based on the following assumptions:

1. No Prestressing reinforcement is excluded from Mn or Vn analysis.
2. Mild reinforcement on the compression side has an insignificant effect on nominal moment capacity. Thus, mild reinforcement on compression side is ignored.
3. Fillets and Tapers have an insignificant effect on capacities. Thus, fillets and tapers are ignored in capacity calculations.
4. Mn is not reduced based on Mn/(1.2Mcr or 1.33Mu) as per AASHTO Manual for Bridge Evaluation 6A.5.7..
5. If the longitudinal strain in the nonprestressed longitudinal tension reinforcement, ε_s, is calculated to be negative (in compression), the value will be set to zero. Per AASHTO LRFD 5.7.3.4.2.
6. When an analysis point is located at a stirrup change point, the smaller Av/s ratio is used.
7. Factored live loads are calculated using the maximum of the single and multiple lane distribution factors.
8. f_{ps} is calculated using strain compatibility and section equilibrium. The section is assumed to not have a net axial load. Stress-strain relationship is per Devalapura and Tadros, PCI

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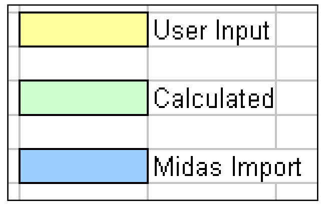
Color coded cells are used in nnnnn_PTGirder.XLS to aid user input. Follow the reference below to determine if the cell is user input, calculated by nnnnn_PTGirder.XLS, or imported from Midas output.



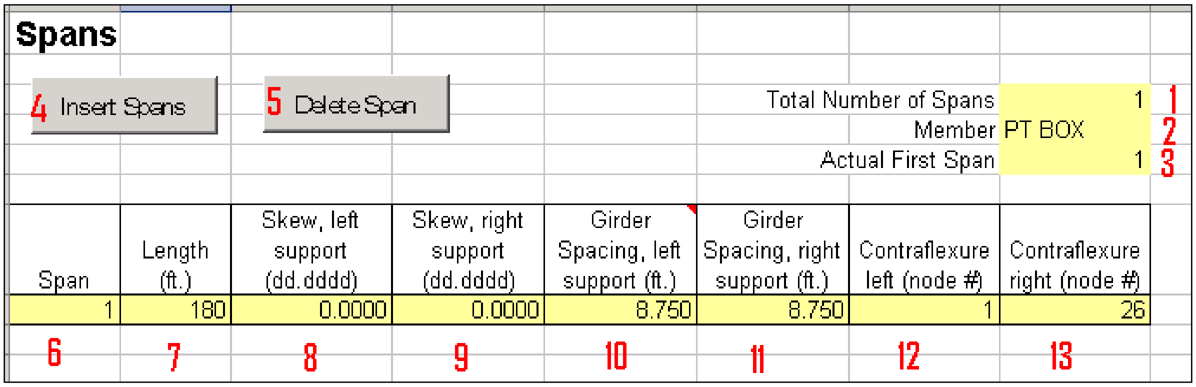
6.5.1 Resistance and Factors

Update the System, Condition, Resistance, Live Load, and Dead Load factors. DC, DW and PS factors do not normally need to be altered. Impact is input for Legal and Permitted vehicles only. Impact adjustments for design loads are included in the Midas output.

6.5.2 Spans

Define the spans that are included in this analysis.

1) Insert the actual number of spans in the structure. (Not necessarily included in analysis)
2) Describe the member being rated by this analysis, such as PT Box.
3) Input the first span in this analysis.
4) Use the Insert Span button to add additional spans for this analysis. Note: Not all of the actual spans are defined here, but only the spans that are being analyzed by nnnnn_PTGirder.XLS.
5) Use the Delete Span button to remove spans that are not necessary.
6) Input the span number. (Begin with 1)
7) Input the span length in feet.
8) Input the skew at the right support.
9) Input the skew at the left support.
10) Input the girder spacing at the left support. Only one girder spacing at a given section can be accommodated by the program. However, this spacing can be different at each section. The program will assume that the spacing varies linearly from the left to the right support.
11) Input the girder spacing at the right support.
12) Input the node that defines the point of contraflexure on the left end of the span. For a simple span analysis this would be the first node in the analysis. For continuous spans determine the contraflexure location by applying a uniform load to the structure. This information is used when calculating the distribution factors.
13) Input the node that defines the point of contraflexure on the right end of the span. For a simple span analysis this would be the last node in the analysis. For continuous spans determine the contraflexure location by applying a uniform load to the structure.



6.5.3 Geometry Calculations (GeometryCalcs)

The GeometryCalcs tab is used to define all the section geometry used for analysis. This tab should be filled out prior to the creation of the Midas model and is a useful reference throughout the rating process. Use calculations within the cells as necessary. Between the in cell calculations and the information provided in the preliminary file enough work needs to be shown for another user to easily determine how the section dimensions were calculated. Some columns are for book keeping purposes while others are required for various macros. The columns that are for book keeping purposes include; Length Within Span, Midas Section #, Midas Element, Ext Web Width, Int Web Width, and Notes.

1) Span Fraction is automatically calculated. The calculation is based on the user input for Midas x-axis coordinate (step 3) and information entered under the spans tab.

2) Enter the distance from the centerline of left support to the node point.

3) Enter the Midas X-axis coordinate. This is the distance along the x-axis from the model origin (0,0,0) to the node point. Note: the first value input here isn't necessarily zero, it could be a negative number due to an overhang past centerline of bearing.

4) Enter the Midas Node #. This is filled out prior to creating the Midas model, thus make sure the nodes are numbered consecutively from 1 to the end.

5) Input the Midas section number. Give geometry change locations a unique cross section number beginning from 1 to N. Most locations are not at unique sections and will not have a cross section drafted, but will instead be calculated as part of a tapered section group, An example of how to name these is TSG 2-3, which would read tapered section group between section two and three. Section names are not used as part of the analysis and can have any name that adequately describes the section. For clarity, do make sure that the section name matches the section name in Midas.

6) Enter the Midas element number. If the model is created from left to right then the elements will begin with 1 and be numbered consecutively to the last element. In the example below the first row will always be 1I. All other locations are assumed to correspond to the J end of the element.

7) Calculated the exterior web width. It isn't necessary to adjust this width for the presence of ducts until step 11.

8) Calculate the interior web width. It isn't necessary to adjust this width for the presence of ducts until step 11.

9) Calculate the effective shear width. Reduce the total width for the presence of post tensioned ducts as required by AASHO LRFD 5.7.2.8.

10) Calculate the average height of the box girder. This is the total height, and is calculated as per section 6.3.1.

Section Geometry Calculations

Set Geo Range

1 Span Fraction	2 Length Within Span (in)	3 Midas x-axis coordin. (in)	4 Midas Node #	5 Midas Section #	6 Midas Element	7 Ext Web Width (in)	8 Int Web Width (in)	9 bv (in)	10 Average Height (in)
1.000	0.000	0.000	1	1	1I	13.70	12.00	46.60	56.38
1.010	15.000	15.000	2	1	1	13.70	12.00	46.60	56.38
1.038	55.590	55.590	3	TSG 1-2	2	13.70	12.00	46.60	56.38
1.050	72.600	72.600	4	TSG 1-2	3	13.70	12.00	46.60	56.38
1.100	145.200	145.200	5	TSG 1-2	4	13.70	12.00	46.60	56.38
1.120	174.000	174.000	6	TSG 1-2	5	13.70	12.00	46.60	56.38
1.150	217.800	217.800	7	TSG 1-2	6	13.70	12.00	46.60	56.38
1.197	285.900	285.900	8	2	7	13.70	12.00	46.60	56.38
1.250	363.000	363.000	9	2	8	13.70	12.00	46.60	56.38
1.300	435.600	435.600	10	2	9	13.70	12.00	46.60	56.38
1.350	508.200	508.200	11	2	10	13.70	12.00	46.60	56.38
1.400	580.800	580.800	12	2	11	13.70	12.00	46.60	56.38
1.450	653.400	653.400	13	2	12	13.70	12.00	46.60	56.38
1.500	726.000	726.000	14	2	13	13.70	12.00	46.60	56.38
1.550	798.600	798.600	15	2	14	13.70	12.00	46.60	56.38
1.600	871.200	871.200	16	2	15	13.70	12.00	46.60	56.38
1.650	943.800	943.800	17	2	16	13.70	12.00	46.60	56.38
1.700	1016.400	1016.400	18	2	17	13.70	12.00	46.60	56.38
1.750	1089.000	1089.000	19	2	18	13.70	12.00	46.60	56.38
1.803	1166.100	1166.100	20	2	19	13.70	12.00	46.60	56.38
1.850	1234.200	1234.200	21	TSG 2-3	20	16.72	12.84	54.31	56.38
1.900	1306.800	1306.800	22	TSG 2-3	21	19.93	13.73	62.52	56.38
1.957	1388.910	1388.910	23	TSG 2-3	22	23.57	14.74	71.82	56.38
1.971	1410.000	1410.000	24	3	23	24.50	15.00	74.21	56.38
1.983	1428.000	1428.000	25	4	24	25.30	15.00	75.80	56.38
2.000	1452.000	1452.000	26	4	25	25.30	15.00	75.80	56.38
2.050	16.800	1468.800	27	4	26	25.30	15.00	75.80	56.38

11) Calculate the deck thickness.

12) Calculate the equivalent deck width. The equivalent deck width is the actual deck width that has been adjusted to account for non-uniform thickness overhangs. This is not to be confused with the Transformed deck width which is adjusted due to differing concrete strengths.

13) Calculate the bottom flange thickness.

14) Calculate the bottom flange width. This width will commonly vary as the girder height changes, due to the inclined exterior stems.

15) Input the deck concrete 28 day compressive strength.

16) Input the beam concrete 28 day compressive strength.

17) Select if this location will be rated for positive moment capacity. This will automatically include the analysis point for a service III check.

18) Select if this location will be rated for negative moment capacity. This will automatically include the analysis point for a service III check.

19) Select if this location will be rated for shear capacity.

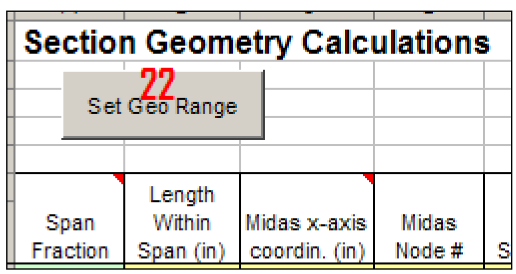
20) Input any descriptive notes that are necessary for clarity.

21) The transformed deck width is automatically calculated in this column. The equation assumes that the deck and girder concrete unit weights are equal, which is a valid assumption for concretes with compressive strengths less than 10ksi. Use this transformed deck width when

drafting sections for use in Midas. Remember to include a static load in the model to account for the difference in weight of the transformed deck width and the equivalent deck width.

11 Deck Thickness (in)	12 Equiv. Deck Width (in)	13 Btm Flange Thickness (in)	14 Bottom Flange Width (in)	Conc Strength (ksi) 15 Deck	 16 Beam	Analysis Type 17 +M	 18 -M	 19 V	20 Notes	21 Transformed Deck Width
12.00	381.00	12.00	303.00	5.00	5.00	No	No	No	CL Bent 2	381.00
12.00	381.00	12.00	303.00	5.00	5.00	No	No	No	Face of Bm "E" Begin Top & Btm Flg Haunch	381.00
11.33	383.68	11.18	303.00	5.00	5.00	No	No	Yes	Critical Shear Section	383.68
11.04	384.90	10.83	303.00	5.00	5.00	No	No	Yes		384.90
9.84	390.89	9.36	303.00	5.00	5.00	No	No	Yes		390.89
9.36	393.70	8.77	303.00	5.00	5.00	No	No	Yes	Stirrup Change from 6" to 12"	393.70
8.63	398.56	7.88	303.00	5.00	5.00	No	No	Yes		398.56
7.50	408.00	6.50	303.00	5.00	5.00	No	No	Yes	End Top and Btm Flg Haunch	408.00
7.50	408.00	6.50	303.00	5.00	5.00	Yes	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	Yes	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	Yes	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	Yes	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	Yes	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	Yes	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	No	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	No	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	No	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	No	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	No	No	Yes		408.00
7.50	408.00	6.50	303.00	5.00	5.00	No	No	Yes	Begin Web and Btm Flg tapers	408.00
7.50	408.00	7.93	303.00	5.00	5.00	No	Yes	Yes		408.00
7.50	408.00	9.45	303.00	5.00	5.00	No	Yes	Yes		408.00
7.50	408.00	11.18	303.00	5.00	5.00	No	Yes	Yes	Critical Shear Section	408.00
7.50	408.00	11.62	303.00	5.00	5.00	No	Yes	No	Face of Bm "X" End Int Web Taper	408.00
7.50	408.00	12.00	303.00	5.00	5.00	No	Yes	No	Face of Bm "X" End Ext Web Tapers and Btm F	408.00
7.50	408.00	12.00	303.00	5.00	5.00	No	Yes	No	CL Bent 3 Left	408.00
7.50	408.00	12.00	303.00	5.00	5.00	No	Yes	No		408.00
7.50	408.00	12.00	303.00	5.00	5.00	No	Yes	No		408.00
7.50	408.00	12.00	303.00	5.00	5.00	No	Yes	Yes	Critical Shear Section	408.00
7.50	408.00	12.00	303.00	5.00	5.00	No	Yes	Yes		408.00

22) Click the "Set Geo Range" button. This button activates a macro that will define the GeometryCalcs range and will also apply the appropriate formatting. The GeometryCalc range is defined up to the first blank row in the Midas x-axis coordinate column.



6.5.4 Distribution Factors (LL_DF)

The Spans and section geometry tabs must be filled out prior to beginning distribution factor calculations.

1) Selected if an interior or exterior girder is being calculated. For cast-in-place boxes or precast bulb-I/T girders that are hybrid with cast-in-place boxes, only interior distribution factors will be calculated. These factors are then multiplied by the total number of stems per AASHTO LRFD 4.6.2.2. Spread boxes will be rated as single girder lines; therefore they will have separate nnnnn_PTGirder.xls files one with interior and one with exterior ratings.

2) Input de in feet. This is the distance from the centerline of the exterior web to face of curb. This is used when calculating the lever rule. If spread boxes are used then de is the distance from CL of the exterior girder to centerline to face of curb.

3) Input the number of beams/webs. If cast-in-place boxes are used the spreadsheet will internally calculate the number of cells from the number of webs.

4) The spreadsheet is only set up to accommodate the below structure types, and all are assumed to have a composite concrete deck unless stated otherwise. Select one of the following:

    Type “b” closed precast boxes (Spread Boxes). Although the spreadsheet can calculate the distribution factors for closed precast boxes, it has the limitation of only allowing one top flange to be defined. Contact the ODOT load rating unit when attempting to analyze this structure type.

    Type “c” Precast open boxes (Spread Boxes).

    Type “d” Cast-in-place multicell boxes.

    Type "f" Precast Solid, Voided, or Cellular Boxes w/ Shear Keys.

    Type “g” Precast Solid, Voided, or Cellular Boxes w/ Shear Keys with or without transverse PT. **Must be sufficiently connected to act as a unit.**

    Type “k” girders are precast type I or T girders. It is only appropriate to analyze these girder types when they are hybrid with cast-in-place multicell boxes. Due to spreadsheet limitations, the top flange of the precast girder will have to be excluded from the analysis. The composite deck will instead be input as the top flange geometry.

    Type “Slabs” Cast-In-Place post-tensioned slabs. Interior strips may be analyzed following the procedures outlined in this chapter. Per AASHTO LRFR 4.6.2.1.4b, longitudinal edge strips shall be designed for one line of wheels and a tributary portion of the design lane. To accomplish this truck and lanes defined in Midas have to be adjusted, see section 6.4.9.5.

5) Input the physical edge to edge width (ft) measured normal to centerline. This dimension is used when calculating distribution factors for slabs.

6) Input the roadway width (ft) measured normal to centerline. This dimension is required for all bridge types.

7) Input the edge of slab to face of barrier (ft) dimension. This dimension is used when calculating distribution factors for slabs.

8) Click the DF Inputs button to population the locations where live load distribution factors need to be calculated. Only locations where ratings are required will be populated. Section properties at each location are used for the distribution factor calculations. The default values entered in steps 1-4 will be automatically populated.

9) The section location is automatically populated.

10) The default number of girders is populated here. The number of girders can be manually varied from section to section, but this should be limited by the Engineers judgment.

11) For hybrid structures, the structure type can be varied at each section.

12) Section Number is populated for reference only.

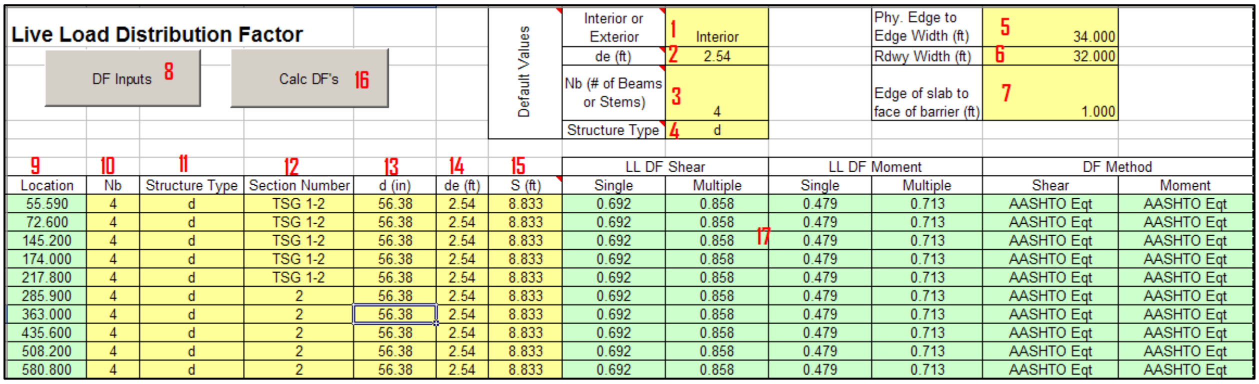
13) The depth of the girder is automatically populated.

14) The default overhang is populated. This can be varied as required for each section.

15) The girder spacing is automatically populated assuming linear variation from left to right support. This can be manually varied as necessary.

16) Click Calc DF’s button to calculate rating factors. If the ranges of applicability, as modified by section 1.4.1.6, are met then the equations in AASHTO LRFD section 4.6.2.2.2 are used. If at a given location the ranges of applicability fail, then the lever rule is used. When applying the lever rule at a given section, the stems are assumed to be spaced uniformly and the alongside truck is allowed to be a minimum of 4 ft from the other truck.

17) If in the Engineer’s judgment, the rating factors need to be modified or calculated externally, then the distribution factors may be manually entered.



Live Load Distribution Factor

DF Inputs 8 | Calc DF's 16

Default Values

Interior or Exterior	1 Interior	Phy. Edge to Edge Width (ft)	5 34.000
de (ft)	2 2.54	Rdwy Width (ft)	6 32.000
Nb (# of Beams or Stems)	3 4	Edge of slab to face of barrier (ft)	7 1.000
Structure Type	4 d		

9	10	11	12	13	14	15	LL DF Shear		LL DF Moment		DF Method	
Location	Nb	Structure Type	Section Number	d (in)	de (ft)	S (ft)	Single	Multiple	Single	Multiple	Shear	Moment
55.590	4	d	TSG 1-2	56.38	2.54	8.833	0.692	0.858	0.479	0.713	AASHTO Eqt	AASHTO Eqt
72.600	4	d	TSG 1-2	56.38	2.54	8.833	0.692	0.858	0.479	0.713	AASHTO Eqt	AASHTO Eqt
145.200	4	d	TSG 1-2	56.38	2.54	8.833	0.692	0.858 17	0.479	0.713	AASHTO Eqt	AASHTO Eqt
174.000	4	d	TSG 1-2	56.38	2.54	8.833	0.692	0.858	0.479	0.713	AASHTO Eqt	AASHTO Eqt
217.800	4	d	TSG 1-2	56.38	2.54	8.833	0.692	0.858	0.479	0.713	AASHTO Eqt	AASHTO Eqt
285.900	4	d	2	56.38	2.54	8.833	0.692	0.858	0.479	0.713	AASHTO Eqt	AASHTO Eqt
363.000	4	d	2	56.38	2.54	8.833	0.692	0.858	0.479	0.713	AASHTO Eqt	AASHTO Eqt
435.600	4	d	2	56.38	2.54	8.833	0.692	0.858	0.479	0.713	AASHTO Eqt	AASHTO Eqt
508.200	4	d	2	56.38	2.54	8.833	0.692	0.858	0.479	0.713	AASHTO Eqt	AASHTO Eqt
580.800	4	d	2	56.38	2.54	8.833	0.692	0.858	0.479	0.713	AASHTO Eqt	AASHTO Eqt

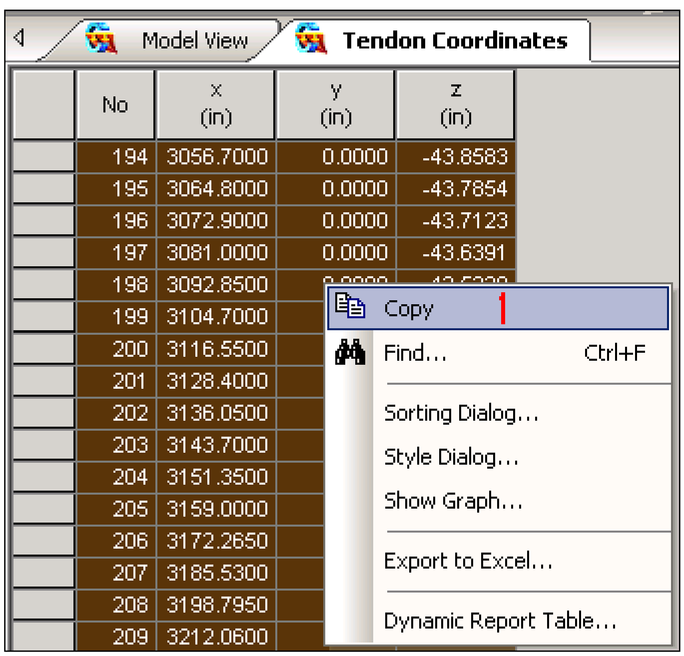
6.5.5 Analysis Pts

Clicking the Get Analysis Pts button will populate the analysis points that were defined in the GeometryCalcs tab. No user input is required here. This is a good time to check that all required analysis points were selected in GeometryCalcs.

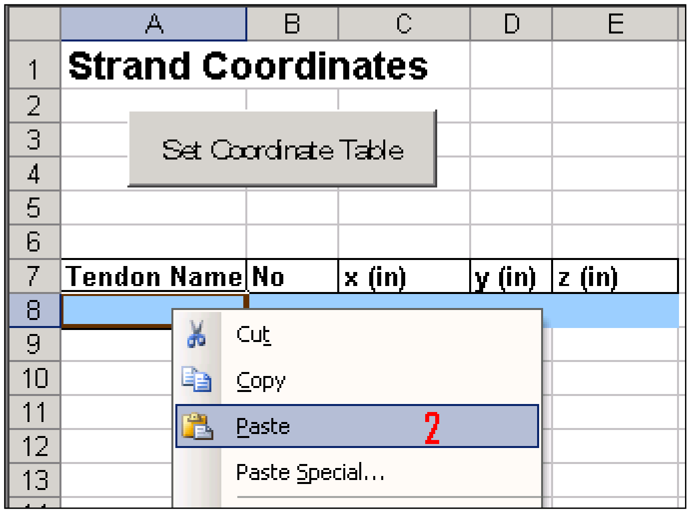
6.5.6 Strand Coordinates

Prestressing strand information is obtained from Midas output. The first step is to define the strand coordinates. Open the Midas model and in the Top Menu for to Results => Results Tables => Tendon => Tendon Coordinates. Make sure the model units are set to inches.

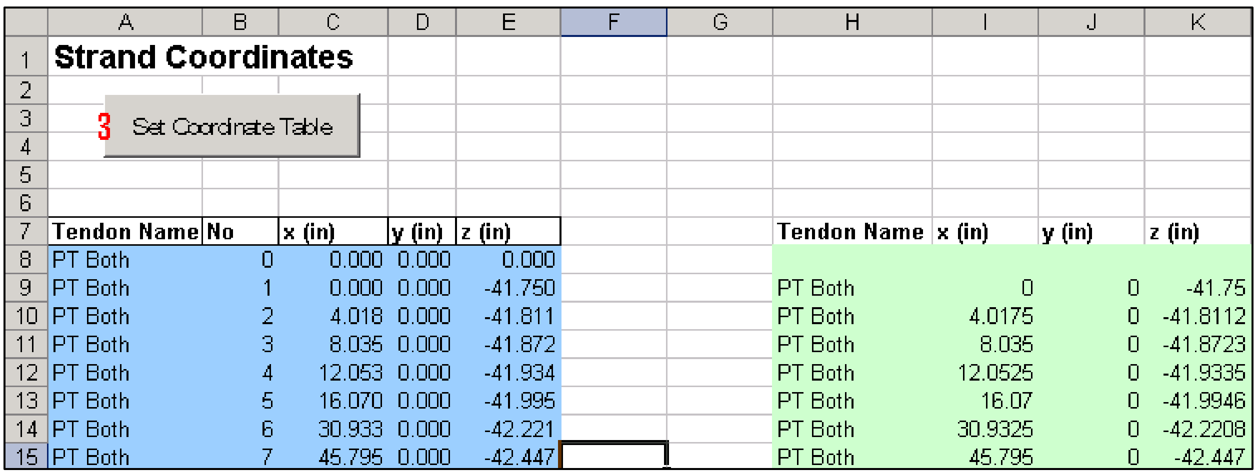
1) Select the entire table (excluding header). Left click on the highlighted cells and then click on copy.



2) Paste the copied data into the Strand Coordinates tab of PTGirder.xls



3) Click on Set Coordinate Table. This macro will populate the table highlighted in green to the right. Midas defines all of its strand coordinates from the beginning of the strand. The table in green will convert the coordinates to the model coordinate system.



Tendon Name	No	x (in)	y (in)	z (in)		Tendon Name	x (in)	y (in)	z (in)
PT Both	0	0.000	0.000	0.000					
PT Both	1	0.000	0.000	-41.750		PT Both	0	0	-41.75
PT Both	2	4.018	0.000	-41.811		PT Both	4.0175	0	-41.8112
PT Both	3	8.035	0.000	-41.872		PT Both	8.035	0	-41.8723
PT Both	4	12.053	0.000	-41.934		PT Both	12.0525	0	-41.9335
PT Both	5	16.070	0.000	-41.995		PT Both	16.07	0	-41.9946
PT Both	6	30.933	0.000	-42.221		PT Both	30.9325	0	-42.2208
PT Both	7	45.795	0.000	-42.447		PT Both	45.795	0	-42.447

6.5.7 Strand Properties

Begin assigning the prestressing strand properties by setting default strand parameters, steps 1-5. When the strands are imported, these defaults will be applied to all strands. If the default parameters vary from one strand to the next, then these can be defined after importing the strands.

1) Select the strand type; Low Relaxation, Stress Relieved, Type 1 Bar, or Type 2 Bar.

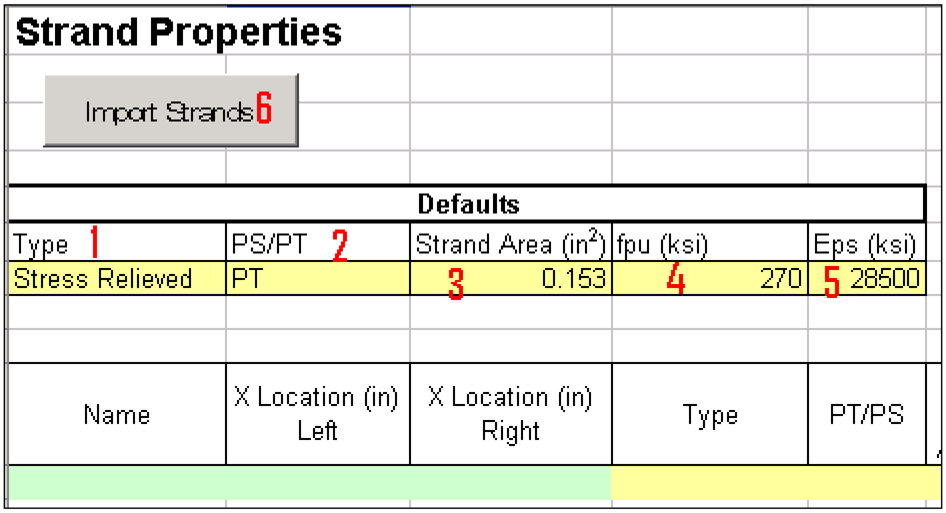
2) Select if this is a prestressed or post-tensioned strand; PS, or PT.

3) Select the area of one strand.

4) Enter the ultimate strength of the prestressing strand.

5) Enter the modulus of elasticity for the prestressing strand.

6) Click Import Strands



All of the prestress and post-tensioned strands that were included in the Midas analysis should now be populated in the table. The load rater can now change the default values for Type, PT/PS, Strand Area, fpu, and Eps for each strand profile. Review the populated list to ensure that all strand profiles were included.

6) Input the number of strands for each profile.

7) Add any necessary comments.

Name	X Location (in) Left	X Location (in) Right	Type	PT/PS	Strand Area (in²)	Number of Strands	fpu (ksi)	Eps(ksi)	Comments
PS Debond D	995.1	1753.20	Stress Relieved	PS	0.153	12	270	28500	PS Girders
PS Debond D-Copy	2741.673	3558.86	Stress Relieved	PS	0.153	12	270	28500	PS Girders
PS Debond E	875.4	1833.00	Stress Relieved	PS	0.153	6	270	28500	PS Girders
PS Debond E-Copy	2628.957	3671.58	Stress Relieved	PS	0.153	6	270	28500	PS Girders
PS Deflected	734.1975	2066.86	Stress Relieved	PS	0.153	15	270	28500	PS Girders
PS Deflected-Copy	2503.7125	3776.505	Stress Relieved	PS	0.153	6 15	270	28500	PS Girders
PS Rod Bent 2	594.605	776.525	Stress Relieved	PS	0.153	8	270	28500	Ledge Beam PS Rod 7
PS Rod Bent 4	3697.07	3866.2425	Stress Relieved	PS	0.153	8	270	28500	Ledge Beam PS Rod
PS Straight	779.675	1944.895	Stress Relieved	PS	0.153	15	270	28500	PS Girders
PS Straight-Copy	2531.85	3696.895	Stress Relieved	PS	0.153	15	270	28500	PS Girders
PT Stage IA Left	-18.21	734.1975	Stress Relieved	PT	0.153	115	270	28500	Post-Tensioned Box Girders
PT Stage IA Right	3684.325	4422.955	Stress Relieved	PT	0.153	115	270	28500	Post-Tensioned Box Girders
PT Stg IB Left Btm	1944.72	2519.28	Stress Relieved	PT	0.153	65	270	28500	Post-Tensioned Box Girders
PT Stg IB Left Top	1980.63	2524.055	Stress Relieved	PT	0.153	50	270	28500	Post-Tensioned Box Girders
PT Stg IB Right Btr	1944.72	2519.28	Stress Relieved	PT	0.153	65	270	28500	Post-Tensioned Box Girders
PT Stg IB Right Tor	1980.63	2555.19	Stress Relieved	PT	0.153	50	270	28500	Post-Tensioned Box Girders
PT Stg II	-18.21	4410.21	Stress Relieved	PT	0.153	95	270	28500	Post-Tensioned Box Girders

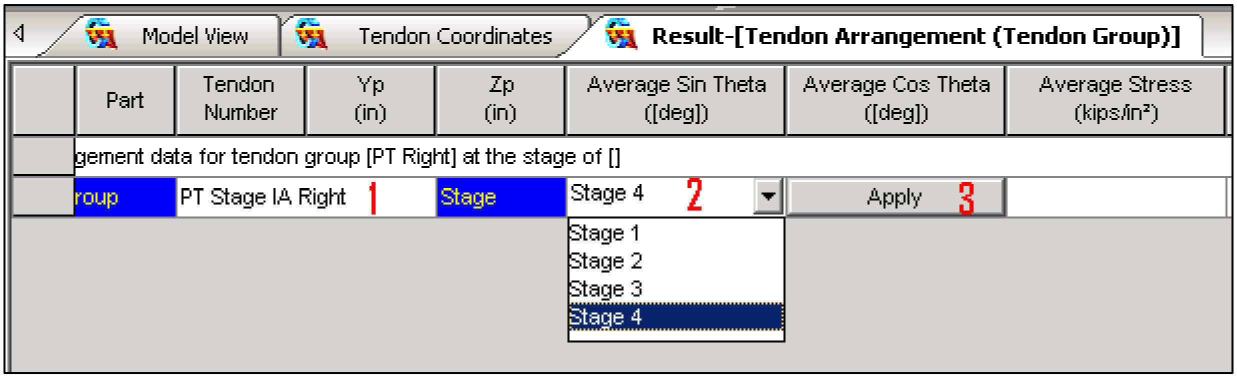
6.5.8 Strand Arrangement

The effective prestress force for each strand profile is obtained from the Midas construction stage analysis. Open the Midas model and in the top menu go to Results => Results Table => Tendon => Tendon Arrangement.

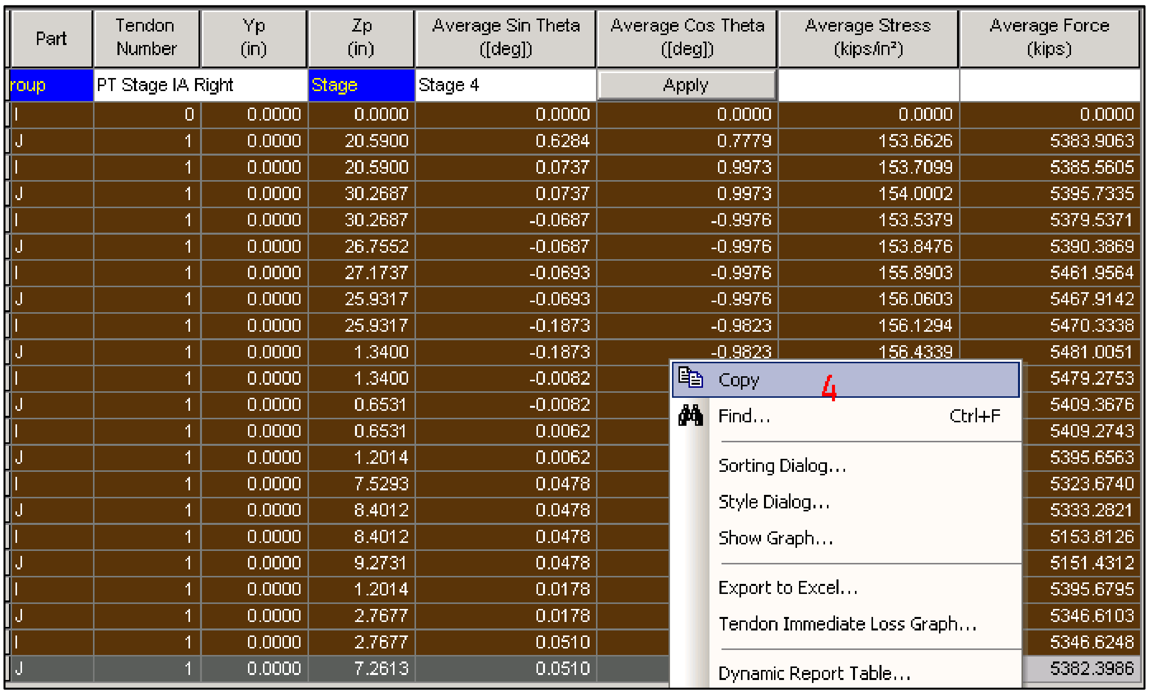
1) Select a tendon group that was defined in the model.

2) Select the last construction stage. This should be the stage that has a 10,000 day construction stage. The last stage is selected so that the time dependent tendon losses are included.

3) Click Apply. Midas will populate the table.

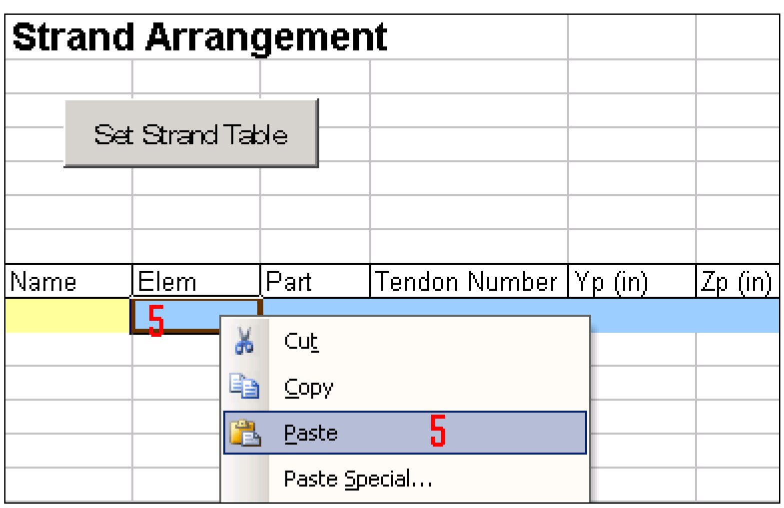


4) Select the entire table (except headings), right click on the selected cells, left click on copy.



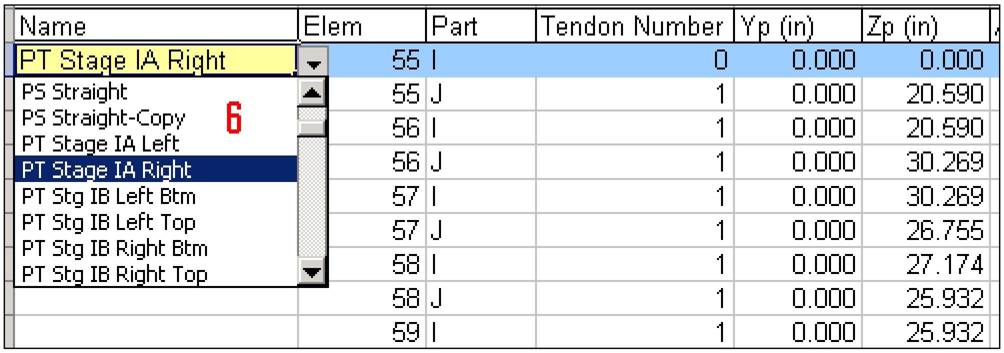
Part	Tendon Number	Yp (in)	Zp (in)	Average Sin Theta ([deg])	Average Cos Theta ([deg])	Average Stress (kips/in²)	Average Force (kips)
roup	PT Stage IA Right		Stage	Stage 4	Apply		
I	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
J	1	0.0000	20.5900	0.6284	0.7779	153.6626	5383.9063
I	1	0.0000	20.5900	0.0737	0.9973	153.7099	5385.5605
J	1	0.0000	30.2687	0.0737	0.9973	154.0002	5395.7335
I	1	0.0000	30.2687	-0.0687	-0.9976	153.5379	5379.5371
J	1	0.0000	26.7552	-0.0687	-0.9976	153.8476	5390.3869
I	1	0.0000	27.1737	-0.0693	-0.9976	155.8903	5461.9564
J	1	0.0000	25.9317	-0.0693	-0.9976	156.0603	5467.9142
I	1	0.0000	25.9317	-0.1873	-0.9823	156.1294	5470.3338
J	1	0.0000	1.3400	-0.1873	-0.9823	156.4339	5481.0051
I	1	0.0000	1.3400	-0.0082			5479.2753
J	1	0.0000	0.6531	-0.0082			5409.3676
I	1	0.0000	0.6531	0.0062			5409.2743
J	1	0.0000	1.2014	0.0062			5395.6563
I	1	0.0000	7.5293	0.0478			5323.6740
J	1	0.0000	8.4012	0.0478			5333.2821
I	1	0.0000	8.4012	0.0478			5153.8126
J	1	0.0000	9.2731	0.0478			5151.4312
I	1	0.0000	1.2014	0.0178			5395.6795
J	1	0.0000	2.7677	0.0178			5346.6103
I	1	0.0000	2.7677	0.0510			5346.6248
J	1	0.0000	7.2613	0.0510			5382.3986

5) Paste the copied data into the first open cell under the Elem Column.



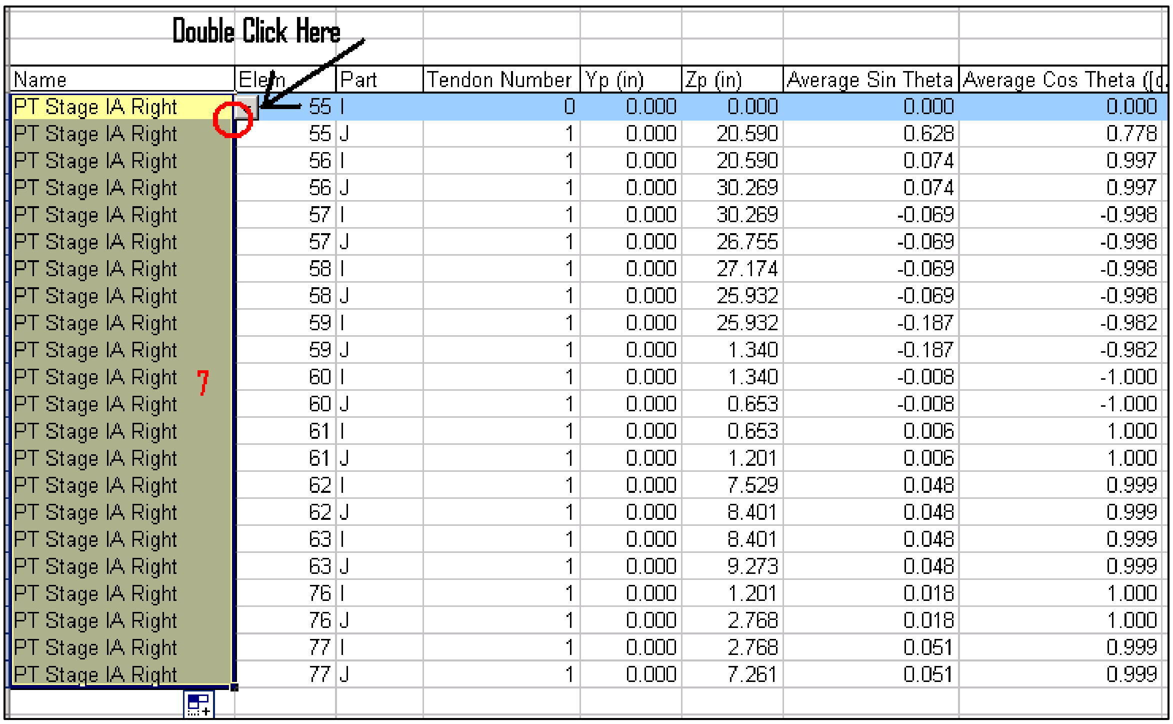
6) Under the Name column select the tendon group from the list. This needs to match the tendon

group selected in step 1.



Name	Elem	Part	Tendon Number	Yp (in)	Zp (in)
PT Stage IA Right	55	I	0	0.000	0.000
	55	J	1	0.000	20.590
	56	I	1	0.000	20.590
	56	J	1	0.000	30.269
	57	I	1	0.000	30.269
	57	J	1	0.000	26.755
	58	I	1	0.000	27.174
	58	J	1	0.000	25.932
	59	I	1	0.000	25.932

7) All the data pasted in step 5 is for the same tendon group. Double clicking the bottom right corner of the name cell will autofill this name in for all the data pasted in step 5.



Name	Elem	Part	Tendon Number	Yp (in)	Zp (in)	Average Sin Theta	Average Cos Theta ([d
PT Stage IA Right	55	I	0	0.000	0.000	0.000	0.000
PT Stage IA Right	55	J	1	0.000	20.590	0.628	0.778
PT Stage IA Right	56	I	1	0.000	20.590	0.074	0.997
PT Stage IA Right	56	J	1	0.000	30.269	0.074	0.997
PT Stage IA Right	57	I	1	0.000	30.269	-0.069	-0.998
PT Stage IA Right	57	J	1	0.000	26.755	-0.069	-0.998
PT Stage IA Right	58	I	1	0.000	27.174	-0.069	-0.998
PT Stage IA Right	58	J	1	0.000	25.932	-0.069	-0.998
PT Stage IA Right	59	I	1	0.000	25.932	-0.187	-0.982
PT Stage IA Right	59	J	1	0.000	1.340	-0.187	-0.982
PT Stage IA Right	60	I	1	0.000	1.340	-0.008	-1.000
PT Stage IA Right	60	J	1	0.000	0.653	-0.008	-1.000
PT Stage IA Right	61	I	1	0.000	0.653	0.006	1.000
PT Stage IA Right	61	J	1	0.000	1.201	0.006	1.000
PT Stage IA Right	62	I	1	0.000	7.529	0.048	0.999
PT Stage IA Right	62	J	1	0.000	8.401	0.048	0.999
PT Stage IA Right	63	I	1	0.000	8.401	0.048	0.999
PT Stage IA Right	63	J	1	0.000	9.273	0.048	0.999
PT Stage IA Right	76	I	1	0.000	1.201	0.018	1.000
PT Stage IA Right	76	J	1	0.000	2.768	0.018	1.000
PT Stage IA Right	77	I	1	0.000	2.768	0.051	0.999
PT Stage IA Right	77	J	1	0.000	7.261	0.051	0.999

8) Continue steps 1 – 7 until all the tendon groups are defined.

6.5.9 Reinforcement

Mild steel reinforcement is input in the same manner as the ODOT Concrete Bridge Generator. Rows 1-3 are for positive flexure (Measured from the bottom) and rows 4-5 are for negative flexure (measured from the top of the girder). Rows can be repeated as necessary.

1) Input the appropriate mild reinforcement yield strength (ksi).

2) Input Youngs Modulus of Elasticity (ksi). 29000 ksi for mild reinforcement.

3) Insert Row button is used to add additional rows. For simple span analysis it is not necessary to input negative reinforcement. This button must be used to maintain the correct cell range formatting.

4) Delete Row button is used to remove unused rows. **Do not delete all of the rows**. One row should be kept so the cell range formatting is not lost.

5) Input the row number. Rows 1-3 are reserved for positive flexural reinforcement. These rows can be repeated as necessary.

6) Input the number of bars for the row being defined. Fractions of bars can be input.

7) Select the bar size from the drop down list. Manually entering a bar number without the "#" sign will generate an error message.

8) Input the vertical distance. If the distance varies along the span, it is acceptable to conservatively input the maximum vertical distance as a first approximation. Rows 1-3 are measured from the bottom and rows 4-5 are measure from the top of the girder to centroid of the reinforcement.

9) Left End Span number. This is the span number defined in this analysis, not necessarily the actual span number.

10) Left End Location. If the bar is embedded past the location where the span is defined, use 0.0in for the left end location and adjust the development length accordingly.

11) Input the development length as determined by AASHTO LRFD 5.10.8.2.1, adjusted as required due to embedment past the end of the span.

12) Bar Length. Do not code in a distance longer than the overall bridge length (Could happen do to defining spans at CL support and not accounting for overhang).

13) Input the right end development length as determined by AASHTO LRFD 5.10.8.2.1, adjusted as required due to embedment past the end of the span.

14) Right end location can be input manually or use a formula to calculate the location based on other input.

15) Input the Right end span number. This is the span location defined in this analysis, not necessarily the actual span number.

16) Provide comments as necessary for clarity.

Insert Row 3	Delete Row 4		Fy 1 40 ksi Es 2 29000 ksi								
Row	# Bars	Bar Size	Vertical Distance (in)	Left End Span	Left End Location (ft)	Left End Development Length (in)	Bar Length (ft)	Right End Development Length (in)	Right End Location (ft)	Right End Span	16 Comment
5 1	6 25.000	#6 7	8 2.620	9 1	10 0.00	11 2.00	12 122.00	13 2.00	14 122.00	15 1	Development Length = 12" but adjusted for 10" embedment past CL Bearing.
2	22.000	#6	9.375	1	1.50	12.00	22.27	12.00	23.77	1	Vertical Dist Varies. Assumed maximum distance for entire length.

6.5.10 Stirrups

Input stirrup information over the range that the analysis will be performed.

1) Select the Aggregate Size; if not provided, assume ¾ in.

2) Input the yield strength of the stirrups.

3) Use the Insert Stirrup button if additional rows are needed.

4) Use the Delete Stirrup button to remove rows that are not needed. Do not delete all of the rows. At least one row needs to remain to maintain the proper cell range formatting.

5) Input the beginning location (in) for the stirrup range. This distance is measured for the beginning of span 1 as defined in this analysis.

6) Input the stirrup spacing (in).

7) Input the stirrup range (in).

8) The End of the range can either be calculated or input manually. Use inches for units.

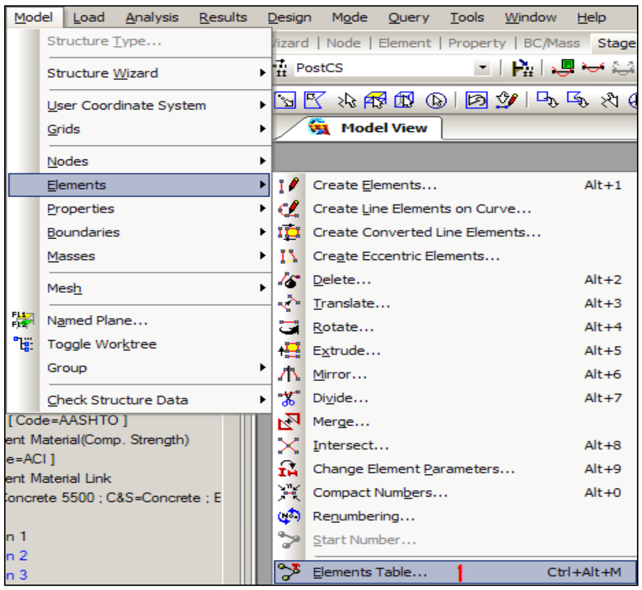
9) Input the total number of stirrup legs. (e.g. A cross-section with four stems and doubled legged stirrups is input as 8 legs).

10) Select the stirrup size of an individual leg.

Aggregate Size (ag)		1 0.75	in.	fy	2 40	ksi	3 Insert Stirrup		4 Delete Stirrup	
Begin	Spacing	Range	End	# Legs	Stirrup Size					
21	12	360	381	8	#5					
5 381	6 18	7 702	8 1083	9 8	10 #5					
1083	12	360	1443	8	#5					

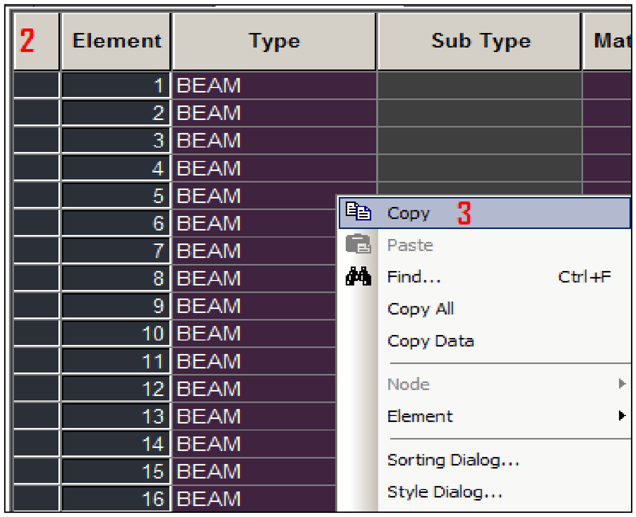
6.5.11 MIDAS Elements

1) MIDAS Elements are copied from Midas. Open PTBOX.mcb and in the top menu go to Node/Element=> Elements Table



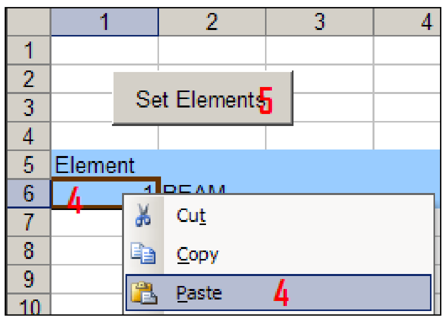
2) Highlight the entire table by left clicking the top left corner.

3) Right click in the highlighted cells and then left click on copy.



4) Go back into nnnnn_PTGirder.XLS and paste the copied values in the first row of the Element column.

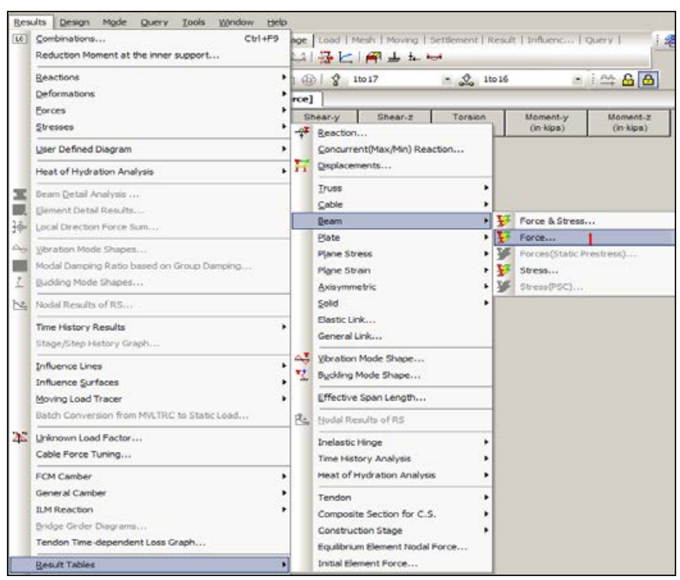
5) Click on the Set Elements button. This should highlight all of the values copied from Midas in Blue.



6.5.12 Max Shear and Moment

Maximum shear and moment values are copied from Midas results and pasted into nnnnn_PTGirder.XLS.

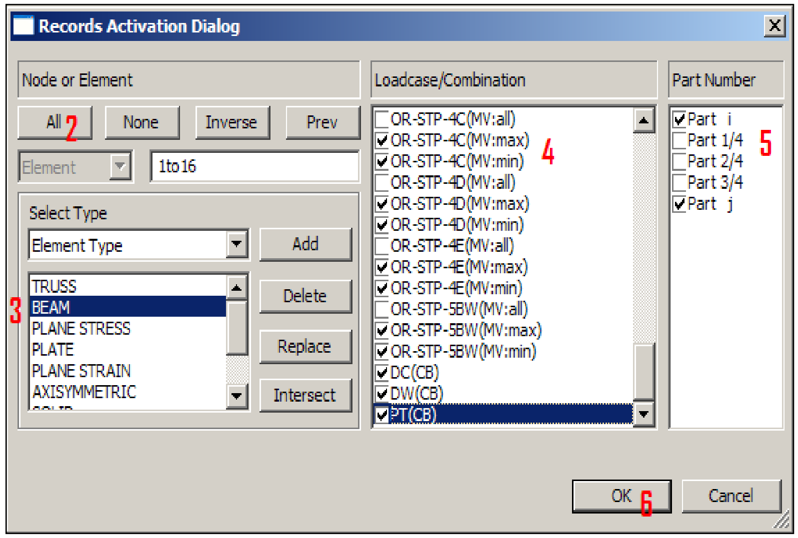
1) Open PTBOX.mcb. In the top menu go to Results => Result Tables => Beam => Force



2) Click the All button to select all Elements.

3) Select Beam for Type.

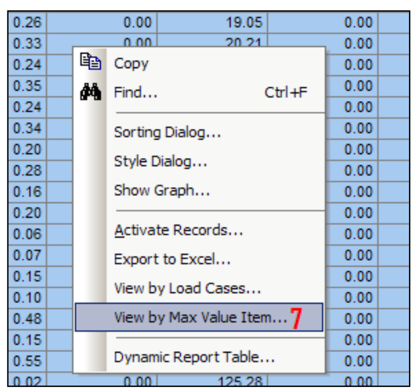
4) Select the maximum and minimum for each Load Case. In addition to the Design, Legal, and Permitted trucks, select DC(CB), DW(CB), and PT(CB) Note: the PT(CB) load case is different then the PT(ST) case. Three of the load cases were defined for use in load rating the crossbeam, and do not need to be selected here. The XB_HL93TRUCK, XB_HL93TANDEM, and XB_HL93LANE are not selected in this step. The PT load case is for secondary post tensioned effects and should therefore be zero for single simply supported spans. Do not select ServiceIII(CB) at this time, this load case will be used later within Section 6.5.17.



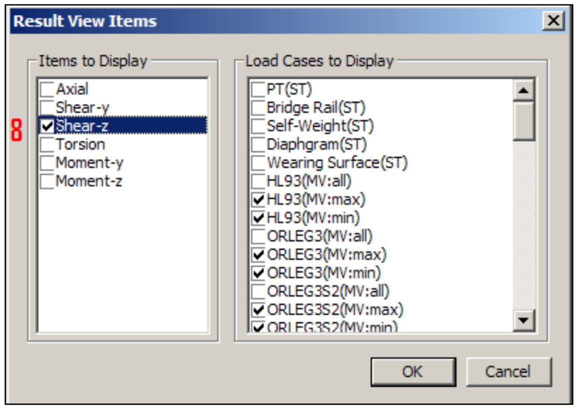
5) Select Part i and Part j only.

6) Click OK. Beam force results for the selected Load Cases are now displayed in a table.

7) Right click in the table and then left click on View by Max Value Item…



8) Select Shear-z for Items to Display. The Load Cases to Display should already be selected from the previous step. If not select the same load cases as shown in step 6. Click OK.



9) Depending on the type of Midas model, the columns in nnnnn_PTGirder.XLS and PTBOX.mcb may not match. Copy all of the data from Max Shear output and paste it into the appropriate column in nnnnn_PTGirder.XLS. It is ok for some columns to be blank. Stage, Step, Step order, and part order may not have values depending to the type of analysis.

10) Click on Set Shear Table to format the correct cell range.

Set Shear Table 10

	Elem	Load	Stage	Step	Step Order	Part	Part Order	Component	Axial (kips)	Shear-y (kips)	Shear-z (kips)	Torsion (in·kips)	Moment-y (in·kips)	Moment-z (in·kips)
6	1	HL93(max)				I[1]		Shear-z	0	0	0	0	0	0
7	1	HL93(max) 9				J[2]		Shear-z	0.02	0	0.53	0	765.19	0
8	2	HL93(max)				I[2]		Shear-z	0.03	0	0.53	0	765.19	0
9	2	HL93(max)				J[3]		Shear-z	0.18	0	2.4	0	3338.41	0
10	3	HL93(max)				I[3]		Shear-z	0.05	0	2.4	0	3338.41	0
11	3	HL93(max)				J[4]		Shear-z	0.18	0	5.95	0	7840.03	0
12	4	HL93(max)				I[4]		Shear-z	0.18	0	5.95	0	7840.03	0
13	4	HL93(max)				J[5]		Shear-z	0.39	0	9.76	0	12149.37	0
14	5	HL93(max)				I[5]		Shear-z	0.3	0	9.76	0	12149.37	0
15	5	HL93(max)				J[6]		Shear-z	0.53	0	13.52	0	15900.4	0
16	6	HL93(max)				I[6]		Shear-z	0.21	0	13.52	0	15900.4	0
17	6	HL93(max)				J[7]		Shear-z	0.35	0	19.05	0	20921.4	0
18	7	HL93(max)				I[7]		Shear-z	0.26	0	19.05	0	20921.4	0
19	7	HL93(max)				J[8]		Shear-z	0.33	0	20.21	0	21895.57	0

11) Return to the Beam Force Result table from Step 6. Repeat Steps 7-10 but select Moment-y in Step 8.

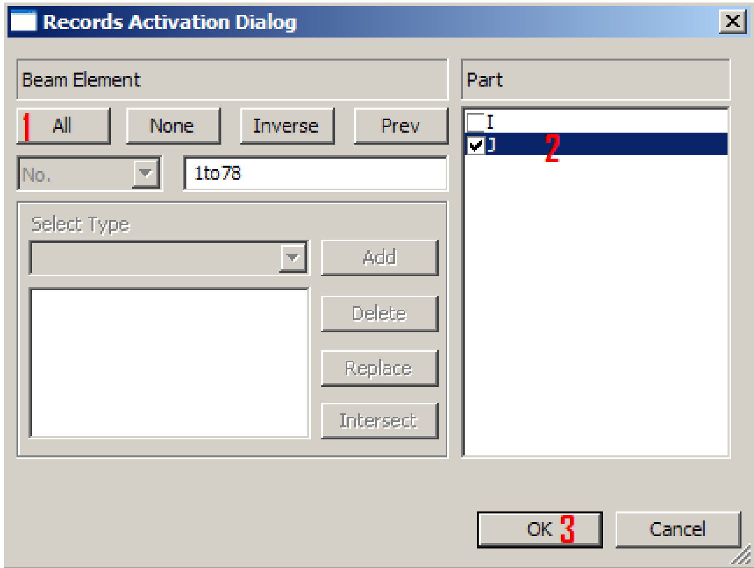
6.5.13 Section Properties

Section properties are calculated during the Midas analysis. These section properties are used during the nominal moment capacity calculations. Open the Midas model, and in the top menu go to Results => Results Tables => Construction Stage => Beam Section Properties at Last Stage… (Make sure units are in inches)

1) Select All

2) Select Part “J”

3) Click OK. This will generate a table showing the section properties at the J end of all elements at the last construction stage.



4) Select and copy the entire table. (Do not include headings)

5) In PTGirder.xls paste the copied table into the Section Properties Tab.

6) Click the Set Sect Prop Table button to define the section properties range.

Section Properties

Set Sect Prop Table 6

Elem	Part	Area (in²)	Ixx (in^4)	Iyy (in^4)	Izz (in^4)	Cyp (in)
5 1	J	10292.0	14019900.0	4417760.0	111655000.0	204.0
2	J	9848.4	13730950.3	4301946.3	108293144.8	204.0
3	J	9662.7	13554973.4	4249586.3	106886099.3	204.0
4	J	8870.3	12678341.2	3998973.2	100891766.8	204.0
5	J	8556.3	12280568.8	3886631.7	98518740.5	204.0
6	J	8079.1	11616271.7	3700649.5	94914997.5	204.0
7	J	7337.8	10406400.1	3372515.1	89324251.3	204.0
8	J	7337.8	10317100.0	3372510.0	89324000.0	204.0
9	J	7337.8	10317100.0	3372510.0	89324000.0	204.0

6.5.14 Factored Loads

1) Click on the Calculate button to activate the macro that will apply the appropriate factors to the Midas output.

Factored Loads	
Calculate 1	
LOCATION :	74.66
SHEAR SINGLE LANE DF	2.87
SHEAR MULTI-LANE DF	3.56
MOMENT SINGLE LANE DF	1.90
MOMENT MULTI-LANE DF	2.84

Axial live load distribution factors are based on engineering judgment. It is assumed that these structure types will distribute the axial forces efficiently. Therefore, the distribution factors are taken as the total number of lanes. No adjustment for the probability of multiple presences is considered. One lane loaded has a live load distribution factor of one, and the multiple lanes loaded distribution factor is calculated as the integer portion of the roadway width divided by twelve feet.

6.5.15 Moment Capacity

1) Use the Insert Moment button to populate the locations where moment capacity is calculated. Even if a flexural rating factor is not being calculated at a given analysis point, the moment capacity still needs to be determined.
2) Use the Delete Analysis Pts tool to delete excess locations
3) Once all analysis points are added, click on the Calculate Button. This will activate a Macro which will calculate the moment capacity for each location.

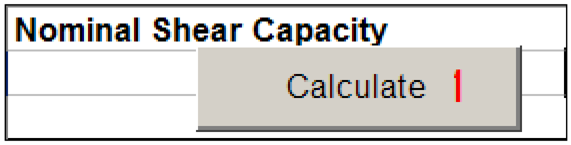
Insert Moment 1 | Delete Moment 2 | Calculate 3

Location, in.	x.xxxL	Section #	H	c (+M)	dp (+M)	Aps (+M)
74.664	2.051L	02	79.460	9.773	40.242	52.326
146.4	2.100L	03	75.240	9.666	42.050	52.326
219.6	2.150L	04	71.410	9.514	43.679	52.326
288.408	2.197L	05	68.260	9.058	45.012	52.326
366	2.250L	06	65.300	9.076	46.285	52.326
380.64	2.260L	07	64.810	9.079	46.498	52.326
439.2	2.300L	08	63.030	9.090	47.262	52.326
512.4	2.350L	09	61.270	9.100	48.023	52.326
585.6	2.400L	10	60.000	9.107	48.566	52.326
658.8	2.450L	11	59.250	9.111	48.891	52.326
732	2.500L	12	59.000	9.113	49.000	52.326

6.5.16 Shear Capacity

Shear Capacity is calculated using the modified compression field theory as specified in AASHTO LRFD 5.7.3.4.2, with the exception that equation 5.7.3.4.2-4 is not used to calculate the longitudinal tensile strain, ε_s. The AASHTO LRFD code makes the assumption that the majority of the tensile reinforcement is on the flexural tension side of the member, which is defined as half the member depth. This assumption will generally lead to ignoring the post-tensioning reinforcement near inflection points (0.25L away from interior supports), which results in high longitudinal tensile strains and low shear capacity. Section 5.7.3.4.2 of the AASHTO LRFD code allows for a more detailed calculation of the longitudinal tensile strain. Therefore, a strain compatibility approach is employed which considers all prestressing and post-tensioning reinforcement when calculating the longitudinal strain.

1) Click on the Calculate button to calculate the Nominal Shear Capacity



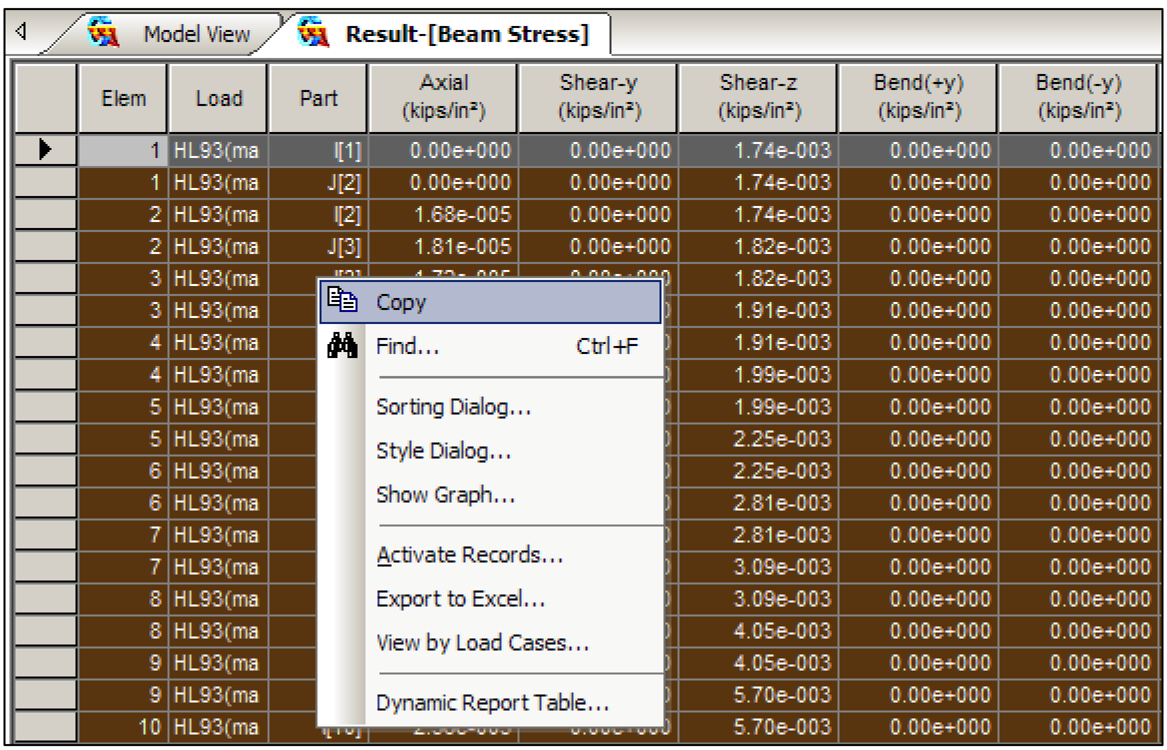
6.5.17 Service III

The stresses for the service III rating factor calculations are from the Midas construction stage analysis. Rating factors for service III are calculated at all flexural analysis locations. Begin by copying the beam stresses from the Midas model.

1) Open the Midas model, and in the top menu go to Results => Results Tables => Beam => Stress…

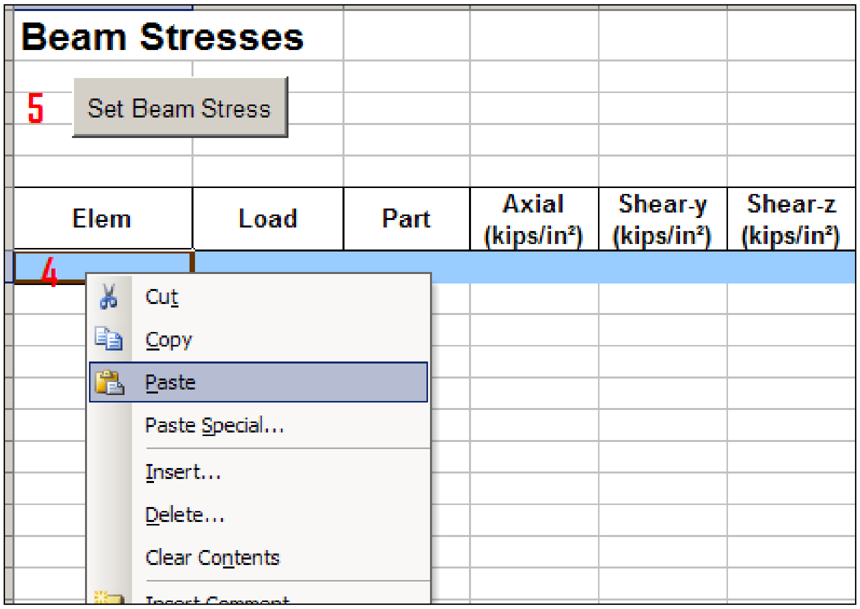
2) Select the HL93(MV:max) and ServiceIII(CB) loadcase/combination and press OK. A Beam Stress table will be opened. Make sure units are in Kip – Inches.

3) Select and Copy all of the data. (Don't include the headers)



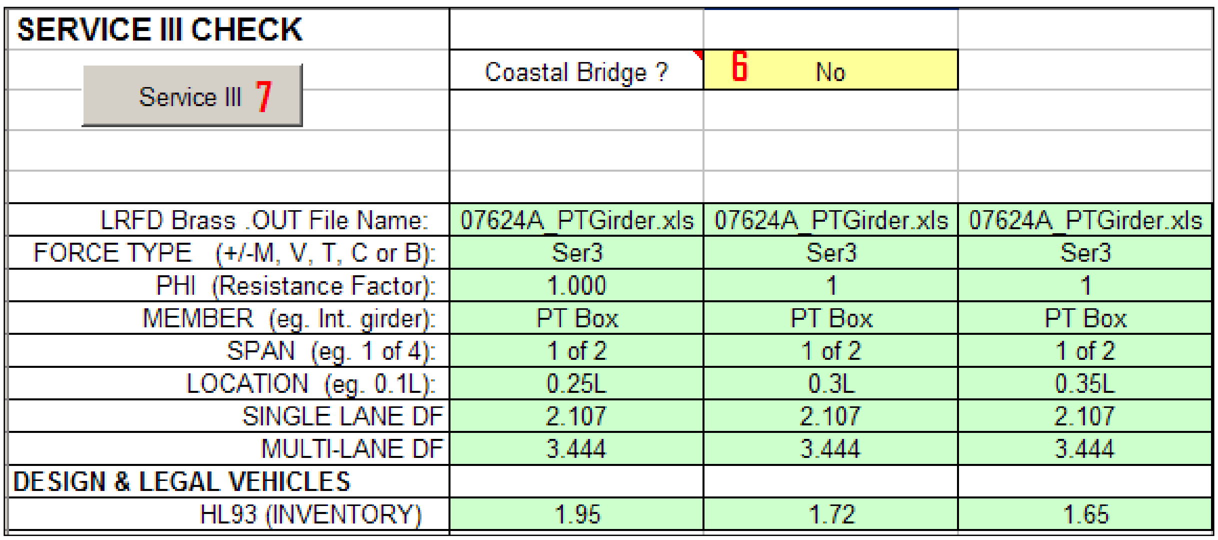
4) Paste the beam stresses under the appropriate heading of the BeamStress tab in PTGirder.xls.

5) Click on the Set beam Stress button. This will define the range for the beam stresses.



6) Select if the bridge is near a coastal region. The allowable stress is calculated as 0.19SQRT(f`c) for in-land bridges, and as 0.0948SQRT(f`c) for coastal bridges. Although, coastal bridge is specified the engineer should use the lower allowable stress when there is reason to believe that the bridge is exposed to highly corrosive environments.

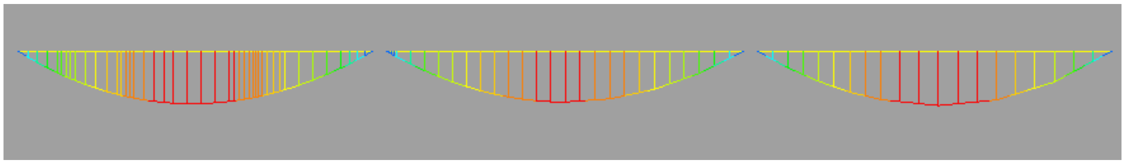
7) Now on the ServiceIII tab of PTGirder.xls, click on the Service III button. This will populate all of the service III rating factors. Rating factors less than or equal to 1.1 will automatically be copied into the RF tab when rating factors are calculated.



<u>Spliced Precast Spread Box Girder Simplification:</u>

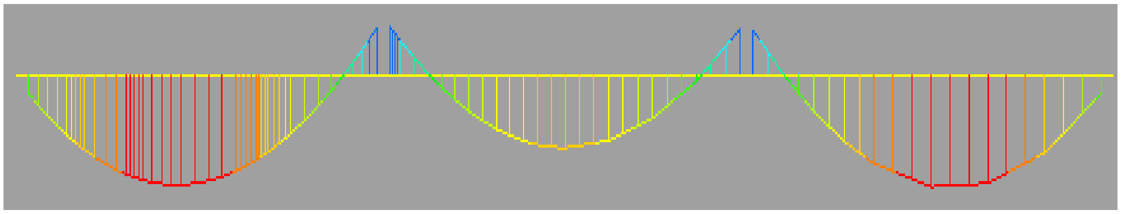
When precast spread box girder bridges are constructed in a manor similar to that shown below, it will be permitted to ignore the construction staging during the Midas analysis. Modeling the bridge in its final configuration without temporary supports or composite sections can significantly reduce the complexity of the model without significantly affecting the results. See below for an example of typical splice girder construction.

Step 1: Construct temporary supports and set precast tubs. The tendon prestress load and girder dead load is resisted by the non-composite tubs. See the beam moment diagram for dead load below:

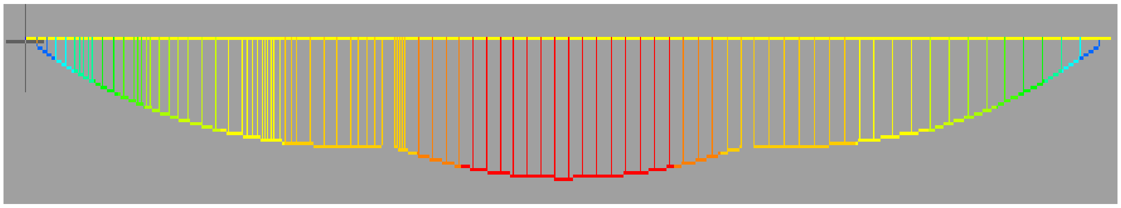


Step 2: Closure pours are made to make the tubs continuous. The structure now acts as a three span continuous for any additional loads.

Step 3: Concrete deck is poured. The additional moment due to the deck dead load is resisted by the non-composite section. This increase in midspan moment is not calculated as $wl^2/8$ because the spans are not simple. See the beam moment diagram for dead load below:



Step 4: Structure is post-tensioned and temporary supports are removed. Removing the temporary supports causes a change in the moment due to dead load, which is now resisted by the composite section. The axial force and moment due to the post-tensioning is also resisted by the composite section. See the beam moment diagram for dead load below:



This construction sequence can be accurately modeled in Midas using composite sections and construction staging. However, the level of effort to create this model is significantly higher then modeling a cast-in-place post tensioned structure. The cast-in-place model uses homogenous sections that are only modeled in the final configuration. This simplified model has been compared to the more elaborate model, and it has been found that the rating factors for service III are very similar. The results are similar because the loads imposed on the final composite structure are considerably larger than the loads resisted by the non-composite structure. Therefore, it is the final composite section and loads that dominate the rating factor calculations.

There are factors that impact the accuracy of the simplified model when analyzing a simple span precast spread box bridge. For example; as the ratio of precast span length and final span length becomes closer to one, the error of this analysis substantially increases. If the precast section length, that is at midspan of the final configuration, is greater than 0.6L of the final span length then perform a more refined model to investigate the stresses through the different construction stages.

6.5.18 Longitudinal Tension Check (LTC)

Calculations for the LTC are performed automatically. If a rating factor is less than 1.1 then it will be automatically inserted into the rating factor sheet. The nnnnn_PTGirder.XLS rating factor calculations automatically check for LTC and import the rating factor when applicable.

Detailed Discussion:

Section 5.7.3.5 of the AASHTO LRFD Bridge Design Specifications has the equation that is used by designers to ensure that there is sufficient longitudinal reinforcement to resist tension forces caused by both shear and flexure. If this equation is not satisfied, the designer simply adds the necessary reinforcement so that the equation is satisfied.

While satisfying the tension check is needed to have an accurate model when using Modified Compression Field Theory (MCFT) to calculate shear capacity, there is no guidance in the LRFR manual for the load rater to use when the tension check fails. This has been brought to the attention of a primary developer of the LRFR code, Bala Sivakumar, PE, who acknowledged that the current code does not fully address this issue. Christopher Higgins, PhD, PE, from Oregon State University, who lead the effort to test full scale beams has emphasized that the tension check is fundamental to the use of MCFT.

There are two areas that need to be addressed before the load rater can be sure that the tension check has failed. First, all of the reinforcement must be accounted for. Since the ODOT ratings originally counted the reinforcement only when it was fully developed, there may have been a significant amount of partially developed reinforcement available to resist tension forces. nnnnn_PTGirder.XLS does account for partially developed reinforcement.

There are differences between the design of new bridges and the rating of current bridges. Section 6.1.3 states that “Design may adopt a conservative reliability index and impose checks to ensure serviceability and durability without incurring a major cost impact. In rating, the added cost of overly conservative evaluation standards can be prohibitive as load restrictions, rehabilitation, and replacement become increasingly necessary.”

nnnnn_PTGirder.XLS calculates a rating factor for the longitudinal tension check using the worst case of the maximum tension forces developed due to maximum shear and concurrent moment, minimum shear and concurrent moment, maximum moment and concurrent shear, and minimum moment and concurrent shear.

The developers of the LRFR code acknowledged that while LRFD does incorporate state-of-the-art design, analysis methods, and loading, that almost all existing bridges were designed using the older AASHTO Standard Specifications for Highway Bridges. Section 6.1.5 states “Where the behavior of a member under traffic is not consistent with that predicted by the governing specifications, as evidenced by a lack of visible signs of distress or excessive deformation or cases where there is evidence of distress even though the specification does not predict such distress, deviation from the governing specifications based upon the known behavior of the member under traffic may be used and shall be fully documented”.

The 1950’s bridges were designed using Working Stress. Once the stresses of the concrete exceed its ability to resist tension, cracking occurs. This initial cracking takes place at a comparatively low level of loading. The bridge is designed to see “service loads” where the forces in the reinforcement are kept well below the yield point. The bridges that Oregon State University instrumented showed that the reinforcement was being operated well below the yield point. During full scale beam tests to failure, the reinforcement was yielding, but at much higher loads than in-service bridges experience, and with much greater distress.

Even though ODOT and nnnnn_PTGirder.XLS have found a way to perform the tension check for load rating, this is still an issue to be solved on a national scale. Based on the guidance from the MBE code, and the lack of distress noted in the vast majority of bridge inspections, Oregon bridges are not being operated anywhere near the level that would cause yielding of the reinforcement as indicated by the failure of the tension check. For those few bridges that do show excessive deterioration, the current LRFR code is sufficient that the known behavior of the member shall be used and be fully documented. Bridges with deterioration consistent with yielding of reinforcement would not be considered for “no work” regardless of the results of the tension check. Calculations for repairs should be done in accordance with the AASHTO LRFD code and therefore the longitudinal reinforcing should always pass the tension check after the repairs are complete.

6.5.19 Rating Factors (RF)

Click on the Rating Factor button to calculate rating factors. These rating factors are manually copied and pasted into the Rating Factor Summary sheet.

6.5.20 PTGirder.xls Submittals

Under the assumptions tab in nnnnn_PTGirder.xls there is a Print button that will activate a macro to print the desired tabs. Not all of the worksheets will be printed. Some page formatting has been automated, but the user should review the printed documents and perform additional formatting as necessary. Information from the following worksheets is to be included in the Calculation book; Assumptions, Resistance Factors, Spans, GeometryCalcs(OK to print as 11x17 with Z fold), LL_DF, Analysis Pts, Strand Properties, Reinforcement, Stirrups, Moment Capacity, Factored Loads, Shear Capacity, and Service 3. Rating factors are included in the summary sheet and will therefore not be printed here.

SECTION 7: LOAD RATING STRAIGHT STEEL I-GIRDER BRIDGES

In order to provide with a complete and concise manual for load rating steel bridges, it is necessary to understand the different classifications of steel bridges in the State of Oregon. These are grouped into seven categories of bridges, composed of unique attributes that separate them from each other in such a way, that they require different methods for the design and analysis of their structures. And they are:

1. Beam-structured steel plate I-girders (built-up or rolled sections)
2. Rigid frame-structured steel I-girder bridges
3. Steel box/tub girders
4. Truss bridges
5. Steel arch rib bridges
6. Suspension bridges
7. Horizontally curved steel plate girder and box/tub girder bridges

The first three types of bridges can be analyzed using the BRASS-GIRDER(LRFD) software only if their girders are horizontally straight. The last four types, on the other hand, cannot be load rated in BRASS because they require a refined method of analysis to determine the distribution of the loads instead of a simple beam-line analysis that BRASS is only capable of. A different program would be required to model and obtain the member forces such types of bridges, such as MIDAS, GTStrudl, or LUSAS. And then the member forces would have to be exported to Excel where the member capacities and rating factors would be computed to complete the load rating.

BRASS cannot model box and tub shapes directly, but instead converts them into I-shapes. Therefore, steel box/tub girders will not be covered within this section of the manual since we will have to address the differences in the LRFD design requirements for boxes and I-shapes.

Due to the complexity of the analysis that is required for the last four structure types, they will not be covered within this section of the manual.

Steel structures are load rated based on the Strength I & II and Service II limit states. According to the MBE code, the Fatigue limit state is optional. Therefore, ODOT has chosen to not perform fatigue analysis during the load rating of steel structures. Only when inspection reports and/or fracture rating of the bridge show deficient or unsatisfactory results, ODOT might decide to proceed with a Fatigue analysis and/or instrumentation of the structure.

7.0 Scoping of Structure

Create a scoping file (nnnnnn_scope.xls) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended affect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0 then, there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

7.1 Decide What Girders to Analyze

Due to the effects of all the various LRFD Distribution Factor provisions, it is difficult to predict which girder will control the load rating. Therefore it is usually necessary to do a separate preliminary file and BRASS input for the exterior girder, and do an exterior girder BRASS run. Then the BRASS output files can be compared to see which has the lower rating factors. In the Load Rating Summary Workbook file, importing the rating factors from both girders is required (be sure to do a "Refresh" after the second import) because it is not uncommon for different girders to control for different loads.

7.2 Preliminary Files for Girders (Mathcad)

For steel plate girder and rigid frame bridges the preliminary file name and extension (Mathcad) for interior girders is INTSTL.xmcd. The preliminary file name and extension for exterior girders is EXTSTL.xmcd. If there are more unique girders of each type, the file names should differentiate between them with some additional identifier (e.g. INTSTL1.xmcd or INTSTLA.xmcd).

7.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description ("Spans" field) from the Bridge Log is adequate for this purpose.

Note: the Mathcad regions at the top in the right margin (outside the printable area) are there for 2 purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

7.2.2 Resistance Factors

Document the decisions regarding all 3 Resistance Factors, with references to the appropriate MBE tables.

BRASS-GIRDER(LRFD) provides input for the MBE Condition Factor ϕ_c (MBE 6A.4.2.3) and System Factor ϕ_s (MBE 6A.4.2.4). However, the ODOT Load Rating Summary Sheet and the ODOT Crossbeam Load Rating Software always require and display the product of all the resistance factors as a single ϕ factor. Therefore, the product of all these resistance factors must always be obtained.

Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure:
$\Phi_f = \phi\ [\ \max\ (\phi_c\phi_{sf}\ ,\ 0.85)\ ]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 6.5.4.2.1)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Shear:
$\Phi_v = \phi\ [\ \max\ (\phi_c\phi_{sv}\ ,\ 0.85)\ ]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 6.5.4.2.1)
and ϕ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).

Generally Φ_f and Φ_v will be the same for redundant members such as girders and will be different for non-redundant members such as single-span and 2-span crossbeams.

7.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into BRASS. The Load Rating Summary Workbook **(LR.XLT)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and effective bridge length. Note that effective bridge length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which Live Load Factor Application is used, ADTT is specified as “one direction”. Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the Live Load Factor Application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the Live Load Factor Application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the “LRFR Strength I & II” table from the live load factor application, and in Mathcad use Edit / Paste Special. In the “Paste Special” dialog box choose the “Paste” button, highlight “Bitmap” in the “As” list, and click the “OK” button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to MBE 6A.4.4.3.

7.2.4 Material Properties

Enter the material properties for both the steel and concrete, and calculate elastic modulus E_c and modular ratio n. Sometimes, several different steel materials are used for the girder components, such as webs, stiffeners or shear connectors. In such cases, it is important to keep a record of where they are applied for future reference. Also, document assumptions made about the material properties if they are not given on the Bridge Plans.

7.2.5 Bridge Average Geometry

Calculate the physical edge-to-edge width of the concrete slab and the roadway width of the bridge. If the width of the slab or roadway changes over the length of the bridge, calculate the average roadway width per span. Enter the skew angle of the bridge. These values are entered in BRASS to calculate the Distribution Factors.

7.2.5.1 Span Layout Information

Depending on the type of bridge and characteristics of the girder profile, different commands will be required to describe the span layout. If the web depth remains constant or varies linearly along the span, use the SPAN-LINEAR (11-1.2) command. The following table describes a bridge with a constant web depth.

Span #	Span Length (ft.)	Web Depth Left (in.)	Web Depth Right (in.)
1	132.000	48.00	48.00
2	132.000	48.00	48.00

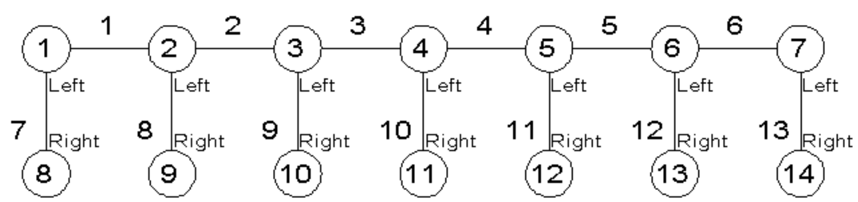
If the span being described has a web depth variation that is a uniform haunch at one or both ends, use the SPAN-UNIF-HAUNCH (11-1.3) command. If the span being described has a web depth variation that is a parabolic haunch, use the SPAN-PARA-HAUNCH (11-1.4) command. The following table describes the data needed to create spans with either uniform or parabolic haunches.

Span #	Span Length (ft.)	Uniform or Parabolic (U,P)	Haunch Type (R,B,L)	Web Depth Left (in.)	1st Haunch Location from Left (ft.)	Web Depth Range 2 (in.)	2nd Haunch Location from Left (ft.)	Web Depth Right End (in.)
1	60.00	U	B	20.00	25.000	30.00	100.000	45.00
2	60.000	P	R	45.00	50.000	60.00		

To define the schedule of the different cross-sections found on the bridge, use the SPAN-SECTION (11-2.1) command. The following table contains the data needed for the SPAN-SECTION command. Note that two span fractions are calculated. BRASS doesn't determine if the right or left section controls at a section change. To ensure the controlling section properties are used, two analysis points are analyzed at each section change; one inch to the left and one inch to the right.

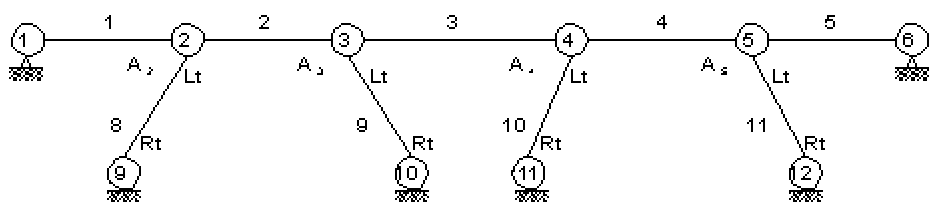
Span # :	1	Span Length :		132.00	
Cross-section # (left)	Distance from left. (ft.)	Distance from left. (in.)	Cross-section # (right)	Span Fraction (Left)	Span Fraction (Right)
1	13.000	156.00	1	0.098	0.099
2	14.000	168.00	2	0.105	0.107
3	23.000	276.00	3	0.174	0.175
4	24.000	288.00	4	0.181	0.182
5	85.000	1020.00	5	0.643	0.645
6	118.500	1422.00	6	0.897	0.898
7	119.000	1428.00	7	0.901	0.902
8	132.000	1584.00	8	0.999	1.001

If the BRASS model is for a framed-structured bridge, the rigidly connected support members (legs) will have to be included. Entering an "F" in the first parameter of the ANALYSIS (4-1.1) command will force BRASS to analyze the structure as a frame. In doing so, spans 1-6 are reserved for the horizontal members (main spans) and spans 7-13 are reserved for the vertical support members (legs). The following figure illustrates the span layout for a frame model.



For the legs, the left end of the span is always the upper node connected to the horizontal span. For a frame analysis, spans 7-8 are required to connect to the specific nodes as shown in the figure above. If the legs are not positioned vertical, use the SPAN-ANGLE (11-6.1) command to define the angle of the legs with respect to the top spans.

If the bridge does not contain a specific span or leg as shown in the above figure, do not include that span in the BRASS model. For example, a 5 span rigid frame without legs at the end supports would be modeled with spans 1-5 for the horizontal members and spans 8-11 for the leg members. The following figure represents this example.



7.2.6 Girder Properties

7.2.6.1 Section Properties of the Non-Composite Girders

The first step is to determine what type of cross-section the girder has. If the girder is a standard rolled shape, the STEEL-WIDE-FLANGE (7-2.1) command can be used. But if the girder is comprised of a built-up plate I-shape, or a non-standard rolled shape, the STEEL-PLATE-GIRDER (7-2.2) command should be used. The cross-section of a riveted girder made up of a web plate and double angle flanges should be defined using the STEEL-RIVETED (7-2.3) command.

Any top or bottom cover plates should be defined using the COVER-PLATE-TOP (7-2.4) or COVER-PLATE-BOTTOM (7-2.5) commands. Cover plates are an additional component of the steel cross-section. Therefore, the cross-section number of the cover plates must correspond to the cross-section number of a defined girder cross-section.

A steel girder with a concrete deck **shall only be considered to be a composite section if there are shear connectors present within the section**. Otherwise, the section will be considered to be a non-composite girder. The NCHRP 12-28(13)A report, *Bridge Rating Through Nondestructive Load Testing*, discusses unintended composite action of bridges. The report states that in a slab-on-girder bridge, the neutral axes of the partially composite beams usually maintain their positions during the early stages of increasing load. The neutral axis tends to move down at higher load levels, thus indicating the deterioration of the composite action.

The NCHRP report also states that it has been observed that when the top flange of a steel girder is partially embedded in the deck slab, the bond resistance is very effective in promoting the composite action. However, even this generally true statement is not free from exceptions. The report states that in bridges tested to failure, it was observed that despite their top flanges being partially embedded in the deck slab, some girders had practically no composite action even at low load levels. The report states that except for a field test, there is no practical way of ascertaining if bond exists between the deck slab and girders. Therefore, all girders will be considered non-composite unless there are shear connectors present within the section.

Article 6A.6.9.3 of the Manual for Bridge Evaluation states; “Compression flanges of sections where the deck is not connected to the steel section by shear connectors in positive flexure may be assumed to be adequately braced by the concrete deck, and the compression flange bracing requirements need not be checked where the top flange of the girder is fully in contact with the deck and no sign of cracking, rust, or separation along the steel-concrete interface is evident.” BRASS has a command to accommodate this feature, such as LAT-SUPPORT-SCHEDULE which defines the location of the lateral supports of the top flanges in a non-composite steel girder over a specified region.

Typically, steel girder geometry changes somewhat extensively throughout the span length of a bridge, and in numerous occasions one may find 15 or 20 distinctive section properties which makes the reading of the span layout quite time consuming (also, notice that most steel bridges make use of symmetry, hence, the cross-sections will be repeated about the symmetry plane in such cases) . Keep in mind that the duplicity of a section property has no effect on the BRASS code, so it is up to the user how to categorize the various cross sections of a span.

When creating a mapping of the section changes on the girder lines, the user will not have to take into account the field splices. Normally in continuous spans, splices are made at or near the points of dead load contra flexure. It is assumed that the structure is as strong or stronger at the splice than around it. Hence, field splices will not be taken into consideration when creating the section changes of the girder layout.

Once the different sections of the bridge have been determined, it is convenient to catalog them into a table for easy data access and to make a quick implementation in the BRASS code, as it is illustrated in the following figure.

Cross-section #	Top Flange W, (in.)	Top Flange t, (in.)	Top Flange Fy, (ksi)	Web t, (in.)	Web Fy, (ksi)	Bottom Flange W, (in.)	Bottom Flange t, (in.)	Bottom Flange Fy, (ksi)
1	12	1.25	50	0.375	50	16	1.25	50
2	12	1.25	50	0.375	50	16	1.625	50
3	12	1.625	50	0.375	50	16	1.625	50
4	12	1.625	50	0.375	50	16	2	50
5	12	2	50	0.375	50	16	2	50
6	16	1.625	50	0.375	50	16	1.625	50
7	16	1.625	50	0.375	50	20	2	50
8	20	2	50	0.375	50	20	2	50

The above figure shows the typical layout of a plate girder with 8 distinctive cross-sections, which catalogs the geometry and material properties of the top and bottom flanges and the web.

Use the COVER-PLATE-TOP (7-2.4) and the COVER-PLATE-BOTTOM (7-2.5) commands to model any cover plates that may exist on the top or bottom flanges of the steel girder at each cross-section. The cover plates are an additional component of the steel cross-section, and the weight of these plates will be automatically included in the girder dead load.

7.2.6.2 Section Properties of the Composite Girder

The composite section can be modeled using the COMPOSITE-SLAB (10-2.1) command, which will require calculating the effective width of the concrete slab. BRASS version 2.0.3 was updated to included the 2008 revision of the 4th Edition LRFD Code. With this update it was no longer necessary to calculate the effective flange width of composite slabs in the preliminary file. The second parameter of COMPOSITE-SLAB command may be left blank to allow BRASS to calculate the effective width.

Once the effective width of the slab has been computed, calculate the number of longitudinal reinforcing bars within the effective slab width and enter them within the appropriate parameter of the COMPOSITE-REBAR (10-2.1) command.

Use the COVER-PLATE-TOP (7-2.4) and the COVER-PLATE-BOTTOM (7-2.5) commands to model any cover plates that may exist on the top or bottom flanges of the steel girder at each cross-section. The cover plates are an additional component of the steel cross-section, and the weight of these plates will be automatically included in the girder dead load. BRASS will now accommodate a steel-concrete composite girder with a top steel cover plate. Therefore, the COVER-PLATE-TOP command can be used with the COMPOSITE-SLAB command.

Span #	Span Length (ft.)	Uniform or Parabolic (U,P)	Haunch Type (R,B,L)	Web Depth Left (in.)	1st Haunch Location from Left (ft.)	Web Depth Range 2 (in.)	2nd Haunch Location from Left (ft.)	Web Depth Right End (in.)
1	60.00	U	B	20.00	25.000	30.00	100.000	45.00
2	60.000	P	R	45.00	50.000	60.00		

7.2.6.3 Shear Connectors Layout

Shear connectors provide a layer of fixation against shear for the deck with the steel girders causing the girder to act as a composite section. Shear connectors are in the form of studs or C-channels.

BRASS has two commands that define the type of shear connectors, where the user specifies the dimensions and properties for the layout of each group of shear connectors. For example, for each group of shear studs, using the SHEAR-CONN-STUD (7-3.1) command the user will have to determine the number of studs transversely, the transverse spacing of the studs, the stud diameter, the stud height, stud tensile strength, and the pitch.

The program will use all of the detailed data for the shear connectors to perform specification checks to see if they pass the design code provisions. The user would then have to search through the BRASS output to determine if the specification checks passed or not, as they have no direct impact on the capacity of the girder. One could argue that if the shear connectors did not pass the design specifications, that at ultimate strength load levels they could fail and then make the girder non-composite. Since this type of failure is rare, and that the MBE code does not require that the shear connectors be checked, we will assume that the shear connectors are designed properly. Therefore, it is not necessary to spend the level of effort required to determine all of the details of the shear connectors.

What does affect the girder capacity is if the girder is considered to be composite or non-composite. The girder cross-sections within the ranges where shear connectors are present are considered composite, otherwise they are considered non-composite. The SHEAR-CONN-SCHEDULE (7-3.3) command is used to describe the composite regions across a span. The following table will be used to collect the data needed to describe the areas where the steel girder is composite:

Areas Where Shear Connectors Are Present			
Span Number	Start from left (in.)	Range (ft.)	Range (in.)
1	0.00	132.00	1584.00
2	0.00	132.00	1584.00

To avoid welding to the tension flange of the steel girders, it was a common practice to eliminate the shear connectors within the negative moment regions of the bridge. Therefore, one should verify on the plans if there are areas where the shear connectors were omitted. Without bridge plans that show that shear connectors are present or bridge instrumentation and load testing that proves otherwise, one should assume that the girders are non-composite.

7.2.6.4 Stiffeners Layout

A web stiffener is, usually an angle or plate, attached to the web of a beam or girder to distribute load, transfer shear, or to prevent buckling of the web to which it is attached. The types of stiffeners found on girders are:

1. Transverse Intermediate
2. Bearing
3. Longitudinal

There are two general types of transverse stiffeners; intermediate stiffeners that are located at points between the supports, and bearing stiffeners that are located at the supports of a span. Intermediate stiffeners are provided in order to prevent the web of the girder from buckling. AASHTO allows intermediate stiffeners to be connected on either one or both sides of the plate girder. For bearing stiffeners, AASHTO recommends that a pair of stiffeners be used (i.e., a stiffener plate on either side of the web).

A longitudinal stiffener, like transverse intermediate stiffeners, is welded to the web plate of a plate girder. The longitudinal stiffener, as its name implies, runs along the length of the stringer. Longitudinal stiffeners are typically provided on only one side of the web. In addition to allowing for an overall reduction in web thickness, a longitudinal stiffener also serves to increase the shear and bending strength of the girder and increase the lateral stiffness.

The user will create groupings for each type of stiffener, and create a table of their schedules on the Preliminary file. The tables will contain the required input parameters that are used in the related BRASS commands (i.e., the BRASS commands for the transverse stiffeners are STIF-TRANS-GROUP (7-8.1), STIF-TRANS-SCHEDULE (7-8.2)). Sometimes, it would be more convenient to model the stiffeners independently (for example by using the STIF-TRANSVERSE (7-4.1) command for transverse stiffeners), rather than using grouping and scheduling. The user should use whatever method is more convenient to them.

The following tables show the data that is required to model the intermediate transverse stiffeners of a bridge using the grouping and scheduling commands.

Types of different transverse stiffeners (STIF-TRAN-GROUP):

Group #	Width (in)	Thickness (in)	Type: (1,2 or 3)	Fy (ksi)
1	4.50	0.3125	1	36.0

Location of the stiffeners on each span (STIF-TRAN-SCHEDULE):

Span # :	1	Span Length (ft):	132.00
Stiff. Group	Spacing (in)	Start from left (in.)	Range (in.)
1	19.00	0.0	38
1	37.67	38.0	226
1	44.00	226.0	1320

Span # :	2	Span Length (ft):	132.00
Stiff. Group	Spacing (in)	Start from left (in.)	Range (in.)
1	44.00	0.0	1320
1	37.67	1320.0	226
1	19.00	1546.0	38

The following table shows the data that is required to model the bearing stiffeners of a particular bridge; which will use the STIF-BEARING (7-4.2) command.

Position of Interest	Width (in.)	Thickness (in.)	Clip (in.)	Number of Pairs	Pair Spacing (in.)	Welded/ Bolted	Yield Strength, (ksi)
100	7	0.750	0.75	1		W	50.0
210	7	0.750	0.75	1		W	50.0

BRASS will automatically create points of interest at each location where a bearing stiffener is being modeled. At these points of interest, BRASS will calculate a Rating Factor for bearing. These points of interest will usually be the first set of analysis points that are reported in the BRASS output.

We have concluded that the bearing stiffeners defined in BRASS have no affect to the shear capacity and the transverse stiffeners have no affect to the bearing capacity. Yet in reality the bearing stiffener does and should affect the shear capacity. Therefore, to get the girder to rate out properly, the transverse stiffeners and a bearing stiffener should both be defined at the same location (if there is a stiffener at the support location). Looking at the example from the BRASS help file for the STIF-TRAN-SCHEDULE (7-8.2) command, they show the transverse stiffeners starting and ending at bearing stiffener locations. This helps reinforce our conclusion that the transverse stiffeners should be defined at bearing stiffener locations.

Longitudinal stiffeners are typically located on the compression side of the girder, thus for continuous span bridges they may overlap near the moment inflection point locations. Due to BRASS not allowing different longitudinal stiffeners to overlap, it is recommended to use the moment inflection point locations or girder splice locations (which usually match the inflection point locations) to switch from one stiffener to the other when they overlap. However, there may be situations where this general guideline will not work and the load rater will have to use their engineering judgment to determine the best location to switch between the different longitudinal stiffeners that are overlapping.

The following tables show the data that is required to model the longitudinal stiffeners for a particular bridge; which will use the STIF-LONG-GROUP (7-8.5) and STIF-LONG-SCHEDULE (7-8.6) commands.

Types of different longitudinal stiffeners (STIF-LONG-GROUP):

Group #	Width (in)	Thickness (in)	Distance to Stiffiner (in)	Web Reference: Top (T), or Bottom (B)	Fy (ksi)
1	4.00	0.3750	14.07	T	36.3
2	4.00	0.3750	14.07	B	36.3
3	4.75	0.3750	14.07	B	36.3

Location of the longitudinal stiffeners on each span (STIF-LONG-SCHEDULE):

Span Number	Stiffener Group	Start Distance (in.)	Range (in.)
1	1	0.00	852.00
1	2	852.00	192.40
1	3	1044.40	167.60
2	3	0.00	159.00
2	2	159.00	201.00
2	1	360.00	936.00
2	2	1296.00	345.75
2	3	1641.75	194.25
3	3	0.00	194.08
3	2	194.08	225.92
3	1	420.00	1284.00
3	2	1704.00	165.92
3	3	1869.92	194.09
4	3	0.00	167.60
4	2	167.60	264.40
4	1	432.00	780.00

7.2.6.5 Cross-bracing of Steel Girders

The information of the cross-bracing of the bridge should be available on the construction plans, and be implemented on the Preliminary Mathcad file before being entered in the BRASS code.

Normally, the cross-bracing schedule for the girders can be easily cataloged into a table defining the location of the bracings (using the BRACING-SCHEDULE (7-8.7) command). See the following table as an example of how to define the cross-bracing.

Span #	Spacing (in.)	Start from left (in.)	Range (in.)
1	278.07	0.00	2224.38
2	283.46	0.00	2834.61
3	278.07	0.00	2224.38

In some cases, as discovered on Frame-structured bridges, BRASS doesn't read the cross-bracing schedule due to some inherent programming glitch. Instead, one will have to create the sections of the bridge that are not braced, using the UNBRACED-LENGTH (7-5.1) command. The UNBRACED-LENGTH command will also need to be used on bridges where there is no bracing at a support. (The BRACING-SCHEDULE command automatically places a brace at each support.)

Either way, it is of great importance that the user check the output file for possible warnings and errors regarding the bracing of the sections. BRASS or the Summary worksheet should notify the user that something might be off. In such cases, the user will be prompted to modify the commands for the cross-bracing.

7.2.7 Component Dead Loads (DC)

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the Preliminary (**.xmcd**) File as they will appear in the BRASS Input (**.**DAT) File. Only four LOAD-DEAD-DESCR commands may be coded in BRASS. Cross frame sand bottom lateral bracings shall be grouped in the first command. Deck and Buildup in the second command. Rails and curbs in the third command, lastly wearing surfaces for the forth. Stiffener dead load should be input as a distributed load using the LOAD-DEAD-UNIFORM command.

Use AASHTO LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c. For dead load calculations, use w_c+0.005 kcf to account for the reinforcement, in accordance with AASHTO LRFD Commentary C3.5.1.

Consider diaphragm/cross-bracing point loads to be part of component load DC. Include any diaphragms/end beams at the end of the girder over the support, as they will be utilized when applying the girder dead load reactions to crossbeams.

When a composite deck is to be defined in BRASS, the uniform dead load of the deck per girder will need to be computed and applied as part of the component load DC.

Special care needs to be given to the exterior girders, which may have different concrete deck loads than the interior girders.

As an addition, the user should consider the weight of the concrete buildup between the top of the steel girder flange to the bottom of the concrete slab. Linearly varying the buildup from the point of maximum camber to the point of minimum camber is typically acceptable. Although the flange thicknesses may vary along the span length it is not necessary to account for minor variations in the buildup. If in the engineer's judgment the buildup calculations need to be refined, follow the following procedure:

Since the top flange can vary in thickness, but the location of the top of the web usually remains constant, it is best to compute the buildup by referencing the location of the top of web. For that, one will have to analyze each cross-section change along the span. The best way to do this is to create a table in the Preliminary Mathcad file, where the top flange thickness of the stringer, deck thickness, and distance from the top of the deck to the top of the web can be specified. Then the buildup can be computed. This can be seen in the following table.

Section	Top Flange Thickness (in.)	Deck Thick. (in.)	Distance top deck to top web (in.)	Top-Flange Width (in)	Buildup (in)	Weight Buildup (klf)
1	0.81	10.04	13.39	22.00	2.54	0.058
2	0.81	10.04	13.39	22.00	2.54	0.058
3	0.81	10.04	13.39	22.00	2.54	0.058
4	0.81	10.04	13.39	22.00	2.54	0.058

Where standard rail drawings occur, wherever possible use the rail dead loads tabulated in Appendix H - ODOT Standard Rail Weights, found in file **RAILDL.XLS**. Provide detailed calculations for the dead load of any rail not found in this summary.

For all concrete decks, assume adequate lateral distribution of loads and distribute the sum of all rail, curb and sidewalk dead loads (stage 2 dead loads) equally among all girders.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16” diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to need to be included in the load rating.

For load rating, we want to consider a utility as a “non-structural attachment” and keep it listed under DC for dead loads. The main reason for this is if a load rater ever comes across a situation where they have to load rate a bridge where they are uncertain of the wearing surface thickness. In that situation they are required to use a DW gamma of 1.50. That way they would only be penalizing the load of the wearing surface, not the utilities, for the uncertainty.

7.2.8 Wearing Surface Dead Loads (DW)

Always separate Wearing Surface dead load (DW) from the component (DC) dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes, and (c) it facilitates input for the Crossbeam Load Rating Software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Show calculations for wearing surface dead load distributed equally to all the girders. Add 1” to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½” to the design thickness of PPC overlays to account for construction variations and uncertainty.

For all concrete decks, assume adequate lateral distribution of loads and distribute the sum of all wearing surface dead loads (stage 2 dead loads) equally among all girders.

7.2.9 Live Loads (LL)

Simply list the four classes of rating loads to be analyzed. (See articles 1.5.1.1 through 1.5.1.5).

Normally live load distribution factors are calculated in BRASS, but in the rare case where they must be calculated manually, the complete calculations should be provided with thorough documentation in this section of the preliminary file. Distribution factors will need to be calculated manually in the case of widened bridges or half-viaducts where the deck was not made continuous between the original and widening structures, or between the viaduct structure and the adjacent pavement. Where there is no barrier to the wheel load at the edge of deck, because of the assumed 20" wide wheel footprint, a full concentrated wheel load can be placed no closer than 10" from the edge of deck.

7.2.10 Analysis Sections

Determine the spans to be investigated. These should be any span that is unique and is not repeated due to symmetry or due to repetition of a span between joints.

Within each span, check for symmetry of sections and loads, and do not identify any analysis points that are structurally symmetrical with analysis points already defined. Defining analysis points that are structurally symmetrical has the potential effect of corrupting the Load Rating Summary Sheet. Because the "Refresh" module is looking for the lowest Rating Factors, defining a symmetrical point causes it to identify the most critical rating location twice, thus preventing it from identifying the second most critical analysis point. The second controlling point is useful information in evaluating potential repairs for the bridge.

In previous versions of BRASS (LRFD) the skew correction factor was applied to the first segment only. Because of this it was important to not code any nodes within the critical section. BRASS now applies the skew correction factor across the entire span. For shear the skew factor will be applied at the support and will decrease linearly to unity at midspan. With this update, section changes (node points) can now be defined within the critical section.

For each unique span in the preliminary file, list each analysis point type as a header, one by one. Under each header provide the calculations necessary to determine or document the location of each investigation point in that category. Thus there will be up to 7 separate calculation sections for each span. In any calculation section, if any particular point duplicates a previously calculated point or is within 1 ft of a previously calculated point, the new point may be omitted. In this case, explain the omission by indicating which previously identified point already covers the current one. To avoid potential errors in engineering judgment, it will be required that both moment and shear be checked at most analysis points. The analysis points are based on:

Bearing Stiffener Locations
Maximum Flexure Locations
Shear at Supports (when there are no bearing stiffeners)
Girder Geometry Change Points
Locations Where the Girder Material Properties Change
Transverse Stiffener Spacing Change Points
Locations of Localized Corrosion

- Bearing Stiffener Locations –
  Wherever a bearing stiffener is specified (at support locations) in the model, BRASS will automatically compute a Bearing Rating Factor. These bearing stiffener locations will be the first set of analysis points that BRASS computes. Along with the Rating Factors for Bearing, the Rating Factors for shear should also be checked at these locations. If the analysis point is at

support where the girder is continuous over the support, the Rating Factors for Negative Moment should also be checked. Otherwise, the Rating Factors for Moment can be ignored since there is zero moment at simple supports.

- Maximum Flexure Locations –
  The maximum flexure locations are the positive moments in each unique span and the negative moments over each unique continuous support. The Rating Factors for both shear and moment should be checked at these locations.

- Shear at Support (when there are no bearing stiffeners) –
  When there is no bearing stiffener detailed at a support location (typically when the girder is integral with supporting crossbeam), the Rating Factors for shear should be checked. If the analysis point is at support where the girder is continuous over the support, the Rating Factors for shear should be checked at the same time as the Rating Factors for negative moment are checked.

- Girder Geometry Change Points –
  The girder geometry change points are the span locations where there is any section loss/gain in its intrinsic properties. That is, any change in web or flange dimension. At these analysis locations, BRASS defaults to using the section properties of the left section.. To ensure that the smaller section properties are analyzed, two analysis points at each section change will be analyzed. If the controlling section is determined and documented in the preliminary file, it is acceptable to analyze only that point. Otherwise, code an analysis point at 1in left and 1in right of the girder geometry change point. For every girder geometry change location, the rating factors for both moment and shear shall be checked.

- Locations Where the Girder Material Properties Change –
  Girder Material Property Change points are the span locations where the type of steel (yield strength) changes in a flange or web. At these analysis locations, one should verify that BRASS is using the weaker section property for the calculation of the girder's capacity. If not, the user should adjust the analysis location two inches in the direction of the weaker section property to force BRASS to use the weaker values to calculate the girder's capacity. For every girder section property change location, the Rating factors for both moment and shear should be checked.

- Transverse Stiffener Spacing Change Points –
  For girders that have transverse stiffeners, if the spacing of the stiffeners change within a span, then the Rating Factors for shear should be checked at the location where the spacing changes. Verify that BRASS is using the larger stiffener spacing when computing the shear capacity at these locations. If BRASS is using the wrong value of the spacing, then the user should modify the analysis location by 2 inches in the direction of the larger stiffener spacing to ensure that BRASS uses the correct value. Unless the stiffener spacing change point coincides with that of another analysis point type, then the rating factors for moment can be ignored at these locations.

- Locations of Localized Corrosion –
  In the rare case of when the inspection report provides detailed information of areas with measured section loss, then those locations should be checked for both moment and shear where the girder is modeled with the remaining section of sound material.

  In most cases, the load rater will have to check the inspection report for the condition states of the elements that are being load rated to determine if the analysis needs to consider the effects of section loss. If the member being evaluated is an unpainted steel element, then any percentage of the member that falls under Condition State 4 will mean that the section loss is sufficient to warrant an analysis to ascertain the impact to the ultimate strength. Likewise, if the member being evaluated is a painted steel element, then any percentage of the member that falls under Condition State 5 will warrant an analysis to ascertain the impact of the section loss to the ultimate strength. For an element to fall within one of these Condition States, the section loss should be greater than 10% of the plate thickness in a critical load area. Unfortunately, when these lowest Condition States are assigned, the inspection report typically does not provide the locations and measurements of the loss or remaining section. Therefore, the load rater will be required to communicate with the person who inspected the bridge to determine the locations and measured section loss of the member so that a proper analysis of the remaining section can be performed. These locations should be checked for both moment and shear.

If the Condition State for the element does not fall under the lowest category as described above, then the locations of localized corrosion do not need to be accounted for in the analysis.

7.3 ODOT Concrete Bridge Generator (CBG)

The ODOT Concrete Bridge Generator is not currently configured to assist with the generation of steel girder BRASS code.

7.4 Analysis of Girders

BRASS-GIRDER will be used to load rate the steel girders. BRASS-GIRDER is different from the previous BRASS-GIRDER(LRFD) program in that it no longer uses text file inputs, but instead utilizes a Graphical User Interface (GUI) with data saved in xml file format. Instead of developing new procedures to populate the GUI of BRASS-GIRDER, this manual will continue to give instructions on how to create the text input file for BRASS-GIRDER(LRFD). Once the file is ready for analysis, the user will run the text input file through the BRASS-GIRDER translator that will create the xml input file used to populate the new GUI. From there the user will be able to run the analysis within BRASS-GIRDER.

BRASS has increased the live load definition limit from 20 to 100 per file. In the past, since ODOT requires more than 20 vehicles to be analyzed in every LRFR load rating, two nearly identical BRASS input files were used to cover all of the different vehicles. Since the transition from using BRASS-GIRDER(LRFD) to using BRASS-GIRDER for the analysis, ODOT has modified all of its tools to only use a single BRASS file with all of the rating vehicles included. Therefore, ODOT will no longer require the two separate nearly identical BRASS "_N" and "_T" files.

7.4.1 BRASS Input File Conventions

Use the heavily commented sample files provided as templates to be copied to a new bridge-number-specific folder (with a new filename if appropriate) and then modified for the actual load ratings. Separate input files will be required for each structure type in any bridge with a combination of structure types, and for interior and exterior girders due to the variability of live load distribution factors in LRFR.

- General conventions

  Use the full length of each command name except the COMMENT (3-1.1) command shall be only COM.

  Precede each command or logical group of similar commands (except for the COMMENT command) with a comment referring to the Article number in the BRASS-GIRDER(LRFD) Command Manual. For example, precede an ANALYSIS (4-1.1) command with a comment command thus:

```
COM 4-1.1
ANALYSIS F, 2, RAT, T, N
```

  Generally, leave in all comments found in the template (unless they become totally irrelevant to a particular input file), modifying them and adding more comments as required to fit the specific conditions of the rating. Use comments liberally with the expectation that someone unfamiliar with the BRASS-GIRDER(LRFD) program and unfamiliar with the bridge will need to read the data file and fully understand it.

Leave parameters blank (spaces between commas) where they are irrelevant to the specific structure. Although trailing commas can be omitted where all parameters to the right are to be blank, it is recommended to clarify your intentions by showing the blank parameters separated by commas. However, avoid leaving blank parameters such as material strengths where default values would apply. Enter the default values to make the dataset more meaningful to a future user.

Show in-line calculations (what the BRASS Manual calls in-line arithmetic) within a parameter (between commas) to convert units from feet to inches where the command parameter requires inches. Similarly, show in-line calculations to show how you determined the vertical dimensions to locate flexural bars. However, note that BRASS has the following limitations on in-line calculations: It cannot handle parentheses within in-line calculations, and it cannot correctly handle more than one multiplication or division operator in any one term, i.e. use no more than one multiplication or division between plus and minus signs. Other than these in-line calculations, the best place to put calculations is in the Preliminary File rather than in the BRASS comments.

Whenever a BRASS-GIRDER(LRFD) input file contains a series of occurrences of the same command, vertically aligning the same command parameters for clarity is encouraged. This practice simplifies the process of changing values of parameters when cloning an old BRASS file for use in a new bridge. Inserting spaces as required to accomplish this is harmless. However, do not use tab characters to accomplish this. They are misinterpreted by BRASS-(LRFD) as the next parameter, and are likely to cause fatal errors.

- Input File Sections

To make it easier for a subsequent user to find their way around the Input File, separate the BRASS input file into logical sections (large groups of commands) by using spaced comments as indicated in the sample files. Typically, an input file for a steel bridge will be divided into the following sections:

```
COM
COM  ***** Information *****
COM

COM
COM  ***** LRFR Load Rating, Strength Limit State *****
COM

COM
COM  ***** Material Properties *****
COM

COM
COM  ***** Section Geometry *****
COM

COM
COM  ***** Span Length and Section Information *****
COM

COM
COM  ***** Dead Loads *****
```

```
COM


COM
COM  ***** Live Loads *****
COM

COM
COM  ***** Distribution Factors *****
COM

COM
COM  ***** Resistance Factors *****
COM

COM
COM  ***** Analysis Sections *****
COM
```

With similar comment sets, subdivide the “Analysis Sections” section into subsections for each category of investigated section for each unique span. (See the sample input files).

- Specific conventions

At the beginning of every input file, use the BRIDGE-NAME (2-1.3) command to provide the 5- or 6-character NBI Bridge Number, followed by the Bridge Name. Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Next, use the ROUTE (2-1.5) command to provide the milepoint and signed Route Number where applicable (always required for State-owned bridges). Note the signed Route Number is not the same as the ODOT internal (maintenance) Highway Number.

Use 2 lines of the TITLE (2-1.6) command. Use the first TITLE line to provide the file name and describe which girder(s) this file applies to. Use the second TITLE line to provide the purpose or work grouping of the Load Rating.

Use the AGENCY (2-1.1) command to identify the Load Rating as being performed according to ODOT standards. This command should always be the same:

```
COM 2-1.1
AGENCY Oregon DOT
```

Use the ENGINEER (2-1.2) command to indicate the load rater.

Use the UNITS (2-1.4) command to force BRASS to always use US (English) units for both input and output. BRASS normally defaults to US units, but it has been found that when referenced dimensions get large, BRASS will automatically assume the large dimensions are in millimeters and will convert the units when it calculates the resistance of the member. Using the UNITS command will not allow BRASS to arbitrarily convert the units during an analysis.

```
COM 2-1.4
UNITS US
```

Use the ANALYSIS (4-1.1) command to provide BRASS with parameters needed to do a rating analysis. The “continuous beam model” is the preferred choice (“B” in parameter 1) as long as there is no need to include columns in the analysis and the bridge has ≤ 13 spans. Except for a rigid frame analysis (with columns) that would require the “frame type model” (“F” in parameter 1).

When there is only one stage of construction, the structure will be considered non-composite, and the slab will not be used in the section analysis computations. Even if shear connectors were defined, the section will still be considered non-composite. For composite structures, three or two stages of loading will need to be specified by placing a “3” or “2” in the second parameter of the ANALYSIS command. If there is sustained dead load on the composite section, three construction stages should be used. If there is no sustained dead load on the composite section, then only two construction stages should be used.

When three construction stages are used, first the bridge is modeled as non-composite and all stage one loads are applied. Next the bridge is modeled as composite steel and concrete with the modular ratio adjusted to allow for creep, usually 3n, and all stage two loads should be sustained loads such as curbing, railing, wearing surface and median where creep would be a factor. The structure is next modeled as a composite steel and concrete with the standard modular ratio (not adjusted for creep) and the live loads are applied.

When two construction stages are used, first the bridge is modeled as non-composite and all stage one loads are applied. Next the bridge is modeled as composite steel and concrete and all live loads are applied. Parameter 5 will be coded as N, for no, to prevent BRASS from interpolating mild steel reinforcement from the left to right cross sections. Partial development is not currently being considered for steel girder analysis. For typical composite steel girder bridges this command would normally be the same:

```
COM 4-1.1
ANALYSIS B, 3, RAT, S, N
```

By default, BRASS will limit the flexural capacity of a steel beam to the first yield on the section, even when the compression flange is fully braced. With a fully braced compression flange, the load rating analysis should be using the full plastic moment capacity (M_p). In order to force BRASS to consider the plastic moment capacity and AASHTO LRFD Appendix A6, the STEEL-SPECIFICATION (7-6.1) command needs to be used. BRASS still checks the bracing condition, so it will only use M_p if it is adequately braced.

```
COM 7-6.1
STEEL-SPECIFICATION Y, Y
```

Use the POINT-OF-INTEREST (4-1.2) command to set BRASS to generate user-defined points of interest from subsequent OUTPUT-INTERMEDIATE (5-2.1) commands.

```
COM 4-1.2
POINT-OF-INTEREST U
```

Leaving the 2nd parameter (Specification Check Output) blank causes BRASS to default to refrain from generating a large additional output (.OUT) file for each point of interest. This is information that is not normally needed. Use of “Y” for parameter 2 to turn on this additional output may be justified at sections where there is a need to account for partially developed bars. If these additional .OUT files are generated, they do not need to be printed in the Load Rating Report.

Use the OUTPUT (5-1.1) command to control the wide variety of output options. Unless there is a problem that requires more detailed intermediate output for investigation, this command should always the same:

```
COM 5-1.1
OUTPUT 4, Y, , , 1, , , , , , , , ,
```

Beginning with BRASS-GIRDER(LRFD) v.1.6.1, the effective top flange width is calculated and applied to the section properties automatically. Use the OUTPUT-EFF-WIDTH (5-7.3) command to direct BRASS to not output its effective flange width calculations. This command should always be the same:

```
COM 5-7.3
OUTPUT-EFF-WIDTH N
```

Use the OUTPUT-STIFFENERS (5-6.1) if information about the transverse, bearing and longitudinal stiffeners is required. In most cases, this command is turned off unless the user requires a check. Ignore stiffener checks per MBE 6.10.2.

```
COM 5-6.1
OUTPUT-STIFFENERS N, N, N
```

Code all BRASS models in the same direction as the girder elevation appears on the plans, i.e. from left to right on the plans, regardless of mile-point direction.

Next is to define the limit states for the load rating. BRASS uses the MAP-LIMIT-STATE (4-5.1) command to set each limit state and level to the load rating procedures. This mapping controls which limit states will be considered when determining the critical rating factors. Also, use the MAP-SPEC-CHECK (4-5.2) command to control the specification checks for each limit state. This is further explained on the next section: Brass Input Adjustments.

In the "Material Properties" section, use the STEEL-MATERIALS (7-1.1) command to provide the material properties for the steel used consistent with the notes on the bridge plans. Although there are exceptions, a typical steel structure from the 1950's or early 1960's would have the following properties command:

```
COM 7-1.1
STEEL-MATERIALS 0.490, 29000, 0.00065
```

To describe the material properties of the concrete slab in the composite section, use the COMPOSITE-MATERIAL (10-1.1) command.

```
COM 10-1.1
COMPOSITE-MATERIALS 4.0, 40, 8
```

In the "Material Properties" section, use the DECK-MATL-PROPERTIES (6-4.1) command to assure that the default wearing surface weight (parameter 3) is set to 0. Without this command, BRASS would generate its own DW load, which we want to define explicitly in the "dead loads" section.

```
COM This command is required to assure default deck Wearing
Surface Weight
COM (parameter 3) is 0 so BRASS does not generate a DW load on
its own
COM 6-4.1
DECK-MATL-PROPERTIES , , 0.0
```

The next step is to create the section geometry of the girder lines. First, the user will reproduce the assorted sections, based on geometry change, found throughout the span profiles on BRASS. There are two major commands to replicate the cross-sections based on the types of girders used: STEEL-WIDE-FLANGE (7-2.1) for wide-flange I-beams and

STEEL-PLATE-GIRDER (7-2.2) for plate girders.

For cross sections that have a composite deck, use the COMPOSITE-SLAB (10-2.1) command to model the composite deck slab. Use the COMPOSITE-REBAR (10-2.2) command to enter the reinforcing steel in the deck of a composite girder. The slab and rebar are an additional component of a cross section defined with the steel commands. Therefore, the cross section number of the slab and rebar must correspond to the cross section number of a defined steel cross section. This command is required only if the section is composite. The dead load of the concrete composite slab is NOT included in the girder dead load.

```
COM Section 1
COM 7-2.2, 10-2.1, 10-2.2
STEEL-PLATE-GIRDER 1, 22.047, 0.813, 70, 0.687, 50, 22.047, 0.750,
70
COMPOSITE-SLAB 1, 137.0, 10.039,
COMPOSITE-REBAR 1, B, 16, 5, 1.496+0.625+0.5*0.625
COMPOSITE-REBAR 1, T, 18, 5, 10.039-2.480-0.5*0.625
```

The shear connectors can be inserted via groups and scheduling. The groups are sorted based on the geometric properties of the studs or c-channels and the width of the top flange. The program will use all of the detailed data for the shear connectors to perform specification checks to see if they pass the design code provisions. The user would then have to search through the BRASS output to determine if the specification checks passed or not, as they have no direct impact on the capacity of the girder. Since the LRFR code does not require that the shear connectors be checked, we will assume that the shear connectors are designed properly. Therefore, it is not necessary to spend the level of effort required to determine all of the details of the shear connectors.

What does affect the girder capacity is if the girder is considered to be composite or non-composite. The use of the COMPOSITE-SLAB command does **NOT** make BRASS consider the section of the girder to be composite. The girder cross-sections within the ranges where shear connectors are present are considered composite, otherwise they are considered non-composite. The SHEAR-CONN-SCHEDULE (7-3.3) command is used to describe the composite regions across a span.

```
COM Composite areas where shear connectors are present.
COM 7-3.3
SHEAR-CONN-SCHEDULE 1, C, , 0.00, 2224.380
SHEAR-CONN-SCHEDULE 2, C, , 0.00, 2834.616
```

There are three types of stiffeners that can be found on the girders: Transverse, Bearing and Longitudinal. For transverse stiffeners, it is more convenient to group them by geometric properties using the STIF-TRAN-GROUP (7-8.1) command, And then to schedule their location by using the STIF-TRAN-SCHEDULE (7-8.2) command. Longitudinal stiffeners are modeled similarly by using the STIF-LONG-GROUP (7-8.5) and the STIF-LONG-SCHEDULE (7-8.6) commands. For bearing stiffeners, it might be more convenient to code them independently by using STIF-BEARING (7-4.2) command. This command can be used repeatedly.

```
COM 7-8.1
COM Groups of transverse stiffeners with similar geometry
STIF-TRAN-GROUP 1, 10.236, 0.75, 1, , 50

COM 7-8.2
COM Placement of transverse stiffener groups, for all spans
STIF-TRAN-SCHEDULE 1, 1, 278.05,
STIF-TRAN-SCHEDULE 2, 1, 283.464,
```

Another important aspect that needs to be taken into account is the cross-bracing components of the spans. This can be done in BRASS using the BRACING-SCHEDULE (7-8.7) command. But sometimes BRASS doesn't process this code correctly, as in the cases of frame-structured bridges, and verification of bracing should be made by checking on the output files for the effective span length, L_b. In such cases, the UNBRACED-LENGTH (7-5.1) command should be employed.

```
COM 7-8.7
BRACING-SCHEDULE 1, 278.05, ,
BRACING-SCHEDULE 2, 283.46, ,
BRACING-SCHEDULE 3, 278.05, ,
```

In the "Span Lengths and Section Information" section, define each span beginning with the appropriate command from Chapter 11 of the *BRASS-GIRDER(LRFD) Command Manual* that describes the profile (depth variation) along the span. Follow this command with a sequence of SPAN-SECTION (11-2.1) commands to assign the previously defined cross sections to cumulative ranges from the left end of the span. The following is an example of the series of commands to define one span:

```
COM --- Span 1, 185.367' Geometry
COM 11-1.2, 11-2.1
SPAN-LINEAR 1, 2224.40, 83.86, 83.86
SPAN-SECTION 1, 1,  448.82, 1
SPAN-SECTION 1, 2,  598.42, 2
SPAN-SECTION 1, 3, 1196.85, 3
SPAN-SECTION 1, 4, 1342.52, 4
SPAN-SECTION 1, 5, 1531.50, 5
SPAN-SECTION 1, 6, 1775.60, 6
SPAN-SECTION 1, 7, 1858.27, 7
SPAN-SECTION 1, 8, 2015.75, 8
SPAN-SECTION 1, 9, 2224.40, 9
```

Use the SPAN-HINGE (11-5.1) command if necessary to define the location of any hinge within the span. This command is optional. The SPAN-HINGE command will only work in areas of the span that are non-composite. BRASS will remove any hinges within a composite section of the span when it makes the girder composite in Stage 2 of loading. Thus, to model a hinge with a composite deck, a portion of the span from two inches on each side of the hinge should be modeled as non-composite.

Also, one may make use of symmetry when recreating the spans of a bridge. This is done simply by using the SPAN-COPY (11-3.1) command.

Use the SUPPORT-FIXITY (11-4.1) command to define the boundary conditions of each span, for example:

```
COM ***** Support Fixities *****
COM --- R = Restrained, F = Free

COM 11-4.1
SUPPORT-FIXITY 1, R, R, F
SUPPORT-FIXITY 2, F, R, F
SUPPORT-FIXITY 3, F, R, F
SUPPORT-FIXITY 4, F, R, F
```

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the BRASS Input (.DAT) file as they were calculated in the

Preliminary (**.X**MCD) File. Diaphragms point loads should be considered part of component load DC. Due to coding limitations, stiffeners will be input as distributed loads assigned to the structures self weight.

COM Stiffener Distributed Load
COM 12-1.3
LOAD-DEAD-UNIFORM SW, 1, 0.00*12, 0.50, 460*12.0, 0.50

Because BRASS calculates girder dead load (self-weight) using the input section dimensions and treats it separately from other dead loads, group the rest of the structure dead loads under the first occurrence of the of the LOAD-DEAD-DESCR (12-1.2) command, using the description (parameter 4) “Other Structure dead loads”. Include loads for diaphragms directly over the supports. While they will not have any effect on the girder analysis, they will be used to calculate dead load reactions used in the crossbeam analysis. Precede each group of LOAD-DEAD-UNIFORM and LOAD-DEAD-POINT commands with an additional identifying comment describing the load. An example of this first (DC) group is given below:

```
COM X-Frames and Btm Lateral Bracing
COM 12-1.2
LOAD-DEAD-DESCR 1, DC, 1, Other Structure Dead Loads
COM  Diaphragms 0.974 k at bents 1 & 4
COM  Diaphragms 0.931 k at bents 2 & 3
COM  Diaphragms 0.460 k at intermediate spacings:
COM     (8 equal spaces at 7.063m for Span 1 & 3)
COM     (10 equal spaces at 7.200m for Span 2)

COM 12-1.4
LOAD-DEAD-POINT 1, 1, , 0.974,    0.00
LOAD-DEAD-POINT 1, 1, , 0.460,  278.05
LOAD-DEAD-POINT 1, 1, , 0.460,  556.10
LOAD-DEAD-POINT 1, 1, , 0.460,  834.15
LOAD-DEAD-POINT 1, 1, , 0.460, 1112.20
LOAD-DEAD-POINT 1, 1, , 0.460, 1390.25
LOAD-DEAD-POINT 1, 1, , 0.460, 1668.30
LOAD-DEAD-POINT 1, 1, , 0.460, 1946.35
LOAD-DEAD-POINT 1, 1, , 0.931, 2224.40
```

Group the next component dead loads (DC) for buildup between the top of girder and the bottom of deck, and for the composite deck weight per girder to be included in the first loading stage. An example of this 2nd (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 2, DC, 1, Deck and Buildup

COM  Buildup per girder, w = 0.075 k/ft at ends & 0.0 k/ft at
midspan
COM 12-1.3
LOAD-DEAD-UNIFORM 2, 1,  0.000*12, 0.075/12, 55.275*12, 0.000/12
LOAD-DEAD-UNIFORM 2, 1, 55.275*12, 0.000/12, 110.55*12, 0.075/12
LOAD-DEAD-UNIFORM 2, 2,  0.000*12, 0.075/12, 55.275*12, 0.000/12
LOAD-DEAD-UNIFORM 2, 2, 55.275*12, 0.000/12, 110.55*12, 0.075/12
LOAD-DEAD-UNIFORM 2, 3,  0.000*12, 0.075/12, 55.275*12, 0.000/12
LOAD-DEAD-UNIFORM 2, 3, 55.275*12, 0.000/12, 110.55*12, 0.075/12
LOAD-DEAD-UNIFORM 2, 4,  0.000*12, 0.075/12, 55.275*12, 0.000/12
LOAD-DEAD-UNIFORM 2, 4, 55.275*12, 0.000/12, 110.55*12, 0.075/12

COM  Deck weight per girder, w = 0.300 k/ft
```

```
COM 12-1.3
LOAD-DEAD-UNIFORM 2, 1, 0.0*12, 0.300/12, 110.55*12, 0.300/12
LOAD-DEAD-UNIFORM 2, 2, 0.0*12, 0.300/12, 110.55*12, 0.300/12
LOAD-DEAD-UNIFORM 2, 3, 0.0*12, 0.300/12, 110.55*12, 0.300/12
LOAD-DEAD-UNIFORM 2, 4, 0.0*12, 0.300/12, 110.55*12, 0.300/12
```

Group the remaining component dead loads (DC) (excluding wearing surface dead loads) in the next LOAD-DEAD-DESCR (12-1.2) command using the description (parameter 4) “Superimposed dead loads”. This group should include LOAD-DEAD_UNIFORM (12-1.3) commands as needed to account for all superimposed (Stage-2) dead loads except the wearing surface. Precede each group of LOAD-DEAD-UNIFORM commands with an additional identifying comment describing the load. An example of this 3rd (DC) group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 3, DC, 2, Rails, Curbs and Fences

COM Rail Dead Load per girder = 0.099 k/ft
COM 12-1.3
LOAD-DEAD-UNIFORM 3, 1, 0.0*12, 0.099/12, 59.0*12, 0.099/12
LOAD-DEAD-UNIFORM 3, 2, 0.0*12, 0.099/12, 65.0*12, 0.099/12
LOAD-DEAD-UNIFORM 3, 3, 0.0*12, 0.099/12, 59.0*12, 0.099/12
```

To facilitate future re-ratings with different wearing surface loads, always apply the wearing surface dead load under its own LOAD-DEAD-DESCR (12-1.2) command separate from all other uniform superimposed dead loads. Precede each LOAD-DEAD-UNIFORM command with an additional identifying comment describing the load. An example of this 4th (DW) dead load group is given below:

```
COM 12-1.2
LOAD-DEAD-DESCR 4, DW, 2, Wearing Surface Dead Load
COM  2.5" + 1" ACWS
COM  Distributed equally to all 4 girders, w = 0.284 k/ft

COM 12-1.3
LOAD-DEAD-UNIFORM 4, 1, 0.0*12, 0.284/12, 140.0*12, 0.284/12
```

Use the BRASS Input Adjustment #1 thru #3 explained below to code the live load and dead load requirements.

To assure that BRASS calculates girder Distribution Factors (number of lanes) according to LRFD 4.6.2.2, the following BRASS-GIRDER(LRFD) commands are required:

- Specify number of girders & spacing with the DECK-GEOMETRY (6-1.1) command. Note that the left and right cantilevers (parameters 4 and 5) are the distances from centerline of exterior girder to edge of *deck*.
- If girder spacings are variable, use the DECK-VSPACING (6-1.2) to define the spacings that differ from the uniform spacing specified in the DECK-GEOMETRY command.
- Specify the edges of the roadway (which limits the extreme transverse wheel positions) by using the DECK-TRAVEL-WAY (6-3.3) command.
- Specify the girder of interest (interior or exterior, using girder numbers starting at the left edge) using the DIST-CONTROL-GIRDER (4-3.1) command.
- Specify type of cross-section, number of lanes and skew using the DIST-CONTROL-LL (4-3.3) command.

If distribution factors in AASHTO LRFD 4.6.2.2 are calculated manually, note that we interpret the definition of d_e in AASHTO LRFD 4.3 as “distance from the *centerline* of the exterior web to the interior edge of curb or traffic barrier.”

Use the BRASS Input Adjustment #4 explained below to code the Resistance Factors.

Use the BRASS Input Adjustment #5 explained below to obtain detailed output regarding the Distribution Factors.

To obtain Rating Factors for flexure and shear points of interest, use OUTPUT-INTERMEDIATE (5-2.1) command grouped in the same order and groupings as the analysis points were calculated in the Preliminary File. Within each span, make sure that none of the analysis points duplicate each other (have identical span fractions), and delete one of each duplicate pair. Precede each OUTPUT-INTERMEDIATE command with a comment (usually text taken from the Preliminary File) explaining which type of force is being investigated (Positive Moment, Negative Moment or Shear), the span number and nearby bent number, and the span fraction.

7.4.2 BRASS Input Adjustments

Because BRASS-GIRDER(LRFD) was designed primarily for LRFD analyses and was created before the *MBE Manual* was published, a number of standard BRASS Input Adjustments are necessary. Fortunately the program is flexible enough to allow an accurate solution with work-arounds (BRASS Input Adjustments). These adjustments will normally apply to every Input File, at least until BRASS-GIRDER(LRFD) is changed. See the sample input files for proper placement of these adjustments.

- BRASS-GIRDER(LRFD) Input Adjustment Type 1:

Use the MAP-LIMIT-STATE (4-5.1) and MAP-SPEC-CHECK (4-5.2) commands to force BRASS to check flexure and shear for only the limit states required by LRFR. These limit states are different than the BRASS-GIRDER(LRFD) defaults. Thus it is necessary to force BRASS to check flexure and shear for Strength-I for Design and Legal loads, and for Strength-II for Permit Loads: For Design Loads (Strength-I Limit State), these commands also force BRASS to use $\gamma_L = 1.75$ (Inventory Level). (The Operating Level $\gamma_L = 1.35$ Rating Factors will automatically be derived from the Inventory Rating Factors in the Load Rating Summary Workbook by multiplying by the γ_L ratio). Use the following sequence of commands, which will normally not change:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 1:
COM  For LRFR specify the Strength and Service
COM  Limit States and Ignore Fatigue Limit States
COM  Design Loads - STRENGTH I, SERVICE II
COM  Legal Loads - STRENGTH I, SERVICE II
COM  Permit Loads - STRENGTH II, SERVICE II
COM  (refer to 4-5.1, Fig.  1) and
COM  specify shear checks for all load types

COM 4-5.1, 4-5.2
MAP-LIMIT-STATE ST, 1, I, Y, N
MAP-LIMIT-STATE ST, 2, N, N, Y
MAP-LIMIT-STATE SE, 2, I, Y, Y

MAP-SPEC-CHECK ST, 1, D, SHR, Y
MAP-SPEC-CHECK ST, 1, L, SHR, Y
MAP-SPEC-CHECK ST, 2, P, SHR, Y
MAP-SPEC-CHECK SE, 2, D, FSF, Y
```

```
MAP-SPEC-CHECK SE, 2, L, FSF, Y
MAP-SPEC-CHECK SE, 2, P, FSF, Y
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 2:

  Use the FACTORS-LOAD-DL command (13-1.2) to force BRASS to use the MBE dead load factors, which are different than the AASHTO LRFD factors used by default. MBE Table 6A.4.2.2-1 requires constant dead load factors γ_{DC} and γ_{DW}, and the footnote allows γ_{DW} to be 1.25 when wearing surface thickness is field-measured, which is normally the case. Therefore, these commands are always required. Since the command only covers one limit state level at a time, use one for Strength-I, one for Strength-II, and one for Service-II:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,
COM  and a constant 1.0 to dead loads for Service II

COM 13-1.2
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL SE, 2, 1.00, 1.00, 1.00, 1.00
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 3:

  Using the BRASS-GIRDER(LRFD) LOAD-LIVE-CONTROL (12-4.1) command to apply the default Design and Legal Load sets would have 3 undesirable consequences:
  (a) BRASS would apply the Fatigue Design Load that is not needed for Steel structures, generating unwanted output
  (b) BRASS would default to listing the Design Load outputs *after* all the other loads, potentially causing confusion in transferring loads to the ODOT Load Rating Summary Workbook
  (c) BRASS would apply the AASHTO 3S2 Legal Load which is lighter than the Oregon Legal 3S2 load.

  Therefore, use the LOAD-LIVE-DEFINITION (12-4.3) commands to define each Design and Legal Load separately, and use the LOAD-LIVE-CONTROL (12-4.1) command to define only parameters 1 (direction control, “B” for traffic in both directions) and parameter 7 (wheel advancement denominator, normally 100), as follows:

```
COM BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 3:
COM All live loads will be entered individually
COM Design Loads entered as live load definitions 1 to 4 (N.DAT
file)
COM Legal Loads entered as live load definitions 1 to 5 (T.DAT
file)
COM SHV Loads entered as live load definitions 6 to 9 (T.DAT file)
COM Permit Loads entered as live load definitions 10 to 19 (T.DAT
file)
COM 12-4.1
LOAD-LIVE-CONTROL B, , , , , , 100
```

  In structures with short spans, especially short cantilevers, BRASS may “crash” because the span is divided into live load advancement increments that are too small. If this occurs and you have a small span, try decreasing parameter 7 to the largest number for which BRASS will work, often 50 or sometimes even less.

Further, because MBE Table 6A.4.2.2.1 requires a different live load factor γ_L for each truck, ADTT and truck weight combination, and BRASS-GIRDER(LRFD) does not provide for a separate live load factor for each truck, more BRASS Input Adjustments are required to define truck specific live load factors.

For Strength Limit States, use the optional FACTORS-LOAD-LL command (13-1.3) such that the universal “gamma LL (Design)” (parameter 3), “gamma LL (Legal)” (parameter 4) and “gamma LL (Permit)” (parameter 5) are all forced to 1.0. Since this command only covers one limit state level at a time, 2 commands are always required (one for Strength-I, and one for Strength-II)

For Service Limit States, use the option FACTORS-LOAD-LL command (13-1.3) such that the universal “gamma LL (Design)” (parameter 3) is forced to the values shown in MBE T6A.4.2.2-1 For service II this would be 1.30 for Design and Legal Loads

```
COM  Use the FACTORS-LOAD-LL command to force
COM  universal gamma-LL to 1.0 for Strength Limit Stages
COM  and 1.30 for Service II

COM 13-1.3
FACTORS-LOAD-LL ST, 1,  1.0, 1.0, 1.0
FACTORS-LOAD-LL ST, 2,  1.0, 1.0, 1.0
FACTORS-LOAD-LL SE, 2,  1.3, 1.3, 1.0
```

With the universal live load factors set to 1.0, truck specific live load factors can be defined using the BRASS command 13-1.6, FACTORS-LOAD-LL-LS. Previous version of BRASS (LRFD) did not accommodate individual truck live load factors. Thus, a work around was developed where the live load factors were input as scale factors. With BRASS v 2.0.3 the FACTORS-LOAD-LL-LS command has been added to resolve this limitation. Live load factors shall be input using this new command. Parameter 6 of command 12-4.3, scale factor, will be reserve for its original purpose. With this update the LR summary sheet will no longer modify the rating factors reported in the BRASS output file.

In the FACTORS-LOAD-LL-LS (13-1.6) commands for each load, enter the specific live load Factor γ_L (from **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable). This command can be copied and pasted from the BRASS tab of LL_Factors_State.XLS.

Thus the complete live load definition command set for input files is as follows:

```
COM  Define each Design and Legal live load separately and
COM  apply the truck specific live load factor (instead
COM  of defining them in the LOAD-LIVE-CONTROL command)
COM  There are 3 reasons...
COM  (a) to prevent BRASS from applying the Fatigue Design Load
COM      that is not needed for RCDG structures
COM  (b) to force BRASS to list the Design Loads outputs in the
COM      same order as ODOT's Load Rating Summary Workbook
COM  (c) to allow use of the Oregon 3S2 Legal Load rather than
COM      the AASHTO 3S2 Design Load

COM Do NOT code the truck specific live load factor in
COM Parameter 6.

COM 12-4.3
LOAD-LIVE-DEFINITION  1, HL-93-TRUCK , DTK, D, ,
LOAD-LIVE-DEFINITION  2, HL-93-TANDEM, DTM, D, ,
```

```
LOAD-LIVE-DEFINITION  3, HL-93-TRKTRA, TKT, D, ,
LOAD-LIVE-DEFINITION  4, HL-93-LANE  , DLN, D, ,

LOAD-LIVE-DEFINITION  5, OR-LEG3     , TRK, L, ,
LOAD-LIVE-DEFINITION  6, ORLEG3S2    , TRK, L, ,
LOAD-LIVE-DEFINITION  7, ORLEG3-3    , TRK, L, ,
LOAD-LIVE-DEFINITION  8, ORLEG3-3    , LGT, L, ,
LOAD-LIVE-DEFINITION  9, LEGAL-LANE  , LLN, L, ,

LOAD-LIVE-DEFINITION 10, OR-SU4      , TRK, L, ,
LOAD-LIVE-DEFINITION 11, OR-SU5      , TRK, L, ,
LOAD-LIVE-DEFINITION 12, OR-SU6      , TRK, L, ,
LOAD-LIVE-DEFINITION 13, OR-SU7      , TRK, L, ,

LOAD-LIVE-DEFINITION 14, EV2         , TRK, L, , , ONE
LOAD-LIVE-DEFINITION 15, EV3         , TRK, L, , , ONE

LOAD-LIVE-DEFINITION 16, OR-CTP-2A   , TRK, P, ,
LOAD-LIVE-DEFINITION 17, OR-CTP-2B   , TRK, P, ,
LOAD-LIVE-DEFINITION 18, OR-CTP-3    , TRK, P, ,

LOAD-LIVE-DEFINITION 19, OR-STP-3    , TRK, P, ,
LOAD-LIVE-DEFINITION 20, OR-STP-4A   , TRK, P, ,
LOAD-LIVE-DEFINITION 21, OR-STP-4B   , TRK, P, ,
LOAD-LIVE-DEFINITION 22, OR-STP-4C   , TRK, P, ,
LOAD-LIVE-DEFINITION 23, OR-STP-4D   , TRK, P, ,
LOAD-LIVE-DEFINITION 24, OR-STP-4E   , TRK, P, ,
LOAD-LIVE-DEFINITION 25, OR-STP-5BW  , TRK, P, ,


COM  Use for spans > 200 ft only...
COM LOAD-LIVE-DEFINITION 24, ORLEG3-3     , LTK, L, ,

COM Truck Specific Live Load Factors


COM 13-1.6
FACTORS-LOAD-LL-LS 1, ST, 1, 1.75
FACTORS-LOAD-LL-LS 2, ST, 1, 1.75
FACTORS-LOAD-LL-LS 3, ST, 1, 1.75
FACTORS-LOAD-LL-LS 4, ST, 1, 1.75

FACTORS-LOAD-LL-LS 5, ST, 1, 1.30
FACTORS-LOAD-LL-LS 6, ST, 1, 1.30
FACTORS-LOAD-LL-LS 7, ST, 1, 1.30
FACTORS-LOAD-LL-LS 8, ST, 1, 1.30
FACTORS-LOAD-LL-LS 9, ST, 1, 1.30

FACTORS-LOAD-LL-LS 10, ST, 1, 1.30
FACTORS-LOAD-LL-LS 11, ST, 1, 1.30
FACTORS-LOAD-LL-LS 12, ST, 1, 1.30
FACTORS-LOAD-LL-LS 13, ST, 1, 1.30

FACTORS-LOAD-LL-LS 14, ST, 1, 1.30
FACTORS-LOAD-LL-LS 15, ST, 1, 1.30

FACTORS-LOAD-LL-LS 16, ST, 2, 1.25
```

```
FACTORS-LOAD-LL-LS 17, ST, 2, 1.25
FACTORS-LOAD-LL-LS 18, ST, 2, 1.30

FACTORS-LOAD-LL-LS 19, ST, 2, 1.10
FACTORS-LOAD-LL-LS 20, ST, 2, 1.25
FACTORS-LOAD-LL-LS 21, ST, 2, 1.00
FACTORS-LOAD-LL-LS 22, ST, 2, 1.00
FACTORS-LOAD-LL-LS 23, ST, 2, 1.00
FACTORS-LOAD-LL-LS 24, ST, 2, 1.00
FACTORS-LOAD-LL-LS 25, ST, 2, 1.00

COM Use for spans > 200 ft only...
COM Replace parameter 3 with the legal live load value.
COM FACTORS-LOAD-LL-LS 24, ST, 1.30
```

The Oregon Legal Load designations listed in this example are applicable to BRASS-GIRDER(LRFD) Version 2.0.0 and later. BRASS-GIRDER(LRFD) runs for versions prior to v2.0.0 used the legal load designations OLEG3, OLEG3S2 & OLEG3-3.

Special note: For one-lane (escorted) special permit reviews and true single-lane bridges (roadway width < 20 ft), it is necessary to enter “ONE” for parameter 7 in the LOAD-LIVE-DEFINITION (12-4.3) command. It is not clear in the BRASS Command Manual, but this parameter is needed to force BRASS to apply only a single-lane loading with the appropriate single-lane Distribution Factors.

Note that in cases where we find bridges with a span longer than 200 ft, we must include a new LOAD-LIVE-DEFINITION which consist of 75% of the Oregon type3-3 legal truck and legal live load lane. For this load combination, BRASS will automatically scale the truck load to the 75% value, thus there is no additional scaling required by the user. In such cases, we would undo the “COM” prefix of this command:

```
COM  Use for spans > 200 ft only...
COM  Replace parameter 6 (scale factor) with
COM  0.75 times the appropriate gamma-L for Legal Loads
COM LOAD-LIVE-DEFINITION 20, ORLEG3-3, LTK, L, ,
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 4:

Use FACTORS-RESIST-MOD (13-2.4) command, entering FL to designate for flexure in parameter 2 and the System Factor for Flexure in parameter 3. For shear, repeat the command entering SH to designate for shear in parameter 2 and the System Factor for shear in parameter 3. Repeat the command one more time for bearing, entering BG to designate for bearing in parameter 2 and the System Factor for bearing in parameter 3.Use FACTORS-RESIST-COND (13-2.5) command, entering the condition factor in parameter 2. Thus the complete phi factor command set is as follows:

```
COM BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 4:
COM  Use the FACTORS-RESIST-MOD command to modify phi-s
COM  Use the FACTORS-RESIST-COND command to modify phi-c
COM  BRASS automatically calculates base phi for flexure,
COM  flexure/tension (RC), shear, and bearing

COM 13-2.4
FACTORS-RESIST-MOD ST, FL, 1.0
FACTORS-RESIST-MOD ST, SH, 1.0
FACTORS-RESIST-MOD ST, BG, 1.0
```

```
COM 13-2.5
FACTORS-RESIST-COND ST, 0.95
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 5:

  To facilitate crossbeam calculations and to clarify what BRASS is doing regarding live load distribution factors, always include the following lines in the BRASS input file at the end of the “Distribution Factors” section:

```
COM 5-5.2
COM  Request output of LL Distribution Factor computations
OUTPUT-DIST-LL Y, Y
```

7.4.2.1 Modifications on Preliminary Files & BRASS Codes based on Bridge Type

There are several alterations or adjustments that will need to be done depending on the type of steel bridge used. This manual is written using an I-plate girder bridge as the generic model for analysis of steel bridges. The basic set up for the other types of steel bridges remains the same, but the user must accommodate numerous modifications on the preliminary files and BRASS codes to implement a frame-structure steel bridge from the generic I-plate girder bridge, for instance.

7.4.2.1.1 Modification 1: Frame-Structure Steel Bridge

Frame-structure steel bridges are easy to distinguish because they exhibit the substructure as part of the superstructure. For that reason, the supports, also called “legs”, need to be taken into consideration as part of the span-layout. Hence, the user must make several modifications to be able to model a frame-structure bridge.

- Use the ANALYSIS (4-1.1) command to provide BRASS with parameters needed to represent a rigid frame analysis (with columns) that would require the “frame type model” (“F” in parameter 1)

```
COM 4-1.1
ANALYSIS F, 2, RAT, T
```

- Use the SPAN-UNIF-HAUNCH (11-1.3) command to provide BRASS with parameters needed to represent the proper layout of a span with haunch at one or both ends. Also, depending whether the haunch variation is uniform, linear or parabolic, the command will vary (i.e. for parabolic haunches, SPAN-PARA-HAUNCH command). The following is an example of a haunch that varies uniformly

```
COM --- Span 1, 49' Geometry
COM 11-1.3, 11-2.1
SPAN-UNIF-HAUNCH 1, 588, R, 33, 318, 50
SPAN-SECTION 1, 1, 318.00, 1
SPAN-SECTION 1, 1, 480.00, 2
SPAN-SECTION 1, 3, 588.00, 4
```

  When recreating the span layout of the bridge, the user needs to implement the supports as part of the structure. Hence, the supports are considered as spans in BRASS (see ANALYSIS command 4-1.1 for detailing).

- Use the SPAN-ANGLE (11-6.1) command to provide BRASS with the angles of the supports.

```
COM 11-6.1
COM Enter angle of the legs with respect to the top spans
SPAN-ANGLE , 60, 120, 60, 120
```

- Because frame legs are an integral part of the superstructure, flexure and shear points of interest must be analyzed for each leg. The point of interest will usually be at the top of the leg where it meets the bottom of the longitudinal girder.

7.4.2.1.2 Modification 2: Steel Box/Tub Girder Bridge

BRASS cannot accurately load rate steel box or tub girder bridges. This bridge type will be added as a separate chapter once the load rating methodology has been tested and finalized by ODOT.

7.4.2.1.3 Modification 3: Truss Bridge and Suspension Span Bridge

This type of bridge cannot be simulated on BRASS using the current or previous software versions. For that reason, ODOT decided to start a new methodology on how to load rate these bridges using MIDAS/civil software package. Nonetheless, MIDAS cannot handle load rating via LRFR. It is used as a finite element analysis tool to obtain the dead load and live load forces and reactions, which are then exported to Excel for load rating analysis.

7.4.2.1.4 Modification 4: Moveable Bridge

Most (if not all) moveable bridges will fall under the load rating methodology for truss bridges.

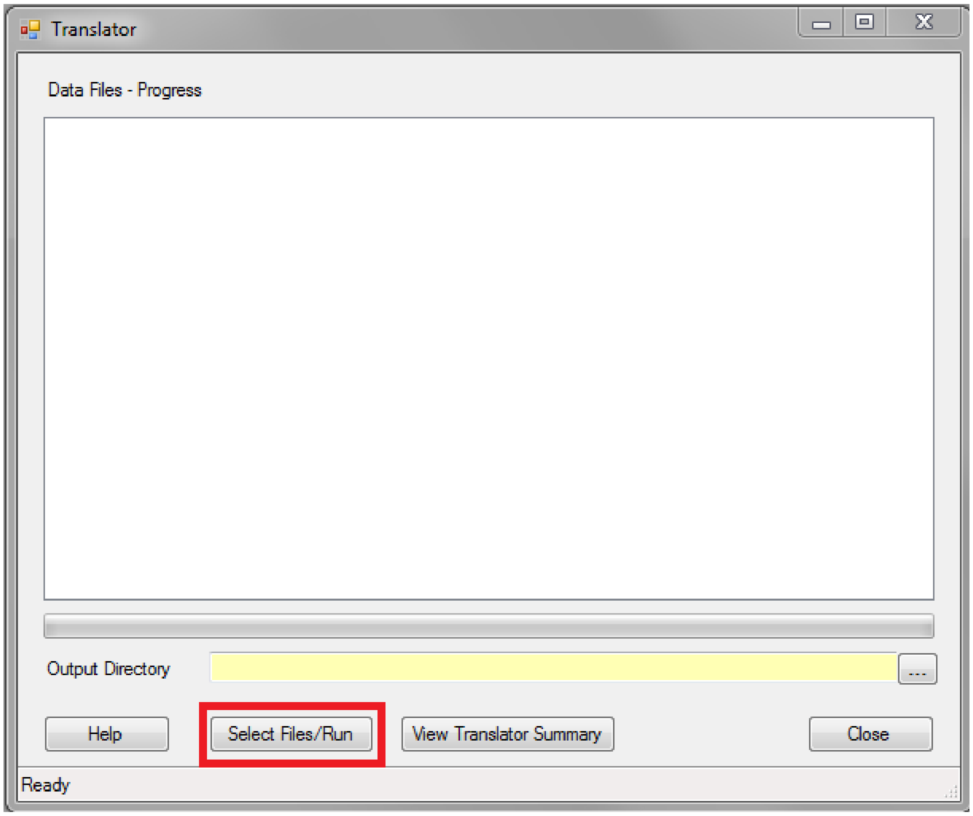
7.4.3 Running BRASS

Open the BRASS-GIRDER GUI interface. Because it is more efficient to use BRASS-GIRDER(LRFD) Input Files generated from previous ones, the GUI interface will not be used to generate input files.

The BRASS-GIRDER(LRFD) input file must first be translated into a BRASS-GIRDER xml file that will then populate the GUI interface in BRASS-GIRDER. The steps for translating and running the input files in BRASS-GIRDER is as follows:

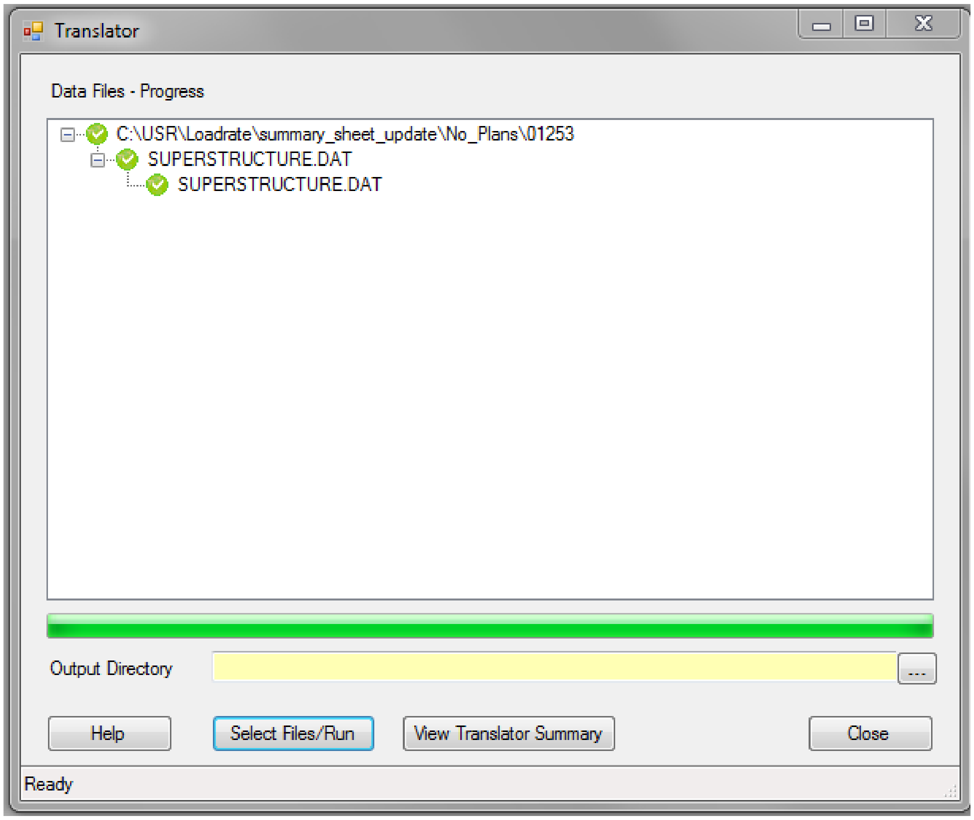
1. Start the BRASS-GIRDER program. From the “File” menu, hover your mouse pointer over “Translate (DAT to XML)”. Select the option for “BRASS-GIRDER(LRFD)”.

2. The Translator window will then open on your screen. Click on the button that says “Select File/Run”, as shown in the red outlined box in the following figure.



3. In the next window that appears, navigate to the location where the BRASS-GIRDER(LRFD) input file that you wish to run is stored, and select that file. Click on the "Open" button at the bottom right of this window.

4. The Translator window will then open back up and the selected file will run through the translation. If there are any errors detected during the translation, a red "X" will be displayed next to the file name in the window and an error file will be generated. Refer to the error file to decipher what is causing the error during translation. Once corrected, follow these steps again to translate the file. If successful, a green check will appear next to the file name as shown in the following figure:



5. Click the “Close” button at the bottom right of the Translator window. Within BRASS-GIRDER, select “Open” under the File menu. Select the BRASS XML file that was just created from the Translator program. Click on the “Open” button at the bottom right of this window.

6. BRASS-GIRDER will then load the model into the GUI. Under the “Execute” menu, select “Analysis Engine” to run the analysis. Or you can simply click on the green traffic light icon on the toolbar.

7. Verify that the output directory is the same as where the input files are located, and then click the “OK” button. A black DOS window will appear showing program progress. Depending on your system speed and memory and the complexity of the structure, the execution process may take a few seconds or several minutes. Upon completion of the analysis, a text output file will be generated within the same directory. You can now use a text editor to open and view the BRASS output.

When making changes or corrections to BRASS files, ODOT prefers that all changes be made within the BRASS-GIRDER(LRFD) input file so that it becomes the master document for the BRASS model. Reviewing this text input file will be quicker and more efficient than trying to navigate the GUI to verify that the bridge is being modelled correctly. Thus, any time the text input file is modified, the above steps will have to be repeated to translate the text input file into a BRASS XML file before the analysis is re-ran in BRASS-GIRDER.

7.4.4 BRASS Errors

If an error file is generated (same prefix, **.**ERR extension), open this file with your text editor and try to interpret what BRASS is telling you. The vast majority of error messages will point you to a straightforward typographical error or omission in your input. At the beginning of your experience with BRASS, do not expect a successful execution until one or more typographical errors have been

corrected.

When executing BRASS-GIRDER, if you get an error message regarding zeros in the stiffness matrix, look at the ANALYSIS (4-1.1) command, parameter 1, and check to see if you are running a Frame type model on a structure with more than 6 spans. In such cases the Beam type model (the recommended default) is required (with a maximum of 13 spans).

When executing BRASS-GIRDER, you may get an error message stating, "*The effective web width (b_v) cannot be zero. This causes a divide-by-zero error in the compression field computations.*" This most likely means that you have selected points that are too close to another defined point of interest within your BRASS input file. A general rule is not to have points closer than six inches from one another. Verify in your input file that you have correctly entered the web width parameter while defining your BRASS sections. Also check in the "Span Length and Section Information" portion of the input file to see that the ranges of the elements are not too close to each other.

A rare error can sometimes occur in executing BRASS-GIRDER where the processing of the analysis takes a considerable amount of time, and then produces a very large output file (around 600 megabytes) along with an error file. The program will report an "Interpolation Error". This occurs on files that have a BRASS span of 99.99 ft and was attempting to increment each truck across the span at 100 increments (as specified in the LOAD-LIVE-CONTROL command). We found that one of two simple workarounds can correct the error: 1) round the BRASS spans from 99.99 ft to 100.00 ft, or 2) increase the live load increment from 100 to 105 in the LOAD-LIVE-CONTROL command. The second method is the preferred option as it only requires a correction in one command, where as adjusting the span lengths would have required doing it for multiple spans for the bridge that experienced this error.

When executing BRASS-GIRDER, if you get an unexpected termination of the program while attempting to run a file, check the BRASS error file (*.err) to see if it states that, "Standard Vehicle: OLEG3S2 is not presently stored in the standard vehicle library file." This usually means that the user did not update the names of the Legal Vehicle in the BRASS input file. In the early part of 2009, ODOT made a small revision to the vehicle library so that both the old Tier 1 and LRFR rating methodologies would use the same legal vehicles for their analysis. As a result, ODOT changed the names of the legal vehicles. To correct the error, make the following changes to the names of the legal vehicles in the BRASS input file:

Original Vehicle Names	Previous Vehicle Name	Current Vehicle Name
OLEG3	ORLEG3	OR-LEG3
OLEG3S2	ORLEG3S2	ORLEG3S2
OLEG3-3	ORLEG3-3	ORLEG3-3
SU4	SU4	OR-SU4
SU5	SU5	OR-SU5
SU6	SU6	OR-SU6
SU7	SU7	OR-SU7

7.4.5 BRASS Output Files

BRASS-GIRDER(LRFD) has been known to "run perfectly" and still produce completely wrong results. Although a successful run may indicate a lack of errors, it is prudent to search the main output (**.**OUT) file for the words "error" and "warning" to check out the seriousness of the problem, and to do a "reality check" on the Rating Factors. Unexpected Rating Factor results often indicate an error in the BRASS coding.

We recommend that, at the very least, load raters routinely employ the following two BRASS verification measures:

(1) Do a reasonability check on the section properties. This is why we routinely code "Y" in

parameter 2 of the OUTPUT (5-1.1) command, to provide a list of girder properties at each node point. (Search the Output File for "Calculated Properties" in each span). It is not uncommon to make errors in the steel section definitions, the SPAN-UNIF-HAUNCH (11-1.3) command or the SPAN-SECTION (11-2.1) commands that can result in a girder profile that is quite different than the one you expected.

(2) Do a reasonability check on the distribution of shears and moments across the structure. This is especially critical if you have an expansion joint within the structure that you have modeled by coding a hinge near one of the internal supports. Check if you are getting nearly-zero moments at the support next to the hinge. (It can't be truly zero because of the offset of the hinge from the support, but the moment value should be quite low). There have been cases where, due to numerical instabilities in the analysis process, unreasonably high moments were present at the support. The solution is usually to increase the offset of the hinge from the support in small increments until the reported moments behave as expected (sometimes increasing the offset by hundredths of a foot can make all the difference!).

If you really have doubts about what BRASS is giving you, be aware that you can use additional commands in the OUTPUT- group BRASS-GIRDER(LRFD) Manual, Chapter 5 to generate additional output that may facilitate your detective work. Use caution – the size of this output can be daunting.

When reading the BRASS Output File, in the Rating Factor Summary sections for Legal Loads, it may be difficult to distinguish between the live load combo cases because two of them are identified as "ORLEG3-3". In these cases, it is possible to distinguish them by looking for the 3-letter BRASS live load Type codes in parentheses. These are defined for parameter 3 of the LOAD-LIVE-DEFINITION command (12-4.3). Thus there will be separate rating factor results for ORLEG3-3 (TRK) which is the Type 3-3 truck by itself, and ORLEG3-3 (LGT) which is the Type 3-3 two-truck train plus Legal Lane load.

7.4.6 BRASS Proportion Checks

BRASS will perform proportion checks for the webs, flanges, and stiffeners. The checks do not impact the capacity analysis but will be reported in the output file. Checking these proportions is useful in refining the design, but is not useful in determining a member's capacity. Per MBE 2011 section 6A.6.9.5, the provision of LRFD Design Article 6.10.2 need not be considered for existing structures during evaluation. LRFD Section 6.10.2 discusses the proportions of webs and flanges but doesn't mention stiffeners. For load rating purposes, it is important to analyze the members based on how they were built. Thus, the proportion checks for webs, flanges, and stiffeners can be ignored.

7.4.7 Continuous Multi-Spanned Bridges with Varied Span Lengths

We were made aware of an issue that occurs with continuous multi-span bridges, when the adjacent span lengths vary by a considerable amount. It was noticed that the maximum positive moment sections were being evaluated at odd locations (0.1L for an end span and 0.4L for an interior span). This was a result of our original practice of basing these locations off of the dead load maximum moment locations and not the factored combined (dead load and live load) maximums. The maximum dead load moment location shifts were due to the uplift in short spans caused by the dead load of an adjacent long span.

To compensate for the uplift effects of dead load on the adjacent short spans, we will now use the maximum and minimum Load Factors stipulated in AASHTO LRFD Table 3.4.1-2. As a result, we have modified the BRASS Input Adjustment Type 2 commands in the BRASS input files to the following:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 2:
COM  Use the FACTORS-LOAD-DL command to force
COM  gamma-D maximum of 1.25 for DC & DW dead loads,
```

```
COM  a gamma-D minimum of 0.90 for DC dead loads,
COM  a gamma-D minimum of 0.65 for DW dead loads,
COM  and a constant 1.0 to dead loads for Service II

COM 13-1.2
FACTORS-LOAD-DL ST, 1, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL ST, 2, 1.25, 0.90, 1.25, 0.65
FACTORS-LOAD-DL SE, 2, 1.00, 1.00, 1.00, 1.00
```

The heavier vehicles will produce a maximum positive moment location closer towards the midspan, while the lighter vehicles will produce a maximum positive moment location away from midspan towards the maximum moment location of the dead load. Therefore, in order to capture the maximum positive moment for the entire suite of vehicles that we use in load rating, we may have to establish a range of points where the different vehicles will produce their maximum positive moment.

In order to facilitate this procedure, we have developed a new application (BRASS Moment Analyzer) that will evaluate the BRASS output files after an initial BRASS run and determine if the maximum positive moment locations for the live loads differ from the dead load locations. If so, the program will then analyze the differences in the locations and then provide a range of recommended positive moment locations (at 20th points) along with the BRASS commands for these new flexural analysis locations that can be copied and pasted into the BRASS input files. The program will create a text file, with the modified name of _MOMENT_INITIAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

After the final BRASS run, the BRASS Moment Analyzer can be used to once again evaluate the BRASS output files. This time, the software will check and report if the maximum combined moment for every vehicle at each analysis point is negative, positive, or contains both negative and positive values. The program will allow the user to print a summary report which they can refer to when selecting the type of moment during the BRASS import of the moment locations on the Load Rating Summary sheet. The program will create a text file, with the modified name of _MOMENT_FINAL.TXT, in the same directory that contains the BRASS output files that were analyzed.

Do not include the BRASS Moment Analyzer output in the printed Load Rating Calc. Book. We only request that the .TXT files that it produces be included with the electronic files for the load rating.

The intent is to only use the BRASS Moment Analyzer for continuous bridges with adjacent span lengths that vary more than 30%.

7.5 Exterior Girder Analysis

Use the interior girder files as a starting point for creating the exterior girder files. Most of the interior girder file will still apply for the exterior girder analysis. Because the interior file is used as a starting point, it is suggested to not begin the exterior girder analysis until thorough checking of the interior files have been completed. Any mistakes found in the interior file would likely also be mistakes in the exterior file

7.5.1 Generating an Exterior Girder Preliminary File from an Interior Girder File

For the typical composite steel structured bridge where the exterior girder design is the same as the interior girder, the task of generating an exterior girder preliminary file from the corresponding interior girder preliminary file generally consists on the following steps:

(1) Make a copy of **INTGIR.XMCD** and rename it **EXTGIR.XMCD**
(2) Change the title (first header)
(3) Check that the stiffeners, bearing, transverse and longitudinal are the same as for the interior

girder. In most cases, the exterior girder will omit some of the stiffeners.

(4) Eliminate all the calculation sections above "Component dead loads (DC)" and replace them with the statement "All factors, material properties, and girder geometry are the same as for the interior girders (see **INTGIR.XMCD**)"
(5) Revise the calculations for actual flange width for girder dead load (over-hang width combined with half the adjacent girder spacing) and adjust the number of bars of reinforcement in the composite deck overhang, if applicable.
(6) Revise the calculations for dead load of the diaphragms or cross-bracing
(7) Document any changes or decisions made regarding the weight of the stiffeners
(8) Eliminate all the calculation sections after "Wearing Surface dead loads (DW)" and append the statement "All live loads and Analysis Sections are the same as for the interior girder (see **INTGIR.XMCD**)".

7.5.2 Generating an Exterior Girder BRASS Input File from an Interior Girder File

For the typical steel structure where the exterior girder design is the same as the interior girder, the task of generating an exterior girder BRASS input file from the corresponding interior girder BRASS input file generally consists on the following steps:

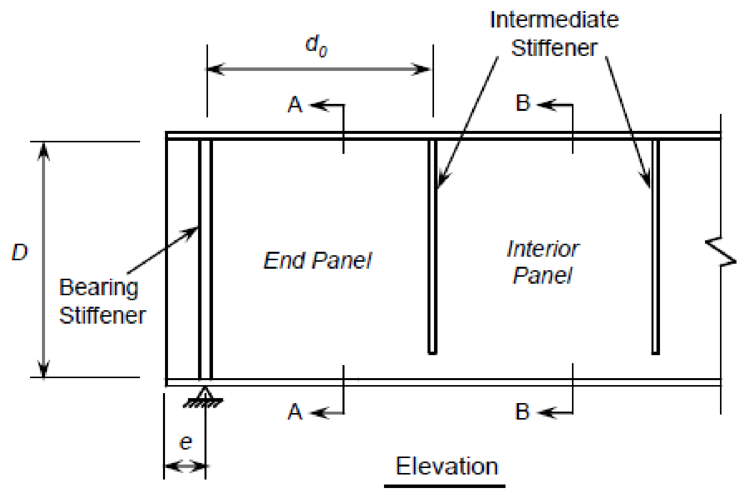
(1) Copy **STLINT.DAT** to **STLEXT.DAT.**
(2) Change the title.
(3) Change the stiffeners schedule, if different from interior girder.
(4) Change the dead loads due to diaphragms (and stiffeners if needed).
(4) Change the dead loads due to deck weight and rails.
(5) Change the girder of interest, i.e. parameter 1 of the DIST-CONTROL-GIRDER command (4-3.1) from 2 to 1.

7.6 Shear Resistance of End Panels in Steel Plate Girders

As we have been rating our older steel plate girder bridges, we have found a reoccurring issue of low shear ratings near the simply supported ends of the plate girders. Typically the rest of the bridge will have good capacity except for at these locations.

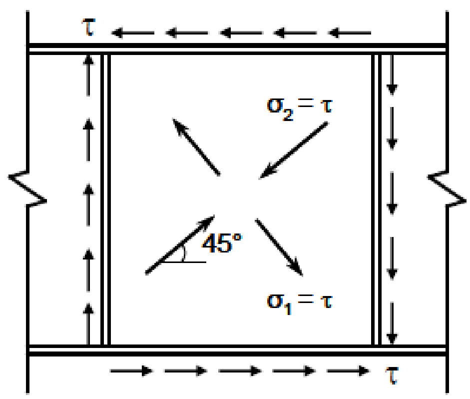
7.6.1 Engineering Mechanics of End Panel Shear Resistance

When we take a closer look at our analysis on any of these load ratings, what we are seeing is a drastic decrease in the shear capacity within the end panel region of the plate girder, which is the zone between the bearing stiffeners and the first intermediate stiffener, as shown in the figure below.



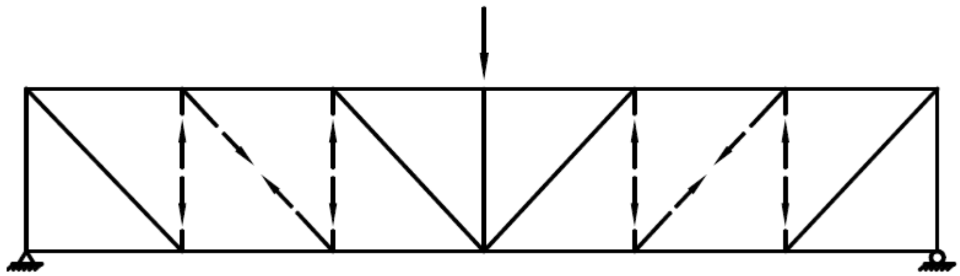
The web areas in between the intermediate stiffeners are the interior panels. To understand why the end panel shear capacity is so much less, we first need to understand what contributes to the interior panel's capacity.

So looking at an interior panel before buckling, the web in shear is initially in a pure shear stress state. The shear stresses present are equivalent to two principal stresses (one in tension and one in compression) that are inclined at 45 degrees to the shear stresses. This shear-transfer mechanism prior to web buckling is referred to as "beam action". When the elastic shear buckling strength of the panel is reached, the panel buckles along the panel diagonal while showing out-of-plane deformation.



(a) Before Buckling

After elastic shear buckling occurs, the principal compressive stresses do not increase any further, and the principal tensile stresses continue to increase and approach the panel yield strength as further buckling occurs along the panel diagonal. This diagonally buckled portion in the panel functions as a tension tie member, while the transverse stiffeners serve as compression strut members in a Pratt truss. This shear transfer mechanism resembling a truss system provides additional post-buckling strength. The inclined tensile membrane stress (or tension-field stress) of the panel is referred to as "tension-field action".



Pratt Truss

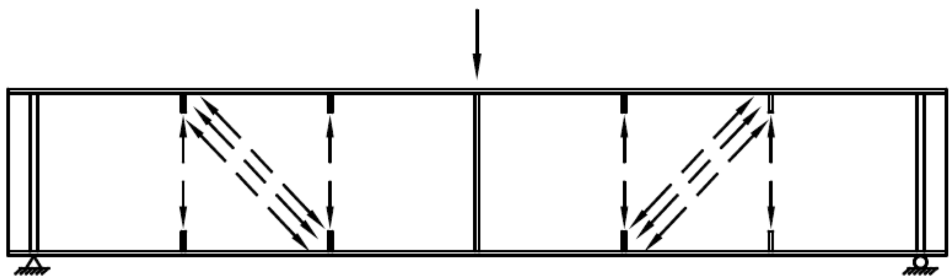


Plate Girder

(b) After Buckling (adapted from Yen and Basler, 1962)

Therefore, the ultimate shear strength of the interior panel of a plate girder consists of two components: the beam action shear strength (shear buckling strength) and tension-field action shear strength (post-buckling strength).

Since an end panel does not have a neighboring panel beyond the support to anchor the horizontal component of the tension-field action, AASHTO LRFD only considers the beam action in computing the nominal shear resistance within the end panel zone of a plate girder.

7.6.2 Using Partial-Tension Field Theory for End Panel Shear Resistance

While looking into this issue, ODOT was made aware of a research report that Caltrans sponsored the University of California at San Diego to investigate this very specific problem.

STRUCTURAL SYSTEMS
RESEARCH PROJECT

Report No.
SSRP-15/02

Shear Resistance of End Panels in Steel and Steel-Concrete Composite Plate Girders

by

Dong-Won Kim

Chia-Ming Uang

Final Report to California Department of Transportation

March 2015

Department of Structural Engineering
University of California, San Diego
La Jolla, California 92093-0085

The research paper investigated partial tension-field action that occurs at the end panel. They concluded that some amount of horizontal force can be anchored by the bearing stiffeners and the extended web portion that is beyond the bearing to the end of the girder.

After contacting Caltrans, we were informed that they had adopted the research into their load rating policy in a memo to load raters in November 2015. After performing our technical review and verification of the research results, ODOT adopted the majority of the research in our load rating practice on July 5th, 2016. The portion of the research that ODOT did not adopt was the contribution of a composite concrete deck to the shear capacity of the steel plate girder.

To compare what affect this method has on a load rating, a major bridge on one of our Interstates where the end panel shear capacity of a steel plate girder was being computed by AASHTO LRFD was resulting with a rating factor for the Type 3S2 vehicle of 0.59. Recomputing the shear capacity at the same location, using the partial-tension field theory provisions that ODOT adopted from the research paper, resulted in the Type 3S2 rating factor to be 2.72; which was comparable to the rating factors that were being computed throughout the rest of the bridge where normal load rating procedures were being used.

7.6.3 End Panel Shear Tool

With the adoption of this research into our load rating methods, ODOT's consultant that was working under contract to load rate steel I-Girder bridges developed an Excel tool that would import the loading data from BRASS, recalculate the shear capacity using the partial-tension field theory, and then provide updated rating factors for each vehicle at the location being revised. This tool has been named **End_Panel_Shear_Span#_Girder#_#L.xlsm**; where the # signs in the name need to be changed to the span number, girder line number, and location within the span (typically either 0.000L or 1.000L) where the end panel shear is being evaluated.

Once a copy of the End Panel Shear tool has been saved and the file name has been updated to reflect the span number, girder line, and location that is being analyized, the yellow fields within the tool need to be populated with the following data:

1. Enter the official bridge name as shown on the bridge inspection report.
2. Enter the bridge number.
3. In the member field, enter the name of the girder line being analyzed. For some bridges, there are different design details for each girder line, which may require a separate analysis for each.
4. Input the overall span number that the analysis point resides in the form of "x" of "y"; where "x" is the span number of the analysis point and "y" is the total number spans in the bridge.
5. Input the the span fraction location of the analysis point within the span in the format of x.xxxL; where 0.000L is the beginning of the span and 1.000L is the end of the span.
6. Input the name of the BRASS-Girder output file. The file must be located in the same folder that the End Panel Shear tool is saved so that the tool can find and inport the necessary data from the BRASS output file.
7. Enter the overall span number that is represented as the first span in the BRASS model. For example, if the bridge has a total of 14 spans, but the BRASS model being referenced only modeled 3 of the spans, with the first span in the BRASS model representing span 9 of the overall bridge, enter a 9 within the End Panel Shear tool.
8. Enter the AASHTO LRFD Resistance Factor for Shear.
9. Enter the Condition Factor.
10. Enter the System Factor.
11. Enter the Web Yield Strength in ksi.
12. Enter the Top Flange Yield Strength in ksi.
13. Enter the Bottom Flange Yield Strength in ksi.
14. Enter the Bearing Stiffener Yield Strength in ksi.
15. Verify the Steel Modulus of Elasticity in ksi.
16. Verify the Poison's Ratio for Steel.
17. Enter the distance from the end of the girder to the center line of bearing in inches.
18. Enter the spacing of the end stiffeners in inches. This is typically the distance from the bearing stiffener to the first transverse stiffener. This cell does a check to see if the value entered is greater than 1.5 times the web clear depth, which does not get entered into the tool until it is imported from the BRASS output. Thus, this cell will turn red to indicate that the check failed since the web clear depth is usually blank at the beginning of a new end panel analysis, until the user imports the BRASS data.
19. Enter the bearing stiffener thickness in inches.
20. Enter the bearing stiffener width in inches.
21. Save the file to retain the data entered.
22. Click the "Import BRASS data" button. If the BRASS output file is saved in the same folder that the End Panel Tool is in, the BRASS data will be automatically imported, new capacities will be computed, and updated rating factors will be computed.

The last step is to copy the updated rating factors from the End Panel Tool and replace them over the original rating factors for this analysis point in the load rating summary sheet.

Steel Girder Shear Capacity in End Panels — **Last Revision: 5/15/2017**

--Calculate Shear Capacity in End Panels using procedure documented in UCSD Research Report No. SSRP-15/02 "Shear Resistance of End Panels In Steel and Steel-Concrete Composite Plate Girders" (Paper) by Kim and Uang.

--Per ODOT direction, consider only the girder contribution (ignoring deck capacity)

BRIDGE NAME:	1	Hwy 1 SB Ramp to Hwy 61 NB over surface sts (W Marquam Int)		INPUT
BRIDGE NUMBER:	2	08591B		OUTPUT
MEMBER:	3	Ext. Girder 1		
SPAN:	4	11 of 14	22	Import BRASS data
LOCATION:	5	1.000L		
BRASS FILE:	6	EXS111.out		
BRASS FIRST SPAN:	7	11	Refer to ODOT LRFR Manual Section 7.6.3 for more information on using this tool.	

Input for Capacity Calculations

Resistance Factor for Shear	ϕ_v =	8	1.00	-	LRFD 6.5.4.2
Condition Factor	ϕ_c =	9	1.00	-	Assumed to be the value for the superstructure
System Factor	ϕ_s =	10	1.00	-	Assumed to be equal to 1.00 for bearings
Web Yield Strength	F_{yw} =	11	50	ksi	
Top Flange Yield Strength	F_{ytf} =	12	50	ksi	
Bottom Flange Yield Strength	F_{ybf} =	13	46	ksi	
Bearing Stiffener Yield Strength	F_{yb} =	14	46	ksi	
Steel Modulus of Elasticity	E =	15	29000	ksi	
Poisson's Ratio for Steel	ν =	16	0.30	-	Use high end of range to be conservative
Web Thickness	t_w =		0.375	in	Imported from BRASS
Web Clear Depth	D =		78	in	Imported from BRASS
Distance from End of Girder to CL Bearing	e =	17	6	in	
Spacing of End Stiffeners	d_o =	18	54	in	Must be less than 1.5*D
Top Flange Thickness	t_{tf} =		0.75	in	Imported from BRASS
Top Flange Width	b_{tf} =		16	in	Imported from BRASS
Bot Flange Thickness	t_{bf} =		1	in	Imported from BRASS
Bot Flange Width	b_{bf} =		22	in	Imported from BRASS
Bearing Stiffener Thickness	t_b =	19	0.875	in	
Bearing Stiffener Width	b_b =	20	7.813	in	$b_b \le 0.5(b_f - t_w)$

Capacity Calculations

Shear buckling coefficient	k =	15.14	-	Paper Eqn. (1.18)
Elastic Shear Buckling Stress	τ_{cr} =	9.173	ksi	Paper Eqn. (6.3)
Shear Yield Stress	τ_{yw} =	28.868	ksi	Paper Sect. 1.3.2
Effective Web Depth	d_e =	3.05	in	Paper Eqn. (6.42)

7.7 Manual Bearing Check of Unstiffened Webs

We normally check the shear at support locations. However, BRASS-GIRDER will only perform a bearing analysis and provide the resulting rating factors for bearing at locations where a bearing stiffener is defined in the BRASS model. BRASS will not perform a bearing check if there are no bearing stiffeners. Per AASHTO LRFD C6.10.11.2.1, bearings without stiffeners must be checked to meet the following limit states:

- Web Local Yielding (AASHTO LRFD D6.5.2)
- Web Crippling (AASHTO LRFD D6.5.3)

A new Excel spreadsheet tool (STBRG_.xlsx) has been created to manually calculate the rating factors for bearing without stiffeners based on the AASHTO LRFD provisions listed above. Since

BRASS only considers the bearing stiffeners working by themselves (without contribution from the web) to support bearing, this tool can also be used to check the bearing of the web by itself (ignoring the bearing stiffeners) when BRASS results with low rating factors for the bearing stiffeners. This can sometimes negate the need to restrict or strengthen a bridge if the web has sufficient capacity to support the bearing forces without the contribution of bearing stiffeners.

7.7.1 Unstiffened Web Bearing Check Tool

The Excel spreadsheet tool named STBRG_.xlsx has been created to manually create the rating factors for Bearing of an unstiffened web of a steel girder. When saving a copy of the tool for a specific bridge, after the underscore in the file name, include information to identify the location of the girder being analyzed (for example STBRG_Int.xlsx, or STBRG_Span2_Ext.xlsx).

Once a copy of the Bearing Check tool has been saved and the file name has been updated to reflect the span number and/or girder line that is being analyized, the yellow fields within the tool need to be populated with the following data:

1. Enter the official bridge name as shown on the bridge inspection report.
2. Enter the bridge number.
3. In the member field, enter the name of the girder line being analyzed. For some bridges, there are different design details for each girder line, which may require a separate analysis for each.
4. Input the overall span number that the analysis point resides in the form of "x" of "y"; where "x" is the span number of the analysis point and "y" is the total number spans in the bridge.
5. Input the the span fraction location of the analysis point within the span in the format of x.xxxL; where 0.000L is the beginning of the span and 1.000L is the end of the span.
6. The Resistance Factor for Bearing and for Web Crippling has been entered as defined by LRFD 6.5.4.2. These fields have been left with a yellow highlight to allow users the option to modify these factors.
7. Enter the Condition Factor.
8. Enter the System Factor.
9. Enter the overall depth of the steel section.
10. Enter the distance from the outer face of the flange to the toe of the web fillet. For rolled sections, get "k" from the steel Manual. For built-up sections, "k" is the distance from the edge of the flange to the outer edge of the web-flange weld.
11. Enter the length of bearing, "N", in inches. At end bearing locations, "N" shall be greater than or equal to "k".
12. Enter the web thickness.
13. Enter the flange thickness.
14. Enter the web yield strength.
15. The steel Modulus of Elasticity has already been entered.
16. Use the drop-down menu to specify if the analysis location is at an interior or end support location.
17. For reference purposes, enter the BRASS output file that was used for dead load and live load reactions.
18. Enter the single-lane Distribution Factor.
19. Enter the multi-lane Distribution Factor.
20. Enter the Legal and Permit Vehicle Live Load Factors.
21. Enter the total unfactored dead load demand.
22. Entert the Live Load demand for each analysis vehicle.
23. The final step in the process is to copy the location data and resulting rating factors and paste them into the load rating summary sheet.

A separate file will be used for each Bearing analysis location.

Steel Bearings Without Stiffeners

Last Revision: 5/22/2017

--Per AASHTO LRFD C6.10.11.2.1, bearings without stiffeners must be checked to meet the following limit states

*Web Local Yielding (AASHTO LRFD D6.5.2)
*Web Crippling (AASHTO LRFD D6.5.3)

BRIDGE NAME: 1
BRIDGE NUMBER: 2
MEMBER: 3
SPAN: 4
LOCATION: 5

INPUT
OUTPUT

Input for Capacity Calculations

Resistance Factor for Bearing	ϕ_b =	6	1.00	-	LRFD 6.5.4.2
Resistance Factor for Web Crippling	ϕ_w =	6	0.80	-	LRFD 6.5.4.2
Condition Factor	ϕ_c =	7	1.00	-	Assumed to be equal to the value for the superstructure
System Factor	ϕ_s =	8	1.00	-	Assumed to be equal to one for bearings
Depth of Steel Section	d =	9		in	
Distance from the Outer Face of the Flange to the Toe of Web Fillet	k =	10		in	For rolled sections, get "k" from Steel Manual. For built-up sections, "k" is the distance from the edge of flange to outer edge of web-flange weld
Length of Bearing	N =	11		in	N shall be greater than or equal to "k" at end bearing locations
Web Thickness	t_w =	12		in	
Flange Thickness	t_f =	13		in	
Web Yield Strength	F_{yw} =	14		ksi	
Steel Modulus of Elasticity	E =	15	29000	ksi	
Interior or End Support?	Loc =	16		-	

Web Local Yielding Capacity	$\phi_c\phi_s\phi_b R_n$ =	0.0	kip
Web Crippling Capacity	$\phi_c\phi_s\phi_w R_n$ =	#DIV/0!	kip

BRASS Output File Used for Reactions: 17

Obtain demands from the BRASS Output file for this girder
Copy-paste values from RF to the summary sheet

File Name	STBRG_.xlsx
Force Type	Bearing
Phi	#DIV/0!
Member	0
Span	0
Location	0
Single-Lane DF	18
Multi-Lane DF	19

23

DESIGN & LEGAL VEHICLES	LL Factor	(Unfactored) DL Demand	LL Demand	Capacity	RF
HL93 (INVENTORY)	1.75	21	22	#DIV/0!	#DIV/0!
TYPE 3	20 1.30	0.0	22	#DIV/0!	#DIV/0!
TYPE 3S2	1.30	0.0	22	#DIV/0!	#DIV/0!
TYPE 3-3	1.30	0.0	22	#DIV/0!	#DIV/0!
TYPE 3-3 & LEGAL LANE	1.30	0.0	n/a	#DIV/0!	
TYPE 3-3 TRAIN & LEGAL LANE	1.30	0.0	22	#DIV/0!	#DIV/0!
SU4 TRUCK	1.30	0.0	22	#DIV/0!	#DIV/0!
SU5 TRUCK	1.30	0.0	22	#DIV/0!	#DIV/0!
SU6 TRUCK	1.30	0.0	22	#DIV/0!	#DIV/0!
SU7 TRUCK	1.30	0.0	22	#DIV/0!	#DIV/0!
CTP VEHICLE, MULTI-LANE					
OR-CTP-2A	20 1.30	0.0	22	#DIV/0!	#DIV/0!
OR-CTP-2B	20 1.20	0.0	22	#DIV/0!	#DIV/0!
OR-CTP-3	20 1.20	0.0	22	#DIV/0!	#DIV/0!
STP VEHICLE, MULTI-LANE					
OR-STP-3	20 1.15	0.0	22	#DIV/0!	#DIV/0!
OR-STP-4A	20 1.20	0.0	22	#DIV/0!	#DIV/0!
OR-STP-4B	20 1.15	0.0	22	#DIV/0!	#DIV/0!
OR-STP-4C	20 1.15	0.0	22	#DIV/0!	#DIV/0!
OR-STP-4D	20 1.15	0.0	22	#DIV/0!	#DIV/0!
OR-STP-4E	20 1.15	0.0	22	#DIV/0!	#DIV/0!
OR-STP-5BW	20 1.15	0.0	22	#DIV/0!	#DIV/0!
SPECIAL	1.00	0.0	n/a	#DIV/0!	

SECTION 8: LOAD RATING TIMBER GIRDER BRIDGES

8.0 Scoping of Structure

Create a scoping file (nnnnnn_scope.xls) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended effect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0 then, there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

8.1 Decide What Girders to Analyze

Due to the effects of all the various LRFD Distribution Factor provisions, it is difficult to predict which girder will control the load rating. Therefore, a separate preliminary file and BRASS input will be required for both the interior and exterior girder. In the Load Rating Summary Workbook file, importing the rating factors from both girders is required (be sure to do a “Refresh” after the second import) because it is not uncommon for different girders to control for different loads.

Exterior girders should be analyzed when $(d_e + S)/S \geq 0.5$ (d_e is the distance from centerline of web for the exterior girder and 2ft from the edge of the travelway and S is girder spacing). It is common for the exterior girders to have more decay than the interior girders. If $(d_e + S)/S \geq 0.25$ and the exterior girder has severe decay or other section loss (Condition State 3 or 4), the load rater should consider evaluating the exterior girder.

It is important to review the Bridge Inspection Report and Timber Boring Report in order to select the girders to analyze. Members that have significant defects (Condition State 3 or 4) should be analyzed even when load effects may be less than a similar member in a longer span.

Members that contain strengthening such as such as fishplate, analysis should be performed to ensure that the capacity of the member is adequate.

Minor variations often occur between girders spacing and member dimensions on timber bridges. It is acceptable to only load rate the worst case scenario (i.e. largest girder spacing and minimum girder).

8.2 Preliminary Files for Girders (Mathcad)

For timber bridges, the preliminary file name and extension (Mathcad) for interior girders is STR_INT.xmcd or SLB_INT.xmcd. The preliminary file name and extension for exterior girders is STR_EXT.xmcd or SLB_EXT.xmcd. For a timber slab bridge, the exterior slab preliminary file may be omitted and calculations included in the SLB_INT.xmcd file. If there are more unique girders of each type, the file names should differentiate between them with some additional identifier (e.g. STR_INT_ORIG.xmcd and STR_INT_WIDEN.xmcd).
Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied factors with parentheses.

8.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge the load rater is working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description (“Spans” field) from the Bridge Log is adequate for this purpose.

Note: the Mathcad regions at the top in the right margin (outside the printable area) are there for 2 purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

8.2.2 Resistance Factors

Document the decisions regarding all 3 Resistance Factors, with references to the appropriate MBE tables.

BRASS-GIRDER(LRFD) provides input for the MBE Condition Factor φ_c (MBE 6A.4.2.3) and System Factor φ_s (MBE 6A.4.2.4). However, the ODOT Load Rating Summary Sheet and the ODOT Crossbeam Load Rating Software always require and display the product of all the resistance factors as a single φ factor. Therefore, the product of all these resistance factors must always be obtained.

Treat the System Factor φ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure:
$\Phi_f = \varphi\ [\ \max\ (\varphi_c \varphi_{sf}\ , 0.85)\ ]$
where φ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 8.5.2.2)
and φ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Shear:
$\Phi_v = \varphi\ [\ \max\ (\varphi_c \varphi_{sv}\ , 0.85)\ ]$

where φ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 8.5.2.2)
and φ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\varphi_c\varphi_s \geq 0.85$ (MBE 6A.4.2.1-3).
Generally, Φ_f and Φ_v will be the same for redundant members such as girders and will be different for non-redundant members such as single-span and 2-span crossbeams.

8.2.2.1 Condition Factor and Timber Defects

The default Condition Factors are identified in Section 1.4.1.3. Special Condition Factors for various timber defects are listed in the subsections below.

When selecting the Condition Factor for a timber bridge, it is important to review the Bridge Inspection Report and Timber Boring Report. The Timber Boring Report will be helpful in determining what Condition Factor to use for each girder analyzed.

When selecting the Condition Factor, the load rater should not double penalize the member being analyzed by reducing the LRFD Adjusted Design Factors (F_b, F_v, and F_{cp}) and the Condition Factor due to the same defect. An example would be the Superstructure Rating (NBI 59) being rated a ‘4’ due to decay and further reducing F_b for decay. If the member has multiple defects such as decay and checking, the load rater may reduce F_b for decay and the Condition Factor for checking.

8.2.2.1.1 Checks and Shakes

When checks and/or shakes are present, the resistance factors listed in the table below should be used.

Checks and Shakes

Condition State	ϕ_c	Description
CS1	1.00	Checking and shakes <5% of member width
CS2	0.95	Checking and shakes 5%-50% of member width
CS3 or CS4	0.85	Greater than 50% of member width

8.2.2.1.2 Splits

Splits are common in the bearing area of the stringer/girder. When splits are present in the bearing area. F_v should be reduced. The amount of the reduction to be used can be determined in the table below. A field inspection of the member may be required to determine the length of the split.

Splits (D, Member Depth) (SL, Split Length)

Length of Split	Reduction to F_v
Less than 1 x D (CS2)	0.85
Greater than 1 x D (CS3)	0.85*D/SL ≤ 0.5

8.2.2.1.3 Decay

Refer to Section 10.3 for decay.

8.2.2.1.5 Cracked Girders

Cracked girders are an indicator of possible overload conditions in the past. The ODOT Bridge Inspection Coding Guide rates the Condition States differently than other defects.

Condition State 2 indicates that the crack is arrested. Condition States 3 and 4 indicate the crack is not arrested.

Condition State 2 is typically the result of a repair in-place such as an adjacent girder being added or fish plates being installed. These repairs may be considered temporary and a separate BRASS _N file may be required for the analysis. In the case of a temporary repair, the member is load rated taking into account the repair for the primary BRASS file and without the repair in the _N file.

For cracked girders not arrested, analyze the girder line adjacent to the cracked girder. The preliminary file and BRASS file should not include the cracked girder line. Since the cracked girder line is being ignored, the adjacent girder line will have a larger girder spacing which will result in lower rating factors. The lever rule should be used for the adjacent girder line.

In some cases, the crack is near the support and extends to the end of the beam. In this case the load rater would still analyze the cracked girder line, but would reduce the section in BRASS to represent the reduced girder. This type of crack is typically the result of a weak section of the beam and not an indicator of possible overload.

8.2.2.1.5 Fire Damage

The table below contains recommended values to use for various Condition States if the extent of the fire damage is unknown. For CS3 and CS4 ODOT recommends performing a field inspection to quantify the type, size, and location of the fire damage. Modify the BRASS sections accordingly.

Fire Damage

Condition State	ϕ_c	Description
CS2	0.95	Fire damage less than 10% of member
CS3 or CS4	0.85	Fire damage greater than 10% of member.

8.2.2.1.6 Bug Infestation

Bug Infestation is difficult to quantify during a field inspection. Table below is recommended values to use for various Condition States. If the load rater thinks that Condition Factors below are conservative, ODOT recommends the load rater gets permission from the owner to perform destructive testing (i.e. Timber Core) in order to better quantify the section loss.

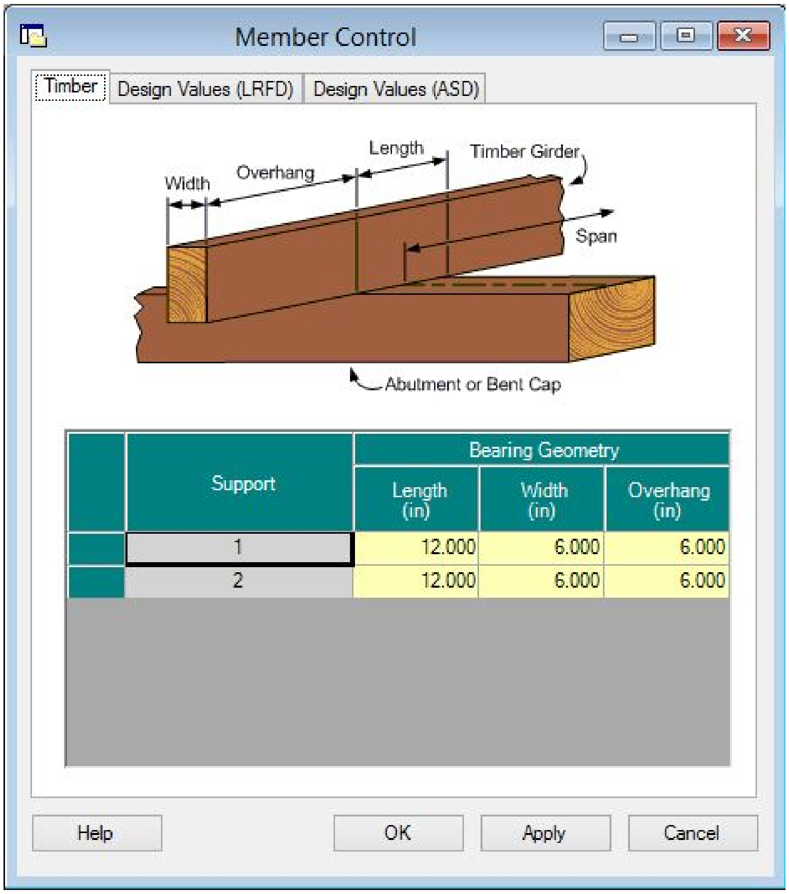
Bug Infestation

Condition State	ϕ_c	Description
CS2	0.95	Bug infestation less than 10% of member
CS3 or CS4	0.85	Bug infestation greater than 10% of member.

8.2.2.1.7 Loss of Bearing Area

Loss of bearing area will affect the bearing capacity of the beam. For Condition State 2 loss of bearing, reduce the bearing width by 10%. For Condition State 3, reduce the bearing width by the amount indicated on the Bridge Inspection Report.

The bearing area is determined in BRASS by the values inputted on Member Control > Timber tab.



8.2.2.1.8 Other Defects

For other defects that may be present, the load rater should use engineering judgement to determine the appropriate method to account for the defect.

8.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into BRASS. The Load Rating Summary Workbook **(LR.XLT)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.
For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction). For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and effective bridge length. Note that effective bridge length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which live load factor application is used, ADTT is specified as “one direction”. Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the live load factor application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the live load factor application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the “LRFR Strength I & II” table from the live load factor application, and in Mathcad use Edit / Paste Special. In the “Paste Special” dialog box chose the “Paste” button, highlight “Bitmap” in the “As” list, and click the “OK” button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor, IM, referring to MBE 6A.4.4.3. For Timber bridges, IM should be 1.0.

8.2.4 Material Properties

When material properties are provided on the plans, use AASHTO LRFD Section 8 to determine the material properties.

The majority of timber bridges do not have plans, and material properties need to be assumed. The following properties may be used, unless there is cause to assume otherwise.

Reference Design Values for Visually Graded Sawn Lumber (AASHTO Table 8.4.1.1.4-1)

Species	Size	F_{bo} (ksi)	F_{vo} (ksi)	F_{cpo} (ksi)	E_o (ksi)
Douglas Fir	Beams and stringers	1.60	0.17	0.625	1600

Reference Design Values for Structural Glulam (AASHTO Table 8.4.1.2.3-1)

Species	Combination Symbol	F_{bo} (ksi)	F_{vo} (ksi)	F_{cpo} (ksi)	E_o (ksi)
Douglas Fir	24F-V4	2.40	0.265	0.650	1800

Reference Design Values for Visually Graded Dimension Lumber (AASHTO Table 8.4.1.1.4-1)

Species	Size	F_{bo} (ksi)	F_{vo} (ksi)	F_{cpo} (ksi)	E_o (ksi)
Douglas Fir	Width greater than or equal to 2in.	1.50	0.18	0.625	1900

1) Typically used in timber slab bridges.

8.2.4.1 Adjusted Design Values

The reference design values are further adjusted to determine the Adjusted Design Values.

$F_b = F_{bo} C_{KF} C_M (C_F or C_V) C_{fu} C_i C_d C_\lambda$ (AASHTO Eqn. 8.4.4.1-1)

$F_v = F_{vo} C_{KF} C_M C_i C_\lambda$ (AASHTO Eqn. 8.4.4.1-2)

$F_{cp} = F_{cpo} C_{KF} C_M C_i C_\lambda$ (AASHTO Eqn. 8.4.4.1-5)

$E = E_o C_M C_i$ (AASHTO Eqn. 8.4.4.1-6)

8.2.4.2 Format Conversion Factor, C_{KF}

The conversion factor is used to convert values for Allowable Stress Design (ASD) to LRFD.

For F_b and F_v use:

$$C_{KF} = \frac{2.5}{\phi}$$

For F_{cp} use:

$$C_{KF} = \frac{2.1}{\phi}$$

8.2.4.3 Wet Service Factor, C_M

For sawn lumber with a moisture content of 19 percent or less, C_M shall be taken as 1.0. For a glue laminated member with a moisture content of 16 percent or less, C_M shall be taken as 1.0. Interior stringers are typically relatively dry and it is safe make these assumptions. In the event the field inspection indicated the beams may be saturated, use the values determined in AASHTO Section 8.4.4.3.

8.2.4.4 Size Factor, C_F, for Sawn Lumber

For sawn beams and stringers with loads applied to the narrow face and for posts and timbers, C_F is determined as:

If d ≤ 12.0 in., then

$$C_F = 1.0$$

If d> 12.0 in., then

$$C_F = \left(\frac{12}{d}\right)^{\frac{1}{9}}$$

Where: d = the depth of member

8.2.4.5 Volume Factor, C_V, for Glulam

Glulam beams with loads applied perpendicular to the wide face of the lamination shall be reduced by C_v.

$$C_V = \left[\left(\frac{12.0}{d}\right)\left(\frac{5.125}{b}\right)\left(\frac{21}{L}\right)\right]^a \leq 1.0$$

Where:

d = depth of component (in.)

b = width of the component (in.), for layups b = width of widest piece

L = length of component measured between contraflexure (ft.)

a = 0.10 for all except Southern Pine

8.2.4.6 Flat-Use Factor C_{fu}

When loads are applied to the narrow face, the Flat-Use Factor C_{fu} is equal to 1.0. Refer to AASHTO Section 8.4.4.6 in the event loads are applied to the wide face.

8.2.4.7 Incising Factor, C_i

The Incising Factor, C_i, applies to dimensional lumber only. Since glulam beams and timber slabs are often comprised of dimensional lumber, it will be applied unless field inspection indicated otherwise.

Design Value	C_i
F_{bo} and F_{vo}	0.80
F_{cpo}	1.00
E_o	0.95

8.2.4.8 Deck Factor, C_d

Deck Factor, C_d will be 1.0 since it does not apply to beams. Refer to AASHTO LRFD Section 8.4.4.8.

8.2.4.9 Time Effect Factor, C_λ

Design Values are adjusted by the Time Effect Factor, C_λ, for Strength I prior to being inputted into BRASS-Girder. BRASS-Girder will calculate the design values for other Limit States.

Limit State	C_λ
Strength I	0.8
Strength II	1.0

8.2.4.10 Beam Stability Factor, C_L

Nominal resistance for moment in AASHTO equation 8.6.2-1 is modified by the Beam Stability Factor C_L. BRASS-Girder does not make the adjustment; therefore, the design value for flexure, Fb, needs to be modified prior to entry into BRASS-Girder.

Beam Stability Factor, C_L, may be set to 1.0 for slab bridges and bridges with a composite concrete deck.

Where the depth of the flexure member does not exceed the width, C_L=1.0.

When there is continuous support of the compression zone of the member to prevent lateral movement and bracing at the supports to prevent rotation, C_L=1.0. Examples in which this may exist would be timber blocks at bearing locations preventing rotation or mechanical deck clips connecting a laminated deck to the girders.

$$C_L = \frac{1+A}{1.9} - \sqrt{\frac{(1+A)^2}{3.61} - \frac{A}{0.95}} \qquad \text{(AASHTO Eqn. 8.6.2-2)}$$

$$A = \frac{F_{bE}}{F_b} \qquad \text{(AASHTO Eqn. 8.6.2-3)}$$

$$F_{bE} = \frac{K_{bE}E}{{R_b}^2} \qquad \text{(AASHTO Eqn. 8.6.2-4)}$$

$$R_b = \sqrt{\frac{L_e d}{b^2}} \qquad \text{(AASHTO Eqn. 8.6.2-5)}$$

Where:

K_{bE} = 0.76 for visually graded lumber; 1.10 for glulam components
F_b = adjusted design value for flexure
E = adjusted modulus of elasticity
C_L = beam stability factor
d = depth of member
b = width of member
L_e = effective unbraced length (in.)

The effective unbraced length, L_e, may be determined as:

- If $L_u/d < 7$, the $L_e = 2.06*L_u$
- If $7 \le L_u/d \le 14.3$, then $L_e = 1.63*L_u+3*d$
- If $L_u/d > 14.3$, then $L_e = 1.84*L_u$

Where:

L_e = distance between point of lateral and rotational support (in.). Timber cross-bracing should not be considered as lateral and/or rotational support.

d = depth of component (in.)

8.2.5 Bridge Average Geometry

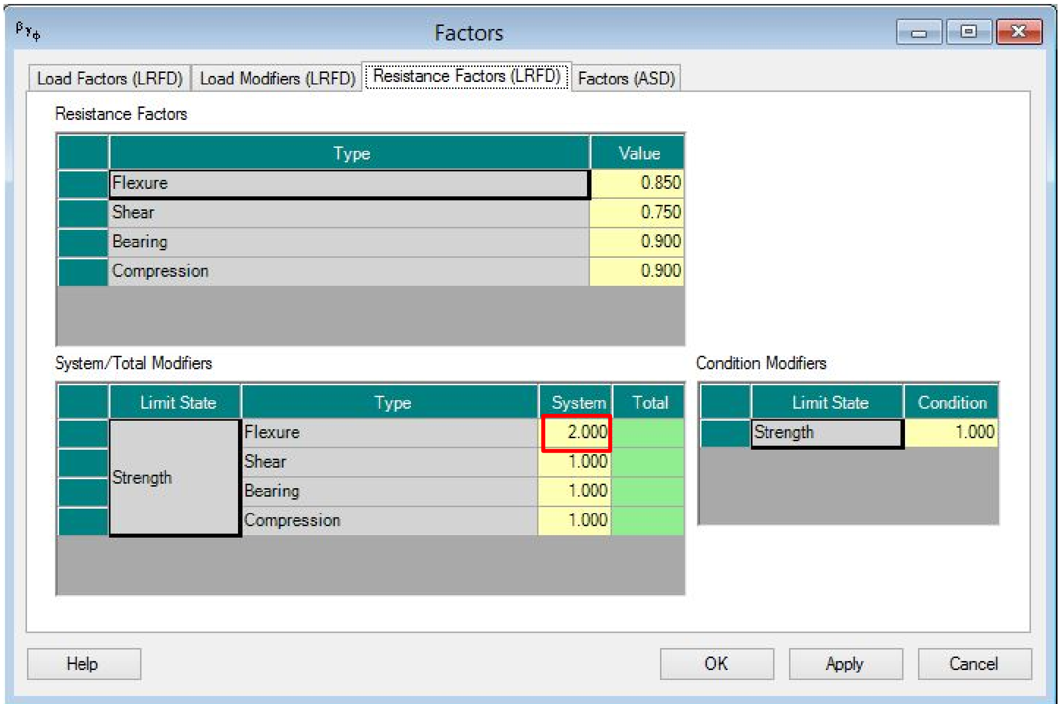
Calculate the physical edge-to-edge width of the bridge deck and the roadway width of the bridge. If the width of the deck or roadway changes over the length of the bridge, calculate the average roadway width per span. Enter the skew angle of the bridge. These values are entered into BRASS to calculate the Distribution Factors.

8.2.6 Girder Properties

8.2.6.1 Section Properties of the Composite Girder

ODOT has a long history of construction of timber superstructures with concrete composite decks. Although they are common in Oregon, there is limited design code and structural analysis software to evaluate the capacity of the sections. Some of the earliest research and design on timber structures with composite decks was performed by McCullough in 1943. The results of what is known as the "Oregon Tests" determined that the ultimate strength of the composite section is at least twice as much as if the section is considered non-composite and deflections will be 25% of the non-composite section.

Due to the limited design code for timber structures with a composite concrete deck, ODOT has developed a procedure that is based on the *Structural Timber Design to Eurocode 5*. The procedure used by ODOT makes assumptions about the failure mechanism and shear connector reduction factor, γ, used in the analysis. The procedure determines the Effective Stiffness for the composite section and compares it to the Stiffness of the timber beam. The System Resistance Factor, ϕ_{sf}, for flexure is then multiplied by the ratio of the Effective Stiffness/Beam Stiffness, in order to be inputted into BRASS. The system resistance factor, ϕ_{sf}, for flexure shall not be taken to be greater than 2.0 without further analysis. Additional capacity for shear is being ignored in the analysis.



See Timber_Composite.xmcd for Calculations.

8.2.6.2 Shear Connectors for Composite Decks

Shear Connection Reduction Factors:

γ_1=

Studs or Nails Only	0.1
Shear Keys Only	0.25
Studs/Nails and Shear Keys	0.4
Wire Mesh	0.4

γ_2= 1.0 for all girders regardless of the type of shear connectors.

8.2.7 Component Dead Loads (DC)

To avoid confusion, dead loads should be grouped under the headings DC and DW and presented in the same order in the Preliminary (.xmcd) File as they will appear in the BRASS Input (.girder) File.

Use AASHTO LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c and timber w_t. For dead load calculations, use w_c+0.005 kcf to account for the reinforcement, in accordance with AASHTO LRFD Commentary C3.5.1.

Show calculations for the girder dimensions.

Consider diaphragm point loads to be part of component load DC. Include any diaphragms/end beams at the end of the girder over the support, as they will be utilized when applying the girder dead load reactions to crossbeams.

Where standard rail drawings occur, wherever possible use the rail dead loads tabulated in Appendix H - ODOT Standard Rail Weights, found in file RAILDL.XLS. Provide detailed calculations for the dead load of any rail not found in this summary. For a typical metal rail with timber post, it can be assumed to be similar to the Standard Drawing B914 with Uniform load of 0.064 k/ft.

For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all rail, curb and sidewalk dead loads (stage 2 dead loads) equally among all girders.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16" diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to need to be included in the load rating.

For load rating, we want to consider a utility as a "non-structural attachment" and keep it listed under DC for dead loads. The main reason for this is if a load rater ever comes across a situation where they have to load rate a bridge where they are uncertain of the wearing surface thickness. In that situation they are required to use a DW gamma of 1.50. That way they would only be penalizing the load of the wearing surface, not the utilities, for the uncertainty.

8.2.8 Wearing Surface Dead Loads (DW)

Always separate wearing surface dead load (DW) from the component (DC) dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes, and (c) it facilitates input for the Crossbeam Load Rating Software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Show calculations for wearing surface dead load distributed equally to all the girders. Add 1" to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½" to the design thickness of PPC overlays to account for construction variations and uncertainty.
For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all wearing surface dead loads (stage 2 dead loads) equally among all girders.

When running boards are present, they should be included in the wearing surface calculations. Use 50 lb/ft^3 for the unit weight.

8.2.9 Live Loads (LL)

Simply list the four classes of rating loads to be analyzed. (See articles 1.5.1.1 through 1.5.1.4).

Normally live load distribution factors are calculated in BRASS, but in the rare case where they must be calculated manually, the complete calculations should be provided with thorough documentation in this section of the preliminary file.
Distribution factors will need to be calculated manually when the structure is comprised of glulam beams with a glulam deck or slab bridges. In the case of glulam beams with a glulam deck and girder spacing greater than 6.0 ft., BRASS-Girder may be set to calculate the lever rule for the distribution factors.

8.2.10 Analysis Sections

Determine the spans to be investigated. These should be any span that is unique and is not repeated due to symmetry or due to repetition of a span between joints.

Within each span, check for symmetry of sections, reinforcement and loads, and do not identify any analysis points that are structurally symmetrical with analysis points already defined. Defining analysis points that are structurally symmetrical has the potential effect of corrupting the Load Rating Summary Sheet. Because the “Refresh” module is looking for the lowest Rating Factors, defining a symmetrical point causes it to identify the most critical rating location twice, thus preventing it from identifying the second most critical analysis point. The second controlling point is useful information in evaluating potential repairs for the bridge.

List the analysis sections for flexure. These are normally the positive moments in each unique span and the negative moments over each unique support.
List the analysis sections for bearing. These points will be inputted at the support locations in BRASS. Typical locations for a single span would be 100.000 and/or 110.000.
List the analysis sections for shear. Per AASHTO LRFD 8.7 (Timber Under Shear), the critical section for shear is at d from the face of support, but the live load should be placed at 3d or 0.25L (whichever is less) from the support. BRASS-GIRDER does not have the ability to place the live load at a different location from the analysis point. Therefore, the location d from the support will be used for both the dead and live load.
In the event a more precise live load is required, the distribution factors can be manually entered for the desired live load effect. The ratio of live load at 3d or 0.25L (whichever is less) and d from the support would be used to manually calculate a new distribution factor.
Other locations which either contain a geometry change (i.e. notch in girder) or defect should be checked for moment and/or shear. Timber slab bridges often have boards which are not continuous. These locations should be checked for moment and/or shear.

8.3 Analysis of Girders

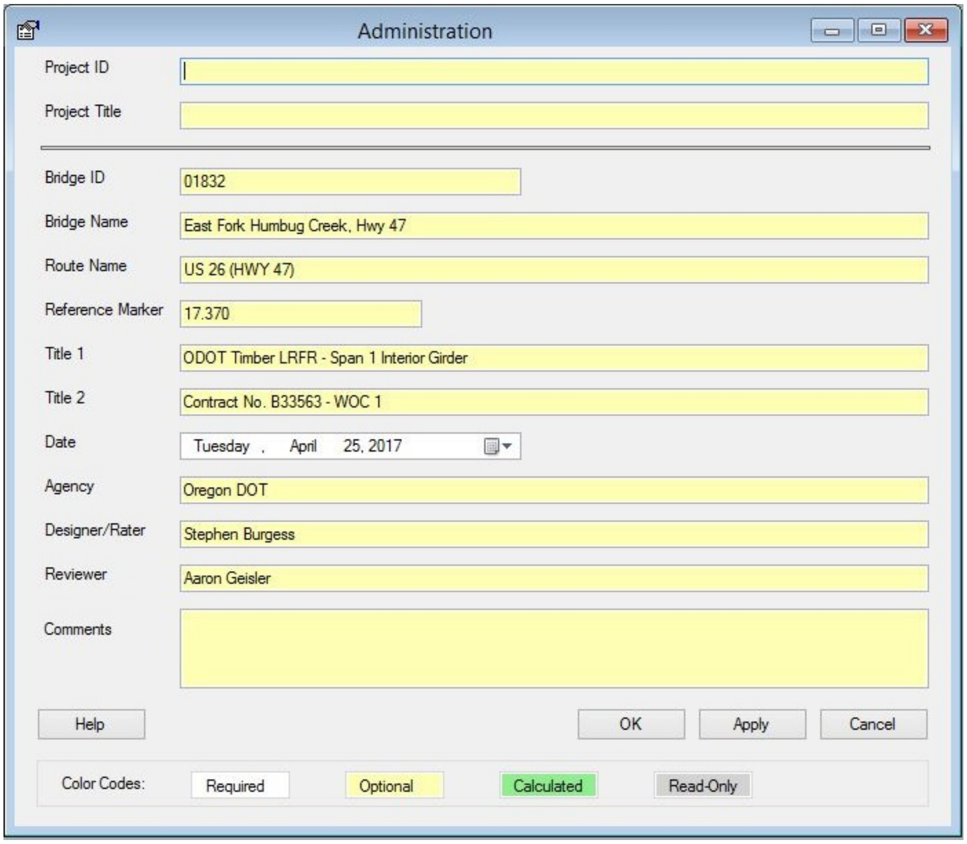
BRASS-GIRDER will be used to load rate timber bridges. BRASS-GIRDER is different from the previous BRASS-GIRDER(LRFD) program in that it no longer uses text file inputs, but instead utilizes a Graphical User Interface (GUI) with data saved in .girder file format. Different from other structure types that use BRASS, timber bridges utilize the GUI for input and analysis.

8.3.1 BRASS Input File Conventions

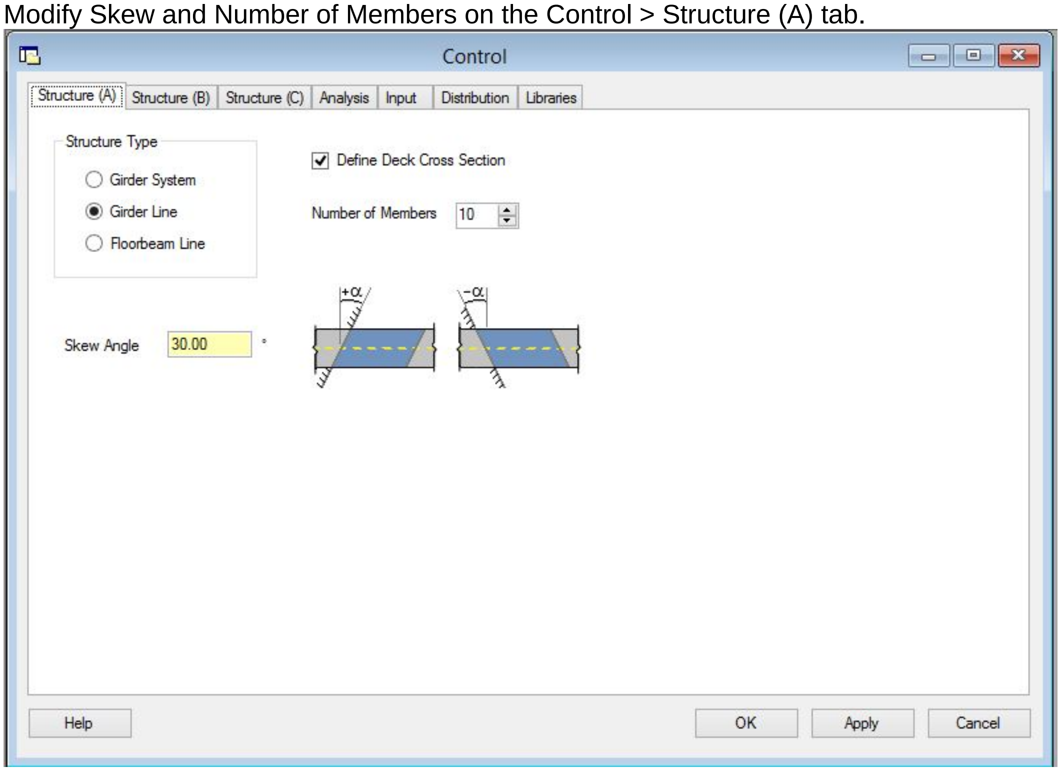
Use the sample files provided as templates to be copied to a new bridge-number-specific folder (with a new filename if appropriate) and then modified for the actual Load Rating. Separate input files will be required for each structure type in any bridge with a combination of structure types, and for interior and exterior girders due to the variability of live load distribution factors in LRFR.

8.3.2 BRASS Input Adjustments

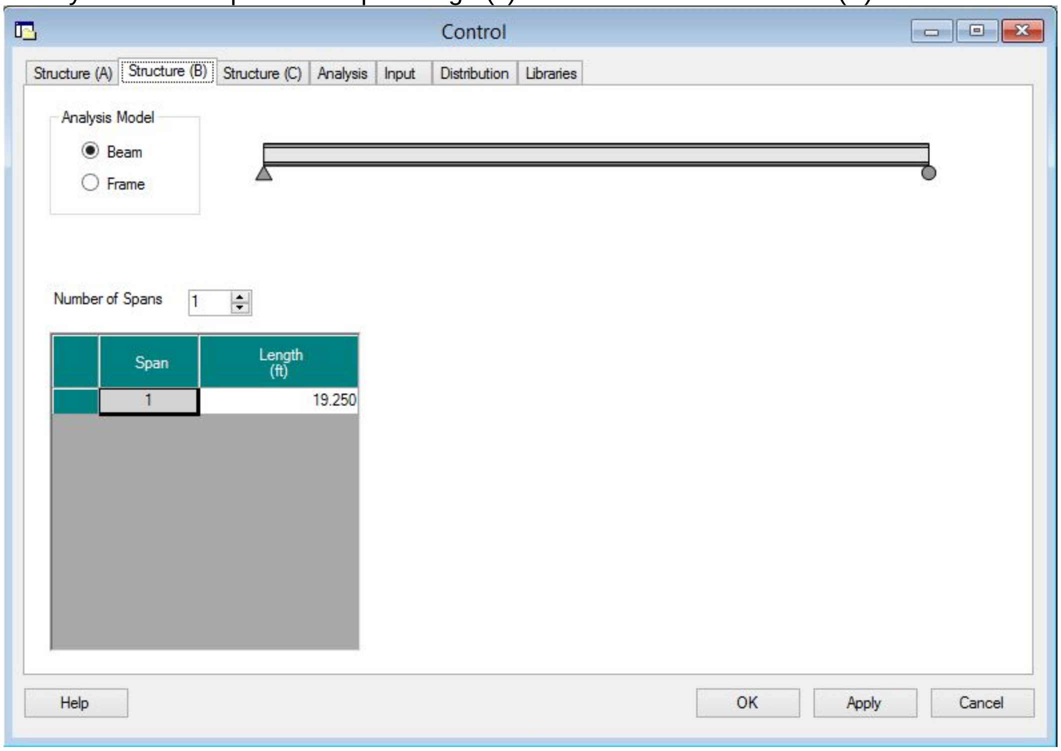
Common tabs that require modification in BRASS are as follows.
Modify the Administration tab with bridge specific information.



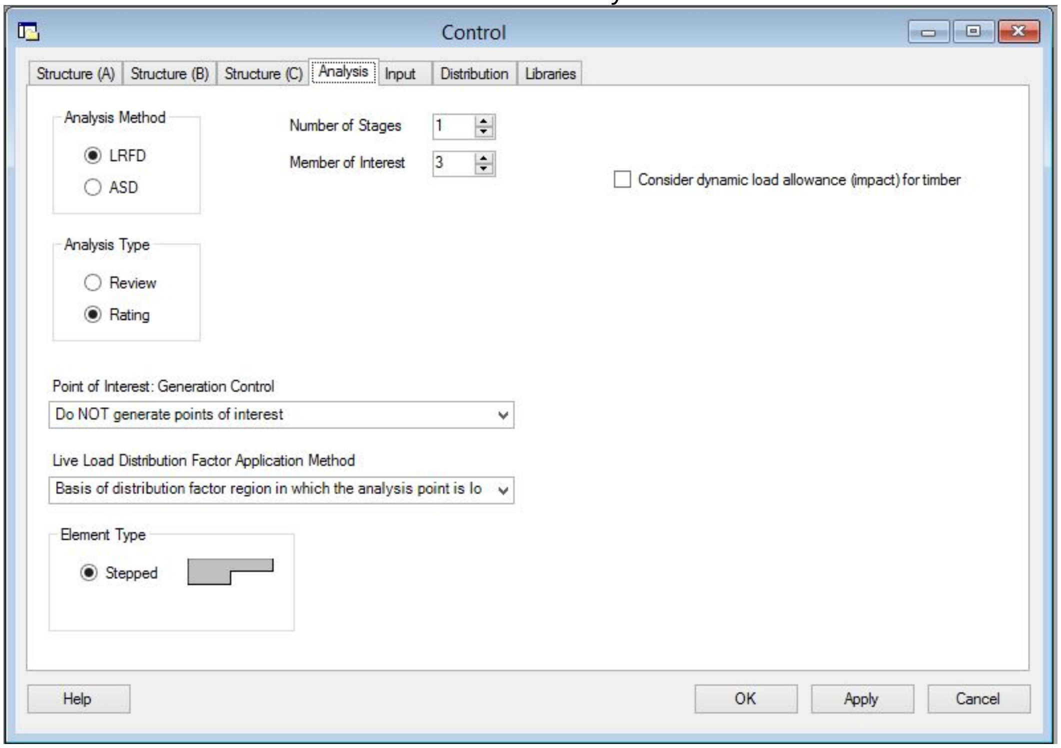
Modify Skew and Number of Members on the Control > Structure (A) tab.



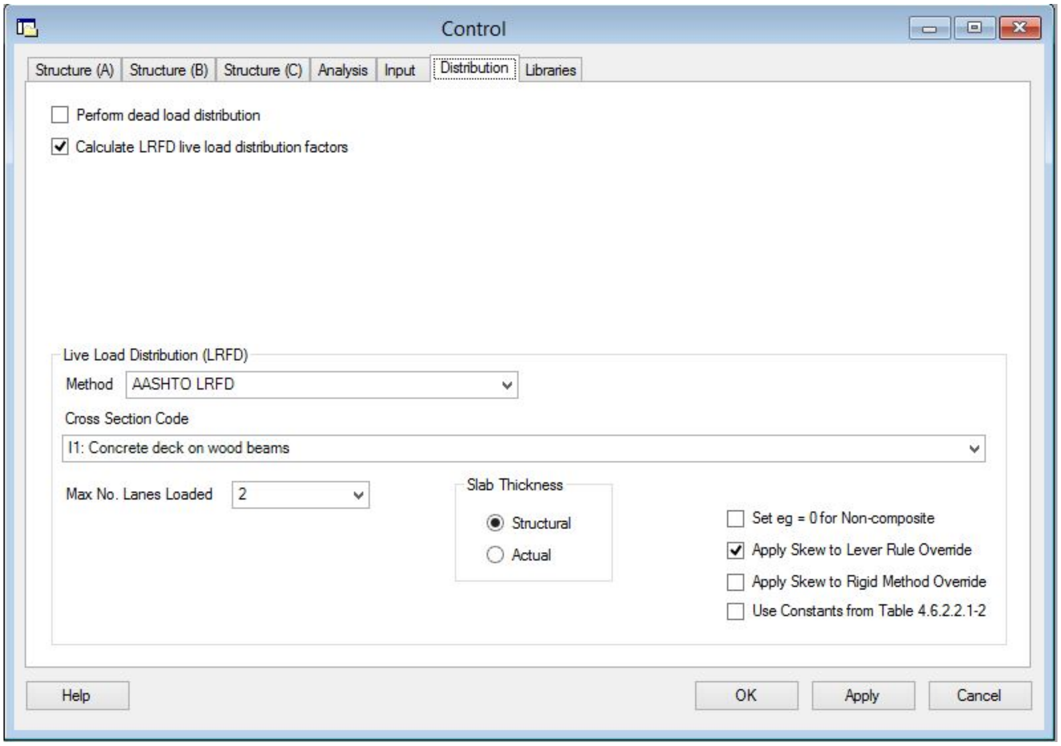
Modify number of spans and span length(s) on the Control > Structure (B) tab.



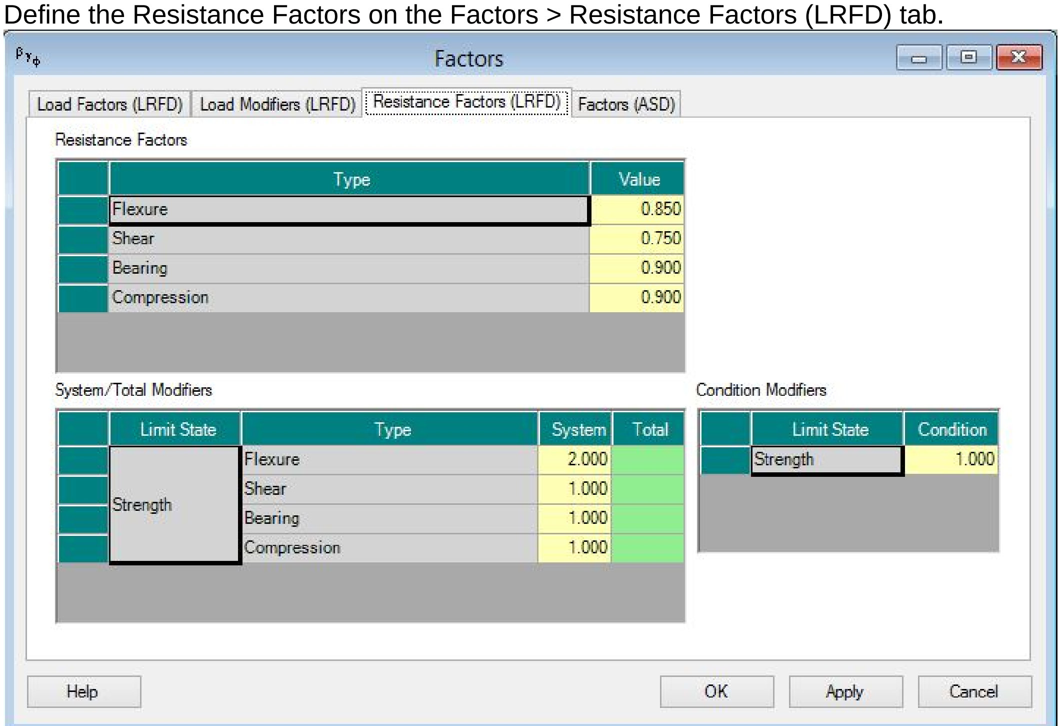
Select the member of interest on the Control > Analysis tab.



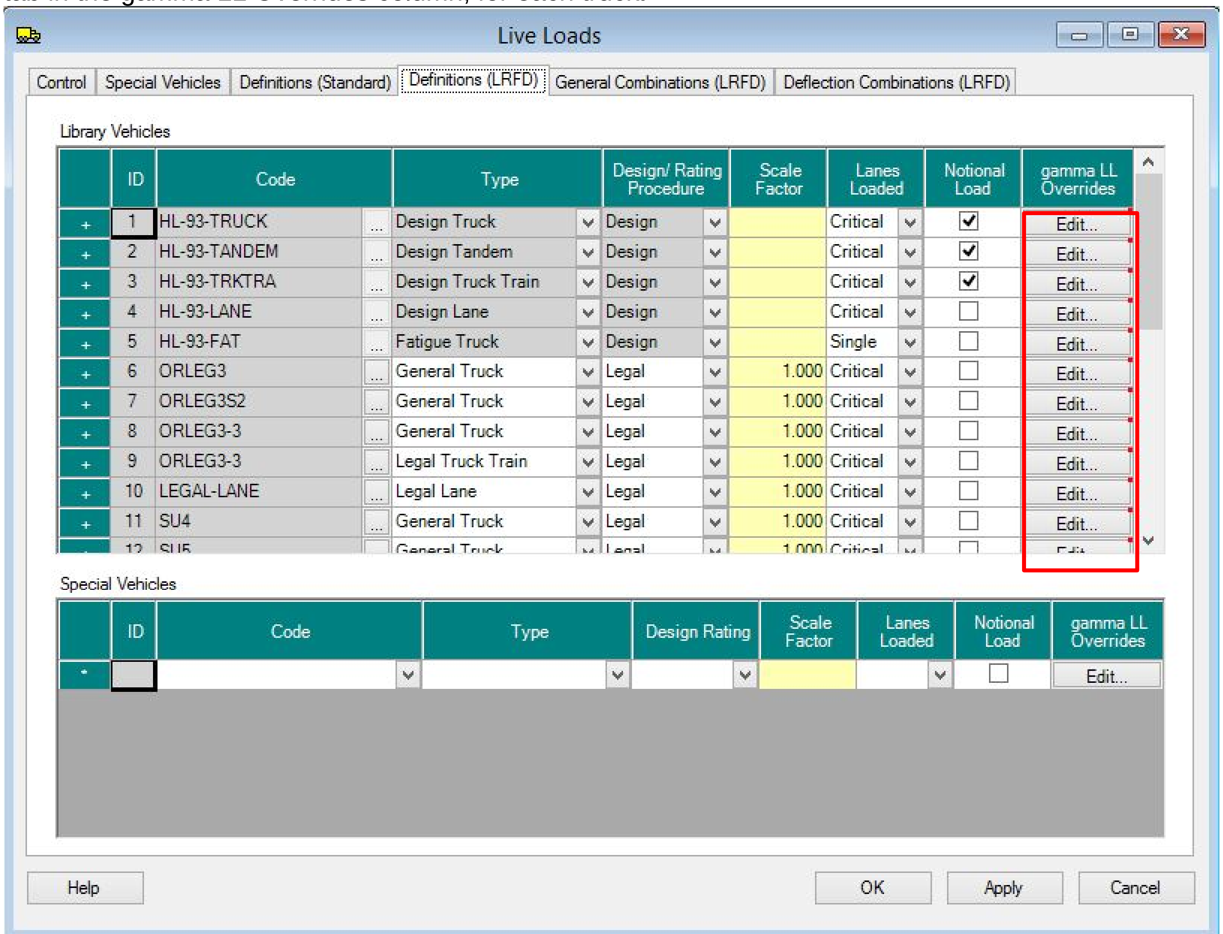
Select the distribution method on the Control > Distribution tab.



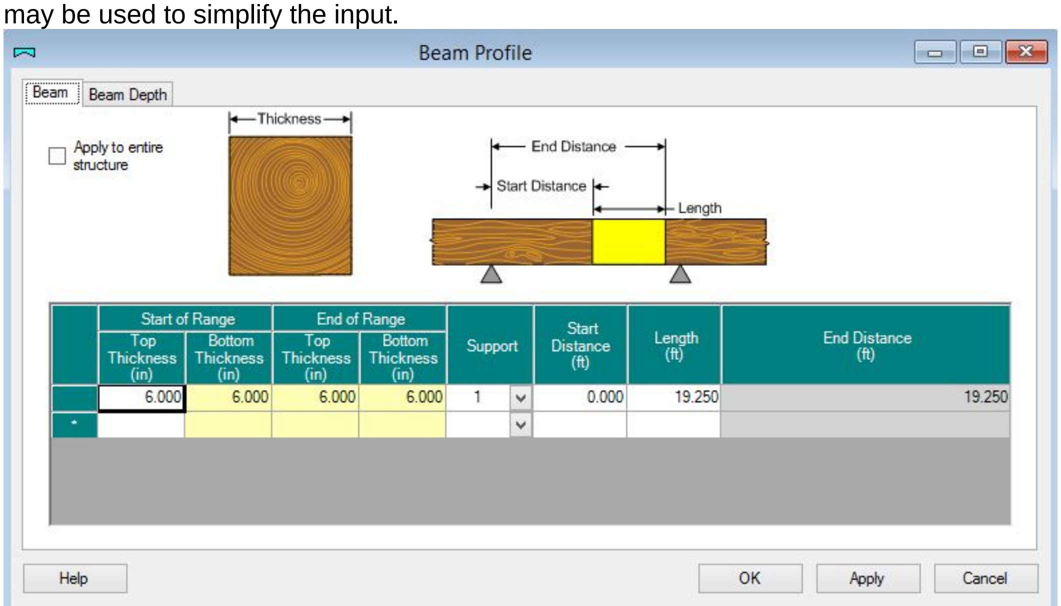
Define the Resistance Factors on the Factors > Resistance Factors (LRFD) tab.



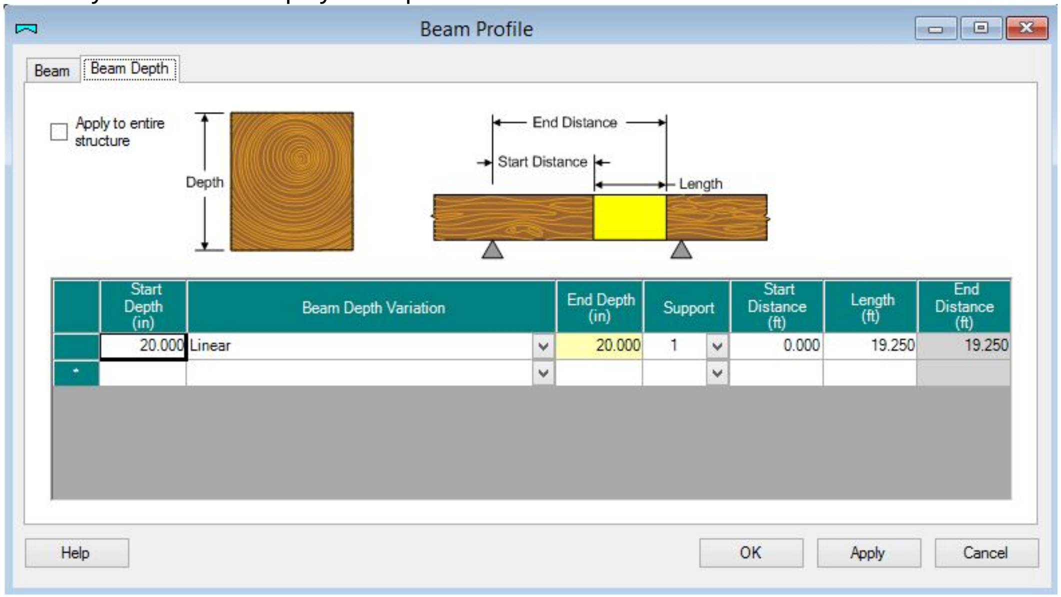
Since Live Load Factors vary for each truck, enter the live load factors on the Live Load > Definitions tab in the gamma LL Overrides column, for each truck.



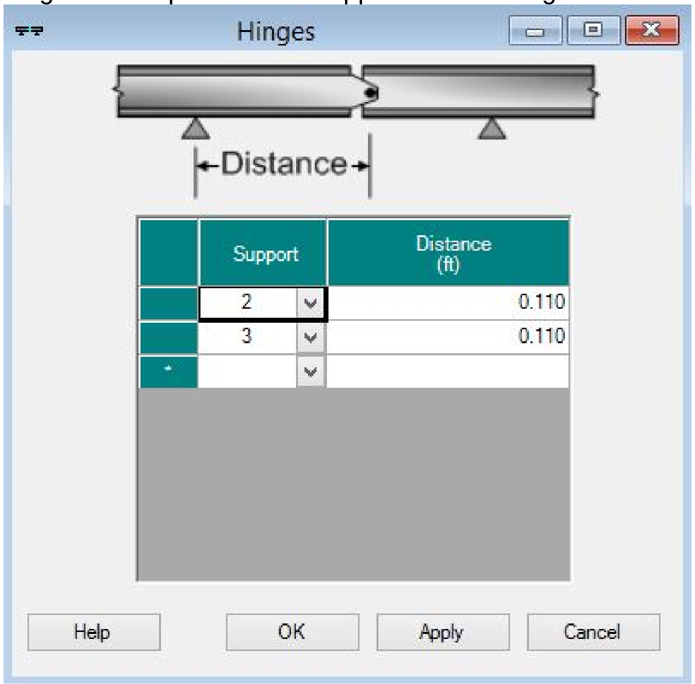
Modify the beam width on the Beam Profile > Beam tab. The “Apply to entire structure” check box may be used to simplify the input.



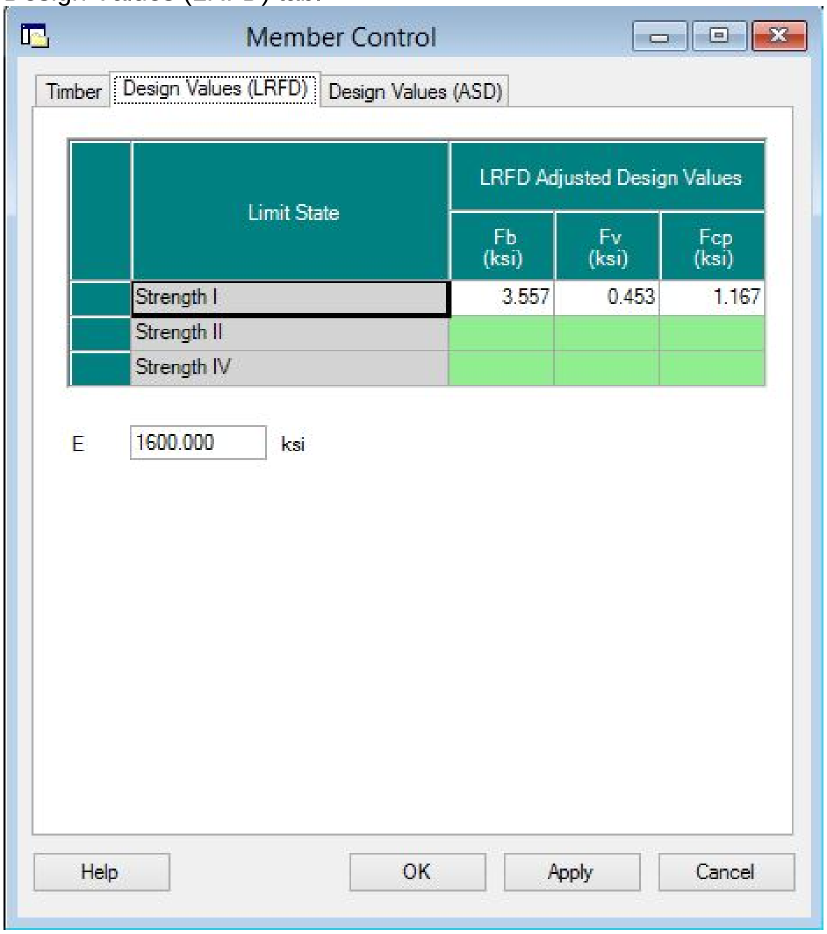
Modify the beam depth on the Beam Profile > Beam Depth tab. The "Apply to entire structure" check box may be used to simplify the input.



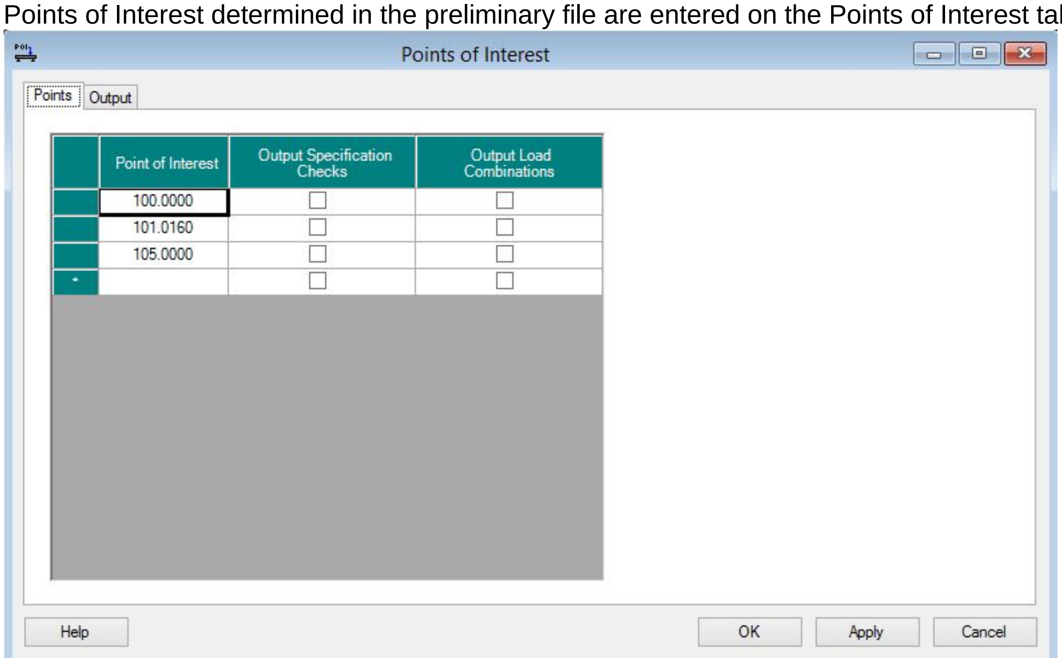
For multi-span bridges that are simply supported and all spans are entered into the BRASS file, hinges are required at the supports. Place hinges at 0.110 ft. from the support on the Hinges tab.



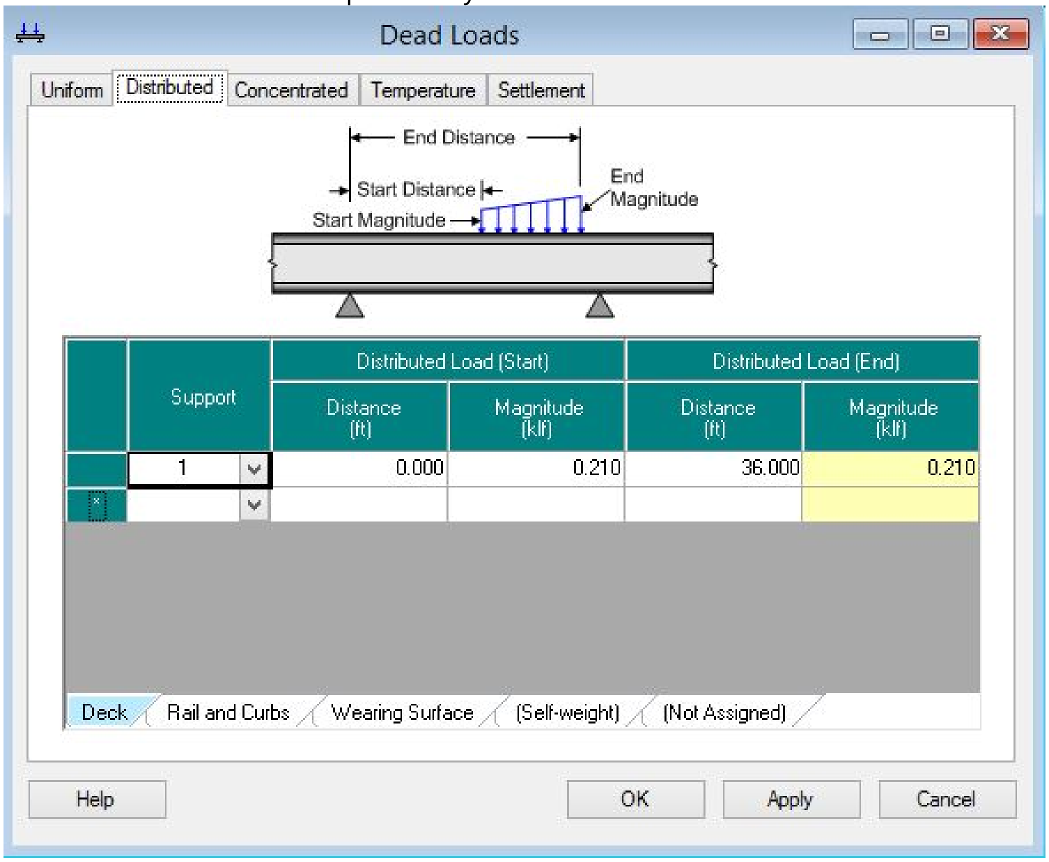
The design reference values calculated in the preliminary file are entered on the Member Control > Design Values (LRFD) tab.



Points of Interest determined in the preliminary file are entered on the Points of Interest tab.



Dead loads calculated in the preliminary file are entered on the Dead Loads tabs.

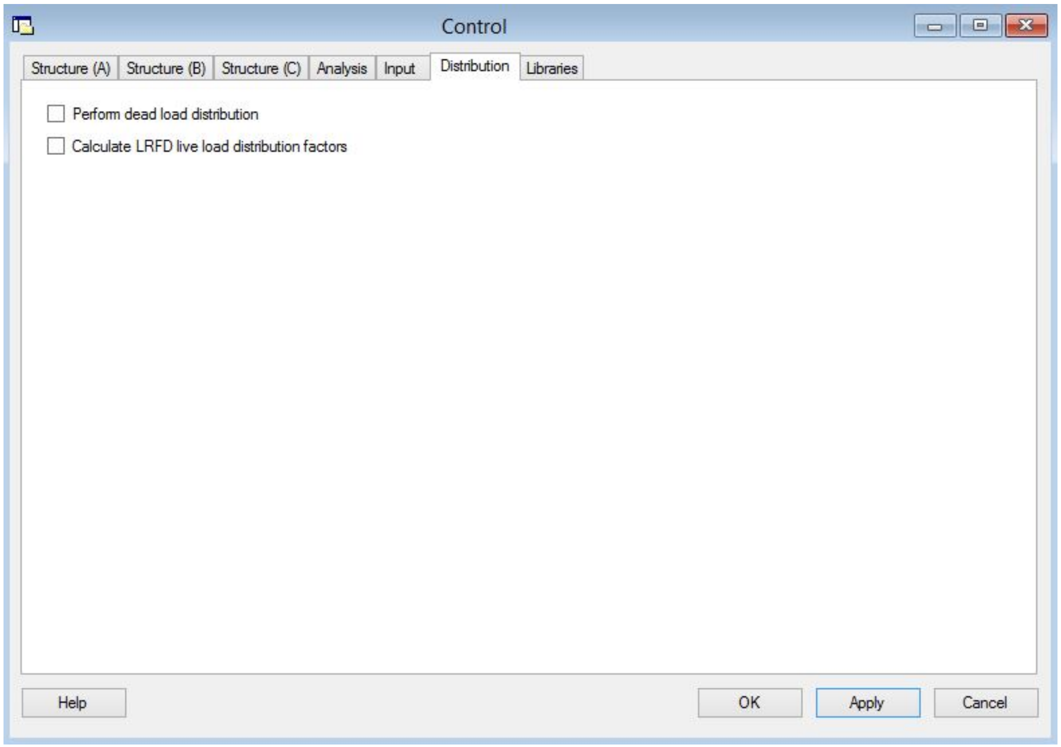


8.3.2.1 Modifications to Preliminary Files & BRASS Codes Based on Bridge Type

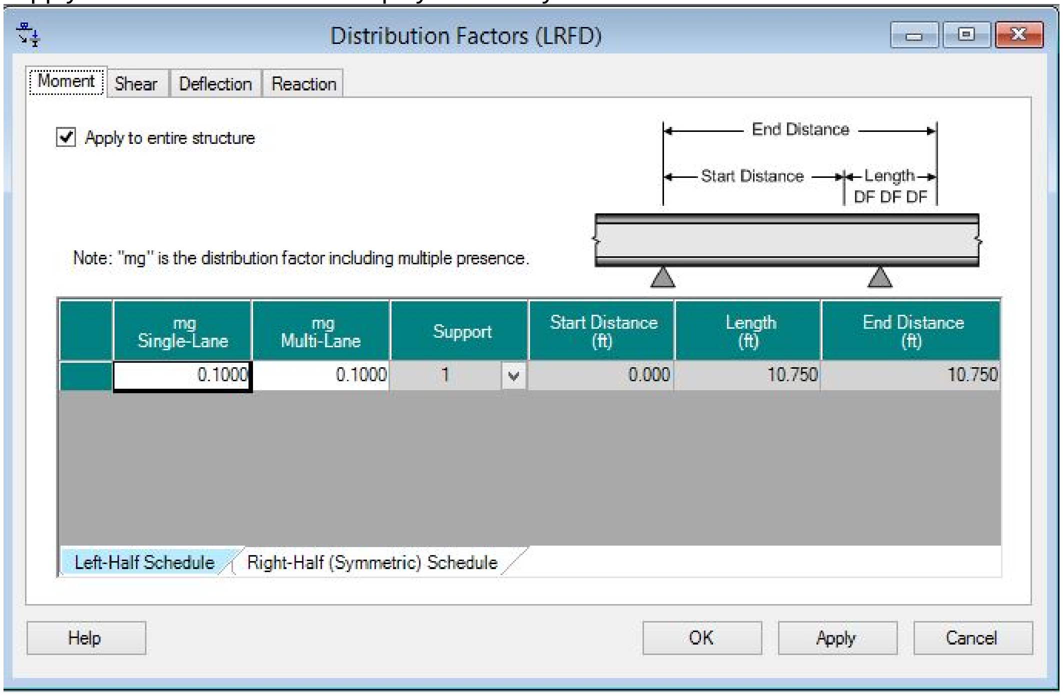
8.3.2.1.1 Modification 1: Manually Entering Distribution Factors

In cases in which distribution factors are manually calculated in the preliminary file, different inputs are required in BRASS to allow the manual entry of the distribution factors. Below are the changes required to allow entry.

Uncheck “Calculate LRFD live load distribution factors” on the Control > Distribution tab.



Distribution Factors (LRFD) tab is now visible and will allow entry of distribution factors. Click the “Apply to entire structure” to simplify data entry.

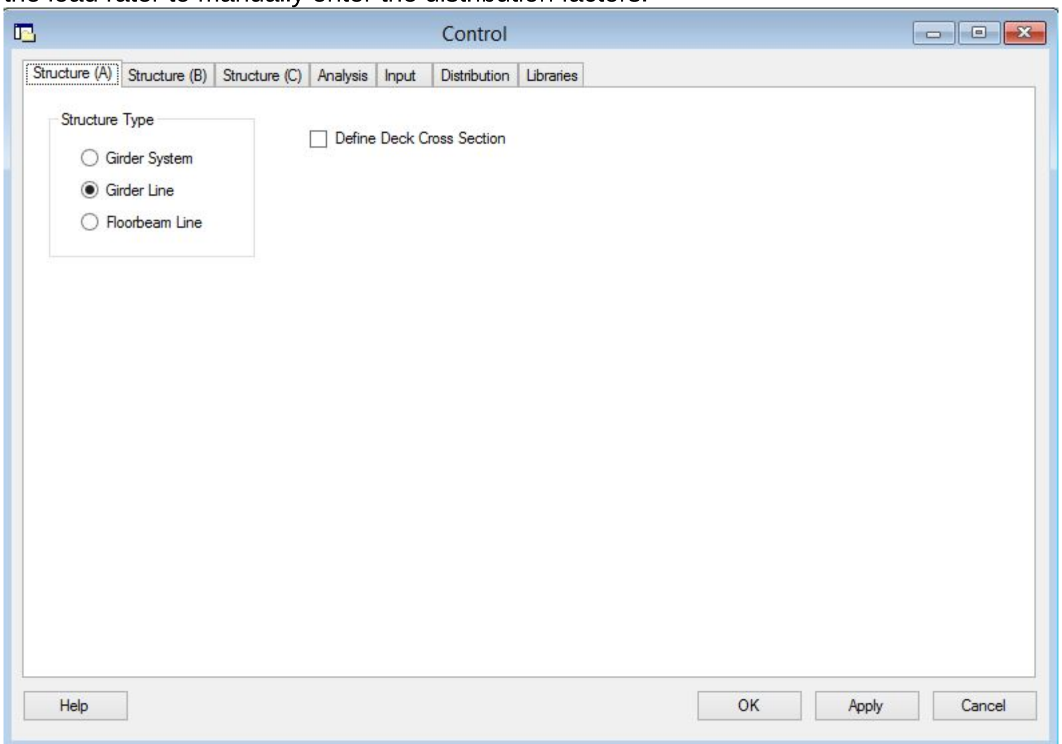


8.3.2.1.2 Modification 2: Timber Slab Bridge

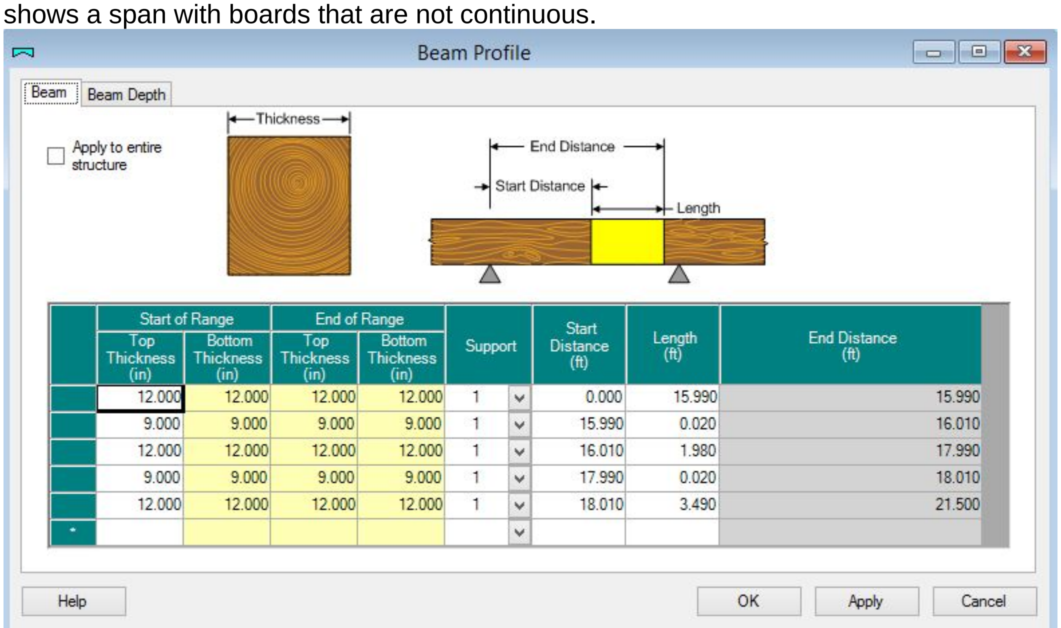
BRASS currently is not configured to run timber slab bridges. Therefore, modifications have to occur in both the preliminary file and BRASS file to analyze this type of structure.

The entire equivalent strip width is typically not entered into BRASS for the beam width. A unit width of 12in. is typically used. In cases where the bridge has slab boards with defects (cracked, decayed, etc.) within the strip width, it may be better to analyze the entire strip width in BRASS. Alternatively, the load rater would ratio the width of the section according to the number of members' defective. The distribution factors are calculated in the preliminary file based on the equivalent strip width equations from AASHTO Article 4.6.2.1.3 and 4.6.2.3. Article 4.6.2.3 is used for spans greater than 15ft. and the span is primarily in the direction parallel to traffic.

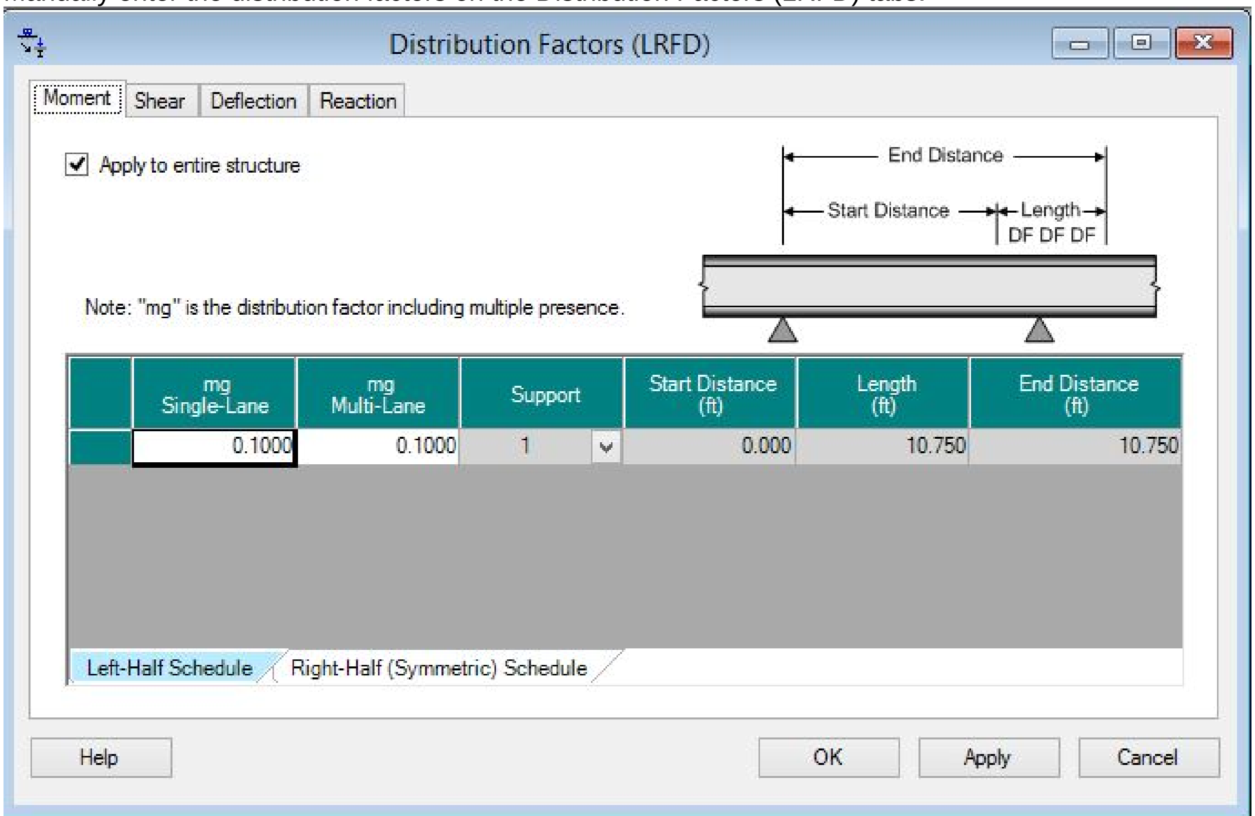
Uncheck the "Define Deck Cross Section" check box on the Control > Structure (A) tab. This will allow the load rater to manually enter the distribution factors.



Enter the beam width for the unit width selected on the Beam Profile > Beam tab. The example below shows a span with boards that are not continuous.

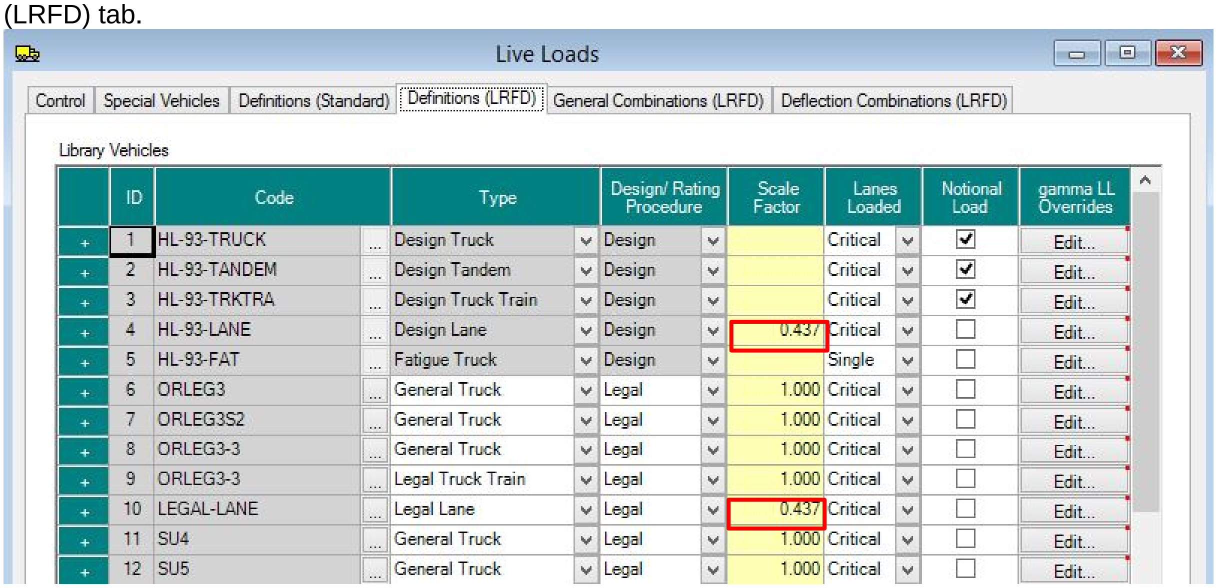


Manually enter the distribution factors on the Distribution Factors (LRFD) tabs.



The edge strip in the preliminary file requires special calculations and data entry into BRASS. The tributary area of the lane may be larger than the edge strip which requires the lane loads be scaled accordingly.

The Scale Factor for the Design Lane and Legal Lane is modified on the Live Loads > Definitions (LRFD) tab.



8.3.3 Generating BRASS "_N" File

When temporary repairs are present on a timber bridge, an "_N" file is required. The purpose of the "_N" file is to analyze the bridge as though the temporary repairs are not present, for design vehicles only. NBI Items 58, 59, 60, 64, and 66 are based on temporary repairs not being present. If temporary repairs are present, NBI Item 103 should be coded 'T'.

Depending on the type of temporary repair, the load rater may need to create a separate preliminary file for the "_N" file. A temporary bent would be an example of when a separate "_N" preliminary file is required.

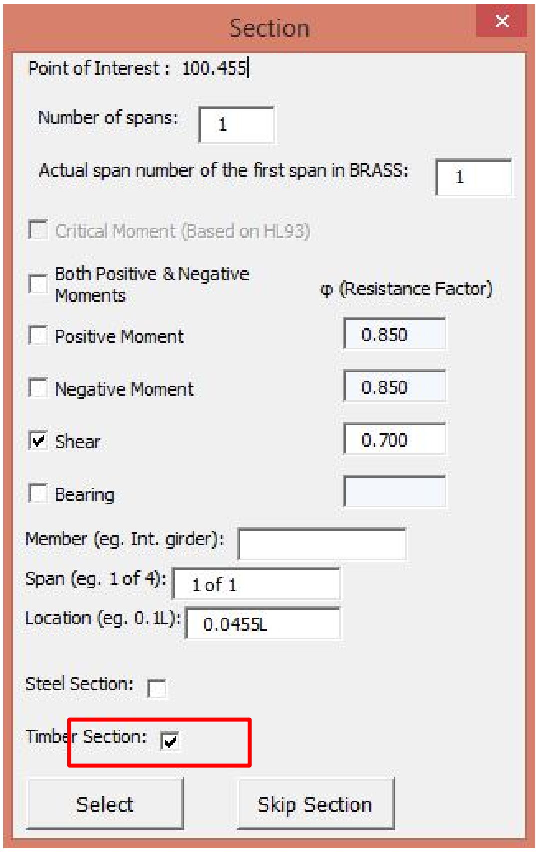
File naming convention should stay the same as the files for the load rated members, but with the addition of "_N" at the end of the file name.

8.3.4 BRASS Input Files

BRASS .girder files generate a .html version of the input data and saves it in the same folder as the .girder file. The .html file should be printed and included in the calculation book.

8.3.5 BRASS Output Files

Use the latest version of BRASS-Girder (7.5) Load Rating Summary Sheet. Check the "Timber Section" check box on the Section tab.



8.4 Exterior Girder Analysis

Use the interior girder files as a starting point for creating the exterior girder files. Most of the interior girder file will still apply for the exterior girder analysis. Because the interior file is used as a starting point, it is suggested to not begin the exterior girder analysis until thorough checking of the interior files have been completed. Any mistakes found in the interior file would likely also be mistakes in the exterior file.

8.4.1 Generating an Exterior Girder Preliminary File from an Interior Girder File

For the typical un-widened timber structure where the exterior girder design is the same as the interior girder, the task of generating an exterior girder preliminary file from the corresponding interior girder preliminary file generally consists on the following steps:

(1) Make a copy of STR_INT.xmcd and rename it STR_EXT.xmcd.

(2) Change the title (first header).

(3) Eliminate all the calculation sections above “Component dead loads (DC)”
and replace them with the statement “All factors and material properties are the same as for the interior girders (see STR_INT.xmcd)”.

(4) Revise the calculations for actual flange width for girder dead load (over-hang width combined with half the adjacent girder spacing).

(5) Revise the calculations for dead load of the diaphragms.

(6) Revise the calculations for liveload distribution factors (if, for some reason, the live load distribution factors are being manually calculated).

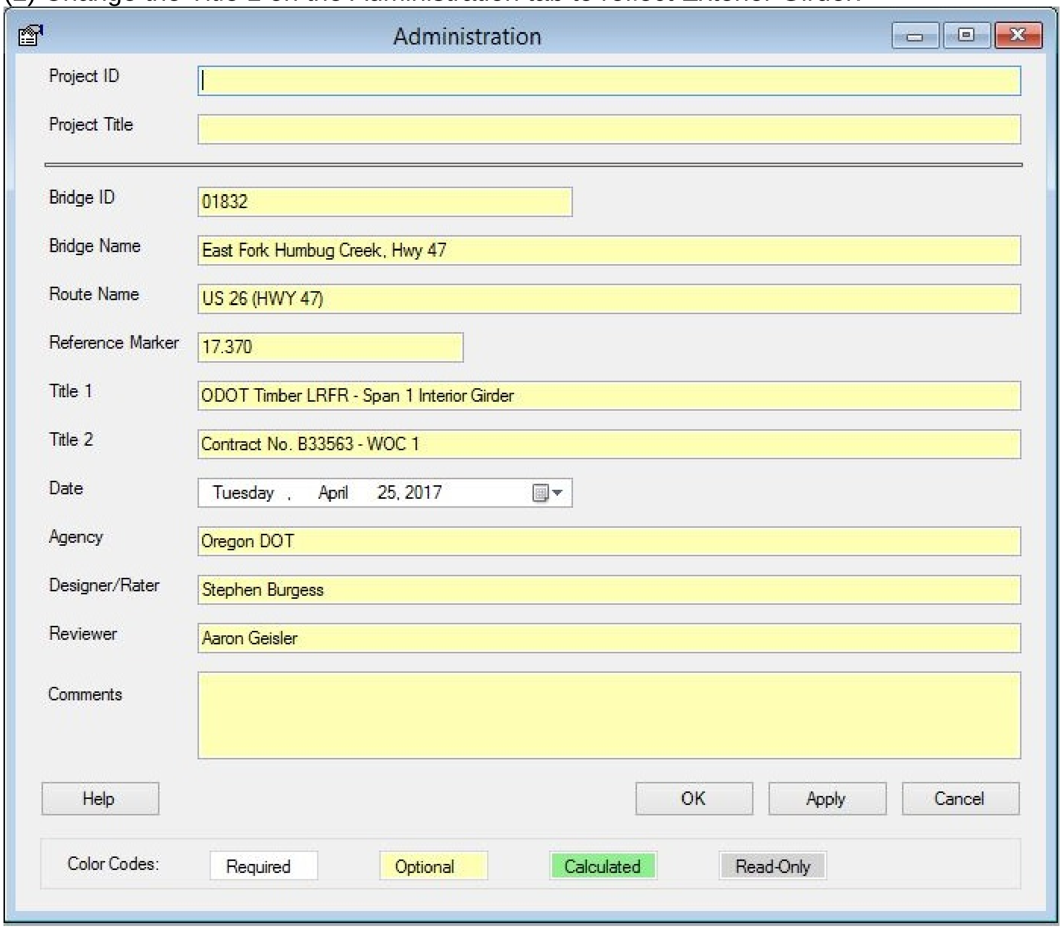
(7) Eliminate all the calculation sections after “Wearing Surface dead loads (DW)” and append the statement “All live loads, Girder Geometry & Analysis Sections are the same as for the interior girder (see STR_INT.xmcd)”.

8.4.2 Generating an Exterior Girder BRASS Input File from an Interior Girder File

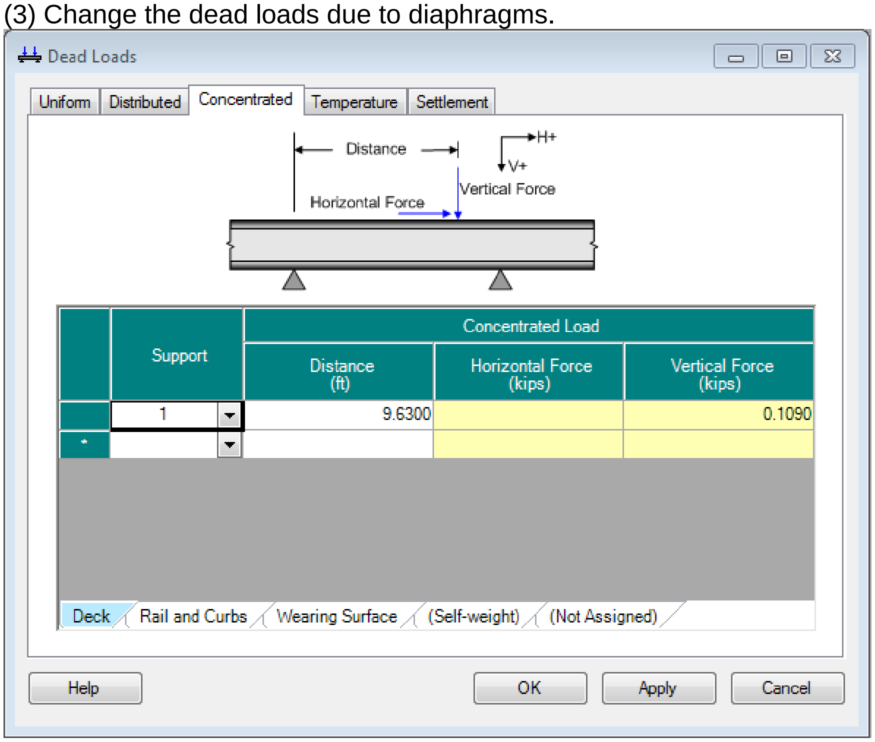
For the typical un-widened timber structure where the exterior girder design is the same as the interior girder, the task of generating an exterior girder BRASS input file from the corresponding interior girder BRASS input file generally consists on the following steps:

(1) Copy **STR_INT.girder** to **STR_EXT.girder**

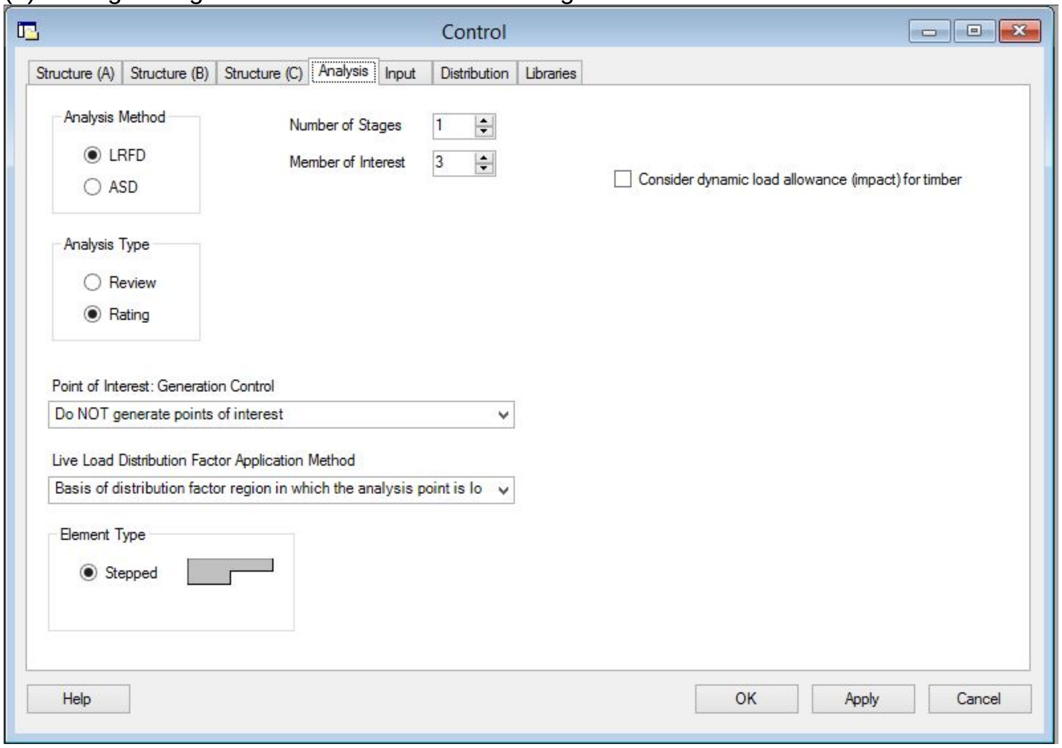
(2) Change the Title 1 on the Administration tab to reflect Exterior Girder.



(3) Change the dead loads due to diaphragms.



(4) Change the girder of interest to the exterior girder.



SECTION 9: LOAD RATING STEEL TRUSS BRIDGES

This chapter covers the load rating of primary steel truss members. Truss members have a wide variety of section configurations. The tools described in this chapter are intended to cover the majority of the sections used on State owned trusses, but shouldn't be considered all inclusive. Contact the load rating section if a unique truss section is encountered that isn't covered by the program. The tools currently accommodate various built-up box section configurations, rolled w-sections, double L's with cover plates, double L's with battens or spacers, and various built-up w-section configurations.

The load rating of gusset and splice plates is not covered in this chapter. Reference section 7 of this manual for the load rating of steel roadway stringers and section 19 for steel floor beam load rating.

9.0 Scoping of Structure

Create a scoping file (nnnnnn_scope.xls) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended effect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0 then, there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

9.1 Analysis Approach

Oregon's steel truss population is primarily composed of built-up box shapes. Bridge engineers detailed cross-sections composed of multiple standard shapes connected with lacing, battens, and plates. The variety of cross-section configurations has been addressed by developing analysis tools that can be modified to accommodate new sections. If the load rater feels that a cross-section is not covered by the current tools, they should contact the Load Rating group for further guidance.

Dead load and live load force effects are calculated using a 2-D finite element analysis in Midas Civil. ODOT has chosen to model trusses as pin connected elements (no flexure). Individual member capacities are calculated using TRUSS_ELEMENT.xlsm. TRUSS_ELEMENT.xlsm is a Microsoft Excel based tool that uses macros to automate the calculation of element capacities. Load effects from the Midas model are factored and rating factors are calculated in nnnnn_TRUSS_LRFR.xlsm.

9.2 Preliminary Files for Girders (Mathcad)

For steel trusses, the preliminary (Mathcad) file name and extension for bridge number "nnnnn" is typically nnnnn_TRUSS.xmcd. For example Cripple Creek with bridge number 08990 would have a preliminary file name of 08990_TRUSS.xmcd.

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied terms with parentheses.

9.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater, date (2nd line left), File Name, and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description ("Spans" field) from the Bridge Log is adequate for this purpose.

Note: The Mathcad regions in the top right margin (outside the printable area) are there for two purposes. The unit definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

9.2.2 Resistance Factors

Document the decisions regarding all 3 resistance factors, condition factor, and system factor, with references to the appropriate MBE tables or AASHTO LRFD tables.

Calculate the combined resistance factor for axial compression, tension fracture in the net section, and tension in the gross section. The combined resistance factors are calculated by nnnnn_TRUSS_LRFR.xlsm.

9.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into nnnnn_TRUSS_LRFR.xlsm. The Load Rating Summary Workbook **(LR.XLT)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.xlsm.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.xlsm.** The two inputs are ADTT (one direction) and effective bridge length. Note that effective bridge length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which Live Load Factor Application is used, ADTT is specified as "one direction". Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the Live Load Factor Application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the Live Load Factor Application (either **LL_Factors_State.xlsm** or **LL_Factors_Local.xlsm** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the “LRFR Strength I & II” table from the live load factor application, and in Mathcad use Edit / Paste Special. In the “Paste Special” dialog box choose the “Paste” button, highlight “Bitmap” in the “As” list, and click the “OK” button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to MBE 6A.4.4.3.

9.2.4 Distribution Factors

nnnnn_TRUSS_LRFR.xlsm can be used to calculate the distribution factors. It calculates distribution factors using the lever rule method. Two distribution factors are calculated; for a single lane loaded, and for multiple lanes loaded. The multiple presence factors specified in AASHTO LRFD Table 3.6.1.1.2-1 are included when determining the live load distribution factor for 2, 3, and 4 lanes loaded. If distribution factors are calculated externally to nnnnn_TRUSS_LRFR.xlsm, document the calculations in the preliminary file.

9.2.5 Material Properties

Document the yield and ultimate strength of all primary elements. The ultimate strength of fasteners used in built-up sections will also need to be documented. If the material properties are not listed in the bridge plans, document how the assumed values were derived. Section 1.4.5 of this manual can be referenced for guidance on selecting steel values based on year of construction.

9.2.6 Bridge Average Geometry

Show calculations for the following bridge geometry used to calculate distribution factors; centerline of truss to centerline of truss, centerline of bridge to centerline of left truss, roadway width, face of left curb to centerline of bridge, and maximum span length.

9.2.6.1 Node Geometry

Document the node locations that will be used for the Midas model. Using an excel spreadsheet will allow the user to copy and paste the node locations from the excel table directly into the Midas model. In addition to defining nodes for each panel point location, the load rater will need to define nodes for the roadway. The roadway nodes will typically be offset vertically from the lower panel point nodes and then attached with rigid links (See section 10.4.8).

9.2.6.2 Element Properties

Throughout the load rating the element number will be used to reference the truss members. It is essential that the element numbers are consistent across the Midas model and capacity calculations. The element numbers are used to reference capacity to load effects when calculating rating factors. Include a elevation view of the truss with the element numbers labeled.

Section properties are typically calculated by TRUSS_ELEMENT.xlsm and the text output files can be reviewed by the load rating engineer. Document any preliminary calculations that are necessary to determine the required user input for TRUSS_ELEMENT.xlsm. At a minimum the unbraced length of the element will need to be calculated for buckling about the x and y axis. Common practice is to automate the calculation of the effective area for tension capacity calculations. If the effective area calculation is not automated, then document the calculations of the net area and shear lag factor for each element.

9.2.7 Component Dead Loads (DC)

The load path should be considered when determining dead loads. For example, although the deck self-weight is a uniform load, its load path is typically stringers to floor beams which are supported by the truss. Therefore, the deck dead load should be applied as a point load where the floor beam connects to the truss. Include dead load calculations for cross bracing, portals, stringers, and floorbeams. The self-weight of primary members will be included in the Midas analysis.

The dead load of fasteners, lacing, battens, and gusset plates is typically accounted for in the load rating with a self-weight factor. The self- weight factor is separate from the dead load factor. The effect of the self-weight factor is to increase the overall self-weight to account for dead load that wasn't included in the Midas Model and is only applied to the static loads that are defined under the "SW" load case. The recommended value for the self-weight factor is 1.35, but the value used is left up to the judgement of the load rating engineer. Loads applied under the DC static load case will not be amplified by the SW factor.

To avoid confusion, dead loads should be grouped under the headings DC and DW in the Preliminary File (**.xmcd**) and entered in the Midas model as separate load cases. Use AASHTO LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c. For dead load calculations, use w_c+0.005 kcf to account for the reinforcement, in accordance with AASHTO LRFD commentary C3.5.1.

Where standard rail drawings occur, use the rail dead loads tabulated in Appendix H – ODOT Standard Rail Weights, found in file **RAILDL.xlsm**. Provide detailed calculations for the dead load of any rail not found in this summary.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16" diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to be included in the load rating.

9.2.8 Wearing Surface Dead Loads (DW)

Always separate wearing surface dead load (DW) from the component (DC) dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes and (c) it facilitates input for the crossbeam load rating software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Show calculations for wearing surface dead load distributed equally to all the girders. Add 1" to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½" to the design thickness of PPC overlays to account for construction variations and uncertainty.
Add a point load at the center of bearing to account for the dead load of the wearing surface that extends beyond the center of bearing (the red shaded area illustrated in Article 5.2.5), if a crossbeam analysis is warranted. Even though this load will have no impact to the load rating of the girder, it will be utilized when applying the girder dead load reactions to crossbeams.

9.2.9 Live Loads (LL)

List the four classes of rating loads to be analyzed. (See Articles 1.5.1.1 through 1.5.1.4).

9.2.10 Analysis Sections

Indeterminate and continuous trusses can make it challenging to determine which members should be analyzed for compression only, tension only, or both. The application of the AASHTO HL-93 lane load and truck train combinations can cause load reversals that weren't considered during the original design. Therefore, the TRUSS_LRFR.xlsm program will automatically calculate tension and compression rating factors for each analyzed member. Document any decisions about zero force members or other members that were determined to not warrant analysis. The summary sheet will automatically remove rating factors for members with zero live load effects.

9.3 TRUSS_ELEMENT.xlsm

TRUSS_ELEMENT.xlsm is a Microsoft Excel based tool that was developed by ODOT for determining the axial capacity of built-up steel members. Text output files are generated by the macros to document the capacity calculations. Two output files are generated for each member; one for compression and one for tension. The TRUSS_ELEMENT.xlsm workbook is just a tool to generate the input and output text files. The file doesn't store information specific to the load rating. Therefore, do not include this file as part of the load rating deliverables.

Truss members have a wide variety of section configurations. The truss element program is intended to cover the majority of the sections used on State owned trusses, but isn't considered all inclusive. Contact the load rating section if a unique truss section is encountered that isn't covered by the program. Depending on the programming level of effort, and the number of trusses with that section, the capacity will either be calculated independently of the TRUSS_ELEMENT.xslm tool, or the section will be added to the tool.

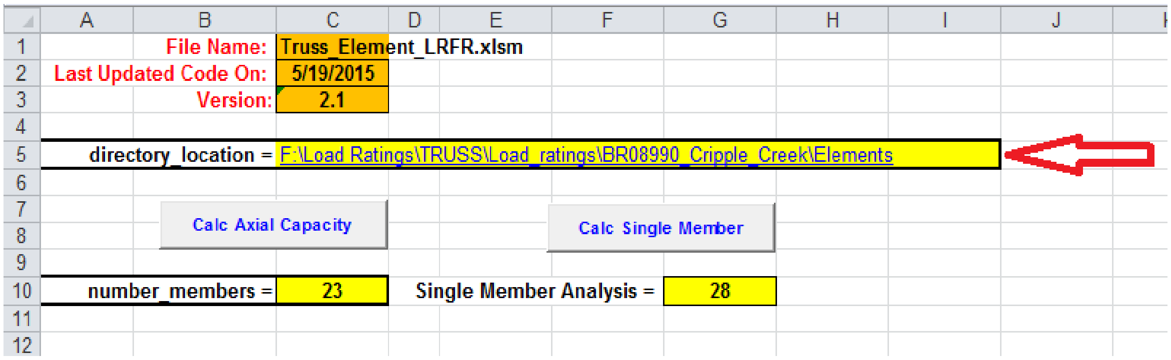
Each unique truss section configuration has its own worksheet within the TRUSS_ELEMENT.xlsm workbook. The sections covered by the tool are updated frequently as new section configurations are encountered. Contact the load rating group if a section that is encountered that isn't supported by the tools.

Cells throughout the worksheet are color coded to provide the load rater guidance. Orange cells are typically standard values that do not require the load rater to modify. Yellow cells required input.

Built-up box sections have up to 142 cells for user input. However, as the load rater defines the specific section type, the amount of input is significantly reduced. To help clarify what input is required for the section of interest, macros are used to hide rows that contain data fields that are not required. The macros are activated automatically as data is input.

9.3.1 General

The load rater will need to designate a directory where the program will create the input and output text files. It is recommended that a folder titled Elements be created within the load rating file to store these files. Input the file path in the directory_location field in the General worksheet.



When the text input files are created with the Truss_Element workbook the output capacity files are automatically generated. However, it is also acceptable to manipulate the text input files directly. When the text files are manually created, or manipulated, the load rater will need to calculate the capacity using the buttons on the General worksheet. The load rater can either select individual members or a range of members.

Once all of the primary truss element output files have been created, the load rater can create a text file that will automate the creation of the truss sections for the Midas analysis. Click the “Generate Midas Section Input” button to create a text file that can be run from the Midas MCT command shell. When the command shell is run in Midas it will create a unique section for each member with the element description and gross area.

9.3.2 Section Input

Although each section requires different user input to define the section geometry, there are several fields that are repeated for each section type and are worth highlighting.

- Member number: Input the member number for that element. This must match the element number used in the Midas model. This number is used throughout the load rating to reference this member.
- Member location: Can be either text or numerical. In general the panel points should be used as the member location, for example; “U0-L1”. The member location is not referenced by the macros, but following consistent naming conventions will aid in future review of the load rating. This description will also be used for the Midas section definition.
- Section loss factor: At times the inspection report will document member section loss as a generalized percentage of the total member area. The section loss factor allows the load rater to type in one reduction that will be applied to the entire section. The thickness of each element is uniformly reduced.
- Automate effective area calcs: The sections effective area is used during the tension capacity calculations. However, determining the effective area of these members would require accurate information about the fastener layouts. Not only is this check tedious, but it requires information that isn’t readily available for most trusses. ODOT has chosen to follow the methodology used in the AISC 13th edition. The assumption is that the tensile rupture strength can be calculated using an effective area that is equal to 75% of the gross area. It is felt that this value is practical to achieve with typical end connections. If the load rater suspects that this is either overly conservative or unconservative for a particular member, then the net area, shear lag factor, and reduction factor can be entered.
- Standard shape selection: Throughout the worksheets there are drop down fields that will automate the input for various standard shapes. The standard shapes are per AISC database V14. If the section of interest isn’t found in this table, or it has unique dimensions, the load rater can select “User” on the drop down list to manually enter the geometry.

Once all the user input is filled in for a member click the “Create Member” button at the top of the spreadsheet. This will create the text input and output files in the directory identified on the General worksheet.

Clicking the “Clear and Reset” button will clear all user data for the worksheet and unhide all of the rows that were hidden throughout the input process. If similar sections are being created, it is not necessary to clear and reset between each member.

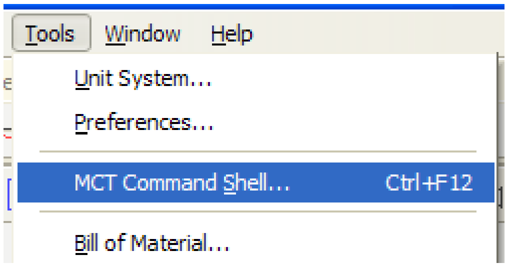
9.4 Midas Civil

Midas Civil is not used to calculate member capacity or rating factors. It is used to calculate member live and dead load effects. Capacity and rating factors are calculated in the Microsoft Excel tools TRUSS_ELEMENT.xlsm and nnnnn_TRUSS_LRFR.xlsm. Midas Civil is a powerful finite element analysis software. The below procedure may be valid on previous versions. If a previous version is used, check the input and output for consistency with this chapter.

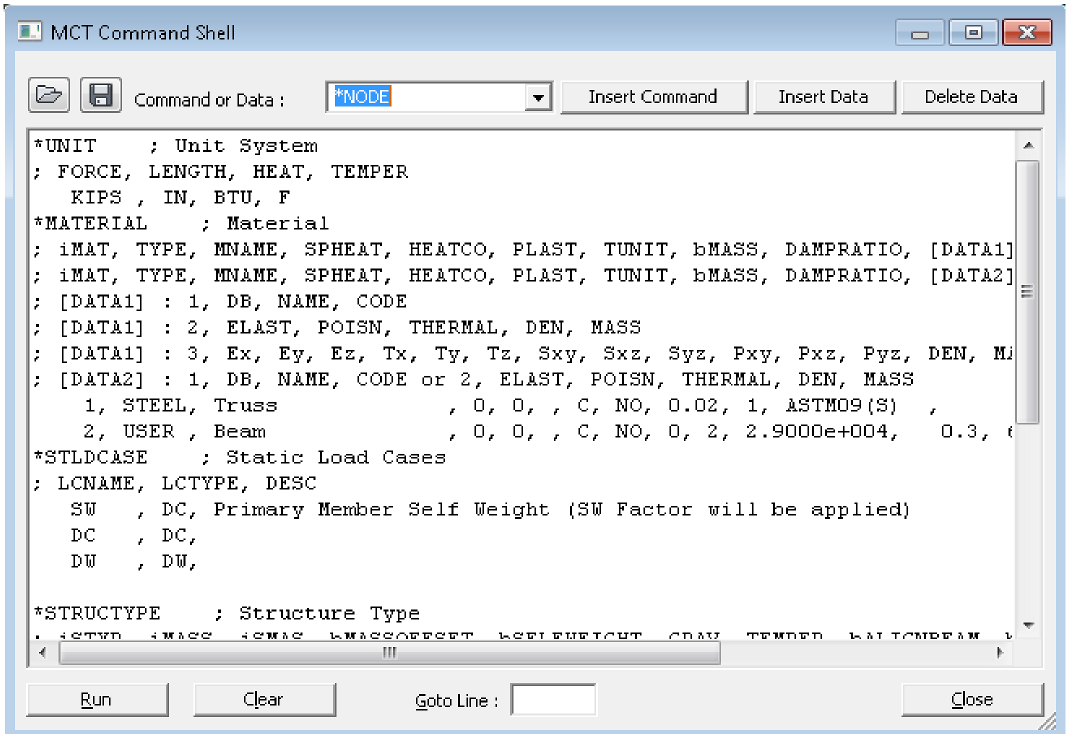
9.4.1 Midas Template

Create a new Midas model and save it with the name nnnnn_TRUSS.mcb.

In the top menu, go to Tools => MCT Command Shell.



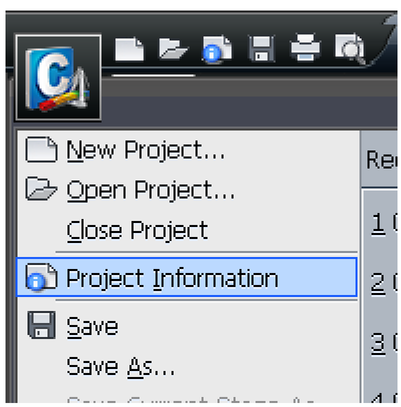
Within the MCT Command Shell, click the open file icon. Open the mct file named "TRUSS_PRELIM.mct", which will populate the MCT Command Shell window with data. At the bottom left of the MCT Command Shell window click on the "Run" button. Then click "Close" at the bottom right.



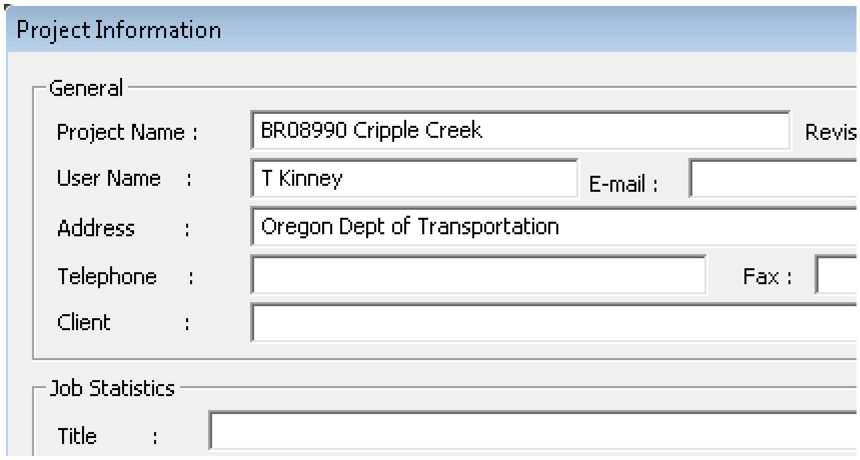
Running the TRUSS_PRELIM.mct file will define the structure type, units, standard load cases, material properties, and turn on the Self Weight load case.

9.4.2 Project Information

In the top menu go to File => Project Information.



Update the project information with the bridge number, engineer's name, and company performing the load rating.



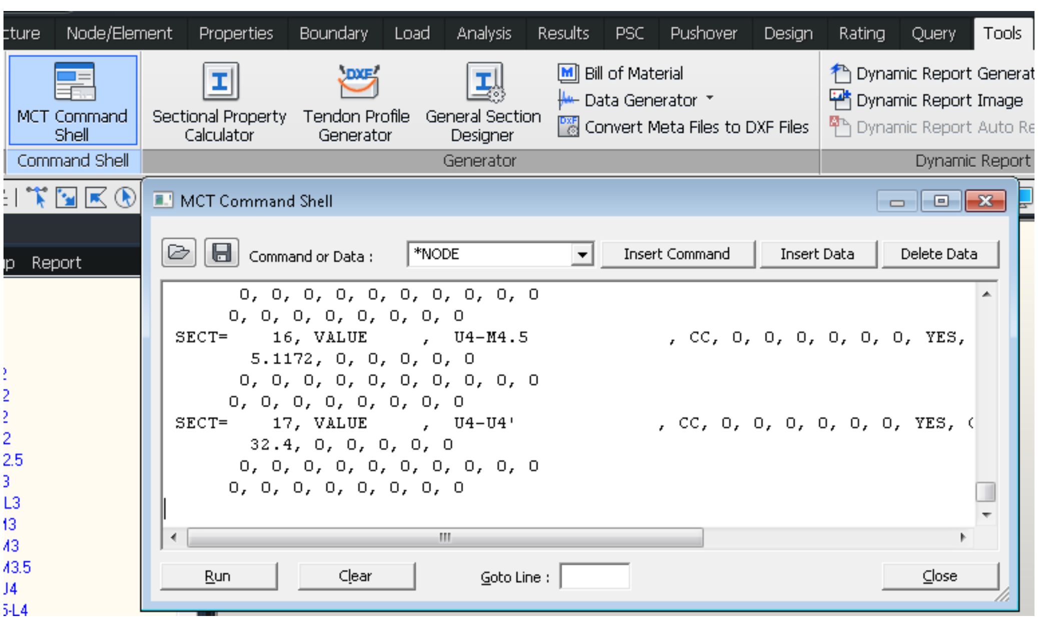
9.4.3 Materials

Two materials have been defined by the command shell; Truss and Beam. The Truss material has a unit weight of 490 pcf while the Beam material is weightless. The Beam material will be assigned to the beam elements which are required to apply live loads to the structure. Update these materials as required. If additional materials need to be assigned go to the top menu under Model => Properties => Materials and select Add.

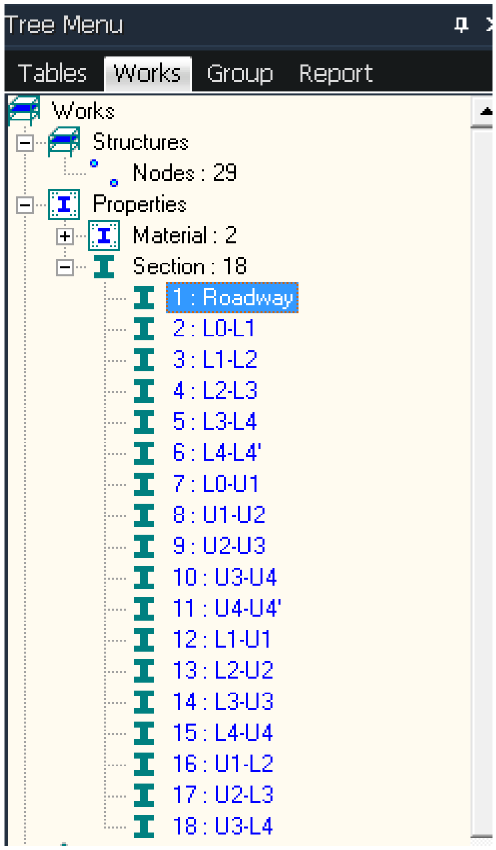
9.4.4 Sections

Cross sections are defined in Midas using general sections. Since the analysis doesn't consider bending in the truss members (pin-pin connections) only the cross-section area needs to be defined. Sections can be manually entered one at a time or the MCT Command shell feature can be used to automate the section creation.

To use the MCT Command shell, the load rater needs to copy the text in the Section_Input.txt file and paste it into the Midas MCT Command Shell tool.



In the top menu click on Tools => MCT Command Shell. Paste the text from the Sections_Input.txt file and click Run. Once completed, check in the works tree to verify that all the sections were created. For additional information on the Sections_Input.txt file see 10.3.1.



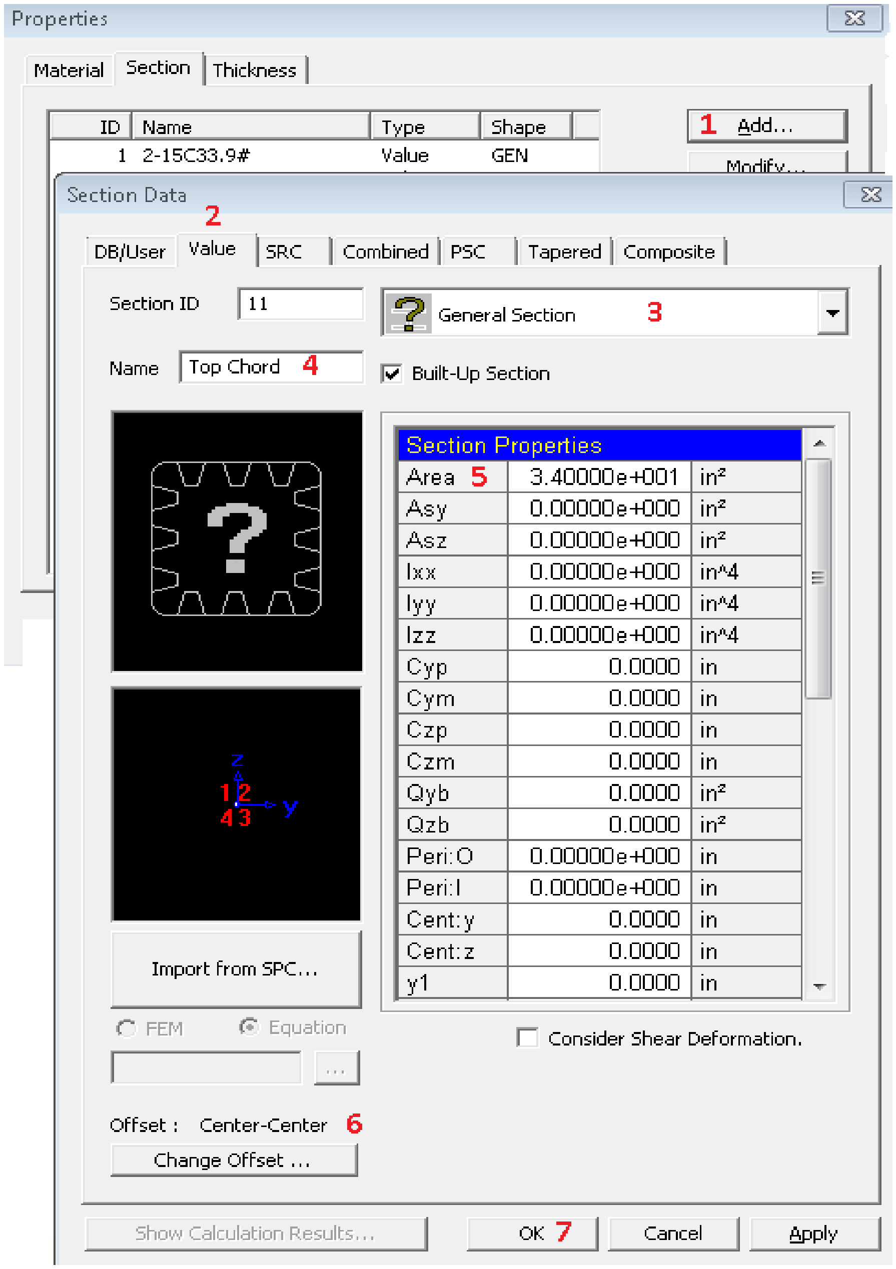
A section that will be used for the roadway beam elements will need to be defined in addition to the truss members. This member is a beam element so it will need more than just the cross section area defined. Roadway stringers on trusses are not usually continuous across the floor beams. In this case, the stiffness of the element doesn't impact the model and the pre-defined Roadway section can be used. For roadway stringers that are continuous, the load rater will need to consider the stiffness of the roadway system

To manually enter section data follow the below procedures:

In the top menu go to Properties => Section => Section Properties.

1) Click Add
2) Select Value
3) In the Drop down list select General Section
4) Define the section name. Using a name that describes the section will provide checkers more useful information than simply assigning the sections an arbitrary section designation. Examples; U1-L2, Top Chord, 2-15C33.9# (Midas allows these characters to be used), etc.
5) Input the cross sectional area. Double check that the units are correct. The area of each element is calculated by Truss_Element.xlsm and can be found in the text output files. Any section loss modeled in the capacity analysis will also be reflected in the calculated area. Keep this in mind, as it may be appropriate to use a reduced section for capacity calculations, but probably not appropriate to use the reduced section in the Midas model to calculate load effects.
6) Confirm that the section is defined as center-center

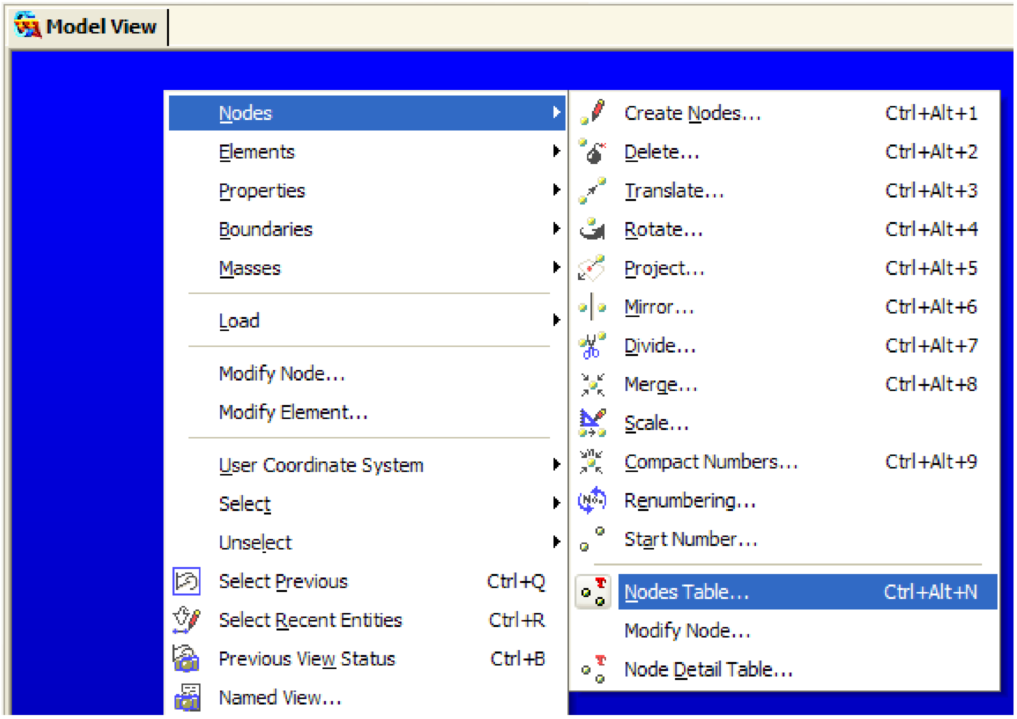
7) Select OK



Repeat the process until all unique sections are defined.

9.4.5 Nodes

Within the Model View window, right click anywhere and select Nodes => Nodes Table…



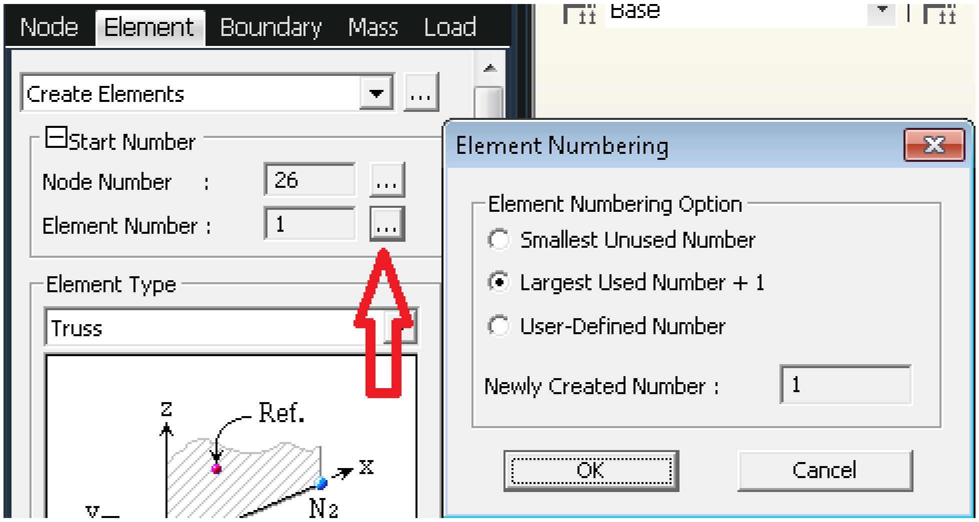
Node locations can either be manually entered, or if the node locations are in a spreadsheet, they can be copied and pasted into the nodes table. If node locations are calculated in a spreadsheet, include this in the Preliminary file.

9.4.6 Elements

The element number in Midas must match the member number defined in the capacity calculations. Midas will default to using the largest unused number for the element definition starting at 1.

In the top menu go to Node/Element => Create Elements.

Click the box with the three dots next to the Element Number input.



Midas has three options for defining element numbers. Any option can be used provided the element numbers match those used in the capacity calculations.

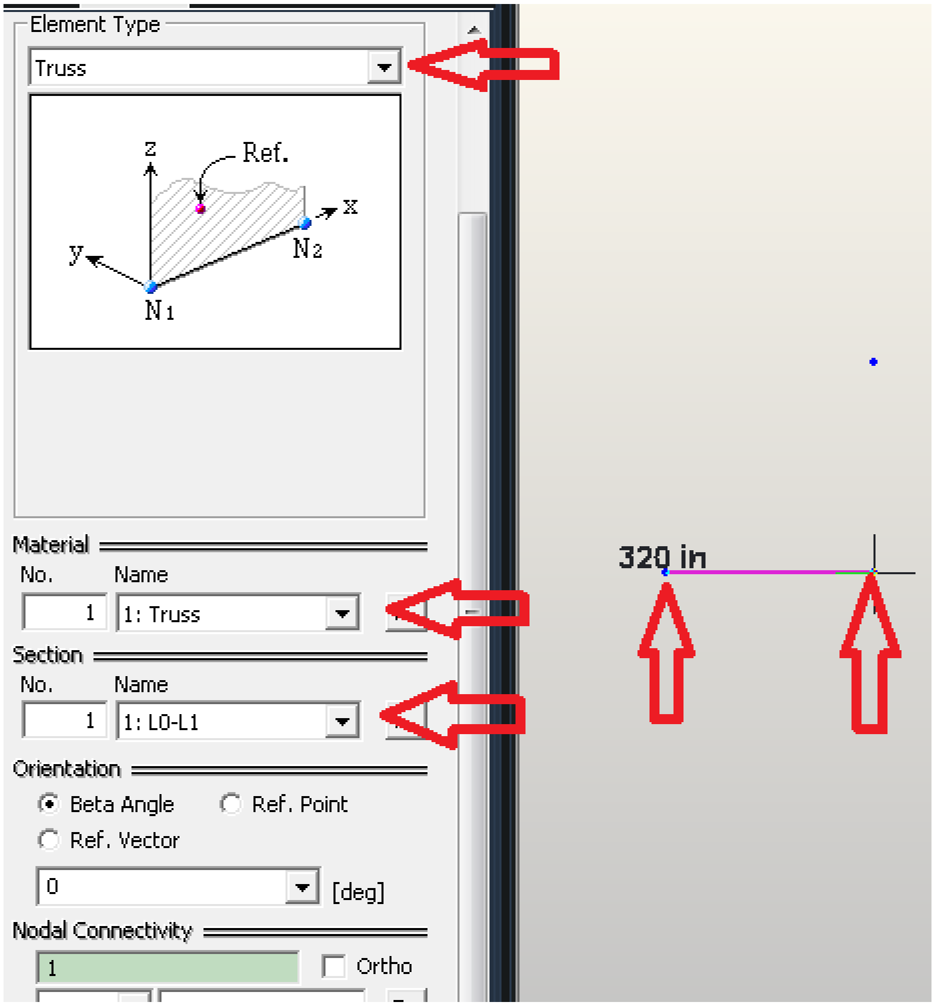
In the Element type drop down list select “Truss”. This will limit the element to axial compression or tension only.

In the Material selection pick the material defined for the primary truss members.

> Note: Since the element capacities are calculated external to Midas, only the unit weight and modulus of elasticity impact the model. Therefore, it isn’t necessary to define materials for each grade of steel.

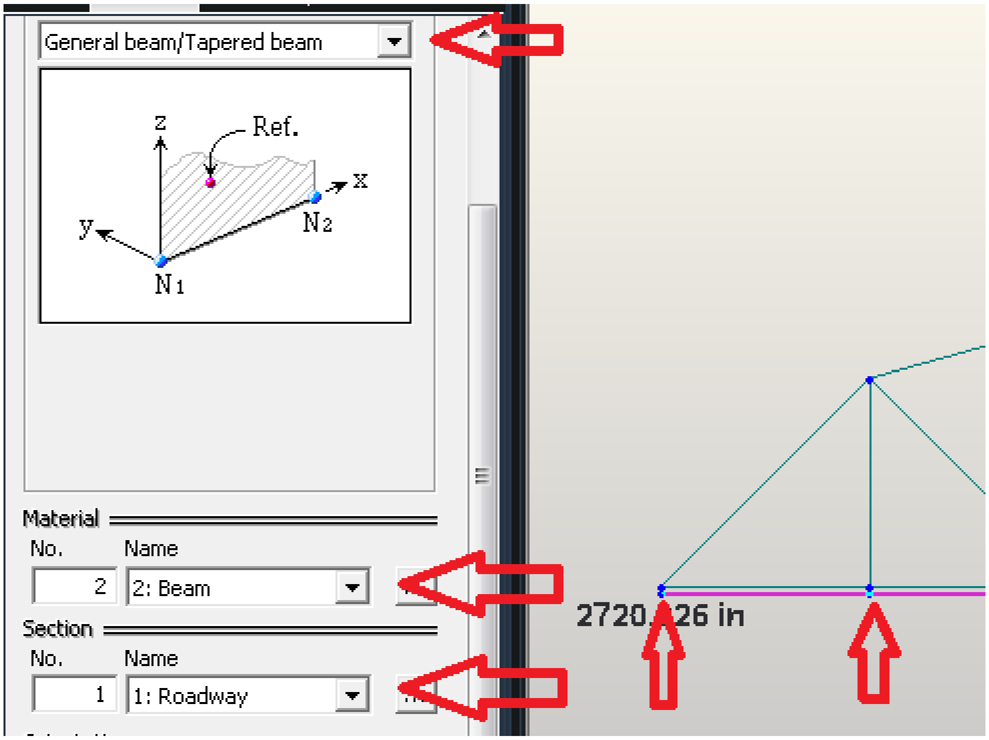
Use the Section name drop down menu to pick the appropriate section for the element being defined.

Use the mouse to select the two nodes that define the element.



Repeat this process until all of the truss elements are defined.

Midas requires beam elements to apply live loads to the model. To define the roadway elements change the Element type to General beam/Tapered beam. Change the material type to beam. Select the Roadway section. Since roadway beams aren't included as part of this analysis, the element number doesn't matter. Use the mouse to select the nodes for the roadway beam.



9.4.7 Global Boundary Conditions

In the top menu go to Boundary => Define Supports. Because the model is 2-D and composed of truss members, only Dx and Dz need to be defined for stability.

Select the appropriate support conditions. Use the mouse to select the node of interest and click apply.

9.4.8 Roadway Beam Boundary Conditions

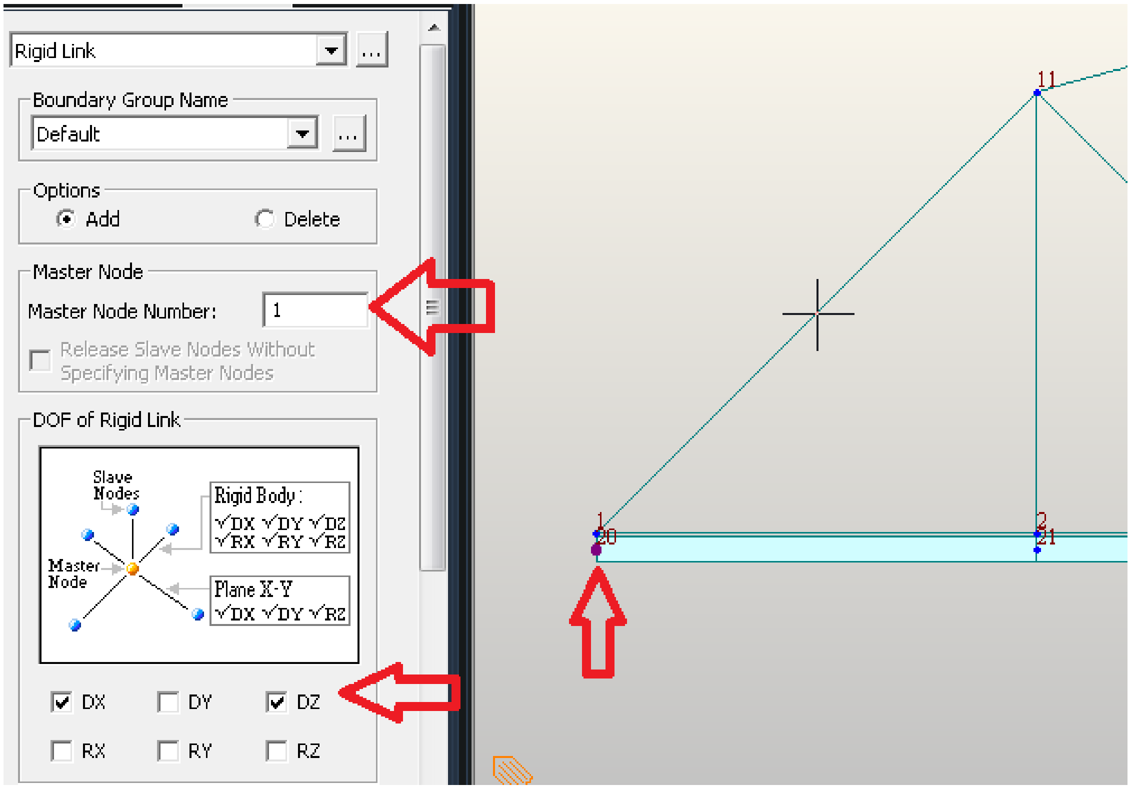
Link the roadway beam and the truss panel pointsusing rigid links.

In the top menu go to Boundary => Rigid Link.

In the model view use the mouse to select the roadway node of interest (Node 20 in the example).

Input the adjacent truss panel point node in the Master Node Number box.

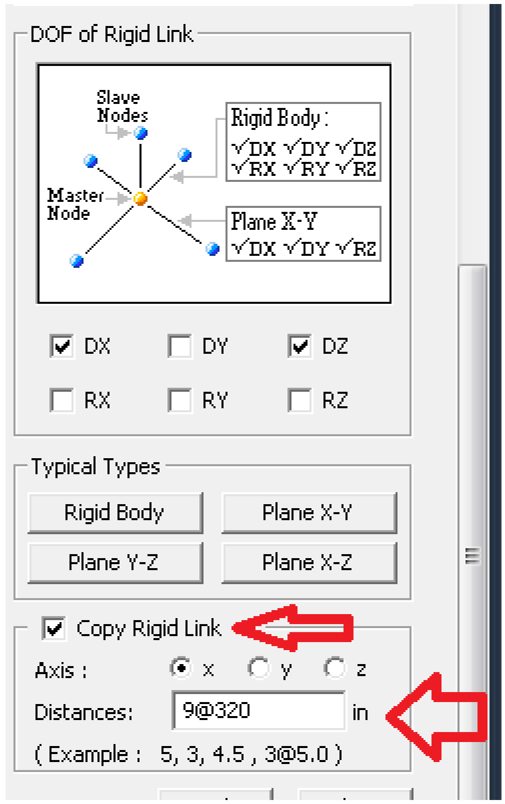
For the DOF for the Rigid link select Dx and Dz.



Midas has a feature to copy rigid links to multiple panel points. Since trusses typically have consistent panel spacing, this feature should be used to reduce the amount of user input.

Select Copy Rigid Link.

Input the number of times to be copied and the spacing between the links. For the example, the spacing is input as 9@320 to copy the link 9 times at 320 inch spaces.



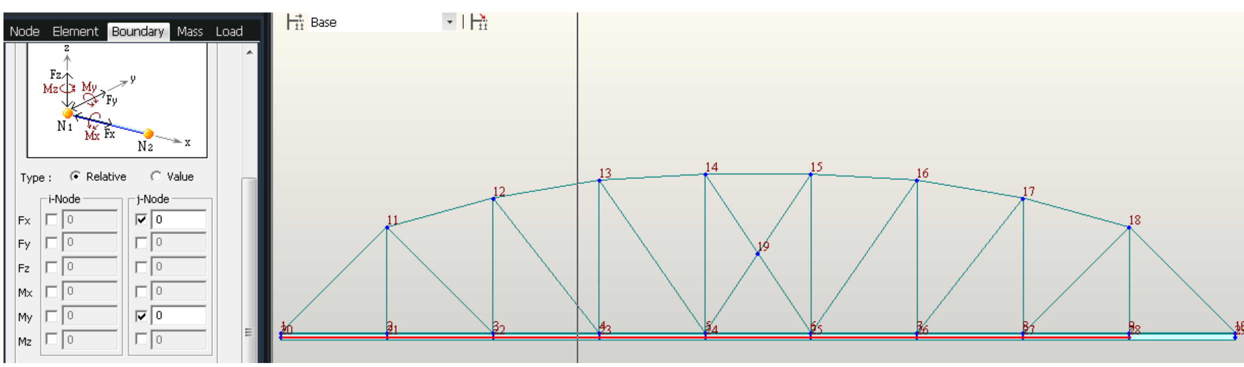
The roadway beam elements are by default continuous across the rigid link supports. Beam end releases are applied to model the roadway beams as simply supported. In addition to releasing moment at the connection the axial restraint is also released. Although the roadway beams may be able to transmit axial loads, it is not desirable to count on this load path during design or load rating.

In the top menu go to Boundary and select Beam End Release.

Select the j-Node for Fx and My.

Select the roadway elements in the model view window. Note that these releases are being applied to the J end of each element. Releases do not need to be applied at the global support locations.

Select Apply.



9.4.9 Load Definition

Both live and dead loads are applied in the Midas model. Dead loads were calculated in the preliminary file and are applied at panel points only. Live loads are applied to the roadway beam elements. The live loads will be a lane load effect only. Live load distribution factors, live load factors, and dead load factors are all applied in the post processing tool.

Three static load cases are defined by the MCT Command shell; SW, DC, and DW. Midas allows the user to define many different load cases. But the post-processing tools will be looking for these three load cases when applying load factors and calculating rating factors. Therefore, additional static load cases should not be added to the model.

9.4.9.1 Static Loads

In the top menu select Load => Nodal Loads.

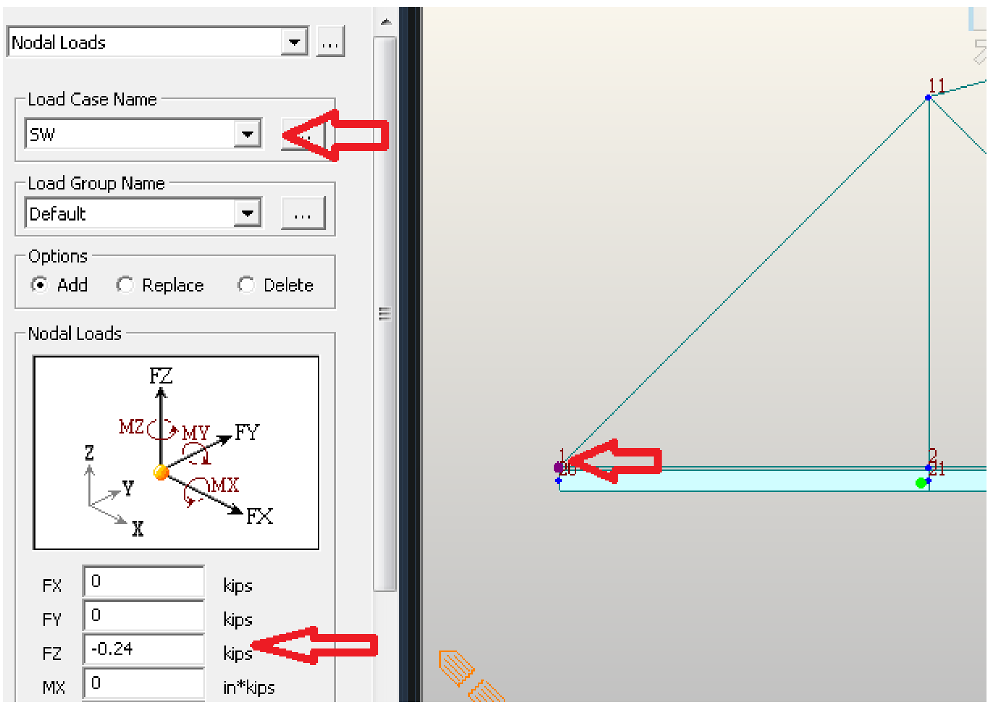
Use the drop down list to select the appropriate Load Case; SW, DC or DW.

To apply loads in the direction of gravity use the Fz input and use a negative value.

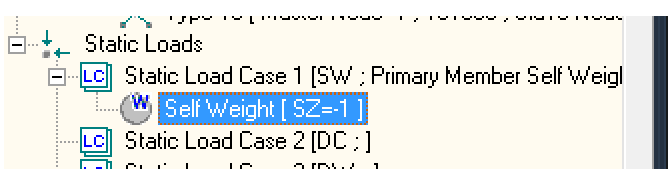
In the Model view select the node(s) where the load is applied.

Select Apply.

Continue until all the nodal loads are applied.



In addition to whatever nodal SW loads may be defined, the primary member self-weight should be used to determine the weight of the primary truss members. By default the Self Weight feature in Midas is turned on. To verify, go to the tree menu and drop down that Static Load Cases. Under Static Load Case 1 there will be the Self Weight loading applied in the –Z axis. This is the direction of gravity.



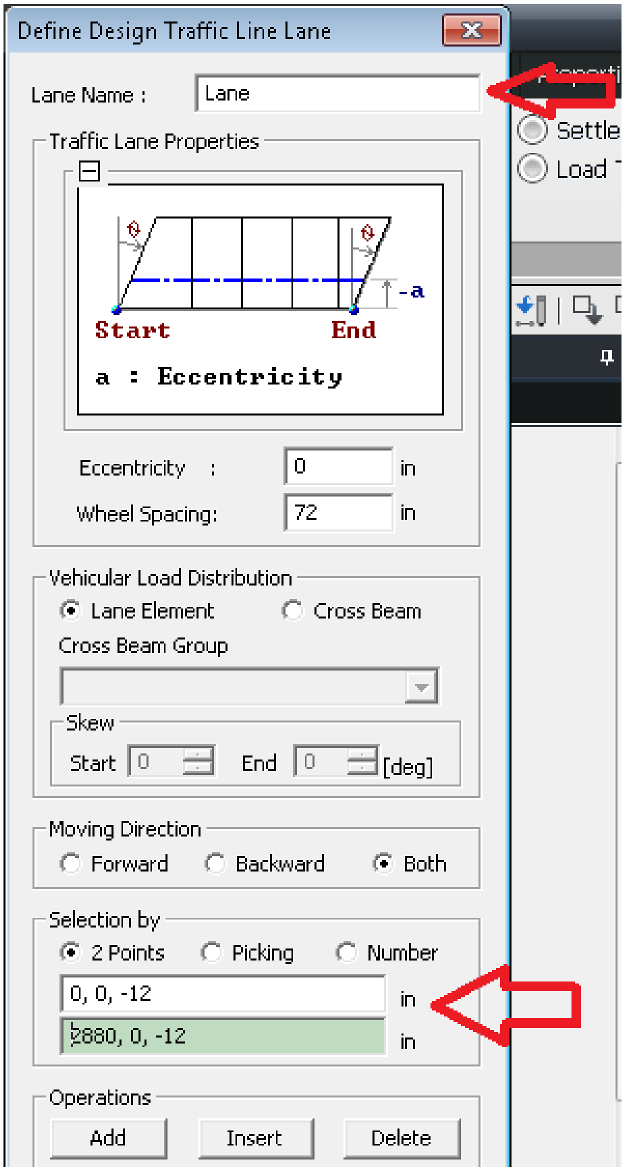
9.4.9.2 Moving Loads

In the top menu go to Load => toggle Moving Load. For the Moving Load Code select AASHTO LRFD.

Select Traffic Line Lanes and click “Add” in the window that pops up.

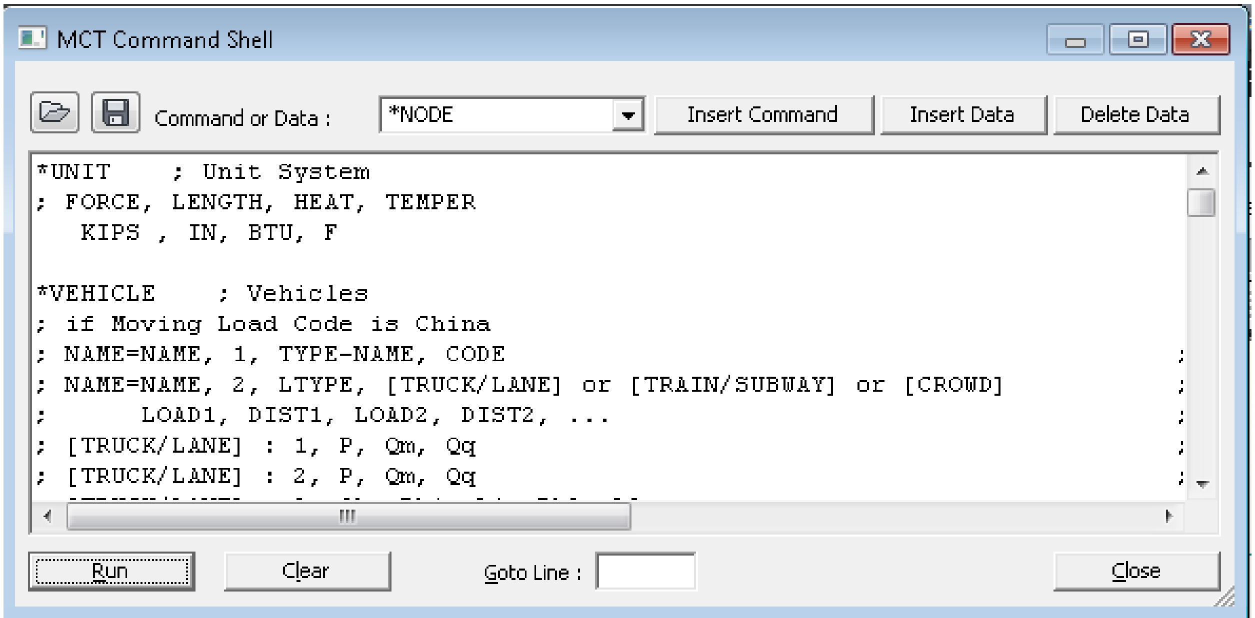
For the Lane Name use “Lane”. A MCT Command shell file will be used to populate the various Design, Legal, and Permit moving load cases. For this command shell to work the Line Lane must be defined as “Lane”.

Select the roadway beam elements to apply the lane load to.



To populate the vehicles go to the top menu go to Tools => MCT Command Shell.

In the MCT Command Shell tool open the TRUSS_VEHICLES.mct and click Run.



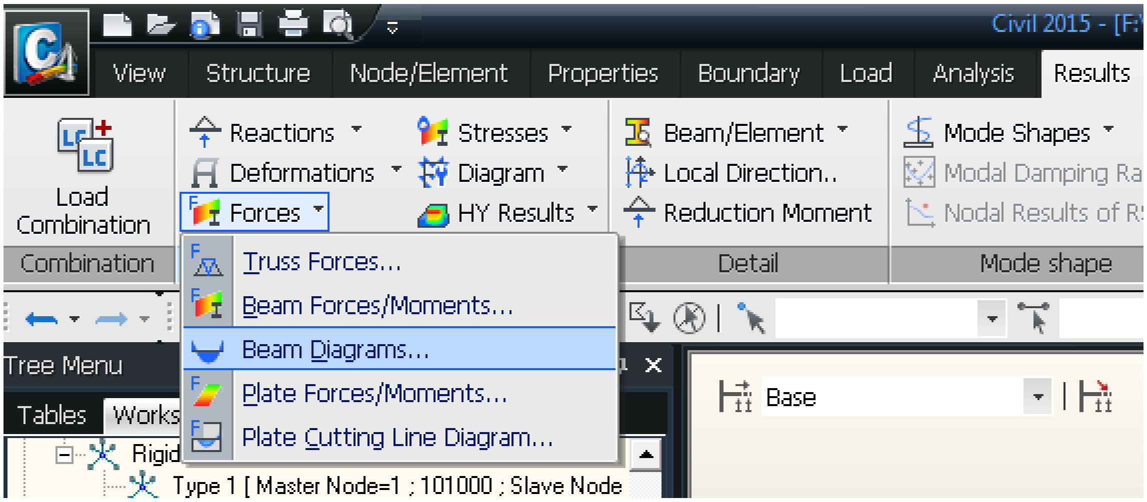
In the Works Tree verify that 21 vehicles, 1 vehicle class, and 20 moving load cases have been defined.

9.4.10 Analysis and Results

In the top menu select Analysis => Perform Analysis. The Message Window is by default at the bottom of the Midas Window. Check the message window after the analysis is complete for any warning or error messages.

Midas provides many options for displaying and review analysis results. Reaction, truss forces, beam diagrams, and deflected shapes should be investigated for errors.

In the top menu select Results => Forces => Beam Diagram. The only beam elements used in the model are the roadway stringers. The volume of rigid links and beam end releases associated with the roadway stringers can lead to errors in the model. Check both the moment diagram (My) and the axial forces (Fx) for errors. Since the roadway stringers are defined with a weightless material use the HL93(All) load case for the review. Make corrections to the roadway beam boundary conditions as required.



Continue to check the Truss forces, deflected shape and reactions until satisfied with the accuracy of the model.

For the rating factor calculations the load effects are output from the Midas model using the tabular features. This is covered in section 10.5.4 of this manual.

9.5 Truss_LRFR.xlsm Tool

The Truss_LRFR.xlsm tool is used to gather the member capacity and load effects. Live load distribution factors are calculated, all applicable load factors are applied, and rating factors are calculated.

Throughout the workbook the cells are color coded to help the load rater identify what cells require user input.

Color Chart	Description
	User input
	Spreadsheet calculation
	Midas Output

9.5.1 Bridge Geometry

The Bridge Geometry worksheet is used to define the truss geometry and to calculate the live load distribution factors. Calculations for the geometry input should be shown in the Mathcad preliminary file. Once the geometry is input, click the “Calc Live Load DFs” button to calculate live load distribution factors for the truss. Live load distribution factors are calculated using the lever rule. If the structure has medians, or unusual deck geometry the load rater will have to manually calculate the live load distribution factors.

BRIDGE INFORMATION

BRIDGE #:	08990	**Version:**	**State Truss LRFR Version 1.0**
BRIDGE NAME:	Clackamas R, Hwy 171 at MP 45.83 (Cripple Creek)	**DATE:**	6/26/2015
FILE NAME:	08990_Truss_LRFR.xlsm	**ENGINEER:**	Travis Kinney
TRUSS TYPE:	1 - 240' Steel through truss	**TRUSS LENGTH:**	240

GENERAL BRIDGE INFORMATION

X-Section Geometry

CL Truss to CL Truss	31	[ft.]
CL Bridge to CL Left Truss	15.5	[ft.]
Road width	26	[ft.]
CL Bridge to Face Left Curb	13	[ft.]

Truss Data...

Span Description	1 of 2	
Max Span Length	240	[ft.]
Number of panels	9	

Calc Live Load DFs

Live Load Distribution Factors

1-Lane Loaded	0.910
Multiple Lanes Loaded	1.129

Note: Maximum of 4 lanes loaded is checked for Multiple Lanes Loaded Case.
Two lanes loaded is assumed for roadway widths greater than 18', but less than 24'.

9.5.2 Load Factors

All the load effects from the Midas Civil analysis are unfactored. Input the appropriate system, condition, and load factors in this sheet. The resistance factors are applied during the capacity calculations. The impact factor for the HL-93 load case is applied during the Midas analysis.

9.5.3 Elements

Document the capacity and section information for each truss member of interest. This information is available in the output files from the capacity calculations. Compiling this information into one spreadsheet expedites the review process. Take time to check over the information to look for errors. There are options to automate the input or it can be manually entered.

To automatically import the element information, define the directory where the element output files are stored. The import tool will search through the output files and populate the information for each element found up to the highest element number defined by the load rater.

Truss Elements

Elements File Directory: V:\LoadRate\Tier2\ODOT_LRFR_Manual\Tru 1

Highest Element Number: 32

Import Elements | Clear Elem Table | Set Elem Range (User)

2

3

Element Number	Type	Location	Gross Area (in^2)	$I_{x\text{-}x}$ (in^4)	$I_{y\text{-}y}$ (in^4)	Fy (ksi)	Section Loss Factor	System Factor	Condition Factor
1	Builtup Box Section	L0-L1	19.8	625.1	676.1	50.0	1.00	0.90	1.00
2	Builtup Box Section	L1-L2	19.8	625.1	676.1	50.0	1.00	0.90	1.00
3	Builtup Box Section	L2-L3	23.4	692.6	676.0	50.0	1.00	0.90	1.00
4	Builtup Box Section	L3-L4	29.3	803.4	684.0	50.0	1.00	0.90	1.00
5	Builtup Box Section	L4-L4'	29.3	803.4	684.0	50.0	1.00	0.90	1.00
10	Builtup Box Section	L0-U1	32.4	1083.2	832.2	50.0	1.00	0.90	1.00
11	Builtup Box Section	U1-U2	32.4	1083.2	798.4	50.0	1.00	0.90	1.00
12	Builtup Box Section	U2-U3	32.4	1083.2	796.3	50.0	1.00	0.90	1.00
13	Builtup Box Section	U3-U4	32.4	1083.2	795.2	50.0	1.00	0.90	1.00
14	Builtup Box Section	U4-U4'	32.4	1083.2	795.1	50.0	1.00	0.90	1.00

If the information is manually entered, the Element range has to be defined. To define the element range click the “Set Element Range (User)” button. The cell fill color should change to blue to indicate that the range has been updated.

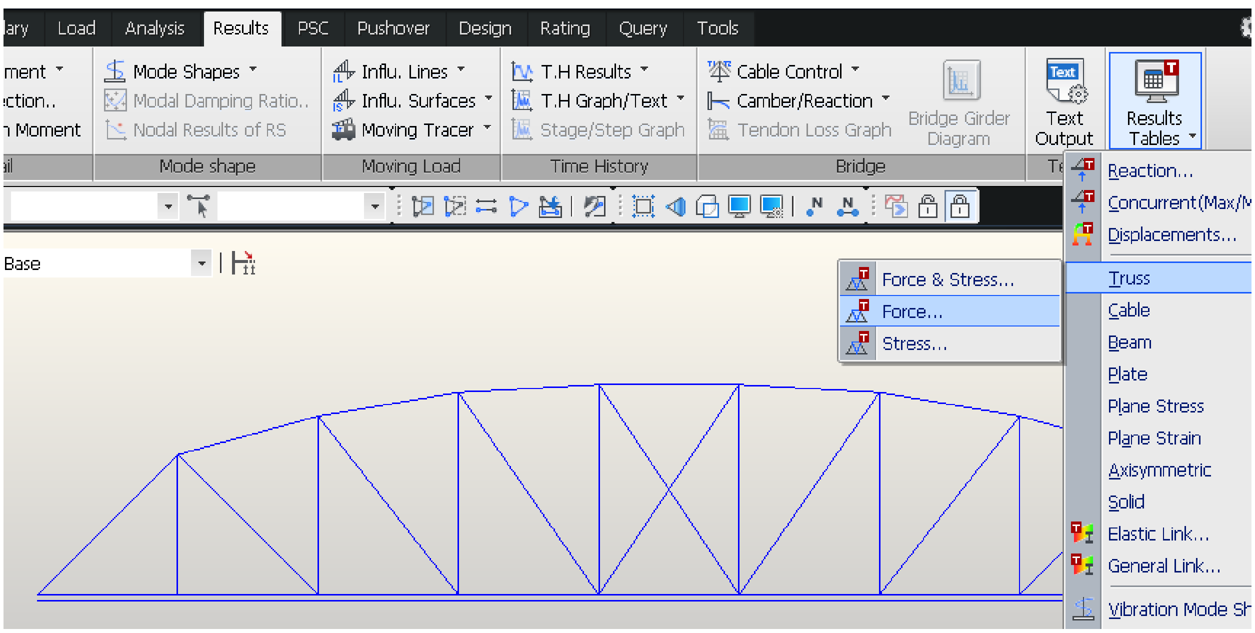
Note: The system and condition factor for each element is populated during the element import process. If the element table is manually populated then the load rater needs to also fill in this information. System factors for truss members are dependent on the local element redundancy (built-up members) not on global system redundancy, and are therefore element specific. Based on the data input during the capacity calculations, the import macro will assign a default system factor for each element. The load rater can overwrite the default values as necessary to properly account for the level of redundancy. The condition factor defaults to the value input on the Load Factors worksheet. If the load rater has already accounted for section loss during the capacity calculations, then it is permissible to adjust the condition factor as appropriate.

9.5.4 Midas Loads

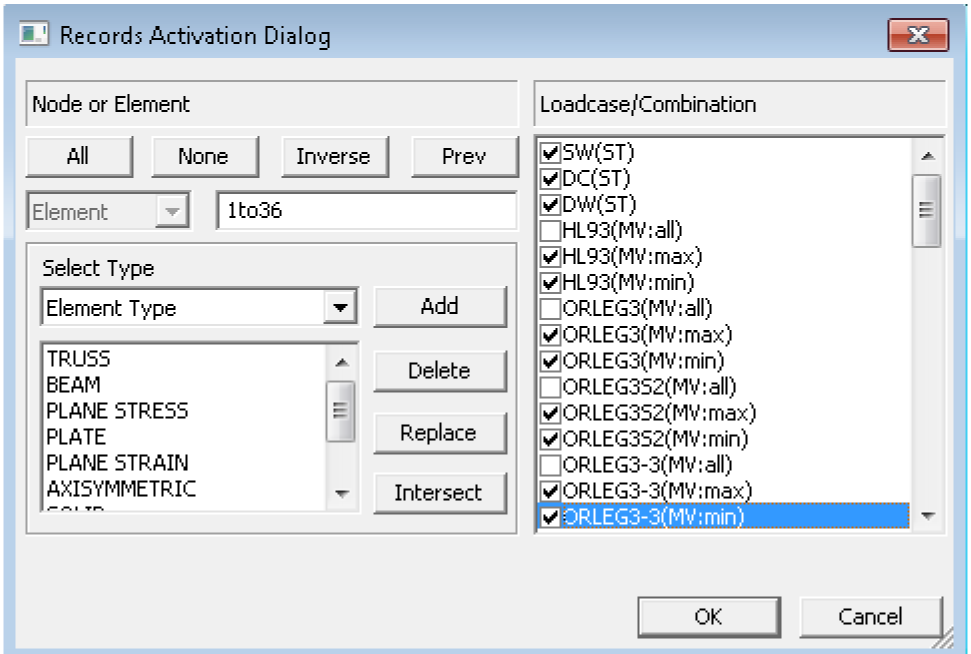
The selfweight (SW), dead load (DC), wearing surface (DW) and live loads from the Midas analysis needs to be copied to the Midas Loads worksheet.

Open the Midas model.

In the top ribbon click on Results => Results Tables => Truss => Force. This will open a Records Activation Dialog.



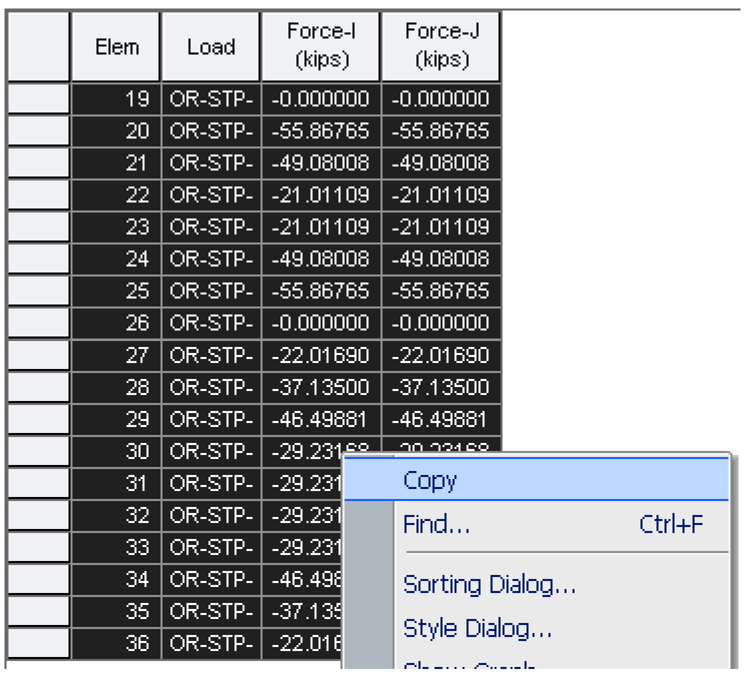
The Loadcase/Combinations need to be manually selected. Check the box next to the SW, DC, and DW loadcase. For each moving Loadcase there will be three options; all, max and min. All the max and min moving loadcases need to be selected.



Once the loadcases are selected click OK to bring up the load table.

Select the table data with the mouse.

Right click in the table and select copy.



Go back to the Midas Loads worksheet in the Truss_LRFR.xlsm tool and paste the data.

Click the “Set Load Table” button to define the cell range.

MIDAS Ouput

Set Load Table

Elem	Load	Force-I (kips)	Force-J (kips)
1	SW	45.95	45.95
2	SW	45.95	45.95
3	SW	63.27	63.27
4	SW	72.13	72.13
5	SW	77.91	77.91
6	SW	72.13	72.13
7	SW	63.27	63.27
8	SW	45.95	45.95
9	SW	45.95	45.95

9.5.5 Factored Loads

Click the “Calc Factored Loads” button to populate the factored loads table. Tension and compression load effects are calculated for each member of interest.

FACTORED LOADS (Includes Live Load Factors, Live Load Distribution Factor, and Impact Factor)
(DC includes SW which has the SW factor applied)

Calc Factored Loads

Element Number:	1	2	3	4	5	10
Element Location:	L0-L1	L1-L2	L2-L3	L3-L4	L4-L4'	L0-U1
Element Type:	Builtup Box Section	Builtup Box Section	Builtup Box Section	Builtup Box Section	Builtup Box Section	Builtup Box Section
SINGLE LANE DF	0.910	0.910	0.910	0.910	0.910	0.910
MULTIPLE LANE DF	1.129	1.129	1.129	1.129	1.129	1.129
Permanent Loads						
Max Axial DC	317.33	317.33	435.90	495.44	527.24	-451.26
Min Axial DC	228.48	228.48	313.85	356.71	379.61	-324.91
Max Axial DW	0.00	0.00	0.00	0.00	0.00	0.00
Min Axial DW	0.00	0.00	0.00	0.00	0.00	0.00
Tension Axial						
HL93 (INVENTORY)	295.70	295.70	404.41	457.00	472.05	0.00
TYPE 3 (50K)	75.55	75.55	103.16	116.32	116.27	0.00

9.5.6 Rating Factors

Click the “Calculate Rating Factors” button to populate the rating factors. Tension and compression rating factors are calculated for each applicable element. Some truss members will be tension or compression only elements. These elements will not have both tension and compression rating factors generated. The tool will check for elements with zero live load effects and will skip the rating factor calculation when appropriate.

The controlling rating factor for each load case is displayed in the first column. Do not copy this column into the load rating summary sheets. It is used for review purposes only.

The rating factors can be copied and pasted directly into the ODOT load rating summary sheet.

SECTION 10: LOAD RATING ARCH BRIDGES

This section covers arch bridges that can be analyzed using 2D models. 3D or torsion effects from loading outside of the 2D plane of the arch rib are not included in this analysis. Arch bridges which require 3D models are not covered in this chapter.

10.1 Scoping of Structure

Create a scoping file (**nnnnn_scope.xlsx**) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended effect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0, then there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

10.2 Preliminary Mathcad File

For arch bridges, the preliminary file name and extension is **nnnnn {Bridge Name}.xmcd**. If there are multiple arches, the file names should differentiate between them with some additional identifier (e.g. **nnnnn {Bridge Name} Span 1.xmcd** and **nnnnn {Bridge Name} Span 2.xmcd**).

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied factors with parentheses.

The following chapters encompass sections that are relevant to both concrete and steel structures. Include the sections as they apply.

10.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file except when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description (“Spans” field) from the Bridge Log is adequate for this purpose.

Note: The Mathcad regions in the top right margin (outside the printable area) are there for two purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

10.2.2 Resistance Factors

Document the decisions regarding all Resistance Factors, with references to the appropriate MBE tables.

Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure in RC Members:
$\Phi_f = \phi$ [max ($\phi_c\phi_{sf}$, 0.85)]
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2) and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Axial Loading:
$\Phi_f = \phi$ [max ($\phi_c\phi_{sf}$, 0.85)]
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 6.5.4.2 for steel and varies for concrete based on the applied loading; phi is calculated during the capacity calculations.) and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Shear:
$\Phi_v = \phi$ [max ($\phi_c\phi_{sv}$, 0.85)]
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 5.5.4.2) and ϕ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).

Generally Φ_f and Φ_v will be the same for redundant members such as girders and will be different for non-redundant members such as single-span and 2-span crossbeams.

10.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into the “Resistance and Load Factors” tab of the various capacity spreadsheets. The Load Rating Summary Workbook **(LR.xltm)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and effective bridge length. Note that effective bridge length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which live load factor application is used, ADTT is specified as "one direction". Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the live load factor application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the Live Load Factor Application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the "LRFR Strength I & II" table from the live load factor application, and in Mathcad use Edit / Paste Special. In the "Paste Special" dialog box choose the "Paste" button, highlight "Bitmap" in the "As" list, and click the "OK" button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to MBE C6A.4.4.3.

10.2.4 Distribution Factors

Document the decisions regarding all Distribution Factors, with references to the appropriate MBE and AASHTO sections.

Per AASHTO 4.6.2.4, use Lever rule to determine the distribution factor for arches that are analyzed as planar structures. For maximum effect, place the truck(s) as close as possible to one of the arches. For additional Lever rule discussion see section 1.4.1.6.

10.2.5 Material Properties

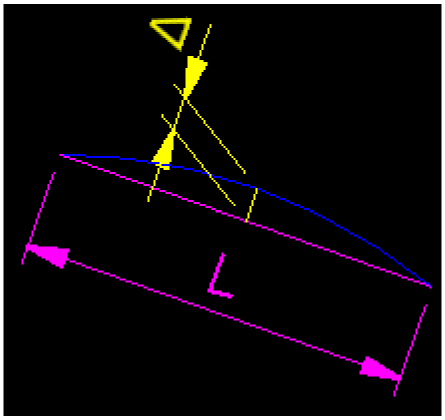
Document decisions, assumptions, and calculations for material properties used in the rating. Refer to codes, shop drawings or construction drawings as appropriate. Use AASHTO LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c. Use AASHTO LRFD Equation 5.4.2.4-1 to determine the elastic modulus of concrete, assuming K_1=1.0. Document any assumptions made about the material properties within the Mathcad preliminary file if they are not given on the bridge plans. Some guidance for historical materials is available in the MBE.

For dead load calculations, use w_c+0.005 kcf to account for the reinforcement, in accordance with AASHTO LRFD Commentary C3.5.1. Precast reinforced concrete shall use a minimum weight of 0.155 kcf. This minimum is based on recommendations from the precast industry. Verify the appropriate weight density is used in the material definition. In some cases, zero-weight materials may be useful in developing the model; clearly describe all assumptions and methodology in development and assignment of material weight properties.

10.2.6 Bridge Geometry

Document overall geometry decisions, assumptions and calculations. Arch structures in particular may have relatively complicated geometry that is best modeled using CAD software or Excel spreadsheets. Provide documentation, clear explanations, and screenshots to describe the methods for determining overall span, arch, and member geometries. Document the arch buckling capacity as calculated per Appendix C - Arch Buckling Analysis in Midas Civil.

Model arches as a series of straight, linearly-varying segments. Calculate or measure the offset distance Δ from the theoretical curve to the CL of straight segment:



Use enough segments such that the ratio Δ/L < 1%. The offset ratio will be reduced as more elements are used.

Define additional nodes/elements at the following Analysis Sections, per section 15.2.12 (as they apply)

- Critical Shear Section Points
- Flexural Bar Cutoff Points
- Member Geometry Change Points
- Stirrup Spacing Change Points
- Any other section or material change location.

Model arch elements at the geometric centroid.

10.2.6.1 Section Properties

Section properties must be determined for each end of each element used in the Midas model. In this portion of the preliminary file, provide a brief description and show these calculations or provide a reference to a separate section property file (CAD, Excel, Mathcad, etc.).

Each unique cross section change location is drawn in CAD (dxf file) and imported into Midas for analysis. Midas is capable of linearly, or parabolically, tapering between unique sections about the y and z axis. This means that only section change locations need to be drafted when these section variations are used. Other section variations such as radially defined sections will need to be defined at each end of each element.

Multi-span bridges that are continuous for live loads will also need to have the support conditions accurately modeled. This includes modeling columns that are integral with the superstructure. Although rating factors will not typically be calculated for columns, they are included because they impact the superstructures stiffness.

Document all decisions and assumptions.

10.2.7 Reinforcement Layout

In this section show all calculations necessary to determine the location of reinforcement that will be used for capacity calculations. It is particularly important when calculating the nominal moment capacity to include the mild steel reinforcement. Although the mild reinforcement does little to the Mn value, it does have an impact when determining if the section is tension controlled and will thus have an impact on φ_f.

10.2.7.1 Flexural Reinforcement

Show any necessary calculations for determining the flexural reinforcement. Calculate ys, the distance from the extreme tension fiber to the centroid of the row being defined. If calculations are necessary to determine the location of bars or development lengths, they are to be shown here.

10.2.7.2 Shear Reinforcement

Document the ranges and span fractions for the shear reinforcement layout for each span. This can be done using an embedded Excel spreadsheet within Mathcad as indicated below or with discrete calculations.

Double-clicking on an embedded spreadsheet activates Excel and its toolbars and functionality become available. An existing embedded Excel spreadsheet can be copied, pasted in another location and modified to do similar calculations for another span. For each span that contains analysis sections, working consecutively from the left end of the span to the right, populate the yellow fields in the following table in the preliminary file. The “Remnant” stirrup space no longer needs to be calculated. Simply input the spacing and the total range that is represented by that spacing.

Shear reinforcement bar size and spacing shall be determined from the plan sheets.

Span # :	1	Length (ft):	180.00		
Begin (in)	Spacing (in)	Range (in)	End (in)	# Legs	Stirrup Size
20	6	216	236	22	#5
236	18	1688	1924	22	#5
1924	6	216	2140	22	#5

10.2.8 Prestressing Properties

Designers commonly provide a few parameters for prestressing strand and leave some flexibility to the post-tensioning contractor on the distribution, size, and sequence of stressing. Typically, a total prestress CG profile, final midspan prestressing force, anchor set, friction factor, wobble coefficient, assumed time dependent losses, and area of prestressing strand are provided on the bridge plans. In the Preliminary (.xmcd) file, under the section titled Prestressing Properties, document all strand properties and calculate the number of prestressing strands to achieve the design requirements.

Unless otherwise stated, assume 1/2in diameter 7-wire strand. This is the most common strand type used within the State. Document the type of strand, stress relieved or low relaxation and any other assumptions under the Prestress Properties heading.

Unless otherwise specified, assume an equivalent anchor set of 5/8in.

Provide any necessary calculations to determine the beginning and ending locations of prestressed or post-tensioning strands. For Midas to correctly output prestressing strand information, a node point must occur at the beginning and ending location of all prestressing strand.

Annual relative humidity is determined per AASHTO LRFD Figure 5.4.2.3.3-1. Interpolation between curves is not necessary, rather select the lower value.

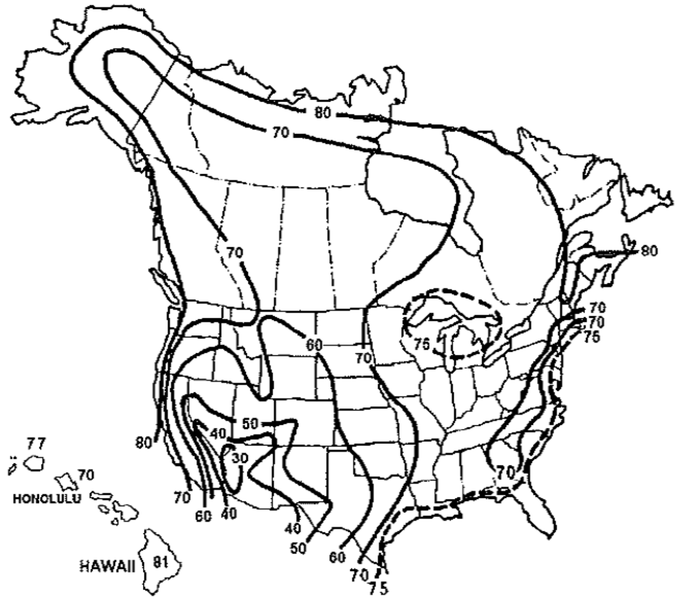


Figure 5.4.2.3.3-1 Annual Average Ambient Relative Humidity in Percent.

10.2.8.1 Number of Strands and Initial Jacking Stress

If the designer provided an equation in the bridge plans that shows how the area of prestressing strands is calculated, then use the provided equation. No iteration is required. The equation is commonly provided under stressing details and is of the following form:

$$AS = \frac{Pj}{0.75 f_s^{'}}$$

Where: Pj is the initial force before anchor set at a specific jacking location.
$f`_s$ is the minimum ultimate strength

If the designer did not provide an equation to calculate the total prestressing area then it will have to be calculated from the information provided. Using the final midspan force and the allowable final stresses an iterative procedure can be used to determine the approximate number of strands. This procedure is outlined below. The example load rating for BR09648 can also be referenced.

Midas Civil can be used to determine the number of strands and the initial jacking stress. This has to be an iterative approach because the number of strands, initial jacking stress, final maximum allowable stress, and final minimum midspan force are inter-dependent. If a maximum allowable final stress is not specified by the plan sheets, then 0.80(f_{py}) shall be used per AASHTO LRFD Table 5.9.2.2-1.

Begin by assuming the maximum allowable jacking stress was used. Calculate the number of strands required using the maximum allowable stress at midspan. Input these values into the Midas model and run the analysis.

Check the results to see if iteration is required. The output can be found under; Results => Results Tables => Tendon =>Tendon Approximate Loss. Final tendon stresses are calculated using the assumed time dependent losses (provided in the plans) plus Immediate Losses calculated by Midas. These results will be used to calculate the inputs for the next iteration.

If the final calculated stress is greater than the allowable stress, at any point along the span, decrease the jacking stress by a value equal to the difference of the calculated and the allowable stress. This will decrease the stress along the entire tendon such that the maximum final stress is less than the maximum allowable stress.

Calculate the final midspan force by multiplying the final midspan stress by the strand area. Compare this force to the per plan minimum final midspan force. If the calculated value is below the required value then more prestressing strand needs to be specified.

For the second iteration, the number of prestressing strands can be calculated by dividing the required midspan force by the calculated force per strand. The calculated force per strand is the strand area multiplied by the midspan tendon stress calculated in the previous iteration.

Continue the iteration process until the calculated final midspan force is above the specified minimum and the calculated maximum final strand stress is below the specified maximum. This should not take more than a few iterations.

Note: The final midspan force calculated in this section is not the same force used in capacity calculations. This section uses an assumed time dependent stress loss value, usually 25 ksi. Capacity calculations use calculated time dependent stress losses. Midas performs a refined time dependent stress loss analysis.

10.2.9 Component Dead Loads (DC)

To avoid confusion, dead loads should be grouped under the headings DC and DW in the Preliminary File (**.xmcd**) and entered in the Midas model as separate load cases. Typical DC loads include rails, sidewalks, decks, girders, diaphragms, flooring systems, arch bracing, and other permanent structural items.

Consider diaphragm point loads to be part of component load DC. Include any diaphragms/end beams at the end of the girder over the support, as they will be utilized when applying the girder dead load reactions to crossbeams.

Where standard rail drawings occur, use the rail dead loads tabulated in Appendix H – ODOT Standard Rail Weights, found in file **RAILDL.XLS**. Provide detailed calculations for the dead load of any rail not found in this summary.

For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all rail, curb and sidewalk dead loads (stage 2 dead loads) equally among all arches.

Add a point load at the center of bearing to account for the dead load of the rails, deck, and girder that extend beyond the center of bearing. Even though these loads will have no impact to the load rating of the girder, they will be utilized when applying the girder dead load reactions to crossbeams.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16” diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to be included in the load rating.

10.2.10 Wearing Surface Dead Loads (DW)

Always separate wearing surface dead load (DW) from the component (DC) dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes, and (c) it facilitates input for the Crossbeam Load Rating Software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Show calculations for wearing surface dead load distributed equally to all the girders. Add 1” to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½” to the design thickness of PPC overlays to account for construction variations and uncertainty.

For all concrete decks and for multi-beam slab bridges, assume adequate lateral distribution of loads and distribute the sum of all wearing surface dead loads (stage 2 dead loads) equally among all girders.

Add a point load at the center of bearing to account for the dead load of the wearing surface that extends beyond the center of bearing (the red shaded area illustrated in Article 5.2.5), if a crossbeam analysis is warranted. Even though this load will have no impact to the load rating of the girder, it will be utilized when applying the girder dead load reactions to crossbeams.

10.2.11 Live Load (LL)

List the four classes of rating loads to be analyzed. (See Articles 1.5.1.1 through 1.5.1.4).

10.2.12 Analysis Sections

Each end of each section will be evaluated for shear, axial, flexure and combined axial and flexure. These sections include, but are not limited to, the following:

- Critical Shear Section Points

  According to AASHTO LRFD Article 5.7.3.2, critical shear section locations shall be taken at shear depth d_v from face of support. AASHTO LRFD Article 5.7.2.8 states that the effective shear depth (d_v) is taken as the distance, measured perpendicular to the neutral axis, between the resultants of the tensile and compressive forces due to flexure; it need not be taken to be less than the greater of 0.9d_e or 0.72*h*. Thus, for flexural members the distance between the resultants of the tensile and compressive forces due to flexure can be determined as:

$$d_v = \frac{M_n}{A_s f_y + A_{ps} f_{ps}}$$ (AASHTO LRFD C5.7.2.8-1)

  For prestressed members with parabolic strands, the calculation of the moment capacity at a given distance from the support in the above equation becomes complicated and would require an iterative approach. To simplify the approach, the critical section at d_v shall be calculated as 0.*72* h (in.) from the support face. Do this for each critical section location (each end of each unique span).

  In the event that the above equation produced a higher d_v, 0.72h will be more conservative as it is located closer to the support thus resulting in higher shear location that is being analyzed. Likewise, if 0.90d_e is greater than 0.72h, using 0.72h will be located closer to the support thus resulting in higher shear location that is being analyzed. In the event that 0.72h is greater than the above equation or $0.90d_e$, then 0.72h will be in compliance with LRFD Article 5.7.2.8.

- Flexural Bar Cutoff Points

  Flexural bar cutoff analysis is not required. The flexural moment capacity is primarily developed by the prestressing tendons. Therefore, it is not necessary to evaluate mild reinforcement bar cutoff locations for post-tensioned box girders.

- Member Geometry Change Points

  Show calculations locating any abrupt change in member cross section, such as the beginnings or ends of haunches, web tapers, partial bottom flanges, or changes in plate thickness.

- Stirrup Spacing Change Points

  These locations are taken from the stirrups schedule spreadsheet embedded in the Preliminary File and adjusted by one stirrup space toward the direction with the greater spacing. At a stirrup spacing change location, a shear crack would propagate across both stirrup spaces. The analysis doesn't interpolate the shear capacity to the left and right of an analysis point. Therefore, moving the analysis point by one stirrup space moves the analysis location away from the transition area providing a more realistic analysis.

  Indicate which stirrup spacing change points in the girder are farther from the support than the critical shear point.

- Any other section or material change location.

10.3 Cross Section Geometry

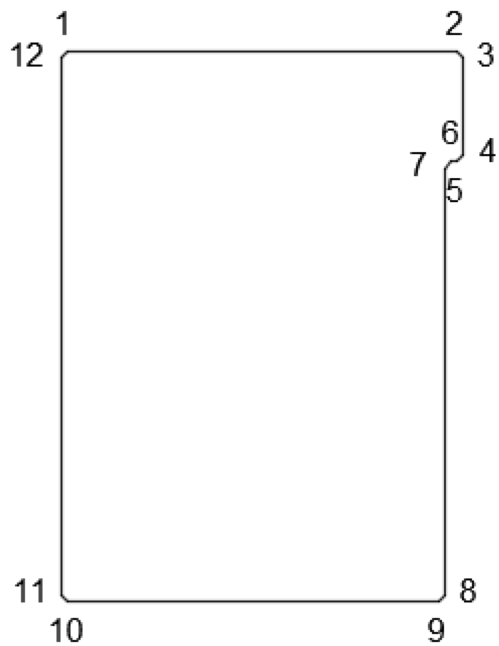
Calculate the section properties at each unique section change location. A combination of MicroStation and the Midas Sectional Property Calculator tool is used.

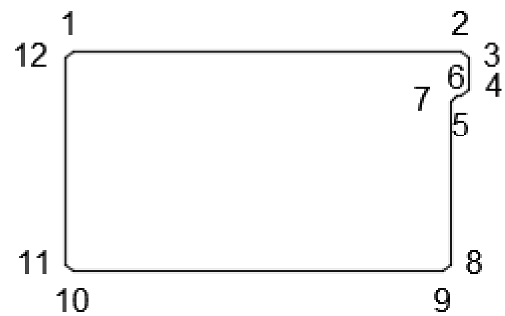
Node points will be created for the ends of spans (CL Bearing), member geometry change points, and all analysis points. Only the section change locations will have a cross section defined. The tapered section group command within Midas is used to taper between sections.

10.3.1 MicroStation Cross Sections

Before beginning work in MicroStation review the list of Section Properties from the preliminary Mathcad file. Reviewing this for completeness can save significant time later. There are two methods for creating cross sections in Midas. The first is to draw each section in MicroStation and then export to the Midas Sectional Property Calculator. The second method is to define the section directly in Midas. Only section change locations have to be defined here. It is acceptable to use AutoCAD to generate the cross sections.

Midas is capable of tapering from one section to the next. However, for this taper to work correctly each cross section must have the same number of joints. Arch section geometry will typically only taper for concrete members. These members are generally rectangular in shape and therefore have the same number of joints. Steel arch sections typically have pronounced geometry section change locations (changes to plate or web thickness). Only sections that are being tapered must have the same number joints. See the example figure below.





Use good drafting techniques when drawing this first section. Make sure all intersecting lines are trimmed and match up correctly. Do not have any overlapping line segments. Draw in all chamfers. Most structures are symmetric about the CL of the section; take advantage by drawing half the section and then make a mirrored copy about the vertical axis. This first section will be the template for all other sections, so take the time to check it for accuracy.

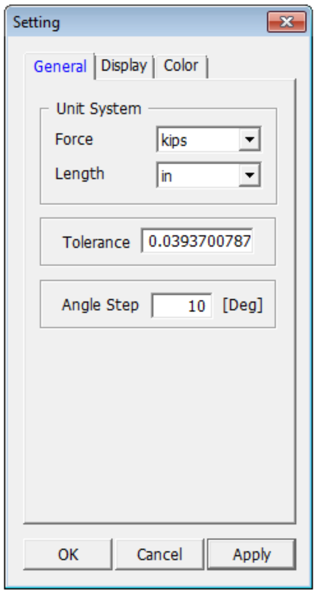
Copy and paste the first cross section to use as a starting point for the next section. Alter the section to match the new cross section dimensions. If a joint is eliminated, place a dummy joint in the new cross section. A dummy joint can be made by breaking a line segment into two line segments at approximately the location where the joint is removed. All of the sections must have the same number of joints for Midas to properly taper from one section to the next.

Continue this process until a cross section exists for each node in the span. Place the cross sections so that they are in sequential order from the first to last. Copy all of the sections and paste them adjacent to the original sections. One set of sections shall have the appropriate dimensioning shown on the drawing along with a section number label. The other set of sections will have no dimensioning or labels. Copy the non-labeled sections into a new file titled Sections and save as a .DXF.

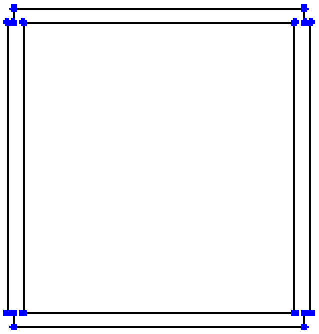
10.3.2 Sectional Property Calculator

The Midas Sectional Property Calculator tool is used to convert the MicroStation Sections.dxf file into a Sections.sec (Section Export File). Once created the Sections.sec file is used by Midas to define the section properties.

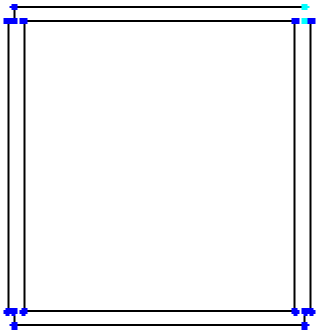
Open Midas and under the tools menu open up the Sectional Property Calculator (SPC). Once open change the force to kips, the length to inches, click Apply and then okay. Apply must be clicked for the tolerance to be recalculated as shown below.



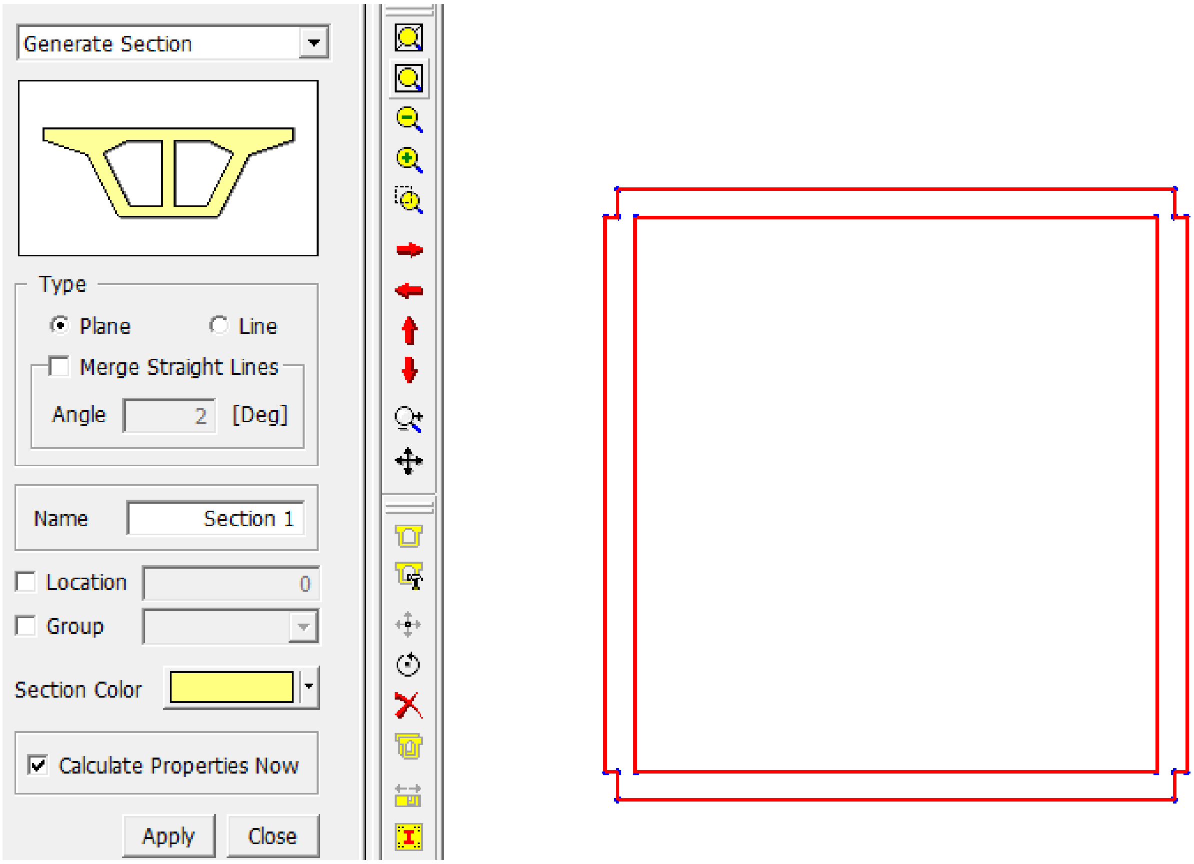
Import the Sections.dxf file created in MicroStation. Go to File => Import => AutoCAD DXF. Browse to the file location and open. The SPC will pop up a window either stating "It will take a very long time for checking the entire curves", or it will pop up "Check the intersection and/or duplication of the imported DXF model data?" If the later occurs, select No. Selecting yes would remove any dummy nodes that were intentionally created while drawing the section in MicroStation.



The imported sections will look similar to those shown below. Check that the node points are all dark blue and have the same number of nodes from one section to the next. If there is an error, the SPC software will display a light blue color at the node, as shown in the top right corner of the lower cross section to the right.



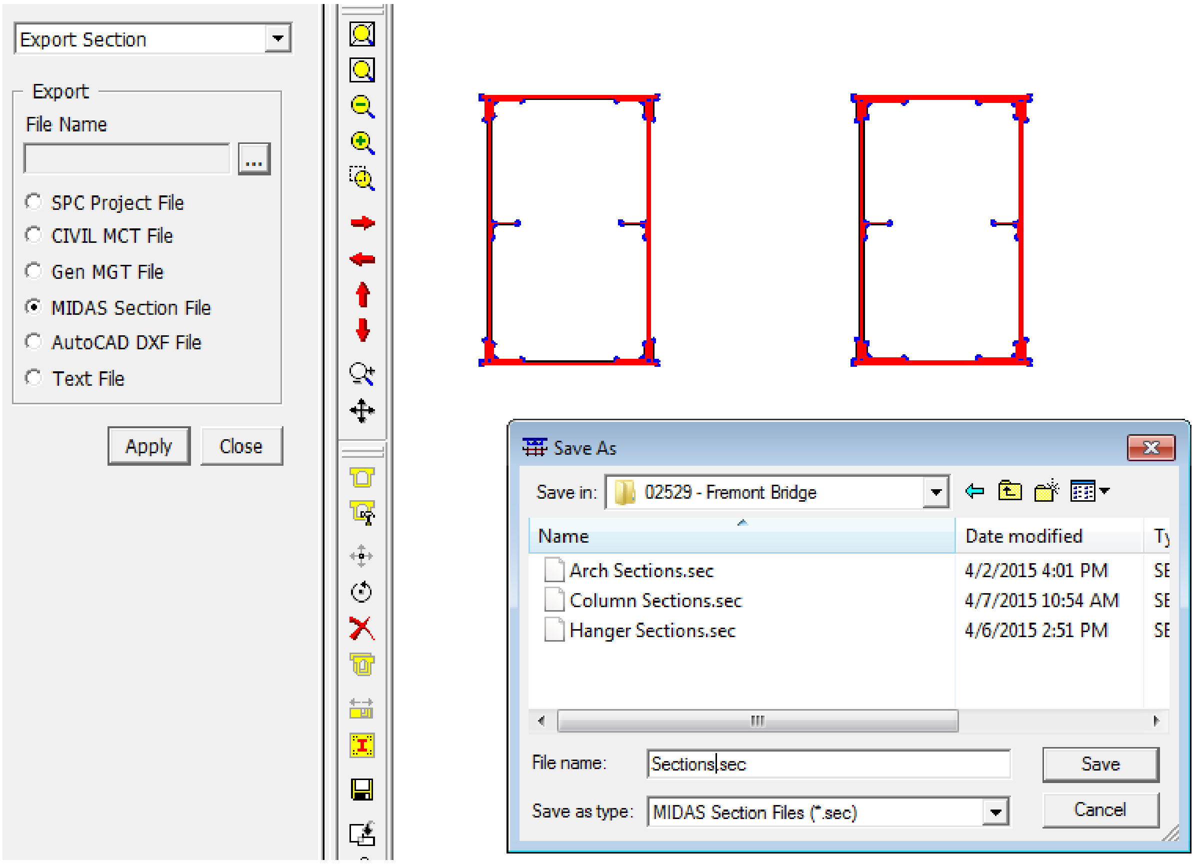
Using the Generate Sections tab (Shown on the next page), generate and calculate the properties for each section. Highlight the cross section with the mouse. Select Plane for Type. Uncheck the Merge Straight Lines (this would remove any dummy joints). Name the section and check the calculate properties now box. Click Apply. See below for a graphic of this setup.



Continue generating sections until all cross sections have been completed.

NOTE: If an error regarding mesh size is reported, close the program and restart by importing the .dxf file. Create all of the sections as shown above, but do NOT select calculate properties now. Once all of the sections are generated, go to the top menu Property => Calculate Section Property. Refine the mesh density as required. Select all of the sections and then click apply. This may take several minutes depending on the number of sections and the mesh size.

On the left tree menu, under Section, select Export. Select Midas Section for the file type and name the file Sections. Highlight all of the sections and click apply. This will create the Sections.sec file that will be imported into Midas.



10.4 Midas Civil

Midas Civil is not used to calculate capacity or rating factors. Rather it is utilized to determine various load effects. Capacity and rating factors are calculated in the appropriate Excel capacity sheets (nnnnn_ConcArch.xlsm, nnnnn_StlArch.xlsm, nnnnn_StlTension.xlsm, and nnnnn_ConcGen.xlsm). Midas Civil is a powerful finite element analysis software. The below procedure may be valid on previous versions. If a previous version is used, check the input and output for consistency with this chapter.

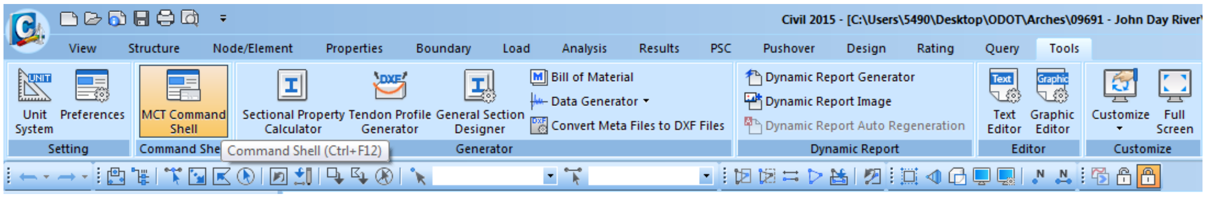
The model used to determine the nonlinear buckling capacity is typically a modification of the primary static and live load model. Where possible, the modeler should use modeling techniques that will reduce the amount of modification required to prepare the nonlinear model. For example, “rigid link” connections that do not perform well in a nonlinear analysis could instead be modeled using members that allow for appropriate model behavior in both the primary and nonlinear models. Some modification will be necessary as the nonlinear analysis requires the removal of any temporary (construction staged) releases, the moving load analysis control, and live load definitions.

Correctly modeling details that affect even minor deflections are critical in both the primary and nonlinear buckling models. Techniques that might be justifiably neglected in standard modeling practice can have a significant impact on arch results. Examples of techniques that must be used in most arch nonlinear analysis include use of axial releases in deck elements at expansion joints, modeling substructure elements instead of replacing them with simple supports and ensuring correct rigid end offset distances are used.

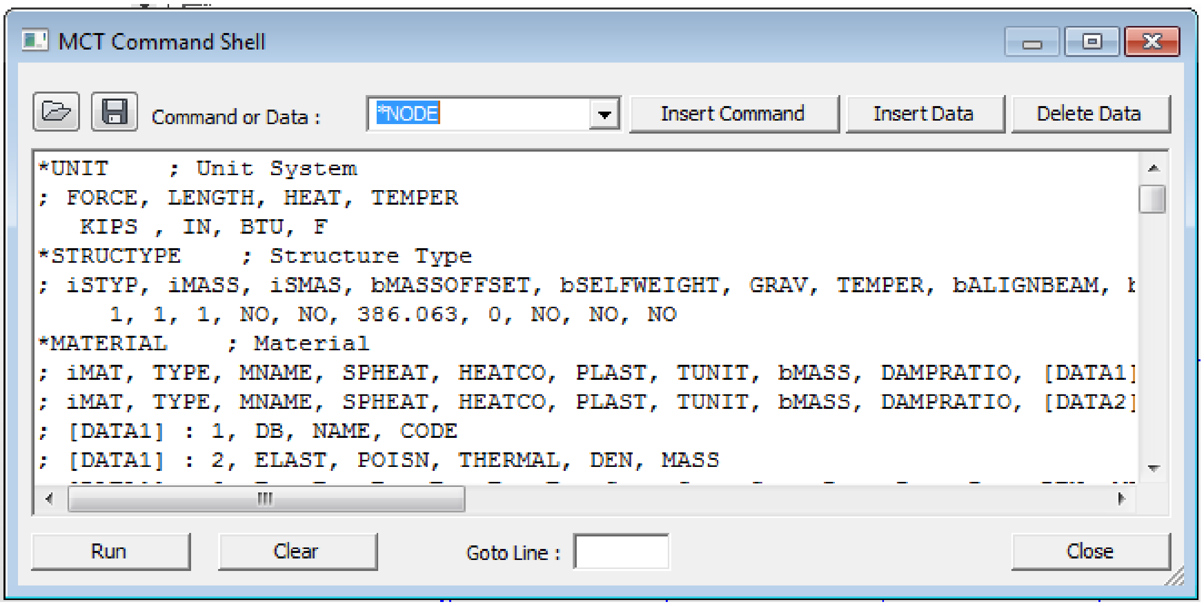
10.4.1 Midas Template

Create a new Midas model and save it with the name nnnnn_ConcArch.mcb or nnnnn_StlArch.mcb.

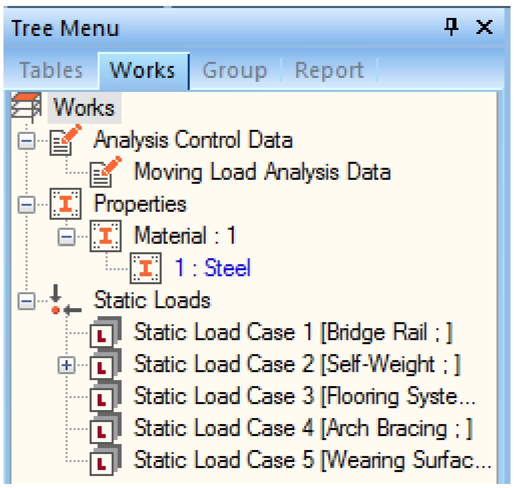
In the top menu, go to Tools > MCT Command Shell.

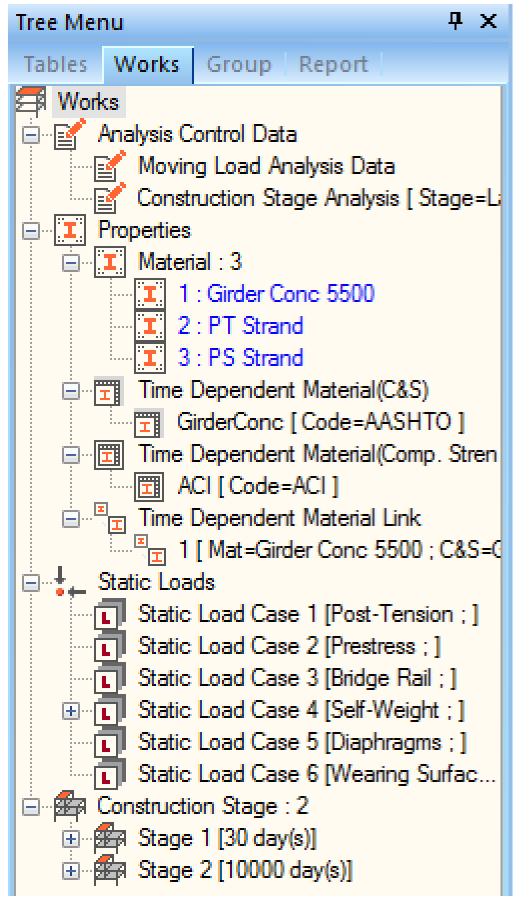


Within the MCT Command Shell, click the open file icon. Open the mct file named "LR_Midas_ConcArch_Data.mct" or "LR_Midas_StlArch_Data.mct" (depending on which arch type is being rated), which will populate the MCT Command Shell window with data. At the bottom left of the MCT Command Shell window click on the "Run" button. Then click on the "Close" button at the bottom right of the MCT Command Shell window.



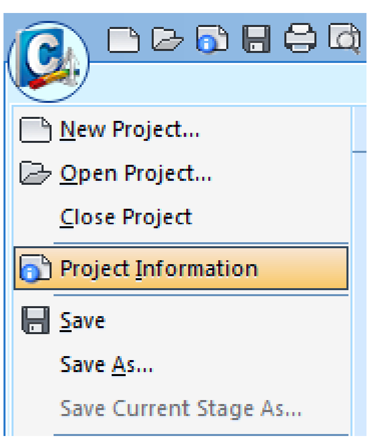
Within the Works Tree Menu there will now be Analysis Control Data, Properties, and Static Loads defined for the model.

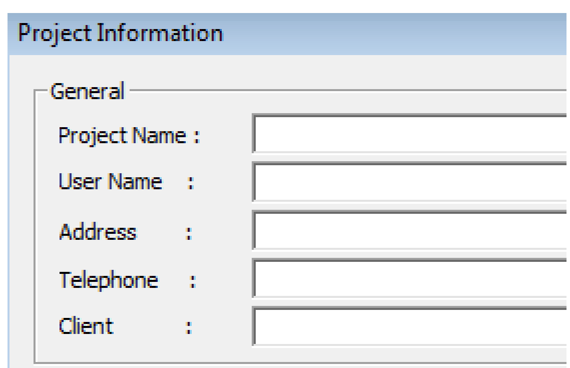




10.4.2 Project Information

Update the project information with the bridge number, engineer's name, and company performing the load rating. In the top menu go to File => Project Information.





10.4.3 Properties

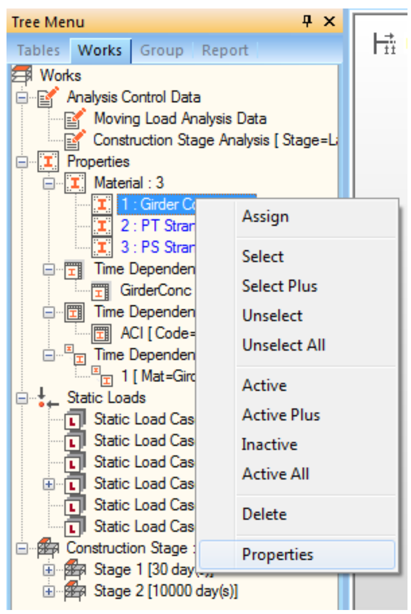
Using the tree menu verify the material properties and make adjustments as necessary. Make sure the input units are correct.

10.4.3.1 Materials

One concrete, one PT strand, and one PS strand material property is predefined as part of the concrete template. A steel material property is predefined as part of the steel template. Update these materials as required. If additional materials need to be assigned go to the top menu under Properties => Materials and select Add. The deck, stem walls, and bottom slab are typically the same concrete strength; regardless the Midas model will assume one concrete strength for the entire superstructure. Likewise, the flanges, webs and stiffeners of steel members are typically the same steel strength. Any variation in concrete/steel strength can be accounted for by using a transformed section. Mild steel reinforcement doesn't need to be defined in Midas. Mild reinforcement will be directly entered into the capacity spreadsheets.

If multiple concrete material properties are used (i.e. different concrete strength for the deck than the arch) in conjunction with construction staging, each concrete material must be associated with the three time dependent material actions listed below.

In the tree menu right click on "Concrete 5500" or whatever material is to be updated, and then left click on "properties".

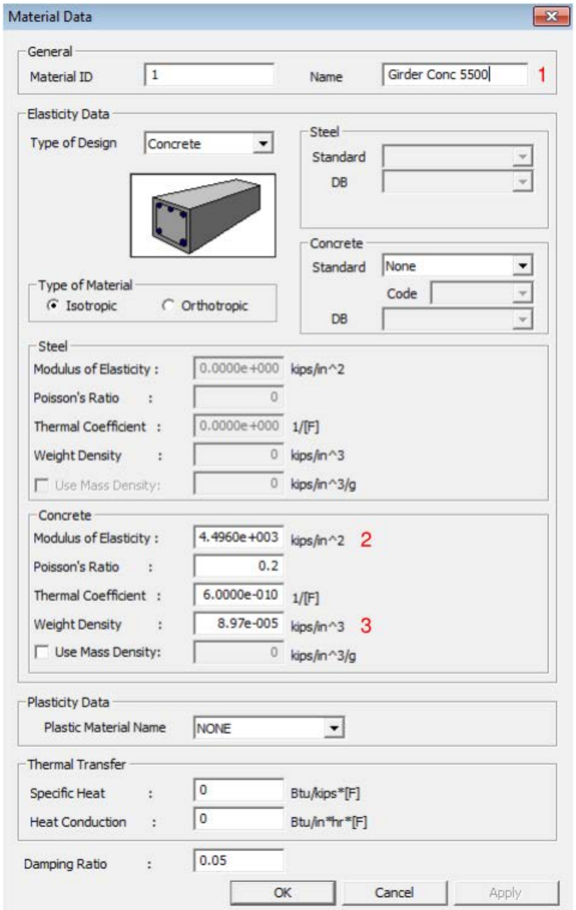


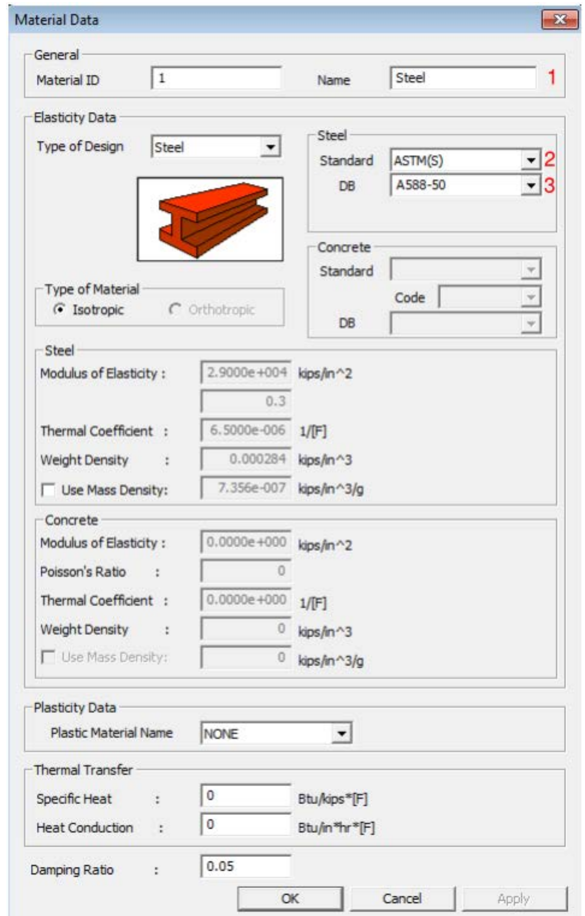
Update the following:

1) Name.

2) Modulus of Elasticity or Steel Standard

3) Weight Density or Steel type (DB). Select OK.



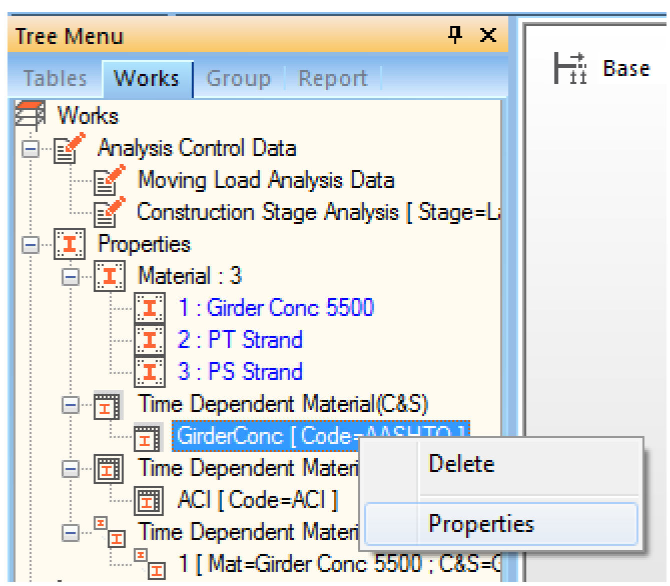


PT and PS Strand material properties should remain unchanged. Note the unit weight is set to 0.0 kips/in^3 because the unit weight of the concrete includes reinforcement.

10.4.3.2 Time Dependent Material (C&S)

Update the properties used to calculate creep and shrinkage.

Right click on Concrete (Code=AASHTO) and left click on properties.

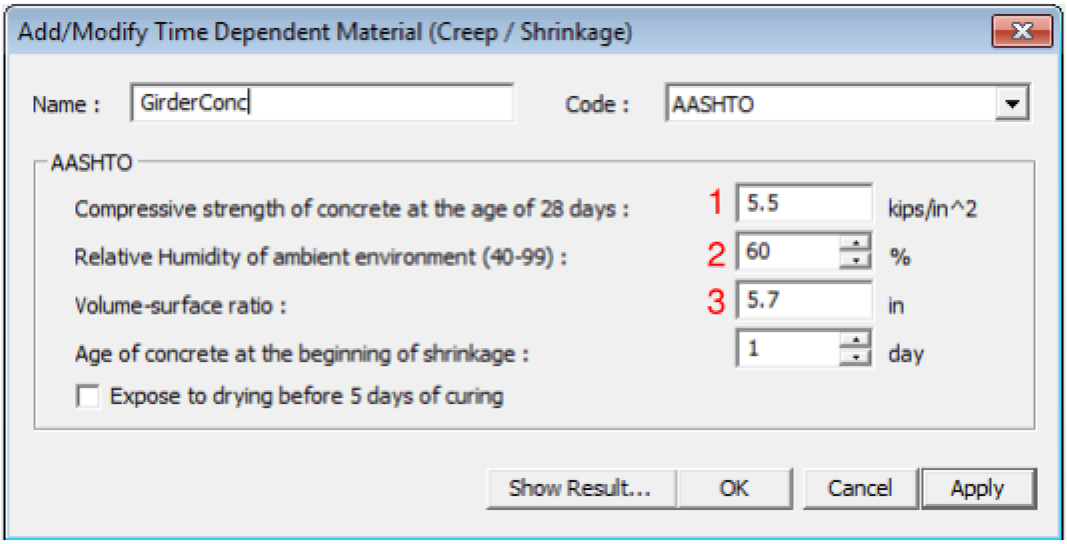


Update the following:

1) Concrete Compressive Strength.

2) Relative Humidity (PER AASHTO LRFD FIGURE 5.4.2.3.3-1).

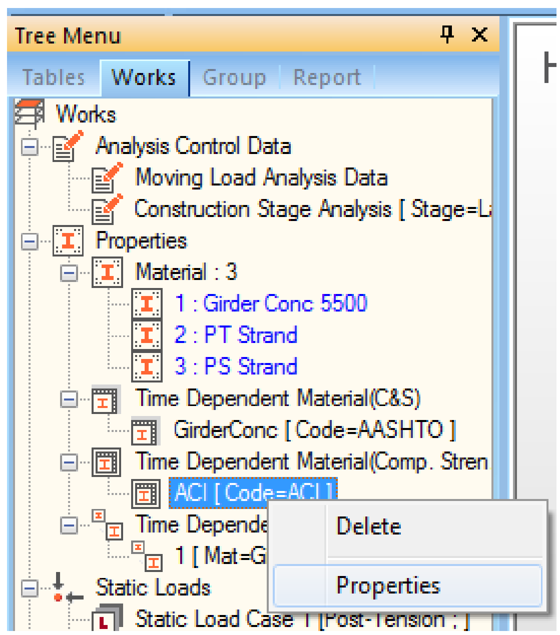
3) Volume-surface ratio. Click on Apply.



10.4.3.3 Time Dependent Material (Comp. Strength)

Update the concrete parameters used to calculate the time dependent compressive concrete strength.

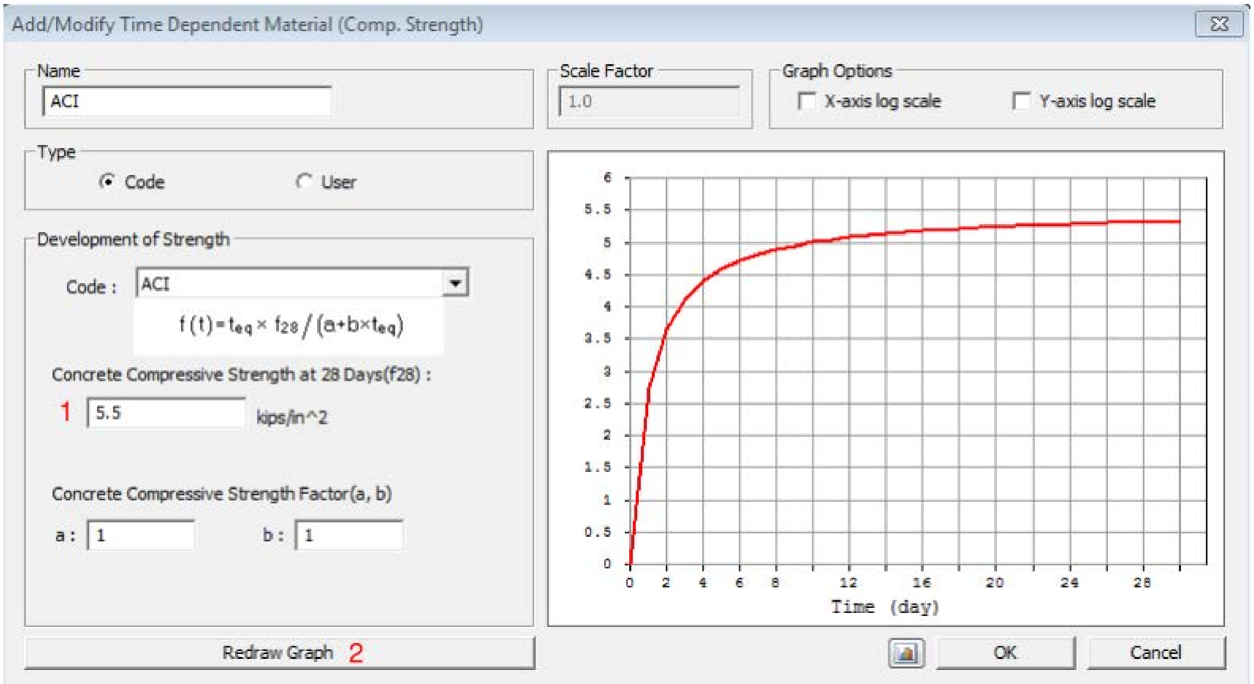
Right click on ACI [Code=ACI] and then left click on properties.



Update the following:

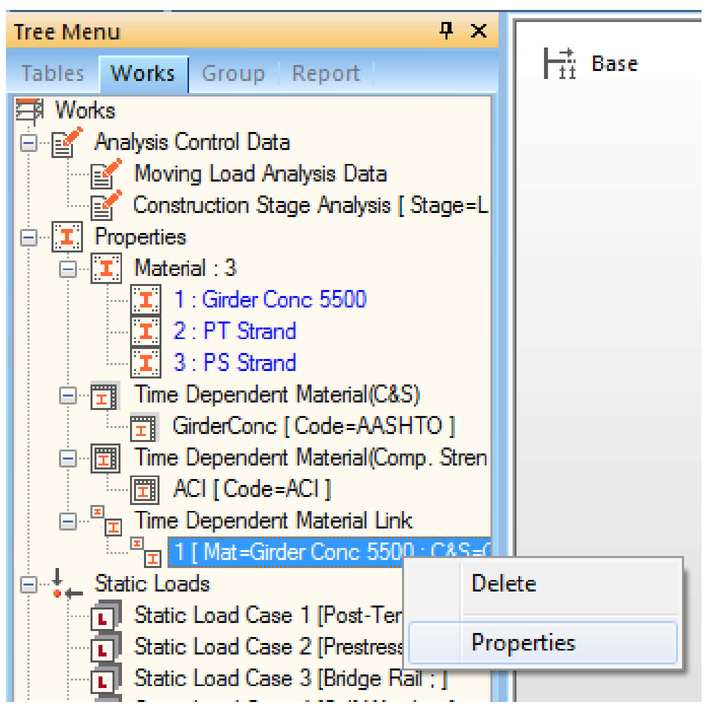
1) Concrete Compressive Strength.

2) Click Redraw Graph. Click OK.



10.4.3.4 Time Dependent Material Link

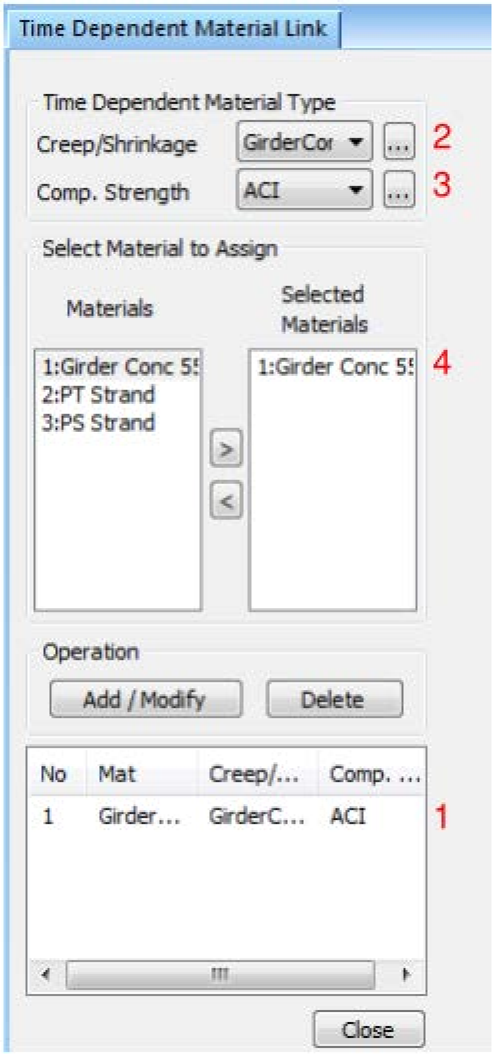
Unless additional materials were defined, this section should remain unchanged. The Time Dependent Material Link assigns defined materials to time dependent properties. Note prestress steel time dependent properties are defined in a different section.



Right click on 1 [Mat=Concrete 5500 ; C&S=Concrete ; E=ACI and then left click on properties.

Check/Update the following:

1) Click on No 1 Concrete.
2) Creep/Shrinkage is Concrete.
3) Compressive Strength is per ACI.
4) Selected material is Concrete. If all is ok then click close, if not update to the correct parameter and then click Add/Modify, then close.

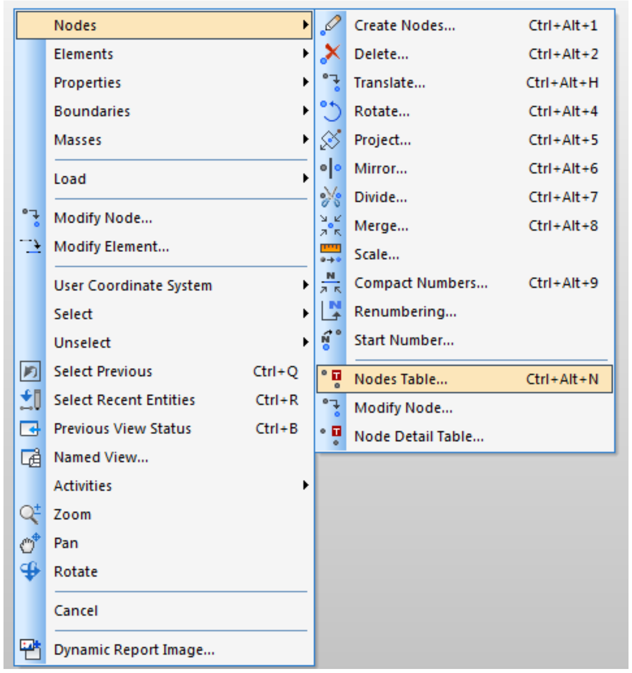


10.4.4 Sections

Cross sections have been defined, and section properties have been calculated for each cross section. These will be imported and tapered as applicable. The sheet references nodes, to sections, to distances.

10.4.4.1 Nodes

Within the Model View window, right click anywhere and select Nodes > Nodes Table.

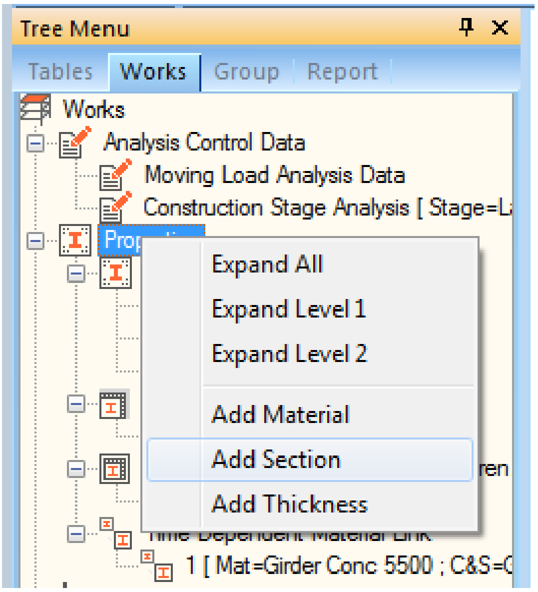


Node locations can either be manually typed into the X column or copy and pasted from a separate geometry spreadsheet.

Node	X(in)	Y(in)	Z(in)
1	0.000000	0.000000	0.000000
2	67.500000	0.000000	51.237557
3	135.000000	0.000000	100.391782
4	202.500000	0.000000	147.462675
5	270.000000	0.000000	192.450237
6	337.500000	0.000000	235.354467
7	405.000000	0.000000	276.175365
8	472.500000	0.000000	314.912932
9	540.000000	0.000000	351.567166
10	607.500000	0.000000	386.138070
11	675.000000	0.000000	418.625641
12	742.500000	0.000000	449.029881
13	810.000000	0.000000	477.350790
14	877.500000	0.000000	503.588366
15	945.000000	0.000000	527.742611
16	1012.500000	0.000000	549.813524
17	1080.000000	0.000000	569.801106
18	1147.500000	0.000000	587.705356
19	1215.000000	0.000000	603.526274
20	1282.500000	0.000000	617.263861

10.4.4.2 Sections

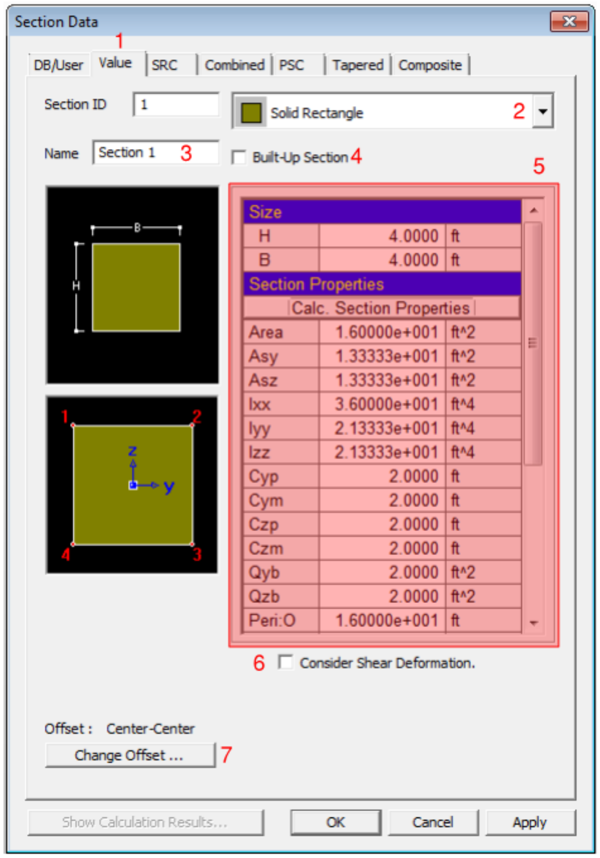
In the Tree Menu, select Properties and right click, then left click on Add Section.

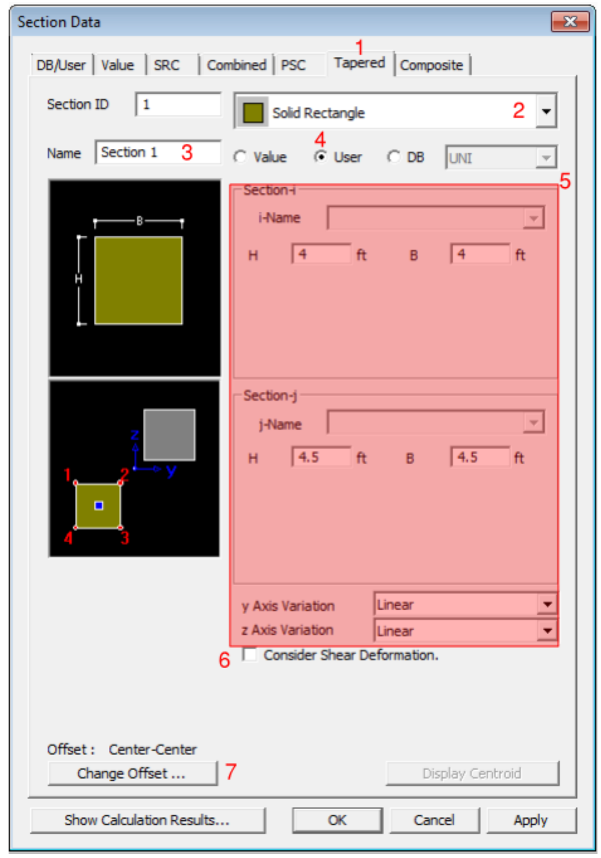


10.4.4.2.1 Defining Sections Within Midas

After you click to Add Section, the Section Data field will pop up:

1) Click on the desired Section Data Tab (2 examples are shown in the figure below).
2) Select section shape.
3) Name the section appropriately.
4) Uncheck the Built-Up Section box or select User input.
5) Enter in the Section dimensional information shown in the shaded area.
6) Uncheck the Consider Shear Deformation box.
7) Click on Change Offset, if necessary. Typically, this will be Center-Center for arches. Click Apply.



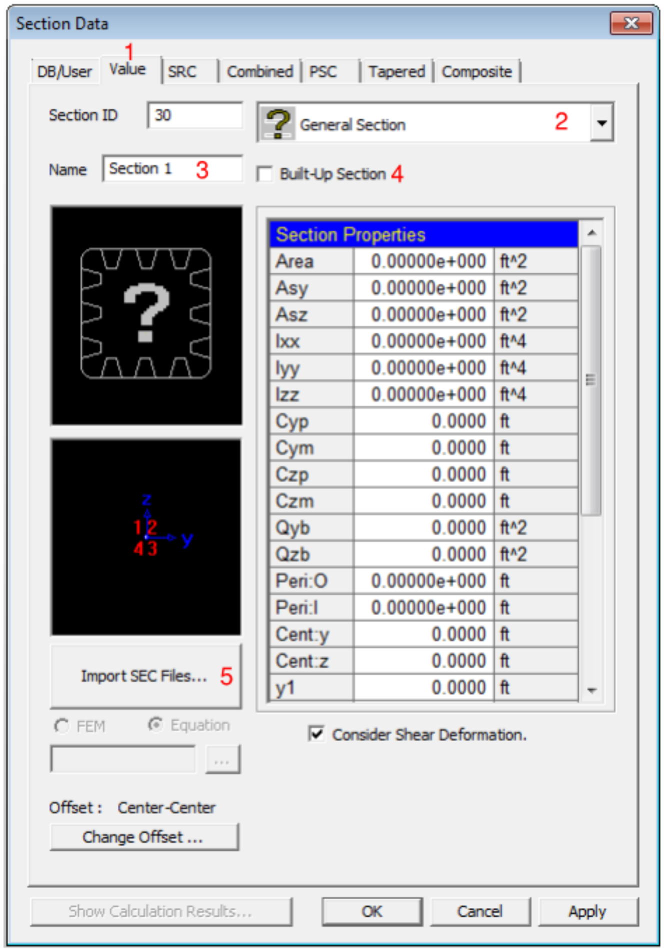


Clicking Apply defines the cross section and brings up the next section. Continue the above steps until all of the cross sections are assigned.

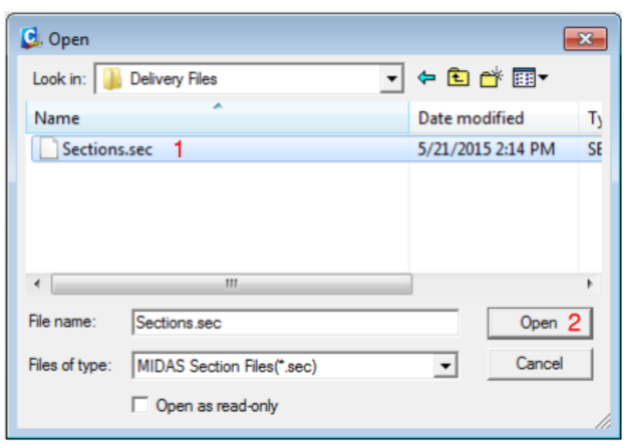
10.4.4.2.2 Importing Sections from Section Property Calculator

After you click to Add Section, the Section Data field will pop up:

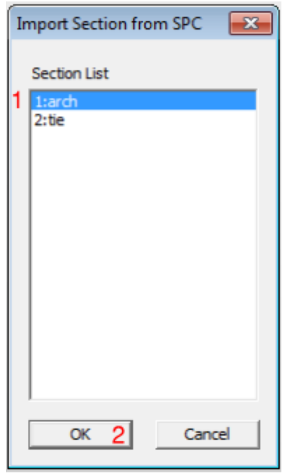
1) Click on the Value tab
2) Select General Section.
3) Name the section appropriately.
4) Uncheck the Built-Up Section box.
5) Click on Import SEC Files…



When Import SEC Files is selected a new box pops open. Midas is searching for the .sec file created during section 15.3.2. Browse to this file, select it (1) and click Open (2).



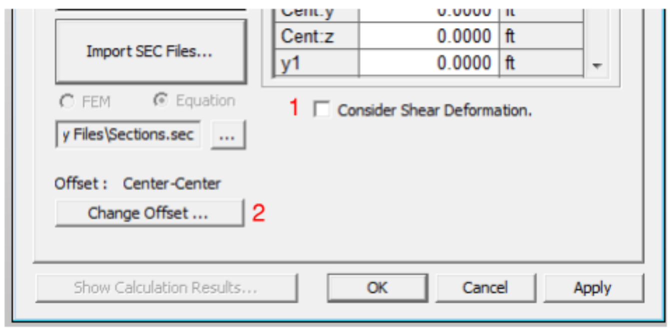
Select the appropriate section (1), and click OK (2). This will populate the Sections Properties field with the values calculated by the Sectional Property Calculator.



Update the following:

1) Uncheck the Consider Shear Deformation box.

2) Click on Change Offset, if necessary. Typically, this will be Center-Center for arches. Click Apply.



Clicking Apply defines the cross section and brings up the next section. Continue the above steps until all of the cross sections are assigned.

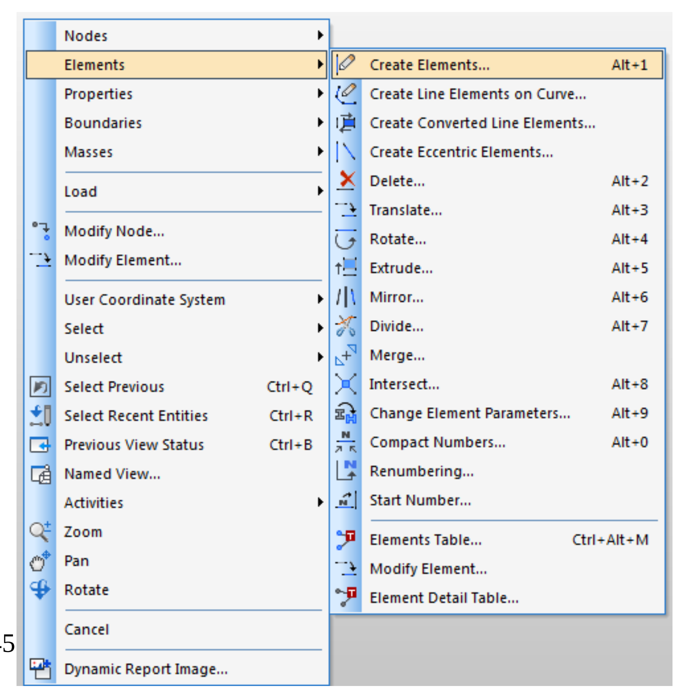
10.4.5 Elements

Within the Model View window, right click anywhere and select Elements > Create Elements.

Make sure to save the file prior to proceeding with creating elements. If the number of joints, per cross section, on end (i) does not match the number on end (j), the model will crash and any unsaved data may be lost.

Select Hidden View (quick command Ctrl + h). This view will give a good graphical representation of the cross sections and will aid in checking the model.

Due to software limitations it is important to align the local axes of the elements in the superstructure. When defining the model all



the elements should be defined from the left to the right, resulting in each element having the (i) end at the left node and the (j) end at the right node. It is acceptable to switch this convention and define all of the elements from right to left. It is NOT acceptable to define some elements from left to right and others from right to left in the same model.

Update the Following:

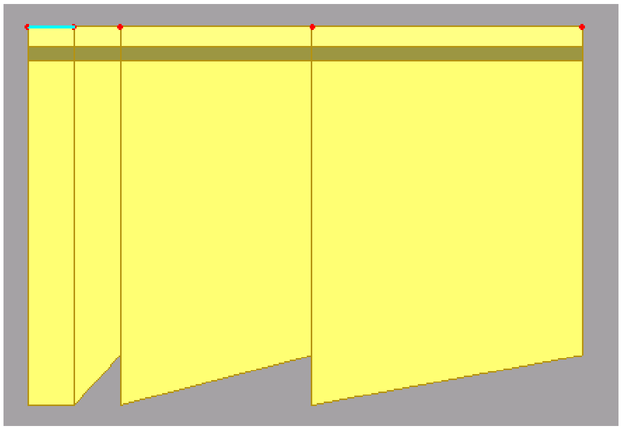
1) Select Create Elements.

2) Select General beam/Tapered beam.

3) Select the Concrete Material defined previously.

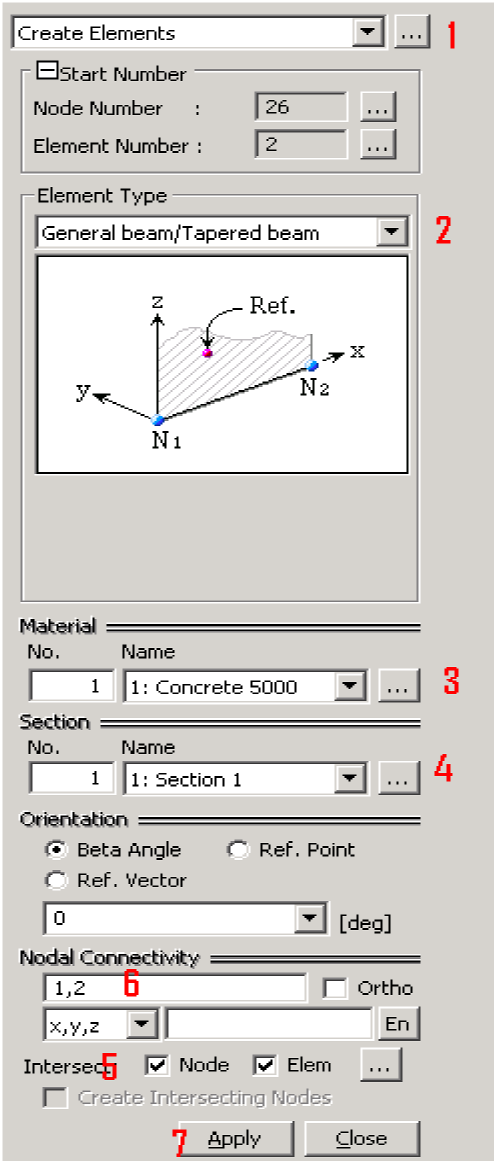
4) Select the appropriate cross section.

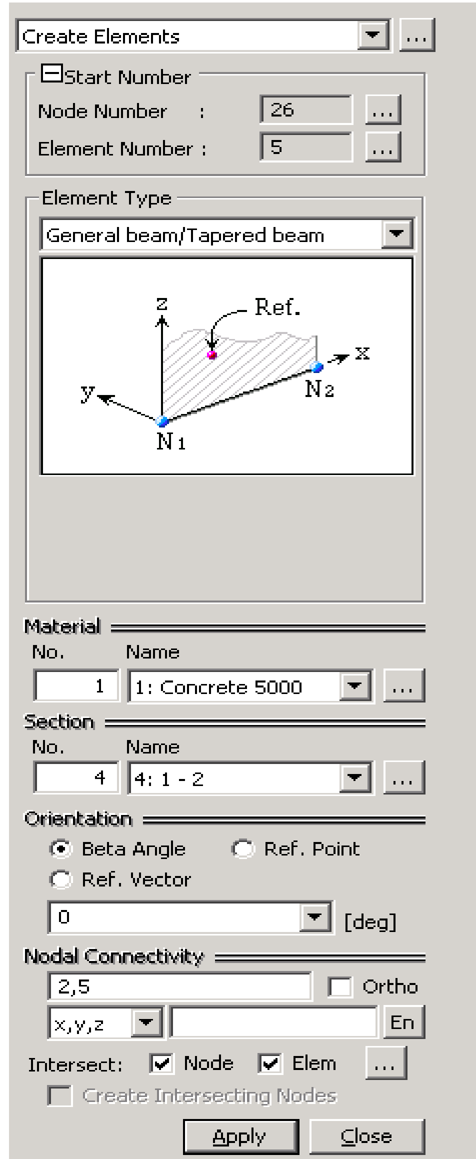
5) Select Intersect Node and Element. When tapered sections are used to define an element and the element is defined across several nodes, the model will have a saw tooth appearance. This is because as the element intersects nodes in the model, it will create additional elements each with the same section for the (i) end and the same section for the (j) end. For example, if the (i) end is section 1 and the (j) end is section 2 and the element begins at node 2 and goes to node 5. As seen to the right, a saw tooth appearance is created as the element intersects node 3 and 4. This is corrected later using the tapered section group command.



6) Type in the beginning and ending node for the specified element. Click Apply

The figure on the left shows the above steps for defining the element that has section 1 defined at both the (i) and (j) end. The figure on the right shows the input for a tapered element, from node 2 to 5, that has cross section 1 defined at end (i) and section 2 at end (j).

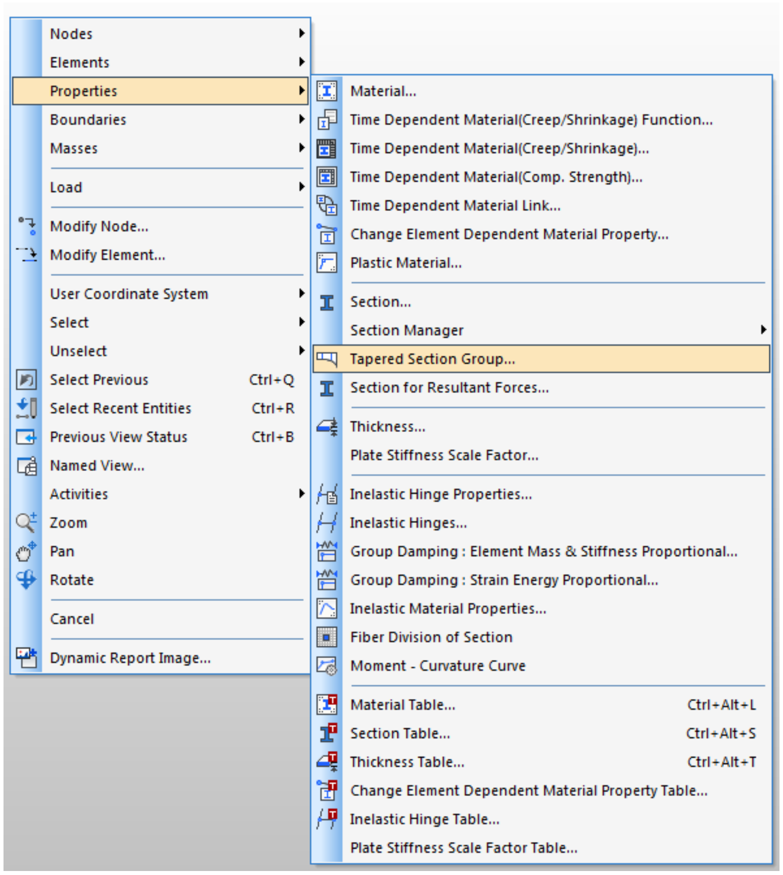




Continue until all of the elements have been created.

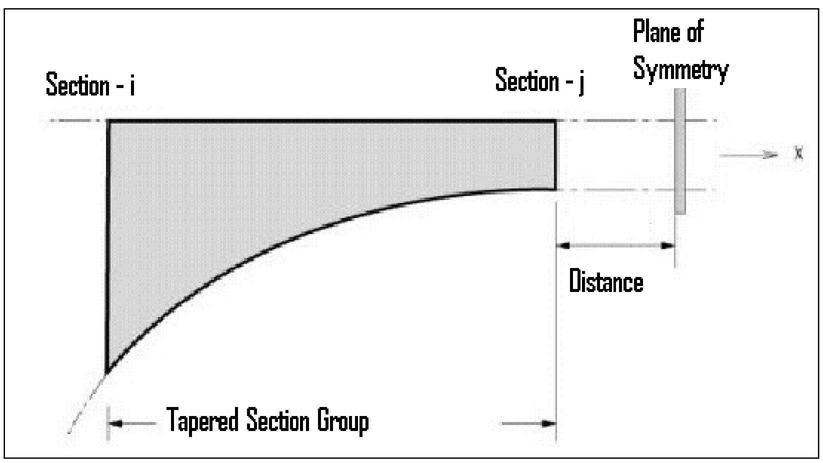
10.4.6 Tapered Section Group

In the top menu go to Model => Properties => Tapered Section Group.



This command is used to taper a section across several elements. Both the y and z axis can be tapered independently and can be tapered as linear or polynomial.

1) Name tapered section group. An example; “1 – 2” for a group that tapers from section 1 at the (i) end of the leftmost element to section 2 at the (j) end of the rightmost element.
2) List all of the elements that are included in the group.
3) Select z-axis variation. For most parabolic structures select a second order polynomial.
4) If a polynomial is selected, the distance to the symmetric plane must be defined. The symmetric plane is the location that the polynomial has zero slope (commonly midspan). If the tapered section group extends to the plane of symmetry then the distance is zero. See below diagram.



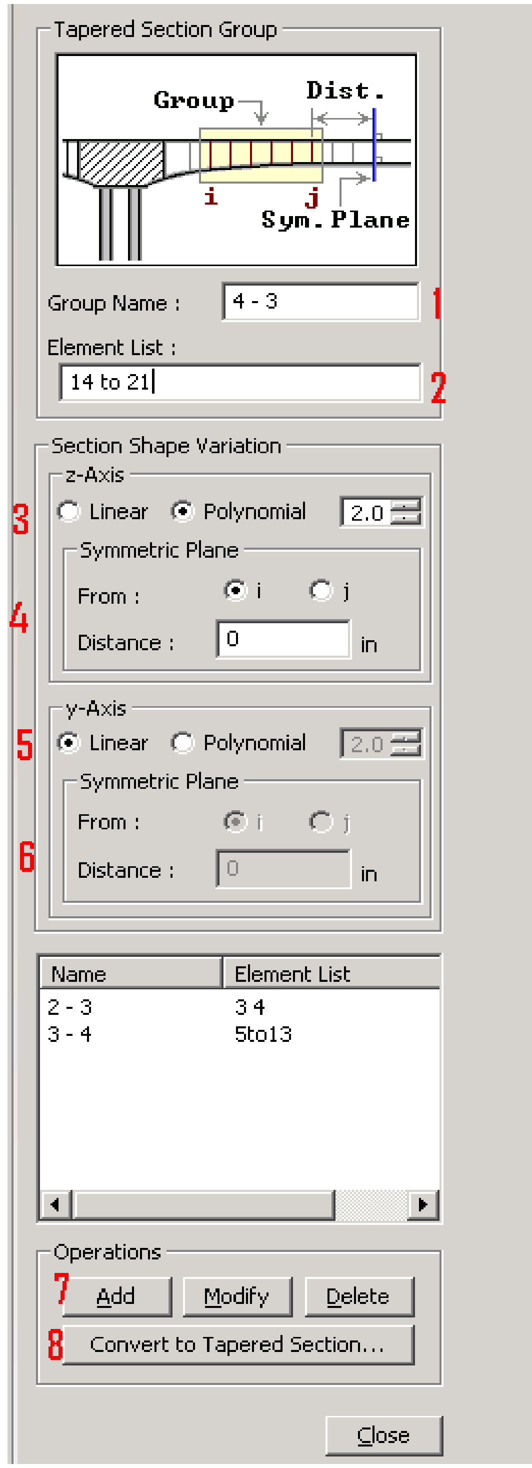
Note: Midas will vary all z-axis dimensions parabolically between sections. If the deck varies linearly and the overall structure depth varies parabolically some error will be introduced as the deck is varied parabolically. This error in dead load is generally small.

5) Select y-axis variation. This variation is typically linear but can also be defined parabolically.

6) If a polynomial is selected, the distance to the symmetric plane must be defined.

7) Click "add" to create the tapered section group. The next tapered section can now be defined.

8) Do NOT click on "Convert to Tapered Section…" button. This will replace the tapered section group with generated sections at each node point. Although the analysis will not be altered, using this feature makes checking a model for accuracy more difficult. It is easier to check a few sections for accuracy and the parameters of a tapered section group than to check a section at each node point.

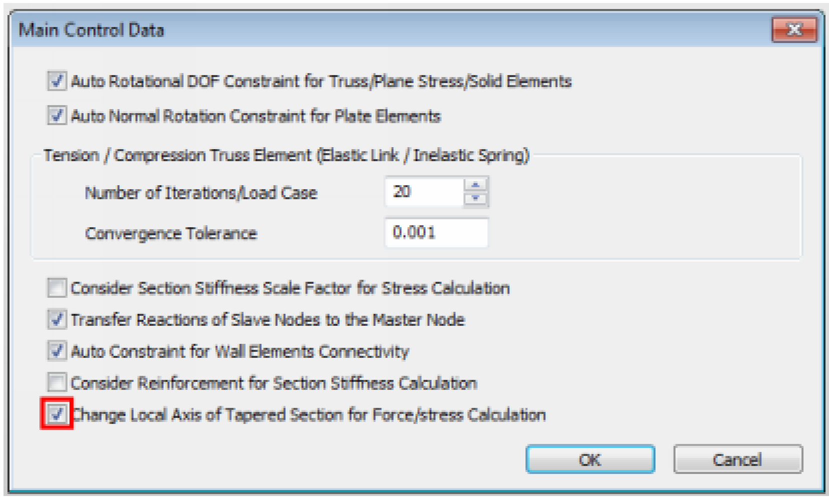


When done, a smooth three dimensional structure should be displayed. This provides a good opportunity to check that the cross sections are input and assigned correctly. The model should be smooth without jumps from one section to the next.

10.4.6.1 Change Local Axis for Force/Stress Calculations

Midas will default to calculating all force effects along the axis of the elements centroid. Tapered elements have a centroidal axis that is not perpendicular to the direction of gravity. Because of the inclined centroidal axis, axial force effects will incorrectly interact with shear effects. In Midas Civil 2013 version 1.2 a new feature has been added to correct this interaction. In the top menu go to Analysis => Main Control Data and check the "Change Local Axis of Tapered Section for Force/stress

Calculation" box. This will force the software to calculate axial force effects perpendicular to the direction of gravity.



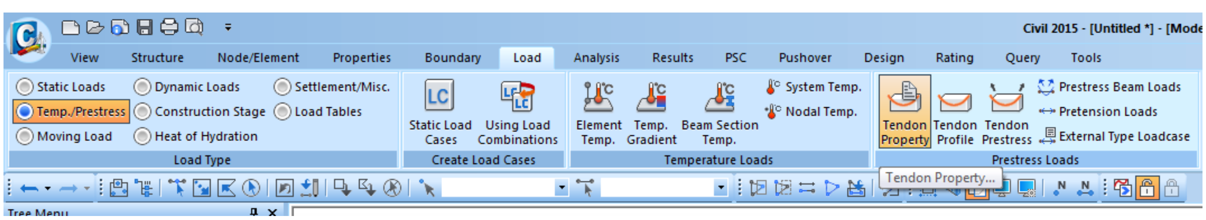
10.4.7 Prestress and Post-Tensioning

Midas provides flexibility in how post tensioning is defined. The example shows a case where half of the strands are stressed from the left end, while the other half are stressed from the right end. No strands are tensioned from both ends. For concrete arches, there are groups pre-defined as PT Right, PT Left, PT Both and PS Sections.

Although the display is showing a 3D model, the analysis is really a 2D beam line analysis. Thus, it is not necessary to code the PT Strands at the actual location (without shop drawings these locations are unknown anyways). All of the prestressing will be coded along CL of the structure and will follow the CG profile provided in the plans. It is important to break out the strands that are tensioned from Left, Right, or Both ends.

10.4.7.1 Tendon Property

In the top menu, select Load => Temp./Prestress => Tendon Property and then click Add.



Update the following:

1) Tendon Name (Identify which end the tendon is stressed from).

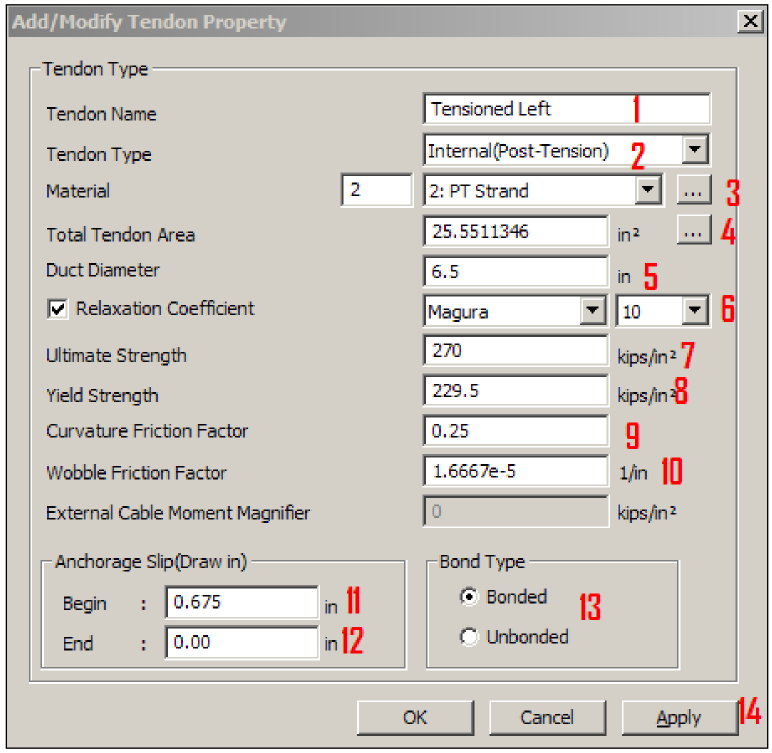
2) Select Internal (Post-Tension) or Internal (Pre-Tensioned) for Tendon Type.

3) Select PT or PS Strand for Material.

4) Total strand area for this tendon group. Reference the number of strands per duct calculation in preliminary Mathcad sheet. The "…" box to the right of this cell brings up a field that will assist with calculating the area of all the strands. This value will be iterated later to determine the actual number of strands per duct.

5) The duct diameter is arbitrary with the exception that the duct area must be larger than the Total Tendon Area (Calculated in step 4). Back calculate the duct diameter based on an area larger than the total strand area.

   a. Note: When Internal (Pre-Tension) tendon type is selected the duct diameter field changes to strand diameter. This equivalent strand diameter is automatically calculated from the tendon area entered in step 4.



6) Select Magura for the relaxation analysis type, and select the appropriate coefficient; 10 for stress relieved and 45 for low relaxation strand.

7) Input the Ultimate Strength.

8) Yield Strength.

9) Curvature Friction factor. (PT Only)

10) Wobble Friction Factor. This value is commonly provided without units. If k = 0.0002 is reported, this value has units of (1/ft) and should be converted to (1/in). (PT Only)

11) Input the appropriate left end anchor set value. If the strand is tensioned from the right only input 0.0in. (PT Only)

12) Input the appropriate right end anchor set value. If the strand is tensioned from the left end only, input 0.0in. (PT Only)

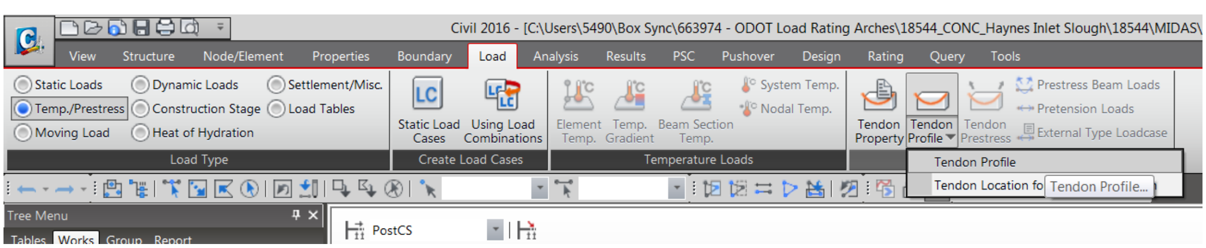
13) Select Bonded or Unbonded for tendon Bond Type. (PT Only)

14) Click Apply.

Continue until all tendon groups are entered; Left, Right, and Both.

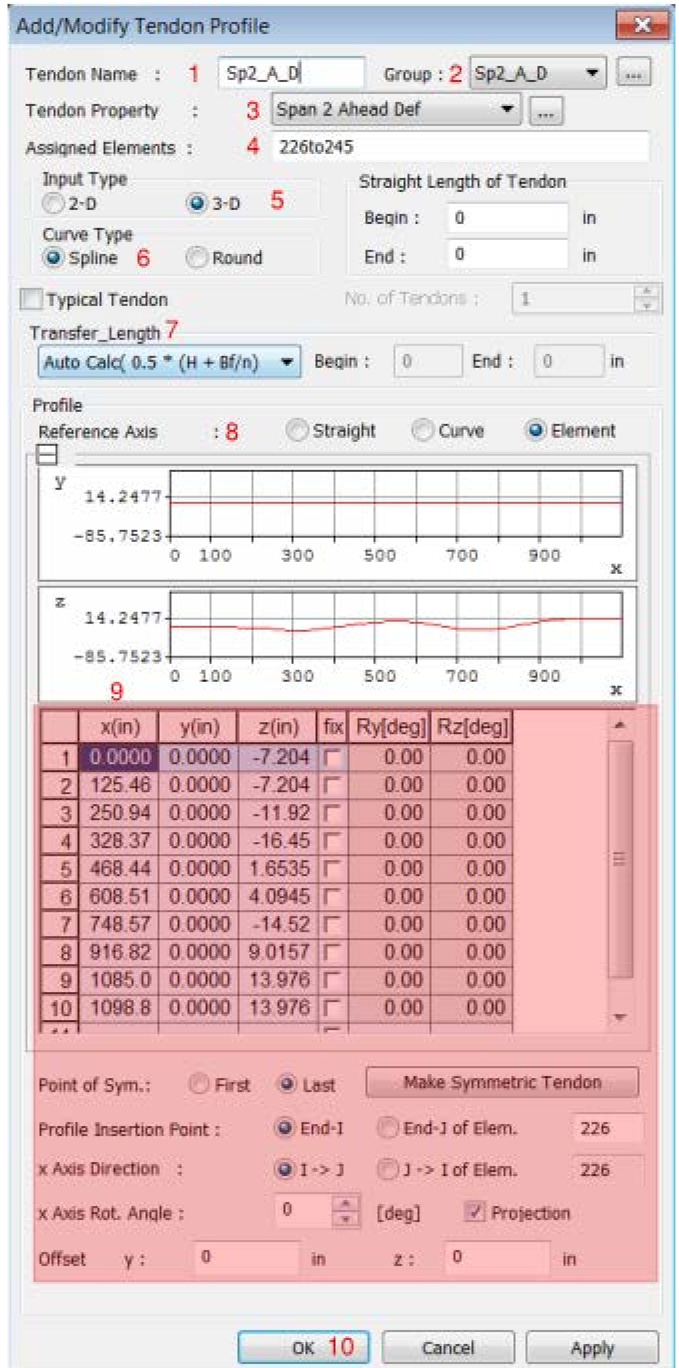
10.4.7.2 Tendon Profile

From the top menu go to Load => Temp./Prestress => Tendon Profile.



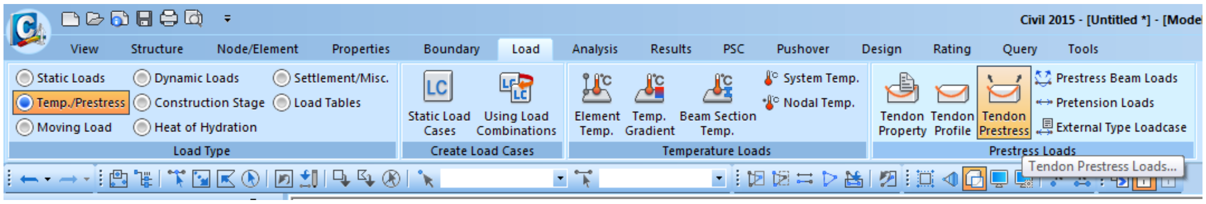
Tendon Profile location will not necessarily be within a stem wall. Because this is a 2D analysis (NOT 3-D) no eccentricity will be built into the tendons. For ease of input, a 3D input type will be selected but the y-coordinate will always have a value of 0.0in.

1) Name the tendon. The name should identify which end the tendon is stressed from.
2) Select one of the predefined Groups.
3) Select the appropriate Tendon Property.
4) Assign all of the elements. This can be done in several ways. One way is to, in the model view, use the mouse to select all elements. Elements can also be manually input by typing “1 to n”. Where n = the last element number.
5) Select 3D for input type.
6) Select Spline curve type.
7) Select Auto Calc for Transfer length.
8) Selected the Reference Axis that makes the most sense for the group of elements being analyzed. For arch members, the tendons may be best described along the element.
9) This section can vary depending on the reference axis selected above. Enter the information as required to define the tendons. After the tendons have been defined, plot them in Midas to confirm the tendon shape is appropriate.
10) Select apply and then OK. Continue until all tendon profiles are defined.



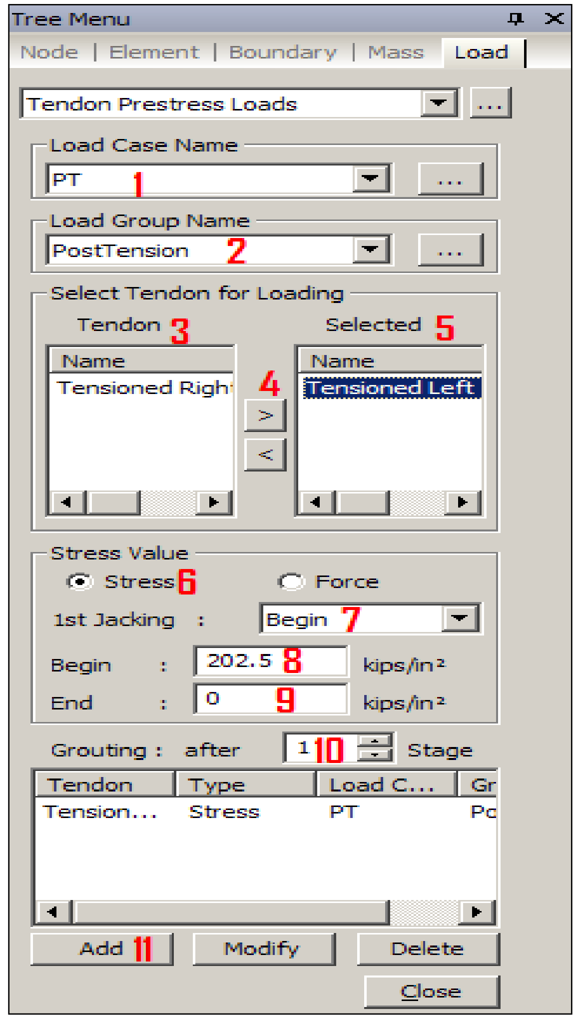
10.4.7.3 Tendon Prestress Loads

Under the top menu, go to Load => Temp./Prestress => Tendon Prestress



1) Select PT or PS for Load Case Name.
2) Select Post-Tension for Load Group Name.
3) Click on the Tendon of Interest.
4) Use the Arrows to Select the Tendon of Interest (move it from the left to the right column).
5) Displays the currently selected Tendon.
6) Select Stress.
7) 1st Jacking can be set to either Begin (left end stressed), End (for right end stressed) or Both (both ends stressed).
8) For left and both ends stressed conditions, enter the initial jacking stress calculated in the preliminary Mathcad file. For right end stressed only leave blank.
9) For right and both ends stressed conditions, enter the initial jacking stress calculated in the preliminary Mathcad file. For left end stressed only leave blank.
10) Specify which stage the tendons are grouted. Unless specified otherwise, assume tendons are grouted after stage 1.
11) Click Add.

Continue until all tendon loads have been defined.

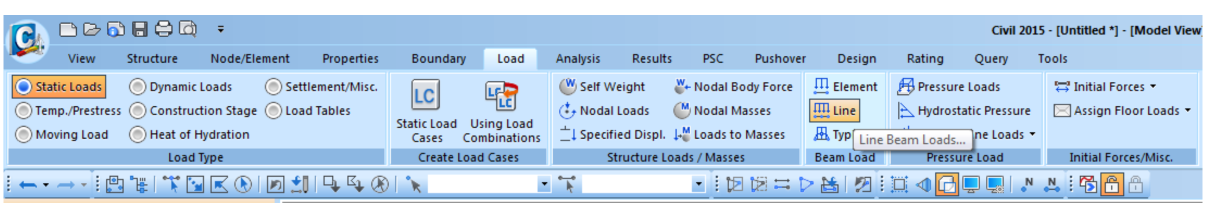


10.4.8 Loads

Several static load cases have been predefined in the template file. Not all of these predefined load cases have to be used for every bridge. Additional load cases can be defined as necessary.

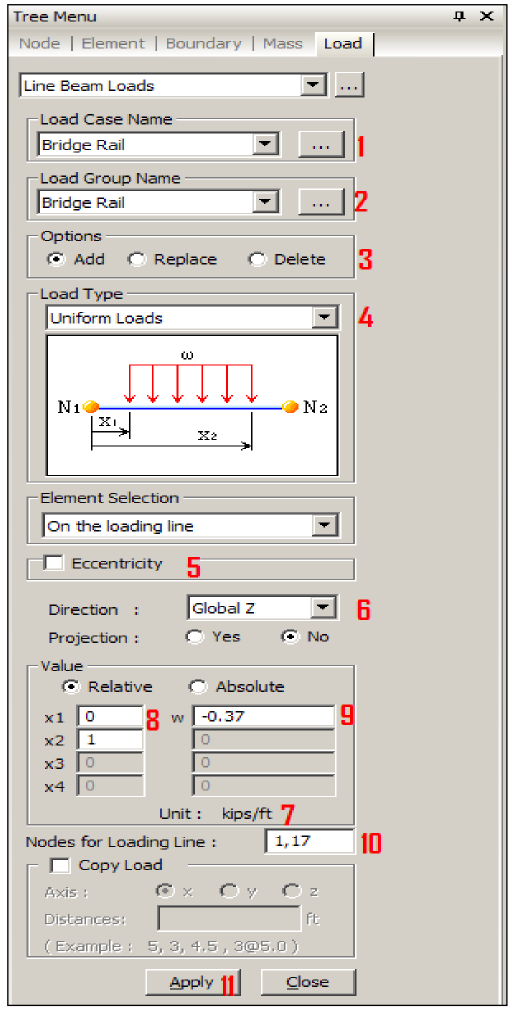
10.4.8.1 Distributed Loads

Under the top menu go to Load => Static Loads => Line



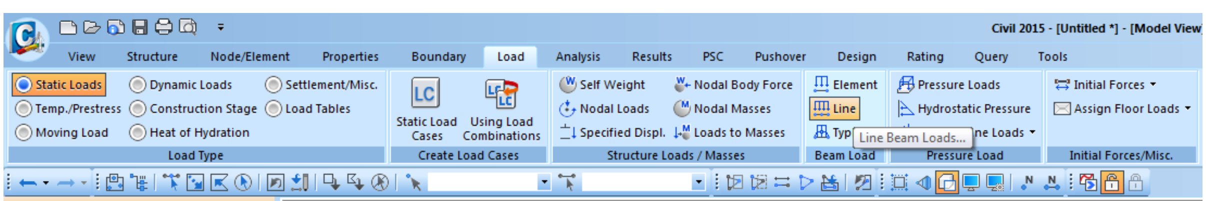
1) Select the appropriate Load Case Name.
2) Select the appropriate Load Group Name.
3) Select if this load is to be added to others, replaced, or deleted. Typically Added is selected.
4) Select loading type.
5) Uncheck the Eccentricity box.
6) Gravity loads are applied in the global Z direction.
7) Check the Input units.
8) Input the location of the loads being defined. Location is input as a span fraction. For uniform loads input the range.
9) Input the magnitude of the load. Negative is in the downward sense.
10) Input the first and last node separated by a comma. This allows for distance to be input as a span fraction in step 8.
11) Click Apply.

Continue until all static loads are defined.



10.4.8.2 Point Loads

Under the top menu go to Load => Static Loads => Line



1) Select the appropriate Load Case Name.
2) Select the appropriate Load Group Name.
3) Select if this load is to be added to others, replaced, or deleted.
4) Select loading type.
5) Uncheck the Eccentricity box.
6) Gravity loads are applied in the global Z direction.
7) Check the Input units.

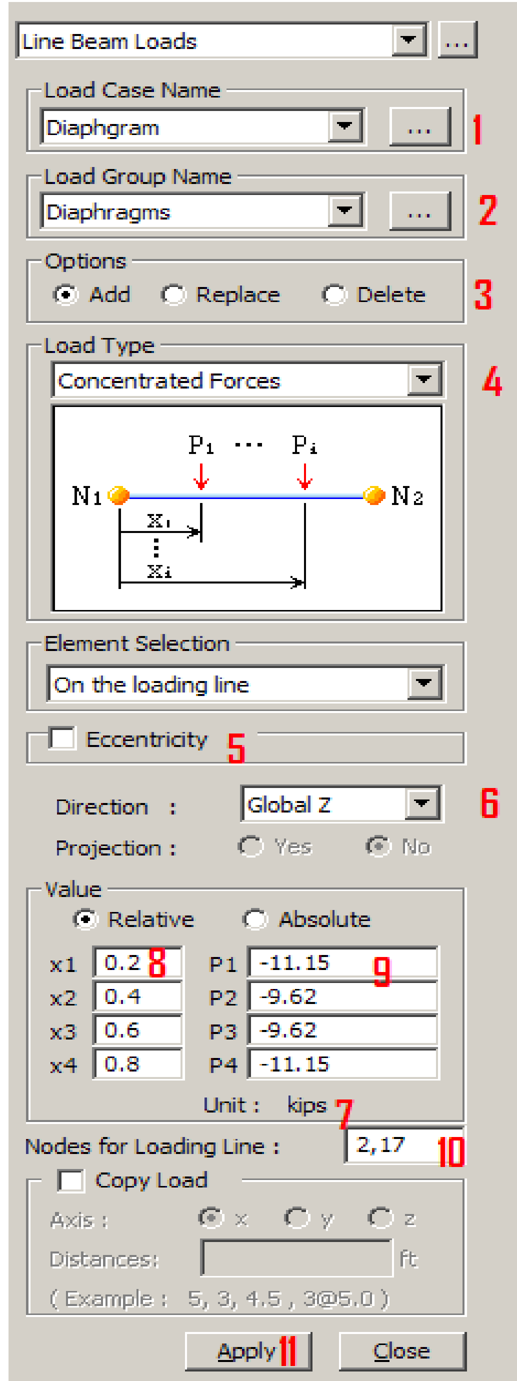
8) Input the location of the loads being defined. Location is input as a span fraction.

9) Input the magnitude of the load. Negative is in the downward sense.

10) Input the nodes at CL of bent separated by a comma. This allows for distance to be input as a span fraction in step 8. In this example the first and last nodes are actually 12 inches past CL of bent. Thus, nodes 2 and 17 are selected for loading line.

11) Click Apply.

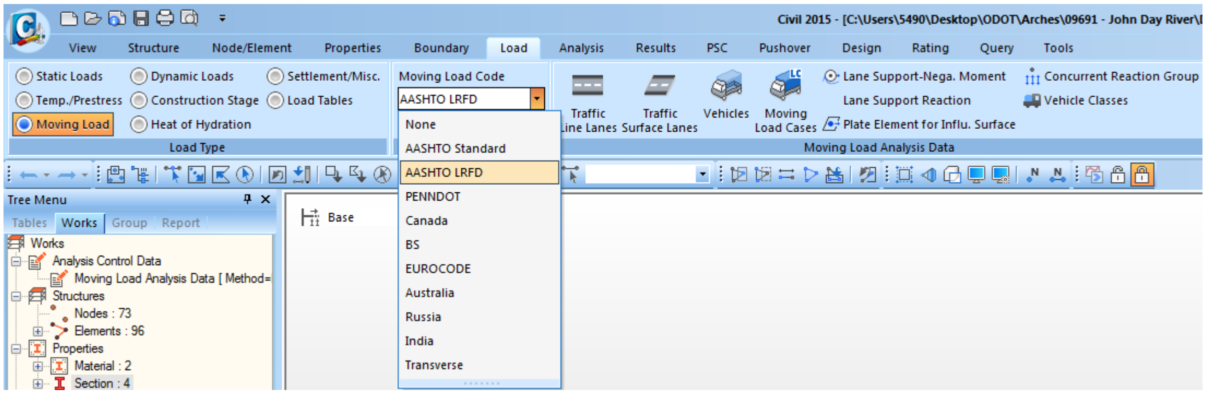
Continue until all static loads are defined.



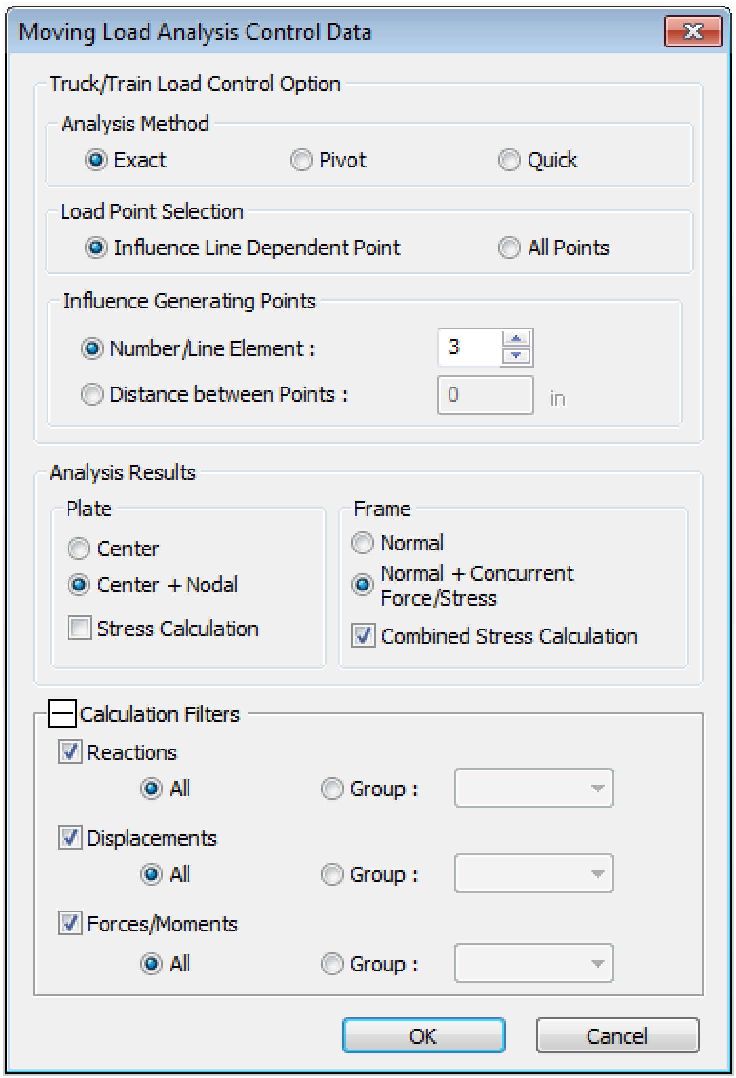
10.4.8.3 Live Loads

Design, Legal, STP, and CTP trucks are defined in the MCT template file. In addition to the vehicles one vehicle class is defined. The HL93 vehicle class includes the HL-93 Tandem and HL-93 Truck. These trucks and class do not need to be altered. Impact factor for design vehicles are included in the truck definition. Legal and permitted impact factors are applied in the capacity spreadsheet files.

Define the moving load code for analysis. In the top menu go to Load => Moving Load => Moving Load Code => Select "AASHTO LRFD"



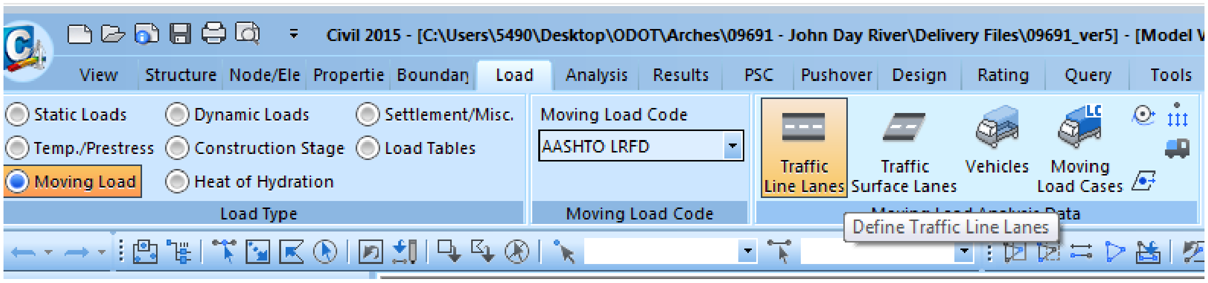
Verify the Moving Load Analysis Control Data matches below. In the top menu go to Analysis => Moving Load

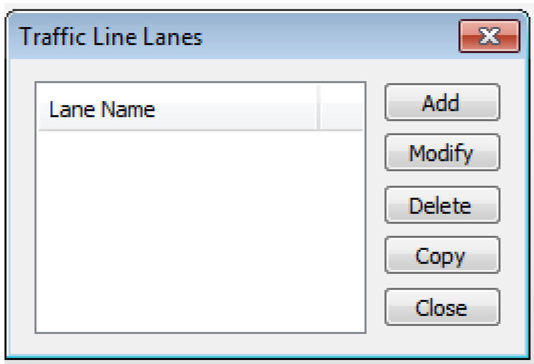


10.4.8.4 Traffic Line Lane

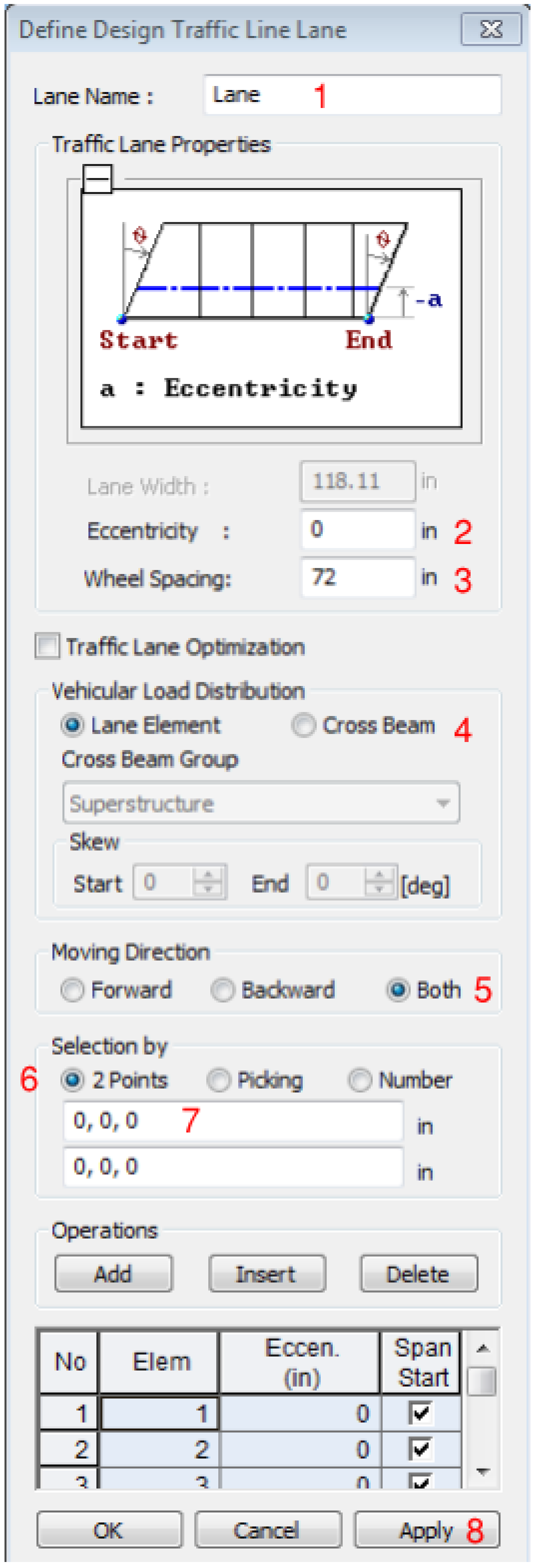
Only one traffic lane, defined along CL of structure needs to be assigned. The live load distribution factors account for the presence of multiple lanes.

Under the top menu go to Load => Moving Load => Traffic Line Lanes => Add



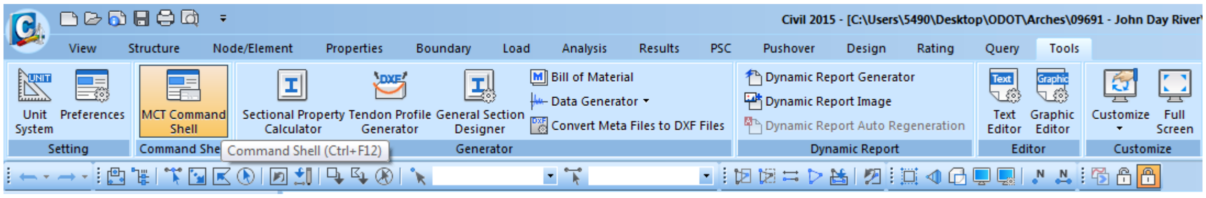


1) Name the traffic line lane “Lane”. The moving load cases that will be imported later require that the lane name is “Lane”. Otherwise, an error will be reported when the moving load cases are imported into the file.
2) Set eccentricity to 0.0ft
3) Set Wheel Spacing to 6.0ft.
4) Select Lane Element for Vehicular Load Distribution.
5) Select Both for Moving Direction.
6) Selection by 2 Points.
7) In the model view pick the two points that will define the traffic lane, typically the first and last node. This should populate the table showing the selected elements and the eccentricity.
8) Click Apply.

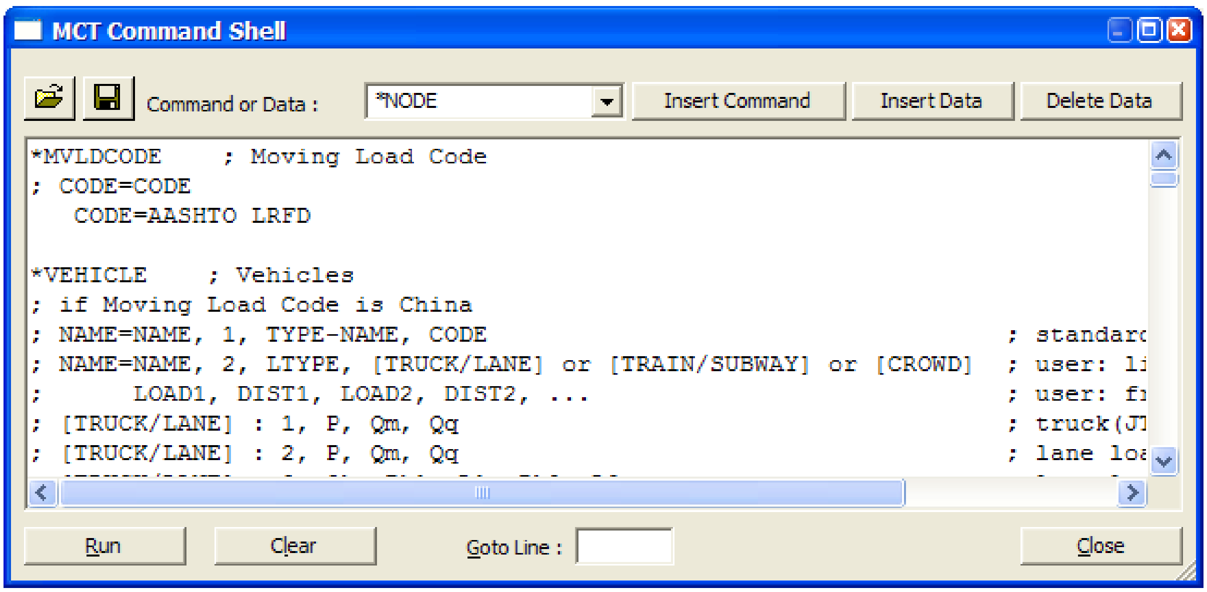


10.4.8.5 Vehicles and Moving Load Cases

The vehicle definitions and moving load cases are already defined in a MCT command file that can be imported after the lane line has been defined in the Midas model. In the top menu, go to Tools > MCT Command Shell.



Within the MCT Command Shell, click the open file icon. Open the mct file named "LR_Midas_Vehicles.mct", which will populate the MCT Command Shell window with data. At the bottom left of the MCT Command Shell window click on the "Run" button. Then click on the "Close" button at the bottom right of the MCT Command Shell window.

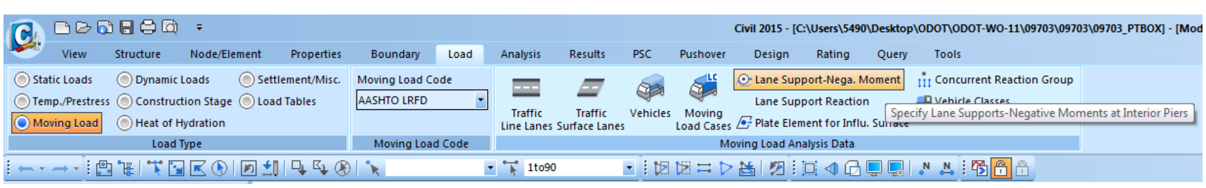


Within the Works Tree Menu there will now be 26 different vehicles, one vehicle class, and 25 different Moving Load Cases defined for the model. This command shell also contains code to populate the dynamic report tables (See section 15.4.14)

10.4.8.6 Lane Supports (Spans Continuous for Live Loads)

When performing a multi-span analysis that is continuous for live loads, the lane support negative moment, and lane supports reactions at interior piers must be activated. This feature will automatically perform the pattern loading, per AASHTO LRFD, to determine the maximum negative moment and reaction at interior supports.

Under the top menu go to Load => Moving Load => Specify Lane Supports-Negative Moments at Interior Piers.



1) Select Lane Supports (Negative Moments at Interior Piers)

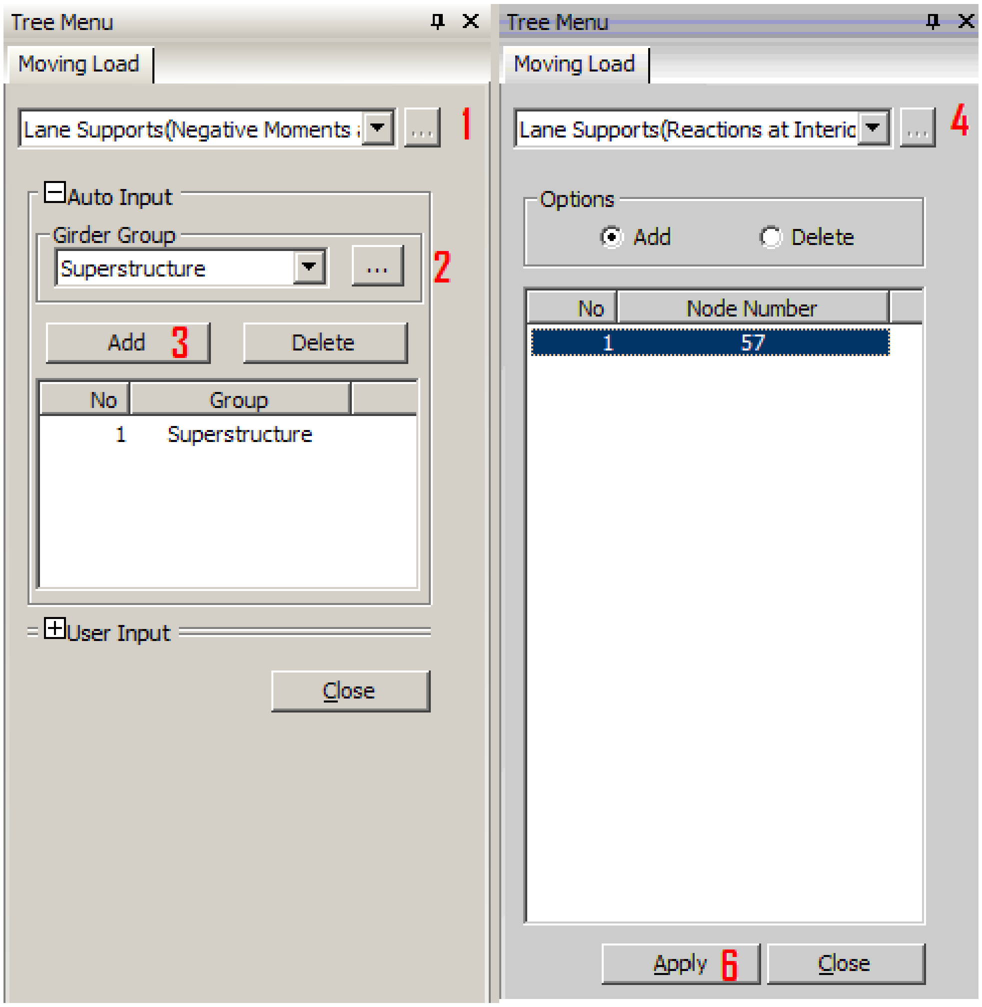
2) Select the structure group that includes the girders. See Section 15.4.10 for additional information on structure groups.

3) Select Add.

4) Select Lane Supports (Reactions at Interior Piers)

5) In the Model View, select the interior nodes where maximum reactions are sought. A support must be defined at this location (Base of interior columns).

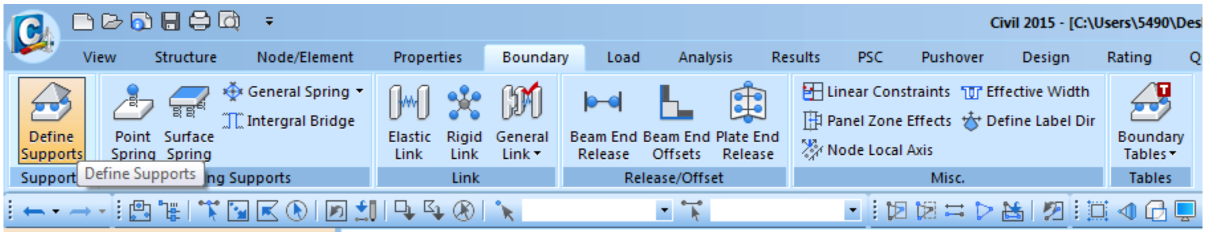
6) Select Add.



10.4.9 Boundary Conditions

Four boundary groups are predefined; Pinned, Roller, Fixed, and RigidLink. Use these groups when defining the supports. These groups will be used during the construction staging analysis.

Under the top menu go to Boundary => Define Supports



1) Select the desired Boundary Group; fixed, pinned or roller.

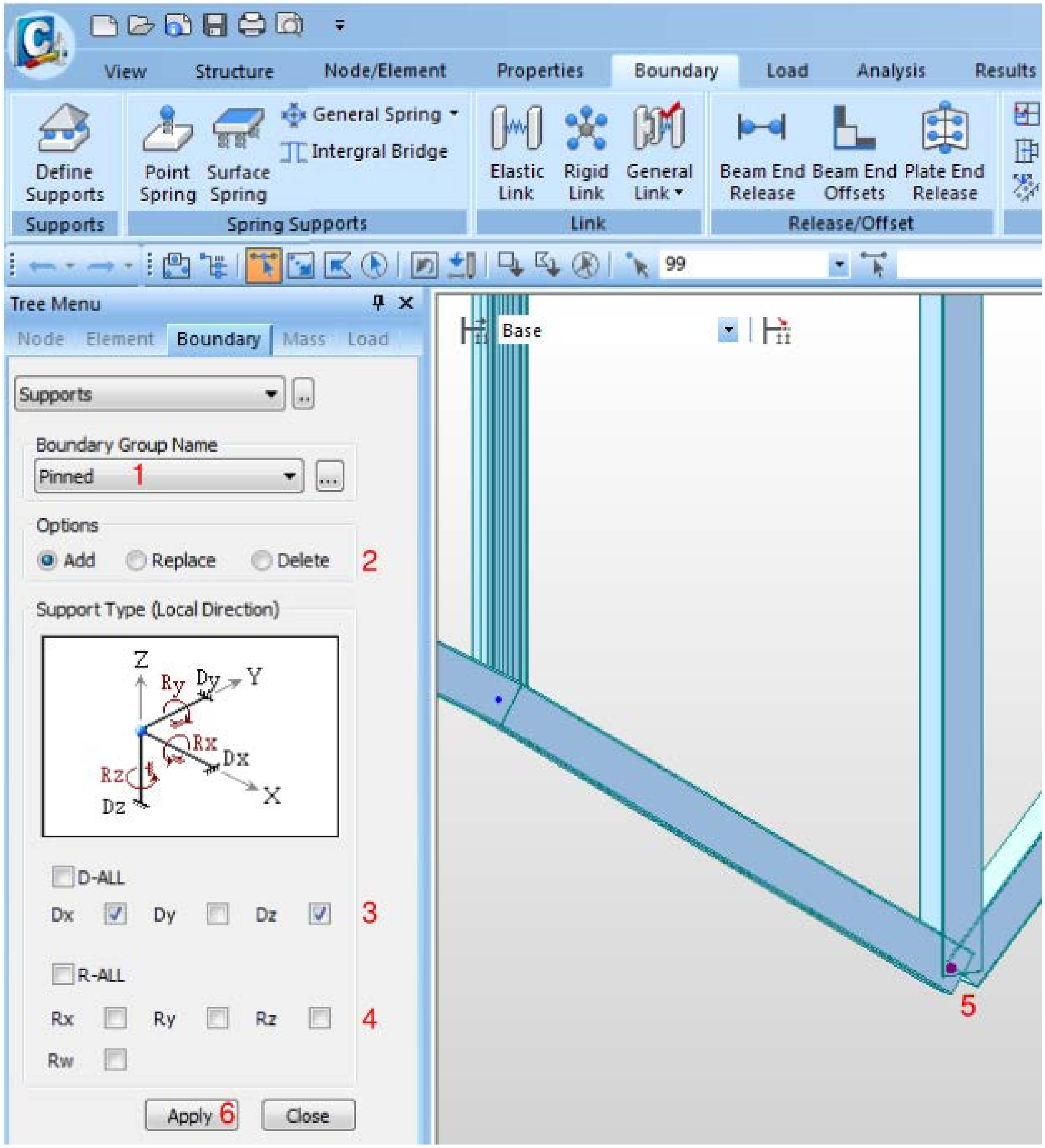
2) Select if this support is being added, replaced, or deleted from a node.

3) Select the translation restrained degrees of freedom. For pinned restrain Dx and Dz, for Roller restrain Dz only.

4) Select the rotational restrained degrees of freedom.

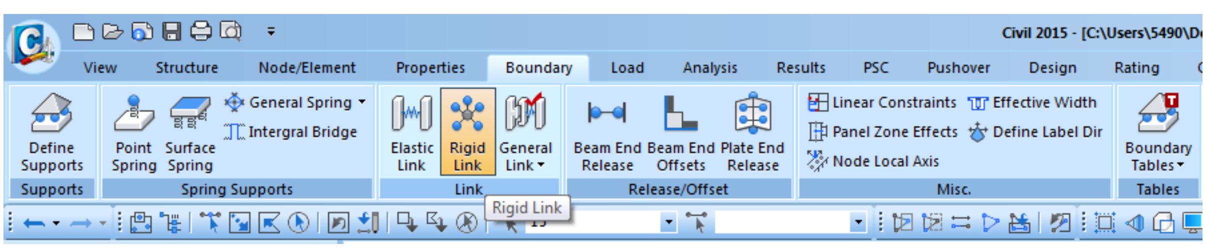
5) Select the node that the support will be assigned to. This can be done in various ways. One option is to use the “Select Single” in the tool bar (Cntrl + Shift + S). Then click on the node point that the boundary will be assigned. When selected the node should change color.

6) Click Apply.

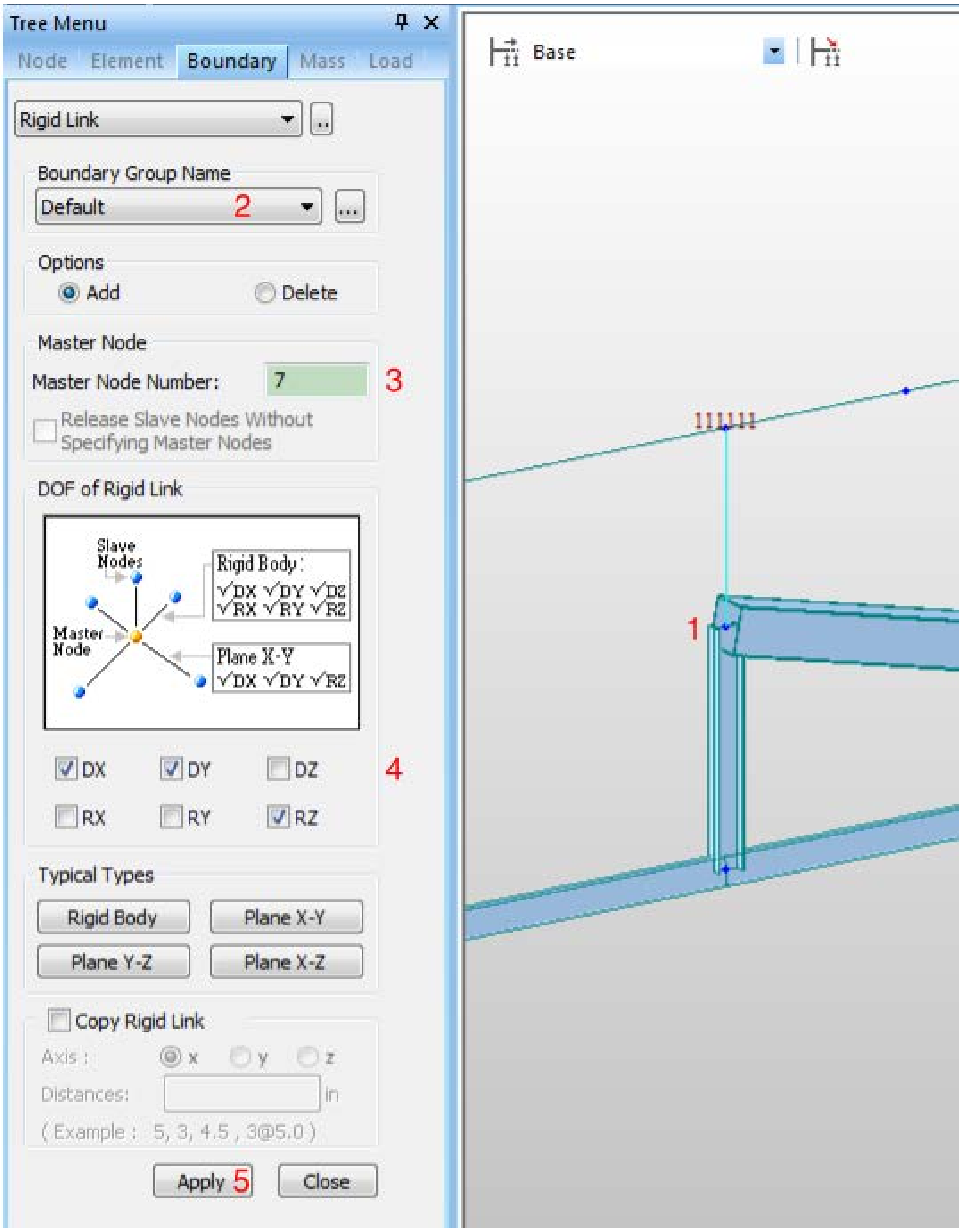


Continue until all boundaries are defined.

When rigid links are needed to connect the elements, in the top menu go to Model => Boundaries => Rigid Link



1) In the model view window select the node that will be the slave node (Top of Column).
2) Select the appropriate boundary group (RigidLink).
3) Specify the master node (Superstructure Node corresponding to CL of Bent). The specified rotations and displacements of this node will be imposed on the slave node.
4) For a 2-D model the rigid link only needs to translate DX, DZ, and RY from the master node to the slave node.
5) Select apply.



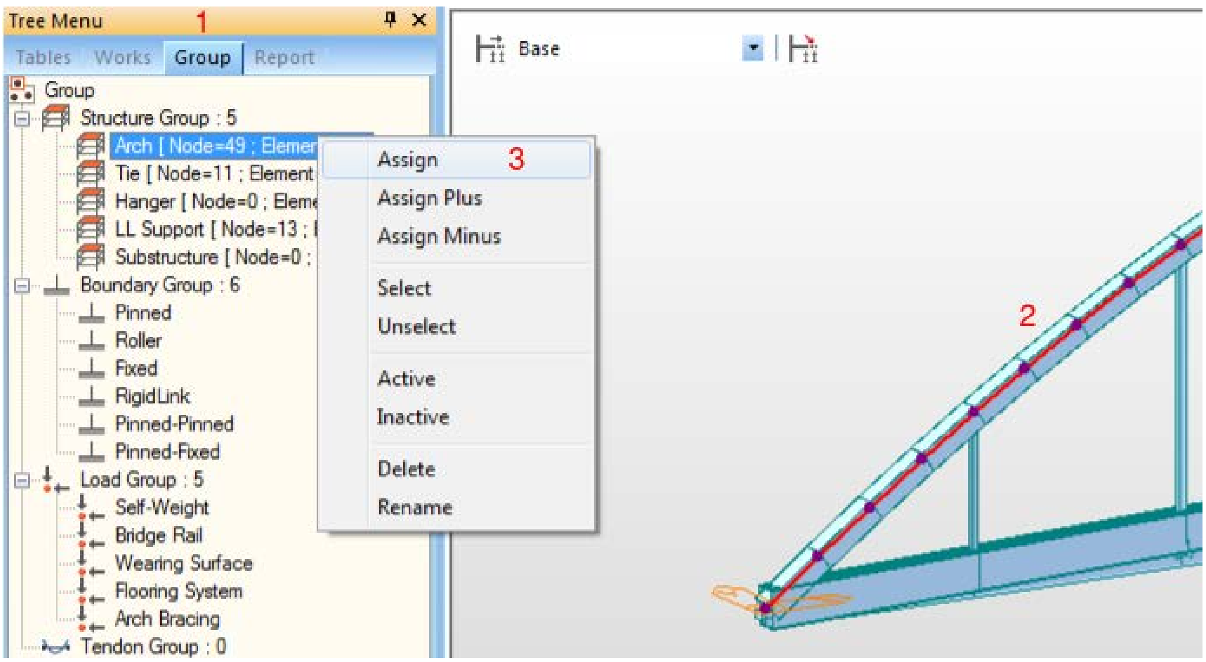
10.4.10 Structure Group

Structure groups are used to activate (or deactivate) elements in the construction staging or to quickly extract the needed member loads. Load effects are pulled from the construction stage analysis. For the analysis to perform correctly, all nodes and elements must be assigned to a structure group. Different structure groups have been predefined in the template files. For a simple span analysis, it isn't necessary to assign any elements or nodes to the substructure group because the substructure isn't included in the model. Bridges with complex construction staging, may require more structure groups than those already predefined.

1) In the Tree Menu, Select the Group tab.

2) Select all of the nodes and elements that will be assigned to the structure group. There are several ways to accomplish this. To select all the nodes and elements the Midas quick command for select all is (Cntrl + Shift + A). Individual elements and nodes can be selected with the Select Single command (Cntrl + Shift + S). Once selected the nodes and elements will appear highlighted in the Model View.

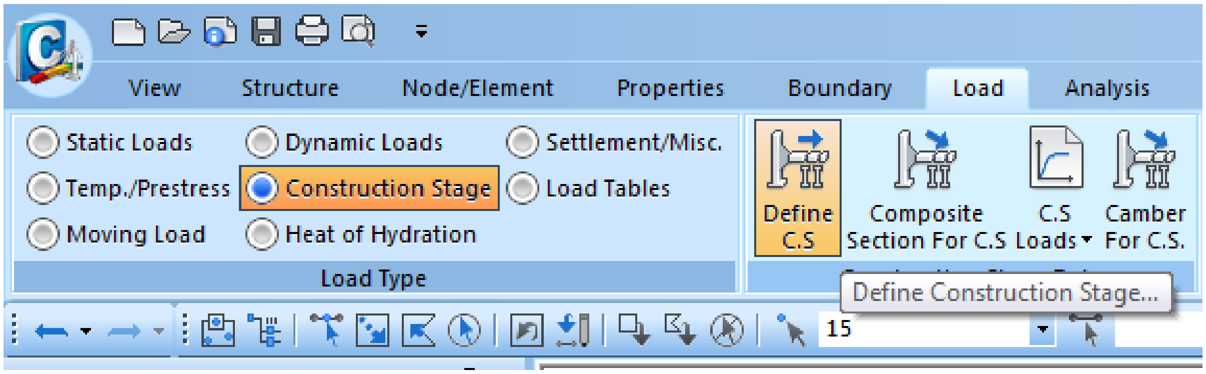
3) Right click on the desired structure group and then left click on Assign.



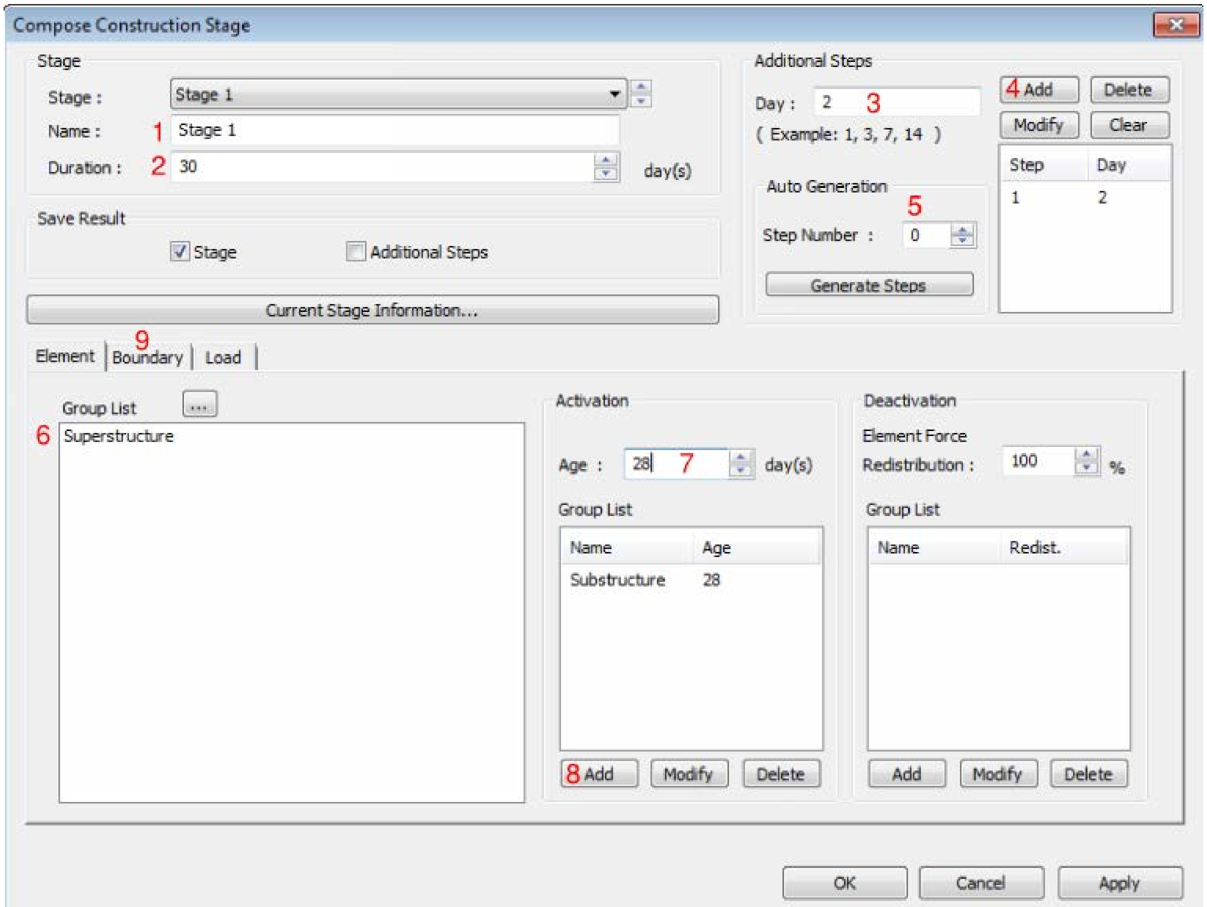
10.4.11 Construction Stage Analysis

In the Tree Menu review the inputs for Construction Stage Analysis. The construction staging will generally be set up to activate the entire structure, boundaries, Prestressing, Post-Tensioning, and DC loads in Stage 1. Wearing surface loads are activated in Stage 2. For elements or loads to be activated, they must be assigned to a Group (see step 15.4.10). Adjust the boundaries, elements, and loads as necessary to reasonably estimate the structures construction sequence and current configuration.

In the top menu go to Load => Construction Stage Analysis Data => Define Construction Stage.



1) Names the construction stage.
2) Define the duration of the construction stage.
3) Additional steps within the construction stage can be defined. These steps allow the application of loads at times other than the beginning and end of a stage. If loads are applied at the beginning or end of the stage then additional steps are not necessary. The default has a step created at day 2. This step is so that post-tensioning strands can be applied after prestressing strands are activated. Midas will include the additional elastic shortening losses in the prestressing strands due to post-tensioning.
4) Click Add to define additional steps.
5) If several steps need to be created in one stage, then the auto generate function can be used.
6) Select the Group that will be activated or deactivated within this stage. Structure groups are activated or deactivated at the beginning of the construction stage.
7) Define the age of the element when it is activated. ODOT will allow the default value of 28 days to be used for the activation of all elements. Without specific knowledge of the construction schedule it is impossible to know the exact construction staging. Using 28 days assumes that the elements have reached the design strength before being loaded.
8) Click Add to place the group into the activation column.
    a. Continue until all desired groups are activated. The default is to activate the Substructure and Superstructure at 28 day strength.
9) Select the Boundary tab to define permanent and temporary supports.



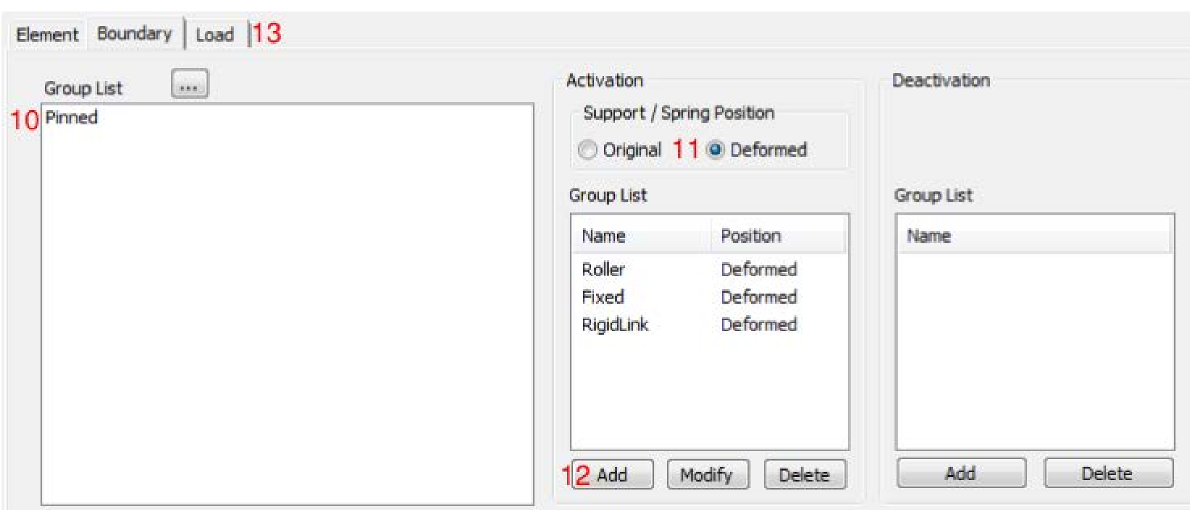
Boundaries are either activated or deactivated at the beginning of the construction stage.

10) Select the Boundary Group to be activated or deactivated.

11) Select deformed or original. Deformed is the default selection.

12) Select Add.

13) Select the Load Tab.



14) Select the Load Group to be activated or deactivated in this stage. Unlike boundary groups and

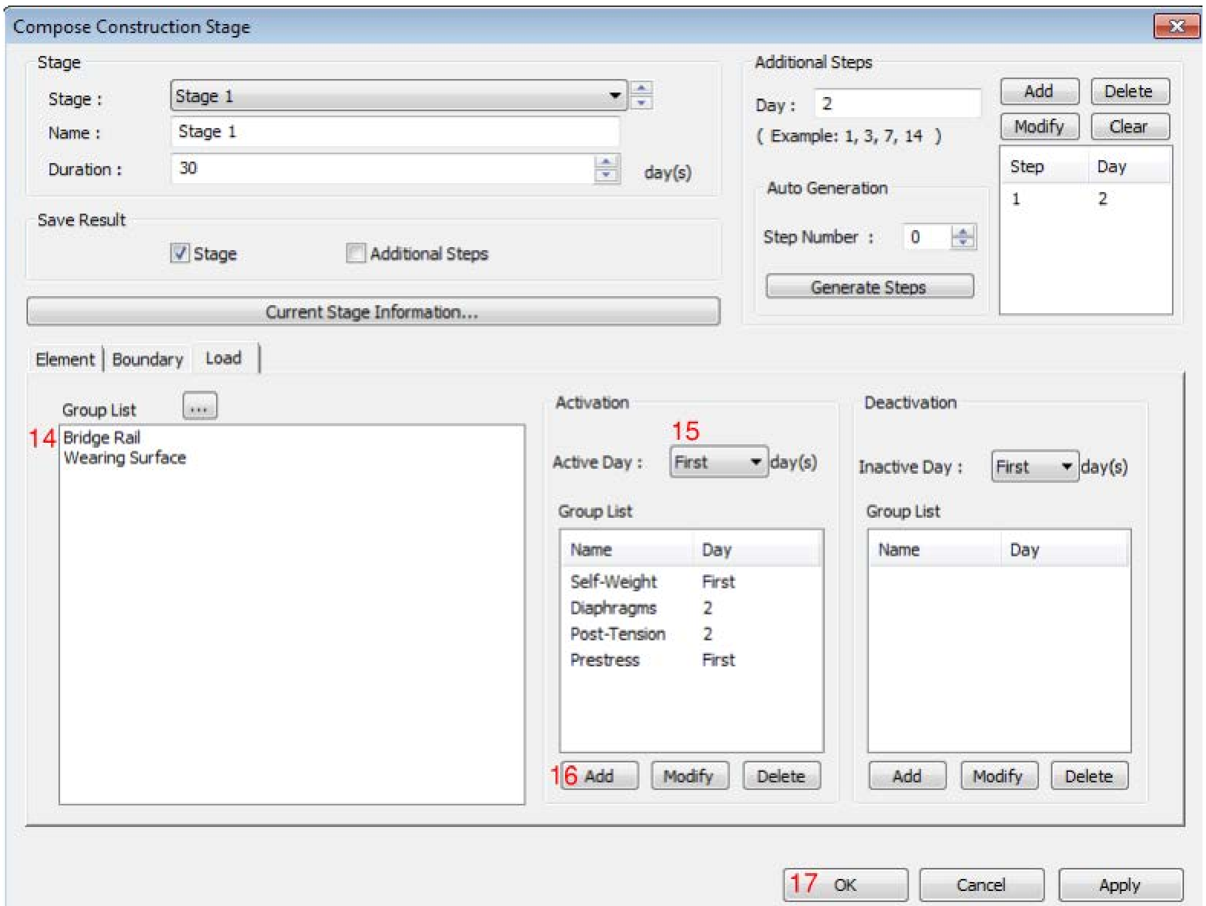
load groups, these can be activated on the first day, last day, or at any defined step.

15) Select if this load is activated or deactivated on the first day, last day, or at a defined step in this stage.

16) Click Add

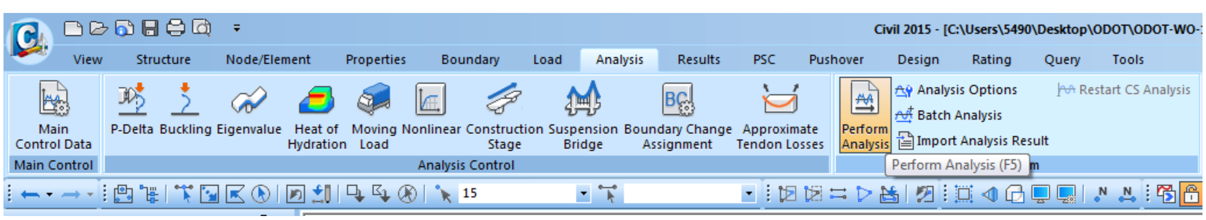
17) Click Ok.

Continue above steps until the structure is defined. The last stage should have a 10,000 day duration. The reason for the long stage is to perform time dependent prestress loss calculations.



10.4.12 Perform Midas Analysis and Review Results

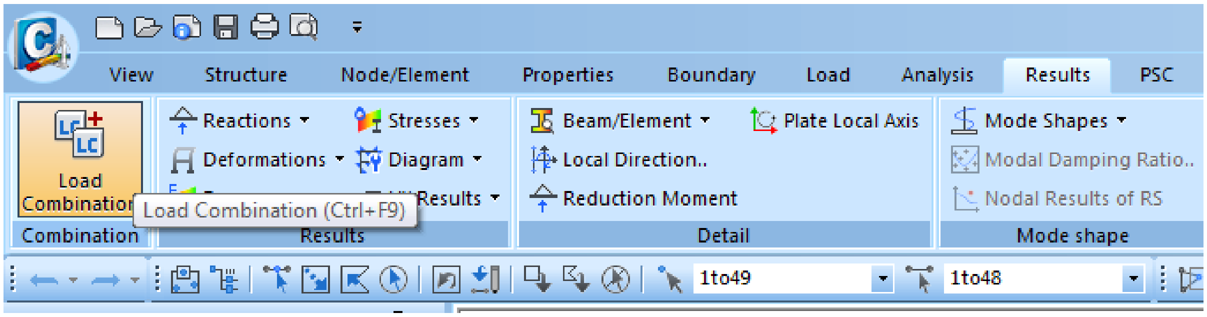
Perform the analysis by going in the top menu to Analysis => Perform Analysis.



10.4.12.1 Load Combinations

Needed load combinations for concrete and steel arches are DC, DW, and Service. For post-tensioned or construction staged arches, add PT Secondary and Vp. PT Secondary is the combination that includes prestressing and long term effects. Vp includes only the primary post-tensioning effects. All of the load factors will be 1.0 because load factors are applied in the capacity spreadsheets.

In the top menu go to Results => Combinations.

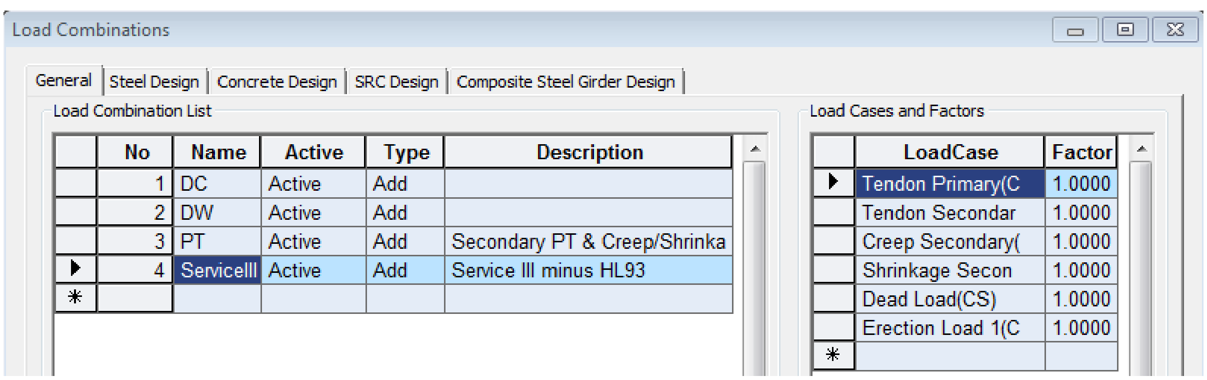


1) For models without construction staging, under DC, make sure the Bridge Rail, Self-Weight, Diaphragm and any additional DC load cases are selected. For models with construction staging, under DC, select Dead Load (CS) only.

2) For models without construction staging, under DW, make sure the Wearing Surface Load case is defined. For models with construction staging, under DW, select Erection Loads 1 (CS) only.

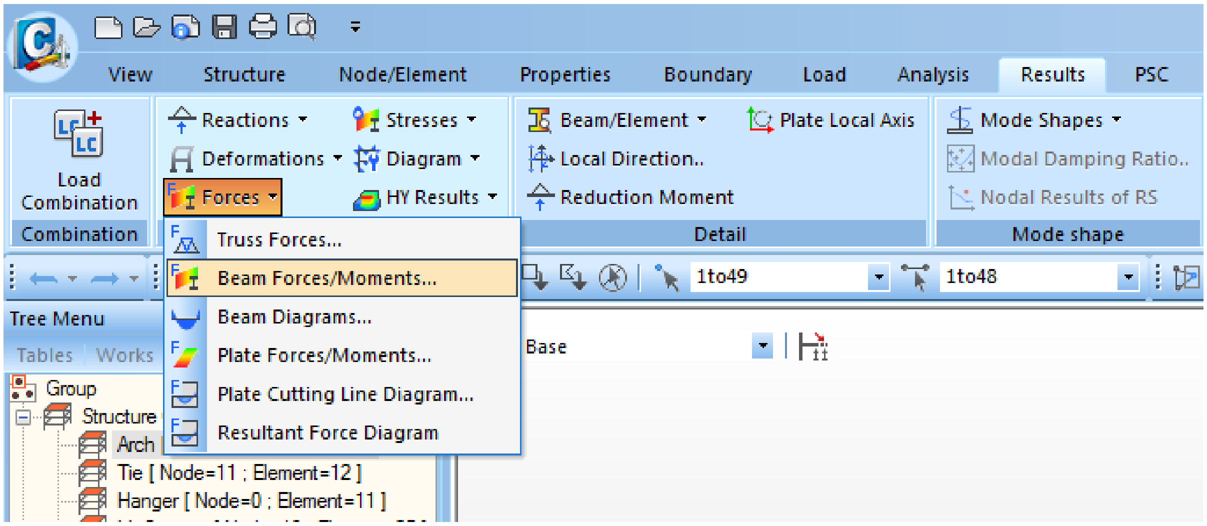
3) Under Secondary, select the Tendon Secondary (CS), Creep Secondary (CS), and Shrinkage Secondary (CS) load cases. Note that these loads are from the construction stage analysis. Vp is a separate load combination that includes primary post-tensioning effects only (Tendon Primary (CS))

4) Service does NOT include the HL93 load effects. The capacity sheets only check service for steel members. For models without construction staging, select the individual static load cases (Bridge Rail, Self-Weight, etc.). For models with construction staging, select Tendon Primary(CS), Tendon Secondary(CS), Creep Secondary(CS), Shrinkage Secondary(CS), Dead Load(CS), and Erection Load(CS). All of these loads are selected from the construction stage analysis. The Service load combination will be combined with the HL-93 load effect to calculate service rating factors in the capacity spreadsheets.



10.4.12.2 Review Results

Review the results for accuracy. Reactions, Deformations, Forces, and Stresses are readily output by going to the top menu under Results => Forces => Beam Forces/Moments. This will bring up a Tree Menu where Reactions, Deformations, Forces and Stresses can be viewed. Change the Load Cases/Combinations until all are verified.



10.4.13 Calculate the Number of Prestressing Strands

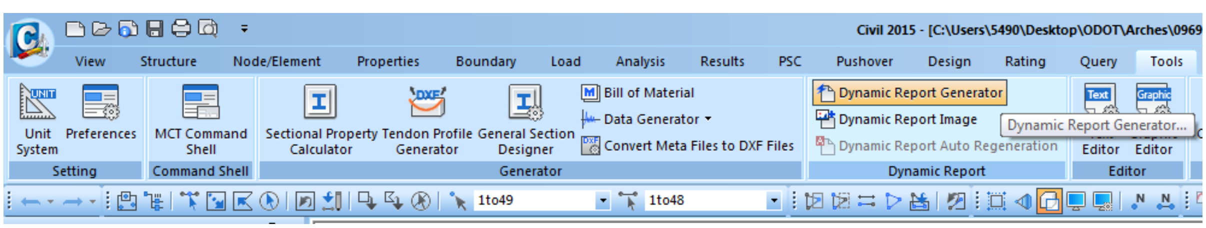
If prestressing area was not provided in the plans, then return to the preliminary file and iterate to determine the minimum number of prestressing strands. If the prestressing strand area was provided, this step may be skipped.

Return to the Mathcad preliminary file to calculate the number of prestressing strands required for analysis. In creating the model the number of strands used was based on an assumed time dependent prestress loss value without including any immediate stress losses. During construction the post tensioning supplier likely used this assumed value for time dependent losses and added the calculated immediate losses to determine the number of strands and initial jacking stress. Perform the iterations as required to obtain the required minimum midspan force while keeping the maximum tendon stress below the allowable maximum.

10.4.14 Dynamic Report Creator

The Dynamic Report Creator is used to generate a word document that contains the Midas model inputs. User Defined Tables were loaded with the Vehicles command shell (See step 6.4.9.5).

In the top menu go to Tools => Dynamic Report Generator.



Select New Document and click OK. This will open a new tab titled Report Editor and will open up a blank word document.

1) Right Click on Header & Footer in the tree menu, and then left click on properties.

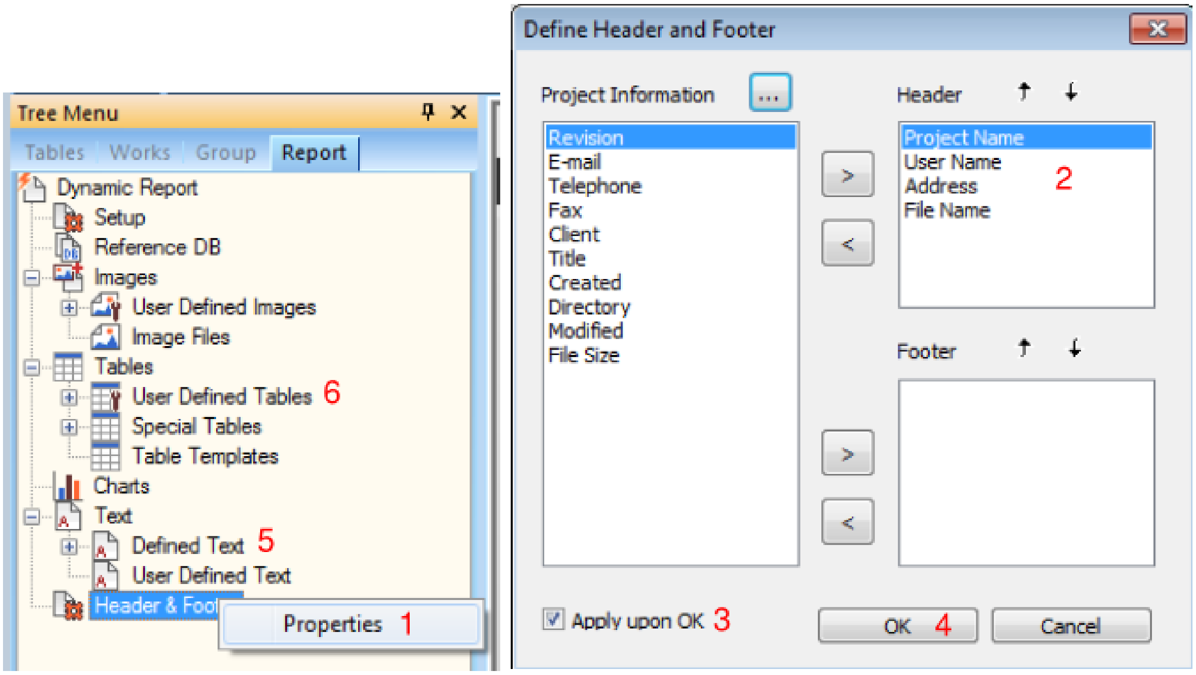
2) Project Name, User Name, Address (Company), and File name should already be selected; If not select these.

3) Select Apply upon OK.

4) Click OK.

5) Right Click on Defined Text and then left click on Insert to Report.

6) Right Click on User Defined Tables and then left click on Insert to Report.

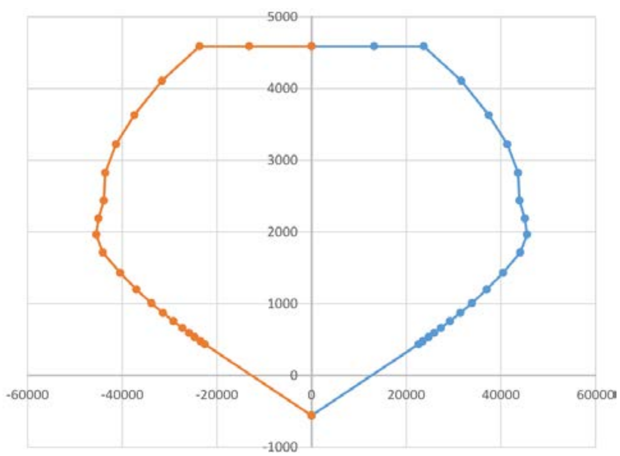


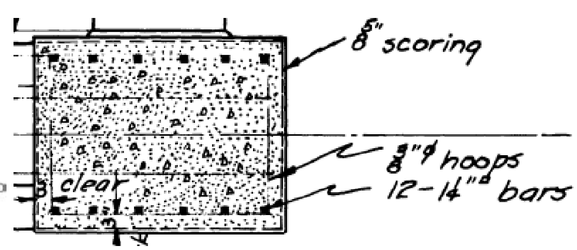
7) Click on the File menu in the Word Document.

8) Click on Save As. Name the file NNNNNMidasData.doc and save to load rating file. This report will be printed to be included in the calculation book.

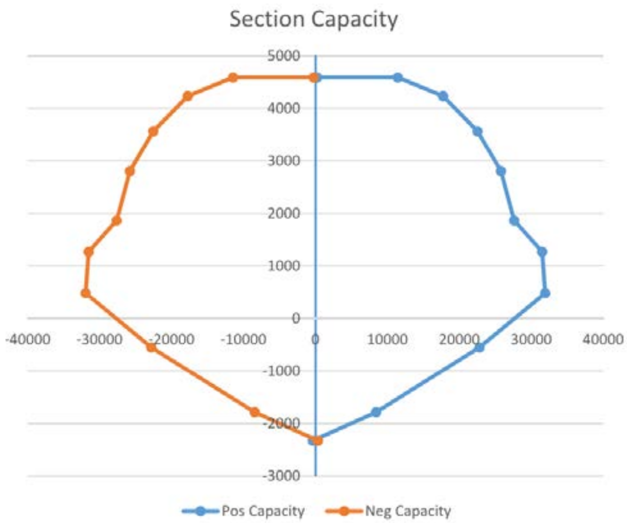
10.5 Capacity and RF Worksheets

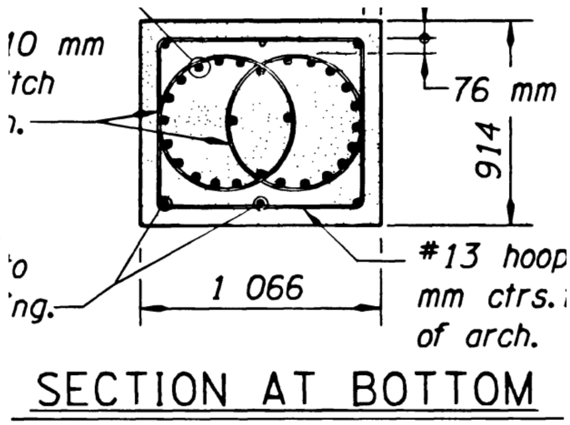
nnnnn_ConcArch.xlsm, nnnnn_StlArch.xlsm, nnnnn_StlTension.xlsm, and nnnnn_ConcGen.xlsm are a series of excel spreadsheets developed to calculate capacities and rating factors for various arch types and material properties. nnnnn_ConcArch.xlsm is used for concrete compression members shown in figure below.



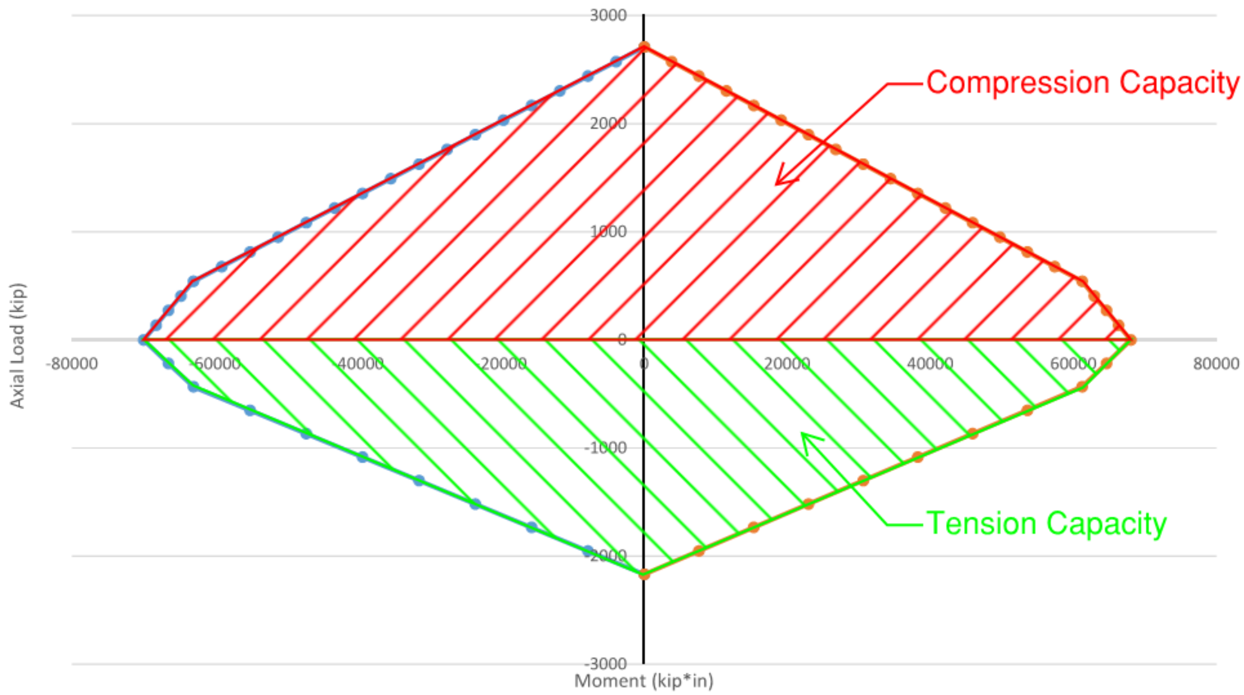


nnnnn_ConcGen.xlsm is used for concrete members with unique configurations, such as unsymmetric reinforcing, irregular reinforcing pattern, composite section, etc. shown in figure below.





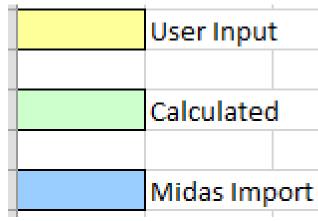
nnnnn_StlArch.xlsm is used for steel compression members. nnnnn_StlTension.xlsm is used for steel tension members. See figure below.



Distribution factors and load effects are imported from the preliminary Mathcad sheet and Midas Civil. Some inputs have macros written to automate the process while other information is manually entered. Where buttons have been provided to perform a task, use the button. Buttons have been provided to not only aid the user, but to also assign cell ranges. You should start at the Assumptions tab and move right, filling out the yellow cells as you go.

10.5.1 Assumptions Tab

Color coded cells are used in the capacity spreadsheets to aid user input. Follow the reference below to determine if the cell is user input, calculated with the spreadsheet, or imported from Midas output.



The following assumptions apply to the capacity spreadsheets.

10.5.1.1 Concrete Arches

1) Capacity calculations are in accordance with AASHTO LRFD unless otherwise noted.
2) Only determine the capacity for 1 span at a time. Separate capacity sheets should be used for each span.
3) The cover dimension is assumed to be clear cover to the shear reinforcing.
4) Moment magnification is calculated using AASHTO 4.5.3.2.2b unless a limit is manually entered by the user on the “Element Properties” tab.
5) All Prestressing steel is included for Mn calculations. fps is calculated using strain compatibility and section equilibrium. See PCI Design Handbook, 6th Ed, Example 4.2.1.6 and Design Aid 11.2.5.
6) Mn is not reduced based on Mn/(1.2Mcr or 1.33Mu). AASHTO Manual for Bridge Evaluation 6A.5.7.
7) If the longitudinal strain in the nonprestressed longitudinal tension reinforcement, εs, is calculated to be negative (in compression), the strain will be set equal to zero per AASHTO LRFD.

10.5.1.2 Steel Arches and Tension Members

1) Capacity calculations are in accordance with AASHTO LRFD for doubly symmetric box shape members.
2) Only determine the capacity for 1 span at a time. Separate capacity sheets should be used for each span.
3) Moment magnification is calculated using AASHTO 4.5.3.2.2b.
4) If live load effect is "compression" (Tension members) or “tension” (Arch members) then the rating factor is based on a compression/tensile live load capacity of zero kips.

10.5.2 General Tab

This tab contains material properties, live load distribution factors, and other general model geometry information. Each of the input values is also named within the sheet, so the user must be careful not to use copy/paste to over-write or delete the assigned name. Also take special note of the input units for all inputs.

Enter in the relevant data in the yellow cells. These values should be directly transcribed from the preliminary Mathcad file.

10.5.2.1 Steel Arches and Tension Members

Tension member file does not include all of the general information below, but the directions are still applicable.

1) Enter in the bridge general information (member name, span number, and total number of spans).
2) Enter in the material properties (steel minimum yield strength, minimum tensile strength, and modulus of elasticity.
3) Enter in the span information. Specify the horizontal length of the span and the length along the arch rib. Enter the arch buckling capacity (P_e) as determine from a buckling analysis. Enter the start of arch location in inches.
4) Enter in the single lane and multiple lane distribution factors.

General Inputs

1 General Information		
Member	STLARCH	
Span Number	1	
Total Number of Spans	1	
2 Material Properties		
Steel fy =	50	ksi
Steel fu =	70	ksi
Steel E =	29000	ksi
3 Span Information		
Span Length	270	ft
Arch Rib Length	293.09	ft
Arch Buckling capacity Pe	17721	kip
Start of arch	0	in
4 Live Load Distribution Factors		
Single Lane DF =	0.952	
Multi Lane DF =	1.267	

10.5.2.2 Concrete Arches

1) Enter in the bridge general information (member name, span number, and total number of spans).
2) Enter in the material properties (concrete strength, reinforcement yield strength, arch concrete modulus of elasticity, reinforcement modulus of elasticity, maximum aggregate size, post-tensioned strand ultimate tendon steel strength, and post-tensioned strand modulus of elasticity). Enter the stress block factor (β_1) specified in AASHTO article 5.7.2.2.
3) Select the shear reinforcement type: Tied vs Spiral.
4) Select whether the structure includes post-tensioned strands: Yes vs No.
5) Select whether the model includes construction staging: Yes vs No.
6) Enter in the single lane and multiple lane distribution factors.
7) Enter the arch model geometry. Enter the x-coordinate from MIDAS for the first node in the first arch span. Depending on how the model was developed, and whether approach spans were included, this value may not be zero. Enter the horizontal arch spans in inches for each arch span; enter “0” for spans that are not applicable.

8) Enter the arch buckling capacity (P_e) as determined from a buckling analysis.

9) Verify the resistance factor for concrete in compression (AASHTO 5.5.4.2.1), the tension controlled strain limit, and the compression controlled strain limit are correct (AASHTO Table C5.7.2.1-1).

   A tolerance for Strain Compatibility is provided as a check for how accurately the program must come to solving strain compatibility for the given set of loads and geometry before accepting the solution. The default tolerance is 5% but can be changed by the user. Decrease the tolerance to increase the accuracy of the capacity results; however, doing so may require a smaller "Step" increment which results in increase computation demand and longer run times.

General Inputs

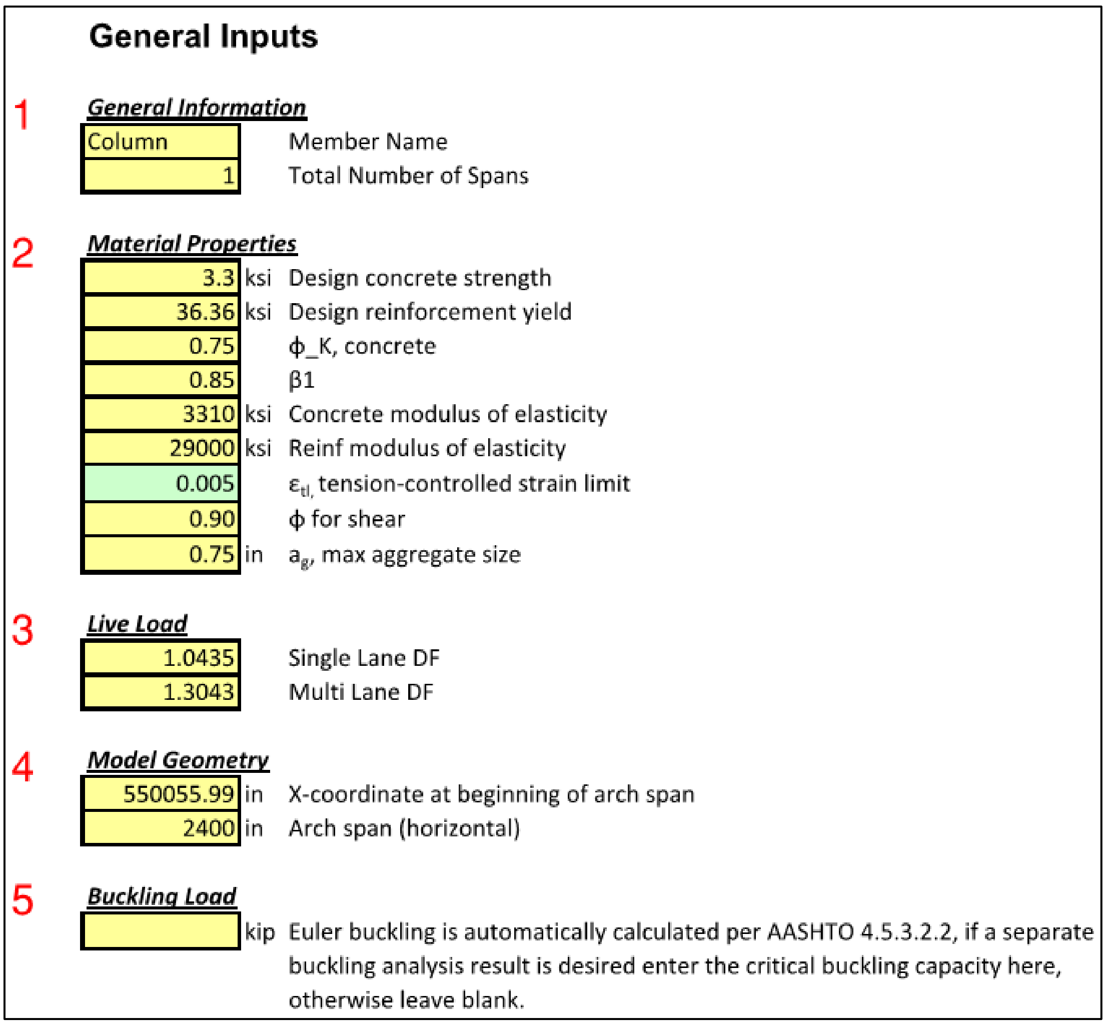
1	***General Information***			
	ConcArch		Member Name	
	3		Span Number	
	3		Total Number of Spans	
2	***Material Properties***			
	4	ksi	Design concrete strength	
	30	ksi	Design reinforcement yield	
	30	ksi	Design shear reinforcement yield	
	3644	ksi	Arch modulus of elasticity	
	Standard Properties			
	0.85		$\beta 1$	
	29000	ksi	Reinf modulus of elasticity	
	0.75	in	a_g, max aggregate size	
	0	ksi	f_{pu}, ultimate tendon steel strength	
	0	ksi	PT modulus of elasticity	
3	***Shear Reinforcement***			
	Tied		Select reinforcement type	
4	***Post Tensioning***			
	No		Select whether the structure includes PT	
5	***Construction Staging***			
	No		Select whether the model includes construction staging.	
6	***Live Load Distribution Factors***			
	0.924		Single Lane DF	
	1.222		Multi Lane DF	
7	***Model Geometry***			
	5760	in	X-coordinate at beginning of arch span	
	1800	in	Arch span (horizontal)	
8	***Buckling Load***			
	3462	kip	Critical buckling load (see prelim file)	
9	***Additional Variables***			
	0.75		ϕ_K, concrete	AASHTO 5.5.4.2.1
	0.0050		ε_{tl}, tension-controlled strain limit	AASHTO Table C5.7.2.1-1
	0.0020		ε_{cl}, compression-controlled strain limit	AASHTO Table C5.7.2.1-1
	5.0%		Strain Compatibility tolerance	
	0.2	in	Strain Compatibility step size	
	2.0%		Interpolation buffer	

The Strain Compatibility Step Size is the increment which the program uses to gradually increase the neutral axis depth until strain compatibility is solved within the solution tolerance limit. The step size can be changed by the user and is set to 0.1 in. by default. If the step size is too large, the program may not be able to solve strain compatibility. If the step size is very small, the program may take a very long time to run while performing thousands of small incremental steps. Experience has shown that a step size of around 0.1 inches is good for section depths of around 30 to 60 inches and the default solution tolerance. For smaller section depths, a step size of 0.01 inches is appropriate.

The Interpolation Buffer is the percent of increased distance that a segment of the P-M capacity curve is extended in order to ensure that an error is not caused by breaking the curve into straight line segments. The default buffer is 2% but can be increased by the user if the program is having difficulty finding an intersection.

10.5.2.3 General Concrete Section

1) Enter in the bridge general information (member name and total number of spans).
2) Enter in the material properties (concrete strength, reinforcement yield strength, resistance factor for concrete in compression, concrete modulus of elasticity, reinforcement modulus of elasticity, resistance factor for shear, maximum aggregate size). Enter the stress block factor (β_1) specified in AASHTO article 5.7.2.2.
3) Enter in the single lane and multiple lane distribution factors.
4) Enter the arch model geometry. Enter the x-coordinate from MIDAS for the first node in the first arch span. Depending on how the model was developed, and whether approach spans were included, this value may not be zero. Enter the horizontal arch spans in inches for each arch span; enter “0” for spans that are not applicable.
5) Euler buckling is calculated per AASHTO 4.5.3.2.2, if a separate buckling analysis results is desired enter the arch buckling capacity (P_e). Otherwise, leave this value blank.

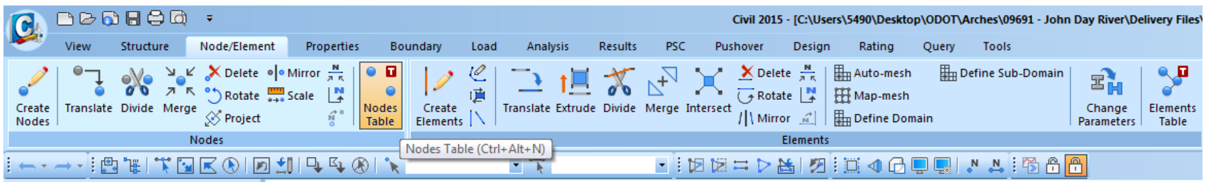


10.5.3 Resistance and Load Factors Tab

Update the System, Condition, Resistance, Live Load, and Dead Load factors. DC, DW and PS factors do not normally need to be altered. Impact is input for Legal and Permitted vehicles only. Impact adjustment for design loads are included in the Midas output. Note that each input is uniquely named, so make sure the names are preserved if copy/paste is used to document these factors.

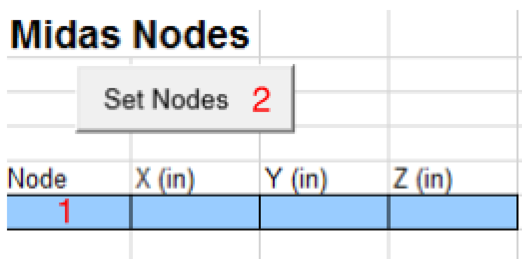
10.5.4 MIDAS Nodes

Input the Nodes from Midas into the capacity spreadsheet. In Midas, go to Nodes/Elements > Nodes Table.



1) Copy all the node data. Paste it into the Nodes Table.

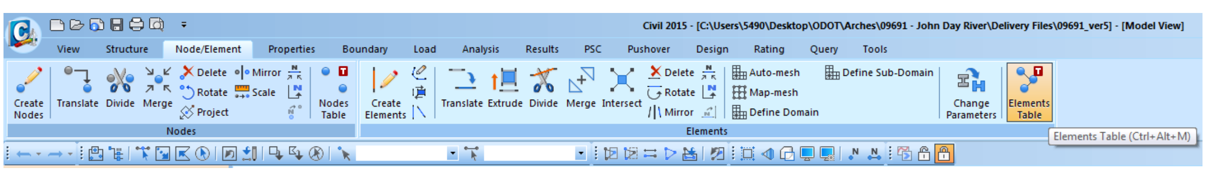
2) Click the Set Nodes button. This should highlight all of the values copied from Midas in Blue.



Note: Ensure the units are in inches.

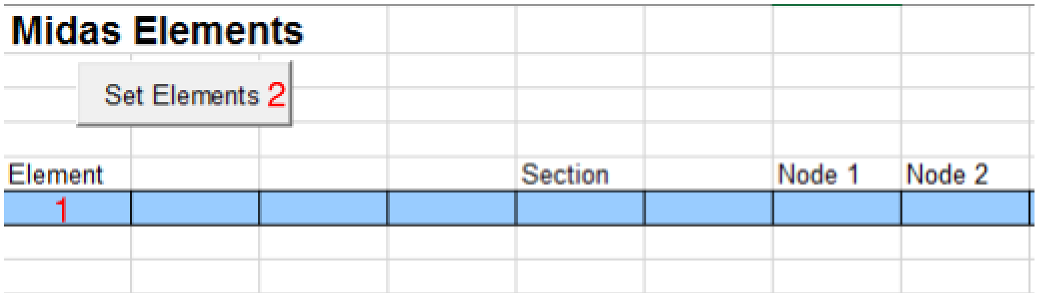
10.5.5 MIDAS Elements

Input the Elements from Midas into the capacity spreadsheet. In Midas, go to Nodes/Elements > Elements Table.



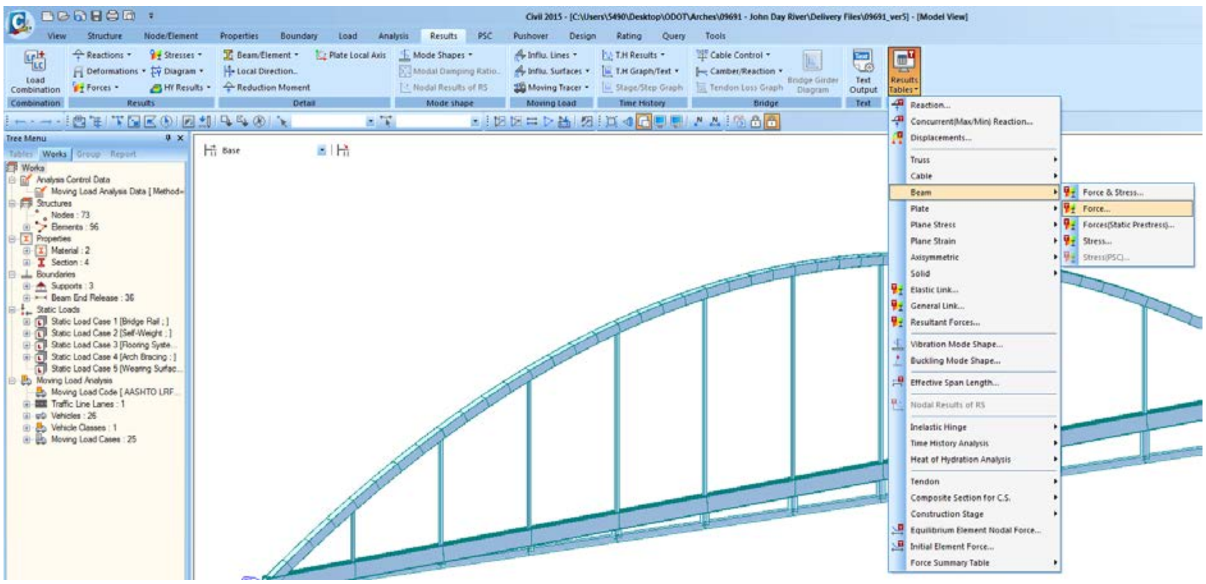
1) Copy all the element data. Paste it into the Elements Table.

2) Click the Set Elements button. This should highlight all of the values copied from Midas in Blue.

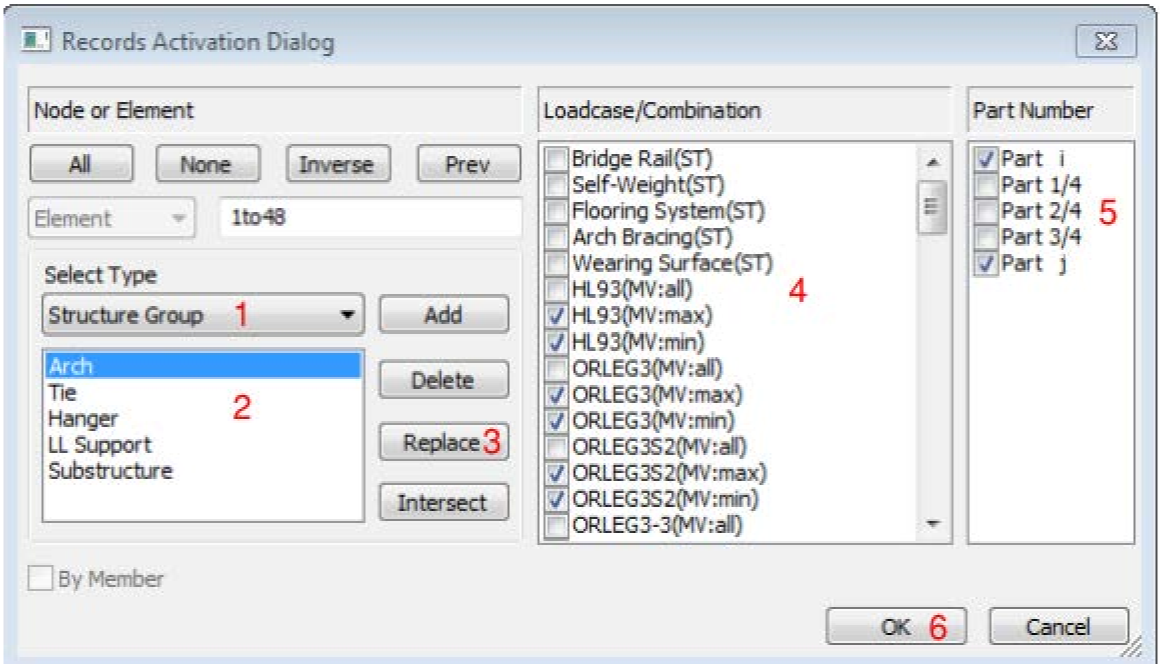


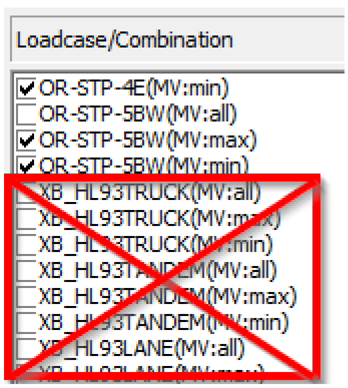
10.5.6 Max Moment, Shear, and Axial

Maximum result values are copied from Midas and pasted into the appropriate mode tab. In Midas, go to Results > Results Tables > Beam > Force.

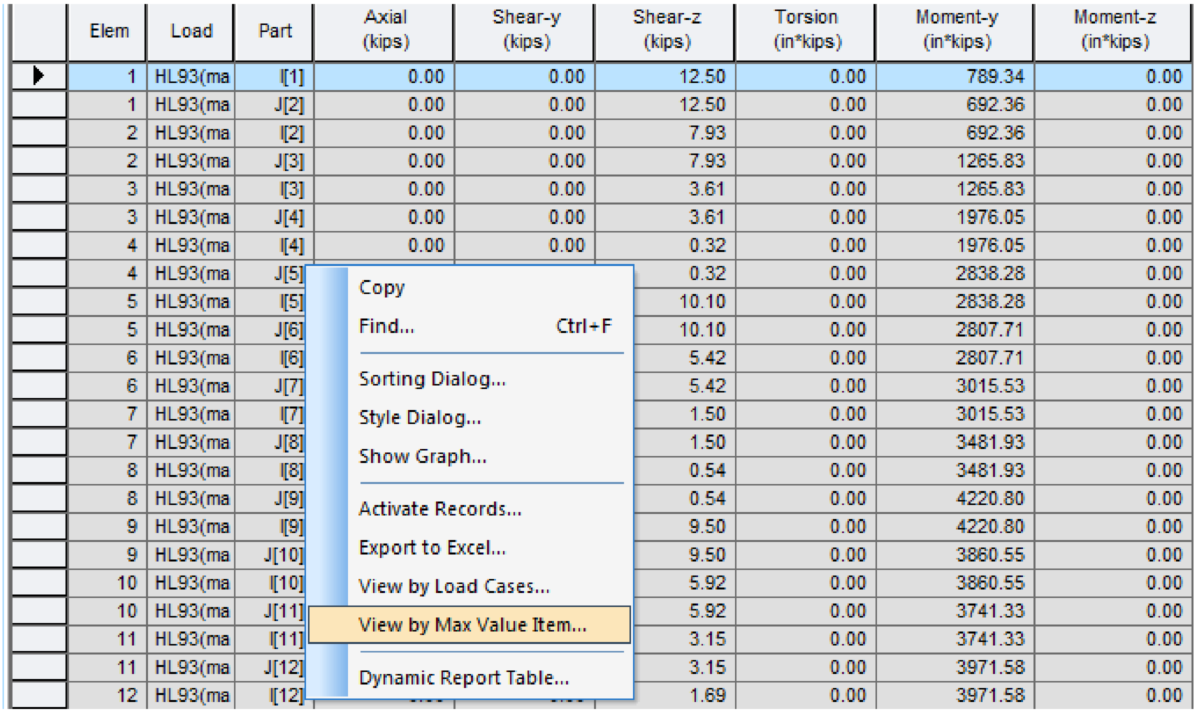


1) Select Structure Group for Type.
2) Select which Group is going to be analyzed.
3) Select Replace to update the Element list.
4) Select the maximum and minimum for each of the Design, Legal, and Permitted truck live loads. In addition, select DC(CB), DW(CB), and for concrete members using the nnnnn_ConcGen.xlsm capacity spreadsheet Secondary(CB). If prestressing/post-tensioned strands are used, select the Vp load case as well. Please note that the live load cases proceeded by XB are needed for rating the substructure and are not needed to load rate the superstructure elements. The Secondary load case is for secondary construction staging effects and should therefore be zero for single simply supported spans.
5) Select Part (i) and Part (j) only.
6) Click OK. Beam force results for the selected Load Cases are now displayed in a table.

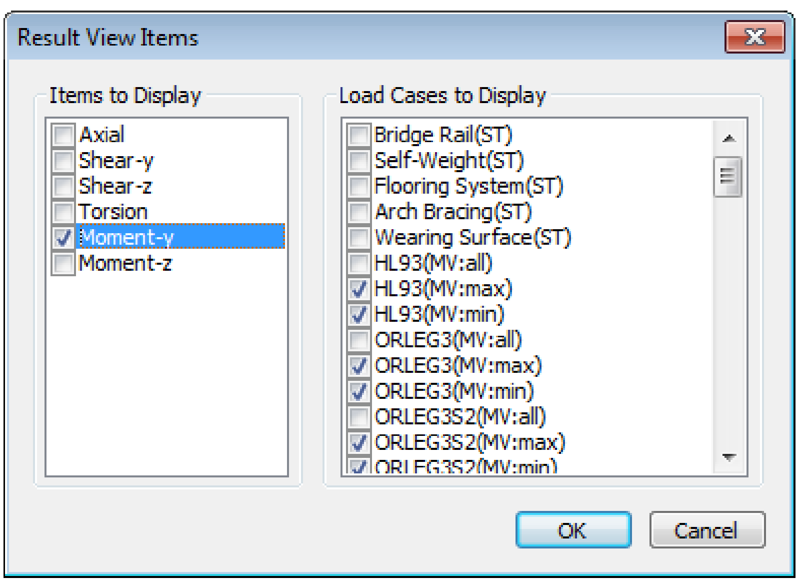

Records Activation Dialog
Node or Element
All
None
Inverse
Prev
Element
1to48
Select Type
Structure Group
1
Add
Arch
Tie
Hanger
LL Support
Substructure
2
Delete
Replace
3
Intersect
Loadcase/Combination
Bridge Rail(ST)
Self-Weight(ST)
Flooring System(ST)
Arch Bracing(ST)
Wearing Surface(ST)
HL93(MV:all)
HL93(MV:max)
HL93(MV:min)
ORLEG3(MV:all)
ORLEG3(MV:max)
ORLEG3(MV:min)
ORLEG3S2(MV:all)
ORLEG3S2(MV:max)
ORLEG3S2(MV:min)
ORLEG3-3(MV:all)
4
Part Number
Part i
Part 1/4
Part 2/4
Part 3/4
Part j
5
By Member
OK
6
Cancel


Loadcase/Combination
OR-STP-4E(MV:min)
OR-STP-5BW(MV:all)
OR-STP-5BW(MV:max)
OR-STP-5BW(MV:min)
XB_HL93TRUCK(MV:all)
XB_HL93TRUCK(MV:max)
XB_HL93TRUCK(MV:min)
XB_HL93TANDEM(MV:all)
XB_HL93TANDEM(MV:max)
XB_HL93TANDEM(MV:min)
XB_HL93LANE(MV:all)

Right click in the table and then left click on View by Max Value Item.



Select for Moment-y values only. The load cases should already be selected from the previous step. Click OK. Ensure that “kips” and “in” are the display units (bottom of MIDAS window).



1) Copy all the moment data. Paste it into the Max Moment Table.

2) Click the Set Moment button. This should highlight all of the values copied from Midas in Blue.

Max Moment

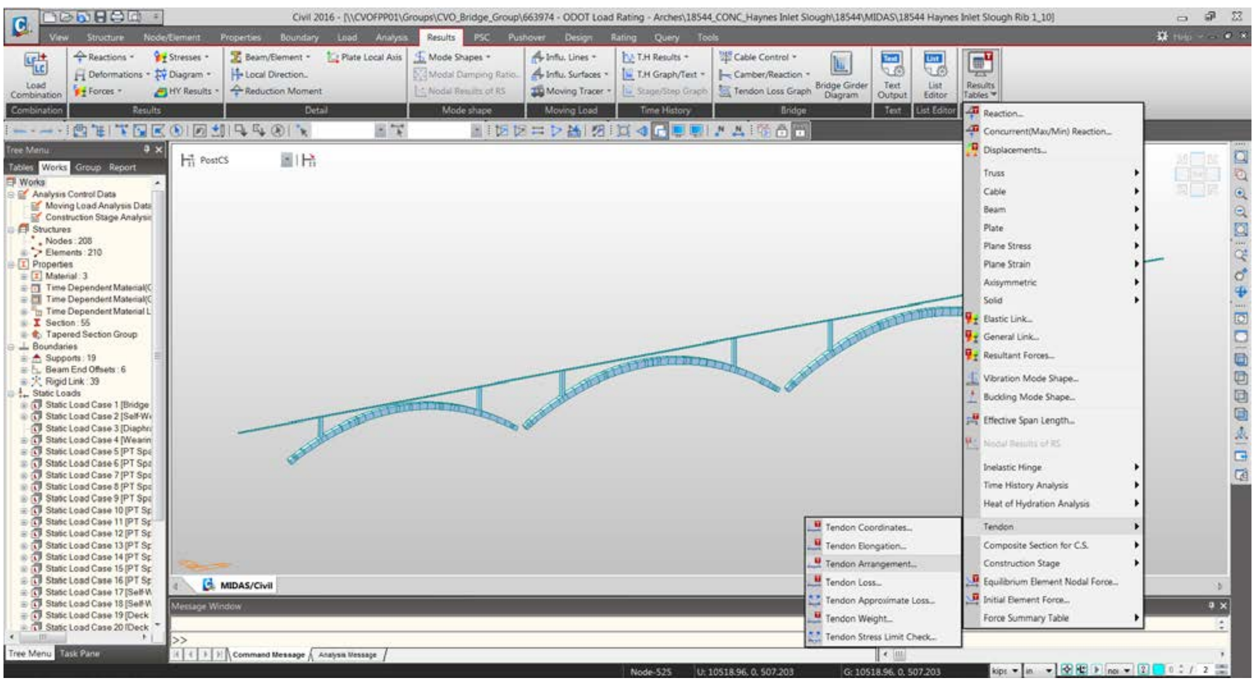
2 Set Moment Tbl

Elem	Load	Part	Component	Axial (kips)	Shear-y (kips)	Shear-z (kips)	Torsion (in*kips)	Moment-y (in*kips)	Moment-z (in*kips)
1									

Return to the Beam Force Result table listed above and right click and left click on View by Max Value Item. Proceed through the same steps above for Shear (Shear-z) and Axial (Axial). Then copy the data in to the Max Shear tab and Max Axial tab, respectively, in the capacity spreadsheet.

10.5.7 Prestressing/Post-Tensioning Strands (Concrete Arch Tool Only)

The effective prestress force for each strand profile is obtained from the Midas construction stage analysis. In Midas, go to Results > Results Tables > Tendon > Tendon Arrangement.



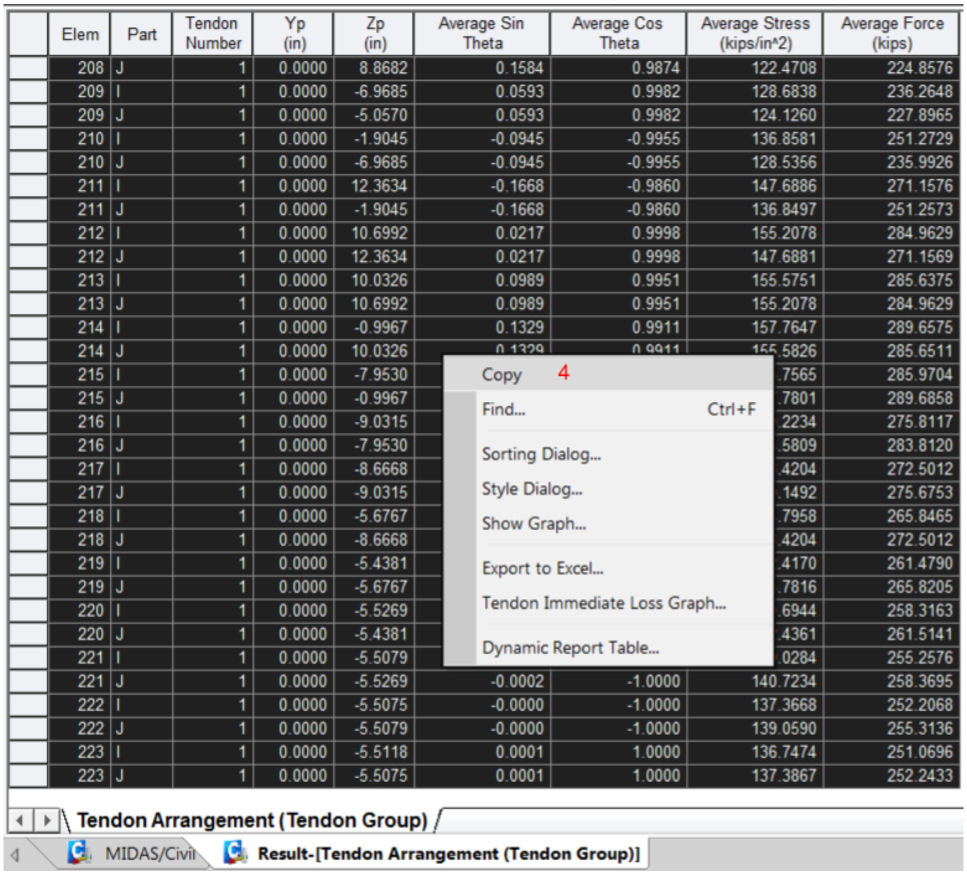
1) Select a tendon group that was defined in the model.

2) Select the last construction stage. This should be the stage that has a 10,000 day construction stage. The last stage is selected so that the time dependent tendon losses are included.

3) Click Apply. Midas will populate the table.

	Elem	Part	Tendon Number	Yp (in)	Zp (in)	Average Sin Theta	Average Cos Theta	Average Stress (kips/in^2)	Average Force (kips)
	The arrangement data for tendon group [Sp2_B_D] at the stage of [Add superstructure loads]								
	Tendon Group	Sp2_B_D 1		Stage	Add superstruc 2	Apply 3			
▶	204	I	1	0.0000	13.8583	-0.0000	-1.0000	107.4289	197.2405
	204	J	1	0.0000	13.8582	-0.0000	-1.0000	106.0688	194.7434

4) Select the entire table (except headings), right click on the selected cells, left click on copy.



Elem	Part	Tendon Number	Yp (in)	Zp (in)	Average Sin Theta	Average Cos Theta	Average Stress (kips/in^2)	Average Force (kips)
208	J	1	0.0000	8.8682	0.1584	0.9874	122.4708	224.8576
209	I	1	0.0000	-6.9685	0.0593	0.9982	128.6838	236.2648
209	J	1	0.0000	-5.0570	0.0593	0.9982	124.1260	227.8965
210	I	1	0.0000	-1.9045	-0.0945	-0.9955	136.8581	251.2729
210	J	1	0.0000	-6.9685	-0.0945	-0.9955	128.5356	235.9926
211	I	1	0.0000	12.3634	-0.1668	-0.9860	147.6886	271.1576
211	J	1	0.0000	-1.9045	-0.1668	-0.9860	136.8497	251.2573
212	I	1	0.0000	10.6992	0.0217	0.9998	155.2078	284.9629
212	J	1	0.0000	12.3634	0.0217	0.9998	147.6881	271.1569
213	I	1	0.0000	10.0326	0.0989	0.9951	155.5751	285.6375
213	J	1	0.0000	10.6992	0.0989	0.9951	155.2078	284.9629
214	I	1	0.0000	-0.9967	0.1329	0.9911	157.7647	289.6575
214	J	1	0.0000	10.0326	0.1329	0.9911	155.5826	285.6511
215	I	1	0.0000	-7.9530			.7565	285.9704
215	J	1	0.0000	-0.9967			.7801	289.6858
216	I	1	0.0000	-9.0315			.2234	275.8117
216	J	1	0.0000	-7.9530			.5809	283.8120
217	I	1	0.0000	-8.6668			.4204	272.5012
217	J	1	0.0000	-9.0315			.1492	275.6753
218	I	1	0.0000	-5.6767			.7958	265.8465
218	J	1	0.0000	-8.6668			.4204	272.5012
219	I	1	0.0000	-5.4381			.4170	261.4790
219	J	1	0.0000	-5.6767			.7816	265.8205
220	I	1	0.0000	-5.5269			.6944	258.3163
220	J	1	0.0000	-5.4381			.4361	261.5141
221	I	1	0.0000	-5.5079			.0284	255.2576
221	J	1	0.0000	-5.5269	-0.0002	-1.0000	140.7234	258.3695
222	I	1	0.0000	-5.5075	-0.0000	-1.0000	137.3668	252.2068
222	J	1	0.0000	-5.5079	-0.0000	-1.0000	139.0590	255.3136
223	I	1	0.0000	-5.5118	0.0001	1.0000	136.7474	251.0696
223	J	1	0.0000	-5.5075	0.0001	1.0000	137.3867	252.2433

5) Paste the copied data into the first open cell under the “Elem” Column.

Prestressing / Post Tensioning

5

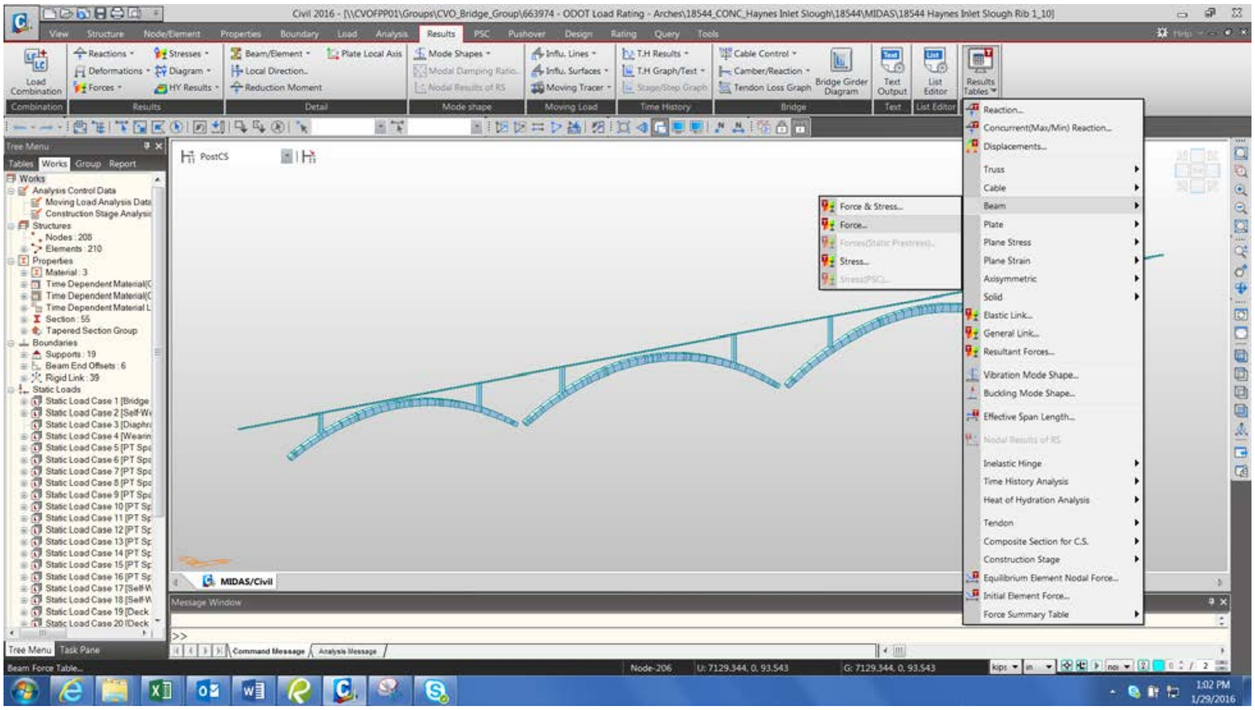
Elem	Part	Tendon Number	Yp (in)	Zp (in)	Average Sin Theta ([deg])	Average Cos Theta ([deg])	Average Stress (kips/in^2)	Average Force (kips)

6) Continue steps 1 – 5 until all the tendon groups are defined for the arch span being rated.

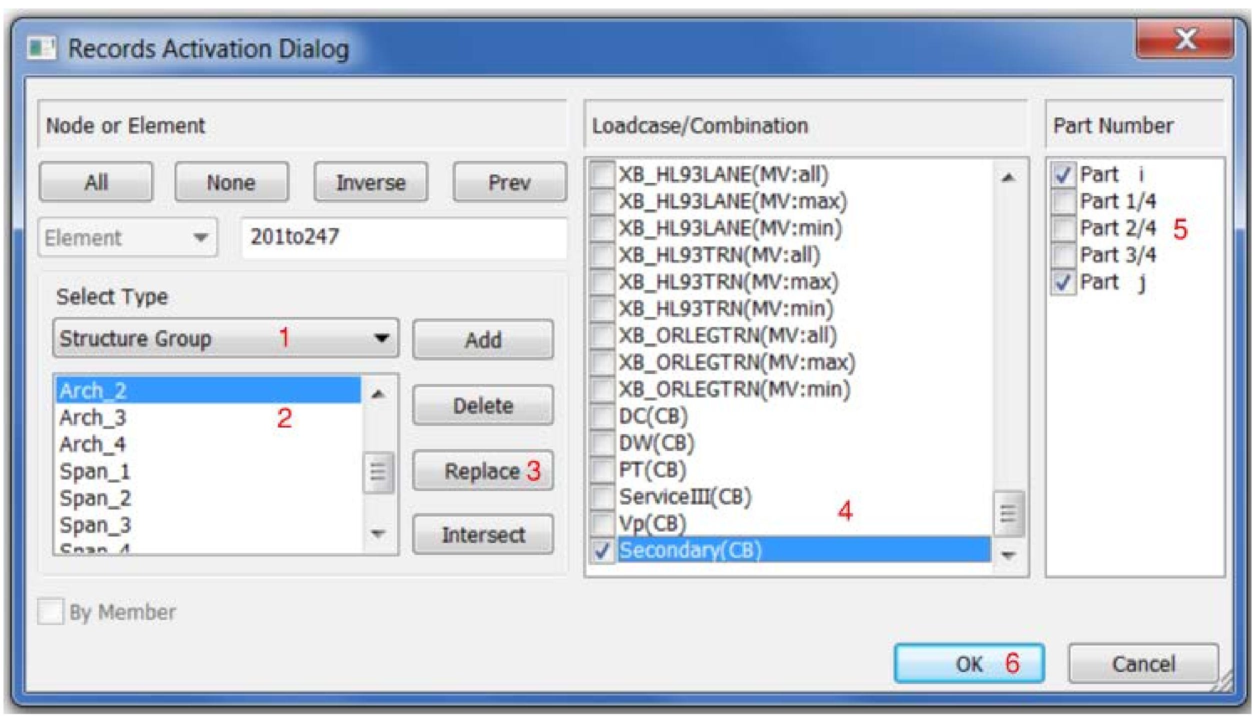
7) Click the Set Ranges button. This should highlight all of the values copied from Midas in Blue.

10.5.8 Secondary Post-Tensioning, Creep, and Shrinkage (Concrete Arch Tool Only)

Maximum result values are copied from Midas and pasted into the appropriate mode tab. In Midas, go to Results > Results Tables > Beam > Force.



1) Select Structure Group for Type.
2) Select which Group is going to be analyzed.
3) Select Replace to update the Element list.
4) Select the Secondary(CB) load case.
5) Select Part (i) and Part (j) only.
6) Click OK. Beam force results for the selected Load Cases are now displayed in a table.



7) Copy all the data. Paste it into the Secondary PT, Creep and Shrinkage Table.

8) Click the Set Ranges button. This should highlight all of the values copied from Midas in Blue.

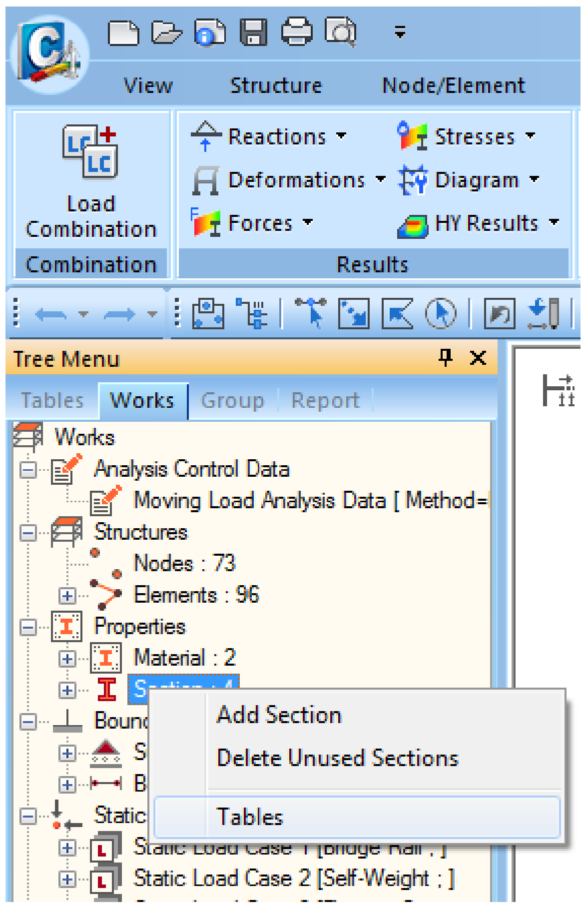
Secondary PT, Creep and Shrinkage

5

Elem	Load	Part	Axial (kips)	Shear-y (kips)	Shear-z (kips)	Torsion (in*kips)	Moment-y (in*kips)	Moment-z (in*kips)

10.5.9 Section Properties

Input the Section Properties from Midas into the capacity spreadsheet. In Midas, go to Works Menu > Right click on Sections > Select Tables.



1) Copy all the section property data. Paste it into the Section Properties tab.

2) Click the Set Sect Prop Table button. This should highlight all of the values copied from Midas in Blue.

Section Properties

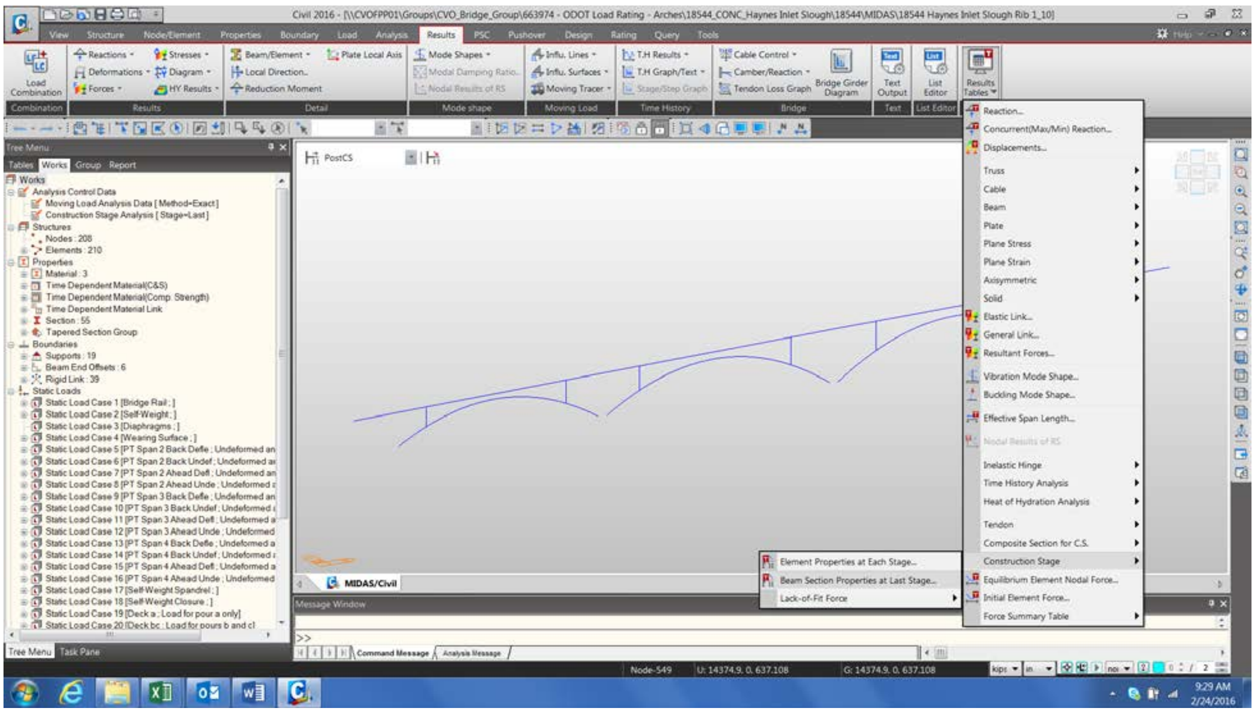
Set Sect Prop Table 2

ID	Type	Shape	Name	Area (in²)	Asy (in²)	Asz (in²)	Ixx (in^4)	Iyy (in^4)	Izz (in^4)	Cyp (in)	Cym (in)	Czp (in)	Czm (in)	Qyb (in²)	Qyz (in²)	Peri.(Out) (in)	Peri.(In) (in)
1																	

10.5.10 Element Section Properties (Concrete Only)

If Midas model includes staged construction, section properties shall be obtained as follows.

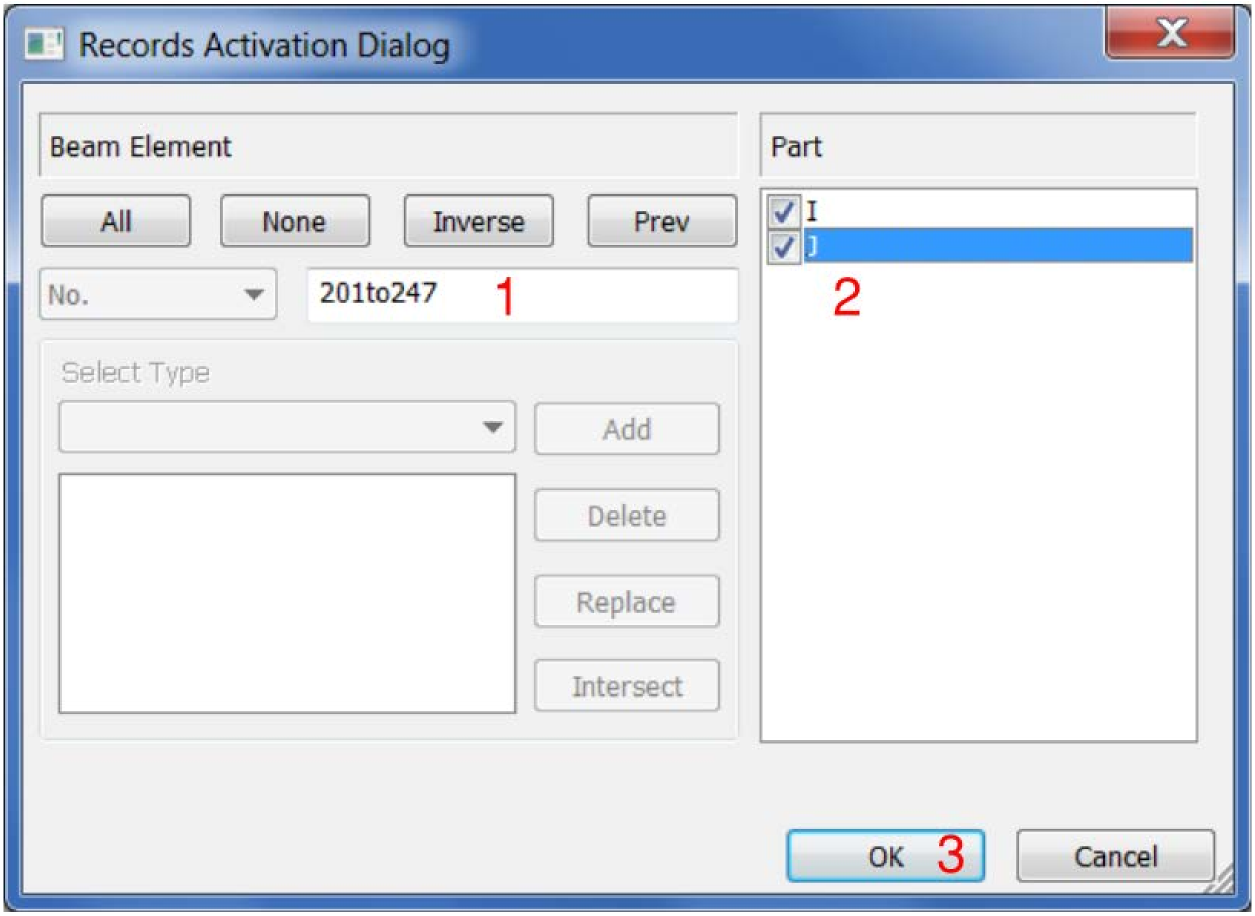
Input the Section Properties from Midas into the capacity spreadsheet. In Midas, go to Results > Results Tables > Construction Stage > Beam Section Properties at Last Stage.



1) Enter the desired elements.

2) Select Part (i) and Part (j).

3) Click OK. Beam Section Properties results for the selected elements are now displayed in a table.



4) Copy the section property data. Paste it into the Element Section Properties tab.

5) Click the Set Sect Prop Table button. This should highlight all of the values copied from Midas in Blue.

Section Properties by Element

Set Sect Prop Table 5

This table is needed only if the model includes construction staging.

Elem	Part	Area (in^2)	Ixx (in^4)	Iyy (in^4)	Izz (in^4)	Cyp (in)	Cym (in)	Czp (in)	Czm (in)	WArea (in^2)	Translational Distance	
4												

10.5.11 Element Properties

10.5.11.1 Steel Arches

Copy down the top row of data (row 6) to account for the number of elements and parts to be analyzed.

1) Enter the element numbers to be analyzed. Remember that there are an “i” and “j” end for each element, so there will be two entries for each element.

2) Enter the part identification for each element. From Midas, this should be “i” and “j”.

3) Enter the arch distance between longitudinal (vertical) panel points. This value is typically the arch length between hangers/columns.

4) Enter the arch distance between transverse panel points. This value is typically the arch length

between diagonal bracing between arch members.

Element Properties

1	2						3	4
Element	Part	Node	Location, in.	x.xxxL	Section #	Element Length (in)	Longitudinal Length between panel points (in)	Transverse Length between panel points (in)
1	i	1	0.00	1.00	1	84.74	331.57	490.52

5) Enter the effective length factor for the longitudinal length between panel points per AASHTO 4.6.2.5.

6) Enter the effective length factor for the transverse length between panel points per AASHTO 4.6.2.5.

7) Enter the flange width and flange thickness. Enter the plate buckling coefficient for the top flange per AASHTO Table 6.9.4.2.1-1.

8) Enter the flange width and flange thickness. Enter the plate buckling coefficient for the bottom flange per AASHTO Table 6.9.4.2.1-1.

		7			8		
5	6	Top Flange			Bottom Flange		
K Long.	K Transverse	Width of Flange, bt (in)	Thickness of Flange, tt (in)	Plate Buckling Coefficient k	Width of Flange, bb (in)	Thickness of Flange, tb (in)	Plate Buckling Coefficient k
1	1	26	0.625	1.4	26	0.532	1.4

9) Enter the web depth, thickness of the web, plate buckling coefficient for the web per AASHTO Table 6.9.4.2.1-1, the number of webs and the number of equally spaced web stiffeners.

10) Enter the transverse web stiffener spacing.

11) Enter in the area enclosed within the centerlines of the plates comprising the box per AASHTO 6.12.2.2.2

12) Enter in the effective section modulus for the top and bottom flange, if different than the section modulus used in the model. For example, if you have slender elements and need to modify a flange width. Sections modulus should be determined about the axis of bending using the effective width of the flanges.

13) Enter the plastic section modulus.

14) Click the “Set Element Properties” button to set the ranges for this tab.

10	11	12	13	14	15	16	17
Depth of Web, D (in)	Thickness of Web, tw (in)	Number of Webs	Equally-spaced stiffeners	Area enclosed within centerlines, A (in^2)	Seff top (in^3)	Seff bottom (in^3)	Plastic Section Modulus, Z (in^3)
26	0.625	2	0	682.3			477.5

9							12		
Webs					10	11	Contains slender elements, ensure an Seff has been entered!		13
Depth of Web, D (in)	Thickness of Web, tw (in)	Plate Buckling Coefficient k	Number of Webs	Long. Equally-spaced web stiffeners	Transv. Shear Stiffener Spacing (in)	Area enclosed within centerlines, A (in^2)	Seff top (in^3)	Seff bottom (in^3)	Plastic Section Modulus, Z (in^3)
26	0.625	1.4	2	0		695.6	480.4	429.6	609.9

Element Properties

Set Element Properties 14

10.5.11.2 Steel Tension Members

Copy down the top row of data (row 6) to account for the number of elements and parts to be analyzed.

1) Enter the element numbers to be analyzed. Remember that there are an “i” and “j” end for each element, so there will be two entries for each element.
2) Enter the part identification for each element. From Midas, this should be “i” and “j”.
3) Enter the overall member design length to be analyzed. For members that are composed of a single element in Midas, this value will be equal to the Element Length. For members that consist of multiple elements, this value will need to be the summation of those elements.

Element Properties

1	2						3
Element	Part	Node	Location, in.	x.xxxL	Section #	Element Length (in)	Design Length (in)
61	i	50	270.00	1.08	3	183.33	183.33

4) Enter the flange width, flange thickness, and the clear width of the flange for the top flange.

5) Enter the flange width, flange thickness, and the clear width of the flange for the bottom flange
6) Enter the web depth, thickness of the web, and the number of webs.

4		5		6		
Top Flange		Bottom Flange		Web		
Width of Flange, bt (in)	Average Thickness of Flange, tt (in)	Width of Flange, bb (in)	Thickness of Flange, tb (in)	Depth of Web, D (in)	Thickness of Web, tw (in)	Number of Webs
8	0.435	8	0.435	8	0.285	1

7) Enter the transverse web stiffener spacing.
8) Enter in the area enclosed within the centerlines of the plates comprising the box per AASHTO 6.12.2.2.2. For wide flange hangers, enter a value equal to the member area.
9) Enter in the effective section modulus for the top flange, if different than the section modulus used in the model. For example, if you have slender elements and need to modify a flange width. Sections modulus should be determined about the axis of bending using the effective width of the flanges.
10) Enter in the effective section modulus for the bottom flange, if different than the section modulus used in the model. For example, if you have slender elements and need to modify a flange width. Section modulus should be determined about the axis of bending using the effective width of the flanges.
11) Enter the plastic section modulus.
12) Enter the diameter of the bolt hole in the member.
13) Enter the number of bolt holes at the critical section.
14) Determine the Net Area of the section in tension.
15) Enter the reduction factor for holes per AASHTO 6.8.2.1. Equal to 0.90 for bolt holes punched full size and 1.0 for bolt holes drilled full size or subpunched and reamed to size.
16) Enter the reduction factor to account for shear lag per AASHTO 6.8.2.2.
17) Click the “Set Element Properties” button to set the ranges for this tab.

7	8	9	10	11		12	13	14	15	16
Transv. Shear Stiffener Spacing (in)	Area enclosed within centerlines, A (in^2)	Seff top (in^3)	Seff bottom (in^3)	Plastic Section Modulus, Z (in^3)	Gross Area, Ag (in^2)	Bolt Hole Size (in)	Number of Bolt Holes at Critical Section	Net Area, An (in^2)	Rp	U
	9.1	25.0	25.0	30.4	9.1	0.938	4.0	8.1	1.0	1.0

Element Properties

Set Element Properties 17

10.5.11.3 Concrete Arches

Copy down the top row of data (row 6) to account for the number of elements and parts to be analyzed.

1) Enter the element numbers to be analyzed. Remember that there are an "i" and "j" end for each element, so there will be two entries for each element.
2) Enter the part identification for each element. From Midas, this should be "i" and "j".
3) Enter the area of steel on the top face of the arch.

1	2							3
Element	Part	Node	x (in)	Loc (in)	L_Span (in)	x.xxxL	Cm	As_top (in^2)
559	I	422	5940.00	180.00	1800	3.100	1.00	1.76

4) Enter the area of steel on the bottom face of the arch.
5) Enter the width of the arch member.
6) Enter the cover distance from the face of the arch member to the outside face of the shear reinforcing.
7) Enter the diameter of the shear reinforcing bar.
8) Enter the diameter of the longitudinal reinforcing bar.
9) Change the value to specify whether to check shear at this location by entering "Y" for yes or "N" for no. Typically all sections are checked for shear, except when looking at sections within the critical shear distance at the ends of the arches.
10) Enter the area of the shear reinforcing in the arch.
11) Enter the spacing of the shear reinforcing in the arch.
12) Enter the section number that corresponds to this element and part number. The section ID numbers are on the Section Properties tab.

4	5	6	7	8	9	10	11	12
As_bot (in^2)	b (in)	Cover (in)	Dia v (in)	Dia s (in)	Shear? (Y/N)	A_v (in^2)	s (in)	Section #
1.76	18.00	3.00	0.375	0.750	Y	0.22	12.00	101

13) Enter the area of prestressing steel.
14) Overwrites the moment magnifier value calculated on the Moment Magnifier tab.
15) Enter comments, as needed.
16) Click the "Set Element Properties" button to set the ranges for this tab.

13			14	15
Prestressing				
Aps (in^2)	yp (in)	PT stress (ksi)	Limit δb	Comments
0.00	0.00	0.00		

16

Set Element Properties

10.5.11.4 General Concrete Sections

Copy down the top row of data (row 6) to account for the number of members and parts to be analyzed.

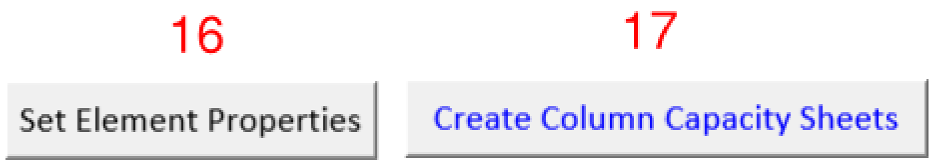
1) Enter the element numbers to be analyzed. Remember that there are an "i" and "j" end for each element, so there will be two entries for each element (member).
2) Enter the part identification for each element. From Midas, this should be "i" and "j".
3) Enter the span number for each element.
4) Enter the overall member design length to be analyzed. For members that are composed of a single element in Midas, this value will be equal to the Element Length. For members that consist of multiple elements, this value will need to be the summation of those elements.
5) Enter the effective length factor in the y-y plane of bending per AASHTO 4.5.3.2.2b.
6) Enter the effective length factor in the z-z plane of bending per AASHTO 4.5.3.2.2b.
7) Enter the moment gradient coefficient per AASHTO 4.5.3.2.2b.

1	2		3		4	5	6	7
Element	Part	Node	Span	Element Length (in)	Design Length vert (in)	K_{yy}	K_{zz}	Cm
261	I	503	1	204.15	204.15	1.00	1.00	1.00

8) Enter the area of steel on the tension face of the member. The load rater will need to evaluate the dead and live load moment diagrams to determine which face of the member is in tension.
9) Enter the width of the member.
10) Enter the cover distance from the face of the member to the outside face of the shear reinforcing.
11) Enter the diameter of the shear reinforcing bar.
12) Enter the diameter of the longitudinal reinforcing bar.
13) Change the value to specify whether to check shear at this location by entering "Y" for yes or "N" for no. Typically all sections are checked for shear, except when looking at sections within the critical shear distance at the ends of the member.
14) Enter the area of the shear reinforcing in the member.
15) Enter the spacing of the shear reinforcing in the member.

8	9	10	11	12	13	14	15
As_tens (in^2)	b (in)	Cover (in)	Dia v (in)	Dia s (in)	Shear? (Y/N)	A_v (in^2)	s (in)
9.60	29.53	2.84	0.500	1.128	Y	0.40	1.77

16) Click the "Set Element Properties" button to set the ranges for this tab.
17) Click the "Create Column Capacity Sheets" button to create a separate capacity tab for each element and end that are entered on the Element Properties tab.



10.5.12 Factored Loads

Click on the "Set Factored Loads" button (for concrete sheets click on "Set Loads Tbls" button) to activate the macro that will generate the factored loads tab.

10.5.13 Moment Magnifier (Concrete Only)

Click on the "Calc Moment Magnifiers" button to activate the macro that will generate the moment magnifier tab.

10.5.14 Design Loads (Concrete Only)

Click on the "Calc Design Loads" button to activate the macro that will generate the design loads tab.

10.5.15 Capacity Tabs

Click on the Calc button in the upper left hand corner to activate the macro that will generate the capacities. This must be done for each capacity tab present in the capacity spreadsheet (Moment, Shear, Axial, and/or Interaction), except for the specific tabs with additional instructions below.

For additional information on the capacity calculations, see the Concrete and Steel Capacity Calculation Appendices.

10.5.15.1 Column Capacity (Concrete Arches)

An additional button was used to greatly reduce the macro run time for this tab. As it is, the macro on this sheet can take a long time to process based on the complex nature of developing an interaction capacity curve for each section and each loading condition.

1) Click the "Set Data (1st)" button to set the ranges for this tab.
2) Click the "Capacity Calc" button to run the capacity macro. Warning: this macro can take a considerable amount of time.

10.5.15.2 P-M Interaction Capacity (General Concrete Sections)

P-M Interaction Capacity tabs will be created for each section to be analyzed when the button is clicked on the Element Properties tab described above. The P-M Interaction capacity tab allows the engineer to enter in values to describe the Moment-Axial capacity curve for a complex section (i.e. rectangular section with circular reinforcing). These values must be determined using external software (i.e. CSI Bridge Section Modeler, SP Column, Xtract, etc.). It is suggested to limit the number of members to be checked in one spreadsheet to 10 members (i.e. 20 unique analysis sections).

1) Enter the Row number from the Element Properties tab that you are analyzing. The element and end will then be calculated and can be used to verify that the correct element is being analyzed.
2) Enter the Element Name. Typically this includes the element and end identifiers and will be shown on the final rating factor table.
3) Adjusting the Vehicle will update the section capacity graph on the tab, but does not change the rating factors.
4) Enter in values to describe the Moment-Axial capacity curve for the element section. Must use all 11 values to get the rating factor calculations to process correctly.

1	Load Row	7		**Element Name**
	Element	261	2	Spandrel Elem 261
	End	I		
3	Vehicle	HL93	Select vehicle loads for graph	

User-input Capacity

	P	M_pos	M_neg
4	2530	0	0
	2530	5806.7654	-5807
	2265	8406.3458	-8406
	1924	10628	-10628
	1527	12517	-12517
	1029	14245	-14245
	653.1775	17117	-17117
	165.2085	18211	-18211
	-498.926	13653	-13653
	-1278	6061.8703	-6062
	-1771.2	0	0

10.5.16 Run Log

The P-M Interaction macro performs a large number of calculations and can take several minutes to complete. A report is generated with each run of the macro in order to provide the user with a summary and basic feedback; this report is formatted as a simple text file and is copied to the Run Log tab. The report includes information about the worksheet version, member name, span data, and a time-stamp to record the time of the last run. Any errors encountered during the column capacity interaction calculation are output with information to identify at which element the error occurred. The report can be used to assist with error checking, verification of the total number of elements to be evaluated, and a record of the last time the macro was run. To save the output, copy and paste to a separate word or text file, the output is overwritten with each run.

For the Steel Arch and Steel Tension Run Log tabs, there is also a diagram, which is described in section below.

10.5.17 Diagram (Concrete Arch Only)

The diagram can be used to review the P-M interaction diagram for a single element under a specified vehicle and effect.

1) Enter the Vehicle Row from the list below
2) Enter the Load Effect from the list below

3) Enter the Row to be displayed from the Moment Capacity Tab.

Diagram **Last Update: 1/19/2017 16:37**

This information is only updated during a run of the Interaction Capacity. Use the yellow boxes to select the load case to display during the next run.

1	6	Vehicle to be displayed	TYPE 3-3 TRAIN & LEGAL LANE
2	8	Effect to be displayed	Min LL P, Min Static
3	11	Data row to be displayed, from "Moment Capacity" tab	

DESIGN & LEGAL VEHICLES

1 HL93 (INVENTORY)
2 TYPE 3 (50K)
3 TYPE 3S2 (80K)
4 TYPE 3-3 (80K)
5 TYPE 3-3 & LEGAL LANE
6 TYPE 3-3 TRAIN & LEGAL LANE
7 SU4 TRUCK (54K)
8 SU5 TRUCK (62K)
9 SU6 TRUCK (69.5K)
10 SU7 TRUCK (77.5K)

CTP VEHICLE, MULTI-LANE

11 OR-CTP-2A (105.5K)
12 OR-CTP-2B (105.5K)
13 OR-CTP-3 (98K)

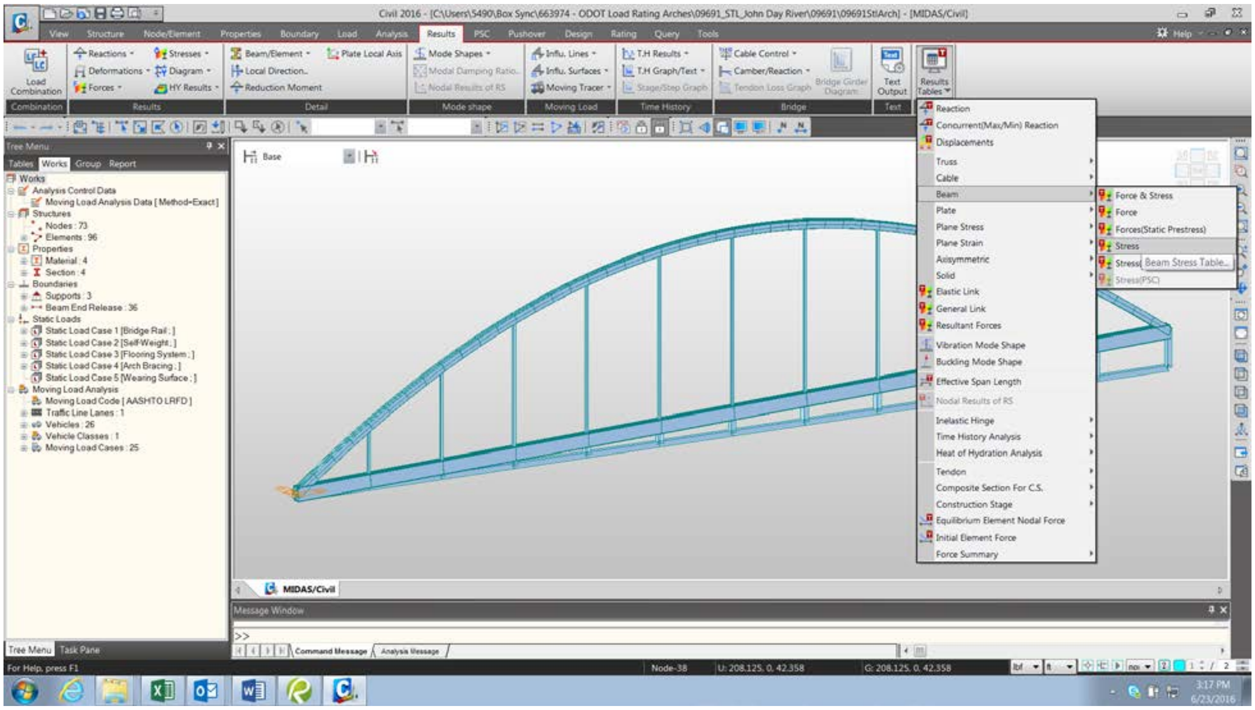
STP VEHICLE, MULTI-LANE

14 OR-STP-3(120.5K)
15 OR-STP-4A (99K)
16 OR-STP-4B (185K)
17 OR-STP-4C (150.5K)
18 OR-STP-4D (162.5K)
19 OR-STP-4E (258K)
20 OR-STP-5BW (204K)
21 SPECIAL

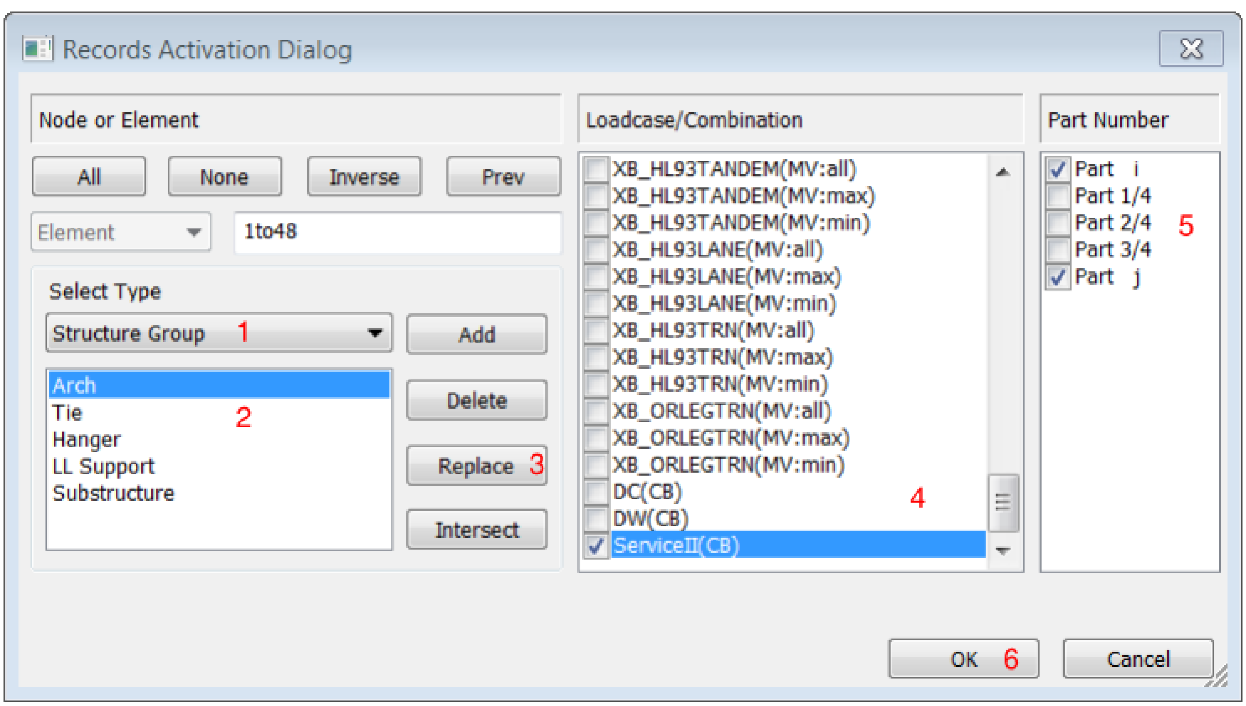
1 Max LL M, Max Static
2 Max LL M, Min Static
3 Min LL M, Max Static
4 Min LL M, Min Static
5 Max LL P, Max Static
6 Max LL P, Min Static
7 Min LL P, Max Static
8 Min LL P, Min Static

10.5.18 Beam Stress (Steel Only)

Rating factors for service II stress are calculated at all flexural analysis locations. Begin by copying the beam stresses from the Midas model. In Midas, go to Results > Results Tables > Beam > Stress.

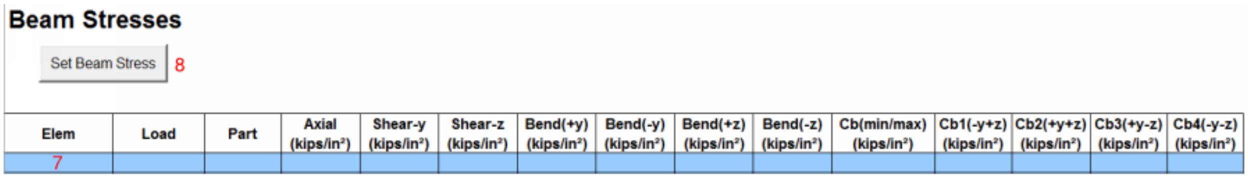


1) Select Structure Group for Type.
2) Select which Group is going to be analyzed.
3) Select Replace to update the Element list.
4) Select the HL93(MV:all) and Service II(CB) load cases.
5) Select Part (i) and Part (j) only.
6) Click OK. Beam force results for the selected Load Cases are now displayed in a table.



7) Copy all the data. Paste it into the BeamStress Table.

8) Click the Set Beam Stress button. This should highlight all of the values copied from Midas in Blue.



10.5.19 Service II (Steel Only)

Click on the **Calc Service II Check** button in the upper left hand corner to activate the macro that will generate the Rating Factors.

10.5.20 Rating Factors (RF)

Click on the Rating Factor button to calculate rating factors. These rating factors are manually copied and pasted into the Rating Factor Summary sheet.

10.5.21 Submittals

Under the assumptions tab in the Capacity and RF Worksheets, there is a Print button that will activate a macro to print the desired tabs. Not all of the worksheets will be printed. Some page formatting has been automated, but the user should review the printed documents and perform additional formatting as necessary. Information from the capacity worksheets is to be included in the Calculation book (varies by capacity worksheet). Rating factors are included in the summary sheet and will therefore not be printed here.

SECTION 11: LOAD RATING STEEL BOX GIRDER BRIDGES

11.0 Scoping of Structure

Create a scoping file (nnnnn_scope.xls) to document decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended effect of causing the point to be reported twice in the load rating summary sheet. Points of symmetry for both the girder and crossbeam will be documented in this scoping summary.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0 there is no need to rate the other similar member.

An example would be crossbeams that have the same cross sections, and reinforcement, but different adjacent span lengths. The capacity of these crossbeams will be the same but the loads will vary due to the different span lengths. In this case the crossbeam with the longer adjacent spans (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0 then, there is no need to rate the other crossbeam. If the load rating reports rating factors less than 1.0, then both members shall be rated. Although the first member will still control the overall load rating, the rating factors for the second member will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

11.1 General

As mentioned in Section 7 of this manual, there are seven different categories of steel bridges in the State of Oregon, each of which require different analysis and design methods. This section covers straight, slightly horizontally curved, and slightly skewed steel box girders that comply with Section 11.1.1 - Limitations on Applicability.

Steel box girder bridges not meeting the limits of applicability defined herein or that otherwise require a refined analysis as described in AASHTO LRFD Article 4.6.3 shall be considered a complex bridge and will not be covered within this section of the manual.

Steel structures are load rated based on the Strength I & II and Service II limit states. According to the MBE code, the Fatigue Limit state is optional. ODOT has chosen to not perform fatigue analysis during the load rating of steel structures. When inspection reports and/or fracture rating of the bridge show deficient or unsatisfactory result, ODOT may decide to proceed with a Fatigue analysis and/or instrumentation of the structure.

For the purposes of this section the terms “box” and “tub” can be used interchangeably. Provisions that apply specifically to closed-box sections or open-tub sections (but not both) will be explicitly identified if necessary.

The primary analysis tools necessary for completion of the load ratings of steel box girders for ODOT are:

- Preliminary Files for Girders (Mathcad) – Section 11.2;

- Midas Civil (Midas) – Section 11.3; and

- Capacity and RF Workbook (Template) – Section 11.4.

11.1.1 Limitations of Applicability of this Section

This section of the manual applies to straight steel box girder bridges and horizontally curved steel box girder bridges with multiple, single-cell box sections that comply with the requirements of AASHTO LRFD Article 4.6.2.2 for approximate methods of analysis and AASHTO LRFD Article 6.11.1, except as amended herein.

AASHTO LRFD Article 4.6.2.2 allows for approximate live load distribution methods for steel box girder bridge design. This article references Article 6.11.2.3 for special requirements for use of the approximate live load distribution factor tables, and references Article 4.6.1.2.4c for requirements related to horizontally curved steel girder bridges.

AASHTO LRFD Article 6.11.2.3 refines the range of applicability of the live load distribution factor tables specified in AASHTO LRFD Article 4.6.2.2.2b for steel box girder bridges. For the purposes of this manual, these sectional requirements are amended as follows:

- Bearing lines shall not be skewed more than 10 degrees;

- The length of the deck overhang including the curb and parapet shall not exceed 60 percent of the center-center distance of the near flanges of the exterior and first interior box, a, or 6.0 ft.

AASHTO LRFD Article 4.6.1.2.4c allows for the effect of curvature to be ignored when determining major-axis bending moments and bending shears when certain geometric conditions are met. However, ODOT requires all curved steel box girders to be modeled using the curved geometry of each rated girder line. For the purposes of this manual, approximate live load distribution methods can be used for horizontally curved steel box girder bridges provided the requirements of AASHTO LRFD Article 4.6.1.2.4c as amended below are met:

- Bearing lines are skewed less than 10 degrees.

The following box girder sections are beyond the scope of this section of the manual:

- Straight or curved sections not meeting the requirements listed above

- Sections with a single box girder with one or more cells (refined analysis required per AASHTO LRFD Article 6.11.1.1)

- Sections with composite concrete bottom box flanges (AASHTO LRFD Article 6.11.1)

- Sections without composite reinforced concrete decks (AASHTO LRFD Article 6.11.1)

- Bridges with span lengths that exceed 350 ft (AASHTO LRFD Article 6.11.1) unless specifically approved by ODOT on a case-by-case basis.

11.1.2 Live Load Distribution for Variable Bridge Width

When determining the live load distribution factors for bridges with variable width, the number of loaded lanes for each section of interest shall be based on the roadway width at each given section.

11.1.3 Effective Box Flange Width

The AASHTO LRFD defines a box flange as a flange that is connected to two webs. As stated in AASHTO LRFD Article 6.11.1.1, box flanges shall be considered fully effective if the width of the flange does not exceed one-fifth of the effective span length. The effective span length for simple spans is taken as the span length, and for continuous spans is taken as the distance between points of permanent load contraflexure.

For calculating flange stresses, the box flange width shall be limited to one-fifth of the effective span length. For calculating nominal resistance, the full box flange width is used regardless.

Straight steel box sections with box flanges that do not exceed one-fifth of the effective span and that otherwise are within the limitations of applicability of this section do not require consideration of torsional or distortional effects (refer to AASHTO LRFD Articles 6.11.1.1 and C6.11.2.3).

11.1.4 St. Venant's Torsional Stresses

St. Venant's torsional stresses shall be included for straight box sections that have box flanges that aren't fully effective. Horizontally curved box sections shall always include St. Venant's torsional effects.

The preferred method for obtaining torsional force effects from applied torsional loads, curvature, or sectional asymmetry is through the Midas modeling. Specific procedures for creating the Midas analysis models to properly capture the torsional force effects are provided in Section 11.3. The torsional web shear is calculated by the Template described in Section 11.4 using the resulting torsional moment.

11.1.5 Transverse Bending Stresses

Transverse bending stresses shall be considered for multiple box sections at the strength limit state. Additionally, transverse bending stresses shall also be considered for the fatigue limit state if fatigue concerns trigger such an evaluation.

11.1.6 Longitudinal Warping Stresses

Longitudinal warping stresses due to cross-sectional distortion shall only be considered at the fatigue limit state and if specific concerns trigger evaluation of fatigue. An evaluation of these stresses is not currently performed by the Template.

11.2 Preliminary Files for Girders (Mathcad)

For steel box girders, the preliminary (Mathcad) file name and extension for bridge #nnnnn is typically nnnnn_STBox.xmcd.

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied terms with parentheses.

11.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater, date (2nd line left), File Name, and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description ("Spans" field) from the Bridge Log is adequate for this purpose.

Note: The Mathcad regions in the top right margin (outside the printable area) are there for two purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

11.2.2 Resistance Factors

Document the decisions regarding all Resistance Factors, with references to the appropriate MBE tables.
Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad:

- For Flexure:

  $\Phi_f = \phi\ [\ \max(\phi_c\phi_{sf}, 0.85)\ ]$
  where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 6.5.4.2.1)
  and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

- For Shear and Bearing:

  $\Phi_v = \phi\ [\ \max(\phi_c\phi_{sv}, 0.85)\ ]$
  where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 6.5.4.2.1)
  and ϕ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).
Generally Φ_f and Φ_v will be the same for redundant members such as girders and will be different for non-redundant members such as single-span and 2-span crossbeams.

11.2.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into the Template. The Load Rating Summary Workbook **(LR.XLT)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and effective bridge length. Note that effective bridge length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which Live Load Factor Application is used, ADTT is specified as "one direction". Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the Live Load Factor Application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the Live Load Factor Application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the "LRFR Strength I & II" table from the live load factor application, and in Mathcad use Edit / Paste Special. In the "Paste Special" dialog box choose the "Paste" button, highlight "Bitmap" in the "As" list, and click the "OK" button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to MBE 6A.4.4.3.

11.2.4 Material Properties

Enter the material properties for the steel box girder and deck concrete, and calculate the elastic modulus for the reinforced concrete deck (E_c). Then compute the modular ratio for concrete materials (n_c). Use AASHTO LRFD Equation 5.4.2.4-1 to determine the elastic modulus of concrete, assuming K_1=1.0. Document assumptions made about the material properties if they are not given on the Bridge Plans.

11.2.5 Deck Geometry and Distribution Factors

Document the deck geometry and span characteristics used to evaluate how the distribution factors will need to be calculated.

Calculate an effective deck width to use for each defined span of the girder. A single width is allowed per span. Calculate the average roadway width for each span.

Calculate the appropriate approximate live load distribution factor as described below. If the tableized distribution factor formulas in AASHTO LRFD Article 4.6.2.2.2b are used, these will automatically be calculated on the 'LL_DF' worksheet in the Template.

For straight steel box girders that meet the limits of applicability of this section, the live load distribution factors for exterior and interior girders are assumed to the be the same. Further, unless there is a significant disparity in dead load or member capacity, there is no need to develop separate analyses for interior and exterior girders for these girders. Straight steel box girders that meet all the requirements discussed in Section 11.1.1 may use the distribution factors from AASHTO LRFD Article 4.6.2.2.2b. Otherwise:

- If the skew angle is less than 10 degrees, then the lever rule can be used to approximate the live load distribution; or

- If the skew angle is 10 degrees or more, a refined analysis is required.

For horizontally curved steel box girders meeting the limits of applicability in Section 11.1.1, an analysis of each girder line shall be performed due to the differences in arc length and radius. These girders shall use the lever rule for approximating the live load distribution. Horizontally curved steel box girders outside the limits of applicability herein shall use refined methods of analysis for determining live load distribution.

11.2.6 Section Properties

Input the plate and deck dimensions required for the Midas Steel Tub Section input parameters for either a box or tub girder for each unique section. These sectional inputs will be copied into the Template and assigned to specific elements when the nodal geometry is defined in the 'GeometryCalcs' worksheet of the Template. Section properties are calculated independently in both the Template and the Midas model.

Midas is capable of linearly or parabolically tapering between unique sections about the y and z axis. This means that only section change locations within these tapered portions need to be input.

11.2.7 Span Information

Define the span length to assume for each span the girder line. Note any necessary clarifications of the plans as well as expansion joint locations. The length of the span should be measured along the centerline of the girder. This is commonly the average length of the two top flanges for open-tub sections.

11.2.8 Shear Connectors

State any assumptions regarding the presence of shear connectors and the assumption on whether or not the deck is considered composite.

11.2.9 Stiffeners

Define the locations, number, and necessary properties of all transverse, longitudinal web, longitudinal flange, and bearing stiffeners measured from the left end of each span along the girder centerline. For bearing stiffeners, document all assumptions necessary to calculate the Reaction Factor on the 'Bearing Stiffeners' worksheet of the Template. This factor is used to capture the presence of multiple bearings per girder, uneven bearing reactions, and/or torsional reaction demands.

11.2.10 Component Dead Loads (DC)

To avoid confusion, dead loads should be grouped under the headings DC1, DC2, and DW in the Preliminary File (**.xmcd**) and entered in the Midas model as separate load cases. Use AASHTO LRFD Table 3.5.1-1 to determine the unit weight of concrete w_c. For dead load calculations, use w_c + 0.005 kcf to account for the reinforcement, in accordance with AASHTO LRFD Commentary C3.5.1.

The self-weight of the deck should be calculated and added as an applied DC1 load rather than relying on the Midas model to calculate the weight based on the effective deck width (see Section 11.3 for instructions). Consider floorbeams as point loads and longitudinal stringers as uniform loads to be part of component load DC1.

Where standard rail drawings occur, use the rail dead loads tabulated in Appendix H - ODOT Standard Rail Weights, found in file **RAILDL.XLS**. Provide detailed calculations for the dead load of any rail not found in this summary.

For all steel box girder bridges, assume adequate lateral distribution of loads and distribute the sum of all rail, curb and sidewalk dead loads equally among all girders.

Add a point load at the center of bearing to account for the dead load of the rails, deck, and girder that extend beyond the center of bearing. Even though these loads will have no impact to the load rating of the girder, they will be utilized when applying the girder dead load reactions to crossbeams.

For most utilities, the dead load is very insignificant when compared to the dead load of the rest of the structure, and therefore can be ignored. However, there can be cases were the utility load can be significant; such as a bridge supporting a 16" diameter concrete lined cast iron water pipe that was computed to add 200 lb/ft of dead load when considered full of water. In this case, the dead load was shared between the two adjacent girders. Therefore, it will be left up to the engineering judgment of the individual load rater to determine if the utility dead load is significant enough to be included in the load rating.

For miscellaneous steel dead load such as transverse stiffeners, longitudinal stiffeners, intermediate diaphragms, laterals, struts, bolts and splices, one can simplify the input by applying 15% of steel box girder section self-weight to account for all the miscellaneous steel elements. As the computation of each item is time consuming and the effect of the difference in the loadings input to the rating factor results is minimal.

11.2.11 Wearing Surface Dead Loads (DW)

Always separate wearing surface dead load (DW) from the component dead loads. This is due to (a) the potential for different dead load factors γ_{DC} and γ_{DW} according to MBE, (b) because this facilitates future re-rating when the wearing surface thickness changes and (c) it facilitates input for the crossbeam load rating software, where it must be kept separate.

Use 150 lb/ft^3 for asphalt wearing surface (0.0125 ksf/inch of wearing surface). Use 135 lb/ft^3 (0.0113 ksf/inch) for overlays of Polyester Polymer Concrete (non-structural). Show calculations for wearing surface dead load distributed equally to all the girders. Add 1" to any non-zero measured ACWS thickness to account for uncertainties in measurement, unless the thickness has been obtained from averaging multiple core samples. Assuming that there is better control on the placement of PPC overlays versus asphalt, add an additional ½" to the design thickness of PPC overlays to account for construction variations and uncertainty.

For all concrete decks, assume adequate lateral distribution of loads and distribute the sum of all wearing surface dead loads equally among all composite girders.

Add a point load at the center of bearing to account for the dead load of the wearing surface that extends beyond the center of bearing if a crossbeam analysis is warranted. Even though this load will have no impact to the load rating of the girder, it will be utilized when applying the girder dead load reactions to crossbeams.

11.2.12 Live Loads (LL)

Simply list the four classes of rating loads to be analyzed. (See articles 1.5.1.1 through 1.5.1.5).

11.2.13 Boundary Conditions

Describe the assumed boundary conditions at each support location for each translational and rotational degrees of freedom. Also define any in-span hinge locations and the associated boundary conditions. Provide a table of the appropriate Midas Civil input for each support or in-span hinge location. Note that the Midas fixity input values for supports is different than for in-span hinges.

11.2.14 Analysis Sections

Determine the spans to be investigated. These should be any span that is unique and is not repeated due to symmetry or due to repetition of a span between joints.

Within each span, check for symmetry of sections and loads, and do not identify any analysis points that are structurally symmetrical with analysis points already defined. Defining analysis points that are structurally symmetrical has the potential effect of corrupting the Load Rating Summary Sheet. Because the "Refresh" module is looking for the lowest Rating Factors, defining a symmetrical point causes it to identify the most critical rating location twice, thus preventing it from identifying the second most critical analysis point. The second controlling point is useful information in evaluating potential repairs for the bridge.

Analysis sections are generally defined for the following locations:

- Bearing Stiffener Locations –

  Along with the Rating Factors for Bearing, the Rating Factors for shear should also be checked at these locations. If the analysis point is at support where the girder is continuous over the support, the Rating Factors for Negative Moment should also be checked. Otherwise, the Rating Factors for Moment can be ignored since there is zero moment at simple supports.

- Maximum Flexure Locations –

  The maximum flexure locations are the positive moments in each unique span and the negative moments over each unique continuous support. The Rating Factors for both shear and moment should be checked at these locations.

- Shear at Support (when there are no bearing stiffeners) –

  When there is no bearing stiffener detailed at a support location (typically when the girder is integral with supporting crossbeam), the Rating Factors for shear should be checked. If the analysis point is at support where the girder is continuous over the support, the Rating Factors for shear should be checked at the same time as the Rating Factors for negative moment are checked.

- Girder Geometry Change Points –

  The girder geometry change points are the span locations where there is any section loss/gain in its intrinsic properties. That is, any change in web or flange dimension. At these analysis locations, the element dimensions on the right side of the node are defined and the Template will automatically calculate the rating factors at the node and 1 inch to the left of each node and report the controlling value. For every girder geometry change location, the rating factors for both moment and shear shall be checked.

- Locations Where the Girder Material Properties Change –

  Girder Material Property Change points are the span locations where the type of steel (yield strength) changes in a flange or web. At these analysis locations, the element material properties on the right side of the node are defined and the Template will automatically calculate the rating factors at the node and 1 inch to the left of each node and report the controlling value. For every girder material property change location, the Rating factors for both moment and shear should be checked.

- Transverse Stiffener Spacing Change Points –

  These points are the locations where the girder transverse stiffener spacing changes within a span. These points are defined in a table that documents the distance from the left end of the span to start of the stiffener spacing and the length along the girder (range) for each different spacing. The stiffener spacing ranges are entered into 'Transverse Stiffeners' worksheet of the Template which calculates capacities and rating factors using the stiffener spacing range pertaining to each node as well as the location 1 inch to the left of each node. The controlling rating factor is then reported on the 'RF' worksheet of the Template. Unless the stiffener spacing change point coincides with that of another analysis point type, then the rating factors for moment can be ignored at these locations.

- Longitudinal Stiffener Change Points –

  These points are the locations where the girder web or girder flanges have changes to longitudinal stiffeners within a span. These points are defined in a table that documents the distance from the left end of the span to start of the stiffener change, the length along the girder (range) to which each change applies, and the the type of longitudinal stiffener (web or flange). This information is entered into the 'Longitudinal Stiffeners' worksheet of the Template which calculates capacities and rating factors using the longitudinal stiffener range pertaining to each node as well as the location 1 inch to the left of each node. The controlling rating factor is then reported on the 'RF' worksheet of the Template. Unless the stiffener spacing change point coincides with that of another analysis point type, then the rating factors for moment can be ignored at these locations.

- Locations of Localized Corrosion –

  In the rare case of when the inspection report provides detailed information of areas with measured section loss, then those locations should be checked for both moment and shear where the girder is modeled with the remaining section of sound material.

  In most cases, the load rater will have to check the inspection report for the condition states of the elements that are being load rated to determine if the analysis needs to consider the effects of section loss. If the member being evaluated is an unpainted steel element, then any percentage of the member that falls under Condition State 4 will mean that the section loss is sufficient to warrant an analysis to ascertain the impact to the ultimate strength. Likewise, if the member being evaluated is a painted steel element, then any percentage of the member that falls under Condition State 5 will warrant an analysis to ascertain the impact of the section loss to the ultimate strength. For an element to fall within one of these Condition States, the section loss should be greater than 10% of the plate thickness in a critical load area. Unfortunately, when these lowest Condition States are assigned, the inspection report typically does not provide the locations and measurements of the loss or remaining section. Therefore, the load rater will be required to communicate with the person who inspected the bridge to determine the locations and measured section loss of the member so that a proper analysis of the remaining section can be performed. These locations should be checked for both moment and shear. If the Condition State for the element does not fall under the lowest category as described above, then the locations of localized corrosion do not need to be accounted for in the analysis.

11.2.15 Additional Modeling Nodes

There are times when additional nodes are justified to avoid producing analysis errors during modeling. Most commonly, these additional nodes are required when modeling a structure has a reduced number of analysis sections due to symmetry, or when the structure is horizontally curved. The elements pertaining to these modeling nodes will need to have sectional properties defined, but the additional modeling node locations should not be included in capacity or rating factor calculations.

At a minimum include nodes at 1/20 points across the entire structure, which will be used in the Midas analysis. Otherwise having large element lengths on the symmetric side of the structure may produce analysis errors. To account for horizontal curvature, add modeling nodes to ensure the curvature effects are more accurately captured (see Section 11.3 for further guidance).

Multi-span bridges that are continuous for live loads will also need to have the support conditions accurately modeled. This includes modeling columns that are integral with the superstructure. Although rating factors are not calculated for columns, they are included because they impact the superstructures stiffness. This is not very common for steel box girder bridges.

Refer to Section 11.3, Midas Civil, for instruction on how to create the input for the Midas analysis file.

11.3 Midas Civil (Midas)

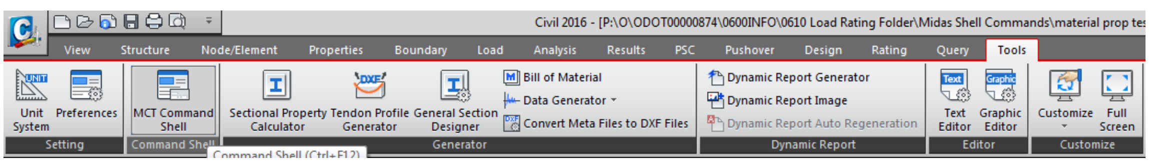
Midas Civil is not used to calculate capacity or rating factors. Rather, it is utilized to determine various force effects necessary for the determination of the limit state demands used in the rating factor calculations by the Template. The below procedure may be valid on previous versions. If a previous version is used, check the input and output for consistency with this chapter.

Due to the interdependency between the Template and the Midas model, a recommended workflow after the creation of the preliminary file is to fill out the ‘Spans’, ‘Midas Section Input’, and ‘GeometryCalcs’ worksheets of the Template prior to the creation of the Midas model. There are MCT shell commands that can be created by the Template to facilitate model development.

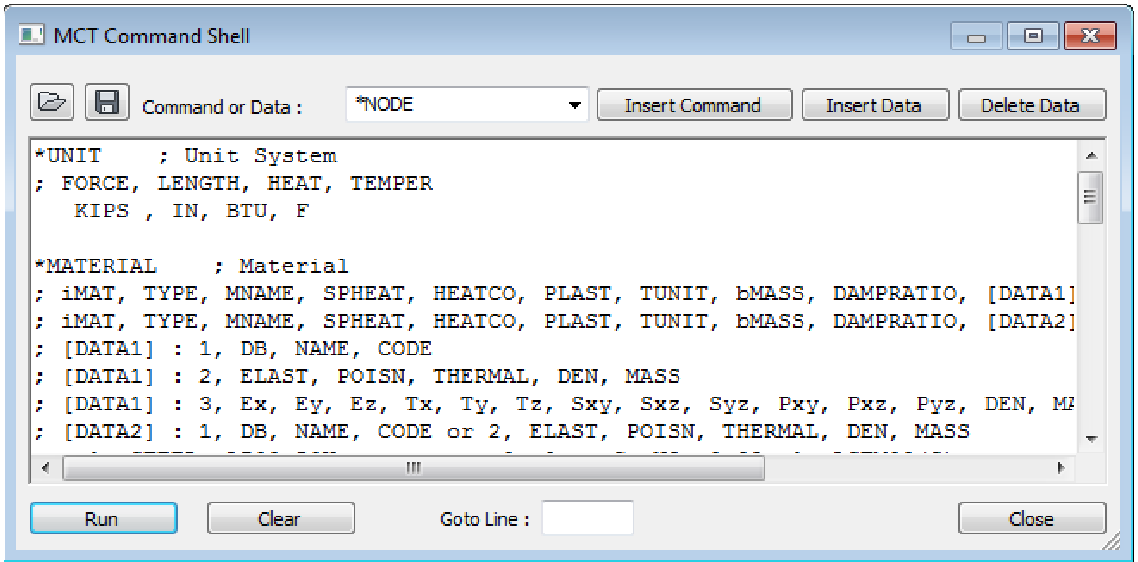
11.3.1 Midas Template

Create a new Midas model and save it with the name nnnnn_STBox.mcb.

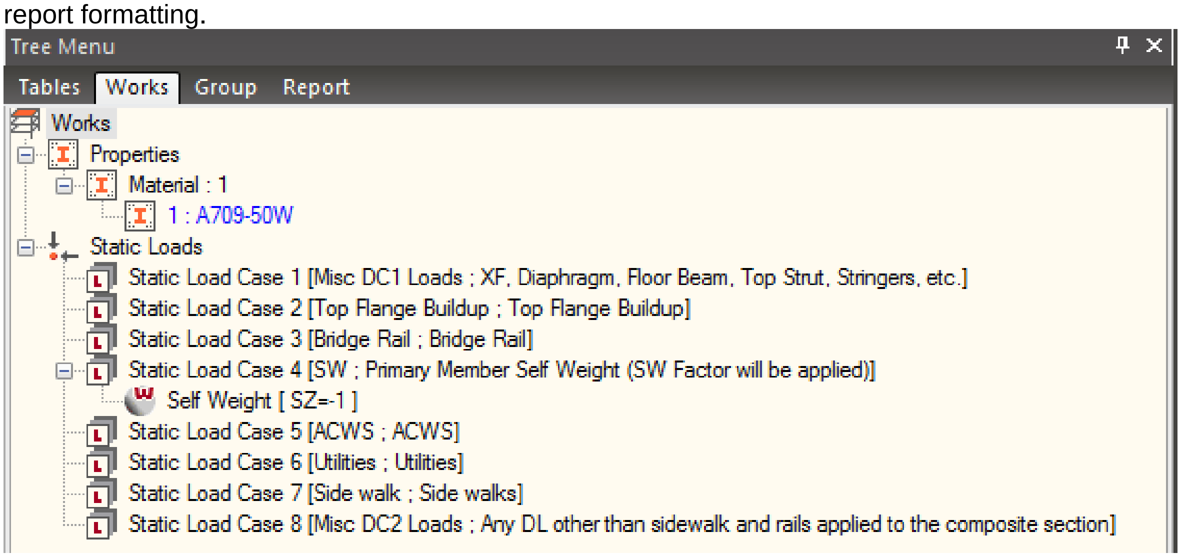
In the top menu, go to Tools > MCT Command Shell.



Within the MCT Command Shell, click the open file icon. Open the mct file named “STBOX_PRELIM.mct”, which will populate the MCT Command Shell window with data. At the bottom left of the MCT Command Shell window click on the “Run” button. Then click on the “Close” button at the bottom right of the MCT Command Shell window.

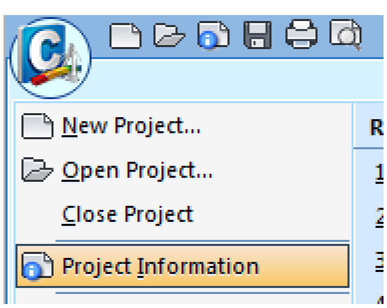


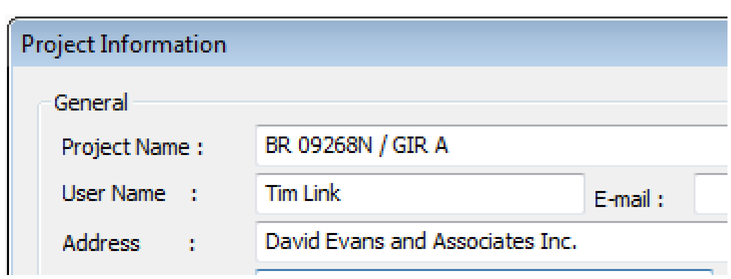
Within the Works Tree Menu there will now be a Material Property and Static Loads defined for the model. The MCT Command Shell will also define the system of units, structure type, load combinations, moving load code, moving load analysis control, structure and boundary groups, and report formatting.



11.3.2 Project Information

Update the project information with the bridge number, Engineer’s name, and company performing the load rating. In the top menu go to upper left hand corner Midas Icon => Project Information.





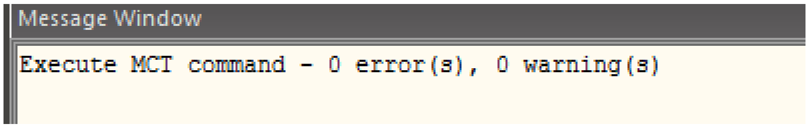
11.3.3 Properties

Ensure the input units are correct. No concrete material properties are required to be defined. Mild steel reinforcement does not need to be defined in Midas. Mild reinforcement will be directly entered into the Template.

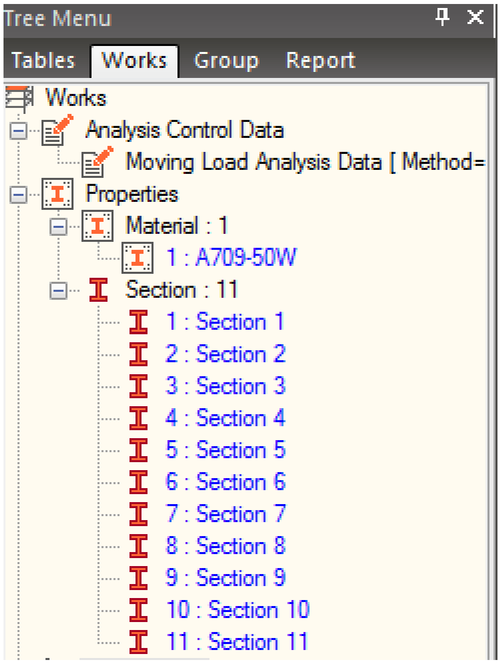
11.3.4 Sections

Tub and Box sections can be generated automatically using the MCT Command Shell text file created by the macros in the 'Midas Section Input' worksheet of the Template (refer to Section 11.4). Note tapered sections can be generated automatically as well The 'Midas Section Input' worksheet has no limit on how many general tub or box sections that can be defined, but only up to 10 tapered sections can be generated at a time. If more than 10 tapered sections need to be defined, the user must either create an additional MCT Command Shell section input text files using the "Create Midas Section Inputs File TAPERED ONLY" button or manually define the additional tapered sections within Midas.

The steps to manually define a tapered section are presented below. In Midas, run the newly generated MCT Command Shell text file named "Midas_Sections_SBG_Shell_Command_Text.mct". After running the file, check the Message Window for any errors or warnings. If there are any errors, scroll up in the Message Window and determine which section is causing the error then go back to 'Midas Section Input' worksheet in the Template and check your inputs. Since the deck self-weight will be applied as a superimposed load ensure that the density ratio Ds/Dc is set to zero in order to only apply the SW factor to the steel weight.



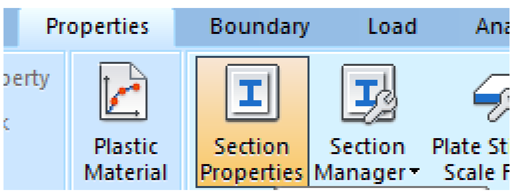
All defined sections should now appear in the Works Tree Menu.

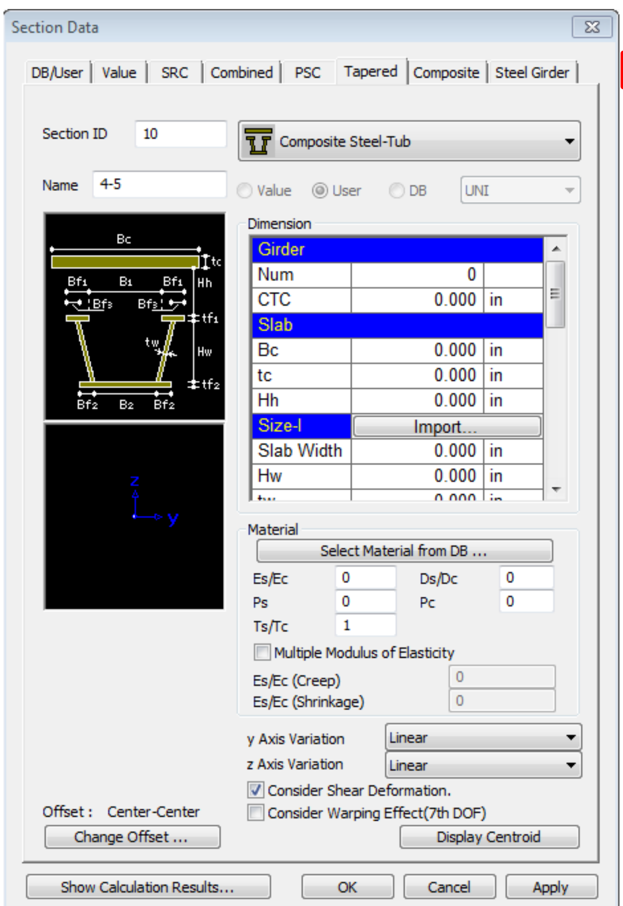


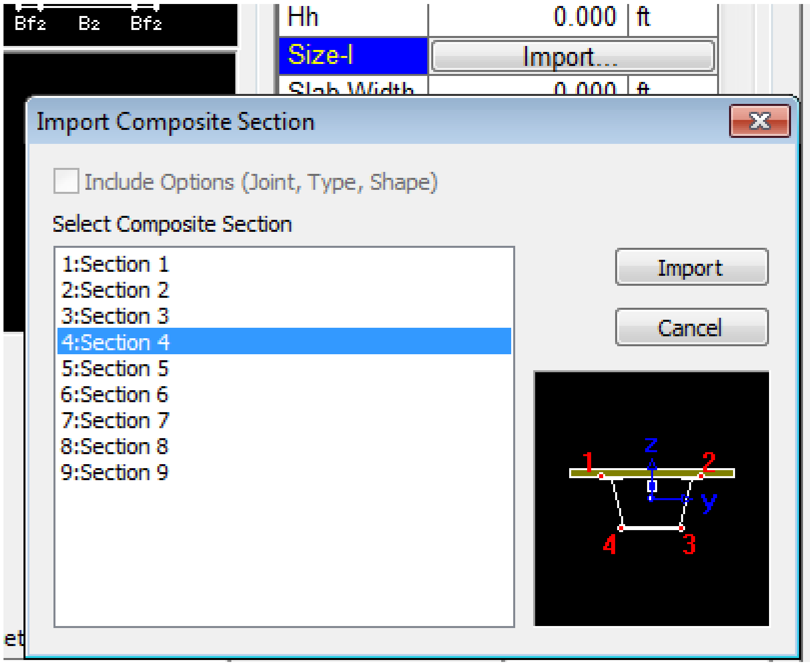
If additional tapered sections need to be defined follow the steps below.

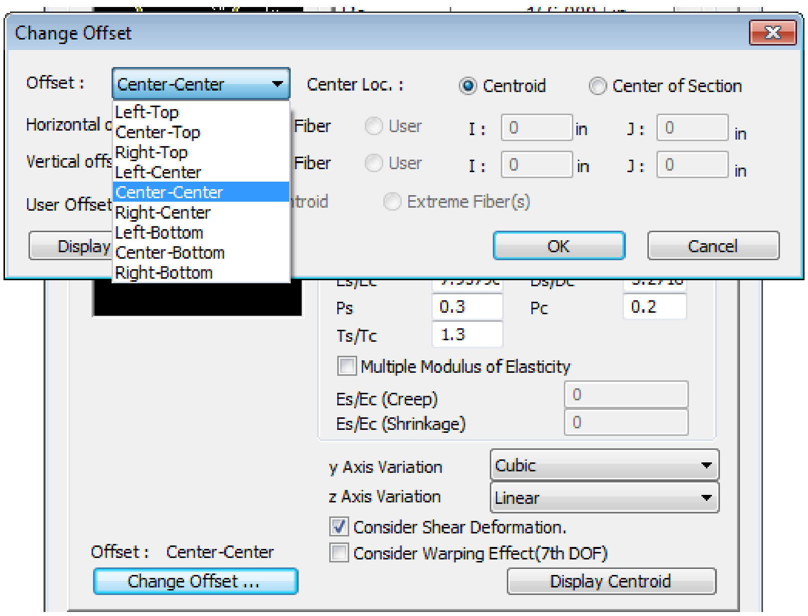
In the top menu go to Properties => Section Properties and click Add. Click on the “Tapered” tab on the top and in the first drop-down box select “Composite Steel-Tub” if the tapered section is a tub or “Composite Steel-Box” if the section is a closed box. Name the tapered section. For good recordkeeping, name the section i-j, where ‘i’ is the section number of ‘i’ end (start) of the tapered element and ‘j’ is the section number of the ‘j’ end (end) of the tapered element. Enter in the slab width (Bc) and thickness (tc) corresponding to the relevant sections. Note the haunch thickness (Hh) can be kept at zero since it does not affect the self-weight of the member and will have very little effect on force demands.

Click the “Import” button located to the right of “Size-I” and select the appropriate previously defined section for the i-end and click the “Import” button. Repeat for the “Size-J” to import the j-end of the tapered section. Next define the material properties inputs located towards the bottom of the dialog window. These values are located in the ‘Midas Section Input’ worksheet in the Template. Finally if the desired offset location is not at the center of the cross-section click the “Change Offset” button and select the desired offset location which needs to match the offset selected in ‘Midas Section Input’ worksheet.



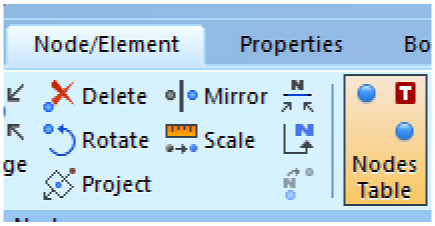



Import Composite Section
Include Options (Joint, Type, Shape)
Select Composite Section
1:Section 1
2:Section 2
3:Section 3
4:Section 4
5:Section 5
6:Section 6
7:Section 7
8:Section 8
9:Section 9
Import
Cancel

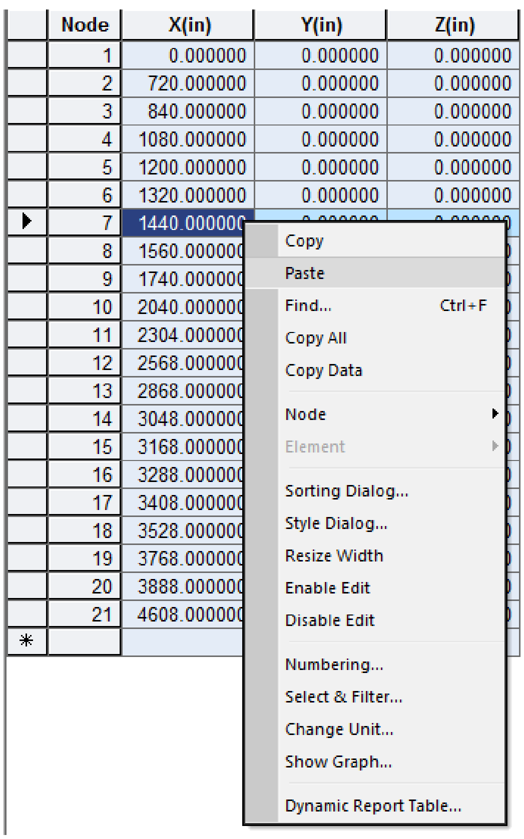

Change Offset
Offset :
Center-Center
Center Loc. :
Centroid
Center of Section
Left-Top
Center-Top
Right-Top
Left-Center
Center-Center
Right-Center
Left-Bottom
Center-Bottom
Right-Bottom
OK
Cancel
Ps 0.3
Pc 0.2
Ts/Tc 1.3
Multiple Modulus of Elasticity
Es/Ec (Creep)
Es/Ec (Shrinkage)
y Axis Variation Cubic
z Axis Variation Linear
Consider Shear Deformation.
Consider Warping Effect(7th DOF)
Offset : Center-Center
Change Offset ...
Display Centroid

11.3.5 Nodes

In the top menu go to Node/Element => Nodes Table to input the nodes coordinates.

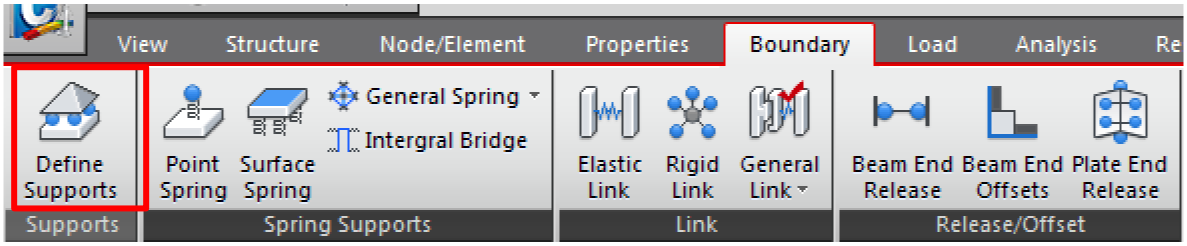


For straight girders node locations can either be manually typed into the 'X' column or copy and pasted from the 'GeometryCalcs' worksheet in the Template. For curved bridges, Y coordinates must also be entered. Note that the X coordinate of curved bridges will not directly correspond to the station values in the 'GeometryCalcs' worksheet. It is recommended to use CAD software to obtain the coordinates for the model based on the alignments defined in the plans and the appropriate offsets to the girder centerline. Note that depending on the chord length between analysis points additional nodes may need to be added to accurately model the curvature of the girder. A general rule of thumb is to not have any chord length exceed R/50, where R is the radius of the curve in feet.



11.3.6 Boundary Conditions

Under the top menu go to Boundary => Define Supports



1) Define the desired Boundary Group; fixed, pinned or roller.

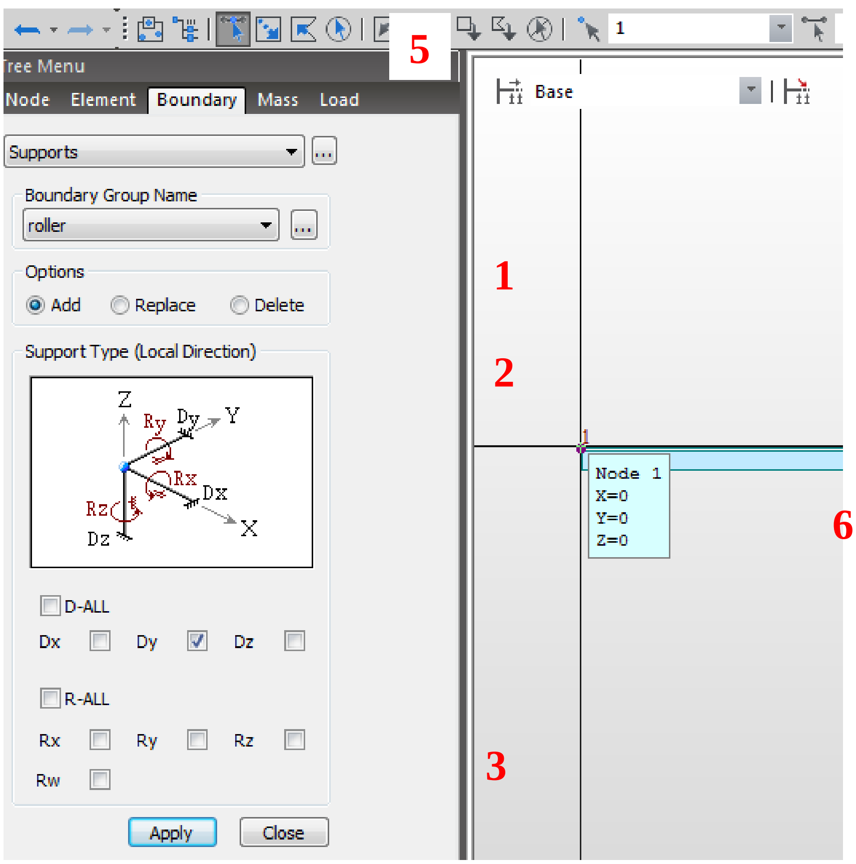
2) Select if this support is being added, replaced, or deleted from a node.

3) Select the translation restrained degrees of freedom. For a pinned support restrain Dx and Dz, for a roller support restrain Dz only. Note for curved bridges Dy may or may not need to be restrained depending on the bearing type.

4) Select the rotational restrained degrees of freedom.

5/6) Select the node that the support will be assigned to. This can be done in various ways. One option is to use the “Select Single” in the tool bar (Ctrl + Shift + S). Then click on the node point that the boundary will be assigned. When selected, the node should change to a red color. Note that this will also add the selected nodes to the selected boundary group.

7) Click Apply.

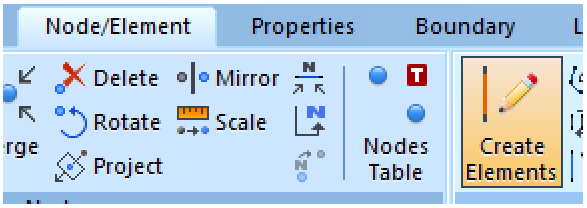


Continue until all boundaries are defined. 4

11.3.7 Elements

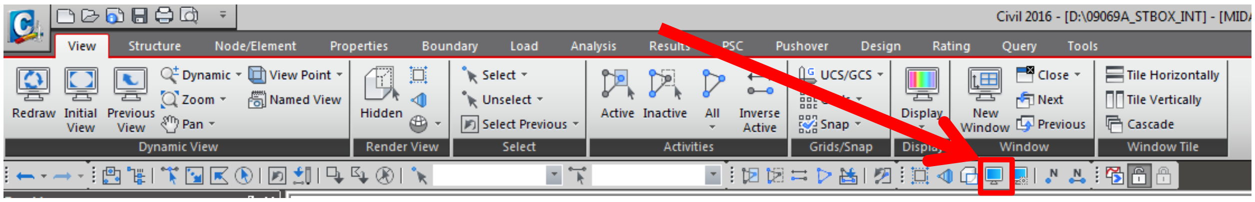
Save the file prior to proceeding with creating elements. If the number of joints per cross section on end (i) does not match the number on end (j), the model will crash and any unsaved data may be lost.

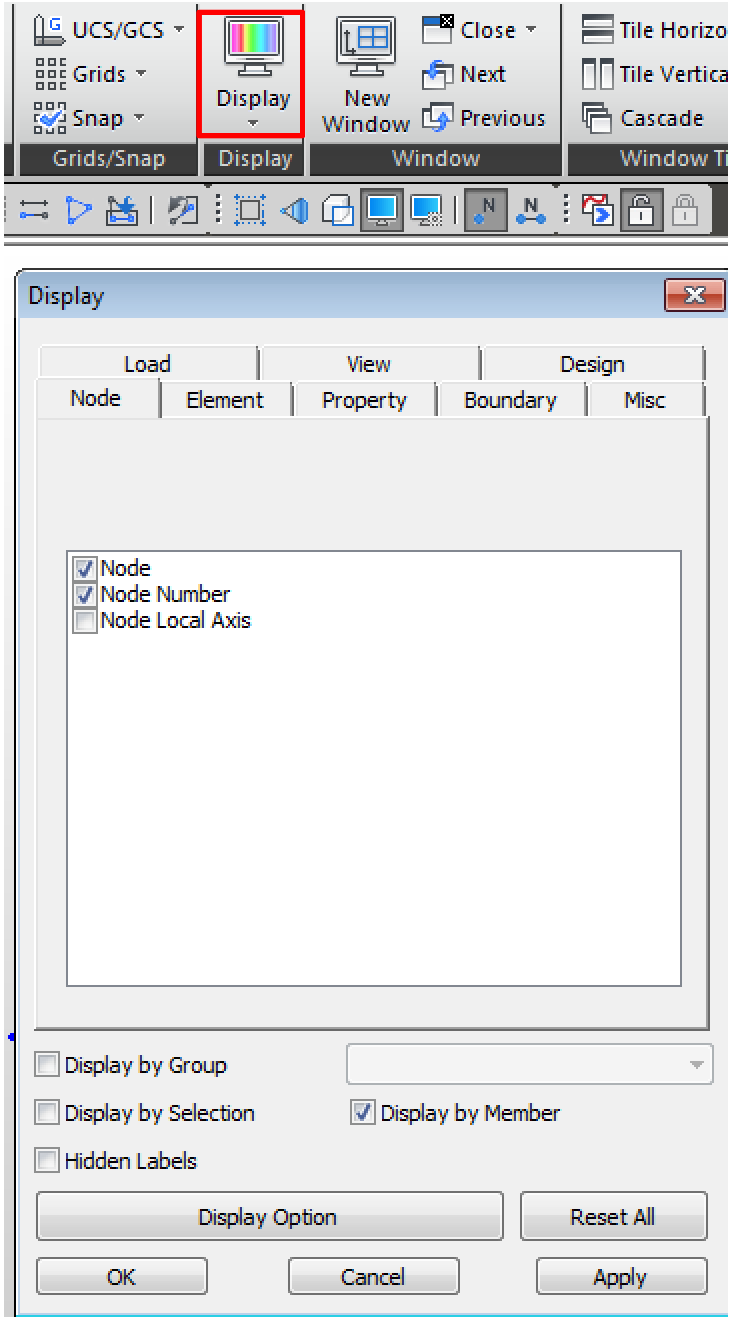
Under the top menu, go to Node/Elements => Create Elements.



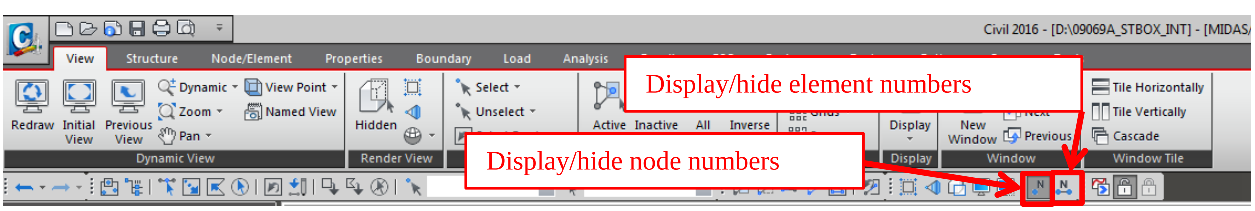
Select Hidden View (quick command Ctrl + h). This view will give a good graphical representation of the cross sections and will aid in checking the model. If the node point is not displayed on screen, go to View => Display to turn on the node display. It is also useful to also display the node number.

Within the Display options you can choose to show boundary conditions, element properties, and many other options. The Display dialog box can also be reached by simply clicking the desktop icon on the top tool bar as shown below.





Node and element numbers can quickly be displayed or removed by clicking the appropriate button on the top tool bar. The below screenshot shows where these buttons are located.



Due to software limitations it is important to align the local axes of the elements in the superstructure. When defining the model all the elements should be defined from the left to the right, resulting in each element having the (i) end at the left node and the (j) end at the right node. It is acceptable to switch this convention and define all of the elements from right to left. It is NOT acceptable to define some elements from left to right and others from right to left in the same model.

Update the Following:

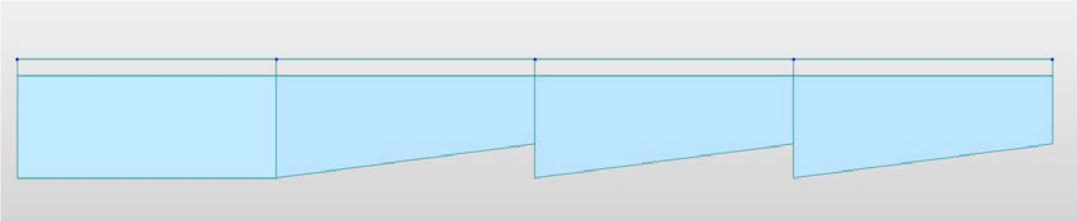
1) From the Node/Element tab in the ribbon, select Create Elements.

2) Select General beam/Tapered beam.

3) Select the Steel Material defined previously.

4) Select the appropriate cross section defined previously.

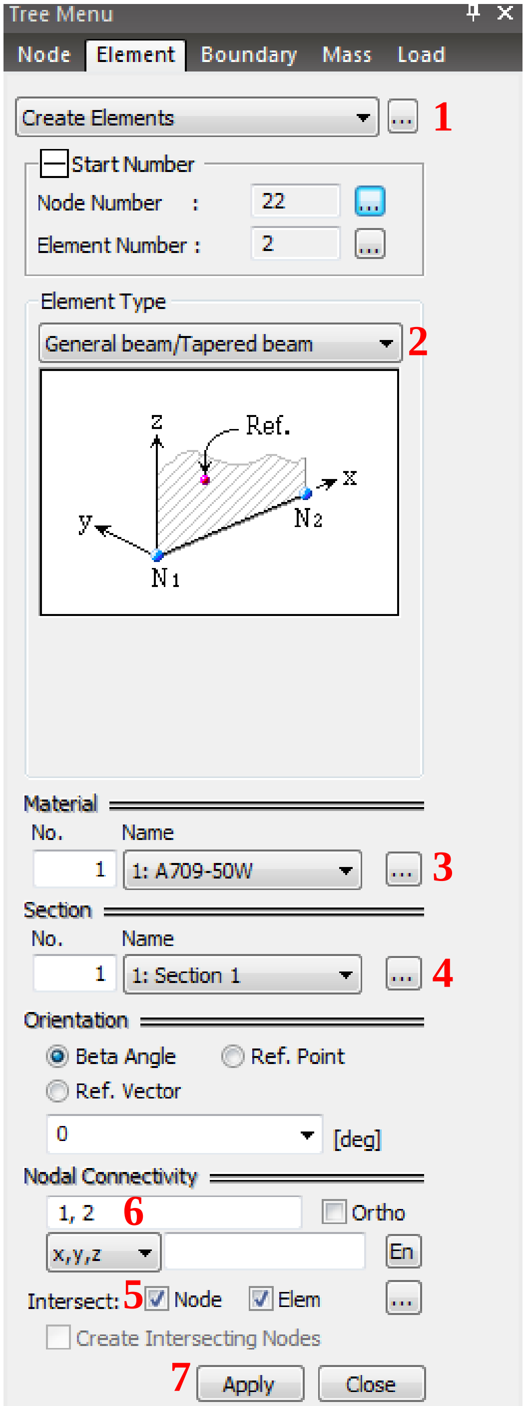
5) Select Intersect Node and Element. When tapered sections are used to define an element and the element is defined across several nodes, the model will have a sawtooth appearance. This is because as the element intersects nodes in the model, it will create additional elements each with the same section for the “i” end and the same section for the “j” end. For example, if the “i” end is section 1 and the “j” end is section 2 and the element begins at node 2 and goes to node 5. As seen below, a saw tooth appearance is created as the element intersects node 3 and 4. This is corrected later using the tapered section group command.

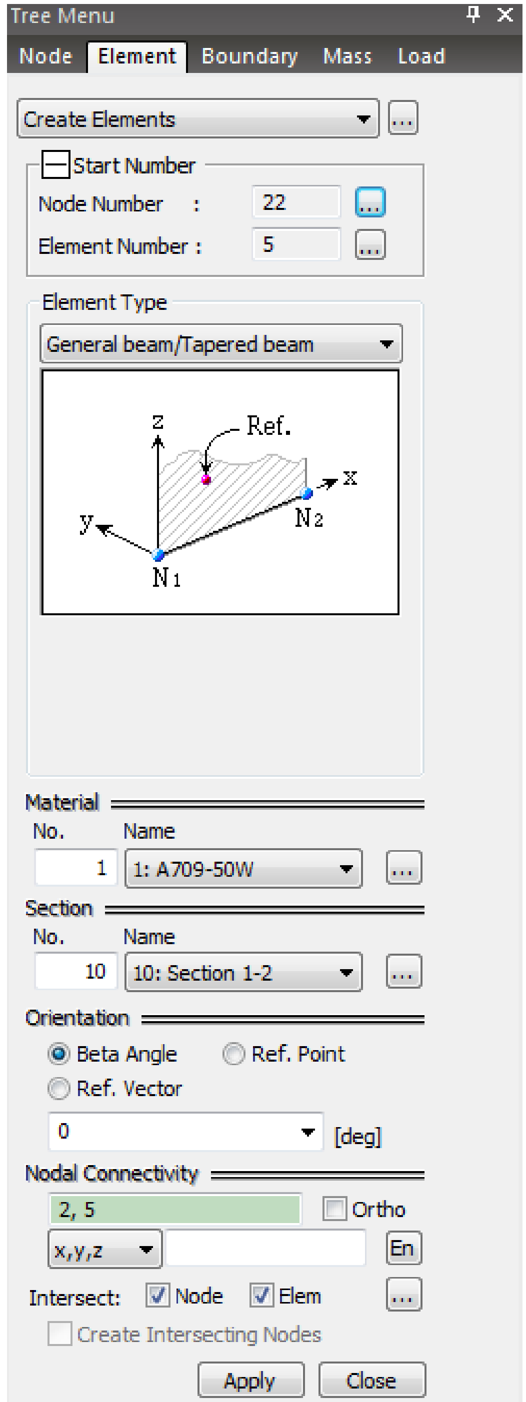


6) Input the beginning and ending node for the specified element. Note that you can also click in this box then click on the desired (i) node then (j) node in the model view.

7) Click Apply.

The figure on the left of the next page shows the above steps for defining an element that has section 1 defined at both the (i) and (j) end. The figure on the right of the next page shows the input for a tapered element, from node 2 to node 5, that has section 1 defined at end (i) and section 2 at end (j).





Continue until all of the elements have been created. Use the ‘GeometryCalcs’ worksheet to reference nodes to the appropriate cross sections. Make sure that element numbers match the values entered into the ‘GeometryCalcs’ worksheet.

11.3.8 Tapered Section Group

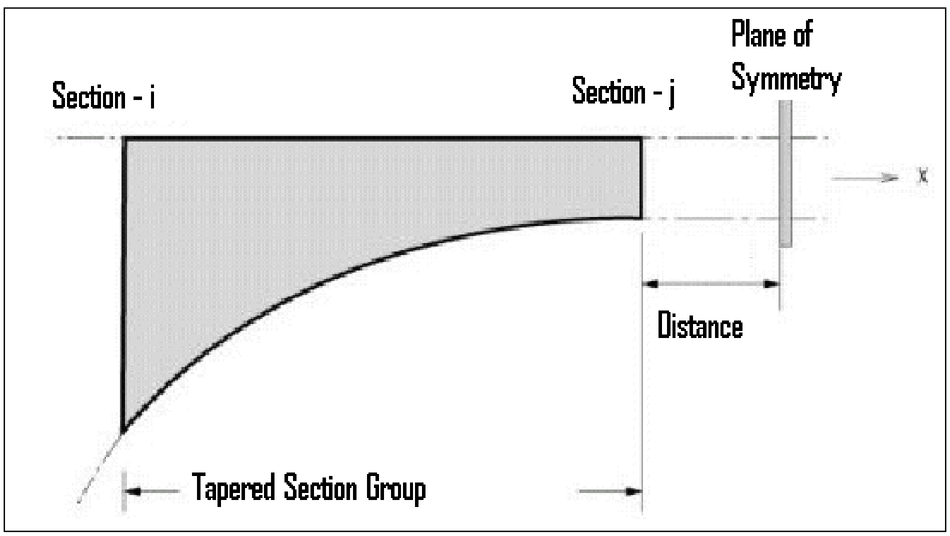
In the top menu go to Properties => Tapered Group. This command is used to taper a section across several elements. Both the y and z axis can be tapered independently and can be tapered as a linear or polynomial function.

1) Name the tapered section group. For example, “1 – 2” for a group that tapers from section 1 at the i end of the leftmost element to section 2 at the j end of the rightmost element.

2) Input all of the elements that are included in the group or select the elements in the model.

3) Select z-axis variation. For most parabolic structures select a second order polynomial.

4) If a polynomial is selected, the distance to the symmetric plane must be defined. The symmetric plane is the location that the polynomial has zero slope (commonly midspan). If the tapered section group extends to the plane of symmetry then the distance is zero. See below diagram.



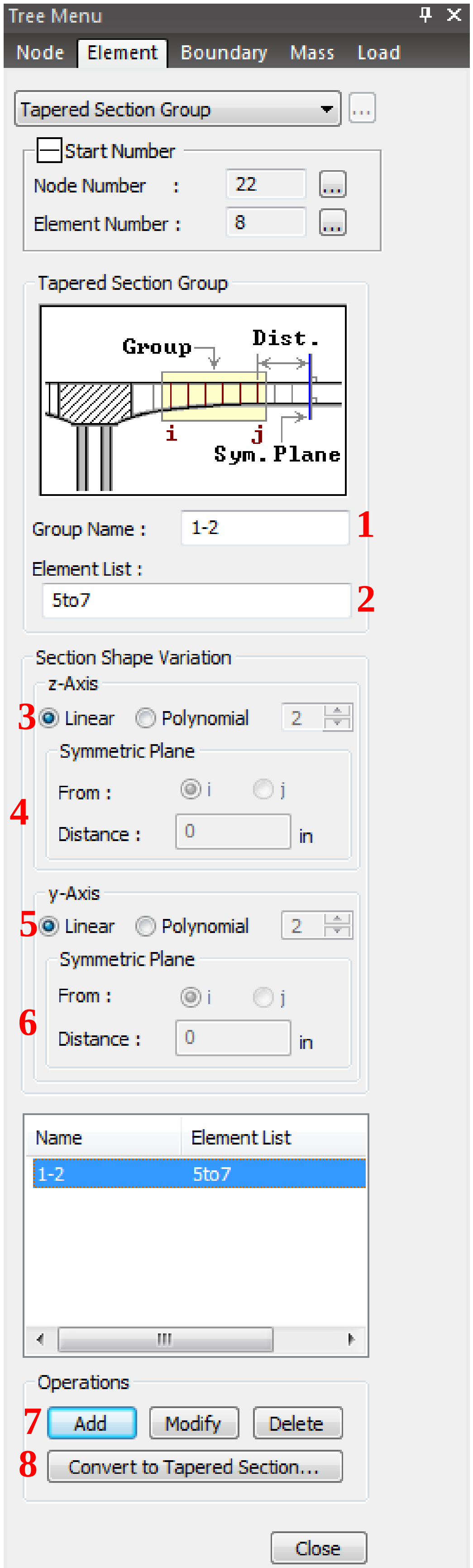
Note: Midas will vary all z-axis dimensions parabolically between sections. If the deck varies linearly and the overall structure depth varies parabolically, some error will be introduced as the deck is varied parabolically. This error in dead load is generally small.

5) Select y-axis variation. This variation is typically linear but can also be defined parabolically.

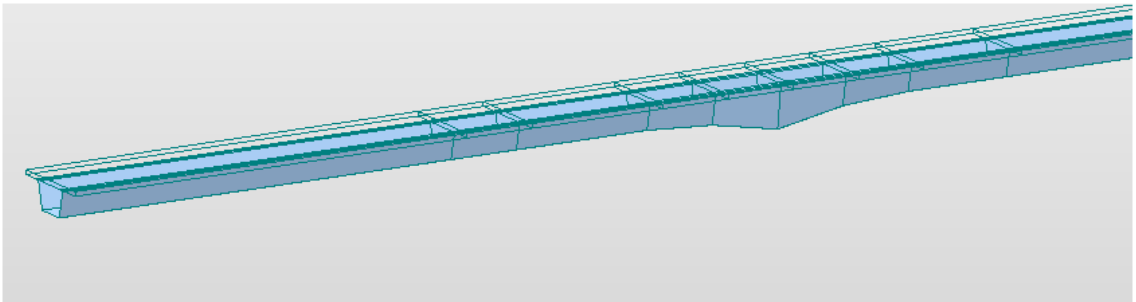
6) If a polynomial is selected, the distance to the symmetric plane must be defined.

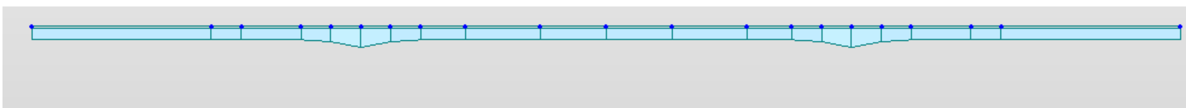
7) Click “Add” to create the tapered section group.

8) Click on “Convert to Tapered Section…” button. This will replace the tapered group with generated new tapered sections for each element that was in the tapered group. You can now view the newly created tapered section properties to obtain the ‘i’-end and ‘j’-end section dimensions, which need to be entered into nnnnn_STBox.xlsm spreadsheet to obtain the capacity at each node. These new section dimensions should also be documented in the Mathcad preliminary file.


Tree Menu
Node
Element
Boundary
Mass
Load
Tapered Section Group
Start Number
Node Number :
22
Element Number :
8
Tapered Section Group
Group
Dist.
i
j
Sym. Plane
Group Name :
1-2
1
Element List :
5to7
2
Section Shape Variation
z-Axis
3
Linear
Polynomial
2
Symmetric Plane
From :
i
j
4
Distance :
0
in
y-Axis
5
Linear
Polynomial
2
Symmetric Plane
From :
i
j
6
Distance :
0
in
Name
Element List
1-2
5to7
Operations
7
Add
Modify
Delete
8
Convert to Tapered Section...
Close

When done, a smooth three-dimensional structure should be displayed. Note that the STBOX_PRELIM.mct shell file sets a display option to display the section at the top center of the cross section. This is a good opportunity to visually check that the cross sections are input and assigned correctly. The model should be smooth without jumps from one section to the next. See below for a 3-Span with parabolic haunches at the interior bents.





11.3.9 Expansion Joints

If there are expansion joints you will need to use a Beam End Release to release the appropriate degrees of freedom at the given location. The steps below show how to apply a Beam End Release. Note that only one element end needs to be released at the node of interest, releasing the ends of both connecting elements at the node will cause analysis errors.

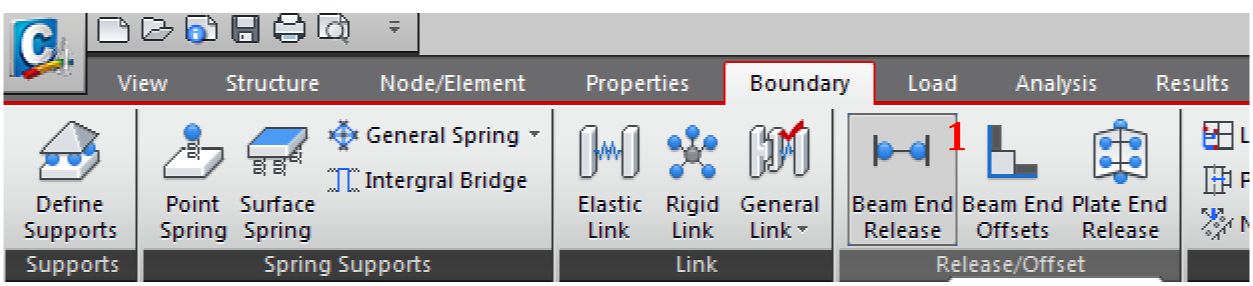
1) In the top ribbon menu under Boundary click on Beam End Release

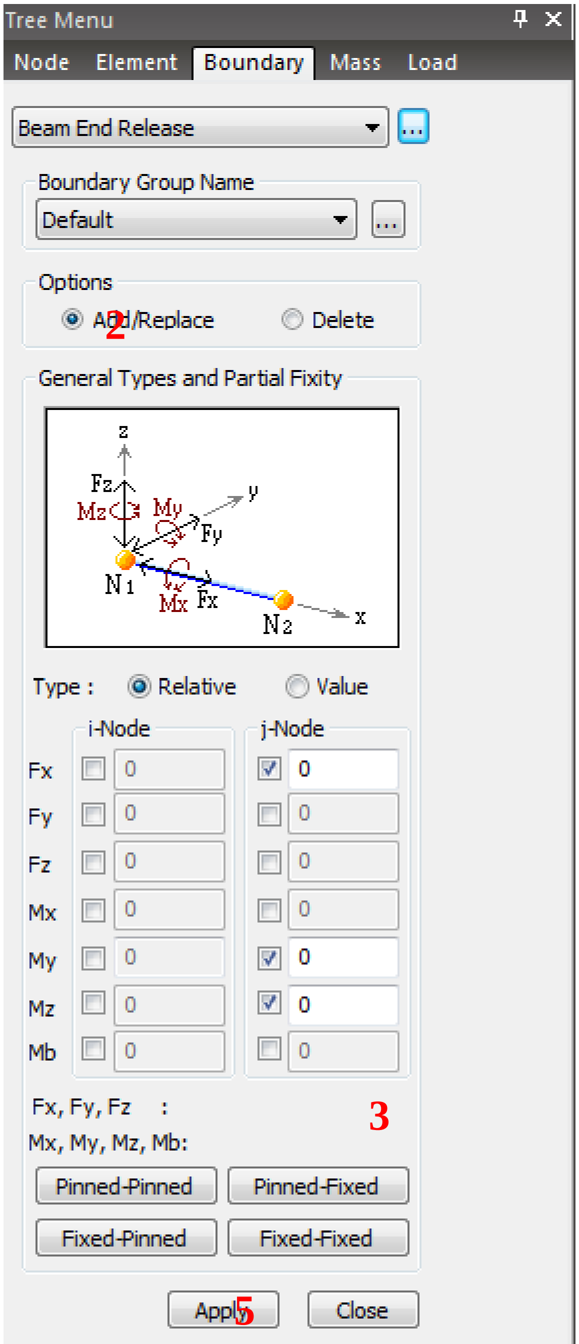
2) Select Add/Replace

3) Click the boxes of the degrees of freedom you wish to release at the appropriate end (note a box without a checkmark represents a fully fixed DOF)

4) Select the element in the model view

5) Click Apply.





11.3.10 Node Local Axis

When modeling a curved bridge, the node local axis must be adjusted at the supports and any other location where longitudinal and transverse reactions, forces, or displacements are needed. For straight bridges (constant "Y" coordinate for all nodes) the node local axis does not need to be adjusted. To adjust the local axis follow the below steps.

1) In the ribbon menu select Boundary and click on Node Local Axis
2) Select Add/Replace
3) Select 3 points Input option. If the angle of rotation about the vertical axis (z) is known from

either CAD or the bridge plans it can be entered directly using the “Angle” input method

4) Click in the P0 text box (will turn green from white) then click on the node in the model view that needs its local axis adjusted. Alternatively you can type in or paste the coordinates of this node

5) Click in the P1 text box and click on next node ahead on station from the node selected in step 4. Again alternatively you can type in or paste the coordinates of this node

6) Click in the P2 text box and type in an arbitrary coordinate that is to the left of the node when looking ahead on station

7) In the model select the node that was used in step 4. Note you can use Ctrl+Shift+S to use the select single tool.

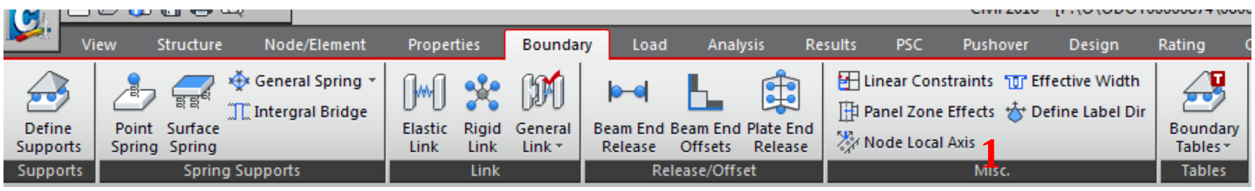
8) Click Apply

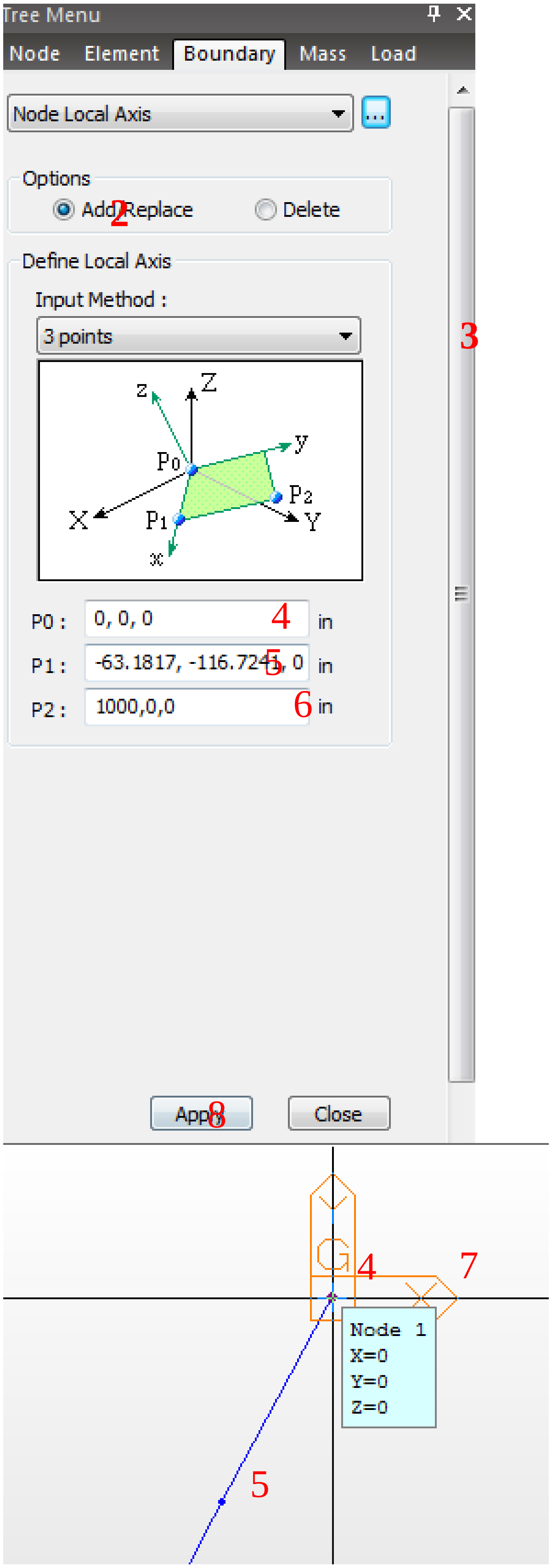
9) Click on the Display Options (Ctrl+E) and under Element click “Local Axis”

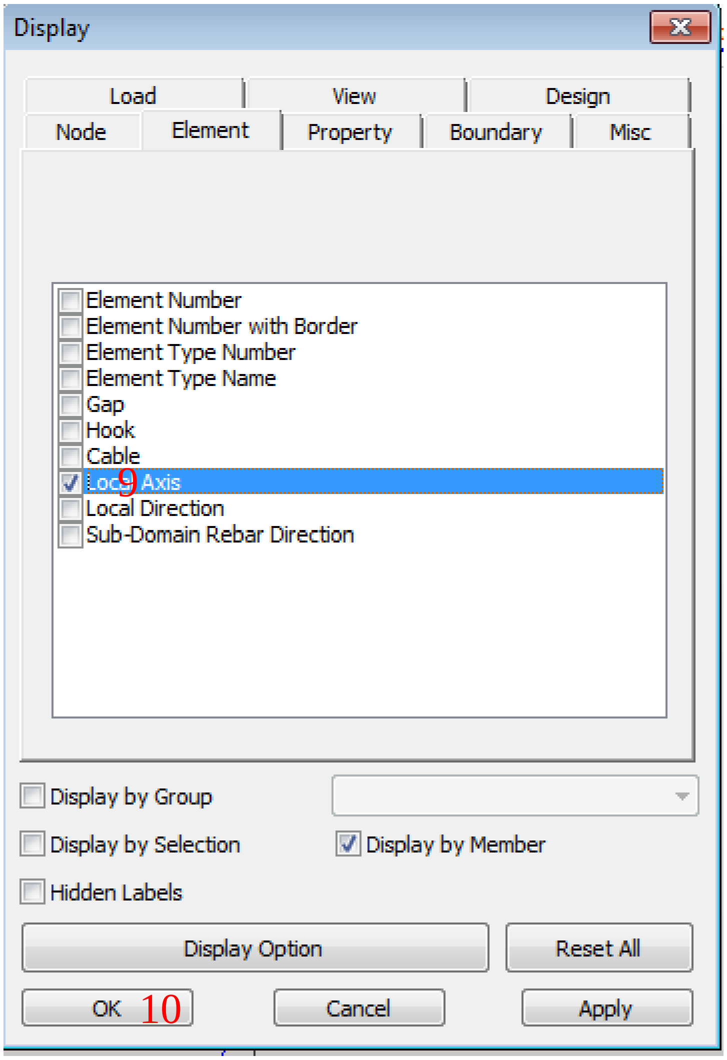
10) Click “OK”

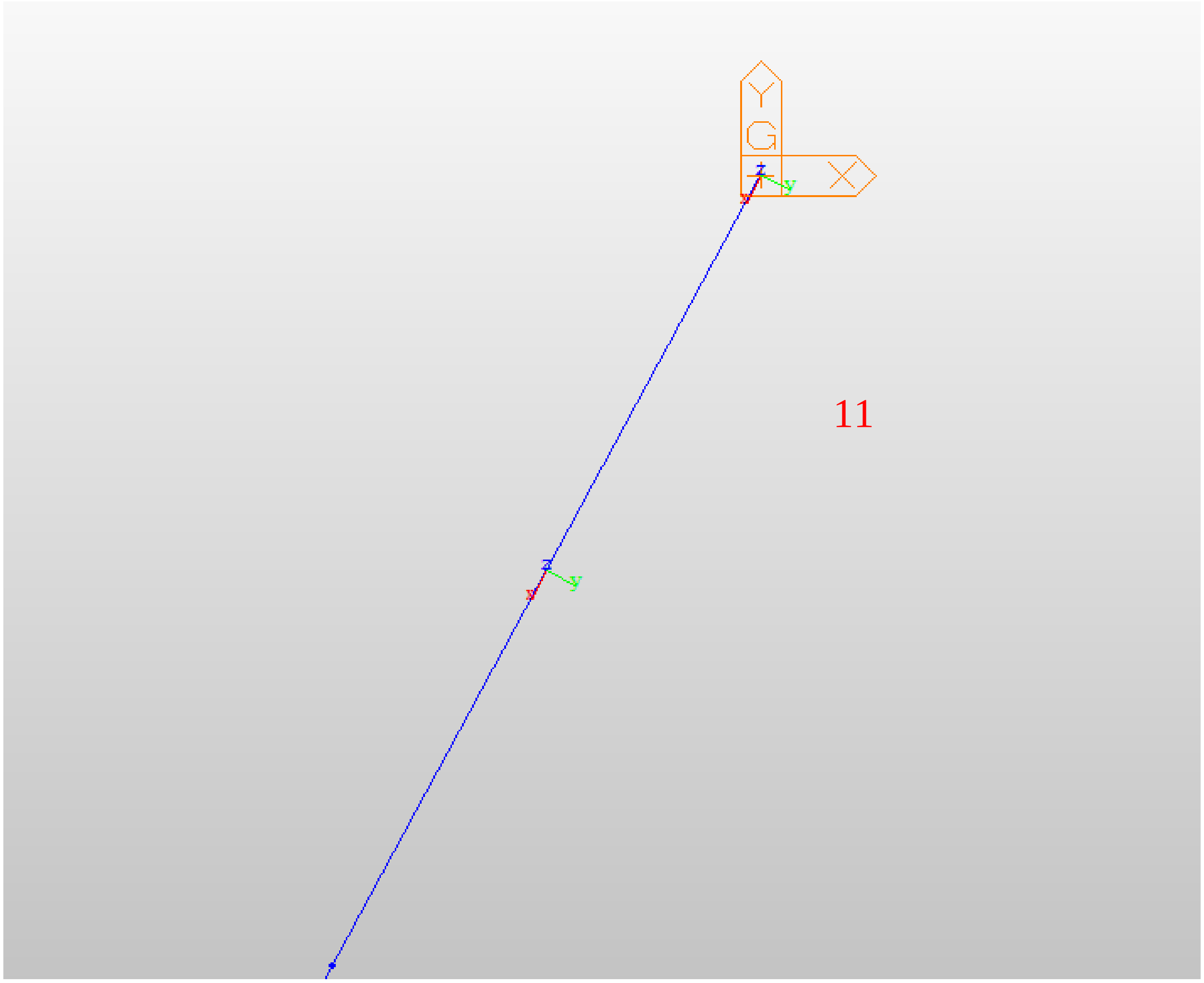
11) In the model view double check that the node local axis and element local axis between the P0 and P1 node match. If the Y axis is in the opposite direction adjust the coordinates in step 6 to be on the right side. Note the node local axis should automatically be shown after defining it, however if it does not you can repeat step 9 but go under the Node instead of Element.

12) Repeat steps 1 through 11 for all boundary nodes.




Tree Menu
Node
Element
Boundary
Mass
Load
Node Local Axis
Options
Add/Replace
Delete
2
Define Local Axis
Input Method :
3 points
3
P0 :
0, 0, 0
4
in
P1 :
-63.1817, -116.7241, 0
5
in
P2 :
1000,0,0
6
in
Apply
8
Close
4
7
Node 1
X=0
Y=0
Z=0
5


Display
Load
View
Design
Node
Element
Property
Boundary
Misc
Element Number
Element Number with Border
Element Type Number
Element Type Name
Gap
Hook
Cable
Local Axis
9
Local Direction
Sub-Domain Rebar Direction
Display by Group
Display by Selection
Display by Member
Hidden Labels
Display Option
Reset All
OK
10
Cancel
Apply



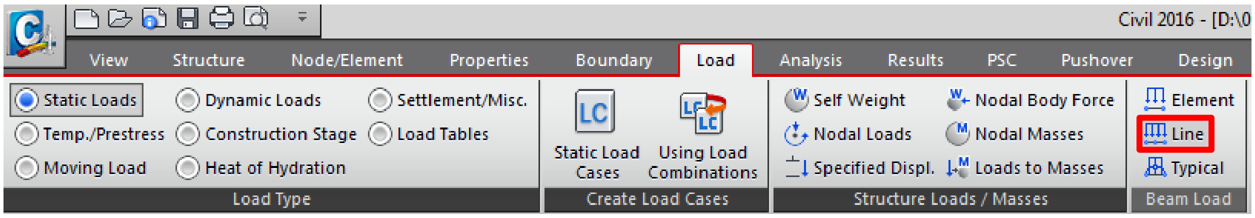
11.3.11 Static Loads

In general, four static load cases are defined: SW, DC1 Loads, DC2 Loads, and DW Loads. These load cases are predefined by the STBOX_PRELIM.mct MCT Command Shell. Not all load cases will be used for every bridge. Additional load cases can be defined as necessary. Note that if additional load cases are added, the default load combinations (DC1, DC2, DW) will have to be modified to include the additional load cases. Self-Weight (SW) includes only the steel box girder flanges and webs. The SW internally calculated loads are increased by a percentage defined in the preliminary file and applied in the load combinations. This self-weight factor can be used to account for the additional self-weight of stiffeners, connection/splice plates, bolts/rivets, and any other additional steel components. The DC1 Loads load case should include all loads applied to the non-composite girders. The selfweight of the concrete deck/top flange should be included in this load case. The DC2 Loads load case includes all superimposed loads after the deck/top flange has become composite with the steel section. The DW Loads load case should include all wearing surface and utilities loads.

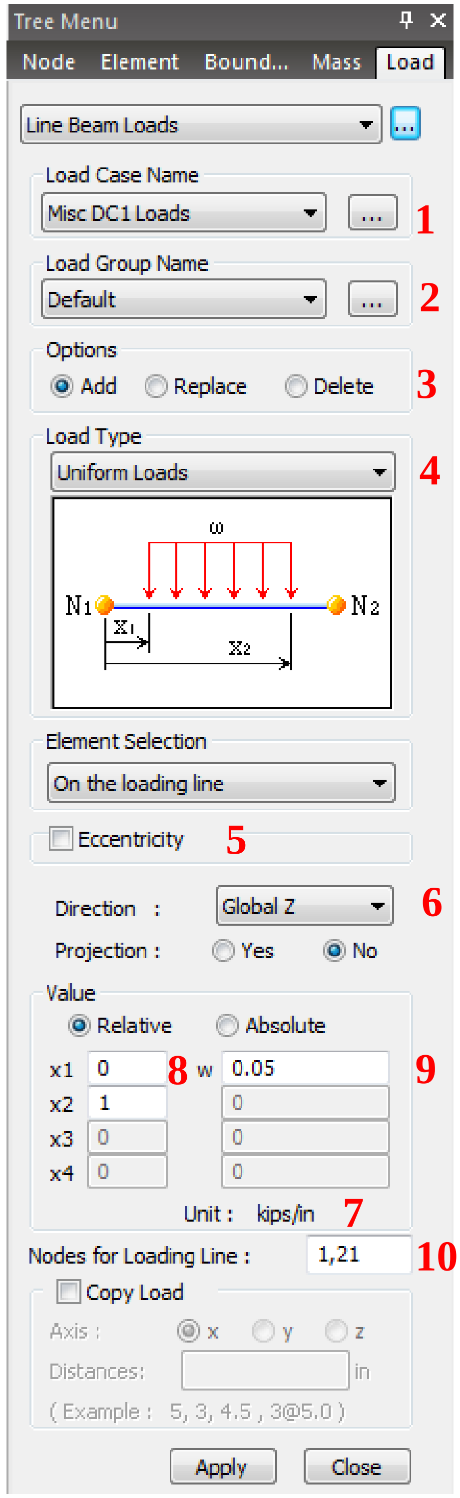
11.3.12 Distributed Loads

When modeling curved bridges it is recommend to use the Element Beam Loads rather than Line Beam Loads. Before using the Element Beam Load method it is recommended to create structure groups for each span to make the load definition more efficient. The Element Beam Load feature is very similar to the Line Beam Load feature described below except that you are picking elements to apply the loads to rather than picking two nodes to define a line.

Under the top menu go to Load => Line Beam Loads:



1) Select the appropriate Load Case Name.
2) Select the appropriate Load Group Name.
3) Select if this load is to be added to others, replace, or deleted. Typically Added is selected.
4) Select loading type.
5) Uncheck the Eccentricity box.
6) Gravity loads are applied in the Global Z direction.
7) Check the input units.
8) Input the location of the loads being defined. Location is input as a span fraction. For uniform loads input the range.
9) Input the magnitude of the load. Negative is in the downward sense.
10) Input the first and last node separated by a comma. This allows for distance to be input as a span fraction in step 8.
11) Click Apply.



Continue until all static distributed loads are defined.

11.3.12.1 Point Loads

Point loads can be defined by Line Beam Loads or by using Nodal Loads for point loads located at a defined node. The below steps show how to define point loads using the Line Beam Load method. Using the Nodal Loads method is not described in this manual but can also be used.

1) Select the appropriate Load Case Name.

2) Select the appropriate Load Group Name.

3) Select if this load is to be added to others, replace, or deleted.

4) Select loading type.

5) Uncheck the Eccentricity box.

6) Gravity loads are applied in the Global Z direction.

7) Check the Input units.

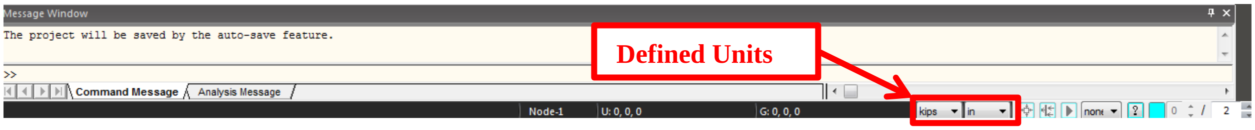
8) Select the location type, Relative or Absolute. Use Relative if you want to specify the point load location by span fraction. Use Absolute if you want to specify the point load location by the actual distance measured from the specified starting node defined in step 11.

9) Input the location of the loads being defined. Location is input as a span fraction if Relative was selected in step 8. Location is input as actual distance if Absolute was selected in step 8. If using Absolute, the distance is measured from the first node defined in step 11. Make sure to check the length units located in the bottom right corner of the screen.

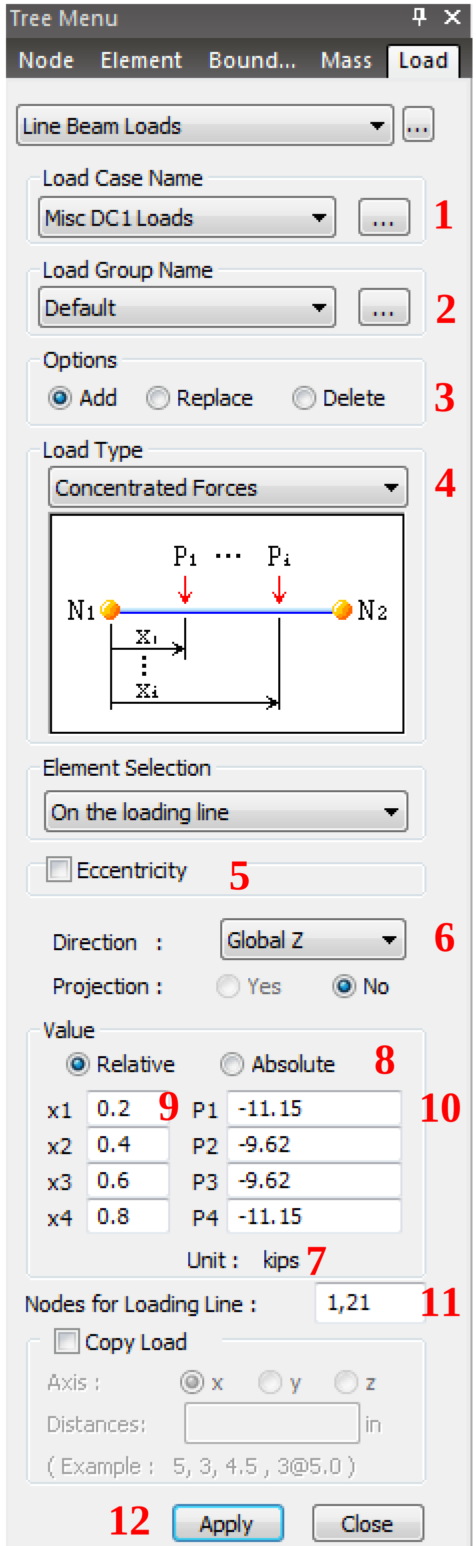
10) Input the magnitude of the load. Negative is in the downward sense.

11) Input the first and last node separated by a comma. This allows for distance to be input as a span fraction in step 9 if Relative was selected in step 8. If using the Absolute location (actual distance), select the first node as the node from which the absolute distance is measured.

12) Click Apply.

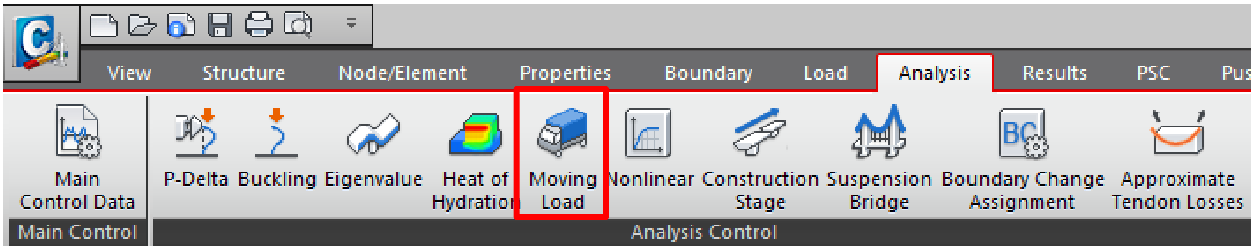


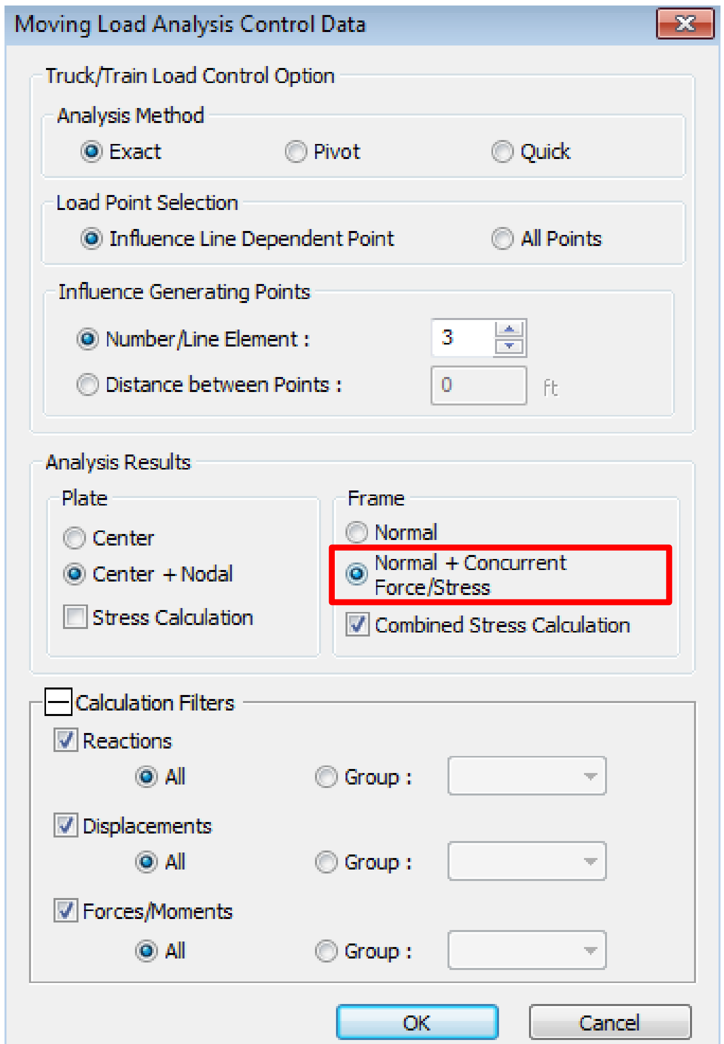
Continue until all static point loads are defined.


Tree Menu
Node
Element
Bound...
Mass
Load
Line Beam Loads
Load Case Name
Misc DC1 Loads
1
Load Group Name
Default
2
Options
Add
Replace
Delete
3
Load Type
Concentrated Forces
4
P1
Pi
N1
N2
X1
Xi
Element Selection
On the loading line
Eccentricity
5
Direction :
Global Z
6
Projection :
Yes
No
Value
Relative
Absolute
8
x1
0.2
9
P1
-11.15
10
x2
0.4
P2
-9.62
x3
0.6
P3
-9.62
x4
0.8
P4
-11.15
Unit :
kips
7
Nodes for Loading Line :
1,21
11
Copy Load
Axis :
x
y
z
Distances:
in
(Example : 5, 3, 4.5 , 3@5.0)
12
Apply
Close

11.3.13 Live Loads

The STBOX_PRELIM.mct file sets the frame analysis result option and defines the moving load code. The following steps show how to do both items within Midas. In the top menu, go to Analysis > Moving Load, make sure “Normal + Concurrent Force/Stress” under Frame Analysis Results is selected.

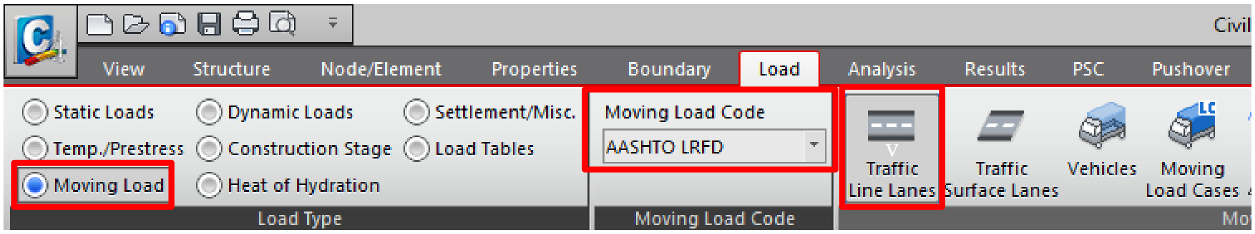




Design, Legal, STP, and CTP trucks are defined in the MCT template file. This step is performed later in section 11.3.15. In addition to the vehicles, one vehicle class is defined. The HL-93 vehicle class includes the HL-93 Tandem and HL-93 Truck. These trucks and class do not need to be altered.

NOTE: Impact factor (of 33%) for design vehicles are included in the Midas truck definition. Legal and permit vehicle impact factors are applied in the nnnnn_STBox.xlsm file.

Define the moving load code for analysis. In the top menu go to Load => Moving Load => Moving Load Code… Select “AASHTO LRFD” from the dropdown menu and click “Traffic Line Lanes”.

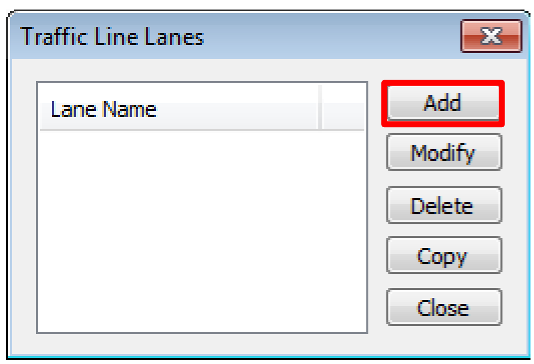


11.3.14 Traffic Line Lane

Only one traffic lane, defined along CL of girder, needs to be assigned. The live load distribution factor accounts for the presence of multiple lanes.

For the case where live load distribution factors are not applicable…

Under the Traffic Line Lanes window, click “Add”.



1) Name the traffic line lane “Lane”. The moving load cases that will be imported later require that the lane name is “Lane”. Otherwise, an error will be reported when the moving load cases are imported into the file.

2) Set eccentricity to 0.0in.

3) Set Wheel Spacing to 72in.

4) Select Lane Element for Vehicular Load Distribution.

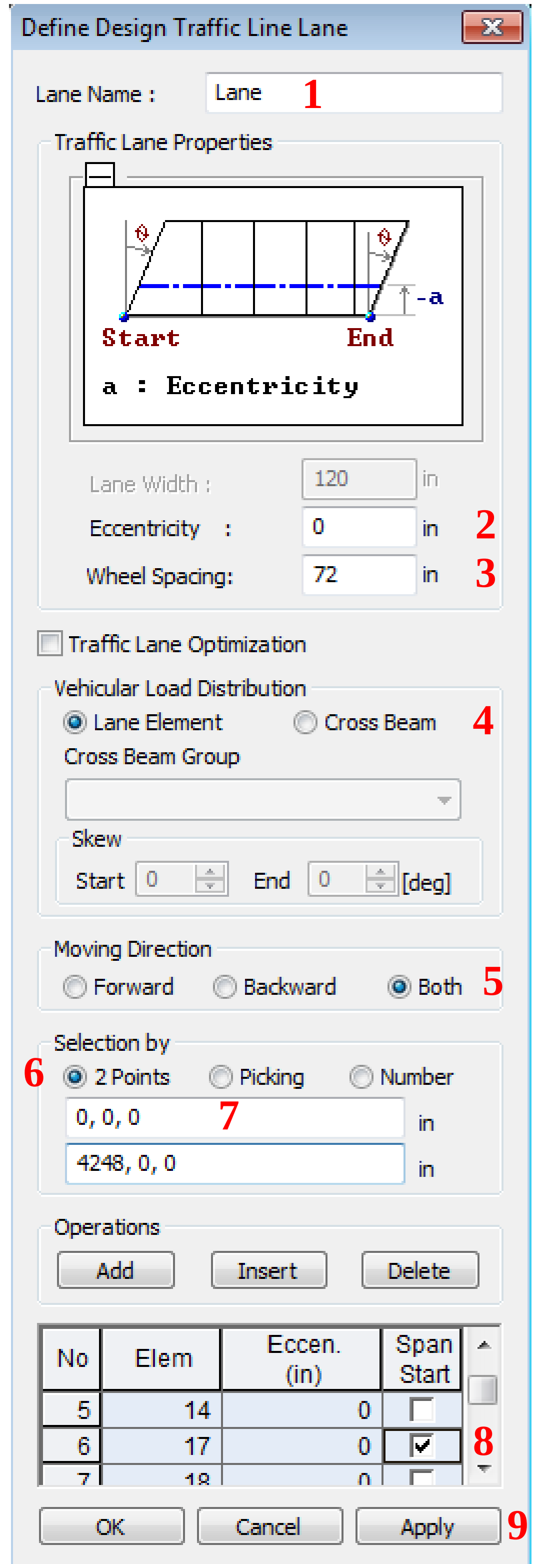
5) Select Both for Moving Direction.

6) Selection by 2 Points. Note if modeling a curved bridge it may be quicker to use the Selection by Number instead of by 2 Points since each chord element will have to be defined separately. For the Selection by Number option simply type “StoL”, where S is smallest element number which should also be the first element at the start of the bridge and L is the largest element number

7) In the model view pick the two points that will define the traffic lane, typically the first and last node. This should populate the table showing the selected elements and the eccentricity.

8) For multi-span continuous bridges; check the "Span Start" box for the first element in each span.

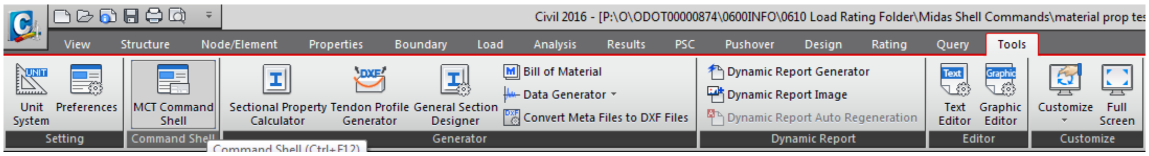
9) Click Apply.



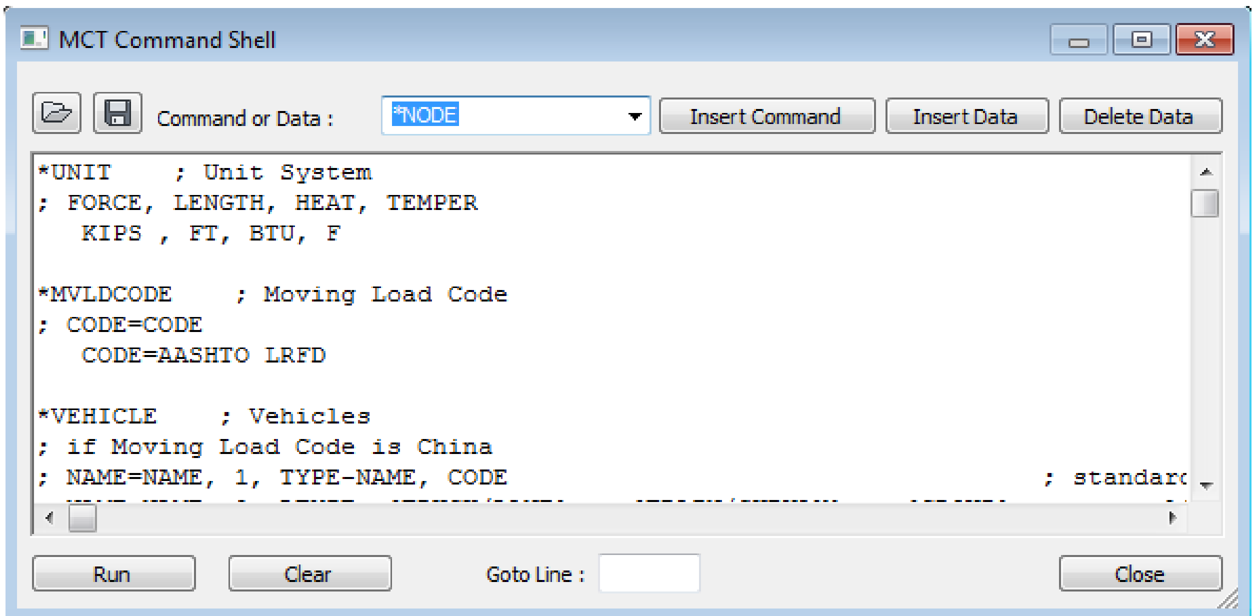
9

11.3.15 Vehicles and Moving Load Cases

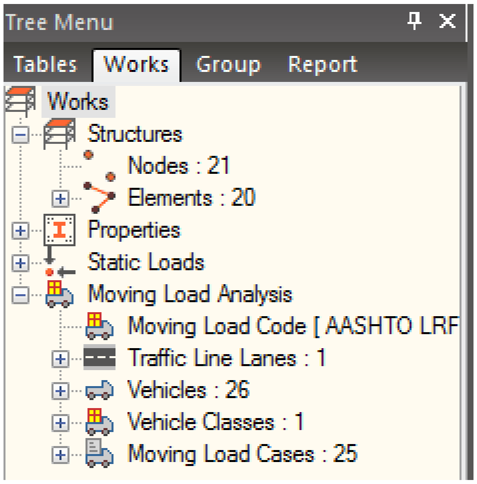
The vehicle definitions and moving load cases are already defined in a MCT command file that can be imported after the lane line has been defined in the Midas model. In the top menu, go to Tools > MCT Command Shell.



Within the MCT Command Shell, click the open file icon. Open the MCT command file named “STBOX_LR_Vehicles.mct”, which will populate the MCT Command Shell window with data. At the bottom left of the MCT Command Shell window click on the “Run” button. Then click on the “Close” button at the bottom right of the MCT Command Shell window.



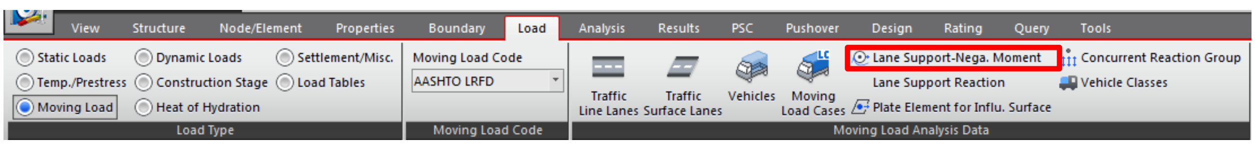
Within the Works Tree Menu there will now be 26 different vehicles, one vehicle class, and 25 different Moving Load Cases defined for the model.



11.3.16 Lane Supports (Spans Continuous for Live Loads)

When performing a multi-span analysis that is continuous for live loads, the lane support negative moment, and lane support reactions at interior piers must be activated. This feature will automatically perform the pattern loading, per AASHTO LRFD, to determine the maximum negative moment and reaction at interior supports.

Under the top menu go to Load => Moving Load => Lane Support – Nega. Moments.



1) Select Lane Supports (Negative Moments at Interior Piers)

2) Select the structure group that includes the girders. See Section 11.3.17 for additional information on structure groups.

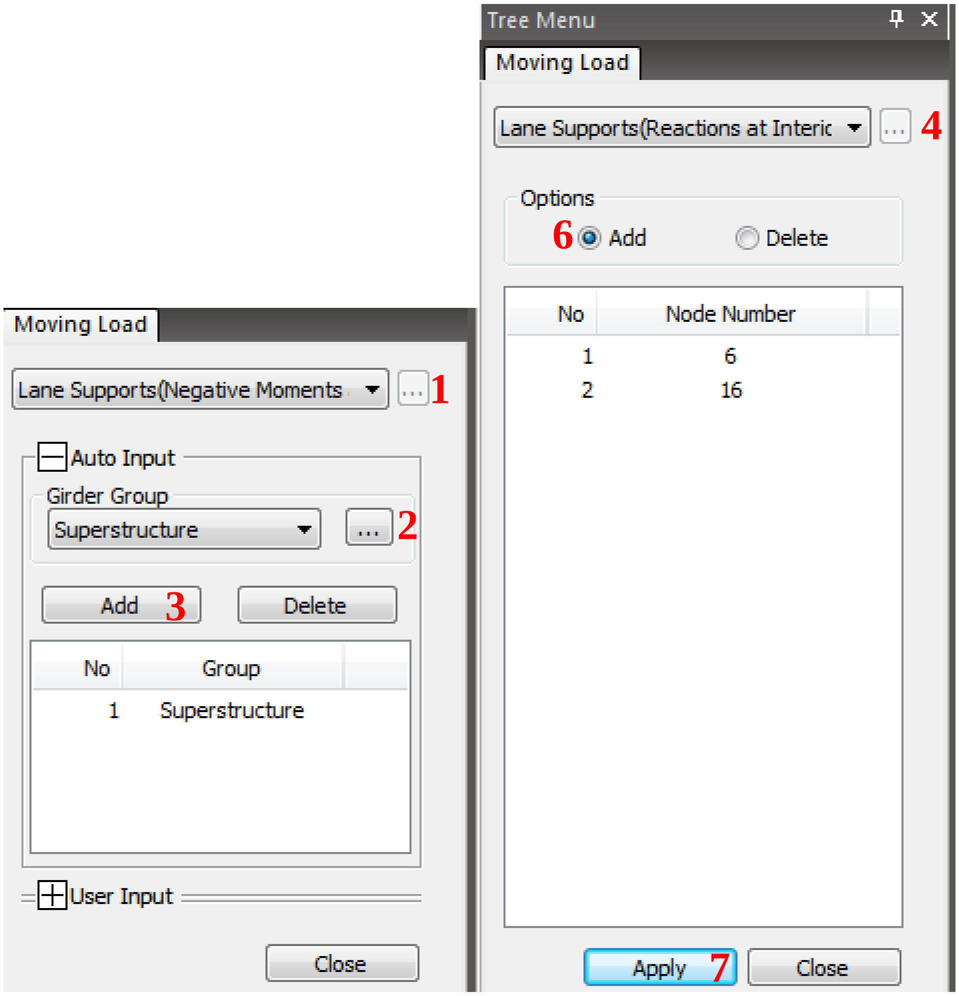
3) Select Add.

4) Select Lane Supports (Reactions at Interior Piers)

5) In the Model View, select the interior nodes where maximum reactions are sought. A support must be defined at this location. Note use the Ctrl+Shift+S shortcut to activate the single select option to select the appropriate node(s) in the model view.

6) Select Add

7) Click Apply.



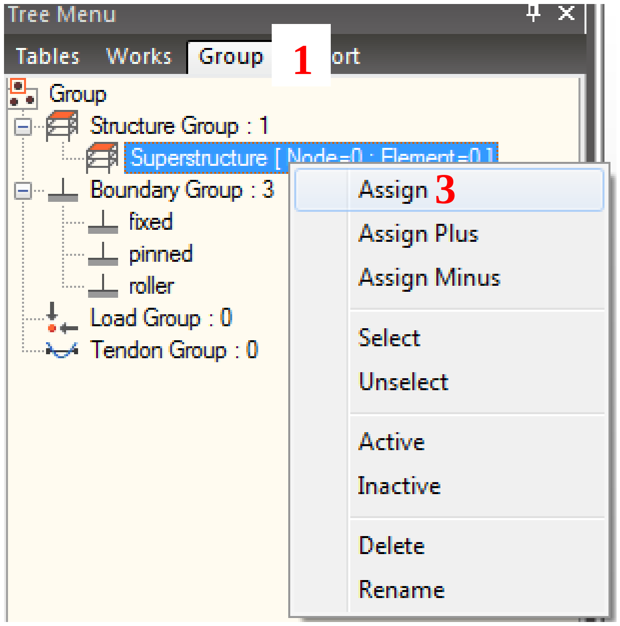
11.3.17 Structure Group

Structure groups are used for the Lane Supports mentioned in section 11.3.16 to perform a multi-span analysis that is continuous for live loads. For the analysis to perform correctly, all nodes and elements must be assigned to a structure group. Superstructure group is defined by default. For a simple span analysis, it isn't necessary to assign any elements or nodes to the superstructure group.

1) In the Tree Menu, Select the Group tab.

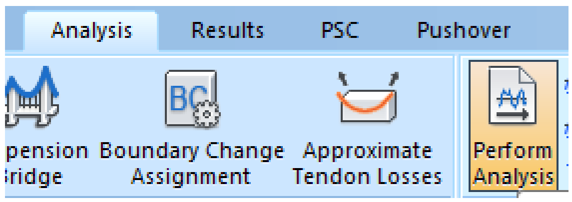
2) Select all of the nodes and elements that will be assigned to the structure group. There are several ways to accomplish this. To select all the nodes and elements the Midas quick command for select all is (Ctrl + Shift + A). Individual elements and nodes can be selected with the Select Single command (Ctrl + Shift + S). Once selected the nodes and elements will appear highlighted in red in the Model View.

3) Right click on the desired structure group (Superstructure is the default structure group) and then left click on Assign.



11.3.18 Perform Midas Analysis and Review Results

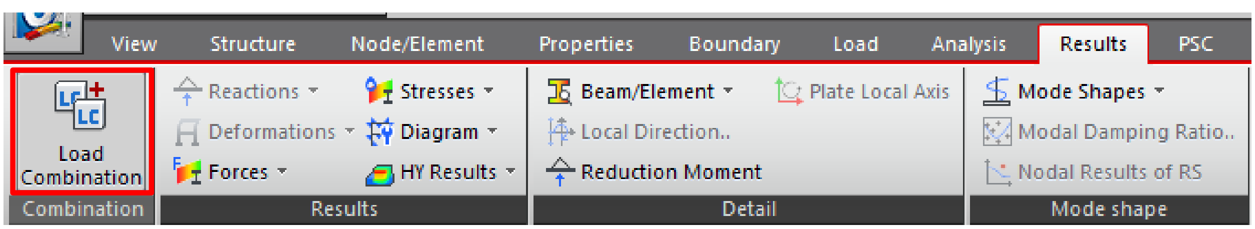
Perform the analysis by going in the top menu to Analysis => Perform Analysis.



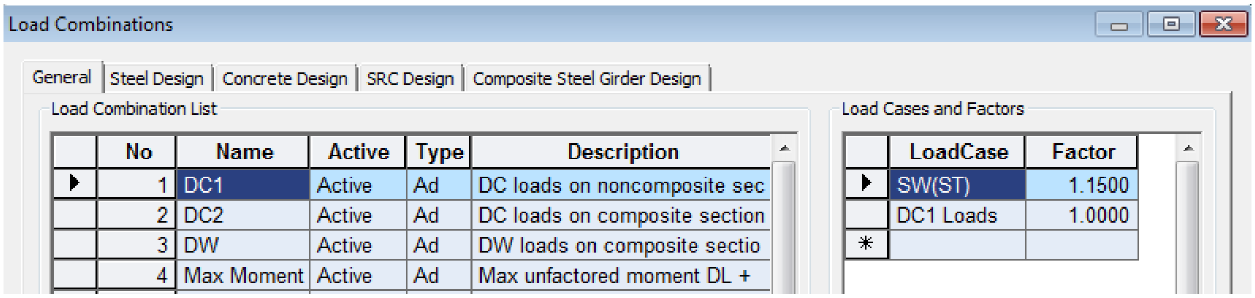
11.3.19 Load Combinations

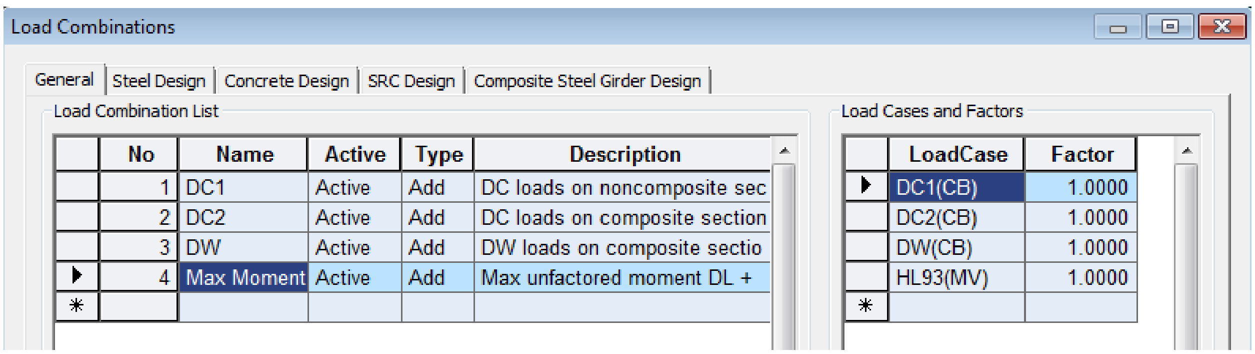
Four load combinations need to be defined for the post-analysis spreadsheet nnnnn_STBox.xlsm. The four combinations are DC1, DC2, DW, and Max Moment. The DC1, DC2, and DW load combinations are automatically generated by the STBOX_PRELIM.mct file. The Max Moment load combination is automatically generated by the STBOX_LR_Vehicles.mct file. All of the following load factors will be 1.0 as load factors are applied in nnnnn_STBox.xlsm except for self-weight (SW), as described below.

In the top menu go to Results => Load Combination.



The command shell applies the default 1.15 (15%) factor to the self-weight (SW) load case. This coefficient may be modified as needed. If any additional load cases were created make sure to add them to the appropriate load combination. Note that all applied loads must be included in either the DC1, DC2, or DW load combinations and the names can't be changed, otherwise the Template will not include them in the rating factor analysis.





11.3.20 Review Results

Review the results for accuracy. Reactions, Deformations, Forces, and Stress are readily outputed by going to the top menu under Results => Forces => Beam Forces/Moments. This will bring up a Tree Menu where Reactions, Deformations, Forces and Stresses can be viewed. Change the Load Cases/Combinations until all are verified.

To confirm the maximum positive moment locations, follow the below steps. Note that these steps represent an approximate method in determining the maximum moment location. The approximate method only evaluates the moment at each elements quarter points. The Beam Detailed Analysis feature can be used to determine the exact location of the maximum moment along an element. However to include the live load demand in the Beam Detailed Analysis the moving live load cases need to be converted into a static load case.

The below steps should be repeated for each span being analyzed where the maximum positive moment location needs to be confirmed. It is recommended to repeat these steps when a new node is added at the determined maximum moment location or when an existing node is moved to the maximum moment location to confirm the location has not changed.

1) In the Tree Menu click on the Group Menu

2) Right click on Structure Group then click on New then name the new structure group to identify the span

3) In the model view select all the nodes and elements of the desired span. This can be done by using the Select by Window option or the Select Single (Crtl+Shift+S)

4) Right click on the structure group created in step 2 and click Assign. This will assign the selected elements and nodes to this structure group. Note this is a convenient time to repeat steps 2 through 4 for each span which the maximum positive moment location needs to be

confirmed

5) Right click on the same structure group and click Active. This will make only the desired span active in the model and remove the rest of the nodes and elements from the model view. Note to make the entire model active again go to the top menu => View => All. However you will only want the span of interest active for the following steps

6) Go to the top menu under Results => Forces => Beam Diagrams

7) Under the Load Cases/Combinations select CBmax: Max Moment

8) Under Components select My

9) Under Type of Display select Contour, Values, and Legend

10) Under Output Section Location select Abs Max and By Member

11) Click Apply

12) In the model view look at the bottom right hand corner in the legend to determine which element of the selected span has the maximum positive moment

13) Hover over the center of the element determined to have the maximum positive moment from step 12; this will show a window displaying the maximum moment at quarter points along the element. Note it is convenient to have the element numbers displayed for this step. If either the I or J end value is the largest then there already exists a node at the maximum positive moment location for this span. If this is the case go back to step 1 and repeat the steps until all spans of interest have been completed. If the maximum value is at either ¼, CNT (½), or ¾ document the location where the value is maximum and continue to the next step

14) If the existing max positive moment location is not at the I-end or J-end node of the element and not representing a geometry change point, transverse stiffener change point, or another analysis point other than maximum positive moment simply adjust the existing node coordinate in the Nodes Table and rerun the analysis and repeat the above steps to confirm the maximum moment location has not changed. If these conditions are not true continue to the next step

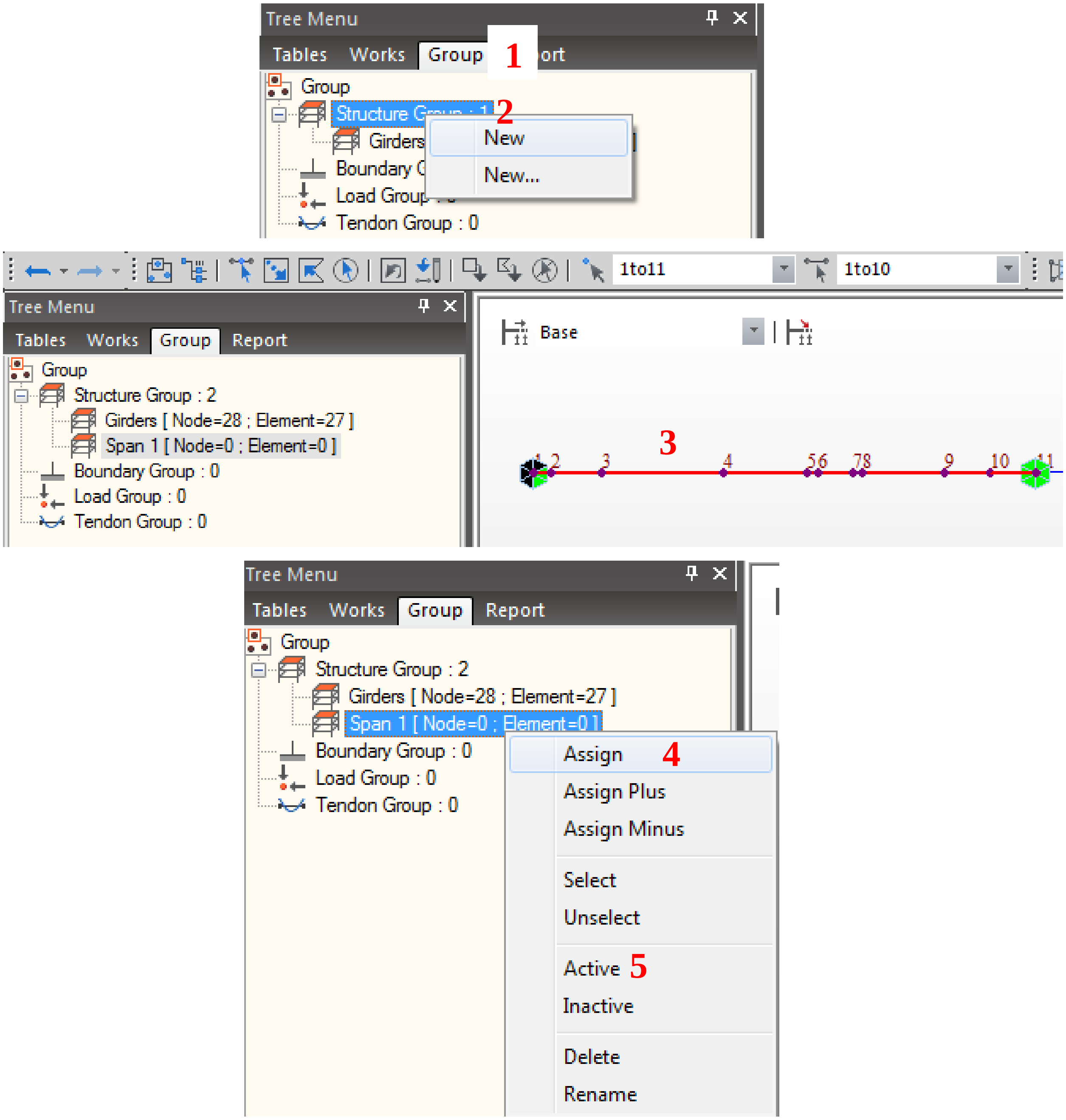
15) Go to the menu under Node/Element => Create Nodes

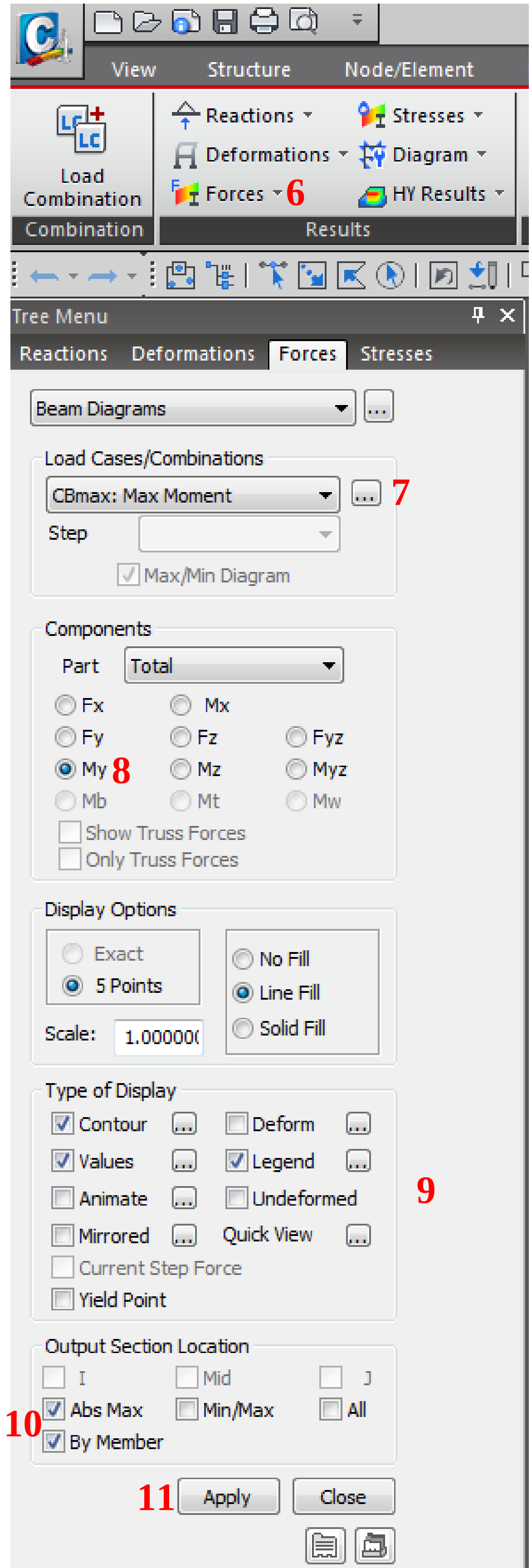
16) Type in the new nodes coordinates determined from step 13

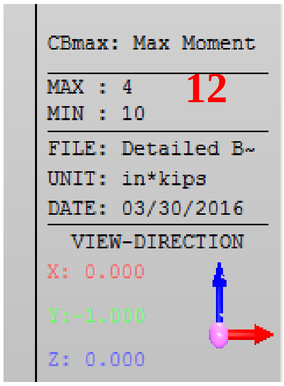
17) Click the Intersect Frame Elements Box

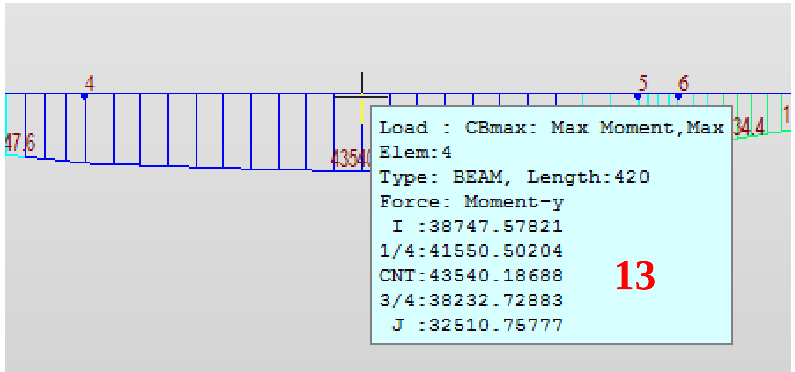
18) Click Apply. This will split the existing element into two new elements connected together by the new node. Note that by doing this the node and element numbers will no longer be in sequential order. It is recommended to renumber the nodes and elements, but not required. However it is required to update the 'GeometryCalcs' worksheet in the Template for either the adjusted node location or for the additional node and element and/or new node and element numbers. The updated/new analysis point should also be documented in the preliminary Mathcad file

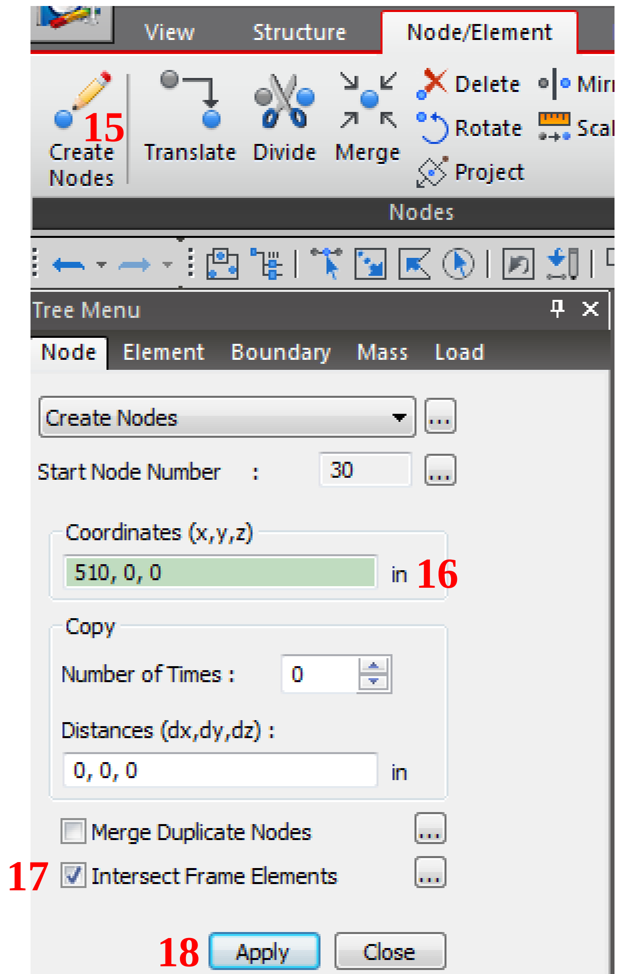
19) Repeat the above steps for each span being analyzed where a node does not exist at the actual maximum positive moment location.


Tree Menu
Tables
Works
Group
1
ort
Group
Structure Group : 1
2
Girders
New
New...
Boundary G
Load Group
Tendon Group : 0
1to11
1to10
Tree Menu
Tables
Works
Group
Report
Group
Structure Group : 2
Girders [Node=28 ; Element=27]
Span 1 [Node=0 ; Element=0]
Boundary Group : 0
Load Group : 0
Tendon Group : 0
Base
3
1 2
3
4
5 6
7 8
9
10
11
Tree Menu
Tables
Works
Group
Report
Group
Structure Group : 2
Girders [Node=28 ; Element=27]
Span 1 [Node=0 ; Element=0]
Boundary Group : 0
Load Group : 0
Tendon Group : 0
Assign
4
Assign Plus
Assign Minus
Select
Unselect
Active
5
Inactive
Delete
Rename


View
Structure
Node/Element
Load Combination
Combination
Reactions
Deformations
Forces
6
Stresses
Diagram
HY Results
Results
Tree Menu
Reactions
Deformations
Forces
Stresses
Beam Diagrams
Load Cases/Combinations
CBmax: Max Moment
7
Step
Max/Min Diagram
Components
Part
Total
Fx
Mx
Fy
Fz
Fyz
My
8
Mz
Myz
Mb
Mt
Mw
Show Truss Forces
Only Truss Forces
Display Options
Exact
5 Points
No Fill
Line Fill
Solid Fill
Scale:
1.00000(
Type of Display
Contour
Deform
Values
Legend
9
Animate
Undeformed
Mirrored
Quick View
Current Step Force
Yield Point
Output Section Location
I
Mid
J
10
Abs Max
Min/Max
All
By Member
11
Apply
Close







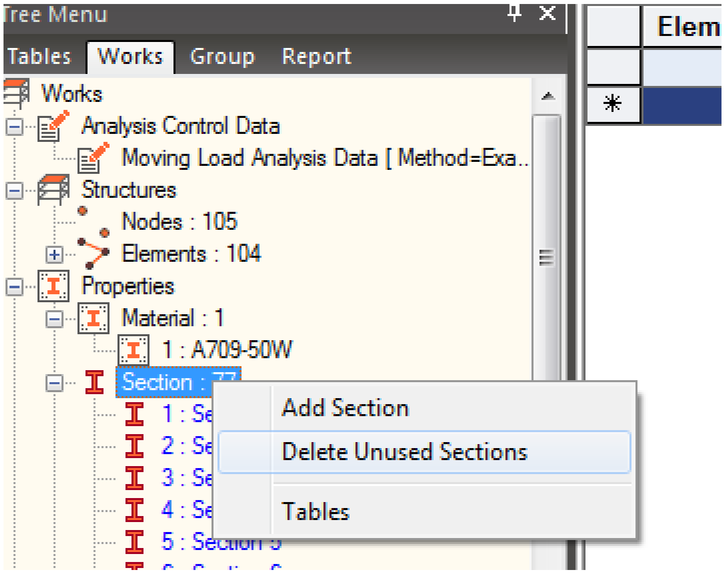
Refer to section 11.4.11 for the steps to extract analysis results from Midas to be copied into the Template.

11.3.21 Dynamic Report Creator

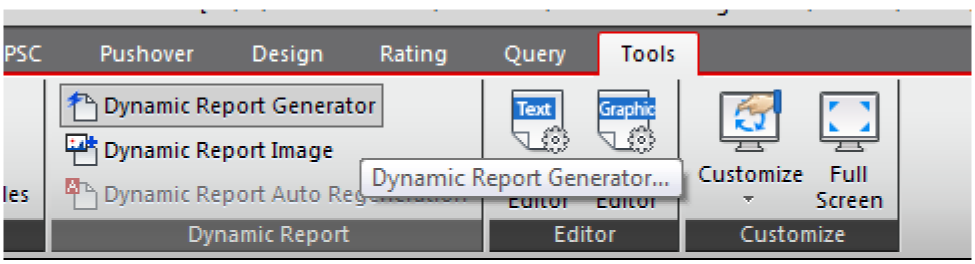
The Dynamic Report Creator is used to generate a Word document that contains the Midas model inputs. User Defined Tables were loaded with the STBOX_PRELIM.mct file.

Prior to creating the report delete any unused sections in order to condense the report. Under the

Tree Menu within the Works Tab right click on Sections: XX and Click Delete Unused Sections. This will delete all the sections in blue which are not used in the model.



In the top menu go to Tools => Dynamic Report Generator.



Select New Document and click OK. This will open a new tab titled Report Editor with a blank word document.

1) Right Click on Header & Footer in the tree menu, and then left click on properties.

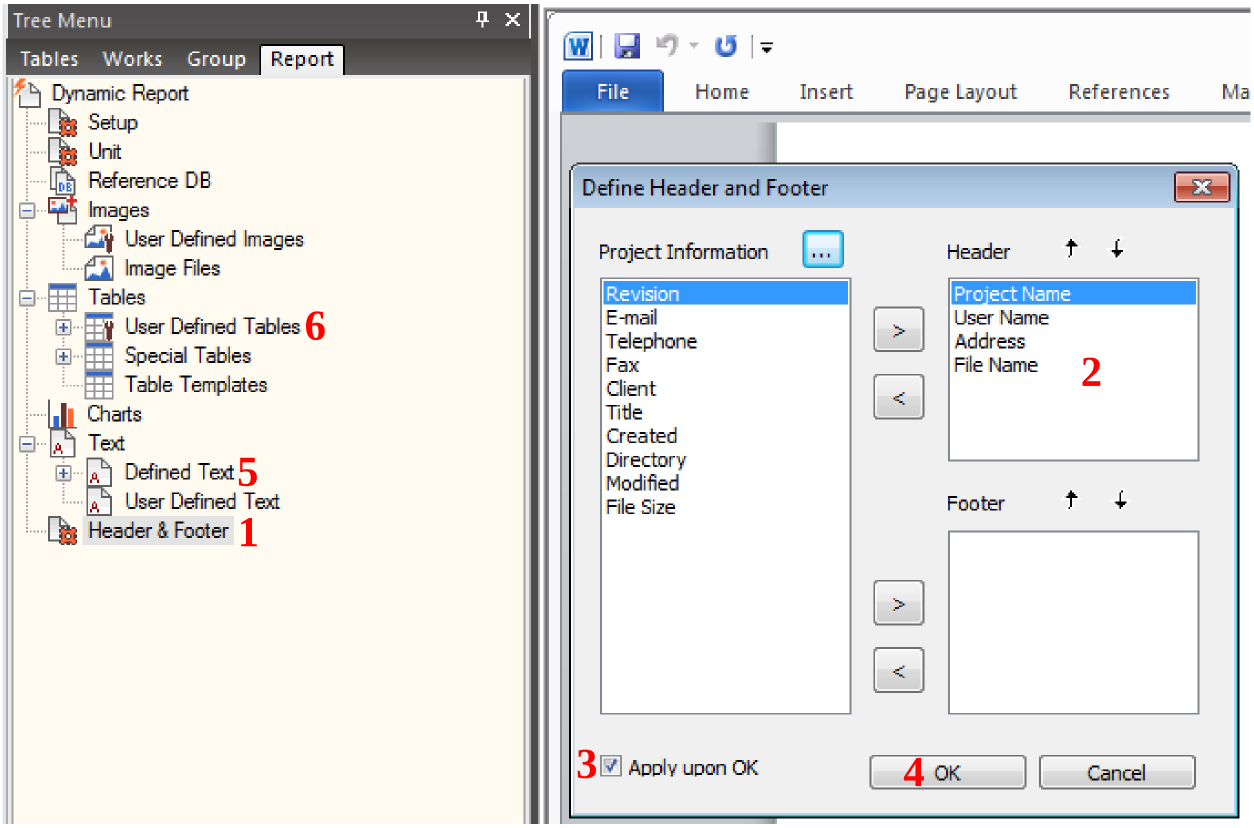
2) Project Name, User Name, Address, and File name should already be selected. If not, select these.

3) Select Apply upon OK.

4) Click OK.

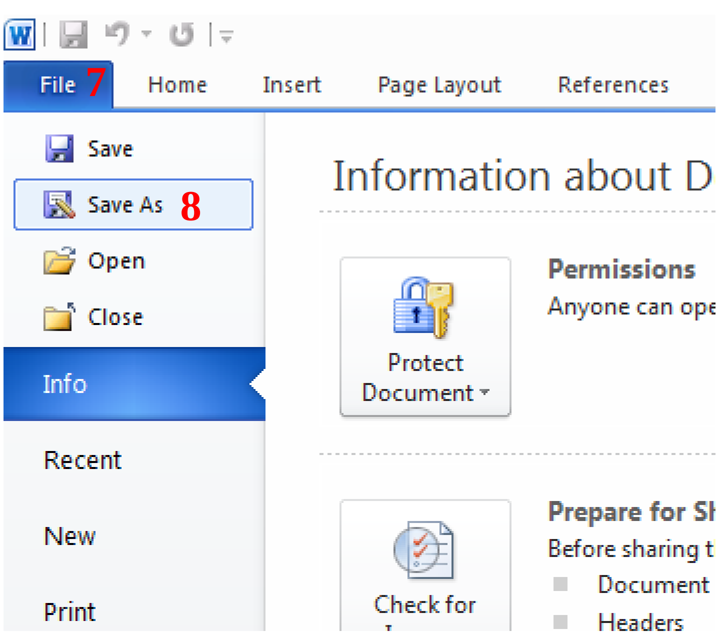
5) Right Click on Defined Text and then left click on Insert to Report.

6) Right Click on User Defined Tables and then left click on Insert to Report.



7) Click on the File menu in the Word Document.

8) Click on Save As. Name the file nnnnn_MidasData.docx and save to the current load rating folder. This report will be printed and included in the calculation book.



11.4 Capacity and RF Worksheet (Template)

For steel box girders, the capacity and rating factors worksheet (Template) file name and extension for bridge #nnnnn is typically nnnnn_STBox.xlsm.

The Template is an Excel spreadsheet developed to calculate capacities and rating factors. Capacities are calculated using the material and sectional information inputs, and limit state demands are calculated using the force effects imported from Midas Civil.

Some fields in the Template are calculated automatically by macros, while other information is entered manually. Where buttons have been provided to perform a task, use the button first and manually revise cell values (if needed) afterward. Buttons have been provided to not only aid the user, but to also assign table ranges, print areas, etc. CAUTION: Failure to use the buttons on each page may cause some table references to be defined incorrectly when subsequent buttons are clicked, possibly causing errors in calculations or failure of the subsequent procedures to run through completion. It is highly recommended that manual changes to calculated cells be avoided on the 'GeometryCalcs' worksheet.

The Template includes the following base assumptions:

1 Superstructure must qualify as a Type 'b' or 'c' steel box girder structure per AASHTO LRFD Table 4.6.2.2.1-1.

2 User must verify whether or not live load distribution factors from AASHTO LRFD Table 4.6.2.2.1-1 are appropriate in accordance with Sections 6.11.1.1 and 6.11.2.3.

3 DC1 dead loads are assumed to act entirely on the steel-only section (prior to concrete deck becoming effective). When bridges are specified as composite, DC2 and DW dead loads are assumed to act on the composite section.

4 Service II checks are computed as part of the overall RF calculations, and results only reported on the overall 'RF' worksheet when min Ser II RF < 1.11.

5 For compact composite sections in positive flexure, check of f_deck <= 0.6 * f"c is not investigated by the template.

6 The RF reported for each force effect at each node is the controlling rating factor stemming from an evaluation of the capacities and demands on each side of the node.

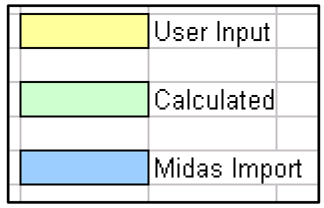
7 Stiffeners are ignored in calculation of gross section properties.

8 Deck buildup area is not input or considered in analysis, but separation between deck and top flange is used in section property calculations.

9 Fillets and tapers are ignored in capacity calculations, unless explicitly modeled in the inputs by the user.

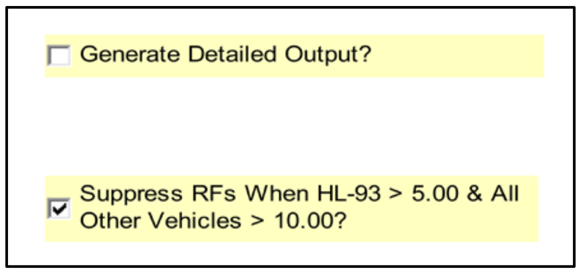
10 Bearing checks assume no eccentric axial bearing load.

Color-coded cells are used in the Template to aid user input. Follow the reference below to determine if the cell is user input, calculated by the Template, or imported from Midas output.



NOTE: If calculated cells are manually overwritten then the user will need to remember to overwrite the calculated value again (if appropriate) the next time the macro button is clicked again.

The Template file has been created with functionality to provide additional information for understanding or confirming the rating factor results. On the 'Assumptions' worksheet the user will see two checkboxes as shown below.



When the 'Generate Detailed Output?' checkbox is selected, select macros will output internal calculation results to text file as the macro procedures are running. The user will be able to view the results of each critical internal calculation that has been coded to produce this output.

Clicking the 'Suppress RFs When HL-93 > 5.00 & All Other Vehicles > 10.00?' checkbox will reduce the volume of results data by eliminating rating factor results that are beyond the defined limits.

The 'GeometryCalcs' worksheet and 'RF' worksheet only show information or results on ONE side of each node. The primary macros on these sheets, however, will create hidden worksheets that display the data for BOTH sides of each node (except for the begin and end of bridge nodes). This information is especially helpful for confirming the Template is using or reporting the correct data.

11.4.1 Resistance and Factors

Update the System, Condition, Resistance, Live Load, and Dead Load factors. DC and DW factors do not normally need to be altered. Impact is input for Legal and Permitted vehicles only. Impact adjustment for design loads is included in the Midas output.

11.4.2 Spans

Define the information for the spans that are included in this analysis:

Spans

14 Insert Span | 15 Delete Span | 16 Set Spans

x-coord at first span start = 0.00 in — 1

Span	C-C Bearing Length (ft)	Simple or Continuous?	Roadway Width (ft)	Box or Tub Section?	Number of Girders	Composite / Noncomposite?	De T
1	106.61	Continuous	40.000	Tub	2	Composite	
2	152.28	Continuous	40.000	Tub	2	Composite	
3	232.36	Continuous	40.000	Tub	2	Composite	
4	195.57	Continuous	40.000	Tub	2	Composite	
5	195.57	Continuous	40.000	Tub	2	Composite	
6	178.06	Continuous	40.000	Tub	2	Composite	
2	3	4	5	6	7	8	

) in

Es = 29000 ksi
n = 8
Fy Deck Rebar = 40 ksi
f'c Deck = 4.00 ksi
— 9

Deck Rebar Top Layer Size	Qty Top Layer Bars (ea)	Deck Top Rebar Dist to Center (in)	Deck Rebar Bot Layer Size	Qty Bot Layer Bars (ea)	Deck Bot Rebar Dist to Center (in)	Allow Compact Section Analysis?	x-Dist at Start of Span (in)
#5	24	2.438	#5	24	5.313	No	0
#5	22	2.438	#5	22	5.313	No	1279.308
#5	18	2.563	#5	18	4.937	No	3106.68
#5	18	2.563	#5	18	4.937	No	5895.012
#5	18	2.563	#5	18	4.937	No	8241.852
#5	18	2.563	#5	18	4.937	No	10588.716

10 (Deck Top rebar columns) 11 (Deck Bot rebar columns) 12 13

1) Input the properties above the ‘Spans’ table used in the analysis of the entire bridge. ‘x-coord at first span start’ defines the x-coordinate in the Midas model of center of bearing of the first span input in the ‘Spans’ table (example: input “-6” if the first span’s starting coordinate is modeled in Midas at x = -6in).

2) Input the span name. Note the name need not begin with “1” for the first span, nor do span names need to be sequential or numerical.

3) Input the center-to-center bearing length of the span.

4) Input if the span is simple or continuous.

5) Input the average roadway width.

6) Input whether the girder of interest is a closed-box or open-tub type.

7) Input the total number of girders for the current span.

8) Select “Composite” as the capacity calculations have been developed assuming a composite deck. For now, if the girder is not composite with a concrete deck or there is no evidence of shear connectors, then capacity and rating factor calculations are required to be performed separately.

9) Enter the steel modulus of elasticity, modular ratio for transforming the concrete deck to steel, the yield stress of the deck reinforcement, and the compressive strength of the concrete deck.

10) Input deck rebar size of top rebar layer. For example, if #5 bars are used, input ‘5’. The template assumes standard US bar sizes; non-standard, square, or metric bar sizes will need to be converted to an equivalent area as the product of an analogous bar size and quantity of bars. Input the number of top layer deck rebars tributary to the girder of interest. Input the vertical distance from TOP of slab to center of the top layer of deck rebar.

11) Input deck rebar size of bottom rebar layer. Input the number of bottom layer deck rebars tributary to the girder of interest. Input the vertical distance from BOTTOM of slab to center of the bottom layer of deck rebar.

12) Specify whether or not the section is allowed to be analyzed as a compact section. Note: Per AASHTO LRFD Article 6.11.6.2, sections may be checked for and analyzed under compact section criteria (Article 6.11.7.1) provided the bridge meets the provisions of Articles 6.11.6.2.2 and 4.6.1.2.4c. Otherwise, the section capacity must be determined from the provisions for noncompact sections (Article 6.11.7.2).

13) The x-Dist at Start of Span will automatically populate when the “Set Spans” button is clicked.

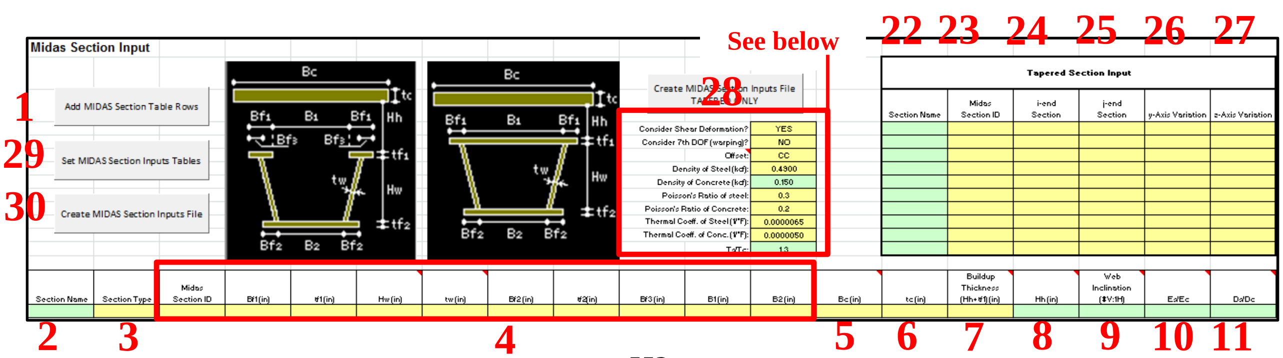
14) Use the “Insert Spans” button to add one row to the end of the current ‘Spans’ table

15) Use the “Delete Spans” button to delete one row from the end of the current ‘Spans’ table. If data is contained in that row, it will also be deleted.

16) Use the “Set Spans” button to set the table extents and print area of the ‘Spans’ worksheet. This button should always be clicked as the last step before proceeding to the subsequent pages.

11.4.3 Midas Section Input

The ‘Midas Section Input’ worksheet is used to define and create the tub and box sections. The values input in this worksheet will be used to automatically populate the ‘GeometryCalcs’ worksheet other than the yield strength of each component. The values input will also be used to generate a Midas MCT Command Shell text file which is used to automatically generate tub, box, tapered tub, and tapered box sections in Midas. Note on this worksheet there are two screen shots from Midas which show a graphical description of each section dimension for a tub or box section.



Consider Shear Deformation?	YES	
Consider 7th DOF warping?	NO	13
Offset:	CC	14
Density of Steel (kcf):	0.4900	15
Density of Concrete (kcf):	0.150	16
Poisson's Ratio of steel:	0.3	17
Poisson's Ratio of Concrete:	0.2	18
Thermal Coeff. of Steel (1/°F):	0.0000065	19
Thermal Coeff. of Conc. (1/°F):	0.0000050	20
Ts/Tc:	1.3	21

1) Click the "Add Midas Section Table Rows" button to add additional rows to lower general table if additional rows are needed. Note this step is not required but can help prevent errors during step 29 caused by formatting

2) Section Name. This cell is set to be "Section X", where X is the number entered into the Midas Section ID. This value can be changed to any desired text or number as long as there are less than 29 characters in the name.

3) Select either "Tub" or "Box" for the section type

4) Type in the Midas Section ID and plate element dimensions or copy and paste from the Mathcad preliminary file section property table. Note that the Midas Section ID value must be a numeric value.

5) Enter in the Bc dimension in inches. This is the tributary/effective deck width determined in the Mathcad preliminary file. Note this value is not transformed.

6) Enter in the deck thickness in inches

7) Enter in the buildup thickness in inches measured from the bottom of the top flange

8) The buildup between the top of the top flange and the bottom of the deck is automatically calculated when the Midas section input table is set. Note this value is only used for the capacity calculations and is set to be zero inches when the Midas MCT command shell text is created. This value has no effect on self-weight and will only have a minor effect of stiffness. If a value other than zero is desired to be used the value must be adjusted within Midas.

9) Web Inclination is calculated automatically. If this value is provided on the plans and does not match the calculated value double check all the other section dimension inputs for errors

10) Modular ratio is automatically taken from the 'Spans' worksheet.

11) Density ratio is calculated automatically. This value should be set to zero if the deck self-weight is input as an applied load.

12) Select "YES" or "NO" if shear deformation should be considered in the Midas model. Note the default value is "YES".

13) Consider the 7th degree of freedom (warping effect)? Select "YES" or "NO", "NO" is the default value

14) Select the desired offset location. CC (center-center) is the default value. The offset location

is where the beam line element will be drawn with respect to the cross-section

15) Density of steel, the default value is 0.490kcf

16) Density of concrete, the default value is 0.150kcf, however this value will automatically be updated based on the inputted value of f'c in the 'Spans' worksheet.

17) Poisson's ratio of steel, the default value is 0.3

18) Poisson's ratio of concrete, the default value is 0.2

19) Thermal coefficient of steel, the default value is 0.0000065 1/ºF

20) Thermal coefficient of concrete, the default value is 0.0000050 1/ºF

21) Ratio of the thermal coefficients of steel to concrete. This value is automatically calculated when the Midas section input table is set.

Note: The settings for steps 12 through 21 are applied to every section created. If there is a reason that these values should be different for certain sections, the value will need to be changed within Midas.

22) Type in the Midas Section ID for each tapered section. Note this must be a numeric value. If there are no tapered sections skip this step and go to step 28.

23) Type in the previously defined Midas Section ID for the i-end of the tapered section. This section must already be defined in the lower table

24) Type in the previously defined Midas Section ID for the j-end of the tapered section. This section must already be defined in the lower table

25) Select the y Axis Variation. The available options in Midas are Linear, Parabolic, or Cubic

26) Select the z Axis Variation. The available options in Midas are Linear, Parabolic, or Cubic

27) Section Name for tapered sections. The default value is "Section I-J", where I is the number entered in step 23 and J is the number entered in step 24. This value can be changed to any desired text or number as long as there is less than 29 characters in the name

28) Click the "Set Midas Sections Inputs Tables" button once all input is complete to set both the general table and the tapered sections table if applicable. This will also calculate values for all green cells.

29) Click the "Create Midas Section Inputs File" button to create the Midas MCT command shell text file used to generate the model sections. The file will be placed in the directory location on the 'Assumptions' worksheet. If no directory location is specified then the file will be placed in the same location as the active workbook.

30) Click the "Create Midas Section Inputs File TAPERED ONLY" to create the Midas MCT command shell text file used to generate the model sections for only the tapered sections. It is good practice to use this button when more than 10 tapered sections need to be defined. The file will be placed in the directory location on the 'Assumptions' worksheet. If no directory location is specified then the file will be placed in the same location as active workbook.

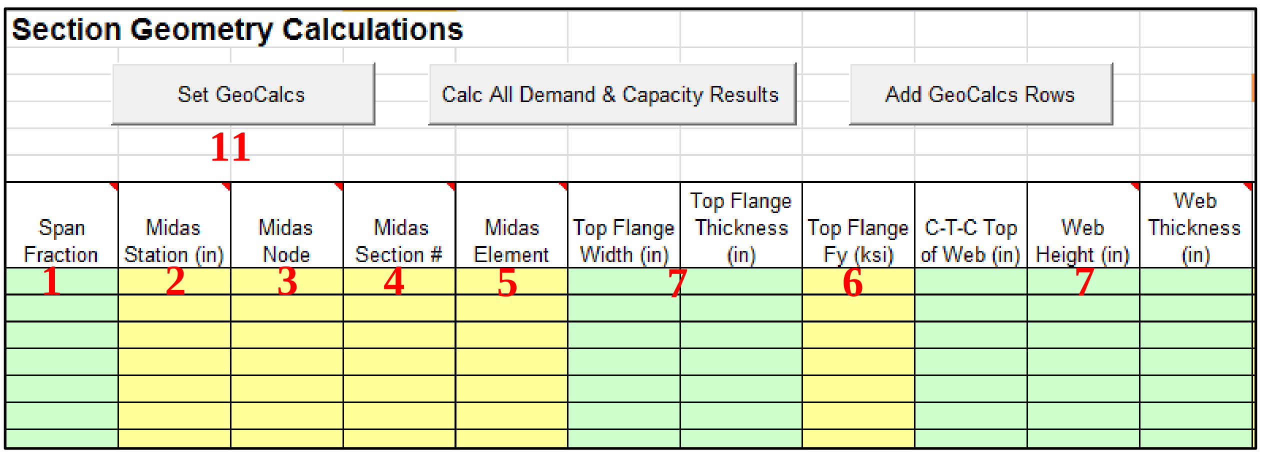
Note: For tapered sections with an analysis point between the I and J ends you will have to create a tapered section group and convert it to individual tapered sections as described in Section

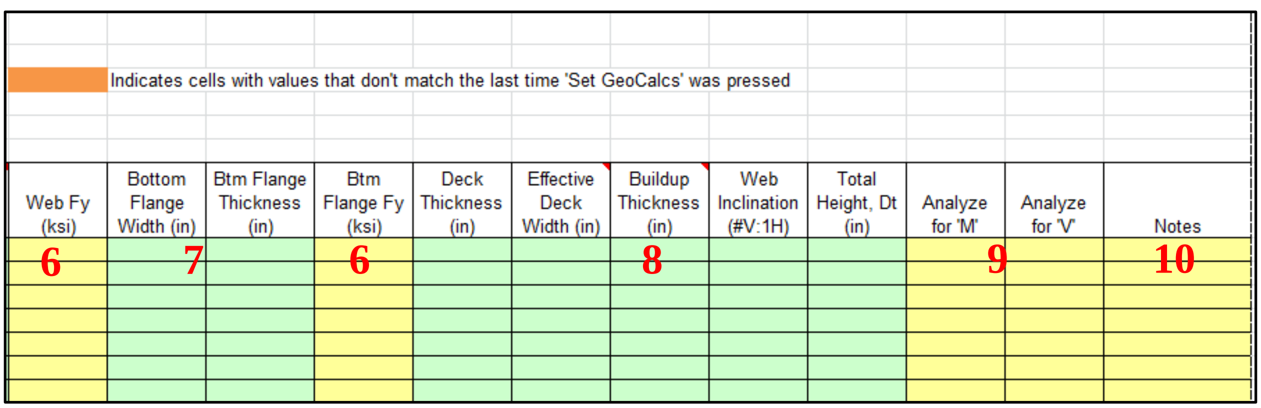
11.3. The newly created sections can then be viewed and the dimensions can be copied into the general table following the above steps in order to populate the 'GeometryCalcs' worksheet with the correct section values.

11.4.4 Geometry Calculations (GeometryCalcs)

The 'GeometryCalcs' worksheet is used to define all the section geometry used for both the Midas model as well as the capacity and rating factor calculations. By convention, the node and section number assignments are defined at the i-end of each defined element. The locations must be organized in ascending order, which will be accomplished with the "Set GeoCalcs" button is pressed. To account for any potential variations in section properties, material properties, or member demands on either side of a node, the template will automatically create additional analysis points 1" to the left of interior nodes so that rating factor calculations can be performed for both sides of each node (except at the beginning and end of the bridge).

Use calculations within the input cells as necessary. Between the in-cell calculations and the information provided in the Mathcad file, enough work needs to be shown for another user to easily determine how the section dimensions were calculated. Some columns are for bookkeeping purposes while others are required for various macros.





1) Span Fraction is automatically calculated when the "Set GeoCalcs" button is pressed.

2) Input the station in inches. Note the station is a relative to the beginning of the bridge and is not the actual station, i.e., the start of the bridge should also be at station 0.00

3) Input the Midas node number. It is best practice to have node numbers in ascending order starting at 1 to avoid error when creating the initial Midas model. Note if an additional node is added to the model it is not necessary to renumber all of the nodes.

4) Input the section number used in the Midas section generator. For all but the last section location, this number should correspond to the section number of the section to the right of a given location. The last location's section number should correspond to the section ending at that location. Note that if a given location is not going to be analyzed for moment nor shear it is okay to leave the Midas Section # blank, however the Midas node and element should still be inputted. When modeling curved bridges you will often need to have additional nodes in order to accurately model the curvature. Since these nodes do not represent a section change it is not necessary to determine the cross-section dimension.

5) Input the Midas element number. This should correspond to the number of the element to the right of the location, except for the last location, which should correspond to the number of the element ending at that location. Similar to the node numbers, it is best practice to have the element numbers start at 1 and increase by 1 in ascending order.

6) Enter the yield strength of the top flange(s), web, and bottom flange.

7) The flange width and thickness, center-to-center distance between the tops of webs, web height (measured perpendicular to the cross slope of the top flanges), web thickness, bottom flange width and thickness, deck thickness, effective deck width, buildup thickness, web inclination, and total height fields will be automatically populated from the input entered on the 'Midas Section Input' worksheet when the "Set GeoCalcs" button is clicked

8) The deck thickness, effective deck width, buildup thickness, web inclination, and total height fields will automatically be populated from the input entered on the 'Midas Section Input' worksheet with the "Set GeoCalcs" button is clicked. NOTE: For Midas modeling purposes it is not critical to capture variations in these fields. However, the user can modify the calculated (populated) values if they deem it is important for capacity calculations.

9) Select the analysis type to be performed for each section. These columns are used to determine which sections have capacities calculated on the 'Moment Capacity' and 'Shear Capacity' worksheets, respectively, as well as which rating factors will be reported on the 'RF' worksheet. If moment analysis is selected, the Template will determine capacities for positive and negative moment, and report rating factors for positive and/or negative moment as applicable based on the max and min moment demands. Rating factors for Bearing will be produced for sections with shear analysis type selected AND bearing stiffener information input for the same location in the 'Bearing Stiffeners' worksheet.

10) The user may enter any desired notes into the "Notes" field. This field will be copied onto the 'Analysis Pts' worksheet.

11) Once all information in the yellow fields has been input into the 'GeometryCalcs' table, click the "Set GeoCalcs" button to automatically calculate the green fields and set the table extents and print area of the GeoCalcs table.

12) If all necessary information has been input by the user, they can click this button to run all capacity calculation and rating factor macro procedures. Alternatively, the user can elect to click the individual macro buttons on each of the pertinent worksheets.

11.4.5 Section Properties

Section Properties

Calc Section Props Table

Orange highlight indicates cells with values that don't match the last time 'Calc Section Props Table' was clicked.

Note: At locations where section changes occur, the section with the lesser section properties is reported here and subsequently used for RF calculations

Span Fraction	Location (in)	Total Steel Depth at Section (in)	Composite / Noncomposite?	Steel Moment of Inertia (in ^{4})	Long-Term As-Constructed Final Moment of Inertia (in^4)	Short-Term As-Constructed Moment of Inertia (in^4)	Steel Section Plus Deck Rebar Moment of Inertia (in^4)
1.000	0.000	48.0670	Composite	38173.0	78344.0	109801.0	53762.0
1.124	158.912	50.4640	Composite	42542.0	86075.0	120506.0	59361.0
1.125	159.912	50.4640	Composite	42542.0	86075.0	120506.0	59361.0
1.183	234.128	51.5910	Composite	44691.0	89855.0	125740.0	62104.0
1.184	235.128	51.7160	Composite	47509.0	96852.0	137447.0	66317.0
1.249	318.824	52.9860	Composite	50155.0	101524.0	143987.0	69693.0

Span Fraction	Steel Only Section Modulus Bottom of Steel (in ^{3})	As-Constructed Long-Term Section Modulus Bottom of Steel (in^3)	As-Constructed Short-Term Section Modulus Bottom of Steel (in^3)	As-Constructed Steel Section & Deck Rebar Section Modulus Bottom of Steel (in ^{3})	Steel Only Section Modulus Top of Steel (in ^{3})	As-Constructed Long-Term Section Modulus Top of Steel (in ^{3})	As-Constructed Short-Term Section Modulus Top of Steel (in ^{3})	As-Constructed Steel Section & Deck Rebar Section Modulus Top of Steel (in ^{3})
1.000	1848.22	2394.35	2608.76	2117.75	1392.49	5104.90	18368.29	2370.36
1.124	1956.02	2522.72	2749.47	2233.54	1481.55	5266.49	18161.82	2485.08
1.125	1956.02	2522.72	2749.47	2233.54	1481.55	5266.49	18161.82	2485.08
1.183	2007.17	2583.76	2816.47	2288.52	1523.98	5344.00	18101.11	2539.61
1.184	2252.35	2888.04	3144.72	2562.46	1551.40	5327.26	17162.23	2566.87
1.249	2316.13	2963.78	3227.86	2630.82	1600.78	5420.13	17185.52	2630.41

Section properties are calculated by the Template automatically, separate from the Midas model. These section properties are used during the nominal moment capacity and rating factor calculations. Moment of inertia and section modulus are calculated at each node defined on the 'GeometryCalcs' worksheet as well as the left side of each interior node for:

- the steel only section;
- the long-term transformed effective deck width (3n) for permanent loads;
- the short-term transformed effective deck width (n) for transient loads; and
- the steel only plus deck reinforcement.

Some notes regarding the use of the buttons on this worksheet:

1) Click the "Calc Section Props Table" to instruct the template to calculate comprehensive section property information for all section locations specified for analysis in the 'GeometryCalcs' worksheet.

2) All fields in the 'Section Properties' worksheet will be populated by the "Calc Section Props Table" button. The user may review this information, and where the user deems appropriate, they may overwrite the calculated values in the table. Caution should be exercised before overwriting the calculated values, as these section property values are used variously in different aspects of subsequent analysis.

3) The table extents, print area, and formatting are set when the "Calc Section Props Table" button is clicked.

11.4.6 Distribution Factors (LL_DF)

The 'Spans' and 'GeometryCalcs' worksheets must be filled out prior to beginning distribution factor calculations since many inputs are pulled directly from these tables. Once the fields have been populated, the user may manually vary these values if the conditions being modeled vary from those generated by the initial inputs. The "Calc DFs" button does not need to be pressed again after manual values are entered. Table extents, print area, and formatting are set when the "Calc DFs" button is clicked.

11.4.7 Analysis Pts

The table on the 'Analysis Pts' worksheet is populated automatically when the "Set GeoCalcs" button is clicked on the 'GeometryCalcs' worksheet. No additional user input is required here and manual changes should not be made.

11.4.8 Transverse Stiffeners

Define the transverse stiffeners for the entire length of the girder. In subsequent calculations, the transverse stiffener spacing is set by identifying stiffener spacing range within which the node is located. Note: the Template does not check to see if the transverse stiffener properties are appropriate to be considered as an effective stiffener. All of the input for this worksheet should be able to be copied in directly from the Mathcad preliminary file.

Transverse Stiffener Schedule

Insert Row | Delete Row | Set Trans Stiff Sched

x-Dist at Start (in)	x-Dist at End (in)	Span Name	Start Distance from Left End of Span (in)	Range (in.)	Stiff Spacing (in)
0.000	159.912	1	0.00	159.91	31.98
159.912	319.824	1	159.91	159.91	39.98
319.824	959.472	1	319.82	639.65	53.30
959.472	1279.308	1	959.47	319.84	39.98

1) Click the “Insert Row” button to add additional rows to the ‘Transverse Stiffeners’ table as needed. Do not attempt to insert rows or expand the defined table range manually, as this may adversely affect how subsequent macros reference the table.

2) Click the “Delete Row” button to delete unused rows. Note that any data contained in the last table row will be lost when the row is deleted.

3) Input the span name, corresponding to the span name defined on the ‘Spans’ worksheet.

4) Input the start distance for the stiffener range, referenced from the left end of the span on which the stiffener group occurs.

5) Input the distance from the starting point over which the stiffener group runs.

6) Input the spacing between stiffeners for the current stiffener group, extending to the right of the starting point.

7) Once all inputs to yellow fields are complete, click the “Set Trans Stiff Sched” button to define the table range and print area for the ‘Transverse Stiffeners’ worksheet, as well as fill in the calculated cells.

11.4.9 Longitudinal Stiffeners

Define the longitudinal flange and web stiffeners for the entire length of the girder. In subsequent calculations, the longitudinal stiffener spacing is set by identifying stiffener spacing range within which the node is located. Note: the Template does not check to see if the longitudinal stiffener properties are appropriate to be considered as an effective stiffener. All of this input should be able to be copied in directly from the Mathcad preliminary file.

Longitudinal Stiffener Schedule

Insert Row | Delete Row | Set Long Stiff Sched

x-Dist Start (in)	x-Dist End (in)	Span Number	Start Distance from Left End of Span (in)	Range (in)	Stiff Location	# of Stiffeners	I_s (in^4)	ds_{top} (in)	ds_{bot} (in)	w_{crit} (in)
0.000	959.472	1	0.00	959.47	Web	1		10.75	43.01	
959.472	1119.384	1	959.47	159.91	Web	2		12.43	12.43	
1119.384	1279.308	1	1119.38	159.92	Web	1		51.64	12.91	
1279.308	1611.564	2	0.00	332.26	Web	1		54.59	13.65	

1) Click the “Insert Row” button to add additional rows to the ‘Longitudinal Stiffeners’ table as needed. Do not attempt to insert rows or expand the defined table range manually, as this may adversely affect how subsequent macros reference the table.

2) Click the “Delete Row” button to delete unused rows. Note that any data contained in the last table row will be lost when the row is deleted.

3) Input the span number of the stiffener group.

4) Input the start distance for the current stiffener group from the left end of the current span. The stiffener group will extend to the right of this point over the distance specified in the Range field.

5) Input the range over which the stiffener group is present. Stiffener groups may overlap, but if a stiffener group is continuous over a support location, one group must be defined to terminate at the end of the current span, and another group must be defined beginning at the start of the next span.

6) Enter “Web” if the longitudinal stiffener group is located on the web, or “Flange” if it is located on the flange.

7) Enter the quantity of stiffeners associated with the stiffener group.

8) For flange stiffeners, enter the I.s term as defined by Article 6.10.11.3.3 and the critical spacing distance w.crit as the larger of the spacing between longitudinal stiffeners, or minimum distance from stiffener to edge of web/flange element.

9) For web stiffeners, input the distances from stiffener elements nearest the edge of the webs to the extreme web fibers (for stiffeners located on the webs only).

10) Once all input values for all yellow fields are established, click the “Set Long Stiff Sched” button to define the table extents and print area for the ‘Longitudinal Stiffeners’ worksheet, and to fill in the calculated cells.

11.4.10 Bearing Stiffeners

Bearing Stiffener Schedule

Insert Row | Delete Row | Calc Bearing Capacities

Note: Bearing Stiffener RF's are computed for the below locations whenever 'Analysis Type "V" ' is selected for that location on "GeometryCalcs" tab

Location (in)	# of Stiffeners	Bearing Area, A_{pn} (in^2)	Effective Gross Section Area (in^2)	Stiffener Height (in)	Stiffener Moment of Inertia (in^4)	Fy Bearing Stiffeners (ksi)	Reaction Factor	Factored Axial Compression Resistance, (phi_c * P_r) (kip)	Factored Bearing Resistance, (phi_b * R_{sb_r}) (kip)
0.000	6	1.50	22.75	17.58	76.97	50.0	1.01	1076.6	630.0

1) Click the “Insert Row” button to add additional rows to the ‘Bearing Stiffeners’ table as needed. Do not attempt to insert rows or expand the defined table range manually, as this may adversely affect how subsequent macros reference the table.

2) Click the “Delete Row” button to delete unused rows. Note that any data contained in the last table row will be lost when the row is deleted.

3) Input the x-coordinate location along the bridge for the bearing stiffener group. NOTE: This distance must correspond to the x-coordinate of the beginning or end of span, as defined on the ‘Spans’ worksheet.

4) Input the quantity of bearing stiffeners associated with the stiffener group being defined by the row. If necessary, multiple rows may be used to define all bearing stiffeners present at a single location along the bridge.

5) Input the bearing area (contact area) and gross cross-sectional area for a single bearing stiffener in the stiffener group.

6) Input the stiffener height, moment of inertia, and bearing stiffener yield strength.

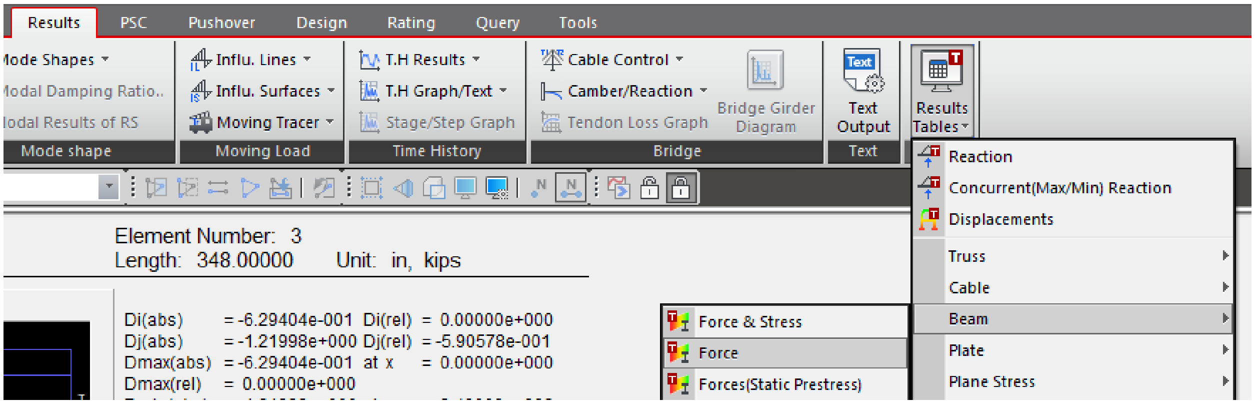
7) To account for multiple bearings per bearing, uneven distribution, and/or torsional reaction demands, input a Reaction Factor as appropriate.

8) Clicking the “Calc Bearing Capacities” button will calculate the factored axial compression resistance, calculate the factored bearing resistance, set the table extents, set the print area, and will format the table.

11.4.11 Max Shear and Max Moment

Maximum shear and moment values are copied from Midas results and pasted into the Template:.

1) Open nnnnn_STBOX.mcb. In the top menu go to Results => Result Tables => Beam => Force

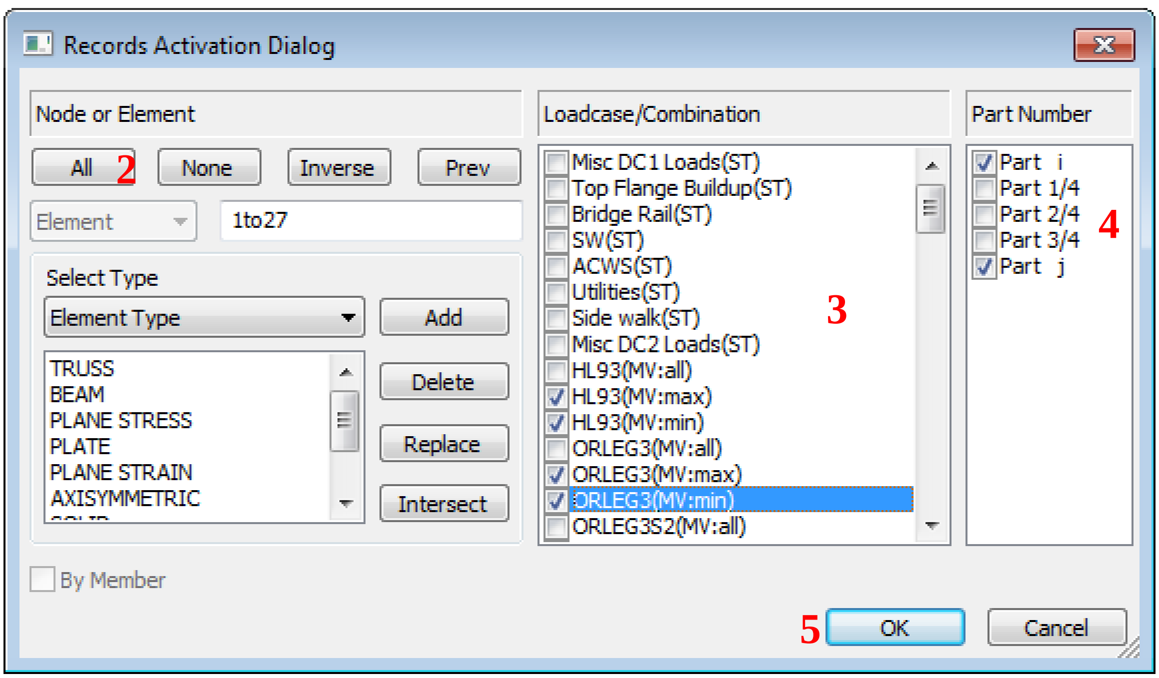


2) Click the "All" button to select all Elements.

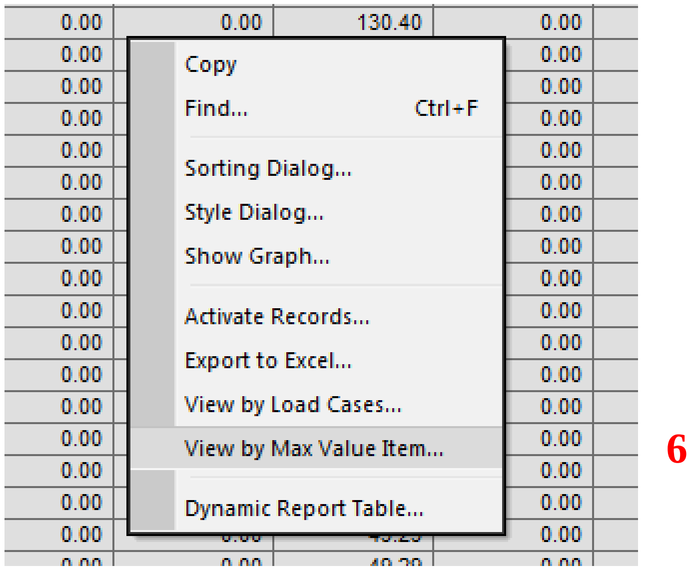
3) Select the maximum and minimum for each moving load case and DC1(CB), DC2(CB), and DW(CB) load case/combinations.

4) Select Part i and Part j only.

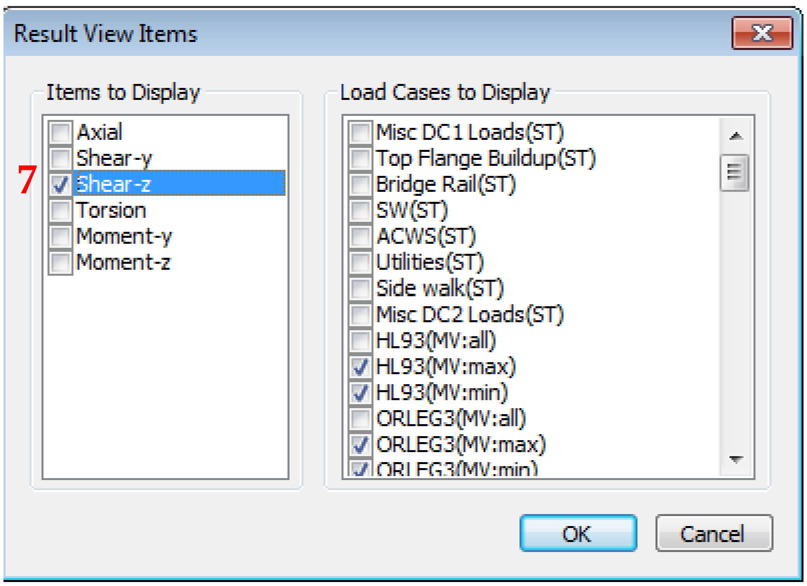
5) Click OK. Beam force results for the selected Load Cases/Combinations are now displayed in a table.



6) Right click in the table and then left click on View by Max Value Item…



7) Select Shear-z for Items to Display. The Load Cases to Display should already be selected from the previous step. If not select the same load cases as shown in step 4. Click OK.



8) Depending on the type of Midas model, the columns in the Template and the Midas model may not match. Copy all of the data from Max Shear output and paste it into the appropriate columns in the Template. It is ok if some columns are blank.

9) Click on Set Shear Table to format the correct cell range.

Max Shear

Set Shear Table 9

Elem	Load	Part	Componen	Axial (kips)	Shear-y (kips)	Shear-z (kips)	Torsion (in·kips)	Moment-y (in·kips)	Moment-z (in·kips)
1	HL93(max)	I[1]	Shear-z	0	0	0	0	0	0
1	HL93(max)	J[2]	Shear-z	0	0	2.39	0	1861.46	0
2	HL93(max)	I[2]	Shear-z	0	0	2.39	0	1861.46	0
2	HL93(max)	J[3]	Shear-z	0	0	13.58	0	8792.94	0
3	HL93(max)	I[3]	Shear-z	0	0	13.58	0	8792.94	0

8

10) Return to the Beam Force Result table from Step 5. Repeat Steps 6-9 but select Moment-y in Step 7.

Max Moment

Set Moment Tbl 9

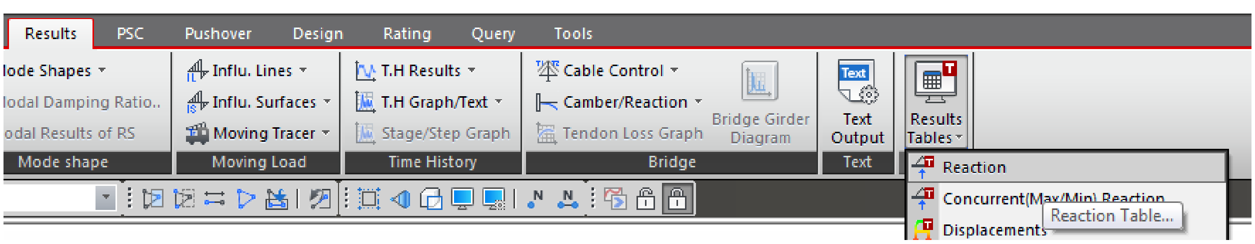
Elem	Load	Part	Component	Axial (kips)	Shear-y (kips)	Shear-z (kips)	Torsion (in·kips)	Moment-y (in·kips)	Moment-z (in·kips)
1	HL93(max)	I[1]	Moment-y	0	0	0	0	0	0
1	HL93(max)	J[2]	Moment-y	0	0	-58.04	0	4580.85	0
2	HL93(max)	I[2]	Moment-y	0	0	-58.04	0	4580.85	0
2	HL93(max)	J[3]	Moment-y	0	0	-35.8	0	14968.36	0

8

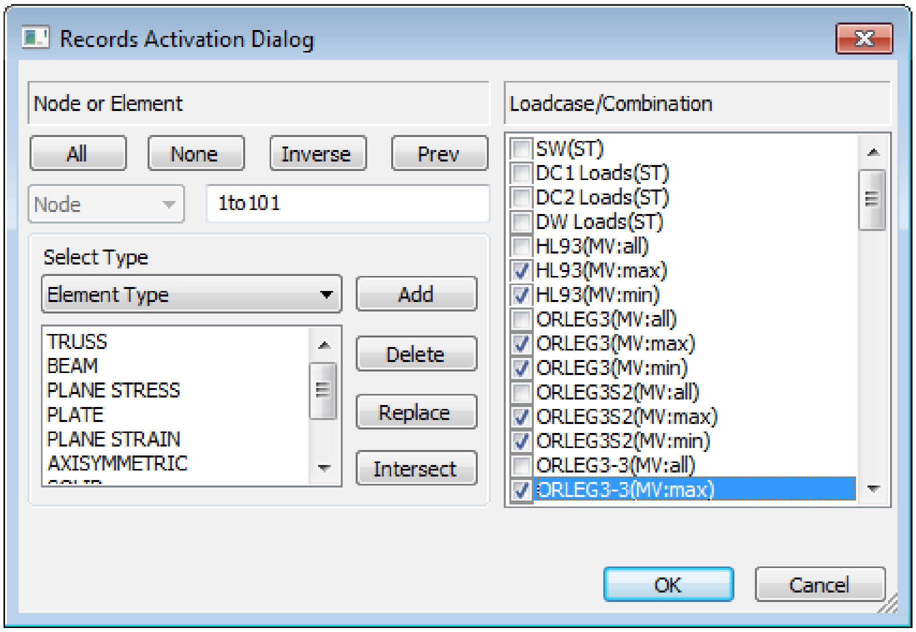
11.4.12 Max Reactions

Maximum reaction values are copied from Midas results and pasted into Template in order to rate the bearing stiffeners.

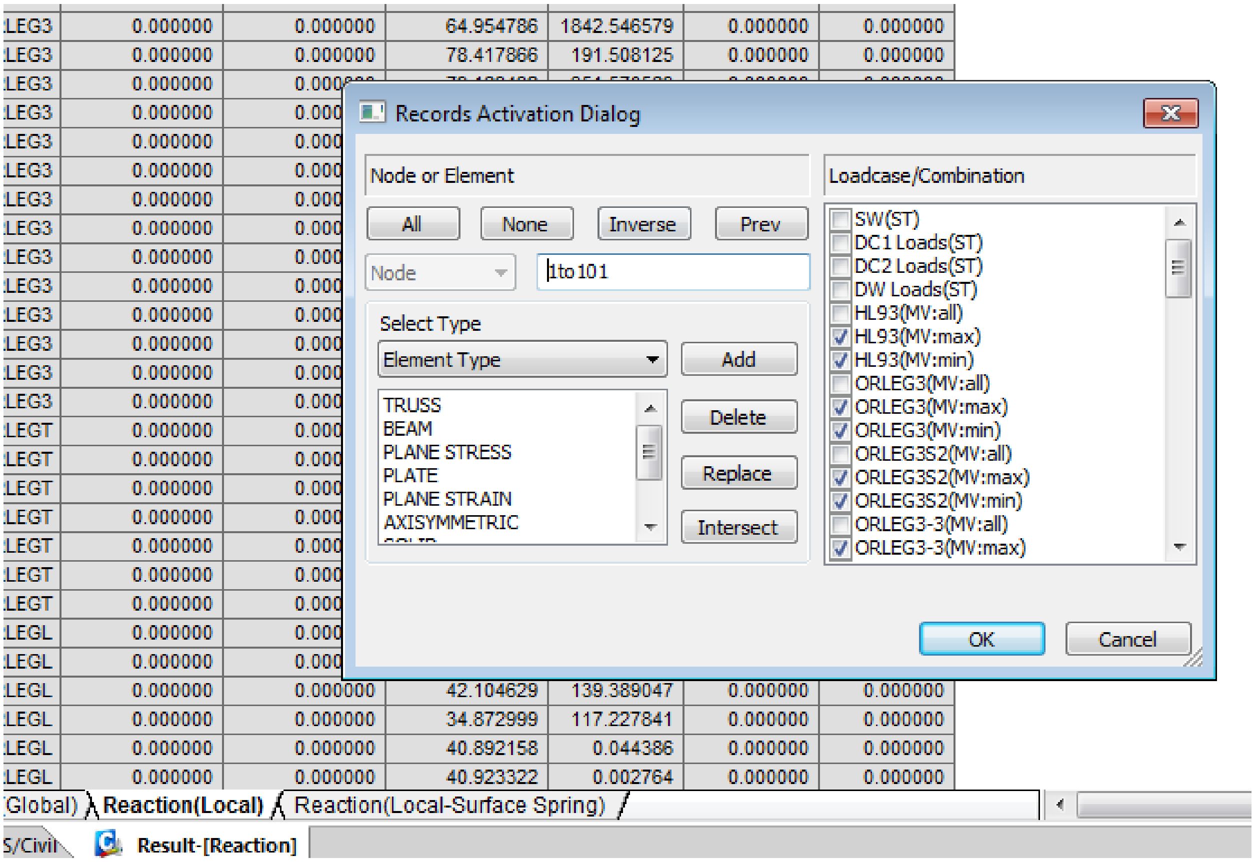
1) Open the Midas model. In the top menu go to Results => Result Tables => Reaction

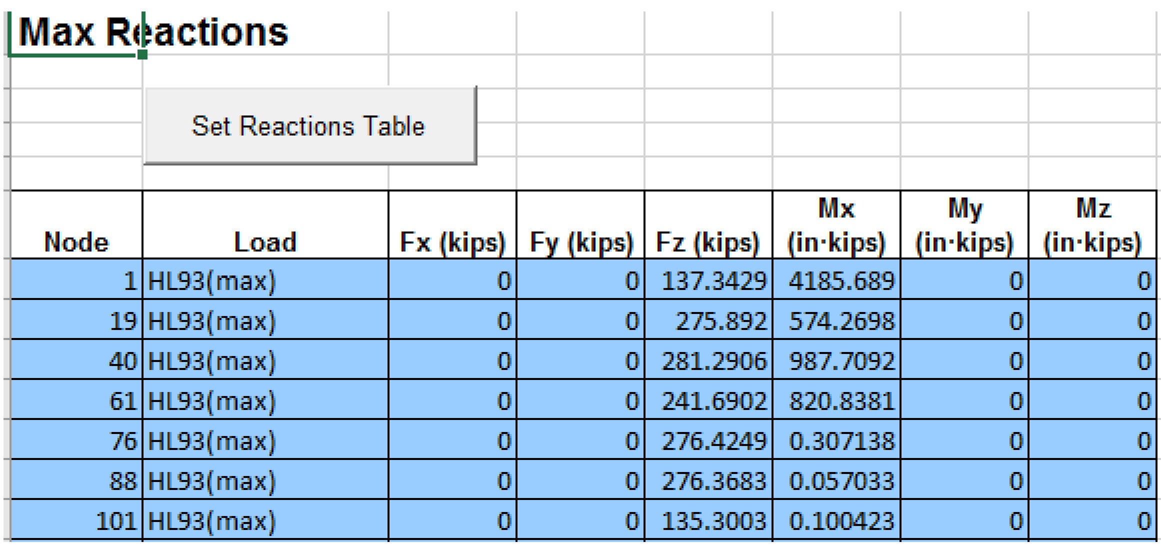


2) Select the Max and Min load case for each moving load and the DC1(CB), DC2(CB), and DW(CB) load combinations. Then click OK.



3) If the girder was modeled straight, then you can directly copy and paste the reactions into the Template. If the girder was modeled curved, then click on the “Reactions(Local)” tab which will pop up the same dialog box from step 2. Confirm all of the correct load cases and combinations are selected. Click OK and then copy and paste the reactions into the Template.





Max Reactions

Set Reactions Table

Node	Load	Fx (kips)	Fy (kips)	Fz (kips)	Mx (in·kips)	My (in·kips)	Mz (in·kips)
1	HL93(max)	0	0	137.3429	4185.689	0	0
19	HL93(max)	0	0	275.892	574.2698	0	0
40	HL93(max)	0	0	281.2906	987.7092	0	0
61	HL93(max)	0	0	241.6902	820.8381	0	0
76	HL93(max)	0	0	276.4249	0.307138	0	0
88	HL93(max)	0	0	276.3683	0.057033	0	0
101	HL93(max)	0	0	135.3003	0.100423	0	0

4) Click Set Reactions Table after pasting in values from Midas.

11.4.13 Factored Loads

Click on the “Calculate” button to activate the macro that will apply the appropriate factors to the Midas output, based on those specified on the ‘Resistance and Factors’ worksheet.

11.4.14 Moment Capacity

The moment capacity for each node location defined on the 'GeometryCalcs' worksheet to require flexural rating, as well as the left side of any of these nodes if they are interior nodes, is calculated on the 'Moment Capacity' worksheet. For steel box and tub sections, AASHTO LRFD Section 6.11.6 is used to calculate moment capacities for compact sections in positive flexure (if appropriate), and flexural stress capacities for all other cases. Clicking the "Calculate" button will fill in all cells (no user input is required), and also set the table extents, print area, and formatting. Number values are reported if demands are present that require rating calculations and "N/A" is reported otherwise.

Nominal Moment Capacity

Calculate

x.xxxL	Location (in)	Section #	Mp (+M) (in·kips)	Mn (+M) (in·kips)	Fnc (+M) (ksi)	Fnt (+M) (ksi)	Fnc (-M) (ksi)	Fnt (-M) (ksi)
1.124	158.912	2	N/A	N/A	50.0	50.0	N/A	N/A
1.125	159.912	3	N/A	N/A	50.0	50.0	N/A	N/A
1.183	234.128	3	N/A	N/A	50.0	50.0	N/A	N/A
1.184	235.128	5	N/A	N/A	50.0	50.0	N/A	N/A

11.4.15 Shear Capacity

The 'Shear Capacity' worksheet is used for calculating the shear capacity for each node location defined on the 'GeometryCalcs' worksheet that requires load rating for shear, including the left side as appropriate.

Nominal Shear Capacity

Fill Sections from Analysis Pts   Calculate

x.xxxL	Location (in)	Section #	phi_v	Stiff/Unstiff?	Int./End Panel?	C	Vp (kip)	Vn (kip)
1.000	0.000	1	1.000	Stiffened	End Panel	0.850	522.0	443.6
1.124	158.912	2	1.000	Stiffened	Interior Panel	0.837	548.9	525.2
1.125	159.912	3	1.000	Stiffened	Interior Panel	0.652	548.9	488.1
1.183	234.128	3	1.000	Stiffened	Interior Panel	0.641	561.5	498.6
1.184	235.128	5	1.000	Stiffened	Interior Panel	0.641	561.5	498.6

1) Use the "Fill Sections from Analysis Pts" button to populate the first three columns, as well as to fill in preliminary values in the "Int./End Panel?" column to reflect whether or not the location appears to be within an interior or end web panel based on current inputs. The values in all other columns are deleted. The user should confirm that the web panel assumption is correct and make justifiable adjustments as necessary.

2) Click the "Calculate" button to command the macro to calculate shear capacities for all listed sections and fill in the other calculated cells. This button also sets the table extents, print area, and formatting.

11.4.16 Rating Factors (RF)

Click on the “Calculate” button to calculate rating factors. This macro will use the demands calculated on the ‘Factored Loads’ worksheet to calculate the factored flexural stress demands (for sections where plastic moment capacities are not appropriate) where moment ratings are required, and the factored shear demands including the torsional web shear forces when shear ratings are required. For large bridges, these computations can take a relatively long duration so status bar updates have been included to keep the user informed on the progress of the subroutine.

Once the calculations are complete, the rating factors are manually copied and pasted into the Rating Factor Summary sheet. As stated previously, Service II rating factors will only appear on this worksheet at section locations with at least one Service II rating factor at or below 1.10. Bearing rating factors are calculated at all sections specified for shear analysis where bearing stiffener properties have been defined for that location on the ‘Bearing Stiffeners’ worksheet.

These results can be sorted horizontally by location and then by force effect, or by force effect and then location. Note that the location sorting is alphabetical instead of numerical.

Rating Factors

Calculate

File Name 08958E_STBoxB_Template_V3.4 **(Copy** and **Paste Special-Values** into Load Rating Summary Sheet**)**

○ Sort By Location ◉ Sort By Force Effect

SECTION EVALUATED	Controlling							
LRFD Brass .OUT File Name:	DO NOT	TBoxB_Template	TBoxB_Template	TBoxB_Template	TBoxB_Template	TBoxB_Template	TBoxB_Template	TBoxB_Template
FORCE TYPE (+/-M, V, T, C or B):	COPY	+M	+M	+M	+M	+M	+M	+M
PHI (Resistance Factor):		1.000	1.000	1.000	1.000	1.000	1.000	1.000
MEMBER (eg. Int. girder):		Tub	Tub	Tub	Tub	Tub	Tub	Tub
SPAN (eg. 1 of 4):		1 of 11	1 of 11	1 of 11	1 of 11	1 of 11	1 of 11	10 of 11
LOCATION (eg. 0.1L):		0.105L	0.204L	0.400L	0.602L	0.841L	0.861L	0.152L
SINGLE LANE DF		1.213	1.213	1.213	1.213	1.213	1.213	1.172
MULTI-LANE DF		1.511	1.511	1.511	1.511	1.511	1.511	1.477
DESIGN & LEGAL VEHICLES								
HL93 (INVENTORY)	1.01	5.30	2.68	1.59	1.84	6.54	7.92	6.62
TYPE 3 (50K)	3.02	16.20	8.26	4.98	5.88	19.70	23.84	19.20
TYPE 3S2 (80K)	2.36	12.18	6.15	3.77	4.43	17.64	23.15	18.55
TYPE 3-3 (80K)	2.32	12.03	6.20	3.76	4.48	18.88	25.02	20.12
TYPE 3-3 & LEGAL LANE								
TYPE 3-3 TRAIN & LEGAL LANE	2.27							
SU4 TRUCK (54K)	2.76	14.86	7.56	4.53	5.35	17.56	21.08	17.02
SU5 TRUCK (62K)	2.45	13.13	6.70	4.01	4.73	15.78	19.06	15.39
SU6 TRUCK (69.5K)	2.23	11.97	6.00	3.60	4.25	14.40	17.46	14.01
SU7 TRUCK (77.5K)	2.06	10.97	5.49	3.27	3.86	13.20	16.09	12.94
CTP VEHICLE, MULTI-LANE								
OR-CTP-2A (105.5K)	2.09	10.86	5.42	3.16	3.73	17.44	21.88	17.62
OR-CTP-2B (105.5K)	2.03	10.31	5.32	3.36	3.91	17.17	22.16	17.87
OR-CTP-3 (98K)	1.72	9.01	4.62	2.79	3.29	12.76	16.44	13.13
STP VEHICLE, MULTI-LANE								
OR-STP-3(120.5K)	1.80	9.83	4.96	2.99	3.52	15.38	20.69	16.25
OR-STP-4A (99K)	1.73	9.09	4.65	2.80	3.31	12.60	16.06	12.80
OR-STP-4B (185K)	1.43	9.16	4.72	2.90	3.40	16.35	20.61	16.57
OR-STP-4C (150.5K)	1.46	9.13	4.54	2.79	3.27	14.21	19.07	15.17
OR-STP-4D (162.5K)	1.29	8.17	4.21	2.45	2.94	13.29	17.26	13.90
OR-STP-4E (258K)	1.27	7.87	4.01	2.53	3.00	13.32	17.28	13.56
OR-STP-5BW (204K)	1.27	8.19	4.18	2.55	3.00	14.71	18.77	15.06
SPECIAL								

11.4.17 Service II

Service II rating factors are calculated automatically as part of the overall rating factor calculations performed on the ‘RF’ worksheet. Only sections with at least one Service II rating factor <= 1.10 will be copied to the overall ‘RF’ worksheet. No interaction from the user is required on this worksheet.

These results will be sorted the same way as the strength rating factors on the ‘RF’ worksheet.

11.4.18 STBox.xlsm Submittals

On the ‘Assumptions’ worksheet in the Template there is a “Print” button that will activate a macro to print the desired tabs. Not all of the worksheets will be printed. Some page formatting has been automated, but the user should review the printed documents and perform additional formatting as necessary. Information from the following worksheets is to be included in the Calculation book; Assumptions, Resistance Factors, Spans, GeometryCalcs (OK to print as 11x17 with Z fold), LL_DF, Analysis Pts, Transverse Stiffeners, Longitudinal Stiffeners, Bearing Stiffeners, Section Properties, Factored Loads, Moment Capacity, and Shear Capacity. Rating factors are included in the summary sheet and therefore will not be printed here.

SECTION 12: LOAD RATING DECKS

This chapter is currently under development and will be included in a future update of ODOT LRFR Manual.

SECTION 13: LOAD RATING REINFORCED CONCRETE CULVERTS

This chapter is currently under development and will be included in a future update of ODOT LRFR Manual.

SECTION 14: LOAD RATING METAL CULVERTS

This section covers CMP (Corrugated Metal Pipe) Culverts. There are 5 classification of CMP Culverts per AASHTO LRFD as follows:

1. Corrugated Metal Pipe Culvert
2. Spiral Rib Steel Pipe Culvert
3. Spiral Rib Aluminum Pipe Culvert
4. Structural Plate Pipe Culvert
5. Long Span Arch Culvert

This section of the manual covers these specific types of culverts but the tools may be modified if there is a different metal or unique condition used outside of this. See Special Considerations (Section 15.3.11) for Structural Plate Box Culverts. If a more detailed analysis is necessary, the finite element modeling software CANDE may be used to affectively model soil-structure interaction (SSI).

14.1 Scoping of Structure

Create a scoping file (**nnnnn_scope.xlsx**) to document important decisions made by the load rating engineer. The effort required to perform a load rating can be reduced by identifying similar members and points of symmetry. It is important to document these locations, so someone can review the load rating at a future date and quickly understand what portions of the structure have been analyzed, and why other members were excluded from the analysis.

Structures will only be analyzed up to points of symmetry. Analyzing past the point of symmetry will have the unintended effect of causing the point to be reported twice in the load rating summary sheet.

Similar elements will be investigated with the goal of reducing the total number of elements to be rated. If a member is similar to another, but can be shown to either have reduced capacity or greater loads, then the controlling member can be rated first. If this member has rating factors greater than 1.0, there is no need to rate the other similar member.

An example would be a facility with three adjacent identical culverts. The capacity of these culverts will be the same but the loads may vary due to different fill depths. In this case the culverts with the maximum and minimum fill depth (higher loads) will be rated first. As long as these rating factors are greater than or equal to 1.0, then there is no need to rate the other culvert. If the load rating reports rating factors less than 1.0, then all three culverts shall be rated. Although the first two culverts will still control the overall load rating, the rating factors for the third culvert will be useful information when determining possible repairs.

Because the scope of the load rating can change depending on the calculated rating factors, revisit the scoping summary at the conclusion of the load rating to ensure it is an accurate reflection of the work performed.

14.1.1 Decide What Culverts to Analyze

Many metal culverts may be placed alongside each other with fill placed between for a particular bridge. Each unique culvert subjected to live load should be analyzed for its maximum and minimum fill heights. This is in order to maximize the live load and vertical earth pressures for the two cases. If many similar culverts exist at a site the controlling maximum and minimum fill conditions can be used for all similar culverts for a particular bridge.

14.2 Preliminary Mathcad File

For metal culverts, the preliminary file name and extension is **nnnnn{Bridge Name}_CMP.xmcd**. If there are multiple metal culverts, the file names should differentiate between them with some additional identifier (e.g. **nnnnn{Bridge Name}_CMP1.xmcd** and **nnnnn{Bridge Name}_CMP2.xmcd**).

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied factors with parentheses.

The following chapters are relevant to both aluminum and steel structures. Include the sections as they apply.

14.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file except when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description (“Spans” field) from the Bridge Log is adequate for this purpose.

Note: The Mathcad regions in the top right margin (outside the printable area) are there for two purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

14.2.2 Resistance Factors

Document the decisions regarding all Resistance Factors, with references to the appropriate MBE tables.

Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure:
$\Phi_f = \phi$ [max ($\phi_c\phi_{sf}$, 0.85)]
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD Table 12.5.5-1)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Shear:
$\Phi_v = \phi$ [max ($\phi_c\phi_{sv}$, 0.85)]
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD Table 12.5.5-1)
and ϕ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).

14.2.3 Load Factors

The vertical pressure (γ_{EV}) from dead load of earth fill is 1.95 for round metal culverts. There is no other dead loads to consider for this load rating. A nonredundant factor (η_R) of 1.05 that will be applied to the factored dead load of earth fill per AASHTO LRFD 1.3.4 & 12.5.4.

The live load factor for HL-93 Inventory Rating is 1.75. This is the factor that is entered into the "Resistance and Load Factors" tab of the various capacity spreadsheets. The Load Rating Summary Workbook **(LR.xltm)** will automatically apply the HL-93 Operating Rating live load factor of 1.35.

For State-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_State.XLS.** The only input is ADTT (one direction).

For Local-Agency-owned bridges, the live load factors for Legal, SHV, Continuous Trip Permit, and Single Trip Permit vehicles are calculated using **LL_Factors_Local.XLS.** The two inputs are ADTT (one direction) and effective bridge length. Note that effective bridge length is either (a) the sum of the longest two consecutive continuous spans, or (b) the longest simple span, whichever is greater.

Regardless of which live load factor application is used, ADTT is specified as "one direction". Thus ADTT for bridges with one direction of traffic is the Average Daily Traffic (NBI Item 29) multiplied by the Average Daily Truck Traffic (Percent) (NBI Item 109). For bridges with two-way traffic, the ADTT entered into the live load factor application is *half* the total ADTT for the structure.

After completing the input, save this bridge-specific copy of the Live Load Factor Application (either **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable) in the load rating file set. To avoid errors in the preliminary file, copy the "LRFR Strength I & II" table from the live load factor application, and in Mathcad use Edit / Paste Special. In the "Paste Special" dialog box choose the "Paste" button, highlight "Bitmap" in the "As" list, and click the "OK" button. This will insert an image of the live load factor application into the Mathcad preliminary file. After pasting, the bitmap can be dragged, and resized using the corner handles, to fit into the Mathcad printable area. Note, pasting the Excel worksheet directly in Mathcad is *not* recommended due to the idiosyncrasies of the live load factor application. Because you are pasting an inert bitmap, if any subsequent changes in live load factor input were to occur, the pasted object should be deleted from the preliminary file, the corrections should be done in the live load factor application and copied and pasted again into the preliminary file as a bitmap.

Document the decisions regarding the Impact Factor IM, referring to MBE C6A.4.4.3.

14.2.4 Bridge Geometry and Design Data

Document overall geometry decisions, assumptions and calculations. The length of culvert should be documented based on drawings or field measurements. The minimum and maximum fill heights from the top of the culvert to the roadway surface should be shown. Note the fill heights (H) from the drawings if they are available or determine from field measurements. The minimum fill height will also be used to check the load rating against AASHTO's minimum cover requirement (See AASHTO LRFD 12.6.6.3) and the subsequent load rating. If the culvert is flexible and the pavement is flexible (asphalt), then the wearing surface depth is decreased from the minimum fill height for the AASHTO minimum fill height (H_{min}). If the culvert is flexible and the pavement is rigid (concrete) then the wearing surface is included in the AASHTO minimum fill height (H_{min}). Record the AC Depth from the Bridge Inspection Report. A 4" AC Depth is assumed if the Bridge Inspection Report does not indicate an AC Depth (or 0.00" AC Depth is shown) but asphalt is observed on the roadway above the culvert of interest. The dynamic load allowance should be calculated per AASHTO LRFD 3.6.2.2. The clear roadway width between faces of guardrails (or traffic rails) should be shown along with how many lanes of truck traffic can fit within this. The span (S) and rise (R) should next be documented. Additionally the "Actual Top Radius" should be documented for all long span and unsymmetrical structure categories (described below). Determine the structure type for the AASHTO LRFD Minimum Cover Allowance per the following:

- Corrugated Metal Pipe – Aluminum or steel factory assembled pipe available in two basic shapes: round and pipe arch. See the Section Property Tables tab in nnnnn_CMP.xlsm for which standard corrugation patterns are available in this structure type.
- Spiral Rib Steel Pipe – Helical box ribs that have continuously welded or locked seams. Manufactured in ¾" x ¾" x 7 ½" or ¾" x 1" x 11 ½" corrugation patterns.
- Spiral Rib Aluminum Pipe – Helical box ribs that have continuously welded or locked seams. Manufactured in ¾" x ¾" x 7 ½" or ¾" x 1" x 11 ½" corrugation patterns.
- Structural Plate Pipe – Field assembled from 6" pitch by 2" depth corrugated steel plates or 9" pitch by 2 ½" depth corrugated aluminum plates. Pipe is available in four basic shapes: round, pipe arch, arch, and underpass. The standard sizes for steel range in span lengths from 5'-26'. Aluminum span lengths as large as 30' in this arch shape are available.
- Long Span Structural Plate – See AASHTO LRFD section 12.8.1 for definition of long span structural plate structures. Long span structural plate structure types are manufactured in both steel and aluminum. The steel long span structural plate culverts are assembled in conventional 6" x 2" corrugated galvanized plates and longitudinal and circumferential stiffening members. The aluminum long span structural plate culverts are assembled using 9" x 2 ½" corrugated plates and aluminum rib stiffeners. Long span structural plate culverts come in five basic shapes in both materials: horizontal ellipse, pipe arch, low profile arch, high profile arch, and pear shape. The span lengths of this structure type range from 19'-4" to 40'.

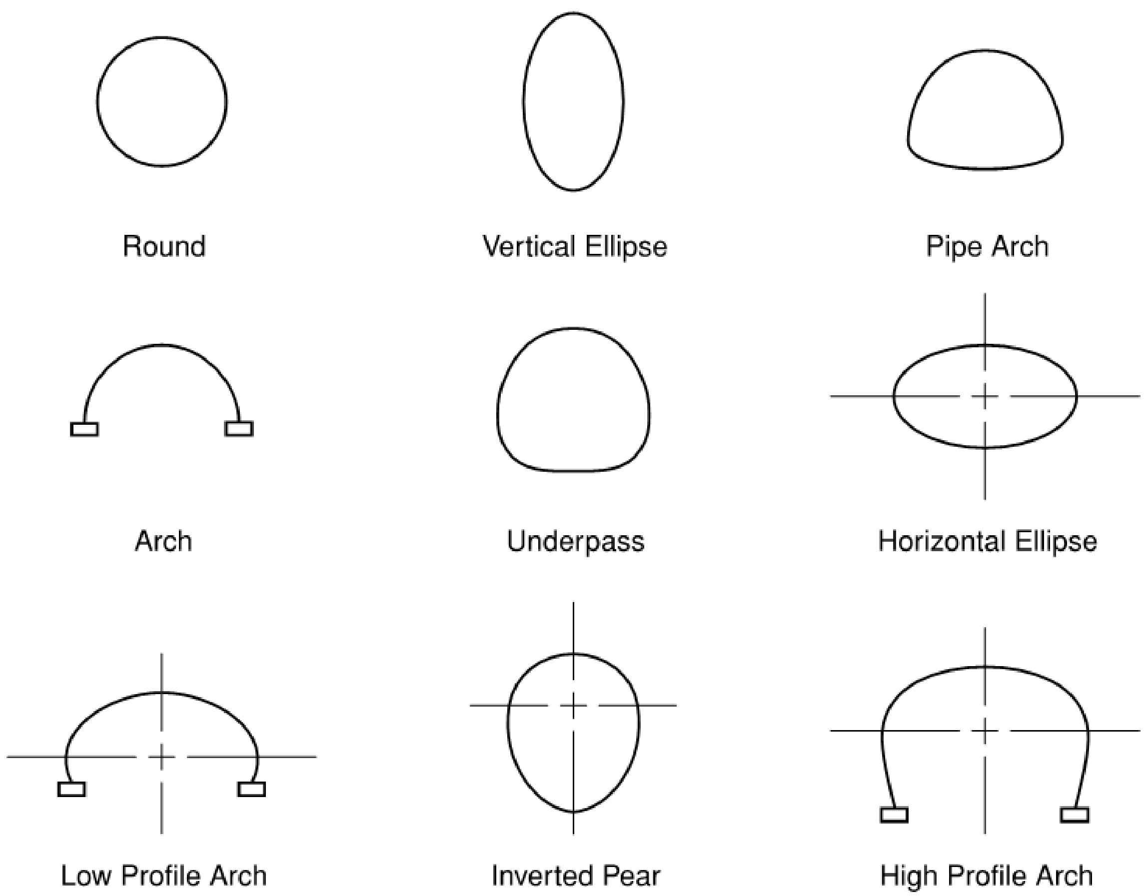


Figure 1: Culvert shape types. Reproduced from Figure A-1.9.6 of the *Structural Design Manual for Improved Inlets & Culverts*, FHWA-IP-83-6.

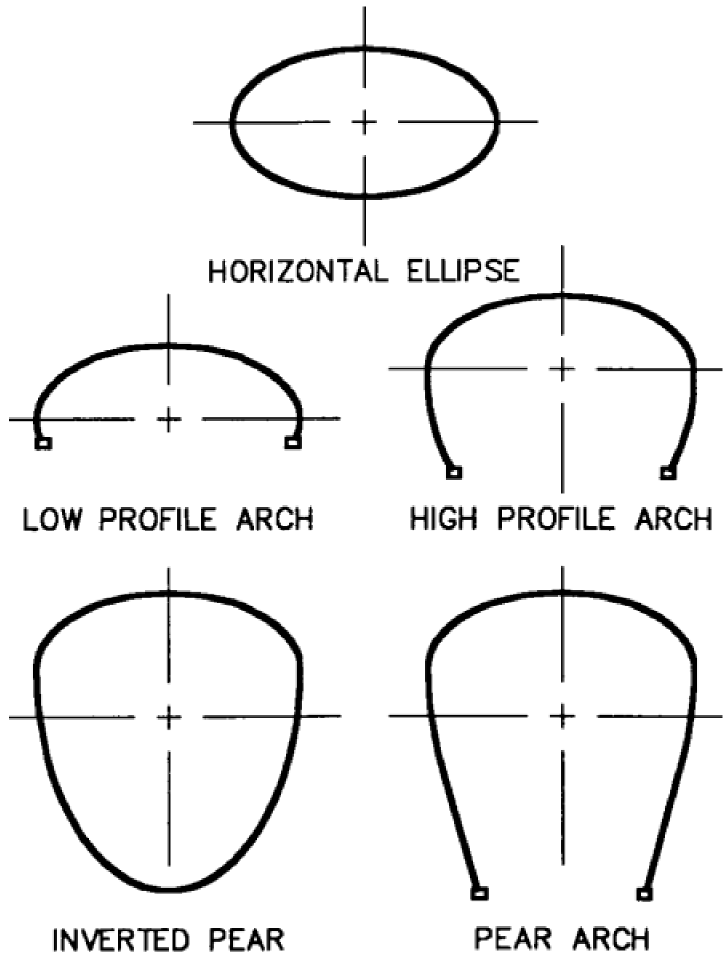


Figure 12.8.1-1—Long-Span Shapes

Figure 2: Long-Span culvert shape types. Reproduced from Figure 12.8.1-1 of *AASHTO LRFD* 7th Ed.

Toggle the seam type as either annular (circular) pipe or helical (spiral). Pipes with annular corrugations have spot welded, riveted, or bolted seams. Pipes with helical corrugations have continuously welded seams or lock seams. Next select the Structure Category to determine the methodology for applying loads to the span. “Typical” is used for the CMP Culverts and uses the span length for applied loading calculations. “Unsymmetrical or deflect over 5%” should be selected if the structure is asymmetrical or has a localized distortion or deflection to warrant this method. “Unsymmetrical or deflect over 5%” uses two times the top radius of the pipe ($2*R_t$) in lieu of span for applied loading calculations. “Long span” should be selected for longer spans that have the shapes shown in Figure 2 and also uses two times the top radius of the pipe ($2*R_t$) for all calculations. Note the “Metal type” as either steel or aluminum in the preliminary file. The corrugation pattern should be recorded as either “c” (width), “d” (depth), and “t” (thickness) or the corrugation pattern (ex. 3 x 1) along with the gage number. When inputting the thickness of the metal use a standard thickness and not the measured value.

14.2.5 Section Properties

The area of steel (A_s), radius of gyration (r), and the moment of inertia (I) can be determined for standard metal culverts from the Section Property Tables tab in nnnnn_CMP.xlsm worksheet. The seam strength can be determined for standard metal culverts from the Seam Strength Tables tab in nnnnn_CMP.xlsm worksheet. The soil density is assumed to be 0.120 kcf for all site conditions. The soil stiffness factor (k) of 0.22 is used for all cases. The live load distribution factor into soil is 1.15 per AASHTO Table 3.6.1.2.6a-1. The critical load parameter (γ_4) can be determined from the Critical Load Parameter Table tab in the nnnnn_CMP.xlsm worksheet.

14.2.6 Live Load (LL)

List the four classes of rating loads to be analyzed. (See Articles 1.5.1.1 through 1.5.1.4).

14.2.7 Analysis Sections

Each CMP Culvert should be analyzed at certain locations along the longitudinal length of the structure. Sections to analyze are only where The CMP Culvert is load rated against the thrust in the side walls from the compression ring nature of the structure. As the top of the culvert goes into compression the side walls thrust or bow out and are resisted by the capacity of the wall and the earth around it. The thrust capacity is taken as the minimum of the wall yielding strength, the wall buckling strength, and the longitudinal seam strength. Only sections of the culvert that are subjected to live load need be load rated. Evaluate each of the following sections along the length of culvert:

- Thickness (gage) changes in pipe walls or plates
- Changes in shape or material condition
- Location of maximum cover subjected to live load
- Location of minimum cover subjected to live load
- Any other section or material change location.

Additionally the CMP Culvert is analyzed and load rated for the AASHTO LRFD Minimum Cover Requirement at the midpoint of the span (the crown of the culvert) for the least amount of fill in areas subjected to live load.

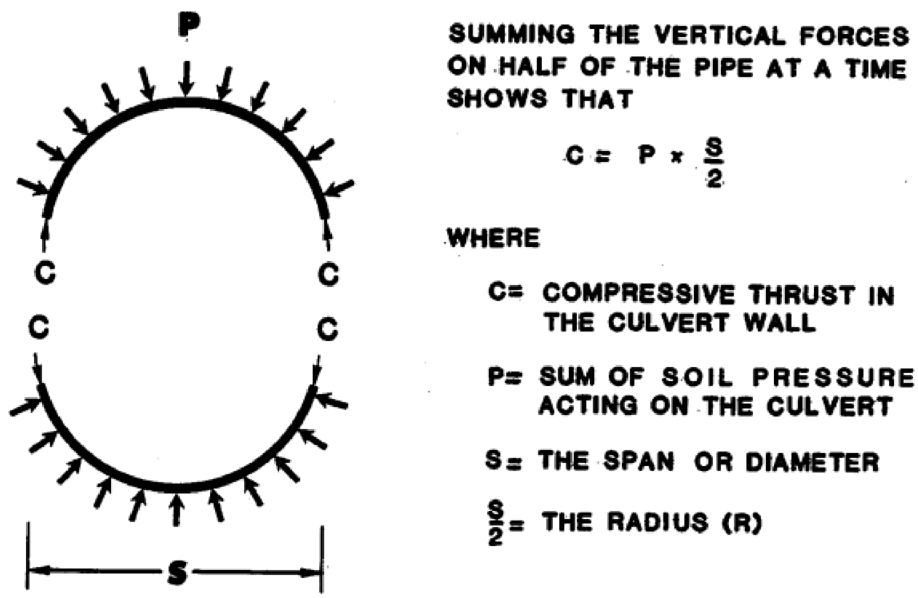


Figure 3: Compressive thrust action in culvert wall resulting from uniform applied pressure. Reproduced from Exhibit 22 of the *FHWA Culvert Inspection Manual*, FHWA-IP-86-2.

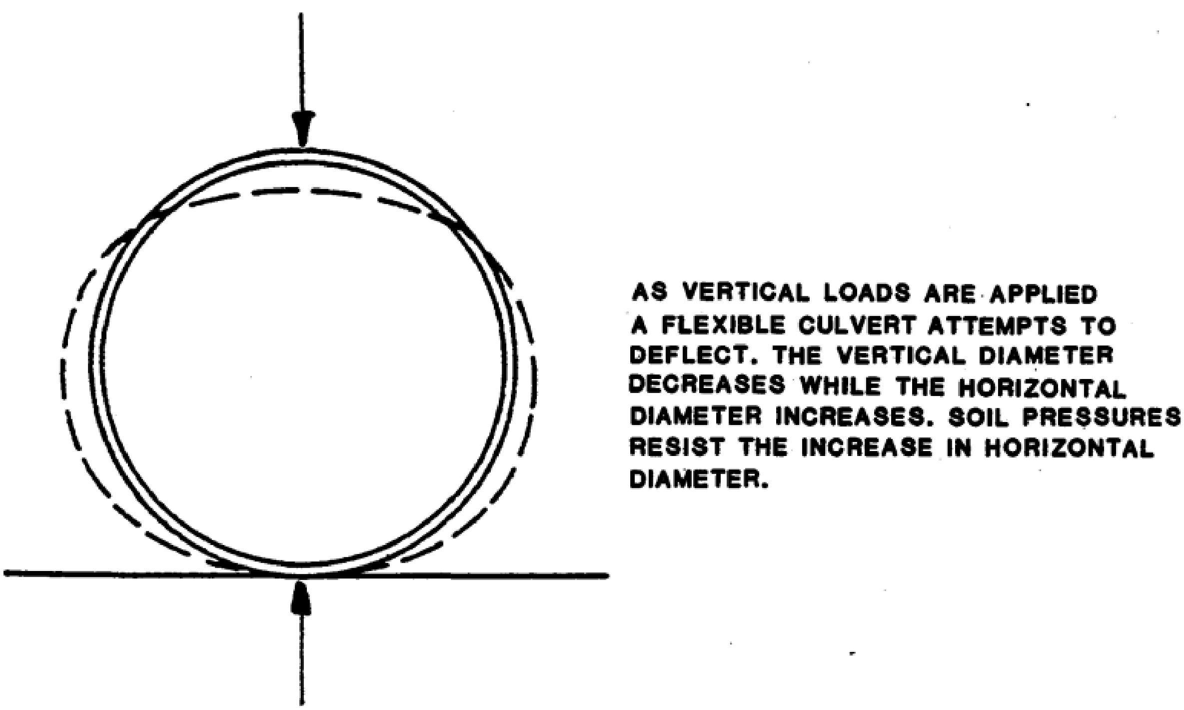


Figure 4: Deflection of culvert walls under vertical load. Reproduced from Exhibit 21 of the *FHWA Culvert Inspection Manual*, FHWA-IP-86-2.

14.3 Capacity and RF Worksheet

nnnnn_CMP.xlsm is a worksheet developed to calculate loads, capacities, and rating factors for CMP Culvert types with steel or aluminum material properties. nnnnn_CMP.xlsm is used for steel compression ring structures. All variables shown in the preliminary Mathcad sheet will be input in nnnnn_CMP.xlsm worksheet. There are no macros in the worksheet and all calculations are performed manually and can be seen in their respective cells. Input variables required for calculations/load ratings are in cell or drop down list that have been highlighted in orange . These inputs should be directly copied over from the preliminary MathCAD file. You should start at the CMP LRFR Input tab and move to the right, filling out the orange cells in the input tab only. The CMP LRFR Output tab has some orange cells and calculations that can be modified, but this should only be done for unique circumstances. Both the CMP LRFR Input and CMP LRFR Output tabs have warnings next to calculations and parameters to let the load rater know when the range of applicability is not met.

14.3.1 CMP LRFR Input

The input tab should be directly filled in from the preliminary MathCAD file. The first input in the CMP LRFR Input is to select the “Structure Type”, which is used to determine the AASHTO Minimum Cover (AASHTO LRFD Table 12.6.6.3-1 & 12.8.3.1.1-1). This determines the value “h” below in the rating factor based on minimum cover requirements.

$$RF_{cover} = \frac{\left(H_{min}\right)^2}{C(h)^2}$$

The “Seam Type” should be selected based on helical (spiral) or annular (circular) orientation of the corrugations and seams. Select the “Structure Category” from the three available options. This determines the methodology for applying the loads to the structure as discussed above in the “Bridge Geometry & Design Data” section. The minimum and maximum fill depth values should be entered from the MathCAD preliminary file and is the value from the top of the culvert to the top of the roadway surface regardless of the pavement type. Next enter in the AASHTO Minimum Cover (H_{min}). This is not to be confused with the minimum fill height just discussed. The AASHTO Minimum Cover Orientation (C12.6.6.3) is the measured minimum fill height minus the asphalt wearing or flexible wearing surface thickness. If the wearing surface is concrete or rigid wearing surface it is equal to the minimum measured fill height. This is shown off to the right of the input in the nonprintable area.

Structure Information (from existing bridge plans & field measurements):				
Structure Type (to determine Minimum Cover):	Corrugated Metal Pipe	← choose from a drop-down list		
Seam Type (to determine Seam Strength):	Helical pipe w/ lock seam or fully welded seam	← choose from a drop-down list		
Structure Category (based on NCSPA Design Data Sheet No. 19)	Typical (NCSPA design data sheet No. 19, II. A. 1.)	← choose from a drop-down list	Warnings:	
Depth of Fill "H" (ft) = (min and max fill depth used for dead load and live load calculations)	3.00	minimum		
	4.00	maximum	No Warnings	
AASHTO Minimum Cover "H_{min}" (ft) = (fill depth used to check minimum cover depth requirement)	3.00	(AASHTO C12.6.6.3)		
Span Length "S" (ft) =	10.00			
Rise "R" (ft) =	10.00	(For documentation purposes, not used in calculations)		
Longitudinal Length of Structure "L" (ft) =	46.00			
Clear Roadway Width (Face to face of guardrail) (ft) =	30.00			
Actual Top Radius "R_t" (ft) = (can be determined by field measurements or hand calculations)	0.00	see * above		
Metal Corrugation & Gage Information:	Metal Type	Steel	← choose from a drop-down list	
	Corrugation (if known)	N/A	← choose from a drop-down list	
	Gage number (if known)	N/A	← choose from a drop-down list	
	c (in) =	3.00	**Note**: if corrugation & gage number are known, leave the input cells for "c", "d" & "t" blank; if corrugation & gage number are unknown, field measurements of "c", "d" & "t" are required.	
	d (in) =	1.00		
	t (in) =	0.111		
Pipe Crown Deflection ** (if any) =	0%			
Metal Loss based on materials field evaluation (if any) =	0%			

Figure 5: Example CMP LRFR worksheet input.

The Span Length “S” should be entered for the applied loadings to the structure for the load rating and analysis. The Rise “R” is not used for analysis but should be entered for documentation purposes and determining the shape and “Structure Category.”

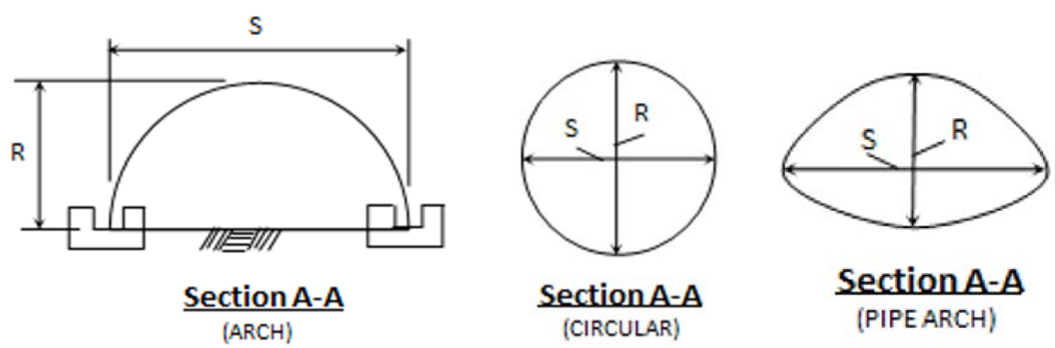


Figure 6: Definition of Span "S" and Rise "R" for culvert shapes.

Enter the longitudinal “Length” of the structure (transversely to the roadway typically) for determining the extent and the amount of live load applied along the culvert, transversely to traffic. The “Clear Roadway Width” should be entered to determine how many lanes of live load are applied to the culvert span length based on the depth of fill and geometry of the CMP Culvert. The “Actual Top Radius” (R_t) needs to be input for long span and unsymmetrical “Structure Category” types. Select the “Metal Type” from the drop down list between Steel and Aluminum. List the corrugation and gage information in one of two ways: either select the pattern of corrugation and gage number or select the c, d, t (described previously and shown below). “Pipe Crown Deflection” (%) and “Metal Loss based on field evaluation” are additional inputs that can decrease the capacity of the structure and may be used in addition to the condition factor.

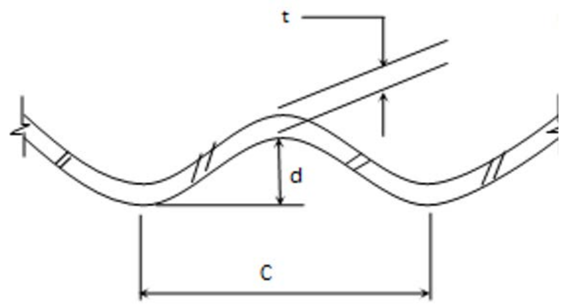


Figure 7: CMP pattern measurements; corrugation length "c", depth "d", and thickness "t."

The Pipe Cross-Section Properties parameters (As, r, & I) can be determined for standard CMP Culverts on the Section Property Tables tab based on the corrugation and gage information. Similarly the Pipe Seam Strength variable can be determined for standard CMP Culverts on the “Seam Strength Tables” tab based on the corrugation, gage, and structure type. The soil density is typically assumed to be 0.120 kcf, but may be adjusted where warranted. The live load distribution factor (LLDF) is 1.15 for LRFD per AASHTO Table 3.6.1.2.6a-1. The critical load parameter (γ_4) is input based on the rise divided by span ratio from the Critical Load Parameter Table tab. If the R/S ratio is greater than 0.5 use the value from the table based on 0.5. The Load Factors should be filled in from the **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** discussed above. Additionally the nonredundant factor (η_R) and vertical pressure (γ_{EV}) from dead load of earth fill should be input here. Lastly, the condition and system factor should be input for a final phi factor to apply to the capacity of the CMP Culvert.

Pipe Cross-Section Properties	A_s (in^2/ft) =	2.133	input these values based on metal type, corrugation, gage number or pipe wall thickness, see tables in worksheet "**section property tables**".
	r (in) =	0.6920	
	I x 10^{-3} (in^4/in) =	146.172	
Pipe Seam Strength	Seam Strength (k/ft) =	132.0	input the seam strength value based on metal type, corrugation, gage number or pipe wall thickness, see tables in worksheet "**seam strength tables**"
Backfill	δ = Soil density (k/ft^3) =	0.120	
	LLDF = Factor for Distribution of Live Load	1.15	(per AASHTO LRFD 3.6.1.2.6)
Critical Load Parameter for Arch	$Rise\ and\ Span\ Ratio\ \frac{R}{S} =$	1.00	input the value obtained from the worksheet "**Critical Load Parameter Table**" based on rise to span ratio and support type, **when R/S ≥0.5, input the value for R/S = 0.5**
	$Critical\ Load\ Parameter\ \gamma_4 = \frac{q_{cr}S^3}{EI} =$	24	
Load Factors	η_R (for nonredundant members) =	1.05	AASHTO LRFD 12.5.4. & 1.3.4
	γ_{EV} (Vertical Earth Pressure for CMPs) =	1.95	**ODOT LRFR Load Factors (See LL_Factors_State.xls or LL_Factors_Local.xlsm)**
	γ_{LL} (HL-93 Loading - Inventory) =	1.75	
	γ_{LL} (HL-93 Loading - Operating) =	1.35	
	γ_{LL} (Legal Loads) =	1.30	
	γ_{LL} (OR-CTP-2A) =	1.25	
	γ_{LL} (OR-CTP-2B) =	1.25	
	γ_{LL} (OR-CTP-3) =	1.30	
	γ_{LL} (OR-STP-3) =	1.10	
	γ_{LL} (OR-STP-4A) =	1.25	
	γ_{LL} (OR-STP-4B) =	1.00	
	γ_{LL} (OR-STP-4C) =	1.00	
	γ_{LL} (OR-STP-4D) =	1.00	
	γ_{LL} (OR-STP-4E) =	1.00	
	γ_{LL} (OR-STP-5BW) =	1.00	
Condition Factor	ϕ_c =	1.00	AASHTO MBE 2nd Edition Table 6A.4.2.3-1 & C6A.4.2.3-1
System Factor	ϕ_s =	1.00	AASHTO MBE 2nd Edition Table 6A.4.2.4-1
	$\phi_c\ \phi_s \geq 0.85$ =	1.00	

** reduction in rise divided by the span length from design shape in the unit of percentage

Figure 8: Example CMP LRFR worksheet input continued.

14.3.2 CMP LRFR Output

The CMP LRFR Output tab uses the CMP LRFR Input tab information to perform analysis and tabulate the load ratings. Orange shaded areas in Output tab are required input. If the culvert has fill depth/depths greater than the span length of the structure and 8ft then the effects of live load may be neglected (see AASTHO LRFD 3.6.1.2.6). A Dead Load Evaluation is tabulated when live load is neglected due to deep fill (wall thrust capacity divided by vertical earth pressure wall thrust force).

14.3.3 Load Rating Summary

Click on the Load Rating Summary tab to view the calculated rating factors from the CMP LRFR Output tab. These rating factors are manually copied and pasted into the Rating Factor Summary sheet. In the Rating Factor Summary sheet leave deck and substructure condition ratings blank. Enter NBI 62 (Culvert Rating) as the Superstructure condition rating. If “Dead Load Evaluation” load ratings are being tabulated in the CMP LRFR Load Rating Summary tab, overwrite the “SPECIAL” truck, set the load factor to 1.95, and verify these are also copied and pasted into the Rating Factor Summary sheet.

14.3.4 Reference Tables

This tab contains VLOOKUP information and drop down list options used on the input and output tabs. This includes AASHTO Minimum Cover heights, structure type, seam type, structure category, minimum top arc thicknesses for long span structural plate culverts, metal type properties, gage information, and corrugation information.

14.3.5 Live Load

The live load tab calculates the longitudinal distribution of the vehicles through varying depths of fill. The transverse distribution is calculated on the CMP LRFR Output tab. Different axle configurations are calculated for the different trucks. The controlling axle configuration is then used in the table at the bottom of the tab which is the live load that is applied to the culvert at the minimum and maximum fill depth cases.

14.3.6 Section Property Tables

This tab is imported information from AASHTO LRFD Section 12, Appendix A12. The cross sectional properties are given in the tab for standard CMP Culverts. With the steel table above and the aluminum table right below. On the left find the standard thickness of the culvert and then follow the row to the right to determine the area of steel (A_s), radius of gyration (r), and the moment of inertia (I) for a specific corrugation pattern and structure type. Alternatively the variables can be found from a manufacturer, drawings, or they can be calculated.

14.3.7 Seam Strength Tables

This tab is also from AASHTO LRFD Section 12, Appendix A12 and is for the longitudinal seam on standard CMP Culverts. Just as the Section Properties Tables tab first locate the aluminum (bottom) or steel table (top). From the thickness of the CMP Culvert and the corrugation pattern you can then determine the minimum longitudinal seam strength to input. Alternatively this value could be used if listed on the drawing or calculated and shown in the preliminary MathCAD file.

14.3.8 NCSPA Design Data Sheet No. 19

This tab of the worksheet is the original copy of the NCSP Design Data Sheet No. 19 for load rating and structural evaluation of in-service corrugated steel structures. This is the original methodology developed for load rating CMP Culverts. AASHTO is referenced throughout the document. This document is the basis for the load rating approach in this worksheet.

14.3.9 Critical Load Parameter Table

The Critical Load Parameter Table tab comes from the *Guide to Stability Design Criteria for Metal Structures,* 5th Edition, T. Galambos. The Three-Hinged Arch Column in the table should be used conservatively. Choose h/L based on the CMP Culvert rise/span. This input variable is for shallow cover fill depths for CMP Culverts that are less than the AASHTO Minimum Cover requirements. This can be viewed under the “Check Minimum Earth Cover” section of the CMP LRFR Output tab. If the critical intensity of distributed load (q_{cr}) is less than the calculated maximum distributed load (q_{max}) then the AASHTO Minimum Cover is modified (h_{mod}), otherwise the standard AASHTO Minimum Cover value is reported for the load rating.

14.3.10 Submittals

Select the first three tabs to print for the calculation book (CMP LRFR Input, CMP LRFR Output, and Load Rating Summary). Not all of the worksheets need to be printed. Page formatting has been automated, but the user should review the printed documents and perform additional formatting as necessary for the calculation book.

14.3.11 Special Considerations

The tools and spreadsheets developed herein have been for corrugated metal pipe (CMP) culverts. These are compression ring structures that have little moment demand. During development of these tools a structural plate box culvert (Bridge 671229) was load rated. The example files may be used as an approach for the load ratings. This structure is controlled by moment and uses AASHTO LRFD Section 12.9 and NCSPA Design Data Sheet No. 19 for the basis of the load rating analysis. The example sheet was modified from an Ohio DOT load rating worksheet.

SECTION 15: LOAD RATING CONCRETE BRIDGES WITHOUT EXISTING PLANS

This procedure pertains to concrete bridges (reinforced or prestressed) that have no plans *and* whose cross-section cannot be estimated from field measurements. Standard precast prestressed concrete slabs and boxes can normally be determined from field measurements. Contact the ODOT Load Rating Unit for questions regarding standard members. The following procedure is NOT a load and resistance factor rating (LRFR), but is rather a load rating that is based on engineering judgment.

15.1 Methodology

Without as built plan sheets, the bridges capacity cannot be calculated. Although the loads could still be factored, the resistance cannot be determined therefore, the LRFR methodology cannot be used. In these situations the service history, span configuration, and member condition will be used to assign the bridge an operating and inventory rating factor.

If a concrete bridge without plans has a long history of service (20 years or more), successfully carrying Oregon Legal Loads without distress, its safe capacity can be assumed to be equal to the worst load effect of the Legal Loads (up to the SU4 vehicle). The HL-93 Design Truck Load Inventory Rating can be considered to be in proportion to the load effect of the Legal Truck Loads. This assessment should then be reduced to account for NBI condition ratings that involve advanced deterioration or section loss (“Poor” or lower).

15.2 Preliminary Files for Superstructure (Mathcad)

For reinforced concrete bridges without existing plans, the preliminary file name and extension for superstructure analysis is SUPERSTRUCTURE.xmcd.

Note: Because the dot multiplier symbol is very small and can easily be overlooked in Mathcad printouts, when typing equations, surround all multiplied factors with parentheses.

15.2.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description (“Spans” field) from the Bridge Log is adequate for this purpose.

Note: the Mathcad regions at the top in the right margin (outside the printable area) are there for 2 purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

15.2.2 Condition Factor

Condition factors used in this analysis are **NOT** the same condition factors from MBE T6A.4.2.3-1 which are reproduced in section 1.4.1.3. The factors listed in Table 8.2.2-1 are not to be used for LRFR analysis. Due to the increased uncertainty in this method of analysis, the condition factors will more severely impact the overall load rating when compared to the LRFR condition factors.

Document any decisions regarding the condition factor of the bridge in this section. In addition to the superstructure condition rating (NBI Item 59), also consider the substructure condition rating (NBI Item 60). Review the inspection notes for any deficiencies in pile caps or crossbeams. If there are notes regarding crossbeams in poor condition, and this condition factor is less than the value listed for the superstructure, then use the substructure condition rating when determining the condition factor.

Table 8.2.2-1

NBI Item 59 (or 60), Superstructure (or Substructure) Condition Rating	Condition Factor (CF)
5 “Fair Condition” or better	1.00
4 “Poor Condition”	0.50
3 “Serious Condition” *****	0.25
2 “Critical Condition” *****	0.12

- For bridges in “Serious” or “Critical” condition, a case-by-case posting evaluation and immediate action are required. Engineering judgment should always be used when determining the necessary immediate action. Examples of immediate action include but are not limited to; restricting traffic to one lane, posting for the minimum of 3 tons GVW, or closure.

15.2.3 Span Layout

Document the span lengths that will be used for analysis. Only unique span lengths should be evaluated. Span lengths can be pulled from the bridge log, field measurements, or the bridge inspection report. Without detailed plans these span lengths will be considered approximate.

Spans will generally be considered to be simply supported. Without detailed as-built drawings showing negative moment steel over interior supports, it is difficult to determine if a structure is continuous. For the purpose of this analysis, it is reasonable to assume that all spans are simply supported for dead and live loads.

15.2.4 Live Loads

List the live load cases for use in analysis. These should always be as shown below:

HL-93 Design Truck
HL-93 Design Tandem
HL-93 Design Truck Train
Design Lane Load
Oregon Legal Type 3 Truck
Oregon Legal Type 3S2 Truck
Legal Type 3-3 Truck
Oregon SU4 Legal Truck
Oregon SU5 Legal Truck
Oregon SU6 Legal Truck
Oregon SU7 Legal TruckFAST Act EV2 Truck
FAST Act EV3 Truck

15.2.5 Analysis Sections

Document the locations that will be analyzed. Normally this will include the BRASS default 1/10th points and 0.45L of the span. Due to variation in axle spaces the maximum live load moment may not be at 0.50L. Therefore, 0.45L will also be analyzed.

15.2.6 BRASS Results

BRASS analysis instructions are listed in section 8.3. The results from the analysis will be documented here for rating factor computations.

After successfully running the BRASS analysis, open SUPERSTRUCTURE.OUT. Scroll down to where the live load girder actions are reported. The BRASS output heading for this section is:

```
            ** UNFACTORED GIRDER ACTIONS DUE TO APPLIED LIVE LOADS **
(Adjusted for Dynamic Load Allowance, Distribution Factors, and Live Load Scale Factor)
                        ** CONSTRUCTION STAGE 1 **
```

This section of the BRASS output file will report the moment, axial, shear, reaction, and deflection actions due to the five live load cases that were defined for analysis. For each load case, go through the analysis points and report the maximum moment.

Below is an example of the BRASS Output file for live load case 1 (AASHTO LRFD HL-93 Design Truck):

POINT NO.	MOMENT POS (ft-kips)	MOMENT NEG (ft-kips)
1-0.000	0.0	-0.0
1-0.100	64.4	0.0
1-0.200	104.3	0.0
1-0.300	127.0	0.0
1-0.400	144.8	0.0
1-0.450	149.1	0.0
1-0.500	150.5	0.0
1-0.600	144.9	0.0
1-0.700	127.0	0.0
1-0.800	104.3	0.0
1-0.900	64.4	0.0
1-1.000	0.0	-0.0

Calculate the maximum moment for the HL-93 Design Vehicle, the standard legal vehicles, and the legal Specialized Hauling Vehicles (SHVs).

The maximum legal load moment will be the greater moment of the following four load cases:

- Oregon Legal Type 3
- Oregon Legal Type 3S2
- Oregon Legal Type 3-3
- Oregon SU4

Maximum HL-93 moment will be the maximum of the following 3 load cases:

- HL-93 Design Truck with the maximum HL-93 Design Lane
- HL-93 Design Tandem with the maximum HL-93 Design Lane
- HL-93 Design Truck Train with the maximum HL-93 Design Lane

15.2.7 Rating Factor Calculations

The maximum moment effect from the legal load trucks is assumed to result in a rating factor equal to 1.0, if the bridge has a history of successfully carrying Oregon legal loads, and has a condition rating greater than or equal to fair. The condition of the bridge is taken into account with the condition factor specified in section 15.2.2. Use equation 15.2.7-1 to calculate the rating factor for the Oregon Legal trucks and the HL-93 Inventory rating.

$$RF_{LoadCase} = \left(\frac{M_{Legal}}{M_{LoadCase}}\right) * (CF) \qquad \text{(Equation 15.2.7-1)}$$

Where: M_{Legal} is the maximum legal load affect from the Type 3, Type 3S2,Type 3-3, and SU4 loading.

$M_{LoadCase}$ is the maximum load affect for the load case of interest. This will be for the other legal loads that have lesser load effects than that used for M_{Legal}, the load effects for the SU5, SU6, and SU7 vehicles, and the load effects for the Continuous Trip and Single Trip Permit Vehicles.

CF is the condition factor from section 15.2.2.

Due to Specialized Hauling Vehicles being relatively new technology, ODOT feels that most bridges have not supported a large population of these vehicles during their service life. Being that the multiple, closely spaced axles, of these vehicles can produce load effects (for some bridges) greater than 50% of what is seen from the standard legal vehicles, ODOT has decided to not allow the SU5, SU6, and SU7 vehicles to cross concrete bridges without plans without some sort of load restriction. For most bridges, these vehicles will result in higher load effects than the standard legal vehicles and the SU4. Since these procedures will set the rating factor to 1.0 for the greatest load effect of the standard legal vehicles and SU4 vehicle for bridges that have a fair or better condition rating, these procedures will result in rating factors less than 1.0 for the SU5, SU6, and SU7 vehicles and for most permit vehicles. This will require that every bridge that is rated by this procedure will end up being load posted for these vehicles.

The rating factor the HL-93 Operating level is calculated using equation 15.2.7-2.

$$RF_{HL93\_Operat} = \left(RF_{HL93\_Invent}\right) * \left(\frac{5}{3}\right) \qquad \text{(Equation 15.2.7-2)}$$

Where: RF_{HL93_Invent} is the inventory rating factor calculated for the HL-93 truck loading using equation 15.2.7-1.

15.3 BRASS Analysis

BRASS-GIRDER will be used to evaluate the live load comparison. BRASS-GIRDER is different from the previous BRASS-GIRDER(LRFD) program in that it no longer uses text file inputs, but instead utilizes a Graphical User Interface (GUI) with data saved in xml file format. Instead of developing new procedures to populate the GUI of BRASS-GIRDER, this manual will continue to give instructions on how to create the text input file for BRASS-GIRDER(LRFD). Once the file is ready for analysis, the user will run the text input file through the BRASS-GIRDER translator that will create the xml input file used to populate the new GUI. From there the user will be able to run the analysis within BRASS-GIRDER. Because only live load moments are needed, the BRASS-GIRDER(LRFD) input file commands will be substantially different than a normal LRFR analysis.

15.3.1 BRASS Input File Conventions

Use the heavily commented sample file provided as a template, copied to a new bridge-number-specific folder (with a new filename if appropriate) and then modified for the actual Load Ratings.

- General conventions

  Use the full length of each command name except the COMMENT (3-1.1) command shall be only COM.

  Precede each command or logical group of similar commands (except for the COMMENT command) with a comment referring to the Article number in the BRASS-GIRDER(LRFD) Command Manual. For example, precede an ANALYSIS (4-1.1) command with a comment command thus:

  ```
  COM 4-1.1
  ANALYSIS B, 1, REV, T, N
  ```

  Generally, leave in all comments found in the template (unless they become totally irrelevant to a particular input file), modifying them and adding more comments as required to fit the specific conditions of the rating. Use comments liberally with the expectation that someone unfamiliar with the BRASS-GIRDER(LRFD) program and unfamiliar with the bridge will need to read the data file and fully understand it.

  Leave parameters blank (spaces between commas) where they are irrelevant to the specific structure. Although trailing commas can be omitted where all parameters to the right are to be blank, it is recommended to clarify your intentions by showing the blank parameters separated by commas. However, avoid leaving blank parameters such as material strengths where default values would apply. Enter the default values to make the dataset more meaningful to a future user.

  Show in-line calculations (what the BRASS Manual calls in-line arithmetic) within a parameter (between commas) to convert units from feet to inches where the command parameter requires inches. However, note that BRASS has the following limitations on in-line calculations: It cannot handle parentheses within in-line calculations, and it cannot correctly handle more than one multiplication or division operator in any one term, i.e. use no more than one multiplication or division between plus and minus signs. Other than these in-line calculations, the best place to put calculations is in the Preliminary File rather than in the BRASS comments.

  Whenever a BRASS-GIRDER(LRFD) input file contains a series of occurrences of the same command, vertically aligning the same command parameters for clarity is encouraged. This practice simplifies the process of changing values of parameters when cloning an old BRASS file for use in a new bridge. Inserting spaces as required to accomplish this is harmless. However, do not use tab characters to accomplish this. They are misinterpreted by BRASS-(LRFD) as the next parameter, and are likely to cause fatal errors.

- Input File Sections

  To make it easier for a subsequent user to find their way around the Input File, separate the BRASS input file into logical sections (large groups of commands) by using spaced comments as indicated in the sample files. Typically, an input file for an RCDG will be divided into the following sections:

  ```
  COM
  COM  ***** Live Load Analysis Only *****
  COM

  COM
  COM  ***** Material Properties *****
  ```

```
COM

COM
COM  ***** Section Geometry *****
COM

COM
COM  ***** Span Length and Section Information *****
COM

COM
COM  ***** Live Loads *****
COM

COM
COM  ***** Distribution Factors *****
COM

COM
COM   ***** Critical Flexural Sections *****
COM
```

- Specific conventions

At the beginning of every input file, use the BRIDGE-NAME (2-1.3) command to provide the 5- or 6-character NBI Bridge Number, followed by the Bridge Name. Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Next, use the ROUTE (2-1.5) command to provide the mile point and signed Route Number where applicable (always required for State-owned bridges). Note the signed Route Number is not the same as the ODOT internal (maintenance) Highway Number.

Use 2 lines of the TITLE (2-1.6) command. Use the first TITLE line to provide the file name and describe which girder(s) this file applies to. Use the second TITLE line to provide the purpose or work grouping of the Load Rating.

Use the AGENCY (2-1.1) command to identify the Load Rating as being performed according to ODOT standards. This command should always be the same:

```
COM 2-1.1
AGENCY Oregon DOT
```

Use the ENGINEER (2-1.2) command to indicate the load rater.

Use the UNITS (2-1.4) command to force BRASS to always use US (English) units for both input and output. BRASS normally defaults to US units, but it has been found that when referenced dimensions get large, BRASS will automatically assume the large dimensions are in millimeters and will convert the units when it calculates the resistance of the member. Using the UNITS command will not allow BRASS to arbitrarily convert the units during an analysis.

```
COM 2-1.4
UNITS US
```

Use the ANALYSIS (4-1.1) command to provide BRASS with parameters needed to do a rating analysis. The “continuous beam model” is the preferred choice (“B” in parameter 1) as long as there is no need to include columns in the analysis and the bridge has $\leq$ 13 spans.

Parameter 3 is coded as “REV” because rating factors from this analysis will not be used. Only the live load effects will be pulled from the BRASS output. This command would normally be the same:

```
COM 4-1.1
ANALYSIS B, 1, REV, T, N,
```

Use the POINT-OF-INTEREST (4-1.2) command to set BRASS to generate user-defined points of interest from subsequent OUTPUT-INTERMEDIATE (5-2.1) commands.

```
COM 4-1.2
POINT-OF-INTEREST U
```

Leaving the 2nd parameter of BRASS command 5-1.1 blank causes BRASS to not report a large additional output file for each point of interest. The additional output information is not normally needed. Use of “Y” for parameter 2 to turn on this additional output may be justified at sections where there is a need to account for partially developed bars. If these additional .OUT files are generated, they do not need to be printed in the Load Rating Report.

Use the OUTPUT (5-1.1) command to control the wide variety of output options. Code the first parameter with “2L” to output the live load actions at all node points. Dead loads do not need to be output for this analysis. This command would normally be the same:

```
COM 5-1.1
OUTPUT 2L, N, , , 1, , , , , , , , ,
```

Beginning with BRASS-GIRDER(LRFD) v.1.6.1, the effective top flange width is calculated and applied to the section properties automatically. Use the OUTPUT-EFF-WIDTH (5-7.3) command to direct BRASS to not output its effective flange width calculations. This command would normally be the same:

```
COM 5-7.3
OUTPUT-EFF-WIDTH N
```

Code all BRASS models in the same direction as the girder elevation appears on the plans, i.e. from left to right on the plans, regardless of mile point direction.

In the “Material Properties” section, use the CONC-MATERIALS (8-1.1) command to provide the material properties consistent with the notes on the bridge plans. Although there are exceptions, a typical RCDG structure from the 1950’s or early 1960’s would have the following properties command:

```
COM 8-1.1
CONC-MATERIALS 0.15, 3.3, 40.0, 40.0, 9, , , 170.0, , ,
```

In the “Section Geometry” section, define one rectangular section. Since this is only a live load moment comparison the actual cross section does not need to be used. Capacities and dead loads will not be calculated. Define a 12” wide rectangular concrete section. This command would normally be the same:

```
COM --- Section 1
COM 8-2.2
CONC-RECT-SECTION 1, 12, 12
```

In the “Span Lengths and Section Information” section, define each span beginning with the appropriate command from Chapter 11 of the *BRASS-GIRDER(LRFD) Command Manual.* Variation in the girder profile need not be accounted for. Follow this command with a SPAN-

SECTION (11-2.1) command to assign the previously defined section to cumulative ranges from the left end of the span. The following is an example of the series of commands to define one span:

```
COM --- Span 1, 19.00' Geometry

COM 11-1.5, 11-1.6, 11-2.1
SPAN-GENERAL-LENGTH 1, 19.00*12
SPAN-GENERAL-SEGMENT 1, 12.00, L, 19.00*12, 12.00
SPAN-SECTION 1, 1, 19.00*12, 1
```

Use the SUPPORT-FIXITY (11-4.1) command to define the boundary conditions of each span, for example:

```
COM --- Support Fixities

COM 11-4.1
SUPPORT-FIXITY 1, R, R, F
SUPPORT-FIXITY 2, F, R, F
```

15.3.2 BRASS Input Adjustments

- BRASS-GIRDER(LRFD) Input Adjustment Type 1-2: These adjustments that are normally listed in the Sections for other bridge types are not necessary for this analysis. The rating factors from this analysis are not being used, only the unfactored live load truck moments are of interest.

- BRASS-GIRDER(LRFD) Input Adjustment Type 3:

Using the BRASS-GIRDER(LRFD) LOAD-LIVE-CONTROL (12-4.1) command to apply the default Design and Legal Load sets would have 3 undesirable consequences:

(a) BRASS would apply the Fatigue Design Load that is not needed for RCDG structures, generating unwanted output
(b) BRASS would default to listing the Design Load outputs *after* all the other loads, potentially causing confusion in transferring loads to the ODOT Load Rating Summary Workbook
(c) BRASS would apply the AASHTO 3S2 Legal Load which is lighter than the Oregon Legal 3S2 load.

Therefore, use the LOAD-LIVE-DEFINITION (12-4.3) commands to define each Design and Legal Load separately, and use the LOAD-LIVE-CONTROL (12-4.1) command to define only parameter 1 (direction control, normally "B" for traffic in both directions) and parameter 7 (wheel advancement denominator, normally 100), as follows:

```
COM  BRASS-GIRDER(LRFD) INPUT ADJUSTMENT TYPE 3:
COM  All live loads will be entered individually
COM  Design Loads entered as live load definitions  1 thru  4
COM  Legal  Loads entered as live load definitions  3 thru  9

COM 12-4.1
LOAD-LIVE-CONTROL B, , , , , , 100
```

In structures with short spans, especially short cantilevers, BRASS may "crash" because the span is divided into live load advancement increments that are too small. If this occurs and you have a small span, try decreasing parameter 7 to the largest number for which BRASS will work, often 50 or sometimes even less.

Thus the complete live load definition command set is as follows:

```
COM Code the HL-93 Design Vehicles, Oregon Legal
COM trucks, and Oregon Permit Vehicles for use in
COM moment comparison. Do not code any live load
COM scale factors (Parameter 6). Live load factors
COM will be set to 1.0 for all vehicles.

COM 12-4.3
LOAD-LIVE-DEFINITION  1, HL-93-TRUCK , DTK, D, ,
LOAD-LIVE-DEFINITION  2, HL-93-TANDEM, DTM, D, ,
LOAD-LIVE-DEFINITION  3, HL-93-TRKTRA, TKT, D, ,
LOAD-LIVE-DEFINITION  4, HL-93-LANE  , DLN, D, ,
LOAD-LIVE-DEFINITION  5, OR-LEG3     , TRK, L, ,
LOAD-LIVE-DEFINITION  6, ORLEG3S2    , TRK, L, ,
LOAD-LIVE-DEFINITION  7, ORLEG3-3    , TRK, L, ,
LOAD-LIVE-DEFINITION  8, OR-SU4      , TRK, L, ,
LOAD-LIVE-DEFINITION  9, OR-SU5      , TRK, L, ,
LOAD-LIVE-DEFINITION 10, OR-SU6      , TRK, L, ,
LOAD-LIVE-DEFINITION 11, OR-SU7      , TRK, L, ,
LOAD-LIVE-DEFINITION 12, EV2         , TRK, L, ,
LOAD-LIVE-DEFINITION 13, EV3         , TRK, L, ,
```

- BRASS-GIRDER(LRFD) Input Adjustment Type 4:

Using the LOAD-LIVE-DYNAMIC BRASS Command 12-4.2, code the fixed impact percentage to 00.0% for all load cases. Since this is only a live load moment comparison, no impact will be applied. The following commands should not be changed:

```
COM Impact is not varied for load comparison. Code 00.0%
COM fixed impact (Parameter 2, and 3) for all load cases.

COM 12-4.2
LOAD-LIVE-DYNAMIC D, 00.0, 00.0,
LOAD-LIVE-DYNAMIC L, 00.0, 00.0,
```

Using the DIST-BEAM-SCHEDULE BRASS command (12-5.1) will manually set the distribution factors equal to 1.0. This analysis is only to compare live load effects. Coding the distribution factors to 1.0 will allow the user to compare unfactored live loads. The following commands should remain unchanged:

```
COM Forces distribution factors equal to 1.0
COM 12-5.1
DIST-BEAM-SCHEDULE 1, V, 1.0, 1.0, , ,
DIST-BEAM-SCHEDULE 1, M, 1.0, 1.0, , ,
DIST-BEAM-SCHEDULE 1, D, 1.0, 1.0, , ,
```

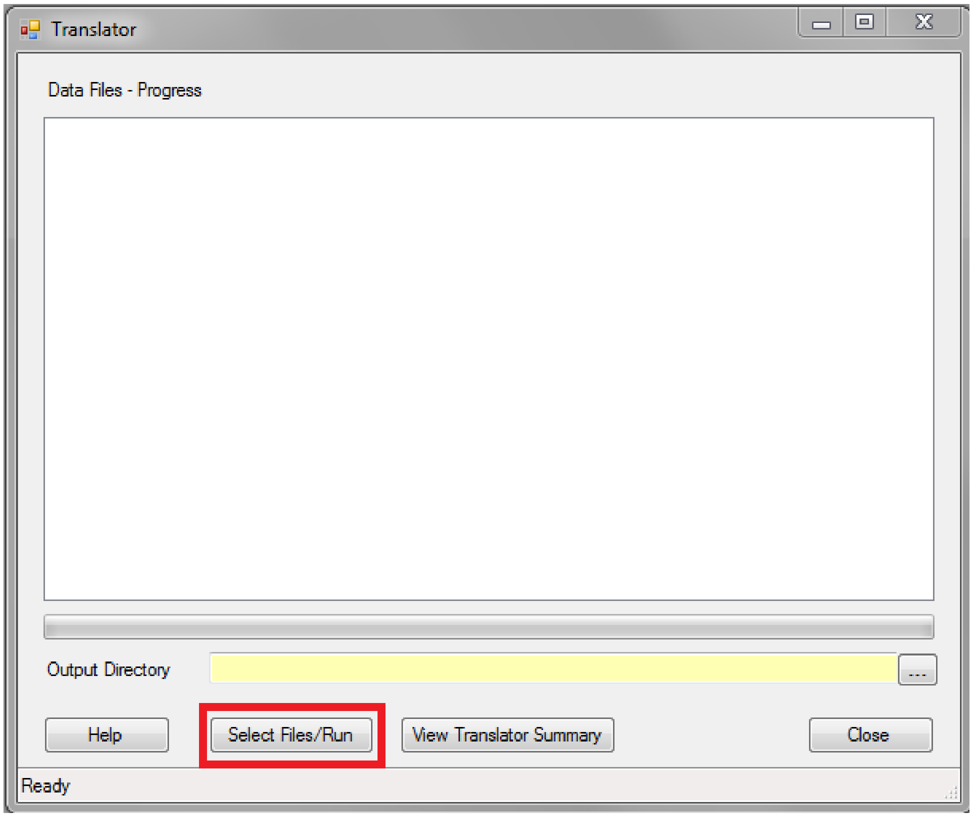
15.3.3 Running BRASS

Open the BRASS-GIRDER GUI interface. Because it is more efficient to use BRASS-GIRDER(LRFD) Input Files generated from previous ones, the GUI interface will not be used to generate input files.

The BRASS-GIRDER(LRFD) input file must first be translated into a BRASS-GIRDER xml file that will then populate the GUI interface in BRASS-GIRDER. The steps for translating and running the input files in BRASS-GIRDER is as follows:

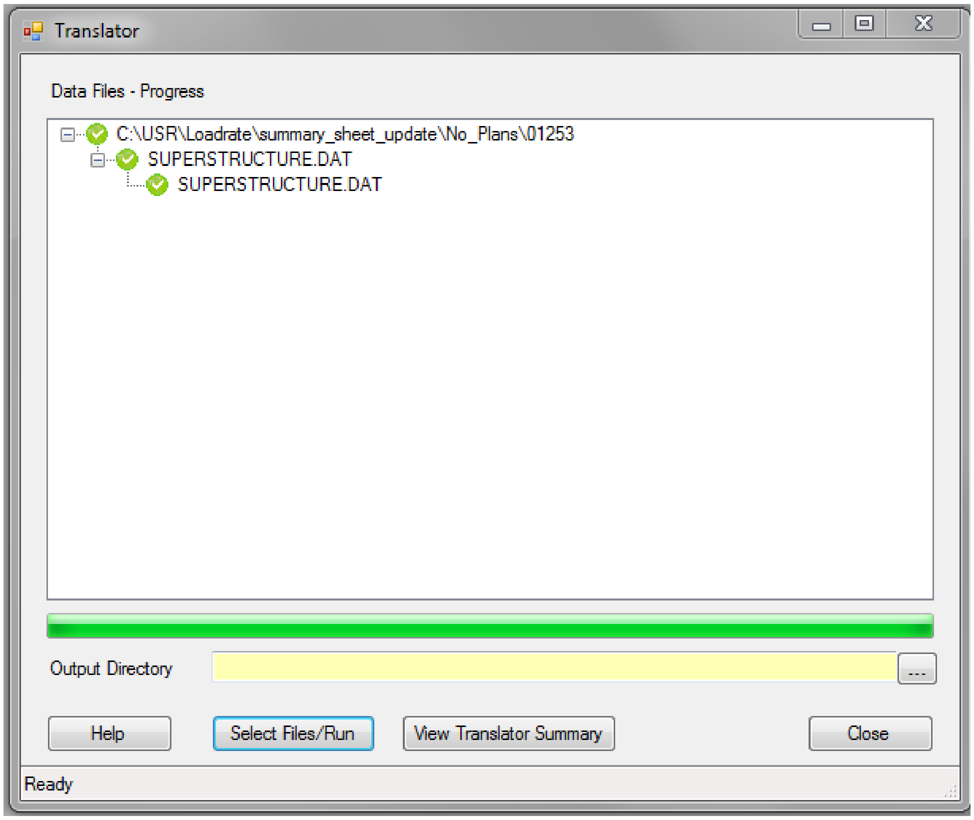
1. Start the BRASS-GIRDER program. From the “File” menu, hover your mouse pointer over “Translate (DAT to XML)”. Select the option for “BRASS-GIRDER(LRFD)”.

2. The Translator window will then open on your screen. Click on the button that says “Select File/Run”, as shown in the red outlined box in the following figure.



3. In the next window that appears, navigate to the location where the BRASS-GIRDER(LRFD) input file that you wish to run is stored, and select that file. Click on the “Open” button at the bottom right of this window.

4. The Translator window will then open back up and the selected file will run through the translation. If there are any errors detected during the translation, a red “X” will be displayed next to the file name in the window and an error file will be generated. Refer to the error file to decipher what is causing the error during translation. Once corrected, follow these steps again to translate the file. If successful, a green check will appear next to the file name as shown in the following figure:



5. Click the “Close” button at the bottom right of the Translator window. Within BRASS-GIRDER, select “Open” under the File menu. Select the BRASS XML file that was just created from the Translator program. Click on the “Open” button at the bottom right of this window.

6. BRASS-GIRDER will then load the model into the GUI. Under the “Execute” menu, select “Analysis Engine” to run the analysis. Or you can simply click on the green traffic light icon on the toolbar.

7. Verify that the output directory is the same as where the input files are located, and then click the “OK” button. A black DOS window will appear showing program progress. Depending on your system speed and memory and the complexity of the structure, the execution process may take a few seconds or several minutes. Upon completion of the analysis, a text output file will be generated within the same directory. You can now use a text editor to open and view the BRASS output.

When making changes or corrections to BRASS files, ODOT prefers that all changes be made within the BRASS-GIRDER(LRFD) input file so that it becomes the master document for the BRASS model. Reviewing this text input file will be quicker and more efficient than trying to navigate the GUI to verify that the bridge is being modelled correctly. Thus, any time the text input file is modified, the above steps will have to be repeated to translate the text input file into a BRASS XML file before the analysis is re-ran in BRASS-GIRDER.

15.3.4 BRASS Errors

If an error file is generated (same prefix, .ERR extension), open this file with your text editor and try to interpret what BRASS is telling you. The vast majority of error messages will point you to a straightforward typographical error or omission in your input. At the beginning of your experience with BRASS, do not expect a successful execution until one or more typographical errors have been

corrected.

When executing BRASS-GIRDER, if you get an error message regarding zeros in the stiffness matrix, look at the ANALYSIS (4-1.1) command, parameter 1, and check to see if you are running a Frame type model on a structure with more than 6 spans. In such cases the Beam type model (the recommended default) is required (with a maximum of 13 spans).

When executing BRASS-GIRDER, you may get an error message stating, "*The effective web width (b_v) cannot be zero. This causes a divide-by-zero error in the compression field computations.*" This most likely means that you have selected points that are too close to another defined point of interest within your BRASS input file. A general rule is not to have points closer than six inches from one another. Verify in your input file that you have correctly entered the web width parameter while defining your BRASS sections. Also check in the "Span Length and Section Information" portion of the input file to see that the ranges of the elements are not too close to each other.

A rare error can sometimes occur in executing BRASS-GIRDER where the processing of the analysis takes a considerable amount of time, and then produces a very large output file (around 600 megabytes) along with an error file. The program will report an "Interpolation Error". This occurs on files that have a BRASS span of 99.99 ft and was attempting to increment each truck across the span at 100 increments (as specified in the LOAD-LIVE-CONTROL command). We found that one of two simple workarounds can correct the error: 1) round the BRASS spans from 99.99 ft to 100.00 ft, or 2) increase the live load increment from 100 to 105 in the LOAD-LIVE-CONTROL command. The second method is the preferred option as it only requires a correction in one command, where as adjusting the span lengths would have required doing it for multiple spans for the bridge that experienced this error.

When executing BRASS-GIRDER, if you get an unexpected termination of the program while attempting to run a file, check the BRASS error file (*.err) to see if it states that, "Standard Vehicle: OLEG3S2 is not presently stored in the standard vehicle library file." This usually means that the user did not update the names of the Legal Vehicle in the BRASS input file. In the early part of 2009, ODOT made a small revision to the vehicle library so that both the old Tier 1 and LRFR rating methodologies would use the same legal vehicles for their analysis. As a result, ODOT changed the names of the legal vehicles. To correct the error, make the following changes to the names of the legal vehicles in the BRASS input file:

Original Vehicle Names	Previous Vehicle Name	Current Vehicle Name
OLEG3	ORLEG3	OR-LEG3
OLEG3S2	ORLEG3S2	ORLEG3S2
OLEG3-3	ORLEG3-3	ORLEG3-3
SU4	SU4	OR-SU4
SU5	SU5	OR-SU5
SU6	SU6	OR-SU6
SU7	SU7	OR-SU7

15.3.5 BRASS Output Files

BRASS-GIRDER has been known to "run perfectly" and still produce completely wrong results. Although a successful run may indicate a lack of errors, it is prudent to search the main output (**.**OUT) file for the words "error" and "warning" to check out the seriousness of the problem, and to do a "reality check" on the Rating Factors. Unexpected Rating Factor results often indicate an error in the BRASS coding.

We recommend that, at the very least, load raters routinely employ the following two BRASS verification measures:

(1) Do a reasonability check on the section properties. This is why we routinely code "Y" in

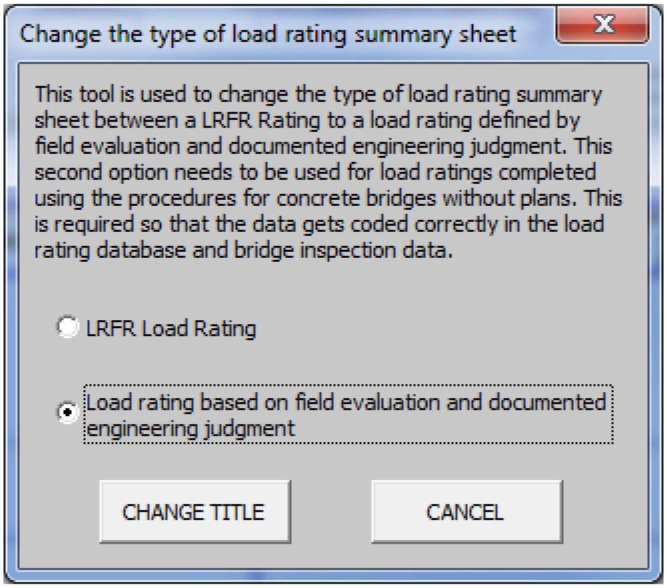
parameter 2 of the OUTPUT (5-1.1) command, to provide a list of girder properties at each node point. (Search the Output File for "Calculated Properties" in each span). It is not uncommon to make errors in the concrete section definitions, the SPAN-UNIF-HAUNCH (11-1.3) command or the SPAN-SECTION (11-2.1) commands that can result in a girder profile that is quite different than the one you expected.

(2) Do a reasonability check on the distribution of shears and moments across the structure. This is especially critical if you have an expansion joint within the structure that you have modeled by coding a hinge near one of the internal supports. Check if you are getting nearly-zero moments at the support next to the hinge. (It can't be truly zero because of the offset of the hinge from the support, but the moment value should be quite low). There have been cases where, due to numerical instabilities in the analysis process, unreasonably high moments were present at the support. The solution is usually to increase the offset of the hinge from the support in small increments until the reported moments behave as expected (sometimes increasing the offset by hundredths of a foot can make all the difference!).

If you really have doubts about what BRASS is giving you, be aware that you can use additional commands in the OUTPUT- group (BRASS-GIRDER(LRFD) Manual, Chapter 5) to generate additional output that may facilitate your detective work. Use caution – the size of this output can be daunting.

15.4 Reporting Rating Factors

The rating factors that were calculated in SUPERSTRUCTURE.XMCD will be reported using the LRFR Load Rating summary sheet. Since these procedures for rating concrete bridges without plans do not produce a LRFR load rating, the user needs to select the "CHANGE TYPE OF LOAD RATING" button along the bottom of the load rating summary sheet. This will then open the following dialog box:



For this type of load rating, the user needs to select, "Load rating based on field evaluation and documented engineering judgment." Then click the "CHANGE TITLE" button at the bottom left of the dialog box. In doing so, the title of every page in load rating summary will be changed from "LRFR Load Rating" to "Engineering Judgment Load Rating." Making this distinction is necessary so that the load rating method is recorded correctly within the National Bridge Inventory (NBI).

15.4.1 Getting Started

Open the Excel template **LR.XLTM** and, after filling in the Bridge Number cell, use File / Save As to save it in the bridge-specific Load Rating folder using the bridge-specific file name LRnnnnnn.XLSM, where nnnnnn is the 5- or 6-digit NBI Bridge Number. The same template will be used for both State and Local Agency Load Rating Summary sheets. **LR.XLTM** contains all the code necessary to run the built-in VBA modules (no separate file is required).

Note: The practice of starting with a complete summary workbook from a previous bridge as a seed file instead of beginning with a blank LR.XLTM template is discouraged. Eventually, the practice of copying seed files from previous load ratings will result in lingering errors from old data, a summary workbook that does not function properly, or one that does not report results consistent with current standards. Always begin a new bridge with a fresh LR.XLTM template. With the possibility of continuing development of the template or changes in reporting requirements, occasionally the template will be updated on the ODOT FTP site, and users will be notified to retrieve the updated file. Note: due to truck name changes required by the anticipated consolidation of BRASS-Girder(STD) and BRASS-GIRDER(LRFD), a different version of **LR.XLTM** is required for use with BRASS-GIRDER(LRFD) Version 7.4 and later. To maintain backwards compatibility with old load ratings, both the old and new versions of **LR.XLTM** are stored in separate folders on the ODOT FTP server.

15.4.2 Summary Workbook Features

The Load Rating Summary Workbook is divided horizontally into the Load Rating Summary Report (Page 1) and the Load Rating Worksheets (Pages 2 and above). The Rating Factors and section information for each investigated section are listed in the Load Rating Worksheets with one column allocated to each investigated section (8 sections per page). This information is summarized by copying the most critical and second most critical sections for each rating vehicle into the Load Rating Summary Sheet (Page 1), by clicking on the **Refresh** button or typing Ctrl-r.

The Load Rating Summary Report (Page 1) is divided vertically into a Bridge Header Area (top half) and the Controlling Rating Factor Area (bottom half). The Header Area contains basic National Bridge Inventory information and certain parameters that may have an influence on the outcome of the Load Rating. The Controlling Rating Factor Area lists the rating vehicles and their live load Factors along the left edge and two groups of columns for the 1st and 2nd controlling members. Each group of columns provides the Rating Factor (R.F.), Limit State, force type (+M,-M or V), combined Resistance Factor (Φ), member description, span and location of the investigated section. Note the Φ column heading refers to the combined Resistance Factor $\Phi = \phi\phi_c\phi_s$.

In both the Load Rating Summary Report (Page 1) and the Load Rating Worksheets (Pages 2 and above) of the Load Rating Summary Workbook, the rating vehicles are divided into horizontal bands (groups of rows) for Design and Legal Loads, CTP (Continuous Trip Permit) Vehicles, and STP (Single Trip Permit) vehicles. The bottom band of rows provides additional Rating Factors for a single lane of STP vehicles as “fall-back” positions for unsuccessful multiple-lane STP ratings. This is accomplished by adjusting the Rating Factor for multiple lanes by multiplying by the ratio of live load distribution factors (γ_L) and dividing out the multiple presence factor (m) that was originally included in the live load distribution factor (gm) by default. The last row of each group of STP vehicles is labeled “SPECIAL” and is reserved for evaluation of a specific super-load permit vehicle (one that exceeds MCTD Tables 4 or 5). When evaluating a super Load, “SPECIAL” in cell R54C2 is overwritten with a specific permit vehicle designation, ideally one that matches the truck name that has been added to the BRASS Vehicle Library. This new designation is then echoed to other appropriate cells.

15.4.3 Header Information

In the comments section document the following: “This rating is based on ODOT LRFR Chapter 8, Load Rating Concrete Bridges without Existing Plans. The bridges capacity could not be calculated. Rating factors were computed based on live load moment comparison and bridge condition.”

In the Bridge Header Area (upper half) of the Load Rating Summary Report, enter all the required bridge inventory and inspection information in the input (boxed) cells. Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

For the Bridge Number, NBI Feature Intersected (Item 6), Bridge Name, Highway Name, Highway Number, Milepost, District, County, Design loading, Owner, Span Description, Other Description, Firm, Engineer, Year of ADTT, Elements 325 and 326, and NBI Status Items #41 and #103, the information must be entered as text.

To ensure data consistency when the Summary Workbook information is imported into the Load Rating Database, please note the following:

- In the “SPAN DESCR” cell, show only the span description (sequential list of span lengths and structure types from the Bridge Log).
- In the “FIRM QC REVIEWER(S)” cell, input the name or names of the individuals who participated in the checking process.
- The “ODOT QC CHECK BY” cell, is reserved for ODOT personnel. Upon submission of a load rating ODOT will perform a cursory review of the load rating. Once finishing the check insert your name verifying that the check was performed.
- In the “OTHER DESCR” cell, put all other descriptions that may define the structure (e.g. sidewalk information, overlay information, deck-to-streambed distance, skew, seismic or metric design note, etc.)
- In the “HIGHWAY NAME” cell, for state-owned bridges use the list in this location:
- http://www.oregon.gov/ODOT/TD/TDATA/rics/docs/2010AlphaNumericHighways.pdf
- In the “HIGHWAY #” cell, enter NBI Item 122 (found in the upper-left corner of the SI&A sheet).
- In the “MILEPOST” cell, enter only the numeric value, without any alphabetic prefix or suffix.
- In the “ADT” and “ADTT” cells, enter the total ADT and ADTT on the entire structure, i.e. the 2-way ADT for a 2-way structure and the 1-way ADT for a 1-way structure. Note - this is for database purposes only, and is *not* the same as the one-direction ADTT that is used to determine live load factors for the load rating.
- Several of the input (boxed) cells are provided with drop-down boxes to limit input choices. In the case of the “DESIGN LOADING” cell, note that some bridge plans will show “H20 – S16” loading, which is the same as HS20 loading. Also note that an “HS” loading is *not* the same as the “H” loading with the same number of tons. Refer to the ***AASHTO Standard Specifications for Highway Bridges*** (2002), Article 3.7, for the older design loadings.
- Where the text begins with a number (Highway Number, Year of ADTT), ensure that Excel treats the cell entry as text by preceding it with an apostrophe.
- For State Bridges, the Highway number is 3 characters, including leading zeros if needed. (For example, Hwy “1” is entered as “001”).
- Enter single dates only, in the form MM/DD/YYYY. Do ***not*** use the Excel TODAY() or NOW() function – dates should reflect when the main load rating work was performed, and should not change whenever someone opens the file.
- For State-owned bridges, in the “OWNER” cell enter “ODOT”, and in the “CALCULATION BOOK” cell enter a calculation book number obtained from the Bridge Section Load Rating Unit. For Load Ratings, always use a calculation book that is separate from the calculation book for design calculations.
- For non-state-owned bridges, to determine what to enter in the “OWNER” cell, use NBI item 22 (2-digit Owner Code) in conjunction with NBI Item 3 (County) or 4 (5-digit Place Code, also known as the FIPS Code). The value of these fields are found in the Structure Inventory and Appraisal Sheet (SI&A) that accompanies the Bridge Inspection Report, and a table of FIPS Codes for Oregon can be found among the load rating references and tools. For example, for a local agency bridge having an Item 26 of “04” (city or municipal highway agency) and an Item 4 of “22550” (Elgin), in the “OWNER” cell the user would enter “City of Elgin”. For a local agency bridge having an Item 22 of “02” (county highway agency) and an Item 3 of

"Clackamas", in the "OWNER" cell the user would enter "Clackamas County". Please note that Items 3 and 4 are not to be used by themselves to determine ownership, because they describe only location, regardless of ownership.

- Use the optional "Comments" area to document any unusual decisions or features about the Load Rating (maximum 250 characters).
- The cells for Impact (1+I) and the dead load factors γ_{DC} and γ_{DW} are provided with their usual default values (they can be changed if necessary). The cells for the number of sections evaluated, and the Inventory and Operating Ratings in HS tons are calculated automatically when information is available. The cell for NBI Item 70 is calculated according to the NBI coding guide using LRFR Equation 6-7 (Article 6.8.3) for the recommended level of posting.

15.4.4 Inserting Rating Factors

Do not use the automated import rating factor tools. The rating factors reported by BRASS are not relevant to this analysis. Instead manually type the rating factors as they were calculated in the SUPERSTRUCTURE.xmcd file. The rating factors will have to be input in the first analysis section column. The refresh button can then be used to copy the rating factors to the first page the summary sheet. An example of the manually input rating factors is shown below:

SECTION EVALUATED	**1**
LRFD Brass .OUT File Name:	Superstructure.xmcd
FORCE TYPE (+/-M, V, T, C or B):	+M
PHI (Resistance Factor):	1.00
MEMBER (eg. Int. girder):	Superstructure
SPAN (eg. 1 of 4):	1 of 1
LOCATION (eg. 0.1L):	Max Moment
SINGLE LANE DF	1.000
MULTI-LANE DF	1.000
DESIGN & LEGAL VEHICLES	
HL93 (INVENTORY)	0.68 St1
TYPE 3 (50K)	1.00 St1
TYPE 3S2 (80K)	1.00 St1
TYPE 3-3 (80K)	1.22 St1
TYPE 3-3 & LEGAL LANE	
TYPE 3-3 TRAIN & LEGAL LANE	
SU4 TRUCK (54K)	**0.87 St1**
SU5 TRUCK (62K)	**0.83 St1**
SU6 TRUCK (69.5K)	**0.80 St1**
SU7 TRUCK (77.5K)	**0.80 St1**

The summary sheet will automatically calculate the Inventory and Operating tonnage values. Rating factors for permit loads will not be calculated at this time.

SECTION 16: LOAD RATING NEW BRIDGES USING AASHTOWare BrDR

This chapter is currently under development and will be included in a future update of ODOT LRFR Manual.

SECTION 17: LOAD RATING GUSSET PLATES

This chapter is currently under development and will be included in a future update of ODOT LRFR Manual.

SECTION 18: LOAD RATING PIN AND HANGER CONNECTIONS

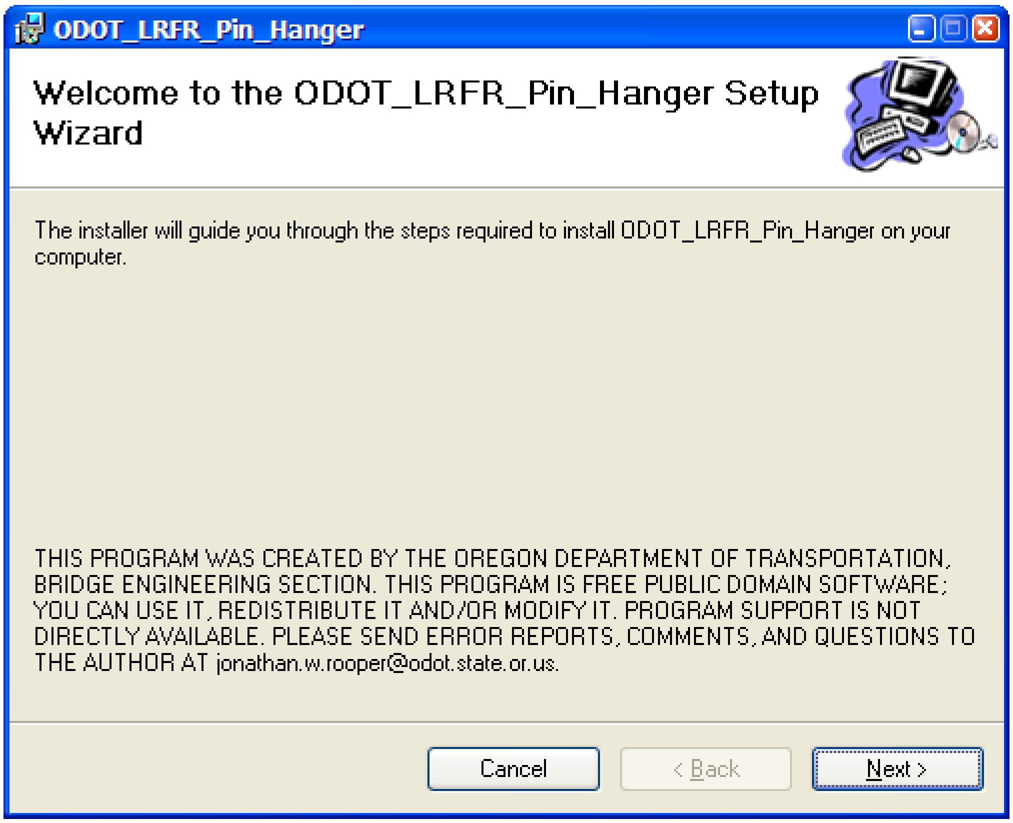
18.1 ODOT LRFR Pin & Hanger (PNH)

The ODOT LRFR Pin & Hanger (PNH) was created by the Oregon Department of Transportation, Bridge Engineering Section. The PNH is a stand-alone windows software package that will evaluate and analyze the pins and hanger bars for all of the various failures modes of a pin and hanger assembly. Once the user enters basic bridge information, pin and hanger geometry, factors and load reactions from BRASS output within the form fields, the program will compute capacities and rating factors for the pin and hangers. The program will also perform an infinite life fatigue check for the hanger bars.

The PNH is solely for the Microsoft Windows operating system and utilizes the Microsoft .NET Framework. The program's native format is the PNH (Pin and Hanger) file format. The PNH is free public domain software; meaning that users are free to use it, redistribute it, and/or modify it. The current version of the PNH is version 2.0.0.

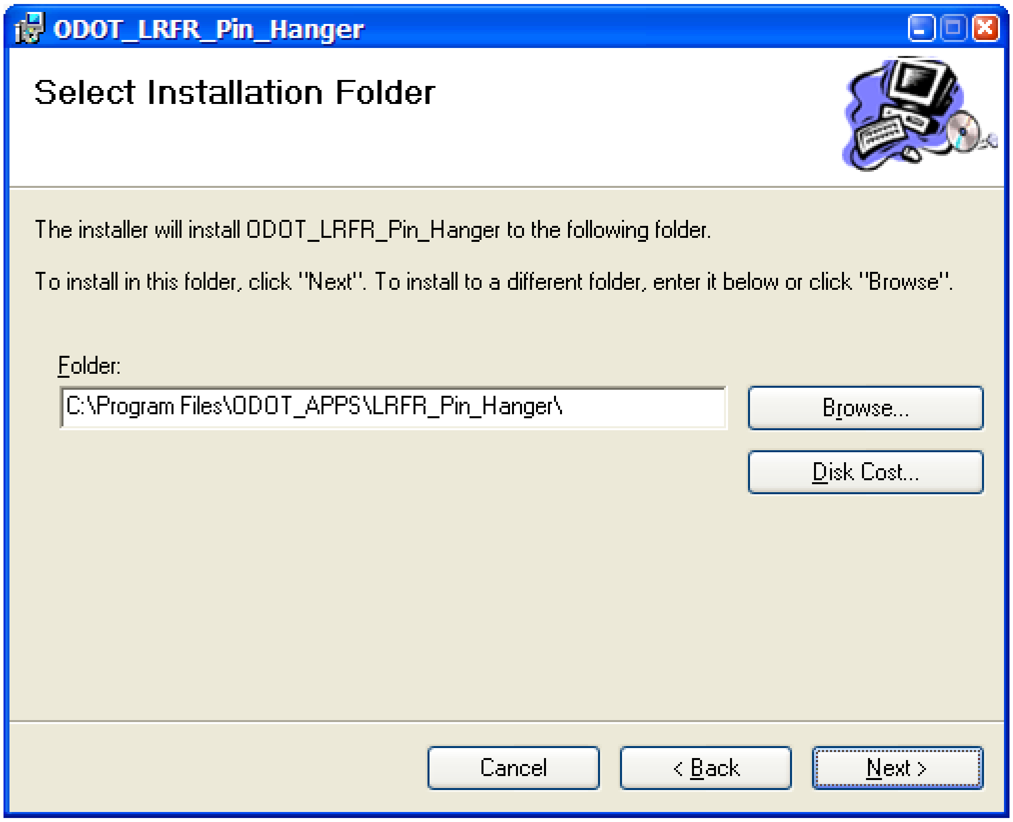
18.2 PNH Installation

A previous version of this software needs to first be uninstalled prior to installing the new version. To install the ODOT LRFR Pin & Hanger, run the Windows Installer Package titled, "ODOT_LRFR_Pin_Hanger(V2.0.1).msi". This will launch the Setup Wizard and pause at the Welcome dialog for the Wizard. Select the "Next" button to continue.



The next dialog will ask the user to select an installation folder to install the ODOT LRFR Pin and Hanger to. The default location is, "C:\Program Files\ODOT_APPS\LRFR_Pin_Hanger\". If the default location is satisfactory or after the preferred folder location has been specified, select the

"Next" button to continue.



The next dialog will ask the user to confirm the installation before it begins. Click the "Next" button to begin the installation.

A dialog with a progress bar will be shown during the installation. This part of the process can take anywhere from a few seconds to a few minutes depending on if the wizard needs to download and install an update to the Microsoft .NET framework to the computer.

The installation will place a shortcut for the program on the users desktop as well as under the Start Menu > All Programs > ODOT Load Rating. When the installation is complete, click the "Close" button to end the Wizard.

18.3 PNH - Overview

When first starting a session of the PNH software, a dialog window explaining the terms of use for the software will be displayed. If the user selects the "DECLINE" button, the session will end and the software will not launch. If the user selects the "I ACCEPT" button, the session will continue and the software will launch.

At the top left of the program there are four buttons associated with icons that are titled "New", "Open", "Save", and "Exit". The "New" button will erase all of the data entered in the form fields and start over with a blank form. The "Open" button will populate the form fields from a saved *.pnh file that was created from using the "Save" button from a previous session. The "Save" button will save the data entered in the form fields in a *.pnh file. The program will incorporate the values entered within the "Bridge Number" and "Span" form fields in the file name during the save process. The "Exit" button will exit and close the current session of the program.

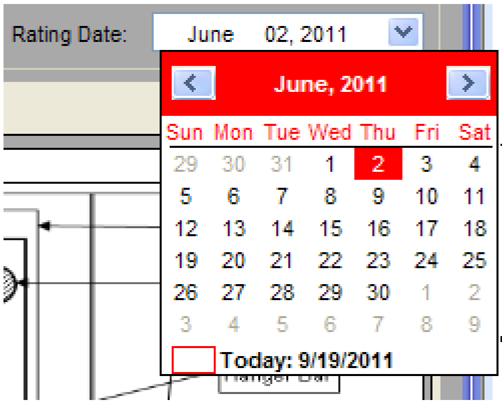
In the middle of the toolbar field is a grayed-out form field for the File Name. Once the basic bridge information has been populated in the top section of the program and the user has selected to save the input, the input file name will be displayed within this field. The file name will default to "Pin_Hanger_XXXXX_span_#.pnh". The "XXXXX" will be the bridge number, and the "#" will be for the span number.

In the top section of the program form is where the user specifies the basic information of the bridge.

In the "Bridge Name" form field, up to 60 characters may be used to enter the bridge name. The user has up to 15 characters to enter the bridge number in the "Bridge Number" form field, which typically only uses 5 to 6 characters. In the "Load Rater" form field, up to 60 characters may be used to enter the name of the engineer that is running the program. The user has up to 60 characters to enter the route name where the bridge is located in the "Route Name" form field. In the "Mile Point" form field, enter the milepost where the bridge is located.

Enter the span number where the pin and hanger or hinge is located. If there are multiple pin and hanger or hinge locations within the span, the user may enter an "a" or "b" to differentiate between the different locations for file naming convention. Within the "Joint Location" field the user enters the span fraction where the pin and hanger is located.

In the "Rating Date" form field, the user can type in the numeric date for the month, day, and year. Or the user can select the drop down calendar view and select the day within the appropriate month and year. Instead of scrolling through the different months within the calendar view, the user can simply select red box that is titled "Today" at the bottom of the calendar view to select the current date.



In the next section, the form consists of two tabs; the Geometry & Material Properties tab, and the Loads and Factors tab. The function of these tabs will be explained later.

18.4 PNH – Geometry & Material Properties Tab

The first section of this tab is for the user to select the Analysis Type; Pin and Hanger or Hinge. The program will default to Pin and Hanger. For a Pin and Hanger analysis, the failure modes for both the pins and the hanger will be analyzed. For a Hinge analysis, the failure modes for only the pin will be analyzed. Different form fields will be available depending on which analysis method is selected.

After the Analysis Type has been selected, fill in the remaining form fields to define the dimensions and material properties for the various parts that make up the connection. They are the Hanger Bars (or Hanger Plate if a Hinge Analysis is being performed), the pin, girder web, pin plates, and spacer or shim plates.

16.5 PNH – Loads and Factors Tab

Enter the BRASS output file names and the BRASS Analysis point that was used for the forces that are entered in the Pin and Hanger program. Enter the percent of Liveload Impact, the single lane and multi-lane distribution factors that were used in the BRASS analysis. Use the “BEAM Distribution Factor Schedule: Shear” in the BRASS Output. The schedule will list the single lane and multi-lane distribution factors for ranges along the span. Simply use the distribution factors for the range where the hinge is located within the span.

Enter the dead load reaction from BRASS, which will be the highest absolute value shear force at the analysis point where the joint is located within the span. Since we are using the highest absolute value of the shear force at the analysis point, do not enter the negative sign when entering the reactions in the Pin and Hanger program. The Dead Load value entered in the program should be the combined (DC +DW) unfactored load.

Within the right portion of the Loads and Factors Tab, enter the live load reaction and respective Live Load Factor for each vehicle. Prior to version 1.0.6 of the Pin and Hanger program the Live Load Factors were already included in the BRASS reactions since we use to code them as a scale factor for each vehicle in the LOAD-LIVE-DEFINITION (12-4.3) BRASS command. We are now requiring that the Live Load factors be coded using the FACTORS-LOAD-LL-LS (13.1.6) BRASS command. As a result, the Live Load Factors are no longer included in the BRASS live load reactions, thus the Pin and Hanger program will include them during the rating factor calculations. Enter the total load reaction, the program will then assume the total load is distributed equally between two hanger plates (or bars) when it performs the analysis.

If Pin and Hanger Analysis is being performed, the HL-93 Fatigue Truck should be coded in the BRASS Input File with a 0.75 Live Load Factor. The Pin and Hanger program will use the reaction for the fatigue vehicle to perform an infinite life fatigue analysis on the hanger bars. If the analysis is for a pure hinge, the fatigue vehicle does not need to be entered in BRASS and the reaction for this vehicle can be left blank or entered as a zero.

Below the BRASS information fields there is a large button that is labeled “Perform Analysis”. The analysis can only be performed after all of the required fields in the “Geometry and Material Properties” tab and the “Loads and Factors” tab are populated. If there is any missing data in any of the required fields, the program will give a notification as to where the data is missing and will not continue to the analysis output.

18.6 PNH – Analysis Output

If all of the required data is complete after selecting the “Perform Analysis” button on the “Loads and Factors” tab, the input tabs will disappear and be replaced with the output tabs. If the analysis was just for a Hinge, there will be two output tabs; one for the Pin Analysis, and one for the Rating Factors. If the analysis is for a pin and hanger, there will be seven output tabs; Pin Analysis, Tension in Net Section, Splitting Beyond Hole, Double Plane Shear, Dishing, Hanger Fatigue, and Rating Factors.

When viewing the output tabs, there will be two buttons that appear in the upper right corner of the program. The print button will print all of the input and output tabs to whichever printer the user selects. The “Back To Input Data” button will bring back the input tabs for the user to make changes, which will hide the output tabs, the print button, and the back to input button.

Most of the output tabs show the different formulas that are used to compute the capacities for the different failure modes that are used for the rating factor calculations. On the “Hanger Fatigue” tab the program will check to see if the hanger bars have infinite fatigue life. Make a notation of the results of this check within the comment section of the load rating summary sheet. If the program reports that the hanger bars do not have infinite fatigue life, along with making a notation on the load rating summary sheet, contact ODOT's Senior Load Rating Engineer to report the finding.

On the Rating Factor Tab, if the user selects all of the cells and hits the right mouse button, a context menu will appear allowing the user to copy the selection to the clipboard. Then in the load rating summary sheet, the user can simply paste the data in the available columns. If the user chooses to hit the Ctrl + C keys to copy instead of the right mouse button, the data along with formatting will be copied to the clipboard. The user would then have to use the Paste Special command in Excel and paste the data as text to have it appear correctly on the summary sheet.

18.7 PNH – Deliverables

Include the input file (*.pnh) with the electronic submittal of the load rating. For the bound hard copy of the load rating calc book, include all of the printed pages (both input & output) that were produced using the print button in the Pin and Hanger program.

SECTION 19: LOAD RATING CROSSBEAMS

This section applies to transverse reinforced concrete, structural steel, and timber beam members that support longitudinal girders or stringers.

Crossbeams that are bearing directly on a web-wall need not be load rated because the wall restricts any beam deflection and the loads are transferred directly into the columns.

Crossbeams that are pile caps need not be load rated if (a) all girders are directly above the piles, (b) all girders are within ½ the pile cap depth away from the piles or (c) the depth of the crossbeam is always equal to or larger than ½ the pile spacing. In case (c), we assume when the depth of the crossbeam exceeds half the pile spacing, the 45-degree failure planes from girder loads overlap, so the majority of the load is carried directly to the piles and not by flexure of the crossbeam. Consider the pile cap to be the structural crossbeam. Back walls may be considered as part of the crossbeam for capacity calculations, if there is sufficient reinforcement extending from the back wall into the crossbeam. In general back walls will only be included as dead load and ignored when calculating capacity. If the back wall is included in the capacity calculation, refer to section 19.4.

Where a bridge contains a series of crossbeams at different bents that are identical in geometry, reinforcement and girder load positions, initially load rate only the bent with the worst loading condition (the one with the largest sum of contributing longitudinal spans). However, if load rating of that bent produces Rating Factors < 1.0, then rate the other bents in the identical series to document all the deficient members and provide information to support future repair decisions.

LRFD 5.5.1.2 states that disturbed/discontinuity regions (D-Regions), which occur in the vicinity of load or geometric discontinuities in concrete members, the strut-and-tie method (STM) of analysis of LRFD Article 5.8.2 or other methods from LRFD Article 5.8.3 or LRFD Article 5.8.4 should be used for the strength and extreme event limit states. However, ODOT's current crossbeam load rating tools and procedures are based on conventional beam theory, which was based on Bernoulli's plane section hypothesis.

ODOT will be developing new RC crossbeam load rating procedures and tools that will be based on the strut-and-tie analysis method. **In the meantime, continue using the current Excel based crossbeam tools and procedures for the load rating of RC crossbeams.**

19.1 Preliminary Files for Crossbeams (Mathcad)

19.1.1 Header

Use the Mathcad header feature to indicate Bridge Number (upper right corner), Bridge Name (top line center), load rater and date (2nd line left) and File Name and Page Number (2nd line right). Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

Since the bridge number and name are contained in the Mathcad header, they do not show up while working on the file, only when printing or doing a Print Preview. To avoid confusion over which bridge you are working on, it is good practice to place the bridge number and name near the top of the file in the right margin (outside the printable area).

Just below the Mathcad header section, document the bridge structure type. For state bridges the span description ("Spans" field) from the Bridge Log is adequate for this purpose.

Note: the weird Mathcad regions at the top in the right margin (outside the printable area) are there for 2 purposes. The units definitions are necessary for Mathcad to understand some commonly used units in structural engineering (without them, Mathcad would generate errors because it is unable to interpret them). The row of nonstandard characters is there in case the user might want to copy them elsewhere to clarify the calculations.

19.1.2 Resistance Factors

Document the decisions regarding all 3 Resistance Factors, with references to the appropriate MBE tables. For crossbeams, determine the Condition Factor ϕ_c (MBE 6A.4.2.3) based on the *Sub*structure Condition Rating (NBI Item 60), except where the crossbeam is in the plane of and integral with the superstructure, then use the *Super*structure condition rating.

The ODOT Crossbeam Load Rating Software always requires and displays the product of all the resistance factors as a single ϕ factor. Therefore, the product of all these resistance factors must always be obtained.

Treat the System Factor ϕ_s for Flexure and Shear and the Combined Factor (Φ) for Flexure and Shear as separate variables in Mathcad.

For Flexure:
$\Phi_f = \phi\, [\max(\phi_c\phi_{sf}, 0.85)]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 6.5.4.2.1)
and ϕ_{sf} is the System Factor for Flexure (MBE Table 6A.4.2.4-1, as modified in Article 1.4.1.4 of this Manual).

For Shear:
$\Phi_v = \phi\, [\max(\phi_c\phi_{sv}, 0.85)]$
where ϕ is the AASHTO LRFD Resistance Factor, based on material and force type (AASHTO LRFD 6.5.4.2.1)
and ϕ_{sv} is the System Factor for Shear (always 1.0 regardless of member, according to MBE 6A.4.2.4, in the note below 6A.4.2.4-1)

These equations account for the intermediate check of $\phi_c\phi_s \geq 0.85$ (MBE 6A.4.2.1-3).

19.1.3 Load Factors

Document the decisions regarding the dead load factors γ_{DC} and γ_{DW}.

For the live load factors γ_L, refer by file name to the interior girder preliminary file that contains live load factor calculations.

Document the value of the impact factor (IM) that was used in the superstructure analysis. When entered in the crossbeam analysis data file, it will originally be used with the girder live load reactions to compute unfactored lane reactions. After the influence line ordinance has been computed for each analysis section, the program will apply the impact factor when computing the rating factors for concrete and steel crossbeams. For timber crossbeams the program will not apply the impact factor when computing the rating factors, as per AASHTO LRFD Article 3.6.2.3.

19.1.4 Material Properties

Enter the material properties and calculate elastic modulus E_c and modular ratio n. Document assumptions made about the material properties if they are not given on the Bridge Plans. Use AASHTO LRFD Equation 5.4.2.4-1 to determine the elastic modulus of concrete.

For timber members with documented decay see section 19.3.

19.1.5 Bent Geometry

Calculate the input parameters required in the **Input** worksheet of the Crossbeam Analysis Data File. This includes:

- Roadway width (normal to the bridge centerline)
- Left curb to centerline of bridge (normal to the bridge centerline)
- Skew of the bent (angle of departure from normal to the bridge centerline, positive if clockwise in plan view)
- Crossbeam span lengths (along the skew of the bent
- Column lengths
- Centerline of bridge to centerline of left column (normal to the bridge centerline)
- Centerline of bridge to centerline of left girder (normal to the bridge centerline)

If the centerline of exterior girders is directly over the centerlines of the columns, the exterior girders may be omitted from the crossbeam analysis, in which case the final dimension in the list above would become:

- Centerline of bridge to centerline of leftmost interior girder (normal to the bridge centerline)

If the exterior girders are omitted, document the decision with an explanatory note.

If the roadway or girder set seems wide compared to the bent width, or if you receive errors when using the Crossbeam Analysis Program, it may be due to the exterior girder dead loads or live loads falling outside the limits of the crossbeam (outside the column centerline). It may be necessary to modify the “stick” model of the bent by inserting short cantilevers on each side to “pick up” the exterior girder reactions. Normally in this case, calculate the required overall crossbeam width as

$$\frac{\Sigma(\text{Girder Spacings})}{\cos(\text{Skew})}$$

Then add a short cantilever on each side whose length is

$(1/2)[\ \Sigma(\text{Girder Spacings}) - \Sigma(\text{Crossbeam Spans})]$, rounded-up slightly.

If you add a short cantilever, your analysis points will be in Span 2, which can be confusing, especially in 2-column bents. An alternate practice would be to move the exterior girder inward, say 0.1 ft, which may eliminate the need for a cantilever without significantly affecting the crossbeam model.

19.1.6 Section Properties

Calculate the area and moment of inertia of each crossbeam span and column. The ***Input*** worksheet of the Crossbeam Analysis Data File requires an average moment of inertia for the whole span but accounts for the variable dead load of haunched cantilever spans by providing for input of different dead loads at each end (w_{left} and w_{right}). The crossbeam dead load entered here should include the dead load of any diaphragms not already accounted for as loads in the girder analysis.

19.1.7 Component Dead Load Reactions (DC)

To avoid confusion, calculate component dead load (DC) reactions separately for interior and exterior girders. Within each girder’s calculation, reactions should be grouped under the headings DC and DW. The ***Input*** worksheet of the Crossbeam Analysis Data File has separate inputs of reactions for

- “Girder” (self-weight),
- “Other Str.” (diaphragms, partial bottom flanges if applicable) and
- “Rails & Curbs” (all superimposed stage-2 dead loads excluding wearing surface)

For slab bridges, the crossbeam software can analyze up to 20 point loads for girder dead load reactions. Therefore, distribute the dead load reaction per slab strip to 20 point loads across the total length of the bent.

For concrete box girder bridges, both conventional, prestressed, and post-tensioend, distribute the component dead load (DC) reaction of the transformed girder evenly among all of the webs, and apply the webs at their actual location across the length of the bent. When Midas is used to perform the superstructure analysis (post-tensioned box girders), then the secondary post-tensioning forces will be included with the dead load. In the Midas model select the last construction stage, and then view the reactions for the summation load case.

For bridges with end panels, assume that the end panel is fully supported by compacted backfill, so that no dead load from the end panel is applied to the end bent. If the backfill under the end panel is eroded or settled out next to the abutment, it is assumed that due to the length and area of the end panel that the majority of the dead load will be supported by the remaining backfill material.

19.1.8 Wearing Surface Dead Load Reactions (DW)

Calculate wearing surface dead load (DW) reactions. The ***Input*** worksheet of the crossbeam analysis data file has separate input (on the right) of reactions for “Wearing Surface”. This separation facilitates re-rating of the bridge for changed wearing surface conditions.

For slab bridges, the crossbeam software can analyze up to 20 point loads for girder dead load reactions. Therefore, distribute the wearing surface (DW) dead load reaction per slab strip in the same manner as the component dead load (DC).

For concrete box girder bridges, both conventional and prestressed, distribute the wearing surface dead load (DW) reaction of the transformed girder evenly among all of the webs, and apply the webs at their actual location across the length of the bent.

19.1.9 Live Load Reactions (LL)

Factored live load girder reactions, from the superstructure analysis, will be converted into live load *lane* reactions within the Crossbeam Analysis Software. This is accomplished in the ***Live Loads*** worksheet of the Crossbeam Analysis Data File by dividing out the live load factor γ_L, the multiple-presence distribution factor for reactions, and the impact (1 + IM). The following conversion equation is used in the ***Live Loads*** worksheet in the crossbeam analysis data File (see Article 19.2.1):

$$LL_{lane} = \frac{LL_{gird}}{\gamma_L\ (mg)\ (1 + IM)}$$

In the crossbeam preliminary file, document the impact factor and the single lane and multiple lane distribution factors for the support being analyzed.

Live load reactions will either be calculated by a BRASS or Midas based analysis. The crossbeam analysis software is setup for unfactored live load reactions. Live load reactions reported in BRASS output include; distribution, scale, and impact factors. With the 2011 update to this manual, the reactions no longer include the live load factor, which was previously coded as the scale factor.

Post-tensioned box girder bridges require a Midas based superstructure analysis. This analysis will report unfactored live load reactions. Crossbeam specific vehicle loadings have been defined by the vehicles command shell, these include; HL93 Truck, Tandem, Lane, and Truck Train in addition to the Oregon legal truck train. Note that the HL93 truck train and the Oregon legal truck train are not reduced. The truck and lane reductions are applied in the XB tool. The XB tool does assume that the live loads have already had the impact factor applied. Calculate the truck reactions with impact in the preliminary file. Input these values into the XB tool. No distribution factor has been applied during the Midas analysis, so these reactions are already for a lane. Set the distribution factor to 1.0 in the XB tool and no additional modification is required.

For bridges with end panels, assume that the end panel is fully supported by compacted backfill, so that no live load from the end panel is applied to the end bent. If the backfill under the end panel is eroded or settled out next to the abutment, it is assumed that due to the length and area of the end panel that the majority of the live load will be supported by the remaining backfill material.

In the case where there is a superstructure expansion joint at the bent, BRASS would need to be coded with a hinge very near this support (it cannot have a hinge *at* a support). If the adjacent superstructure segments (continuous girders between joints) have different numbers or types of girders, a single BRASS model that is correct for all the segments will be impossible. This is because BRASS can use only one set of girder type and spacing information at a time to determine LRFD Distribution Factors. The separate BRASS models will analyze the girders correctly, but each model ends its respective "structure" at the expansion joint and thus will not calculate the correct live load reaction at the bent with the expansion joint. However, because the crossbeam software uses only *lane* reactions, a multi-segment BRASS "Reaction File" can be used that models only one type and number of girders throughout the bridge to determine reactions at the bent with the expansion joint. However wrong these girder reactions might be for individual segments, the crossbeam software divides out the erroneous distribution factor (gm) to obtain the correct *lane* reactions for the crossbeam analysis.

For bridges that have the distribution factor (gm) adjusted for the loading effects due to skew, the crossbeam software divides out the adjusted distribution factor (gm) to obtain the correct *lane* reactions for the crossbeam analysis. Therefore, there is no need to manually adjust the reactions or the distribution factors to account for skew corrections from the superstructure analysis in the live load reactions (LL) portion of the preliminary file.

Where applicable, document the use of a Reaction File in the Live Load Reactions (LL) portion of the Preliminary File for each crossbeam.

19.1.10 Analysis Sections

Within each span, check for symmetry of sections, reinforcement and loads, and do not identify any analysis points that are structurally symmetrical with analysis points already defined. Defining analysis points that are structurally symmetrical has the potential effect of corrupting the Load Rating Summary Sheet. Because the "Refresh" module is looking for the lowest Rating Factors, defining a symmetrical point causes it to identify the most critical rating location twice, thus preventing it from identifying the second most critical analysis point. The second controlling point is useful information in evaluating potential repairs for the bridge.

Under a separate headline "Analysis Sections for Flexure", calculate the location of the Load Rating analysis sections for flexure (measured from centerline of left support).

Under a separate headline "Analysis Sections for Shear", subdivide the calculation sections for the various categories of shear analysis points using underlined headlines in the same order as was done in the interior girder Preliminary File. The calculation procedures here are similar to those in the corresponding calculation section in the interior girder Preliminary File, except the Bar Cutoff section locations are calculated in Mathcad instead of in an external Excel tool. Remember that the points of interest (sections to be evaluated for shear) will be at the actual bar cutoff point and not the adjusted point for development length, assuming that this is the most conservative and likely point where a crack might develop. In crossbeams, where a single large stirrup space coincides with the location of longitudinal girders framing into the side(s) of the crossbeam, the stirrup spacing change can be ignored.

The calculation tool **dv_Calculator.XLS** is used to determine the shear depth d_v for the crossbeam and is referenced in the Preliminary File to in a manner similar to the interior girder Preliminary File.

AASHTO LRFD Article 5.7.3.4.2, General Procedure for MCFT shear capacity evaluation requires that all of the development length of the tensile reinforcement be ignored. This seems to be overly conservative when it comes to analyzing crossbeams. Since the crossbeams have relatively short spans, this requirement would end up treating most spans as having little to no flexural reinforcement after ignoring all partially developed tension bars. Therefore, when inputting the data in the ***Capacity*** sheet of the Crossbeam Analysis Data File (Excel), calculate and account for the partial development of any tensile reinforcement that is not fully developed, along with the fully developed tensile bars for a given analysis section.

For crossbeams at the interior supports of continuous cast-in-place slab bridges, where the crossbeam projects below the bottom of the adjacent longitudinal slab no more than ½ the adjacent slab depth, consider the crossbeam to act as a slab member, and therefore do not check any analysis sections for shear. For example, if a continuous cast-in-place slab has haunches down to an 18" depth at the interior bents, if an interior crossbeam projects 9" or less below the adjacent slab, shear in the crossbeam can be ignored. This provision does not apply to end bents, because on one side of the crossbeam there is no confinement from the slab.

Since crossbeams have relatively short spans, the rule of ignoring shear points within the middle third of the span shall not apply. Therefore all shear points that fall in between critical shear locations on a crossbeam should be analyzed. Critical shear location is normally h/2 from face of each unique support. Other shear points of interest include geometry change points and stirrup spacing change points.

To locate the face of support for circular columns, use the face of column as the face of a square column having the equivalent cross-section area. For a column having a diameter D, the distance from the centerline to the equivalent column face would be

$$\frac{\sqrt{\left(\frac{\pi D^2}{4}\right)}}{2}$$

For ob-round columns (those having a rectangular section with a semi-circular section added on each side), treat the semi-circular portion the same way as for the circular columns and add half the equivalent column face to half the rectangular portion of the section.

19.2 Analysis of Crossbeams

To facilitate the analysis and load rating of crossbeams (bent caps) and transverse floor beams, since 1995, ODOT has provided and maintained its own Crossbeam Load Rating Software based on Microsoft Excel. This tool has been upgraded for Tier-2 (LRFR) procedures and has received numerous enhancements. The software uses the Direct Stiffness Method of analysis using beam elements. Sidesway, lateral movement, axial and shear deformations are not considered. Superstructure dead load is applied through the girder lines. Live load lane reactions from the superstructure are applied directly to the crossbeam with no distribution through the deck and the girder system. This is normally a somewhat conservative assumption. The ODOT Crossbeam Load Rating Software is limited to 8 columns with 9 spans (with end cantilevers), and up to 8 analysis sections can be investigated in a single analysis run.

ODOT considers this software to be adequate for load rating purposes for most crossbeam and bent geometries. The simplifying assumptions may not be appropriate for unusual bent geometries, such as significantly differing column lengths or unusually stiff crossbeams.

If a load rater is concerned that this software may not be an appropriate analysis tool for a particular crossbeam or bent, a proposal of an alternative analysis method may be made to the ODOT Bridge Load Rating Unit. This proposal should include what software package would be used and a detailed explanation of all proposed element types, analysis and boundary condition assumptions. No alternative analysis is acceptable without written approval of the ODOT Bridge Load Rating Unit. If the ODOT Bridge Load Rating Unit determines that an alternate analysis procedure is necessary, acceptable software packages would be limited to those that are readily available within ODOT so that an existing load rating can quickly be revised or a permit vehicle quickly evaluated. If an alternative analysis is approved and used, the alternative analysis can be used to generate influence line ordinates that may be entered into the appropriate locations in the ODOT Crossbeam Software.

The ODOT Crossbeam Load Rating Software consists of 2 components:

- The Crossbeam Analysis Data File. This file is crossbeam-specific, started with the Crossbeam Analysis Data Template **XB_RC.XLT** and saved as a workbook that refers to a specific bent number (for example **XB_Bent1.XLS**). This template is specific as to a type of material (for steel crossbeams there is **XB_S.XLT**, and for timber crossbeams there is **XB_T.XLT**).

- The Crossbeam Analysis Program **XB_MAIN.XLS**. This is the “analysis engine” that takes input data from the Crossbeam Analysis Data File, and for each input analysis section it generates influence lines, performs the analysis, and writes output data back to the Crossbeam Analysis Data File.

These 2 components must be open simultaneously to perform a crossbeam analysis. Briefly, the workflow using these 2 files is described as follows, using a reinforced concrete crossbeam analysis as an example (the location for the input of some variables may vary between the different crossbeam types, but the overall workflow is similar):

A. Open Excel.

B. Open a Crossbeam Analysis Data Template, **XB_RC.XLT** (for Reinforced Concrete Crossbeams) and fill out the yellow cells in the worksheets ***Input, Live Loads,*** and ***Capacity*.**

C. Save the data template as an appropriately named Excel workbook, for example: **XB_BENT1.XLS**. See below for detailed discussion of the templates.

D. Open the Crossbeam Analysis Program **XB_MAIN.XLS**.

E. From **XB_MAIN.XLS**, choose an analysis section from the Data Template. **XB_MAIN.XLS** will calculate the dead load actions and the single and multiple lane live load influence ordinates for each investigated section, and provide the tools to use them to position the live loads correctly.

F. From **XB_MAIN.XLS**, store the results into the ***Output*** worksheet of the Crossbeam Analysis Data File. For each investigated section, print the ***Main, Graphics*** and ***Live_Load*** worksheets in **XB_MAIN.XLS**. See below for detailed discussion of **XB_MAIN.XLS**.

G. Repeat steps E & F for each investigated crossbeam section to complete the analysis cycle.

H. In the ***Capacity Table*** worksheet enter the Impact, the Single-Lane and Multi-Lane Distribution Factors in row 10. For each investigated section enter the PHI (Resistance Factor) in row 15. Then choose the appropriate capacity calculation method (usually “M” for moment or “V_General” for shear) using the drop-down boxes in row 13. In the Crossbeam Analysis Data File, the nominal capacity for each investigated section is then calculated in the ***Capacity Table*** and ***Capacity*** worksheets, and the Rating Factors are calculated in the ***RF*** worksheet. If using the General Procedure of calculating shear capacity, in the ***Capacity Table*** worksheet, for each shear section investigated, the shear capacity varies with each applied load, which is a characteristic of the shear-moment interaction of MCFT. For RC crossbeams, the ***Capacity Table*** sheet should be reviewed at this time to verify the reasonability of the calculated capacity values.

I. After all the investigated sections have been stored to the Crossbeam Analysis Data File, review the Rating Factors in the ***RF*** Sheet. Print the ***Input***, ***Live Loads, Capacity, Output***, ***Capacity Table*** (XB_RC.XLT only) and ***RF*** Sheets.

J. Copy the Rating Factor results into Load Rating Summary Workbook, using the Paste Special, Values command in Excel.

19.2.1 Reinforced Concrete Crossbeam Analysis Data File (Excel)

XB_RC.XLT – Introduction

This template file is for load rating reinforced concrete crossbeams. A separate file is used for each crossbeam analysis. The template should first be stored in your …\XLStart folder (e.g. C:\Program Files\Microsoft Office\Office11\XLStart), so it can be accessed from the **F**ile, **N**ew option in Excel. Always use the latest version of this template file from the ODOT FTP Server. (Note: Versions of XB_RC.XLT prior to 6.1 do not calculate d_v and shear capacity correctly in some cases). When **XB_RC.XLT** is opened, it is displayed as **XB_RC1**. Use the **F**ile Save **A**s command to save the file as a bent-specific Excel workbook (**.**XLS) file. An example would be **XB_BENT1.XLS**.

The workbook includes 8 visible sheets, ***Input, Live Loads, Capacity, Output, Capacity Table, Mu & Vu, RF*** and ***Info.*** Cells in light yellow require input by the user. Cells in light violet are calculated and filled in during **XB_Main.XLS** analysis. The load rater is expected to include hard copies of all sheets of the workbook, except the ***Mu & Vu*** and ***Info*** sheets, in the Load Rating Report.

> Note that a red triangle appears in the upper right corner of certain cells. These cells include notes which explain the required input. Hover over or double-click on the cell to access the note.

Input includes the information required to describe the geometry, dead loads and sections to be evaluated.

Live Load is where the user inputs the girder factored live load reactions from the BRASS Output File, as well as the live load factor γ_L, for each rating vehicle This and other input parameters are used to calculate live load single-lane reactions for use in the crossbeam analysis.

Capacity includes the geometry and reinforcing input necessary to calculate the nominal capacity, or the capacity may be input directly by the user (on the ***Capacity Table*** sheet).

Output contains the results of each investigated section from the **XB_MAIN.XLS** analysis.

Capacity Table is where the user inputs the Impact, and the BRASS Single-Lane and Multi-Lane Distribution Factors in row 10. The user also inputs the combined Resistance Factor (Φ) in row 15 and chooses the capacity calculation method (normally “M” for moment and “V_General” or “V_App_B5” for shear) for each section using the drop-down boxes in row 13. For crack locations that are inside the critical shear location near a simple support, the AASHTO LRFD 5.7.3.4.1 Simplified Procedure for Non-prestressed Sections, is applicable. This is due to the Modified Compression Field Theory (MCFT) not providing accurate results for areas with high shear and low moment, basically near a simple support. This section of the LRFD code sets beta and theta to 2.0 and 45 degrees, which in turn makes the expressions for shear strength become essentially identical to those traditionally used for evaluating shear resistance (also known as the LFD Method). This method is also applicable to sections having a total depth < 16 in. In these cases, choose the “User” option in row 13 and manually enter the capacity for the HL93 (INVENTORY) vehicle, using the

Simplified Shear Capacity V_n found in row 70 of the "Capacity" worksheet. **Note: Selection of the capacity calculation method prior to using XB_MAIN.XLS can lead to erroneous results.** The remainder of the sheet lists the capacity of the member for each load at each point of interest - capacity varies with load for shear points when the AASHTO LRFD General Procedure (MCFT) is used. The user can manually input the capacity for a section while the calculation mode is set to "User". To use the same capacity for every vehicle, enter the capacity for the HL93 (INVENTORY) vehicle first. This will populate every vehicle for that section with the same capacity. To enter a different capacity for each vehicle, simply enter the capacity in the row for the corresponding vehicle.

Mu & Vu will compute the factored shear and moment for each vehicle at each analysis section. This sheet is used as a resource for when the capacity will need to be manually computed, such as for a crossbeam that has been post-tensioned. Allowing the crossbeam program to compute the V_c and V_s for the section, the user then can manually compute the V_p for each load by using the factored loads from the ***Mu & Vu*** sheet. Once the V_p has been computed for each load, they should be added to the values shown on the ***Capacity Table*** sheet and then manually entered on the ***Capacity Table*** sheet for each vehicle after switching the Calculation method back to "User".

RF lists the Rating Factor for each load at each point of interest.

Info provides information which supports the ***Capacity*** worksheet.

19.2.1.1 XB_RC.XLT - *Input* worksheet

This section describes the contents of the ***Input*** Sheet contained in the **XB_RC.XLT** template.

GENERAL INFORMATION.....Enter the information requested. This information is echoed in the ***Output,*** Sheets and is copied to **XB_MAIN.XLS** during the critical section analysis. For the member description, be brief, as the description must be able to fit in a column of the Load Rating Summary Workbook. Use "XB Bent1" for example.

ROADWAY INFORMATION.....Enter the roadway width and distance from the left curb to the bridge centerline measured in feet and normal to the bridge centerline.

BENT ALIGNMENT.....Enter the skew in decimal degrees. The skew is measured from the normal to the bridge centerline position to the centerline of the bent. Positive skew is shown on the template and is described as a clockwise rotation looking ahead on station and measured from the normal to bridge centerline position. Actually, the sign of the skew does not matter, only the magnitude. However, the graphics plan view presentation may be incorrect.

MATERIAL PROPERTIES.....Enter the weight of concrete and concrete strength for the crossbeam and columns. The modulus of elasticity is calculated per AASHTO.

CROSSBEAM INFORMATION.....Enter the geometry to describe the crossbeam. All dimensions are measured in the plane of the bent. A maximum of nine spans are allowed. A span is the length of a cantilever measured from the end to the centerline of the column or the distance between centers of columns. If the span is a cantilever, enter a "C" into the column with the heading "C or H ?". (Make sure there is no space after the "C"). If a hinge occurs at the right end of the span, enter a "H". No column can exist directly at a hinge location. The span length is measured in feet, moment of inertia of the span in the plane of the bent is given as ft^4. The analysis assumes prismatic sections only. Since we are not concerned with deflections, I_{avg} is appropriate for cantilever spans. However, w_{left} and w_{right} sections allow the user to input the uniform weight of the span at the left and right ends of each span. A linear transition is assumed between these points. Enter the weight in kips per lineal foot.

COLUMN INFORMATION.....Based on the crossbeam information, the expected number of columns is calculated and displayed in a red font. If this number does not match your situation, check your

CROSSBEAM INFORMATION. For each column, enter the column length, cross-sectional area and bending moment of inertia in the plane of the bent. Also, enter the end conditions of the column, “P” for pinned and “F” for fixed. Do not use “F” for a fixed top unless the top reinforcement appears to have sufficient area and anchorage to resist negative moment. The user must also enter the distance from the left column to the centerline of the bridge. This distance is measured normal to the bridge centerline. Note that it is possible to code nine spans, assuming no cantilevers, would require ten columns. If this situation is encountered the number of spans will have to be decreased such that a maximum of eight columns are coded.

ANALYSIS SECTION INFO.....Enter up to 8 sections to evaluate. Because the software generates a node at each active evaluation section, the section cannot coincide with an existing node. This should not be a problem because the critical section for bending and shear are generally taken at the face of support or at d_v from the face of support, respectively. Remember to avoid evaluating sections that are structurally symmetrical with previously defined sections.

List the span that the analysis section is located (See CROSSBEAM INFORMATION) and the distance from the left end of the span to the critical section measured in feet and along the span. ΔX must be greater than zero and less than the span length. Enter the analysis type, +M for positive moment (tension in the bottom fiber), -M for negative moment, and V for shear. Assure that these cell entries are text by starting each of them with an apostrophe.

GIRDER GEOMETRY AND LOADING.....Enter the distance from the centerline of the left girder to the centerline of the bridge. This distance is measured normal to the bridge centerline. Enter the BRASS reference file (output file name). This information is not used; it is simply the reference for the girder dead load reactions. Enter the spacing between girders normal to the bridge centerline. Based on the number of spacings you enter, the number of girders is calculated and presented. Four separate Component dead load (DC) columns are available. The user can input a descriptive name at the top of each column. The recommended descriptions are: “Girder” for girder self-weight, “Other Str.” for other stage-1 structure dead loads (usually the diaphragms), and “Rails/Curbs” to include all stage-2 dead loads except wearing surface. Enter the girder reaction for each load case. The four columns will be added and this information will be used in the analysis and reported as the structure dead load. A separate column is provided for the Wearing Surface dead load (DW). DC and DW are kept separate to simplify the future addition or removal of wearing surfaces. Supporting calculations for the separation of wearing surfaces should be included as equations in these cells or included in the Crossbeam Preliminary File (Mathcad) which supports the calculations for the crossbeam.

ENGINEER COMMENTS.....Enter any comments in this area that would make your assumptions clearer to a future user. If the decision is made to use the LRFD 5.7.3.4.1 Simplified Procedure for calculating shear capacity, it should be explained and justified in this comment area.

19.2.1.2 XB_RC.XLT – *Live Loads* worksheet

This section describes the contents of the ***Live Loads*** Sheet contained in the **XB_RC.XLT** template. Enter the reactions for each rating vehicle as listed in the Crossbeam Preliminary File. Enter the live load factors for each rating vehicle as listed in the Girder Preliminary File, using only the yellow cells. In the cells to the right, the sheet calculates the factored and unfactored live load reactions, and the lane load combination required by the LRFD code.

Within the “Design & Legal Vehicles” section of this sheet there tends to be some confusion on what data is required for a given bridge, mainly with the “TYPE 3-3 & LEGAL LANE”, the “TYPE 3-3 TRAIN & LEGAL LANE”, and the “LEGAL LANE” reactions. The “TYPE 3-3 & LEGAL LANE” vehicle is only required for spans greater than 200 feet, and will normally be coded in BRASS as the 20^{th} rating vehicle. The “TYPE 3-3 TRAIN & LEGAL LANE” vehicle is only used for checking negative moments over interior supports, thus there will not be a reaction for this vehicle for bents that are acting as simple supports.

For both of the above vehicle combinations, the MBE code requires that the Type 3-3 vehicle be reduced to 75%, but the full lane load of 0.2 kips/ft is applied. BRASS already has it built in to the programming to take 75% of the truck load for computing the rating factors for these load combinations. Looking at the BRASS output file, you can verify under the "LIVE LOAD COMBINATIONS SUMMARY" (which is just after the live load distribution factors summary) that the truck is taken at 0.75 and the lane is taken at 1.0 for these combinations.

The live load reactions for each truck that we get from BRASS are supposed to be the unfactored girder actions. This is not a true statement because the distribution factor, impact factor, and scale factor have already been applied. But these are the full vehicle reactions for each truck, thus they have not been adjusted to the 75% as required for the load combination. Therefore we enter the full reaction into the ***Live Loads*** sheet of the crossbeam file. The crossbeam file is will automatically adjust the reaction to 75% when it converts the truck reaction into an unfactored lane load reaction.

The factored reaction for the "Type 3-3 & Legal Lane" vehicle is the truck load only for this load case (which is usually applied as load number 20 in the “_T” file for spans greater than 200'). Likewise, the "Type 3-3 Train & Legal Lane" vehicle is the truck load only for this load case (which is applied as load number 4 in the “_T” file for analyzing negative moment over supports). Finally, the legal lane load reaction is entered for the "Legal Load" (which is applied as load number 5 in the “_T” file). When calculating the unfactored lane load reaction for these special load cases, the crossbeam file will combine the lane load with the appropriate vehicles.

19.2.1.3 XB_RC.XLT - *Capacity* worksheet

This section describes the contents of the ***Capacity*** Sheet contained in the XB_RC template. The section capacity is calculated based on the section geometry input by the user. It is assumed that the user has evaluated each critical section and the results have been placed in the ***Output*** Sheet. Cells in light yellow require input by the user.

MATERIAL PROPERTIES.....Input the yield strength of the reinforcement and concrete compressive strength. β_1 is calculated based on AASHTO criteria.

SECTION GEOMETRY.....Describe the cross section geometry. T or rectangular sections may be input. Input the “Comp. Flange - Web Width” (read that dash as “minus”) and the “Flange Thickness” only if the section is modeled as a T-section. Refer to LRFD Article 4.6.2.6.5, Transverse Floorbeams and Integral Bent Caps, to determine the effective compression flange of an integral bent cap.

POST-TENSIONING.....Describe the post-tensioning reinforcement at each section. If there is no post-tensioning in the member simply leave this section blank. Since the shear capacity is related to the moment capacity, this information will need to be included for all analysis points. Currently all of the prestressing must be lumped into a single row. Input the combined cross sectional area for all of the prestressing strands and the distance to the centroid. If multiple rows are combined then input the distance to the equivalent centroid. Input the effective stress in the prestressing steel after losses (f_{pe}). If the tendon is fully bonded, then this is all that needs to be input for the Post-Tensioning section. If unbonded tendons are used, input the length of the tendon between anchorages (l_i) and the number of support hinges that the tendon crosses between anchorages (N_s) (AASHTO LRFD 5.7.3.1.2).

TENSION REINFORCEMENT.....Describe the tension reinforcement (partial developed bars combined with fully developed bars) at each section. For negative moment sections, it is preferable to include all longitudinal bars present within the effective top flange width. This information is required for shear and bending since the structural depth is used in both calculations. Three rows or locations of reinforcement are available. Input the bar size number, number of bars and distance from the tension fiber to the centroid of the reinforcement being described. For square bars, refer to the ***Info*** sheet for the # bar equivalent. For instance, a 1-1/4 inch square bar is equivalent to a #11.

Input the bar size number and not the “#” sign. The “#” sign is included in the cell’s format. The total reinforcement and effective structural depth is calculated at the bottom of this section.

SHEAR REINFORCEMENT.....Describe the shear reinforcement in this section in four rows of data. If shear is evaluated, input the shear reinforcement area and spacing, maximum aggregate size (defaults to 0.75 in), the Longitudinal Reinforcement Spacing, and angle of inclination of the stirrups to the horizontal α (defaults to 90°).

The Longitudinal Reinforcement Spacing, S_x, is the lesser of d_v or the maximum distance between layers of longitudinal crack control reinforcement, where the area of the reinforcement in each layer is not less than $0.003*b_v*S_x$ as shown in AASHTO LRFD Figure 5.7.3.4.2-3 (shown here to the right).

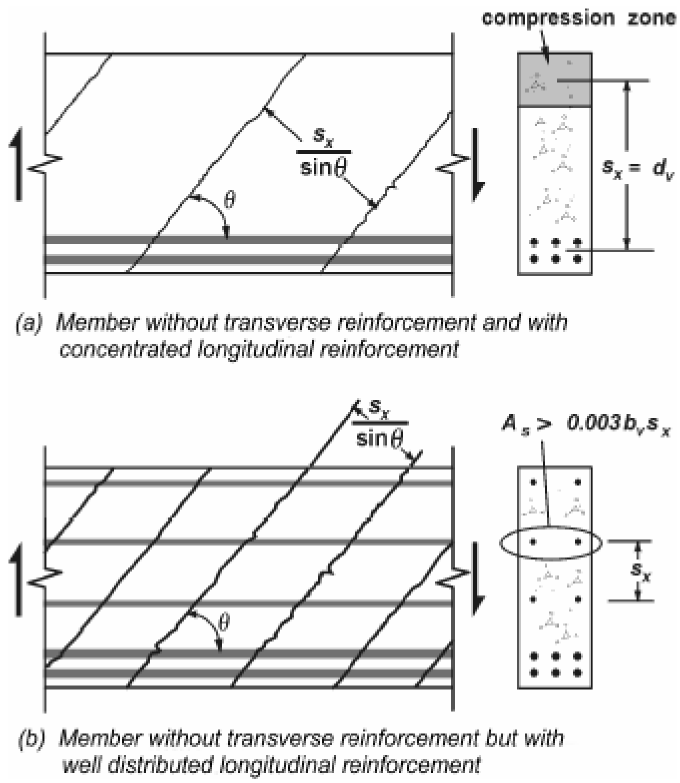


Figure 5.8.3.4.2-3 Definition of Crack Spacing Parameter, s_x.

FLEXURE CAPACITY....This area of the ***Capacity*** sheet calculates the nominal moment capacity. The forces of the internal couple T and C and the depth of compression block “a” are provided. The strength reduction factor, ϕ□ is not included in the nominal capacity (row 57). In row 58 a check is made to ensure the section is ductile according to AASHTO LRFD 5.6.3.3. If the section fails the check of $\phi M_n > 1.2\ M_{cr}$, or $1.33M_u$ (AASHTO LRFD 5.6.3.3, Minimum Reinforcement) then a note of “Under-Reinforced” is displayed. The cracking moment is calculated based on the gross section properties and section modulus of the tension fiber which is set to the modulus of rupture, $7.5\ (f'c)^{0.5}$. ϕ is set to 0.90 in this calculation. If the reinforcement ratio ρ is > ρ_b, (AASHTO LRFD 5.5.4.2 and 5.6.2.1) a note of “Compression Controlled” is displayed. If the reinforcement ratio ρ is between $0.63\rho_b$ and ρ_b, a note of “Transition” (between tension-controlled and compression-controlled) is displayed. Otherwise, the section is considered tension-controlled and a note of “Ductile” is displayed. In the transition region in between compression-controlled and tension-controlled, ϕ varies linearly between the two regions. For any case, the capacity is still calculated assuming the reinforcement to yield and the strain at the extreme fiber of the concrete to be 0.003, but it is reduced by multiplying by the “phi-modifier” calculated to accomplish the reduced ϕ according to AASHTO LRFD 5.5.4.2.

Row 64 provides the maximum percentage of negative moment redistribution allowed under AASHTO LRFD 5.6.3.4. This percentage is a function of the calculated longitudinal strain ε_x. A reduction percentage less than or equal to this maximum may be applied to reduce negative moment in order to increase a low negative moment Rating Factor. However, this adjustment must be accompanied by a corresponding increase in positive moments to maintain equilibrium, which means increasing the positive moments and reducing the positive moment Rating Factors accordingly.

SHEAR CAPACITY.... Most commonly, the General Procedure (AASHTO LRFD 5.7.3.4.2) is used, and “V_General” is selected in row 13 of the ***Capacity Table*** worksheet. For this method, because shear capacity varies with the rating load, nominal capacities V_n are listed in the ***Capacity Table*** worksheet.

The "**SHEAR CAPACITY"** area of the ***Capacity*** sheet calculates the nominal shear capacity using the AASHTO LRFD Simplified Procedure (AASHTO LRFD 5.7.3.4.1), followed by the worst-case results of the General Procedure (AASHTO LRFD 5.7.3.4.2). Row 67 calculates the minimum amount of transverse reinforcement that is required to restrain the growth of diagonal cracking and to increase ductility of the section, as per AASHTO LRFD 5.7.2.5. This value is used to determine if the section has the minimum transverse reinforcement when using the General Procedure for the shear capacity.

For the Simplified Procedure, V_c, reduces to $2(f'_c)^{0.5}b_wd$, which does *not* vary with rating load. The stirrup contribution, V_s, is reduced to A_vf_yd/s (same as the General Procedure with $\beta = 2.0$ and $\theta = 45°$, equivalent to the old LFD method for shear capacity). Normally this method would be chosen only for (a) a section within d_v of the support face (the "zone of confusion"), or (b) a shallow section (depth < 16 inches), or (c) a section without stirrups. To utilize this method, select "User" in row 13 the ***Capacity Table*** worksheet, and manually enter the capacity for the HL93 (INVENTORY) vehicle, using the nominal shear capacity V_n provided in row 70 of the ***Capacity*** worksheet.

The reinforcing steel capacity V_s corresponding to the minimum A_v under LRFD 5.7.2.5 is calculated in row 72. The maximum nominal capacity V_n under AASHTO LRFD 5.7.3.3 is calculated in row 73. Row 75 performs both of these checks and reports whether the shear section is

- "Ductile" (both of these checks pass),
- "Non-Ductile" (LRFD Equation 5.7.3.3-2 fails and section is over-reinforced), or
- "Under-Rein." (where steel shear capacity V_s is less than the steel capacity with minimum stirrups $V_{s,min}$).

Row 80 shows the worst-case nominal shear capacity V_n from all of the LRFD General Procedure (MCFT) calculations for the section found in the ***Capacity Table*** worksheet. Row 78 shows the steel capacity component V_s, while row 77 reports the corresponding maximum θ that was used. Similarly, Row 79 shows the concrete capacity component V_c, while row 76 reports the corresponding minimum β that was used. Conservatively, this worst-case V_n from the General Procedure calculations, rather than V_n from the Simplified Procedure, is used in the ductility comparisons mentioned above.

Row 81, concrete A_c, is provided for potential future enhancements (to handle negative strains from post-tensioning), and is not used in any calculations at this time.

19.2.1.4 XB_RC.XLT - *Output* worksheet

This section describes the contents of the ***Output*** sheet contained in the XB_RC template. It is assumed that the user has used XB_MAIN.XLS to evaluate each investigated section and the results have been placed in the ***Output*** sheet. Cells in light violet contain information filled in by **XB_MAIN.XLS** during the analysis.

XB_MAIN.XLS recognizes the type of analysis selected and if it is shear, places the V and corresponding M influence ordinates in the ***Output*** worksheet of the data template.

SECTION EVALUATED.....The information provided by the user in the Critical Section area of the ***Input*** worksheet is copied and placed in this area.

DEAD LOAD....The dead load results are listed here from the **XB_MAIN.XLS** analysis.

INFLUENCE ORDINATES....**XB_MAIN.XLS** calculates and places the influence line ordinates here. The influence ordinate is the ratio of the actual shear or bending force produced by single or multiple lane loading divided by the single lane reaction.

19.2.1.5 XB_RC.XLT – *Capacity Table* worksheet

This visible worksheet provides a place for the display of shear capacity, which varies from vehicle to vehicle in the LRFD General Procedure (MCFT). It is assumed that the user has used XB_MAIN.XLS to evaluate each investigated section and the results have been placed in the ***Output*** sheet. The user must input the Impact, the BRASS Single-Lane and Multi-Lane Distribution Factors in row 10. The user also inputs the combined Resistance Factor (Φ) in row 15.

The impact factors are entered into BRASS, and then the factored reactions are entered into the crossbeam file. The crossbeam program does remove the impact factor to determine the lane reactions, but whenever it calculates the capacity or rating factors it puts the impact factor back into the live load. Therefore, as long as the correct impact factor is in the BRASS files, the rating factors will be correct (0 or Null will cause the rating factors to blow up).

If a separate reaction file is created to determine the bent reactions (mixed superstructure types or prestressed girders made continuous for live load), the Distribution Factors may be set to 1.0 in the BRASS files, but the impact factors need to be the correct factors run in the BRASS reaction file.

If it is ever deemed necessary to check a crossbeam with a different impact factor, the factored reaction has to be modified. This modification can occur with either (1) a new BRASS run, (2) in the preliminary file for the bent, or (3) directly in the crossbeam file. For the last two methods, multiply the factored reaction by the new impact factor and divide by the old impact factor.

SECTION CAPACITY....The nominal capacity of the critical section can be calculated by the program or input by the user. Four options are provided: “User”, “M”, “V_General (the normal choice for LRFR shear capacity using MCFT), and “V_App_B5”. If “V_General” is chosen, the shear capacity is calculated using the direct solution MCFT General Procedure (AASHTO LRFD 5.7.3.4.2). If “V_App_B5” is chosen, the shear capacity is determined using the MCFT alternate method (iterative solution with tables) allowed in AASHTO LRFD Appendix B5. To avoid errors, make this capacity calculation selection only **after** the analysis cycle with **XB_MAIN.XLS** is complete. Note: If you notice a column of negative Rating Factors in the ***RF*** worksheet or a blank column in the ***Capacity Table*** worksheet, it may be because the ***Capacity Table*** worksheet has not been updated. When in doubt, click on the “Recalculate Capacities” button on the ***Capacity Table*** worksheet.

When choosing “M” the flexural capacity is calculated according to AASHTO LRFD 5.6.3.2. In the rare case where tension does not control the capacity, the Resistance Factor ϕ is to be reduced according to AASHTO LRFD 5.5.4.2. The software accounts for this reduction internally by calculating a “ϕ modifier" (shown in row 63 of the ***Capacity*** worksheet) and applying it directly to the nominal capacity M_n, rather than changing the combined Φ factor already input above.

Normally shear need not be evaluated within d_v of the face of a support nor in the middle 1/3 of a span. However, a section affected by significant cracking (> 0.040” wide) in the region within d_v of the support face, may warrant a shear investigation in this region. In such an investigation, since the “V_General” (MCFT) approach is less conservative in this “zone of confusion”, shear capacity should be evaluated using the Simplified Procedure in AASHTO LRFD 5.7.3.4.1. This is accomplished in row 13 of the ***Capacity Table*** worksheet by choosing the “User” option in the drop-down list in the appropriate column, and then manually entering a “user” capacity for the HL93 (INVENTORY) vehicle using the Simplified Procedure nominal capacity V_n provided in the corresponding column in row 70 of the ***Capacity*** worksheet. This is equivalent to setting β=2.0 and θ=45° in MCFT, and is essentially the same as the traditional, and conservative, LFD method of shear evaluation. Given that all the analysis theories tend to fall apart in the “zone of confusion”, reducing the section capacity to account for the missing concrete at a utility hole provides an additional level of accuracy that is not justified.

If confronted with low Rating Factors for crossbeam shear, it is permissible to “go fishing”, trying various shear calculation methods in search of the greatest capacity. Both the “V_General” option and the alternate “V_App_B5” method are equally acceptable in the LRFD code, and in many cases will yield a greater capacity. When "fishing" for the greatest capacity, do *not* choose "User" with a capacity from the Simplified Procedure except in those rare cases where its use is appropriate. The Simplified Procedure is acceptable only for (a) a section within d_v of a non-continuous support face (the "zone of confusion"), or (b) a shallow section (total depth < 16 inches), or (c) a section without stirrups.

If "User" is selected, the cells are unprotected (yellow) and the engineer may input an externally calculated capacity or an equation for each live load. This option may be used if the addition of compression reinforcement is included, axial force is present, or vertical and sloped stirrups exist together, etc. To use the same capacity or equation for all live loads, enter the value for the HL93 (INVENTORY) first, and this will populate all of the other live loads with the same value. If the user selects any other option, the cell is protected and the value of the capacity is listed based on the inputs in the ***Capacity*** worksheet. See **XB_RC.XLT** - ***Capacity*** worksheet for further discussion.

19.2.1.6 XB_RC.XLT – *Mu & Vu* worksheet

The ***Mu & Vu*** worksheet will compute the factored shear and moment for each vehicle at each analysis section. This sheet is used as a resource for when the capacity will need to be manually computed, such as for a crossbeam that has been post-tensioned. Allowing the crossbeam program to compute the V_c and V_s for the section, the user then can manually compute the V_p for each load by using the factored loads from the ***Mu & Vu*** sheet. Once the V_p has been computed for each load, they should be added to the values shown on the ***Capacity Table*** sheet and then manually entered on the ***Capacity Table*** sheet for each vehicle after switching the calculation method back to "User".

The top portion of the worksheet is the V_u table, and the bottom portion is the M_u table. When the force type for a section is V (based on what was analyzed in XB_MAIN.XLS), the values shown in the V_u table correspond to the influence ordinates that produce the greatest V_u. The values shown in the M_u table then correspond to the concurrent moment. Likewise, when the force type for a section is +M or –M, the values shown in the M_u table correspond to the influence ordinates that produce the greatest M_u. The values shown in the V_u table then correspond to the concurrent shear.

The "Calculate Loads" button at the top of the worksheet should be used after changes have been made to any factors that affect the factored live load.

19.2.1.7 XB_RC.XLT - *RF* worksheet

This sheet calculates the rating factors for each rating vehicle at each investigated section. This sheet is identical to the Load Rating Worksheet (pages 2 and above of the Load Rating Summary Workbook). It is assumed that the ***Output*** Sheet is complete and the user has input the AASHTO LRFD dead load factors (γ_{DC} and γ_{DW}), Impact (1 + IM) and multiple presence Distribution Factors for the single and multiple lane cases (mg) in the ***Capacity Table*** worksheet. (The Distribution Factors mg must be the mg values for reactions at this bent for the same girder(s) used for girder live load Reactions entered in the ***Live Loads*** worksheet).

The rating factors can be directly transferred to the Load Rating Summary Workbook. With both the Crossbeam Analysis Data File ***RF*** worksheet and the Load Rating Summary Workbook open, each critical crossbeam section can be copied and the pasted into the corresponding location using the Edit Paste Special, Values to avoid transferring formulas and colors. (The cells where the rating factors are presented in the ***RF*** worksheet have been defined as a variable name so this process may be automated in the future).

> In the Crossbeam Analysis Data File, if you see a "#VALUE!" error in cells of the ***RF*** worksheet or the message "See Table" in cells of the ***Capacity Table*** worksheet, this is normally an indication that macros were invoked prematurely by selection of the capacity calculation method (using the drop-down box in row 13 of the ***Capacity Table*** worksheet) before the analysis cycle with **XB_MAIN.XLS** was complete. The solution is as follows:

(1) Go to the ***RF*** worksheet and note in which section number (column) the "VALUE" errors occur
(2) Go to the ***Capacity Table*** worksheet
(3) For each section (column) where you had noted error messages, deselect the capacity calculation type by choosing "User" in the drop-down pick-list
(4) For the same sections (columns), reselect the appropriate capacity calculation type. This should re-activate the capacity calculations with the expected input data.

The Rating Factors for the load cases "CTP VEHICLE W/3S2 VEHICLE" and "STP VEHICLE W/3S2 VEHICLE" are calculated using the modified equation that accounts for Legal 3S2 vehicles in adjacent lanes (See note at the end of Article 1.4.1.1).

Do NOT use the summary sheet equations to calculate the bottom set of rating factors for crossbeams. The entire set of Rating Factors should be copied from the crossbeam program and pasted into the Summary Sheet program. The reason the two programs provide different values are that the LR summary sheet uses the distribution factors to adjust from multi lane to single lane rating factors. The crossbeam program is using the computed lane load reactions combined with the multi and single lane influence line ordinates to adjust the rating factors. Thus, since they have different loading conditions the two programs will not produce the same results.

19.2.1.8 XB_RC.XLT - *Info* worksheet

This section contains the information related to the reinforcement. The conversion between standard bars and square bars are given for reference. Only standard bar equivalents for square bars can be input into the ***Capacity*** Sheet.

19.2.2 Steel Crossbeam Analysis Data File (Excel)

XB_S.XLT – Introduction

This template file is for load rating steel crossbeams. A separate file is used for each crossbeam analysis. The template should first be stored in your …\XLStart folder (e.g. C:\Program Files\Microsoft Office\Office11\XLStart), so it can be accessed from the **F**ile, **N**ew option in Excel. Always use the latest version of this template file from the ODOT FTP Server. When **XB_S.XLT** is opened, it is displayed as **XB_S1**. Use the **F**ile Save **A**s command to save the file as a bent-specific Excel workbook (**.**XLS) file. An example would be **XB_BENT1.XLS**.

The workbook includes 6 visible sheets, ***Input, Live Loads, Capacity, Output, RF*** and ***Service II RF.*** Cells in light yellow require input by the user. Cells in light violet are calculated and filled in during XB_MAIN.XLS analysis. The load rater is expected to include hard copies of all sheets of the workbook in the Load Rating Report.

Note that a red triangle appears in the upper right corner of certain cells. These cells include notes which explain the required input. Hover over or double-click on the cell to access the note.

Input includes the information required to describe the geometry, dead loads and sections to be evaluated.

Live Load is where the user inputs the girder factored live load reactions from the BRASS Output File, as well as the live load factor γ_L, for each rating vehicle. This and other input parameters are used to calculate live load single-lane reactions for use in the crossbeam analysis.

Capacity includes the geometry and material property input necessary to calculate the nominal capacity. Alternatively, the capacity may be input directly by the user on the ***Output*** sheet.

Output contains the results of each investigated section analysis. The user also inputs the combined Resistance Factor (Φ) and chooses the capacity calculation method (normally "M" for moment or "V" for shear) for each section using the drop-down boxes in row 17. **Note: Selection of the capacity calculation method prior to using XB_MAIN.XLS can lead to erroneous results.**

RF lists the Rating Factor for each load at each point of interest for the Strength Limit States.

Service II RF lists the Rating Factor for each load at each point of interest for the Service 2 Limit State.

19.2.2.1 XB_S.XLT - *Input* worksheet

This section describes the contents of the ***Input*** Sheet contained in the **XB_S.XLT** template.

GENERAL INFORMATION.....Enter the information requested. This information is echoed in the ***Output,*** Sheets and is copied to **XB_MAIN.XLS** during the critical section analysis. For the member description, be brief, as the description must be able to fit in a column of the Load Rating Summary Workbook. Use "XB_Bent1" for example.

ROADWAY INFORMATION.....Enter the roadway width and distance from the left curb to the bridge centerline measured in feet and normal to the bridge centerline.

BENT ALIGNMENT.....Enter the skew in decimal degrees. The skew is measured from the normal to the bridge centerline position to the centerline of the bent. Positive skew is shown on the template and is described as a clockwise rotation looking ahead on station and measured from the normal to bridge centerline position. Actually, the sign of the skew does not matter, only the magnitude. However, the graphics plan view presentation may be incorrect.

MATERIAL PROPERTIES.....Enter the modulus of elasticity for the crossbeam and columns.

CROSSBEAM INFORMATION.....Enter the geometry to describe the crossbeam. All dimensions are measured in the plane of the bent. A maximum of nine spans are allowed. A span is the length of a cantilever measured from the end to the centerline of the column or the distance between centers of columns. If the span is a cantilever, enter a "C" into the column with the heading "C or H ?". (Make sure there is no space after the "C"). If a hinge occurs at the right end of the span, enter a "H". No column can exist directly at a hinge location. The span length is measured in feet, moment of inertia of the span in the plane of the bent is given as ft^4. The analysis assumes prismatic sections only. Since we are not concerned with deflections, I_{avg} is appropriate for cantilever spans. However, w_{left} and w_{right} sections allow the user to input the uniform weight of the span at the left and right ends of each span. A linear transition is assumed between these points. Enter the weight in kips per lineal foot.

COLUMN INFORMATION.....Based on the crossbeam information, the expected number of columns is calculated and displayed in a red font. If this number does not match your situation, check your CROSSBEAM INFORMATION. For each column, enter the column length, cross-sectional area and bending moment of inertia in the plane of the bent. Also, enter the end conditions of the column, "P" for pinned and "F" for fixed. Do not use "F" for a fixed top unless the connection is detailed to resist negative moment. The user must also enter the distance from the left column to the centerline of the bridge. This distance is measured normal to the bridge centerline. Note that it is possible to code nine spans, assuming no cantilevers, would require ten columns. If this situation is encountered the number of spans will have to be decreased such that a maximum of eight columns are coded.

ANALYSIS SECTION INFO.....Enter up to 8 sections to evaluate. Because the software generates a node at each active evaluation section, the section cannot coincide with an existing node. This should not be a problem because the critical section for bending and shear are generally taken at the face of support. Remember to avoid evaluating sections that are structurally symmetrical with previously defined sections.

List the span that the analysis section is located (See CROSSBEAM INFORMATION) and the distance from the left end of the span to the critical section measured in feet and along the span. ΔX must be greater than zero and less than the span length. Enter the analysis type, +M for positive moment (tension in the bottom fiber), -M for negative moment, and V for shear. Assure that these cell entries are text by starting each of them with an apostrophe.

LOADING.....Enter the distance from the centerline of the left girder to the centerline of the bridge. This distance is measured normal to the bridge centerline. Enter the BRASS reference file (output file name). This information is not used; it is simply the reference for the girder dead load reactions. Enter the spacing between girders normal to the bridge centerline. Based on the number of spacings you enter, the number of girders is calculated and presented. Four separate Component dead load (DC) columns are available. The user can input a descriptive name at the top of each column. The recommended descriptions are: “Girder” for girder self-weight, “Other Str.” for other stage-1 structure dead loads (usually the diaphragms), and “Rails/Curbs” to include all stage-2 dead loads except wearing surface. Enter the girder reaction for each load case. The four columns will be added and this information will be used in the analysis and reported as the structure dead load. A separate column is provided for the Wearing Surface dead load (DW). DC and DW are kept separate to simplify the future addition or removal of wearing surfaces. Supporting calculations for the separation of wearing surfaces should be included as equations in these cells or included in the Crossbeam Preliminary File (Mathcad) which supports the calculations for the crossbeam.

ENGINEER COMMENTS.....Enter any comments in this area that would make your assumptions clearer to a future user.

19.2.2.2 XB_S.XLT – *Live Loads* worksheet

This section describes the contents of the ***Live Loads*** Sheet contained in the **XB_S.XLT** template. Enter the reactions for each rating vehicle as listed in the Crossbeam Preliminary File. Enter the live load Factors for each rating vehicle as listed in the Girder Preliminary File, using only the yellow cells. In the cells to the right, the sheet calculates the factored and unfactored live load reactions, and the lane load combination required by the LRFD code.

Within the “Design & Legal Vehicles” section of this sheet there tends to be some confusion on what data is required for a given bridge, mainly with the “TYPE 3-3 & LEGAL LANE”, the “TYPE 3-3 TRAIN & LEGAL LANE”, and the “LEGAL LANE” reactions. The “TYPE 3-3 & LEGAL LANE” vehicle is only required for spans greater than 200 feet, and will normally be coded in BRASS as the 20th rating vehicle. The “TYPE 3-3 TRAIN & LEGAL LANE” vehicle is only used for checking negative moments over interior supports, thus there will not be a reaction for this vehicle for bents that are acting as simple supports.

For both of the above vehicle combinations, the LRFR code requires that the Type 3-3 vehicle be reduced to 75%, but the full lane load of 0.2 kips/ft is applied. BRASS already has it built in to the programming to take 75% of the truck load for computing the rating factors for these load combinations. Looking at the BRASS output file, you can verify under the "LIVE LOAD COMBINATIONS SUMMARY" (which is just after the live load distribution factors summary) that the truck is taken at 0.75 and the lane is taken at 1.0 for these combinations.

The live load reactions for each truck that we get from BRASS are supposed to be the unfactored girder actions. This is not a true statement because the distribution factor, impact factor, and scale factor have already been applied. But these are the full vehicle reactions for each truck, thus they have not been adjusted to the 75% as required for the load combination. Therefore we plug the full reaction into the ***Live Loads*** sheet of the crossbeam file. The crossbeam file will automatically adjust the reaction to 75% when it converts the truck reaction into an unfactored lane load reaction.

The factored reaction for the "Type 3-3 & Legal Lane" vehicle is the truck load only for this load case (which is usually applied as load number 20 in the "_T" file for spans greater than 200'). Likewise, the "Type 3-3 Train & Legal Lane" vehicle is the truck load only for this load case (which is applied as load number 4 in the "_T" file for analyzing negative moment over supports). Finally, the legal lane load reaction is entered for the "Legal Load" (which is applied as load number 5 in the "_T" file). When calculating the unfactored lane load reaction for these special load cases, the crossbeam file will combine the lane load with the appropriate vehicles.

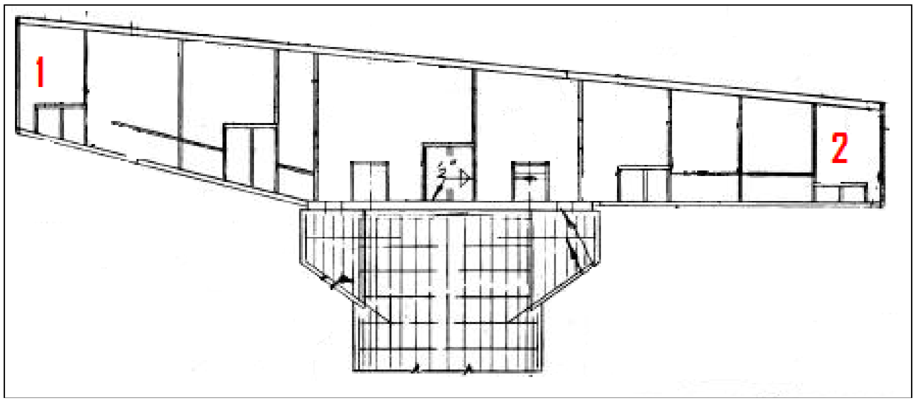
19.2.2.3 XB_S.XLT - *Capacity* worksheet

This section describes the contents of the ***Capacity*** Sheet contained in the XB_S template. The section capacity is calculated based on the section geometry input by the user. It is assumed that the user has evaluated each critical section and the results have been placed in the ***Output*** Sheet. Cells in light yellow require input by the user.

MATERIAL PROPERTIES.....Input the yield strength of the steel crossbeam.

SECTION GEOMETRY.....Describe the cross section geometry. Input the "Flange Width", the "Flange Thickness", the "Web Thickness", the "Total Height" of the beam, and the Unbraced Length (L_b) at each section. Where the longitudinal beams are connected integral to the side of the crossbeam, the unbraced length will be the longitudinal girder spacing. Where the longitudinal beams rest on top of the crossbeam, the unbraced length will be the crossbeam span length. However, when the longitudinal girders rest on top of the crossbeam, the unbraced length could be the girder spacing if there is a sufficient connection between the longitudinal girder and the top flange of the crossbeam to provide lateral support to the compression flange of the crossbeam.

End Panel vs Interior Panel….. When analyzing a steel member, the difference between interior and end panels may not always be intuitive. A panel is the segment of the beam between transverse stiffeners. An end panel is defined at the first stiffener space adjacent to where the beam is no longer continuous. See the below image of a steel hammer head crossbeam. The end panels are panels 1, and 2. The location of support does not affect if the panel is defined as interior, or an end panel.



Section Properties..... This area of the ***Capacity*** sheet calculates the depth of the web in compression at the plastic moment (D_{cp}), the radius of gyration with respect to the vertical axis in the plane of the web (r_y), the effective radius of gyration for lateral torsional buckling (r_t), the elastic section modulus (S), and the plastic section modulus (Z) of the steel beam.

FLEXURE CAPACITY....This area of the ***Capacity*** sheet calculates the nominal moment capacity. The first part of this section checks to see if the beam satisfies the compactness criteria for web slenderness and flange slenderness as per AASHTO LRFD Articles 6.10.2.1 and 6.10.2.2. Then the limiting unbraced length (L_p) to achieve the nominal flexural resistance (plastic moment) under uniform bending is calculated. The limiting unbraced length (L_p) should be greater than the unbraced length (L_b) specified within the "Section Geometry" input area.

If the web slenderness and flange slenderness checks are satisfied, a black text "yes" will be displayed for each check. Otherwise, a red text "no" will be displayed. If L_p is greater than L_b, the value of L_p will be displayed in black text to indicate that the value is acceptable for the moment capacity calculation. Otherwise, the value will be displayed in red text. The capacity for bending, $M_n = F_y * Z$, is calculated for beams satisfying all three of the above criteria. Otherwise, a value of "N/A" is reported and the capacity must be computed and input manually by the user.

SHEAR CAPACITY.... This area of the ***Capacity*** sheet calculates the nominal shear capacity of the unstiffened web based on AASHTO LRFD Article 6.10.9.2.

19.2.2.4 XB_S.XLT - *Output* worksheet

This section describes the contents of the ***Output*** sheet contained in the XB_S template. It is assumed that the user has used XB_MAIN.XLS to evaluate each investigated section and the results have been placed in the ***Output*** sheet. Cells in light violet contain information filled in by **XB_MAIN.XLS** during the analysis. Cells in light yellow require input by the user.

XB_MAIN.XLS recognizes the type of analysis selected and if it is shear, places the V and corresponding M influence ordinates in the ***Output*** worksheet of the data template.

SECTION EVALUATED.....The information provided by the user in the Critical Section area of the ***Input*** worksheet is copied and placed in this area. The combined LRFR resistance factor, Φ□ is required input (row 12). This is the only input needed prior to analysis with **XB_MAIN.XLS**.

SECTION CAPACITY....The nominal capacity of the critical section can be calculated by the program or input by the user. Three options are provided: "User", "M", and "V". To avoid errors, make this capacity calculation selection only **after** the analysis cycle with **XB_MAIN.XLS** is complete. Note: If you notice a column of negative Rating Factors in the *RF* worksheet, it may be because the Nominal Capacity (row 19) of the ***Output*** worksheet has not been updated. When in doubt, the best solution is go to the appropriate column in row 17 (drop-down boxes) of the ***Output*** worksheet, and select some calculation method other than "V" and then re-select it ("de-select and re-select").

When choosing "M", the flexural capacity is calculated according to AASHTO LRFD 6.10.7.1.2. The flexural capacity is calculated for beams satisfying the compactness criteria of AASHTO LRFD 6.10.2.1 and 6.10.2.2. Otherwise the flexural capacity must be input manually. When choosing "V", the shear capacity is computed assuming the web is unstiffened as per AASHTO LRFD 6.10.9.2.

If "User" is selected, the cell is unprotected (yellow) and the engineer may input an externally calculated capacity or an equation. This option may be used if the section is non-compact or the beam is something other than a doubly-symmetric rolled or fabricated I-section, non-composite, and non-hybrid. If the user selects any other option, the cell is protected and the value of the capacity is listed based on the inputs in the ***Capacity*** worksheet. See **XB_S.XLT** - ***Capacity*** worksheet for further discussion.

DEAD LOAD....The dead load results are listed here from the **XB_MAIN.XLS** analysis.

INFLUENCE ORDINATES....**XB_MAIN.XLS** calculates and places the influence line ordinates here. The influence ordinate is the ratio of the actual shear or bending force produced by single or multiple lane loading divided by the single lane reaction.

19.2.2.5 XB_S.XLT - *RF* worksheet

This sheet calculates the rating factors for each rating vehicle at each investigated section. This sheet is identical to the Load Rating Worksheet (pages 2 and above of the Load Rating Summary Workbook). It is assumed that the ***Output*** Sheet is complete and the user has input the AASHTO LRFD dead load factors (γ_{DC} and γ_{DW}), Impact (1 + IM) and multiple presence Distribution Factors for the single and multiple lane cases (mg) in the ***RF*** worksheet. (The Distribution Factors mg must be the mg values for reactions at this bent for the same girder(s) used for girder live load reactions entered in the ***Live Loads*** worksheet).

The impact factors are entered into BRASS, and then the factored reactions are entered into the crossbeam file. The crossbeam program does remove the impact factor to determine the lane reactions, but whenever it calculates the capacity or rating factors it puts the impact factor back into the live load. Therefore, as long as the correct impact factor is in the BRASS files, the rating factors will be correct (0 or Null will cause the rating factors to blow up).

If a separate reaction file is created to determine the bent reactions (mixed superstructure types or prestressed girders made continuous for live load), the Distribution Factors may be set to 1.0 in the BRASS files, but the impact factors need to be the correct factors run in the BRASS reaction file.

If it is ever deemed necessary to check a crossbeam with a different impact factor, the factored reaction has to be modified. This modification can occur with either (1) a new BRASS run, (2) in the preliminary file for the bent, or (3) directly in the crossbeam file. For the last two methods, multiply the factored reaction by the new impact factor and divide by the old impact factor.

The rating factors can be directly transferred to the Load Rating Summary Workbook. With both the Crossbeam Analysis Data File ***RF*** worksheet and the Load Rating Summary Workbook open, each critical crossbeam section can be copied and the pasted into the corresponding location using the Edit Paste Special, Values to avoid transferring formulas and colors. (The cells where the rating factors are presented in the ***RF*** worksheet have been defined as a variable name so this process may be automated in the future).

> In the Crossbeam Analysis Data File, if you see a "#VALUE!" error in cells of the ***RF*** worksheet, this is normally an indication that macros were invoked prematurely by selection of the capacity calculation type (using the drop-down box in row 17 of the ***Output*** worksheet) before the analysis cycle with **XB_MAIN.XLS** was complete. The solution is as follows:
>
> (1) Go to the ***RF*** worksheet and note in which section number (column) the "VALUE" errors occur
> (2) Go to the ***Output*** worksheet
> (3) For each section (column) where you had noted error messages, deselect the capacity calculation type by choosing "User" in the drop-down pick-list
> (4) For the same sections (columns), reselect the appropriate capacity calculation type. This should re-activate the capacity calculations with the expected input data.
>
> The Rating Factors for the load cases "CTP VEHICLE W/3S2 VEHICLE" and "STP VEHICLE W/3S2 VEHICLE" are calculated using the modified equation that accounts for Legal 3S2 vehicles in adjacent lanes (See note at the end of Article 1.4.1.1).

Do NOT use the summary sheet equations to calculate the bottom set of rating factors for crossbeams. The entire set of Rating Factors should be copied from the crossbeam program and pasted into the Summary Sheet program. The reason the two programs provide different values are that the LR summary sheet uses the distribution factors to adjust from multi lane to single lane rating factors. The crossbeam program is using the computed lane load reactions combined with the multi and single lane influence line ordinates to adjust the rating factors. Thus, since they have different loading conditions the two programs will not produce the same results.

19.2.2.6 XB_S.XLT – *Service II RF* worksheet

This sheet is nearly identical to the ***RF*** worksheet, except that all of the dead load and live load factors have automatically been set to the Service II Limit State for the calculation of the rating factors. If any of the Service II Rating Factors for a given analysis point are less than 1.1, then report all of the Service II Rating factors for that particular analysis point on the Load Rating Summary. Otherwise, all of the Service II Rating Factors that are greater than 1.1 do not need to be copied to the Load Rating Summary.

19.2.3 Timber Crossbeam Analysis Data File (Excel)

XB_T.XLT – Introduction

This template file is for load rating timber crossbeams. A separate file is used for each crossbeam analysis. The template should first be stored in your …\XLStart folder (e.g. C:\Program Files\Microsoft Office\Office11\XLStart), so it can be accessed from the **F**ile, **N**ew option in Excel. Always use the latest version of this template file from the ODOT FTP Server. When **XB_T.XLT** is opened, it is displayed as **XB_T1**. Use the **F**ile Save **A**s command to save the file as a bent-specific Excel workbook (**.**XLS) file. An example would be **XB_BENT1.XLS**.

The workbook includes 5 visible sheets, ***Input, Live Loads, Capacity, Output,*** and ***RF.*** Cells in light yellow require input by the user. Cells in light violet are calculated and filled in during XB_MAIN.XLS analysis. The load rater is expected to include hard copies of all sheets of the workbook in the Load Rating Report.

> Note that a red triangle appears in the upper right corner of certain cells. These cells include notes which explain the required input. Hover over or double-click on the cell to access the note.

Input includes the information required to describe the geometry, dead loads and sections to be evaluated.

Live Load is where the user inputs the girder factored live load reactions from the BRASS Output File, as well as the live load factor γ_L, for each rating vehicle. This and other input parameters are used to calculate live load single-lane reactions for use in the crossbeam analysis.

Capacity includes the input for section geometry, material property, and timber capacity factors necessary to calculate the nominal capacity. Alternatively, the capacity may be input directly by the user on the ***Output*** sheet.

Output contains the results of each investigated section analysis. The user also inputs the combined Resistance Factor (Φ) for flexure and shear and chooses the capacity calculation method ("M" for moment or "V" for shear) for each section using the drop-down boxes in row 17. **Note: Selection of the capacity calculation method prior to using XB_MAIN.XLS can lead to erroneous results.**

RF lists the Rating Factor for each load at each point of interest for the Strength Limit States.

19.2.3.1 XB_T.XLT - *Input* worksheet

This section describes the contents of the ***Input*** Sheet contained in the **XB_T.XLT** template.

GENERAL INFORMATION.....Enter the information requested. This information is echoed in the ***Output,*** Sheets and is copied to **XB_MAIN.XLS** during the critical section analysis. For the member description, be brief, as the description must be able to fit in a column of the Load Rating Summary Workbook. Use "XB_Bent1" for example.

ROADWAY INFORMATION.....Enter the roadway width and distance from the left curb to the bridge centerline measured in feet and normal to the bridge centerline.

BENT ALIGNMENT.....Enter the skew in decimal degrees. The skew is measured from the normal to the bridge centerline position to the centerline of the bent. Positive skew is shown on the template and is described as a clockwise rotation looking ahead on station and measured from the normal to bridge centerline position. Actually, the sign of the skew does not matter, only the magnitude. However, the graphics plan view presentation may be incorrect.

MATERIAL PROPERTIES.....Enter the modulus of elasticity for the crossbeam and columns.

CROSSBEAM INFORMATION.....Enter the geometry to describe the crossbeam. All dimensions are measured in the plane of the bent. A maximum of nine spans are allowed. A span is the length of a cantilever measured from the end to the centerline of the column or the distance between centers of columns. If the span is a cantilever, enter a “C” into the column with the heading “C or H ?”. (Make sure there is no space after the “C”). If a hinge occurs at the right end of the span, enter a “H”. No column can exist directly at a hinge location. The span length is measured in feet, moment of inertia of the span in the plane of the bent is given as ft^4. The analysis assumes prismatic sections only. Since we are not concerned with deflections, I_{avg} is appropriate for cantilever spans. However, w_{left} and w_{right} sections allow the user to input the uniform weight of the span at the left and right ends of each span. A linear transition is assumed between these points. Enter the weight in kips per lineal foot. If the unit weight is not provided on the bridge plans, it is recommended to use 0.050 kcf. This value is taken from AASHTO LRFD Table 3.5.1-1 for soft wood, since timber in Oregon is typically soft.

COLUMN INFORMATION.....Based on the crossbeam information, the expected number of columns is calculated and displayed in a red font. If this number does not match your situation, check your CROSSBEAM INFORMATION. For each column, enter the column length, cross-sectional area and bending moment of inertia in the plane of the bent. Also, enter the end conditions of the column, “P” for pinned and “F” for fixed. Do not use “F” for a fixed top unless the connection appears to be detailed to resist negative moment. The user must also enter the distance from the left column to the centerline of the bridge. This distance is measured normal to the bridge centerline. Note that it is possible to code nine spans, assuming no cantilevers, would require ten columns. If this situation is encountered the number of spans will have to be decreased such that a maximum of eight columns are coded.

ANALYSIS SECTION INFO.....Enter up to 8 sections to evaluate. Because the software generates a node at each active evaluation section, the section cannot coincide with an existing node. This should not be a problem because the critical section for negative bending and shear are generally taken at the face of support or at d from the face of support, respectively. Remember to avoid evaluating sections that are structurally symmetrical with previously defined sections.

Per AASHTO LRFD 8.7 (Timber Under Shear), the critical section for shear is at d from the face of support, but the live load should be placed at 3d or 0.25L (whichever is less) from the support. This means that the section to be analyzed on the ***Capacity*** worksheet may not match the “Analysis Section” on the ***Input*** worksheet. Therefore, the “Analysis Section” for shear on the ***Input*** worksheet needs to be the lesser of 3d or 0.25L to ensure that the live load is placed in the correct location. And then the corresponding section on the ***Capacity*** worksheet will need to define the cross-section geometry at d from the face of support so that the correct capacity is calculated for the loading condition.

List the span that the analysis section is located (See CROSSBEAM INFORMATION) and the distance from the left end of the span to the critical section measured in feet and along the span. ΔX must be greater than zero and less than the span length. Enter the analysis type, +M for positive moment (tension in the bottom fiber), -M for negative moment, and V for shear. Assure that these cell entries are text by starting each of them with an apostrophe.

GIRDER GEOMETRY AND LOADING.....Enter the distance from the centerline of the left girder to the centerline of the bridge. This distance is measured normal to the bridge centerline. Enter the BRASS reference file (output file name). This information is not used; it is simply the reference for the girder dead load reactions. Enter the spacing between girders normal to the bridge centerline. Based on the number of spacings you enter, the number of girders is calculated and presented. Four separate Component dead load (DC) columns are available. The user can input a descriptive name at the top of each column. The recommended descriptions are: “Girder” for girder self-weight, “Other Str.” for other stage-1 structure dead loads (usually the diaphragms), and “Rails/Curbs” to include all stage-2 dead loads except wearing surface. Enter the girder reaction for each load case. The four columns will be added and this information will be used in the analysis and reported as the structure dead load. A separate column is provided for the Wearing Surface dead load (DW). DC and DW are kept separate to simplify the future addition or removal of wearing surfaces. Supporting calculations for the separation of wearing surfaces should be included as equations in these cells or included in the Crossbeam Preliminary File (Mathcad) which supports the calculations for the crossbeam.

ENGINEER COMMENTS.....Enter any comments in this area that would make your assumptions clearer to a future user.

19.2.3.2 XB_T.XLT – *Live Loads* worksheet

This section describes the contents of the ***Live Loads*** Sheet contained in the **XB_T.XLT** template. Enter the reactions for each rating vehicle as listed in the Crossbeam Preliminary File. Enter the live load factors for each rating vehicle as listed in the Girder Preliminary File, using only the yellow cells. In the cells to the right, the sheet calculates the factored and unfactored live load reactions, and the lane load combination required by the LRFD code.

Within the “Design & Legal Vehicles” section of this sheet there tends to be some confusion on what data is required for a given bridge, mainly with the “TYPE 3-3 & LEGAL LANE”, the “TYPE 3-3 TRAIN & LEGAL LANE”, and the “LEGAL LANE” reactions. The “TYPE 3-3 & LEGAL LANE” vehicle is only required for spans greater than 200 feet, and will normally be coded in BRASS as the 20th rating vehicle. The “TYPE 3-3 TRAIN & LEGAL LANE” vehicle is only used for checking negative moments over interior supports, thus there will not be a reaction for this vehicle for bents that are acting as simple supports.

For both of the above vehicle combinations, the LRFR code requires that the Type 3-3 vehicle be reduced to 75%, but the full lane load of 0.2 kips/ft is applied. BRASS already has it built in to the programming to take 75% of the truck load for computing the rating factors for these load combinations. Looking at the BRASS output file, you can verify under the "LIVE LOAD COMBINATIONS SUMMARY" (which is just after the live load distribution factors summary) that the truck is taken at 0.75 and the lane is taken at 1.0 for these combinations.

The live load reactions for each truck that we get from BRASS are supposed to be the unfactored girder actions. This is not a true statement because the distribution factor, impact factor, and scale factor have already been applied. But these are the full vehicle reactions for each truck, thus they have not been adjusted to the 75% as required for the load combination. Therefore we plug the full reaction into the ***Live Loads*** sheet of the crossbeam file. The crossbeam file is will automatically adjust the reaction to 75% when it converts the truck reaction into an unfactored lane load reaction.

The factored reaction for the "Type 3-3 & Legal Lane" vehicle is the truck load only for this load case (which is usually applied as load number 20 in the “_T” file for spans greater than 200'). Likewise, the "Type 3-3 Train & Legal Lane" vehicle is the truck load only for this load case (which is applied as load number 4 in the “_T” file for analyzing negative moment over supports). Finally, the legal lane load reaction is entered for the "Legal Load" (which is applied as load number 5 in the “_T” file). When calculating the unfactored lane load reaction for these special load cases, the crossbeam file will combine the lane load with the appropriate vehicles.

19.2.3.3 XB_T.XLT - *Capacity* worksheet

This section describes the contents of the ***Capacity*** Sheet contained in the XB_T template. The section capacity is calculated based on the section geometry input by the user. It is assumed that the user has evaluated each critical section and the results have been placed in the ***Output*** Sheet. Cells in light yellow require input by the user.

Material Properties.....AASHTO LRFD Section 8.2 defines Beams and Stringers (B&S) as rectangular pieces that are 5.0 or more inches thick (nominal), with a depth more than 2.0 inches (nominal) greater than the thickness. B&S are graded primarily for use as beams, with loads applied to the narrow face. Even though for timber crossbeams the width is often greater than the depth, they shall be considered as Beams and Stringers for determining material properties and factors.

AASHTO LRFD adopted the NDS tables for F_{bo} and F_{vo} (the allowable stress for flexure and shear). Input the reference design value of wood in flexure (F_{bo}) and in shear (F_{vo}). If the material properties of the timber cap are not provided on the plans, use the following values of F_{bo} = 1.35 ksi and F_{vo} = 0.17 ksi as a default. These values are from AASHTO LRFD Table 8.4.1.1.4-1 for Douglas Fir with a Size Classification of “Beams and Stringers” and a Grade of “Number 1”.

As a result of adopting the NDS tables in LRFD, the conversion factor (C_{KF}) was added to convert ASD to LRFD (see AASHTO LRFD 8.4.4.2). This factor should always be 2.5/phi for crossbeams. The phi factor used in the conversion factor (C_{KF}) is only the LRFD Resistance Factor ϕ for flexure or shear and not the combined phi (Φ) which includes the condition and system phi factors. The reason for this is as follows: since ϕ is in the denominator for the C_{KF} equation and the nominal capacity is multiplied by the combined phi (Φ), if the combined phi (Φ) was used, any change of the condition phi (ϕ) would have no effect.

The Wet Service Factor (C_M) for Sawn Lumber shall be 1.0 for both flexure and shear. This value is obtained from AASHTO LRFD Table 8.4.4.3-1, for a nominal thickness of greater than 4.0 inches. In the rare (and unlikely) event that the crossbeam is comprised of a glued laminated timber, the value of C_M for flexure shall be 0.80; and the value of C_M for shear shall be 0.875. These values are obtained from AASHTO LRFD Table 8.4.4.3-2.

For sawn lumber crossbeams with loads applied to the wide face, use a Size Factor (C_F) of 0.86. For sawn lumber crossbeams with loads applied to the narrow face, calculate the Size Factor using the following equation:

$$C_F = \left(\frac{12}{d}\right)^{\frac{1}{9}}$$

which is AASHTO LRFD Equation 8.4.4.4-2; where d = net width of the crossbeam. If d is $\leq$ 12 inches, then C_F = 1.0.

For horizontally laminated glulam crossbeams, with loads applied perpendicular to the wide face of the laminations, the volume factor (C_V), given below, shall be computed when the depth, width, or length of the glued laminated crossbeam timber exceeds 12.0 in., 5.125 in., or 21.0 ft., respectively.

$$C_v = \left[\left(\frac{12.0}{d}\right)\left(\frac{5.125}{b}\right)\left(\frac{21}{L}\right)\right]^a \leq 1.0$$

which is AASHTO LRFD equation 8.4.4.5-1, where:

> d = depth of the crossbeam (in.)
>
> b = width of the crossbeam (in.). For layups with multiple piece laminations (across the width), b will equal the width of the widest piece. Therefore, b will be $\leq$ 10.75 in.

L = length of the crossbeam measured between points of contraflexure (ft.)

a = 0.05 for Southern Pine and 0.10 for all other species.

Since the size factor (C_F) is used for sawn lumber and the volume factor (C_V) is used for glulam lumber, either the size factor or the volume factor needs to be specified in the ***Capacity*** sheet, but not both. According to LRFD, the volume factor (C_V) shall not be applied simultaneously with the beam stability factor, C_L, therefore the software will automatically apply the lesser of these factors.

For normal bridge superstructure types (girder/stringer), the deck factor (C_d) for the crossbeam shall be equal to 1.0.

For short spans with a timber slab superstructure comprised of stressed wood, nail-laminated, and spike laminated decks constructed of solid sawn lumber 2.0 in. to 4.0 in. thick that are supported directly by the timber crossbeam, the deck factor for the timber crossbeam shall be as specified in the following table:

Table 8.4.4.8-1 Deck Factor for Stressed Wood and Laminated Decks.

Deck Type	Lumber Grade	C_d
Stressed Wood	Select Structural No. 1 or No. 2	1.30 1.50
Spike-Laminated or Nail-Laminated	All	1.15

For short spans with a timber slab superstructure comprised of wood planks of 4 x 6 in., 4 x 8 in., 4 x 10 in., or 4 x 12 in., with the load applied to the wide face of the planks, that are supported directly by the timber crossbeam, the deck factor for the timber crossbeam shall be as specified in the following table:

Table 8.4.4.8-2 Deck Factor for Plank Decks.

Size (in.)	C_d
4 × 6	1.10
4 × 8	1.15
4 × 10	1.25
4 × 12	1.50

The Flat-Use Factor and Incising Factor were ignored in the timber crossbeam program since these factors relate to dimensional lumber, and there are no cases anticipated where dimensional lumber would be used for a crossbeam.

The time effect factor (C_λ) shall be chosen to correspond to the appropriate strength limit state as specified in LRFD 8.4.4.9. For Strength I Limit State, $C_\lambda = 0.8$. For Strength II Limit State, $C_\lambda = 1.0$.

Section Geometry....Describe the cross section geometry. The program assumes that the beam is a rectangular section that is non-composite. Input the beam “Width”, and the beam “Height” at each analysis section.

Section Properties.....This area of the ***Capacity*** sheet calculates the elastic section modulus (S) for each analysis section.

Flexure Capacity....This area of the ***Capacity*** sheet calculates the nominal moment capacity for both Strength I and Strength II Limit States of the rectangular timber crossbeam based on AASHTO LRFD Article 8.6.2. In the first part of this section, the engineer needs to enter the Euler buckling coefficient for the beam (K_{bE}).

For visually graded lumber, $K_{bE} = 0.76$
For glulam members, $K_{bE} = 1.10$

Enter the unsupported length (L_u) of the timber crossbeam. The unsupported length should be the pile spacing (crossbeam span length).

The program then displays the computed values for the effective unbraced length (L_e), the slenderness ratio (R_b), the critical buckling design value (F_{bE}), the adjusted flexure design values (F_b) for both Strength I and Strength II, the ratio of the critical buckling design value to the adjusted flexure design values (A), the beam stability factors (C_L), and the nominal moment resistance values (M_n).

Shear Capacity....This area of the ***Capacity*** sheet calculates the nominal shear capacity of the rectangular timber crossbeam based on AASHTO LRFD Article 8.7. The program displays the adjusted shear design values (F_v) for both Strength I and Strength II, and then displays the nominal shear resistance values (V_n).

19.2.3.4 XB_T.XLT - *Output* worksheet

This section describes the contents of the ***Output*** sheet contained in the XB_T template. It is assumed that the user has used XB_MAIN.XLS to evaluate each investigated section and the results have been placed in the ***Output*** sheet. Cells in light violet contain information filled in by **XB_MAIN.XLS** during the analysis. Cells in light yellow require input by the user.

XB_MAIN.XLS recognizes the type of analysis selected and if it is shear, places the V and corresponding M influence ordinates in the ***Output*** worksheet of the data template.

SECTION EVALUATED.....The information provided by the user in the Critical Section area of the ***Input*** worksheet is copied and placed in this area. The combined MBE resistance factors, Φ□ for flexure and shear are required to be input in rows 12 and 13, respectively. This is the only input needed prior to analysis with **XB_MAIN.XLS**.

SECTION CAPACITY....The nominal capacity of the critical section can be calculated by the program or input by the user. Three options are provided: “User”, “M”, and “V”. To avoid errors, make this capacity calculation selection only **after** the analysis cycle with **XB_MAIN.XLS** is complete. Note: If you notice a column of negative Rating Factors in the *RF* worksheet, it may be because the Nominal Capacity (rows 20 and 21) of the ***Output*** worksheet have not been updated. When in doubt, the best solution is go to the appropriate column in row 18 (drop-down boxes) of the ***Output*** worksheet, and select some calculation method other than “V” and then re-select it (“de-select and re-select”).

When choosing “M”, the flexural capacity is calculated according to AASHTO LRFD 8.6.2. When choosing “V”, the shear capacity is computed as per AASHTO LRFD 8.7.

If “User” is selected, the cells (rows 20 and 21) are unprotected (yellow) and the engineer may input an externally calculated capacity or an equation. If the user selects any other option, the cell is protected and the value of the capacity is listed based on the inputs in the ***Capacity*** worksheet. See **XB_T.XLT** - ***Capacity*** worksheet for further discussion.

DEAD LOAD....The dead load results are listed here from the **XB_MAIN.XLS** analysis.

INFLUENCE ORDINATES....**XB_MAIN.XLS** calculates and places the influence line ordinates here. The influence ordinate is the ratio of the actual shear or bending force produced by single or multiple lane loading divided by the single lane reaction.

19.2.3.5 XB_T.XLT - *RF* worksheet

This sheet calculates the rating factors for each rating vehicle at each investigated section. This sheet is identical to the Load Rating Worksheet (pages 2 and above of the Load Rating Summary Workbook). It is assumed that the ***Output*** Sheet is complete and the user has input the LRFD dead load Factors (γ_{DC} and γ_{DW}), Impact (1 + IM) and multiple presence Distribution Factors for the single and multiple lane cases (mg) in the ***RF*** worksheet. (The Distribution Factors mg must be the mg values for reactions at this bent for the same girder(s) used for girder live load reactions entered in the ***Live Loads*** worksheet).

The impact factors are entered into BRASS, and then the factored reactions are entered into the crossbeam file. The crossbeam program removes the impact factor to determine the lane reactions. When it calculates the capacity or rating factors it will use an impact factor of 1.0, as per AASHTO LRFD 3.6.2.3. Therefore, as long as the same impact factor that was used in the BRASS files is specified in the ***RF*** worksheet, the rating factors will be correct (0 or Null will cause the rating factors to blow up).

If a separate reaction file is created to determine the bent reactions (mixed superstructure types or prestressed girders made continuous for live load), the Distribution Factors and Impact Factor may be set to 1.0 in the BRASS files.

The rating factors can be directly transferred to the Load Rating Summary Workbook. With both the Crossbeam Analysis Data File ***RF*** worksheet and the Load Rating Summary Workbook open, each critical crossbeam section can be copied and the pasted into the corresponding location using the Edit Paste Special, Values to avoid transferring formulas and colors. (The cells where the rating factors are presented in the ***RF*** worksheet have been defined as a variable name so this process may be automated in the future).

> In the Crossbeam Analysis Data File, if you see a "#VALUE!" error in cells of the ***RF*** worksheet, this is normally an indication that macros were invoked prematurely by selection of the capacity calculation type (using the drop-down box in row 18 of the ***Output*** worksheet) before the analysis cycle with **XB_MAIN.XLS** was complete. The solution is as follows:
>
> (1) Go to the ***RF*** worksheet and note in which section number (column) the "VALUE" errors occur
> (2) Go to the ***Output*** worksheet
> (3) For each section (column) where you had noted error messages, deselect the capacity calculation type by choosing "User" in the drop-down pick-list
> (4) For the same sections (columns), reselect the appropriate capacity calculation type. This should re-activate the capacity calculations with the expected input data.
>
> The Rating Factors for the load cases "CTP VEHICLE W/3S2 VEHICLE" and "STP VEHICLE W/3S2 VEHICLE" are calculated using the modified equation that accounts for Legal 3S2 vehicles in adjacent lanes (See note at the end of Article 1.4.1.1).

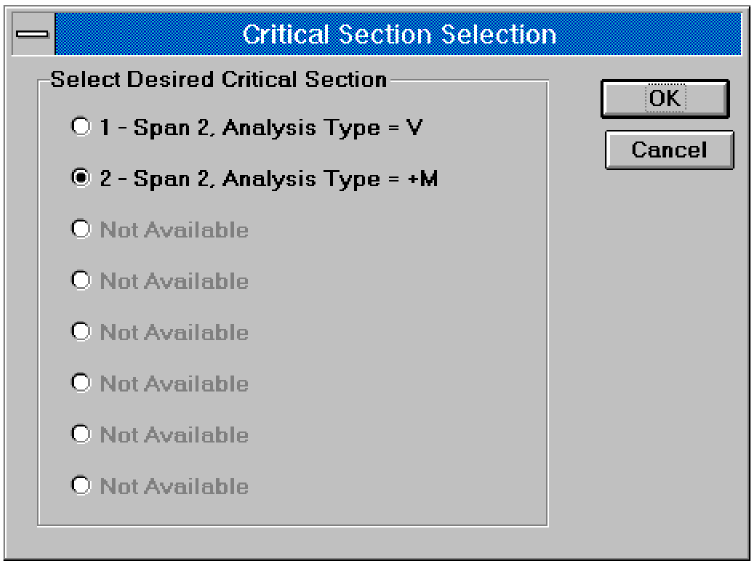
Do NOT use the summary sheet equations to calculate the bottom set of rating factors for crossbeams. The entire set of Rating Factors should be copied from the crossbeam program and pasted into the Summary Sheet program. The reason the two programs provide different values are that the LR summary sheet uses the distribution factors to adjust from multi lane to single lane rating factors. The crossbeam program is using the computed lane load reactions combined with the multi and single lane influence line ordinates to adjust the rating factors. Thus, since they have different loading conditions the two programs will not produce the same results.

19.2.4 Crossbeam Analysis Program (Excel)

XB_MAIN.XLS – Introduction

XB_MAIN.XLS is the "analysis engine" that performs the crossbeam analysis for each investigated section identified by the engineer in the ***Input*** worksheet of the Crossbeam Analysis Data File. **XB_MAIN.XLS** stores the results in the ***Output*** worksheet of the Crossbeam Analysis Data File. As such, **XB_MAIN.XLS** is not part of the load rating file set for any particular bridge and need not be saved for any bridge.

To evaluate a crossbeam, the user must first open and fill out the ***Input*** worksheet and all other inputs (yellow cells) of a Crossbeam Analysis Data Template such as **XB_RC.XLT** (or **XB_S.XLT** for steel). Save the Data Template as an Excel workbook (now referred to as a Crossbeam Analysis Data File) in the load rating file set. Use a crossbeam-specific name such as **XB_BENT1.XLS**. Open **XB_MAIN.XLS** and input the name of the Crossbeam Analysis Data File in the cell labeled: "Data File Name" located in the ***Main*** worksheet (and hit "Enter"). The Crossbeam Analysis Data File must also be open. Activate the "Collect Data" button. If you encounter a "Subscript out of range" error, you are probably using an obsolete version of XB_Main.XLS - make sure you are using the latest version available from the ODOT FTP Server. The crossbeam input data will be collected by **XB_MAIN.XLS**. You will see a dialog box and be prompted for the section to be evaluated. When you select a section, you may see a warning message regarding the previous critical section not being stored. Disregard this message if you are just starting your analysis cycle. An example is shown below.



Once the investigated section is selected, **XB_MAIN.XLS** generates the model, performs the matrix analysis, develops the influence line for the investigated section, and calculates the actions for the structure dead load and wearing surface. The dead load results are placed in the ***Main*** worksheet. The user is then placed in the ***Live_Load*** worksheet and the software is prepared to evaluate the Single Lane Live Load Analysis. Move the vehicle(s) to maximize the desired action, or use the "Auto Place" button to make the program investigate all possible live load locations. Note that no wheel load should be positioned closer than 2 ft from the edge of the 12-ft lane. The influence line is plotted to scale with the roadway and is a visual guide only. The actions of the vehicle location are calculated using the matrix analysis software and not by interpolating the ordinates of the influence line.

After obtaining the desired results, engage the "Store to Main" button. This button places the results of the analysis on the ***Main*** worksheet and activates the Multiple Lane Live Load Analysis. The same process used in the Single Lane Live Load Analysis is used to maximize the multiple lane live load desired action. If the "Auto Place" button is used, the program investigates all possible live load locations and 2-lane combinations. The "Store to Main" button copies the results in the ***Main*** worksheet and returns the user to the ***Main*** Sheet. If the results are satisfactory, engage the "Print All Sheets" button to print the ***Main*** and ***Graphics*** Sheets, and the Single and Multiple Live Load Analyses of the ***Live_Load*** Sheet. Then, engage the "Store Section Results To Datafile" button to store the results in the appropriate column of the ***Output*** worksheet of the Crossbeam Analysis Data File. Engage the "Collect Data" button to repeat the process to evaluate each of the remaining investigated cross sections. After all investigated sections have been evaluated and the results stored in the Crossbeam Analysis Data File, return to the Data File and save it. If you haven't done so already, input the remaining information in the yellow input cells in the Data File (as described above) to calculate the Rating Factors.

XB_MAIN.XLS - Structure Description

XB_MAIN.XLS consists of 6 worksheets, 1 dialog box, and 5 modules. Only three worksheets are visible and accessible to the user: ***Main***, ***Graphics***, and ***Live_Load***. The other sheets are hidden and protected. DO NOT try to activate any macros except by using the assigned button shown on the ***Main*** and ***Live_Load*** worksheets.
The ***Main*** worksheet is used to collect and store information between **XB_MAIN.XLS** and the Crossbeam Analysis Data File. The ***Graphics*** worksheet provides a Plan and Elevation presentation of the crossbeam and bent geometry. The ***Live_Load*** worksheet provides the tools to evaluate the single and multiple lane liveload analyses, and influence line analysis.

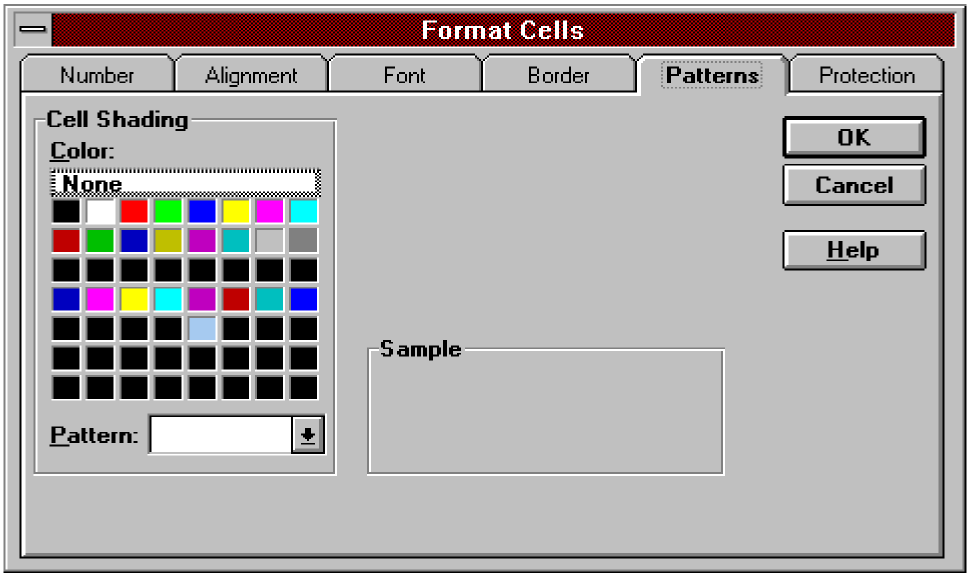
XB_MAIN.XLS – *Main* worksheet

The ***Main*** worksheet is used to collect and store information between **XB_MAIN.XLS** and the Crossbeam Analysis Data File. The analysis results are stored in the ***Main*** worksheet for the user to view prior to storing the information in the Data File.

The user has the capability to change the pattern or color of the cells which require input and cells where critical results are presented. Due to the desire to have consistent meaning of color schemes among load ratings (for example, light yellow always indicating user input), the use of the cell color feature is discouraged. It is only provided to enhance readability for color-blind users. Input the desired pattern number or color as shown below. Yellow (19) and Violet (24) are the numbers used when the software is initially opened.

19	Input Color for Data Input by User, Original Color = 19.
24	Input Color for Critical Information or Results, Original Color =24.

The color options are shown below and are numbered from left to right. For example, the top right color is 8.



Engage the “Color” button to change the colors.

XB_MAIN.XLS – *Graphics* worksheet

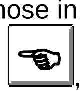
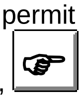
The ***Graphics*** worksheet provides a Plan and Elevation representation of the crossbeam and bent geometry to enable the engineer to evaluate the correctness of the model. The investigated section is shown as a small red circle. Though no consistent scale is used, the plan and elevation are proportioned horizontally to fit in the shaded area. The column height is independent of the input length and a constant length is always shown. The end conditions of columns are shown with a white circle if pinned and if the column is fixed at the base, a fixed notation is shown. This sheet is unprotected and the user may wish to re-align the text graphics boxes to improve the presentation. It is important to check this sheet to make sure the crossbeam model the program is using is the structure you expected it to be.

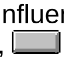
XB_MAIN.XLS - *Live_Load* worksheet

The ***Live_Load*** worksheet provides the tools to evaluate the single lane and multiple lane live load analyses and the influence line analysis. After the user selects the investigated section, the dead load actions and influence line ordinates are calculated. The user is placed in the Single Lane Live Load Analysis section. A plot of the roadway and single lane vehicle is presented with the influence line for the desired action and the investigated section.

<u>“SINGLE LANE LIVE LOAD ANALYSIS” section:</u> Check to ensure the Single Lane Live Load Analysis is the active load case. If not, engage the “Activate Single LL” button. There are four ways to move the vehicle to the desired location.

(1) Input the desired location of the first wheel line as measured from the left curb and normal to the bridge centerline. It remains the responsibility of the user to ensure the “Vehicle Wheel Line Spacing (ft.):” is set to 6 feet. The crossbeam software performs appropriate adjustments to wheel spacing to account for skew. The adjustment of wheel spacing is intended for use with non-standard width vehicles, such as those in special permit reviews. To update the graphics, engage the “Draw” button.

(2) Engage the left, , or right,  hand buttons. This will move the truck left or right by the increment specified by the user. The graphics are updated automatically.

(3) The maximum and minimum influence ordinates and the corresponding locations are given to the left of the graphics. Two buttons,  are shown where the maximum and minimum influence values

and locations are displayed. Engage either button  to place the first axle at this location. The graphics are automatically updated. These Minimum and Maximum buttons provide a good starting point, but is often necessary to adjust the load locations by 6 ft, or by 4 ft if between lanes, to get a different wheel at a critical location on the influence line. In these cases be sure to update the graphics using the "Draw" button. For shear influence lines it is often necessary to adjust by a small increment such as 0.01 ft to gat the most critical loading.

(4) The "Auto Place" button can be used to allow the program to determine the most critical live load location. In this case, the user is given a dialog box to choose the truck movement increment and the maximum concurrent force types to focus on. The dialog box will default to the force type that is stipulated under the "Analysis Type" cell for the section under investigation. The use of smaller truck movement increments provides greater accuracy in determining critical load placement, but also increases calculation time.

Once the desired position and action is obtained and you are satisfied that the moment or shear displayed in the Critical Section box is maximized, engage the "Store to Main" button to place the results in the ***Main*** Sheet. The Multiple Lane Live Load Analysis is setup at this point. The "Print Page" button can be used to print the Single Lane Live Load Analysis. Alternatively, use the "Print All Sheets" button located in the ***Main*** worksheet to print all of the results <u>after</u> the analysis of the single and multiple lane live load analyses are complete.

<u>"MULTIPLE LANE LIVE LOAD ANALYSIS" section:</u> Check to ensure the Multiple Lane Live Load Analysis is the active load case. If not, activate the "Activate Multiple LL" button. The position of the vehicle is modified in the same manner as in the Single Lane Live Load Analysis. However, for the multiple lane analysis, the spacing between the vehicles is also variable. If the multiple lanes analysis is not applicable to the current crossbeam and roadway geometry, such as a single lane roadway width, engage the "NA – Same as Single" button to place the results from the Single Lane Live Load Analysis into the Multiple Lane Live Load Analysis in the ***Main*** Sheet. If the vehicle spacing is changed from 4 ft, be sure to reset it to 4 ft before analyzing the next analysis point.

The "Auto Place" button can be used to allow the program to determine the most critical combination of live load location and spacing between the two lanes. The use of smaller truck movement increments provides greater accuracy in determining critical load placement, but also increases calculation time. This is especially true in the multiple-lane analysis case. When analyzing multiple lane load case the "Auto Place" feature has a minimum "Adjacent Vehicle Spacing (ft.):" of 4 feet and will automatically set the spacing to this limit. It remains the responsibility of the user to ensure the "Vehicle Wheel Line Spacing (ft.):" is set to 6 feet. The crossbeam software performs appropriate adjustments to wheel spacing to account for skew. The adjustment of wheel spacing is intended for use with non-standard width vehicles, such as those in special permit reviews.

Once the desired position and action is obtained, engage the "Store to Main" button to place the results in the Main sheet. The Main sheet will be activated at this time.

"INFLUENCE LINE GENERATION" section: The influence line is calculated 2 feet from each curb. This distance may be modified by the user in this bottom section of the ***Live_Load*** Sheet. The columns are shown in the graphics presentation if they are within the influence line.
The user may change the increment of the influence line generation by changing the IL_Increment (ft.) in the "INFLUENCE LINE GENERATION" section. The smaller the increment, the more accurate the influence line presentation; however, the time of analysis will increase to calculate the influence ordinates. As stated previously, the influence line is simply a graphical tool, the ordinates are *not* used in the analysis. Also, if a wheel line is placed outside the influence line, the results are calculated providing the wheel line is located on the supporting crossbeam.

<u>GRAPHICS PRESENTATION:</u> The graphics presentation of the vehicle roadway and influence line can be adjusted to fit your monitor. Follow the instructions presented at the right of the graphics. Optionally you could save **XB_MAIN.XLS** so the graphics alignment is saved for future analysis, but

normally this file is not included in the Load Rating File Set.

19.2.5 Crossbeam Analysis Software Topics

Error Trapping

XB_MAIN.XLS includes some rudimentary error trapping. Most of the error trapping is evaluated when the information is transferred from the Crossbeam Analysis Data File to **XB_MAIN.XLS**. The trapping which exists in the software is listed below.
Message: "File is Not Open or Incorrect Name. Check Extension."
The filename input in ***Main*** worksheet is incorrect or the desired file is not open.
Message: "Critical Section location incorrect, 0 < X < Span Length. Check INPUT Sheet of Active Data File."
An investigated section location has been requested which does not satisfy the requirements of the software.
Message: "Girder location outside crossbeam. Check left girder offset, spacing or crossbeam geometry."
A girder location is outside the limits of the crossbeam. If a girder is placed directly over an exterior column, this error may occur. For this case, do not enter the girder load since the loading does not produce forces in the crossbeam. Otherwise, increase the limits of the crossbeam or tighten the spacing of the girders and review the geometry in the ***Graphics*** Sheet of XB_MAIN.XLS. Then, adjust your model accordingly.
Message: "IL Unit Load outside crossbeam. Check roadway geometry and/or extend crossbeam."
During the development of the influence line, the unit load is located outside the limits of the crossbeam. It may be necessary to artificially extend the crossbeam with short cantilevers to pick up the unit load. Also, check the roadway geometry. If the crossbeam is adjusted, recognize that the dead load will be changed. Note this in the "Engineer Comments" location.
Message: "Hey Sparky!!, Critical Error, Check your Input."
This comment is a "catch all" other errors statement with a little humor. Check your input for such errors as entering text where numeric fields are required, etc.

Cell Information and Notes.

Excel allows notes to be attached to cells. If a cell has a note, a red triangle is placed in the upper right hand corner. To view the notes the user simply hovers over or double clicks on the cell and the information box will appear with the note. All of the software contains notes to help the user understand the required information. Excel is commonly set up to allow the user to edit the contents of the cell directly in the cell. If you double click on a cell with a note and nothing happens, you will need to disable this option to view the notes. From Tools, select Options…, and the "Edit' tab, and under settings, disable Edit Directly in Cell. Also, it is possible to add notes to unprotected cells even if the sheet is protected. Therefore, the user may edit or add notes to the cells for future use.

Cell Patterns and Print Shading.

Excel allows the user to print sheets in a black and white mode only. This allows the user to use multiple colors on the worksheet and not print the shading. A light yellow background has been used for user input and a light violet background has been used for analysis results. For instance, the Graphics sheet in the **XB_MAIN.XLS** shows the plan and elevation on a light violet background. This area will appear gray when printing. To turn the shading off, activate File, Page Setup..., "Sheet" tab, and check "Black and White".

Printing Multiple Sheets.

A simple way to print multiple sheets at one time is to activate all the worksheets and engage the print icon. To do this, move your mouse pointer into the tab region showing the names of the worksheets in the workbook. Hit the right button of the mouse and click on "Select All Sheets" from the pop-up dialog box. Then, engage the print icon. Hit the right button again to view the dialog box and click on "Ungroup Sheets". Alternatively, the user can use the select all worksheets using the combination of the mouse and shift key, or group sheets one at a time by using the combination of the mouse and Ctrl key.

19.3 Timber Members with Decay

Review the inspection report and boring logs to determine the extent of timber deterioration. There is a wide variation in the level of detail provided on boring reports. To supplement the boring reports, the members condition state (Elements 216 or 235) provides additional clarification. The Bridge Inspection Pocket Coding Guide has very specific definitions for the different condition states; using these definitions can be very useful when dealing with incomplete or missing boring reports.

19.3.1 Timber Boring Report

Timber boring reports should provide enough information to develop a cross section with dimension of deterioration and the range that the cross section applies. This level of detail requires the member be drilled horizontally and then vertically to form a useful understanding of the deterioration. Common practice is to only bore horizontally into the member. Although this will give good information regarding the width of the decay, it will not reveal the depth of the decay. In this situation the decay is assumed to be square, so the width of decay is the same as the height of decay. This doesn't necessarily mean that the centroid of the decay and the centroid of the member are at the same location. The decay should be placed vertically in the member such that the worst case is evaluated. For negative flexure this would be at the top of the member, and for positive flexure place the decay at the bottom of the member.

Boring reports should also provide enough information to determine the length of the decay. It has been noticed that sometimes only the location of the boring is provided, and no effort was made to determine the length of the decay. In this situation assume that the decay extends to the next reported boring.

If dimensions of the boring are not provided or no boring report at all is provided, the condition state from the bridge inspection report will be used to estimate the section loss. The Bridge Inspection Pocket Coding Guide (Section 19.3.2) is a useful reference for correlating the condition state to section loss.

19.3.2 Bridge Inspection Pocket Coding Guide

The Bridge Inspection Pocket Coding Guide shows the criteria used by the bridge inspector when determining the condition of timber pile caps and abutments. It is available online under Bridge Inspection Manuals at http://www.oregon.gov/ODOT/HWY/BRIDGE/standards_manuals.shtml. The condition state of a member will be reduced based on cracks, splits, checks, and decay. Cracks, splits, and checks typically reduce the members shear capacity, while decay reduces both shear and moment capacity.

Unless stated otherwise in the bridge inspection report, assume the condition state of a member is based on decay; not cracks, splits, or checks. In the Pocket Coding Guide there is a correlation between the condition state of the element and the cross sectional area. When there is insufficient information to determine the actual amount of decay in a member, then the decay will be back calculated based on the criteria provided in the pocket coding guide. Calculate the percent decay as follows:

$$\%Decay = \frac{\%Decay_{ConditionState(N)} + \%Decay_{ConditionState(N+1)}}{2}$$

Where N is the reported condition state

Assume that the % Decay is the average of the minimum decay for the condition state reported and the minimum decay for the next higher condition state.

For example: an element coded as condition state 2. Condition state 2 has a minimum decay of 10%. Condition state 3 has a minimum decay of 30%. Therefore, the percent decay is assumed to be (10%+30%)/2 = 20%.

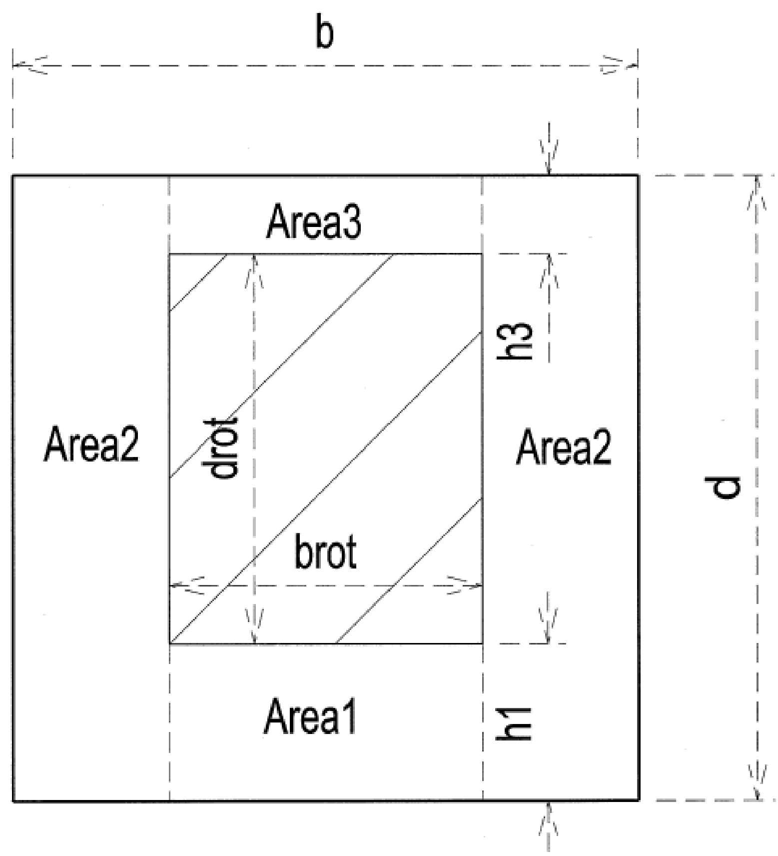
If a member is coded as condition state 1 then no reduction is necessary. If an element is listed as condition state 4, then a detailed boring report will have to be provided before performing the load rating. Contact the ODOT load rating unit for any additional clarification.

19.3.3 Timber_Decay.XMCD

Timber_Decay.XMCD is a Mathcad sheet that has been developed to assist with computing the reduced reference design values for members with decay. Reduction factors for shear, positive moment and negative moment are calculated based on the sections geometry. The reference design values are then multiplied by these reduction factors to obtain a new adjusted design value. Once completed, copy this sheet into the applicable crossbeam preliminary file.

Design values presented in AASHTO LRFD 8.4.1.1.4, for visually graded sawn lumber, includes reductions based on the assumption that there are checks, splits, and cracks in the member. The footnotes to NDS table 4A through 4E no longer include discussion about increasing the design shear stress based on knowledge of the check, split or crack. Therefore, the reference design values will not be increased based on the lack of checks, splits, and cracks in the member. A member’s reference design values may be decreased due to defects if, in the Engineers judgment, the members’ current condition is not adequately represented by the reference design values.

The timber cross section is broke into four rectangular areas to ease computations. Areas one through three are the areas that are solid timber, while the fourth area is the decayed potion of the cross section. Area one is immediately below the decay and its width equals the width of the decay. Area two is on the sides of the decay and extends the full height of the member. Finally area three is the section above the decay and its width is equal to the width of the decay. If the member has decayed from the top down then area three will have no height and therefore no area.



Gross Section:

Input the gross width, b, and gross height, d, to calculate the gross section properties. The gross properties are calculated by XB_T.XLS and are calculated here so that these values can be factored out of the adjusted design values.

Decay in the Member:

Input the height of section one, h_1, the height of section three, h_3, and the width of the decay, b_{rot}. Based on these inputs, the net section modulus is calculated for both positive and negative flexure. The adjustment values for flexure are determined by dividing the net section modulus by the gross section modulus.

The shear adjustment factor is based on the maximum horizontal shear stress. From strengths of materials it can be recalled that the horizontal shear stress can be related to the perpendicular shear by the following formula:

$$f_v = \frac{VQ}{Ib}$$

Q, I and b are calculated for the net and gross section. It is assumed that the maximum horizontal shear occurs at the neutral axis. The neutral axis is also assumed to pass through the decayed area, meaning that b is taken as ($b - b_{rot}$). V, the perpendicular shear force is not dependent on the cross sectional properties, so it will be the same for both the gross and net section. f_{vgross} is divided by f_{vnet} to form the shear adjustment factor, β_v.

19.3.4 Timber Piles with Decay

Since substructure elements are not required to be load rated, there is no special analysis performed to compute the remaining capacity of a timber pile with decay in its center. ODOT's current practice is to ignore the existence of a pile when there is a 1" shell, or less, of sound material in the timber pile. Thus load rating the crossbeam with the pile removed as a support.

Since limits of decay/rot is not a nice clean and uniform geometry, when the shell starts getting less than 1", one would expect that there will be areas in the cross section with considerably less (to possibly zero) thickness of sound material. A single bore hole through the pile will not provide an exact measurement for the entire cross section. Thus, it makes sense from a public safety standpoint to start omitting the piles when the decay/rot leaves 1" shell or less of sound material.

19.4 RC Crossbeam with Integral Back Wall

In the past ODOT directed load raters to exclude the effect of back walls when computing the capacity of crossbeams. Only the dead load of the back wall was included in the analysis. When the crossbeam is relatively small compared to the back wall, excluding the capacity of the back wall, can significantly underestimate the total capacity. Therefore, the back wall may be included in the capacity calculations of the crossbeam if the two members are integral.

When flexure is considered, horizontal shear stresses are across the cap and back wall interface. For the cap and the back wall to act integrally, there must be mild steel reinforcement across this interface to resist this horizontal shear stress. Rather than calculating the horizontal shear stresses at this interface, the reinforcement details will be examined to determine if the members are integral.

Assume that the cap and the back wall are integral, if well distributed vertical mild reinforcement extends from the bottom of the cap to the top of the back wall. This full depth vertical reinforcement is also necessary to keep the shear capacity calculations from becoming overly complicated.

In the Mathcad preliminary file, calculate the section properties of the member being analyzed. For a T or L shaped member, use the parallel axis theorem when calculating the moment of inertia. When calculating the section properties use the actual section as shown on the plans, which may not be the same section input for capacity analysis. The difference between the two sections is in how the ODOT crossbeam software is set up to receive cross section input.

The ODOT crossbeam software is only capable of accepting a "T" or rectangular cross section. If a "T" section is modeled, then the flange must be the compression flange. Because of this limitation, the reinforcement used for analysis may not reside within the cross section defined. In figure 19.4-1, the area highlighted in red is the concrete section that will be modeled for positive flexure. Due to the software limitations the entire cross section can not be input; however all of the reinforcement may still be used. Only two of the bottom six number eight reinforcing bars lie within the modeled section, however all six will be included for positive flexure analysis. Like wise the corbel may not be included in the cross section but, for negative flexure, the longitudinal reinforcement in the corbel may be included. See figure 19.4-2 for a section showing the cross section input for negative flexure.

Figure19.4-1

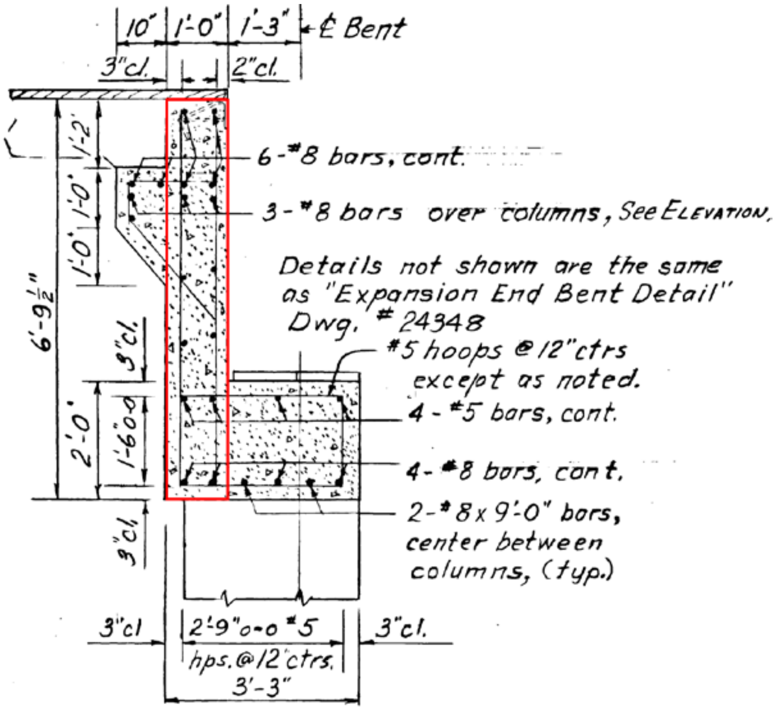
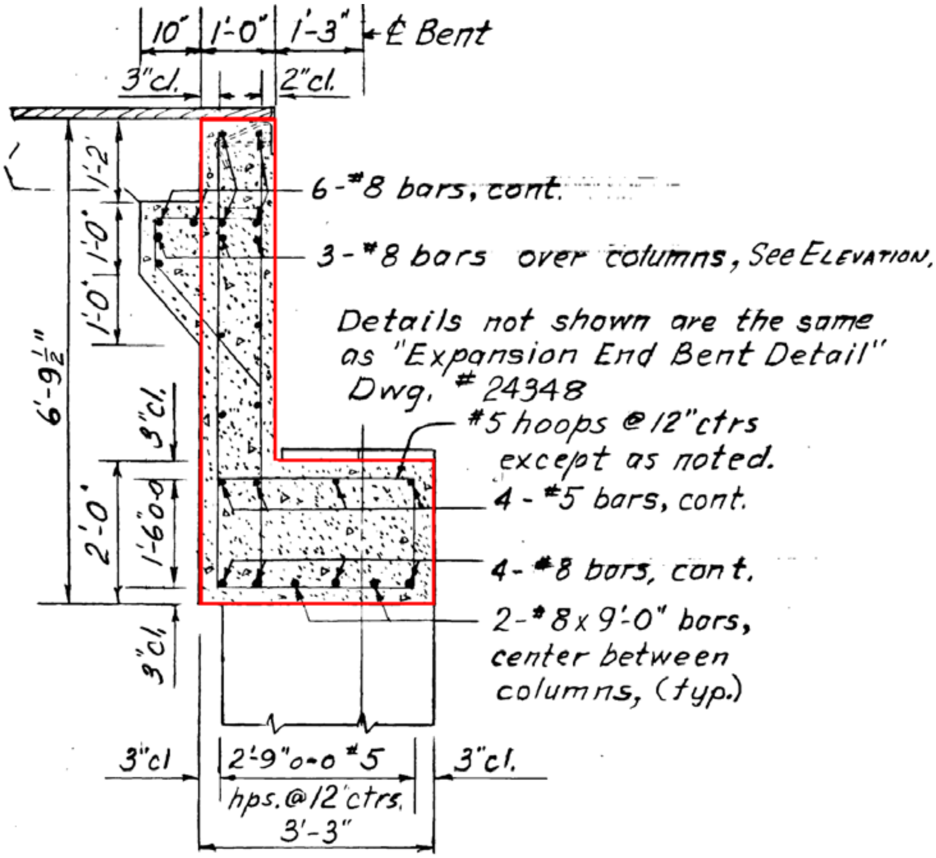
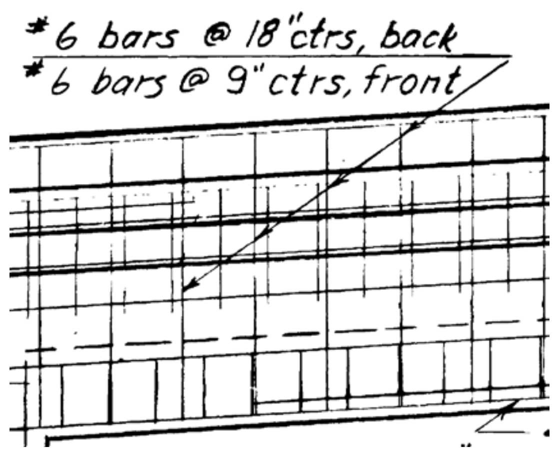


Figure 19.4-2



The ODOT crossbeam analysis software assumes that the shear reinforcement extends the full height of the section being modeled. To avoid complicating the shear capacity calculations, or reworking the analysis software, any shear reinforcement that doesn't extend the full height of the section shall be ignored. Reference figure 19.4-2; the cap has number five hoops at twelve inch centers, which will not be included in the capacity analysis. The shear capacity will rely on the number six vertical bars and the front and back face of the back wall. Although these bars do extend the full depth of the modeled section, the front and back steel spacing is not uniform, see figure 19.4-3. The ODOT software can not accept two different stirrup spaces for one analysis point. To work around this limitation, calculate one equivalent stirrup spacing. Below is an example of how this has been calculated for the back wall shown in figure 19.4-3.

Figure 19.4-3



Begin by calculating the total area of reinforcement per foot:

Area of one number six bar = $0.44in^2$

$$A`_s = \frac{0.44in^2}{18in} + \frac{0.44in^2}{9in} = 0.88\frac{in^2}{ft}$$

In the Capacity tab of the XB.XLS file, input $0.88in^2$ for A_v (Stirrup area) and 12in for the effective stirrup spacing,

The inclusion of the back wall is meant to benefit the overall rating factors for a crossbeam analysis. If the inclusion of the back wall increases flexural capacity but decreases shear capacity, it is permissible to use the back wall for flexural analysis and neglect it for the shear analysis. This could happen if the vertical reinforcement in the back wall is substantially less than the stirrups in the pile cap. Trial and error may be used when determining if the back wall should be included for capacity calculations. Be sure to document any decisions clearly in the Mathcad preliminary file.

SECTION 20: CONCRETE MEMBERS WITH INTERNAL SHEAR ANCHORS

A popular method in Oregon for the shear strengthening of reinforced concrete members is the installation of Internal Shear Anchors (ISA) that are epoxied within the deficient shear zones of the member. Since the "STIRRUP-SCHEDULE" command in BRASS-GIRDER will only take one stirrup group to occupy a length of space along a girder, the Internal Shear Anchors need to be integrated with the existing stirrups. Two things that this integration has to account for are:

1. Internal Shear Anchors usually have a higher strength compared with the existing reinforcement
2. Internal Shear Anchors are typically installed inside the girders at an angle, where the stirrups are typically vertical.

The following two sections are sample calculations that can be used in a Mathcad preliminary file to integrate the Internal Shear Anchors with the existing stirrups so that they can be modelled in the BRASS-GIRDER analysis.

20.1 Internal Shear Anchor Material Strength Adjustment

The following calculations are an example of calculating a modular ratio for the Internal Shear Anchors (ISAs) to the existing reinforcement and then adjusting the area(s) of the ISAs by the modular ratio.

Reinforcement: $f_y := 33 \cdot ksi$ (Longitudinal) (unknown grade, use ODOT LRFR Tbl. 1.4.3 prior to 1954)

$f_{ys} := 33 \cdot ksi$ (Stirrups)

$f_{y.isa} := 105 \cdot ksi$ (Internal Shear Anchors, AASHTO M314 Grade 105)

$$n_{isa} := \frac{f_{y.isa}}{f_{ys}} = 3.18$$

Shear Reinforcement Layout:

Existing Shear reinforcement: 1/2" ϕ double leg stirrups = 0.40 in^2

$A_{stir} := (2) \cdot \left(0.20in^2\right) = 0.40 \cdot in^2$ (Group 1, Dwg. 6788)

Internal Anchor Shear reinforcement: 3/4" ϕ internal anchor = 0.44 in^2 (single), 0.88 in^2 (double)

$A_{isa.1ut} := 0.44in^2$ (area of single anchor, untransformed, Dwg. 92482)

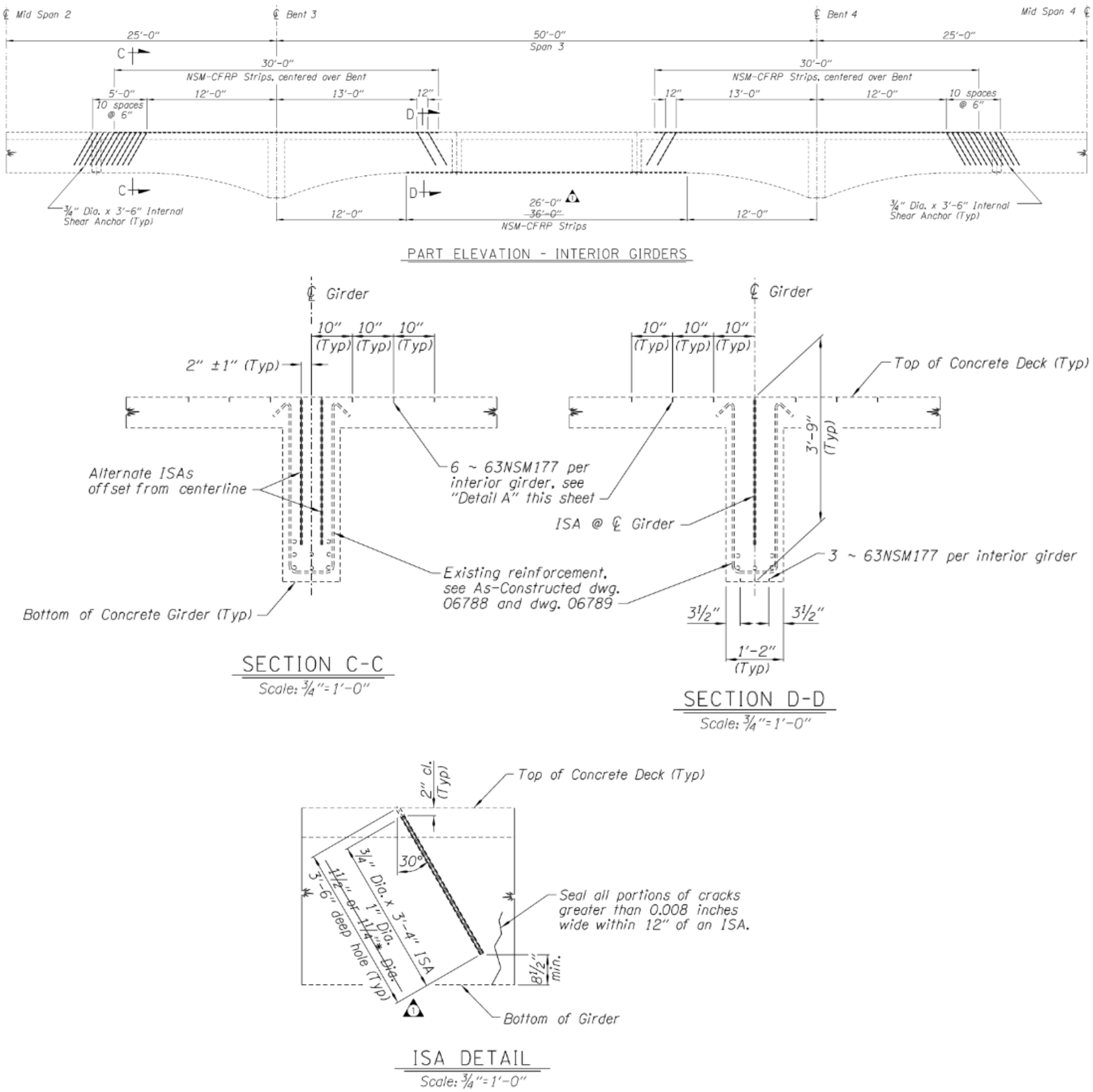
$A_{isa.2ut} := 0.88in^2$ (area of double anchor, untransformed, Dwg. 92482)

$A_{isa.1} := \left(A_{isa.1ut}\right) \cdot \left(n_{isa}\right) = 1.40 \cdot in^2$ (area of single anchor, transformed)

$A_{isa.2} := \left(A_{isa.2ut}\right) \cdot \left(n_{isa}\right) = 2.80 \cdot in^2$ (area of double anchor, transformed)

20.2 Internal Shear Anchor Inclination Adjustment

The following calculations are an example of a conservative, yet easy way to add the inclined Internal Shear Anchors with the existing stirrups so that they can be specified into a single stirrup schedule within BRASS-GIRDER.



Original Stirrups --

$n_{2.1} := 1$	$s_{2.1} := 3\text{in}$	(distance to first stirrup from face of beam)
$n_{2.2} := 12$	$s_{2.2} := 12\text{in}$	(12@12")
$n_{2.3} := 16$		(16 equal spaces)
$n_{2.4} := 12$	$s_{2.4} := 12\text{in}$	(12@12")
$n_{2.5} := 1$	$s_{2.5} := 3\text{in}$	(distance from first stirrup to face of beam)

$s_{o.2} := (0.5)\cdot(b_F) + (n_{2.1})\cdot(s_{2.1}) = 15.00\cdot\text{in}$ (distance to 1st stirrup inside BRASS span)

$s_{e.2} := (0.5)\cdot(b_G) + (n_{2.5})\cdot(s_{2.5}) = 12.00\cdot\text{in}$ (distance from last stirrup inside BRASS span)

Find the spacing of the "16 equal spaces":

$$s_{2.3} := \frac{\left[L_{span_2} - s_{o.2} - (n_{2.2})\cdot(s_{2.2}) - (n_{2.4})\cdot(s_{2.4}) - s_{e.2}\right]}{n_{2.3}} = 17.81\cdot in$$

Internal Shear Anchors (ISA) (Dwg. 92482) --

$A_{isa.2} = 2.80\cdot in^2$ (area of double anchor, recalled)

$L_{isa} := 3ft + 6in$ (length of anchor)

$\phi_{isa} := 90deg - 30deg = 60.00\cdot deg$ (angle of anchor)

$\Delta_{achr} := \left(\frac{L_{isa}}{2}\right)\cdot\left(\cos\left(\phi_{isa}\right)\right) = 10.50\cdot in$ (horizontal distance from lower tip to midpoint of anchor)

$n_{isa.2} := 10$ $\quad s_{isa.2} := 6in$ (10@6")

$s_{o.isa.2} := L_{span_2} - 12ft - \Delta_{achr} - (n_{isa.2})\cdot(s_{isa.2}) = 385.50\cdot in$ (distance to first anchor)

$s_{e.isa.2} := s_{o.isa.2} + (n_{isa.2})\cdot(s_{isa.2}) = 445.50\cdot in$ (distance to last anchor)

$s_{e.2.3} := s_{o.2} + (n_{2.2})\cdot(s_{2.2}) + (n_{2.3})\cdot(s_{2.3}) = 444.00\cdot in$ (distance to end of original stirrup spacing change from 17.81" to 12")

$\Delta_{isa.2} := s_{e.isa.2} - s_{e.2.3} = 1.50\cdot in$ (difference between end points between the 17.81" spacing and the internal shear anchors)

Note: The end of the shear anchors is nearly (1.5") at the same original stirrup spacing change point between 17.81" and 12". Assume the internal shear anchors end at the exact same location as the end of the 17.81" stirrup spacing.

$A_{isa.2.ft} := \frac{A_{isa.2}}{(s_{isa.2})\cdot\sin\left(\phi_{isa}\right)} = 6.47\cdot\frac{in^2}{ft}$ (area of vertical stirrup per foot)

The internal shear anchors overlap with the original stirrups spaced at 17.81". Calculate the stirrup spacing that are equivalent to the total area per foot of original stirrups and internal shear anchors.

Overlap Zone - Existing 16@17.81" + ISA 10@6":

$A_{ol.2} := \frac{A_{stir}}{s_{2.3}} + A_{isa.2.ft} = 6.74\cdot\frac{in^2}{ft}$ (total area per foot)

$s_{ol.2} := \frac{A_{stir}}{A_{ol.2}} = 0.71\cdot in$ (equivalent 1/2" ϕ stirrup spacing)

$s_{o.isa.2} = 385.50\cdot in$ (start of overlap zone, recalled)

$s_{e.2.3} = 444.00\cdot in$ (end of overlap zone, assume equal to end of 16@17.81" spacing, recalled)

$R_{ol.2} := s_{e.2.3} - s_{o.isa.2} = 58.50\cdot in$ (range of overlap zone)

$n_{ol.2} := \frac{R_{ol.2}}{s_{ol.2}} = 82.09$ (equivalent number of spaces to get correct range)

Remaining "16 equal spaces" --

$$n_{2.3.r} := \frac{\left[(n_{2.3})\cdot(s_{2.3}) - R_{ol.2}\right]}{s_{2.3}} = 12.72$$

(number of 17.81" spaces without shear anchors)

Combined Stirrup Table --

Span # :	2			Span Length	50.00	ft	
Section	Stirrup # (Group)	Spaces	Spacing (in.)	Start (in.)	Range (in.)	End (in.)	Span Fraction
1	1	12	12	15.00	144	159.00	0.025
2	1	12.72	17.81	159.00	226.5432	385.54	0.265
3	1	82.09	0.71	385.54	58.28	443.83	0.643
4	1	12	12	443.83	144	587.83	0.740

Original Stirrup Table (for reference only) --

Span # :	2			Span Length	50.00	ft	
Section	Stirrup # (Group)	Spaces	Spacing (in.)	Start (in.)	Range (in.)	End (in.)	Span Fraction
1	1	12	12	15.00	144	159.00	0.025
2	1	16	17.81	159.00	284.96	443.96	0.265
3	1	12	12	443.96	144.00	587.96	0.740

Internal Shear Anchor Table (for reference only) --

Span # :	2			Span Length	50.00	ft	
Section	Stirrup # (Group)	Spaces	Spacing (in.)	Start (in.)	Range (in.)	End (in.)	Span Fraction
1	1	10	6	385.50	60	445.50	0.643

20.3 ISA Rating Procedure Applicability and Refinements

This procedure is good for high strength bars, stainless steel, or other steel materials having E_s = 29,000 ksi. In Titanium bar case (E_s = 15,500 ksi.), this procedure can be used as well since the elastic modulus of transverse reinforcement is not used in an equation for the shear capacities and rating factor calculations.

When using AASHTO LRFD Eq. 5.7.3.3-4 (below) to calculate the shear capacity from inclined stirrups, it yields 15% more capacity from the ISAs than what is being computed from following the procedures within this section. The ISA inclined angle (alpha) cannot be added directly to the LRFD equation within BRASS-GIRDER due to the existing stirrups for most bridges are normally in a vertical position and the software only allows a single schedule/type of stirrups to exist within a region of a girder.

$$V_s = \frac{A_v f_y d_v (\cot\theta + \cot\alpha)\sin\alpha}{s}$$

AASHTO LRFD 5.7.3.3-4

When rating factors end up being right below 1.0 while following this procedure for transforming the internal shear anchors into an equivalent schedule of the existing stirrups, an option to improve the rating factors would be to manually compute the shear capacities for the controlling locations by taking the shear capacities of the original girder and adding the shear capacity of the ISAs computed from AASHTO LRFD Eq. 5.7.3.3-4. Then a manual calculation of the rating factors using the new capacities can be done.

SECTION 21: LRFR LOAD RATING SUMMARY REPORT (EXCEL)

21.1 Getting Started

Open the Excel template **LR.XLTM** and, after filling in the Bridge Number cell, use File / Save As to save it in the bridge-specific Load Rating folder using the bridge-specific file name LRnnnnnn.XLSM, where nnnnnn is the 5- or 6-digit NBI Bridge Number. The same template will be used for both State and Local Agency Load Rating Summary sheets. **LR.XLTM** contains all the code necessary to run the built-in VBA modules (no separate file is required). Using the "Browse" button provided to navigate to the desired location eliminates typo errors in the path. This path will facilitate use of the **Import BRASS** module.

Note: The practice of starting with a complete summary workbook from a previous bridge as a seed file instead of beginning with a blank LR.XLTM template is discouraged. Eventually, the practice of copying seed files from previous load ratings will result in lingering errors from old data, a summary workbook that does not function properly, or one that does not report results consistent with current standards. Always begin a new bridge with a fresh LR.XLTM template. With the possibility of continuing development of the template or changes in reporting requirements, occasionally the template will be updated on the ODOT FTP site, and users will be notified to retrieve the updated file. Note: due to truck name changes required by the anticipated consolidation of BRASS-Girder(STD) and BRASS-GIRDER(LRFD), a different version of **LR.XLTM** is required for use with BRASS-GIRDER(LRFD) Version 2.0.0 and later. To maintain backwards compatibility with old load ratings, both the old and new versions of **LR.XLTM** are stored in separate folders on the ODOT FTP server.

21.2 Summary Workbook Features

The Load Rating Summary Workbook is divided horizontally into the Load Rating Summary Report (Page 1) and the Load Rating Worksheets (Pages 2 and above). The Rating Factors and section information for each investigated section are listed in the Load Rating Worksheets with one column allocated to each investigated section (8 sections per page). This information is summarized by copying the most critical and second most critical sections for each rating vehicle into the Load Rating Summary Sheet (Page 1), by clicking on the **Refresh** button or typing Ctrl-r.

The Load Rating Summary Report (Page 1) is divided vertically into a Bridge Header Area (top half) and the Controlling Rating Factor Area (bottom half). The Header Area contains basic National Bridge Inventory information and certain parameters that may have an influence on the outcome of the Load Rating. The Controlling Rating Factor Area lists the rating vehicles and their live load factors along the left edge and two groups of columns for the 1st and 2nd controlling members. Each group of columns provides the Rating Factor (R.F.), Limit State, force type (+M,-M or V), combined Resistance Factor (Φ), member description, span and location of the investigated section. Note the Φ column heading refers to the combined Resistance Factor $\Phi = \phi\phi_c\phi_s$.

In column 3, enter the live load factors (γ_L) for each rating vehicle from **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable. For all Legal Loads γ_L is always the same, so it should be entered only for Legal Type 3 (row 33), and is calculated in rows 34-41.

In both the Load Rating Summary Report (Page 1) and the Load Rating Worksheets (Pages 2 and above) of the Load Rating Summary Workbook, the rating vehicles are divided into horizontal bands (groups of rows) for Design and Legal Loads, CTP (Continuous Trip Permit) Vehicles, and STP (Single Trip Permit) vehicles. The bottom band of rows provides additional Rating Factors for a single lane of STP vehicles, at less than 10 mph, as "fall-back" positions for unsuccessful multiple-lane STP ratings. This is accomplished by adjusting the Rating Factor for multiple lanes by multiplying by the ratio of live load distribution factors (γ_L) and dividing out the multiple presence factor (m) that was originally included in the live load distribution factor (gm) by default. The last row of each group of STP vehicles is labeled "SPECIAL" and is reserved for evaluation of a specific super-load permit vehicle (one that exceeds MCTD Tables 4 or 5). When evaluating a super Load, "SPECIAL" in cell

R54C2 is overwritten with a specific permit vehicle designation, ideally one that matches the truck name that has been added to the BRASS Vehicle Library. This new designation is then echoed to other appropriate cells.

21.3 Header Information

In the Bridge Header Area (upper half) of the Load Rating Summary Report, enter all the required bridge inventory and inspection information in the input (boxed) cells. Use the Bridge Name as defined in the Definitions, Article 1.3.3 of this Manual.

For the Bridge Number, NBI Feature Intersected (Item 6), Bridge Name, Highway Name, Highway Number, Milepost, District, County, Design loading, Owner, Span Description, Other Description, Firm, Engineer, Year of ADTT, Elements 325 and 326, and NBI Status Items #41 and #103, the information must be entered as text.

To ensure data consistency when the Summary Workbook information is imported into the Load Rating Database, please note the following:

- In the “SPAN DESCR” cell, show only the span description (sequential list of span lengths and structure types from the Bridge Log).
- In the “FIRM QC REVIEWER(S)” cell, input the name or names of the individuals who participated in the checking process.
- The “ODOT QC CHECK BY” cell, is reserved for ODOT personnel. Upon submission of a load rating ODOT will perform a cursory review of the load rating. Once finishing the check insert your name verifying that the check was performed.
- In the “OTHER DESCR” cell, put all other descriptions that may define the structure (e.g. sidewalk information, overlay information, deck-to-streambed distance, skew, seismic or metric design note, etc.)
- In the “HIGHWAY NAME” cell, for state-owned bridges use the list in this location:
- http://www.oregon.gov/ODOT/TD/TDATA/rics/docs/2010AlphaNumericHighways.pdf
- In the “HIGHWAY #” cell, enter NBI Item 122 (found in the upper-left corner of the SI&A sheet).
- In the “MILEPOST” cell, enter only the numeric value, without any alphabetic prefix or suffix.
- In the “ADT” and “ADTT” cells, enter the total ADT and ADTT on the entire structure, i.e. the 2-way ADT for a 2-way structure and the 1-way ADT for a 1-way structure. Note - this is for database purposes only, and is *not* the same as the one-direction ADTT that is used to determine live load factors for the load rating.
- Several of the input (boxed) cells are provided with drop-down boxes to limit input choices. In the case of the “DESIGN LOADING” cell, note that some bridge plans will show “H20 – S16” loading, this is the same as HS20 loading. Also note that an “HS” loading is *not* the same as the “H” loading with the same number of tons. Refer to the ***AASHTO Standard Specifications for Highway Bridges*** (2002), Article 3.7, for the older design loadings.
- Where the text begins with a number (Highway Number, Year of ADTT), ensure that Excel treats the cell entry as text by preceding it with an apostrophe.
- For State Bridges, the Highway number is 3 characters, including leading zeros if needed. (For example, Hwy “1” is entered as “001”).
- Enter single dates only, in the form MM/DD/YYYY. Do ***not*** use the Excel TODAY() or NOW() function – dates should reflect when the main load rating work was performed, and should not change whenever someone opens the file.
- For State-owned bridges, in the “OWNER” cell enter “ODOT”, and in the “CALCULATION BOOK” cell enter a calculation book number obtained from the Bridge Section Load Rating Unit. For Load Ratings, always use a calculation book that is separate from the calculation book for design calculations.
- For non-state-owned bridges, to determine what to enter in the “OWNER” cell, use NBI item 22 (2-digit Owner Code) in conjunction with NBI Item 3 (County) or 4 (5-digit Place Code, also known as the FIPS Code). The value of these fields are found in the Structure Inventory

and Appraisal Sheet (SI&A) that accompanies the Bridge Inspection Report, and a table of FIPS Codes for Oregon can be found among the load rating references and tools. For example, for a local agency bridge having an Item 26 of "04" (city or municipal highway agency) and an Item 4 of "22550" (Elgin), in the "OWNER" cell the user would enter "City of Elgin". For a local agency bridge having an Item 22 of "02" (county highway agency) and an Item 3 of "Clackamas", in the "OWNER" cell the user would enter "Clackamas County". Please note that Items 3 and 4 are not to be used by themselves to determine ownership, because they describe only location, regardless of ownership.

- Use the optional "Comments" area to document any unusual decisions or features about the Load Rating (maximum 250 characters).
- The cells for Impact (1+I) and the dead load factors γ_{DC} and γ_{DW} are provided with their usual default values (they can be changed if necessary). The cells for the number of sections evaluated, and the Inventory and Operating Ratings in HS tons are calculated automatically when information is available. The cell for NBI Item 70 is calculated according to the NBI coding guide using LRFR Equation 6-7 (Article 6.8.3) for the recommended level of posting.

In the Controlling Rating Factor Area of column 3, enter the live load factors γ_L for each truck, calculated in the application file **LL_Factors_State.XLS** or **LL_Factors_Local.XLS** as applicable.

21.4 Obtaining Rating Factors from BRASS

The detailed load rating results for each investigated section must be provided in the Load Rating Worksheet (Pages 2 and above), using a separate column for each section evaluated.

The Load Rating Summary Workbook is provided with a number of VBA modules to facilitate common tasks. The buttons provided along the bottom of Page 1 activate the following modules:

Utilities (also obtainable by typing Ctrl-u) – opens a dialog box offering two different data importing options from older Summary Workbooks. Make sure that each older Summary Workbook is open when importing the data in the new Summary Workbook. The two import options are as follows:

Import Header and Live Load Factors – This option is used to import the Bridge Header Area (upper half of Page 1) of the Load Rating Summary Report and the Live Load Factors from an older version Summary Workbook.

Import All Rating Factors – This option is used to import all of the Rating Factors from an older version Summary Workbook.

Change Type of Load Rating – changes the title of every page of the load rating summary between a "LRFR Load Rating" to an "Engineering Judgment Load Rating". Since the procedures for rating concrete bridges without plans do not produce a LRFR load rating, making this distinction is necessary so that load rating method is recorded correctly within the National Bridge Inventory (NBI).

Insert Page (or Ctrl-n) – adds a new blank worksheet page (8 section columns) to the right edge of the worksheet. This action may be needed to provide space to enter Rating Factors from sources other than BRASS.

Delete Page (or Ctrl-x) – removes the rightmost worksheet page (8 section columns) from the worksheet. This module will not remove Page 1 or 2.

Clear Last Page (or Ctrl-k) – removes the data and resets the formulas on the rightmost worksheet page. This module will only remove the data from Page 2 or above.

Change Limit State (or Ctrl-l) – allows the user to select the desired limit state of the rating factors for selected cells in Page 2 or above.

Import BRASS (or Ctrl-i). – automates the transfer of Rating Factors from the Rating Factor Summary (**.**RFS) File (a subset of the large BRASS Output File)

Refresh (or Ctrl-r) – summarizes all Rating Factors, updating the Load Rating Summary Report (Page 1) with the most critical and second most critical Rating Factors for each rating vehicle

Print (or Ctrl-p) – Opens a dialog box for selecting the page printing options.

To use the **Import BRASS** module:

- In the input field at the top of the "File Location" dialog, enter the full path and file name for the output (….OUT) file. For Summary Workbooks with a "Latest Revision" date of 1/1/2008 or later, use the "Browse" button provided in this dialog to navigate to the desired bridge folder and .OUT file. This eliminates typo errors in the path.

- From the radio buttons, select the appropriate option. Normally this would be "Import BRASS Output for ALL Vehicles". (The 2nd option is only for importing the N File Rating Factors into existing sections, which is used for the NBI Rating of temporary shored bridges since the design vehicles need to be analyzed while ignoring any temporary shoring. The 3rd option is reserved for Super Load permit evaluation. The 3rd and 4th options produce different dialogue behaviors). Make corrections to the file path name if necessary and click "Continue". The check box for "Import Service II" is for structural steel members, and the box for "Import Service III" is for prestressed concrete members. These boxes are irrelevant for reinforced concrete members.

- A second dialog appears, titled "Output file for Distribution Factors" appears with another default path in the input field. The file and path entered here is where the summary worksheet will go to find the Distribution Factors that BRASS used. By default it is the **.**OUT file with the same path and prefix as was entered previously. A check box to "Import Live Load Factors" is available on this dialog box. This feature should only be used when the Live Load Factors are defined using the FACTORS-LOAD-LL-LS commands in BRASS. Make corrections to the output file location if necessary and click "Continue". Sometimes Microsoft Excel will report a warning message stating that "This file is not a recognizable format". This message stems from the file type being imported having the extension of .OUT and not being associated as an Excel compatible file. Simply click the "OK" button to continue with the import procedure. Distribution factors should not be entered manually in the Summary Workbook. If there is an error in the calculation of Distribution Factors by BRASS notify ODOT of the problem.

- The "Section" dialog will appear for each investigated section in the Rating Factor Summary. The purpose of this dialog is to provide the summary worksheet with appropriate section header (column header) information for the investigated section. The first time it appears, fill in the total number of spans for the bridge (not just the number of spans in the imported BRASS run). Since BRASS runs often times only model a portion of the total bridge, the import tool has a feature to adjust the BRASS spans to match the actual bridge span location. The first span in BRASS is always 1, but on the actual bridge it may be a different span number. Enter the actual bridge span number of the first BRASS span that is currently being imported. The BRASS import will automatically correct the location to the correct "span" of "spans" designation. Using the check boxes, choose the appropriate force type(s) (Positive Moment, Negative Moment, Shear or Bearing) to be rated for this section. For continuous steel sections, instead of selecting the positive or negative moment force types, select the "Critical Moment (Based on HL93). This will import the critical moment (negative or positive) that is controlling for each analysis point based on the HL93 live load envelope. Fill in the appropriate short member name, which will be "remembered" in subsequent appearances of this dialog. Examples of appropriate names would be "Int. Girder", "Ext. Girder", "Wid. Girder", "PS Int. Girder", etc. At the bottom of the dialog, check the "Steel Section" box if the section is in a structural steel member (steel requires a different programming branch).

- When the information is complete, click the "Select" button to go to the "Section" dialog for the next investigated section. Static information from the previous dialog will reappear. If the analysis points were entered in BRASS in a consistent manner (meaning all the moment sections together, then all the shear sections together), then the dialog boxes will appear with the correct radio buttons and other information so that no further input is necessary (just click "Select" to accept the defaults). This should speed up the process significantly. If the sections were in BRASS in some other order, it will be necessary to carefully review and change the data in the dialog for each investigated section. If you receive the message “You flopped the nuts!” your BRASS import has been successful. (This is a term borrowed from the world of poker, and reflects the idiosyncrasies of the summary sheet’s programmer)!

The **Import BRASS** module can be used consecutively to import Rating Factors from more than one BRASS output file (for example, interior and exterior girders).

21.5 Service III Rating Factors for Prestressed Girders

During the import process for prestressed girders, the program will lookup the Service III rating factor that is reported for each analysis point in the BRASS output. It will then ratio out the live load factor of 1.75 that was used for the HL-93 vehicle in BRASS and applies the correct live load factor of 0.80 that is required for Service III to compute the correct Service III Rating Factor. This is done for only the HL-93 Design vehicle, as this is the only load that is required to have a Service III limit check for Load Rating.

Excel use to have a maximum limit to the number of columns that can be used in a spreadsheet, which we kept approaching as we create additional sections to analyze and additional forces and limit states to check for each section. Therefore, to minimize the risk of exceeding the maximum column limit in Excel, the Load Rating Summary Workbook will only report Service III Rating Factors when they are less than or equal to 1.1. When the Service III Rating Factor is less than 1.1, a separate column will be created for the analysis section with only the Service III Rating Factor for the HL-93 vehicle, which is shaded so that it stands out from the normal analysis sections.

21.6 Longitudinal Tension Check Rating Factors

During the import process for reinforced concrete and prestressed girders, the program will look up the Longitudinal Tension Check rating factors that is reported for each analysis point in the BRASS output. BRASS is reporting four different Longitudinal Tension Check rating factors at each point for the following force combinations; maximum moment with concurrent shear, minimum moment with concurrent shear, maximum shear with concurrent moment, and minimum shear with concurrent moment. The program will evaluate all four force combinations and choose the controlling (lowest) Longitudinal Tension Check rating factor for each truck.

Excel currently has a maximum limit to the number of columns that can be used in a spreadsheet, which we keep approaching as we create additional sections to analyze and additional forces and limit states to check for each section. Therefore, to minimize the risk of exceeding the maximum column limit in Excel, the Load Rating Summary Workbook will only report the Longitudinal Tension Check Rating Factors when they are less than or equal to 1.1. When a Longitudinal Tension Check Rating Factor is less than 1.1 for any one of the rating vehicles, a separate column will be created for the analysis section that is reporting the controlling Longitudinal Tension Check Rating Factors for all of the rating vehicles.

The “Refresh” button tool on the front page of the Load Rating Summary sheet has been updated to only include the Rating Factors for the Long. Reinforcement Check on page 1 of the summary sheet when the Superstructure Condition Rating is less than 5. These Rating Factors will still be reported on pages 2 and above. ODOT is basing this after MBE Article 6A.1.5, Application of AASHTO LRFD Bridge Design Specifications. This section states, “Where the behavior of a member under traffic is not consistent with that predicted by the governing specifications, as evidenced by a lack of visible signs of distress or excessive deformation… , deviation from the governing specifications based on the known behavior of the member under traffic may be used and shall be fully documented.”

21.7 Service II Rating Factors for Steel Girders

During the import process for steel girders, the program will lookup the Service II rating factor that is reported for each analysis point in the BRASS output. It will then ratio out the live load factor of 1.75 that was used for the HL-93 vehicle in BRASS and applies the correct live load factor of 1.30 that is required for Service II to compute the correct Service II Rating Factor. For the Legal vehicles, the import process will lookup and ratio out the live load factors that BRASS used and applies the correct live load factor of 1.30 that is required for Service II. This same process is done for the Permit vehicles, except that the correct live load factor of 1.0 for Service II is used.

Excel use to have a maximum limit to the number of columns that can be used in a spreadsheet, which we kept approaching as we create additional sections to analyze and additional forces and limit states to check for each section. Therefore, to minimize the risk of exceeding the maximum column limit in Excel, the Load Rating Summary Workbook will only report Service II Rating Factors when they are less than or equal to 1.1. When the Service II Rating Factor is less than 1.1, a separate column will be created for the analysis section with the Service II Rating Factors, which is shaded so that it stands out from the normal analysis sections.

21.8 Obtaining RF’s from Microsoft Excel (X-Beam and PT BOX Girders)

For crossbeam sections, cast-in-place post-tensioned box girders, or any other rating factors for which the **Import BRASS** module is not applicable, it is necessary to manually complete the 6 header cells for each column with all the information requested, beginning with the first available blank column at the right edge of the Load Rating Summary Workbook. This information includes the name of the applicable crossbeam Analysis Data File or other analysis output file from which Rating Factors will be obtained. Using the Crossbeam Load Rating Software, the “RF” worksheet in the crossbeam-specific Analysis Data File will present Rating Factors in the same order as the Load Rating Summary Workbook. With both files open it is most efficient to copy contiguous blocks of column headers or Rating Factors. **Use Excel’s Edit / Paste Special / Values** to deposit them into the first available empty columns at the right end of the Load Rating Summary Workbook. Pasting **values** (not cells) is necessary to preserve the correct (default) Limit State in the Rating Factor cells and to avoid corruption of the spreadsheet’s format

If the Limit States need to be corrected, it is possible to select any block of Rating Factor cells and use "Ctrl-L" to activate the **Change Limit State** module dialog box to choose the correct Limit State associated with each LRFR Rating vehicle.

21.9 Completion Tasks

Use the **Refresh** button (or type Ctrl-u) to assure that the worst-case and second-worst-case Rating Factors are brought forth and summarized on Page 1.

After the refresh, if the cell for “Bridge Posting Status (Item 70):” is 4 or less, change the cell for “Operational Status (Item 41):” to “B” to document the reality that the bridge is open and posting is recommended but not legally implemented.

Use the Print button (or type Ctrl-p) and in the “Print Pages” dialog, select the applicable pages to print. For the Load Rating Summary Report, this would normally be the Load Rating Summary Report (Page 1) and the Load Rating Worksheets (pages 2 and above). Use the “Print” button on the dialog to print the workbook. Because the print area must be reset for each page to accommodate a varying number of pages, the printing process may take a significant amount of time.

21.10 Trouble Shooting Common Errors

Empty columns in the summary sheet for shear points that there are no rating factors for:

The Service III toggle is on by default. When this is on, the import program will automatically select both shear and positive moment rating factors for points between 0.4 to 0.6L. The rater has to physically turn off the Service III at the beginning of the import process (which he/she should not be doing if it is a prestress rating).

If the Service III is turned off, the import program will default to only positive moment for points between 0.4 to 0.6L.

For non-prestressed load ratings, if the Service III is not turned off during the import process, the program will attempt to import both shear and positive moment for the 0.4 to 0.6L points. However, since the bridge is not prestressed, BRASS should have been coded to only check positive moment. This results in some empty columns in the summary sheet for shear points that there are no rating factors for. This should be something that the load rater would notice if they quickly review the results of the imported rating factors.

We felt that it was better to leave the Service III option checked on, since the chances of raters forgetting to turn it on and missing the additional points for prestress bridges was greater. Plus, we felt that for non-prestress bridges, at least all of the rating factors that were analyzed would still get imported if Service III was not turned off.

SECTION 22: DELIVERABLES

22.1 Load Rating Report Preparation

Prepare a Load Rating Report for each bridge that is load rated, commonly referred to as a Load Rating Calc Book. A load rating calc book can either be a digital pdf document that is digitally sealed and signed or a hard copy that is a printed, stamped, bound and labeled calculation book.

Include printouts of all pertinent supporting documents and files from the Load Rating. Input files are required, but output files are typically not. This is for two reasons; output files can be readily reproduced from the input file, and output files are typically very large.

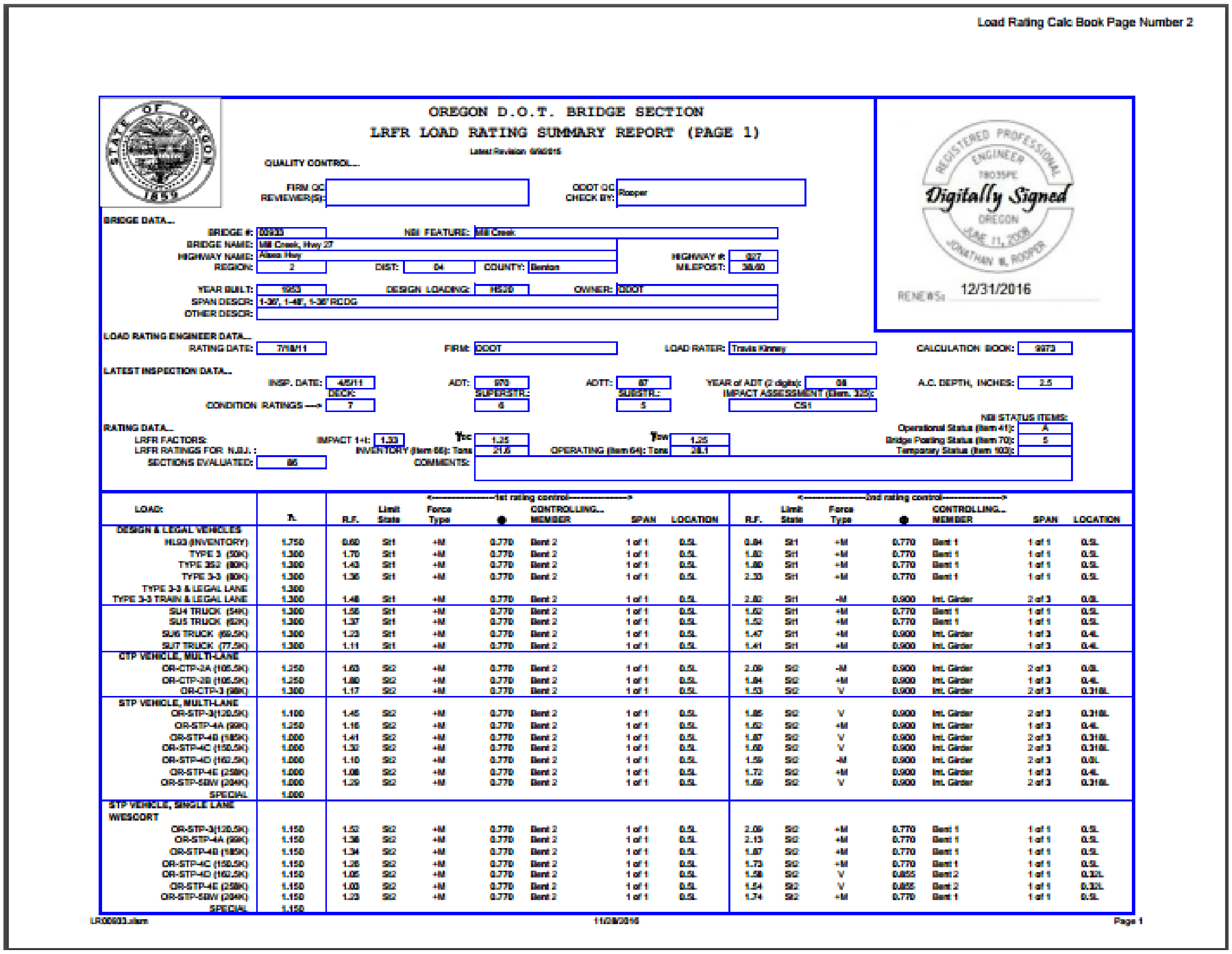
Printed Load Rating Calc Books for state-owned bridges will require a load rating calc book number, which will be used for cataloging the load ratings for retrieval when they are sent to the State Archives for storage. Contact the ODOT bridge load rating unit to request a load rating calc book number.

There is no need for a load rating calc book number for local agency bridge load ratings and digital load rating calc books, since they are not sent to the state archives for storage,

22.1.1 Digital Load Rating Calc Books

The digital load rating calc book will be a single pdf file that contains all of the same pages (in the same order) that are currently contained in the printed hard-copy of the load rating calc books. The file will be digitally sealed and signed following the requirements outlined in the Oregon Administrative Rules, Division 25 (Digital Seal and Signature). The Engineer of Record that is sealing and signing the load rating will place the electronic image of their PE stamp on the load rating summary sheet within the pdf document.

The naming convention of official load rating calc book will be: **LRCB_nnnnn.pdf**; with the nnnnn term being the bridge number. Number each page consecutively with a number in the upper right hand corner. Since the different files that were used in the load rating analysis often have their own page numbering layouts, use the prefix “Load Rating Calc Book Page Number” for the page numbering of the final load rating calc book. The following image of a digitally signed load rating summary sheet illustrates the preferred placement and formatting of the page numbering.



Load Rating Calc Book Page Number 2

OREGON D.O.T. BRIDGE SECTION

LRFR LOAD RATING SUMMARY REPORT (PAGE 1)

Latest Revision 6/9/2015

QUALITY CONTROL...

FIRM QC REVIEWER(S):

ODOT QC CHECK BY: Rooper

BRIDGE DATA...

BRIDGE #: 00933 | NBI FEATURE: Mill Creek
BRIDGE NAME: Mill Creek, Hwy 27
HIGHWAY NAME: Alsea Hwy | HIGHWAY #: 027
REGION: 2 | DIST: 04 | COUNTY: Benton | MILEPOST: 38.60
YEAR BUILT: 1953 | DESIGN LOADING: HS20 | OWNER: ODOT
SPAN DESCR: 1-36', 1-48', 1-36' RCDG
OTHER DESCR:

LOAD RATING ENGINEER DATA...

RATING DATE: 7/18/11 | FIRM: ODOT | LOAD RATER: Travis Kinney | CALCULATION BOOK: 9973

LATEST INSPECTION DATA...

INSP. DATE: 4/5/11 | ADT: 970 | ADTT: 87 | YEAR of ADT (2 digits): 08 | A.C. DEPTH, INCHES: 2.5
CONDITION RATINGS ---> DECK: 7 | SUPERSTR.: 6 | SUBSTR.: 5 | IMPACT ASSESSMENT (Elem. 325): CS1

RATING DATA...

LRFR FACTORS: IMPACT 1+I: 1.33 | γ_{DC} 1.25 | γ_{DW} 1.25
LRFR RATINGS FOR N.B.I. : INVENTORY (Item 66): Tons 21.8 | OPERATING (Item 64): Tons 28.1
SECTIONS EVALUATED: 86 | COMMENTS:

NBI STATUS ITEMS:
Operational Status (Item 41): A
Bridge Posting Status (Item 70): 5
Temporary Status (Item 103):

LOAD:	γ_L	R.F.	Limit State	Force Type	●	CONTROLLING... MEMBER	SPAN	LOCATION	R.F.	Limit State	Force Type	●	CONTROLLING... MEMBER	SPAN	LOCATION
		<----1st rating control---->							<----2nd rating control---->						
DESIGN & LEGAL VEHICLES															
HL93 (INVENTORY)	1.750	0.60	St1	+M	0.770	Bent 2	1 of 1	0.5L	0.84	St1	+M	0.770	Bent 1	1 of 1	0.5L
TYPE 3 (50K)	1.300	1.70	St1	+M	0.770	Bent 2	1 of 1	0.5L	1.82	St1	+M	0.770	Bent 1	1 of 1	0.5L
TYPE 3S2 (80K)	1.300	1.43	St1	+M	0.770	Bent 2	1 of 1	0.5L	1.80	St1	+M	0.770	Bent 1	1 of 1	0.5L
TYPE 3-3 (80K)	1.300	1.36	St1	+M	0.770	Bent 2	1 of 1	0.5L	2.33	St1	+M	0.770	Bent 1	1 of 1	0.5L
TYPE 3-3 & LEGAL LANE	1.300														
TYPE 3-3 TRAIN & LEGAL LANE	1.300	1.48	St1	+M	0.770	Bent 2	1 of 1	0.5L	2.82	St1	-M	0.900	Int. Girder	2 of 3	0.0L
SU4 TRUCK (54K)	1.300	1.58	St1	+M	0.770	Bent 2	1 of 1	0.5L	1.62	St1	+M	0.770	Bent 1	1 of 1	0.5L
SU5 TRUCK (62K)	1.300	1.37	St1	+M	0.770	Bent 2	1 of 1	0.5L	1.52	St1	+M	0.770	Bent 1	1 of 1	0.5L
SU6 TRUCK (69.5K)	1.300	1.23	St1	+M	0.770	Bent 2	1 of 1	0.5L	1.47	St1	+M	0.900	Int. Girder	1 of 3	0.4L
SU7 TRUCK (77.5K)	1.300	1.11	St1	+M	0.770	Bent 2	1 of 1	0.5L	1.41	St1	+M	0.900	Int. Girder	1 of 3	0.4L
CTP VEHICLE, MULTI-LANE															
OR-CTP-2A (105.5K)	1.250	1.63	St2	+M	0.770	Bent 2	1 of 1	0.5L	2.09	St2	-M	0.900	Int. Girder	2 of 3	0.0L
OR-CTP-2B (105.5K)	1.250	1.80	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.84	St2	+M	0.900	Int. Girder	1 of 3	0.4L
OR-CTP-3 (98K)	1.300	1.17	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.53	St2	V	0.900	Int. Girder	2 of 3	0.318L
STP VEHICLE, MULTI-LANE															
OR-STP-3(120.5K)	1.100	1.45	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.85	St2	V	0.900	Int. Girder	2 of 3	0.318L
OR-STP-4A (99K)	1.250	1.16	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.62	St2	+M	0.900	Int. Girder	1 of 3	0.4L
OR-STP-4B (185K)	1.000	1.41	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.87	St2	V	0.900	Int. Girder	2 of 3	0.318L
OR-STP-4C (150.5K)	1.000	1.32	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.60	St2	V	0.900	Int. Girder	2 of 3	0.318L
OR-STP-4D (162.5K)	1.000	1.10	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.59	St2	-M	0.900	Int. Girder	2 of 3	0.0L
OR-STP-4E (258K)	1.000	1.08	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.72	St2	+M	0.900	Int. Girder	1 of 3	0.4L
OR-STP-5BW (204K)	1.000	1.29	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.69	St2	V	0.900	Int. Girder	2 of 3	0.318L
SPECIAL	1.000														
STP VEHICLE, SINGLE LANE W/ESCORT															
OR-STP-3(120.5K)	1.150	1.52	St2	+M	0.770	Bent 2	1 of 1	0.5L	2.09	St2	+M	0.770	Bent 1	1 of 1	0.5L
OR-STP-4A (99K)	1.150	1.38	St2	+M	0.770	Bent 2	1 of 1	0.5L	2.13	St2	+M	0.770	Bent 1	1 of 1	0.5L
OR-STP-4B (185K)	1.150	1.34	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.87	St2	+M	0.770	Bent 1	1 of 1	0.5L
OR-STP-4C (150.5K)	1.150	1.26	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.73	St2	+M	0.770	Bent 1	1 of 1	0.5L
OR-STP-4D (162.5K)	1.150	1.05	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.58	St2	V	0.855	Bent 2	1 of 1	0.32L
OR-STP-4E (258K)	1.150	1.03	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.54	St2	V	0.855	Bent 2	1 of 1	0.32L
OR-STP-5BW (204K)	1.150	1.23	St2	+M	0.770	Bent 2	1 of 1	0.5L	1.74	St2	+M	0.770	Bent 1	1 of 1	0.5L
SPECIAL	1.150														

LR00933.xlsm 11/28/2016 Page 1

All of the load rating examples have a completed digitally signed load rating calc book that can be referenced as to how they should be organized. The load rating examples are on the ODOT FTP site, which can be found at: ftp://ftp.odot.state.or.us/Bridge/LoadRating/LRFR/Examples/

22.1.2 Printed Load Rating Calc Books

Print the rating factor summary sheets one-sided. Other files may be printed two sided. Punch and assemble all printed files into a calculation book binder in the prescribed order and page-numbered consecutively in the upper right corner. Normally it is expected that a complete Load Rating Report can be bound in a single Calculation Book, not to exceed 2.5 inches in thickness.

If load rating a very large structure where the bound book thickness of the report would exceed 2.5 inches in thickness, split the report between 2 (or more) bound books with separate calculation book numbers, by appending an "A" to the original book number and then append a "B", "C" etc. for the subsequent books. Continue the page numbering so that it is consecutive from one book to the next. Provide an identical, complete Table of Contents in each book, documenting the entire set of printed files and indicating the calculation book number as well as the page number where each printed file is bound. Do not create the split from one book to another within a printed file. Separate the books either before or after an entire printed file. In the Load Rating Summary Workbook, in the "CALCULATION BOOK" cell provide the number of the book that contains the stamped printout of the Summary Spreadsheet file. In the "COMMENTS" cell, list each of the calculation book numbers containing the report.

Bind the calculation book with a dark blue Accopress type binder (between separate stiff covers connected with flat binding posts that allow insertion or removal of sheets). Number each page consecutively with a number in the upper right hand corner. Attach a label on the front cover that includes the calculation book number (state owned bridges only), the Bridge Number, and the name of the bridge.

On all prints of the Load Rating Summary Report (Page 1), whether part of the bound report or separate from it, in the space provided in the upper right corner of Page 1, provide the required Oregon P.E. stamp, signature and P.E. expiration date of the engineer in responsible charge of the Load Rating.

22.1.3 Assembled Order for Load Rating Calc Books

For Midas, Microsoft Excel, and BRASS based analysis, bind the information printed in the Load Rating Report (calculation book) for Bridge No. nnnnnn in the following order: (Note: not all of the following are applicable for any given structure)

1. Scoping Summary Sheet (nnnnn_Scope.XLS)
2. Load Rating Summary Report (**LRnnnnnn.XLS**, originally from **LR.XLT**) **-** Stamped and signed by a registered Oregon P.E. in the box provided. Include the P.E. license expiration date.
3. Table of contents (**TOC.XLS**) showing the final (bound) page number of the beginning of each file.
4. Bridge Drawings (inserted as 11 x 17 in Landscape layout for digital load rating calc books or printed on 11 x 17 sheets with a “Z” fold to fit among the 11x8½ pages for printed calc books).
5. Inspection Report (**BIRnnnnnn.pdf**).
6. Crack Map Report, if available (**CRnnnnnn.XLS**).
7. Timber Boring Report, if available (**TBnnnnnn.PDF**)
8. Other relevant correspondence.
9. Preliminary file for Post-Tensioned Box Girder (**PTBOX.xmcd**).
10. Midas Model Data Profile (nnnnnMidasData.doc).
11. Capacity and Rating Factor Worksheet (nnnnn_PTGirder.XLS).
12. Preliminary file for interior RCDG (**INTGIR.xmcd**).
13. Concrete Bridge Generator file for interior RCDG (nnnnnn**_IntGir.CBG**).
14. Effective Shear Depth Calculations (**dv_Calculator.XLS**).
15. Preliminary file for Exterior girder (for example **EXTGIR.xmcd**).
16. Concrete Bridge Generator file for exterior RCDG (nnnnnn**_ExtGir.CBG**).
17. BRASS input for Interior girder LRFR Analysis, Design, Legal, CTP & STP Loads (for example **INTGIR.DAT**).
18. BRASS input for Exterior girder LRFR Analysis, Design, Legal, CTP & STP Loads (for example **EXTGIR.DAT**).
19. BRASS input file for reactions (**REACTION.DAT**).
20. Preliminary File for Crossbeam (**XB_BentN.xmcd**).
21. Crossbeam Analysis Data file (**XB_BentN.XLS**). Include prints from XB_MAIN.XLS for each investigated section.
22. Pin and Hanger Analysis file (Pin_Hanger_nnnnn_Span_X.pnh).

Repeat items 9 through 13 as required for each unique cast-in-place post-tensioned box girder span.
Repeat items 14 through 23 as required for each additional unique girder line.
Repeat items 24 and 25 as required for each unique crossbeam.
Repeat item 26 as required for each unique hinge or Pin and Hanger.

Please note: The **XB_MAIN.XLS** is not included in the Load Rating File Set. The file LL_Factors_State.XLS (or LL_Factors_Local.XLS, as applicable) should always be included in the Load Rating File Set, but since it is embedded in the first Preliminary File, it need not be printed and bound separately in the calculation book, nor included in the TOC.

22.2 Electronic Files Preparation

The following versions of software should be used for ODOT Load Rating (refer to Article 1.5.4 for more information):

- BRASS-GIRDER™ (Version 7.5.0).
- Mathcad Version 15 or Mathcad Prime 2.0.
- Microsoft™ Excel 2010**.**
- Microsoft Word 2010.
- ODOT Concrete Bridge Generator (CBG) version 1.0.13
- ODOT BRASS Moment Analyzer version 2.0.0
- ODOT LRFR Pin and Hanger (PNH) version 2.0.0
- MicroStation V8i
- Midas Civil 2016

For **printed load rating calc books**, prepare a CD (or DVD) containing the complete Load Rating File Set. The files that are submitted should not be protected or encrypted in any way. Submittals should include the Load Rating File Set for each bridge in its own bridge-numbered folder on its own CD/DVD. Do not split the files for any single bridge among 2 CD's. Identify the Bridge Number on the top surface of the CD/DVD. Automated backup files with *.BAK or *.$$$ extensions created by programs should not be included in the Load Rating File Set. Attach the CD or DVD containing computer calculation files in a manila envelope (or other holder/sleeve that is designed to hold a CD/DVD) attached to the inside of the back cover of the Load Rating Report (calculation book).

For **digital load rating calc books**, prepare a CD or other physical storage media (such as DVD or USB flash drive) containing the complete Load Rating File Set along with the digital load rating calc book. Other than the digitally sealed load rating calc book, the other supporting files that are submitted should not be protected or encrypted in any way. Digital load rating submittals may include the Load Rating File Sets for multiple bridges, with each bridge having its own bridge-numbered folder on a single CD or other physical storage media. Do not split the files for any single bridge among different CD's/storage media. Automated backup files with *.BAK or *.$$$ extensions created by programs should not be included in the Load Rating File Set.

The following is an example of a Load Rating File Set for Bridge 00933, a 3-span RCDG bridge which requires analysis of both interior and exterior girders, and has 4 bents with 2 unique crossbeams:

File Name:	**Description:**
BIR00933.HTM	Bridge Inspection Report in HTML format (optional for non-state bridges)
SIA00933.HTM	SI&A Sheet in HTML format (optional for non-state bridges)
CR00933.XLS	Excel Crack Map Report
10782.TIF	Scanned bridge drawing
INTGIR**.xmcd**	Interior Girder Preliminary File in Mathcad. Develops input parameters for INTGIR**.**DAT
00933_IntGir.CBG	Interior Girder Concrete Bridge Generator File
EXTGIR**.xmcd**	Exterior Girder Preliminary File in Mathcad. Develops input parameters for EXTGIR**.**DAT
00933_ExtGir.CBG	Exterior Girder Concrete Bridge Generator File
INTGIR**.**DAT	Interior Girder BRASS Input File
INTGIR**.**OUT	Interior Girder BRASS Output File (warning, very large!)
INTGIR**.**DST	Interior Girder BRASS output of Distribution Factor calculations

INTGIR.EFF	Interior Girder output of Effective Flange Width calculations
INTGIR.RFS	Interior Girder Rating Factor Summary. A subset of INTGIR.OUT created to facilitate automated input of rating factors to the Summary Workbook LR00933.XLS
EXTGIR.DAT	Exterior Girder BRASS Input File
EXTGIR.OUT	Exterior Girder BRASS Output File (warning, very large!)
EXTGIR.DST	Exterior Girder BRASS output of Distribution Factor calculations
EXTGIR.EFF	Exterior Girder output of Effective Flange Width calculations
EXTGIR.RFS	Exterior Girder Rating Factor Summary. A subset of EXTGIR.OUT created to facilitate automated input of rating factors to the Summary Workbook LR00933.XLS
LL_Factors_State.XLS	Excel application that determines LRFR live load factors for State-owned bridges. Supports Preliminary Files for girders.
dv_Calculator.XLS	Excel application that determines d_v for various sections. Supports Preliminary Files for girders.
BarCutoffs.XLS	Excel application to locate effective flexural bar cutoffs and determine nodes between elements for BRASS analysis. Supports Preliminary Files for girders
XB_Bent1**.xmcd**	Bent 1 Crossbeam Preliminary File in Mathcad. Develops parameters for XB_Bent1.XLS
XB_Bent1.XLS	Bent 1 Crossbeam Analysis Data File in Excel. Used with Crossbeam Analysis Program XB_MAIN.XLS to analyze the crossbeam and determine its Rating Factors
XB_Bent2**.xmcd**	Bent 2 Crossbeam Preliminary File in Mathcad. Develops parameters for XB_Bent2.XLS
XB_Bent2.XLS	Bent 2 Crossbeam Analysis Data File in Excel. Used with Crossbeam Analysis Program XB_MAIN.XLS to analyze the crossbeam and determine its Rating Factors
LR00933.XLS	Excel Load Rating Summary Workbook, summarizes all the rating factors and determines the first and second controlling member sections
TOC.XLS	Excel Table of Contents file indicating page numbers for the beginning of each file in the printed copy of the Load Rating Report
INTGIR_MOMENT_INITIAL.TXT	Text file containing the initial run output of the ODOT BRASS Moment Analyzer. Only used for continuous bridges with adjacent spans lengths that vary more than 30%.
INTGIR_MOMENT_FINAL.TXT	Text file containing the final run output of the ODOT BRASS Moment Analyzer. Only used for continuous bridges with adjacent spans lengths that vary more than 30%.
Label.DOC	Cover Label for bound printed copy of the Load Rating Report.
Pin_Hanger_08347_Span_9a.pnh	Pin and Hanger input file.
00933_Scope.XLS	Scoping summary sheet printed single sided. Use multiple if necessary.

Non-bridge-specific tools such as **Bar_Ld.XLS**, **RAILDL.XLS**, Excel templates and the Crossbeam Analysis Software **XB_MAIN.XLS** should be omitted from the Load Rating File Set.

22.3 Submittals

Deliver load ratings by mail, or in person, to the following:
Senior Load Rating Engineer
ODOT Bridge Engineering Section
4040 Fairview Industrial Drive SE, MS #4
Salem, OR 97302

22.3.1 Printed Load Rating Calc Book Submittals

For Load Ratings, submit the following:

For state-owned bridges:

(a) 1 printed, bound and labeled copy of the Load Rating Report
(b) 1 CD containing the complete Load Rating File Set in a bridge-numbered folder
(c) Cover letter indicating the firm, Load Rating Engineer and contract under which the load Rating was performed, and identifying any Rating Factors < 1.0

For local-agency-owned bridges being performed without owner's involvement (the two copies listed below are required so that ODOT retains a copy and a copy can be sent to the owner by ODOT)**:**

(a) 2 printed, bound and labeled copies of the Load Rating Report
(b) 2 CDs (one attached to each bound report) containing the complete Load Rating File Set in a bridge-numbered folder
(c) Cover letter indicating the firm, Load Rating Engineer and contract under which the load Rating was performed, and identifying any Rating Factors < 1.0

For local-agency-owned bridges being performed with the owner's involvement (will assume that a copy of the load rating will be given to the owner directly, thus ODOT requires only one copy is submitted to ODOT for our records)**:**

(a) 1 printed, bound and labeled copy of the Load Rating Report
(b) 1 CD containing the complete Load Rating File Set in a bridge-numbered folder
(c) Cover letter indicating the firm, Load Rating Engineer and contract under which the load Rating was performed, and identifying any Rating Factors < 1.0

22.3.2 Digital Load Rating Calc Book Submittals

For digital load rating calc books, regardless of bridge owner, submit the following:

(a) 1 CD (or other physical storage media such as DVD or USB flash drive) containing the digitally sealed load rating calc book and the complete Load Rating File set in a bridge numbered folder. Multiple bridge load ratings may be submitted on a single CD/ other storage media (such as DVD or USB flash drive).
(b) A separate cover letter for each bridge load rating being submitted indicating the firm, Load Rating Engineer and contract under which the load Rating was performed, and identifying any Rating Factors < 1.0

SECTION 23: ODOT QUALITY CONTROL & QUALITY ASSURANCE

23.1 General

This section provides specific procedures to ensure competent engineering for this type of Bridge Work. It is directed at internal activities within ODOT performed by the Load Rating Unit of the Bridge Program Team, but is applicable to all personnel performing this type of work.

Load Ratings are performed at the direction of the Bridge Program Unit Manager, Senior Load Rating Engineer, or may be generated when conditions change, or on the recommendation of a Bridge Inspector according to *The ODOT Bridge Inspection Manual*, Section 8.3, Deficiency Documentation and Reporting Requirements.

Engineers and technicians selected for Load Rating Engineering shall have the appropriate coursework and experience to perform work expected in their position and the capability to backup personnel in related positions. Training and development opportunities will be provided to improve skills, fill gaps and enable coverage of related areas.

Engineers and technicians shall only be assigned work appropriate for their specific discipline and for which they have sufficient capability to successfully accomplish. As a part of training and development, less experienced engineers and technicians may be assigned work under the direct supervision of a senior engineer or technician which is above their current capability.

23.2 Procedures

LRFR procedures are documented in the comprehensive ODOT LRFR Manual. For structure types that are not covered in the ODOT LRFR Manual, it is expected that the methodology and workflow be as consistent as possible with the other structure types already covered in the manual. All load ratings in LRFR follow the same Load and Resistance Factor philosophy, and are performed on various sets of vehicles:

(1) a specified set of Design Loads, used only for reporting to the National Bridge Inventory (NBI), not for load restriction recommendations

(2) the 3 Oregon Legal Loads as defined in the Oregon Revised Statutes, for potential load posting recommendations.

(3) a set of 4 Specialized Hauling Vehicles (SHVs), short but heavy legal vehicles that have more serious load effects than the standard Legal Loads, for potential load posting recommendations.

(4) a set of 3 LRFR “CTP” vehicles representative of the Continuous Trip Permits issued for generally unrestricted travel (with a few exceptions) by ODOT’s Motor Carrier Transportation Division (MCTD), for potential load restriction recommendations.

(5) a set of 7 LRFR “STP” vehicles representative of the Single Trip Permits issued for specific routes by MCTD, for potential load restriction recommendations

23.3 Qualifications

LRFR Load Ratings must be stamped by an Oregon Registered Professional Engineer who has performed the Load Rating or is in responsible charge of the work.

23.4 Review and Reports

LRFR Load Rating Reports are standardized as described in ODOT LRFR Manual. These reports, procedures and the software on which they are based, are standardized for efficiency and repeatability. Due to the consistency of the report format, any engineer familiar with ODOT LRFR procedures should be able to pick up any prior load rating and follow the sequence of calculations and update it for new conditions quickly and efficiently.

23.5 LRFR Quality Control

Quality Control shall consist of an examination of the Load Rating Summary Sheet for each LRFR load rating, using the LRFR QC Checklist. Each of the considerations on the checklist must be judged acceptable before uploading the results into the LRFR Load Rating Database:

23.6 LRFR QC Checklist

All completed LRFR Load Ratings should be checked according to these criteria:

(1) Adequate header information (bridge number, name, span description etc. to identify the bridge in the database.

(2) Check that Live Load Factors, Impact Factors and Resistance Factors are reasonable and consistent with the LRFR Specifications and ODOT-specific live load calibration, and the bridge conditions in the Bridge Inspection Report.

(3) Check to see if the Rating Factors are consistent with the NBI condition ratings from the Bridge Inspection Report.

If any of these criteria are not met, the Load Rating should be given an independent LRFR Quality Assurance Review, as defined in the next section.

23.7 LRFR Quality Assurance

Quality Assurance review should consist of an examination of LRFR Load Rating Reports that fail the Quality Control Review. The QA review should be made by an independent Load Rating Engineer according to the LRFR QA Checklist:

23.8 LRFR QA Checklist

Quality Assurance review should consist of an examination of LRFR Load Rating Reports by an independent Load Rating Engineer according to the following checklist:

(1) Physical requirements of the Load Rating Report submittal (binding, page numbering, file media, tabs, P.E. stamp, signature & expiration date)

(2) Layout of the Load Rating Report (order of contents)

(3) Inclusions of the Load Rating Report (Inspection Report, SI & A Sheet, As-built Plans)

(4) Preliminary Files for BRASS-GIRDER(LRFD) runs
   a. Appropriate use of file naming convention
   b. LRFR General, System & Condition Factors for flexure and shear chosen to be consistent with degree of redundancy and Superstructure Condition Rating (NBI Item 59) on the Inspection Report
   c. LRFR Condition factor ignored (set to 1.0) where appropriate (RC structures)
   d. Appropriate LRFR Deadoad Factors chosen
   e. Accurate Deadload calculations for BRASS-GIRDER(LRFD) input (account for haunches, horizontal flares, diaphragms, wearing surface with allowance for uncertainty, rails, sidewalks etc)
   f. Appropriate interpretation of web depths for BRASS-GIRDER(LRFD) input

g. Appropriate input for BRASS-GIRDER(LRFD) to determine LRFD Liveload Distribution Factors
h. Appropriate use of Excel tool to determine LRFR Liveload Factors based on one-direction ADTT from SI&A sheet (watch for use of 2-direction ADTT)
i. Appropriate Impact Factor based on Element 325 in Inspection Report
j. Appropriate interpretation of boundary conditions for BRASS-GIRDER(LRFD) input
k. Appropriate use of Excel tool to determine shear distance
l. Appropriate determination of critical shear sections with haunch files where applicable
m. Correct use of ODOT Concrete Bridge Generator software
n. Correct location of stirrup change points
o. Appropriate elimination of very close investigation sections

(5) BRASS-GIRDER(LRFD) coding & runs
a. Appropriate use of file naming conventions
b. Appropriate use of commenting
c. Identify in file if BRASS-Girder span must differ from Numbering on plans
d. Input consistent with Preliminary file
e. Use of inches (or feet*12) for all BRASS-GIRDER(LRFD) input dimensions
f. BRASS-GIRDER(LRFD) Input Adjustments (workarounds) interpreted correctly
g. Appropriate definition of separate sections (all unique combinations of section dimensions and longitudinal rebar configuration)
h. Appropriate definition of spans and section ranges
i. BRASS-GIRDER(LRFD) runs successfully and error-free
j. BRASS-GIRDER(LRFD) output is used to verify the expected variation in section properties (reality check of the model)
k. BRASS-GIRDER(LRFD) output is used to verify the loads at boundary conditions (reality check of the forces)
l. BRASS-GIRDER(LRFD) output passes reality check on Rating Factors obtained
m. Correct subset of BRASS-GIRDER(LRFD) output is obtained for automated Rating Factor extraction

(6) Preliminary Files for Crossbeam runs
a. Appropriate use of file naming convention
b. Appropriate LRFR Liveload Factors taken from Preliminary Girder File
c. Resistance Factors chosen based on appropriate NBI Item (Substructure or Superstructure) depending on Crossbeam configuration
d. Appropriate calculation of input geometry and properties from Plans
e. Skew accounted for correctly
f. Appropriate use of short cantilevers to assure the crossbeam model supports all the superstructure loads
g. Appropriate Deadload reactions transferred from BRASS-GIRDER(LRFD) output
h. Appropriate Liveload lane reactions calculated from BRASS-GIRDER(LRFD) output
i. Appropriate choice of investigated crossbeam sections

(7) LRFR Crossbeam Software runs
a. Appropriate use of file naming convention
b. Appropriate choice of boundary conditions crossbeam model (model graphics reality check)
c. Correct transfer if input parameters from Preliminary File
d. Correct Deadload reactions transferred from Preliminary File
e. Correct Liveload reactions transferred from Preliminary File
f. Crossbeam Software runs error-free

(8) Summary Spreadsheet
a. Appropriate use of file naming convention
b. Header data filled in completely & correctly (for database integrity)

c. Correct transfer of Rating Factors from BRASS
d. Correct transfer of Rating Factors in blocks from Crossbeam Software
e. Correct use of programming modules to summarize controlling Rating Factors
f. Interpretation of Rating Factor results translated into appropriate restriction recommendations

SECTION 24: BRIDGE LOAD RESTRICTIONS

24.1 Load Restriction Management

When a Load Rating has been completed and Rating Factors for one or more of the standard legal vehicles (other than Design Loads) or Specialized Hauling Vehicles (SHV) are determined to be less than 1.0, the Load Rating Engineer must begin the ODOT Undercapacity Bridge Resolution Process.

There are two governing procedures for load restrictions on ODOT owned bridges, one from a Bridge Section perspective, and one from an ODOT-wide perspective. These procedures overlap somewhat, and both must be followed.

(1) From a Bridge Section perspective, the bridge Load Restriction process is outlined in a flowchart called the ODOT Undercapacity Bridge Resolution Process. The flowchart is included in Appendix A - Undercapacity Resolution Process for ODOT Bridges of this manual. This process consists of Part 1 (first two pages of the flowchart), which covers the decisions and potential steps in the Load Rating process that precedes the determination that the bridge is undercapacity, and Part 2 (last two pages of the flowchart) which deals with all the decisions and options available to ODOT, and the 90 day timeline to resolve undercapacity bridges, once the bridge has been determined to be undercapacity.

(2) From an ODOT-wide perspective, the bridge load restriction process is contained in ODOT Policy Document PMT_06-01, “Size and Weight Restrictions on State Highways”. A copy of the policy is included in Appendix B - ODOT Policy PMT 06-01 of this manual. This document describes the process of stakeholder involvement and details all the required handoffs and meetings with various parties both within and outside of ODOT.

For local-agency-owned bridges, once a load rating that shows that the rating factors are less than 1.0 for the standard legal vehicles or SHVs has been reviewed and accepted by ODOT, the 90 day clock begins to have the bridge posted for load, repaired/strengthened, or temporarily shored. ODOT will begin by sending the bridge owner a posting recommendation letter that describes the deficient load capacity, along with which bridge elements/members control the load rating, and the recommended load posting. The posting recommendation letter will often give a load posting deadline that is just shy of the full 90 days so that ODOT has time to follow up with the owner to ensure that the bridge is actually posted or repaired before the 90 day due date has passed.

24.2 Qualifications

A Bridge Restriction Recommendation Letter must be stamped by the Oregon State Bridge Engineer, an Oregon Registered Professional Engineer. This letter is normally prepared by the Load Rating Engineer who performed the Load Rating (if load rated by ODOT) or conducted the review of the Load Rating (if load rated by a consultant) of the undercapacity bridge.

24.3 Review

Due to the politically sensitive nature of bridge load restrictions, the following reviews are required.

(1) The State Bridge Engineer reviews all proposed bridge restrictions before signing and stamping the Bridge Restriction Recommendation Letter.

(2) An independent Load Rating Engineer reviews of the Bridge Restriction Recommendation Letter produced by the Load Rating Engineer of the undercapacity bridge.

24.4 Load Restriction Checklist

To avoid unforeseen problems in restriction Response Team Meetings, before the Bridge Restriction process is launched, the following actions should take place:

(1) Load Rating of the undercapacity bridge should be reviewed independently by another Load Rating Engineer.

(2) Determine if alternative analysis techniques might be appropriate

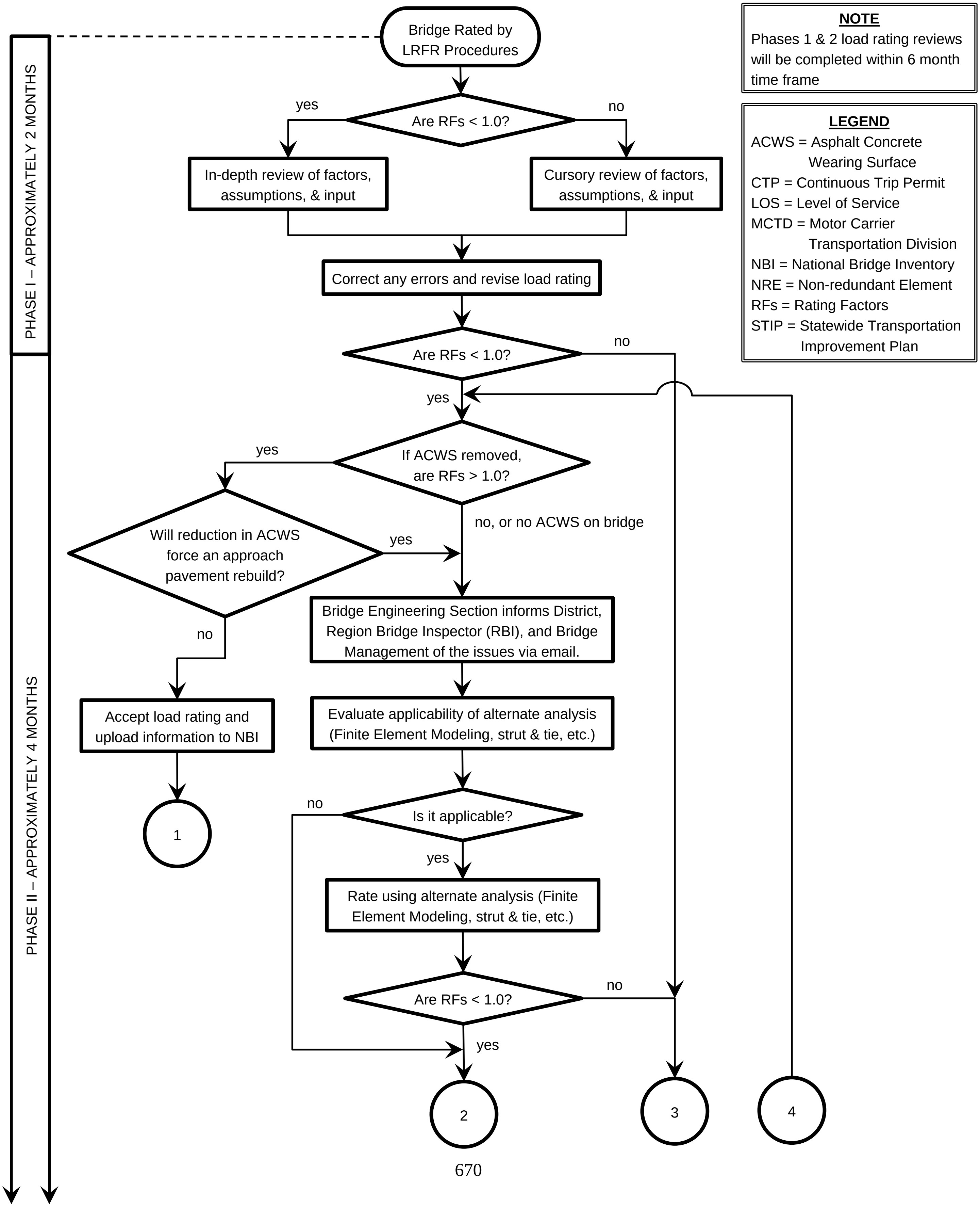
(3) The collected peripheral data should be reviewed by another Load Rating Engineer for
   a. credibility of inspection data
   b. current inspection monitoring frequency
   c. current instrumentation and crack mapping
   d. plans for repair or replacement in OTIA, STIP or MBM programs
   e. ADTT and level of STP permits issued
   f. suitability of alternative routes
   g. restrictions on alternate routes
   h. nearby restrictions on the route in question
   i. nearby construction work
   j. history of restrictions in the area
   k. feasibility of repair options, both temporary and permanent

(4) Bridge Section consensus on the restriction level recommendation.

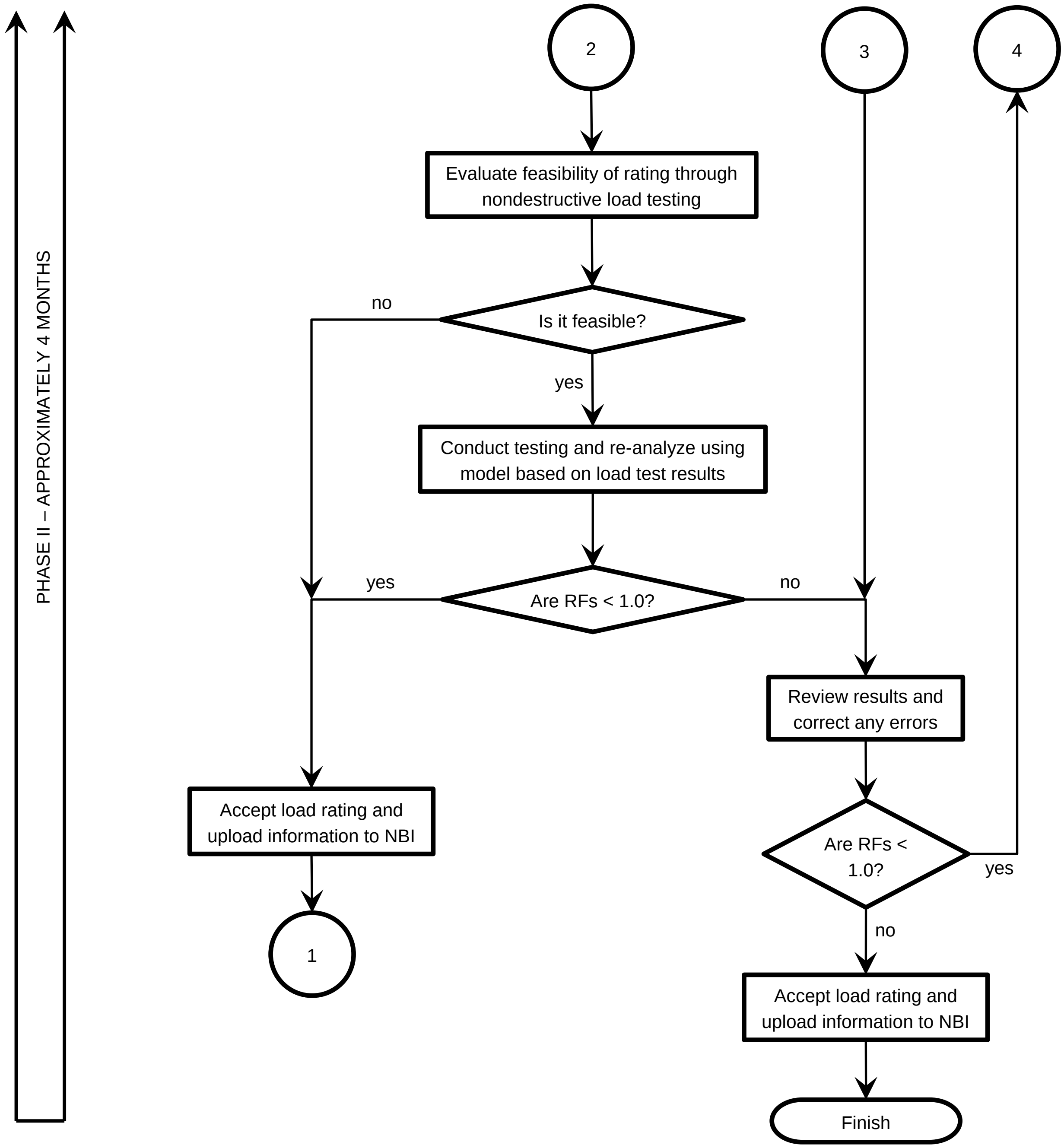
24.5 Load Restriction Follow-up

The Bridge Program Unit, Load Rating Team tracks all restriction letters to assure that the recommended posting and/or repair is accomplished in a timely manner in accordance with the 90 day limit to have the deficiency addressed as required by FHWA.

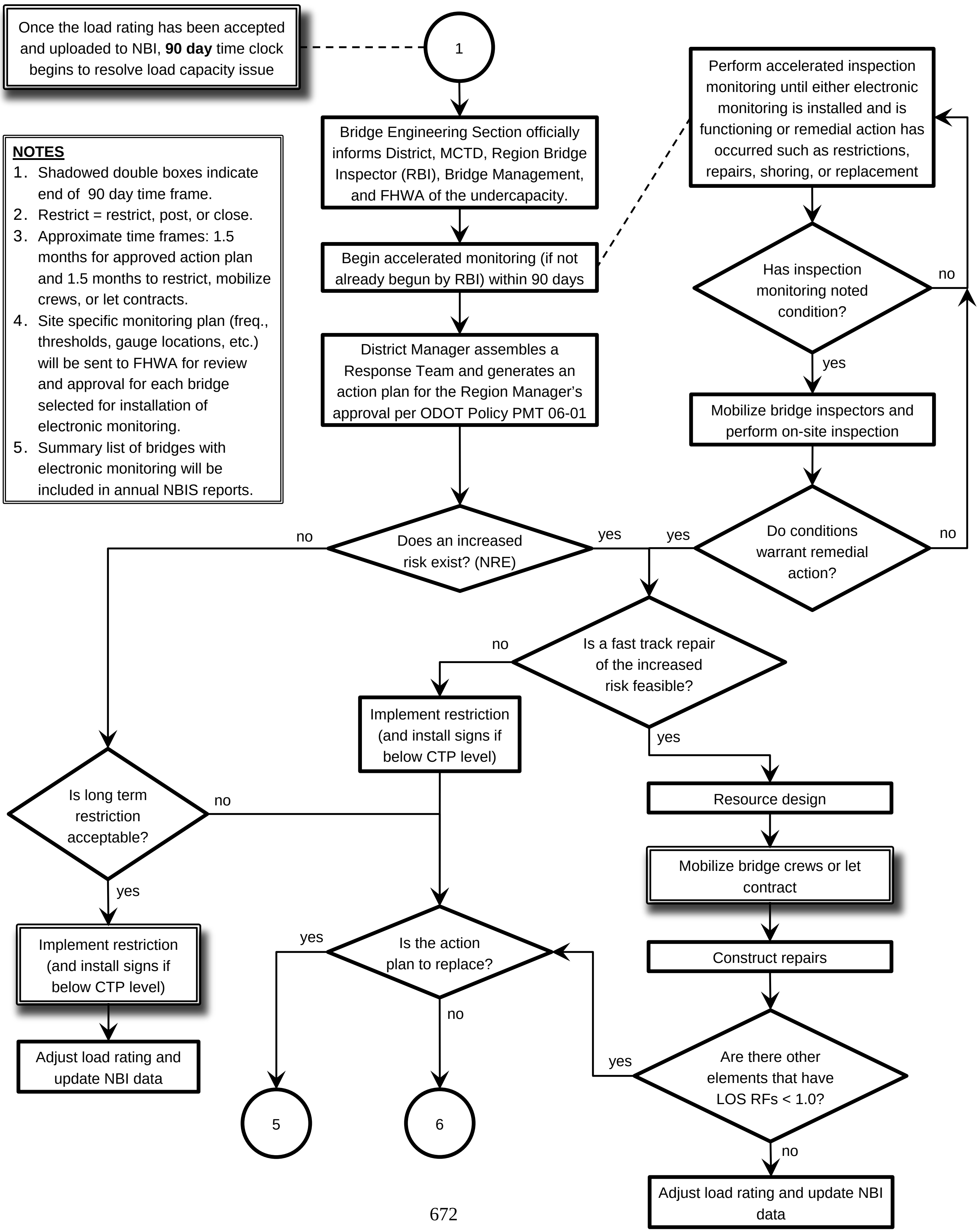
APPENDIX A – UNDERCAPACITY RESOLUTION PROCESS FOR ODOT BRIDGES



APPENDIX A – UNDERCAPACITY RESOLUTION PROCESS FOR ODOT BRIDGES (Continued)



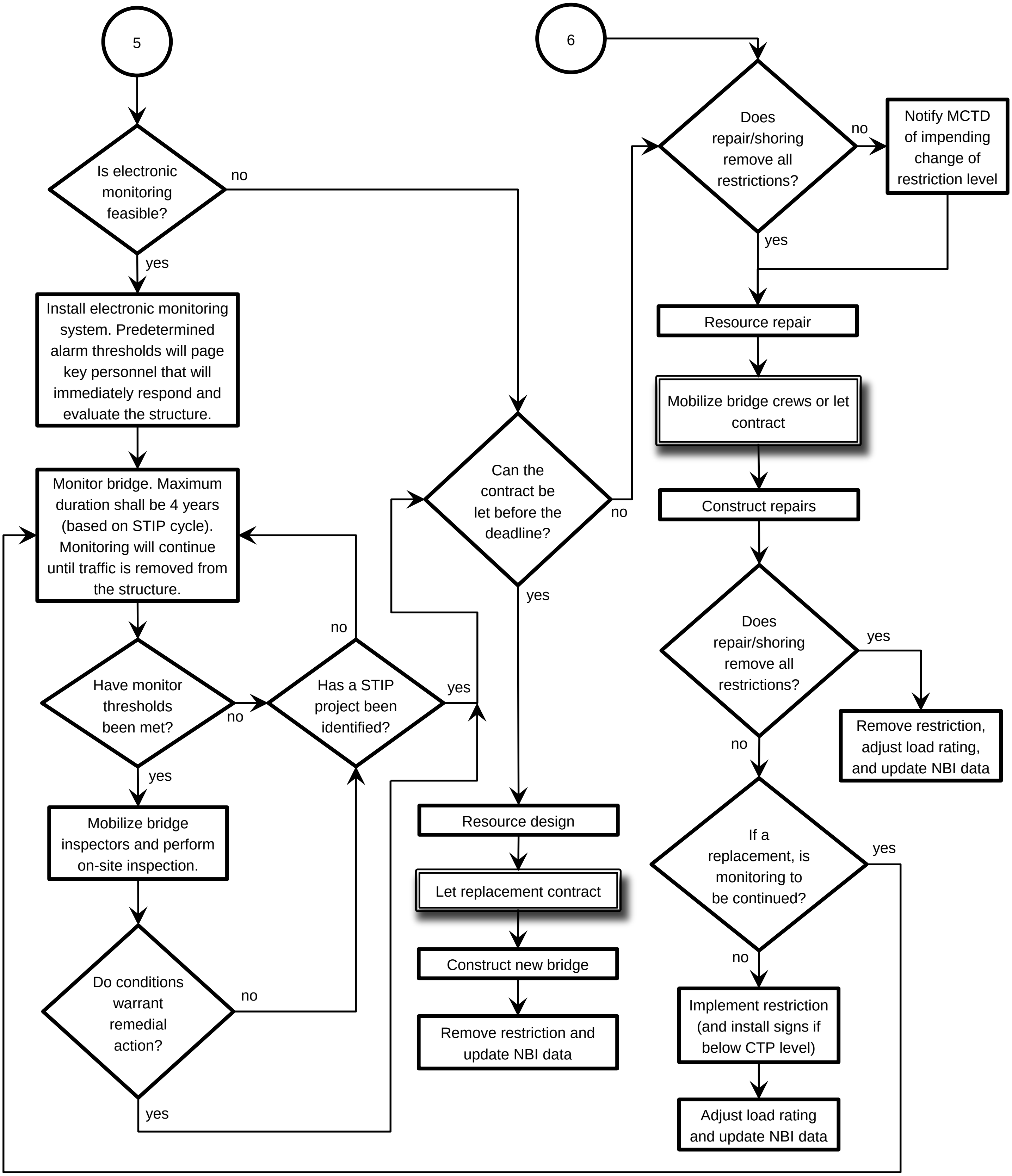
APPENDIX A – UNDERCAPACITY RESOLUTION PROCESS FOR ODOT BRIDGES (Continued)



NOTES

1. Shadowed double boxes indicate end of 90 day time frame.
2. Restrict = restrict, post, or close.
3. Approximate time frames: 1.5 months for approved action plan and 1.5 months to restrict, mobilize crews, or let contracts.
4. Site specific monitoring plan (freq., thresholds, gauge locations, etc.) will be sent to FHWA for review and approval for each bridge selected for installation of electronic monitoring.
5. Summary list of bridges with electronic monitoring will be included in annual NBIS reports.

APPENDIX A – UNDERCAPACITY RESOLUTION PROCESS FOR ODOT BRIDGES (Continued)



APPENDIX B – ODOT POLICY PMT 06-01

Oregon Department of Transportation POLICY	NUMBER PMT 06-01	SUPERSEDES 06/29/06
	EFFECTIVE DATE 11/25/2015	PAGE NUMBER 01 OF 09
	VALIDATION DATE	
	REFERENCE OAR 734-050-0090; 734-020-0150; ODOT Policy DES 05-02; Mobility Procedures Manual	
SUBJECT SIZE AND WEIGHT RESTRICTIONS ON STATE HIGHWAYS	APPROVED SIGNATURE Signature on File	

PURPOSE

Ensure that the Oregon Department of Transportation (Department) maintains viable routes to move freight throughout the state from border to border.

Ensure collaboration with other restrictions that are a direct result of either highway work or a natural disaster or events that we know could cause issues.

Ensure that the Highway Division, the Motor Carrier Transportation Division (MCTD), the Communications Division, and the Assistant Director work in coordination with impacted industries and local jurisdictions to analyze options and alternatives to determine alternate routes around restrictions that can remain for the duration of the restriction. Or look for ways to get those impacted through, which may be an option on some projects, especially if detour is unable to handle the loads. This might include some advance notifications and possibly wait times while adjustments are made. Some Bridge restrictions can be met with low speed and single vehicle on bridge and on center of structure.

Ensure Public Works, County and City, are notified and involved and participate in proposed actions and possible detours.

Ensure that elected officials have relevant information and have the opportunity to express concerns prior to public announcement of proposed or adopted alternate routes.

Ensure that the timing of restrictions minimizes the impact to industries and local jurisdictions as much as possible, while still protecting the highway infrastructure.

Ensure the safety of the traveling public and protection of State resources by timely implementation of bridge weight restrictions or adjustments/improvements that can be implemented quickly and reasonably that either limit or remove the restrictions and need to proceed with notifications.

Ensure that, in the event an immediate restriction or closure is necessary, appropriate communication and analysis occurs as quickly as possible.

APPENDIX B – ODOT POLICY PMT 06-01 (Continued)

Ensure the process outlined in Oregon Administrative Rule (OAR) 734-050-0090 for designating highway weight restrictions is followed when the weight restriction on bridges is below what is routinely allowed on a highway or section of highway.

POLICY

It is the policy of the Department to work collaboratively with and minimize the impact, where possible, to the motor carrier industry and local government when it becomes necessary to restrict the allowable size and weight of loads on the state highway system in order to maintain safe travel.

GUIDELINES

As outlined in Attachment A, concerns with the integrity of bridges on the state highway system are to be raised to the Bridge Load Rating Engineer (BLRE) by bridge inspectors or District maintenance personnel. Concerns may also be identified by the BLRE as part of evaluating bridge inspection reports and load rating calculations according to ODOT Policy DES 05-02.

If after reviewing a concern, a load restriction is determined not to be necessary; BLRE so notes and notifies the person raising the concern. If a load restriction is necessary, BLRE notifies the State Bridge Engineer. If the State Bridge Engineer concurs, the BLRE notifies the Region Manager, District Manager, MCTD Freight Mobility Coordinator, Communications Division, and the Assistant Director of the need to restrict loads on the bridge.

If conditions observed by visual inspection raise significant and imminent safety concerns, a District Manager may act under the authority of OAR 734-020-0150 to close or otherwise restrict traffic on the bridge immediately and expedite the steps outlined in this policy.

If a restriction to height, length, or width is determined to be necessary for either planned construction, maintenance work or County, City or permitted work, the Project Leader, Project Manager, Consultant Project Manager, County, City or permittee or District Manager is responsible for notifying MCTD prior to the commencement of work. The MCTD Freight Mobility Coordinator will work with the Project Leader, Project Manager, Consultant Project Manager, County, City or permittee or District Manager to engage affected members of the freight community according to the guidelines in the *Mobility Procedures Manual* and will keep the District Manager informed.

Individual roles and responsibilities for weight restrictions on bridges can be found in Attachment A. Individual roles and responsibilities for size restrictions as a result of planned construction or maintenance work can be found in Attachment B.

In the case of an emergency, it may be necessary to restrict the size and/or weight of vehicles traveling on the roadway. The District Manager may immediately restrict the size of or type of a vehicle traveling on the roadway or close the structure or roadway affected due to a natural disaster or other unforeseen circumstance. The District Manager in consultation with the BLRE may immediately close or restrict the weight size or type of vehicles traveling

APPENDIX B – ODOT POLICY PMT 06-01 (Continued)

on a structure due to a natural disaster or other unforeseen circumstance. Upon making the decision a restriction or closure is necessary, the District Manager will if needed take immediate action to protect the public and the facility then notify the Region Manager, Communications staff, and MCTD. If immediate action is not needed to protect the safety of the traveling public or structure, the notifications will be performed prior to taking action. The aforementioned staff will work to notify the public as quickly as possible and in the case of an emergency are not required to follow the steps outlined in Attachments A and B.

APPENDIX B – ODOT POLICY PMT 06-01 (Continued)

Attachment A

BRIDGE LOAD RESTRICTION ROLES AND RESPONSIBILITIES

RESPONSIBILITY	STEP	ACTION
Originator Bridge Inspectors or District Maintenance Personnel or Bridge Load Rating Engineer	1	Identify need to review load rating on bridges and raise the concern to the BLRE. Identify concern with bridge load capacity as part of evaluating bridge inspection reports or performing load rating calculations.
Bridge Load Rating Engineer	2	Review concern identified by originator and analyze load carrying capacity of the bridge to determine whether load restriction is necessary.
	3	If load restriction is not necessary, note in load rating database and notify originator, as appropriate and copy the District Manager.
State Bridge Engineer	4	If load restriction is necessary, provide information on severity of bridge condition and timeframe for restriction to the District Manager, MCTD Administrator and Freight Mobility Coordinator, Communications Division, Assistant Director, and Federal Highway Administration (FHWA) taking into account the time to prepare and implement detours without compromising the integrity of the bridge. Note: Starting with step 4, there is a three-month target to complete the remaining steps of the weight restriction process.
District Manager	5	Assemble a Response Team consisting of the BLRE, Area Manager, and representatives from MCTD, Region traffic, the motor carrier industry as identified by MCTD, local government public works or engineering staff, and others as appropriate.

APPENDIX B – ODOT POLICY PMT 06-01 (Continued)

RESPONSIBILITY	STEP	ACTION
MCTD Freight Mobility Coordinator	6	Notify Division Administrator a load restriction may be necessary. Provide estimate to the District Manager of impact of restricting a bridge in terms of volume and type of trucks that will be detoured. Contact members of the motor carrier industry for participation in the Response Team.
Bridge Load Rating Engineer	7	Provide information to the District Manager on other load-restricted bridges in the area.
Area Manager	8	Provide information to the District Manager on scheduled highway construction projects that may impact possible detour routes.
District Manager	9	Accept input from the motor carrier industry, state and local government, and others for review by the Response Team. In order for input to be considered by the Response Team, comments must be provided to the District Manager.
Response Team	10	Meet to review data collected and consider potential alternate routes, taking into account impacts to the industry and local jurisdictions, and concerns submitted to the District Manager.
Bridge Load Rating Engineer	11	Analyze affected structures on alternative detour routes being considered and make detour recommendations to the Response Team.
District Manager	12	Prepare report of the Response Team meeting(s) for the Region Manager. Reports should include: • The highway or section of highway affected; • Bridge name and number; • Bridge inspection and evaluation results; • Estimated types and volume of trucks to be detoured; • List of competing restrictions, either present or planned (such as highway projects), on roadways in the area that could be detour routes;

APPENDIX B – ODOT POLICY PMT 06-01 (Continued)

RESPONSIBILITY	STEP	ACTION
		• Lists of impacts to the corridor; • Detour routes considered and tentatively selected for the duration of the restriction; • Load restriction level; • Date the load restriction will be implemented; • Duration of the load restriction; • Sign plan; • Any special requirements (pilot car, time of day restriction, etc.); • Methods to mitigate impacts to communities (no engine brakes, slow speeds, etc.); • Any proposed responsibility to recondition or repave detour route after bridge is reopened; and • Any provisions necessary to ensure viability of detour route for duration of the detour.
Region Manager	13	Discuss report with MCTD Administrator, State Bridge Engineer, and the Assistant Director. If concurrence is not reached, return report to the District Manager for further work by the Response Team. When concurrence is reached, approve report on behalf of the Director ordering the restriction of the bridge load.
District Manager	14	Inform local elected officials of impending action.
	15	Distribute approved report to Response Team and Transportation Data Section and MCTD Administrator.
Transportation Data Section	16	Create Video Log of selected detour route.
Communications Division	17	Prepare draft notification to the public; the motor carrier industry; and MCTD, including a fact sheet describing the problem and planned solution. Forward to District Manager.
District Manager	18	Provide notification to Region Manager for review.
Region Manager	19	Review draft notification with the District Manager, MCTD

APPENDIX B – ODOT POLICY PMT 06-01 (Continued)

RESPONSIBILITY	STEP	ACTION
		Administrator, and Assistant Director. Provide feedback to the Communications Division of any necessary changes. If acceptable, approve draft notification.
MCTD Freight Mobility Coordinator	20	Notify MCTD Division Administrator. If necessary, notify annual permit holders impacted by the load-restricted bridge.
Communications Division	21	Distribute notification of load-restricted bridge to the public and the motor carrier industry. Notification to the motor carrier industry is handled by the MCTD Public Information Representative.
District Manager	22	Direct crews to erect signs informing motorists of the bridge load restriction where posting is required and notify BLRE that signs have been requested.
Bridge Load Rating Engineer	23	Add bridge to the restricted bridge list.

APPENDIX B – ODOT POLICY PMT 06-01 (Continued)

Attachment B
NON-BRIDGE RESTRICTION ROLES AND RESPONSIBILITIES

If a width, height, or length restriction is necessary during the course of a highway project, the Project Leader, Project Manager, Consultant Project Manager, or the Design Coordinator will notify the Area Manager, District Manager, MCTD Freight Mobility Coordinator, and Communications Division of the need to possibly restrict the movement of freight. The timelines and format for notification of reduced vertical clearance as a result of construction have been outlined in a memo from the State Construction and Materials Engineer. These guidelines should be followed in addition to the process outlined below.

RESPONSIBILITY	STEP	ACTION
Originator Project Leader, Project Manager, or Consultant Project Manager	1	Identify need to restrict some freight movement during the project as a result of staging plans. Contact MCTD Freight Mobility Coordinator to obtain information on impacts, and to provide project information including planned restrictions, delays, and detours when work zones restrict the width, height, length, or weight of vehicles. Inform Area and District Manager of possible restrictions.
MCTD Freight Mobility Coordinator	2	Provide estimate to the Project Leader, Project Manager, or Consultant Project Manager of impact of restriction in terms of volume and type of trucks that will be detoured. Contact members of the motor carrier industry for input and collaboration. If detour is necessary may arrange for a test run as needed.
Project Leader, Project Manager, or Consultant Project Manager	3	Provide information to the Area Manager, District Manager and Region Mobility Liaison regarding potential restrictions. Contact local governments to discuss the potential of using roads for a detour and provide the information supplied by MCTD as to the size and volume of vehicles that would be detoured. Provide a sign plan for the detour to MCTD.
Area Manager/ Mobility Liaison	4	Provide information to the Project Leader on scheduled highway construction projects that may overlap this project or could impact possible detour routes.

APPENDIX B – ODOT POLICY PMT 06-01 (Continued)

RESPONSIBILITY	STEP	ACTION
Project Leader, Project Manager, or Consultant Project Manager	5	Accept input from the motor carrier industry, state and local government, and others for review. Discuss information with Area Manager, MCTD Freight Mobility Coordinator, and Region Mobility Liaison. If it is deemed necessary, a meeting is scheduled with the motor carrier industry. Assure Area and District Manager are kept informed of progress.
MCTD Freight Mobility Coordinator	6	Assemble members of the motor carrier industry to meet with Project Leader, Project Manager, or Consultant Project Manager, Mobility Liaison, and/or Area Manager and local government if needed.
Project Leader, Project Manager, or Consultant Project Manager	7	Prepare a report of the meeting for the Region Mobility Liaison. Report should include: • The highway or section of highway affected; • Estimated types and volume of trucks to be detoured; • List of competing restrictions, either present or planned (such as highway projects), on roadways in the area that could be detour routes; • Detour routes considered and tentatively selected for the duration of the restriction; • Date the restriction will be implemented; • Duration of the restriction; • Sign plan; • Any special requirements (pilot car, time of day restriction, etc.); • Methods to mitigate impacts to communities (no engine brakes, slow speeds, etc.); • Any proposed responsibility to recondition or repave detour route after bridge is reopened; and • Any provisions necessary to ensure viability of detour route for duration of the detour.
Project Leader, Project Manager, or Consultant Project Manager	8	Share report with MCTD. If concurrence is not reached, forward information to the MCTD Administrator.

APPENDIX B – ODOT POLICY PMT 06-01 (Continued)

RESPONSIBILITY	STEP	ACTION
		When concurrence is reached, send PD16 Mobility Consideration Checklist to MCTD Freight Mobility Coordinator to sign. Inform local elected officials of impending action. Ensure that the standard specification around notification to MCTD for restrictions is included in the contract.
Communications Division	9	Prepare draft Public Information Paper to the public, motor carrier industry, and MCTD including a fact sheet describing the problem and planned solution. Forward to Project Leader, Project Manager, or Consultant Project Manager and MCTD for review.
Project Leader, Project Manager, or Consultant Project Manager	10	Review draft Public Information Paper with Area Manager, District Manager and Region Mobility Liaison and MCTD. Provide feedback to Communications Division of any necessary changes. If acceptable, approve draft notification.
MCTD Freight Mobility Coordinator	11	Upon receipt of Restriction Notification (Form 735-2357) notify Communications to send the traffic and/or trucking advisory to motor carrier industry. If necessary, notify annual permit holders impacted by the restriction by letter.
Communications Division	12	Distribute notification of restriction to the public and the motor carrier industry.

APPENDIX C – ARCH BUCKLING ANALYSIS IN MIDAS CIVIL

This section describes a method by which critical buckling load capacity of a concrete or steel arch may be determined using Midas Civil software. The analysis procedure is based on the methodology presented in *Eurocode 3 – Design of Steel Structures, Part 2 – Steel Bridges, Section D.3 "Arched Bridges"* and is accomplished by giving the arch an initial imperfection deflection and then incrementally increasing load until instability failure is observed in the structure. This procedure is applicable to both steel and concrete arches. The basis for using the Eurocode procedures is described in Section C.7.

C.1 Set Up Model with Initial Imperfections

Open an existing Midas model or create a new one with an arch described by nodes in the X-Z plane. This model should be saved as a new file since several modifications to the structure and load will be made that apply only to the buckling analysis.

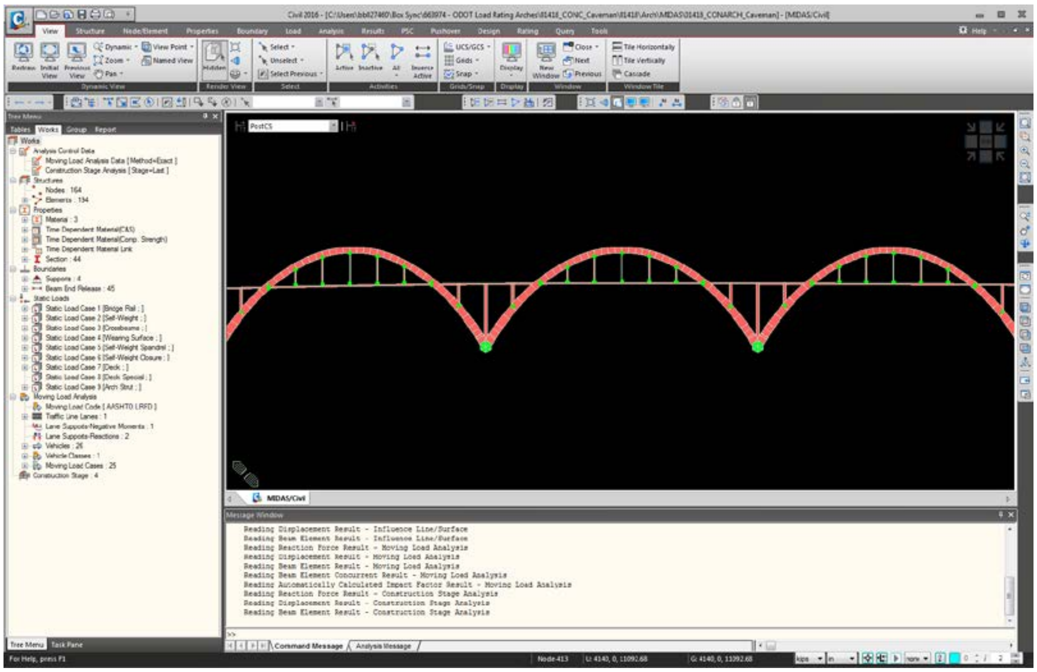


Figure 9: Arch bridge model in Midas Civil.

In order to induce buckling, an initial deflection is required and can be assigned to the arch as an initial geometric imperfection. For fixed and two-hinge arches, the shape of the arch imperfection is anti-symmetric sinusoidal, demonstrated and exaggerated in Figure 2 below. For three-hinged arches a second symmetric buckling mode needs to be investigated.

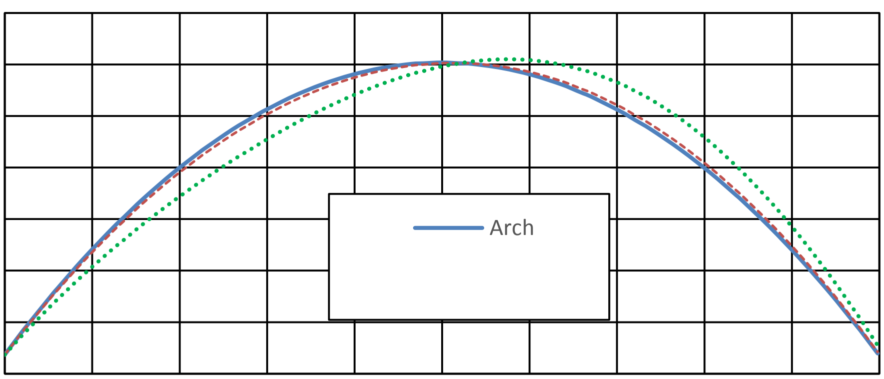
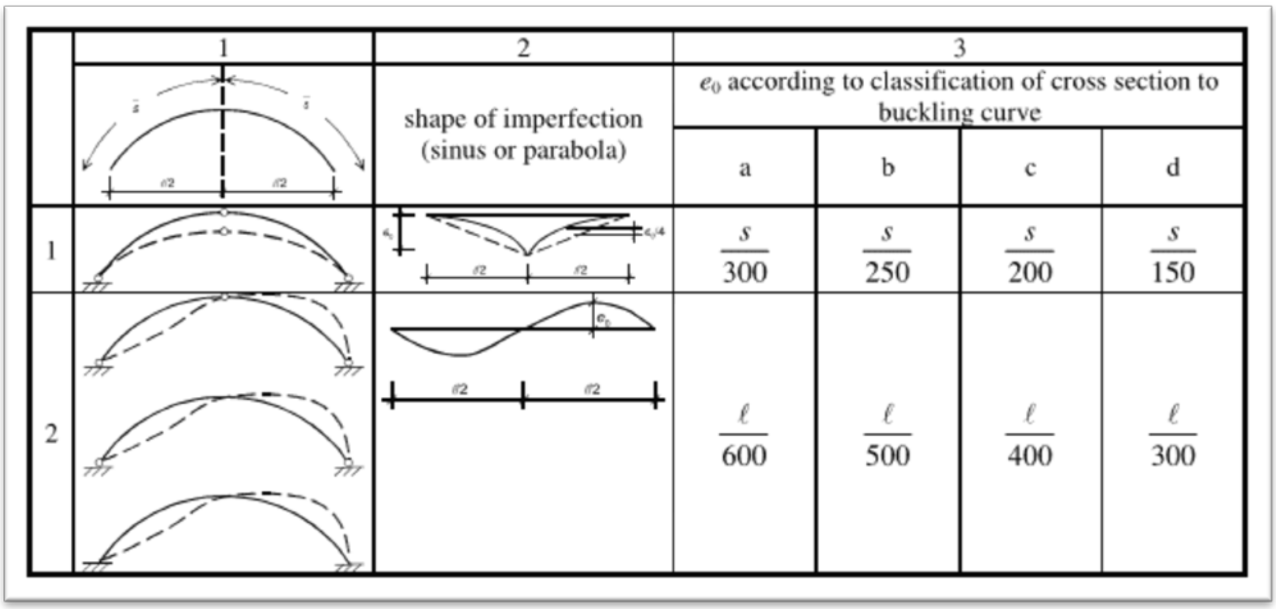


Figure 10: Arch bridge model with initial deflection.

The shape of the geometric imperfection is determined by the fixity conditions of the arch at the ends and center as shown in Figure 3; this is called the buckling “mode.” If an arch could be loaded beyond failure the shape of the buckling would change to a higher mode shape. Due to fixity conditions some arches may be difficult to readily classify into expected mode shapes.

To determine the mode shapes, run a “Buckling” analysis in Midas (see section 3.6 for further discussion). The critical buckling load computed by the Eigenvalue solution for Mode 1 is a good starting point for the expected failure load of the nonlinear analysis.

The magnitude of geometric imperfections are a function of the allowable construction tolerances from theoretical dimensions for fabrication and construction of arch rib. Classifications “a” through “d” in Figure 3 refer to different arch rib cross sections as shown in Figure 4.



	1	2	3			
		shape of imperfection (sinus or parabola)	e_0 according to classification of cross section to buckling curve			
			a	b	c	d
1			$\frac{s}{300}$	$\frac{s}{250}$	$\frac{s}{200}$	$\frac{s}{150}$
2			$\frac{\ell}{600}$	$\frac{\ell}{500}$	$\frac{\ell}{400}$	$\frac{\ell}{300}$

Figure 11: Shape and amplitudes of imperfections for in plane buckling of arches. Reproduced from Table D.8 of Eurocode 3 Part 2.

For steel bridges, the overall magnitude of the imperfection is also a function of the material yield stress and the residual stresses in the cross section (the structural imperfections). Figure 4 illustrates section configurations used for typical compression members, and is further sub-divided into cases corresponding to the relative slenderness (width to thickness ratios) of the plates comprising the section. Generally, smaller width to thickness ratios (i.e., thicker plates) generate higher residual stresses in the section, which tend to reduce buckling capacity. This is reflected in the analysis by increasing the magnitude of the imperfection.

Most of the steel arch ribs encountered in the Oregon bridges are built-up box sections. As seen in Figure 4, the classification for the box section is either “b” or “c”. The first step in selecting the appropriate imperfection curve for buckling is identifying the width thickness ratios of the plates. For a welded box section with steel yield strengths between 35 ksi and 65 ksi, and either h/t or b/t ratios less than 30, or web to flange welds greater than ½ the flange thickness, the section classification is “c”, corresponding to a maximum imperfection, e_o, of L/400 on an anti-symmetric buckling shape. For all other conditions the section classification is “b”.

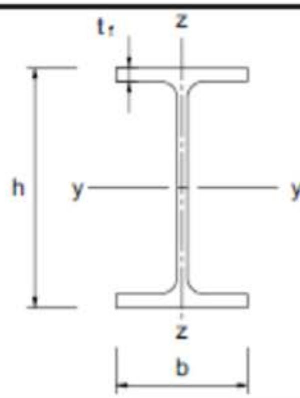
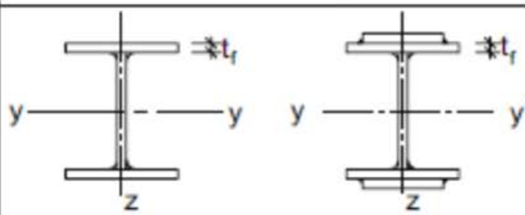
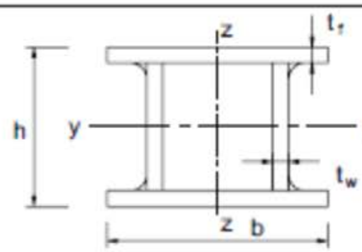
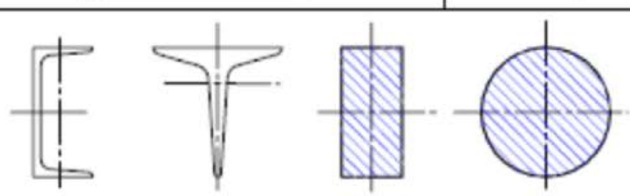
Cross section		Limits		Buckling about axis	Buckling curve: S 235, S 275, S 355, S 420	Buckling curve: S 460
Rolled sections		$h/b > 1{,}2$	$t_f \leq 40$ mm	y – y z – z	a b	a_0 a_0
			$40 \text{ mm} < t_f \leq 100$	y – y z – z	b c	a a
		$h/b \leq 1{,}2$	$t_f \leq 100$ mm	y – y z – z	b c	a a
			$t_f > 100$ mm	y – y z – z	d d	c c
Welded I-sections		$t_f \leq 40$ mm		y – y z – z	b c	b c
		$t_f > 40$ mm		y – y z – z	c d	c d
Hollow sections		hot finished		any	a	a_0
		cold formed		any	c	c
Welded box sections		generally (except as below)		any	b	b
		thick welds: $a > 0{,}5t_f$ $b/t_f < 30$ $h/t_w < 30$		any	c	c
U-, T- and solid sections				any	c	c
L-sections				any	b	b

Figure 12 - Selection of buckling curve for a cross section. Reproduced from Table 6.2 of Eurocode 3 Part 1-1.

For concrete arches, the overall magnitude of the applied structural imperfections may be determined in accordance *with Eurocode 2 – Design of Concrete Structures, Part 2 – Concrete Bridges*, Section 5.2, and is a function of the arch span length only. The calculation is summarized below:

1) Solve for an inclination, θ_1, given by $\theta_1 = \theta_0 \alpha_h$ where

   θ_0 Is the basic value: $\theta_0 = {}^{1}/_{200}$

   α_h Is the reduction factor: $\alpha_h = {}^{2}/_{\sqrt{l}} \leq 1$

   l Is the projected length (half wavelength)

2) The magnitude of the initial geometric imperfection for concrete arches (also referred to as "amplitude") is then taken as: $a = \theta_1 \, {}^{l}/_{2}$

C.2 Determine and Apply the Initial Deflected Shape

The following procedure is used to apply the imperfection to individual points along the arch.

1) Obtain the coordinates of the arch in the X-Z plane from MIDAS by right clicking on "Nodes" on the tree menu and selecting "Tables." This will generate a table with X, Y, and Z coordinates for each node as shown in Figure 5.

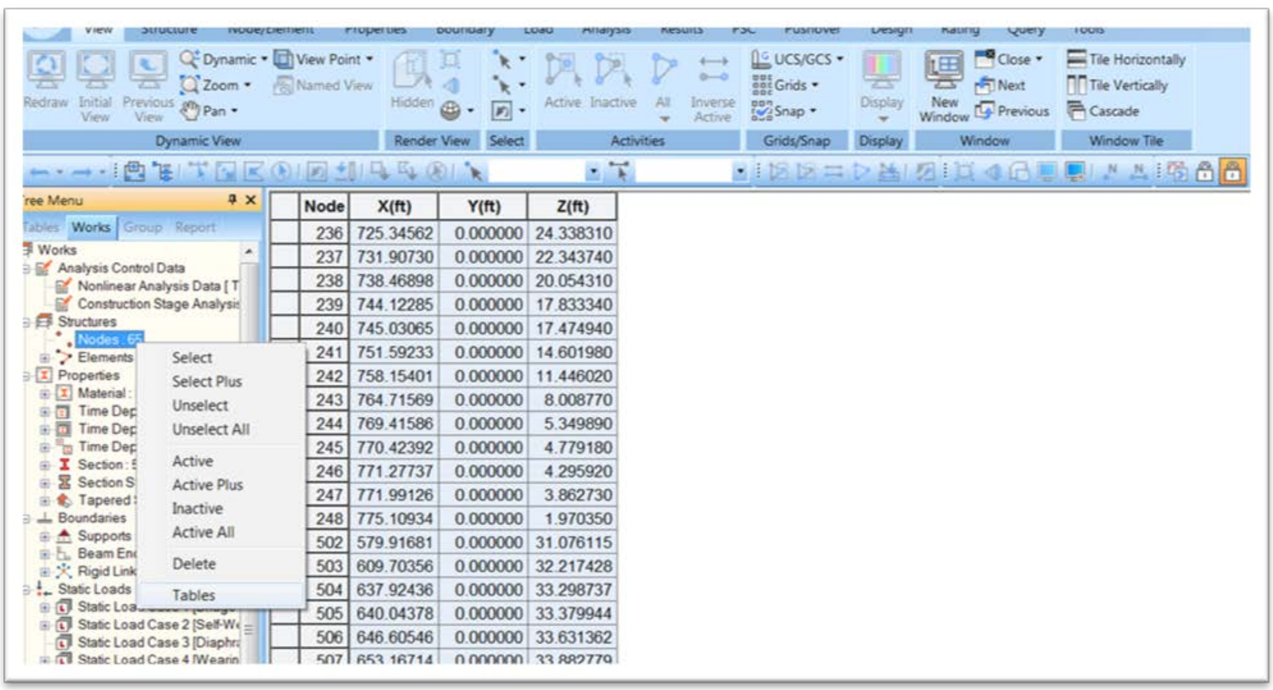


Figure 13: Nodal coordinate retrieval.

2) Ensure the model units are set to FEET. Select the coordinates for the nodes which make up the arch and copy the data to MS Excel or a similar utility. If you are unsure which nodes correspond to the arch, use the "Display Node Numbers" tool from the View Control menu while on the Model View tab. You can also sort and filter the Midas Nodes table by right clicking in the table and selecting the "Sorting Dialog" (e.g. sort in order of "x" distance) and the "Select & Filter Dialog" (e.g. only show arch nodes).

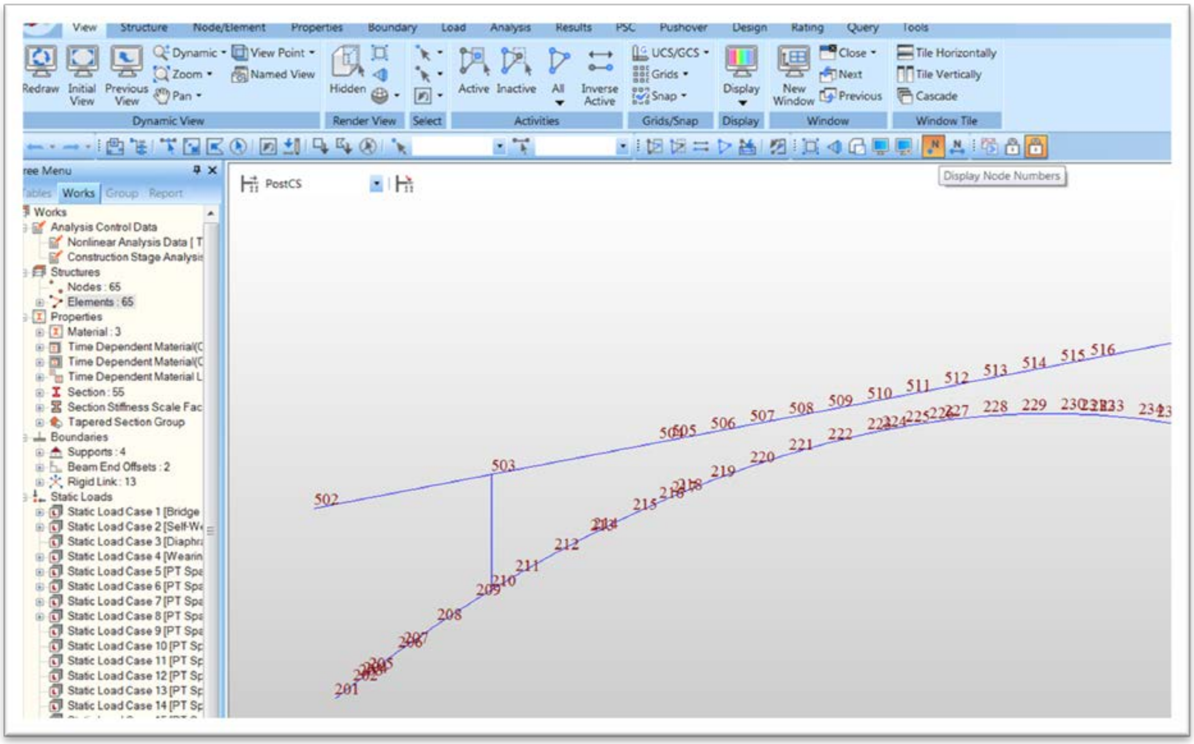


Figure 14: Display of node numbers.

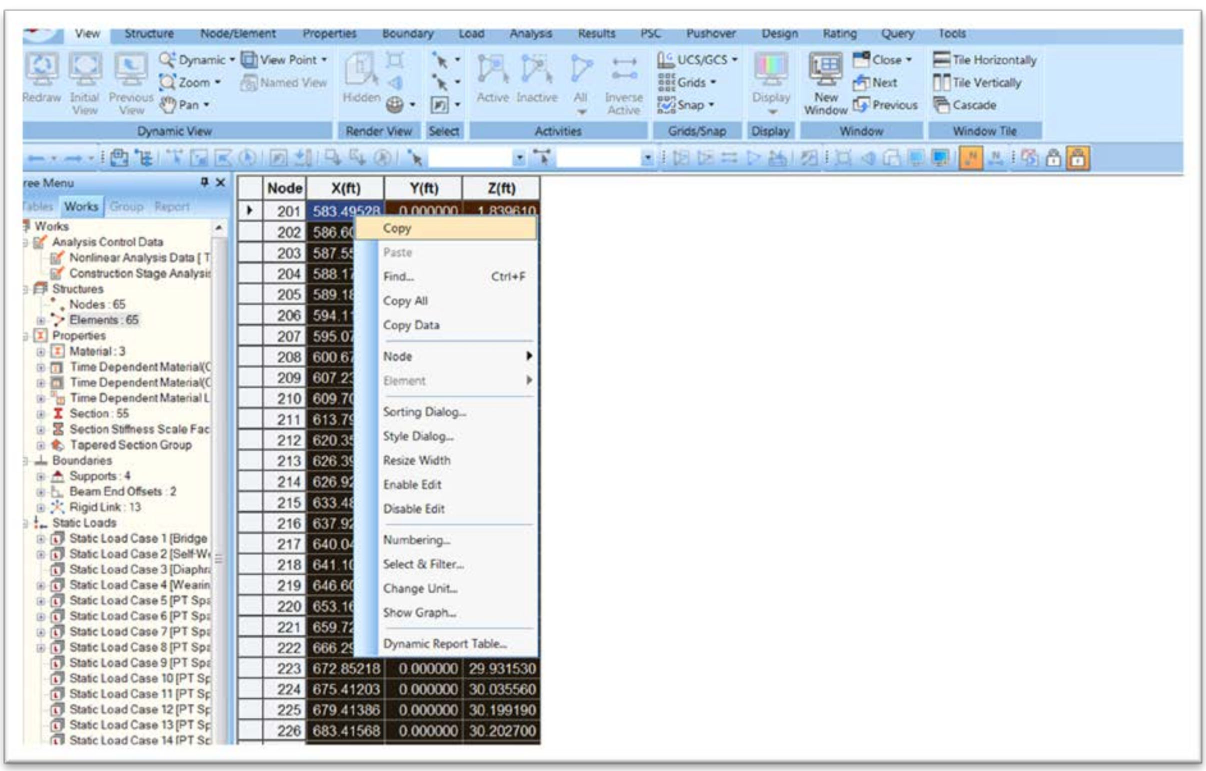


Figure 15: Copying of node coordinates.

3) Solve for new Z-coordinates by adding a calculated imperfection, z_i, to each current Z-coordinate. Values for this calculation are described below and Table 1 shows an example calculation for the

first eight nodes of an arch.

z_i is the Z-coordinate imperfection at coordinate "i", $z_i = \Delta \sin(2\pi * \frac{x_i}{L})$. Eq. 1-1

x_i is the X-coordinate distance from left end node of arch at coordinate "i."

L is the horizontal length of arch.

Δ is the magnitude of the arch deflection from Section 1.1.

Table 1: Sample calculation of initial deflected coordinates.

x_i	X-coordinate	Y-coordinate	Z-coordinate	Imperfection	New Z
(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
			Z	z_i	$= Z + z_i$
0.00	583.4953	0	1.839613	0.0000000	1.83961
3.11	586.6092	0	3.664345	-0.0651036	3.59924
4.06	587.5503	0	4.215879	-0.0846789	4.13120
4.68	588.1766	0	4.557474	-0.0976596	4.45981
5.69	589.1846	0	5.107373	-0.1184670	4.98891
10.62	594.112	0	7.795276	-0.2178922	7.57738
11.58	595.079	0	8.283621	-0.2368177	8.04680
17.18	600.6737	0	11.10892	-0.3410569	10.76787

4) Copy the new Z-coordinates to the Midas model.

a. On the "Nodes" tab highlight the applicable arch nodes.

b. Right click and select "Paste."

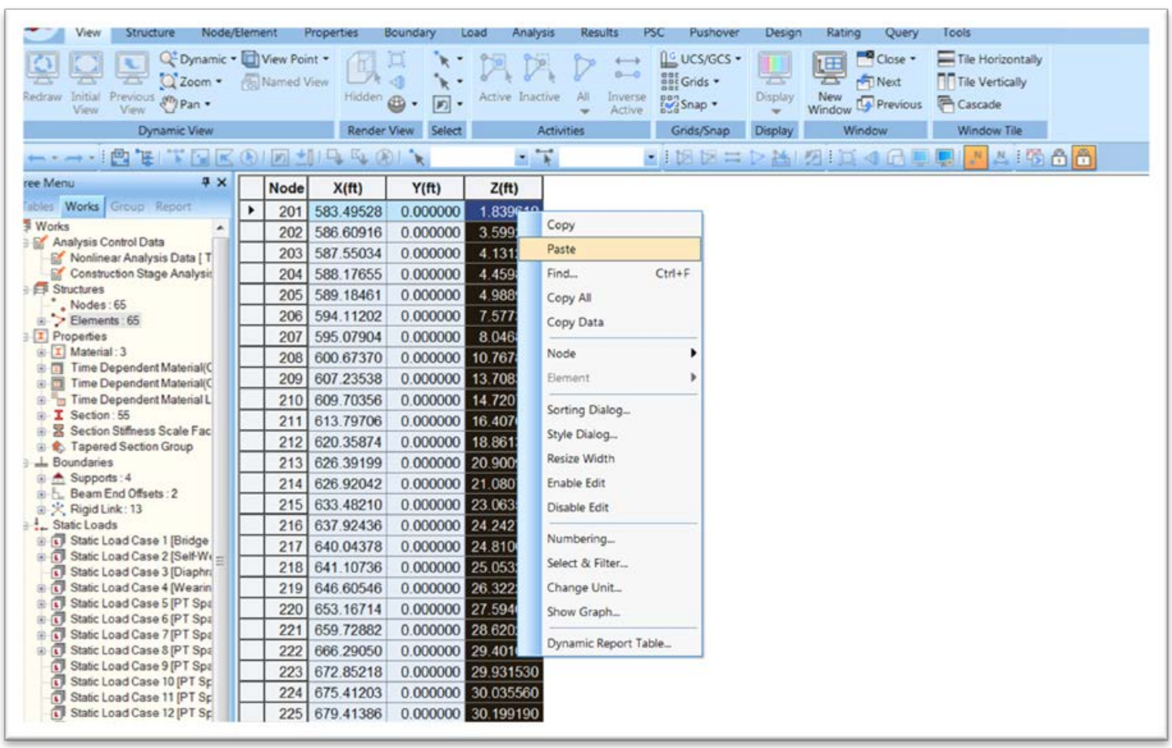


Figure 16: Pasting the new coordinates back into the Midas model.

C.3 Modify Section Stiffness

If the arch to be analyzed is constructed of steel, no stiffness modification is necessary. If the arch is reinforced concrete, the section stiffness should be reduced to account for cracked section stiffness. The methodology of AASHTO 5.7.4.3 is followed to calculate an appropriate stiffness reduction:

$$EI = \frac{\frac{E_c I_g}{2.5}}{1+\beta_d}$$ (Equation reproduced from AASHTO Eq. 5.7.4.3-2.)

The equation includes a βd factor which is calculated as the ratio of maximum factored permanent load moment to maximum factored total load moment. As a simplification, βd is set to 0.6 (similar to ACI318-14 R6.6.4.4.4) which reduces the stiffness calculation to 0.25*Ec*Ig. If the moment magnifiers are found to fall outside of reasonable values, βd factor should be calculated in detail and over-written in the capacity spreadsheet by the load rater.

Apply the calculated stiffness reduction to the arch sections.

1) On the ribbon click on “Properties.” Click on “Section Manager” and select “Stiffness.”
2) If the model contains Construction Staging, create a Boundary Group with a name such as “Cracked” in order to activate the modified stiffness.
3) Apply the stiffness reduction (e.g. 0.25) to Ixx, Iyy, Izz for each Section & Element of the arch
4) If Construction Stage analysis is used in the model the “Cracked” boundary group will need to be activated in the final stage.

NOTE: It is equivalent to manually reduce the modulus of elasticity “E” in the material definition instead of using a stiffness scale factor in the “Section Manager.”

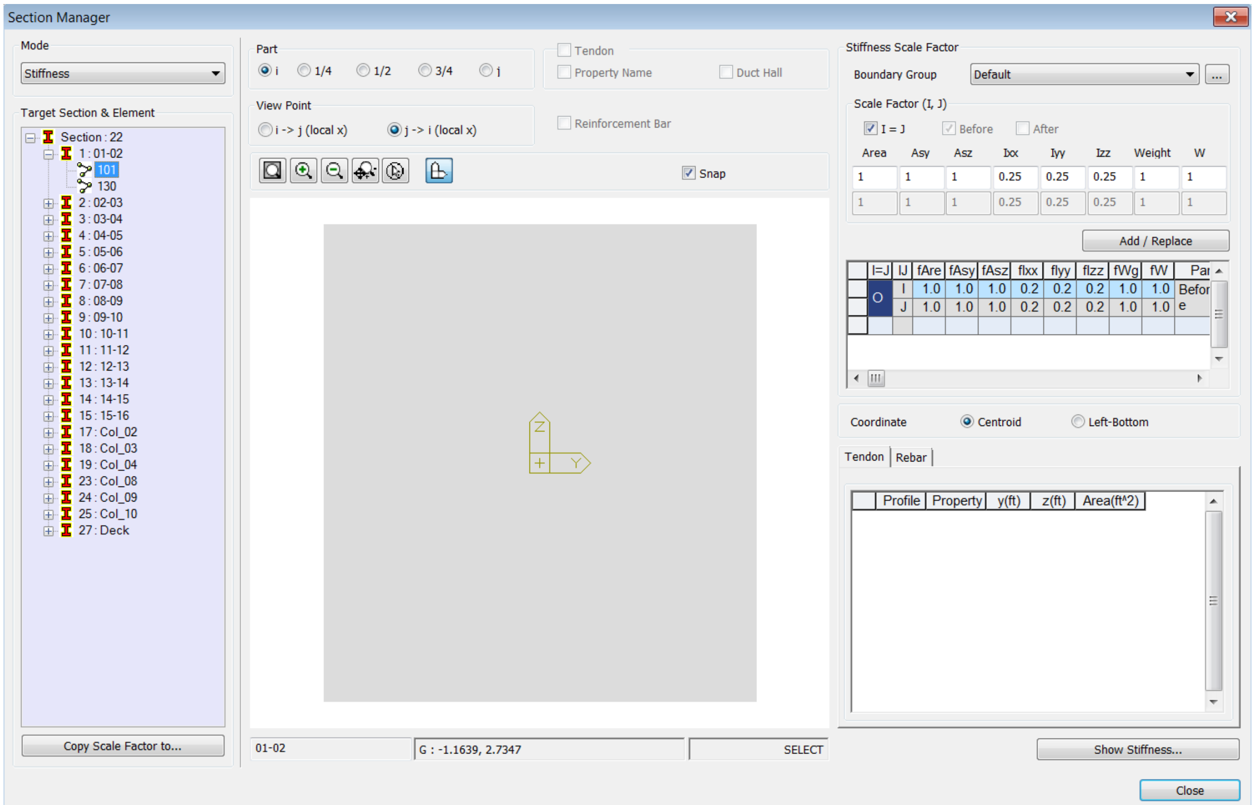
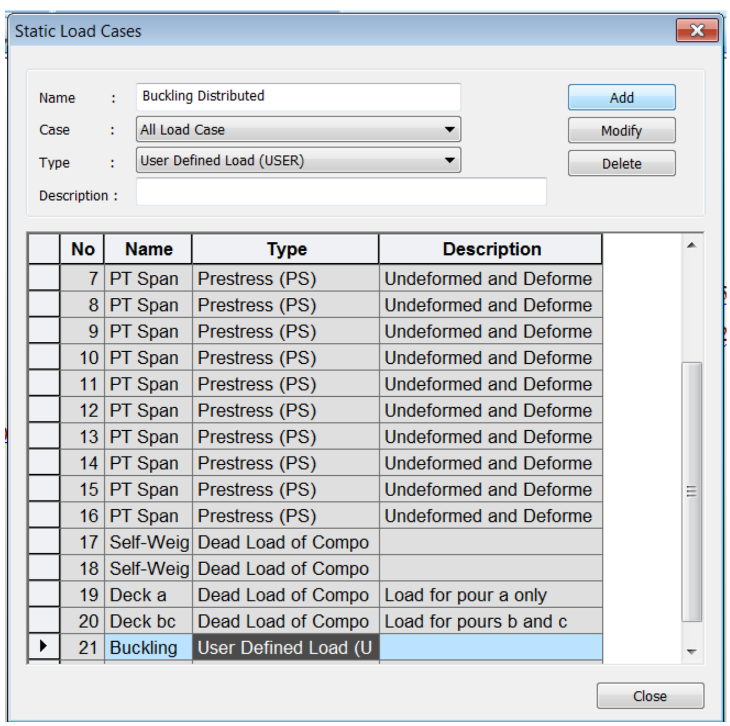


Figure 17: Reducing section stiffness to model cracked section properties for a concrete arch.

C.4 Set Up the Buckling Load Case

Add a new load case and apply a uniformly distributed unit load to the bridge deck.

1) Click on “Load” from the ribbon.
2) From the “Create Load Cases” group click on the “Static Load Cases” button.
3) Create a new static load case with the following parameters:
   a. Give the load case a distinguishable name such as “Buckling Distributed.”
   b. Case should be set to “All Load Cases.”
   c. Type is “User Defined Load (USER).”
   d. Click “Add” to add the new load case to the list.
   e. Click “Close” to close the Static Load Cases menu.
4) From the “Load” tab on the ribbon,



select “Static Loads.”

5) Apply a uniform unit load using either ELEMENT or LINE loading.

   a. Use the load case which was just created, “Buckling Distributed.”

   b. Direction should be “Global Z.”

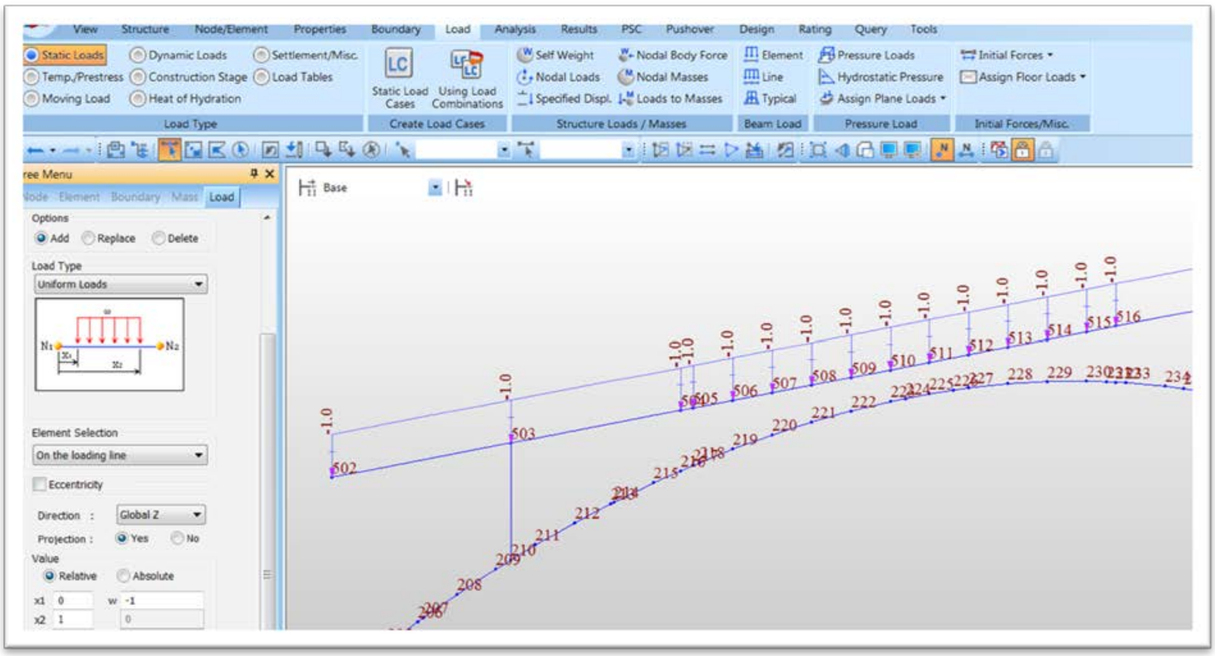
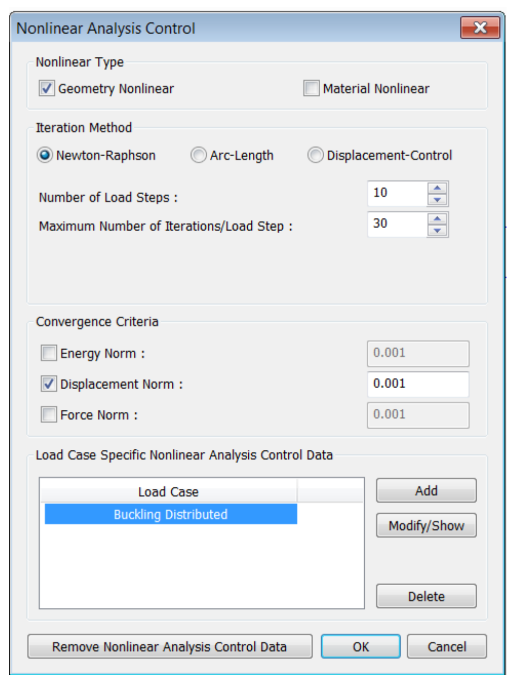


Figure 18: Arch model showing node numbers and a distributed unit load of 1 kip/ft. applied to the bridge deck.

Setup the Midas analysis with a new nonlinear load case. Navigate to the “Nonlinear Analysis” option in the “Analysis” menu: NOTE: A “Pushover” analysis may be performed as an alternate to the “Nonlinear Analysis”, but as discussed in Section C.11, that is not recommended.



1) On the ribbon click “Analysis”

2) Click on “Nonlinear” and update the menu to match the following parameters.

4) Nonlinearity type should be Geometry only, not Material.

5) Iteration method is “Newton-Raphson”

6) For convergence criteria only select Displacement Norm with a criteria of 0.001.

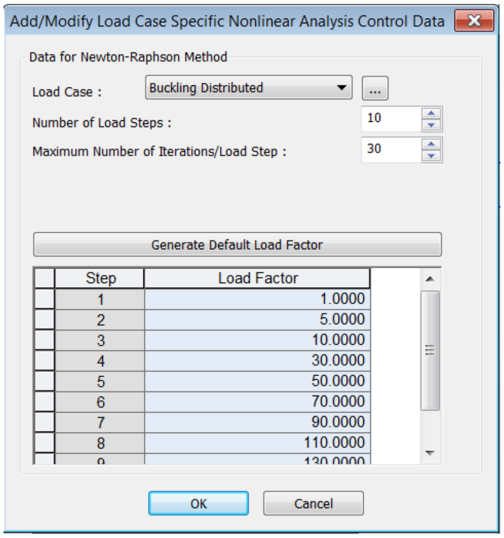
7) For the load case click “Add” and select the “Buckling Distributed” load case which was previously created.

   a. Set the number of load steps to at least 10.

   b. Input each load factor in increasing values. The goal is to provide enough load to see increasing compression in the arch and then to also surpass the compressive capacity of the arch. Experience has shown that increments of 5 to 20 are a good place to start. **NOTE: These load factors are an initial guess, use the Eigenvalue Mode 1 critical load as an approximate expected failure load (see section C.14).** After the analysis has been run it is likely these factors will need to be adjusted in order to hone-in on the actual buckling capacity of the arch. The user may be able to reduce the number of analysis iterations by increasing the number of load steps in order to use a lower increment.

c. Click “OK” to close the Load Case Control.

8) Click “OK” to close the Nonlinear Analysis Control.



C.5 Run the Midas Analysis

If a moving load analysis is in the model it will have to be removed before the non-linear buckling analysis can be run.

1) Remove any existing moving load analysis data by deleting all vehicle assignments, followed by deleting all lane definitions. Then right click on the “Moving Load Analysis Data” under Analysis Control Data in the works tab of the tree menu and delete.

2) On the ribbon click “Analysis”. Click on “Perform Analysis”.

C.6 Check the Midas Analysis and Repeat the Procedure as Necessary

View the results of the analysis.

1) On the ribbon click “Results”, Click on “Forces” and select “Beam Diagrams.”

3) On the tree menu that is brought up set the following parameters.

a. Select the “Buckling Distributed” load case.

b. Select “NL: Step 1”

c. For Components select “Fx”

4) Click “Apply”, this will bring up a view similar to the one shown in Figure 11. It may be helpful to set a dark background color in order to better view the load contours.

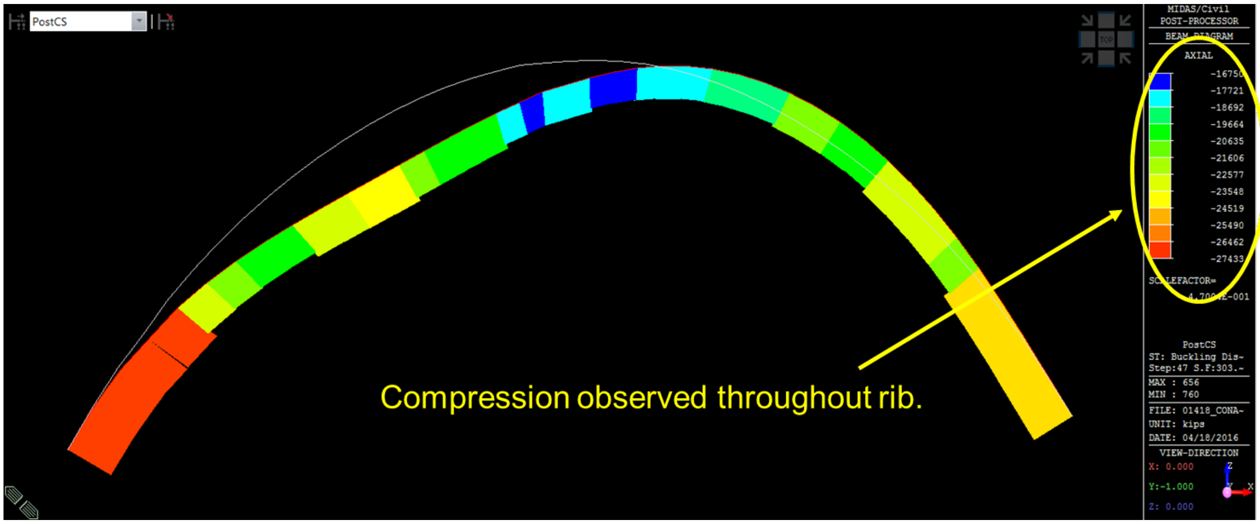


Figure 19: Viewing results of the analysis.

The arch should be in compression and therefore the forces are negative in the legend on the right.

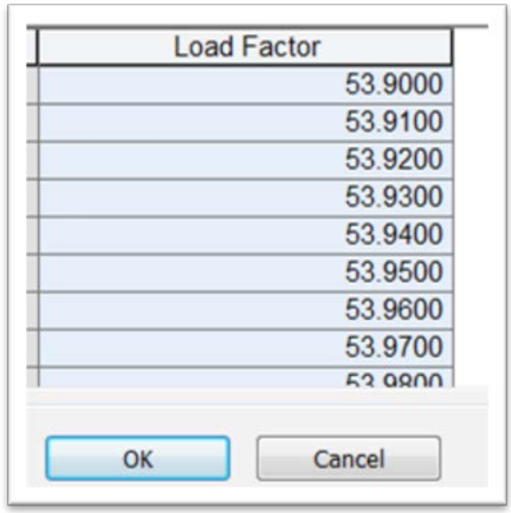
5) From the tree menu, select "NL: Step 2" and click "Apply" to advance to the next step in load factor. The forces should increase.

6) Continue to advance the load factors until the forces in the arch decrease or even switch from compression to tension (positive values in legend). The tension result is non-real and the switch is an indication that the load factors have increased the load sufficiently to surpass the compressive capacity of the arch.

7) **The magnitude of the axial force in a quarter-point element of the arch at the load factor step before the switch to tension is the compressive buckling capacity of the arch.** However, it is likely that the capacity is not described well enough yet by the increment in load factors.

Figure 20: Example Step 6, non-real result, arch forces have switch from compression to tension.

8) Modify the Nonlinear Analysis Control Load Factors to smaller increments at the approximate magnitude at which the transition from compression to tension was observed. The initial steps should remain the same (steps 1 through 10), add more steps if necessary and use many more steps of decreasing increments at the approximate load factor that buckling was observed.



9) Run the analysis again and repeat the evaluation of the results. An increase in the maximum compressive force should be observed until the buckling load is achieved. This process should be iterated until small increases in load cause large displacements or decrease in arch loads. Several iterations will likely be required to sufficiently refine the results. See Section C.1 for a discussion on graphical representation of the buckling capacity which verifies the example failure in Figure 12 at a Step Factor (S.F.) of “304.”

C.7 Background & Basis for Methodology

Buckling governs the capacity for the two actions acting on the arches, Moment and Compression.

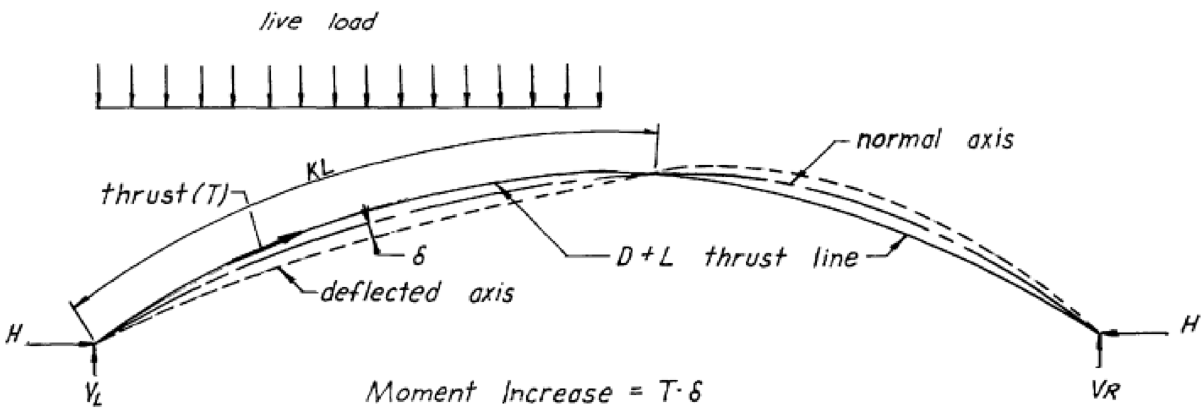


Figure 21: deflected shape of buckled arch and specification of moment increase as the product of the thrust and the deflection.

AASHTO Chapter 6.9.4 provides some guidance on calculation of arch capacity and is based on Euler buckling:

$$P_e = \frac{\pi^2 EI}{(K\ell_u)^2}$$

The Euler buckling load is needed to determine the appropriate moment magnification (AASHTO 4.5.3.2.2c).

$$\delta_b = \frac{C_m}{1 - \dfrac{P_u}{\phi_K P_e}} \geq 1.0$$

All of the inputs for calculation of Euler buckling can be determined from the geometry and material definitions of arch bridge drawing sets, except for the slenderness term “K.” AASHTO Table 4.5.3.2.2c-1 (reproduced below) provides values for K which cover a limited number of situations.

Table 4.5.3.2.2c-1—*K* Values for Effective Length of Arch Ribs

Rise to Span Ratio	3-Hinged Arch	2-Hinged Arch	Fixed Arch
0.1–0.2	1.16	1.04	0.70
0.2–0.3	1.13	1.10	0.70
0.3–0.4	1.16	1.16	0.72

The AASHTO equations for moment magnification and the provided values for K are based on the Nettleton paper on Arch Bridges. A snapshot of Nettleton’s summary of K values is reproduced below.

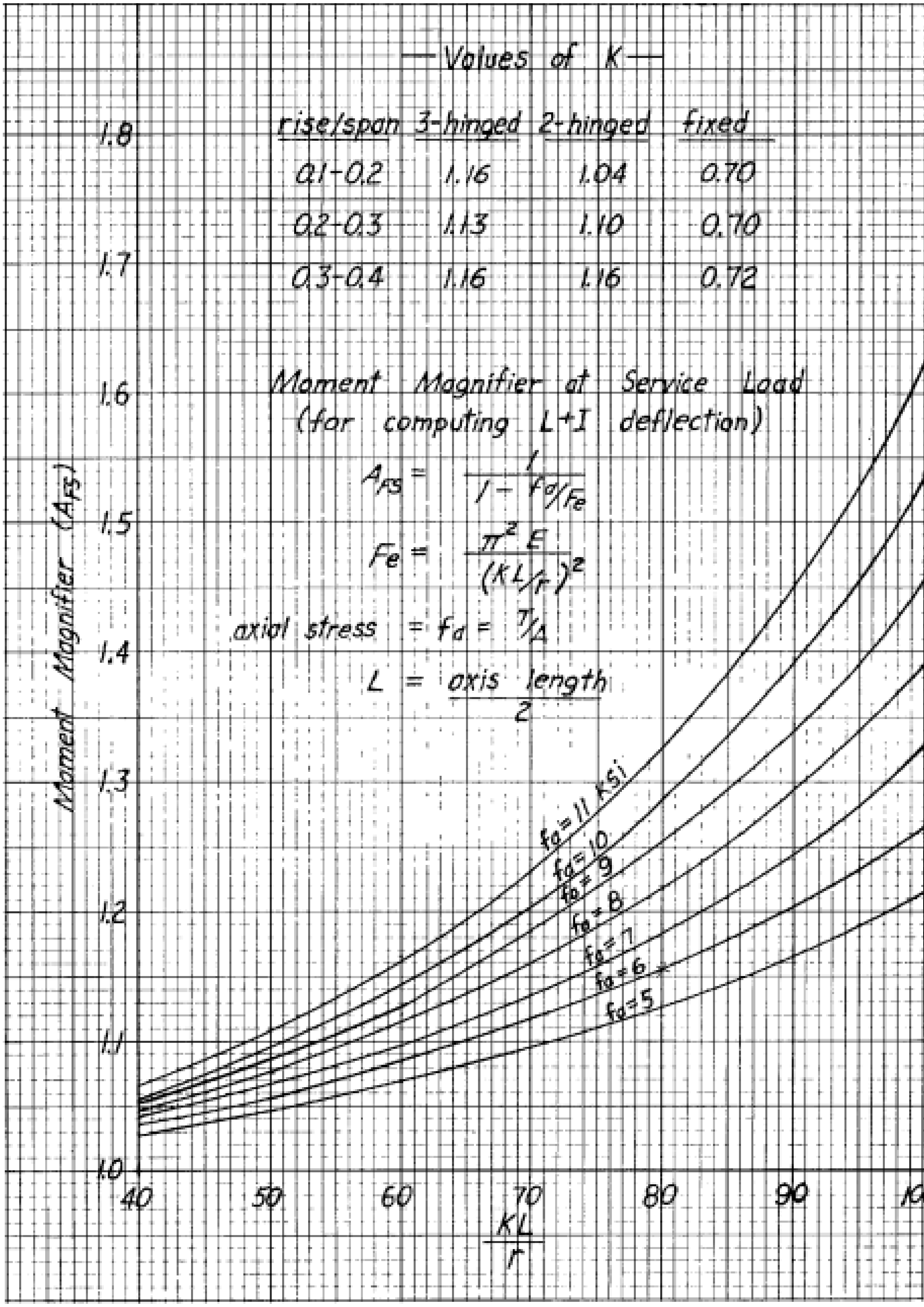


Figure 22: Moment magnifier chart and K-factor table for arches. (Nettleton)

These AASHTO and Nettleton values for K also agree with Eurocode effective length factors (referred to by the term “Beta”).

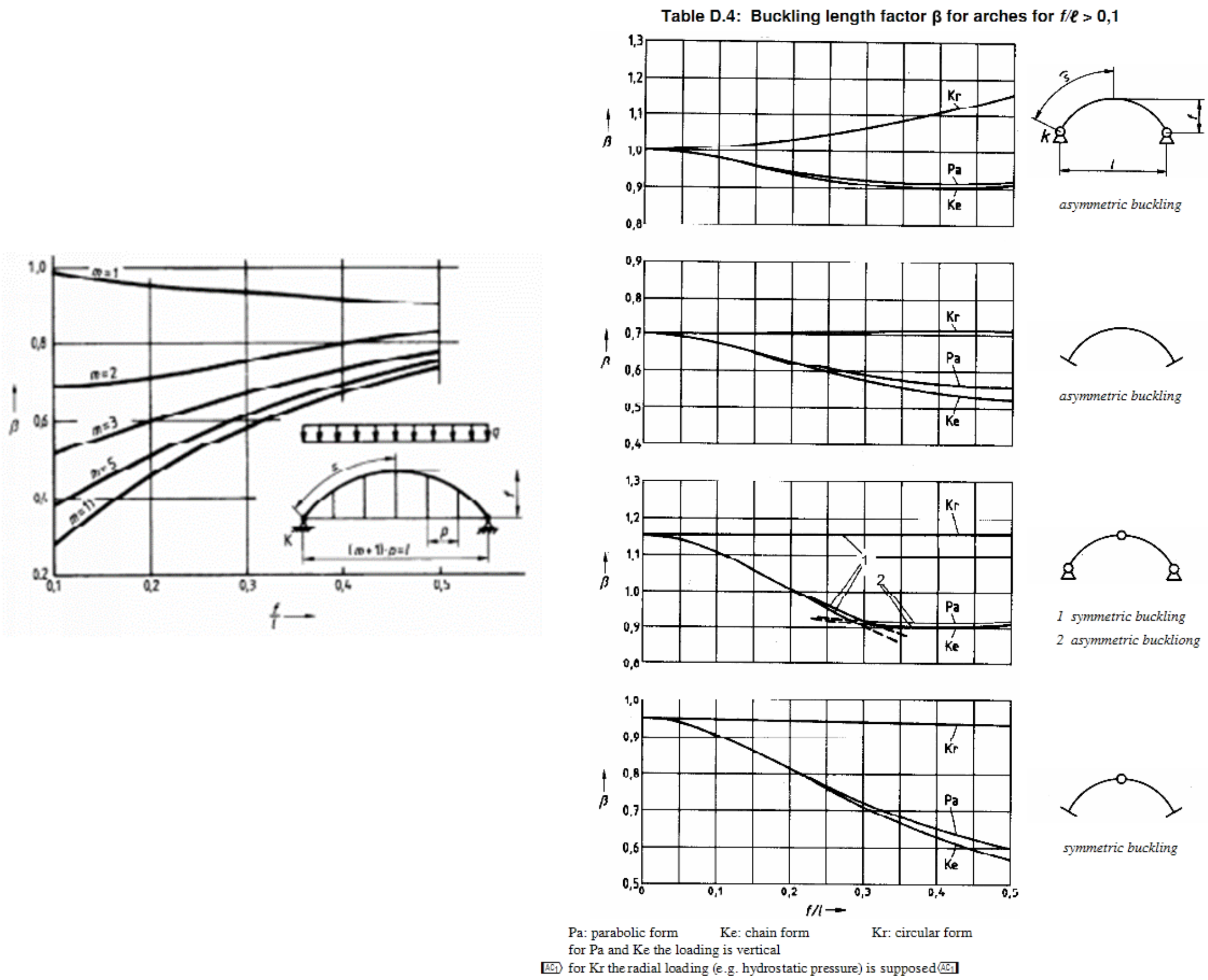


Figure 23: Eurocode buckling factor determinations. (Eurocode 3 - Design of steel structures - Part 2: Steel Bridges)

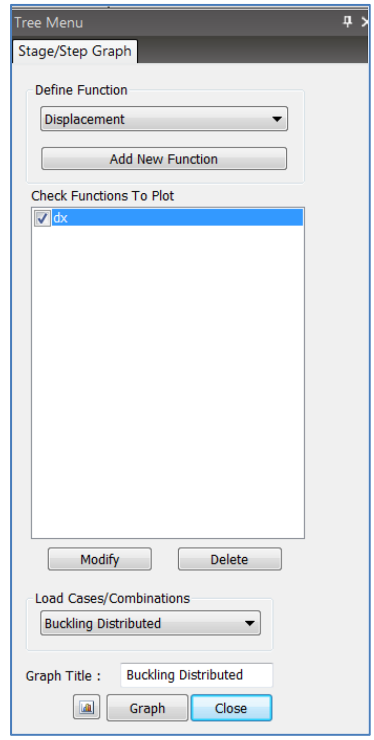
Though there is agreement among these methodologies, they all require uniform section properties and are limited by arch boundary conditions which must match the tables/figures. If an arch does not meet this criteria, a detailed buckling analysis must be performed such as the non-linear analysis procedure provided in Section C.1.

C.8 Other Considerations for Non-Linear Analysis in Midas

During the development of this procedure several questions were raised regarding the tools and capabilities of the Midas software. The sections below offer guidance on how to use certain Midas tools and why certain tools were not used.

C.9 Graphical Representation of Critical Buckling Capacity

A graphical representation of the non-linear buckling analysis can be obtained by the following steps.



1. On the ribbon click “Results”

2. Click on “Stage/Step Graph.”

3. From the Tree Menu select “Displacement” and the click to “Add New Function.”

    a. Input a node number which corresponds to the quarter-point on the arch.

    b. Name the function something such as “Buckling” or “dz.”

    c. Select “DZ” or “DX” and click “Ok.” Depending on the mode shape, the controlling deflection may be in either the x or z direction.

4. Click the checkbox to select the function just created.

5. Select the “Buckling Distributed” load case and click “Graph.”

This will generate a graph in a new window that tracks the Z-coordinate displacement of the selected node as the load was progressively increased during the non-linear analysis. See the example in Figure 16 below. The top of this curve clearly shows the large displacements that begin to occur with very small increases in load when the arch is loaded close to its buckling capacity. The load factor at failure, which can be determined from the y-axis of Figure 16, corresponds with the beam diagram observation of failure described in Section 1.6 and Figure 12.

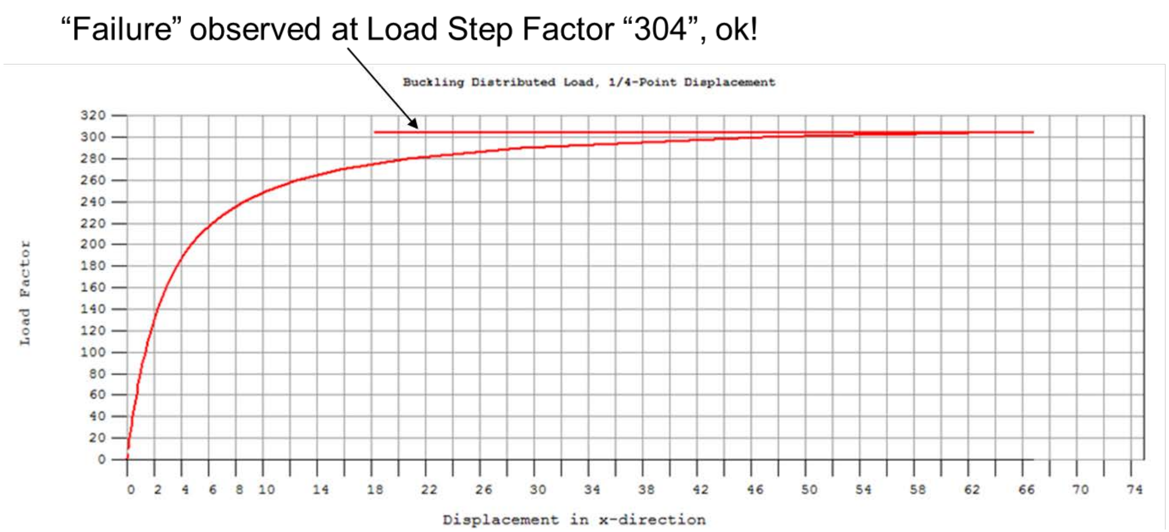


Figure 24: Example graph of ¼-point displacement vs load applied during the non-linear analysis.

“Collapse occurs when the stiffness matrix of the structure becomes singular and thus unsolvable. A singular matrix indicates the structure has ***no predictable deformation under any loading***.” (LARSA 4D Documentation - Analysis Reference)

C.10 Selection of Arch Rib Quarter-Point for Capacity

Section C.6 specifies that the arch rib quarter-point is selected as the element to be tracked for buckling capacity. There are several reasons for selecting the quarter-point instead of the reaction thrust or other point:

1) Axial stress varies along the rib at the load step of critical buckling load, it is maximum at the supports and usually minimum at midspan. The quarter point is a good average stress.
2) The quarter-point is approximately the location of maximum displacement.
3) In the case of an arch rib which varies in cross-section, the use of the reaction or "thrust" in the rib would be an over-estimation of the buckling capacity for the more slender arch elements near midspan.
4) Tracking a buckling capacity for each individual element along an arch rib is data intensive and results in an unnecessarily high degree of accuracy for the purposes of the moment magnification.
5) The quarter point is also used by several of the analysis references such as the selection from Nettleton copied below:

T = arch rib thrust at the quarter point (approximately equal to H x secant of slope of line from springing to crown).

A = arch rib area at the quarter point

$$F_e = \frac{\pi^2 E}{\left(\frac{kL}{r}\right)^2} \quad \text{the Euler buckling stress}$$

L = half the length of the arch rib (approximately equal to ℓ/2 x secant of slope of line from springing to crown)

r = radius of gyration at the quarter point

Figure 25: Euler buckling calculation and variable definitions for arches. (Nettleton)

C.11 Non-Linear "Pushover" Analysis vs. Eigenvalue "Buckling" Analysis

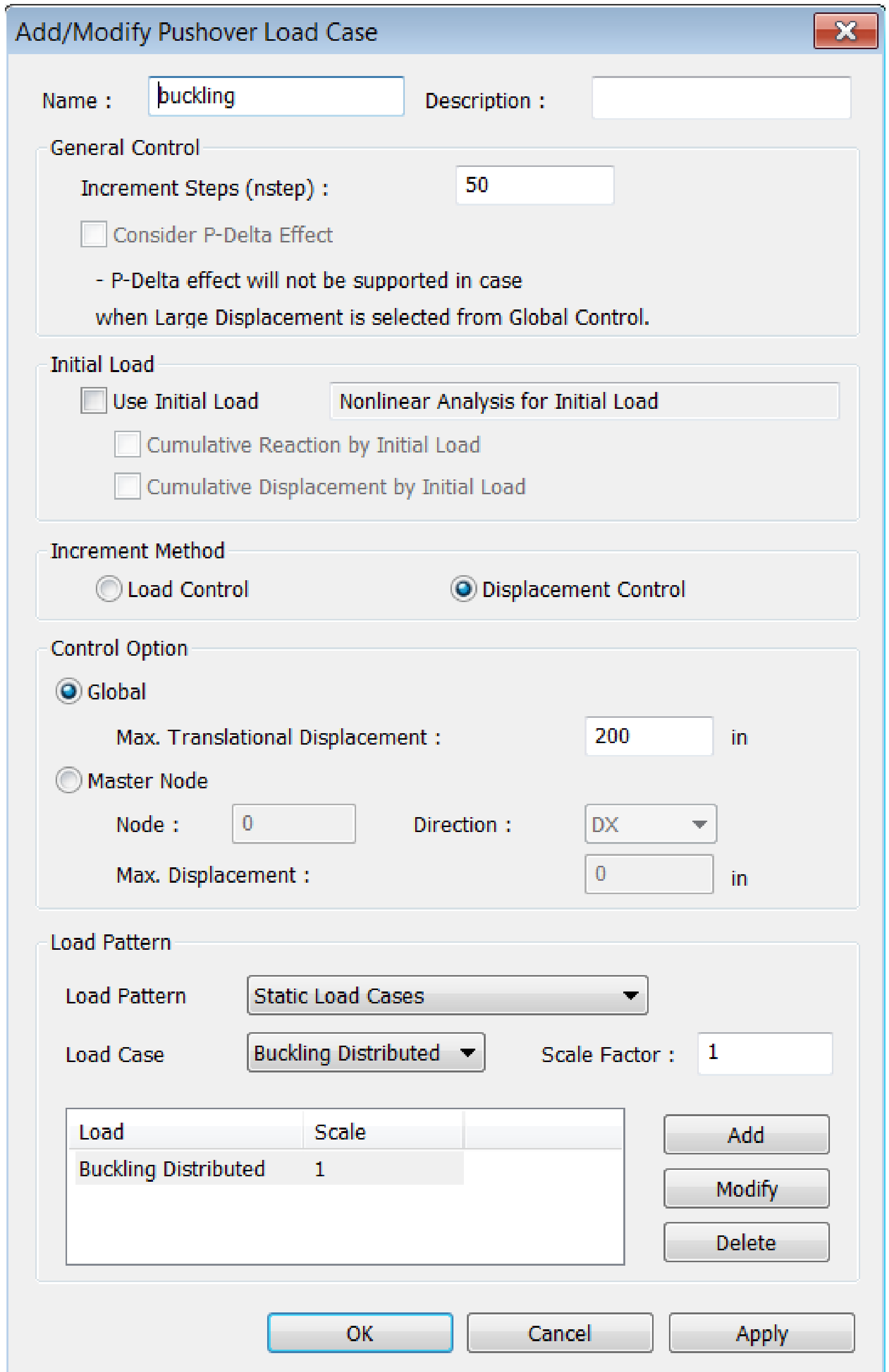
The pure theoretical mathematical solution of the equation of motion for each mode is known as the Eigenvalue Buckling Analysis. As a direct solution, it would seem that the Eigenvalue Analysis would be the preferred methodology. However, there is agreement among both the technical community and the software community regarding the use of Non-Linear procedures instead of Eigenvalue Buckling; the excerpts below are a sampling of discussions on this topic.
"Nonlinear buckling analysis is more accurate than eigenvalue analysis because it employs nonlinear, large-deformation, static analysis to predict buckling loads. Its mode of operation is very simple: it gradually increases the applied load until a load level is found whereby the structure becomes unstable." (ANSYS Tutorials - Buckling)

"Nonlinear buckling analysis provides greater accuracy than elastic formulation (Eigenvalue)." (CSi Knowledge Base)

"The nonlinear buckling analysis provides a more accurate indication of buckling than other methods. A linear bifurcation buckling analysis, usually based on eigenvalue solutions, oversimplifies buckling behavior and often under- or over-estimates buckling conditions." (LARSA 4D Documentation - Analysis Reference)
"For a detailed structural buckling assessment a geometrically nonlinear analyses should be carried out." (LUSAS Finite Element Analysis)

C.12 Midas Built-In Pushover Analysis

Midas has a Pushover Analysis tool as one of the analysis control options. This analysis can be set up through the Pushover Global Control menu and by selecting the “Buckling Distributed” load case as the Pushover Load Case.



Comparison tests were performed to evaluate the performance of the “built-in” pushover analysis versus the manual nonlinear analysis outlined by this procedure. Good correlation was achieved between simplistic column and frame models; however, the “built-in” analysis tool does not perform well with the more complex geometry and staged construction models which are common to arches. This “built-in” pushover analysis tool may be of interest for further research and investigation to possibly simplify the manual iteration of scaling load factors. A sample output from the “built-in” pushover analysis is provided below.

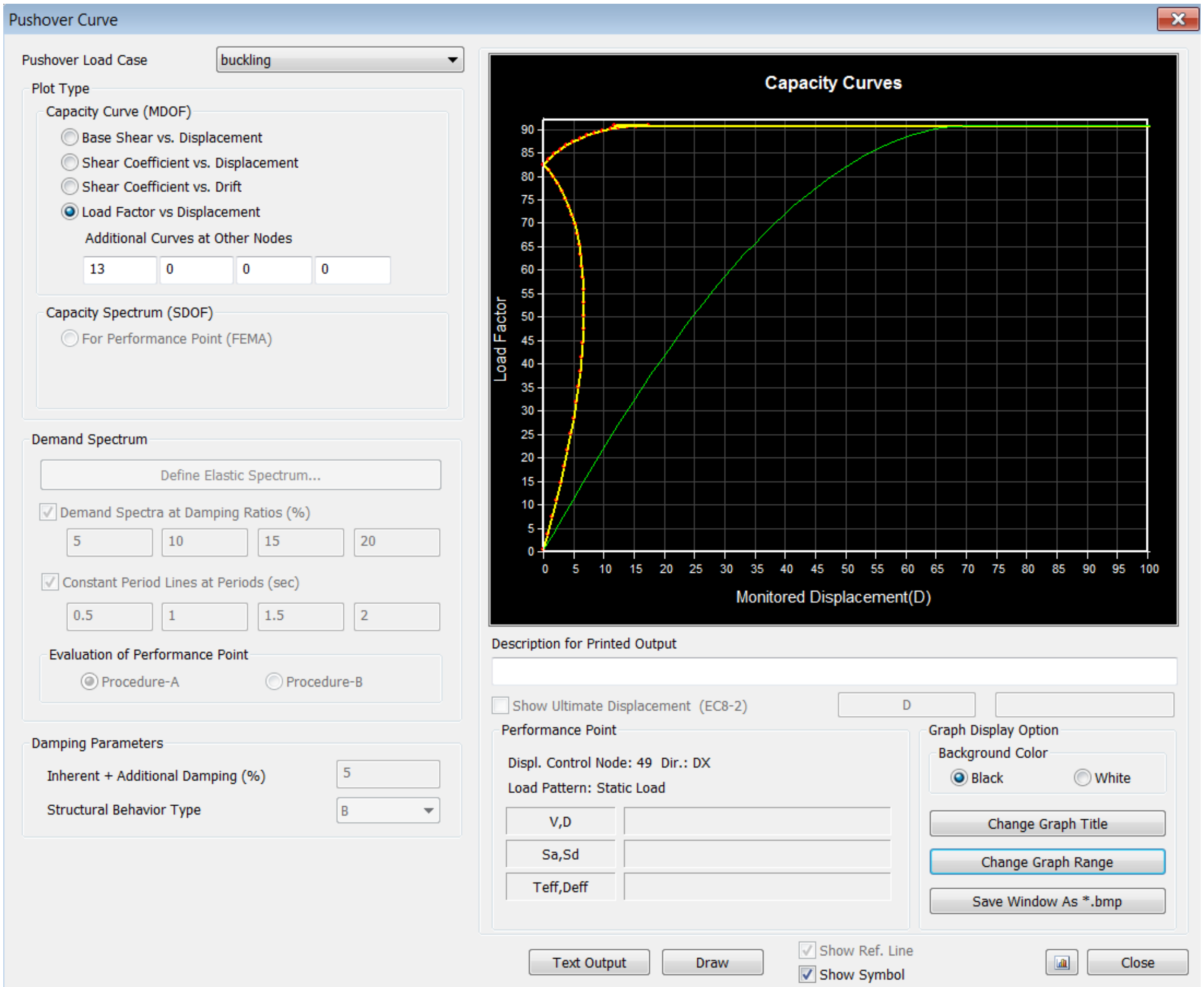


Figure 26: Sample output from Midas "built-in" nonlinear pushover analysis.

C.13 Multi-span Buckling

Multiple spans can be input into a non-linear model. The critical buckling capacity can be conservatively taken for the quarter-point segment in the arch which fails first, or each arch span can be analyzed independently. Experience has shown that for similar length, rise, and cross-sectional definitions using the critical buckling capacity of the arch which fails first as the capacity for all spans is an efficient and not overly conservative method.

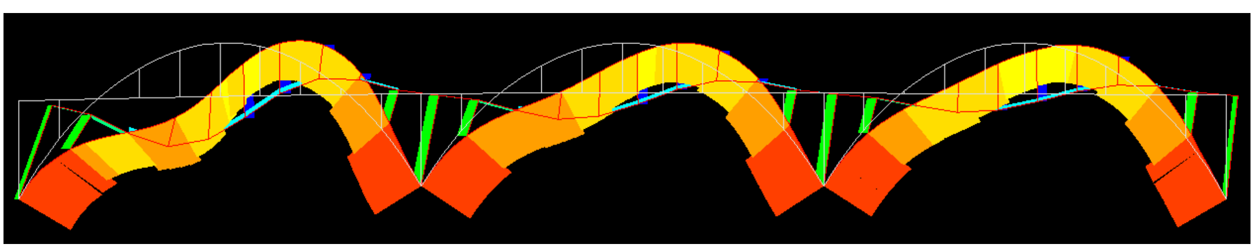
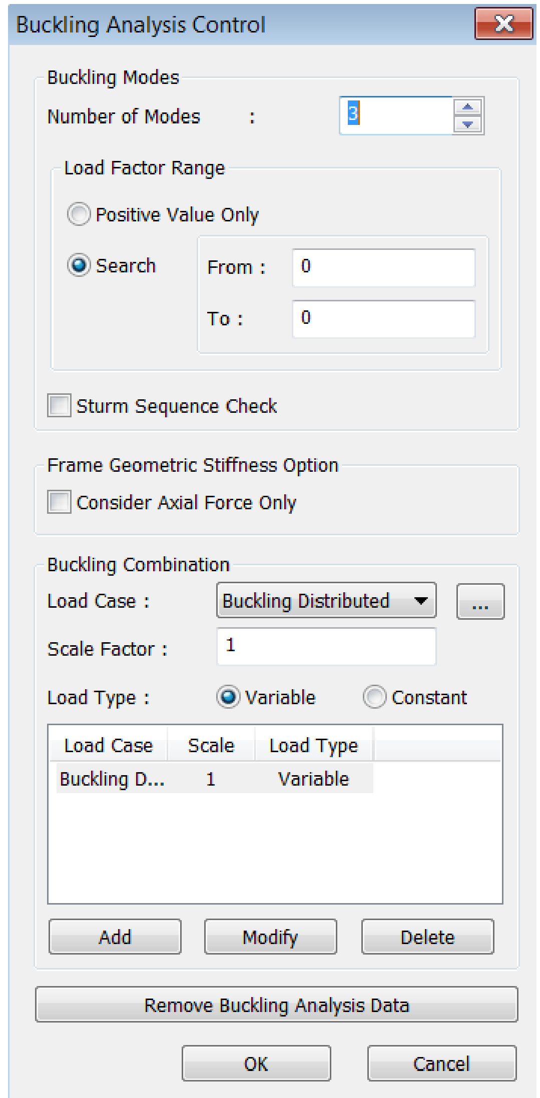


Figure 27: Example buckling model of multi-span arch bridge, the far-left span is buckling first.

C.14 Midas "Buckling" Analysis Tool



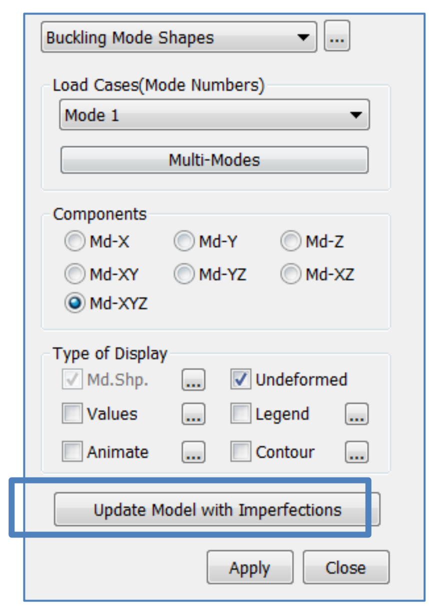
Midas has a built-in buckling analysis tool which runs a simplified eigenvalue buckling solution. This analysis can be helpful for determining the initial "mode" shape for the arch. Additionally, the displaced position of the nodes produced by the buckling analysis can be used to update the base model for use in the pushover analysis instead of manually assigning the displaced shape.

To run a buckling analysis select Buckling from the Analysis Global Control menu, choose two or three modes and enter the "Buckling Distributed" load case defined in Section C.4 above as variable.

From the Results Global Control menu select Mode Shapes > Buckling Mode Shapes. While displaying each mode it is helpful to have only the arch elements active. Figures 20 through 22 show an example output of the buckling mode shapes.

These shapes are computed with Eigenvectors and are thus Eigenvalue solutions that have an associated critical buckling load. This buckling load may be incorrect (high or low) by as much as 30%; however, it can be used as a starting point for the expected failure load of the nonlinear analysis. To determine the Eigenvalue critical buckling load, turn on the legend when viewing the Mode 1 shape, multiply the critical load factor by the axial force (from the static buckling distributed load) at the arch quarter point.

NOTE: the buckling analysis results are very sensitive to beam end releases, rigid links, and other boundary conditions.



If the boundary conditions of the bridge model are such that the expected simple half-span sine-wave is not the mode 1 shape, it may be desirable to use this analysis result to update the model with these displacements instead of independently calculating the displaced shape as discussed in section C.2. To do this, click the "Update Model with Imperfections" button on the Buckling Modes Shapes control menu.

This will open a dialog box from which you can select the desired mode and then must tell Midas how to scale the displacements. Determination of the magnitude of the displacements is discussed in section C.1, this calculated maximum displacement may be entered or a separate calculation may be performed to determine the scale or maximum value.

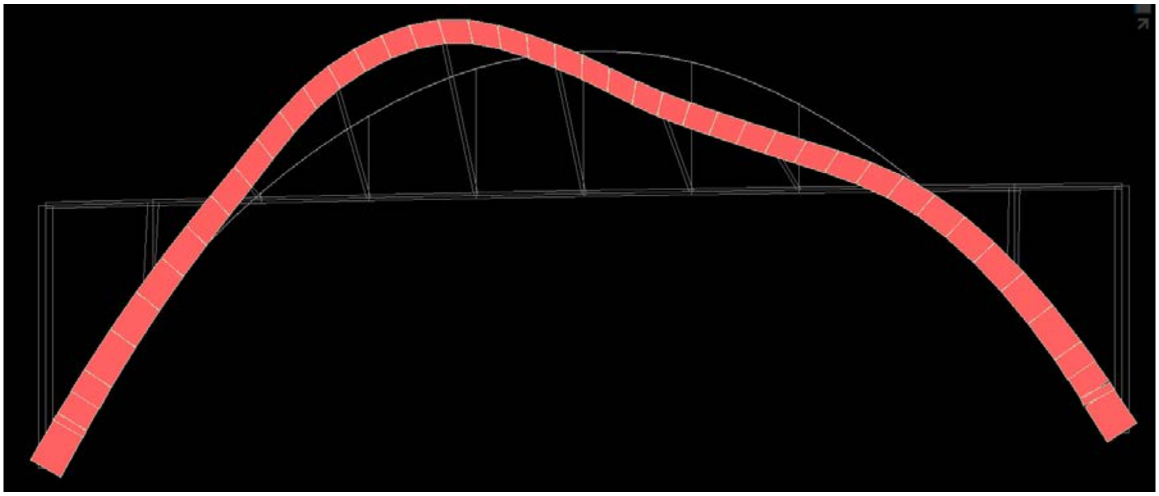


Figure 28: Typical arch buckling mode shape “Mode 1.” Buckling occurs over a half-span of the arch.

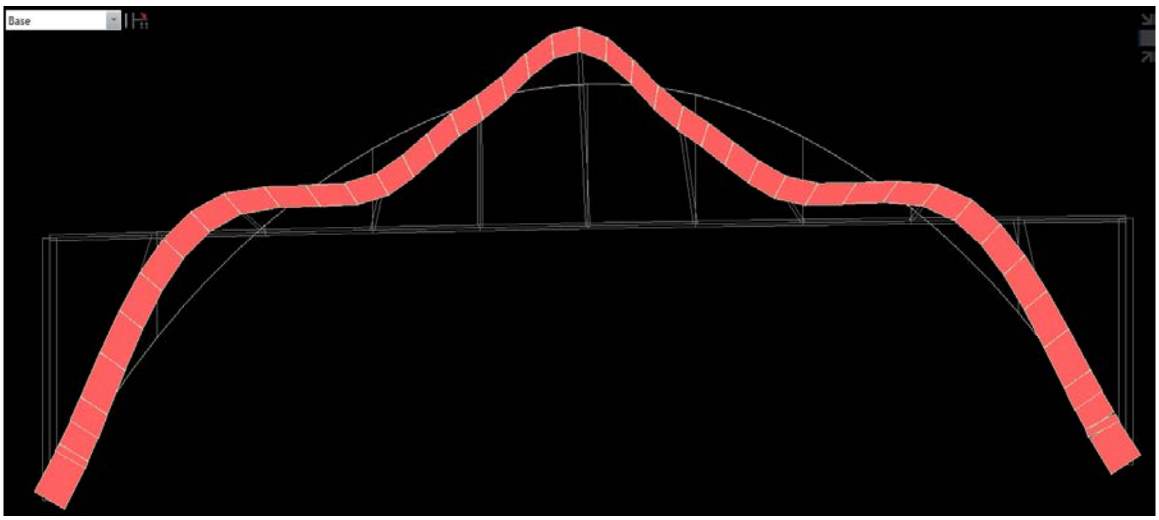


Figure 29: Arch shape for higher buckling mode. Buckling occurs over a quarter-span of the arch.

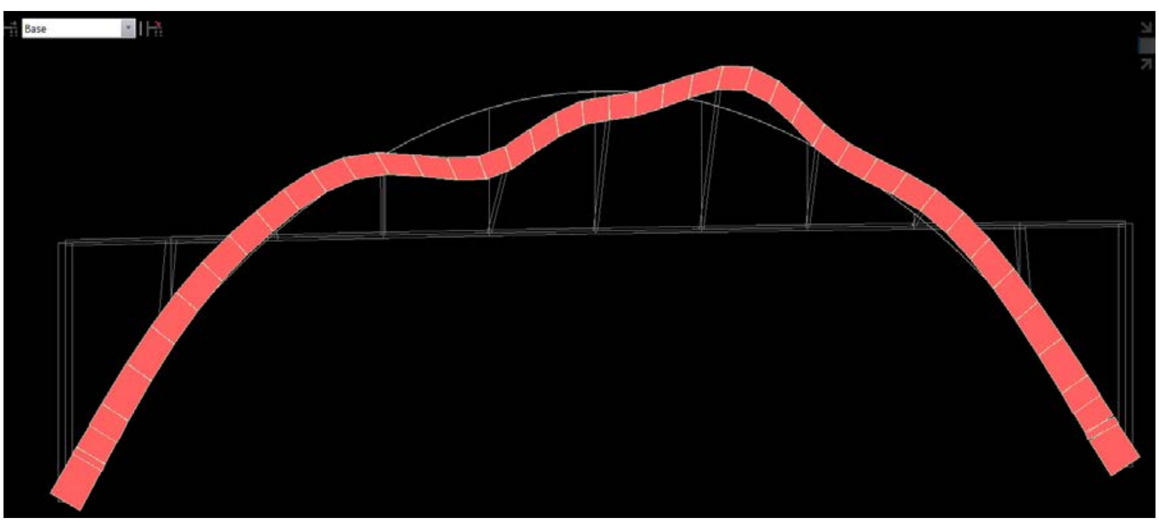


Figure 30: Buckling mode shape for arch with significant rigidity, such as when there is no moment release for columns or hangers. Buckling occurs within the unsupported length between bracing or over two supports.

C.15 References

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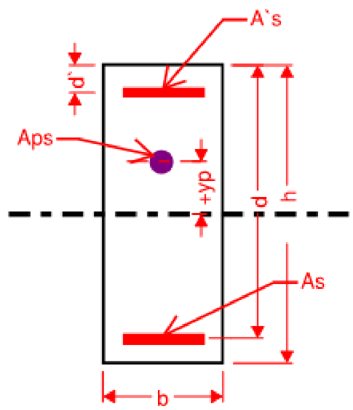
APPENDIX D - CONCRETE ARCH CAPACITY CALCULATION

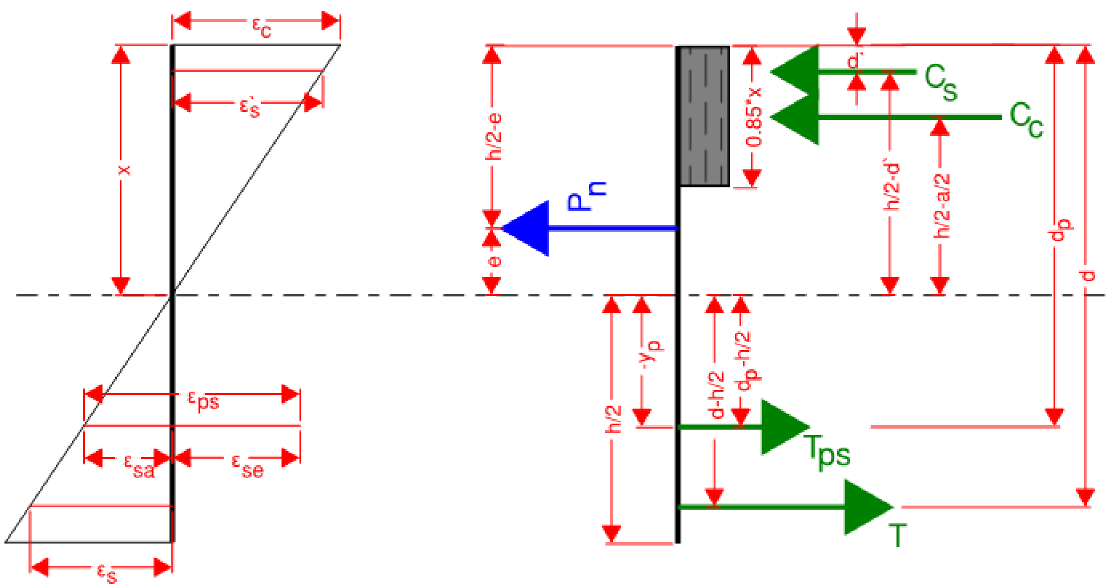
This appendix describes the methodology by which the Capacity tabs of the Concrete excel tools determine factored capacities for the given section. The capacity tabs of the tools do not require input from the user; however, an explanation of the approach and assumptions used is given here, in case the user needs to make changes for a specific structure.

D.1.1 P-M Capacity Determined by Strain Compatibility & Equilibrium

Capacity calculations are based on statics of these diagrams:



Assume h = d + d`



Strain Diagram

Free Body Diagram

The following relationships are used to calculate forces and capacity.

Concrete compression

The force C_c in the compression zone of the concrete is given by:

$$C_c = 0.85 * f'_c * b * a$$

The depth of the compression zone *a* is calculated as:

$$a = 0.85 * x$$

Steel Compression

Calculation of the force C_s in the reinforcement located in the compression zone of the concrete is dependent on whether the compression steel yields. Strain in the compression steel is based on the strain diagram above, with the concrete compression at 0.003 at capacity:

$$\varepsilon'_s = \frac{0.003}{x} * (x - d')$$

The compression steel yields if $\varepsilon'_s > f_y / E_s$. In that case, the force in the compression steel, with a correction for displaced concrete is:

$$C_s = A'_s * \left(f_y - 0.85 * f'_c\right)$$

If the compression steel strain $\varepsilon'_s < f_y / E_s$, then the reinforcement does not yield and the force in the compression steel is:

$$C_s = A'_s * (E_s * \varepsilon'_s - 0.85 * f'_c)$$

Steel Tension

Calculation of the force T in the reinforcement located in the tension zone of the concrete is dependent on whether the tension steel yields. Strain in the tension steel is based on the strain diagram above, with the concrete compression at 0.003 at capacity:

$$\varepsilon_s = \frac{0.003}{x} * (d - x)$$

The tension steel yields if $\varepsilon_s > f_y / E_s$. In that case, the force in the tension steel:

$$T = A_s * f_y$$

If the tension steel strain $\varepsilon_s < f_y / E_s$, then the reinforcement does not yield and the force in the tension steel is:

$$T = A_s * E_s * \varepsilon_s$$

Prestressed/Post-tensioned Strand

Calculation of the force T in the prestressed/post-tensioned strand located in the concrete is dependent on whether the strand yields. Strain in the strand is based on the strain diagram above, with the concrete compression at 0.003 at capacity:

$$\varepsilon_{se} = \frac{\varepsilon_c * d_p}{x} - \varepsilon_c$$

The strain in the strand due to post-tensioning is:

$$\varepsilon_{sa} = \frac{f_{se}}{E_{ps}}$$

The total strain in the strand is:

$$\varepsilon_{ps} = \varepsilon_{se} + \varepsilon_{sa}$$

The total stress in the strand is dependent on the yield capacity of the strand and the total strand strain. For 250ksi strand and the total strand strain is less than 0.0076, the stress is:

$$f'_{ps} = E_{ps} * \varepsilon_{ps}$$

Otherwise, the stress is:

$$f'_{ps} = 250 - \frac{0.04}{\varepsilon_{ps} - 0.0064}$$

For 270ksi strand and the total strand strain is less than 0.0086, the stress is:

$$f'_{ps} = E_{ps} * \varepsilon_{ps}$$

Otherwise, the stress is:

$$f'_{ps} = 270 - \frac{0.04}{\varepsilon_{ps} - 0.007}$$

The force in the strand is:

$$T_{ps} = A_{ps} * f'_{ps}$$

Neutral Axis Location

Because the same resistance factor *Φ* is used for both the axial load P_u and flexure M_u, the resistance factor is not required to determine the eccentricity e_0:

$$e_0 = \frac{\frac{\delta * M_u}{\Phi}}{\frac{P_u}{\Phi}} = \frac{\delta * M_u}{P_u}$$

Taking the sum of moments about the location of P_n to be equal to zero:

$$0 = T * \left(d - \frac{h}{2} + e\right) - C_c * \left(\frac{a}{2} - \left(\frac{h}{2} - e\right)\right) + C_s * \left(\frac{h}{2} - e - d'\right)$$

All values in this expression are known except for the neutral axis location *x*. (Note that the forces *T*, C_c and C_s and the depth *a* also vary with x.) A very small initial value is input, and the forces and moment equation calculated using $e = e_0$. If the equation does not equal zero, then the value of *x* is incrementally increased and the calculations performed again. When the expression is zero (or, when the sign changes from positive to negative), the input *x* is stored as the neutral axis for the section at capacity. Associated values of eccentricity *e*, strains ε_s and ε'_s, and forces *T*, C_c and C_s are all output to the spreadsheet to facilitate QC review.

Axial Capacity

With the neutral axis determined and values for forces *T*, C_c and C_s available, the nominal section capacity P_n is:

$$P_n = \mathrm{T} - C_s - C_c$$

The associated moment is:

$$M_n = P_n * e$$

Per AASHTO LRFD Eq. 5.6.4.4-2 and 5.6.4.4-3, the capacity P_n is limited to:

$$P_n = 0.85 * \left[0.85 * f'_c * \left(A_g - A_{st}\right) + f_y * A_{st}\right]$$

for members with spiral reinforcement, or

$$P_n = 0.80 * \left[0.85 * f'_c * \left(A_g - A_{st}\right) + f_y * A_{st}\right]$$

for members with tie reinforcement.

D.1.1.1 Resistance Factors

For tension-controlled sections ($\varepsilon_s < \varepsilon_{cl}$), $\Phi = 0.90$. For compression-controlled sections ($\varepsilon_s > \varepsilon_{tl}$), $\Phi = 0.75$. For sections with tensile steel strain between the compression and tension limits, the resistance factor is calculated from AASHTO LRFD Eq. 5.5.4.2-2:

$$0.75 \leq \Phi = 0.75 + \frac{0.15 * (\varepsilon_t - \varepsilon_{cl})}{(\varepsilon_{tl} - \varepsilon_{cl})} \leq 0.90$$

The tension limit strain ε_{tl} is calculated on the GENERAL tab based on the tension reinforcement yield strength, per AASHTO LRFD 5.6.2.1-1. The compression limit ε_{cl} is taken as the tensile strain at the balanced strain condition, per AASHTO LRFD 5.6.2.1. The resistance factor *Φ* is applied to both the axial load P_u and moment M_u.

D.1.1.2 Rating Factors from P-M Interaction

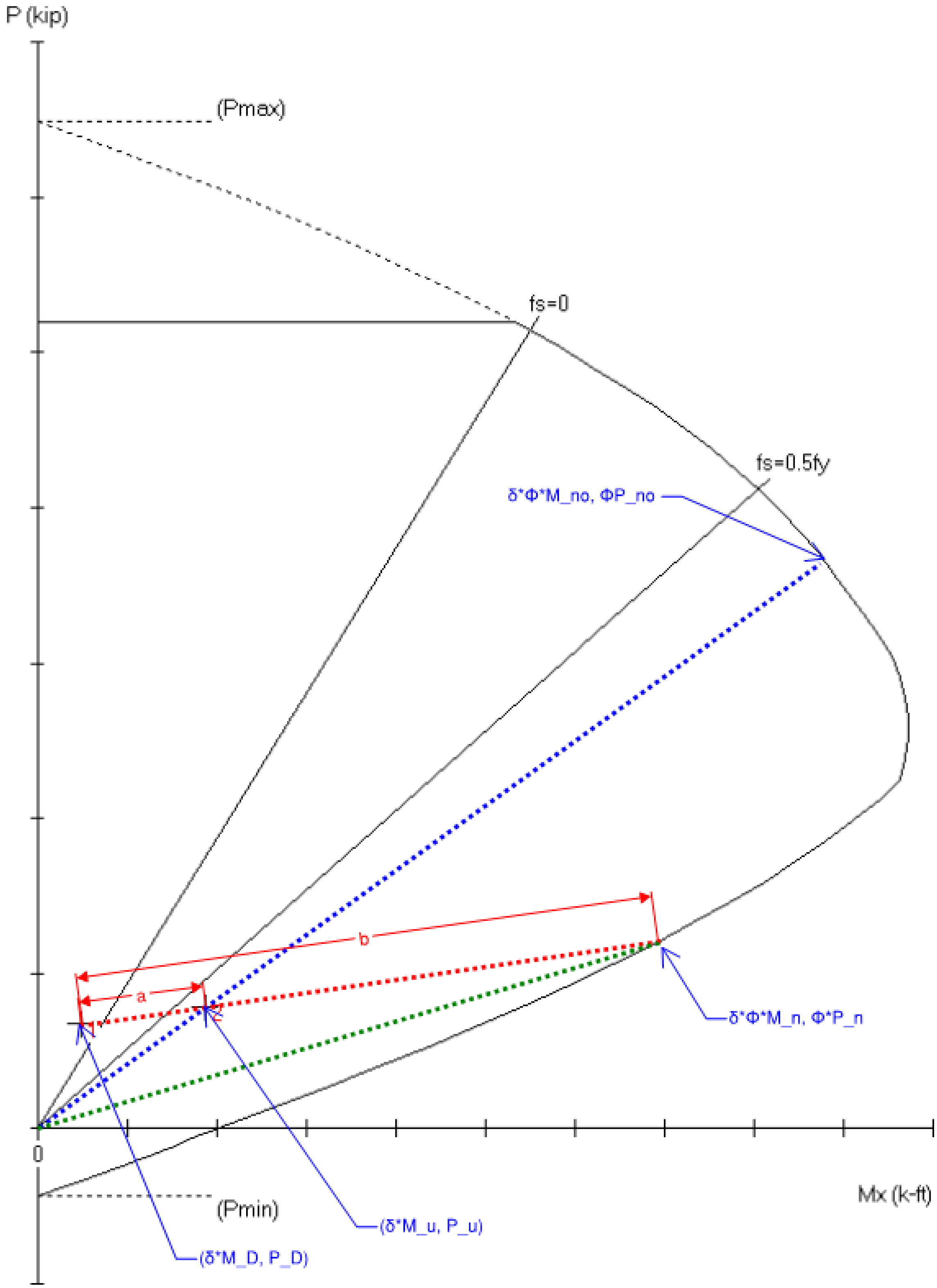


Figure 31 - Rating Factor Procedure

The procedure for determining the rating factor:

1. Establish point 1 using **δ*M_D** and **P_D**
2. Establish point 2 using **δ*M_u** and **P_u**
3. Determine the slope of the line between points 1 and 2:

$$m = \frac{P_u - P_D}{\delta * M_u - \delta * M_D} = \frac{P_L}{\delta * M_L}$$

4. Determine the value of *x* and *Φ* based on P_u.
5. Determine the column capacity value Φ^*P_{no} using the eccentricity defined by **δ*M_u** and **P_u** (blue dashed line)
   a. If $\Phi^*P_{no} > P_u$, then
      i. Increase the input axial load $P_u = P_u$ + PStep (step value = lesser of 0.1 kip or P_u/100)
      ii. Increase the input flexure $\delta^*M_u = \delta^*M_u$ + PStep/m
      iii. Determine a new value P_{no} using the eccentricity defined by **δ*M_u** and **P_u** (revised blue dashed line)
      iv. Determine the value of *Φ* based on P_{no}.
      v. Repeat Step 5a as needed until $\Phi^*P_{no} < \Phi^*P_u$
   b. If $\Phi^*P_{no} \le P_u$, then
      i. Decrease the input axial load $P_u = P_u$ - PStep
      ii. Decrease the input flexure $\delta^*M_u = \delta^*M_u$ - PStep/m
      iii. Determine a new value P_{no} using the eccentricity defined by **δ*M_u** and **P_u** (revised blue dashed line)
      iv. Determine the value of *Φ* based on P_{no}.
      v. Repeat Step 5b as needed until $\Phi^*P_{no} > \Phi^*P_u$
6. Limit the
7. Determine the distances "a" and "b" using known values of axial load and flexure

$$a = \sqrt{(P_u - P_D)^2 + (\delta * M_u - \delta * M_D)^2} = \sqrt{{P_L}^2 + \delta * {M_L}^2}$$

$$b = \sqrt{(\Phi * P_n - P_D)^2 + (\delta * \Phi * M_n - \delta * M_D)^2}$$

8. Rating factor is the ratio of the distances:

$$RF = \frac{b}{a}$$

Distance "a" on the diagram represents the portion of the section capacity used by the applied live load. Distance "b" on the diagram represents the "live load capacity" of the section beyond the applied factored loads **δ*M_D** and **P_D**. Thus, the rating factor for the section is the total live load capacity "b" divided by the live load only effect "a."

Due to the signs of the resulting moments, it is possible that the slope of the red line *m* could be higher than the initial slope of the line representing the initial eccentricity to (**δ*M_{no}**, **P_{no}**). Where this is the case, Step 6 will reduce the input values of **P_u** and **δ*M_u** and Step 7 will increase the values of **P_u** and **δ*M_u** until convergence of the column capacity is achieved.

Cases where the initial Φ^*P_{no} is determined to be outside of the moment interaction curve correspond to sections with a rating factor less than 1.0. If $\Phi^*P_{no} < P_D$, then the rating factor will be negative.

For each section, the combination of geometry, reinforcement and factored loading are used to calculate a moment capacity. The traditional moment-interaction diagram is divided into three "regions":

- Region 1, where capacity is based on "short column" (low eccentricity) capacity
- Region 2, where behavior is more like a column than a beam
- Region 3, where behavior is more like a beam than a column

Region 1 is the capacity of a column with very little eccentricity or slenderness effects. P_0 is the column capacity for zero eccentricity of the axial load, and the Region 1 moment capacity is taken as either *0.80* P_0 for tied columns, or *0.85* P_0 for spirally-reinforced columns. The transition between Region 1 and Region 2 is at the location where the Region 1 capacity intersects the moment-interaction curve for higher axial loading.

The transition between Regions 2 and 3 is at the point defined by the “balanced strain” condition. At the balanced strain condition, the combination of axial load and moment causes a concrete compressive strain equal to 0.003 simultaneous with the tension steel yielding. When the compressive stress equals 0.003 but the tension steel has not yielded, the column capacity is “compression controlled” and the capacity will be in Region 2. If the tension steel yields before the concrete compressive strain equals 0.003 then the section is referred to as “tension controlled” and the capacity will be in Region 3.

D.1.1.3 Balanced Strain Condition

The first step in computing the section capacity is to determine the balanced condition, or strain which defines the transition between Regions 2 and 3.

The distance x_b from the compression face of concrete to the neutral axis at the balanced strain condition is taken as:

$$x_b = \frac{0.003}{\frac{f_y}{E_s} + 0.003} * d$$

The value of β_1 is calculated on the GENERAL tab, based on the design compressive strength of the arch concrete. The Whitney approximation for effective depth of concrete in compression is then $a_b=\beta_1 * x_b$. Main tension steel force $T=f_y * A_s$.

Compression steel typically yields at balanced strain conditions, and the equations used in this method make that assumption. A compression steel yielding check is made.. The balanced axial force $P_b=C_c+C_s-T$.

The balanced eccentricity e_b is measured from the plastic centroid of the centroid, and d'' is the distance from the plastic centroid to the tension reinforcement. The template is set up for rectangular sections with the same tension and compression reinforcing. Taking moments about the plastic centroid of the section:

$$P_b * e_b = C_c * \left(d - \frac{a}{2} - d''\right) + C_s * (d - d' - d'') + T * d''$$

The balanced eccentricity $e_b=M_b/P_b$.

Strain in the extreme tension steel ($\varepsilon_s = \varepsilon_{cl}$) is calculated as:

$$\varepsilon_{cl} = (0.003) * \frac{(d - x_b)}{x_b}$$

Per AASHTO 5.7.2.1, ε_{cl} represents the strain in the tension steel at the balanced strain condition, which is also the compression-controlled strain limit.

D.1.1.4 Maximum Axial Capacity

The Region 1 (“short column”) capacity is dependent only on material and geometric properties. The spreadsheet determines the upper capacity P_0 from the input parameters. A_g is the gross section area, and A_{st} is the total longitudinal reinforcement area:

$$P_0 = 0.85 * f'_c * (A_g - A_{st}) + A_s * f_y$$

The type of shear reinforcement (“Tied” or “Spiral”) is input on the GENERAL tab, and is typically consistent for the length of the member. The maximum $P_n = 0.80 * P_0$ for sections with tied shear stirrups, or $P_n = 0.85 * P_0$ for spiral shear reinforcement.

D.1.1.5 Factored Forces

The determination of the appropriate capacity region depends on the strain which depends on the applied loading. The section's static DC and DW loads (minimum and maximum) are displayed. Combined minimum and maximum static loads are combined with the minimum and maximum live load results separately. In MIDAS, negative axial loads are compression and positive are tension, while minimum and maximum shears and moments simply denote the direction of the load. For axial loads, "MAX" is returned for the maximum compression (largest negative). For moments, "MAX" is returned for the largest magnitude (positive or negative). Combinations for axial and flexural loads are displayed.

D.1.1.6 Balanced Strain Check

For each set of factored loading Pu and Mu, the eccentricity is calculated as:

$$e = \frac{M_u}{P_u}$$

The eccentricity e is compared to e_b; if the strain is higher than balanced, the capacity region will be 3 (tension controls). If lower than balanced, the capacity region will be 2 (compression controlled) or 1 (short column).

D.1.2 Euler Buckling

AASHTO LRFD 5.12.6.2 states that the moment magnification method from AASHTO LRFD 4.5.3.2.2 may be used for estimating the effective design length. The provisions of AASHTO LRFD 5.6.4.3 for slenderness of concrete compression members are not used to calculate slenderness effects, because AASHTO LRFD 5.12.6.2, specifically written for concrete arch ribs, allows the direct use of AASHTO LRFD 4.5.3.2.2 if the modulus of elasticity is estimated using a concrete strength of 0.40 f'c. This value for E_c is calculated on the GENERAL tab.

The critical buckling load P_e is calculated independently using a nonlinear analysis. See the Buckling Appendix.

D.1.3 Shear Capacity

The General Procedure within the AASHTO LRFD Sectional Design Model approach for calculating shear capacity is used for all rated elements. Some user input is required to complete the rating.

D.1.3.1 Section Geometry

Shear reinforcement area and spacing, and shear width b_v are referenced from other areas of the spreadsheet. The "Min Check" column returns a "Yes" if the minimum shear reinforcement in AASHTO LRFD Eq. 5.7.2.3. Standard calculations for the neutral axis location c, the compression depth a, and the depth to tension steel d_s are displayed. The c/d_s ratio is checked in accordance with AASHTO LRFD Eq. 5.6.2.1-1; "OK" verifies that using f_y in place of f_s in the Flexural Resistance equations of AASHTO LRFD 5.6.3.2 is allowed, while "NG" forces the value of d_v to be set to zero. (A strain compatibility approach would be required to determine the tension steel stress f_s.) Compression steel is conservatively ignored, in accordance with AASHTO LRFD 5.6.2.1. The final value is the upper limit on the nominal shear capacity, based on the section geometry per AASHTO LRFD Eq. 5.7.3.3-2.

D.1.3.2 Factored Static Loads

Min and Max load results are shown and combined into minimum and maximum static load results.

D.1.3.3 Section Rating

For each vehicle, the Min and Max shear (with corresponding moment and axial) are displayed. The tensile steel strain ε_s is calculated from AASHTO LRFD Eq. 5.7.3.4.2-4:

$$\varepsilon_s = \frac{\frac{|M_u|}{d_v} - 0.5 * P_u + \left|V_u - V_p\right| - A_{ps} * f_{po}}{E_s * A_s + E_p * A_{ps}}$$

Note that the axial load is multiplied by (-1) because the reported values are positive for compression, but the AASHTO definition is positive for tension. If the strain is calculated as a negative value, the sheet will set it to zero in accordance with AASHTO LRFD 5.7.3.4.2.

The assumed crack angle θ is calculated using AASHTO LRFD Eq. 5.7.3.4.2-3. The crack spacing parameter s_{xe} is calculated using the assumption that $s_x = d_v$, which is valid for a single row of transverse reinforcement. Parameters β for cases where minimum transverse reinforcement is met, and where minimum transverse reinforcement is not met, are calculated from AASHTO LRFD Eqs. 5.7.3.4.2-1 and 5.7.3.4.2-2, respectively. The appropriate value for β is chosen based on the minimum reinforcement check performed earlier.

Concrete shear capacity V_c is calculated using AASHTO LRFD Eq. 5.7.3.3-3 and the steel shear capacity V_s using AASHTO LRFD Eq. 5.7.3.3-4. The lesser of $V_c + V_s$ or $V_{n\,max}$ is used as the capacity in the rating factor calculation for the section.

APPENDIX E – STEEL ARCH CAPACITY CALCULATION

This appendix describes the methodology by which the Capacity tabs of the Steel excel tools determine factored capacities for the given section. The capacity tabs of the tools do not require input from the user; however, an explanation of the approach and assumptions used is given here, in case the user needs to make changes for a specific structure.

This appendix is based on the **XXXXX_StlArch.xlsm** tool which assumes that the member is a steel box section and is in compression. However, these notes also apply to the **XXXXX_StlTension.xlsm** tool which performs the same capacity calculations with the exception of axial tensile capacity instead of axial compressive capacity. For other geometric or load conditions the user must take care to modify the spreadsheet as necessary.

E.1.1 Moment Capacity

This tab should require no input from the user. An explanation of the approach and assumptions used is given here, in case the user needs to make changes for a specific structure. All information is inputted in the ELEMENT PROPERTIES tab of the tool.

<u>Flange Nominal Flexural Resistance</u>

For steel boxed shaped members the nominal flexural resistance for the top and bottom flange is calculated by AASHTO LRFD Eq. 6.12.2.2.2-1:

$$M_n = \left[1 - \frac{0.064F_ySl}{AE}\left(\frac{\Sigma\left(\frac{b}{t}\right)}{I_y}\right)^{0.5}\right]$$

The plastic moment is calculated in accordance with AASHTO LRFD Eq. 6.12.2.2.2-2:

$$M_p = F_yZ$$

The compact flange slenderness limit is found with AASHTO LRFD Eq. 12.2.2.2-5:

$$1.12\sqrt{\frac{E}{F_y}}$$

The non-compact flange slenderness limit is calculated according to AASHTO LRFD Eq. 6.12.2.2.2-6:

$$1.40\sqrt{\frac{E}{F_y}}$$

If the top or bottom flanges are calculated by the sheet to be a slender element then ensure that S_{eff} has been entered into the sheet.

For flange local buckling where the compression flange slenderness is greater than the limiting slenderness for a compact flange, the flange local buckling must be checked. If the compression flange slenderness λ_f, is less than or equal to the limiting slenderness for a non-compact flange λ_{fp}, then the nominal flexural resistance shall be calculated per AASHTO LRFD Eq. 6.12.2.2.2-3:

$$If\ \lambda_f \leq \lambda_{rf}\ , then$$

$$M_n = M_p - \left(M_p - F_y S\right)\left(3.57\frac{b_{fc}}{t_{fc}}\sqrt{\frac{F_y}{E}} - 4.0\right) \leq M_p$$

If the compression flange slenderness λ_f, is greater than the limiting slenderness for a compact flange λ_{rf}, then the nominal flexural resistance shall be calculated per AASHTO LRFD Eq. 6.12.2.2.2-4:

$$If\ \lambda_f > \lambda_{rf}\ , then$$

$$M_n = F_y S_{eff}$$

If the web slenderness D/t_w is less than the web slenderness limit then the web is nonslender. The limiting slenderness for a compact web is modeled by AASHTO LRFD Eq. 6.12.2.2.2-10:

$$\lambda_{pw} = 2.42\sqrt{\frac{E}{F_y}}$$

For web local buckling for slender webs, the nominal flexural resistance shall be calculated per AASHTO LRFD Eq. 6.12.2.2.2-9:

$$M_n = M_p - \left(M_p - F_y S\right)\left(0.305\frac{D}{t_w}\sqrt{\frac{F_y}{E}} - 0.738\right) \leq M_p$$

A ‘component rating factors’ is calculated on both the Moment and Axial Capacity tabs; however, these rating factors are not used in the final rating summary, but are only useful in determining how close that particular component is to its capacity. The actual rating factor is determined based on the interaction of both moment and axial, see Section 1.1.4.

E.1.2 Axial Capacity

This tab should require no input from the user. An explanation of the approach and assumptions used is given here, in case the user needs to make changes for a specific structure. All information is inputted in the ELEMENT PROPERTIES tab of the tool.

E.1.2.1 Elastic Flexural Buckling Resistance

The elastic critical buckling resistance, P_e, shall be calculated from AASHTO LRFD Eq. 6.9.4.1.2-1:

$$P_e = \frac{\pi^2 E}{\left(\frac{Kl}{r_s}\right)^2} A_g$$

The elastic critical buckling resistance is calculated for both longitudinal and transverse buckling. The design P_e is controlled by the lesser value of the longitudinal buckling, the transverse buckling, and the arch buckling capacity determined using a non-linear buckling analysis (see Buckling Appendix).

The minimum critical buckling resistance is used to determine the moment magnifier as described in the Arch Buckling Appendix.

E.1.2.2 Nonslender Member Elements

The slenderness of the web and the top and bottom flanges are determined using the limit equation for AASHTO LRFD Eq. 6.9.4.2.1-1:

$$\frac{b}{t} \leq k\sqrt{\frac{E}{F_y}}$$

If the equation is true then the element is nonslender.

E.1.2.3 Slender Stiffened Elements

The effective width for the top and bottom flanges of square and rectangular box sections are determined by AASHTO LRFD Eq. 6.9.4.2.2-10:

$$b_e = 1.9t\sqrt{\frac{E}{f}}\left[1 - \frac{0.38}{\left({}^{b}/{}_{t}\right)}\sqrt{\frac{E}{f}}\right] \leq b$$

The effective width for webs is modeled by AASHTO LRFD Eq. 6.9.4.2.2-11:

$$b_e = 1.9t\sqrt{\frac{E}{f}}\left[1 - \frac{0.34}{\left({}^{b}/{}_{t}\right)}\sqrt{\frac{E}{f}}\right] \leq b$$

Additionally the effective width of the web b_e can be modified by the presence of stiffeners. To find the effective width the web is divided into $(n + 1)$ segments, where n equals the number of interior stiffeners with an assumed equal spacing. The effective web height b is assumed to equal $\frac{D}{(n+1)}$. To obtain the total effective web area multiply the segment effective web area by $(n + 1)$.

For elements that are slender and unstiffened, a reduction factor Q is assumed to be equal to 1.0. For elements that are slender and stiffened the reduction equation $Q = Q_s * Q_a$ is applied, where Q_s is taken as 1.0 and Q_a is calculated in accordance with AASHTO LRFD Eq. 6.9.4.2.2-9:

$$Q_a = \frac{A_{eff}}{A}$$

The equivalent nominal yield resistance in kips is noted in the following equation:

$$P_0 = QF_yA_g$$

The nominal compressive resistance is determined with a buckling curve in accordance with AASHTO LRFD 6.9.4.1.1 section. If $\frac{P_e}{P_o} \geq 0.44$ then AASHTO LRFD Eq. 6.9.4.1.1-1 is applicable:

$$P_n = \left[0.658^{\left(\frac{P_o}{P_e}\right)}\right]P_o$$

If $\frac{P_e}{P_e} < 0.44$ then AASHTO LRFD Eq. 6.9.4.1.1-2 is applicable:

$$P_n = 0.877P_e$$

For determining the effective web area for axial capacity, the sheet currently assumes an equal spacing of stiffening elements. If the stiffeners either have insufficient stiffness to be effective as stiffeners, or are spaced in an unequal pattern, then the user must calculate the effective web area and manually over-ride the values calculated in the Axial Capacity tab.

E.1.2.4 Tension Effect and Tension Members

When a compression member has a live load component in *tension*, the “capacity” is conservatively set to zero axial load and associated moment. If the element is in fact a tension member, the **XXXXX_StlTension.xlsm** tool should instead be used which calculates an axial tensile capacity in lieu of axial compressive capacity. For additional discussion, see the LRFR ODOT Load Rating Manual Section on Arch Load Ratings.

Tensile capacity is the minimum of the yielding and fracture limit states, computed in accordance with AASHTO LRFD 6.8.2.1.

E.1.3 Shear Capacity

This tab should require no input from the user. An explanation of the approach and assumptions used is given here, in case the user needs to make changes for a specific structure. All information is inputted in the ELEMENT PROPERTIES tab of the tool. For the final calculation of the nominal shear resistance V_r, as noted in the sheet will be maximum calculated V_n of the stiffened and unstiffened nominal shear resistance values.

E.1.3.1 Nominal Resistance of Stiffened Webs

In order to check the nominal shear resistance of an interior web panel the following statement provided by AASHTO LRFD Eq. 6.10.9.3.2-1 must be true and will output ‘YES’ in the sheet:

$$\frac{2Dt_w}{\left(b_{fc}t_{fc} + b_{ft}t_{ft}\right)} \leq 2.5$$

The shear buckling coefficient k, was determined in accordance with AASHTO LRFD Eq. 6.10.9.3.2-7:

$$k = 5 + \frac{5}{\left(\frac{d_o}{D}\right)^2}$$

The ratio of the shear buckling resistance to the shear yield is determined based on three equations, with the maximum possible value of C being equal to 1.0. See AASHTO LRFD section 6.10.9.3.2 for conditions of the equation noted below.

AASHTO LRFD Eq. 6.10.9.3.2-4:

$$If\ \frac{D}{t_w} \leq 1.12\sqrt{\frac{Ek}{F_{yw}}}, then\ C = 1.0$$

AASHTO LRFD Eq. 6.10.9.3.2-5:

$$If\ 1.12\sqrt{\frac{Ek}{F_{yw}}} < \frac{D}{t_w} \leq 1.40\sqrt{\frac{Ek}{F_{yw}}}\ , then\ C = \frac{1.12}{\frac{D}{t_w}}\sqrt{\frac{Ek}{F_{yw}}}$$

AASHTO LRFD Eq. 6.10.9.3.2-6:

$$If\ \frac{D}{t_w} \leq 1.40\sqrt{\frac{Ek}{F_{yw}}}, then\ C = \frac{1.57}{\left(\frac{D}{t_w}\right)^2}\left(\frac{Ek}{F_{yw}}\right)$$

The nominal shear resistance for unstiffened webs are calculated in accordance with AASHTO LRFD Eq. 6.10.9.2-1:

$$V_n = V_{cr} = CV_p$$

The plastic shear force in kips, V_p is calculated by AASHTO LRFD Eq. 6.10.9.3.2-3:

$$V_p = 0.58 F_{yw} D t_w$$

E.1.3.2 Nominal Resistance of Unstiffened Webs

In the event that there are stiffened members, user can input stiffener spacing into the SHEAR CAPACITY tab in the column headed ‘Stiffener Spacing d_o (in). The nominal shear resistance for stiffened webs are calculated in accordance with AASHTO LRFD Eq. 6.10.9.3.2-2.

$$V_n = V_p \left[C + \frac{0.87(1 - C)}{\sqrt{1 + \left(\frac{d_o}{D}\right)^2}} \right]$$

E.1.4 Interaction Capacity

A factored axial-moment (P-M) interaction diagram is generated using the factored axial and moment capacities previously determined and the equations from AASHTO LRFD 6.8.2.3 and 6.9.2.2. This curve is similar to the one shown in Figure 1, and a unique load line is generated for each max and min dead load and live load case for each section. The Run Log tab contains output for one section, including the diagram shown in Figure 1, for review purposes.

Note that the diagram is shown as positive axial force (P) for both the StlArch and StlTension tools. This is done by converting the negative compressive forces from Midas to positive values in the StlArch tool and by maintaining the positive tensile forces from Midas in the StlTension tool.

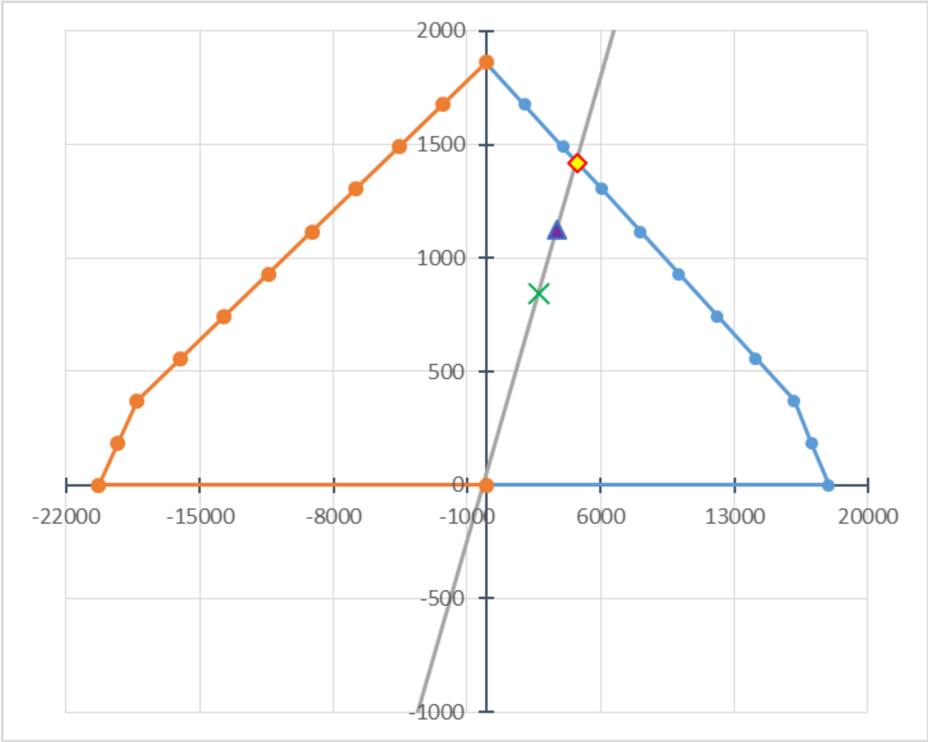


Figure 32: Example Factored P-M Diagram and Load Line

The blue line on this diagram is the calculated factored positive capacity and the orange line is the calculated factored negative capacity. The green X on the diagram represents the factored dead load, the purple triangle represents the factored dead plus live load, and the yellow diamond represents the intersection with the capacity curve where the capacity is determined.
For a discussion of how the rating factors are determined using this diagram, see the Concrete Capacity Appendix Section D.1.1.2.

E.1.5 Service II Check

A Service II check is computed for both the flanges and webs based on the beam stress in the elements from the Midas model. The Bend Buckling Resistance, Fcrw in ksi, is computed per AASHTO LRFD 6.10.1.9.1-1. The flange stress capacity is determined by the formula $f_r = 0.8 * f_y$ in accordance with MBE Section 6A.6.4.2.2.

If any Service II load ratings are less than 1.10, they are reported on the RF summary table on the “RF” tab.

APPENDIX F – ARCH SPANDREL COLUMNS IN TRANSVERSE DIRECTION

This section applies when columns are directed to be rated in the transverse (out-of-plane) direction. The usual lateral forces on a bridge such as wind and seismic are not applicable to load rating; however, lateral dead load and live load forces are transferred to columns when the columns are fixed to a crossbeam. When the column is pinned to the crossbeam, there is no live load moment or shear in the column that can be transferred from the crossbeam since the ODOT crossbeam load rating tool assumes no axial compression or tension in the crossbeam.

By rating the columns in the transverse direction with forces obtained from the ODOT crossbeam tool the column is loaded with the maximum moment and axial force that can be placed based on the crossbeam geometry. These applied live loads most likely do not occur simultaneously with the maximum moment and axial force in the longitudinal direction. It is therefore appropriate to load rate the columns for P-M interaction and shear for the longitudinal and transverse cases independently. There is a concurrent transverse force effect for the maximum longitudinal force effect, and vice-versa; however, to obtain and load rate for the concurrent effects requires a full 3D analysis model and generation of a 3D capacity interaction spherical surface. Full 3D load rating of columns is a complex and rigorous analysis which is outside the scope of typical load ratings.

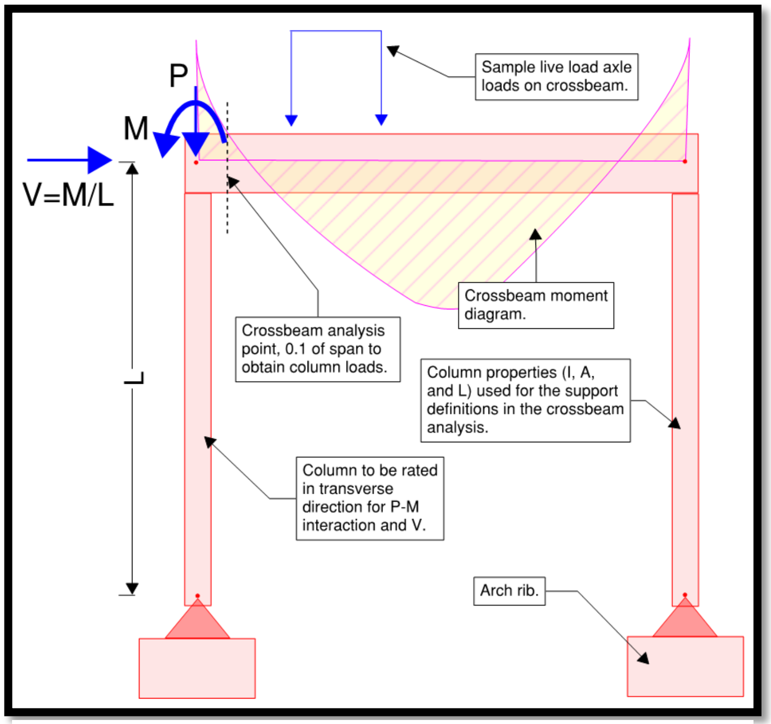
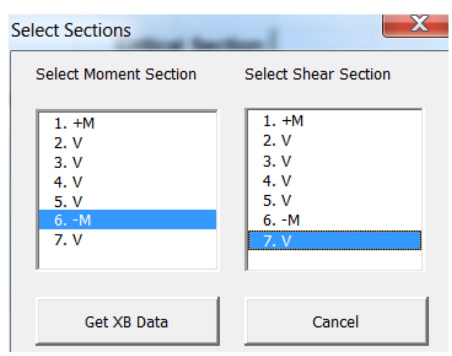


Figure F-33: Transverse column load rating diagram.

For cases when the columns are fixed to the crossbeam transversely the forces may be obtained from the ODOT crossbeam tool by applying a negative moment and shear analysis point at 0.1 of the span. The crossbeam supports are input based on the column properties (length (L), moment of inertia (I), and area (A)). The crossbeam shear force at this location is assumed to apply directly as the axial force (P) in the column. The crossbeam moment at this location is assumed to apply directly as the moment (M) in the column. The shear at the top of the column is calculated as the moment (M) divided by the length of the column (L) if the crossbeam column input is pinned at the base; see Figure F-33. If the column is fixed at the base then the shear is calculated as M / (2L/3).

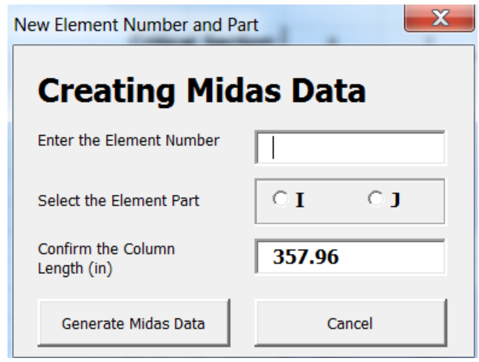
F.1 Obtaining transverse column forces.



Once the crossbeam tool has been run as usual with the additional negative moment and shear analysis points, the resulting dead loads and live loads to apply to the columns are located in the crossbeam results. To transform these loads into a format which is easily input into the loads tabs of any of the arch tools use the “XB to Midas” translator excel tool.

a) Click on the “Import XB Data” button; a dialog will prompt the user to select the crossbeam excel workbook and analysis sections, the tool then copies the total factored load, unfactored dead load, column length, and dead load factors. An additional table on the translator input then factors the dead load and subtracts it from the total load to obtain the factored live load force effects.

b) Click on the “Create Element Sheets” button; a dialog will prompt the user to enter an element number and part, and confirm the column length which is pre-filled using the crossbeam support length converted to inches.



c) Click “Generate Midas Data” to initiate the translation of the crossbeam forces into Midas style tables.

Multiple tables of column data can be created in the same translator workbook by importing new crossbeam loads and then clicking the “Create Element Sheets” button. The translator workbook does not allow multiple sheets with the same element name and part; if this occurs, the program will ask the user to enter a different element name or part. The translator tool also has a “Summary” tab with a “Refresh Summary” button at the top. By clicking the “Refresh Summary” button all the load data for each column sheet in the workbook will be copied to the summary tab to allow the user to select and copy all the column load data at once.

F.2 Performing the load rating for columns in transverse direction.

Copy the translated data to any of the arch load rating tools (steel, concrete, or general) in the appropriate force effect tabs: Moment, Shear, and Axial. The load rating tools can then be operated as usual with two important distinctions:

- The live loads are already factored by the crossbeam tool; therefore, all Live Load Factors, Distribution Factors, and Impact should be set to 1.0 in the load rating tool.
- Pay careful attention to the use of appropriate section properties. For example, I_x vs. I_y, or height vs. length of an element as the load rating tool default equations are setup assuming element properties from the X-Z plane of a Midas model.

APPENDIX G – ARCH ANALYSIS FOR LONG TERM EFFECTS (CREEP & SHRINKAGE)

AASHTO MBE 6A.5.10 states that "Typically, temperature, creep, and shrinkage effects need not be considered in calculating load ratings for components that have been provided with well-distributed steel reinforcement to control cracking. *These effects may need to be considered in the strength evaluation of long span, framed, and arch bridges.*" (emphasis added)
Time dependent analysis may be performed in Midas Civil using the Construction Staging analysis control with or without inclusion of secondary forces (creep and shrinkage). A model which is Construction Staged for other purposes, such as changes in boundary conditions with time, may or may not also include automated generation of time-dependent creep or shrinkage forces.

G.1 Determining whether to include long-term effects.

For arch load rating, the effect of long-term creep and shrinkage has been investigated and the following procedure for determining whether to evaluate long-term secondary effects is recommended:
A time dependent analysis for consideration of secondary forces per section 1.2 is warranted if:

- The arch bridge is complex in some way that requires full 3D modeling.
- The arch bridge is prestressed or post-tensioned.
- The arch bridge is historic construction with low material strengths and spandrel columns which are not hinged (keyed) to relieve longitudinal column moment.

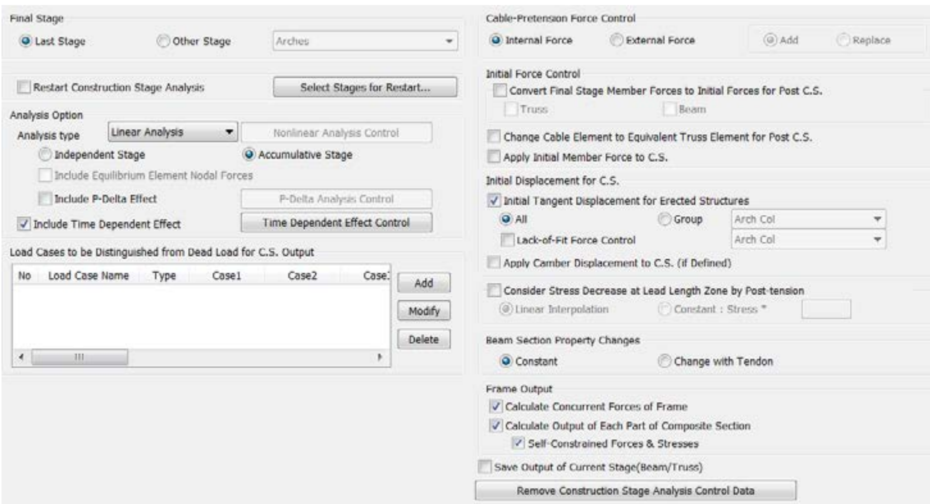
Secondary forces may be disregarded if:

- The arch is of modern construction (modern material strengths and detailing) and not prestressed or post-tensioned.
- The arch bridge is of historic construction but details hinged spandrel columns.

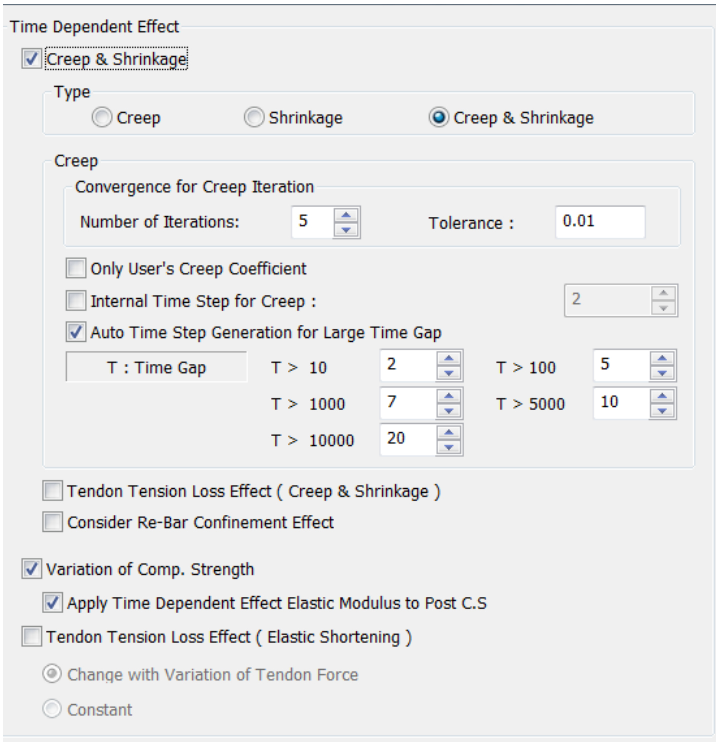
G.2 Procedure for evaluating long-term effects.

Perform the following steps if a time dependent analysis of the arch bridge model with consideration of secondary forces is warranted.

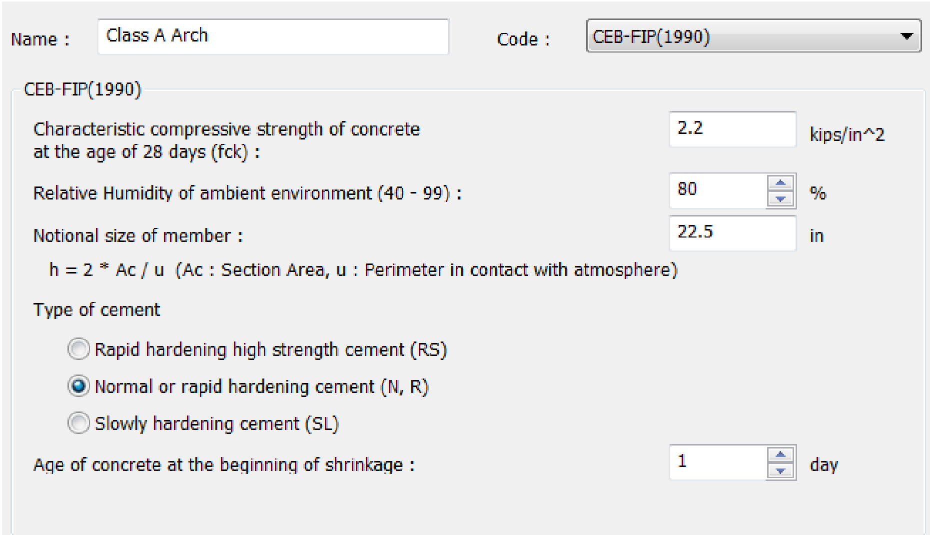
1. Set up a Construction Staged analysis with model stages as appropriate (boundary conditions, elements, and loads activation/deactivation).
2. Ensure the following options are selected from the Construction Stage Analysis control:



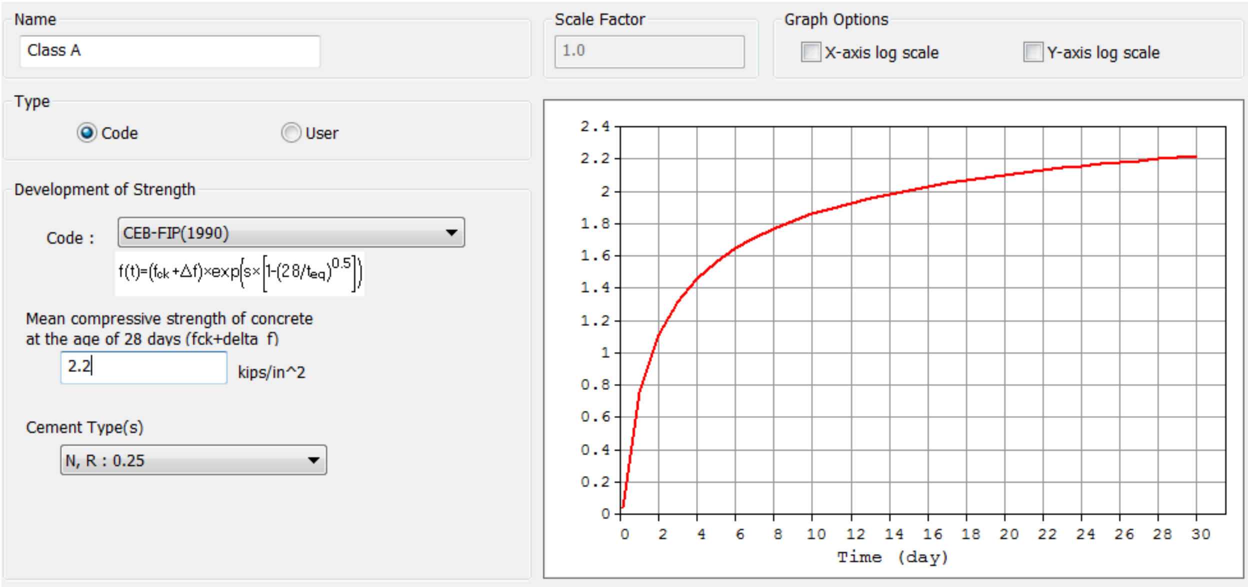
3. Ensure the following options are selected from the Time Dependent Effect Control:



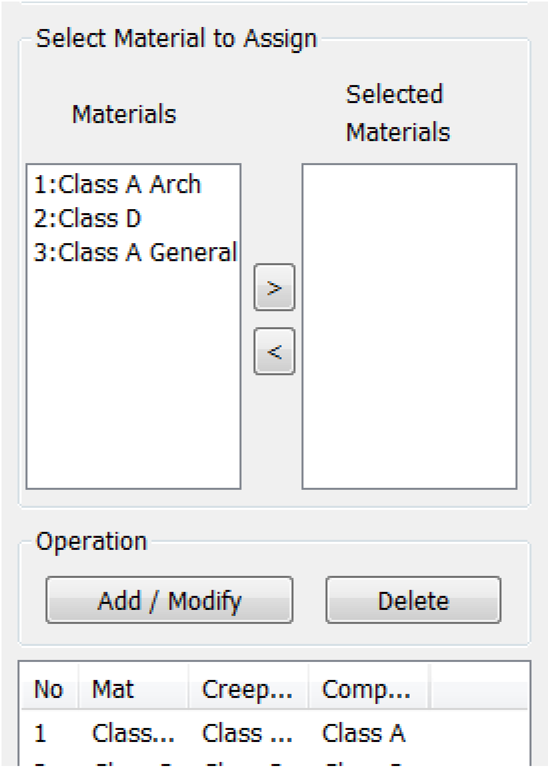
4. Set up a Time Dependent Material. The CEB-FIP (1990) creep and shrinkage model is recommended since the AASHTO LRFD creep and shrinkage model produce inaccurate results for the low strength concrete that is typical of historic arch bridges. Other time dependent material models may be used based on engineering judgement.
    a. Characteristic compressive strength of the concrete (fck) is the same as the concrete compressive strength (f'c).
    b. Relative Humidity may be determined from AASHTO Fig 5.4.2.3.3-1.
    c. For CEB-FIP, the notional size of member is the volume-to-surface ratio of the element multiplied by two (2).



5. Set up a Time Dependent Material Compressive Strength. A compressive strength model which matches the creep/shrinkage model is recommended.



6. Link the time dependent material properties; this enables the Midas Construction Staging analysis engine to activate and apply the time dependent material properties.

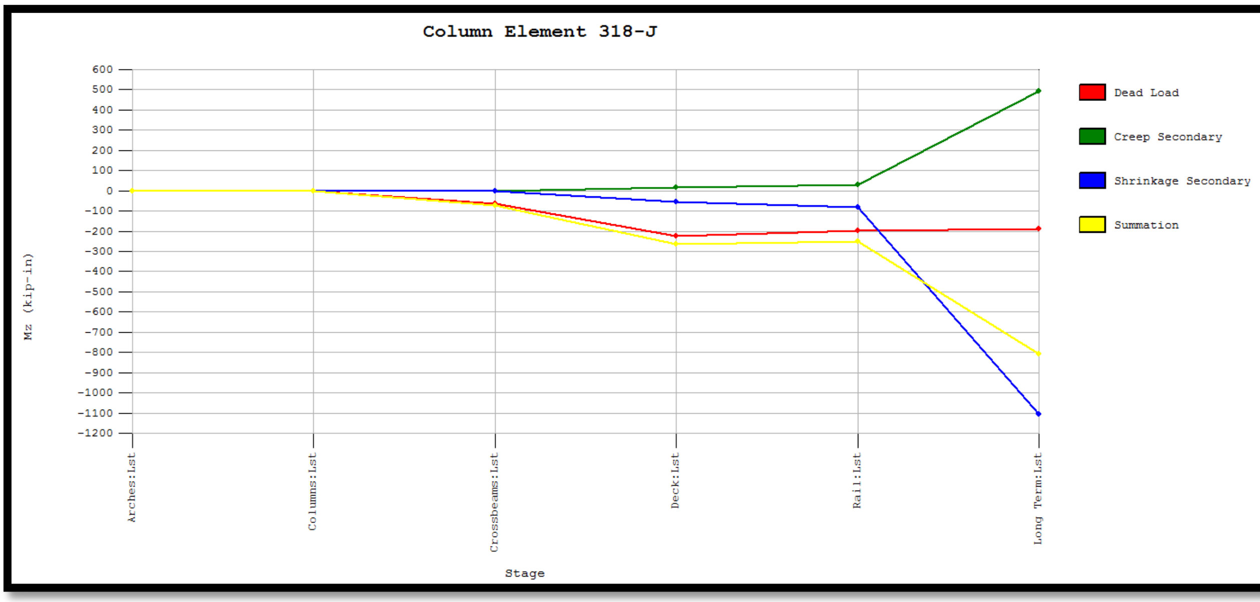


7. Add a construction stage at the end of all other stages which is long enough to capture long-term effects, 10000 days is recommended.

8. Run the Construction Stage analysis and review the results.

a. Particular attention should be paid to the review of spandrel column forces. Differential movement of the arch ribs vs. the deck/superstructure from long-term effects may induce large forces in the spandrel columns.

b. In cases where a historic bridge has spandrel columns with small cross-sections, lightly reinforced, and not hinged by design, the moments which develop from long-term secondary forces are likely to exceed the moment capacity in some of the spandrel columns. If load rated for this condition, the analysis would result in a negative rating. The following diagram shows moment in a spandrel column which increases with time (construction stages) due to secondary forces. These are unfactored moments and the capacity of this column is roughly 1000 kip-in. The summation of dead load, creep, and shrinkage at the end of the "Long Term" stage is nearly equal to the capacity of the section, there will be no reserve capacity for live load.



c. The physical reality of this situation is that cracks will form in the concrete and reinforcing steel will yield, which will relieve the bending moment force in the spandrel column (hinge). While this could be deemed to be a structural failure, this response does not necessarily limit or reduce the load carrying capacity of the structure. *Therefore, this low rating can be ignored provided the self-forming hinge is included in the model and activated at the time the forces exceed the capacity. The forces will then re-distribute in the model.*

d. Re-run the staged analysis with column hinges applied at the appropriate stage and then export forces and rate column and arch elements as specified elsewhere in this chapter.

9. The load cases for creep and shrinkage are taken from the Construction Stage results and may be either included in the DC combination as the Construction Stage "Summation" case or by creating a separate Load Combination in Midas called "Secondary" with "Creep Secondary" and "Shrinkage Secondary" terms specified as the load cases. Either method is processed correctly in the various arch load rating spreadsheets.

APPENDIX H – ODOT STANDARD RAIL WEIGHTS

SUMMARY OF ODOT STANDARD RAIL WEIGHTS

Revised 12/02/02

Dwg.	Wt, k/ft	Description:	Comment:
		RECENT STANDARD BRIDGE RAILS (ENGLISH OR METRIC SYSTEM)...	
BR200	0.335	Concrete Bridge Rail Type F	Same as Dwg 43495
BR206	0.163	2-tube Curb Mount Rail	Same as Dwg 43497
BR216	0.290	Sidewalk Mounted Combination Bridge Rail	Same as Dwg 50507
BR220	0.290	Flush Mounted Combination Bridge Rail	Same as Dwg 50508
BR226	0.061	2-tube Side Mount Rail	Same as Dwg 50494
BR233	0.035	Thrie-Beam Rail	Same as Dwg 43542
BR240	0.279	Protective Fencing, type "A" section, w/comb. Rail	Same as Dwg 50810
BR240	0.095	Protective Fencing, type "B" section, w/small curb	Same as Dwg 50810
BR240	0.261	Protective Fencing, type "C" section, w/type F rail	Same as Dwg 50810
BR246	0.314	Pedestrian Rail	Same as Dwg 34959
BR250	0.025	Pedestrian Rail on Concrete Parapet	Same as Dwg 46610
BR253	0.304	Chain Link Fencing on Concrete Parapet	Same as Dwg 47204
BR256	0.348	Pedestrian Rail on Type F Concrete Rail	Same as Dwg 47168
BR260	0.339	Chain Link Fencing on Type F Concrete Rail	Same as Dwg 43855
BR263	0.512	Concrete Median Barrier	Same as Dwg 42807
BR266	0.041	Thrie-Beam Rail Retrofit for Curb & Parapet Rail	Same as Dwg 47646
BR280	0.338	Type "F" Concrete Rail Repl. of Existing Parapet Rail	
BR283	0.249	Type "F" Concrete Rail Retrofit of Existing Parapet Rail	Same as Dwg 49061
BR286	0.098	Retrofit for Standard Steel Handrail with Sidewalk	Same as Dwg 50030
BR290	0.518	3'-6" Type "F" Concrete Bridge Rail	Now discontinued
		RECENT STANDARD BRIDGE RAILS...	
61118	0.405	Tall concrete "F" Rail	
50810	0.072	Protective Fencing, type "B" section, w/curb	includes curb, not sidewalk
50810	0.020	Protective Fencing, type "A" section, no curb	
50508	0.280	Flush Mounted Combination Rail, 3'-6" high	
50508	0.290	Flush Mounted Combination Rail, 4'-6" high	
50507	0.280	Sidewalk Mounted Combination Rail, 3'-6" high	
50507	0.290	Sidewalk Mounted Combination Rail, 4'-6" high	
50494	0.061	2-tube Side Mount Rail	
50030	0.098	Retrofit for Standard Steel Handrail with Sidewalk	excludes existing rail & curb
49061	0.249	Type "F" Conc. Rail Retrofit of Exist. Parapet w/3" curb proj.	excludes existing parapet & curb
49061	0.220	Type "F" Conc. Rail Retrofit of Exist. Parapet w/6" curb proj.	excludes existing parapet & curb
49061	0.275	Type "F" Conc. Rail Retrofit of Exist. Parapet w/1'-6" curb proj.	excludes existing parapet & curb
47646	0.041	Thrie-Beam Rail Retrofit for Curb & Parapet Rail	excludes existing curb & parapet
47204	0.304	Chain Link Fencing on Parapet	
47168	0.348	Pedestrian Rail on Type "F" Concrete Rail	
46610	0.314	Pedestrian Rail on Concrete Parapet	
43855	0.339	Chain Link Fencing on Type "F" Conc. Rail	
43542	0.035	Thrie-Beam Rail	
43498	0.153	3-tube Curb Mount Rail	includes curb, not sidewalk
43497	0.163	2-tube Curb Mount Rail	includes curb, not sidewalk
43495	0.335	Concrete Bridge Rail Type F	
43444	0.029	Metal Rail with Tubing (side-mounted)	
42807	0.512	Concrete Median Barrier	includes 1" grout
40790	0.058	Protective Fencing, type "B" section, w/curb	includes curb, not sidewalk
40790	0.020	Protective Fencing, type "A" section, no curb	
34959	0.025	Pedestrian Rail	

APPENDIX H – ODOT STANDARD RAIL WEIGHTS (Continued)

Dwg.	Wt, k/ft	Description:	Comment:
		"HISTORIC" STANDARD BRIDGE RAILS...	
42724	0.335	Concrete Bridge Rail Type F	
42563	0.377	Concrete Bridge Rail Type F	
42562	0.312	Concrete Parapet with Chain Link Fencing	
42561	0.310	Concrete Parapet with Metal Railing	
39854	0.031	Details for Permanent Pile Trestle Bridges	
38640	0.329	Concrete Bridge Rail	
35269	0.165	3-tube Curb Mount Rail	includes curb, not sidewalk
35268	0.033	Side mount 5" Str. Tubing Rail (2 tubes)	
34959	0.021	Pedestrian Rail	
34610	0.036	5" Struct. Tubing Rail (2 tubes), Slab Mounted	
34610	0.173	5" Struct. Tubing Rail (2 tubes), Curb Mount	includes curb, not sidewalk
33500	0.027	Metal Rail with Tubing 2'-4.5" Mount Height	
33258	0.026	Metal Rail with Tubing 1'-9" Mounting Height	
33053	0.052	4-Tube Square Tubing Rail for Side Mounting	
31896	0.052	4-Tube Square Tubing Rail, Metric	
31755	0.134	Curbed 3-tube Rectangular Tubing Rail	includes curb, not sidewalk
31754	0.100	Curbed 3-Tube Oblong Tubing Rail	includes curb, not sidewalk
30276	0.043	3-tube Square Tubing Rail for Side Mounting	
30069	0.042	3-tube Square Tubing Rail for Top Mounting	
28610	0.209	2-tube Rectangular Tubing Rail	includes curb, not sidewalk
27214	0.021	Pedestrian Rail	
27155	0.445	Parapet Rail Type G	
26047	0.457	Std. Median Barrier on Structure	
24992	0.021	Pedestrian Handrail	
24719	0.072	3-tube Aluminum Pedestrian Handrail	includes curb, not sidewalk
24293/4	0.439	1-pipe Parapet Rail Type G (assume steel)	
23937/8	0.421	1-pipe Parapet Rail Type G (assume steel)	
23670	0.048	3-tube Rectangular Tubing Rail	
23653	0.016	3-tube Oblong Tubing Rail (no curb)	
23610	0.209	2-tube Rectangular Tubing Rail	includes curb, not sidewalk
23603	0.185	2-tube Oblong Tubing Rail	includes curb, not sidewalk
23279	0.421	1-pipe Parapet Rail Type G (assume steel)	
23185	0.215	1-pipe Parapet Rail Type "C" (assume steel)	excludes wide curb/sidewalk
23185	0.411	1-pipe Parapet Rail Type "D" (assume steel)	includes brush curb
23018	0.225	2-pipe Parapet Rail (assume steel)	excludes wide curb/sidewalk
22856	0.015	Aluminum Pedestrian Rail	
22702	0.048	3-tube Rectangular Tubing Rail	
22701	0.210	2-tube Rectangular Tubing Rail	includes curb, not sidewalk
22638	0.020	Rectangular Tube Pedestrian Handrail	
22593	0.210	2-tube Rectangular Tubing Rail	includes curb, not sidewalk
22436	0.439	1-pipe Parapet Rail Type G (assume steel)	
22431	0.439	1-pipe Parapet Rail Type G (assume steel)	
22150	0.048	3-tube Rectangular Tubing Rail	
21976	0.225	2-pipe Parapet Rail (assume steel)	excludes wide curb/sidewalk
20653	0.453	Concrete Curb & Parapet	
20343	0.038	Pedestrian Handrail	
20342	0.225	2-pipe Parapet Rail (assume steel)	excludes wide curb/sidewalk
20341	0.215	1-pipe Parapet Rail Type "C" (assume steel)	excludes wide curb/sidewalk
20341	0.411	1-pipe Parapet Rail Type "D" (assume steel)	includes brush curb
20340	0.223	Concrete Parapet Rail Type "A"	excludes wide curb/sidewalk
20340	0.420	Concrete Parapet Rail Type "B"	includes brush curb
20301	0.215	1-pipe Parapet Rail (assume steel) Type "C"	excludes wide curb/sidewalk
19478	0.222	2-pipe Parapet Rail (assume steel) Type "A"	excludes curb/sidewalk
19478	0.561	2-pipe Parapet Rail (assume steel) Type "B"	includes safety curb
19477	0.549	Single Pipe Parapet Rail Plan "A" (with safety curb)	
19477	0.354	Single Pipe Parapet Rail Plan "B" (with brush curb)	

APPENDIX H – ODOT STANDARD RAIL WEIGHTS (Continued)

Dwg.	Wt, k/ft	Description:	Comment:
19476	0.506	Concrete Parapet Rail Plan "A"" (with safety curb)	
19476	0.308	Concrete Parapet Rail Plan "B" (with brush curb)	
18814	0.491	Single Pipe Parapet Rail Plan "A" (with safety curb)	
18814	0.354	Single Pipe Parapet Rail Plan "B" (with brush curb)	
18657	0.221	2-pipe Parapet Rail Type "A" (assume steel)	excludes wide curb/sidewalk
18657	0.495	2-pipe Parapet Rail Type "B" (assume steel)	includes safety curb
18542	0.295	Steel Handrail	includes curb
17368	0.221	2-pipe Parapet Rail Type "A" (assume steel)	excludes wide curb/sidewalk
17368	0.495	2-pipe Parapet Rail Type "B" (assume steel)	includes safety curb
17363	0.483	Pipe Parapet Handrail	includes safety curb
16127	0.226	2-pipe Parapet Rail Type "A" (assume steel)	excludes wide curb/sidewalk
16127	0.506	2-pipe Parapet Rail Type "B" (assume steel)	includes safety curb
15599	0.491	Conc. Parapet for Precast Slabs, Section D-D	
15599	0.282	Wood Post Rail for Precast Slabs, Section F-F	
15287	0.435	Concrete Handrail	
15250	0.350	Pipe Parapet Handrail	includes safety curb
14657	0.483	Pipe Parapet Handrail	includes safety curb
14656	0.445	Concrete Handrail Solid Type	
14654	0.458	Steel Handrail for Br's w/o Sidewalks	includes safety curb
14654	0.149	Steel Handrail for Br's w/ Sidewalks	includes small toe curb
13722	0.302	Concrete Handrail	
13610	0.297	Concrete Handrail without Curb	
13103	0.483	Pipe Parapet Handrail (assume steel)	includes safety curb
12763	0.709	Conc. Parapet for Std. Precast Beams	includes safety curb
12457	0.455	Aluminum Handrail for Br's w/o Sidewalks	includes safety curb
12457	0.146	Aluminum Handrail for Br's w/ Sidewalks	includes small toe curb
12085	0.410	Concrete Handrail	
11917	0.418	Concrete Handrail, Solid Type	
11207	0.418	Concrete Handrail, Solid Type	
10734	0.422	Concrete Handrail, Solid Type	
10664	0.405	Concrete Handrail, Solid Type	
10555	0.497	Conc. Rail for Standard 40' Rigid Frame	
10429	0.405	Concrete Handrail, Solid Type	
10219	0.162	Steel Handrail	excludes sidewalk
10169	0.405	Concrete Handrail, Solid Type	
B914	0.064	Metal Rail on Timber Structures	includes timber curb
9402	0.626	Steel Replacement Rails for Composite Handrail	
9233	0.367	Steel Handrail for Br's w/o Sidewalks	includes safety curb
9233	0.149	Steel Handrail for Br's w/ Sidewalks	includes small toe curb
8956	0.263	Steel Handrail (angles) for Br's w/o Sidewalks	includes safety curb
8956	0.095	Steel Handrail (angles) for Br's w Sidewalks	includes small toe curb
8840	0.364	Concrete Handrail, Low Type	includes safety curb
8417	0.367	Steel Handrail for Br's w/o Sidewalks	includes safety curb
8417	0.149	Steel Handrail for Br's w/ Sidewalks	includes small toe curb
8186	0.367	Steel Handrail	includes safety curb
8186	0.628	Concrete Handrail	includes double curb
8064	0.033	Rail for Standard Pile Trestle	excludes sidewalk
8018	0.628	Concrete Handrail	includes double curb
8018	0.144	Intermediate Curb	
7600	0.240	Timber Handrail for Br's w/o Sidewalks	includes safety curb
7600	0.135	Timber Handrail for Br's w/ Sidewalks	includes small toe curb
7044	0.149	Steel Handrail for Br's w Sidewalks	includes small toe curb
7044	0.255	Steel Handrail for Br's w/o Sidewalks	includes safety curb
7000	0.226	Concrete Handrail	
6818	0.165	Steel Handrail	includes toe curb
6535	0.226	Concrete Handrail (Rail Type) for Br's w/ Sidewalks	includes small toe curb

APPENDIX H – ODOT STANDARD RAIL WEIGHTS (Continued)

Dwg.	Wt, k/ft	Description:	Comment:
6535	0.354	Concrete Handrail (Rail Type) for Br's w/o Sidewalks	includes safety curb
6534	0.222	Concrete Handrail (Rail Type) for Br's w/ Sidewalks	includes small toe curb
6534	0.354	Concrete Handrail (Rail Type) for Br's w/o Sidewalks	includes safety curb
6517	0.029	Steel Handrail Type LB	
6481	0.114	Steel Handrail Type LA	includes toe curb, excludes sidewalk
6436	0.208	Steel Handrail Type KY for Br's w/o Sidewalks	includes safety curb
6436	0.127	Steel Handrail Type KY for Br's w/ Sidewalks	includes small toe curb
6416	0.159	Steel Handrail	includes toe curb
6313	0.359	Concrete Rail (w/ P/C spindles) for Br's w/ Sidewalk	includes safety curb
6313	0.237	Concrete Rail (w/ P/C spindles) for Br's w/o Sidewalk	includes small toe curb
5903	0.261	Concrete Handrail (Gothic Arches) (Br's w/sidewalks)	excludes sidewalk
5735	0.226	Concrete Handrail (Rail Type) for Br's w/ Sidewalks	includes small toe curb
5735	0.347	Concrete Handrail (Rail Type) for Br's w/o Sidewalks	includes safety curb
5155	0.024	Rail for Standard Pile Trestle	excludes sidewalk
5032	0.284	Concrete Handrail (Gothic Arches) (Br's w/sidewalk)	excludes sidewalk
4997	0.409	Concrete Handrail (Gothic Arches) (Br's w/o sidewalk)	includes safety curb
4788	0.073	Movable Span Handrail	excludes sidewalk
4519	0.297	Concrete & Timber Handrail	excludes sidewalk
4441	0.305	Timber Handrail (with spindles)	
4220	0.396	Conc. Handrail Type D (Roman Arches) (Br's w/o sdwk.)	includes safety curb
4210	0.279	Conc. Handrail Type D (Roman Arches) (Br's w/ sdwk.)	excludes sidewalk
4050	0.269	Conc. Handrail Type D (Roman Arches) (Br's w/ sdwk.)	excludes sidewalk
3813	0.264	Conc. Handrail Type C (Roman Arches) (Br's w/ sdwk.)	excludes sidewalk
3802	0.390	Conc. Handrail Type B (Roman Arches) (Br's w/o sdwk.)	includes safety curb
1532	0.354	Handrail - B (Concrete with precast "webs")	

APPENDIX I – RERATING LOAD POSTED BRIDGES FOR SHVs

U.S. Department of Transportation
Federal Highway Administration

Oregon Division

530 Center Street NE, Suite 420
Salem, Oregon 97301
503-399-5749
503-399-5838 (fax)
www.fhwa.dot.gov/ordiv

April 21, 2015

In Reply Refer To:
HAD.2-OR
File:
407.1

Bruce Johnson
State Bridge Engineer
Oregon Department of Transportation
4040 Fairview Industrial Dr SE
Salem, OR 97302

Subject: Rerating Load Posted Bridges for Specialized Hauling Vehicles

Dear Mr. Johnson:

We have reviewed your request not to require bridges with a single load posting of 15 tons or less to be rerated for Specialized Hauling Vehicles (SHVs) and the supporting documentation contained in ODOT's parametric study report, *Load Comparison for Posted Bridges*. We have found that the parametric study provides a logical analysis and reasonable conclusions to support the request and the proposed approach will reduce the number of bridges needing to be re-rated for AASHTO SHVs (SU4 – SU7); screening out those low capacity bridges where AASHTO SHVs won't control the posting, thereby reducing workload and at the same time ensuring safety will not be compromised.

We are approving ODOT's request to not require re-rating for AASHTO SHVs, i.e., SU4 to SU7, for bridges already posted at a gross weight of 15 tons or less. However, this approval is contingent on:

1. The bridge has a valid load rating determined by one of the AASHTO recognized load rating methods;
2. The load rating of the bridge is consistent with the current structural and loading conditions, and AASHTO Routine Commercial Traffic Legal Loads, i.e. Type 3, 3S2 and 3-3 have been rated for this bridge;
3. The safe posting load shown on the posting sign does not exceed the operating rating of AASHTO Type 3 vehicle; and
4. Documentation is essential to meet the NBIS requirement. It is required that the analysis is documented in the bridge's load rating file and the proposed approach be documented in ODOT's load rating procedures manual. Should improvements be made to the bridge to raise the posting limit sometime in the future, the procedures should ensure the SHV loadings are evaluated at that point.

APPENDIX I (Continued) – RERATING LOAD POSTED BRIDGES FOR SHVs

If you have any questions or require further clarification regarding this approval, please contact me at 503-316-2564 or email timothy.rogers@dot.gov.

Sincerely,

Timothy Rogers
Bridge Engineer

Cc: ODOT (Bert Hartman, Bridge Program Unit Manager)
(Jon Rooper, Senior Load Rating Engineer)

APPENDIX J – LOAD COMPARISON FOR POSTED BRIDGES

OREGON DEPARTMENT OF TRANSPORTATION
BRIDGE ENGINEERING SECTION

LOAD COMPARISON FOR POSTED BRIDGES

COMPARISON OF BRIDGE LOAD EFFECTS BETWEEN A TYPE 3 LEGAL VEHICLE AND A SU4 LEGAL VEHICLE AT A 20 TONS POSTED LOAD LIMIT

BY: JON ROOPER, P.E.

FEBRUARY, 2015

4040 FAIRVIEW INDUSTRIAL DRIVE SE, MS #4
SALEM, OREGON 97302

APPENDIX J (Continued) – LOAD COMPARISON FOR POSTED BRIDGES

LOAD COMPARISON FOR POSTED BRIDGES

COMPARISON OF BRIDGE LOAD EFFECTS BETWEEN A TYPE 3 LEGAL VEHICLE AND A SU4 LEGAL VEHICLE AT A 20 TONS POSTED LOAD LIMIT

INTRODUCTION

Specialized Hauling Vehicles (SHVs) are described as single unit trucks having closely-spaced multiple axles, often with lifting or articulating axles. SHVs are often used in construction, waste management, bulk cargo and commodities hauling industries. These truck configurations are designed to comply with the Federal Bridge Formula B (Formula B), established by Congress in 1975. SHVs were designed to maximize the weight that could be carried on a vehicle while still operating as "legal" trucks and thereby not require a permit to operate on the highway system. The optimization of vehicles described as SHVs produces heavy 4-axle, 5-axle, 6-axle, and 7-axle loads over a short length. As a result, while satisfying Formula B, SHVs can produce load effects such as bending moment and shear on some bridge spans that are larger than those from standard legal vehicles such as the Type 3, 3-3, and 3S2.

Recognizing the increased load effects (bending moment and shear) that can be produced by SHVs on some bridge types and spans, the Federal Highway Administration (FHWA) issued a Memorandum, called HIBT-10 (shown in Appendix A), clarifying analysis, rating, and posting bridges for SHVs to comply with the requirements of the National Bridge Inspection Standards (NBIS). HIBT-10 divided all bridges into two groups: Group 1 - bridges with spans less than 200 feet with legal load (Type 3, Type 3S2 or Type 3-3) rating factors less than 1.3, and Group 2 –bridges not in Group 1. Group 1 bridges should be re-rated after their next NBIS inspection, but not later than December 31, 2017. Group 2 bridges should be rated not later than December 31, 2022.

There are 31 bridges in Oregon that currently have a single-load posting of 20 tons or less. The Oregon DOT has requested approval by FHWA for these bridges to be exempt from having to be re-rated since Specialized Hauling Vehicles would not control on these bridges since they also have to adhere to the single-load posting limits that are signed and enforced at each of these structures. FHWA is in disagreement with this assumption, therefore this study was performed to evaluate the load effects of a Type 3 legal vehicle and a four axle SU4 vehicle both adhering to a 20 tons load posting on bridge spans ranging from 10 feet to 180 feet. The intent is to prove that the load effects are essentially the same for these two vehicles at the 20 tons posted load limit. Thus, reinforcing the Oregon DOT's decision to not require that bridges with a load posting of 20 tons or less be re-load rated for SHVs.

VEHICLE MODELS

The standard vehicle models do not represent a specific vehicle, but instead were developed to model the extreme loading effects of single-unit vehicles. The Type 3 legal vehicle is a three axle vehicle with a gross weight of 50,000 LBS. (25 tons). Figure 1 shows the vehicle model for the Type 3 truck.

APPENDIX J (Continued) – LOAD COMPARISON FOR POSTED BRIDGES

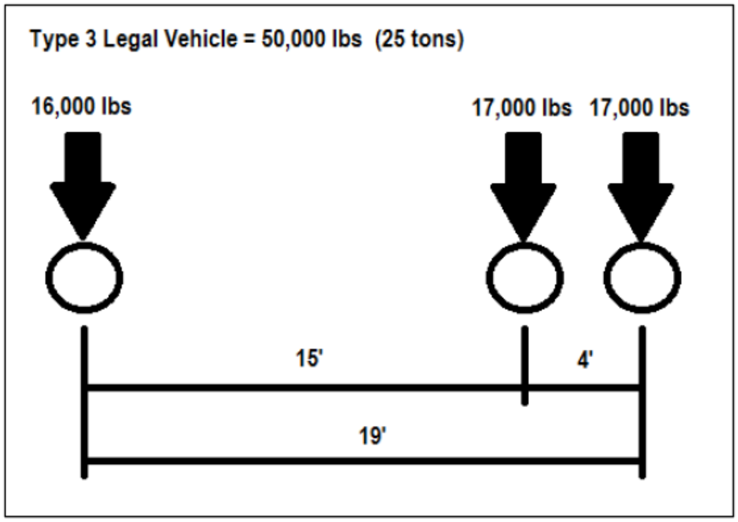


Figure 1

The SU4 legal vehicle is a four axle vehicle with a gross weight of 54,000 LBS. (27 tons). Figure 2 shows the vehicle model for the SU4 truck.

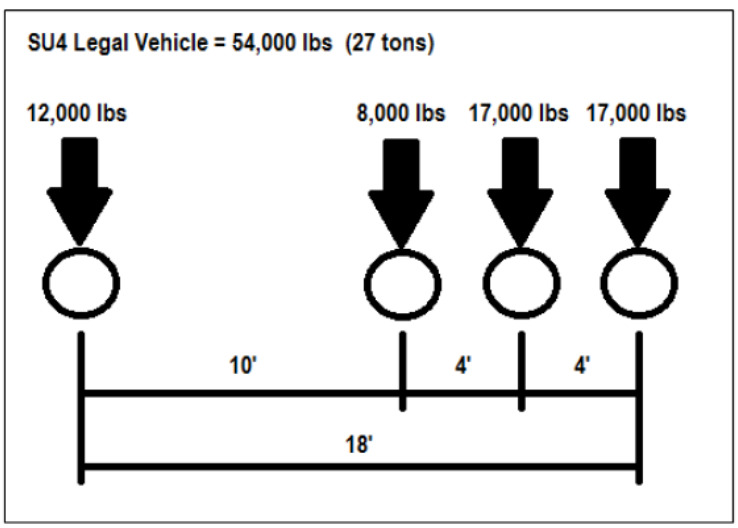


Figure 2

3

APPENDIX J (Continued) – LOAD COMPARISON FOR POSTED BRIDGES

The first task was to identify what the Type 3 and SU4 axle weights would be at a 20 tons load limit. Understanding that different vehicles will have different unloaded and loaded axle weights, we started out by measuring the empty weight of an ODOT maintenance dump truck in order to get a general idea of what a typical vehicle would weigh while empty. The ODOT dump truck that we measured is shown in Figure 3.

Figure 3

The axle spacings of this vehicle were physically measured and then we had the driver go through a nearby ODOT weigh station to accurately measure the axle weights. The axle weights and spacing of this empty dump truck are shown in Figure 4.

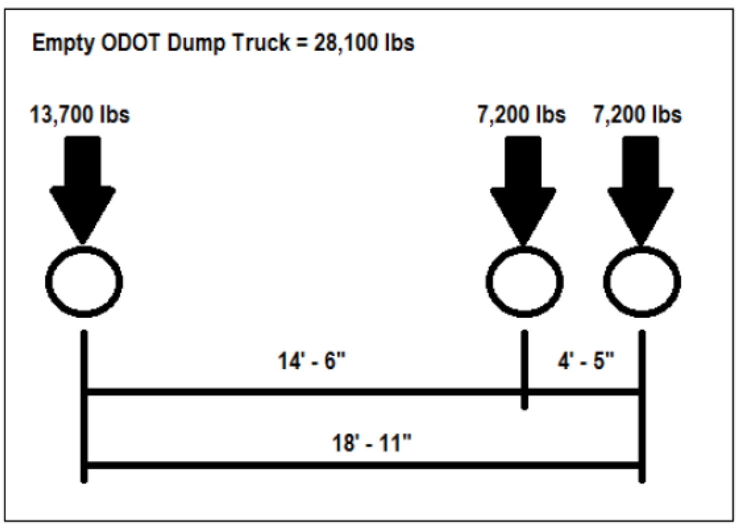


Figure 4

4

APPENDIX J (Continued) – LOAD COMPARISON FOR POSTED BRIDGES

We then had the driver load the dump truck half full with gravel and go through the weigh station again to measure the axle weights. Figure 5 shows the axle weights of this dump truck with a half load of gravel.

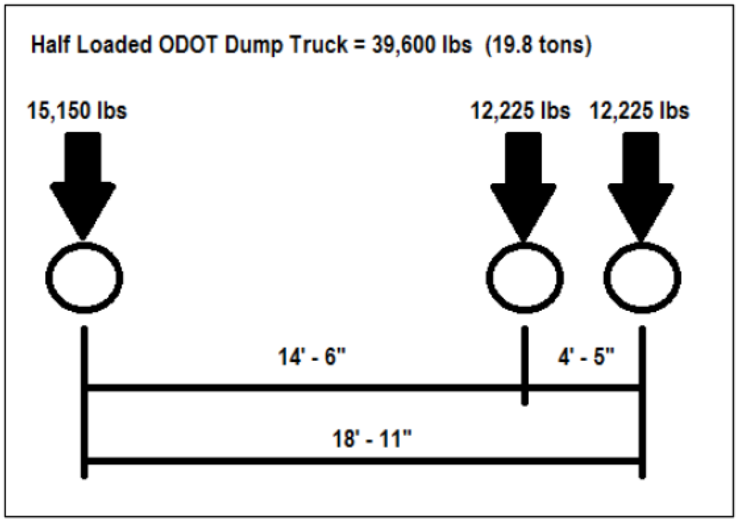


Figure 5

Since the half loaded ODOT dump truck nearly weighs 20 tons, the Type 3 vehicle model will have its axle weights adjusted to match, with the exception of increasing axles two and three by 200 LBS. so that the gross vehicle weight will equal 20 tons exactly. Figure 6 illustrates the modified Type 3 vehicle that will be used in this study.

It is understood that under real world conditions, there would be no reason to operate a SU4 vehicle with the lift axle in the down position when the vehicle is restricted to 20 tons. Most operators prefer to drive their vehicles with the lift-axles raised when they are not needed as it reduces tire wear on those axles and increases maneuverability of the vehicle. With the lift axles in the up position, the vehicle configuration nearly matches the Type 3 vehicle.

For this study, we will assume that the SU4 vehicle is being operated with the lift axle in the down position; supporting 8,000 LBS. For the steer axle of the modified SU4 vehicle that will adhere to a 20 tons load posting, we will use the same weight ratio of the Modified Type 3 Vehicle to the Standard Type 3 Vehicle.

$$\frac{x}{12{,}000\,\mathrm{LBS}} = \frac{15{,}150\,\mathrm{LBS}}{16{,}000\,\mathrm{LBS}} \qquad x = 11{,}360\,\mathrm{LBS}$$

With 11,360 LBS. for the steer axle and 8,000 LBS. being supported by the lift axle, the remaining 20,640 LBS. will be supported equally by the remaining two axles. Figure 7 illustrates the modified SU4 vehicle that will be used in this study.

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APPENDIX J (Continued) – LOAD COMPARISON FOR POSTED BRIDGES

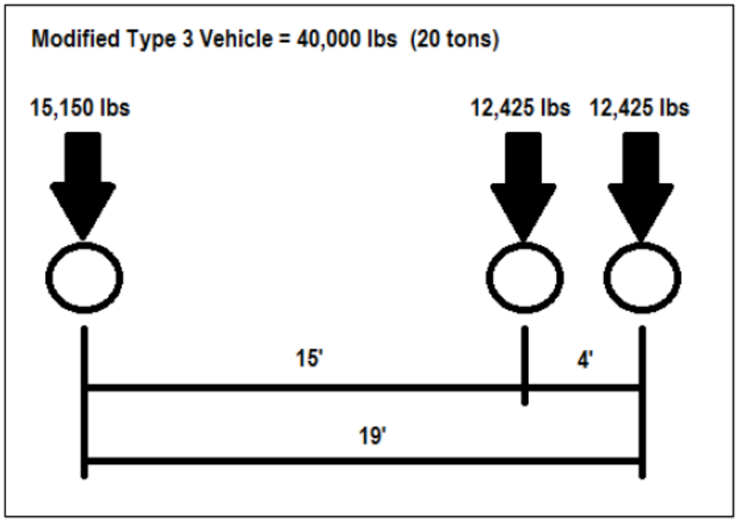

Figure 6

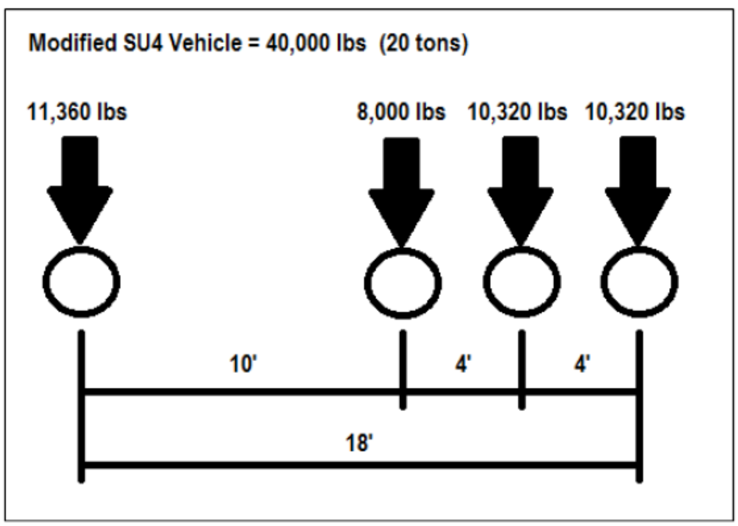

Figure 7

6

APPENDIX J (Continued) – LOAD COMPARISON FOR POSTED BRIDGES

ANALYSIS OF LOAD EFFECTS

Using Midas Civil 2015, the unfactored live load shear and moment for the Modified Type 3 and Modified SU4 vehicles were analyzed for simple span lengths ranging from 10 feet to 180 feet. The following table provides the results of this analysis:

	Type 3 Modified		SU4 Modified		SU4 Effects Greater Than Type 3	
Span Length (ft)	Unfactored Shear (kips)	Unfactored Moment (ft*kips)	Unfactored Shear (kips)	Unfactored Moment (ft*kips)	Shear	Moment
10	23.86	45.45	21.73	41.95	-8.93%	-7.70%
11	24.40	52.19	22.88	50.55	-6.23%	-3.14%
12	24.85	59.64	23.84	59.14	-4.06%	-0.84%
13	25.23	67.1	24.65	67.73	-2.30%	0.94%
14	25.56	74.55	25.34	76.32	-0.86%	2.37%
15	25.84	82.01	25.95	84.91	0.43%	3.54%
16	26.09	89.46	26.47	93.51	1.46%	4.53%
17	26.31	96.92	26.94	102.1	2.39%	5.34%
18	26.51	104.37	27.35	110.69	3.17%	6.06%
19	26.68	111.83	28.44	119.28	6.60%	6.66%
20	27.75	119.28	29.41	127.87	5.98%	7.20%
21	28.71	126.74	30.30	136.47	5.54%	7.68%
22	29.59	134.19	31.10	145.06	5.10%	8.10%
23	30.39	141.65	31.84	153.65	4.77%	8.47%
24	31.12	149.1	32.51	162.24	4.47%	8.81%
25	31.80	156.56	33.13	170.83	4.18%	9.11%
26	32.42	164.01	33.70	179.42	3.95%	9.40%
27	33.00	171.47	34.23	188.02	3.73%	9.65%
28	33.53	178.92	34.72	196.61	3.55%	9.89%
29	34.03	186.38	35.18	208.61	3.38%	11.93%
30	34.50	193.83	35.61	220.61	3.22%	13.82%
32	35.34	217.83	36.38	244.61	2.94%	12.29%
34	36.09	241.83	37.07	268.61	2.72%	11.07%
36	36.75	265.83	37.67	292.61	2.50%	10.07%
38	37.34	289.83	38.22	316.61	2.36%	9.24%
40	37.87	313.83	38.71	340.61	2.22%	8.53%
42	38.36	337.83	39.15	364.61	2.06%	7.93%
44	38.79	361.83	39.55	388.61	1.96%	7.40%
46	39.19	385.83	39.92	412.61	1.86%	6.94%
48	39.56	409.83	40.26	436.61	1.77%	6.53%
50	39.90	433.83	40.57	460.61	1.68%	6.17%

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APPENDIX J (Continued) – LOAD COMPARISON FOR POSTED BRIDGES

	Type 3 Modified		SU4 Modified		SU4 Effects Greater Than Type 3	
Span Length (ft)	Unfactored Shear (kips)	Unfactored Moment (ft*kips)	Unfactored Shear (kips)	Unfactored Moment (ft*kips)	Shear	Moment
52	40.21	457.83	40.85	484.61	1.59%	5.85%
54	40.50	481.83	41.12	508.61	1.53%	5.56%
56	40.77	505.83	41.36	532.61	1.45%	5.29%
58	41.02	529.83	41.59	556.61	1.39%	5.05%
60	41.25	553.83	41.80	580.61	1.33%	4.84%
70	42.21	673.83	42.69	700.61	1.14%	3.97%
80	42.94	793.83	43.35	820.61	0.95%	3.37%
90	43.50	913.83	43.87	940.61	0.85%	2.93%
100	43.95	1033.83	44.28	1060.61	0.75%	2.59%
120	44.62	1273.83	44.90	1300.61	0.63%	2.10%
140	45.11	1513.83	45.34	1540.61	0.51%	1.77%
160	45.47	1753.83	45.68	1780.61	0.46%	1.53%
180	45.75	1993.83	45.93	2020.61	0.39%	1.34%

CONCLUSIONS

Based on the tabulated results presented in the previous section, it is apparent that the Modified SU4 vehicle still produces greater load effects than the Modified Type 3 vehicle. Therefore these results dispute the Oregon DOT's initial argument that Specialized Hauling Vehicles would not control on bridges with a single load posting of 20 tons or less.

However, the vehicle weight of the empty ODOT dump truck that is shown in Figure 4 is just over 14 tons. The statistical probability of a SHV operating with the lift axle(s) in the down position while it is empty (or nearly empty) is extremely low. These vehicles would have their lift axles disengaged (in the up position), which would make them fall under the Type 3 vehicle model for load posting.

Since it does not make sense to load rate for a class of vehicles where the empty weight of the vehicle is equal or more than the posted load limit of a bridge, the Oregon DOT will seek approval from FHWA to not require bridges with a single load posting of 15 tons or less to be re-rated for SHVs. Following this approach will only require two bridges to be re-rated for SHVs out of the 31 that have been identified as having a single load posting of 20 tons or less.

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