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# BRIDGE DESIGN MANUAL

SECTION 1: DESIGN STANDARDS

BRIDGE ENGINEERING SECTION

OREGON DEPARTMENT OF TRANSPORTATION

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Note: Revisions for **Spring 2022** are marked with **yellow highlight**. Deleted text is not marked; past editions of the BDM are available on the Bridge Engineering Section website for comparison.

# 1.1 Introduction

*BDM Section 1* contains standards and practices pertinent to highway bridges and structures design.

See *BDM Section 2* for design guidance pertinent to highway bridges and structures design.

See *BDM Section 3* for standards and practices pertinent to design procedures and quality processes for completing highway bridge and structure design.

See *Bridge CAD Manual (BCM)* for standards and practices pertinent to detailing of highway bridges and structures.

## 1.2 Bridge Design, General

### [1.2.1 Bridge Design Standards](#)

### [1.2.2 Bridge Design Deviations](#)

### [1.2.3 Bridge Design Deliverables](#)

### [1.2.4 Bridge Design Procedures](#)

## 1.2.1 Bridge Design Standards

### 1.2.1.1 Standard Specifications and Standard Drawing Manuals

- *LRFD Bridge Design Specifications (9th Edition, 2020)* published by the American Association of State Highway and Transportation Officials (AASHTO).
- *AASHTO Guide Specifications for LRFD Seismic Bridge Design (2nd Edition, 2011 with 2012, 2014 and 2015 interims)*.
- *AASHTO Guide Specifications for Seismic Isolation Design, 4<sup>th</sup> Edition (2014)*
- *AASHTO LRFD Guide Specifications for Accelerated Bridge Construction (1st Edition, 2018)*.
- *LRFD Guide Specifications for the Design of Pedestrian Bridges (2nd Edition, December 2009 with 2015 interims)* published by AASHTO.
- *Manual for Railway Engineering of the American Railway Engineering and Maintenance-of-Way Association (AREMA)* as modified by the individual requirements of each railroad company.
- *Oregon Standard Specifications for Construction*, published by ODOT and pertinent special provisions (for all construction except bridges carrying railways).
- *Oregon Standard Drawings*, published by Oregon Department of Transportation, Standards Engineer.

*The International Building Code (IBC)* as adopted by Oregon does not apply to structures within a public right of way, such as bridges, culverts, retaining walls, traffic structures, signals, sound walls, or railings. Ref: *Oregon Structural Specialty Code, Section 101.2.1 General*

### 1.2.1.2 Use of Oregon Standard Drawing and Standard Details

The Standard Drawings and Standard Details prepared by ODOT have been developed through a long history of collaboration with Oregon contractors and fabricators. Consider impacts to both when making modifications.

Use Oregon Standard Drawings without significant change, as determined by the drawing Engineer of Record. Where a significant change to a standard drawing is needed, submit a design deviation request to the State Bridge Engineer. Where an equivalent ODOT Standard Drawing or accompanying design detail exists, do not use Standard Drawings or design details

from another state or agency without approval of a design deviation from the State Bridge Engineer.

The standard details do not include the seal of the [technical owner](#). The designer or the Engineer of Record (EOR) is responsible for sealing the contract plans with the standard details, and the design calculations which is specific to the project where the standard details are used.

## 1.2.2 Bridge Design Deviations (DD) and Roadway Design Exceptions (DE)

The bridge design field is an art that is constantly changing. It is understood that designers will occasionally use innovative details or methods that differ from those contained in this manual and on the standard drawings. Designers having experience in other states may also want to introduce details and methods which have worked well in those states. In addition, context-sensitive design requires the exercise of engineering judgement and sometimes leads to details or methods that satisfy the intent of this manual or the standard drawings, but do not meet the **letter** of these documents.

**Submit a request for a Design Deviation according to the process below before replacing an established drawing or method from this manual.** This includes design methods or details established in other states, presented in research reports, or developed by designers. Engineers are encouraged to exercise good engineering judgment, which may result in innovative solutions, including new materials or techniques. Design Deviations allow the opportunity for these ideas to be documented and shared, potentially resulting in revisions to standard practice in the *BDM*.

In cases where a Standard Drawing or *BDM* design requirement is not applicable to the project circumstances and must be modified, a Design Deviation is necessary. This commonly occurs to meet a project goal, incorporate new technology or to meet a technical requirement e.g. significant modification to accommodate project geometry; ADA requirements; any modified attachments; existing elements; Local Agency standards; or aesthetics. Modifications made in these instances cannot be based on preference or economy. They must be justified by structure geometry, configuration, constructability, and intended purpose. Use a Standard Drawing when it satisfies the need. When modifying a Standard Drawing, comply with appropriate design specifications (*LRFD*, *BDM*, etc.) to the fullest extent possible.

Modifications to Standard Drawings on repair and rehabilitation projects do not require Design Deviations, except on bridge rail drawings or when new design techniques or materials are used. This is due to the often unique needs and project specific circumstances on rehab and repair projects. These projects must still comply with *LRFD* and *BDM* design requirements or a design deviation is necessary. The Bridge Reviewer should devote extra attention to modified drawings and raise concerns to the Standard Drawing owner when appropriate.

Some elements of bridge work may require a Roadway Design Exception (refer to *ODOT Highway Design Manual Section 14* for more about Roadway Design Exceptions). All Design

Exceptions related to bridge rail must be signed by the State Bridge Engineer prior to approval by the State Roadway Engineer. In addition, when Design Exceptions involve structural work, such as sidewalk widening, the State Bridge Engineer is expected to concur. A Design Deviation is not required for project elements where a Design Exception is submitted. When it is unclear whether a Deviation or Exception is required, contact the relevant bridge [technical resource](#) as early in the design process as possible.

When the State Bridge Engineer needs to provide concurrence on a Roadway Design Exception, modify the Roadway Design Exception process as follows:

1. Complete the Roadway Design Exception Form. It will be necessary to get information from both Roadway and Traffic designers to complete the form. Contact the ODOT Design Exception Mailbox ([ODOTDesignExceptions@odot.oregon.gov](mailto:ODOTDesignExceptions@odot.oregon.gov)) to get a control number.
2. Add a **Concurred By** signature line for the State Bridge Engineer between the **ODOT Region Tech Center Manager or Region Roadway Manager** line and the **State Roadway Engineer** line.
3. Send a link to the draft Design Exception to the relevant bridge [technical resource](#) and all necessary Region resources, for review prior to signing.
4. After addressing comments, save the Design Exception as a PDF, create the necessary signature fields, and sign the file.
5. Submit a link to the file for Region signatures according to the appropriate Region process.
6. After Region signatures are complete, the Design Exception should be submitted to the ODOT Design Exception Mailbox for final processing. Depending on the Region, this step may be the responsibility of the designer.
7. The form will be sent to Bridge Section for the State Bridge Engineer's signature as part of final processing.
8. The submitter will be notified once signing of the Design Exception is complete.

### DESIGN DEVIATIONS

Prior to submitting a design deviation request, contact the relevant bridge [technical resource](#) for guidance. They can discern when a design deviation is necessary; an email inquiry about the proposed modification suffices for confirmation on whether a formal design deviation is necessary or not.

A design deviation form is available on the ODOT Bridge Engineering website. In the request, include a brief description of the project, an explanation of the issues, what is being proposed, a justification for the proposed deviation, and any supporting documents. The request may be submitted by email. Send deviation requests to both:

Ray Bottenberg, Interim State Bridge Engineer, [Raymond.D.BOTTENBERG@odot.oregon.gov](mailto:Raymond.D.BOTTENBERG@odot.oregon.gov)

Rebecca Burrow, Bridge Design Manual Standards Engineer, [Rebecca.Burrow@odot.oregon.gov](mailto:Rebecca.Burrow@odot.oregon.gov)

The request will be distributed to and evaluated by the BDM technical resources. The State Bridge Engineer makes the final decision to accept or reject a request for design deviation. A response to each request will be returned by email within 10 business days.

### TECHNICAL BULLETINS

When technical issues arise between scheduled BDM updates which require urgent distribution of guidance to the design community, a Technical Bulletin is issued. Check the ODOT Bridge Engineering web page for status of Technical Bulletins.

## 1.2.3 Bridge Design Categories

### 1.2.3.1 Bridge Design Categories, General

Bridge design categories determine the design criteria and requirements for projects on bridges. These categories include: Modernization, Retrofit, Preservation, or Maintenance.

For projects involving multiple bridges, determine the category per bridge. Bridge Program will complete an initial categorization at desk scoping, when possible. Validate the categorization during field scoping. For projects initiating outside Bridge Program, establish the bridge design category at field scoping. Contact the Bridge Design Manual Standards Engineer with questions regarding the bridge design category. Document the identified category in the Bridge Design Criteria. When project needs change after scoping, contact the Program Manager according to *BDM 3.9.5* prior to changing the design category for any bridge.

These categories operate independently from the roadway design standards identified in the *Highway Design Manual 1.3.2.2*. A project involving bridges will have both a roadway design standard and at least one bridge design category. For projects initiating outside of Bridge Program, the bridge design category may be based on the work required by the roadway design standard; however the bridge design category must still be determined.

The design requirements governed by these categories include:

- The level of alternatives analysis required and type of documentation, i.e.:
  - Bridge TS&L Report.
  - Bridge Strategy Memo.
  - Bridge Design Criteria and Standards Assessment (DCSA).
- The extent of bridge rail work.
- The level of seismic retrofit.
- The amount of Bridge Section review required.

Roadway design standards and other agreements govern work outside of the bridge footprint, including approach slabs, drainage features and bridge rail transitions.

### **1.2.3.2 Bridge Modernization**

The bridge modernization design category applies to the following project types:

- New bridge construction.
- Bridge replacement.
- New bridge deck or superstructure.
- Phase 2 seismic retrofit projects.
- Bridge widening requiring the addition of one or more girder lines.

On bridge modernization work, use full current bridge design standards for the entire bridge, except where practical design opportunities or innovations are available. In these cases, document all variations from bridge standards in Design Deviations or Exceptions, as described in *BDM 1.2.2*. Per *BDM 3.9.5*, submit a Bridge TS&L Report for all bridge modernization category work.

### **1.2.3.3 Bridge Retrofit**

The bridge retrofit design category includes any work that upgrades the functional characteristics of a bridge, including load-carrying capacity, except that covered by modernization. A bridge retrofit project can include multiple work elements. Potential work elements include:

- Bridge strengthening.
- Structural overlays.
- Overhang or sidewalk widening.
- Bridge raising.
- Bridge rail replacement.

When evaluating projects that include bridge retrofit work during the scoping and Project Initiation phases, consider the bridge holistically. Consider what other related elements of the bridge should also be updated. As an example, retrofitting a bridge rail may be appropriate during a structural overlay, or a strengthening may also include phase 1 seismic retrofit. Clearly document modifications to scope from this process in the project documents (Scoping Notes, Project Charter, CMR or DCSA, depending on project phase) and solicit Program Manager approval prior to proceeding.

Identify required Design Deviations and Design Exceptions in the DCSA. Use a Bridge Strategy Memo, according to *BDM 3.9.6*, to communicate these decisions to the project team.

### 1.2.3.4 Bridge Preservation

The bridge preservation design category applies to work that does not change the functional characteristics of a bridge, including load-carrying capacity. Relevant work includes:

- Bridge coating.
- Joint repairs and replacements.
- Protective screening.
- Phase 1 seismic retrofit.
- Deck overlays (that do not trigger updating the load rating per *ODOT LRFR 1.7*).

The following qualify as bridge preservation, unless other work requires another category:

- Bridge rail height modifications using *BR285* or similar.
- Strengthening required to carry temporary construction loads, i.e. containment.

This category of work does not require Design Deviations. Instead, use the DCSA to document project decisions, such as overlay type, and as documentation of communication with the relevant technical specialist. Use the DAP Narrative to communicate all bridge work with the project team, without requiring a Bridge TS&L Report or Bridge Strategy Memo.

When using innovative methods on bridge preservation projects, submit a BDM Revision Request form so the method can be evaluated and possibly adopted into the BDM. Thoroughly describe the method and how it applied to the project(s) on which the innovation was used.

### 1.2.3.5 Bridge Maintenance

The bridge maintenance category includes those projects, of any scale, that are funded exclusively with Major Bridge Maintenance (MBM) funds or other similar sources of state funding. Design these projects according to the *Bridge Maintenance Design Manual* and coordinate with the Bridge Maintenance Engineer and the District Bridge Supervisor.

## 1.2.4 Bridge Design Procedures

See *BDM 3* for the following information:

- Design software.
- Overview of design procedures.
- Roles & responsibilities.
- Quality.
- QPL / Research.
- Preliminary design / TS&L.
- Final design / PS&E.
- Advertisement and award.
- Construction support.
- Other discipline coordination



## 1.3 Loads and Distributions

### 1.3.1 Dead Loads

When additional dead load is added to an existing bridge, review the latest load rating or conduct load rating for feasibility study of a project at project initiation. See *BDM 3.10.8*. Contact the [Senior Load Rating Engineer](#) when you need assistance in a load rating.

It is critical to know the load capacity of each bridge prior to increasing dead load or any change to section properties of main load carrying members.

For all non-load-path-redundant steel truss bridges, verify that the stress levels in all structural elements, including gusset plates, remain within applicable requirements whenever planned modifications or operational changes may increase stresses.

#### 1.3.1.1 Box Girder Deck Forms

Where deck forms are not required to be removed, include an allowance of 0.010 ksf for form dead load.

#### 1.3.1.2 Shortening

Include the elastic effects of stressing (pre or post tensioned) after losses in the dead load. Ignore the long term effects of shrinkage and creep on indeterminate reinforced concrete structures.

#### 1.3.1.3 Utilities

Where holes are provided for future utilities, estimate the dead load of such

### C1.3.1

When the load rating of the existing structure is available, check the latest Bridge Inspection Conditions' Rating Report against condition rating used for load rating.

A load rating that reflects the current condition of each bridge is valuable and is used to identify when a bridge needs load posting or strengthening. Rating of a structure decreases with an increase in dead load and may result in a bridge load posting.

#### C1.3.1.1

#### C1.3.1.2

The assumption that forces produced by these processes will be relieved by the same processes.

utilities as that for a water filled pipe of 2 inches smaller

nominal diameter than that of the hole. For 12 inch holes, assume the dead load is 0.090

### 1.3.1.4 Wearing Surface

Provide the minimum present wearing surface (PWS) and future wearing surface (FWS) allowances shown in *Table 1.3.1.4-1* for all vehicular bridges.

klf.

### C1.3.1.4

When ACP is used, the 3 inch minimum ACP thickness is intended to provide sufficient thickness such that future maintenance resurfacing can be performed by removal and replacement of the upper 1 ½ inches.

Generally FWS is not required for pedestrian structures. When the width of the pedestrian bridge allows trucks to pass regularly, FWS may be warranted. Consult the [BDM Deck Specialist](#) and [BDM 1.5.1](#).

Table 1.3.1.4-1 Wearing Surface Dead Loads

Bridge Type	Present Wearing Surface (psf)	Future Wearing Surface (psf)
All bridges with CIP concrete decks	0	40, (3 inches)
PPC	12, (1 inch) *	25, (2 inches)
Side-by-side construction	0	40, (3 inches)
* For side-by-side construction with PPC, provide additional PWS allowance above the 12 psf as needed to account for crown and superelevation buildup.		

## 1.3.2 Live Loads

### 1.3.2.1 New Vehicular Traffic Structure

Design by *AASHTO LRFD Bridge Design Specifications* using all of the following loads:

- Service and Strength I Limit States:
  - HL-93: Design truck (or trucks per *LRFD 3.6.1.3*) or the design tandems and the design lane load.
- Fatigue truck per *LRFD 3.6.1.4*
- Strength II Limit State:
  - ODOT OR-STP-5BW permit truck.
  - ODOT OR-STP-4E permit truck.

### C1.3.2.1

ODOT Permit Loads are shown in *ODOT LRFR Figure 1.5.1.5B*.

For single span bridges with prismatic girders, use *Figures 1.3.2.1-1 to 1.3.2.1-4* to help determine the controlling permit truck for various span lengths.

Figure 1.3.2.1-1 Live Load Plus Impact for Single Span Prismatic Members – Bending Moment at Mid-Span, Strength Limit States (span lengths 30 – 160 feet)

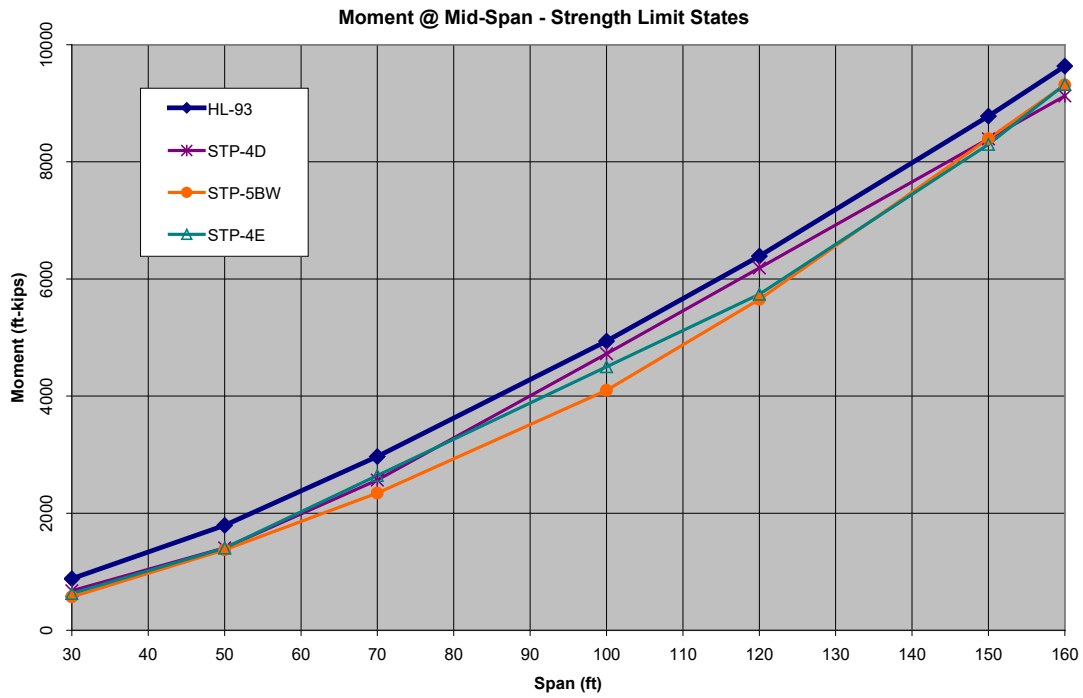


Figure 1.3.2.1-2 Live Load Plus Impact for Single Span Prismatic Members – Bending Moment at Mid-Span, Strength Limit States (span length 160 – 400 feet)

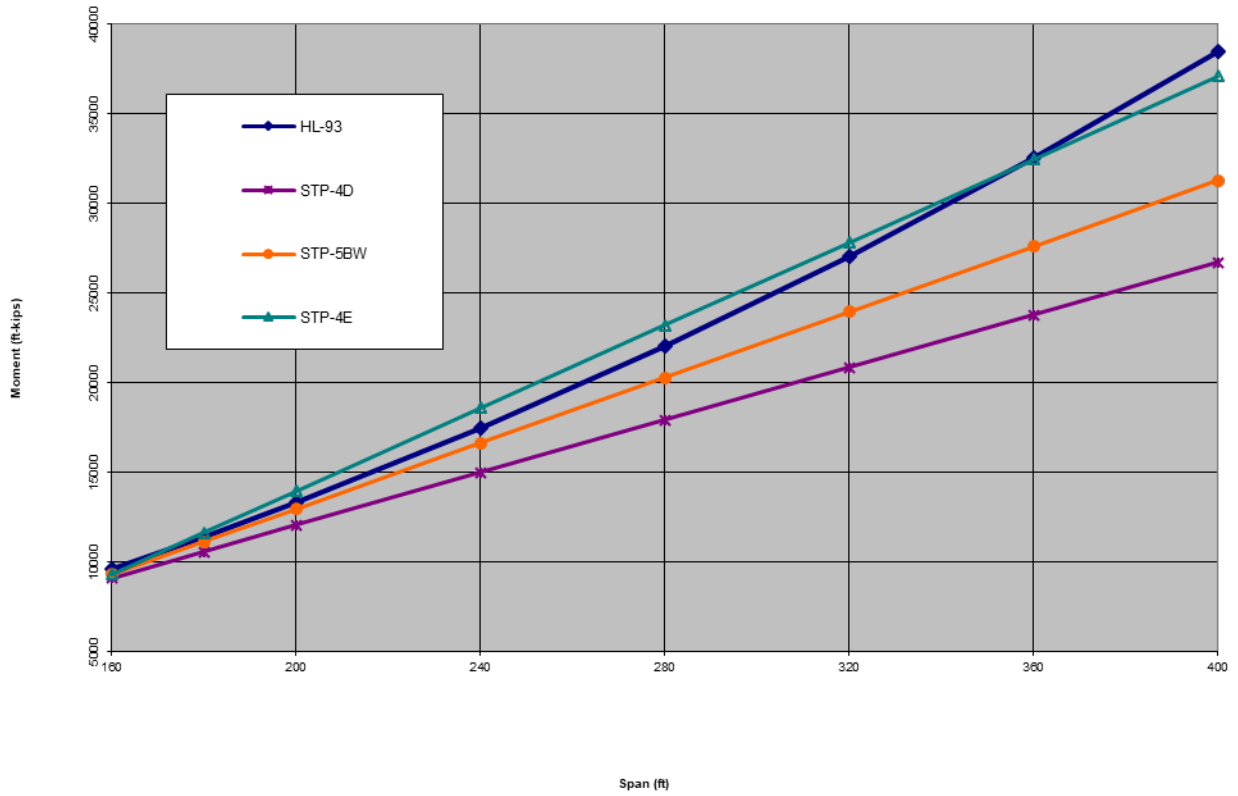


Figure 1.3.2.1-3 Live Load Plus Impact for Single Span Prismatic Members – Maximum Shear, Strength Limit States (span length 30 – 160 feet)

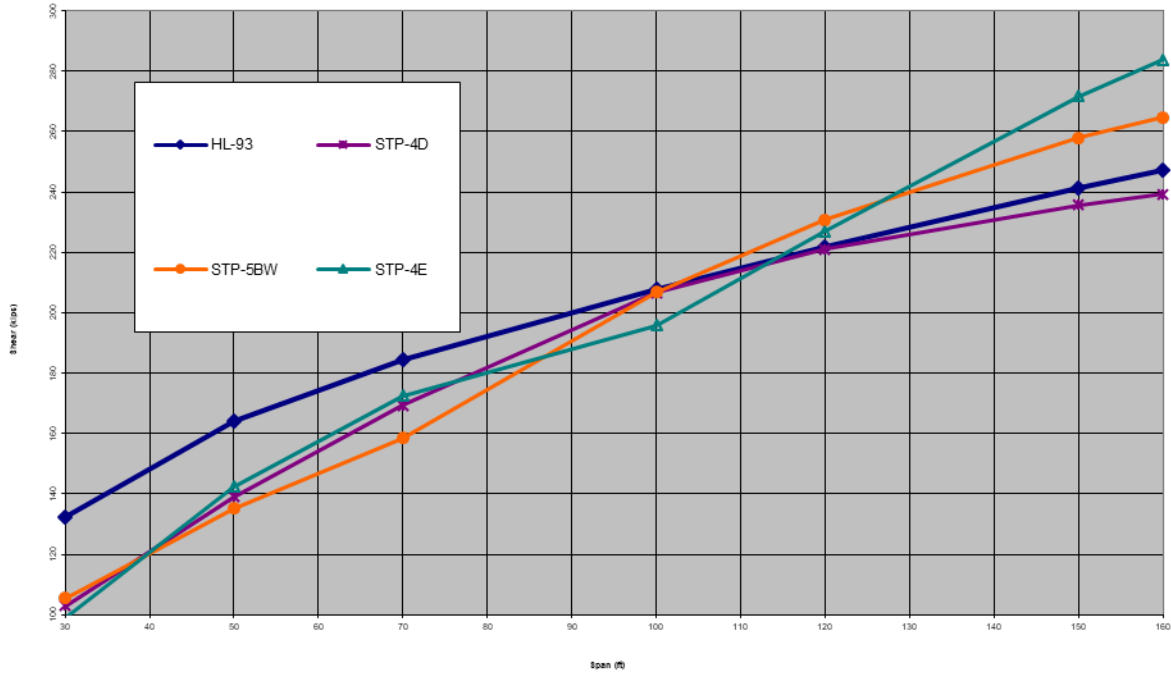
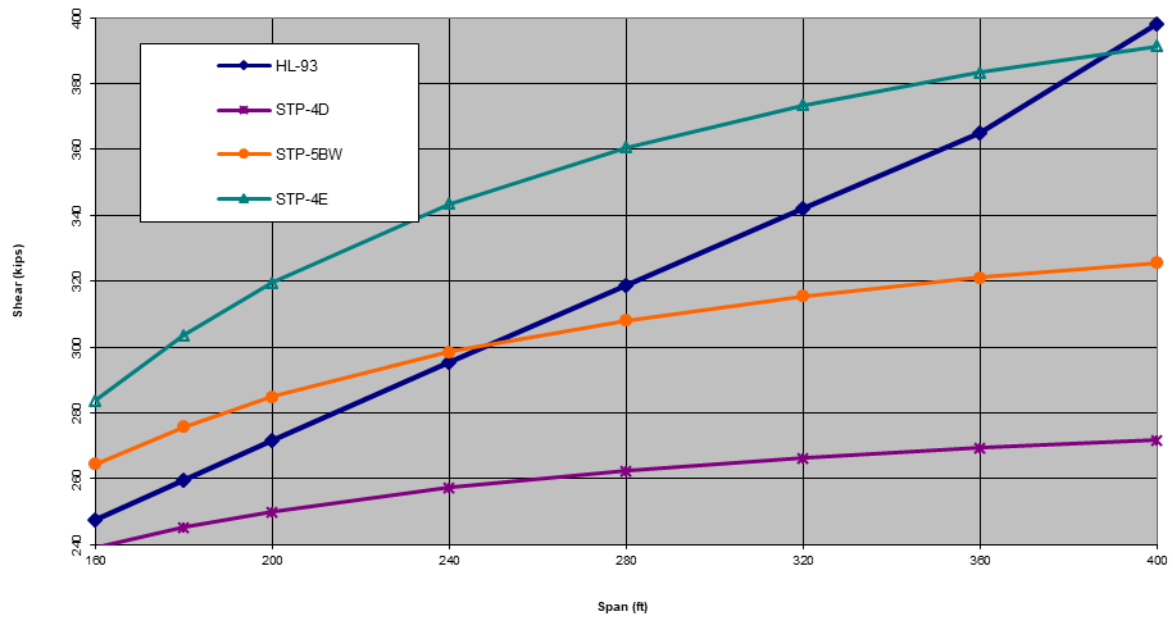


Figure 1.3.2.1-4 Live Load Plus Impact for Single Span Prismatic Members – Maximum Shear, Strength Limit States (span length 160 – 400 feet)



### 1.3.2.2 Pedestrian Structures

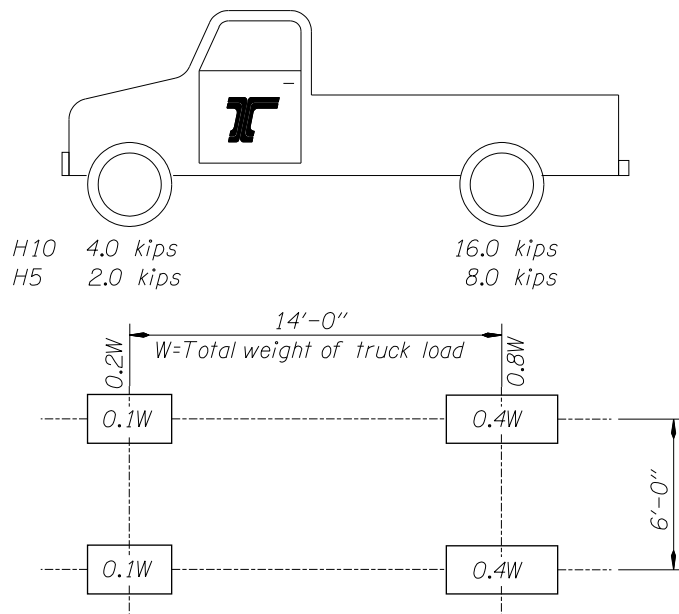
### C1.3.2.2

For bridges designed for pedestrian or bicycle traffic only, use a live load of 0.090 ksf. When an agency design vehicle is not specified, use *AASHTO* Standard H-5 or H-10 Truck loading as shown in *Figure 1.3.2.2-1* to check the longitudinal beams. A vehicle impact allowance is not required.

For a pedestrian or bikeway bridge clear deck width less than 7 feet do not consider the maintenance truck. See also the *AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges*.

Figure 1.3.2.2-1 H-5 or H-10 Truck Loading

Clear deck width 7' to 10' 10,000 lb. (H5 Truck)  
 Clear deck width over 10' 20,000 lb. (H10 Truck)





### C1.3.2.3

#### 1.3.2.3 Widening of Vehicular Traffic Structures

When widening an existing structure, design the widening using the loading in *BDM 1.3.2.1*. Designs using a lesser design live load will require a design deviation from the State Bridge Engineer.

Do not use live loading less than the design live load for the existing structure.

#### 1.3.2.4 Structure Repair and/or Strengthening

Design repair or strengthening projects for the maximum load effect from the following permit trucks using the *AASHTO LRFD Bridge Design Specifications* Strength II Limit State:

- ODOT OR-STP-4D.
- ODOT OR-STP-5BW.
- ODOT OR-STP-4E.

For repair and/or strengthening of prestressed concrete structures, ensure the requirements of Service I and III Limit States are satisfied using HL-93 loading.

#### 1.3.2.5 Live Load Distribution Factors

Use the live load distribution factors and procedures provided in the *AASHTO LRFD Bridge Design Specifications* to determine load effects on bridge members for new, replacement, and strengthening bridge designs.

### C1.3.2.4

See *BDM 1.3.2.1* and *ODOT LRFR Manual 1.5* for vehicle descriptions and *LRFD Table 3.4.1-1* for Load Factors.

See *BDM 1.30* for additional criteria for strengthening bridges.

### C1.3.2.5

Higher level techniques such as finite element analysis or grillage analysis will not be accepted as a basis for adjustment of live load distribution factors in *LRFD 4.6.2.2.2* and *4.6.2.2.3* for design of new bridges.

Higher level techniques such as finite element analysis or grillage analysis will not be accepted as a basis for adjustment of live load distribution factors in LRFD 4.6.2.2.2 and 4.6.2.2.3 for design of new bridges.

For bridges outside of the range of applicability of *LRFD 4.6.2.2.2* and *4.6.2.2.3* submit design deviation according to *BDM 1.2.2*. Use the following information to support using refined method of analysis per *LRFD 4.6.3*:

- Name, version, and release date of design software used to perform refined method of analysis.
- Proposed table of live load distribution factors for controlling moment and shear at critical locations in each span. This aids in permit issuance and load rating of the bridge for all standard load rating trucks listed in *ODOT LRFR Manual Section 1.5* and report rating factors using *ODOT LRFR Section 11 Load Rating Summary Workbook* (excel).
- Apply an additional 1.10 factor to the **distribution factor** obtained from the refined method of analysis.
- Include in the calculation book a comparison of the moment and shear for an equivalent single girder line with AASHTO distribution factors vs refined method of analysis (with lower distribution factors and lower demands) for both the live load and dead load.

The required information will aid future load rating and structural evaluation for these bridges.

- The 1.10 factor is conservatively included to determine a **distribution factor using the refined method of analysis.**

## 1.3.3 Sidewalk Loading

## C1.3.3

For sidewalks not separated from traffic by a structural rail, account for the potential for a truck to mount the sidewalk. Design the sidewalk for the greater of:

- 0.075 ksf pedestrian loads considered simultaneously with the vehicular load in the adjacent lane as stated in *BDM 3.6.1.6* of the *LRFD Bridge Design Specifications*. Per *LRFD 3.6.2.1*, impact does not apply to pedestrian loads.
- The *LRFD* design truck placed with a line of wheels 2 feet from the face of rail. Do not apply a lane load with the design truck, but do include impact. Consider this load only under the Strength I limit state. Do not consider trucks or vehicle loads in adjacent lanes. Do apply the multiple presence factor for this case.

In addition to the above cases, ensure the supporting member (exterior girder) is adequate for HL-93 loading when the sidewalk is removed and an approved barrier type (*BR290* or *BR208*) is placed at the edge of deck per *BDM 1.13.5*.

## C1.3.4

### 1.3.4 Vehicular Collision Forces: CT

Modify *LRFD 3.6.5* as follows:

Where the design choice is to redirect or absorb the collision load, use pier systems with three or more columns. Specify pier protection that consists of a minimum 42 inch high MASH crash tested rigid TL-5 barrier with standard pin anchorage to subgrade.

Depending on the clear distance from the face of the pier component to the traffic face of the barrier, use minimum column sizes as follows:

- For 0 to 3.25 feet clear distance, use a minimum 48 inch circular (or equivalent square) column with 1 1/8 percent minimum longitudinal steel reinforcement and #4 spiral reinforcement with 4 inch pitch.
- For 3.25 feet or greater clear distance, use a minimum 36 inch circular (or equivalent square) column with 1 1/8 percent minimum longitudinal reinforcement and #4 spiral reinforcement with 4 inch pitch.

The standard detail for barrier protection of a structure (column, wall, traffic support pole, or other structure) places the curb face of the barrier 4 feet minimum from the face of the structure. This detail dates back at least as far as the mid 1990's. The 4 feet dimension is intended to allow room for **rollover** when a truck impacts the barrier. It should be noted that barrier impacts can create a rollover scenario that exceeds 4 feet. Therefore, you should consider clear distances exceeding 4 feet when you can without impacting roadway width standards.

AASHTO 9th Edition updated this spacing to 3.25 feet to match current research.

When 4 feet or more clear distance can be provided, the proposed barrier placement detail will meet standards and no special consultation with the roadway designer is necessary. It should be understood that such a detail may pose some risk of structure impact, even when small.

Where the 4 feet clear distance cannot be achieved, consult with the roadway designer to confirm what clear distance can be provided. Any clear distance less than 4 feet results in additional risk for catastrophic impact of the structure being

Earth mounds are no longer an acceptable method of column protection. Existing earth mounds do not need to be removed.

protected. Therefore, consider reducing roadway shoulder width. The desired result should be to find an acceptable balance between roadway risk (due to inadequate shoulder width) and structure risk (impact to the structure being protected).

When evaluating the roadway and structure risk, take the following factors into account:

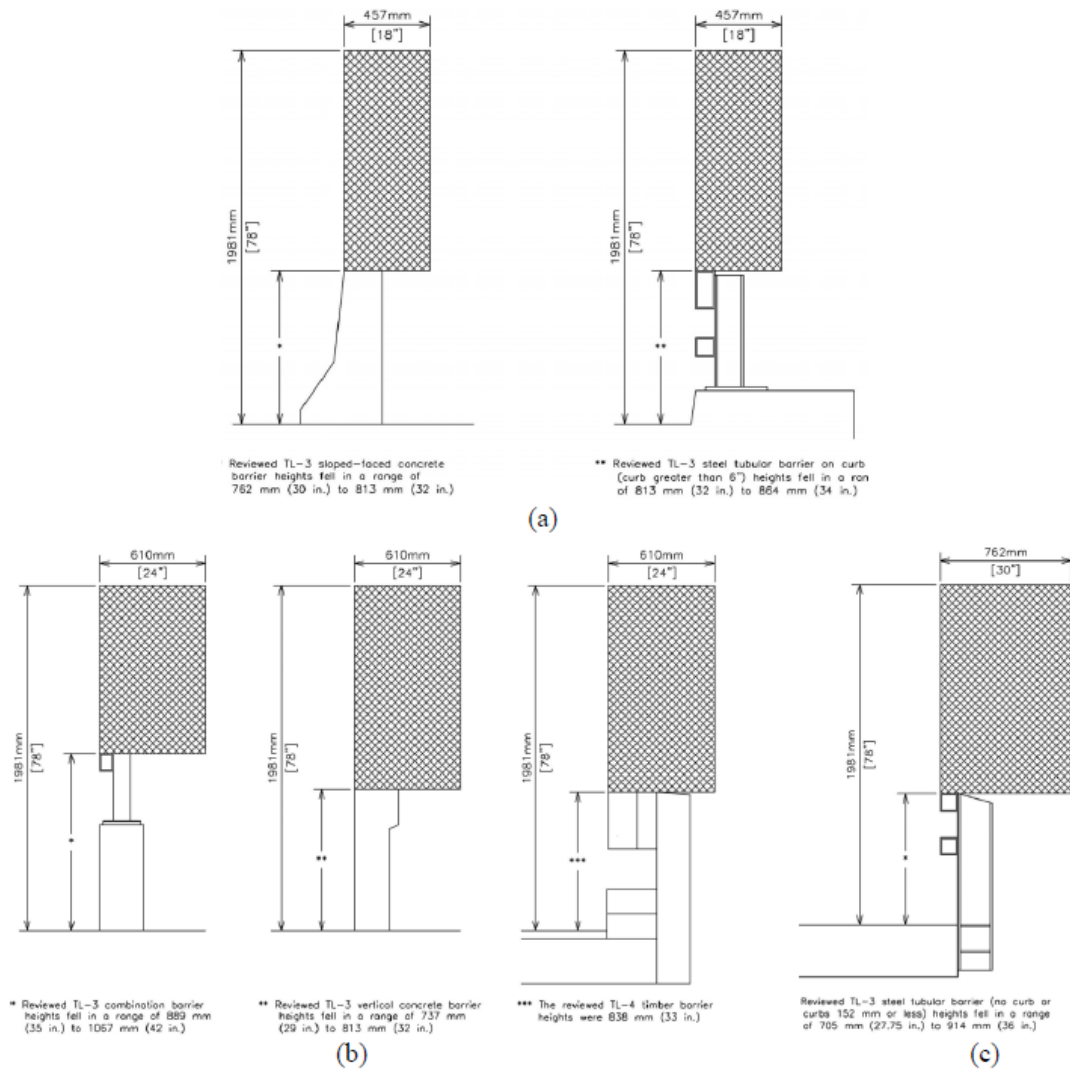
- Alignment of the roadway – straight vs. curved, inside of curve vs. outside of curve.
- Length of roadway width reduction (example, single sign support vs. long retaining wall).
- Ability of the structure to absorb a hit (single column vs. wall abutment).
- Traffic volume – higher traffic volume means higher risk of an incident.
- Consequences of structure failure.

When clear distance must be minimized, provide 3 inch minimum clear distance from the back of pinned barrier to the face of the structure. Understand that use of this detail includes accepting significant risk. The 3 inch minimum clear distance is intended to minimize the amount of horizontal impact load that would be transferred from the impacted barrier to the structure being protected. The void between the back of the barrier is typically filled with pea gravel. Note that 3 inch concrete surfacing is often provided at the top of barrier for aesthetic purposes. This surfacing is expected to disintegrate upon impact and so would not be expected to transmit unacceptable forces to the structure being protected.

In cases where reduction of the clear distance width provides an unacceptable risk against rollover, the barrier can be transitioned from a safety shape to vertical. Vertical barrier will reduce vehicle rollover and in some cases can provide an installation with an acceptable level of risk.

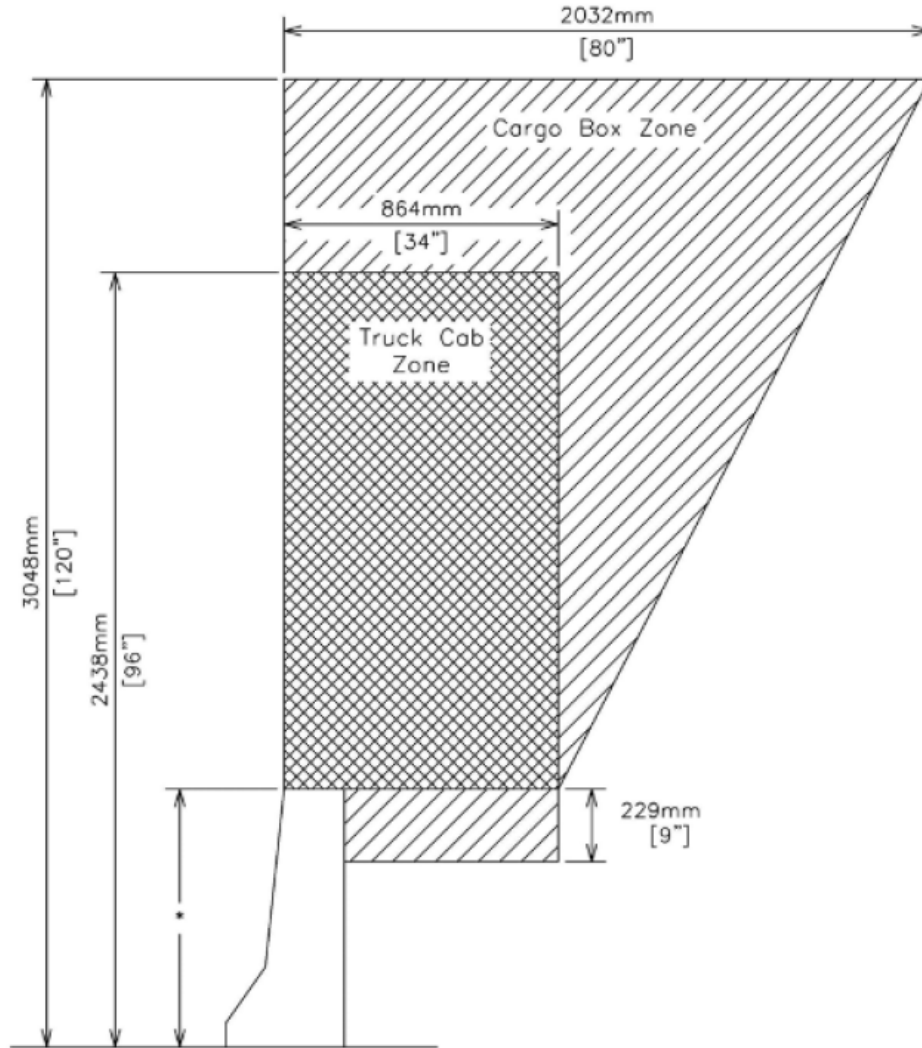
Intrusions zones for TL3 and TL4 barrier per *Guidelines for Attachments to Bridge Rails and Median Barriers Midwest Roadside Safety Facility (MwRSF)*; University of Nebraska-Lincoln, Nebraska, 2003 are shown in *Figures 1.3.4-1 and 1.3.4-2*.

Figure 1.3.4-1 TL-3 Zones of Intrusion



**Figure 2.1. TL-3 Zone of Intrusions for**  
**(a) Sloped Face Concrete Barrier and Steel Tube Rail on Curbs > 6 inches;**  
**(b) Vertical Face Concrete Barrier and Combination Concrete and Steel Rail;**  
**and (c) Steel Tube Rail on Curbs > 6 inches (3).**

Figure 1.3.4-2 TL-4 Zones of Intrusion



\* Reviewed TL-4 barrier heights fell in a range of 737 mm (29 in.) to 1067 mm (42 in.)



### 1.3.5 Change in Foundations Due to Limit State for Scour

In lieu of *LRFD 2.6.4.4.2* bullet two and *LRFD 3.7.5*, apply the Extreme Limit States in accordance with *LRFD 3.4.1*. Only include the anticipated scour depth due to channel degradation in Extreme Event I Limit State. *LRFD 2.6.4.4.2* bullet one still applies.

### C1.3.5

Obtain estimates of channel degradation from the hydraulic designer.

### 1.3.6 Thermal Forces

Use the temperature ranges shown in *Table 1.3.6-1*. Figure the rise and fall in temperature from an assumed temperature at time of erection.

### C1.3.6

Table 1.3.6-1 Temperature Ranges for Thermal Forces

Section*	Climate	Metal Structures	Concrete Structures	Annual Mean Temperature
Section I	Mild	+10 <sup>0</sup> F. to +110 <sup>0</sup> F.	+22 <sup>0</sup> F. to +72 <sup>0</sup> F.	52 <sup>0</sup> F
Section II	Moderate	-10 <sup>0</sup> F. to +120 <sup>0</sup> F.	+12 <sup>0</sup> F. to +82 <sup>0</sup> F.	52 <sup>0</sup> F
Section III	Rigorous	-30 <sup>0</sup> F. to +120 <sup>0</sup> F.	0 <sup>0</sup> F. to +82 <sup>0</sup> F.	47 <sup>0</sup> F

\* Section I designates that portion of the state west of the coast range.  
 Section II designates the valley region between the coast range and Cascade Mountains.  
 Section III designates the Cascade Mountains and all of eastern Oregon. For structures in the Columbia River Gorge, use Section III.

## C1.3.7

### 1.3.7 Wind Load

Determine wind load according to *LRFD 3.8.1*. Determine the design 3 second gust wind speed used in the determination of design wind loads on bridges and walls from the figure shown in standard drawing [TM672](#) *LRFD Ultimate Design Wind Speed Map*.

The wind velocity map is adapted from *AASHTO LRFD Bridge Design Specifications* and uses the wind speed maps shown in the *2014 Oregon Structural Code* to account for locations in the state with special wind regions.

## 1.4 Structural Analysis

### 1.4.1 Ductility, Redundancy and Operational Importance C1.4.1

Apply the ductility and redundancy factors per *LRFD 1.3.3, 1.3.4* and *1.3.5* without change. Consider all bridges as **typical**, ( $\eta I = 1$ ) for the operational importance factor.

Submit a deviation to the State Bridge Engineer before using a redundancy factor less than 1.0.

# 1.5 Concrete

[1.5.1 Concrete, General](#)

[1.5.2 Concrete Finish](#)

[1.5.3 Concrete Bonding Agents](#)

[1.5.4 Curing Concrete](#)

[1.5.5 Reinforcement](#)

[1.5.6 Precast Prestressed Concrete Elements](#)

[1.5.7 Cast-In-Place Superstructure](#)

[1.5.8 Post-Tensioned Structures](#)

[1.5.9 Camber Diagrams](#)

[1.5.10 Pour Schedules](#)

[1.5.11 Concrete Anchors](#)

## 1.5.1 Concrete, General

Designate the concrete class by the minimum compressive strength at 28 days followed by the maximum aggregate size (e.g., Class 4000 –  $\frac{3}{4}$ ). Unless otherwise specified, Class 3300 – 1  $\frac{1}{2}$ , 1 or  $\frac{3}{4}$  is called for by the Standard Specifications. The maximum ultimate strength on which allowable stresses are based is 5000 psi, except for prestressed concrete. Use High Performance Concrete (HPC) in all cast-in-place concrete decks and approach slabs, with the exception of pedestrian bridge decks. Pedestrian bridge decks do not require HPC unless they are at a location using significant amounts of deicing chemicals.

Table 1.5.1-1 Classes of Concrete (For design and to be shown on plans)

Class of Concrete	Concrete Location
HPC 4500 – 1-1/2	All poured decks (except box girder decks that require greater strength and Pedestrian Bridge decks) Note: This concrete strength works well with both Grade 80 and Grade 60 rebar and therefore would facilitate use of Grade 80 rebar, but still allow contractors to consider Grade 60 rebar without the need to change to a different concrete mix. The use of more coarse aggregate is to achieve more durable decks.
HPC 4500 – 1-1/2	Approach Slabs
4000 – 3/8	Drilled Shafts
XXXX – 3/4	Prestressed members (Does not include poured deck on prestressed members, see above)
XXXX – 1/2 or 3/8	Post-tensioned box girder bottom slab and stem walls
XXXX – 3/4	Compression Members
3300 – 1-1/2, 1, or 3/4	All other concrete

Use internally cured concrete for bridge deck when shrinkage cracking is a concern. Internal curing (IC) is a practical way of supplying additional curing water throughout the concrete mixture. This water can improve the hydration of cement, reduce autogenous shrinkage, and improve durability. Use of IC with lightweight fine aggregate for concrete is allowed to mitigate cracking due to shrinkage in bridge decks.

ODOT implemented internally cured concrete on a few projects in recent years. Due to its fairly new application, contact the [Technical Specialist](#) and the Structure Materials Engineer prior to selecting internal curing. Internally cured concrete utilizes lightweight fine aggregate (LWFA) according to *ASTM C1761*. The availability of lightweight fine aggregates (expanded clay or shale) depends on the local suppliers.

By replacing normal weight fine aggregate with lightweight fine aggregate for IC, the unit weight of the concrete is lighter. For concrete having an equilibrium density less than 0.135 kcf, the concrete can be considered lightweight concrete. When using lightweight concrete, adjust reinforcement development length for lightweight concrete per *LRFD 5.10.8.2. SP 02001* is required when internally cured concrete is specified. Curing time before subsequent loading may be shortened.

## 1.5.2 Concrete Finish

Concrete finishes are defined in *SP 00540.53* of the *Oregon Standard Specifications for Construction*. The usual finishes are General Surface Finish and Class 1 Surface Finish. Occasionally, Class 2 Surface Finish is used as mentioned in the following paragraph.

Concrete finishes are selected as follows:

- For bridges whose superstructure and substructure can be viewed by the public, such as grade separations and river crossings in or near populated areas, exposed surfaces receive a Class 1 Surface Finish. In special situations of high visibility to traffic or people, use of a Class 2 Surface Finish may be considered. Normally, it is limited to the concrete rail sides facing the roadway/bikeway and the tops.
- For bridges not viewed by large segments of the public, such as stream crossings in sparsely populated areas, exposed surfaces, except portions of the concrete bridge rail, receive a General Surface Finish. The concrete rail sides facing the roadway/bikeway and tops receive a Class 1 Surface Finish.

Review your selected surface finish with your design team.

Pedestrian concrete bridge decks do not require Deck Roadway Texturing with saw cutting according to *SP 00540.50(c)*. Instead apply a Deck Sidewalk Finish according to *SP 00540.50(d)*.

Do not use color additives in concrete mixes. Provide color to concrete only by coating with either concrete stain or concrete paint products from the QPL.

Include details similar to *Figures 1.5.2-1, 1.5.2-2, or 1.5.2-3* for all contract plans:

Figure 1.5.2-1 Concrete Finish Detail for Box Girder Bridges

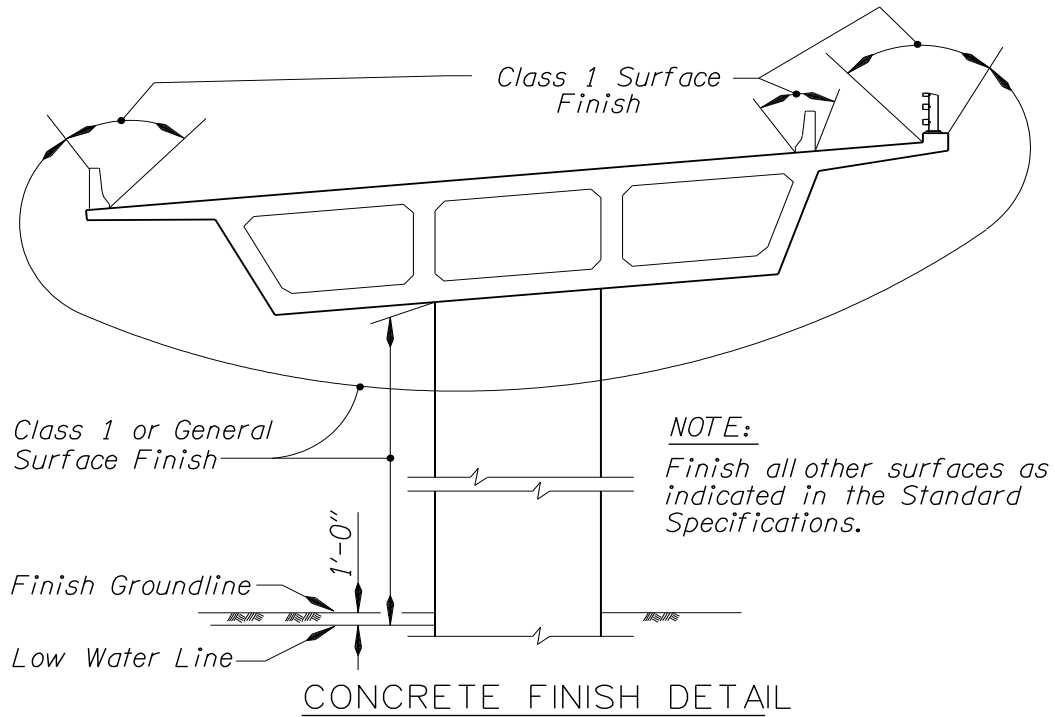


Figure 1.5.2-2 Concrete Finish Detail for Precast/Prestressed Concrete Girder Bridges

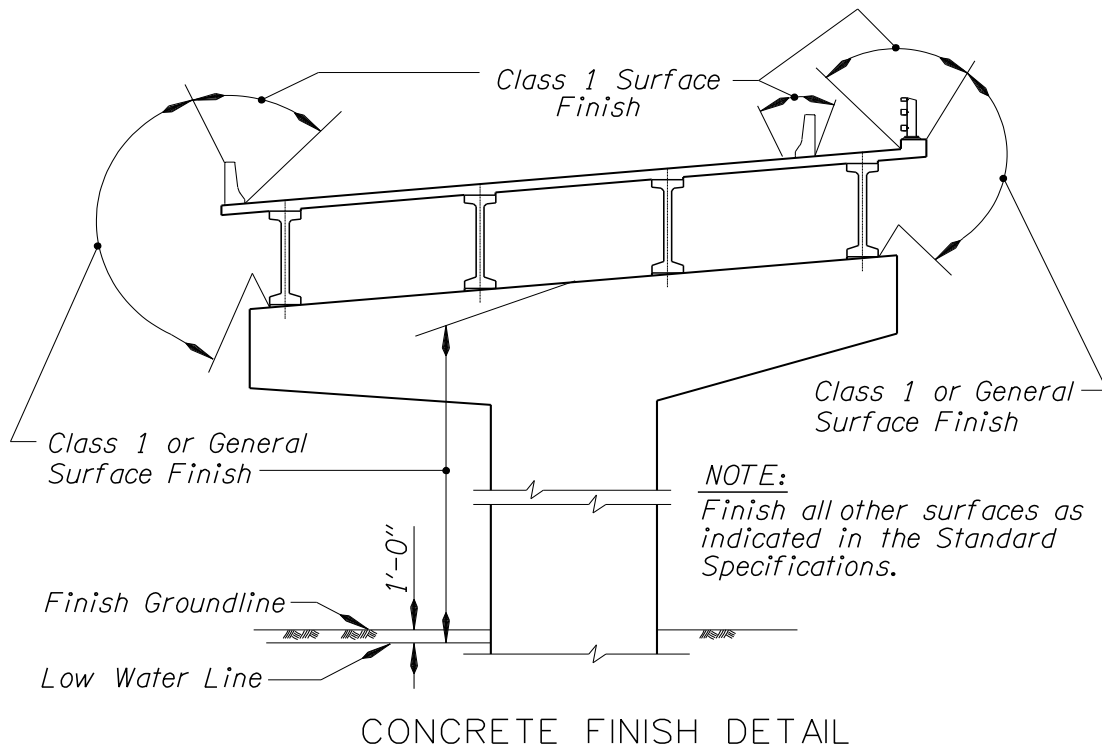
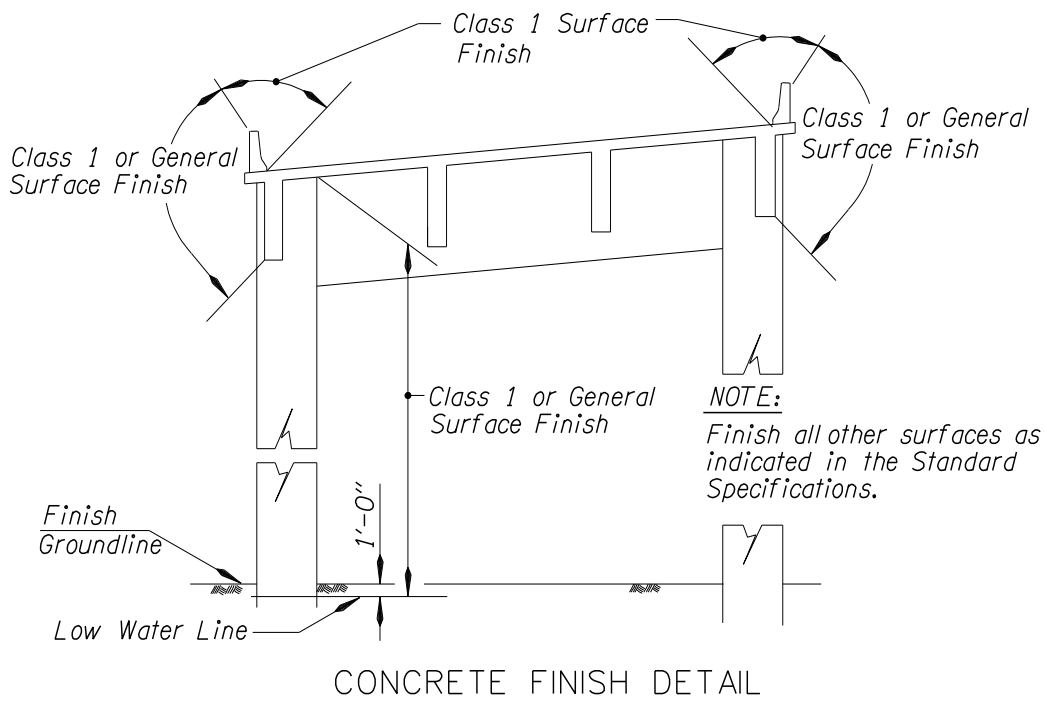


Figure 1.5.2-3 Concrete Finish Detail for Reinforced Concrete Deck Girder Bridges





### **1.5.3 Concrete Bonding Agents**

Bonding agents are used to help new concrete adhere to existing concrete. To obtain better bond with agents the existing surface must be clean, dry and at proper temperature. The surfaces must also be well exposed to facilitate brush application of the bonding agent. Two principal bonding agents are in use today:

- Epoxy - These agents provide the best bond when properly applied. However, they are highly volatile and when the agent is allowed to dry before placement of the new concrete, a bond breaker may be formed. For this reason restrict the use of epoxy agents to critical situations where control can be guaranteed.
- Concrete - These agents have longer pot life and improved bond. They may be applied with greater lead time, but have the same application requirements as epoxy agents.

At normal construction joints, a bonding agent is not generally needed. Mating surfaces prepared to the specifications are considered sufficient to provide acceptable bond and shear transfer through the roughened surface and rebar holding a tight joint.

## 1.5.4 Curing Concrete

*SP 00540.51* in the standard specifications require cast-in-place concrete to be cured with water. Design all structures assuming concrete is cured using the ODOT standard. Acting as EOR, assure that alternate curing methods are not allowed without prior approval of the Structure Materials Engineer.

Bridge decks must also be cured with water. Although ODOT does use curing compounds for some pavement and sidewalk applications, curing compounds are not be allowed on bridge decks. ODOT experimented with curing compounds in the early 1990s. The results were not consistent from batch to batch. Also, more recent experiments with curing compounds revealed that cylinders cured with a curing compound achieved only 80 percent compressive strength compared to water cured cylinders.

The ODOT water cure requirement also applies to bridge columns, abutments and retaining walls. Since it is difficult to keep vertical surfaces saturated during the cure period, vertical forms must often be left in place for the entire cure period. Contractors will often request to use a curing compound so that forms can be stripped sooner and production increased. However, due to the negative impacts of curing compounds, their use is rarely permitted.

For applications that receive a coating, use of curing compounds can inhibit adherence of the coating. Generally, curing compounds must be removed by sandblasting before subsequent coatings can be applied. Removal of a curing compound would be even more problematic on textured surfaces.

In summary, do not use curing compounds. Exceptions require approval from the Structure Materials Engineer, but do not require a design deviation from Bridge Section.

## 1.5.5 Reinforcement

Make sure there is enough room for bars to fit and to place concrete. Be sure steel can be placed and supported. Show bolster bars on reinforcement details when needed.

Table 1.5.5-1 Standard Bar Chart

Bar #	Nominal Dia. (inch)	Area (in <sup>2</sup> )	Weight (lb/ft)
3	0.375	0.11	0.376
4	0.500	0.20	0.668
5	0.625	0.31	1.043
6	0.750	0.44	1.502
7	0.875	0.60	2.044
8	1.000	0.79	2.670
9	1.128	1.00	3.400
10	1.270	1.27	4.303
11	1.410	1.56	5.313
14	1.693	2.25	7.650
18	2.257	4.00	13.60

Provide a minimum 2 inch covering measured from the surface of the concrete to the face of any uncoated or coated reinforcing bar except as shown in *Table 1.5.5-2*.

Table 1.5.5-2 Minimum Bar Cover

<b>Location:</b>	<b>Cover (inch)</b>
Top of deck slab (main reinforcing)*	2.5
Bottom of deck slab*	1.5
Stirrups and ties in T-beams, bottom rebar of slab spans, and curbs and rails*	1.5
Stirrups in box girder stems with non-bundled ducts **	2.5
Stirrup ties in box girder stems with non-bundled ducts **	2
Bottom slab steel in box girders	1
All faces in precast members (slabs, box beams and girders)	1
Pier and column spirals, hoops or tie bars+ (increase to 4 inch when exposed to marine environment or concrete is deposited in water)	2.5
Footing mats for dry land foundations (use 6 inch when ground water may be a construction problem)	3
Footing mats for stream crossing foundations	6
<p>*Use 2 inches minimum cover for all surfaces exposed to the effects of a marine environment, <i>BDM 1.26</i>.</p> <p>**For box girder stems with bundled ducts, provide 3 inches clearance to ducts and place stirrups directly against ducts.</p> <p>+Cover over supplementary crossties may be reduced by the diameter of the tie.</p>	

### 1.5.5.1 Reinforcement for Shrinkage and Temperature

Provide reinforcement for shrinkage and temperature stresses near exposed surfaces and in structural mass concrete according to *LRFD 5.10.8*. Use an area of reinforcement per surface of at least 0.0008 times the gross concrete area with a minimum of #4 at 18 inch centers. Space the reinforcement no farther apart than three times the concrete thickness or a maximum of 18 inch centers.

Table 1.5.5.1-1 Temperature & Shrinkage Reinforcement Spacing

Thickness (inches)	A <sub>s</sub> (in <sup>2</sup> /foot)	Maximum Bar Size and Spacing for One Surface (inches)			
6	0.062	#4 @ 18			
9	0.091	#4 @ 18			
12	0.118	#4 @ 18			
15	0.144	#4 @ 15			
18	0.170	#4 @ 12			
21	0.194	#4 @ 12	#5 @ 18		
24	0.217	#4 @ 10	#5 @ 15		
27	0.239	#4 @ 10	#5 @ 15		
30	0.260		#5 @ 12	#6 @ 18	
36	0.300		#5 @ 12	#6 @ 15	
48	0.371		#5 @ 10	#6 @ 12	#7 @ 18
60	0.433			#6 @ 12	#7 @ 15

Since the amount of reinforcement is somewhat empirical, convenient spacing can be assumed as shown in *Table 1.5.5.1-1*. *Table 1.5.5.1-1* is intended for preliminary purposes only. It is based on a least width dimension of 10 feet.

### 1.5.5.2 Spacing of Shear Reinforcement

Where shear reinforcement is required and placed perpendicular to the axis of the member, spacing is not to exceed 18 inches.

### 1.5.5.3 Negative Moment Reinforcement

For cantilever crossbeams with wide bents, extend at least half of the negative reinforcement the full length of the crossbeam.

### 1.5.5.4 Minimum Bar Spacing

Table 1.5.5.4-1 Minimum Bar Spacing

Bar #	Nominal Dia.(d <sub>b</sub> ) (inch)	2.5 x d <sub>b</sub> or 1.5+d <sub>b</sub> (inch)	(1.5x1.5) + d <sub>b</sub> for 1.5 agg. (inch)	(1.5x0.75)+ d <sub>b</sub> for 0.75 agg. (inch)
3	0.375	1-7/8	2-5/8	1-1/2
4	0.500	2	2-3/4	1-5/8
5	0.625	2-1/8	2-7/8	1-3/4
6	0.750	2-1/4	3	1-7/8
7	0.875	2-3/8	3-1/8	2
8	1.000	2-1/2	3-1/4	2-1/8
9	1.128	2-7/8	3-3/8	2-1/4
10	1.270	3-1/4	3-1/2	2-3/8
11	1.410	3-5/8	3-5/8	2-1/2
14	1.696	4-1/4	4	2-7/8
18	2.257	5-5/8	4-1/2	3-3/8

### 1.5.5.5 Modified Tension Development Length - GRADE 60 - Uncoated Deformed Bars

Provide details to achieve  $\lambda_{rc} = 0.4$  reference to *LRFD 5.11.2.1*. The following modified tension development length is calculated using  $\lambda_{rc}$ , reinforcement confinement factor, equal to 0.4.

Table 1.5.5.5-1 Modified Tension Development Length – Grade 60 – Uncoated Deformed Bars - Top bars are horizontal bars placed so that more than 12 inches of fresh concrete is cast below the reinforcement.

<b>Bar #</b>	<b>L<sub>d</sub> (in) f'c =3.3 ksi</b>	<b>L<sub>d</sub> (in) f'c =4.0 ksi</b>	<b>L<sub>d</sub> (in) f'c =4.5 ksi</b>	<b>L<sub>d</sub> (in) f'c =5.0 ksi</b>	<b>L<sub>d</sub> (in) f'c =6.0 ksi</b>
3	15.46	14.04	13.24	12.56	12.00
4	20.61	18.72	17.65	16.74	15.28
5	25.76	23.40	22.06	20.93	19.11
6	30.92	28.08	26.47	25.12	22.93
7	36.07	32.76	30.89	29.30	26.75
8	41.22	37.44	35.30	33.49	30.57
9	46.50	42.23	39.82	37.77	34.48
10	52.35	47.55	44.83	42.53	38.82
11	58.12	52.79	49.77	47.22	43.10
14	69.79	63.39	59.76	56.69	51.75
18	93.03	84.50	79.67	75.58	69.00

Table 1.5.5.5-2 Modified Tension Development Length – Grade 60 – Uncoated Deformed Bars – Other Horizontal Bars

<b>Bar #</b>	<b>L<sub>d</sub> (in) f'c =3.3 ksi</b>	<b>L<sub>d</sub> (in) f'c =4.0 ksi</b>	<b>L<sub>d</sub> (in) f'c =4.5 ksi</b>	<b>L<sub>d</sub> (in) f'c =5.0 ksi</b>	<b>L<sub>d</sub> (in) f'c =6.0 ksi</b>
3	12.00	12.00	12.00	12.00	12.00
4	15.85	14.40	13.58	12.88	12.00
5	19.82	18.00	16.97	16.10	14.70
6	23.78	21.60	20.36	19.32	17.64
7	27.74	25.20	23.76	22.54	20.58
8	31.71	28.80	27.15	25.76	23.52
9	35.77	32.49	30.63	29.06	26.53
10	40.27	36.58	34.48	32.71	29.86
11	44.71	40.61	38.29	36.32	33.16
14	53.68	48.76	45.97	43.61	39.81
18	71.56	65.00	61.28	58.14	53.07

### 1.5.5.6 Modified Tension Development Length - GRADE 60 – Epoxy Coated Deformed Bars

Provide details to achieve  $\lambda_{rc} = 0.4$  reference to *LRFD 5.11.2.1*. The following modified tension development length is calculated using  $\lambda_{rc}$ , reinforcement confinement factor, equal to 0.4.

Table 1.5.5.6-1 Modified Tension Development Length – Grade 60 – Epoxy Coated Deformed Bars - Top bars are horizontal bars placed so that more than 12 inches of fresh concrete is cast below the reinforcement.

Bar #	$L_d$ (in) $f'c = 3.3$ ksi	$L_d$ (in) $f'c = 4.0$ ksi	$L_d$ (in) $f'c = 4.5$ ksi	$L_d$ (in) $f'c = 5.0$ ksi	$L_d$ (in) $f'c = 6.0$ ksi
3	20.21	18.36	17.31	16.42	14.99
4	26.95	24.48	23.08	21.90	19.99
5	33.69	30.60	28.85	27.37	24.98
6	40.43	36.72	34.62	32.84	29.98
7	47.17	42.84	40.39	38.32	34.98
8	53.90	48.96	46.16	43.79	39.98
9	60.80	55.23	52.07	49.40	45.09
10	68.46	62.18	58.62	55.61	50.77
11	76.00	69.03	65.09	61.75	56.37
14	91.26	82.89	78.15	74.14	67.68
18	121.66	110.50	104.18	98.84	90.23
* Cover less than 3db or clear spacing between bars less than 6db.					



Table 1.5.5.6-2 Modified Tension Development Length – Grade 60 – Epoxy Coated Deformed Bars – Other Horizontal Bars

<b>Bar #</b>	<b>L<sub>d</sub> (in) f'c =3.3 ksi</b>	<b>L<sub>d</sub> (in) f'c =4.0 ksi</b>	<b>L<sub>d</sub> (in) f'c =4.5 ksi</b>	<b>L<sub>d</sub> (in) f'c =5.0 ksi</b>	<b>L<sub>d</sub> (in) f'c =6.0 ksi</b>
3	17.84	16.20	15.27	14.49	13.23
4	23.78	21.60	20.36	19.32	17.64
5	29.73	27.00	25.46	24.15	22.05
6	35.67	32.40	30.55	28.98	26.45
7	41.62	37.80	35.64	33.81	30.86
8	47.56	43.20	40.73	38.64	35.27
9	53.65	48.73	45.94	43.59	39.79
10	60.40	54.86	51.73	49.07	44.80
11	67.06	60.91	57.43	54.48	49.73
14	80.52	73.14	68.95	65.42	59.72
18	107.35	97.50	91.93	87.21	79.61
* Cover less than 3db or clear spacing between bars less than 6db.					

Table 1.5.5.6-3 Modified Tension Development Length – Grade 60 – Epoxy Coated Deformed Bars - Top bars are horizontal bars placed so that more than 12 inches of fresh concrete is cast below the reinforcement

<b>Bar #</b>	<b>L<sub>d</sub> (in) f'c =3.3 ksi</b>	<b>L<sub>d</sub> (in) f'c =4.0 ksi</b>	<b>L<sub>d</sub> (in) f'c =4.5 ksi</b>	<b>L<sub>d</sub> (in) f'c =5.0 ksi</b>	<b>L<sub>d</sub> (in) f'c =6.0 ksi</b>
3	18.55	16.85	15.88	15.07	13.76
4	24.73	22.46	21.18	20.09	18.34
5	30.92	28.08	26.47	25.12	22.93
6	37.10	33.70	31.77	30.14	27.51
7	43.28	39.31	37.06	35.16	32.10
8	49.46	44.93	42.36	40.18	36.68
9	55.80	50.68	47.78	45.33	41.38
10	62.82	57.06	53.80	51.03	46.59
11	69.74	63.35	59.73	56.66	51.72
14	83.74	76.06	71.71	68.03	62.11
18	111.64	101.40	95.60	90.70	82.79
* Cover not less than 3db and clear spacing between bars not less than 6db.					

Table 1.5.5.6-4 Modified Tension Development Length – Grade 60 – Epoxy Coated Deformed Bars – Other Horizontal Bars

<b>Bar #</b>	<b>L<sub>d</sub> (in) f'c = 3.3 ksi</b>	<b>L<sub>d</sub> (in) f'c = 4.0 ksi</b>	<b>L<sub>d</sub> (in) f'c = 4.5 ksi</b>	<b>L<sub>d</sub> (in) f'c = 5.0 ksi</b>	<b>L<sub>d</sub> (in) f'c = 6.0 ksi</b>
3	14.27	12.96	12.22	12.00	12.00
4	19.02	17.28	16.29	15.46	14.11
5	23.78	21.60	20.36	19.32	17.64
6	28.54	25.92	24.44	23.18	21.16
7	33.29	30.24	28.51	27.05	24.69
8	38.05	34.56	32.58	30.91	28.22
9	42.92	38.98	36.75	34.87	31.83
10	48.32	43.89	41.38	39.26	35.84
11	53.65	48.73	45.94	43.59	39.79
14	64.42	58.51	55.16	52.33	47.77
18	85.88	78.00	73.54	69.77	63.69
* Cover not less than 3db and clear spacing between bars not less than 6db.					

### 1.5.5.7 Class B Tension Lap Splice (in) - GRADE 60 – Uncoated Deformed Bars

Provide details to achieve  $\lambda_{rc} = 0.4$  reference to *LRFD 5.11.2.1*. The following modified tension development length is calculated using  $\lambda_{rc}$ , reinforcement confinement factor, equal to 0.4.

Table 1.5.5.7-1 Class B Tension Lap Splice – Grade 60 – Uncoated Deformed Bars - Top bars are horizontal bars placed so that more than 12 inches of fresh concrete is cast below the reinforcement

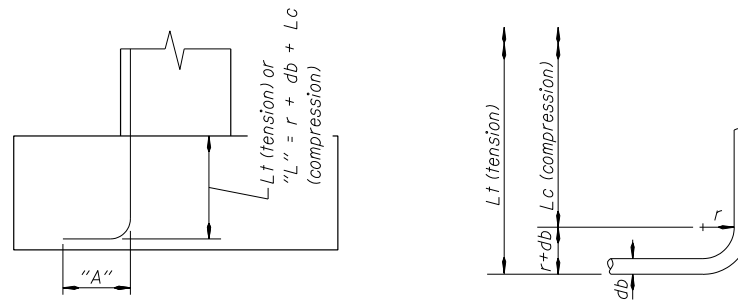
Bar #	$L_d$ (in) $f'c = 3.3$ ksi	$L_d$ (in) $f'c = 4.0$ ksi	$L_d$ (in) $f'c = 4.5$ ksi	$L_d$ (in) $f'c = 5.0$ ksi	$L_d$ (in) $f'c = 6.0$ ksi
3	20.09	18.25	17.21	16.33	15.60
4	26.79	24.34	22.94	21.77	19.87
5	33.49	30.42	28.68	27.21	24.84
6	40.19	36.50	34.42	32.65	29.81
7	46.89	42.59	40.15	38.09	34.77
8	53.59	48.67	45.89	43.53	39.74
9	60.45	54.90	51.76	49.11	44.83
10	68.05	61.81	58.28	55.29	50.47
11	75.56	68.63	64.70	61.38	56.03

Table 1.5.5.7-2 Class B Tension Lap Splice – Grade 60 – Uncoated Deformed Bars – Other Horizontal Bars

Bar #	$L_d$ (in) $f'c = 3.3$ ksi	$L_d$ (in) $f'c = 4.0$ ksi	$L_d$ (in) $f'c = 4.5$ ksi	$L_d$ (in) $f'c = 5.0$ ksi	$L_d$ (in) $f'c = 6.0$ ksi
3	15.46	15.60	15.60	15.60	15.60
4	20.61	18.72	17.65	16.74	15.60
5	25.76	23.40	22.06	20.93	19.11
6	30.92	28.08	26.47	25.12	22.93
7	36.07	32.76	30.89	29.30	26.75
8	41.22	37.44	35.30	33.49	30.57
9	46.50	42.23	39.82	37.77	34.48
10	52.35	47.55	44.83	42.53	38.82
11	58.12	52.79	49.77	47.22	43.10

### 1.5.5.8 Minimum Column Bar Lengths in Footings – GRADE 60 Bars & $f'c = 3.3$ ksi

Figure 1.5.5.8-1 Minimum Column Bar Lengths in Footings



**Note:**  
 Increase  $L_t$  or  $L_c$  20 percent for epoxy coated bars  
 "A" and  $r + db$  are standard 90° hook dimensions  
 $L_c$  is the compression development length  
 $L_t$  is the tension development length for standard hooks

COMPRESSION DEVELOPMENT LENGTH - HOOKED BARS						
BASIC COMPRESSION DEVELOPMENT (length for hooked bars $\lambda dh$ )	BAR SIZE	"A"	$r + db$	COMPRESSION "L" * (single bar)	COMPRESSION "L" * (two bar bundle)	COMPRESSION "L" * (three bar bundle)
1'-4"	6	1'-0"	3"	1'-2"	1'-4"	1'-5"
1'-7"	7	1'-2"	3 1/2"	1'-4"	1'-6"	1'-8"
1'-9"	8	1'-4"	4"	1'-6"	1'-9"	1'-10"
2'-0"	9	1'-7"	6"	1'-10"	2'-1"	2'-3"
2'-3"	10	1'-10"	7"	2'-3"	2'-7"	2'-9"
2'-6"	11	2'-0"	7 1/2"	2'-8"	3'-1"	3'-4"
3'-0"	14	2'-7"	11"	3'-10"	4'-5"	4'-10"
3'-11"	18	3'-5"	1'-3"	6'-3"	7'-6"	8'-2"

**\*Note:**  
 $L_c + (r + db)$  and including 0.75 modification factor for reinforcement enclosed within a spiral per LRFD 5.11.2.2.2

TENSION DEVELOPMENT LENGTH HOOKED BARS			
BAR SIZE	"A"	BASIC TENSION DEVELOPMENT (length for hooked bars $\lambda dh$ )	MODIFIED TENSION "L" ** $0.7 \lambda dh$
6	1'-0"	10"	7"
7	1'-2"	1'-1"	9"
8	1'-4"	1'-5"	1'-0"
9	1'-7"	1'-9"	1'-3"
10	1'-10"	2'-3"	1'-7"
11	2'-0"	2'-9"	1'-11"
14	2'-7"	3'-11"	2'-9"
18	3'-5"	7'-0"	4'-11"

**\*\*Note:**  
 #11 bars and smaller, adequate side and hook extension cover per LRFD 5.11.2.4.2

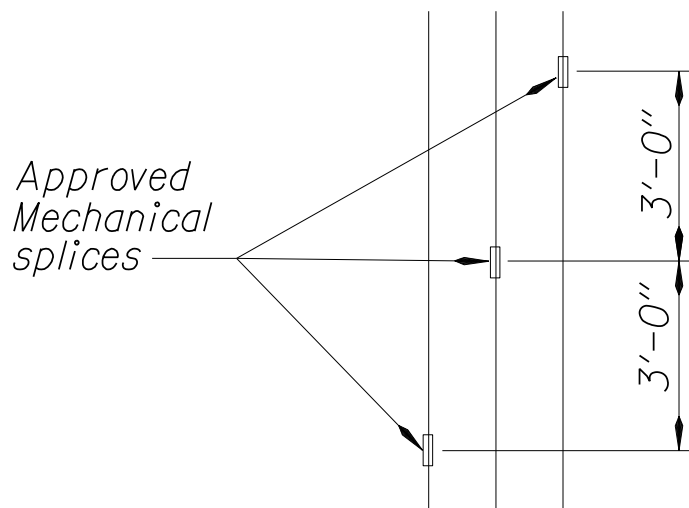
### 1.5.5.9 Welded Splices and Mechanical Connections

When field welding of reinforcing steel is anticipated, use *ASTM A706* reinforcing steel. Welding of *ASTM A615*, Grade 60 reinforcing steel is not permitted without prior approval from the [ODOT welding specialist](#).

Welding of *ASTM A706* for splices for column spiral reinforcing is permitted.

Use approved mechanical splices for #14 and #18 vertical column bars. Stagger splices as shown in *Figure 1.5.5.9-1*, to avoid adjacent bars being spliced in the same plane.

Figure 1.5.5.9-1 Mechanical Splice Staggering



#### MECHANICAL SPLICE STAGGERING

Show lap splices on structure plans with the option of approved mechanical splices available to the contractor.

Special cases such as steel in back walls of abutments of post-tensioned concrete bridges and splicing reinforcement in existing structures may require the use of mechanical splices.

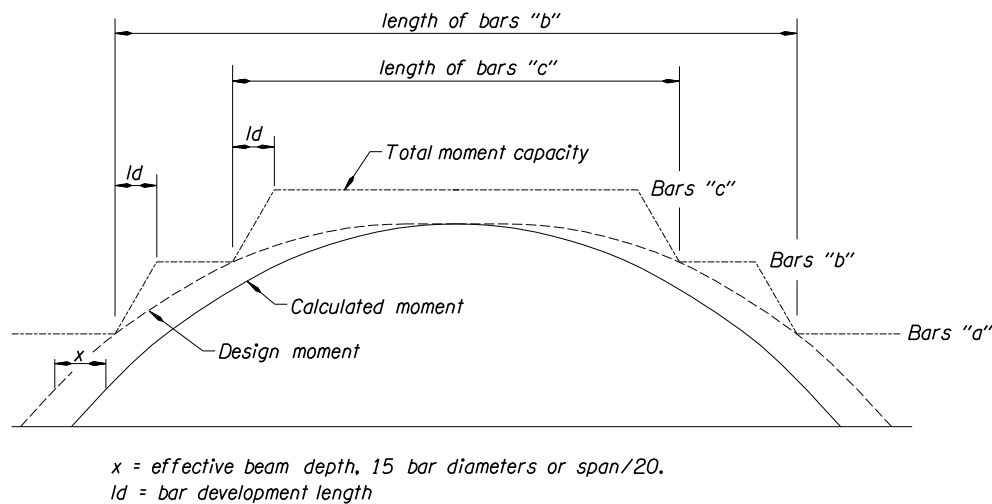
### 1.5.5.10 \*Lap Splices – GRADE 60

(Reserved)

### 1.5.5.11 Development of Flexural Reinforcement

The added length,  $X$ , is to provide for unanticipated loading conditions or shifting of the moment diagram due to shear cracking.

Figure 1.5.5.11-1 Development of Flexural Reinforcement



### 1.5.5.12 Distribution of Flexural Reinforcement

For moderate exposure conditions, use  $\gamma_e = 1.0$ . For severe exposure conditions such as structures subject to the effects of sea spray, deicing chemicals or other corrosive environments, use  $\gamma_e = 0.75$ . In decks, use  $\gamma_e = 1.0$ .

### 1.5.5.13 Bundled Bars

Tie bundled bars with #9, or heavier, wire at 4 foot maximum centers. Use of bundled #14 or #18 bars requires the approval of the supervisor.

When bundled bars are used in columns, the minimum clear distance between bundles is 2.5 times the diameter of the largest bar in a bundle.

It is preferred bundled bars not be used in bridge decks. When they are used, increase the thickness of the deck by the diameter of the bar throughout the length where bundling is used.

### 1.5.5.14 Headed Reinforcement

Headed reinforcement can be used to reduce congestion or reduce development length over a standard hook. Headed reinforcement will always require less development length compared to a standard hook.

Headed rebar is only available for *ASTM A706* and *ASTM A615* applications. It is not available for stainless steel applications. The cost of headed rebar will generally exceed that of a standard hook. Therefore, only use them where the benefit of reduced congestion and/or shorter development length is significant.

Do not use headed reinforcement where their use will reduce concrete cover below the minimum required. For this reason, it may be necessary to use standard hooked bars in the corners of a rebar cage that otherwise contains headed bars.

Designate bars which require headed reinforcement on the plans. The *SP 00530* boiler plate special provision requires headed reinforcement to meet *ASTM A970*. It also requires headed reinforcement products be selected from the *ODOT QPL*. Therefore, there is no reason to say anything other than **headed bar** on the plans.

Heads may be square, rectangular, round or oval. Minimum head size for square and round heads are provided in *Table 1.5.5.14-1*. Rectangular and oval head area must exceed 10 times the bar area.

Table 1.5.5.14-1 Minimum Head Size for Headed Reinforcement

Bar Size	Min. Width for Square Heads (inch)	Min. Diameter for Round Heads (inch)
4	1-1/2	1.6
5	1-3/4	2.0
6	2-1/8	2.3
7	2-1/2	2.7
8	2-3/4	3.1
9	3-1/8	3.5
10	3-1/2	4.0
11	4	4.4
14	4-3/4	5.3

Headed reinforcement will not require project testing. Testing is required as part the QPL approval process. QC testing by the manufacturer is also required by *ASTM A970*.

When proposed by a contractor, headed reinforcement meeting the minimum head size requirement will generally be acceptable as a direct replacement for standard hooks, except where the head will not allow the required minimum concrete cover.

Use the minimum development lengths for headed reinforcement shown in *Table 1.5.5.14-2*.

Table 1.5.5.14-2 Development Length for Headed Reinforcement,  $F_y = 60$  ksi

Bar #	$f'c = 3.3$ ksi (inch)	$f'c = 4.0$ ksi (inch)	$f'c = 5.0$ ksi (inch)
4	6	5	5
5	7	6	6
6	8	8	7
7	10	9	8
8	12	10	9
9	18	14	10
10	22	18	11
11	25	20	12
14	36	28	15

Note: Increase lengths for epoxy coated bars per *LRFD 5.11.2.1.2*.

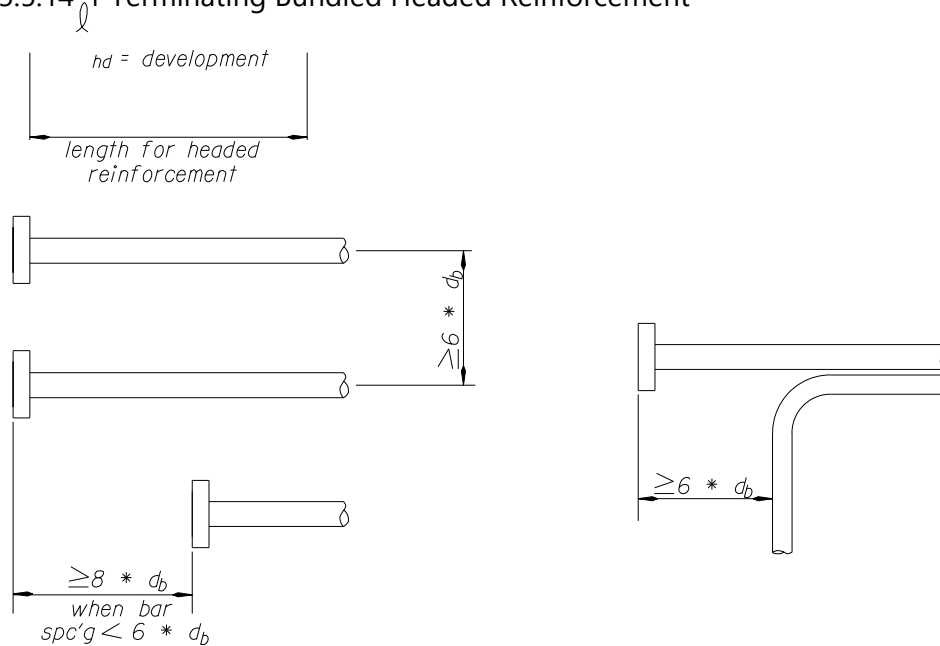
Apply the modification factors and tie requirements in *LRFD 5.11.2.4.2* and *LRFD 5.11.2.4.3* to headed reinforcement also.

Place adjacent headed bars at a minimum spacing of  $6 * db$ . Spacing less than  $6 * db$  can be used when heads from adjacent bars are spaced longitudinally (along the length of the bar) a minimum of  $8 * db$  as shown in *Figure 1.5.5.14-1*.

When bundled bars are used, one bar in the bundle may be terminated using headed rebar. Terminate other bars in the bundle using standard hooks as shown in *Figure 1.5.5.14-1*.



Figure 1.5.5.14-1 Terminating Bundled Headed Reinforcement



Use of headed reinforcement can result in high concrete compressive stresses under the bar head. Consider the load path for head compression loads and provide distribution steel perpendicular to a headed bar to ensure satisfactory distribution of compressive stresses. The following articles may be useful to understand the load distribution of headed bars:

- *Strut-and-Tie Models for Headed Bar Development in C-C-T Nodes*, Chun and Hong, ACI Structural Journal, Vol. 106, No. 2, March-April 2009, pg. 123-130.
- *Investigation of Dispersion of Compression in Bottle-Shaped Struts*, Sahoo, Singh and Bhargava, ACI Structural Journal, Vol. 106, No. 2, March-April 2009, pg. 178-186.

*LRFD 5.11.3* allows for mechanical devices as anchorage. Headed rebar meeting or exceeding the size required by *ASTM A970* has been extensively tested. A summary of testing can be found in *Texas Research Report 1855-1*, [Anchorage Behavior of Headed Reinforcement Literature Review](#), May 2002.

The minimum development lengths for headed reinforcement are based on the greater of:

- 50 percent of the equivalent hooked bar development length or
- Calculations using a combination of head bearing capacity and bar development.




Development length calculations were based on concrete bearing capacity under the head plus additional straight bar development length as required to fully develop the yield strength of the bar. The concrete bearing capacity was taken from *LRFD equation 5.7.5-2* and was adjusted using a resistance factor of 0.7 for bearing on concrete per *LRFD 5.5.4.2.1*. Some of the proposed development lengths were increased to provide reasonable transitions between different bar sizes.

*ACI 318* allows headed reinforcement, but requires a development length equal to 75 percent of the equivalent hooked bar development length. ODOT view this as overly conservative for bridge applications.

Table 1.5.5.14-3 illustrates the difference between ODOT and ACI development length requirements.

Table 1.5.5.14-3 Comparison of Headed Reinforcement Development Length

f'c	3.3 ksi			4.0 ksi			5.0 ksi		
	Calc (inch)	ODOT (inch)	ACI (inch)	Calc (inch)	ODOT (inch)	ACI (inch)	Calc (inch)	ODOT (inch)	ACI (inch)
#4		6	7.8		5	7.1		5	6.4
#5	4	7	9.8	2	6	8.9	0	6	8.0
#6	8	8	11.8	6	8	10.7	3	7	9.6
#7	10	10	13.7	8	9	12.5	4	8	11.2
#8	12	12	15.7	9	10	14.3	3	9	12.7
#9	18	18	17.7	14	14	16.1	7	10	14.4
#10	22	22	19.9	18	18	18.1	9	11	16.2
#11	25	25	22.1	19	20	20.1	7	12	18.0
#14	36	36	26.6	28	28	24.1	12	15	21.6

-  Development length controlled by 50 percent of equivalent hooked bar development length
-  Development length based on ODOT calculations, but less than ACI development length
-  Development length based on ODOT calculations and exceeds ACI development length

ACI development length = 75 percent equivalent hooked bar development length

Calc = Calculated development length from combination of head capacity and bar development

For concrete strengths above 5.0 ksi, the required minimum development length for headed reinforcement can be calculated using 50 percent of the equivalent hooked bar development length.

## 1.5.5.15 High Strength Reinforcement

### 1.5.5.15.1 ASTM A706 Grade 80

ASTM A706 Grade 80 reinforcement is available on the market. The cost premium for A706 Grade 80 reinforcement is approximately 6 to 10 percent above Grade 60. Local steel mills (Cascade Steel Rolling Mills) are producing #5, #8, and #11 bars on a regular cycle and stock these bars. Avoid specifying other bar sizes, otherwise a minimum (combined size and length) of 50 tons is required. However, there can be some flexibility for smaller quantities. Contact Cascade Steel Rolling Mill for requirements when high strength rebar in non-standard rebar sizes is considered for a project with less than 50 tons.

When using *A706* Grade 80 reinforcement, the design yield strength is 80 ksi. *ASTM A706* reinforcement is weldable. Welding would be needed when A706 Grade 80 reinforcement is used for confinement hoops. The contractor needs to submit a PQR and WPS for approval as is typical for any rebar welding.

#### **1.5.5.15.2 ASTM A1035 Grade 100**

*ASTM A1035* Grade 100 reinforcement has a design yield strength of 100 ksi. Proprietary products that meet the requirements of *ASTM A1035* specifications are sold under the brand names of ChromX 9100 (formerly known as MMFX2), ChromX 4100, and ChromX 2100. The main difference between the three products is the chromium content; the higher the number, the greater chromium content.

The reduced chromium content results in lower cost, when high corrosion resistance is not required. The products are not weldable. Currently, Cascade Steel produces ChromX 9100, ChromX 4100, and ChromX 2100 with a cost premium of approximately 192, 70 and 45 percent respectively. Cascade Steel carries some inventory of #5, #8 and #11 bars. For non-stock items, a minimum (combined size and length) of 50 tons is required. However, there can be some flexibility for smaller quantities. Contact Cascade Steel for requirements when high strength rebar in non-stock rebar sizes is considered for a project with less than 50 tons.

#### **1.5.5.15.3 ASTM A615 Grade 100**

Grade 100 reinforcement according to *ASTM A615* requirements is available. The cost premium for *A615* Grade 100 reinforcement is approximately 35 percent above Grade 60. Similar to other high strength reinforcement products, even though there is a required minimum order of 50 tons for combined size and length, there can be some flexibility for smaller quantities. Contact Cascade Steel for requirements when high strength rebar is considered for a project with less than 50 tons.

The cost premiums shown in this article are preliminary and for rebar production only.

#### **1.5.5.15.4 Application of High Strength Reinforcement**

Do not use high strength reinforcement in members designed for plastic seismic performance, such as bridge columns. Although A706 Grade 80 reinforcement has similar ductile properties compared to A706 Grade 60, testing of full-scale seismic models sufficient to satisfy AASHTO concerns has not yet been completed.

The stress-strain property of A1035 Grade 100 is very different from A706. There is not a well defined yield plateau. More experimental testing is necessary before its full implementation in members designed to form plastic hinges. The overstrength magnifier as defined for A706 in the *Guide Specifications for LRFD Seismic Bridge Design* may not be appropriate. At this time, an overstrength magnifier of 1.4 is recommended when high strength reinforcement is used in capacity-protected members.

Use of high strength reinforcement is recommended in the following areas:

- Bridge decks – When high strength reinforcement is used in a bridge deck, use it for both longitudinal and transverse bars. Refer to *Figure 1.9.1-6* and *Figure 1.9.1-7* for deck reinforcement design charts.
- Drilled shafts – Use of high strength reinforcement reduces cost and congestion in drilled shafts thereby making them more constructible. Drilled shafts are designed for elastic seismic performance and so there would typically be no concern with the seismic performance.
- Crossbeams & End beams – Use of high strength reinforcement can reduce cost and congestion in negative and positive moment areas of crossbeams and end beams. Normally these members are capacity-protected; therefore they are designed to remain elastic during a seismic event. High strength reinforcement can be used for temperature steel and stirrups as well.

Grade 80 bars are a better option for a replacement of Grade 60 bars due to lower cost premium and shorter development length compared to Grade 100 bars. In addition, Grade 80 has stress-strain behavior similar to Grade 60 with greater yield stress and ultimate strength.

Within the same member, do not mix different rebar grades of the same bar size. This policy is to avoid any confusion that may occur during construction. It is acceptable to specify different rebar grades in the same member, when the different grades of bar are also significantly different in bar size (at least two bar sizes apart). For instance, longitudinal #8 bars in a crossbeam can be Grade 80 bars, whereas #5 stirrups and temperature bars can be Grade 60.

*Table 1.5.5.15.4-1* illustrates rebar quantities in the previously mentioned members that are allowed to be reinforced with high strength reinforcement. The quantities shown in *Table 1.5.5.15.4-1* will be different when high strength reinforcement is used. A reduction of 10 to 30 percent in quantities can be anticipated when Grade 60 rebar is replaced by Grade 80 reinforcement.

All bridges in *Table 1.5.5.15.4-1* consist of precast prestressed concrete girders with a CIP deck. Most spans are simple for dead load and made continuous for live load. The bridges include drilled shafts with different lengths depending on the soil condition at the sites. Several bar sizes are grouped together since these bars can be alternately used in the design to reduce a number of different bar sizes. Specify only a few and commonly available bar sizes in each member.

Table 1.5.5.15.4-1 Comparison of High Strength Rebar Quantities

Bridge No.	Length (feet)	Deck Area (ft <sup>2</sup> )	No. Drilled Shafts	Span Description	Deck (tons)		Crossbeams* (tons)		Drilled Shafts (tons)	
					#4 - #6	#7 - #9	#4 - #7	#8 - #11	#5 - #6	#9 - #11
22008	968	44015	8 – 8 foot	6 – 150 foot 1 – 50 foot deck girder spans	106	45	54	51	43**	218**
21576	249	31665	15 – 6 foot	2 – 122 foot deck girder spans	87	20	36	55	48	87
21343	524	25152	4 – 8 foot	3 – 180 foot deck girder spans	75	57	29	18	6	37
22248	84	11344	16 – 3 foot	1 - 80 foot deck girder span	33	1	12	8	4	10
* Includes intermediate diaphragms, end beams and cap beams.										
** A706 Grade 80 rebar.										

As shown in *Table 1.5.5.15.4-1*, when non-stock rebar is specified, the amount of deck reinforcement in one bar group can meet the required minimum quantity for the first three bridges. The rebar quantities in crossbeams and end beams are not sufficient when a 20 percent reduction due to the use of high strength rebar is applied. For drilled shafts, the amount of reinforcement in one bar group can meet the required minimum quantity only for the first two bridges. However, when high strength rebar of the same size is also used in other members of the bridges, it is possible that the quantities of each bar size will reach the minimum order requirement.

Showing two options of rebar grades on bridge plans is encouraged to accommodate a Contractor that may not be able to obtain high strength bars during a construction project. When this approach is taken, all dimensions need to be prepared to work with both options, especially details related to splice lengths and development lengths. Splice lengths and development lengths for high strength rebar are longer compared to Grade 60.

Couplers are available on the market for high strength reinforcement. These couplers are capable of meeting 125 percent of yield strength. The ODOT Materials Lab has the capability to test rebar couplers up to #14 bars in Grade 100.

### 1.5.5.16 Glass Fiber Reinforced Polymer (GFRP) Reinforcement

Glass fibers have an advantage over other fibers for composite materials because of an economical balance of cost and specific strength properties. Glass fibers are commercially available and exhibit good electrical insulation properties. When glass fibers are encapsulated in suitable resin as a system, the composite material is less sensitive to alkaline environment, freezing and thawing condition, and extremely elevated temperature. These properties make GFRP suitable for use as reinforcement for concrete structures. Through a number of research projects, it has been found that GFRP bars exhibit minimal loss in strength when subjected to sustained tension and have good resistance to fatigue. When GFRP bars are embedded inside concrete, there is no UV exposure concern.

ODOT has used GFRP bars on a number of projects particularly in bridge decks and sound walls. Using GFRP bars in the bridge decks was due to good corrosion-resistant and non-conductive properties. The non-conductive property of GFRP bars does not have detrimental effect to cathodic protection system often used for preserving coastal bridges as long as electrical continuity of adjacent steel reinforcement is maintained. For sound walls, wall weight needed to be minimized, see *BDM 1.15.2*. Use of GFRP bars resulted in thickness reduction, since smaller concrete cover could be specified.

Since the release of the 1<sup>st</sup> Edition of the *AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete* in 2009, there have been advancements in material specifications along with new knowledge and field experiences. AASHTO published the 2<sup>nd</sup> edition of the guide specifications in 2018, which incorporated the new comprehension and extended design provisions for other structural members in addition to bridge decks and traffic railings.

For material specifications, *ASTM D7957* published in 2017 includes requirements for material standards of GFRP reinforcing bars. GFRP bars are commercially available from multiple manufacturers and can be produced for construction with a reasonable lead time.

GFRP rebar is a good corrosion-resistant reinforcement alternative for reinforced concrete bridges in corrosive environment compared to ferrous reinforcement due to cost and material strength. Use of GFRP bars does not require electrical isolation to other ferrous reinforcement. Tensile strength of GFRP bars is slightly higher than mild steel reinforcing bars, however GFRP bars have linear elastic behavior, much lower modulus of elasticity, and smaller ultimate tensile strain. Deformation or surface texture, or both, are required to ensure adequate bond capacity. Nominal material properties used for design are shown in *Table 1.5.5.16-1*.

Table 1.5.5.16-1 Material Properties for Design of GFRP Reinforced Concrete

Material Property	Material Value
Ultimate tensile strength (ksi)	90 ksi (#4 - #6) 75 ksi (#7 - #10)
Tensile modulus of elasticity (ksi)	6,500
Ultimate tensile strain (inch/inch)	1.1

GFRP reinforcement is recommended for structural members that are located in corrosive environment and do not require high ductility. Service limit states often control design over strength limit states. Do not use GFRP reinforcement in structural members designed for seismic loads and to form plastic hinges.

GFRP bar weight is lighter than steel reinforcement, therefore construction workers are able to handle the reinforcing bars with ease, but more rebar ties are required to maintain GFRP bar position in the rebar cage during concrete pour. GFRP bars are susceptible to abrasion and impact from studded tires and removal tools, therefore use in bridge concrete deck is limited in specific area as shown in *Table 1.26.3-1*.

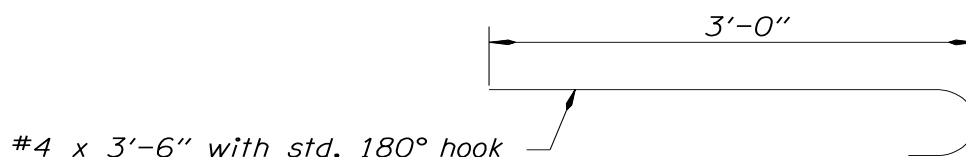
### 1.5.5.17 Bar Lengths

Use stock bar lengths whenever possible without sacrificing economy. Unless absolutely necessary, do not call for bars longer than 60 feet because they are difficult to handle and transport. Bar lengths specified include hook lengths unless detailed otherwise.

Table 1.5.5.17-1 Bar Length Stock Lengths

Bar Size	Stock Length *
#3	20 feet and 40 feet
#4 and #5	20, 30 and 40 feet
#6 thru #18	60 feet
*Only small quantities of #14 and #18 bars are stockpiled by the supplier because of size and weight and may require special mill orders.	

Figure 1.5.5.17-1 Specified Length of Bar with Hook



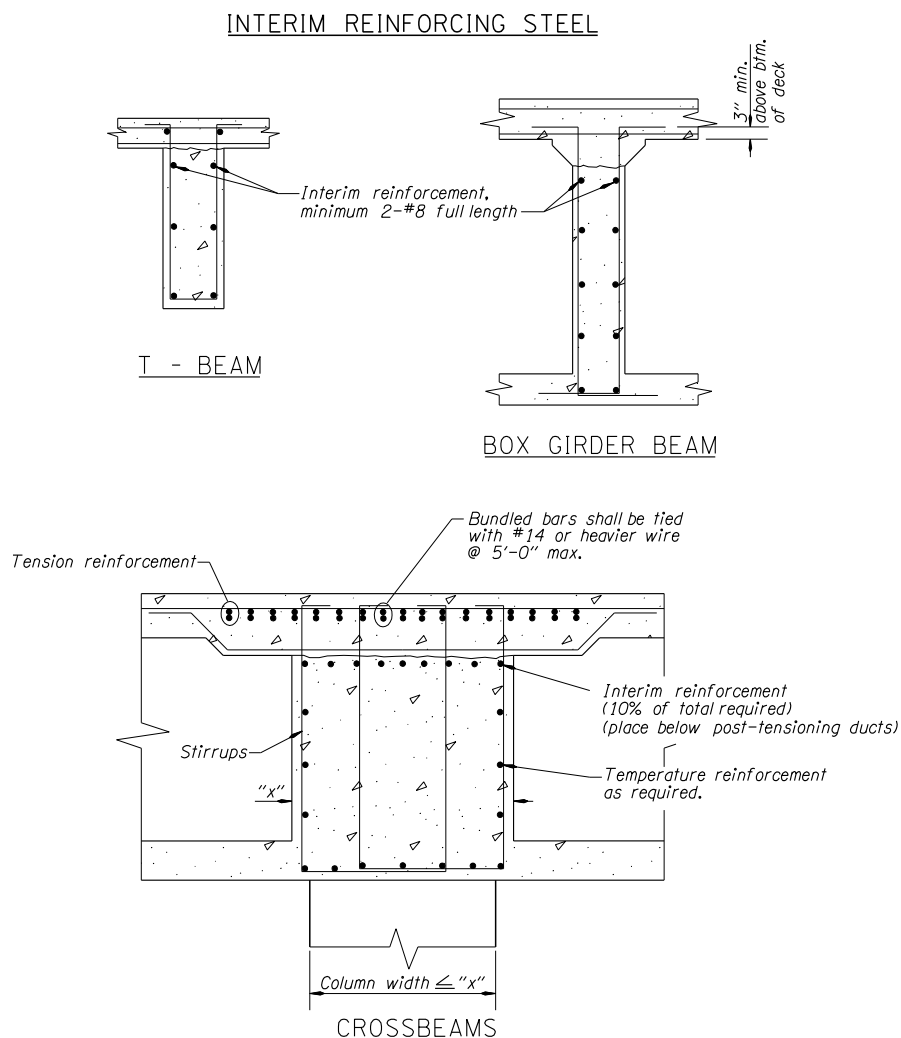
### 1.5.5.18 Interim Reinforcement for T-Beams and Box Girders

When the deck slab of a continuous T-beam or box girder is placed after the concrete in the stem has taken its set, place at least 10 percent of the negative moment reinforcing steel full length of the longitudinal beam to prevent cracks from falsework settlement or deflection. In lieu of the above requirement, two #8 bars full length of longitudinal girders may be used.

Locate a portion of the negative reinforcement in the stem of the crossbeam below the level of the deck slab construction joint in concrete crossbeams whose principal negative reinforcement lies in the deck slab. Provide sufficient ultimate reinforcement capacity to support 150 percent of the dead load of the crossbeam and superstructure 5 feet along the centerline of the structure either side of the center of bent. Use no less than 10 percent of the total negative reinforcement.

In cases where the bent crossbeams are skewed to the deck steel, place the top crossbeam steel in the top of the stem below the deck (dropped panel). See *Figure 1.5.5.18-1* for typical details.

Figure 1.5.5.18-1 Interim Reinforcement

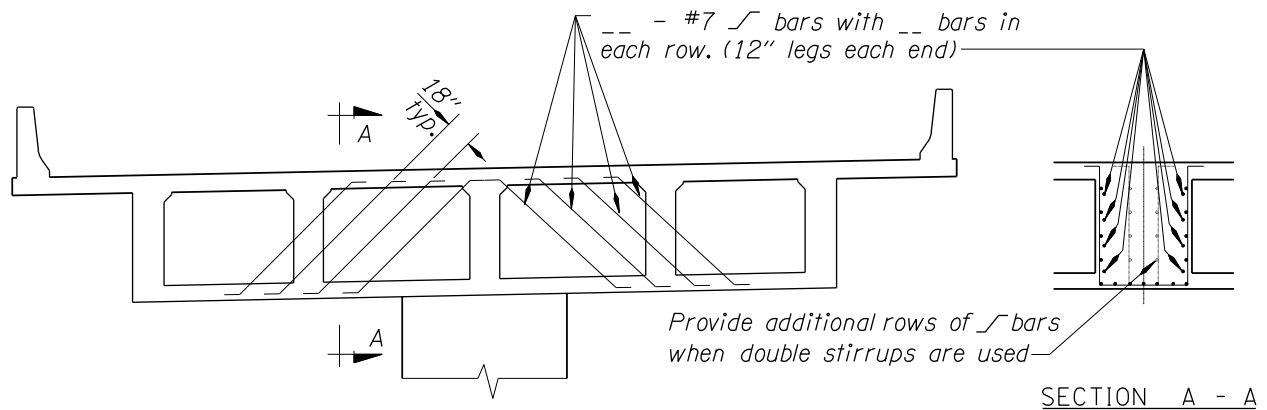




### 1.5.5.19 Additional Shear Reinforcement

As shown below, provide additional reinforcement to the calculated shear reinforcement in cantilevered portions of crossbeams. Pay careful attention to clearances and possible conflicts with post-tensioning ducts and other reinforcement. Detail the size and number of bars to provide at least 20 percent of the factored Strength I Limit State shear demand at the face of the column. Apply this provision to cantilevered sections of crossbeams when the crossbeam cantilever from the face of the column exceeds the crossbeam depth at the face of the column. This additional reinforcement may be omitted when the shear reinforcement provided from the critical shear section to the face of column provides 20 percent additional capacity above the controlling strength limit state.

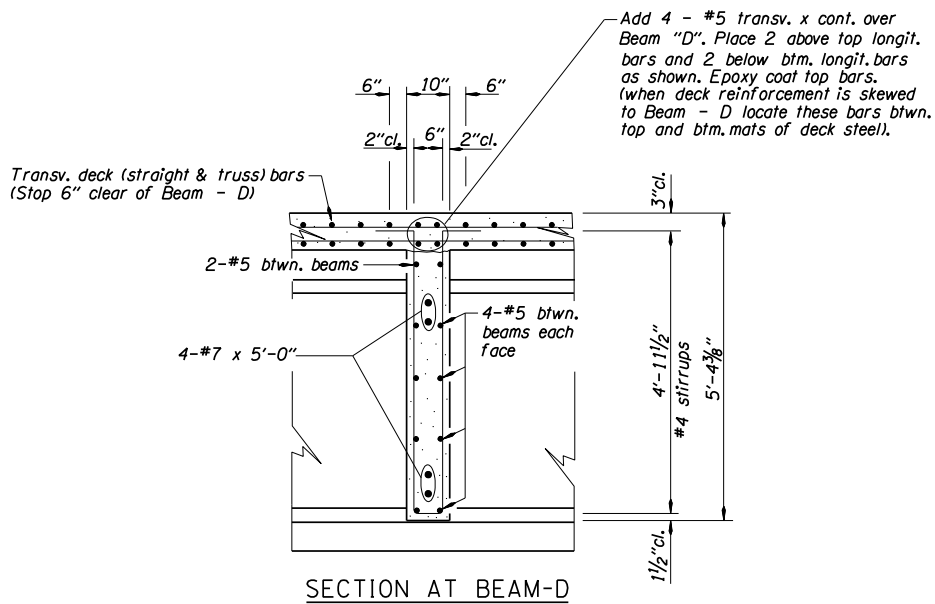
Figure 1.5.5.19-1 Additional Shear Reinforcement in Cantilevered Sections



### 1.5.5.20 Diaphragm Beam Reinforcement

Figure 1.5.5.20-1 below assumes the deck reinforcement is stopped 6 inches clear of the transverse beams. The added bars provide reinforcement for Beam-D and the deck overhang. When straight bars are used, the spacing of the deck steel will be continuous over the transverse beams and no additional bars will be required.

Figure 1.5.5.20-1 Diaphragm Beam Reinforcement



## 1.5.6 Precast Prestressed Concrete Elements

### 1.5.6.1 Design of Precast Prestressed Elements

The nature of precast prestressed elements requires special handling in several areas.

#### DESIGN – GENERAL

Each precast prestressed element is to be designed job specific.

Deck requirements:

- **Side-by-side slabs and box beams:** 5 inch minimum HPC thickness with a single mat of reinforcement (8 inch maximum centers each way). 7 inch minimum thickness for any portions overhanging the exterior slab or box beam.
- **Side-by-side Bulb-T and deck Bulb-T girders:** 7-1/4 inch minimum HPC thickness with two mats of reinforcement (8 inch maximum centers in each mat and each direction).
- **Spread slabs and box beams:** 8 inch minimum HPC thickness with two mats of reinforcement (8 inch maximum centers in each mat and each direction).
- **Bulb-T (not side-by-side) and Bulb-I girders:** 8 inch minimum HPC thickness (see *BDM 1.9.1*).
- **Deck Bulb-T girders with UHPC connection:** Precast concrete Deck Bulb-T girders are connected using UHPC at flange ends to form bridge deck. Air entrained concrete is required for girder top flange portion (8 inch minimum thickness). The deck girder system and connection details are shown in *Figure 1.5.6.1-1* and *1.5.6.1-2* respectively. See *BDM 1.9.1.5.1* for more information on UHPC. ¾ inch thick minimum PPC overlay is applied on top of the deck girder system.

Figure 1.5.6.1-1 Section View of Deck Bulb-T Girder System with UHPC Connections

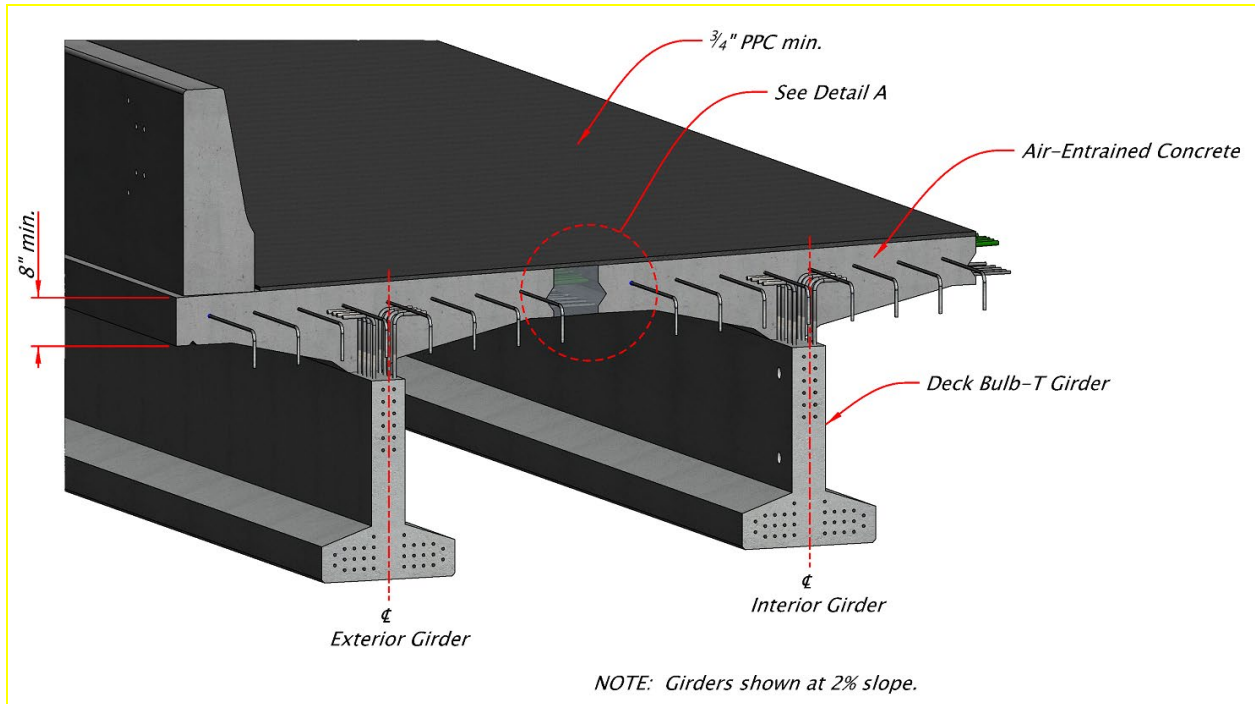
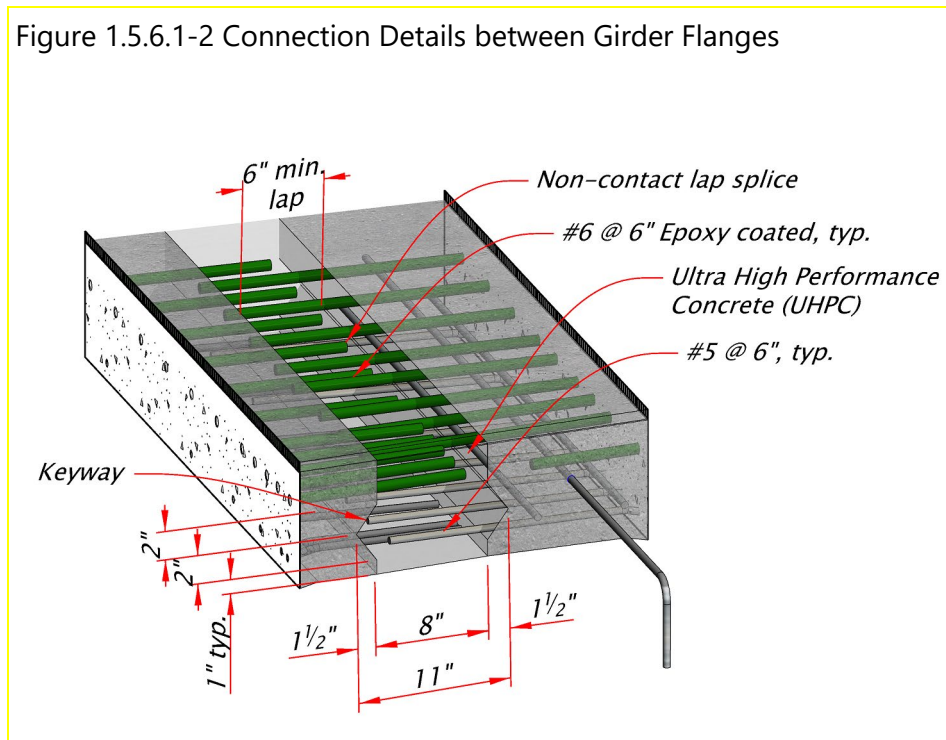


Figure 1.5.6.1-2 Connection Details between Girder Flanges



- HPC decks must be cast-in-place, unless full-depth precast panels are used with either longitudinal post-tensioning or ultra-high performance concrete closures.
- Asphalt concrete wearing surfaces are not recommended on concrete bridge decks and may be used only with an appropriate membrane per *BDM 1.26.4*. Approval from the bridge owner is required for the use of asphalt concrete wearing surfaces on all new bridges.
- Concrete Strength – Ensure design compressive strengths of concrete are not significantly higher than design requirements and are within the following allowable ranges of design compressive strengths. List the required concrete strengths in the General Notes.
- The allowable range of design compressive strengths of concrete at 28 days ( $f'c$ ) to be used are shown in *Table 1.5.6.1-1*.

Table 1.5.6.1-1 Allowable Design Compressive Strength Ranges

Precast Element	Minimum	Maximum
for precast, prestressed slabs and box beams	4000 psi	7000 psi
for precast, prestressed girders, and integral deck girders	5000 psi	9000 psi

When precast, prestressed members are used without a cast-in-place deck, the 28 day compressive strength is limited to 6000 psi. This limitation is required to ensure adequate air entrainment and to ensure adequate workability. Higher strength

concretes generally are less workable and therefore are more difficult to achieve an acceptable finish suitable for a riding surface. When a separate concrete mix (6000 psi or less) is used for the top flange, then higher strengths (up to 9000 psi) may be used for the remainder of the member.

- The allowable range of design compressive strengths of concrete at release of all prestress ( $f'c$ ) to be used are 4000 psi minimum and 7000 psi maximum.
- Do not exceed the compressive strengths listed above without an approved design deviation from the State Bridge Engineer.
- Concrete Tensile Stress Limits:
  - 
  - Modify [LRFD Table 5.9.2.3.1b-1](#) as follows:
    - Modify the 9th bullet to  $0.0948 * \text{sqrt}(f'c)$ , where  $f'c$  is in ksi.
    - **No Tension** criteria in 6th and 8th bullets still apply.
  - Modify [LRFD Table 5.9.2.3.2b-1](#) as follows:
    - Modify the 1st and 8th bullets to  $0.0948 * \text{sqrt}(f'c)$ , where  $f'c$  is in ksi.
    - **No tension** criteria in 3rd, 5th and 7th bullets still apply.
  - Simple Span Girders Made Continuous for Live Load – When precast girders are made continuous for live load, design the positive moment area as if the girder was simply-supported. A maximum concrete tensile stress up to  $0.19 * \text{sqrt}(f'c)$  in the positive moment area will be allowed for this condition. Also ensure that the maximum concrete tensile stress in the positive moment area does not exceed  $0.0948 * \text{sqrt}(f'c)$  when the girder is considered continuous for live load.
- Use a load factor of 0.80 for live loads in Service III load combination to check tensile stresses in prestressed concrete members with prestressing strands and reinforcing bars.

## PRESTRESS LOSSES

Calculate prestress losses in precast members according to [LRFD 5.9.3.4](#) – Refined Estimates of Time-Dependent Losses. This method of calculating losses is the **Detailed** method presented in [NCHRP Project No. 18-07](#).

An Excel spreadsheet for calculating prestress losses using the *NCHRP 18-07* methods is available from the Bridge Engineering Section. This spreadsheet includes multiple methods for calculating prestress losses. Use the **Detailed** method.

Prestress loss estimates have generally been in the 35 to 45 ksi range. The [LRFD 5.9.3.4](#) loss calculations appear to be consistent with earlier loss predictions. And these loss levels have

resulted in relatively accurate predictions of camber at the time of deck placement. There has also been no record of service cracking in bridges designed using these prestress loss levels.

Using prestress gain from loads permanently applied to girders, such as selfweight, bridge deck, superimposed dead loads, is allowed.

Do not include the prestress gain due to application of live load in the total long-term loss calculation.

The amount of prestress gain due to application of live load can be more than 20 percent of the total prestress loss. ODOT's policy of not including this gain results in a conservative estimate of final girder stresses. Note that prestress loss affects girder stress, but does not change the ultimate strength or capacity to carry permit loads.

Transforming the prestressing strand to increase section properties is not recommended. As stated in [NCHRP 18-07](#), prestress losses should be calculated differently (no elastic losses or gains) when transformed properties are used for the prestressing strand. When so, the final girder stresses will be approximately the same whether gross or transformed section properties are used. Therefore, there is no significant advantage in using transformed section properties.

### **GIRDER SHAPE SELECTION**

General – The Oregon Bulb-T girder shape is preferred for most Oregon bridge applications. This shape has a 4 foot wide top flange. This top flange provides safety for workers who must form bridge decks and ensures stability of the girder during shipping. Use Bulb-T girder shapes whenever it is appropriate to do so.

Bulb-I girders are a standard variation of the Bulb-T. To make a Bulb-I, the fabricator will start with the Bulb-T form and add blockouts to portions of the top flange to make the Bulb-I shape. Use the Bulb-I shape only when it has benefits over a Bulb-T. Since Bulb-I girders have a narrow top flange, it requires less concrete build-up over the girder compared to a Bulb-T. Therefore, bridges with high superelevation (generally, greater than 7 percent) may be candidates for the Bulb-I shape.

Since the Bulb-I section is 3 inches taller than the equivalent Bulb-T, it may be preferred for span lengths slightly longer than the equivalent Bulb-T capability. A Bulb-I section may provide benefits over a deeper Bulb-T section. However, due to shipping stability and worker safety concerns, a deeper Bulb-T might still be preferred when the deeper section can be accommodated within the available vertical clearance.

Modified Bulb-T girders include those having a non-standard top flange width and those having a wider web. Fabricators are generally able to adjust the top flange width anywhere from 24 inches to 48 inches. At least 3 inches can also be added to the top flange. Discuss any modifications to the top flange with fabricators before placing modified details on plan sheets. Design deviations are not required for top flange modifications.

Only adjusted web thickness when necessary to accommodate post-tensioning (such as for spliced girders). For such cases, increase the web thickness from 6 inches to 7.5 inches. When doing so, increase the top and bottom flange widths by the same amount.

BT90 & BT96 girder sections are the largest in the Oregon inventory. These sections have a 5 foot wide top flange which is necessary to ensure shipping stability of very long girders. Do not consider changes to the top flange width without concurrence from fabricators. The longest girder available from fabricators is around 185 feet total length. Verify availability for any girder length exceeding 180 feet.

BT96 girders have not yet been used in Oregon. Verify availability of this section before specifying it on a project.

Roadway surface is directly provided by Deck-Bulb Tee girders with UHPC connection. Because girders are erected plumb, the top flanges are required to be cast on a slope equal to a specified superelevation. To ensure constructability of flange concrete, a superelevation is limited to 5 percent maximum. Specify thicker PPC overlay (3.75 inches maximum) and thickened flange near beam ends as required to match roadway vertical profile. See *DET3385* and *DET3386* for details.

Due to its function as the roadway surface, construction requires minimal differential camber between adjacent girders in the span. The construction specification requires a tight camber difference, however there will be some residual camber variation due to construction tolerances. Also, overfilling of the connection is a common placement method for casting UHPC. As a result, grinding is required to smooth out the uneven surface. Subtract ½ inch flange thickness in the design to account for top surface grinding. 15 percent over designed capacities are recommended as reserve capacities for locked-in force effects from the girder camber adjustment during construction.

AASHTO Type II, Type III, Type IV, and Type V shapes do not have the same efficiency as Bulb-T shapes. Therefore, use Bulb-T shapes in most cases. Use of AASHTO shapes is generally limited to bridge widenings where the existing bridge has AASHTO shapes. There may also be rare cases when an AASHTO shape may provide slightly less vertical clearance compared to the available Bulb-T shape.

WSDOT Shapes - WSDOT girder section may be specified, when there is no Oregon section that can meet an application or provide efficient design for certain situations. WSDOT girder sections may be an acceptable alternate based on cost and availability. The standard specifications allow contractors to propose an alternate shape provided it is similar to the specified shape and meets all project requirements (see *SP 00550.03*). Design WSDOT shape girders according to ODOT design requirements. Consult with fabricators for availability of WSDOT girder section forms. Two WSDOT shapes are allowed:

- WF girders: WF36G to WF83G girders. The maximum form length for the WF shapes varies depending on the girder section ranging 80ft – 170ft.



- WF Deck girders (UHPC): WF39DG to WF53DG girders. WF Deck girders are designed to be erected side-by-side and the top flanges are connected using UHPC. WF Deck girder forms will need modification because of the required thicker top flange due to the ODOT requirements, as a result there will be a cost premium to modify the forms.

Spliced girders with post-tensioning can be used to extend span capabilities of precast concrete girders. Consult with fabricators regarding the appropriate section and segment lengths for spliced girder applications.

Consult with fabricators before considering using haunched girders. Although haunches may provide an aesthetic benefit, any structural benefit from haunching a prestressed girder is minimal.

Trapezoidal Box Girders are available for applications that require special aesthetic considerations. Trapezoidal box girders can either have a uniform depth or parabolic haunches. Horizontally curved trapezoidal boxes have been used in Colorado.

### **STRAND TYPE**

Bulb-T and AASHTO girders were developed for use with 0.5 inch diameter prestressing strand. Do not consider use of 0.6 inch diameter strand for these sections without first consulting with fabricators. Modification of the girder section may be needed to accommodate 0.6 inch strand. BT90/96 sections were developed for use with 0.6 inch strand.

### **SHIPPING**

When selecting the appropriate girder type, review potential shipping routes to make sure the proposed girder type can be shipped to the bridge site. Narrow roads and sharp curves may restrict the length of girder that can be used. Fabricators can generally provide assistance in this analysis.

### **FABRICATORS**

The following northwest precast concrete fabricators can provide precast concrete members to Oregon bridge projects:

- Concrete Tech, Tacoma, WA.
- Knife River, Harrisburg, OR and Spokane, WA.

### **DETAILING – GENERAL**

Camber - See *BDM 1.5.9* for special requirements pertaining to ACWS, sidewalk, and rail requirements.

Deck Drainage - See *BDM 1.24* for details specific to slab and box beam elements.

Girder Storage and Shipment - *SP 00550.49* prohibits transportation before seven days and only after the 28 day compressive strength has been achieved. There may be special construction

circumstances when a member needs to be transported and placed before the seven days, but it is not recommended before the 28 day compressive strength has been achieved.

When design requires a delay for placing the girder on bearing devices to decrease the bearing thickness or encasing the beam ends for fixed connection to reduce restraint moments due to long-term shrinkage and creep effect, specify a required wait time on the plan sheet.

Skew - Limit skew to 45 degrees for precast slabs and 30 degrees for precast boxes. Excessively skewed slabs and boxes tend to warp more, making fit and obtaining uniform bearing on the bearing pads more difficult. Stair stepping the bearing pads may be necessary to obtain uniform bearing.

Stage Construction of slabs and boxes with cast-in-place HPC decks - Do not use side-by-side slabs or boxes with HPC decks when precast elements must be placed in stages. Such stage construction does not allow tie rods to be placed as detailed in *BR445*. Spread slabs or boxes with a 7 ¼ inch minimum deck thickness (two mats of deck steel) would be an acceptable option for bridges constructed in stages.

Transverse Connection for Side-by-Side Slabs and Boxes – Connect side-by-side slab and box elements with transverse tie rods as detailed on *BR445*. Alternate connection details, such as intermittent weldments, are not allowed.

Surface Finish for Precast Members - The standard specifications requires a light broom finish on the tops of members having an asphalt wearing surface for members having a HPC deck. A light broom finish combined with extending stirrup legs up into the deck is considered sufficient to provide adequate capacity to ensure composite action between the girder and deck. It is not necessary to require additional roughening.

Interface Shear – For all members with a cast-in-place deck, provide interface shear reinforcement full length of the member regardless of whether or not it is required by design. This requirement is satisfied by extending stirrups from the precast member up into the deck slab and will result in minimum reinforcement across the interface shear plane equal to two #4 bars at 18 inch centers.

Joint and Keyway details - see standard drawings for recommended details.

## **1.5.6.2 Design and Detailing of Precast Prestressed Girders**

### **1.5.6.2.1 Stay-in-Place Forms**

Where the spacing between edges of precast concrete girder flanges is no greater than 2 feet, steel stay-in-place deck forms may be used. However, do not use stay-in-place forms in exterior bays.

Steel stay-in-place deck forms may also be used behind end beams where the deck is continuous over interior bents. Hot-dip galvanize all steel stay-in-place forms.

When stay-in-place deck forms are used, provide a minimum section modulus of 0.15 in<sup>3</sup>/ft and a maximum form height of 1 ½ inches. Install stay-in-place forms such that the top of the form is at the design bottom of deck thickness. The weight of a form meeting these requirements is likely to be less than 2 psf. This weight is not significant and need not be included in the design. However, add 10 psf additional non-composite dead load in the girder design to account for extra concrete weight.

Do not use stay-in-place forms at deck overhang areas or where the edges of girder flanges are greater than 2 feet apart. In such cases, access for inspection and future maintenance of the deck precludes the use of stay-in-place deck forms.

Do not use stay-in-place forms in coastal areas.

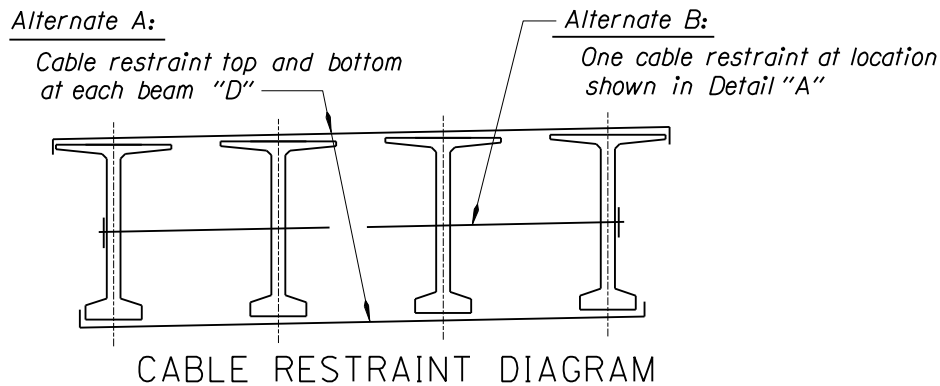
These provisions apply to precast girders, slabs and boxes.

Where stay-in-place forms are considered, add the following statement with the loading section of the general notes:

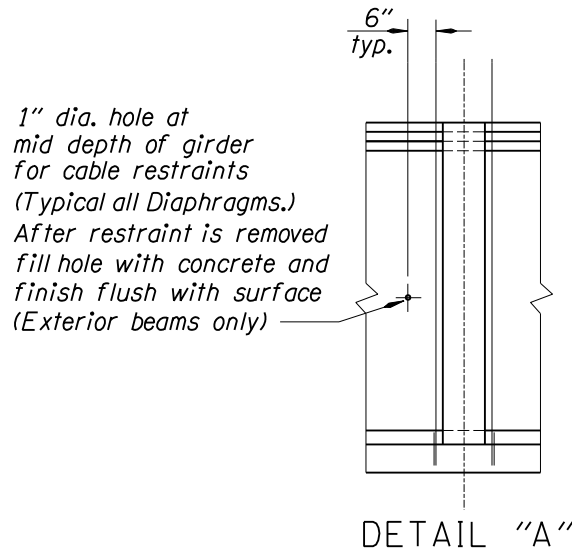
Stay-in-place deck forms may be used except for exterior overhangs and between the exterior girder and the first interior girder on each side of the structure. XX psf additional non-composite dead load has been included in the girder design to account for extra concrete and form weight associated with stay-in-place forms.

**1.5.6.2.2 Diaphragm Beam Restraint**

Figure 1.5.6.2.2-1 Diaphragm Beam Restraint



*Snug fit prestressed beams against forms prior to diaphragm pour. Restraint to remain in place a minimum of two days after completion of diaphragm pour.*



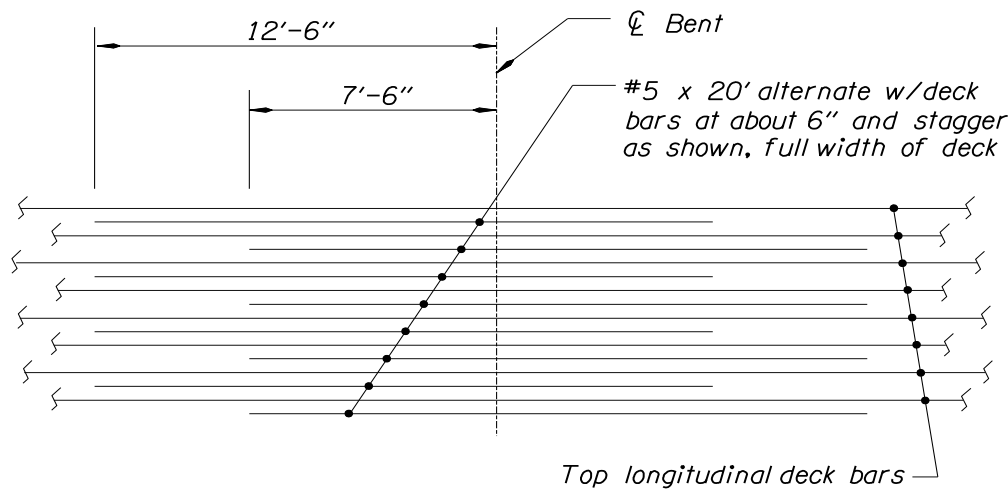
**1.5.6.2.3 Beam Seat or Top of Crossbeam Elevation**

Provide a note on the plans indicating when the beam seat (or top of crossbeam) elevations shown are for deck buildups based on three months camber. Adjust the beam seat (or top of crossbeam) elevations during construction to correct for the revised deck buildups.

### 1.5.6.2.4 Continuous Deck Reinforcement

Provide additional deck reinforcement for bridges composed of precast simple span elements with continuous deck as shown below. This detail does not apply to bridges made continuous for live load. When girders are made continuous for live load, the deck reinforcement must resist the negative moments generated. The result will be substantially more deck steel than the detail below. *NCHRP Report 519* provides design examples for girders made continuous.

Figure 1.5.6.2.4-1 Interior Bent with Continuous Deck



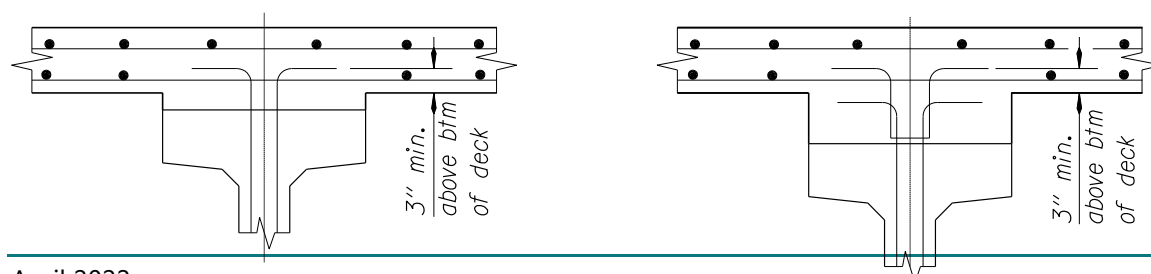
### INTERIOR BENT WITH CONTINUOUS DECK

### 1.5.6.2.5 Beam Stirrups

Bulb-T and Bulb-I standard drawings show stirrups with 90 degree shop bent hooks at the top of the girder. These hooks must protrude at least 3 inches above the bottom of the deck. When they do not, because of excessive build-up, the standard drawing requires the use of U bars to fill the gap.

There is no need for the stirrup hooks or U bars to extend to the top mat of deck reinforcement, as has been shown in the past. Detail plans to reflect these requirements.

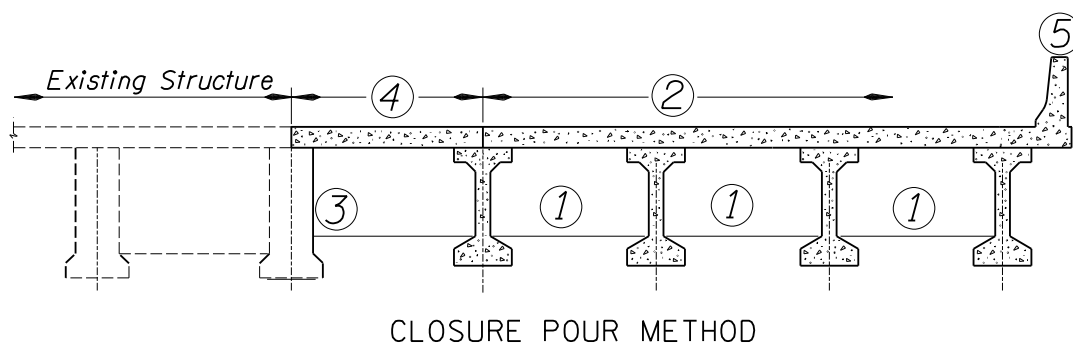
Figure 1.5.6.2.5-1 Beam Stirrup Details



**1.5.6.2.6 Structure Widening, Precast Beam Bridges**

Detail connections between superstructures to prevent widening dead loads from being transferred to the existing beams. This may be accomplished by delaying the connection pour (diaphragm and deck) until most of the dead load is applied to the widening. The designer chooses the appropriate placement method.

Figure 1.5.6.2.6-1 Closure Pour Method

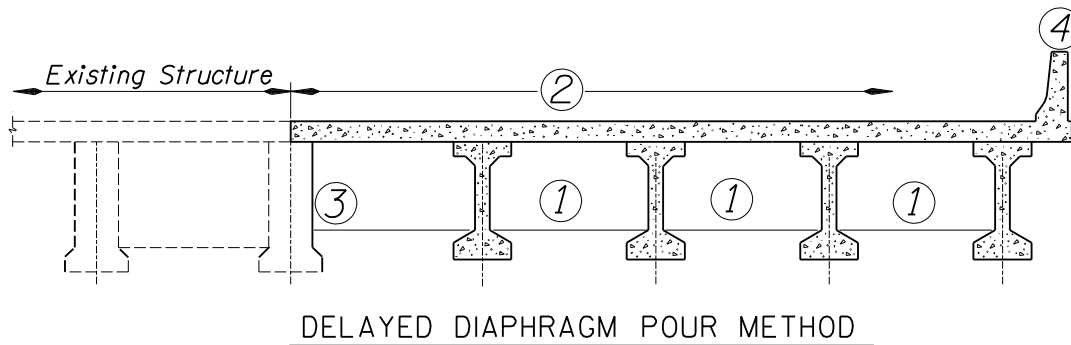


POUR SCHEDULE  
(INCLUDING CLOSURE POUR)

- ① Make pour in diaphragms
- ② Make pour in deck slab. Delay pour ② a min. of 3 days after pour ①.
- ③ Make pour in diaphragm of closure pour section.
- ④ Make pour in deck slab of closure pour. Delay a minimum of 3 days after pour ③.
- ⑤ Make pour in bridge rail.

Note: In the above closure pour method, the deck screed machine would normally be placed or supported on the widening beams. As the concrete is placed, the beams tend to deflect equally. This equal deflection normally gives better control of deck thickness and deck steel cover.

Figure 1.5.6.2.6-2 Delayed Diaphragm Pour Method



POUR SCHEDULE

- |   |  |
|---|--|
| <p>① Make pour in diaphragms</p> <p>② Make pour in deck slab. Delay pour ② a min. of 3 days after pour ①. Blockout deck as required to make pour ③.</p> | <p>③ Make pour in diaphragm closure a minimum of 3 days after pour ②.</p> <p>④ Make pour in bridge rail.</p> |
|---|--|

Note: In the above delayed diaphragm pour method, the deck screed machine rails would normally be placed or supported with one rail on the existing structure and one rail on the widening beams. As the concrete is placed, the new beams would tend to deflect more than the existing composite beams. This unequal deflection makes it more difficult to control deck thickness and deck steel cover, especially at the new beam adjacent to the existing structure.

### 1.5.6.2.7 Deck Pour Sequence

Place decks on precast prestressed beams no less than 60 days after stress transfer. This is to allow a majority of the prestress camber to occur, thus enabling more accurate determination of beam build-up for the deck screeding.

### 1.5.6.2.8 Diaphragm Beams

Intermediate diaphragms distribute loads from over-height vehicle, vessel and large debris collision. Use CIP diaphragm beams at ends of each span. Use full depth CIP diaphragms. Full depth diaphragms are more effective in distributing the impact loads.

Use the span length criteria in *Table 1.5.6.2.8-1* to determine the number of intermediate diaphragms for bridges crossing over major truck routes including Interstate 5, Interstate 84 and routes with 20 year projected ADTT greater than 5000; or waterways where there is a high probability of large debris or vessel collision.

Table 1.5.6.2.8-1 Criteria to Determine Number of Intermediate Diaphragms

Span Length (feet)	Location of Diaphragm
40 – 80	Midspan
81 – 120	1/3 points
Greater than 120	1/4 points

For other bridges, one set of intermediate diaphragms at midspan is recommended. Stagger and place intermediate diaphragms perpendicular to girder centerline, when the skew is greater than 25 degrees.

Install temporary diaphragms midway between the end and midspan diaphragm beams before pouring the end and midspan diaphragm beams (*see BR350*). Temporary beams may be removed after removing the deck overhang brackets.

### 1.5.6.2.9 Earthquake Restraint Details

See *Cost Data Books* for sample plans and details.

### 1.5.6.2.10 Fixed Girder Connections

Where girder ends are designed with a fixed connection to an end beam or bent cap, embed the girder into the end beam (or bent cap) a minimum of 8 inches. Provide transverse bars/rods through the girder ends as shown on the standard drawings (*BR300 & BR310*). In addition to the above requirements, provide strand extensions and/or dowels at the end of the girder as needed to ensure adequate transfer of loads to the substructure.

To minimize restraint moments due to girder creep and shrinkage, establish continuity when the age of the girders is at least 28 days after casting. Submit a design deviation when the construction schedule requires earlier continuity construction. When a certain concrete age is required by design to minimize the time-dependent effect, include the following note in the plan sheet with continuity details:

Place continuity diaphragm at least XX days after the girders are manufactured.

### 1.5.6.2.11 Girder Spacing

Limit girder spacing to 9 feet for girder sections up to BT72 and 1.5 times girder depth for larger girders.

## PRECAST MEMBERS TOPPED WITH ACWS



Side-by-side elements have been historically topped with ACWS over a waterproofing membrane. This type of construction works well in a stage construction scenario as long as the elements are placed consecutively from one side to the other.

When using this type of construction, the previous stage precast element at the stage construction joint must carry some of the wearing surface dead load from the subsequent stage since adjacent slabs must have their tie rods connected before the wearing surface is placed for the subsequent stage. This additional load is generally ignored (i.e., the members are designed as if they were all placed in one stage). Long term creep is thought to mitigate this condition. To date, annual inspections have found no distress in precast elements due to this practice.

For cases where elements cannot be placed consecutively from one side to the other, it becomes impossible to place standard transverse tie rods. For this reason, select a different structure type (ex., spread slabs or girders with CIP deck) when elements cannot be placed consecutively. Any side-by-side precast slab or box element must be connected to adjacent elements with transverse tie rods as detailed in *BR445*. Alternate details, such as intermittent weldments, are not allowed.

The use of asphalt concrete wearing surfaces are no longer recommended due to long term maintenance concerns.

#### **PRECAST MEMBERS TOPPED WITH CIP CONCRETE**

Side-by-side elements may be topped with an HPC deck. See *BDM 1.5.6.1* for minimum deck thickness and reinforcing requirements.

For this type of construction, the deck dead load is substantially larger than the PPC or ACWS case. For this reason, this type of construction must be detailed to prevent the deck dead load from later stages from being transferred to previous stages.

One solution to this problem is to provide a space (12 to 18 inches) between the stages that is filled with a CIP closure girder which is placed after full deck dead load is applied to both adjacent sections. For this case, design the precast members adjacent to the construction joint as exterior girders. Design the CIP closure girder to carry a contributory portion of live load under the strength limit states.

Use of spread slabs or boxes is another possible solution for stage construction. When so, use 7 ¼ inch minimum deck thickness with two mats of steel as required by *BDM 1.5.6.1*.

Any side-by-side precast slab or box element must be connected to adjacent elements with transverse tie rods as detailed in *BR445*. Alternate details, such as intermittent weldments, are not allowed.

## 1.5.7 Cast-In-Place Superstructure

### 1.5.7.1 General Design

#### STRUCTURE DEPTHS

See *BDM 2.5.2(2)* for minimum depth and live load deflection requirements.

#### COMPUTATIONS OF DEFLECTIONS

Base computed deflections on the effective moment of inertia of the section.

Estimate long term deflections as instantaneous deflection times a factor of three for reinforced concrete elements.

### 1.5.7.2 Interim Reinforcement for T-Beams

See *BDM 1.5.5.18*.

### 1.5.7.3 Diaphragm Beam Steel

See *BDM 1.5.5.20*.

### 1.5.7.4 Box Girder Stem Flare

Taper changes in girder stem thickness for a minimum distance of 12 times the difference in stem thickness. See Standard Detail *DET3125* for details.

### 1.5.7.5 Shear Keys and Construction Joints

Normally, shear keys at construction joints are unnecessary. Show construction joints with a roughened surface finish unless shear keys are required and shown on the plans.

At construction joints between the stem and slab of concrete girder bridges, use the following note:

Roughened surface finish. See *SP 00540.43(a)*.

### 1.5.7.6 Standard Access and Ventilation in Concrete Box Girders

Provide permanent access to all cells of concrete box girders. Access may require using manholes and/or access holes through bottom slabs, diaphragm beams, crossbeams and

longitudinal beams. Standard Drawings *BR135* and *BR136* show standard access and ventilation details. See *BDM 2.6* for additional accessibility guidance.

In addition to the standard drawing for Access Holes, draw a section on the plans normal to the girder through the access hole showing the relationship of the longitudinal stems, utility lines, and crawl holes to the access hole and ladder. When the drawing is to scale, dimensions need not be shown.

Use the following guidelines tempered with engineering judgment.

- Deck Access Holes – Avoid placing access holes through the deck of a structure. There is a potential for the access hole cover to leak. Also avoid disruption of traffic and the need for traffic protection and direction.
- Bottom Slab Access Holes - Single span bridges will normally require one access hole per cell. Multiple span bridges will normally require one access hole per cell at each end of the bridge. Locate access holes in accordance with the guidelines shown on the standard drawings. An 8 feet minimum height to the access hole is recommended to discourage unauthorized access into the structure. Keep the inspector in mind when choosing the access locations. Do not place access holes over railroad tracks.
- Girder Stem Access Holes - Girder stem access holes are to be provided through the interior stems at the midpoint of all spans. These lateral access points will allow the inspector to complete their inspection of span or spans without having to exit and reenter the structure.
- Crossbeam Access Holes - These are not detailed on the standard drawing since their design will vary widely because of structural requirements. However, only one access hole will be required per crossbeam when the girder stem access holes are provided.
- Bottom Slab Ventilation Holes - These ventilation holes, similar to the bottom slab access holes in design except top opening, are intended to be used in all cells of each span not having access holes. Generally, the ventilation holes would be located near the opposite end of the span from an adjacent span having access holes. The holes provide additional ports for removing forms, serves as an exhaust hole when forced ventilation is required and provides additional natural ventilation.
- Stem Ventilation Holes - These holes provide for the escape of lighter-than-air gases and are located near the high point of each span as detailed on the standard drawings.
- Ladder Support - The ladder support provides a safe support for the ladder while the inspector unlocks the access hole cover. After the cover is unlocked, reposition the ladder through the access hole so the inspector can grab onto the ladder while entering or leaving the box girder cell.
- Access Cover Prop - The access cover prop is designed to facilitate the opening or closing of the cover when the ladder is supported by the ladder support. Once the

ladder is through the access hole, release the prop so the cover will lie flat. The prop would be reengaged upon exiting the box.

### 1.5.7.7 Form Removal

All forms are to be removed from cells where access is provided.

Deck forms to be removed may be supported off the bottom slab when the bottom slab is fully supported, designed to support the added load and has no detrimental effect on the structure.

Deck forms for non-accessible cells may be left in place. Deck forms left in place are not to be supported off the bottom slab. Web supported deck forms are acceptable. Include an allowance for deck form dead load in the design loads, see *BDM 1.3.4*.

### 1.5.7.8 Bottom Slab Details

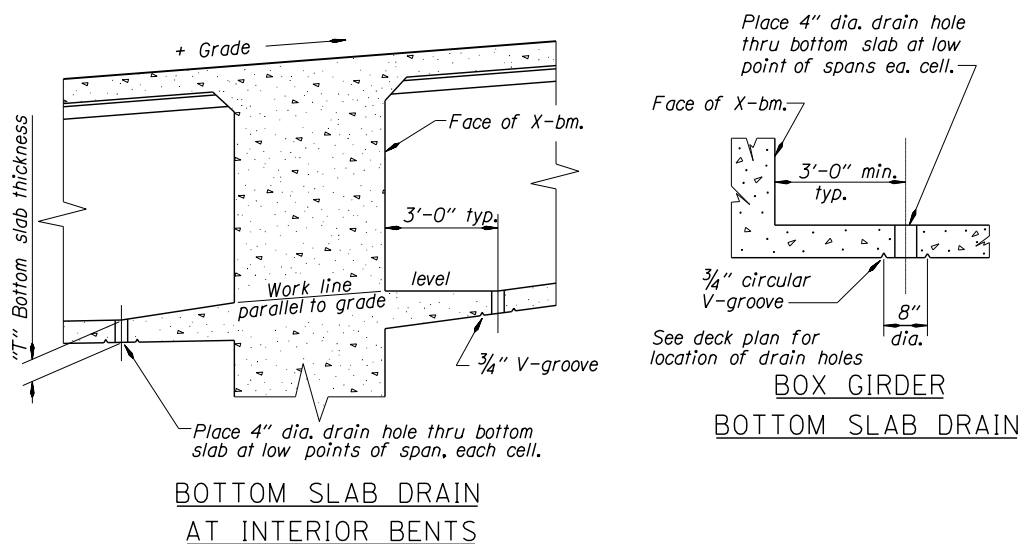
Generally, show the bottom slab of box girders to be parallel to the top slab in transverse section so that all girder stems will be the same depth.

Provide a bottom slab thickness of no less than 6 inches.

For skewed box girders, orient bottom slab transverse bars the same as the deck transverse bars. See *BDM 1.9.1* and *LRFD 9.7.1.3* for requirements.

Place a 4 by 4 inch drain hole through each diaphragm beam at the low point of each cell. Place a 4 inch diameter drain hole through the bottom slab at the low point of each series of cells in a span. For cells that carry water lines, increase 4 inch diameter to 6 inch diameter.

Figure 1.5.7.8-1 Bottom Slab Drain Details



### **1.5.7.9 CrossBeams**

See *BDM 1.5.5.18* and *BDM 1.5.5.19*.

### **1.5.7.10 Fillets**

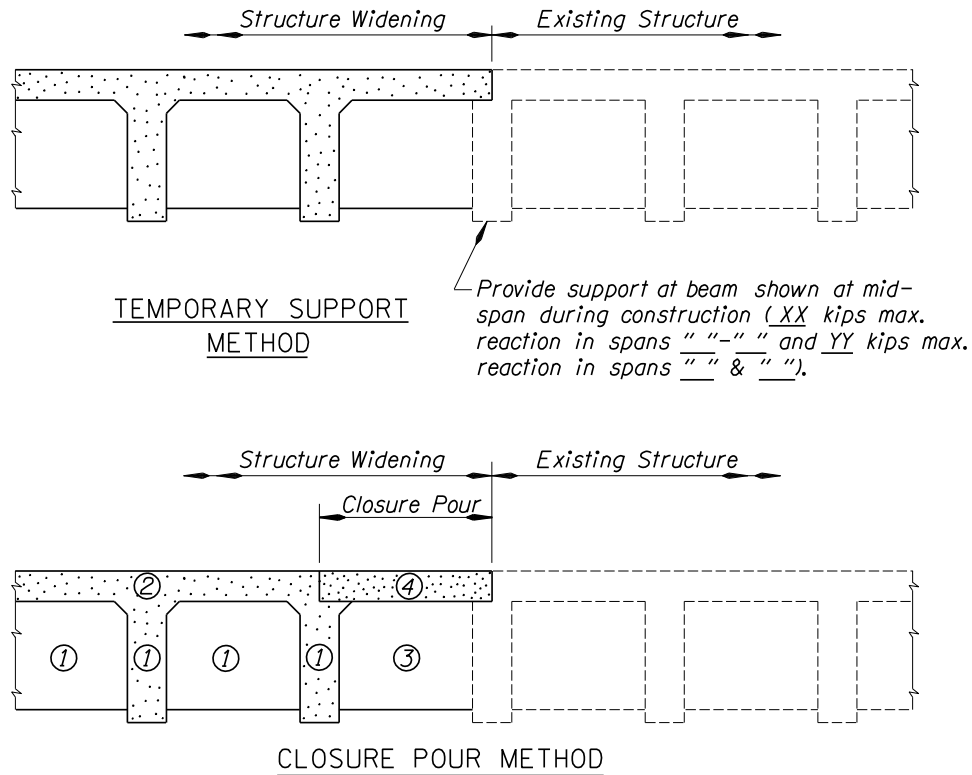
Provide adequate fillets at the intersections of all surfaces within the cell of a box girder, except at the junction of web and bottom flange where none are required.

Provide a 4 by 4 inch fillet at the intersection of the crossbeam and the deck; and the end diaphragm beam and the deck. For additional detailing requirements see *BDM 1.9.1.1*.

### **1.5.7.11 Structure Widening, Cast-in-Place Superstructures**

Detail connections between superstructures to prevent widening dead loads from being transferred to the existing beams. One method is to temporarily support the beam adjacent to the widening during construction. Designate locations where supports are required and expected maximum reactions. An alternate method requires closure pours for the diaphragm and deck slab.

Figure 1.5.7.11-1 Closure Pour Method for CIP Superstructures



Provide support at beam shown at mid-span during construction ( $XX$  kips max. reaction in spans "—" and  $YY$  kips max. reaction in spans "—" & "—").

POUR SCHEDULE

- ① Pour longitudinal beams and diaphragm beams shown to the bottom of the top fillets.
- ② Pour ② includes top fillets and deck slab. Pour ② to be delayed a minimum of 3 days after pour ①. A deck construction joint may be made over any diaphragm beam. Delay pouring adjacent section of deck a minimum of 36 hours.
- ③ After falsework removal, pour diaphragm closure section.
- ④ Make closure pour in deck slab. Delay a minimum of 3 days after pour ③.

### 1.5.7.12 Stay-in-Place Forms for Deck

For deck construction, stay-in-place forms will not be allowed. Loss of access for inspection and future maintenance of the deck preclude the use of stay-in-place deck forms.

## 1.5.8 Post-Tensioned Structures

### 1.5.8.1 General Design

#### STRUCTURE DEPTHS

See *BDM 2.5.2(2)* for minimum depth and live load deflection requirements.

#### SHRINKAGE AND CREEP STRESSES

The stresses in the superstructure and substructure of post tensioned concrete bridges which result from elastic shortening may be assumed to remain in the structure indefinitely. The stresses which might be assumed to develop as the result of shrinkage and creep may be assumed to be relieved by creep.

#### SHORTENING OF POST TENSIONED BRIDGES

Values in *Table 1.5.8.1-1* for shortening of post tensioned, cast in place concrete bridges are based on field measurements by the ODOT Bridge Section. Compare the design values with the field measured values and use the more conservative value.

Table 1.5.8.1-1 Shrinkage prior to tensioning (theoretical)

Shrinkage Time Period	Shortening Length (inch/foot)
0.4 x .0002 ft/ft x 12 in/ft x 100 ft =	0.10/100
Elastic shortening	0.44/100
Shrinkage and creep after tensioning to 1 year	0.29/100
Shrinkage and creep 1 year to 20 years (anticipated)	0.10/100

These structures were stressed to an average concrete stress of 1200 psi (1000 to 1300 psi). For other values, the elastic shortening and creep is roughly proportional. ODOT data indicates that variation of these values by 50 percent would not be unusual.

#### DEFLECTIONS

Estimate long term deflections as the net instantaneous deflection (*DL + Prestress*) times a factor of two for cast-in-place post-tensioned elements.

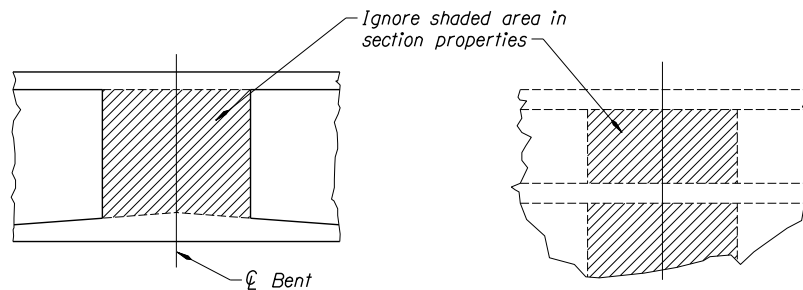
**CURVED POST-TENSIONED DUCTS**

Design for the radial prestress forces resulting from curved tendons in post-tensioned structures. Additional shear/flexural reinforcement may be required to resist the lateral web forces and ties to resist the web bursting forces.

**DESIGN MOMENTS AT INTERIOR BENTS OF POST-TENSIONED BRIDGES**

For crossbeams with widths less than the distance between the top and bottom slab, do not include the crossbeam in the superstructure section properties. Project the stem and slab dimensions to the centerline of the bent and use those dimensions to calculate section properties. Use the negative moment at the bent centerline for design.

Figure 1.5.8.1-1 Crossbeam Section Properties



For greater crossbeam widths, use the above section properties and consider adding supplementary reinforcing steel across the top of the crossbeam to control any theoretical cracking that may occur from live loading.

**SKewed BOX GIRDERS**

Box girder bridges with skews of over 20 degrees cannot be safely designed without taking into account the effects of skew. These effects generally increase as any of the following increase: skew angle, span length, torsional rigidity of the superstructure. The principal effect of skew is to increase the reactions at the obtuse corner of the structure and to reduce those at the acute corners (sometimes even causing uplift). This increases shear in the beams adjacent to the obtuse corners and produces transverse shear in the deck and bottom slab. These effects can be reduced by reducing the skew, which generally means lengthening the structure and/or by placing crossbeams at interior bents normal to the centerline of the structure.

When torsion due to skew is a problem, consider reducing the torsional stiffness of the structure. RCDG bridges, either cast in place or with precast girders, are torsionally limber. For additional detailing of skewed decks see *BDM 1.9.1.1*.

Do not design box girder bridges with bents skewed more than 45 degrees from the normal to the structure centerline.

Careful design of post tensioning with regard to the deflection and slope of the girder at a skewed end can nullify or reverse the tendency of the obtuse corner of the skewed structure to



take a disproportionate part of the dead load. Theoretically, this could be done so that under full  $DL + LL + I$ , the reactions would be equal at all bearings. Even an approximation of this condition will benefit the design.

#### CONCRETE TENSILE STRESS LIMITS

The concrete tensile stress limits given in *BDM 1.5.6.1* also apply to post-tensioned members.

### **1.5.8.2 General Details**

Details and practices stated in *BDM 1.5.7* generally apply to post-tensioned box girders as well as conventional box girders.

#### CONVENTIONAL BOX GIRDERS

See Standard Details *DET 3125* and *DET 3130* for general details.

#### PRECAST TRAPEZOIDAL BOX GIRDERS

See Standard Drawing *BR133* and Standard Details *DET 3131*, *DET 3132* and *DET 3134* for general details.

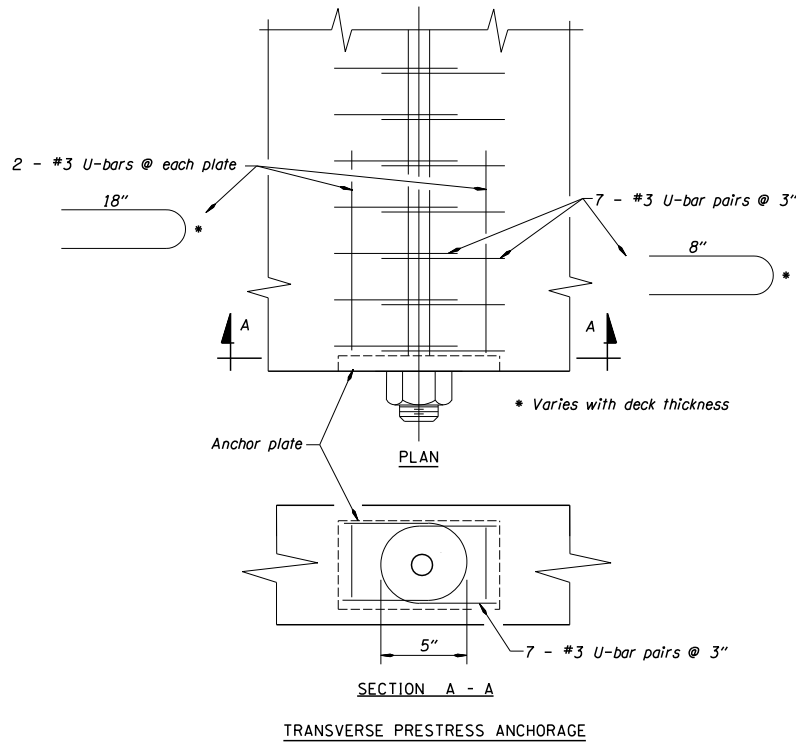
#### ACCESS AND VENTILATION

See Standard Drawings *BR135* and *BR136* for general details.

### **1.5.8.3 Post-Tensioned Deck Overhangs**

Place post-tensioning ducts and deck reinforcement normal to the centerline of the structure.

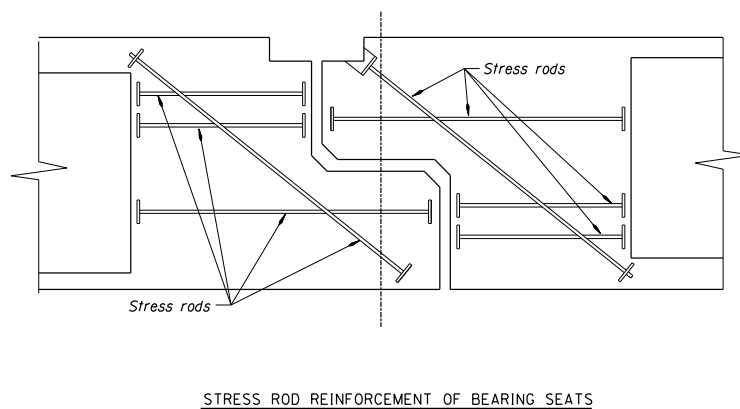
Figure 1.5.8.3-1 Transverse Prestress Anchorage



### 1.5.8.4 Stress Rod Reinforcement of Bearing Seats

A recent example of a stress-rod reinforced bearing seat is shown below. In order to retain a significant amount of prestressing force, provide a rod with stressed length of not less than 10 feet.

Figure 1.5.8.4-1 Stress Rod Reinforcement of Bearing Seats



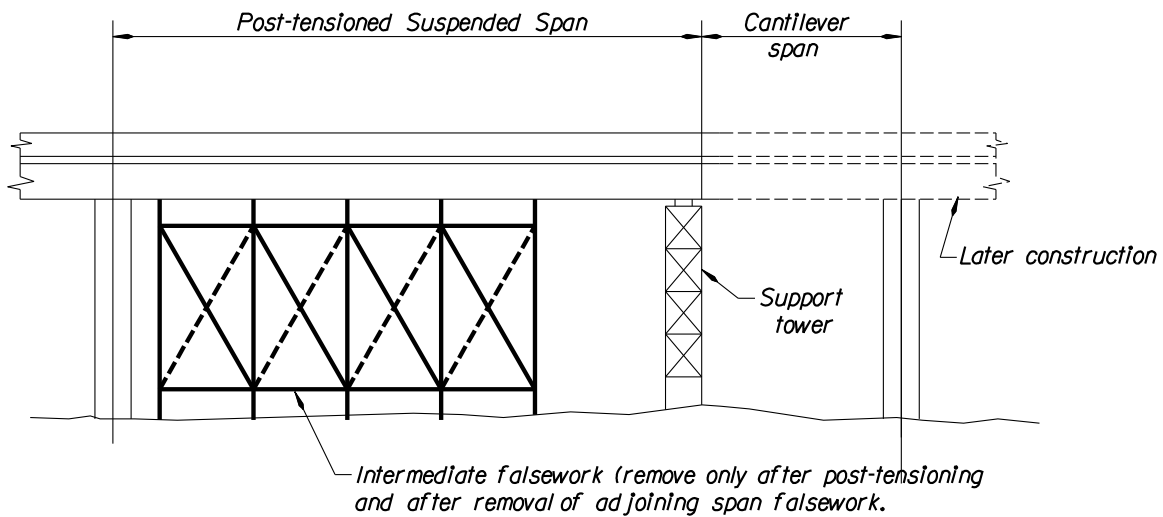
### 1.5.8.5 Segmental Construction

Where precast and cast-in-place concrete elements are joined in a continuous, segmental structure, chamfer the exterior corners of the cast-in-place portion to match the precast elements. It is standard practice to chamfer precast elements, even though the chamfer may not be shown on our drawings or the shop drawings.

### 1.5.8.6 Support Tower Details and Notes

Design the support tower at the end of the suspended span to support the reaction from the suspended span including the additional reaction due to post tensioning. Show on the plans the approximate total reaction in kips. Design the tower to accommodate the elastic shortening of the superstructure due to post tensioning. Make provisions so that the superstructure may be returned to the plan elevation (raised or lowered) in the event that actual settlement at the top of the tower differs from the anticipated settlement. Keep the support tower in place until the suspended span is fully supported by the cantilever and adjoining span.

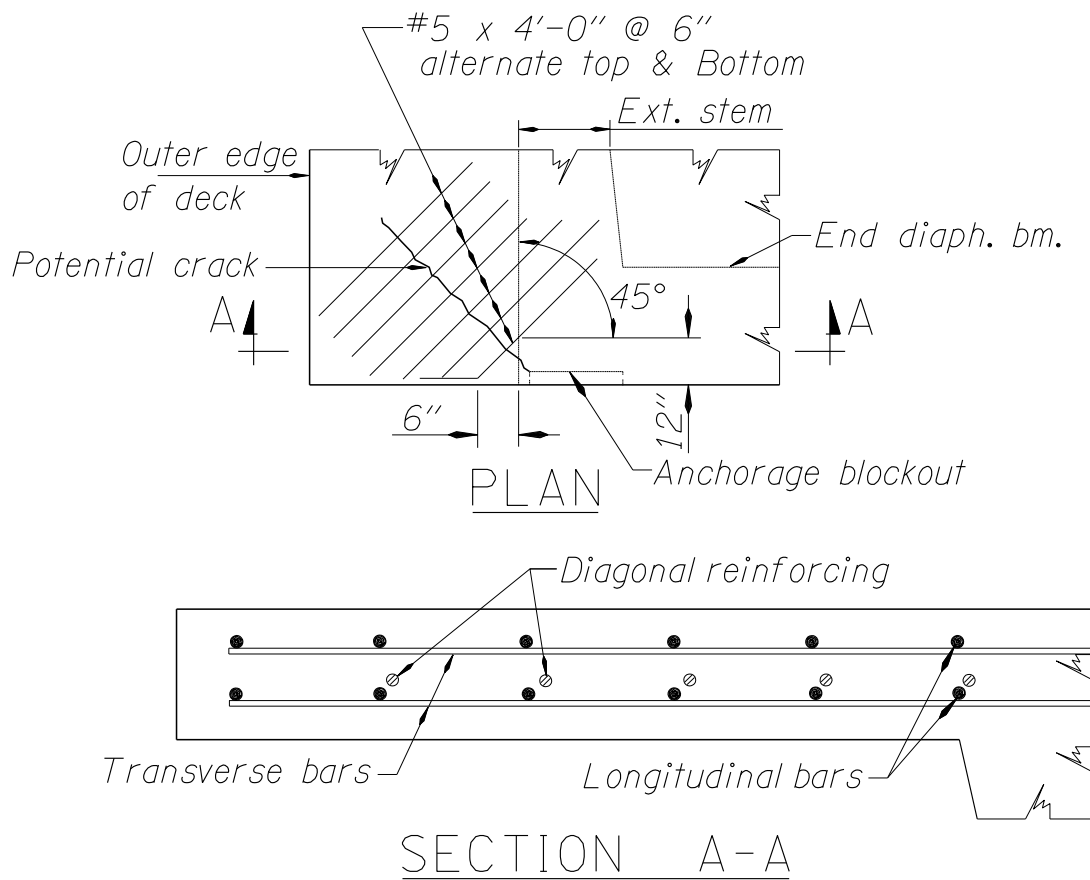
Figure 1.5.8.6-1 Support Tower Details



### 1.5.8.7 Reinforcement of Deck Overhangs

In order to prevent cracking at the end of post-tensioned spans, extend the end diaphragm beam to the edge of the deck or provide additional diagonal deck reinforcement similar to shown below.

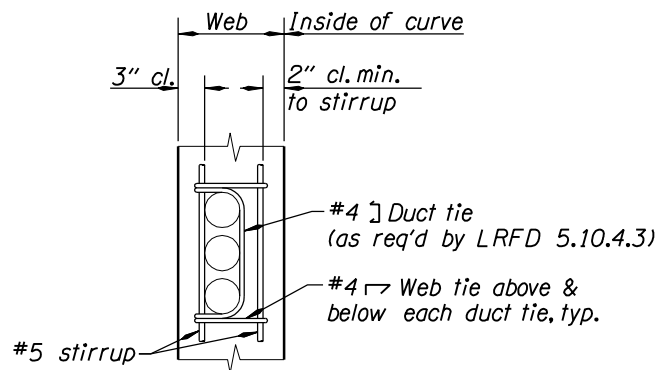
Figure 1.5.8.7-1 Deck Overhang Reinforcement Detail



### 1.5.8.8 Post-Tension Strand Duct Placement

Place ducts for post-tensioned bridges using the detail provided on *DET3130*. The most common type of duct arrangement has been the bundled duct detail. This detail can be used when the duct size does not exceed 4 ½ inches and when the horizontal curvature of the bridge does not require the use of supplemental ties (see *LRFD 5.10.4.3*). When the horizontal curvature does result in the need for supplemental ties, do not use bundled ducts. When supplemental ties are required due to horizontal curvature, use the following detail:

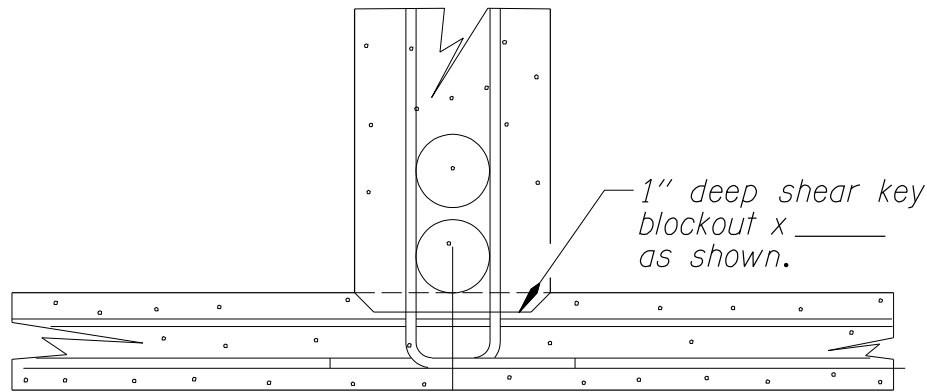
Figure 1.5.8.8-1 Typical Web and Duct Tie Detail



TYPICAL WEB AND DUCT TIE DETAIL

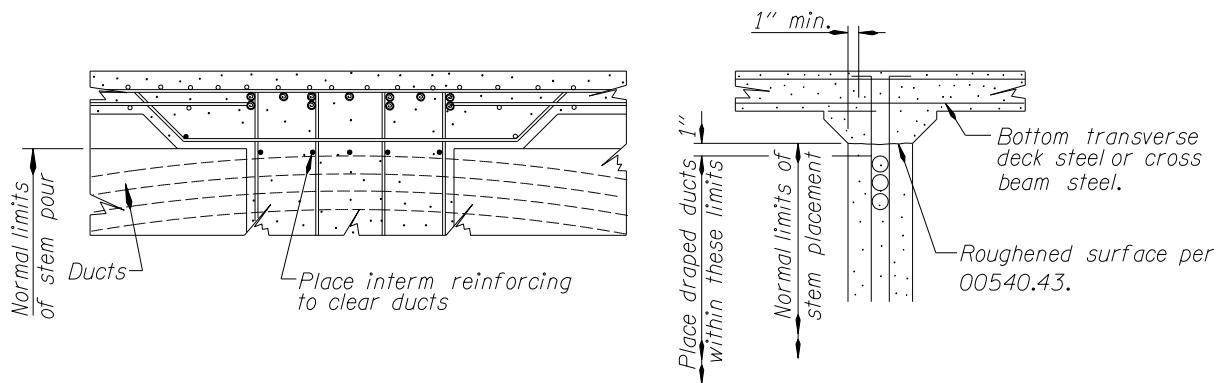
Detail post tensioned box girders to allow pouring the bottom slab and stems as separate pours. Design the prestressed tendon path to ensure that the ducts do not fall in the area of the bottom slab. See Standard Details *DET 3125* and *DET 3130* for general details. To ensure the ducts are fully encased in concrete, do not place ducts in the bottom slab and keep ducts at least 1 inch below the fillet construction joints near the top slabs. Show *Figures 1.5.8.8-2 and 1.5.8.8-3* on the project plans when needed.

Figure 1.5.8.8-2 Low Point Detail



LOW POINT DETAIL

Figure 1.5.8.8-3 High Point Detail



HIGH POINT DETAIL

In some cases it may be necessary to place ducts outside the limits shown above. When so, special concrete placement details will normally be needed to ensure the ducts are fully encased in properly consolidated concrete for the entire length of the bridge. For these cases, submit a design deviation request which shows the proposed duct placement detail. Include with the request the details and/or specification language intended to ensure the concrete will be fully consolidated in areas where the ducts penetrate either into the bottom slab or above the stem fillet construction joint.

## 1.5.9 Camber Diagrams

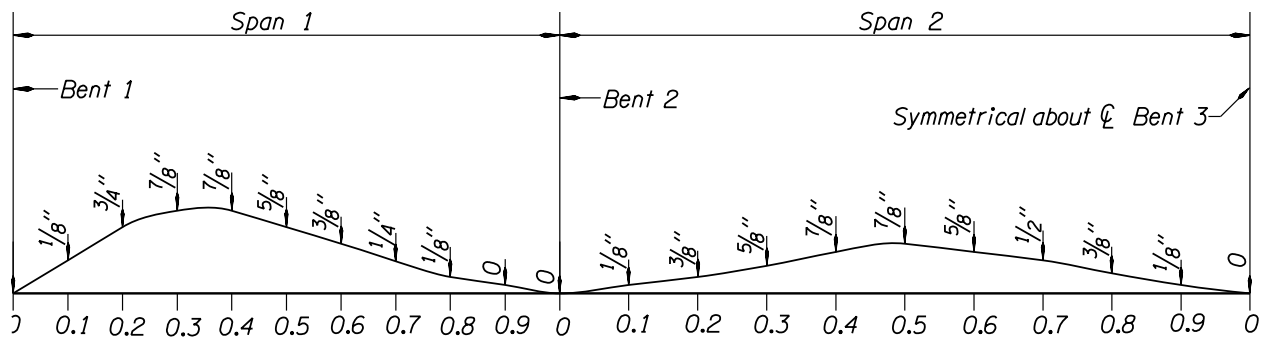
### 1.5.9.1 Camber Diagrams, General

Show camber diagrams on the plans for all types of cast-in-place concrete structures. The camber diagram shall be titled, **Camber Diagram** and be accompanied by the applicable portions of the following note:

Camber is designed to compensate for deflection due to prestressing, the dead load of all concrete, stay-in-place forms and wearing surface and the long-term effects of shrinkage and creep.

An example of a camber diagram for a cast-in-place structure is shown below in *Figure 1.5.9.1-1*.

Figure 1.5.9.1-1 Camber Diagram Example



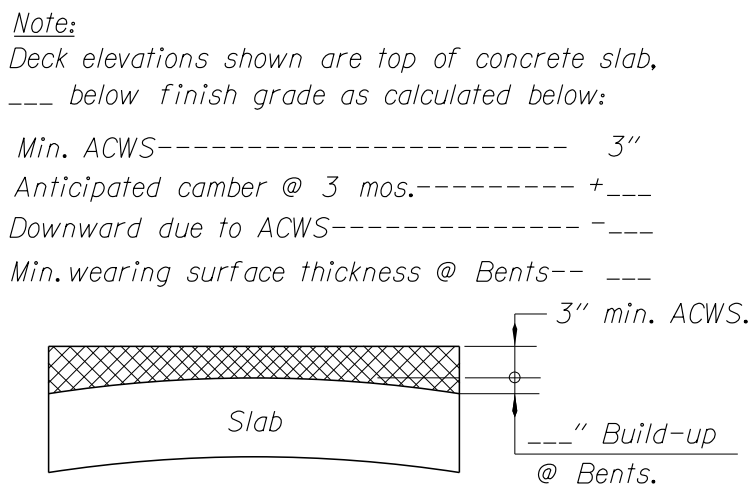
*Note:*  
Camber is designed to compensate for deflection due to prestressing, the dead load of all concrete, stay-in-place forms and wearing surface and the long term effects of shrinkage and creep.

CAMBER DIAGRAM

## 1.5.9.2 Precast Slabs and Box Beams

Camber of precast elements has increased in recent years due to higher strand forces. Reflect allowances for camber and grade correction in top of slab elevations. Rail posts lengths and curb heights will have to be increased accordingly near the ends to obtain the proper finish rail height and curb exposure. Note on the typical deck section that post lengths may vary due to camber and/or superelevation. Include information on the contract plans as follows:

Figure 1.5.9.2-1 ACWS Build Up Detail



ACWS BUILD - UP DETAIL

## 1.5.10 Pour Schedules

### 1.5.10.1 Pour Schedules, General

In order to avoid misunderstanding and claims by the contractor, take care to make sure that construction sequences and pouring schedules are clearly described. Particular care is needed when symmetrical structures are covered by sketches showing half of the structure.

In general, longitudinal pours in continuous spans are stopped near the bents to allow concrete shrinkage to occur in the majority of the span. Closure pours over the bent are generally shorter to minimize shrinkage cracking that could occur between fixed supports or placements.

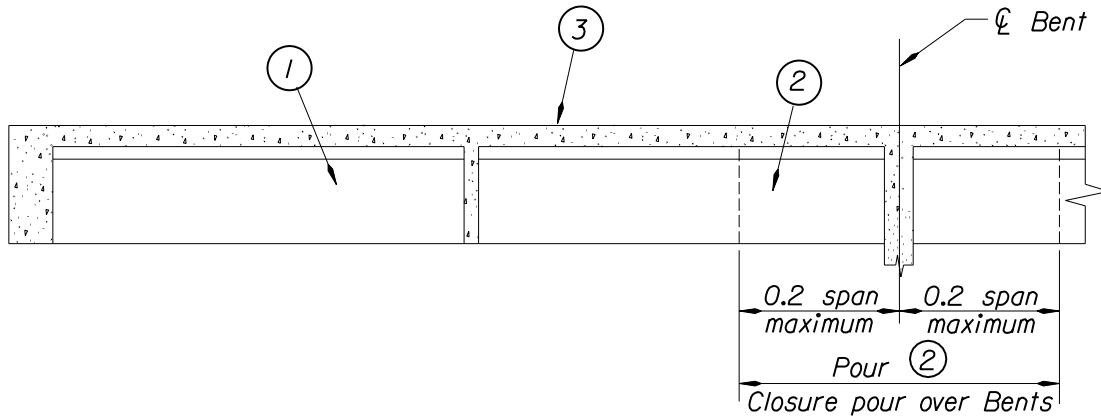
It is recommended to place bottom slab or beam construction joints at a falsework bent rather than a permanent bent. Cracking may develop at a permanent bent, when the adjacent falsework settles or deflects during the concrete placement.



### 1.5.10.2 T-Beams Supported on Falsework

A typical sketch and pour sequence is shown below in *Figure 1.5.10.2-1*.

Figure 1.5.10.2-1 Pour Sequence Example Detail

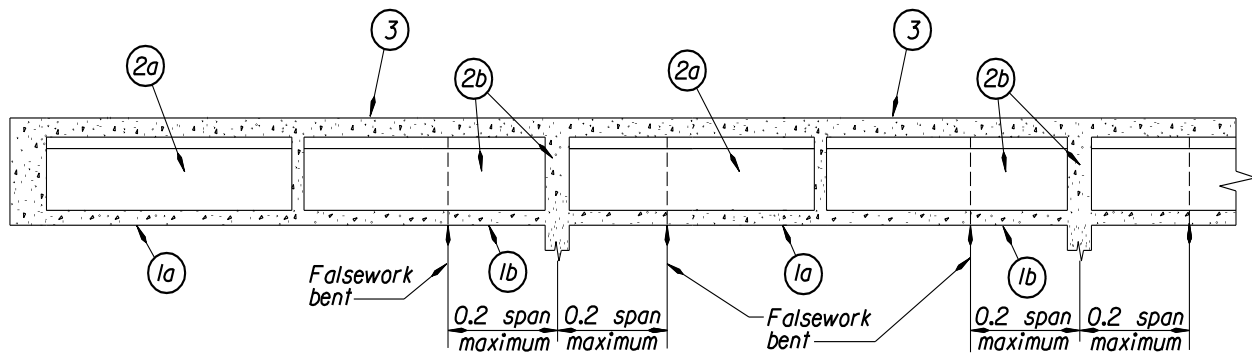


#### POUR SCHEDULE

1. Pours (1) and (2) are the longitudinal and transverse beams to the bottom of deck (or fillets). Make all pours (1) prior to pours (2). Beam construction joints shall not be near a permanent bent but shall be made at a falsework bent. Delay adjacent beam pours by a minimum of three days.
2. Pour (3) is the (fillets and) deck. Pour (3) to be delayed a minimum of three days after completion of all pours (2). A deck construction joint may be made over any transverse beam. Delay pouring adjacent sections of deck a minimum of five days. Do not remove bulkheads for deck pours until at least three days after completion of pour. Deck pours may extend over any part of a span or spans so long as they meet these requirements.

### 1.5.10.3 Box Girders on Falsework

Figure 1.5.10.3-1 Pour Schedule Example Detail



**POUR SCHEDULE:**

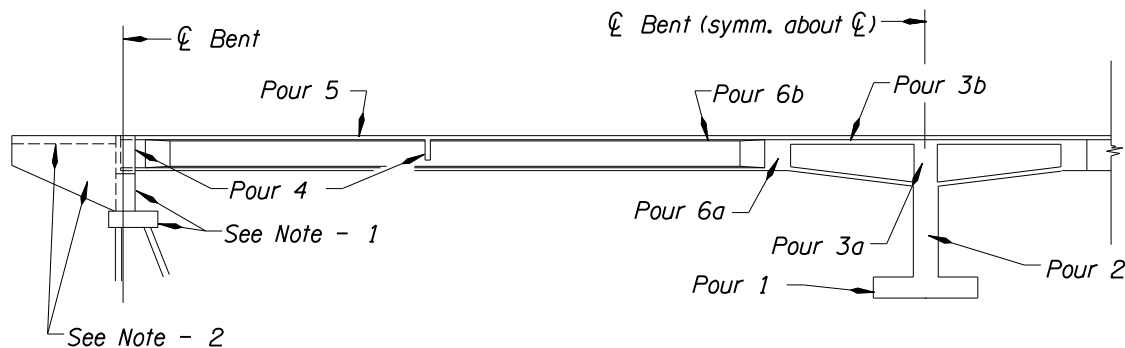
1. Pours (1a) and (1b) are the bottom slab. Stop pours (1) at a falsework bent and not at a permanent bent. Delay a minimum of three days between adjacent pours (1). Complete all pours (1a) prior to starting pours (1b). Complete all pours (1) prior to starting pours (2).
2. Pours (2a) and (2b) are the longitudinal and transverse beams to the bottom of the fillets. Stop pours (2) over a falsework bent. Delay the start of pours (2) a minimum of five days after bottom slab pours (1) are complete. Delay a minimum of three days between adjacent pours (2).
3. Pour (3) includes the fillets and deck slab. Pour (3) to be delayed a minimum of three days after completion of all pours (2). Pours (3) may be stopped over any transverse beam, with the use of a deck construction joint. Delay a minimum of five days between adjacent pours (3). Do not remove bulkheads for deck pours until at least three days after completion of the pour. Deck pours may extend over any part of a span or spans as long as they meet these requirements.

Generally, it is preferred that the bottom slab be completely poured first and separately from the longitudinal beams. This ensures a more uniform bottom slab thickness, the slab provides a good base for stem forms, and the continuous bottom slab helps stabilize the falsework system. It also allows the falsework to take its initial settlement without affecting other superstructure components.

### 1.5.10.4 Drop-In Precast Prestressed Elements

Complicated types of construction require detailed construction sequence notes, such as the following:

Figure 1.5.10.4-1 Pour Schedule Example Detail



**POUR SCHEDULE:**

1. Make pour (1).
2. Make pour (2), includes Bent 2 column.
3. Make pour (3a), includes bottom slab and webs to bottom of top fillet, Beam C to bottom of deck.
4. Make pour (3b), includes deck and top fillets for cast in place section. Delay pour (3b) a minimum of three days after completion of pour (3a).
5. Apply Stage I post tensioning to cast in place section. Stressing to begin a minimum of 14 days after completion of pour (3), but not until concrete in pour (3) has reached its design strength.
6. Place prestressed beams. Beams to be placed so that the number of beams in one span does not exceed by more than four the number in the opposite span.
7. Make pour (4), includes diaphragm beams **D** and end beams **E**.
8. Make pour (5), (no less than 60 days after transfer of stress in precast, prestressed beams), includes deck on prestressed beams to diaphragm beam nearest Bent 2.
9. After pour (5) has been made in Spans 1 and 2, make pour (6a), includes remainder of Beam C. Let concrete take initial set, and make Pour (6)b, includes remainder of deck.
10. Apply Stage II post tensioning to assembled Spans 1 and 2. Stressing to begin a minimum of 14 days after completion of Pour (6), but not until concrete in pour (6) has reached its design strength.
11. Pour Curbs

## NOTES:

- 1. Bents 1 and 3 footings and walls may be poured any time up to seven days prior to placing of prestressed beams, but concrete must have reached its design strength prior to beam placement. No part shall interfere with post tensioning operations.
- 2. Paving slab and sidewalls may be poured at any time except that no part shall interfere with post tensioning operations.
- 3. Screed deck concrete parallel to bents.
- 4. Composite decks and/or closure pours shall not be made until at least 60 days have elapsed from the time of transfer of prestressing force in the precast elements.

### 1.5.10.5 Continuous Cast-in-place Slabs on Falsework

For pours over 600 cy, allow a transverse deck construction joint at  $0.2 * (\text{span})$  from the next interior bent.

### 1.5.10.6 End Bents

When the fit of superstructure elements is critical, be sure to consider the end bent construction sequencing. Normally the end wall construction is delayed until the superstructure elements are in place. Delaying the end wall construction also allows the contractor to compensate for errors in superstructure element lengths and end bent locations. Show a construction sequence diagram, with notes, as needed.

### 1.5.10.7 Steel Girders

See *BDM 1.6.2.14* for example.

## 1.5.11 Concrete Anchors

### 1.5.11.1 Anchor Bolts / Rods

#### 1.5.11.1.1 Materials

Anchor bolts / rods, including those for bridges, signs, traffic signals, and illumination structures, should normally be specified according to one of the following specifications:

- *ASTM F1554* is the preferred specification.
- *ASTM F1554*, Grade 36 for low-strength.
- *ASTM F1554*, Grade 55 for medium-strength.
- *ASTM F1554*, Grade 105 for high-strength.

Equivalent ASTM designations for anchor bolts / rods are:

- *ASTM A307*, Low-strength carbon steel bolts for general use (non-headed rods conform to *ASTM A36*).
- *ASTM A449*, Medium carbon steel bolts and rods to 3 inch diameter. Proof load requirements are similar to *ASTM F3125* GR A325.

Galvanize anchor bolts or rods full length, when galvanizing is desired.

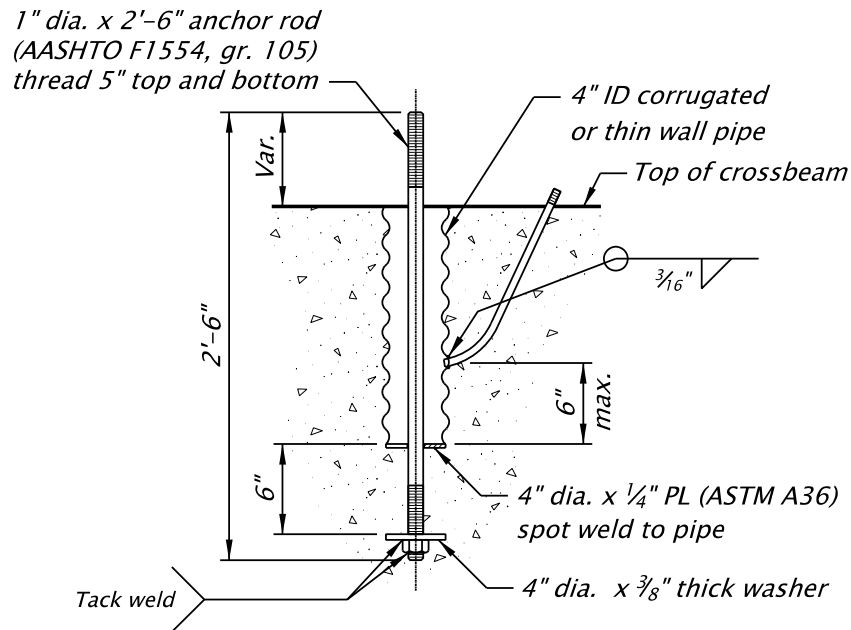
Anchorage of anchor bolts and rods may be accomplished by hooks for *ASTM A307* and Grade 36 materials. For higher strength materials, a bearing plate tack welded to a nut or a plate between two nuts should be used.

When tensioning of anchor rods or bolts is desired, load indicator washers may be used up to 1¼ inch diameter (the largest available). Specify load indicator washers on the plans or in the Special Provisions, when required. Recognize that concrete creep and shrinkage may significantly reduce anchor rod stress over time.

#### 1.5.11.1.2 Anchor Bolt Sleeves

To allow for some flexibility in placement and small corrections in bearing locations, an anchor bolt sleeve is often used. The anchor bolt can be field bent slightly to fit the required bearing location. The bearing plate can be temporarily shimmed and then the pad constructed or the pad can be constructed with a blockout around the bolt. The sleeve is grouted at a later time. There are commercially produced anchor bolt sleeves or a fabrication detail can be added to the drawings.

Figure 1.5.11.1.2-1 Anchor Rod Detail



**ANCHOR ROD DETAIL**

**1.5.11.2 Post-Installed Anchors**

**1.5.11.2.1 Materials**

**RESIN BONDED ANCHORS**

Normally specify *ASTM F1554*, as the anchor rod material. ASTM specifications may be substituted as shown in *Table 1.5.11.2.1-1*.

Table 1.5.11.2.1-1 ASTM Material Substitutions

<b>Anchor Rod Specifications</b>	<b>ASTM Specifications</b>
ASTM F1554 GR 36	A307
ASTM F1554 GR 105	A193 (Grade B7) or A449
M31 Rebar, Grade 60	A706 or A615

Galvanizing is only required when portions of the anchor are exposed.

Anchor rods do not necessarily need to be fully threaded. Specify the thread length to best fit the particular application.

**BONDING MATERIAL**

Use a resin bonding system from the Division's QPL for anchor bolts 1 inch diameter or less. For larger anchors, use other types of anchorage such as epoxy grout or cementitious grouts with traditional development lengths.

**MECHANICAL ANCHORS**

A mechanical anchor system consists of multiple materials and differs from one manufacturer to another. Corrosion-resistant materials are required for mechanical anchors installed in bridge elements. As a minimum, specify hot-dip galvanized coating. Type 316 stainless steel is preferred. All mechanical anchor products on the QPL have an option for providing corrosion-resistant materials. Use the same type of materials for attachments connected to mechanical anchors. When this is unavoidable, provide electrical isolation for all dissimilar metals to avoid galvanic corrosion.

**1.5.11.2.2 Design**

Ensure that post-installed anchors are embedded in good concrete without active cracks. Avoid using anchors in sections of the bridge with high tensile stresses perpendicular to anchor holes. Drilled holes in concrete attract or even induce cracks at the hole location. Cracks in the concrete will then tend to break down the bond between concrete and epoxy resin for resin bonded anchors or compromise the mechanical anchor system. Do not use post-installed anchors to resist earthquake forces in plastic hinge zones. Use of post-installed anchors for shear lugs and beam seat extensions is acceptable.

**RESIN BONDED ANCHORS**

Design the steel portion (rod or reinforcement) of the concrete anchor according to the appropriate *AASHTO design specification*. Do not specify anchors larger than 1 inch in diameter using a resin bonded anchor system.

Table 1.5.11.2.2-1 Anchor Diameters and Stress Areas

Diameter (inch)	Stress Area (in <sup>2</sup> )	Bar Size	Stress Area (in <sup>2</sup> )
0.5	0.142	4	0.20
0.625	0.226	5	0.31
0.75	0.334	6	0.44
0.875	0.462	7	0.60
1.00	0.606	8	0.79

*FHWA Technical Advisory T5140.34* regarding use of adhesive anchor under sustained tension loads was issued in January 2018. According to the Technical Advisory, FHWA recommends that post-installed adhesive anchors can be used for resisting sustained tension loads only when specific requirements are met. The recommendations were based on *NCHRP Reports 639 and 757, ACI 318, and ACI 355.4*. Anchoring to concrete design guidance was added to *Section 5 of the AASHTO LRFD design specifications*, which refers to the *ACI design code*. The new requirements apply to all new Federal-aid projects.

Design resin bonded anchors with loads, load factors, and load combinations specified in *LRFD Section 3* and with resistance factors according to *ACI 318 Chapter 17* with the following modifications:

- Uncracked concrete is assumed for design of resin bonded anchor system.
- Use a resin bonded anchor system in concrete with a compressive strength of 2,500 – 8,000 psi.
- Use resistance factors as shown in *Table 1.5.11.2.2-2* for applicable failure modes.

Table 1.5.11.2.2-2 Resistance Factors for Design of Resin Bonded Anchors

Failure Mode	Strength Reduction Factor $\phi$		
	Strength Limit State		Extreme Event II Limit State
	Others	Sustained Tension	
Reinforcement in tension	0.75	0.75	1.00
Concrete breakout in tension	0.65	0.65	0.90
Adhesive bond in tension	0.65	0.33	0.90
Reinforcement in shear	0.65	0.65	1.00
Concrete breakout in shear	0.70	0.70	0.90
Concrete pryout in shear	0.70	0.70	0.90

- For concrete breakout strength in tension,  $k_c = 24$ . Use  $\psi_c, N = 1.0$ .
- Use characteristic bond stresses from *Table 1.5.11.2.2-3* for bond strength calculation. The bond stresses shown in the table are obtained from the Evaluation Service Report (ESR) of epoxy resin products on the QPL. The reports are approved by the *International Code Council Evaluation Service, Inc. (ICC-ES)*. The recommended bond stresses are based on threaded rod or reinforcing bars installed in holes drilled with a hammer drill and carbide bit.



Table 1.5.11.2.2-3 Characteristic Bond Stress for Bond Strength in Tension Check

Short-Term Peak Temperature (24 hrs.)	Load Application	$\tau_{uncr}$ (psi)
Equal or Less than 130 F	Others	1200
	Sustained Tension	480
Greater than 130 F but less than 176 F	Others	800
	Sustained Tension	320

Before 2019, ODOT used a set of equations developed in-house using historical test data for calculating anchor capacities. The equations are located in *Appendix 1.5.11.2.2*.

**MECHANICAL ANCHORS**

Each manufacturer establishes its own material strength and it differs for different anchor sizes. Do not specify anchor sizes larger than 3/4 inch (nominal) in diameter. Use the nominal material strengths for anchor design found in *Table 1.5.11.2.2-4*.

Table 1.5.11.2.2-4 Material Properties for Design of Mechanical Anchors

<b>Undercut Anchor</b>		
Material (psi)	Stainless Steel	Hot-Dip Galvanized
Yield strength	87,000	Not on the QPL
Tensile strength	105,000	Not on the QPL
<b>Expansion and Screw Anchors</b>		
Material (psi)	Stainless Steel	Hot-Dip Galvanized
Yield strength	75,000	55,000
Tensile strength	90,000	75,000

Design mechanical anchors with loads, load factors, and load combinations specified in *LRFD Section 3* and with resistance factors according to *ACI 318 Chapter 17* with the following modifications:

- Assume uncracked concrete for design of mechanical anchor system.

- Use a mechanical anchor system in concrete with a compressive strength of 2,500 – 8,000 psi.
- Use resistance factors as shown in *Table 1.20.2.2-5* for applicable failure modes.

Table 1.5.11.2.2-5 Resistance Factors for Design of Mechanical Anchors

Failure Mode	Strength Reduction Factor $\phi$	
	Strength Limit State	Extreme Event II Limit State
Reinforcement in tension	0.75	1.00
Concrete breakout in tension	0.65	0.90
Pullout strength in tension	0.65	0.90
Reinforcement in shear	0.65	1.00
Concrete breakout in shear	0.70	0.90
Concrete pryout in shear	0.70	0.90

- For concrete breakout strength in tension,  $kc = 24$ . Use  $\psi_c, N = 1.0$ .

Mechanical anchors from each manufacturer have different details and specifications. The recommended design parameters listed in *Table 1.5.11.2.2-6* ensure that an anchor product on the QPL can meet the design requirements.

Table 1.5.11.2.2-6 Design Parameters for Mechanical Anchor design

<b>Undercut Anchor</b>					
Nominal Diameter (inch)	0.375	0.500	0.625	0.750	
Anchor O.D., $d_a$ (inch)	0.625	0.750	1.000	1.125	
Effective embedment depth, $h_{ef}$ (inch)	3.75	4.75	7.25	9.75	
Effective cross-sectional area, $A_{se}$ (in <sup>2</sup> )	0.078	0.131	0.226	0.334	
Pullout strength, $N_{p, uncr}$ (lbs) Use $\psi_c, P = 1.0$	12600	16000	21000	31000	
Hole depth (inch)	4.75	5.75	8.25	10.75	
Minimum member thickness (inch)	7.25	8.0	10.75	14.0	
<b>Expansion Anchor</b>					
Nominal Diameter (inch)	0.250	0.375	0.500	0.625	0.750
Anchor O.D., $d_a$ (inch)	0.250	0.375	0.500	0.625	0.750
Effective embedment depth, $h_{ef}$ (inch)	1.5	2.0	3.25	4.0	5.0
Effective cross-sectional area, $A_{se}$ (in <sup>2</sup> )	0.020	0.051	0.101	0.162	0.237
Pullout strength, $N_{p, uncr}$ (lbs) Use $\psi_c, P = 1.0$	1600	3200	5400	7100	11600
Hole depth (inch)	2.75	3.25	4.50	5.25	6.25
Minimum member thickness (inch)	4.0	4.25	5.5	6.25	7.5
<b>Screw Anchor</b>					
Nominal Diameter (inch)	0.250	0.375	0.500	0.625	0.750
Anchor O.D., $d_a$ (inch)	0.250	0.375	0.500	0.625	0.750
Effective embedment depth, $h_{ef}$ (inch)	1.5	2.0	2.5	3.5	4.0
Effective cross-sectional area, $A_{se}$ (in <sup>2</sup> )	0.024	0.099	0.183	0.276	0.414
Pullout strength, $N_{p, uncr}$ (lbs) Use $\psi_c, P = 1.0$	900	3000	3600	4800	9500
Hole depth (inch)	2.75	3.25	4.0	5.25	6.0
Minimum member thickness (inch)	4.0	4.25	5.0	6.25	7.0

Undercut anchors are good alternative to resin bonded anchors for overhead situation with sustained tension loading.

Overall design calculations for mechanical anchors are similar to resin bonded anchors without bond strength check. Adequate member thickness is important for mechanical anchors to avoid

splitting failures. When the member thickness is limited and there is not much space for a longer anchor than the design, add a note on the plan.

For mechanical anchors, the difference between effective embedment depth of anchors ( $h_{ef}$ ) and total drilled hole depth can vary from ½ to 2 inches depending on each manufacturer. Use the hole depths shown in [Table 1.5.11.2.2-6](#) as a guide to ensure that anchors will fit inside the member and around existing rebar during the design.

When any of the above design requirements cannot be met, contact [BDM technical resource](#) for guidance.

### **1.5.11.2.3 Drilling Holes in Concrete**

When existing reinforcing steel is required by design, require bars to be located prior to drilling.

Drill holes according to manufacturer's recommendations. Spalling of adjacent concrete is the main concern when determining the hole location and type of drill to be used. When recommendations to prevent spalling do not exist, use the following drilling methods:

#### **RESIN BONDED ANCHORS**

When center of hole is 6 inches or less from the edge of concrete use either a diamond bit core drill or a carbide bit rotary hammer with four cutting edges on the diameter.

When center of hole is more than 6 inches from the edge of concrete use either an air hammer, maximum 9 pound class, or a carbide bit rotary hammer with two cutting edges on the diameter.

#### **MECHANICAL ANCHORS**

Use either a diamond bit core drill or a carbide bit rotary hammer with four cutting edges on the diameter.

#### **GROUTED ANCHORS**

Any type of drill will normally be acceptable. Grouted anchors should always be placed more than 6 inches from the nearest concrete edge.

### **1.5.11.2.4 Plan Details**

Post-installed anchors are considered critical when failure of the anchors can compromise public safety. Anchors installed in the following members are considered critical.

- Items attached from tunnel ceiling or under bridge deck.
- Bridge rail anchor.
- Shear lug.
- Beam seat extension.
- Sign structure support.

- Structural connection between existing and new concrete or different materials.
- Fencing support.

List all anchors specified for a construction project in *SP 00535.45(c)*. Indicate which tests are required for the specified anchors, especially for critical anchors. For anchors that are not critical and will not see significant loads, tests during construction may be omitted.

### RESIN BONDED ANCHORS

For horizontal applications, show drilled holes angled down a minimum of 15 degrees on plan sheets. For thin members, such as bridge decks, a smaller angle of drilled holes may be specified to avoid protrusion of the anchors. Specify a minimum drilled angle of 5 degrees. When any down angle of drilled holes will not work with the design, specify horizontal drilled holes. *SP 00535* will require a certified anchor installer to ensure good quality of installed resin bonded anchors.

When critical resin bonded anchors are used, include the following note on the plans:

Provide and install (\_\_\_" diameter F1554 Grade (36) (55) (105)) or (#\_\_ AASHTO M 31, Grade 60 rebar) resin bonded anchors with epoxy resin from the QPL. The characteristic bond stress used in the design is \_\_\_ psi. The minimum pullout strength is \_\_\_ lbs with a minimum embedment ( $h_{ef}$ ) of \_\_\_ in. Install anchors according to the manufacturer's recommendations.

The minimum pullout strength is the smaller unfactored strength of steel reinforcement and adhesive bond in tension obtained from calculation. For anchors subjected to sustained tension, the characteristic bond stress is reduced by a factor of 0.40 in design as shown in *Table 1.5.11.2.2-3*, however use the characteristic bond stress of 1,200 psi in calculation for the minimum pullout strength and show it on the plans for field testing purposes.

### MECHANICAL ANCHORS

When critical mechanical anchors are specified, include the following note on the plans:

Provide and install \_\_\_" nominal diameter Type (A Undercut) (B Expansion) (C Screw) mechanical anchors using a product from the QPL. The minimum pullout strength is \_\_\_ lbs with a minimum effective embedment depth ( $h_{ef}$ ) of \_\_\_ in. (The maximum depth of the drilled hole is \_\_\_ in.) For the design, the steel anchor yield strength is \_\_\_ psi and the tensile strength is \_\_\_ psi. Provide anchor materials with (Type 316 stainless steel) (hot-dip galvanized coating). Install anchors according to the manufacturer's recommendations.

The minimum pullout strength is the controlling factored strength of the mechanical anchor system in tension using resistance factors for Extreme Event II Limit State.

### **1.5.11.2.5 Testing Requirements**

Two types of field tests are required during construction to ensure proper installation and to achieve as-specified capacity of post-installed anchors. Demonstration Test includes installation of anchors using the same material and methods as shown on the plan and testing the anchors to a load at minimum pull out strength. Production Test is performed during construction on actual anchors used in final position up to a load level specified in the Special Provisions.

### **1.5.11.2.6 Construction**

Drill types - See *BDM 1.5.11.2.3* or *SP 00535* for the drill type to be used.

Holes - Holes for resin bonded anchors are normally 1/8 inch diameter larger than the nominal bolt diameter. Holes should be cleaned with compressed air, a non-metallic brush and water. Concrete dust is one of the most destructive elements to a resin bonded system and water is the best method to remove the dust. Holes for mechanical anchors are dependent on the type and manufacturer. Holes for grouted anchors are normally 1/4 inch diameter larger than the anchor diameter.

Temperature - Epoxy resin is not allowed for low temperature applications. The set times become quite long at low temperatures. It will normally be better to use a deeper embedment with a non-epoxy product at low temperatures.

Tightening – *SP 00535* requires tightening to only 1/4 turn past snug tight. Consider what tightening is appropriate for the application and show on the plans, when different than the specifications. Anytime load indicator washers are used, tightening must meet the washer requirements. Also check when distribution plates are needed to transfer the bearing loads (from the tensioned bolt) to the concrete.

## 1.6 STEEL STRUCTURE DESIGN AND DETAILING

### [1.6.1 Structural Steel, General](#)

### [1.6.2 Structural Steel, Design](#)

### [1.6.3 Welding](#)

### [1.6.4 Galvanizing and Painting](#)

### [1.6.5 Bolts and Connections](#)

## 1.6.1 Structural Steel, General

This chapter covers primarily the design and construction of steel plate and box girder bridge superstructures. It provides guidance for bridge designers working on ODOT projects to achieve optimal quality and value in steel bridges.

### 1.6.1.1 Design Considerations

Familiarity with design and construction specifications is the key for steel bridge design. Designs that merely satisfy the design specifications are often problematic. Good designs must consider and reflect fabrication requirements, construction techniques, and maintenance needs. In particular, the designer must consider the following:

- Use the most recent version of the design specifications.
- Become familiar with construction and fabrication specifications and standard drawings applicable to steel structures.
- Evaluate how construction and fabrication specifications influence the design and what modifications or special provisions may be required.
- During the initial evaluation of design options, consider consulting with the Steel Bridge Standards Engineer, fabricators, steel erectors, or contractors for ideas on achieving an economical, easy to build, and robust design.
- Ensure all individual bridge components fit well together by accounting for how rotation, deflection (especially differential deflection), twist, stiffness (vertical bending, lateral bending, and torsion), and skew affect interaction between different elements.
- Provide clear and distinct load paths that mitigate or, preferably, eliminate out-of-plane bending.
- Provide adequate access for bolting, welding, and painting. Keep design simple by maximizing the use of common details and minimizing the number of plate sizes

and rolled shapes fabricators are required to purchase. Complicated details are always difficult to fabricate and build.

- Do not use details that permit water and debris to collect on girders.

### 1.6.1.2 Codes and Standards

Design according to *AASHTO LRFD Bridge Design Specifications* unless specified otherwise in this document. See [NSBA Guide to Navigating Routine Steel Bridge Design](#) for a guide to designing routine steel I-girder bridges.

The following *AASHTO/NSBA Steel Bridge Collaboration* publications are available to aid in the design and fabrication of steel bridges. These publications can be downloaded from the AISC website at [www.aisc.org/nsba/nsba-publications/aashto-nsba-collaboration/](http://www.aisc.org/nsba/nsba-publications/aashto-nsba-collaboration/):

- *G13.1-2019, Guidelines for Steel Girder Bridge Analysis.*
- *G12.1-2020, Guidelines to Design for Constructability.*
- *G1.4-2006, Guidelines for Design Details.*
- *S10.1-2019, Steel Bridge Erection Guide Specification.*
- *G9.1-2004, Steel Bridge Bearing Design and Detailing Guidelines.*
- *G1.2-2003, Design Drawing Presentation Guidelines.*
- *S2.1-2018, Steel Bridge Fabrication Guide Specification.*
- *S8.1-2014, Guide Specification for Application of Coating Systems with Zinc-Rich Primers to Steel Bridges.*
- *S8.2-2017, Specification for Application of Thermal Spray Coatings for Steel Bridges.*
- *G1.3-2002, Shop Detail Drawing Presentation Guidelines.*
- *G1.1-2000, Shop Drawing Approval Review/Approval Guidelines.*
- *G4.4-2006, Sample Owners Quality Assurance Manual.*
- *G4.1-2019, Steel Bridge Fabrication QC QA Guidelines.*
- *G2.2-2016, Guidelines for Resolution of Steel Bridge Fabrication Errors.*
- *G4.2-2006, Recommendations for the Qualification of Structural Bolting Inspectors.*

The following *FHWA Steel Bridge Design Handbook*, which includes 19 volumes of steel bridge design aids and six design examples, are also available as design aids and can be downloaded from the FHWA website at: [www.fhwa.dot.gov/bridge/steel/pubs/hif16002/](http://www.fhwa.dot.gov/bridge/steel/pubs/hif16002/).

- Bridge Steels and Their Mechanical Properties–Volume 1.
- Steel Bridge Fabrication–Volume 2.
- Structural Steel Bridge Shop Drawings–Volume 3.
- Structural Behavior of Steel–Volume 4.
- Selecting the Right Bridge Type–Volume 5.
- Stringer Bridges–Making the Right Choices–Volume 6.
- Loads and Load Combinations–Volume 7.
- Structural Analysis–Volume 8.
- Redundancy–Volume 9.



- Limit States–Volume 10.
- Design for Constructability–Volume 11.
- Design for Fatigue–Volume 12.
- Bracing System Design–Volume 13.
- Splice Design–Volume 14.
- Bearing Design–Volume 15.
- Substructure Design–Volume 16.
- Bridge Deck Design–Volume 17.
- Load Rating of Steel Bridges–Volume 18.
- Corrosion Protection of Steel Bridges–Volume 19.
- Design Example 1: Three-span Continuous Straight Composite Steel I-Girder Bridge.
- Design Example 2A: Two-span Continuous Straight Composite Steel I-Girder Bridge.
- Design Example 2B: Two-span Continuous Straight Composite Steel Wide-Flange Beam Bridge.
- Design Example 3: Three-Span Continuous Horizontally Curved Composite Steel I-Girder Bridge.
- Design Example 4: Three-Span Continuous Straight Composite Steel Tub Girder Bridge.
- Design Example 5: Three-Span Continuous Horizontally Curved Composite Steel Tub-Girder Bridge.

### **1.6.1.3 ODOT Steel Bridge Practice**

ODOT does not require Certified Erector qualification for erection of steel bridges. For complex projects in which a contractor with such qualification is deemed necessary, obtain Bridge Engineering Section approval prior to including such requirement in the contract documents.

Curved and skewed deck girder bridges have the potential for three dimensional deflection and rotation. Longer spans magnify the rotation of the girders and cause unaccounted stresses on the diaphragm connections. Include a note in the contract drawings stating that the girder webs are plumb in the final condition. This requires the erector to force fit the diaphragms with the girders out-of-plumb prior to deck placement. Rotation of girders resulting from the deck placement plumbs the girders web and releases stresses caused from force fitting the diaphragms. See *BDM 1.9.1.1* for additional detailing requirements of skewed decks.

Steel tub (box) girders are visually pleasing structures and are more expensive than usual steel plate girders because of fabrication cost. One of the main concerns in steel tubs or box girders in the State of Oregon is corrosion inside the girders. In the construction drawings, require inside surfaces of boxes or tubs (bottom flange, top flange, web and diaphragm) to be painted with a silver gray prime coat. Painting inside the tub (box) girders will prevent corrosion resulting from leakage thru the deck and condensation. Light color paint also increases illumination inside the tub (box) and eases detection of corrosion or cracks in steel members. Consider other corrosion protection measures as specified herein.

Whenever the end of steel members is cast inside concrete, the end of the member cast in concrete requires a three coat paint system as shown in *Figure 1.6.2.15-3*.

## FATIGUE DESIGN REQUIREMENTS

Design all welded and bolted connections for infinite fatigue design life using ADTT from *LRFD Table 6.6.1.2.3-2*. Do not use details category E or E' in any connections for primary load-carrying members.

### 1.6.1.4 Estimating Structural Steel Weights & Preliminary Design

For preliminary quantities or preliminary girder design, an estimate of steel weights for built-up plate composite I-girders can be obtained from the [Span to Weight Curves](#) from the AISC website. The *Steel Span to Weight Curves* are the quickest way to determine the weight of steel per square foot of bridge deck for straight, low skew, plate girder bridges. The Curves are organized by span arrangement (1, 2 or 3 or more span bridges) and girder spacing. The Curves also provide a good double check for final quantities.

For a more detailed design, refer to the [Continuous Span Standards](#) on the AISC website. The Continuous Span Standards include 88 unique solutions for three span bridges with center spans between 150 feet and 300 feet, girder spacing between 7 feet 6 inches and 12 feet, and plate girder designs utilizing both homogenous and hybrid steel options. Each conceptual solution presented in these tables is organized based on the following:

- Girder plate sizes.
- Diaphragm spacing.
- Intermediate stiffener sizes and locations.
- Shear connector spacing.
- Camber.
- Girder weights.

For preliminary quantities and girder design of short span bridges (40 to 140 feet), refer to *Short Span Steel Bridge Alliance* website: <https://www.shortspansteelbridges.org/resources/espan140/>

## BID ITEMS

Use following bid items for structural steel. Use horizontally curved steel (plate or box) girder bid item when the radius of horizontal curve on the structure is less than 1000 feet.

- Steel Rolled Beam.
- Steel Plate Girder.
- Steel Box Girder.
- Steel Plate Girder with haunch.
- Trapezoidal Steel Box Girder with haunch.
- Horizontally Curved Steel Plate Girder.
- Horizontally Curved Steel Box Girder.
- Specialty Bridges (tied arches, Cable Stayed).
- Structural Steel Maintenance.

## 1.6.2 Structural Steel, Design

### 1.6.2.1 Steel Grade Selection

Identify all steel by grade on the contract plans.

Provide structural steel for bridges conforming to *ASTM A709 (AASHTO M270)*. These specifications include Grades 36, 50, 50W, HPS 50W, and HPS 70W. *ASTM A709* steel specifications are written exclusively for bridges wherein supplementary requirements for Charpy V-Notch Impact tests are mandatory. Grade HPS 70W steel has recently been developed and provides high strength, enhanced durability and improved weldability. Depending on the availability, Grade HPS 70W may be economical only in hybrid girders. With Grade 50W webs, use a hybrid configuration with HPS 70W tension and compression flanges in high moment regions. Specify Grade HPS 50W and HPS 70W to be **Quenched and Tempered** in the contract document and for thermo-mechanical control processed require the contractor to provide test samples at both ends of each rolled plate. Plates that pass the required test are acceptable for fabrication.

Provide structural steel for steel piling, metal sign structures and other incidental structures conforming to *ASTM A36*, *ASTM A572* or *ASTM A588*. Incidental structures include luminaire and traffic signal supports, bridge metal rails and metal rail posts, guardrail connections, earthquake restraints, bridge deck expansion joints, fencing post connections, etc. Merchant quality steel (non-spec) is used in items such as catch basin frame, catch basin, deck drain grate, manhole rungs and steps, access hole cover, guardrail spacer blocks, shims, anchor bolt plate embedded in concrete, etc. where a high degree of internal soundness, chemical uniformity or freedom of surface defects are not required. Acceptance of such items is on the basis of visual inspection.

*ASTM A36*, *A572*, or *A588* may be used for structural steel for bridges provided the supplementary Charpy V-Notch Impact test requirements are included in the Special Provisions. When Charpy V-Notch Impact tests are required for *ASTM A36*, *A572* or *A588* structural steel, use the supplementary requirements of *ASTM A709*.

Do not use *A709* (Grades 36, 50, 50W) steels for plates thicker than 3 inches, nor butt welds in tension members over 3 inches. Limit plate thickness for HPS 50W and HPS 70W to 2 inches. Consult with the Steel Bridge Standards Engineer for specific project needs.

Specify *ASTM A709* Grade 50 steel for all structures that require yield strengths between 36 ksi and 50 ksi and are to be painted or galvanized.

### 1.6.2.2 Weathering Steel

Similar to regular construction steel, weathering steels also rust under a wide range of exposure conditions, but during this process it forms oxides that remain tightly adherent to the steel substrate and develops a much more stable oxide layer than non-weathering steel. Shortly after blast cleaning to remove mill scale, weathering steel turns **rusty** in appearance. Through several cycles of wetting and drying (usually between 6 and 24 months, depending on the environment), the surface of the steel develops a tight oxide coating (patina) that provides its own corrosion resistant surface finish, eliminating the need for painting and resulting in minimal future maintenance and lower life cycle costs.

Consider the use of *ASTM A709* Grade 50W, HPS 50W, and HPS 70W weathering steel with some caution. Poor performance of weathering steel was attributed to improper detailing and overextension of the technology to highly corrosive applications such as marine environments, excessive application of deicers, accumulated debris, and long periods of wetness.

Conditions or locations of concern include:

#### ENVIRONMENT

- Marine Coastal areas (as defined in *BDM 1.26.1*).
- Frequent high rainfall, high humidity or persistent fog.
- Industrial areas where concentrated chemical fumes may drift onto the structure.

#### LOCATION

- Grade separations in tunnel like conditions.
- Low level water crossings.
- Conditions that do not allow for the drying of the steel necessary to develop a good patina.

Good performance from weathering steel can be achieved with proper design and detailing. The Engineer must be aware of and comply with the following requirements:

- Provide adequate drainage beneath overpass structures to prevent ponding and continual traffic spray from below. Communicate the importance of adequate drainage to roadway designers.
- Do not detail deck drains that can discharge water onto the steel, especially in regions that use de-icing chemicals.
- Avoid any type of open joint that allows runoff to reach the steel.
- Provide details that take advantage of natural drainage.
- Provide drip plates (also called drip tabs) to divert runoff water and protect abutments and columns from staining.
- Eliminate details that retain water, dirt, and other debris. Provide stiffener clips for proper ventilation and drainage.

Review the following references for appropriate application of weathering steel:

- [FHWA Steel Bridge Design Handbook: Volume 19 – Corrosion Protection of Steel Bridges](#)
- [FHWA Technical Advisory T 5140.22, “Uncoated Weathering Steel in Structures”](#)
- [NCHRP Report 314, Guidelines for the Use of Weathering Steel in Bridges](#)

Refer to *ASTM G101 “Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels”* for long term corrosion exposure data. Weathering capability is calculated using the heat analysis compositions in an equation to calculate an atmospheric corrosion resistance index, **I**. The higher the index, **I**, the more corrosion resistant is the steel. Data show that in industrial and rural environments, the rate of corrosion for weathering steel stabilizes to a negligible corrosion rate of approximately 0.3 mils per year per side (or lower in many cases). Understanding the steady state corrosion rate of weathering steel allows the designer to determine the amount of sacrificial plate thickness to include in the design once the service life has been established.

### **1.6.2.3 Simple-Spans-Made-Continuous**

Span configuration plays an important role in using steel efficiently. Two span continuous girders are not always efficient because of high negative moments. Three span units with interior spans about 20 to 30 percent longer than end spans are preferable, but not always possible. The designer is encouraged to consider Simple-Spans-Made-Continuous bridges in the design of multi-span structures when efficient span configuration is not achievable. Simple-Spans-Made-Continuous bridges reduce uplift in unbalanced spans, reduce negative moments at the bents, simplify fabrication, and eliminate the need for bolted field splices.

Critical to the functionality of Simple-Spans-Made-Continuous structures is the continuity connection at the interior bents. Use of concrete diaphragms over the bridge piers is a feasible connection detail for providing live load continuity over the pier in an SDCL (simple for dead and continuous for live load) steel girder system when conventional construction methods are employed. See *DET3620*.

For designs intending to eliminate the deck joint at interior bents while allowing simple-span bridge behavior to be retained, consider the use of Ultra-High Performance Concrete (UHPC) link slabs as a continuity connection. Link slabs are proven to be an economical detail for eliminating deck joints on bridges. Elimination of the deck joint increases a bridge’s service life, reduces the need for frequent maintenance, and provides a smooth riding surface. See *BDM 1.9.1.5.1* for more information UHPC.

As new research in steel industry practices are continuously improving, designers are encouraged to discuss with the Steel Bridge Standards Engineer regarding the most appropriate connection details for design and construction.

### 1.6.2.4 Uplift

When the end spans are much shorter than the interior spans, uplift at the girder ends can occur and create design and construction problems. When end spans are too long in relation to interior spans, a disproportionate amount of steel will be required for the end spans.

Always consider the presence of uplift at the ends of continuous girders, particularly with light, rolled beam units or short end spans. Commentary to *AASHTO LRFD Bridge Design Specifications, Article C3.4.1*, indicates that uplift needs be checked under a strength load combination. It also provides guidance in the appropriate use of minimum and maximum load factors. Uplift restraint, when needed, must satisfy the Strength limit state and the Fatigue and Fracture limit state.

### 1.6.2.5 Girder Spacing

Use wider girder spacing to reduce the number of girders lines, which reduces shop and field labor. Many studies show that the weight of structural steel per square foot of deck area decreases as girder spacing increases. However, consider the following for optimization of girder spacing:

- ODOT prefers a minimum of four I-shaped beams/girder span for vehicular bridges.
- Stability and redundancy of the structure during future re-decking.
- Thicker concrete deck increases superstructure weight due to more concrete & reinforcing steel,
- Wide girder spacing can create challenges for deck formwork, and slabs (or floor systems) cannot adequately support certain overloads.
- On straight bridges, interior and exterior girders must be detailed identically. Spacing must be such that the distribution of wheel loads to the exterior girder is close to that of the interior girder.

### C1.6.2.5

Refer to *G12.1-2020, Guidelines to Design for Constructability Article 1.2* for more information. Generally, for a bridge with an average span length less than 175 feet, there is not an appreciable difference in the structural steel unit weight for the various girder spacing summarized in the graph in *G12.1 Article 1.2*. For a bridge with an average span length more than 175 feet, the designer may want to consider a wider girder spacing, perhaps between 11 and 13 feet, as this wider girder spacing trends to a lighter steel superstructure.

The fatigue live load specified in *AASHTO LRFD Article 3.6.1.4* shall be used for checking girder details in accordance with *Article 6.6*. A single fatigue truck, without lane loading or variable axle spacing, is placed for maximum and minimum effect to a detail under investigation. The impact is 15 percent, regardless of span length. As specified in *Article 3.6.1.1.2*, multiple presence factors are also not to be applied to the fatigue limit state check for which one design truck is used. The load factor is 1.75. It is generally possible to meet the constant

amplitude fatigue limit (CAFL) requirement for details with good fatigue performance. Limiting the calculated fatigue range to the CAFL ensures infinite fatigue life.

With wider girder spacing and *AASHTO* simplified live load distribution factor, the fatigue limit-state check at the crossframe connection-plate weld to the bottom flange could control the design of the bottom flange. It is prudent for the designer to consider moving the crossframe away from high flexural location, or use refined analysis to determine the stress at the crossframe connection-plate weld to the bottom flange to achieve economical girder design, rather than increase the bottom flange thickness for the entire girder segment.

Bolted tab plate detail is not recommended (Refer to [G12.1-2020, Guidelines to Design for Constructability Article 2.1.2.2](#)).

### **1.6.2.6 Shop Lengths of Welded Girders**

Optimize the girder segments by reducing the number of field splices. Maximum girder or girder field segment lengths without a field splice is 130 feet to 150 feet depending upon cross section. There may be locations where girder lengths will be controlled by weight or access to the bridge site. Long and deep girders may also require auxiliary lateral support during transportation.

It is typical to show an optional bolted field splice to allow the fabricator and contractor some flexibility in fabrication and transportation. Locate field splices in welded steel beams by not exceeding the following shop lengths and mass (all field splices must be bolted):

- 150 feet when bridge site is readily accessible (longer girders have been fabricated and hauled to project sites, however contact fabricators and the Steel Bridge Standards Engineer when project needs requires girder segments longer than 150 feet).
- 130 feet when bridge site is not readily accessible.
- Fabricators are limited to their shop crane sizes. Contact fabricators in the state of Oregon for project specific needs and requirements.

For curved girders, limit the girder sweep plus the flange width to 6 feet for ease of shipping. The current legal vehicle width is 8 feet 6 inches without a permit. Limiting the overall shipping width of curved girders to 6 feet permits fabricators to offset the girder on the trailer, as is frequently done, while not exceeding an overall width of 8 feet 6 inches. Add optional field splices if required.

### **1.6.2.7 Rolled Beam Sections**

Rolled beams can be more economical than plate girders for their applicable span lengths (up to 80 feet) because of decreased fabrication costs. Do not use sections smaller than W18. Select beams that have a top flange that is sufficiently wide to provide adequate spacing for three stud connectors per row. The beams must be large enough that the elastic neutral axis of the composite section is within the steel beam (not within the slab or haunch). Rolled beams usually do not need bearing stiffeners. Verify the need of bearing stiffeners for rolled beams by using the provisions in LRFD D6.5. The diaphragms between beams usually consist of rolled shapes with channels being the most common choice.



## 1.6.2.8 Plate Girders

See Standard Details *DET3600*, *DET3605* and *DET3610* for general details.

### 1.6.2.8.1 Flange Width and Thickness

Minimize the number of changes in flange size, as the cost of a butt weld will offset a considerable length of excessive flange area. When locating flange thickness transitions (shop flange splices), include no more than two butt splices or three different flange thicknesses for an individual flange between field splices, except for unusual cases such as very long or heavy girders or mill length availability limits.

Constant width flanges enable the fabricator to order the flanges in multiple width plates which are more economical than universal mill plates. The shop flange splices can be made while the plates are in wide slabs and cut to widths simultaneously with multiple cutting torches. Limit the maximum change between adjacent plates to 6 inches in width, at both welded and bolted connection section changes.

Efficiently locating thickness transitions in plate girder flanges is a matter of plate length availability and the economics of welding and inspecting a splice compared to the cost of extending a thicker plate. Refer to [NSBA G12.1 Guidelines to Design for Constructability Article 1.5.1](#) for optimizing flange thickness transitions. The rule of thumb is to limit flange transitions such that the smaller flange at a welded transition is no less than 50 percent of the area of the larger flange, which accomplishes two things. First, the bending stress gradient in the girder web due to the change in section properties does not become overly steep when this criterion is met. It has also been demonstrated in past designs that, when the flange transition results in greater than a 50 percent reduction in flange area, either the transition is not in the optimum location or an additional transition may prove to be economical.

The minimum size flange is  $\frac{3}{4}$  by 12 inch. The minimum  $\frac{3}{4}$  inch flange thickness is to minimize the distortion of the flange due to welding of the flange to the web.

It may not be prudent to minimize the top flange. Flange width affects girder stability during handling, erection, and deck placement. Keep the girder length (field section length) to flange width ratio below 85. The girder needs significant lateral load capacity to resist lateral transportation loads and lateral loads from deck overhang brackets and deck placements. Another side benefit of providing generous top flange is that the non-composite deflections are reduced.

Make top and bottom flanges a constant width where possible. Minimizing the number of changes in the top flange will also facilitate easier deck forming. When a change in bottom flange width is needed, make it at a bolted splice location.

Limit the maximum flange thickness to 3 inches. At welded flange splices, the thinner plate must not be less than one-half the thickness of the thicker plate.

Generally, use a minimum flange width that is equal to the width of the flange resisting the maximum positive moment. Widen the flange as necessary in negative moment areas so the flange thickness will not exceed 3 inches at the bent.

#### **1.6.2.8.2 Web Depth and Thickness**

Girder depths, particularly for haunched girders, may be limited because of transportation constraints.

Use constant depth girders where possible. Commonly used web plates range from 48 to 96 inches. Minimum web thickness is  $\frac{1}{2}$  inch. Thinner plate is subject to excessive distortion from welding.

Use web plate of sufficient thickness to eliminate the need for transverse stiffeners either entirely or partially. In high shear regions, when transverse stiffeners spaced at about 8 to 10 feet prevent the need for a thicker web, the use of a stiffened web can be justified. The labor to place and weld one foot of stiffener is equal to about 25 pounds of steel. Unstiffened webs reduce fabrication, painting costs (for non-weathering steel) and flange sizes. Thicker webs are also helpful in reducing web distortion due to welding and in supporting deck overhang brackets for the deck placement.

Design web plates in  $\frac{1}{16}$  inch increments with a note that the contractor may increase the web thickness shown by  $\frac{1}{16}$  inch at no additional cost to the state. Minimize web transitions as the cost of a butt weld web splice often exceeds the cost of the added material between sections.

The cost of a square butt joint web splice is equal to about 800 pounds of steel per foot of splice. When web plates are over 80 feet long and constant thickness, provide the fabricator an optional shop splice on the design plans. The most economical bid can then be prepared according to the mill length extras, market areas available, and transportation and handling costs.

#### **1.6.2.8.3 Girder Splices**

Locate splices to avoid conflicts with wind bracing, diaphragms and/or intermediate stiffeners. Layout locations of all intermediate stiffeners, diaphragms and wind bracing to avoid conflicts with the flange cutoff points (and possible splice locations).

Splices are a natural location to make changes in the flange size to eliminate flange welds. Maintain the same web thickness on each side of the splice. For flexural members, it is recommended that the smaller section at the point of splice be taken as the side of the splice that

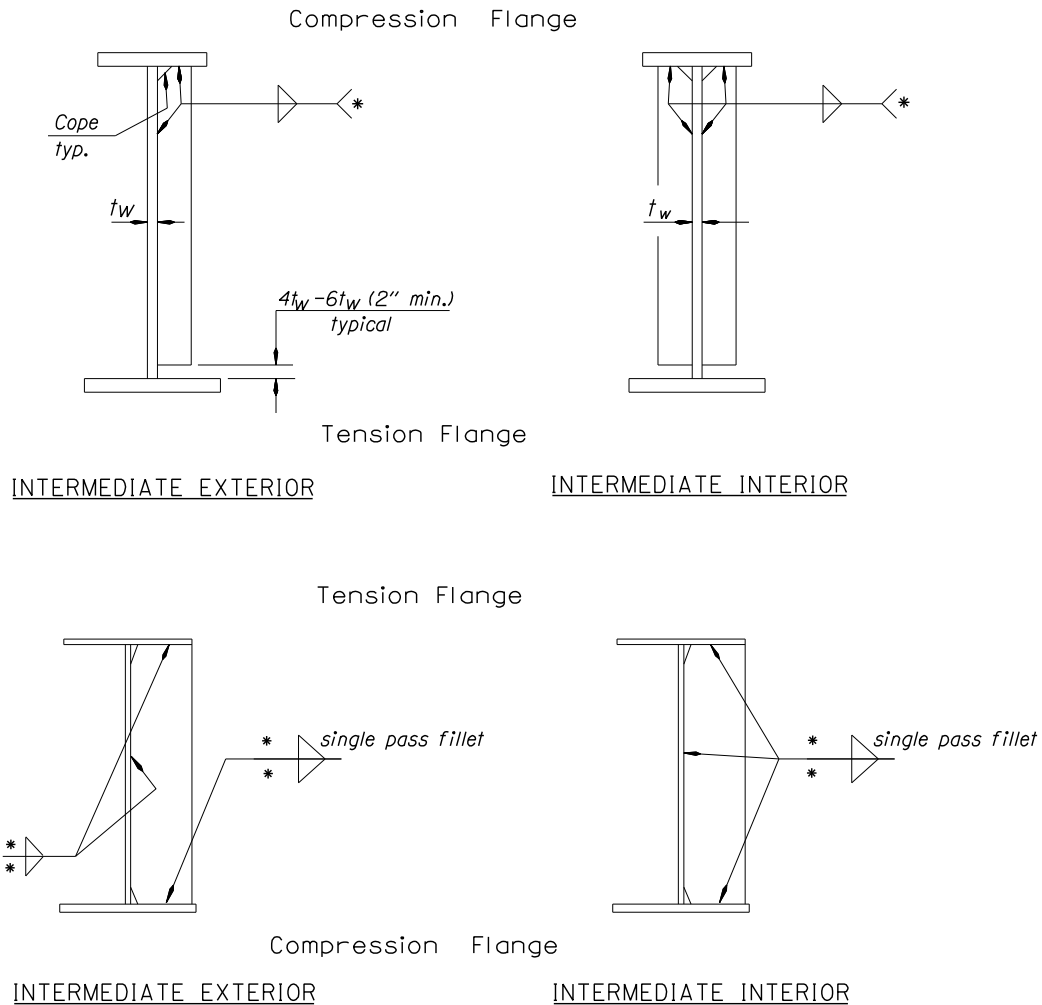
has the smaller calculated moment of inertia for the non-composite steel section.

#### **1.6.2.8.4 Intermediate Web Stiffeners**

Where transverse intermediate stiffeners are used, provide them on both faces of the webs of interior girders and on the interior faces, only, of exterior girders. Specify stiffener widths in  $\frac{1}{2}$  inch increments. Specify thickness in  $\frac{1}{8}$  inch increments using  $\frac{3}{8}$  inch as an absolute minimum.

Rigidly connect the stiffeners to the compression portions of the flanges. Stiffeners may be welded to compression flanges. Ends welds about  $\frac{1}{4}$  inch away from the edge (snipe, clip, etc.) to avoid a poor quality weld termination.

Figure 1.6.2.8.4-1 Intermediate Web Stiffeners



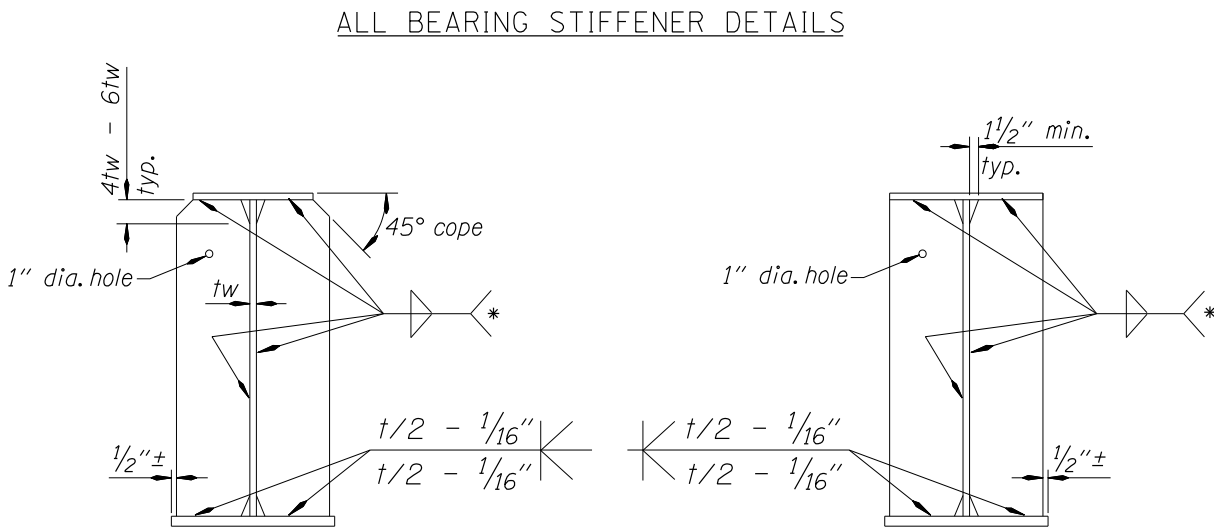
- For stiffener thickness connecting to tension flange  $\leq 1/2"$ . See figure 1.2.1.3B
- \* Size fillet welds in accordance with AASHTO LRFD. Minimum weld sizes not less than  $1/4"$  for  $t \leq 3/4"$  or  $5/16"$  for  $t > 3/4"$ .
  - \* Compression and tension flanges reverse near interior bents for continuous girder.
  - \* Seal all weld terminations of stiffeners with structural steel caulking from QPL, typical.

INTERMEDIATE WEB STIFFENERS

### 1.6.2.8.5 Bearing Stiffeners

Bearing stiffeners and the web act as a column section, transferring loads from the superstructure to the substructure. In combination with the end frames, they also transfer lateral loads from the superstructure to the substructure. Minimum size of fillet weld is the minimum specified in *BDM 1.6.3.2*. Fabricators strongly discourage full-penetration welding of bearing stiffeners to flanges. Full-penetration welds distort the bearing area of the bottom flange. Select bearing stiffener widths in increments of  $\frac{1}{2}$  inch. Specify thickness in  $\frac{1}{8}$  inch increments. Bearing stiffeners should extend to about  $\frac{1}{2}$  to  $\frac{3}{4}$  inch from the flange edge.

Figure 1.6.2.8.5-1 Bearing Stiffener Detail



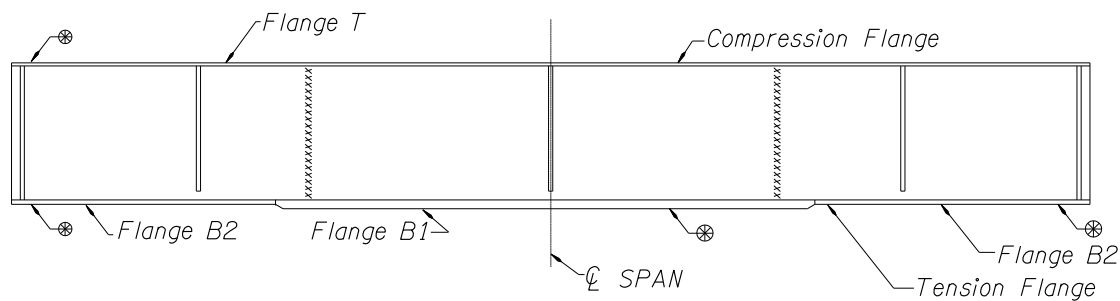
Limit bearing stiffeners skew angle at end bents or interior bents to the values shown in *Figure 2.3* of the *AWS D1.5* for bearing stiffeners to web connection. Discard the footnotes of the figure which permits angles less than 60 degrees. When the skew angle exceeds limit shown on the Figure, use bent plates.

### 1.6.2.9 Check Samples and Fracture Critical Members

#### CHECK SAMPLES

Tension members and elements that require notch toughness check samples are to be clearly identified on the plans. Check samples are required for cross-frame members on curved steel girders.

Figure 1.6.2.9-1 Check Sample Identification Detail

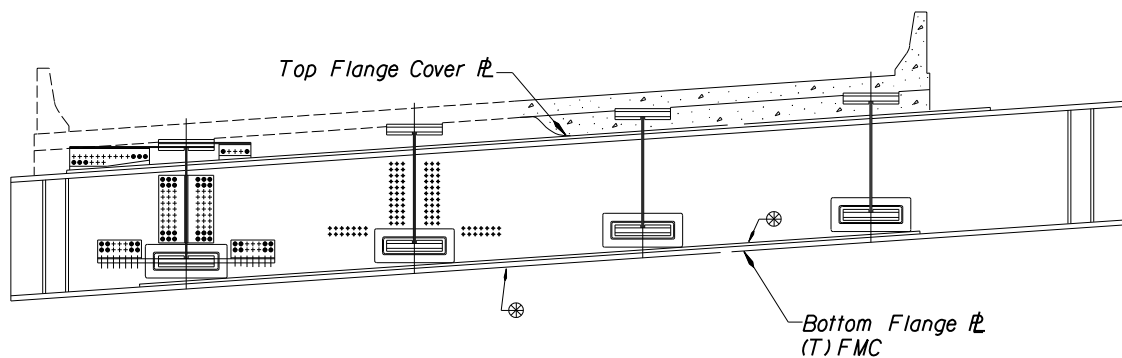


⊗ Indicates check sample required from flange plates so marked. See Special Provisions.

#### FRACTURE CRITICAL MEMBERS

Clearly identify fracture-critical members on the plans.

Figure 1.6.2.9-2 Fracture Critical Member Identification Detail



Fracture critical members are shown as (T) FMC. See Special Provisions for requirements.

## C1.6.2.10

### 1.6.2.10 Fit-up and Intermediate Cross-Frames

Fit-up of steel bridge members is a critical component in the overall success of a project. The designer must be able to clearly convey to the fabricator and erector the intent of the design as it relates to bolting and pinning, camber, bolted field splices, and differential deflections. State in the contract documents the fit condition for which the cross-frames or diaphragms are to be detailed according to *LRFD 6.7.2*.

Steel bridges, including straight and skewed bridges, should be detailed so they are plumb in the final condition. For steel girder bridges this means that the girder webs should be plumb after deck and barrier placement. This is accomplished by detailing the cross-frames to the final position. The girders are then installed to fit the cross-frames, requiring that for skewed bridges they be **rolled** during fit-up so that they are out of plumb under steel dead loads. The design intent again needs to be spelled out clearly on the plans so that the fabricator and erector are aware of the intent when bidding and constructing the project. Tolerances for web plumbness/girder layover are specified in the [\*AASHTO/NSBA Guide Specification S10.1-2014, Steel Bridge Erection Guide Specification Section 9\*](#).

Steel Dead Load Fit (SDLF, also known as Erected Fit): For bridges which are detailed for SDLF the girder webs should be plumb (within reasonable construction tolerance) at the end of steel erection, prior to deck placement. When they are not plumb at the end of steel erection (prior to deck placement), the engineer should be consulted and remedial action should be considered. Later, when the deck is placed, the webs will lay over and be out of plumb. This sequence of webs being plumb prior to deck placement and out of plumb after deck placement is normal and generally does not represent a problem.

Total Dead Load Fit (TDLF, also known as Final Fit): For bridges which are detailed for TDLF the girder webs should be plumb



(within reasonable construction tolerance) at the end of deck placement. The webs will be out of plumb at the end of steel erection, prior to deck placement. When the webs are plumb at the end of steel erection (prior to deck placement), or are out of plumb in the wrong direction or beyond reasonable construction tolerances, remedial action should be considered. When the webs are in

their correct, anticipated out of plumb position prior to deck placement, then when the deck is placed the webs will rotate (twist) to a plumb position (within reasonable construction tolerance), at least at the supports. This sequence of webs being out of plumb prior to deck placement and plumb after deck placement is normal and generally does not represent a problem.

### **SKewed AND CURVED I-GIRDER BRIDGE FIT AND FRAMING ARRANGEMENTS**

See [Skewed and Curved Steel I-Girder Bridge Fit \(Standalone Summary\)](#) and [Skewed and Curved Steel I-Girder Bridge Fit \(Full Document\)](#) for more information.

Recommended fit conditions for the following I-girder bridges (*LRFD 6.7.2*):

- Straight bridges where one or more support lines are skewed more than 20 degrees from normal.
- Horizontally-curved bridges where one or more support lines are skewed more than 20 degrees from normal and with an L/R in all spans less than or equal to 0.03.
- Horizontally-curved bridges with or without skewed supports and with a maximum L/R greater than 0.03.

where:

L = actual span length bearing to bearing along the centerline of the bridge (feet)

R = girder radius at the centerline of the bridge (feet)

Fit Condition – deflected girder geometry associated with a targeted dead load condition for which the cross-frames are detailed to connect to the girders.

Table 1.6.2.10-1 Recommended Fit Conditions for I-Girder Bridges

Loading Condition Fit	Construction Stage Fit	Description
No-Load Fit (NLF)	Fully-Cambered Fit	The cross-frames are detailed to fit to the girders in their fabricated, plumb, fully-cambered position under zero dead load.
Steel Dead Load Fit (SDLF)	Erected Fit	The cross-frames are detailed to fit to the girders in their ideally plumb as-deflected positions under bridge steel dead load at the completion of the erection.
Total Dead Load Fit (TDLF)	Final Fit	The cross-frames are detailed to fit to the girders in their ideally plumb as-deflected positions under the bridge total dead load.

Table 1.6.2.10-2 Recommended Fit Conditions for Straight I-Girder Bridges (including Curved I-Girder Bridges with L/R in all spans less than or equal to 0.03)

Span Length	Recommended	Acceptable	Avoid
<b>Square Bridges and Skewed Bridges up to 20 deg Skew</b>			
Any span length	Any		None
<b>Skewed Bridges with Skew greater than 20 degree and <math>I_s \leq 0.30</math> +/-</b>			
Any span length	TDLF or SDLF	-	NLF
<b>Skewed Bridges with Skew greater than 20 degree and <math>I_s &gt; 0.30</math> +/-</b>			
Span lengths up to 200 feet +/-	SDLF	TDLF	NLF
Span lengths greater than 200 feet +/-	SDLF	-	TDLF & NLF

Table 1.6.2.10-3 Recommended Fit Conditions for Horizontally Curved I-Girder Bridges

$((L/R)_{MAX} > 0.03)$

<b>Radial or Skewed Supports</b>			
Span Length	Recommended	Acceptable	Avoid
$(L/R)_{MAX} \geq 0.2$	NLF	SDLF	TDLF
All other cases	SDLF	NLF	TDLF
Detail for a Steel Dead Load Fit, unless the maximum L/R is greater than or equal to 0.2.			

When  $(L/R)_{MAX} \geq 0.2$ , detail for No-Load Fit, unless the additive locked-in force effects from Steel Dead Load Fit detailing are considered.

### DESIGN

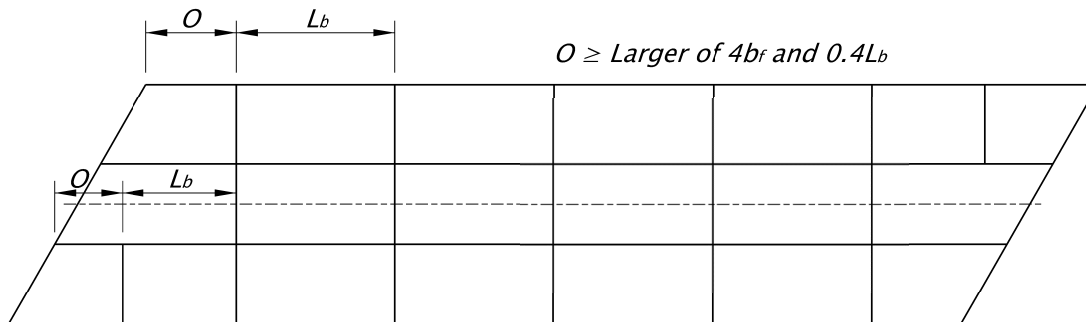
Design and detail cross frame based on rational analysis for all stages of construction and service life according to [LRFD 6.7.4](#).

- Rational analysis of cross-frames depends on accurately analyzing the structure and determining the appropriate force effects.
- When a bridge is designed using line girder analysis methods, the cross-frames should be evaluated for minimum stability bracing strength and stiffness requirements as well as wind loads and construction loads.
- Where cross frame fatigue forces control the design, live load force effects in cross-frames and diaphragms should be calculated by 2D grid or 3D analysis model. See [G13.1-2019, Guidelines for Steel Girder Bridge Analysis](#) Section 4 and Appendix B.
  - [LRFD C6.6.1.2.1](#) – Calculate fatigue stress using only a single transverse lane position. Determine maximum fatigue stresses in cross frames with the truck confined to one critical transverse position per each longitudinal position throughout the length of the bridge. Standard grid design software is generally not considering this. This requires isolating loading from individual lanes in the analysis. To satisfy this requirement, an influence-surface grid of 5 feet (longitudinal) by 4 feet (transverse) has been shown to adequately capture the maximum force effects.
  - For 2D models using equivalent beam, use Timoshenko beam approach, see [G13.1-2019, Guidelines for Steel Girder Bridge Analysis](#) [Section 3.11.3](#). The Timoshenko beam approach provides the most realistic estimate of the cross-frame stiffness because it considers both flexural and shear deformations. Include the transverse stiffness of the deck.

For skewed (greater than 20 degrees) and curved I-girder bridges:

- See [LRFD C6.7.4.2](#) for discussion about beneficial framing arrangements in skewed and curved I-girder bridges to alleviate detrimental transverse stiffness effects.
- It is recommended to offset the first intermediate cross-frame placed normal to the girders adjacent to a skewed support:

Figure 1.6.2.10-1 Cross Frame Layout for Bridge with Skewed Support



- Framing of a normal intermediate cross-frame into or near a bearing location along a skewed support line is strongly discouraged unless the cross-frame diagonals are omitted.
- At skewed interior bents and end bents, place cross-frames along the skewed bearing line, and locate intermediate cross-frames greater than or equal to the recommended minimum offset from the bearing lines.
- For curved I-girder bridges, provide contiguous intermediate cross-frame lines within the span in combination with the recommended offset at skewed bearing lines.

## MEMBER SELECTION AND DETAILING

Select the most economical cross-frame members which meet the strength and detailing requirements of the design. Minimize the number of different types or sizes of members used in a given design. Consider the following for cross-frame member selection:

- Equal leg angles are often more cost-effective than unequal leg angles. Do not use back-to-back angles as cross-frame members. Common angle sizes for diaphragms range from L3 x 3 x 5/16 to L6 x 6 x 5/8.
- WT sections may be used when design forces exceed the capacity of angle sections,. Do not use WT shapes in small quantities.
- If channel sections are used, C shapes are preferable to MC shapes. A bent-plate diaphragm, in the shape of a channel, is a possible option to provide to the fabricator for diaphragms on shallow plate girders (4-foot-deep web or less) or rolled beams.
- Design and detail cross-frames such that they can be erected as a single unit. Fabricators and erectors discourage diaphragms that require erection in separate pieces.
- Efficient cross frames are as deep as practical so that the diagonals of the cross frame have large enough angles to prevent the gusset-type plates at the ends of the cross frame from becoming too large.

See the following reference for additional guidance:

- [Proposed Modification to AASHTO Cross-Frame Analysis and Design](#)
  - [Appendix B: Cross-Frame Design Example \(Straight Bridge\)](#)
  - [Appendix C: Cross-Frame Design Example \(Curved Bridge\)](#)
- *G12.1-2020, Guidelines to Design for Constructability Section 2.2.6*
- *FHWA Steel Bridge Design Handbook: Volume 13 – Bracing System Design*

In choosing between intermediate cross-frames of **K** or **X** form, in general use the **X** form when the ratio of the beam spacing to the frame depth is less than two and the **K** form when the ratio is greater than two. Consider a solid plate diaphragm when the depth of the frame approaches 3 feet or less.

Also consider maintenance and inspection requirements in the cross-frame design. Providing adequate clearance for sandblasting and painting is recommended. Avoid inaccessible areas. It may also be necessary to provide for maintenance walkways and/or utilities through the cross-frames.

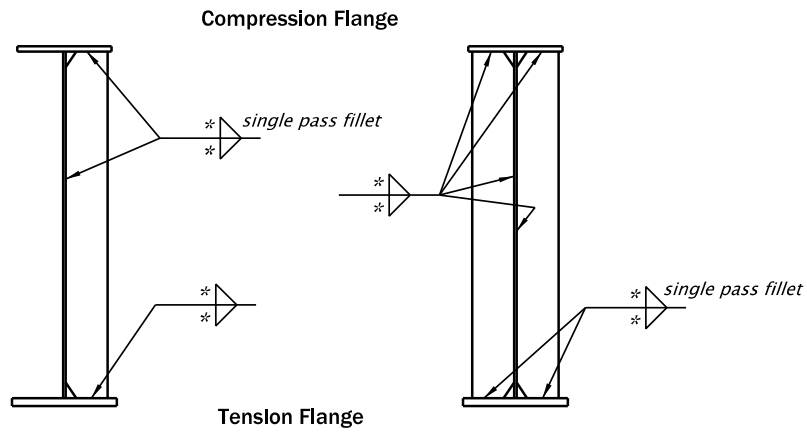
Rigidly connect cross-frames to the top and bottom flanges to prevent web distortions and cracking. Weld stiffeners to compression and tension flanges as shown on *Figures 1.6.2.10-2 and 1.6.2.10-3*. Stop ends of welds about 1/4 inch away from the edge (snipe, clip, etc.) to avoid a poor quality weld termination.

Where two adjacent plate girders have significant differential deflection, such as the first row of cross-frame from the end bents, do not use the **K** or **X** type of cross-frames. Use details shown on *Figure 1.6.2.18-2*. Check fatigue requirements of all welded connections.

Provide intermediate cross-frames between the box girders. Submit a request for a design deviation to the State Bridge Engineer when a project requires omitting intermediate cross-frames or diaphragm between steel tub or box girders.

Connection Plates for Bracing Members - Cope diaphragm connection plates, which are welded to both the web and flange of a plate girder, a minimum of 1 ½ inches to prevent intersection of the two welds. Avoid lateral connection plates for lateral bracing which will be connected to the web of the plate girder or box girders. Bolt lateral connection plates to the flange of the steel girder. Cope lateral connection plates to be clear of any transverse web stiffener or diaphragm connection plate.

Figure 1.6.2.10-2 Transverse Connection Plates



**INTERMEDIATE EXTERIOR**

**INTERMEDIATE INTERIOR**

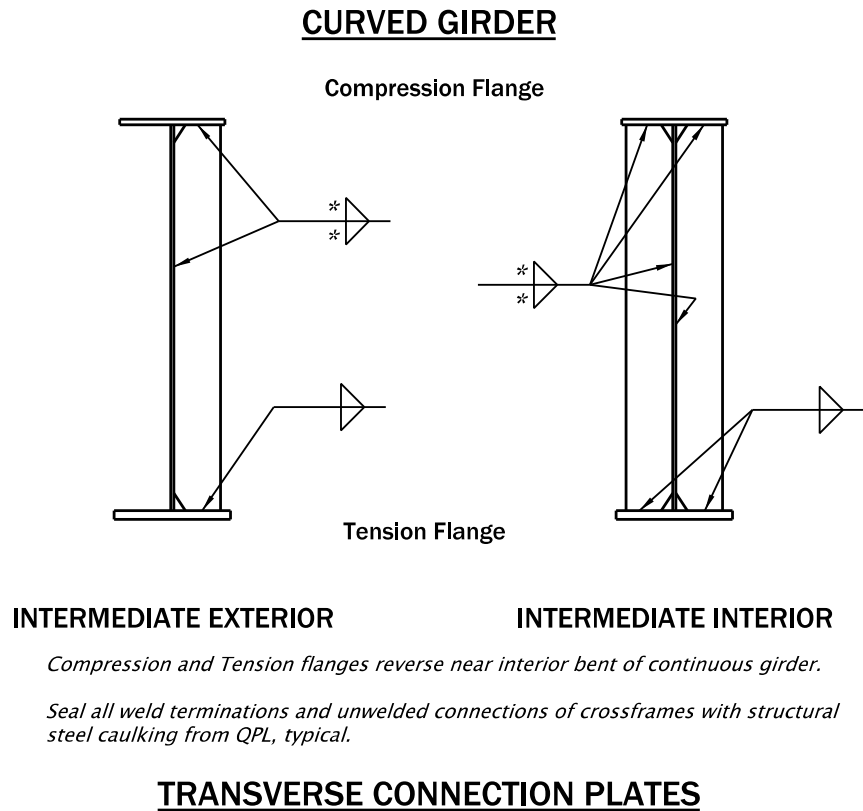
*\* Size fillet welds in accordance with AASHTO LRFD minimum welds sizes shall not be less than 1/4" for  $t \leq 3/4"$  or  $7/16"$  for  $t > 3/4"$ .*

*Compression and Tension flanges reverse near interior bent of continuous girder.*

*Seal all weld terminations and unwelded connections of crossframes and stiffeners with structural steel caulking from QPL, typical.*

**TRANSVERSE CONNECTION PLATES**

Figure 1.6.2.10-3 Transverse Connection Plates on Curved Girders





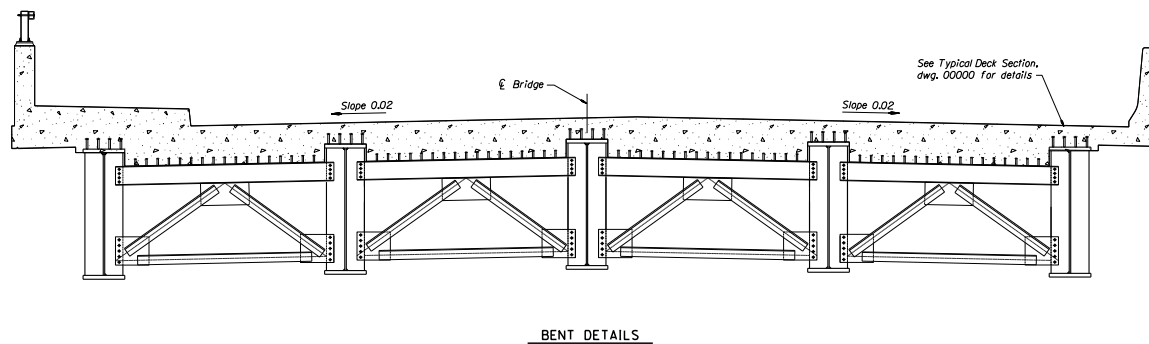
### 1.6.2.11 Cross-Frames at Bents

Cross-frames at bents are more critical to transfer seismic forces from the superstructure to the substructure. One solution is to use detail *Figure 1.6.2.11-1* with a W shape beam between the girders at the top of the cross-frame. Welded studs are added to the top flange of these W shape beams to provide the lateral resistance. The shear studs at the ends are critical in transferring the transverse seismic forces from the deck slab into the steel superstructure. A top chord connecting the deck slab to the end cross frames was found to be effective in transferring these forces and resist rotation at the top of the girders in the absence of sufficient studs on top of the girders.

When a joint system is required for a cross-frame at end bents, it may be necessary to use details similar to cross-frames at continuous beam interior bents. See *Figure 1.6.2.11-1*.

Diaphragms or cross-frames are required along skewed interior bents and end bents. See *BDM 1.6.2.10* for more information.

Figure 1.6.2.11-1 Cross Frame Details at Bent



It is desirable to have all cross-frame member centerlines intersecting at a common point. But, it is often easier to design for the eccentric loads in the connection than to get a common intersection point of the member centerlines.

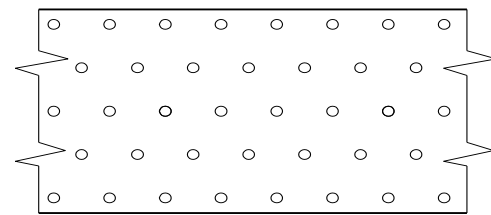
### 1.6.2.12 Composite Action and Flange Shear Connectors

Provide shear connectors in all portions of continuous spans, positive or negative moment. Old practice was to not use concrete reinforcement to increase the moment capacity of composite girders in the negative moment areas. However, for deflection and moment calculations include longitudinal reinforcing steel in the composite section properties of the girder in the negative moment areas.

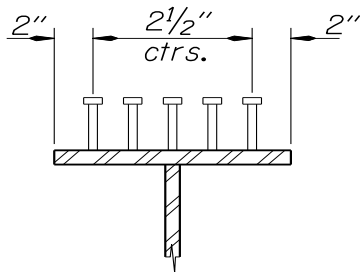
Extend shear connectors at least 1 inch above the mid depth of the deck. Generally, the deck build up on steel girders is constant except for bridges with variable cross-slopes (super elevation) along the bridge. However the top flange plate thicknesses may vary. Consider the effect of top flange thickness variation and bridge deck super elevations when checking the shop drawings or specifying the shear connector's length. The advantages of longer shear connectors are in distributing load to larger area of the bottom mat reinforcing steel when a girder fails in fatigue. The concrete deck will distribute a portion of the unsupported load of the failed girder to adjacent girder/girders.

Figure 1.6.2.12-1 Shear Connector Layout

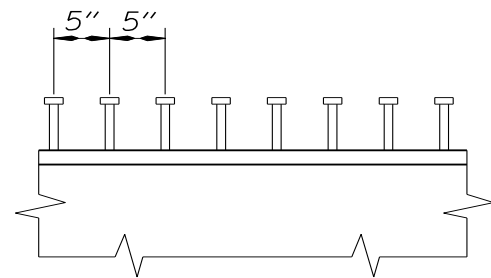
*Where transverse deck reinforcing is to be placed skewed with the centerline of the girder, the studs shall be placed in rows parallel to the direction of the deck steel.*



PLAN



TRANSVERSE



LONGITUDINAL

MINIMUM SHEAR CONNECTOR SPACING  
 Max. shear connector spacing (longitudinal = 2'-0")

### 1.6.2.13 Beam Camber

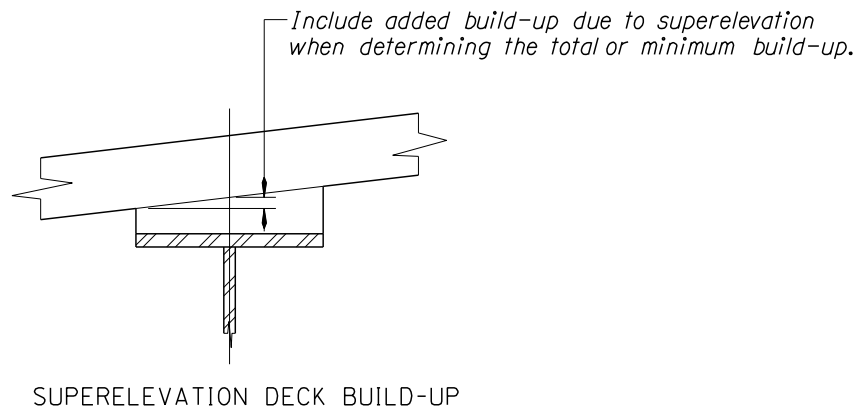
#### GENERAL

Steel beams are cambered to compensate for dead load, shrinkage deflections and gradelines. The final position of the bottom flange is either flat or follows the grade, except in a sag vertical curve. Do not place a final negative camber in a beam. Profile grades can be incorporated into the camber by either added camber in the beam or by varying the deck flange build-ups along the beam. Sag vertical curves always require flange build-ups. Consider the superelevation of the deck in the design of minimum flange build-ups.

Slope adjustment or build-up for straight girders on curved roadways must also be considered. Deck grades are based on the roadway centerline and straight girders are offset at midspan from the centerline. As a result, the adjustment is the superelevation times the midspan offset. Additional beam camber at midspan or additional build-up at the ends will be required. See *Figure 1.6.2.13-1*.

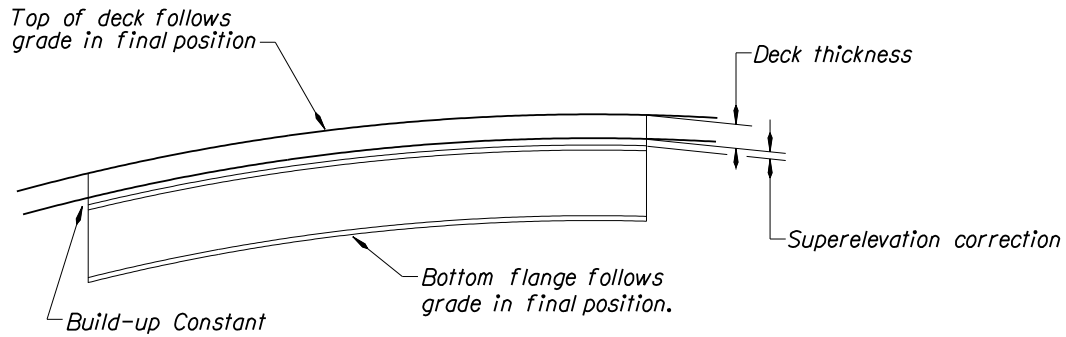
In addition to girder deflections, show girder rotations at bearing stiffeners. This will allow shop plan detailers to compensate for rotations so that bearing stiffeners will be vertical in their final position.

Figure 1.6.2.13-1 Superelevation Deck Build-Up



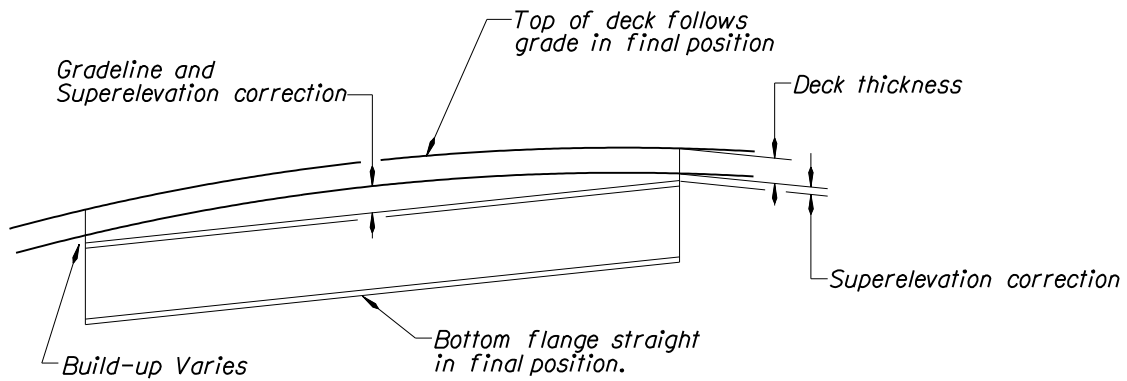
Sketches of the camber options for simple spans are shown in *Figures 1.6.2.13-2* through *1.6.2.13-4*.

Figure 1.6.2.13-2 Case 1: Crest Vertical Curve with Beam Grade Camber



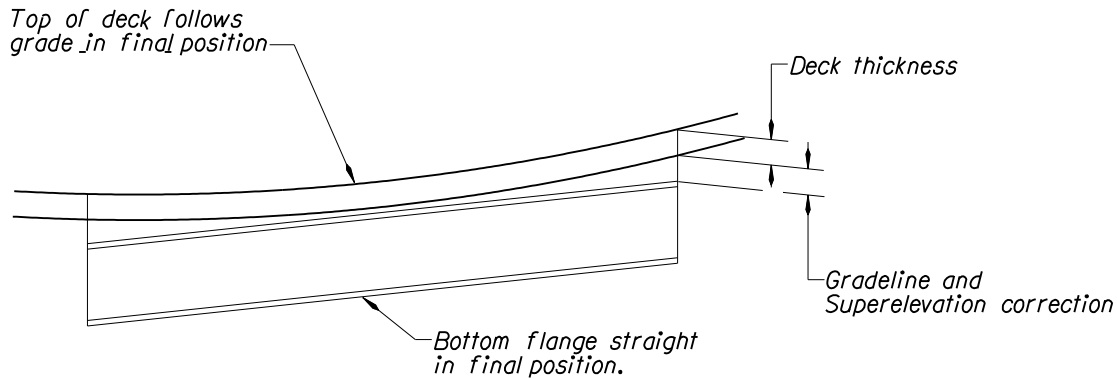
CASE 1 : CREST VERTICAL CURVE WITH BEAM GRADE CAMBER

Figure 1.6.2.13-3 Case 2: Crest Vertical Curve with Build-Up for Grade Camber



CASE 2 : CREST VERTICAL CURVE WITH BUILD-UP FOR GRADE CAMBER

Figure 1.6.2.13-4 Sag Vertical Curve with Build-Up for Grade Camber



CASE 3 : SAG VERTICAL CURVE WITH BUILD-UP FOR GRADE CAMBER

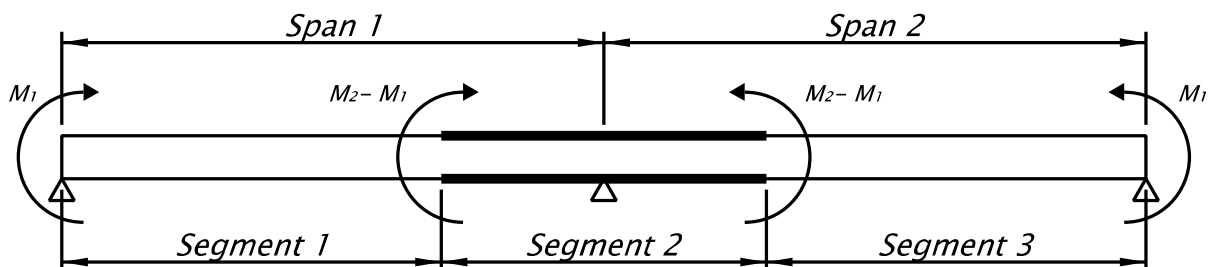
SHRINKAGE CAMBER

Bridge deck shrinkage has a varying degree of effect on superstructure deflections. The designer shall use some judgment in evaluating this effect on camber. Bridge deck shrinkage should be the smallest portion of the total camber. It has greater influence on shallower girder sections, say rolled beams. Simple spans will see more effect than continuous spans. For calculation, apply a shrinkage strain of 0.0002 to the long-term composite section using  $3n$ . Tests have indicated that the unit shrinkage of the slab in composite beams (i.e., the shrinkage strain adjusted for long-term relaxation effects) may be taken equal to 0.0002.

The steel stresses in straight simple spans may be approximated by considering the composite cross-section as an eccentrically loaded column with a load of  $0.0002EcnAc$  applied at the centroid of the slab and using  $n = Es/Ec$ .

Example of a two span bridge with two different girder sections:

Figure 1.6.2.13-5 Example of Applied Moments on two span bridge



For two span bridge, the magnitude of the applied moments is equal to the compression force times the distance from the mid-depth of the deck to the c.g. of the composite section for that segment. Where two segments join the applied moment is the difference between the calculated moments for each segment.

The deflections of the first pour are based on the whole girder acting non-composite, then the deflections of the second pour are based on the area of the first pour acting compositely with the rest of the girder non-composite and so on until the last pour. The deflections due to each pour sequence are added together and only the total is shown in the camber table.

For structures requiring close tolerances on girder cambers, refined analysis of shrinkage effects utilize structural analysis software such as MIDAS Civil may also be used provided they are based on the same concrete shrinkage strain.

CAMBER DIAGRAMS

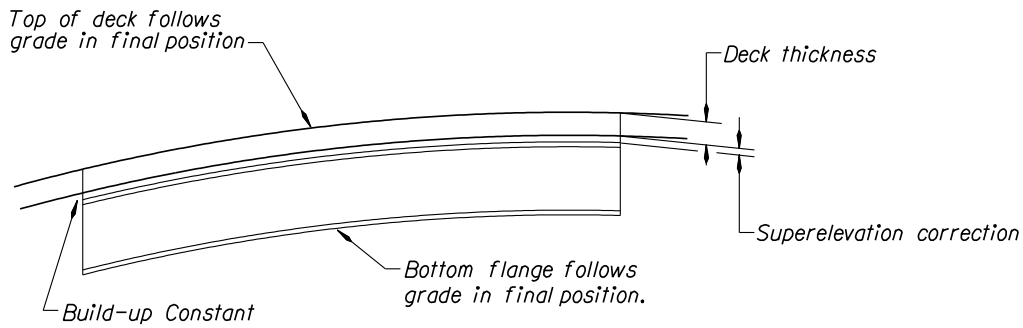
Show the data in *Table 1.6.2.13-1* for steel beam camber on the contract drawings.

Table 1.6.2.13-1 Steel Beam Camber Example

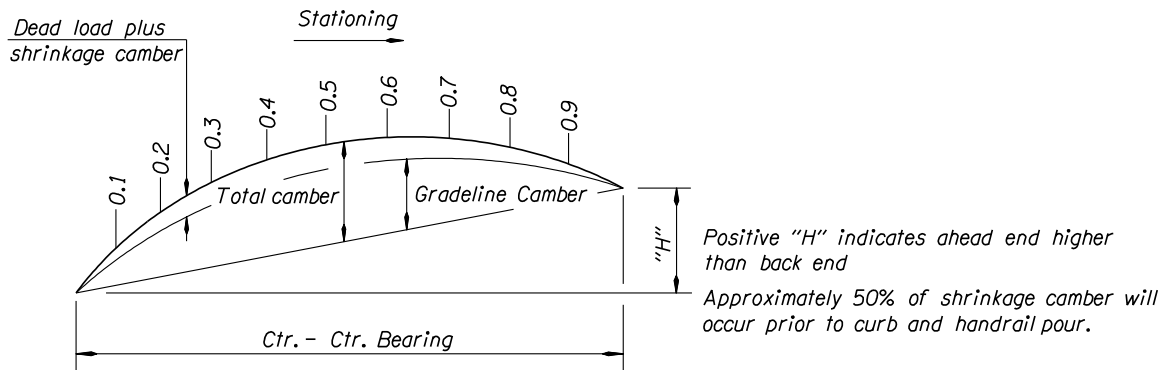
<b>Camber Item</b>	<b>Value</b>
Grade line camber	
Dead load camber	
Superimposed Dead load camber	
Shrinkage camber	
Total Camber	
Camber due to weight of steel beam and diaphragm	

Camber diagram examples are shown in *Figures 1.6.2.1.3-6* and *1.6.2.1.3-7*.

Figure 1.6.2.13-6 Camber Diagram Example 1



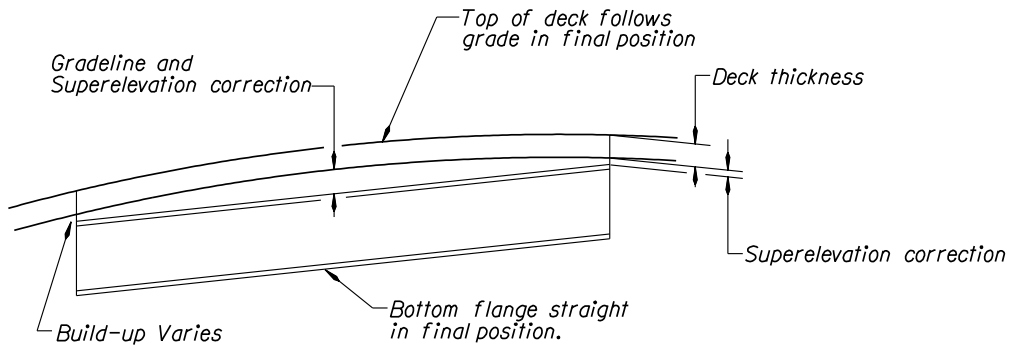
CREST VERTICAL CURVE WITH BEAM GRADE CAMBER



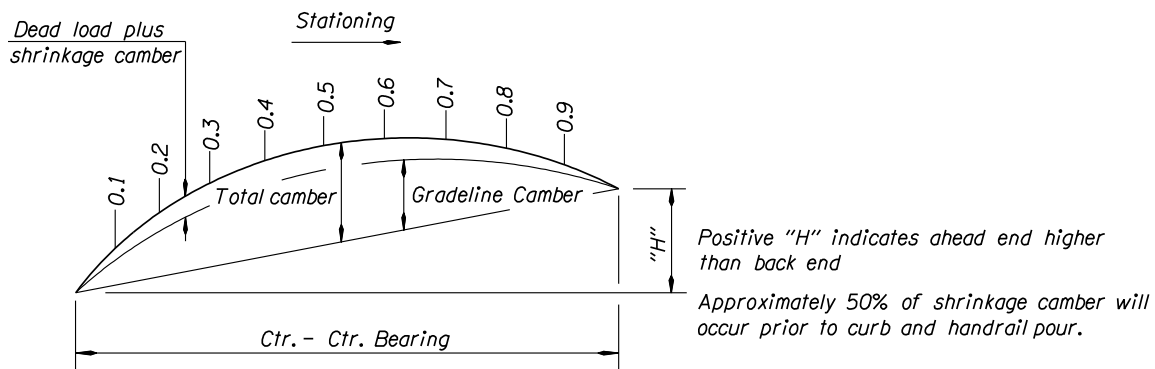
GIRDER CAMBER											
Span	Item	Camber									H inches
		0.1 Pt.	0.2 Pt.	0.3 Pt.	0.4 Pt.	0.5 Pt.	0.6 Pt.	0.7 Pt.	0.8 Pt.	0.9 Pt.	
1	Beam Dead Load + Diaphragms	5/8"	1"	1 3/8"	1 1/2"	1 3/8"	1 1/8"	3/4"	3/4"	1/16"	+ 16 3/8"
	Deck Dead Load + Form	1 3/8"	2 1/2"	3 3/16"	3 1/4"	3 3/16"	2 3/16"	1 3/8"	1 1/16"	1/4"	
	Sidewalk, Rail & WS Dead Load	3/8"	5/8"	1 3/16"	7/8"	1 3/16"	1 5/16"	5/8"	5/16"	1/16"	
	Shrinkage	5/8"	1"	1 1/4"	1 1/4"	1 1/8"	1"	3/4"	1/2"	1/4"	
	Sub Total	3"	5 1/8"	6 5/8"	6 7/8"	6 3/8"	5 1/8"	3 1/2"	1 7/8"	5/8"	
	Gradeline	3/8"	3/4"	1"	1 1/8"	1 1/4"	1 1/8"	1"	3/4"	3/8"	
	Total	3 3/8"	5 7/8"	7 5/8"	8"	7 5/8"	6 1/4"	4 1/2"	2 5/8"	1"	
2	Beam Dead Load + Diaphragms	1/16"	1/4"	5/8"	7/8"	1 1/16"	1 1/16"	5/8"	5/16"	1/16"	+ 7 3/8"
	Deck Dead Load + Form	1/8"	3/4"	1 5/8"	2 7/16"	3 1/16"	3 1/4"	1 5/8"	1 3/16"	1/8"	
	Sidewalk, Rail & WS Dead Load	1/16"	1/4"	1/2"	1 3/16"	7/8"	1 3/16"	1/2"	1/4"	1/16"	
	Shrinkage	-1/4"	-3/8"	-3/8"	-3/8"	-3/8"	-1/4"	-1/8"	-1/8"	0	
	Sub Total	0	7/8"	2 3/8"	3 3/4"	4 1/4"	3 7/8"	2 3/4"	1 1/4"	1/4"	
	Gradeline	5/8"	1 1/4"	1 5/8"	1 3/4"	1 7/8"	1 3/4"	1 5/8"	1 1/4"	5/8"	
	Total	5/8"	2 1/8"	4"	5 1/2"	5 1/8"	5 5/8"	4 3/8"	2 1/2"	7/8"	



Figure 1.6.2.13-7 Camber Diagram Example 2



CREST VERTICAL CURVE WITH BUILD-UP FOR GRADE CAMBER



GIRDER CAMBER											
Span	Item	Camber									H inches
		0.1 Pt.	0.2 Pt.	0.3 Pt.	0.4 Pt.	0.5 Pt.	0.6 Pt.	0.7 Pt.	0.8 Pt.	0.9 Pt.	
1	Beam Dead Load + Diaphragms	5/8"	1"	1 3/8"	1 1/2"	1 3/8"	1 1/8"	3/4"	3/4"	1/16"	+ 16 3/8"
	Deck Dead Load + Form	1 3/8"	2 1/2"	3 3/16"	3 1/4"	3 3/16"	2 3/16"	1 3/8"	1 1/16"	1/4"	
	Sidewalk, Rail & WS	3/8"	5/8"	13/16"	7/8"	1 3/16"	15/16"	5/8"	5/16"	1/16"	
	Shrinkage	5/8"	1"	1 1/4"	1 1/4"	1 1/8"	1"	3/4"	1/2"	1/4"	
	Sub Total	3"	5 1/8"	6 5/8"	6 7/8"	6 3/8"	5 1/8"	3 1/2"	1 7/8"	5/8"	
	Gradeline	None	None	None	None	None	None	None	None	None	
	Total	3"	5 1/8"	6 5/8"	6 7/8"	6 3/8"	5 1/8"	3 1/2"	1 7/8"	5/8"	
2	Beam Dead Load + Diaphragms	1/16"	1/4"	5/8"	7/8"	1 1/16"	1/16"	5/8"	5/16"	1/16"	+ 7 3/8"
	Deck Dead Load + Form	1/8"	3/4"	15/8"	2 7/16"	3 1/16"	3 1/4"	15/8"	13/16"	1/8"	
	Sidewalk, Rail & WS	1/16"	1/4"	1/2"	13/16"	7/8"	13/16"	1/2"	1/4"	1/16"	
	Shrinkage	-1/4"	-3/8"	-3/8"	-3/8"	-3/8"	-1/4"	-1/8"	-1/8"	0	
	Sub Total	0	7/8"	2 3/8"	3 3/4"	4 1/4"	3 7/8"	2 3/4"	1 1/4"	1/4"	
	Gradeline	None	None	None	None	None	None	None	None	None	
	Total	0	7/8"	2 3/8"	3 3/4"	4 1/4"	3 7/8"	2 3/4"	1 1/4"	1/4"	

### 1.6.2.14 Deck Pouring Sequence

Deck pouring sequences for continuous steel spans must be developed according to the span and deflection characteristics of the particular bridge.

The general principal is to first place the sections that are outside of the negative moment zones. Subsequent placements may produce negative flexure in the previously placed sections (See *LRFD C6.10.3.7* for commentary). Provide minimum negative flexure slab reinforcement per *LRFD 6.10.3.7* as needed. Set retarding admixture may be required to reduce excessive induced stresses in adjacent spans placed sequentially.

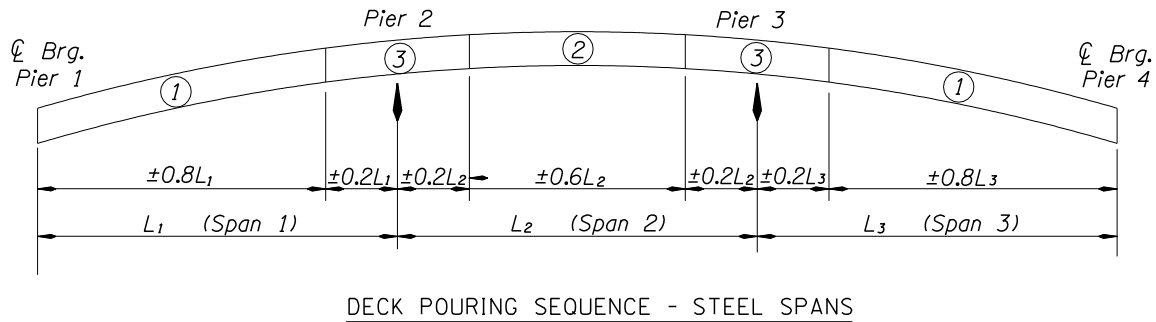
Any changes to the pouring sequence during construction must be analyzed by the Contractor's engineer to determine any effects on stresses and camber. This review will need to be completed early in the process, because it may affect the beam fabrication.

The following steps are a general rule for pouring sequence of continuous steel bridges:

1. Pour (1) consists of all positive moment areas along the bridge which will not cause upward deflection on other span/s. No waiting period is required between these spans.
2. Pour (2) consists of multiple separate placements of all positive moment areas of spans that cause upward deflection on other spans. The wait period between these span placements is a minimum of three days after the last pour (1) ended and reaches 70 percent of final strength. When multiple spans are placed sequentially in the same pour, set retarding admixture may be required to reduce excessive induced stresses in adjacent spans.
3. Pour (3) consists of all negative moment areas. The pour can be placed a minimum three days after the last pour (2) ended.

The pouring sequence of three span continuous balanced bridges is shown in *Figure 1.6.2.14-1*.

Figure 1.6.2.14-1 Deck Pouring Sequence – Steel Spans



POURING SEQUENCE

1. Make Pours (1) . May be made simultaneously or separately as desired by the contractor.
2. After a minimum of 3 days after the completion of Pour (1) and concrete has reached 70% full strength. Make Pour (2) .
3. After minimum of 3 days after completion of Pour (2), make Pours (3) . Pours (3) may be made simultaneously or separately.

Note: Deck concrete shall be placed and screeded parallel to bents.

The deck pouring sequence for bridges designed continuous for live load consists of two pours. Pour (1) for all positive moment areas except for closure pours. Pour (2) consists of all closure pours at interior and/or end bents a minimum of three days after pour (1).

### 1.6.2.15 End Bents Detailing

It is desirable to eliminate end bent joints or make construction jointless to protect the girder steel from leaking joints. See *BDM 1.11.2.4* for additional guidance.

Use the extended deck detail or semi integral abutments similar to *Figures 1.6.2.15-1* or *1.6.2.15-2*.

Use the integral abutments when geometry and span length allow. Show a coated or painted section at the ends of plate girders. On jointless bridges coat or paint the end of the girder for a length of 1 foot outside the concrete interface and 4 inches inside the concrete interface. See *Figure 1.6.2.15-3*.

Where joints cannot be avoided, show a coating or painting detail at the end of plate girders. Coat or paint the end of the girder for a length at least 1.5 times the depth of the girder and all attachments within this limit. See *Figure 1.6.2.15-4*. The paint color is to match the developed weathering steel patina 2.5 years after completion of the bridge construction. See *Figure 1.6.2.15-4*.

Figure 1.6.2.15-1 Extended Deck Details at End Bents

EXTENDED DECK DETAILS

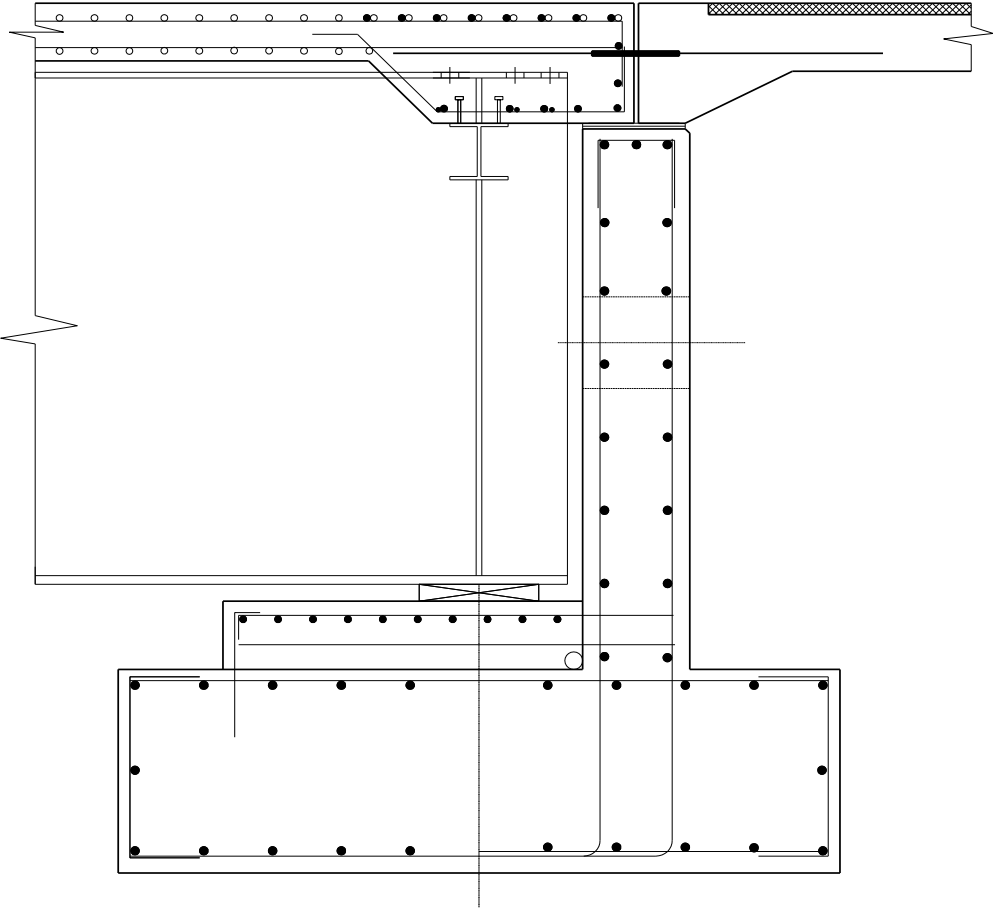


Figure 1.6.2.15-2 Semi Integral Bent Detail

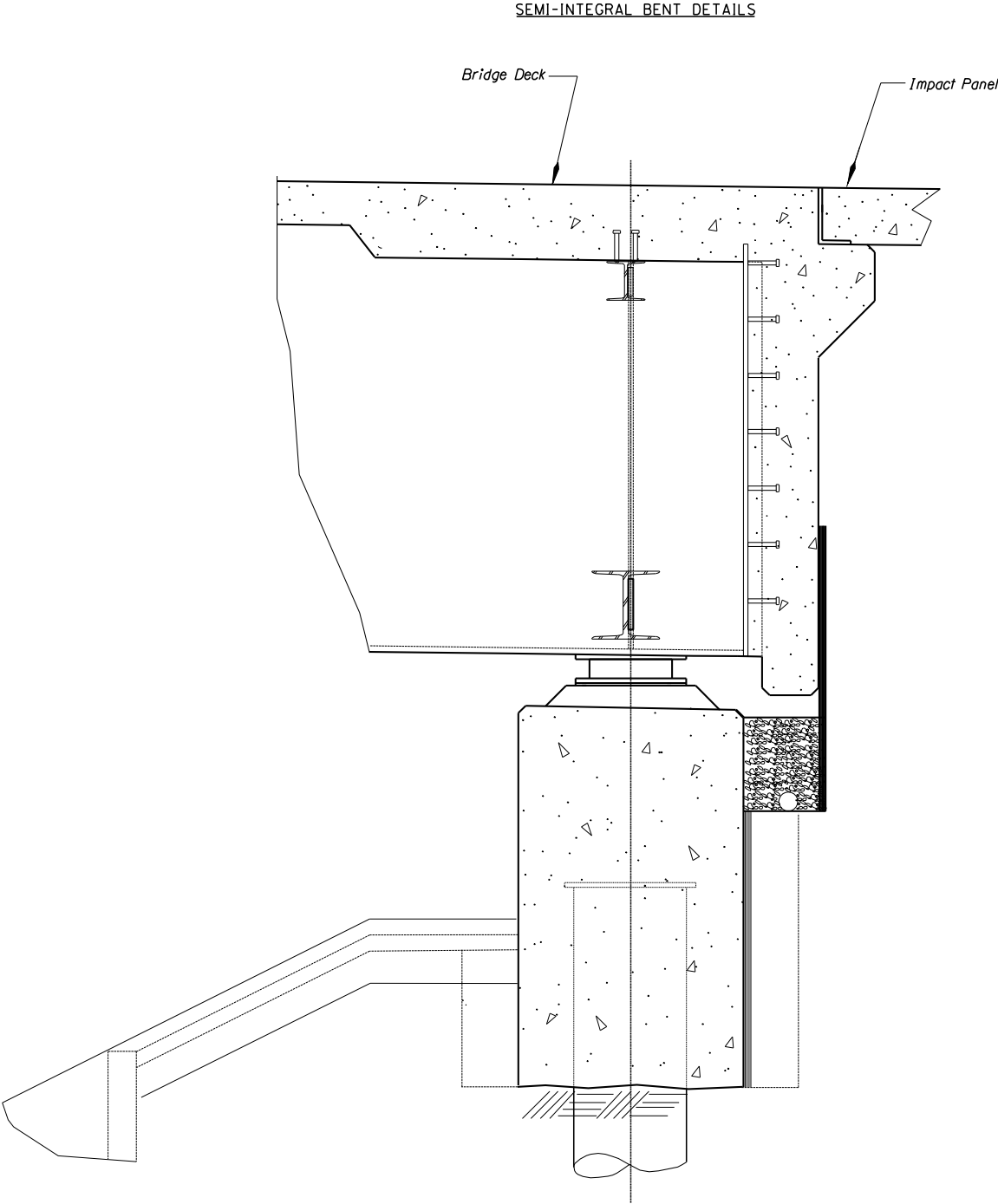


Figure 1.6.5.15-3 Integral Bent Detail

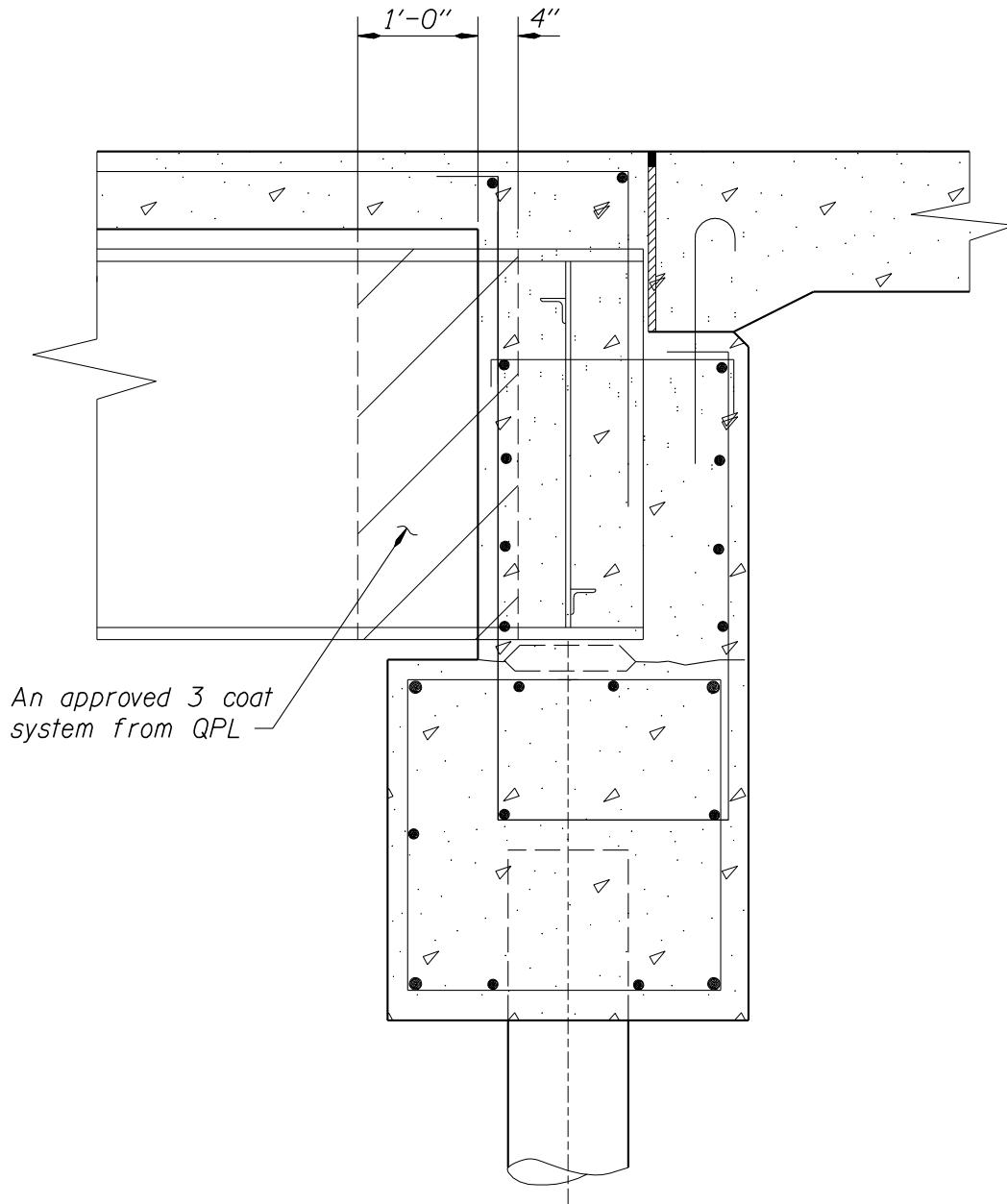
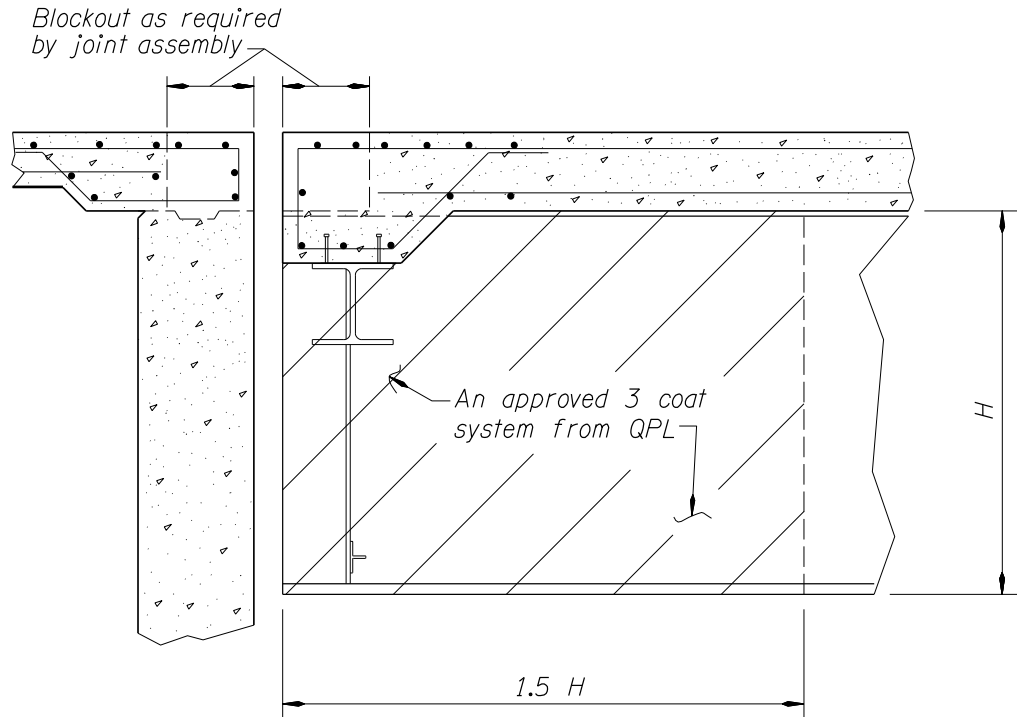


Figure 1.6.2.15-4 Girder End Coating Limit



### 1.6.2.16 Expansion Joint Blockouts

Show a blockout detail (see *Figures 1.14.2.4-1*) on the plans to allow the expansion joint assembly to be placed a period of time after the final deck pour. Providing a blockout makes the adjacent deck pour easier, provides smoother deck transition to joint, and allows the majority of the superstructure shrinkage to occur prior to joint assembly placement.

### 1.6.2.17 Bearings and Anchor Rods

Due to high cost, try to avoid using built up steel bearings, pot bearings, and spherical bearings.

Design integral jointless bridges or use elastomeric bearings wherever possible.

Use circular elastomeric bearings on curved steel girders.

See also *BDM 1.14.1*.

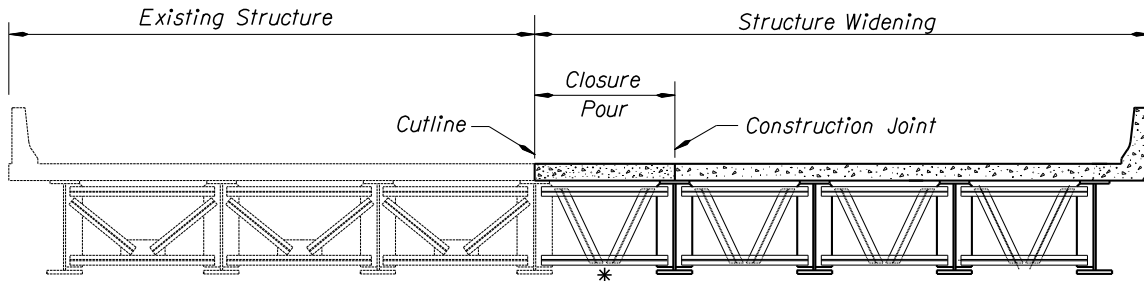
See [G9.1-2004, Steel Bridge Bearing Design and Detailing Guidelines](#) for additional guidance.

See *Drawing E2.3* for prefer bearing anchor rods connection detail.

### 1.6.2.18 Structure Widening

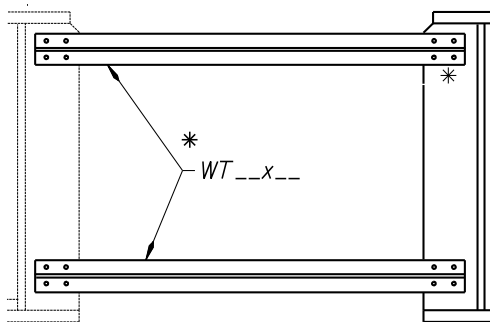
Generally, to avoid transferring dead loads from the widening to existing beams, diaphragms are temporarily connected to resist lateral loads only and a closure pour is made between the deck pours. An example is shown below.

Figure 1.6.2.18-1 Widening Closure Pour Detail



*Note:*  
Place closure pour a minimum of 3 days after adjacent deck widening concrete placement.

Figure 1.6.2.18-2 Temporary Diaphragm Connection Detail



\* NOTE : Install temporary 4-\_\_\_ dia. H. S. bolts (A325) (snug tight) in each end of each horizontal WT\_\_x\_\_ and omit the diagonal WT\_\_x\_\_'s until the entire deck and closure pours have been completed.



## 1.6.3 Welding

### 1.6.3.1 Welding, General

#### TECHNICAL ASSISTANCE

The [ODOT welding specialist](#) may be consulted for assistance with welded connections.

#### GENERAL CATEGORIES OF WELDING

The following four categories loosely describe the most common types of welding needed for design work in roadway and bridge sections.

**Incidental Structures (*AWS D1.1*):** Welding under this category consists of light structural joining such as handrails, fencing, and sheet metal products. In general the weld is not required to fully develop the strength of the joining parts. Visual inspection of the final product is all that is expected.

**General Structural Welding (*AWS D1.1*):** Welding under this category consists of partially or fully developing the strength of the joining parts such as pile splices and attachments, guard rails, signing and lighting support, expansion joints (unless prefabricated by an approved supplier), seismic restraint fixtures and bearings (unless directly welding to main structural elements of a bridge). In general the weld will develop the ultimate strength of the joining parts but is not expected to provide maximum fatigue life unless nondestructive testing is specified for acceptance.

**Structural Welding of Reinforcing Steel (*AWS D1.4*):** Welding under this category consists of splicing and/or anchoring either new construction or existing reinforcing steel in concrete columns and girders. Note that *LRFD 9.7.2.5* does not allow welded splices of bridge deck reinforcement due to fatigue considerations. The particular weld joint design usually consists of either flare-bevel welds or butt joints with back up bars see *Figure 1.11.3.6-2* for examples. In general it is desired to develop the full strength of the reinforcing steel to be joined. Almost any type of reinforcing steel can be successfully welded provided the chemistry of the steel is known (from either mill certifications or field testing) and an appropriate welding procedure is developed and followed. Unknown steels need to have a sample extracted (approximately 2 to 4 grams) and testing for chemistry. The welding procedure is developed from *AWS D1.4* using the carbon equivalent method. This type of welding is almost always performed in the field and thus needs to be monitored by a certified welding inspector (CWI). Acceptance is usually based on visual examination but other methods can be used when the designer is concerned about fatigue. Make sure that the Contractor provides a CWI during field welding.

**Bridge Welding (*AWS D1.5*):** Welding under this category consists of fabricating or modifying any main load path carrying members of a bridge that have some or all portions that experience

tensile stresses under normal loads. This includes girders, floor beams, stringers, trusses, and hanger assemblies. The member does not necessarily have to be fracture critical. In general the welding is expected to develop both full ultimate strength of the joining parts and maximum fatigue performance. Joint toughness and nondestructive testing are typically required for acceptance.

Certification of Steel Fabricators: *SP 00560.30* requires the American Institute of Steel Construction (AISC) Category CBR (Major Steel Bridges) Certification for fabricators of structural steel bridges. When the structure is Fracture Critical, the fabricator also is required to have the AISC Fracture Critical endorsement.

### TYPICAL PATHWAYS FOR SUCCESSFUL WELDING IN YOUR DESIGN

Incidental welding:

- Specify the welds needed on the drawings (type, size, and length).
- In general welding procedure specifications and welder certification are not required to be submitted.
- Quality assurance will be based on general appearance (visual testing) only. When you want a trained person to inspect the workmanship send a copy of the plans to the ODOT Portland Materials Inspection Crew. The same inspectors will also check for quality of painting and galvanizing. When the workmanship is poor then the parts can be rejected.

General Structural Welding:

- Specify the welds needed on the drawings (type, size, and length). Even though the Standard Specifications invoke *AWS D1.1* welding code for all incidentals structures, it is recommended that the following statement be included on the drawings (usually the plan and elevations):
  - All welding shall conform to the AWS D1.1 Structural Welding Code.
- Generally welding procedure specifications (WPS) and welder certification are required to be submitted and approved. Any shop drawings that have welding shown are not legally approved until the WPS are approved under *AWS D1.1*.
- Quality assurance is typically based on visual inspection by a certified welding inspector (CWI) and may also incorporate nondestructive testing such as ultrasonic (UT), radiographic (RT), and magnetic particle (MT) testing when specified on the design drawings. Various stages of the fabrication process may also be monitored if necessary. It is recommended that a copy of all plans and specifications that require this category of welding be sent to the ODOT Portland Materials Inspection Crew.

Reinforcing Steel Welding:

- Specify the welds needed on the drawings (type, size, and length).
- In the general notes for the job, put the following:
  - All reinforcing steel welding shall conform to *AWS D1.4 Structural Reinforcing Steel*

- When the steel is not *ASTM A615* or *A706* a field chemistry sample needs to be extracted and analyzed for the carbon equivalent. The welding procedure shall be based on this information. When the steel is *A615* or *A706* the *D1.4* welding code has recommended heat inputs.
- Inform the ODOT Portland Materials Office of the work and have a CWI review the welding procedure, welder certification and observe the welding.

### Bridge Welding:

- Specify the welds needed on the drawings (type, size, and length). Calling out the specific weld ID number (i.e. TC-U4a is an example) is preferable but not required. Typically this category of welding requires a significant Quality Assurance (QA) effort so please include this in your construction cost estimate.
- Even though the Standard Specifications invoke *AWS D1.5* welding code for all bridge welding it is recommended that the following statement be included on the drawings (usually the plan and elevations):

All welding shall conform to the *AWS D1.5 Bridge Welding Code*.
- Welding procedure specifications (WPS) and welder certification are required to be submitted and approved by the Engineer of Record. Any shop drawings that have welding shown are not legally approved until the WPS are approved under *AWS D1.5*.
- Quality assurance is based on a more complicated Owner/Fabricator relationship that involves frequent inspections during the entire fabrication and erection process. Most individuals involved have stringent requirements for their duties including certified welders, inspectors, fabricators, and testing personnel. Most welding in this category requires some form of nondestructive testing for acceptance. Theoretically all materials and processes are traceable with archived documentation. Send a copy of all plans and specifications that require this category of welding to the ODOT Portland Materials Inspection Crew.

### 1.6.3.2 Fillet Welds

When adequate structural performance from fillet welds in T and corner joints can be obtained, use fillet weld in preference to groove welds. Fillet welds can be non-destructively inspected with greater certainty of result and at lower cost. The minimum fillet weld size for prequalified joints is shown in *Table 1.6.3.2-1*.

Table 1.6.3.2-1 Minimum Fillet Weld Size for Joints

Material Thickness of Thicker Part Joined (T) (inch)	Minimum Size* of Fillet Weld (inch)
To $\frac{3}{4}$ inclusive	$\frac{1}{4}$ **
Over $\frac{3}{4}$	$\frac{5}{16}$ **
* Except that the weld size need not exceed the thickness of the thinner part joined. For this exception, take particular care to provide sufficient preheat to ensure weld soundness.	
** Welds of this size must be made in a single pass.	

Size fillet welds in accordance with *AASHTO LRFD Design Specifications*.

#### WEB TO FLANGE CONNECTION

Use the minimum fillet weld necessary to join the flange to the web. This size will vary along the length of the girder depending on the size of the plates being joined. To calculate shear stress capacity of fillet welds (equal legs) use equation *LRFD 6.13.3.2.2b*.

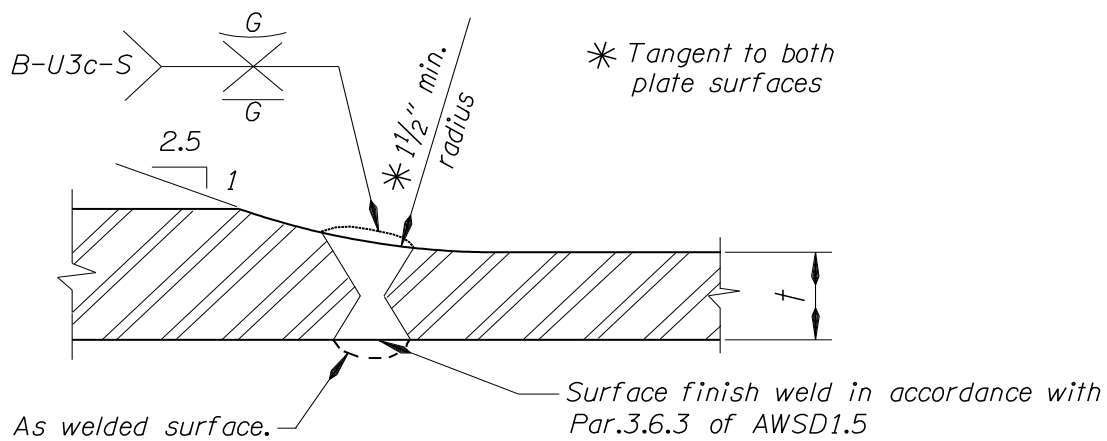
### 1.6.3.3 Flange Welds

The design tensile stress in butt welded joints may equal the allowable stress in the base metal.

Show flange butt weld splices as in the detail below. Include this detail on all steel structure plans. Indicate the type of butt weld splice for each splice on the plans. This may be accomplished by:

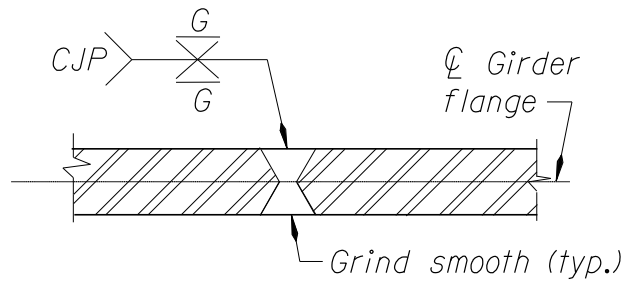
- Adding the word **tension** or **compression**, whichever is the case, to the tail of the weld symbol.
- Indicating which flanges or which portions of the flanges are in compression (C) and which are in tension (T).

Figure 1.6.3.3-1 Unequal Thickness Flange Splice



## FLANGE SPLICE

Figure 1.6.3.3-2 Equal Thickness Flange Splice

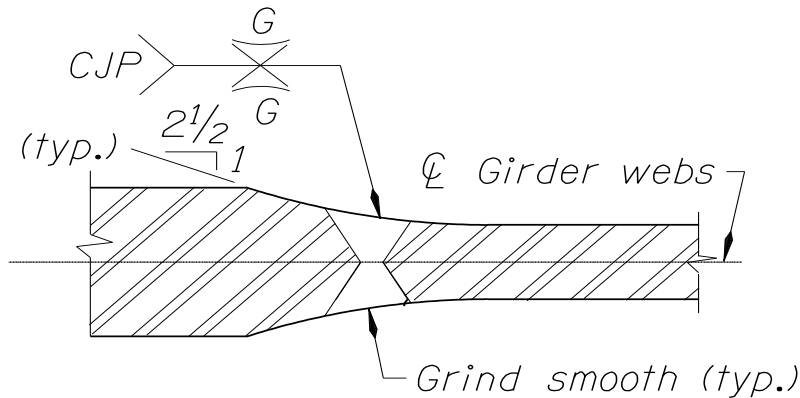


EQUAL THICKNESS FLANGE SPLICE

**1.6.3.4 Welded Web Splices in Steel Bridge Girders**

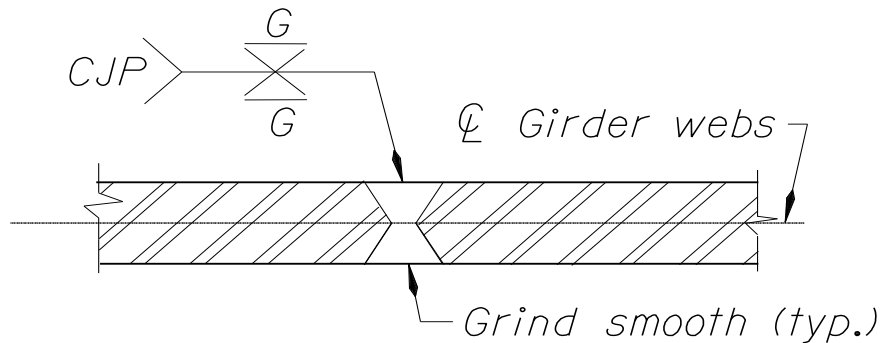
Use complete joint penetration butt weld in web splices. Grind off 100 percent of the weldments reinforcing of all web splices. To facilitate NDE during fabrication, specify on the design drawings which portion of the girder webs are tension and compression. See *Figures 1.6.3.4-1 and 1.6.3.4-2*.

Figure 1.6.3.4-1 Unequal Thickness Web Splice



UNEQUAL THICKNESS WEB SPLICE

Figure 1.6.3.4-2 Equal Thickness Web Splice



## EQUAL THICKNESS WEB SPLICE

### 1.6.4 Galvanizing and Painting

#### 1.6.4.1 Processes

Galvanizing is a process of applying a sacrificial metal (zinc) to a base metal. The zinc will corrode, or sacrifice itself, to protect the base metal. Hot-dip galvanizing involves cleaning the items with a combination of caustic and acidic solutions and the dipping them into a tank of molten zinc for a specified period of time. After removal, small items are spun to remove excess zinc.

Mechanical galvanizing involves cleaning as mentioned above and then loading the items in a multi-sided rotating barrel. The barrel contains a mixture of various sized beads and water. As the barrel turns, chemicals and powdered zinc are added. The collision between the items, the glass beads and zinc causes the zinc to cold weld to the part. Powdered zinc is added until the required thickness is obtained.

Hot-dip galvanizing has proven to provide better long term corrosion protection and should be required for all galvanized items.

#### 1.6.4.2 Detailing

To ensure proper hot-dip galvanizing, venting and drain holes must be provided in details. These insure proper circulation and removal of cleaning solutions and the molten zinc. They may also prevent potential explosions during dipping caused by trapped air.

Provide a minimum vent opening of 25 to 30 percent of the cross-sectional area of a tubular section when full open venting is not possible. Provide drains holes at closed corners or clip all corners at gusset plates to allow complete drainage.

### 1.6.4.3 Silicon Control

The silicon content of the steel influences the corrosion resistance and strength of the galvanized coating and the thickness of the zinc layer. The silicon content of the steel must be held within either of the range of 0 to 0.06 percent, or 0.153 to 0.25 percent to obtain and maintain a pleasing appearance. Call out all members that will have visual impact on the drawings with **Galvanize - Control Silicon**. Examples of these members are the chords, posts and diagonals of sign bridges; arms and shafts of luminaire, sign and signal support structures; steel traffic rail posts and railing members and pedestrian railings.

For economic reasons, silicon need not be controlled in galvanized structural members that are hidden from motorist view or are too small to have significant visual impact. Generally, these members that are too small to have significant visual impact are steel shapes whose least dimension does not exceed 3 inches.

An example of an exception is pedestrian rail members that should have silicon control. Examples of hidden members and others which for practical reasons do not require silicon control are base plates and guard rail connection plates, flex-beam rails and their posts and single-post, breakaway sign posts.

The general notes on each contract drawing that includes members are to be called out as **Galvanize-Control Silicon**. The specification for control of silicon in steels to be galvanized is included in the *Standard Specifications for Construction*.

### 1.6.4.4 Painting or coating of new or existing metal

Coating of metal structures is discouraged in most circumstances due to maintenance costs of recoating. Weathering steel and galvanizing are preferred options. Sacrificial thickness is another option that may be appropriate in some circumstances. Perform a life cycle cost comparison when considering sacrificial thickness vs coated steel. Include the cost comparison in the TS&L narrative. Coating steel may be appropriate in the following situations:

- Marine environments (as defined in *BDM 1.26.1*).
- When use of weathering steel is improper per *BDM 1.6.2.2*.
- Structure is easily accessible and has minimally restricted lane closures (i.e. does not cross a roadway).

Coating work consists of preparing and coating new metal structures and features in the shop and in the field, and preparing and coating existing metal structures. This includes all:

- Interior and exterior steel surfaces.
- Steel railings, bridge bearings, and bridge expansion joint assemblies.
- Other miscellaneous steel.



Coating of metal structures shall be in conformance with *SP 00594* and the special provisions. Powder coating is discussed in *SP 00593*.

#### **1.6.4.4.1 Design Features of Coated Steel**

Provide the following design features for bridges fabricated from coated structural steel:

1. Where structure access and lane closures are expected to be improbable, consider providing additional vertical clearance beyond the required minimum (per *BDM 3.14.4.2*) according to the following criteria. Allow for future ACWS overlay when applicable.
  - For box girders: Half of the box girder bottom flange width plus 1 foot, but not exceeding 3 feet.
  - For plate girders: Width of the girder bottom flange, but not exceeding 3 feet.
  - All other situations: 1.5 feet.

Additional vertical clearance only needs to be provided at girders over traffic lanes or where low water clearance is expected. This is to allow a minimal amount of access for work platforms and performing the work on the lowest members over traffic, without affecting freight movement. Evaluate providing additional clearance with the project team based on the following criteria:

- Projected AADT – projected AADT high enough to impact future lane closures.
- Railroad project involvement – railroad involvement will restrict structure access.
- Freeway projects - either on or above.
- Urban locations – surroundings (buildings, structures, utilities, etc.) may confine and limit access.

Weigh the economic impact of increasing vertical clearances against future recoating maintenance.

- When evaluating increased project construction cost due to a raised profile, consider the following items that may be affected:
  - Roadway construction due to a grade profile change.
  - Environmental impact and mitigation.
  - Additional right-of-way needs.
  - Retaining wall(s) needs.
  - Seismic requirements (i.e. increased column heights, foundation stabilization).
  - Over-height warning system - for protecting workers on platforms over live traffic.

When only the minimum required clearance is provided (no additional), it will be more difficult and costly to recoat the bridge in the future. Reduced clearances typically require lane closures, detours, or night work to gain access to the work. In high traffic areas where lane closure are prohibited the efficiency of the work can be further degraded when allowable work shifts are too short. Evaluate the following items, with assistance from the Senior Cost Engineer and the Senior Structure Coatings Engineer, when considering lifecycle costs of future painting when only the minimum required clearance (no additional) is provided:

- Over-height warning system.
- Additional traffic control.
- Detours.
- Effect of night work.
- Mobilizing and demobilizing equipment each work shift; effect of work shifts that are not long enough for reasonable efficiency
  - Increase in access and containment cost due to complexity and additional setups.
  - Increase in surface preparation cost due to reduced efficiency.
  - Increase in coating application cost due to reduced efficiency.
  - Increase in traffic control or detour costs due to reduced efficiency.
- Increased overhead costs due to reduced efficiency (longer calendar duration of work)
  - Delay costs borne by the public.

Document the various clearance alternatives, including cost comparisons (based on the items outlined above) and justifications in the TS&L narrative. Submit a design deviation when providing additional clearance beyond the required minimum.

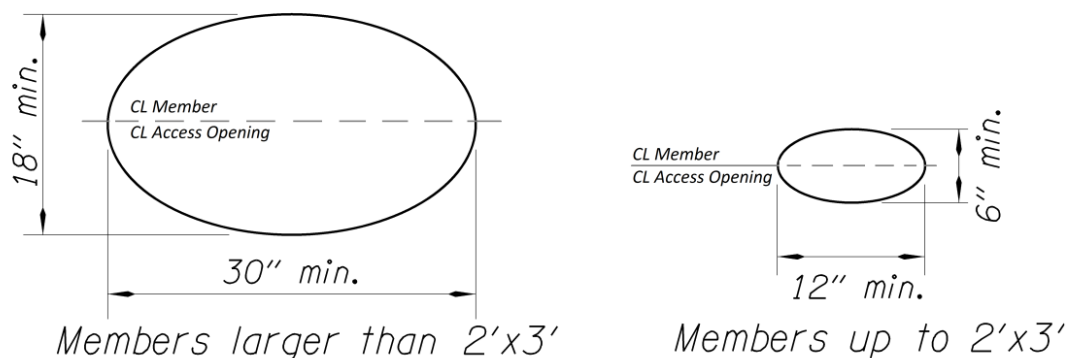
2. A minimum of 3 feet horizontal separation between the front face of traffic rail and the nearest steel surface (e.g. tied arch and stacked deck structures). This is to allow a minimal amount of access for scaffolding, worker and/or traffic protection shielding, and performing the work on the members closest to traffic, without affecting traffic or freight movement.
3. Stainless steel padeyes, stainless steel eyebolts or deck inserts located at appropriate intervals (approximately 15 by 15 foot to 20 by 20 foot grid typical) for support of future work platforms from upper structure members above roadway, main structure members below roadway, and the deck. This is to allow surface preparation and coating of members without having to move hangers, beam clamps, chains, cables or chokers. These temporary attachment points require extra work and often receive poor surface preparation and coating. List the allowable loading for the attachment points in the structural notes on the bridge plans. This requirement may be coordinated with the inspection requirements of *BDM 2.6.2*.

4. In the LRFD Strength and Service design include a Temporary Load representing the dead loads, live loads and wind loads acting on work platforms, scaffolding and containment needed to recoat the bridge. Add this Temporary Load to each applicable Load Combination as shown in *LRFD Table 3.4.1*, using a load factor of:
  - 1.50 for Strength and Extreme Event limit states.
  - 1.00 for Service I and Fatigue limit states.
  - 1.25 for Service II limit state.

Design work platforms that access the structure with little need for scaffolding for a **DL + LL** of 25 pounds per square foot of platform area. Design work platforms that require significant scaffolding to reach the structure for a **DL + LL** of at least 50 pounds per square foot. Assume work platforms and containment extent to 5 feet beyond the sides of the structure and full length to 5 feet beyond the ends of the entire structure or each span. List the permissible work platform sizes and loading, and the permissible containment sizes and wind speeds in the structural notes on the bridge plans. It may be necessary to separate the work platforms and/or containment into zones for structural reasons, in which case carefully size the zones to allow efficient work by the recoating contractor.

5. Do not create spaces where blind sides of members cannot be reached for surface preparation and coating work.
6. Closed members or areas which are too small for workers to enter to perform surface preparation and coating work are highly discouraged. When the member is too small for a worker to turn around in, but larger than 2 by 3 feet, provide access openings 18 by 30 inches minimum with semicircular ends, spaced from 42 to 60 inches on centers. For members up to 2 by 3 feet, provide hand hole access 6 by 12 inches with semicircular ends, spaced 30 inches on center. For members large enough for workers to enter see *BDM 2.6* for additional accessibility guidance.

Figure 1.6.4.4.1-1 Access Openings for Closed Members



Be aware of an existing structure's condition prior to completing TS&L of a recoating project. Recoating of an existing bridge is very costly and requires a careful examination of the structure's condition. Older structures are typically painted and have potential deficiencies that may need to be addressed during a recoating project. Collect all necessary information for such projects. The [Steel Bridge Recoating Checklist](#) provides a list of required information and guidance on specifications. Complete the checklist and include in the TS&L Report.

## 1.6.5 Bolts and Connections

Design all high-strength bolted connections as slip-critical connections. Assume Class B faying surfaces where inorganic zinc primer is used. When steel will be given a full paint system in the shop, the primed faying surfaces need to be masked to maintain the Class B surface.

Include additional costs for access, paint removal and recoating rivet or bolt replacements, when rivets or bolts are outside normal paint area limits.

### 1.6.5.1 High Strength Bolts

High-Strength Bolt Use Guidelines:

- *ASTM F3125* GR A325 & GR F1852 - Headed structural bolt for use in structural connections. These may be hot-dip galvanized. Do not specify for anchor bolts.
- Use Type 3 bolts conforming to *ASTM F3125* when specifying weathering steel.
- *ASTM A449* - Steel bolts and studs for general applications including anchor bolts. Recommended for use where strengths equivalent to *ASTM F 3125* GR A325 bolts are desired but custom geometry or lengths are required. Strengths for *ASTM A449* bolts are equivalent to GR A325 up to 1 inch diameter. When using bolts of larger diameter, a reduction in strength as indicated in the table below shall be accounted for. These bolts may be hot-dip galvanized. Do not use these as anchor bolts for seismic applications due to low CVN impact toughness.
- *ASTM F3125* GR A490 & GR F2280 - Alloy steel headed structural bolt for use in structural connections. Do not use *ASTM F3125* GR A490 bolts in bridge applications. When there is a compelling reason to use *ASTM F3125* GR A490 bolts, request a BDM Deviation. When a deviation is approved, do not galvanize these bolts because of high susceptibility to hydrogen embrittlement. Instead of galvanizing, require two or three coats of approved zinc rich paint. Do not specify for anchor bolts.
- *ASTM F1554* Grade 105 - Higher strength anchor bolts to be used for larger sizes (1½ to 4 inch). When used in seismic applications, such as bridge bearings that resist lateral loads, specify supplemental CVN requirement S4 with a test temperature of -20 degree Fahrenheit. Lower grades may also be suitable for sign structure foundations. This specification should also be considered for seismic restrainer rods, and may be galvanized.

### 1.6.5.2 Properties of High-Strength Bolts

Table 1.6.5.2-1 Properties of High Strength Bolts

Material	Bolt Diameter (inch)	Tensile Strength (ksi)	Yield Strength (ksi)
ASTM F3125 GR A325 & GR F1852	1/2 – 1 1/2	120	92
	Over 1 1/2	--	Not Available
ASTM A449	1/4 – 1	120	92
	1 1/8 – 1 1/2	105	81
	1 3/4 – 3	90	58
	Over 3	--	Not Available
ASTM F1554 GR 105	1/4 – 3	125 – 150	105
ASTM F1554 GR 55	1/4 – 4	75 – 95	55
ASTM F1554 GR 36	1/4 – 4	58 – 80	36
ASTM F3125 GR A490 & GR F2280	1/2 – 1 1/2	150 – 173 (max)	130
	Over 1 1/2	--	Not Available

## **1.7 RESERVED**

(Reserved)

## 1.8 TIMBER BRIDGE DESIGN AND DETAILING

[1.8.1 Timber Bridge Locations](#)

[1.8.2 Timber Design and Details](#)

[1.8.3 Timber Connections](#)

[1.8.4 Timber Rails](#)

[1.8.5 Preservative Treatments](#)

[1.8.6 Field Installation](#)

### 1.8.1 Timber Bridge Locations

Timber structures may be considered as an alternate to concrete structures on low volume highways or roads with an AADT of less than 500, especially for sites located away from possible concrete sources. Timber bridges are generally best suited to the drier climate east of the Cascade Mountains. Consult the region's project development team in the early stages of a project to determine whether a timber bridge is desired.

### 1.8.2 Timber Design and Details

Before specifying structural grades for timber members, check with the fabrication industry for actual availability.

Consider timber dry for design unless submerged.

ODOT does not design composite wood-concrete structures and has no corresponding construction specifications.

For structures carrying only pedestrian and/or bicycle traffic, the maximum allowable live load deflection is:

- For simple or continuous spans, *Deflection = span/360*
- For cantilever arms, *Deflection = arm length/135*

### 1.8.2.1 Glued laminated timber bridges

Glued laminated timber bridge single spans are generally feasible up to 50 feet. To achieve longer spans, consider cantilever techniques. The width of glued laminated beams is generally limited to 10  $\frac{3}{4}$  inch or less, but 12  $\frac{3}{4}$  inch, 14  $\frac{3}{4}$  inch, and 16  $\frac{3}{4}$  inch widths are available for extra cost.

Give consideration to performance specification for glued laminated timber members. Identifying actual stresses for bending, horizontal shear, etc., is preferred by the fabrication industry instead of specifying an actual glued laminated timber grades.

The preference of the Bridge Section at this time is the use of a non-interconnected glued laminated timber deck as opposed to an interconnected glued laminated timber deck. A longitudinal timber stiffener under the deck between longitudinal beams for transverse deck bridges may be beneficial for differential deflection control.

- A glued laminated longitudinal deck bridge is a possible solution for short spans (under 25 feet) with a tight freeboard clearance requirement. These deck members could be used in a continuous span arrangement to increase member efficiency.

Include a waterproofing membrane according to *BDM 1.26.4* when using an asphalt wearing surface.

For smaller timber members, such as posts, rails, etc., specifying solid sawn timber as an option to glued laminated timber may be more cost effective.

Timber substructures are not recommended.

## 1.8.3 Timber Connections

Use of the **Weyerhaeuser clip** to connect timber decking to timber beams allow for easy fabrication and installation of the timber members.

Steel diaphragm beams, as opposed to timber diaphragm beams, between longitudinal glued laminated timber beams are recommended.

Use slotted holes whenever possible in the steel connectors to allow for shrinkage and expansion of the wood, and for construction tolerances.

## 1.8.4 Timber Rails

A crash-tested rail has been completed for a longitudinal glued laminated timber deck bridge. Several other glued laminated timber bridge configurations will be crash-tested in the near future. Thrie beam railing can be used as an alternate in lieu of timber.



## **1.8.5 Preservative Treatments**

Pentachlorophenol Type A (heavy solvent) or Pentachlorophenol Type C (light solvent) is recommended for most locations as a preservative treatment.

Eliminate all field cuts and bores when possible. Treat any field modifications with copper naphthanate.

## **1.8.6 Field Installation**

Shop assembly of the timber bridge components immediately after fabrication is recommended to eliminate any possible future field installation problems, especially on more complicated projects.

Field staking of the structure before fabrication is recommended to eliminate any future installation problems.

## 1.9 DECKS

### [1.9.1 Design and Detailing](#)

### [1.9.2 Deck Screeding](#)

### [1.9.3 Deck Construction Joints](#)

### [1.9.4 Deck Overlays](#)

## 1.9.1 Design and Detailing

### 1.9.1.1 Design

Design decks according to *AASHTO LRFD Bridge Design Specifications*.

Do not use the empirical design method for deck reinforcing steel. Excessive deck cracking, apparently due to under reinforcement, precludes the use of this method.

Do not consider bridge railings to be structurally continuous for the purposes of distributing the deck loads per *LRFD 3.6.1.3.4* as this limits options for bridge rail retrofits in the future.

For additional deck requirements on precast prestressed elements, see *BDM 1.5.6.1*.

For deck protective practice requirements, such as cover and reinforcement type, see *BDM 1.26.3* and *1.26.4*.

For cast-in-place decks, discount ½ inch deck thickness when calculating composite properties for girder/slab systems. For a typical 8 inch deck, consider 7 ½ inches structural and ½ inch a sacrificial wearing surface and included as non-composite dead load.

The preferred orientation of the top mat of deck steel will have the transverse bars on top when the direction of primary loading is transverse.

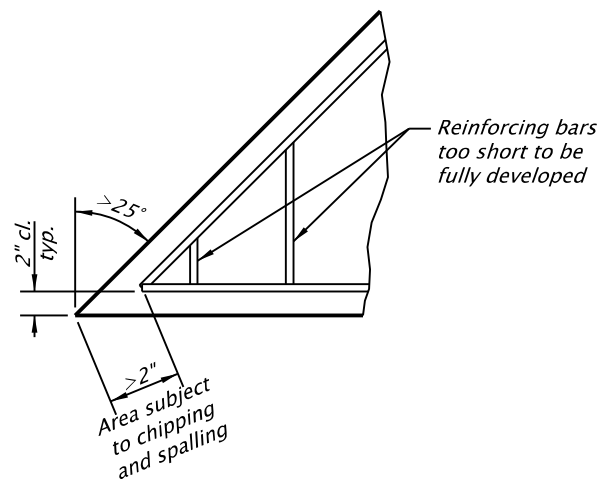
### SKEWED DECKS

For skewed decks, orient transverse bars according to *LRFD 9.7.1.3*. Per *LRFD 9.7.1.3*, the primary reinforcement may be orientated along the skew for skew angles that do not exceed 25 degrees, where the skew angle is measured from a line that is perpendicular to the centerline of the bridge to the centerline of the support. However, there is no guidance when skew angle exceeds 25 degrees.

The acute corners of a skewed (greater than 25 degrees) concrete deck slab are often difficult to adequately reinforce. As the angle of skew increases, large portions of the deck can be

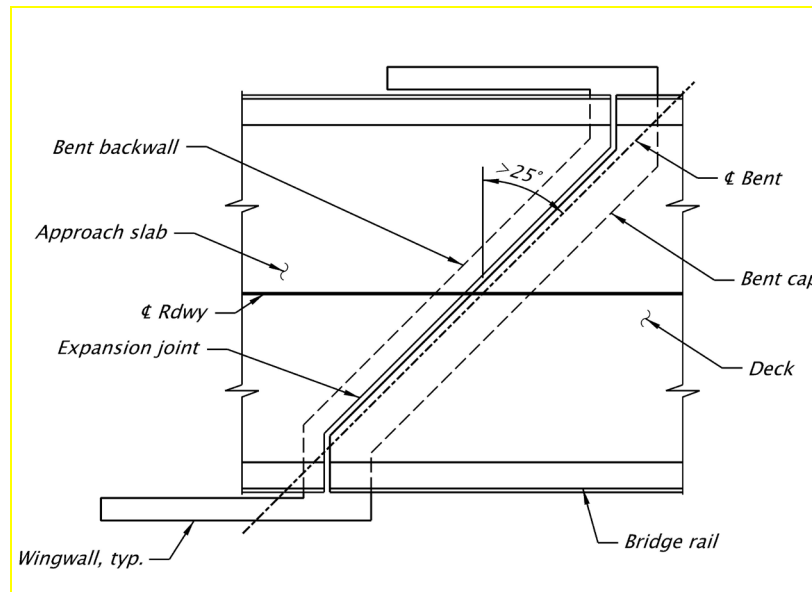
unreinforced and therefore subject to spalling and chipping, as shown in *Figure 1.9.1-1*. Because the orthogonal bars are too short to develop, it is typically necessary to detail diagonal bars that extend into the deck over the girders, to carry the deck overhang loads. Similarly, acute corners in concrete barriers are also difficult to reinforce, and require special consideration.

Figure 1.9.1-1 Inadequate reinforcement provided in acute corner of concrete deck slab



Use breakback detailing where the ends of the skewed deck are turned so that the end is normal to the longitudinal edge of the deck, as shown in *Figure 1.9.1-2*. This breakback detailing effectively eliminates the acute and obtuse corners of the concrete deck and barriers. Use a minimum breakback width of 3 feet and increase width with increased skew angle.

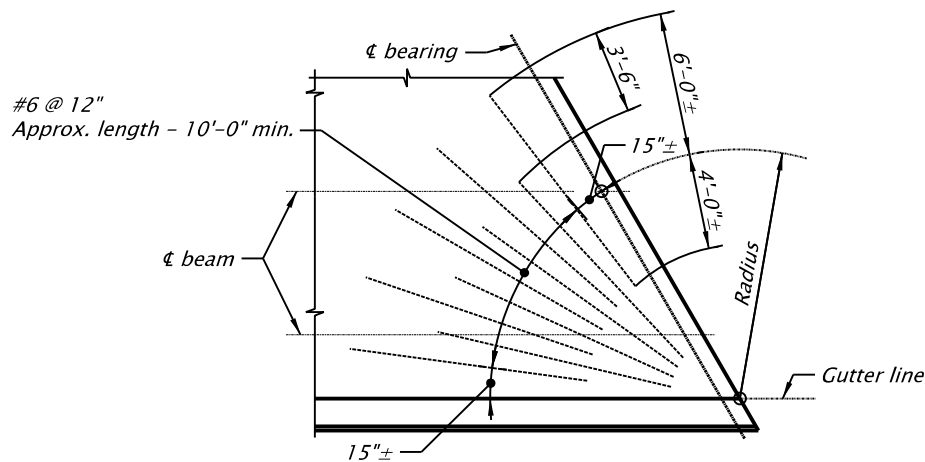
Figure 1.9.1-2 Breakback detailing to eliminate skew effects associated with detailing acute corners at ends of skewed deck slab



On skewed bridges with concrete end diaphragms and when a breakback detail is not used, place additional reinforcement in a radial manner to eliminate diagonal cracks which form in the acute corners of concrete deck. See [Figure 1.9.1-3](#) for the reinforcement pattern. The objective of the reinforcement fan is to offset buildup of shrinkage across the long diagonal dimension of the slab which would pull a shrinkage crack across the weak corner of the slab. A portion of the bars must extend back into the corner sufficiently to terminate above the junction of exterior beam and end diaphragm. Place a note on the plans that states:

Place the corner reinforcement beneath the longitudinal and transverse reinforcement in the top of the slab.

Figure 1.9.1-3 Corner Reinforcing Detailing



In skewed box girders, orient bottom slab transverse bars the same as the deck transverse bars.

See *BDM 1.5.7.8* for additional bottom slab requirements. Note the intended bar placement on the bridge contract plans.

See *BDM 1.9.2* for detailing requirements due to screed machines on skewed decks.

### REINFORCING

Do not use deck reinforcement larger than a #6 bar in typical deck steel, except when needed to resist negative moment for continuous-span girders. When necessary, larger bars may be used in distinct sections such as joints and post tensioned anchorage areas. When the top mat has longitudinal bars on top, place any longitudinal reinforcement larger than a #6 bar in the bottom mat.

Unless a project specific deck reinforcement design is developed, for design and detailing use the *Concrete Deck Reinforcement (LRFD Design)*, *Figure 1.9.1-4* or *1.9.1-5* for Grade 60 reinforcement and Concrete Class HPC 4500, or *Figure 1.9.1-6* or *1.9.1-7* for Grade 80 reinforcement and Concrete Class HPC 4500.

Use of Grade 80 rebar is expected to reduce construction cost and potentially reduce rebar congestion. Verify the quantity of deck steel to determine if Grade 80 rebar is appropriate:

- When the quantity of deck steel using Grade 80 rebar exceeds 30 tons, provide details only for Grade 80 rebar.
- When the quantity of deck steel using Grade 80 rebar is less than 30 tons, provide details for both Grade 80 and Grade 60 rebar. Use Grade 80 for the primary details with Grade 60 shown as an alternate.

Ensure project specific deck design conforms to the following minimum requirements:

- *LRFD Section 4.6.2.1.*
- Concrete Class: HPC4500 – 1-1/2 (except box girder decks that require greater strength).
- Reinforcement: Grade 60 or Grade 80.
- Reinforcement no larger than #6 bar (except in distinct areas).
- Reinforcement spacing  $\geq 5$  inches and  $\leq 8$  inches (applies to top mat only).
- Surface wear allowance equal to ½ inch.
- Limit top of concrete compressive service stress due to positive moment in the deck (between girders) to  $0.4f'_c$ .

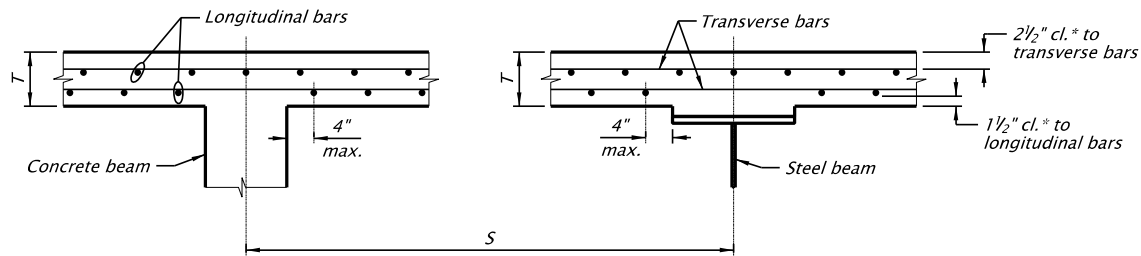
Note that *LRFD 5.7.3.4 (Control of Cracking by Distribution of Reinforcement)* is applicable for negative moment steel for bridges made continuous for live load, but is not applicable to bridge deck slab reinforcement. The 8 inch maximum bar spacing is adequate to control cracking in bridge decks.

Submit a design deviation request for any concrete bridge deck designs not meeting any one of the minimum requirements listed above in *Figures 1.9.1-4, 1.9.1-5, 1.9.1-6, or 1.9.1-7*. With the design deviation request, include the following:

- Design loading assumptions (dead, live, and future wearing surface).
- Documentation of which minimum requirements were met and which were not met.
- Orientation of the top mat (longitudinal on top or transverse on top).
- Deck thickness.
- Maximum service stress in the top of the deck due to positive moment in the deck (between girders).
- Maximum service stress in the bottom of the deck due to negative moment in the deck (over a girder).

Use cast-in-place HPC concrete or full depth precast deck panels with high-strength abrasion-resistant concrete in accordance with *BDM 1.9.1.5* for bridge decks. Partial depth precast deck panels are not permitted.

Figure 1.9.1-4 CONCRETE DECK REINFORCEMENT (LRFD DESIGN) with TRANSVERSE BARS ON TOP Steel Girders & Cast-In-Place Concrete Box Girders - Simple Spans



**Assumptions:**

**Specifications:** LRFD 4.6.2.1

**Concrete Class:** HPC 4500

**Reinforcement:** Grade 60

**Top Mat Orientation:** Transverse bars on top

**Dead Load:** 150 pcf + 50 psf future wearing surface

**Deck DL moments:** Negative  $-0.10wS^2$   
Positive  $+0.08wS^2$

**Live Load:** LRFD Table A4-1 using 6 inch from  $\text{\textcircled{C}}$  of girder to the negative moment design section

**Design Moment:**  $1.25*DL + 1.5*DW + 1.75*LL$  (Impact included in LRFD Table A4-1 live loads)

**Surface Wear:** 1/2 inch allowance for surface wear subtracted from positive moment  $d$ .

**Steel Girders:** Top flange width not less than 24 inch. Project specific design is required when top flange is less than 24 inch

**Concrete Box Girders:** Girder stem width not less than 12 inches. For girder stem greater than or equal to 16 inches, use Deck Design Chart for Precast P/S Concrete Members.

**Note:**  
Additional reinforcement to accommodate rail loads at deck overhangs is not included in these details. The designer is responsible for design of overhangs.

**Note:**  $S$  is measured parallel to the transverse bars. Bar spacing is measured perpendicular to the bars.

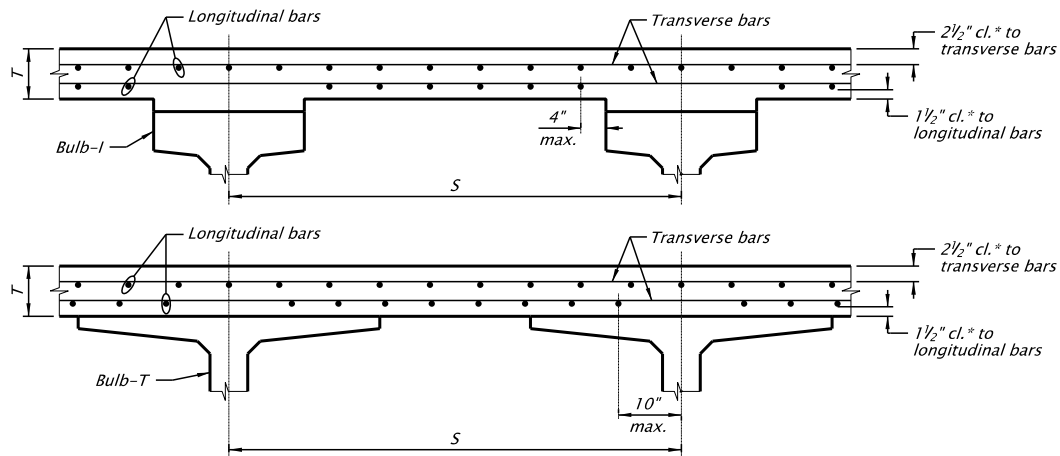
Place bottom mat bars directly below and in line with a top mat bar. At expansion and construction joints, however, it is not necessary for all bottom mat bars to be directly below a top mat bar.

\* For coastal locations, specify 2 inch clear top and bottom. See also BDM 1.26.3 for additional corrosion protection recommendations.

Steel Girders & CIP Concrete Box Girders

Girder Spacing	Deck Thickness	Transverse Bars	Longitudinal Bars
5'-0"	8"	#4 @ 6 1/2"	#4 @ 8"
5'-3"	8"	#4 @ 6 1/2"	#4 @ 8"
5'-6"	8"	#4 @ 6 1/2"	#4 @ 8"
5'-9"	8"	#4 @ 6 1/2"	#4 @ 8"
6'-0"	8"	#4 @ 6"	#4 @ 8"
6'-3"	8"	#4 @ 6"	#4 @ 8"
6'-6"	8"	#4 @ 6"	#4 @ 8"
6'-9"	8"	#4 @ 6"	#4 @ 8"
7'-0"	8"	#4 @ 5 1/2"	#4 @ 8"
7'-3"	8"	#4 @ 5 1/2"	#4 @ 8"
7'-6"	8"	#4 @ 5 1/2"	#4 @ 8"
7'-9"	8"	#4 @ 5 1/2"	#4 @ 8"
8'-0"	8"	#4 @ 5"	#4 @ 7"
8'-3"	8"	#4 @ 5"	#4 @ 7"
8'-6"	8"	#4 @ 5"	#4 @ 7"
8'-9"	8"	#5 @ 6 1/2"	#5 @ 8"
9'-0"	8 1/4"	#5 @ 6 1/2"	#5 @ 8"
9'-3"	8 1/4"	#5 @ 6 1/2"	#5 @ 8"
9'-6"	8 1/2"	#5 @ 6 1/2"	#5 @ 8"
9'-9"	8 1/2"	#5 @ 6 1/2"	#5 @ 8"
10'-0"	8 1/2"	#5 @ 6 1/2"	#5 @ 8"
10'-3"	8 3/4"	#5 @ 6"	#5 @ 8"
10'-6"	8 3/4"	#5 @ 6"	#5 @ 8"
10'-9"	9"	#5 @ 6"	#5 @ 8"
11'-0"	9"	#5 @ 6"	#5 @ 8"
11'-3"	9"	#5 @ 5 1/2"	#5 @ 8"
11'-6"	9 1/4"	#5 @ 5 1/2"	#5 @ 8"
11'-9"	9 1/4"	#5 @ 5 1/2"	#5 @ 8"
12'-0"	9 1/4"	#5 @ 5 1/2"	#5 @ 8"
12'-3"	9 1/2"	#5 @ 5 1/2"	#5 @ 8"
12'-6"	9 3/4"	#5 @ 5 1/2"	#5 @ 8"
12'-9"	9 3/4"	#5 @ 5"	#5 @ 7"
13'-0"	10"	#5 @ 5"	#5 @ 7"
13'-3"	10"	#5 @ 5"	#5 @ 7"
13'-6"	10 1/4"	#5 @ 5"	#5 @ 7"
13'-9"	10 1/4"	#5 @ 5"	#5 @ 7"
14'-0"	10 1/2"	#5 @ 5"	#5 @ 7"
14'-3"	10 1/2"	#5 @ 5"	#5 @ 7"
14'-6"	10 3/4"	#5 @ 5"	#5 @ 7"
14'-9"	10 3/4"	#5 @ 5"	#5 @ 7"
15'-0"	11"	#5 @ 5"	#5 @ 7"

Figure 1.9.1-5 CONCRETE DECK REINFORCEMENT (LRFD DESIGN) with TRANSVERSE BARS ON TOP  
Standard Precast Prestressed Concrete members - Simple Spans



**Assumptions:**

**Specifications:** LRFD 4.6.2.1

**Concrete Class:** HPC 4500

**Reinforcement:** Grade 60

**Top Mat Orientation:** Transverse bars on top

**Dead Load:** 150 pcf + 50 psf future wearing surface

**Deck DL moments:** Negative -  $0.10wS^2$

Positive  $+0.08wS^2$

**Live Load:** LRFD Table A4-1 using 8 inches from  $\phi$  of girder to the negative moment design section

**Design Moment:**  $1.25*DL + 1.5*DW + 1.75*LL$  (Impact included in LRFD Table A4-1 live loads).

**Surface Wear:** 1/2 inch allowance for surface wear subtracted from positive moment  $d$ .

**Note:**  
Additional reinforcement to accommodate rail loads at deck overhangs is not included in these details. The designer is responsible for design of overhangs.

Note: S is measured parallel to the transverse bars. Bar spacing is measured perpendicular to the bars.

Place bottom mat bars directly below and in line with a top mat bar. At expansion and construction joints, however, it is not necessary for all bottom mat bars to be directly below a top mat bar.

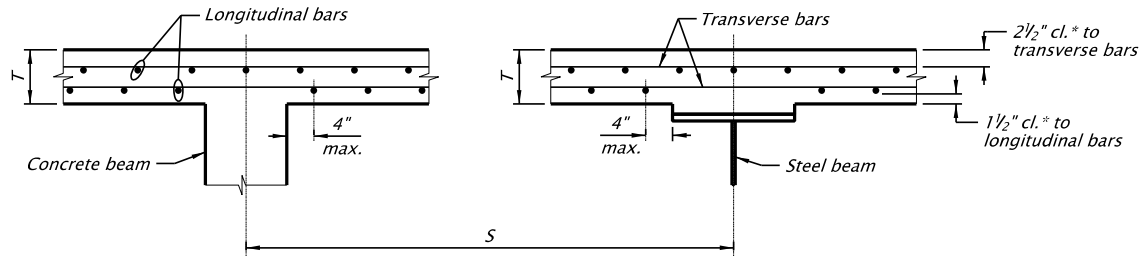
\* For coastal locations, specify 2 inches clear top and bottom. See also BDM 1.26.3 for additional corrosion protection recommendations.

**Precast Prestressed Concrete Members**

Girder Spacing	Deck Thickness	Transverse Bars	Longitudinal Bars
5'-0"	8"	#4 @ 6 1/2"	#4 @ 8"
5'-3"	8"	#4 @ 6 1/2"	#4 @ 8"
5'-6"	8"	#4 @ 6 1/2"	#4 @ 8"
5'-9"	8"	#4 @ 6 1/2"	#4 @ 8"
6'-0"	8"	#4 @ 6 1/2"	#4 @ 8"
6'-3"	8"	#4 @ 6"	#4 @ 8"
6'-6"	8"	#4 @ 6"	#4 @ 8"
6'-9"	8"	#4 @ 6"	#4 @ 8"
7'-0"	8"	#4 @ 5 1/2"	#4 @ 8"
7'-3"	8"	#4 @ 5 1/2"	#4 @ 8"
7'-6"	8"	#4 @ 5 1/2"	#4 @ 8"
7'-9"	8"	#4 @ 5 1/2"	#4 @ 8"
8'-0"	8"	#5 @ 7 1/2"	#5 @ 8"
8'-3"	8"	#5 @ 7 1/2"	#5 @ 8"
8'-6"	8"	#5 @ 7 1/2"	#5 @ 8"
8'-9"	8"	#5 @ 7"	#5 @ 8"
9'-0"	8 1/4"	#5 @ 7"	#5 @ 8"
9'-3"	8 1/4"	#5 @ 7"	#5 @ 8"
9'-6"	8 1/2"	#5 @ 7"	#5 @ 8"
9'-9"	8 1/2"	#5 @ 7"	#5 @ 8"
10'-0"	8 1/2"	#5 @ 7"	#5 @ 8"
10'-3"	8 1/2"	#5 @ 6 1/2"	#5 @ 8"
10'-6"	8 3/4"	#5 @ 6 1/2"	#5 @ 8"
10'-9"	8 3/4"	#5 @ 6 1/2"	#5 @ 8"
11'-0"	9"	#5 @ 6 1/2"	#5 @ 8"
11'-3"	9"	#5 @ 6"	#5 @ 8"
11'-6"	9 1/4"	#5 @ 6"	#5 @ 8"
11'-9"	9 1/4"	#5 @ 6"	#5 @ 8"
12'-0"	9 1/2"	#5 @ 6"	#5 @ 8"



Figure 1.9.1-6 CONCRETE DECK REINFORCEMENT (LRFD DESIGN) with TRANSVERSE BARS ON TOP Steel Girders & Cast-In-Place Concrete Box Girders - Simple Spans



**Assumptions:**

**Specifications:** LRFD 4.6.2.1

**Concrete Class:** HPC 4500

**Reinforcement:** Grade 80

**Top Mat Orientation:** Transverse bars on top

**Dead Load:** 150 pcf + 50 psf future wearing surface

**Deck DL moments:** Negative  $-0.10wS^2$

Positive  $+0.08wS^2$

**Live Load:** LRFD Table A4-1 using 6" from  $\phi$  of girder to the negative moment design section

**Design Moment:**  $1.25*DL + 1.5*DW + 1.75*LL$  (Impact included in LRFD Table A4-1 live loads)

**Surface Wear:** 1/2 inch allowance for surface wear subtracted from positive moment  $d$ .

**Steel Girders:** Top flange width not less than 24 inches. Project specific design is required when top flange is less than 24 inches.

**Concrete Box Girders:** Girder stem width not less than 12 inches. For girder stem greater than or equal to 16 inches, use Deck Design Chart for Precast P/S Concrete Members.

Note:

Additional reinforcement to accommodate rail loads at deck overhangs is not included in these details. The designer is responsible for design of overhangs.

Note:

$S$  is measured parallel to the transverse bars. Bar spacing is measured perpendicular to the bars.

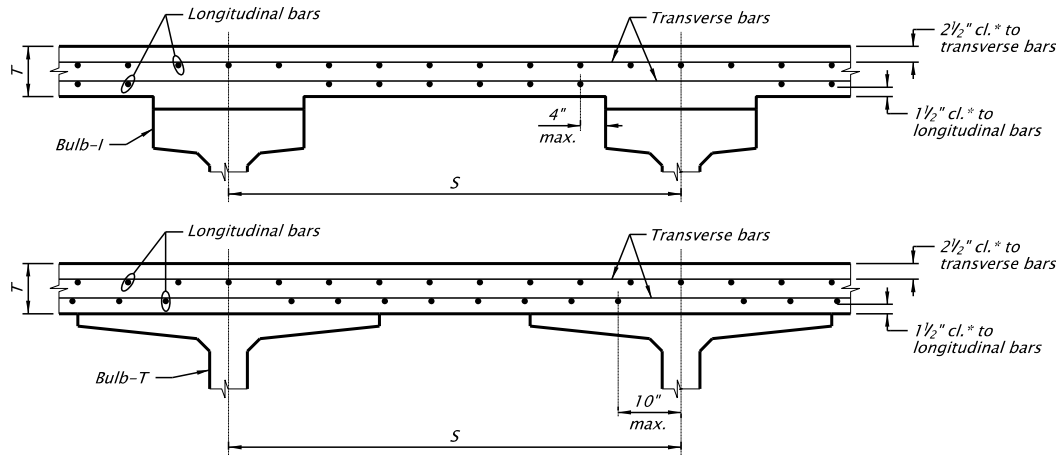
Place bottom mat bars directly below and in line with a top mat bar. At expansion and construction joints, however, it is not necessary for all bottom mat bars to be directly below a top mat bar.

\* For coastal locations, specify 2 inches clear top and bottom. See also BDM 1.26.3 for additional corrosion protection recommendations.

**Steel Girders & CIP Concrete Box Girders**

Girder Spacing	Deck Thickness	Transverse Bars	Longitudinal Bars
5'-0"	8"	#4 @ 8"	#4 @ 8"
5'-3"	8"	#4 @ 8"	#4 @ 8"
5'-6"	8"	#4 @ 7 1/2"	#4 @ 8"
5'-9"	8"	#4 @ 7 1/2"	#4 @ 8"
6'-0"	8"	#4 @ 7"	#4 @ 8"
6'-3"	8"	#4 @ 7"	#4 @ 8"
6'-6"	8"	#4 @ 6 1/2"	#4 @ 8"
6'-9"	8"	#4 @ 6 1/2"	#4 @ 8"
7'-0"	8"	#4 @ 6"	#4 @ 8"
7'-3"	8"	#4 @ 6"	#4 @ 8"
7'-6"	8"	#4 @ 6"	#4 @ 8"
7'-9"	8"	#4 @ 5 1/2"	#4 @ 8"
8'-0"	8"	#4 @ 5 1/2"	#4 @ 8"
8'-3"	8"	#4 @ 5 1/2"	#4 @ 8"
8'-6"	8"	#4 @ 5 1/2"	#4 @ 8"
8'-9"	8"	#4 @ 5 1/2"	#4 @ 8"
9'-0"	8 1/4"	#4 @ 5 1/2"	#4 @ 8"
9'-3"	8 1/4"	#4 @ 5 1/2"	#4 @ 8"
9'-6"	8 1/2"	#4 @ 5 1/2"	#4 @ 8"
9'-9"	8 1/2"	#4 @ 5"	#4 @ 7"
10'-0"	8 3/4"	#4 @ 5"	#4 @ 7"
10'-3"	8 3/4"	#4 @ 5"	#4 @ 7"
10'-6"	8 3/4"	#4 @ 5"	#4 @ 7"
10'-9"	9"	#4 @ 5"	#4 @ 7"
11'-0"	9"	#5 @ 6"	#5 @ 8"
11'-3"	9"	#5 @ 6"	#5 @ 8"
11'-6"	9 1/4"	#5 @ 6"	#5 @ 8"
11'-9"	9 1/4"	#5 @ 6"	#5 @ 8"
12'-0"	9 1/2"	#5 @ 6"	#5 @ 8"
12'-3"	9 1/2"	#5 @ 6"	#5 @ 8"
12'-6"	9 3/4"	#5 @ 6"	#5 @ 8"
12'-9"	9 3/4"	#5 @ 5 1/2"	#5 @ 8"
13'-0"	10"	#5 @ 5 1/2"	#5 @ 8"
13'-3"	10"	#5 @ 5 1/2"	#5 @ 8"
13'-6"	10 1/4"	#5 @ 5 1/2"	#5 @ 8"
13'-9"	10 1/4"	#5 @ 5 1/2"	#5 @ 8"
14'-0"	10 1/2"	#5 @ 5 1/2"	#5 @ 8"
14'-3"	10 1/2"	#5 @ 5 1/2"	#5 @ 8"
14'-6"	10 3/4"	#5 @ 5 1/2"	#5 @ 8"
14'-9"	10 3/4"	#5 @ 5 1/2"	#5 @ 8"
15'-0"	11"	#5 @ 5 1/2"	#5 @ 8"

Figure 1.9.1-7 CONCRETE DECK REINFORCEMENT (LRFD DESIGN) with TRANSVERSE BARS ON TOP Standard Precast Prestressed Concrete members - Simple Spans



**Assumptions:**

**Specifications:** LRFD 4.6.2.1

**Concrete Class:** HPC 4500

**Reinforcement:** Grade 80

**Top Mat Orientation:** Transverse bars on top

**Dead Load:** 150 pcf + 50 psf future wearing surface

**Deck DL moments:** Negative  $-0.10wS^2$   
Positive  $+0.08wS^2$

**Live Load:** LRFD Table A4-1 using 8 inches from  $\phi$  of girder to the negative moment design section

**Design Moment:**  $1.25*DL + 1.5*DW + 1.75*LL$  (Impact included in LRFD Table A4-1 live loads)

**Surface Wear:** 1/2 inch allowance for surface wear subtracted from positive moment  $d$ .

Note:  
Additional reinforcement to accommodate rail loads at deck overhangs is not included in these details. The designer is responsible for design of overhangs.

Notes:

S is measured parallel to the transverse bars. Bar spacing is measured perpendicular to the bars.

Place bottom mat bars directly below and in line with a top mat bar. At expansion and construction joints, however, it is not necessary for all bottom mat bars to be directly below a top mat bar.

\* For coastal locations, specify 2 inch clear top and bottom. See also *BDM 1.26.3* for additional corrosion protection recommendations.

Precast Prestressed Concrete Members

Girder Spacing	Deck Thickness	Transverse Bars	Longitudinal Bars
5'-0"	8"	#4 @ 7 1/2"	#4 @ 8"
5'-3"	8"	#4 @ 7 1/2"	#4 @ 8"
5'-6"	8"	#4 @ 7 1/2"	#4 @ 8"
5'-9"	8"	#4 @ 7 1/2"	#4 @ 8"
6'-0"	8"	#4 @ 7"	#4 @ 8"
6'-3"	8"	#4 @ 7"	#4 @ 8"
6'-6"	8"	#4 @ 6 1/2"	#4 @ 8"
6'-9"	8"	#4 @ 6 1/2"	#4 @ 8"
7'-0"	8"	#4 @ 6 1/2"	#4 @ 8"
7'-3"	8"	#4 @ 6"	#4 @ 8"
7'-6"	8"	#4 @ 6"	#4 @ 8"
7'-9"	8"	#4 @ 6"	#4 @ 8"
8'-0"	8"	#4 @ 6"	#4 @ 8"
8'-3"	8"	#4 @ 5 1/2"	#4 @ 7 1/2"
8'-6"	8"	#4 @ 5 1/2"	#4 @ 7 1/2"
8'-9"	8"	#4 @ 5 1/2"	#4 @ 7 1/2"
9'-0"	8 1/4"	#4 @ 5 1/2"	#4 @ 7 1/2"
9'-3"	8 1/4"	#4 @ 5 1/2"	#4 @ 7 1/2"
9'-6"	8 1/2"	#4 @ 5 1/2"	#4 @ 7 1/2"
9'-9"	8 1/2"	#4 @ 5 1/2"	#4 @ 7 1/2"
10'-0"	8 1/2"	#4 @ 5"	#4 @ 7"
10'-3"	8 1/2"	#4 @ 5"	#4 @ 7"
10'-6"	8 3/4"	#4 @ 5"	#4 @ 7"
10'-9"	8 3/4"	#4 @ 5"	#4 @ 7"
11'-0"	9"	#4 @ 5"	#4 @ 7"
11'-3"	9"	#4 @ 5"	#4 @ 6 1/2"
11'-6"	9 1/4"	#4 @ 5"	#4 @ 6 1/2"
11'-9"	9 1/4"	#4 @ 5"	#4 @ 6 1/2"
12'-0"	9 1/2"	#4 @ 5"	#4 @ 6 1/2"

### 1.9.1.2 Detailing

Wearing surface on cast-in-place concrete decks – New structures with cast-in-place decks will not have an AC wearing surface without a Design Deviation.

When an ACWS is used, a waterproofing membrane per *BDM 1.26.4* is required. When a Class F mix (free draining) is used, give special attention to drainage details at joints and deck drains to prevent trapping water adjacent to these areas.

Occasionally there are requests to install thermal ice-melting equipment on bridge decks or problematic sections of highway. Bridge Section recommends against these installations unless there is a natural source of warm water at the bridge, as exists in the city of Klamath Falls. All other installations in Oregon have been turned off due to overly expensive power bills and/or early failure of key components. A Design Deviation is necessary to install a thermal system on a bridge deck. Contact the Bridge Preservation and Design Engineer for further information.

For typical deck steel placed in two mats, place bottom mat bars such that each bottom mat bar is directly below and in line with a top mat bar. At deck expansion joints and at deck construction joints, however, it is not necessary for all bottom bars to be directly below a top bar.

Inlaid Durable Striping on Bridge Decks – Concrete deck surface removal of up to ¼ inch is acceptable for placing longitudinal inlaid striping on new bridges. Placement of such striping will likely reduce wear at stripe locations. In nearly all cases, the majority of wear for concrete bridge decks occurs within the travel lane. Therefore, it is unlikely ¼ inch maximum removal will significantly impact bridge load capacity.

Allow concrete removal using a diamond grinder according to *SP 00503*. Note that *SP 00503* also permits removal by micro-milling and by hydroblasting. However, only allow diamond grinding for striping applications. Note that *SP 00850* also requires diamond grinding equipment for installation of inlaid/grooved pavement markings.

Do not allow inlaid striping on concrete decks where the striping would be placed in the transverse direction. Concrete removal for such striping would reduce the load capacity of the bridge.

For existing concrete bridge decks, allow inlaid striping only in the longitudinal direction **and** in locations where there is no significant rutting or other deck wear.

Do not allow rumble strips on concrete bridge decks.

Allow raised pavement markers on concrete bridge decks only when they can be installed without removal of any deck concrete (no grooving).

For existing asphalt concrete wearing surfaces, grooving up to 5/8 inch depth for striping (longitudinal or transverse) or rumble strips is acceptable.

Limit the use of stay-in-place forms for decks as required in *BDM 1.5.6.2.1* and *1.5.7.12*.

### 1.9.1.3 Vibrations

Vibrations from adjacent traffic and/or construction activity are not likely to cause cracking in freshly placed deck concrete. One ODOT project recorded vibrations up to 0.6 in/sec during a second stage deck placement with only minor deck cracking near the closure area. Typical deck closure placements may have even higher vibrations. For this reason, minor cracking can be expected in deck closures placed under traffic. However, this cracking rarely results in long-term maintenance concerns. See the **Deck Closure Pours** discussion below for a discussion of closure pour options.

*Table 1.9.1-1* is a very rough guide to vibration levels.

Table 1.9.1-1 Vibration Levels

Measured Vibration (inch/second)	Vibration Perception Level
0.08	vibrations perceptible
0.1	continuous vibrations may begin to annoy people
0.2	short-term vibrations may begin to annoy people
0.4 to 0.6	typical max. short-term vibration, concrete bridge < 100 foot span
0.6 to 1.0	typical max. short-term vibration, concrete bridge > 100 foot span

Although damage to concrete due to vibrations is rare, it is good practice to avoid unnecessary vibrations where reasonable measures can be taken. For staged construction, providing deck closure segments is preferred to minimize both vibrations and the effects of adding additional deck dead load, creep and shrinkage to the first stage.

Providing either a joint or closure segment between substructure (cap) stages will also reduce potential for traffic vibrations to be transmitted through those elements. See *BDM 1.11.2.4* for more discussion.

Where there is a concern that vibrations may be excessive, the following practices can be considered as mitigation:

- Low-slump concrete – Although concrete damage due to vibrations is rare, use of low-slump concrete (greater than 4 inches) will minimize the risk. ODOT’s HPC deck concrete mix is generally a low-slump mix that meets this requirement. Therefore, generally no change to the standard HPC deck concrete mix is necessary.
- Reinforcing details – Do not use hooked bars in closure segments. Ensure lap splices are in contact and well-tied as much as possible. Where lap splices cannot be in

- contact, use two rows of longitudinal bars tied to both lap splice segments to create a rebar mat that cannot be easily moved.
- Retarder admixture – Varying amounts of set retarder admixture can be used such that the entire deck will set up at about the same time. The Structure Quality Engineer from the ODOT Construction Section can assist in determining when this admixture is needed and how to apply it.
  - Reduce vehicle speed – Where vibration is due to adjacent traffic, reducing vehicle speed will generally reduce the amount of vibrations. However, vehicle speeds will generally need to be reduced down to around 15 mph before a significant reduction in vibrations can be obtained. Therefore, only consider this measure in extreme circumstances. Where possible, moving traffic laterally from an adjacent deck placement will likely be more effective than reducing vehicle speed.
  - See *BDM 1.11.2.4* for joint options at integral abutments.

### 1.9.1.4 Deck Closure Pours

Where deck closures are placed under traffic, minor cracking within the closure can be expected. This cracking is typically minor and does not result in significant long-term maintenance. The amount of cracking expected will be a function of the traffic induced vibrations at the site. See *BDM 1.9.1.3* for discussion of closure pour options.

The use of polypropylene fibers are required in all portions of the deck, including the deck closures.

### 1.9.1.5 Concrete Deck Panels

Standard details are available for precast concrete deck panels to be used with precast concrete girders and steel girders. Bridge deck construction can be accelerated by using precast deck panels. At the same time, deck quality can be improved compared to CIP deck construction since precast deck panels are fabricated under factory-controlled conditions. The current standard details for precast deck panels limit the maximum deck panel length to 50 feet and the effective width to 10 feet. These dimensions are limited by shipping weight and maximum shipping width (assuming panels are placed flat).

To make deck panels fit on a bridge span, provide either CIP end segments or precast exterior deck panels (end pieces). CIP end segments can accommodate construction tolerances; variations; and are a better option for most cases. For a precast option, a different panel width may be required. When deck panels are post-tensioned, end pieces may need to be thickened to accommodate post-tensioning anchorages.

Prestressed reinforcement is typically used on the long side of deck panels that span between the bridge girders. This is the main reinforcement that provides flexural strength for resisting applied loads during shipment, erection, superimposed dead load, and vehicular live load.

Panel thickness may be increased to accommodate final surface grinding and reinforcement detailing.

Deck panels can accommodate skew, superelevation, slight horizontal curve, and vertical roadway profile. For a mild vertical roadway profile, a flat layout of deck panels constructed on bridge girders is adequate and makes the construction of joint connections easier. When the vertical roadway profile is significant, chorded deck panels are recommended to fit the profile with CIP reinforced concrete joints connecting the deck panels. Reinforcement and anchor bolts for bridge railing can be cast into the deck panels as well.

Two possible types of transverse joint connections are CIP reinforced concrete and longitudinal post-tensioning along the length of the bridge. Each connection type has its own advantages and disadvantages.

#### 1.9.1.5.1 Cast-in-place Option

For CIP joint connections, Ultra High Performance Concrete (UHPC) is the preferred material due to its superior bond properties, durability, compressive strength, and tensile strength. There are a number of proprietary UHPC products on the global market, such as BCV®, BSI®, CRC®, Densit®. The only satisfactory UHPC joint material available on the domestic market is Ductal® JS1000 by Lafarge North America, Inc. Since use of this material would be considered a **sole source**, a finding of public interest letter (with approval from FHWA) must be secured before going to bid. In the past there was also an issue with steel fibers used in the Ductal® JS1000 product since the steel fibers were manufactured in Europe and therefore did not meet the **Buy America** provisions for steel. Based on an *FHWA Policy Memorandum* published on February 12, 2014, steel fiber reinforcement, as used in the Ductal® JS1000 product, is now produced by Bekaert Corporation at a production facility in Rome, GA and commercially available to all potential purchasers. For other UHPC products made outside the USA, they would be able to meet the **Buy America** requirements as long as they used the steel fibers from the Rome, GA facility.

Note also that there are other types of steel fiber reinforcement that are made in the USA. However, at this time only those from the Rome, GA are thought to meet the size and shape needed for the UHPC application.

Due to the nature of new superior materials, UHPC is much more expensive than conventional concrete. Based on an FHWA publication, *FHWA-HRT-13-100* published October 2013, the commercially available product by Lafarge is sold for about \$2000/yd<sup>3</sup>. This price includes material cost of the proprietary blend and fiber reinforcement, as well as costs associated with development and delivery. The same publication also reveals that there are a number of researchers, who have conducted testing programs to develop non-proprietary cost-effective UHPC mixes, which meet all the requirements for UHPC. All materials used in the research project were locally available in three regions across the U.S. One of the material sources is from the Pacific Northwest area. The result shows that it is possible to produce UHPC under

\$1000/yd<sup>3</sup> using these domestic materials with a non-proprietary blend. Note that the fiber reinforcement is responsible for one half the total cost.

With the excellent bond behavior provided by UHPC, a non-contact splice length for rebar extending out from deck panels is significantly shorter than that required in conventional concrete. To ensure good bonding against precast deck panels, pre-wetting the interface and an exposed aggregate finish is recommended. FHWA Research, Development, and Technology published *FHWA-HRT-14-084* in October 2014. This document provides substantial information regarding design and construction of UHPC.

### 1.9.1.5.2 Post-Tensioning Option

Two post-tensioning options are recommended, i.e. grouted keyway and match cast joints. During the design, a point of no movement and the direction of the movement due to post-tensioning need to be identified and accordingly detailed on the bridge plan. Compressive stresses from post-tensioning in positive bending zones need to be accounted for in the composite section. Placing P/T ducts at the CG of the deck panel section is ideal, so that camber or deflection of deck panels do not occur after post-tension. When there are geometric constraints that prevent locating P/T ducts at the CG of the section, the movement after post-tensioning needs to be considered in the design or provide hold-down devices to maintain the deck panel position.

#### GROUTED KEYWAY

This post-tensioning option includes deck panels constructed with shear key edges, erected on girders having a 1-3/4 inch wide space, filled with keyway grout, and then post-tensioned together. The grouted keyways are similar to the joints between precast prestressed slab and box girders. Post-tensioning ducts are spliced in pockets with an air and water-tight seal. All splicing pockets and keyways need to be filled with grout and gain specified strength before the post-tensioning operation to ensure continuous flow of the compressive force.

#### MATCH CAST

The other recommended post-tensioning option is match casting. Deck panels are match cast at the precaster site. Each deck panel is identified, delivered to the site, and erected in sequence as an erection plan. Duct couplers used in precast segmental construction are recommended. With a proper installation, this type of duct couplers provides a continuous, air, and water tight seal. In the U.S. a number of P/T suppliers can provide segmental-type duct couplers. Historically only a few suppliers have furnished post-tensioning for bridge construction projects in Oregon. Verify coupler availability before a project goes to bid. Since duct coupler dimensions vary from different suppliers, detail deck panels to fit all possible duct couplers.

Applying epoxy at deck panel interfaces is recommended before post-tensioning. As each deck panel is added, temporary post-tensioning is used to secure the new panel to previously installed panels until the epoxy begins to set. The epoxy serves as a lubricant during placement

of the deck panels, prevents water intrusion, and provides some tensile strength across the joint. This construction technique reduces the number of pockets in the finished deck panels.

### **1.9.1.5.3 Leveling Bolts**

Leveling bolts are used to place deck panels to the appropriate elevation before duct splice openings and joints are filled with concrete or grout. During erection of deck panels, leveling bolts are required to rest on all supporting girders to ensure proper load distribution. Steel plates placed on top of precast concrete girders under the leveling bolts are recommended to accommodate deck panel erection. Leveling bolts may be removed or left in place by cutting down the top 1 ½ inch minimum below the finish surface. Fill leveling bolt holes with non-shrink grout.

## **1.9.2 Deck Screeding**

### **1.9.2.1 General**

Consider deck constructability issues when specifying deck screeding requirements.

When the deck width or skewed dimension causes the length of the screed equipment to be excessive (more than 100 feet), the deck may need to be placed in stages with or without a closure pour. Where staging is shown on the plans, place a longitudinal joint along a longitudinal beam line and not in a wheel line. Consider this in the beam layout.

Also on skewed decks, a sharp vertical curve on the structure may cause problems with screeding on the skew. It may be necessary to perform some unique sequencing, such as preloading the deck with plastic concrete far enough ahead of the screed machine to preload the beams to get unison deflections and allow the screed to run normal to the beams.

Consider whether the finishing machine can follow the actual slope of the roadway in one placement. Deck screeds can accommodate a crown section in one placement, full width, when the superelevation remains constant. When the superelevation rates vary, the deck will normally need to be placed in separate placements. As noted previously, it is best to have a longitudinal joint along a longitudinal beam and to consider this in the beam layout.

When a structure has different skews at adjacent bents, base the skew of the screed equipment on the average of the bent skews.

When a structure is curved with radial bents, the screed equipment and deck placement remains normal to the roadway centerline. In this case, the screed equipment must be equipped with variable speed capacity at both ends.

Perform sufficient geometric calculations to determine the best method or direction of deck screeding. When necessary, place the required sequencing and/or direction of screeding, skewed or normal, on the detail plans.



### 1.9.2.2 Beams not Supported by Falsework

The main concern of this type of placement is that the beams deflect equally in unison, so deck thickness and clearances end up as shown on the plans. To deflect equally the beams need to be loaded equally. Thus when the structure has a skew, the screed should run on a skew, parallel to the bents.

Add a note to the plans specifying that the screed equipment shall run parallel to the bents.

### 1.9.2.3 Falsework Supported Beams

There is less concern regarding how the concrete is placed for falsework supported beams. There will still be a small amount of falsework crush due to the added dead load of the deck. Ideally it would be best to place and screed skewed decks on the skew, but practically it is not required.

## 1.9.3 Deck Construction Joints

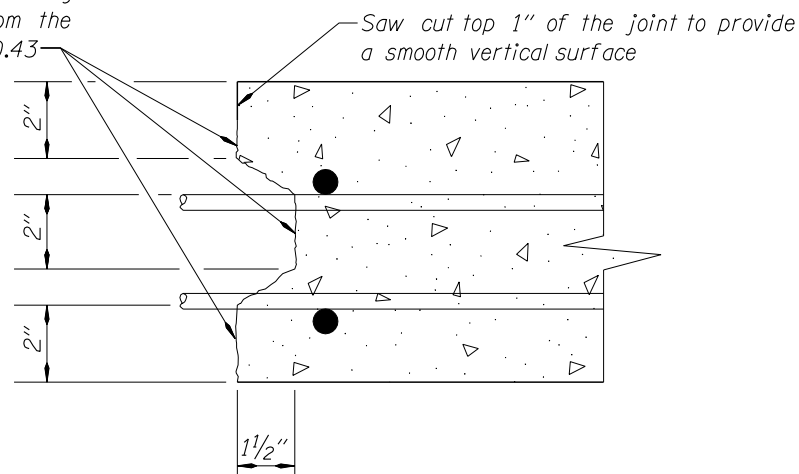
Minimize the number of deck construction joints to avoid potential leaks through the deck. However, it is often necessary to provide deck construction joints to avoid shrinkage or deflection cracking. See *BDM 1.6.2.15* for more information on joints on steel structures, and *BDM 1.11.2.4* for options to eliminate joints.

Normally for non-continuous spans, deck concrete placements are full length or stopped at a transverse beam. The construction joint surface is normally vertical and roughened, according to *SP 00540.43(a)*, between placements.

For continuous spans or for emergency situations, provide a shear key with a roughened surface between placements. Show typical key details on the plans as detailed in *Figure 1.9.3-1*.

Figure 1.9.3-1 Shear Key Detail

*Provide a roughened surface by using a concrete surface retarder from the QPL in accordance with 00540.43*



## 1.9.4 Deck Overlays

### 1.9.4.1 Introduction

The purpose of an overlay on a bridge deck can be to:

- Restore the structural integrity of the deck.
- Improve the load capacity.
- Improve or restore rideability.
- Improve skid resistance.
- Improve deck drainage.
- Improve deck cross-section.
- Seal deck cracking.
- Provide sacrificial wearing surface.

There are three overlay categories available for use on bridge decks:

- Structural Concrete Overlays (SC).
- Polymer Concrete Overlays (PC) – Including Multi-Layer Polymer Concrete Overlay (MPCO) and Premixed Polymer Concrete (PPC).
- Asphalt Concrete Wearing Surface (ACWS).

The term **structural** is used to describe an overlay that is rigid enough and thick enough to increase the stiffness of the deck and decrease live load deflections. SC overlays are typically placed on a bridge deck with a minimum thickness of 2 inches. Include the structural overlay in the stiffness and capacity calculation. SC overlays typically have a compressive strength and elastic modulus similar to conventional concrete, but it may vary depending on the specific product used. Do not include the top ½ inch of overlay in the structural deck thickness, since it is considered a sacrificial wearing surface.

Polymer Concrete (PC) is used in special situations where structural integrity is not an issue and does not add to the deck stiffness.

ACWS may only be used with membrane waterproofing. Use ACWS only on bridges with existing ACWS. Consider the option of replacing the ACWS with another overlay type, where roadway ACP depths allow.

ACWS does not add to the deck stiffness and is not considered to be a **structural** overlay.

Overlay selection is discussed further in [BDM 1.9.4.7](#).

### 1.9.4.2 Structural Concrete Overlays

SFC, often referred to as Microsilica Concrete (MC), has been the most common structural overlay type for the last decade. Due to problems with cracking, High Performance Concrete (HPC) overlays are now preferred. HPC is a similar mix to SFC, but uses larger aggregate, among other changes, to reduce cracking.

Other structural overlay materials include High-Early and Latex Modified. Specification of these overlay types requires a Design Deviation.

Review [SP 00559](#) for structural overlay requirements and restrictions.

### C1.9.4.2

SFC is a specialized concrete mix with a silica fume modifier. Batching is normally done at a batch plant. SFC placement is accomplished with more conventional construction methods.

Latex Modified Concrete (LMC) is a concrete mix with a latex emulsion modifier. The latex emulsion has a milky color and texture and is added during batching. Batching is done in mobile mixers at the job site.

LMC overlay technology has been used since 1958, and the design life of the material can be predicted from historical data, but it has not been used in Oregon for many years.

The use of LMC offers many construction advantages. Since the material is batched in a mobile mixer, the pour schedule does not depend upon the concrete plant schedule. Also, the pour is not influenced by the projects distance from the concrete plant. LMC was a common type of structural overlay in the past. Equipment may be available, but verify with local contractors before specifying LMC.

LMC does have some disadvantages. Placement of the LMC overlay is labor intensive, increasing construction costs. The rate of construction for an LMC overlay is about 6400 sf to 7400 sf per 8 hour work shift. LMC is also sensitive to atmospheric conditions which often controls the pour schedule and contract time as well. Review [SP 00559](#) for placing limitations. Surface preparation and curing are the most critical factors to achieving a good quality end product and are often the most neglected.

### 1.9.4.3 Polymer Concrete Overlays – General

Polymer is a very general term used to classify a wide variety of compounds that chemically combine in a reaction (polymerization).

Polymer binder resins are formulated in hundreds of different combinations, depending upon the properties desired. The most common categories of polymer binder resins in use as bridge deck overlays or patching material include epoxy and polyester.

PC is a composite material in which coarse aggregate is bound together with the polymer binder resin.

PC can be placed as an overlay in generally two different ways – as a MPCO (also known as broom and seed) or as PPC, which is screed finished to grade.

The most common polymer used for MPCOs is epoxy.

The most common polymer used for PPCs is polyester.

PC overlays have many construction advantages:

- PC overlay flexibility reduces the potential for cracking due to thermal or design load movement.
- PC overlays are very light as compared to SC overlays. This reduction in dead load can be significant on load posted bridges or movable bridges.
- PC overlay construction time is much less compared to SC overlay applications. The short construction time provides a great advantage in time critical urban areas.
- PC overlay bond strength is typically double that of an SC overlay.

PC overlays also have some construction disadvantages:

- Atmospheric conditions: The prepared deck surface must be dry prior to placement. This provision could influence construction schedules. For off-season applications, *SP 00556* and *SP 00557* provide guidance for Inclement Weather Plans, which can involve heating the bridge deck to force it to dry. This will impact traffic control requirements and costs, so avoid scheduling PC overlays for winter applications when possible.

#### 1.9.4.3.1 Multi-layer Polymer Concrete Overlays

MPCO's are a composite material formed by combining polymer binder resin and coarse aggregates.

MPCO's are constructed using any of the commonly available polymer resins. Each resin has its own advantages and disadvantages and should be used in accordance with manufacturer's recommendations.

MPCO's have a significantly lower modulus compared to PCC and therefore cannot be considered a **structural** overlay. MPCO's have been used on the interstate and appear to be performing well. MPCO's are typically placed to a nominal 3/8 inch thickness.

MPCO's applications don't require specialized equipment and are well suited for maintenance crews and smaller contractors. There have, however, been advances in application methods which have increased application efficiency vs. traditional manual application methods.

MPCO aggregates have a tendency to polish in the wheel lines, potentially reducing skid resistance as compared to other overlay types. Avoid high traffic volume locations when selecting MPCO's. Consult with the Bridge Maintenance Engineer for additional guidance.

A typical MPCO is constructed by first removing all dirt, debris and laitance on the deck surface. This is best accomplished with the use of a shot blast system. Since the deck surface must be clean and dry prior to the application of the MPCO, the industry recommends the use of the shot blasting method. Shot blasting leaves the surface dry and vacuumed.

A layer of polymer is next applied to the prepared deck using a squeegee, broom, spray bar or other methods at a rate specified by the manufacturer. The aggregate is then broadcast, at a specified rate, over the surface. The excess aggregate is swept off the surface. Apply lifts according to manufacturer's directions to achieve a nominal 3/8 inch thickness. Place additional MPCO material in ruts to provide a finished MPCO surface that is free of ruts, depressions, and irregularities.

Application rates can be estimated from between 2000 to 4000 square feet/hr.

The finished MPCO surface is not tined or screeded.

Refer to either the Conditional Products List or the Qualified Products List for MPCO products that are being evaluated for approval or have been approved for use. MPCOs and MPCO Aggregates are listed separately on the QPL. The MPCO binder manufacture is required to select the appropriate MPCO Aggregate from the QPL. *SP 00556* covers the use of MPCOs.

#### **1.9.4.3.2 Premixed Polymer Concrete Overlays**

PPC is a composite material formed by combining polymer binder resin and coarse aggregates in a mobile mixer, then applied to the deck and screed finished to grade. See *BDM 1.9.2* for screed information.

PPC has a significantly lower modulus compared to PCC and therefore cannot be considered a **structural** overlay.

PPC overlays have been used on the interstate and appear to be performing well. Preliminary numbers indicate a slight advantage over MPCO's in skid resistance.

PPC overlays are typically placed to a nominal 3/4 inch thickness and are more appropriate for minor grade improvements than MPCO's, due to the grade controls of the screed finish

machine. Due to the increased material thickness, PPC overlays are more expensive than MPCO's.

PPC is rapid setting and is best placed with a screed finish machine whenever practical. There are circumstances where a screed cannot be used, such as along the gutter lines which will require manual finishing. Application rates can be estimated at a maximum of 5000 square feet/hr. Unit weight of PPC is typically 135 pcf.

A typical PPC is constructed by first removing all dirt, debris and laitance on the deck surface. This can be accomplished with the use of a shot blast system. Since the deck surface must be clean and dry prior to the application of the PPC mixture, the industry recommends the use of the shot blasting method over the others. Shot blasting leaves the surface dry and vacuumed.

A layer of primer is next applied to the prepared deck surface using a squeegee or brooms. Next the polymer resin binder is mixed with the other components into a premixed condition. The premixed material is then placed onto the primed surface and finished to grade with specialized equipment designed for PPC applications. Silica sand is broadcast in areas of high resin content to maintain skid resistance.

The final product looks similar to PCC but with longitudinal tining.

PPC is currently not listed on the QPL and needs to be specified accordingly. *SP 00557* covers the use of PPC.

#### **1.9.4.4 Field Investigation**

Upon receiving a project assignment, review the latest bridge inspection report, noting the ratings for the deck, superstructure, bridge rails, deck joints and deck drains. A site visit may also be needed to gather additional information. Obtain guidance from the Senior Bridge Corrosion Engineer and, per their guidance, core the deck and test for chloride levels or other chemicals of interest. In rare cases, additional cores may be required for compressive strength testing or to perform petrographic analysis.

Use rebar detector to locate existing deck reinforcement. Avoid coring through existing rebar.

For chloride testing take minimum 4 inch diameter cores with minimum 4.5 inches long. Take a minimum of four cores at a frequency of a pair of two cores for every 10,000 square feet of bridge deck, not to exceed 12 cores total. For each pair include one core within a wheel track/rut and one core between wheel track/ruts. Sampling a single lane of a multilane structure is often sufficient.

Take photos of the cores and core holes to assist designer. Log photos and cores holes on a pdf of the existing plan sheet. Provide information in Chloride Report or ProjectWise as appropriate.

Test all cores for chloride analysis according to *ASTM C1152* or *AASHTO T260*. Discard the top ¼ inches and slice in ½ inch increments to a depth of 2.75 inches below the surface of the

concrete or the bond line between overlay and substrate materials. Typically, an additional 2 inches below the deepest test is necessary to cut and pulverize the core for testing. For thin decks or thick overlays where 2.5 inch depth testing is not practical, test as many sample depths as possible without taking a full depth core.

Spread locations of coring evenly throughout the surface area of the deck without causing major traffic interruption. Avoid coring at locations where worker and public safety is compromised. Repair core locations with a rapid setting repair mortar from *Section 02015.20* of the QPL.

### **1.9.4.5 Warrants for Overlays**

Use the following overlay criteria and engineering judgment to determine whether an overlay is warranted.

- Bridge deck overlays are not recommended when any of the following conditions are met:
  - The deck condition is rated as a seven or greater (category three) in Item 58 of the bridge inspection report. The deck is still in good condition.
  - Delaminated, patched or cracked areas are less than one percent of the deck area. The deck is still in good condition.
- Bridge deck overlays are not recommended, and deck replacement should be considered, when any of the following conditions are met:
  - The deck condition is rated as a four or less (category one) in item 58 of the bridge inspection report and any additional investigation confirms that the deck deterioration has become too severe to repair.
  - Delaminated, patched or cracked areas are greater than 15 percent of the deck area and any additional investigation confirms that the deck deterioration has become too severe to repair.
  - Corrosion has deteriorated the deck to an extreme level or the chloride content exceeds 0.040 percent by mass of sample at the depth of rebar. See *BDM 1.9.4.6*.
- Bridge deck overlays are recommended when any of the following conditions are met:
  - The deck condition is rated as a five or six (category two). See item 58 of the bridge inspection report.
  - The deck condition is rated as a four or less (category one) in item 58 of the bridge inspection report and thorough investigation shows that the deck deterioration has not become too severe to repair.
  - Delaminated, patched or cracked areas are greater than 15 percent of the deck area and thorough investigation shows that the deck deterioration has not become too severe to repair.
  - Delaminated, patched or cracked areas are greater than five percent but less than 15 percent of the deck area.

- Delaminated, patched or cracked areas are greater than one percent but less than five percent of the deck area and the annual average daily traffic (AADT) is at least 3000.
- Delaminated, patched or cracked areas are greater than one percent but less than five percent of the deck area and the structure carries interstate highway traffic.
- Corrosion has not deteriorated the deck to an extreme level or the chloride content is less than 0.040 percent by mass of sample at the depth of rebar. See *BDM 1.9.4.6*.
- MPCOs may be used as a preservation measure on decks in good condition at the request of maintenance.

**Thorough investigation** means a delamination survey of the entire deck and chloride profiles taken from areas of highest exposure to drainage, and requires concrete cores. Chloride content at the surface is not adequate as levels can vary greatly. These results are used to determine the remaining concrete deck integrity before determining the appropriate deck treatment or when deck replacement is warranted.

### 1.9.4.6 Corrosion Considerations

Determine whether the structure is in a **marine environment**. A marine environment is defined in *BDM 1.26.1*.

When the structure is in a marine environment, deck rebar corrosion is visible, or there is other reason to suspect the structure may be occasionally salted during winter months, discuss the proposed overlay project with the Senior Bridge Corrosion Engineer. Replacement of an existing deck may need to be considered depending upon the extent of chloride content and rebar corrosion. When the maximum acceptable chloride level in the deck has been exceeded, deterioration of the deck rebar will continue regardless of the presence of a new overlay.

#### ACWS WITH MEMBRANE WATERPROOFING

FHWA requires deck surface protection from top down chloride intrusion. Therefore, when ACWS is the only feasible option for overlay, install a waterproofing membrane per *BDM 1.26.4*.

### 1.9.4.7 Design and Construction Considerations

After determining whether a bridge deck overlay is warranted, consider whether a SC overlay, a PC overlay or an ACWS will be used. Typically, one type will be better suited for the project than the other. Some factors to consider are:

- Short construction time windows (typically in urban areas) favor a PC overlay or an ACWS over a SC overlay due to speed of placement and cure time. LMC requires a 4 day cure time. SFC requires a 7 day cure time.



- Dead weight critical structures favor a PC overlay over a SC overlay or an ACWS because of their thin, lightweight nature. However, contribution of a structural overlay can be included in stiffness and strength calculations of deck sections.
- Decks requiring extensive buildup due to grade corrections or wheel rutting favor a SC overlay or an ACWS over a PC overlay due to the difficulty and cost of building up a PC overlay.
- The construction budget. When the initial cost is a major consideration, ACWS is the least expensive.
- Region/Project Manager's experience. During the Scoping and TS&L design phase, check with region project development team to see if they have a preference between the different types of overlays.
- SC overlays need elastomeric concrete nosings or armored corners at the bridge ends and joints. It may be possible to place a PC overlay and not do any work to the joints.

Check the structure for the possibility of a bridge rail and/or bridge rail transition retrofit or replacement, deck joint repair or replacement, the addition of reinforced concrete approach slabs, the addition of protective fencing, the need for scour protection, seismic retrofit and bearing repair.

For load restricted bridges, confirm that the weight of the overlay construction equipment will not overstress the bridge. Restrictions may be required on the spacing of a paving train or the size of the milling equipment.

*Table 1.9.4.7-1* provides guidance for selecting an overlay type based on design criteria.

Table 1.9.4.7-1 Overlay Type Selection

DESIGN CRITERIA	ACWS	MPCO	PPC	SC
Economy - Initial Cost	X			
Construction Time - Fastest	X	X	X	
Grade Correction or Buildup Required	X		X	X
Dead Load Limitations		X	X	
Deck Sealer for Corrosion Protection		X	X	X
Proven Longevity				X
Low Traffic Volumes	X	X		
Deck Crack Sealer		X		

During the overlay selection process, review the structure's **As Constructed** plans, paying special attention to the following items:

- Effect of Additional Dead Load - Typically the dead load from a 2 inch concrete overlay has little effect on the capacity or operation of the structure. Exceptions to

- this are load posted bridges or movable bridges, where a SC overlay's dead load may have a significant impact. A thinner or PC overlay may be required.
- Existing Bridge Rail – Review the existing bridge rail for functional adequacy and replace if unacceptable (see *BDM 1.13*). Check the dimension from the top of the rail to the overlay finish grade to make sure that the minimum rail height is still met.
  - Deck Joints – Clean and repair deck joints (when necessary) prior to placing the overlay. Review the Bridge Inspection Report or field notes for information to determine if any deck joint work is needed. Additionally a field trip may be necessary in order to determine the best type of joint repair or replacement. See Standard Joint Drawings for typical deck joint reconstruction details. See Standard Specifications and *SP 00585* for expansion joints. Replace Asphaltic Plug Joint Seals when overlay thickness exceeds 3/8 inch.
  - Elastomeric concrete nosing is recommended for SC overlays, because of the high incidence of debonding at expansion joints or at bridge ends. See *SP 00584* for specifications developed for concrete nosing.
  - Deck Drains – Note existing deck drains on the overlay plan view. Raise deck drain grates to match the new deck surface. For a PC overlay, the existing deck drain taper is adequate. Verify if deck drain grates need to be upgraded for bicycle safety. See *BDM 1.24* for additional information about bridge drainage.
  - Bridge Approach Slabs – Confirm the need for bridge approach slabs by reviewing the current Bridge Inspection Report and the Maintenance file records. A field trip may be necessary to determine whether or not adding approach slabs to the structure is the best choice to minimize pavement cracks and/or settlement at the bridge ends.

Bridges constructed after 1960 generally have paving ledges at the bridge ends, even though approach slabs were not installed at the time of construction. For older bridges, without paving ledges, or for bridges with paving ledges that are too small, new corbels will need to be detailed to provide support for proposed bridge approach slabs.

Traffic restrictions may require staging of the approach slab installation or the use of Type III cement (high early strength concrete) to accelerate construction times.

See *BDM 1.23* and *SP 00545* for additional information about bridge approach slab design.

Check for the presence of an existing overlay or wearing surface. When one is present, note what material type it is. Also, check for the presence of an existing waterproof membrane. Some Oregon bridges may have asbestos containing membranes, which require additional testing and care during removal. This information is used in estimating unit costs for deck preparation. Use *SP 00504* for removal of existing overlays and membranes.

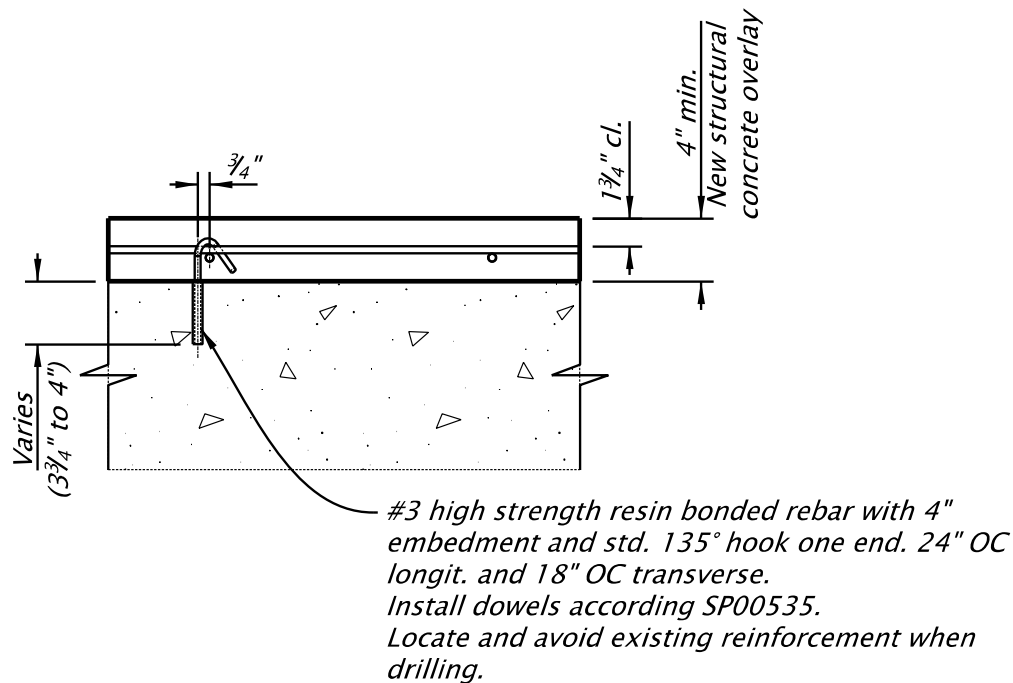
There is a statewide priority list for protective fencing. Since the 1993 law (*ORS 366.462*), when a structure to be overlaid crosses over a roadway and does not have existing protective screening, consult with the Bridge Standards and Program Engineer during scoping to determine whether screening is appropriate to include with the overlay project.

SC OVERLAY DEPTH

On SC overlay projects, adjust nominal overlay depths according to the following guidelines:

- For depths of 2 to 3 inches: use a full depth SC overlay with no added reinforcing.
- For depths between 3 to 4 inches contact the [BDM Technical Resource](#) for options to decrease shrinkage.
- For depths 4 inches or greater: provide shear dowels from existing concrete to improve bond according to *Figure 1.9.4.7-1*.

Figure 1.9.4.7-1 Shear Dowel Detail



- For depths greater than 5 inches, include both shear dowels and temperature reinforcing steel. Dowels are designed for shear loading only.

**1.9.4.8 [Removed]**

**1.9.4.9 TP&DT / Stage Construction**

Temporary protection and direction of traffic (TP&DT) requirements are important design considerations and could control project cost, project scheduling and, as a result, the type of overlay. Urban projects or narrow roadway width structures may require very short overlay cure times that could limit the use of a SC overlay. Discuss traffic control issues early in the project with both region project development team and the Traffic Control Designer.

When stage construction is proposed, arrange the stage construction widths so that the overlay can be constructed in widths between 6 feet and 30 feet which are comfortable widths for SC overlay finishing machines and placement of PC overlays or ACWS. Avoid placing longitudinal construction joints in the wheel paths.

### **1.9.4.10 Quantity Estimates**

All overlays require the use of *SP 00504*. Bridge decks with existing ACWS also require *SP 00503*.

Use any necessary removal bid items, depending on the existing bridge deck surface. All existing overlay removal is measured by square yard. When the ACWS is too thick to be removed in one pass (i.e. greater than 2 inches), increase the unit cost for the additional passes required. For structures with ACWS, core samples may need to be taken to determine the thickness. Identify any membranes present during coring operations. Bonded waterproofing membranes, such as spray-on or polymer membranes have an additional bid item in *SP 00504* for removal. Fabric membranes are removed as incidental to *SP 00503*.

Once the existing overlay or membrane is removed, the deck is prepared per *SP 00504*. Class 1 Preparation takes place in areas where no additional concrete removal is necessary to reach sound concrete. This level of preparation is not measured and payment for it is included in the construction of the new overlay.

Class 2 Preparation is any removal of unsound concrete that does not extend the full depth of the deck. It is measure by the square yard. The repair method and pay item for Class 2 preparation varies depending on the new overlay type.

Class 3 Preparation is any removal that extends through the entire deck. Class 3 Deck Preparation is usually required due to severe deep delaminations, a severely cracked deck in all directions, a badly spalled bottom deck or poor aggregates. In most cases, the quantity of Class 3 Deck Preparation is very small. If so, no bid item is necessary. The work will normally be performed on an extra work basis.

When there is a known quantity, a separate bid item should be used. The quantity should be estimated after consulting with maintenance and the bridge inspector. A field visit may be required. Additional Class 3 Deck Preparation beyond the known quantity can then be paid for as extra work.

A deck survey is required to confirm the estimated quantity of both Class 2 and Class 3 Deck Preparation. Visual inspection and sounding (e.g. chain drag) are the primary methods for determining quantities. Advanced non-destructive evaluation (NDE) methods, such as infrared scanning, impact echo, or ground penetrating radar (GPR) have been used in limited, high-risk, environments. Consult with Structure Services prior to using advanced methods.

A typical SC overlay for a bridge deck consists of the following structure bid items in addition to any Removal items:

- Class 2 preparation for SC Overlay Installations (per sy)- *SP 00504*.
- Furnish Concrete Overlay (per cy) – *SP 00559*.
- Construct SC Resurfacing (per sy) – *SP 00559*.
- Saw Cut Texturing (per sy) – *SP 00559*.

Class 1 Deck Preparation, which is not paid or measured separately from the overlay placement, includes roughening the surface to a surface texture depth profile of 1/8 in.

Furnish Concrete Overlay – Calculate this quantity from the Class 1 deck preparation area and a depth of 1/2 inch greater than the specified minimum depth. This increase accounts for field quantity overruns due to minor grade corrections and irregular Class 1 deck preparation.

When Class 2 deck preparation has been identified, add that quantity into the **Furnish Concrete Overlay** total. Work with the roadway designer to confirm that the 3D model, when available, and roadway finish grade profile match the estimated overlay quantities.

Construct SC Resurfacing – This quantity is typically measured for gutter to gutter and end joint to end joint.

A typical PC overlay for a bridge deck consists of the following structure bid items in addition to any removal bid items:

- Class 2 Preparation (per sy) – *SP 00504*.
- Furnish MPCO Material (per sy) – *SP 00556*.

Or

- Furnish PPC Material (per cy) – *SP 00557*.
- Construct PC Concrete Overlay (per sy) – *SP 00556* or *SP 00557*.

Deck Preparation - Deck preparation for PC overlays is constructed per *SP 00504*. Class 1 Preparation for PC Overlays requires roughening the existing deck to a 1/16 inch surface texture profile depth. Class 2 Preparation for PC Overlays includes repairing the deck with a PCC repair material at least 5 days prior to placing the overlay.

Furnish PC concrete overlay – Calculate this quantity from deck area (gutter to gutter and end joint to end joint) and a depth of 1/8 inch greater than the specified nominal depth.

Construct PC concrete overlay – Calculate this quantity from the deck area (gutter to gutter and end joint to end joint).

A typical ACWS for an existing bridge deck consists of the following bid items:

- Bridge Deck Cold Plane Pavement Removal (per sy) – *SP 00503*.
- Class 2 Preparation (per sy when needed) – *SP 00504*.
- Membrane waterproofing (per sy).
- Asphalt concrete mixture (per ton).

The membrane waterproofing bid item includes full compensation for applying the membrane waterproofing system and the asphalt tack coat.

The asphalt concrete bid item is typically the responsibility of the roadway designer. Communicate with the roadway designer to make sure all the bid items are covered.

In addition to these bid items, the following items may also be required:

- Deck joints (each or linear feet).
- Deck drain construction (each).
- Bridge rail retrofit or replacement (linear feet).
- Reinforced concrete approach slabs (per sy).

### 1.9.4.11 Preparing Plans and Specifications

Use detail reference notes to indicate the overlay construction work required and other work, such as:

- Construction of approach slabs.
- Construction of paving ledges.
- Deck drain raising locations.
- Expansion joint work.
- Bridge rail retrofit or replacement.
- Bridge rail transition retrofit or replacement.
- Protective fencing.
- Stage construction (coordinate with the Traffic Control Plans Unit).

Miscellaneous details may need to be added to clarify the work to be done in specific areas. These details can be placed on the plan sheet or a second sheet when more space is required.

When stage construction is used, temporary concrete barrier may be required on the bridge deck. Check with the Traffic Control Designer for recommendations. See [BDM 1.13.1.10](#) for temporary barrier detailing and anchorage requirements.

Indicate in the **Designer's Notes to Specifications** under which bid item the miscellaneous details are to be paid for. Expansion joints and deck drain work may be paid for under the bid item for overlay construction when the cost is minor. Approach slabs, paving ledges, bridge railing and protective fencing will need separate bid items.

## 1.10 FOUNDATION CONSIDERATIONS

### [1.10.1 Foundations, General](#)

### [1.10.2 Lateral Earth Restraint](#)

### [1.10.3 Underwater Construction](#)

### [1.10.4 Foundation Modeling \(Foundation Springs\)](#)

### [1.10.5 Foundation Design](#)

### 1.10.1 Foundations, General

The geotechnical designer will provide data and recommendations with respect to types of footings, footing elevations, nominal and factored resistances, types of piling, pile tip reinforcing, and drilled shaft tip elevations which are to be used at each bridge site. The designer should be satisfied that the recommendations are adequate with respect to factored loads and economy. When there are questions in this matter, they should be discussed with the geotechnical designer. Special factors in the type of construction selected may cause a reconsideration of the original recommendation. Some basic guidelines include:

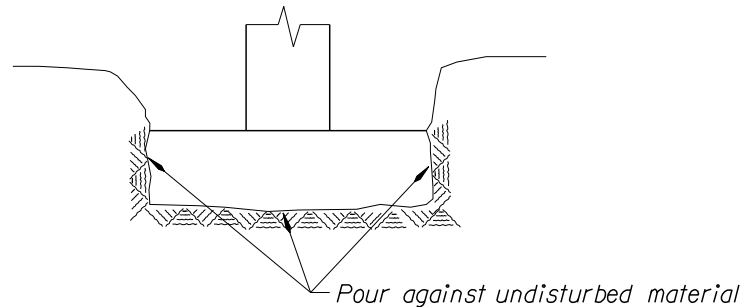
- When the Geotechnical Report is not available, the fact should be noted and the basis for the design of the footings should be indicated.
- Except for special cases, provide a minimum of 2 feet of cover over the top of spread footings.
- Make the top of footings within the right of way of the Union Pacific Railroad a minimum of 6 feet below the bottom of the low rail to allow for future underground utilities.

### 1.10.2 Lateral Earth Restraint

When passive earth pressures are used in design to resist seismic or other lateral loads, detail the plans to ensure assumed soil conditions exist after construction. Where possible, plans should specify placing footings against undisturbed material. The soil type may be such that it will not stand vertically after excavation. When soil is disturbed, *SP 00510.41* requires backfilling with compacted granular material. When there are questions concerning this, consult with the geotechnical designer. When the excavation will not stand vertically, add a reference note, **See Standard Specifications for Construction** to the **Structure Excavation Limits** detail shown on the plans. The Contractor will be allowed to excavate beyond the

footing limits and backfill with compacted granular structure backfill (*SP 00510.46*). When footings, such as pile supported, etc., do not require the lateral soil resistance for stability, then do not call for pouring against undisturbed material.

Figure 1.10.2-1 Lateral Earth Restraints



## 1.10.3 Underwater Construction

### 1.10.3.1 Underwater Foundation Design Considerations

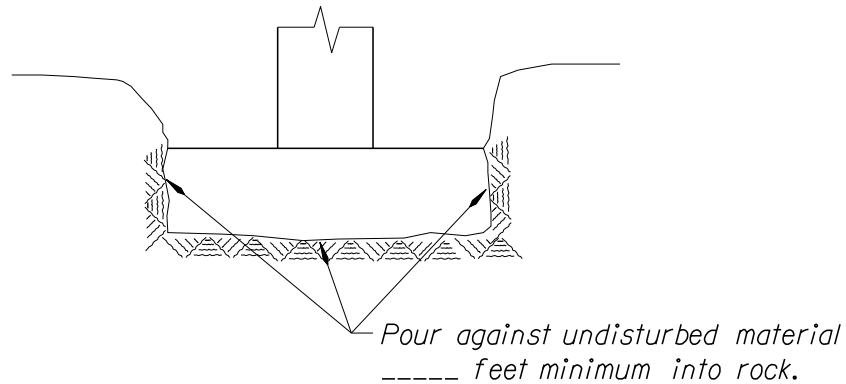
- Requirements for scour protection, potential scour depths and elevations, recommendations for riprap protection can be found in the Hydraulic Report.
- The seal size, which ultimately determines the cofferdam size should be large enough to accommodate the footing plus footing forms inside the cofferdam walers. A minimum of 2 feet on each side of the footing should be provided.
- Require the contractor to remove all underwater formwork.
- In streams where there is a potential for scour, riprap should be placed as soon as possible and before removal of the cofferdam.
- Scour calculations do not take into account debris loading. A pile of debris will cause a larger obstruction thereby increasing the scour depth.
- Streambeds are often **mobile** and the top few feet or so are moving downstream all the time. During extreme flood events the mobile streambed material cannot be counted on for protection.
- The depth component of the bearing resistance equation has the most significant contribution to the footing's ability to support the load.
- Riprap is not considered permanent protection against scour for seals.
- When placing a footing in a stream, the material around and over the footing has been reworked and doesn't have the in situ strength of the native streambed.
- Another factor that is not always taken into account during a scour calculation is that the stream may be degrading or have the possibility of degrading in the future.



### 1.10.3.2 Footing Embedment

On stream crossings and where horizontal forces are involved, the following sketch should appear on the plans if the foundation material is suitable.

Figure 1.10.3.2-1 Footing Note Callouts at Streams



The bottom of footings in streambeds shall be a minimum of 6 feet below the normal streambed, except in solid rock. When in solid rock, the top of the footing shall be flush with the rock line.

### 1.10.4 Foundation Modeling (Foundation Springs)

In foundation modeling it is common practice to first assume translational and rotational fixity of the foundation supports and perform a preliminary structural frame analysis. The resulting reactions are checked against the factored resistances. This procedure underestimates global deflections but establishes an upper bound for forces. This type of foundation modeling may be sufficient in certain loading conditions, such as thermal expansion, where deflections are not a controlling factor in design provided the forces are not excessive. However, under higher lateral loading conditions, such as moderate to severe seismic loading, more accurate deflections and forces are desirable. Excessively conservative design forces can be expensive to accommodate. In these cases, foundation springs are typically used in the structural frame analysis. The computer program such as Midas Civil or SAP2000 allows the use of these springs. Foundation springs are typically equivalent linear springs representing the translational (horizontal), axial (vertical) and rotational load-deflection behavior of a nonlinear soil response. The use of foundation springs can significantly reduce the upper bound foundation reactions and more accurately models the entire soil-structure interaction system. Nominal geotechnical resistances are typically used with seismic loading conditions unless otherwise directed by the geotechnical designer. Factored resistances are typically used for all

other load combinations. Factored resistance is the nominal resistance multiplied by the appropriate resistance factor.

### **1.10.4.1 General Modeling Techniques**

There are three options for foundation modeling:

- (Option 1) Fixed foundations.
- (Option 2) Fully coupled foundation spring model.
- (Option 3) Uncoupled translation and rotational springs.

Option 1 fixes all foundation supports in the computer model. The resulting forces are simply compared to the resistances stated either in the Geotechnical Report or as determined in this section of the design manual. When the resulting forces exceed the resistances, foundation modeling using springs is recommended.

Option 2 allows stiffness coupling for both shear and moment and also cross-coupling (off diagonal). This option is not required for most problems. This option should be used for drilled shafts, trestle piles and for some pile foundations where the piles are connected to the substructure or superstructure such that a fixed condition exists. A massive footing with deeply embedded piles is an example. The method is applicable to all types of foundations.

Option 3 is the most commonly used method to represent footing and piling flexibility. It is a simplified version of the fully coupled spring model (Option 2) and is used in cases where there is no significant moment transfer between superstructure and foundation elements. This option is appropriate for most problems except as noted in Option 2 above. Use this option with vertical piling only. Battered piles result in larger lateral stiffness, which this option does not presently address.

### **1.10.4.2 General Procedures and Typical Values**

The following guidelines are provided for Option 3 as general information, and are intended to be supplemented with engineering judgment. Methods are presented for developing foundation springs, including factored and nominal resistances, for the following foundation types:

- Abutments and wingwalls.
- Spread footings.
- Piles and pile caps.

Foundation springs are typically nonlinear in form although some are represented in bilinear form. The curve typically consists of an initial (straight line) stiffness followed by a nonlinear relationship leading up to a nominal resistance. Various methods are used, depending on the type of spring, to develop the entire nonlinear load-deflection curve (spring).

The procedures described in this section, and typical values, come from the following sources:

- *Seismic Design of Highway Bridges*, Workshop Manual by Imbsen & Associates, Inc., prepared for the FHWA, October, 1989.
- *Design and Construction of Driven Pile Foundations*, FHWA Workshop Manual, Volume 1, December, 1996.
- Design Manual 7.2, *Foundations and Earth Structures*, Dept. of the Navy, May, 1982.
- *Foundation Analysis and Design*, (4th ed.) by Joseph E. Bowles.
- *Design Manual for the Foundation Stiffnesses Under Seismic Loading*, prepared for Washington DOT by Geospectra, April, 1996.
- *Design Guidance: Geotechnical Earthquake Engineering For Highways*, Volumes I & II; FHWA Report No. *FHWA-SA-97-076-77*, May, 1997.
- Pile capacity and stiffness work done by Bridge Engineering and Geotechnical Group personnel in 1996 and 1997.

Standard Penetration Test (SPT) numbers presented in the Design Manual ( $N_c$  values) refer to  $N$  values for granular soils corrected to an effective overburden pressure of 1 tsf. Uncorrected  $N_c$  values should be used for cohesive soils. The geotechnical designer should be consulted for representative values to use in these methods.

#### 1.10.4.2.1 Abutments and Wingwalls

Use translational springs in both the longitudinal and transverse directions.

##### TRANSLATIONAL STIFFNESS

The abutment and wingwall translational stiffness should account for displacements resulting from expansion joints associated with seat abutments.

Initial backfill stiffness, is determined by the backfill of the abutment and wingwalls. Wingwalls should be modeled similar to the abutment. Direction of the wingwall contribution is into the approach fill. The initial stiffness should be adjusted proportional to the backwall width and height according to the following equation where the height of the backwall is normalized (Maroney 1995).

Use this value for unknown backfill or when the backfill does not meet the requirements shown on *DET3160*.

$$k_i = \frac{20 \frac{\text{kips}}{\text{in}}}{ft}$$

When the approach fill is constructed/reconstructed using granular structure backfill and meeting the limits shown on *DET3160* the following value for initial stiffness can be used.

$$k_i = \frac{50 \frac{\text{kips}}{\text{in}}}{ft}$$

The stiffness of the abutment is calculated with the following:

$$K_{abut} = k_i * W * \frac{H}{5.5ft}$$

Where:

$$k_i = \text{the initial stiffness with units of } \frac{\text{kips}}{\text{in}} \text{ per } \frac{\text{ft}}$$

$W$  = the width of the abutment with units of ft

$H$  = the height of the abutment with units of ft

Piles: Refer to *Pile Supported Footings and Abutments* (see *BDM 1.10.4.2.4*). Use pile translational stiffnesses in tables below for loading conditions other than seismic. For seismic loading conditions, perform an analysis using soil response program such as LPILE. Consult with the geotechnical designer to verify LPILE soil properties.

### TRANSLATIONAL CAPACITIES

The passive force resisting the movement at the abutment is modeled using a bi-linear curve with respect to displacement. The ultimate static passive force should be calculated using the following equation. Maximum passive force can only be applied once the soil has been mobilized. Acceptable passive mobilization values are found in *AASHTO Table C.3.11.1-1*. When the wall is backfilled with a medium dense sand or compacted silt a value of

**0.02H** (where  $H$  is the height of the wall in ft) should be used. When granular structure

backfill is used to fill the active and passive wedge a value of **0.01H** should be used to determine if mobilization occurs. Only when this deformation is equal to or exceeds this value, then the ultimate passive force can be employed.

$$F_{ult} = WH^2 \frac{5ksf}{5.5ft}$$

Where:

$F_{ult}$  = the maximum passive force with units of kips

$W_{bw}$  = the width of the backwall in feet

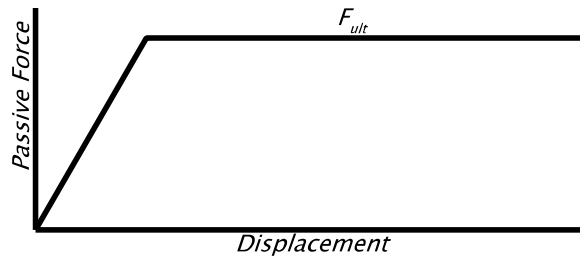
$H_{bw}$  = the height of the backwall and cap in feet

Piles: For seismic loading, use ultimate values derived from LPILE analysis by comparing the maximum yield moment of the pile to the maximum moment output from LPILE. Take end slope and side slope effects into account. Generally assume dense granular fill representing granular wall backfill. This material should be present in the entire passive wedge area. Consult with the geotechnical designer to verify LPILE soil properties. Use allowable pile capacities in tables below for loading conditions other than seismic.

TRANSLATIONAL LOAD-DEFLECTION CURVE

Use the initial stiffness up to the capacity limit. The curve form is:

Figure 1.10.4.2.1-1 Translational Load Deflection Curve



1.10.4.2.2 Skewed Abutments with Wingwalls

Recent large scale testing and numerical modeling of skewed abutments with wingwalls parallel with the roadway show a significant reduction in passive pressure as well as increased displacements, and increased bending moment that must be accounted for in design (Rollins and Snow, 2019). When the abutment is skewed the passive force calculated above is further reduced using the following and applied perpendicular to the skewed bent.

$$F_{ult-skew} = F_{ult} * R_{skew}$$

$$R_{skew} = e^{-\frac{\theta}{45}}$$

Where:

$F_{ult}$  = the maximum static passive resistance.

$F_{ult-skew}$  = the ultimate static passive resistance on a skewed bridge permitted by ODOT.

$\theta$  = skew angle of the bridge with units of degrees

$R_{skew}$  = the reduction factor

To allow for modeling of the bridge in the longitudinal direction the ultimate static passive resistance distribution is modified by increasing it at the obtuse corner of the bridge deck by 1.25 and decreasing at the acute corner by 0.75 as shown in the *Figures 1.10.4.2.2-1 and 1.10.4.2.2-2*.

Figure 1.10.4.2.2-1 Skewed Abutment Loading, Plan View

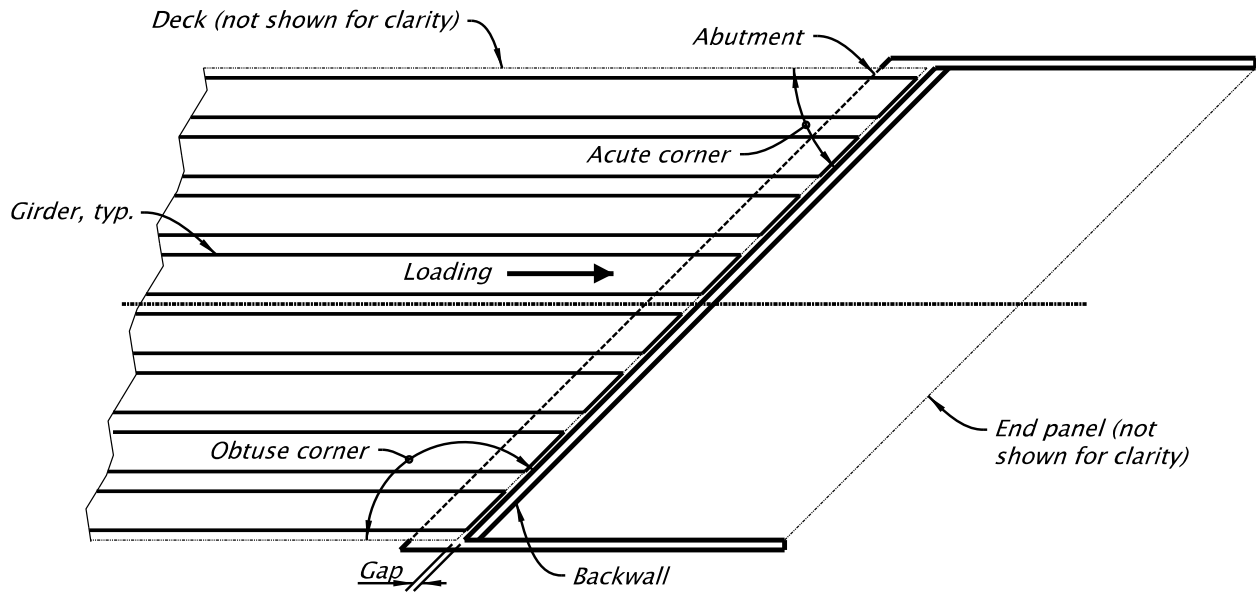
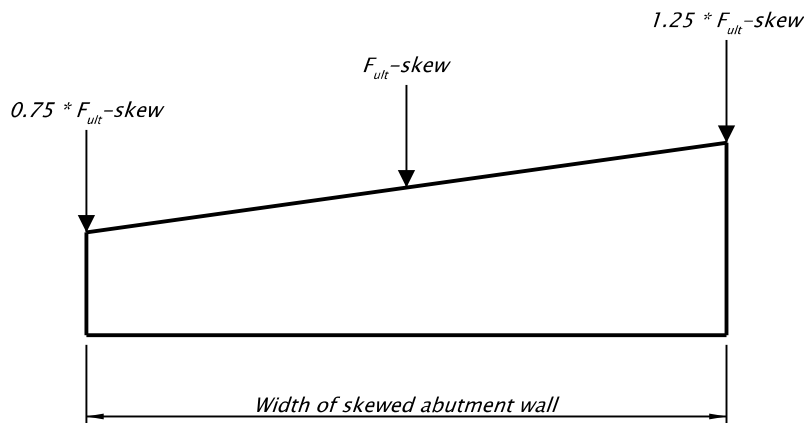


Figure 1.10.4.2.2-2 Skewed Abutment Loading, Elevation View



### 1.10.4.2.3 Spread Footings

Unless constructed on solid bedrock, use translational and rotational springs in both the longitudinal and transverse directions. In general, footings keyed into a rock mass that has an elastic (Young's) modulus typically greater than 14,000 ksf (Unconfined Compressive Strength = 1000 psi) can be considered **fixed** against both rotation and translation. Consult with the geotechnical designer to determine the compressibility of very soft or highly fractured bedrock materials.

TRANSLATIONAL AND ROTATIONAL STIFFNESSES

Use the equivalent circular footing formulas with information from *Table 1.10.4.2.3-1*, to develop translational and rotational spring constants. Consult with the geotechnical designer for the appropriate soil values to use in *Table 1.10.4.2.3-1*.

Table 1.10.4.2.3-1 Soil Properties

Soil Classification	SPT "Nc"*	E (ksf)	Poisson's Ratio (ν)	G (ksf)
Granular				
V. Loose	4	300	.35	110
Loose	10	1000	.35	370
Medium	30	2000	.35	750
Dense	50	3000	.35	1100
Cohesive				
Soft	4	400	.50	150
Stiff	8	1000	.50	350
Very Stiff	16	1500	.50	500
Hard	32	2000	.50	650
* <b>Nc</b> is the average of <b>Nc</b> values over a depth of 2B below the footing, ( <i>B = footing width</i> ).				

STIFFNESS CALCULATIONS FOR SPREAD FOOTINGS

Spring constants for rectangular footings are obtained by modifying the solution for a circular footing bonded to the surface of an elastic half-space. The formula is as follows where:

*k* = initial stiffness (spring constant)

*α* = foundation shape correction factor; (from graph)

*β* = embedment factor, (from graph)

*K<sub>0</sub>*  
= stiffness coefficient for the equivalent circular footing (see formulas in *Table 1.10.4.2.3-2*)

The stiffness term, *K<sub>0</sub>*, is calculated using the equations in *Table 1.10.4.2.3-2*.

Table 1.10.4.2.3-2 Stiffness Equations for Spread Footings

Displacement Degree-of-Freedom	$K_0$
Vertical translation	$4GR/(1 - \nu)$
Horizontal translation	$8GR/(2 - \nu)$
Torsional rotation	$16GR^3/3$
Rocking rotation	$8GR^3/(3(1 - \nu))$
Note: G = Shear Modulus (low strain range) $\nu$ = Poisson's ratio for elastic half-space material R = Equivalent footing radius as determined from the following equations	

Figure 1.10.4.2.3-1 Equivalent Radii, R, for Rectangular Footing Spring Constants

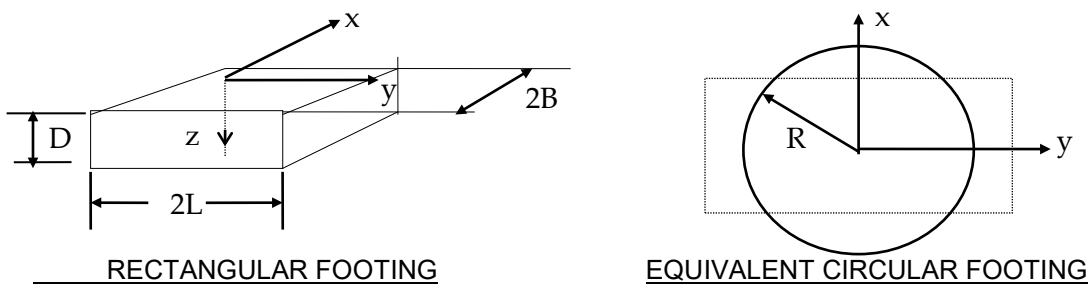




Figure 1.10.4.2.3-2 Shape Factors for Rectangular Footings

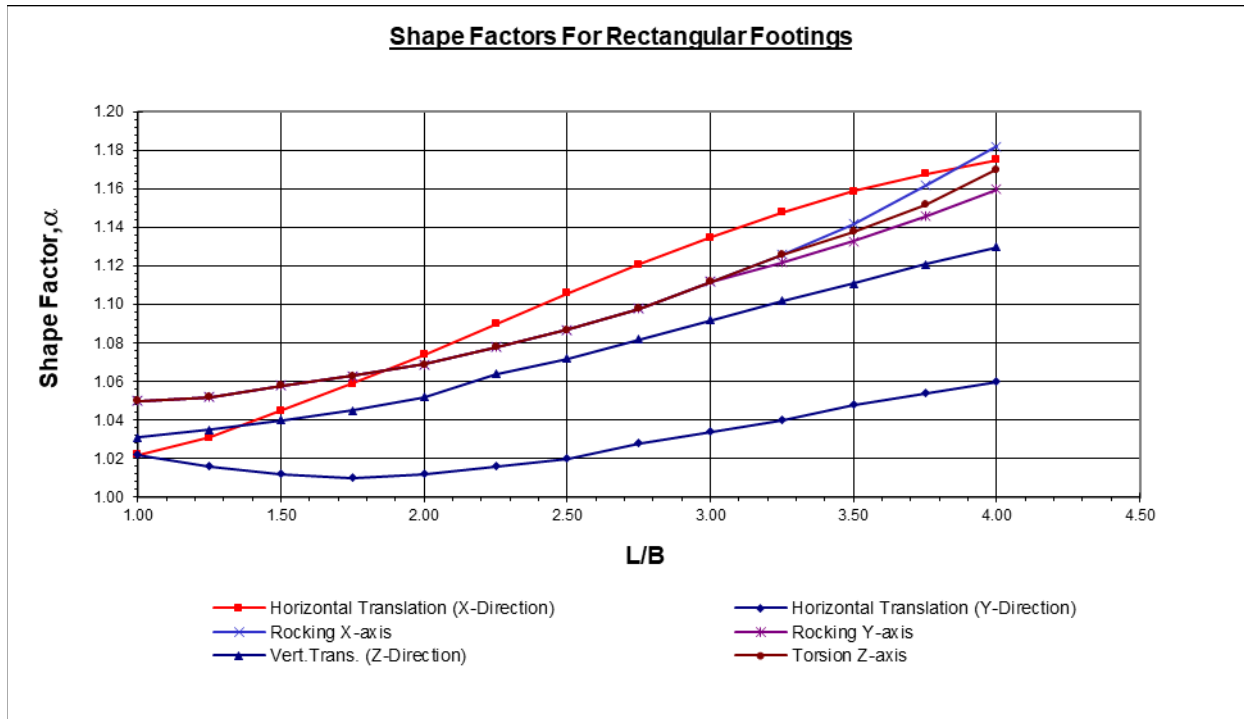
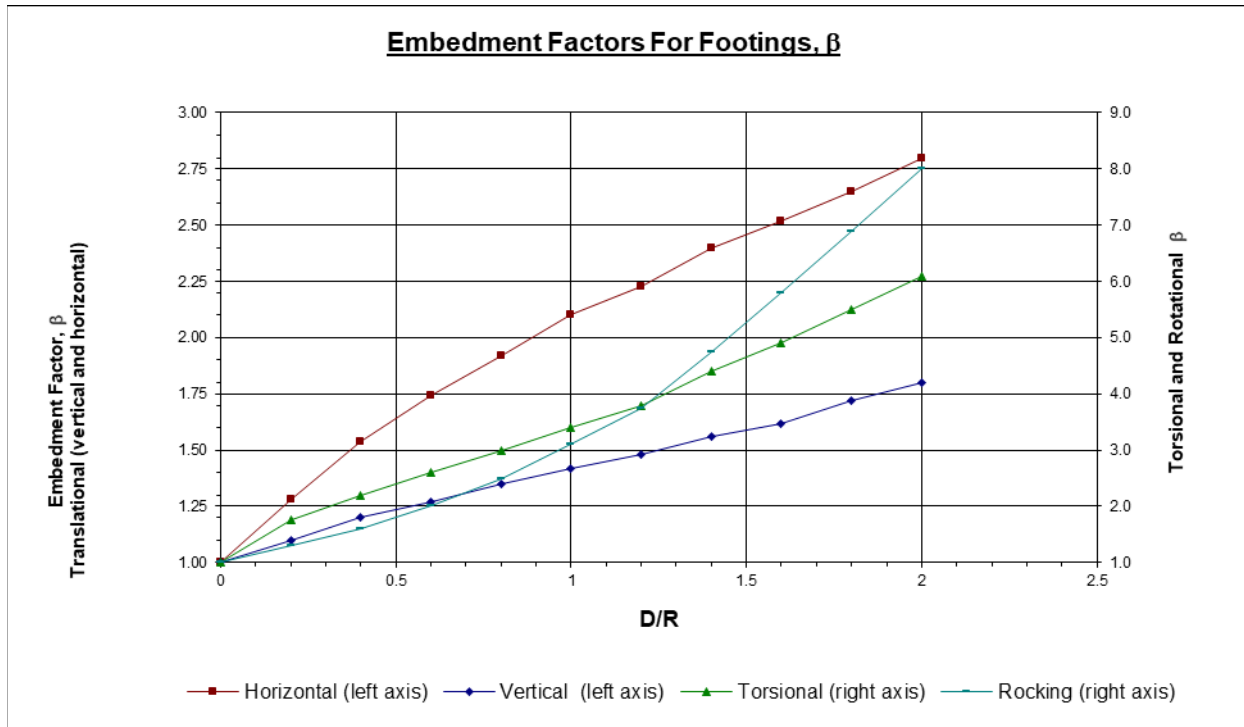


Figure 1.10.4.2.3-3 Embedment Factors for Footings,  $\beta$



EQUIVALENT RADIUS:

TRANSLATIONAL:

$$R = \sqrt{\frac{4BL}{\pi}}$$

ROTATIONAL:

$$R = \left[ \frac{(2B)(2L)^3}{3\pi} \right]^{1/4} \quad ; \text{ for x-axis rocking}$$

$$R = \left[ \frac{(2B)^3(2L)}{3\pi} \right]^{1/4} \quad ; \text{ for y-axis rocking}$$

$$R = \left[ \frac{4BL(4B^2 + 4L^2)}{6\pi} \right]^{1/4} \quad ; \text{ for z-axis torsion}$$

### TRANSLATIONAL CAPACITIES

The use of the following values depends on the footing construction method (i.e. formed with backfill material or poured against undisturbed material). Only the passive resistance developed from the front face of the footing, combined with the shear resistance along the

footing base, is considered. Column and footing side resistance is neglected. Consult with the geotechnical designer for recommended soil properties, groundwater levels and proper effective unit stress to use in the analysis. Also consider scour effects.

Use the values from *Table 1.10.4.2.3-3* in the general formula:

$$\begin{aligned} \text{Force Capacity} &= (Kp \times \text{effective unit stress} \times \text{footing face area}) \\ &+ (Su \times \text{footing face area}) + (\Sigma \times \text{support reaction}) \\ &+ (Su \times \text{footing base area}) \end{aligned}$$

Use appropriate components depending upon soil type. Consult with the geotechnical designer for the appropriate soil values to use.

Note: *Effective Unit Stress* = (*Buoyant Unit Weight*  $\times$  *Depth to middle of footing*)

Table 1.10.4.2.3-3 Translational Capacities

Soil Classification	SPT "Nc"	STATIC CAPACITY			Total Unit Wt. (k/ft <sup>3</sup> )
		K <sub>p</sub>	Su (ksf)	μ	
<b>Granular</b>					
V. Loose	4	2.7	0	.34	0.090
Loose	10	3.0	0	.40	0.100
Medium	30	3.7	0	.47	0.115
Dense	50	4.6	0	.56	0.120
<b>Cohesive</b>					
Soft	4	-	0.5	-	N.A.
Stiff	8	-	1.0	-	N.A.
Very Stiff	16	-	2.0	-	N.A.
Hard	32	-	4.0	-	N.A.

Deflection required to fully activate capacities (©max):

Granular:

$$Loose = .06H$$

$$Dense = .02H$$

Cohesive:

$$Soft = .04H$$

$$Stiff = .02H$$

$$H = \text{Soil surface to middle of footing depth}$$

Specific applications may require the use of less than the full capacity due to deflection restrictions.

### ROTATIONAL CAPACITIES

The rotational capacity is typically determined by comparing the total footing pressure, including the overturning moment, to the factored bearing resistance provided in the Geotechnical Report, unless otherwise directed by the geotechnical designer. The bearing resistance of footings with overturning moments and eccentricity are determined using **effective** footing dimensions.

**TRANSLATIONAL LOAD-DEFLECTION CURVE**

The following equation may be used in conjunction with the translational stiffnesses and capacities for developing a translational load-deflection curve for spread footings and pile caps.

$$P = \frac{\Delta}{\frac{1}{k_{max}} + \left[ R_f \times \frac{\Delta}{P_{ult}} \right]}$$

where: *P* = Load at deflection  $\Delta$

*P<sub>ult</sub>* = Ultimate passive force (neglect base shear for pile caps)

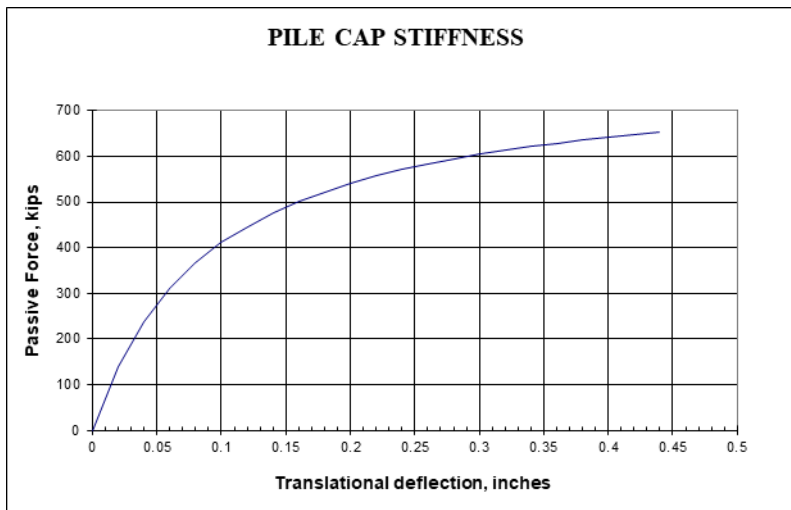
*k<sub>max</sub>* = Initial stiffness

*R<sub>f</sub>* = Ratio between the actual and the theoretical ultimate force. *R<sub>f</sub>* can be determined by substituting  $\Delta_{max}$  from the previous section for  $\Delta$  and *P<sub>ult</sub>* for *P* in the above equation and solving for *R<sub>f</sub>*.

$\Delta$  = Translational deflection, inches

An example of the use of this equation is given below. This graph represents the form of the equation only.

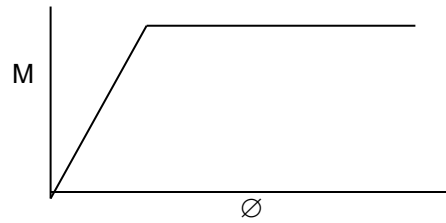
Figure 1.10.4.2.3-4 Pile Cap Stiffness



**ROTATIONAL LOAD-DEFLECTION CURVE**

Use the initial stiffness up to the capacity limit. The curve form is show in *Figure 1.10.4.2.3-5*.

Figure 1.10.4.2.3-5 Rotational Load-Deflection Curve Form



#### 1.10.4.2.4 Pile Supported Footings and Abutments

Use translational and rotational springs for pile supported footings in both the longitudinal and transverse directions. This approach is recommended in cases where seismic loading is the controlling factor in the structural frame analysis. Springs may also be used to model pile supported footings in non-seismic conditions at the designer's discretion. Nominal resistances may be used for both non-seismic and seismic design conditions unless otherwise recommended by the geotechnical designer.

In cases where seismic loading is not the maximum group loading for the structure, the stiffnesses and nominal lateral resistances given in the following tables are acceptable for most design cases, provided the site conditions generally satisfy the assumptions made in developing these values. In general, for soils with  $N_c$  values less than four, the pile translational stiffness should be evaluated using a soil response program such as LPILE programs and the geotechnical designer should be consulted for further guidance.

The use of battered piles is generally discouraged due to the greatly increased stiffness contribution from the battered piles. This in turn can result in excessive battered forces and induce undesired or unrealistic uplift forces in adjacent piles. In lieu of battered piles, it is recommended to use vertical piles throughout the footing.

Refer to the seismic design example problem for further clarification.

#### TRANSLATIONAL STIFFNESSES

Normally the translational stiffness should include the lateral pile stiffnesses (total pile group stiffness) plus the passive soil stiffness on one side of the footing. Typically, a single lateral pile-head stiffness is estimated from either the pile-top, load-deflection curve generated by LPILE soil response program output or from pile stiffness values given in the following tables. This single pile-head stiffness is then multiplied by the number of piles in the group and the resulting group stiffness value is then multiplied by a group reduction factor depending on pile spacing. Instead of using a group reduction factor, account for pile group effects using p-y curve multipliers as described under **Pile Group Reduction Factors and p-y Multipliers**.

Pile cap, or footing, stiffnesses should be developed using the methods described under **Spread Footings**, except the soil stiffness contribution along the base of the pile cap should be neglected. This is accomplished by calculating the stiffness of the pile cap (footing) at the ground surface ( $D = 0$ ) and subtracting this value from the stiffness calculated for the

embedded pile cap footing. The resulting stiffness curve is then combined with the pile group stiffness curve as described in **Translational Load-Deflection Curve**.

**SEISMIC CONTROLLED LOADING CONDITION – EXTREME EVENT LIMIT STATE**

The pile-head translational stiffness curve is generated using a soil response program such as LPILE using soil input parameters supplied by the geotechnical designer. Pile head boundary conditions (fixed, free or fixed-translational) must be assigned by the designer. Refer to the LPILE computer program manuals. This method is shown in *Figure 1.10.4.2.4-1*.

**NON-SEISMIC LOADING CONDITIONS**

Use the following pile stiffnesses for non-seismic loading conditions provided the site conditions generally satisfy the assumptions given.

Table 1.10.4.2.4-1 Pile Translational Stiffness (kip/inch) – HP Piles

Axis - W=Weak S=Strong	SPT "Nc"*	HP 10x42		HP 12x53		HP 12x74		HP 14x89		HP 14x117	
		W	S	W	S	W	S	W	S	W	S
Granular											
V. Loose	4	5	8	6	10	7	11	9	13	10	14
Loose	10	12	14	12	18	14	20	16	24	18	24
Medium	30	16	20	18	27	20	30	25	38	28	41
Dense	50	25	34	29	44	31	46	40	61	44	64
Cohesive											
Soft	4	2	2	2	3	2	3	3	4	3	4
Stiff	8	4	6	5	7	6	8	7	9	7	9
Very Stiff	16	8	10	9	12	10	13	12	15	12	16
Hard	32	14	19	17	22	18	24	21	27	23	30

Table 1.10.4.2.4-2 Pile Translational Stiffness (kip/inch) – Pipe Piles

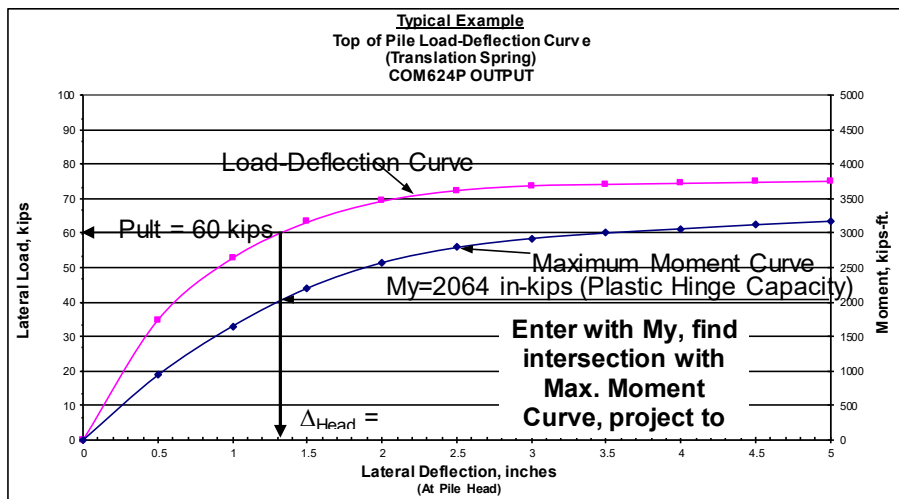
Pipe Piles	SPT "Nc"*	12x 0.25	12x 0.38	16x 0.38	16x 0.50	24x 0.38	24x 0.50
Granular							
V. Loose	4	7	8	11	12	20	22
Loose	10	14	15	20	21	33	37
Medium	30	20	23	29	34	48	57

Dense	50	32	37	46	54	81	87
Cohesive							
Soft	4	2	3	3	3	4	4
Stiff	8	6	7	8	9	11	12
Very Stiff	16	10	11	13	14	18	18
Hard	32	18	20	24	26	34	36

Table 1.10.4.2.4-3 Pile Translational Stiffness (kip/inch) – Prestressed Piles

Prestressed Piles	SPT "Nc"*	12 inch	14 inch	16 inch
Granular				
V. Loose	4	8	8	11
Loose	10	12	14	19
Medium	30	22	24	28
Dense	50	34	38	45
Cohesive				
Soft	4	3	3	3
Stiff	8	7	7	8
Very Stiff	16	12	12	14
Hard	32	22	23	26

Figure 1.10.4.2.4-1 Example of Top of Pile Load-Deflection Curve (Translational Spring)





**TRANSLATIONAL CAPACITIES**

The base shear resistance of pile supported footings, or caps, is typically not included in calculating the nominal passive resistance. The same equation used for determining the nominal translational capacity of footings should be used for pile caps, neglecting all base shear resistance. The nominal passive resistance of pile caps can be used for both seismic and non-seismic design conditions.

Use the nominal resistances in the following table for non-seismic loading conditions provided the site conditions generally satisfy the assumptions given.

Table 1.10.4.2.4-4 Nominal Pile Translational Resistances (kip/inch) – HP Piles

H-piles W=Weak S=Strong	SPT "Nc"*	HP 10x42		HP 12x53		HP 12x74		HP 14x89		HP 14x117	
		W	S	W	S	W	S	W	S	W	S
Granular											
V. Loose	4	12	21	14	25	25	43	29	50	41	69
Loose	10	13	23	16	27	28	48	33	55	46	82
Medium	30	16	26	17	31	31	53	37	62	51	86
Dense	50	17	29	20	34	34	59	41	69	57	93
Cohesive											
Soft	4	16	25	17	28	29	47	34	53	45	69
Stiff	8	20	34	22	37	38	63	43	70	59	94
Very Stiff	16	24	43	25	47	49	83	55	90	76	122
Hard	32	30	54	29	58	58	104	63	113	92	155

\*The **Nc** values to use are the averaged **Nc** values over a depth of 8 to 10 pile diameters (8D to 10D).

Table 1.10.4.2.4-5 Nominal Pile Translational Resistances (kip/inch) – Pipe Piles

Pipe Piles	SPT "Nc"*	12x 0.25	12x 0.38	16x 0.38	16x 0.50	24x 0.38	24x 0.50
Granular							
V. Loose	4	22	29	43	52	85	103
Loose	10	25	32	48	57	95	113
Medium	30	29	37	54	65	107	130
Dense	50	31	41	60	71	118	143
Cohesive							
Soft	4	26	34	46	55	82	98
Stiff	8	34	44	60	72	104	126
Very Stiff	16	42	56	74	91	130	158
Hard	32	50	69	91	110	151	187
*The <b>Nc</b> values to use are the averaged <b>Nc</b> values over a depth of 8 to 10 pile diameters (8D to 10D).							

Table 1.10.4.2.4-6 Nominal Pile Translational Resistances (kip/inch) – Prestressed Piles

Prestressed Piles	SPT "Nc"*	12 inch	14 inch	16 inch
Granular				
V. Loose	4	12	16	23
Loose	10	15	18	25
Medium	30	18	20	29
Dense	50	20	23	31
Cohesive				
Soft	4	18	19	25
Stiff	8	22	23	31
Very Stiff	16	27	27	36
Hard	32	29	29	43
*The <b>Nc</b> values to use are the averaged <b>Nc</b> values over a depth of 8 to 10 pile diameters (8D to 10D).				

The above translational stiffnesses and allowable capacities are based on the Broms’ method and the following assumptions:

- Free head condition, no applied moment.
- Pile top at the ground surface.
- Level ground surface.
- One, uniform soil layer with uniform soil properties.
- No groundwater.
- Static loading, no cyclic soil degradation.
- Constant pile properties and dimensions.
- Stiffnesses are for first ½ inch deflection (initial secant modulus).
- Values are for **long** pile conditions and minimum pile embedment depths are required. When pile lengths are less than 75 percent of the assumed penetration lengths in *Table 1.10.4.2.4-7*, a separate Broms’ or LPILE analysis is required.

Table 1.10.4.2.4-7 Pile Penetration Lengths

Soil Classification	“Nc”	Assumed Length (feet)
Granular	4	55
	10	50
	30	40
	50	35
Cohesive	4	55
	8	50
	16	40
	32	35

The geotechnical designer should be consulted for piles installed in conditions outside of the above stated assumptions and/or a LPILE analysis should be performed.

For seismic design conditions, the maximum moment capacity of the pile (My) must be calculated separately and compared to the LPILE output to determine the nominal lateral resistance and associated deflection. An example is shown in *Figure 1.10.4.2.4-1*.

**TRANSLATIONAL LOAD-DEFLECTION CURVE**

Translational Load Non-seismic - Deflection estimates for piles designed under non-seismic conditions should be determined using the initial pile stiffness values given in the above tables

extended up to the nominal pile resistance (bilinear curve). This curve, representing the pile group, is then added to the load-deflection curve developed for the pile cap. A LPILE analysis may also be used as described below if so desired.

Translational Load Seismic - Deflection estimates for seismic design conditions are determined from the composite load deflection curves developed by combining the pile group stiffness from the LPILE analysis with the stiffness contribution from the pile cap. An example of this procedure is provided in the section on **Load-Deflection Curves, Stiffness Iteration Analysis and Capacity Checks**.

### **PILE GROUP EFFECTS AND P MULTIPLIERS**

The P multiplier approach, utilizing the LPILE program, is recommended to evaluate the response of pile groups subjected to lateral loads. The P multipliers are applied to standard p-y curves to account for pile group effects. *LRFD 10* should be referenced for the P multiplier values to be used in the analysis. The P multipliers are dependent upon the center to center spacing of piles in the group in the direction of loading expressed in multiples of pile diameter. The geotechnical designer should be consulted for the procedures to use in this design approach.

### **ROTATIONAL STIFFNESSES**

Normally the rotational stiffness should only include the moment versus rotation stiffness from the pile group. The pile cap is usually considered rigid in this analysis and no additional stiffness due to soil bearing at the base of the pile cap/footing is included. Therefore, the rotational stiffness of pile caps is simply a function of pile axial compression and the pile group layout. See the example problem in the Bridge Example Designs notebook for more details. Static formulas for pile compression are typically used. The computer program APILE may also be used for a more detailed analysis of the predicted load-deflection behavior of a single, axially loaded pile. This program takes into account unusual soil conditions and the nonlinear aspects of pile-soil interaction. The geotechnical designer should be consulted for axial pile stiffnesses using the APILE program.

The following formulas for axial pile stiffness may be used in developing rotational stiffnesses for pile supported footings. For friction piles, the APILE program may also be utilized to better model axial stiffness when axial loads are greater than about half of the nominal resistance of the pile.

End bearing pile:	where:
$K_v = \frac{AE}{L}$	$K_v = \text{Axial Pile Stiffness (kN/mm)}$
Friction Piles:	$A = \text{Area of pile normal to load}$
$K_v = \frac{2AE}{L}$	$L = \text{Length of pile}$
	$E = \text{Young's Modulus of Pile Material}$

Compute the rotation stiffness (M vs.  $\emptyset$ ) for a pile group as follows:

Assume a pile head deflection for the pile farthest from the pile group centroid.

Using the appropriate relation from above, determine the pile force accompanying this assumed pile head deflection. Prorate the other pile forces by their location relative to the group centroid. Piles on one side of the centroid will have positive forces and piles on the other side will have negative forces (uplift).

Determine the pile group moment by summing the product of the pile force and the pile-to-group centroid distance for all piles. This is the moment (M) required to rotate the footing through an angle of  $\emptyset$ . Determine the angle  $\emptyset$  as the arctan of the assumed extreme pile head deflection divided by the pile-to-centroid distance.

The relation of M to  $\emptyset$  is the initial rotation stiffness.

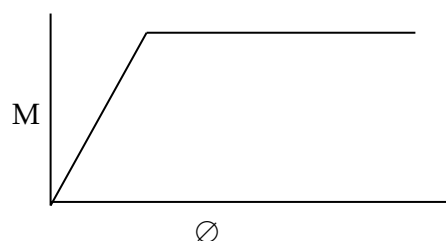
**ROTATIONAL RESISTANCES**

For pile supported footings, compare computed pile loads to nominal axial pile resistances for seismic cases and to factored axial pile resistances for non-seismic cases, unless otherwise recommended by the geotechnical designer.

**ROTATIONAL LOAD-DEFLECTION CURVE**

Use the initial stiffness up to the resistance limit. The curve form is:

Figure 1.10.4.2.4-2 Rotational Load-Deflection Curve



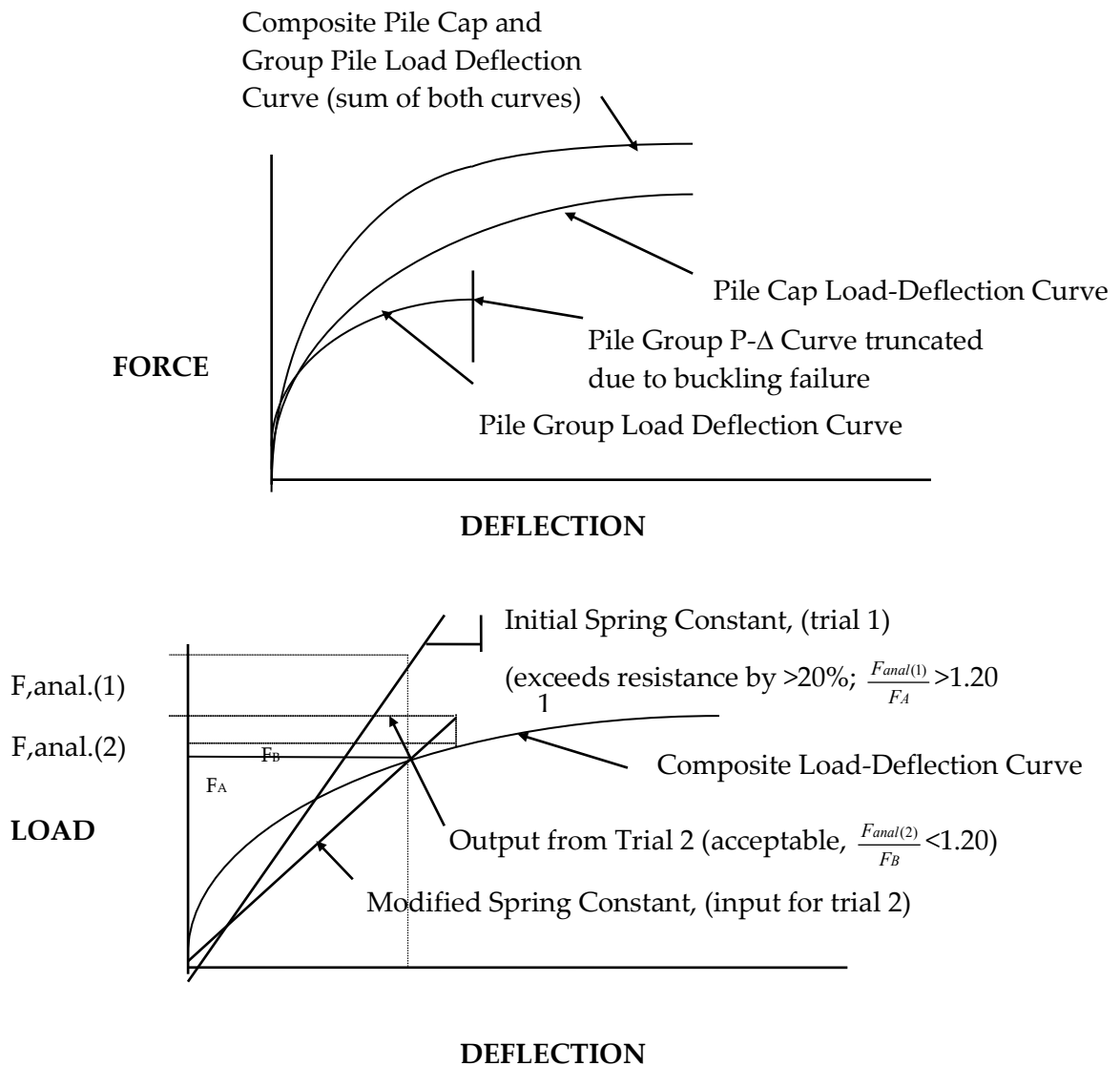
**LOAD-DEFLECTION CURVES, STIFFNESS ITERATION ANALYSIS AND CAPACITY CHECKS**

Using the previous information one develops a composite load-deflection relationship for each applicable support spring. Next, an initial spring constant is assumed, the structure and loading analyzed and the resulting load-deflection position compared to the initial assumption. Cycling through this process may be needed to achieve reasonable closure. See the graphical explanation below.

It is also necessary to check the required resistance against the factored or nominal resistance. Resistance factors of 1.0 are typically used in the case of seismic design, however this should be verified by the geotechnical designer. Factored resistances are used for all other cases. For the rotational capacity, this is normally done by checking the resultant forces against the maximum (nominal), effective soil bearing resistance (footings) or nominal pile resistance.

For lateral pile resistances, the nominal resistance is either the maximum determined from the LPILE analysis (based on  $M_y$  of the pile for seismic design), or from the tables. The nominal resistance may also be a function of maximum allowable structural deflections. When the limiting resistance is exceeded when using the initial spring coefficient then modified springs are required as shown in the graphical explanation below, *Figure 1.10.4.2.4-3*.

Figure 1.10.4.2.4-3 Modified Springs: (A) Development of Composite Load, Deflection Curve (B) Spring Iteration Process and Resistance Check



### 1.10.4.3 Drilled Shaft Modeling (Fully Coupled)

Programs Midas Civil or SAP2000 and LPILE can be used in an iterative approach to model a drilled shaft supported structure. The approach is to determine the approximate force magnitudes for the controlling loading and then use these forces to develop a better representation of the superstructure/shaft/soil problem. This allows a good approximation of soil stiffness non-linearity as well as the non-linearity of the shaft-soil interaction.

The following steps would be typical for drilled shaft modeling for design and checking:

- Develop a full Midas Civil or SAP2000 model (superstructure with substructure) using shaft fixity at two shaft diameters below the groundline. Using the model, run the controlling load case – typically seismic loading will be the controlling case and the worst effect, either longitudinal or transverse, will be used for the next steps.
- Develop LPILE models (shaft with soil) for each bent using the full shaft from its tip to its connection to the superstructure.
- Using the top of shaft shear and moment results from the first Midas Civil or SAP2000, load the LPILE models to develop a stiffness matrix for each shaft. This represents a condensing of the substructure/soil effect to the point of connection with the superstructure. The LPILE program can develop a stiffness matrix.
- Develop a new Midas Civil or SAP2000 model using only the superstructure and supports represented by the LPILE developed substructure stiffness matrices. Run the same controlling load case.
- Use the top of shaft shear and moment results from this latest Midas Civil or SAP2000 to again load the LPILE models to develop new substructure stiffness matrices.
- Use the latest Midas Civil or SAP2000 model with the most recent substructure stiffness matrices and again run the same controlling load case.
- Compare the results of this Midas Civil or SAP2000 with the previous Midas Civil or SAP2000 run for correlation. When the results do not correlate well, cycle through steps five and six to get better convergence. Results which change no more than 15 percent per cycle are normally sufficiently close and further cycling is not required.

## 1.10.5 Foundation Design

Foundation design should be performed in accordance with the most current version of the *AASHTO LRFD Bridge Design Specifications*. Foundation design should also follow the policies and guidelines described in the *ODOT Geotechnical Design Manual*, available through the ODOT Geo-Environmental Section web page.

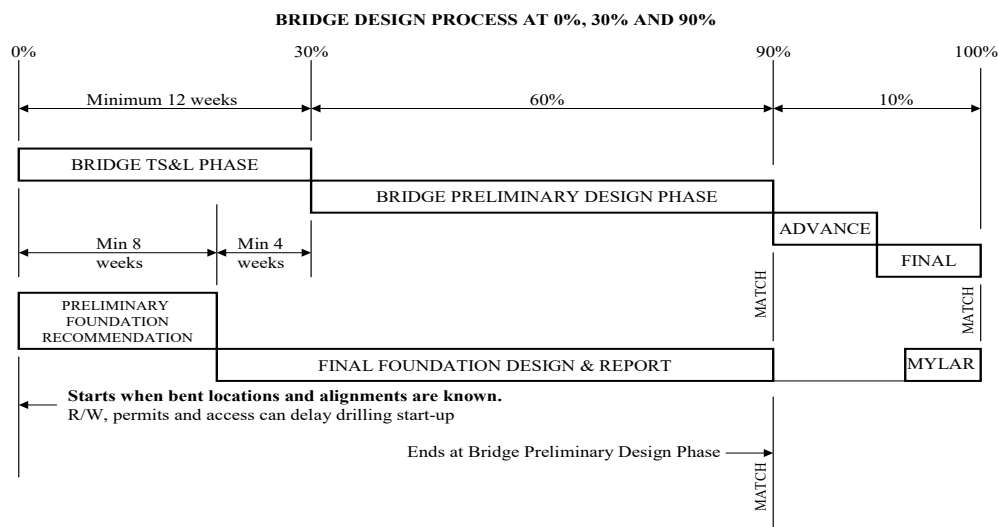
FHWA foundation design manuals are also acceptable methods for use in foundation design. Subsurface investigations for all structures should be conducted in accordance with the *AASHTO Manual On Subsurface Investigations (1988)*. Materials classifications should be in accordance with the *ODOT Soil and Rock Classification Manual (1987)*.



### 1.10.5.1 Foundation Design Process

A flow chart showing the overall foundation design process, related to plans development, is provided in *Figure 1.10.5.1-1*. It is important for the foundation and bridge designers to establish and maintain good communication and exchange of information throughout the entire bridge design process. Any questions regarding foundation design issues should be brought to the attention of the geotechnical designer as early as possible in the design process. For most typical bridge design projects two Geotechnical Reports are provided, the TS&L Foundation Design Memo and the Geotechnical Report. A description of the phases follows.

Figure 1.10.5.1-1 Bridge Design Process at 0, 30 and 90 percent



#### TS&L FOUNDATION DESIGN MEMO

The purpose of this memo is to provide sufficient data for developing TS&L plans and cost estimates and for permitting purposes. The memo is generally provided before the subsurface investigation is completed. It provides a brief description of the proposed project, the anticipated subsurface conditions (based on existing geologic knowledge of the site and/or as-constructed information) and presents preliminary foundation design recommendations such as foundation types and preliminary resistances. The potential for liquefaction and associated effects are also briefly discussed. The memo is to be provided no later than two-thirds of the way through the TS&L design process.

#### GEOTECHNICAL REPORT

This report is to be provided by the end of the Preliminary Bridge Design phase, which is usually 90 percent design. It provides the final foundation design recommendations for the

structure and a Geotechnical Data Sheet for each structure. In order to conduct a proper foundation investigation and complete this report the geotechnical designer will need the following information:

- Bent locations and layout.
- Proposed roadway grade (fill heights).
- Anticipated foundation loads.
- Foundation size/diameter and depth required to meet structural needs.
- Allowable structure settlements (total and differential).
- Proposed retaining wall locations.
- Estimated scour depths (from Hydraulics Report).
- Construction or environmental constraints that could affect the type of foundation selected.

The report will contain the all geotechnical data on the site including final boring logs, Geotechnical Data Sheets, laboratory test results, foundation soil design parameters, recommended foundation types, sizes and resistances, and other recommendations. Construction recommendations are included along with project specific specifications, which are to be included in the contract Special Provisions. Seismic foundation design recommendations are provided including site characterization and soil coefficients, estimated ground acceleration and any liquefaction mitigation measures considered necessary (See *BDM 1.17*).

The geotechnical designer should review the final Plans and Special Provisions for the structure to make sure they are consistent with the design recommendations provided in the Geotechnical Report. Any discrepancies should be resolved and addendums to the report issued when necessary. A copy of the Geotechnical Report should be included in the project file and is made available to contractors through the Project Manager's Office when the project is advertised for bid.

### **1.10.5.2 Bridge Foundation Records**

**As-constructed** records on existing bridge foundations may be found in the Salem Bridge Engineering Office from the following sources:

- Pile Record Books.
- **As-constructed** Bridge Plans (available through ODOT intranet).
- Microfilm Construction Records.
- Bridge Maintenance Files.

### **1.10.5.3 Spread Footing Foundation Design**

Spread footings are considered early on in the design process as a possible economical foundation option when the foundation conditions are suitable. The design of spread footings

is usually an interactive process between the geotechnical and structural designers. The bottom of spread footings should be at least 6 feet below the bottom of the streambed unless non-erodible bedrock is present. The bottom of spread footings should also be below the estimated depth of scour for the 500 year flood event. The top of the footing should be below the depth of scour estimated for the 100 year event. Spread footings are not to be constructed on soils that may liquefy under earthquake loading. When spread footings are recommended the geotechnical designer will provide the following design recommendations in the Geotechnical Report:

### FOOTING ELEVATIONS

The elevations of the proposed footings will be provided along with a clear description of the foundation materials the footing is to be constructed on.

### NOMINAL AND FACTORED BEARING RESISTANCES

The nominal and factored bearing resistances will be provided for various effective footing widths likely to be used. Resistance factors for all applicable load combinations should be consistent with the most recent version of *AASHTO LRFD Bridge Design Specifications*.

Bearing resistances corresponding to 1 inch of settlement (Service Limit State) should also typically be provided unless other settlement limits are established by the structural designer. The structural designer should communicate all footing settlement limits to the geotechnical designer. For soil conditions, the bearing resistances provided assume the footing pressures are uniform loads acting over effective footing dimensions  $B'$  and  $L'$  (i.e. effective footing width and length  $((B \text{ or } L) - 2e)$ ) as determined by the Meyerhof method. For footings on rock, the resistances provided assume triangular or trapezoidal stress distribution and maximum toe bearing conditions.

Minimum footing setback on slopes and embedment depths will be provided.

### SLIDING STABILITY AND ECCENTRICITY

The following soil parameters will be provided for calculating frictional sliding resistance and active and passive earth pressures:

- Soil Unit Weight,  $\gamma$  (soil above footing base).
- Soil Friction Angle,  $\phi$  (soil above footing base).
- Active Earth Pressure Coefficient,  $K_a$ .
- Passive Earth Pressure Coefficient,  $K_p$ .
- Coefficient of Sliding,  $\tan \delta$ .

### OVERALL STABILITY

The geotechnical designer will evaluate overall stability using the maximum footing load which can be applied to the design slope while maintaining resistance factor of 0.65 as outlined in *LRFD 11.6.2.3*.

### 1.10.5.4 Pile Foundations

When spread footings are unsuitable or uneconomical for foundation support, driven piles should be considered. Consult with the geotechnical designer to determine the most appropriate pile type, size and bearing resistance to support the desired pile loads. Typical pile types, sizes and structural resistances ( $0.9f_y \times \text{Sectional area of pile}$ ) used on ODOT projects are listed below in *Table 1.10.5.4-1*. The geotechnical designer should provide the nominal resistances required to achieve the required resistance for each limit state.

Table 1.10.5.4-1 Steel HP – Pile Structural Resistance

SHAPE	STRUCTURAL RESISTANCE $f_y = 36 \text{ ksi (kips)}$	STRUCTURAL RESISTANCE $f_y = 50 \text{ ksi (kips)}$	STRUCTURAL RESISTANCE $f_y = 60 \text{ ksi (kips)}$
HP 10x42	402	558	--
HP 10x57	541	752	--
HP 12x89	839	1166	1399
HP 12x117	1115	1548	1858
HP 14 x 117	1115	1548	1858
HP 16 x 141	1351	1877	2252
HP 16 x 183	1753	2435	2921
HP 18 x 204	1950	2709	3251

Table 1.10.5.4-2 Steel Pipe – Piles Structural Resistance

SHAPE	STRUCTURAL RESISTANCE $f_y = 35 \text{ ksi (kips)}$	STRUCTURAL RESISTANCE $f_y = 45 \text{ ksi (kips)}$
PP 16 x 0.375	580	745
PP 18 x 0.5	865	1113
PP 24 x 0.5	1162	1494

When steel piles are installed under environmental conditions meeting corrosion criteria as described in *BDM 1.26.5*, specify a method of corrosion protection for the steel piles or

determine required cross-section of the steel piles throughout the minimum design life. Corrosion rates for sacrificial thickness are specified in *BDM 1.26.5*.

Do not use precast prestressed or timber piles.

#### **1.10.5.4.1 Piling Considerations**

##### **(1) PILE RESISTANCE**

Nominal pile resistances will be provided according to *AASHTO LRFD* design procedures. The resistance factor will be provided according to the construction quality control method recommended in the Geotechnical Report (i.e. dynamic formula, wave equation, Pile Driving Analyzer, etc.). The geotechnical and bridge designers should confer to make sure the pile types and sizes selected take full advantage of the available geotechnical and structural resistances when possible.

##### **(2) DOWNDRAG LOADS**

Pile downdrag loads, due to soil settlement other than that caused by dynamic (seismic) loading, are added to the factored vertical dead loads on the foundation in the Strength Limit state. Load Factors for downdrag loads will be recommended by the geotechnical designer. Transient loads should not be included with the downdrag loads in either the strength or service limit state calculations. Downdrag loads resulting from liquefaction or dynamic (earthquake) induced soil settlement should be considered in the Extreme Event limit state pile design. Downdrag loads resulting from soil liquefaction are different than those caused from static loading and they should not be combined in the Extreme Limit state analysis.

At sites where downdrag conditions exist, the pile must overcome the frictional resistance in the downdrag zone during installation. This resistance should not be included in the calculation of available factored resistance since after installation it reverses over time becoming the static downdrag load.

##### **(3) UPLIFT CAPACITY**

In general, the uplift resistance is the same as the pile friction (side) resistance. Resistance factors and factored uplift resistances will be provided in the Geotechnical Report. Friction resistance in downdrag zones should be considered available for uplift resistance. The geotechnical designer should be consulted regarding the ability of the piles to resist uplift forces under various loading conditions (static or dynamic).

##### **(4) MINIMUM PILE TIP ELEVATION**

Minimum pile tip elevations (embedment depths) are typically required to meet one or more of the following design requirements:

- Lateral Load.
- Scour.
- Liquefaction.
- Uplift loads.

- Settlement and/or Downdrag.
- Required soil/rock bearing strata.

The required pile tips elevations should be shown on the plans and labeled as **Required Minimum Pile Tip Elevations**. Large lateral loads due to seismic, or other, conditions may result in the need for additional piling, or larger piles, in order to satisfy lateral deflection criteria or other requirements. This may in turn result in individual axial pile loads being much less than the maximum factored resistances available (either geotechnical or structural). Conversely, when pile tip elevations are needed to meet scour, uplift, or other requirements, the piles may need to be driven through very dense materials to nominal resistances much higher than needed for supporting just the axial loads. Close communication is needed between the geotechnical and bridge designers to determine the most economical foundation design under these conditions.

#### (5) PILE GROUP SETTLEMENT

Pile group settlement should be compared to the maximum allowable settlement and pile depths or layout adjusted if necessary to reduce the estimated settlement to acceptable levels.

#### (6) PILE GROUP EFFECTS

For pile group lateral load analysis use the p-y multiplier methods described in *LRFD* and the FHWA Manual on the *Design and Construction of Driven Pile Foundations*.

#### (7) PILE SPACING

Use a minimum spacing of 3 feet for piles placed underwater. Above water pile spacing should be no closer than 2.5B.

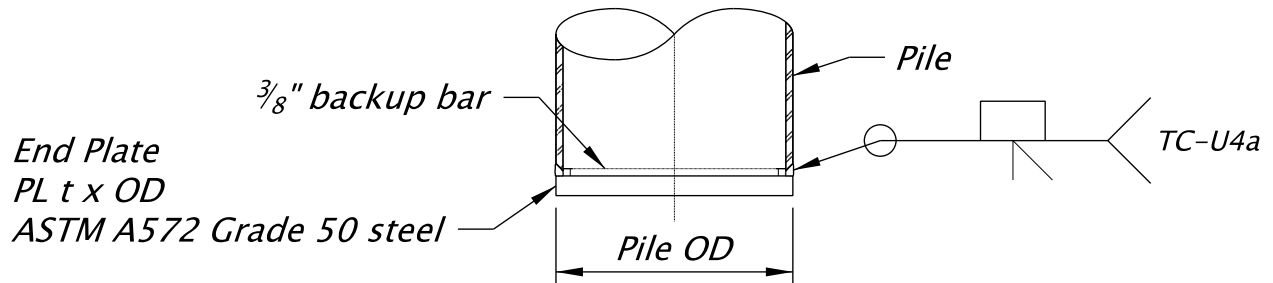
#### (8) PILE TIP TREATMENT

Where pile tip reinforcement is required, specify commercial cast steel points or shoes.

Where closed-ended pipe piles are required, specify a welded end plate and/or a welded end plate with stiffeners having the same diameter as the pipe pile. An analysis was performed for a range of pipe pile sizes which verified sufficiency and the minimum dimensions for the end plate and stiffeners. This analysis was conducted using **0.9fy** as the maximum load, which is the maximum stress the pile will undergo and what is allowed during pile driving. Provide dimensions for the end plate and stiffeners on plan sheets for each project. Deviation from the minimum dimensions below requires project specific shell and buckling analyses and driving stress from the geotechnical designer.

*Table 1.10.5.4.1-3* provides the minimum dimensions for a welded end plate and a welded end plate with stiffeners. Use these dimensions with *Figures 1.10.5.4.1-1* and *Figures 1.10.5.4.1-2*. The figures are available online in the Standard Details at the following location [Welded Plate Details](#). These details are available for project specific use.

Figure 1.10.5.4.1-1 Welded End Plate

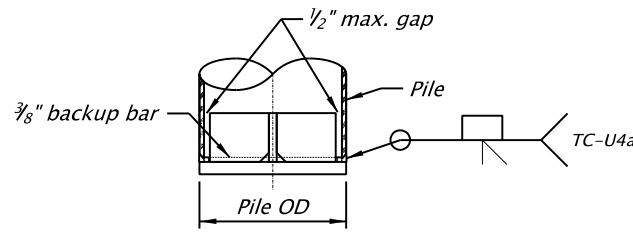


PILE END SECTION

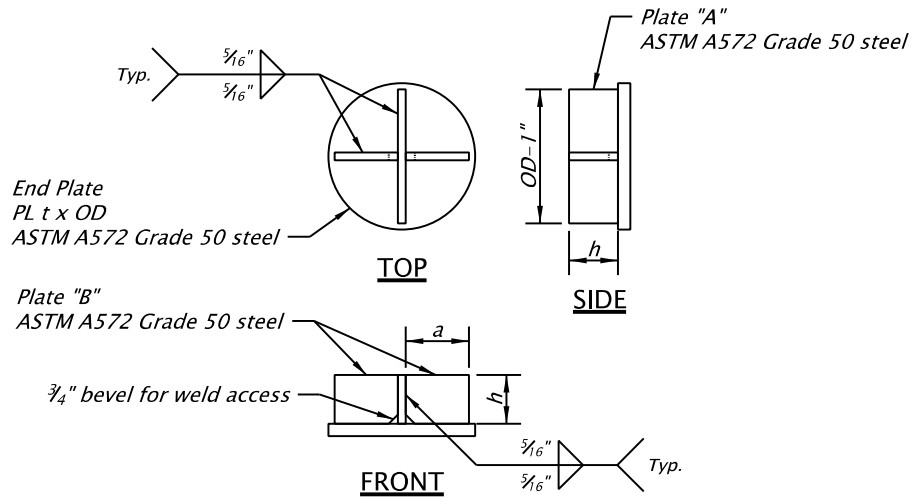
WELDED END PLATE

*See Table 1.10.5.4*

Figure 1.10.5.4.1-2 Welded End Plate with Stiffeners



**PILE END SECTION**



**WELDED END PLATE WITH STIFFENERS**

See Table 1.10.5.4

Table 1.10.5.4.1-3 Minimum Dimensions for Welded End Plates

Pipe Pile Size	End Plate Thickness - No Stiffeners		End Plate Thickness with Stiffeners					
	Gr 2 Pipe	Gr 3 Pipe	Gr 2 Pipe			Gr 3 Pipe		
	t	t	End Plate	Stiffeners (Plates A & B)	Plate B Length	End Plate	Stiffeners (Plates A & B)	Plate B Length
			t	h x t	a	t	h x t	a
PP12 $\frac{3}{4}$ x $\frac{3}{8}$	2.25	2.5	1.00	4 x 0.375	5.500	1.25	4 x 0.500	5.250
PP12 $\frac{3}{4}$ x $\frac{1}{2}$	2.50	2.75	1.00	4 x 0.500	5.375	1.75	4 x 0.500	5.125
PP16 x $\frac{3}{8}$	2.50	2.75	1.00	6 x 0.375	7.125	1.25	6 x 0.375	6.938



PP16 x 1/2	2.75	3.00	1.25	6 x 0.375	7.000	1.50	6 x 0.500	6.750
PP18 x 3/8	2.50	2.75	1.00	6 x 0.500	8.125	1.25	6 x 0.500	7.875
PP18 x 1/2	3.00	3.25	-	-	-	-	-	-
PP24 x 1/2	3.25	3.75	-	-	-	-	-	-
t = thickness; h = height; a = length								

## (9) PILE FOUNDATION DESIGN RECOMMENDATIONS

The geotechnical designer will provide final foundation recommendations in the Geotechnical Report, or earlier in the design process as needed. The following recommendations will typically be provided as a minimum:

- **Pile Resistance:** The nominal pile resistances ( $R_n$ ) will be provided along with estimated pile lengths for one or more pile types. These values may be in tables or graphs of  $R_n$  versus depth may be provided. Modified  $R_n$  values will be provided as necessary to account for scour, and/or liquefaction conditions. The resistance factor will be provided along with the recommended method of construction control (i.e. dynamic formula, wave equation, etc.). Downdrag loads, when present, will be provided along with an explanation of the cause of the downdrag loads. The depth or thickness of the downdrag zone will be provided.
- The nominal pile uplift resistance will be provided either as a function of depth or for a given pile length (typically associated with the minimum tip elevation). The pile uplift resistance will be provided for normal static conditions and for any reduced capacity condition such as scour or liquefaction. The resistance factor will be provided.
- **P-Y Curves:** Foundation design parameters will be provided to develop p-y curves for lateral load analysis using either the LPILE or other soil response computer programs. Two sets of data may be required, one for static conditions and one for dynamic (liquefied soil) conditions.
- **Required Pile Tip Elevations:** Required minimum pile tip elevations will be provided along with an explanation of their basis. These tip elevations (minimum pile embedment) should be checked to see if they need to be modified to meet other design requirements, such as lateral loading requirements. Any changes to the recommended required tip elevations should be reviewed by the geotechnical designer.
- **Special Provisions:** The following foundation related items will be provided, as necessary, for Section *SP 00520* of the project Special Provisions:
  - Wave Equation Input (when WEAP is specified for driving criteria).
  - Recommended number of pile splices.
  - Pile tip treatment, tip reinforcement recommendations and specifications.

- Recommendations regarding pile freeze, jetting, preboring or use of followers.

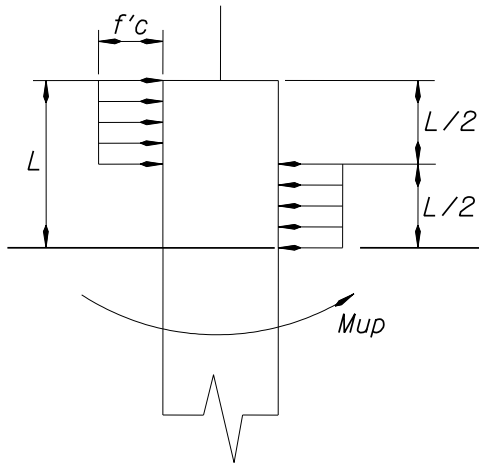
**1.10.5.4.2 Piling Details****(1) STEEL PILE FOOTING EMBEDMENT TO DEVELOP FIXITY**

It may be necessary to develop lateral load resistance in piles or pile groups. To develop the required lateral load capacities, piles must be embedded in pile caps or footings adequately to develop the full moment capacity of the pile section.

When lateral load capacity is not needed, a pile embedment length of 12 inches is sufficient.

A simplified method of determining minimum pile embedment was developed as shown in *Figure 1.10.5.4.2-1*.

Figure 1.10.5.4.2-1 Method to Determine Steel Pile Embedment to Develop Fixity



$$M_{up} = \phi f'c D \left( \frac{L}{2} \times \frac{3L}{4} - \frac{L}{2} \times \frac{L}{4} \right)$$

$$M_{up} = \phi f'c D L^2 \left( \frac{3}{8} - \frac{1}{8} \right)$$

$$4M_{up} = \phi f'c D L^2$$

$$L = \sqrt{\frac{4M_{up}}{\phi f'c D}}$$

Typical minimum embedment to develop fixity for  $f'c = 3.3 \text{ ksi}$  and  $fb = 36 \text{ ksi}$  is as follows in [Table 1.10.5.4.2-1](#).

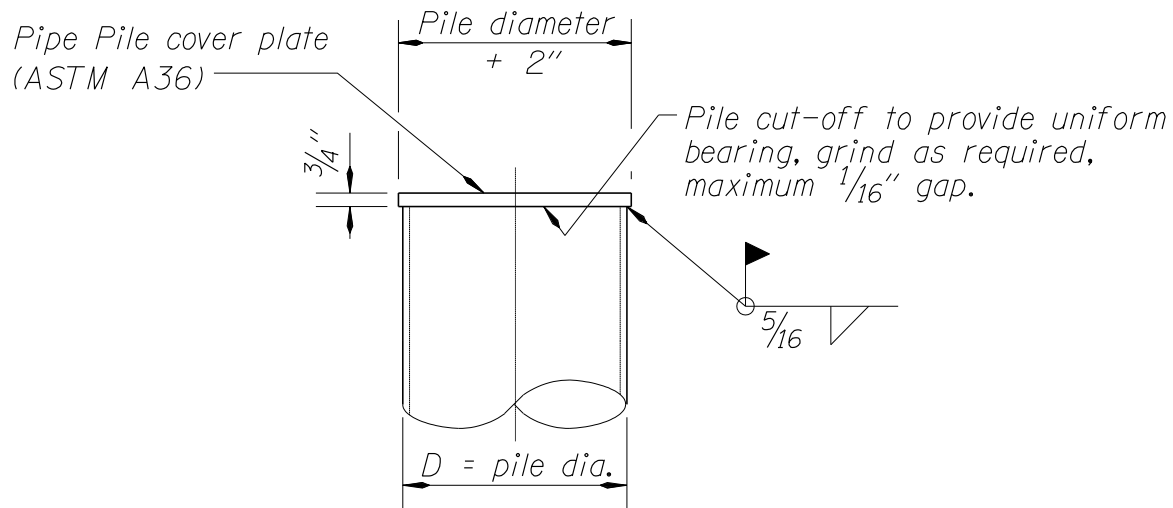
Table 1.10.5.4.2-1 Minimum Pile Embedment for Fixity

Piles	Minimum Embedment (inch)
HP 10X42 and HP 12x53	20
HP 12X74 and HP 14X89	24
HP 14X117	27
PP 10 ¾ X 0.38 and PP 12 ¾ X 0.38	15
PP 16 X 0.38 and PP 16 X 0.50	20

**(2) PIPE PILE COVER PLATES**

Provide a welded cover plate as detailed below in *Figure 1.10.5.4.2-2*.

Figure 1.10.5.4.2-2 Pipe Pile Cover Plate



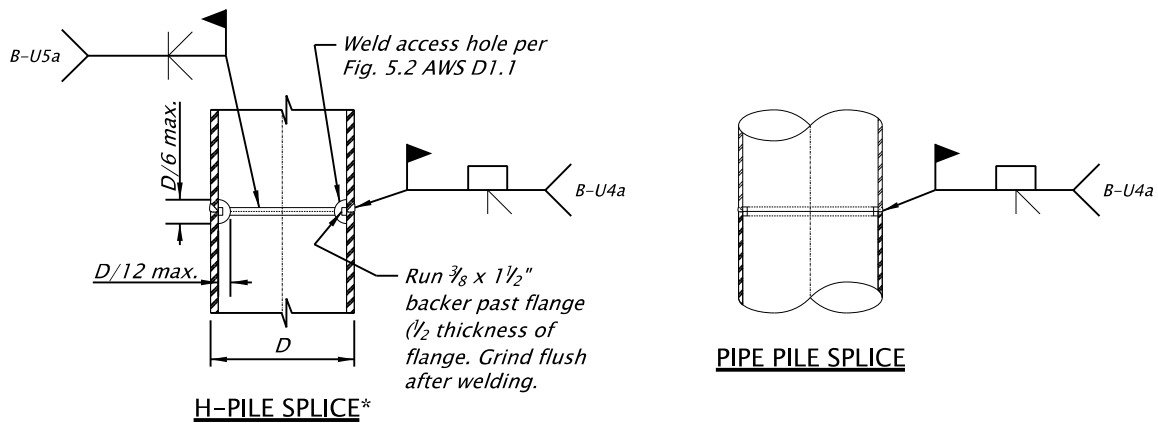
*Note:*  
 Use for piles 18" diameter or less. For larger piles, design the plate thickness.

PIPE PILE (CLOSED ENDED)

(3) STEEL PILE SPLICES

When splicing of steel piles is anticipated, show one or both of the following details on the plans.

Figure 1.10.5.4.2-3 Steel Pile Splices

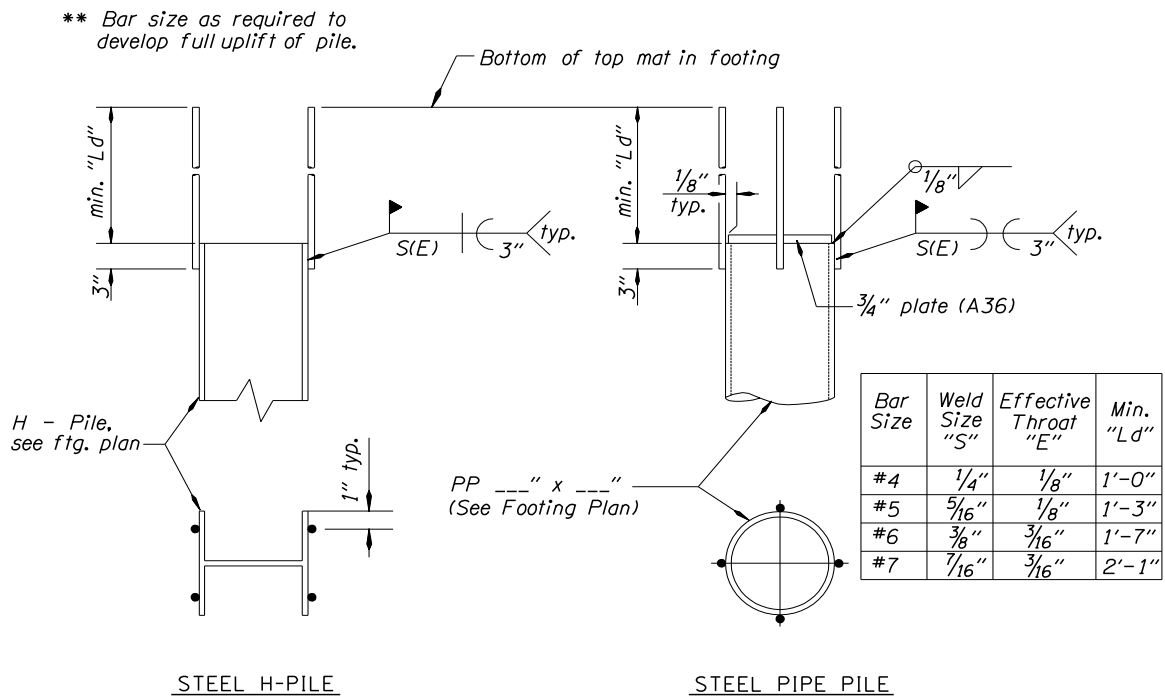


\* – Manufactured A709 Grade 36 H-pile splices may be used when located a minimum of 40 feet below the bottom of the footing and installed according to the manufacturer’s recommendations.

(4) ANCHOR PILES

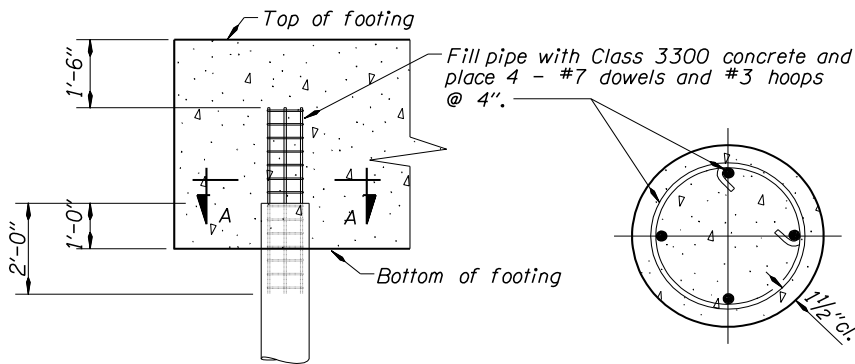
Two methods of anchoring piles are shown in *Figure 1.10.5.4.2-4*. Other methods such as extending the top plate and using welded studs or other shear connectors may be appropriate.

Figure 1.10.5.4.2-4 Anchor Pile Details (A) Steel H-Pile (B) Steel Pipe Pile (C) Filled Pipe Pile



\* Provide ASTM A706, except ASTM A615 Grade 60 or ASTM A496 may be used if copies of the chemical composition analysis are submitted and approved as weldable by the engineer.

ANCHOR PILE DETAILS



FILLED PIPE PILE ANCHOR DETAILS

### 1.10.5.5 Drilled Shafts

Consider the use of drilled shafts for bridge foundations only when the geotechnical designer has recommended drilled shafts for the preferred foundation type and the design is economical (relative to other deep foundation designs). Consult with the geotechnical designer regarding site constraints, environmental issues, constructability and lateral loads before selecting drilled shafts for foundation design. The location of drilled shafts should be made early in the design process so an exploration drill hole can be located as close as possible to all drilled shaft locations for design and construction purposes.

A Drilled Shaft Task Force Group exists to aid geotechnical and bridge designers in resolving constructability issues, revising specifications, and successfully implementing new technology. The Drilled Shaft Task Force Group is led by the Senior Bridge Geotechnical Engineer and comprised of ODOT personnel and representatives from the drilled shaft industry. Consider engaging this group early in the design process.

#### DRILLED SHAFT DESIGN

##### (1) Drilled Shaft Diameters, Cover Requirements, and Horizontal Tolerances

The geotechnical and bridge designers should confer early in the design process to decide the most appropriate shaft diameter(s) to use for the bridge given the axial and lateral loads, column diameter, subsurface conditions, and other relevant factors.

Common shaft sizes range from 3 to 12 feet in diameter. Large shafts are difficult to construct to precise horizontal tolerances. Do not design columns the same diameter as the shaft. Consider allowable horizontal tolerances, 3 inches for 6 feet shaft or smaller; and 6 inches for shaft larger than 6 feet, in shaft sizing and design. Provide additional shaft capacity to resist possible load demands in shaft that is not constructed at as-specified location.

Size drilled shaft diameters, concrete cover in drilled shafts, and column diameter using the *Table 1.10.5.5-1*.

Table 1.10.5.5-1 Drilled Shaft Dimensions

Diameter (feet)		Concrete Cover (inches)	Horizontal Tolerance (inches)
Shaft	Max. Column		
3	2	3	3
3.5	2.5	4	
4	3		
4.5	3.5		
5	4		
5.5	4.5		
6	4	6	6
7	5		
8	6		
9	7		
10	8		
11	9		
12	10		

(2) Non-Contact Shaft/Column Splice

Detail shaft/column splice regions in accordance with *Figures 1.10.5.5-1* or *1.10.5.5-2*. The splice region is  $(1.7Ld + a)$  rounded up to the nearest 3 inches. Note that  $Ld$  is the modified development length per *LRFD 5.11.2.1*. The non-contact splice detail allows the column to be adjusted horizontally when the shaft is slightly out of position (but still within the horizontal tolerance for the shaft). The shaft vs. column size limits are selected to ensure this adjustment can be made without increasing the tolerance more than the standard 1 inch for the column.

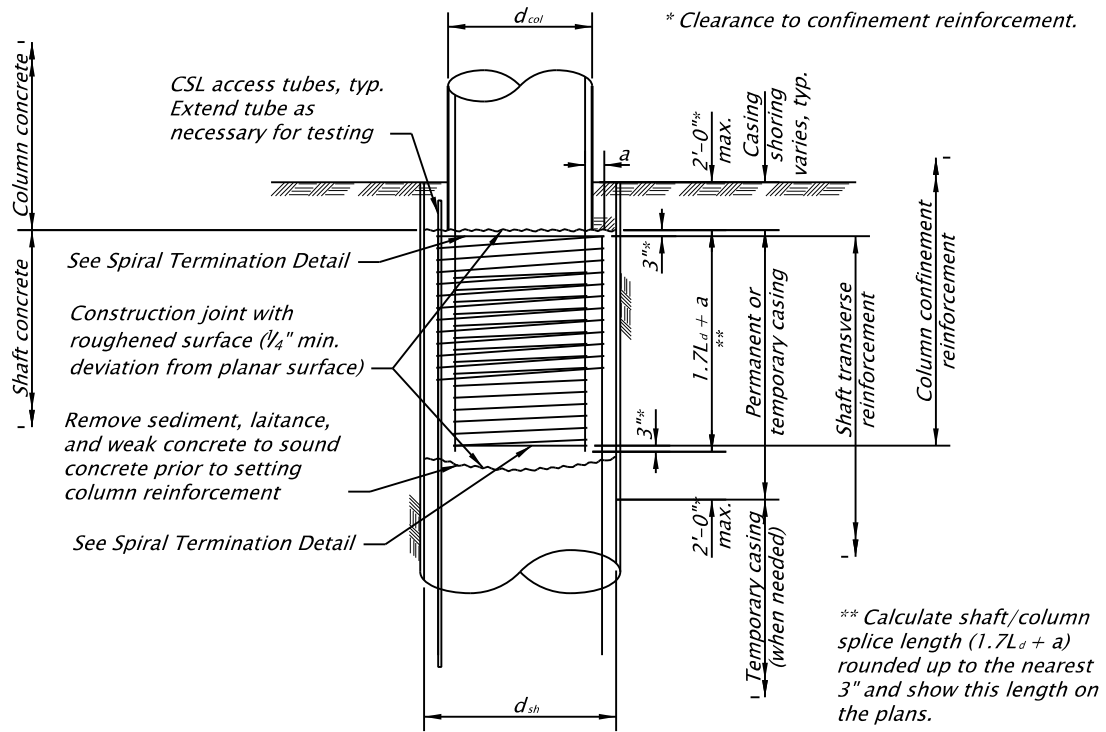
Non-contact splices require a lot of equipment, often in space-limited areas. Use of permanent casing should be considered for instances when the geotechnical designer recommends or identifies caving conditions, restricted space, and worker safety. Permanent casing changes the resistance of the drilled shaft. Use of permanent casing must be communicated with the geotechnical designer so new depth vs resistance graphs can be developed and provided to the bridge designer. Permanent casing may result in longer drilled shafts.

Often, during construction temporary casing cannot be extracted. Bridge designers should review the consequences of temporary casing becoming permanent casing. Communicate with the geotechnical designer these consequences so that an appropriate Drilled Shaft Installation



Plan is approved during construction. Casing configurations shown on *Figures 1.10.5.5-1* and *1.10.5.5-2* are shown as examples only.

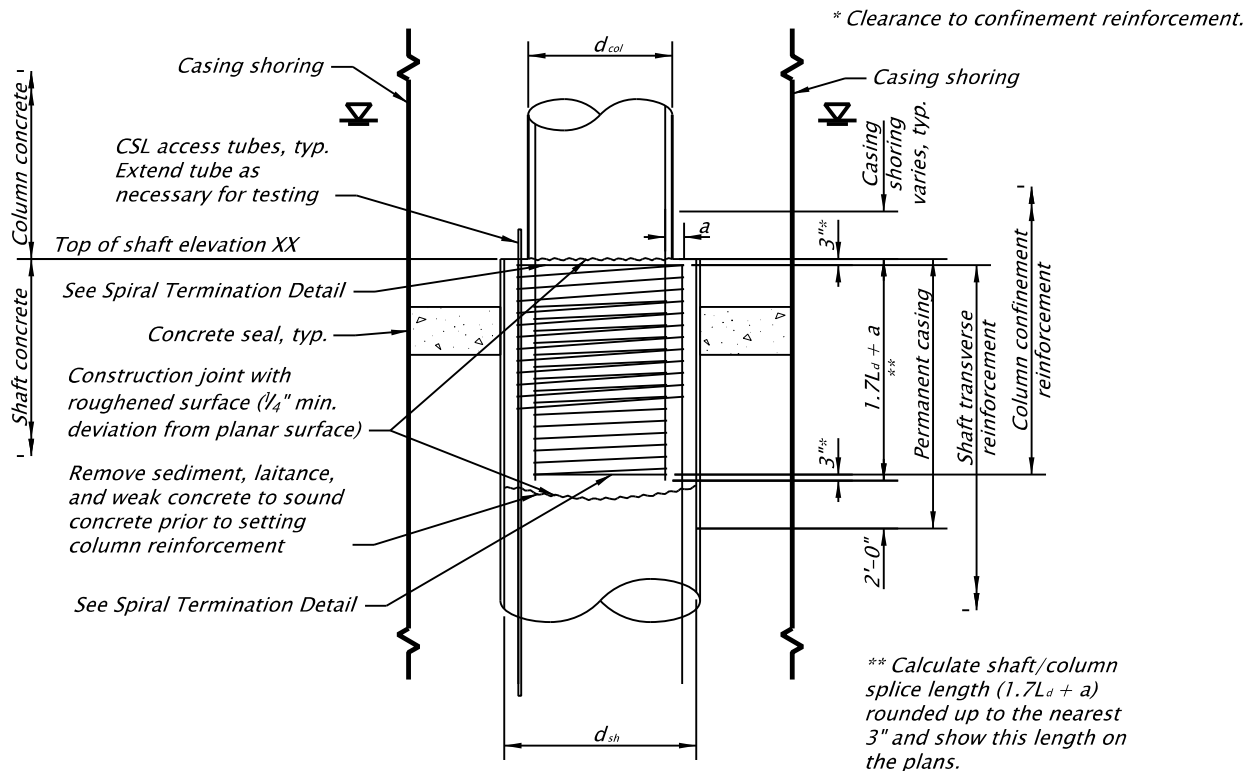
Figure 1.10.5.5-1 In-Ground Non-Contact Drilled Shaft Splice



$a = \frac{1}{2}$  (shaft spiral dia. - column spiral dia.)  
 $d_{col}$  = column diameter  
 $d_{sh}$  = shaft diameter  
 $L_d$  = Modified tension development length per LRFD 5.11.2.1.1

**IN-GROUND SHAFT SPLICE**

Figure 1.10.5.5-2 In-Water Non-Contact Drilled Shaft Splice



$a = \frac{1}{2}$  (shaft spiral dia. - column spiral dia.)  
 $d_{col}$  = column diameter  
 $d_{sh}$  = shaft diameter  
 $L_d$  = Modified tension development length per LRFD 5.11.2.1.1

**IN-WATER SHAFT SPLICE**

(3) Downdrag Loads

Downdrag loads, due to soil settlement other than that caused by dynamic (seismic) loading, are added to the factored vertical loads on the foundation in the Strength Limit state. Load Factors for downdrag loads will be provided by the geotechnical designer. Downdrag loads resulting from liquefaction or dynamic (seismic) induced soil settlement should be considered as a permanent load and included the Extreme Event Limit State shaft design.

(4) Shaft Uplift Resistance

Shaft uplift resistance is usually the same as the side friction resistance. Friction resistance in downdrag zones should be considered available for uplift resistance.

### (5) Shaft Rock Sockets

Minimum shaft embedment depths into hard rock, or rock sockets, may be required due to one or more of the following design requirements or conditions:

- Lateral Load, due to earthquake loading.
- Scour.
- Liquefaction.
- Uplift loads.
- Settlement and/or downdrag.
- Required soil/rock bearing strata.

For rock sockets constructed inside shafts that will require either temporary or permanent casing, consider designing the diameter of the rock socket smaller than the diameter of the cased shaft above the rock socket. This is necessary to accommodate rock auger tools which are smaller in diameter than the nominal outside diameter of the cased shaft. Reduce the shaft diameters of rock sockets by at least 6 inches in these cases.

The required rock socket embedment depths should be shown on the plans. Under this condition, shaft tip elevations should be shown as **Estimated Tip Elevations** since they are likely to change depending on the actual elevation of the top of rock or hard bearing strata encountered during construction. The geotechnical designer should provide an additional shaft length that accounts for the uncertainty in the top of the bearing layer and this additional length should be specified in the Special Provisions. In these cases, add the additional reinforcement required for this additional shaft length into the estimated quantities provided in *SP 00512*. Also adjust the concrete quantities to include this additional length. Extra reinforcement length can quickly and easily be cut off to provide the proper cage length once the final tip elevation is determined.

### (6) Shaft Settlement

Refer to *AASHTO* methods to calculate the settlement of individual shafts or shaft groups. Compare this settlement to the maximum allowable settlement and modify the shaft design if necessary to reduce the estimated settlement to acceptable levels. End bearing shafts on soil will typically settle more than friction shafts in order to mobilize end bearing resistance.

### (7) Shaft Group Effects

For group lateral load analysis use the p-y multiplier methods described in *AASHTO* and the FHWA Manual *Drilled Shafts: Construction Procedures and Design Methods*.

### (8) Shaft Spacing

Use a minimum spacing of 3 feet for drilled shafts.

(9) Shaft Foundation Design Recommendations

The geotechnical designer will provide final foundation recommendations in the Geotechnical Report, or earlier in the design process as needed. The following recommendations will typically be provided as a minimum:

- Shaft Resistance: The nominal shaft resistance ( $R_n$ ) will be provided along with estimated shaft tip elevations for one or more shaft diameters. This may be in the form of tables or graphs of  $R_n$  versus depth may be provided. Modified  $R_n$  values will be provided as necessary to account for scour, liquefaction or downdrag conditions. The resistance factors used will be provided. Downdrag loads, when present, will be provided along with an explanation of the cause of the downdrag loads. The depth or thickness of the downdrag zone will be provided.
- Shaft Settlement: Estimates of shaft settlement will be provided for the range of loads expected. The geotechnical designer will need to know the anticipated service loads on the shaft for these calculations along with any limiting settlement criteria.
- Shaft Uplift Resistance: When required for design, the nominal shaft uplift resistance will be provided either as a function of depth or for a given shaft length. The uplift shaft resistance will be provided for normal static conditions and for any reduced capacity condition such as scour or liquefaction. The resistance factors used will be provided.
- P-Y Curves: Foundation design parameters will be provided to develop p-y curves for lateral load analysis. Two sets of data may be required, one for static conditions and one for dynamic (liquefaction) conditions when they exist.
- Special Provisions: The following foundation related items will be provided, as necessary, for *SP 00512*:
  - Designation as either a **friction** or **end-bearing** shaft; for cleanout purposes.
  - Permanent casing (when recommended by geotechnical designer or otherwise required).
  - Crosshole Sonic Log testing requirements.

(10) Post Installation Verification Testing

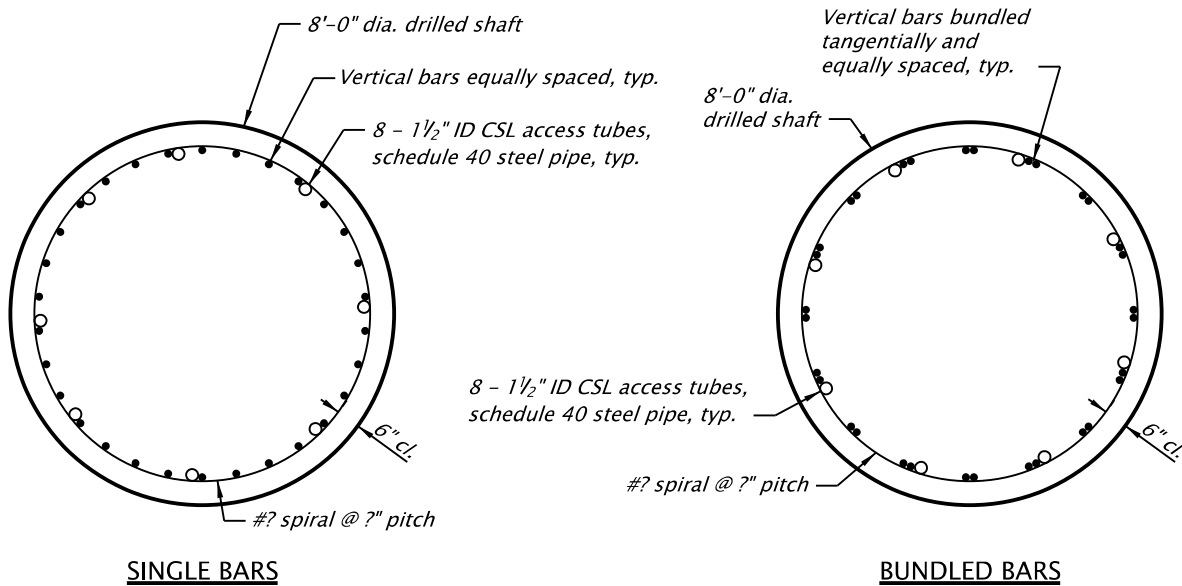
Crosshole Sonic Log (CSL) Testing

In general CSL tubes are installed in all drilled shafts unless otherwise recommended in the Geotechnical Report. CSL tubes may not be required in some cases where foundation conditions may be very favorable and there is redundancy in the foundation design. Consult with the geotechnical designer regarding the CSL testing that should be performed on the project.

The rule of thumb is one CSL tube per foot diameter of shaft, with no less than four tubes and rounding up. They are equally spaced around the shaft as shown in *Figure 1.10.5.5-3*.

CSL tubes are comprised of 1½ inch inner diameter, schedule 40 steel pipe, must be water tight and removable caps at the top for access. PVC access tubes can be used however are discouraged because debonding is more prevalent than with steel.

Figure 1.10.5.5-3 CSL Tubes in Drilled Shaft



CSL TUBES IN DRILLED SHAFT

Thermal Integrity Profile Testing

Thermal Integrity Profile (TIP) testing is a post installation integrity verification test and should be considered in addition to CSL testing in some cases. TIP should be used for drilled shafts which are non redundant, or large, or constructed underwater. Unlike CSL, TIP is able to provide rebar cage cover in addition to integrity of the drilled shaft core. TIP thermal sensors are spaced at 1 foot intervals. Quality control specifications for the use of TIP are being developed, contact the Senior Bridge Geotechnical Engineer for additional guidance.

(11) Shaft Reinforcement

Determine the moment to be transferred from the column to the top of shaft according to the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*. The maximum shaft moment depends on the soil-structure interaction and is generally be larger than the top of shaft moment.

Design shaft transverse reinforcement for the lesser of the plastic shear or elastic seismic shear of the column. Since the shaft diameter must exceed the column diameter, the shaft essentially remains elastic under seismic loads. If so, there is no need to satisfy the volumetric ratio and spacing requirements for transverse reinforcement in *LRFD 5.13.4.6.3*.

As well as meeting plastic shear or seismic shear demands, ensure shaft transverse reinforcement within the non-contact splice region meets the requirements in *LRFD 5.11.5.2.1*.

Detail shaft reinforcing to minimize congestion and facilitate concrete placement. Space both longitudinal and transverse reinforcement to provide 5 inches minimum and 9 inches maximum clear spacing between bars. In non-contact splice regions, transverse reinforcement spacing in the column can be as small as 3 inches in some cases. Provide 5 inches minimum clear spacing between transverse reinforcement in the shaft to minimize congestion. Transverse shaft reinforcement may include spiral bars, hoops and/or bundled pairs.

#### (12) Shaft Concrete

Use Class 4000 – 3/8 concrete in all drilled shafts. Concrete for drilled shafts should generally have a high slump and relatively small aggregate size in order to properly flow through the shaft reinforcement and provide the required fluid pressures against the sides of the bore hole. This is necessary to develop the desired friction resistance. Placement of concrete may be by free fall (in dry holes) or by tremie pipe (in dry or wet holes). At the present time, free fall placement of concrete in dry holes is allowed to unlimited depths. Refer to the report *Effects of Free Fall Concrete in Drilled Shafts (ADSC Report No. TL112)* for more information.

#### (13) Reinforcement Connections

Do not specify hooked longitudinal bars at the top of the shaft (extending into footings or caps) that will conflict with temporary casing removal. Design and detail reinforcement considering the requirements of temporary casing.

#### (14) Reinforcement Splicing

For shafts constructed at locations where a minimum penetration into the rock (or hard strata) is required and the elevation of the top of rock is uncertain, consider adding additional lengths of reinforcement to avoid the need for splicing. Once the final tip elevation is determined, any remaining rebar length can be cut off and removed. Splicing of reinforcement is undesirable because it usually results in delaying the concrete pour which could lead to other problems. When splicing is required, provide splicing details on the plans.

#### (15) Shaft Elevations

Show or list the **Top of Shaft** elevation on the plans for each drilled shaft. This elevation is the top of the drilled shaft concrete. Also show or list shaft tip elevations. When shaft tip elevations are anticipated to vary due to uncertainties in the top of the bearing strata then label these as **Estimated Tip Elevations** and show the required penetration depth into the bearing strata.

#### (16) Permanent Casing

The use of permanent casing may be beneficial in locations especially where the top of shafts are constructed in open water such as rivers or lakes. The use of permanent casing can simplify construction by eliminating the need for any temporary casing and forms. When permanent casing is desired it should be taken into account in the structural analysis of the bridge because it

increases the stiffness and strength of the shaft and may significantly affect the overall response of a bridge subject to large lateral loads. It also affects the geotechnical side resistance. Consult with the geotechnical designer when permanent casing is to be used.

When permanent casing is specified remember to take OSHA requirements into account when determining casing lengths. OSHA may require casing to extend at least 2 feet above the ground surface during construction. This additional length may later be cut off and removed after the shaft is constructed.

When permanent casing is required, provide casing diameters, thicknesses and lengths in the special provisions.

#### (17) Shaft Diameter for Seismic Analysis

Drilled shafts are generally constructed slightly larger than the nominal diameter shown. For example, in soil conditions where casing is required, a 6 foot diameter shaft cannot be drilled inside a 6 foot diameter casing. A larger size casing diameter is required. Discuss with the geotechnical designer whether or not casing may be required and a larger shaft size should be checked in the structure stiffness analysis (i.e., seismic analysis). An oversize of 6 inches is recommended for shafts up to 6 feet diameter and 12 inches is recommended for larger diameter shafts.

#### (18) Drilled Shaft Preconstruction Meeting

Preconstruction meetings are held prior to beginning drilled shaft construction. This meeting should be attended by the structural designer who designed the shaft.

### **1.10.5.6 Seismic Foundation Recommendations**

The geotechnical designer shall provide the seismic ground motion values for the Cascadia Subduction Zone Earthquake and the 1000-year return period earthquake. Liquefaction potential is addressed along with recommendations regarding estimated lateral deformations of embankments and/or dynamic settlement and downdrag potential. Downdrag loads resulting from liquefaction or dynamic compaction (settlement) will be provided. Liquefaction mitigation measures and recommendations are addressed if necessary (see *BDM 1.17.4* for Liquefaction Mitigation Procedure).

### **1.10.5.7 Overall Stability Evaluation**

The geotechnical designer shall evaluate the overall stability of the approach fills leading up to the bridge and all other unstable ground conditions, such as landslides or rockslides, that may affect the structure. This analysis shall include both static and dynamic analysis of slope stability as related to the service and extreme limit state designs. This analysis is to determine potential impacts to the bridge and approach fills which may result from embankment instability, landslide movements, settlement or other potential ground movements. A thorough

geotechnical investigation, focused on slope instability, should be conducted in accordance with *the ODOT Geotechnical Design Manual (GDM)*. Methods for evaluating overall stability and for estimating settlements and displacements are also described in the *GDM*. The overall stability analysis should include both non liquefiable and liquefiable foundation soil conditions as appropriate. This evaluation should be completed as early as possible in the design process to allow for possible changes in location and/or modifications to the bridge design to accommodate slope instability conditions. Coordinate with the geotechnical designer to resolve any slope instability issues that will affect the final bridge design.

For the Service Limit State, the overall stability of bridge approach fills not supporting abutment spread footings should provide a minimum factor of safety of 1.3, (roughly equivalent to a resistance factor of 0.75). A factor of safety of 1.5 against overall stability should be provided for end bent spread footings supported directly on embankments or bridge retaining walls. For bridges that are located in landslide areas, or in areas that could be affected by slide movements, the slide should be stabilized to the same factors of safety as stated above for approach fills or as determined by the Region Tech Center Geotechnical Section and Senior Bridge Geotechnical Engineer.

For Extreme Limit State I (seismic loading) conditions, the overall stability and displacement of the approach fills should be evaluated. In addition, other potentially unstable ground conditions, such as landslides or rockfalls, should also be investigated and evaluated for their potential impacts on the structure due to earthquake forces. A minimum factor of safety of 1.1 should be provided for the pseudo static analysis of bridge approach fills, landslides and any other potentially unstable ground conditions that may affect the structure. This criterion applies to sites with or without liquefiable foundation soils. In addition to this requirement, ground displacements (lateral and vertical) should be estimated and evaluated in terms of meeting the seismic design performance criteria described in *BDM 1.17.1*. This performance criterion also applies to liquefiable or non-liquefiable foundation soil conditions. The Newmark approach is recommended for estimating the lateral displacements of approach fills, adjacent slopes, landslide masses or other ground features that may affect the structure. Other methods for estimating lateral ground deformations under seismic loading are presented in the *ODOT Geotechnical Design Manual*. When estimated ground displacements result in excessive deformation or damage to the bridge such that the performance criteria cannot be met, then mitigation measures should be pursued. The limits of liquefaction mitigation described in *BDM 1.17.4* also apply to all non-liquefiable soil conditions that require mitigation measures to meet the specified performance criteria.



# 1.11 Substructures

## [1.11.1 Retaining Structures, General](#)

### [1.11.2 End Bents](#)

### [1.11.3 Interior Bents](#)

## 1.11.1 Retaining Structures, General

Retaining walls that support bridge bents will typically be designed by the bridge designer, and drawings will be included with the structure drawings.

For all other free-standing retaining walls, refer to the *ODOT Geotechnical Design Manual, Chapter 15*.

Retaining wall project development activities require integrated and coordinated effort of bridge, geotechnical, geology, and roadway disciplines. Additional disciplines could be necessary dependent on the project. It is common for either the bridge engineer or geotechnical engineer to take the lead role in retaining wall design. Coordination in the design process includes:

- Determine if retaining wall is needed and wall location design - [Roadway, Retaining Wall Designer].
- Subsurface investigation planning, execution, identifying ground water, soil and rock properties for design [Geotechnical, Geology].
- Identify structure types for consideration, loading conditions, perform analysis and design, estimate cost, and recommend structure type [Geotechnical, Bridge or both]
- Evaluate recommended structure type (technical and cost estimate check), evaluate constructability [Retaining wall designer, Retaining wall checker, other project reviewers].
- Project design changes that affect the retaining wall [Project team process coordination]. Coordinate with other design elements.

The Retaining Wall chapter of the *ODOT GHE CAD Manual* provides guidance for Contract Plan Sheet development for retaining walls:

- Proper plan sheet series by retaining wall category (within J series of a bridge, a separate J series for the retaining wall, or G series).
- Reference as needed to the *Bridge CAD Manual (BCM)*.
- Sources of information for title block, structure name, structure number, BDS drawing number, calculation book number, file V-number, when applicable.
- Plans content by retaining wall category and system type.
- Plans Checklist

## 1.11.2 End Bents

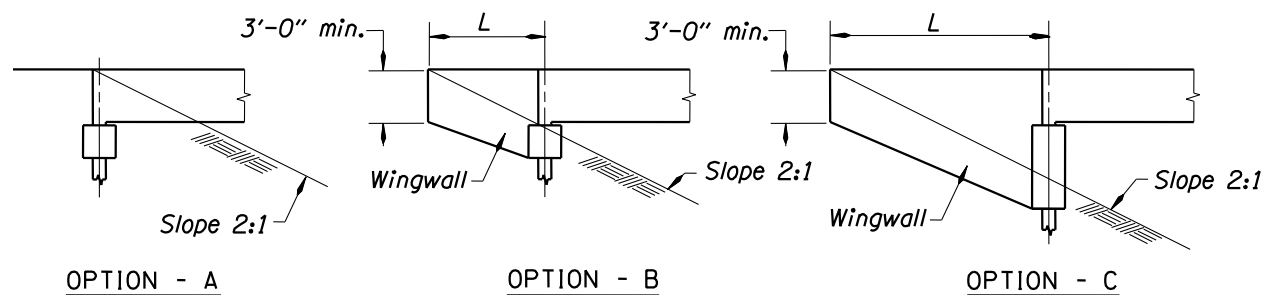
### 1.11.2.1 Determining Bridge Length

Options for the end bent in relation to the end fill intersection with the finish grade are shown in *Figure 1.11.2.1-1* and include:

- Option A, no wingwalls, but a longer structure than for options B and C.
- Option B, the structure length is shorter, but short wingwalls to retain the fill.
- Option C, the structure length is shorter yet, but longer wingwalls and a taller abutment wall to retain the fill.

Generally, option B will provide the least cost, especially for prestressed slab spans. For option C, larger longitudinal forces from lateral soil loads must be resisted by the superstructure and substructure.

Figure 1.11.2.1-1 End Bent Location Options

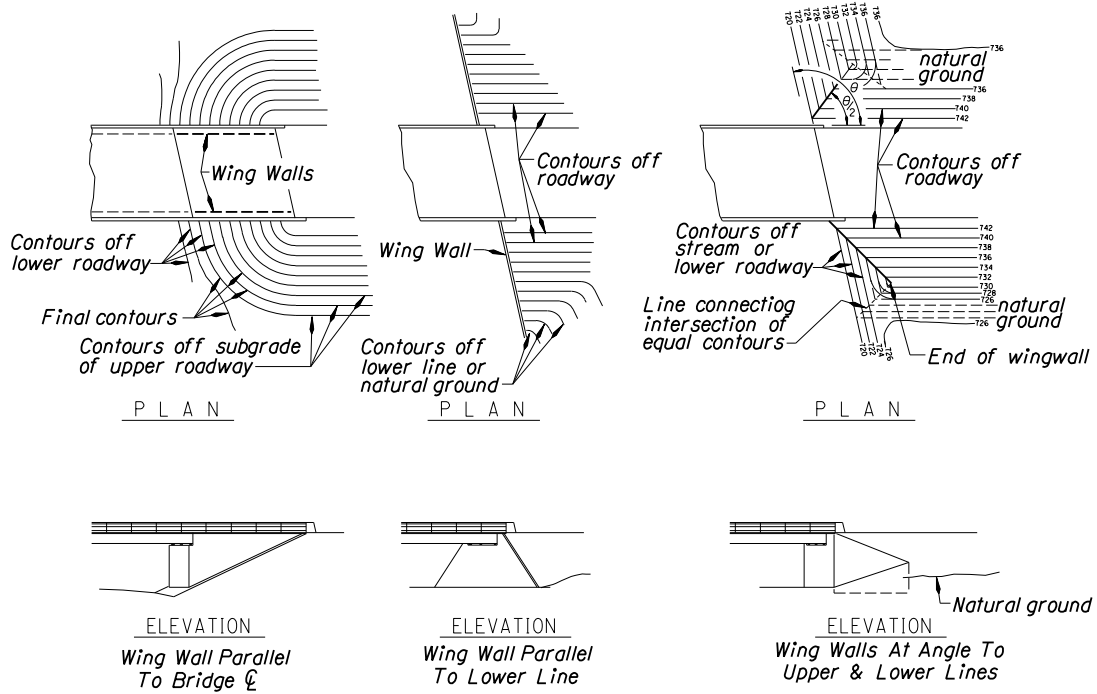


### 1.11.2.2 Wingwall Location

Wingwalls for end bents may be located as follows:

- Walls parallel to the structure are used for filled or **false** (unfilled) bents. These are generally used for grade separation structures where the face of the bent is quite a distance back from the toe of the slope under the structure.
- Walls parallel to bridge bents are generally avoided due to safety or stream flow considerations.
- Walls at an angle to both structure and lower roadway or stream. The angle is generally half the angle between the structure and the lower roadway or stream center lines, as this usually leads to a minimum length wall. The end of the wall is determined by plotting final contours off the upper and lower profile lines. The point where the contours of equal elevation intersect determines the location of the end of the wall.

Figure 1.11.2.2-1 Wingwalls at End Bents



WING WALLS AT BENTS

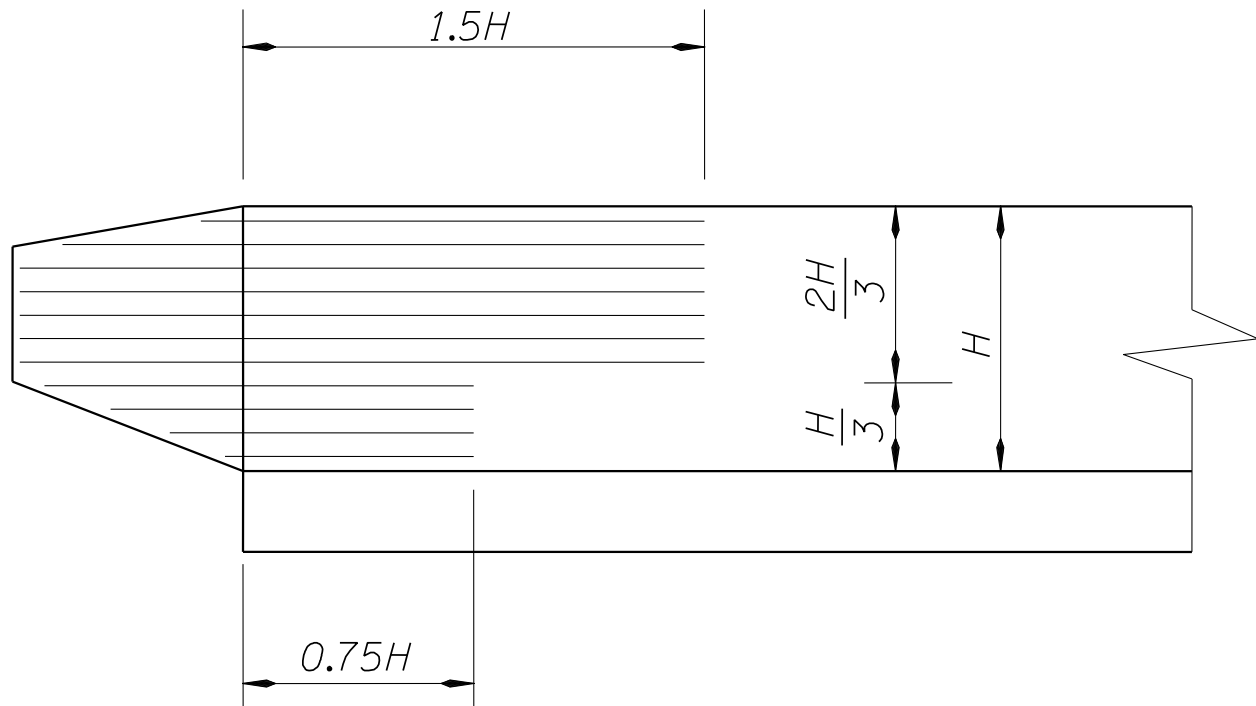
### 1.11.2.3 Wingwall Design and Construction

For cantilever wingwalls on abutments with relatively stiff footings (footing width is at least three times abutment wall thickness), the horizontal reinforcement in the fill face of the abutment wall resisting the moment caused by earth pressure on the wingwall need not extend farther from the wingwall-abutment juncture than the following:

- 1.5H for the top 2/3 of the abutment wall height.
- 0.75H for the bottom 1/3 of the abutment wall height.

Where abutment walls with wingwalls are designed with thickened tops for bearing seats or backwalls, those thickened portions should be designed to carry 1/2 to 2/3 of the bending moment in the upper half of the abutment wall. Reinforcing between the abutment wall and the wingwall should extend beyond the juncture enough to develop the strength of the bar reinforcement.

Figure 1.11.2.3-1 Wingwall Reinforcement



#### CONSTRUCTION

When wingwalls are cantilevered from an abutment or pilecap, the designer should consider all stages of construction. When the abutment or pilecap would be unstable or overstressed under the dead load of the wingwalls before the superstructure and/or backfill are placed, the **Bent**

**Construction Sequence** on the plans should require that the concrete in the wingwalls not be placed until the superstructure and/or backfill are in place. Do not count on there being soil under the wingwall unless the wall has its own footing.

The height of the wingwall at the outer end of the wall should be a minimum of 3 feet. The slope of the bottom of the wall should be a maximum of 2:1.

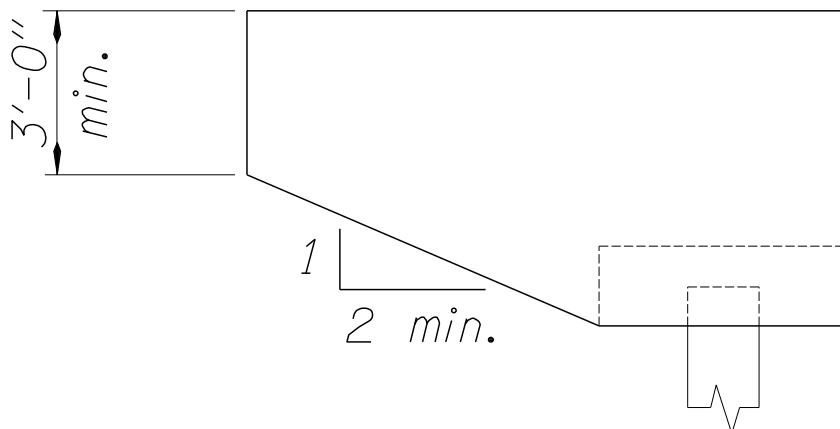
The Special Provisions and detail drawings should require that the embankment fill be placed to the elevation of the bottom of the wall before the wingwalls are constructed. In other words, bridge end bent wingwalls shall be cast against undisturbed material or well compacted backfill. The designer may want to use some discretion in this matter. A 24 foot wall would normally always need to be constructed on compacted fill, while a 6 foot wall could be constructed and backfilled at later time.

For walls shorter than about 8 feet, the bottom of the wall can be formed level, at the discretion of the designer or at the contractor's option. This adds some cost in materials, which may be offset by cost savings from easier construction. Potential benefits:

- Wingwalls are founded on level ground, no sloped or elevated bottom forms are required.
- Adds stability to abutment.
- Helps contain approach embankment at stream crossings when primary scour protection fails.

Due to concerns about stability and the potential for migrating of fresh concrete over the top of wingwall forms, the slope of the top of a wingwall should not exceed the maximum slope of the adjacent embankment nor 1.5:1 without a special stability investigation.

Figure 1.11.2.3-2 Wingwall Slopes



## 1.11.2.4 End Bents

### GENERAL

Where end bents or retaining walls are located adjacent to roadway construction, locate the top of footings at or below the elevation of the bottom of the roadway subgrade. Locate the top of the footing a minimum of 1 foot below the surface of the ground. The effect of items such as utilities, ditches and future widening should also be considered.

### TERMINOLOGY

In this section and elsewhere in the *BDM*, the terms **end bent** and **abutment** are used interchangeably. **Integral Abutment** is the industry standard term used to describe abutments that provide a continuous connection between the superstructure and the substructure. However, for consistency on ODOT bridge drawings, all bridge support locations are referred to as **bents**. Refer to the glossary in the *Appendix Section 1* for definitions of the terms **Abutment**, **Bent** and **Pier**. A possible exception could include the rehabilitation of an existing bridge, where the original plans called out **abutments** or **piers**, etc. and it would be less confusing to keep the same terminology as the existing plans.

### DESIGN

Lateral earth pressures at the end bent must be well thought out by both the bridge engineer and the geotechnical engineer. To more consistently model the behavior of the bridge and to ensure the design loads are constructed a [detail](#) has been developed for use in the plan set. The bridge engineer is responsible for including the completed detail, and pay limit diagram. The load diagram and associated notes in the plan set will be provided by the geotechnical engineer.

Provide access for inspection of bearings, shear lugs and backwalls for semi-integral abutments and access inspection for backwalls of integral abutment per *BDM 2.6.2*.

### C DESIGN

Historically a one foot neat-line with drain material has been used as a detail. This detail allows for easy calculation of the excavation and drain material quantities. However, the detail does not provide limits for the backfill at the end bents and wingwalls and while the specifications require granular structure backfill there is not consistent direction for the extent of the backfill. Thus, there are no assurances that the designed lateral earth pressures are achieved in construction which will also limit deformation.

When Earthquake Restraining Systems and Earthquake Resisting Elements are used for passive restraint the engineering soil parameters and construction become more critical for the operational performance of the bridge. Increases in height to mobilize the passive soil pressure for seismic resistance may be necessary to achieve sufficient resistance.

**BENTS ON MSE WALLS**

Refer to the *ODOT Geotechnical Design Manual, Chapter 15* for the design of MSE Walls. Provide a concrete facing for all MSE abutment walls and wingwalls.

**INTEGRAL ABUTMENTS**

Use integral abutments wherever site conditions and structure geometry are suitable for such structures and the conditions and criteria described in this section are met. In integral abutments, expansion joints and bearings are eliminated and the superstructure is fully integral with the abutment. This results in numerous potential benefits including:

- Greater structure redundancy.
- Simplified construction.
- Reduced construction cost and time.
- Reduced maintenance cost.
- Stiffer longitudinal response at abutments.

For a continuous bridge with expansion end bent connections, the interior bents take all of the longitudinal and transverse force effects. By using integral abutments in place of the expansion end bent connections, some of the longitudinal and transverse forces are distributed into the integral abutment (piles and backfill soils), thereby reducing the net forces on the interior bents. Integral abutments can reduce the longitudinal and transverse force effect considerably in a continuous bridge as compared to a bridge with expansion joints at the abutments.

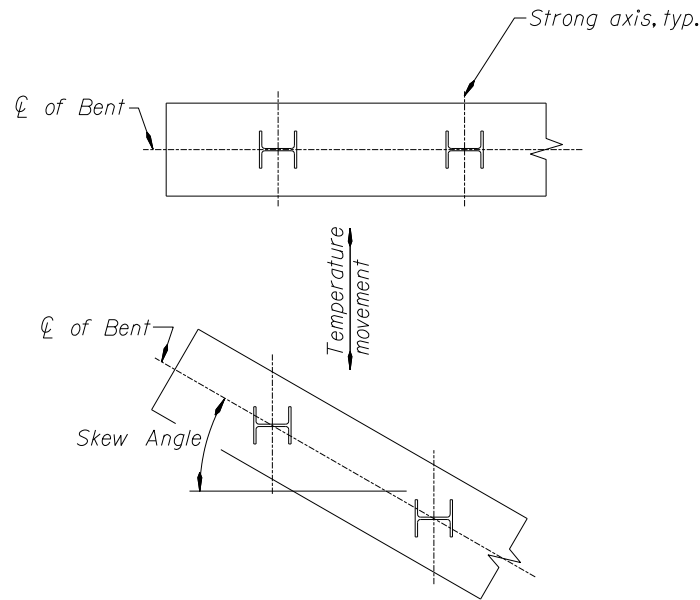
Use integral abutments under the following conditions:

- When the end bent is founded on steel pipe piles or H-piles. Do not place integral abutment foundations on top of, or through, MSE retaining wall reinforced backfill. For all other foundation types, see [guidelines for semi-integral abutments](#).
- When bed rock is a minimum of 12 feet from the bottom of the pile cap. Avoid using pre bored piles when bed rock is close to the surface, since this type of construction has been uneconomical.
- When there is negligible potential of abutment settlement which does not affect the serviceability of the bridge.
- When the radius of horizontal curvature is greater than 1200 feet.
- When the skew angle is less than 30 degrees.
- When, for all service limit states, movement at the top of integral abutment piles does not exceed  $\pm 1.5$  inches from the undeflected position. The corresponding range of pile movement is therefore 3 inches when the superstructure is made integral with the piles at the mean annual temperature.

Design Guidelines for Integral Abutments:

- Use a U-shaped abutment (wingwalls parallel to roadway alignment) when possible.
- Use H-pile with strong axis in the direction of temperature movement. See *Figure 1.11.2.4-1*.

Figure 1.11.2.4-1 H-Pile Orientation

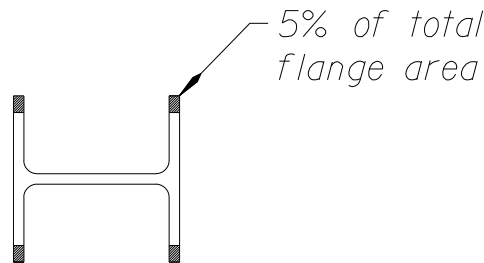


- Embed piles into the pile cap to develop moment fixity. See [BDM 1.10.5.4\(1\) Piling Details](#).
- Preboring may be necessary in some cases where pile design stresses are excessive due to thermal movements and cannot be accommodated without special foundation design and construction. The cost of preboring for the piles should be compared to the benefits gained by using an integral abutment design. Increasing the number of piles or the use of larger piles in the abutment may decrease individual pile stresses to acceptable limits. When preboring is required, and cost effective, then consider preboring an oversized hole. The prebore dimensions should be at least 4 inches or more in diameter larger than the diagonal dimension of the pile and large enough to accommodate the estimated pile deflection. Backfill the area around the pile with loose sand conforming to the current [SP 00360.10](#) or as recommended by the geotechnical designer. Do not compact the sand backfill material. Bentonite or pea gravel backfill are not recommended since they may not provide for the long term flexibility required of the pile and soil system. The depth of prebore should be 10 feet or more or as required to provide the required pile flexibility to decrease pile stresses to an acceptable limit.
- Detail piles of integral abutments to resist uplift force from temperature differential between top and bottom of the pilecap. Refer to [Figure 1.10.5.4-6](#) for pile anchorage details.
- The design of integral abutment bridges with a grade change between abutments should consider both vertical and horizontal components of bridge longitudinal



- loads such as uniform temperature changes, creep, shrinkage, braking, seismic, and lateral earth pressure, on the resulting axial and flexural stresses in the piles.
- Develop a LPILE model using the full pile for soil and pile interaction. Evaluate pile deflections, bending moments and stresses using LPILE computer program analysis.
  - At the service limit state, H-pile flange yielding at each flange tip should not exceed five percent of the total flange area. See *Figure 1.11.2.4-2*. For steel pipe piles no yielding of section is permitted.

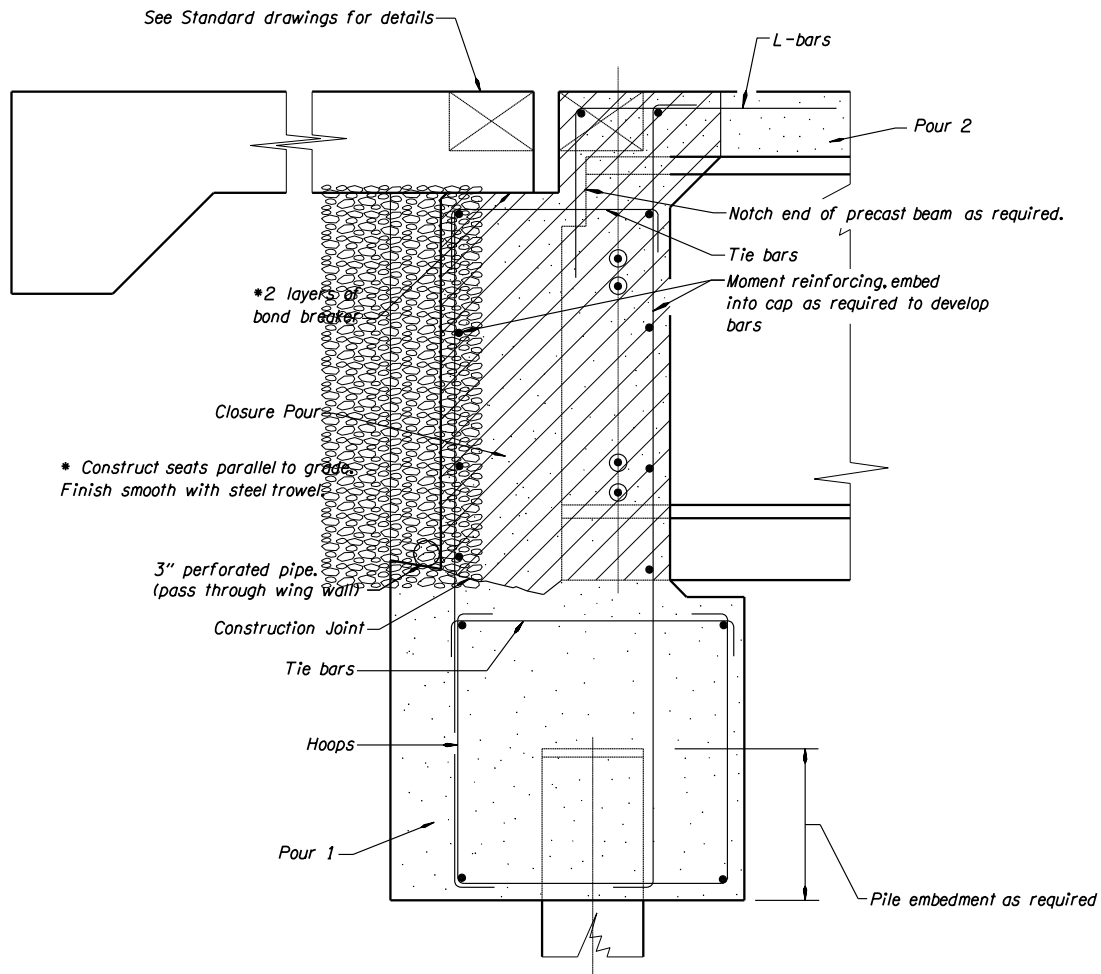
Figure 1.11.2.4-2 H-Pile Flange Yielding



- Consider the relative stiffness of the superstructure, substructure and any asymmetric span lengths in calculating end bent movement. Consider the potential for unequal thermal movements at end bents (integral abutments) due to asymmetric span lengths or changes in substructure stiffness.
- Consider torsion in components connected to integral abutments.
- Consider the combination of worst case events (except seismic) with temperature rise and fall.
- Specify placement and compaction requirements and an increased frequency of field density test requirements of the backfill material (minimum of two tests per stage of construction at each end bent) to achieve consistent soil stiffness behind both end bents.
- Consider the friction force between the bottom of the approach slab and structure back fill (expansion and contraction) in the superstructure design at the service limit state. Assume a friction coefficient of 0.54 unless specific measures are taken to reduce friction.
- Connect superstructure and end bents with a closure pour. Require a minimum of three days wait period between concrete deck placement and closure pour to release shrinkage stress in bridges with steel superstructures and include long term creep in your design for concrete superstructures. Include a note which requires backfill behind the abutment after closure pour.
- Where the range of abutment movement is 1 inch or less, the approach slab may be fixed to the superstructure and thermal movements accounted for by providing a saw cut in the approach pavement at the end of the approach slab. Where the range of abutment movement exceeds 1 inch, provide an expansion joint between the

- approach slab and the deck so the approach slab is not dragged back and forth with thermal expansion and contraction. See *Figure 1.11.2.4-3*.
- In integral abutment bridge staged construction, a continuous abutment is capable of transferring traffic live load vibrations in one stage to the girders and the deck that are under construction in another stage. These vibrations can damage fresh concrete in the deck. To minimize these vibrations, provide an expansion joint or closure segment in the integral abutment located between the stages of construction. See *BDM 1.9.1.3* for more discussion on vibrations.
  - Specify deck casting sequences and deck closure pours at integral abutment connections and specify the range of temperature when the contractor may place the concrete on the plans and in the special provisions. Keep the range of temperature in the closure pour to not adversely affect the pile stress during temperature fall or rise.
  - See design example in the following publication of the American Iron and Steel Institute *HIGHWAY STRUCTURES DESIGN HANDBOOK, Vol. II Chapter 5, Integral Abutments For Steel Bridges*, prepared for the National Steel Bridge Alliance by Tennessee DOT.

Figure 1.11.2.4-3 Integral Abutment Joint



### SEMI-INTEGRAL ABUTMENTS

Recommendations for integral abutments also apply to semi-integral abutments, except as noted in this subsection.

Consider the use of semi-integral abutments, rather than integral abutments, on foundations that are stiff in the longitudinal direction, such as spread footings, drilled shafts, and concrete piles. These foundations do not provide the required flexibility in the longitudinal direction required for integral abutments. Also consider semi-integral abutments, rather than integral abutments, when the abutment is founded on top of or passes through MSE retaining wall reinforced backfill.

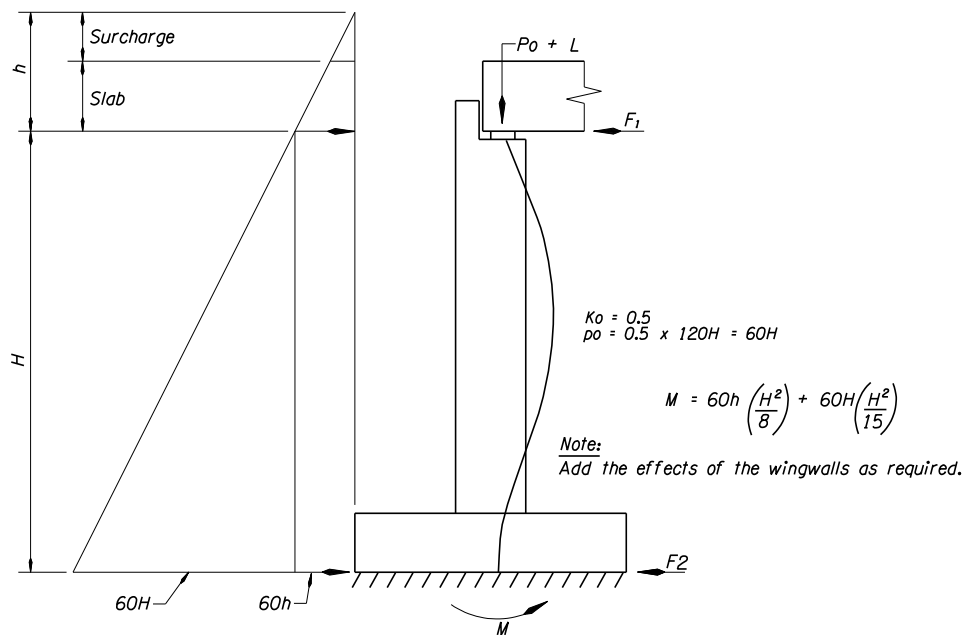
Two points that need to be evaluated on semi-integral abutments (especially on skewed bridges) are torsional forces affecting the bearings, and the effectiveness of shear keys used. When geometry requires a stiff footing, this type of construction is recommended.

For skewed bridges, consider the load path from thermal forces to the substructure. Skewed semi-integral abutments may rotate (finish condition).

### 1.11.2.5 Strutted Abutments

Abutments of single span bridges with the superstructure in place before backfilling may be designed using the strutting action to resist earth pressure overturning. For such abutments, apply soil pressure based on an at-rest or neutral condition of the soil. Footings for these abutments are not required to satisfy the **uniform bearing** under the dead load requirement. Investigate the bridge for the case of backfill being washed out behind one abutment. For this case, use active soil pressures with no live load surcharge on the opposite abutment. A factor of safety against overturning of the whole structure of 1.25 will be considered adequate, and 125 percent of the allowable bearing pressure will be acceptable.

Figure 1.11.2.5-1 Strutted Abutment Loading



### 1.11.2.6 Pile Cap Abutment Details

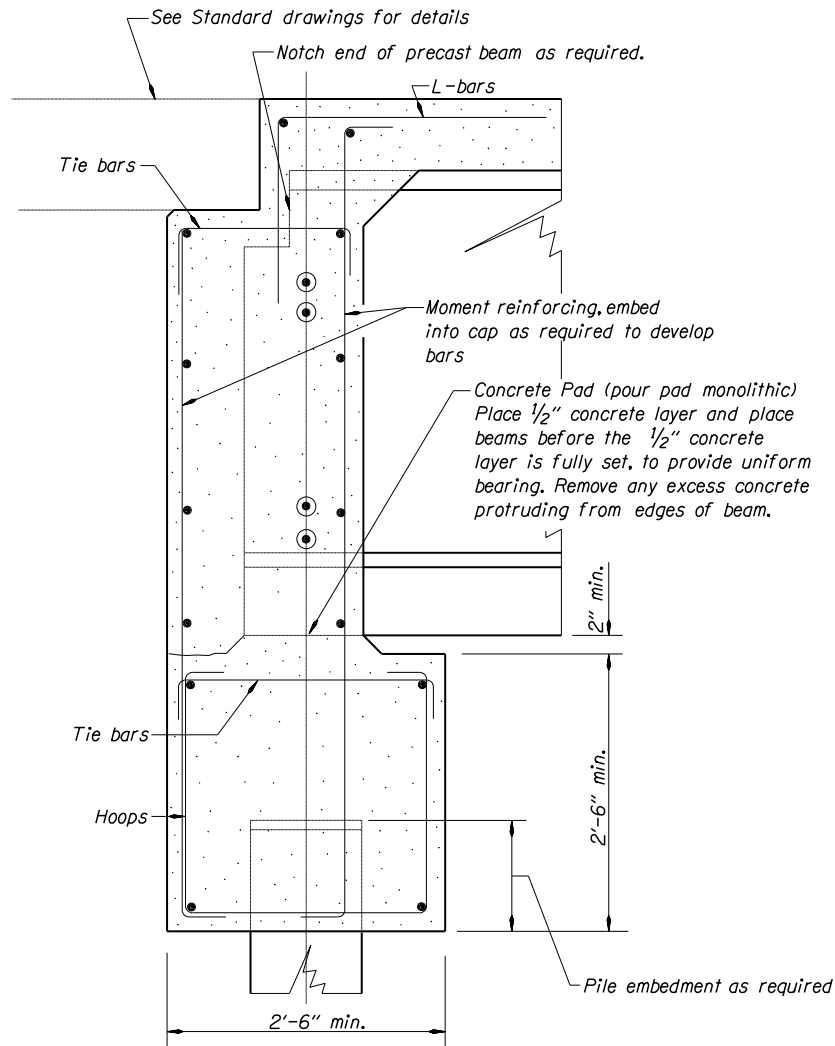
#### PILE CAP ELEVATIONS

Show the bottom of the pile cap elevations on the pile cap **Elevation** view. When the pile cap is sloped, show the elevation at each end.

#### FIXED (INTEGRAL) ACTION

Double row of reinforcing bars provides the connection between superstructure and substructure. Shear and moment are transferred. Pile embedment to develop fixity is required, when the number and size of piles are selected to resist a specified load.

Figure 1.11.2.6-1 Integral Abutment Detail

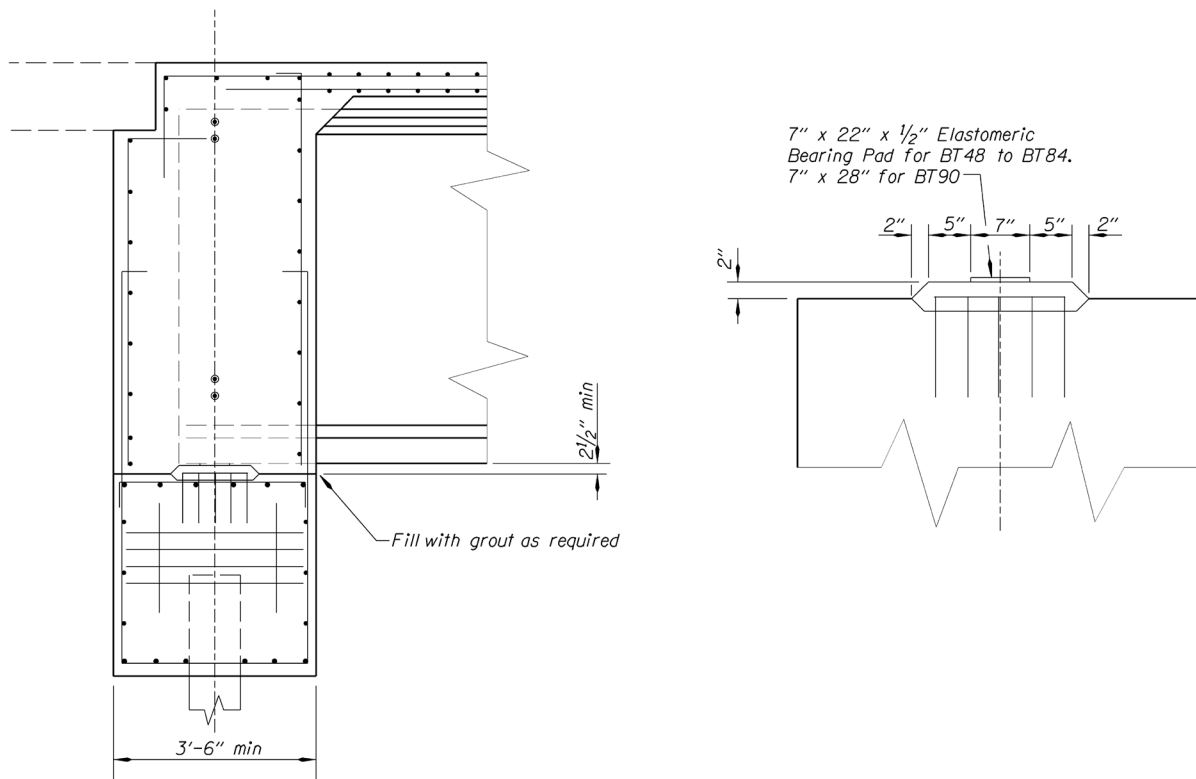


**FIXED (INTEGRAL) ACTION WITH ELASTOMERIC BEARING PADS**

This option allows the use of a ½ inch elastomeric bearing pad to be placed on top of the concrete grout pad. The precast beam can then be placed on top of the pad prior to the placement of the full width backwall. The beam should be placed just after a wet ½ inch grout layer has been placed under the bearing pad as specified in *BDM 1.14.1.6*. A double row of reinforcing bars provides the connection between superstructure and substructure. Shear and moment are transferred. Pile embedment to develop fixity is required, when the number and size of piles are selected to resist a specified load.

A reinforced concrete pad is required to resist temporary bearing loads. Hand placement of grout under the bottom flange of the beam may be required to fill the 2½ inch gap.

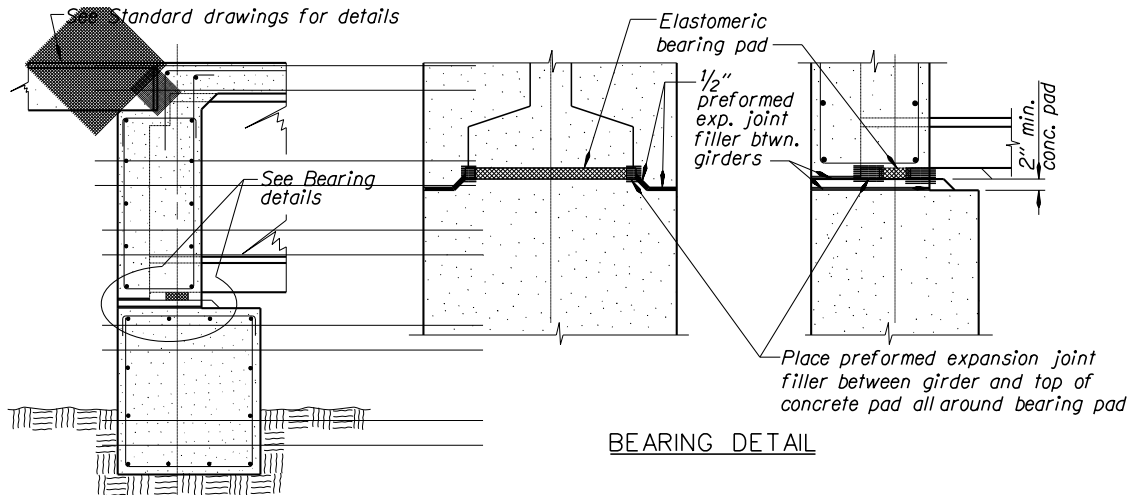
Figure 1.11.2.6-2 Grout Pad Detail



The performance of the ½ inch bearing pad under the vertical load and rotation resulting from deck load and diaphragm load was evaluated according to *LRFD 14.7.6.3.5b* for BT48 to BT90 girders. For BT48 to BT84 girders, a 7 by 22 inch pad is required. For BT90 girders, a 7 by 28 inch pad is required. Beam weight was not included in the end rotation calculations because the wet grout layer placed below the elastomeric pad at the time of beam placement eliminates any rotation of the pad due to beam end rotation from beam dead load.

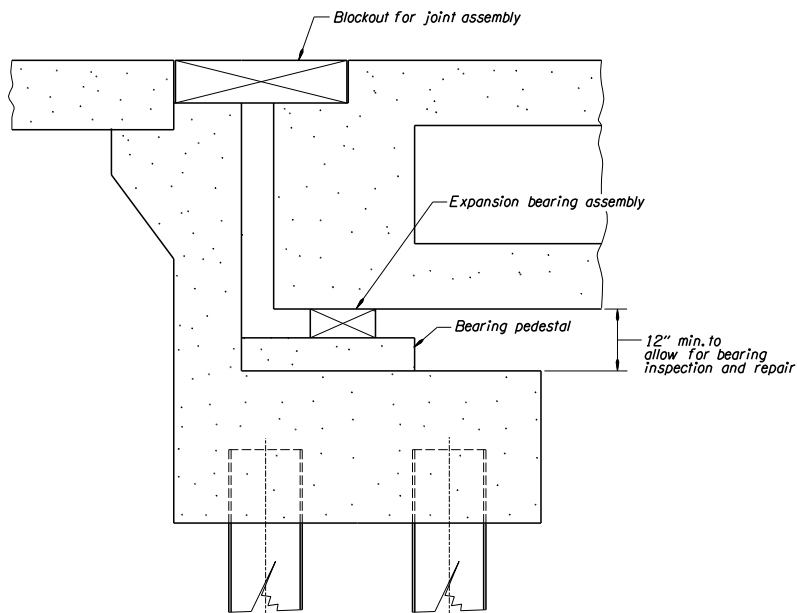
Expansion allowed (nominal amount of movement) – No reinforcement is provided between the superstructure and substructure. This type is appropriate when nominal movement is expected on a non-yielding type of foundation.

Figure 1.11.2.6-3 Bearing Detail



Expansion allowed (movement allowed as required) - No reinforcement is provided between the superstructure and substructure. This type is appropriate when movement needs to be accommodated in the design. Various types of bearings and joints can be used for the movement required.

Figure 1.11.2.6-4 Expansion Details



### 1.11.2.7 Abutment Details for Prestressed Slabs

See *BDM Appendix 1.11* for Prestressed Slab End Bent Design/Detail Sheets for more details.

#### SHALLOW ABUTMENTS (PILE CAP) – PRECAST SLAB OR BOX

Most common and most economical type of end bent. It requires the least amount of excavation and cast-in-place concrete.

Figure 1.11.2.7-1 Shallow Abutment - Precast Slab or Box detail

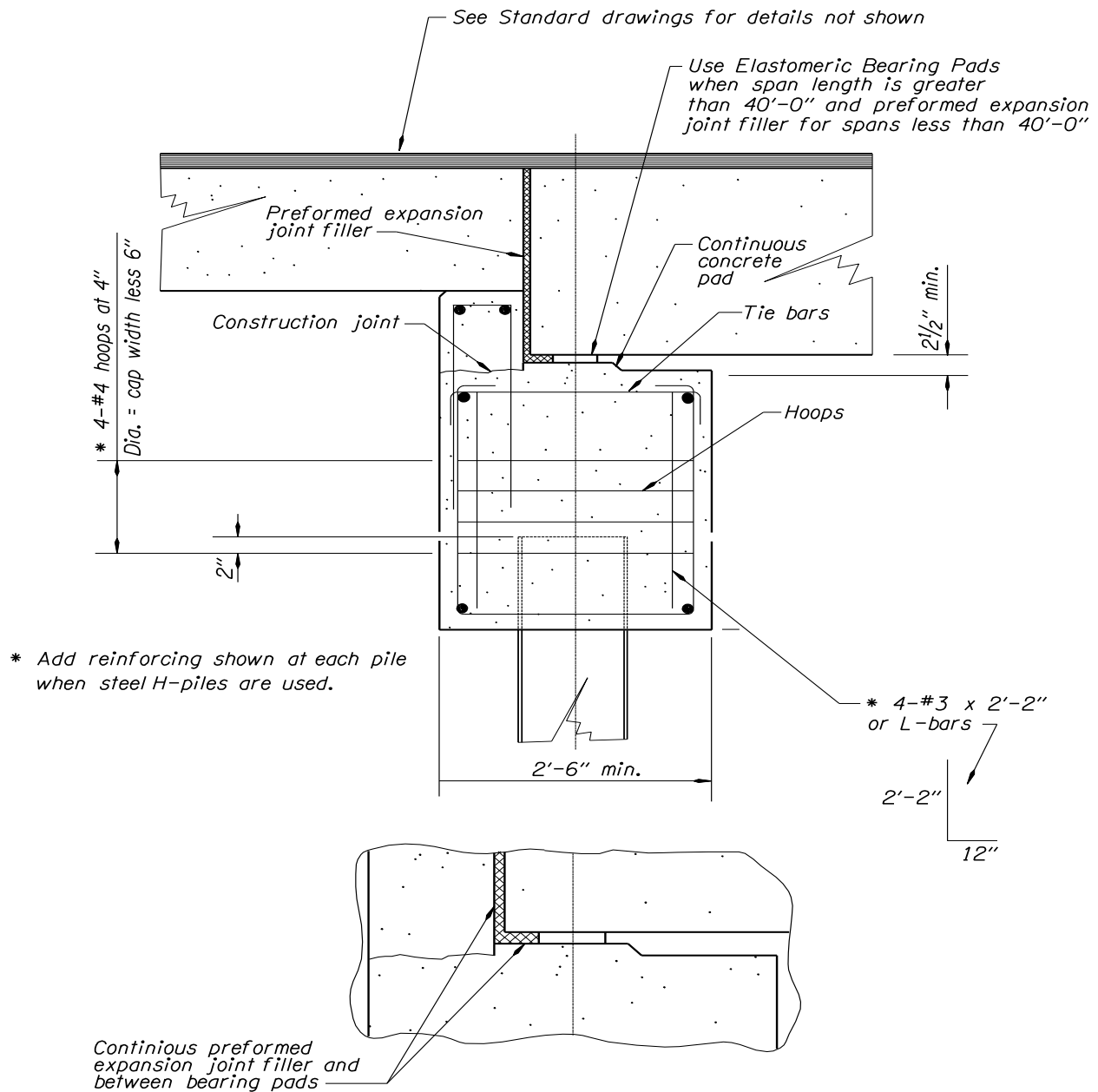
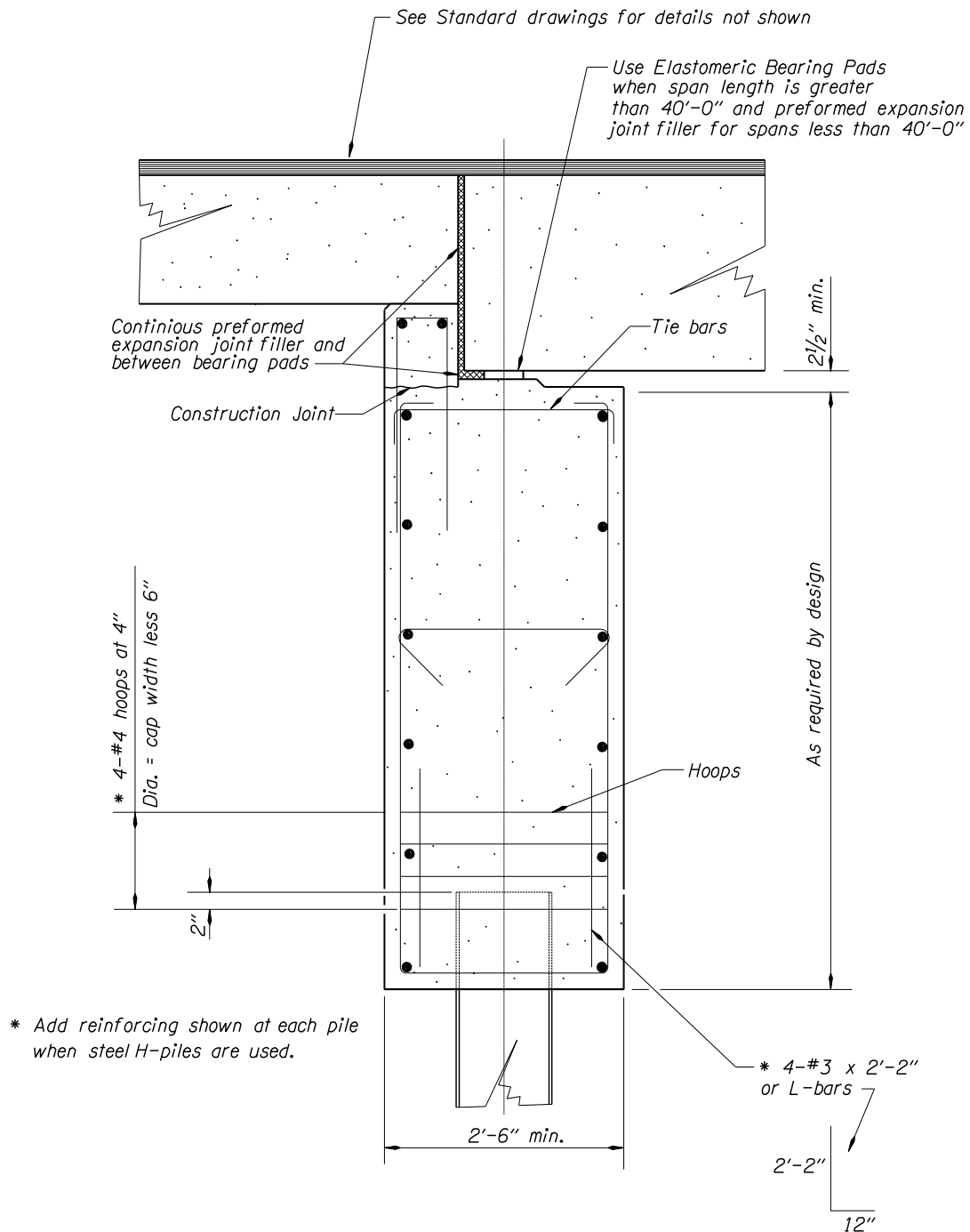




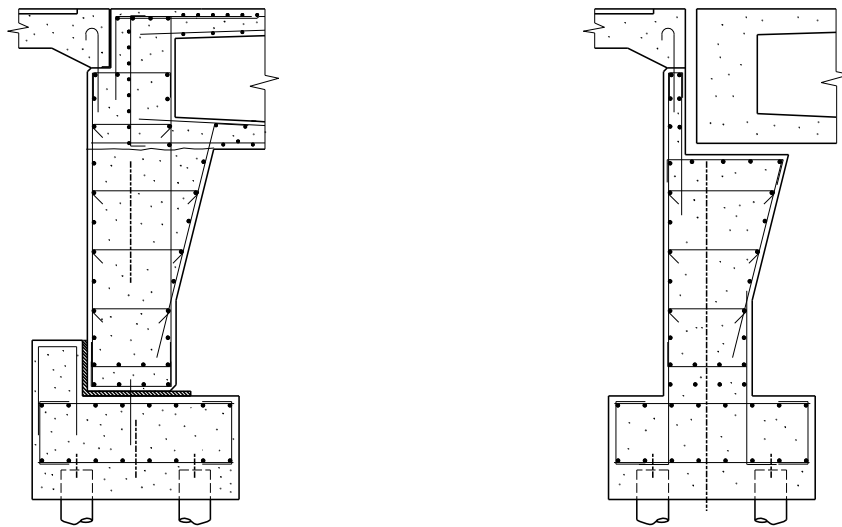
Figure 1.11.2.7-2 Partial Depth Abutment - Precast slab or box detail



### 1.11.2.8 Forming of Backwalls for End Beams

Details should be developed that will allow the removal of forming materials. Forming materials, including expanded polystyrene must be removed. Forming material is normally not yielding and can cause cracking as the structure expands and contracts.

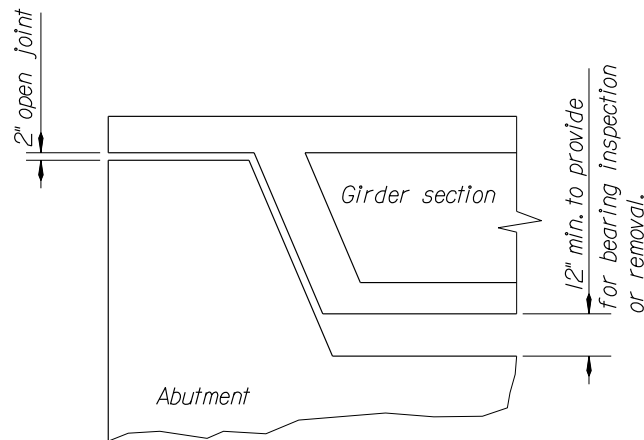
Figure 1.11.2.8-1 Backwalls for End Beam form detail



### 1.11.2.9 Bent Joint Details

Provide an open joint between the abutment and the deck-and-girder section, as shown below. Note on the plans of post-tensioned structures that when expanded polystyrene is used to form the joint, it must be removed before tensioning.

Figure 1.11.2.9-1 Bent Joint Detail



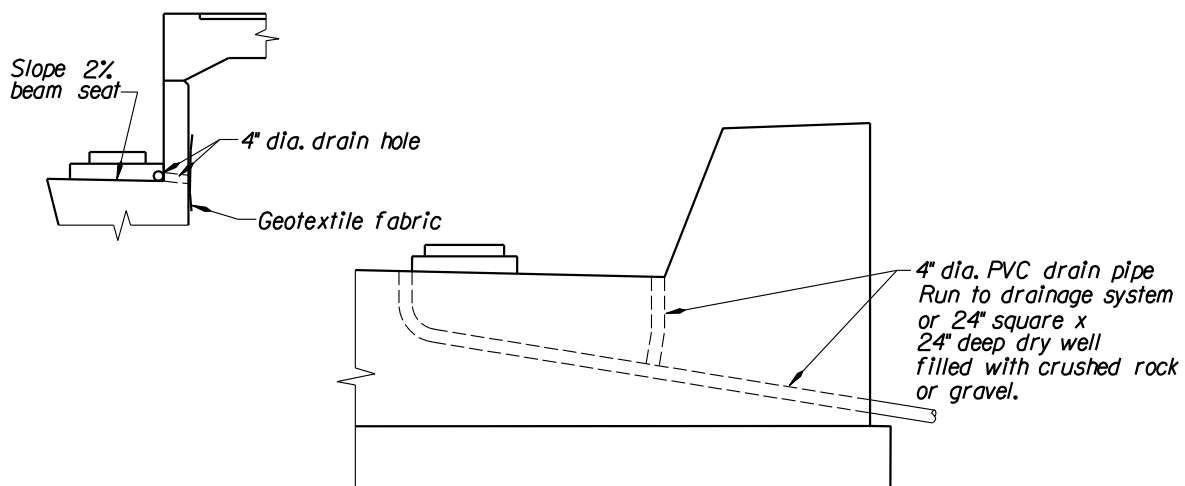
### 1.11.2.10 Backwall Reinforcement for Post-tensioned Structures

When detailing the vertical reinforcement for the backwalls of abutments for post-tensioned spans, the designer should take into account the location of the post-tensioning anchorages. Spacing of bars and/or splicing details should be such that the vertical bars do not have to be bent out of the way for the post-tensioning operation and bent back to their final positions.

### 1.11.2.11 Beam Seat Drainage

Slope the beam seats of abutments to drain away from the front face. Provide scuppers through the bearing pedestals and backwall or drain pipes at low points to pick up any water that might leak into this area.

Figure 1.11.2.11-1 Beam Seat Drainage Detail



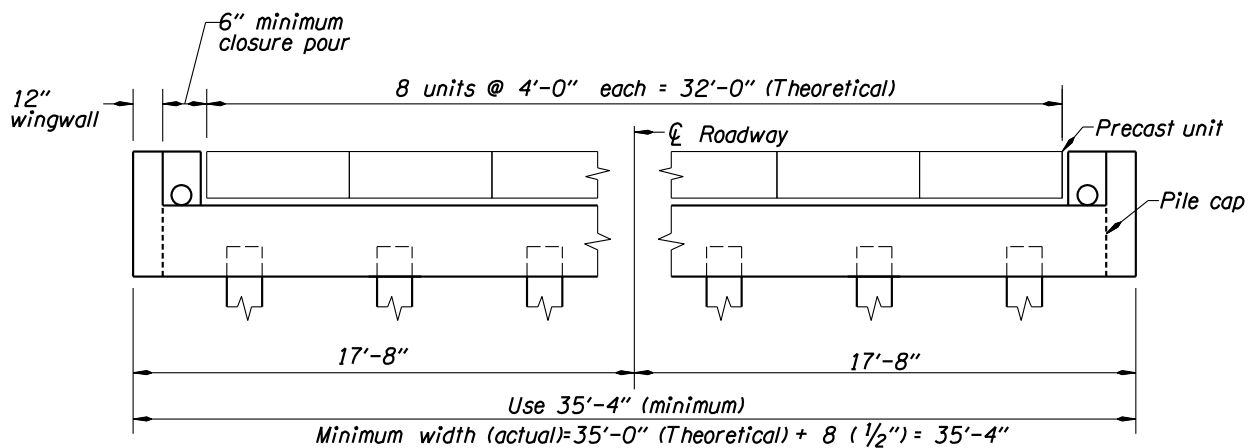
### **1.11.2.12 Reinforced Concrete Approach Slabs**

See *BDM 1.23* for approach slab requirement criteria. Detail all bridges with paving ledges or other provisions so that present or future reinforced concrete approach slabs can be supported. Detail structures with sidewalks with a ledge or other provision to support an approaching concrete walk (present or future) when there is no approach slab in the walk area. When reinforced concrete approach slabs are required, show them on the bridge plans and include them in the bridge quantity estimate. In most cases, the bridge rail should be extended to the end of the approach slab.

### 1.11.2.13 Bent Width Provisions with Precast Units

All pile caps, crossbeams, abutments, etc. supporting adjacent precast units (such as slabs, boxes, integral bulb-T's, etc.) should be detailed for the total width of all units with an additional width of a minimum of ½ inch per precast unit. This is required because unit fit-up is not exactly true and **growth** in width occurs. The 6 inch minimum closure pour on each side of the exterior units at abutments as shown on End Bent Detail drawing may be used for adjustment due to these misfits. The 6 inch dimension may be increased where necessary for wider roadways.

Figure 1.11.2.13-1 Bent Width Dimensions



## 1.11.3 Interior Bents

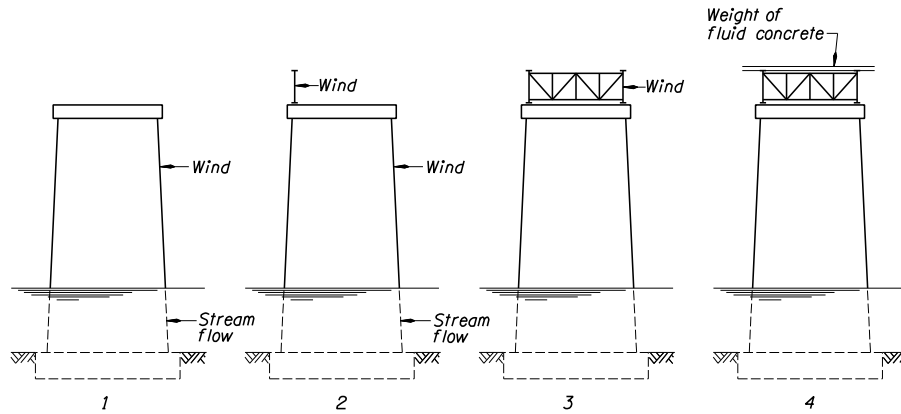
### 1.11.3.1 Interior Bents, Design and Detailing

#### DESIGN

Design structure for stability under all stages of construction. The following conditions, in particular, should be checked:

- Stream flow and wind load w/o superstructure.
- Dead load of one or more girders plus wind load and stream flow. Note: Contractor is responsible for stability of girder itself.
- Lateral system must be sufficient to insure stability of girders under wind load without deck.
- Top flanges must have sufficient support not to buckle under dead load of (fluid) concrete without the aid of deck forms.

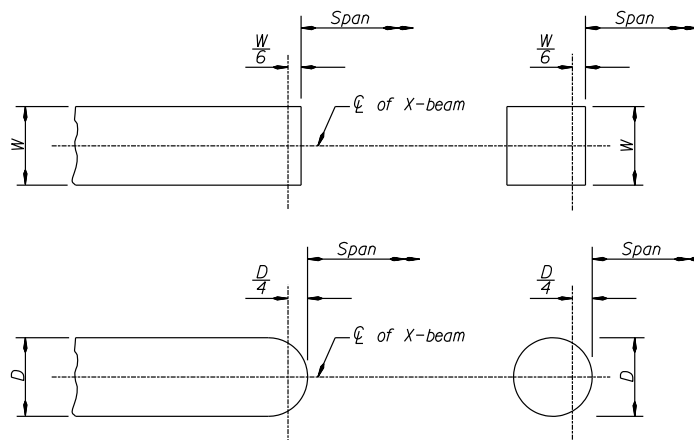
Figure 1.11.3.1-1 Construction Stability Conditions



**EFFECTIVE SPAN LENGTH**

When computing the maximum negative moment for a crossbeam on a column or pier, the crossbeam may be considered to be supported by a concentrated reaction, the distance show in *Figure 1.11.3.1-2* inside the face of the column or pier.

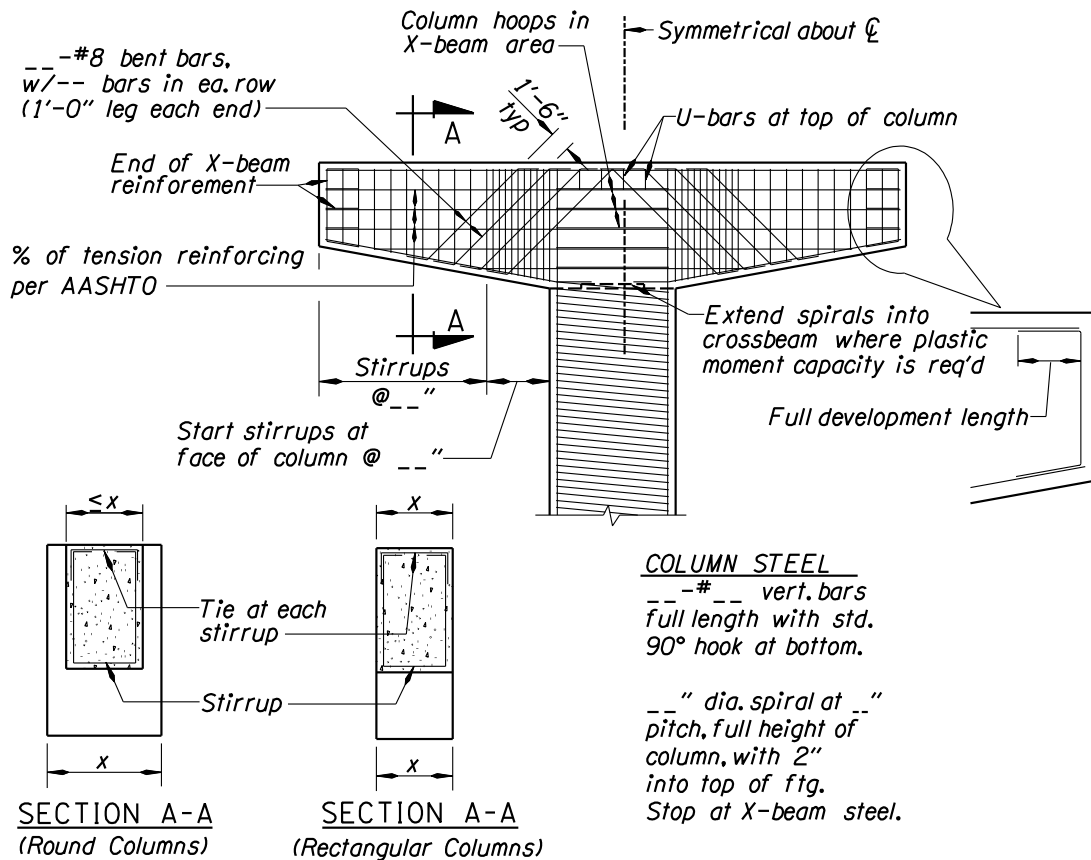
Figure 1.11.3.1-2 Effective Span Length



**DETAILING**

Provide all dimensions and details necessary for the reinforcing steel fabricator and contractor to construct it.

Figure 1.11.3.1-3 Structure Detailing Requirements



**NOTE:**  
*X-beams, columns and footings should be sized to be structurally adequate and esthetically proportional.*

See *BDM 1.11.3.5* and *BDM 1.11.3.6* for details of column reinforcing.

**1.11.3.2 Interior Bent Details for Prestressed Slabs**

See *BDM Appendix 1.11* for Prestressed Slab Interior Bent Design/Detail Sheets.

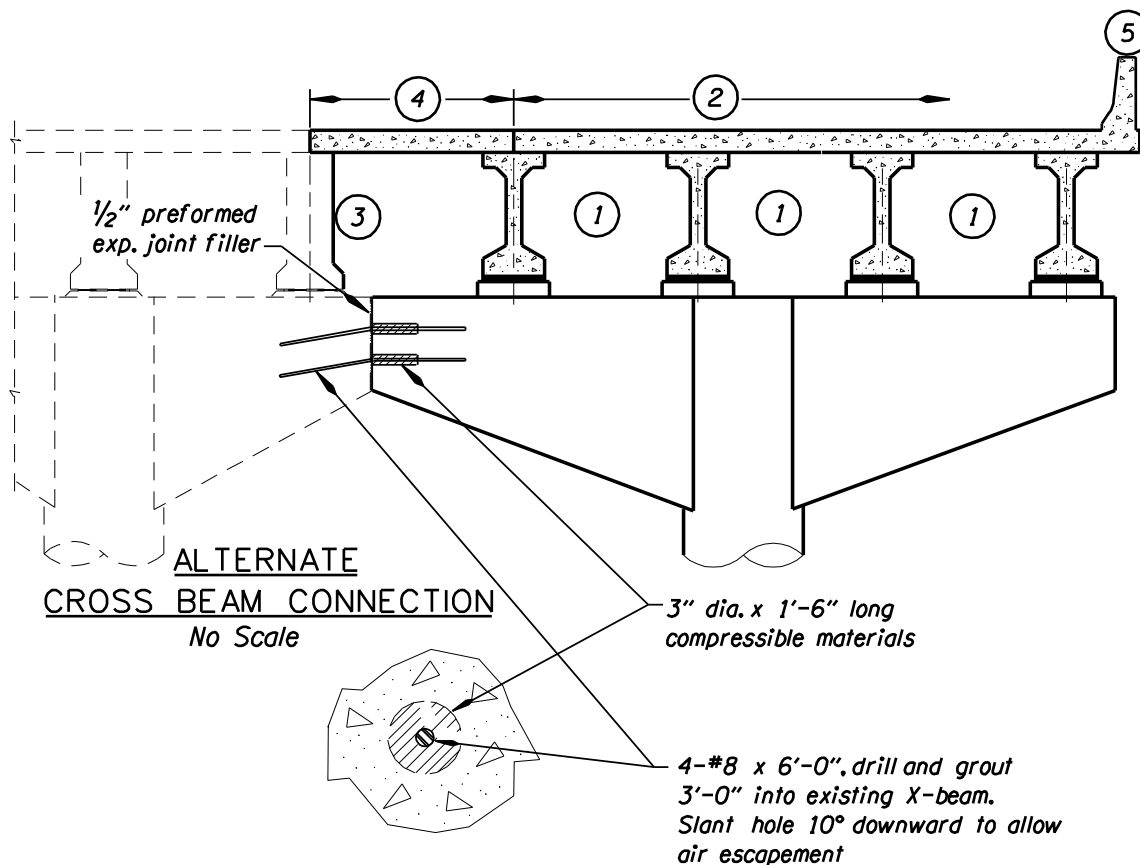
### 1.11.3.3 Structure Widening, Interior Bents

Generally, connections between structure bents should be detailed to tie the structures together, but prevent dead load and concrete shrinkage loads from being transferred to existing bents.

Example details are shown in *Figures 1.11.3.3-1 and 1.11.3.3-2.*

The method below allows the new x-beam to deflect during the construction loadings with minor load transfer to the existing crossbeam.

Figure 1.11.3.3-1 Structure Widening Detailing Example



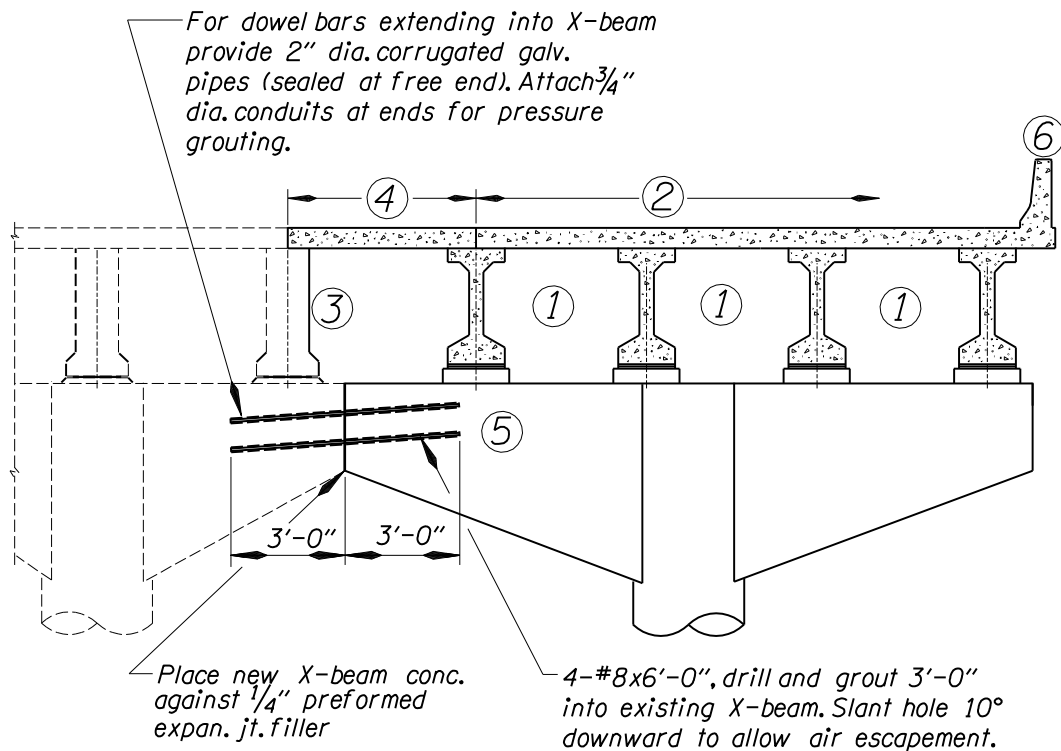
**POUR SCHEDULE  
(INCLUDING CLOSURE POUR)**

- ① Make pour in end beams and diaphragms
- ② Make pour in deck slab. Delay pour ② a min. of 3 days after pour ①. A transverse deck construction joint may be made at any diaphragm beam. Delay pouring adjacent deck sections a minimum of 36 hours.
- ③ Make pour in end beams and diaphragm of closure pour section.
- ④ Make pour in deck slab of closure pour. Delay a minimum of 3 days after pour ③.
- ⑤ Make pour in bridge rail.



The method in *Figure 1.11.3.3-2* allows the widening construction to be completed before the connecting bars are grouted and able to transfer loading from the new crossbeam to the existing crossbeam.

Figure 1.11.3.3-2 Structure Widening Detailing Example



CROSS BEAM CONNECTION AND CLOSURE POUR DETAIL

No Scale

POUR SCHEDULE

(INCLUDING CLOSURE POUR)

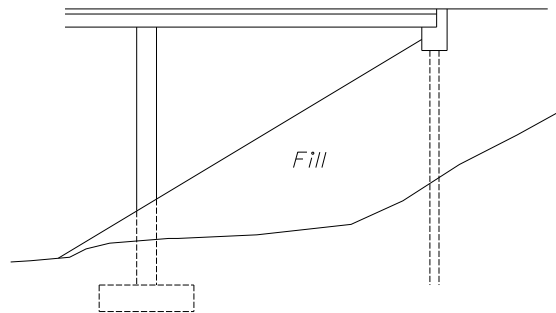
- |   |  |
|---|--|
| <p>① Make pour in end beams and diaphragms</p> <p>② Make pour in deck slab. Delay pour ② a min. of 3 days after pour ①. A transverse deck construction joint may be made at any diaphragm beam. Delay pouring adjacent deck sections a minimum of 36 hours.</p> | <p>③ Make pour in end beams and diaphragm of closure pour section.</p> <p>④ Make pour in deck slab of closure pour. Delay a minimum of 3 days after pour ③.</p> <p>⑤ Pressure grout dowels in cross beam.</p> <p>⑥ Make pour in bridge rail.</p> |
|---|--|

o

### 1.11.3.4 Columns in Slopes

Special attention should be given to situations where new fill could exert lateral pressure against bents other than the end bents. Such situations may require special construction sequence notes and/or special footing design including battered piling.

Figure 1.11.3.4-1 Additional column loading situations



### 1.11.3.5 Column Design, General

See *BDM 1.3.4* for column loading criteria for vehicular impact, depending on type and location of barrier used (ODOT Instructions for *LRFD 3.6.5*).

For column designs controlled by seismic loading, provide shear and confinement reinforcement detailing according to *2nd edition of AASHTO Guide Specifications for LRFD Seismic Bridge Design, Section 8.6*.

For both tied and spiral columns, ensure adequate space for man access for tying and inspection.

Multiple interlocking spirals are the preferred choice for non-circular columns. Use 0.75 spiral diameters as the maximum center-to-center spacing of spirals. In this way, the smaller column dimension will dictate the larger column dimension. Closer center-to-center spacing of spirals is possible but would reduce the access space for tying and inspection. At least four vertical bars must be placed within the spiral overlap area. A photo log from FHWA is available showing how multiple spirals have been constructed.

Corners will normally be filleted or rounded. Using rectangular corners would normally require nominal corner vertical bars with ties developed within the core area. Such ties would interfere with bar tying and inspection. Therefore, design corners to be considered **expendable** in an earthquake, by detailing the rebar so that it is not developed within the core.

Bundled bars should only be oriented tangentially (both bars touching the spiral). Multiple concentric rings of bars are not a constructible option with multiple interlocking spirals, but may be used in detailing of circular columns.

Apply *LRFD equations (5.7.4.6-1, 5.10.11.4.1d-1, 5.10.11.4.1d-2 and 5.10.11.4.1d-3)* using volumes for a single spiral, using a theoretical minimum cover column with 2 inches of cover to determine gross area in these equations. The maximum spiral yield strength to be used in determining spiral spacing is 60 ksi. The heavier spiral confinement requirements for plastic hinge areas do not apply to tops of columns that are pinned.

Where columns are supported by drilled shafts, use a non-contact splice as shown in *Figures 1.10.5.5-1 or 1.10.5.5-2*. Ensure column diameter is less than shaft diameter according to *BDM 1.10.5.5(1)*. Provide confinement reinforcement meeting the requirements in *LRFD 5.10.11.4.1d* for column segments extending into drilled shaft as shown in *Figures 1.10.5.5-2 and 1.10.5.5-2*.

Specify *ASTM A706* reinforcement for vertical column bars when columns are supported on drilled shafts or when plastic hinging is anticipated in either the top or bottom of the column.

Specify  $\frac{3}{4}$  inch maximum aggregate size in footings, columns and crossbeams. To maintain the shape of the spirals, use a maximum vertical bar spacing of 8 inches.

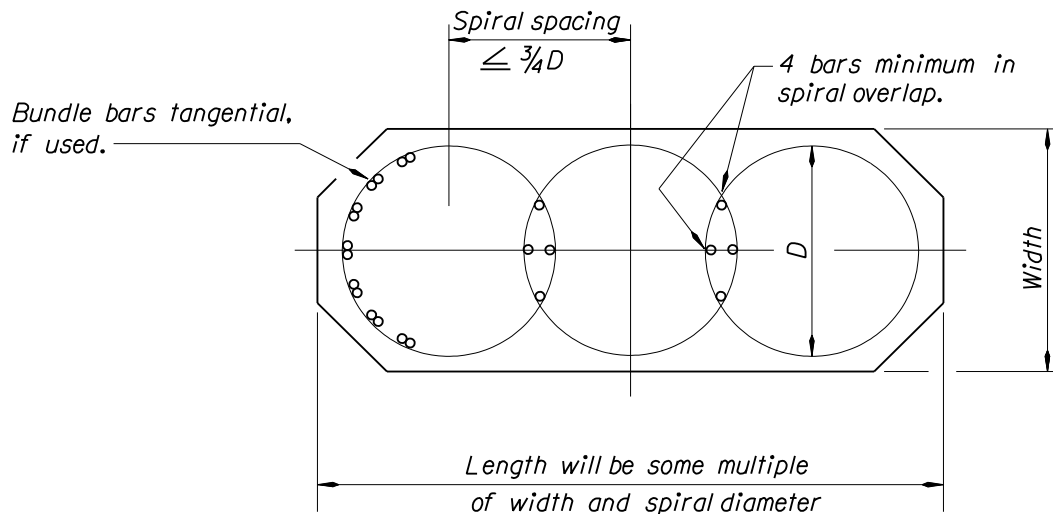
Containing an 8 inch diameter drain pipe within the column and taking it out between spread bars at the bottom is not an option since confinement requirements would be violated.

### 1.11.3.6 Spiral Reinforcing

Use spiral reinforcing for all columns. For column designs not controlled by seismic loading, extend spirals from a minimum 2 inches below the top of the footing to the bottom of the steel in the cross beam or longitudinal beam.

Where plastic moment capacity is required between column-to-crossbeam connections, extend the spirals into the crossbeam to the top crossbeam steel.

Figure 1.11.3.6-1 Spiral Reinforcing



The following notes apply to the specification above and are for designer information only:

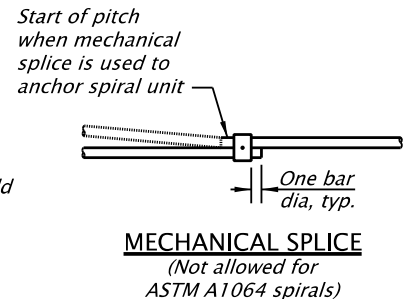
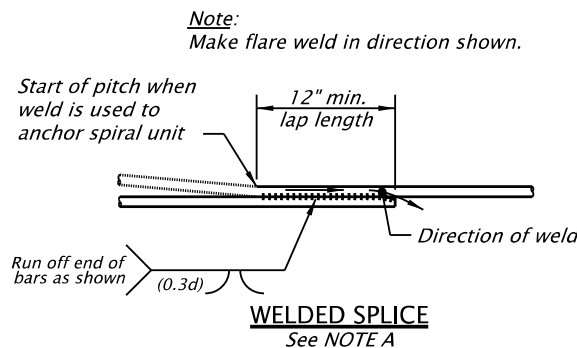
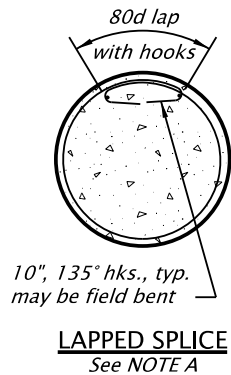
- Deformed bars (ASTM A615 Grade 60 or ASTM A706) can be specified in sizes from #3 through #6.
- A706 is formulated to be weldable so submission of chemical analysis is unnecessary. It is also preferred because it is the most ductile.
- A1064 plain steel wire cannot be mechanically spliced because it lacks deformations. It is available only in sizes 5/8 inch diameter or less.
- ASTM A1064 and A615 Grade 60 bars are available in coils. Average A1064 bar coils have a weight of approximately 1500 pound, and A615 deformed bar coils have a weight of 3000 pound to 4500 pound, depending on the size of the bar.
- For ease of handling, spirals are generally fabricated without splicing in weights up to a maximum of 200 pound per piece for diameters 8 feet and under.
- Coated spiral bars are fabricated using ASTM A706 bars. Stock lengths are generally 40 feet to 60 feet. Bars are spliced using the weld lap splice method. Maximum shipping mass is 200 pound for ease of handling and protection of the coating.
- Approved mechanical fasteners may be used provided the full strength of the bar is developed.
- Use of lapped splices should be avoided because of the 80d lap requirement and because hooks into the core will inhibit access for tying and inspection. Use of lapped splices is not permitted for spirals less than 3 foot diameter. Although the lap splice detail is structurally acceptable, and permissible by the code, it causes construction challenges. While casting concrete, the tremie gets caught in the protruding 10 inch hooks, making accessibility to all areas and its withdrawal cumbersome.
- The plans should state the type of spiral reinforcement used in computing reinforcing quantities. Normally the designer should assume A706 with welded splices.

Standard spiral splice and termination details are shown in *Figure 1.11.3.6-2*.

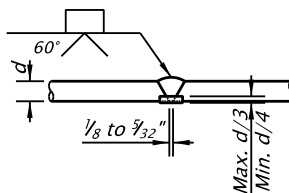
Figure 1.11.3.6-2 Spiral splice and termination detail

**NOTE A:**

Use ASTM A706 for all welded splices, except ASTM A615 Grade 60, ASTM A1064 may be used if copies of the chemical composition analysis are submitted and approved as weldable by the Engineer. Anchor spirals at each end or discontinuity with one extra turn and a splice to itself as shown. Where permitted on plans, provide closed hoops conforming to the requirements of this detail. Lapped splice is not allowed within  $\frac{1}{6}$  the column height or max. column cross sectional dimension or 18" from top of footing or bottom of cap beam, or in columns with spirals less than 3'-0" in diameter.



**SPIRAL SPLICE/TERMINATION DETAIL**



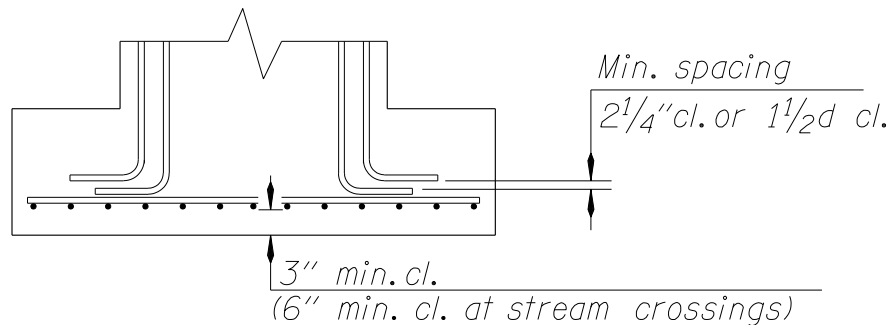
**ALTERNATE WELDED SPLICE  
(EXCEPT ASTM A1064)**

Weld reinforcing steel splices in accordance with ANSI/AWS D1.4 "Structural Welding Code Reinforcing Steel"

### 1.11.3.7 Column Steel Clearance in Footings

Column steel hooks are placed on top of the footing mat to avoid the need for threading footing steel through the column steel cage.

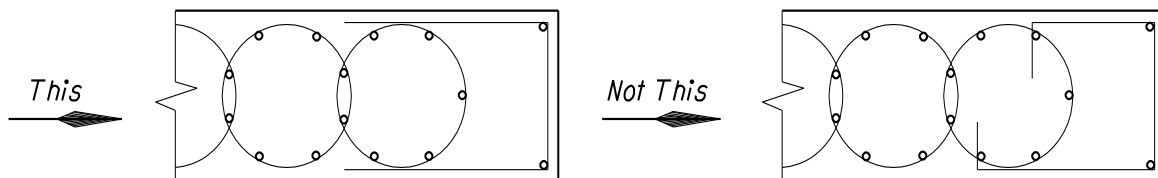
Figure 1.11.3.7-1 Column Steel Hooks Detailing



### 1.11.3.8 Column Hoops

Due to seismic requirements, use hoops and ties only to supplement spiral reinforcement for architecturally shaped columns to provide some confinement to concrete that is **expendable** in a major seismic event. Terminate these supplemental hoops and ties without the normal extension (hooks) into the interior mass of the column concrete. Because these architectural features are expendable and are not considered in the analysis and design we want to allow their failure. They should be detailed so they do not add undesired stiffness and strength.

Figure 1.11.3.8-1 Column Steel Hoops



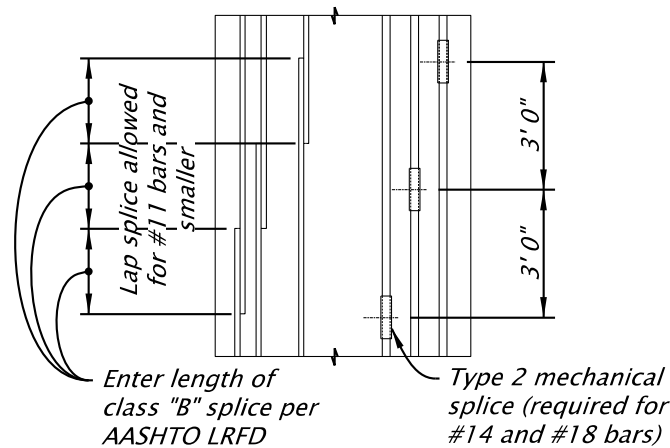
### 1.11.3.9 Vertical Bar Splices

Do not splice vertical column bars for columns less than 30 feet in length (no footing dowels). For longer columns, splices may be made as shown below in the middle half (preferably at mid-height) of the column (outside the plastic moment areas). Lap splice is allowed for #11 bars and smaller. For #14 and #18 bars Type 2 mechanical splice is required. Type 2 mechanical splice is

required to develop at least 125 percent of the specified minimum yield strength and 100 percent of the specified tensile strength of the reinforcing bars.

The development requirements may require 180 degree hooks of the column verticals in the cap beam. Pay attention to how the column verticals, extended spirals, bottom cap beam bars, and post-tensioning ducts all fit together.

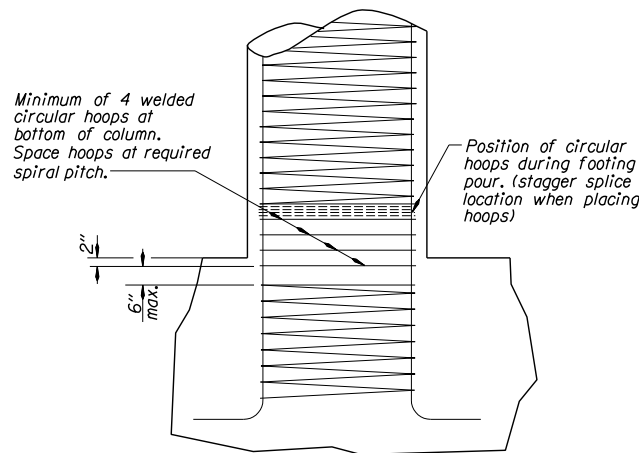
Figure 1.11.3.9-1 Vertical Bar Splices



### 1.11.3.10 Optional Hoop Detail at Bottom of Column

The detail below will facilitate more effective concrete placement in the core area of the footing. The 6 inch gap is used to facilitate placement of the top mat of reinforcement.

Figure 1.11.3.10-1 Optional hoop detail at bottom of column



OPTIONAL HOOP DETAIL AT BOTTOM OF COLUMN

### 1.11.3.11 Footing Reinforcing

Provide a mat of reinforcing steel (minimum of #5 bars at 12 inch centers each way) in the top of all footings. When calculated loads require larger amounts of reinforcement, the latter controls. Also provide U-bars at 12 inch centers around the periphery of the footing.

Extend spirals at least two inches into the footing. Place the footing top mat immediately below the spiral termination. Place additional spirals below the mat (use a 6 inch spiral gap) down to the vertical bar's point of tangency. Use the same spiral pitch at all locations.

See *Guide Spec. 6.4.7* for footing joint shear reinforcement for Seismic Design Category (SDC) C and D.

Figure 1.11.3.11-1 Example of Footing Reinforcing

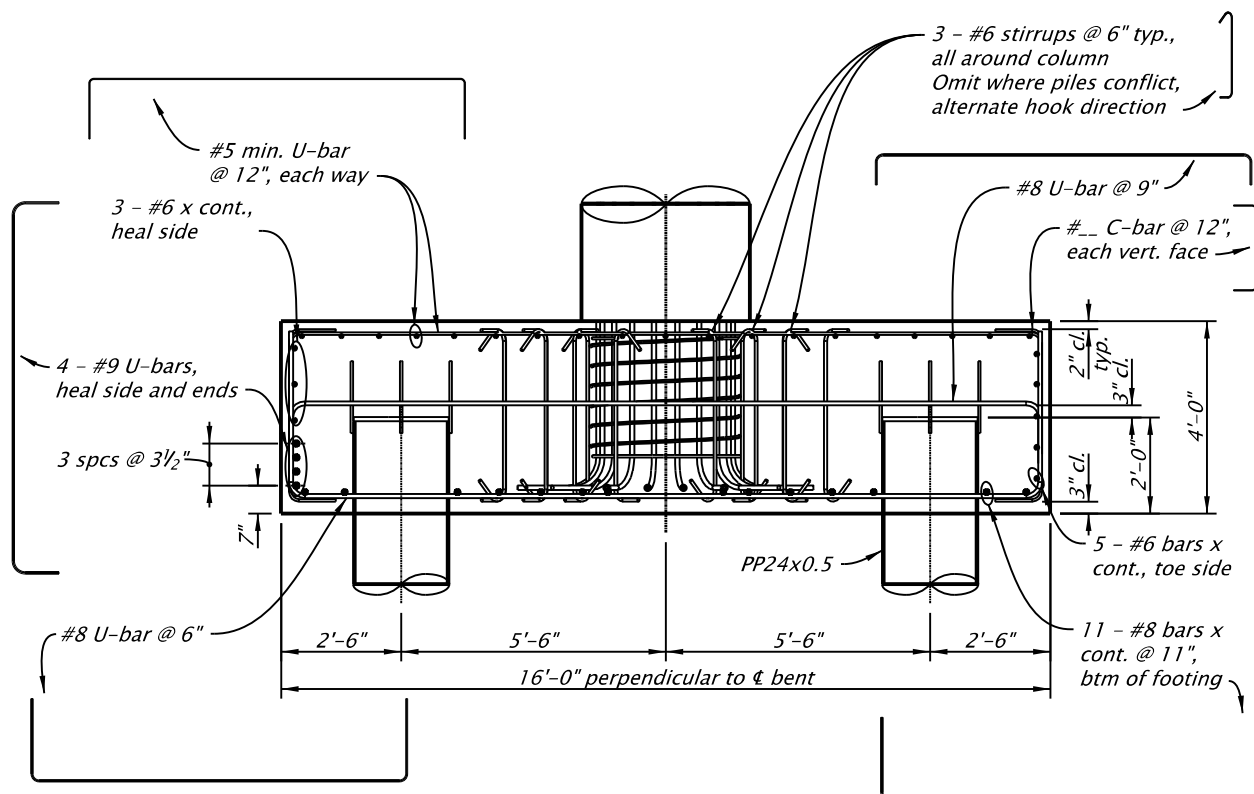
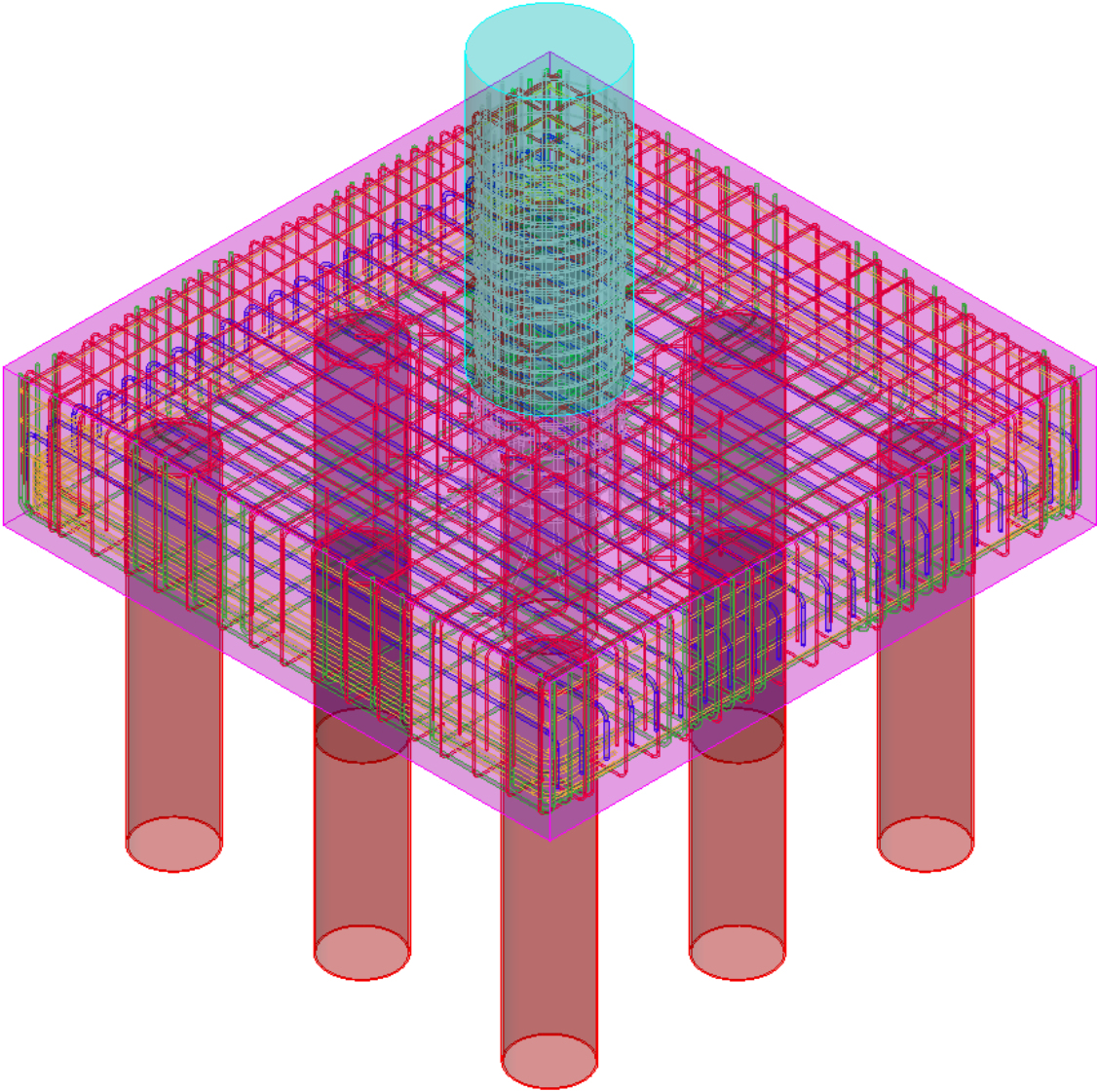




Figure 1.11.3.11-2 Example of Footing Reinforcing, Isometric View



### **1.11.3.12 Sloped Footings**

General criteria for sloped footing tops are:

- The required footing thickness adjacent to the column should be at least 4 foot 6 inches. No minimum edge thickness is specified except as required for shear.
- The amount of concrete saved should be at least 10cy.
- The top may be sloped either two ways or four ways, but should not be steeper than 2:1.
- A horizontal area should be provided 6 inches to 12 inches wide outside the base of the column to facilitate forming the column.

## 1.12 Buried Structures

### [1.12.1 Culvert Design, General](#)

### [1.12.2 Tunnels \(structural elements\)](#)

## 1.12.1 Culvert Design, General

A single culvert span, or out-to-out sum of closely spaced culvert spans, of 20 feet or more is defined as a **bridge** and is included in the National Bridge Inventory (NBI). NBI culverts must be load rated per the *ODOT Load Rating Manual*.

Large culverts are defined as a diameter or span 6 feet or greater.

Precast culverts are designed by the manufacturer according to *SP 00595*. Ensure that the designs of large culverts comply with the following requirements:

- Precast elements consist of individual cells with continuous vertical joints, unless an engineered substructure is provided.
- For precast wingwalls, provide positive connections between wingwalls and RCBC end sections with short closure pours or weldments.
- Provide reinforcement continuity between precast footings and concrete aprons.

## C1.12.1

Refer to the *ODOT Highway Design Manual* and *Hydraulics Manual* for additional guidance. The Region Tech Centers will typically design or administer concrete culverts, metal pipe culverts and pipe arches.

Large culverts are processed like bridges. Request a structure number, drawing number(s), etc. for large culverts.

Use the following criteria to determine the use of rail standards:

- For culverts under 6 feet in span or diameter, use roadway standards.
- For culverts between 6 and 20 feet in span, use roadway standards unless the location is considered high risk.
- Follow the guidance of *BDM 1.13.9* for guardrail layout in low fill.
- For NBI culverts, use bridge standards unless fill depth is greater than 2 feet 8 inches.

The decision of whether to use roadway or bridge railing standards on a culvert is related to both culvert length and fill depth.

## **1.12.2 Tunnels (structural elements)**

(Reserved for future use)

## 1.13 Rails, Impact Attenuators and Protective Screening

### 1.13.1 Bridge Rail, General

The current roadside safety crash test standard is the *Manual for Assessing Safety Hardware (MASH) 2016*.

After Dec. 31, 2019, all bridge rails on the National Highway System (NHS) must meet MASH, per [AASHTO/FHWA Joint Implementation Agreement for Manual for Assessing Safety Hardware \(MASH\)](#). When no MASH alternative exists, states can approve lesser standards, but should aim for MASH whenever possible.

Due to the change to MASH, where this section is in conflict with *LRFD Section 13*, the BDM controls for all state-owned

### C1.13.1

Bridge rails are roadway safety features. In most cases, the primary goal is keeping vehicles, bicycles and pedestrians on the road safely. Due to the dynamic nature of impacts, crash testing of all roadway safety features is performed to assure that critical failure modes such as vehicular stability and occupant compartment deformation are satisfied. MASH establishes the vehicles, speeds, and angles for the collisions required to achieve a passing crash test.

Prior to MASH, the controlling crash test standard was NCHRP 350, which itself replaced NCHRP230. MASH crash test vehicles are taller than previous standards, requiring higher railings to maintain stability.

MASH requirements are directed at new construction. Thus far, AASHTO has not set acceptance criteria for retrofitting existing non-standard bridge rails, leaving it to the owner to establish warrants.

In Oregon, local agency projects off the NHS may use NCHRP 350, at the request of the local agency. Use *LRFD Chapter 13*, rather than this chapter, when local agency projects use NCHRP 350.

bridges and bridges on the NHS.

AASHTO is currently preparing to update *LRFD Section 13* to better accommodate Under MASH, roadside safety features are evaluated based on six different Test Levels (TL), each including different vehicles and crash speeds and angles. The levels are intended to correlate to different levels of traffic.

In Oregon, bridges on or over all interstate routes and National Highway System (NHS) routes require a **minimum** crash test rating of TL-4 for all bridge rails. ODOT promotes highway planning that replaces or upgrades railing on existing bridges on these routes to TL-4.

FHWA allows existing bridge rails that are compliant with NCHRP 350 to remain in place under certain circumstances. All undamaged rails constructed after 1994 are assumed to be compliant. Contact the [BDM Technical Resource](#) for rails for pre-1994 rails when compliance cannot be established.

To determine the appropriate TL for a bridge, follow the procedure of [NCHRP Report 22-12\(03\)](#), which uses a risk-based methodology. When this method does not correlate well with a specific bridge site, contact the [BDM Technical Resource](#) for alternatives.

In addition to the safety requirements of MASH, bridge rails should also meet OSHA requirements for the safety of maintenance and inspection personnel. *OSHA "Fall Protection – Walking-Working Surfaces"* requires a 42-inch high railing or other fall protection accommodations.

MASH testing.

More information on the different test levels is available in *LRFD 13.7.2*.

TL-3 is the lowest level FHWA permits on NHS routes.

See *BDM 1.13.6* and *1.13.7* for more information on when NCHRP 350 compliant rails must be replaced.

In some situations, the test level reached through *NCHRP Report 22-12(03)* may not be appropriate due to other design features or conditions, such as wide sidewalks or very low speeds. In these cases, prepare a Design Exception to use a different test level.

On state highways, 42-inch high bridge rails are preferred. *BR200* has transverse holes to enable workers to tie off for fall protection. Rail height is measured vertically from a 10-foot straight edge placed perpendicular to the lanes on the bridge deck to the top of the highest load resisting rail member.

### 1.13.1.1 Design Exception Process

Submit Design Exceptions per *BDM 1.2.2*.

Include in the Design Exception:

- Discussion of why an ODOT standard is not appropriate.
- Evaluation of appropriate test level.
- Crash test data documentation for alternate rail or one similar to the proposed design and conclusions that the rail performed acceptably in all three categories (structural adequacy, vehicle stability and occupant compartment deformation).

### 1.13.2 ODOT Standard Vehicular Railings

*Table 1.13.2-1* lists the ODOT standard bridge railings with current MASH test levels. Transitions are presented in *BDM 1.13.8*. More information about these rails are available in the standard drawing reports and on Projectwise.

Table 1.13.2-1 MASH Bridge Rails

Drawing No.	Description	Tested or Evaluated	MASH Test Level	OSHA Compliant
BR200	Concrete Bridge Rail Type <b>F</b>	Evaluated	3	With Anchorages
BR208	3-Tube Curb Mount Rail	Tested	4	Yes
BR214	Concrete Parapet with Steel Post	Evaluated	4	No
BR216	Sidewalk Mounted Combination Bridge Rail	Evaluated	4	Yes
BR222	Vertical Concrete Parapet, 42-Inch	Evaluated	4	Yes
BR285	Type <b>F</b> Concrete Rail Rectangular Tube Retrofit	Evaluated	4	Depending on existing
BR290	3 foot 6 inch Type <b>F</b> Rail	Evaluated	5	Yes

Table 1.13.2-2 lists other ODOT standard bridge railings that have not yet been evaluated or tested under MASH. Use of these rails on a state highway requires a Design Exception. More information about the specific rails is available in the standard drawing reports.

Table 1.13.2-2 ODOT Standard Bridge Rails without a MASH Crash Test Equivalency

Drawing No.	Description	Crash Test Standard	Estimated NCHRP 350 Test Level
BR206	2-Tube Curb Mount Rail	NCHRP-350	4
BR212	Concrete Post and Beam Bridge Rail	Unknown	-
BR220	Flush Mounted Combination Bridge Rail	NCHRP 230	4
BR221	32 inch Vertical Concrete Parapet	NCHRP 230	4
BR226	2-Tube Side Mount Rail	NCHRP 230	4
BR233	Thrie-Beam Rail and Transition	NCHRP 230	2
BR250	Pedestrian Rail on Sidewalk Mounted Concrete Parapet	None	2
BR253	Sdwk. Mounted Conc. Parapet with Chain Link Fencing	None	2
BR256	Pedestrian Railing on Type F Concrete Bridge Rail	NCHRP 350	4
BR260	Chain Link Fencing on Type F Concrete Bridge Rail	NCHRP 350	4
BR266	Modified Type 2A Rail	NCHRP 230	2
BR273	Thrie Beam Rail Retrofit for Curb and Parapet Rail	NCHRP 350	4

### 1.13.2.1 Rail Orientation

Orient bridge rail posts and joints normal to grade in the longitudinal direction and vertical in the transverse direction for ease of construction and aesthetics.

Apply modifications to all rail components so they are all oriented the same (i.e. concrete parapet and attachments).

### 1.13.2.2 Rail Aesthetics

Maintain the minimum concrete cover requirements when using architectural treatments on concrete bridge rails. Cover can be increased to accommodate formliner patterns. Architectural treatment on the traffic face of a traffic barrier is only permitted within the limits of [NCHRP Report 554](#). When that standard is met, no design exception is required.

### C1.13.2.1

When deck superelevations exceed 8 percent, consideration can be given to orienting posts normal to grade in both directions to be more aesthetically pleasing.



### 1.13.2.3 Other Crash Tested Rails

Bridge rail designs from any state or local agencies that have been crash tested to MASH may be used with a Design Exception. Submit requests to the [BDM Technical Resource](#) for frequently used rails to be added to ODOT's Bridge Rail Standard Drawings.

### 1.13.2.4 Non-Standard Rails

On a case-by-case basis, rails that have not been crash tested may be permitted on state-funded projects with the submission of a Design Exception. The rails must be designed according to *LRFD Section 13*, and usage must be limited to TL-2 locations. Contact the [BDM Technical Resource](#) early in the project when this option is considered for a state-owned bridge.

## 1.13.3 Bicycles and Pedestrians

Use bicycle and pedestrian railing or combination railing on the outside of structures that are specifically designed to carry bicycle and pedestrian traffic. Combination railing alone may be used in conjunction with a raised curb and sidewalk where vehicular design speeds are less than 40 mph. Separate bicycle and pedestrian traffic from vehicular traffic by a combination rail when vehicular design speeds exceed 40 mph and provide a pedestrian railing on the exterior of the walkway.

Bicycle and pedestrian rails must exceed 42 inches in height. Opening sizes on bicycle, pedestrian and combination rails are defined by *LRFD 13.8.1*.

Use curbs above the level of the sidewalk under all pedestrian railings where there will be significant pedestrian, vehicular or boat traffic under the structure. Runoff from sidewalks does not need to be carried off a structure, see *BDM 1.24.5* for additional guidance.

## C1.13.3

At locations with high bicyclist traffic, rail height can be increased up to 54 inches.

This requirement is intended to keep debris from being kicked under the railing onto traffic below.

## 1.13.4 Joints in Concrete Bridge Rail

### SCORING JOINTS

Place scoring joints at 15 foot maximum centers, equally spaced between Type 'B' joints and expansion joints. Show the location of each joint on the deck plan without dimensions.

The joint spacing must equal or exceed the critical length,  $L_c$ , of the yield line failure pattern (see *LRFD A13.3.1*) for a vehicle impact within a wall segment. The bottom two longitudinal bars are continuous through scoring joints but terminate two inches before all other joint types.

### TYPE 'B' JOINTS (AT INTERIOR BENTS WITH CONTINUOUS DECK)

To reduce shrinkage cracks in the rail, form a joint using ¼ inch preformed expansion joint filler through the rail. These joints also reduce the tendency of the rail to act compositely with the superstructure.

### AT BRIDGE DECK EXPANSION JOINTS

Provide rail joints at every bridge deck expansion joint to prevent cracking or spalling of the rail or structure. Show rail details at expansion joints on the drawings. Skew rail joints to match the deck joint for skew angles up to 20 degrees. For skew angles in excess of 20 degrees, orient the rail joint normal to the rail. Do not leave rail joints as open joints, including joints between the bridge end and bridge approach slab. See expansion joint standard drawings for the rail joint material and arrangement. For expansion joints greater than two inches, use expansion joint cover plates to prevent vehicle snagging.

## C1.13.4

For typical ODOT standard concrete rails, space joints in the range of 10 to 15 feet. Do not consider these joints to be end segments for the purpose of overhang calculations

For ODOT Standard Rails,  $L_c$  is listed on the [ODOT Bridge Engineering website – Software Tools for Design](#). It is typically in the range of 8.5 to 12.5 feet.

Do not consider these joints to be end segments for the purpose of overhang calculations.

It is a potential problem when water passes through the joint and erodes the embankment. RR overcrossings may have additional requirements for joints in rails, depending on the RR.

## 1.13.5 Bridge Modernization Projects

## C1.13.5

On Bridge Modernization projects, replace bridge rails to meet the required MASH TL criteria at the bridge site. The structural designer works with the project team to select the best rail for a given site.

Considerations include:

- Roadway geometry.
- Traffic volume.
- Speed.
- Truck traffic.
- Accident history.
- Pedestrian needs.
- Sight distance.
- Occupant risk.
- Aesthetics.
- Corridor context.
- Maintenance.
- Inspection.
- Cost/benefit and related factors.

For new bridges, design the overhang to resist the test level of the rail or TL-4, whichever is greater. When designing deck overhangs per LRFD, rail design capacities are available for ODOT standard rails on the [ODOT Bridge Engineering website – Software Tools for Design](#). Using the calculated parapet resistance,  $M_c$  and T, of the parapet at its base per *LRFD A13.4.2*. LRFD rail design capacities will give overly conservative results in most cases.

The intent is to reduce the risk of future strengthening over the life of the bridge.

*LRFD A13.4.2* describes the design approach for deck overhangs supporting concrete parapet railings. The design approach does not specify vehicular-collision loads. Overhangs are designed for the maximum inelastic force effects generated and transmitted by the railing resisting a vehicular impact. This results in an extremely conservative deck overhang that is not in accordance with observed field behaviors.

Instead, for *LRFD A13.4.2* design case 1 for concrete parapet railings in TL-4 locations, design the deck overhang to resist the lesser of a vehicular impact moment,  $M_{CT}$ , and coincidental axial tension force,  $T_{CT}$ , calculated as follows, for the end and wall conditions:

$$M_{CT,end} = \frac{1.25 \times F_t \times H_e}{L_{c,end} + H_e + X} \text{ and}$$

$$T_{CT,end} = \frac{1.25 \times F_t}{L_{c,end} + H_e + X}$$

$$M_{CT,wall} = \frac{1.25 \times F_t \times H_e}{L_c + 2H_e + 2X} \text{ and}$$

$$T_{CT,wall} = \frac{1.25 \times F_t}{L_{c,end} + 2H_e + 2X}$$

Where:

$H_e$  = Effective height of the vehicle rollover force (ft).

$L_c$  = Critical length of yield line failure pattern (ft).

$X$  = Lateral distance from toe of barrier to deck design section (ft).

$F_t$  = Transverse force specified in Table 1.13.5 for MASH TL-4 impact load for different barrier heights (kips).

Table 1.13.5-1 Design Forces and Designations for Standard Barrier Heights (in)

Standard Barrier Heights	36 inch	39 inch	42 inch
$F_t$ Transverse (kip)	67.2	72.3	79.1
$F_L$ Longitudinal (kip)	21.6	23.6	26.8
$F_v$ Vertical (kip)	37.8	32.7	22
$L_t$ and $L_L$ (ft)	4	5	5
$H_e$ (in)	25.1	28.7	30.2

Based on observations of impacted bridge railings from crash testing, an overhang designed with typical deck reinforcing of #5 at six inches does not fail when a railing failure occurs due to a collision. See *TTI Test Report No. 9-1002-5*, Figures 3.1-3.3, 6.3 and 6.4. In the absence of a more rigorous method for designing overhangs, many states use the loads shown here, based on finite element impact simulations from NCHRP funded research.

The end condition, at bridge ends and expansion joints, controls design due to the limited distribution length.

When designing or checking overhangs, do not reduce capacity due to development length of the deck bars.

## 1.13.6 Bridge Retrofit Projects

### 1.13.6.1 Process

Establish required test level for the site. Upgrade the rail when any of the safety warrants exist (*BDM 1.13.6.3*), regardless of project scope. Otherwise, when project scope impacts the rail, assess the existing bridge rail for structural adequacy, vehicle stability, and occupant compartment deformation, in the post-project configuration (*BDM 1.13.6.2*).

Based on the deficiencies and required test level, select a retrofit or replacement option. When an appropriate standard drawing or detail is not available, it is permissible to design one for a specific project. A Design Exception is required in these cases.

### 1.13.6.2 Assessment of Existing Bridge Rails

#### STRUCTURAL ADEQUACY

Structural adequacy is a function of a barrier's ability (including deck overhang) to effectively contain and redirect a vehicle. Vehicles may not penetrate, underride, or override the barrier. It is possible to use engineering analyses, based on yield line theory or plastic design procedures, to compute the load capacity of rigid or semi-rigid barriers. Then compare that with known design forces for the desired test level. All aluminum tube rails are structurally inadequate.

Impact loading is different in effect from sustained loading. Testing shows that typical development length calculations do not apply.

## C1.13.6

### C1.13.6.1

When a deck overlay will reduce the relative height of the rail, this negatively impacts the structural adequacy of the rail.

Research is on-going into the behavior of resin bonded anchors under impact loading. Anticipate new standard rail attachment details upon completion of this research.

### C1.13.6.2

For more information on the assessment of existing bridge rails, see NCHRP 22-14(03).

Since structural adequacy also requires the vehicle not override the barrier, barrier height is critical. For required height based on test levels, see *Table 1.13.6-1*.

Table 1.13.6-1 Minimum Bridge Rail Heights

Test Level	Minimum Height (inches)
TL-2	27
TL-3	29
TL-4	36
TL-5	42

These heights are not the same as *LRFD Table A13.2.1* due to MASH testing.

**VEHICLE STABILITY**

In order to ensure the safety of vehicle occupants, a vehicle must remain upright during and after a collision with the barrier. MASH evaluates this based on a maximum pitch and roll of the vehicle during testing. This is a common failure mode for bridge rails.

Whenever possible, assess this through comparison with previously crash tested rails.

Curbs and sidewalks that project in front of the face of rail negatively impact vehicle stability. Comply with *LRFD 13.7.1.1* for sidewalk height.

Many states only permit unprotected curbs and sidewalks, where design speeds are 45 mph or less.

**OCCUPANT COMPARTMENT DEFORMATION**

Occupant compartment deformation is commonly associated with snagging of the vehicle on the rail. Consider extensions or recessions beyond two inches as potential snag points; rails comprised of separate unconnected elements.

Improved vehicle design has reduced occupant compartment deformation, making this a less critical factor for evaluating barriers under MASH. Rails that satisfied this criteria under NCHRP 350 should be expected to meet MASH testing as well.

Evaluate snag hazard based on post setback distance, ratio of contact width to height, and vertical clear opening based on *LRFD Section 13*.

### 1.13.6.3 Safety Warrants

Rails are considered candidates for retrofit or replacement as part of a bridge retrofit category project when any of the following are true:

- Three or more accidents or a fatality has occurred in the past five years at the bridge site.
- The rail is in a condition state four.
- The rail height is less than 27 inches.
  
- The rail has aluminum components.
  
- The bridge is located on an interstate or high-speed, high-volume facility (for this purpose high volume is considered AADT of 30,000 or higher and has shoulder widths of less than three feet).
- A safety assessment by the Region Traffic Engineer recommends an upgrade.

### C1.13.6.3

Existing rails may be raised to meet height requirements, provided the existing strength capacities are not reduced by the revised configuration.

Aluminum rails are structurally inadequate under most impact conditions. In some cases it is possible to simply replace aluminum tubes with steel tubes without significant cost.

Consult the Region Traffic Engineer for concurrence, when postponing or deferring a rail upgrade on a bridge retrofit category project. The Region Traffic Engineer will perform a safety assessment to analyze existing safety hazards and determine when the implementation includes the appropriate solution.

See *HDM 106.4, 111* and *119* for additional information on safety assessments. Document their concurrence in the DCSA.

### 1.13.6.4 Deck Anchorage

Options for anchoring a replacement bridge rail to an existing deck include through bolting and resin bonded anchors. When through bolting, oversize the drilled holes to create ¼ inch annular space, seal the bottom of the bolt hole and grout the annular space around the bolt with high strength grout.

### 1.13.6.5 Overhang Capacity

It is only necessary to strengthen a bridge deck overhang as a result of a rail retrofit or rail replacement when any resulting damage would be within a traffic lane. To determine this, identify the critical sections in the deck. When a critical section is within a traffic lane, evaluate the capacity to demand ratio and design a strengthening when less than 60 percent.

## 1.13.7 Bridge Preservation Projects

Bridge preservation projects only require bridge rail modifications when:

- The relative height of the existing bridge rail is reduced below 29 inches (32 inches on interstates and other divided highways).
- The project is part of a 3R project on an NHS route and the existing bridge rail is not NCHRP 350 compliant.

In these cases, correct the deficiency or submit a Design Exception.

Correct transitions and blunt ends per BDM 1.13.8.

### C1.13.6.4

This is required to ensure shear loads from impact transmit evenly to the deck.

### C1.13.6.5

The intent of this policy is to avoid unnecessary deck strengthening for situations that will not cause loss of life or irreparable damage to the bridge. Capacities below 60 percent indicate the possibility of concrete deck cracking. Cracks under live traffic are harder to repair. All other cracks that may occur after a collision can be repaired as part of rail repair.

### C1.13.7

Where projects negatively impact bridge rail height, *BR285* is a reasonable, cost-effective repair.



## 1.13.8 Bridge Rail Transitions

Rail transitions are required on rail installations. They provide a controlled variation in stiffness from the approach guardrail to the more rigid bridge rail. The current transitions are crash-tested and have very close post spacing.

Select a transition, in conjunction with the roadway designer, appropriate for the speed.

All projects must upgrade transitions when unprotected ends or unconnected transitions are present per [Technical Bulletin RD20-01\(B\)](#). *RD20-01(B)* applies unless the work is considered a single function project that does not permanently modify the traveled way.

Problems have arisen when the first post off the structure conflicts with the bridge end. Consider any post conflicts and detail a solution in the contract plans. Prepare a design exception when adjusting the post spacing.

## C1.13.8

Research indicates transitions that passed NCHRP 350 testing will continue to meet MASH criteria (*NCHRP Project 22-14(03)*).

In low speed locations (45 mph or less) where approach rail is not used, slope the bridge rail end down or shield it using a crash cushion. See *HDM 405.4* for additional guidance.

Possible remedies include:

- Remove concrete to allow room for the normal post to fit.
- Add a concrete pad (with anchor bolts) to the existing concrete, and add a base plate to the first post.
- Mount a structural steel spacer block to a vertical face of a rail end block, in place of a post.

## 1.13.9 Rails over Low Fill Culverts

When applicable, use Standard Drawing *RD470* for guardrail over low-fill culverts. When span lengths are over 25 feet, use Standard Drawing *BR266*, Modified Type 2A Rail, when the fill height above a box culvert or rigid frame is less than the standard embedment of timber guardrail posts.

Using this standard drawing eliminates the need for transitions.

## 1.13.10 Temporary Barriers

FHWA requires that temporary bridge rails meet TL-3 performance criteria using successfully crash tested systems. Ordinarily temporary bridge rail is constructed from pin and loop median barrier secured against sliding and overturning as shown in Standard Details *DET3295* and *DET3296*. Restraints are not required when the barrier can be displaced 5.5 feet or more away from the traffic side(s) without infringing on a traffic lane, a work area, or beyond the edge of the deck.

Coordinate with the Traffic Control Plans (TCP) designer to confirm the assumed layout of temporary barrier on the bridge agrees with the final layout shown in traffic control plans, and to determine when the detail plans must note the reflectorized barrier. Modify *DET3295* accordingly.

## C1.13.9

*BR266* uses the same system reported in the *Transportation Research Record No. 1198*.

During the test, the steel posts yielded about 32 inches, which is similar to ODOT's timber post system. The crash test report claims this system is acceptable for fill heights from zero to three feet.

## C1.13.10

The ODOT anchored barrier is adapted from barrier used in a Lincoln, Nebraska crash test, documented in report *TRP-03-134-03* dated August 22, 2003. The current standard detail does not reflect the validated test results from Nebraska's 2019 [crash test](#).

For more information regarding temporary barriers, see *Section 2.6.1* and *3.4.25* of TCP Design Manual.

Use resin bonded anchor bolts with fully threaded rods in accordance with ASTM F1554 Grade 36. Use anchor bolts for through bolting in accordance with ASTM A307 or ASTM F1554 Grade 36. Use nuts in accordance with ASTM A563 or ASTM A194. Use flat washers in accordance with ASTM F436 and plate washers shall be in accordance with ASTM A36 or ASTM A709 Grade 36.

Install four anchor bolts per barrier on the traffic side, as shown in Standard Details [DET3295](#) and [DET3296](#). Do not drill into or otherwise damage the tops of supporting beams or girders, bridge deck expansion joints or drains. Install anchor bolts and nuts so that the maximum extension beyond the face of the barrier units is ½ inch. Snug tighten the nuts on the anchor bolts. For through bolted installations, snug tighten the double nuts on the underside of the deck against each other to minimize the potential for loosening.

Omit one anchor bolt within a single barrier unit when a conflict exists between the anchor bolt location and a bridge deck expansion joint or drain. Install each adjacent barrier units with the standard four anchor bolts.

Other temporary rail options: At least one crash tested proprietary steel safety shape rail system exists, which could be a contractor option for temporary rail use. Example: see [FHWA Acceptance Letter B-](#)

## 1.13.11 Protective Screening or Protective Fencing

Oregon law mandates the installation of protective screening. *ORS 366.462* states:

1. The DOT shall construct fences on all freeway overpasses that are built on and after Nov. 4, 1993. The fences shall be designed to deter persons from throwing objects from the overpasses onto the freeways.
2. The DOT shall construct fences on existing freeway overpasses that involve the greatest risk factors.

### 1.13.11.1 General

### C1.13.11.1

Provide protective screening at the following locations on projects that modify the rail or when required by the facility owner:

- All structures crossing freeways (interstates and similar controlled access highways with at least four lanes) that carry vehicles and/or pedestrians.
- Pedestrian structures which cross high-speed facilities (posted speed equal to or greater than 55 mph) and are located within half mile of a school, playground, park, athletic field, shopping center, or other facility likely to generate pedestrian traffic
- Structures with sidewalks which cross high-speed facilities (posted speed equal to or greater than 55 mph) and are located within half mile of a school, playground, park, athletic field, shopping center, or other facility likely to generate pedestrian traffic
- All other structures (with or without sidewalks) crossing high-speed facilities (posted speed equal to or greater than 55 mph) with regular pedestrian traffic
- Railroad overcrossings, when
- In front of ITS elements attached to bridge structures.

Contact the Bridge Standards and Program Manager for a list of applicable freeways.

required by the railroad.

Protective screening need not be provided at freeway ramp structures that typically do not have any provisions for pedestrians.

When a project impacts the bridge rail, install protective screening when any of the situations above apply.

### **1.13.11.2 Protective Screening Design Criteria**

Design protective screening to deter persons from throwing objects from the overpasses onto freeways. Design protective screening using the following criteria:

- Use dead load per standard drawing.
- Able to carry pedestrian rail loading when pedestrians are not separated.
- Openings three inch square or less. Minimize projected area to less than 30% of total area.
- No more than one quarter inch opening between the bottom of screening and top of concrete surface.
- Minimum eight feet high from top of walk surface. Minimum 10 feet high at railroad overcrossings from top of walk surface. When ornamental screening has a variable height, maintain minimum height at all locations crossing over travel lanes.

### **C1.13.11.2**

A two inch chain link mesh is generally acceptable, with a one inch mesh being used for special cases.

Use details that are difficult to climb (e.g. no handrail).

Ensure the bottom of screening has sufficient stiffness to prevent permanent large deflections.

- Provide splash boards in ice or snow zones at railroad crossings; where switching occurs; and where there are other frequent activities. See *BR245* for splash board details.

Protective screening limits and extents:

- Provide protective screening over all travel lanes plus a minimum of 10 feet beyond the travel lanes on each side.
- Where on or off ramps also cross under a structure, ensure screening extends a minimum of 10 feet beyond the end of any ramp travel lanes.
- For divided highways, continue protective screening uninterrupted through the median.
- Provide protective screening on both sides of a structure, even when a sidewalk is provided on only one side. Where twin structures cross a high-speed facility, provide protective screening for the center opening between structures.
- Provide protective screening 25 feet minimum from centerline of nearest track or railroad access road.

### **1.13.11.3 Design Deviations**

Submit a design deviation when protective screening is not provided for structures specified in *BDM 1.13.4*.

Coordinate with roadway to consider future widening when determining screening limits.

In areas where aesthetics is a consideration and when screening does not extend to the end of the structure, provide a transition panel (sloped panel or partial height panel) at the end of each run of screening as an aesthetic termination.

For unusually wide medians and divided highways with a significant elevation difference for each direction, protective screening may be interrupted through the median with the use of transition panels.

### **C1.13.11.3**

Due to public safety concerns, public and/or legislative oversight of design deviations for protective screening is likely.

Submit a design deviation when protective screening details deviate from standard drawings, as is the case for retrofit installation.

Submit a design deviation request to exclude screening at locations that present a sight distance hazard.

Screening may obscure sight distance on horizontally curved structures; of signage; and the intersection sight distance at ramps, cross-streets, or driveway accesses off the end of the structure. Non-signalized intersections increase this potential hazard. Specialized designs may be considered to address sight distance issues, such as adjusting screening limits.

Provide the following with a design deviation request:

- Basis for the proposed design deviation
- A description of pedestrian activity including width of sidewalks and proximity to pedestrian sources such as schools, playgrounds, parks, shopping center or athletic fields
- The history of incidents and signs of graffiti at the bridge site or sites in the vicinity
- The distance to adjacent bridges also crossing the facility and whether they have screening

In addition, when the basis for the design deviation is for sight distance provide the following:

- Concurrence from the Region Roadway Manager
- A plan of the bridge showing sight lines obstructed by the proposed screening
- The approximate cost of widening the structure when widening would avoid a sight distance hazard

### **1.13.11.4 Screening Type Considerations**

When placing a barrier between the sidewalk and roadway, use protective screening in place of a pedestrian rail along the outer edge of the structure.

When no separated barrier exists, place screening behind or attached to the combination rail along the outer edge of the structure.

When installing ITS elements on a structure, use Type 'A' fencing.

Use Type 'A' fence *BR240* on pedestrian bridges.

#### **VERTICALLY CURVED SCREENING**

Consider curved screening when a sidewalk is present. Curved screening does not require end treatment. Curved screening can be used in combination with Type A, B, C and D fence.

### **C1.13.11.4**

Protective screening affects bridge inspection using under bridge inspection trucks (UBITs). Details should be discussed with the Region Bridge Inspector prior to installation over bridges with limited inspection access.

Certain sweepers will not fit through curved fence enclosures. Region 1 sweepers measure 10 foot 5 inches. Standard Drawing *BR240*, Type 'A' Fence has provisions to allow access. Contact the District Bridge Supervisor to determine an acceptable type of fence.

Curved screening is an additional deterrent because it forces the thrower into the roadway in order to clear the screening. Curved screening may cause additional sight obstruction. Curved screening may require additional height to accommodate bicycles and, in some cases, horses with riders. Curved screening is not preferred in the Portland area due to aesthetic concerns.



## HORIZONTALLY CURVED STRUCTURES

On structures with tight horizontal curves, consider using straight screening rather than curved. When chorded screening is used on a tight curve, ensure any **gap** between the bottom of screening and the curved edge of the bridge does not exceed three inches. Such **gaps** may be closed using plates attached to concrete surfaces near the bottom of the screening.

### 1.13.11.5 Screening Aesthetics

#### AESTHETIC CONSIDERATIONS

Chain link is the most economical screening available and used as the default screening type. However, chain link has very low aesthetic value.

It is difficult to construct curved screening on a tight curve and obtain proper fit of the chain link fabric.

### C1.13.11.5

There are proven low-cost methods available for improving the aesthetics of chain link screening:

- End treatment\_ – Providing a special termination section at each end of each screening run is a low-cost and effective aesthetic enhancement. This can be as simple as tapering the ends (for example, see *DWG 65137*) or a reduced-height panel. Any end treatment with a height less than the minimum required must start at least 10 feet beyond any travel lanes or ramps (25 feet from tracks or access road for railroad crossings).
- Color – Use of vinyl-coated chain link can improve the appearance of chain link at a very modest increase in cost. Possible colors are black, navy blue, or dark green, depending on location. Hot-dip galvanize screening before vinyl-coating.

Designers are encouraged to seek input from others (designers, district, and/or local community) when using aesthetic concepts outside these methods.

### ORNAMENTAL SCREENING:

ODOT has received requests to install ornamental screening on structures. See Standard Detail *DET3243* and *DET3244*. Address the following before a request can be processed:

- Funding – Ornamental screening can be included in bridge modernization and retrofit projects when deemed an important architectural item by the project team and supported by the environmental study. For retrofit to an existing structure (not associated with an ODOT project), include possible funding sources with the proposal.
- Permits – When an entity outside ODOT proposes to install a feature in ODOT right-of-way, it must obtain a permit from the district office.
- Design – Do not create a distraction for drivers with ornamental protective screening. Review design outside of ODOT's normal standards through a review process with the district maintenance, Region Tech Center and others to assure it is appropriate and meets ODOT clearances and standards.

- Maintenance – Establish maintenance responsibility in case of damage or deterioration. Districts receive funding to maintain ODOT standards. When designed and installed by forces outside of ODOT, resources are required to maintain it, which should include a bond, city or county taking responsibility.

Powder coat ornamental screening. Paint can be used, when requested, for a specific reason and agreed to by maintenance.

Also see *BDM 2.3.10*, Structure Appearance and Aesthetics, Ornamentation.

## **1.13.12 Impact Attenuators**

Attenuators are required in areas where hazardous objects cannot be removed from the possible paths of vehicles. Such locations include gore points of diverging roadways and columns in medians.

Avoid geometry where attenuators will be required on structures.

# 1.14 Bearings and Expansion Joints

## [1.14.1 Bearings](#)

### [1.14.2 Expansion Joints](#)

## 1.14.1 Bearings

### 1.14.1.1 Design, General

Provide provisions for bearing replacement, including temporary jacking and support for all manufactured bridge bearings. There is a potential of bearing failure during the service life of a bridge, which requires that provisions for bearing replacement be provided in the design drawings. Providing temporary jacking support (design, detailing and construction) on existing structures is complex and increases the maintenance cost and life cycle cost of a bridge. Including consideration of jacking and temporary support in the original design will reduce future rehab cost and ease future bearing replacement. This work may require pilecap or crossbeam widening, or widening under each girder. Show grout pad locations in the contract drawings for temporary jacking support and a bearing replacement sequence and minimum jacking loads. Check the adequacy of all affected structural elements during bearing replacement and stability of the structure.

### 1.14.1.2 Elastomeric Bearing Pads

Elastomeric bearings are used to accommodate movements on short to medium-span structures. The three types of pads include:

- plain pads.
- laminated pads reinforced with fabric (fiberglass).
- laminated pads reinforced with steel.

Plain pads are made from elastomer molded or extruded into large sheets, vulcanized and then cut to size.

Do not use cotton duck pads or random Oriented Fiber Pads bearing for slabs and box beams construction. Use plain elastomeric (neoprene) pads instead.

Fabric reinforced pads are made from alternate layers of elastomer and fabric (usually fiberglass) in large sheets, vulcanized and then cut to size. Fabric reinforced pads are restricted to short to medium spans with little or no skew.

Steel reinforced pads are made from alternate layers of elastomer and steel cut to size and then vulcanized. A thin cover layer of elastomer encapsulates the steel to prevent corrosion. The exposed edge voids in the pads caused by the steel laminate restraining devices are shop sealed with an appropriate caulking material.

Use **Method A** to design elastomeric bearings. Where there is a need to use **Method B**, specify in the Special provisions and contract drawing that the **Method B** was used. Elastomeric bearings designed using **Method B** requires extra testing.

Use the following movements for pad thickness design:

$$ES + LF1 * (CR + SH) + LF2 * (TF \text{ or } TR)$$

Where:

ES = elastic shortening movement

CR = creep movement  $CR = (ES) * (CF)$

SH = shrinkage movement

TF = temperature fall movement

TR = temperature rise movement

CF = creep factor

LF<sub>1</sub> = from *LRFD 3.4.1*

LF<sub>2</sub> = TU, Load Factor from *LRFD Table 3.4.1-1*

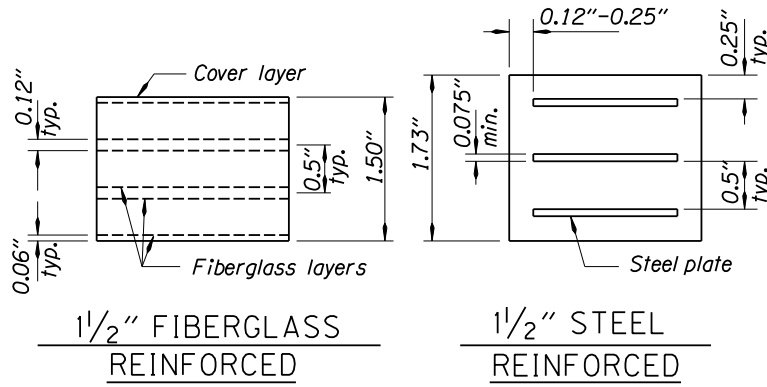
Use proper signs and the Service Limit State Load Factor that produces the largest movement in each load combination.

The final elastomer thickness is two times the design movement. Size the nominal pad thickness in multiples of ½ inch, from ½ inch to 6 inches maximum. The actual finished thickness will vary depending on the type of reinforcement. Fabric has a negligible thickness. Steel plate thickness may vary with the manufacturer, but be a minimum of 14 gauge.

The creep factor above is taken as 1.5 for both prestressed and post-tension concrete structures. Shrinkage movement is calculated using 0.0004 times the total length of the structure. For prestressed concrete structures 40 percent of this movement takes place within the first thirty days after manufacture. Therefore, the amount of creep and shrinkage movement for these structures, after placement, can normally be taken as 60 percent of the total.

Values for shortening of post-tensioned, cast-in-place concrete bridges have been determined by field measurements by the ODOT Bridge Section. See *BDM 1.5.8.1*. Compare the design values with the field measured values and use the more conservative values.

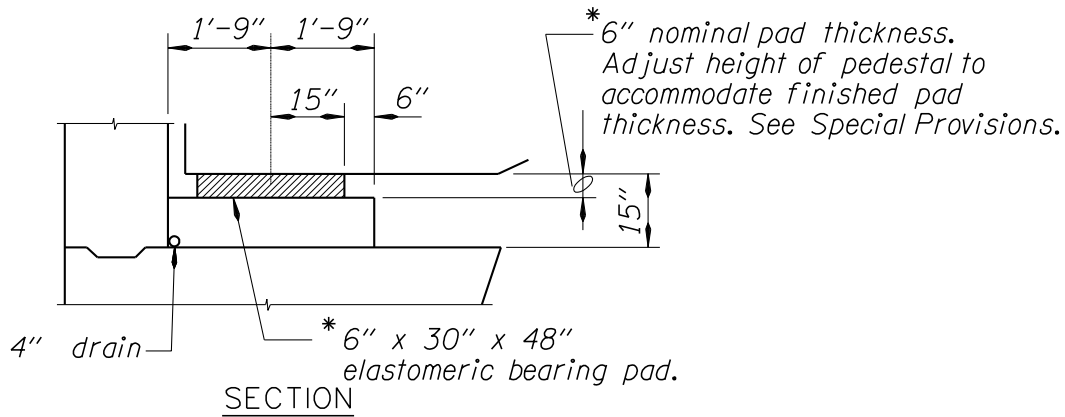
Figure 1.14.1.2-1 Standard Bearing Pad Detail



Pad thickness called for on detail plans is the total thickness of the elastomer required. When bearing pad elevations are shown, list the assumed finished pad thickness. Use circular elastomeric bearing pads for curved steel girders.

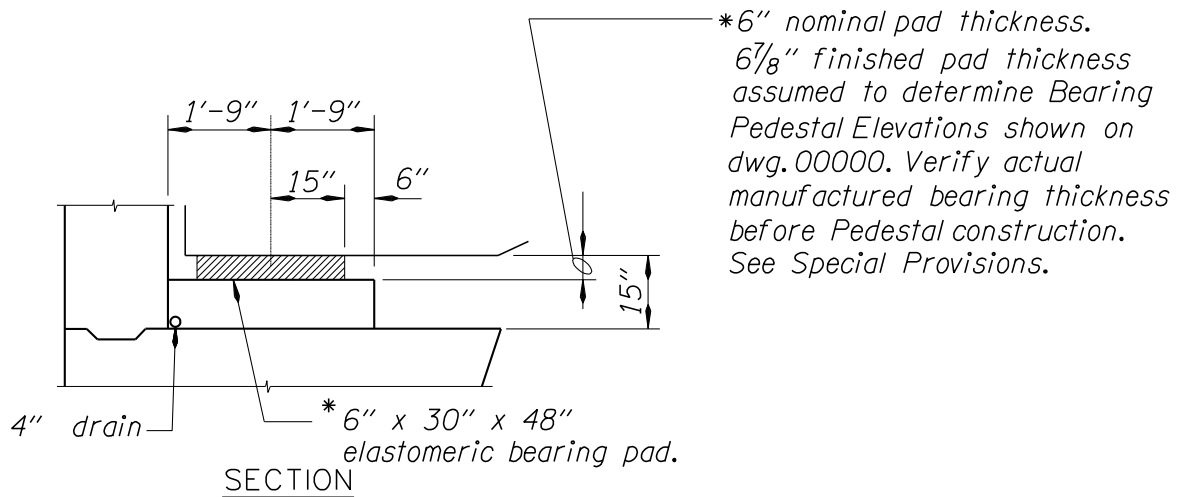
Examples are shown below in *Figure 1.14.1.2-2*.

Figure 1.14.1.2-2 Elastomeric Bearing Pad Examples



ELASTOMERIC BEARING PAD

(No Elevations Shown)



ELASTOMERIC BEARING PAD

(Elevations Shown)

For prestressed slab and box beam bearing pad sizes, use [Figure A1.11.1.7-4](#) (end bents) or [Figure A1.11.2.2-3](#) (interior bents).

### 1.14.1.3 Proprietary Pot, Disc, Slide, Radial, or Spherical Bearings

These bearings are normally used on long-span and post-tensioned concrete structures where the design movement cannot be accommodated with elastomeric bearings.

When provided to allow longitudinal movement for concrete superstructures, design bearings to accommodate the anticipated effects of shrinkage, creep and elastic shortening (where applicable) as well as temperature.

Use the following movements for proprietary bearings:

$$\text{Shortening: } ES + LF1 * (CR + SH) + LF2(TF)$$

$$ES + LF1 * (CR + SH) + LF3(EQ)$$

$$\text{Lengthening: } LF2 * (TR)$$

$$ES + LF1 * (CR + SH) + LF3(EQ)$$

Where:

ES = elastic shortening movement

CR = creep movement  $CR = (ES) * (CF)$

SH = shrinkage movement

TF = temperature fall movement

TR = temperature rise movement

CF = creep factor

EQ = Maximum design earthquake displacement (movable bearings)

LF<sub>1</sub> = from *LRFD 3.4.1*

LF<sub>2</sub> = TU, Load Factor from *LRFD Table 3.4.1-1*

LF<sub>3</sub> = Load Factor from *LRFD Table 3.4.1-1*

Use proper signs and the Service Limit State Load Factor that produces the largest movement in each load combination.

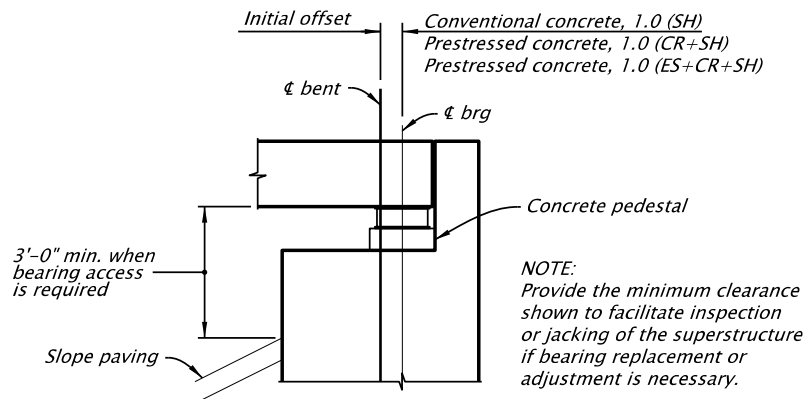
The creep factor above is taken as 1.5 for both prestressed and post-tension concrete structures. Shrinkage movement is calculated using 0.0004 times the total length of the structure. For prestressed concrete structures 40 percent of this movement takes place within the first thirty days after manufacture. Therefore, the amount of creep and shrinkage movement for these structures, after placement, can normally be taken as 60 percent of the total.



Values for shortening of post-tensioned, cast-in-place concrete bridges have been determined by field measurements by the ODOT Bridge Section. See *BDM 1.5.8.1*. Compare the design values with the field measured values and use the more conservative values.

Detail the initial position of expansion bearings so that the bearing will behave satisfactorily after the design movement has taken place.

Figure 1.14.1.3-1 Bearing Position to Allow Movement



Performance Specifications for Approved Proprietary Bridge Bearings are now covered by the *Standard Specifications*. Approved bearings are listed in the *Qualified Products List*, which is available on the ODOT website.

The designer must check the shop drawings, specified test results, and certifications for compliance with these specifications.

When proprietary bearings are used, show the following details and information in the contract plans:

**SCHEMATIC DRAWING**

A schematic drawing of the bearing showing the method of attachment of the upper and lower units to the superstructure and substructures, respectively. See *Figure 1.14.1.3-2* for an example.

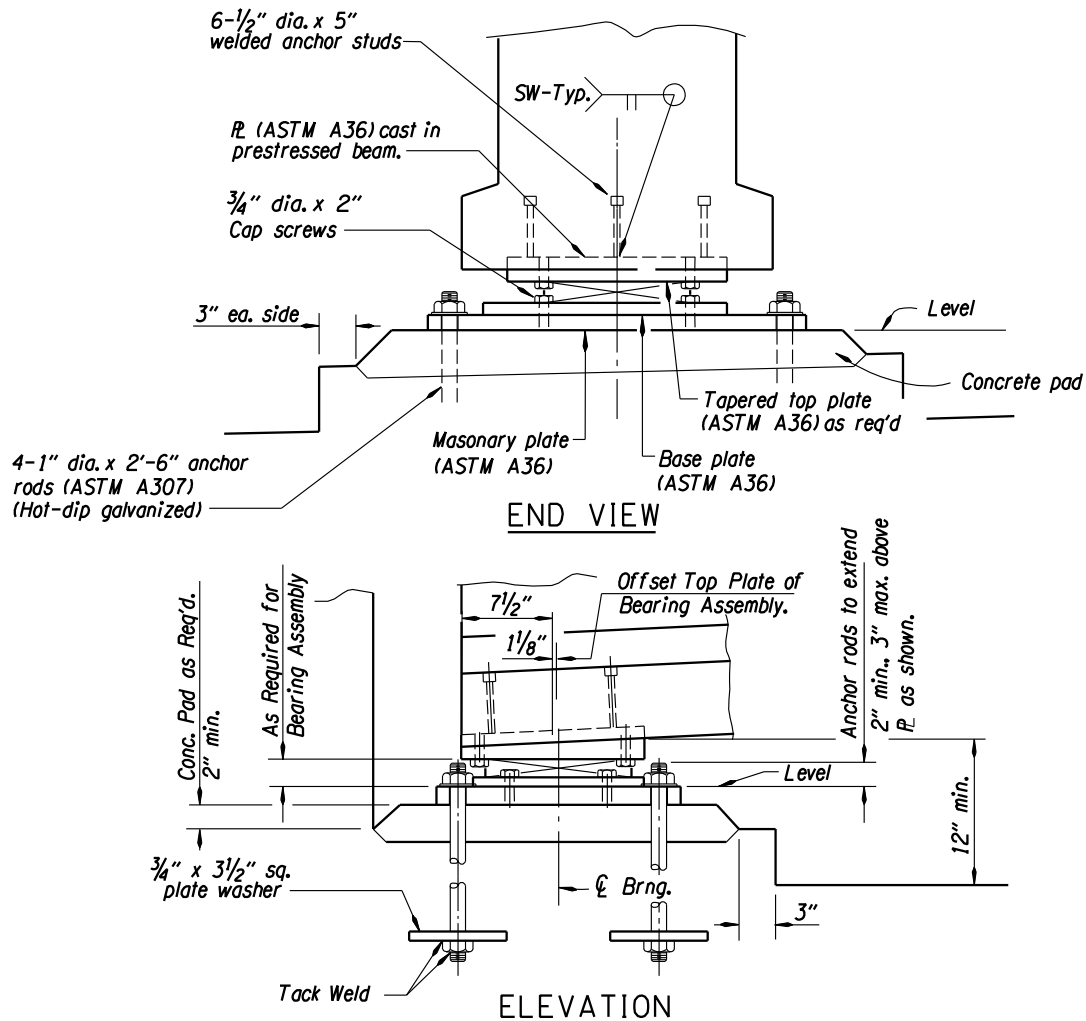
**DESIGN NOTES**

List design notes for:

- Required clearance to edge of concrete support.
- Maximum allowable concrete bearing stress.
- Minimum rotational capacity of bearing (not less than 0.015 radian).
- Any restriction as to type of bearing (pot, disc or spherical).
- Reference to bearing schedule for load and movement capacity.
- Reference to standard specifications for painting.
- Reference to the *Qualified Products List* for approved bearings.

Paint all exposed surfaces of the bearing devices except teflon, stainless steel, machine finished or polished bearing surfaces, as set forth in *SP 00594*. Provide a primer coat only for portions to be in contact with concrete and for steel to steel contact surfaces.

Figure 1.13.1.3-2 Schematic of Bearing Showing Attachment



### BEARING SCHEDULE

Include the following items in the Bearing schedule:

- Location of bearing (bent number).
- Number of bearings required (number per bent).
- Bearing fixity (fixed, guided or non-guided).
- Final dead load (load/bearing).
- Vertical design capacity (dead load + live load + impact, load/bearing).

- Horizontal design capacity of fixed and guided bearings (not less than 10 percent of the vertical design capacity).

The specification requires each guided bearing to resist the entire horizontal load at any one bent. Use no more than two guided bearings per bent or hinge. Where more than two guided bearings are required, provide devices independent of the bearings to resist horizontal loads. Use non-guided bearings at these locations.

Design movements for:

- Mean temperature.
- Temperature rise.
- Temperature fall.
- Creep, shrinkage and elastic shortening.
- Change in bearing centerline per specified temperature increment.

Ensure the top bearing plate dimensions are adequate to compensate for the initial bearing offset shown.

Provide additional bolted plates with the top and bottom plates of the bearing assembly to facilitate removal of bearing for repair or replacement and to provide a level surface for the bearing unit.

Figure 1.14.1.3-3 Bearing Schedule

BEARING SCHEDULE													
Bent	No. Req'd	Type	Design Load Capacities in kips per Bearing			Initial Offset	Calculated movements			Movement per 10°F Temp. change	Minimum Movement Capacity from Initial Position		
			Vertical	Lateral	Longit.		30°F Temp. Rise	40°F Temp. Fall	Creep, shrinkage & Elastic shortening		Temp. Rise Direction	Temp. Fall Direction	Total
1 & 5	4	Guided	1000	*600	—	3"	7/8"	1 1/4"	4 1/2"	5/16"	1 1/2"	7 1/2"	9"

\* Reduce design load to 200 kips for PTFE surface only.

### 1.14.1.4 Bearing Replacement

Consider the potential of expansion bearing replacement during the life of the structure in sizing of crossbeams and bents. Provisions may need to be made for jacking locations.

When a bent is accessible (close to the ground, out of traffic, etc.) it may be assumed that a falsework jacking bent can be constructed and no special provisions on the bent are required. See [BDM 1.38.4](#) for additional guidance.

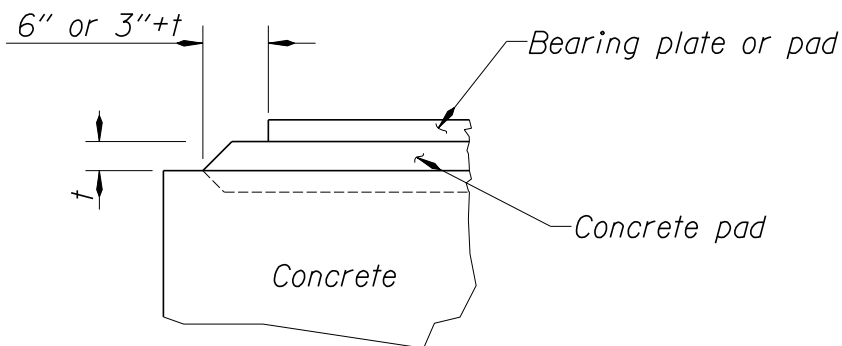
When the bent is not easily accessible, provide provisions for jacking, such as a wider crossbeam or strengthened diaphragm beam.

### 1.14.1.5 Reinforced Concrete Bearing Seats

#### CLEARANCE

The minimum horizontal clearance from the edge of a bearing plate, or 1 inch and thicker elastomeric bearing pad, to the edge of a concrete bearing seat shall be 6 inches, or 3 inches plus the thickness of grout under the bearing, whichever is greater. Where the bearing is skewed with the bent, this dimension may be reduced at the corner of the pad. Locate anchor bolts a minimum of 6 inches clear of the nearest face of concrete.

Figure 1.14.1.5-1 Concrete Bearing Seat Clearance



#### ADDITIONAL REINFORCEMENT

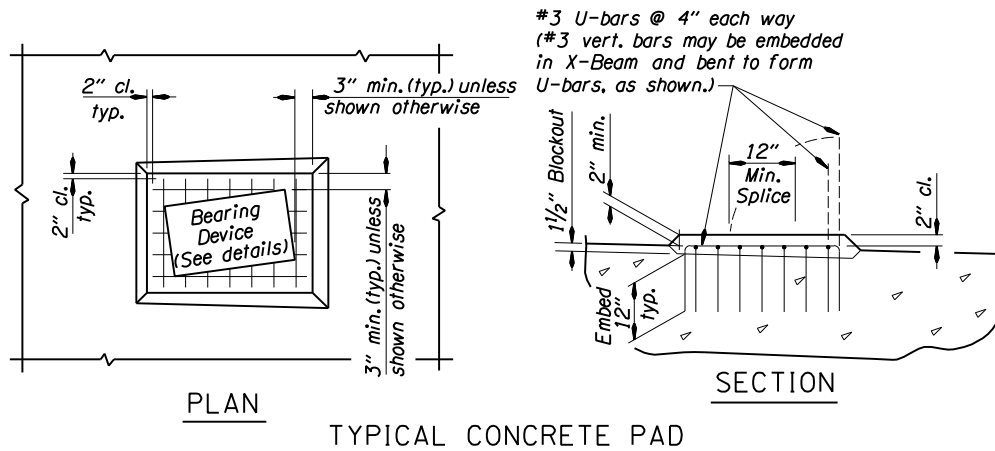
Generally, detail a reinforced concrete buildup, as shown below, under the bearings of all prefabricated beams, except precast slabs and box beams less than 70 feet in length.

Certain bearings may require no concrete buildup but have the bearing surface ground to grade.

Figure 1.14.1.5-2 Typical Concrete Pad Details

**Note:**

Pour 2" concrete pad, allow concrete to cure 3 days or until concrete obtains design strength.



### 1.14.1.6 Unreinforced Bearing Seats (Prestressed Slabs and Boxes)

#### GENERAL

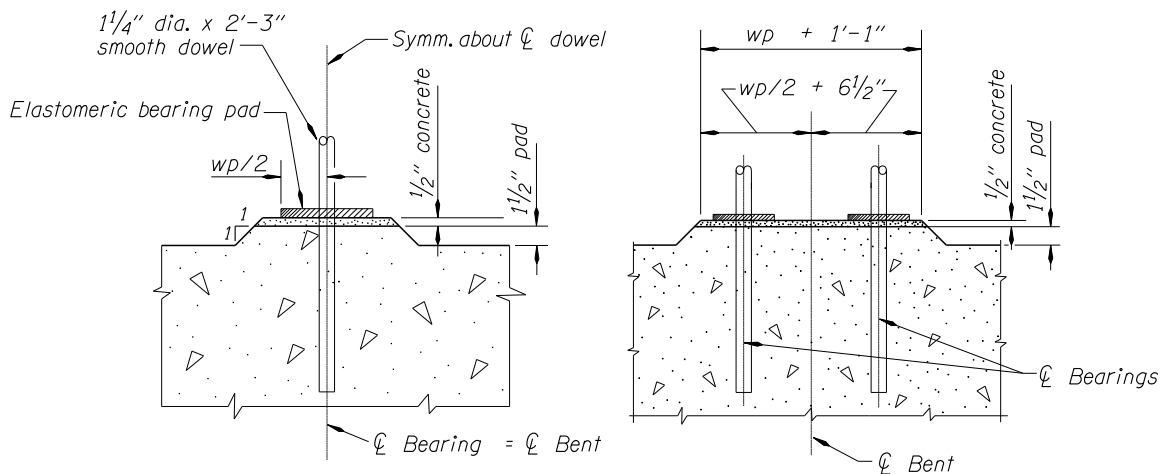
For prestressed slabs and boxes, provide bearing details as shown in *Figure 1.14.1.6-1*.

Set precast concrete slabs over 40 feet in length on elastomeric bearing pads. Do not allow cotton duck pads as a replacement for elastomeric bearing pads.

Figure 1.14.1.6-1 Bearing and Concrete Pad Details

**Note:**

Place 1/2" concrete layer on concrete pad, place elastomeric bearing pads and preformed expansion joint filler on concrete layer. Place slabs on bearing pads before the concrete layer is fully set to ensure uniform bearing across full width of the slab. If uniform bearing is not achieved, lift slab and repeat procedure. Remove any excess concrete protruding above the bearing pads immediately after placing slab.



BEARING AND CONCRETE PAD DETAILS

**CONSTRUCTION PROCEDURE**

STEP 1. Pour 1½ inch concrete pad, allow concrete to cure for three days or until concrete obtains design strength.

STEP 2. Place ½ inch concrete layer as shown in *Figure 1.14.1.6-1*.

## 1.14.2 Expansion Joints

### 1.14.2.1 Definitions and General Information

**Armored Joint** - Steel armoring to protect the vertical edges of a joint opening. The armor may be steel shapes.

**Asphaltic Plug Joint (APJ) Systems** - A closed expansion and contraction joint system composed of aggregate and flexible binder material placed over a steel bridging plate.

**Closed Expansion Joint** - A joint in which a seal material is placed to prevent water or debris from entering the joint. This includes poured joint seals, compression joint seals, asphaltic plug joint systems, preformed strip seals, and modular bridge joint systems.

**Control Joint** - A joint created by sawing a groove in a surface and filling it with a poured material, creating a weakened vertical plane that controls the location of cracking developed due to restraint stresses.

**Filled Joint** - A filled joint using a preformed joint filler placed prior to the concrete pour. Hot applied joint sealant is placed on top of the joint filler.

**Hot Applied Joint Sealant** - A hot-poured asphaltic material used for sealing cracks and joints from water penetration to prolong pavement and joint life.

**Modular Bridge Joint Systems (MBJS)** - A closed expansion and contraction joint using a series of continuous preformed strip seals inserted into steel shapes to seal the joint.

**Poured Joint Seal** - A closed expansion and contraction joint sealed with a rapid-cure poured joint sealant (2 part silicone).

**Precompressed Foam Silicone Joint (PFSJ) Seal** - A closed expansion and contraction joint system consisting of a preformed, pre-compressed, silicone-coated, self-expanding foam joint system bonded to joint faces using epoxy adhesive.

**Preformed Compression Joint Seal** - A closed expansion and contraction joint sealed with a continuous preformed elastomeric compression gland.

**Preformed Joint Filler** - A preformed expansion joint material having small extrusion and substantial recovery after release from compression.

**Preformed Strip Seal System** - A closed expansion and contraction joint using a continuous preformed elastomeric gland (strip seal) inserted into an extruded or formed steel retainer bar with steel anchors.

### 1.14.2.2 Design Guidelines for Joint Seals and Systems

Consider integral abutment or semi-integral abutment wherever criteria in *BDM 1.11.2.4* are met. Design expansion joints to provide for the effects of temperature, shrinkage and creep.

Use skew angle a minimum of  $\pm 5$  degrees different from snow plow angle for all joints except asphaltic plug joints. Normally the angle of attack of snowplows is skewed 30 degrees to the roadway alignment. Snowplow blades can fall into the joint where the skew angle of the joint matches the snowplow's angle, resulting in danger to the snowplow driver or traffic. Consider the effect of skew angles on future widening of the structure.

#### STRIP SEAL SYSTEM

Use preformed single strip systems to seal deck joints with up to 4 inch range of movement (1½ inch minimum installation width). For joints of greater anticipated movement, use a modular bridge joint system. It is not recommended to use a modular bridge joint system solely to provide for possible seismic movements.

#### PREFORMED COMPRESSION SEAL

Preformed compression seals may be specified for joints with a design movement of up to 1½ inches. Specify a seal size to ensure that the seal remains in compression throughout the service life.

#### POURED JOINT SEAL

Poured joint seal may be specified for a design movement up to 1½ inches.

#### ASPHALTIC PLUG JOINT SYSTEM

Asphaltic plug joint systems are suitable for joints between two pavements with asphalt concrete wearing surface and may be specified where following conditions are satisfied:

- Maximum range of design movement up to 1 ½ inches (total).
- Maximum bridge skew less than 45 degrees.
- Maximum lateral movement at joint ¼ inch.
- Maximum vertical movement at joint (uplift) ¼ inch.
- Maximum superelevation of 6 percent.

Asphaltic plug joint systems do not perform well under following conditions:

- Where traffic is accelerating or decelerating, such as intersection with traffic lights or stop signs.
- Bridge with a curved horizontal alignment.
- Longitudinal joint between two structures. Skid resistance of this joint diminishes with time and it may become a hazard to motorcyclist and bicyclists.



### PRECOMPRESSED FOAM SILICONE JOINT SEAL

Specify precompressed foam silicone joint seals for joint rehabilitation only. PFSJ seals may be specified for joints with a design movement up to 2 ½ inches. Limit a joint installation width smaller than 3 inches to ensure joint performance. Field verify the joint width. This joint system can be field-spliced, which makes it suitable for staged construction and partial joint repair. Specify factory-fabricated bends for inside corners at the gutter line. Field verify a bend angle required for the existing inside corner and show the bend angle on project plans. When joints cross sidewalk on a bridge, specify a PFSJ seal system that is suitable for pedestrian traffic and provide joint details according to *RD722*. Splicing between bridge and pedestrian PFSJ seals are possible.

### FILLED JOINT

Use filled joints for short span bridges with pin end bent connection. These joints are the least expensive joint and easy to repair.

### CONTROL JOINT

Use a control joint to control the location of cracking at the end of bridge approach slab and in pavement over joints. For rehabilitation projects, control joints can be used in continuous concrete bridge deck over intermediate bents when it is necessary to control cracking in a particular location. Use ½ inch sawcut width to accommodate hot applied joint sealant installation. The control joint may be specified for contraction movement up to ¼ inch.

Check the *Qualified Products List* for the currently acceptable materials and joint systems.

## 1.14.2.3 Expansion Joint Setting

Use a minimum change of joint width due to shrinkage of ¼ inch per 100 feet for the full length of non post-tensioned concrete segments (both pretensioned and conventional).

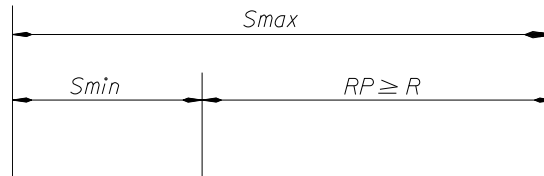
Use a minimum change of joint width due to creep and shrinkage of ½ inch per 100 feet for the contributing length of post-tensioned segments.

Use the following equations for calculating thermal effects:

Steel Girder Superstructure:  $R = LF * (TR + TF)$

Concrete Superstructure:  $R = LF * (TR + TF) + LF * (CR + SH)$

Figure 1.14.2.3-1 Calculation of Thermal Effects



Where:

$S_{min}$  = Minimum serviceable seal width

$S_{max}$  = Maximum serviceable seal width

R = Required seal range

RP = Provided seal range ( $S_{max} - S_{min}$ )

CR = Creep movement  $CR = (ES) * (CF)$

SH = Shrinkage movement

TF = Temperature fall movement

TR = Temperature rise movement

ES = Elastic shortening

CF = Creep factor

LF = Load Factor from *LRFD Table 3.4.1-1* and *LRFD 3.4.1*

Use the Strength Limit State Load Factor that produces the largest movement in each load combinations.

Table 1.14.2.3-1 Creep and Shrinkage Factors

Thermal Effect	Conventional Concrete	Prestressed Concrete	P/T Concrete
Creep: Creep Factor	--	1.5	1.5
Portion of Creep to use	--	50 percent	70 percent
Shrinkage: ultimate	0.0004	0.0004	0.0004
Portion of Shrinkage to use	60 percent	60 percent	60 percent

For the compression seals shown on Drawing *BR140*  $S_{min}$  and  $S_{max}$  are the width of the seal under a compressive force of 50 and 10 pounds per inch, respectively. In skewed joints,  $S_{min}$  and  $S_{max}$  may be limited by the allowable shear deformation of the seal. For the seals shown on *BR140*, always limit shear deformation of the seal to 10 degrees.

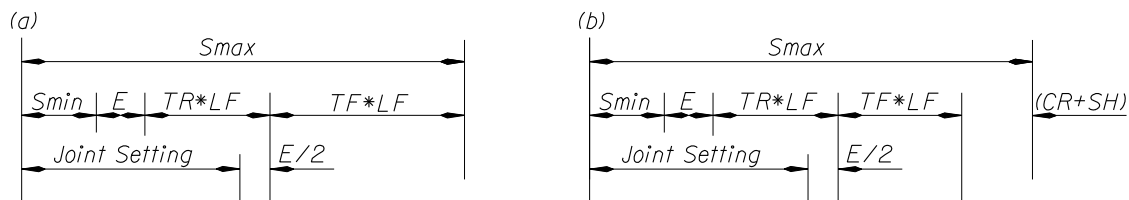
**JOINT SETTING AT MEAN TEMPERATURE**

In most cases, the range of serviceable seal width provided by a standard joint seal (RP) will be somewhat larger than the range required by design (R). Equally distribute this excess

$[E = RP - R]$  for expansion and contraction.

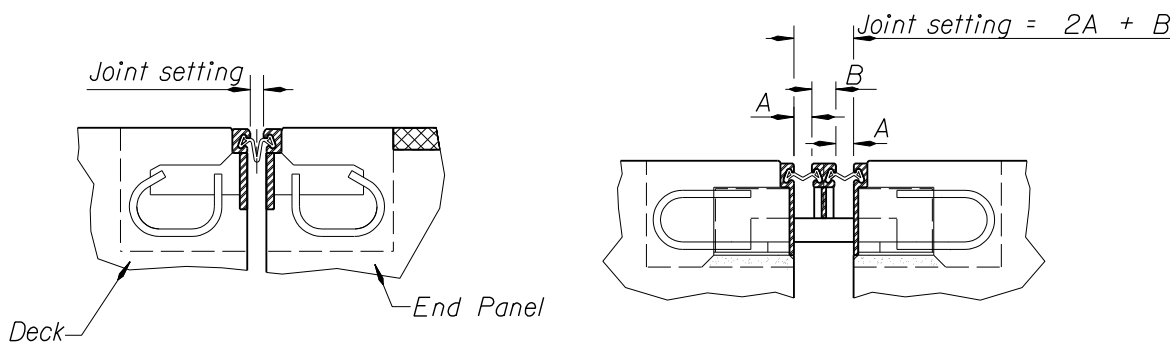
The following schematics show joint settings for the two design cases above.

Figure 1.14.2.3-2 Joint Setting Schematic



Use the form in *Figure 1.14.2.3-3* to call out joint settings on the plans.

Figure 1.14.2.3-3 Joint Setting Call-outs



Decrease Joint setting \_\_\_ inches for every 10°F of structure temperature above \_\_\_°F.

Increase joint setting \_\_\_ inches for every 10°F of structure temperature below \_\_\_°F.

Expansion joints are normally set after pretensioning is complete, so elastic shortening is not included in the joint setting width.

### 1.14.2.4 Details for Expansion Joints

See Standard Drawings *BR139, BR140, BR141, BR145, BR157, DET3138 and DET3150* for joint details.

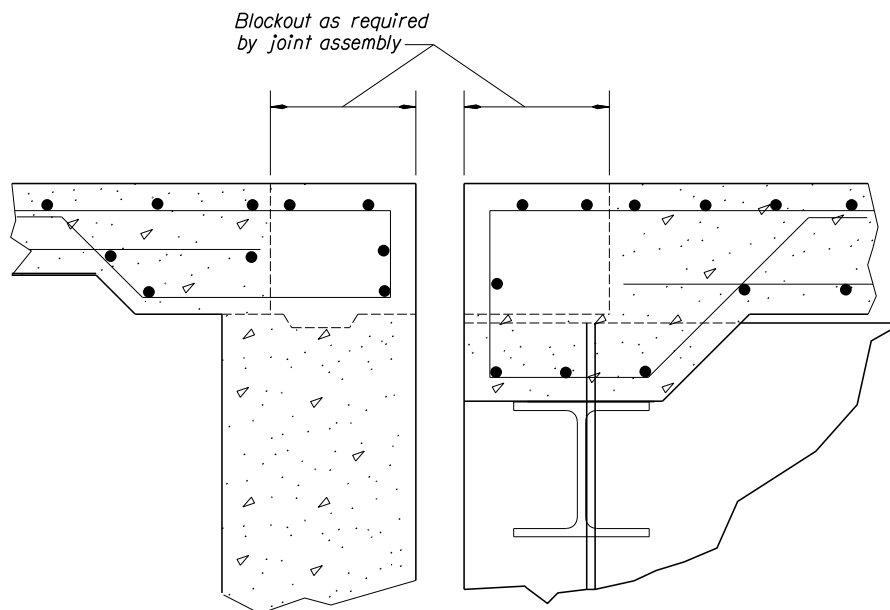
Drawings *BR141, BR145 and DET3150* show the depth of metal to be 8 inches, with a plate being welded to the 2 inch deep rail section.

For modular joints, the bottom of the rail section must be the same depth as the bearing boxes, as noted as **Point F** on *DET3150*.

#### EXPANSION JOINT BLOCKOUT

Show a blockout detail on the plans to allow the expansion joint assembly to be placed a period of time after the final deck pour. Providing a blockout makes the adjacent deck pour easier, provides smoother deck transition to joint, and allows the majority of the superstructure shrinkage to occur prior to joint assembly placement.

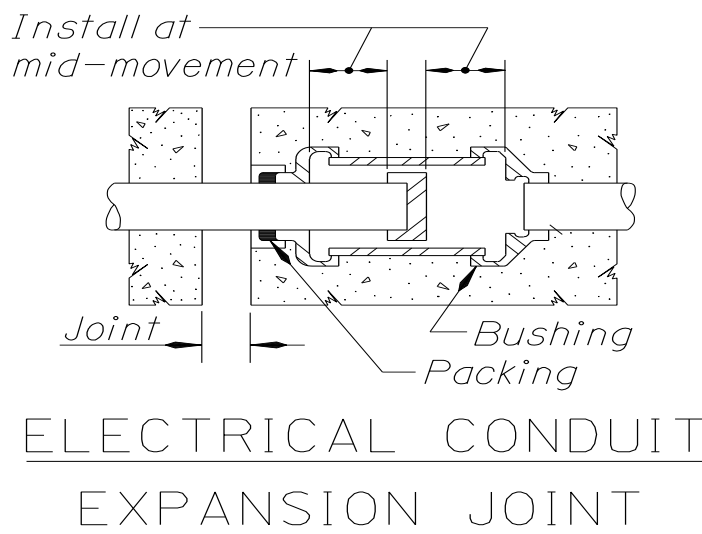
Figure 1.14.2.4-1 Expansion Joint Blockout



### ELECTRICAL CONDUIT EXPANSION JOINT

At those locations on the structure where an electrical conduit crosses an expansion joint, show a detail similar to *Figure 1.14.2.4-2* on the plans.

Figure 1.14.2.4-2 Electrical Conduit Expansion Joint



### 1.14.2.5 Measurement and Payment of Joints

List joint types and estimated quantities of joints in *SP 00585*.

Normally, filled joints do not need bid items, because the payment for filled joints is included in payment for constructing bridge elements next to the filled joints. Hot applied joint sealant in filled joints is also included.

Control joints shown on *BR165*, which includes sawcutting and hot applied joint sealant, are paid with paving work. For rehabilitation projects, new control joints are sometime specified. When the control joint is not included in payment for paving work, *SP 00585* has an option to list the new control joints as a bid item.

Hot applied joint sealant is usually paid with paving work. When replacement of hot applied joint sealant is specified for rehabilitation projects and is not paid with paving work. Use *SP 00585* to add the hot applied joint sealant work to the list of bid items.

## 1.15 Soundwalls

### [1.15.1 Soundwalls, General](#)

### [1.15.2 Soundwalls mounted on Bridges](#)

#### 1.15.1 Soundwalls, General

Design soundwalls according to the guidelines provided in *LRFD Section 15*, and *ODOT Geotechnical Design Manual, Section 16.6*.

Investigate the soil condition specific to the soundwall site and include in the Geotechnical Report.

The design and detailing requirements for soundwalls on bridges and retaining walls adjacent to the traveling public are different than the ones away from the traveling public. The failure of these soundwalls is a safety hazard for the traveling public.

#### 1.15.2 Soundwalls mounted on Bridges

Do not locate soundwalls on bridge structures where feasible alternative locations exist.

#### C1.15.1

It is recommended that this be taken care of early in the project's development.

#### C1.15.2

Soundwalls on bridge structures cause a disproportionate increase in bridge cost because of strengthening the deck overhang and exterior girder. These structures may cause increase in risk to traffic below during seismic events or in case of vehicular impact. In addition, soundwalls on bridges interfere with normal maintenance inspection access and detract from the aesthetic quality of the structure.

Where feasible alternative locations do not exist and soundwalls must be located on bridges, limit the total height, as measured from the top of bridge deck to the top of the soundwall, to 8 feet. A design deviation is required for soundwalls taller than 8 feet.

Only crash tested soundwalls are allowed on bridges.

On bridges where the soundwall does not meet crash test requirements of MASH Test Level 4, place soundwalls a minimum of 4 feet beyond the gutter line of an ODOT approved standard bridge railing.

In lieu of crash-testing, design soundwalls for vehicular collision forces according to *LRFD Section 15.8.4*.

Soundwalls may be combined with the traffic railing as long as the structural system meets the crash test requirements of MASH Test Level 4 criteria.

## 1.16 ADA Compliance for Bridge Work

### [1.16.1 Americans with Disabilities Act Compliance for Bridge Projects](#)

### [1.16.2 General Guidance](#)

### [1.16.3 Work Activity Triggers](#)

### [1.16.4 Design Considerations](#)

### 1.16.1 Americans with Disabilities Act Compliance for Bridge Projects

The *Americans with Disabilities Act of 1990 (ADA)* prohibits discrimination and ensures equal opportunity for persons with disabilities in employment, state and local government services, public accommodations, commercial facilities, and transportation. Implementation guidelines, standards, and court decisions provide guidance on how to comply with the law.

Although these sources are applied to transportation construction and maintenance decisions, there is limited guidance about specific work activities on bridges. This document provides guidance on the ADA application to the unique situations created by bridge rehabilitation and maintenance projects.

### 1.16.2 General Guidance

The ADA regulation prohibits discrimination against people with disabilities by government entities. Government entities must make services accessible and usable to all people, including people with disabilities. For the purpose of this document, the sidewalk of a bridge is a facility that, when provided, must be accessible and usable by people with disabilities, regardless of whether the bridge is in an urban or rural setting. The Oregon Department of Transportation (ODOT) has an obligation to ensure that a bridge infrastructure is accessible and usable, including bridge sidewalk facilities. ODOT addresses that obligation in several ways. Through the [ODOT ADA Title II Transition Plan](#), all pedestrian facilities are brought into compliance over time. Specific work will also trigger a requirement to bring certain facilities into compliance at the same time as the work is performed. Examples of specific work that triggers accessibility improvements include when a new bridge is constructed, when a new sidewalk is added to a bridge, or when the level of work on a bridge is considered to be an **alteration**. Activities that result in below-standard sidewalks require a design exception. Additionally, a project's scope of work must not be modified solely to avoid triggering accessibility upgrades.



### 1.16.2.1 Altering Access or Usability of a Pedestrian Access Route

When alterations affect access to a sidewalk on a bridge, it is necessary to ensure that the sidewalk can be accessed from the approaching shoulder or sidewalk utilizing a curb ram design. When alterations affect the usability of the sidewalk itself, it is necessary to ensure that the sidewalk is readily accessible to people with disabilities to the maximum extent feasible unless it is technically infeasible to do so. Explore alternatives to improve the level of accessibility of an existing sidewalk when it is below ODOT standards. Address accessibility barriers which include narrow passages, obstructions or routes lacking sufficient passing space. Alterations must follow current ODOT policy.

Where sidewalks are not present, pedestrian travel may be expected on or along the roadway except where prohibited. Pedestrian travel in the shoulder or in the roadway when there is no shoulder is allowed, but not an exclusive service. When a sidewalk is not present, treat the existing shoulder as a pedestrian access route when determining the impact of alterations.

### 1.16.3 Work Activity Triggers

The [US DOJ/FHWA memorandum](#) defines an **alteration** as: A change that affects or could affect the usability of all or part of a building or facility. Alterations of streets, roads, or highways include activities such as reconstruction, rehabilitation, resurfacing, widening, and projects of similar scale and effect. Activities defined as maintenance by the US DOJ/FHWA on streets, roads, or highways, such as filling potholes, are not alterations. Upgrade each facility or part of a facility that is altered to be readily accessible and usable by individuals with disabilities to the maximum extent feasible.

Examples of alterations of bridges include rail retrofit, widening, bridge deck concrete overlays, and asphalt concrete overlays when part of a full width paving project that extends beyond the bridge. Further, when changes are made that affect the accessibility or usability of the pedestrian access route, accessibility requirements need to be addressed. An existing bridge is considered to have a sidewalk, or pedestrian access route, when the horizontal surface is at least 32 inches wide. Conversely, when the clear horizontal surface is less than 32 inches, it is not considered to be a pedestrian facility.

The work types in the list below are not considered **alterations** and are considered maintenance activities. The list is not exhaustive. Evaluate additional activities on the basis of their impact to the usability of the pedestrian facility; activities that affect the usability are considered **alterations**.

Individual activities that do not result in changes to usability of the pedestrian facility:

- Structural deck overlays, premixed polymer concrete overlays, deck seals, and ACWS overlays, provided these activities do not overlap the pedestrian facility (sidewalk, shoulder, and/or crosswalk).
- Thin bonded polymer system overlays and deck seals that do or do not overlap the pedestrian facility (sidewalk, shoulder, and/or crosswalk).
- Deck repair patching, repair of deck soffit, full depth deck repair when these activities do not span the length of the bridge or more than  $\frac{3}{4}$  of the width of the pedestrian facility (sidewalk, shoulder, and/or crosswalk).
- Under deck superstructure repair.
- Spot sidewalk repair.
- Repair of sidewalk soffit, repair of longitudinal sidewalk beams, repair of cantilevered sidewalk supports.
- Bridge Painting, cathodic protection.
- Repair in-kind of existing bridge rails.
- Concrete patching of superstructure elements, prestressed components, concrete surface finishing.
- Bonded structural strengthening (FRP, titanium, other metals, surface or near-surface), resin injection of concrete cracks.
- Seismic retrofits.
- Expansion joint repair or replacement.
- Bearing device cleaning and lubrication.
- Substructure or Foundation repair.

### **1.16.3.1 Existing Bridges**

Existing bridges may support pedestrian facilities, either by providing a sidewalk or by providing adequate shoulder width. Do not reduce existing pedestrian facilities below applicable standards.

Existing bridges that have **safety curbs** do not have sidewalks. **Safety curbs** are features with similar appearance as sidewalks, but are provided as part of a bridge rail system and do not provide access for pedestrians. The clear width of the horizontal surface of a **safety curb** is less than 32 inches.

Figure 1.16.3.1-1 Existing Bridge Rail, Section with Safety Curb

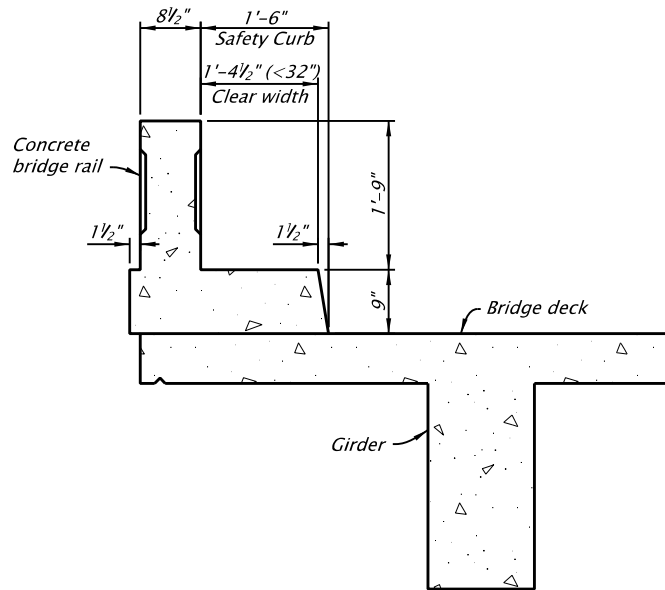


Figure 1.16.3.1-2 Existing Bridge, Section with Sidewalk

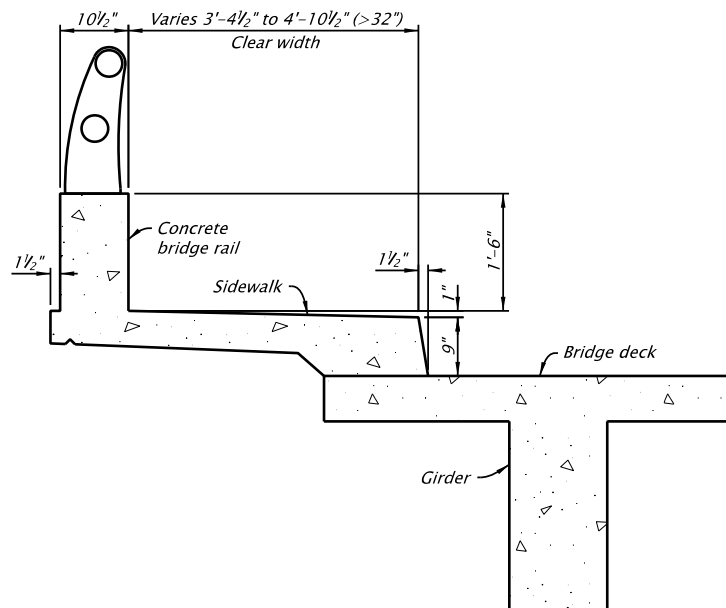
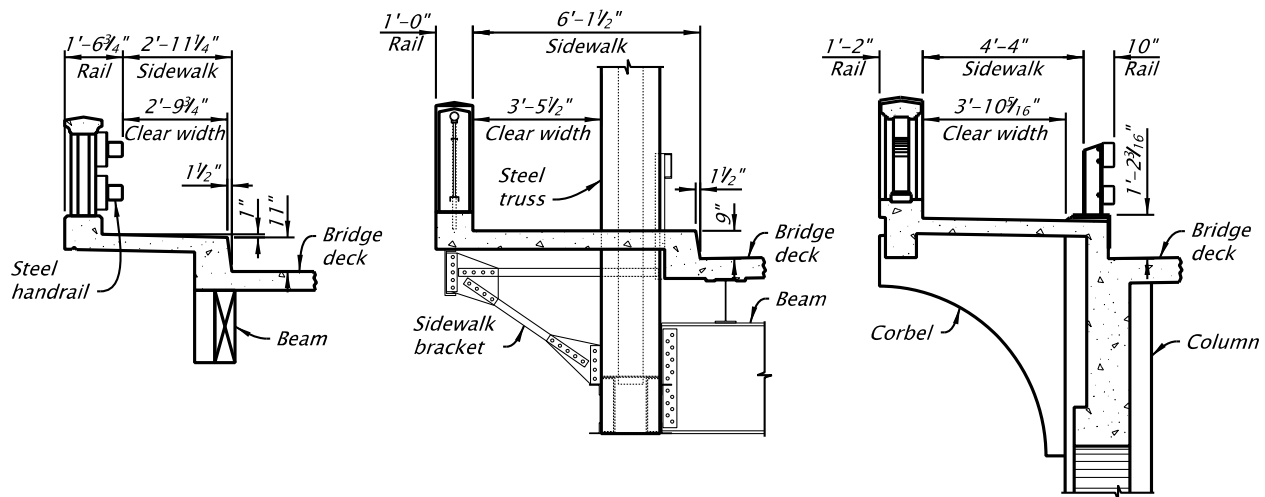


Figure 1.16.3.1-3 Existing Bridge, Clear Width Examples



When work on an existing bridge with sidewalk is an alteration as described in [BDM 1.16.3](#), upgrade accessibility to meet full standards or to the maximum extent feasible. Refer to [HDM 810.7](#) for sidewalk requirements.

Feasibility of upgrades depends on numerous factors including:

- Structural capacity of the bridge to accept additional dead load and pedestrian load. Perform load rating to determine when the main structural system has additional capacity to support the upgrade.
- Additional strengthening required to support the proposed upgrade. Determine when the project may include girder strengthening.
- Structural system.
  - Thickness and reinforcement of existing concrete cantilevered sidewalks (when the existing sidewalk is thin and lightly reinforced, strengthening of the existing sidewalk might not be feasible, for example).
  - Spacing and configuration of sidewalk brackets and edge beams supporting a sidewalk.
  - Bridge deck thickness.
  - Girder spacing (may limit reasonable widening).
  - Presence of truss or arch members above deck.
- Interaction of the proposed upgrade with future program work such as rail retrofit or bridge deck widening (when a major rail or widening project is planned or needed, it

may be most reasonable to improve accessibility at the same time).

- Historic preservation needs (some accessibility modifications may impact the significance of historic features of the bridge, while others may be acceptable due to limited scope of impacts or reversibility). See [BDM 1.16.4.1](#) for historic bridges.
- Roadway geometrics or roadway cross section. Roadway geometrics and cross section elements that can be reconfigured to increase accessibility of the pedestrian access route or sidewalk on one or both sides of the bridge need to be evaluated.

Document the feasibility of upgrades or reasonable upgrades/options considered. Document the rationale (i.e., the justification) for why the upgrade(s) or option(s) was (were) not feasible.

### 1.16.3.2 Rail Retrofit or Replacement

Bridge rail replacement requires upgrade of existing pedestrian facilities unless a design exception is obtained. For installation of bridge rail retrofit or bridge rail transitions at bridge ends, do not decrease the width of an existing sidewalk unless the final sidewalk width results in an accessible pedestrian route. Submit a design exception when sidewalk clear width is less than ODOT standard width.

### 1.16.3.3 Intersections on Bridge Structures

In some cases, intersections are located on bridge structures or at the bridge ends. The ADA requires providing or upgrading curb ramps at intersections in projects that either provide sidewalk or alter streets, roadways, or highways and span from one intersection to another. When a bridge alteration project includes an intersection it triggers the obligation to provide curb ramps at the intersection. Coordination with the roadway designer is critical in preparing curb ramp details for construction and should be reviewed by both disciplines for constructability. [Appendix 1: ADA Design of Bridge Curb Ramps](#) or [Appendix 2: ADA Bridge Works Examples](#) are posted on the [Bridge Standards website](#) for general guidance.

### 1.16.3.4 Temporary Traffic Control and Work Zones

For temporary traffic control and construction work, avoid impacting the pedestrian access route to the maximum extent feasible. When an existing pedestrian route is available and is impacted by work activities, provide a temporary accessible route for pedestrian traffic. For example, when an existing shoulder across a structure is four feet wide, provide a four-foot temporary pedestrian access route for pedestrian traffic. See [Temporary Pedestrian Accessible Routes \(TPAR\)](#) for more guidance.

## 1.16.4 Design Considerations

### 1.16.4.1 Historic Bridges

For bridges that are considered a historic resource, where accessibility modifications may impact the significance of historic features of the bridge, consult with the Region Environmental Coordinator and the Historic Resource Coordinator to ensure the State Historic Preservation Office (SHPO) comments are addressed. Where upgrading accessibility would conflict with federal law regarding historic preservation, neither law supersedes the other.

When there is a conflict between federal historic preservation requirements and accessibility requirements, a Design Exception is required to validate and justify any deviation from meeting the accessibility standards. With the supporting document in the Design Exception, include a letter from SHPO declaring that an adverse effect would be caused by meeting the full requirements of the ADA. Ensure the letter describes whether alternative designs or incremental ADA improvements would create adverse effects. Consider and document mitigations that will be used to minimize the impact to pedestrians with disabilities. Mitigating options might be posted minimum widths or possible accessible detours.

### 1.16.4.2 Technical Infeasibility and Design Exception

ADA compliance requirements are not the same as ODOT geometric design standards. The Roadway design exception process is used when geometric standards cannot be achieved. ODOT also uses the Roadway design exception process to document when it is technically infeasible to meet all the ADA criteria. Early coordination before DAP with the ODOT Roadway Engineering Unit regarding impacts to either the ODOT geometric standards or the ADA requirements is especially important. Justification for not meeting standards is a required section of the design exception request. While costs can be used to justify exceptions to geometric standards it is not a justification for ADA criteria. See [Section 1000 of the ODOT HDM – Design Exceptions](#) for the design exception process.

- 4R Standard: 4R or modernization projects are considered the highest level of design and as such ODOT geometric standards for horizontal and vertical alignments, super elevation, lane width, shoulder width, sidewalk width are expected to be used. Document the justification for any non-standard feature not meeting the geometric design standards and the options considered in a design exception request. ODOT geometric standards for sidewalk width are wider than the minimum ADA compliance width but the ODOT geometric standard of 7 foot wide sidewalks are required unless there is an approved design exception.
- 3R Standard: 3R or Rehabilitation projects are more common than 4R projects. These projects are able to retain many of the existing geometric features even when they do not meet full ODOT geometric design standards. On a 3R project a sidewalk that

does not meet the full 7 foot width but does meet the accessibility criteria of a 5 foot wide sidewalk does not require a design exception. When the sidewalk width is below 5 foot, a design exception is required and 5 foot by 5 foot passing spaces must be provided every 200 feet along the sidewalk. Other geometric features that are non-standard need to be evaluated by the Roadway designer for design exception requirements.

- 1R Road Paving: 1R or Resurfacing projects are the most common project type. These projects have a narrow scope defined to just surface treatments. When the resurfacing is classified as an alteration and road pavement surfacing extends from one intersection to another, provide or upgrade curb ramps at all intersections and crossings. Utilize the [ODOT curb ramp process](#) for upgrading curb ramps.
- Single Function Standard: Single Function projects are very limited in scope. The feature addressed in a single function project is to use 4R design standards for that specific feature. Design exceptions are not required for non-standard geometric elements not impacted by the single function work. When the sidewalk is not being modified, but the railing is being modified, which reduces the width of the sidewalk below the minimum 4 foot width, a design exception is required. When the reduction in usable sidewalk width retains the minimum 4 foot width, but not the ODOT standard width, a design exception is required for not meeting the ODOT standard.

## 1.17 Seismic Design

[1.17.1 Design Philosophy](#)

[1.17.2 Applications of AASHTO LRFD Bridge Design Specifications](#)

[1.17.3 Applications of AASHTO Guide Specs for LRFD Seismic Bridge Design](#)

[1.17.4 Liquefaction Evaluation and Mitigation Procedures](#)

[1.17.5 Costs](#)

[1.17.6 Instrumentation](#)

[1.17.7 Dynamic Isolators](#)

[1.17.8 Seismic Restrainer Design \(New Designs And Retrofits\)](#)

### 1.17.1 Design Philosophy

The 2008 Interim Revisions to the 4<sup>th</sup> edition of the *AASHTO LRFD Bridge Design Specifications* were developed in late 2007. Though these revisions still support a “force-based” design philosophy, they represent a significant update to many areas of the seismic design provisions in *AASHTO LRFD Bridge Design Specifications*. In 2008, AASHTO also adopted the *Guide Specifications for LRFD Seismic Bridge Design*, a standalone document, which represents a “displacement-base” design philosophy.

Design all bridges for full seismic loading according to the 2<sup>nd</sup> edition of *AASHTO Guide Specifications for LRFD Seismic Bridge Design (Guide Spec.)*. Obtain approval by the State Bridge Engineer if the use of *AASHTO LRFD Bridge Design Specifications* is to be considered for any unique project on state-owned bridges.

Comply with ODOT’s additional requirements and guidelines summarized in *BDM 1.17.2* if designing seismically according to *AASHTO LRFD Bridge Design Specifications* or *BDM 1.17.3* if designing seismically according to *AASHTO Guide Specifications for LRFD Seismic Bridge Design*.

Notify and consult ODOT Bridge Section for decisions involving deviations to the standard seismic design practices described in this manual. Deviations from the following guidelines should be justified and documented. The documentation should be in the permanent bridge records.

At the end of the design process, complete and submit a copy of the [Seismic Design/Retrofit Data Sheet](#) to ODOT Bridge Section mailbox ([Bridge@odot.oregon.gov](mailto:Bridge@odot.oregon.gov)).

**Seismic load effects should be considered for all projects using the following guidelines:**



## 1.17.2 Applications of AASHTO LRFD Bridge Design Specifications

### 1.17.2.1 General Considerations

**New Bridges:** Design all bridge components for full seismic loading according to the current edition of *AASHTO LRFD Bridge Design Specifications*, except as modified by *BDM 1.11.3.5* to *1.11.3.11*, and *1.17.1* to *1.17.8*. Consider the load factor for the Live Load on Extreme Event Load Combination I,  $\gamma_{EQ} = 0$  (*LRFD 3.4.1*), unless the bridge is designated by Bridge Section as a major, unusual or unique structure.

The Structural Engineer/Designer should rely on the project Geotechnical Designer to provide the seismic hazards, ground motions, deformations and additional permanent loads.

Design new bridges on or West of US97 for a two-level performance criteria; Life Safety and Operational. Design new bridges east of US97 for the Life Safety criteria only.

Seismic Design Criteria for Life Safety and Operational are described below.

**“Life Safety” Criteria:** Design all bridges for a 1000-year return period earthquake (7% probability of exceedance in 75 years) to meet the “Life Safety” criteria using the 2014 USGS Hazard Maps. The probabilistic hazard maps for an average return period of 1000-year and 500-year are available at [ODOT Bridge Section website](#), but not available on USGS website. To satisfy the “Life Safety” criteria, use Response Modification Factors from *LRFD Table 3.10.7.1-1* using an importance category of “**other**”.

To aid in providing consistency and efficiency, Bridge Section has developed an excel application for constructing the probabilistic response spectrum using the general procedure (three-point curve). Latitude, Longitude, and Site Class are the needed input. Version 2014.16 of this excel application has been released to incorporate the updated Site Coefficients associated with the 2014 hazard maps and can be obtained at the following link:

<https://www.oregon.gov/ODOT/Bridge/Pages/Seismic.aspx>

Replace *LRFD Tables 3.10.3.2-1*, *3.10.3.2-2*, and *3.10.3.2-3* with Tables 1.17.3-1A, 1.17.3-1B, 1.17.3-1C.

**“Operational” Criteria:** Design all bridges on and West of US97 to remain “Operational” after a full rupture of Cascadia Subduction Zone Earthquake (CSZE). The full rupture CSZE hazard maps are available at the [ODOT Bridge Section website](#). To satisfy the “Operational” criteria, use Response Modification Factors from *LRFD Table 3.10.7.1-1* using an importance category of “**essential**”. When requested in writing by a local agency, the “Operational” criteria for local bridges may be waived.

The CSZE is a deterministic event, and a deterministic Design Response Spectrum must be generated. To allow for consistency and efficiency in design for the CSZE, an application for

generating the Design Response Spectra has been developed by Portland State University. Latitude, Longitude, and  $V_{s,30}$  are the needed input for running the application. This application can be accessed at the following link:  
<https://www.oregon.gov/ODOT/Bridge/Pages/seismic.aspx>

**Non-conventional Bridges:** *LRFD 3.10.1* states that the seismic provisions of that manual are applicable for conventional bridges. For seismic design of non-conventional bridges, consult with the Senior Seismic Standards Engineer to discuss whether special analysis and design procedures are warranted.

**Bridge Widening:** Design selected bridge portions for seismic loading as directed by the flowchart shown in *Figure 1.17.2-1A*. Design by the same criteria as for "New Bridges".

Potential Factors Affecting Seismic Performance of Bridge Widening – The following considerations refer to the flow chart in *Figure 1.17.2-1A*. The consideration number refers to the corresponding numbered decision box on the flow chart.

### Consideration 1

- Widening without adding new columns will make a bridge more vulnerable to seismic loads. Clearances for railroads or highways under structures may prevent adding new columns.

### Consideration 2

- Widening on both sides will increase the potential for the new portion to be able to resist seismic loads for the full widened structure.
- Widening on one side only may actually result in a completed structure that is more vulnerable than the original structure.
- If widening is on one side only, is there a possibility another future widening could be placed on the opposite side?
- It will not normally be practical for a widening to resist the total seismic load (existing and widening) when widening on only one side; however, there could be exceptions.

### Consideration 3

- A formal seismic analysis may be required to answer this question. A "yes" answer to Consideration 3 assumes only minimal work (such as column jacketing) will be needed for the existing structure.
- Although the existing structure may have inadequate capacity, it will have some capacity that can probably be taken advantage of.
- If existing columns are not stressed beyond the elastic range they will probably not need a Phase 2 retrofit.
- The existing structure will have to go through the same deformations as the new portion even though the capacity may not be included in the seismic analysis.

### Consideration 4

- Structures which are connected must have compatible deflections at connections.

- We are usually not concerned about the seismic load generated from one structure colliding with an adjacent structure; however, there could be exceptions.
- Providing a joint between the widening and existing structure will probably increase the potential for the new portion to resist seismic loads. If the widening adds enough width for at least two lanes and the longitudinal joint would not be in a travel lane, a joint should be considered.

### Consideration 5

- Base isolation is strongly encouraged, especially when bearing replacement is required anyway.
- When footing strengthening is required, Phase 2 will probably not be practical due to the high cost. If cost is the primary decision factor, a realistic estimate of Phase 2 retrofit cost should be prepared. Don't say it costs too much without knowing how much too much is!
- The closer footings are to the ground surface, the more practical Phase 2 will become.

### Consideration 6

- If you can't see the new portion acting separately, do not waste time assuming it will!
- Widening with only one new column per bent vs. multiple columns on the existing structure probably do not need to be modeled separately.
- When widening with 2 or more columns or with drilled shafts, it is probably reasonable to model the new structure separately.
- Consider the potential for another future widening. Perhaps size the footings larger than necessary.

### Consideration 7

- Is it even possible to close the structure to replace it? Can it be replaced in stages? Is it historic?
- A new structure will usually be far superior to a "band-aided" structure.

### Consideration 8

- FHWA requirements take effect when the new structure actually has more travel lanes than the existing structure. Widening that adds only shoulder width or median width are not affected. FHWA requirements may assist in convincing Region of including Phase 2 seismic retrofit, but it is not intended to force a Phase 2 retrofit when it really is not practical.
- For projects exempt from FHWA review, the Technical Services Branch Manager will approve exceptions to FHWA policy.

### Consideration 9

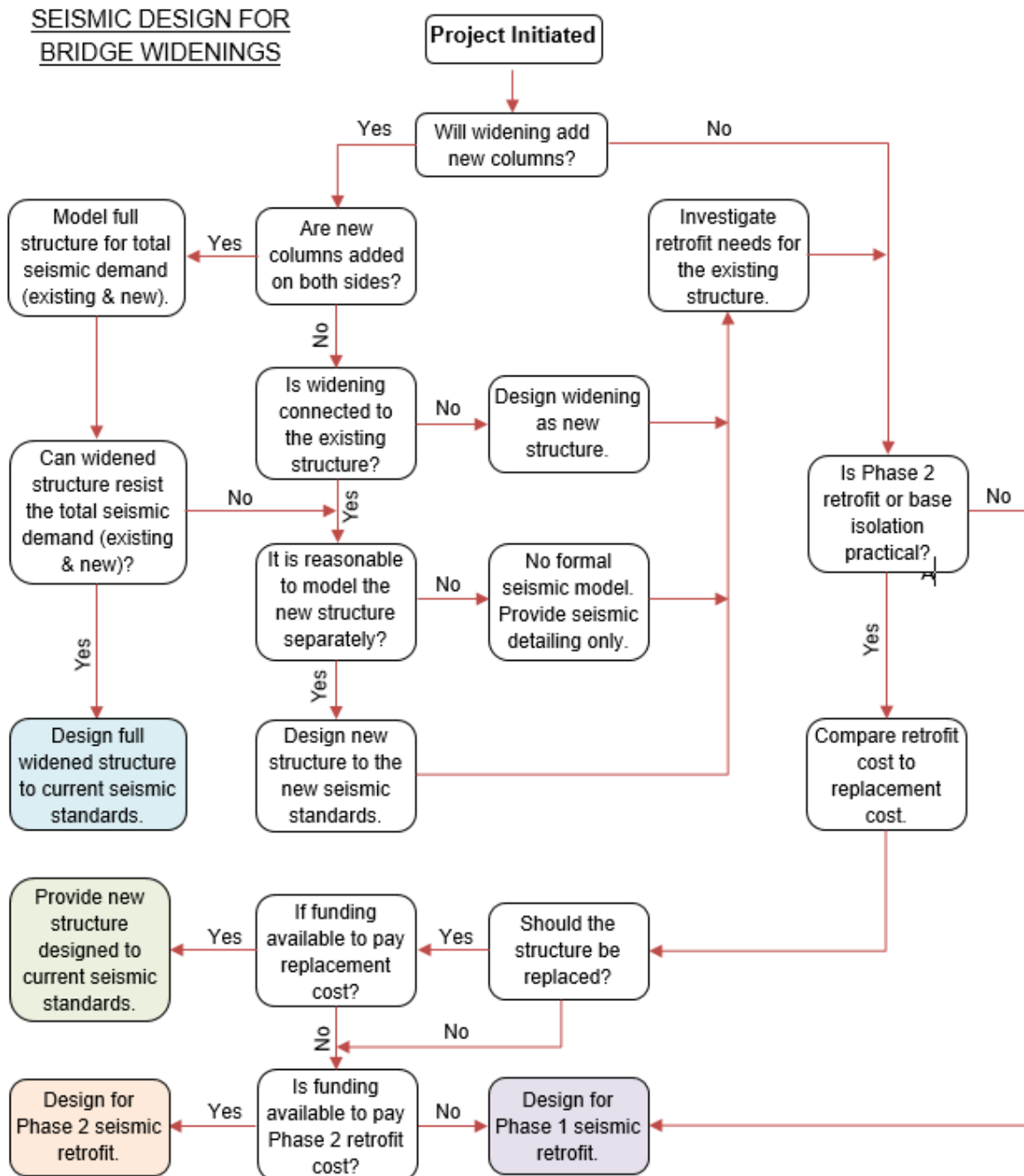
- Region holds the money. They may have factors/priorities we don't know about.
- Refusal by Region to fund the needed retrofit and refusal by FHWA to grant an exception (if federal funding) could lead to cancellation of the project.

- It would be desirable to calculate a cost-benefit ratio.

Seismic Detailing for Bridge Widenings: *Figure 1.17.2-1A* provides a framework for evaluating the level of seismic design required for bridge widenings. When detailed seismic modeling and analysis is not required, provide seismic detailing of all new bridge components. Seismic detailing consists of providing the reinforcement of the Earthquake Resisting Elements within the limits recommended in the design specifications, including:

- Maximum and minimum shear reinforcement (per *Guide Specs 8.6.4 & 8.6.5*)
- Maximum and minimum longitudinal reinforcement (per *Guide Specs 8.8.1 & 8.8.2*)
- Maximum spacing of longitudinal reinforcement (6" or 8", depending on the shape of the column)
- Minimum size of lateral reinforcement (per *Guide Specs 8.8.9*)
- Maximum spacing of lateral reinforcement in plastic region (4"), where the plastic hinge region is determined according to the *Guide Specs 4.11.7*
- Joint proportioning (per *Guide Specs 8.13.2*) and minimum joint shear reinforcing (per *Guide Specs 8.13.3*)

Figure 1.17.2.1-A



**Notes:**

1. Document all seismic-related decisions with a memo to the file.
2. The Bridge Section Seismic Committee will be available to assist in the decision process when requested by the designer.
3. The designer should strive for higher levels of seismic design/retrofit whenever practical.
4. See preceding pages for potential factors affecting seismic design decisions.

**Seismic Retrofit:** There is currently no funding within ODOT solely to upgrade the seismic load resistance of selected structures. However, when the seismic retrofit design is included in a project, use a phased approach for establishing a practical and economical retrofit strategy. The publication "Seismic Retrofitting Manual for Highway Structures" (FHWA-HRT-06-032) is recommended as a reference source to supplement the Bridge Design Manual and Bridge CAD Manual.

The following steps are provided to help designers initiating the design process:

- Most Oregon bridges fall under importance category of “**standard**”, based on the Bridge Importance Category definitions provided on *FHWA-HRT-06-032*. Contact Bridge HQ when this category becomes questionable for a given structure.
- Contact Bridge HQ for information on the Anticipated Service Life (ASL) of the bridge.
- Revise the top-half of the Table 1-2 of *FHWA-HRT-06-032* with the following:

**Table 1.17.2-1A**

**Minimum performance levels for retrofitted bridges**

EARTHQUAKE GROUND MOTION	BRIDGE IMPORTANCE and SERVICE LIFE CATEGORY					
	Standard			Essential		
	ASL 1	ASL 2	ASL 3	ASL 1	ASL 2	ASL 3
Lower Level Ground Motion  Cascadia Subduction Zone Earthquake – Full Rupture	PL0 <sup>4</sup>	<del>PL3</del> PL2	<del>PL3</del> PL2	PL0 <sup>4</sup>	<del>PL3</del> PL2	PL3
Upper Level Ground Motion  7 percent probability of exceedance in 75 years;  return period is about 1,000 years.	PL0 <sup>4</sup>	PL1	PL1	PL0 <sup>4</sup>	PL1	PL2

For assessing the seismic performance of existing bridges use the following concrete strain limits for existing bridge columns with poor confinement detailing:

<b>Design</b> \ <b>Confinement</b>	Inadequate Hoops and Hoop Spacing <sup>1</sup>	
	Inadequate Lap Splice <sup>2</sup>	Adequate Lap Splice
Operational	0.002	0.002
Life Safety	0.003	0.004

- 1) As adequate hoops are qualified those that meet the definition of “seismic hooks” in Article 8.8.9 of *AASHTO Guide Specifications for Seismic Bridge Design* and are spaced no more than 6 inches apart.
- 2) As adequate lap splice are qualified those that meet the requirements of Article 5.10.8.4.3a of *AASHTO LRFD Bridge Design Specifications* for Class B splice.

**Phase 1**

The Phase 1 Seismic Retrofit is considered to achieve “Life Safety” performance of Oregon bridges under seismic induced loading. Work during this phase is intended to prevent superstructure pull-off and bearing failure. Phase 1 Retrofit is not required on bridge painting projects or any projects where the scope of work does not extend below the deck.

Incorporate Phase 1 Seismic Retrofit on bridge rehabilitation projects when bridges are located in Seismic Zone 3 or 4. Bridges located in Seismic Zone 2 may be considered for Seismic Retrofit if situated between bridges (on the same route) that have received or are receiving Seismic Retrofit, or between new bridges built to current seismic design standards.

As a minimum, for a Phase 1 Retrofit ensure that the girders will not pull off longitudinally or slide off laterally from the bents. This will normally involve addition of cable restraints, shear blocks, and/or beam seat lengthening and widening.

Identify a seismic design concept which will accomplish the intent to preclude span pull off or collapse of the superstructure. Depending on the concept selected, some strengthening of the superstructure may be required to ensure loads generated at the restraints or shear blocks can be transmitted without exceeding design stresses in the superstructure. For steel truss bridges, ensure all truss elements and connections provide sufficient resistance to failure or plastic deformation under seismic induced loading. Short pedestals or secondary columns above the main bent cap level must also be investigated for seismic induced loading and strengthened or braced, if necessary.

Upgrade existing bearings to elastomeric bearings, if needed to assure the designer’s concept will work. Upgrading bearings to elastomeric should, also, be considered to improve seismic performance when existing bearings are known to have poor seismic performance, such as steel rocker bearings. Analysis for Phase 1 Retrofit will normally consist of a single degree of freedom model, which may be sufficient for normal bridges. However, a higher level analysis may be required, if needed to fully develop the designer’s concept, or for bridges with irregular column lengths of multi-column bents or if the bents have significantly different stiffness. Use



full column sections (uncracked) for this level of analysis to develop connection design loads. This is the minimum level of work that must be included. A cracked section analysis may be used to investigate the maximum anticipated movements.

### *Phase 2*

Work during this phase involves substructure (columns, footings and foundations) ductility enhancement and strengthening. Any additional or deferred Phase 1 Retrofit work would also be included. The end product is a retrofitted bridge with as much seismic loading resistance as a new bridge would have for the site. The Phase 2 Seismic Retrofit is considered to achieve the "Operational" performance of Oregon bridges under the seismic loading induced by the full rupture of Cascadia Subduction Zone Earthquake.

Evaluate the structure to investigate the level of effort and scope of work needed to do Phase 2 Retrofit. Phase 2 involves a complete seismic analysis of the widened or rehabilitated bridge for full seismic loading, including consideration of strengthening or restraints to the superstructure, substructure and foundations. The work may involve column and footing strengthening or enlargement, or the use of isolation bearings, and soil improvement, if there is potential for liquefaction. The decision about whether to actually do Phase 2 Retrofit in the project will be made after developing a retrofit concept, rough cost estimate and evaluation of the relative importance of the bridge to the transportation network, in comparison to the estimated cost and available funding for the project. The remaining service life, existing condition, and retrofit cost versus replacement cost are also important factors and must be evaluated. Consult with the Bridge Section before proceeding with any Phase 2 seismic retrofit. The flowchart for seismic design of widenings in *BDM 1.17.2.1 (Figure 1.17.2-1A)* can be used as a guide to make the decision.

A seismic retrofit analysis typically requires the use of a "Site Factor" to develop the response spectrum used in the analysis. Site factors are based on the soil conditions at the site, (categorized as Site Classes A - F) as described in the FHWA Seismic Retrofitting Manual for Highway Structures, Table 1-3. For most normal bridges requiring Phase 1 retrofit work the site class can be determined using either existing soils data or a general knowledge of the site geology and soil conditions. If limited knowledge is available the default designation of Site Class D is acceptable. However, for Phase 2 level retrofit analysis more detailed soils information is required to better determine the design response spectrum and also to adequately characterize and model the foundations in the analysis. Additional exploration work may be required to obtain this information. This additional work is justified due to the increased cost of Phase 2 retrofit work and the need for a more refined analysis.

### **Rail Upgrade, Deck Overlays, Preservations, Repair, Strengthening, and Others:**

These projects should include seismic retrofit as described previously for "Seismic Retrofit".

**Temporary Detour Bridges:**

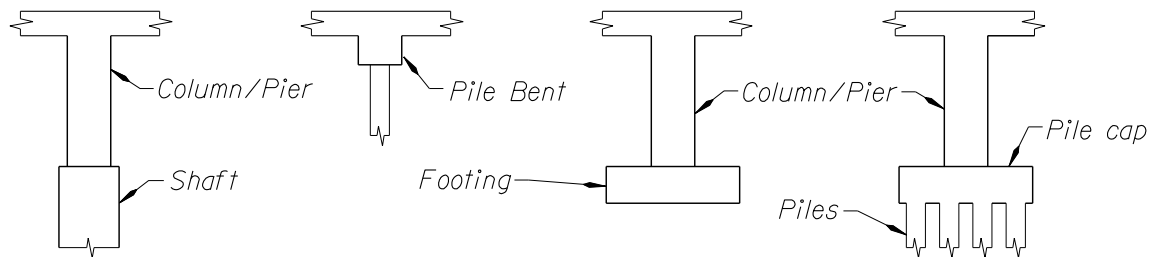
Design all temporary detour bridges meeting one of the following criteria according to *LRFD 3.10.10*:

- Bridge is expected to be in service for more than one year and ADT > 10,000
- Bridge is expected to be in service for more than two years

For all other temporary detour bridges, provide the minimum support length requirement according to *LRFD 4.7.4.4*.

**1.17.2.2 Specification Interpretations and Modifications**

Nomenclature:



**Figure 1.17.2-2A**

Response Modification Factors and other Special Items:

All Single Spans:

- No response modification factors -- not applicable.
- Provide for connection force of: "Tributary weight" x "A<sub>s</sub>", where A<sub>s</sub> = F<sub>pga</sub> \* PGA, or provide the specified minimum support length according to *LRFD 4.7.4.4*.
- Free standing abutments (expansion jointed systems) are to be designed for pseudostatic Mononobe-Okabe method lateral earth forces.

Seismic Zone 1:

- No response modification factors -- not applicable.
- Provide for connection force of:  
 $0.15 * F_v$ , when  $A_s < 0.05$ , or  
 $0.25 * F_v$ , when  $A_s \geq 0.05$ , where  $F_v$  is the vertical reaction at connection, or provide the specified minimum support length.

Seismic Zone 2:

- Design and detail Zone 2 structures by Zone 3 and 4 criteria except for the following design provisions:
- When determining the capacity for compression-controlled sections for extreme event limit state use Resistance Factors of  $\Phi=0.75$  as specified for Zone 2 in *LRFD 5.5.4.2.1*.

- When designing the reinforcement for compression members, design in accordance with *LRFD 5.7.4.2* "Limits of Reinforcement" for Seismic Zone 2.

**Zones 3 and 4:**

- Columns and Piers:
  - Moment: R = 2 to 5 (*LRFD Table 3.10.7.1-1*, right column)
  - Shear: R = 1
  - Axial: R = 1

**NOTE:** The plastic hinging capacity should be determined from column interaction curves with axial and moment  $\Phi$  values of 1.0. Enter the curve with the unfactored dead load axial force (plus any redundancy induced axial force due to lateral seismic loading), determine the accompanying moment capacity and multiply this value by 1.3. This is the plastic moment capacity.

**Foundations:**

- Pile Bent: Treat as columns and piers (R=5). Design splices to at least the lesser of  $1.3(M_{plastic})$  for the portion above or below the splice. This splicing requirement does not apply to full penetration welded splices.

**Footing - pile cap - piles:**

- Moment, shear & axial: R = 1 (elastic analysis forces) or,
- Moment: Plastic moment capacity of the selected column.
- Shear and Axial: Value accompanying the plastic moment capacity of the column (see "Columns" above).

**Other Special Items:**

- Confining Reinforcement (plastic hinge zones)
  - Provide transverse reinforcement for confinement in plastic hinging zone to satisfy *LRFD equations 5.7.4.6-1, 5.10.11.4.1d-1, 5.10.11.4.1d-2 and 5.10.11.4.1d-3*.
  - Plastic zone limits are defined as the greatest of maximum column dimension, (column height)/6, or 18 inches.
  - Extend confining reinforcement into footing or crossbeam by the greatest of (maximum column dimension)/2, or 15 inches.
  - Maximum confining reinforcement spacing is the lesser of (the least member dimension)/4, or 4 inches.
  - Shear reinforcing meeting the detailing requirements of confining reinforcement may be considered as part of the required confining reinforcing.

**Column Moment Strength Reduction Factor ( $\Phi$  factor)**

- Use  $\Phi = 0.9$  on checking the P- $\Delta$  Requirements as per *LRFD 4.7.4.5*.

**Column Shear Strength Modifications (end regions)**

- End region limits are defined as the greatest of maximum column dimension, (column height)/6 or 18 inches.
- If axial stress  $> 0.1f'_c$  use  $V_c$  as specified in *LRFD 5.8.3*. Vary  $V_c$  linearly from normal value to 0 for axial stress between  $0.1f'_c$  and 0.

**Longitudinal Reinforcement Development**

- Provide anchorage development for steel stress  $\geq 1.25f_y$ .

### 1.17.2.3 Detailing

(1) Columns:

For column design and reinforcement practices, see *BDM 1.11.3*.

(2) Footings:

- All footings must have a top mat of bars whether or not uplift is calculated. Extend spirals at least 2 inches into top of the footing. Place the footing top mat immediately below the spiral termination. Place additional spirals below the mat (use a 6 inch spiral gap) as needed to meet the confining reinforcement layout of *BDM 1.11.3.11*. Use the same spiral pitch at all locations. See the optional detail for alternate containment reinforcing in the column to footing connection in *BDM 1.11.3.10*.
- Note the allowable reduction in reinforcement development length for bars enclosed within a spiral (*LRFD 5.11.2.1.3*).

(3) Crossbeams:

- For column to crossbeam connections where plastic moment capacity is required, provide spirals extending into the crossbeam in the same general manner as described above for the column-to-footing connection.

### 1.17.2.4 Structure Modeling

(1) Structure Modeling, General:

- Use a "first cut" analysis with fixed supports. These results will be easier to interpret than a spring supported model and will give a baseline for comparison with additional analyses. With these results, make a rough substructure design. Now a new analysis can be performed with footing springs and the substructure design checked and refined. Additional cycles of redesign, analysis, and force comparison to previous analyses could be used in some cases but generally would not be required or warranted.
- A reasonable target for a seismic design check is 20 percent. Designer and Checker should resolve differences greater than 20 percent, but it is impractical to try to refine the design beyond that.

(2) Footing Springs:

See *BDM 1.10.4*.

(3) Programs:

- The Uniform Load and single mode dynamic analysis methods are acceptable for many structures (see the code limitations) but multi-mode dynamic analysis by computer may be easier. The result of any analysis method must be judged for correctness. Is the result reasonable? Reviewing the calculated periods, modal participation factors and mode shapes can greatly aid this judgment. A high level of engineering judgment will be required at all times.
- MIDAS and GTStrudl are ODOT's primary in-house static and dynamic analysis programs, and are available for bridge designers working at Bridge HQ or Region Tech Centers. Many design firms have adopted the use of SAP2000 or STAAD for seismic design of bridges. Other programs are also acceptable, provided the programs satisfy the analysis requirements and have been previously verified.

(4) Sample Problems:

- Sample problems are shown in the Bridge Example Design notebook, and can be downloaded under [Seismic Design Examples](#).

### 1.17.2.5 Footing/Pile Cap Design

(1) Piling:

- Nominal pile resistances should be used with the seismic load case (*LRFD Table 3.4.1-1, Extreme Event-I*) to determine pile requirements. Uplift resistance may be used for friction piles if the piles are properly anchored. Consult with the Geotechnical designer for site specific values. Piles under tension that are not capable of resisting uplift should be neglected during analysis for seismic loadings. The remaining piles must provide sufficient support and stability.

(2) Reinforcing Steel:

- Control of cracking requirements of *LRFD 5.7.3.4* do not apply to seismic load cases.
- Pile supported footings should normally have the bottom mat reinforcing above the pile tops. Footings with this scheme are preferable to thinner footings with the bottom mat detailed lower (between the piling). This is for constructability.

## 1.17.3 Applications of AASHTO Guide Specs for LRFD Seismic Bridge Design

### 1.17.3.1 General Considerations

As of 2009, ODOT has fully adopted the use of *AASHTO Guide Specifications for LRFD Seismic Bridge Design* for designing Oregon bridges subjected to earthquake loading. The following summarizes ODOT's additional requirements and deviations from the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*.

Design all bridge components for full seismic loading according to the 2<sup>nd</sup> edition of *AASHTO Guide Specifications for LRFD Seismic Bridge Design (Guide Spec.)*, except as modified by *BDM 1.11.3.5 to 1.11.3.11*, and *1.17.1 to 1.17.8*. Consider the load factor for the Live Load on Extreme Event Load Combination I,  $\gamma_{EQ} = 0$ , unless the bridge is designated by Bridge Section as a major, unusual or unique structure.

The Structural Engineer/Designer should rely on the project Geotechnical Designer to provide the seismic hazards, ground motions, deformations and additional permanent loads.

Design new bridges on or West of US97 for a two-level performance criteria; Life Safety and Operational. Design new bridges east of US97 for the Life Safety criteria only.

Seismic Design Criteria for Life Safety and Operational are described below.

"Life Safety" Criteria: Design all bridges for a 1000-year return period earthquake (7 percent probability of exceedance in 75 years) to meet the "Life Safety" criteria using the 2014 USGS Hazard Maps. The probabilistic hazard maps for an average return period of 1000-year and 500-year are available at [ODOT Bridge Section website](#), but not available on USGS website.

To aid in providing consistency and efficiency, Bridge Section has developed an excel application for constructing the probabilistic response spectrum using the general procedure

(three-point curve). Latitude, Longitude, and Site Class are the needed input. Version 2014.16 of this excel application has been released to incorporate the updated Site Coefficients associated with the 2014 hazard maps and can be obtained at the following link:

<https://www.oregon.gov/ODOT/Bridge/Pages/seismic.aspx>

To satisfy the “Life Safety” criteria, comply with the following requirements and guidelines:

Seismic Design Categories (SDC) A, B and C

- Meet all design requirements for SDC A, B and C according to the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*.

Seismic Design Category (SDC) D

- Meet all design requirements for SDC D according to the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*, except as modified below:
  - The maximum concrete strain in confined section of the columns ( $\epsilon_{cc}$ ) does not exceed 90% of the ultimate concrete strain ( $\epsilon_{cu}$ ), computed by Mander’s model.
  - The maximum strain of reinforcing steel does not exceed the  $\epsilon_{R_{su}}$  as defined on Table 8.4.2-1 of the AASHTO Guide Spec.
  - The maximum strain of prestressing steel does not exceed  $\epsilon_{R_{ps,u}} = 0.03$

The above guidelines are applicable even for the other Seismic Design Categories, if Pushover Analysis will be used instead of the implicit equation.

Replace *AASHTO Guide Spec Table 3.4.2.3-1* with two following tables:

Table 1.17.3-1A

Values of Site Factor,  $F_{pga}$ , at Zero-Period on Acceleration Spectrum

Site Class	Mapped Peak Ground Acceleration Coefficient (PGA) <sup>1</sup>					
	PGA ≤ 0.1	PGA = 0.2	PGA = 0.3	PGA = 0.4	PGA = 0.5	PGA ≥ 0.6
A	0.8	0.8	0.8	0.8	0.8	0.8
B	0.9	0.9	0.9	0.9	0.9	0.9
C	1.3	1.2	1.2	1.2	1.2	1.2
D	1.6	1.4	1.3	1.2	1.1	1.1
E	2.4	1.9	1.6	1.4	1.2	1.1
F2	*2	*2	*2	*2	*2	*2

Table 1.17.3-1B

Values of Site Factor,  $F_a$ , for Short-Period Range of Acceleration Spectrum

Site Class	Mapped Spectral Acceleration Coefficient at Period 0.2 sec ( $S_s$ ) <sup>1</sup>					
	$S_s \leq$	$S_s = 0.5$	$S_s = 0.75$	$S_s = 1.0$	$S_s = 1.25$	$S_s > 1.5$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	0.9	0.9	0.9	0.9	0.9	0.9
C	1.3	1.3	1.2	1.2	1.2	1.2
D	1.6	1.4	1.2	1.1	1.0	1.0
F3	2.4	1.7	1.3	*3	*3	*3
F2	*2	*2	*2	*2	*2	*2

Replace AASHTO Guide Spec Table 3.4.2.3-2 with following table:

**Table 1.17.3-1C**

**Values of Site Factor,  $F_v$ , for Long-Period Range of Acceleration Spectrum**

Site Class	Mapped Spectral Response Acceleration Coefficient at Period 1.0 sec ( $S_1$ ) <sup>1</sup>					
	$S_1 < 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 = 0.5$	$S_1 > 0.6$
A	0.8	0.8	0.8	0.8	0.8	0.8
B	0.8	0.8	0.8	0.8	0.8	0.8
C	1.5	1.5	1.5	1.5	1.5	1.4
D <sup>3</sup>	2.4	2.2 <sup>3</sup>	2.0 <sup>3</sup>	1.9 <sup>3</sup>	1.8 <sup>3</sup>	1.7 <sup>3</sup>
E <sup>3</sup>	4.2	3.3 <sup>3</sup>	2.8 <sup>3</sup>	2.4 <sup>3</sup>	2.2 <sup>3</sup>	2.0 <sup>3</sup>
F <sup>2</sup>	*2	*2	*2	*2	*2	*2

Notes:

<sup>1</sup> – Use straight-line interpolation for intermediate values of PGA,  $S_s$ , or  $S_1$ .

<sup>2</sup> – Perform a site-specific geotechnical investigation and dynamic site response analysis for all multi-span bridges in Site Class F.

<sup>3</sup> – Consider performing a ground motion hazard analysis and/or dynamic site response analysis for multi-span bridges.

**“Operational” Criteria:** Design all bridges on and West of US97 to remain “Operational” after a full rupture of Cascadia Subduction Zone Earthquake (CSZE). The full rupture CSZE hazard maps are available at the [ODOT Bridge Section website](https://www.oregon.gov/ODOT/Bridge/Pages/Seismic.aspx).

The CSZE is a deterministic event, and a deterministic Design Response Spectrum must be generated. To allow for consistency and efficiency in design for the CSZE, an application for generating the Design Response Spectra has been developed by Portland State University. Latitude, Longitude, and  $V_{s,30}$  are the needed input for running the application. This application can be accessed at the following link:

<https://www.oregon.gov/ODOT/Bridge/Pages/Seismic.aspx>

To satisfy the “Operational” criteria, comply with the following requirements and guidelines:

Seismic Design Categories (SDC) A, B, C and D

- Verify the “Operational” performance for Cascadia Subduction Zone Earthquake when potentially liquefiable soils are present on site.

Seismic Design Categories (SDC) A and B

- No structural analysis is required for “Operational” criteria.

Seismic Design Category (SDC) C



- Satisfy *equation 4.8-1* of the AASHTO Guide Spec ( $\Delta^L_D < \Delta^L_C$ ) for each bridge bent, where  $\Delta^L_C$  is determined from the *equation 4.8.1.1* of the AASHTO Guide Spec (displacement capacity for SDC B).

Seismic Design Category (SDC) D

- Meet all design requirements for SDC D according to the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*, except as modified below:
  - Ensure the maximum concrete strain in confined section of the columns does not exceed  $\epsilon_{cc} = 0.005$
  - Ensure the maximum strain of reinforcing steel does not exceed  $2^* \epsilon_{sh}$ , where  $\epsilon_{sh}$  is defined on *Table 8.4.2-1* of the AASHTO Guide Spec.
  - Ensure the maximum strain of prestressing steel (for 270 ksi strands) does not exceed  $\epsilon_{ps,EE} = 0.0086$

Non-conventional Bridges: *Guide Spec. 3.1* states that the seismic provisions of this Manual are applicable for conventional bridges. For seismic design of non-conventional bridges, consult with the Senior Seismic Standards Engineer to discuss whether special analysis and design procedures are warranted.

Pedestrian Bridges: Design new pedestrian bridges over roads carrying vehicular traffic per the requirements of this section. Pedestrian bridges that do not cross roads carrying vehicular traffic do not need be designed for the “Operational” Criteria.

Buried Structures: According to *Guide Spec. 3.1*, buried structures, generally, do not need be designed for seismic loads. However, for all buried structures supported on piling or drilled shafts type foundations, design the structure for seismic loading as required by this section.

### 1.17.3.2 Specification Interpretations and Modifications

The following items summarize ODOT’s additional requirements and deviations from *AASHTO Guide Specifications for LRFD Seismic Bridge Design*:

- Design all bridges to satisfy the Type-1 Global Seismic Design Strategy (ductile substructure with essentially elastic superstructure), *Guide Spec. 3.3*. However, in case of a steel substructure, design the bridge according to the latest edition of the *AASHTO LRFD Bridge Design Specifications*.
  - Type-2 Global Seismic Design Strategy (essentially elastic substructure with ductile superstructure) is not permitted by ODOT.
  - Type-3 Global Seismic Design Strategy (elastic superstructure and substructure with a fusing mechanism between the two) can be considered if approved by the State Bridge Engineer. Include a clear description of the selected Seismic Design Strategy in the calculation book for the structure.
- The following types of Earthquake Resisting Systems (ERS) or Earthquake Resisting Elements (ERE) provided in *Guide Spec. 3.3* are permissible ERS or ERE for ODOT bridges:
  - Type 1, 2, 3, 4 and 5 on *Figure 3.3-1a*

- Types 1, 2, 3, 7, 8, 9, 10, 11\*, 12 and 14 on *Figure 3.3-1b*
- \* To use this Earthquake Restraining Element the following must be applied:
  1. Liquefaction induced-lateral spread and slope instability are deemed unlikely to occur under the design earthquake.
  2. For the Life Safety criteria a maximum of 70% of the passive abutment resistance can be used in seismic analyses in accordance with AASHTO Guide Spec.
  3. For the Operational criteria a maximum of 30% of the passive abutment resistance can be used in seismic analyses.
- Obtain approval from the State Bridge Engineer before considering the application of the following types of Earthquake Resisting Systems (ERS) or Earthquake Resisting Elements (ERE) provided in *Guide Spec. 3.3*:
  - Type 6 on *Figure 3.3-1a*
  - Types 4, 5, and 6 on *Figure 3.3-1b*
  - Types 1 and 2 on *Figure 3.3-2*
- The following types of Earthquake Resisting Systems (ERS) or Earthquake Resisting Elements (ERE) provided in *Guide Spec. 3.3* are not permissible ERS or ERE for ODOT bridges:
  - Type 13 on *Figure 3.3-1b*
  - Types 3, 4, 5, 6, 7, 8 and 9 on *Figure 3.3-2*
  - Types 1, 2, 3 and 4 on *Figure 3.3-3*
- Identify the ERS for bridges in SDC B (*Guide Spec. 3.5*) when  $0.25 \leq S_{D1} < 0.30$ .
- Pushover analysis can be used instead of the implicit equations to determine the Displacement Capacity for SDC B and C as prescribed on *Guide Spec. 3.5*. When pushover analysis is performed, provide SDC D Level of Detailing regardless of the design SDC.
- Satisfy the balanced stiffness and balanced frame geometry requirements for all bridges in SDC C and D (*Guide Spec. 4.1.2* and *4.1.3*).
- Use Procedure Number 2 (Elastic Dynamic Analysis) to determine seismic designs for all bridges with two or more spans (*Guide Spec. 4.2*).
- Use Procedure 3, (Nonlinear Time History Analysis) if the Geotechnical Engineer is performing a site-specific hazard motion analysis and any of the following exists:
  - The maximum bridge span length is more than 300 feet or the total bridge length is more than 1,800 feet
  - Bridge geometry does not allow for the balanced stiffness or balanced frame geometry requirements be satisfied
  - Special bearing and damping devices (isolation bearing, shock transmission units, etc.) and non-conventional expansion joints are expected to be installed

Nonlinear Time History Analysis is the most expensive seismic analysis procedure; however, the extra design cost is often offset by construction cost savings and can be effectively used to manage risk.

Consult the project Geotechnical Engineer to determine if there are geotechnical factors that may lead to pursuing the development of ground response and non-linear time history analyses. Some of these could include:

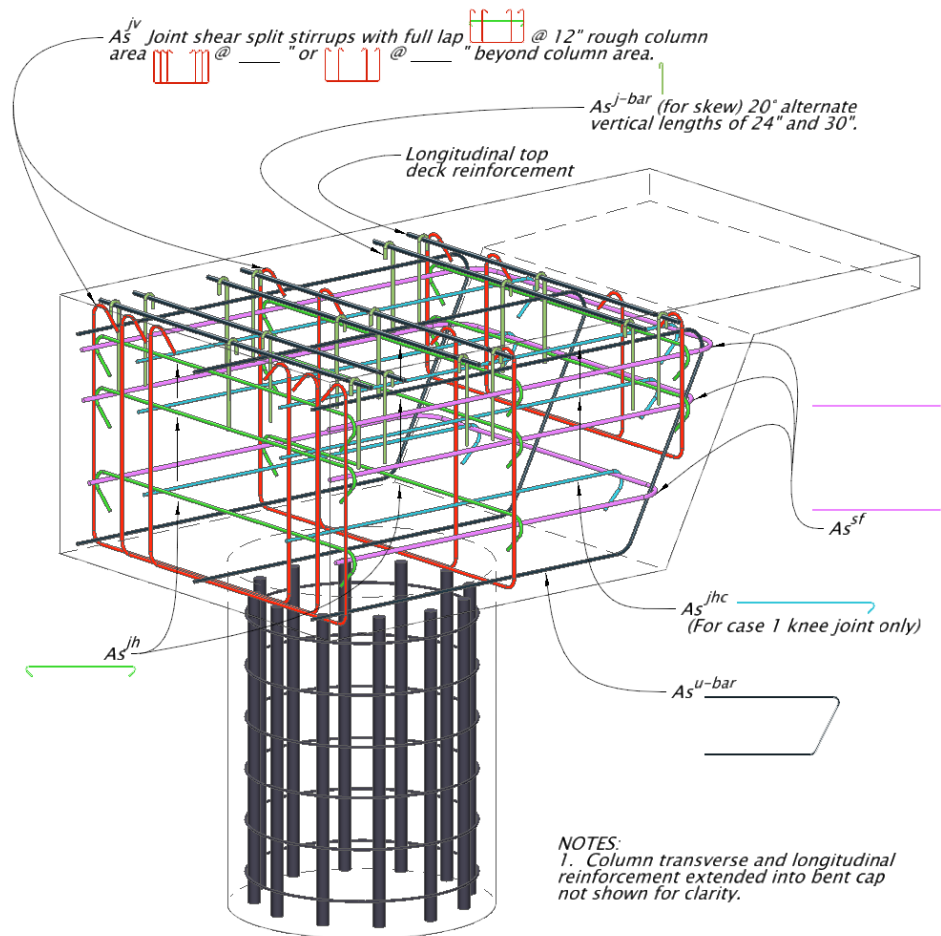
- Bridge is within 6 miles of an active fault
- Soils at bridge site are defined as Site Class "E" or "F" soils
- Soil profile supporting the bridge varies significantly among bridge bents
- Use a Damping Ratio of 5 percent (*Guide Spec. 4.3.2*) on all new bridges for seismic

loading. The application of the reduction factor,  $R_D$ , is not allowed without approval from the State Bridge Engineer.

- Use Design Method 3 (Limited-Ductility Response in Concert with Added Protective systems) for designing the lateral seismic displacement demand (*Guide Spec. 4.7.1*) only upon approval from the State Bridge Engineer.
- For SDC C or D, if columns or pier walls are considered an integral part of the energy-dissipating system but remain elastic at the demand displacement (*Guide Spec. 4.2*), design and detail the capacity protected members to resist the lesser of:
  - 2.0 times the elastic forces resulting from the demand displacement
  - Column/pier overstrength plastic moment and shear
- Design Longitudinal Restrainers (*Guide Spec. 4.13.1*) in accordance with *BDM 1.17.8*.
- Participation of the approach slab, wingwalls, and backwalls in the overall dynamic response of bridge systems may be considered in seismic design of bridges using *BDM 1.10.4.2*.
- Select the Foundation Modeling Method (FMM) (*Guide Spec. 5.3.1*) according to *BDM 1.10.4*.

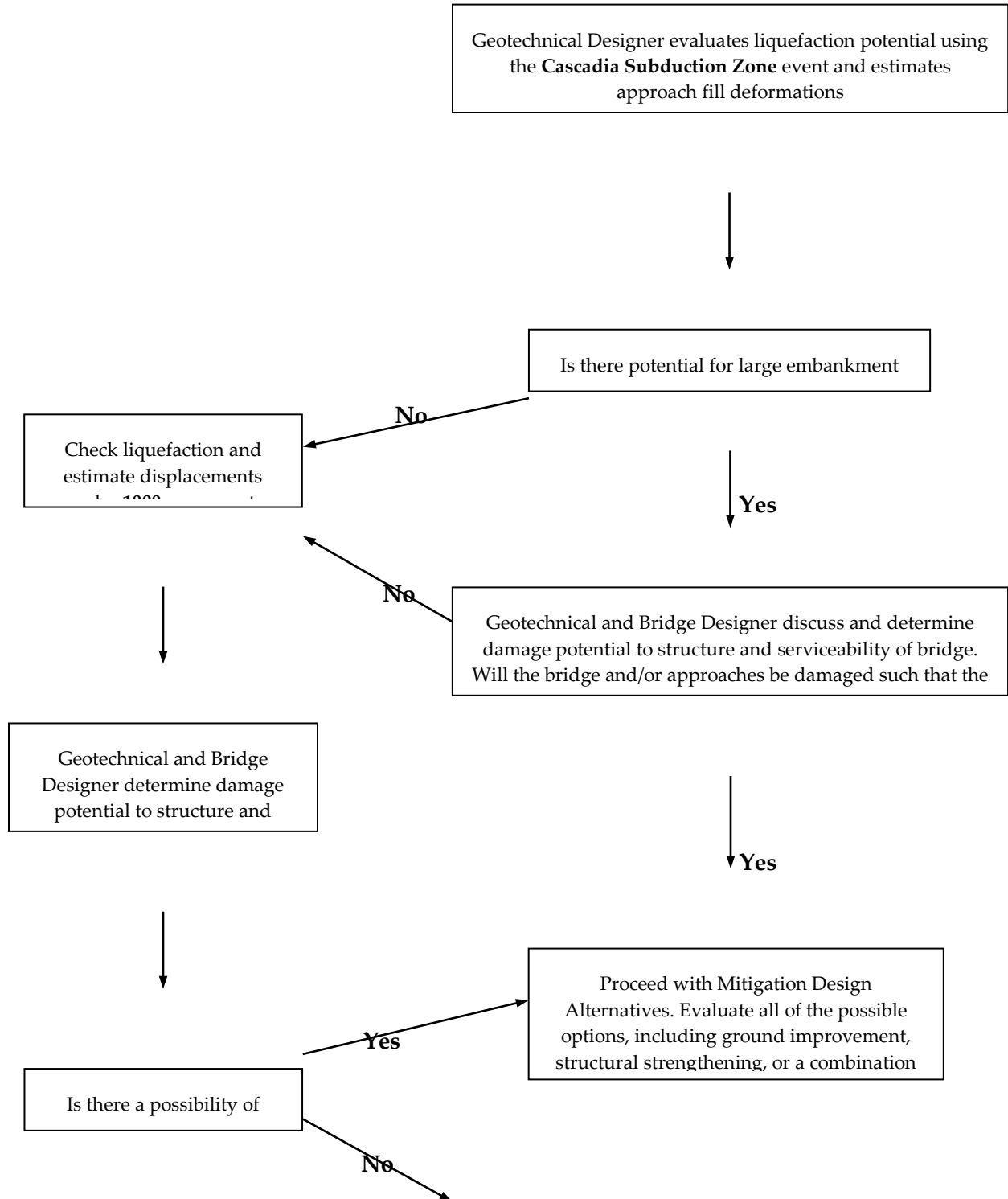
Do not allow uplift or rocking of spread footings in all SDCs.

- Perform Liquefaction Assessment for all bridge sites according to *Chapter 6* of the ODOT Geotechnical Design Manual.
- Use the provisions in *Guide Spec. 7.2* in conjunction with the forced-based seismic design procedure utilized in the *AASHTO LRFD Bridge Design Specification* and requirements of this section of the BDM.
- Provide minimum shear reinforcement for bridges in SDC A, when  $0.10 \leq SD1 \leq 0.15$ , according to the requirements of *Guide Spec. 8.6.5* for SDC B, in addition of satisfying the requirements of *Guide Spec. 8.2*.
- Do not use wire rope or strands for spirals, and high strength bars with yield strength exceeding 75 ksi. Deformed welded wire fabric (*Guide Spec. 8.4.1*) may be used with approval from the State Bridge Engineer.
- The same size vertical bars may be used inside and outside of interlocking spirals (*Guide Spec. 8.6.7*).
- Provide minimum longitudinal reinforcement (*Guide Spec. 8.8.2*) of 1 percent for columns in SDC B, C and D.
- Extend the vertical column bars into oversized drilled shaft according to *BDM 1.10.5.5*, in lieu of *Guide Spec. 8.8.10*.
- Revise the third bullet of *Guide Spec. 8.13.4.1.1* as follows:
  - Exterior column joints for box girder superstructures and other superstructure types if the cap beam extends beyond the joint far enough to develop the longitudinal cap reinforcement.



## 1.17.4 Liquefaction Evaluation and Mitigation Procedures

- The liquefaction potential of foundation soils will be determined by the Geotechnical designer. If foundation soils are predicted to liquefy, the effects of liquefaction on foundation design and performance will be provided as described in *BDM 1.10.5*. The need for liquefaction mitigation will be in accordance with the following ODOT Liquefaction Mitigation Policy.



Typical Design

**Note 1:** For meeting the performance requirements of the Cascadia Subduction Zone event (Operational), lateral deformation of approach fills of up to 12 inches are generally considered acceptable under most circumstances pending an evaluation of this amount of lateral deformation on abutment piling and abutment/cap. Larger structural lateral deformations and settlements may be acceptable under the 1000 year event as long as the “Life Safety” criteria are met.

**Note 2:** The bridge should be open to emergency vehicles after the Cascadia Subduction Zone event, following a thorough inspection. If the estimated embankment deformations (vertical or horizontal or both) are sufficient enough to cause concerns regarding the serviceability of the bridge, mitigation is recommended.

**Note 3:** Geotechnical and Bridge Designer to submit all liquefaction mitigation designs and cost estimates to Bridge Standards for review and approval.

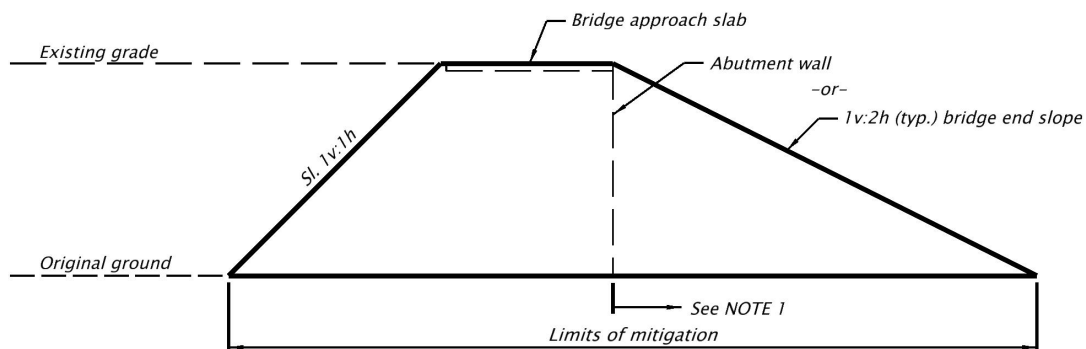
A continuous discussion between the Geotechnical and Bridge Designers is to be expected for determining the most cost-effective mitigation alternative. The iteration for both geotechnical and structural analyses start with the Geotechnical Designer providing the Bridge Designer the following information:

- lateral soil displacement,
- vertical soil displacements,
- vertical and horizontal loading on piling and/or end bent due to the soil displacement

Bridge Designer determines the lateral and vertical deformation demand and capacity of the bridge foundation and follows up with the Geotechnical Designer on the need for soil mitigation. Evaluation of the mitigation alternatives should consider both structural improvements and soil mitigation by maintaining a cost balance and equal risk between these two forms of mitigation. Final cost estimates should reflect this evaluation.

Refer to ODOT research report SPR Project 361: “Assessment and Mitigation of Liquefaction Hazards to Bridge Approach Embankments in Oregon”, Nov. 2002 and “Ground Modification Methods Reference Manual, [Volume I](#) & [Volume II](#)”, (Pub. No. FHWA-NHI-16-027 & NHI-16-028) for mitigation alternatives and design procedures.

As a general guideline, the foundation mitigation should extend from the toe of the bridge end slope (or face of abutment wall) to a point that is located at the base of a 1:1 slope which starts at the end of the bridge approach slab:



**NOTE 1:** Extend ground improvement beyond the abutment face as needed for design.

## 1.17.5 Costs

(1) Construction costs:- Apply the following factors to TS&L (preliminary) structure cost estimates to approximate the additional cost of seismic criteria (excluding liquefaction):

- Single Spans: 1.00
- Multiple Spans: 1.30 Irregular (widely varying columns lengths or support materials; unusual geometry or curvature)

- 1.10 Other

(2) Design costs:- Apply the following factors to TS&L (preliminary) design cost estimates to approximate the additional cost of seismic design criteria (excluding liquefaction):

- Single Spans: 1.00
- Multiple Spans: 1.20 Trestles  
1.50 Irregular (widely varying columns lengths or support materials; unusual geometry or curvature)  
1.35 Other

## 1.17.6 Instrumentation

Consider placement of accelerometers on the ground and on structure portions for large or unusual structures. Consult with the State Bridge Engineer to determine if this is appropriate and fits with the ODOT Strong Motion Program.

### 1.17.6.1 Dynamic Isolators

Isolators may be useful for either new construction or retrofit work. Isolators change structure response by lengthening the periods of primary vibration. This tunes the structure response away from the typical earthquake's maximum response frequencies. This effect, along with added damping, works to reduce the system response. The result is reduced substructure forces.

Typical steps to model an isolated structure include:

1. Compute service loads (D, L, LF, CF, W, WL, R, S and T) for the worst single girder.
2. Use these loads, and the applicable seismic loading, in the Dynamic Isolation System, Inc. (DIS) program PC-LEADER to get a preliminary isolator size and its properties. DIS has given us permission to use the program even though we will not specify only their bearing.
3. Develop a full structural model (superstructure, substructure, and bearings/isolators). Normally this will be done on a per girder basis so the substructure should be proportioned to fit this basis. The model can often be a two dimensional model.
4. In the structural model use the equivalent isolator stiffness (K<sub>eff</sub>). This stiffness should be further modified to fit modeling assumptions of a bearing cantilevered from the substructure at interior supports.

5. Load the structural model with dynamic loading through a modified response spectrum. The response spectrum can be taken from the PC-LEADER output or developed from the Guide Specification for Seismic Isolation Design.
6. Develop another full structural model to represent the "as-is" structure. Dynamically load this model with a normal response spectrum. This gives a basis to evaluate the isolation effectiveness.
7. It may be necessary or desirable to adjust the relative isolator stiffness to better distribute the dynamic forces. It is important the final isolator properties function adequately for service loads. The isolator characteristics must also be realistic and achievable.

An example isolator modeling is given in the Bridge Example Design notebook.

Other computer programs are acceptable, provided the programs satisfy the analysis requirements and have been previously verified.

## 1.17.8 Seismic Restrainer Design (New Designs and Retrofits)

### 1.17.8.1 Seismic Restrainer Design, General

The intent is to prevent superstructure pull-off and bearing failure. Work restrainers only in the elastic range. Design the restrainer connection for 125 percent of the restrainer design force.

Note that *LRFD 3.10.9.5* requires "sufficient slack" so that the restrainer does not start to act until the design displacement is exceeded.

Restrainers may be omitted where the available seat width meets or exceeds "N" of the Design Specifications and 4 times the calculated design earthquake elastic deflection. Seat widths meeting these criteria are presumed to accommodate the large elasto-plastic movements of a real structure under seismic loading.

Design restrainers for a minimum force equal to the peak site bedrock acceleration coefficient "A" times the weight of the lighter portion being connected.

In all instances it is necessary to design or check the transfer mechanism for force transfer from superstructure to substructure (bearings, diaphragms).

### 1.17.8.2 Information for Restrainer Design

#### (1) Concrete:

Concrete bearing strength based on  $0.85f'_c$  ( $\Phi = 1.0$ ).

Maximum increase for supporting surface wider than loaded area = 2.0.

Multiply by 0.75 when loaded area is subject to high edge stresses.

For concrete shear lugs, use *LRFD equation 5.8.4.1-1* for shear friction as outlined in *LRFD 5.8.4*.



**(2) Structural Steel:**

Design structural steel members using the *AASHTO LRFD Bridge Design Specifications*.

**(3) Fasteners:**

(Steel to Steel)

		A 307		A 325	
Diameter	Nominal Area (in <sup>2</sup> )	Tension (0.76 x 60 ksi)	Shear (0.38 x 60 ksi)	Tension (0.76 x 120 ksi)	Shear (0.38 x 120 ksi)
0.75"	0.4418	20.1 k	10.1 k	40.3 k	20.1 k
0.875"	0.6013	27.4 k	13.7 k	54.8 k	27.4 k
1.0"	0.7854	35.8 k	17.9 k	71.6 k	35.8 k

Note: Tension loads are based on *LRFD equation 6.13.2.10.2-1*.

Shear loads are based on *LRFD equation 6.13.2.7-2* assuming one shear plane per bolt and with threads included in the shear plane.

Shear loads may be increased 25% if the threads are excluded from the shear plane.

**(4) Steel Rods:**

		A307 Fu = 58 ksi	A449 Fu varies	
Diameter	Stress Area (in <sup>2</sup> )	Tension (kips) Ft=Fy=36 ksi	Tension (kips) Ft = Fy	Fy (ksi)
0.750	0.334	12.0	30.7	92
0.875	0.462	16.6	42.5	
1.00	0.606	21.8	55.8	
1.125	0.763	27.5	61.8	81
1.250	0.969	34.9	78.5	
1.375	1.155	41.6	93.9	
1.500	1.405	50.6	114.0	
1.750	1.900	68.4	110.0	58

2.250	2.500	90.0	145.0	
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Tensioning of A 449 steel rods must be specified, if required by the design.

Tensioning requirements are not part of the specification as they are with A 325.

Use nominal area for elongation calculations.

**(5) Wire Rope:**

See *BDM 1.17.8.6* for a complete discussion of Structural Wire Rope, Wire Rope Connections & Turnbuckles.

$$F_t = (0.95)(176.1 \text{ ksi})(\text{area}) = 0.95(\text{minimum breaking strength}).$$

Note: Yield strength is approximately equal to minimum breaking strength.

<u>Diameter (in)</u>	<u>Area (in<sup>2</sup>)</u>	<u>Minimum Breaking Strength (kips)</u>	<u>Design Load (kips)</u>
1/2	0.119	23.9	22.7
3/4	0.268	52.9	50.2
7/8	0.361	71.6	68.0
1	0.471	93.0	88.3
1 3/8	0.906	173.0	164.0

The area values above are based on ASTM A603. The minimum breaking strength above is based on ASTM A1023. The design load above is based on 0.95 x the minimum breaking strength. For sizes other than 7/8 inch diameter, ASTM A1023 is likely to be used.

E for wire rope = 10,000 ksi

f<sub>y</sub> for wire rope = 176.1 ksi

ASTM A603 lists the E for structural wire rope as 20,000 ksi for "prestretched" wire rope. Wire rope used for seismic applications will not be prestretched, however, so an E of 10,000 ksi should be used.

**(6) Resin Bonded Anchors:**

See *BDM 1.5.11.2*, "Post-Installed Anchors"

**(7) Concrete Inserts:**

Use hot-dip galvanized expanded coil concrete inserts with closed-back ferrule threaded to receive UNC threaded bolts.

Inserts are readily available in 1/4 inch sizes. Other sizes are only available in very large quantities. Therefore, only the standard sizes listed below are recommended.

Diameter ( in )	Tension ( kips ) A307 or A325	Shear ( kips )	
		A307	A325
3/4	12.6	7.4	12.6
1	19.3	13.4	19.3
1-1/4	34.4	21.4	34.4
1-1/2	54.3	31.0	54.3

Tension and shear capacity for concrete failure is based on equation 6.5.2 from the *PCI Design Handbook* (3<sup>rd</sup> Edition) with  $\Phi = 1.0$  and with a factor of safety of 1.5. Equation 6.5.2 controls both shear and tension for shallow embedment depths. See the *PCI Design Handbook* for group effects, edge distance effects and combined tension and shear.

Tension capacity of the insert cannot exceed the tension capacity of the bolt. Shear capacity of the insert cannot exceed the shear capacity of the bolt or the insert tension capacity.

Tension capacity of the bolt =  $0.76A_b f_{ub}$ , where  $A_b$  = bolt stress area (*LRFD equation 6.13.2.10.2-1*).

Shear capacity of the bolt =  $0.38A_b f_{ub}$  (*LRFD equation 6.13.2.7-2*).

### 1.17.8.3 Longitudinal Restrainer Design

(1) In-span hinges: Use the following general procedure (a modified CALTRANS method):

- Estimate restrainers to use (with elongation) and gapping desired/allowed.
- Determine joint openings (including approximate temperature movement (fall) and creep and shrinkage if appropriate).
- Determine frame stiffness and capacity.
- Determine adjacent frame stiffness and capacity.
- Plot force/deflection relationship considering component stiffnesses, joint openings (including temperature, creep, and shrinkage openings), and restrainer gapping.
- Assume a final force and deflection under single-mode response to get equivalent stiffness.
- Calculate period and resulting response coefficient.
- Calculate dynamic force and locate on the force/deflection curve.
- Review that the force capacity of the system is not exceeded, the assumed/acceptable deflection is not exceeded, and the equivalent stiffness and period are approximately as before.
- If checks are not okay modify system and recycle through as needed.

(2) Bents with superstructure continuous over the bent:

- Connect superstructure to substructure with capacity to form plastic hinging in the column(s).

(3) Bents with only the deck continuous over the bent:

- Connect each span to substructure to form plastic hinging in the column(s).

(4) Bents with no superstructure continuity over the bent:

- With frames each side of bent:

Connect each span to substructure to form plastic hinging in the column(s). Also connect adjacent superstructure portions by the same techniques as “in-span hinges.” The adjacent super-structure portions may be connected by span to substructure connections of adequate capacity to function for both portions.

- With simple spans each side of bent:

Connect each span to the substructure to form plastic hinging in the column(s).

**NOTE:** The plastic hinging capacity should be determined from column interaction curves with axial and moment  $\Phi$  values of 1.0. Enter the curve with the unfactored dead load axial force (plus any redundancy induced axial force due to lateral seismic loading), determine the accompanying moment capacity and multiply this value by 1.3. This is the plastic moment capacity.

### **1.17.8.4 Transverse Restrainer Design**

(1) In-span hinges:

- Design for force transfer of 2.5(A)(supported dead load).

(2) Bents with superstructure continuous over the bent:

- Connect supported spans with force to form a failure mechanism (plastic hinging at the top of frame (column or crossbeam) and plastic hinging at bottom of column).

(3) Bents with only the deck continuous over the bent:

- Connect supported spans with force to form a failure mechanism (plastic hinging at the top of frame (column or crossbeam) and plastic hinging at bottom of column).
- Prorate design force to ahead and back side of bent by dead load ratio.

(4) Bents with no superstructure continuity over the bent:

- Connect supported spans with a force equal to 2.5(A)(supported dead load).

**NOTE:** The plastic hinging capacity should be determined from column interaction curves with axial and moment  $\Phi$  values of 1.0. Enter the curve with the unfactored dead load axial force (plus any redundancy induced axial force due to lateral seismic loading), determine the accompanying moment capacity and multiply this value by 1.3. This is the plastic moment capacity.

### 1.17.8.5 Hold-downs

Hold-downs or bearing replacement may be needed at vulnerable bearings such as fixed or rocker type steel bearings.

### 1.17.8.6 Structural Wire Rope (Cables) and Turnbuckles

Structural wire rope (cable) may be used in seismic retrofit and safety cable applications. For these applications, structural wire rope must have zinc coating for corrosion protection. *ASTM A603* structural wire rope with a Class C coating is the preferred wire rope specification. This wire rope has large wires and significant zinc coating. However, *A603* wire rope is only available by special order at a minimum of 10,000 feet.

ODOT has a stockpile of 7/8 inch diameter *A603* wire rope that is available for use on seismic retrofit applications. The stockpile material was purchased as part of the Willamette River (Abernethy) Br. (Seismic Retrofit) Section (Contract No. 12349). The wire rope was received at the District 2B Lawnfield facility in Clackamas on September 19, 2000. As of October 2009, 2500 feet of the stockpile wire rope was still available. The Agency is no longer stockpiling wire rope.

Use *A603* wire rope for all coastal seismic retrofit applications. When there is not sufficient quantity of wire rope available in the stockpile, a new order of 10,000 feet should be purchased using project funds. Such a purchase will require preapproval from FHWA since the excess wire rope will be stockpiled for use on future projects.

For non-coastal applications, *A603* wire rope is still preferred. However, *ASTM A1023* wire rope can be used where less corrosion protection is considered acceptable. *A1023* wire rope uses smaller wires and has approximately one-third the zinc coating compared to *A603*. However, *A1023* wire rope is readily available on the market and so does not need to be stockpiled. Optional sizes of *A1023* wire rope are also readily available. Those sizes are listed in *BDM 1.17.8.6.4*.

*A603* and *A1023* are the only wire rope specifications recommended for seismic retrofit applications. Other types of wire rope investigated are *ASTM A586* and *ASTM A741*. *A586* wire rope is used for high-strength structural tension members, but is not readily available on the market. *A741* wire rope is used for safety barrier applications (such as I-5 median between Portland and Salem). *A741* has less strength compared to *A603* and *A1023*, is difficult to make swaged connections, and is also not readily available.

7/8 inch diameter wire rope is recommended for most seismic retrofit applications. 1/2 inch diameter wire rope is recommended for safety cable applications and seismic retrofit applications where the wire rope must be wrapped around tight corners. Bending radius for A603 and A1023 wire rope are shown in *Table 1.17.8.6-1 and Table 1.17.8.6-2*.

Table 1.17.8.6-1 A603 Wire Rope Bending Radius

Wire Rope Diameter (inch)	Suggested (inch)	Minimum (inch)
1/2	18	11
7/8	32	18

Table 1.17.8.6-2 ASTM A1023 Wire Rope Bending Radius

Wire Rope Diameter (inch)	Suggested (inch)	Minimum (inch)
1/2	13	9
3/4	19	13
7/8	23	15
1	26	17
1-3/8	35	24

The bending radius values above are based on a *1997 Bethlehem Wire Rope product catalog* from Williamsport Wire Rope Works, Inc.

### 1.17.8.6.1 General Notes for Structural Wire Rope, Turnbuckles and Connections

Use the following general notes on the plans for structural wire rope in seismic retrofit applications using the 7/8 inch diameter wire rope from the ODOT stockpile:

Zinc-coated 7/8 inch diameter structural wire rope for seismic restraint devices will be provided by the Agency.

Use the following general notes on the plans for structural wire rope in seismic retrofit and/or safety cable applications using ASTM A1023 wire rope:

Provide zinc-coated X" (1/2", 3/4", 7/8", 1" or 1 3/8") structural wire rope for seismic restraint devices (and/or safety cables) according to ASTM A1023.

Use the following general notes on the plans for turnbuckles and wire rope connections in seismic retrofit and/or safety cable applications:

Provide hot-dip galvanized turnbuckles according to ASTM F1145.

Provide hot-dip galvanized socket connections. Ensure socket connections can develop the minimum breaking strength of the connecting wire rope.

**1.17.8.6.2 Special Provisions for Wire Rope**

Under the heading **Structural Wire Rope for Seismic Restraints & Safety Cables** use the following:

[When using 7/8 inch wire rope from the ODOT stockpile for seismic retrofit:]

Zinc-coated 7/8" diameter structural wire rope for seismic restraint devices will be provided by the Agency. Agency provided wire rope was manufactured according to ASTM A603 with Class C coating. Wire rope construction is 6 x 7 with a Wire Strand Core (WSC). Agency provided wire rope has been previously certified to meet a minimum breaking strength of 71,600 pounds. Wire rope is stored on spools with up to 2500 feet on each spool.

Agency provided wire rope is stored at the following location:

c/o District 2B Manager  
Oregon Department of Transportation  
9200 SE Lawnfield Rd  
Clackamas, OR 97015  
Phone: 971-673-6200

Notify Bridge Engineering Headquarters of the quantity of wire rope removed within 24 hours. Follow up this notification with a written memo documenting the time of removal, quantity removed (to the nearest foot), and the project for which it will be used. Send the memo to:

**State Bridge Operations Engineer**  
Bridge Engineering Headquarters  
4040 Fairview Industrial Drive SE, MS #4  
Salem, OR 97302-1142  
Phone: 503-986-3323  
FAX: 503-986-3407

The quantity of wire rope included for use in this project, including both testing and installation, is (\_\_\_\_) linear feet. This quantity of wire rope will be provided at no cost to the Contractor. Additional wire rope required by the Contractor due to fabrication errors and/or waste must be purchased from the Department at the Department's cost as established by the Engineer.

[When using ASTM A1023 wire rope for seismic retrofit:]

Provide zinc-coated X" (1/2", 3/4", 7/8", 1" or 1 3/8") diameter wire rope for seismic restraint devices according to ASTM A1023. Provide 6 x 19 wire rope construction with a steel core. Manufacture wire rope from extra improved plow steel. Ensure a minimum breaking strength of XX,XXX pounds (insert appropriate strength from design properties in *BDM 1.17.8.6.4*).

[When using 1/2 inch wire rope for safety cable:]

Provide zinc-coated 1/2" diameter structural wire rope for safety cable according to ASTM A1023. Provide 6 x 19 wire rope construction with a steel core. Manufacture wire rope from extra improved plow steel. Ensure a minimum breaking strength of 23,900 pounds.

### **1.17.8.6.3 Special Provisions for Turnbuckles and Socket Connections**

Use the following special provisions for turnbuckles and/or socket connections in seismic retrofit and/or safety cable applications:

Provide Type 1 hot-dip galvanized turnbuckles according to *ASTM F1145*.

- Ensure turnbuckles develop the minimum breaking strength of the connecting wire rope.
- Provide turnbuckles with a 24 inch take-up unless shown otherwise.
- Test turnbuckles according to the requirements outlined in *ASTM A1023*.
- For seismic restraint devices, provide either a jam nut or lock wire at each end of each turnbuckle. For safety cables, provide lock wire at each end of each turnbuckle. Provide 14 gage or heavier lock wire that is either hot-dip galvanized or plastic coated.

Testing for Socket Connections – Select an independent laboratory to test three sets of wire rope assemblies. Provide approximately 3 foot segments of wire rope with galvanized stud attachments at each end. Provide stud attachments of similar size and material as to be used on the project. Test each wire rope assembly to failure in tension. Ensure the tested wire rope assembly develops the minimum breaking strength of the wire rope and ensure that failure does not occur in the connecting parts. Ensure all three wire rope segments meet the minimum breaking strength requirement. However, when the wire rope breaks at a load less than the minimum breaking strength of the wire rope **and** at a location at least 6 inches from a connection, that test will be disregarded. When any wire rope assembly fails to meet these requirements, except as noted above, revise the connection details and prepare and test three new wire rope assemblies.



**1.17.8.6.4 Design Properties**

Modulus of elasticity for wire rope (non-prestretched) = 10,000 ksi.

Table 1.17.8.6.4-1 Approximate gross metallic area & minimum breaking strength for wire rope

Wire Rope Diameter (inch)	Area (in <sup>2</sup> )	Strength (lb)	Weight (lb/ft)
1/2	0.119	23,900	0.46
3/4	0.268	52,900	1.04
7/8	0.361	71,600	1.41
1	0.471	93,000	1.85
1-3/8	0.906	173,000	3.49

Area values above are approximate and are based on *ASTM A603*. Minimum breaking strength and weight values above are based on *ASTM A1023*. Note that A1023 does not provide area values. Weight values for A603 are slightly smaller.

The sizes of *ASTM A1023* zinc-coated wire rope shown above are readily available from northwest suppliers.

## 1.18 FRP Composites

### [1.18.1 FRP Composites](#)

#### **1.18.1 [FRP Composites](#)**

(Reserved for future use)

## 1.19 (Reserved)

## 1.20 (Reserved)

## 1.21 (Reserved)

## **1.22 (Reserved)**

## 1.23 Bridge Approach Slabs and Slope Paving

### 1.23.1 Bridge Approach Slabs and Supports

Provide reinforced concrete bridge approach slabs for bridges.

Show the general outline of approach slabs on the bridge plans with reference to the slab details shown on Bridge Standard Drawings or detail plans.

Detail ledges or other methods of approach slab support on all bridges (even when approach slabs are not called for when the bridge is built).

For integral and semi-integral end bents, design and provide additional confinement and dowel reinforcement at bearing seat connection where the approach slab movement is used to accommodate thermal expansion.

### C1.23.1

Approach slabs were formerly known as bridge end panels in Oregon.

Refer to *BDM 1.26.3* for approach slabs corrosion protective practices, such as reinforcement type and cover.

For bridges with sidewalks and no approach slabs, provide a method of supporting approaching sidewalks at the bridge ends (present or future).

For integral and semi-integral end bents where the approach slab movement is used to accommodate thermal expansion, consider providing a sleeper slab and joint at the roadway end of the approach slab to accommodate movement. Consider replacing the 180-degree hook bars with a horizontal connection bar for approach panels being dragged for thermal movements.

The required width of the approach slab depends on the approach rail type.

- When the approach rail is a flex-beam rail, provide an approach slab width of inside face to inside face of the flex-beam rails at the end of the bridge.
- Where the approach rail is concrete barrier, support the barrier on the approach slab and provide a slab width equal to the out-to-out dimension of the barriers at the end of the bridge. Add one foot to each side to the approach slab width where the barriers are precast.

Use a nominal approach slab length of 20 feet, unless otherwise required due to site-specific settlement concerns.

Use asphalt concrete pavement (ACP) on the approach slab, when the approach is flexible pavement. Where the approach roadway is rigid pavement, provide a sleeper slab at the roadway end of the approach slab. Work with the pavement designer to modify *DET1604* to the site.

When widening a bridge with existing approach slabs, use the same approach slab length for the new portion as the existing. Connect the new approach slab segment to the existing with dowels.

Avoid supporting barriers on wingwalls (rail cast with wingwall) because water leaks into the subgrade along the wall. Rather, place barriers on approach slabs.

The measured length of approach slabs is 20 feet 4 inches to simplify rebar fabrication while accommodating two inch cover.

Following the introduction of *DET3160* and the use of granular structural backfill behind the abutment, it is no longer required to use 30 foot long approach slabs for typical bridges.

With flexible pavement, if the approach slab settles, compensating overlays can be easily feathered onto the existing ACP.

The intent of adding a sleeper slab and joint for rigid pavement is to reduce roadway impact on the bridge.

Evaluate the roadway end of the approach slab for movement. Consider if a larger bridge joint is appropriate to address any anticipated large movement.

It is not necessary to add approach slabs to an existing bridge where ongoing settlement is not an issue and no impacts to the abutments, grade or backfill are included in the project.

Approach slabs on new bridges may be excluded under certain unique conditions, which must be documented in a design deviation. Include a geotechnical and structural evaluation as supporting documents to the design deviation.

## 1.23.2 Skewed Bridge Approach Slabs

See *BDM 1.9.1* for reinforcing details in acute corners of approach slabs.

### FLEXIBLE APPROACH PAVEMENT

For bridges with paved approach slabs, detail the roadway end of the bridge approach slab to parallel the bridge end.

### RIGID APPROACH PAVEMENT

For bridges with unpaved approach slabs, detail the roadway end of the bridge approach slab normal to the roadway centerline.

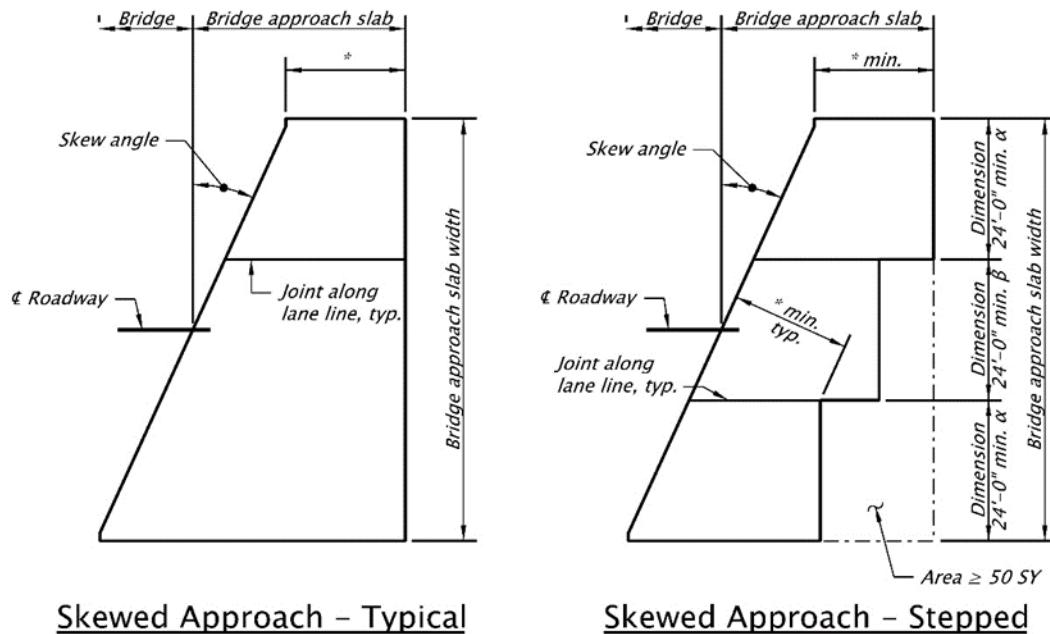
On-going settlement is noted in maintenance records or when inspection element 999 (roadway impact) is in condition state three or higher.

## C1.23.2

Skews greater than 25 degrees may require modification of the expansion joint. Skews greater than 45 degrees require a unique design for the approach slab reinforcement.

The roadway end of bridge approach slabs may be stepped to reduce size. A general rule of thumb is that when approach slab area can be reduced by 50 SY or more, consider methods for reducing approach slab area. Provide a minimum 20-foot approach slab length at any point. When stepped, provide the absolute minimum number of steps and locate the longitudinal construction joint(s) on lane lines. See *Figure 1.23.2.1-1* for clarification.

Figure 1.23.2.1-1 Stepped Approach Slab



- $\alpha$  - Dimension may be one lane width plus the shoulder width if the shoulder  $\geq 8'-0"$
- $\beta$  - Dimension may be two lane widths
- \* - Minimum Approach Slab Length per 1.23.1

### 1.23.3 Slope Paving and Railroad Slope Protection

Where required, provide slope paving on the bridge end fill according to Bridge Standard Drawing [BR115](#).

For a highway bridge crossing over a railroad, consult with the railroad to determine required slope protection.

### C1.23.3

Slope paving is generally required where a roadway passes under a bridge. Also consider slope paving where a bridge crosses over a sidewalk or park.

Rock slope protection may be required on the end fill slope of railroad undercrossings.

## 1.24 Bridge Drainage

Some form of drainage system is normally needed on or adjacent to bridges that have curbs or concrete parapet rails. The Roadway Plans drainage details should be carefully reviewed. When drains are required, the Hydraulics Unit will do the design and determine the size and spacing. The hydraulics designer will need the bridge length, deck grades, cross-slope, typical section, and deck surface to determine the deck drain layout.

Normally, drainage retrofitting needs to be addressed only when the project involves a major rehabilitation of the bridge. Generally, retrofitting existing bridges from a **direct discharge** to a piped system is not necessary. Bridge widening normally can use the same type of drainage system as the existing bridge.

### 1.24.1 Design Considerations

The primary objective of the bridge deck drainage system is to remove runoff from the bridge deck before it collects in the gutter, shoulder or lane thus exceeding the allowable design spread of water. A properly designed bridge deck drainage system should incorporate features to facilitate and minimize maintenance activities. The benefits of a properly designed and maintained deck drainage system include the following:

- Efficient removal of water from the bridge deck which decreases the risk of hydroplaning and enhances public safety.
- Long-term maintenance and service life of the bridge is improved.
- Preservation of the structural integrity of the bridge.
- Enhanced aesthetics by elimination of superstructure and substructure staining.
- Minimized or eliminated erosion on bridge end slopes.

Special environmental considerations may be required on some projects (see Environmental *BDM 3.14.8*). Hydraulic requirements take precedence over water quality requirements (see Storm Water *BDM 3.14.9*).

Capture drainage upslope of the bridge in inlets before coming onto the bridge. When grades allow, carry drainage off the bridge to inlets. Drainage not carried to inlets at the ends of the bridge is removed from the bridge deck using drains.

Drains are not allowed to discharge directly into:

- designated water quality limited streams.
- streams with severe non-point source pollution problems or
- streams with populations of listed, proposed or candidate threatened and endangered species of fish or other aquatic life.

In these cases provide a piping system that carries the drainage to a storm water collection swale or other dispersal system. However, only roadway surface runoff needs to be actively contained and treated because it is a pollutant source. Sidewalks are not seen as a pollutant source, and



thus sidewalk runoff does not need to be transported off the structure but can sheet flow off. Include sidewalk runoff in drainage calculations. When new sidewalks are added to an existing bridge where storm water previously sheet flowed off the side, the runoff from the roadway surface will need to be contained and treated for the new condition.

When the above conditions are not present, direct discharge to the ground below may be allowed. Drainage directly discharged to the ground below is not to cause erosion or be a hazard to the public. To prevent exposure of the superstructure to the drainage, carry it by drain pipes to 3 inches below the bottom of the superstructure.

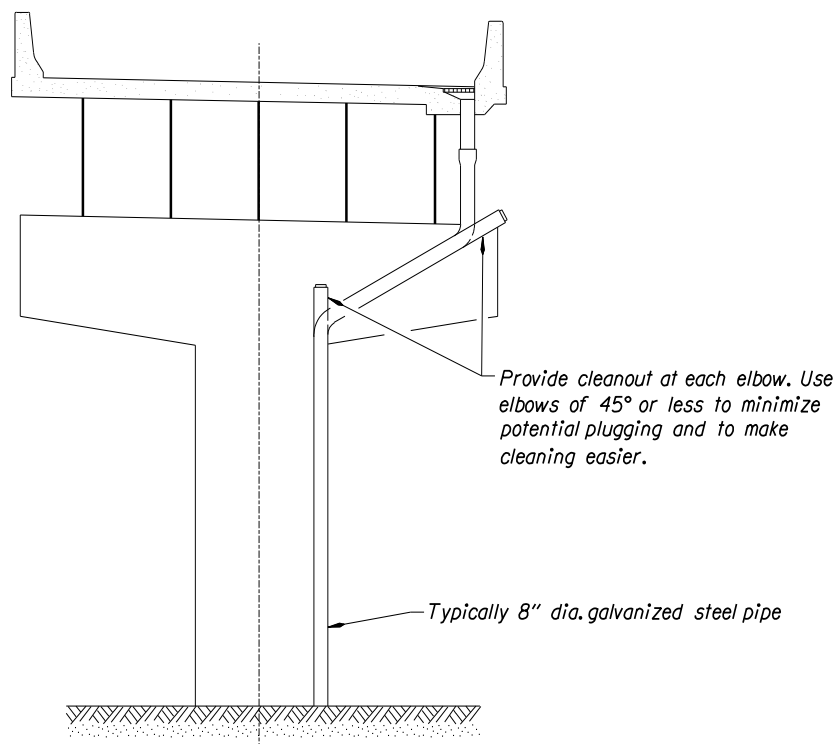
In all cases, the bridge designer is to coordinate with the Project Team members representing Environmental and Storm Water to determine the appropriate bridge drainage system.

## 1.24.2 Detailing

Indicate drain locations on the General Plan and Girder Layout sheets, and appropriate Detail sheets (see *DET 3120* for general details) that are inserted in plans. Show drain pipes and details on abutment, interior bent, deck and girder detail sheets. On viaducts or structures with extensive piping, provide a separate sheet showing entire drainage layout. The following figures are examples of different applications.

Provide minimum 8 inch diameter galvanized steel drain pipe.

Figure 1.24.1-1 Drain Pipe Detail



Present seismic design requirements for concrete containment within columns precludes placement of drain pipes within columns.

Deck drains and drain pipes become easily clogged and are a continual maintenance problem. High pressure hoses used for cleaning cannot make 90 degree turns. For 90 degree pipe connections, use 2-45 degree connections or a 4 foot minimum radius sweeping 90 degree connection. Add clean-out ports or junction boxes at every 90 degree connection. Clean-outs should be at a 45 degree angle to the main line.

The bridge designer must verify that the gutter profiles do not result in **birdbaths** or unsightly dips in the rail. When there is a question, plot the gutter grade.

Place drains upslope from expansion joints to capture drainage before it reaches the joints.

When long pipe runs are utilized for longer crossings (greater than 100 feet) and bridges with multiple spans, match pipe grade with roadway grade and see the following references for additional guidance:

- *Bridge Crossing with Ductile Iron Pipe, DIPRA.*
- *Guidelines for Bridge Water Pipe Installations, Raj B, Mark P and Web C.*

Provide sufficiently sturdy and properly located pipeline support to accommodate the weight of the pipe, its contents and other applicable loadings such as joint movement, seismic activity, traffic vibrations, insulation, etc.

Include expansion/contraction couplings on plans when required (longer than 100 feet lengths). The number and location of expansion/contraction couplings, if required, are determined by the length and design of the bridge in consideration of the maximum anticipated temperature differential. Locate expansion/contraction couplings in the pipeline adjacent to bridge expansion joints.

Figure 1.24.6-2 Bridge Drainage Plan and Elevation

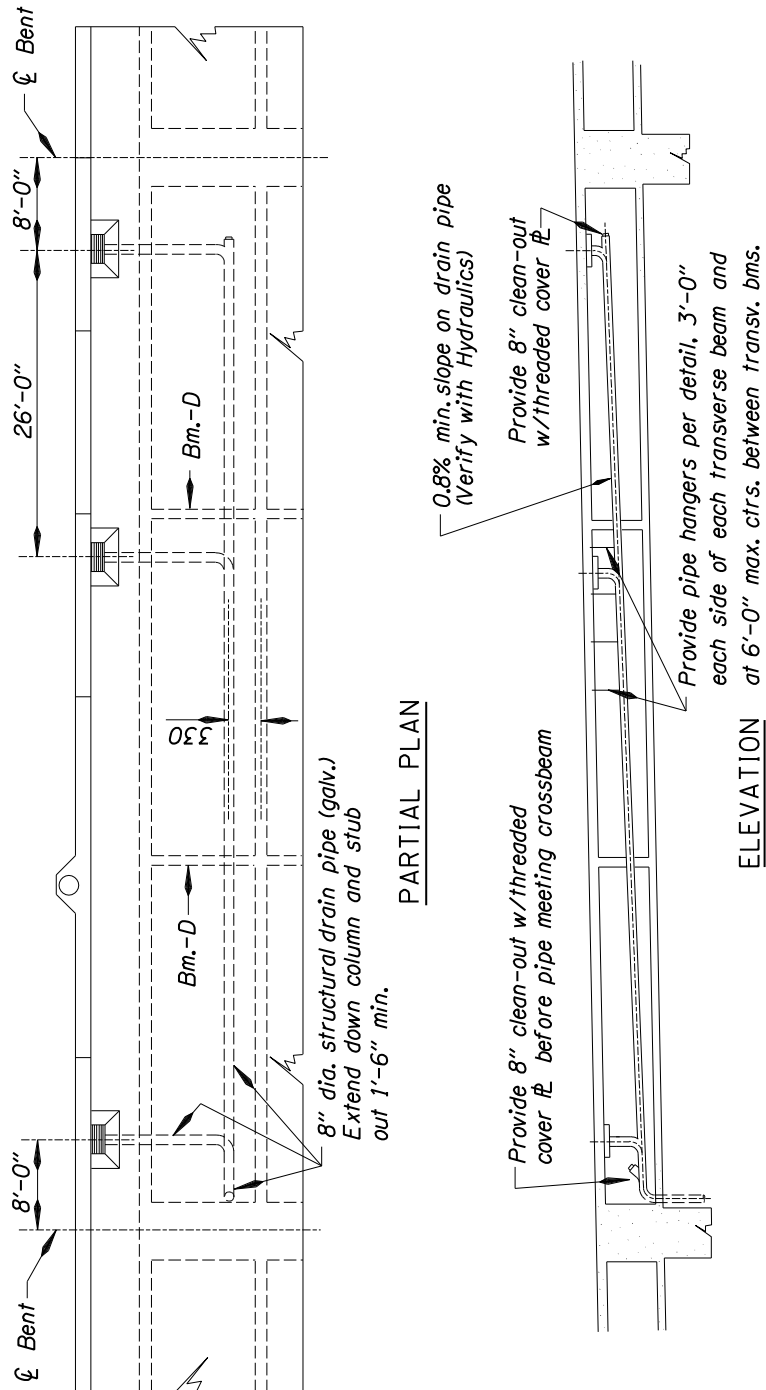
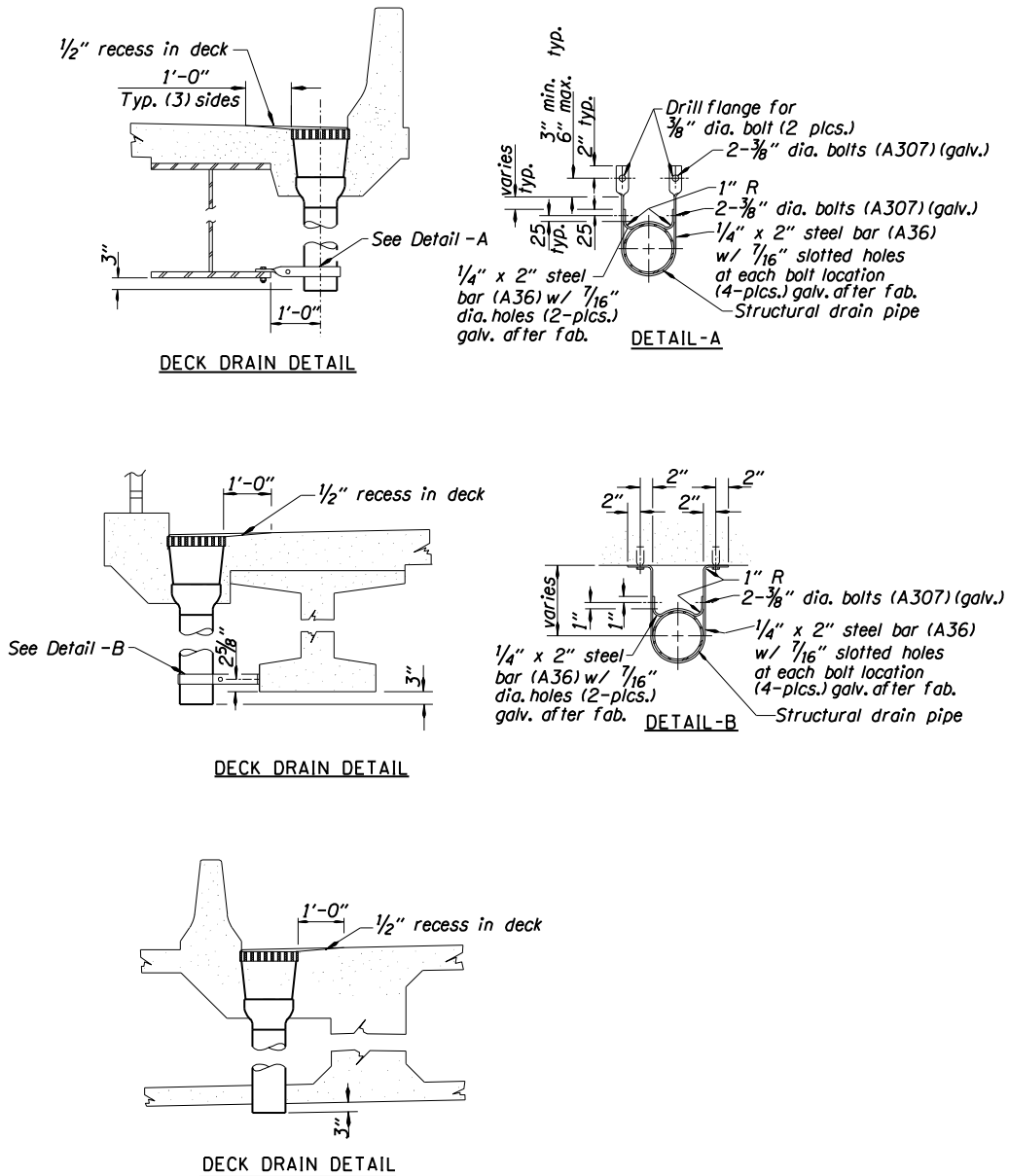


Figure 1.24.6-3 Bridge Deck Drain Details



## 1.25 Utilities

### [1.25.1 General Requirements](#)

### [1.25.2 Design and Detailing Guidelines](#)

### [1.25.3 Providing for Utility Installations](#)

### [1.25.4 Special Utility Considerations](#)

### [1.25.5 Attachments to Existing Bridges](#)

### [1.25.6 Utility Costs and Agreements](#)

### 1.25.1 General Requirements

As an early design task, determine if there are:

- Requirements for carrying existing and future utilities on bridges.
- Requirements for accommodating utilities in the vicinity of box culverts, sound walls, or retaining walls, especially mechanically stabilized earth (MSE) walls.

Design utility installations so that a failure will not:

- result in damage to the bridge.
- be a hazard to traffic.
- endanger the public.

When a proposed utility installation requires a structural evaluation, the utility plans and calculations must be stamped by an Engineer that is registered in the State of Oregon.

Include calculations for the following in the submittal:

- Vertical, lateral, and longitudinal loading, as appropriate.
- Maximum and operating pressures for pressurized systems.
- Waterline thrust blocks.
- Loadings to be carried by the bridge and their location.

When the proposed utility weighs more than 100 pounds per linear foot, the utility company will be required to provide a load rating of the bridge, with the utility loading superimposed onto the bridge, so that it can be determined whether the bridge has sufficient loading carrying capacity for the installation of the utility. When available, ODOT will provide a set of bridge plans for their use. All plans must be field verified, because not all As-Constructed bridge plans are accurate.

Use existing utility provisions located on the bridge, when possible.

Locate the utility installation to minimize the effect on the appearance of the bridge; minimize installation, inspection, and maintenance access problems; and minimize the risk of potential vehicle impacts when the bridge spans another roadway or railroad crossing. In most cases, this will mean installing the utility between girders or in the sidewalk or rail. Locate the utility as close as possible to the exterior of the bridge to allow access by snoper crane, when no other access is provided. This may not be possible when staging of the bridge is not compatible. See [BDM 2.6](#) for safety and accessibility guidance.

Provide sufficient space around utilities for maintenance activities such as cleaning and repainting steel members.

Do not extend utilities and supports below the bottom of the superstructure except when transitioning to a buried utility. Transitions are only allowed at bents or abutments.

When the utility is placed on the outside of the rail or exterior girder on stream crossings, place it on the downstream side of the bridge to minimize the chance of damage from floating debris.

Do not hang utilities against the sides of decks that have no curb. When required to put them on the side, move them out from the deck so they do not trap debris.

Avoid exterior mounted utilities in heavily sanded areas.

Some bridges have drains through the concrete railing, do not attach utilities below these drains.

Avoid attaching utilities to timber elements. Many timber elements require replacement during the bridge's life.

Avoid going through shallow end bents with no approach slab and a history of approach settlement. Excavation may increase settlement, settlement may cause the utility to shear, or the utility may get in the way of installing sheet pile or approach slabs in the future.

The utility will agree that they will promptly respond to and provide a process to repair failing utilities and removing abandoned utilities.

Utilities are to be labeled at each approach or first anchorage to the bridge and every 200 feet according to *American Public Works Association (APWA)* standards with color code and owner, contact information, etc. Adjust spacing to include one label in each bay bounded by beams and diaphragms. See [SP 00589](#) for additional requirements.

Install wire line type crossings in conduit.

Provide expansion fittings at each expansion joint or install on rollers as allowed by applicable safety codes. Install appropriate jumpers across expansion fittings for electrical installations.

High voltage power distributions lines greater than 22,000 volts will generally not be allowed, except in extraordinary circumstances where alternate crossings are not practical. In general, additional cost to the utility will not be considered reason enough to place power lines on bridges. Lines with voltage greater than 600 volts will be evaluated on a case-by-case basis and require written approval from the State Bridge Engineer.

Provide adequate shielding for electric power distribution lines to eliminate adverse effects of electromagnetic fields on radio signals, fuel injection systems, reinforcing and structural steel, and maintenance personnel. Provide adequate circuit protection to reduce the risk of electric shock hazards and allow for disconnection of the line upon request from ODOT. Locate disconnects within 1000 feet of the utility's first anchorage to the bridge.

## 1.25.2 Design and Detailing Guidelines

Utility attachments may exert large forces at the point of connection. Design individual members and the entire bridge for all loads imposed by the utility. Consider loads or movements that might be imposed on the utility by the bridge, such as from temperature or earthquake movements.

Ensure all loads are considered in the design, including dead, temperature, vibration, inertia loads, etc. Use longitudinal **and** transverse supports or anchorages as needed.

Include calculations for attachment connections or brackets designed by the utility company in the submittal for the designer to review. State maximum design and operating pressures for pressure systems. See *SP 00589* for additional requirements.

Design attachments that use a single anchor at each attachment point to remain serviceable if one of the other nearest attachments were to fail.

When drilled concrete anchors are required, follow the requirements of *BDM 1.5.11.2*.

Place holes in transverse members near the inside face of the outside longitudinal beams.

Maintain the alignment of utility holes as straight as possible, both vertically and horizontally, to avoid difficulties in placing utility pipes.

Construction tolerances and variables need to be considered in the design of brackets and hangers. Incorporate slotted holes, adjustable rod lengths, etc. into the attachment design.

Where utility holes are provided in the ends of the bridges for future utilities and an approach slab is required, provide each hole with concrete culvert pipe, galvanized smooth steel pipe (1/4 inch min. thickness), or Sch. 40 PVC pipe of the same inside diameter as the utility hole, extending from the hole to a point 5 feet minimum beyond the end of the approach slab. Extend such pipes parallel to the centerline of the bridge. Form a hole 1 inch larger in diameter than the pipe into the backwall or end beam. After the pipe is installed, fill the void around the pipe with a compressible material.

Utility holes and pipes under approach slabs may need to be a larger diameter to accommodate joint splices, couplers, or bells at connections.

In the absence of specific instructions from the utility company, provide hot-dip galvanized expanded coil concrete inserts with closed-back ferrule, threaded for 3/4 inch diameter bolts installed in the deck at 10 foot maximum centers above each line of utility holes (minimum insert length 4 and 5/8 inch, minimum safe working load in tension 5,890 pounds). When the

inserts are not to be used immediately, install short galvanized bolts in the inserts to prevent rusting of the threads.

Encased conduit is to be PVC or approved equal pipe. Hot-dip galvanize external steel conduit.

Provide suitable expansion joints at bridge expansion joints.

Hot-dip galvanize steel utility supports, including fasteners and anchorages.

On steel bridges suspend utility lines from the deck; do not hang from cross-frames, diaphragms, or main beams.

On prestressed slab or box bridges provide for future utilities through the end wall closure pours with capped 8 inch diameter blockouts or by embedding a 6 inch diameter PVC pipe in the wall and extending it 8 to 10 feet beyond the bridge bent. See *Appendix Figure A1.11.1.7-1*.

### 1.25.3 Providing for Utility Installations

When allowed by the bridge design, provide for utilities as follows:

- Agency Communication Infrastructure – on new National Highway System bridges, provide a minimum of two – 2 inch I.D. conduits for highway communications use. Follow the detailing guidelines for utility installation in *BDM 1.25.4*.
- For bridges carrying a freeway over a river, provide for utilities that have been approved by the FHWA. Provide for future utilities on a judgment basis.
- For bridges carrying highways over freeways and other classes of highways, provide for utilities that have requested space. Provide for future utilities on a judgment basis.

Also see *BDM 1.25.5* for acceptable accommodation of utilities in bridges.

Provide for future utilities based on the proximity to heavily populated areas and the probability of future requests for utilities.

- For bridges inside city limits, provide for future needs with two 12 inch diameter holes on each side of the bridge in addition to the specific utility requirements.

Provide access for utilities as follows:

- Utilities are not accommodated on bridges unless access can be provided for inspection and maintenance by the utility, with the exception of telephone and electrical conduits continuously encased in concrete.
- Do not provide access from the freeway for bridges carrying highways over freeways. In special cases, access may be provided from freeway right-of-way, but not from the traveled roadway or shoulders.

### 1.25.4 Special Utility Considerations



**GAS LINES**

Gas lines, or other lines carrying volatile materials, are to be Schedule 40 steel pipe or approved equal, and cased full length of enclosed or box type bridges. Install automatic shut-off valves at or near each end of the bridge.

Casings must be vented to outside of the bridge at each end and at high points.

Protect exposed lines from damage, both accidental and intentional. This could include barrier and fencing with locked access.

Provide transverse supports for gas lines.

Submit proposals for approval with details of the pipe, casing, vents and attachments to the bridge. Submit calculations to show that the proposed piping and casing system will be adequate for the intended purpose.

Have gas line corrosion protection systems reviewed by the Bridge Section Preservation Unit.

**WATER LINES AND SEWER LINES**

Case water and sewer lines placed adjacent to bridge footings if failure of the line could cause undermining of the footing or be an environmental hazard.

Water lines are to be hot-dip galvanized steel, ductile iron pipe, or approved equal. Corrosion protection systems may include cathodic protection.

Provide transverse supports near each coupling for water lines.

In box girders, make provisions for a water line failure. Provide additional drain holes or grating at low points in the cells. Provide low pressure sensing shut-off valves fully encase the line.

Provide water line thrust blocks as required.

**TRAFFIC BARRIER**

Limit the number and size of conduits in the bridge rail to assure ease of placement and proper consolidation of the concrete. Give special attention to details at expansion joint couplings because these tend to be much larger in diameter than the conduit.

## 1.25.5 Attachments to Existing Bridges

Requests for attachments to existing bridges normally come to the Region's District Bridge Supervisor. The District Bridge Supervisor submits the proposal to the Region Bridge Lead Engineer for review, comments, and recommendations. The Regions will make the final decision on any proposal. See *SP 00589* for additional requirements.

Review attachments to existing bridges with the same concerns and considerations of new bridges. Some additional concerns include:

- Attach conduits or brackets to concrete bridges with resin bonded concrete anchors per *BDM 1.5.11*.
- Consider mechanical anchors on a project-by-project basis when the following considerations are satisfied:
  - Anchors are of a type that will maintain capacity under dynamic or vibratory type loads.
  - Provide at least two anchors (4:1 safety factor per anchor) per attachment for redundancy, or design attachments with a single anchor to provide a factor of safety of 6:1.
  - Avoid drilling through reinforcing steel. When critical reinforcing steel is hit, move the anchor location and patch the hole with an approved patching material. The level of concern about cutting reinforcement depends on the location of the section, amount of reinforcement at the section, and the type of reinforcement (moment, shear, temperature, etc.).
  - Protect exposed pipe and hardware against corrosion.
  - Include utility hanger details in the utility request.
  - Drill holes with low-impact rotary drill.
  - Patch any abandoned holes.

## 1.25.6 Utility Costs and Agreements

On new construction, the State normally provides the concrete inserts in the deck for hangers, holes through diaphragms, crossbeams and endwalls, and pipes under the approach slabs. This is regarded as providing minimal accommodation which essentially has zero or negligible cost (**de minimus**, or below the threshold of actually costing the program) compared to not providing these items, and is acceptable per a January 2005 opinion from the Oregon Department of Justice. All other costs for materials and labor related to the utility installation are the responsibility of the utility company.

When a utility company requests the addition of conduits in a sidewalk or concrete rail, special attachment brackets, inspection walkways, etc., it is the expense of the utility company.

In such a case, the State and the utility company need an agreement before the work can be included in the project. The Utility & Railroad Coordinator in the Right of Way Section writes the agreement. Notify the Utility & Railroad Coordinator as soon as possible in the project development process (preferably at the TS&L stage or before), to ensure an agreement can be reached and the work can be included in the project.

## 1.26 Corrosion Protection

### [1.26.1 Marine Environment](#)

### [1.26.2 Marine Environment Protection](#)

### [1.26.3 Deck and Approach Slab Reinforcement Protection](#)

### [1.26.4 Waterproofing Membranes](#)

### [1.26.5 Protection for Steel Piling](#)

The level of effort to prevent reinforcing steel corrosion depends mainly on the potential for exposure to a corrosive environment.

### 1.26.1 Marine Environment

For the purposes of determining when the specified corrosion protection is required a Marine Environment is defined as any of the following:

- A location in direct contact with ocean water, salt water in a bay, or salt water in a river or stream at high tide (substructure).
- A location within ½ mile of the ocean or salt water bay where there are no barriers such as hills and forests that prevent storm winds from carrying salt spray generated by breaking waves.
- A location crossing salt water in a river or stream where there are no barriers such as hill and forests that prevent storm winds from generating breaking waves.

### 1.26.2 Marine Environment Protection

Provide the following minimum protection system for structures in a Marine Environment:

- Stainless steel for all deck, girder and crossbeam reinforcing steel.
- Black steel (no epoxy coating) for prestressing strands in precast members (to allow for future cathodic protection if needed).
- Minimum 2 inch cover on all cast-in-place members.
- HPC (microsilica) for all precast and cast-in-place concrete.

Review additional protection measures including concrete sealers, cathodic protection or others with the Corrosion Specialist on a project-by-project basis.

## 1.26.3 Deck and Approach Slabs Reinforcement Protection

The protection system for deck and approach slab reinforcement is shown in *Table 1.26.3-1*. Required reinforcement cover for all decks is 2 ½ inches for the top mat and 1 ½ inches for the bottom mat.

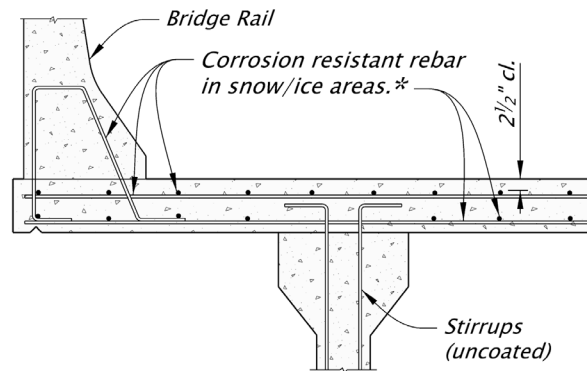
For reinforcing steel extending out of the deck or approach slab into bridge rails, curbs or sidewalks, use the same type of reinforcement as used in the deck or approach slab. Use black (uncoated) steel for all other bridge rail, curb or sidewalk reinforcement.

Examples are shown in *Figures 1.26.3-1* and *1.26.3-2*.

Table 1.26.3-1 Deck and Approach Slab Reinforcement Protective Practices

	<b>Coastal Areas (within 1 air mile of the Pacific Ocean)</b>	<b>Snow/Ice Areas*</b>	<b>Mild Areas**</b>
Concrete Type	HPC (microsilica)	HPC (microsilica)	HPC (microsilica)
Reinforcement Type	<u>Deck</u> – Stainless steel or GFRP top and bottom mats  <u>Approach Slab</u> – Black (uncoated) top and bottom mats	Epoxy coated or ChromX 4100 top and bottom mats in both the deck and approach slab	Black (uncoated) top and bottom mats in both deck and approach slab
* Snow/Ice areas are defined as all areas of central and eastern Oregon, the Columbia River Gorge, Jackson County, and any other areas above 1500 feet elevation or otherwise identified by the associated maintenance district.			
** Mild areas are defined as all areas not in a coastal area or in a snow/ice area. This includes all of western Oregon below 1500 feet elevation that is not within 1 mile of the Pacific Ocean.			

Non-Coastal Cast-in-place Decks - For cast-in-place concrete decks, provide 2 ½ inches of cover over the top mat of reinforcing steel. When a corrosion protection system is required, provide corrosion resistant rebar for top and bottom longitudinal and transverse mats (including **truss** bars) and for all bars extending from the deck into the sidewalk, curb or railing. Stirrups for precast girders do not need to be corrosion resistant.

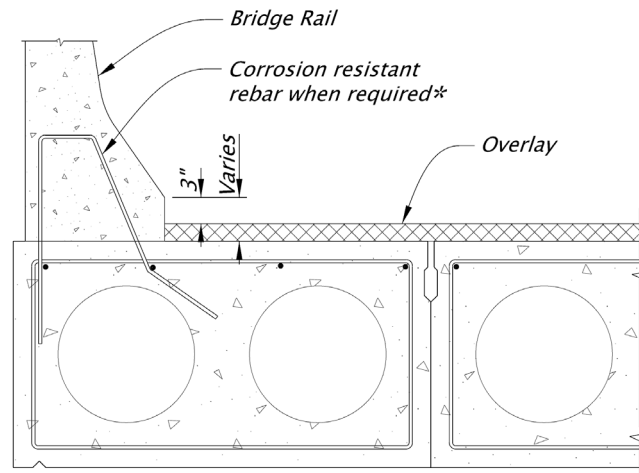


\* See Table 1.26.3A for definition of snow/ice areas.

Figure 1.26.3-1 Reinforcement Protection for Non-Coastal CIP Decks

Non-Coastal Precast Slabs and Boxes - Precast slabs and box beams require PPC overlay or cast-in place HPC deck. ACWS with waterproof membrane may be used on existing bridges. When corrosion protection systems are required, provide corrosion resistant rebar for the top mat bars and bars extending from the precast elements into the sidewalk, curb or railing. See the standard drawings for other corrosion resistant bars in the precast slabs and box beams.

When multiple metals are specified for reinforcing bars in the same elements, provide electrical isolation between the different rebar metals to avoid galvanic corrosion.



\* See Table 1.26.3A for locations where Corrosion resistant rebar is required.

Figure 1.26.3-2 Reinforcement Protection for Non-Coastal Precast Slabs and Boxes

## 1.26.4 Waterproofing Membranes

Waterproofing membranes are used as part of an overall deck protection concept. They are required when paving a bridge with asphaltic concrete wearing surface (ACWS). Membranes serve the following purposes:

- Protect reinforcing steel in concrete members from corrosion by preventing moisture from roadway runoff (which potentially contains chlorides and other contaminants) from penetrating the concrete surface.
- Protect galvanized tie rods in precast prestressed concrete members placed side-by-side from roadway runoff.
- Protect timber bridge decks from moisture damage.
- Prevent roadway runoff water from passing through bridge elements to a roadway, bikeway or pedestrian way underneath the bridge.
- Prevent untreated roadway runoff water from passing through bridge elements to a waterway underneath the bridge.

Spray and Polymer waterproofing membranes are selected from the *ODOT Qualified Products List*.

Rolled membranes are specified by *SP 00592* and accepted according to *SP 00592.10*. There is not currently a rolled membrane section in the *ODOT Qualified Products List*.

Consult with Structure Services to select the correct membrane type for each structure.

### NEW STATE BRIDGES

For new bridges, ACWS is not permitted without a design deviation.

### EXISTING STATE BRIDGES

FHWA requirements for State owned bridges states that **If deicing salts may be used in the future, some type of deck protection shall be used.**

All areas of Oregon potentially use deicing chemicals. Actual use of deicing chemicals in the project area can be verified by contacting the Region District Maintenance Manager.

Perform chloride testing on the existing bridge deck when warranted per *BDM 1.9.4.4* to verify existing chloride levels are acceptable.

Use a structural concrete overlay when warranted by *BDM 1.9.4.5*.

As mobilization is a significant cost to bridge paving projects, do not skip bridges during roadway paving operations. Remove all ACWS and existing membranes during paving projects, except when the existing membrane is a spray or polymer membrane that is performing well. When possible, protect these types of membranes in place during paving operations.

### NEW OR EXISTING LOCAL AGENCY BRIDGES

A deck protection system is desirable and should be investigated on each project, whether NHS or Non-NHS. All federally funded projects require a deck protective system.

When a Local Agency chooses not to use a cast-in-place deck or ACWS with a waterproofing membrane for side-by-side construction, obtain written confirmation from the Local Agency. Include a copy of the Local Agency confirmation in the calculation book. Also confirm with the project environmental coordinator whether elimination of a membrane is acceptable when there is potential for roadway runoff to enter a waterway by leakage through adjacent bridge members.

## 1.26.5 Protection for Steel Piling

Assess all steel piling used in permanent structure applications for corrosion potential and design for the long term effects of corrosion. Reference *LRFD 10.7.5* for design requirements and guidance regarding steel pile corrosion assessment and protection. The design requirements and guidance provided in *LRFD* are further defined and supplemented in this section. Guidance on the extent of site investigations, including the soil sampling and testing required for corrosion assessment, are presented in the *ODOT GDM*.

The corrosion potential of buried steel piling depends primarily on the electrochemical nature of the soil surrounding the piling and the presence of oxygen and moisture. In this case,



corrosion is most likely to occur at or above the water table and in disturbed stratified soils such as man-made fills, especially those containing cinders, slag or ash.

Steel pilings in waterways that extend above ground such as in estuaries, lakes or streams may also be subject to significant corrosion, especially in marine environments where the salinity of the water may be very high.

Recommended pile corrosion assessment measures, and associated design guidance, is provided below for two distinct site conditions (or physical environments): Marine and Non-Marine.

### **MARINE ENVIRONMENTS**

Marine Environments, as defined in *BDM 1.26.2*, are typically the most highly corrosive conditions found and require the highest level of protection against steel pile deterioration. Protect all steel piling in Marine Environments with one or more of the corrosion protective systems described below. Project sites located beyond the limits described for Marine Environments may still have a significant potential for pile corrosion depending on site specific conditions. For example, if brackish water is present, or there are other indications of potential corrosive conditions consider additional soil and water testing to assess the need for additional pile corrosion protective measures.

### **CORROSION PROTECTIVE SYSTEMS**

Corrosion protection systems may be provided by the use of coatings, concrete encasement, cathodic protection, or selection of corrosion-resistant alloys. Guidance on protective coatings and cathodic protection systems are discussed below. The other protective measures, such as concrete encasement or special steel alloys, may also be considered on a case by case basis. Contact the Senior Bridge Corrosion Engineer for additional guidance.

#### **(1) Protective Coatings**

When specifying protective coatings on steel pilings, two types of coating systems are available to designers, 3-coat system and a 4-coat system.

The 3-coat protective coating system is comprised of a zinc-rich primer followed by two coats of moisture-cured urethane/urethane-tar. The 4-coat protective coating system includes the same 3-coat protective coating system followed by a top coat.

Specify the 4-coat protective coating system for piles in direct contact with water. Coat piles full length at bents with pile tips within 25 feet of groundline. Specify 3-coat protective coating system for all other cases. Coat all other piles from final cutoff elevation to 25 feet below groundline.

Use both *SP 00520* and *SP 00594* for protective coatings. *SP 00520* identifies where and what kind of coating system is to be used. *SP 00594* provides the preparation, application, materials, testing, measurement and payment for the specified coating system.

#### **(2) Cathodic Protection**

Galvanic anode cathodic protection can be applied to existing steel pilings or to new steel piling installations. For new piling installations, use cathodic protection in conjunction with protective coatings in order to minimize anode consumption.

Guidance for design and installation of anode systems for pilings in marine waters is provided by *NACE Standard SP0176*. Guidance for design and installation of anode systems for pilings in soil is provided by *NACE Standard SP0169*.

Make the electrical connection to the piling by brazing a brass stud on the downstream side of the piling. Provide the following project note:

Remove coating from piling surface (approximately 4 by 4 inch area) and install ½ by 13 by 2 inch brass stud using an approved brazing process. Provide 2 brass nuts and 2 brass washers with stud. Recoat piling surface with protective coating after installation of brazed stud.

This method of corrosion protection requires regularly scheduled inspections of the exposed piling and periodic maintenance for the replacement of anodes.

#### **NON-MARINE ENVIRONMENTS**

Non-marine environments are all locations not designated as **Marine Environments**. In these areas, piles that are permanently buried and are always below the water table have a low potential for steel corrosion and therefore soil investigations and testing are not required. These areas generally have low corrosion potential; however there are special circumstances or site conditions that indicate the potential for severe corrosion potential, such as:

- Landfills or fill materials composed of cinders, ash or slag.
- Sources of mine or industrial drainage (acidic groundwater).
- Sites with stray electrical currents, such as electric (DC) transit systems, or high voltage power lines.

Investigate these highly corrosive sites with a thorough soil and groundwater testing program consisting of soil resistivity, pH, sulfate and chloride concentrations. Corrosion protection systems, as described for Marine Environments, are required when any of the following conditions are found:

- Soil resistivity is less than 2000 ohm-cm.
- Soil pH is less than 5.5.
- Sulfate concentrations are greater than 1000 ppm.
- Chloride concentrations are greater than 500 ppm.

When all soil test results pass the above criteria, follow the corrosion design procedures described below for routine, non-marine environments.

For routine Non-Marine environments, the minimum amount of field investigation consists of resistivity and pH testing of the soils in the vicinity of the proposed piling. When soil resistivity is greater than 2000 ohm-cm and soil pH is greater than 5.5, no further evaluation is required

and the steel piling should be designed with a minimum sacrificial steel thickness as described below. When either test result does not meet the resistivity or pH criteria then conduct additional testing, consisting of chloride content and sulfate content, and consult the Senior Bridge Corrosion Engineer to evaluate the need for either corrosion protective systems or other alternatives.

Additional guidance and background information on the corrosion of steel piling in non-marine environments can be found in [NCHRP Report 408](#) and [AASHTO R-27-01 \(2015\)](#). The minimum pH criteria of 4.0 recommended in these reference documents does not supersede the 5.5 value used in *LRFD*.

**RECOMMENDED SACRIFICIAL STEEL THICKNESS**

For sites where the measured resistivity and pH results indicate low corrosion potential a sacrificial steel thickness may be used to account for steel section loss over the life of the structure. Determine thickness loss over a minimum design life depending on project design criteria and use this reduced thickness in the pile design. At a minimum, specify a thickness loss of 1/16 inch to account for possible corrosion loss occurring in the steel piles. Corrosion rates for use in determining thickness loss are specified below (ref. *WSDOT BDM, 2014*).

Table 1.26.5-1 Corrosion Rates

<b>Pile Environment</b>	<b>Corrosion rate (inch/year)</b>
Soil embedded zone (undisturbed soil)	0.001
Soil embedded zone (fill or disturbed natural soils)	0.003
Immersed zone (fresh water)	0.002

Double the corrosion loss for steel H-piling since there are two surfaces on either side of the web and flanges that are exposed to corrosive conditions. For pipe piles, shells, and casings, the corrosion allowance is only needed for the exterior surface of the pile. The interior of the pile will not be exposed to sufficient oxygen to support significant corrosion.

Use this approach with caution since it can limit opportunities to extend the life of the structure in the future.

## 1.27 On-Bridge Sign & Illumination Mounts

### [1.27.1 Traffic Structures Mounted on Bridges, General](#)

### [1.27.2 On-Bridge Sign Mounts](#)

### [1.27.3 On-Bridge Illumination Mounts](#)

## 1.27.1 Traffic Structures Mounted on Bridges, General

The following traffic structures may be located on bridges, although standard traffic lighting poles are the only traffic structures with standard bridge connection designs. The placement of other traffic structures on bridges should be discouraged. In special cases where other (larger) traffic structures must be located on a bridge, they should be connected directly to a bent.

- Standard lighting poles.
- Camera poles.
- Structure mounted signs (signing for traffic passing under bridge).
- Miscellaneous small signs (signing for traffic on bridge).

When a traffic structure is on a bridge, the bridge designer will be responsible for the connection between the traffic structure and the bridge, including the anchor bolts, and will review or check the shop drawings associated with the bridge design responsibilities. In this case, the Traffic Structures Designer will have very limited involvement with the bridge structure. The *ODOT Traffic Structures Design Manual* has design loads and guidance for many common applications.

The decision on whether the traffic structure may be located on the bridge and the exact location of the traffic structure on the bridge will be made by the bridge designer in conjunction with the project team. Structure mounted signs should preferably not exceed 7 feet in height. However, especially in urban areas the required sign legend may dictate a larger sign panel. The bridge designer should work with the project team to arrive at an acceptable solution, considering effects on aesthetics, sight distance, and related factors.

The bridge designer will be responsible for the connection between the traffic structure and the Bridge, including the anchor bolts, and will review or check the shop drawings associated with the bridge design responsibilities.

## 1.27.2 On-Bridge Sign Mounts

Position all new side mounted signs on bridges such that the bottom of the sign or lighting bracket does not extend below the bottom of the bridges (bottom of girder flange). To ensure

that the bottom of the sign is above the bottom of the bridge, maintain at least a nominal 2 inch dimension between the bottom of the sign and the bottom of the bridge to account for construction tolerances and bracket arm sag. Design bridge side mounted sign brackets to account for the weight of added lights, and for the wind effects on the lights to ensure bracket adequacy if lighting is attached in the future.

Do not place signs under bridge overhangs. Do not place signs directly under the drip-line of the structure. Provide a minimum 2 inches of clearance between the back side of the sign support and edge of the bridge.

### **1.27.3 On-Bridge Illumination Mounts**

[Reserved for future use]

## 1.28 Truss and Monotube Cantilever Sign Bridges

### [1.28.1 Truss and Monotube Cantilever Sign Bridges, General](#)

#### 1.28.1 Truss and Monotube Cantilever Sign Bridges, General

Refer to ODOT Traffic Standard Drawings website 600 series drawings for standard truss and monotube cantilever sign bridges. For new truss and monotube cantilever sign bridges design, see *ODOT Traffic Structures Design Manual* and *LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 1st Edition* for further guidance.

See *ODOT Geotechnical Design Manual (GDM) Chapter 16* Foundation Design for Signs Signals, Luminaires, Sound Walls and Buildings for foundation design guidance for truss and monotube cantilever sign bridges.

## 1.29 Bridge Raising

### [1.29.1 Bridge Raising, General](#)

### [1.29.2 Bridge Raising Using Falsework](#)

### [1.29.3 Bridge Raising Using Chip-in Method](#)

#### 1.29.1 Bridge Raising, General

Provide enough information in the contract document that enables the Construction Contractor's engineer to design supporting elements for a bridge raising and stability of the structure during this operation.

Different construction procedures could be employed in raising a bridge. More common procedures are using falsework or **chip-in** construction. A check needs to be made whether the bridge should be open to permit loads while under construction. Take a concrete sample of each column to verify the column's concrete strength.

#### 1.29.2 Bridge Raising Using Falsework

Design assumptions and criteria include:

- Total dead load: Superstructure and substructure above the **chip-in** point, superimposed dead loads, utilities, signs, other dead loads that will remain on the bridge during the raising operation (field verify all dead loads at Project Initiation).
- Design live load: HS-25 when bridge is open.
- Close the bridge during the actual raising operation.
- For falsework design use 1.5 load factor for dead and live loads.
- When bridge is open to permit loads use 1.5 dead load factor and 1.35 live load factor.
- Temporarily pin concrete barriers that protect the bridge from damage from adjacent traffic. Provide at least 1 foot clearance between the barrier and the bridge or falsework elements.

#### 1.29.3 Bridge Raising Using Chip-in Method

The **chip-in** method is a popular construction method for raising bridges. In this method concrete at the mid-point of each column is removed to provide enough room to place a jack and shims. The remaining concrete is removed and the reinforcing steel severed. After the

bridge deck is brought to the desired elevation, the severed reinforcing steel is spliced and the void between the two portions of the column is filled with non-shrink concrete.

Design assumptions and criteria include:

- Total dead load: Superstructure and substructure above the **Chip-in** point, superimposed dead loads, utilities, signs, other dead loads that will remain on the bridge during the raising operation (field verify all dead loads at Project Initiation).
- Design live load: HS-25 when bridge is open during **Chip-in** operation; however, traffic should not be permitted in the lane adjacent to the columns that **chip-in** is in progress.
- Close the bridge during the actual raising operation.
- For dead loads and super imposed dead loads use 1.5 dead load factor.
- When bridge is open to traffic after the raising operation use 1.35 live load factor.
- Bridge cannot be open to permit loads unless adequacy and stability of bridge was checked for permit loads. In this case use 1.35 load factor for permit loads.
- Temporarily pin concrete barriers that protect the bridge from damage from adjacent traffic. Provide at least 1 foot clearance between the barrier and the bridge elements.



## 1.30 Strengthening of Bridges

### [1.30.1 Strengthening of Bridges, General](#)

### [1.30.2 Strengthening Methods and Details](#)

### [1.30.3 Existing Rebar and Concrete Cover Investigation](#)

### [1.30.4 Epoxy Injection](#)

## 1.30.1 Strengthening of Bridges, General

The terms **strengthening** and **repair** are sometimes used interchangeably to describe an action, but they are not the same. Strengthening is the addition of load capacity beyond the level provided for in the original design. Repair is the restoration of the load capacity to the level of the original design.

Bridge strengthening is required when the critical load rating factor for a bridge falls below 1.0. Design bridge strengthening to resist the live load given in *BDM 1.3.2.4.*

When critical load rating factors are below 1.0 or when the bridge inspection report indicates quality issues, consider conducting material testing according to *The Manual for Bridge Evaluation Sections 5.3 and 5.4*. Take concrete compressive cores from each concrete grade, with at least three samples from each. Additional sampling locations or tests may be required for large bridges or to address localized problems. Repair all concrete sampling locations with hand patching materials from *SP 02015.30* of the QPL designated for vertical and overhead application.

Bridge repair projects are typically limited to isolated portions of the bridge and address specific needs such as substructure issues and collision damage. Examples of such cases are:

- Footings and/or columns.
- Piling.
- Girder damage from over height collision.
- Bridge rail collision damage.

In rare cases there may be extenuating circumstances to support a **do nothing** or reduced design criteria. For such cases, approval of a design deviation is required. FHWA review will also be required when a bridge is to remain in service with a critical rating factor less than 1.0. Factors to be considered in the design deviation approval process may include:

- Estimated cost of repair or strengthening.
- Existing permit truck volume and potential for future increases.
- Existing girder cracking.
- Number of lanes and shoulder widths.
- Alternate routes available.
- Existing bridge detailing.

## 1.30.2 Strengthening Methods and Details

The following are preferred methods for strengthening girders in flexure and shear. Alternative methods are encouraged and can be used with an approved design deviation (used to document use of innovative materials).

### 1.30.2.1 Section Enlargement

Adding depth and width to beams can increase flexural and shear capacity. Interface shear reinforcement details are important to ensure composite section behavior between new and old concrete. Steel dowels can be used for achieving the composite section by drilling holes into the existing concrete substrate, installing reinforcing bars or bolts, and anchoring the steel dowels with epoxy resin. For bridge elements that require section enlargement with concrete cover less than 4 inch thick and are situated in a marine environment, consider using nylon drywall anchors or stainless steel screw anchors to attain composite section.

Consider high strength rebar for flexural and shear reinforcement in new concrete section, when space is limited. The high strength rebar reduces size and quantity of new rebar.

### 1.30.2.2 Post-Tensioning

Post-tensioning is an active means to restore or increase flexure, shear, and anchorage capacity of bridge structural elements. Ensure that force due to post-tensioning is not excessive to avoid unintended cracking.

When longitudinal post-tensioning is used as part of a strengthening system, understand that long-term relaxation of the post-tensioning system may reduce the effectiveness of the strengthening. Account for any long-term relaxation unless provision for future tightening is included. When strengthened structural elements are located in corrosive environment, consider using corrosion-resistant high-strength bars, strands, and anchorage assemblies. Use of corrosion-resistant ducts filled with grout to encase P/T strands is also an option.

### 1.30.2.3 Internal Shear Anchors

Internal shear anchors (ISA) for shear strengthening can be installed either from above or below the girder. Installation from above may be easier and considered where practical. Specialty contractors are generally available for drilling 1 inch diameter holes up to 48 inches in depth. For this reason, limit internal shear anchor size to  $\frac{3}{4}$  inch. Do not use larger sizes or depths unless the availability of multiple contractors has been verified. Internal shear anchors should normally be placed at an angle 30 degrees from vertical. This angle provides 96 percent of the capacity compared to 45 degree anchors and is much easier to install.

Internal shear anchors require development length at each end of the rod. Calculate the required embedment depth to develop anchor rod ultimate strength according to *ACI 318 17.4.5* with modification according to *BDM 1.20.2.2*. Provide adequate bar length greater than the calculated embedment length at both ends. The effective length of an internal anchor is the

length remaining after subtracting the development length at each end of the bar. The shear capacity from internal shear anchors in normal weight concrete can be calculated as follows:

$$V_{s\_ISA} = \frac{A_s f_y d_{v\_ISA} (\cot \theta + \cot \alpha) \sin \alpha}{s_{ISA}}$$

where:

Effective shear depth,  $d_{v\_ISA} = L_{eff} \sin \alpha$

Effective length,  $L_{eff} = L_{anchor} - 2L_{d\_ISA}$

Development length,  $L_{d\_ISA} = \frac{A_s f_y}{\tau_{uncr} \pi d_a}$

$A_s$  = area of internal shear anchor (in.<sup>2</sup>)

$f_y$  = minimum specified yield strength of ISA (ksi)

$d_a$  = diameter of ISA (in<sup>2</sup>)

$\tau_{uncr}$  = characteristic bond stress (ksi) (see *Table 1.20.2.2-3*)

$L_{anchor}$  = total length of ISA (in.)

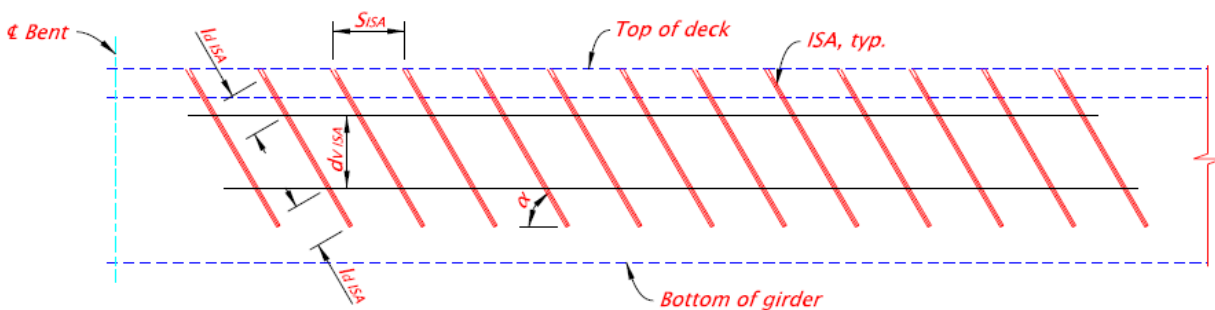
$\alpha$  = angle of inclination of ISA to longitudinal axis (degrees)

$\theta$  = angle of inclination of diagonal compressive stresses (degrees)

$s_{ISA}$  = spacing of ISA (inch)

Parameters in the above equations are shown in *Figure 1.30.2.3-1*.

Figure 1.30.2.3-1 Internal Shear Anchors



### 1.30.2.4 Carbon Fiber Reinforced Polymer (CFRP) Wet-Layup System

Design CFRP strengthening according to *ACI 440.2R-08* or *AASHTO Guide Specifications for Design of Bonded FRP Systems for Repair and Strengthening of Concrete Bridge Elements*. Do not use

CFRP laminate strips unless the critical rating factor is greater than 0.80. Strengthening with CFRP laminate strips can be considered a long-term (more than 20 years) strengthening solution. Use intermittent strips with 4 inch minimum gap on girder webs for shear strengthening to allow for inspection of the bare concrete between the strips. Do not specify more than three plies of CFRP laminate to avoid crack-induced debonding failure mode.

Provide positive anchorage at the ends of CFRP laminate strips. Anchorage using CFRP laminate strips transverse to the loaded direction is not acceptable. Proper surface preparation is critical to ensure a successful FRP application.

### **1.30.2.5 Near Surface Mounted System**

Near surface mounted (NSM) system includes cutting shallow grooves into existing concrete substrate and embedding reinforcement surrounded by epoxy resin inside the groove. NSM is less prone to delamination, environmental degradation and allows for effective inspection of concrete surfaces compared to the CFRP wet-layup system. Consider the following reinforcement materials for near surface mounted application:

- CFRP bar.
- High strength bar.
- Stainless steel bar.
- Titanium alloy bar.

NSM system can be used for flexure, shear, and anchorage strengthening of bridge structural elements. Consider using NSM system for the following bridge elements:

- Cap beams.
- Girders.
- Deck overhang.
- Bridge deck.
- Footing.

CFRP is a conductive material, which can develop galvanic corrosion, when installed in concrete elements reinforced with steel rebar. Electrical isolation details are required. CFRP has linear properties up to rupture. To avoid a brittle failure, design ultimate strain is limited well below the rupture strain, therefore bond strength between CFRP bars, epoxy resin, and concrete is required to develop the tensile capacity. On the other hand, metal reinforcement has a yield point with large strain before fracture and can be bent for mechanical anchorage into concrete substrate. Mechanical anchorage at terminations is added for metal reinforcement by using standard 90 degree hooks at both ends to provide anchorage. Design NSM-CFRP system according to *ACI 440.2R-08*.

NSM system using stainless steel and titanium alloy bars was investigated through tests for strength and long-term performance at OSU. See *ODOT SPR 750*, and *SPR 775* research reports for test information. The research studies found that the materials are suitable for strengthening

bridge structural elements. However, NSM system with titanium alloy bars (NSM-TiABs) is more efficient than the system with stainless steel rebar due to higher strength.

*ASTM B1009* describes material standards for NSM system with titanium alloy bars. See *AASHTO Guide for Design and Construction of Near-Surface Mounted Titanium Alloy Bars for Strengthening Concrete Structures* for design guidance and design examples with the following modifications:

- Reduce nominal cross sectional area using a factor of 0.96 due to surface deformations to enhance bond.
- Use a specified yield strength of 130 ksi for design.
- Specify a maximum system length of 19 feet (excluding the hooks) for #5 bars or smaller and a maximum system length of 18 feet for #6 bars. The stock length for titanium bars is 20 feet total including the lengths of hook tails. Lengths up to 35 feet are possible, but not recommended. The additional length results in a much higher unit cost.
- Avoid specifying #6 titanium alloy bars, due to the required 12 inch hook tails.

Consider smaller diameter bars for strengthening thin structural elements, since required tail length for end hooks is shorter. For instance, use #3 bars for deck overhang strengthening, where a tail length of 5 inches is required for hook ends.

Even though titanium alloy bars have the strength advantage over CFRP, stainless steel, and other high strength bars, unit cost of titanium alloy bars is much higher than the others. Therefore NSM-TiABs is more suitable for localized strengthening such as poor anchorage, specific deficient areas, etc.

Concrete substrate for NSM system needs to be in good condition without significant cracking, spalling and delamination. When concrete cover repair is required, additional steps for strengthening would negate advantage of NSM construction. For structural elements with extensive concrete damage, section enlargement with high strength rebar would be more appropriate.

### 1.30.2.6 Other Strengthening Systems

External stirrups (vertical rods) have been used for temporary shear strengthening of concrete girders, but they are not considered adequate for permanent strengthening.

Do not use bonded and/or bolted steel plates attached to the sides of concrete girders for shear strengthening without prior approval from Bridge Section.

### 1.30.2.7 Strengthening Plan Details

EOR of a bridge design project is responsible for strengthening design except for CFRP wet-layup and CFRP-NSM systems. For the CFRP strengthening systems, provide the following information on plan sheets for contractor's CFRP strengthening designers:

- Existing reinforcing details including material properties, concrete section, and relevant reinforcing details for capacity calculation.
- Locations and limits of deficiencies in structural element.
- Required total capacity from existing section and strengthening system.
- Conceptual strengthening details.
- Required minimum material properties of CFRP.
- Required locations of CFRP reinforcement termination for full development.
- A reduction factor of 0.85 ( $\psi_f$ ) required in the strength contribution of CFRP reinforcement.

Also include the following data of CFRP and composite materials used for the design of the CFRP strengthening system in General Notes sheet:

- Section properties.
- Ultimate and design tensile strength.
- Tensile modulus of elasticity.
- Ultimate strain.

When the CFRP strengthening system used in construction is different from design plans, document CFRP and composite material properties listed above in as-constructed drawings. The material data are necessary for future evaluation and load rating of the bridge.

### **1.30.3 Existing Rebar and Concrete Cover Investigation**

Obtain as-constructed drawings and evaluate existing bar size, location, spacing, and cover thickness during design. Ensure that strengthening system is possible to be constructed, especially the strengthening methods that require drilling or cutting into existing concrete section. It is often difficult to avoid existing deck steel or existing flexural steel. The designer needs to give clear instructions to the contractor concerning how potential conflicts are to be either avoided or resolved. Possible solutions are:

- Locate existing bars and measure concrete cover using high precision rebar detector or Ground Penetrating Radar (GPR) before drilling holes or groove cutting.
- Expose the top mat of reinforcement before drilling.
- Relocate drilled hole or groove to an equivalent location, when a conflict is discovered.
- Add reinforcement, when cutting existing bar cannot be avoided.

## 1.30.4 Epoxy Injection

Epoxy inject shear and/or shrinkage cracks with widths 0.016 inches and larger and where the bridge is:

- Located in a Snow/Ice area.\*
- Located in a Coastal Area (within 1 air mile of the Pacific Ocean).
- The bridge shows signs of corrosion.

\* Snow/Ice areas are defined as all areas of central and eastern Oregon, the Columbia River Gorge, Jackson County, and any other areas above 1500 feet elevation. These areas are intended to include all areas with the potential to receive periodic application of deicing chemicals.

Epoxy injection is not considered a strengthening method for either flexure or shear. However, it improves corrosion protection. Injection of cracks smaller than 0.016 inches is difficult and is only marginally effective. Cracks greater than 0.040 inches will require strengthening so the bridge will not be considered to be structurally deficient.

During installation of FRP repairs, epoxy inject shear and/or shrinkage cracks in the repair area with widths 0.016 inches and greater.

Reference concrete crack widths in specification documents and on plan sheets using one of the available widths provided on the ODOT crack comparator (gauge). The available widths (in inches) are as follows:

- 0.008
- 0.010
- 0.013
- 0.016
- 0.020
- 0.025

For concrete cracks greater than 0.025 inches, show crack size to the nearest hundredth.

## **1.31 (Reserved)**

## **1.32 Preservation and Repair**

(Reserved for future use)

## **1.33 Bridge Paint**

(Reserved for future use)

## **1.34 (Reserved)**

## **1.35 Covered Bridges**

(Reserved for future use)

## **1.36 Moveable Bridges**

(Reserved for future use)

## **1.37 (Reserved)**



## 1.38 Bridge Temporary Works

### 1.38.1 General

Temporary works include any temporary construction used to construct highway related structures but are not incorporated into the final structure.

Temporary works required for construction of permanent structures include:

- Diversion bridge.
- Work bridge.
- Falsework.
- Formwork.
- Shoring.
- Cofferdams.
- Temporary retaining structures.

Design temporary works, except seismic loading, according to the *AASHTO Guide Design Specifications for Bridge Temporary Works, 2nd Edition, 2017*, unless specified otherwise herein.

Construct temporary works according to *AASHTO Construction Handbook for Bridge Temporary Works, 2nd Edition, 2017*, unless included in the Oregon Standard Specifications for Construction and Special Provisions.

### C1.38.1

The following tables include common Special Provisions and Standard Specifications.

Table 1.38.1-1 Special Provisions

Title	Section Number
Temporary Roadbed and Surfacing	00230
Diversion Bridges	00250
Agency Provided Temporary Bridges	00251
Temporary Work Bridges	00252
Temporary Work Access and Containment	00253
Temporary Retaining Walls	00256

Table 1.38.1-2 Standard Specifications

Title	Section Number
Structure Excavation and Backfill (shoring and cofferdams)	00510
Structural Concrete (Falsework)	00540
Trench Protection	00405.41(f)
Temporary Trench Plating	00405.46(c)
Jacking Pits	00406.41(b)

## 1.38.2 Diversion Bridges

Diversion bridges are those bridges with a maximum service life of five years to carry traffic while an existing structure is replaced. Diversion bridges have the same

### HYDRAULICS REQUIREMENTS

Hydraulic requirements apply to diversion structures designed by ODOT, and those designed by a Contractor.

The hydraulics report provides recommendations for the diversion bridge. The data will include seasonal limitations, flow area of the structure, and minimum elevation of the diversion roadway.

Prepare a brief statement about the proposed location of the diversion. Other information about the diversion may include a discussion of maintenance needs such as monitoring for debris or scour. The diversion structure must conform to the temporary water management plan regarding fish passage.

Only use a dry season diversion during the dry season. The hydraulics report defines the start and end of the dry season. The design and check floods are based on the maximum predicted discharges for the months the diversion will be in place. Use the 2-year flood as the minimum design flood event.

An all-year diversion may be used throughout the year. The all-year diversion must pass the 5-year flood event at a minimum. Use the 10-year and 25-year check flows to determine the risk of damage when they occur during the time the diversion is in place.

requirements as that of a permanent structure, except as specified in this section.

Design diversion bridges using latest edition *AASHTO LRFD Bridge Design Specifications*. For seismic design requirements, refer to *BDM 1.17.2.1*.

The minimum road elevations for dry season and all-year diversions are the elevations at which the roadway will not overtop during the 2-year or 5-year flows, respectively. *Section 3.9* of the ODOT Hydraulics Manual furnishes more detailed guidance on requirements for either duration detour.

Consider and address other issues, such as maintenance needs, fish passage, navigational clearance, or other site-specific needs.

The crossing of FEMA floodways with temporary structures requires special consideration. Temporary structures must meet additional hydraulic requirements when they are in place across the floodway between November 1 and May 31.

During the design process, contact Region Tech Center staff for assistance as soon as possible when the structure is to cross a floodway during these months.

*Section 3.9* of the ODOT Hydraulics Manual furnishes more detailed guidance on FEMA policy requirements.

**STRUCTURAL REQUIREMENTS**

Design all structures on public roads, temporary or permanent, to carry all anticipated loads, and forces. Temporary structures must also resist lateral loads caused by hydraulics, debris, ice, wind and other applied forces when they exist. Design diversion bridges over waterways assuming scour depths and design flood in accordance with the ODOT Hydraulics Manual and Hydraulics Report.

Mechanically connect members of the diversion bridge together. Design mechanical connections with a minimum capacity to resist a load in any direction, including uplift on the stringer, of not less than 500 pounds. Install all associated connections before traffic is allowed to pass beneath the span. All members at a connection need to resist the developed connection force. Design the substructure to resist all applied combined axial and lateral loads and the minimum connection design force.

**1.38.2.1 Agency Provided Diversion Bridge**

ODOT has one-lane and two-lane diversion bridges ready to erect at different locations. Provide a drawing showing the bridge footprint and foundation drawings.

Use Special Provision (*SP 00251*) for these diversion bridges.

Contractor designed diversion bridge will follow all required design steps as the design of permanent bridges. Provide necessary data to the contractor in the Special Provisions (*SP 00250*) to accelerate design such as:

- Geotechnical report.
- Hydraulics report.
- Environmental study and limitations.
- In water work window.

Furnish information on the plans not limited to following:

- Minimum structure width, length and number of traffic lanes.
- Permit load (for permit load route).
- Minimum vertical and horizontal clearances when over crossing existing highway.
- All project specific requirements (utilities, sidewalk, railroad, etc.).

**C1.38.2.1**

Contact the Bridge Operations Engineer for availability, scheduling and technical information of these bridges.

### **1.38.3 Falsework**

#### **GENERAL**

Provide minimum jacking force capacity for lifting an existing superstructure for bearing replacement or bridge raising of 1.50 times superstructure loads (including any supported live loads) at jacking time.

The vertical load used for the design of falsework posts and foundation shall be at least 150 percent of the distributed load to that post.

When an existing structure footing supports the post, limit the stress on the concrete footing from all combined loads to 80 percent of permissible concrete stress. Additionally limit the foundation loads to the allowable foundation bearing capacity.

Seismic design load is not required for temporary falsework.

For falsework spans over roadways and railroads, mechanically connect all falsework stringers to the falsework cap or framing. The mechanical connections shall be capable of resisting a load in any direction, including uplift on the stringer, of not less than 500 pounds. Install all associated connections before traffic is allowed to pass beneath the span.

For falsework over navigable waterways, obtain US Coast Guard (USCG) approvals and/or permits, as required. Provide details, clearances, requirements and details required by the USCG.

### **C1.38.3**

Refer to *SP 00540.41* and *SP 00540.42* for additional design requirements at highway and railroad traffic openings.

Refer to [Caltrans Falsework Manual](#) for more guidance and example problems.

Provide, as a minimum, the following design calculations and detailing of falsework drawings, for a falsework supported by existing columns of a structure for widening projects or maintenance work:

- Complete connection details.
- Location of resin bonded anchors with a note to locate the existing reinforcing prior to drilling holes with GPR or approved equal method.
- Provide note for the contractor to field verify the location of holes prior to connection fabrication when using resin bonded anchor rods or thru holes for bolted connections to support endplates or bracket connections.
- Connection designed for 150 percent of the applied loads.
- Connection designed for wind load.
- Stress on existing column and supporting foundation does not exceed 80 percent allowable of each member.
- Limit the foundation loads to the allowable foundation bearing capacity.

### BRIDGE DECK FALSEWORK

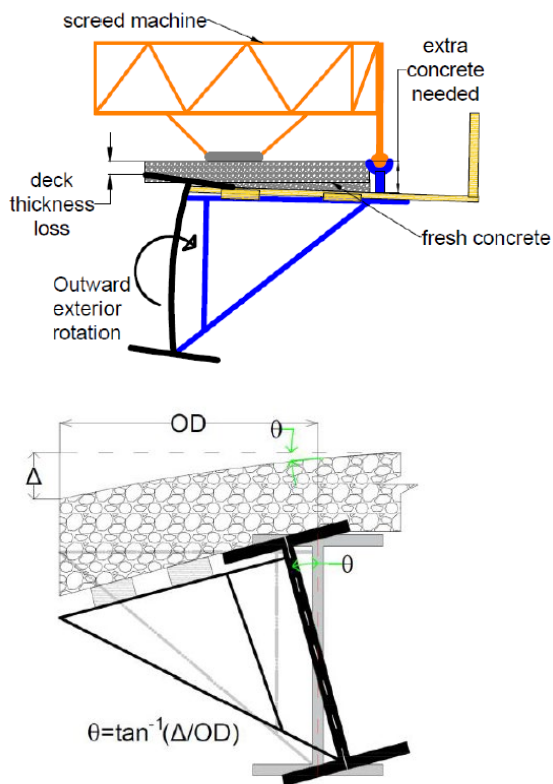
The deck form for interior girders is usually set on the joists hung on from top flanges or supported by post from bottom flanges. ODOT does not recommend use of embedded hangers welded to top flanges or shear studs projecting from top flanges.

Do not drill or punch holes through the girder flanges or the web of interior girders for temporary work.

The *Construction Handbook for Bridge Temporary Works* has design examples for cantilever deck forming for steel girders and deck overhang brackets.

During deck placement operations there is a tendency for exterior girder to laterally deflect and rotate. When the deflection at the overhang tip ( $\Delta$ ) is larger than 3/16in, the displacement and rotation can lead to thin decks and an upward shift in bar mats which can decrease concrete cover. The tendency to laterally deflect and rotate is greater for shallow girders with large deck overhang.

Figure 1.38.4-1 Girder Rotation



Horizontal loads applied to the girder flanges by the falsework will produce a torsional moment in the girder. To prevent possible overstressing of the permanent diaphragm connections and distortion on girder web, the falsework design must include temporary struts and/or ties to resist the full torsional moment and to prevent appreciable relative vertical movement between the edge of deck form and the adjacent steel girder.

Include the following requirements in the specification to control the manner falsework loads are applied to the steel girder, and thus prevent undesirable distortion of the permanent structure.

The contractor is responsible to provide sufficient temporary bracing to minimize lateral deflection and rotation of exterior steel girders during deck placement. Partially or fully installed permanent bracing as shown in the plans shall not be assumed sufficient to minimize lateral deflection and rotation of exterior girders during deck placement.

Construct falsework and concrete forms on steel structures such that loads applied to girder webs:

- Are applied within 6 inches of a flange or stiffener.
- Do not produce local distortion of the web.
- Provide temporary struts and ties to resist lateral loads applied to girder flanges and prevent appreciable vertical movement between the edge of deck form and the adjacent steel girder.

- Temporary bracing shall not be welded to the steel girders or its attachments including the studs.

When drilled holes are used to attach the falsework brackets, note the following issues:

- Leaving bolt holes unfilled can reduce the fatigue performance of the member.
- Unfilled holes need subsequent bridge inspection.
- Moisture entrapment and acceleration of main member deterioration due to rust.

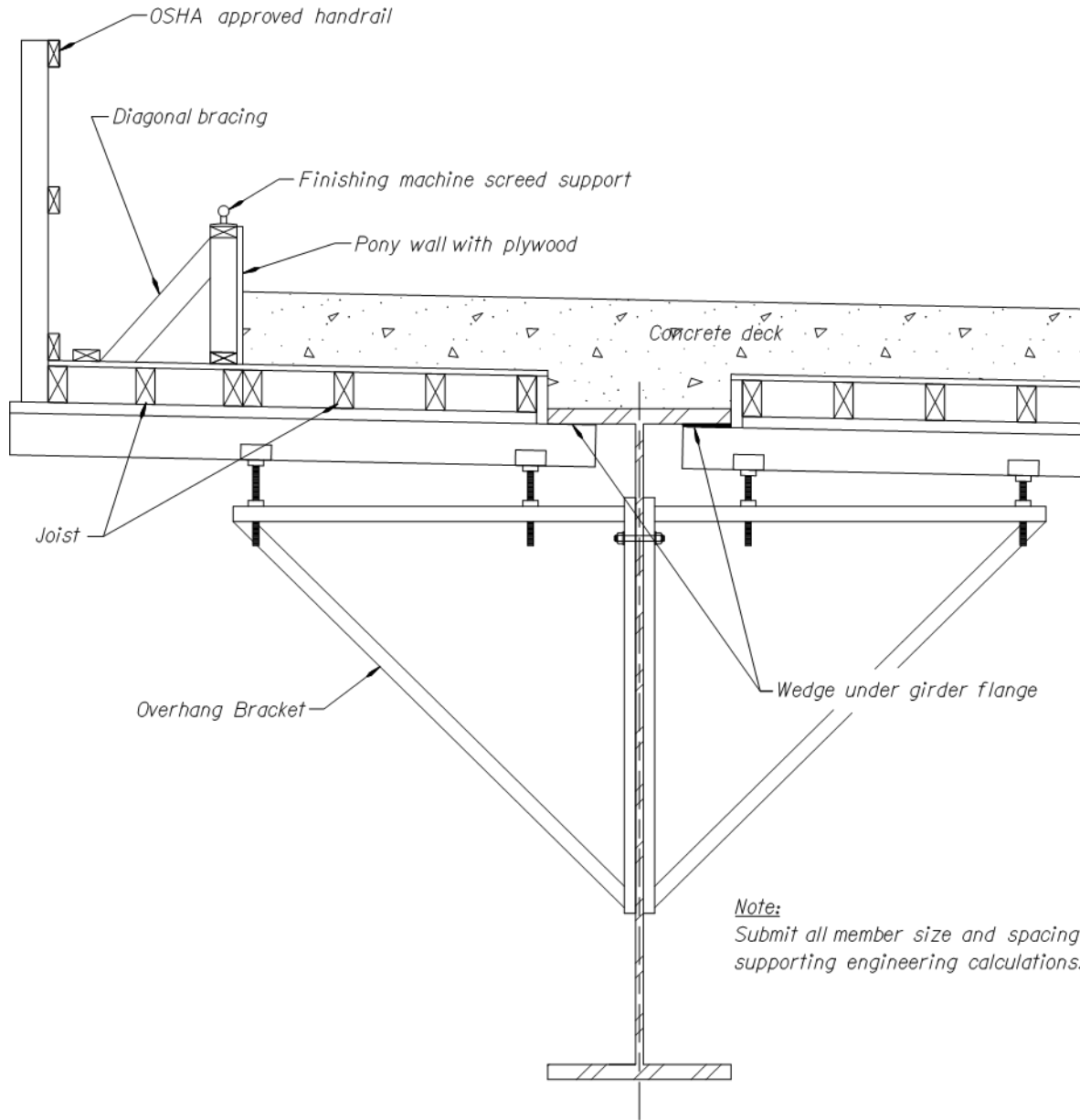
When drilled holes are used to attach the falsework brackets, the contractor is responsible to fill the hole with a high-strength *ASTM AF3125* Type 3 fully tensioned bolt, rotational capacity testing not required. The use of button-head twist-off bolts (*ASTM F1852* or *F2280*) is also allowed and may improve the aesthetics.

The contractor may provide double overhang brackets to minimize lock in stresses in exterior girders. *Figure 1.38.4-2* illustrates typical deck forming details using opposed overhang brackets attached to a steel girder.



Figure 1.38.4-2 – Typical Deck Forming

Detail



*Note:*  
Submit all member size and spacing with supporting engineering calculations.

**PILING**

When using piling to support the falsework, the falsework plans shall specify the minimum required bearing capacity and the required depth of penetration for the piling. Provide the field method for determining the required pile bearing capacity.

Also, the falsework drawings shall show the maximum horizontal distance the top of a falsework pile may be pulled in order to position the pile under the cap. The falsework plans shall show the maximum allowable deviation of the top of the pile, in the final position, from a vertical line through the point of fixity of the pile.

The calculations shall account for pile stresses due to combined axial and flexural stress and secondary stresses. Show the stresses and deflections in load supporting members in the design calculations.

**SPREAD FOOTINGS**

When spread footings are used to support falsework, the falsework plans shall specify the minimum required bearing capacity, depth of embedment for the footings, and maximum allowable settlement. Design spread footings to adequately resist all imposed vertical loads and overturning moments.

Provide the soil parameters and groundwater conditions in the design calculations for the spread footings. Provide design calculations for allowable bearing capacity and settlement.

Show the estimated footing settlement under the imposed design loads on the plans. Provide provisions for addressing the effects of footing and falsework settlement.

**BRACING**

Do not attach bracing to concrete traffic barrier, guardrail posts, or guardrail.

Design all falsework bracing systems to resist the horizontal design loads in all directions with the falsework in either the loaded or unloaded condition. The falsework plans must show all bracing, connection details, specific locations of connections, and hardware used.

Thoroughly analyze falsework diagonal bracing. Give particular attention to the connections. The allowable stresses in the diagonal braces may be controlled by the joint strength or the compression stability of the diagonal.

Design cross-bracing members and connections to carry tension, as well as compression, to prevent falsework beam or stringer compression flange buckling. The falsework plans must show all components, connection details and specific locations. Install bracing, blocking, struts, and ties required for positive lateral restraint of beam flanges at right angles to the beam in plan view. When possible, set bracing in adjacent bays in the same transverse plane. However, when because of skew or other considerations, it is necessary to offset the bracing in adjacent bays, the offset distance shall not exceed twice the depth of the beam.

Provide bracing to withstand all imposed loads during erection of the falsework and all phases of construction for falsework adjacent to any roadway, sidewalk, or railroad track which is open to the public. Install all details of the falsework system that contribute to horizontal stability and resistance to impact, including the bolts in bracing, at the time each element of the falsework is erected and shall remain in place until the falsework is removed. The falsework plans shall show provisions for any supplemental bracing or methods to be used to conform to this requirement during each phase of erection and removal. Include wind loads in the design of such bracing or methods.

## **1.38.4 Shoring**

Refer to the *ODOT Geotechnical Design Manual Section 15.3.26* for the design of temporary shoring, and defined shoring systems. Shoring is exclusive of cofferdams.

See *SP 00510.04* for plan requirements. Modify the special provision to include acceptable types of shoring as allowed. Consult with the geotechnical designer to determine safe slopes, minimum shoring lengths, and when there are unusual soil, clearance, or site conditions that may make shoring construction difficult.

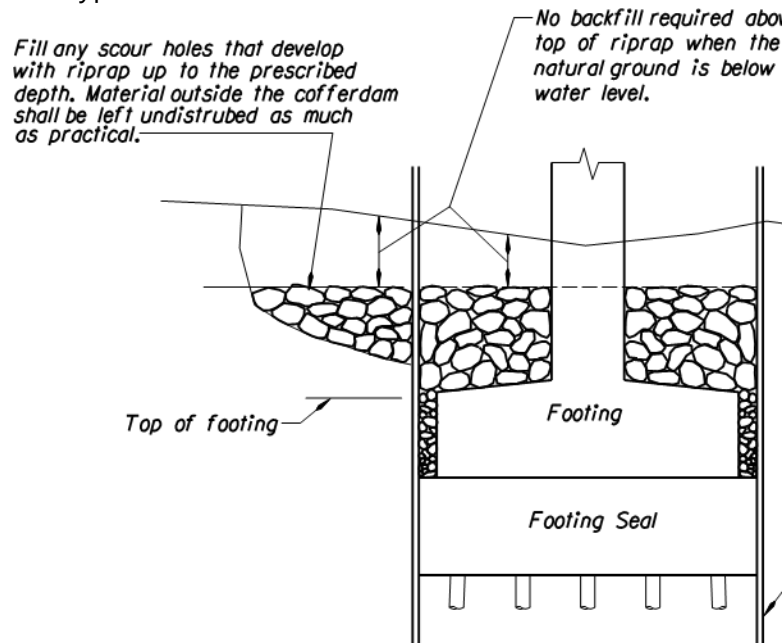
Provide shoring stationing on the project plans and list stationing in the Special Provision.

## **1.38.5 Cofferdams**

### **1.38.5.1 Earth Pressure**

When cofferdams are required and passive earth pressures are assumed in the design, show a detail similar to *Figure 1.38.6.1-1* on the plans. Material outside cofferdams should also be undisturbed and backfilled with riprap when disturbed

Figure 1.38.5.1-1 – Typical Cofferdam Detail



## 1.38.5.2 Cofferdam Seals

### SEALS, GENERAL

Only use seals when the sheet piles cannot be driven to sufficient depth to cut off the water pressure.

The sheet piling must penetrate and form a seal in the soil so that there is no water flow under the sheet piling. In practice there will be some water entering the cofferdam. Energy is dissipated as the water flows down around the bottom of the sheet piles. Develop a flow net to determine the actual hydrostatic forces. The equipotential flow lines will show a reduction in the hydrostatic uplift forces. The hydrostatic uplift forces will be resisted by the friction between the soil and the sheet piles and the buoyant weight of the soil plug. Additionally, horizontal hydrostatic forces are present and must be designed for. These are special conditions and require detailed hydraulic and foundation studies.

### COFFERDAMS WITHOUT SEALS

There may be some locations and soil types where a seal may not be required for footing and column construction. The normal sequence of construction for a cofferdam without a seal includes:

Water level is the same inside and outside the cofferdam:

- Construct cofferdam - normally driven interlocking steel sheet pile.
- Cut vent holes in the sheet piling. Place vent holes at the maximum design water level elevation and allows water to enter the cofferdam. Cut a vent hole at the design elevation

to prevent cofferdam failure.

- Excavate material inside the cofferdam to the bottom of the footing elevation. Excavation may also be done after dewatering, when there is no seal required, when the internal bracing is in place.
- Place internal bracing. Usually horizontal bracing consists of wales, frames, and/or struts to resist the horizontal hydrostatic forces.
- Drive footing piles, when required. This may also be done after dewatering and after excavation.

Water is removed from the cofferdam:

- Install continuous pumping system. Cofferdams are never completely watertight and a sump system is normally installed to keep the cofferdam relatively dry.
- Cut piles to the specified elevation, when used.
- Construct footing and column in the dry.

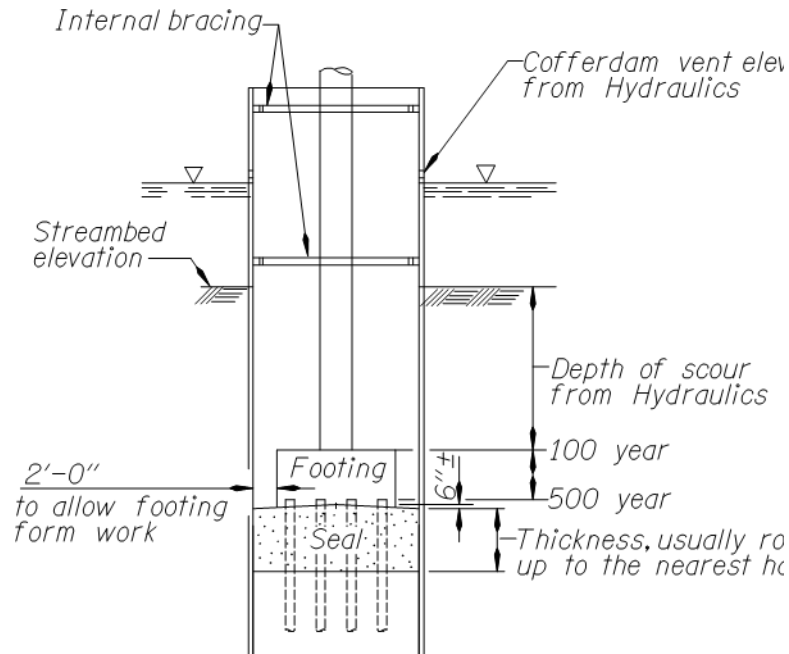
Cofferdam is flooded:

- Remove internal bracing.
- When agreed to by the environmental section, riprap is placed before or after the sheet piling is removed. It may be desirable to place riprap inside the cofferdam. Check with the geotechnical designer.
- Extract sheet piling.

### **COFFERDAMS WITH A SEAL**

A seal is usually an unreinforced mass of concrete that seals the bottom of a cofferdam and allows construction of the footing and column inside of a dewatered or dry cofferdam. (See *Figure 1.38.6.2-1*)

Figure 1.38.6.2-1 – Seal Thickness Detail



The normal sequence of construction of a cofferdam with a seal depends on water level.

When water level is the same inside and outside the cofferdam:

- Construct cofferdam - normally driven interlocking steel sheet pile.
- Cut vent holes in the sheet piling. Place vent holes at the maximum design water level elevation and allows water to enter the cofferdam. Cut a vent hole at the design elevation to prevent cofferdam failure. The contractor may propose to use a lower vent elevation and thinner seal, when the anticipated water elevation is lower at the time of construction.
- Excavate material inside the cofferdam to the bottom of the seal elevation.
- Place internal bracing. Usually horizontal bracing consists of wales, frames, and/or struts to resist the horizontal hydrostatic forces.
- Drive footing piles, when required.
- Place seal concrete.
- With a tremie: A tremie is a long pipe that extends to the bottom of the seal and prevents the concrete from segregating as it passes through the water, as well as permitting a head to be maintained on the concrete during placement. The bottom of the tremie is kept submerged in the mass of concrete to minimize water intrusion into the mix.
- With a concrete pump: Similar principle to the tremie.

When water is removed from the cofferdam:

- Dewater cofferdam, only after the concrete has gained sufficient strength to resist hydrostatic loads.
- Install continuous pumping system. Cofferdams are never completely watertight and a sump system is normally installed to keep the cofferdam relatively dry.
- Cut piles to the specified elevation, when used.
- Prepare seal for footing construction. Level and clean, as needed, for constructing footing

forms.

- Construct footing and column in the dry.

When cofferdam is flooded:

- Remove internal bracing.
- Place rip-rap before or after the sheet piling are removed. It may be desirable to place rip-rap inside the cofferdam. Check with the geotechnical designer.
- Extract sheet piling.

### **1.38.5.3 Seal Design Considerations**

The seal forms a plug at the bottom of the cofferdam. It uses a combination of seal mass and/or friction between the seal concrete and piling to resist the hydrostatic forces.

Scour protection for the footing influences the location (depth) of the footing and must be incorporated into the design. The Hydraulics Unit provides this information.

The top of the footing should be below the 100-year scour depth and the bottom of footing below the 500-year scour depth. The Hydraulics Unit provides these elevations.

Normally the friction or bond between the seal concrete and steel piling is assumed to be 10 psi for the surface area of the embedded pile. Check with the geotechnical designer for bond values of other pile types.

An uplift capacity of driven piling should also be obtained from the geotechnical designer to include in the overall stability or factor of safety of the system.

The minimum factor of safety of the system should be one. Note: The actual factor of safety is greater because the bond between the seal and sheet piling has been neglected.

A general rule of thumb, or good starting point, for seal thickness is 0.40 times (head of water plus an estimated seal thickness) for spread footings and 0.25 times (head of water plus an estimated seal thickness) for pile supported footings.

Use a minimum depth of seal of four feet, where piles are calculated to resist uplift in order to reduce seal depth.

Design pile footings that includes a seal for bending and shear ignoring any beneficial effects of the seal. This is due to the uncertain quality of the seal concrete and because the seal may be reduced or eliminated during construction.

There are two ways of looking at the cofferdam system when determining the seal thickness. Each should result in the same seal thickness:

- Method 1: Assume there is some leakage around the seal and the actual water level inside the cofferdam is at the top of the seal. Base the hydrostatic uplift force on the depth of water to the top of the seal, but because it is submerged the weight of the seal must be determined using the buoyant weight. Examples of this design are shown in *BDM Appendix 1.38.5.3*.
- Method 2: Assume the seal prevents any leakage and the hydrostatic uplift depth is to the bottom of the seal. Use the full weight of the seal to resist the uplift forces.



## **APPENDIX – SECTION 1 – Glossary**

### **A**

**Abutment** - Supports at the end of the bridge used to retain the approach embankment and carry the vertical and horizontal loads from the superstructure. Current terminology is bent or end bent.

**Access Control** - The condition where the legal right of owners or occupants of abutting land to access a highway is fully or partially controlled by the Department of Transportation.

**Advance Plans** – 95-100% complete plans including special provisions, normally sent at 15 weeks.

**Advertisement** - The period of time between the written public announcement inviting proposals for projects and the opening of the proposals (bid or letting date).

**Aggregate** - Inert material such as sand, gravel, broken stone, or combinations thereof.

**Aggregate, Coarse** - Aggregates predominantly retained on the No. 4 sieve for portland cement concrete and those predominantly retained on the 1/4" for asphalt concrete.

**Aggregate, Fine** - Those aggregates which entirely pass the 3/8" sieve.

**Aggregate, Dense Graded** - A well-graded aggregate so proportioned as to contain a relatively small percentage of voids.

**Aggregate, Open Graded** - A well-graded aggregate containing little or no fines, with a relatively large percentage of voids.

**Aggregate, Well-Graded** - An aggregate possessing proportionate distribution of successive particle sizes.

**Air-Entraining Agent** - A substance used in concrete to increase the amount of entrained air in the mixture. Entrained air is present in the form of minute bubbles and improves the workability and frost resistance.

**Allowable Headwater** - The maximum elevation to which water may be ponded upstream of a culvert or structure as specified by law or design.

**Allowable Span** – The greatest horizontal distance permitted between supports.

**Anchor Bolts** - Bolts that are embedded in concrete which are used to attach an object to the concrete such as rail posts, bearings, steel girder-to-crossbeam connections, etc.

**Annual Average Daily Traffic (AADT)** – The average 24-hour traffic volume at a given location over a full 365 day year.

**Anode** - The positively charged pole of a corrosion cell at which oxidations occur.

Apron - The paved area between wingwalls at the end of a culvert.

Arch - A curved structure element primarily in compression, producing at its support reactions having both vertical and horizontal components.

Arch Pipe - A conduit in the form of a broad arch without a bottom.

Average Daily Traffic (ADT) - The average 24-hour traffic volume at a given location for some period of time, being the total volume during a stated period divided by the number of days in that period. Unless otherwise stated, the period is a year.

Axle Load - The load borne by one axle of a traffic vehicle.

Award - Written notification to the bidder that the bidder has been awarded a contract.

### **B**

Backfill - Material used to replace or the act of replacing material removed during construction; also may denote material placed or the act of placing material adjacent to structures.

Backwater - The water upstream from an obstruction in which the free surface is elevation above the normal water surface profile.

Bar Chair - A device used to support horizontal reinforcing bars above the base of the form before the concrete is poured.

Bar Cutting Diagram - A diagram used in the detailing of bar steel reinforcement where the bar lengths vary as a straight line.

Base Course - The layer of specified material of designed thickness placed on a subbase or a subgrade to support a surface course.

Bascule Bridge - A bridge over a waterway with one or two leaves which rotate from a horizontal to a near-vertical position, providing unlimited clear headway.

Base Flood - Flood having 1% chance of being exceeded in any given year.

Battered Pile - A pile driven in an inclined position to resist horizontal forces as well as vertical forces.

Beam - Main longitudinal load carrying member in a structure, designed to span from one support to another (girder).

Bearings - Device to transfer girder reactions without overstressing the supports.

Bearing Capacity - The load per unit area which a structural material, rock, or soil can safely carry.

Bearing Failure - A crushing of material under extreme compressive load.

Bearing Seat - A prepared horizontal surface at or near the top of a substructure unit upon which the bearings are placed.

**Bearing Stiffener** - A stiffener used at points of support on a steel beam to transmit the load from the top of the beam to the support point.

**Bedrock** - The solid rock underlying soils or other superficial formation.

**Bench Mark** - A relatively permanent material object bearing a marked point whose elevation above or below an adopted datum is known.

**Bent** - Supports at the ends or intermediate points of a bridge used to retain approach embankments and/or vertical and horizontal loads from the superstructure.

**Bicycle Lane** - A lane in the traveled way designated for use by bicyclists.

**Bicycle Path** - A public way physically separated from the roadway, that is designated for use by bicyclists.

**Bid Schedule** - The list of bid items, their units of measurement, and estimated quantities, bound in the proposal booklet. (When a contract is awarded, the Bid Schedule becomes the Schedule of Contract Prices.)

**Bidder** - Any qualified individual or legal entity submitting a proposal in response to an advertisement.

**Biennium** - For the State of Oregon, a two-year period, always odd numbered years, starting July 1 and ending two years later on June 30.

**Bleeding (Concrete)** - The movement of mixing water to the surface of freshly placed concrete.

**Bowstring Truss** - A general term applied to a truss of any type having a polygonal arrangement of its top chord members conforming to or nearly conforming to the arrangement required for a parabolic truss.

**Box Beam** - A hollow structural beam with a square, rectangular, or trapezoidal cross-section.

**Box Culvert** - A culvert of rectangular or square cross-section.

**Breakaway** - A design feature that allows a device such as a sign, luminaire, or traffic signal support to yield or separate upon impact. The release mechanism may be a slip plane, plastic hinges, fracture elements, or a combination of these.

**Bridge** - A structure spanning and providing passage over a river, chasm, road, or the like, having a length of 20 feet or more from face to face of abutments or end bents, measured along the roadway centerline.

**Bridge Approach** - Includes the embankment materials and surface pavements that provide the transition between bridges and roadways.

**Bridge Approach Slab** - A reinforced concrete slab placed on the approach embankment adjacent to and usually resting upon the abutment back wall; the function of the approach slab is to carry wheel loads on the approaches directly to the abutment, thereby eliminating any approach roadway misalignment due to approach embankment settlement.

**Bridging** - A carpentry term applied to the cross-bracing fastened between timber beams to increase the rigidity of the floor construction, distribute more uniformly the live load and minimize the effects of impact and vibration.

**Bridge Railing** - A longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure.

**Brush Curb** - A curb 10" or less in width, which prevents a vehicle from brushing against the railing or parapet.

**Buckle** - To fail by an inelastic change in alignment as a result of compression.

**Built-Up Member** - A column or beam composed of plates and angles or other structural shapes united by bolting, riveting or welding.

**Bulkhead** – A partition built into wall forms to terminate each placement of concrete.

**Buoyancy** - Upward force exerted by the fluid in which an object is immersed.

**Bushings** - A lining used to reduce friction and/or insulate mating surfaces usually on steel hanger plate bearings.

**Butt Splice** - A splice where the ends of two adjoining pieces of metal in the same plane are fastened together by welding.

**Butt Weld** - A weld joining two abutting surfaces by combining weld metal and base metal within an intervening space.

### C

**Cable-Stayed Bridge** - A bridge in which the superstructure is directly supported by cables, or stays, passing over or attached to towers located at the main piers.

**CADD** - Computer-Aided Design and Drafting.

**Caisson** - A watertight box of wood or steel sheeting; or a cylinder of steel and concrete, used for the purpose of making an excavation. Caissons may be either open (open to free air) or pneumatic (under compressed air).

**Camber** - A predetermined vertical curvature built into a structural member, to allow for deflection and/or vertical grade.

**Cast-in-Place** - The act of placing and curing concrete within formwork to construct a concrete element in its final position.

**Catch Basin** - A receptacle, commonly box shaped and fitted with a grided inlet and a pipe outlet drain, designed to collect the rain water and floating debris from the roadway surface and retain the solid material so that it may be periodically removed.

**Catenary** - The curve obtained by suspending a uniform rope or cable between two points.

**Cathode** - The negatively charged pole of a corrosion cell that accepts electrons and does not corrode.

**Cathodic Protection** - A means of preventing metal from corroding; this is done by making the metal a cathode through the use of impressed direct current and by attaching a sacrificial anode.

**Catwalk** - A narrow walkway to provide access to some part of a structure.

Chain Drag - A series of short medium weight chains attached to a T-shaped handle; used as a preliminary technique for inspecting a large deck area for delamination.

Chamfer – A beveled edge formed in concrete by a triangular strip of wood (chamfer strip) placed in a form corner.

Change Order - A written order issued by the Engineer to the Contractor modifying work required by the contract and establishing the basis of payment for the modified work.

Chord - A generally horizontal member of a truss.

Clay - Soil passing a No. 200 sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents.

Clear Zone - Roadside border area, starting at the edge of the traveled way, that is available for safe use by errant vehicles. Establishing a minimum width clear zone implies that rigid objects and certain other hazards with clearances less than the minimum width should be removed and relocated outside the minimum clear zone, or remodeled to make breakaway, shielded, or safely traversable.

Closed Spandrel Arch - A stone or reinforced concrete arch span having spandrel walls to retain the spandrel fill or to support either entirely or in part the floor system of the structure when the spandrel is not filled.

Cobbles - Particles of rock, rounded or not, that will pass a 12" square opening and be retained on a 3" sieve.

Cofferdam - A barrier built in the water so as to form an enclosure from which the water is pumped to permit free access to the area within.

Cohesionless Soil - A soil that when unconfined has little or no strength when air-dried and that has little or no cohesion when submerged.

Cohesive Soil - A soil that when unconfined has considerable strength when air-dried and that has significant cohesion when submerged. Clay is a cohesive soil.

Commission - The Oregon Transportation Commission.

Composite Section - Two sections made of the same or different materials together to act as one integral section; such as a concrete slab on a steel or prestressed girder.

Compression Seals - A preformed, compartmented, elastomeric (neoprene) device, which is capable of constantly maintaining a compressive force against the joint interfaces in which it is inserted.

Concept Plans – plans to determine the basic features of a project including alignments, typical sections, slopes, preliminary drainage and TS&L bridge plans.

Concrete Overlay – 1.5" to 2" of concrete placed on top of the deck, used to extend the life of the deck and provide a good riding surface.

Contract - The written agreement between the Division and the Contractor describing the work to be done and defining the obligations of the Division and the Contractor.

Contract Plans - Detailed drawings and diagrams usually made to scale showing the structure or arrangement, worked out beforehand, to accomplish the construction of a project and/or object(s).

**Contract Time** - The number of calendar days shown in the proposal which is allowed for completion of the work.

**Contraction Joint** - A joint in concrete that does not provide for expansion but allows for contraction or shrinkage by the opening up of a crack or joint.

**Contractor** - The individual or legal entity that has entered into a contract with the Division.

**Coordinates** - Linear or angular dimensions designating the position of a point in relation to a given reference frame. It normally refers to the State Plane Coordinate System.

**Core** - A cylindrical sample of concrete removed from a bridge component for the purpose of destructive testing.

**Counterfort Wall** - A reinforced concrete retaining wall whose vertical stem has triangular-shaped ribs projecting into the soil and spaced at regular intervals to provide strength and stability.

**Crash Cushion** - An impact attenuator device that prevents an errant vehicle from impacting fixed object hazards by gradually decelerating the vehicle to a safe stop or by redirecting the vehicle away from the hazard.

**Crash Tests** - Vehicular impact tests by which the structural and safety performance of roadside barriers and other highway appurtenances may be determined. Three evaluation criteria are considered, namely (1) structural adequacy, (2) impact severity, and (3) vehicular post-impact trajectory.

**Creep** - Time dependent inelastic deformation under elastic loading of concrete or steel resulting solely from the presence of stress.

**Cross-bracing** - Bracing used between stringers and girders to hold them in place and stiffen the structure.

**Cross-section** - The exact image formed by a plane cutting through an object usually at right angles to a central axis.

**Crown Section** - Roadway section with the height of the center of the roadway surface above its gutters.

**Culvert** - Federal Highway Administration definition: "A structure not classified as a bridge having a span of 20 feet or less spanning a watercourse or other opening on a public highway"; a conduit to convey water through an embankment.

**Curb** - A vertical or sloping member along the edge of a pavement or shoulder forming part of a gutter, strengthening or protecting the edge, and clearly defining the edge of vehicle operators. A curb is a horizontal offset varying from 10" to less than 18". The surface of the curb facing the general direction of the pavement is called the "face".

**Curing** - The preparation of a material by chemical or physical processing for keeping or use; treating concrete by covering its surface with some material to prevent the rapid evaporation of water.

**Cut-Off-Wall** - A wall built at the end of a culvert apron to prevent the undermining of the apron.

## D

**Dead End** - End of post-tensioned bridge where tendons are anchored but no jacking takes place (opposite of jacking end).

**Dead Load** - Structure weight including future wearing surface on deck and attachments.

**Deadman** - A concrete mass, buried in the earth behind a structure, that is used as an anchor for a rod or cable to resist horizontal forces that act on the structure.

**Deformed Bars** - Concrete reinforcement consisting of steel bars with projections or indentations to increase the mechanical bond between the steel and concrete.

**Delamination** - Subsurface separation of concrete into layers.

**Department** - The Department of Transportation of the State of Oregon.

**Design Volume or Design Hourly Volume** - A volume determined for use in design representing traffic expected to use the highway. Unless otherwise stated, it is an hourly volume.

**Diaphragm** - Structural: A structural member used to tie adjoining girders together and stiffen them in a lateral direction as well as to distribute loads.

**Diamond Grinding** - Process to abrade or remove a surface, such as concrete, by the cutting action of rotating circular blade with diamond-tipped teeth.

**Direct Tension Indicator** - Load-indicating washer for bolts.

**Doby** - A precast block of concrete of various sizes used to support or provide clearances between reinforcing bars and formwork.

**Dolphins** - A group of piles or sheet piling driven adjacent to a pier. Their purpose is to prevent extensive damage or possible collapse of a pier from a collision with a ship or barge.

**Draped Strands** - Strand pattern for prestressing strands, where strands are draped to decrease the prestressing stress at the ends of the girder where the applied moments are small.

**Drift Pin** - A metal pin, tapered at both ends, used to draw members of a steel structure together by being driven through the corresponding bolt holes.

**Drip Groove** - A groove formed into the underside of a projecting concrete sill or coping to prevent water from following around the projection.

## E

**E** - modulus of elasticity of a material; the stiffness of a material.

**E&C** – Engineering & Contingencies. Engineering costs are ODOT's costs to administer the construction contract. Contingencies are unforeseen costs due to construction extra work price agreements or types of problems caused by weather, accidents, etc. by the contract pay item.

**Elastomeric Bearing Pads** - Pads  $\frac{1}{2}$ " and less in thickness made of all rubber-like material that supports girders and concrete slabs; pads over  $\frac{1}{2}$ " in thickness consist of alternate laminations of elastomer and metal.

End-Bearing Pile - A pile which provides support primarily due to reaction at its tip.

Environmental Classes – Classes (1, 2 or 3) that ????????

Environmental Class I Environmental Impact Statement: Projects that normally involve significant changes in traffic capacities and patterns. These projects generally involve major right-of-way acquisitions. Both draft and final Environmental Impact Statements are required.

Environmental Class II Categorical Exclusions: Projects that normally involve the improvement of pavement conditions on traffic safety, but little, if any, change in traffic capacities or patterns. Right-of-way requirements must be minor. These projects are categorically excluded from further environmental documentation, unless permit requirements indicate otherwise.

Environmental Class III Environmental Assessment: Projects that do not clearly fall within Class I or Class II. These projects require assessments to determine their environmental significance.

Epoxy - A synthetic resin which cures or hardens by chemical reaction between components which are mixed together shortly before use.

Epoxy Coated Rebar - Steel reinforcement coated with a powdered epoxy resin, to prevent corrosion of the bar steel.

Expansion Bearings - Bearings that allow longitudinal movement of the superstructure relative to the substructure and rotation of the superstructure relative to the substructure.

Expansion Device - A device placed at expansion points in bridge superstructures to carry the vertical bridge loads without preventing longitudinal movement.

Expansion Joint - A joint in concrete that allows expansion due to temperature changes, thereby preventing damage to the structure.

Extra Work - Work not included in any of the contract items as awarded but determined by the Engineer necessary to complete the project according to the intent of the contract. This may be paid on a negotiated price, force account, or established price basis.

Extrados - The curved edge of an arch rib or barrel formed by the intersection of the top and side arch surfaces.

## F

Falsework - In general, a temporary construction work on which a main or permanent work is wholly or partially supported until it becomes self-supporting. For cast-in-place concrete or steel construction, it is a structural system to support the vertical and horizontal loads from forms, reinforcing steel, plastic concrete, structural steel, and placement operations.

Fatigue - The tendency of a member to fail at a lower stress when subjected to cyclical loading than when subjected to static loading.

Fatigue Crack - Any crack caused by repeated cyclic loading.

Federal-Aid System of Highways - The national system of interstate highways, Federal-aid highway system,



system of secondary and feeder roads, Federal-aid grade crossing projects, federal forest highway systems and projects and other highway and related projects, all within the meaning of the Federal-Aid Road Act (1916), and all acts amendatory thereof and supplementary thereto, and the federal regulations issued under such acts.

Fender - A structure that acts as a buffer to protect the portions of a bridge exposed to floating debris and water-borne traffic from collision damage.

Fiscal Year - For the State of Oregon, July 1 through June 30 of the next year; for the Federal government, October 1 through September 30 of the next year. The Federal fiscal year (FY) is broken into quarters:

F1Q (October, November, December)

F2Q (January, February, March)

F3Q (April, May, June)

F4Q (July, August, September)

Felloe Guard - Timber curb, usually 10" x 12", bolted to timber deck and timber rail post. Sometimes called wheel guard.

Filler Plate - A steel plate or shim used for filling in space between compression members.

Fixed Bearings - Bearings that do not provide for any longitudinal movement of the superstructure relative to the substructure, but allows for rotation of the superstructure relative to the substructure.

Flat Slab - A reinforced concrete superstructure that has a uniform depth throughout.

Flood Plain - An area that would be inundated by a flood.

Floodway - A stream channel plus any adjacent flood plain areas that must be kept free of encroachment so that the 100-year flood can be conveyed without substantial increases in flood heights.

Floor Beam - A transverse structural member that extends from truss to truss or from girder to girder across the bridge.

Flux - A material that protects the weld from oxidation during the fusion process.

Force Account Work - Items of extra work ordered by the Engineer that are to be paid for by material, equipment, and labor.

Forms - A structural system constructed of wood or metal used to contain the horizontal pressures exerted by plastic concrete and retain it in its desired shape until it has hardened.

Fracture Critical Members - Members of a bridge where a single fracture in a member can lead to collapse.

Fracture Mechanics - Study of crack growth in materials.

Free-Standing Retaining Wall – A retaining wall that is not part of the bridge abutment walls.

Friction Pile - A pile that provides support through friction resistance along the surface area of the pile.

Functionally Obsolete Bridges - Those bridges which have deck geometry, load carrying capacity (comparison of the original design load to the current state legal load), clearance, or approach roadway alignment which no longer meet the usual criteria for the system of which they are a part as defined by the Federal Highway Administration.

### G

Gabions - Rock-filled wire baskets used to retain earth and provide erosion control.

Galvanic Action - Electrical current between two unlike metals.

Galvanize - To coat with zinc.

Geotextiles - Sheets of woven or non-woven synthetic polymers or nylon used for drainage and soil stabilization.

Girder - Main longitudinal load carrying member in a structure (beam).

Glare Screen - A device used to shield a driver's eye from the headlights of an oncoming vehicle.

Grade Separation - A crossing of two highways or a highway and a railroad at different levels.

Gravity Wall - A retaining wall that is prevented from overturning by its weight alone.

Green Concrete - Concrete that has set but not appreciably hardened.

Grid Flooring - A steel floor system comprising a lattice pattern which may or may not be filled with concrete.

Grout - A mixture of cementitious material and water having a sufficient water content to render it a free-flowing mass, used for filling (grouting) the joints in masonry, for fixing anchor bolts and for filling post-tensioning ducts.

### H

Hammerhead Pier - A pier that has only one column with a cantilever cap and is somewhat similar to the shape of a hammer.

Hanger Plate - A steel plate that connects the pins at hinge points thus transmitting the load through the hinge.

Haunch - An increase in depth of a structural member usually at points of intermediate support.

Haunched Slab - A reinforced concrete superstructure that is haunched (has an increased depth) at the intermediate supports.

Headwall - A concrete structure at the ends of a culvert to retain and protect the embankment slopes, anchor the culvert, and prevent undercutting.

High Performance Concrete (HPC) – Concrete with enhanced properties including higher strength, greater durability and decreased permeability.

High Performance Steel (HPS) - Steel with enhanced properties including increased durability and weldability.

Hinge - A device used to hold the ends of two adjoining girders together, but does not allow for longitudinal

movement of the superstructure. A point in a structure where a member is free to rotate.

Holddown Device - A device used on bridge abutments to prevent girders from lifting off their bearings as a result of the passage of live load over the bridge.

Honeycomb - A surface or interior defect in a concrete mass characterized by the lack of mortar between the coarse aggregate particles.

Howe truss - A truss of the parallel chord type with a web system composed of vertical (tension) rods at the panel points with an X pattern of diagonals.

Hydration - The process by which cement combines with water to form a hard binding substance.

Hybrid Girder - A steel plate girder with the web steel having a lower yield strength than the steel in one or both flanges.

Hydrodemolition - Process to abrade or remove a surface, such as concrete, by streams of water ejected from a nozzle at high velocity.

### I

Incidental Work - Work necessary for fulfillment of the contract but which is not listed as a pay item in the contract and for which no separate or additional payment will be made.

Initial Set (Concrete) - Initial stiffening of concrete, with time based upon penetration of a weighted test needle. In the field, it is commonly assumed to be the time when the dead weight of vibrator does not penetrate into the concrete.

Inlet Control - The case where the discharge capacity of a culvert is controlled at the culvert entrance by the depth of headwater and the entrance geometry, including barrel shape, cross-sectional area, and inlet edge.

Intermediate Stiffener - A vertical transverse steel member used to stiffen the webs of plate girders between points of support.

Internal File Number - Number assigned by the Bridge Front Office as part of office automation (computerized files) and used to track all files.

Invert - The bottom or lowest point of the internal surface of the transverse cross-section of a pipe.

Inventory Rating (Design Load) - Load level that produces normal design stresses in the structures. The inventory rated load is the load that can safely utilize an existing structure for an indefinite period of time.

International System of Units (SI) - The modernized metric system.

Intrados - The curved edge of an arch rib or barrel formed by the intersection of the bottom and side arch surfaces.

Isotropic - Have the same material properties in all directions, e.g., steel.

### J

Jacking End - End of post-tensioned bridge where jacking takes place (opposite of dead end).

Jetting - Forcing water into holes in an embankment to settle or to compact the earth. Forcing water through holes in piles to install the piles to a specified depth before driving.

### K

Key Number - Number assigned to a project by Program Section to identify it in the Project Control System (PCS). All structures in a project have the same key number.

Kilogram (kg) - The base unit for mass in the International System of Units (metric).

King Post Truss - Two triangular panels with a common center vertical; the simplest of triangular trusses.

### L

Lacing - Small flat plates used to connect individual sections of built up members.

Laitance - A weak mortar that collects at the surface of freshly placed concrete, usually caused by an excess of mixing water or by excessive finishing.

Lamellar Tear - Incipient cracking between the layers of the base material (steel).

Lateral Bracing - Bracing placed in a horizontal plane between steel girders near the bottom and/or top flanges.

Latex Modified Concrete (LMC) - Emulsion of synthetic rubber or plastic obtained by polymerization used as a concrete additive to decrease permeability.

Leaf - The movable portion of a bascule bridge which forms the span of the structure.

Lenticular Truss - A truss having parabolic top and bottom chords curved in opposite directions with their ends meeting at a common joint; also known as a fish belly truss.

Level of Performance - The degree to which a longitudinal barrier, including bridge railing, is designed for containment and redirection of different types of vehicles.

Liquid Penetrant Inspection - Nondestructive inspection process for testing for continuities that are open to the surface, by using a liquid dye.

Live Load - Force of the applied moving load of vehicles and/or pedestrians.

Load Rating - Evaluation of the safe live load capacity of the weakest member of a bridge.

LRFD - Load Resistance Factor Design.

Longitudinal Stiffener - A longitudinal steel plate (parallel to girder flanges) used to stiffen the webs of welded plate girders. Normally thicker webs are used to eliminate longitudinal stiffeners.

Low Relaxation Strands - Prestressing tendons that are manufactured by subjecting the strands to heat treatment and tensioning causing a permanent elongation. This increases the strand yield strength and reduces strand relaxation under constant tensile stress.

### M

Magnetic Particle Inspection (MT) - Nondestructive inspection process for testing for the location of surface cracks or surface discontinuities, by applying dry magnetic particles to a weld area or surface area that has been suitably magnetized.

Microsilica (Silica Fume) (MC) - Very fine non-crystalline silica used as an admixture in concrete to improve the strength, permeability and abrasion resistance.

Minor Structure Concrete (MSC) - Nonstructural concrete furnished according to contractor proportioning, placed in minor structures and finished as specified. Previously called commercial concrete.

Modular Expansion Joints - Multiple, watertight joint assemblies for bridges requiring expansion movements greater than 4 inches.

Mud Sill - A timber platform laid on earth as a support for vertical members or bridge falsework.

Mylars - Full-size drawings on mylar. The final "legal" drawing used for signatures and printing contract plans.

### N

NDT - Nondestructive testing, a method of checking the structural quality of materials that does not damage them.

Negative Moment - The moment causing tension in the top fibers and compression in the bottom fibers of a structural member.

Negative Reinforcement - Reinforcement placed in concrete to resist negative bending moments.

Newton (N) - The derived unit for force (mass times acceleration or kg times  $m/s^2$ ) in the International System of Units (metric).

Nominal - Used to designate a theoretical dimension, size, or slope that may vary from the actual by a very small or negligible amount. Example: a 1" nominal diameter steel pipe has an actual 0.957" inside diameter.

Nominal Pile Resistance – LRFD term for the maximum axial pile bearing resistance. Equivalent to the ultimate pile capacity term used in allowable stress design.

Non-Redundant Structure - Type of structure with single load path, where a single fracture in a member can lead to the collapse of the structure.

Nosing – A bulkhead at the ends of bridges or at expansion joints made of a durable material to protect and reinforce the slab edge. It also provides a smooth edge or surface at expansion joints to facilitate

installation and provide a better seal.

### O

Operating Rating (Permit Loads) - The absolute maximum permissible stress level to which a structure may be subjected. It is that stress level that may not be exceeded by the heaviest loads allowed on the structure. Issue special permits for heavier than normal vehicles only if such loads are distributed so as not to produce stress in excess of the operating stress.

Outlet Control - The case where the discharge capacity of a culvert is controlled by the elevation of the tail water in the outlet channel and the slope, roughness, and length of the culvert barrel, in addition to the cross-sectional area and inlet geometry.

Orthotropic - A description of the physical properties of a material that has pronounced differences in two or more directions at right angles to each other.

### P

Parapet - A low concrete rail designed and placed to prevent traffic from passing over the edge of a bridge deck or end of box culvert.

Pascal (Pa) - The derived unit for pressure or stress ( $\text{Pa}=\text{N}/\text{m}^2$ ) in the International System of Units (metric).

Paving Dam – (see Nosing) - – A bulkhead at the ends of bridges or at expansion joints made of a durable material to protect and reinforce the slab edge and provide a stopping place for the wearing surface.

Paving Ledge – A ledge or corbel attached to the end beam of a bridge, to provide support for a current or future approach slab.

Performance Level - See Level of Performance.

Pier - Intermediate substructure unit of a bridge. Current terminology is bent.

Pile - A long, slender piece of wood, concrete, or metal to be driven, jettied, or cast-in-place into the earth or river bed to serve as a support or protection.

Pile Bent - A pier where the piles are extended to the pier cap to support the structure.

Pile Cap - A member, usually of reinforced concrete, covering the tops of a group of piles for the purpose of tying them together and transmitting to them as a group the load of the structure that they support.

Pipe Arch - A conduit in the form of a broad arch with a slightly curved integral bottom.

Plastic Deformation - Deformation of material beyond the elastic range.

Positive Moment - In a girder the moment causing compression in the top flange and tension in the bottom flange.

Post-Tensioning - Method of prestressing in which the tendon is tensioned after the concrete has cured.

Pot Bearing - A bearing type that allows for multi-directional rotation by using a neoprene or spherical bearing element.

Prestress Camber - The deflection in prestressed girders (usually upward) due to the application of the prestressing force.

Pratt Truss - A truss with parallel chords and a web system composed of vertical posts with diagonal ties inclined outward and upward from the bottom chord panel points toward the ends of the truss; also known as N-truss.

Preliminary Plans – 85-90% complete plans, normally sent at 20 weeks.

Prestressed Concrete - Concrete in which there have been introduced internal stresses (normally pretensioned steel) of such magnitude and distribution that the stresses resulting from given external loadings are counteracted to a desired degree

Pretensioned - Any method of prestressing in which the strands are tensioned before the concrete is placed.

Project Manager - The Engineer's representative who directly supervises the engineering and administration of a contract.

Proposal - A written offer by a bidder on forms furnished by the Division to do stated work at the prices quoted.

PS&E - Literally, Plans, Specifications, and Estimates. Usually it refers to the time when the plans, specifications, and estimates on a project have been completed and referred to FHWA for approval. When the PS&E has been approved, the project goes from the preliminary engineering phase to the construction phase.

Pumping - The ejection of mixtures of water, clay and/or silt along or through transverse or longitudinal joints, crack or payment edges, due to vertical movements of the roadway slab under traffic.

## Q

Queen-post Truss - A parallel chord type of truss having three panels with the top chord occupying only the length of the center panel; unless center panel diagonals are provided, it is a trussed beam.

## R

Radiographic Inspection - Nondestructive inspection process where gamma rays or X rays pass through the object and cast an image of the internal structure onto a sheet of film as the result of density changes.

Redundant Structure - Type of structure with multiple-load paths where a fracture in a single member cannot lead to the collapse of the structure.

Reflection Crack - A crack appearing in a resurfacing or overlay caused by movement at joints or cracks in the underlying base or surface.

Rehabilitation – Work required to restore the structural integrity of a bridge, or bridge element, as well as work necessary to correct major safety defects. Rehabilitation activities are considered bridge preservation.

Reinforced Pile Tip - Metal reinforcement fastened to the pile tip to protect it during driving.

Replacement – Total reconstruction of a structurally deficient or functionally obsolete bridge, or bridge element, with a new one constructed in the same vicinity. The replacement structure, or element, must comply with current design codes, policies and practices.

Residual Camber - Camber due to the prestressing force minus the dead load deflection of the girder.

Retrofit – Work required to upgrade a bridge, or bridge element, beyond its original intended purpose and design capacity. This work often includes strengthening to add structural capacity.

Right of Way - Land, property, or property interest, usually in a strip, acquired for or devoted to transportation purposes.

Riprap - A facing of stone used to prevent erosion. It is usually dumped into place, but is occasionally placed by hand.

Roadside Barrier - A longitudinal barrier used to shield roadside obstacles or non-traversable terrain features. It may occasionally be used to protect pedestrians from vehicle traffic.

Roadway - The portion of a highway, including shoulders, for vehicular use.

Rubble - Irregularly shaped pieces of varying size stone in the undressed condition obtained from a quarry.

## S

Sacrificial Anode - The anode in a cathodic protection system.

Sand - Particles of rock that will pass a No. 4 sieve and be retained on a No. 200 sieve.

Scaffolding - Temporary elevated walkway or platform to support workmen, materials and tools.

Scarify - To loosen, break up, tear up, and partially pulverize the surface of soil, or of a road.

Scour - Erosion of a river bed area caused by water flow.

Scour Protection - Protection of submerged material by steel sheet piling, riprap, mattress, or combination of such methods.

Screeding - The process of striking off excess material to bring the top surface to proper contour and elevation.

Seal - A concrete mass (usually not reinforced) poured under water in a cofferdam that is designed to resist hydrostatic uplift. The seal facilitates construction of the footing in dry conditions.

Shear Connector - A connector used to joint cast-in-place concrete to a steel section and to resist the shear at the connection.

Shear Lag - Nonuniform stress pattern due to ineffective transmission of shear.

Shed Roof - Roadway section with the height of one gutter greater than the centerline and other gutter.



Sheet Pile - A pile made of flat or arch cross-section to be driven into the ground or stream bed and meshed or interlocked with like members to form a wall, or bulkhead.

Sheet Pile Cofferdam - A wall-like barrier composed of driven piling constructed to surround the area to be occupied by a structure and permit dewatering of the enclosure so that the excavation may be produced in the open air.

Shoofly - Detour alignment of temporary railroad track and bridge around the site of a permanent railroad bridge replacement.

Shotcrete - Mortar or concrete pneumatically projected at high velocity onto a surface.

Shoulders - The portions of the roadway between the traveled way and the inside edges of slopes of ditches or fills, exclusive of auxiliary lanes, curbs, and gutters.

Shy Distance (E-Distance) - The distance from the edge of the traveled way beyond which a roadside object will not be perceived as an immediate hazard by the typical driver, to the extent that the vehicle's placement or speed will be changed.

Shrinkage - Contraction of concrete due to drying and chemical changes, dependent on time.

Silt - Soil passing a No. 200 sieve that is non-plastic or exhibits very low plasticity.

Simple Spans - Spans with the main stress carrying members non-continuous, or broken, at the intermediate supports.

Skew or Skew Angle - The acute angle formed by the intersection of a line normal to the centerline of the roadway with a line parallel to the face of the abutments or piers, or in the case of culverts with the centerline of the culverts. Left hand forward skew indicates that, look up station, the left side of the structure is further up station than the right hand side. Right hand skew indicates that the right side of structure is further up station than the left side.

Slip Base - A structural element at or near the bottom of a post or pole that will allow release of the post from its base upon impact while resisting wind loads.

Slope - The degree of inclination to the horizontal. It is sometimes described by such adjectives as steep, moderate, gentle, mild or flat.

Slope Paving - Pavement placed on the slope in front of abutment to prevent soil erosion.

Soffit - The bottom surface of a beam or an arch rib or barrel.

Spandrel - The area between the roadway and the arch in the side view of an arch bridge.

Special Provisions - The special directions, provisions, and requirements peculiar to the project that augment the standard specifications. They are commonly referred to as "specials".

Specifications - The body of directions, provisions, and requirements, together with written agreements and all documents of any description, made or to be made, pertaining to the method or manner of performing the work, the quantities, and the quality of materials to be furnished under the contract.

Spread Footing - A footing that is supported directly by soil or rock.

Spur Dike - A wall or mound built or extended out from the upstream side of an abutment used for training

the stream flow to prevent erosion of stream bank. May also be used where there is no bridge, but the stream flows along the side of highway embankment.

Stainless Steel Teflon Bearings - Incorporated stainless steel and teflon with steel to provide the necessary expansion movement.

St. Venant Torsion - Uniform torsion resulting in no deformation of the cross-section.

State Plane Coordinates - The plane-rectangular coordinate system established by the United States Coast and Geodetic Survey. Plane coordinates are used to locate geographic position.

Station - A distance of 100 feet measured horizontally.

Stirrup - Vertical U-shaped or rectangular shaped bars placed in concrete beams to resist the shearing stresses in the beam.

Strengthening – Work to add structural capacity to a bridge element or structure.

Stress Relieved Strands - Any prestressing tendons that are manufactured by relieving the high residual stresses that were introduced into the steel during the wire drawing and stranding operations. Stress relieving is not a heat treatment and does not change the strand yield strength.

Strip Seal Joint - Molded neoprene glands inserted and mechanically locked between armored interfaces of extruded steel sections.

Structurally Deficient Bridges - Those bridges which have been (1) restricted to light vehicles only, (2) closed, or (3) require immediate rehabilitation to remain open, as defined by the Federal Highway Administration.

Subgrade - The top surface of completed earthwork on which subbase, base, surfacing, pavement, or a course of other material is to be placed.

Substructure - Those parts of a structure which support the superstructure, including bents, piers, abutments, and integrally built wingwalls, up to the surfaces on which bearing devices rest. Substructure also includes portions above bearing surfaces when those portions are built integrally with a substructure unit (e.g. backwalls of abutments). When substructure and superstructure elements are built integrally, the division between substructure and superstructure is considered to be at the bottom soffit of the longitudinal or transverse beam, whichever is lower. Culverts and rigid frames are considered to be entirely substructure.

Sufficiency Rating - A method of evaluating data by calculating four separate factors to obtain a numeric value which is indicative of bridge sufficiency to remain in service. The result of this method is a percentage in which 100 percent would represent an entirely sufficient bridge and zero percent would represent an entirely insufficient or deficient bridge.

Superelevation - The difference in elevation between the inside and outside edges of a roadway in a horizontal curve; required to counteract the effects of centrifugal force.

Superplasticizer - A high range water-reducing admixture that increases the slump of freshly mixed concrete without increasing the water content.

Superstructure - Those parts of a structure above the substructure, including bearing devices.

**Surcharge** - Any load that causes thrust on a retaining wall, other than backfill to the level of the top of the wall. Also preloading of an embankment to minimize the time for initial consolidation of the subsurface soils.

**Suspension Bridge** - A bridge in which the floor system is supported by catenary cables which are supported upon towers and are anchored at their extreme ends.

**Suspender** - A wire cable, metal rod or bar connected to a catenary cable of a suspension bridge at one end and the bridge floor system at the other, thus transferring loads from the roadway to the main suspension members.

## T

**Tack Welds** - Small welds used for temporary connections.

**Telltale (Tattletale)** - Any device designed to indicate movement of formwork or falsework.

**Tendon** - A name for prestressed reinforcing element whether wires, bars, or strands.

**Tenon** - A constant diameter extension welded to the tip of the tapered metal arm of a luminaire support pole to receive the luminaire.

**Thixotropy** - Property of a material that enables it to stiffen in a short period on standing, but to acquire a lower viscosity again on mechanical agitation. A property desirable for post-tensioning duct grout.

**Three-Dimensional Finite Element Analysis** - Analysis in which a three-dimensional continuum is modeled as an assemblage of discrete elements in three-dimensional space.

**Three-Hinged Arch** - An arch which is hinged at each support and at the crown.

**Through Structure** - A structure that has its floor connected to the lower portion of the main stress-carrying members, so that the bracing goes over the traffic. A structure whose main supporting members project above the deck or surface.

**Tining** - Is used on finished concrete deck or slab surfaces to provide friction and reduce hydroplaning. Grooves are placed in the plastic concrete or cut into the hardened concrete.

**Torsional Stress** - Shear stress on a transverse cross-section resulting from a twisting action.

**Transformed Section** - A hypothetical section of one material so as to have the same elastic properties as a section of two materials.

**Transition** - A section of barrier between two different barriers or, more commonly, where a roadside barrier is connected to a bridge railing or to a rigid object such as a bridge pier. The transition should produce a gradual stiffening of the approach rail so vehicular pocketing, snagging, or penetration at the connection can be avoided.

**Traveled Way** - The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

**Tremie** - A pipe or tube through which concrete is deposited underwater.

Trial Batch - A batch of concrete prepared to establish or check proportions of the constituents.

Turnbuckle - A long, cylindrical, internally threaded nut used to connect the elements of adjustable rod and bar members.

Turn-of-the-Nut - A bolt-tightening method.

Two-hinged Arch - A rigid frame which may be arch-shaped or rectangular but is hinged at both supports.

### U

Ultrasonic Inspection - A non-destructive inspection process where by an ultra-high frequency sound wave induced into a material is picked up in reflection from any interface or boundary.

Unbonded Strands - Strands so coated as to prevent their forming a bond with surrounding concrete. Used to reduce stress at the ends of a member.

Underpinning - The addition of new permanent support to existing foundations to provide additional capacity.

Uplift - A force tending to raise a structure or part of a structure and usually caused by wind and/or eccentric loads, or the passage of live-load over the structure.

Utility - A line, facility, or system for producing, transmitting, or distributing communications, power, electricity, heat, gas, oil, water, steam, waste, storm water not connected with highway drainage, or any other similar commodity which directly or indirectly serves the public. The term utility shall also mean the utility company, district, or cooperative, including any wholly owned or controlled subsidiary.

### V

Vierendeel Truss - A Pratt truss without diagonal members and with rigid joints between top and bottom chords and the verticals.

Vibrator - An oscillating device inserted at selected locations to consolidate fresh concrete.

### W

Wales - Horizontal support members in close contact with a row of sheet piles in a cofferdam or shoring wall. Sometimes called whalers.

Warrants - The criteria by which the need for a safety treatment or improvement can be determined.

Warren Truss - A triangular truss consisting of sloping members between the top and bottom chords and no verticals; members form the letter W.

Water/Cement Ratio - The weight of water divided by the weight of cement in a concrete; ratio controls the strength of the concrete.

Waterproofing Membranes - Impervious material overlaid with bituminous concrete to protect decks from the infiltration of chlorides and resulting deterioration.

Wearing Surface - The top layer of a pavement designed to provide structural values and a surface resistant to traffic abrasion.

Weep Hole - A drain hole through a wall to prevent the building up of hydraulic pressure behind the wall.

Weld Inspection - Covers the process, written procedure, and welding in process. Post weld heat maintenance if required, post weld visual inspection and non-destructive testing as specified in contract and Standard Specifications.

Welded-Wire Fabric - A two-way reinforcing mat, fabricated from cold-drawn steel wire, having parallel longitudinal wires welded at regular intervals to parallel transverse wires.

Well-Graded - An aggregate possessing a proportionate distribution of successive particle sizes.

Wetlands - Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Wheel Load – Half of an axle load.

Wingwall - A wall attached to the abutments of bridges or box culverts retaining the roadway fill. The sloping retaining walls on each side of the center part of a bridge abutment.

### X

### Y

Yield - Permanent deformation (permanent set) which a metal piece takes when it is stressed beyond the elastic limit.

Young's Modulus - modulus of elasticity of a material (E); or the stiffness of a material.

### Z

# APPENDIX – SECTION 1 – Abbreviations (Initialisms and Acronyms)

## A

A&E	Architectural and Engineering
AADT	Annual Average Daily Traffic
AASHO	American Association of State Highway Officials (1921-1973)
AASHTO	American Association of State Highway and Transportation Officials (since 1973)
AB	Anchor bolt
ABC	Accelerated Bridge Construction
AC	Asphalt Concrete
ACEC	American Council of Engineering Companies of Oregon
ACI	American Concrete Institute
ACP	Asphalt Concrete Pavement
ACT	Area Commission on Transportation
ACWS	Asphalt concrete wearing surface
ADA	Americans with Disabilities Act
ADT	Average daily traffic (see Definitions)
ADTT	Average Daily Truck Traffic
AEE	Association of Engineering Employees
AHP	Analytic Hierarchy Process
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AITC	American Institute of Timber Construction
a.k.a.	Also known as
ANSI	American National Standards Institute
AOC	Association of Oregon Counties
AOH	Access Oregon Highways
AP	Angle Point
APA	American Plywood Association

API	Area of Potential Impact
APJ	Asphaltic Plug Joint
APM	Area Project Manager
APWA	American Public Works Association
AREA	American Railway Engineering Association
AREMA	Manual for Railway Engineering of the American Railway Engineering and Maintenance-of-way Association
ARRA	American Response and Recovery Act
ARS	Accident Records System (Accident Data Unit, Transportation Research Section)
ARTBA	American Road and Transportation Builders Association
ASAP	As soon as possible
ASCE	American Society of Civil Engineers
ASCII	American Standard Code for Information Interchange (refers to files that are pure text)
ASTM	American Society for Testing and Materials
ATA	Agreement to Agree
ATC	Applied Technology Council
ATR	Automatic Traffic Recorder
ATPM	Asphalt-treated permeable material
AWPA	American Wood Products Association
AWS	American Welding Society

**B**

B-Team	Team of Bridge Engineering Section Supervisors & Engineers
BCM	Bridge CAD Manual
BAMS	Bid Analysis Management System
BBS	Bulletin Board System (computers)
BDC	Bridge Design Coordinator
BDM	Bridge Design Manual
BDS	Bridge Design System (AASHTO software)
BDS	Bridge Data System (ODOT software)
BDWO	Bridge Design Work Order
BIOS	Basic Input/Output System (computers)
BLM	Bureau of Land Management (U.S. Dept. of Interior)
BLT	Bridge Leadership Team
BMP	Best Management Practice

BMS	Bridge Management System
BNRR	Burlington Northern Railroad
Bot.	Bottom
BPR	Bureau of Public Roads (now FHWA)
BRASS	Bridge Rating and Analysis of Structural Systems (software)
BRSFUP	Bridge Rail Safety Features Upgrade Program
Bt.	Bent
BUBB	Bargaining Unit Benefit Board
BVC	Begin vertical curve

**C**

C	Degrees Celsius Compression
CAC	Citizens Advisory Committee or Community Action Committee
CAD	Computer-aided drafting/computer-aided design
CADD	Computer-aided drafting and design
CAE	Computer-aided engineering
CAFL	Constant Amplitude Fatigue Limit
CalTrans	California Department of Transportation
CBC	Conventional Bridge Construction
CBR	Major Steel Bridges
CCT	Concrete Control Technician
CETAS	Collaborative Environmental and Transportation Agreement for Streamlining
CD-ROM	Compact Disk - Read-Only Memory
CF	Cubic feet
CFRP	Carbon Fiber Reinforced Polymer
CFS	Cubic Feet per Second
CG	Center of Gravity
CICS	Customer Information and Control System (Transportation inventory and Mapping Unit software on the mainframe)
CIM	Corporate Information Management
CIP	Cast-in-place
CIS	Career Information System (Training & Employee Development Sect.)
CLT	Construction Leadership Team
CMP	Construction Mitigation Plan Construction Management Plan



	Corrugated metal pipe
CMR	Change Management Request
COGO	Coordinate Geometry language
COM	Communications port (serial port on a computer)
CP	Cathodic protection
CPM	Critical Path Method (method of scheduling)
	Consultant Project Manager
CPU	Central Processing Unit (computers)
CQC	Complete Quadratic Combination (method of combining seismic forces or displacements)
CRF	Code of Federal Regulations
CRSI	Concrete Reinforcing Steel Institute
CRT	Cathode Ray Tube display (monitor)
CS <sup>3</sup>	Context Sensitive and Sustainable Solutions
CSL	Crosshole Sonic Log
CTP	Continuous Trip Permit
CUP	Conditional Use Permit
CWI	Certified Welding Inspector
CY	Cubic yard
CZM	Coastal Zone Management

**D**

DAP	Design Acceptance Plans
DAW	Design Acceptance Workshop
DB	Design-Build
DBA	Doing Business As
DBE	Disadvantaged Business Enterprises
DCSA	Bridge Design Criteria and Standards Assessment
DD	Bridge Design Deviation
DE	Design Exception
DEC	Digital Equipment Corporation
DEIS	Draft Environmental Impact Statement
DEQ	Department of Environmental Quality (Oregon)
DHV	Design hourly volume
Dia.	Diameter
DL	Dead load

---

DLCD	Department of Land Conservation and Development (Oregon) (formerly LCDC)
DLT	Discipline Leadership Team
DOGAMI	Department of Geology and Mineral Industries (Oregon)
DM	District Manager
DMS	District Maintenance Supervisor (old)
DMV	Division of Motor Vehicles
DOJ	Department of Justice
DOS	Disk Operating System for personal computers
DOT	Department of Transportation
DQP	Design Quality Plan
DS	Top of deck to streambed distance
DSL	Division of State Lands (Oregon)
DTI	Direct Tension Indicator (load indicating washer for bolts)

**E**

E	East
E&C	Engineering and Contingencies (used in cost estimates)
EA	Expenditure Account Environmental Assessment
EAC	Emulsified Asphalt Concrete
EAP	Employee Assistance Program
EB	Eastbound
ECL	East city limits
EDMS	Electronic Data Management System
EEO	Equal Employment Opportunity program
EEO/AA	Equal Employment Opportunity/Affirmative Action
EF	Each face
EIS	Environmental Impact Statement
El.	Elevation
Elev.	Elevation
ELT	Environmental Leadership Team
Emb.	Embankment
EOR	Engineer of Record
EP	Edge of pavement
EPA	Environmental Protection Agency (U.S.)
ES	Edge of shoulder

ESA	Endangered Species Act or Environmental Site Assessment
ESR	Evaluation Service Report
EVC	End vertical curve
EW	Each way
Exp.	Expansion

**F**

F	Degrees Fahrenheit
FAPG	Federal Aid Policy Guide (replaced FHPM 12/9/91)
FAS	Federal Aid Secondary (class of highways)
FAT	File Allocation Table (on a computer disk)
FBN	Film base negative
FBPM	Film base positive matte
FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FF	Far face (don't use for "fill face")
FFO	Full Federal Oversight
FHP	Federal-Aid Highway Program
FHPm	Federal Highway Program Manual (replaced by FAPG)
FHWA	Federal Highway Administration (formerly BPR)
FIPS	Federal Information Processing Standards system (IBM software)
FIS	Flood Insurance Studies (conducted by FHWA)
FONSI	Finding Of No Significant Impact
FRP	Fiber Reinforced Polymer
FS	Far side
ft-k	foot-kips
ft-lbs	foot-pounds
FTA	Federal Transit Administration
FTP	File Transfer Protocol
FWS	Future Wearing Surface

**G**

Ga.	Gauge
GAO	General Accounting Office
GDM	Geotechnical Design Manual

GFRP	Glass Fiber Reinforced Polymer
GHLT	Geo-Hydro Leadership Team
GIS	Geographic Information System
GLO	Government Land Office
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GR	Guard Rail
Gr.	Grade
GSA	General Services Administration
GSP	Galvanized Steel Pipe
GUI	Graphical User Interface for computers (such as Windows)

**H**

HBP	Highway Bridge Program (funding)
HBR	Highway Bridge Replacement (type of funding)
HBRR	Highway Bridge Replacement and Rehabilitation (type of funding)
HDD	Hard Disk Drive
HDM	Highway Design Manual
HIP	Highway Improvement Plan (6-year plan of ODOT)
HLT	Highway Leadership Team
HMAC	Hot Mix Asphalt Concrete
HOV	High Occupancy Vehicle
HP&R	Highway Planning & Research program
HPC	High Performance Concrete
HPS	High Performance Steel
HQ	Headquarters
HS	High Strength
HSIS	Highway Safety Information System (FHWA database)
Ht.	Height
HW	High Water
HWM	High Water Mark

**I**

I/O	Input/Output
I4R	Interstate Resurfacing, Restoration, Rehabilitation and Reconstruction (funding category)

IAMP	Interchange Area Management Plan
IBC	International Building Code
IBM	International Business Machines
IC	Internal Curing
ICC-ES	International Code Council Evaluation Service, Inc.
ID	Inside diameter
IDE	Internal Drive Electronics (type of computer hard disk)
IDT	Idaho Department of Transportation
IF	Inside face (don't use!)
IGA	Inter-Governmental Agreement
IO	Intermodal Oregon
ILT	Intermodal Leadership Team
IS	Information Systems
ISB	Information Systems Branch
ISPF	Integrated System Productivity Facility (IBM mainframe software)
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
IT	Information Technology
ITIS	Integrated Transportation Information System
ITS	Intelligent Transportation Systems
IWRC	Independent Wire Rope Core (cables)

**J**

J	Joule, metric energy unit
JCL	Job Control Language (mainframe)
JTA	Oregon Jobs and Transportation Act of 2009

**K**

k	Kilo, one thousand
K	Kip (kilopound, 1000 pounds)
kg	Kilogram, metric mass unit
km	Kilometer (1000 meters)
kN	KiloNewton, metric force unit
KSF	Kips per Square Foot
KSI	Kips per Square Inch

**L**

LAN	Local Area Network (computers)
Lbs	Pounds
LC	Length of curve
LCD	Liquid Crystal Display (computers)
LCDC	Land Conservation and Development Commission (Oregon) (now DLCD)
LF	Linear feet
LL	Live load
LMC	Latex Modified Concrete
LOC	League of Oregon Cities
LPA	Local Public Agency
LPT	Line Printer (parallel computer port)
LRFD	Load Resistance Factor Design
<i>LRFD</i>	<i>AASHTO LRFD Bridge Design Specifications</i>
L.S.	Lump Sum
LSDC	Low slump dense concrete
LT	Leadership Team

**M**

m	Meter, metric length unit
	Milli, one thousandth
M	Mega, one million
MALT	Modes and Area Leadership Team
MAPS-21	Moving Ahead for Progress in the 21 <sup>st</sup> Century (funding)
MASH	Manual for Assessing Safety Hardware
MBJS	Modular Bridge Joint System
MBM,MFBM	Thousand feet board measure
MBM	Major Bridge Maintenance
MC	Microsilica modified concrete
MCTD	Motor Carrier Transportation Division
MH	Manhole
MHz	MegaHertz (millions of cycles per second)
MLT	Maintenance Leadership Team
MP	Microfilm print
	Milepoint, milepost (even milepoint)

MPCO	Multi-Layer Polymer Concrete Overlay
MPO	Metropolitan Planning Organization
MOA	Memorandum of Agreement
<b>MOT</b>	<b>Maintenance of Traffic</b>
MOU	Memorandum Of Understanding
MSC	Minor structure concrete
MSCS	Management Scheduling Control System (to replace PCS)
MS-DOS	Microsoft Disk Operating System
MSDS	Material Safety Data Sheet
MSE	Mechanically Stabilized Earth (retaining walls)
MSL	Mean Sea Level
MT	Magnetic Particle
MTPA	Major Transportation Projects Agreement

**N**

N	North
	Newton, metric force unit
NACE	National Association of Corrosion Engineers
NAVD 88	North American Vertical Datum 1988
NB	Northbound
NBI	National Bridge Inventory
NBIS	National Bridge Inspection Standards
NCEER	National Center for Earthquake Engineering Research (Buffalo, NY)
NCHRP	National Cooperative Highway Research Program (from the Transportation Research Board)
NCL	North city limits
NDE	Non-destructive Evaluation
<b>NDT</b>	<b>Non-destructive Testing</b>
NEPA	National Environmental Protection Act of 1969
NF	Near face
NGVD	National Geodetic Vertical Datum (MSL = 0.0)
NHI	National Highway Institute
NHPP	National Highway Performance Program
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
NICET	National Institute for Certification in Engineering Technologies

NLF	No Load Fit
NMFS	National Marine Fisheries Service
NOAA	National Oceanic & Atmospheric Administration (U.S. Dept. of Commerce)
NSBA	National Steel Bridge Alliance
NSM	Near Surface Mount
NSPE	National Society of Professional Engineers
NT	New Technology (new version of Microsoft Windows)
NTS	Not to Scale

**O**

OAR	Oregon Administrative Rule
OBIS	Oregon Bridge Inventory System
OC	On Center (center-to-center)
OCAPA	Oregon Concrete & Aggregate Producers Association, Inc.
OD	Outside Diameter
ODF&W	Oregon Department of Fish and Wildlife
ODOT	Oregon Department of Transportation
OERS	Oregon Emergency Response System
OG	Original Ground
OHP	Oregon Highway Plan
OHWM	Ordinary High Water Mark
OIT	Oregon Institute of Technology
OMUTCD	Oregon Manual on Uniform Traffic Control Devices
OO, O-O	Out-to-out
OPEU	Oregon Public Employees Union
OPL	Office of Project Letting
OPO	ODOT Procurement Office
Ops.	Operations
ORS	Oregon Revised Statutes
OS	Operating System
OSHA	Occupational Safety and Health Administration (U.S.)
OSHD	Oregon State Highway Division
OSP	Oregon State Police Oregon State Parks
OSU	Oregon State University
OTC	Oregon Transportation Commission



OTIA	Oregon Transportation Investment Act (I, II, & III)
OTP	Oregon Transportation Plan
Oxing	Overcrossing
OZ	Ozalid print

**P**

Pa	Pascal, metric stress or pressure unit
PA	Price Agreement
PBLT	Planning Business Line Leadership Team
PC	Point of curvature Polymer Concrete
P/C	Precast Concrete
PCA	Portland Cement Association
PCC	Portland Cement Concrete Point on compound curve
PCF	Pounds per Cubic Foot
PCI	Prestressed Concrete Institute
PCP	Prestressed concrete pipe
PCS	Project Control System (to be replaced by MSCS) Point of change from circular curve to spiral
PDG	Project Delivery Guide
PDLT	Project Delivery Leadership Team
PE	Professional Engineer (registered) Preliminary engineering
PEBB	Public Employees Benefit Board
PERS	Public Employees Retirement System
PFSJ	Precompressed Foam Silicone Joint
PI	Point of intersection Public Information
PL	Project Leader Performance Level of bridge rail
PM	Project Manager
PMC	Polymer-modified concrete
PMS	Pavement Management System
PMT	Photo transfer paper
PO	Purchase Order

POC	Point on circular curve
POR	Professional of Record
POS	Point on spiral
POT	Point on tangent
PP	Pipe Pile
PPC	Premixed Polymer Concrete Precast Prestressed Concrete
PQR	Pre-Qualification Request
PR	Project Request (Federal-Aid Program) Public Relations
Prest.	Prestressed
PRC	Point of reverse curve
PRN	Printer port (parallel port on computer, =LPT)
PS	Point of change from tangent to spiral
P/S	Prestressed Concrete
PS&E	Plans, Specifications & Estimate
PSBS	Project Specifications Bid System
PSC	Point of change from spiral to circular curve
PSF	Pounds per Square Foot Precast Spread Footing
PSI	Pounds per Square Inch
PSK	Personal Services Contract
PSU	Portland State University
PT	Point of tangency
P/T	Post-tensioned concrete
PTI	Post-Tensioning Institute
PUC	Public Utility Commission
PVC	Point on vertical curve Polyvinyl chloride
PVI	Point of vertical intersection
PWRR	Portland Western Railroad
PWS	Present Wearing Surface

**Q**

QA	Quality Assurance
QC	Quality Control

QCT	Quality Control Technician
QPL	Qualified Products Listing

**R**

R	Radius
R, 1R	Resurfacing
R.	Range (surveying)
R/D	Rough Draft
R/W	Right of Way
R&D	Research and Development
RAM	Random Access Memory
RBI	Region Bridge Inspector
RBLE	Regional Bridge Lead Engineer
RC	Reinforced Concrete
RCB	Reinforced Concrete Box
RCBC	Reinforced Concrete Box Culvert
RCBG	Reinforced Concrete Box Girder
RCDG	Reinforced Concrete Deck Girder
RCP	Reinforced Concrete Pipe
Rdwy.	Roadway
REA	Revised Environmental Assessment
RE-CP	Resident Engineer – Consultant Projects
Rev.	Revised; revision date
RFI	Request for Information
RFP	Request for Proposals
RFQ	Request for Qualifications
RLT	Roadway Leadership Team
RMS	Root Mean Square (statistical average)
ROD	Record of Decision
ROM	Read-Only Memory
RR	Railroad
RRR, 3R	Resurfacing, Restoration and Rehabilitation
RRRR, 4R	Resurfacing, Restoration, Rehabilitation and Reconstruction
RSA	Response Spectrum Analysis
RT	Radiographic

**S**

S	South
S.	Section (surveying)
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy of Users of 2005
SB	Southbound
SC	Structural Concrete
SCL	South city limits
SCSI	Small Computer Systems Interface (type of computer hard disk)
SDC	Seismic Design Category
SDCL	Simple for Dead and Continuous for Live Load
SDLF	Steel Dead Load Fit
SEAO	Structural Engineers Association of Oregon
SEAOC	Structural Engineers Association of California
Sec.	Section (map location)
Sect.	Section (on a drawing)
SF	Square feet
SFC	Silica Fume Concrete
SFLMC	Silica Fume Latex-Modified Concrete
SH, Shld	Shoulder
SHPO	State Historic Preservation Office
SHRP	Strategic Highway Research Program
SI	"Système Internationale" (International System of units)
SI&A	Structure Inventory and Appraisal
SIBC	Slide In Bridge Construction
SIMM	Single In-line Memory Module (type of memory chips)
SLT	Safety Leadership Team
SOQ	Statement of Qualifications
SOW	Statement of Work
SP	<i>ODOT Construction Specifications</i>
SPC	Seismic Performance Category
SPFPC	System Productivity Facility for Personal Computers (data file editing software)
SPIS	Safety Priority Index System
<b>SPMT</b>	<b>Self-Propelled Modular Transporters</b>
SPRR	Southern Pacific Railroad
SPT	Standard Penetration Test for soils

SR	Sufficiency Rating
SRCM	Soils and Rock Classification Manual (ODOT)
SRSS	Square Root of the Sum of the Squares (method of combining seismic forces or displacements)
SSDM	Strategic Systems & Data Management (a unit within Technical Services)
SSPC	Structural Steel Painting Council
STE	Supervising Transportation Engineer
STIP	State Transportation Improvement Program
STP	Single Trip Permit
	Surface Transportation Program
S.T.R.	Section, Township and Range (surveying)
STRAHNET	Strategic Highway Corridor Network
STRUDL	Structural Design Language
SW	Sidewalk
SY	Square Yard

**T**

T.	Township (surveying)
	Tangent
	Tension
T&E	Threatened and Endangered
Tan.	Tangent
TAC	Technical Advisory Committee
TAG	Technical Advisory Group
TB	Test boring
TCP	Traffic Control Plan
TDLF	Total Dead Load Fit
TEAMS	Transportation Environment Accounting System
TF	Top Face
TFE	Polytetrafluoroethylene (sliding surface for bearings)
TH	Test hole
Thk	Thick, thickness
TIFIA	Transportation Infrastructure Finance and Innovation Act (FHWA)
TIP	Transportation Improvement Plan
	Thermal Integrity Profile

TL	Test Level
TLC	Technical Leadership Center
TLT	Technical Leadership Team
TMOC	Transportation Management Operations Center
TMP	Traffic Management Plan
TP&DT	Temporary Protection and Direction of Traffic
TPAR	Temporary Pedestrian Accessible Routes
<b>TPM</b>	<b>Transportation Project Manager</b>
TRB	Transportation Research Board
TS	Tube, Structural
TS&L	Type, Size and Location (formerly called preliminary)
TSF	Tons per Square Foot (don't use)
TSO	Time Sharing Option (on mainframe computer)
TTS	Tracings To Specifications
Typ.	Typical

**U**

UBC	Uniform Building Code
UBIT	Under Bridge Inspection Truck
UFAS	Uniform Federal Accessibility Standards
U of O	University of Oregon
UHPC	Ultra High Performance Concrete
UP	University of Portland
UPRR	Union Pacific Railroad
URLT	Utility Relocation Leadership Team
USACE, ACOE	U.S. Army Corps of Engineers
USC&GC	United States Coast and Geodetic Survey
USCG	United States Coast Guard
USFS	U.S. Forest Service (Dept. of Agriculture)
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
USRS	U.S. Reclamation Service
<b>UST</b>	<b>Underground Storage Tank</b>
UT	Ultrasonic
Uxing	Undercrossing

UV Ultraviolet

**V**

V. Version (software)  
Var. Varies  
VC Vertical curve  
VE Value Engineering  
VGA Video Graphical Array (computers)  
VM Vicinity Map  
VMT Vehicle miles of travel

**W**

W West  
W/ With  
W/O Without  
WAN Wide Area Network (computers)  
WATS Wide Area Telephone Service  
WB Westbound  
WCL West city limits  
WCLIB West Coast Lumber Inspection Bureau  
W.M. Willamette Meridian  
WOC Work Order Contract  
WPS Welding Procedure Specifications  
WS Wearing surface  
WSDOT Washington State Department of Transportation  
WSC Wire Strand Core (cables)  
Wt. Weight  
WWF Welded Wire Fabric  
WWM Welded Wire Mesh  
WWPA Western Wood Products Association  
WYSIWYG What-you-see-is-what-you-get (computer interface)

**X**

X'Sect Cross-section  
XF Xerox film

Xing

Crossing

XV

Xerox vellum

**Y**

**Z**



# APPENDIX – Section 1.2 – AASHTO/BDM Cross-Reference

Table A1.2 -1 AASHTO/BDM Cross Reference

Bridge Design Manual		AASHTO LRFD Cross-References		
BDM Section	Title	LRFD Section	Title	Comments
3.14.7.2 3.18.3	Bridge Length	2.6.4.3	Bridge Waterway	BDM adds specific design floods and minimum freeboard to AASHTO specs.
3.18.2(2)	Structure Depth	2.5.2.6.3-1	Span to Depth Ratios	BDM gives span-to-depth ratios for concrete bridges but leaves span-to-depth ratios for steel bridges to AASHTO.
3.18.2(2)	Structure Depth	2.5.2.6.2	Criteria For Deflection	BDM states that AASHTO optional live load deflection criteria is not required for bridges that satisfy the span-to-depth ratios in BDM <del>2.5.2.6.3-1</del> 3.18.2(4)
3.17.1(1)	Bridge Types and Economics	4.6.2.1.4, 5.14.4.1, 9.7.1.4	Slab Edge Beam Requirements	BDM Yields to AASHTO Requirements. AASHTO requirements also apply to CIP voided slabs if design deviation is approved.
3.14.7.1	Hydraulics, General	2.6.4.4.2	Bridge Scour	BDM states that bottom of spread footings should be 6 feet below normal streambed. AASHTO states that the bottom of footing should be below the scour depth.
1.10.5.3	Spread Footing Foundation Design	10.6.1.2	Bearing Depth	BDM states that spread footings should be at least 6 feet below streambed and also below the scour depth for the 500-year flood event. AASHTO states that the footings should be located to bear below the maximum anticipated

Bridge Design Manual		AASHTO LRFD Cross-References		
BDM Section	Title	LRFD Section	Title	Comments
				depth of scour.
1.10.5.3(2)	Nominal and Factored Bearing Resistances	10.5.5.2.2	Spread Footings	BDM resistance factors for bearing of spread footings are higher than those shown in Table 10.5.5.2.2 in the AASHTO Specs for extreme event conditions of scour and earthquake loading.
1.10.5.3(4)	Spread Footing Stability	11.6.2.3	Overall Stability	BDM specifies a factor of safety 1.5 for overall stability. AASHTO specifies phi factors for stability = 0.75 or 0.65 depending on geotechnical information.
1.10.5.4(1)	Pile Resistance	10.7.3.8	Nominal Axial Pile Resistance	BDM refers specifically to AASHTO specs for determining axial pile capacity.
1.10.5.5(1)	Drilled Shaft Diameters and Requirements	10.8.1.3	Shaft Diameter	BDM states that smallest shaft diameter is 12 inches. AASHTO adds that if the shaft is to be manually inspected, the diameter should not be less than 30 inches.
1.10.5.5(1)	Column Diameter	10.8.1.3	Maximum Column Size	AASHTO states that columns on top of drilled shafts can be the same size as the drilled shaft, but BDM requires that columns be smaller than shafts by 6 inch or 1 foot depending on shaft diameter.
1.10.5.5(7)	Shaft Settlement	10.8.2.2	Shaft Settlement	BDM refers to AASHTO for the determination of drilled shaft settlement.
1.10.5.5(12)	Shaft Reinforcement	5.13.4.6.3	Volumetric Reinforcement Ratio and transverse rebar spacing	BDM overrides LRFD 5.13.4.6.3 because the shaft diameter is always larger than the column diameter.

Bridge Design Manual		AASHTO LRFD Cross-References		
BDM Section	Title	LRFD Section	Title	Comments
1.10.5.5(12)	Shaft Reinforcement	5.13.4.6.3	Volumetric Reinforcement Ratio and transverse rebar spacing	BDM adds a formula for computing transverse reinforcement required in non-contact splice region.
1.10.5.5(14)	Shaft Reinforcement Cover	5.12.3-1	Cover for Main Reinforcing Steel	BDM provides specific reinforcement cover requirements for drilled shafts.
1.3.1(4)	Load From Wearing Surface	3.5.1-1	Unit Weights	BDM assumes 150 pcf for ACWS, but AASHTO assumes 140 pcf.
1.3.6	Thermal Forces	3.12.2.1-1	Temperature Ranges	Temperature ranges vary slightly between BDM and AASHTO for Moderate and Rigorous Climates
1.4.1	Ductility, Redundancy, and Operational Importance	1.3.3, 1.3.4, 1.3.5	Ductility, Redundancy, and Operational Importance	BDM requires State Bridge Engineer approval for Redundancy Factor less than 1.0, and it states that for the Operational Importance Factor, use a value of 1.0 for all bridges, assuming all bridges to be "typical".
1.3.3	Sidewalk Loading	3.6.1.6	Pedestrian Loads	BDM adds specific details for applying vehicular live load to curb mountable sidewalks.
1.4.2	Shear Correction Factor for Skewed Girders	4.6.2.2.3c	Skewed Bridges	BDM includes additional design criteria for the application of the skew correction factor for computing shear in skewed beams.
1.11.2.3	Wingwall Design and Construction	11.6.1.5.2	Wingwalls	BDM adds bar extension requirements for abutments on stiff footings to distribute flexure. AASHTO does state that bar lengths should vary to avoid "planes of weakness"
1.17	Seismic Design	3.10, 5.10.11, 5.13.4.6, 11.6.5, 11.8.6,	Earthquake Effects	BDM specifies the use of AASHTO Guide Specifications for LRFD Seismic Bridge Design for projects

Bridge Design Manual		AASHTO LRFD Cross-References		
BDM Section	Title	LRFD Section	Title	Comments
		11.10.7		initiated after May 1st 2009. For projects initiated before May 1st 2010, BDM specifies the use of AASHTO LRFD Bridge Design Specifications. Additional requirements and guidelines for both AASHTO documents are included in the BDM.
1.5.1	Concrete, General	5.4.2.1	Compressive Strength	BDM has independent concrete classes.
1.5.1	Concrete, General	5.4.2.4	Modulus of Elasticity	BDM and AASHTO have same formula
1.5.5.1.2	Minimum Bar Covering	5.12.3	Concrete Cover	BDM and AASHTO have separate tables
1.5.5.1.3	Reinforcement for Shrinkage and Temperature	5.10.8	Shrinkage and Temperature Reinforcement	BDM bases reinforcement area on concrete thickness only, but AASHTO bases reinforcement area on ratio of volume of section to perimeter of section. AASHTO also has additional required minimum spacing for specific elements.
1.5.5.1.6	Minimum Bar Spacing	5.10.3	Spacing of Reinforcement	BDM specifies 2.5d for the bar spacing, but AASHTO specifies 1.5d for clear distance between bars. Both state 1.5 inches minimum clear between bars and 1.5(maximum aggregate size) for minimum clear between bars.
1.5.5.1.8	Compression Development Length	5.11.2.2.1	Compression Development Length	AASHTO gives two equations with the one that results in the lowest value controlling. BDM specifies the largest value from the equations.
1.5.6.1	Precast Prestressed Elements	5.9.4.1.2-1, 5.9.4.2.2-1	Tensile Stress Limits	AASHTO allows $0.19\sqrt{f'c}$ for certain situations but BDM allows only $0.0948\sqrt{f'c}$
1.5.8.8	Post-Tension Strand Duct	5.10.3.3.2	Post-Tensioning	AASHTO specifies spacing requirements; BDM doesn't call out

Bridge Design Manual		AASHTO LRFD Cross-References		
BDM Section	Title	LRFD Section	Title	Comments
	Placement		Ducts C-C Spacing	spacing requirements.
1.14.1.2	Elastomeric Bearing Pads	14.7.5, 14.7.6	Elastomeric Pads and Steel Reinforced Elastomeric Pads	BDM specifies that AASHTO Method A should be used to design bearing pads unless there is a specific need to use AASHTO Method B.
1.14.1.3	Proprietary Pot, Disc, Slide, Radial, or Spherical Bearings	5.4.2.3	Shrinkage and Creep	BDM provides a simplified approach for determining creep and shrinkage coefficients.
1.9.1	Deck Design and Detailing	9.7.2	Empirical Design of Decks	BDM excludes the use of the Empirical Method in AASHTO for deck design
1.9.1	Deck Design and Detailing	4.6.2.1	Decks	BDM deck design tables utilize AASHTO specifications from LRFD 4.6.2.1 to develop reinforcement values.
1.14.2	Deck Expansion Joint Seals	14.5.6.6	Compression and Cellular Seals	AASHTO specifies a maximum skew angle for compression joint seals equal to 20 degrees, but this limitation is not stated in the BDM or Standard Drawing.
1.13.1	Rail Selection	13.7.2	Test Level Selection Criteria	AASHTO Defines Test Level Criteria
1.13.1	Rail Selection	A13.2	Traffic Rail Design Forces	AASHTO provides design forces in rails in Table A13.2-1
1.6.2.8.3	Steel Girders	C6.13.6.1.4a	Flexural Members	BDM modifies this AASHTO comment to reflect moment of inertia of the smaller section rather than the smaller flange.
1.8.5	(Timber) Preservative Treatment	8.4.3.2	(Wood) Treatment Chemicals	AASHTO has specific requirements for the use of wood preservative chemicals on pedestrian bridges.
1.15.1	Soundwalls,	1-2.1.2	Wind Load	AASHTO Guide Specs for Sound

Bridge Design Manual		AASHTO LRFD Cross-References		
BDM Section	Title	LRFD Section	Title	Comments
	General	(AASHTO Guide Specs for Sound Barriers)		Barriers provides wind load equations and exposure categories. Example designs are also provided
1.15.1	Soundwall Seismic Load	1-2.1.3 (AASHTO Guide Specs for Sound Barriers)	Seismic Load	AASHTO Guide Specs for Sound Barriers provides equations and factors for seismic loads on sound barriers.
1.15.1	Soundwall Overturning Factor of Safety	1-8.2 (AASHTO Guide Specs for Sound Barriers)	Spread Footings	BDM uses AASHTO factors of safety with slight modifications. (Ice and snow load not included)
3.14.4.2	Roadway Clearances	2.3.3.3	Highway Horizontal Clearances	AASHTO calls out horizontal clearance requirements that are consistent with the values shown in BDM Figure 3.14.4.2A-B
1.38.3	Falsework	Figure 16 (AASHTO Construction Handbook for Bridge Temporary Works)	Bridge Deck Falsework	See AASHTO Figure 16 for conceptual layout of deck overhang falsework.
1.38.5.2	Cofferdams and Seals	Page 71 (AASHTO Construction Handbook for Bridge Temporary Works)	Sealing and Buoyancy Control	AASHTO confirms that force from sheet pile friction should not be included in uplift resistance.
1.3.4	ODOT Design Instructions for AASHTO LRFD Bridge Design Specifications	3.6.5	Vehicular Collision Force	BDM adds specific requirements for barriers in front of obstacle components.

<b>Bridge Design Manual</b>		<b>AASHTO LRFD Cross-References</b>		
<b>BDM Section</b>	<b>Title</b>	<b>LRFD Section</b>	<b>Title</b>	<b>Comments</b>
1.3.5	ODOT Design Instructions for AASHTO LRFD Bridge Design Specifications	2.6.4, 3.7.5	Hydraulic Analysis	BDM modifies AASHTO specs regarding scour depth and degradation and Extreme Limit States

## APPENDIX – Section 1.5.11.2.2 – Resin Anchor Design

This appendix contains the legacy equations used by designers prior to 2019, which were replaced by the equations according to *ACI 318 Chapter 17* with ODOT modifications. Use the legacy equations only when it is required.

### GENERAL EQUATION FOR RESIN TENSION CAPACITY

Ultimate tension capacity =  $R_0 \cdot R_1 \cdot R_2 \cdot \pi \cdot D \cdot E \cdot [U(\max) - (35 \text{ lb/in}^3 \cdot E)]$   
where:

$$\pi = \text{Pi} = 3.14159$$

D = anchor diameter (inches)

E = anchor embedment (inches)

U(max) = 1400 psi for “low strength” resin  
= 2300 psi for “high strength” resin

$R_0$  = reduction factor for non-redundant applications. This applies when anchors are used with only two anchors per attachment.

$R_0 = 0.85$  for non-redundant horizontal applications

$R_0 = 1.0$  for all other applications

$R_1$  = reduction factor due to edge distance

$R_1 = 1.0 - (1.5 - A)/2.5$  when edge distance  $< 1.5 \cdot E$

$R_1 = 1.0$  when edge distance  $\geq 1.5 \cdot E$

where A = edge distance/E

$R_2$  = reduction factor due to anchor spacing

$R_2 = 1.0 - (1.0 - B)/1.7$  when anchor spacing  $< 1.0 \cdot E$

$R_2 = 1.0$  when anchor spacing  $\geq 1.0 \cdot E$

where B = anchor spacing/E

Specify edge distance and anchor spacing greater than  $6 \cdot D$  or  $0.5 \cdot E$ , whichever is greater.

When rebar is anchor material, add two times the anchor diameter to the required anchor embedment. This extra embedment is necessary for rebar since the exact location of rebar deformations cannot be known. Most of the tension load in a rebar anchor is transferred to the concrete at the deformation location. For this reason fully-threaded anchors are generally preferred for most resin-bonded anchor applications.

For horizontal applications, add 20 percent to the required anchor embedment. This extra embedment is necessary since full resin coverage cannot be assured for horizontal applications. Horizontal applications angled down a minimum of 15 degrees do not require the additional 20 percent.



**RESIN TENSION EQUATION: SERVICE LOADS**

Ultimate tension capacity  $\geq 3$  \* design tension load

**RESIN TENSION EQUATION: SEISMIC LOADS**

Ultimate tension capacity:

$\geq 1.9$  \* design seismic load for “low strength” resin

$\geq 1.6$  \* design seismic load for “high strength” resin

Note: for seismic loading, maximum rod loading  $\leq 0.9 F_y$

$F_y$  = Yield strength of the anchor rod

**RESIN TENSION EQUATION: LRFD LOADS**

$0.5$  \* Ultimate tension capacity  $\geq$  factored load

**GENERAL EQUATION FOR RESIN SHEAR CAPACITY**

Ultimate Shear Capacity =  $R_1 * R_2 * \lambda * D * E * f'_c$  where:

- $D$  = anchor diameter (inches)
- $E$  = anchor embedment (inches)
- $f'_c$  = compressive strength of concrete
- $\lambda = 0.75$  for “low strength” resin
- $\lambda = 1.0$  for “high strength” resin
- $R_1$  = reduction factor due to edge distance
  - $R_1 = 1.0 - (1.5 - A)/2.0$  when edge distance  $< 1.5 * E$
  - $R_1 = 1.0$  when edge distance  $\geq 1.5 * E$
- $R_2$  = reduction factor due to anchor spacing
  - $R_2 = 1.0 - (1.0 - B)/1.7$  when anchor spacing  $< 1.0 * E$
  - $R_2 = 1.0$  when anchor spacing  $\geq 1.0 * E$

If concrete for an existing structure appears to be in good condition, use  $f'_c = 1.2$  times the concrete strength shown on the existing plans.

**RESIN SHEAR EQUATION: SERVICE LOADS**

Ultimate shear capacity  $\geq 3$  \* design shear load

**RESIN SHEAR EQUATION: SEISMIC LOADS**

Ultimate shear capacity  $\geq 1.7$  \* design seismic shear load

**RESIN SHEAR EQUATION: LRFD LOADS**

0.5 \* Ultimate shear capacity  $\geq$  factored load

**COMBINED RESIN TENSION AND SHEAR**

Combined Stress Ratio (CSR)  $\leq$  1.0

$$CSR = (f_t / F_t) + (f_v / F_v)^2$$

$f_t$ ,  $f_v$  = factored loads (i.e., the right side of service load, seismic, or LRFD equations)

$F_t$ ,  $F_v$  = capacities (i.e., the left side of service load, seismic, or LRFD equations)

# APPENDIX – Section 1.11 – Substructures

Figure A1.11.1.7-1 End Bent Details for Prestressed Slabs and Boxes

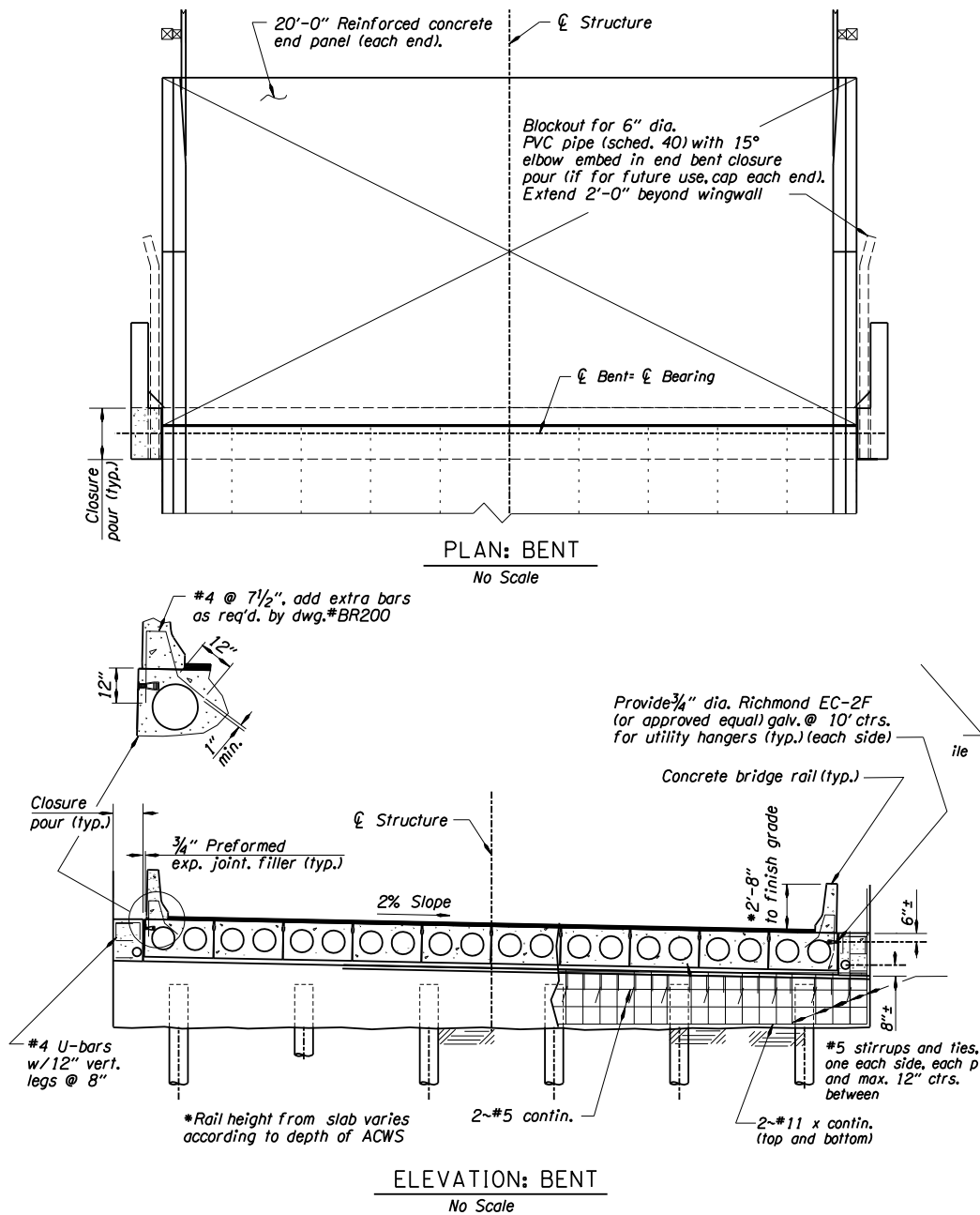


Figure A1.11.1.7-2

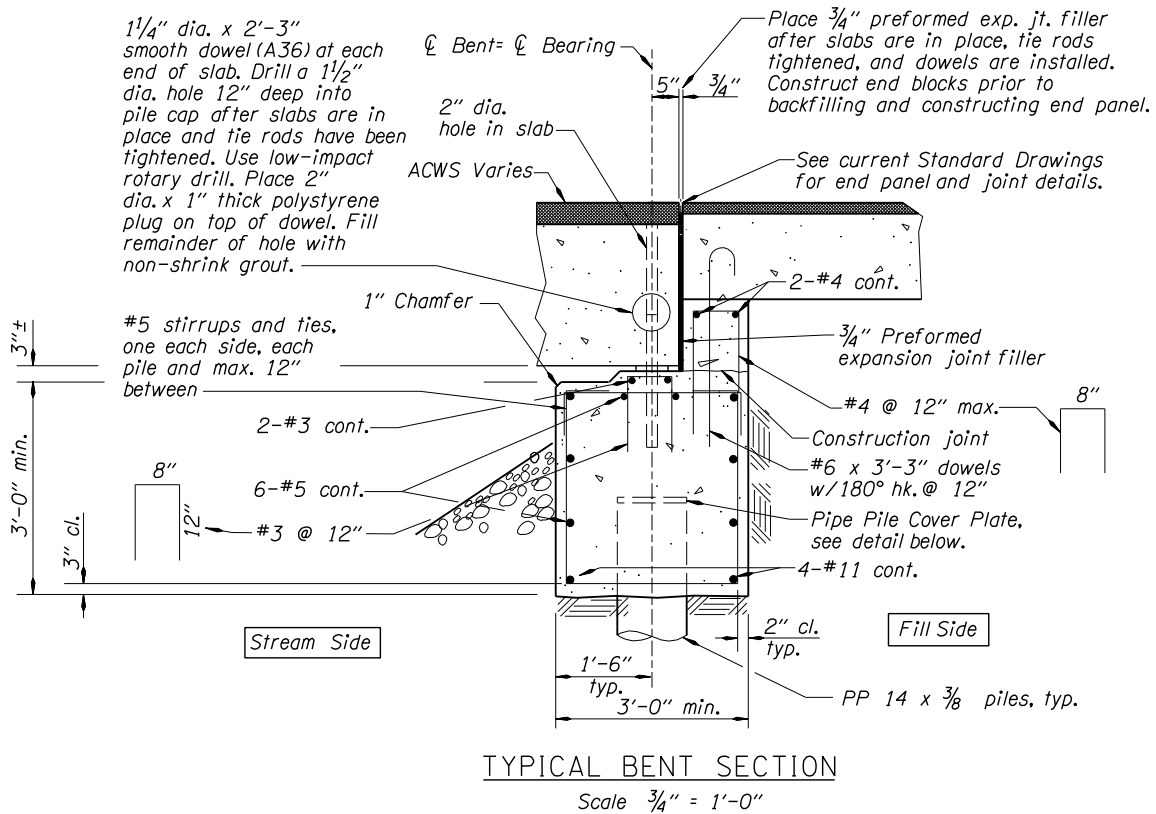


Figure A1.11.1.7-3

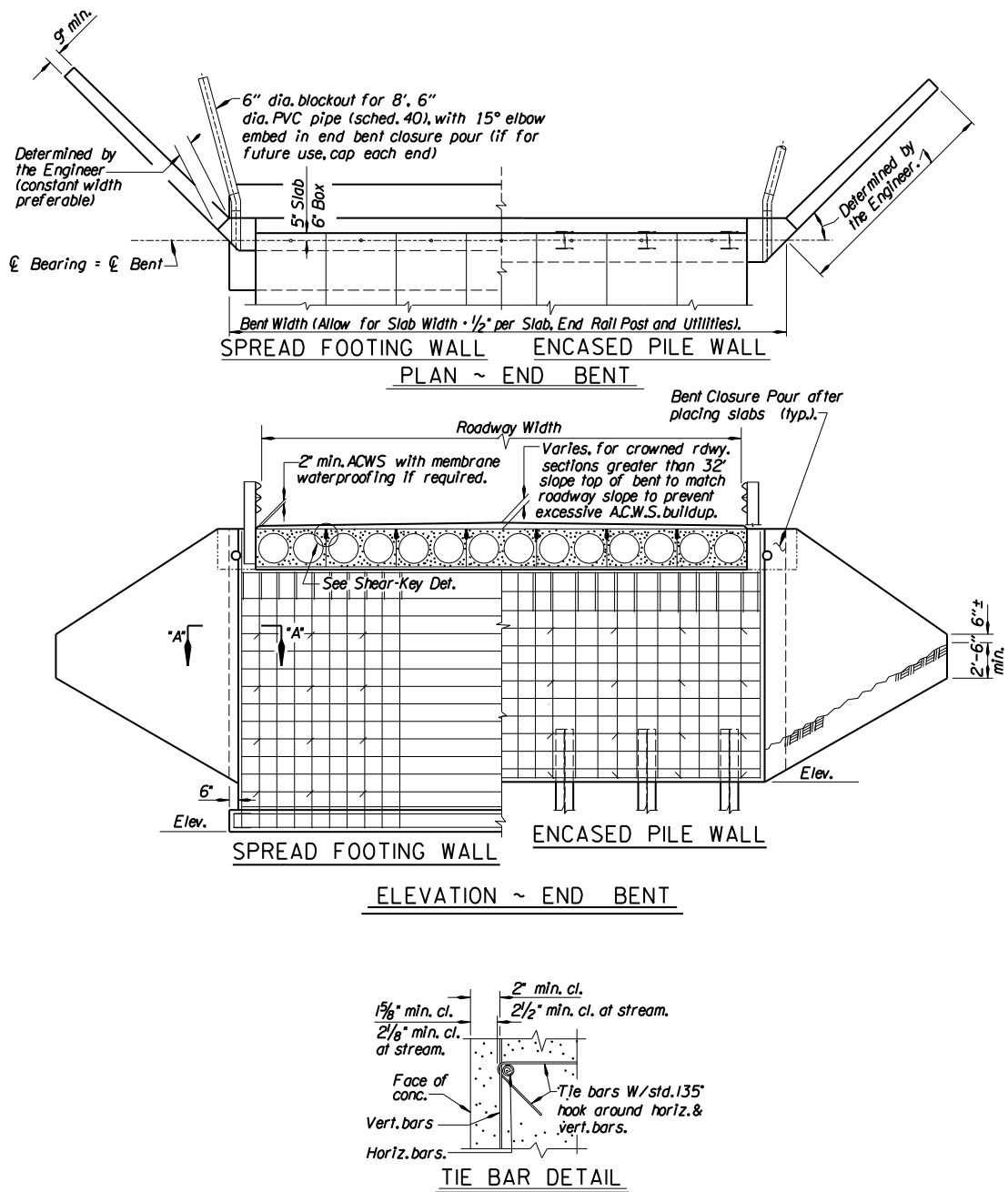
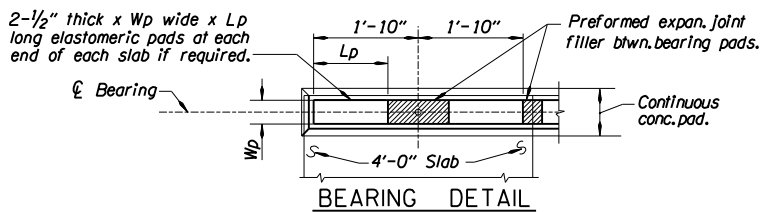
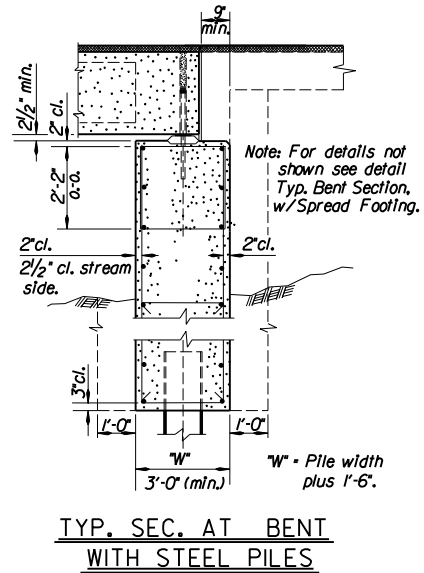
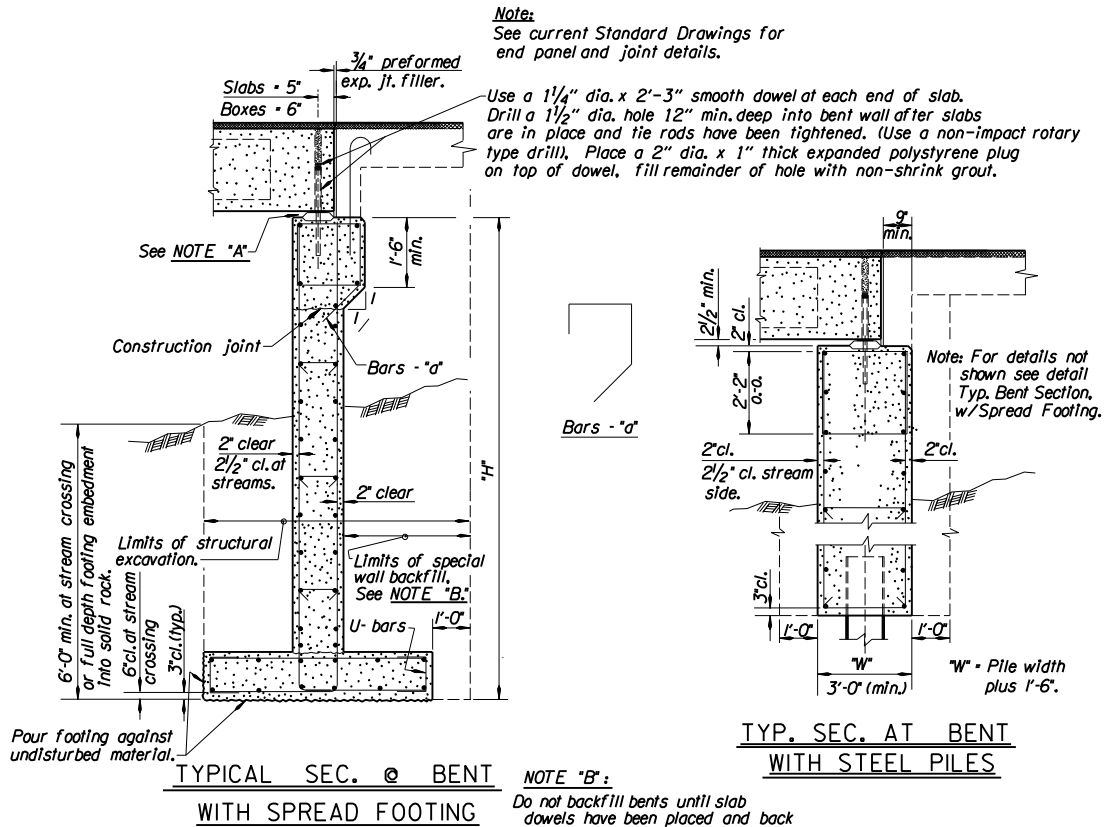
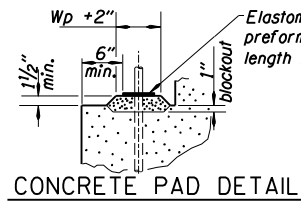


Figure A1.11.1-7-4



Slab Depth	Wp	Lp
15"	5"	16"
18"	5"	18"
21"	5"	20"
26"	5 1/2"	20"
30"	6"	20"



**NOTE "A":**  
Pour 2" concrete pad. Place 1/2" concrete layer a min. of 3 days after pad is poured. Place elastomeric bearing pads and prestressed slabs before 1/2" concrete is fully set to insure uniform bearing across full width of slab. If uniform bearing is not achieved, lift slab and repeat procedure. Any excess concrete protruding above bottom of bearing pads shall be removed immediately after placing slab.

Figure A1.11.1.7-5

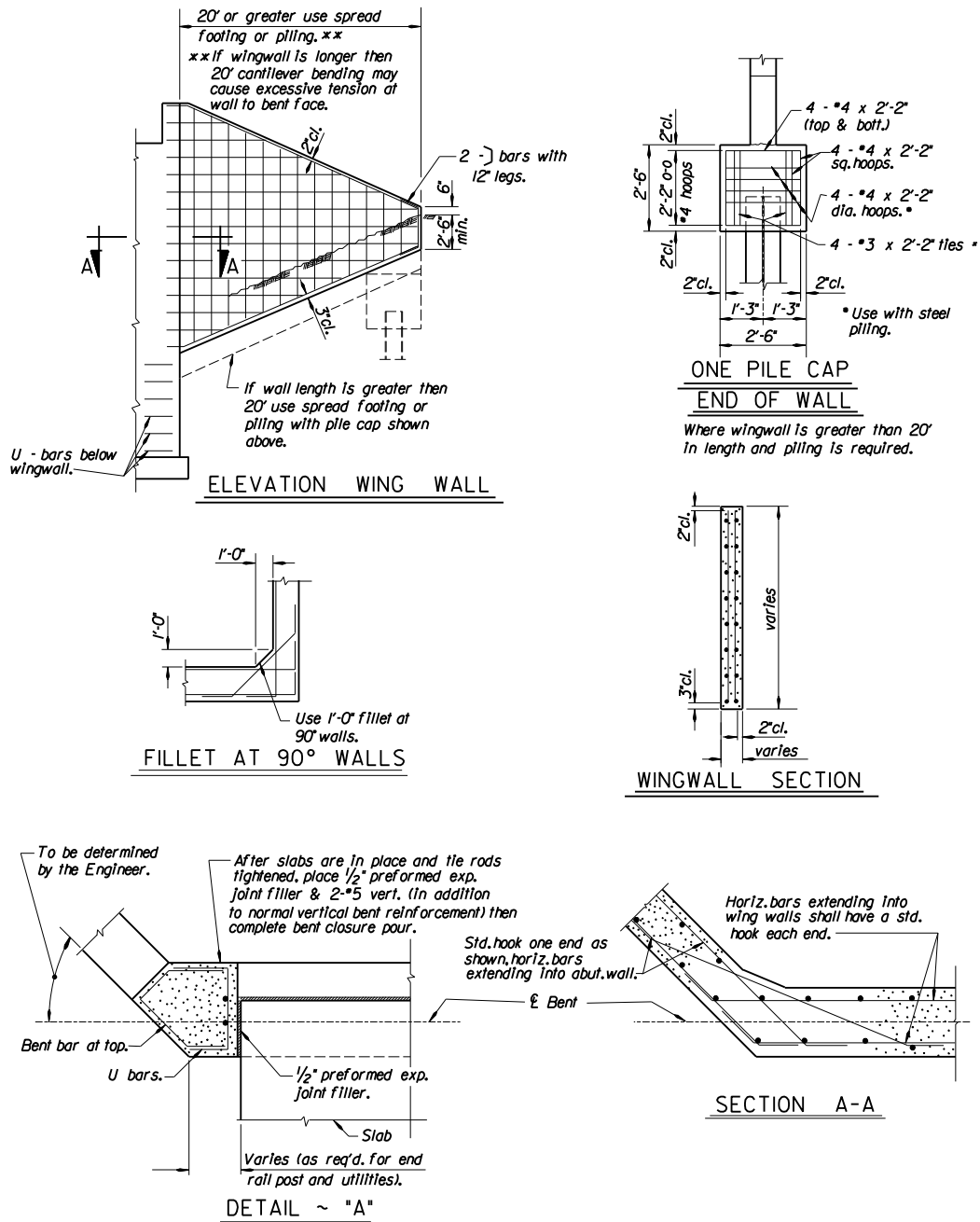


Figure A1.11.2.2-1 Interior Bent Details for Prestressed Slabs and Boxes

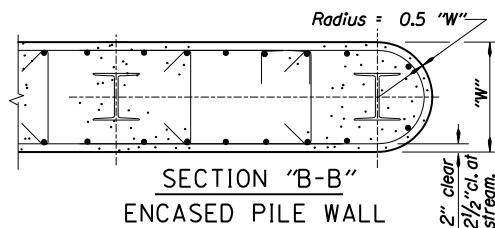
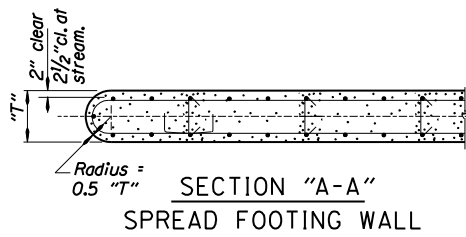
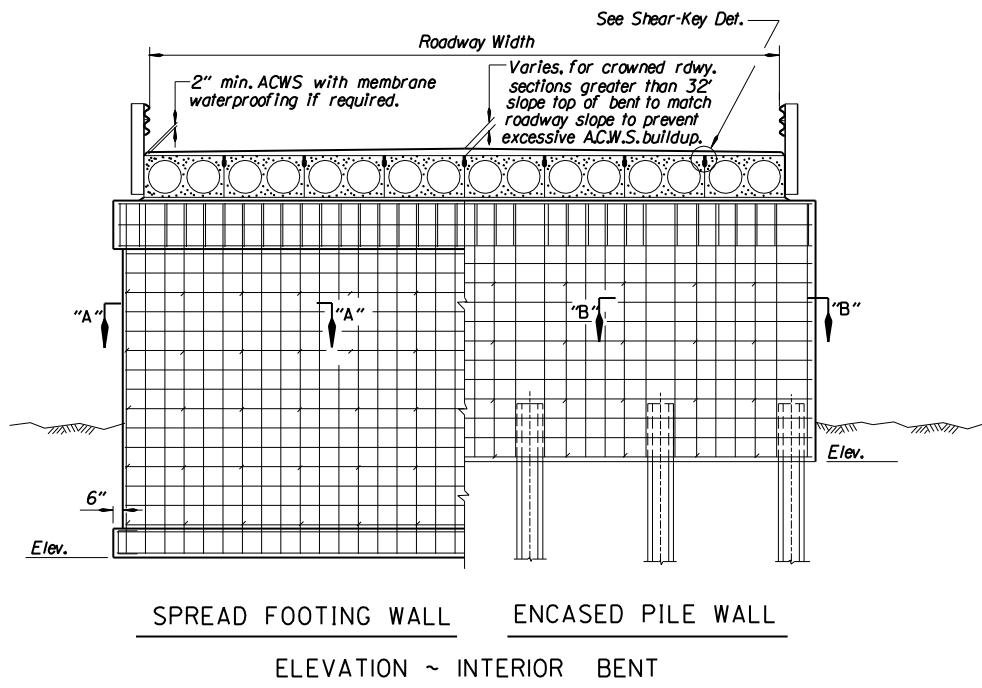
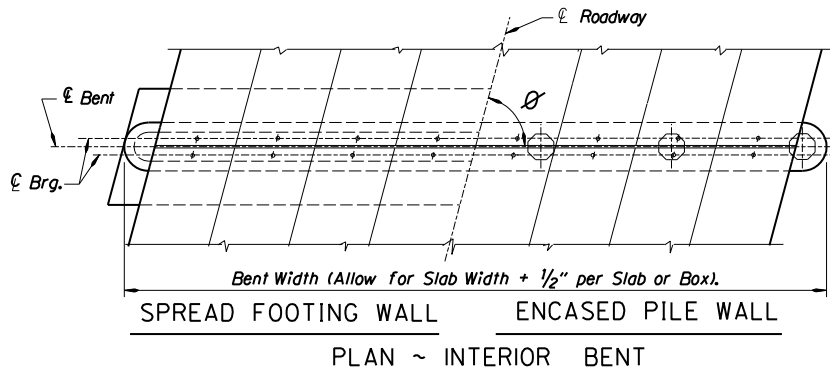




Figure A1.11.2.2-2

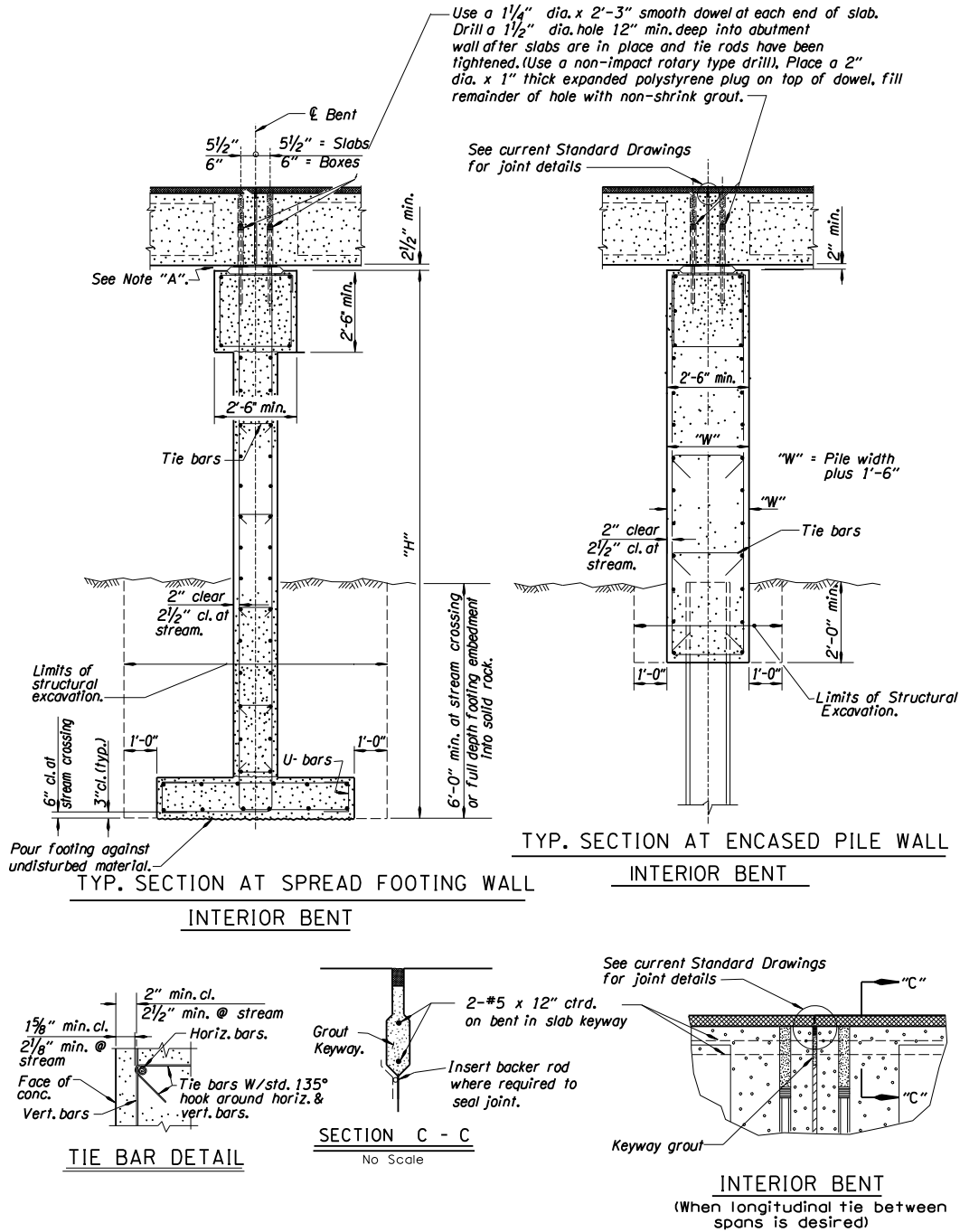
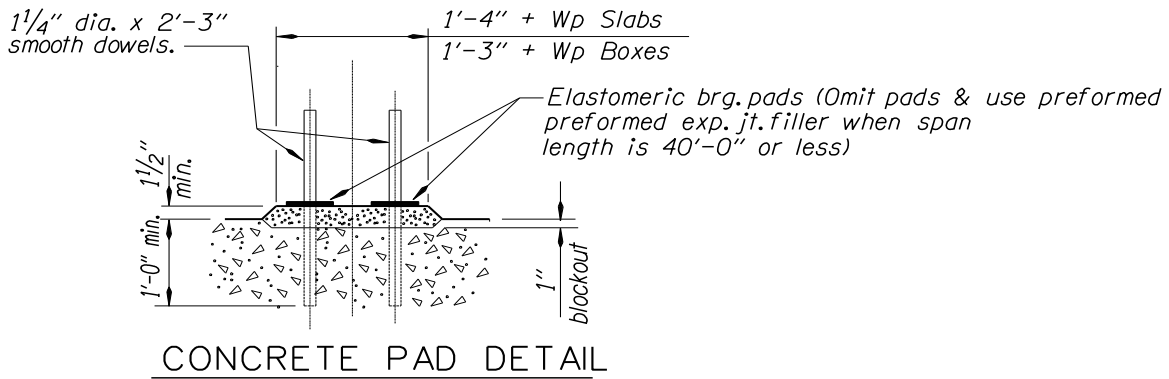
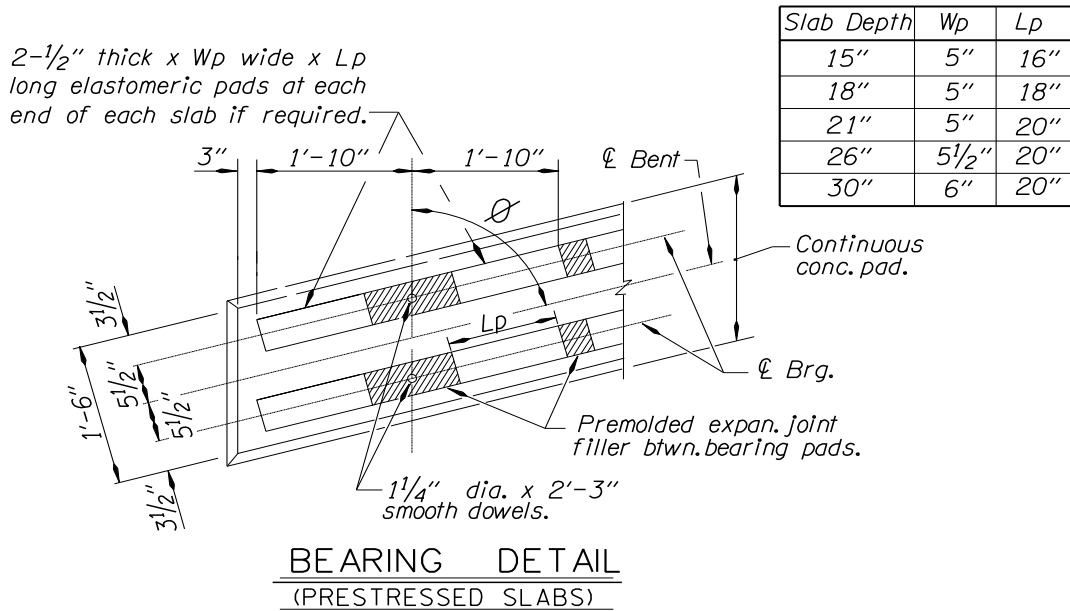


Figure A1.11.2.2-3



See Note "A" below

(Concrete pad to be reinforced when length exceeds 70')

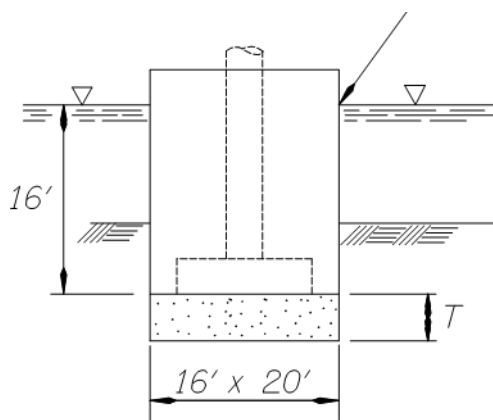
**NOTE "A":**

Pour 2" concrete pad. Place 1/2" concrete layer a min. of 3 days after pad is poured. Place elastomeric bearing pads and prestressed slabs before 1/2" concrete is fully set to insure uniform bearing across full width of slab. If uniform bearing is not achieved, lift slab and repeat procedure. Remove any excess concrete protruding above bottom of bearing pads immediately after placing slab.

# APPENDIX – Section 1.38 – Bridge Temporary Works

## SPREAD FOOTING EXAMPLE (USING METHOD 1):

Figure A1.38.5.3-1 – Method 1



Determine the seal thickness for a 16' x 20' cofferdam. Water depth is 16 feet from the vent to the top of the seal.

$$\text{Estimated } T = 0.4 * (16' + 10' \text{ est. thickness}) = 10.4'$$

Summing vertical forces:

*Uplift force = weight of water displaced*

$$\text{Uplift force} = (\text{Area}) * (\text{Depth of Water}) * (\text{Unit force of water})$$

$$\text{Uplift force} = (16') * (20') * (16' \text{ water depth}) * (0.0624 \text{ k/ft}^3)$$

*Force of seal = buoyant force of the seal*

$$\text{Force of seal} = (16') * (20') * (T' \text{ seal thickness}) * (0.15 \text{ k/ft}^3 - 0.0624 \text{ k/ft}^3)$$

Uplift force = Force of seal

Solving for T:

$$T = 11.4'$$

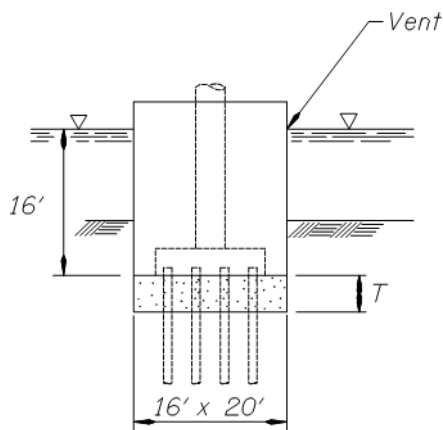
Use 11.5' seal thickness.

Note: F.S = 1.0 for T = 11.4'

**PILE-SUPPORTED EXAMPLE (USING METHOD 1):**

Determine the seal thickness for a 16' x 20' cofferdam, with 12 – 12" diameter steel piles. Uplift capacity is 10 kips per pile. Water depth is 16 feet from the vent to the top of the seal.

Figure A1.38.5.3-2 – Method 1 Pile Supported



$$\text{Estimated } T = 0.25 * (16' + 10' \text{ est. thickness}) = 6.5'$$

Summing vertical forces:

*Uplift force = weight of water displaced*

$$\text{Uplift force} = (16') * (20') * (16' \text{ water depth}) * (0.0624 \text{ k/ft}^3)$$

$$\text{Uplift force} = 319.49k$$

*Weight of seal = buoyant force of the seal*

*Weight of seal*

$$= (16') * (20') * (T' \text{ seal thickness}) * (0.15 \text{ k/ft}^3 - 0.0624 \text{ k/ft}^3)$$

$$\text{Weight of seal} = 28.03 * (T) \text{ k/ft}$$

*Pile displaced concrete*

$$= (12 \text{ pile}) * (0.785 \text{ ft}^2) * (T') * (0.15 - 0.0624) \text{ k/ft}^3$$

$$\text{Pile displaced concrete} = 0.825 * (T) \text{ k/ft}$$

$$\text{Bond on piles} = (12 \text{ pile}) * \pi * 1' * 6.5' * 0.010 \text{ ksi} * 144 \text{ in}^2/\text{ft}^2$$

$$\text{Bond on piles} = 352.86 \text{ k}$$

$$\text{Pile uplift capacity} = (12 \text{ pile}) * (10 \text{ k/pile})$$

$$\text{Pile uplift capacity} = 120 \text{ k} < 352.86 \text{ k}$$

Use 120 k

$$\text{Uplift force} = (\text{Seal weight}) - (\text{Pile disp. conc.}) + (\text{Pile uplift capacity})$$

$$319.49 k = 28.03 (T) - 0.825 (T) + 120$$

Solving for T:

$$T = 7.33'$$

Use 7.5' seal thickness.

Note: F.S. = 1.0 for T = 7.33'