

DB Section 141.12 - Geotechnical

(a) Scope - This Section covers investigations, analyses, design, and construction of all geotechnical elements associated with Bridge structures, retaining walls culverts, embankments, and slopes.

(b) Standards and References - Design-Builder shall perform all geotechnical Work in accordance with the requirements of this Section 141.12.

(1) Standards

- ODOT *Geotechnical Design Manual* (GDM)
- AASHTO LRFD *Bridge Design Specifications*
- ODOT *Bridge Design and Drafting Manual*
- ODOT *Highway Design Manual*
- **DB Standard Specifications** (Parts 00200 through 03000 of the *Oregon Standard Specifications for Construction*)
- AASHTO *Manual on Subsurface Investigations*
- “Standard Practice for Description and Identification of Soils” (Visual-Manual Procedure) ASTM D2488-00
- ODOT *Soil and Rock Classification Manual*
- “Design and Construction of Driven Pile Foundations,” Vols. 1 and 2, FHWA-HI-97-013 and -014, 1998
- “Drilled Shafts: Construction Procedures and Design Methods,” FHWA-IF-99-025, 1999
- “Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines,” FHWA-NHI-00-043, 2001
- “Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes,” FHWA NHI-00-044, March 2001
- “Earth Retaining Structures,” FHWA-NHI-99-025, 1999
- “Soil Nail Walls,” FHWA-IF-03-017 (GEC 7), 2003
- “Shallow Foundations,” FHWA-IF-02-054 (GEC 6), 2006
- “Soil Slope & Embankment Designs,” FHWA-NHI-01-026, 2002
- “Geosynthetic Design and Construction Guidelines,” FHWA-HI-95-038 (April, 1998)
- AREMA *Manual for Railroad Engineering*
- “Rockfall Catchment Area Design Guide,” FHWA Final Report, SPR-3 (032) (2001)
- FHWA, *Bridge Technology, Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications*, found at: <http://www.fhwa.dot.gov/bridge/checklist.htm>
- “Geotechnical Instrumentation,” FHWA-HI-98-034, 1998

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- AASHTO LRFD Bridge Construction Specification

(Other Standards applicable to report formats and contents and investigations are found in the relevant text.)

(2) References

- ODOT *Manual of Field Test Procedures*
- “Training Course in Geotechnical and Foundation Engineering: Subsurface Investigations,” FHWA-HI-97-021, 1997
- “Evaluation of Soil and Rock Properties,” FHWA-IF-02-034 (GEC 5), 2002
- “Geotechnical Earthquake Engineering for Highways,” Vols. 1 & 2, FHWA-SA-97-075 & -076 (GEC 3), 1997
- USGS *Seismic Hazard Maps*, found at <http://eqhazmaps.usgs.gov>
- “Micropiles – Design and Construction Guidelines,” FHWA SA-97-070, 2000
- ODOT Recommended Guidelines for liquefaction Evaluation Using Ground Motions from Probabilistic Seismic Hazard Analysis ODOT Research Report “FHWA Assessment and Mitigation of Liquefaction Hazards to Bridge Approach Embankments in Oregon” SPR 361, 2002

(c) Requirements – All geotechnical work shall be in accordance with the applicable requirements of the ODOT GDM. All geotechnical reports shall be prepared in accordance with the criteria set forth in this Subsection by a Design Professional with a minimum of five (5) years of geotechnical engineering experience in the State of Oregon. All geotechnical Work shall be conducted under the direction of this Design Professional. All design calculations and Plans shall be checked, signed and stamped by a Design Professional.

(1) Geotechnical Investigation Plan – Design-Builder shall prepare a Geotechnical Investigation Plan and provide it to Agency PM within 45 Calendar Days of NTP. Agency’s Review and Comment will be completed and returned to Design-Builder within 15 Calendar Days. The plan shall include the criteria or rationale used in developing the plan, and shall identify the locations of all field investigation sites, in-situ testing sites, and borings, together with their depths, sampling intervals, and a description of both the field and laboratory testing programs utilized. The plan shall also include a traffic control plan, a safety/hazard analysis plans, and a list of all permits required to perform the geotechnical investigation.

(2) Subsurface Investigation and Data Analysis

a. General - Design-Builder shall be familiar with available geotechnical, geologic, seismic, hydrogeology, and soils literature, shall be familiar with the existing site conditions, both native and man-made, shall interpret the existing geotechnical data pertaining to the Project Site, and shall perform all additional subsurface investigations and field and laboratory testing as may be necessary to satisfy itself as to (a) the nature of the Soil, Rock, groundwater, and subsurface conditions across the Project Site and all variations in groundwater and subsurface conditions; (b) the geological formations within, and attributes of, the Project Site; (c) the nature of the Work to be performed; (d) appropriate methods of construction; (e) critical

combinations of loading; (f) seismic setting of site, and (g) all other factors impacting evaluation.

Laboratories shall be certified and shall have documentation of calibration within the last year for all Equipment used for testing.

Information obtained using a pocket penetrometer or field torvane shall not be the primary means for development of geotechnical parameters.

b. Requirements - Design-Builder must comply with the following in performing field and laboratory investigations:

1. Supervision - All boring and in-situ testing and inspection, and all laboratory classification and testing, shall be performed by geologists or geotechnical engineers under the direct supervision of a Design Professional with a minimum of 10 years' experience in the performance and supervision of geotechnical investigations.

2. Location and Ground Surface Elevation - Design-Builder shall determine the coordinate location and ground surface elevation for each boring and field investigation site, and shall show the coordinates, station and offset, and elevation for each individual boring log or investigation record. Coordinates and station and offset shall be referenced to the Project survey control. Elevations shall be referenced to the Project datum and horizontal control system. Boring horizontal coordinates shall be accurate to +/-1.0 foot; vertical coordinates shall be accurate to +/- 0.5 foot.

3. Logs - Final boring and Rock core logs shall be prepared using geotechnical software by gINT software.

Design-Builder shall classify Rock in accordance with the ODOT *Soil and Rock Classification Manual*.

Design-Builder shall classify Soil in accordance with the "Standard Classification of Soils for Engineering Properties" (Unified Soil Classification System) ASTM D2487-00, and "Standard Practice for Description and Identification of Soils" (Visual-Manual Procedure) ASTM D2488-00.

(3) Geotechnical Design Report

a. Draft Geotechnical Design Report / Draft Geotechnical Data Sheets - Design-Builder shall document all geotechnical data and findings, including a summary of existing information, results of the field subsurface investigations and mapping, results of the laboratory tests, and geotechnical and foundation analyses and design, in the form of a Draft Geotechnical Design Report (DGDR) and Draft Geotechnical Data Sheets in accordance with the FHWA *Bridge Technology, Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications*. The DGDR shall follow the requirements provided in the ODOT GDM, Section 21.4.

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b. Final Geotechnical Design Report / Final Geotechnical Data Sheets - Design-Builder shall document all geotechnical data and findings, including without limitation a summary of existing information, results of the field subsurface investigations and mapping, results from the laboratory tests, and geotechnical and foundation analyses and design. The documentation shall be consolidated in the form of a Final Geotechnical Design Report (FGDR) and Final Geotechnical Data Sheets signed and stamped by a Design Professional. Design-Builder shall prepare the FGDR and Final Geotechnical Data Sheets in accordance with the ODOT GDM, Sections 21.4.2.1 and 21.7, and shall ensure that the recommendations shown in the FGDR meet all Contract requirements. Design-Builder's FGDR shall include the Geotechnical Report Review Checklist, as provided in ODOT GDM, Appendix 21-A.

c. Geotechnical Recommendations - Design-Builder shall use the findings and recommendations shown in the FGDR to develop the foundation design for the Structures.

d. Field Testing Frequency - Design-Builder shall ensure that the field testing frequency meets the minimum requirements stated in the ODOT *Manual of Field Test Procedures*.

e. Revised Geotechnical Design Report / Revised Geotechnical Data Sheets - Where the geotechnical design and geotechnical-related construction differ from the information described in the FGDR, Design-Builder shall revise, in a timely manner, the FGDR and Final Geotechnical Data Sheets to reflect the as-constructed changes. Design-Builder shall ensure that all Revised Geotechnical Data Sheets are included in a Revised Geotechnical Design Report (RGDR). The RGDR shall be signed and stamped by a Design Professional.

(4) Foundation Design - Foundation and geotechnical design for Structures shall follow the ODOT GDM.

a. Wave Equation Analyses - The constructability of a pile design and the development of pile-driving criteria shall be performed using a Wave Equation Analysis for Piles (WEAP) computer program in accordance with AASHTO *Standard Specifications for Highway Bridges*.

Results of the drivability analysis and pile-driving criteria shall be submitted at least seven (7) Calendar Days prior to driving piling. Drivability analysis shall be conducted for all hammers and pile types proposed for use, and for each Bridge foundation.

b. Deep Foundation Testing and Monitoring

- **Pile Driving Records** - All pile-driving records shall be recorded in the standard ODOT Pile Record Book, Form 734-3485. Design-Builder shall provide all information required in the ODOT Pile Record Book. The hammer stroke and final pile tip elevations must be recorded. Design-Builder shall provide all completed Pile Record Books to Agency PM after pile driving is completed for each Work Location. Design-Builder shall assign one inspector per each pile-driving rig.

- **Pile Driving Analyzer (PDA)** - PDA may be used on large projects or on projects with many long, high-capacity piles, where high driving stresses are anticipated, to test new pile hammers or to verify questionable hammer performance, or where verification of skin friction for uplift capacity is required. A signal matching analysis (CAPWAP) of the dynamic test data must be used to determine the ultimate capacity. A Design Professional shall determine if PDA will be required.

c. Drilled Shaft Integrity Testing - Integrity testing consisting of Crosshole Sonic Logging (CSL) shall be performed on all non-redundant drilled shafts, and for redundant drilled shafts, on at least one shaft at each bent or abutment. Steel tubes to allow CSL testing shall be installed in all drilled shafts. The first drilled shaft installed at a location shall be tested so that the method and Equipment can be approved by the supervising Design Professional. If subsurface conditions vary at a Bridge site, the supervising Design Professional may require that additional shafts be tested. All CSL tests shall be reviewed and approved by the supervising Design Professional, as well as any remedial measures or repairs that may be needed.

(5) Retaining Wall Design - The following criteria shall apply to permanent wall Structures.

a. Acceptable and Unacceptable Wall Types

1. Acceptable Wall Types - Acceptable retaining wall types include gravity, cantilever, tangent or secant pile systems, and soldier pile and lagging, Soil nail and shotcrete, and mechanically-stabilized earth (MSE) walls.

- **MSE Walls** - The MSE wall systems listed in the ODOT GDM as “approved,” “conditional,” or “experimental,” may be considered for use for retaining walls up to 30 feet in height.
- **Soil Nail Walls** - Soil nail walls are acceptable to Agency, and shall be designed in accordance with “Soil Nail Walls,” FHWA-IF-03-017 (GEC 7), 2003.
- **Other Wall Systems** - Other acceptable wall systems are conventional cast-in-place concrete retaining walls, concrete crib walls (not allowed within 50 feet of Bridges), and wire enclosed riprap (gabions) less than 10 feet in height (applied in stream banks only).

The wall systems identified in this Subsection are acceptable, provided that Design-Builder demonstrates that the wall system selected can accommodate the anticipated total and differential settlements over the required service life of the Structure.

2. Unacceptable Wall Types - Metal walls, including bin walls and sheet pile walls, recycled material walls, timber walls, walls utilizing geo-fabrics, and unfinished wire fabric walls shall not be allowed for permanent retaining walls.

b. Design Criteria

1. Service Life - The service life of all retaining walls shall be 75 years.

2. Seismic Case - All retaining walls supporting Bridge approach fill or affecting the performance or structural integrity of the Bridge (within 500 feet), shall be designed for the seismic case of the peak horizontal ground acceleration corresponding to a return period of 1,000 years. All other walls shall be designed for the seismic case of earthquake acceleration corresponding to a return period of 500 years.

- 1000 year event (5% exceedance in 50 years): This level of shaking should not result in total collapse of the Bridge. The embankments (approach fills) may undergo large displacements as long as the displacements do not result in total collapse of the Structure.
- 500-year event (10% exceedance in 50 years): This level of shaking should result in the Bridge being accessible to emergency traffic immediately following the event.

3. Stability and Settlement of Walls - All retaining wall designs shall address internal, external and global (overall) stability and settlements (total and differential) of the walls in accordance with the requirements of the ODOT GDM.

4. MSE Walls (including modular block MSE walls) - Design-Builder shall use the ODOT GDM as required. All retaining walls at a Work Location shall have the same finish and appearance.

c. Geometry - Retaining-wall layout shall address slope maintenance above and below the wall. Returns into the retained fill or cut at retaining wall ends shall be provided where possible. Final tolerances shall be 5/8" (0.05 feet) in 10 feet for level and plumb. Where five (5) foot (minimum) of generally level terrain is not available between the wall and ROW line for maintenance, the wall shall be located at the ROW line.

Design-Builder shall provide adequate surface and subsurface drainage in the design and construction of all retaining walls. A system shall be provided to intercept or prevent surface and ground water from entering behind the walls. Drainage shall be provided along the retaining wall and into a drain. A fence or pedestrian railing shall be provided at the top of retaining walls over six (6) feet high where access is open to the public.

d. Plans and Calculations - Design-Builder shall provide Plans and design calculations meeting AASHTO LRFD *Bridge Design Specifications*, including a global stability and seismic analysis.

(6) Fill / Embankment Design

a. Slope Stability - Design-Builder shall design slopes in accordance with the "Soil Slope and Embankment Designs," FHWA-NHI-01-026, 2002. Design-Builder shall design embankment slopes no steeper than 1:2, vertical: horizontal.

Analysis shall consider the effects of deterioration and loss of Soil resistance due to local climatic and construction conditions. All fill slopes shall be designed to minimize, to the extent practicable, erosion by rainfall and runoff and future raveling of the Rock cuts. Adequate surface/subsurface drainage and erosion control provisions shall be incorporated in the design and construction of all fill slopes.

Slope stability analysis shall be conducted using a two-dimensional slope stability computer program such as XSTABL. Analysis of embankment configuration and slope design shall include potential for circular and wedge type failures. Slope stability analysis shall confirm that the embankment slope designs provide global slope stability under static loads as specified herein. The analysis shall include consideration of the effect of potential seepage forces, design flood levels, rapid drawdown and any weak deposits and seams that are adversely impacted by water flow. Permanent fill/embankment slope design and non-permanent slopes shall meet ODOT GDM requirements.

b. Settlement - Design-Builder shall conduct an analysis to estimate Soil settlements induced by embankment loads, including immediate settlement in granular soils, and both immediate and consolidation settlements in cohesive soils. Design-Builder shall design embankments in order to limit total long-term settlements to two (2) inches during a period of 50 years after completion of the Pavement construction for the embankment. Differential settlement across fill/Structure interfaces shall be limited to ½ inch.

c. Reinforced Soil Slope (RSS) Design - The design procedures and considerations for reinforced Soil slopes shall conform to the requirements of "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines," FHWA-NHI-00-043.

Adequate surface and subsurface drainage provisions, and slope protection and erosion control provisions, shall be incorporated into the RSS designs in accordance with the requirements of "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines," FHWA-NHI-00-043, and as required herein.

d. Fill / Embankment and Reinforced Soil Slope Construction Considerations - Alternative methods of embankment construction shall be compared for safety and cost-effectiveness. The main considerations shall be to provide adequate safety factors against external and internal stability and global (overall) stability and bearing capacity failures, and to reduce the settlement to within the allowable range as specified herein. In addition, the design must provide for adequate surface and subsurface drainage, slope protection, and erosion control for the slopes, and prevent the development of long-term maintenance problems for Agency.

e. Drainage - The design shall incorporate an adequate system of surface and subsurface drainage and surface protection, with sufficient capacity for the design rainfall run-off, so as to prevent (a) erosion of the slopes that could result in erosion rills and gullies and surface sloughing, and (b) build-up of groundwater that could result in slope instability. In addition, surface drainage systems, consisting of drain rocks, filter fabric, and drain pipes, must be provided at locations where the

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embankments cross over creeks, streams, or valleys. Notwithstanding the requirements of the relevant Standards, the design shall address the long-term performance of the drainage and erosion control system for each embankment or fill under local conditions.

Where horizontal drains are to be used, a protective measure must be devised to protect the drains from freeze/thaw. A long-term maintenance program must be developed by Design-Builder and presented to Agency to safeguard the long-term functionality of the horizontal drains.

f. Soil Improvement - Alternative Soil improvement methods that increase Soil strength and reduce compressibility in order to increase the safety factors for external, internal, and global stability, and reduce settlements to the allowable range specified herein, may be allowed in the design if they are suitable for local conditions and selected fill/embankment installation methods. Techniques such as vertical drains, surcharge, stone columns, vibro-compaction, lime columns, cement columns, deep Soil mixing, grouting, and the use of lightweight fill may be included in the design in order to expedite the consolidation of areas, where it is required to increase bearing capacity or reduce post-construction settlements. Selection of the type of Soil improvement method shall be restricted to methods which have documented successful results in equivalent Soil conditions for equivalent applications, and shall depend on the engineering properties of the subsoil, Material quality, performance, supply, and installation time. Available expertise shall also be considered.

The performance of all ground improvement techniques shall be verified with a pre-production field testing program developed to demonstrate that the proposed methods and design will provide the ground improvement level required to satisfy the performance requirements specified herein.

g. Bridge End Panels - To provide a smooth transition from at-grade section to elevated sections of grade separation Structures, Bridge end panels shall be provided at the abutments.

(7) Cut Slopes (Soil/Rock) - Design-Builder shall review the existing conditions of the Soil/ Rock slopes and undertake to:

- Demonstrate that the existing slopes are in stable condition before proceeding with design and construction of permanent Structures
- Verify the structural stability of the Soil/Rock slopes for final site conditions and develop measures to mitigate slope instability

Design-Builder shall be responsible for the correction of all distress (i.e., bulging of shotcrete, shotcrete cracking, slope deflections, slope sloughing off) that may be induced to Structures/properties as a result of construction. Therefore, Design-Builder shall establish a baseline to monitor all distress of the Structures/properties adjacent to the proposed Work. In addition, Design-Builder shall establish trigger criteria and undertake remediation, if such trigger values are exceeded.

The maximum permissible deflections and/or movements shall not exceed 0.5 inch. If such value is exceeded, Design-Builder shall undertake remedial measures to stabilize the slope.

a. Soil Cut Slopes - Geotechnical analyses of Soil cut slopes (existing and new) shall be performed to assess Soil slope stability along new and existing Soil cut slopes. The analyses shall include:

- Review of existing geologic and geotechnical data
- Collection of new geologic and geotechnical data
- Evaluation of the potential slope stability problems
- Slope design and stabilization measures

Soil properties for slope stability analyses shall be obtained from existing data provided in the Geotechnical Data Report (if deemed appropriate by Design-Builder) and data generated from the subsurface investigation, field mapping and laboratory testing completed by Design-Builder. The data collected shall include mapping information, boring data and other geotechnical/geologic data. Potential circular and wedge-type failure modes shall be analyzed for each Soil cut and each slope and orientation. Geotechnical analyses of Soil cut slopes shall be performed using Soil mechanics software, such as XSTABL. The analyses shall cover the following:

- Slopes with a variety of slope angles
- Slope face orientation (i.e., slope facing towards north, south, east and west)
- Boundaries between materials to show different types and thicknesses
- Shear strength of the Soil to be defined in terms of Mohr-Coulomb criteria
- Groundwater levels to be applied to show a dry slope and groundwater table within the slope
- Seepage encountered on slope faces
- External loads where applicable
- Shape and position of rupture surface defined as circular and as straight-line segments
- Slope geometry, material boundaries and rupture surface to be plotted
- Factor of safety of 1.3 or greater for static stability, and 1.0 or greater for seismic stability

Slopes that do not meet the required safety factor referenced above shall be reconfigured with a reduced slope angle or shall be supported with a retaining wall or ground supporting systems.

b. Rock Cut Slopes

1. Rock Slope Stability - Geotechnical analyses of Rock cut slopes shall be performed to assess Rock slope stability along new and existing Rock cuts. The analyses shall include:

- Review of existing geologic and geotechnical data
- Collection of new geologic and geotechnical data

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- Evaluation of the potential slope stability problems
- Slope design and stabilization measures
- Rock fall hazard analyses

Rock properties (if any) for slope stability analyses shall be obtained from existing data provided in the **DB Special Provisions**, Attachment "A" and data generated from the subsurface investigation, field mapping and laboratory testing completed by Design-Builder. The data collected shall include Rock mapping information, boring data and other geotechnical/geologic data. Discontinuity orientation and strength shall be evaluated, and discontinuity sets shall be established for each Rock cut for use in stability analyses. Rock cuts with well-defined sets of discontinuities shall be evaluated for stability (potential planar, wedge and toppling failure modes) using Rock mechanics analytical methods as described and defined in "Corrosion/Degradation of Soil Reinforcements for Mechanically Stabilized Earth Walls and Reinforced Soil Slopes," FHWA NHI-00-044, 2001, and Rock mechanics software (DIPS or SWEDGE). Planar, wedge and toppling failures shall be analyzed for potential occurrence for each Rock cut and each slope and orientation. Groundwater shall be considered in the planar and wedge slope stability analysis. A dry slope condition shall be analyzed, and a partially-saturated slope shall be analyzed. The factor of safety for Rock slope stability shall be 1.3 or greater for static stability, and 1.0 or greater for seismic stability.

For Rock cuts which do not exhibit well-defined sets of discontinuities, slope stability analyses shall be performed using Soil mechanics methods. These analyses shall use a computer program, such as XSTABL. The analyses shall cover the same factors as listed in Subsection (c)(7)-a above, "Soil Cut Slopes."

2. Rock Fall Modeling - Rock fall modeling or Rock fall simulation analyses shall be performed to predict Rock fall behavior and to design Rock fall catchment widths and depths for each Rock cut. The Colorado Rock Fall Simulation Program (CRSP) shall be used. Rock fall paths shall be plotted and histograms of bounce height, Rock velocity, and energy shall be obtained and plotted for various Rock block sizes. The number of Rock blocks landing on Roadways shall be stated. The maximum energy at an analysis point shall be used to design Rock fall catchment barriers. The program shall complete a minimum of 500 iterations for each cut and block size modeled. A minimum of two (2) block sizes (average and maximum) shall be modeled for each slope configuration. Block size shall be established based on Rock mapping and Rock fall hazard-mapping data determined by Design-Builder during Design-Builder's investigation program. Rock cut slope roughness factor and tangential and normal coefficients shall be based on field data and suggested values from the verified software program. A basis for value selection shall be provided as part of the analysis documentation. Existing cuts and new cuts shall be modeled as stated above. Existing cuts shall model existing conditions (slope, ditch width and depth) to verify if existing slope conditions/configuration are adequate to contain rockfalls as defined below. All cuts shall be modeled to determine optimal ditch width and depth.

3. Stabilization Measures - For all Rock cut slopes that do not meet the design criteria referenced above for stability, Design-Builder shall implement the following measures:

- Reduce the Slope angle to produce a stable slope
- Provide Rock reinforcement, such as Rock bolts/dowels, high-strength Rock anchors, tied-back walls, or buttresses, in accordance with the guidelines included in Subsection (b)(1) "Standards," above

For all Rock cut slopes that do not meet the design criteria referenced above for Rock fall potential, Design-Builder shall implement the following measures:

- Reconfigure the Rock slope or increase the Rock fall catchment ditch width and depth to provide an adequate catchment area.
- Provide Rock fall catchment barriers, such as concrete or gabion walls, Rock fall catchment fences (woven wire-rope nets), or wire mesh drapery hung on the Rock face/slope. Rock fall catchment barriers shall be designed to resist the maximum energy obtained in the Rock fall simulation analyses.

(8) Erosion Control and Drainage - Erosion control and drainage measures shall be evaluated, and designed for all new and existing slopes. Erosion of slopes presents a significant maintenance issue and stability problem on slopes. Rock and Soil strata that are susceptible to erosion and/or freeze/thaw shall be mapped and delineated for all existing and new fills and cuts. Slope protection measures shall be evaluated based upon site-specific conditions, such as surface and subsurface conditions, cut geometry, and susceptibility to erosion or deterioration. Each cut and fill slope that requires erosion control and drainage measures shall be evaluated for the following:

a. Reduction of Water Flow Across Slope - Where slope revegetation cannot be sufficiently established, Design-Builder shall reduce the quantity of water flowing over the slope from upland areas by means of drainage or interceptor ditches across the top of the slope and down the ends of the slope. At the base of the slope, water shall be directed to a discharge point. Design-Builder shall coordinate discharge point drainage with the at-grade drainage system for the Highway.

Drainage or interceptor ditches shall be lined and capable of carrying water generated from upland areas based on the 100-year storm event. Lining Materials shall be cast-in-place concrete, pre-cast concrete, reinforced shotcrete, or asphalt. Rock check dams to slow flows shall be designed and installed based on flow calculations.

b. Slope Revegetation - Where the slope can be made to support vegetation, local plantings shall be used to establish root systems to stabilize the surface of the slope and prevent deterioration of the slope. Design-Builder shall design and provide systems of degradable woven blankets to temporarily hold plantings in place and minimize erosion to the extent practicable until vegetation has established a stable root system.

c. Slope Armor - Where slopes will not support vegetation, slope cover/protection or permanent facing shall be used to protect the slope. Such measures as

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mattress-shaped steel wire mesh containers, gabions, articulated concrete blocks, fabric formed concrete, shotcrete, geosynthetic cells filled with gravel, and rip-rap (crushed stone) placed on a graded filter shall be evaluated, designed and installed. Stone sizes shall be designed base on design water flows.

d. Subsurface Water Control - Design of subsurface water drainage features shall be evaluated as water control measures. Design shall address the use of horizontal drains, blanket drains, trench drains and geocomposites for both cut and fill slopes. Design shall address outlet design and long-term performance and maintenance requirements for the drainage system.

e. Springs and Water Seepage - Any springs and water seepage identified in the field must be contained by means of drainage systems. Design shall address long-term performance and maintenance requirements for the drainage system.

(9) Miscellaneous Construction Considerations

a. Temporary Excavation Support - Temporary excavation support required during construction shall be designed to withstand short-term loading due to earth pressures, groundwater pressures, surcharge pressures, and construction Equipment loading. Working Plans for temporary decking, sheeting, and bracing shall be signed and stamped by a Design Professional.

Surcharge pressures due to construction Materials and Equipment, Structures, and point, line and area loads, shall be included in lateral earth pressure diagrams. Construction Materials and Equipment loads shall be estimated using a minimum 600 psf distributed area load.

Design-Builder shall indicate on the Working Plans special requirements for the installation and removal of temporary bracing systems that relate to the designs of underpinning and protection walls, such as levels of bracing tiers, the maximum distances of excavation below an installed brace, and the amount of preloading.

b. Dewatering and Groundwater Control - Excavations that are left open to precipitation, that extend below groundwater levels, that encounter water seepage, or that are made in existing bodies of water, will require some form of dewatering or groundwater control. Design-Builder shall evaluate the potential need for dewatering and groundwater control when designing a Structure. Examples are constructing Bridge pier, abutment, and culvert foundations near or over existing streams and creeks.

c. Rock Excavation - Design-Builder shall protect the Rock surfaces to preserve their strength and character.

Rock excavation may be done either by mechanical Equipment; by using explosives in drill-and-blast operations, or both. Blasting of Rock shall be undertaken by controlled blasting techniques (cushion (trim), pre-splitting, smooth-wall blasting, and line drilling). Design-Builder shall select the Rock excavation method that minimizes, to the extent practicable, vibration, over-breaks, fly Rock and airblast.

Design-Builder shall repair all blast and vibration-induced damage at no cost to Agency.

d. Quality Assurance During Blasting Operations - Design-Builder is required to do the following:

1. Obtain copies of all applicable codes, Standards, regulations, and ordinances, and keep readily-accessible copies at the Project field office at all times.
2. Retain a blasting specialist with a minimum of 15 years of blasting experience and 10 years of experience in responsible charge of blasting operations to supervise all field blasting operations and personnel. Such blasting specialist shall possess all required federal, State and local licenses and permits.
3. Submit to Agency a Blasting Plan for the areas to be excavated by means of controlled blasting not less than 14 Calendar Days before commencing any blasting operations in that area, or at any time a proposal to change the drilling and blasting methods is made. The plan shall describe everything necessary to excavate the Rock using the controlled blasting techniques selected by Design-Builder. The plan shall be prepared and signed by the blasting specialist.

e. Damage Repair - Damage to existing Structures or property caused by the blasting shall be repaired by Design-Builder at no cost to Agency.

Design-Builder shall notify Agency immediately of any blasting-induced damage.

f. Fly Rock Control - Design-Builder shall control fly Rock at no cost to Agency.

g. Notification - Design-Builder shall notify each adjoining property owner, Agency, and local Authorities, in writing, prior to each blast. The notice shall indicate the date and time of the proposed blast and include any safety precautions required of the adjoining property owner.

h. Mapping - All Rock excavation surfaces shall be mapped under the supervision of a Design Professional to ensure that the final excavation surfaces are examined, and to aid in the discovery of unanticipated adverse geologic conditions. The mapping shall serve as documentation of the geologic conditions encountered on the site mapped during construction.

i. Photography - Photographs shall be taken of all excavated surfaces and construction operations. All photographs must be properly labeled with date, subject, direction of view, vantage point, and photographer.

(10) Substructures and Culverts - All culverts and substructures shall have a 50-year service life with respect to corrosion. Corrosion potential shall be based on pH and electrical resistivity tests conducted on Soil, Rock, and groundwater samples derived from the Project Site.

(11) Construction Instrumentation Monitoring Program - Design-Builder shall prepare programs for using instrumentation to monitor the vibration, noise, acceleration, vertical settlement and lateral movement of temporary support Structures and adjacent ground, and permanent Structures during and after construction, according to accepted industry standards and the Standards set forth in Subsection (b)(1) "Standards," above. Design-Builder shall prepare a Working Plan detailing the proposed program of instrumentation and monitoring, establishing threshold values of the monitored parameters, and describing the response plans that will be implemented when threshold parameters are exceeded. Design-Builder shall provide, install and monitor the instrumentation during and after construction, and shall interpret the data. Construction instrumentation monitoring reports shall be provided to Agency PM on a weekly basis. Corrective action shall be taken where the instrumentation data so warrant.

a. Monitoring of Existing Structures and Utilities - Adjacent Structures and Utilities are to be protected against damage due to the construction of the permanent Structures. Limiting values of movement (horizontal and vertical) and distortion on each Structure and Utility within the Project Site shall be established. To establish these limiting values, Design-Builder shall consider the nature of the Structures and Utilities within the Project Site, including their use, foundation systems, structural design and current condition. Records of Structures and Utilities, where available, shall be examined during the design stage, and where no record exists; pre-construction assessments shall be made of existing Structures and Utilities and clearly documented. These assessments shall be the subject of verification at the commencement of the construction phase and prior to commencement of any adjacent construction activity. Monitoring of each Structure and Utility shall be required during construction.

In order to determine the performance of the permanent Structures, a system of construction monitoring shall be established to include the following:

- Measurement of groundwater levels
- Measurement of blast-induced and pile-driving-induced vibrations and displacement
- Monitoring of settlement and tilt of the permanent Structures and adjacent area both during and after construction. In all cases, monitoring shall be initiated well in advance of construction to establish baseline readings
- Measurement of lateral movement of excavation support walls and permanent Structures
- Measurement of noise level induced by construction activities

The extent of the monitoring program will depend on the size and type of the Structures. A detailed monitoring program shall be prepared for each Structure affected by the construction.

Where adjacent properties may be affected by the construction, the monitoring program shall allow for readings on fixed points on the Structures to permit both total and differential settlements to be assessed and lateral movements to be determined.

b. Instrumentation - The instrumentation utilized in carrying out the monitoring program shall include appropriate types and quantities of monitoring instruments capable of measuring horizontal and vertical movement, tilt of adjacent Structures, Soil pore pressure, vibration, and noise, as applicable.

Instrumentation to be used in the monitoring program to control and assist design and construction may include:

- Piezometers and observation well
- Inclinometers
- Survey stations on Structures and at ground level locations
- Tiltmeters
- Seismographs
- Noise/sound level sensors/meters
- Deep and shallow settlement points and extensometers
- Crack gauges
- Strain and load-measuring devices

The types and numbers of instruments will depend on factors including the size, type and location of proposed Work.

(12) Preconstruction Survey - Design-Builder and Agency shall conduct a joint pre-construction survey of the Project Site for purposes of generating photographic and video documentation of existing damage, leaks and cracks. This pre-construction survey shall form the basis against which all new cracks, existing progressive cracks, or damage will be measured. Design-Builder shall submit to Agency at the beginning of construction the records and photo/video documentation of the pre-construction survey, which have been signed and stamped by a Design Professional.

(13) Submittals - Design-Builder shall prepare design calculations and Plans of all geotechnical elements associated with Rock and Soil slopes, fill / embankments, retaining walls, Bridges, and culverts, as specified in this Section. The design calculations and Plans shall be signed and stamped by a Design Professional and submitted along with the following submittals to Agency PM for Review and Comment:

- **Geotechnical Investigation Plan** - within 45 Calendar Days of NTP
- **Draft Geotechnical Design Report (DGDR) and Draft Geotechnical Data Sheets** - at Definitive Design
- **Final Geotechnical Design Report (FGDR) and Final Geotechnical Data Sheets** - at Readiness-for-Construction
- **Revised Geotechnical Design Report (RGDR) and Revised Geotechnical Data Sheets** - as required, following construction and as part of the Project Records
- **Preconstruction Survey** - at Readiness-for-Construction
- **Results of the wave equation analysis** - at least seven (7) Calendar Days prior to pile driving
- **Pile Record Books** - upon completion of pile installation

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- **Instrumentation Plan** - at least 14 Calendar Days prior to installation of instrumentation
- **Weekly Construction Instrumentation and Monitoring Report** - weekly
- **Blasting Plan** - not less than 14 Calendar Days before commencing blasting operations, or at any time a proposal to change drilling and blasting methods is made
- **Drilled Shaft Integrity Testing Report** - within seven (7) Calendar Days following completion of crosshole sonic logging testing on first shaft, and prior to start of construction on subsequent shafts at each Bridge