NHDOT Geotechnical Engineering And Geological Requirements

A. Geotechnical Investigation and Data Analysis

The Design Builder shall be familiar with available geotechnical information as well as geologic, seismic, hydrogeology and soils literature for the project site. The Design Builder shall be familiar with the existing site conditions, both native and man-made, shall interpret the existing geotechnical information pertaining to the project site, and shall perform (or request from the NHDOT) additional subsurface investigations as needed, and conduct field and laboratory testing as may be necessary to satisfy itself as to the nature of the soil, rock, and groundwater conditions across the project site. The assessment of the site shall include all variations in groundwater and subsurface conditions, geological formations within the site, attributes of the project site, the nature of the work to be performed, appropriate methods of construction, critical combinations of loading, seismic setting of the site, and any other factors relevant to the proposed project work.

B. Geotechnical Engineering Report Requirements

The Design Builder shall prepare a final geotechnical engineering report for the entire project, completing it to the general outline provided in Appendix A. The outline is a guide only, and the geotechnical engineer shall include sections in the geotechnical report as necessary to address all aspects of the proposed project designs. The geotechnical report shall summarize information used in the geotechnical engineering analysis and shall provide design and construction recommendations to address geotechnical features within the project including roadway, bridge and other structures. The design and construction recommendations shall be consistent with all applicable NHDOT and AASHTO standards including seismic requirements. The report will be subject to review by the NHDOT for acceptance prior to the report's finalization.

The geotechnical report shall be prepared by a Professional Engineer licensed in the State of New Hampshire. The Engineer shall have experience in the practice of geotechnical engineering, which shall include experience on at least five roadway projects and five bridge projects completed for state transportation agencies. The qualifications of the geotechnical engineer shall be submitted for approval, and the NHDOT reserves the right to deny approval if the qualifications are considered inadequate.

The Design Builder will be required to follow the NHDOT Standard Specifications and to comply with existing NHDOT Special Provisions for roadway, bridge and other work expected within the project. The following NHDOT special provisions for retaining walls shall be reviewed for incorporation into the work:

- Granular Backfill for MSE Walls (Item 209.5)
- Mechanically Stabilized Earth Retaining Wall (Item 592.1)
- Precast Concrete Modular Wall (Item 592.31)

C. Rock Slope Design Requirements

C.1 Qualifications for Rock Slope Design

The rock slope design and design of remediation measures shall be performed by a Professional Engineer or Professional Geologist licensed in the State of New Hampshire. The Designer shall have experience in the design, construction and remediation of rock slopes to include experience in the following areas:

- Rock slope field data collection
- Rock mass rating systems
- Discontinuity and rock mass shear strength
- Kinematic slope stability analysis via stereonet projection
- Two and three dimensional limit equilibrium block stability analysis
- Two dimensional force and moment equilibrium rock mass analysis
- Rockfall modeling
- Rock slope remediation strategies (slope reconfiguration, drainage, block reinforcement, wire mesh, wire-rope nets, buttresses, rockfall catchment fences, rockfall barriers and scaling)
- Blasting techniques

Experience shall include designing a minimum of ten rock slopes in excess of 30 feet in height and designing rock slope remediation measures at six project sites. The Designer shall also have training in one or more courses in Rock Mechanics and/or Rock Slope Engineering. Proof of experience and training must be provided to the NHDOT for review and approval.

C.2 Submittals, Inspections and Reviews for Rock Slope Work

C.2.1 Review and approval of qualifications: A summary of the formal education, training and experience of the personnel responsible for the rock slope design, and the design and construction of rock slope remediation measures shall be submitted to the NHDOT for review and approval. The NHDOT reserves the right to deny approval if the education, training and experience do not meet the minimum requirements and/or are not considered adequate to perform the rock slope design work required by this document. The rock slope design will not be allowed to begin until approval has been given by the NHDOT.

C.2.2 Review of rock slope design: The Design Builder shall prepare plans and cross sections and complete design calculations of all geotechnical elements associated with the rock slope. All geotechnical/geologic data, rock stability analyses, rock fall simulation analyses, stereographic projections, slope designs and ditch catchment designs shall be submitted to the NHDOT for review and approval, prior to finalizing the rock slope design. Design calculations and plans

shall be signed and stamped by a Professional Engineer or Professional Geologist licensed in the State of New Hampshire.

C.2.3 Inspection of rock slopes: The newly excavated rock slopes shall be subject to inspection by the NHDOT upon the completion of any portion of the rock excavation work to review rock slope conditions.

C.2.4 Submittal of design for rock slope stabilization/remediation measures: The Design Builder shall submit the proposed locations and the design of all rock slope stabilization/remediation measures to the NHDOT for review and approval. The installation of rock slope stabilization/remediation measures will not begin until the NHDOT has granted approval. Design calculations and plan for rock slope stabilization/remediation measures shall be signed and stamped by a Professional Engineer or Professional Geologist licensed in the State of New Hampshire.

C.2.5 Inspection of rock slope stabilization/remediation measures: Rock slope stabilization/remediation measures shall be subject to inspection by the NHDOT upon completion of the installation. Additional measures by the Design Builder may be required if the NHDOT determines that the stability of the rock slopes is not adequate and/or the safety of the public is at risk.

C.3 Criteria for Design and Construction of NHDOT Rock Slopes

C.3.1 Rock Slope Stability and Design – Geotechnical analyses of rock slopes shall be performed to assess rock slope stability along new and existing rock 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
- Rock fall hazard analyses

Rock properties for slope stability analyses shall be obtained from existing data provided in the Geotechnical Baseline Report and data generated from subsurface investigations, field mapping and laboratory testing completed by the Design Builder. The data collected shall include rock mapping information, boring data and other geotechnical/geologic data. Discontinuity, orientation and strength shall be evaluated; discontinuity sets shall be established for each rock slope for use in stability analyses. Rock slopes 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 "Geotechnical and Foundation Engineering - Rock Slopes," FHWA HI-99-007,

1998. Planar, wedge and toppling failures shall be analyzed for potential occurrence for each rock slope, and each slope and orientation. 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.

The slope angle for each rock slope shall be selected based on the rock conditions at the site and the orientation of the discontinuities within the rock. Stereographic projections shall be utilized in the interpretation of the geologic structural data collected for each rock slope.

Presplitting will be required in rock slopes where the designed slope is 10 feet or more in height above the bottom of the ditch. Unless otherwise approved, the NHDOT Standard Specifications requires presplit holes to be not greater than 3 inches in nominal diameter, and spaced 36 inches on center. The presplit holes shall be drilled along the presplit line and at the required slope inclination to the full depth of the slope or to a predetermined stage (lift) elevation. Rocks slopes that are presplit shall not be flatter than 1H:2V or steeper than 1H:8V. Refer to the NHDOT Standard Specifications, Section 203, paragraph 3.3, Presplitting for additional requirements.

A 12-foot wide clear zone needs to be constructed at the top of the rock slope, measured back from the crest of the rock face. All vegetation and overburden need to be removed within the clear zone. This clear zone at the top of the rock slope will eliminate potential tree roots that can grow into cracks in the rock, prying loose rock. The clear zone also provides a buffer zone, in the event that back break occurs at the crest of the rock slope. Back break at the crest could potentially undercut a soil slope located above the rock slope. Any soil slope above the rock slope should begin at the back of the clear zone and extend upward at a 2H:1V or flatter angle to where it intersects the existing ground surface.

C.3.2 Rock Fall Modeling and Design of Catchment Ditch – 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 slope. The Colorado Rockfall Simulation Program (CRSP) shall be used for rock fall modeling. Rock fall paths shall be obtained and plotted for various rock block sizes. The number of rock blocks landing on the roadway 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 slope 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 the Design Builder during the Design Builder's investigation program. Rock 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 slopes and new slopes shall be modeled as stated above. Existing slopes shall be modeled using existing conditions (slope, ditch width and depth) to verify if the existing slope conditions/configuration are adequate to contain rock falls as defined below. All slopes shall be modeled to determine optimal ditch width and depth.

In addition to performing rock fall modeling or rock fall simulation analyses, the Oregon Department of Transportation, Rockfall Catchment Area Design Guide shall be used in the design of ditches in rock slope areas. The ditches should be designed to retain approximately 95% of rockfall. Both the Rock fall modeling analyses and rock fall catchment design shall be modified accordingly if a toe berm is constructed at the toe of the rock slope.

C.3.3 Stabilization/Remediation Measures for Rock Slopes – For all rock slopes that do not meet the design criteria referenced above for stability, the Design Builder shall implement the following measures:

- Reduce the slope angle to produce a stable slope
- Provide rock reinforcement, such as rock bolts, rock dowels, tied back walls, or buttresses
- Provide horizontal drains in rock to lower the pore water pressure

For all rock slopes that do not meet the design criteria referenced above for rock fall potential, the 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 analysis.
- Remove unstable rock remaining on rock slope by measures such as trim blasting, mechanical scaling and hand scaling.
- Provide energy absorbing crushed stone in the ditch area to cushion the impact of falling rocks and reduce bounce/roll of rock fragments.

To reduce back break along the crest of the rock, to minimize blast damage to the rock and to improve breakage along the slope line:

- Utilize controlled blasting methods such as line drilling, pre-shearing, cushion blasting and unloaded gas relief holes between loaded presplit holes

The Design Builder will be required to following the NHDOT Standard Specifications and to comply with existing NHDOT Special Provisions for rock slope related work. The following items in the Standard Specifications shall be reviewed for incorporation into the work:

- Presplit Holes (Item 203.81)
- Extra Drilled Holes without Explosives (Item 203.82)

The following NHDOT special provisions for rock slopes items shall be reviewed for incorporation into the work:

- Rock Bolts (Item 225.2)
- Rock Dowels (Item 225.3)
- Horizontal Drains (Item 224.1)
- Rock Fall Netting (Items 225.1, 670.0532, 670.0531) (Refer to Design Guidelines For Wire Mesh/Cable Net Slope Protection, WA-RD612.2, Research Office, Washington State Department of Transportation, April 2005)
- Energy Absorbing Stone (Item 315.5)
- Rock Scaling –Hand Method (Item 203.91), Machine Method (Item 203.92)
- Best Management Procedures for Blasting (Section 203 Amendment to NHDOT Standard Specifications)

Note - Due to past long-term maintenance problems and failures of epoxy grouted bolts and anchors, only cement grouted rock bolts, dowels and anchors shall be used.

C.3.4 Quality Assurance During Blasting Operations – To assure that the blasting operation is conducted safely and that the rock slope is constructed in a stable condition while ensuring the safety and convenience of the public, follow the requirements in the NHDOT Standard Specifications under Section 203.3.2 Rock Excavation as amended by the special provision for Section 203 - Best Management Procedures for Blasting. Damage to existing structures or property caused by the blasting shall be the responsibility of the Design Builder to remedy. The Design Builder shall notify the NHDOT immediately of any blast-induced damage and/or blasting complaints.

APPENDIX A

Geotechnical Engineering Report Outline

Geotechnical Engineering Report Outline

1.0 Subsurface Explorations and Laboratory Testing Used in Completing Geotechnical Report
2.0 Proposed Project Work Description
3.0 Subsurface Conditions at Proposed Improvements
4.0 Geotechnical Engineering Recommendations
- 4.1 Roadways
  - 4.1.1 Structural Section Extra Sand Depth for Frost Protection
  - 4.1.2 Longitudinal and Transverse Underdrain Requirements
  - 4.1.3 Organic Soil Deposit (Muck) Treatments
  - 4.1.4 Embankment Construction and Slope Requirements
  - 4.1.5 Soil Excavation and Soil Slope Requirements
  - 4.1.6 Bedrock Excavation and Rock Slope Requirements
- 4.2 Structures
  - 4.2.1 Bridge
    - 4.2.1.1 Subsurface Conditions at Substructure Locations
    - 4.2.1.2 Support Material Properties
    - 4.2.1.3 Foundation Type and Frost Embedment Depth
    - 4.2.1.4 Foundation Engineering Properties and Capacities
    - 4.2.1.5 Engineering Analyses of Foundations
    - 4.2.1.6 Structure Backfill Requirements
    - 4.2.1.7 Foundation Testing and Special Requirements
  - 4.2.2 Retaining Walls
    - 4.2.2.1 Subsurface Conditions at Wall Locations
    - 4.2.2.2 Support Material Properties
    - 4.2.2.3 Wall Type and Frost Embedment Depth
    - 4.2.2.4 Foundation Engineering Properties and Capacities
    - 4.2.2.5 Engineering Analysis of Foundation
    - 4.2.2.6 Wall Backfill Requirements
    - 4.2.2.7 Wall Foundation Testing and Special Requirements
  - 4.2.3 Other Minor Structures
    - 4.2.3.1 Traffic Signal Foundations
    - 4.2.3.2 Overhead Sign Foundations
    - 4.2.3.3 Stormwater Treatment Basins
  - 4.2.4 Seismic Assessment and Requirements
- 4.3 Construction Requirements
  - 4.3.1 Dewatering
  - 4.3.2 Vibration Monitoring
  - 4.3.3 Sequencing for Geotechnical Features

5.0 Subsurface Exploration Plan
6.0 Tables and Figures
7.0 Exploration Logs and Laboratory Test Results