Attachment "A" Geotechnical Services Document

This attachment details the minimum requirements and expectations for performing geotechnical engineering services for the DOTD. This attachment is intended to be an overview of expectations and may not be 'all-inclusive'.

Geotechnical Engineering Analysis and Design

Requirements for this contract are described in the following sections. All geotechnical engineering shall be performed in accordance with present design requirements and standard engineering practice. These services include, but are not limited to:

1. Slope stability (embankment & excavation);
2. Embankment settlement;
3. Pile foundations;
4. Drilled shaft foundations;
5. Other foundations;
6. Pile-supported approach slab design data;
7. Bridge foundation static and dynamic load test program;
8. Earth retaining structures;
9. Culverts;
10. Geotechnical analysis & design recommendations report;
11. Construction monitoring;
12. Geotechnical instrumentation;
13. Other geotechnical features; and
14. List of published geotechnical DOTD reports and forms plus other technical references.

These items are described in more detail below:

1) SLOPE STABILITY (Embankment & Excavation):

The objective of a Slope Stability Analysis is to determine the factor of safety of the proposed embankment or excavation on the project subsurface soils and make appropriate engineering design recommendations. A maximum resistance factor of 0.75 is considered adequate for embankment side and end slopes. For cut sections, a maximum resistance factor of 0.65 is desirable. For short-term drawdown conditions, a maximum resistance factor of 0.85 is considered adequate.

a) Standard Procedure

The embankment/excavation slope stability analysis shall consist of:

1. Modeling the appropriate boring logs to define the critical embankment/excavation geometry (cross-section) with subsurface soils;
2. Interpreting the laboratory test data to determine drained and/or un-drained shear strength design parameters;
3. Performing the stability analysis utilizing the Bishop, Spencer, and/or sliding block method deemed appropriate by the engineer. PCSTABL 4.0 or SLIDE 6.0 (or newer version) is recommended for analysis;
4. Determining the maximum resistance factors for both long- and short-term conditions at the critical fill heights at each bridge end, along the approach embankment (intermediate fill height) and in critical cut sections. Maximum resistance factor should also be taken into consideration for rapid drawdown conditions when applicable;
5. Analyzing different methods for mitigating possible stability problems and, if necessary, making recommendations for geotechnical instrumentation to monitor stability performance;
6. Defining areas of highly erodible materials and analyzing erosion control measures;
7. Preparing a report with all the above information and engineering recommendations; and

8. Interpreting slope stability data from all geotechnical instrumentation monitoring devices and making appropriate recommendations during construction.

b) Deliverables

Deliverables for slope stability analyses shall include:

1. Printout of critical stability circle and/or block for each design case;
2. Geotechnical models (cross-sections) and design input parameters;
3. Summary table with critical fill heights and resistance factors, or critical excavation cross-sections with resistance factors;
4. Certification that the modeled embankments meet the required long and short-term resistance factors;
5. Summary of alternatives for mitigating possible stability problems with resistance factors and estimated costs;
6. Specifications for slope stability mitigation measures;
7. Geotechnical Instrumentation Plan (if recommended);
8. Recommended erosion control measures;
9. Construction Slope Stability notes for the Bridge General Notes Sheet; and
10. Graphical presentation of lateral movements obtained from Geotechnical Instrumentation data during construction monitoring.

2) EMBANKMENT SETTLEMENT

The Objective of a Consolidation/Settlement Analysis is to determine the amount of settlement in inches/feet, to estimate the time required for settlement to take place in days/months/years when the proposed embankment is constructed on the project subsurface soils, and to make appropriate Engineering Design Recommendations relative to consolidation settlement.

a) Standard Procedure

The embankment settlement analysis shall consist of:

1. Modeling the appropriate boring logs to define the critical embankment geometry (cross-section) with subsurface soils;
2. Interpreting the consolidation test data to determine design consolidation soil parameters;
3. Performing a settlement analysis for the critical bridge end fill heights and for intermediate fill heights (as needed);
4. Determining the predicted total consolidation settlement, the predicted 90% consolidation settlement and the time periods for the predicted settlement to occur;
5. Making recommendations to reduce the amount of consolidation settlement and/or to accelerate the settlement through the use of lightweight fills, surcharge placement, wick drains or other methods determined by the engineer if the predicted time for 90% of the settlement to occur is excessive (greater than 5 months);
6. Providing all analyses and information including special provisions relating to surcharge quantities and limits, wick drain information and layouts and settlement monitoring instrumentation details if mitigation is required;
7. Assessing the impact of predicted settlement and recommended mitigation on pavement, culverts, retaining walls and bridge abutments;
8. Preparing a report with all the above information and engineering recommendations; and
9. Interpreting settlement data from all geotechnical instrumentation devices and make recommendations for surcharge removal or other geotechnical related construction activity during construction.

b) Deliverables

Deliverables for settlement analyses shall include:

1. Geotechnical models (cross-sections) with design input parameters;
2. Printout of settlement analysis for each design case;
3. Presentation of settlement analysis in graphical form (Settlement vs. Time of Consolidation curves) with clear indications of total predicted

settlement, 90% predicted settlement, and the effect of surcharging and/or placing wick drains (Hand calculations should be included);

4. Assessment of the potential impact of predicted settlement and any recommended mitigation on pavement, culverts, retaining walls, and bridge abutments;
5. Wick drain design sheets;
6. Specifications for recommended settlement mitigation measures (surcharge, wick drains, etc.);
7. Geotechnical Instrumentation Plan with Drawings and Specifications, if recommended;
8. Graphical output of actual field settlement data obtained from Geotechnical Instrumentation during construction monitoring; and
9. Construction Settlement notes for the Bridge General Notes Sheet.

3) PILE FOUNDATIONS

The Objective of a Pile Design Analysis is to determine the pile type, pile capacity, lateral load requirements, and pile length for the project subsurface soils considering pile set-up, downdrag (negative skin friction), potential scour, and other project related factors.

a) Standard Procedure

The pile foundation analysis shall consist of:

1. Modeling the appropriate deep boring logs and/or cone penetration test (CPT) sounding data to define the project subsurface soil profile;
2. Obtaining Standard Penetration Test (SPT) N-values and interpreting the laboratory test data to determine pile design soil parameters;
3. Performing pile static analyses to determine pile type, pile capacity, and plan pile tip elevation or length;
4. Estimating foundation settlement and “downdrag” loads;
5. Performing lateral load analyses;

6. Estimating scour depths;
7. Performing wave equation analyses to determine pile drivability and evaluate hammer suitability;
8. Assessing constructability issues such as installation sequencing, heave and/or lateral pile movement, installation aids (jetting or augering), etc.; and
9. Furnishing test pile recommendations (feasibility, location, test pile tip elevation, etc.) and pile driving analyzer (PDA) recommendations.

b) Deliverables

Deliverables for pile foundation analyses shall include:

1. Design spreadsheets or calculations indicating the geotechnical design parameters utilized for each boring log, including scour elevations if applicable, for the pile type selected;
2. Graphical or tabulated representation of the pile capacity vs. tip elevation (not depth of penetration);
3. If the FHWA software Driven 1.2 is used, include an electronic copy of the data file generated along with a hard copy of the input and output;
4. Lateral load analyses;
5. Recommended plan pile tip elevations for all bents (shown in the Pile Data Table);
6. Feasibility study for utilizing a test pile or other field verification methods (comparison of various resistance factors associated with different field verification methods);
7. Drivability recommendations;
8. Pile installation criteria with discussion of potential installation issues;
9. Pile Driving Analyzer (PDA) or other field monitoring recommendations;
10. Hammer approval method recommendations;
11. Necessary pay items and corresponding quantities for test piles, indicator piles, and monitor piles;

12. Special Provisions for Dynamic Monitoring and Dynamic Analysis, if recommended for project;
13. Special Provision for Static Load Test, if recommended for project;
14. Considerations for “downdrag” effects on piles;
15. Considerations for pile “setup”;
16. Uplift capacity of group piles if required by project conditions; and
17. Pile notes for the Bridge General Notes Sheet.

4) DRILLED SHAFT FOUNDATIONS

The Objective of a Drilled Shaft Analysis Design is to determine the diameter, tip elevation and installation procedure for the project subsurface soil conditions.

a) Standard Procedure

The drilled shaft foundation analysis shall consist of:

1. Modeling the appropriate deep boring logs and/or cone penetration test (CPT) sounding data to define the project subsurface soil profile;
2. Obtaining Standard Penetration Test (SPT) N-values and interpreting the laboratory test data to determine drilled shaft design soil parameters;
3. Selecting appropriate design equations for the project soil types to determine ultimate base and side resistance and selecting appropriate resistance factors;
4. Performing axial and lateral load analyses to determine drilled shaft diameter and tip elevation; and
5. Performing analyses to determine appropriate construction methods for project soil conditions.

b) Deliverables

Deliverables for drilled shaft foundation analyses shall include:

1. Design spreadsheets or calculations indicating the geotechnical design parameters utilized for each boring log or reach, including scour elevations if applicable;
2. Graphical or tabulated representation of the drilled shaft capacity vs. tip elevation for each shaft diameter;
3. Lateral load analyses;
4. Considerations for "downdrag";
5. Recommended plan drilled shaft diameters and tip elevations for all bents (shown in the Drilled Shaft Data Table);
6. Recommended construction methods with discussion of potential installation issues;
7. Recommendations for construction quality control;
8. Drilled shaft notes for the Bridge General Notes Sheet;
9. Special Provision for Integrity Testing, if required for project; and
10. Special Provision for drilled shaft Load Test, if required for project.

5) OTHER FOUNDATIONS

If other types of foundation are recommended for the specific project conditions, the standard procedure format and the deliverables format outlined for piles and drilled shafts shall be followed with specific design details for the type of foundation recommended.

6) PILE-SUPPORTED APPROACH SLABS

The DOTD normally uses a timber pile supported approach slab to minimize differential settlement in the transition zone between the approach embankment and the bridge abutment.

a) Deliverables

Deliverables for pile supported approach slabs shall include:

1. Layout showing pile locations;

2. Pile diameter and length; and
3. Drivability recommendations.

7) BRIDGE FOUNDATION LOAD TEST PROGRAM:

If the project subsurface conditions are difficult, significant uncertainties exist in the foundation design, and cost savings can be predicted, a load test program may be appropriate. Depending on project conditions, a load test program may be included either in the Design or in the Construction phase.

a) Deliverables

Deliverables for the load test program shall include:

1. Location and Type of proposed load test;
2. Design of test foundation (pile, drilled shaft, or other);
3. Dynamic test procedures and schedules;
4. Load increment requirements;
5. Maximum test load;
6. Instrumentation requirements;
7. Load test Layout and Design Sheets for plans;
8. Special Provisions for construction of test foundation and load test methodology;
9. Interpretation of load test results and recommendations; and
10. Foundation load test report.

8) EARTH RETAINING STRUCTURES

A Retaining Wall is normally required if adequate space (right-of-way) is not available for a slope. The DOTD has used Mechanically Stabilized Earth (MSE) Walls, Gravity Concrete Walls, Sheet Pile Walls, plus other types for transportation projects. The selection of the most appropriate retaining wall type

for the specific project requirements and site and subsurface conditions can have profound effects on the project cost and constructability.

Every retaining wall type has a unique design procedure and generally requires the services and coordination of a Geotechnical Engineer and a Structural Engineer. The following criteria are generally required for analysis and design of all Retaining Wall types:

a) General Deliverables

Deliverables for all earth retaining structures shall include:

1. Earth pressure distributions;
2. Bearing capacity of the foundation soil or rock;
3. Analyses for sliding and overturning and mitigation recommendations;
4. Settlement and rotation analyses and mitigation recommendations;
5. Drainage recommendations;
6. Global stability analyses and mitigation recommendations;
7. Backfill properties;
8. Wall components/materials;
9. Wall construction procedures;
10. Wall layout with plan view, elevation view, typical sections, and details;
11. Quantities table with applicable General Notes;
12. Design life considerations; and
13. Special Provisions.

b) Mechanically Stabilized Earth (MSE) Walls

The AASHTO LRFD Bridge Specifications, latest edition as well as all supplements shall be followed for analysis and design of all MSE Walls. The DOTD developed "MSEW Design Guide, G.E.D.G. No. 8", latest edition may be used as a reference. Only DOTD approved wall systems will be allowed.

Additional Deliverables for MSE Walls shall be as outlined in the DOTD MSEW Design Guide and as required to identify the MSE specific design and construction requirements:

1. Type and size of facing element;
2. Type, size, and design length of reinforcement elements;
3. Type of connections;
4. Minimum embedment requirements;
5. Backfill material requirements; and
6. Specific requirements associated with a temporary wall, if applicable.

c) Concrete Walls

Cast-In-Place concrete gravity or cantilever walls are generally limited to small applications or specialized situations because of the development of more economical wall types. Standard design and construction procedures are well documented in many geotechnical books and other publications.

Deliverables for concrete walls are same as outlined under General Deliverables above.

d) Sheet Pile Walls

The resistance factors from the AASHTO Bridge Design Specifications, latest edition, shall be used to design sheet pile walls. The DOTD's "Preliminary" Design Guide titled "DOTD CANTILEVER SHEET PILE DESIGN GUIDELINES" may be used as a reference.

Additional deliverables for sheet pile walls shall be as outlined in the DOTD Guidelines:

1. Sheet pile section and type;

2. Minimum section modulus;
3. Minimum depth of penetration;
4. Moment of inertia requirements;
5. Estimated long- and short-term deflections;
6. Anchor/tieback loads;
7. Long- and short-term stability including drawdown and liquefaction considerations;
8. Complete design details of sheet piling, backfill, drainage, and connections;
9. Corrosion protection measures; and
10. Construction constraints.

e) Other Retaining Wall Types

Other types of retaining walls that may be appropriate for DOTD transportation projects are drilled shaft walls, soldier pile & lagging walls, slurry walls, anchored (tied-back) walls, soil nailed walls, reticulated micropile walls, jet-grouted walls, and deep soil mixing walls. These walls shall be designed using generally recognized design procedures applicable to the specific type of wall used.

Note that reinforced soil slopes may, in some cases, be an economical alternative to a retaining wall.

9) CULVERTS

The geotechnical design review of the culvert locations shown in the plans shall consist of earth pressure calculations, bearing capacity analyses, settlement analyses and a constructability review of the culvert. Recommendations for bedding material, foundation supported options, insitu bearing improvements and construction procedures should be addressed.

a) Deliverables

Deliverables for culverts shall include:

1. Earth pressure calculations and recommendations;
2. Bearing capacity calculations and recommendations;
3. Settlement and differential settlement estimates with design parameters;
4. Recommendations for bedding material and/or other foundation support options; and
5. Any specialized construction procedures and recommendations.

10) GEOTECHNICAL ANALYSIS & DESIGN RECOMMENDATIONS REPORT

No standard report format is required and the Consulting Firm may use its own format. However, the report shall contain a background description of the project such as location, geological irregularity (as applicable), engineering features and requirements, etc. and shall include all the applicable deliverables specified in this document.

11) CONSTRUCTION MONITORING

The following sections describe the various types of construction monitoring that can be expected on DOTD projects.

a) Pile Foundations

The pile foundation construction scope of work shall consist of providing the following geotechnical services during the construction phase of the project:

1. Hammer approval utilizing the Wave Equation analyses (if alternate hammer approval method is not specified);
2. Dynamic monitoring the installation of test piles, monitor piles, indicator piles and/or production piles with the Pile Driving Analyzer (PDA);
3. Analysis of PDA data utilizing CAPWAP AND GRLWEAP;
4. Generating bearing capacity graphs (Inspector's Charts);
5. Recommending pile driving criteria; and
6. Recommending final pile tip elevations based on the results of load tests and/or dynamic analyses.

The dynamic pile monitoring includes supplying all equipment, strain gages, and accelerometers to collect data. The data collected for potential pile damages and providing pile driving assistance shall be analyzed and interpreted to determine the pile resistance.

The deliverables for construction monitoring of pile foundations shall include the following:

1. Hammer approval documentation;
2. PDA testing and analysis report with (1) PDA plots of pile capacity, driving stresses and energy transfer; (2) CAPWAP pile capacity summary table; and (3) Inspector's charts;
3. All electronic files related to PDA testing and CAPWAP analyses; and
4. Final pile tip elevations and order length recommendations to the Structural Fabrication Engineer.

b) Drilled Shaft Foundations

The drilled shaft foundation construction scope of work shall include the construction monitoring items outlined in the DOTD Guide titled "Drilled Shaft Foundation Construction Inspectors Manual" plus any special considerations specified in the Plan Notes.

The Deliverables for construction monitoring of drilled shafts shall include those required in the guide manual and the following:

1. Comments/recommendations on Contractor's "Drilled Shaft Installation Plan";
2. Drilled shaft soil/rock excavation logs;
3. Drilled shaft slurry logs;
4. Drilled shaft concrete placement logs;
5. Theoretical concrete volume vs. actual concrete volume graph;

6. Interpreted shaft diameter vs. depths (elevations);
7. Excavation rate and concrete placement rate vs. depths (elevations);
8. Inspection report with (1) Description of drilling method, clean-out methods, bottom inspection methods and findings and concrete placement and effectiveness; (2) Record of slurry properties (if applicable); and (3) description of difficulties encountered; and
9. Integrity testing (cross-hole sonic logging or other) interpretation and recommendations.

c) Other Foundations

The scope of work for other foundations and the deliverables shall be as recommended in the geotechnical analysis & design recommendations report.

12) GEOTECHNICAL INSTRUMENTATION

The objective of geotechnical instrumentation in construction monitoring is to record and interpret the Instrumentation data and compare actual soil behavior to that predicted by design. Each type of Instrumentation has an intended purpose and allows major decisions to be made by Construction Managers that affect construction safety (prevent major failures), scheduling, and construction costs. No instrumentation shall alter the performance of the geotechnical design. The usual Instrumentation specified to monitor foundation performance on projects where stability and settlement are critical are slope inclinometers, piezometers, and settlement devices. The geotechnical analysis & design recommendations report should recommend an instrumentation layout and the frequency of readings.

a) Deliverables

The deliverables for geotechnical instrumentation shall include:

1. Plan and elevation location, details, and applicable notes for all instrumentation;

2. Specifications for furnishing, installation, monitoring, and reporting for all instrumentation;
3. Graphical presentation of lateral movement data and action recommendations;
4. Graphical presentation of actual field settlement data and action recommendations; and
5. Interpretation of other instrumentation data as recommended in the geotechnical analysis & design recommendations report and action recommendations.

13) OTHER GEOTECHNICAL FEATURES

Construction Monitoring and Construction Inspection of other geotechnical features such as Embankments and Excavation Earthwork, Drilled Shafts, Earth Retaining Structures, Soil Stabilization, etc. in the project shall be as required by the DOTD Standard Specifications. If special Construction Inspection and/or Monitoring are required for special Geotechnical features, they will be as recommended in the "Geotechnical Analysis & Design Recommendations Report," Construction "Plan Notes," and "Special Provisions."

14) LIST OF PUBLISHED GEOTECHNICAL DOTD REPORTS AND FORMS PLUS OTHER TECHNICAL REFERENCES

Most of the following can be obtained at the DOTD web site (www.dotd.state.la.us) or at the FHWA Bridge/Geotechnical web site (www.fhwa.dot.gov/bridge).

a) DOTD Reports and Forms "Latest Editions"

DOTD references include, but are not limited to, the following:

1. AASHTO LRFD Bridge Design Specifications, latest edition and supplements;
2. Standard Specifications;
3. Bridge Design Manual;

4. Road Design Manual;
5. Hydraulics Manual;
6. Materials Sampling Manual;
7. Materials Testing Procedures Manual;
8. Drilled Shaft Foundation Construction Inspection Manual;
9. Drilled Shaft Construction Logs;
10. "Preliminary" DOTD Sheet Pile Design Guidelines;
11. MSEW Design Guide, Geotechnical Engineering Design Guide (G.E.D.G.) No. 8;
12. LTRC "PILECPT" Software;
13. Pile and Driving Equipment Data Form;
14. Deep Soil Boring Request and Field & Laboratory Request Form (in one sheet);
15. Wick Drain Design Sheets; and
16. DOTD Testing Procedures Guidelines For Standard Format

b) Other Technical References:

The DOTD has used the following as technical references and guidelines in the design and construction monitoring of Geotechnical features for DOTD projects in the past and are recommended for use by the Geotechnical Engineering Consultant community. This list is not all encompassing and other publications may be used and referenced. Additions will be made as this Document is updated.

1. Subsurface Investigations Manual, Publication No. FHWA HI-97-021, Nov. 1997;
2. Manual On Subsurface Investigations, Published by AASHTO, 1988;
3. AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing, PART I – SPECIFICATIONS and PART II – TESTS, current edition;
4. ASTM Procedures and Regulations, current edition;

5. Design of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Vol. I, FHWA-NHI-10-024, FHWA GEC 011. November 2009;
6. Design of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Vol. II, FHWA-NHI-10-025, FHWA GEC 011. November 2009;
7. Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines, FHWA-NHI00-043, 2001;
8. Geosynthetic Design and Construction Guidelines Manual, Publication No. FHWA HI-95-038, April 1998;
9. Geotechnical Instrumentation Manual, Publication No. FHWA HI-98-034, October 1998;
10. Drilled Shafts: Construction Procedures and LRFD Design Methods, FHWA-NHI-10-016, GEC 010, May 2010;
11. Soils and Foundations Reference Manual Vol. 1 FHWA NHI-06-088, 2006;
12. Soils and Foundations Reference Manual Vol. 2 FHWA NHI-06-089, 2006;
13. Geosynthetic Design and Construction Guidelines Manual, Publication No. FHWA HI-95-038, April 1998;
14. Ground Improvement Technical Summaries, DP 116, Publication No. FHWA-SA-98-086;
15. Design and Construction of Driven Pile Foundations, Volumes 1 & 2, Publications No. FHWA-HI-05-042 and FHWA-HI-05-042, April 2006;
16. Design and Construction of Stone Columns Vols. I and II (FHWA Geotechnical Library);
17. Soil Slope and Embankment Design, Reference Manual, FHWA-NHI, 2003;
18. Geotechnical Engineering Circular No. 3 - LRFD Seismic Analysis and Design of Transportation, 2011;
19. Geotechnical Engineering Circular No. 4 Ground Anchors and Anchored Systems, 1999;
20. Geotechnical Engineering Circular No. 5 Evaluation Of Soil and Rock Properties, 2002;
21. Geotechnical Engineering Circular No. 6 Shallow foundations, 2002;

22. Geotechnical Engineering Circular No. 7 Soil Nail Walls FHWA-IF-03-017, March 2003;
23. Manual for Design & Construction Monitoring of Soil Nail Walls, Publication No. FHWA-SA-96-069, November 1996;
24. Soil Nailing Field Inspectors Manual, (DP 103), Publication No. FHWA-SA-93-068, April 1994;
25. EM 1110-2-2504 Design of Sheet Pile Walls US Army Corps, 1994;
26. NAVFAC Design Manuals, DM 7.1, DM 7.2 and DM7.3, May 1982; and
27. USS Steel Sheet Pile Design Manual .