STATE OF OKLAHOMA

DEPARTMENT OF TRANSPORTATION

GEOTECHNICAL SPECIFICATIONS

August 2021

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Part 1

Geotechnical Specifications for Roadway Design

OKLAHOMA
Transportation

STATE OF OKLAHOMA
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL SPECIFICATIONS FOR ROADWAY DESIGN

August 25, 2021

GENERAL: These specifications provide the procedures for obtaining the geotechnical information, for highway design and construction, required by the Roadway Design Division of the Oklahoma Department of Transportation (ODOT). These specifications include the general guidelines for conducting geotechnical investigations and are governed by the "Geotechnical Engineering Circular No. 5 - Evaluation of Soil and Rock Properties", FHWA-IF-02-034, April 2002, the most current AASHTO and ASTM test procedures, and AASHTO R-10.

Geotechnical information is obtained through subsurface investigations, field tests, and the corresponding laboratory tests conducted on samples obtained in the field. Direction and oversight of these operations are provided by the Geotechnical Engineer with day to day coordination through the project geotechnical specialist.

A Geotechnical Engineer is a registered professional engineer with geotechnical expertise. A geotechnical specialist is a civil engineer, geologist, engineering geologist, or a trained, experienced, qualified individual that has been certified by the ODOT Materials Division or other approved designated authority.

The Geotechnical Engineer is required to submit a boring, sampling, and testing plan to ODOT for approval prior to beginning the subsurface exploration in order to resolve all matters with regard to sampling, testing and analysis of data. The Department's geotechnical policies and procedures will represent the state of the practice and will govern.

In conducting geotechnical investigations, the Geotechnical Engineer is responsible for and will be compensated for the following items of work:

- Securing right-of-way
- Filing and obtaining U.S. Army Corps of Engineers Wetland Permits.
- Locating and marking utility crossings, with OKIE, where borings, test pits, or trenches are required in the geotechnical investigation.
- Planning and arranging for traffic control when required in conducting the geotechnical investigation. Traffic control is to be subcontracted outside of ODOT and is required to meet the most current Manual on Uniform Traffic Control Device Specifications during the geotechnical investigation.
- Provide the required location of all test borings and pavement core locations conducted in the preliminary soil surveys, detailed soil investigations and geological investigations. The survey shall be referenced to plan station and offset from the centerline of survey, construction reference line (CRL) or base line given on the project plans. If the project is a

new alignment that is beyond the reasonable reach by a measuring tape of 100 ft. from a reference line, then a supplemental survey contract may be approved.

- Dozer services required for access to test boring locations.
- Borehole closing when applicable.

SCOPE: The geotechnical investigation shall consist of performing all or parts of the following surveys and investigations required by the Roadway Design Division of ODOT and as directed by ODOT at the time of contract negotiations.

PRELIMINARY SOIL SURVEYS

1. **Pedological and Geological Survey:** A Pedological and Geological Survey is required for new highway alignments, new construction parallel to existing highway alignments, and new construction requiring a raising of the grade on and above existing highway alignments. A Pedological Soils Survey is reliant on knowledge of the soil series mapping units and the corresponding taxonomic classification system established by the Natural Resources Conservation Service (NRCS). More detailed information about Pedological Soil Surveys and the NRCS Soil Classification System are provided in Appendix 1. The general procedures for conducting the Pedological activities are presented below in option A and option B as directed. This includes the procedures for sampling and testing.

   <u>**Option A**</u>

   a. The pedological survey requires plotting the Center Reference Line (CRL) or the Centerline (CL) for the proposed highway alignment on the appropriate U.S. Department of Agriculture Soil Conservation (SCS) county soil survey report map sheet(s). The map units are delineated on aerial photographs that comprise the aforementioned sheets. They are usually scaled at 1:20,000 and occasionally 1:24,000; either is acceptable. The plotting procedure is also used to establish the length of each soil series map unit (soil phase) as the alignment crosses the map unit delineation. These lengths or distances are to be summed and provided in the report. The CRL and CL locations are taken from the project plans. In the case of soil series complexes, as map units, e.g. Niotaze-Darnell, each series is to be located and treated separately. The type and degree of assistance, as well as the names of the NRCS, or other soils scientist(s) personnel rendering assistance, shall be documented and referenced in detail.

   b. Take adequate sample quantities at the site of each soil series to ensure proper testing of each soil horizon as well the composite bulk sample(s). Pits are acceptable and may be a preferred method. These are to be made along the CRL or CL or referenced to them. If the map unit repeats within the alignment, it need not be resampled, if the series is confirmed by boring to be the same.

c. A composite bulk sample is defined as a mixture of the total depths (thicknesses) of each of the B and C horizons. For example, if a soil series description lists the B horizons as Bt1, Bt2, Btk, Bt3, and B/C, these together will constitute one composite "B" bulk sample. Subsequently, the C/B and C horizons will constitute a second bulk sample "C", for soil series that contain those particular horizons. In the event that the map unit does not have a B horizon but has an A/C horizon instead, the composite bulk sample shall be taken of the total depth of horizons listed below the A horizon e.g. the A/C or B/C horizon. It is important that the bulk sample be a well-blended mixture of soils that are representative of all the respective horizons in the composite sample. In most cases, soil map unit revisions and recorrelations have probably been made to at least a few of the map units encountered along the CRL. This new information is available at the local NRCS field offices, usually located in the county seat or the NRCS State Soil Scientist in Stillwater OK. The NRCS Web Soil Survey, http://websoilsurvey.nrcs.usda.gov/app/ is also a good source for county soils maps and information. Copies of all official soils series descriptions, including the new recorrelated series are required for inclusion in the Pedological report.

d. Use the soil map unit with its associated current official soil series description and classification as a guide for sampling and other engineering interpretations. For example, the official description of Kirkland clay loam, 0 – 1% slope; Fine mixed, superactive, thermic Udertic Paleustoll, 6/99, is to be used as a guide for sampling. The Fine mixed, superactive, thermic, Udertic Paleustaoll is the soil series taxonomic description. It consists of the order, suborder, great group, subgroup modifier, particle size, mineralogy, and soil temperature. In this description the typical thickness of the A horizon is 8 inches, the Btl horizon is typically 8 to 19 inches thick, the 2Bt3 is 75 to 82 inches thick, etc. In the map unit of interest, the depths and thickness of the subhorizons may vary from that of the description given in the county soil survey report and/or in the official soil series description. However, they must be within the "Range in Characteristics," as described in the official soil series description (OSD). A Soil Taxonomy Statement is required for each soil series consisting of a written interpretation of each taxonomy description sub-part for a total of seven parts. Guidelines for preparing the Soil Taxonomy Statement are included in Appendix 1.

e. There may be inclusions of a contrasting or similar soil series within the map unit being sampled. They may be listed and described in the "Competing Series" or the "Geographically Associated Soils" paragraphs in the official soil series descriptions. Select the best-fit soil series description from this list, if possible, for the inclusion in the report.

f. Laboratory tests required for all representative subhorizon samples for each soil series are as follows:

1. Plastic Limit, AASHTO T90
2. Liquid Limit, AASHTO T89
3. Gradation required for complete soil classification, AASHTO T88
4. pH, AASHTO T289
5. Electrical Resistivity, AASHTO T288

6. Soluble Sulfates, for projects in ODOT Field Divisions 4,5,6,&7, OHD L-49

g. Laboratory tests required for the bulk composite sample for the B and C horizons of each soil series are as follows:

1. Plastic Limit, AASHTO T90
2. Liquid Limit, AASHTO T89
3. Gradation required for complete soil classification, AASHTO T88
4. Moisture-Density, AASHTO T99 – (include a minimum of 5 points)
5. Resilient Modulus, AASHTO T307
6. Soluble Sulfates, for projects in ODOT Field Divisions 4,5,6,&7, OHD L-49

h. The geologic portion of this survey shall consist of the inclusion of a representative sample of the R horizon. A geologic statement describing the R horizon in geological terminology shall be included in the report. If the R horizon is shale it shall be sampled and subjected to the soil laboratory tests listed under paragraph “f” above. The terminology for describing the R horizon material shall be taken from the “Standard Guide for the Description of Surface and Subsurface Geological Rock Formations of Oklahoma” found in Appendix 3.

i. The quantities of soil required for the tests are provided in AASHTO R-13.

j. Personnel requirements. The person performing the pedological soil survey and providing the report shall hold a Bachelor of Science (BS) degree in Soil Science. The person may hold a BS in a natural science (i.e. geology or forestry) provided the natural science has a minimum of 30 credit hours of natural sciences with 15 of those hours in soil science. Alternatively, a resume of pertinent education and experience shall be submitted to the Geotechnical Engineer of the Oklahoma Department of Transportation for review and approval.

Option B

The CRL or centerline of the proposed project is to be plotted on the soil survey map as in Option A. The soil series are to be organized by the Soil Taxonomy Order. The most predominant soil series (largest lineal extent) for each Order in the project extent is to be sampled and tested as required in Option A

2. **Shoulder Soil Survey:** A Shoulder Soil Survey is required for the widening of existing pavement at grade. This survey shall apply to the adding of shoulders, lanes and medians to existing pavements. The general procedure for conducting the shoulder soil survey is as follows:
    a. The sampling location shall be within the station extents of the widening section using the average width of the improvement and a sampling interval of 750 feet. Sample locations shall apply to all widening extents as detailed in the project plans, i.e., outside pavement shoulder, both pavement shoulders (in the case of two-lane highway or street), inside shoulder (in the case of four-lane highway or street), and in median areas.

b. The sampling depth shall be 36 inches consisting of the top 6 inches and the bottom 30 inches provided that there is a reasonable consistency and similarity of material. If different material is encountered in the bottom 30 inches, subdivide the layers and include a sample from each layer.
c. Report the extent(s) of similar soil classifications within the station extents of the project.
d. Record the depth of groundwater or perched water zones measured from the top of ground elevation at the end of drilling.
e. A composite bulk sample(s) of the full sampling depth representative of the whole project extent or of each different soil extent as identified in item 2c.
f. Laboratory tests required of all sample interval depths and/or soil layers are as follows:
   1. Plastic Limit, AASHTO T90
   2. Liquid Limit, AASHTO T89
   3. Gradation required for complete soil classification, AASHTO T88
   4. Moisture-density, AASHTO T99
   5. Resilient modulus, AASHTO T307
   6. Soluble Sulfates, for projects in ODOT Field Divisions 4,5,6, & 7, OHD L-49
g. Guidelines for quantities of soil samples are given in AASHTO R13

3. **In-Place Soil Survey:** The In Place Soil Survey is required for new construction when the design calls for separation of the grading and paving contracts. It may also be used to evaluate the subgrade of existing pavement sections which are to be reconstructed with no change in grade or alignment. The general procedure for conducting the In-Place Soil Survey is the same as for the Shoulder Soil Survey with the following exceptions:
   a. The sampling interval for grading projects is 1000 ft. or wherever there is a visual change in soil types. Sampling locations for existing pavement sections will most likely be project specific such as at a bridge approaches and underpasses.
   b. The sampling depth shall be 36 inches unless otherwise noted. Sample and test the different soil types encountered in the boring and record the extent(s) of similar soil classifications within the station extents of the project.

4. **Pavement and Subgrade Soil Survey:** A Pavement and Subgrade Soil Survey is required when the properties of an existing pavement structure and the underlying subgrade soils are needed for evaluation of the pavement load capacity and for an overlay design. The Falling Weight Deflectometer (FWD) is required for evaluating the pavement structure (surface, base, and subbase). The general procedure for conducting pavement deflection tests shall meet all requirements of the ASTM D4694 and D4695 with the following additional requirements:

a. FWD tests are to be conducted in the outside wheel path in a staggered pattern at a spacing of 250 feet along the highway centerline. Additional requirements for the FWD analysis are as follows:

   1. The FWD is to be operated during a time frame of April through November or when the ambient temperature has been a minimum of 45 degrees for 3 successive days prior to and during the testing operations.

   2. The air and pavement temperatures are to be recorded by the FWD equipment for each test location and according to ASTM D4695, Subsection 7.1.5.

   3. At each FWD test location, the test procedure shall be according to ASTM D4694, Subsection 9. Load and deflection sensors are to be in current calibration at the time of testing, as required by ASTM D4694, Subsection 8. Deflection testing shall include 2 seating drops and 4 recording drops per test location. The test load for the 4 recording drops are based upon highway classification; Interstate highways will be tested with a 15,000 lb. load, U.S. designated highways will be tested with a 12,000 lb. load, State highways will be tested with a 9,000 lb. load, Local and County roads will be tested with a 7,500 lb. load.

b. Back calculation analysis of the pavement section shall be made using the most current edition of the Modulus program. For asphalt pavement sections, provide the back calculated resilient modulus of the subgrade and the elastic modulus of the composite pavement structure. For concrete pavement sections, provide the modulus of subgrade reaction, the pavement section thickness, and the pavement condition as determined according to the survey described in item 5d. A copy of the FWD report shall be submitted, in Microsoft Excel Format, electronically to the ODOT Pavement Engineer.

c. A minimum of five pavement cores per mile (more if there is an obvious change in pavement structure) shall be taken to document the thicknesses, types, and condition of the payment layers. Take the cores at FWD test locations. Provide a digital, color photograph of each core with scale. Record the layer thicknesses and the degree of stripping or deterioration of asphalt pavement cores. Record honeycomb, deterioration cracking (D-Cracking), and separations in concrete pavements. Examples of the required core logs are provided in Appendix 5. Cores shall be taken in the middle of the slab in PCC Pavements. Ground Penetrating Radar may be used to reduce the number of cores taken to accurately determine the pavement section profile.

d. Pavement surface condition shall be described according to the distress patterns as detailed in the FHWA publication No. FHWA-RD-03-031 “Distress Identification Manual for the Long Term Pavement Performance Program”.

e. For plain jointed, rigid pavements, joint efficiency shall be tested in each direction, in the right wheel path of the right lane, every 600 feet (180m) at the transverse contraction joint. A core shall be cut through the joint at the test site and the core condition reported.

f. The pavement subgrade shall be sampled to a depth of 36 inches below existing pavement. Dynamic Cone Penetration tests, DCPT, may be requested to further evaluate the strength and consistency of the subgrade.

g. Report the extent(s) of similar subgrade soils within the station extents of the project.

h. Record the depth of groundwater or perched water zones measured from the top of ground elevation at the end of drilling.

i. Laboratory tests required of granular bases, subbases, and subgrade soils are as follows:
   1. Plastic Limit, AASHTO T90
   2. Liquid Limit, AASHTO T89
   3. Gradation required for complete soil classification, AASHTO T88

j. Guidelines for quantities of soil samples are given in AASHTO R13.

5. **Borrow Pit Investigation:** A borrow pit investigation is required where selective subgrade topping is requested. The specifications for selective subgrade topping are provided in the most current issue of the ODOT Standard Specifications for Highway Construction, Section 202.2 B.
   a. The size of the borrow pit shall be based on plan estimates of borrow quantities needed.
   b. A borrow pit location within a 30-mile haul distance of the project is acceptable.
   c. As a minimum requirement, a boring shall be drilled at each geometric corner and two near the center. A minimum depth of ten feet per boring shall be analyzed for select material.
   d. Record the depth of groundwater or perched water zones measured from the top of the ground elevation at the end of drilling.
   e. If the borrow source is rock, investigate the rippability by use of seismic velocity. Refer to the seismic velocity charts found in the Appendix 3 to estimate the rippability of rock.
   f. If the borrow sources can be select graded in a cut section of the proposed project site, the above items c. through e. all apply.
   g. If a borrow source is unavailable, then a pavement layer requiring borrow may be substituted with an equivalent layer of chemically stabilized soil or a soil-aggregate blend.

h. Soils that are to be placed within the top 2 ft. of the grading section shall be tested for soluble sulfates according to OHD L-49.

i. Laboratory tests required of borrow pit soil samples are as follows:

   i. Plastic Limit, AASHTO T90
   ii. Liquid Limit, AASHTO T89
   iii. Gradation required for complete soil classification, AASHTO T88
   iv. Soluble Sulfates, for projects in ODOT Field Divisions 4,5,6, & 7, OHD L-49

6. **Resilient Modulus Tests:** Resilient modulus testing is required for the pavement design of all State and Federal Aid highway projects. This test is conducted, according to the requirements of AASHTO T-307, on composite bulk samples obtained in Pedological, Shoulder, and In Place Soil Surveys. Resilient Modulus testing for ODOT shall be conducted by a qualified technician having a minimum of 2 years continuous experience in resilient modulus testing.

   ODOT requires two resilient modulus tests for each composite sample:
   <u>For A-1 to A-5 Soils:</u>
   - One test at 95 % of maximum dry density, optimum moisture content
   - One test at 95 % of maximum dry density, 2 % wet of optimum moisture content.

   <u>For A-6 to A-7 Soils:</u>
   - One test at 95 % of maximum dry density, optimum moisture content
   - One test at 95 % of maximum dry density at the corresponding moisture content at which 95% dry density intersects the wet side of the moisture/density curve.

7. **Laboratory Tests:** All laboratory tests required for the Preliminary Soil Surveys shall be performed by technicians certified by the Highway Construction Materials Certification Board in a laboratory qualified by the ODOT Materials Division.

DETAILED SOIL INVESTIGATION: A detailed Soil Investigation is required for analyzing the geotechnical problems related to roadway designs. These geotechnical problems include embankment and foundation soil settlement and stability, cut and natural slope stability, problem soils related to roadway subgrades and embankments, roadway structures, and construction recommendations. A detailed soil investigation of these problems is required in conjunction with the Pedological and Geological Survey. The interpretation and judgment of the pedological and geological site conditions is the responsibility of the Geotechnical Engineer.

1. **Embankment and Foundation Soil Settlement and Stability (Embankments Between 0-10 feet Above Natural Ground Line):** Estimates of embankment and underlying foundation soil settlement, slope stability and design slopes are required. These estimates are made by assuming reasonable parameters for anticipated embankment and foundation soils based

on the soil series types occurring within the project extent. These estimates are required for embankments crossing each soil series encountered along the project alignment. Use NAVFAC D 7.01 to determine estimates of reasonable soil parameters for anticipated embankment and foundation soils as described by the pedological soil units.

2. **Embankment and Foundation Soil Settlement and Stability (Embankments Greater Than 10 Feet Above Natural Ground Line):** Estimates of embankment and underlying foundation soil settlement and stability are required. Borings are to be typically spaced every 200 feet (erratic conditions) to 500 feet (uniform conditions), with at least one boring made in each Pedological soil unit. The primary borings are to be Standard Penetration Test (SPT) borings. These borings, which are for obtaining soil samples and information, should be supplemented with in situ field tests such as the Cone Penetration Test (CPT) or the Flat Plate Dilatometer Test (DMT) to obtain additional information for determining the soil and rock subsurface conditions as follows:
    a. Stratigraphy
        1) Physical description and extent of each stratum
        2) Thickness and elevation of top and bottom of each stratum
    b. For cohesive soils (each stratum)
        1) Natural moisture contents
        2) Atterberg limits
        3) Presence of organic materials
        4) Evidence of desiccation or previous soil disturbance, shearing or slickensides
        5) Swelling characteristics
        6) Shear strength
        7) Compressibility – **NOTE:** The Standard Penetration Test is not to be used for shear strength or compressibility analysis in cohesive soils. Shear strength and compressibility can be determined by laboratory consolidation tests conducted on undisturbed soil samples or by in situ field tests such as the Cone Penetration Test (CPT) or the Flat Plate Dilatometer Test (DMT).
    c. For granular soils (each stratum)
        1) In-situ density (average and range) typically determined from Standard Penetration Tests (SPT) or Cone Penetration Tests (CPT)
        2) Grain-size distribution (gradation)
        3) Presence of organic materials
    d. Ground water (for each aquifer if more than one is present)
        1) Piezometric surface over the site area, existing, past, and probable range in future (observation at several times.)
        2) Perched water table

e. Bedrock

1) Depth and elevation over the entire site

2) Type of rock (Lithology)

3) Extent and character of weathering

4) Joints, including distribution, spacing, whether open or closed, and joint filing.

5) Faults

6) Solution features in limestone or other soluble rocks

7) Core recovery and soundness (RQD)

f. Engineering Analysis. The minimum guidelines required for engineering analysis, based upon soil classification, are given in Table 1 of Appendix 2. Additional guidelines should be noted for the following conditions:

1) When soft ground is encountered (SPT 'N' Resistance < 4), conduct in situ tests and/or undisturbed sample exploration in each soil series mapping unit. Conduct continuous in situ tests and/ or undisturbed sampling throughout the foundation soils until firm material (SPT 'N' Resistance > 30) or rock is encountered.

2) When medium stiff to very stiff (5 < SPT 'N' resistance < 30) is encountered, follow the minimum sampling and testing criteria in Table 2 of Appendix 2.

3) If rock is encountered within a depth equal to twice the embankment height, conduct continuous rock coring as detailed in Table 2 of Appendix 2.

4) Groundwater investigations shall be made according to Table 2 of Appendix 2.

5) For bridge embankment headers, conduct a detailed study of the embankment and foundation soils within 200 feet back and 200 feet forward of each bridge abutment.

3. **Cut and Natural Slope Stability:** Cut slopes greater than 30 feet below the natural ground line in soil shall be analyzed for both end of construction and long germ slope stability conditions. If slope materials are overconsolidated (OCR > 2) then the residual shear strength shall be used in the long-term slope stability analysis. Soils coming from cuts that will be placed within the top 2 ft. of the grading section shall be checked for soluble sulfates according to OHD L-49.

4. **Problem Soils Related to Roadway Subgrades and Embankments:** Additional field exploration, laboratory testing and analysis are required to determine the long-term performance and/or suitability of the following soil and rock that may be incorporated into the roadway subgrade and embankment or found in the foundation soils below the roadway embankment:

a. Organic soils

b. Normally consolidated clays

c. Expansive clays and shales

d. Dispersive soils

e. Collapsible soils

f. Degradable shales

g. Caliche

h. Mine spoils (all types) and caves

i. River or stream meander loops and cutoffs and ox-bow lakes

j. Karst features (e.g., gypsum, limestone)

These soils and conditions are coordinated with the Pedological and Geological Survey and Borrow Pit Investigation. The interpretation and judgment of these soil conditions is the responsibility of the Geotechnical Engineer.

5. **Roadway Structures:** Check the bearing capacity, settlement and stability of roadway structures (i.e. retaining walls) according to the most current AASHTO Standard Specifications for Highway Bridges.

6. **Construction Recommendations:** The Geotechnical Engineer may recommend chemically stabilized bases, subbases and subgrades as directed by ODOT or in lieu of select borrow requirements of the most current edition of the Oklahoma Department of Transportation (ODOT) Standard Specifications for Highway Construction. These recommendations are limited to lime, fly ash, CKD, and Portland cement and the method of evaluation shall follow ASTM D4609, OHD L-50 and OHD L-51.

GEOLOGICAL INVESTIGATION: A Geological Field Investigation is required for any or all of the following:

1. rock cuts of 10 feet or greater
2. shallow rock mapped within a proposed cut section
3. rock mechanics analysis
4. geological hazards
5. rock fills

A geological field investigation may consist of the following elements:

1. borings
2. slope stability analysis
3. rippability ratings
4. evaluation of geological hazards
5. shear strength of rock fills
6. evaluation of excavated rock for use as a source of aggregate
7. Geological statements.

The Geological Investigation is in conjunction with the Pedological and Geological Survey. Dimensions are to be in English or metric units, whichever is compatible with the Plans. Any interpretations and judgements made of the site geologic conditions are the responsibility of the Geotechnical Engineer. The investigation may include the following:

1. **Borings:** Space borings through cut sections within the project extent every 100 feet in the longitudinal centerline (CL or CRL) direction. Provide a minimum of two borings along a straight line perpendicular to the centerline or planned slope face to establish a geological cross-section of the cut. Two of these borings shall be continuously cored to characterize the soil and/or rock properties. The depths of all borings are to extend a minimum of 10 feet below the deepest plan grade. Record the location of perched or permanent water tables for a minimum of 24 hours.
2. **Seismograph Surveys:** Seismograph Surveys of cut sections may be required. The equipment must be capable of determining rock properties throughout the entire depth of the cut, plus 10 feet below plan grade. Depths to each rock layer must be accurate to the nearest foot.
3. **Rock Stability Analysis:** Rock stability analysis is required when the dip of the geological formation exceeds 20 degrees into the slope face. Ensure the analysis meets all the requirements of the kinematic slope stability program, RockPack III (or equivalent), using the stereographic projection procedure. This analysis is necessary to determine the slope stability of closely spaced (2 ft. or less) rock joints (fractures) and/or tilted (dipping greater than 10 degrees) rock strata of the cut slope. These measurements will allow development of the local structural geology, in three dimensions, required for making this analysis. The data that is required for this analysis is the dip, and dip direction of both the rock strata and of the joints (fractures) in the rock. The equipment necessary to obtain the dip, and joint orientation data is a Clar and/or Brunton compass. This device gives magnetic headings and dip angles. Trenching or oriented cores may be necessary in order to expose enough rock strata to make the measurements. The shear strength of the jointed rock shall be based on the requirements of the Hoek-Brown (1988) criteria. If the observations identify joints (fractures) in which shear failures may occur, or fractures that contain soil infilling; then, the shear strength of the infilling or fractures is required to be taken into account in the overall slope stability analysis. In argillaceous massive shales (non-laminar), slope stability analysis shall be based on the use of a soil mechanics approach.
4. **Rippability:** Determine rippability by a refraction seismograph. The seismograph must be capable of providing valid, useable signals for calculating the depth to bedrock to nearest foot. It must be capable of sensing rock layers to the depth of the proposed cut. Calculations of rock rippability shall be made from the resulting sound wave velocities. The rock rippability rating of each layer shall be reported as rippable, marginal, or non-rippable.
5. **Geologic Hazards:** Identify any geologic hazards (e.g. sinkholes, landslides, and others). These are to be precisely located and dimensioned to the nearest foot. Record all occurrences in the final report. GPS coordinates may be used in addition to Public Land Survey legal descriptions. Locations must be referenced to the CL or CRL by plan station and offset.
6. **Rock Fill Embankments:** Determine the shear strength values of rock fill embankments. The model will be generated by using the results of the triaxial shear tests. Conduct the testing on 1-in. size aggregates from the specified rock fill aggregate source.
7. **Geologic Site Assessment:** Provide a geologic site assessment of the rock type and layering conditions in the cuts along the CL or CRL. This report will be based on available geologic maps, bulletins etc., along with a field, on-site investigation. The assessment will pertain to

the geologic conditions and character of the rock strata as provided in the above geologic information sources.

8. **Equipment:** List the equipment used to make the observations (e.g. borings, seismograph surveys, rippability, and stability analysis) in the report. Provide the make, model, and manufacturer.

Descriptive Terminology and Rock Classification: The descriptive terminology and rock classification shall be based upon the "Standard Guide for the Description of Surface and Subsurface Geological Rock Formations of Oklahoma" as presented in Appendix 3. The finished boring log shall be a compilation of all classification and description from laboratory tests and field logging.

GEOTECHNICAL EXPLORATION, IN SITU TEST PROCEDURE:

1. The most current issue of the following ASTM Standards for in situ testing will govern and shall be used.
    a. Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils – ASTM D1586
    b. Electronic Friction Cone and Piezocone Penetration Testing of Soils – ASTM D5778
    c. Mechanical Cone Penetration Test – ASTM D3441
    d. Flat Plate Dilatometer Test – ASTM D 6635
    e. Pressuremeter Test – ASTM D 4719
    f. Vane Shear Test – ASTM D 2573
    g. Dynamic Cone Penetrometer Test – ASTM D 6951

2. The most current issue of the following ASTM and AASHTO Standards for sampling will govern and shall be used.
    a. Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils – ASTM D1586
    b. Practice for Thin-Walled Tube Geotechnical Sampling of Soils – ASTM D1587
    c. Practice for Rock Core Drilling and Sampling of Rock for Site Investigation – ASTM D2113
    d. Practice for Preserving and Transporting Soil Samples – ASTM D4220
    e. Collection and Preservation of Water Samples – AASHTO R24
    f. Standard Test Method for Determining Subsurface Liquid Levels in Borehole or Monitoring Well (Observation Well) – ASTM D4750

3. **Bore Hole Completion and Site Restoration:** All borings should be properly closed at the end of the field exploration for safety considerations and to prevent cross contamination of soil strata and groundwater. The general procedures for borehole completion and site restoration are as follows:
    a. <u>Responsibility</u> The driller is responsible for properly plugging the borehole.

b. Timetable Ensure borings are plugged within 10 days of completion of drilling or groundwater observations to prevent contamination of groundwater.

c. Backfill Consider the following:

1. For Pedological, shoulder, and in-place borings, backfill and compact the borehole with borehole cuttings.
2. In pavements, backfill the boreholes with cuttings. Compact, by tamping, the cuttings to a depth of 6 in. below the bottom of the pavement. Fill the remainder of the boring with either quick setting concrete or asphalt patch depending upon the pavement type.
3. For embankment and cut section borings, follow the procedures outlined in **AASHTO R-22**.

d. Property Cleanup As practical, the site should be returned to its original conditions. For sensitive locations, take before and after photographs to address possible complaints from the landowner.

4. **Field Logging:** Field logs shall be based upon the descriptive terminology and classification of rock detailed in the "Standard Guide for The Description of Surface and Subsurface Geological Rock Formations of Oklahoma" as presented in Appendix 3.
5. **Method of Drilling:** An appropriate method of rotary drilling shall be used for the foundation and geologic conditions encountered. These are described in the AASHTO Manual on Subsurface Investigations, 1988. There is no restriction on the type of drill equipment other than it shall be capable of performing all of the field sampling and testing as outlined in the above referenced manual. Samples may be taken from the flight augers unless water table conditions are encountered. The practice of auger refusal is **not** an acceptable technique for defining the top of bedrock. The top of bedrock shall be established by sampler refusal as outlined in **ASTM D 1586 - Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils.** For borings over water in lakes or rivers, drilling operations shall be performed on a barge supported by spud rods firmly anchored at each corner.
6. **Geologic Statement:** A general geologic review and assessment(s) shall be provided as a statement in the Geologic Investigation. It will include cross section(s) and provide drawings, showing the orientation of the rock masses or layered rock formations at each cut section investigated. The drawings will provide station designations along the centerline of survey or CRL and offset distances left and/or right. The geologic summary will be provided based on all available geologic information. Examples of such sources are as follows:

a. Oklahoma Geological Survey

b. Oklahoma Water Resources Board

c. U.S. Geological Survey

d. Tulsa Geological Society, and others

LABORATORY TESTS: All laboratory testing shall be performed by technicians certified by the Highway Construction Materials Certification Board in a laboratory qualified by the ODOT Materials Division.

1. Where appropriate, soils and rock samples are to be tested and results reported according to the most current AASHTO/ASTM Standards for the following tests:
    a. Soils Classification, Gradation and Plasticity Index – AASHTO T88, T89, and T90
    b. Moisture Content, AASHTO T265
    c. Specific Gravity, AASHTO T100
    d. Chunk Density, AASHTO T233
    e. Hydrometer, AASHTO T88
    f. Double Hydrometer, ASTM D4221
    g. Pinhole Test, ASTM D4647
    h. pH, AASHTO T289
    i. Moisture-Density Test
        1) Standard, AASHTO T99
        2) Modified, AASHTO T180
    j. Electrical Resistivity, AASHTO T288
    k. Slake Durability, ASTM D4644
    l. Unconfined Compression Test, AASHTO T208
    m. Point Load Test, ASTM D5731
    n. One-Dimensional Consolidation Test, AASHTO T216
    o. Drained Direct Shear Test, AASHTO T236
    p. Triaxial Sheer Test
        1) Unconsolidated Undrained, ASTM D2850
        2) Consolidated Undrained, ASTM D4767
    q. Residual shear strength, ASTM D6467
    r. One Dimensional Swell or Settlement Potential of Cohesive Soils, ASTM D456

2. Classification and description of soils and compaction shales follow the practice as outlined in ASTM D2487 and D2488. For classification purposes, define, test, and report for the following particle size distribution.

    3 in. (75mm)

    ¾ in. (19mm)

    No. 4 (4.75mm)

    No. 10 (2.00mm)

    No. 40 (425mm)

    No. 200 (75mm)

3. A pocket penetrometer or any other "pocket" measurement device shall **not** be used to determine rock or soil properties for the purposes of this investigation.

FINAL WRITTEN REPORT: The final report shall be written by a Geotechnical Engineer with a broad experience and background in engineering for the type of roadway work identified in the project. All pertinent information to be included in the final report is detailed in Appendix 4 – Guidelines For Preparing Geotechnical Reports. Appendix 5 provides the Standard Forms for Reporting Geotechnical Information.

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1. American Society for Testing and Materials, Special Technical Publication No. 479, "Special Procedures for Testing Soil and Rock for Engineering Purposes", 5th Edition, 1968.
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3. "Soil Survey Manual", U.S. Department of Agriculture, Soil Survey Division Staff, Handbook No. 18, 1993.

STATE OF OKLAHOMA
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL SPECIFICATIONS FOR ROADWAY DESIGN

June 29, 2011

APPENDIX 1. - GUIDELINES AND BACKGROUND INFORMATION FOR PROVIDING SOIL CLASSIFICATION INFORMATION

Purposes: The purpose of these guidelines is to describe a systematic practice for providing a Pedological Survey report. These guidelines will include methods for providing the most up to date and meaningful soil classification information. Soil samples are to be taken from within named, mapped units as contained in County Soil Survey report. Every soil series associated with the named map unit(s) is to be sampled and tested. Therefore, for proper and current classification of the sampled soil, a copy of the official soil series description must be provided. The description includes the classification. The included description shall be the most current version of the sampled soil series as certified by the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Services (SCS). For example, a 1968 soil survey report map unit symbol CrE, red clay land, "probably has been recorrelated to "Vernon clay loam, 8- 20% slopes", or similar soil series. Thus, an official copy of the Vernon soil series is to be provided in the pedological report. If in the extent of alignment, the map unit repeats a soil series, it need not be sampled again. However, borings must be made in the subsequent map unit to verify that the soil series is indeed the same within the allowable ranges as stated in the official soil series description paragraph, "Range in Characteristics."

Scope. This method covers that portion of the Pedological system used for identification and classification of natural soil profiles in their undisturbed state as developed in their natural environment. This system includes topographic and drainage characteristics as well as those particular features that are influenced by broader climatic factors, such as temperature and rainfall.

Soil Profile:

1. A vertical cross section of soil layers constitutes the soil profile which is composed of six master horizon layers designated O, A, E, B, C, and R.

2. The O horizon is a surface horizon dominated by organic matter. It is composed of partially decomposed leaves, needles, twigs, etc., left on the surface. Soils of forested areas of southeastern Oklahoma commonly contain O horizons.

3. The A horizon is the usual topsoil layer. It is dark by virtue of an accumulation of organic matter but is not dominated by it. It is mostly mineral matter. This layer is usually present in all Oklahoma soils.

4. The E horizon is a subsurface horizon. It's the leached horizon. It's usually lighter in color than the A or the underlying B horizon. It contains predominantly uncoated sand and silt particles. These layers are common in flat-lying clay soils and forested soils of the eastern ½ of Oklahoma.

5. The B horizon is a subsurface horizon. It's often called the subsoil. It is a layer or accumulation of silicate clay, iron, aluminum, humus, carbonates, gypsum, or silica or combinations of these. In most Oklahoma soils the accumulation of clay causes the B horizon to be "heavy" or more clayey than the above horizons. Often a fairly new soil

will have a B horizon that it is just forming and will have a structure B prior to the many years it takes for clay, etc. accumulation to occur.

6. The C horizon lies below the B horizon and is little affected by the processes that formed the horizons above. It's usually unconsolidated or uncemented and related to the horizons above. However; it may not be related to the horizons above. It could be alluvial sediment or weakly cemented rock.

7. The R horizon is hard bedrock. If the R horizon is shale, it's still usually too firm to be easily dug with hand tools. Shale is usually rippable, other rock types are generally not.

8. Transitional layers are common. These include AB, EB, BE, or BC. These occur in soils with thick transition layers in which the properties of one horizon dominates over the other. They generally occur in deep, gently sloping to flat soils.

Soil Classification:

1. The primary purpose of soil classification is to describe a soil in sufficient detail to permit engineers to recognize features significant to design and if need be, to obtain samples in the field.

2. Highway engineers have found that the soil classification system with its wide range of soil information could be used in the general identification of soil, after which he could classify the various soil materials for engineering purposes. The U.S. Department of Agriculture classification system is used primarily for agronomic purposes. However, after testing and correlation with engineering properties and performance, it then becomes a system of classification suitable for use by the highway, railroad, or airport engineer.

USDA Classification System:

1. This system of soil classification or identification is based on the fact that soils with the same weather (rainfall and temperature rages), the same topography (hillside, hilltop, valley, etc.), and the same drainage characteristics (water-table height, speed of drainage, etc.) will grow the same type of vegetation (either oaks or bluestem grasses or a combination) and will generally be the same kind of soil.

2. This classification system is important basically because a subgrade or a particular soil series, horizon and particle size (texture) will perform the same wherever it occurs since such important factors as rainfall, freezing, groundwater table, capillarity of the soil, etc., are factors in the identification and classification. This is the only system which directly employs these important factors. Its value and use can be extended widely as soon as the engineering properties, such as load-carrying capacity, susceptibility to moisture change, or general performance has been established for a particular soil series. This is because soils of the same particle size, horizon and series name are the same and will, under comparable conditions, behave the same wherever they occur. Thus, engineers operating within designated soil geographic regions, after identifying similar soils, through the system, could exchange accurate pavement-design and other performance data.

3. The classification currently being used is described in the 2nd Edition of "Soil Taxonomy" 1999, as shown below.

SOIL ORDERS COMMONLY FOUND IN OKLAHOMA BY AREA RANKING

Order	Formative Syllable	Derivation	Meaning
Mollisols	oll	mollis, soft topsoil	dark topsoil
Alfisols	alf	pale, thin, topsoil	none
Inceptisol	ept	inception	new soil
Ultisol	ult	last, ultimate	old soil
Entisol	ent	recent	very new soil
Vertisol	ert	vertical	heaving/swelling
Aridisol	id	arid	dry

Mollisols are the prairie soils and thus are the most common in Oklahoma, occupying about 18 million acres. Alfisols occupy about half of that or 9.8 million acres. Inceptisols and Ultisols occupy 6.1 and 4.0 million acres respectively. The remaining are the Entisols, Vertisols, and Aridisols, which occupy 2.6, 0.59, and 0.25 million acres respectively.

Other soil Orders that are not commonly found in Oklahoma include Gelisols (frozen soils), Spodosols (wood ash), Andisols (volcanic, e.g. ash, lava), Oxisols (tropical conditions), and Histosols (organic matter, bogs).

4. Soils Orders are subdivided into Suborders, Groups, Subgroups, Families, Series, and Phases. Each classification has significance for engineering. These subgroupings are based on such things as water tables, moisture regimes, and particle sizes

5. Suborders are based on those characteristics that seem to produce genetic similarities. The suborders narrow the broad climatic range permitted in the orders. The soil properties used to separate suborders mainly reflect either the presence or absence of the water table or soil differences resulting from the climate and vegetation. The suborders have names composed of only two syllables. For example, Aquolls are the Mollisols resulting from high water tables (aquic + oll = wet Mollisol), while the Udolls are the moist Molllisols because of a moist climate (udic + oll = moist Mollisol). These suborder names are the endings of the great groups in each suborder.

6. Groups or "Great Groups" are divided on the basis of uniformity in the kinds and sequences of major soil horizons and features. The horizons on which the divisions are based are those in which clay, iron, or humus has accumulated. The features on which the divisions are based are the properties of clays, soil temperature, and major differences in chemical composition (mainly calcium, magnesium, sodium, and potassium). Another syllable or two is added in front of the suborder name to indicate how each great group differs from others in the same suborder. The name of each group is the last word in the name of the subgroup. An example of a Great Group

names would be Argiaquoll. An Argiaquoll is a wet, prairie soil that has a clay accumulation B (subsoil) horizon.

7. Groups are divided into subgroups. One of the subgroups in each great group represents the central (typic) segment or concept of the group and the others, called intergrades, have properties of another great group, suborder or order. Subgroups may also be made in those instances where soil properties intergrade outside the range of any other great group, suborder, or order. The names of subgroups are derived by placing one or more adjectives before the name of the great group. An example classification is: Typic Hapludalf. Thus, a Typic = typical, Hapl = minimum horizon development, ud = moist; alf = Alfisol soil order. So, the names are connotative of major properties of the kinds of soil included in each category. The names also indicate how they are related to each higher classification category.

8. Subgroups are divided into families primarily on the basis of properties imported to the growth of the plants or to the behavior of soils used in engineering. Among the properties considered important are texture (particle size distribution), mineralogy, reaction, soil temperature, permeability, thickness or horizons, and consistence. Each family name also shows the placement of these soils in every higher category of the system and tells how the family differs from other families in the subgroup. For example, the Miami series is in the “fine-loamy, mixed active mesic” family of Oxyaquic Hapludalfs. This means that their subsoils contain 18 to 35% clay (fine Loamy) a mixture of minerals (mixed), the ratio of cation exchange capacity over clay content percentage of the soils is between 0.40 and 0.60 (active), and has a mean annual soil temperature between 47- and 59-degrees F (mesic). Oxyaquic connotes redox features (mottles) in the upper part of the B horizon and is saturated for short periods during each year. The Hapludalf great group has a minimum number of horizons characteristic of the Udalf suborder and are the more moist soils in the Alfisol order.

9. Soils within each family are divided into soil series and the soil series are further broken down into soils phases. Similar soils within a family that developed in the same age, climate, vegetation, and local environment acting on parent material are given a soil series designation. All soil profiles of a certain soil series are similar in all respects with the exception of possible variation of slope or particle size distribution (texture) of the surface horizon. The soil series were originally named after a town, county, stream or similar geographical source, such as “Clarita” or “Denise”, where the soil was first identified and mapped. There are many exceptions today. For instance, a Gasil soil series is related to the Galey soil series but there is no such location as “Gasil”.

10. The texture of the surface soil or A horizon may vary slightly within the same soil series. The soil mapping unit is therefore a result of subdividing into the final classification unit, which includes the soil series name, surface texture and slope or other observable surface characteristic useful for describing map delineations. The description of the slope, stoniness, and similar easily observable surface features is called the soil phase. This was formerly called the soil type. For example, if the texture of the A horizon of an Enterprise soil series is very fine sandy loam, then the soil map unit will be described as an Enterprise very fine sandy loam. Other landscape observable characteristics, such as

slope, or stoniness will be phase criteria. Thus, the Enterprise map unit or soil phase may now be described an Enterprise very fine sandy loam, 5-20 percent slopes.

11. The description of the soil series provides the key to identification and classification. It gives the significant characteristics involved in most design, construction, and maintenance problems. Characteristics of importance are the nature of the parent material, including geological origin, texture, and chemical constituents. No less important are environmental conditions which influence soil behavior. Local environment including topography, drainage, and location of the ground water table are dominating factors. For instance, a soil map unit soil series name classified as a "fine, smectitic, superactive, thermic Udic Haplustert" can quickly state that the soil is shrinking/swelling soil (ert), on the dry side but moist in the growing season, commonly cracking and containing slickensides (ust + Udic), and has minimal horizon development (Hapl). The term thermic denotes a warm temperature regime, 47 to 59 degrees F, smectitic denotes the dominant clay mineral type, namely smectite (an expansive clay type), superactive is the ration of cation exchange capacity over clay content, and fine indicates a soil high in clay content. . Fine describes particle size and amount; in this case the clay content of the soil massive is less than 60 per cent. Thus, classification with its subsequent interpretation gives strong clues toward the engineering properties and performance of a given soil series.

12. The classification is present in every official soil series description obtained from the NRCS database web site. This is why it's important to identify and sample the correct soil series within map unit.

13. If the Pedological investigator encounters a significant extent of a soil dissimilar or not fitting the one described for the map unit, the soils(s) is to be sampled according to the convention set forth in Appendix 3. Such dissimilar soils are called "inclusions". For example, the soil inclusion may be described and labeled as "red clay soil similar to Vernon clay loam occurring in the KaA, Kirkland silt loam 0-1% slope, map unit". Make sure the location is properly noted, e.g. Station 457 + 16, 11 feet right of CL. Horizons of the inclusion are to be estimated as closely as possible, labeled, and samples taken and submitted for laboratory analysis.

The Role of NRCS: All of Oklahoma has been mapped by the NRCS. The more recently published surveys have the soil series classifications listed therein. Copies of the county soil survey reports are available in the counties where the construction activity is to take place. These can be obtained at the local county NRCS filed offices or the County Cooperative Extension Office. These are usually located in the county seat cities. The reports contain maps based on aerial photographs. If copies are not available in the counties, then contact the NRCS State Soil Scientist in Stillwater, OK to locate a source of the required information.

The NRCS Web Soil Survey, http://websoilsurvey.nrcs.usda.gov/app/ is also a good source for county soils maps and information.

The county soil survey reports, with their included maps, are the basic publications for discovering the soil series at a given location or roadway alignment. The NRCS is constantly working to update and recorrelate the soil series in Oklahoma. The most current NRCS county soil legend must be used to ensure that the mapped unit(s) and its classification and sampling are current to the date of the Pedological report.

Locating a current legend can be done in at least three ways:

1) By contacting the local NRCS field office, usually in the county seat,
2) By contacting the Geotechnical Branch, Materials Division, Oklahoma Department of Transportation, 200 NE 21st Street, Oklahoma City, Oklahoma 73105, phone (405) 522-4998 or,
3) By calling the NRCS State Soil Scientist

Please provide to them the county, map symbol, and soil series name. They will provide, from soils legend, the most current unit name.

Once the current soil series name has been attained, contact the Natural Resources Conservation Service database to obtain the most current official soil series description(s). Their web site address is: http://soils.usda.gov/technical/classification/osd/index.html . Select the category "soil series by name". Descriptions of the Soil Series are to be included in the Pedological report.

Summary: The Pedological Survey report consists of the following required elements:

1. Aerial photographs at 1:20,000 scale, (or the scale as utilized by NRCS in their county soils reports) with delineated map units and proposed location or CRL/CL alignment plotted thereon (reproduction from county soil survey report) are required. Obtaining copies of Digital Orthophoto Quad sheets, at a website address of the Oklahoma Conservation Commission, may allow a greater accuracy and ease of plotting.

2. The traversed distance of each alphabetized map unit is to be summed and reported in feet.

3. A set of official soil series description sheets from the official NRCS national database source (Iowa State) is to be included. These are for the soil series found along the alignment extent or at the location of interest.

4. A numerical listing in alphabetical order of the soil series found long the alignment and their classification is to be provided in the report, for example: 1. Burleson Soil Series, Fine, smectitic, thermic, Udic Haplustert.

5. Soil samples from all horizons, according to the official soil series description, are to be taken. Also, a large composite sample of the major horizons, excluding the A horizon, are to be taken and listed. The sampling method is described in paragraph 1.c. of the Geotechnical Specifications for Roadway Design. This is to be done for each soil series present along the alignment. The samples are then to be submitted to a certified laboratory for testing.

6. The required laboratory tests for the above samples as listed in paragraphs 1.f. and 1.g. of the Geotechnical Specifications for Roadway Design.

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June 29, 2011

APPENDIX 2. - GUIDELINES FOR ANALYSIS, BORING, SAMPLING, AND TESTING

Purposes: These guidelines provide the basic criteria for:

(1) Geotechnical engineering analysis for roadway embankments and retaining walls

(2) Boring, sampling and testing

These guidelines are intended to provide, to the Geotechnical Engineer, a minimum approach to providing geotechnical information based upon the various soil types encountered at the project location. The Geotechnical Engineer is not limited to these guidelines if site conditions warrant the need for further sampling, testing, and/or analysis.

TABLE 1: GEOTECHNICAL ENGINEERING ANALYSIS REQUIRED FOR EMBANKMENTS, AND RETAINING WALLS

Soil Classification			Embankment and Cut Slopes		Retaining Walls Conventional, Crib & Reinforced Soil	
Unified	**AASHTO(1)**	**Soil Type**	**Slope Stability(2) Analysis**	**Embankment Settlement Analysis**	**Lateral Earth Pressure**	**Stability Analysis**
GW	A-1-a	Gravel well graded	Stability analysis generally not required if cut or fill slope is 1-1/2 Horizontal to 1 Vertical or flatter and water table in cut slope is drawn down by underdrains. Erosion of slopes may be a problem for SW or SM soils.	Settlement analysis generally not required except possibly for SC soils.	GW, SP, SW, & SP soils generally suitable for backfill behind or in retaining or reinforced soil walls. GM, GC, SM, & SC soils generally suitable if have less than 15% fines. Lateral earth pressure analysis required using soil angle of internal friction.	All walls should be designed to provide minimum F.S. =2 against overturning and minimum F.S. =1.5 against sliding along base. External slope stability considerations same as previously given for cut slopes and embankments.
GP	A-1-a	Gravel poorly graded				
GM	A-1-b	Gravel silty				
GC	A-2-6 A-2-7	Gravel clayey				
SW	A-1-b	Sand well graded				
SP	A-3	Sand poorly graded				
SM	A-2-4 A-2-5	Sand silty				
SC	A-2-6 A-2-7	Sand clayey				
ML	A-4	Silt inorganic Silt sandy	Stability analysis required unless non-plastic Erosions of slopes may be a problem.	Settlement analysis required unless non-plastic	These soils are not recommended for use directly behind or in retaining or reinforced soil walls.	
CL	A-6 Lean Clay	Clay in-organic	Required	Required		
OL	A-4	Silt	Required	Required		

TABLE 1: GEOTECHNICAL ENGINEERING ANALYSIS REQUIRED FOR EMBANKMENTS, AND RETAINING WALLS

Soil Classification			Embankment and Cut Slopes		Retaining Walls Conventional, Crib & Reinforced Soil	
Unified	**AASHTO(1)**	**Soil Type**	**Slope Stability(2) Analysis**	**Embankment Settlement Analysis**	**Lateral Earth Pressure**	**Stability Analysis**
MH	A-5	Silt inorganic	Stability Analysis required Erosion of Slopes may be a problem	Required	These soils are not recommended for use directly behind or in retaining walls.	All walls should be designed to provide minimum F.S. =2 against overturning and minimum F.S. =1.5 against sliding along base. External slope stability considerations same as previously given for cut slopes and embankments
CH	A-7	Clay inorganic "fat clays"	Required	Required		
OH	A-7	Clay organic	Required	Required		
PT	---	PEAT	Required	Required Long-term settlement can be significant.		
Rock			Fills-Analysis not required for slopes 1-1/2 Horizontal to 1 Vertical or Flatter. Cuts-Analysis required but depends on spacing, orientation, and strength of discontinuities, durability of the rock.	Not Required	Lateral earth pressure analysis required using rock backfill angle of internal friction.	
REMARKS: Soils -Temporary ground water control may be needed for foundation excavation in GW through SM soils. Rock - Durability of shales (silt-stones, clay-stones, mud-stones, etc.) to be used in fills, should be checked. Non-durable shales should be embanked as soils, i.e., placed in maximum 12" looses & compacted with heavy sheepsfoot or grid rollers.						

(1) Approximate correlation to United (Unified Soil Classification system is preferred for geotechnical engineering usage – AASHTO system was developed for rating pavement subgrades).

(2) These are general guidelines – detailed slope stability analysis may not be required where past experience in area in similar soils or rock gives required slope angles.

TABLE 2: GUIDELINE "MINIMUM" BORING, SAMPLING AND TESTING CRITERIA

Sand-Gravel Soils

SPT (split-spoon) samples should be taken at 5-foot (2m) intervals (2m) Intervals or at significant changes in soil strata.

SPT jar or bag samples shall be taken for classification testing and verification soil identifications.

Silty-Clay Soils

SPT and "undisturbed" thin wall tube samples should be taken at 5 foot (2m) intervals or at significant changes in strata.

Take alternate **SPT** and thin wall tube samples in the same boring or take thin wall tube samples in a separate undisturbed boring.

SPT jar or bag samples shall be taken for classification testing and verification of field visual soil identification.

Thin wall tube samples should be sent to the lab to conduct consolidation testing (for settlement analysis) and strength testing (for slope stability and foundation bearing capacity analysis).

Field vane shear testing is also recommended to obtain in-place sheer strength of soft clays, silts, and well-rotted peats.

Rock

Continuous cores should be obtained in rock or shales using double or triple tube core barrels.

In structural foundation investigations, core a minimum of 10 feet (3m) into rock to insure it is bedrock and not a boulder.

Core samples should be sent to the lab for possible strength testing (unconfined compression) for foundation investigation.

Percent core recovery and **RQD** value should be determined in field or lab for each core run and recorded on boring log.

Ground Water

Water level encountered during drilling, at completion of boring, and at 24 hours after completion of boring should be recorded on boring log.

In low permeability soils such as silts and clays, a false indication of the water level may be obtained when water is used for drilling fluid and adequate time is not permitted after hole completion for the water level to stabilize (more than one week may be required). In such soils a plastic pipe water observation well shall be installed to allow monitoring of the water level over a period of time.

Artesian pressure and seepage zones, if encountered, should also be noted on the boring logs.

The top foot or so of the annual space between water observation well pipes and boreable wall should be backfilled with grout, bentonite, or sand-cement mixture to prevent surface water inflow which can cause erroneous groundwater level readings.

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APPENDIX 3. - STANDARD GUIDE FOR THE DESCRIPTION OF SURFACE AND SUBSURFACE GEOLOGICAL ROCK FORMATIONS OF OKLAHOMA

This guide provides standard methods of describing geologic rock formations as required by the Materials Division of the Oklahoma Department of Transportation (ODOT). These descriptions shall be of such quality and quantity as to provide complete and accurate rock type information useful to ODOT.

This guide is to be used to describe various sedimentary and igneous consolidated rock formations, henceforth called "units," in the State of Oklahoma. Such units are exposed at the earth's surface as well as in borings. These rock units may lie exposed naturally, undisturbed by man or be present in man-made cuts, pits, ditches, or similar features. Loose uncompacted earth materials, such as alluvium, are considered unconsolidated and are not included in this guide.

In addition, this guide applies to descriptions of rock types as recovered from drill bit cuttings, or as observed in cores. It is structured such that the description of rock characteristics most pertinent to the construction or repair of ODOT facilities is emphasized. Other more detailed terms may be used to describe obvious features of the rock units; i.e. carbonaceous, veins, mottles, or fissures, but they must be defined in the "Glossary of Geology" (1). The person or persons using this guide to describe rock types must be a geologist, geological engineer, civil engineer, or a trained, experienced, qualified individual that has been certified by the ODOT Materials Division or other approved designated authority.

Geographic locations of the geological log or outcroppings must be described from plans by Station to the nearest foot and tenth, when such information is available. A minimum of a legal description accurate to the nearest 100 ft. is required when plans or other detailed location information is not available. Global Positioning System (GPS) locations are acceptable. All locations shall be referenced to plan station and offset. Elevations of the ground surface to the nearest tenth of a foot are required for all borings. As a minimum, all boring logs shall include the following ancillary information:

1. Stratigraphic location, to nearest 0.1 foot, of any sample(s) or tests taken.
2. Name of contractor
3. Name of logger
4. Core or hole diameter, in inches
5. Boring number
6. Date drilled or logged
7. Bit type
8. Method of drilling

When cores are taken, identify the Rock Quality Designation (RQD) according ASTM D 6032. For continuous core sampling, use the Rock Mass Ratings (Geomechanics Classification) procedure identified in ASTM D 5878. The following is a list of the rock characterization elements to be used in describing the rock units. The elements describing the character of rock types are to be presented in the report in the order listed.

1. Rock Type (Lithology)
2. Color
3. Thickness
4. Gradation
5. Texture
6. Pores
7. Cementation
8. Hardness
9. Layering (or bedding)
10. Joints

Not all of the above elements will be present at a given site. The type of construction being considered, the character of the rock encountered, and the method of investigation are examples of situations that will dictate the elements used to describe the rock (unit(s) in the report.

Types and Descriptions of Rock

The term lithology pertains to the rock type being observed and described. The following rock descriptions represent the rock types or lithologies commonly found in Oklahoma. They occur as outcroppings or as recovered in cores. These example descriptions are to be included in the Geotechnical Report. The most common rock types are listed first.

1. **Shale.** Shales are fine grained sedimentary rocks consisting of compacted and hardened clay, silt or a combination of the two particle sizes. Shales normally contain at least 67% clay, with the remainder being silt with a chemical or crystalline material acting as a cementing agent. Shales are by far the most common of the sedimentary rocks. They are usually identified in the field by their laminated or fissile appearance. Shales can be any color. They are usually gray, brown, olive, or black in the eastern half of Oklahoma and shades of red often with greenish-gray spots or layers in western Oklahoma. The reddish shales of western Oklahoma commonly do not exhibit strong laminations but are more massive or blocky in appearance. They usually exhibit a smooth, sometimes waxy feel.

2. **Sandstone.** Sandstones are medium grained, consolidated, sedimentary rocks composed primarily of 85-90% quartz grains and 10-15% of a cementing agent such as

calcium carbonate which will fizz upon the application of a hydrochloric acid solution (HCL, 1 part concentrated hydrochloric acid in three parts distilled water) or more commonly, silica. The cementing medium commonly contains minor amounts of silt and/or clay. The quartz grains are sand sized and can be seen with the naked eye. Sandstones are commonly reddish in western Oklahoma. In eastern Oklahoma, sandstone is most commonly brown to yellowish but many are gray. They usually exhibit a gritty feel.

3. **Limestone.** Limestones are sedimentary rocks consisting of more than 95% of the mineral calcite (calcium carbonate). The remaining 5% is commonly dolomite. They occur in beds or layers. They may contain minor amounts of chert (silica), clay, pyrite, feldspar, and siderite. They will fizz upon the application of a hydrochloric acid solution. They may be massive or contain visible fossils. They may increase in fossil content to the point of being composed entirely of fossil shells of various types and sizes. These are common in southeastern Oklahoma. Limestones are most commonly whitish or cream in color but range through brown and red, to black. Limestones are commonly hard but may be soft and chalky.

4. **Gypsum.** Gypsum is a rock composed of the mineral gypsum, which is hydrous calcium sulfate. Gypsum occurs as massive layers or beds. It normally does not contain any particles of sand, silt, or clay. It is white in color and may occasionally contain streaks of reddish brown. Gypsum is softer than limestone and will not fizz upon the application of a hydrochloric acid solution. Gypsum is found in the western half of Oklahoma.

5. **Anhydrite.** Anhydrite is a rock similar to gypsum. It occurs in beds or layers. It is composed of calcium sulfate without the water of hydration, which is present in gypsum. Anhydrite is slightly harder than gypsum but still a soft rock. Anyhydrite generally has the same appearance as gypsum and occurs associated with gypsum in western Oklahoma.

6. **Siltstone.** Siltstones are consolidated sedimentary rocks that contain at least 70% silt sized particles with the remainder being clay size particles. They can be any color. They usually appear flaggy to thin bedded but are not as fissile as shales. Siltstones are usually soft but may occasionally be hard.

7. **Conglomerate.** Conglomerates are consolidated sedimentary rocks that contain rounded to subangular fragments larger than sand size (2mm). They appear to be a “gravelstone”. Often the particles range up to small boulder (12 inch) size. The particles are usually rounded to subrounded. The matrix is commonly silt and sand

cemented by calcium carbonate (which will fizz upon the application of a hydrochloric acid solution), iron oxide, silica, or clay. Conglomerates are usually brownish to reddish in color. They are usually found in massive beds and associated with sandstones. Conglomerates are usually hard but range from soft to hard. They are named by the composition of the "gravel" fragments. For example, if the gravel-sized material is mostly limestone, the rock is described as a limestone conglomerate.

8. **Dolomite.** Dolomite is a sedimentary rock that contains more than 50% of the mineral dolomite, which is a calcium/magnesium carbonate, CaMg(CO3). Dolomite commonly contains more than 90% dolomite with the remaining percentage being calcite. It will not fizz upon the application of a hydrochloric acid solution. However, it will fizz if powdered (e.g. with knife scratches or similar techniques). Dolomite commonly occurs with limestones or interlayered with limestones. Most Oklahoma dolomite is white, ranging to light gray or sometimes slightly pinkish. Dolomite is commonly hard, durable rock. Dolomite occurs in all areas of Oklahoma except the panhandle.

9. **Caliche.** Caliche is a rock-like soil deposit of the high plains of northwestern Oklahoma. It is calcareous and will fizz upon the application of a hydrochloric acid solution. It may contain various amounts of gravel, sand, silt, and clay locally. Caliche occurs as a 2 to 3 ft thick bed or layer at or near the soil surface. Sometimes the caliche is degraded and soft, being easily dug with a knife. Caliche is usually whitish or light gray.

10. **Granite.** Granite is an igneous rock (not bedded) that is hard, dense and crystalline. The rock is composed of crystals of quarts, feldspar, and a minor amount of dark minerals. Feldspar gives granite its color. Colors range from salmon in the Wichita Mountains of southwestern Oklahoma, light reddish purple in the Tishomingo area, to grayish in the Arbuckles. Weathered granite is usually whitish and soft.

11. **Gabbro, Anorthosite, Prophyry, and Basalt.** These rocks are igneous and similar in physical properties and mode of occurrence to granite. These are all hard-dense rocks that are not bedded, except basalt, which appears as a lava flow atop Black Mesa in the extreme northwestern tip of Cimarron County in the panhandle. The other rocks occur in association with granite. Gabbros are hard, dark to black colored rocks occurring in masses or veins. Anorthosites are composed primarily of feldspar. In Oklahoma They are hard, dark grayish and also occur in masses or veins. Porphyry is a hard, coarsely crystalline rock with the same mineral content as granite or any other igneous rock.

12. **Chert.** Chert (sometimes called flint) is a very hard, dense, siliceous sedimentary rock. Chert consists of interlocking invisible microcrystalline or cryptocrystalline quartz crystals of less than 30 µm. Chert has a splintery fracture. It commonly occurs as nodules or concretions

in limestones. Chert only occasionally occurs in beds. It will not fizz upon the application of a hydrochloric acid solution. This is commonly medium to dark gray but due to impurities, may be brown, black, reddish, or whitish. Chert is more commonly found in northeastern Oklahoma.

These rock types are not always pure. For example: Sandstones may contain more than just sand grains. If it contains a calcareous matrix or cementing agent, then it should be called limy or calcareous sandstone. If limestone is composed mostly of whole or broken fossils, it should be described as a fossiliferous, etc.

Descriptions for the rock types should be based on the following:

1. **Color:** Describe the color using Munsell rock color chart notations and symbols
2. **Thickness:** Record the thickness of each rock type either in an outcropping or in a log should to the nearest 0.1 foot. The elevation in feet and nearest tenth is required on all logs or other appropriate or designated reports.
3. **Texture:** The term texture refers to the arrangement of grains, particles, or crystals on a freshly exposed rock surface, as easily seen by the naked eye. Texture indicates the appearance as megascopic or microscopic as seen on the surface of mineral aggregate. The following describes the texture of geometrical aspects of the rock grains.

   a. **Grain Size:** There are two major grain size classes:

      - Coarse grained. This texture is one in which the large crystals or grains can be seen easily by the naked eye.
      - Fine grained. This texture is one whose grains cannot be seen without magnification.

   b. **Grain Shape:** There are six grain shape classes:

      - Very angular
      - Angular
      - Subangular
      - Subrounded
      - Rounded
      - Very rounded

   c. **Grain Arrangement:** From a morphological standpoint, rock texture is grouped into three main groups.

      - Homogenous
      - Nonhomogeneous (or Hetrogeneous)
      - Layered

For example: a rock may be described as, “coarse grained, subrounded, homogeneous, etc.”

4. **Cementation:** Cementation is a term used to describe the natural cementing agents surrounding the grains and binding the grains together making a rigid and compact mass. They may include the following:

   a. **Siliceous:** A granular rock with the mass cemented by silica. It is hard and cannot be scratched by a knife blade. It will not fizz upon the application of a hydrochloric acid solution. It is usually shades of gray but may be any color.

   b. **Calcareous:** A rock with calcareous or limy cement. It is not as hard as the siliceous cement. It ranges from fairly hard to soft. It will fizz upon the application of a hydrochloric acid solution. It is usually whitish but may be any color.

   c. **Ferruginous:** A rock cemented by iron. It is usually hard to very hard. It is dark red in color; sometimes it will show yellowish streaks or pockets.

   d. **Argillaceous:** A rock cemented by clay. It is usually soft and can be any color.

5. **Hardness:** The rock hardness* classes most pertinent to engineering are as follows:

   a. **Soft:** The rock can be worked with a shovel, friable, can be broken by hand in a dry to moist hand specimen, easily carved with a knife when moist. The red clay shales and mudstones of western Oklahoma are usually soft.

   b. **Moderately Hard:** The rock cannot be worked with a shovel. It can be worked with a geology hammer, or pick. It can be scratched with a penny. Examples of such rocks are the gypsums, anhydrites, and caliches of western Oklahoma. Many sandstones and siltstones are among this class, as well as some black shales in the Quachita Mountains of southeastern Oklahoma.

   c. **Hard:** The rock cannot be worked with a pick. It has a ring when struck with a hammer. It cannot be scratched with a penny but can with a knife. Most competent rocks are within this category. Most limestones, sandstones, and dolomites are examples.

   d. **Very Hard:** The rock has a distinct ring when struck with a hammer. Cannot be scratched with a knife. Examples include the siliceous limestones of eastern Oklahoma and the granites and other igneous rocks of the Witchitas and Arbuckles.

*These are hammer tests. They should be made with a 2 lb hammer on a 4 inch or so diameter specimen lying on a flat hard surface. Friable hand specimens should also be about 4 inches. The hammer soundness test on rock outcrops should be on layers at least 1 ft thick.

6. **Layering:** Most of the rocks of Oklahoma occur as beds or layers. The exceptions are the granites and other ingenious rocks of the Wichitas and Arbuckles. Include a description of the character of the beds or layers from the list below in the Geotechnical report.

   a. **Fissile:** Splits easily along closely spaced plains of 1/16 inch or less. Many shales of eastern Oklahoma are fissile.

   b. **Very Thin Bedded:** Beds of 1/16 to 2 in. (known as stringers)

   c. **Thin Bedded:** Beds of 2 inches to 2 feet.

   d. **Thick Bedded:** Beds of 2 to 4 feet. Beds in excess of 4 feet are described as "very thick bedded".

   e. **Massive Bedded:** Beds exceeding 4 feet. Usually describes homogeneous beds that have little or no evidence of minor joints, laminations, or imperfections. Gypsums are commonly massive bedded.

7. **Joints, Faults, and fractures:** A Joint is defined as a surface of a fracture or a discontinuity in a rock mass, without displacement (faulting). If displacement of the sides of the rock, relative to one another, can be observed along the discontinuities, then the feature is by definition a fault. Sedimentary rocks will usually have two sets of parallel joints. All the features defined above are considered discontinuities within a rock mass. Note: Unusual conditions where rocks are observed exhibiting closely spaced (measured in inches or fractions thereof) joints and faults may be described as fractured or highly fractured. Their rating classes are as follows:

   a. **Very Low Jointing.** A distance of more than 6.5 ft between discontinuities.

   b. **Low Jointing.** A distance 2.0 to 6.5 feet between discontinuities.

   c. **Medium Jointing.** A distance of 8 inches to 2.0 feet between discontinuities.

   d. **High Jointing.** A distance of 2.5 to 8 inches between discontinuities.

   e. **Very High Jointing.** A distance of less than 2.5 inches between discontinuities.

8. **Pores:** The open spaces in a rock or soil. Pores are to be observed with the unaided eye. Measure, describe, and report where there are obvious features in a hand specimen or length of core. Use the following class sizes:

   a. **Very Fine.** Less than 1.0 mm.
   b. **Fine.** 1 to 2 mm
   c. **Medium.** 2 to 5 mm
   d. **Coarse.** 5 to 10 mm*
   e. **Very Coarse.** More than 10 mm*
   f. **Vugs.** 5 to 30 mm

   **If irregular shaped coarse and very coarse pores are present in limestones, dolomites, or gypsums, they may be described as having vugs or vuggy (small cavity in a rock).*

References:

a. **Jackson, J.A. "Glossary of Geology," America Geological Institute, Fourth Edition, 1997.**
b. **Geological Society of America, "Rock Color Chart, Munsell," 8th Printing, 1995.**
c. **Jumikis, A.R., "Rock Mechanics," Second Edition, Trans. Tech Publs., Federal Republic of Germany, 1983.**
d. **Compton, R.R. "Geology in the Field," John Wiley and Sons, 1985.**
e. **American Association of State Highway and Transportation Officials, "Particle Size Analysis of Soils," T-88, 1999.**
f. **"Standard Field Descriptions of Sedimentary Rocks," Research Section, Materials Division " 1961**
g. **Schoeneberger, P.J. et al., "Field Book for Describing and Sampling Soils," Version 1.1, USDA, NRCS, Lincoln NE, 1998.**

Other Relevant Publications:

"Engineering Classification of Geologic Materials," Vols. 1-8 Research and Development Div., ODOT, Curtis Hayes, Principal Investigator, 1965 to 1972.

EXAMPLES

The features listed in the above Guide are to be noted in the report or log as observed in cuttings, cores, and outcroppings. The most current versions of Rock Quality Designations (ASTM D6032), Rock Mass Ratings (ASTM D5868), and Diamond Core Drilling for Site Investigation (ASTM D2113) are to be used. When coring, NX Core sizes are preferred; a minimum of NQ is required.

The following is an example of core log from a bridge boring:

Surface Elevation___________ft   Station___________+__________, feet left or right

0.0 – 3.3	Fine sand (2.5 Y8/6), alluvium, not covered
3.3 – 13.5	Shale – Red (10R5/8), sandy, mottled with yellow (5Y8/6), soft, fissile
13.5 – 15.5	Siltstone – Gray (10YR3/1), mod. Hard, thin bedded.
15.5 – 23.0	Sandstone – Red (10R6/6), mottled with yellow (5Y7/8), mostly fine ranging to coarse grains, becoming coarser with depth, med graded, mod. hard, massive, calcareous, many fine pores.
23.0 – 23.7	Limestone Conglomerate – Reddish – brown (5YR5/4), limestones are light gray (10YR7/1), mod. hard, particle sizes range from clayey matrix up to about 4 in gravel, well graded, calcareous cement, few coarse pores, thin bedded.
23.7 – 30.1	Limestone – Gray (10YR7/1), hard, thick bedded, contains two thin zones (1/2 in) of broken fossil shells at 28.6 and 29.1
30.1 – 33.6	Dolomite – Pinkish gray (5YR6/2), sandy, hard, thin bedded, occasional, large pores, vuggy
33.6 – 39.3	Interbedded dolomite and shale – Dolomite; pinkish gray (5YR6/2), shale; very dark gray (5YR3/1), dolomite is thin bedded, hard; shales range from thin to thick bedded, minor small pyrite, mod. hard, becomes predominantly shale @ 37.0
39.3	TD, shale – very dark gray, (5YR3/1), as described above.

Logged by:	Bit Type, Size, Design:	Date of Start, Finish:
Contractor:	Ground Water Level, Dates:	Other ASTM 2113 Boring Items as Appropriate
Hole Diameter (core):	Project Identification:	

The following is an example of a description of an outcropping along a proposed roadway alignment:

Station 139 + 50, from centerline 12 ft right.

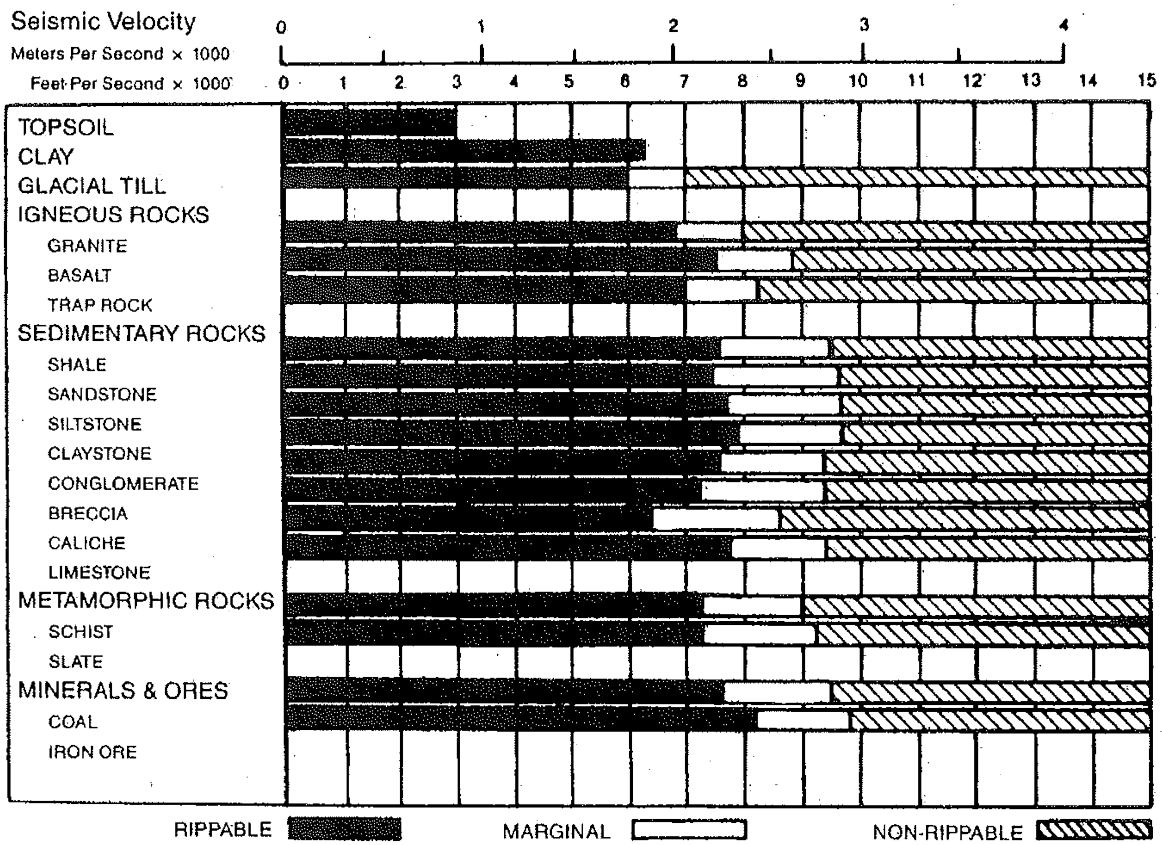
Layer	**Thickness (ft.)**	**Description**
1	0 – 10.3	Sandstone, brown (10YR5/3), fine, poorly graded, moderately hard, mostly thin bedded, high jointing; one thick bed at 5.3 to 7.8 ft. Sandstone contains thin stingers of brown sandy shale near the base and grades to
2	10.3 - 15.5	Interbedded sandstone and sandy shale, brown (10YR5/3), mostly soft ranging to mod. hard, very thin bedded ranging to thin bedded, high jointing, becoming more shale-like at the base.
3	15.5-26.6	Shale, very dark grayish brown (10YR3/2), soft fissile, contains veins of reddish yellow (7.5YR6/8) going at all angles.
4	26.6	Elev. Of roadway grade

Seismic Velocity Charts for Estimating the Rippability of Various Soil and Rock Formations

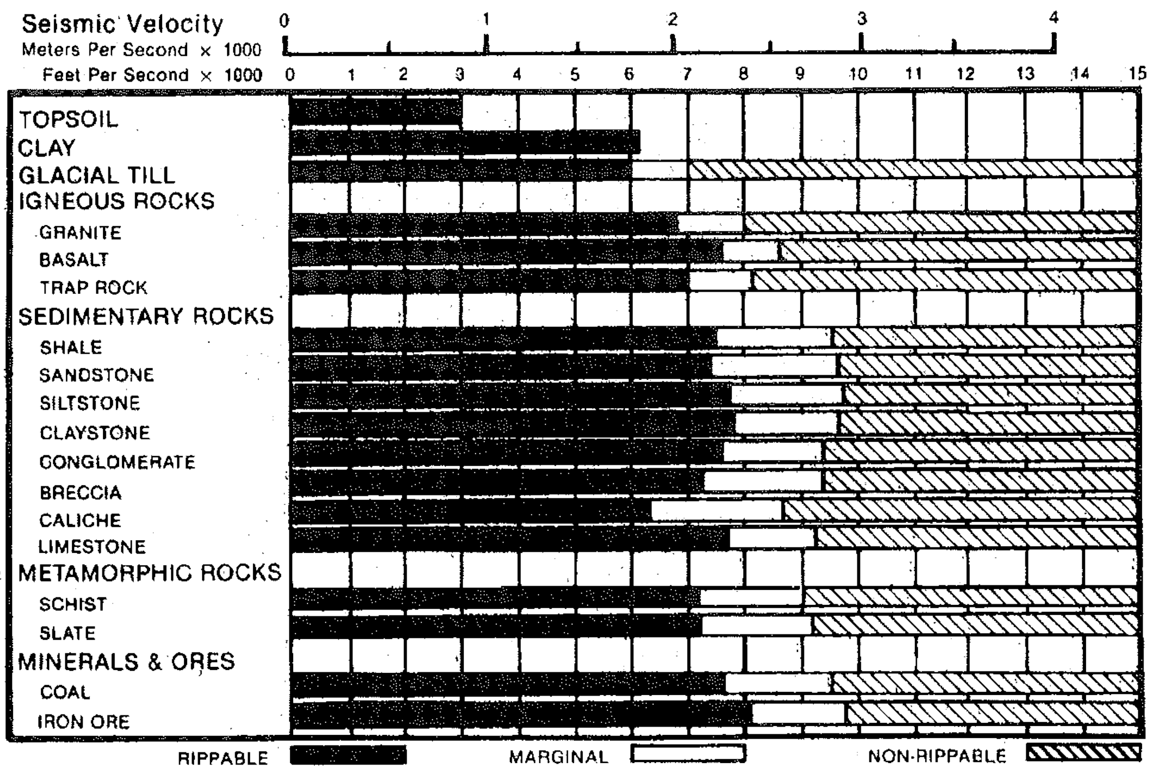
Rippers

D8L Ripper Performance

- Multi or Single Shank No. 8 Ripper
- Estimated by Seismic Wave Velocities



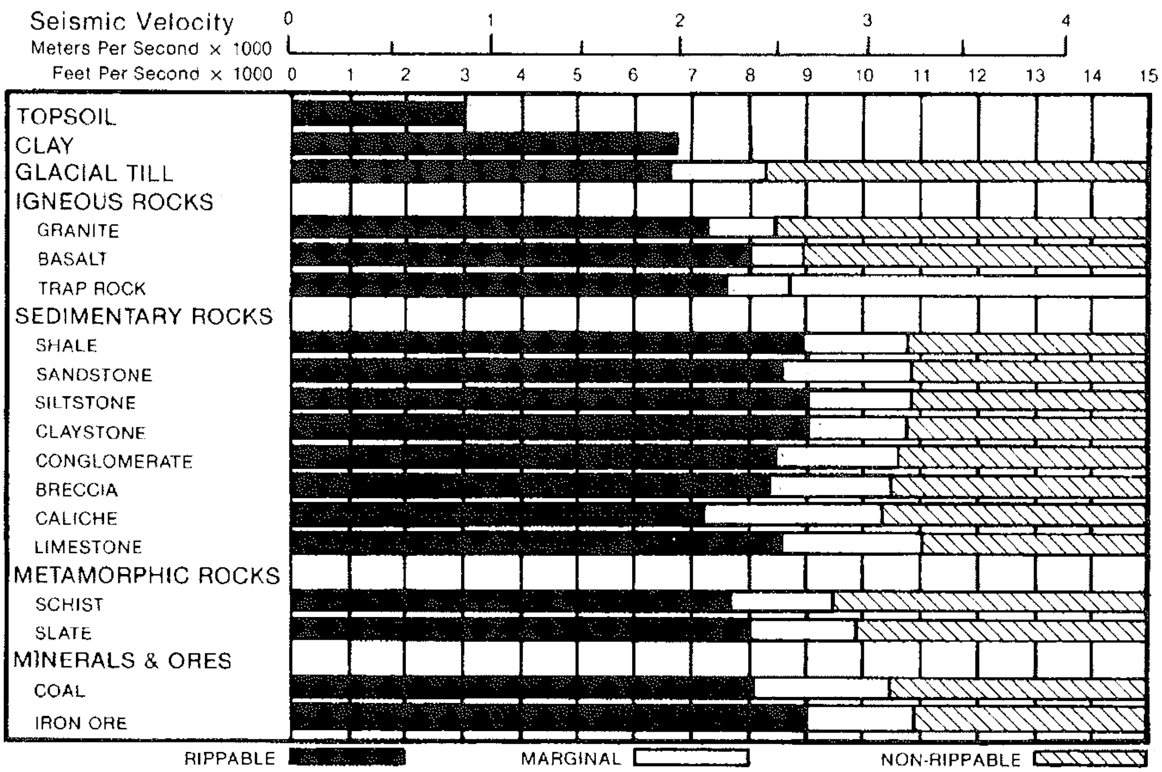
D9N Ripper Performance
- Multi or Single Shank No. 9 Ripper
- Estimated by Seismic Wave Velocities



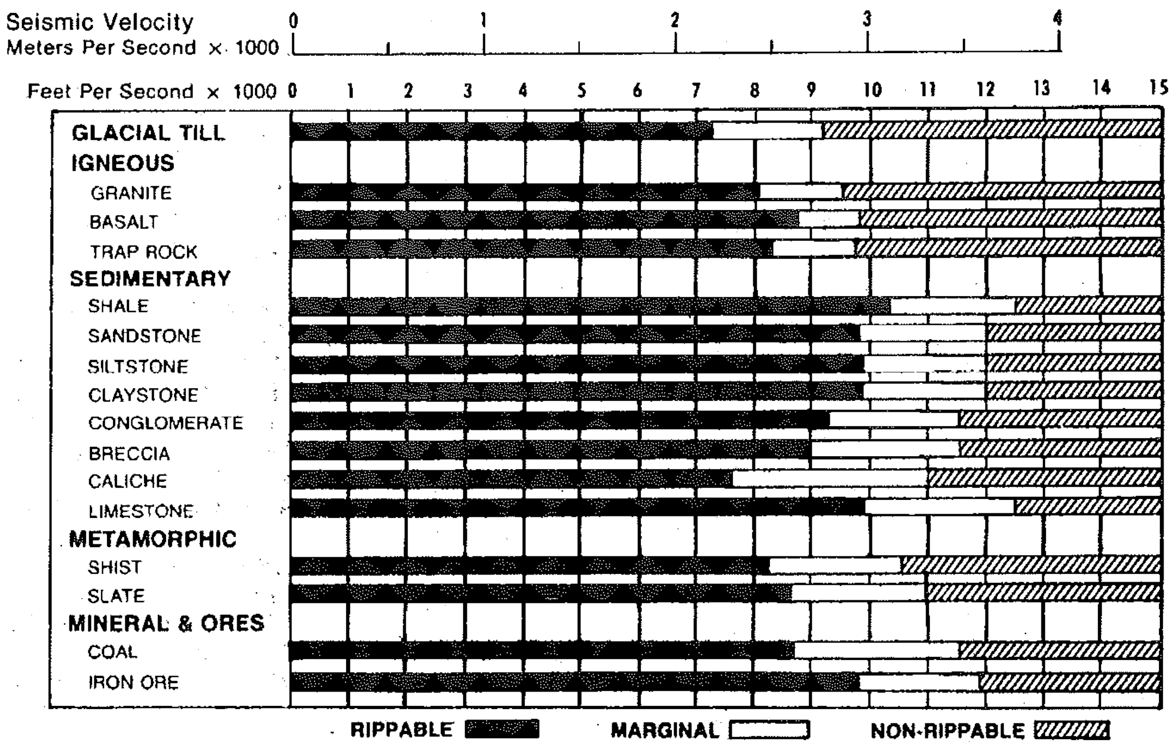
Rippers

D10N Ripper Performance

- Multi or Single Shank No. 10 Ripper
- Estimated by Seismic Wave Velocities

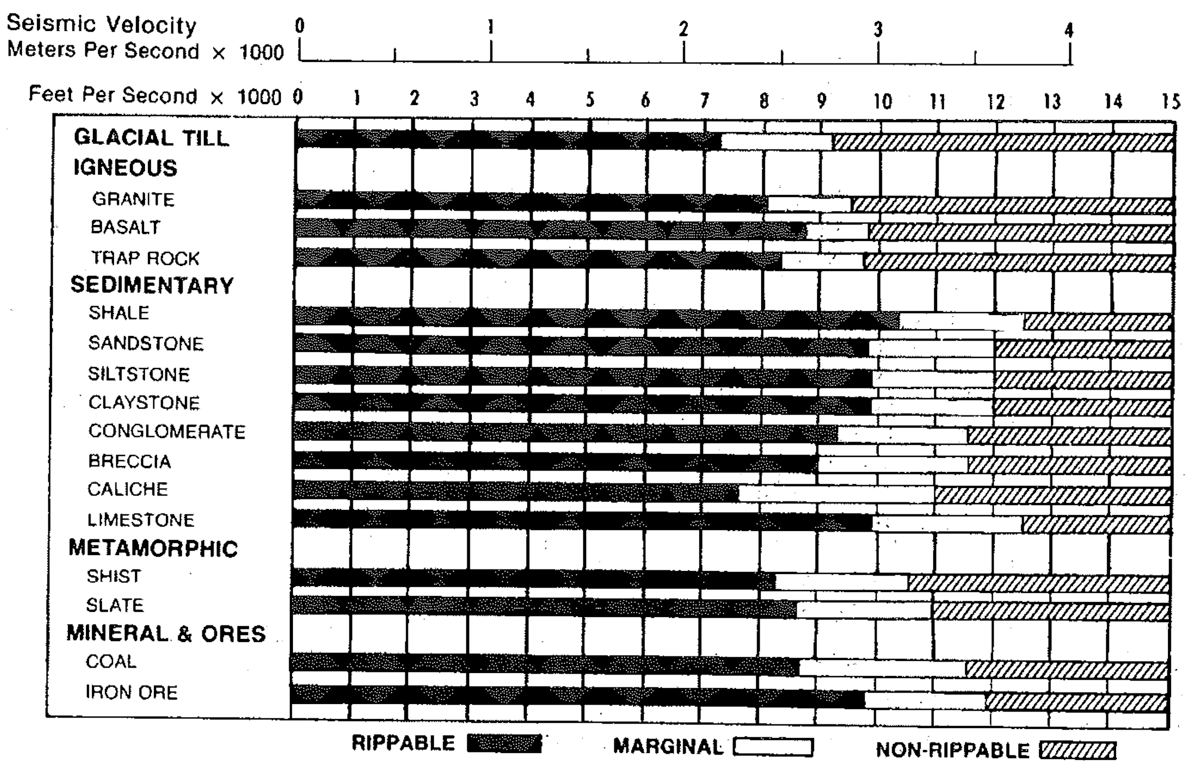


D10N Impact Ripper Performance
• Single Shank Impact Ripper
• Estimated by Seismic Wave Velocities



Rippers

D11N Ripper Performance
- Multi or Single Shank No. 11 Ripper
- Estimated by Seismic Wave Velocities



STATE OF OKLAHOMA DEPARTMENT OF TRANSPORTATION GEOTECHNICAL SPECIFICATIONS FOR ROADWAY DESIGN

JUNE 29, 2011

APPENDIX 4. - GUIDE FOR PREPARING GEOTECHNICAL REPORTS

This purpose of this guide is to provide clear and concise methods for preparing geotechnical reports for the Oklahoma Department of Transportation. When used as described, this information will provide consistent and appropriately documented geotechnical reports.

Overview

Geotechnical reports provide written documentation of findings from preliminary investigations, field explorations, laboratory testing, geotechnical evaluations and construction planning reviews. The Geotechnical Engineer responsible for the report should have broad experience in geotechnical engineering and a background in engineering for the type of roadway work identified in the project. The project geotechnical specialist, responsible for the report preparation, should have a broad background in civil engineering with a good basic knowledge of the soils and geology of Oklahoma as well as an understanding of the designs that are required to remedy the problems at a certain specific location(s). The project geotechnical specialist should anticipate possible design and construction issues and provide recommendations and solutions to mitigate or eliminate problems as well as any comments concerning possible limitations or other construction problems. The recommendations should be brief, concise and include the reasons for the recommendations. Provide any supporting data (e.g., graphics, tabular data, and calculations) in the appendices of the report.

Supplemental Geotechnical Report

Occasionally, the project design team may request the Geotechnical Engineer to conduct additional geotechnical reviews or studies. Based on these reviews or studies, the project geotechnical specialist will prepare a supplemental report to the geotechnical report. The supplemental report should only address the analysis and alternatives for those elements requested for additional geotechnical review or study.

Special Reports

Occasionally, the project geotechnical specialist may be required to prepare a special geotechnical report not related to a particular project (e.g., landslides, rock falls). Typically, these reports are prepared under emergency conditions and, as a result, only include recommendations to mitigate immediate problems. The special report should include the methods of analysis, calculations, design assumptions, computer programs used and other information as applicable to arrive at the design recommendations.

Geotechnical Reports

The Final Geotechnical Report for Roadway Design should contain all the geotechnical data and recommendations required for design. The report should be organized to include Transmittal Information about the report, General Information about the project, Field Investigation and Laboratory Testing Information, and the Geotechnical Information required for Roadway Design projects. These are described in greater detail in succeeding sections of this appendix. In addition to this required information, the final geotechnical report should include the following, where applicable:

- design geotechnical data;
- design computations as required by the consultant's agreement;
- quality assurance/quality control certifications including lab and technician certification; and
- any alternative designs considered.

The Geotechnical Engineer is required to conduct a quality assurance review of the report before it is submitted to ODOT. The quality assurance review should include checking all calculations, as well as a review by a senior engineer or geologists of the approach, assumptions, results and conclusions/recommendations of any work carried out for the project. The report should also be edited to be free of grammatical and spelling errors, and graphics should be legible and easy to interpret. Geotechnical reports must be dated, signed, and sealed by a Professional Engineer licensed in the State of Oklahoma.

The Geotechnical Engineer shall submit the final geotechnical report to ODOT in two hard copies and one PDF copy on CD.

The Department, upon review of the final written report and boring logs, will exercise final authority as to whether the consultant has provided sufficient information or if additional data or borings are required. The Department further reserves the right to review all phases of the geotechnical report, including all field and laboratory data, computations and analysis.

GEOTECHNICAL EVALUATION REPORT

In general, organize all geotechnical project reports using the following format.

Transmittal Information

The project geotechnical specialist should use the following format when preparing the transmittal memorandum for the geotechnical report:

1. Addressee (To): Address the memorandum to the ODOT Division Engineer (e.g., Roadway Design Division, Bridge Division, Field Division) responsible for the project oversight.

2. Contact. Provide the name, telephone number and email of the individual(s) that can be contacted for additional information or questions.

3. Signature (From): Prepare the report for the Geotechnical Engineer's signature. Also, include the report author and title directly underneath the author's signature line.

4. Date. Include the date the report is submitted to the addressee.

5. Subject. In the subject, include the official construction project number, job piece number, and project description.

General Project Information

The project geotechnical specialist is responsible for preparing a detailed geotechnical engineering report outlining the findings of the field and laboratory investigations and, where applicable, results from the geotechnical engineering analyses, designs for geotechnical features and recommendations and alternatives for potential issues affecting the project alignment or construction.

Not all of the subject areas listed in the following Sections will be required for every geotechnical report and adjustments may be required as deemed necessary. The level of coverage for each item will also vary from project-to-project. Although in-depth coverage of individual details is usually not provided in the report, provide sufficient detail to allow the reader to fully understand the problem and any proposed recommendations. Detailed analyses may be added as appendices to the report.

The following provides the topic areas, listed in order, to be addressed in geotechnical reports:

1. Introduction. Identify the purpose of the report and provide a very brief summary of what is included in the report.

2. Project Information. Include the following in the project description:

    - construction project number and job piece number;
    - the county where the project is located;
    - route number or street name;
    - nearby towns and/or cities;

- the project location with respect to the highway mileage markers and/or project length;
- general scope of the project (e.g., roadway reconstruction, pavement widening and/or overlay);
- major features of the project (e.g., four-span structure, retaining wall, final roadway widths, design speed); and
- other applicable elements of the project (e.g., deep cuts or fills, special drainage considerations, detour requirements).

3. Area Geology. Note the topography of the project area. Identify the soil and rock type formations within the project area. Note the predominate soil and rock types that can be found within the project area. If available, provide a description of the soil and rock formations (e.g., expansive soils, dispersive clay, karst).

4. Site Reconnaissance. Note any geotechnical features found during the investigation, including, but not limited to, the following:

- outcrops of bedrock;
- existing cuts and fills, including slope angles;
- evidence of current or past landslides;
- surface soils;
- potential problem soils such as dispersive or expansive clays sulfate bearing soils;
- groundwater conditions (e.g., springs, streams, irrigation);
- wetland locations;
- areas that may require subexcavation or other foundation stabilization/drainage measures;
- locations that may require rock excavations, including areas that may require blasting;
- locations that will require extensive excavations and/or fills;
- roadway patching that may indicate subgrade problems;
- the type of vegetation or lack thereof;
- location of nearby buildings, drainage structures, bridges, utilities, etc.; and
- other features that may affect the project alignment, right-of-way and/or design.

5. Subsurface Investigation. Document the insitu tests conducted and their results. Provide the preliminary soil classifications determined from the subsurface investigation. Indicate any special considerations required for the subsurface investigation (e.g., location of utility lines, steep terrain, nearby structures, wetlands, private property, and required permits). Include the proposed scope of the field and laboratory work that appears to be necessary for future phases of the project.

6. Design and Construction Recommendations. Where applicable, provide design and construction recommendations to the project designer so that it can be considered during the design phase. Include the information noted in Sections 3.2.4 and 3.2.5, as applicable.

7. Report Limitations. Provide possible constraints so they may be considered during the preliminary stage of design.

Field Investigation and Labortory Testing Information

Geotechnical investigation and testing information is a vital part of geotechnical reports. The information in geotechnical reports should provide written documentation of findings from the field explorations and laboratory testing. Where applicable, the project geotechnical specialist should include the following information in the geotechnical report:

1. Pedological Investigation. The pedological investigation should include and consist of the following elements:

   - Include aerial photographs at 1:20,000 scale (or the scale that is used by NRCS in their county soil survey reports) with delineated map units and proposed location or center reference line/centerline alignment plotted thereon (reproduction from county soil survey report) are required. Obtain copies of Digital Orthophoto Quad sheets from the Oklahoma Conservation Commission website.

   - Sum and report the traversed distance of each alphabetized map unit in feet.

   - Include a set of official soil series description sheets from the official NRCS national database source (Iowa State). These are for the soil series found along the alignment extent or at the location of interest.

   - Provide a numerical listing in alphabetical order of the soil series found along the alignment along with their Taxonomic classification (e.g., Burleson Soil Series, Fine, smectitic, thermic, Udic Haplustert).

   - Include field logs of the soil samples taken from all soil horizons for each soil series. Describe the results according to the official soil series description. Also, a large composite sample of the major horizons, excluding the A horizon, are to be listed.

   - As an option to using county soil survey maps, the soil map units may be plotted on digital orthophoto quad sheets. These are at 1:24,000 scale and are appropriate for the report. These can be obtained at the State of Oklahoma Conservation Commission.

   - Provide a list of the required laboratory tests conducted and the findings from these tests. Standard forms for reporting Pedological Investigation information are provided in Appendix 5.

2. Shoulder Survey/In Place Soils Investigation. The Shoulder/In Place soils investigation should include the following information:

    - Field logs of the soil samples taken with depths and station extents of similar soil types within the project extents. Note on the logs which soils samples were used to conduct resilient modulus tests.

    - Provide a list of the required laboratory tests conducted and the findings from these tests. Standard forms for reporting Shoulder Soils/In Place Soils Investigation information are provided in Appendix 5.

3. Pavement and Subgrade Soils Investigation. The Pavement and Subgrade Soils Investigation should include the following information:

    - Back calculated FWD data of the pavement section in tabular format. Include a CD with the back calculated data in Excel format for further analysis.

    - Detailed core logs with color photo of core. Note the pavement layer thicknesses and condition.

    - Pavement surface condition survey as detailed in FHWA-RD-03-031

    - Field logs of the soil samples taken with depths and station extents of similar soil types within the project extents. Note on the logs which soils samples were used to conduct resilient modulus tests.

    - Provide a list of the required laboratory tests conducted and the findings from these tests. Standard forms for reporting Pavement and Subgrade Soils Investigation information are provided in Appendix 5.

4. Subsurface Investigation. When summarizing the subsurface investigation include the following information, where applicable:

    - permission from property owners;

    - number of borings taken and dates that the boring work took place;

    - summary of the soil and rock types found;

- general description of the land formation (e.g., gullies, excavations, slopes, stream banks) and vegetation;
- study of existing structures;
- location of underground and overhead utilities:
- presence of surface water and stream debris;
- subsurface water table and location on the boring logs;
- unusual drilling conditions;
- any additional subsurface testing that was conducted (e.g., groundwater monitoring, seismic), the equipment used, the stationing and other applicable information relative to the test;
- results of the in-situ tests (e.g., SPT, CPT);
- boring logs, maps indicating the boring locations, including the plan station and offset, data from site tests, etc., in the appendices; and
- location for material and borrow sources.

5. Laboratory Testing. Indicate the laboratory tests that were completed on the soil and rock samples. Include a summary of the laboratory testing results. Discuss the results of these laboratory tests.

6. Soil Classification. Identify soil classifications in sufficient detail to permit engineers to recognize features significant to design and, if need be, to obtain samples in the field.

7. Geological Surface and Subsurface Rock Formation Information. Geological rock formation information should be provided using the standard methods of rock type descriptions as described in Appendix 3. Provide complete and accurate rock type information useful to designer. In addition, include the descriptions of rock types as recovered from drill bit cuttings or as observed in cores. The geological information provided should be structured so that the description of rock characteristics more pertinent to the construction or repair of ODOT facilities is emphasized.

   Where cores are taken, provide the Rock Quality Designation (RQD) in accordance with ASTM D 6032. If Rock Mass Ratings (Geomechanics Classification) are required note these according to ASTM D 5878. The following is a listing of the rock characterization elements to be used in describing the rock units. The elements describing the character of Oklahoma rock types are to be presented in the report in the order listed:

- rock type (lithology),
- color,
- thickness,
- gradation,
- texture,
- pores,
- cementation,
- hardness,
- layering (or bedding), and
- joints.

Not all of the above elements will be present at a given site. The type of construction being considered, the character of the rock encountered, and the method of investigation are examples of situations that will dictate the elements used to describe the rock unit(s) in the report.

An example of the type of report is found in Appendix 3 "Standard Guide for the Description of Surface and SubSurface Geological Rock Formations of Oklahoma".

8. <u>Plans and Boring Logs</u>. Geographic locations of the geological log or outcroppings must be described from plans by Station to the nearest tenth of a foot, where the information is available. A minimum of a legal description accurate to the nearest 100 ft is required when plans or other detailed location information is not available. Global Positioning Systems (GPS) locations are acceptable; however, bore hole locations must be referenced to the plan station and offset. Elevations of the ground surface to the nearest tenth of a foot are required for all borings. At a minimum, include the following ancillary information on the logs:

- construction project number and job piece number;
- stratigraphic location, to nearest 0.1 ft, of any samples or tests taken;
- name of contractor;
- name of the driller
- name of logger;
- core or hole diameter, in inches;
- boring number;
- date the drilling or logging was performed;
- type of equipment used (e.g., bit type used);
- name of engineer and/or geologist, onsite, responsible for the field boring logs and interpretation of the geologic profile; and
- method (or combination) of drilling used.

Geotechnical Engineering for Roadway Design

This section of the report is generally prepared for the roadway design and covers roadway embankments, side slopes, rock cuts, pavement subgrade, etc. For each item discussed in the report, the project geotechnical specialist should clearly indicate the following:

- applicable station-to-station distance, width and depth of the area of concern;
- interpretation and analysis of the drawings, logs and data;
- any specific recommendations and/or alternatives to mitigate or eliminate the concern;
- detailed drawings or sketches and tabular data, these may be included in the appendices; and
- where necessary, include applicable special provisions.

The design portion of the geotechnical engineering roadway alignment section should include, but is not limited to, the following topics:

1. Alignment Recommendations. Identify recommended revisions to the horizontal and vertical alignment from the preliminary plans.

2. Right-of-Way Considerations. Note where additional right-of-way may be required to accommodate landslide areas, cut and embankment slopes, rock containment, etc.

3. Specific Findings and Design Recommendations. The alignment section may include discussions and recommendations on the following:

   a. Cuts and Embankments. If the project has cuts or embankments, address the following:

      - Provide the location and description of existing surface and subsurface drainage.

      - Identify and report springs and excessive wet areas.

      - Identify and report slides, slump and faults along the alignment.

      - Identify special cuts and embankments. Characterize the area or volume of material, station along alignment or reference line, distance left or right from alignment or reference line, etc.

      - Provide subsurface drainage recommendations.

      - Recommend undercut extents, if required.

- Identify unusual erosion control measures that may be necessary.

- Provide recommended limits on cut and fill slopes.

- Provide shrink-swell factors for earthwork calculations.

- Provide the parameters that characterize the discontinuity and rock mass, excavation, slopes, blasting requirements, containment areas, etc. Identify recommended rock extents that are rippable and areas that will need to be blasted.

- Provide recommended rock slope stabilization measures.

b. Soft Ground. If the embankment is over soft ground, provide the following:

- Include recommendations for alternative embankment designs if problematic soils (e.g., dispersive clays, silt) are anticipated from local embankment borrow sources.

- Provide the estimated short and long-term settlement.

- Provide alternative designs, conceptual construction sequencing, time needs, and address long-term settlement, including surcharging and/or wick drains where applicable, and slope stability. Identify methods of analysis, factors of safety, design codes with version, etc.

- Provide recommendations and specifications for monitoring settlement and slope stability.

c. Floodplains. If the embankment is in a floodplain, provide the following:

- Give recommendations for alternative embankment designs if problematic soils (i.e., dispersive clays, silty soils) are anticipated using local borrow sources.

- Include recommended special provisions for the embankment.

- Identify recommended embankment protection for hydraulic impacts on the embankment including rapid draw down, scour, wave action, etc.

d. Landslides. For landslides, address the following:

- Include landslide movement history, past maintenance works, previous correction measures, etc.

- Provide scaled cross-section showing ground surface conditions before and after failure.

- Identify failure planes, excavation/buttressing limits, recommended slopes, instrumentation requirements, results from the slope stability analysis, and drainage requirements.

- Summarize causes of the slide.

- Provide alternative designs and benefits/limitations of each design.

- Provide construction sequence and special provisions.

e. Retaining Walls. Provide internal wall stability design parameters and global retaining wall stability analysis.

f. Drainage. Discuss excavation concerns, erosion protection, culvert bedding materials, geotextile fabrics, water table levels, dewatering recommendations and settlement considerations.

g. Stability Analysis. Address the methods used (e.g., computer programs), assumptions made for soil strength parameters (e.g., strength), groundwater conditions, selected factors of safety or resistance factors, conclusions from analyses (slope angles and heights), and recommended methods of mitigation (e.g., regrading, reaction berms, ground improvement).

h. Settlement Analysis. Discuss methods used to calculate the settlement analysis, assumptions for soil parameters (e.g., preconsolidation pressure, compression index, recompression index, coefficient of consolidation), groundwater conditions, conclusions from analyses, recommended mitigation. (e.g., dig outs and subexcavation, use of light-weight fills, wick drains and preloading, staged construction).

i. Computer Programs. Include a summary of the analyses and list of software programs used.

j. Results. Describe the limitations of the analyses and results.

k. Special Issues. Identify special issues to consider during construction, including construction staging, scheduling of preloads, special field testing and instrumentation.

Appendices

If available, include the following in the appendix of the report:

1. Maps. If deemed appropriate, include geological or highway maps and indicate the applicable geotechnical features on the maps.

2. Boring Logs. If boring logs are available from previous projects in the area and they are applicable to the project, include copies of these logs.

3. Photographs. If photographs were taken during the site investigation, include applicable photographs showing only the major geotechnical features. On the photograph, indicate the reason for the photograph (e.g., steep rock cuts, landslides), the location (e.g., reference post, stationing) and direction the picture was taken.

4. Design Calculations. Include the detail design calculations and results used in making the analyses and recommendations.

REFERENCES

1. State of Oklahoma Department of Transportation *Geotechnical for Roadway Design*, Appendix A3, June 11, 2001.

2. State of Oklahoma Department of Transportation *Standard Guide for the Description of Surface and Subsurface Geological Rock Formation of Oklahoma*, Attachment 1 to Appendix A1 and Appendix A3, June 5, 2001.

3. State of Oklahoma Department of Transportation *Guidelines and Background Information for Providing Soil Classification Information*, Attachment 2 to Appendix A3, June 12, 2001.

4. State of Oklahoma Department of Transportation *Specifications for Geotechnical Investigation of Bridge and Related Structures*, Appendix A1, June 5, 2001.

5. *Subsurface Investigations – Geotechnical Site Characterization*, NHI-01-031, FHWA.

6. *Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications*, ED-88-053, FHWA.

7. Geotechnical Engineering Circular No. 5, *Evaluation of Soil and Rock Properties*, IF-02- 034, FHWA.

STATE OF OKLAHOMA
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL SPECIFICATIONS FOR ROADWAY DESIGN

June 29, 2011

APPENDIX 5. - STANDARD FORMS FOR REPORTING GEOTECHNICAL INFORMATION

In order to ensure uniformity in the information submitted to ODOT, certain standard report formats will be required as follows:

1. Pedological & Geological Soils Test Data
2. Resilient Modulus Test Data
3. Resilient Modulus of Subgrade Soil (AASHTO T 307-99)
4. Shoulder Soils Survey
5. Pavement Core Data and In-place Soils
6. Pavement Core logs
7. Soil Series Characteristics
8. FWD Report for Flexible Pavement
9. FWD Report for PC Concrete Pavement

While these forms may be re-created in an electronic format and the general parameters adjusted as necessary, the content and specific presentation of the information must not be modified.

In addition to these standard report Formats, ODOT will require the utilization of the following unique software package gINT® in the development and compilation boring log information.

<u>EXAMPLE</u> TYPE OF SURVEY

Surveyed by: ____________________ **Sheet**______**of** _______

____

____

Date Surveyed: ___________________

Pedological & Geological Soils Survey

Project ____________________________________

County_____________**Location** ______________

____

Field No.	Soil Group	Station	Description	Depth (in)	L.L.	P.I.	Percent Passing						OSI	pH	Resis. (Ω·Cm)	Soluble Sulfates (mg/kg)
							3 in.	¾ in.	#4	#10	#40	#200				
		120+53, 35 ft. rt.	Renfrow Series													
1A	A-6(14)		'A' Horizon	0 - 9	37	18	100	100	100	100	100	97.6	15	7.82	616	ND
1B	A-6(14)		'BA' Horizon	9 - 13	30	16	100	100	100	100	100	94.0	12	5.71	1144	ND
1C	A-7-6(27)		'Btss1' Horizon	13 - 25	46	30	100	100	100	100	100	87.9	21	6.5	1100	ND
1D	A-7-6(32)		'Btss2' Horizon	25 - 40	48	34	100	100	100	100	100	91.3	23	7.76	484	ND
1E	A-7-6(27)		'Btss3' Horizon	40 - 65	44	31	100	100	100	100	100	89.0	20	7.59	224	ND
1F	A-7-6(27)		'C' Horizon	65 - 75	43	30	100	100	100	100	100	90.1	20	7.33	163	ND
			Geology-Clay shale													
Mr-1A	A-7-6(21)		'B' Composite	9 - 65	41	22	100	100	100	100	100	90.9	17			
Mr-1B	A-7-6(27)		'C' Composite	65 - 75	43	30	100	100	100	100	100	90.1	20			

EXAMPLE TYPE OF SURVEY

Surveyed by: ___________________ **Sheet**______**of** _______

________________________________ **Pedological & Geological Soils Survey** **Project** ___________________________________

________________________________ **County**_____________**Location** ______________

Date Surveyed: __________________ ____

Field No.	Soil Group	Station	Description	Depth (in)	L.L.	P.I.	Percent Passing 3 in.	¾ in.	#4	#10	#40	#200	OSI	pH	Resis. (Ω·Cm)	Soluble Sulfates (mg/kg)
		432+65, 50 ft. rt.	Burford Series													
2A	A-6(9)		'A' Horizon	0 - 9	34	13	100	100	100	98	96	78.1	12	8.26	5180	ND
2B	A-6(13)		'Bw' Horizon	9 – 22	35	16	100	100	100	100	98	84.9	13	8.25	4850	ND
2C	A-6(10)		'Bk' Horizon	22 – 32	34	13	100	100	100	99	98	84.4	12	7.51	524	11,500
2D	A-6(12)		'2BCk' Horizon	32 – 38	33	15	100	100	100	99	98	86.0	13	7.78	508	10,500
2E	A-6(11)		'2C' Horizon	38 - 60	34	16	100	100	99	99	95	78.6	13	7.89	571	2500
2F	A-7-6(27)		Geology-Clay shale	60+												
Mr-2A	A-6(11)		'B' Composite	9 – 38	34	16	100	100	100	100	100	90.9	17			
Mr-2B	A-6(12)		'C' Composite	38 - 60	34	16	100	100	99	99	95	78.6	13			

Project No. STP-123C (123), 12345(04)   County Mayes County

Location US 69 from Choteau to SH 20

EXAMPLE Resilient Modulus Test Data

Laboratory No.		6783		6789		6792	
Sample No.		1	2	1	2	1	2
Station		105+05		113+85		127+90	
Location		35 ft lt. CL		20 ft rt CL		18 ft rt CL	
Depth (inches)		12 – 60					
Soil Series		Dennis “B”		Parsons “B”		Bates “B”	
Sieve Size		Percent Passing		Percent Passing		Percent Passing	
1” / 25.0 mm		100		100		100	
No. 4 / 4.75 mm		100		100		100	
No. 10 / 2.0 mm		100		100		100	
No. 40 / 0.425 mm		99		99		99	
No. 200 / 0.075 mm		95.0		85.2		84.6	
Liquid Limit		71		36		56	
Plasticity Index		49		20		40	
Standard Density , PCF		93.0		99.2		102.6	
Optimum Moisture, %		24.6		17.7		21.8	
AASHTO Class		A-7-6(52)		A-6 (16)		A-7-6(35)	
Molded Density, PCF		90.1	88.2	97.2	94.9	100	97.4
Molded Moisture Content, %		24.2	26.9	17.1	19.2	21.4	23.5
Est. Compaction Factor – Shrink /		9.6 % Swell		6.2% Swell		1.6 % Swell	
Resilient Modulus, PSI		See enclosed data and graphs		See enclosed data and graphs		See enclosed data and graphs	

Project No. STP-123C (123), 12345(04)
Location US 69 from Choteau to SH 20

EXAMPLE Resilient Modulus of Subgrade Soils (AASHTO T-307) Data

County Mayes County

Soil Series Parsons ‘B’
Sample No. 1A
Material Type Type 2
Test Date June 11, 2011

AASHTO Class A-6 (16)
Std. Density, pcf 99.2
Molded Density, pcf 97.2
Opt. Moisture, % 17.7
Molded Moisture, % 17.5

Colum #	1	2	3	4	5	6	7	8	9	10	11	12	13
Parameter	Chamber Confining Pressure	Nominal Maximum Axial Stress	Actual Applied Max. Axial Load	Actual Applied Cyclic Load	Actual Applied Contact Load	Actual Applied Max. Axial Stress	Actual Applied Cyclic Stress	Actual Applied Contact Stress	Recov. Def. LVDT # 1 Reading	Recov. Def. LVDT # 2 Reading	Average Recov. Def. LVDT 1 & 2	Resilient Strain	Resilient Modulus
Designation	S3	Scyclic	Pmax	Pcyclic	Pcontact	Smax	Scyclic	Scontact	H1	H2	Havg	er	Mr
Unit	psi	psi	lbs	lbs	lbs	psi	psi	psi	in	in	in	in/in	psi
Precision	—	—	—	—	—	—	—	—	—	—	—	—	—
Sequence 1	6	2	29.011	24.235	4.775	2.310	1.930	0.380	0.00092	0.00189	0.00141	0.00015	13016
Sequence 2	6	4	54.237	46.928	7.310	4.318	3.736	0.582	0.00273	0.00360	0.00316	0.00033	11222
Sequence 3	6	6	78.831	68.990	9.841	6.276	5.493	0.783	0.00506	0.00588	0.00547	0.00058	9539
Sequence 4	6	8	103.541	91.221	12.320	8.244	7.263	0.981	0.00770	0.00843	0.00807	0.00085	8555
Sequence 5	6	10	128.324	113.514	14.810	10.217	9.038	1.179	0.01027	0.01088	0.01057	0.00111	8121
Sequence 6	4	2	26.721	23.791	2.930	2.127	1.894	0.233	0.00129	0.00228	0.00178	0.00019	10098
Sequence 7	4	4	51.121	45.681	5.440	4.070	3.637	0.433	0.00360	0.00456	0.00408	0.00043	8471
Sequence 8	4	6	75.529	67.571	7.957	6.013	5.380	0.634	0.00635	0.00725	0.00680	0.00072	7515
Sequence 9	4	8	100.921	90.457	10.464	8.035	7.202	0.833	0.00920	0.00996	0.00958	0.00101	7143
Sequence 10	4	10	125.497	112.578	12.919	9.992	8.963	1.029	0.01198	0.01273	0.01236	0.00130	6891
Sequence 11	2	2	24.475	22.792	1.683	1.949	1.815	0.134	0.00174	0.00276	0.00225	0.00024	7667
Sequence 12	2	4	47.585	43.381	4.204	3.789	3.454	0.335	0.00468	0.00566	0.00517	0.00054	6344
Sequence 13	2	6	71.775	65.072	6.704	5.715	5.181	0.534	0.00816	0.00905	0.00861	0.00091	5717
Sequence 14	2	8	97.198	88.043	9.155	7.739	7.010	0.729	0.01143	0.01225	0.01184	0.00125	5626
Sequence 15	2	10	121.138	109.461	11.676	9.645	8.715	0.930	0.01444	0.01502	0.01473	0.00155	5620

* Reported results are based on the average of the last 5 cycles of each load sequence
**Detailed report (Hard Copy), as recommended by AASHTO T 307-99, is available at ODOT (Materials Division, Soils and Foundations Branch)
*** Peaks and valleys were recorded per load cycle

Resilient Modulus of Subgrade Soil (AASHTO T 307-99)

(Summary Sheet 2)

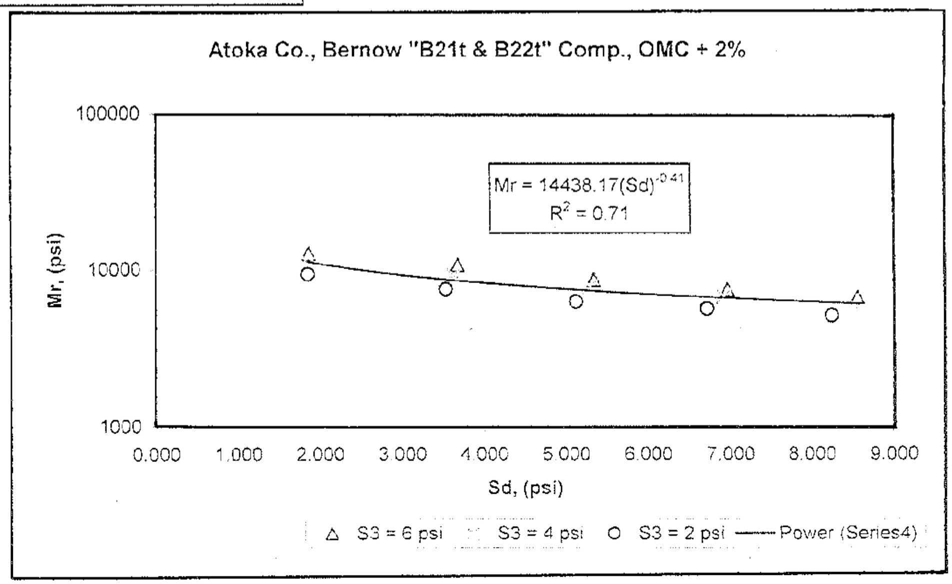
1. Sample Number	4136-2
2. Material Type	Type 2
3. Test Date	2/7/2007

Desired S3 (psi)	Desired Sd (psi)	Actual Sd (psi)	Actual Mr (psi)	Log (Sd) (psi)	Log (S3) (psi)	Log (Mr) (psi)	Calculated[1] Mr (psi)
6	1.8	1.863	12676	0.27	0.78	4.10	11203
6	3.6	3.678	10704	0.57	0.78	4.03	8489
6	5.4	5.337	8579	0.73	0.78	3.93	7294
6	7.2	6.966	7422	0.84	0.78	3.87	6543
6	9	8.557	6611	0.93	0.78	3.82	6016
4	1.8	1.865	11003	0.27	0.60	4.04	11199
4	3.6	3.632	9225	0.56	0.60	3.96	8533
4	5.4	5.294	7736	0.72	0.60	3.89	7318
4	7.2	6.920	6717	0.84	0.60	3.83	6560
4	9	8.499	6012	0.93	0.60	3.78	6033
2	1.8	1.850	9302	0.27	0.30	3.97	11236
2	3.6	3.530	7466	0.55	0.30	3.87	8632
2	5.4	5.119	6219	0.71	0.30	3.79	7418
2	7.2	6.715	5564	0.83	0.30	3.75	6641
2	9	8.242	5069	0.92	0.30	3.70	6109

[1]: Model # 1

Model #1: $Mr = K1 \times Sd^{K2}$

S3 (psi)	K1	K2	R^2
6	17405	-0.43	0.96
4	14645	-0.40	0.97
2	12162	-0.41	0.99
All	14438	-0.41	0.71



<u>EXAMPLE</u> TYPE OF SURVEY

Surveyed by: ___________________

____

____

Date Surveyed: __________________

Shoulder / In Place Soils Survey

Sheet______**of** _______

Project _____________________________________

County_____________**Location** ______________

____

Field No.	Soil Group	Station	Description	Depth (in)	L.L.	P.I.	Percent Passing						OSI	M.C. %	Soluble Sulfates (mg/kg)
							3 in.	¾ in.	#4	#10	#40	#200			
		115+50, 18'RT													
1A	A-6(11)		Lean Clay	0 - 6	30	13	100	100	100	100	99.4	90.0	15	24.4	ND
1B	A-6(16)		Lean Clay	6 - 22	33	19	100	100	100	100	100	92.2	12	24.1	ND
1C	A-6(18)		Lean Clay	22 - 36	38	26	100	100	100	100	100	91.5	21	21.8	245
Mr-1A	A-6(18)		Composite- Lean Clay	0 - 36	37	26	100	100	100	100	100	92.1	20	24.0	229
		120+50, 16'lt													
2A	A-6(16)		Lean Clay with Sand	0 - 6	36	20	100	100	100	100	97.8	83.5	15	25.9	ND
2B	A-6(20)		Lean Clay	6 - 27	30	15	100	100	100	100	100	92.7	12	20.9	125
2C	A-6(13)		Lean Clay	27 - 36	35	22	100	100	100	100	100	100	16	26.7	260
Mr-2A	A-6(16)		Composite- Lean Clay	9 - 27	33	19	100	100	100	100	99.3	92.2	14	22.6	244

EXAMPLE TYPE OF SURVEY

Surveyed by: ___________________ **Sheet**______**of** _______

____

____

Date Surveyed: __________________

Shoulder / In Place Soils Survey
"Same As Approach"

Project ___________________________________
County_____________**Location** ______________
____

Field No.	Soil Group	Station	Description	Depth (in)	L.L.	P.I.	Percent Passing 3 in.	¾ in	#4	#10	#40	#200	OSI	M.C. %	Soluble Sulfates (mg/kg)
		160+00, 17' Lt													
1A	A-6(11)		Lean Clay	0 - 6	30	13	100	100	100	100	99.4	90.0	15	24.4	255
1B	A-6(16)		Lean Clay	6 - 30	33	19	100	100	100	100	100	92.2	12	24.1	134
1C	A-6(18)		Lean Clay	30 - 36	38	26	100	100	100	100	100	91.5	21	21.8	437
Mr-1A	**A-6(18)**		**Composite- Lean Clay**	0 - 36	37	26	100	100	100	100	100	92.1	20	24.0	289
		165+00, 16'Rt													
2A			Similar as 1A												
2B			Similar as 1B												
2C			Similar as 1C												
		170+00, 16' Lt													
3A	A-2-4(0)		Silty Sand	0 – 6	NP	NP	100	91	83	76	64	26.0	0	12.7	260
3B	A-4(0)		Silty Sand	6 – 16	NP	NP	100	100	95	88	86	82.9	0	14.5	357
3C			Similar as 1C	16 - 36											
		175+00, 15' Rt													
4A	A-4(0)		Silty Sand	0 – 6	NP	NP	100	100	91	89	86	81.2	0	14.9	138
4B	A-4(0)		Silty Sand	6 – 18	NP	NP	100	100	100	100	92	83.2	0	15.1	175
4C	A-4(0)		Silty Sand	18 - 36	NP	NP	100	100	100	95	88	82.7	0	16.5	211
Mr-2A	**A-4(0)**		**Composite- Silty Sand**	0 - 36	NP	NP	100	100	98	95	90	82.1	0		185
		180+00, 16'Lt													
5A			Similar as 4A	0 – 6											
5B			Similar as 4A	6 – 12											
5C	A-6(16)		Lean Clay with Sand	0 - 6	36	20	100	100	100	100	97.8	83.5	15	25.9	244
5D	A-6(20)		Lean Clay	6 - 27	30	15	100	100	100	100	100	92.7	12	20.9	311

Project No. STP-123C(123), 12345(04)
Location US 69 From Choteau to SH 20
County Mayes

EXAMPLE

PAVEMENT CORE DATA & IN-PLACE SOILS

Soil No.	Field No.	Soil Group	Station	CL RT-LT	Description	Depth (in)	L.L.	P.I.	Percent Passing # 4	# 10	# 40	# 200	OSI	MC %
			86+05	5’ Rt.	Type S4 Asphalt	0-2	Major Stripping							
					Type S3 Asphalt	2-5	Minor Stripping							
					Type S3 Asphalt	5-8	Minor Stripping							
					Type S3 Asphalt	8-11								
					Aggregate Base	11-18								
7297	1A	A-6(19)			Lean Clay with Sand	18-36	40	23	98	97	95	85.1	17	21.1
			87+30	6’ Lt.	Type S4 Asphalt	0-2								
					Type S3 Asphalt	2-4,5	Major Stripping							
					Type S3 Asphalt	4.5-7.5	Deteriorated							
					Type S3 Asphalt	7.5-11								
					Aggregate Base	11-18.5								
7298	2A	A-2-6(0)			Silty Clayey Gravel with Sand	18.5-25.5	28	12	56*	42	35	27.5	4	16.8
7299	2B	A-6(11)			Lean Clay with Sand	25.5-36	34	16	99	97	90	77.8	13	20.4
					*Maximum Size Passing One Inch Sieve									

EXAMPLE **<u>ASPHALT CORE LOG</u>**

TOP

CORE LOG

PROJECT NO.	STPY-123C(123)
JOB PIECE NO.	12345(04)
LOCATION	SH-123
COUNTY	OKLAHOMA
DATE	JUNE 11, 2011
CONTROL SECTION	
CORE	1
STATION	325+50, 10' RT
LANE DIRECTION	NB
CHAINAGE	
GPS	

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*
1	Asphaltic Concrete	1 3/4	Type B, separation at 1 3/4 inches
	Asphaltic Concrete	2	Type B
	Asphaltic Concrete	1 1/2	Type B
	Asphaltic Concrete	1 1/2	Type B
	Asphaltic Concrete	2 1/2	Type A
	Total Core Thickness	9 1/4	
2	Asphaltic Sand and Gravel, black (5YR 2.5/1)	5	
3	Clayey Gravel, reddish-brown (5YR 4/4)	—	

*** Asphalt type based on visual observation only**

CORE DATA

Surface Material Type: ☑ A.C. ☐ P.C.C. ☐ Continuously Reinforced Concrete

Stripping or Separation in Asphalt: ☐ Stripping ☑ Separation ☐ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

EXAMPLE CONCRETE CORE LOG

TOP

CORE LOG

PROJECT NO.	STPY 123C(123)
JOB PIECE NO.	12345(04)
LOCATION	SH-123
COUNTY	OKLAHOMA
DATE	JUNE 11, 2011
CONTROL SECTION	
CORE	15
STATION	657+72, 10' FT
LANE DIRECTION	SB
CHAINAGE	
GPS	

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*
1	Portland Cement Concrete	9 5/8	Separation at 9 5/8"
	Asphaltic Concrete	6 1/8	Type C
	Total Core Thickness	15 3/4	
2	Stabilized subgrade - Silty clayey sand, yellowish-brown (10YR 4/4)	7 1/2	
3	Lean clay, brown (7.5YR 4/4)	—	

*** Asphalt type based on visual observation only**

CORE DATA

Surface Material Type: ☐ A.C. ☑ P.C.C. ☐ Continuously Reinforced Concrete

Stripping or Separation in Asphalt: ☐ Stripping ☑ Separation ☐ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

Stabilized Subgrade Beneath Pavement or Sub-base? ☑ Yes ☐ No ☐ Unknown

Project No. STP-123C(123), 12345(04)
Location US 69 From Choteau to SH 20
County Mayes

Table 1 Typical Characteristics of Soil Series

Soil Series	Lineal Extent (ft)	Slope Variability %	Parent Material	Depth to Bedrock (in)	Drainage	Permeability	Shrink-Swell Potential	Comments
Bates	1550	1 - 5	Sandstone	30 - 34	Well	Moderate	Low to moderate	- moderate corrosion risk to concrete - low strength
Dennis	4320	1 - 3	Shale	60	Mod. Well	Slow	Moderate to high	- high corrosion risk to uncoated steel - moderate corrosion risk to concrete - low strength - perched water table 2-3 ft Dec.- April
Okemah	980	0 - 1	Shale	60	Mod. Well	Slow	High	- high corrosion risk to uncoated steel - moderate corrosion risk to concrete - low strength - perched water table 2-3 ft Dec.- April
Parsons	1340	0 - 1	Shale	60	Poor	Very slow	High	- high corrosion risk to uncoated steel - moderate corrosion risk to concrete - low strength - perched water table 2-3 ft Dec.- April
Verdigris	130	Nearly level	Alluvium	> 72	Moderately Well	Moderate	Moderate	– subject to flooding

EXAMPLE FWD REPORT FOR FLEXIBLE PAVEMENT

Project No. STPY-150B(042)

U.S. Highway 177 From Carter/Murray County Line Extending North 5 Miles

Murray County, Oklahoma

Station (ft)	Direction	Asphalt Thickness (in)	Base Thickness (in)	Asphalt Temp. (F)	Asphalt Elastic Modulus (ksi)	Asphalt Elastic Modulus @ 68 F (ksi)	Equivalent Pavement Modulus (ksi)	Subgrade Resilient Modulus (ksi)	Design Subgrade Resilient Modulus (ksi)
10020	NB	8.3	12.0	52	455	295	56	23.6	7.9
10258	NB	8.3	12.0	52	455	296	72	17.7	5.9
10511	NB	8.3	12.0	52	227	148	83	31.3	10.4
10763	NB	8.3	12.0	52	227	149	112	25.9	8.6
11002	NB	8.3	12.0	52	181	119	49	23.2	7.7
11253	NB	8.3	12.0	53	181	120	48	24.7	8.2
11508	NB	6.0	8.0	52	268	176	69	13.8	4.6
11753	NB	9.3	12.0	53	268	176	104	19.2	6.4
12012	NB	9.3	12.0	52	255	167	105	14.7	4.9
12250	NB	9.3	12.0	53	255	168	141	13.4	4.5
12509	NB	9.3	12.0	53	320	213	125	17.8	5.9
12755	NB	9.3	12.0	53	637	425	221	25.8	8.6
13006	NB	9.3	12.0	53	315	210	363	53.6	17.9
13263	NB	8.3	6.0	53	315	210	145	24.2	8.1
13497	NB	8.3	6.0	53	315	209	94	27.2	9.1
13763	NB	8.3	6.0	53	150	99	72	28.7	9.6
13999	NB	8.3	6.0	53	150	99	168	33.5	11.2
14252	NB	8.3	6.0	53	477	314	56	19.6	6.5
14499	NB	12.0	6.0	53	477	315	59	13.3	4.4
14760	NB	12.0	6.0	53	202	133	275	19.4	6.5
15013	NB	8.8	6.0	53	202	135	84	13.0	4.3
15280	NB	8.8	6.0	53	202	136	54	26.6	8.9
15511	NB	8.8	6.0	53	470	316	185	26.9	9.0
15756	NB	8.8	6.0	53	470	316	67	24.6	8.2
16002	NB	8.0	6.0	53	470	316	142	19.8	6.6
16256	NB	8.0	6.0	53	470	313	157	17.8	5.9
16500	NB	8.0	6.0	53	506	337	158	23.2	7.7
16751	NB	8.0	6.0	53	224	149	118	15.5	5.2
16999	NB	9.8	6.0	53	224	149	68	15.6	5.2
17253	NB	9.8	6.0	53	460	304	150	14.4	4.8
17508	NB	9.8	6.0	53	460	307	157	12.8	4.3
17759	NB	9.8	6.0	53	154	102	184	13.7	4.6
18014	NB	9.8	6.0	53	154	103	192	25.5	8.5
18256	NB	8.0	6.0	53	565	378	205	21.5	7.2
18498	NB	8.0	6.0	53	565	377	192	23.2	7.7
18760	NB	8.0	6.0	53	290	193	124	23.8	7.9
18997	NB	8.0	6.0	53	290	192	140	19.5	6.5
19246	NB	7.3	6.0	53	290	194	107	19.2	6.4
19492	NB	7.3	6.0	53	290	194	82	18.2	6.1
19752	NB	7.3	6.0	53	172	115	79	21.2	7.1
			No. of Tests	40					
				Average	326	217	127	22	7.2
				Std Dev	137	92	67	7	2.5

Example: FWD Report For Asphalt Pavement

Proj. No. SSP-114B(185)SS, J.P. No. 24112(04) | **Location: SH-39, East of Lexington**

12,000 lb test load | **County : Cleveland**

Station (ft)	Lane	Asphalt Thickness (in.)	Asphalt Temp. (°F)	Asphalt Elastic Modulus at 77°F (ksi)	Equivalent Pavement Modulus (ksi)	Subgrade Resilient Modulus (ksi)	Design Subgrade Resilient Modulus (ksi)
81500	EB	14.2	73	463	463	19.6	6.5
82000	EB	14.2	74	97	97	14.6	4.9
82500	EB	14.2	74	126	126	15.7	5.2
83000	EB	14.2	74	164	164	16.4	5.5
83500	EB	14.2	74	102	102	36.6	12.2
84000	EB	14.2	74	270	270	21.7	7.2
84500	EB	14.2	74	250	250	18.9	6.3
85000	EB	9.5	73	184	184	22.1	7.4
85500	EB	9.5	74	100	100	23.2	7.7
86000	EB	9.5	74	67	67	16.0	5.3
86500	EB	9.5	74	132	132	10.5	3.5
87000	EB	9.5	74	294	294	16.2	5.4
87500	EB	9.5	75	64	64	10.4	3.5
88000	EB	9.5	74	93	93	13.4	4.5
88500	EB	13.0	73	56	56	7.3	2.4
89000	EB	13.0	73	54	54	8.3	2.8
89500	EB	13.0	73	49	49	7.4	2.5
90000	EB	13.0	73	112	112	16.8	5.6
90500	EB	13.0	74	76	76	15.5	5.2
91000	EB	13.0	73	69	69	18.6	6.2
91500	EB	13.0	74	123	123	17.9	6.0
92000	EB	10.5	74	113	113	17.9	6.0
92500	EB	10.5	75	85	85	15.9	5.3
93000	EB	10.5	74	72	72	15.8	5.3
93500	EB	10.5	75	213	213	12.7	4.2
94000	EB	10.5	75	118	118	13.8	4.6
94500	EB	10.5	75	102	102	12.0	4.0
95000	EB	10.5	74	60	60	18.4	6.1
95500	EB	10.5	74	108	108	17.9	6.0
96000	EB	10.5	76	92	92	17.8	5.9
96500	EB	10.5	74	115	115	17.1	5.7
97000	EB	10.5	76	122	122	15.7	5.2
97500	EB	10.5	76	167	167	10.7	3.6
98000	EB	10.5	76	219	219	13.4	4.5
98500	EB	10.5	76	169	169	9.8	3.3
99000	EB	10.5	76	178	178	13.4	4.5
99500	EB	10.5	76	181	181	15.6	5.2
100000	EB	10.5	75	102	102	15.4	5.1
100500	EB	10.5	76	250	250	13.5	4.5
101000	EB	10.5	76	126	126	15.5	5.2
101300	EB	10.5	75	84	84	9.5	3.2
			No. Tests:	41			
			Average:	137	**137.057**	**15.583**	**5.194**
			Std Dev.:	81	**81.432**	**5.073**	**1.790**
			85%:	69	**69.263**	**10.500**	**3.500**

EXAMPLE FWD REPORT FOR PC CONCRETE PAVEMENT

PROJECT NO. STP-123C (123) 12345(04)

US 69 from Choteau to SH20

Mayes County

Station	Station (ft)		PCC Thickness (in.)	Soil Asph. Base Thickness (in.)	Equivalent Pavement Modulus (ksi)	Static Modulus of Subgrade Reaction (psi/in)	Subgrade Resilient Modulus (ksi)	Design Subgrade Resilient Modulus (ksi)
17.853	94264	NB	9.5	5.5	1391	135	15.600	3.900
17.913	94581	SB	9	4.5	2749	112	11.800	2.950
17.916	94596	NB	9.5	5.5	1460	101	11.400	2.850
17.965	94855	SB	9	5	1827	141	19.500	4.875
18.026	95177	NB	9.5	5.5	822	87	25.800	6.450
18.081	95468	SB	9	5	1807	261	27.500	6.875
18.115	95647	SB	9	5	2050	218	24.900	6.225
18.183	96006	NB	8.75	5.25	1208	142	17.300	4.325
18.205	96122	SB	9	5	2841	93	10.200	2.550
18.26	96413	SB	9	5	2788	112	11.700	2.925
18.311	96682	NB	8.75	5.25	1635	45	5.600	1.400
18.358	96930	NB	9.25	5.5	946	144	28.400	7.100
18.422	97268	SB	9	5	2541	75	8.900	2.225
18.429	97305	NB	9.25	5.5	1301	70	8.100	2.025
18.498	97669	SB	9	5	2190	223	24.200	6.050
18.534	97860	NB	9.5	5.5	1970	45	5.600	1.400
18.573	98065	NB	9.5	5.5	2290	95	11.300	2.825
18.647	98456	SB	9	5	2786	134	13.500	3.375
18.678	98620	SB	9	5	2234	137	14.900	3.725
18.765	99079	NB	9.5	5.5	2212	56	7.200	1.800
18.795	99238	NB	9.25	4.75	1967	70	7.900	1.975
18.837	99459	SB	9	4.5	2449	106	11.300	2.825
18.874	99655	SB	9	4.5	2129	175	17.600	4.400
18.912	99855	NB	9.25	4.75	1637	110	11.200	2.800
18.946	100035	NB	9	6	1113	113	14.400	3.600
19.035	100505	NB	9	6	1267	88	10.700	2.675
19.059	100632	SB	9	4.5	2933	79	8.900	2.225
19.131	101012	SB	9	4.5	2635	91	9.300	2.325
19.167	101202	SB	9	4.5	2916	89	9.400	2.350
19.284	101820	SB	9	6	2040	135	15.300	3.825
19.287	101835	NB	9	6	1919	74	8.300	2.075
19.375	102300	SB	9	6	1898	149	16.800	4.200
19.393	102395	SB	9.25	6	2148	155	14.900	3.725
19.447	102680	NB	9	6	2208	52	6.600	1.650
19.518	103055	SB	9.25	6	1895	85	9.600	2.400
19.54	103171	NB	9.5	6	1307	131	15.000	3.750
19.573	103345	NB	9.5	5.5	1766	79	10.000	2.500
19.625	103620	SB	9.5	5.5	2069	101	9.300	2.325
19.672	103868	NB	9.5	5.5	1728	110	10.900	2.725
19.753	104296	NB	9.5	5.5	1784	74	8.600	2.150
19.79	104491	SB	9.5	5.5	1072	228	18.500	4.625
19.835	104729	NB	9.5	5.5	1408	97	11.200	2.800
19.895	105046	SB	9.5	5.5	2818	122	12.900	3.225
				# of Tests	43.0			
				Average	1844.8	117.8	12.363	3.091
				Std Dev.	590.4	74.7	4.821	1.205

Part 2

Geotechnical Specifications for Bridges and Related Structures

OKLAHOMA
Transportation

STATE OF OKLAHOMA
DEPARTMENT OF TRANSPORTATION
SPECIFICATIONS FOR THE GEOTECHNICAL INVESTIGATION
OF BRIDGES AND RELATED STRUCTURES

August 25, 2021

GENERAL: The general procedure for the execution of investigation for bridge and related structures' foundations shall be governed by the AASHTO Manual on Subsurface Investigations, 1988, and Geotechnical Engineering Circular No. 5, "Geotechnical Site Characterization", FHWA NHI-16-072, April 2017. Unless otherwise noted herein by the following exceptions or amplifications, said investigations shall subscribe to, as a minimum requirement, the general guidelines given in Chapters 1.0 through 10.0 and Appendices A through H of the AASHTO Manual on Subsurface Investigations and Geotechnical Engineering Circular No. 5.

The Consultant is required to furnish the Department with the proper data on the engineering properties and analysis and design requirements as specified in and according to the most current AASHTO LRFD Design Specifications including interims. These AASHTO specifications are minimum requirements, and the Consultant may exceed them. The Consultant is responsible for providing the Department with sufficient information as necessary to verify foundation adequacy.

In making geotechnical investigations, the Consultant is responsible for damages that occur to property as a result of those investigations. The Consultant is required to submit verification that permission of the property owner for access to the site has been granted, and that OKIE confirmation numbers have been obtained for all underground and overhead utilities to the Department for approval prior to beginning the subsurface exploration. A pre-work conference is required to resolve all matters with regard to sampling, testing, and analysis of data. The Department's geotechnical policies and procedures represent the state of practice and will govern. All references to AASHTO and ASTM standards and test procedures refer to the most recent version of the standard or test procedure, unless otherwise noted. The Consultant will follow the proposed boring plan provided with the Task Order and comply with the conditions of the 404 permit and USFWS Consultation as applicable.

ENVIRONMENTAL REQUIREMENTS: On most projects, the Geotechnical Task Orders will be issued after the Environmental Studies are complete for the project and prior to Right-of-Way and Utilities meeting. The Geotechnical Consultant will submit the proposed sampling and drilling plan which will show any clearing outside the maintained right-of-way and pads or haul roads constructed in waters to ODOT's Environmental Programs Division The proposed sampling and drilling plan will be on an aerial map showing the proposed access path locations, boring points and any areas proposed for bulldozer work clearly shown at an appropriate scale (1"=400 FT or larger is preferred). In addition, the Geotechnical consultant will provide shapefiles georeferenced in State Plane North or South in feet or KMZ files indicating proposed locations of such. The review of the proposed plan will be completed within 30 days of submittal of complete information. If the project is located in a US Army Corps of Engineers (USACE) property, additional 60 days will be required for coordination with the USACE office. If there are no impacts to species or jurisdictional waters or wetlands, work can start immediately after the review.

If impacts to waters and wetlands are identified, the Geotechnical Consultant will work with the Designer and ODOT's Environmental Programs Division to minimize the impact and include the impacts due to geotechnical work. The appropriate 404 permit from US Army Corps of Engineers (USACE) required for the geotechnical investigation will be obtained by ODOT's Environmental Programs Division and the geotechnical consultant shall comply with the permit conditions and adhere to the proposed sampling and drilling plan.

If impacts to any threatened and endangered species are identified, the Designer will work with the Geotechnical Consultant and the Department's Environmental Programs Division to minimize the impact and include the impacts due to geotechnical work in the information provided for US Fish and Wildlife Services (USFWS) Consultation for the project. Additional information from the Geotechnical Consultant regarding the type of work and equipment used may be required. The USFWS consultation and any survey will be completed by ODOT's Environmental Programs Division and the Geotechnical Consultant shall comply with the conditions of the consultation and adhere to the proposed sampling and drilling plan. If the project is located in a Critical Habitat for any threatened and endangered species, formal consultation with USFWS will be required and this process could take 6 months or more.

The Geotechnical Consultant shall notify the Field Districts prior to performing any field work. The Geotechnical Consultant shall obtain permission from property owners prior to doing any field work in properties outside of ODOT Right-of-Way. The Geotechnical Consultant shall be responsible for restoring the property to the original conditions prior to field work. These include but not restricted to repairing fences, filling up holes, etc.

If the Geotechnical Consultant encounters or exposes any abnormal condition indicating the presence of a hazardous material or toxic waste, the Consultant shall immediately suspend the work in the area and notify the Department. The Consultant may continue the work in unaffected areas of the project, unless otherwise directed by the Department. Abnormal conditions include, but are not limited to, the presence of the following:

1. Barrels, drums, tanks, or other chemical containers;
2. Noxious odors emanating from the soil or water table;
3. Excessively hot earth or smoke indicating a possible chemical reaction;
4. Stained or oily soil or groundwater; or
5. Any other condition that indicates a hazardous material or toxic waste.

The Consultant shall treat these conditions with extreme caution and shall not attempt work without appropriately trained, qualified, and equipped personnel.

If disposing of soil or rock cuttings containing suspected to contain hazardous material or toxic waste, the Consultant shall comply with all applicable local, State, and federal rules and regulations. The disposal work may be performed by the Consultant under a supplemental agreement to the Contract or by the Department.

EXCEPTIONS TO AND AMPLIFICATIONS OF BORING PLAN: At least one boring will be made at each pier element and two borings at each pile bent and abutment. Additional requirements are noted below in item numbers one through eighteen (1-18).

1. **Square or Rectangular Footings and Raft Foundations:** For large square or rectangular footings and raft foundations, least dimension 20 feet (6.10m), more than one boring will be required at such foundations as directed by the Department. All of these borings shall be sampled as indicated in items 4 and 5.

2. **Spread Footings and Deep Foundations:** Where substructure units will be supported on spread footings, the minimum depth of the subsurface exploration shall extend below the anticipated bearing level a minimum of two footing widths for isolated, individual footings where $L \leq 2B$, and four footing widths for footings where $L \geq 5B$. For intermediate footing lengths, the minimum depth of exploration may be estimated by linear interpolation as a function of L between depths of 2B and 5B below the bearing level. Greater depths may be required where warranted by local conditions.

   Where substructure units will be supported on deep foundations, the depth of the subsurface exploration shall extend a minimum of 30 feet (9.14m) below the top of the rock. Where pile or drilled shafts will be used, the subsurface exploration shall extend at least two times the maximum pile group dimension below the anticipated tip elevation, unless the foundations will be end bearing on or in rock. For piles bearing on rock, exclusive of shale, a minimum of 20 feet (6.10m) of rock core shall be obtained at each exploration location to ensure the exploration has not been terminated on a boulder. Borings shall extend to a minimum depth of 120 feet (36.58m) if rock or shale is not encountered.

3. **Additional Borings:** Additional borings at each pier location will be necessary in non-uniform conditions, such as erosive rock formation, in both the longitudinal and transverse direction to the bridge centerline. A differential depth of 5 feet (1.52m) or more in any boring in profile shall constitute a condition that will require additional borings. Seismic survey can be substituted in lieu of borings to verify depth differentials. Should the average RQD from all core runs for any one boring be less than 45 percent, then an additional boring under the requirements of 5a will be required, and an explanation will be required as to why this has occurred. Also, if the RQD is less than 20 percent in any one core run, then an additional 10 feet (3.05m) of coring will be required. The RQD is to be based on 5-foot (1.52m) core runs only.

4. **Sampling Interval:** The maximum sampling interval throughout the boring depth is 5.0 feet (1.52m) in homogeneous strata. In nonhomogeneous strata, the sampling interval is less than 2.5 feet (0.76m) with testing and sampling at changes in strata. The standard penetration test split-barrel sampler will be used in all cases except when soft clays or silts are encountered, in which case thin-wall tube samples may be substituted.

5. **Weathered Rock or Shale:** When weathered rock or shale is encountered, the Standard Penetration Test (SPT) shall be made at the top of the weathered rock or shale and continued until refusal is met in accordance with current ASTM D 1586 Section 7.1. Thereafter, one of the following is required:

   a. Continuous core barrel sampling according to current ASTM D 2113 (minimum size NWG and NQ_3WL) to a total depth of 30 feet (9.14m) and shall be restricted to locations shown on the enclosed map or as directed. All core logs shall include the information as required by ASTM D5878.

b. Pressuremeter tests immediately following the refusal of the standard penetration test and at 5-foot (1.52m) intervals thereafter to a total depth of 30 feet (9.14m).

c. Dynamic Cone Penetrometer Test described in Item 12 and under Field Tests shall be made at the top of the weathered rock or shale following the refusal of the Standard Penetration Test and at 5-foot (1.52m) intervals, or as directed in Item 12. The use of the Dynamic Cone Penetrometer Test described in Item 3 under Field Tests shall be restricted in use to locations shown on enclosed map or as directed. Note the Dynamic Cone Penetrometer Test is a Department Bridge Division test.

6. **Recommended Load Carrying Capacity:** When directed by the Department, the Consultant shall recommend the load carrying capacity for the rock or shale, including end bearing and side shear (skin resistance) and other foundation analysis as required by procedures outlined in the most current AASHTO LFRD Standard Specifications for Highway Bridges including Interims. When directed by the Department to recommend load capacity for LFRD projects identified on the enclosed map or as directed, analysis will require the use of the unconfined compressive test and/or point load test on rock core specimens. Where applicable the Pressuremeter test, ASTM D 4719, may be used in shale to estimate end bearing and side shear. Rock Mass Modulus may be estimated based on methods using the rock mass rating (RMR) or the RQD. The use of other in-situ tests (i.e., borehole dilatometer and the borehole jack, ASTM D 4971) may also be acceptable. Typically, settlements or deformations within a rock foundation will be controlled by the deformation modulus corresponding to the overall rock mass and will not be controlled by the deformation modulus of intact rock. The deformation modulus of intact rock serves only as the upper bound of the rock mass modulus. The Hoek-Brown Strength criteria for fractured rock shall be used in the estimation of end bearing and side for spread footings and drilled shafts in fractured rock.

7. **Structures Less Than 250 Feet (76.20m) in Length:** In the alluvium and bedrock, at least one pier and both abutment borings are required to be sampled as indicated in Items 4 and 5, logged, tested in the laboratory by appropriate test procedure, and described according to current ASTM D2487 and D2488. At all other borings, the bedrock is to be sampled as indicated in Item 5, logged, and described according to current ASTM D2487 and D2488. If required, the recommended load carrying capacity as described in Item 6 shall be based on the composite data from all boring locations.

8. **Structures Between 250 and 600 Feet (76.20m and 182.87m) in Length:** In the alluvium and bedrock, at least two pier and both abutment borings are required to be sampled as indicated in Items 4 and 5, logged, tested in the laboratory by appropriate test procedure, and described according to current ASTM D2487 and D2488. At all other borings, the bedrock is to be sampled as indicated in Item 5 and logged and described according to current ASTM D2487 and D2488.

9. **Structures Greater Than 600 Feet (182.87m) in Length:** In the alluvium and bedrock, at least three pier and both abutment borings are required to be sampled as indicated in Items 4 and 5, logged, tested in the laboratory by appropriate test procedure, and described according to current ASTM D2487 and D2488. At all other borings, the bedrock is to be sampled as indicated in Item 5 and logged and described according to current ASTM D2487 and D2488. In addition to Item 13 requirements, for depths to top of rock greater than 60 feet (18.29m), at least one boring shall be sampled continuously by the Standard Penetration Test (SPT) and logged, tested in the laboratory

by appropriate test procedure, and described according to current ASTM D2487 and D2488 and/or Cone Penetration Test (CPT, CPTU) according to the current ASTM 5778 for the full depth of the boring. For structures in excess of 1500 feet (457.18m), borings may be spaced at 100-foot (30.48m) intervals in a staggered pattern.

10. **Borings in Bodies of Water:** For borings in bodies of water (i.e., lakes, rivers and streams), all underlying soil material shall be sampled continuously by SPT, according to current ASTM D1586 procedure, until weathered rock or shale is encountered, and thereafter sampling shall be according to Items 5a, 5b, and 5c requirements. In the case of when soft clays or silts are encountered above weathered rock or shale, thin-walled tube samples may be substituted.

11. **Parallel Structures:** For new parallel structures or widening of an existing structure and addition of a new parallel structure, treat as separate bridges requiring borings for each bridge respectively.

12. **Dynamic Cone Penetrometer Test:** If the Dynamic Cone Penetrometer test is used to determine the load carrying capacity as required in Item 6, then a minimum of seven (7) consecutive cone tests having a penetration resistances of two consecutive 50 blows per 6 inch (152.4mm) increment are required at a maximum of 5 foot (1.52m) intervals, and shall continue to the bottom of the boring. Following the first Dynamic Cone Penetrometer test, do not discontinue Dynamic Cone Penetrometer testing at 5-ft (1.52m) intervals through the remainder of the boring, even if a test results in less than 50 blows per 6-inch (152.4mm) increment.

13. **Rock Depths Greater Than 60 Feet (18.29m):** For depths to top of rock greater than sixty (60) feet (18.29m) in cohesive and/or granular materials, an estimate of point and skin resistance for friction piles or drilled shafts by static analysis of the various layers shall be made by the SPT and/or CPT methods for the full depth of the boring. This requirement shall be in addition to Item 5 requirements when the rock depth is greater than 60 feet (18.29m).

14. **Scour Depth:** For scour depth estimates, the mean D_{50} (mean diameter of the bed material) in granular alluvium is required. Gradation samples shall be tested in the laboratory by appropriate test procedure and described by ASTM D2487 on all samples taken according to the 5-foot (1.52m) intervals in Item 4 in granular alluvium. The depth of weathered rock or shale described in Item 5 is required. In rock or shale sampled by continuous core barrel, fracture spacing shall be plotted per foot of depth for all core runs. The following criteria are required at pier locations.

    a. One boring for structures less than 250 feet (76.20m) in length.
    b. Two borings for structures between 250 and 600 feet (76.20m and 182.87m) in length.
    c. Three borings for structures greater than 600 feet (182.87m) in length.

15. **Water Table and Water Sampling:** The water table shall be measured at the end of drilling and at 24 hours in all boreholes as specified in the most current ASTM D4750. The Consultant will confirm and monitor the presence of artesian water. For structures located in Districts 5 and 6 or at locations where available sources of geological and/or geotechnical literature and data indicate the presence of salts, or when stream surface, soil surface, or surface vegetation indicate the presence of salts, water samples shall be taken from surface pools and from at least two boreholes at 10-foot (3.05m) intervals. For county bridge structures water samples shall be taken from

surface pools and from at least one boring at a depth of 10 feet (3.05m) below the water table. Also, water samples are required as indicated above when available literature and/or data suggest the presence of gypsum, or when boring logs indicate the presence of gypsum interbedded within the soil or rock.

16. **Bridge Approach Embankment Settlement and Slope Stability:** For embankment heights that are greater than 15 feet (4.57m), settlement and slope stability predictions shall be made according to the requirements of the Specifications for Geotechnical Investigations for Roadway Design. Settlement predictions by in situ tests (CPTU and DMT) are allowed and preferred.

17. **Retaining Walls:** Geotechnical investigation as set forth in this specification will be required for all retaining wall footings and wall pressures. In the rigid gravity, semi-gravity, non-gravity cantilevered, mechanically stabilized earth (MSE), prefabricated modular and anchored retaining walls, spacing of borings for retaining walls will be at intervals of 100 to 200 feet (30 to 60m) along the back face of the wall. Additional requirements are specified in Chapter 11 of the AASHTO LRFD Design Specifications including interims. For walls where settlement is evaluated, settlement predictions by in-situ tests (CPTU and DMT) are allowed and preferred.

    In the case of anchored walls, borings must be drilled along the centerline of, in front of, and behind the proposed wall according to the following requirements:

    a. Wall borings (borings performed along the actual wall centerline) are required at 100 ft to 200 ft spacing, and should extend at least to a depth H below the planned bottom of the excavation, where H is the height of the wall at that location.
    b. Borings drilled behind the wall are required at a distance of 1.0 - 1.5Hbehind the back face of the wall and at critical section centerline at a 150 foot (45.72m) spacing. Back borings should extend to a depth 2H below final grades. If the ground behind the wall slopes up, borings should be drilled within a distance of 1.5H to 2H from the wall. These borings should be deep enough to allow assessing potentially larger sliding masses occurring up the slope.
    c. Borings drilled in front of the wall should be spaced up to 200 ft along the alignment, be located between 0.75H to H in front of the wall, and be advanced to at least to a depth H below the planned bottom of the excavation.
    d. Where soft to very soft fine-grained soils exist within the terminal boring depths outlined herein, the depth should be increased at least by H for borings along and behind the wall, and by 0.5H for borings in front of the wall.
    e. All borings within a 200 foot (60.96m) spacing of critical section centerline will be sampled as specified in Item 4.
    f. Carefully record water level and caving of borings.
    g. Soil tests for anchor environment shall include electrical resistivity, pH, and sulfate(s) tested in a minimum of two back borings at 5-foot (1.52m) intervals.

    Geotechnical evaluations for retaining walls including external stability (sliding, overturning, bearing capacity), global stability, and settlement shall be performed according to AASHTO LRFD Bridge Design Specifications and shall be addressed in the geotechnical report. Internal stability of MSE walls is addressed by the Contractor responsible for wall construction. External stability analyses for MSE Walls should address compound stability wherein failure planes intersect the reinforced fill and exit below the toe of the wall.

18. **Integral Abutments:** For embankment heights that are greater than 15 feet (4.57 m) settlement and lateral squeeze predictions of the foundation soil shall be made according to the requirements of the Specifications for Geotechnical Investigations for Roadway Design.

FIELD RECONNAISSANCE AND TOLERANCE:

1. Observe and report the following site conditions in reference to the geotechnical investigation of the structure:

    a. Surface soil types.
    b. Gullies, excavations, slopes or stream banks.
    c. Surface and subsurface water.
    d. Topography and vegetation.
    e. Location of existing structures.
    f. Unusual drilling conditions.
    g. Underground and overhead utilities.
    h. Permission of property owners.
    i. Stream debris.

2. Deviations from the boring location plan are allowed, due to inaccessible conditions, when approved by the Department.

3. Vertical control of all borings shall be plus or minus (±) 0.10 foot (0.03m), as documented by survey notes. Elevations shall be taken with an engineer's level (i.e., Wye Level or higher equivalent). If the project is a new alignment that is beyond reasonable reach by a distance measuring tape of 100 feet (30.48 m) from a reference line, then request a survey contract item.

4. The tolerance in hole location shall be plus or minus (±) 1.0 foot (0.3m), by taping or chaining.

METHOD OF DRILLING: An appropriate method of rotary drilling shall be used for the foundation and geologic conditions encountered as specified in the AASHTO Manual on Subsurface Investigations, 1988. Drilling with continuous flight augers is prohibited. There are no other restrictions on the type of drill equipment, other than that it shall be capable of performing all of the field sampling and testing outlined in the AASHTO Manual on Subsurface Investigations, 1988. The practice of auger refusal using a solid core or hollow-stem auger is not an acceptable technique for identifying top of rock. For borings over water in lakes or rivers, drilling operations shall be performed on a barge supported by spud rods at all barge corners which are anchored firmly into underlying geology.

SAMPLING: The most current issue of the following ASTM and AASHTO Standards will govern and shall be used:

1. ASTM D1586, Method for Standard Penetration Test and Split Barrel Sampling of Soils.
2. ASTM D1587, Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes.
3. ASTM D2113, Practice for Rock Core Drilling and Sampling of Rock for Site Exploration.

4. ASTM D4220, Practice for Preserving and Transporting Soil Samples.
5. AASHTO T264, Collection and Preservation of Water Samples.
6. ASTM D4750, Standard Test Method for Determining Subsurface Liquid Levels in Borehole or Monitoring Well (Observation Well).

FIELD TESTS: The most current issue of the following ASTM Standards will govern and shall be used:

1. Standard Penetration Test (SPT) - ASTM D1586. Partial increments of the Standard Penetration Test should be measured to the nearest 1/16 of an inch (1.59mm). All SPT field N-values are to be corrected to a 60 percent efficiency.
2. Cone Penetration Test (CPT, CPTU) - ASTM D 5778. For the CPTU a u piezocone tip is required.
3. Flat Dilatometer Test (DMT) - ASTM D6635
4. Pressuremeter (PMT) - ASTM D 4719
5. Borehole Jack Test - ASTM D 4971
6. Dynamic Cone Penetrometer Test - This test is adopted by the Department's Bridge Division and described generally in subsection B.4.2 of the AASHTO Manual on Subsurface Investigations, 1988. The Dynamic Cone Penetrometer test used by the Department Bridge Division is known as the Texas Cone Penetrometer Test. Deviations from the AASHTO Manual on Subsurface investigations, 1988, are as follows: 10 blows to seat the cone and the penetration in inches per 50 blows for the first and second 50 blows; if 6 inches (152.4m) of penetration is obtained before 50 blows, then the number of blows per 6 inches (152.4m) shall be recorded for a total of 12 inches (304.8mm).. Hammers furnishing equivalent energy to a 170-pound (77.11kg) hammer with a 24-inch (609.6mm) drop will be acceptable. The dynamic cone penetrations should be reported to the nearest 1/16 of an inch (1.59 mm).
7. Field Permeability Tests - ASTM D6391

LABORATORY TESTS: Engineering judgment should be used in developing the laboratory testing program. The intent of the laboratory testing program is to provide information necessary to properly characterize the site. It is not necessary to perform all soil classification tests on all samples, for example. In developing the program, consideration should be given to the visually/manually observed soil classification types throughout the subsurface and the relative benefits of performing a specific laboratory soil classification test.

Laboratory testing shall be performed by technicians certified by the Highway Construction Materials Certification Board in a laboratory qualified by the Department Materials Division. For all samples taken, the following shall apply:

1. Soil and rock samples are to be tested in the laboratory and results reported according to the most current ASTM Standards for the following tests:
   a. Soil Classification (Gradation and Plasticity Index).
   b. Moisture Content.
   c. Specific Gravity.
   d. Density (AASHTO procedure only).
   e. Hydrometer, Double Hydrometer Pinhole Test.
   f. Slake Durability.
   g. Unconfined Compression Test: to the extent that sample quality allows, tests are to be

conducted at intervals small enough to provide a valid average of the type of rock under consideration as required by ASTM D7012.

h. Point Load Test.

i. One-Dimensional Consolidation Test.

j. Drained Direct Shear Test.

k. Triaxial Shear Test.
   1) Unconsolidated Undrained.
   2) Consolidated Undrained-Pore Pressure Measurement.

l. Percent Swell and Swell Pressure Test.

m. SO_4 ion (ppm) by AASHTO T290, ASTM D4327.

n. CL ion (ppm) by AASHTO T291, ASTM D4327.

o. Electrical Resistivity by AASHTO T288, ASTM G187 (or ASTM G57).

p. pH by AASHTO T289, ASTM G51.

2. Water samples are to be taken at a minimum of 10 feet (3.05m) intervals with a positive sealing sampler in at least two bore holes. Water levels shall be allowed to reach an equilibrium condition before sampling. Borings advanced by mud (bentonite slurry) rotary drilling technique shall be bailed before water sampling, and groundwater levels should be allowed to reach an equilibrium condition. Where needed, casing must be installed. Samples are to be analyzed for:

   a. CL ion (ppm) by AASHTO T260 (Alternate Method Number 1 - Potentiometric Titration).
   b. SO_4 ion (ppm) by AASHTO T105, ASTM C114.
   c. pH by ASTM G51.

3. Classification and description of soils and compaction shale shall follow ASTM D 2487 and D2488. For clarification purposes, define and test for the following particle size distribution:

   3 in. (75mm)
   3/4 in. (19mm)
   No. 4 (4.75mm)
   No. 10 (2.00mm)
   No. 40 (425µm)
   No. 200 (75µm)

4. Handheld Soil Testing Devices:

   a. A Torvane shear device (ASTM D8121) may be used to approximate shear strength of cohesive soils. Use of the Torvane device is particularly encouraged for very soft soil samples which deform under their own weight.
   b. A pocket penetrometer may be used for qualitative purposes only, and shall not be used to determine rock or soil properties.

5. Soil tests required for anchored retaining wall anchor environments are:

   a. Electrical resistivity, ASTM G57, AASHTO T289.
   b. pH by AASHTO T289, ASTM D4972.
   c. SO_4 ion (ppm) by AASHTO T290, ASTM D4327.

6. Soil tests required for drilled shafts located in Districts 5 and 6:

   a. SO_4 ion (ppm) by AASHTO T290, ASTM D4327.

b. CL ion (ppm) by AASHTO T291, ASTM D4327.
c. Electrical Resistivity by AASHTO T288, ASTM G187 (or ASTM G57).
d. pH by AASHTO T289, ASTM G51.

FIELD LOGGING: Descriptive terminology and classification of rock shall be based on the requirements of subsection E.6 in the AASHTO Manual on Subsurface Investigations, 1988 as well as the Department's local practice. The finished boring log shall be a compilation of all classification and description from laboratory tests and field logging.

GEOLOGIC STATEMENT: A general review and assessment of specific site geology shall be reported based on all available soil surveys and geologic publications and maps for the location. All sources shall be documented.

MINIMUM PLUGGING REQUIREMENTS FOR GEOTECHNICAL BORINGS: The general procedure for the plugging of Geotechnical Borings shall be governed by the current Oklahoma Water Resources Board specifications "Plugging Requirements for Geotechnical Borings". Unless otherwise noted herein by the following exceptions or amplifications, said procedures shall subscribe to, as a minimum requirement, the general guidelines given in 785:35-11-1 and 11-2 of the Oklahoma Water Resource Board's Regulations.

Exceptions and Amplifications to the above are as follows:

1. Responsibility for proper plugging lies with the Consultant.
2. Borings shall be plugged to prevent pollution of groundwater within ten (10) days of completion of drilling.
3. A multi-purpose completion report shall be submitted to the Oklahoma Water Resources Board within thirty (30) days of completion and plugging of each geotechnical boring and to the Department in the Final Written Report.
4. Guidelines for borehole plugging, grouting procedures, grout mixes, etc., are explicitly detailed in the Oklahoma Water Resources Board's Specifications.

FINAL WRITTEN REPORT: In addition to the graphical and tabular data, a written report shall also be made. It shall contain all required data, and when requested, an interpretation and analysis of the data along with definite engineering recommendations for design based upon the various factors. The geotechnical report shall be thorough in reporting all backup data and calculations documenting analyses and recommendations in accompanying appendices to the report. The materials and conditions which may be encountered during construction shall also be discussed. The Geotechnical Engineer responsible for the report preparation should have a broad enough background in engineering to have some knowledge of the type of structures which normally would be used in a certain location, including their foundation requirements and limitations. Geotechnical problems that may impact design performance and construction based on the findings of the geotechnical report shall be reported and recommendations made. The recommendations should be brief, concise and, where possible, definite. Reasons for recommendations and their supporting data should be included. The units in the analyses and final report shall be consistent with plan requirements and directives. The final report will require GINT computer generated boring logs. The final report shall be submitted electronically in pdf format. Foundation boring log plan sheet(s) shall be submitted electronically in both a .dgn and .pdf format that is transferrable to the Bridge Division Design plan sheets in accordance with formats provided with Task Orders. A physical hard copy of the report is not required unless specifically requested with the Task Order. The written report should include the following specific items:

1. **Pile Support**

   a. Method of support: Friction or end bearing, in rock or soil or both.
   b. Suitable pile type or types: Reasons for choice and/or exclusion of types.
   c. Pile tip elevations:
      1) Estimated - Average values, with range of variation if desirable.
      2) Specified - Explain reasons, such as driving through fill, negative skin friction, scour, underlying soft layers, piles and uneconomically long, etc.
   d. Allowable pile loading: Specify method of analysis.
   e. Settlement considerations: Requirements of structure vs. soil conditions. Specify method of analysis.
   f. Cut-off elevations: Water table, etc.
   g. Test piles required: Location for maximum utility.
   h. Load tests required and use of dynamic pile driving formula.
   i. Effects on adjacent construction.
   j. Corrosion effects of various soils and waters, and possibility of galvanic reaction.
   k. Scour depth knowledge.
   l. P-Y curve analysis, when specified on Task Orders.

2. **Drilled Shaft Support**

   a. Method of support: Friction or end bearing, in rock or soil or both.
   b. Suitable drilled shaft size: Reasons for choice and/or exclusion of sizes.
   c. Drilled shaft base elevations.
   d. When coring and unconfined compression testing are the methods of testing, provide the appropriate friction or bearing values in accordance with AASHTO LRFD. Include a description of rock joints; open or closed, intact or tightly jointed, joint condition, joint orientation and a description of any material that may be filling joints and seams.
   e. Settlement considerations: Requirements of structure vs. soil conditions. Specify method of analysis.
   f. Cut-off elevations: Water table, etc.
   g. Drilled shafts required: Locations for maximum utility.
   h. Corrosion effects of various soils and waters.
   i. Scour depth knowledge.
   j. When bedrock is not found, P-Y curve analysis.

3. **Footing Foundation Support**

   a. Elevation of footing.
   b. Allowable soil pressure - for bearing and for settlement; considering soil, adjacent foundations, water table, etc.
   c. Material on which footing is to be placed.
   d. Scour depth.

4. **Construction Considerations**

   a. Water table: Fluctuations, control in excavations, pumping, tremie seals, etc.
   b. Adjacent structures: Protection against damage from excavation, pile driving, drainage, etc.
   c. Pile driving: Difficulties or unusual conditions which may be encountered.
   d. Excavation: Control of earth slopes including shoring, sheeting, bracing, and special procedures, variation in, type of material encountered, etc.
   e. AASHTO LRFD Seismic Soil Site Classification.

Additional Information: The Consultant shall provide the following to the Department, all of which should be included in the report:

1. Name of the Professional Engineer, Engineer-in-Training and/or Geologist at the site preparing any field boring logs and interpreting the geologic profile.
2. Name of the driller. Logging by driller in lieu of an Engineer and/or Geologist will not be allowed.
3. Type of equipment used.
4. Method (or combination) of drilling used.
5. Size of drive hammer and free fall used on sampler in dynamic tests.
6. Type and size of core barrels.
7. Description of sampler(s). Diameter of any casing used.
8. A report shall specify current ASTM / AASHTO specification numbers.
9. Deviation from sampling and field-testing equipment requirements as specified by current ASTM and/or AASHTO Standards.

ACCEPTANCE: The Department, upon review of the final report and foundation boring log plan sheet(s), shall exercise final authority as to whether the Consultant has provided sufficient information or if additional data or borings are required. The Department further reserves the right to review all phases of the geotechnical report including all field and laboratory data, computations, and analysis.