# CHAPTER 4

# SUBSURFACE INVESTIGATION GUIDELINES

## GEOTECHNICAL DESIGN MANUAL

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# CHAPTER 4

# SUBSURFACE INVESTIGATION GUIDELINES

## 4.1 INTRODUCTION

A subsurface investigation is typically required for new or replaced structures and roadway alignments, including realignments involving earthwork. Examples of this include bridge replacements, widening of existing bridges, roadway realignments including widenings, pedestrian and wildlife bridges, ERSs, pipes or culverts (greater than or equal to 48 inches in diameter), overhead sign-structures, sound barrier walls, and other miscellaneous structures.

This Chapter presents guidelines to be used in the development of subsurface investigations, both preliminary and final. The actual type of subsurface investigation, depth, location, and frequency of all testing locations shall be based on project specific information. Subsurface investigations shall also indicate the testing intervals to be used if different from the standard intervals contained in this Chapter. The specific process requirements for conducting field and laboratory testing are contained in Chapter 5. The requirements of this Chapter shall be applied to all projects prepared by or provided to SCDOT (regardless of contracting method including encroachment permit requests).

The subsurface investigation shall include all backup documentation available. This backup documentation may include, but is not limited to, previous soil borings in the general vicinity of the project; USDA soils maps, USGS topographic maps, aerial photographs, existing plans, and wetland inventory maps. In addition, the backup documentation should include information pertaining to the existence or extent of geologic conditions (including but not limited to artesian conditions, karstic formations, etc.) that may be present at the project site or in the immediate vicinity of the site that may affect the project. Further, geologic conditions shall be noted on the boring records and the geotechnical reports shall discuss the impacts of geologic conditions on the construction of the project.

A detailed subsurface investigation plan (including preliminary and final explorations, if possible) shall be prepared prior to the commencement of any field operations. For consultant projects, regardless of contracting method, the GEC shall submit the subsurface investigation plan to the respective RPG/GDS, for review and acceptance. The RPG/GDS will approve any deviations from the standards established in this Chapter. The plan shall describe the anticipated soil or rock stratification as the basis of the planned exploration and shall outline the proposed testing types (borings/soundings), depths, and locations of all testing. The subsurface investigation plan shall conform to the requirements of this Manual. In addition, the GEC is responsible for ascertaining that all testing locations are clear of utilities and shall prepare and submit an encroachment permit with the respective RME for all testing locations located within the SCDOT Right-of-Way (ROW). The encroachment permit application will follow the guidelines established by SCDOT. For all testing locations located outside of the SCDOT ROW, prepare an access permission request (see GDF 004 in Appendix A) indicating all testing locations and forward the request to SCDOT Right-of-Way Office (ROWO). The ROWO will obtain the necessary access permissions for the affected property owners and will inform the RPG/GDS once these permissions have been obtained or not. Frequently, explorations must be conducted in sensitive environmental areas or in high hazard traffic areas. The GEC's exploration plan shall describe any special access requirements or traffic control requirements necessary to protect the interests of SCDOT during the field investigation phase and shall be included with the encroachment permit

application. The GEC is responsible for all special access requirements and traffic control and shall coordinate these activities with the RME. All traffic control shall conform to the latest Department guidelines.

## 4.2 SUBSURFACE INVESTIGATION

Subsurface investigations are typically conducted in 2 phases; preliminary and final. The location and spacing of all testing locations shall be coordinated between the preliminary and final subsurface investigations. The preliminary subsurface investigation should be conducted early enough in the design process to assist in the selection of foundation types, in determining location and length of the bridge/structure, and in identifying areas requiring additional exploration during the final exploration. The testing locations for the preliminary subsurface investigation should be easily accessible and within the current SCDOT ROW. The final subsurface investigation should take into account the testing locations from the preliminary subsurface investigation. Boring locations that require construction of access entry ways shall be provided to the Environmental Services Office (ESO) for inclusion in a Programmatic Categorical Exclusion (CE). Coordinate with the ESO to determine what documentation will be required. The requirements for the preliminary and final subsurface investigations, including frequency and spacing of testing locations, are presented in the following Sub-sections and Sections.

### 4.2.1 Preliminary Subsurface Investigation

The purpose of the preliminary subsurface investigation is to collect enough basic information to assist in development of preliminary plans. The results of the preliminary subsurface exploration shall be presented as indicated in Chapter 21. The testing locations should be located in readily accessible locations within the SCDOT ROW and should, as indicated previously, be coordinated with the final subsurface investigation. Any testing locations that need to be located outside of the SCDOT ROW will require coordination with the ESO and the ROWO to determine what documentation will be required. The preliminary subsurface investigation shall include the collection of shear and compression wave velocity data to depths of at least 100 feet beneath the existing ground surface, but may be extended to the practical limit of the equipment used to measure the shear or compression wave velocities. There are two exceptions, the first is for bridges that meet the requirements to be a “Low Volume Bridge” (see PCDM-11) where collection of shear and compression wave velocities is not required. . PCDM-11 is available on the SCDOT website, under Business, Construction Standards, Preconstruction Design Memorandums. The second is if in the opinion of the GEOR that materials meeting the requirements of the B-C Boundary (see Chapter 12) will be encountered at a shallower depth, then the collection of shear and compression wave velocities may terminate at a shallower depth. However, the second exception shall be approved in writing from the OES/GDS. Perform 1 shear and compression wave velocity test for bridges with a length of less than or equal to 500 feet. For bridges with lengths greater than or equal to 1,000 feet perform 1 shear and compression wave velocity test per 500 feet of bridge. For bridges between 500 and 1,000 feet contact the OES/GDS for guidance. In addition, if surface methods are used to determine the shear wave velocity, then either testing shall be conducted adjacent to a proposed boring or a boring shall be performed in the area of the surface method. The shear wave velocity profile shall be calibrated with the boring and collected shear wave velocities shall be used as described in Chapter 12. Compression wave velocities shall not be obtained for Operational Classification (OC) III bridges (see Seismic Specs for definitions of OC) located within the Piedmont Geologic Physiographic Province.

The preliminary subsurface investigation shall include a laboratory testing program that will consist primarily of index testing. For bridge and structure borings, index testing shall be performed on all of the samples collected that have an $N_{60}$ less than or equal to 35 blows per foot (bpf) and having an estimated age of Pleistocene and younger. The exceptions to this are if the compression wave velocity is less than or equal to 3,500 feet per second (i.e. $V_p \leq 3{,}500$ fps) or if the bridge has a Seismic Design Category (SDC) of A, as defined in the Seismic Specs, and the PGA is less than or equal to 0.20g (PGA $\leq$ 0.20g), then an SSL analysis will not be required (see Chapter 13). In addition, this testing shall not be required for "Low Volume Bridges". The GEOR shall determine how many index tests will be performed. Index testing shall consist of the following tests:

- Grain-size Distribution with wash No. 200 Sieve
- Moisture-Plasticity Relationship Determination (Atterberg Limits)
  - Performed only on samples with more than 20 percent passing #200 sieve
- Natural Moisture Content

The geologic age shall be estimated using the information presented in Chapter 11 and other publically available geologic information or literature. All publically used resources shall be documented in accordance with accepted industry reference standards.

The laboratory testing program shall also include grain-size analysis, including hydrometer, on all soil samples within the upper 15 feet of the bottom of the water crossing. However, if the scour depth and/or elevation is known or estimated and is deeper than 15 feet below the bottom of the water crossing, then grain-size analysis including hydrometer will be conducted to this scour depth and/or elevation. This analysis is required in determining the amount of scour predicted for a bridge over a body of water and shall be provided to the HEOR; however, the HEOR shall be consulted to determine if this analysis is required. If the analysis is required, the GEOR and HEOR shall discuss the proposed locations of the soil testing locations and sample depths from where the grain-size analysis with hydrometer shall come from.

Electro-chemical testing (pH, resistivity, chloride, and sulfate testing) shall be performed to determine the potential impacts of the soils, groundwater, and surface water on the structural components. Electro-chemical testing of soil samples should be considered from the existing ground surface to a depth of at least 6 pile diameters below the groundwater interface or 3 feet below the deepest anticipated groundwater depth, whichever is deeper. Surface water shall also be tested in coastal regions where the potential intrusion of brackish (higher salinity) water may occur in tidal streams. In addition, surface water shall also be tested when in the opinion of the GEOR there is potential source of environmental concern along a stream or river. A field resistivity test may also be conducted in addition to laboratory resistivity testing.

In addition, a composite bulk sample shall be obtained of the existing embankment material. The composite sample shall have the following laboratory tests performed:

- Moisture-density Relationship (Standard Proctor)
- Grain-size Distribution with wash No. 200 Sieve
- Moisture-Plasticity Relationship Determination (Atterberg Limits)
  - Performed only on samples with more than 20 percent passing #200 sieve
- Natural Moisture Content
- Direct Simple Shear Test

  - Performed only on samples with less than or equal to 20 percent passing #200 sieve
  - Sample remolded to 95 percent of Standard Proctor value
  - Sample moisture content shall be between -1 percent to +2 percent of optimum moisture content
- Consolidated-Undrained Triaxial Shear Test with pore pressure measurements
  - Performed only on samples with more than 20 percent passing #200 sieve
  - Sample remolded to 95 percent of Standard Proctor value
  - Sample moisture content shall be between -1 percent to +2 percent of optimum moisture content

For projects located in the Piedmont Physiographic Province unconfined compression testing of rock core samples is required. The unconfined compression testing should be performed on more than 50 percent of the rock cores with lowest Rock Quality Designation (RQD). Provided enough sample is available to meet the length to diameter ratio required for testing. The remaining unconfined compression tests shall be performed on rock cores with the highest RQD values and the longest coring rates (see Chapters 5 and 6). While the compression results on the lowest RQD specimens will typically govern design, the compression results on the highest RQD specimens will help determine the size of the construction equipment required.

The information (i.e. field and laboratory data) collected during the preliminary subsurface investigation will be used to refine the final subsurface investigation. All field and laboratory data and any preliminary recommendations shall be reported as required in Chapter 21 and shall include a completed GeoScoping form. The preliminary geotechnical recommendations provided are used to evaluate the Design Field Review (DFR) plans. After the DFR has been conducted, a detailed final subsurface soil exploration is conducted based on the required structures or geotechnical issues identified during the DFR.

### 4.2.2 Final Subsurface Investigation

The purpose of the final subsurface investigation is to collect detailed subsurface information for use in developing final reports and construction plans. The results of the final subsurface exploration shall be presented as indicated in Chapter 21. The final testing locations shall be located along the proposed alignment of the roadway and bridge structure whether within or outside of the existing SCDOT ROW. The testing locations should be coordinated with the preliminary exploration to avoid testing in the same location and to assure that the entire construction area is adequately explored. If the preliminary subsurface investigation encounters thick deposits (i.e. strata thickness greater than 3 feet) of fine-grained very soft to firm soils, then a field vane shear test (FVST) should be performed in the layer during the final subsurface investigation. In addition, a pore pressure dissipation test should also be conducted using the electro-piezocone (CPTu). The RPG/GDS shall be contacted to provide a review and acceptance of the final subsurface investigation testing locations prior to commencement of the final subsurface investigation. At this time it will be determined if the FVST and pore pressure dissipation test is to be performed. Further, an explanation of how the FVST and pore pressure dissipation test results are anticipated being incorporated into the design shall be provided. The information collected during the final subsurface investigation shall be used to develop the final foundation and earthwork recommendations for the project.

The final subsurface investigation shall include additional laboratory analyses. These additional laboratory analyses should include additional index property testing as well as sophisticated shear and consolidation testing. Index testing (see previously presented list) should be performed on 100 percent of the samples from the borings located at the ends of the bridge and 100 feet from the end of the bridge. Further, index testing should be performed on 75 percent of the samples from the interior bridge bent borings. This testing requirement only applies to soils that have an $N_{60}$ less than or equal to 35 blows per foot (bpf) and having an estimated age of Pleistocene and younger. The exceptions previously presented still apply in the final subsurface exploration. As in the Preliminary Subsurface Exploration, if the site meets the criteria for no SSL (see Section 4.2.1 and Chapter 13), the GEOR shall determine how many index tests will be performed. The shear testing shall meet the requirements presented below. The amount of index testing outside of the limits defined previously is at the discretion of the GEOR.

- Grain-size Distribution with wash No. 200 Sieve
- Moisture-Plasticity Relationship Determination (Atterberg Limits)
  - Performed only on samples with more than 20 percent passing #200 sieve
- Natural Moisture Content
- Direct Simple Shear Test
  - Performed only on samples with less than or equal to 20 percent passing #200 sieve
  - Sample remolded to 95 percent of Standard Proctor value
  - Sample moisture content shall be between -1 percent to +2 percent of optimum moisture content
- Consolidated-Undrained Triaxial Shear Test with pore pressure measurements
  - Performed only on samples with more than 20 percent passing #200 sieve
  - Sample remolded to 95 percent of Standard Proctor value
  - Sample moisture content shall be between -1 percent to +2 percent of optimum moisture content

For projects located in the Piedmont Physiographic Province unconfined compression testing of rock core samples is required for the design of drilled shafts and drilled piles. The purpose of this rock core testing is to evaluate foundation capacity (lowest RQD) and to assist the Contractor in selecting construction equipment (highest RQD). Unconfined compression testing should be performed on rock cores with both the highest and lowest RQDs. A minimum of 10 unconfined compression tests should be performed (5 on the lowest RQD material and 5 on the highest RQD material). However, if in the opinion of the GEOR, more unconfined compressions may be performed. The GEOR should attempt to keep the number of low RQD and high RQD materials tested approximately equal. If there are not enough useable samples for the testing, the GEOR shall contact the RPG/GDS and discuss how many unconfined compression tests can be performed and on which samples. Provided enough sample is available to meet the length to diameter ratio required for testing. While the compression results on the lowest RQD specimens will typically govern design, the compression results on the highest RQD specimens will help determine the size of the construction equipment required.

## 4.3 SUBSURFACE INVESTIGATION METHODS

This Section discusses the number, location and anticipated depth of all testing locations. As indicated previously, the preliminary and final subsurface investigations shall be coordinated to assure that the complete structure (whether bridge or roadway embankment) is adequately explored. The frequency and spacing of test locations will depend on the anticipated variation in subsurface conditions and the type of facility to be designed. A surveyor licensed pursuant to the laws of South Carolina shall locate (station, offset, and GPS coordinates (latitude and longitude)) and establish ground elevation at all testing locations using NAVD 88. If a different datum is used, the GEOR shall indicate which datum was used and explain why it was used. The testing location frequency/spacing and depth criteria indicated below are the minimum requirements. Any requests to deviate from these minimum requirements shall be made in writing and shall be forwarded to the RPG/GDS for consideration and acceptance. All testing shall be to a sufficient depth to effectively evaluate the appropriate limit state conditions and shall fully penetrate any formation that will affect performance (e.g., settlement or slope instability of a roadway embankment or roadway structure). Soil test borings, CPTu soundings, FVST and/or dilatometer (DMT) soundings are to be conducted at test locations. No more than half of the testing locations can be CPTu or DMT soundings. The use of “soil test boring” shall include the Standard Penetration Test (SPT) unless specifically indicated otherwise. In addition, 1 soil test boring shall be performed adjacent to a CPTu sounding to allow for correlation of the CPTu sounding to the actual soils encountered on site. Further, this soil test boring shall be continuously sampled for the upper 50 feet and sampled every 5 feet thereafter to the anticipated depth of CPTu sounding or to the actual termination depth of CPTu sounding, whichever is shallower. The soil test boring shall be located no more than 5 feet from the location of the CPTu sounding and shall be at the same approximate elevation as the CPTu sounding.

Soil test borings shall include the SPT and the SPTs shall be conducted as indicated in Chapter 5. Since SPT samples are highly disturbed, these samples can only be used for index and classification testing. If high quality consolidation and shear strength data are required then undisturbed samples will be required. The collection of undisturbed samples (location and depth) shall be determined by the GEOR of the project. Wash rotary drilling methods (see Chapter 5) shall be used for projects in the following counties: Aiken, Allendale, Bamberg, Barnwell, Beaufort, Berkeley, Calhoun, Charleston, Chesterfield, Clarendon, Colleton, Darlington, Dillon, Dorchester, Florence, Georgetown, Hampton, Horry, Jasper, Kershaw, Lee, Lexington, Marion, Marlboro, Orangeburg, Richland, Sumter, and Williamsburg. These counties are typically located within the Coastal Plain Physiographic Province of South Carolina, with the remaining South Carolina Counties located in the Piedmont Physiographic Province of South Carolina (see Chapter 11 for a detailed geologic discussion). However, the Coastal Plain extends into Edgefield, Fairfield, Lancaster and Saluda Counties, even though these counties are normally considered to be Piedmont counties; therefore, for those portions of these counties that are located in the Coastal Plain, wash rotary drilling methods shall be required. Variations to this requirement shall be made in writing and shall be forwarded to the RPG/GDS for review and concurrence.

In areas of difficult access (e.g., wetland areas or areas that contain streams or creeks) beneath proposed fill embankments or along crossline pipes, manual augers (MA) with dynamic cone penetrometers (DCPs) may be utilized to evaluate undercutting requirements. The DCPs should be performed approximately on 1 foot increments.

### 4.3.1 Bridge Foundations

All bridges (vehicular, pedestrian, wildlife, etc.) shall have soil testing taken at each end bent and at interior bents to meet the minimum geotechnical site investigation indicated below:

**Table 4-1, Bridge Foundation Minimum Requirements**

| Bridge Foundation Type | Minimum Geotechnical Site Investigation |
|---|---|
| Pile Foundation | Minimum 1 testing location per interior bent[1,2] |
| | Minimum 2 testing locations per end bent[3,4] |
| Single Foundation - Drilled Shaft (hammerhead) | Minimum 1 testing location per foundation location |
| Multiple Foundation – Drilled Shaft | Minimum 2 testing locations per bent location[5,6] |
| Shallow Foundation – Founded on Soil | Minimum 3 testing locations per bent location |
| Shallow Foundation – Founded on Rock | Minimum 2 testing locations per bent location |

[1]Spacing between testing locations may be increased, but shall be approved prior to field operations and shall include justification; spacing may not exceed 100 feet except on pedestrian bridges where the spacing may not exceed 200 feet, longitudinally.
[2]An additional boring shall be required if the interior bent width is 100 feet or more. The bent length is typically transverse to the centerline of the bridge.
[3]One testing location shall be a soil test boring.
[4]Includes both driven and drilled piles. Drilled piles are only allowed at end bents. Prior approval of the OES/GDS and the OES/SDS shall be required prior to using drilled piles at interior bents.
[5]An additional boring is required if 5 or more drilled shafts will support the bent/footing. To reduce design and construction risk due to subsurface condition variability and the potential for construction claims, at least 1 exploration per shaft should be considered for large diameter shafts (e.g., greater than 5 ft in diameter), especially when shafts are socketed into bedrock.
[6]Minimum 1 testing location per bent is allowed in Aiken, Allendale, Bamberg, Barnwell, Beaufort, Berkeley, Calhoun, Charleston, Chesterfield, Clarendon, Colleton, Darlington, Dillon, Dorchester, Florence, Georgetown, Hampton, Horry, Jasper, Kershaw, Lee, Marion, Marlboro, Orangeburg, Sumter, and Williamsburg Counties.

All boring/soundings taken for deep foundations shall extend below the anticipated pile or drilled shaft tip elevation a minimum of 3 times the diameter/width of the shaft/pile or a minimum of 2 times the minimum pile group dimension, whichever is deeper, but no less than 10 feet below the anticipated pile or drilled shaft tip elevation.

All boring/soundings taken for shallow foundations shall extend beneath the anticipated bearing elevation to the Depth of Significant Influence (DOSI) as indicated in the following table:

**Table 4-2, Minimum DOSI**

| Shallow Foundation Case | Minimum Testing Depth[1] |
|---|---|
| $L < 2B$ | 2B |
| $2B \leq L \leq 5B$ | 3B |
| $5B < L < 10B$ | 4B |
| $10B \leq L$ | 6B |

[1]Beneath the anticipated bearing elevation
L = Length of spread footing; B = Width of spread footing (minimum side dimension of footing)

All bridge foundations (deep and shallow) bearing on rock shall have a minimum of 10 feet of rock coring or the minimum testing depth requirements listed above, whichever is greater. It is highly recommended to have rock coring done as close to the proposed shaft or pile location as possible. South Carolina geology can have a rock formation that changes in a number of feet along the length or the width of the bridge.

#### 4.3.1.1 Bridge Scour Analysis Requirements

As indicated previously, approximately 75 percent of the soil samples obtained from beneath a stream channel shall have grain-size with wash #200 Sieve analyses performed. The GEOR shall coordinate with the HEOR on the need for conducting hydrometer analyses. This testing should be performed at both end bents, regardless of whether the bridge is single span or multi-span, from depths that approximate the bottom of the stream channel and extend to a depth of least 15 feet below the approximate bottom of the stream channel. However, if the scour depth and/or elevation is known or estimated and is deeper than 15 feet below the bottom of the water crossing, then additional grain-size analysis including hydrometer will be conducted to this scour depth and/or elevation. For multi-span bridges, laboratory testing samples shall be obtained from the SPT samples obtained from the soil test borings located at the interior bent locations to the depths described previously. For a single span bridge, perform a soil test boring to a depth of least 15 feet beneath the approximate bottom of the stream channel, if requested by the HEOR. If the approximate bottom of the stream channel for single span bridge is comprised of very dense or hard soils, then extend the boring to a depth of 10 feet beneath the bottom of the stream channel unless otherwise requested by the HEOR. For stream channels, beneath single span bridges, that are comprised of rock, extend the boring to a depth of 5 feet for rock with a Rock Quality Designation (RQD, see Chapter 6) greater than 0. For rock with a RQD equal to 0 extend the boring 10 feet. The GEOR shall coordinate with the HEOR concerning the requirement for a soil test boring in the interior of a single span bridge. This boring may be extended to a deeper depth if the scour depth and/or elevation is preliminarily estimated to be deeper than 15 feet. Similarly to the soil samples obtained from the end bents, all of the soil samples obtained from this boring shall have grain-size including hydrometer analyses performed to a depth of 15 feet below the approximate bottom of the stream channel. The results of the laboratory testing shall be reported as indicated in Chapter 7.

### 4.3.2 Earth Retaining Structures

All ERSs shall have a minimum of 2 testing locations per ERS with additional testing locations performed at least every 50 feet along the ERS line, if the ERS is within 100 feet of bridge abutments. ERSs more than 100 feet from the bridge abutment shall have a minimum of 2 testing locations per ERS with additional testing locations performed at least every 100 feet along the ERS line. ERSs with heights of less than 5 feet do not require a geotechnical exploration unless in the opinion of the GEOR an exploration is warranted, or if the ERS is part of a compound slope (i.e. the ground surface either slopes up from the top of the wall or slopes down from the bottom of the wall (see Figure 18-18)). Mechanically Stabilized Earth (MSE) walls shall have testing locations at both the wall line and within the reinforced zone at the same intervals specified above. The testing locations within the reinforced zone shall be located approximately a distance equal to the wall height from the wall line. In addition, all anchored walls shall have testing locations at both the wall line and within the anchored zone at the same intervals specified above with the testing locations within the anchored zone located approximately a distance equal to the height

of the wall from the wall line. The testing at the locations indicated shall extend to depths sufficient to effectively evaluate all the limit states for the roadway structure. At a minimum, the testing locations shall extend to a depth of at least twice the height of the wall beneath the anticipated bearing elevation or to auger refusal, whichever is shallower.

### 4.3.3 Embankments

All roadway embankments that do not meet the requirements of Table 4-3 shall have 1 testing location at least every 500 feet along the roadway embankment. In addition at the discretion of the GEOR, testing locations along the roadway embankment may be performed at a closer interval. Roadway embankments meeting the requirements of Table 4-3 are not required to be explored; however at the discretion of the GEOR borings may be performed within these embankments (meeting the requirements of Table 4-3) if areas are noted during the site visit that may adversely affect the performance of the embankment. In addition, the bridge embankment (embankments within 100 feet of a bridge end) shall have a minimum of 3 testing locations; 2 at the bridge end (which are also used for bridge foundation design) and 1 at a point 100 feet from the bridge end. The testing location 100 feet from the bridge end must be extended to a depth that is sufficient to effectively evaluate the Extreme Event (EE) I limit state for the bridge embankment design (i.e. the side and end slopes).

**Table 4-3, No External Slope Stability Analysis**

| Embankment Slope | Total Embankment/Slope Height[1] |
|---|---|
| 2H:1V | $\leq$ 10 ft |
| 3H:1V or flatter | $\leq$ 15 ft |

[1]Includes the design scour depth, if scour present

Reinforced Soil Slopes (RSS) located outside of the bridge embankment shall have a minimum of 2 testing locations, with 1 test located at either end of the RSS section, with additional testing locations added for every 200 feet of RSS length. The testing locations shall extend to a sufficient depth to effectively evaluate the performance of the embankment. RSSs beyond the bridge embankment shall not be analyzed for the EE I limit state. RSSs that are bridge embankments shall have 1 test located every 100 feet of total RSS length, in addition, to the soil test borings located at either end of the RSS. These testing locations within the bridge embankment shall extend to a sufficient depth to effectively evaluate all limit state conditions.

### 4.3.4 Cut Excavations

All cut excavations having an exposed height of 5 feet or greater shall have 1 test location performed to the depths indicated below. Cut excavations greater than 300 feet in length shall have 2 test locations per cut excavation with additional testing locations performed at least every 300 feet along the cut area. All testing locations shall be performed to a depth of at least twice the depth of the cut below the anticipated bottom depth of the cut or to auger refusal, whichever is shallower. Begin rock coring operations at auger refusal. Rock coring is to extend to at least 5 feet below the anticipated bottom depth of the cut. In addition, perform a compression wave test within all areas of cut greater than 5 feet for sites located in the Piedmont Geologic Physiographic Province (see Chapter 11).

Collect a composite bulk sample from the area of the cut excavations, but no less than every 300 feet. The composite sample shall have the following laboratory tests performed:

- Moisture-density Relationship (Standard Proctor)
- Grain-size Distribution with wash No. 200 Sieve
- Moisture-Plasticity Relationship Determination (Atterberg Limits)
  - Performed only on samples with more than 20 percent passing #200 sieve
- Natural Moisture Content
- Direct Simple Shear Test
  - Performed only on samples with less than or equal to 20 percent passing #200 sieve
  - Sample remolded to 95 percent of Standard Proctor value
  - Sample moisture content shall be between -1 percent to +2 percent of optimum moisture content
- Consolidated-Undrained Triaxial Shear Test with pore pressure measurements
  - Performed only on samples with more than 20 percent passing #200 sieve
  - Sample remolded to 95 percent of Standard Proctor value
  - Sample moisture content shall be between -1 percent to +2 percent of optimum moisture content

### 4.3.5 Culverts/Pipes

New pipes and culverts that cross the project alignment in a transverse direction (i.e., an open drainage system), with a current ADT $\geq$ 5,000 vehicles per day (Average Daily Traffic; vpd), having a diameter or an inside cross-sectional dimension greater than or equal to 48 inches, and are being founded at or below the original grade, shall have a minimum of 1 test location at each end of the pipe or culvert and every 100 feet along the pipe or culvert. Pipe and culvert extensions, having a diameter or an inside cross-sectional dimension greater than or equal to 48 inches, shall have a minimum of 1 test location at each extension. For extensions greater than 50 feet, testing locations shall be spaced every 50 feet. All testing locations shall extend to a depth sufficient to effectively evaluate all limit states as directed by the SEOR and/or the HEOR. The testing depths shall be measured from the anticipated bearing elevation. Testing may be terminated above the anticipated depth if auger refusal is encountered. For all other pipe and culverts (smaller diameter, less ADT, etc.) that are founded within the proposed embankment or that run parallel (longitudinal) (i.e., a closed drainage system) to the roadway centerline, the exploration requirements shall conform to the requirements for embankments. Pipe and culverts located in the Piedmont Counties (see Chapter 11) having a diameter or an inside cross-sectional dimension greater than or equal to 48 inches that are to be founded in the existing subgrade and that run parallel (longitudinal) (i.e., a closed drainage system) to the roadway centerline shall have test locations every 500 feet. Where shallow rock is anticipated, extend the testing method to a depth of 5 feet deeper than the proposed invert elevation or to auger refusal, whichever is shallower. The DME or the RME may request additional testing locations for smaller diameter pipes and culverts. The subsurface investigation should attempt to characterize possible unsuitable soil conditions for which pipes and culverts are anticipated to be founded in.

### 4.3.6 Sound Barrier Walls

Sound barrier walls may be supported by either shallow foundations or deep foundations. Testing locations for sound barrier walls shall be placed at the beginning and ending of the wall, at the location of major changes in the wall alignment and at a maximum spacing of 200 feet. For sound barrier walls located on top of a berm, the testing locations shall extend a minimum of twice the berm height plus twice the height of the proposed sound barrier wall for shallow foundations and shall extend to a depth sufficient to effectively evaluate the appropriate limit state requirements for this type of foundation. For sound barrier walls not located on top of a berm, the testing locations shall extend a minimum of twice the height of the proposed sound barrier wall for shallow foundations and shall extend to a depth sufficient to effectively evaluate the appropriate limit state requirements for this type of foundation. If deep foundations are used to support the sound barrier walls, the testing shall extend a minimum of 5 feet beneath the anticipated deep foundation tip elevation.

### 4.3.7 Ground Improvement Methods

Certain ground improvement methods will require additional geotechnical investigations, both in the field as well as in the laboratory. The GEOR is required to understand which ground improvement methods require additional geotechnical investigation and to establish the scope of services required to meet the requirements for the anticipated ground improvement method. The additional geotechnical investigation may be conducted during the Final Subsurface Investigation, but may also need to be conducted in a Supplemental Subsurface Investigation. Prior approval will be required for all Supplemental Subsurface Investigations.

### 4.3.8 Miscellaneous Structures

Miscellaneous structures such as overhead signs and light poles should have a minimum of 1 test location performed per foundation location unless directed otherwise by the OES/GDS. All test locations shall extend to the same depth criteria as specified for the bridge test locations for the same type of foundation.

### 4.3.9 Pavement Structures

Subsurface investigation requirements for pavement structure design vary with location, traffic level, and project size. Requirements for pavement structure design subsurface investigations are provided in SCDOT's Pavement Design Guidelines (latest edition), which is published by the Office of Materials and Research (OMR). Contact the OMR Geotechnical Materials Engineer for further information.