Chapter 21

GEOTECHNICAL REPORTS

GEOTECHNICAL DESIGN MANUAL

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CHAPTER 21

GEOTECHNICAL REPORTS

21.1 INTRODUCTION

This Chapter presents the requirements for the preparation of geotechnical reports that will be used to design projects both by and for SCDOT. Geotechnical reports are prepared to convey information concerning subsurface conditions, foundations and construction considerations (plan notes) to other members of the project team. SCDOT uses 5 basic types of reports to convey geotechnical and site-specific seismic response information.

- Geotechnical Subsurface Data Report - GSDR
- Geotechnical Baseline Report - GBR
- Preliminary Geotechnical Engineering Report
    - Bridge – PBGER
    - Road - PRGER
- Final Geotechnical Engineering Report
    - Bridge – BGER
    - Road - RGER
- Site-Specific Seismic Response Analysis Report - SSRA

The GSDR is used to convey geotechnical information on traditional (design-bid-build (DBB)) projects and is typically included in the construction information to supply the Contractor with available geotechnical data. The GBR is primarily issued in conjunction with Design/Build (D/B) projects. Typically a bridge replacement project will have both Bridge and Roadway Geotechnical Engineering Reports (Preliminary and Final) prepared. At the discretion of the GEOR, a single GER may be issued that covers both Bridge and Roadway. However, if combined both a Preliminary (PGER) and Final (GER) is recommended. In addition, some bridge replacement projects may not require a RGER, while some road projects may not require a BGER. The OES/GDS should be contacted if there is a question concerning whether a report (Roadway or Bridge) is required. Typically, a PBGER and PRGER will be issued for the project prior to the Design Field Review (DFR). A BGER and RGER are issued at the completion of final field operations and generally after the DFR. In some circumstances a Site-Specific Response Analysis Report (SSRA) is prepared to provide an in-depth discussion of the seismic response of a specific site. The following Sections discuss each of the types of reports used by SCDOT.

To assist SCDOT in the handling and distribution of the various geotechnical documents, all reports shall be named using the following, where XXXXX is the project name:

- GSDR – XXXXX (e.g., GSDR – RBO 12 Mile Creek)
- GBR – XXXXX (e.g., GBR – Port Access Road)
- PRGER – XXXXX (e.g., PRGER – RBO 12 Mile Creek)
- PBGER – XXXXX (e.g., PBGER – RBO 12 Mile Creek)
- RGER – XXXXX (e.g., RGER – RBO 12 Mile Creek)
- BGER – XXXXX (e.g., BGER – RBO 12 Mile Creek)
- SSRA – XXXXX (e.g., SSRA – RBO 12 Mile Creek)

21.2 GEOTECHNICAL INFORMATION REPORTS

21.2.1 Geotechnical Subsurface Data Report - GSDR

The GSDR is used to convey only factual geotechnical subsurface information to the project team as well as the selected construction Contractor and is typically used with traditional DBB projects. A GSDR does not provide any engineering analysis (preliminary or final). Engineering interpretation in the GSDR shall be limited to the determination, by the GEOR, and placement of geologic formation names on the soil test boring records. In addition, subsurface profiles may be included in the GSDR. These subsurface profiles may contain stratigraphic lines, provided the lines have been developed by the GEOR. If stratigraphic lines are included with the profile, a statement indicating that the lines are the interpretation of the GEOR should be included. However, for GSDRs used on D/B projects neither the geologic formation names nor the stratigraphic lines on the subsurface profile shall be provided. A GSDR shall include an introduction, a project description and any procedural variations from the field or laboratory testing methods as described in this Manual. The Appendices should at a minimum contain project and testing location plans, the completed GeoScoping form (also called a Site Reconnaissance form), field exploration records (soil test boring logs, cone penetrometer and dilatometer records, etc.), and the results of all laboratory testing. Each field exploration record should contain the testing location and should correspond to the testing location plan. The laboratory testing results should indicate the location and depth of each sample clearly on the test result. In addition, all laboratory testing results should be presented in a tabularized format as a summary prior to the results of individual testing being presented. All field and laboratory testing records shall conform to the requirements of this Manual. A draft GSDR will be submitted to the Department for review. Upon completion of review and editing the final GSDR will be submitted in accordance with the submission requirements of this Chapter. A copy of the final GSDR should be sent to the Letting Preparation Engineer or the designated representative for inclusion in the Contract Documents.

21.2.2 Geotechnical Baseline Report - GBR

The GBR is used to provide limited (preliminary) geotechnical information on a D/B project, thus permitting the contractor to bid on the project with a certain degree of knowledge and acceptable risk. A GBR provides limited engineering interpretations or very preliminary engineering recommendations. The GBR should be used in conjunction with project specific D/B criteria. The GBR should contain at a minimum an introduction, project description, objective and scope of the geotechnical exploration and general recommendations concerning foundations and/or ground improvement requirements. In addition, the GBR should include the final ADRS curve to be used on the project if possible. Further the GBR should also indicate if soils having the potential for SSL are present on site and if any ground improvement may be required. Any procedural variations from the field testing methods as described in this Manual should be discussed or mentioned. The narrative portion of this type of report is anticipated to be relatively short, with the Appendices of the report being large. The Appendices should at a minimum contain project and testing location plans, the completed GeoScoping form (also called a Site Reconnaissance form), field exploration records (soil test boring logs, cone penetrometer and dilatometer records, etc.), and the results of all laboratory testing. All field and laboratory testing records shall conform to the requirements of this Manual. Each field exploration record should contain the location of the testing and should correspond to the testing location plan. Any guides used to interpret the data should also be included. The laboratory testing results should indicate the location and depth of each sample clearly on the test result. Any procedural variations from the laboratory testing methods described in this Manual should be indicated. A draft GBR shall be submitted to the Department for review. Upon completion of review and editing the final GBR should be submitted in accordance with the submission requirements of this Chapter.

21.3 BRIDGE GEOTECHNICAL ENGINEERING REPORTS

The Bridge Geotechnical Engineering Reports provide geotechnical information related specifically to the design of the bridge and shall include a discussion of the foundations and the bridge embankment. The contents of both preliminary (PBGER) and final (BGER) geotechnical engineering reports are described in the following Sections.

21.3.1 Preliminary Bridge Geotechnical Engineering Report - PBGER

The purpose of the PBGER is to provide the SEOR and the design team with preliminary information that may be used in the preliminary design of the bridge project. Typically, the preliminary report is issued prior to the DFR so that the information can be used during the field review and in development of preliminary bridge plans. The preliminary report should include, at a minimum, the following items:

a. General Project Information
b. General Geology
c. Soils Encountered
d. Seismic
   + Acceleration Design Response Spectrum (ADRS)
   + SSL Results
e. Bridge Embankment
   + Preliminary slope stability analysis
   + Preliminary settlement analysis
   + Construction Difficulties
   + Temporary Shoring
f. Bridge Foundations
   + Type and Size
   + Preliminary input files for LPILE
   + Construction Difficulties
   + Vibration Monitoring Assessment
   + Corrosion Potential Results
g. Geohazards
   + Mucking requirements
   + Potential for long waiting periods for settlement
   + Preliminary ERS Selection Matrix
   + Preliminary Ground Improvement Selection Matrix
   + Karst voids/sink holes
   + Artesian conditions

Items a through c above should be used to provide a general description of the project and the soils encountered; in depth details are not required. The preliminary seismic information consists of the ADRS curve and the results of SSL analysis. The ADRS and SSL analysis are conducted in accordance with the procedures provided in Chapters 12 and 13. The ADRS may be either preliminary or final depending on the number of testing locations, depth of testing and type of geotechnical exploration. The design seismic event for bridges is based on the classification of the bridge. Typically the SEE is the primary design seismic event for most bridges in South Carolina. However, certain classifications of bridges require both the SEE and the FEE as the design seismic event (refer to the Seismic Specs). The SSL analysis will be based on the available ADRS curve, design seismic event and the available soil information.

Preliminary slope stability analysis of the end slopes at the bridge location is based on the slopes indicated on the preliminary bridge plans. The preliminary stability analysis is performed in accordance with the procedures outlined in Chapter 17. The purpose of this analysis is to determine if the designed embankment slope will achieve the required stability or if a flatter slope or reinforcement is required. A flatter slope may cause the bridge to become longer. The settlement analysis should provide an indication of the amount and time anticipated for settlement to occur, because these factors may have an impact on the construction of the project. Further any settlement located at the end slopes will induce downdrag on the end bent piles. The results of the preliminary settlement analysis and any impacts to the bridge should be discussed in the PBGER. Any potential construction difficulties, such as mucking/undercutting, should be identified and preliminarily discussed in the PBGER. In addition, the impact of the preliminary SSL analysis shall be discussed including any impacts to the bridge foundation system including but not limited to downdrag, slope instability, the requirement for ground improvement, include a discussion of the Ground Improvement Selection Matrix, to mitigate SSL, etc.

The bridge foundations provided in the preliminary report are limited to type and size. Actual capacity determinations are not made until the completion of all field work. If there are limitations in the foundation type, the limitations should be defined as part of the preliminary report; therefore, aiding the SEOR and the design team in the final selection of foundations. The preliminary LPILE input files should be a first estimate based on the results of the preliminary subsurface exploration. The preliminary LPILE input files may require revision based on the results of the final exploration. Any potential construction difficulties, such as anticipated hard driving or the requirement for ground improvement, should be reported. In addition, a preliminary evaluation of the potential need for vibration monitoring should be reported. The corrosion potential of soils, groundwater and surface water, as applicable, should also be provided in the PBGER for use by the SEOR.

The PBGER shall also include a preliminary discussion of potential construction issues, which include, but are not limited to, mucking requirements, anticipated waiting periods to allow for settlement to occur and if ERSs (temporary or permanent) should be anticipated including a discussion of the results of the ERS Selection Matrix. The mucking requirements should identify the need for mucking and an approximate area and depth. The mucking requirements may be based on visual observation of the project site.

The Appendix should include the results of field testing related to the bridge, any laboratory work, and the ADRS curve. In addition, a field testing location plan and the completed GeoScoping form (also called a Site Reconnaissance form) should be provided. In addition, the results from preliminary SSL and slope stability analyses shall also be provided. The Appendix should also contain a copy of the ERS and/or Ground Improvement Selection Matrix as required. For in-house projects, the locations of field tests are typically presented on the Bridge Plan and Profile sheet. In addition, during the preparation of the PBGER, results of hydrometer and grain-size tests are forwarded to the OES/HDS for use in scour studies for the bridge project.

21.3.2 Final Bridge Geotechnical Engineering Report (BGER)

The BGER is produced after completion of all field work and receipt of loading information from the SEOR (see GDF 001 in Appendix A). The BGER should contain detailed information about the project. This report will be used by the project design team to develop the final design for the bridge project.

The BGER should include a detailed description of the project to include bridge length, structure type, foundation type and size proposed by the SEOR and loading information. In addition to the bridge information, information describing the bridge embankments should also be provided including slope height, the length of the bridge embankment and approximate slope angle. Included with the project information should also be a discussion of the existing site conditions at the time of field work. This description should include items such as surface water, exposed rock, vegetation, etc. This is not meant to be a complete list of items describing the actual site conditions. The report should include any items that, in the opinion of the GEOR may affect design or construction. The field and laboratory testing procedures should also be discussed, but this discussion should be limited to deviations from the standard test methods (see Chapter 5). In addition, any non-standard testing procedures shall be discussed. Additionally, any corrections to in-situ testing should also be discussed as well as the results of any calibrations to the field testing equipment. The location of each testing location should also be indicated (see Table 21-1) as well as the type and number of laboratory tests (see Table 21-2). Testing procedures for non-standard tests should be included in the Appendix of the report.

Table 21-1, Soil Testing Location Table

Test Number	Test Hole Local	Station*	Offset*	Elevation** (ft)	Depth (ft)
STB-1	Road	24+99.94	16.84-R	7.24	30
STB-2	Road/Bridge	26+25.52	21.41-R	8.29	80
STB-3	Road	27+27.36	29.23-R	7.07	30
HA-1	Road	23+50.60	17.36-R	6.88	7
HA-2	Road	24+50.18	24.28-R	4.60	1.5
HA-3	Road	25+45.66	23.52-R	9.68	7
HA-4	Road	26+68.55	25.96-R	6.85	7
SCPT-1	Road/Bridge	25+45.03	14.03-R	9.00	14***
DMT-1	Road/Bridge	26+29.19	12.38-R	8.98	16***
MASW/MAM	Road/Bridge	23+75****	13-R****		210

*Indicate where station and offset are measured from (i.e., existing centerline, proposed centerline, etc.)
**NAVD 88
***Depth of refusal.
****Array centered at this station and offset.

Table 21-2, Laboratory Testing Table

Test Type	Quantity
Atterberg Limits	15
Full Sieve Analysis	15
Moisture Content	15
Organic Loss	3
Laboratory Compaction	1
Consolidation	1
Direct Shear	1
Triaxial	1
Corrosion Series	2

The next section of the BGER should consist of discussions of the area geology as it pertains to the overall project, followed by a specific discussion of the soils located at the project site. The overall geologic discussion should be limited to the geologic stratigraphic province (see Chapter 11). This discussion should be followed by a detailed discussion of the soils encountered along the bridge alignment including the bridge embankment. The subsurface conditions should be described as to the type of soil; thickness; and strength of each soil layer as represented by the field work (see Table 21-3). The soil type should be defined based on the field work as corrected with laboratory testing results. Soils that will behave mechanically similarly should be grouped together as a subsurface unit. The thickness may be based on the depth below existing grade or based on elevation. The use of elevations is the preferable way of indicating soil thickness. The soil strength may be represented as blow count or other measured indices from the field testing.

Table 21-3, Soil Stratification Table

Geologic Formation	Elevation of Top of Layer (ft)	Depth to Top of Layer (ft)	USCS Soil Type	SPT-N Values (bpf)	Average CPT Tip Resistance (tsf)	Average DMT p_1 Pressure (tsf)	Comments
Fill	+20	0	SM	3 to 6	73.9	3.8	Existing embankment
Holocene Sediment	+14	6	SM	0 to 1	22.4	3.2	Original ground surface
Cooper	+10	10	SM/ML	12 to 25	138.5	43.7	

After detailing the project information, site conditions and subsurface conditions, the next section of the BGER is the seismic design section. The seismic design section should detail the effects of the design seismic event (see Chapter 12) on the proposed bridge project. A final ADRS should be developed based on the subsurface conditions encountered. The final ADRS will be developed in accordance with Chapter 12. If SSL is indicated during the preliminary investigation, a more detailed SSL analysis is required. The SSL analysis will be conducted in accordance with Chapter 13. The detailed SSL analysis should include the extent, both horizontally and vertically, and determination of the amount of induced potential settlement. The potential settlement is accounted for in the determination of downdrag load on interior bent foundations. End bent foundations have more considerations than just downdrag of the fill materials. The stability of the bridge embankment shall be determined and discussed. The effect of the stability of the bridge embankment and its effect on the lateral stability of the end bent piles must also be addressed.

Both the lateral and vertical stability of the bridge embankment will be addressed in this report along with the effects of the stability on the end bent foundations.

After discussing the geology and seismicity of the project, the next sections of the BGER should address the bridge embankments and any ERSs if present. The results of the settlement and stability analyses performed in accordance with Chapters 17 and 18 are discussed. Provide a settlement profile transverse to the direction of travel across the embankment (see Table 21-4). If an ERS is present within the bridge embankment provide settlement profiles along the top of the ERS and transverse to the ERS at either end of the ERS, the approximate mid-point and at least every 100 feet along the ERS. The discussion should include both the static (Service and Strength limit states) and extreme events (EE I and II limit states) performance of the bridge embankment and any ERSs. The results of the analysis should be compared to the performance criteria contained in Chapter 10. If the performance criteria are exceeded, then either geotechnical (see Chapter 19) or structural remediation will be required. Further discuss the impacts of the movements induced by the EE I limit state on the bridge. The effects of the settlement should be explained and any measures required to decrease excessive time for settlement to occur should be provided.

Table 21-4, Location of Settlement Determination[1]

Left toe of slope	Right edge of pavement
Left shoulder break	Right shoulder break
Left edge of pavement	Right toe of slope
Centerline of embankment	

[1]Looking up station

After discussing the bridge embankments, the next sections of the BGER should address the foundations required to support the structure. The foundation section should include a discussion of resistance factors, including not only the resistance factors, but also how the factors were selected. Both the factored design load and nominal capacities should be provided (see Tables 21-5, 21-6 and 21-7). The notes below Tables 21-6 and 21-7 are not to be included in the BGER. The type of foundation (shallow footings, piles or drilled shafts) should be provided next, along with the size of the foundations. The depth required to achieve the nominal resistance should be provided along with the minimum depth required to achieve lateral stability. Also to be included in this section of the report are any displacements associated with Service or EE I limit state loads. This section of the report shall also indicate which limit state (Strength, Service, Extreme Event I or Extreme Event II) and which stability condition (axial – compression, axial – tension or lateral) governs the selection of foundation size and bearing depth (see Table 21-7).

Table 21-5, Bearing Resistance

Factored Design Load (includes 3 feet of backfill)	295 kips
Factored Net Bearing Resistance	4.6 ksf
Geotechnical Resistance Factor	0.45
Required Net Nominal Bearing Resistance	10.2 ksf

Table 21-6, Pile Resistance

	Strength or Service Limit State[1,2]	EE I or EE II Limit State[1,3]
Factored Design Load	112 kips[4]	152 kips[4]
Geotechnical Resistance Factor[5]	0.40	1.00
Nominal Resistance	280 kips	152 kips
Resistance from: Design Flood Scourable Soils[6] Soils undergoing static downdrag[6]	 40 kips 0 kips	NA
Resistance from Liquefiable Soils[7]	NA	220 kips
Required Driving Resistance	320 kips	372 kips

[1]Use only 1 column; middle column represents static resistance while last column represents Extreme Event resistance. Use the column that governs driving resistance.

[2]Indicate whether Strength or Service limit state controls resistance

[3]Indicate whether EE I or EE II limit state controls resistance

[4]Factored design loads include DD or DD_{SL}. Note that in this example the Strength limit state DD = 0.0 kips

[5]Use appropriate construction control resistance factor

[6]Design flood scour and static downdrag are not included with Extreme Event limit state loading conditions

[7]Full resistance that is developed by soils within the liquefiable zone during pile installation

Table 21-7, Drilled Shaft Resistance

	Strength or Service Limit State[1,2]	EE I or EE II Limit State[1,3]
Factored Design Load	1400 kips[4]	1800 kips[4]
Factored Resistance – Side	1130 kips	1430 kips
Factored Resistance – End	270 kips	370 kips
Geotechnical Resistance Factor – Side[5]	0.50	1.0
Geotechnical Resistance Factor – End[5]	0.50	1.0
Total Nominal Resistance	2800 kips	1800 kips

[1]Use only 1 column; middle column represents static resistance while last column represents Extreme Event resistance, use the column that governs resistance

[2]Indicate whether Strength or Service limit state controls resistance

[3]Indicate whether EE I or EE II limit state controls resistance

[4]Factored design loads include DD or DD_{SL}. Note that in this example the Strength limit state DD = 0.0 kips

[5]Use appropriate construction control resistance factor for static and φ_{EQ} equal to 1.0 for seismic

Table 21-8, Governing Conditions

Limit State	Loading Direction
Strength	Axial – Compression
Service	Axial – Tension
Extreme Event I	Lateral
Extreme Event II[1]	-

[1]Indicate whether EE II is induced by scour, vehicular, or vessel impact

Construction considerations should follow the discussion of the bridge embankment and bridge foundations. This section shall address the installation of the foundation and the confirmation of foundation capacity. For driven piles, this section shall include preliminary wave equation parameters that were used to confirm drivability of the piles. The range of hammer energies should be provided (see Table 21-8). For drilled shafts, any special construction considerations, such as Crosshole Sonic Logging (CSL) tubes, shall be included in this section. If shallow foundations are the recommended foundation type to support the structure, this section shall include the procedures for verifying bearing capacity.

Table 21-9, Drivability Analysis

Skin Quake (QS)	0.10 in
Toe Quake (QT)	0.08 in
Skin Damping (SD)	0.20 s/ft
Toe Damping (TD)	0.15 s/ft
% Skin Friction	80%
Distribution Shape No.	1
Resistance Distribution Model	Proportional[1]
Toe No. 2 Quake	0.15 in
Toe No. 2 Damping	0.15 s/ft
End Bearing Fraction (Toe No. 2)	0.95
Pile Penetration	80%
Hammer Energy Range	25 – 60 ft-kips

[1]Resistance Distribution Model options – proportional, constant skin friction, constant end bearing

Included in the construction considerations is a discussion of and requirements for temporary shoring as required for stage construction of either the bridge or the bridge embankment. The discussion should also include which type of shoring is or is not permitted (i.e., temporary MSE walls should not be used in a cut condition). The parameters to be used in temporary shoring design should be provided as indicated in Table 21-9.

Table 21-10, Temporary Shoring Wall Soil Design Parameters

Depth[1] (ft)	c (psf)	Phi (ϕ) (degrees)	Saturated Unit Weight (γ_{sat}) (pcf)	K_o	K_a	K_p
0-7	-	32	100	0.47	0.31	3.25
7-14	343	-	86	1.0	1.0	1.0
14-19	-	30	109	0.50	0.33	3.0
> 19	550	35	120	0.43	0.27	3.69

[1]Elevation may be substituted for Depth, if Elevation is used include appropriate units

The final section of the report consists of notes that are required to be placed on the plans. The plan notes are project specific but should include foundation capacity tables consisting of factored design loads, nominal resistances, and resistance factors. The required depth to achieve axial or lateral capacity and minimum depth if capacity is achieved prior to required depth shall be provided. This section of the report shall be tailored to the requirements of the specific project and shall provide the information required in Chapter 22. However, in GEC prepared reports, an additional report section is added that consists of any limitations to the report. This section is not required in reports prepared by the RPG/GDS.

The Appendix of the BGER should include the locations of the soil testing locations, a subsurface profile and the completed GeoScoping form (also called a Site Reconnaissance form). The soil testing reports (i.e., the boring logs and CPT sounding logs, etc.) should be followed by the report of laboratory testing. Only the testing reports that pertain to the bridge and bridge embankment should be included in the Appendix. The BGER Appendix should include the final ADRS curve and the results of the detailed liquefaction study, if performed. In addition, also include a calculation package that indicates the method of analysis used, any assumptions made and the soil parameters used. This is not meant to include the printout results from computer programs. The results of lateral pile analyses should also be included in the Appendix of the report. For projects performed by the RPG/GDS, the lateral pile analysis input screens will be provided and the SEOR will perform the actual lateral pile analysis. For GEC prepared reports, the GEC may provide a complete analysis or may provide the input for the analysis depending on the contractual relationship between the GEC and the SEOR. Further include the final ERS Selection Matrix; the final Ground Improvement Selection Matrix; and the final Pile Cost – PDAvsNo-PDA spreadsheets as separate Appendices. In addition, the Appendix of the BGER shall include any Special Provisions pertaining to geotechnical issues that are required for the project. Included in this section of the Appendix are those Special Provisions previously prepared by SCDOT as well as any Special Provisions written by the GEC. Contact the OES/GDS to determine which Special Provisions are currently available.

21.4 ROADWAY GEOTECHNICAL ENGINEERING REPORTS

The Roadway Geotechnical Engineering Reports provide geotechnical information related specifically to the design of roadway embankments and any structures other than bridges and bridge embankments. The contents of both preliminary (PRGER) and final (RGER) geotechnical engineering reports are described in the following sections.

21.4.1 Preliminary Roadway Geotechnical Engineering Report - PRGER

The purpose of the PRGER is to provide the designers with preliminary information that may be used in the preliminary design of the roadway embankment and roadway structures. Typically, the preliminary report is issued prior to the DFR so that the information can be used during the field review and in development of preliminary road plans. The preliminary report should include, at a minimum, the following items:

a. General Project Information
b. General Geology
c. Soils Encountered
d. Embankment
    + Preliminary slope stability analysis
    + Preliminary settlement analysis
    + Construction Difficulties
    + Temporary Shoring
e. Roadway Structure Foundations
    + Seismic
        Acceleration Design Response Spectrum (ADRS)
        SSL Results
    + Type and Size
    + Construction Difficulties
    + Corrosion Potential Results
f. Geohazards
    + Mucking requirements
    + Potential for long waiting periods for settlement

+ Preliminary ERS Selection Matrix
+ Preliminary Ground Improvement Selection Matrix

Karst voids/sink holes Items a through c above should be used to provide a general description of the project and the soils encountered; in depth details are not required. Preliminary slope stability analysis is based on preliminary road plans and is performed in accordance with the procedures outlined in Chapter 17. The purpose of this analysis is to determine if the designed embankment slope will achieve the required stability or if a flatter slope or reinforcement is required. The settlement analysis should provide an indication of the amount and time anticipated for settlement to occur, because these factors may have an impact on the construction schedule of the project. Any potential construction difficulties, such as mucking/undercutting, should be identified and preliminarily discussed in the PRGER.

For some roadway structures, the preliminary seismic information consists of the ADRS curve and the results of SSL analysis. The ADRS and SSL analysis are conducted in accordance with the procedures provided in Chapter 12 and Chapter 13. The ADRS may be either preliminary or final depending on the number of testing locations, depth and type of geotechnical exploration. In addition, the ADRS shall be provided for both the SEE and the FEE. The SSL analysis will be based on the available ADRS curve and the available soil information.

The need for temporary shoring to allow for staged construction of the roadway embankment should also be identified in the PRGER. The Appendix should include the results of field testing related to the road embankments, roadway structures and bridge (if present on the project), and any laboratory work. In addition, a field testing location plan, the completed GeoScoping form (also called a Site Reconnaissance form) and the ADRS curve, if required, should be provided.

21.4.2 Final Roadway Geotechnical Engineering Report - RGER

The RGER is produced after completion of all field work and receipt of revised roadway plans from the project designers based on the results of the DFR. The RGER should contain detailed information about the project. This report will be used by the project designers to develop the final design for the roadway project.

The RGER should include a detailed description of the project to include the roadway length and any roadway structures that may be required to complete the project. Included with the project information should also be a discussion of the existing site conditions at the time of field work. This description should include items such as surface water, exposed rock, vegetation, etc. This is not meant to be a complete list of items describing the actual site conditions. The report should include any items that in the opinion of the GEOR may affect design or construction. The field and laboratory testing procedures should also be discussed, but this discussion should be limited to the standard test methods used (see Chapter 5). The location of each test should also be indicated (see Table 21-1) as well as the type and number of laboratory tests (see Table 21-2). Testing procedures for non-standard tests should be included in the Appendix of the report.

The next section of the RGER should consist of discussions of the area geology as it pertains to the overall project, followed by a specific discussion of the soils located at the project site. The overall geologic discussion should be limited to the geologic stratigraphic province (see Chapter 11). This discussion should be followed by a detailed discussion of the soils encountered along the roadway alignment. The subsurface conditions should be described as to the type of soil, thickness of each soil type, and soil strength as represented by the field work. The soil type should be defined based on the field work (see Table 21-3). Soils that will behave mechanically similarly should be grouped together as a subsurface unit. The layer thickness may be based on the depth below existing grade or based on the elevation. The use of elevations is the preferable way of indicating soil layer thickness. The soil strength may be represented as blow count or other measured indices from the field testing. In addition, the longitudinal extent of each soil layer should be indicated, since longitudinal changes in soil types may affect construction.

After detailing the project information, site conditions and subsurface conditions, the next section of the RGER is the seismic design section, this section of the report only applies to roadway structures, specifically ERSs. The seismic design section should detail the effects of the design seismic event (see Chapter 12) on the proposed road project. A final ADRS should be developed based on the subsurface conditions encountered. The final ADRS will be developed in accordance with Chapter 12. The ADRS shall be based on both the SEE and FEE seismic events. If the site screens for SSL during the PRGER, a detailed SSL study is required. The SSL study will be conducted in accordance with Chapter 13. The detailed SSL study should include the extent, both horizontally and vertically, and determination of the amount of induced potential settlement. In addition, the potential for slope instability of roadway structure should also be determined.

After discussing the geology and seismicity of the project, the next sections of the RGER shall address the roadway embankments (fills and cuts) and other (i.e., culverts, overhead signs, retaining walls, etc.) roadway structures. Other roadway structures here are typically retaining walls, but may also include culverts (pipe, box or floorless), sound barrier walls and other miscellaneous structures. The GEOR is required to provide engineering recommendations for pipes and culverts with diameters equal to or greater than 48 inches. For pipes and culverts with diameters less than 48 inches the GEOR will provide the estimated SPT N-value based on the closest boring to allow for the determination of undercutting and reinforcement requirements detailed on the SCDOT Standard Drawings. The results of the settlement and stability analyses performed in accordance with Chapters 17 and 18 are discussed. The discussion shall include both the static (Strength and Service limit states) and extreme events (EE I and II limit states) performance of the roadway structure. Provide a settlement profile transverse to the direction of travel across the embankment (see Table 21-4) or along the alignment of hydraulic structures that may be present within the roadway embankment. Provide a settlement profile along all hydraulic structures having diameters equal to or greater than 48 inches and an ADT greater than or equal to 5,000 (ADT $\geq$ 5,000). If an ERS is present within the roadway embankment provide settlement profiles along the top of the ERS and transverse to the ERS at either end of the ERS, the approximate mid-point and at least every 100 feet along the ERS. The results of the analysis should be compared to the performance criteria contained in Chapter 10. If the criteria are exceeded, then site remediation will be required (see Chapter 19). In addition, this section of the report should provide the results of settlement analysis (see Chapter 17). The effects of the settlement should be explained and any measures required to decrease excessive time for settlement to occur should be provided.

Construction considerations should follow the discussion of the slope stability and settlement analyses. The material properties used during slope stability analysis should be provided in this section (see Table 21-11), because the embankment design is based on these properties being achieved during construction. If the material properties do not exceed those allowed for the specific county the project is located in, no additional information is required. Chapter 7 should be consulted for the allowable shear strengths by county. If the shear strengths must exceed those allowed in the Project County, then “Borrow Material – Controlled Fill” shall be used and the notes provided in Chapter 22 shall be used. If ground improvements are required to achieve satisfactory performance of the embankments or roadway structures, the improvements should be discussed in this section. This discussion shall include the ground improvement method, the ground improvement selection matrix, the expected result of the improvement and the procedures required for verification of the improvement.

Table 21-11, Fill Material Properties Table

Soil Property	Required Property	
	Total	Effective
Internal Friction, φ	32°	18°
Cohesion , c	150 psf	500 psf
Total Unit Weight, γ	120 pcf	

A more in-depth discussion of the requirements for temporary shoring should be included, if the temporary shoring is required for staged construction or the installation of ground improvement. The discussion shall also include what type of shoring is or is not permitted (i.e., temporary MSE walls shouldn't be used in a cut condition). The parameters to be used in temporary shoring design shall be provided as indicated in Table 21-12.

Table 21-12, Temporary Shoring Wall Soil Design Parameters

Depth[1] (ft)	c (psf)	Phi (ϕ) (degrees)	Saturated Unit Weight (γ_{sat}) (pcf)	K_o	K_a	K_p
0-7	-	32	100	0.47	0.31	3.25
7-14	343	-	86	1.0	1.0	1.0
14-19	-	30	109	0.50	0.33	3.0
> 19	550	35	120	0.43	0.27	3.69

[1]Elevation may be substituted for Depth, if Elevation is used include appropriate units

The final section of the RGER consists of notes that are required to be placed on the plans. This section of the report shall be tailored to the requirements of the specific project and shall provide the information required in Chapter 22. However, in GEC prepared reports, an additional report section is added that consists of any limitations to the report. This section is not required in reports prepared by the RPG/GDS.

The Appendix of the RGER should include the locations of the soil testing locations, a subsurface profile and the completed GeoScoping form (also called a Site Reconnaissance form). The soil testing reports (i.e., the boring logs and CPT sounding logs, etc.) should be followed by the report of laboratory testing. Only the testing reports that pertain to the embankment and roadway structures should be included in the Appendix. The RGER Appendix should include the final ADRS curves and the results of the detailed liquefaction study, if performed. The results of slope stability analyses should also be included in the Appendix of the report. Further include the final ERS Selection Matrix and the final Ground Improvement Selection Matrix as separate Appendices. In addition, the Appendix of the RGER shall include any Special Provisions pertaining to geotechnical issues that are required for the project. Included in this section of the Appendix are those Special Provisions previously prepared by SCDOT as well as any Special Provisions written by the GEC. Contact the OES/GDS to determine which Special Provisions are currently available.

21.5 SITE-SPECIFIC SEISMIC RESPONSE ANALYSIS REPORT - SSRA

The purpose of the Site-Specific Seismic Response Analysis Report (SSRA) is to provide the results of a site-specific response analysis. The requirements for conducting a site-specific response analysis are contained in Chapter 12. The SSRA should include a detailed description of the project to include bridge length, structure type, foundation type and size proposed by the SEOR and loading information. The results of shear and compression wave velocity testing should be discussed, and included in this discussion should be the testing procedure used to obtain the shear and compression wave velocities.

The next section of the SSRA should consist of a discussion of the area geology as it pertains to the overall project, followed by a specific discussion of the soils located at the project site. The overall geologic discussion should include geologic stratigraphic province (see Chapter 11) and geologic formations that will affect the design of the bridge foundations. This discussion should be followed by a detailed discussion of the soils encountered along the project alignment. Also included in this section of the report should be discussion of the project seismicity to include the approximate magnitude and distance from the project site to the anticipated seismic source (M and R, respectively). Included in this section of the report is a discussion of the time histories. Most time histories (synthesized due to a lack of actual time history records in South Carolina) will be developed using SCENARIO_PC (latest edition); however, actual time histories may also be used. A detailed explanation of the selection of an actual time history shall be provided and should include at a minimum include, the M and R and geologic condition where the time history was obtained, along with any scaling required to match the Uniform Hazard Spectrum (UHS) at the project site. The use of actual time histories requires the prior approval of the OES/GDS.

A detailed SSL study and analysis shall not be reported in the Site-Specific, but shall be reported in the BGER or the RGER, if required. The exception to this is if the amount of liquefaction is significant (see Chapter 12), which may cause a non-linear analysis to be required. The report shall clearly indicate whether a linear or non-linear site response analysis was performed. If a non-linear analysis is required, a discussion of the calibration of the non-linear model with the linear model shall be included. Included in the report shall be a table indicating the geologic profile to the B-C boundary that was used in the modeling (see Table 21-13). In addition, the sensitivity analysis shall be discussed in detail in this section. The discussion should include which soil parameters were varied and how the variation was determined. In addition, multiple seismic events (minimum of 7) shall be used. As a result of the sensitivity analysis performed, a series of site-specific horizontal acceleration response spectra (ARS) curves may be developed. A single recommended site-specific horizontal ARS curve should be superimposed on the graph. The method of selecting the recommended site-specific ARS curve should be documented in the report. The selection of the recommended site-specific ARS curve may be based on the sum of the squares (SRSS), the arithmetic mean, critical boundary method, or other method deemed appropriate. Use of other methods beyond those included here to develop the ARS curve, requires the prior approval of the OES/GDS. However, if less than 7 seismic events are used an envelope of all ARS curves is required to develop the final ARS curve.

The 3-point ADRS curve shall be determined as if the site-specific analysis was not performed. The 3-point ADRS curve and the selected site-specific ARS curve shall be superimposed on each other and the final ADRS curve shall be determined in accordance with Chapter 12.

Table 21-13, One-Dimensional Soil Column Model

Geologic Time	Layer No.	Layer Thickness, *H*	Soil Formation	Soil Description (USCS)	*PI*	FC	Total Unit Weight, γ_{TW}	Shear Wave Velocity, V_S	Shear[(1)] Modulus Reduction Curve	Equivalent [(1)] Viscous Damping Ratio Curve
Quaternary	1									
	2									
Tertiary	3									
	4									
Cretaceous	5									
	6									
Bed Rock	i									

Note: PI = Plasticity Index; FC=% Passing the #200 sieve
(1) Indicate the cyclic stress-strain behavior method used by indicating reference (i.e., Andrus et al. (2003).

21.6 SUBMISSION REQUIREMENTS

All reports submitted to SCDOT shall bear the stamp of the Professional Engineer in charge as required by South Carolina law. Submit electronically one complete color copy in .PDF format of each revised final report including all Appendices. In addition, submit electronically all preliminary and draft reports.