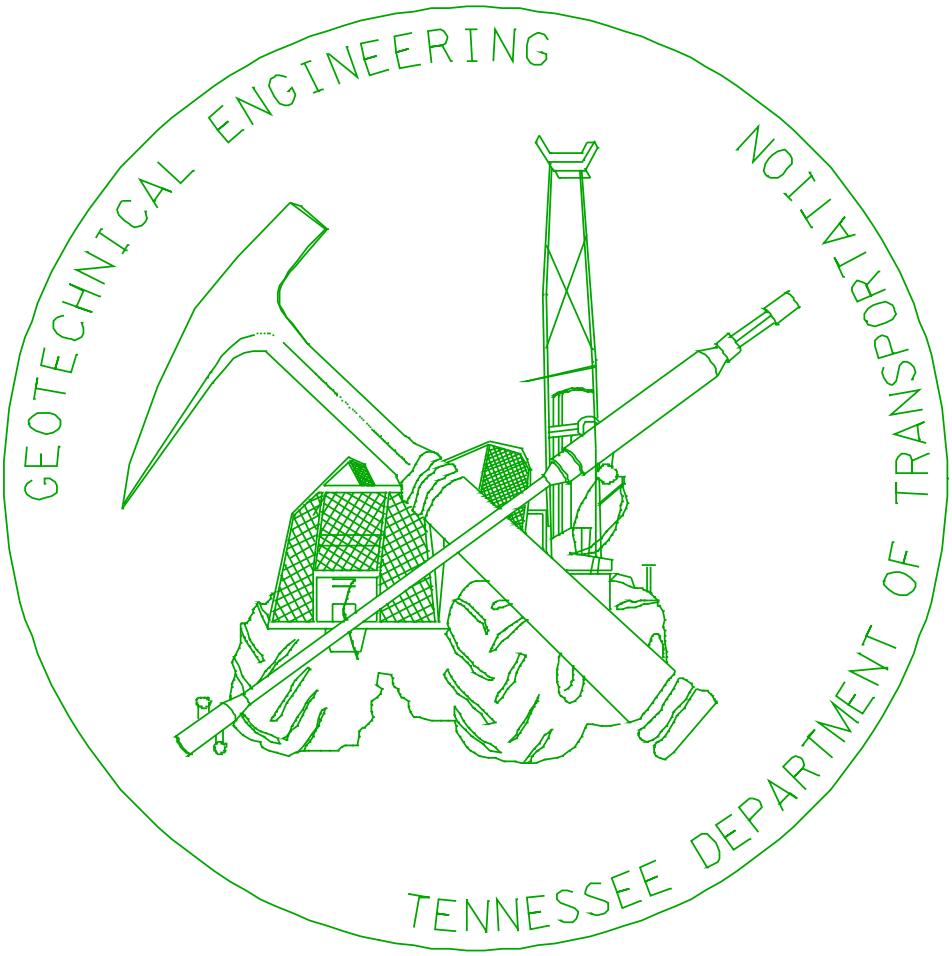
Section 1:

Geotechnical Report Manual



6601 Centennial Boulevard
Nashville, TN 37243-0360
(615) 350.4132

TDOT Geotechnical Manual

Section 1: Geotechnical Report Manual

Tennessee Department of Transportation
Geotechnical Engineering Section
6601 Centennial Boulevard
Nashville, TN 37243-0360
615-350-4132

Report Date:
December 15, 2007
revised Jan 15, 2011

Report Number	GEO-01.01	**Version**	1.1
Author	Vanessa Bateman, PG, PE	**Phone**	615-350-4133

Abstract

Section 1 of the TDOT Geotechnical Manual consists of a report and style guide for the most common TDOT projects that may be completed by or for the Geotechnical Engineering Section. It includes example reports, drawings and supporting forms that may be needed.

The following appendices are included with this manual

Appendix A - Example Report and Drawings

Appendix B - Supporting Documentation

Key Words

Site investigation, soil testing, laboratory testing, geotechnical engineering, foundation design, soils classification, rock testing

56 Pages

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Introduction

Guidelines for geotechnical work should always be taken as a starting place for reports and investigations. Common sense and general geotechnical practice should always be used. The intent of this document is to set out the information required to achieve the ends needed for TDOT projects. Included here are example drawings sheets, example reports and lists of required information for an investigation. This does not mean that there is no room for new techniques, better investigation methods or that the only information to be gathered at a site is set forth in this document. Each site and each project have their own unique problems and challenges. The intent of this document is to provide guidance for TDOT needs; not to attempt to codify all potential circumstances that the geotechnical engineer or engineering geologist may encounter.

A note on nomenclature

Throughout this document, divisions and sections within TDOT will be referred to using part of their name as a proper noun. For example, Structures, for the Structures Division or Geotechnical for the Geotechnical Engineering Section. Consultants may be hired by TDOT to perform these functions, and these general headings extend to the TDOT designated representatives.

Common Name	TDOT Department
Structures	Structures Division
Design	Design Division
ROW	Right of Way
Geotechnical	Geotechnical Engineering Section: Division of Materials and Tests
Environmental	Environmental Division
Maintenance	Maintenance Division
Construction	Construction Division

Other abbreviations used in this document are as follows: Geotech for the geotechnical engineer or geologist working on a project and GES for the Geotechnical Engineering Section.

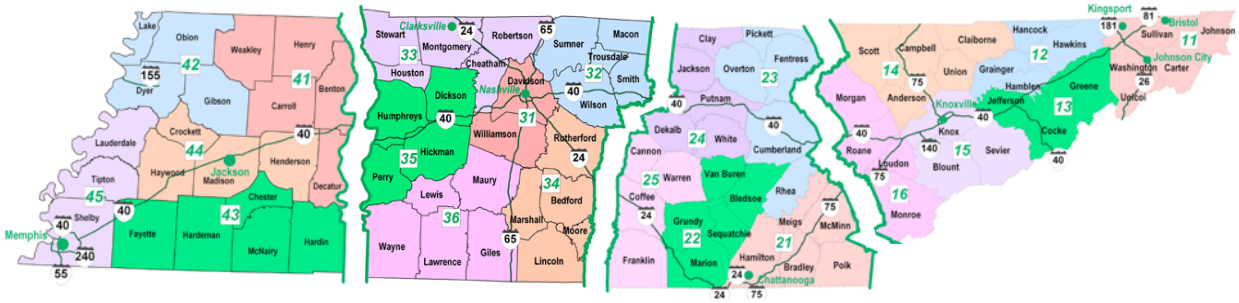
Procedures and Tests referenced

Numerous laboratory tests and drilling methods are referenced in this manual. While the actual AASHTO procedure and codes are not listed for all methods - current AASHTO codes shall be used as the standard.

A partial list with relevant AASHTO test designations are listed below. AASHTO methods shall be used unless otherwise specified.

Test / Procedure	AASHTO Designation
Penetration Test and Split-Barrel Sampling of Soils	T 206
Thin-Walled (Shelby) Tube Sampling of Soils	T 207
Liquid Limit	T 89
Plastic Limit	T 90
Natural Moisture	T 265
Particle Size Analysis	T 88
AASHTO Soil Classification	M 145
Proctor Tests - Method A	T 99
California Bearing Ratio	T 193
Soil pH	T 289
Soil Resistivity	T 288
Sulfate Soundness	T 104
1D Consolidation	T 216
Specific Gravity	T 100
U-U Triaxial Test	T 296
C-U Triaxial Test	T 297
Unconfined Compression	T 208
Direct Shear	T 236

TDOT Regions and Geotechnical Offices



Region 4 **Region 3** **Region 2** **Region 1**

There are two geotechnical offices located within the state of Tennessee in the Department of Transportation: one in Nashville and one in Knoxville. All TDOT geotechnical work goes through one of these two offices. Region 1 work is the responsibility of the Knoxville Geotechnical Office. Work in Regions 2-4 are the responsibility of the Nashville Geotechnical Office. The Geotechnical Engineering Section is part of the Division of Materials and Tests, located in Nashville which is part of the Engineering Bureau under TDOT's Chief Engineer.

Geotechnical Engineering Section Manager

Robert Jowers, Civil Engineering Manager 2

6601 Centennial Boulevard
Nashville, TN 37248-0360
(615) 350.4133

Nashville Geotechnical Office

Travis Smith, Civil Engineering Manager 1

6601 Centennial Boulevard
Nashville, TN 37248-0360
(615) 350.4136

Knoxville Geotechnical Office

David Barker, Transportation Manager 1

7345 Region Lane
Knoxville, TN 37914
(865) 594.2700

Geotechnical File Numbers and Project Numbers

All geotechnical projects have a GES File Number. This file number is to be used on all reports, documents, drawings and correspondence as is the primary means for tracking projects within the Geotechnical Engineering Section. TDOT Project numbers are often shown on plans provided by Design and include the PE (preliminary engineering) number. This number should also be used on all reports, documents and correspondence. Another number which has come into common use at TDOT is the PIN number. This is a number that is permanently assigned to a project.

GES File Number Structure

GES File Number	County	Sequence	Fiscal Year
2600106	26	001	06

TDOT Project Number Structure

TDOT Project Number	County	Section Number	Job			Funds	
			Type Work	State System	Job Sequence Number	Federal	State
26011-1205-04	26	11	1	2	05	0	4

County - All counties in Tennessee are numbered in Alphabetical Order 1-95. Anderson County is 01 and Wilson County is 95. Development district projects use 96, region wide projects use 98 and Statewide projects use 99.

Sequence - Used with the GES File Number. A sequence number of 001 indicates the first project to be assigned a file number in a given fiscal year. Likewise a sequence number of 152 would be the 152nd project to be assigned a file number in a given year.

Fiscal Year - Fiscal year project was requested.

Section Number - This is assigned by Planning. It is a number given to a section of a highway that has similar geometrics or operating characteristics. It is used to subdivide a roadway into convenient or logical units.

Job - This is the job number assigned to a project, it has 3 components: 1. Type Work, 2. State System, 3. Job Sequence Number.

Type Work - This code indicates what type of work is being performed under the project number. Geotechnical studies for new projects almost always come under Code 1.

Code	Description
0	PE (Preliminary Engineering) for Planning and Environmental Studies
1	PE for Survey and Road Design
2	Right of Way Acquisition
3	Construction and Reconstruction
4	Routine Maintenance
5	PE for Structure Design
7	Planning and Research Projects
8	Resurfacing Projects
9	Outdoor Advertising, Mass Transit, Waterways and Rail

State System - This number indicates the roadway type.

Code	Description
1	Interstate
2	State Highway System (State Routes)
3	Rural System
4	Local County Roads
5	Local City Streets
6	No System
7	New Urban System

Job Sequence Number - Indicates the order a in which a project number was assigned along a section of roadway. A job sequence number of 001 indicates the first project issued along that section. Likewise a job sequence number of 011 indicates the 11th project issued along that section.

Funds - indicates the funding source for the project. It has two components: 1. Federal and 2. State.

Federal Funds - This code indicates the Federal appropriation authorized for the project.

Code	Description
0	No federal funds
1	Federal Aid - Primary
2	Federal Aid - Secondary
3	Federal Aid - Grade Crossing, Overhead Separations, Tunnels, Underpasses etc.
4	Federal Aid - Interstate
5	Federal Aid - Urban
6	Federal Aid - Appalachia
7	Federal Aid - HPR
8	Federal Aid - Forest Highways
9	Federal Aid - Other

State Funds - This number indicates TDOT's accounting fund used for the project.

Code	Description
3	Rural and Secondary Roads Fund
4	State Highway Fund
9	Aeronautics

Chapter 1: West Tennessee Bridges

West Tennessee Bridges are those bridges in which rock is generally greater than 100 feet in depth. These are primarily located west of the Tennessee River and in TDOT Region 4. However, these provisions can be used for any bridge where friction piles are the preferred foundation alternative. For all other bridges, please see Chapter 2: General Bridge Projects.

Goals of investigation

The primary goal of a bridge project in West Tennessee is to gather subsurface data for the design of bridge piles, to check the slope stability of the embankment, to provide information for scour analysis, and to provide information for pavement design. Typically this involves drilling a minimum of 2 deep holes and liquefaction analysis. The end product of the investigation is a geotechnical report that addresses these issues as well as a bridge foundation data sheet that is prepared for the Structures Division.

This bridge foundation data sheet, along with the geotechnical report will be used to design the appropriate foundations. The data sheet will be included as a plans sheet. The Structures Division will use the geotechnical report to complete their design and will include other appropriate plans sheets for the foundations. If there are stability considerations that require alteration to the site or involve some geotechnical work, cross sections shall be supplied to detail the work needed. All appropriate recommendations, such as slope ratios and other geotechnical elements needed to address slope stability at the embankments shall be included on these cross sections as the geotechnical report will not be directly incorporated into the plans. Please see "Bridge and Approach Projects" also included in this manual for further detail

Drilling Requirements

For each bridge, at least 2 holes shall be drilled to sufficient depth for piles to support a bridge. These must be drilled down to at least 10 feet of soil below any layers that are predicted to liquefy. AASHTO guidelines do not require liquefaction analysis for 1 span bridges, however even for these small bridges, unless very dense sand is hit, TDOT Geotechnical will typically drill from 75-90 feet in depth. Larger, more critical bridges will require more drilling. SPT or CPT shall be performed sufficient to describe the site for the purposes of:

1. Liquefaction Analysis,
2. Pile design,
3. Corrosion checks, and
4. Scour calculations
5. Seismic Stability of the bridge approach embankment

Samples shall be taken at least every 5 feet. More holes may be appropriate at the site for a large bridge, for an interstate bridge or where there is significant variation in the subsurface conditions. Shelby tubes sufficient for checking embankment stability at the bridge may also be needed. Other drilling techniques that provide the necessary information may also be acceptable. For project where CPT testing is performed, at least one hole shall be SPT, in order to gather samples for laboratory testing. All layers of soil shall be identified and appropriate parameters recorded during exploration.

Critical interstate bridges may require more complex analyses, please see current AASHTO guidelines for guidance. The required analyses may require additional exploration and more complex techniques.

Laboratory Analysis

If a bridge project has not had a “bridge and approach” report performed at the site before bridge foundation exploration, then all of the testing and laboratory analysis required for those projects shall be performed.

All SPT samples shall have gradation, hydrometer, atterberg limits, pH and Resistivity tests performed. Each sample shall be classified by both AASHTO and USCS systems. Other testing may be performed as needed to provide sufficient information for the prediction of liquefaction and corrosion.

Engineering Analysis

One of the main geotechnical issues in West Tennessee is the New Madrid Seismic Zone. Acceleration maps are available from a variety of sources including the USGS as well as some studies performed by University of Memphis. Liquefaction analysis must be performed on all coarse-grained materials and TDOT Geotechnical typically performs these for every appropriate SPT sample taken. AASHTO requires that this analysis be performed within a seismic risk area for all bridges larger than 1 span. All layers that have the potential for liquefaction must be clearly noted on the foundation data sheet supplied with the geotechnical report. Stability analysis of the bridge approach embankment under seismic loads is required for all bridges larger than 1-span. Additional work may be required to design an approach embankment that is sufficiently stable under seismic loads.

Critical and interstate bridges may require more complex analyses, please see current AASHTO guidelines for guidance. These analyses may include, site specific seismic analysis, CPT testing, soil-structure interaction considerations among others.

Geotechnical Report and Drawings

The geotechnical report for a West Tennessee bridge project should detail the investigations and the recommendations for the site. Recommendations for design parameters such as fs and qb shall be supplied for

concrete friction piles, pipe piles and steel H piles. All cross sections provided with the report shall have explanatory material included in the report. For example, if a cross section is provided that is typical for station 30+00 to 34+50, there should be a section in the report that specifically references this drawing and provides a description of the repair and any needed geotechnical notes. All typed boring logs shall be included with the report as well as any laboratory results. This report will primarily be used by the GES and as a reference for the exploration performed at the site.

Report Format

Executive Summary or Cover Letter – This section gives a brief summary of the report. It shall also state if potentially acid producing materials was found or not found on a project.

Introduction – Brief summary of the project and location. Any special constraints such as limited right of way are noted here.

Geology, Soils and Site Conditions – All geology, soils and site conditions that may affect the project.

Surface and Subsurface Exploration – Exploration Performed

Recommendations – Provide recommendations for construction purposes such as types of foundations recommended, any site improvements and identification of soil layers that are representative for scour analysis.

Special Notes and Specifications – Any special notes to be included in the plans, these should also be on the cross sections, if provided. This section may be omitted if no special notes or specifications are required.

Appendix – Documents, boring logs and supporting information.

- Foundation Data Sheet
- Boring Logs
- Laboratory Testing
- Engineering Analyses and supporting Documents

The GES requires that all project documents be provided in both electronic and paper form.

Foundation Data Sheet Elements

The geotechnical sheets for a West Tennessee bridge project shall include a plan view layout of the drill holes, drill holes plotted by depth and any cross sections required to illustrate geotechnical design elements. The initial bridge sketch is provided either by the Structures Division or their designated representative. Drill holes and geotechnical information shall be plotted on these sheets. Cross sections, if any, shall also be included. Information other than foundation recommendations and layers representative for scour included in the report, but not on these sheets, may not make it into the construction plans. If this occurs, these geotechnical recommendations would then likely be ignored. *It is critical that recommendations be illustrated with geotechnical plans sheets*. The following elements must be included:

General Layout of Site – Plan view showing drilling and sampling locations. Usually placed on the bridge sketch supplied by Structures.

Graphical Boring Logs – Showing all drill logs, these must show elevations and material types with elevations included. Fs and qb factors shall be shown as well as N values and all layers identified as subject to liquefaction shall be shown.

Example Reports and Geotechnical Sheets

The following pages show an example report and bridge sheet for a West Tennessee Bridge Project. Please see *Section 1: Appendix A - Examples* for these documents.

- West Tennessee Bridge Report
- West Tennessee Bridge Sketch

Supporting Documentation

Static Pile Capacity Charts - See *Section 1: Appendix B - Supporting Documents* for the "Static Pile Capacity" charts as developed and used at TDOT. Please note that one sheet shows only the unit pile and one specifies a particular concrete friction pile. If these charts are used for design, use the unit chart for fs and qb. The other chart was designed as a field aid to check bearing during exploration. This chart is to be used at the geotechnical engineer / engineering geologists risk. These charts when used as a field aid will *not* guarantee that adequate exploration has been performed, as these charts do not account for liquefaction. These values may not be accurate where proper SPT procedures are not used. They were developed for a CME drill rigs with use of automatic hammers calibrated to 60% energy (N_{60}). Other equipment may give different results. Please note that the maximum values of fs and qb are achieved with N=30. For blow counts above this value, do not extrapolate further values, but use the values for N=30. For steel or pipe piles the fs values given on the chart are reduced by 1/3.

Chapter 2: General Bridge Projects

General bridge projects are all those which do not use friction piles for support. These projects will generally be all of those in Regions 1-3 and some in Region 4. When rock is greater than 100 feet, friction piles should be considered and if chosen as the foundation alternate, the provisions for West Tennessee Bridge Projects shall be followed.

Goals of Investigation

The goal for non-west Tennessee bridge projects is to provide recommendations for appropriate bridge foundations and to evaluate embankment stability. If significant alterations are being made to the surrounding ground, a bridge and approach project should also be completed. These projects may have highly variable bedrock and be subject to karst related problems. Sufficient drilling must be completed in order to design appropriate foundation; this information is then sent on to TDOT Structures or their designated representatives. The primary end products for this type of investigation is a bridge foundation data sheet and a bridge foundation report used to describe appropriate foundation alternatives. A preferred alternative shall be laid out, but other foundation alternatives may be given in the report. Unlike retaining wall foundations, however, not every alternative will be shown on the drawings. Alternatives shall be discussed in the geotechnical report, and the foundation type actually used will be selected by Structures, with the consultation of Geotechnical. TDOT routinely uses integral abutments for bridges, further detail on this type of abutment is below, however, the use of this abutment type requires some special design consideration for foundation recommendations when rock is shallow.

Drilling Requirements

The drilling performed at the site can be highly variable according to the depth of solid rock and the variability of the site. TDOT Geotechnical generally recommend at least one to three holes per substructure, but this number may be increased when there is significant site variability. Appropriate explorations may include, but are not limited to, wireline drilling, SPT samples, auguring and hollow-stem auguring. Foundation types that are typically selected are shallow spread footings on rock, steel H piles and drilled shafts. Other alternatives such as micropiles and more innovative methods may also be recommended where appropriate, particularly if these methods are more suitable to site conditions than more "traditional" methods. Please note that at this time the Structures Division does not accept spread footings on soil for bridge foundations. It is the judgment of the Structures Division that the settlement risk is too high to allow such a foundation.

It is also important to pay particular attention to the bridge layout sketch as provided by Structures. Many bridge projects may involve a retaining wall used to limit the approach fill, and may not be given out as separate projects. Sheet piles walls to be used during construction may also be shown. If there is a retaining wall

shown on a sketch, it is the responsibility of the Geotech to complete appropriate drilling, reporting and drawings for this structure in addition to the bridge exploration. Please see *Chapter 4: Retaining Wall Projects* included in this manual. Samples of soil shall be taken as appropriate in order to design the selected foundations and to evaluate embankment stability. Rock samples are also generally taken for laboratory testing. Please note that if advanced methods such as p-y analyses are used for lateral capacity of soils for deep foundations, additional drilling and sampling may be required. At least one SPT hole per abutment or bent/pier is is recommended where this analysis is to be performed. In general, this type of analysis will only be performed where there is a large bridge or where the geotechnical investigation shows instability or settlement problems in the approach embankment. Contact the TDOT Structural Engineer for if p-y analysis is desired due to geotechnical considerations or to check and see if this type analysis would be performed due to structural considerations. RQD and recovery shall be recorded for all rock samples and photographs shall be taken of all rock core.

Some rules of thumb employed at TDOT for sufficient drilling are as follows. As always, judgement, AASHTO guidelines and generally accepted geotechnical practice should also be used:

1. Shallow foundations in rock - at least 10 feet of good bedrock
2. Driven piles in rock - at least 5 feet of good bedrock
3. Drilled shafts in rock - at least 15-20 feet of good bedrock.
4. Pre-drilled piles in rock - at least 5 feet of good bedrock below the pile
5. Sufficient soil sampling to conduct bridge approach embankment slope stability and settlement analysis, generally at least 2 tubes per embankment per soil type present.

Please note that with drilled shafts the appropriate depth of rock to be drilled will vary depending upon whether or not the shaft will be end bearing or will be carried in side friction. TDOT Structures may elect to support the shaft in side bearing only, in end bearing only or using both side and end bearing. Variances from this deign chosen for the bridge shall be discussed with Structures. Also, please note that AASHTO guidelines specify a depth below the base of the shaft of 1.5* shaft diameter in flat lying rock and 2*shaft diameter in tilted rock. The cutoff between flay lying rock and tilted rock as specified in AASHTO is 10 degrees. While this may be a conservative requirement, it remains in the current standards. This can be of great significance during exploration as this can increase the amount of rock that should be cored for the project in order to fulfill this design requirement.

Karst issues and problems shall also receive special consideration. Bridge foundations in highly cavernous rock can present very difficult issues both in exploration and in constructability. Constructability concerns should be addressed by the Geotech. Drilled shafts may require casing due to cavities in rock. Shallow foundations, which may appear appropriate when looking at the ground surface may turn out to be impractical due to only a small amount of competent rock in a layer. Also, due to the highly variable nature of many karst rocks, additional drill holes, or additional depth may be necessary in order to adequately design the

bridge foundations. Similar problems may occur when a bridge site is located in an area where there has been faulting.

Notes for Bridges with Integral Abutments

TDOT Structures routinely uses integral abutments in Tennessee where the bridge lengths are less than 800 feet for concrete bridges and less than 400 feet for steel bridges. This abutment type, where feasible, eliminates the need for expensive expansion joints, reduces longitudinal loads on bents, simplifies abutment details and makes for a bridge more resistant to excessive loading and seismic events.[1] However, use of these abutments has an affect on both drilling that is be performed at a site and recommendations for foundations. Bridges require the ability for some lateral movement and the length of the bridge as well as the material type will dictate whether or not a bridge required one or both of the integral abutments to be "free" for some lateral movement or if one can be "locke in." The general rule of thumb is as follows:

TDOT Structures - Integral Abutment Use Guidelines[2]

Bridge Material	Length	Abutments
Concrete	400 feet or less	1 "free" integral abutment needed (providing up to 2" of lateral movement).
Steel	200 feet or less	1 "free" integral abutment needed (providing up to 2" of lateral movement).
Concrete	400 - 800 feet	2 "free" integral abutments needed (providing up to 4" of lateral movement).
Steel	200 - 800 feet	2 "free" integral abutments needed (providing up to 4" of lateral movement).
Concrete	>800 feet	Expansion joints required
Steel	>400 feet	Expansion joints required

[1] Integral Abutment Design (Practices in the United States), Wasserman, Edward. Presented at the 1st U.S.-Italy Seismic Bridge Workshop (http://people.ce.gatech.edu/~rd72/italy/index.html), Pavia, Italy, April 19-20, 2007.

http://people.ce.gatech.edu/%7Erd72/italy/papers/S2-2_Integral%20Abutment%20Practices%20in%20the%20United%20State-3.pdf

[2] Oral communication: Cabrina Dieters, TDOT Structral Division, January 2011.

Where abutment foundations will already be supported by steel piles, this abutment can be considered "free." If both abutments are supported by piles, no further exploration is required. However, where a shallow foundation is used, or where a drilled shaft is being considered, further work is needed. For a spread footing on rock to be used as a "free" integral abutment, a separator layer is needed, otherwise it is considered locked and cannot provide the lateral movement the bridge may require. TDOT Structures generally uses a one foot of 57 stone as a separator layer between the bottom of the abutment and the rock layer below. This separator layer and use of a spread footing for an integral abutment is generally most cost effective where rock is 0 - 3 feet from the bottom of the abutment.

Where there more than 3 feet in depth from the bottom of the integral abutment, however, TDOT Structures prefers to use steel "H" piles, due primarily to cost considerations in the construction of the abutment. In this case, the steel piles are at a minimum of 10 feet in length from the bottom of the pile cap, and are "pre-drilled" into the underlying soils and rock. PIles are placed in these pre-drilled holes which are larger than the piles and surrounded by lean concrete, gravel or sand.

At this time, TDOT has not used an integral abutment design with either drilled shafts or micropiles. If one of these foundation alternatives is preferred in order to solve a geotechnical site problem, contact TDOT Structures in order to discuss what further steps may be required.

Notes for Embankment Stability and Integral Abutments

Generally, integral abutments in Tennessee are supported by a single row of vertical steel H piles. One important consideration for this abutment type from the geotechnical exploration and analysis is that there not be excessive settlement or movement in the bridge approach embankment. Native soils expected to cause excessive settlement, instability in existing bridge approach embankments for in-place bridges, weak soils or expected potential movement due to seismic or other considerations shall be explored and clearly noted. In the past, bridge abutment explorations seldom considered the approach embankment condition unless obvious distress in the current bridge was noted. Tube samples, where applicable, shall be taken and both settlement and slope stability analysis of the bridge approach embankments shall be completed.

Notes for Rock Cuts in front of Bridge Abutments

In general, TDOT policy is to set back abutments from a rock cut face at least 10 feet. This is done to accommodate weathering of the rock cut face over time, reduce the influence of the foundation on the rock cut face and to account for the potential of over-break or mistakes during construction. However, every rock cut shall be drilled and/or investigated sufficiently to determine if this "default" offset is sufficient at the bridge location. Rock structure and potential structural failure modes shall be investigated and the rock shall be assessed for soundness. Where rock shows a high potential of weathering (shales, claystones, argillaceous limestones etc.) the weathering rate shall be assessed and a further offset may be required. Any potential

structural failure of the rock, such as plane shear failures, wedge failures or toppling failures shall be clearly discussed and analyzed. Loads applied by the bridge can be obtained through TDOT Structures where this analysis is necessary. The likelihood of raveling failures at the top of the rock cut due to blasting error or discontinuous slabs of rock shall also be assessed. If a further offset is required due to site conditions, this shall be clearly discussed in the report and brought to the immediate attention of the Geotechnical Manager and TDOT Structures.

Laboratory Analysis

Laboratory analysis may include, but not be limited to, unconfined compressive tests for rock as well as gradation, classification, atterberg limits, pH and hydrometer analysis for soils. Additionally, direct shear, triaxial or other strength tests may be appropriate for checking soil embankment or rock cut stability. Settlement analysis shall be performed where soils emankments may settle.

Engineering Analysis

Bearing capacity analysis is the primary calculation that must be performed for this type of project. Others may include stability analysis, settlement analysis, p-y analysis and others as needed. Side friction calculations may need to be made for drilled shafts and other deep foundations. There are many methods for calculating the appropriate factors in soils and rock. Where AASHTO code specifies a particular calculation method, this shall be used. When no AASHTO code specifies the calculations, TDOT requires that the methods used be generally accepted and have documentation in the engineering literature. If a new or unfamiliar method is applied, checks with other methods or documentation for the method may be requested. Kinematic analysis and rock slope stability checks shall be made where there is a rock cut below a bridge foundation that may affect that foundation.

Geotechnical Report and Drawings

The geotechnical report for a bridge foundation report shall include details of the investigation, boring logs, engineering analysis and recommendations for foundation types and parameters necessary for design of the selected foundation types. These reports are generated to aid Structures in design as well as to document work and reasoning for Geotechnical.

New or innovative foundations may require more lengthly explanations as to why these are most appropriate for the site. A preferred alternative shall be selected, though other appropriate foundation types may be detailed in the report. This type of report is used both by the Geotechnical Section and the Structures Division. Structures will select and design the foundations based on the information contained in the geotechnical report. All appropriate parameters for foundation design shall be included in the report. These may include items such as the following:

- Elevation of foundation bearing layer
- Elevation of first encounter of rock
- Type(s) of foundations recommended
- Bearing Capacity of rock: ultimate and allowable along with appropriate factor of safety
- Offest of foundation from rock cut face required
- Appropriate depth of rock socket
- Lateral capacity of soil or rock
- Side Friction factors

Geotechnical Report Format

Executive Summary or Cover Letter – This section gives a brief summary of the report. It shall also state if potentially acid producing materials was found or not found on a project.

Introduction – Brief summary of the project and location. Any special constraints such as limited right of way are noted here.

Geology, Soils and Site Conditions – All geology, soils and site conditions that may affect the project.

Surface and Subsurface Exploration – Exploration Performed

Recommendations – Provide recommendations for foundation design. This includes foundation type and all parameters needed for design.

Appendix – Documents and supporting data

- Foundation Data Sheet
- Boring Logs - these must include location data on the typed logs.
- Laboratory Testing
- Engineering Analyses
- Other documents

Foundation Data Sheet Elements

Unlike many other types of geotechnical drawings, the foundation data sheets for bridges do not require that all recommendations be reflected on the plans. These may be made in the geotechnical report; the Structures Division or their representative will provide other drawings for bridge foundations as required. If any alterations need to be made to the site due to embankment stability issues or rock cut stability issues cross sections detailing these requirements may be necessary.

General Layout of Site – plan view showing drilling and sampling locations. Usually placed on the bridge sketch supplied by Structures.

Graphical Boring Logs – showing all drill logs, these must show elevations and material types with elevations included.

Elevation Chart - showing the existing ground elevation at the time of exploration and first rock encounter elevation for all borings.

Example Reports and Bridge Foundation Data Sheets

Please see *Section 1: Appendix A - Examples* for these documents.

- General Bridge Report
- General Bridge Sketch

Chapter 3: Bridge and Approaches

A bridge and approach project consists of the geotechnical investigation for the roadway and slopes leading up to and away from a bridge locations. Despite the name, it does not include the investigation for the bridge structure, covered under Chapters 1 and 2. A consultant may be given both the bridge and the bridge and approaches to complete. These should be written up as separate reports, though they may be submitted in one binder. The bridge and approaches are primarily used by Design, bridge structure investigations are primarily used by Structures.

Goals of Investigation

The end result of a bridge and approach investigation project is to supply Geotechnical Sheets that describe any pertinent geotechnical issues and to provide appropriate CBR values for pavement design. These projects are often small and are in support of a bridge replacement or improvement. These differ from bridge projects where there is a large line improvement or change in that they are much more limited in affected area. These projects range from the very simple, which require little or no drilling to large cuts and fills which may require extensive geotechnical recommendations.

A bridge and approach investigation shall be structured to provide appropriate geotechnical sheets (both plan view and cross sections) to lay out geotechnical design elements. This may include not only appropriate slope ratios for soil cuts and fills, but large rock cuts, accommodation for weak soils or wetland areas, sinkholes, landslides and other special geotechnical issues.

The primary end products are the geotechnical sheets, which will be included in the plans. The report will be used by the GES and will also be a reference available at request. It provides supplementary data and explanatory materials, some of which will not be included in the contract plans and documents. These are of great importance when evaluating geotechnical designs, dealing with construction related issues and understanding the reasons behind recommendations given. The report will be used by the GES, but the geotechnical sheets become part of the contract plans.

Drilling Requirements

At least one CBR sample sufficient for pavement design shall be taken at each bridge and approach project. Other drilling and site investigation needed shall be at the judgment of the engineering geologist or geotechnical engineer. This in turn depends upon the scale of the project and the amount of drilling needed to provide appropriate cross sections and geotechnical plans sheets. For a minor project where there are very small cuts and fills and no stability issues expected, this may requie a site visit and a CBR sample (or samples). For a project with large cuts and fills or major geotechnical issues, this may require an extensive inves-

tigation. Where CBR samples are likely to yield CBR results < 5 additional volume of material may be needed to complete laboratory analysis.

Laboratory Analysis

The California Bearing Ratio test (CBR) is a requirement for TDOT projects as TDOT Pavement Design uses the results from this test. As typical for the CBR tests, proctors, gradation, plasticity and classification shall be reported along with the CBR results. Additionally, a small sample shall be taken of the CBR sample sufficient to obtain in-situ moisture for the soil. Other samples may be taken at the site as well, depending upon the scale and nature of the cuts and fills for the project. All soil samples shall have gradation, hydrometer, plasticity tests and shall be classified by both USCS and AASHTO soil classification systems. Samples taken in order to perform slope stability and settlement calculations may be required and include, but are not limited to triaxial tests, unconfined compression tests and direct shear tests.

Where the CBR sample gives a result of CBR < 5, lime stabilization or other subgrade stabilization methods must be evaluated, this may require additional laboratory analysis with lime stabilized CBR tests performed.

Engineering Analysis

Types of analysis that have been needed for past TDOT Bridge and Approach projects include slope stability and settlement. Other analyses may be needed for complex and non-routine projects.

Geotechnical Reports and Drawings

The geotechnical report for a bridge and approach project shall detail the investigations and the recommendations for the site. All cross sections provided with the report shall have explanatory material included in the report. For example, if a cross section is provided that is typical for station 30+00 to 34+50, there shall be a section in the report that specifically references this drawing and provides a description of the recommendation and any needed geotechnical notes. A “Soil and Subgrade” report shall be included in the appendix and any CBR sample taken shall be included on this sheet. All typed boring logs shall be included with the report as well as any laboratory results. This report will primarily be used by the GES and as a reference for the exploration performed at the site.

Geotechnical Report Elements

Executive Summary or Cover Letter – This section gives a brief summary of the report. It shall also state if potentially acid producing materials was found or not found on a project.

Introduction – Brief summary of the project and location. Any special constraints such as limited right of way are noted here.

Geology, Soils and Site Conditions – Any geology, soils and site conditions that may affect the project.

Surface and Subsurface Exploration – Exploration Performed

Recommendations – Provide recommendations for construction purposes such as allowable slopes, undercutting and replacement or other pertinent recommendations. The CBR values recommended for pavement design shall be included here.

Special Notes and Specifications – Any special notes to be included in the plans, these should also be on the retaining wall sheet(s). This section may be omitted if no special notes or specifications are required.

Appendix – Documents and other supporting data

- Geotechnical Sheets
- Soil and Subgrade report
- Boring Logs
- Laboratory Testing
- Engineering Analyses

Geotechnical Sheet Elements

The geotechnical sheets for a bridge and approach project shall include a plan view layout of the drill holes, drill holes plotted in relationship to centerline grade and any cross sections required to illustrate geotechnical design elements.

The initial layout sheets come from the preliminary design plans. Geotechnical data is added after exploration. These are the sheets that will be included in the plans. Information other than recommended CBR values for pavement design included in the report, but not on these sheets, may not make it into the construction plans. If this occurs, these geotechnical recommendations would then likely be ignored. It is critical that recommendations be illustrated with geotechnical plans sheets.

General Layout of Site – Plan view showing drilling and sampling locations. This may also show limits of geotechnical design elements, such as plan view limits of undercutting. It shall include a soil description chart. The format for this chart is shown in Section 1: Appendix B - Supporting Documentation under the title “Soil Description Sheet.” Where soils on the chart show an “in-situ moisture” that is significantly wetter or dryer of optimum than the proctor test, this shall be clearly noted on these sheets with a statement that includes a notice to the contractor that wetting, drying or additional handling of these soils may be required.

Centerline grade sheets with graphical logs of drilling – Showing all drill logs, these must show elevations and material types in relationship to the grade at centerline for the project. These may also show interpretations.

Cross Sections for the Project – Cross sections that describe the recommendations shall be included with the geotechnical sheets. For very small and simple projects, only one cross section may be needed. Cross sections shall be provided to illustrate geotechnical design elements that

are recommended for the project or to illustrate materials to be encountered. Recommended slope ratios shall be shown.

Geotechnical Notes – Added as needed. They could be included directly on the cross sections or on the general layout sheets. These notes can also be included on a separate plans sheet. Please remember that these will be plans documents, so only appropriate material should be included.

Example Reports and Geotechnical Sheets

Please see *Section 1: Appendix A - Examples* for these documents.

- Bridge and Approaches Report
- Bridge and Approaches - Drawing

Supporting Documentation

Soil and Subgrade Report - A copy of the soil and subgrade report that shall be included with the report can be found in *Section 1: Appendix B - Supporting Documentation.*

Soil Description Sheet - Soils tested on the project shall be included on this sheet in the report and it shall also be reproduced on the geotechnical plans sheets. A copy of this description sheet can be found in *Section 1: Appendix B - Supporting Documentation.*

Chapter 4: Retaining Walls

Retaining wall projects for TDOT consist of geotechnical investigations of soil, rock and slope conditions for wall foundations and for excavations needed to construct the wall. Types of retaining walls that are acceptable for a site will need to be evaluated and all appropriate design parameters detailed.

Goals of Investigation

The end result of a retaining wall investigation is to provide enough data so that a structural engineer may complete retaining wall design for a given site and to aid construction contractors in bidding the project. In the past TDOT Structures would design a concrete cantilever wall for each site and any different wall types were submitted as value engineering projects. Now, when retaining walls are included as part of a project, these are designed by the contractor's consultant. The final geotechnical product is a retaining wall sheet for each wall that will be included in the roadway plans. These retaining wall sheets will be the reference that the structural engineer will use to design an appropriate retaining wall for the site.

An investigation shall be structured so that the geotechnical engineer or engineering geologist provides a list of all of the appropriate retaining wall types and all of the appropriate foundation types for these walls. All relevant parameters for the re-taining wall design shall be included on the retaining wall sheet as well as any special conditions, foundation alternative descriptions and additional notes needed to provide data to the structural engineer and the con-struction engineer who will later oversee building of the wall.

The primary end product of a retaining wall investigation is the retaining wall sheet, which will be included in the plans. The report will be used by the GES and will also be a reference available at request. It provides supplementary data and explanatory materials, some of which will not be included in the contract plans and documents. These are of great importance when evaluating retaining wall designs, dealing with construction related issues and understanding the reasons behind retaining wall and foundation alternatives given. The report will be used by the GES, but the retaining wall sheet becomes part of the contract plans.

One very important point when selecting retaining walls for a site: **particular attention must be paid to the right-of-way available for construction**. If there is insufficient right-of-way for a particular wall type, either it should not be used, or the need for additional right-of-way must be clearly noted. A retaining wall that cannot be reasonably built at a site shall not be included as a recommended option.

Drilling Requirements

Typically, TDOT borings are advanced to 1.5 times the wall height below the proposed bottom of footing if in soil. This rule of thumb will generally result in getting data that is within 2 times the foundation width. When initial drilling indicates questionable soil conditions (i.e. soft soil), extend borings to rock or to dense granular material (West Tennessee) as needed. Split spoon samples shall be taken where needed. Representative Shelby tube samples shall be taken of each soil type expected beneath the foundation. If rock is encountered less than 10 feet below proposed bottom of footing, the rock below the footing support elevation shall be cored to obtain 7 to 10 feet of relatively sound continuous rock sufficient to support all retaining wall types feasible for the site.

Generally, TDOT exploration starts with drill holes approximately every 50 to 100 feet depending on consistency of soil and rock conditions expected. This may be expanded or reduced depending upon the consistency of conditions and the judgment of the geotechnical engineer or engineering geologist. If rock is encountered, space borings to determine an accurate rock line. This is often approximately 50 feet unless very erratic rock depths or poor quality rock is encountered.

Laboratory Analysis

The purpose of laboratory testing is to both determine the soil design parameters used for wall design and estimate amount of settlement a wall may undergo. The suggested testing described below is usually sufficient for small to medium size walls (less than 20 feet high) while more detailed and sophisticated tests may be required for higher walls.

First, all split spoon and Shelby tube samples shall be tested for moisture content, gradation and classification, including atterberg limits. Additionally, the Shelby tube samples shall be tested so that the engineering geologist or geotechnical engineer may choose appropriate strength parameters (c and φ) for the soils that will support the wall and be located behind the wall. Triaxial tests are preferred when possible. Consolidation tests should be performed on soil samples below proposed footing depth.

The number of tube samples and tests will depend on the size of wall, the variability of the type soils and the judgment of the engineering geologist or geotechnical engineer.

Engineering Analysis

It is not the purpose of this document to present all the engineering analysis involved with retaining wall design. Entire textbooks are available for review. The NAVFAC DM-7.1 and 7.2 are good sources. AASHTO codes are also used at TDOT. However, analyses need to be made to provide the structural engineer with adequate information for wall design. The following information is needed:

Appropriate φ and Unit Weight if In-situ Soils and Backfill: Highly plastic clay material shall not be used as backfill.

Sliding Coefficients: NAVFAC 7.2-63 Table 1 for friction and adhesion factors for soil at bearing level is a good reference for these factors.

Provide an allowable bearing pressure: Based on a suitable bearing capacity analysis. Show the Factor of Safety (FS) used for each wall type. The GES uses AASHTO requirements; FS=3.0 for concrete cantilever walls and FS=2.5 for MSE walls.

Factors of safety to be used in design: TDOT follows AASHTO guidance and requires a FS=2.0 against overturning and FS=1.5 against sliding.

Allowable construction slopes: For example 1:1. Where there is insufficient room for a slope and a vertical cut is needed, recommendations for additional shoring shall be shown.

Lateral Capacity of Rock: For any walls using piles or shafts socketed into rock, the lateral capacity of the rock shall be provided.

Foundation Improvements: Detail any foundation improvements needed to support the wall types shown.

Settlement: Estimate both total and differential settlement from consolidation tests of soil below footing level using net increase in pressure. That is, subtract removed overburden (if any) from increase in pressure due to wall to obtain net increase in pressure.

Global Stability: Check overall stability from a slope stability standpoint.

Seismic Considerations: Check liquefaction of soil and seismic stability where needed. See current AASHTO specifications for requirements.

Unusual Problems: Determine if any possible unusual problems need analysis such as lateral squeeze. Where retaining walls are founded on soils in a slide complex area, the foundation alternatives shall be clearly evaluated and stated on the report and drawings. Discussion of risks of founding the retaining wall in a slide complex deposit shall be discussed and the potential influence of that slide deposit on the retaining wall and surrounding structures / roadway features shall be analyzed and discussed.

Geotechnical Reports and Drawings

All the information included on the retaining wall sheet shall be included in the report along with appendices that detail the analyses performed for the project. All typed boring logs shall be included with the report. The initial layout sheet is provided by the Design Manager and geotechnical data is added after exploration.

Geotechnical Report Elements

Executive Summary or Cover Letter – This section gives a brief summary of the report. It shall also state if potentially acid producing materials was found or not found on a project.

Introduction – Brief summary of purpose of the wall, general size, general type (cut or fill) and location. Any special constraints such as limited right of way are noted here.

Geology, Soils and Site Conditions – Geology, soils and site conditions that may affect the project.

Surface and Subsurface Exploration – Exploration Performed

Recommendations – For retaining wall projects, the text of the retaining wall sheet is included in this section, along with any pertinent discussion of the recommendations. Detail acceptable wall types and provide parameters for design including any needed foundation improvements. Provide recommendations for construction purposes such as allowable temporary cut slopes, special drainage, undercutting or other pertinent recommendations

Special Notes and Specifications – Any special notes to be included in the plans, these should also be on the retaining wall sheet(s).

Appendix – Documents and supporting information
Retaining Wall Sheet(s) and any applicable cross sections
Boring Logs
Laboratory Testing
Engineering Analyses

Retaining Wall Sheet Elements

General Layout of Retaining Wall – Showing the wall in relationship to its surroundings

Cross Sections – At least one cross section showing wall

All borings for the project – These must show elevations and material types. This is a graphical log that should match up with written boring logs.

Acceptable Wall Types – The geotechnical engineer / engineering geologist shall specify all wall types acceptable at the location.

Wall and Foundation Parameter data – Any parameters for all wall types included on the sheet sufficient that the structural engineer may design the wall.

Factors of Safety to be used – This includes factors of safety against sliding, overturning and bearing capacity.

Allowable construction slopes – specify allowable temporary construction slopes. If 1:1 or shallower slopes are not acceptable due to right of way constraints, this needs to be stated on the sheet. For slopes steeper than 1:1 temporary shoring requirements shall be shown.

Allowable bearing – allowable bearing of soil or rock in a given interval for a given foundation type.

Any explanatory foundation notes – please add any explanatory material needed such as depths of excavation and replacement or other pertinent data.

Other notes – any notes needed for design or construction not specified above.

Example Reports and Geotechnical Sheets

Please see *Section 1: Appendix A - Examples* for these documents:

- Retaining Wall Report
- Example Retaining Wall Sheets

Chapter 5: Intersections and Small Lines

These differ from full scale line projects only in the geographic extent of the project. Small lines are those projects in support of a roadway alignment that are generally less than 2.5 miles in length. However, these projects can involve extensive investigations if they incorporate structures, geohazard problems and/or large cuts and fills. These projects may be given out separately from the structures used on the project. Guidance for the investigations of structures are included as separate chapters in this manual.

Goals of Investigation

The end result of an intersection or small line investigation project is to supply Geotechnical Sheets that describe any pertinent geotechnical issues, identify potential geohazards, provide CBR values for pavement design and to provide proctor samples from cut areas on the site that may supply fill to the site. These projects are often small and may involve only very slight cuts and fills. Interchange projects frequently occur in urbanized areas where very little drilling can be performed due to utilities, site access issues and existing structures. These projects range from the very simple, which require little or no drilling to large cuts and fills which may require extensive geotechnical recommendations.

These investigations shall be structured to provide appropriate geotechnical sheets (both plan view and cross sections) to lay out geotechnical design elements. This may include not only appropriate slope ratios for soil cuts and fills, but large rock cuts, accommodation for weak soils or swampland areas, sinkholes, landslides and other special geotechnical issues.

The primary end products are the geotechnical sheets, which will be included in the plans. The report will be used by the GES and will also be a reference available at request. It provides supplementary data and explanatory materials, some of which will not be included in the contract plans and documents. These are of great importance when evaluating geotechnical designs, dealing with construction related issues and understanding the reasons behind recommendations given. The report will be used by the GES, but the geotechnical sheets become part of the contract plans.

Drilling Requirements

At least one CBR sample sufficient for pavement design shall be taken at each site. For small lines, it is appropriate to take several CBR samples from the site, depending upon the soils present and the extent of the project. Proctor samples from on-site soils that may be used as fill shall also be taken. If no areas of soil cut are present, these are not necessary. Other drilling and site investigation needed shall be at the judgment of the engineering geologist or geotechnical engineer. This in turn depends upon the scale of the project and the amount of drilling needed to provide appropriate cross sections and geotechnical plans sheets. For a

minor project where there are very small cuts and fills and no stability issues expected, this may mean a site visit and a CBR sample (or samples). Where CBR samples are likely to yield CBR results < 5 additional volume of material may be needed to complete laboratory analysis. For a project with large cuts and fills or major geotechnical issues, this may mean an extensive investigation. Soil and rock expected to be encountered on the site shall be noted. Particularly if potentially acid producing rock or other challenging earth material is found.

Laboratory Analysis

The California Bearing Ratio test (CBR) is a requirement for TDOT projects as TDOT Pavement Design uses the results from this test. As typical for the CBR tests, proctors, gradation, plasticity and classification shall be reported along with the CBR results. Where the CBR sample gives a result of CBR < 5, lime stabilization or other subgrade stabilization methods must be evaluated, this may require additional laboratory analysis with lime stabilized CBR tests performed.

All soil sampled at the site shall have moisture, gradation, plasticity and classification tests completed. Where settlement is a concern, samples shall have a 1-D consolidation test performed. Where slope stability issues are expected, appropriate tests that provide slope stability parameters for use in slope stability analysis shall be performed. These include triaxial tests, direct shear or unconfined compression tests.

Engineering Analysis

Types of analysis that have been needed for past interchange and small line projects include slope stability and settlement calculations. Other analyses may be needed for complex and non-routine projects. If settlement at a site is expected to present a problem, particularly if the settlement will take longer than construction to complete, alternatives to cope with the settlement shall be detailed in the report and in geotechnical sheets provided in the plans. Wait times for settlement and geotechnical designs such as wick/sand drains shall be included.

Typical slopes used for TDOT projects are 3:1 slope ratios for soil and 1.5:1 for rock fill slopes. Rock cuts may vary from vertical to 0.25:1 to other slope ratios as appropriate. If the rock is of sufficiently poor quality it may be wise to set slope ratios in a more typical soil configuration. These slopes can be altered at the discretion of the geotechnical engineer / engineering geologist if the analysis supports different slope configurations. Rock slope stability including rockfall considerations shall also be checked at the site where appropriate. Guidance for typical rockfall design can be found in Chapter 7 of this manual. However, please note that these provisions are not meant to replace analysis and judgement. It is the responsibility of the Geotech to check that designed slopes for a project are stable.

Geotechnical Reports and Drawings

The geotechnical report for interchange and small line projects shall detail the investigations and the recommendations for the site. All cross sections provided with the report shall have explanatory material included in the report. For example, if a cross section is provided that is typical for station 30+00 to 34+50, there should be a section in the report that specifically references this drawing and provides a description of the recommendation and any needed geotechnical notes. A "Soil and Subgrade" report shall be included in the appendix and any CBR sample taken shall be included on this sheet. All typed boring logs shall be included with the report as well as any laboratory results. This report will primarily be used by the GES and as a reference for the exploration performed at the site.

The geotechnical sheets for an interchange and small line project shall include a plan view layout of the drill holes, drill holes plotted in relationship to centerline grade and any cross sections required to illustrate geotechnical design elements. These shall include the Soil Description Sheet which may be placed either as a separate plans page or on the plan view pages of the site.

The initial layout sheets come from the preliminary design plans. Geotechnical data is added after exploration. These are the sheets that will be included in the plans. Information other than recommended CBR values for pavement design included in the report, but not on these sheets, may not make it into the construction plans. If this occurs, these geotechnical recommendations would then likely be ignored. It is critical that recommendations be illustrated with geotechnical plans sheets.

Geotechnical Report Elements:

Executive Summary or Cover Letter – This section gives a brief summary of the report. It shall also state if potentially acid producing materials was found or not found on a project.

Introduction – Brief summary of the project and location. Any special constraints such as limited right of way are noted here.

Geology, Soils and Site Conditions – Geology, soils and site conditions that may affect the project.

Surface and Subsurface Exploration – Exploration Performed

Recommendations – Provide recommendations for construction purposes such as allowable slopes, undercutting and replacement or other pertinent recommendations. The CBR values recommended for pavement design shall be included here.

Special Notes and Specifications – Any special notes to be included in the plans, these should also be on the geotechnical sheet(s).

Appendix – Documents and supporting information
Geotechnical Sheets
Soil and Subgrade report

Soils Description Sheet
Boring Logs
Laboratory Testing
Engineering Analyses

Geotechnical Sheet Elements

General Layout of Site – Plan view showing drilling and sampling locations. This may also show limits of geotechnical design elements, such as limits of undercutting, areas of sinkhole repair or areas of soft ground improvement.

Centerline grade sheets – Showing all drill logs, these must show elevations and material types in relationship to the grade at centerline for the project.

Cross Sections for the Project – Cross sections that describe the recommendations should be included with the geotechnical sheets. For very small and simple projects, only a few cross sections may be needed. Cross sections shall be provided to illustrate geotechnical design elements that are recommended for the project.

Soil Description Sheet/Table - For all soils that have been sampled on the project, the laboratory analysis along with descriptions of the soil shall be included on the plans. This includes proctor test results, atterberg limits as well as in-situ moisture and soil classification by both AASHTO and the Unified Soil Classification System. This can be presented as a chart at the beginning of the plans sheets or the soils present on a particular sheet can be shown as a table on the plan view pages. The format for this chart is shown in Section 1: Appendix B - Supporting Documentation under the title "Soil Description Sheet." Where soils on the chart show an "in-situ moisture" that is significantly wetter or dryer of optimum than the proctor test, this shall be clearly noted on these sheets with a statement that includes a notice to the contractor that wetting, drying or additional handling of these soils may be required.

Geotechnical Notes – Added as needed. They could be included directly on the cross sections or on the general layout. Notes can also be included on a separate plans sheet. Please remember that these will be plans documents, so only appropriate material should be included.

Example Reports and Geotechnical Sheets

The following pages show an example report for a Intersection and Small Line project. Plans sheets should be similar to those provided for a line project. Please see *Section 1: Appendix A - Examples* for these documents.

- Intersection and Small Line Report
- Example Line Sheet (Plan View)
- Example Line Sheet (Profile View)
- Example Line Sheet (Cross Section)

Supporting Documentation

Soil and Subgrade Report - A copy of the soil and subgrade report that shall be included with the report can be found in Section 1: Appendix B - Supporting Documentation.

Soil Description Sheet - An example soil description sheet can be found in Section 1: Appendix B - Supporting Documentation. All soils samples on a project shall be summarized in this chart and it shall be included both in the report and on the geotechnical sheets.

Chapter 6: Lines

Roadway alignment projects may vary from completely new alignments, to widening of existing alignments. Drilling requirements may be far more extensive for new alignments, but there can also be significant drilling and sampling needed for widening projects, particularly where there are large cuts and fills. These projects may be given out separately from the structures used on the project. Guidance for the investigations of structures are included as separate chapters in this manual.

Goals of Investigation

The end result of a line investigation project is to supply Geotechnical Sheets that describe any pertinent geotechnical issues, provide CBR values for pavement design and to provide proctor samples from cut areas on the site that may supply fill to the site. Some cuts and fills at the site may be quite large and require special recommendations such as reinforced soil slopes, undercutting, rock pads, specific rock cut geometries, settlement mitigation or other geotechnical mitigations and designs. Lines may be located both in urban and rural environments and utilities may present significant site access issues. These projects range from the very simple, which require only routine drilling to large cuts and fills which may require extensive geotechnical recommendations.

These investigations shall be structured to provide appropriate geotechnical sheets (both plan view and cross sections) to lay out geotechnical design elements. This may include not only appropriate slope ratios for soil cuts and fills, but large rock cuts, mitigtation for weak soils or swampland areas, sinkholes, landslides and other special geotechnical issues.

The primary end products are the geotechnical sheets, which will be included in the plans. The report will be used by the GES and will also be a reference available at request. It provides supplementary data and explanatory materials, some of which will not be included in the contract plans and documents. These are of great importance when evaluating geotechnical designs, dealing with construction related issues and understanding the reasons behind recommendations given. The report will be used by the GES, but the geotechnical sheets become part of the contract plans.

Drilling Requirements

CBR samples shall be taken where there is a significant change in the soil that will be or may be used underneath pavement. Multiple CBR's are often taken for line projects, depending upon the length. Where CBR samples are likely to yield CBR results < 5 additional volume of material may be needed to complete laboratory analysis. CBR samples shall not be taken from fill areas unless the fills are expected to be extremely small. These samples are used solely for pavement design and are not relevant for other geotechnical rec-

ommendations. Proctor samples from on-site soils that may be used as fill shall also be taken. If no areas of soil cut are present, these are not necessary. In the case where CBR and proctors are inappropriate, small bag samples sufficient for classification and moisture content can also be taken. Where rock cuts are present, rock drilling will be required in order to characterize the on-site rock, check for soundness and provide data for cut slope design. Other drilling and site investigation shall be at the judgment of the engineering geologist or geotechnical engineer. This in turn depends upon the scale of the project and the amount of drilling needed to provide appropriate cross sections and geotechnical plans sheets. For a minor project where there are very small cuts and fills and no stability issues expected, this may require only limited drilling, Proctor and CBR samples. For a project with large cuts and fills or major geotechnical issues, this may require an extensive investigation. Soil and rock expected to be encountered on the site shall be noted, particularly if potentially acid producing rock or other challenging earth material is found.

Rules of Thumb for Line Drilling

The following table represents some standard rules of thumb within TDOT for sufficient drilling for alignments. As with all other guidance of this type, judgement, AASHTO recommendations and standard geotechnical practice shall be used to fit the site exploration to the conditions encountered. This chart shall be used for informational purposes only and the site investigation shall be adjusted as needed. Lines which are primarily widening of an existing alignment may require less drilling and new alignment, particularly those with special geotechnical problems such as geohazards, settlement areas, large cuts and fills, ponds, wetlands or other issues.

Auger drilling[3]

Soil Cuts and Fills	Depth of Fill; Height of Cut	Cut or Fill	Spacing and Type	Depth
Small Cuts and Fills	D<10; H<10	Cut	Auger on maximum of 600’ spacing.	To 10’ below ditchline or at rock refusal
		Fill	Auger on maximum of 600’ spacing.	To 2 x Depth of embankment fill
Cuts and Fills	10’ > D > 20’ ; 10; > H > 20’	Cut	Auger Maximum of 200’ Spacing	To 10’ below ditchline or at rock refusal, Rock coring down to 5 feet below ditchline if rock encountered before base of cut.

[3] Note: for new alignment this spacing generally has a boring at left of centerline, near centerline and right of centerline. For very large cuts and fills this may require 1-3 holes to the left or right. These holes may be staggered and are NOT required to be on a regular pattern. Too regular a pattern in drilling and sampling can result in sampling error.

Soil Cuts and Fills	Depth of Fill; Height of Cut	Cut or Fill	Spacing and Type	Depth
		Fill	Auger Maximum of 400' spacing	Depth x 1.5 (Fill Height) or rock refusal
Larger Cuts and Fills	D > 20'; H>20	Cut	Auger Maximum of 100' spacing	To 10' below ditchline or at rock refusal. Rock coring down to 5 feet below ditchline if rock encountered before base of cut.
		Fill	Auger Maximum of 300' Spacing	Depth x 2 (Fill Height) or rock refusal

Supplementary drilling[4]

Cut or Fill	Depth of Fill; Height of Cut	Length of Cut or Fill	Number of Borings	Depth
Cut	D < 40	L < 600'	At least 1	Located in deepest portion of the cut, at least 15 feet below ditchline.
	D < 40	L > 600'	Spaced out at no more than 400' in length	Located in deepest portion of the cut, at least 15 feet below ditchline.
	D > 40	L < 600'	Spaced out at no more than 400' in length, minimum of 2 borings	Attempt to sample deepest portion of the cut, at least 15 feet below ditchline.
	D > 40	L < 600'	Spaced out at no more than 300' in length, minimum of 2 borings	Attempt to sample deepest portion of the cut, at least 15 feet below ditchline.
Rock Cuts	D > 10'	L < 200'	At least 2	To 5 feet below ditchline

[4] Includes rock core, split spoon sampling and tubes as appropriate. Please note that these guidelines may not be sufficient in structurally complex rock. Additional drilling will be required if needed to predict potential structural failures in rock cuts such as plane shear, wedge failure and toppling failures.

Cut or Fill	Depth of Fill; Height of Cut	Length of Cut or Fill	Number of Borings	Depth
	D > 10’	L > 200’	Spaced out at no more than 200’ in length. Minimum of 3	To 5 feet below ditchline
Fills	H < 30	L < 600’	At least 1	To 2 x depth of proposed embankment. Core at least 5 feet of rock if refusal is higher than 2 x embankment depth
	H < 30	L > 600’	At least 2, spaced no more than 400 feet apart	To 2 x depth of proposed embankment. Core at least 5 feet of rock if refusal is higher than 2 x embankment depth
	H > 30	L < 600’	At least 2	To 2 x depth of proposed embankment.
	H > 30	L > 600’	At least 2, spaced no more than 300 feet apart	Core at least 5 feet of rock if refusal is higher than 2 x embankment depth

Laboratory Analysis

The California Bearing Ratio test (CBR) is a requirement for TDOT projects as TDOT Pavement Design uses the results from this test. As typical for the CBR tests, proctors, gradation, plasticity and classification shall be reported along with the CBR results. Where the CBR sample gives a result of CBR < 5, lime stabilization or other subgrade stabilization methods must be evaluated, this may require additional laboratory analysis with lime stabilized CBR tests performed. All soil sampled at the site shall have moisture, gradation, plasticity and classification tests completed. Where settlement is a concern, samples shall have a 1-D consolidation test performed. Where slope stability issues are expected, appropriate tests that provide slope stability parameters for use in slope stability analysis shall be performed. These include triaxial tests, direct shear or unconfined compression tests.

Engineering Analysis

Types of analysis that have been needed for line projects include slope stability and settlement calculations. Other analyses may be needed for complex and non-routine projects. If settlement at a site is expected to present a problem, particularly if the settlement will take longer than construction to complete, alternatives to cope with the settlement shall be detailed in the report and in geotechnical sheets provided in the plans. Wait times for settlement and geotechnical designs such as wick/sand drains shall be included. Stability of proposed rock cuts may also need to be analyzed in order to prevent rockfall and rock slope stability issues.

Typical slopes used for TDOT projects are 3:1 slope ratios for soil and 1.5:1 for rock fill slopes. Rock cuts may vary from vertical to 0.25:1 to other slope ratios as appropriate. If the rock is of sufficiently poor quality it may be wise to set slope ratios in a more typical soil configuration. These slopes can be altered at the discretion of the geotechnical engineer / engineering geologist if the analysis supports different slope configurations. Rock slope stability including rockfall considerations shall also be checked at the site where appropriate. This may involve the use of rock bolts, welded wire mesh draping, rockfall catchment fences, shotcrete and other mitigation methods. Guidance for typical rockfall design can be found in Chapter 7 of this manual. However, please note that these provisions are not meant to replace analysis and judgement. It is the responsibility of the Geotech to check that designed slopes for a project are stable.

Geotechnical Reports and Drawings

The geotechnical report for line projects shall detail the investigations and the recommendations for the site. All cross sections provided with the report shall have explanatory material included in the report. For example, if a cross section is provided that is typical for station 30+00 to 34+50, there should be a section in the report that specifically references this drawing and provides a description of the repair and any needed geotechnical notes. A “Soil and Subgrade” report shall be included in the appendix and any CBR samples taken shall be included on this sheet. All typed boring logs, laboratory results and soil description sheets shall be included with the report. This report will primarily be used by the GES and as a reference for the exploration performed at the site.

The geotechnical sheets for a line project shall include a plan view layout of the drill holes, drill holes plotted in relationship to centerline grade and any cross sections required to illustrate geotechnical design elements. Included on these plan view layout sheets are some summary soils testing and identification data. Please see Section 1: Appendix A for examples of typical geotechnical sheets.

The initial layout sheets come from the preliminary design plans. Geotechnical data is added after exploration. These are the sheets that will be included in the plans. Information other than recommended CBR values for pavement design included in the report, but not on these sheets, may not make it into the construc-

tion plans. If this occurs, these geotechnical recommendations would then likely be ignored. It is critical that recommendations be illustrated with geotechnical plans sheets.

Geotechnical Report Elements:

Executive Summary or Cover Letter – This section gives a brief summary of the report. It shall also state if potentially acid producing materials was found or not found on a project.

Introduction – Brief summary of the project and location. Any special constraints such as limited right of way are noted here.

Geology, Soils and Site Conditions – Geology, soils and site conditions that may affect the project.

Surface and Subsurface Exploration – Exploration Performed

Recommendations – Provide recommendations for construction purposes such as allowable slopes, undercutting and replacement or other pertinent recommendations. The CBR values recommended for pavement design shall be included here.

Special Notes and Specifications – Any special notes to be included in the plans, these should also be on the geotechnical sheet(s).

Appendix – Documents and supporting information
Geotechnical Sheets
Soil and Subgrade report
Soils Description Sheet
Boring Logs
Laboratory Testing
Engineering Analyses

Geotechnical Sheet Elements

General Layout of Site – Plan view showing drilling and sampling locations. This may also show limits of geotechnical design elements, such as plan view limits of undercutting. Selected soils data are also shown on these sheets.

Centerline grade sheets – Showing all drill logs, these must show elevations and material types in relationship to the grade at centerline for the project.

Cross Sections for the Project – Cross sections that describe the recommendations should be included with the geotechnical sheets. For very small and simple projects, only a few cross sections may be needed. Cross sections shall be provided to illustrate geotechnical design elements that are recommended for the project.

Soil Description Sheet/Table - For all soils that have been sampled on the project, the laboratory analysis along with descriptions of the soil shall be included on the plans. This includes proctor test results, atterberg limits as well as in-situ moisture and soil classification by both AASHTO and the Unified Soil Classification System. This can be presented as a chart at the beginning of the plans sheets or the soils present on a particular sheet can be shown as a table on that sheet. . The format for this chart is shown in Section 1: Appendix B - Supporting Documentation under the

title “Soil Description Sheet.” Where soils on the chart show an “in-situ moisture” that is significantly wetter or dryer of optimum than the proctor test, this shall be clearly noted on these sheets with a statement that includes a notice to the contractor that wetting, drying or additional handling of these soils may be required.

Geotechnical Notes – These would be added as needed. They could be included directly on the cross sections or on the general layout. These notes can also be included on a separate plans sheet. Please remember that these will be plans documents, so only appropriate material should be included.

Example Reports and Geotechnical Sheets

The following pages show an example report and bridge sheet for a Line Project. Please see *Section 1: Appendix A - Examples* for these documents.

- Example Line Report
- Example Line Sheet (Plan View)
- Example Line Sheet (Profile View)
- Example Line Sheet (Cross Section)

Supporting Documentation

Soil and Subgrade Report - A copy of the soil and subgrade report that shall be included with the report can be found in Section 1: Appendix B - Supporting Documentation.

Soil Description Sheet - An example soil description sheet can be found in Section 1: Appendix B - Supporting Documentation. All soils samples on a project shall be summarized in this chart and it shall be included both in the report and on the geotechnical sheets.

Chapter 7: Landslides and Rockfall

Landslide (including rockslides) and rockfall projects can be the most challenging of TDOT Geotechnical projects, but often vary significantly in size and scope. These projects may be small scale typical soil failures to very large scale projects which require extensive investigation and analysis. Typically, these projects will be given out to consultants only on an emergency basis, that is just after a slide has occurred at a site where rapid repair is a high priority. Potential landslides and rockfall may need to be analyzed on other projects such as lines or interchanges in order to ensure that an existing slide does not worsen or cause a failure in the roadway. Stability checks should be made in rock with complex structure to ensure that new rock cuts will not result in an increased risk of sliding or rockfall. A variety of methods are available to mitigate or repair landslides and rockfall sites and TDOT will need recommendations for alternatives that may include both short term recommendations and longer term mitigation and repair.

Goals of Investigation

The end result of a landslide and rockfall investigation for TDOT is to provide comprehensive recommendations and alternatives for the repair or mitigation of the landslide or rockfall. Many projects may be so large in scope that complete repair of these sites may not be feasible. In these cases, recommendations for mitigation of the problem will be needed. Multiple reports may be required for these investigations with early reports detailing possible alternatives with a discussion of relative risk and costs. Later, after consultation with TDOT, plans and cross sections along with a final report may be needed.

All details on construction of the mitigation or repair will need to be shown in the geotechnical sheets. The report will be used by the GES and will also be a reference available at request. It provides supplementary data and explanatory materials, some of which will not be included in the contract plans and documents. These are of great importance when evaluating geotechnical designs, dealing with construction related issues and understanding the reasons behind recommendations given. The report will be used by the GES, but the geotechnical sheets become part of the contract plans.

Drilling Requirements

Unlike typical geotechnical work, there are no specific rules of thumb for drilling landslide and rockfall projects. Sufficient drilling to analyze the problem in order to design appropriate repair and mitigation strategies shall be used. It is the responsibility of the Geotech to ensure that sufficient work has been completed in order to properly analyze the problem. There are numerous publications available that detail investigations of landslides, rockfall and rockslides. Split spoon sampling, test pits, Shelby tubes, auguring, washboring and coring are all drilling methods which may be used on a project depending upon the type and nature of the failure at the site. It is critical to identify the limits of the failure surface when completing an investigation.

Laboratory Analysis

Appropriate tests that provide slope stability parameters for use in slope stability analysis shall be performed. These include triaxial tests, direct shear or unconfined compression tests. Other speciality tests may be used as needed.

Engineering Analysis

Slope stability calculations sufficient to predict and mitigate or repair the site shall be performed. TDOT presently uses GSTABL 7 with STEDWin for soil slope stability isses, although other software may be used to analyze the problem. Back calculation of the failure may be particularly useful for these projects and may provide more realistic data than laboratory sampling under some circumstances. Rock slope failures are more problematic, and it is critical that the failure surfaces be adequately identified and analyzed by recognized methods. Plane shear and wedge failures will need to be analyzed with appropriate analysis methods. Again, there are numerous geotechnical publications which detail these analyses as well as the potential pitfalls and necessary parameters.

Geotechnical Reports and Drawings

The geotechnical report for line projects shall detail the investigations and the recommendations for the site. All cross sections provided with the report shall have explanatory material included in the report. For example, if a cross section is provided that is typical for station 30+00 to 34+50, there should be a section in the report that specifically references this drawing and provides a description of the repair and any needed geotechnical notes. A plan view layout sheet showing the locations of the drilling and sampling sites along with limits of existing failure and any other important features. Cross sections showing all of the geotechnical design elements shall be included with the final report. A geotechnical notes sheet will also typically be needed for these projects. Additionally, any sheets needed to explain design elements such as rock bolts, soil nails, horizontal drainage, etc. shall also be included. Please see Section 1: Appendix A for examples of typical geotechnical sheets. Information included in the report, but not on these sheets, may not make it into the construction plans. If this occurs, these geotechnical recommendations would then likely be ignored. It is critical that recommendations be illustrated with geotechnical plans sheets.

Geohazard Documentation needed:

For all landslides, rockfall and rockslides GPS coordinates of the site shall be taken and reported in WGS84 (NAD83) datum in decimal degrees. The area of the slide shall be mapped, and individual features may also be mapped and noted. A geohazard inventory form shall be filled out for all sites as this will be used to upload the data on the slide/rockfall area into the TDOT Geohazard Management System. In addition to the

inventory form, the features and area of the slide shall be shown on an aerial photograph of the site. Google maps, Bing or other online resources may be used as the "base map" aerial photograph of the site.

Geotechnical Report Elements:

Executive Summary or Cover Letter – This section gives a brief summary of the report. It shall also state if potentially acid producing materials was found or not found on a project.

Introduction – Brief summary of the project and location. Any special constraints such as limited right of way are noted here.

Geology, Soils and Site Conditions – Geology, soils and site conditions that may affect the project.

Surface and Subsurface Exploration – Exploration Performed

Recommendations – Provide recommendations for construction purposes such as allowable slopes, undercutting and replacement or other pertinent recommendations.

Special Notes and Specifications – Any special notes to be included in the plans, these should also be on the geotechnical sheet(s).

Appendix – Documents and supporting information
Geotechnical Sheets
Boring Logs
Laboratory Testing
Engineering Analyses
Geohazard Inventory Forms / Map

Geotechnical Sheet Elements

General Layout of Site – Plan view showing drilling and sampling locations along with general limits of the slope failure and other pertinent features including the limits to the new repair.

Centerline grade sheets – Showing all drill logs, these must show elevations and material types in relationship to the grade at centerline for the project.

Cross Sections for the Project – Cross sections that describe the recommendations should be included with the geotechnical sheets. For very small and simple projects, only a few cross sections may be needed. Cross sections shall be provided to illustrate geotechnical design elements that are recommended for the project. Graphical boring logs, as appropriate, may also be included on these cross sections.

Geotechnical Notes – These would be added as needed. They could be included directly on the cross sections or on the general layout. These notes can also be included on a separate plans sheet. Please remember that these will be plans documents, so only appropriate material should be included.

Example Reports and Geotechnical Sheets

The following pages show an example report and rock slope standard drawing for a Landslide or Rockfall Project. Please see *Section 1: Appendix A - Examples* for these documents.

- Example Line Rockfall Report
- Rock Slope Standard Drawing
- Please see Example Line sheets for further guidance for plans sheets.

Supporting Documentation

Geohazard Inventory Forms: Please see Section 1: Appendix B - supporting documents for Geohazard Inventory forms.

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Chapter 8: Sinkholes and Subsidence

Sinkholes and subsidence issues will generally be part of other projects, rather than given out to consultants as separate projects. They may occur on many different project types, but all require additional investigation and recommendations. Many areas of Tennessee are prone to sinkhole and karst related problems due to the underlying geology. Sinkholes and subsidence areas may already be present on a site, or may occur during or after construction. Non-landslide subsidence problems may be due to settlement of soils or as is frequently the case in West Tennessee due to erodible soils, piping and water problems.

Goals of Investigation

The end result of a sinkhole or subsidence investigation for TDOT is to provide comprehensive recommendations and alternatives for the repair or mitigation. This includes delineating the affected areas and to the extent possible examining the causes of the sinkhole or subsidence problem. It is particularly important to examine potential causes of failure when there is a “sudden” sinkhole collapse as a repair not designed to address the root cause may not fix the problem. Multiple reports may be required for these investigations with early reports detailing possible alternatives with a discussion of relative risk and costs. Later, after consultation with TDOT, plans and cross sections along with a final report may be needed.

All details on construction of the mitigation or repair will need to be shown in the geotechnical sheets. The report will be used by the GES and will also be a reference available at request. It provides supplementary data and explanatory materials, some of which will not be included in the contract plans and documents. These are of great importance when evaluating geotechnical designs, dealing with construction related issues and understanding the reasons behind recommendations given. Remember that the report will be used by the GES, but the geotechnical sheets become part of the contract plans.

All sinkholes on any type of project are to be spatially located by both station and offset and GPS coordinates. A sinkhole evaluation form shall be filled out for every sinkhole location whether or not mitigation is recommended. Please see Appendix B - Supporting Documentation for a Sinkhole Evaluation Form. The Geotech shall bring all of these locations to the attention of Design to ensure that all of these locations are included on the plans.

Drilling Requirements

Unlike typical geotechnical work, there are no specific rules of thumb for drilling sinkhole and subsidence projects. Sufficient drilling to analyze the problem and design appropriate repair and mitigation strategies should be used. It is the responsibility of the geotech to ensure that sufficient work has been completed in order to properly analyze the problem. TDOT will generally drill around sinkholes and in some subsidence

areas in order to better define the nature and type of problem presented by the problem site. There are numerous publications available that detail investigations of sinkholes. Split spoon sampling, test pits, shelby tubes, auguring, washboring and coring are all drilling methods which may be used on a project depending upon the type and nature of the failure at the site. It is critical to identify the limits of the failure when completing an investigation. A sinkhole repair along a linear feature may require a larger repair than first appears from surface expression. Sinkholes have been known in the past to fail right beside an existing repair.

Laboratory Analysis

In the case of sinkholes, TDOT typically will perform soil classification, Atterberg limits and sieve analysis. However, other subsidence problems may require additional tests such as the 1D Consolidation test or tests that better define the erodibility of the on site soils.

Engineering Analysis

There are few reliable mathematical methods for analyzing sinkhole related problems and none used in the practical application of sinkhole repair at TDOT. Here, as with many areas of geotechnical work, experience and judgement have to be the guide. Subsidence issues, depending on the cause, can be modeled using the 1D Consolidation Test for sites where the problem is due to the consolidation and settlement of soils. For subsidence areas where a surcharge or drainage may be needed sufficient analysis shall be performed to predict the magnitude of the surcharge, the drainage needed and the time of settlement. Erodibility calculations are also available, but may or may not provide additional guidance when repairing sites where water is plucking or piping soils.

Geotechnical Reports and Drawings

The geotechnical report for sinkhole and subsidence projects shall detail the investigations and the recommendations for the site. All cross sections provided with the report shall have explanatory material included in the report. For example, if a cross section is provided that is typical for station 30+00 to 34+50, there should be a section in the report that specifically references this drawing and provides a description of the repair and any needed geotechnical notes. A plan view layout sheet showing the locations of the drilling and sampling sites along with limits of existing failure and any other important features. Cross sections showing all of the geotechnical design elements shall be included with the final report. A geotechnical notes sheet will also typically be needed for these projects. Additionally, any sheets needed to explain design elements such as rock pads, geotextile fabric, compaction grouting points or any other elements. TDOT has a standard drawing for sinkhole repair alternatives which may be used as guidance. However, as with other TDOT drawings, these must be used with caution and judgement. It is up to the Geotech to make sure that the repair is appropriate for the site. It is insufficient simply to site the standard drawing and provide no addi-

tional thought or judgement to the matter. Please see Section 1: Appendix A for examples of typical geotechnical sheets. Also, please see Section 1: Appendix B - Supporting Documentation: Geohazard Inventory form.

Information included in the report, but not on the geotechnical sheets, may not make it into the construction plans. If this occurs, these geotechnical recommendations would then likely be ignored. It is critical that recommendations be illustrated with geotechnical plans sheets. A separate report is not needed where the sinkhole or subsidence issue is part of a larger report i.e. a line project. It may be included as part of other reports, though separate sheets detailing the specific repairs and mitigation techniques will be needed. A separate report will only be needed if the project assigned is specifically a sinkhole or subsidence project. This would occur, for example, if a Geotechnical firm were called to come out in response to a sinkhole problem on a construction site where the report had already been previously completed.

Geohazard Documentation needed:

For all sinkholes and settlement areas, whether or not mitigation will be performed, GPS coordinates of the site shall be taken and reported in WGS84 (NAD83) datum in decimal degrees. The area affected shall be mapped and noted. A geohazard inventory form shall be filled out for all sites as this will be used to upload the data on the sinkhole or settlement area into the TDOT Geohazard Management System. In addition to the inventory form, the features and area of the sinkhole shall be shown on an aerial photograph of the site. Google maps, Bing or other online resources may be used as the “base map” aerial photograph of the site.

Geotechnical Report Elements:

Executive Summary or Cover Letter – This section gives a brief summary of the report. It shall also state if potentially acid producing materials was found or not found on a project.

Introduction – Brief summary of the project and location. Any special constraints such as limited right of way are noted here.

Geology, Soils and Site Conditions – Geology, soils and site conditions that may affect the project.

Surface and Subsurface Exploration – Exploration Performed

Recommendations – Provide recommendations for construction purposes such depth of excavation, compaction grouting parameters, geotechnical elements and limits of repairs.

Special Notes and Specifications – Any special notes to be included in the plans, these should also be on the geotechnical sheet(s).

Appendix – Documents and supporting information
Geotechnical Sheets
Boring Logs
Laboratory Testing

Engineering Analyses
Sinkhole Evaluation Form(s) - as appropriate

Geotechnical Sheet Elements

General Layout of Site – plan view showing drilling and sampling locations along with general limits of the failure and other pertinent features including the limits to the new repair.

Cross Sections for the Project – Cross sections that describe the recommendations should be included with the geotechnical sheets. For very small and simple projects, only a few cross sections may be needed. Cross sections shall be provided to illustrate geotechnical design elements that are recommended for the project. Graphical boring logs, as appropriate may be included on these cross sections.

Geotechnical Notes – These would be added as needed. They could be included directly on the cross sections or on the general layout. These notes can also be included on a separate plans sheet. Please remember that these will be plans documents, so only appropriate material should be included.

Example Reports and Geotechnical Sheets

The following pages show an example drawings for a Sinkhole and Subsidence project. Reports should be similar to those provided for a line project. Please see *Section 1: Appendix A - Examples* for these documents.

- Intersection and Small Line Report
- Example Line Report
- Example Sinkhole Sheet (Cross Section)
- Example Sinkhole Treatment

Supporting Documentation

Geohazard Inventory Forms: Please see Section 1: Appendix B - supporting documents for Geohazard Inventory forms.

Chapter 9: Preliminary Investigations

A preliminary geotechnical investigation is provided to the Planning Section within the TDOT Environmental Bureau in order to provide information in support of environmental documents and to provide a preliminary assessment as to the feasibility of a project or its alternates. These investigations differ from other TDOT projects in that drilling and sampling may not be required, or if they are required, are performed on a much more limited basis than with a full scale investigation. Cross sections of the project are often not available and the project may be shown on a set of "Functional Drawings" (a set of drawings where the line is shown with a backdrop of an aerial photo of the site).

Goals of Investigation

Preliminary investigations are provided as a first look at the feasibility of a project and to identify potential geotechnical and environmental related issues that may come up on the project. For a line project there may be only one alignment to be studied, there may be multiple alignments or only a corridor may have been defined. Where there are multiple alignments, a preferred alignment, from a geotechnical standpoint shall be identified. Geological hazards and other geotechnical issues that may cause problems with construction, have a significant cost of mitigation or pose environmental issues and threats shall be identified for all alternates. Specific attention should be paid to the presence of sinkholes, landslides, rockfall, subsidence areas, soft or unstable ground, wetland locations, springs, seeps and potentially acid producing rock. Any of these threats which are identified at the site shall be clearly noted in the report. See chapters 7 and 8 for guidance on these individual features.

Unlike many other TDOT projects, the end product of a preliminary investigation is a report which may be supported with maps, drawings or cross sections; but is not a part of contract plans. Preliminary investigations are used by TDOT in order to support feasibility studies, picking an alignment, assessing alternate alignments, as technical support for environmental documents and for assessing preliminary costs of a project. These projects may be very simple and require a single site visit and a reasonable desk study or they may be complex and require drilling, sampling and complex analyses.

Drilling Requirements

For simple projects, drilling and sampling may not be required. For more complex projects, it will depend upon the specific project and the goals for the investigation at the time of investigation. This will need to be assessed on a case by case basis depending upon the complexity of the project and TDOT needs.

Laboratory Analysis

For simple projects, laboratory analysis may not be required. For more complex projects, it will depend upon the specific project and the goals for the investigation at the time of the investigation. This will need to be assessed on a case by case basis depending upon the complexity of the project and TDOT needs.

Engineering Analysis

For simple projects, engineering analysis may not be required. For more complex projects, it will depend upon the specific project and the goals for the investigation at the time of the investigation. This will need to be assessed on a case by case basis depending upon the complexity of the project and TDOT needs. These may include any or all of the techniques described in other chapters of this manual.

Geotechnical Reports and Drawings

The geotechnical report for a preliminary investigation project should detail the investigations and the recommendations for the site. Geohazards at the site and any features which are expected to cause geotechnical problems shall be clearly identified. Maps, drawings and photographs may be attached as needed in order to clarify or bring out key points and issues. This report will be used by the GES as a reference for the exploration performed at the site and as support for Planning and Environmental documents.

Geohazard Documentation needed:

For all geohazards, GPS coordinates shall be taken and reported in WGS84 (NAD83) datum in decimal degrees. The area affected shall be mapped and noted. A geohazard inventory form shall be filled out for all geohazard sites as this will be used to upload the data into the TDOT Geohazard Management System. In addition to the inventory form, the features and area of the geohazard shall be shown on an aerial photograph of the site. Google maps, Bing or other online resources may be used as the “base map” aerial photograph of the site.

Geotechnical Report Elements

Executive Summary or Cover Letter – This section gives a brief summary of the report. It shall also state if potentially acid producing materials was found or not found on a project.

Introduction – Brief summary of the project and location. Any special constraints such as limited right of way are noted here.

Geology, Soils and Site Conditions – Any geology, soils and site conditions that may affect the project.

Surface and Subsurface Exploration – Exploration Performed. Please include site visits and surface exploration. Subsurface investigation, if performed shall be detailed here as well.

Recommendations – Provide recommendations for choosing an alignment and documentation of problems noted at the site along with potential mitigation methods. These may be very detailed or very general depending upon the complexity of the project.

Appendix – Documents and other supporting data

- Geotechnical Sheets and drawings
- Maps
- Boring Logs - if applicable
- Laboratory Testing - if applicable
- Engineering Analyses - if applicableGeotechnical Sheet Elements

If geotechnical sheets are to be used for a preliminary report, please see other chapters in the manual for general guidance as to the appropriate information to include on the sheet for the type of project. For example, a preliminary investigation of a line which included exploration and will include geotechnical sheets shall attempt to incorporate all the information for a line project.

Example Reports and Geotechnical Sheets

Please see *Section 1: Appendix A - Examples* for this document.

- Example Preliminary Report

Chapter 10: Pyrite and Potential APR

Potentially acid producing rock may be found on any project type, however, as these projects present special environmental and permitting projects, some additional information is required. TDOT maintains a guideline document "Guideline for Acid Producing Rock Investigation, Testing, Monitoring and Mitigation" October 2007 as well as a Special Provision 107L (http://www.tdot.state.tn.us/materials/geotech/consultantinfo.htm). This shall be used as a reference for both appropriate testing and suggested methods of mitigation. Also posted to the TDOT website are a set of "guidance" design drawings used for encapsulation and blending designs on projects (http://www.tdot.state.tn.us/materials/geotech/consultantinfo.htm).

A rock or soil formation may produce acid when excavated and exposed to air, water and *Thiobacillius* bacteria. Sulfide minerals, most commonly pyrite, produce this acid as a byproduct of the breakdown of the sulfur. This can cause environmental issues and impacts and may require special handling and procedures.

Goals of Investigation

Projects which include potentially acid producing rock must have the potential problem formations identified and tested. Intervals of excavated rock that may produce acid under the right conditions need to be assessed and recommendations as to handling and final placement of the rock shall be established. At this time TDOT uses several standard methods for dealing with these materials. For rock judged not to present a potential for acid production, for example limestone, nothing more need be done. For rock with a low potential for producing acid blending with lime is used and for rock with a moderate to high potential for producing acid, encapsulation of the material is used.

Drilling Requirements

Sufficient drilling to identify, sample and test problem and potentially problematic formations shall be completed. document "Guideline for Acid Producing Rock Investigation, Testing, Monitoring and Mitigation" October 2007. Drilling must be sufficient to show the horizontal and vertical extent of problem layers on the project to identify areas that must have special treatment and to calculate quantities.

Laboratory and Engineering Analysis

For most projects, an Acid Based accounting of the samples will be required. This includes an assessment of the paste pH, Acid Potential (AP), Neutralization Potential (NP), AP-NP (the calcium carbonate deficiency) as well as tests of total sulfur and pyritic sulfur. Other testing procedures are available such as the humidity cell and leach tests. All laboratory tests should be assessed for reasonableness and whether or not the samples are representative of the material out in the field. Multiple parameters may be needed in order to

assess whether or not a soil or rock can produce acid in the field. Additionally, site assessments of the same material placed in the field may also need to be completed or addressed.

Geotechnical Reports and Drawings

Geotechnical Report

Generally, there is not a separate report provided for sites which contain potentially acid producing rock. Please see other chapters in this manual for the appropriate report format for the specific project type on which these materials have been identified.

Geotechnical Sheet Elements

If encapsulation or other special handing procedures are required these shall be shown on additional geotechnical sheets. Please ensure sufficient notes are provided in order to construct any proposed mitigation or repair. See the guidance "design drawings" used for encapsulation and blending designs on projects posted to the TDOT website at http://www.tdot.state.tn.us/materials/geotech/consultantinfo.htm).

Encapsulation on a project
- DWG1A_revised2010.pdf - Geomembrane Option
- DWG1B_revised2010.pdf - Clay Option
- DWB1C_revised 2010.pdf - Encapsulation Details

Offsite Encapsulation or blending
- DWG2_revised2009.pdf - Off site final cover layout
- DWG3_revised2009.pdf - Off site encapsulation cell
- DWG3A_revised2009.pdf - Off site encapsulation cell additional details

Partial Encapsulation
- DWG4_revised2009.pdf - On Site partial encapsulation
- DWG5_revised2009.pdf - Off site partial encapsulation

Blending - Onsite
- DWG6_revised03_2010 - On site blending example

Chapter 11: Noise Walls

TO BE ADDED

Chapter 12: High Mast Lighting Projects

TO BE ADDED

Chapter 13: Value Engineering Projects

Occasionally, a geotechnical firm will be called upon by a construction company to assist with a Value Engineering Project for TDOT. These projects, initiated by the contractor are intended to be a method where a construction company can introduce new and innovative techniques to TDOT that also save money over the original recommendations for the site. The cost savings of the new methods are split between the contractor and the state. These proposals must be submitted for approval to Construction as well as other areas within TDOT. VE proposals that contain geotechnical elements must be submitted for approval to the Geotechnical Engineering Section as well. Technical justification and additional information may be required.

Role of the Geotechnical Engineer/Engineering Geologist

Value Engineering (VE) proposals that involve geotechnical elements or design must involve a geotechnical engineer or engineering geologist who has a professional license with the State of Tennessee. A VE proposal will typically be submitted by a contractor to the department. Typical documentation that will be included in one of these proposals are details on the requested change and money that will be saved by implementing the proposal. What is often missing from VE projects that contain geotechnical elements are geotechnical reports, calculations and guidance.

When a VE project involves geotechnical elements, a geotechnical engineer or engineering geologist must submit engineering calculations, details of investigations (if any) and a geotechnical report summarizing recommendations. The geotechnical engineer is taking responsibility for the geotechnical elements of the plan and should not consider their role as merely supporting with no professional responsibility. It is recommended that a Geotechnical Consultant / Designer who has been requested by a contractor to provide geotechnical information / design as a part of a VE contact the Geotechnical Engineering Section to discuss, clarify and confirm what geotechnical information /design is expected and required.

For example, a project where a new type of retaining wall is added. The area may require a foundation investigation, if one has not already been completed, or may require additional geotechnical investigation in order to make appropriate and prudent engineering calculations. A report, details of the investigation and engineering calculations shall be submitted with the VE proposal exactly as if TDOT had asked the geotechnical engineer to supply such needed information for design. It is not sufficient for a project that contains significant geotechnical elements to provide only drilling with no recommendations. Neither is it acceptable to only discuss the potential “cost savings” of the project. All VE projects need to have supporting documentation that indicate professional staff have designed and evaluated the proposed plan. Contractors who submit VE proposals that contain significant geotechnical elements are encouraged to retain responsible and professional engineering services from a geotechnical firm or geotechnical engineer / engineering geologist.

Chapter 14: Scope of Work

Part of the responsibility of a Geotechnical firm hired directly by TDOT or through another consultant is to provide a detailed scope of work for approval before any exploration begins. This may include a cover letter which provides a summary of the work to be completed at the site as well as other supporting documentation. Firms in the past have provided charts of proposed boring locations as well as plans sheets which show proposed boring locations. These may be required in the case of a complex project and may be particularly helpful of projects where there has been a design change that necessitates additional drilling and exploration.

Required Paperwork and Submittals

For all geotechnical work completed by consultant either directly for TDOT or through another consultant, a "Manhour Requirements and Cost Estimate" form must be filled out for the project and submitted to the TDOT Geotechnical Engineering Section. This cost estimate details the scope of work and pricing for each item in this scope of work. It must be approved by TDOT Geotechnical prior to any work other than preparation of scope to begin. Please note that scope preparation is considered part of the cost of doing business and is not a reimbursable expense.

The "Manhour Requirements and Cost Estimate" form details all expected items needed for completing the project, the estimated quantities of such items, the basis of payment and the cost per basis of payment as well as the total amount for each item. It is divided up into several sections.

Manhour Requirements and Cost Estimate form

Cost Cover Sheet - This sheet contains basic reference information including the project location data, Geotechnical Consultant Name, Date Prepared, Project Number, Geotechnical Office Number and Contact information for the preparer.

1.00 Drilling Costs - All drilling items are shown on this sheet and are to be listed on a per unit basis. For instance, Rock coring is charged on a per-foot basis. Specialty items not listed such as CPT drilling may be added to this sheet with the agreement of TDOT Geotechnical. The total estimated cost of drilling items is shown at the bottom of the page.

2.00 Lab Testing Costs - All laboratory testing items are shown on this sheet and are to be listed on a per unit basis. For instance, the Atterberg Limit test is charged on a per sample basis. Please note that tests which require multiple points, such as the C-U triaxial test are still charged on a per total test, not per point basis. So a test which may take 3 samples to complete, would still be charged as only 1 single test, because several points are required in order to provide a complete single test result. Specialty items not listed such as may be added to this sheet with the agreement of TDOT Geotechnical. The total estimated cost of laboratory testing items is shown at the bottom of the page.

3.00 Manpower Costs - All expected manpower hours estimated for the project are to be detailed on this sheet. It breaks down cost by tasks and by category of staff. These are charged on a per man hour basis. The hourly rate is determined on sheet 3.01 Manpower Breakdown. If CAD services are to be provided by others, such as the Design Consultant, the CAD technicians estimated hours may be shown either on the Geotechnical Consultants cost estimate **or** on the Design Consultants cost estimate, not both.

3.01 Manpower Breakdown - This is a particularly critical sheet in the cost estimate. Failure to complete this sheet correctly can result in audits by the state or in dismissal of a consultant from a contract.

Direct Pay Rate - This is the actual rate paid to a member(s) of the Geotechnical Consultants staff. Evidence that this is the case may be required by TDOT.

Maximum Overhead Rate - This rate is determined by audit and can vary from Consultant to Consultant. This maximum overhead rate only applies where there are state only funded projects. Federal funds projects used the overhead rate established by audit. For state fund only projects, if the consultant has an overhead rate higher than 1.45, the maximum allowable rate that may be used is 1.45.

Profit Multiplier - TDOT currently allows a profit multiplier of 2.35.

Profit Rate - For projects that are completed through a Design Consultant, the profit rate is the same as that established for the Design Consultant. This is typically no more than 0.12.

Hourly Rate - This is determined by the following formula:
= Direct Pay Rate + Direct Pay Rate * Profit Multiplier + Direct Pay Rate * Profit Multiplier * Profit Rate

4.00 Other Costs - This sheet details other costs involved with the project that do not neatly fit onto one of the other sheets such as Per-Diem, Lodging and Mileage. Equipment rental and plans reproduction may also be included on this sheet. However, the only equipment rental which may be allowed will be speciality equipment. The consultant may not charge for standard geotechnical exploration or supporting equipment, neither may laboratory testing equipment rental be charged. Charges will only be allowed with prior authorization from TDOT Geotechnical and this will only be granted in unusual cases. Further explanation and justification for these charges may be requested. Also, plans printing may not be charged by the Geotechnical Consultant if that function is to be handled by the Design Consultant, unless the Design Consultant is not charging TDOT for the printing. Items listed under other expenses may only be pre-approved and as is the case for equipment rental will only be granted in unusual cases. Appropriate item numbers will be assigned by TDOT as needed. As with other sheets the total estimate of other expenses must be shown at the bottom of the sheet.

Costs-Summary - This final sheet summarizes the costs of Drilling Services, Laboratory Services, Manpower Requirements and Other Expenses in order to show a final "Total Not-to-Exceed" cost for the project.

For any project, the total that may be charged to the state for the Geotechnical work shall be no more than the "Total Not-to-Exceed" costs shown on an approved "Manhour and Requirements Cost Estimate Form." Individual items used may vary somewhat from the estimate provided depending upon the needs of the project, but in no case will additional funds be provided unless the consultant receives an approval for a supplement to the original scope of work. A supplement request must be provided in the same format as that

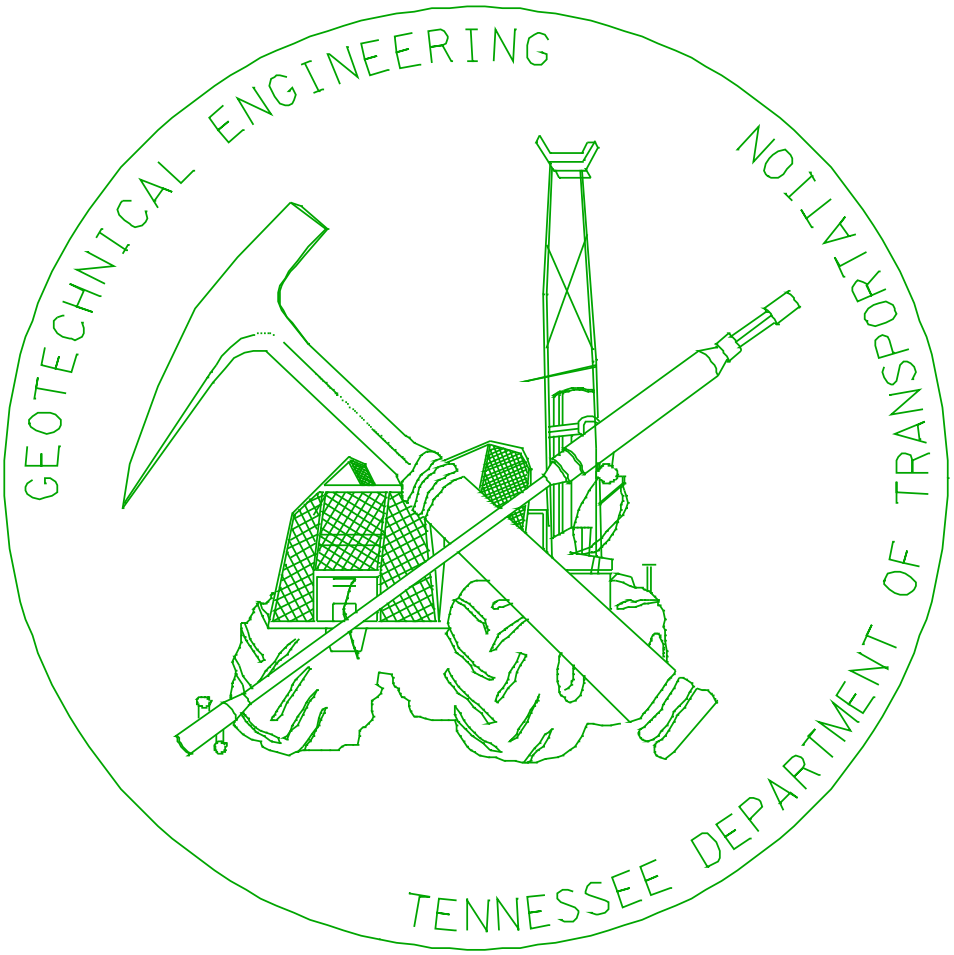
for the original scope of work, but may require additional meetings and justification before approval. If a specific Cost Estimate has not been approved, then no money will be paid for any work completed after the previously agreed upon costs have already been used and/or billed. Additional scope for additional work may not be approved by TDOT. For projects where work is completed directly for the Geotechnical Engineering Section, only Geotechnical approval needs to be received before work can begin. However, for projects completed through a design consultant, approval through both Geotechnical and Design will be required. If there is any significant change to a scope of work between the time it is submitted to Geotechnical and the time is submitted through Design, that change must be approved by Geotechnical before it is submitted to Design.

Supporting Documentation

Manpower Requirements and Cost Estimate Sheet - This must be filled out for projects where there are scope negotiations.

Section 1: Appendix A

Example Reports and Drawings



6601 Centennial Boulevard
Nashville, TN 37243-0360
(615) 350.4132

BRIDGE FOUNDATION REPORT
State Rout 436 over South Fork Obion River
Station 68+00.00, LM 3.89
Carroll County
State Project No. 09035-1217-94
PIN#: 101692.00

Executive Summary

State Route 436 over South Fork Obion River is a two-span bridge replacement of an existing bridge and realignment of bridge center line. The gradation, plasticity, pH, and natural moisture results are all found in the contractor's Boring Records. The bridge shall be supported by concrete friction piles. Seismic analysis calculations were performed and liquefiable samples are noted on foundation data sheet.

BRIDGE FOUNDATION REPORT

State Rout 436 over South Fork Obion River
Station 68+00.00, LM 3.89
Carroll County
State Project No. 09035-1217-94
PIN#: 101692.00

Introduction

This report concludes the geotechnical investigation for the State Route 436 over the South Fork Obion River in Carroll County. This project is a two-span bridge replacement of an existing bridge, and a shift of bridge centerline 33' to the west.

Geology, Soils, and Site Conditions

The site is located within the Gulf Costal Plain province of Tennessee and the Obion River flood plain. Soil at the site is characterized by a poorly drained gray, friable, silty loam. Soil is underlain primarily by sand with interbedding of clays and silts. Rock is not present at the site. Due to the poorly draining soils the site remains flooded through most of the winter and spring.

Surface and Subsurface Exploration

Two borings were conducted at this location. Both holes were offset to the east due to flooding at site. Split spoon sampling was conducted at five foot intervals for classification and laboratory analysis. Laboratory analysis and drilling logs are attached to this report.

Recommendations and Discussion

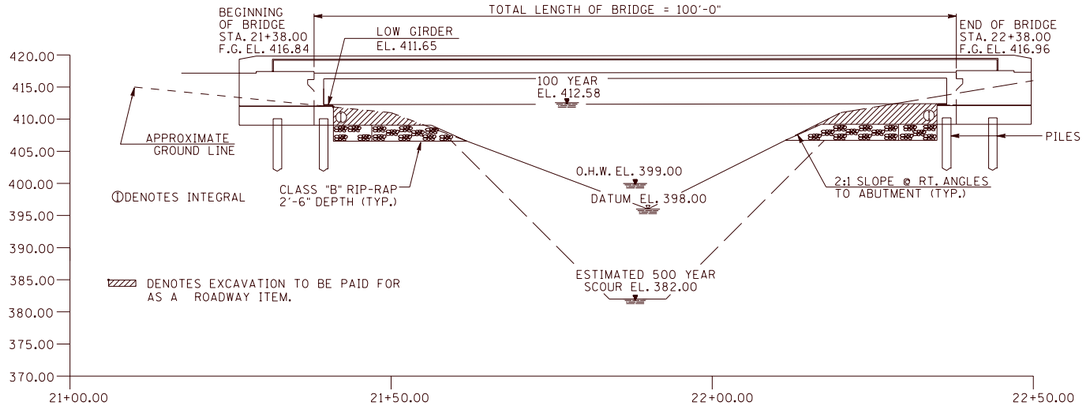
This bridge shall be supported by concrete friction piles. The skin friction (f_s) and end bearing (q_b) values are shown on the Foundation Data Sheet.

Values for pH tests are located on the boring logs. Samples from Boring 1, disregarding samples 1 and 2, shall be taken as a representative for scour. Seismic analysis indicates that liquefaction will occur at locations indicated on the Foundation Data Sheet. No skin friction should be accumulated for the liquefiable layers, and the pile tip should rest at least 5 feet below these liquefiable samples. If steel pipe piles or steel H piles are used, reduce the skin friction values (F_s) by one-third.

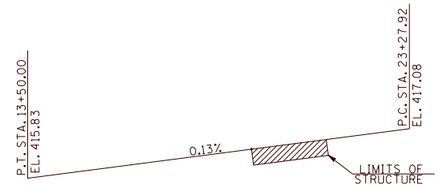
If there are questions concerning this report, please contact the Geotechnical Engineering Section.

Robert Jowers, P.E.
Civil Engineering Manager 2

West Tennessee Bridge Sketch



ELEVATION
SCALE : 1" = 10'-0"

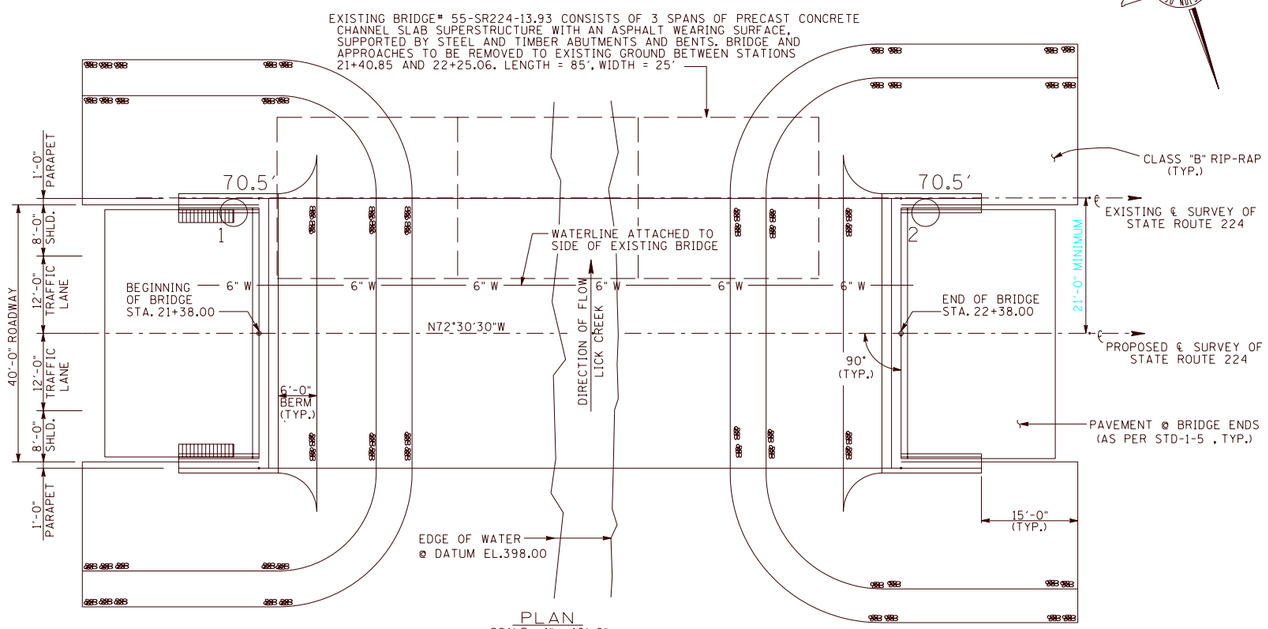


GRADE SKETCH
(STATE ROUTE 224)

P.E. NO. 55014-1209-94		
PROJECT NO.	YEAR	SHEET NO.
BR-STP-224(10)	2005	

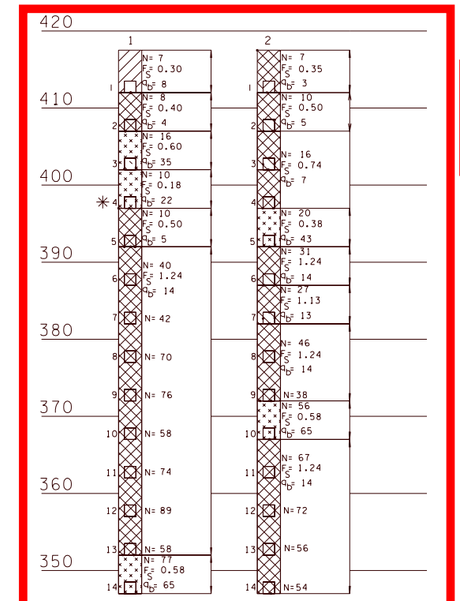
REVISIONS

NO.	DATE	BY	BRIEF DESCRIPTION



PLAN
SCALE : 1" = 10'-0"

DENOTES 2'-0" X 8'-7" END OF BRIDGE DRAINS (STD-1-6, 7, AND 9).



N = AVERAGE N VALUE FOR INTERVAL SHOWN
F_S AND q_b VALUES SHOWN ARE FOR DRIVEN CONCRETE PILES ONLY.

Info Needed on Sheets provided to TDOT for West TN type bridge

NOTES:

REQUIRED:

1) SUFFICIENT GROUND, ROCK AND CORING INFORMATION FOR BRIDGE FOUNDATION.

2) APPROXIMATE EXISTING GROUND AND ROCK LINE.

BENCHMARKS:

1) BM #1 STA 24+71.73 58.75' (LT.)
N 339300.66 E 1238667.55
ELEV. 412.46

2) BM #2 STA 20+53.01 76.91' (LT.)
N 339147.53 E 1239057.46
ELEV. 415.14

NOTE: THIS DRAWING IS FOR FOUNDATION DATA ONLY AND IS NOT TO BE USED AS A LAYOUT.

2025 ADT = 4160
40'-0" ROADWAY W/ STD-1-1 PARAPET
DESIGN SPEED = 50 MPH

LEGEND

CLAY
SILT
SAND

GROUND AND ROCK ELEVATIONS
1 G 417.5
R -----
2 G 417.5
R -----

70.5' — TERMINATED DEPTH

HOLE NO 1 2

SPLIT SPOON SAMPLE NO 1

✳ LIQUIFACTION IS PROBABLE AT THESE LOCATIONS

Fs = side friction value for interval (TSF)
qb = end bearing for layer (TSF)

EXAMPLE BRIDGE SHEET

HYDRAULIC DATA

DRAINAGE AREA = 10.30 mi.
DESIGN DISCHARGE (100 YR.) = 4,070 cfs
WATER AREA PROVIDED BELOW EL. 412.66 = 766.58 ft
100 YR. VELOCITY = 5.49 fps
100 YR. BRIDGE BACKWATER = 0.43 ft. @ EL.412.58 ft.
ROADWAY OVERTOPPING EL. = 414.90 ft.
500 YR. DISCHARGE = 5,400 cfs @ EL. 413.90.

NOTE: ANY EXCAVATION OF THE STREAM CHANNEL AREA (e.g. FOR PIER FOOTING OR RIP-RAP PLACEMENT) SHALL BE SEPARATED FROM FLOWING WATER, AND PERFORMED DURING LOW-FLOW CONDITIONS. THIS SHALL BE ACCOMPLISHED BY THE USE OF COFFERDAMS, FLUMES, LINED DIVERSION CHANNEL WITH SAND BAG BERM, OR DIVERSION PIPE WITH SAND BAG DAM AT PIPE INLET.

DESIGNED BY	K.E. / J.P.C.	DATE	01-04 / 05-04
DRAWN BY	FRANK F. FROST	DATE	02-24-04
SUPERVISED BY	RLH/JKZ / J.P.C.	DATE	02-24-04 / 05-04
CHECKED BY		DATE	

CORRECT: Edward P. Wasserman
ENGINEER OF STRUCTURES

dgnspec
dgnlib
Time

...\LOCALS~1\Temp\EXAMPLE.dgn 6/2/2005 12:32:25 PM

General Bridge Report

FOUNDATION REPORT
Fancher Mill Road over
Taylor Creek
State Project No. 93039-1405-94
Pin No. 010964.00
White County

Executive Summary

Summarized in this report are the results of a subsurface investigation for the project stated above located in White County. The proposed project consists of relocating the existing bridge 340ft. to the northwest and straightening the roadway in order to eliminate the existing curve in the southwest approach. It is recommended that this proposed bridge structure be supported on spread footings seated on sound shaley limestone. Enclosed are the Boring Records, Foundation Data Sheet, and recommendations for foundation design.

General Bridge Report

Purpose of Investigation

Summarized in this report are the results of a subsurface investigation for the project stated above located in Wayne County. The proposed project consists of relocating the existing bridge 340ft. to the northwest and straightening the roadway in order to eliminate the existing curve in the southwest approach. Enclosed are the Boring Records, Foundation Data Sheet, and recommendations for foundation design.

Geology of Area

White County lies on the edge of the Eastern Highland Rim physiographic province. The underlying material in the Cassville Quadrangle is made up of Mississippian aged shaley limestone from the Warsaw Formation. This shaley limestone is calcareous, argillaceous, medium- to dark-gray, fine- to medium-grained, and thin-bedded to laminated with shale partings.

Soil/Rock Conditions

Six boreholes were washed or cored at the investigated site to find refusal elevations and to examine the details and particulars of the rock. The extracted rock was gray, thin-bedded shaley limestone that was slightly weathered with crystallized vugs, calcite veins, and stylolites. Some of the interbedded shale and shale partings were washed out while drilling. Solid rock was visible at the bottom of the creek bed.

Abutment 1

The refusal elevation for the first abutment was found at 860.0ft. and 861.0ft. Spread footings or point bearing steel “H” piles with pile tip protection are recommended for this abutment. The ultimate bearing capacity of the limestone is 100TSF, using a factor of safety of 3.0. This gives an allowable bearing capacity of 33TSF.

Pier 1

Refusal elevation for this pier is 838.0ft. A solid rock bottom was visible beneath the shallow water in the creek bed. Spread footings seated on sound limestone are recommended to support this pier. The ultimate bearing capacity of the limestone is 100TSF, using a factor of safety of 3.0. This gives an allowable bearing capacity of 33TSF.

Pier 2

Refusal elevation for pier 2 is 838.4ft. Spread footings placed on rock are recommended to support this pier. The ultimate bearing capacity of the limestone is 100TSF, using a factor of safety of 3.0. This gives an allowable bearing capacity of 33TSF.

Abutment 2

The refusal elevations for the second abutment were found at 857.8ft and 859.4ft. Spread footings or point bearing steel “H” piles with pile tip protection are recommended for this abutment. The ultimate bearing capacity of the limestone is 100TSF, using a factor of safety of 3.0. This gives an allowable bearing capacity of 33TSF.

If there are questions concerning this report, please contact the Geotechnical Engineering Section.

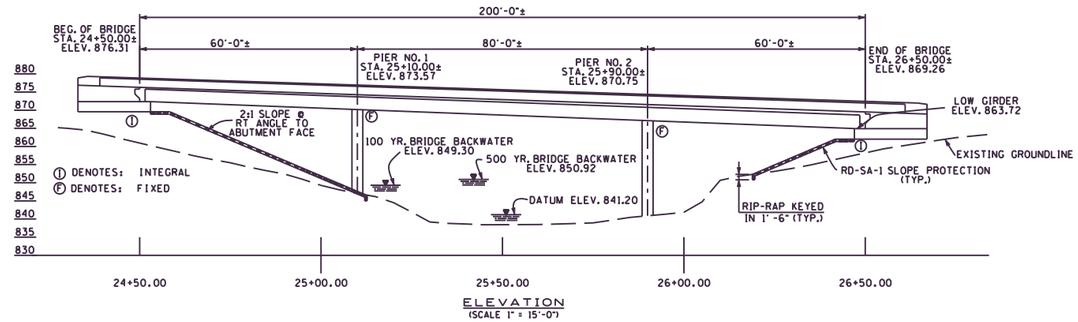
Chilyere Anglin Smith
Geologist 3

Robert Jowers, P.E. Civil
Engineering Manager 2

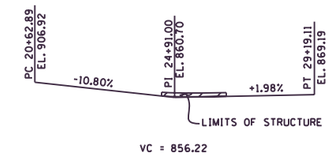
MLO:CAS:CJW
01-24-07

General Bridge Sketch

FD187F.DGN



ELEVATION
(SCALE 1" = 15'-0")



GRADE SKETCH
(FANCHER MILL ROAD)

P.E. NO. 93039-1405-94

PROJECT NO.	YEAR	SHEET NO.
BRZE-9300(35)	2006	

REVISIONS

NO.	DATE	BY	BRIEF DESCRIPTION

NOTES:

REQUIRED:

1) SUFFICIENT GROUND, ROCK AND CORING INFORMATION FOR BRIDGE FOUNDATION.

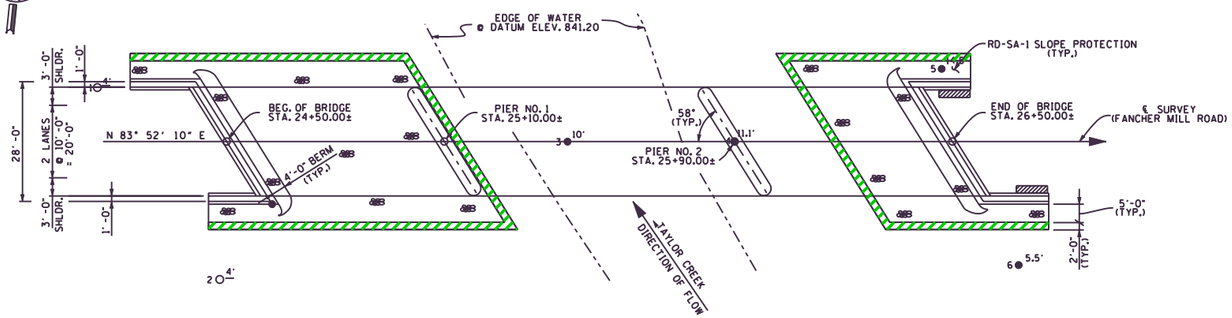
2) APPROXIMATE EXISTING GROUND AND ROCK LINE.

BENCHMARKS:

GPS # S1 (GPS 93-FAN-01)
N 606569.5746
E 2083152.9117
ELEV. 876.09

GPS # S2 (GPS 93-FAN-02)
N 606507.5242
E 2082708.7433
ELEV. 876.05

NOTE: THIS DRAWING IS FOR FOUNDATION DATA ONLY AND IS NOT TO BE USED AS A LAYOUT.



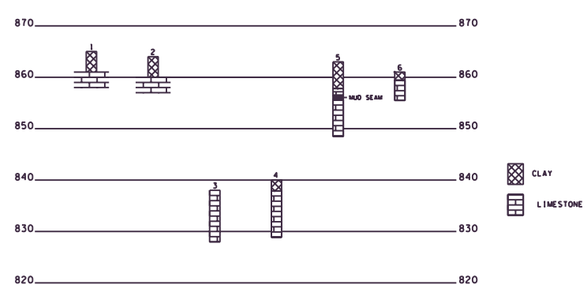
PLAN
(SCALE 1" = 15'-0")

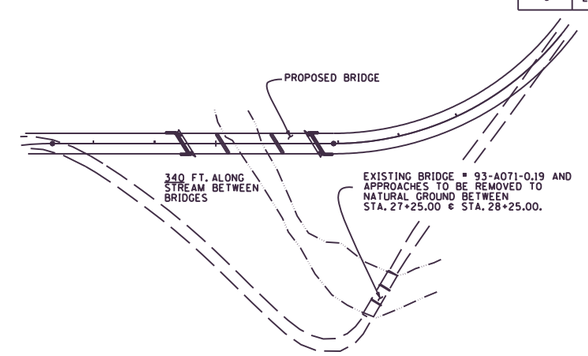
DENOTES: 2' X 8'-7" END OF BRIDGE DRAIN. (SEE STD. DWG. NO. STD-1-6,7, & 8.)

BORING NO. 2 4' DEPTH TO REFUSAL

CORE NO. 6 5.5' TOTAL DEPTH DRILLED

BORING NO.	STATION	OFFSET DISTANCE	DEPTH	GROUND ELEVATION	ROCK ELEVATION
1	24+16.00	12.0' LT	4.0'	865.0	861.0
2	24+47.00	35.0' RT	4.0'	864.0	860.0
3	25+43.00	0.00'	10.0'	838.0	838.0
4	25+90.00	0.00'	11.1'	840.5	838.4
5	26+48.00	17.0' LT	14.5'	863.0	857.8
6	26+66.00	30.0' RT	5.5'	861.0	859.4





EXISTING BRIDGE LOCATION DETAIL

2029 ADT = 760
28'-0" ROADWAY WITH STD-1-1 PARAPET
DESIGN SPEED = 40 mph

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
FOUNDATION DATA
FANCHER MILL ROAD
OVER
TAYLOR CREEK
STATION 25+50.00
BRIDGE I.D. NO. 93A0710001
WHITE COUNTY
2006

DESIGNED BY J. SHAVER (J.B.S.) DATE 05-05
DRAWN BY CHRIS STAPLER DATE 06-06
SUPERVISED BY S.M.E. / J.B.S. DATE 06-06
CHECKED BY DATE

CORRECT Edward P. Wasserman
ENGINEER OF STRUCTURES

9318605plot.dgn 3/16/2007 2:22:15 PM

Bridge and Approaches Report

GEOTECHNICAL REPORT
Bridge and Approaches along
Jim Bob Scruggs Road Over Sugar Creek, L.M. 2.55
Project No.27945-1487-94
Pin No. 103885.00
Gibson County

Executive Summary

This report presents geotechnical recommendations for the Jim Bob Scruggs Road bridge and approaches over Sugar Creek. The existing 1-span bridge will be replaced with a 2 barrel reinforced concrete box bridge. A sample was taken along the approach location on Jim Bob Scruggs Road. The sample taken is a silt with gravel with an AASHTO classification of type A-4. Slope and CBR recommendations are included within the report.

GEOTECHNICAL REPORT
Bridge and Approaches along
Jim Bob Scruggs Road Over Sugar Creek, L.M. 2.55
Project No.27945-1487-94
Pin No. 103885.00
Gibson County

Introduction

This report presents geotechnical recommendations for a site investigation conducted to study the geologic setting and conditions for the above project. Improvements will be made by reconstructing the bridge of Jim Bob Scruggs Road at Station 57+22.00. The existing 1-span bridge will be replaced with a 2 barrel reinforced concrete box bridge.

Geology, Soils and Site Conditions

The proposed bridge replacement is located north of Jackson in Gibson County, which is in the Gulf Coastal Plain. The geologic material in the area is comprised of Tertiary coastal plain sediments and recent alluvium. The soil investigated was soft, moist, brown clay. The investigated area was a rural residential area. The outlying surface area is relatively flat and vegetated by trees, grasslands and cultivated fields. Minimum erosion was visible on the steep embankment slopes due to the vegetation.

Surface and Subsurface Exploration

A bulk bag sample was taken at Station 58+00 on Jim Bob Scruggs Road. Through laboratory testing the sample is silt with some gravel with an AASHTO classification of type A-4.

Pavement Design Recommendations

A slope ratio of 3:1 or flatter is an adequate design for the proposed project. The recommended CBR value for pavement design is 4.0.

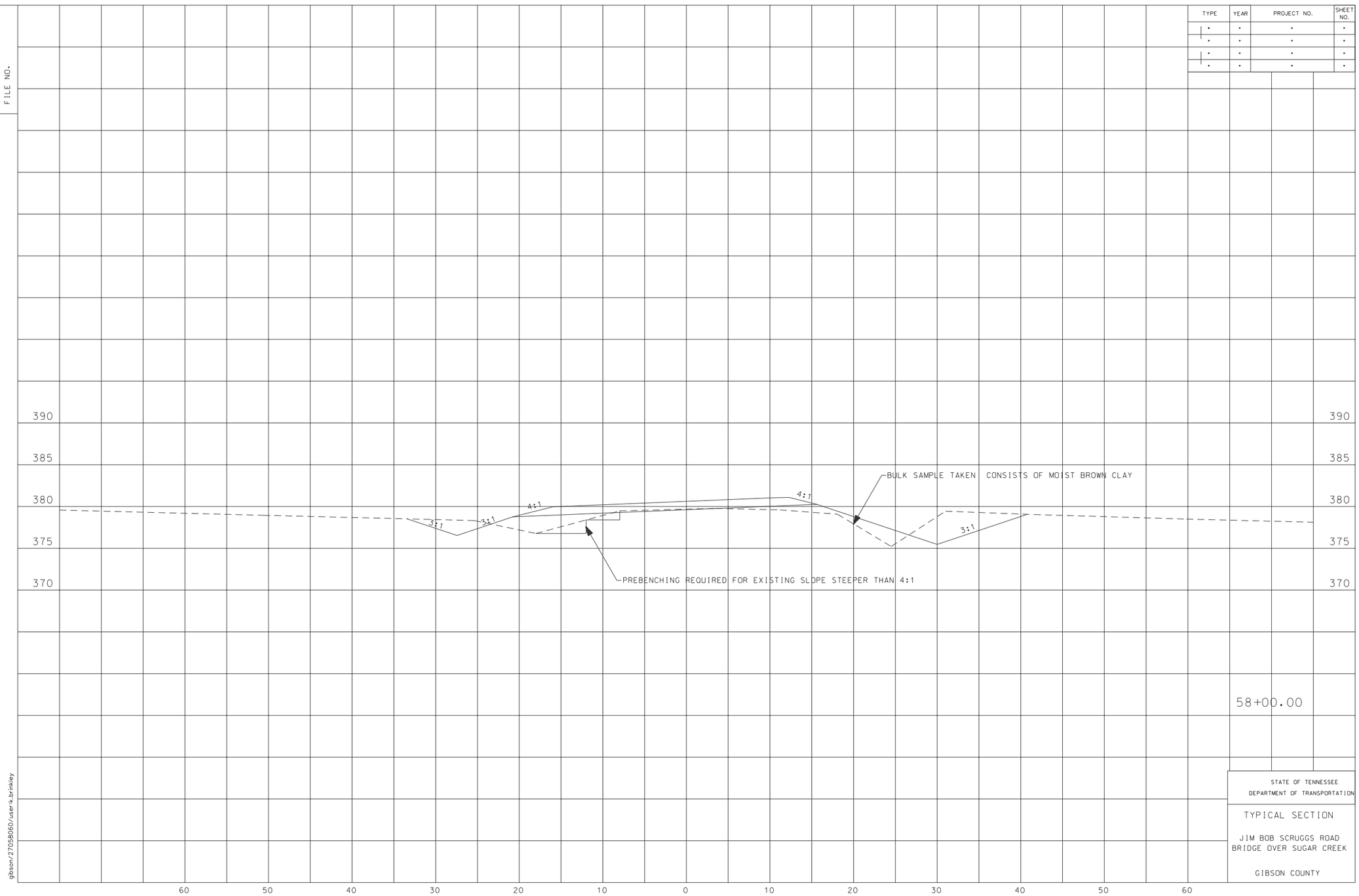
Bridge and Approaches - Example Drawing

SNAP PT

SNAP PT

TENNESSEE D.O.T.
DESIGN DIVISION
FILE NO.

TYPE	YEAR	PROJECT NO.	SHEET NO.
•	•	•	•
•	•	•	•
•	•	•	•
•	•	•	•



STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

TYPICAL SECTION

JIM BOB SCRUGGS ROAD
BRIDGE OVER SUGAR CREEK

GIBSON COUNTY

gibson/27058060/user:k.brinkley

RETAINING WALL REPORT
Central Pike
Wall No. 1, and Wall No. 2
Project No. 19958-1780-54, PIN No. 101200.00
Davidson County

Executive Summary

This report summarizes the results of the subsurface investigation accomplished for the referenced project with respect to recommendations for foundation design. The structure is designed to prevent encroachment to the adjacent commercial business (Tract 7). Based on the drilling, it is recommended that the structure is supported on in-place limestone. The acceptable wall types for this cut wall are cast-in-place concrete gravity wall, concrete cantilever, (reverse L-type included) Mechanically Stabilized Earth (MSE) walls with either Segmental Precast or Modular Block Facing, and a soldier pile/lagging cantilever wall. The boring data suggests that the wall may encounter bedrock above the bottom of the proposed wall and rock excavation will likely be required for construction. All wall types are acceptable if a temporary construction easement can be obtained, however, given the reason for the wall at this location, a soldier pile and lagging wall is the most effective for this location in that it requires little excavation behind the walls. A reversed L shape wall also limits needed construction easement.

Retaining Wall Report

Introduction

As part of a project designed for transportation improvements to increase the level of service for Central Pike including the intersection with State Route 24 (Lebanon Pike), this structure was requested by the Nashville Metro Department of Public Works to save a parking lot on Tract 7. According to the cross sections provided to the Geotechnical Engineering Section, the roadway grade along this site will be lowered to achieve the necessary minimum clearance between the roadway and an overhead railroad that is up station. Therefore, the increased lane widths and overall carrying capacity resulted in limited right-of-way constraints with the parking lot and the need to utilize a retaining structure. When completed, the cut wall will measure approximately 145 feet in length, up to 11 feet in height and located 48.5 feet right of the proposed centerline.

Two exploratory borings were accomplished near the footprint for the proposed retaining wall to define the general subsurface conditions at the site. A detailed description of the individual borings is shown on the Conceptual Drawing and Boring Records attached to the end of this report.

Geology, Soils and Site Conditions

The project area is located within a physiographic region of Tennessee known as the Central basin. The regional topography consists of gently rolling hills to bluffs or steepened slopes overlooking Stones River and Clover Bottom. In the immediate area much of the original surface cover has been reworked to accommodate the variety of land uses, including residential, warehousing and industrial and commercial.

Available geologic mapping (USGS Geologic Map of the Nashville East Quadrangle, 1966) indicates the site is underlain by the Bigby-Cannon Limestone Formation, representing the Ordovician Geologic period. The Bigby-Cannon formation typically consists of a medium dark to light gray, medium-grained, thin- to medium-bedded limestone. The residuum formed by the in-place weathering of the parent limestone consists of brown to reddish-brown silty clay. The soil/rock interface can be highly irregular due to soil-filled slots extending deep into the rock mass and rock pinnacles protruding into the soil overburden layer.

Surface and Subsurface Exploration

As discussed previously, the subsurface conditions in the vicinity of the proposed wall were explored with two borings. This was due to the underground and overhead utilities, as well as, lack of a working area in the parking lot. Where possible, the consistency of the soils was estimated based on the amount of effort required to advance the casing.

Boring 1 encountered 5.5 feet of wet to slightly moist, dark to reddish brown silty clay with trace amounts of gravel overlying slightly to moderately weathered limestone. Boring 2 consisted of nearly 7 feet of dark to light brown silty clay with varying amounts of gravel and 5 feet of boulder clay overlying unweathered limestone at a depth of 12 feet. It is not known if the latter deeper overburden depth is due to the nearby hills that have been cut and the low areas filled to make road frontages more accessible or if this is a vertical solution zone in the underlying bedrock.

The above subsurface description is of a generalized nature to highlight the major subsurface stratification features and material characteristics. The boring logs

included in the report should be reviewed for specific information at individual boring locations. The stratifications shown on the boring logs represent the conditions only at the actual boring locations. Variations may occur and should be expected between boring locations.

Recommendations and Discussion

Geotechnical recommendations provided in this report and on the Retaining Wall Conceptual Drawing are based on information provided to the Geotechnical Engineering Section at the time of the request to conduct the geotechnical investigation. The Roadway and/or Structural Designer should review the report and drawings and determine if pertinent information regarding the retaining wall construction – such as available right-of-way, traffic sequencing or utility placement – remains valid. If any design information that may affect wall design or construction is altered after the time of the geotechnical report, this information should be provided to the Geotechnical Engineering Section for review.

Excavation for the wall and/or its footing shall not be accomplished until the contractor has labor and material resources available to begin and continue wall construction immediately after excavation. All walls must follow the design guidelines established in the TDOT Earth Retaining Structures Manual. All temporary construction slopes shall be placed at a maximum of a 1:1 slope in soil and shall not be left open without shoring for any longer than absolutely necessary. The contractor building the wall shall ensure that these temporary back slopes are not and do not become unstable. If slope is unstable, becomes unstable, is cut steeper than a 1:1 slope or is unacceptable for another reason, then temporary shoring shall be used. Any unusual

soil conditions other than those assumed should be reported to the Geotechnical Engineering Section. Specific geotechnical parameters are described in the following recommendations.

Acceptable Wall Types

- Cast-in-Place Concrete Gravity Wall
- Cast-in-Place Concrete Cantilever Wall (including Reverse L)
- Mechanically Stabilized Earth (MSE) Wall – Segmental Precast
- Mechanically Stabilized Earth (MSE) Wall – Modular Block
- Soldier Pile

The boring data suggests that the retaining wall will be placed on in-place limestone at elevations ranging from approximately 441 feet at the beginning of the wall, Station 19+89 to an elevation of 432 feet at Station 21+35 or the end of the wall. This will involve some excavation of soil and limestone bedrock near the base of the proposed wall. For soldier pile wall, piles shall be pre-drilled and socketed into rock down to the elevation required for stability by the wall designer utilizing in-place rock strength of 10,000 psi. The Geotechnical design requirements and parameters for the proposed retaining wall are as follows:

Wall Data

Shear Strength Data	**ϕ**	**γ (pcf)**
Select Backfill*	35	---
In situ soil	25	120
Sliding Coefficient of Friction (Concrete on Limestone)	F= 0.6	

Factors of Safety to be used

Condition	**FS**
Overturning	2.0
Sliding	1.5
Bearing Capacity MSE Wall	2.5
Bearing Capacity Other Walls	3.0

Allowable Temporary Construction Slopes in Soil	1:1

Maximum Allowable Bearing

Condition	CIP Concrete Gravity Wall	MSE Wall
Limestone	15 TSF (Allowable) 45 TSF (Ultimate)	18 TSF (Allowable) 54 TSF (Ultimate)

*Select Backfill unit weight to be determined by contractor/wall designer depending on actual backfill material used. Select backfill is defined as material meeting specifications in Section 4.5, Part F, Chapter 3 of TDOT Earth Retaining Structures Manual. In order to utilize ϕ for select backfill design, select backfill must be placed for a minimum zone formed by a 1:1 slope from 2 feet behind the bottom of the back of the wall footing or reinforced soil zone for MSE walls up to finished grade.

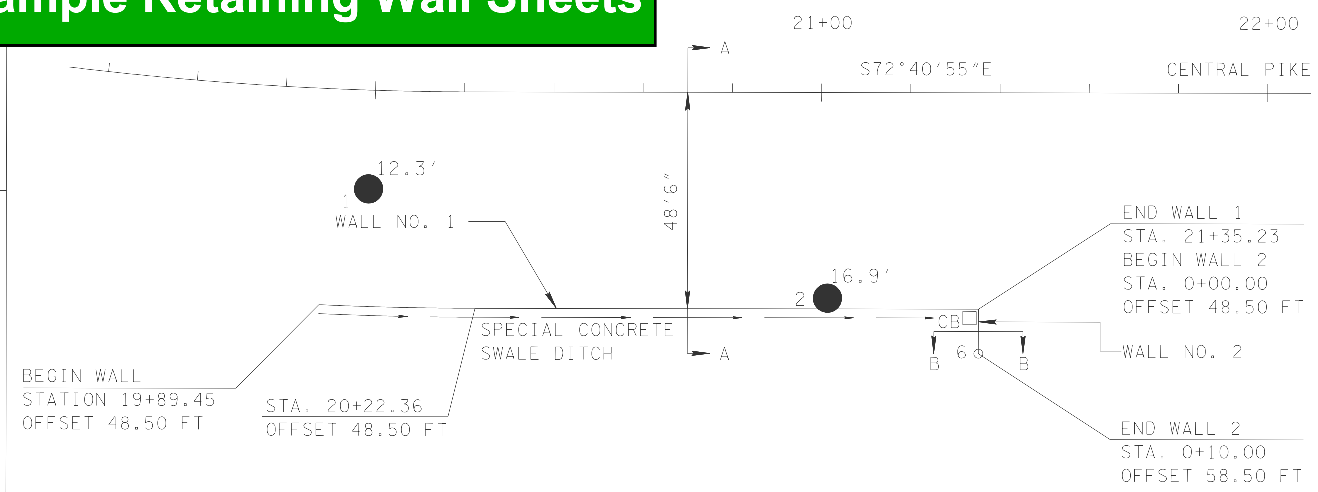
Specific Design Requirements

The wall shall have a drainage gutter at the top designed to carry surface runoff to either or both ends of walls. A drainage gutter typical is shown for reference; however, actual details to be provided in contractor's wall design plans. If a Concrete Cantilever Wall is used, the wall designer must provide for a drainage layer behind the wall stem with adequate drainage provided via weep holes.

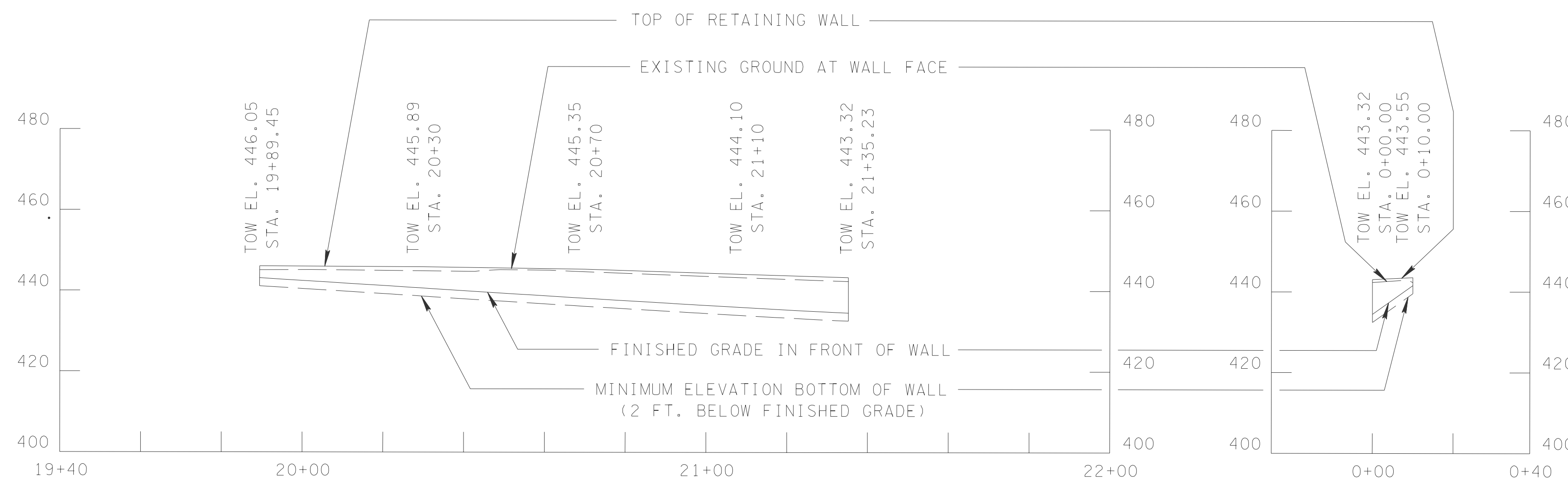
Example Retaining Wall Sheets

TENNESSEE D.O.T.
DESIGN DIVISION
FILE NO.

TYPE	YEAR	PROJECT NO.	SHEET NO.
R.O.W.	2006	STP-M-4967(1)	12

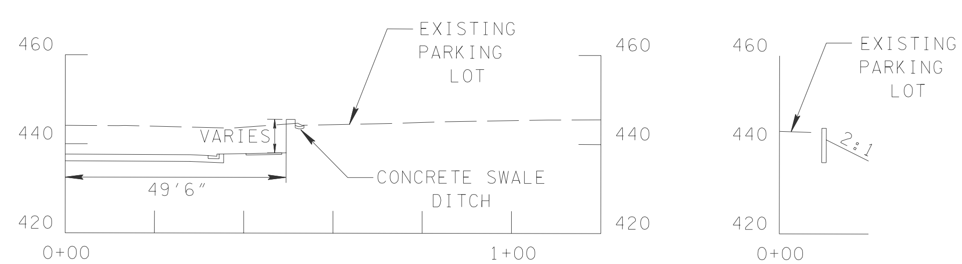


WALL PLAN VIEW (SCALE 1"=20')



WALL NO. 1
WALL ELEVATION VIEW
WALL FACE AREA = 1233 FT^2

WALL NO. 2
WALL ELEVATION VIEW
WALL FACE AREA = 72.91 FT^2



SECTION A-A

SECTION B-B

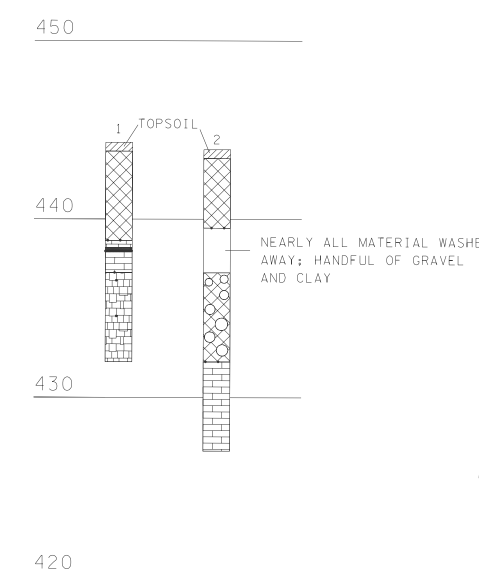
Special Note Regarding Retaining Walls:

Unless specifically stated otherwise in the contract plans, the bidding for, the design of and the construction of retaining walls shown in the plans shall be governed by the TDOT Earth Retaining Structures Manual. This Manual is available on the TDOT Web Site under the Information for Contractors link. This Manual shall be considered as one of those documents which the Bidder/Contractor has examined and made himself familiar with as described in Section 102.04-Examination of the Site, the Work, the Plans, and the Specifications in the TDOT Standard Specifications for Road and Bridge Construction.

NOTE:

BORING DEPICTIONS SHOWN ON FOUNDATION DATA SHEET INDICATE GENERAL SOIL AND ROCK TYPES AT THE SPECIFIC BORING LOCATIONS.

TO ASSIST IN BID PREPARATION FOR FOUNDATION CONSTRUCTION, DETAIL ROCK AND SOIL DESCRIPTION AND, ON SOME PROJECTS, ROCK CORE SAMPLES ARE AVAILABLE FOR INSPECTION AT THE MATERIALS AND TESTS HEADQUARTERS AT 6601 CENTENNIAL BLVD., NASHVILE, TN. (615) 350-4130.

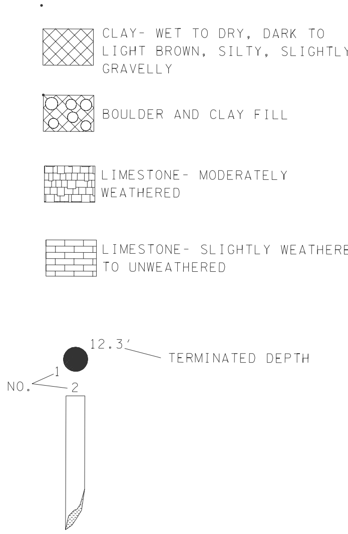


GROUND AND ROCK ELEVATIONS

1. G.444.3
R.438.8

2. G.443.9
R.432.0

LEGEND



STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

RETAINING WALL NO.2
CENTRAL PIKE
STA.0+00.00
TO
STA.0+10.00
DAVIDSON COUNTY

Example Retaining Wall Sheets

TENNESSEE D.O.T
DESIGN DIVIS
FILE NO.

TYPE	YEAR	PROJECT NO.	SHEET NO.
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Retaining Wall

Geotechnical recommendations provided in this report and on the Retaining Wall Conceptual Drawing are based on information provided to the Geotechnical Engineering Section at the time of the request to conduct the geotechnical investigation. If any design information that may affect wall design or construction is altered after the time of the geotechnical report, this information should be provided to the Geotechnical Engineering Section for review.

Excavation for the wall and/or its footing shall not be accomplished until the contractor has labor and material resources available to begin and continue wall construction immediately after excavation. All walls must follow the design guidelines established in the TDOT Earth Retaining Structures Manual, revised December 2004. All temporary construction slopes shall be placed at a maximum of a 1:1 slope in soil and shall not be left open without shoring for any longer than absolutely necessary. The contractor building the wall shall ensure that these temporary back slopes are not and do not become unstable. If slope is unstable, becomes unstable, is cut steeper than a 1:1 slope or is unacceptable for another reason, then temporary shoring shall be used. Any unusual soil conditions other than those assumed should be reported to the Geotechnical Engineering Section. Specific geotechnical parameters are described in the following recommendations.

Acceptable Wall Types

- Cast-in-Place Concrete Gravity Wall
- Cast-in-Place Concrete Cantilever Wall (including Reverse L)
- Mechanically Stabilized Earth (MSE) Wall – Segmental Precast
- Mechanically Stabilized Earth (MSE) Wall – Modular Block
- Soldier Pile

Based on the drilling, it is recommended that the structure is supported on soil at the minimum embedment depth shown on the conceptual depth. This shall involve some excavation of limestone bedrock near the base of the proposed wall. For soldier pile wall, piles shall be pre-drilled and socketed into rock down to the elevation required for stability by the wall designer utilizing intact rock strength of 30,000 psi. The Geotechnical design requirements and parameters for the proposed retaining wall are as follows:

Wall Data

Shear Strength Data	ϕ	γ (pcf)
Select Backfill*	35	---
In situ soil	25	120
Sliding Coefficient of Friction (Concrete on Limestone)		F= 0.6
Sliding Coefficient of Friction (Concrete on Clay)		F= 0.35

Factors of Safety to be used

Condition	FS
Overturning	2.0
Sliding	1.5
Bearing Capacity MSE Wall	2.5
Bearing Capacity Other Walls	3.0

Allowable Temporary Construction Slopes in Soil	1:1
Allowable Temporary Construction Slopes in Rock	Vertical

Maximum Allowable Bearing

Condition	CIP Concrete Gravity Wall	MSE Wall
Limestone	15 TSF (Allowable) 45 TSF (Ultimate)	18 TSF (Allowable) 54 TSF (Ultimate)
Soil	1 TSF (Allowable) 3 TSF (Ultimate)	1.1 TSF (Allowable) 3.3 TSF (Ultimate)

Earth Pressure Coefficients

Active	0.41
Passive	2.46

*Select Backfill unit weight to be determined by contractor/wall designer depending on actual backfill material used. Select backfill is defined as material meeting specifications in Section 4.5, Part F, Chapter 3 of TDOT Earth Retaining Structures Manual. In order to utilize ϕ for select backfill design, select backfill must be placed for a minimum zone formed by a 1:1 slope from 2 feet behind the bottom of back of wall footing or reinforced soil zone for MSE walls up to finished grade.

Specific Design Requirements

The wall shall have a drainage gutter at the top designed to carry surface runoff to either or both ends of walls. A drainage gutter typical is shown for reference; however, actual details to be provided in contractor's wall design plans. If a Concrete Cantilever Wall is used, the wall designer must provide for a drainage layer behind the wall stem with adequate drainage provided via weep holes.

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

RETAINING WALL NO.2
CENTRAL PIKE
STA.0+00.00
TO
STA.0+10.00
DAVIDSON COUNTY

Example Retaining Wall Sheets

TENNESSEE D.O.T.
DESIGN DIVISION
FILE NO.

TYPE	YEAR	PROJECT NO.	SHEET NO.
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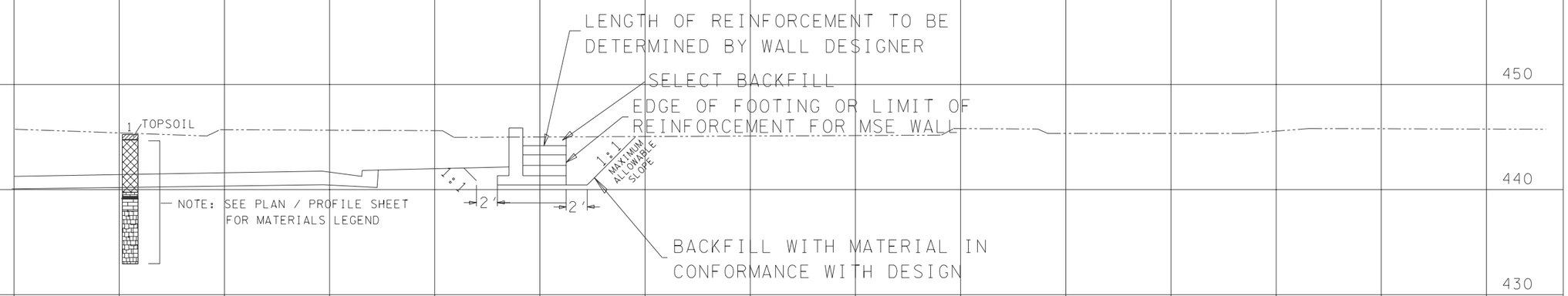

20+00

MECHANICALLY STABILIZED EARTH (MSE)

--SEGMENTAL PRE-CAST

--MODULAR BLOCK FACING

SPREAD FOOTING FOUNDATION ON ROCK

(ELEVATION TO VARY FROM 441' TO 432')

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

RETAINING WALL NO.1
CENTRAL PIKE
STA.19+89.45 TO
STA. 21+35.23
DAVIDSON COUNTY

0 50 100

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Intersection and Small Line Report

GEOTECHNICAL REPORT

Intersection Improvement and Signalization
State Route 149 and River Road @ L.M. 13.08
State Project No. 63023-1235-94; PIN No. 104051.00
Montgomery County

Executive Summary

This report summarizes the site investigation for the above referenced project on March 30, 2005. The investigation was in response to a request by TDOT Region 3 Survey and Design to a preliminary right-of-way field review that was held on April 1, 2005. The proposed project is included in the future construction of an extension of State Route 374 between State Route 13 southwest of Clarksville and U.S. 79 (SR-76) west of Clarksville. When completed, this extension will provide the final link for the by-pass that would circle the city of Clarksville.

Slopes on the project shall be placed at no more than 3:1. If 3:1 is not reasonable for Right of way, then 2.5:1 slopes shall be allowed. This is especially important for the Station interval 52+50 to 58+00. For all slopes it is recommended to use an Erosion Control Blanket (Type II) for the highly erosive soil. Debris placed along River Road, from approximate Station 7+00 to Station 9+00, right of centerline, shall be removed. The CBR for pavement design shall be no more than 6.

Intersection and Small Line Report

Introduction

This report summarizes the site investigation for the above referenced project on March 30, 2005. The investigation was in response to a request by TDOT Region 3 Survey and Design to a preliminary right-of-way field review that was held on April 1, 2005. The proposed project is included in the future construction of an extension of State Route 374 between State Route 13 southwest of Clarksville and U.S. 79 (SR-76) west of Clarksville. When completed, this extension will provide the final link for the by-pass that would circle the city of Clarksville.

Geology, Soils and Site Conditions

The project is located in the northwestern portion of Central Tennessee within the Highland Rim Physiographic Region. The topography of the project vicinity is characterized as nearly level with hillsides that fall away to form hollows and wide valleys. The geologic map of the area indicates that the project is underlain by bedrock representing the St. Louis Limestone Formation. The St. Louis Limestone within the region occurs in part as fossil-fragmental limestone and dolomitic siltstone. For this project, the St. Louis has been weathered to a residuum consisting of red- to reddish-brown clay soil with rounded pebbles to angular cobbles (blocks) of chert. The only exposure of in-place rock was at the base of the very deep gully (left of centerline) near the proposed toe of the fill slope at Station 53+00 and at the op of the existing ditch (right of centerline) at Station 67+00.

Surface and Subsurface Exploration

No subsurface exploration was accomplished for the project. Site was examined at surface. Area soils and geologic maps were used in preparation of this report.

The following are observations and comments that may be used for final design plans as no subsurface exploration was accomplished for the project.

Beginning of Project to Station 59+50 – Left of Centerline

The terrain approximates a 2:1 slope with sloughing and shallow slides just below the shoulder of the road and huge erosion gullies down slope. The cherty clay soil is so easily eroded that undermining of the soil beneath the outlet end of the existing corrugated metal pipe has resulted in about 10 feet of the pipe uncoupling into two pieces. The concrete wing wall is still attached to the end of one section of the pipe. With the loss of some of the pipe, a hole developed to about 15 feet in depth and 20 feet in diameter. From this point, erosion created a very deep gully down slope, exposing limestone in one area. At the intersection of State Route 149 and River Road is an undetermined fill area for an unknown depth, surface evidence consisting of piles of construction debris, i.e., bricks, fill dirt, chunks of concrete. A maximum 11 feet of sidehill fill is proposed for this entire section on current design slopes of 2:1 up to Station 58+00. From here, design proposes 3:1 to 6:1 slopes for the remainder of the section.

Station 59+50, Left of Centerline to end of Project

Mainly ditch line cut and fill sections on proposed 4:1 and 6:1 slopes. From a geotechnical standpoint, problems that cannot be compensated for in the design and/or construction phases are not anticipated.

Beginning of project to Station 59+50, Right of Centerline

Adjacent to either side of the unnamed road are Tracts 3 and 8. Scattered gully formation and standing water at the pipe inlet was observed on Tract No. 3 along with soil-infilling of the ditches. Concrete blocks, bricks, rock and gravel mixed with dirt indicate recent in-filling of a section of Tract No. 8 adjacent to the unnamed road. There is little to no grass cover and there is recent cutting of trees and brush within the basin

and near the inlet pipe. The majority of this interval will consists of embankment up to 5 feet with minor cuts of approximately 2 feet on slopes ranging from 2:1 to 6:1.

Station 59+50, Right of Centerline to end of Project

Once past the business on Tract No. 8, construction will entail a maximum 5 feet of embankment on current design slopes ranging from 2:1 to 6:1. From near Station 66+00 to the end of the project, there is in-place limestone exposed along the top of the ditch. Tract No. 18 has been recently cleared for a future business revealing the red cherty clay that is present on this project. As with the left side of the proposed project, from a geotechnical standpoint, there does not appear to be any problems that cannot be compensated for during the design and/or construction phases.

Recommendations

It is recommended that the existing embankments are grubbed, slide or sloughed material is removed and the embankment is pre-benched according to Section 205.03 of the Standard Specifications for Road and Bridge Construction prior to additional fill placement. A representative cross section is shown at Station 52+50. Side cast placement of fill down the existing slopes shall not be allowed. Topsoil shall not be stockpiled at the tops of excavated or embankment slopes. It is recommended that the extremely large gullies will require removal of all loose and organic material to a sufficient depth and width to allow construction equipment to place and compact fill material prior to embankment construction. The Geotechnical Engineering Section reiterates the desire to maintain 3:1 or flatter slopes throughout the project. If a 3:1 slope cannot be constructed in place of 2:1 slopes, it is recommended that the Design consultant check and see if 2.5:1 slopes can be used in place of 3:1 slopes. This is especially important for the Station interval 52+50 to 58+00. For all slopes it is recommended to use an Erosion Control Blanket (Type II) for the highly erosive soil.

On River Road, from approximate Station 7+00 to Station 9+00, right of centerline, the property owner has end dumped construction material parallel to the existing highway. The depth of the debris is unknown; however, for construction purposes, it is recommended that the debris is removed to natural ground assuming a minimum 3' depth from the edge of the proposed toe of fill slope up to the edge of existing roadway. This material is considered waste and shall be placed in an appropriate waste area off-site of the project. The project engineer may need to adjust the actual limits during construction. A representative cross section is shown at Station 8+00 (River Road).

A pavement design using a CBR of 6 (county average) is recommended provided the subgrade is compacted according to specifications. Once the project is brought to grade, CBR samples should be obtained to verify the design value.

If there are questions concerning this report, please contact the Geotechnical Engineering Section.

Robert Jowers, P.E.
Civil Engineering Manager 2

MLO:RJJ:LGW
09/20/05

Example Line Report

GEOTECHNICAL REPORT
State Route 374 (Warfield Blvd.) From South of Dunbar Cave Road
To Stokes Road
Project No. 6311-1216-14
Pin No. 100290.00
Montgomery County

EXECUTIVE SUMMARY

This project may be constructed using a maximum slope ratio of 2:1 where the slopes will be constructed in soil, however, slopes constructed as shown on the cross-sections with slope ratios flatter than 2:1 will result in increased slope stability. Where rock is encountered in the cuts, a vertical slope is recommended for the rock with a 15 feet wide bench at the soil/rock interface and the upper soil laid back on a 2:1 slope. A uniform catchment width of 24 feet from the face of the curb to the face of the rock slope is recommended where rock cuts are proposed. Two areas will require rock pads to protect the proposed embankment from potential standing water and to facilitate drainage of buried sinkholes. Two potential sinkholes exist that will require treatment.

Example Line Report

GEOTECHNICAL REPORT
State Route 374 (Warfield Blvd.) From South of Dunbar Cave Road
To Stokes Road
Project No. 6311-1216-14
Pin No. 100290.00
Montgomery County

INTRODUCTION

This project involves the widening and improvement of an approximately 1.7 mile section of State Route 374. This project is necessary to relieve congestion and improve safety in this area.

GEOLOGY, SOILS, AND SITE CONDITIONS

This project is located in the Western Highland Rim Province of Middle Tennessee and is underlain by cherty clay resting upon limestone indicative of the St. Louis Limestone and Warsaw Limestone.

SURFACE AND SUBSURFACE EXPLORATION

Visual observation was accomplished for the entire project and detailed drilling was done in the area of the buried sinkholes and the proposed rock cuts. The remainder of the project was spot drilled. Refer to boring logs and soils sheets for details.

RECOMMENDATIONS

Station 44+64.53 To Station 51+00

This interval consists of alternating cut and fill sections with cut depths of up to 25 feet and fill heights of up to 10 feet. A maximum slope ratio of 2:1 is recommended for the slopes in the interval. Pre-benching of the existing fill slope prior to fill placement is required for all existing slopes steeper than 4:1. Refer to cross-section station 46+00.

Station 51+00 to Station 66+00

This interval involves alternating cut and fill sections with cut depths of up to 50 feet and fill heights of up to 15 feet. Rock cut slopes are proposed from RT Station 51+50 to RT Station 55+50 and RT Station 57+50 to RT Station 63+00. It is recommended that the rock in this area be placed on a vertical slope. A 24 foot rockfall catchment width is required from the face of the proposed curb to the toe of the rock face. For aesthetic reasons it is recommended that the 24 foot catchment width be carried through the entire cut area. This will result in excessive catchment width in some areas; however, the cut face will appear smooth and consistent. It is recommended that a 15 foot wide bench be constructed on top of the vertical slope at the soil/rock interface with the upper soil material laid back on a 2:1 slope. Refer to cross-section station 54+00, 59+00, and 61+50. A shotcrete wall is proposed from LT Station 58+25 to LT Station 61+75. The cross-sections show this proposed wall to be offset from the existing rock face by a minimum of five feet. The existing rock face appears stable. Sufficient room exists between the existing rock face and the face of the proposed curb to accommodate rock fall catchment requirements. It is recommended that this wall be eliminated and the gap between the back edge of the sidewalk and the existing rock face be backfilled with common roadway embankment to create a flat catchment area. Refer to cross-sections Station 59+00 and 61+50. A maximum slope ratio of 2:1 is recommended for the remainder of the slopes in this interval.

Station 66+00 to Station 91+00

This interval consists of alternating cut and fill sections with cut depths of up to 25 feet and fill heights of up to 30 feet. A maximum slope ratio of 2:1 is recommended for the cut and fill slopes in this interval; however, slopes constructed as shown on the cross-sections with slope ratios flatter than 2:1 will result in increased slope stability. From RT station 84+00 to RT Station 86+50 a 2:1 slope is proposed. The existing slope in this area is a 3:1 slope. A 3:1 slope ratio is recommended at this location to preserve the consistency of the slope and to reduce the possibility of slope stability problems that may develop by keying a 2:1 slope into an existing 3:1 embankment. If a 3:1 slope causes right-of-way issues in this area, use a slope ratio that will cause the toe of the proposed slope to match the toe of the existing slope (approximately 2.6:1). Pre-benching of this existing slope prior to fill placement is required for existing slopes steeper than 4:1; however, pre-benching is recommended for all slopes where sliver type fills are proposed. Refer to cross-section Station 84+00. A retaining wall is proposed from LT Station 69+00 to LT Station 72+50. Specific recommendations for this structure will be made in a separate report when an investigation is requested.

Station 91+00 to Station 118+00

This interval involves alternating cut and fill sections with cut depths of up to 8 feet and fill heights of up to 25 feet. A maximum slope ratio of 2:1 is recommended for the cut and fill slopes in this interval. Pre-benching of the existing fill slopes is required for existing slopes steeper than 4:1; however, pre-benching is recommended for all slopes where sliver type fills are proposed. Refer to cross-section

Station 105+00. A rock pad will be required at LT Station 112+00 to LT Station 116+00. This area is near an existing sinkhole that functions as an outlet for significant surface runoff. It is recommended that this area be cleared of all organic debris. A layer of Geotextile fabric (Type IV, high survivability, Item No 740-10.04) be placed beneath the entire proposed embankment footprint and should extend a minimum of 25 feet up the side of the existing embankment. Graded solid rock shall then be placed on the fabric to a minimum depth of five feet. A layer of Geotextile fabric (Type IV, high survivability, Item No. 740-10-04.) shall then be placed on top of the rock pad. The remainder of the embankment in this area may consist of common roadway embankment. Refer to cross-section 114+50.

Station 118+00 to Station 155+86.85

This interval consists of alternating cut and fill sections with cut depths of up to 18 feet and fill heights of up to 15 feet. A maximum slope ratio of 2:1 is recommended for the slopes in this interval; however, slopes constructed with slope ratios flatter than 2:1 as shown on the cross-sections will result in increased slope stability. The cut area from LT Station 119+00 to LT Station 129+00 may contain several localized pods of pinnacle type rock outcrops. It is recommended that any pinnacle type rock encountered be included with the soil overburden and be laid back on the appropriate slope. Refer to cross-section station 121+00. Evidence of two potential sinkhole openings exist left of station119+10. One exists as an area that has sunk in the existing roadway ditch and has been repaired with aggregate and asphalt. The other is a sunk-in hole in the existing ditch between the outlet of the Pinnacle Lounge and Arcade

parking lot drain and the existing under-drain in their entrance. The area has been repaired with rip rap but the opening has re-occurred. Both areas are affected by surface drainage. The opening of the existing roadway ditch is under the proposed roadway in an area of approximately a three foot fill. It is recommended that this area be excavated to rock or as deep as is practical (20' maximum). A layer of Geotexile fabric shall be placed so as to line the excavation. The excavation shall then be backfilled with graded solid rock up to proposed sub-grade elevation. The second opening is located in or near the proposed roadway ditch-line in an area of an approximately 15 foot cut. After the cut has been excavated to proposed ditch-line elevation, it is recommended that the sinkhole be excavated to rock or as deep as is practical (20' maximum). A layer of Geotextile fabric shall be placed so as to line the excavation. The excavation shall then be backfilled with graded solid rock to approximately two feet below proposed ditch-line grade. A layer of Geotextile fabric shall be placed on top of the graded solid rock and the remainder of the fill may consist of common roadway embankment. It is recommended that the proposed roadway ditch be lined with Geo-membrane from the end of the proposed 24" CMP to Station 120+50 to prevent surface runoff from entering the sinkhole. The exact location and the relationship of these two openings to one another will not be fully known until the cut is excavated. Adjustments to these recommendations may be required in the field during construction. A sinkhole/wetland area exists from LT Station 130+50 to LT Station 132+50. This area is currently handling significant surface drainage and will continue to function as drainage when the proposed roadway is completed. It is recommended that the area immediately under the roadway footprint be cleared of all brush and organic

debris. A layer of Geotextile fabric (Type IV, high survivability, Item No. 740-10.04) shall then be placed beneath the entire proposed embankment footprint at this location, including a minimum distance of 28 feet up the existing embankment area. This area shall then be backfilled with graded solid rock to a minimum depth of six feet. A layer of Geotextile fabric shall then be placed on top of the Graded Solid Rock. The remainder of the fill material in this area may consist of common roadway embankment. Refer to cross-section Station 132+00. The portion of the sinkhole not affected by the proposed embankment should be left as-is to the extent practical and still achieve embankment/rock pad construction.

PAVEMENT DESIGN RECOMMENDATIONS:

It is recommended that one continuous pavement section be designed using the County average CBR value of CBR = 6.0.

If there are any questions concerning this report please contact the Geotechnical Engineering Section.

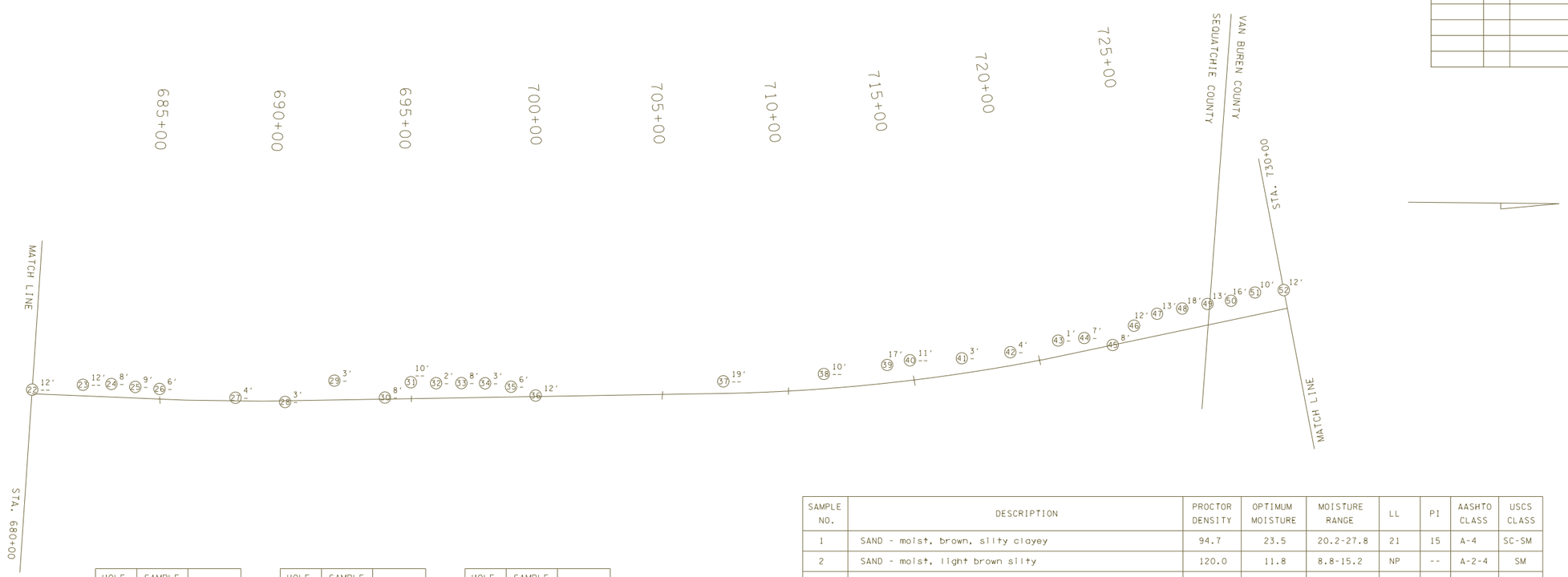
Robert Jowers. P.E. Civil
Engineering Manager 2

MLO:MP:CJW
02/01/07

Example Line Sheet (Plan View)

TENNESSEE D.O.T.
DESIGN DIVISION
FILE NO.

TYPE	YEAR	PROJECT NO.	SHEET NO.



HOLE NO	SAMPLE NO	DEPTH
22	5	0-1
	6	1-12
23	5	0-2
	6	2-10
	† 7	10-11
	6	11-12
24	6	0-8
25	6	0-9
26	5	0-1
	6	1-6
27	5	0-1
	6	1-4
28	† 8	0-3
29	5	0-2
	6	2-3
30	5	0-2
	† 9	2-8
31	5	0-6
	9	6-9
	2	9-10
32	1	0-2
33	5	0-2
	† 14	2-6
	6	6-8

HOLE NO	SAMPLE NO	DEPTH
34	6	0-3
35	1	0-6
36	5	0-2
	6	2-11
	† 10	11-12
37	8	0-6
	† 11	6-17
	† 12	17-19
38	8	0-8
	† 13	8-10
39	5	0-1
	6	1-9
	11	9-17
40	5	0-1
	6	1-9
	CBR 2	9-11
41	11	0-3
42	11	0-4
43	4	0-1
44	8	0-1
	11	1-7
45	4	0-1
	11	1-7
	9	7-8

HOLE NO	SAMPLE NO	DEPTH
46	13	0-1
	6	1-10
	11	10-12
47	† 15	0-4
	† 16	4-13
48	15	0-4
	16	4-6
	5	6-18
49	† 17	0-2
	16	2-4
	15	4-13
50	15	0-2
	16	2-3
	15	3-16
51	15	0-2
	16	2-8
	† 18	8-10
52	15	0-4
	16	4-6
	15	6-12

† INDICATES LOCATION WHERE SAMPLE WAS TAKEN AND LAB TEST PERFORMED.
ALL OTHER SAMPLE NUMBER LABELS INDICATE AN APPARENT SIMILARITY
BASED ON VISUAL IDENTIFICATION IN THE FIELD.

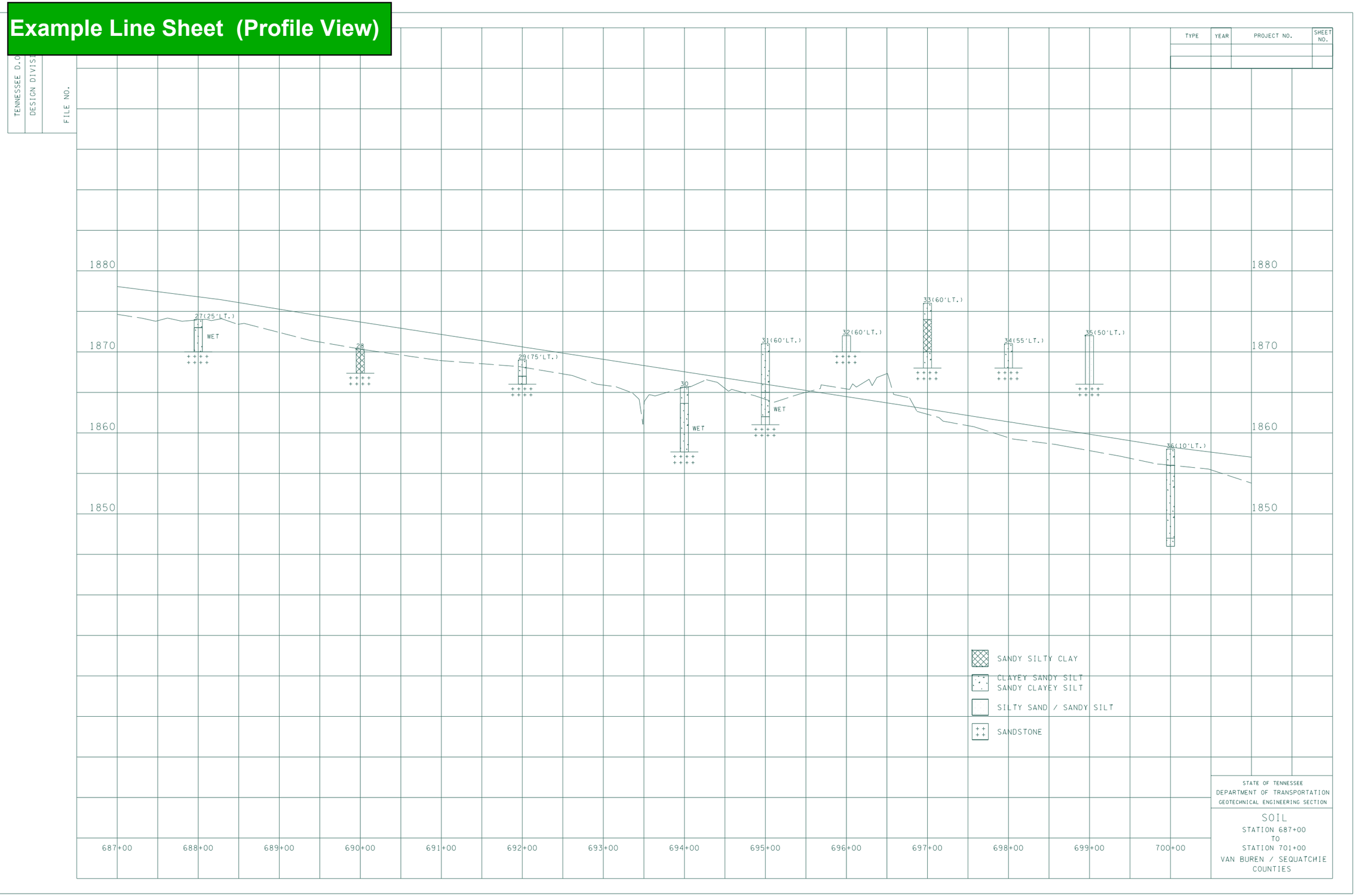
SAMPLE NO.	DESCRIPTION	PROCTOR DENSITY	OPTIMUM MOISTURE	MOISTURE RANGE	LL	PI	AASHTO CLASS	USCS CLASS
1	SAND - moist, brown, silty clayey	94.7	23.5	20.2-27.8	21	15	A-4	SC-SM
2	SAND - moist, light brown silty	120.0	11.8	8.8-15.2	NP	--	A-2-4	SM
3	CLAY - dry, gray with mottled sandy, silty	111.2	13.2	9.5-18.0	21	14	A-4	CL-ML
4	CLAY - moist, reddish-brown with gray mottled lean	104.6	19.5	15.6-23.5	37	22	A-6	CL
5	CLAY - moist, brown, sandy, lean	109.6	14.5	9.9-18.5	28	20	A-4	CL
6	SAND - light grayish-brown, silty, clayey	119.4	11.2	8.5-14.8	17	13	A-4	SC-SM
7	SAND - dry, grayish, silty	109.0	14.5	7.8-19.4	NP	--	A-2-4	SM
8	CLAY WITH SAND - wet, stiff, grayish-brown, lean	102.2	20.2	14.1-24.4	34	22	A-6	CL
9	CLAY - wet, greenish-brown, lean	111.0	15.2	11.2-18.7	28	19	A-4	CL
10	SAND - moist, black, silty, clayey	111.0	12.6	7.8-17.5	18	14	A-4	SC-SM
11	SHALE - cry, gray	-----	----	--------	--	--	---	--
12	SHALE - wet, gray	-----	----	--------	--	--	---	--
13	CLAY - wet, reddish-brown, sandy, silty	113.0	13.8	11.2-17.4	22	16	A-4	CL-ML
14	CLAY - dry, reddish-brown, sandy, lean	108.0	17.5	13.0-21.1	29	18	A-6	CL
15	CLAY - moist, reddish-brown, sandy, silty	113.3	13.3	9.2-17.5	22	16	A-4	CL-ML
16	CLAY WITH SAND - moist, gray, lean	107.2	14.2	8.2-19.2	27	18	A-4	CL
17	CLAY WITH SAND - reddish-brown, lean	105.1	17.2	14.2-21.6	37	23	A-6	CL
18	SHALE- dry, gray	-----	----	--------	--	--	---	--

CBR NO.	DESCRIPTION	DENSITY	OPTIMUM MOISTURE	MOISTURE RANGE	LL	PI	AASHTO CLASS	USCS CLASS	CBR
2	SHALE - grayish-brown	-----	----	---------	----	--	----	-----	---

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

SOIL
STATION 680+00
TO
STATION 730+00
VAN BUREN / SEQUATCHIE
COUNTIES

Example Line Sheet (Profile View)



Example Line Sheet (Cross Section)

TENNESSEE D.O.T.
DESIGN DIVISION
FILE NO.

TYPE	YEAR	PROJECT NO.	SHEET NO.
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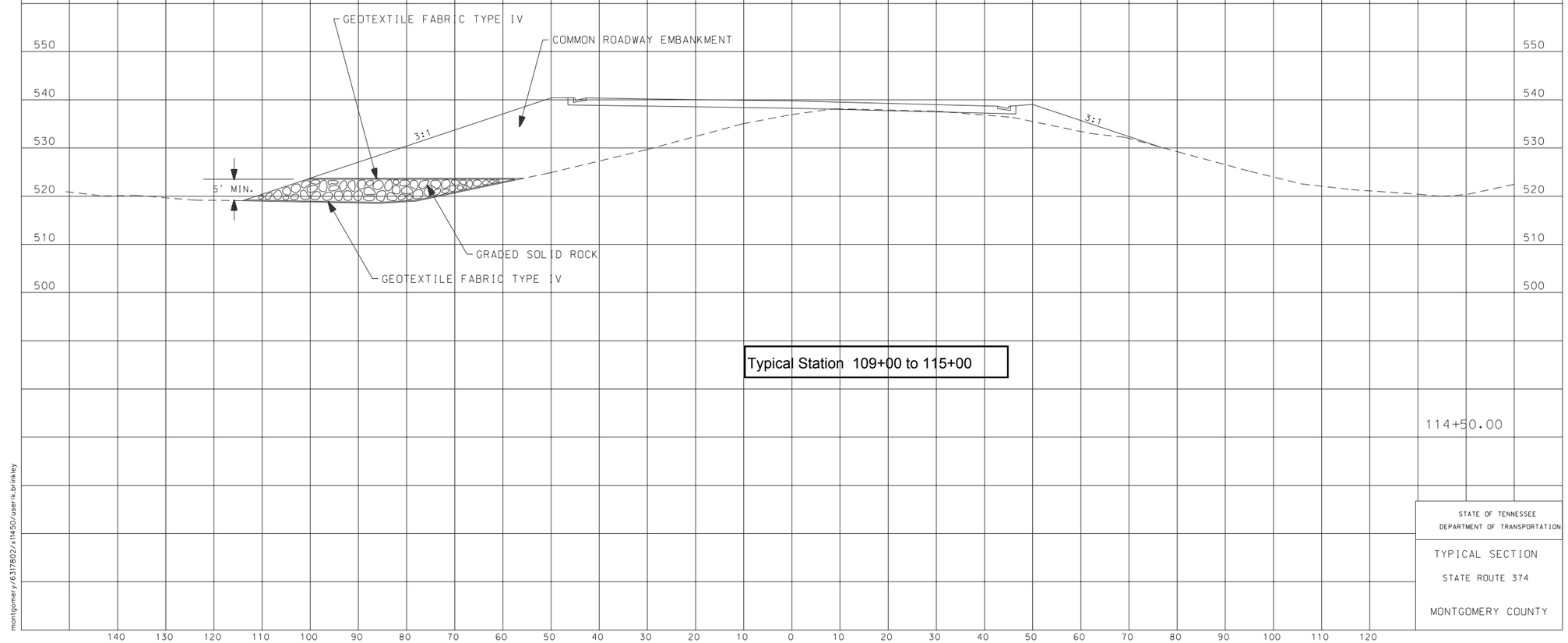
.	.	.	.
.	.	.	.

GRADED SOLID ROCK

BORROW EXCAVATION (GRADED SOLID ROCK) SHALL CONSIST OF THE REMOVAL AND SATISFACTORY PLACEMENT OF SOUND, NON-DEGRADABLE ROCK WITH A MAXIMUM SIZE OF 3 FEET (1 METER). AT LEAST 50 PERCENT OF THE ROCK SHALL BE UNIFORMLY DISTRIBUTED BETWEEN 1 FOOT (30 CENTIMETERS)AND 3 FEET (1 METER) IN DIAMETER AND NO GREATER THAN 10 PERCENT SHALL BE LESS THAN 2 INCHES (50 MILLIMETERS) IN DIAMETER. THE MATERIAL SHALL BE ROUGHLY EQUI-DIMENSIONAL IN SHAPE. THIN, SLABBY MATERIAL WILL NOT BE ACCEPTED. THE CONTRACTOR SHALL BE REQUIRED TO PROCESS THE MATERIAL WITH AN ACCEPTABLE MECHANICAL SCREENING PROCESS THAT PRODUCES THE REQUIRED GRADATION. WHEN THE MATERIAL IS SUBJECTED TO FIVE ALTERATIONS OF THE SODIUM SULFATE SOUNDNESS TEST (AASHTO T-104), THE WEIGHTED PERCENTAGE OF LOSS SHALL NOT BE MORE THAN 12. THE MATERIAL SHALL BE APPROVED BY THE ENGINEER BEFORE USE.



Typical Station 109+00 to 115+00

114+50.00

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

TYPICAL SECTION

STATE ROUTE 374

MONTGOMERY COUNTY

montgomery/6317802/x11450/userrk.brinkley

SNAP PT

Example Line Sheet (Cross Section)

TENNESSEE D.O.T.
DESIGN DIVISION
FILE NO.

TYPE	YEAR	PROJECT NO.	SHEET NO.
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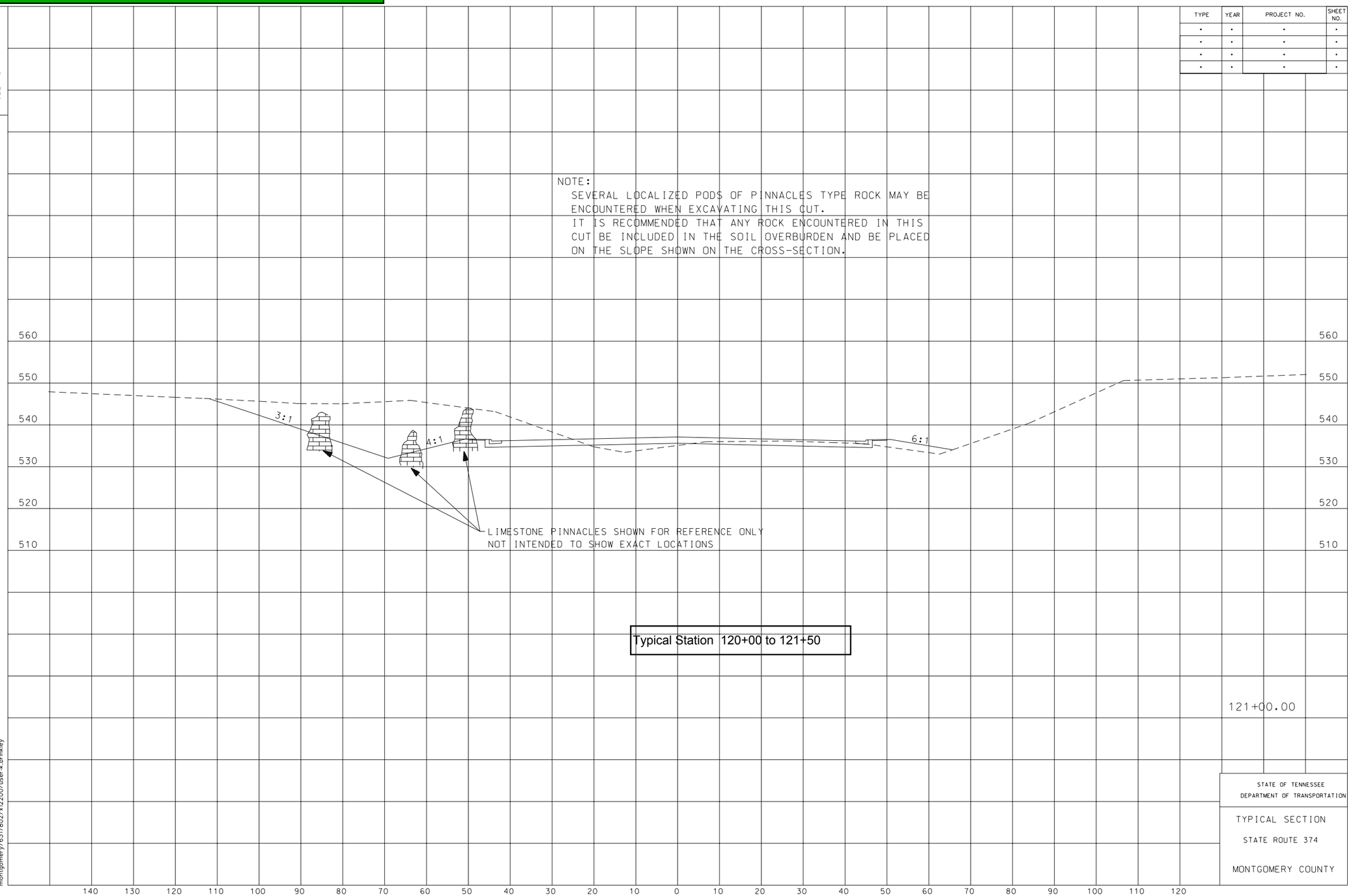
NOTE:
SEVERAL LOCALIZED PODS OF PINNACLES TYPE ROCK MAY BE ENCOUNTERED WHEN EXCAVATING THIS CUT.
IT IS RECOMMENDED THAT ANY ROCK ENCOUNTERED IN THIS CUT BE INCLUDED IN THE SOIL OVERBURDEN AND BE PLACED ON THE SLOPE SHOWN ON THE CROSS-SECTION.



STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

TYPICAL SECTION

STATE ROUTE 374

MONTGOMERY COUNTY

montgomery/6317802/x12200/user:k.brinkley

SNAP PT

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Example Rockfall Report

PRELIMINARY GEOTECHNCIAL REPORT
Rockfall Mitigation Assessment
State Route 25
From Approximate L.M. 8.5 to L.M. 8.9, Left of Centerline
Project No. 80000-4200-04
Smith County

Introduction

This report summarizes the preliminary evaluation of possible design considerations required to mitigate the rockfall events at the referenced site. The project is located in an inside curve of a side hill cut above the Cumberland River and has a latest available 2005 ADT of 9560. It is also opposite of the scenic overlook. The TDOT Rockfall Hazard Rating System has rated the cut as an “A” type hazard, which means that there is a moderate-to-high potential for rockfall activity, but a moderate Rockfall Closure impact.

Discussion

The rockfall history of the cut is that rockfall events occur often and have been since the initial roadway construction. Bedrock along the existing slope consists of flat-lying limestone and interbedded shale that is very thin- to medium-bedded. The predominant geologic structure that controls the stability of the rock cut is columnar jointing coupled with tension cracks. Differential weathering of these two rock types results in the undermining of tall triangular wedges that pull loose from the slope and topple onto the roadway. Maintenance reports that this slope is most problematic during the winter months due to freeze and thaw changes.

The most recent field inspection of the site took place on February 12, 2007. Several photographs were taken of the slope and observations were noted of recent rock raveling of the cut face into the ditch. Another area of concern was the potential for one large wedge failure near the eastern end of the cut that will result in closure of the

road for a short period of time. There is rock debris in the existing ditch that was piled up against the rock wall by previous fall material.

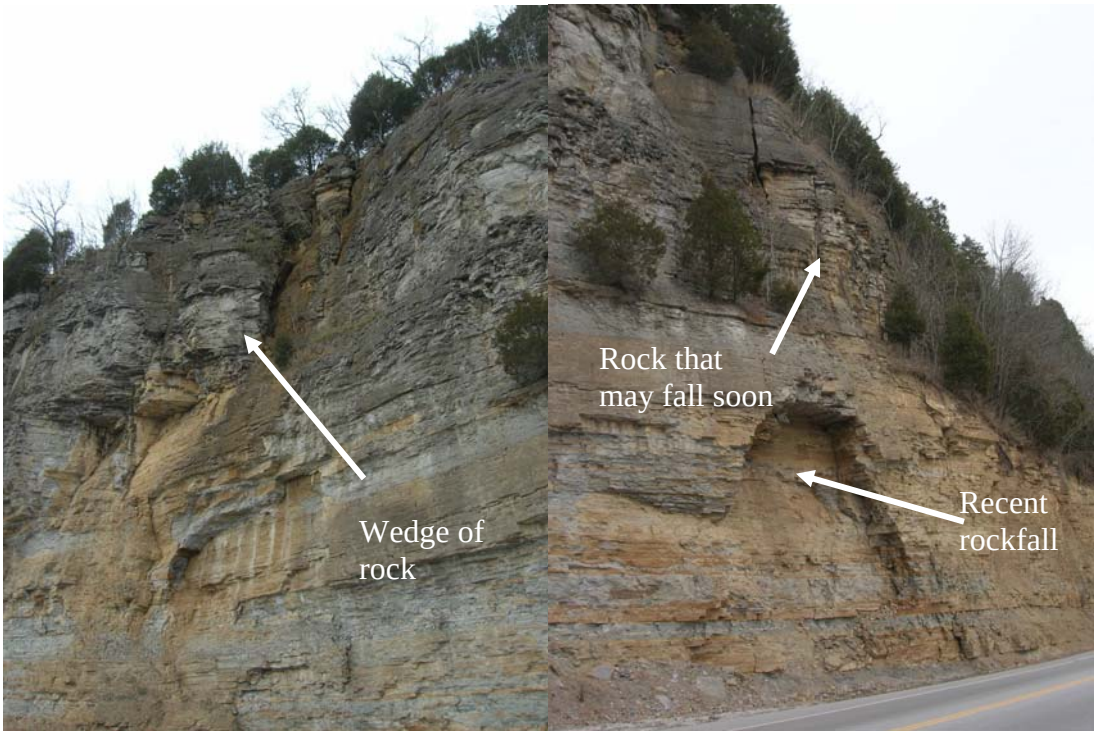


Figure 1: A. View of Wedge of rock at upper edge of slope. B. View of recent rock failure and upper area of rock that may fall.

Recommendations

There are several possible mitigation methods that could be used on this site. These vary in cost and effectiveness.

- Move the roadway toward the river. There is a very large paved shoulder/overlook area for much of the rock cut.
- Add a couple of additional Falling Rock signs along the road. This will do nothing to prevent rocks from landing in the roadway but should better alert the public to the hazard. At the moment there are two signs, one on either side of the cut. Many drivers may miss the one sign that they see from their direction.

- Scaling and trim blasting could be performed along the cut to remove all loose material. This will include removal of all rock debris from the limited catchment area at the base of the rock cut. All trees should be removed from the cut and also from at least 6 feet from the edge of the cut. Scaling would be used to bring down rock that may fall. This will not remove the entire hazard and does not address the ditch width. Also, this work cannot be performed with a standard backhoe. Special equipment will be needed to remove the material safely.
- A combination Jersey barrier and 10 foot high rockfall fence could be used at the edge of the current ditch. This would reduce some of the rockfall problems. If used in combination with Scaling and Trim Blasting, this would provide a significant reduction in rockfall hazard. However, this will not prevent all of the rocks from getting in the road. When tall triangular wedges of rock fail, a significant amount of rockfall could topple over the fence and into the paved roadway.
- Installation of a draped wire mesh hung on the face of a rock slope can be an effective method of containing rock falls close to the face and preventing them from bouncing on to the road. Because the mesh absorbs some of the energy of the falling rock, the existing dimensions of the ditch at the toe of this slope would still be tolerable. Periodic removal of rock may be required if there are large rockfall events.
- The most effective treatment for this site is to re-cut the slope to the latest TDOT rockfall standard design which would require a minimum of a 41-foot ditch width at the base of a .25:1 slope over 80 feet in height. A clean, presplit face would significantly reduce the amount of rockfall and the ditch should be adequate to catch over 90% of the rockfall from the slope. If a safety shaped Jersey barrier were added at the edge of the ditch the catchment should increase to over 95%.

Example Rockfall Report

The following table provides general cost comparisons for the various alternatives.

Rockfall Site
File Number: 80SR025000008.5L
Location: SR 25, Log Mile 8.5 to 8.9, Left of Centerline
County: Smith

Slope Height	up to 110 feet
Slope Length	1467 feet
Existing Ditch Width	up to 12 feet including shoulder slope
Ditch Width needed*	45 feet including shoulder slope

Preferred Option – Re-cutting of Slope

Element	$ Cost	Per unit	Needed at site	Unit	Total cost per Element
Excavation Unclassified	$2.57	yd^3	269,000	yd^3	$691,500
Presplitting of Rock Excavation	$8.72	yd^2	18,000	yd^2	$162,000
Traffic Control	$200.00	Day	30		$6,000.00
					$859,500

Other Options

Element	$ Cost	Per unit	Needed at site	Unit	Total cost per Element
Jersey Barrier	$50.00	yd^2	1467	yd^2	$73,350
Machine Scaling	$25.00	yd^2	18,000	yd^2	$450,000
Rockfall Control Fence	$250.00	LF	1467	LF	$366,750
Vegetation Removal	$10.00	yd^2	18,000	yd^2	$180,000
Wire Mesh	$35.00	yd^2	18,000	yd^2	$630,000

*Ditch width that would need to be added to conform to the Tennessee Department of Transportation's Rockfall Catchment Ditch guidelines

The recommended solution for this site is a re-cut of the slope. This will bring the cut up to current design standards for rockfall catchment. Posting signs is the least expensive option but provides no hazard reduction. Re-cutting the slope is likely the most expensive option but provides the best mitigation.

Example Rockfall Report

GEOTECHNICAL REPORT

Preliminary Geotechnical Study of State Route 112
From State Route 12 (Ashland City Highway)
To State Route 115 (Briley Parkway)
State Project No. 19046-1214-14, PIN No. 103764.00
Davidson County

Executive Summary

The Geotechnical Engineering Section has completed a site investigation for the referenced subject project. The existing cuts slopes indicate future construction will consists of shaly, cobbly rubble with thin slabs of limestone and phosphatic clay. There may be the occasional medium-bedded limestone represented as boulders. There were no noticeable wetland areas within the proposed right-of-way that will require fill material to reach the proposed subgrade elevation. In summary, there are no geotechnical or geologic conditions along the proposed roadway widening that would require altering the current functional plans. Therefore, it is recommended to design slopes of 2:1 or flatter for right-of-way considerations.

Example Rockfall Report

Introduction

This report summarizes the site investigation for the proposed widening of State Route 112 on February 27-28, 2007. The project begins just north of the intersection of State Route 12 (Ashland City Highway) and continues north to State Route 155 (Briley Parkway). The project will consist of 5 twelve foot traffic lanes and four foot shoulders to include curb and gutter with eight foot sidewalks. Included are bikeways and grass utility strips all within a 92-foot right-of-way. The increased lane widths and overall carrying capacity will result in the removal and replacement of the existing bridge structure spanning Whites Creek. It is our understanding that most of the proposed widening will be symmetrical to the present roadway centerline except for those areas that will require shifting the roadway to minimize property damage.

Geology, Soils and Site Conditions

The project area is located within a physiographic region known as the Central Basin, (the outer part of the Nashville Basin) which is characterized by gently rolling to hilly uplands. The majority of the widening is along an urban corridor cover with buildings of various types and isolated wooded/pastured fields. Available geologic mapping (USGS Geologic Map of the Nashville West Quadrangle, 1966) indicates the site is underlain by the phosphatic limestone, representing the Ordovician Geologic Period. Residual soil formed by the in-place weathering of the parent limestone is brown phosphatic clay. Exposed level bedded limestone is highly weathered, thin-bedded to slabby and interbedded with gray calcareous shale. Near the southern approach to Whites Creek and across from the fire hall, thicker bedded limestone is

exposed. The soil overburden appears relatively shallow, even within the multiple solution zones that are another characteristic of rock lithologies.

Recommendations and Discussions

The existing cut slopes involve both soil and rock that range from vertical to near 2:1. From the north side of Whites Creek to E. Hamilton Road, left of the existing roadway embankment, is a narrow floodplain currently being utilized for dumping construction debris consisting of boulder rock and clay soil. Judging from the natural ground line adjacent to the man-made fill, it is approximately 5-6 feet in depth and the top of the material approximates the existing roadway grade.

In summary, there are no geotechnical or geologic conditions along the proposed roadway widening that would require altering the current functional plans. It is recommended to design cut and fill slopes of 2:1 or flatter for right-of-way considerations. Pavement costs may be slightly higher than average due to the expected low CBR values of the phosphatic clay soil.

If there are questions concerning this report, please contact the Geotechnical Engineering Section.

Randall J. Jones, P.G.
Operations Specialist 2

Robert Jowers, P.E.
Civil Engineering Manager 2

MLO:RJJ:CJW
March 6, 2007

Rock slope Standard Drawing

REV. 10-15-02: NEW SHEET.

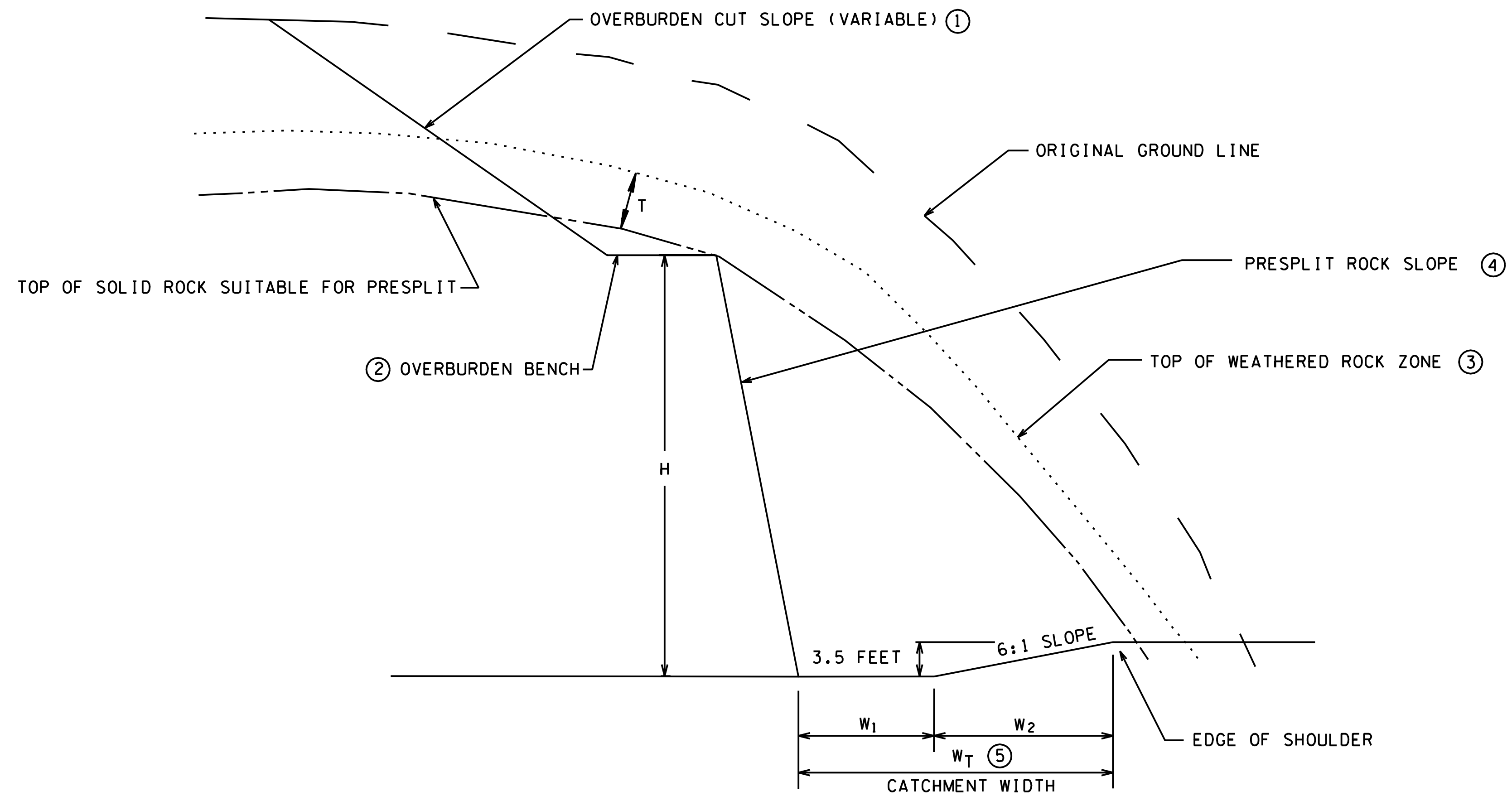


FIGURE 1. ROCK CUT SLOPE AND CATCHMENT WIDTH DETAILS

PRESPLIT ROCK SLOPE				
H (FT)	VERTICAL		0.25 H : 1 V OR FLATTER	
	⑤ W_T (FT)	W_1 (FT)	W_T (FT)	W_1 (FT)
0-40	21	0	21	0
40-50	21	0	27	6
50-60	24	3	33	12
60-70	28	7	37	16
70-80	32	11	41	20
80-120	36	15	45	24
120-160	40	19	51	30
160-200	52	31	63	42

TABLE 1. ROCK CUT PRESPLIT SLOPES

FOOTNOTES

① SEE GEOTECHNICAL REPORT FOR ALLOWABLE OVERBURDEN CUT SLOPE RECOMMENDATIONS.

② OVERBURDEN BENCH TO BE MINIMUM OF 10' WIDE AS SPECIFIED IN GEOTECHNICAL REPORT. NO INTERMEDIATE BENCHES ARE TO BE USED UNLESS RECOMMENDED IN THE REPORT.

③ TOP OF WEATHERED ROCK ZONE (HENCE, THE THICKNESS -T) WILL BE VARIABLE. GEOTECHNICAL REPORT WILL PROVIDE PROJECT SPECIFIC GUIDANCE ON THICKNESS TO USE IN THE CROSS-SECTION DEVELOPMENT. THIS ZONE MAY CONTAIN ROCK PINNACLES, ROCK LENSES, OR WEATHERED ROCK MIXED WITH SOIL. BLASTING MAY BE REQUIRED TO REMOVE. CONSIDER EXCAVATION ITEM IN THIS ZONE TO BE UNCLASSIFIED, COMMON.

④ PRESPLIT SLOPE TO BE PROVIDED FOR SPECIFIC ROCK CUT INTERVALS IN GEOTECHNICAL REPORT. IT IS ASSUMED PRESPLIT FACES WILL BE FORMED OR SCALED OF LOOSE ROCKS AND OVERHANGS IN ACCORDANCE WITH TDOT STANDARD SPECIFICATIONS.

⑤ W_T IS HORIZONTAL DISTANCE FROM SHOULDER (MID-POINT OF SLOPE ROUNDING) TO BASE OF PRESPLIT ROCK SLOPE. W_T WILL BE 21 FEET OR GREATER IN ALL CASES. FOR ALL FORESLOPES OTHER THAN 6:1, SEE GEOTECHNICAL REPORT.

GENERAL NOTES

Ⓐ IF W_T CANNOT BE ACHIEVED DUE TO RIGHT-OF-WAY RESTRICTIONS OR EXCESSIVE EXCAVATION, THEN A COMBINATION OF A NARROWER ROCKFALL DITCH (W_1), ROCKFALL CATCHMENT FENCE OR BARRIER, OR ROCKSLOPE MESHING WILL BE REQUIRED. CONTACT GEOTECHNICAL ENGINEERING SECTION OR GEOTECHNICAL CONSULTANT FOR GUIDANCE.

Ⓑ A UNIFORM CATCHMENT WIDTH (W_T) BASED ON THE HIGHEST ROCK CUT SLOPE (H), SHOULD BE USED.

Ⓒ FOR LONG CUT SLOPES WHERE A PREDOMINANT CUT HEIGHT EXISTS FOR SEVERAL STATIONS, UTILIZE W_T FOR THAT GIVEN CUT HEIGHT (H). TRANSITION TO VARIOUS CATCHMENT WIDTHS ON A RATIO NO GREATER THAN 4 FEET HORIZONTAL W_T PER 100 FOOT STATION INTERVAL.

☒ MINOR REVISION -- FHWA APPROVAL NOT REQUIRED.

STATE OF TENNESSEE DEPARTMENT OF TRANSPORTATION

DESIGN AND CONSTRUCTION DETAILS FOR ROCK CUT SLOPE AND CATCHMENT

10-15-02 | RD01-S-11B

$FILE$ $TIME$ $DATE$ 2/4/2005 $$$$DGNSPEC$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

Example Sinkhole Sheet (Cross Section)

TENNESSEE D.O.T.
DESIGN DIVISION
FILE NO.

TYPE	YEAR	PROJECT NO.	SHEET NO.
•	•	•	•
•	•	•	•
•	•	•	•
•	•	•	•

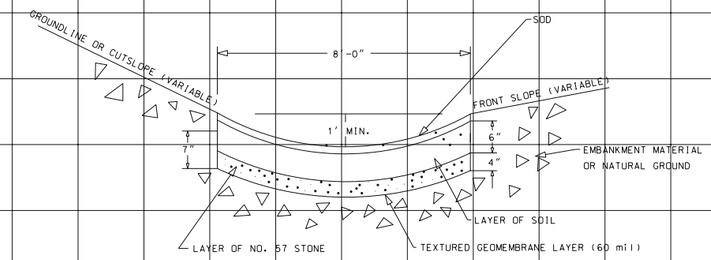
SINKHOLE TREATMENT 2 AND 2A , INACTIVE

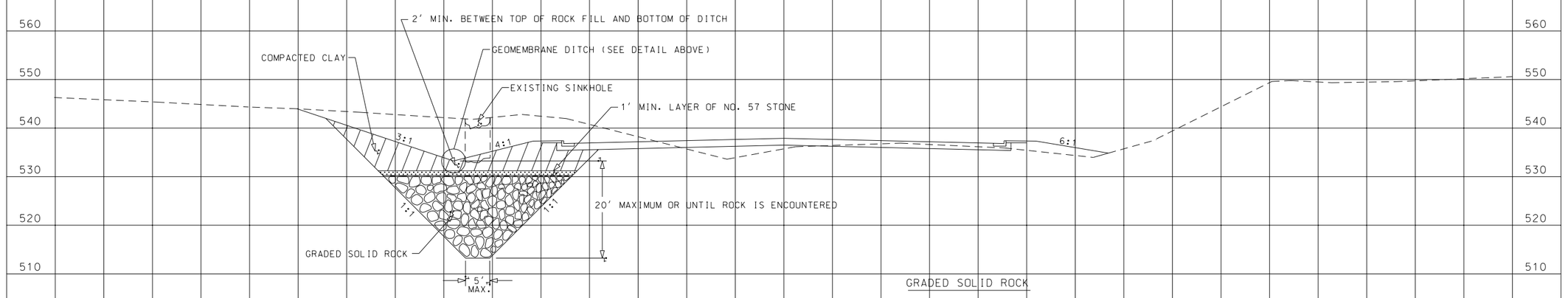
NOTE: AFTER EXCAVATION IS COMPLETE AND ROCK OPENING IS EXPOSED, THE SITE AND TREATMENT METHOD SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS. ANY CHANGE IN THE NO. 57 STONE FILL OR THE CLAY CAP SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS.

SEQUENCE OF CONSTRUCTION:

1. EXCAVATE SINKHOLE TO DEFINE OPENING IN BEDROCK MAKING SURE TO REMOVE ALL SOIL AND DEBRIS.
2. FIT THE OPENING WITH KEYSTONE ROCK, WHICH SHALL BE OF SUFFICIENT SIZE TO LOCK IN PLACE WITHOUT CREATING AN AIRBLOCK TO SUBSURFACE DRAINAGE.
3. BACKFILL WITH GRADED SOLID ROCK (CLASSIFICATION 203.02, BORROW EXCAVATION) UP TO SPECIFIED GRADE.
4. PLACE TYPE IV GEOTEXTILE ON TOP OF GRADAED SOLID ROCK. PLACE NO. 57 STONE ON TOP OF GEOTEXTILE.
5. CONSTRUCT COMPACT CLAY CAP. SOIL SHOULD BE OF TYPE AASHTO A-6 OR A-7-6.
6. PLACE GEOMEMBRANE ON TOP OF SOIL CAP BEFORE CONSTRUCTION OF ANY OVERLYING STRUCTURES OR EMBANKMENTS. THERE SHOULD BE A MINIMUM OF 1.5 FT. OF SOIL PLACED OVER THE MEMBRANE.
7. DITCH SHOULD BE PAVED OR LINED WITH A GEOMEMBRANE.

GEOMEMBRANE LINED SOD DITCH





GRADED SOLID ROCK

BORROW EXCAVATION (GRADED SOLID ROCK) SHALL CONSIST OF THE REMOVAL AND SATISFACTORY PLACEMENT OF SOUND, NON-DEGRADABLE ROCK WITH A MAXIMUM SIZE OF 3 FEET (1 METER). AT LEAST 50 PERCENT OF THE ROCK SHALL BE UNIFORMLY DISTRIBUTED BETWEEN 1 FOOT (30 CENTIMETERS) AND 3 FEET (1 METER) IN DIAMETER AND NO GREATER THAN 10 PERCENT SHALL BE LESS THAN 2 INCHES (50 MILLIMETERS) IN DIAMETER. THE MATERIAL SHALL BE ROUGHLY EQUI-DIMENSIONAL IN SHAPE. THIN, SLABBY MATERIAL WILL NOT BE ACCEPTED. THE CONTRACTOR SHALL BE REQUIRED TO PROCESS THE MATERIAL WITH AN ACCEPTABLE MECHANICAL SCREENING PROCESS THAT PRODUCES THE REQUIRED GRADATION. WHEN THE MATERIAL IS SUBJECTED TO FIVE ALTERATIONS OF THE SODIUM SULFATE SOUNDNESS TEST (AASHTO T-104), THE WEIGHTED PERCENTAGE OF LOSS SHALL NOT BE MORE THAN 12. THE MATERIAL SHALL BE APPROVED BY THE ENGINEER BEFORE USE.

120+00.00

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

TYPICAL SECTION

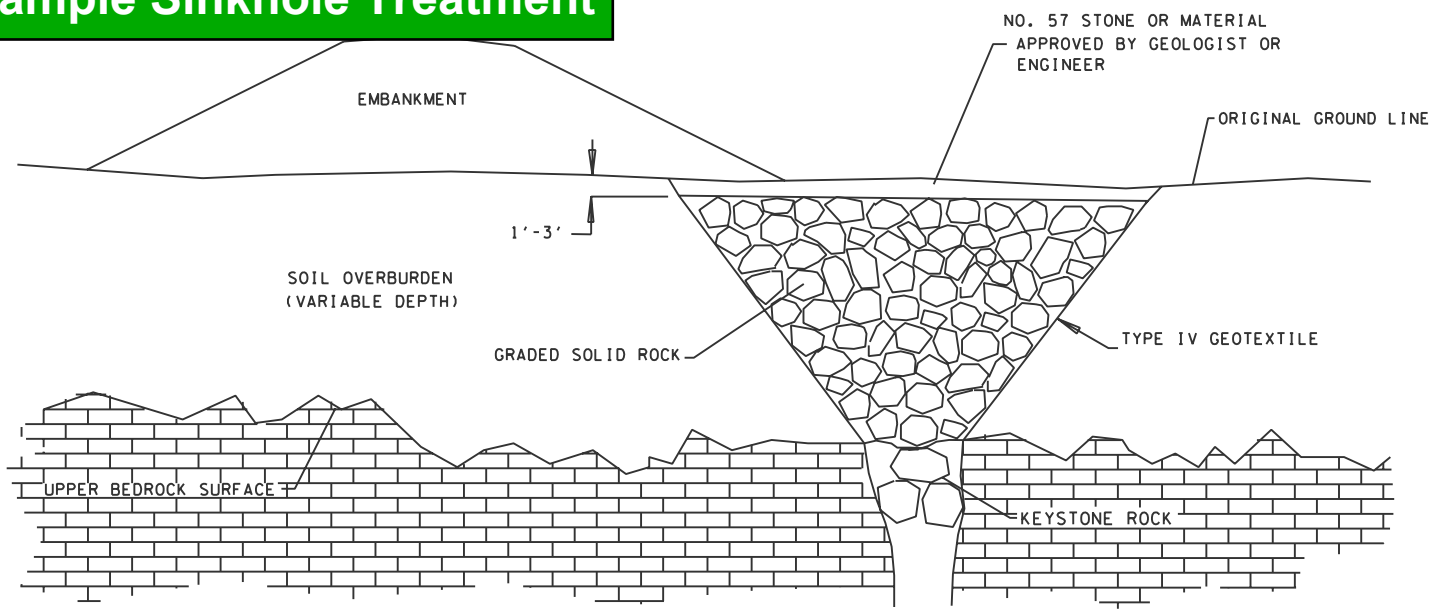
STATE ROUTE 374

MONTGOMERY COUNTY

140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80 90 100 110 120

montgomery/6317802/x12000/user:k.brinkley

Example Sinkhole Treatment



SINKHOLE TREATMENT 1

SINKHOLE TREATMENT 1, ACTIVE

NOTE: AFTER EXCAVATION IS COMPLETE AND ROCK OPENING IS EXPOSED, THE SITE AND TREATMENT METHOD SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS. THE TOP 1-3 FT. OF MATERIAL SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS.

SEQUENCE OF CONSTRUCTION:

1. EXCAVATE SINKHOLE TO DEFINE OPENING IN BEDROCK MAKING SURE TO REMOVE ALL SOIL AND DEBRIS.

2. FIT THE OPENING WITH KEYSTONE ROCK, WHICH SHALL BE OF SUFFICIENT SIZE TO LOCK IN PLACE WITHOUT CREATING AN AIRBLOCK TO SUBSURFACE DRAINAGE.

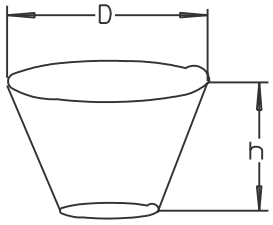
3. PLACE THE TYPE IV GEOTEXTILE FABRIC ON EXCAVATED SLOPES AND BASE OF SINKHOLE.

4. BACKFILL TO A MAXIMUM OF 1 FT. OF THE SPECIFIED GRADE WITH GRADED SOLID ROCK (CLASSIFICATION 203.02, BORROW EXCAVATION).

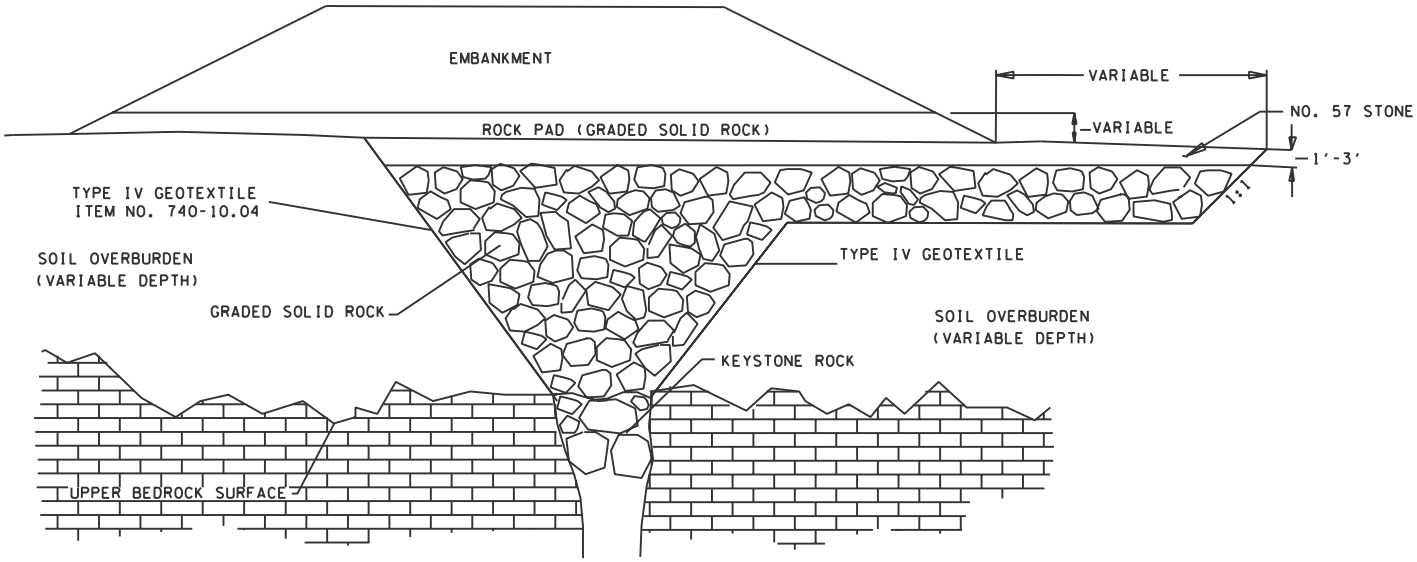
5. BACKFILL TO GRADE WITH A MINIMUM OF 1 FT. OF NO.57 STONE ON TOP OF THE GRADED SOLID ROCK AND TYPE IV GEOTEXTILE.

EQUATION FOR ESTIMATING SINKHOLE VOLUME, WHERE THE SIDES OF THE SINKHOLE ARE AT 1:1 SLOPES.

$$\text{VOL. } 1{:}1 \approx 0.13D^3 - (0.5D - h)^3$$



Example Sinkhole Treatment



SINKHOLE TREATMENT 1A

SINKHOLE TREATMENT 1A ACTIVE

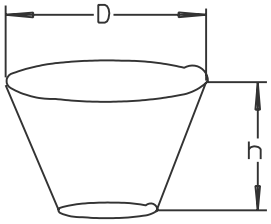
NOTE: AFTER EXCAVATION IS COMPLETE AND ROCK OPENING IS EXPOSED, THE SITE AND TREATMENT METHOD SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS. THE TOP 1-3 FT. MATERIAL SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS.

SEQUENCE OF CONSTRUCTION:

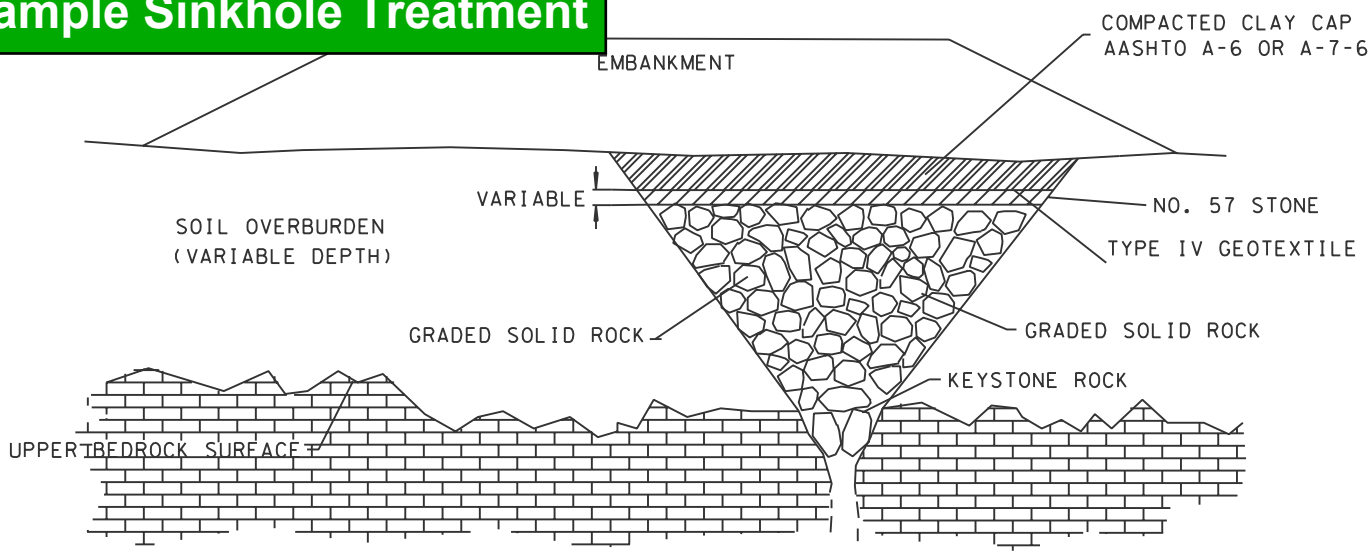
1. EXCAVATE SINKHOLE TO DEFINE OPENING IN BEDROCK AND EXCAVATE TONGUE DOWN TO THE DEPTH SHOWN MAKING SURE TO REMOVE ALL SOIL AND DEBRIS FROM THESE EXCAVATIONS.
2. FIT THE OPENING WITH KEYSTONE ROCK, WHICH SHALL BE OF SUFFICIENT SIZE TO LOCK IN PLACE WITHOUT CREATING AN AIRBLOCK TO SUBSURFACE DRAINAGE.
3. PLACE THE TYPE IV GEOTEXTILE FABRIC.
4. BACKFILL TO WITHIN 1.5-3 FT.OF THE SPECIFIED GRADE WITH GRADED SOLID ROCK.
5. PLACE THE TYPE IV GEOTEXTILE ON TOP OF GRADED SOLID ROCK.
6. BACKFILL TO GRADE WITH NO. 57 STONE.

EQUATION FOR ESTIMATING SINKHOLE VOLUME, WHERE THE SIDES OF THE SINKHOLE ARE AT 1:1 SLOPES.

$$\text{VOL. } 1{:}1 \approx 0.13D^3 - (0.5D - h)^3$$



Example Sinkhole Treatment



SINKHOLE TREATMENT 2

SINKHOLE TREATMENT 2 AND 2A , INACTIVE

NOTE: AFTER EXCAVATION IS COMPLETE AND ROCK OPENING IS EXPOSED, THE SITE AND TREATMENT METHOD SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS. ANY CHANGE IN THE NO. 57 STONE FILL OR THE CLAY CAP SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS.

SEQUENCE OF CONSTRUCTION:

1. EXCAVATE SINKHOLE TO DEFINE OPENING IN BEDROCK MAKING SURE TO REMOVE ALL SOIL AND DEBRIS.

2. FIT THE OPENING WITH KEYSTONE ROCK, WHICH SHALL BE OF SUFFICIENT SIZE TO LOCK IN PLACE WITHOUT CREATING AN AIRBLOCK TO SUBSURFACE DRAINAGE.

3. BACKFILL WITH GRADED SOLID ROCK (CLASSIFICATION 203.02, BORROW EXCAVATION) UP TO SPECIFIED GRADE.

4. PLACE TYPE IV GEOTEXTILE ON TOP OF GRADAED SOLID ROCK. PLACE NO. 57 STONE ON TOP OF GEOTEXTILE.

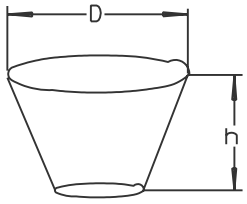
5. CONSTRUCT COMPACTED CLAY CAP. SOIL SHOULD BE OF TYPE AASHTO A-6 OR A-7-6.

6. PLACE GEOMEMBRANE ON TOP OF SOIL CAP BEFORE CONSTRUCTION OF ANY OVERLYING STRUCTURES OR EMBANKMENTS. THERE SHOULD BE A MINIMUM OF 1.5 FT. OF SOIL PLACED OVER THE MEMBRANE.

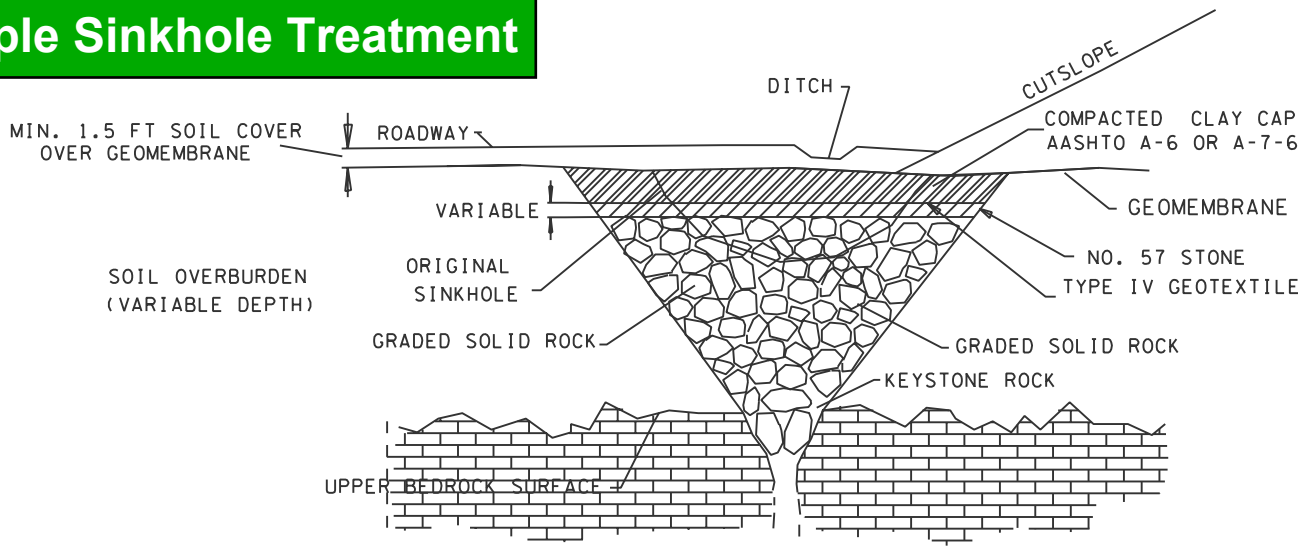
7. DITCH SHOULD BE PAVED OR LINED WITH A GEOMEMBRANE.

EQUATION FOR ESTIMATING SINKHOLE VOLUME, WHERE THE SIDES OF THE SINKHOLE ARE AT 1:1 SLOPES.

$$\text{VOL. } 1{:}1 \approx 0.13D^3 - (0.5D - h)^3$$



Example Sinkhole Treatment



SINKHOLE TREATMENT 2A

SINKHOLE TREATMENT 2 AND 2A , INACTIVE

NOTE: AFTER EXCAVATION IS COMPLETE AND ROCK OPENING IS EXPOSED, THE SITE AND TREATMENT METHOD SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS. ANY CHANGE IN THE NO. 57 STONE FILL OR THE CLAY CAP SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS.

SEQUENCE OF CONSTRUCTION:

1. EXCAVATE SINKHOLE TO DEFINE OPENING IN BEDROCK MAKING SURE TO REMOVE ALL SOIL AND DEBRIS.

2. FIT THE OPENING WITH KEYSTONE ROCK, WHICH SHALL BE OF SUFFICIENT SIZE TO LOCK IN PLACE WITHOUT CREATING AN AIRBLOCK TO SUBSURFACE DRAINAGE.

3. BACKFILL WITH GRADED SOLID ROCK (CLASSIFICATION 203.02, BORROW EXCAVATION) UP TO SPECIFIED GRADE.

4. PLACE TYPE IV GEOTEXTILE ON TOP OF GRADAED SOLID ROCK. PLACE NO. 57 STONE ON TOP OF GEOTEXTILE.

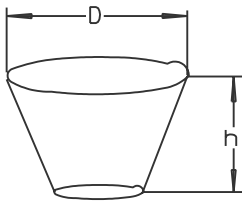
5. CONSTRUCT COMPACTED CLAY CAP. SOIL SHOULD BE OF TYPE AASHTO A-6 OR A-7-6.

6. PLACE GEOMEMBRANE ON TOP OF SOIL CAP BEFORE CONSTRUCTION OF ANY OVERLYING STRUCTURES OR EMBANKMENTS. THERE SHOULD BE A MINIMUM OF 1.5 FT. OF SOIL PLACED OVER THE MEMBRANE.

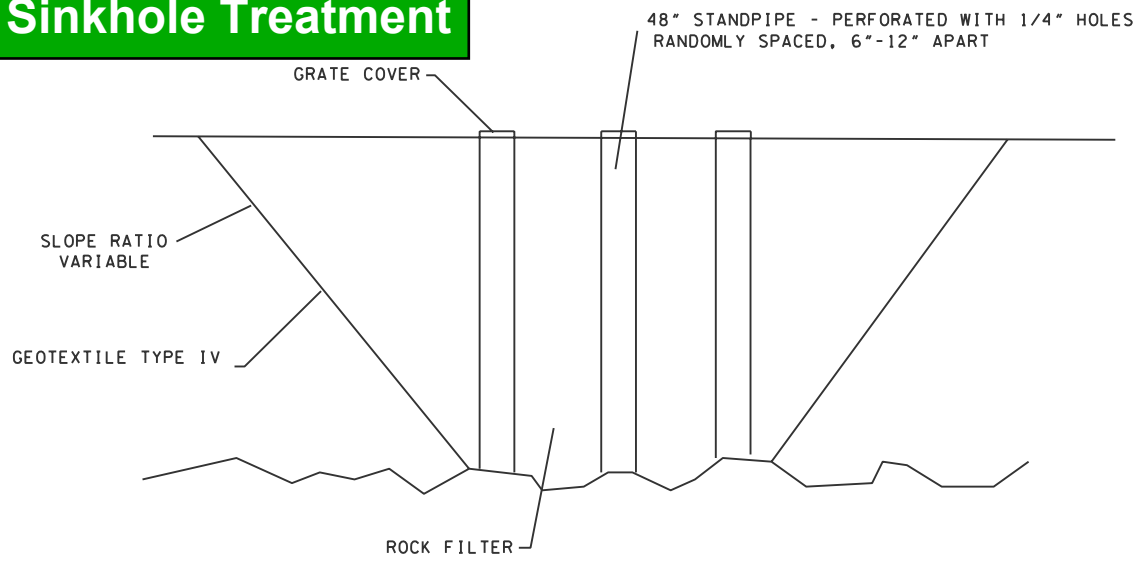
7. DITCH SHOULD BE PAVED OR LINED WITH A GEOMEMBRANE.

EQUATION FOR ESTIMATING SINKHOLE VOLUME, WHERE THE SIDES OF THE SINKHOLE ARE AT 1:1 SLOPES.

$$\text{VOL. } 1{:}1 \approx 0.13D^3 - (0.5D - h)^3$$



Example Sinkhole Treatment



SINKHOLE TREATMENT 3

SINKHOLE TREATMENT 3, ACTIVE

NOTE: AFTER EXCAVATION IS COMPLETE AND ROCK IS EXPOSED, THE SITE AND TREATMENT METHOD SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS.

SEQUENCE OF CONSTRUCTION

1. EXCAVATE SOIL DOWN TO BEDROCK TO LIMITS SPECIFIED BY THE ENGINEER OR GEOLOGIST.

2. LOCATE ALL OPENINGS WITHIN THE PITS, REMOVE ALL LOOSENED MATERIAL. ALL EXCAVATED MATERIALS SHALL BE REMOVED FROM THE BASIN.

3. INSTALL 48" DIAMETER VERTICAL STANDPIPES OVER THE LOCATED OPENINGS. THESE PIPES SHOULD BE PERFOFATED FOR AT LEAST THE LOWER 5 FT. WITHIN 1/4" HOLES SPACES 6-12" APART.

4. PLACE TYPE IV GEOTEXTILE FABRIC AS SHOWN OR AS DIRECTED BY THE ENGINEER OR GEOLOGIST TO PREVENT THE LATERAL INFLOW OF FINES.

5. BACKFILL WITH A ROCK FILTER TO A HEIGHT OF 3.5" BELOW THE TOP OF THE STANDPIPE.

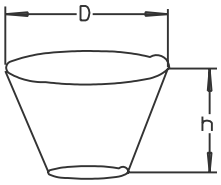
THE ROCK FILTER MATERIAL SHALL CONSIST OF A MIXTURE OF LIMESTONE SHOT ROCK AND CRUSHED STONE TO MEET THE FOLLOWING GRADATION:

SIZE RANGE (ALONG ITS MAXIMUM DIMENSION)	VOLUME
2'-1'	60-40%
1'-6"	40-20%
6"-2"	20-10%
LESS THAN 2"	5-0%

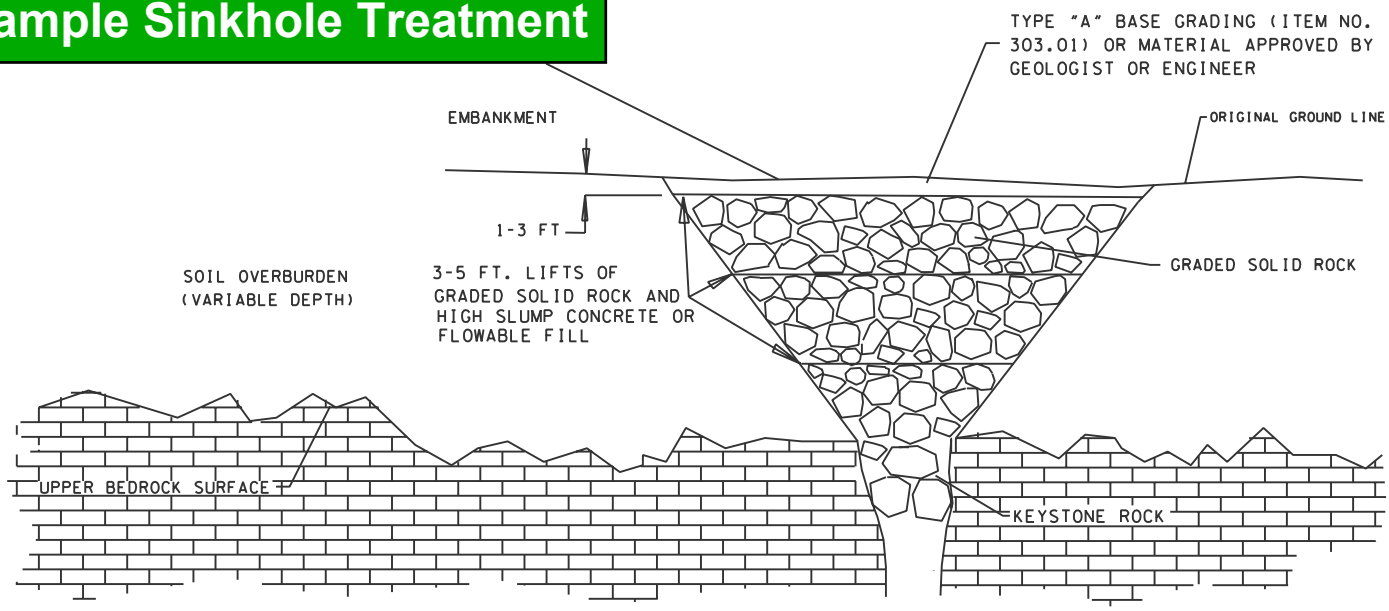
6. THE ROCK FILTER MATERIAL SHALL BE PLACED WITH A CLAMSHELL. NO END DUMPING WILL BE PERMITTED.

EQUATION FOR ESTIMATING SINKHOLE VOLUME, WHERE THE SIDES OF THE SINKHOLE ARE AT 1:1 SLOPES.

$$\text{VOL. } 1{:}1 \approx 0.13D^3 - (0.5D - h)^3$$



Example Sinkhole Treatment



SINKHOLE TREATMENT 4

SINKHOLE TREATMENT 4, INACTIVE

NOTE: AFTER EXCAVATION IS COMPLETE AND ROCK OPENING IS EXPOSED, THE SITE AND TREATMENT METHOD SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS. ANY CHANGE IN THE THE NO.57 STONE FILL SHALL BE APPROVED BY A REPRESENTATIVE OF THE GEOTECHNICAL ENGINEERING SECTION OF THE DIVISION OF MATERIALS AND TESTS.

SEQUENCE OF CONSTRUCTION

1. EXCAVATE SINKHOLE TO DEFINE OPENING IN BEDROCK AS DEFINED BY THE ENGINEER OR GEOLOGIST MAKING SURE TO REMOVE ALL SOIL DEBRIS.

2. FIT THE OPENING WITH KEYSTONE ROCK, WHICH SHALL BE OF SUFFICIENT SIZE TO LOCK IN PLACE WITHOUT CREATING AN AIRBLOCK TO SUBSURFACE DRAINAGE.

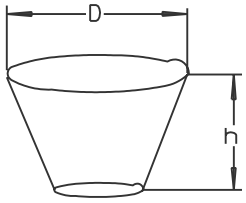
3. ALTERNATE LAYERS OF GRADED SOLID ROCK (CLASSIFICATION 203.02, BORROW EXCAVATION) (3-5 FT. IN DEPTH) AND HIGH SLUMP CONCRETE (OR FLOWABLE FILL).
   HIGH SLUMP CONCRETE SHALL BE CONCRETE WITH A SLUMP OF 7-9"

   HIGH SLUMP CONCRETE OR FLOWABLE FILL SHALL BE APPLIED AFTER A LAYER OF GRADED SOLID ROCK UNTIL THE CONCRETE (OR FLOWABLE FILL) JUST COVERS THE GRADED ROCK LAYER. THE NEXT LAYER OF GRADED SOLID ROCK SHALL BE PLACED IMMEDIATELY AFTER THE PLACEMENT OF THE CONCRETE (OR FLOWABLE FILL). THE PURPOSE OF THIS IS TO INTERMIX THE MATERIALS. THE WORK SHALL NOT BE INTERRUPTED AFTER THE PLACEMENT OF CONCRETE (OR FLOWABLE FILL) EXCEPT FOR THE TOP LAYER. IF WORK CANNOT BE FINISHED IN A SPECIFIED INTERVAL, WORK MAY BE STOPPED ONLY AFTER A COMPLETE LAYER OF GRADED SOLID ROCK HAS BEEN PLACED.

4. AFTER THE FINAL LAYER OF CONCRETE (OR FLOWABLE FILL) HAS BEEN SET, BACKFILL TO GRADE WITH TYPE "A" BASE GRADING (ITEM NO. 303.01) OR OTHER MATERIAL APPROVED BY THE ENGINEER OR GEOLOGIST.

EQUATION FOR ESTIMATING SINKHOLE VOLUME, WHERE THE SIDES OF THE SINKHOLE ARE AT 1:1 SLOPES.

$$\text{VOL. } 1{:}1 \approx 0.13D^3 - (0.5D - h)^3$$



Example Preliminary Report

Preliminary Geotechnical Report

State Route- 317 (Apison Pike), From Old Lee Highway
2.30 miles to East of State Route-321 West of Collegedale
Project No. 33070-1228-14
Pin No. 107637.01
Hamilton County

Summary

This project may be constructed as shown in the transmitted sheets of aerial photographs and drawings using the proposed route. The proposed project consists of widening and improvements along 2.30 miles of State Route-317 (Apison Pike) from the intersection of Old Lee Highway east to a point west of the intersection with State Route-321. The project area is described as "Section 1" on the provided Project Corridor map and Functionals. No pyritic rock was observed in the investigation area. Several stream crossings will be required and the proposed route may encroach on existing streams that are immediately adjacent to the existing roadway. A small sinkhole was noted near the proposed centerline of the project near the western end. Colluvial soils may be present on the slopes of hills from near the beginning to the center of the project. No other specific geologic hazards were observed or noted during the field investigation and literature review. No pyritic rock is expected to be excavated on the project

Example Preliminary Report

Preliminary Geotechnical Report
State Route- 317 (Apison Pike), From Old Lee Highway
2.30 miles to East of State Route-321 West of Collegedale
Project No. 33070-1228-14
Pin No. 107637.01
Hamilton County

Introduction

The proposed project consists of widening and improvements along 2.30 miles of State Route-317 (Apison Pike) from the intersection of Old Lee Highway east to a point west of the intersection with State Route-321. The project area is described as "Section 1" on the provided Project Corridor map and Functionals.

Geology, Soils, and Site Conditions

This project is located in the western portion of the Valley and Ridge Physiographic Province of Southeastern Tennessee and is underlain by cherty clays and clays resting upon easterly dipping Cambrian to Ordivician age dolomites and limestones. The western portion of the project ascends, crosses, and decends a low ridge. The eastern section of the project crosses a small valley that contains the flood plain of Wolftever Creek.

Surface and subsurface Exploration

Visual observation was accomplished for the entire project along with review of the available literature for this area. No Geotechnical difficulties are anticipated other than those listed in the following discussion.

Discussion

Several areas of potential concern were noted along the proposed route. These included a sinkhole, possible colluvial soil mantels above small to medium sized cuts and several stream crossings and encroachment areas.

A sinkhole was noted near the centerline of the proposed improvements approximately 0.15 miles east of the intersection of S.R.-317 and Pattentown Road. The sinkhole, estimated to be 25 feet across and 10 feet deep, did not appear active. No other sinkholes were noted in the project foot print, however several large sinkholes were noted near the site on the USGS topographic map. Further investigation, along with possible sinkhole mitigation efforts, of this area will be required.

Possible colluvial soil mantels were noted in two areas that may be expected to be in roadway cuts. The first area is a saddle between two hills that may require a cut to lower the grade. The area begins at the intersection Pattentown Road and proceeds east a distance of approximately 0.2 miles. Cuts in this area may require flatter slopes and benches to prevent slope failures. The second area is located in a left hand curve on the north side of S.R. -317 between approximately 0.3 miles and 0.6 miles east of the intersection with Branston Road. The existing roadway is in a small cut of thin bedded nodular, cherty, weathered, dolomite of the Chepultepec Dolomite. The proposed centerline shown in the photos and maps is at least 100 feet north of the existing centerline and may have cuts of at least 20 feet in height. Cuts in this area may require flatter slopes and benches to prevent slope failures. Further investigation of these areas is recommended for this route prior to beginning this project.

An unnamed tributary to Wolftever Creek crosses, and abuts, S.R.-317 along several portions of the eastern two thirds of the proposed project. Construction, as planned, will encroach on the unnamed tributary and may require realignment of the stream channel or the road.

No other geotechnical difficulties are anticipated or were observed during field reconnaissance or in the literature review. A thorough geotechnical investigation of the alignment, any bridge and approaches, and bridge foundations will be needed to confirm the results of this report.

Any questions concerning this report should be directed to the Geotechnical Engineering Section.

Samuel P. Williams, P.G.
Geologist 2

M. Leonard Oliver, P.E.
Civil Engineer, Manager II

MLO:SPW:CJW
September 21, 2007

Example Preliminary Report

Preliminary Geotechnical Report,

Intersection of State Route 34 with State Route 37
Bluff City,
Project No. 82100-1203-14
Sullivan County

Executive Summary

A preliminary geotechnical study of the Intersection of State Route 34 with State 37 in Sullivan County was conducted. The proposed improvements consist of five options. There does not appear to be any significant geotechnical problems along the proposed interchange boundaries that cannot be addressed in the design or construction phase. No pyritic rock is expected to be excavated on the project.

Example Preliminary Report

Preliminary Geotechnical Report,

Intersection of State Route 34 with State Route 37
Bluff City,
Project No. 82100-1203-14
Sullivan County

Introduction

The Tennessee Department of Transportation (TDOT) is planning to improve the intersection of State Route 34 (US-11E) and State Route (US-19E) in Sullivan County in the vicinity of Bluff City in East Tennessee. The intersection is to be improved for the anticipated increase of traffic volume in the future and to improve the safety of the intersection.

Five improvement options have been proposed for the intersection of State Route 34 and State Route 37. They are a diamond interchange, a trumpet interchange, a signalization, a roundabout, and a single point urban interchange. The intersection is in a rural area with rolling hills and surrounded by farm land, except for a couple of nearby businesses. This report concerns the preliminary evaluation of the geotechnical engineering aspects for the improvement.

Geology

The project site is in a rural area located in the Valley and Ridge Province. The underlying geology consists of the Knox Group, which consists of thick bedded siliceous dolomite and interbedded limestone. The Knox Group is one of the most important aquifers in East Tennessee.

Conclusions

Based on the observation in the field, there does not appear to be any significant geotechnical problems along the proposed interchange boundaries that cannot be addressed in the design or construction phase. If any further information is needed regarding the proposed project, please contact the Geotechnical office.

Lori McDowell
Operations Specialist 1

Harry Moore
Transportation Manager 1

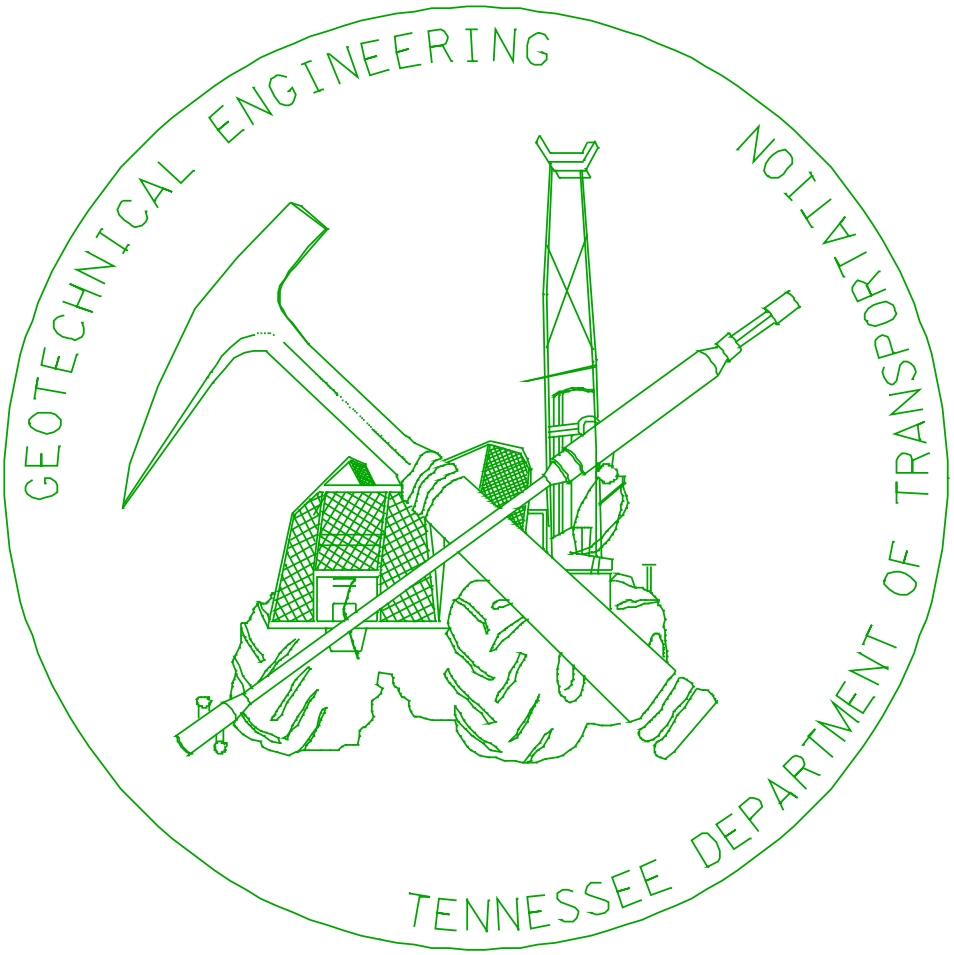
M. Leonard Oliver,
Civil Engineering Manager 2

Attachment
March 12, 2007

Figure 1 Photo shows the intersection of SR 34 and SR 37and the direction of view is to the north.

Section 1: Appendix B

Supporting Documentation



6601 Centennial Boulevard
Nashville, TN 37243-0360
(615) 350.4132

Static Pile Capacity Charts

Static Pile Capacity

for 5 ft or 1.524 m length 14" square concrete Piles

Clay					Silt					Sand				
	English Units		Metric Units			English Units		Metric Units			English Units		Metric Units	
N	Fst (T)	Qbt (T)	Fst (kN)	Qbt (kN)	N	Fst (T)	Qbt (T)	Fst (kN)	Qbt (kN)	N	Fst (T)	Qbt (T)	Fst (kN)	Qbt (kN)
1	1	0	13	0	1	1	0	9	0	1	0	0	2	0
2	3	0	24	0	2	2	0	17	0	2	1	0	7	0
3	4	0	33	0	3	3	0	24	0	3	1	0	11	0
4	5	0	41	0	4	4	0	35	0	4	2	0	15	0
5	6	3	52	24	5	5	7	46	61	5	2	15	20	133
6	7	4	63	36	6	6	10	54	85	6	3	18	24	157
7	8	4	74	36	7	7	11	63	97	7	3	20	26	182
8	9	5	82	48	8	8	12	69	109	8	3	23	28	206
9	11	5	93	48	9	8	14	74	121	9	4	26	33	230
10	12	7	104	61	10	9	15	82	133	10	4	30	37	267
11	13	7	113	61	11	10	16	91	145	11	5	33	41	291
12	14	8	121	73	12	11	18	100	157	12	5	35	46	315
13	14	8	128	73	13	12	19	106	170	13	6	38	50	339
14	15	10	137	85	14	13	20	113	182	14	6	41	54	363
15	16	10	145	85	15	14	22	121	194	15	7	44	59	388
16	17	10	154	85	16	14	23	128	206	16	7	48	63	424
17	18	11	163	97	17	15	26	137	230	17	7	50	67	448
18	19	11	171	97	18	16	27	145	242	18	8	53	72	472
19	20	12	178	109	19	17	29	154	254	19	8	56	74	497
20	21	12	186	109	20	18	30	160	267	20	9	58	78	521
21	22	14	193	121	21	19	31	167	279	21	9	61	82	545
22	22	14	199	121	22	20	33	173	291	22	10	65	87	581
23	23	15	208	133	23	20	34	180	303	23	10	68	91	605
24	24	15	217	133	24	21	35	186	315	24	11	71	95	630
25	25	16	223	145	25	22	37	193	327	25	11	73	100	654
26	26	16	228	145	26	22	38	197	339	26	12	76	104	678
27	26	18	234	157	27	23	39	202	351	27	12	79	108	703
28	27	18	241	157	28	23	42	208	376	28	13	83	113	739
29	28	19	249	170	29	24	44	215	388	29	13	86	117	763
30	29	19	258	170	30	25	45	221	400	30	14	88	121	787

English Units	Metric Units
End Area of a 14" square Pile = 1.36 ft²	End Area of a .356 m square Pile = .1265 m²
Surface Area of a one foot length of Pile = 4.67 ft	Surface Area of a 1 m length of Pile = 1.422 m²
A bearing of 100 Tons is required when piles end in sand (70' min. depth for liquef	A bearing of 890kN is required when piles end in sand (21.5 m min. depth for liquef
A bearing of 125 tons is required when piles end in clay	A bearing of 1100 kN is required when piles end in clay
Friction (Fst) = 4.67*Depth*Fs (T)	Friciton (Fst) = 1.422*Depth*Fs (kN)
End Bearing (Qbt) = 1.36*Qb (T)	End Bearing (Qbt)= .1265*Qb (kN)

Note: All values of Fst and Qbt are figured according to the above formulas at **5 ft** or **1.524 m** in depth

Static Pile Capacity

Unit Length Concrete Piles

Clay					Silt					Sand				
	English Units		Metric Units			English Units		Metric Units			English Units		Metric Units	
N	Fs (TSF)	Qb (TSF)	Fs (kPa)	Qb(kPa)	N	Fs (TSF)	Qb (TSF)	Fs (kPa)	Qb(kPa)	N	Fs (TSF)	Qb (TSF)	Fs (kPa)	Qb(kPa)
1	0.06	0	6	0	1	0.04	0	4	0	1	0.01	0	1	0
2	0.11	0	11	0	2	0.08	0	8	0	2	0.03	0	3	0
3	0.16	0	15	0	3	0.12	0	11	0	3	0.05	0	5	0
4	0.20	0	19	0	4	0.17	0	16	0	4	0.07	0	7	0
5	0.25	2	24	192	5	0.22	5	21	479	5	0.09	11	9	1053
6	0.30	3	29	287	6	0.26	7	25	670	6	0.11	13	11	1245
7	0.35	3	34	287	7	0.30	8	29	766	7	0.13	15	12	1436
8	0.40	4	38	383	8	0.33	9	32	862	8	0.14	17	13	1628
9	0.45	4	43	383	9	0.36	10	34	958	9	0.16	19	15	1819
10	0.50	5	48	479	10	0.40	11	38	1053	10	0.18	22	17	2107
11	0.54	5	52	479	11	0.44	12	42	1149	11	0.20	24	19	2298
12	0.58	6	56	575	12	0.48	13	46	1245	12	0.22	26	21	2490
13	0.62	6	59	575	13	0.51	14	49	1341	13	0.24	28	23	2681
14	0.66	7	63	670	14	0.54	15	52	1436	14	0.26	30	25	2873
15	0.70	7	67	670	15	0.58	16	56	1532	15	0.28	32	27	3064
16	0.74	7	71	670	16	0.62	17	59	1628	16	0.30	35	29	3352
17	0.78	8	75	766	17	0.66	19	63	1819	17	0.32	37	31	3543
18	0.82	8	79	766	18	0.70	20	67	1915	18	0.34	39	33	3735
19	0.86	9	82	862	19	0.74	21	71	2011	19	0.36	41	34	3926
20	0.90	9	86	862	20	0.77	22	74	2107	20	0.38	43	36	4118
21	0.93	10	89	958	21	0.80	23	77	2202	21	0.40	45	38	4309
22	0.96	10	92	958	22	0.84	24	80	2298	22	0.42	48	40	4596
23	1.00	11	96	1053	23	0.87	25	83	2394	23	0.44	50	42	4786
24	1.04	11	100	1053	24	0.90	26	86	2490	24	0.46	52	44	4980
25	1.08	12	103	1149	25	0.93	27	89	2586	25	0.48	54	46	5171
26	1.10	12	105	1149	26	0.95	28	91	2681	26	0.50	56	48	5363
27	1.13	13	108	1245	27	0.97	29	93	2777	27	0.52	58	50	5554
28	1.16	13	111	1245	28	1.00	31	96	2969	28	0.54	61	52	5841
29	1.20	14	115	1341	29	1.03	32	99	3064	29	0.56	63	54	6033
30	1.24	14	119	1341	30	1.06	33	102	3160	30	0.58	65	56	6224

English Units

End Area of a 14" square Pile = 1.36 ft²
Surface Area of a one foot length of Pile = 4.67 ft
A bearing of 100 Tons is required when piles end in sand (70' min. depth for liquef
A bearing of 125 tons is required when piles end in clay
Friction = 4.67*Depth*Fs (T)
End Bearing = 1.36*Qb (T)

Metric Units

End Area of a .356 m square Pile = .1265 m²
Surface Area of a 1 m length of Pile= 1.422 m²
A bearing of 890kN is required when piles end in sand (21.5 m min. depth for liquef
A bearing of 1100 kN is required when piles end in clay
Friciton = 1.422*Depth*Fs (kN)
End Bearing = .1265*Qb (kN)

Soil and Subgrade Report

TENNESSEE DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
GEOTECHNICAL ENGINEERING SECTION
NASHVILLE, TENNESSEE

SOIL AND SUBGRADE CONDITION AND EVALUATION REPORT

PROJECT NO. _____ COUNTY: _____ REGION: _____
LOCATION: _____

					T-99: (Proctor)	
Station or Sample No.	Percentage Passing No. 200	Predominant Soil Type	Group Index	CBR	Density (lb/ft^3)	Optimum Moisture (%)

M. Leonard Oliver, Civil Engineering Manager 2
Geotechnical Engineering Section

MLO::LGW

GES File No.

Soil Description Sheet

County: _____ **Proj. No:** _____
Book _____ **File No.** _____

Project: _____

_____

Sample Data

Sample No.	Description	In-Situ Moist	Density	Opt Moist	Moisture range	PL	LL	AASHTO Class	USCS Class

Soil Description Sheet

CBR Data

CBR No.	Description	In-Situ Moist	Density	Opt moist	Moisture range	PL	LL	AASHTO Class	USCS Class	CBR

Spoons/Tubes Data

Sample No.	Station	Depth	Description	In situ Moist	LL	PI	AASHTO Class	USCS Class

Manhour Requirements and Cost Estimate

TN TDOT Department of Transportation

version 1.1

TENNESSEE DEPARTMENT OF TRANSPORTATION

DIVISION OF MATERIALS AND TESTS
GEOTECHNICAL ENGINEERING SECTION

SOIL AND GEOLOGICAL SURVEY REPORT

MANHOUR REQUIREMENTS AND COST ESTIMATE

Instructions:
(Enter state route number, project description,county, consultant's name, prepared by name, and date prepared. This information will be transferred to all other sheets. The date prepared must be entered in the appropriate cell on this sheet to remove these instructions prior to printing.)

<COUNTY>

<ROUTE NUMBER>

<DESCRIPTION>

<GEOTECHNICAL CONSULTANT>

Prepared By:	<NAME>
Date prepared:	<TODAY'S DATE>
Project No.	<PROJECT NO.>
Geotechnical Office No.	<GEOTECH OFFICE NO.>

<CONTACT NAME>
<CONTACT ADRESS>
<CONTACT ADRESS>
<CONTACT ADRESS>
<BUSSINESS TELEPHONE>
<EMAIL ADRESS>

Section III

Standard Cost Estimate For Soil And Geological Survey Report

1.00 Drilling Services

County: <COUNTY>
Route: <ROUTE NUMBER>
Description: <DESCRIPTION>
Project No.: <PROJECT NO.>
Geotechnical Office No.: <GEOTECH OFFICE NO.>
Consultant: <GEOTECHNICAL CONSULTANT>
Prepared By: <NAME>
Date Prepared: <TODAY'S DATE>

For further explanation of Item No. and Description refer to attached "Pay Item Numbers and Methods of Measurement for Cost Estimates".

Item No.	Description	Estimated Quantities	Basis of Payment		Price	Amount
1.01	Mobilization		each	@		$0.00
1.03	Drill Rig Moving \ Standby Time		hour	@		$0.00
1.04	Soil Auger Drilling		vertical foot	@		$0.00
1.05	Wash Boring		vertical foot	@		$0.00
1.06	Soil Drilling and Split Barrel Type Sampling on Land		vertical foot	@		$0.00
1.07	Soil Drilling and Thin Wall Tube Type Sampling on Land		vertical foot	@		$0.00
1.08	Rock Coring		vertical foot	@		$0.00
1.10	Water Hauling		working day	@		$0.00
1.11	Bulldozer		operating hour	@		$0.00
1.12	Traffic Control		direct cost	@		$0.00

Total Estimated Drilling Costs	**$0.00**

Section III

Standard Cost Estimate for Soil and Geological Survey Report

2.00 Laboratory Services

County: <COUNTY>
Route: <ROUTE NUMBER>
Description: <DESCRIPTION>
Project No.: <PROJECT NO.>
Geotechnical Office No.: <GEOTECH OFFICE NO.>
Consultant: <GEOTECHNICAL CONSULTANT>
Prepared By: <NAME>
Date Prepared: <TODAY'S DATE>

For further explanation of Item No. and Description refer to attached "Pay Item Numbers and Methods of Measurement for Cost Estimates".

Item No.	Description	Estimated Quantities	Basis of Payment		Rate	Amount
2.01	Atterberg Limits		each	@		$0.00
2.02	Natural Moisture Content		each	@		$0.00
2.03	Particle Size Analysis		each	@		$0.00
2.04	AASHTO Classification		each	@		$0.00
2.05	Proctor Density Test		each	@		$0.00
2.06	California Bearing Ratio		each	@		$0.00
2.07	pH		each	@		$0.00
2.31	Acid-Base		each	@		$0.00
2.40	Sulfate Soundness		each	@		$0.00
2.09	Consolodation Properties		consolodation properties	@		$0.00
2.1	Triaxial Compression UU		strength properties	@		$0.00
2.11	Triaxial Compression CU		strength properties	@		$0.00
2.1	Unconfined Compression		per test	@		$0.00
2.63	CD Direct Shear		strength properties	@		$0.00
Total Estimated Laboratory Services Cost:						**$0.00**

Section III

Standard Cost Estimate for Soil and Geological Survey Report

3.00 Manpower Requirements

County: <COUNTY>
Route: <ROUTE NUMBER>
Description: <DESCRIPTION>
Project No.: <PROJECT NO.>
Geotechnical Office No. <GEOTECH OFFICE NO.>
Consultant: <GEOTECHNICAL CONSULTANT>
Prepared By: <NAME>
Date Prepared <TODAY'S DATE>

See "Pay Item Numbers and Methods of Measurement for Cost Estimates" for further description of services required by state.

Item No.	ACTIVITY	PRINCIPAL	SENIOR ENGINEER	STAFF ENGINEER	GEOLOGIST	TRAINING ENGINEER	SUPERVISING DRILLER	STAFF CADD TECHNICIAN
		MAN-HOUR	MAN-HOUR	MAN-HOUR	MAN-HOUR	MAN-HOUR	MAN-HOUR	MAN-HOUR
3.10	Project Planning and Coordination							
3.20	Field Activities							
3.30	Data Assimilation							
3.40	Engineering Analyses							
3.50	Report Preparation							
3.60	Drawing Preparation							
3.70	Post-Report Confrence and Review							
Total Estimated Hours								
Hourly Rate		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Subtotal of Estimated Man-hour Costs		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

Total Estimate of Man-hour Requirements:	**$0.00**

Section III

Standard Cost Estimate for Soil and Geological Survey Report

3.00 Manpower Requirements, Hourly Rate Breakdown

County: <COUNTY>
Route: <ROUTE NUMBER>
Description: <DESCRIPTION>
Project No.: <PROJECT NO.>
Geotechnical Office No. <GEOTECH OFFICE NO.>
Consultant: <GEOTECHNICAL CONSULTANT>
Prepared By: <NAME>
Date Prepared <TODAY'S DATE>

Hourly Rate Breakdown	PRINCIPAL	SENIOR ENGINEER	STAFF ENGINEER	GEOLOGIST	TRAINING ENGINEER	SUPERVISING DRILLER	STAFF CADD TECHNICIAN
	MAN-HOUR	MAN-HOUR	MAN-HOUR	MAN-HOUR	MAN-HOUR	MAN-HOUR	MAN-HOUR
Direct Pay Rate	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Maximum Overhead Rate (no more than 1.45)	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Profit Multiplier	2.35	2.35	2.35	2.35	2.35	2.35	2.35
Profit Rate * (supplied in decimals)	0.12	0.12	0.12	0.12	0.12	0.12	0.12
* use the same rate as with the desigr contract for the project.							
Hourly Rate	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

Section III
Standard Cost Estimate for Soil and Geological Survey Report
4.0 Other Expenses

County: <COUNTY>
Route: <ROUTE NUMBER>
Description: <DESCRIPTION>

Project No.: <PROJECT NO.>
Geotechnical Office No.: <GEOTECH OFFICE NO.>
Consultant: <GEOTECHNICAL CONSULTANT>
Prepared By: <NAME>
Date Prepared: <TODAY'S DATE>

Distance to Jobsite:

Company Headquarters: <CITY,STATE>	Job Site: <CITY,STATE>

Travel Expenses				
Item No.	Description	Days	Rate*	Total
4.10	Travel Day Per Diem			$0.00
4.11	Non Travel Day Per Diem			$0.00
4.12	Lodging			$0.00

*Must be in accordance with applicable TDOT Travel Regulations

Milage\Transportation Expenses				
Item No.	Description	Miles	Milage Rate*	Total
4.20	Passenger Truck			$0.00
4.21	Tractor Trailer Truck			$0.00
4.22	Water Truck			$0.00
4.23	Truck Mounted Drill			$0.00
4.24	Other Mileage			$0.00

*Must be in accordance with applicable TDOT Travel Regulations

Equipment Rental				
Item No.	Description	Days	Daily Rate	Total
4.30	Equipment Rental			$0.00

Plans Reproduction Costs				
Item No.	Description	Units	Unit Price	Total
4.40	Full Size Bond			$0.00
4.41	Half-Size Bond			$0.00
4.42	Full Size Mylar			$0.00
4.43	Photocopies			$0.00

Other Expenses				
Item No.	Description	Units	Unit Rate	Total
4.50	Other Expenses			$0.00

Total Estimate of Other Expenses:	**$0.00**

Section III

Standard Cost Estimate for Soil and Geological Survey Report

SUMMARY OF COST ESTIMATES

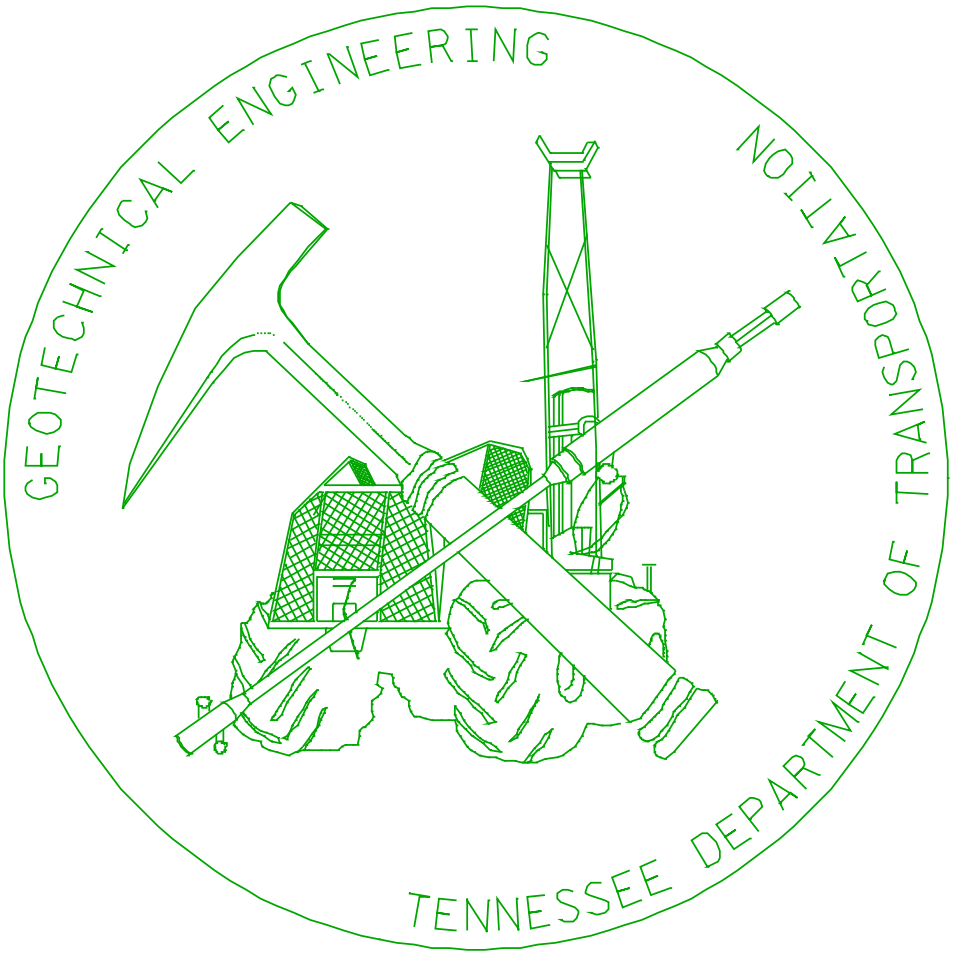
County: <COUNTY>
Route: <ROUTE NUMBER>
Description: <DESCRIPTION>
Project No.: <PROJECT NO.>
Geotechnical Office No.: <GEOTECH OFFICE NO.>
Consultant: <GEOTECHNICAL CONSULTANT>
Prepared By: <NAME>
Date Prepared: <TODAY'S DATE>

1.00 Drilling Services	$0.00
2.00 Laboratory Services	$0.00
3.00 Manpower Requirements	$0.00
4.00 Other Expenses	$0.00

Total Not-to-Exceed Costs	$0.00

Section 2:

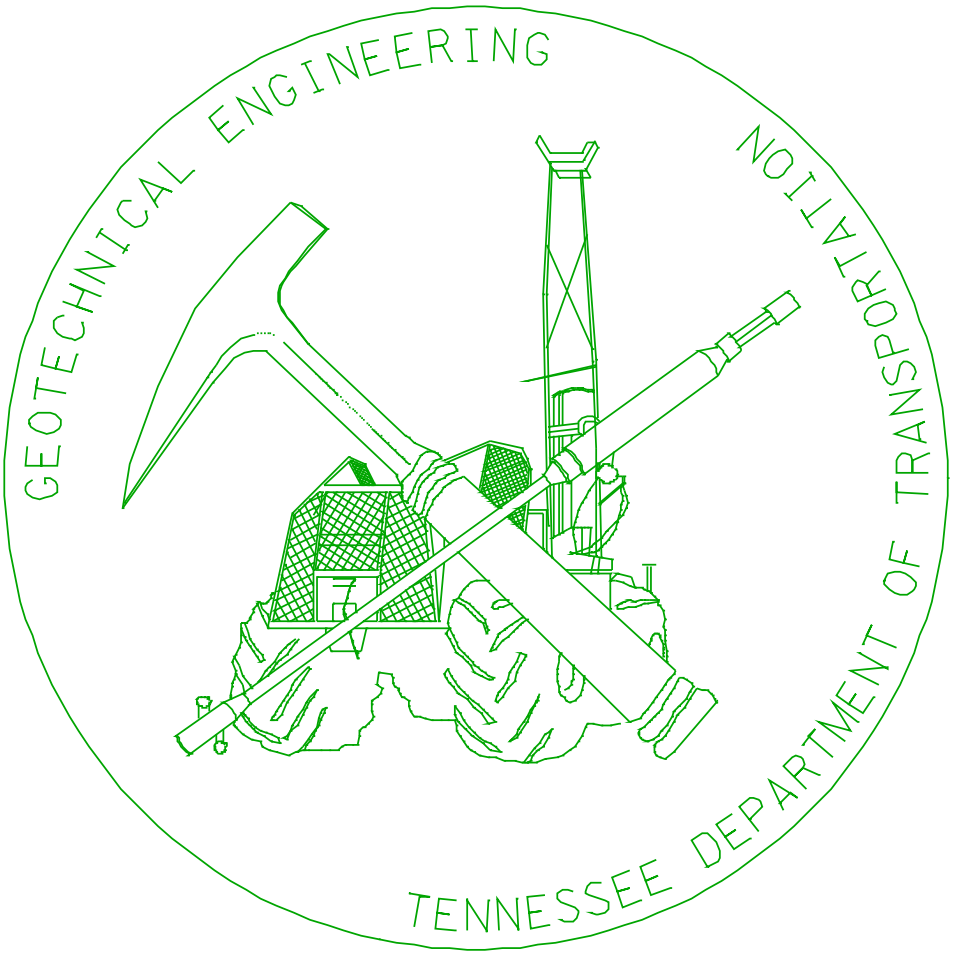
Geotechnical Drillers Manual



6601 Centennial Boulevard
Nashville, TN 37243-0360
(615) 350.4132

Section 3:

Geotechnical Reference Manual



6601 Centennial Boulevard
Nashville, TN 37243-0360
(615) 350.4132

TDOT Geotechnical Manual

Section 3: Geotechnical Reference Manual

Tennessee Department of Transportation
Geotechnical Engineering Section
6601 Centennial Boulevard
Nashville, TN 37243-0360
615-350-4132

Report Date:
March 15, 2007

Report Number	GEO-01.03	**Version**	1.0
Author	Vanessa Bateman, PG, PE	**Phone**	615-350-4130

Abstract

Key Words

Site investigation, soil testing, laboratory testing, geotechnical engineering, foundation design, soils classification, rock testing

Pages

Introduction

Chapter 1: Site Investigations

The goals and objectives of a geotechnical site investigation can vary greatly depending upon the type of investigation needed. Section 1: Consultant Geotechnical Manual covers the most common types of geotechnical investigations required by staff of the GES. However, the purpose of that section of the manual is to give an overall picture of TDOT needs, not to explain how to conduct a site investigation. Many of the tools and techniques detailed here will be applicable to some or all of the types of site investigation that may need to be performed.

There are generally 3 phases to any site investigation:

- **Desk Study and Preliminary Survey** - This portion of the investigation involves gathering of data already available about the site. This data may be fairly general, but can often lead to vital clues that focus the investigation.
- **Detailed Investigation at the site for geotechnical design** - This involves drilling, sampling and any other investigation technique needed in order to provide an excellent geotechnical design and recommendations.
- **Construction Review** - Review of construction documents to ensure that recommendations have been implemented correctly and thoroughly can be vitally important. A geotechnical investigation is wasted, if the recommendations are not implemented or are not implemented correctly.

Desk Study and Preliminary Survey

The purpose of a desk study is to make your site investigation more effective. This is done by gathering as much information as is reasonably possible about the likely ground conditions (such as topography, soil and tock types and water issues), to identify previous uses of the site, such as current alterations, old mines, etc. and if possible to get a first look at access to the site.

Geological information, topographical maps, aerial photographs and old documents may provide insights into the ground conditions and highlight potential problems such as sinkholes and landslides. This general information is used along with a preliminary survey, which includes a walk overview of the site. Particular attention should be paid to any geological hazards that may be present on the site that can affect the geotechnical design. The desk study puts the site in context, it allows a broad overview of the area before jumping right in to the detailed portion of the investigation. It also keeps the geologist or engineer from repeating work that may already have been completed at the site. Old reports and boring logs can be an excellent source of information to supplement and investigation. The detail of the desk study may vary with the type of project, and may not take very long. But the context of the site and the available information for the site should always be considered before beginning detailed field work.

Typically available resources:

1:24 000 Quadrangle Topographic Maps - we have statewide coverage available in paper map form stored in the Geotechnical Section file area in the map drawers.

1:24 000 Quadrangle Geology Maps - these have good coverage in Central Tennessee, but may be spotty in portions of East Tennessee and West Tennessee. Some areas may be covered by geological reports and publications issued by the USGS or by the TDEC Division of Geology.

1:250 000 Geology Map of the state - this is a very general geological map, but it does at least show the "big picture" of the geology across the state. A copy of this 4 panel map is framed on the wall in the Nashville Geotechnical Office.

Geological Publications - these can be found in the Materials and Tests library or are directly available from TDEC Division of Geology or the USGS.

County Soil Maps - these are produced through the NRCS and in recent years these have become available on-line. Old paper copies can be found in the library, but newer maps can be accessed through an internet web mapping application.
http://websoilsurvey.nrcs.usda.gov/app/

Aerial photography - the more detailed the better - these are often in black and white. But can be quite useful for a site to check for geologically related and water issues as well as changes to the site over time.

Terrashare - this is software supported by TDOT that delivers digitized maps. These can be the 1:24 000 quadrangle topographic maps as well as various scales of aerial photography. They include DOQQ's (digital orthographic quarter quadrangles) produced by the USGS and some aerial photography directly produced by TDOT.

Old Structural drawings and recording of foundation type for bridges - these records are often absent or unavailable, but can be very useful for problem bridges. These can be requested from the Structures Division.

Old geotechnical reports, boring logs and testing - a site may have been looked at several times over the years. This is particularly true of challenging sites and problems such as landslides and sinkholes. It's always good to do a quick check and find our what information and plans were drawn up in the past. It may be very relevant to your investigation.

Rockfall sites and landslide sites web map application - this site shows all currently geographically located high hazard rockfall sites and some landslide sites. While this may have limited application for a bridge project - it may particularly relevant to a call from Maintenance or when working on a line or interchange. A detailed database is also available on our Geotechnical shared drive.
http://jj00wa206/Mapserv/RockMS/RockMS.html

DEM: Digital elevation maps and contours along roadway alignments - These are layers that are being included in the Microstation drawings produced by Survey and Design and are often available by request. They are seldom included in plans by default.

Plans and Cross Sections provided by Design - these ay be generated by TDOT design or by a consultant design firm.

GIS at TDOT - maintains some information accessible by a GIS program including roadway alignments, some water related issues such as wetlands and other data. More data layers are being produced and added and the body of information available as an electronic map is expected to continue to grow.

Old APR/TPR reports - These may have more relevance for line projects, but they can provide valuable information about the purpose of the project and how long it has been in the planning stages as well as occasional notes of particular environmental challenges. When working on a site and dealing with property owners, it's good to know if this project has been around the department for a very long time. Photographs of the site as well as other pertinent data may be available from these reports.

What to look for when performing a desk study

There are many different geological clues which may turn out to be the key to performing a thorough site investigation. Knowing what to look for, even before going out to the site can be vital. If you do not know what you should be looking for, you may well miss what you need to see.

Identify geological province and units expected at the site - particularly any units which may be outcropping.

Sinkhole Formers and Problem Rocks - Particular attention should be paid to any units that are known sinkhole formers or often contain significant quantities of pyrite. Special attention and investigation may need to be made if we are making significant cuts into pyritic (or other sulphate minerals: marcasite, pyrotthite, etc) bearing rocks.

Landslide formations - Known landslide prone formations such as the Pennington Shale should be identified.

Nature and type of surficial deposits - where possible. Soil maps can provide vital information such as depth to bedrock and soils which have trouble draining. Many soil maps in Tennessee contain some basic engineering parameter data such as USCS classification, AASHTO classification, permeability and suitability for various engineering uses.

General thickness of soil and rock units - this can assist the geo in understanding the constraints at a site and assist in planning drilling.

Significant rock structure - Is there any locally significant rock structure? Dipping beds, faults, existing wedge or plane shear failures or other known structural issues.

Topographic clues to karst terrain or wet areas - Are there any topographic clues that indicate the presence of a sinkhole or problem water areas? i.e. damp areas on aerial photography, a large cluster of trees in the middle of a field, closed circular depressions on a topographic map.

Topographic clues to ancient landslides - Are there ay topographic clues that indicate a current or ancient landslide? Ancient landslides may be characterized by hummocky ground and by "wiggly" topographic lines,

Numerous reports - Has this site been visited repeatedly over there years with numerous reports? This is often due to repeated problems at the site, or lack of money for repair.

Rockfall Sites - Are there any A or B rockfall sites along the project - what kinds of geological problems are present at these sites. If there are wedge failures along existing rock cuts there may be potential wedge failures along new rock cuts.

Old mine and quarry locations - phosphate mines, gravel pits, old coal mines, limestone adits, or other previous works which could pose geotechnical problems.

Flood prone areas - the soil may be softer here and less consolidated - it may affect stability of embankments.

Locations of springs and seeps - these are not just an environmental issue. The proximate cause of many geotechnical problems and issues is water. A spring, buried by a roadway fill and inadequately drained can cause a landslide.

Drainage patterns in the area - Is it dendritic or deranged? Are there numerous springs and areas where streams seem to disappear? Swallets indicate karst issues at a site and should always be noted where possible.

What to look for in a preliminary or walkover survey

Landslide clues - scarps present on site - old or new - cracks in pavement at the roadway level, hummocky ground, tilting or "drunk" trees, old toe bulges

Sinkhole and karst clues - closed circular depressions, clusters of trees in a field (though this could be due to other factors), disappearing streams (swallet).

Rockfall clues - repeated strikes on the pavement, numerous rocks in the road

Problem and unstable soils - settlement at bridge approaches in fills, very erodible soils, saturated soils with water loving vegetation. All of these may require special mitigation techniques and investigation

Wetlands - we may indeed build on them, but they provide some special challenges for stability.

Springs and seeps - The proximate cause of many geotechnical problems and issues is water. A spring, buried by a roadway fill and inadequately drained can cause a landslide.

Existing roadway settlement or pavement issues - while the GES does not design pavement, looking at the existing roadway, particularly for bridge and approach projects and lines may provide some vital clues to potential problems at the site.

Figure 1-1. Field Observations: Army COE Manual EM1110-1804, Jan 2001

Table 3-2
Special Geologic Features and Conditions Considered in Office Studies and Field Observations

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Landslides	Stability of natural and excavated slopes	Determine presence or age in project area or at construction sites Compute shear strength at failure. Do failure strengths decrease with age of slopes-- especially for clays and clay shales?	Estimate areal extent (length and width) and height of slope Estimate ground slope before and after slide (may correspond to residual angle of friction) Check highway and railway cuts and deep excavations, quarries, and steep slopes	Are landslides found offsite in geologic formations of same type that will be affected by project construction? What are probable previous and present ground water levels? Do trees slope in an unnatural direction?
Faults and faulting; past seismic activity	Of decisive importance in seismic evaluations; age of most recent fault movement may determine seismic design earthquake magnitude, may be indicative of high state of stress which could result in foundation heave or overstress in underground works	Determine existence of known faults and fault history from available information Examine existing boring logs for evidence of faulting from offset of strata	Verify presence at site, if possible, from surface evidence; check potential fault traces located from aerial imagery Make field check of structures, cellars, chimneys, roads, fences, pipelines, known faults, caves, inclination of trees, offset in fence lines	Are lineaments or possible fault traces apparent from regional aerial imagery?
Stress relief cracking and valley rebounding	Valley walls may have cracking parallel to valley. Valley floors may have horizontal cracking. In some clay shales, stress relief from valley erosion or glacial action may not be complete	Review pertinent geologic literature and reports for the valley area. Check existing piezometer data for abnormally low levels in valley sides and foundation; compare with normal ground water levels outside valley	Examine wells and piezometers in valleys to determine if levels are lower than normal ground water regime (indicates valley rebound not complete)	
Sinkholes; karst topography	Major effect on location of structures and feasibility of potential site (item 13)	Examine air photos for evidence of undrained depressions	Locate depressions in the field and measure size, depth, and slopes. Differences in elevation between center and edges may be almost negligible or many feet. From local residents, attempt to date appearance of sinkhole	Are potentially soluble rock formations present such as limestone, dolomite, or gypsum? Are undrained depressions present that cannot be explained by glaciation? Is surface topography rough and irregular without apparent cause?

(Sheet 1 of 4)

Table 3-2 (Continued)

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Anhydrites or gypsum layers	Anhydrites in foundations beneath major structures may hydrate and cause expansion, upward thrust and buckling Gypsum may cause settlement, subsidence, collapse or piping. Solution during life of structure may be damaging	Determine possible existence from available geologic information and delineate possible outcrop locations	Look for surface evidence of uplift; seek local information on existing structures Check area carefully for caves or other evidence of solution features	Are uplifts caused by possible hydrite expansion or "explosion"?
Caves	Extent may affect project feasibility or cost. Can provide evidence regarding faulting that may relate to seismic design. Can result from unrecorded mining activity in the area		Observe cave walls carefully for evidence of faults and of geologically recent faulting. Estimate age of any broken stalactites or stalagmites from column rings	Are any stalactites or stalagmites broken from apparent ground displacement or shaking?
Erosion resistance	Need for total or partial channel slope protection is determined	Locate contacts of potentially erosive strata along drainage channels	Note stability of channels and degree of erosion and stability of banks	Are channels stable or have they shifted frequently? Are banks stable or easily eroded? Is there extensive bank sliding?
Internal erosion	Stability of foundations and dam abutments affected. Gravelly sands or sands with deficiency of intermediate particle sizes may be unstable and develop piping when subject to seepage flow	Locate possible outcrop areas of sorted alluvial materials or terrace deposits	Examine seepage outcrop areas of slopes and riverbanks for piping	
Area subsidence	Area subsidence endangers long- term stability and performance of project	Locate areas of high ground water withdrawal, oil fields and subsurface solution mining of underground mining areas	Check project area for new wells or new mining activity	Are there any plans for new or increased recovery of subsurface water or mineral resources?
Collapsing soils	Need for removal of shallow foundation materials that would collapse upon wetting determined	Determine how deposits were formed during geologic time and any collapse problems in area	Examine surface deposits for voids along eroded channels, especially in steep valleys eroded in fine-grained sedimentary formations	Were materials deposited by mud flows?

(Sheet 2 of 4)

Figure 1-1. Field Observations: Army COE Manual EM1110-1804, Jan 2001 Continued

Table 3-2 (Continued)

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Locally lowered ground water	May cause minor to large local and area settlements and result in flooding near rivers or open water and differential settlement of structures	Determine if heavy pumping from wells has occurred in project area; contact city and state agencies and USGS	Obtain ground water levels in wells from owners and information on withdrawal rates and any planned increases. Observe condition of structures. Contact local water plant operators	
Abnormally low pore water pressures (lower than anticipated from ground water levels)	May indicate effective stresses are still increasing and may cause future slope instability in valley sites	Compare normal ground water levels with piezometric levels if data are available		Is the past reduction in vertical stresses a possible cause of low pore water pressure. Examples are deep glacial valleys and deep excavations like that for the Panama Canal, where pore pressures in clay shale were reduced by stress relief.
In situ shear strength from natural slopes	Provides early indication of stability of excavated slopes or abutment and natural slopes around reservoir area	Locate potential slide areas. Existing slope failures should be analyzed to determine minimum in situ shear strengths	Estimate slope angles and heights, especially at river bends where undercutting erosion occurs. Determine if flat slopes are associated with mature slide or slump topography or with erosion features	Are existing slopes consistently flat, indicating residual strengths have been developed?
Swelling soils and shales	Highly preconsolidated clays and clay shales may swell greatly in excavations or upon increase in moisture content	Determine potential problem and location of possible preconsolidated strata from available information	Examine roadways founded on geologic formations similar to those at site. Check condition of buildings and effects of rainfall and watering	Do seasonal ground water and rainfall or watering of shrubs or trees cause heave or settlement?
Varved clays	Pervious layers may cause more rapid settlement than anticipated. May appear to be unstable because of uncontrolled seepage through pervious layers between overconsolidated clay layers or may have weak clay layers. May be unstable in excavations unless well points are used to control ground water	Determine areas of possible varved clay deposits associated with prehistoric lakes. Determine settlement behavior of structures in the area	Check natural slopes and cuts for varved clays; check settlement behavior of structures	

(Sheet 3 of 4)

Table 3-2 (Concluded)

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Dispersive clays	A major factor in selecting soils for embankment dams and levees	Check with Soil Conservation Service and other agencies regarding behavior of existing small dams	Look for peculiar erosional features such as vertical or horizontal cavities in slopes or unusual erosion in cut slopes. Perform "crumb" test	
Riverbank and other liquefaction areas	Major effect on riverbank stability and on foundation stability in seismic areas	Locate potential areas of loose fine-grained alluvial or terrace sand; most likely along riverbanks where loose sands are present and erosion is occurring	Check riverbanks for scallop-shaped failure with narrow neck (may be visible during low water). If present, determine shape, depth, average slope, and slope of adjacent sections. Liquefaction in wooded areas may leave trees inclined at erratic angles. Look for evidence of sand boils in seismic areas	
Filled areas	Relatively recent filled areas would cause large settlements. Such fill areas may be overgrown and not detected from surface or even subsurface evidence	Check old topo maps if available for depressions or gullies not shown on more recent topo maps	Obtain local history of site from area residents	
Local overconsolidation from previous site usage	Local areas of a site may have been overconsolidated from past heavy loadings of lumber or material storage piles			Obtain local history from residents of area

(Sheet 4 of 4)

Detailed investigation of a site

The specifics of an investigation will vary based on the type of investigation that has been requested. Please see Section 1: Geotechnical Consultant Manual for typical investigation types along with information on TDOT needs and goals of these investigations.

It should be noted that the GES performs site investigation for a number of different areas within TDOT or their designated representative:

Structures Division - Bridge and Retaining Walls

Design Division - Lines, interchanges, SIA's (state industrial access roads), bridge and approaches (the roadway portion of a bridge project) and Retaining Walls

Maintenance Division - sinkholes, landslides, settlement and other issues related to the ground and water when they judge that they need outside help.

Construction - problems during construction of foundations, retaining walls, slopes, line recommendations - issues such as sinkholes, landslides and rockfall which may occur during construction - aid in understanding geotechnical designs and intentions.

Project Management - Occasionally Geos may be requested to attend public meetings in order to be available for geological and geotechnical related questions.

Responsibilities of the Geo during exploration

Determine amount, location and depth of drilling - and investigation required to provide a solid geotechnical recommendations for a project.

To determine needed laboratory analysis for samples - to communicate these to the appropriate technicians and drillers.

To finish these projects in a timely and comprehensive manner

To write clear reports and drawings that illustrate geotechical design elements

To answer questions, provide clarification and additional assistance - to Design, Structures, Maintenance, Construction to others within TDOT regarding these assigned projects.

Rules of thumb and geotechnical investigations

There are many "rules" and "rules of thumb" present in geotechnical engineering manuals, papers and textbooks. However, always remember, through the use of the desk study and subsequent investigation, the point to to construct a model of your site in your head. This model cannot be rigid and must be able to adapt to changing circumstances.

To know that you are in a karst prone area, with a formation that contains numerous cavities illuminates the problem when you have boreholes on bridge that are wildly inconsistent. It sheds light on why you may have a change in the rock when there is a fault in the area. But the next borehole may also provide the insight. Do not be wedded to "this type of project requires this kind of drilling." This manual will lay out some general information as to what kind of drilling is expected. But in reality, what is sufficient may vary somewhat between geo to geo and from site to site.

A bridge located on horizontally bedded sandstone will present different challenges than that within the influence zone of the Wells Creek Structure. If you return to the office and find that you are having trouble deciding on the geotechnical design elements, you may have performed an insufficient investigation. We have available a number of tools and techniques for investigation, any one of which may be successfully applied to the site. It is important to concentrate on what you can learn from each site - not solely on what the "rules" of investigation are for each type of project. Knowledge, past experience and theory are all very useful, but the writers of textbooks and manuals are not present at your site to see the special challenges that your site may present. It is vital to understand that our goal is to construct a model of the subsurface in our minds that lets us predict the problems and design solutions in order to successfully build projects. Our job is to anticipate geotechnical problems before they are encountered and to present an appropriate and comprehensive solutions to Structures, Design, Maintenance or Construction.

The importance of clear communication of results

One of the most critical elements of any geotechnical investigation is the reporting of results. The end users of our reports and recommendations must be able to find the information that they need in a clear and readable format. This can pose some significant challenges to the geo as we must provide reports, drawings and recommendations to very different groups. Structures, Design, Maintenance and Construction all use our information differently. Remember that if we are not able to communicate our results and recommendations to our "customers" they will not benefit from our work and our investigations are worthless. A geotechnical investigation does not stand as an end in and of itself. We provide these services ultimately so that the department may build bridges and roadways more efficiently and effectively and to help safeguard the public. When we fail to anticipate a landslide that occurs during construction, it is the taxpayers that have to foot the bill. A geotechnical investigation can save an immense amount of money during construction and when dealing with maintenance issues. Our job is to anticipate geotechnical problems and communicate our findings and recommendations in order to prevent these issues. In the end, a "perfect" geotechnical investigation can only really been seen in retrospect, after construction of the road, bridge or maintenance repair. If cost over-runs on a project are not caused by geotechnical issues, we have succeeded. If we can reduce the costs of bridge foundations, retaining walls and road construction then we have succeeded. If a project is built without encountering any unexpected ground and geotechnical conditions then we have succeeded.

Special Note on holes located on bridge sketches and retaining walls

These holes are marked by Structures and do not indicate where you **must** drill; these are points of reference only and are to be used to assist in the location of your borings. Just because there is only one hole marked on a substructure does not mean that you must drill at that stake or that you must drill only one hole - it does not mean that is what Structures wants. It is up to the geo to determine what kind of drilling, how much and how deep. The geo assigned to the project is ultimately responsible to see that a sufficient exploration is performed at the site.

Typical Drilling Techniques used by TDOT Crews

There are many exploration techniques that are available in order to complete a site investigation. However, The GES does not have the capability to perform every drilling and sampling technique that has been developed for geotechnical applications. We do maintain our own drill crews and can perform the standard suite of geotechnical drilling and laboratory testing.

Continuous flight augers - This type of drilling is generally performed in order to gather soil samples for line , bridge and approach and interchange projects. It allows for fast drilling in soils, and for large bulk samples to be taken for laboratory testing such as Proctors and CBR's. This technique is not suitable where there are large numbers of boulders as the augers may not be able to penetrate or may "walk" off of plumb to the point where the hole can no longer be continued.

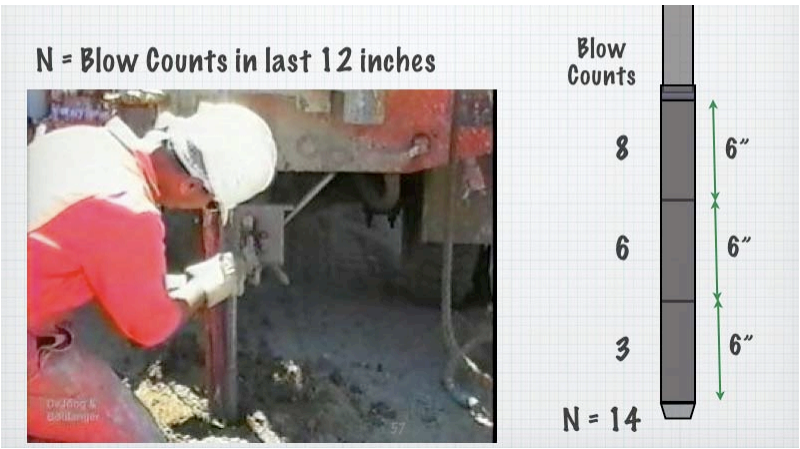
Figure 1-2. Views of Continuous Flight Augers

Hollow stem augers with or without SPT (split spoon sampling) - Hollow stem augers differ from continuous flight augers in that they have a hollow center and allow the gathering of other sample types through their core. These test may be SPT (split spoon sampling) or Shelby Tubes. Bulk samples can also be gathered from hollow stem augers, but their primary use is for the gathering of more undisturbed samples. Typically this method is used on West Tennessee bridge projects (for SPT sampling) as well as for any project where slope stability or consolidation of soils may be an issue (for shelby tube sampling).

Figure 1-3. Hollow Stem Augers

SPT (Split Spoon Testing) Sampling - This type of sampling uses an 18" long split "spoon" of a specific size that is hammered into the ground at a specific force (using a 140 lb hammer over a 30 inch drop). The number of blows required to force the spoon to penetrate for 6 inch intervals is recorded. A specific parameter, known as the N value is the sum of the blows for the last 12 inches of the spoon. The first 6 inches are considered seating blows and are not used for later calculations. These samples, and the blow counts are typically used in order to determine some in-situ strength parameters of soils. They are used primarily for West Tennessee Bridge projects and for any project where more detailed sampling of soil is needed than can be supplied by continuous flight augers.

Figure 1-4. Views of SPT Sampling a) open spoon with sample, b) spoon tip, c) how to calculate blow counts



Shelby tube sampling - Considered an "undisturbed sample" a shelby tube is a 2 foot long thin walled tube that is used to gather soil samples for laboratory testing. These tests may tell us something about the strength of the soil (Triaxial, Direct Shear or Unconfined Compression Tests) or about how much settlement to expect on a site (1D Consolidation Test). These samples are gathered in the field through the continuous flight auger, but are only suitable for relatively cohesive soils. Sands, unless they contain a very significant quantity of clay will not stay in the tube and provide poor samples back at the lab. Gravel content or boulders may make shelby tube sampling impractical or impossible. Successful samples are usually gathered in silts and clays with a low gravel content. They may be used for retaining wall foundations placed or soil or for slope stability analysis for a line or landslide.

Figure 1-5. Shelby Tube Sampling

Wireline drilling (NQ core) - Wireline drilling is used at TDOT in order to obtain rock core samples for logging and testing. This type of drilling is typically performed for bridge and retaining wall foundations as well as for rock cuts along an alignment. TDOT uses the NQ core size and water is the lubricating fluid.

Figure 1-6. Wireline core drillings and samples

Washboring - Like continuous flight augers, this drilling method is used primarily in soil. Unlike augers, however, washboring can be more successful in bouldery deposits. TDOT uses washboring principally when we are interested only in the location of the top of rock or when getting a hole prepared for later coring in rock. It returns no samples, though the return water can be examined for small particles which may indicate the type and nature of the deposit. It is a very rapid method of exploration.

Figure 1-7. Washboring tips

Documentation of Field Exploration

Proper documentation of field exploration is a vital part of any site investigation and is necessary if the site investigation is to be successful. A poorly documented site can lead to numerous problems, particularly if a site receives intermittent attention over a span of years. Boreholes must be located and properly logged in order to complete analyses. Samples must be properly tagged in order to ensure that the correct laboratory testing is performed and no engineering analysis can be trusted if we are not clear where the samples were taken. There are many different possible forms and methods for documenting a site exploration, however, the methods employed by TDOT will be described in this manual.

Boreholes and logs

At this time, TDOT does not use a specialty boring log application. Boreholes are recorded out in the field during exploration in the field books of the Driller Crew Chief and the Geo present at the site. Borehole information is reviewed by the Geo after exploration is complete and typed boring logs (using templates in MS Word) are used for the final versions to be included in the file and report.

Two separate boring log forms are used in the office depending upon the type of drilling completed at the site. For auguring and bulk sampling along an alignment or for an interchange we use the “Boring Log” template should be used N:\Geotech\WIX\Forms\BorLog.doc.

For core holes, SPT sampling, shelby tubes and for projects where there is very limited drilling the “Boring Record” template should be used N:\Geotech\WIX\Forms\BoringR1.doc.

Figure 1-8. Boring Log Form used for Lines and Interchanges

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING

BORING LOG

Project Reference Number 7404306 Region 3
Project Number 74010-1228-14 County Robertson Co.
Location Right-Of-Way SR-11 near Walling Rd. to Memorial Blvd.
Date Started 01-31-07 Date Completed 02-20-07
Geologist/Soils Engineer Mike Perkins Drill Crew Chief Jeremy Milliken

Station	Hole No.	Location Reference C/L	Depth	Sample No.	Description
Depth in Feet					
143+50	1	100′ LT	0		CLAY – moist reddish brown with sand
			5	1	CLAY – moist, dark brown
			15	2	CLAY – moist to wet, reddish brown
			30		Boring Terminated
143+50	2	C/L	0		CLAY – moist reddish brown with sand
			4		CLAY – c.f. Sample 1
			13		CLAY – c.f. Sample 2
			30		Boring Terminated
143+50	3	100′ RT	0		CLAY – moist reddish brown with sand
			5	1	CLAY – c.f. Sample 1
			18	2	CLAY – c.f. Sample 2
			30		Boring Terminated
144+50	4	100′ LT	0		CLAY – moist reddish brown with sand
			2	CBR 1	CLAY – moist, dark brown
			15		CLAY – c.f. Sample 2
			27		Boring Terminated
143+50	5	C/L	0		CLAY – moist reddish brown with sand
			3		CLAY – c.f. Sample 1
			15		CLAY – c.f. Sample 2
			27		Boring Terminated
143+50	6	100′ RT	0		CLAY – moist reddish brown with sand
			5		CLAY – c.f. Sample 1
			15		CLAY – c.f. Sample 2
			27		Boring Terminated
144+00	7	C/L	0	CBR 2	CLAY – moist reddish brown
			5		Boring Terminated

c.f. indicates an apparent silimarily of material based on visual identification

Figure 1-9. Boring Record form used for Core, SPT and Shelby Tubes

DT-0197
Form SG-103
REV. 10-88

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING
BORING RECORD

Project Number 80000-1234-04 Project Reference Number GES File No. 8010306 Region 4
Description South Lake Road over Big Creek
Geologist/Soils Engineer Bateman Drill Crew Chief Anderson County Smith
Station Number 142+50 Location Reference C/L 15' LT
Bent Number Pier Number 2 Abutment Number
Hole Number 5 Top Hole Elevation 320.7 Rock Elevation 311.7 Bottom Elevation 292.2

Stratum Depth	Sample Depth From	Sample Depth To	Sample/Run No.	Sample Type	Core Recovered	Standard Penetration/RQD	Description
Depth in Feet							
0				A			CLAY – moist, reddish brown
9.0	9.0	13.5	1	NQ	4.3	97%	LIMESTONE – slightly weathered, light grey with occasional vugs and cherty [Ft. Payne Formation]
	13.5	18.5	2	NQ	4.0	87%	
17.5							CAVITY – mud filled (reddish brown clay)
18.2							LIMESTONE – slightly weathered, light grey with occasional vugs and cherty [Ft. Payne Formation]
	18.5	23.5	3	NQ	5.0	95%	
	23.5	28.5	4	NQ	4.8	97%	
28.5							Boring Terminated

Sample Type
T- Thin Wall
S- Split Spoon
B- Bulk
W- Wash

AX – Core
BX – Core
NX – Core
NQ – Core

Water Table 7.0 ft
Water Table +24
Casing Size
Spoon Size
Hammer Weight
Fall

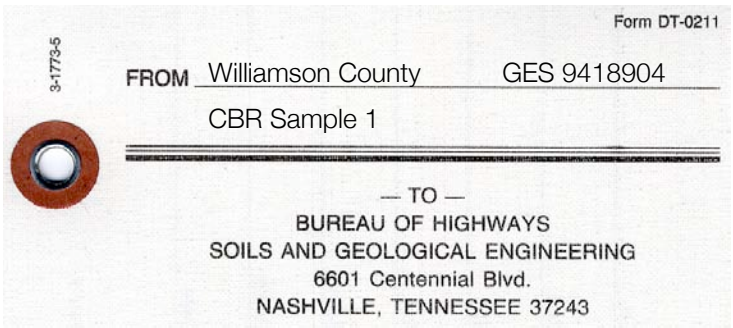
Date 2/25/07
Page 1 of 1 Pages

Rock Core logging requirements

Waiting for George?

Proper tagging and handling of samples

Samples taken out in the field need to be have sample tags filed out and attached to ensure that the soil sample does not get separated from the tag. It is particularly important that special care be taken with Proctor sample and CBR sample tags as these are used as the primary means of identifying a sample through all stages of the laboratory testing. Please mark CBR clearly on any sample tag for a CBR sample or the CBR test may not get completed in the lab.



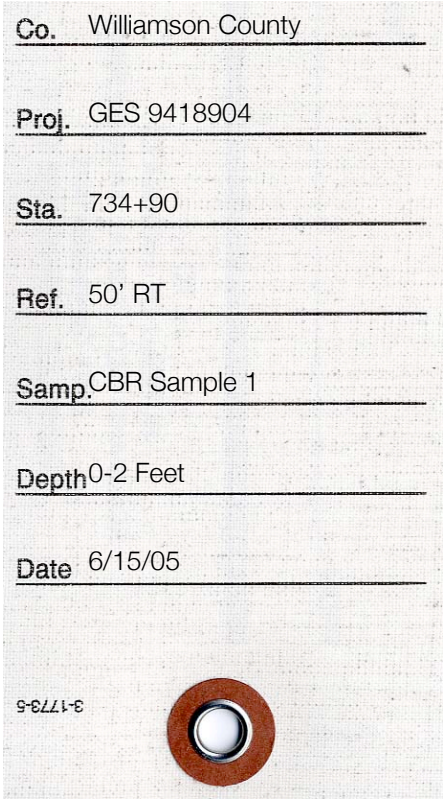


Figure 1-10. Sample Tags filled out for a CBR Sample

These tags may also be used with Shelby Tube samples, however, if this is done the sample tag must be placed inside a sealed ziploc type bag before being taped to the shelby tube. Tubes are stored in a moisture room and the sample tag will degrade unless it is sealed away from the moisture.

Small bag samples are used for split spoon samples or where samples are taken simply for classification purposed. These small bags also need to be properly labeled. Please make sure that you include the project data, location data and the SPT test results on the bag.

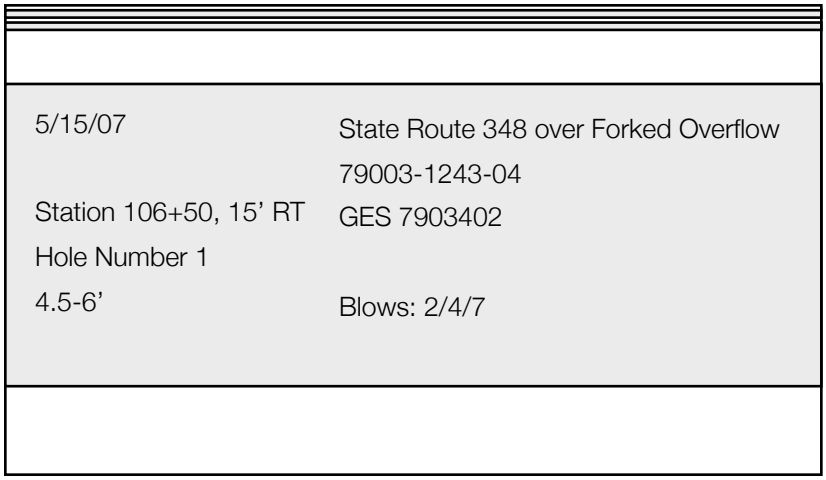


Figure 1-11. Sample bag for SPT tests and small samples

Laboratory Testing Assignment Sheets

The T-2 form is used to assign laboratory tests for samples brought back to the lab. The form lists all of the standard testing performed in the soil lab. Please make sure to place proctor samples and CBR samples on separate forms as this makes it easier for the soil laboratory to process samples. Likewise please separate spoon samples from shelby tube samples and put them on their own sheets. The T-2 form can be found on the Geotechnical shared drive N:\Geotech\Standard Forms\T-2 Sheet Unprotected.xls.

Rock core samples must be submitted to the Concrete Lab on a standard form used for concrete cylinders.

Figure 1-12. Soil Lab Assignment Sheet

TDOT
Division of Materials and Tests
Geotechnical Engineering
Soils Laboratory Assignments

Project # 94015-1228-94 Sampled by Bateman Date Sampled 6/15/05
County Williamson Submitted by Bateman Date Turned In 6/15/05
File # 9418904 Region 3 Job Description Bridge and Approaches over Beech Creek and Little Harpeth River

SAMPLE IDENTIFICATION					SOIL CLASSIFICATION PROPERTIES						SOIL STRENGTH TESTS			COMP			CONS		
Sample Number	Sample Type *	Station Number	Centerline Reference	Sample Depth	Moisture Content	Natural Density	Specific Gravity	Atterburg Limits	Dry Sieve	Hydrometer	Unconfined Compression with Stress / Strain	Direct Shear	Triaxial **	T-99 (standard)	T-180 (modified)	CBR	Standard Loads ***	Additional Loads (tsf)	Comments
1	B	734+90	50' RT	0-2 feet	x			x	x	x						x			
2	B	763+00	30' RT	0-2 feet	x			x	x	x						x			

* Sample Type

J - Jar (split spoon)
T - Thin Wall Tube
B - Bulk Bag Sample

** Triaxial Tests

Q - Unconsolidated - Undrained
R/R - Consolidated - Undrained with Pore Pressure
S - Consolidated - Drained

Laboratory Use Only

Date Began _____
Date Completed _____
Serial Number _____

*** Loads - .25. .5. 1. 2. 4. TSF

Construction Review

Geotechnical projects are ultimately not complete until after the geotechnical design has been implemented and project construction is complete. It does not end with the issuance of a geotechnical report - though a project may require no further geotechnical input for some time after a report is issued.

A very important part of the work of the geotechnical engineering section is to review construction plans and make sure that geotechnical recommendations have been implemented properly. The Construction Field Review is generally the last point where changes can be made to a project before it goes to a letting. After a project is let, any changes are "changed conditions" and may make the project more expensive.

TDOT is a big organization and it takes a large number of people working on a project in order to bring it to completion. Like all large organizations, there is the chance for information and recommendations to get miscommunicated, lost or ignored. It is critical during the construction field review process to identify any potential geotechnical issues and to make sure that appropriate recommendations have been implemented and that all drawings and note pages have been included in the plans. If this has not been done, this needs to be brought to the immediate attention to the design manager. Also, it is important to review other aspects of the plans, not just to check to see if geotechnical sheets have been included. While the GES is not responsible for erosion control plans, hydraulic designs, ROW etc. there exists some potential for conflict in these areas. The location of a detention pond on top of a sinkhole, the relocation of a stream by cutting our the toe of an old landslide, etc. all of these can cause significant problems during construction and the geo needs to be on guard for these types of conflicts. Sometimes slopes are steepened to deal with a right of way problem in soils that will fail on these steeper slopes. The GES may or not be notified of these changes; others in the department may not know that they have made changes to the plans that conflict with good geotechnical design. The construction field review notification and meeting is the time to check and make sure that this has not happened.

While the production of complete plans is the ultimate responsibility of the design manager - if there is a geotechnical issue the GES will be called out to deal with the problem and will be answerable for that problem. We will have to find out how the problem happened and how to solve it.

In addition to review of plans before letting the GES may be called out to a site to interpret or adapt geotechnical recommendations. We may also be called out to deal with unanticipated conditions. This, too is a part of of a geotechnical investigation. We try, whenever possible, to keep the geo who performed the investigation during the design phase involved in the construction phase. This is done for several reasons: 1) the geo who did the investigation is likely the person who knows the most about a particular project, 2) it is easier for the person who made the original recommendations to interpret these recommendations and 3) it is easier to improve our work if we can see the results of the recommendations, drawings and reports that we issue. If a geo never sees the results of his or her work, it is far more difficult to improve.

Chapter 2: Principles of Soil and Rock Mechanics

Effective and Total Stress

Basic Measurements of Strength

Active and Passive Earth Pressures

Chapter 3: Laboratory Testing

Introduction

There are a number of tests that can provide data and insight for a site investigation. Knowing which tests need to be run for what kinds of projects and how to use that data is the responsibility of the Geo assigned to complete the project. It is important to know when these tests can provide reliable information, and when to discard the results due to problems such as non-representative (or insufficiently representative) samples, scale effects, testing error and modeling error.

We use these tests in empirical formulae and analyses that work to help us model our site. But do not confuse a test result with reality. We test in order to provide us guidance and insight, not to discover the absolute "right" answer. There are too many unknowns. Our sampling programs are often far too small to provide a sufficient amount of data for a valid statistical sample, much less provide certainty at a site. We cannot achieve absolute certainty with our investigations or our laboratory tests.

> "It is important to keep in mind that natural soil deposits are variable in composition and state of consolidation; therefore it is necessary to use considerable judgement based on common sense and practical experience in assessing test results and knowing where reliance can be placed on the data and when they should be discarded. **It is dangerous to put blind faith in laboratory tests, especially when they are few in number.** The test data should be studied in conjunction with borehole records and the site observations, and any estimations of bearing pressures or other engineering design data obtained from them should be checked as far as possible with known conditions and past experience."
>
> **--M.J. Tomlinson** from *Foundation Design and Construction*, 5th ed. Longman Scientific and Technical, Essex, England, 842 pages, 1986.

Testing provides us valuable information about the soils and rock on our site and the kind of behavior we can expect from these materials. We use them routinely in our analyses and investigations, but always remember the limitations present and do not take any test result as gospel requiring no further thought or judgement.

Classification Tests

Atterberg Limits (ASTM 4318, AASHTO T 89, T 90, T 91)

The atterberg limit test is primarily a means to measure the plasticity of soil and indicates whether a soil fraction can be considered a silt or clay based on the plasticity of the material. It indicates the behavior of the soil at different water contents once it has been remolded. The atterberg limits tests defines the moisture contents for a particular soil where these behavior changes occur. However, please remember that it tests only the fraction of soil that passes the Number 40 sieve. It is commonly used along with mechanical sieving results with the Unified Soil Classification System for classifying the soil.

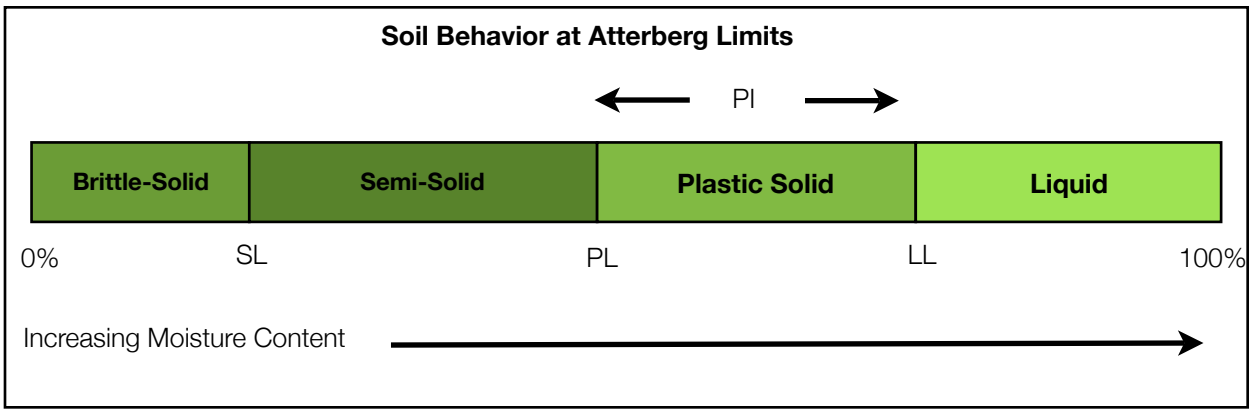


Figure 3-1. Atterberg Limit Definitions

In situ Water Content percent (w) - determined by the natural moisture test. Percentage of water content in soil. Defined as weight of water (W_w) divided by weight of dry sample (W_s).
$w = W_w/W_s*100$

Plastic Limit (PL) - the moisture content at which the soil stops behaving like a solid and starts behaving like a plastic material. In the test this is the moisture content at which the soil begins to crumble when rolled out into a thread with a diameter of approximately 3 mm in segments that are approximately 3 mm to 10 mm in length.

Liquid Limit (LL) - the moisture content at which the soil stops behaving like a plastic material and starts behaving like a liquid. In the test this is the moisture content of the soil where a groove cut into the soil placed in the liquid limit device starts to close with approximately 25 blows. In British Practice, the liquid limit of a soil can be used to predict the class of plasticity expected from the soil.

Plasticity Index (PI) = LL - PL The plasticity index can be used to indicate soil behavior and properties, for example, higher PI soils tend to be predominantly clay where lower PI soils may be a silt. A soil with no PI would be a gravel or a sand.

Liquidity Index (LI) = (w-PL) / (PI) The liquidity index can be used as an indicator of the stress history of a soil. Normally consolidated soils (NC) should have a LI ≈ 1. Overly consolidated soils should have a LI ≈ 0.

Shrinkage Limit (SL) - This limit is that water content which defines the limit of volume change of the soil with decreasing moisture. That is the point where removal of water will not produce a volume change in the soil. According to Terzaghi and Peck (1967) the soil becomes slightly lighter in color in this state. The TDOT soil lab does not routinely perform this test because the results can be somewhat unreliable.

Estimated Man Hours Per Sample: 1 hr

Plasticity of Soil	Liquid Limit (BSCS)	Liquid Limit (USCS)
Low	<35%	>50%
Intermediate	35 - 50%	
High	50 - 70%	≥50%
Very High	70 - 90%	
Extremely High	>90%	

Figure 3-2. Plasticity Ranges for Soils by Liquid Limit by British Practice (BSCS) and American Practice (USCS)

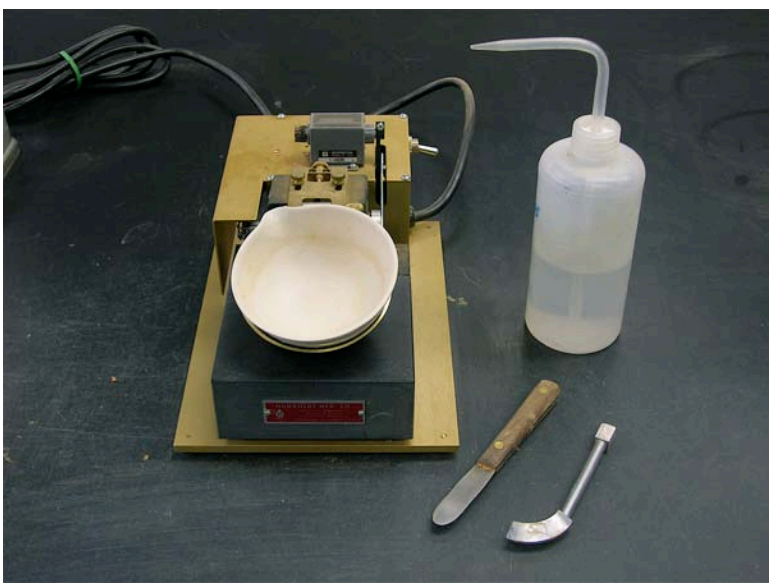


Figure 3-3. Photos of Atterberg Limit Equipment and testing

Sieve Testing - Mechanical Gradation (ASTM D 422, D 1140, AASHTO T 88)

Sieve analysis is performed on soils in order to better define the grain size distribution of the sample and to aid in classification of soil. A grain size curve can be generated from the results of the analysis and these results can be used to indicate certain soil properties. It indicates whether a soil is a gravel, sand, clay or silt by texture. Soil is placed through a series of screens and the percent by weight retained on each sieve is recorded. The standard suite of sieves used in the TDOT laboratory can be seen in figure 3-4.

Material by Texture (USCS)		Sieve Name	Sieve Size (mm)
Gravel	coarse	2”	50
		1 1/2”	37.5
		1”	25
	fine	3/4”	19
		3/8”	9.5
Sand	coarse	No. 4	4.75
	medium	No. 10	2.00
	fine	No. 40	0.425
		No. 100	0.150
Clay and Silt		No. 200	0.075

Figure 3-4. Sieve Sizes in Standard Use at TDOT Soil Lab

Soil particles smaller than No. 200 can be sieved, however the smallest standard sieve size is No. 240. For particles smaller than the No. 200, a hydrometer is used to differentiate between the clay and the silt particles by size. Grains can be plotted on a grain size distribution chart.

Estimated Man Hours Per Sample: 3/4 hr.

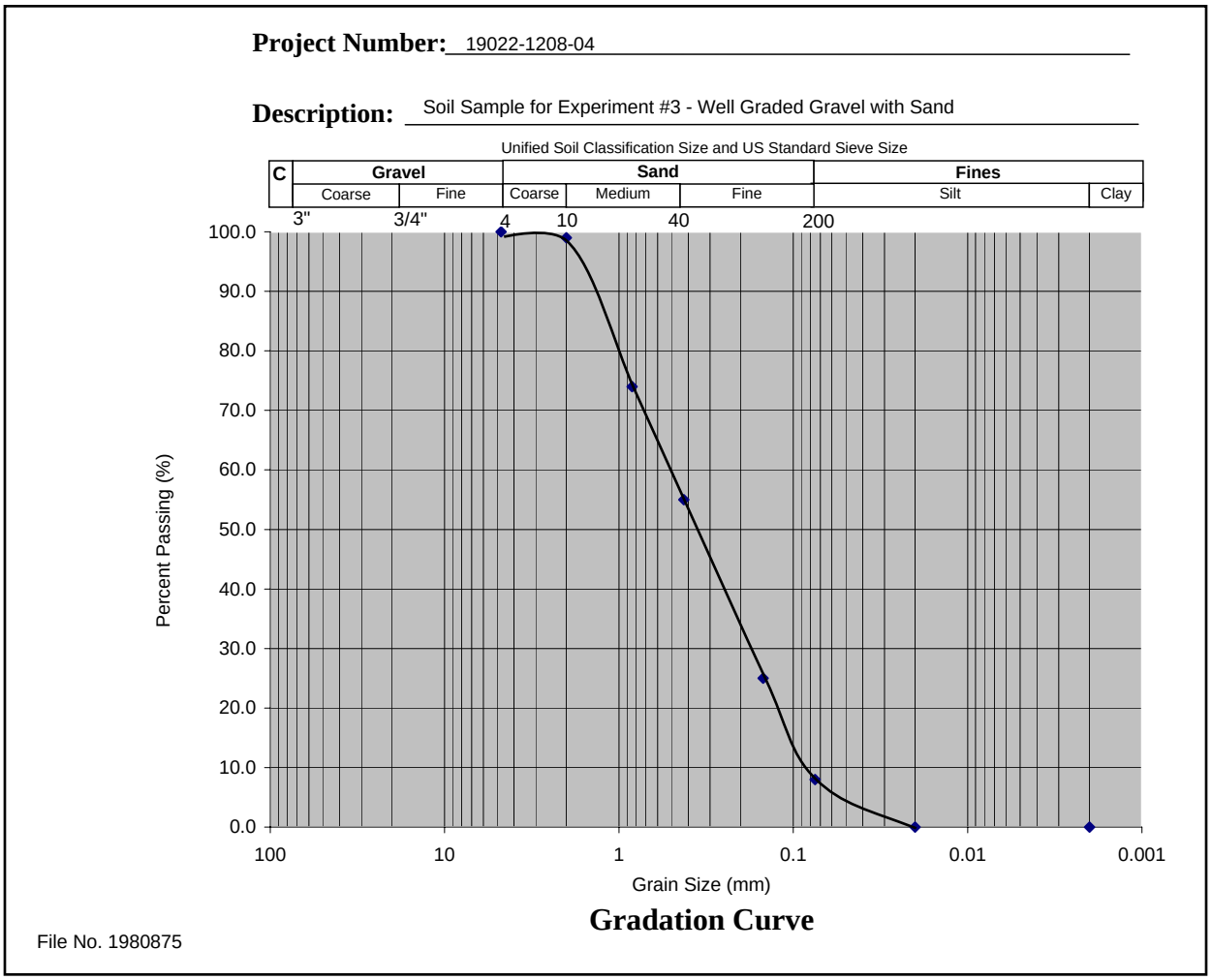


Figure 3-5. Grain Size Distribution Chart

Hydrometer (ASTM D1140, AASHTO T 88)

The hydrometer is used to differentiate between clay size and silt sized particles in soil. It is based on the theory that soil particles of a different size will settle out at different rates (Stokes Law). It assumes that all of the particles are spherical. Soil and a dispersing agent (sodium hexophosphate) are placed in a graduated cylinder and allowed to soak for at least 12 hours. After this time frame the soil solution and de-ionized water are placed in a graduated cylinder with a hydrometer. After 24 hours the hydrometer is read and the results are used to determine the clay fraction (percent assumed to be less than 0.002 mm).

Silt and Clay - Percentage of soil sample that is finer than the number 200 sieve.

Clay - Percentage of soil sample that is considered to be smaller than 0.002 mm

Estimated Man Hours Per Sample: 0.5 hr. - however, the test may take 2 days to complete.

Original to:
Headquarters Materials and Tests
Copies to:
Regional Materials and Tests
Project Supervisor

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

SAMPLE

REPORT ON SAMPLE OF SOIL

Project Reference No. *SP* County *Montgomery* Region *3*
Project No. *12345-6789-10*
Location *(Project Site)* Soils Engineer *Jim Williams*
Report No. *123* Date Sampled *12-Jan-03*
Serial No. *456* Date Reported *12-Feb-03*

GRADATION - TOTAL PERCENT PASSING						
Sample No.	*1-G*	*2-G*	*3-G*			
Station	*229+75*	*232+00*	*231+90*			
Depth, ft.	*2*	*3*	*2*			
Location, ft.	*12' R*	*12' L*	*12' L*			
2"						
1-1/2"						
1"						
3/4"		*100*	*100*			
3/8"		*95*	*92*			
No. 4	*100*	*87*	*89*			
No. 10	*85*	*84*	*76*			
No. 40	*29*	*25*	*15*			
No. 100	*6*	*10*	*9*			
No. 200	*3.0*	*2.0*	*1.5*			
Silt and Clay						
Clay						
SOIL CONSTANTS						
Liquid Limit	*30*	*25*	*23*			
Plastic Limit	*19*	*20*	*18*			
Plasticity Index	*11*	*5*	*5*			
Cal. P.I.						
Type	*Granular Material*	*Granular Material*	*Granular Material*			
Group	*A-2-6(0)*	*A-2-4(0)*	*A-2-4(0)*			
DENSITY						
Density	*100.0*	*102.5*	*101.5*			
Moisture	*19.0*	*22.5*	*19.0*			

Form DT-0218 English (Rev. 10-02)

Figure 3-6. Soil Laboratory Report

Natural Moisture Content (ASTM D 4959, AASHTO T 265)

A natural moisture content test is completed in order to determine the moisture content (expressed in percent) of a soil that is sampled out in the field. This test is run routinely on spoon samples, but also on proctor and CBR samples. Moisture content of on-site soils can give clues to soil behavior. For instance, if a soil that is to be compacted has a moisture content significantly higher that the optimum moisture given by the proctor test, it can indicate that the soil will be difficult or impossible to compact to specification unless it is dried out. It is defined as the mass of water contained in a sample divided by the mass of solids contained in a sample. A sample is placed in a container, weighed, then placed in a drying oven until the moisture in the soil is driven off. The mass of material that remains in the container is the mass of solids.

Percent Moisture (m) = Mass water/Mass solids * 100 = Mw/Ms * 100 The percent moisture is defined by this ratio partially because it is an easy calculation to make given that we can measure the mass of water and mass of solids easily in the laboratory.

Estimated Man Hours per Sample: 10 min

Specific Gravity of Soil (ASTM D 854, AASHTO T 100)

The specific gravity of soil is used in several different calculations to determine soil properties. It can be required in order to take test results and obtain values needed for void ratio, degree of saturation and also with many weight-volume relationships. It is used in the calculations for the triaxial test, hydrometer test, as well as fort the 1-D consolidation test. This value is often assumed to be 2.7 and generally ranges between 2.65 and 2.85 for most soils. Soils with significant organic content or porous grains may have specific gravities less than 2.0. Soils with very heavy particles, such as those with significant metals or heavy minerals may have values for specific gravity above 3.0.

Specific Gravity (G) = Mass of sample / Mass of distilled water of same volume = Ms / Mw

Estimated Man Hours Per Sample: 3/4 hour

Soil Type	Specific Gravity
Quartz Sand	2.64-2.66
Silt	2.67 - 2.73
Clay	2.70 - 2.90
Chalk	2.60 - 2.75
Loess	2.65-2.73
Peat	1.30 -1.90

Figure 3-7. Specific Gravity of selected soil Types from Braja M. Das, Principles of Foundation Engineering 4th Edition (1999)

Classification of Soil by AASHTO Method (AASHTO M 145)

The AASHTO soil classification is set up as an evaluator for soil used as subgrade. Group classifications and group numbers all indicate how suitable a soil is for use as pavement subgrade. The general form is a group classification followed by a group number in parenthesis. For example A-5 (6). The group number indicates how suitable a soil is for pavement when compared to other soils in its group classification. The larger the number, the poorer the soil. Sieve analysis and atterberg limits are necessary in order to classify a soil by the AASHTO system. TDOT has a program called **Classify** that will complete the classification of the soil when given sieve and atterberg limit test results. That program can be found here: N:\Geotech\Programs\Classify\

AASHTO Soil Classification (M 145)

General Classification	Granular Materials 35% or less passing No. 200 sieve							Silt-Clay Materials >35% passing No. 200 sieve			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, % Passing No. 10 (2.0 mm) No. 40 (0.45 mm) N0. 200 (0.075 mm)	50 max 30 max 15 max	... 50 max 25 max	... 51 max 10 max	... ... 35 max	... ... 35 max	... ... 35 max	... ... 35 max	... ... 36 min	... ... 36 min	... ... 36 min	... ... 36 min
Characteristics of Fraction passing No. 40 sieve Liquid Limit Plasticity Index	... 6 max		... N.P.	40 max 10 max	41 min 10 max	40 max 11 min	41 min 11 min	40 max 10 max	41 min 10 max	40 max 11 min	41 min 11 min[a]
Usual types of significant constituent materials	stone fragments, gravel and sand		fine sand	silty of clayey gravel and sand				silty soils		clayey soils	
General rating as subgrade	excellent to good							fair to poor			

[a.] PI of A-7-5 subgroup is ≤ LL-30. PI of A-7-6 subgroup is > LL-30.

Figure 3-8. Classification of soil by AASHTO Method

Group Classification - This is the AASHTO class (A-1-a, A-2, A-7-6, etc) that is assigned to the soil. Using sieve analysis and the atterberg limit test results the classifier starts from the left hand side of the chart and stops when all criteria are met. Unlike the USCS method, the dividing line between granular and fine grained materials is 35% passing the No. 200 sieve instead of 50% passing. This group classification indicates usual types of materials, but does not name a soil sand, silt or clay. The further right you go on the chart, the poorer the material is for use as a roadway subgrade.

Group Index Number (GI) - This is a calculated number that indicates how good a soil is for use as a subgrade within its own class. The higher the number, the poorer the soil is for this use. All group index numbers are rounded to a whole number. If the number given by the equation is negative, then the group index is reported as zero. So results are reported in the form of A-7-6 (15). Group Index numbers of zero indicate the best soil of the type, group indexes greater than 5 indicate that the soil is poor for the type, and GI's greater than 10 indicate that the soil is very poor.

For all soils except A-2-7 and A-2-6:

$$GI = (F_{200} - 35)[0.2+0.005(LL-40)]+0.01(F_{200}-15)(PI-10)$$

Where: F_{200} = % Passing No. 200 Sieve
LL = Liquid Limit of Soil
PI = Plasticity Index

For A-2-7 and A-2-6 Soils

$$GI = 0.01(F_{200}-15)(PI-10)$$

Example Problem
51% Passing No. 200 Sieve
LL = 35
PL = 27

PI = LL - PL = 35 - 27 = 8

First Classification that meets all criteria A-4

$$GI = (F_{200} - 35)\ [0.2 + 0.005\ (LL-40)]+0.1(F_{200} - 15)(PI-10))$$
$$GI = (51 - 35)\ [0.2 + 0.005\ (35-40)]+0.1(51 - 15)(8-10)$$
$$GI = (16)\ [0.2 + 0.005\ (-5)]+0.1(36)(-2)$$
$$GI = 0.175-7.2$$

$GI < 0$, therefore $GI = 0$

AASHTO Soil Classification: A-4 (0)

Figure 3-9. Example AASHTO Classification Problem

Expected Man Hours per Sample: 10 min

Material Type	AASHTO Classification		Typical Characteristics
Granular Materials	A-1		Well-graded mixtures, coarse to fine with non-plastic or slightly plastic soil binder. Suitable, or can be made suitable for use as granular base course
		A-1-a	Stone fragments or gravel, may have well graded soil binder
		A-1-b	Coarse sands with or without a well graded soil binder
	A-2		Wide range of granular soils that do not fit into A-1 or A-3 because of fines content, plasticity or both. Inferior to A-1 because of poor grading, inferior binding or both. Generally used with concrete pavements.
		A-2-4 A-2-5	Granular materials that have a soil binder that would be characteristic of A-4 or A-5 (portion passing No. 40 sieve)
		A-2-6 A-2-7	Granular materials that have a soil binder that would be characteristic of A-6 or A-7 (portion passing No. 40 sieve)
	A-3		Sands that do not have good soil binder and coarse material. Typically sands such as stream deposited mixtures of poorly graded sands
Silt-Clay Materials	A-4		Composed predominantly of silt with only small amounts of coarse material and small amounts of clay. Maybe sandy. Relatively unstable at all moistures and have poor stability and bearing capacity at high moisture.
	A-5		Similar to A-4, includes poorly graded soils that contain mica and diatoms which may give the soil some elastic properties.
	A-6		Composed predominantly of clay with some small amounts of coarse materials. They have lower stability at higher moisture contents and may have shrinkage cracks during dry weather.
	A-7		These are composed predominantly of clay, but are more elastic than A-6 soils. They can be difficult to compact when the moisture content is too high or low.
		A-7-5	A-7 soils that have somewhat moderate PI's in comparison to their LL's, but they may be highly elastic and have considerable volume change
		A-7-6	A-7 soils that have high PI's in comparison to their LL's and may have extremely high volume change.

Figure 3-10. Characteristics of Soil by AASHTO Classification from Asphalt Institute, Soils Manual for Design of Pavement Structures (MS-10), 2nd Edition 1964.

Classification of Soil by USCS Method (ASTM D 2487)

Soil classified by the USCS Method receives both a symbol and a named description of the material. This system was originally developed by Prof. Casagrande in 1940's for the Army Cops of Engineers in order to provide a classification system that could predict the engineering behavior of soil. It divides soil up into fine grained and coarse grained soils and specifies whether a soil is a gravel, sand, silt or clay. Coarse grained soils are divided up according the texture and fine grained soils are divided up according to plasticity. This classification system is commonly used in industry and a modified version of this classification system is in common practice in the United Kingdom. TDOT has a program called **Classify** that will complete the classification of the soil when given sieve and atterberg limit test results. That program can be found here: N:\Geotech\Programs\Classify\

USCS Soil Classification System (USCS)

Major Division			Group Symbol	Typical Names
Coarse Grained Soils > 50% retained on the No. 200 Sieve	**Gravels** > 50% retained on No. 4 Sieve	Clean Gravels	GW	Well graded gravels, gravel/sand mixtures, few or no fines,
			GP	Poorly graded gravel, gravel/sand mixtures, few or no fines,
		Gravels with fines	GM	Silty gravels, gravel/sand/silt mixtures
			GC	Clayey gravels, gravel/sand/clay mixtures
	Sands ≥ 50% passes the No. 4 Sieve	Clean Sands	SW	Well graded sands and gravelly sands, few or no fines
			SP	Poorly graded sands and gravelly sands, few or no fines
		Sands with fines	SM	Silty Sands, sand/mixtures
			SC	Clayey sands, sand/clay mixtures
Fine Grained Soils ≥ 50% passing the No. 200 Sieve	**Silts and Clays** LL ≤ 50%		ML	Inorganic silts, very fine sands, rock flour, silty or clayey very fine sands, clayey silt with slight plasticity
			CL	Inorganic clays, lean clays, with low to medium plasticity
			OL	Organic silts and clays of low plasticity
	Silts and Clays LL > 50%		MH	Elastic silts, often micaceous or diatomaceous, inorganic silts
			CH	Inorganic clays, fat clays, high plasticity
			OH	Organic Clays, medium to high plasticity
Highly organic soils			PT	Peat, muck and other highly organic soils

Figure 3-11. USCS Soil Classification System

ASTM D 2487 has several flow charts that can be used in order to classify soils according to the USCS method. These are used in order to get not only the group symbol, but to also provide a description of the soil. There are two different flow charts, one for the granular material and the other for fine grained soils. Soils that are intermediate between two symbols use a dual symbol such as GP-GM.

Group Symbol - This symbol is made up of two components, the prefix and suffix that have specific meanings.

Prefix	
G	Gravel
S	Sand
M	Silt
C	Clay
O	Organic
Pt	Peat

Suffix	
W	Well-graded
P	Poorly graded
H	High LL
L	Low LL

Examples: GW, ML

Figure 3-12. Components of USCS Symbol

Group Name - This is the soil description given for groups of soils classified by the USCS. Please see Figures 3-12 and 3-14 for examples.

D_{60} = Grain diameter at 60% passing - read off of a grain size distribution chart. See Figure 3-13 for an example.

D_{30} = Grain diameter at 30% passing - read off of a grain size distribution chart. See Figure 3-13 for an example.

D_{10} = Grain diameter at 10% passing - read off of a grain size distribution chart. See Figure 3-13 for an example.

Uniformity Coefficient (Cu) = D_{60} / D_{10} This equation is used to differentiate between certain gravels and sands. See figure 3-11 for an example.

Coefficient of Curvature (Cc) = $(D_{60})^2 / (D_{10} * D_{10})$ This equation is used to differentiate between certain gravels and sands. See figure 3-13 for an example.

Percent Retained - Percent by weight of soil sample retained on a specific sieve.

Percent Passing - Percent by weight of soil sample that passes a specific sieve.

Plus No. 200 = 100 - Percent Passing No. 200. Amount retained on the No. 200 sieve by weight of sample

Plasticity Chart - Chart showing LL of a soil vs. the PI. It is used to help differentiate between Clays and Silts as well as soils of low plasticity and high plasticity.

A-line - Line on Plasticity Chart that separates Clays and Silts.

U-line - Line beyond which soils should not plot.

Estimated Man Hours per sample - 20 minutes

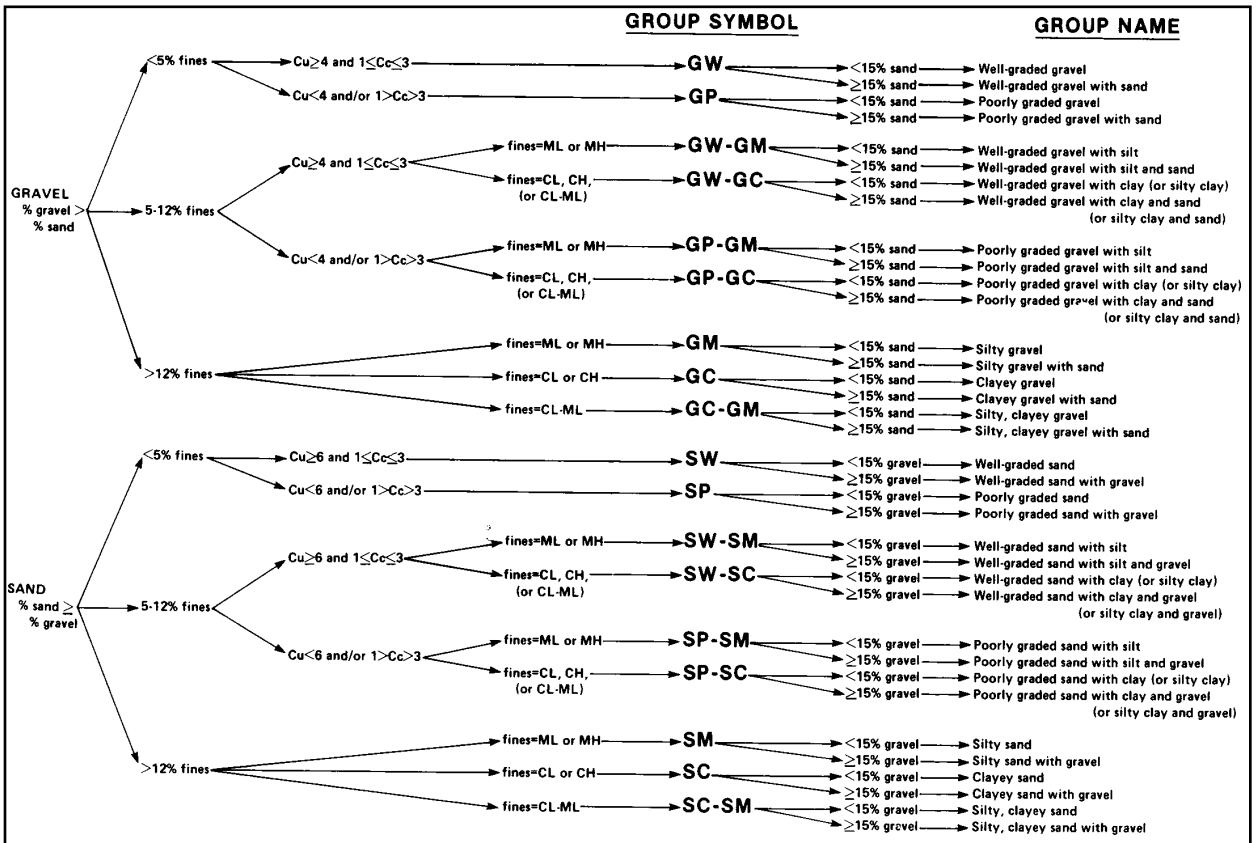


Figure 3-12. Flow chart from ASTM D 2487 for classifying coarse grained soils by USCS

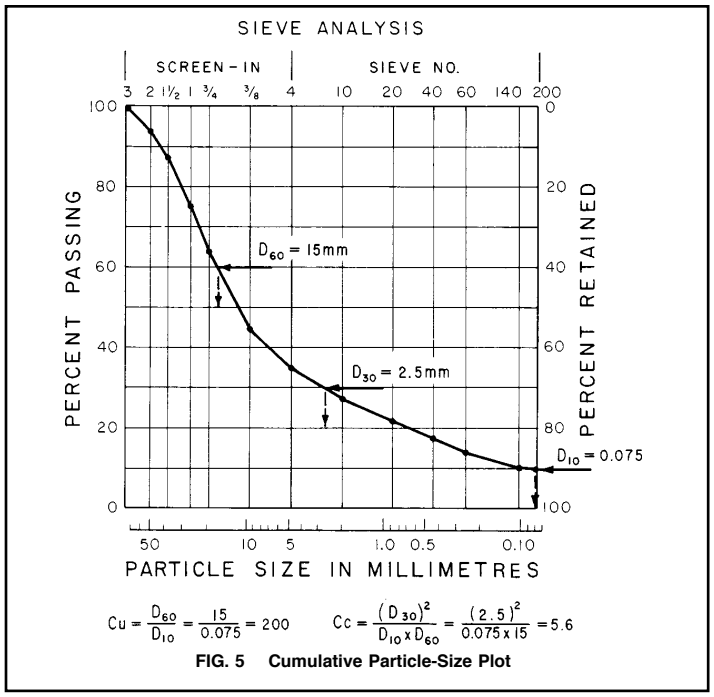


Figure 3-13. Calculation of Coefficients for Coarse Grained Soils from ASTM D 2487

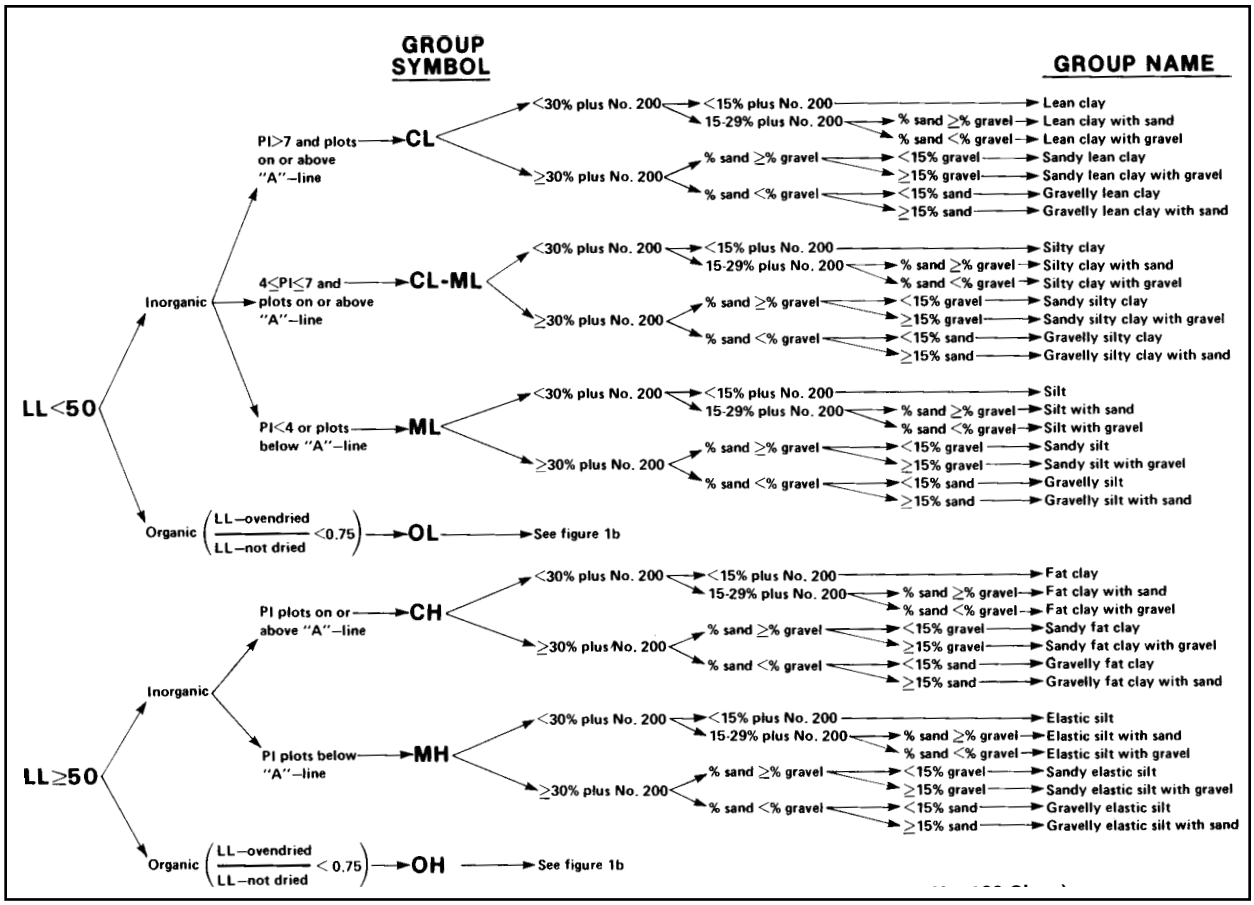


Figure 3-14. Flow chart from ASTM D 2487 for classifying fine grained soils by USCS

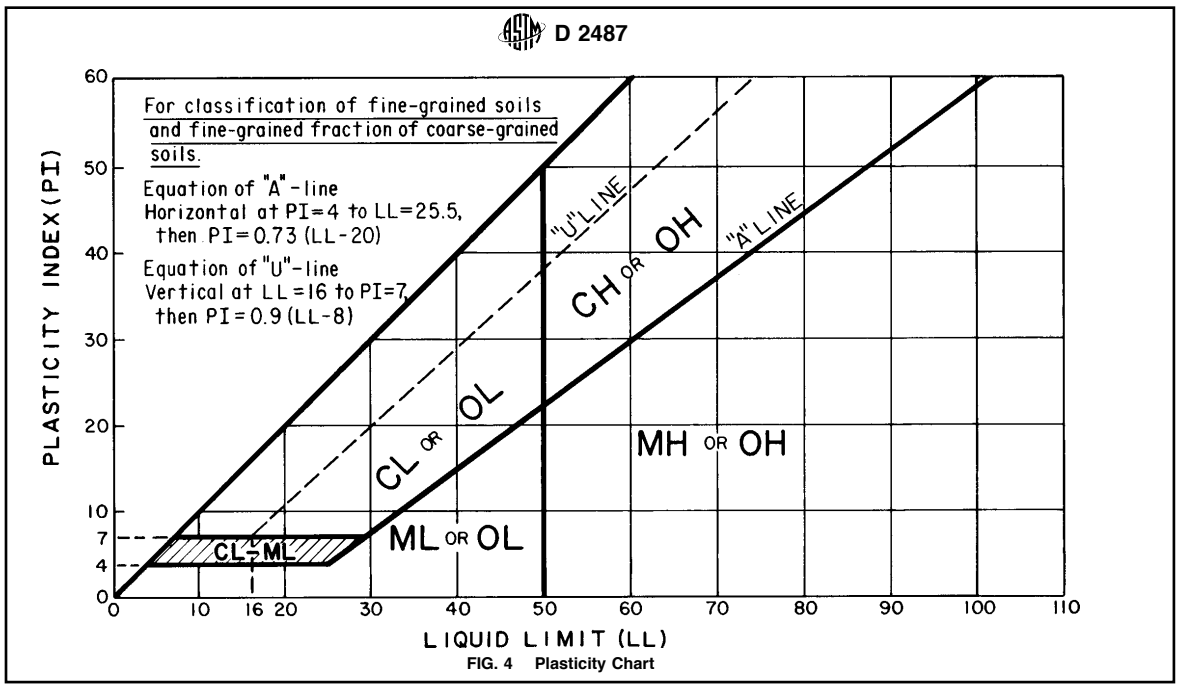


Figure 3-15. Plasticity Chart from ASTM D 2487

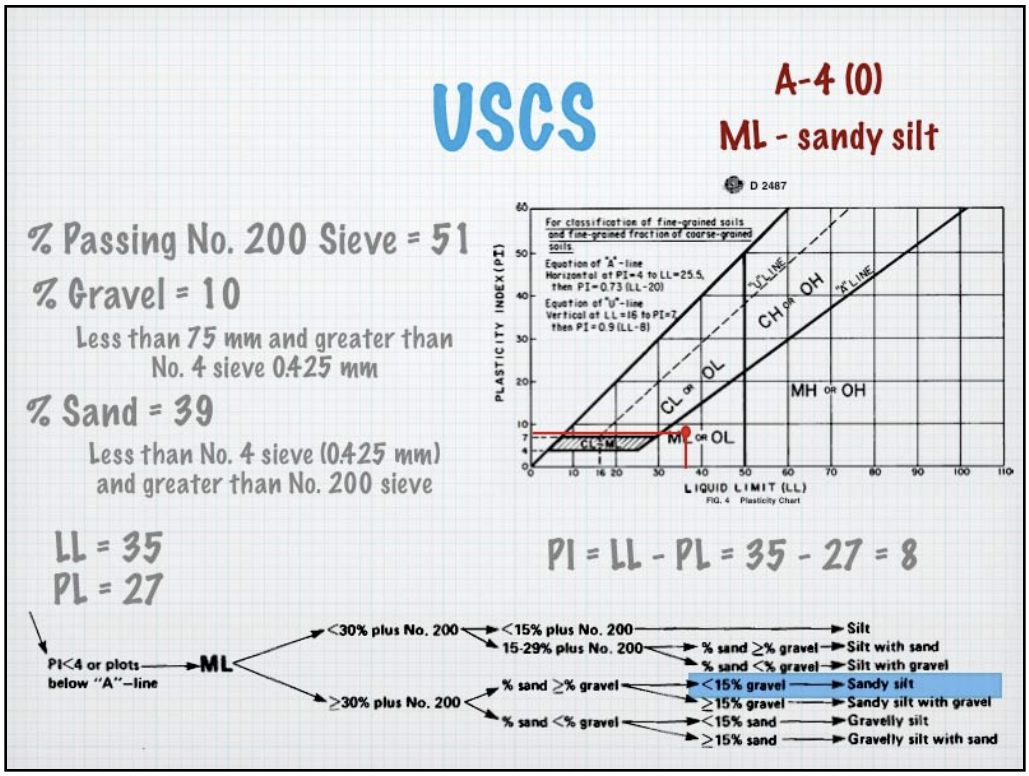


Figure 3-16. Example Problem Classification of Fine Grained Soil by USCS

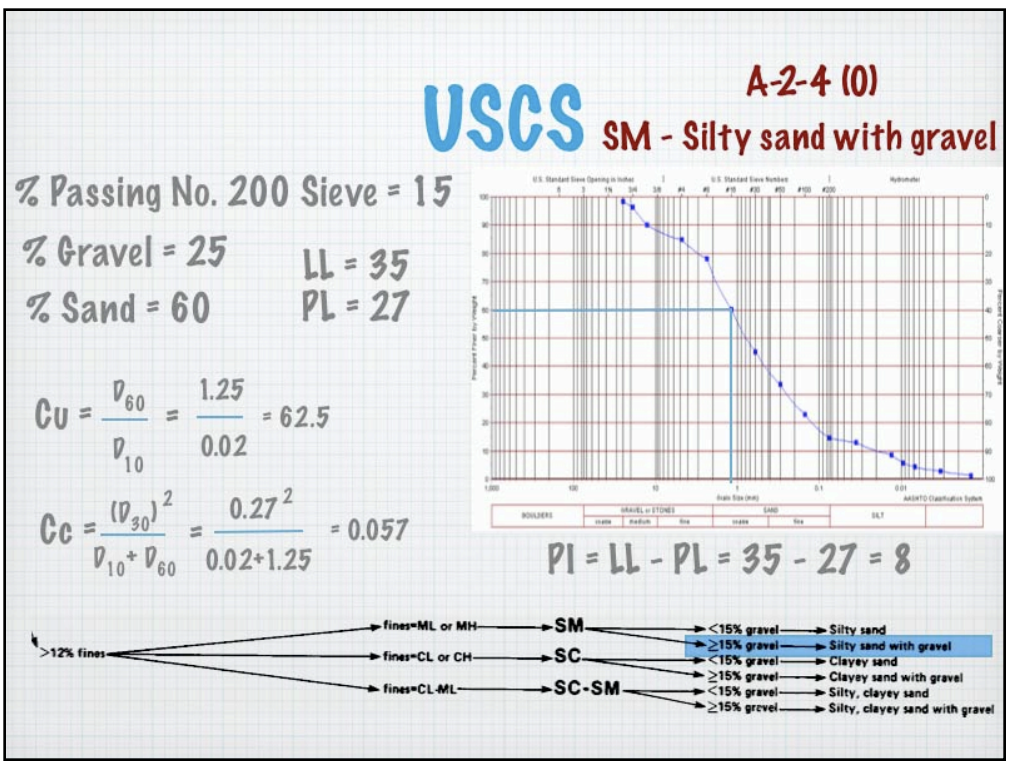


Figure 3-17. Example Problem Classification of Granular Soil by USCS

Density and Pavement Design Tests

Proctor (ASTM D 698, D 1557, AASHTO T 99, T 180)

The proctor test is used to determine specifications for compaction of soil out in the field. It estimates a maximum dry density and optimum moisture for a given soil. These parameters can then be tested as soil is placed and compacted in the field and compared with a laboratory value to determine if the soil has been sufficiently compacted. Proper compaction of soil minimizes settlement and consolidation of soils after an embankment has been placed. It also increases the strength and stiffness of the soil as well as increasing the stability of embankment slopes. Generally for "standard loads" the soil out in the field should be at least 95% of the maximum dry density found in the laboratory. This is the standard used in TDOT specifications. If soil is not within the moisture range possible for 95% of the maximum dry density, then proper compaction will likely not be achieved as the soil is either too dry or to wet to reach 95% of the laboratory value. This test is performed on soils that are be used as fill material on a construction site and representative samples. Samples are routinely taken by the GES for lines and interchanges and may be taken for other sites where compaction control is expected to be needed during construction.

Please note that this is done for the fraction of the soil that will pass the number 4 sieve, so if there is a significant cobble content in the soil (for instance some of the cherty soils of Montgomery County) the results may not always be accurate. Also, this is not a fundamental property of a soil. The maximum dry density and moisture content required to achieve this density varies according to the compactive effort applied. It is possible to have maximum dry densities in the field that are larger than 100% of the maximum dry density. For most circumstances, this should not be significantly higher than 100% unless there is a problem with the test or the wrong proctor curve is being used out in the field. The standard proctor has been in use for many years at TDOT and appears to be a reasonable and sufficient test for determining compaction out in the field.

For a standard proctor, soil is placed in a proctor mold in 3 lifts. This soil is compacted with 25 blows of a hammer that weighs 5 1/2 lbs dropped at a weight of 12 inches above the sample. The "A" mold used at TDOT for the standard proctor has a volume of 1/30th of a cubic foot of soil.

Maximum dry density (γ_{max}) - the maximum dry density of the soil that can be achieved by the test. Also called the maximum dry unit weight.

Optimum Moisture Content (w_{opt}) - the moisture content required to achieve the maximum dry density of the soil.

Moisture Range - the range of moisture content for a given soil for which it is theoretically possible to achieve 95% compaction according to the laboratory proctor curve.

Dry Unit weight (γ_d) - the dry unit weight of the soil is defined as the weight of the soil solids / volume of material = W_s/V. The relationship between the moisture content, dry unit weight and wet unit weight can be described by this equation: $\gamma_d = \gamma_T/(1+w)$.

Total Unit weight (γ_T) - this is the wet unit weight of the soil. It is defined as the total weight of the soil sample/ volume = W/V. It can be described by the equation $\gamma_T = \gamma_d * (1+w)$

Zero air voids curve - the curve on the proctor curve that is determined by the theoretical density of the soil if there were no air voids present in the sample. Proctor points should not plot outside of this. This is not routinely plotted on TDOT soil laboratory results, but may be included on results from consultants. The general shape of the proctor curve can be seen in figure 3-17. However, this is an idealized curve. Actual proctor curves may vary somewhat in shape and may not always be as symmetrical as the curve shown.

Estimated Man Hours Per Sample: 2 hours - this may be spaced over several days

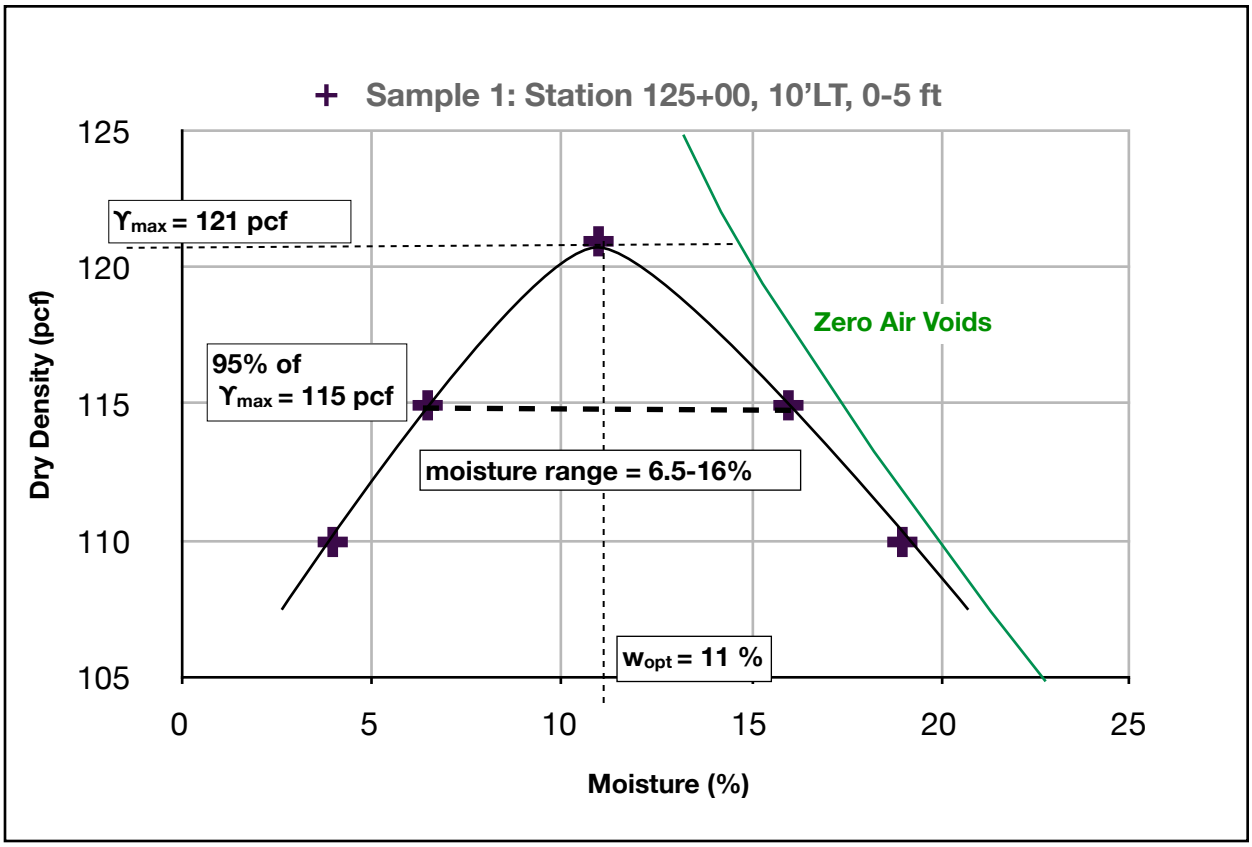


Figure 3-17. Proctor Curve for soil sample showing 95% of maximum dry density and moisture range

Figure 3-18. Photographs of Proctor Samples and Testing

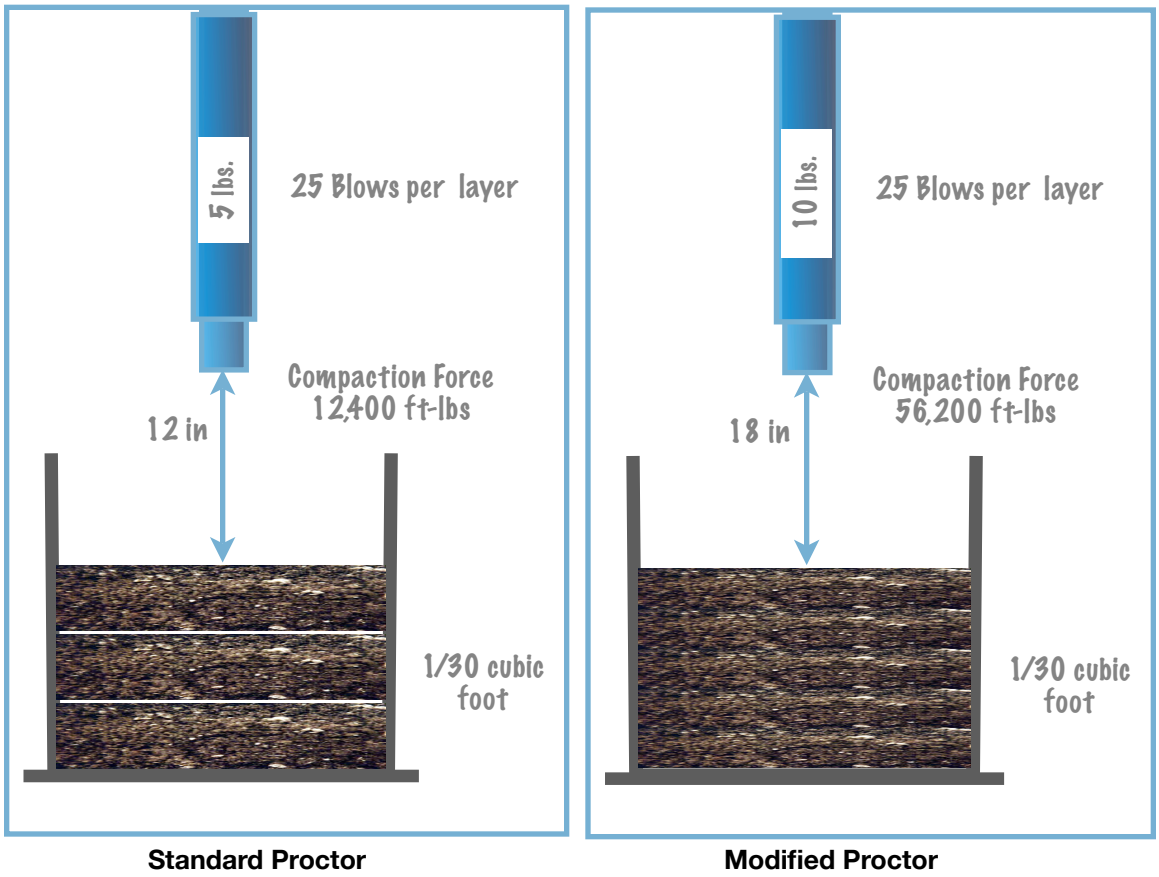


Figure 3-19. Diagram of Proctor Sample Testing

CBR - California Bearing Ratio (ASTM D 1883, AASHTO T 193)

This test method was developed to evaluate soils for their potential strength as subgrade, subbase and base course for pavements. It is routinely used by TDOT Pavement Design in order to properly design asphalt pavement and is based on empirical correlations. It does not measure a fundamental property of a soil. Samples are taken from material to be used as fill in the field and are brought back to the laboratory for testing. The bearing ratio is given as the unit load required to cause a specific sized piston to penetrate to a certain depth divided by the standard load required to cause the same penetration in crushed limestone. Samples are soaked in order to simulate conditions in the field over the long term. TDOT uses the CBR value at 0.2 in of penetration.

Please note that for poor soils, particularly organic or fat clays, the difference between a test result CBR of 2 and a CBR of 3 may not be significant. Clayey soils may show some variation in CBR values for the same soil across several tests.

CBR Value - California Bearing Ratio value at 0.2 given from the test results.

Expected Man Hours Per Sample - 2 hours

Figure 3-20. CBR Testing - CBR Samples on Cart and CBR Sample on Load Frame for Testing

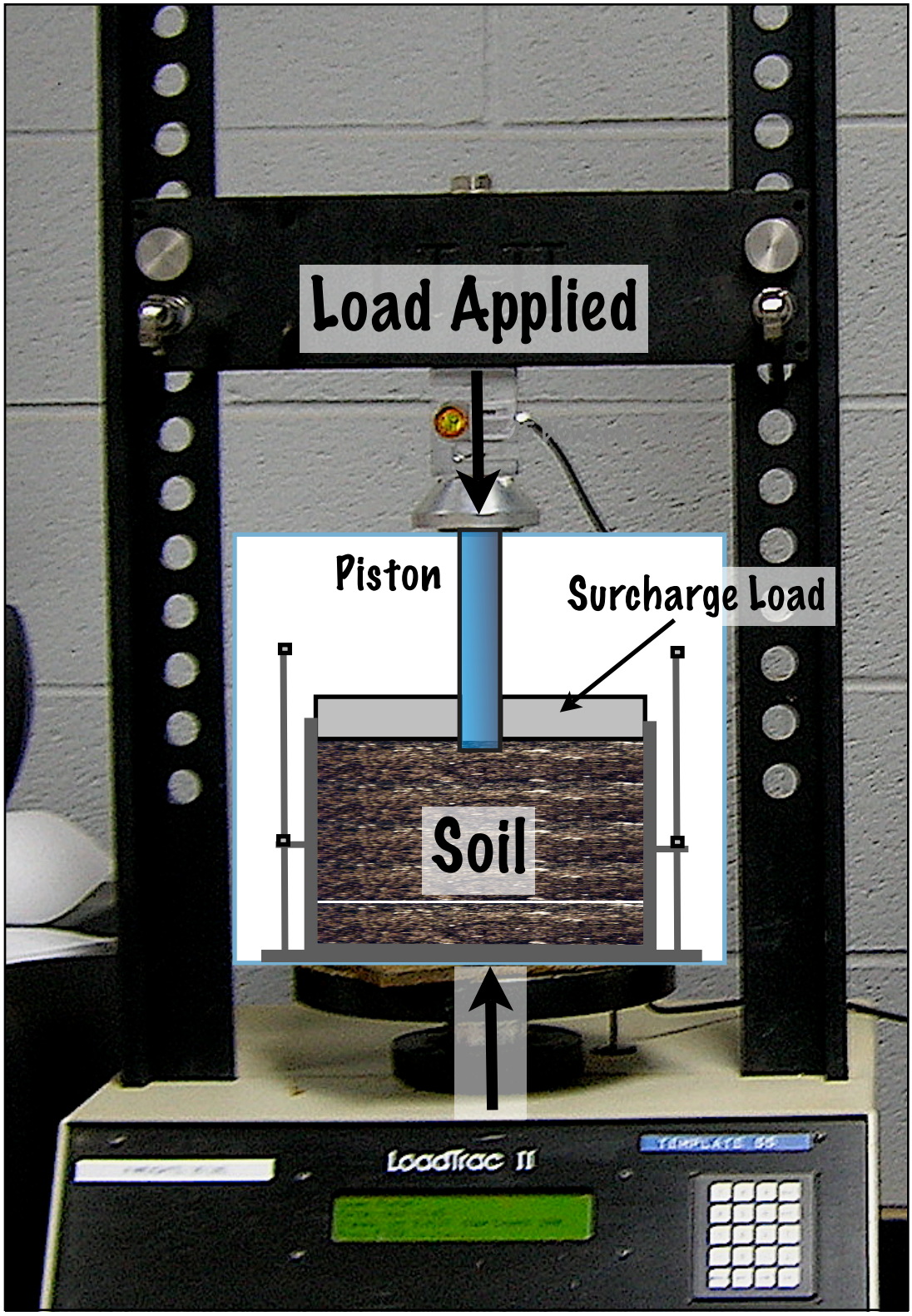


Figure 3-21. Diagram of CBR Test in Load Frame

Soil Type	USCS Soil Symbol	USCS Soil Type	Typical CBR Range
Coarse grained soils	GW	Well graded gravel	40 - 80
	GP	Poorly graded gravel	30 - 60
	GM	Silty gravel	20 - 60
	GC	Clayey gravel	20 - 40
	SW	Well graded sand	20 - 40
	SP	Poorly graded sand	10 - 40
	SM	Silty Sand	10 - 40
	SC	Clayey Sand	5 - 20
Fine grained soils	ML	Silt	15 or less
	CL	Lean Clay	15 or less, typically 3-7
	OL	Organic Clay	5 or less
	MH	Elastic Silt	10 or less
	CH	Fat Clay	15 or less, typically 2-5
	OH	Organic Clay	5 or less

Figure 3-21. Typical CBR Values by USCS Soil Type after Washington State DOT Pavement guide: http://training.ce.washington.edu/WSDOT/

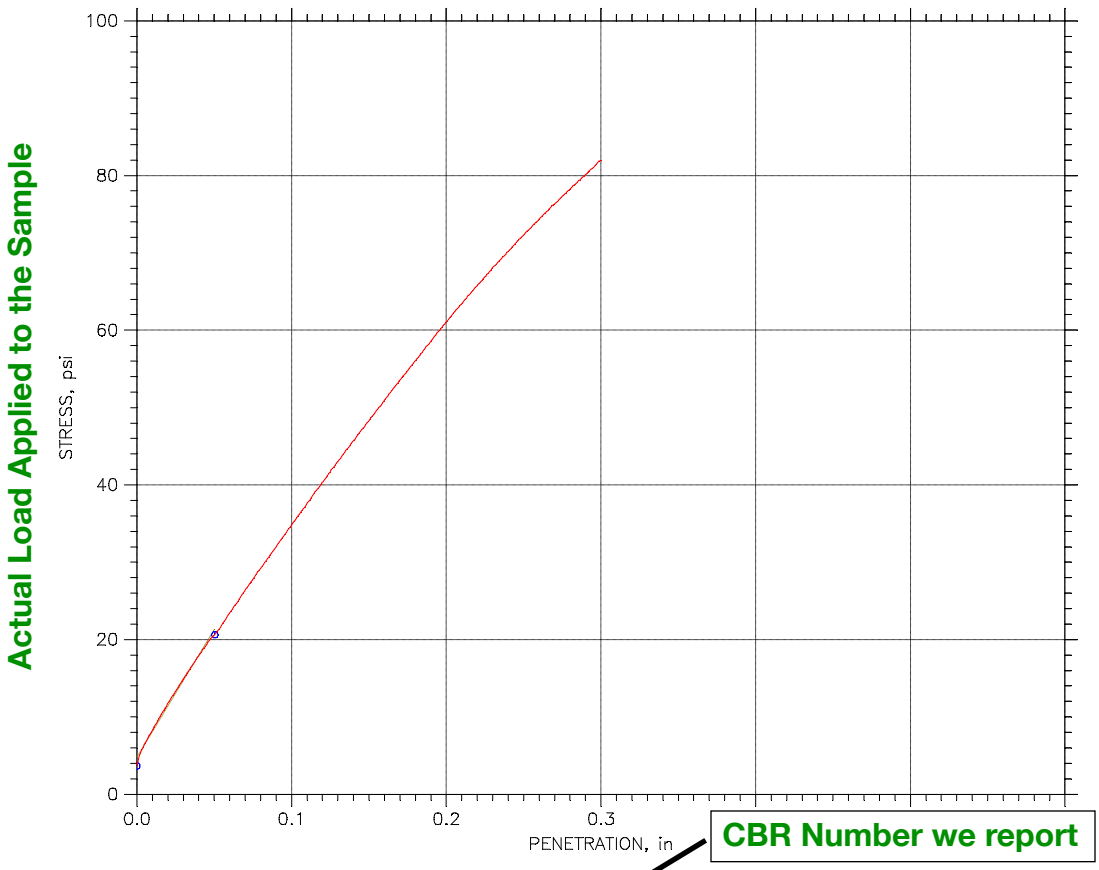
Soil Type	AASHTO Classification		Typical CBR Range
Coarse grained soils	A-1	A-1-a	30-100
		A-1-b	20-50
	A-2	A-2-4	40-100
		A-2-5	20 - 60
		A-2-6	12 - 30
		A-2-7	8 - 15
	A-3		10 - 100
Fine grained soils	A-4		3 - 22, typically 3 - 15
	A-5		1 - 7
	A-6		15 or less, typically 2-8
	A-7	A-7-5	15 or less, typically 3-8
		A-7-6	7 or less, typically 2-6

Figure 3-22. Typical CBR values by AASHTO Soil Type

General Use	Rating	Typical CBR Range
Subgrade	Excellent	20 - 100
	Good	10 - 20
	Medium	5 - 10
	Poor	1 - 5
Subbase	Excellent	50 - 100
	Good	30 - 60
	Acceptable	20 - 30
	Unacceptable	1 - 20
Base	Acceptable	80 -100
	Unacceptable	1 - 80

Figure 3-23. General Rating of Soil by CBR Range for use as Subgrade, Subbase or Base

CALIFORNIA BEARING RATIO TEST REPORT



Soil Sample Data

Sample Height: 4 in	California Bearing Ratio		
Sample Area: 27.391 in^2	at 0.1 in: 3	at 0.3 in: 4	at 0.5 in: N/A
Sample Volume: 109.56 in^3	at 0.2 in: 4	at 0.4 in: N/A	
Sample Mass: 4000 gm			
Sample Condition: Soaked			
Swell: -93.38 %			
Surcharge: 9070 gm			
Void Ratio: 0.56			
Wet Unit Weight: 139.08 pcf			
Dry Unit Weight: 108.21 pcf			

Moisture Content Data

Water Content	Before	Top	Average
Tare ID	p1		
Tare Mass, gm	0	0	0
Mass Tare + Wet Soil, gm	500	0	0
Mass Tare + Dry Soil, gm	389	0	0
Water Content, %	28.53	0.00	0.00

TDOT

Project: SR2 Over Duck River	Location: 19+45	Project No.: Coffee
Boring No.:	Tested By: rdj	Checked By:
Sample No.: CBR 1	Test Date: 10/21/03	Depth: 1-3
Test No.:	Sample Type: Modified	Elevation: n/a
Description:		
Remarks: ASTM D1883/T193		

Figure 3-21. CBR Lab Test Report with annotations

Strength Tests

Unconfined Compression of Soil (ASTM D 2166, AASHTO T 208)

The purpose of this test is to provide a measure of the undrained shear strength of cohesive soils. The test is usually performed on clays because other soil types typically lack enough internal cohesion to make an adequate sample. The sample must be able to maintain its shape after extraction from a Shelby Tube with no confining pressure, making this an entirely impractical test for sands.

A soil sample is extracted from a shelby tube in the laboratory, cut to size and placed in a load frame. The soil sample must have a height to diameter ratio of between 2.0 and 2.5 to be considered valid for the test. It also must have a diameter greater than 1.3 inches. Typical shelby tube samples will have a diameter of 2.8 inches. This test is a variant of the triaxial test, where load is applied in only one direction. It can be performed on remolded samples, but this typically is not done at TDOT.

Undrained shear strength of soil (c_u or s_u) = 1/2 q_u This is often referred to as cohesion in textbooks and manuals. It is simply a measure of the strength of the soil where no drainage of the soil occurs. This strength parameter might be used where load was applied suddenly to a clay (as in the placement of retaining wall or large embankment) where the soil does not have a chance to drain and thus consolidate. It can be used in bearing capacity equations or with slope stability analysis.

Unconfined compressive strength of soil (q_u) = 2 * c_u The compressive stress applied to the soil (Load / applied area) at 15% strain or at failure - whichever comes first. This is usually visually fairly easy to identify as the sample will noticeably deform on the load frame. The TDOT soil laboratory uses a computer controlled system that generates a graph of the testing results as well as the final reported number.

Vertical strain - also called axial strain = $\Delta H/H$ This is a ratio that measures the change in the height of the sample divided by the original height of the sample. Usually expressed in percent.

Man hours per sample - 0.5 hours

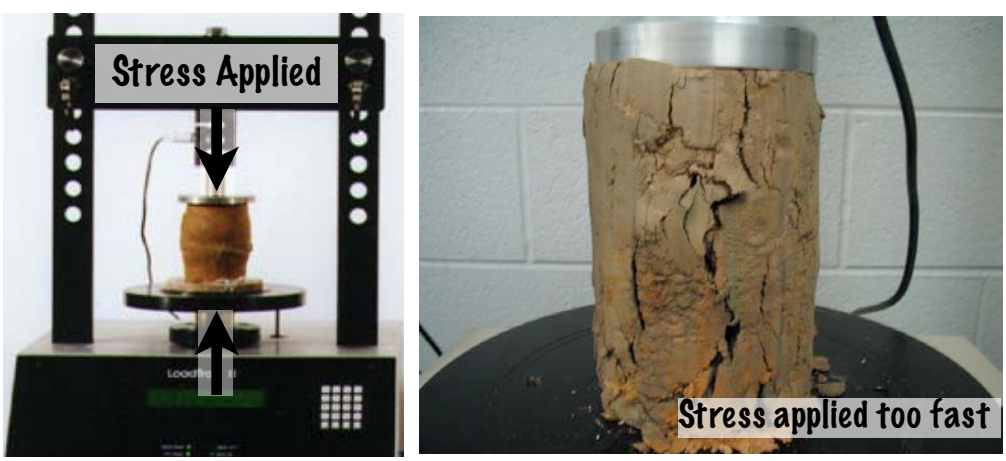
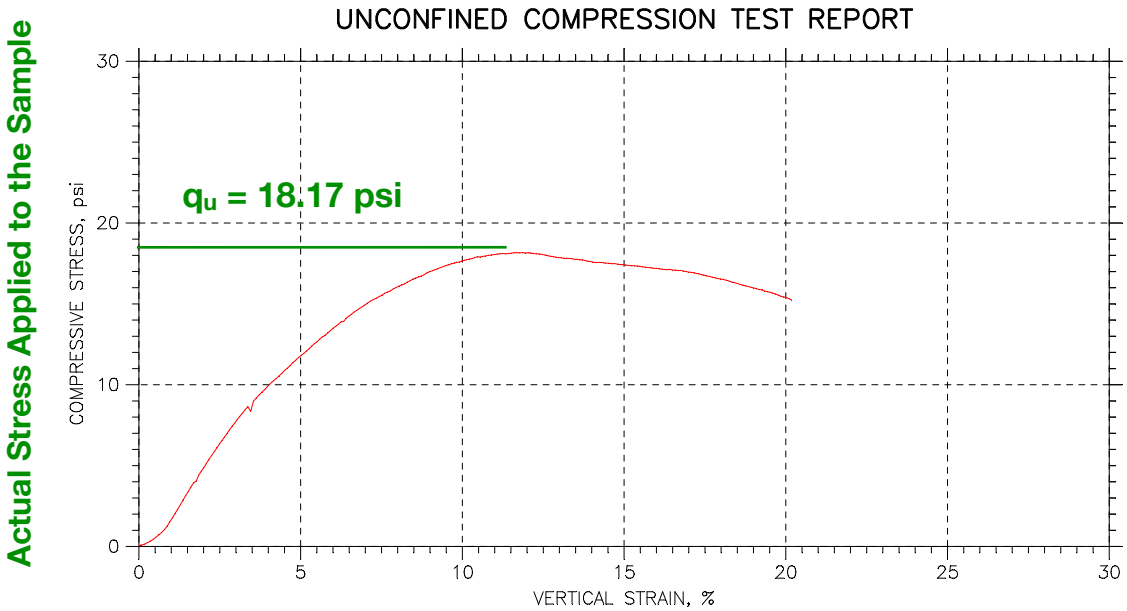


Figure 3-22. Views of Unconfined Compressive Strength Testing



Symbol					
Test No.		TUBE 4			
Initial	Diameter, in	Soil Sample Data	2.838		
	Height, in		5.591		
	Water Content, %		14.54		
	Dry Density, pcf		110.8		
	Saturation, %		80.67		
	Void Ratio		0.47		
Unconfined Compressive Strength, psi		Test Data	18.17		
Undrained Shear Strength, psi			9.084		
Time to Failure, min			11.752		
Strain Rate, %/min			1		
Estimated Specific Gravity		Soil Sample Data	2.61		
Liquid Limit			26		
Plastic Limit			17		
Plasticity Index			9		
Failure Sketch					

q_u Reported by test

c_u = 1/2 q_u Number we use

TDOT	Project: SHELBY
	Location: 30+88 58RT'
	Project No.: 7914705
	Boring No.: TUBE 4
	Sample Type: Shelby Tube
	Description: CLASS A-4 GROUP 6
	Remarks: ASTM D2166

Figure 3-23. Unconfined Compression Test Report

Unconfined Compression of Rock (ASTM D 2938)

This test is very similar to that of unconfined compression of soil, however the loads applied are significantly higher and the unconfined compression number is often used directly in calculations. At TDOT this test is performed in the concrete lab with the same equipment used for compression tests on concrete.

Like the soil compression test, the sample must have a height to diameter ratio between 2 and 2.5 or the test cannot be considered valid. Samples must be have a diameter greater than 1.8 inches. NQ core samples meet this criteria. The test is run until the sample breaks - rock samples seldom deform noticeably before they fail. Test results are reported on the same form that is provided for concrete breaks. However, a few calculations are required of the Geo receiving the data as the test report only the peak load when the sample reached failure.

Peak Load at failure (P) - this is the load applied to the sample when it reached failure and broke. Reported in pounds.

Contact area (A) = cross sectional area of rock core = $\pi^{*}d^2/4$

Unconfined compressive strength of rock (q_u) - Peak load at failure / contact area = P / A. This number is to assist in calculating the bearing capacity of rock. It is also used in several different rock mass rating systems, including the RMR in use at TDOT. Please note that this is the strength of the *rock fabric*, not the *rock mass* as a whole. You cannot directly take this number and assume that this is the maximum load that a rock can support out in the field. This number is **always** reduced to account for fractures, discontinuities and other weaknesses that may be present in the rock beneath a footing in the field.

Figure 3-24. Diagram of Rock Core Testing and Photo of NQ core samples taken out in the field

Height of Sample (in)

Diameter of Sample (in)

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
NASHVILLE

H 4.04
D 1.86

~~Sample~~ No. 633

Rock Core
FIELD RECORD ON ~~CONCRETE~~ SPECIMEN

Project Reference No. 2701506 County Campbell Reg. 1

Project No. 07005-1215-14

Submitted by McDOWELL Made by Plemons

~~Cylinder~~ Hole No. 9A Date made 1-23-07 Age of Test

Amount Represented Station No. 200 + 88±

Exact Location 10'± Lt. of ℄, depth 3.5'-5.4'
weathered SANDSTONE; Formation-Briceville shale

Design No. Class of Concrete Slump Air %

Brand of Cement Location

Source of F.A. Location

Source of C.A. Location

Ready-Mix Co. Location

Required Design Strength

Remarks: Require Rock core unconfined Compression Results

LABORATORY TEST RESULTS

~~Cylinder~~ Core No. 3		$A = \pi * d^2/4$
Serial No.	07P2722	$A = \pi * 1.86^2/4 = 2.717$ in
Report No.		
Date Tested	2-21-07	
Date Reported		$q_u = P/A$
Pounds ~~Per Sq. In.~~	P = 24,670	

Test Results (Ave. of 2 cylinders) $q_u = 9079$ P.S.I.

Remarks:

Tested by Approved
Materials and Tests Engineer

Form DT-0062

Number we use

Figure 3-25. Test report for unconfined compressive strength of rock.

Direct Shear Test (ASTM D3080, AASHTO T208)

The direct shear test gives a measurement of the strength soil sample and it gives both cohesion and friction angle of the soil as long as the test is performed at a reasonable rate. A small sample of soil is placed in the shear box and is sheared along a pre-determined horizontal plane. The test can also be used to give residual strength parameters where the test is run in repeated cycles.

TDOT still uses a non-automated direct shear testing machine, so results are monitored by a soil lab technician who then writes down readings from a dial gauge. The dial gauge reading at failure for a given normal stress applied is recorded. At least 3 points at different normal loads are required to complete the test. Samples are taken directly from shelby tubes and are cut down to fit in the shear box for testing.

Direct shear tests give soil strength results that can be used for retaining walls, bearing capacity and slope stability. However, please note that this test, while relatively fast, has some limitations. The soil does not make it's own failure plane, the failure is forced upon the sample by the testing apparatus. This can be especially significant for landslides because and existing failure surface may have significantly less strength than a new failure surface. Residual shear stress numbers may better model this situation or simple back calculation using slope stability software. No pore pressure measurements are made during the testing of the sample, and the results are only good for similar moisture contents. Also, gravel can artificially raise the shear strength given with the test because it has a large effect on the small sample being tested - but this may not translate into a stronger material in the field. If the soil is sheared too quickly, or if the sample is not saturated you may also get shear strength parameters that are overestimated.

Normal Load - this the weight applied vertically to the sample.

Normal Stress (σ_n) - the stress applied vertically to the sample = normal load / Area

Shear Load - this is the load applied horizontally to the sample

Shear Stress (τ) - the stress applied vertically to the sample = shear load / Area.

Cohesion (c) - the intercept of the shear strength line on the shear stress axis. It is a measure of the strength of the soil at the specific water content of the soil.

Friction angle (ϕ) - the angle of the shear strength line on the shear stress vs. normal stress graph. It is also a measure of the strength of the soil.

Failure envelope - line on shear stress vs. normal stress graph that defines c and ϕ. It is a straight line defined by the following equation: $\tau = c + \sigma_n \tan \phi$. Stresses in soil that plot above this line are predicted to fail by the laboratory results. Stresses that plot below this line should not fail.

Man hours per sample - 2 hours

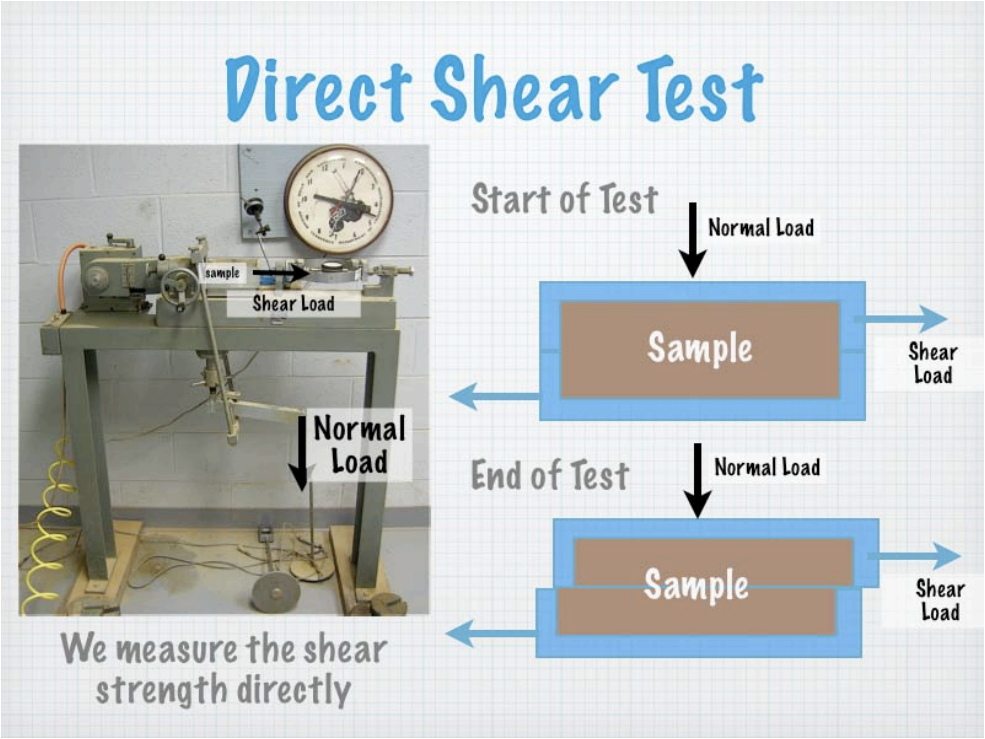


Figure 3-26. Diagram of Shear Strength Test

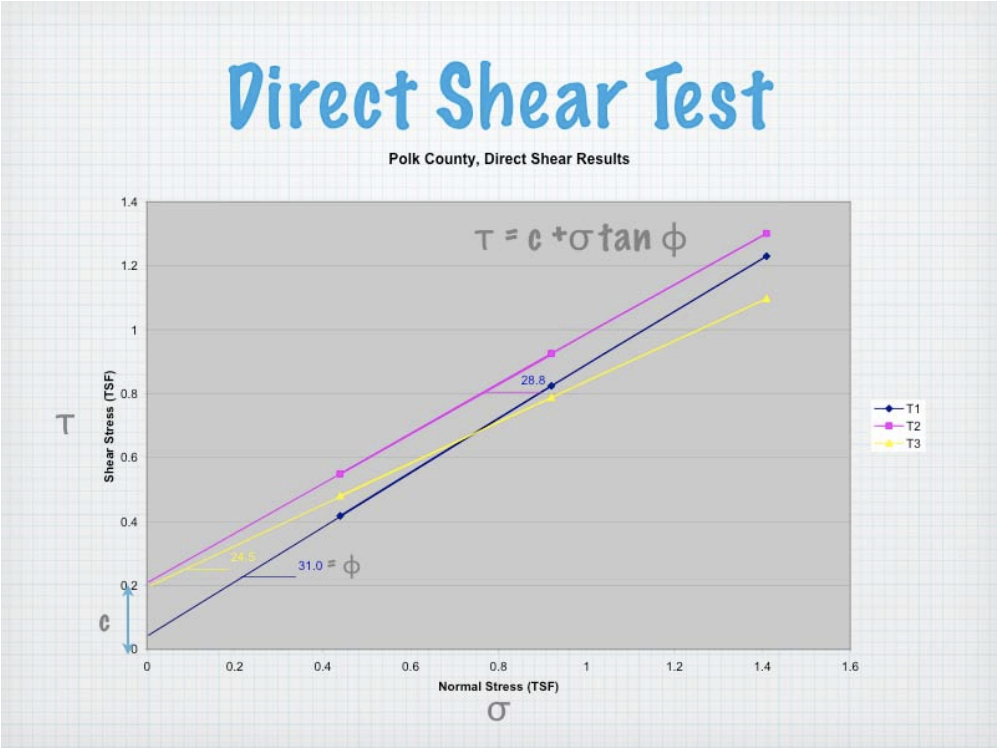


Figure 3-27. Graph of Direct Shear Test Results for 3 tests

Triaxial Test (ASTM D 4767, D 2850 AASHTO T 297, T 296)

There are 3 main types of triaxial tests, but only two are routinely performed at TDOT:

1. **Unconsolidated Undrained (UU)** - also called the Q or "quick" test. This test can be routinely performed by TDOT soil laboratory technicians. For this test the water content of the specimen is not allowed to change during the test. Results will depend on the moisture content of the soil at the time of testing and can vary depending upon this moisture content. This test is usually conducted only on clay soils.

2. **Consolidated Undrained (CU)** - also called the R test. This is the most common test performed at TDOT for triaxial test results. Pore pressure measurements are taken during this test. The sample is saturated and the soil is consolidated before it is loaded to failure. Loads are applied both horizontally and vertically to the sample. The sample is not allowed to drain, but pore pressure measurements are taken during the test.

3. **Consolidated Drained (CD)** - also called the S test. This is rarely performed at TDOT and will require special considerations for test set-up and performance. This test would need to be set up and run by one of the Geos rather than a soil laboratory technician. For this test the sample is saturated and consolidated before being loaded to failure. Like the CU test, loads are applied both horizontally and vertically. Unlike the CU test, however, the sample is allowed to drain during the test so no excess pore pressures are built up.

The purpose of a triaxial test is to provide a strength measurement of the soil. It provides a failure envelope for the soil as well as cohesion and friction angle for the soil. The CU test with pore pressure measurements is the most commonly run test at TDOT because it is shorter than the CD test and also provides strength measurements for drained conditions. It gives us effective stress parameters (c' and ϕ') that can be used in bearing capacity as well as slope stability calculations. For slopes and foundations the CU test gives us strength parameters for the long term conditions. The UU test provides only c (or s_u) and gives very similar results to the Unconfined compression test results of soil, though the UU test usually gives a c that is slightly higher. These results are used for short term conditions and loading before the soil has an opportunity to drain.

For the triaxial test a soil sample is taken from a shelby tube and is placed inside a testing chamber. Loads are applied to the soil vertically (σ_1) and horizontally (σ_3) by the use of "confining pressure" applied through the use of water. TDOT uses an automated triaxial testing apparatus that has computer controlled loads and pore pressure measurements. Soil samples are contained in a special rubber membrane and two water pumps are used with the test. The first applied the confining pressure around the sample, the second saturates the sample and measures pore pressures during the test.

Major principal stress (σ_1) - This is the stress applied to the soil by the load frame in the vertical direction. This is the load applied to the sample divided by the cross sectional area of the sample. This is considered a normal stress.

Minor principal stress (σ_3) - The stress applied to the soil by the surrounding water. It is applied to the sample horizontally around the entire sample. For the UU test this is zero, the CU test always uses a minor principal stress. This is considered a normal stress.

Deviator stress = σ_1 - σ_3 This is the difference between the major principal stress and the minor principal stress.

Pore Pressure (u) - water pressure that build up due to the addition of loads to the sample.

Shear stress (τ) - stress on the sample at the shear plane. Unlike the direct shear test, the soil sample makes its own shear plane.

Back Pressure - pressure applied to the sample in order to saturate the sample during the saturation phase.

B-value $= u/\sigma_3$. For most soils, reasonable saturation can be obtained when the B-value ≥ 0.95 the soil can be said to be saturated. This parameter is measured during the saturation phase, when the sample reaches a B-value of 0.95, the saturation phase ends and the soil is considered to be at 100% saturation. Some fat clays are very difficult to saturate and may take several cycles to saturate - some will not fully saturate in any reasonable period of time.

Vertical effective consolidation stress - stress condition to which the sample is consolidated.

Mohr-coulomb failure envelope - this is the line on the Mohr's circle graph (shear stress vs. normal stress) that defines the failure envelope for the soil. Soil stress conditions that plot below this point are predicted to be stable, those above are predicted to fail. The line is defined by the following equation: $\tau = c + \sigma_n \tan \phi$.

Mohr's Circles - These are plotted on the test results for the sample. Please see Chapter ## for more information.

Man hours per sample UU Test - 1 hour for setup, test takes 1-3 hours to complete

Man hours per sample CU Test - 1 hour for setup per point, test may take 1-3 days.

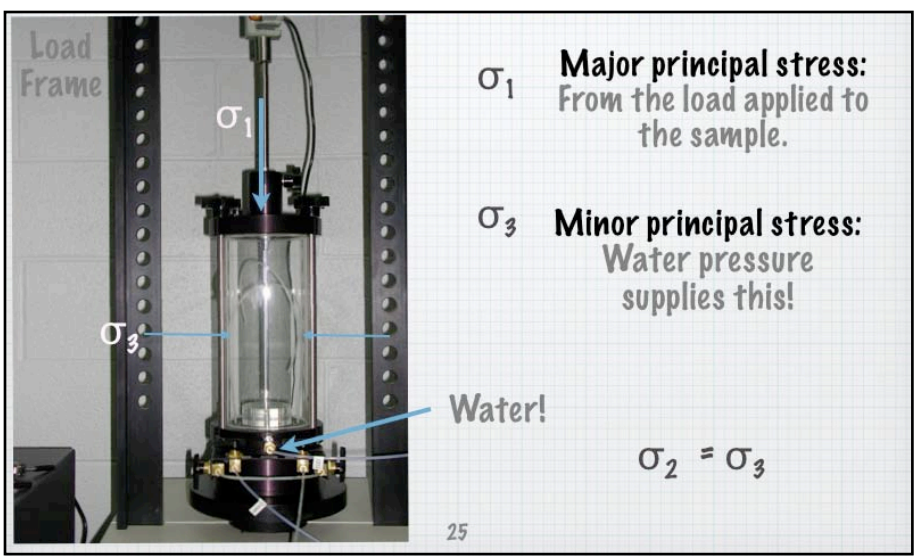


Figure 3-28. Diagram of loads for the CU triaxial test.

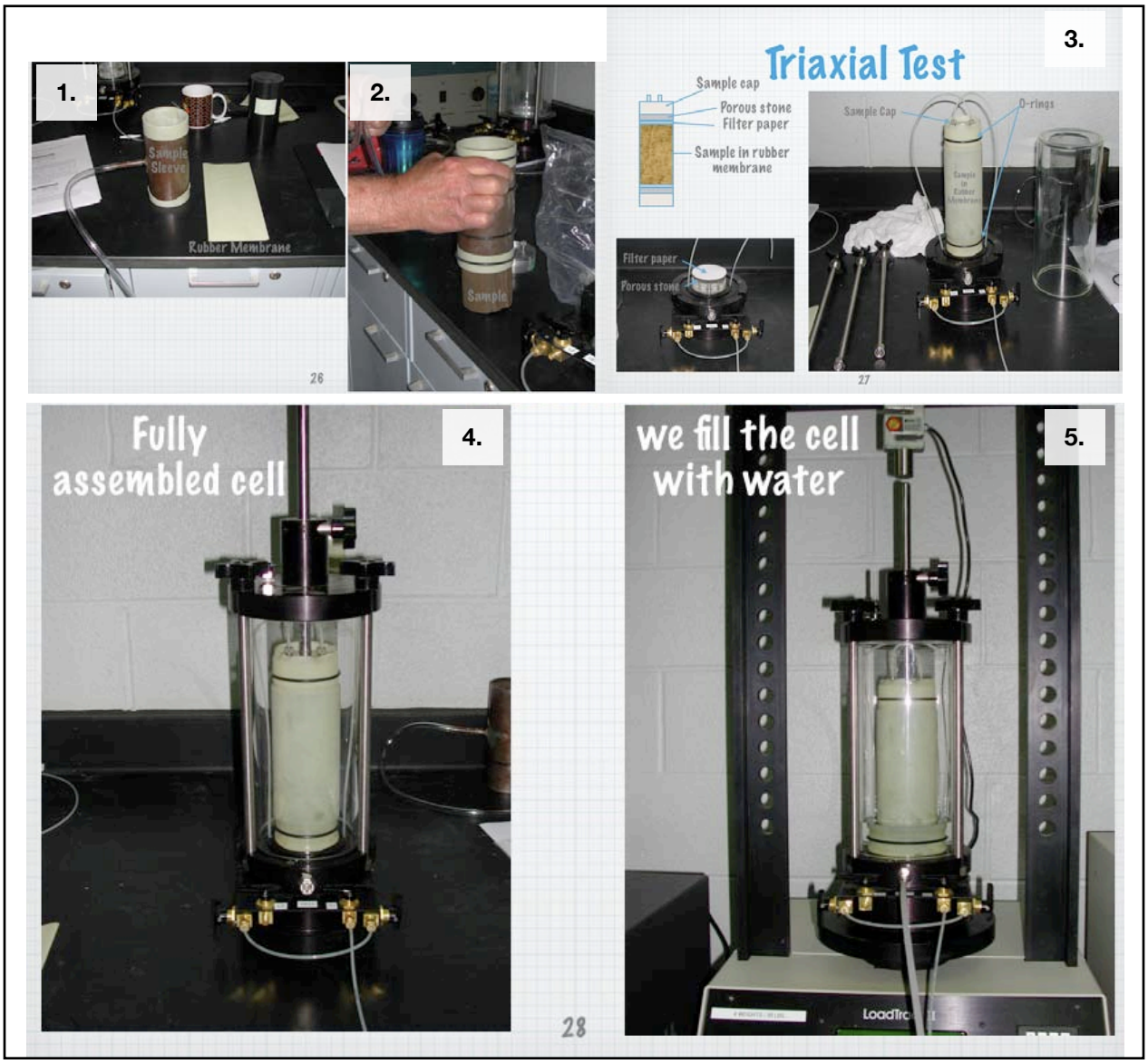


Figure 3-29 Preparation of a Triaxial Sample for testing

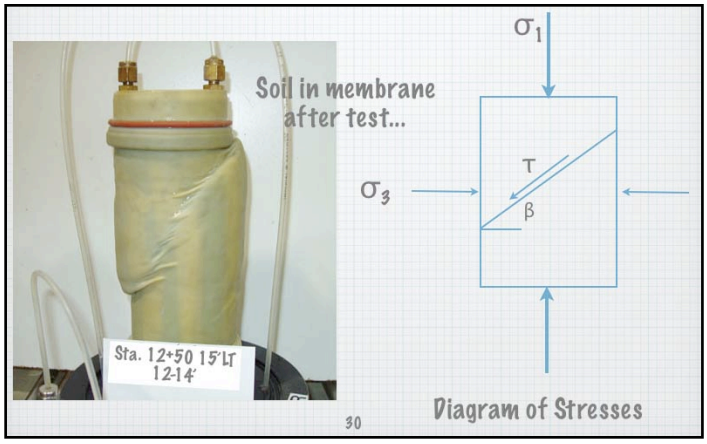


Figure 3-30. Triaxial Testing Results with Stress Diagram

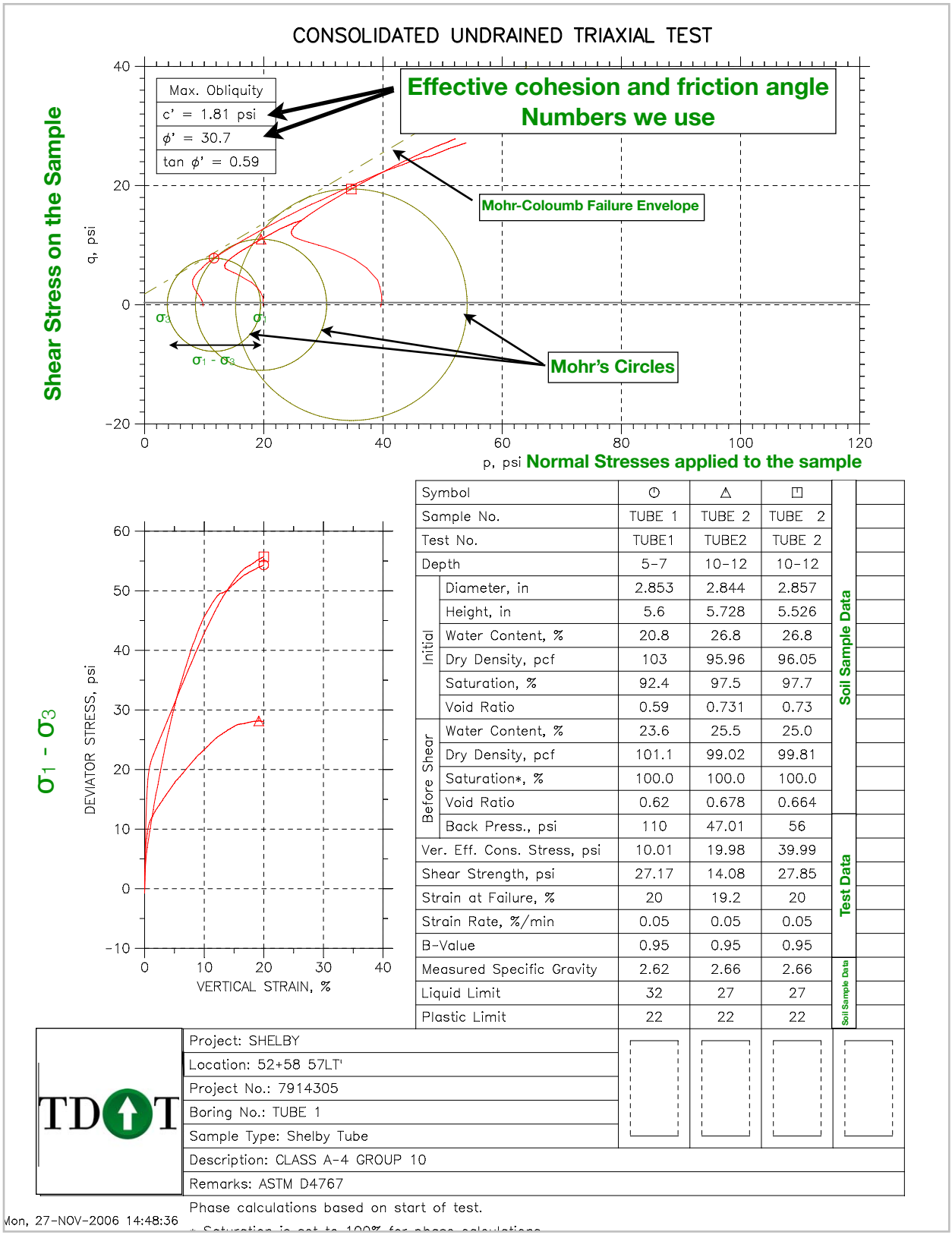


Figure 3-31. Test Report for CU Triaxial Test

Consolidation and Swell Tests

One Dimensional Compression Test (AASHTO D 2435, T 216)

The purpose of the one dimensional compression test is to provide soil parameters which can be used to estimate both differential and settlement beneath a structure or an embankment. The test, properly interpreted helps us to predict the rate of settlement as well as the magnitude of settlement to expect. However, the test provides us with an estimate only. Actual settlement in the field may vary from the laboratory value.

A soil sample is taken from a shelby tube, cut down to size and is placed in an oedometer with porous stones placed below and on top of the sample. The sample is covered in water and load is applied to it in increments or steps.

Step	Load (TSF)		Step	Load (TSF)
1	0.125		11	2
2	0.25		12	4
3	0.5		13	8
4	1.0		14	16
5	2.0		15	32
6	1.0		16	8
7	0.5		17	2
8	0.25		18	0.5
9	0.5		19	0.25
10	1			

Figure 3-32. Standard Load increments on sample during 1-D Consolidation Test in TDOT Soil Lab

The sample is loaded until secondary compression begins and then it automatically moves to the next step. TDOT uses an automated system that monitors the change in height of the sample so that each double load does not need to remain on the sample for 24 hours.

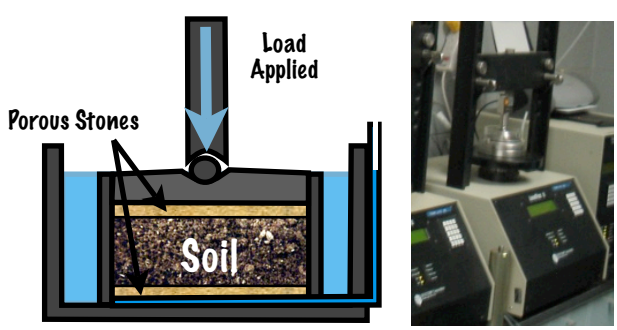


Figure 3-33. Oedometer and Sample

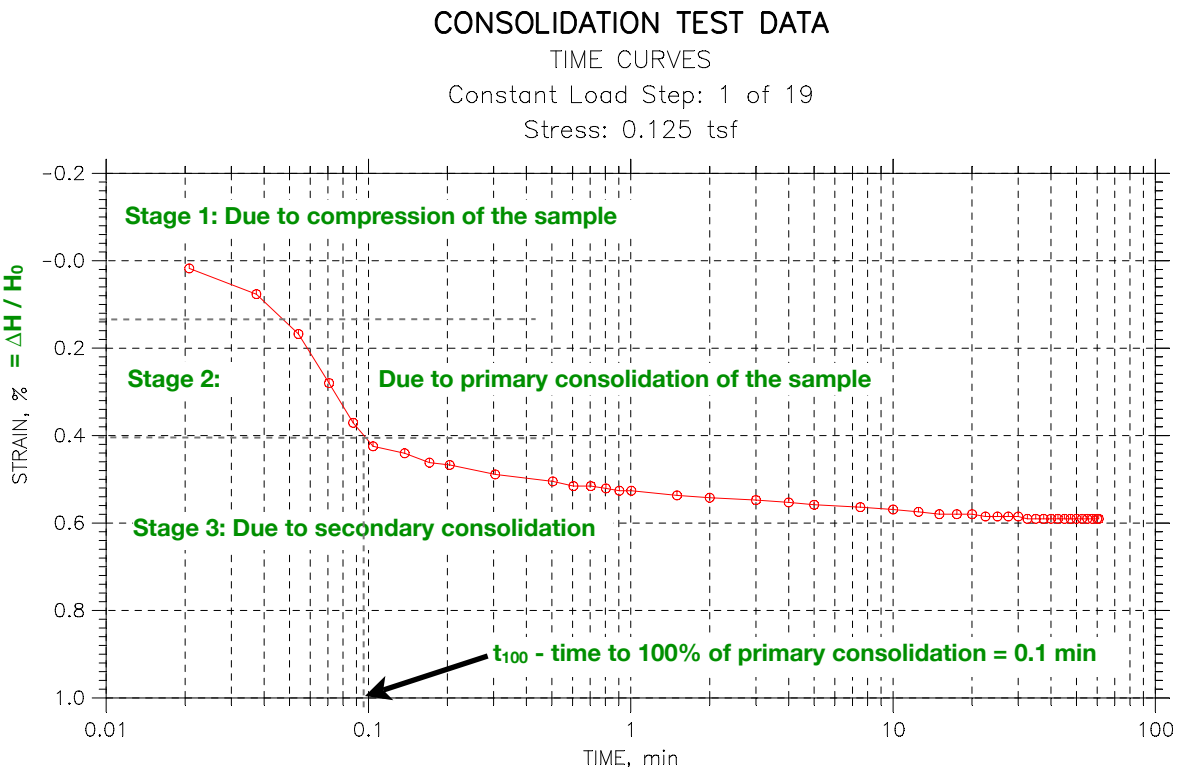


Figure 3-34. Strain vs time from TDOT Test report for a step showing Compression, Primary Consolidation and Secondary Consolidation.

Consolidation - Process by which the volume of soil is reduced through squeezing out of water and air from the soil as well as readjustment of soil particles. With clay this process may take some time to complete due to the low permeability of the soil. This can result in settlement at a site for months or years after a load is applied.

When a new vertical pressure is appled to a saturated clay or organic soil that pressure is carried initially by the pore water in the soil - because water cannot drain quickly from these soils. This causes the increase in the pore pressure of the soil. Over time, as water drains from the soil these pore pressure dissipate and the new vertical pressure is carried by the soil grains.

Primary Consolidation - This is where the majority of the volume change of the soil occurs. Immediately after the load is applied to the soil there is pore pressure buildup as water in the sample cannot escape quickly due to the low permeability of the soil. This pore pressure dissapates over time. Typically by the end of this stage there is no excess pore pressure buildup due to load.

Secondary Consolidation - This is due not to expelling of water, but apparently to re-adjustment of the clay particles over time. Also called creep.

Strain = ΔH / H_0 This the measure of the change in height of the sample divided by the original height of the sample. The sample cannot change in width because it is confined by a ring in the oedometer. ΔH = change in height, H_0 = initial sample height.

Vertical Pressure (σ'_{va}) - Vertical pressure applied to the sample during the test. It is plotted on a log scale for the test report. See figure 3-35 for and example.

Preconsolidation Pressure (σ'_p) - This is a measure of the load that has been on a soil at sometime in the past. It is the pressure that has caused some consolidation in the soil in the past. The Cassagrande Method for estimating the preconsolidation pressure from test results can be seen in Figure 3-35.

Overburden Pressure (σ'_v) - existing pressure on a soil out in the field due to the weight of overlying soil. See Chapter ## for methods for calculating overburden pressure.

Normally Consolidated soil (NC) - soil that in the field has had approximately the same amount of pressure applied to it in the past as is currently applied by the existing overburden pressure. Where: $\sigma'_v \approx \sigma'_p$. This would be true of soils that have had no additional overburden in the past.

Overly Consolidated soil (OC) - soil that in the field has had more pressure applied to it in the past than is being currently applied by the existing overburden pressure. Where: $\sigma'_v < \sigma'_p$. Soils that were located beneath glaciers in the past or those located beneath a large recent excavation would be considered OC.

Under Consolidated soil (UC) - soil that in the field has more pressure applied on it right now than has been applied in the past. Where: $\sigma'_v > \sigma'_p$. This is a soil that has not yet had time to fully react to the load that has been placed upon it.

Overconsolidation Ratio = σ'_p/σ'_v A number used to describe the stress history of a soil. UC soils have an OCR <1, NC soils have an OCR ≈ 1 and OC soils have an OCR > 1.

Point of Maximum curvature - an inflection point on the Strain vs. Vertical stress graph that is used as the starting point for estimating the preconsolidation pressure that has been previously applied to the sample.

Modified Compression Index ($C_{\epsilon c}$) = $(C_c) / (1+e_o) = \Delta \epsilon / (\Delta \log \sigma'_{va})$ This is the compression index that can be read directly off of the strain vs. vertical stress graph. It is defined as the slope of line E. shown on Figure 3-36. This line is the corrected virgin compression curve for the sample. See figure 3-37 for an example.

Compression Index (C_c) = $C_{\epsilon c} (1+e_o) = -\Delta e/(\Delta \log \sigma'_{va}) = \Delta \epsilon / (\Delta \log \sigma'_{va})*(1+ e_o)$ This is the slope of line E (the corrected virgin compression curve for the sample) on the the void ratio vs. vertical stress graph. It is drawn by the same method as is used for the strain vs vertical stress graph shown in Figure 3-36. It should be noted that there are several empirical methods for estimating C_c as well:

Terzaghi and Peck (1967)	For Undisturbed Clays:	$\mathbf{C_c} = 0.009\ (LL - 10)$
Terzaghi and Peck (1967)	For Disturbed Clays:	$\mathbf{C_c} = 0.007\ (LL - 10)$
Rendon-Herrero (1983)	For Clays	$\mathbf{C_c} = 0.141 * G_s^{1.2}\ ((1+e_o)/G_s)^{2.38}$
Nagaraj and Murty (1985)	For Clays	$\mathbf{C_c} = 0.243\ (LL/100)*G_s$

Where: LL = Liquid Limit, G_s = Specific Gravity of Soil

Coefficient of Swell ($C_{\epsilon s}$) - also called the recompression index. This is the slope of the line along the rebound curve shown on the strain vs. vertical stress graph. It is generally much smaller in size than $\mathbf{C_{\epsilon c}}$**.** Usually $\mathbf{C_{\epsilon c}} \approx 1/5$ to $1/10\ C_{\epsilon c}$**.**

Coefficient of Consolidation (c_v) - This is a measure of the speed and magnitude that a soil will deform under load. This coefficient is generally smaller for soils with soils of higher liquid limit and larger for soils with smaller liquid limits. This value is calculated for different vertical pressures during the test and is presented on our test reports. See Figure 3-##. It is calculated by our automated system by the log root of time method using the following equation:

$c_v = 0.197*(H_{dr})^2/t_{50}$ for a particular vertical pressure (t_{50} may be different for different loads)

Where:

H_{dr} = the average longest drainage path during consolidation - for our test samples this is 1/2 the average height of the specimen during consolidation.

t_{50} = time it takes to get to 50% of primary consolidation. This is 1/2 the t_{100} shown on figure 3.34.

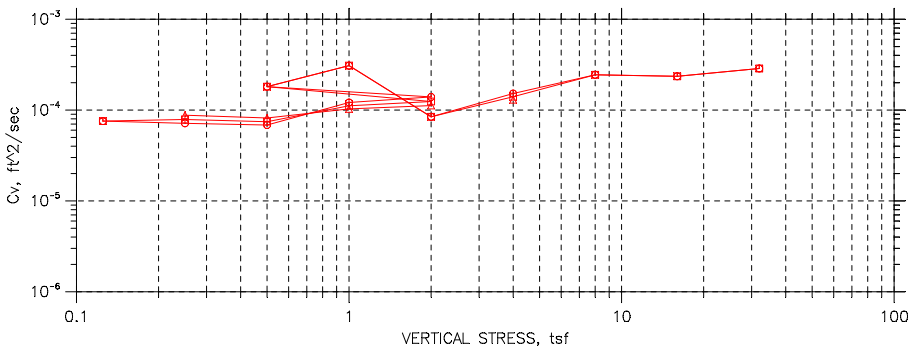


Figure 3.35. Graph on Test report of the coefficient of consolidation (c_v).

Cassagrande Method for Calculation of Preconsolidation Pressure - Please see Figure 3.36 for an illustration of this method on a TDOT test report.

A. Point of Maximum Curvature - Find the point of maximum curvature on the graph. This point can be thought of as the axis of a change of shape. Draw a point at this location.

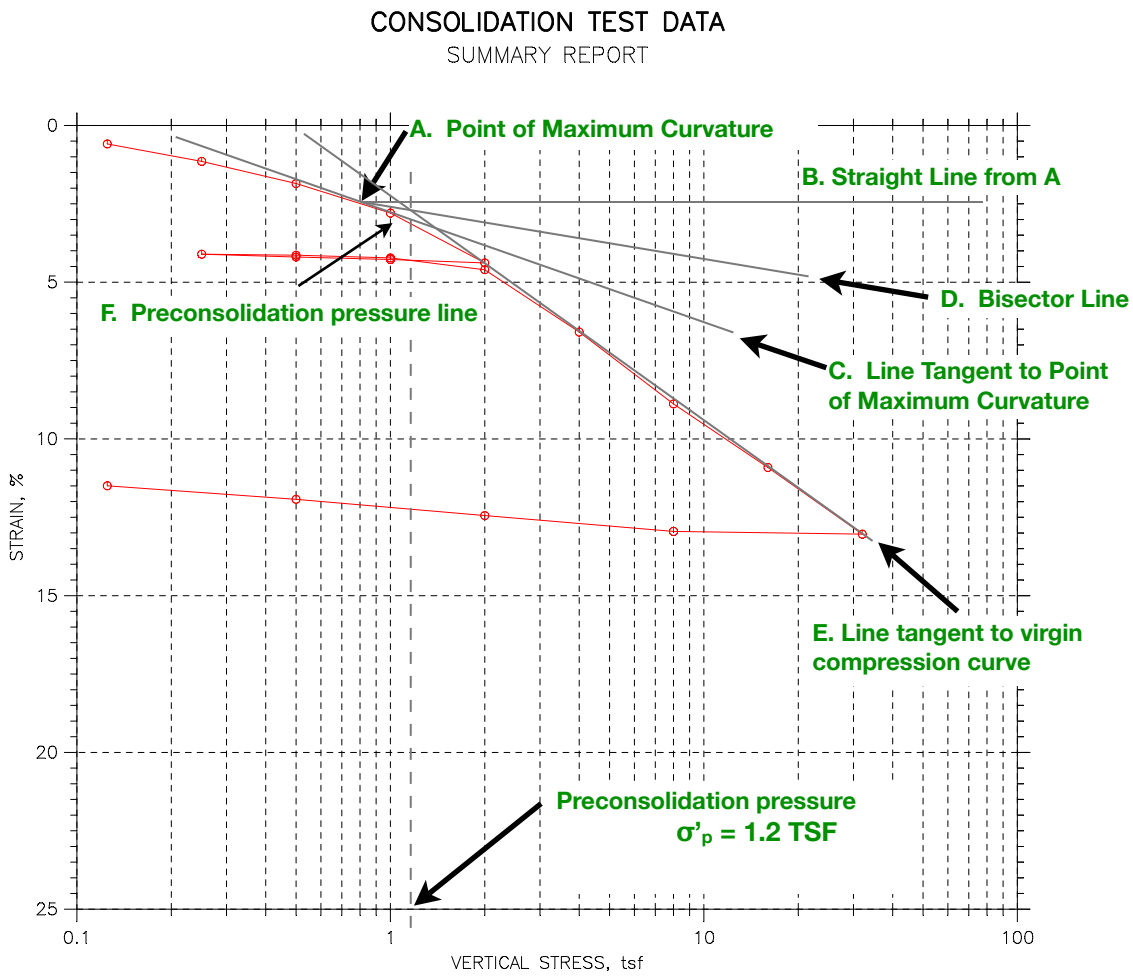
B. Straight Line from A - Draw a straight horizontal line from the point of maximum curvature (A).

C. Line Tangent to Point of Maximum Curvature - Draw a line that is tangent to the point of maximum curvature (A)

D. Bisector Line - Draw a line that goes through the point of maximum curvature (A) that bisects the angle made by lines B. and C.

E. Line Tangent to Virgin Compression Curve - Draw a line that is tangent to the virgin compression curve.

F. Preconsolidation Pressure Line - Locate the intersection between line E. and line D. Draw a straight vertical line down to the Vertical Stress axis. The preconsolidation pressure can then be read off of that axis.



Determined by Casagrande Method from Test Graph
Determines which settlement equation to use!

Estimated overburden pressure at depth where sample was taken

						Before Test	After Test
Test Data	Overburden Pressure: 0 tsf			Water Content, %	Test Data	20.41	18.59
	Preconsolidation Pressure: 1.2 TSF			Dry Unit Weight, pcf		102.5	115.8
	Compression Index: 0			Saturation, %		86.49	111.97
Soil Sample Data	Diameter: 2.45 in	Height: 0.95 in		Void Ratio		0.63	0.45
	LL: 29	PL: 19	PI: 10	GS: 2.68			
	Soil Sample Data						

e_0 = initial void ratio

Project: SHELBY	Location: 40'RT	Project No.: 7917203
Boring No.: HOLE 2	Tested By: RDJ	Checked By: RDJ
Sample No.: T 2	Test Date: 05-19-05	Depth: 27'-10'
Test No.: CON T2	Sample Type: Shelby Tube	Elevation: ---
Description: CLASSIFICATION A-4 GROUPNO 6		
Remarks: ASTM D2435, AASHTO T-216-02		

TN TDOT Department of Transportation

Tue, 24-MAY-2005 09:37:12

Figure 3-36. One Dimensional Consolidation Test Report: Estimating the Preconsolidation Pressure by Casagrande's Method

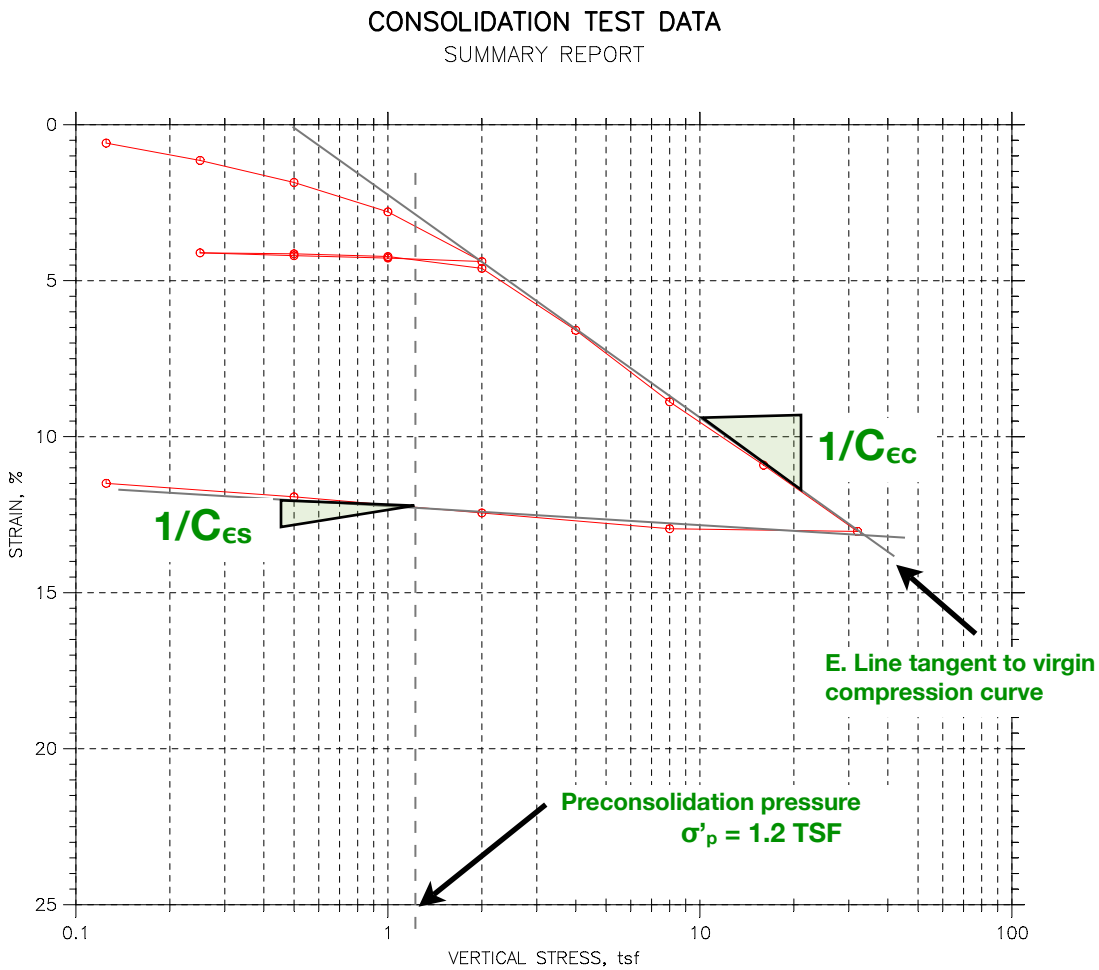


Figure 3-38. Modified Compression Index and Swell Index shown on Consolidation Test Results Graph (strain vs vertical pressure)

Please see Chapter ## for calculating settlement of layers out in the field using these test results.

Electrochemical Testing

pH (ASTM D 49720, G 51, AASHTO T 289)

Typically these tests are completed in order to provide Structures with information on the corrosion potential of soils in which friction piles will be installed. It provides a supplement to the resistivity test (described below) and it helps to identify soils and conditions where we can expect the corrosion of metal to accelerate. This is a test that is typically performed for all soils on West Tennessee Bridge Projects. It can be performed for tests of backfill used with metal strips in MSE Walls.

The sample of soil is mixed with distilled water and allowed to stabilize. The temperature is taken and a pH meter is used to determine the pH of the sample.

> **pH** - a measure of the acidity or alkalinity of a solution or material. A pH of 7 is considered neutral. pH < 7 would indicate acidity and pH > 7 indicates alkalinity.
>
> **Man hours per test** - 20 minutes

Resistivity (ASTM D 1125, G 57, AASHTO T 288)

Typically these tests are completed in order to provide Structures with information on the corrosion potential of soils in which friction piles will be installed. It provides a supplement to the pH test (described above) and it helps to identify soils and conditions where we can expect the corrosion of metal to accelerate. This is a test that is typically performed for all soils on West Tennessee Bridge Projects. It can be performed for tests of backfill used with metal strips in MSE Walls.

The sample of soil is mixed with distilled water and allowed to stabilize with a cure time of at least 12 hours. The soil is then placed in a soil box in layers and compacted with hand pressure. A meter is then used to measure the resistivity of the soil.

> **Resistivity** - reported in ohms x cm. The resistance in Ohms of a soil sample x the multiplying constant determined by the soil box and testing apparatus. Typical soil box setups as described in AASHTO T 288 gives 6.67 cm as the multiplying contastant.\
>
> **Man hours per sample** - 20 minutes, but soil sample has to have a minimum cure time of 12 hours once it is mixed with water.

Chemical Testing

Acid Based Accounting Testing (EPA 600/2-78-054, ASTM D 1757, D 2492)

This test is not normally performed by the TDOT soil or chemical laboratory. This is routinely given out to consultant in order to obtain test results. However, this testing is required for all rocks that will be exposed on a project that may contain potentially acid producing minerals. Pyrite and other sulfides can react with water, oxygen and a bacteria (Thiobacillus ferrooxidans) to product acid runoff. This generally occurs where

rock is blasted or excavated and the surface area of the potentially acid producing rock is greatly increased. Historically, this type of drainage has been associated with coal mining in Tennessee, particularly with strip mines. For certain condition

Neutralization Potential (NP) - Expressed in tons of Calcium Carbonate per 1000 tons of material. It is determined by reacting a 2 gram rock sample with an acid

Potential Acidity from total sulfur (AP) - Expressed in tons of Calcium Carbonate per 1000 tons of material.

Net Neutralization Potential / Calcium Carbonate Deficit (NNP) = NP - AP Expressed in tons of Calcium Carbonate per 1000 tons of material.

Fizz -
Paste pH -
Percent Sulfur -
Percent pyritic sulfur -

Chapter 4: Bearing Capacity Analysis

Shallow Foundations

Shallow Foundations on Soil

Shallow Foundations on Rock

Special Notes for Retaining Wall Foundations

Deep Foundations

Friction Piles

Driven Piles

Drilled Shafts

Chapter 5: Slope Stability Analysis

Chapter 6: Unstable Soils

Chapter 7: Sinkholes

Chapter 8: Rockfall

Chapter 9: Retaining Walls