Revised Subsurface Exploration
and Geotechnical Engineering Report
Roanoke County Greenway
East Roanoke River Greenway Connector

Roanoke County, Virginia
F&R Project No. 62W0288.2

Prepared For:
Roanoke County
1206 Kessler Mill Road
Salem, Virginia 24153

Prepared By:
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May 2020

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F&R Project No.: 62W0288.2

20 November 2018
Revised 1 May 2020

Roanoke County
1206 Kessler Mill Road
Salem, Virginia 24153

Attention: Ms. Lindsay B. Webb, MPA
Parks Planning and Development Manager

Subject: Subsurface Exploration and Geotechnical Reporting
East Roanoke River Greenway Connector
Under Blue Ridge Parkway
Pavement Design Recommendations
Roanoke County, Virginia

Dear Ms. Webb:

The purpose of this report is to present the results of the subsurface exploration program and geotechnical engineering analyses undertaken by Froehling & Robertson, Inc. (F&R) in connection with the above referenced project. The attached report presents our understanding of the project, reviews our exploration procedures, describes existing site and general subsurface conditions, and presents our evaluations, conclusions, and recommendations.

We have enjoyed working with you on this project. Please contact us if you have any questions regarding this report.

Sincerely,
FROEHLING & ROBERTSON, INC.

COMMONWEALTH OF VIRGINIA
STEPHEN D. HJELLE
Lic. No. 047697
PROFESSIONAL ENGINEER

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APPENDICES

1.0 INTRODUCTION

This report presents the results of the subsurface exploration program and geotechnical engineering analyses undertaken by Froehling & Robertson, Inc. (F&R) for the proposed trail improvements to the Roanoke River Greenway located in East Roanoke County, Virginia (see Site Vicinity Map, Drawing No. 1 in Appendix I). This portion of the Greenway will be located on and near Highland Road in the area where it extends under the Blue Ridge Parkway. Our understanding of the project is based on information provided by Mr. Christopher Burns, P.E. of Balzer and Associates, Inc. (Balzer) and our experience with similar projects. Overall improvements will reportedly include new multi-use path pavement, re-purposing at least a portion of Highland Road to a multi-use path on the existing Highland Road, and general supporting development. Limitations on the use of this report and the information provided within are discussed in Section 7.0 (Limitations).

2.0 PURPOSE & SCOPE OF SERVICES

The purpose of our subsurface exploration and testing program was to explore the subsurface conditions in the areas of the new multi-use path, and provide geotechnical engineering design and construction recommendations for the planned construction.

F&R's scope of services included the following:

- Visit the site to observe existing surface conditions. Roanoke County arranged for the marking of the boring locations;
- Coordinate utility clearance with Miss Utility services;
- Review readily available geologic information relative to the project site;
- Performance of a subsurface exploration program consisting of four (4) Standard Penetration Test (SPT) borings drilled to depths of 10 feet below the existing ground surface;
- Performance of a geotechnical laboratory testing program on selected samples;
- Preparation of typed boring logs;
- Performance of a geotechnical engineering evaluation of the subsurface conditions with regard to their general suitability for the proposed construction;
- Preparation of this geotechnical report.

Our scope of services did not include any borings for, or evaluation of, pedestrian bridges or retaining walls (MSE or otherwise). Nor did it include any borings for, or evaluation of, stormwater ponds. Our scope of services also did not include survey services, quantity estimates, preparation of plans or specifications, formal slope stability analyses, evaluations of earthquake motions, the identification and evaluation of wetlands or other environmental aspects of the project site, site civil design, environmental design, or erosion and sediment control design.

3.0 PROJECT INFORMATION

3.1 Project Description

We understand that as part of the Roanoke River Greenway in East Roanoke County, Virginia a 1,700 foot section of Greenway to the west will connect under the Blue Ridge Parkway. Recommendations regarding new pavement are needed in these areas. To this end, four additional SPT borings were requested at this Blue ridge Parkway Extension.

We were provided with plan sheet from you entitled, "*East Roanoke River Greenway Connector – Concept Plan – Option A, Sheet No. C3*", by Balzer and Associates, Inc., dated October 6, 2017 (filename: *ERRG Connector Boring Locations.pdf*) indicating the proposed development area and requested boring locations. Site grading information was included on this plan, however definitive elevations are not indicated, only topographic lines. Additional information was provided by you in a series of emails and telephone conversations.

The particular segment of new trail runs from station 10+00 to 27+67. We anticipate that the new trail will be a shared-use path. The trail will be accessible to pedestrian and bike traffic as well as light infrequent ATV or golf cart style maintenance traffic and infrequent emergency vehicles. No definitive traffic loading information has been provided at this time.

3.2 Site Description

The project site extends approximately 940 feet west and 540 feet east of Blue Ridge Parkway where it intersects Highland Road. The new trail and parking area are located directly north of Highland Road with the trail running parallel to the existing roadway. The trial crossing of Blue Ridge Parkway will utilize the existing underpass. Grades along the proposed trail alignment on the west side of Blue Ridge Parkway generally slope downward from south to north falling away from the existing Highland Road roadway. On the east side of Blue Ridge Parkway, site grades along the trail alignment generally increase from south to north, with site grades falling toward Highland Drive. To facilitate grade changes onsite, we anticipate that up to three constructed slopes may be required. No definitive slope cross sections have been provided at this time.

Ground cover across the site generally consists of brush and wooded areas. Based on observations of utility clearance at the site, no buried utilities are present in the project vicinity. However, overhead power lines were observed. Other undisclosed buried utilities may also be present onsite.

3.3 Regional Geology

The project site lies within the Blue Ridge geologic province of Virginia. Available geologic references report that the site is underlain by Middle Proterozoic-aged rocks. This formation is part of the Blue Ridge Basement Complex and is characterized by granulite and gneiss metamorphic rocks containing quartz.

The soils resulting from in-situ weathering of these rocks, without significant transportation, are called residual soils and may retain some of the structure of the parent rock from which they weathered. The residual soil profile generally grades downward gradually from fine-grained plastic soils near the ground surface to coarse-grained at greater depth. Intermediate geomaterial (IGM) is defined, for engineering purposes, as residual material with standard penetration resistances in excess of 100 blows per foot.

A transitional zone of partially weathered rock of varying thickness occurs between the coarse-grained residual soils and the underlying bedrock. Weathering of the parent bedrock is generally more rapid near fracture zones and therefore, the bedrock surface may be irregular. Irregular patterns of differential weathering may also result in zones of rock and IGM embedded within the more completely weathered residual soils.

4.0 EXPLORATION PROCEDURES

4.1 Soil Test Borings

F&R's exploration program for the trail improvements consisted of four (4) SPT borings, Borings 18R-01 through 18R-04, performed on 1 October 2018 and drilled to depths of 10 feet.

The boring locations were marked by others prior to our mobilization. The approximate locations of the borings are shown on the attached Boring Location Plan (Drawing No. 2, Appendix II). In consideration of the methods used in their determination, the boring locations shown on the attached Boring Location Plan should be considered approximate.

F&R's test borings were performed in accordance with generally accepted practice using a Terramac Diedrich D50 Turbo drill rig. Hollow-stem augers were advanced to pre-selected depths, the center plug was removed, and representative soil samples were recovered with a standard split-spoon sampler (1-3/8 in. ID, 2 in. OD) in general accordance with ASTM D 1586, the Standard Penetration Test. In this test, a weight of 140 pounds is freely dropped from a height of 30 inches to drive the split-spoon sampler into the soil. The number of blows required to drive the split-spoon sampler three consecutive 6-inch increments is recorded, and the blows of the last two increments are summed to obtain the Standard Penetration Resistance (N-value in blows per foot, bpf). The N-value provides a general indication of in-situ soil conditions and has been correlated with certain engineering properties of soils.

An automatic hammer was used to perform the Standard Penetration Test (SPT) on this project. Research has shown that the Standard Penetration Resistance (N-value) determined by an automatic hammer is different than the N-value determined by the safety hammer method. Most correlations that are published in the technical literature are based on the N-value determined by the safety hammer method. This is commonly termed N_{60} as the rope and cathead with a safety hammer delivers about 60 percent of the theoretical energy delivered by a 140-pound hammer falling 30 inches. Several researchers have proposed correction factors for the use of hammers other than the safety hammer to correct the values to be equivalent to the safety hammer SPT N_{60}-values. The correction is made using the following equation:

$$N_{60} = N_{field} \times C_E$$

N_{field} in the equation above is the SPT N-value as recorded with the equipment utilized in the field, and for our use of this equation, C_E a relative hammer efficiency ratio, i.e. our automatic hammer efficiency divided by the theoretical N_{60} efficiency (60%). Based on the calibrated efficiency of 85.6% for Terramac Diedrich D50 Turbo drill rig, a value of 1.43 should be used for C_E.

Representative portions of the split-spoon soil samples obtained throughout the exploration program were placed in glass jars and visually classified by F&R personnel in the field, in general accordance with VDOT Materials Division Manual of Instructions (Chapter 3). The samples were transported to our laboratories for further visual evaluation and selected laboratory testing.

Prior to demobilization, the boreholes were backfilled with auger cuttings. Periodic observation of the backfilled boring should be performed, as the boring backfill could settle over time resulting in subsidence of the ground around the borehole.

4.2 Laboratory Testing

Selected soil samples were tested in general accordance with applicable American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), and/or Virginia Test Method (VTM) standards. The soil tests presented in this report were performed by F&R's Roanoke AASHTO accredited laboratory. Results of the laboratory tests are summarized in the following tables and specific results of the gradation, Standard Proctor, and CBR, are provided in Appendix III. The number and types of tests performed as part of our exploration and testing program are provided below.

- Atterberg Limits (VTM 7 or ASTM D-4318) – 2 tests
- Natural Moisture Content (ASTM D2216) – 18 tests
- Mechanical Gradation Analysis of Soils (VTM-25 or ASTM D-422) – 1 test
- Standard Proctor (AASHTO T 99 Method A, Standard Virginia VTM-1 Corr. or ASTM D-698, Method A) – 2 tests
- California Bearing Ratio (VTM 8) – 1 test

4.2.1 Soil Classification Test Results

Two soil classification tests including Atterberg Limits and gradation tests were performed to evaluate the characteristics of the existing onsite soils. The following results from the testing are provided:

Table 1 – Soil Classification Test Results

Boring ID	Sample Depth (feet)	Sample Type	Moisture Content (%)	% Retained on the No. 4	% Finer than No. 200	Atterberg Limits			USCS/AASHTO Classification
						L.L.	P.L.	P.I.	
18R-01	0 -10	Bulk	29.2	6	39	36	19	17	Dark brown clayey SAND (SC)
18R-03	0 – 2	Jar	24.8	0	53	44	22	22	Red brown sandy lean CLAY (CL)
18R-04	0 - 10	Bulk	29.7	0	73	58	37	21	Red brown elastic SILT (MH) with sand

4.2.2 Natural Moisture Content Test Results

Twenty natural moisture content tests were performed on recovered split spoon samples. The results from the testing are provided below:

Table 2 – Natural Moisture Content Test Summary

Boring ID	Sample Depth (ft)	Natural Moisture Content (%)
18R-01	0 – 2	28.6
18R-01	2 – 4	21.4
18R-01	4 – 6	22.5
18R-01	6 – 8	17.9
18R-01	8 – 10	12
18R-02	0 – 2	16
18R-02	2 – 4	21.8
18R-02	4 – 6	18.1
18R-02	6 – 8	35.2
18R-02	8 – 10	38.4
18R-03	4 – 6	20.7
18R-03	6 – 8	17.7
18R-03	8 – 10	13.1
18R-03	4 – 6	12
18R-04	0 – 2	35.7
18R-04	2 – 4	31

18R-04	6 - 8	34.9
18R-04	8 - 10	39.2

4.2.3 California Bearing Ratio and Standard Proctor Test Results

One California Bearing Ratio (CBR) test and two Standard Proctor tests were performed on bulk samples to estimate engineering properties for use in trail and parking lot support evaluations. The results from the testing are provided below:

Table 3 – Standard Proctor, and CBR Test Summary

Boring ID	Sample Depth (ft)	Natural Moisture Content (%)	Optimum Moisture Content (%)	Maximum Dry Density (pcf)	CBR
18R-01*	0 - 10	29.2	14.7	116.3	11.7
18R-04	0 - 10	29.7	25.3	96.3	8.2

***Rock Corrected Results**

5.0 SUBSURFACE CONDITIONS

5.1 Subsurface Conditions

5.1.1 General

The subsurface conditions discussed in the following paragraphs and those shown on the attached Boring Logs represents an estimate of the subsurface conditions based on interpretation of the boring data using normally accepted geotechnical engineering judgments. The transitions between different soil strata are usually less distinct than those shown on the boring logs. Although individual soil test borings are representative of the subsurface conditions at the boring locations on the dates shown, they are not necessarily indicative of subsurface conditions at other locations or at other times. Sometimes the relatively small amount of material recovered in a sample does not allow for definitive origin definition. In these instances the term “Possible” is applied (i.e. possible alluvium, etc.). Data from the specific test borings are shown on the attached boring logs in Appendix II.

5.1.2 Existing Fill Materials

Existing fill materials include those materials deposited by man. Materials identified as existing fill were encountered in each of the borings, except Boring 18R-04, to depths ranging from approximately 3 to 4 feet below the existing ground surface. The fill soils generally consisted of clayey sand (SC) and fat clay (CH). Standard penetration resistance N_{60} values in the sampled fill ranged from 3 to 26 blows per foot (bpf).

5.1.3 Alluvial Soils

Possible alluvial soils, formed by the deposition of flowing waters, were encountered below fill materials in Boring 18R-01 at a depth of 4 feet below existing site grades. Sampled alluvial soils were generally described as clayey sand (SC). The N_{60} value within the sampled alluvium was 14 bpf.

5.1.4 Residual Soils

Materials identified as residual soil were encountered in each of the test borings. Sampled residual soils were generally described as silty sands (SM), clays (CH and CL), and silts (ML and MH). N_{60} values within the sampled residuum ranged from 6 to 79 bpf, typical values ranged from 10 to 41 bpf. Residual soils were encountered beneath existing fill materials and possible alluvial soils and extended through boring termination.

5.1.5 Subsurface Water

Groundwater was encountered during our drilling operations in Borings 18R-03 and 18R-04 at depths of 7.1 and 9 feet, respectively. No long term subsurface water measurements were taken.

6.0 DESIGN AND CONSTRUCTION RECOMMENDATIONS

6.1 General

The following evaluations and recommendations are based on our observations at the site, interpretation of the field and laboratory data obtained during this exploration, and our experience with similar subsurface conditions and projects. Soil penetration data has been used to evaluate proposed site development support. Subsurface conditions in unexplored locations may vary from those encountered. If the structure locations, loadings, or elevations are changed, we should be notified and requested to confirm and, if necessary, re-evaluate our recommendations.

Determination of an appropriate foundation system for a given structure is dependent on the proposed structural loads, soil conditions, and construction constraints such as proximity to other structures, etc. The subsurface exploration aids the geotechnical engineer in determining the soil stratum appropriate for structural support. This determination includes considerations with regard to both factored bearing resistances and compressibility of the soil strata. In addition, since the method of construction greatly affects the soils intended for structural support, consideration must be given to the implementation of suitable methods of site preparation, fill compaction, and other aspects of construction.

6.2 Shared Use Paths

We understand that the planned East Roanoke River Greenway Connector will include new sections of Shared Use Paths (Bike and Pedestrian). In general, we would anticipate these paths to follow typical VDOT design standard including minimum widths of 10 feet, 2 foot shoulders, and 3 foot clear zones. The exact level of service of the path has not been provided at this time.

We understand that you desire to utilize the following pavement section for paths that are asphalt surfaced.

Table 4 – Asphalt Surfaced Path Section

PATH SECTION		
LAYER	**VDOT SPECIFICATION**	**THICKNESS (INCHES)**
Surface Course	Asphalt Concrete (SM-9.5A)	2.0
Subbase Course	Type I Crushed Aggregate (No. 21A)	8.0

Based on our preliminary calculations, using assumed loading information, and our experience with similar projects, this asphalt surfaced path section should perform adequately for its intended purpose. Please see following sections for guidance regarding pavement design, drainage, and subgrade preparation.

6.3 Pavement

The thicknesses of the pavement section analyzed are directly related to the service life, the initial cost of placement, the preparation of the soil subgrade, and the method by which the granular base and the pavement are placed. We anticipate that the planned parking area will service automobile traffic (20 parking spaces cycling 10 times daily) and occasional heavy trash/disposal vehicle traffic (1 weekly). No definitive traffic loading information has been provided at this time. The following pavement section has been designed and evaluated using the *American Association of State Highway and Transportation Officials* (AASHTO) *Guide for Design of Pavement Structures* (1993). For our preliminary design purposes, we used the following flexible asphalt parameters:

Table 5 – Traffic Design Parameters

Design Parameter	East Roanoke River Greenway Parking
Design Life (years)	20
Initial Serviceability	4.2
Terminal Serviceability	2.9
Reliability (%)	90

Standard Deviation	0.49
ESALs	Standard Duty (2,808)
Drainage Coefficient	1

Once final traffic loads are available, F&R should be notified so that we can adjust our pavement design recommendations as necessary. Our preliminary pavement design has been based upon CBR value of 5.5 which is 2/3 of the average site soaked CBR value of 8.2 (laboratory determined). Subsequently, all final subgrades within the pavement area should be carefully evaluated by the geotechnical engineer for their suitability for pavement and/or new fill support. If encountered in pavement areas, any unsuitable materials should be undercut and either replaced with engineered fill or re-compacted fill. The following pavement design sections are recommended for new pavement construction.

Table 6 – Standard Pavement Section

PAVEMENT SECTION		STANDARD
LAYER	VDOT SPECIFICATION	THICKNESS (INCHES)
Surface Course	Asphalt Concrete (SM-9.5)	1.5
Base Course	Asphalt Concrete (IM-19)	2.0
Subbase Course	Type I Crushed Aggregate (No. 21A or 21B)	6.0

An important consideration with the design and construction of pavements is surface and subsurface drainage. Where standing water develops, softening of the subgrade and other problems related to the deterioration of the pavement can be expected. Furthermore, good drainage should minimize the possibility of the subgrade materials becoming saturated over a long time. We anticipate that the groundwater table will not significantly affect the performance of pavements; however, there is the possibility that water may accumulate at the base of the pavement section. This may occur through seasonal fluctuations of the groundwater table or through surface water seeping through the asphalt or penetrating through cracks, and accumulating within the recommended stone base layer on any underlying elastic silt or fat clay subgrades.

If the presence of water within the aggregate base layer is anticipated, edge drains (VDOT UD-4) could be used along both sides of the pavement section.

Surface runoff water that is trapped during construction on the exposed subgrade soils or that could later infiltrate through cracks in the asphalt could create localized deterioration of the soil's bearing capacity. Standing water that may develop on the surface of the pavement may be minimized by:

- adequate design (surface graded to control runoff to desired locations - catch basins, drain inlets, gutters, etc.);
- adequate compaction of each lift of pavement section component material (to minimize localized settlements that result in ponding);
- accurate grading of each lift of pavement section component material (to achieve the desired design grades and roadway crown);
- installing temporary weep holes in drainage structures, construction of drainage swales and diversion ditches and proper backfill and grading behind curbs to minimize water intrusion from behind the curbs.

6.4 Earthwork

Earthwork operations should be performed in accordance with VDOT Road and Bridge Specifications (specifically Section 303) and the VDOT *Special Provision for Section 303 – Earthwork*. Before proceeding with construction, any topsoil, roots, pavement, structure remnants, and other deleterious non-soil materials should be stripped or removed from the proposed construction area. During the clearing and stripping operations, positive surface drainage should be maintained to prevent the accumulation of water.

After stripping, all subgrades should be carefully evaluated by a geotechnical engineer, or a representative under the supervision of a geotechnical engineer. At that time, the engineer may require proofrolling of the subgrade that should be performed during a time of good weather and not while the site is wet, frozen, or severely desiccated. The purpose of the proofrolling is to locate soft/loose, weak, or excessively wet soils present at the time of construction and provides an opportunity for the geotechnical engineer to locate inconsistencies intermediate of our boring locations. If conditions warrant, the extent of undercutting and/or in place stabilization required can best be determined by the geotechnical engineer at the time of construction.

Unsuitable material for use as embankment fill and in cut areas for subgrade directly beneath pavements and bedding for minor structures is defined by VDOT as: soils with a Unified Soil Classification System (USCS) classification of CH or MH with LL>40 and PI>20, a California Bearing Ratio (CBR) of 2 or less and a swell greater than 5% as determined from CBR testing using VTM-8. Saturated and/or very loose to loose or very soft to soft soils that exhibit pumping or heaving during the above recommended proofrolling operation would also be considered unsuitable. Topsoil or other organic material are also considered unsuitable for use in embankment fills other than as cover for slopes for the purpose of establishing vegetative cover.

Controlled structural fill may be constructed using the non-organic on site soils. We recommend that structural fill be compacted to at least 95 percent of the Standard Proctor (AASHTO T 99) maximum dry density and that the moisture content be maintained within 20 percent of the optimum moisture content as determined from the Standard Proctor density test. Fill materials should be placed in horizontal lifts with maximum thickness of 8 inches loose measure, per Section 303.4 of the VDOT Specifications. New fill should be adequately keyed into stripped and scarified subgrade soils. During fill operations, positive surface drainage should be maintained to prevent the accumulation of water. In confined areas, such as utility trenches, portable compaction equipment and thin lifts of 3 to 4 inches may be required to achieve specified degrees of compaction.

Dense graded aggregate (VDOT 21A or 21B) placed as pavement base course should be compacted to 100 percent of maximum dry density per AASHTO T 99, Standard Proctor Method.

Generally, we do not anticipate significant problems controlling moistures within approved fill during periods of dry weather, but moisture control may be difficult during winter months or extended periods of rain. We recommend that the contractor have equipment on site during earthwork for both drying and wetting of fill soils. Attempts to work the soils when wet can be expected to result in deterioration of otherwise suitable soil conditions or of previously placed and properly compacted fill.

If construction traffic or weather has disturbed the subgrade, the upper 8 inches of soils intended for structural or pavement support should be scarified moisture controlled, if necessary, and re-compacted. Each lift of fill should be tested to confirm that the recommended degree of compaction is attained. In confined areas, a greater frequency may be required.

6.5 Groundwater Conditions

For the purposes of this report, groundwater is defined as water encountered below the existing ground surface. Based on the data obtained during our exploration program, we anticipate that water will be encountered below planned construction depths. However, the contractor should be prepared to dewater if conditions vary from those during our drilling operations. Fluctuations in subsurface water levels and soil moisture should be anticipated with changes in precipitation, run-off, and seasonal changes.

7.0 LIMITATIONS

There are important limitations to this and all geotechnical studies. Some of these limitations are discussed in the information prepared by GBA, which is included in Appendix IV. We ask that you please review this GBA information.

This report has been prepared for the exclusive use of Roanoke County and VDOT for specific application to the East Roanoke River Greenway Connector project in Roanoke County, Virginia, in accordance with generally accepted soil and foundation engineering practices. No other warranty, express or implied, is made. Our conclusions and recommendations are based on design information furnished to us, the data obtained from the previously described subsurface exploration program, and generally accepted geotechnical engineering practice. No claim is made as to the accuracy of the information contained in information provided by others.

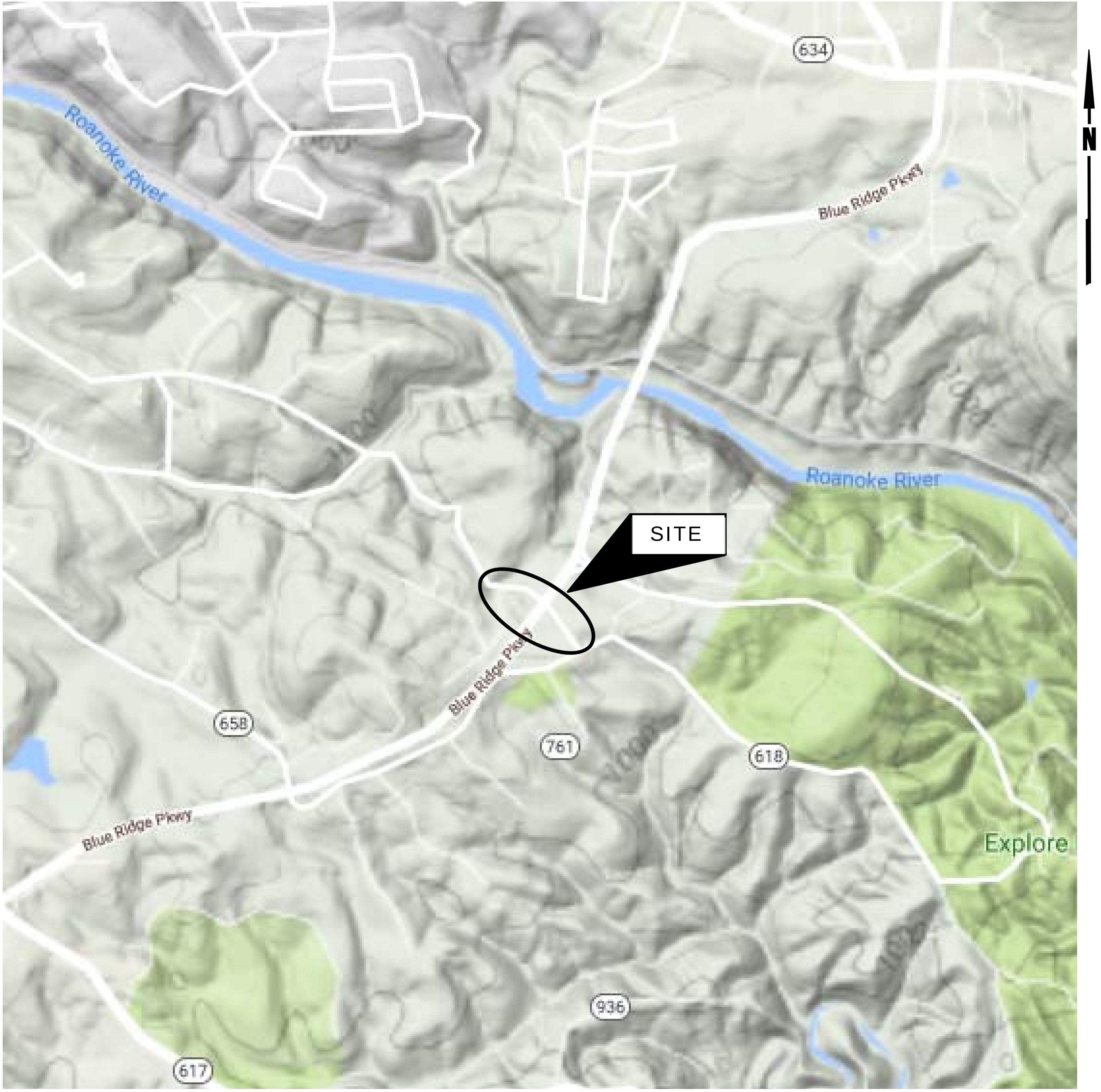
The subsurface conditions discussed in this report and those shown on the boring logs represent an estimate of the subsurface conditions based on interpretation of the boring data, using normally accepted geotechnical engineering judgments. The topsoil and soil information discussed in this report, and shown on the attached boring logs are generally based on visual observation and should be considered approximate. The transitions between different soil strata are usually less distinct than those shown on the boring logs. Although individual test borings are representative of the subsurface conditions at the boring locations on the dates shown, they are not necessarily indicative of subsurface conditions at other locations or at other times.

The conclusions and recommendations do not reflect variations in subsurface conditions that could exist intermediate of the boring locations or in unexplored areas of the site. Should such variations become apparent during construction, it will be necessary to re-evaluate our conclusions and recommendations based upon on-site observations of the conditions. Regardless of the thoroughness of a subsurface exploration, there is the possibility that conditions between borings will differ from those at the boring locations, that conditions are not as anticipated by the designers, or that the construction process has altered the soil conditions. Therefore, experienced geotechnical engineers should evaluate earthwork, pavement, and foundation construction to verify that the conditions anticipated in design actually exist. Otherwise, we assume no responsibility for construction compliance with the design concepts, specifications, or recommendations.

In the event that changes are made in the design or location of the proposed structure, the recommendations presented in the report shall not be considered valid unless the changes are reviewed by our firm and conclusions of this report modified and/or verified in writing. If this report is copied or transmitted to a third party, it must be copied or transmitted in its entirety, including text, attachments, and enclosures. Interpretations based on only a part of this report may not be valid. This report contains 13 pages of text and the attached appendices.

APPENDIX I

PROJECT SITE MAP



Adapted from *Google* imagery. No claim is made as to the accuracy of the indicated exploration location other than for conceptual purposes to illustrate the exploration location relative to existing site features, etc. In consideration of the methods used in their determination, as well as the base map's accuracy, the exploration location shown should be considered approximate.

FROEHLING & ROBERTSON, INC.
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DATE: October 2018
SCALE: As Shown (Approx.)
DRAWN: EKP 62W0288

Roanoke County
East Roanoke River Greenway Extension - Blue Ridge Pkwy
Roanoke County, Virginia

SITE
VICINITY
MAP

DRAWING NO.
1

APPENDIX II

SUBSURFACE EXPLORATION DATA

UNIFIED SOIL CLASSIFICATION SYSTEM

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS
(more than 50% of material is larger than No. 200 sieve size.)

	Clean Gravels (Less than 5% fines)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	▨	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	▨	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)		
	▨	GM	Silty gravels, gravel-sand-silt mixtures
	▨	GC	Clayey gravels, gravel-sand-clay mixtures
	Clean Sands (Less than 5% fines)		
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	▨	SW	Well-graded sands, gravelly sands, little or no fines
	▨	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)		
	▨	SM	Silty sands, sand-silt mixtures
	▨	SC	Clayey sands, sand-clay mixtures

FINE-GRAINED SOILS
(50% or more of material is smaller than No. 200 sieve size.)

SILTS AND CLAYS Liquid limit less than 50%	▨	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	▨	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	▨	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	▨	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	▨	CH	Inorganic clays of high plasticity, fat clays
	▨	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	▨	PT	Peat and other highly organic soils

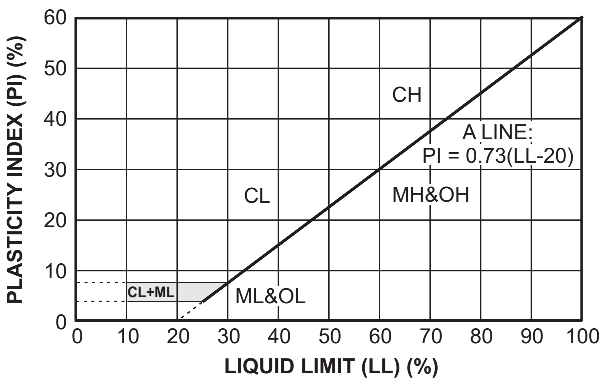
LABORATORY CLASSIFICATION CRITERIA

GW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with P.I. greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for GW	
SM	Atterberg limits below "A" line or P.I. less than 4	Limits plotting in shaded zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent	GW, GP, SW, SP
More than 12 percent	GM, GC, SM, SC
5 to 12 percent	Borderline cases requiring dual symbols

PLASTICITY CHART



Note: Adapted from provided site plan entitled "East Roanoke River Greenway Connector – Concept Plan – Option A, Sheet No. C3", by Balzer and Associates, Inc., dated October 6, 2017 (filename: *ERRG Connector Boring Locations.pdf*) and Google Imagery.

FROEHLING & ROBERTSON, INC.
Engineering Stability Since 1881
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Roanoke, Virginia 24012-5624 I USA
T 540.344.7939 I F 540.344.3657

DATE: November 2018
SCALE: Approx. As Shown
DRAWN: EKP
62W0288

Roanoke County
East Roanoke River Greenway Extension - Blue Ridge Pkwy
Roanoke County, Virginia

BORING
LOCATION
PLAN

DRAWING NO.
2

Virginia Department of Transportation

PROJECT #: UPC 113356
LOCATION: Roanoke County, VA
STRUCTURE: PATH

18R-01

PAGE 1 OF 1

STATION:
LATITUDE: 37.247446° N
SURFACE ELEVATION: ft

OFFSET:
LONGITUDE: 79.876787° W
COORD. DATUM: NAD 83

Date(s) Drilled: 10/1/18 - 10/1/18
Drilling Method(s): 2.25" ID HSA
SPT Method: Automatic Hammer
Other Test(s):
Driller: B. Maxson
Logger: M. Kiser

GROUND WATER
NOT ENCOUNTERED DURING DRILLING
NO LONG TERM MEASUREMENTS TAKEN

FIELD DATA			SOIL				ROCK						LAB DATA		
									DIP °						
N60	DEPTH (ft)	ELEVATION (ft)	STANDARD PENETRATION TEST HAMMER BLOWS	SOIL RECOVERY (%)	SAMPLE LEGEND	SAMPLE INTERVAL	CORE RECOVERY (%)	ROCK QUALITY DESIGNATION	STRATA	JOINTS	STRATA LEGEND	FIELD DESCRIPTION OF STRATA	LIQUID LIMIT LL	PLASTICITY INDEX PI	MOISTURE CONTENT (%)
7	0.5 1.0 1.5 2.0		1 2 3 2	88		2						0.0 / *Fill*, red-brown, fine, FAT CLAY FILL, trace gravel, contains mica, firm, moist **CH**			28.6
3	2.5 3.0 3.5 4.0		1 1 1 1	58		4						2.0 / *Fill*, red-brown and brown, fine to medium, CLAYEY SAND FILL, very loose, wet **SC**			21.4
14	4.5 5.0 5.5 6.0		1 3 7 4	65		6						4.0 / *Possible Alluvium*, gray with brown inclusions, fine to coarse, CLAYEY SAND, medium dense, with gravel, wet **SC**			22.5
41	6.5 7.0 7.5 8.0		9 14 15 24	71		8						6.0 / *Residual*, mottled brown, red, and gray, fine to coarse, SILTY SAND, with gravel, dense, moist **SM**			17.9
79	8.5 9.0 9.5 10.0		16 11 44 39	71		10						8.0 / *Residual*, mottled red-brown and gray, fine to coarse, SILTY SAND, with gravel, very dense, wet to moist **SM**			12.0
												Boring termination depth 10'			

REMARKS: Rig Type: Diedrich D50 Turbo.
Bulk sample taken from 0' - 10'
Above strata descriptions are based on N60 values (calculated from field blow counts and rig hammer efficiency of 85.6%).

PAGE 1 OF 1

18R-01

VDOT
Virginia Department of Transportation

PROJECT #: **UPC 113356**
LOCATION: **Roanoke County, VA**
STRUCTURE: **PATH**

18R-02

PAGE 1 OF 1

STATION:
OFFSET:
LATITUDE: 37.247444° N
LONGITUDE: 79.875865° W
SURFACE ELEVATION: ft
COORD. DATUM: NAD 83

Date(s) Drilled: 10/1/18 - 10/1/18
Drilling Method(s): 2.25" ID HSA
SPT Method: Automatic Hammer
Other Test(s):
Driller: B. Maxson
Logger: M. Kiser

GROUND WATER
NOT ENCOUNTERED DURING DRILLING
NO LONG TERM MEASUREMENTS TAKEN

FIELD DATA / LAB DATA

N60	DEPTH (ft)	ELEVATION (ft)	STANDARD PENETRATION TEST HAMMER BLOWS	SOIL RECOVERY (%)	SAMPLE LEGEND	SAMPLE INTERVAL	CORE RECOVERY (%)	ROCK QUALITY DESIGNATION	STRATA	JOINTS	STRATA LEGEND	FIELD DESCRIPTION OF STRATA	LIQUID LIMIT LL	PLASTICITY INDEX PI	MOISTURE CONTENT (%)
10	0.0 - 2.0		3 3 4 5	71	☒	2					▨	0.0 / *Fill*, brown, fine to coarse, CLAYEY SAND FILL, contains asphalt debris, medium dense, moist **SC**			16.0
26	2.0 - 4.0		5 8 10 24	92	☒	4					▨	2.0 / *Fill*, red-brown, brown, and white, fine to coarse, CLAYEY SAND FILL, contains rock fragments, medium dense, moist **SC**			21.8
40	4.0 - 6.0		7 14 14 14	96	☒	6					▒	4.0 / *Residual*, red-brown, brown, and white, fine to coarse, SILTY SAND, dense, moist **SM**			18.1
11	6.0 - 8.0		2 3 5 9	90	☒	8					▒	6.0 / *Residual*, mottled red-brown and gray, fine to medium, SILTY SAND, medium dense, moist **SM**			35.2
10	8.0 - 10.0		4 3 4 7	100	☒	10					▒	8.0 / *Residual*, mottled red-brown, brown, black, and gray, fine to medium, SILTY SAND, medium dense, moist **SM**			38.4

Boring termination depth 10'

REMARKS: Rig Type: Diedrich D50 Turbo.
Bulk sample taken from 0' - 10'
Above strata descriptions are based on N60 values (calculated from field blow counts and rig hammer efficiency of 85.6%).

PAGE 1 OF 1

18R-02

SPT_LOGA:62W-0288.GPJ:SPT7.GDT:gINT_version 8.30.003:11/12/18:Froehling & Robertson

Virginia Department of Transportation

PROJECT #: **UPC 113356**
LOCATION: **Roanoke County, VA**
STRUCTURE: **PATH**

18R-03

PAGE 1 OF 1

STATION:
OFFSET:
LATITUDE: 37.246927° N
LONGITUDE: 79.874759° W
SURFACE ELEVATION: ft
COORD. DATUM: NAD 83

Date(s) Drilled: 10/1/18 - 10/1/18
Drilling Method(s): 2.25" ID HSA
SPT Method: Automatic Hammer
Other Test(s):
Driller: B. Maxson
Logger: M. Kiser

GROUND WATER
⊻ FIRST ENCOUNTERED AT 7.1 ft DEPTH
NO LONG TERM MEASUREMENTS TAKEN

FIELD DATA / LAB DATA

N60	DEPTH (ft)	ELEVATION (ft)	SOIL: STANDARD PENETRATION TEST HAMMER BLOWS	SOIL: SOIL RECOVERY (%)	SAMPLE INTERVAL	ROCK: CORE RECOVERY (%)	ROCK: ROCK QUALITY DESIGNATION	ROCK: DIP °: STRATA	ROCK: DIP °: JOINTS	LIQUID LIMIT (LL)	PLASTICITY INDEX (PI)	MOISTURE CONTENT (%)	FINES CONTENT -#200 (%)
9	0.5 1.0 1.5 2.0		2 3 3 3	85	2					44	22	24.8	53.0
6	2.5 3.0 3.5 4.0		1 2 2 2	100	4							20.7	
11	4.5 5.0 5.5 6.0		3 3 5 6	94	6							17.7	
29	6.5 7.0 ⊻ 7.5 8.0		3 9 11 14	100	8							13.1	
37	8.5 9.0 9.5 10.0		6 11 15 19	100	10							12.0	

FIELD DESCRIPTION OF STRATA

0.0 /
Fill, red-brown, fine to medium, SANDY LEAN CLAY FILL, contains root material and mica, stiff, moist **CL**

3.0 /
Residual, mottled gray and brown, fine, SANDY LEAN CLAY, firm, wet, **CL**

4.0 /
Residual, mottled brown, red, and gray, fine, SANDY LEAN CLAY, stiff, wet to moist **CL**

6.0 /
Residual, mottled gray and brown, fine to medium, SILTY SAND, medium dense, moist **SM**

8.0 /
Residual, mottled gray and brown, fine to medium, SILTY SAND, dense, moist **SM**

Boring termination depth 10'

REMARKS: Rig Type: Diedrich D50 Turbo.
Bulk sample taken from 0' - 10'
Above strata descriptions are based on N60 values (calculated from field blow counts and rig hammer efficiency of 85.6%).

PAGE 1 OF 1

18R-03

SPT_LOGAB:62W-0288.GPJ:SPT7.GDT:gINT_version 8.30.003:11/12/18:Froehling & Robertson

Virginia Department of Transportation

PROJECT #: UPC 113356
LOCATION: Roanoke County, VA
STRUCTURE: PATH

18R-04

PAGE 1 OF 1

STATION:
OFFSET:
LATITUDE: 37.245848° N
LONGITUDE: 79.873505° W
SURFACE ELEVATION: ft
COORD. DATUM: NAD 83

Date(s) Drilled: 10/1/18 - 10/1/18
Drilling Method(s): 2.25" ID HSA
SPT Method: Automatic Hammer
Other Test(s):
Driller: B. Maxson
Logger: S. Hjelle

GROUND WATER
⊻ FIRST ENCOUNTERED AT 9.0 ft DEPTH
NO LONG TERM MEASUREMENTS TAKEN

FIELD DATA

N60	DEPTH (ft)	ELEVATION (ft)	SOIL: STANDARD PENETRATION TEST HAMMER BLOWS	SOIL: SOIL RECOVERY (%)	SAMPLE INTERVAL	ROCK: CORE RECOVERY (%)	ROCK: ROCK QUALITY DESIGNATION	ROCK: DIP °: STRATA	ROCK: DIP °: JOINTS	LAB DATA: LIQUID LIMIT LL	LAB DATA: PLASTICITY INDEX PI	LAB DATA: MOISTURE CONTENT (%)
9	0.5 1.0 1.5 2.0		2 3 3 4	83	2							35.7
21	2.5 3.0 3.5 4.0		3 9 6 9	96	4							31.0
13	4.5 5.0 5.5 6.0		4 4 5 6	92	6							
14	6.5 7.0 7.5 8.0		3 5 5 6	67	8							34.9
14	8.5 9.0 ⊻ 9.5 10.0		4 5 5 6	63	10							39.2

FIELD DESCRIPTION OF STRATA

0.0 /
Residual, red-brown, fine, ELASTIC SILT, with sand and root material, stiff, moist **MH**

2.0 /
Residual, orange-red brown, fine to medium, ELASTIC SILT, with sand, very stiff, moist **MH**

3.42 /
Residual, light orange-red brown, fine to medium, SANDY ELASTIC SILT, stiff, moist **MH**

5.5 /
Residual, yellow-orange brown with black striations, fine to medium, SANDY SILTY, stiff, moist **ML**

Boring termination depth 10'

REMARKS: Rig Type: Diedrich D50 Turbo.
Bulk sample taken from 0' - 10'
Above strata descriptions are based on N60 values (calculated from field blow counts and rig hammer efficiency of 85.6%).

APPENDIX III

LABORATORY TEST RESULTS

SINCE 1881

Froehling & Robertson, Inc.

LABORATORY TEST SUMMARY SHEET

Sheet: 1 of 1

Project No: 62W-0288

Client: Roanoke County Parks & Recreation

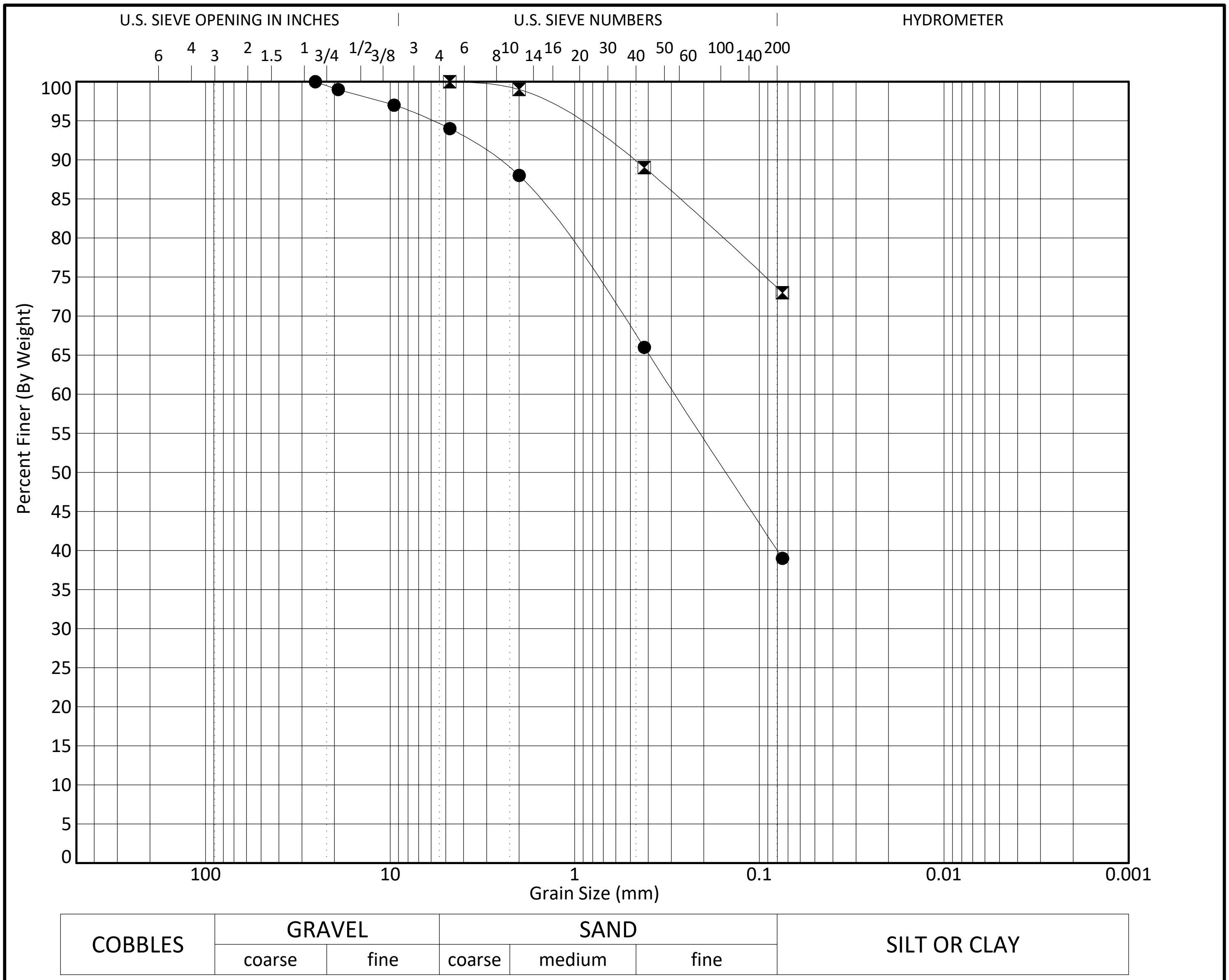
Project: East Roanoke River Greenway Expansion - Blue Ridge Parkway (UPC 113356)

City/State: Roanoke County, VA

Boring/ Sample No.	Depth (ft)	LL	PL	PI	Water Content (%)	% Gravel	% Sand	% Fines	USCS Class.	AASHTO Class.	Maximum Dry Density (pcf)	Optimum Water Content (%)	CBR Value
18R-01	0.0 - 2.0				28.6								
18R-01	0.0 - 10.0	36	19	17	29.2	6.0	55.0	39.0	SC	A-6	116.3	14.7	11.7
18R-01	2.0 - 4.0				21.4								
18R-01	4.0 - 6.0				22.5								
18R-01	6.0 - 8.0				17.9								
18R-01	8.0 - 10.0				12.0								
18R-02	0.0 - 2.0				16.0								
18R-02	2.0 - 4.0				21.8								
18R-02	4.0 - 6.0				18.1								
18R-02	6.0 - 8.0				35.2								
18R-02	8.0 - 10.0				38.4								
18R-03	0.0 - 2.0	44	22	22	24.8	0.0	47.0	53.0	CL	A-7-6			
18R-03	2.0 - 4.0				20.7								
18R-03	4.0 - 6.0				17.7								
18R-03	6.0 - 8.0				13.1								
18R-03	8.0 - 10.0				12.0								
18R-04	0.0 - 2.0				35.7								
18R-04	0.0 - 10.0	58	37	21	29.7	0.0	27.0	73.0	MH	A-7-5	96.3	25.3	8.2
18R-04	2.0 - 4.0				31.0								
18R-04	4.0 - 6.0												
18R-04	6.0 - 8.0				34.9								
18R-04	8.0 - 10.0				39.2								

GRAIN SIZE DISTRIBUTION

Project No: 62W-0288
Client: Roanoke County Parks & Recreation
Project: East Roanoke River Greenway Expansion - Blue Ridge Parkway (UPC 113356)
City/State: Roanoke County, VA



Boring No.			Depth	Classification	LL	PL	PI	Cc	Cu
●	18R-01	at	0.0	CLAYEY SAND (SC)	36	19	17		
⧗	18R-04	at	0.0	ELASTIC SILT with SAND (MH)	58	37	21		
		at							
		at							
		at							

Boring No.			Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	18R-01	at	0.0	25.4	0.286			6.0	55.0	39.0	
⧗	18R-04	at	0.0	4.75				0.0	27.0	73.0	
		at									
		at									
		at									

Froehling & Robertson, Inc.

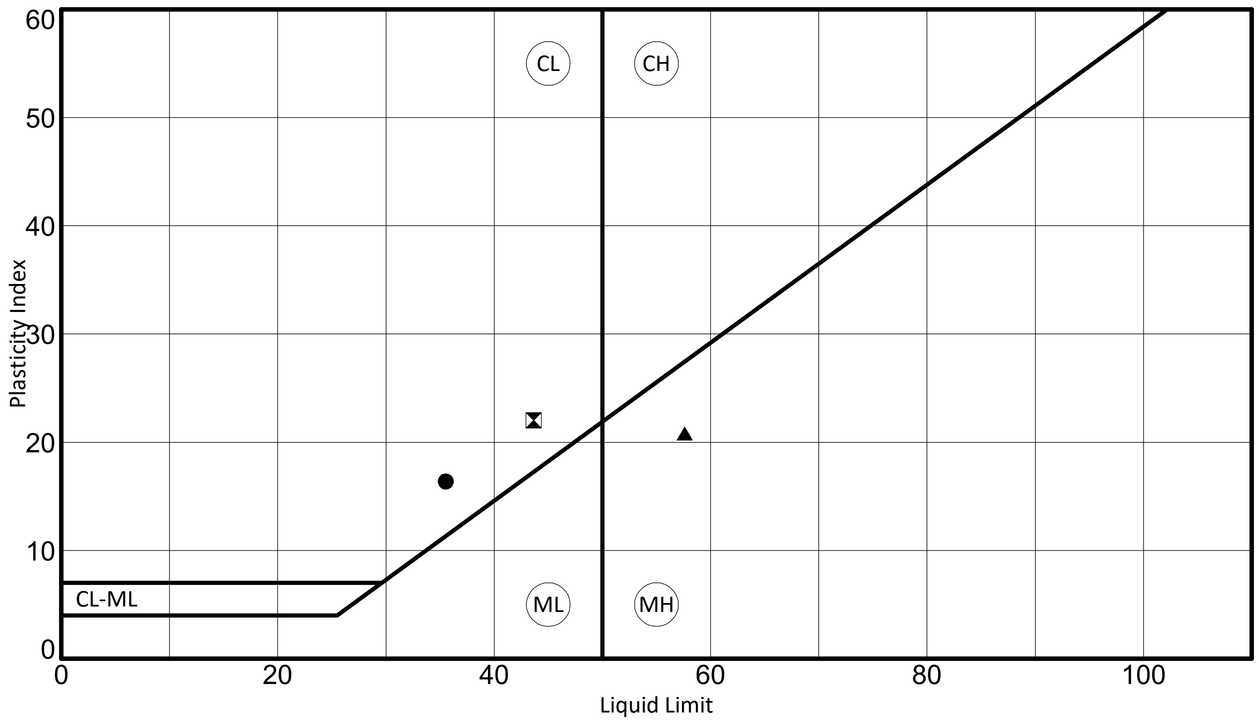
ATTERBERG LIMITS

Project No: 62W-0288

Client: Roanoke County Parks & Recreation

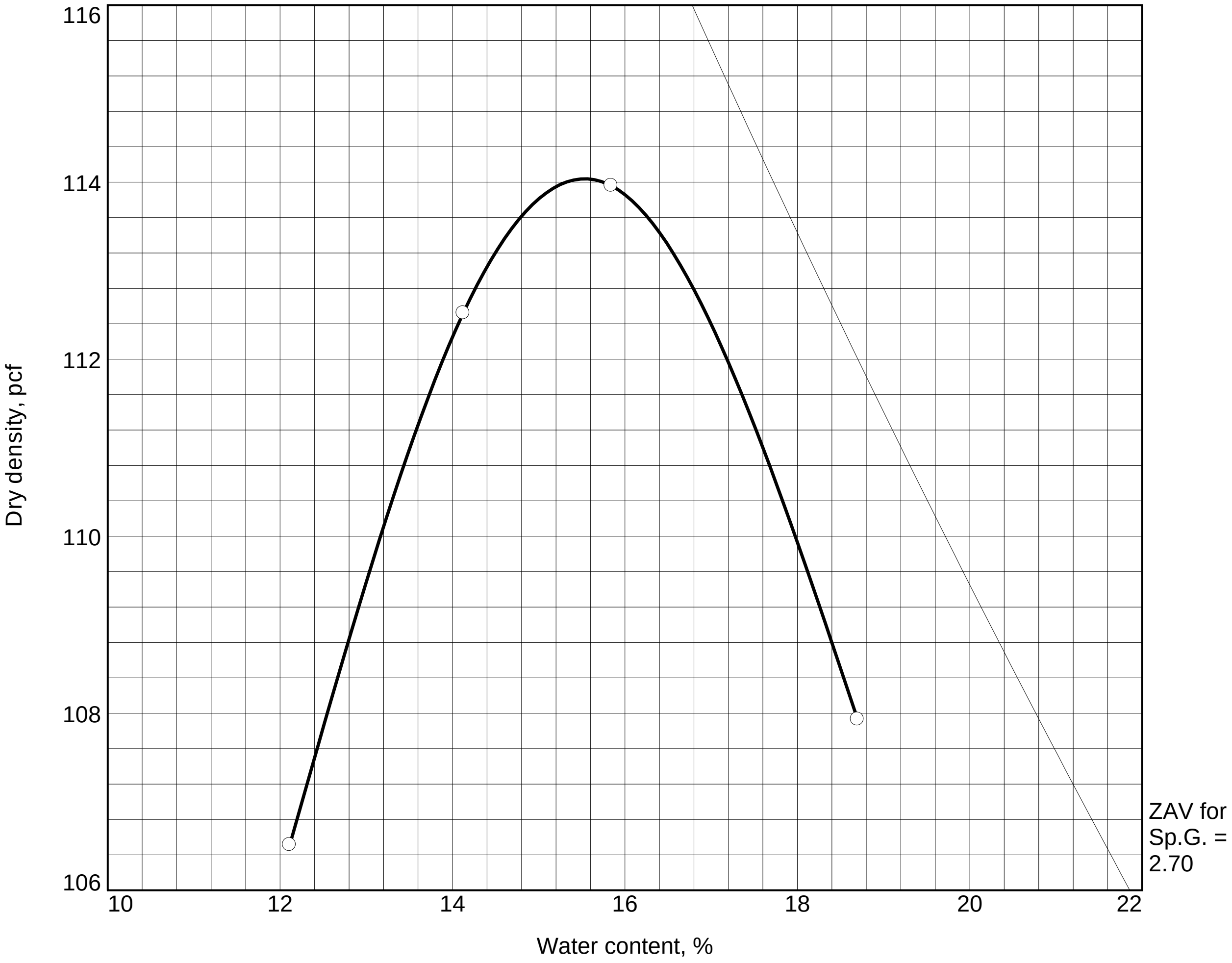
Project: East Roanoke River Greenway Expansion - Blue Ridge Parkway (UPC 113356)

City/State: Roanoke County, VA



Boring No.		Depth	LL	PL	PI	Fines	Classification	% Natural Water Content
●	18R-01	at 0.0	36	19	17	39	CLAYEY SAND (SC),{A-6}	29.2
☒	18R-03	at 0.0	44	22	22	53	SANDY LEAN CLAY (CL),{A-7-6}	24.8
▲	18R-04	at 0.0	58	37	21	73	ELASTIC SILT with SAND (MH),{A-7-5}	29.7

MOISTURE DENSITY RELATIONSHIP



Test specification: VTM-1, Std. VTM correction

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > #4	% < No.200
	USCS	AASHTO						
0'-10'	SC	--	29.2	--	36	17	6	39

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 114.0 pcf Optimum moisture = 15.5 %	Dark brown clayey SAND (SC)

Project No. 62W-0288 **Client:** Roanoke County Parks & Recreation

Project: East Roanoke River Greenway Extension Blue Ridge Parkway

○**Source of Sample: 18R-01**, 0'-10' **Sample Number:** 128708

FROEHLING & ROBERTSON, INC.

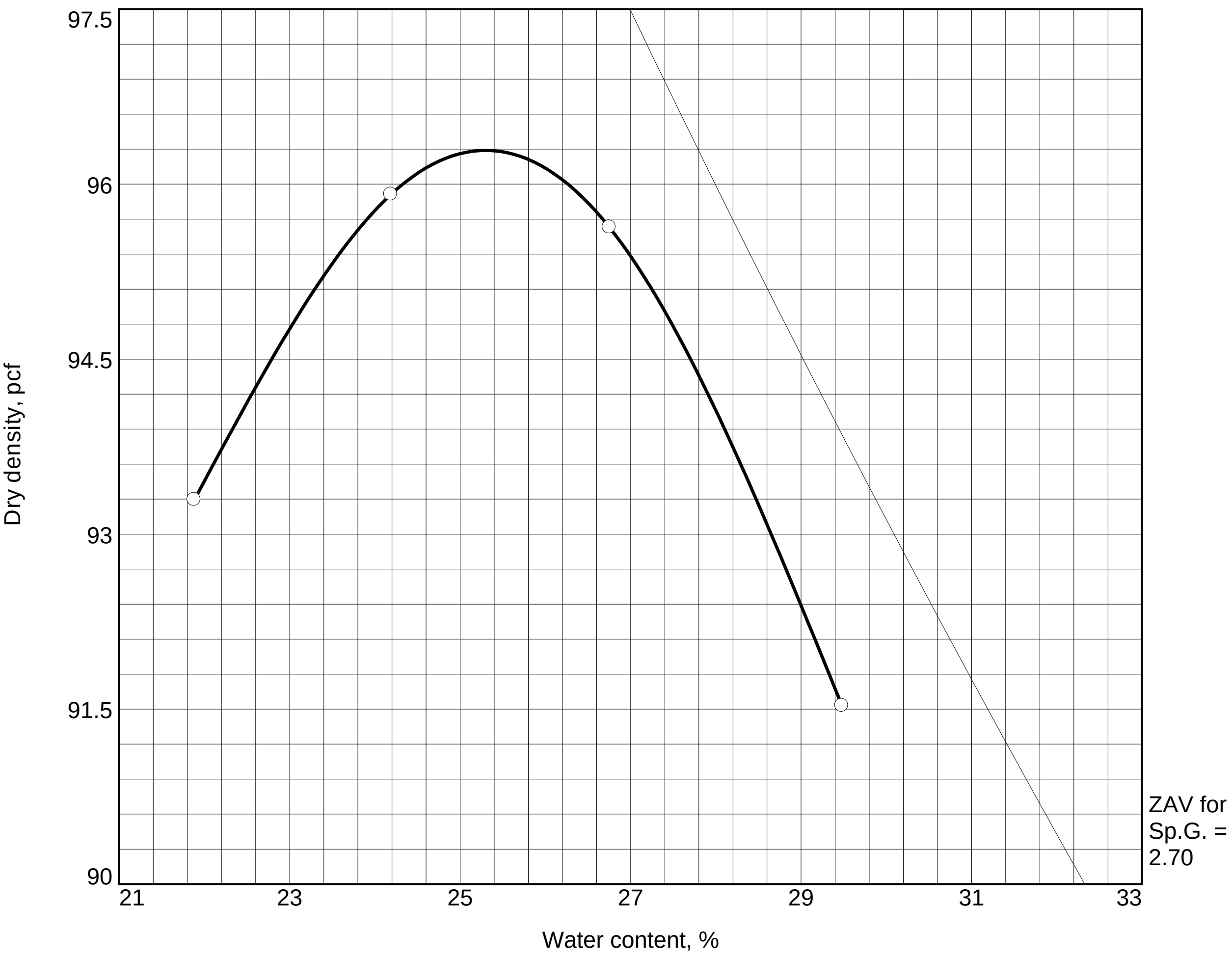
Remarks:

October 18, 2018

Est. Sp. Gr. of +No.4: 2.2

Sp. gr. for ZAV is an assumed value.

MOISTURE DENSITY RELATIONSHIP



Test specification: VTM-1, Std. VTM correction

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > #4	% < No.200
	USCS	AASHTO						
0'-10'	MH	--	29.7	--	58	21	0	73

TEST RESULTS	MATERIAL DESCRIPTION
Maximum dry density = 96.3 pcf Optimum moisture = 25.3 %	Reddish Brown elastic SILT with sand

Project No. 62W-0288 **Client:** Roanoke County Parks & Recreation

Project: East Roanoke River Greenway Extension Blue Ridge Parkway

○**Source of Sample: 18R-04,** 0'-10' **Sample Number:** 128709

FROEHLING & ROBERTSON, INC.

Remarks:

October 16, 2018

No estimated Sp. Gr. of +No. 4 (No +4 mat'l. in sample)

Sp. gr. for ZAV is an assumed value.

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California Bearing Ratio (VTM-8)

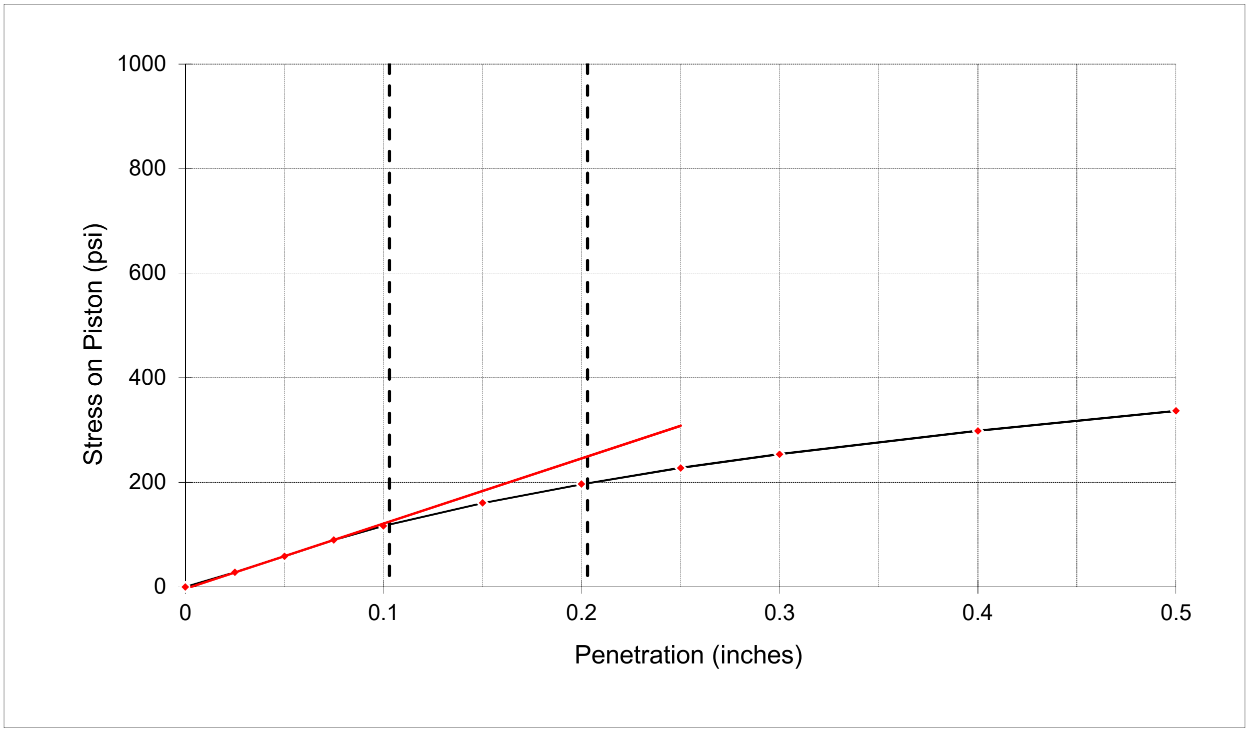
Record No.: 62W-0288

Test Date: October 29, 2018

Client: Roanoke County Parks & Rec.
Project: E Roanoke River Greenway Ext. BR Pkway

Proctor Compaction Method: VTM-1

X **Soaked CBR**
___ **Unsoaked CBR**



CBR: penetration @ 0.1 in. 11.7

Swell (%): 0.3%

Dry Density Before Soaking (pcf): 114.2

Dry Density as Percentage of Maximum Dry Density: 98.2%

Percentage of +No. 4 in sample 6

Surcharge Weight (lb): 10

Moisture Content Before Soaking (%): 14.6%

Maximum Dry Density (pcf): 116.3
Optimum Moisture Content (%): 14.7

Visual Description:
Dark brown clayey SAND (SC)

F&R Lab No.: 128708

Source: 18R-01, 0'-10'

FROEHLING & ROBERTSON, INC.

Performed By: M. Henry

FROEHLING & ROBERTSON, INC.
Engineering Stability Since 1881
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Roanoke, Virginia 24012
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California Bearing Ratio (VTM-8)

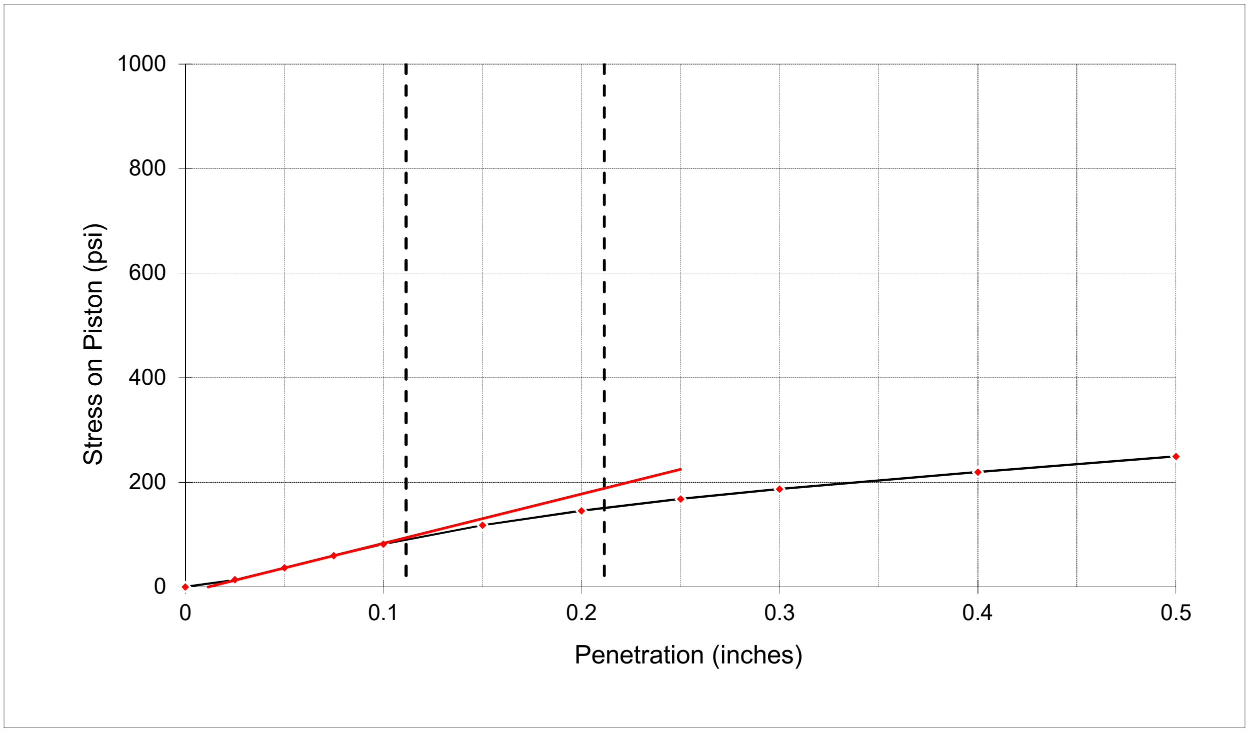
Record No.: 62W-0288

Test Date: October 19, 2018

Client: Roanoke County Parks & Rec.
Project: E Roanoke River Greenway Ext. BR Pkway

Proctor Compaction Method: VTM-1

X **Soaked CBR**
____ **Unsoaked CBR**



CBR: penetration @ 0.1 in.: 8.2

Swell (%): 0.6%

Dry Density Before Soaking (pcf): 96.3

Dry Density as Percentage of Maximum Dry Density: 100.0%

Percentage of +No. 4 in sample: 0

Surcharge Weight (lb): 10

Moisture Content Before Soaking (%): 26.0%

Maximum Dry Density (pcf): 96.3
Optimum Moisture Content (%): 25.3

Visual Description:
Red brown elastic SILT with sand (MH)

F&R Lab No.: 128709

Source: 18R-04, 0'-10'

FROEHLING & ROBERTSON, INC.

Performed By: M. Henry

APPENDIX IV

GBA PUBLICATION

Important Information about This

Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

The Geoprofessional Business Association (GBA) has prepared this advisory to help you – assumedly a client representative – interpret and apply this geotechnical-engineering report as effectively as possible. In that way, clients can benefit from a lowered exposure to the subsurface problems that, for decades, have been a principal cause of construction delays, cost overruns, claims, and disputes. If you have questions or want more information about any of the issues discussed below, contact your GBA-member geotechnical engineer. Active involvement in the Geoprofessional Business Association exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project.

Geotechnical-Engineering Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical-engineering study conducted for a given civil engineer will not likely meet the needs of a civil-works constructor or even a different civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client. *Those who rely on a geotechnical-engineering report prepared for a different client can be seriously misled.* No one except authorized client representatives should rely on this geotechnical-engineering report without first conferring with the geotechnical engineer who prepared it. *And no one – not even you – should apply this report for any purpose or project except the one originally contemplated.*

Read this Report in Full

Costly problems have occurred because those relying on a geotechnical-engineering report did not read it *in its entirety*. Do not rely on an executive summary. Do not read selected elements only. *Read this report in full.*

You Need to Inform Your Geotechnical Engineer about Change

Your geotechnical engineer considered unique, project-specific factors when designing the study behind this report and developing the confirmation-dependent recommendations the report conveys. A few typical factors include:

- the client's goals, objectives, budget, schedule, and risk-management preferences;
- the general nature of the structure involved, its size, configuration, and performance criteria;
- the structure's location and orientation on the site; and
- other planned or existing site improvements, such as retaining walls, access roads, parking lots, and underground utilities.

Typical changes that could erode the reliability of this report include those that affect:

- the site's size or shape;
- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light-industrial plant to a refrigerated warehouse;
- the elevation, configuration, location, orientation, or weight of the proposed structure;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes – even minor ones – and request an assessment of their impact. *The geotechnical engineer who prepared this report cannot accept responsibility or liability for problems that arise because the geotechnical engineer was not informed about developments the engineer otherwise would have considered.*

This Report May Not Be Reliable

Do not rely on this report if your geotechnical engineer prepared it:

- for a different client;
- for a different project;
- for a different site (that may or may not include all or a portion of the original site); or
- before important events occurred at the site or adjacent to it; e.g., man-made events like construction or environmental remediation, or natural events like floods, droughts, earthquakes, or groundwater fluctuations.

Note, too, that it could be unwise to rely on a geotechnical-engineering report whose reliability may have been affected by the passage of time, because of factors like changed subsurface conditions; new or modified codes, standards, or regulations; or new techniques or tools. *If your geotechnical engineer has not indicated an "apply-by" date on the report, ask what it should be*, and, in general, *if you are the least bit uncertain* about the continued reliability of this report, contact your geotechnical engineer before applying it. A minor amount of additional testing or analysis – if any is required at all – could prevent major problems.

Most of the "Findings" Related in This Report Are Professional Opinions

Before construction begins, geotechnical engineers explore a site's subsurface through various sampling and testing procedures. *Geotechnical engineers can observe actual subsurface conditions only at those specific locations where sampling and testing were performed.* The data derived from that sampling and testing were reviewed by your geotechnical engineer, who then applied professional judgment to form opinions about subsurface conditions throughout the site. Actual sitewide-subsurface conditions may differ – maybe significantly – from those indicated in this report. Confront that risk by retaining your geotechnical engineer to serve on the design team from project start to project finish, so the individual can provide informed guidance quickly, whenever needed.

This Report's Recommendations Are Confirmation-Dependent

The recommendations included in this report – including any options or alternatives – are confirmation-dependent. In other words, *they are not final*, because the geotechnical engineer who developed them relied heavily on judgment and opinion to do so. Your geotechnical engineer can finalize the recommendations *only after observing actual subsurface conditions* revealed during construction. If through observation your geotechnical engineer confirms that the conditions assumed to exist actually do exist, the recommendations can be relied upon, assuming no other changes have occurred. *The geotechnical engineer who prepared this report cannot assume responsibility or liability for confirmation-dependent recommendations if you fail to retain that engineer to perform construction observation.*

This Report Could Be Misinterpreted

Other design professionals' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer serve as a full-time member of the design team, to:

- confer with other design-team members,
- help develop specifications,
- review pertinent elements of other design professionals' plans and specifications, and
- be on hand quickly whenever geotechnical-engineering guidance is needed.

You should also confront the risk of constructors misinterpreting this report. Do so by retaining your geotechnical engineer to participate in prebid and preconstruction conferences and to perform construction observation.

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can shift unanticipated-subsurface-conditions liability to constructors by limiting the information they provide for bid preparation. To help prevent the costly, contentious problems this practice has caused, include the complete geotechnical-engineering report, along with any attachments or appendices, with your contract documents, *but be certain to note conspicuously that you've included the material for informational purposes only*. To avoid misunderstanding, you may also want to note that "informational purposes" means constructors have no right to rely on the interpretations, opinions, conclusions, or recommendations in the report, but they may rely on the factual data relative to the specific times, locations, and depths/elevations referenced. Be certain that constructors know they may learn about specific project requirements, including options selected from the report, *only* from the design drawings and specifications. Remind constructors that they may perform their own studies if they want to, and *be sure to allow enough time* to permit them to do so. Only then might you be in a position to give constructors the information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions. Conducting prebid and preconstruction conferences can also be valuable in this respect.

Read Responsibility Provisions Closely

Some client representatives, design professionals, and constructors do not realize that geotechnical engineering is far less exact than other engineering disciplines. That lack of understanding has nurtured unrealistic expectations that have resulted in disappointments, delays, cost overruns, claims, and disputes. To confront that risk, geotechnical engineers commonly include explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely*. Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The personnel, equipment, and techniques used to perform an environmental study – e.g., a "phase-one" or "phase-two" environmental site assessment – differ significantly from those used to perform a geotechnical-engineering study. For that reason, a geotechnical-engineering report does not usually relate any environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated subsurface environmental problems have led to project failures*. If you have not yet obtained your own environmental information, ask your geotechnical consultant for risk-management guidance. As a general rule, *do not rely on an environmental report prepared for a different client, site, or project, or that is more than six months old.*

Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

While your geotechnical engineer may have addressed groundwater, water infiltration, or similar issues in this report, none of the engineer's services were designed, conducted, or intended to prevent uncontrolled migration of moisture – including water vapor – from the soil through building slabs and walls and into the building interior, where it can cause mold growth and material-performance deficiencies. Accordingly, ***proper implementation of the geotechnical engineer's recommendations will not of itself be sufficient to prevent moisture infiltration.*** Confront the risk of moisture infiltration by including building-envelope or mold specialists on the design team. ***Geotechnical engineers are not building-envelope or mold specialists.***

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