# FINAL REPORT
# STRUCTURE FOUNDATION EXPLORATION
# BRIDGE OVER TOUSSAINT CREEK
# OTT-51-03.85
# OTTOWA COUNTY, OHIO

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**NEAS PROJECT 22-0027**

**November 8, 2022**

## EXECUTIVE SUMMARY

The proposed project includes the design and replacement of the existing the bridge over Toussaint Creek on SR-51 as the proposed project OTT-51-03.85 (PID 80032) 2 miles southeast of the village of Genoa, Ottawa County, Ohio. National Engineering and Architectural Services Inc. (NEAS) has been contracted to perform geotechnical engineering services to supplement the design of the proposed bridge. The purpose of the geotechnical engineering services was to perform geotechnical explorations within the project limits to obtain information concerning the subsurface soil and groundwater conditions relevant to the design and construction of the project.

The subsequent document presents the results of a structure foundation exploration with respect to the proposed construction of the bridge over Toussaint Creek on SR-51. As part of the exploration, NEAS advanced two structure borings, designated B-001-0-21 and B-002-0-21, to a depth of approximately 52.5 feet below the existing ground surface at the rear and forward abutments of the referenced bridge and conducted laboratory testing of collected samples to characterize the soils for engineering purposes. The proposed bridge is a single span bridge with new composite reinforced concrete deck on new integral reinforced concrete abutments with HP pile foundations. The new bridge will be approximately 40 feet wide and 75 feet long.

The subsurface profile at the bridge site is generally consistent with the geological model for the project in regard to the materials encountered. The subsurface profile at the bridge site generally consists of eighteen- to nineteen-inch-thick existing pavement section (asphalt and granular base) underlain by primarily cohesive silty-clay till with minor non-cohesive gravel and stone fragments with sand. Bedrock was encountered within depths of both the borings performed.

Subgrade analyses were performed for the referenced project site to evaluate the soil characteristics for use in pavement design. Unstable subgrade conditions that may require some form of subgrade stabilization within the subgrade per GB1 guidelines were encountered within the project site. The subgrade conditions encountered along SR-51 alignment within the project limits include areas of weak soils and high moisture content soils. Therefore, we recommend spot stabilization in the form of Excavate and Replace (Item 204 with Geotextile) be performed.

Based on the project proposed cross-sections, sidehill fills will be required for the right side embankment slopes at both sides of the bridge. A special benching scheme similar to that shown in Figure 1 of the ODOT GB2 should be used in areas where special benching is recommended. The height and width dimensions of the special benching scheme shown in the figure should be arranged to minimize the required cut and fill quantities, though the height of a single bench shall not exceed 20 ft without a stability analysis and design per OSHA requirements. Additionally, it may be appropriate to adjust the bench slope shown from a 1H:1V to a 1.5H:1V slope since the existing slope is made up of Type C materials. The benched material should be replaced with compacted engineered fill per Item 203 of the ODOT CMS, while proper lift thicknesses and material density should be maintained in the proposed fill per Item 203.06 of the ODOT CMS.

Bridge analyses of deep foundation systems were performed for the two substructure locations for the bridge based on the developed soil profiles at the referenced boring locations. The driven pile foundation system at the proposed substructures will consist of HP steel piles driven to refusal on bedrock. The factored resistance for piles driven to refusal on bedrock is typically governed by structural resistance as opposed to driving resistance for friction piles. Based on our analysis, the deep foundation system will consist of end bearing piles and it is our opinion they will be seated on dolomite bedrock at the approximate elevations of between 568.4 ft and 568.2 ft amsl. Based on the email from Prime AE Group dated November 8, 2022, the scour will not pass through the first layer of the soils at the creek bottom. Therefore, HP piles at both abutments will penetrate at least greater than 15-ft below the maximum estimated scour depth.

Settlement analysis was performed for the proposed rear abutment behind which there will be about 11.8 feet of new embankment fill. Based on our analysis the ground surface at the rear abutment is estimated to experience about 3.5 inches of immediate settlement and 5.6 inches of long-term (consolidation) settlement from the induced loads associated with the 11.8-ft high embankment. The immediate settlement is expected to take place during construction prior to bridge loading and is not anticipated to be a concern; however, ninety percent (90%) of the long-term settlement will take place 260 days following embankment construction. Since the embankment fill above the rear abutment footing (less than 2 ft wide) will be carried by the rear abutment, the surcharge loads will then be transferred from the abutment to the piles; therefore, it is our opinion that the piles will not be subjected to downdrag loads. However, the proposed rear approach slab will experience the above estimated settlement without ground improvement.

Global stability was performed for the proposed bridge abutments for long-term (Effective Stress) and short-term (Total Stress) slope stability. Based on our slope stability analyses for the referenced abutment locations, the minimum slope stability safety factors for short-term (Total Stress) and long-term (Effective Stress) conditions exceeded the desired value of 1.54. It is our opinion that the subsurface conditions encountered at the project site are generally satisfactory and the site can be considered to be stable at short-term and long-term condition.

A seismic site class was also determined at the overall bridge site, in which a Seismic Site Class of E is recommended.

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# 1. INTRODUCTION

## 1.1. General

NEAS presents our Structure Foundation Exploration Report to supplement the design and replacement of the existing bridge carrying SR-51 over Toussaint Creek as the proposed project OTT-51-03.85 (PID 80032) 2 miles southeast of the village of Genoa, Ottawa County, Ohio. This report presents a summary of the encountered surficial and subsurface conditions and our recommendations for bridge foundation design and construction in accordance with Load and Resistance Factor Design (LRFD) method as set forth in AASHTO's Publication *LRFD Bridge Design Specifications, 9th Edition* with 2020 interim revisions (BDS) (AASHTO, 2020) and *ODOT's 2022 LRFD Bridge Design Manual* (BDM) (ODOT, 2022).

The exploration was conducted in general accordance with Barr Engineering, Inc.'s DBA NEAS, Inc. proposal to Prime AE Group, Inc., dated November 24, 2021 and with the provisions of ODOT's *Specifications for Geotechnical Explorations* (SGE) (ODOT, 2022). With respect to the proposed bridge replacement project, two structure borings, designated B-001-0-21 and B-002-0-21, were drilled to depths of approximately 52.5 feet below the existing ground surface at the rear and forward abutments of the referenced bridge.

The scope of work performed by NEAS as the referenced project included: a review of published geotechnical information; performing 2 total test borings; laboratory testing of soil samples in accordance with the SGE; performing geotechnical engineering analysis to assess foundation design and construction considerations; and development of this summary report.

## 1.2. Proposed Construction

The proposed project consists of the replacement of the bridge over Toussaint Creek on SR-51. The existing bridge is a two-span steel multibeam bridge on full height abutments and a wall type pier. The proposed bridge is a single span bridge with reinforced concrete deck on semi-integral abutments on HP piles driven to refusal on bedrock.

# 2. GEOLOGY AND OBSERVATIONS OF THE PROJECT

## 2.1. Geology and Physiography

The project site lies in the Woodville Lake-Plain Reefs, which is a very low relief lacustrine plain with low dunes and lake-margin features, punctuated by more than 75 ancient bedrock reefs rising 10 feet to 40 feet above the level of the plain and ranging in area from 0.1 to 3.0 square miles. The oblong reefs are thinly draped with drift. The elevation of this region is at the elevation of 600 feet to 775 feet. The till in this region is described as thin to absent Wisconsinan-age wave-planed clay till, lacustrine deposits and sand over Silurian-age reefal Lockport dolomite (ODGS, 1998).

The geology at the project site is mapped as an average of 10 ft of Holocene-age alluvium underlain by an average of 40 ft of Wisconsinan-age silty clay till, all underlain by Silurian-age Dolomite bedrock (ODGS, 2005). The alluvium is described as including a wide variety of textures from silt and clay to boulders; commonly containing organics and generally not compact. The silty clay till is described as unsorted mix of silt, clay, sand, gravel, and boulders with high carbonate content, may contain silt, sand, and gravel lenses and is very sparsely pebbly. Joints/fractures are common. Differentiated from other till units by having a higher clay content. Silty clay till at depth may include unspecified till units of various lithologies and may include clay and silt beds.

Based on the Bedrock Geologic Units Map of Ohio (USGS & ODGS, 2006), bedrock within the project area consists of Dolomite, of the Lockport Dolomite formation. This formation is comprised of Silurian-age Dolomite. The Dolomite found in this formation is described as shades of white to medium gray in color, medium to massive bedded, fine to coarse crystalline, fossiliferous, and vuggy. The bedrock appears to follow the natural topography of the site which is relatively flat (ODGS, 2003). Based on the ODNR bedrock topography map of Ohio, bedrock elevations at the project site can be expected at about 560 ft amsl, putting bedrock at depths ranging from about 35 ft below ground surface (bgs) to about 40 ft below ground surface (bgs).

The soils at the project site have been mapped (Web Soil Survey) by the Natural Resources Conservation Service (USDA, 2015) as primarily Genesee silt loam. Soils in the Genesee series are characterized as very deep, well drained soils formed in loamy alluvium on flood plains. The Genesee series is comprised of primarily fine-grained soils and classifies as A-4 and A-6 type soils according to the AASHTO method of soil classification.

## 2.2. Hydrology/Hydrogeology

Groundwater at the project site can be expected at an elevation consistent with that of the nearby Toussaint Creek as it is the most dominant hydraulic influence in the vicinity of the project's boundaries. The water level of the Toussaint Creek may be generally representative of the local groundwater table. However, it should be noted that perched groundwater systems may be existent in areas due to the presence of fine-grained soils making it difficult for groundwater to permeate to the phreatic surface.

The project site is located within a regulatory floodway (Zone AE) based on available mapping by the Federal Emergency Management Agency's (FEMA) National Flood Hazard mapping program (FEMA, 2016).

## 2.3. Mining and Oil/Gas Production

One active surface mine (ID# IM-0292) is noted on ODNR's Mines of Ohio Locator about 1.25 miles west of the project site (ODNR [1], 2022).

No oil or gas wells are noted on ODNR's Ohio Oil & Gas Locator in the vicinity of the project site (ODNR [2], 2020).

## 2.4. Historical Records and Previous Phases of Project Exploration

No reports/plans were available for review or evaluation for this report for estimating bedrock elevation according ODOT's Transportation Information Mapping System (TIMS)., therefore; historic borings are not referenced within this report nor within the bridge specific project developed Structure Foundation Exploration Sheets.

## 2.5. Site Reconnaissance

A field reconnaissance visit for the bridge carrying SR-51 over Toussaint Creek was conducted on May 10, 2022, approximately 2 miles southeast of the village of Genoa in Ottawa County, Ohio. During our field reconnaissance, site conditions were noted and photographed. Land use at the project site can be described as a combination of woodland, agricultural and residential.

The existing bridge carrying SR-51 over Toussaint Creek is a two-span, steel multi-beam bridge with one lane of traffic in each direction on a concrete deck with an asphalt wearing course (Photograph 1). The bridge sits atop full height concrete abutments and a concrete wall type pier with concrete wingwalls. Foundation type was unknown at the time of the site visit. The roadway embankment slopes at the site, generally appeared to be stable with no signs of instability observed during our site visit. The existing roadway embankments appeared to be at about a 2 Horizontal to 1 Vertical (2H:1V) slope and were lightly vegetated. Overall, the bridge appeared to be in fair condition with wear and degradation observed on the bridge superstructure and substructure. Heavy corrosion and section loss was observed in the mid-span beam ends and the intersecting stringers (Photograph 2). The midspan expansion joint seal was observed to have failed. The area around the bearing seats of both abutments were observed to have cracking, efflorescence and heavily spalling with exposed corroded rebar (Photograph 3). The southeastern abutment was observed to have a large crack running almost the full height of the abutment on the western end (Photograph 4). A large drainpipe was observed to be running through the northwestern abutment (Photograph 5). The central pier was observed to have cracking and spalling with exposed rebar that was concentrated around the bearing seats and was noted to be especially deteriorated at the eastern end (Photograph 6). Retaining walls were observed past the western ends of both abutments. The retaining wall just past the southeastern abutment was observed to be in markedly worse condition (heavy cracking, spalling and disintegration) (Photograph 7) than the retaining wall just past the northwestern abutment (cracking and light spalling) (Photograph 8). The underside of the bridge deck was observed to be in good condition with the only signs of distress being cracking, spalling and exposed rebar near the guardrail connections. Heavy scour was not observed at the abutments or pier, however the level of the Toussaint Creek made ascertaining the amount of scour difficult. No apparent signs of structural distress of the bridge due to geotechnical concerns were observed during our field reconnaissance visit.

In general, the existing bridge structure appeared to be well drained with no signs of significant erosion at the bridge site. Some erosion of the creek banks was observed west of the existing bridge. The asphalt wearing course was observed to be in poor condition with signs of surface wear. The area around the expansion joints was noted as being especially distressed. Longitudinal and transverse cracking was common in the asphalt wearing course as well as map cracking, raveling, potholing, patching, and crack sealing deficiencies (Photograph 9). Water was directed directly off of either side of the roadway and bridge deck. No signs of standing water were observed.

Photograph 1: Steel Multi-Beam Superstructure of Bridge

Photograph 2: Corrosion and Section Loss at Mid-Span Beam Ends and Stringers

Photograph 3: Heavy Spalling and Exposed Rebar at Southeastern Abutment Bearing Seats

Photograph 4: Large Crack in Southeastern Abutment

Photograph 5: Drainage Pipe Running Through Northwestern Abutment

Photograph 6: Spalling and Exposed Rebar at Eastern End of Pier

Photograph 7: Retaining Wall Connected to the Southeastern Abutment

Photograph 8: Retaining Wall Connected to the Northwestern Abutment

Photograph 9: Asphalt Wearing Course

# 3. EXPLORATION

## 3.1. Field Exploration Program

The exploration for proposed bridge was conducted by NEAS between June 1, 2022 and June 3, 2022 and included 2 structure borings drilled to a depth of 52.5 ft bgs. The boring locations were selected by NEAS in general accordance with the guidelines contained in the SGE with the intent to evaluate subsurface soil and groundwater conditions. Borings were typically located near the substructure of the proposed bridge in locations that were not restricted by maintenance of traffic, underground utilities or dictated by terrain (i.e. steep embankment slopes). Each as-drilled project boring location and corresponding ground surface elevation was surveyed in the field by NEAS (project surveyor) following completion. Each individual project boring log (included within Appendix B) includes the recorded boring latitude and longitude location (based on the surveyed Ohio State Plane North, NAD83, location) and the corresponding ground surface elevation. Elevations of the borings are shown on Table 1 below.

Table 1: Project Boring Summary

| Boring Number | Location (Sta/offset) | Latitude | Longitude | Elevation (NAVD 88) (ft) | Depth (ft) | Substructure |
|---|---|---|---|---|---|---|
| B-001-0-21 | Sta. 102+78, 14' RT | 41.506050 | -83.320695 | 608.9 | 52.5 | Rear Abutment |
| B-002-0-21 | Sta. 104+02, 14' LT | 41.506289 | -83.321032 | 608.7 | 52.5 | Forward Abutment |

Structure borings were drilled using a CME 55X truck mounted drilling rig utilizing 3.25-inch diameter hollow stem augers. In general, soil samples were recovered continuously to a depth of 7.5 ft bgs, then at intervals of 2.5-ft to a depth of 31.5 ft bgs and at 5.0-ft intervals thereafter using a split spoon sampler (AASHTO T-206 "Standard Method for Penetration Test and Split Barrel Sampling of Soils."). Both borings encountered bedrock and were advanced for sampling using an NQ2-seris core barrel, water circulation method. The soil samples obtained from the exploration program were visually observed in the field by the NEAS field representative and preserved for review by a Geologist and possible laboratory testing. Standard penetration tests (SPT) were conducted using a CME auto hammer that has been calibrated to be 79% efficient (indicated on the boring logs) on January 24, 2022.

Field /boring logs were prepared by drilling personnel, and included lithological description, SPT results recorded as blows per 6-inch increment of penetration and estimated unconfined shear strength values on specimens exhibiting cohesion (using a hand-penetrometer). Groundwater level observations were recorded both during and after the completion of drilling. These groundwater level observations are included on the individual boring logs. After completing the borings, the boreholes were backfilled with either auger cuttings, bentonite chips, or a combination of these materials.

## 3.2. Laboratory Testing Program

The laboratory testing program consisted of classification testing and moisture content determinations. Data from the laboratory-testing program were incorporated onto the boring logs (Appendix B). Soil samples are retained at the laboratory until ODOT Stage 2 approval, after which time they will be discarded.

### *3.2.1. Classification Testing*

Representative soil samples were selected for index properties (Atterberg Limits) and gradation testing for classification purposes on approximately 59% of the samples. At each boring location, samples were selected for testing with the intent of identification and classification of all significant soil units. Soils not selected for testing were compared to laboratory tested samples/strata and classified visually. Moisture content testing was conducted on all samples. The laboratory testing was performed in general accordance with applicable AASHTO specifications.

A final classification of the soil strata was made in accordance with AASHTO M-145 “Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes,” as modified by ODOT “Classification of Soils” once laboratory test results became available. The results of the soil classification are presented on the boring logs provided in Appendix B.

### *3.2.2. Standard Penetration Test Results*

Standard Penetration Tests (SPT) and split-barrel (commonly known as split-spoon) sampling of soils were performed at varying intervals (i.e., 2.5-ft or 5.0-ft intervals) in the project borings performed. To account for the high efficiency (automatic) hammers used during SPT sampling, field SPT N-values were converted based on the calibrated efficiency (energy ratio) of the specific drill rig's hammer. Field N-values were converted to an equivalent rod energy of 60% ($N_{60}$) for use in analysis or for correlation purposes. The resulting $N_{60}$ values are presented on the boring logs provided in Appendix B.

### *3.2.3. $D_{50}$ values for Scour Evaluation*

Grain size distribution testing was performed on the obtained streambed samples to develop $D_{50}$ values (i.e., the diameter in the particle-size distribution curve corresponding to 50% finer). Scour critical shear stress and erosion category were determined based upon the equations found in section 1302 of the Geotechnical Design Manual. The calculated $D_{50}$ values as well as the scour critical shear stress and erosion category are shown in Table 2 below and the developed particle-size distribution curves are included with the associated boring logs within Appendix B.

Table 2: Scour Analysis Parameters

| Boring Number | Specimen Elevation (ft) | ODOT (Modified AASHTO) ~ USCS Classification | D50 (mm) | Scour Critical Shear Stress, $\tau_c$ (psf) | Erosion Category (EC) |
|---|---|---|---|---|---|
| B-001-0-21 | 590.9' - 588.9' | A-6a ~ Sandy Lean Clay (CL) | 0.014 | 0.156 | 3.255 |
| | 588.9' - 587.4' | A-4a ~ Lean Clay with Sand (CL) | 0.012 | 0.387 | 2.754 |
| | 587.4' - 585.9' | A-6a ~ Lean Clay with Sand (CL) | 0.010 | 0.751 | 3.255 |
| | 585.9' - 584.4' | A-6a ~ Lean Clay with Sand (CL) | 0.005 | 0.821 | 3.337 |
| B-002-0-21 | 590.7' - 589.2' | A-1-b ~ Silty Sand with Gravel (SM) | 1.011 | 0.021 | 2.206 |
| | 589.2' - 587.7' | A-6a ~ Lean Clay with Sand (CL) | 0.010 | 0.693 | 3.337 |
| | 587.7' - 586.2' | A-4a ~ Sandy Lean Clay (CL) | 0.005 | 0.966 | 3.550 |
| | 586.2' - 584.7' | A-4a ~ Sandy Lean Clay (CL) | 0.032 | 0.403 | 2.868 |

# 4. FINDINGS

The subsurface conditions encountered during NEAS's explorations are described in the following subsections and on each boring log presented in Appendix B. The boring logs represent NEAS's interpretation of the subsurface conditions encountered at each boring location based on our site observations, field logs, visual review of the soil samples by NEAS's geologist, and laboratory test results. The lines designating the interfaces between various soil strata on the boring logs represent the approximate interface location; the actual transition between strata may be gradual and indistinct. The subsurface soil and groundwater characterizations included herein, including summary test data, are based on the subsurface findings from the geotechnical explorations performed by NEAS as part of the referenced project, and consideration of the geological history of the site.

## 4.1. Subsurface Conditions

The subsurface profile at the bridge site is generally consistent with the geological model for the project in regard to the materials encountered. The subsurface profile at the bridge site generally consists of eighteen- to nineteen-inch-thick existing pavement section (asphalt and granular base) underlain by primarily cohesive silty-clay till with minor non-cohesive gravel and stone fragments with sand. Bedrock was encountered within depths of both the borings performed.

### *4.1.1. Overburden Soil*

At the proposed bridge site, the soils encountered below the pavement section comprised of primarily cohesive silty-clay till to a depth of 36.5 ft bgs (elevation 572 ft asml). The exception that a thin layer of non-cohesive soil classified as Stone Fragments with Sand (A-1-b) was encountered at the depths between 17.4 ft bgs and 19.5 ft bgs (elevations 591.3 ft and 589.2 ft asml, respectively). Below the silty-clay till, a four feet thick granular soil classified as Stone Fragments with Sand (A-1-b) were encountered in both borings.

The cohesive natural silty-clay till encountered are classified on the borings logs as Sandy Silt (A-4a), Silt and Clay (A-6a), Silty Clay (A-6b) and Clay (A-7-6). The soils of this stratum can be described as having a medium stiff to hard consistency based on $N_{60}$ values between 4 and 68 and unconfined compressive strengths (estimated by means of hand penetrometer) between approximately 1.0 and 4.5 ton per square foot (tsf). Natural moisture contents of the cohesive silty-clay till ranged from 10 to 28 percent in moisture. Based on Atterberg Limits test performed on representative samples of the natural till soils, the liquid and plastic limits ranged from 20 to 46 percent and 13 to 23 percent, respectively.

The non-cohesive soils in this stratum are classified on the boring logs as Gravel and Stone Fragments with Sand (A-1-b). These non-cohesive soils are described as very loose to medium dense in compactness correlating to $N_{60}$ values between 3 and greater than 50. The majority natural moisture content of the outwash stratum ranged from 6 to 8 percent.

### *4.1.2. Groundwater*

Groundwater measurements were taken during the boring drilling procedures and immediately following the completion of each borehole. Groundwater was encountered during drilling and after drilling in both bridge borings (see Table 3). Based on these borings, groundwater was encountered between depths of 20.0 and 18.0 ft bgs (elevations 588.9 ft and 590.7 ft amsl, respectively).

It should be noted that groundwater is affected by many hydrologic characteristics in the area and may vary from those measured at the time of the exploration.

Table 3: Groundwater Summary

| Boring ID | Free Water Depth (ft) | Free Water Elevation (ft) | Static Water Depth (ft) | Static Water Elevation (ft) |
|---|---|---|---|---|
| B-001-0-21 | 20.0 | 588.9 | - | - |
| B-002-0-21 | 18.0 | 590.7 | - | - |

### *4.1.3. Bedrock*

Bedrock was encountered in both project borings performed at the proposed bridge substructures and was classified as Dolomite. Bedrock was presented at a depth of 40.5 ft bgs (elevations 568.4 and 568.2 ft amsl). The top 2 feet of dolomite was observed to be gray, highly weathered, slightly strong. The cored dolomite was observed to be gray and brownish gray, unweathered to slightly weathered, moderately strong to strong, thin to medium bedded. Recovery of the bedrock core runs performed ranged from 97 to 99 percent while the Rock Quality Designation (RQD) values ranged from 80 to 88 percent. A summary of the bedrock data is presented in Table 4 below.

Table 4: Bedrock Summary

| Boring Number | Type of Rock | Depth to Bedrock (ft) | Depth to Top of Core Sample (ft) | Elevation of Top of Rock (ft) | Bedrock Recovery (%) | Bedrock RQD (%) |
|---|---|---|---|---|---|---|
| B-001-0-21 | Dolomite | 40.5 | 42.5 | 568.4 | 99 | 80 |
| B-002-0-21 | Dolomite | 40.5 | 42.5 | 568.2 | 97 | 88 |

## 5. ANALYSES AND RECOMMENDATIONS

The proposed project consists of the replacement of the bridge over Toussaint Creek on SR-51 in Ottawa County, Ohio. It is our understanding that the proposed bridge is a single span bridge on new semi-integral reinforced concrete abutments with HP pile foundations.

Based on the above information in addition to: 1) the soil characteristics gathered during the subsurface exploration (i.e., SPT results, laboratory test results, etc.); 2) the developed generalized soil profile and estimated engineering properties and other design assumptions presented in subsequent sections of this report; and, 3) the proposed bridge site plans provided by Prime AE Group, Inc. Geotechnical design elements for the proposed project will include:

- Pavement Design and Recommendations
- Deep Foundation Analysis
- Settlement
- Global Stability

The geotechnical engineering analyses were performed in accordance with ODOT's BDM (ODOT, 2022) and AASHTO's LRFD BDS (AASHTO, 2020). Design recommendations are provided in the following sections.

## 5.1. Soil Profile for Analysis

For analysis purposes, each substructure location (boring log) was reviewed and a generalized material profile was developed for analysis. Utilizing the generalized soil profile, engineering properties for each soil strata were estimated based on the field (i.e., SPT $N_{60}$ Values, hand penetrometer values, etc.) and laboratory (i.e., Atterberg Limits, grain size, etc.) test results using correlations provided in published engineering manuals, research reports and guidance documents. The developed soil profile and estimated engineering soil properties for use in analysis (with sited correlation/reference material) is summarized within Tables 5 through 6 below.

Table 5: Soil Profile and Estimated Engineering Properties - At Boring B-001-0-21

**OTT-51-03.85 over Toussaint Creek: Rear Abutment, B-001-0-21**

| Soil Description | Unit Weight(1) (pcf) | Moist Unit Weight(1) (pcf) | Saturated Unit Weight(1) (pcf) | Undrained Shear Strength(2) (psf) | Effective Cohesion(3) (psf) | Effective Friction Angle(3) (degrees) |
|---|---|---|---|---|---|---|
| Silt and Clay<br>Elevation (608.9 ft - 600.9 ft) | 108 | 108 | 118 | 1,100 | 100 | 22 |
| Sandy Silt<br>Elevation (600.9 ft - 598.4 ft) | 102 | 102 | 112 | 450 | 50 | 20 |
| Silt and Clay<br>Elevation (598.4 ft - 595.9 ft) | 108 | 108 | 118 | 800 | 100 | 21 |
| Clay<br>Elevation (595.9 ft - 590.5 ft) | 112 | 102 | 112 | 500 | 50 | 20 |
| Silt and Clay<br>Elevation (590.5 ft - 588.9 ft) | 112 | 102 | 112 | 450 | 50 | 20 |
| Sandy Silt<br>Elevation (588.9 ft - 587.4 ft) | 122 | 112 | 122 | 2,500 | 150 | 25 |
| Silt and Clay<br>Elevation (587.4 ft - 581.9 ft) | 122 | 112 | 122 | 2,900 | 150 | 25 |
| Sandy Silt<br>Elevation (581.9 ft - 572.4 ft) | 130 | 120 | 130 | 5,150 | 225 | 27 |
| Gravel with Sand<br>Elevation (572.4 ft - 568.4 ft) | 140 | 130 | 140 | - | - | 37 |

*Notes:*
1. *Values interpreted from Geotechnical Bulletin 7 Table 1.*
2. *Values calculated from Terzaghi and Peck (1967) if $N1_{60}$<52, else Stroud and Butler (1975) was used.*
3. *Values interpreted from Geotechnical Bulletin 7 Table 2.*

Table 6: Soil Profile and Estimated Engineering Properties - At Boring B-004-0-21

| OTT-51-03.85 over Toussaint Creek: Forward Abutment, B-002-0-21 | | | | | | |
|---|---|---|---|---|---|---|
| **Soil Description** | **Unit Weight$^{(1)}$ (pcf)** | **Moist Unit Weight$^{(1)}$ (pcf)** | **Saturated Unit Weight$^{(1)}$ (pcf)** | **Undrained Shear Strength$^{(2)}$ (psf)** | **Effective Cohesion$^{(3)}$ (psf)** | **Effective Friction Angle$^{(3)}$ (degrees)** |
| Silty Clay<br>Elevation (608.7 ft - 600.7 ft) | 110 | 110 | 120 | 1,450 | 115 | 23 |
| Clay<br>Elevation (600.7 ft - 598.2 ft) | 108 | 108 | 118 | 950 | 100 | 22 |
| Silt and Clay<br>Elevation (598.2 ft - 595.7 ft) | 105 | 105 | 115 | 600 | 75 | 21 |
| Sandy Silt<br>Elevation (595.7 ft - 591.3 ft) | 118 | 108 | 118 | 800 | 100 | 21 |
| Gravel with Sand<br>Elevation (591.3 ft - 589.2 ft) | 128 | 118 | 128 | - | - | 34 |
| Silt and Clay<br>Elevation (589.2 ft - 587.7 ft) | 125 | 115 | 125 | 3,350 | 180 | 25 |
| Silty Clay<br>Elevation (587.7 ft - 586.2 ft) | 135 | 125 | 135 | 5,850 | 250 | 28 |
| Sandy Silt<br>Elevation (586.2 ft - 574.7 ft) | 130 | 120 | 130 | 4,700 | 225 | 27 |
| Sandy Silt<br>Elevation (574.7 ft - 572.2 ft) | 140 | 130 | 140 | 7,950 | 250 | 28 |
| Gravel with Sand<br>Elevation (572.2 ft - 568.2 ft) | 140 | 130 | 140 | - | - | 37 |

*Notes:*

1. *Values interpreted from Geotechnical Bulletin 7 Table 1.*
2. *Values calculated from Terzaghi and Peck (1967) if N1$_{60}$ <52, else Stroud and Butler (1975) was used.*
3. *Values interpreted from Geotechnical Bulletin 7 Table 2.*

## 5.2. Pavement Design and Recommendations

The subgrade analysis was performed in accordance with ODOT's GB1 criteria utilizing the ODOT provided *GB1: Subgrade Analysis Spreadsheet* (GB1_SubgradeAnalysis.xls, Version 14.6 dated February 11, 2022). Input information for the spreadsheet was based on the soil characteristics gathered during NEAS's subgrade exploration (i.e., SPT results, laboratory test results, etc.), and our geotechnical experience. For analysis purposes, the roadway elevations were determined based on the proposed profiles shown in the site plans provided by Prime AE Group, Inc. via email on May 23, 2022.

A GB1 analysis was performed to identify the method, location, and dimensions (including depth) of recommended subgrade stabilization in the referenced project plan. Appropriate stabilization of the subgrade will ensure a constructible pavement buildup, enhance pavement performance over its life, and help reduce costly extra work change orders (ODOT SGE, 2022). In addition to identifying stabilization recommendations, pavement design parameters are also determined to aid in pavement section design. The subsections below present the results of our GB1 analysis including pavement design parameters and unsuitable subgrade conditions if any identified within the project limits. GB1 analysis spreadsheet for the referenced roadway segment is provided in Appendix C.

### *5.2.1. Pavement Design Recommendations*

It is our understanding that pavement analyses and design are to be performed to determine the proposed pavement section of SR-51. GB1 analyses were performed using the subgrade soil data obtained for the referenced roadway segment to evaluate the soil characteristics for use in pavement design. The subgrade analysis parameters recommended for use in pavement design for the referenced roadway segment are presented in Table 7. Provided in the table are average Plasticity Index (PI) values, ranges of maximum, minimum and average $N_{60L}$ values for the indicated segments as well as the design CBR value recommended for use in pavement design.

Table 7: Pavement Design Values

| Segment | Maximum $N_{60L}$ | Minimum $N_{60L}$ | Average $N_{60L}$ | Average PI Values | Design CBR |
|---|---|---|---|---|---|
| SR-51 | 11 | 5 | 8 | 15 | 6 |

### *5.2.2. Unsuitable/Unstable Subgrade*

Per ODOT's GB1, the presence of select subgrade conditions may require some form of subgrade stabilization within the subgrade zone for new pavement construction. These unsuitable and unstable subgrade conditions generally include the presence of rock, specific soil types, weak soil conditions, and overly moist soil conditions. With respect to the planned roadways, these subgrade conditions are further discussed in the following subsections.

#### *5.2.2.1. Rock*

Rock was not encountered within top 2 ft of the proposed grade in both borings performed; therefore, no specialized remediation efforts are required.

#### *5.2.2.2. Prohibited Soils*

Prohibited soil types, per the GB1, include A-4b, A-2-5, A-5, A-7-5, A-8a, A-8b, and soils with liquid limits greater than 65. No prohibited soils were encountered within the subgrade of the referenced project roadway.

#### *5.2.2.3. Weak Soils*

Soils for which the lowest $N_{60}$ ($N_{60L}$) at the referenced boring location is less than or equal to 12 bpf and in some cases less than 15 bpf (i.e., where moisture content is greater than optimum plus 3 percent) subgrade stabilization depths are recommended per *Figure B - Subgrade Stabilization* within the GB1. It should be noted that for the purposes of this report the term "weak soils" has been assumed to represent subgrade soils of these conditions. At the project site, weak soils were encountered in one project boring B-001-0-21 within the subgrade depth, are summarized in Table 8 below.

Table 8: Weak Soils Summary

| Boring ID | $N_{60L}$ | Subgrade Depth (ft) | Remediation Depth (inches) | | |
|---|---|---|---|---|---|
| | | | Excavate and Replace (Item 204 w/ Geotextile) | Excavate and Replace (Item 204 w/ Geogrid - SS | Chemical Stabilization (Item 206) |
| B-001-0-21 | 13 | 0.0 - 1.5 | 12 | N/A | 14 |
| Note: N/A, Not Applicable based on GB1- Figure B - Subgrade Stabilization | | | | | |

#### *5.2.2.4. High Moisture Content Soils*

High moisture content soils are defined by the GB1 as soils that exceed the estimated optimum moisture content (per *Figure A - Optimum Moisture Content* within the GB1) for a given classification by 3 percent or more. At the project site, high moisture content soils were encountered in one boring B-001-0-21 within the subgrade depth, are summarized in Table 9 below.

Table 9: High Moisture Content Soils Summary

| Boring ID | Soil Type | Moisture Content (%) | Optimum Moisture Content (%) | Depth Below Subgrade (ft) |
|---|---|---|---|---|
| B-001-0-21 | A-6a | 17 | 14 | 0.0 - 1.5 |

### *5.2.3. Stabilization Recommendations*

### *5.2.3.1. Subgrade Stabilization*

Unstable subgrade conditions, specifically weak and high moisture content soils, were encountered in boring B-001 as previously indicated in Section 5.2.2. of this report. Therefore, NEAS recommend spot stabilization in the form of Excavate and Replace as summarized in Table 10 below. Chemical stabilization is not recommended due to chemical stabilization is generally more economical when stabilizing large areas (approximately greater than 1 mile of roadway) per ODOT's GB1. Excavations are estimated to extend to a depth of 12 inches below the proposed subgrade with the excavated material being replaced with material in accordance with Section F "Excavate and Replace (Item 204)" of the ODOT GB1. Stabilization limits should extend 18-inches beyond the edge of the proposed paved roadway, shoulder or median and it is recommended removing any topsoil, existing pavement materials or abandoned structure foundation materials.

Table 10: Stabilization Recommendations

| Segment | Average $N_{60L}$ | Remediation Depth (inches) | | |
|---|---|---|---|---|
| | | Excavate and Replace (Item 204 w/ Geotextile) | Excavate and Replace (Item 204 w/ Geogrid - SS 861) | Chemical Stabilization (Item 206) |
| Begin to Sta. 102+93 | 10 | 12 | N/A | 14 |
| Sta. 104+02 to End | 12 | N/A | N/A | N/A |
| Note: N/A, Not Applicable based on GB1- Figure B - Subgrade Stabilization | | | | |

### *5.2.3.2. Chemical Stabilization*

Another alternative is chemical stabilization utilizing cement as the stabilization chemical. Designer should perform a cost analysis of the stabilization options using bid tabs. Generally, chemical stabilization is more economical when stabilizing large areas (approximately greater than 1 mile of roadway) per ODOT's GB1. Additionally, the chemical stabilization of the subgrade soils of the above referenced roadway should be performed to the recommended depths provided in above and extend a minimum of 18-inches beyond the edge of the paved roadway, shoulder or median. The mix design should be conducted in accordance with ODOT's CMS Supplement 1120 (Mixture Design for Chemically Stabilized Soils). For design purposes it may be assumed that the lime addition will be 5% using the following formula.

$$\text{Cement: } C = 0.75 \times T \times 115 \times 0.05$$

Where:

C = amount of chemical in pounds / square yard and

T = thickness of the treatment zone in inches

A dry density of 115-pounds per cubic foot (pcf) is assumed.

### *5.2.4. Embankment Construction Recommendations*

Based on the project proposed cross-sections, sidehill fills will be required for the right side embankment slopes at both sides of the bridge. For sidehill fills planned on existing slopes steeper than 4H:1V, ODOT's GB2 recommends that *the embankment slopes be constructed utilizing special benching in order to blend the new embankment with the existing slope to prevent the development of a weak shear plane at the interface between the proposed fill and existing slope material* (ODOT [2], 2017). A special benching scheme similar to that shown in Figure 1 of the ODOT GB2 should be used in areas where special benching is recommended. The height and width dimensions of the special benching scheme shown in the figure should be arranged to minimize the required cut and fill quantities, though the height of a single bench shall not exceed 20 ft without a stability analysis and design per OSHA requirements. Additionally, it may be appropriate to adjust the bench slope shown from a 1H:1V to a 1.5H:1V slope since the existing slope is made up of Type C materials. The benched material should be replaced with compacted engineered fill per Item 203 of the ODOT CMS, while proper lift thicknesses and material density should be maintained in the proposed fill per Item 203.06 of the ODOT CMS. In situations where it is not practical to extend the final bench through the existing roadway due to maintenance of traffic concerns, a benching scheme similar to that shown in Figure 1a of the ODOT GB2 can be used in order to avoid impacting the existing roadway, guardrail or shoulder. This scheme results in the placement of a temporary over-steepened fill that can later be "shaved-off" to bring the slope to the final proposed grade.

## 5.3. Bridge Foundation Analysis and Recommendations

A foundation review was completed for a deep foundation system for the referenced widening bridge based on the following design information: 1) the Site Plan for Bridge No. OTT-51-03.85 conducted by Prime AE Group, Inc.; 2) historical plans; and 3) subsequent conversations with Prime AE. A driven pile foundation system was evaluated for all the substructure locations. The proposed deep foundation systems will be designed according to LRFD and ODOT BDM criteria. The summary and results of our deep foundation evaluation are presented in subsequent sections.

### *5.3.1. Pile Foundation Recommendations*

We recommend that a driven pile foundation be used for support of the abutments, with the piles consisting of steel "H" piles driven to bedrock refusal. Refusal is met during driving when the pile penetration is an inch or less after receiving at least 20 blows from the pile hammer. According to the site plan provided by Prime AE Group, Inc., abutments are going to be supported by HP piles. An "H" pile driven to refusal on bedrock is typically governed by structural resistance as opposed to driving resistance for friction piles. Therefore, the total factored loads for any single steel "H" pile are shown in Table 11 (ODOT, 2022). This total factored load (single pile) for an HP pile may be used to support the abutment foundation under the following conditions: 1) piles are installed in accordance with Sections 507 and 523 of the ODOT Construction and Material Specifications (CMS); 2) the piles are axially loaded pile with negligible moment; 3) steel piles have a yield strength of 50 kips per square inch (ksi); 4) assumed no appreciable loss of section due to deterioration throughout the life of the structure; 5) steel "H" piles are assumed to be subject to damage due to severe driving conditions equating to a structural resistance factor of 0.5; and, 5) the piles are fully braced along their length.

Driven to bedrock refusal, the pile tip elevations for the abutments are estimated to be about the elevations of top of bedrock shown on the boring logs. Pile lengths based on the "Estimated Length" and "Order Length" definitions and formulas presented in Section 305.3.3 "Pile Foundations" of the BDM, are shown in Table 11. Based on the email from Prime AE Group dated November 8, 2022, the scour will not pass through the first layer of the soils at the creek bottom. Therefore, HP piles at both abutments will penetrate at least greater than 15-ft below the maximum estimated scour depth.

Table 11: Estimated HP Pile Lengths and Maximum Factored Structural Resistance

| Pile Type | Maximum Factored Structural Resistance (kips) | Bottom of Pile Cap Elevation (ft amsl) | Geotechnical Pile Length (ft) | Estimated Pile Length$^{(2)}$ (ft) | Order Length$^{(2)}$ (ft) |
|---|---|---|---|---|---|
| **OTT-51-03.85 Bridge: Rear abutment, B-001-0-21** | | | | | |
| HP 10x42 | 310 | 595.36 | 27 | 30 | 35 |
| HP 12x53 | 380 | | | | |
| HP 14x73 | 530 | | | | |
| **OTT-51-03.85 Bridge: Forward abutment, B-002-0-21** | | | | | |
| HP 10x42 | 310 | 593.28 | 25 | 30 | 35 |
| HP 12x53 | 380 | | | | |
| HP 14x73 | 530 | | | | |

*Notes:*
*1. Based on definitions and formulas presented in Section 305.3.3 of the 2020 BDM.*

### *5.3.2. Pile Drivability*

Pile driveability is highly reliant upon the specific equipment used in construction. Therefore, it is recommended that the contractor provide an analysis to demonstrate that the equipment and piles planned for use are capable to driven to refusal on bedrock without overstressing the piles.

The minimum rated energy of the hammer used to install the piles shall be (43,000) foot-pounds. Ensure that stresses in the piles during driving do not exceed (45,000) pounds per square inch.

### *5.3.3. Settlement*

The planned bridge rear abutment is a semi-integral abutment founded on piles behind which there will be about 11.8 feet of new embankment fill. In order to estimate the maximum total and differential settlement that could result within the subsurface soils supporting the proposed semi-integral rear abutment, NEAS reviewed: 1) the proposed Bridge Site Plan prepared by Prime AE; 2) Service Limit State loading conditions; and, 3) test borings and laboratory data developed as part of this report. Utilizing this information and the software entitled FoSSA 2.0 by ADAMA Engineering, Inc., settlement models were developed and analyzed for both elastic (immediate) and consolidation (long term) settlement.

Based on our analysis the ground surface at the rear abutment is estimated to experience about 3.5 inches of immediate settlement and 5.6 inches of long-term (consolidation) settlement from the induced loads associated with the 11.8-ft high embankment. The settlement analysis results can be found in Appendix D. The immediate settlement is expected to take place during construction prior to bridge loading and is not anticipated to be a concern; however, ninety percent (90%) of the long-term settlement will take place 260 days following embankment construction. Since the embankment fill above the rear abutment footing (less than 2 ft wide) will be carried by the rear abutment, the surcharge loads will then be transferred from the abutment to the piles; therefore, it is our opinion that the piles will not be subjected to downdrag loads. However, the proposed rear approach slab will experience the above estimated settlement without ground improvement.

### *5.3.4. Global Stability*

For purposes of evaluating the stability of the abutments, NEAS reviewed the cross-section and project boring logs to determine the subsurface soil conditions that posed the greatest potential for slope instability. Based on our review, NEAS developed a representative cross-sectional model at each abutment to use as the basis for global stability analyses. The models were developed from NEAS's interpretation of the available information which included: 1) the Bridge Site Plans prepared by Prime AE Group, Inc.; and, 2) test borings and laboratory data developed as part of this report. With respect to the soil's engineering properties, the provided Soil Profile Estimated Engineering Properties presented in Section 5.1 of this report were used in our analyses.

The above referenced slope stability models were analyzed for long-term (Effective Stress) and short-term (Total Stress) slope stability utilizing the software entitled Slide 7.0 by Rocscience, Inc. Specifically, the Bishop, Spencer and GLE analysis methods were used to calculate a factor of safety (FOS) for circular type slope failures. The FOS is the ratio of the resisting forces and the driving forces, with the desired safety factor being more than about 1.54 which equates to an AASHTO resistance factor less than 0.65 (per AASHTO, 2017 - the specified resistance factors are essentially the inverse of the FOS that should be targeted in slope stability programs). For this analysis, a resistance factor of 0.65 or lower is targeted as the slope contains or supports a structural element.

Based on our slope stability analyses for the referenced abutment locations, the minimum slope stability safety factors for short-term (Total Stress) and long-term (Effective Stress) conditions exceeded the desired value of 1.54. It is our opinion that the subsurface conditions encountered at the project site are generally satisfactory and the site can be considered to be stable at short-term and long-term condition. The results of the analyses are summarized in Table 12. The graphical output of the slope stability program (cross-sectional model, calculated safety factor, and critical failure plane) is presented in Appendix E.

Table 12: Global Stability Analysis Summary

| Global Stability Analsysis at Bridge OTT-51-03.85 | | | | | |
|---|---|---|---|---|---|
| Location | Boring No. | Description | Minimum Factor of Safety | Equivalent Resistance Factor | Status (OK/NG) |
| Rear Abutment | B-001-0-21 | Short Term | 4.55 | 0.22 | OK |
| | | Long Term | 2.95 | 0.34 | OK |
| Forward Abutment | B-002-0-21 | Short Term | 6.25 | 0.16 | OK |
| | | Long Term | 3.62 | 0.28 | OK |

## 5.4. Seismic Design Parameters

It is NEAS's opinion that the subsurface conditions encountered at the proposed Bridge OTT-51-03.85 site are characterized as a Seismic Site Class of E – Soft Clay Soil, with $\overline{N}$ <15 blows/ft, in accordance with Section 3.10.3.1, Method B, of the LRFD BDS.

# 6. QUALIFICATIONS

This investigation was performed in accordance with accepted geotechnical engineering practice for the purpose of characterizing the subsurface conditions at the site of OTT-51-03.85 bridge carrying SR-51 over Toussaint Creek. This report has been prepared for Prime AE, ODOT and their design consultants to be used solely in evaluating the soils underlying the bridge site and presenting geotechnical engineering recommendations specific to this project. The assessment of general site environmental conditions or the presence of pollutants in the soil, rock and groundwater of the site was beyond the scope of this geotechnical exploration. Our recommendations are based on the results of our field explorations, laboratory tests result from representative soil samples, and geotechnical engineering analyses. The results of the field explorations and laboratory tests, which form the basis of our recommendations, are presented in the appendices as noted. This report does not reflect any variations that may occur between the borings or elsewhere on the site, or variations whose nature and extent may not become evident until a later stage of construction. In the event that any changes in the nature, design or location of the proposed bridge is made, the conclusions and recommendations contained in this report should not be considered valid until they are reviewed, and have been modified or verified in writing by a geotechnical engineer.

It has been a pleasure to be of service to Prime AE Group, Inc. in performing this geotechnical exploration for OTT-51-03.85 Bridge project. Please call if there are any questions, or if we can be of further service.

Respectfully Submitted,

**National Engineering and Architectural Services Inc.**

Chunmei He, Ph.D., P.E.
*Project Manager/Geotechnical Engineer*

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# APPENDIX A

# BORING PLAN

# OTT-51-03.85

TARGET BORING PLAN

# APPENDIX B

# BORING LOGS AND TEST RESULTS

PROJECT: OTT-51-03.85
TYPE: BRIDGE
PID: 80032 SFN: 6201172
START: 6/1/22 END: 6/3/22

DRILLING FIRM / OPERATOR: NEAS / J. HODGES
SAMPLING FIRM / LOGGER: NEAS / J. HODGES
DRILLING METHOD: 3.25" HSA / NQ2
SAMPLING METHOD: SPT / ST / NQ2

DRILL RIG: CME 55X
HAMMER: CME AUTOMATIC
CALIBRATION DATE: 1/24/22
ENERGY RATIO (%): 79

STATION / OFFSET: 102+78, 14' RT.
ALIGNMENT: SR-51
ELEVATION: 608.9 (MSL) EOB: 52.5 ft.
LAT / LONG: 41.506050, -83.320695

EXPLORATION ID
B-001-0-21

PAGE
1 OF 2

| ***MATERIAL DESCRIPTION AND NOTES*** | ELEV. 608.9 | DEPTHS | SPT/ RQD | $N_{60}$ | REC (%) | SAMPLE ID | HP (tsf) | GRADATION (%) GR | CS | FS | SI | CL | ATTERBERG LL | PL | PI | WC | ODOT CLASS (GI) | HOLE SEALED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **12.0" ASPHALT AND 7.0" BASE (DRILLERS DESCRIPTION)** | 607.3 | | | | | | | | | | | | | | | | | |
| VERY STIFF TO HARD, BROWN AND BROWNISH GRAY, **SILT AND CLAY**, SOME TO "AND" SAND, TRACE TO LITTLE GRAVEL, DAMP TO MOIST | 600.9 | | 5<br>4<br>6 | 13 | 56 | SS-1 | 4.25 | 6 | 6 | 22 | 34 | 32 | 29 | 17 | 12 | 17 | A-6a (7) | |
| | | | 4<br>4<br>6 | 13 | 67 | SS-2 | 2.50 | - | - | - | - | - | - | - | - | 19 | A-6a (V) | |
| | | | 3<br>2<br>2 | 5 | 44 | SS-3 | 2.50 | 15 | 11 | 30 | 25 | 19 | 28 | 15 | 13 | 15 | A-6a (3) | |
| | | | 4<br>3<br>2 | 7 | 100 | SS-4 | 2.25 | - | - | - | - | - | - | - | - | 20 | A-6a (V) | |
| STIFF, BROWN, **SANDY SILT**, TRACE CLAY, TRACE GRAVEL, MOIST | 598.4 | | 2<br>1<br>2 | 4 | 100 | SS-5 | 1.50 | - | - | - | - | - | - | - | - | 20 | A-4a (V) | |
| STIFF, BROWN AND BROWNISH GRAY, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, WET | 595.9 | | 2<br>2<br>3 | 7 | 100 | SS-6 | 1.50 | - | - | - | - | - | - | - | - | 27 | A-6a (V) | |
| STIFF TO VERY STIFF, GRAY MOTTLED WITH BROWN AND BLACK, **CLAY**, "AND" SILT, LITTLE TO SOME SAND, TRACE GRAVEL, SLIGHTLY ORGANIC, CONTAINS WOOD FRAGMENTS, MOIST TO DAMP | 590.5 | | 1<br>2<br>2 | 5 | 100 | SS-7 | 2.00 | 1 | 1 | 20 | 38 | 40 | 46 | 23 | 23 | 28 | A-7-6 (14) | |
| | | | 2<br>1<br>2 | 4 | 100 | SS-8 | 1.50 | - | - | - | - | - | - | - | - | 23 | A-7-6 (V) | |
| STIFF, GRAY, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, MOIST | 588.9 | W 588.9 | | | 100 | ST-1 | 1.50 | 9 | 10 | 13 | 34 | 34 | 30 | 17 | 13 | 18 | A-6a (8) | |
| HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE GRAVEL, DAMP | 587.4 | | 4<br>7<br>9 | 21 | 100 | SS-9 | 4.50 | 6 | 6 | 12 | 45 | 31 | 23 | 15 | 8 | 13 | A-4a (8) | |
| HARD, GRAY, **SILT AND CLAY**, LITTLE TO SOME SAND, TRACE GRAVEL, DAMP TO MOIST | 581.9 | | 9<br>10<br>14 | 32 | 100 | SS-10 | 4.50 | 8 | 7 | 14 | 32 | 39 | 28 | 15 | 13 | 13 | A-6a (8) | |
| | | | 4<br>8<br>11 | 25 | 100 | SS-11 | 4.50 | 3 | 6 | 11 | 32 | 48 | 31 | 17 | 14 | 14 | A-6a (10) | |
| | | | 3<br>6<br>9 | 20 | 100 | SS-12 | 4.25 | 2 | 5 | 9 | 32 | 52 | 31 | 16 | 15 | 19 | A-6a (10) | |
| HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE GRAVEL, SS-14 CONTAINS A 2" STONE FRAGMENT, DAMP | | | 9<br>12<br>17 | 38 | 100 | SS-13 | 4.50 | 4 | 9 | 26 | 38 | 23 | 20 | 13 | 7 | 10 | A-4a (5) | |

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 10/6/22 12:41 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\OTT-51-3.85\GINT FILES\OTT-51-3.85.GPJ

| PID: 80032 | SFN: 6201172 | PROJECT: OTT-51-03.85 | STATION / OFFSET: 102+78, 14' RT. | START: 6/1/22 | END: 6/3/22 | PG 2 OF 2 | B-001-0-21 |
|---|---|---|---|---|---|---|---|

| MATERIAL DESCRIPTION AND NOTES | ELEV. 578.9 | DEPTHS | SPT/ RQD | $N_{60}$ | REC (%) | SAMPLE ID | HP (tsf) | GRADATION (%) GR | CS | FS | SI | CL | ATTERBERG LL | PL | PI | WC | ODOT CLASS (GI) | HOLE SEALED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE GRAVEL, SS-14 CONTAINS A 2" STONE FRAGMENT, DAMP *(continued)* | | 31 | 8<br>12<br>23 | 46 | 100 | SS-14 | 4.50 | - | - | - | - | - | - | - | - | 12 | A-4a (V) | |
| | 572.4 | 35–36 | 13<br>18<br>16 | 45 | 100 | SS-15 | 4.50 | - | - | - | - | - | - | - | - | 10 | A-4a (V) | |
| VERY DENSE, GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP | 568.4 | 40 (TR) | 50 | - | 50 | SS-16 | - | - | - | - | - | - | - | - | - | 8 | A-1-b (V) | |
| **DOLOMITE**, GRAY, HIGHLY WEATHERED, SLIGHTLY STRONG. | 566.4 | 42 | 50/2" | - | 50 | SS-17 | - | - | - | - | - | - | - | - | - | - | Rock (V) | |
| **DOLOMITE**, GRAY AND BROWNISH GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, MODERATELY STRONG TO STRONG, VERY FINE TO MEDIUM GRAINED, THIN TO MEDIUM BEDDED, VUGGY, STYLOLITIC, BEDDING DISCONTINUITIES: LOW ANGLE, FRACTURED TO SLIGHTLY FRACTURED, NARROW TO TIGHT, SLIGHTLY ROUGH TO VERY ROUGH, BLOCKY, GOOD TO VERY GOOD SURFACE CONDITION; RQD 80%, REC 99%.<br>@47.0' TO 47.3'; LARGE VUG PARTIALLY FILLED WITH CALCITE<br>@48.7' TO 49.7'; BECOMES MODERATELY STRONG DUE TO NUMEROUS SMALL VUGS | 556.4 | 43–52 (EOB) | 80 | | 99 | NQ2-1 | | | | | | | | | | | CORE | |

NOTES: GROUNDWATER ENCOUNTERED AT 20.0' DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; PUMPED 100 GAL. BENTONITE GROUT

PROJECT: OTT-51-03.85
TYPE: BRIDGE
PID: 80032 SFN: 6201172
START: 6/3/22 END: 6/3/22

DRILLING FIRM / OPERATOR: NEAS / J. HODGES
SAMPLING FIRM / LOGGER: NEAS / J. HODGES
DRILLING METHOD: 3.25" HSA / NQ2
SAMPLING METHOD: SPT / NQ2

DRILL RIG: CME 55X
HAMMER: CME AUTOMATIC
CALIBRATION DATE: 1/24/22
ENERGY RATIO (%): 79

STATION / OFFSET: 104+02, 14' LT.
ALIGNMENT: SR-51
ELEVATION: 608.7 (MSL) EOB: 52.5 ft.
LAT / LONG: 41.506289, -83.321032

EXPLORATION ID
B-002-0-21

PAGE
1 OF 2

| ***MATERIAL DESCRIPTION AND NOTES*** | ELEV. 608.7 | DEPTHS | SPT/ RQD | $N_{60}$ | REC (%) | SAMPLE ID | HP (tsf) | GRADATION (%) | | | | | ATTERBERG | | | WC | ODOT CLASS (GI) | HOLE SEALED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | GR | CS | FS | SI | CL | LL | PL | PI | | | |
| **12.0" ASPHALT AND 6.0" BASE (DRILLERS DESCRIPTION)** | 607.2 | | | | | | | | | | | | | | | | | |
| VERY STIFF TO HARD, BROWN BECOMING GRAY, **SILTY CLAY**, LITTLE TO SOME SAND, TRACE GRAVEL, CONTAINS IRON STAINING, DAMP TO MOIST | | | 4<br>5<br>6 | 14 | 39 | SS-1 | 4.50 | 6 | 7 | 13 | 30 | 44 | 35 | 19 | 16 | 17 | A-6b (10) | |
| | 604.2 | | 3<br>5<br>5 | 13 | 72 | SS-2 | 3.75 | 1 | 3 | 19 | 38 | 39 | 37 | 17 | 20 | 18 | A-6b (12) | |
| MEDIUM STIFF TO STIFF, DARK GRAY, **SILTY CLAY**, SOME SAND, TRACE GRAVEL, MOIST | | | 2<br>1<br>7 | 11 | 22 | SS-3 | 1.00 | - | - | - | - | - | - | - | - | 24 | A-6b (V) | |
| | 600.7 | | 2<br>3<br>5 | 11 | 44 | SS-4 | 1.25 | 6 | 7 | 21 | 32 | 34 | 35 | 19 | 16 | 23 | A-6b (9) | |
| STIFF TO VERY STIFF, BROWN AND BROWNISH GRAY, **CLAY**, SOME SILT, LITTLE SAND, TRACE GRAVEL, MOIST | 598.2 | | 1<br>2<br>4 | 8 | 100 | SS-5 | 2.00 | 1 | 3 | 13 | 34 | 49 | 42 | 19 | 23 | 23 | A-7-6 (14) | |
| MEDIUM STIFF TO STIFF, BROWNISH GRAY AND GRAY, **SILT AND CLAY**, "AND" SAND, LITTLE GRAVEL, DAMP | 595.7 | | 4<br>2<br>2 | 5 | 89 | SS-6 | 1.00 | 13 | 12 | 29 | 27 | 19 | 27 | 16 | 11 | 16 | A-6a (3) | |
| LOOSE, GRAY AND BROWN, **SANDY SILT**, TRACE TO LITTLE CLAY, TRACE GRAVEL, SLIGHTLY ORGANIC, CONTAINS TRACE IRON STAINING, WET | | | 2<br>1<br>3 | 5 | 100 | SS-7 | - | - | - | - | - | - | - | - | - | 24 | A-4a (V) | |
| | 591.3 | | 3<br>3<br>4 | 9 | 100 | SS-8 | - | - | - | - | - | - | - | - | - | 22 | A-4a (V) | |
| DENSE, GRAY, **STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP | 589.2 | W 590.7 | 5<br>9<br>16 | 33 | 44 | SS-9 | - | 41 | 22 | 16 | 16 | 5 | NP | NP | NP | 6 | A-1-b (0) | |
| HARD, BROWN, **SILT AND CLAY**, LITTLE SAND, TRACE GRAVEL, DAMP | 587.7 | | 5<br>8<br>13 | 28 | 100 | SS-10 | 4.50 | 4 | 5 | 14 | 39 | 38 | 31 | 17 | 14 | 15 | A-6a (10) | |
| HARD, BROWN, **SILTY CLAY**, LITTLE SAND, TRACE GRAVEL, DAMP | 586.2 | | 16<br>17<br>20 | 49 | 100 | SS-11 | 4.25 | 2 | 4 | 8 | 36 | 50 | 35 | 18 | 17 | 18 | A-6b (11) | |
| HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE TO LITTLE GRAVEL, DAMP | | | 9<br>10<br>21 | 41 | 100 | SS-12 | 4.25 | 11 | 14 | 17 | 32 | 26 | 24 | 15 | 9 | 12 | A-4a (5) | |
| | | | 6<br>14<br>19 | 43 | 100 | SS-13 | 4.50 | 6 | 9 | 16 | 36 | 33 | 24 | 14 | 10 | 10 | A-4a (7) | |
| | | | 8<br>11<br>20 | 41 | 100 | SS-14 | 4.50 | - | - | - | - | - | - | - | - | 12 | A-4a (V) | |

DEPTHS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 10/6/22 12:41 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\OTT-51-3.85\GINT FILES\OTT-51-3.85.GPJ

| PID: 80032 | SFN: 6201172 | PROJECT: OTT-51-03.85 | STATION / OFFSET: 104+02, 14' LT. | START: 6/3/22 | END: 6/3/22 | PG 2 OF 2 | B-002-0-21 |
|---|---|---|---|---|---|---|---|

| ***MATERIAL DESCRIPTION AND NOTES*** | ELEV. 578.7 | DEPTHS | SPT/ RQD | $N_{60}$ | REC (%) | SAMPLE ID | HP (tsf) | GRADATION (%) | | | | | ATTERBERG | | | | ODOT CLASS (GI) | HOLE SEALED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | GR | CS | FS | SI | CL | LL | PL | PI | WC | | |
| HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE TO LITTLE GRAVEL, DAMP *(continued)* | | 31 | 5<br>11<br>14 | 33 | 100 | SS-15 | 4.50 | - | - | - | - | - | - | - | - | 15 | A-4a (V) | |
| | 572.2 | 32<br>33<br>34<br>35<br>36 | 22<br>23<br>29 | 68 | 100 | SS-16 | 4.50 | - | - | - | - | - | - | - | - | 10 | A-4a (V) | |
| VERY DENSE, GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP | 568.2 | 37<br>38<br>39<br>40<br>TR | 50 | - | 67 | SS-17 | - | - | - | - | - | - | - | - | - | 11 | A-1-b (V) | |
| **DOLOMITE**, GRAY, HIGHLY WEATHERED, SLIGHTLY STRONG. | 566.2 | 41<br>42 | 50/4" | - | 75 | SS-18 | - | - | - | - | - | - | - | - | - | - | Rock (V) | |
| **DOLOMITE**, GRAY AND BROWNISH GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, STRONG, VERY FINE TO MEDIUM GRAINED, VERY THIN TO THICK BEDDED, VUGGY, STYLOLITIC, BEDDING DISCONTINUITIES: LOW ANGLE, HIGHLY FRACTURED TO SLIGHTLY FRACTURED, NARROW TO TIGHT, SLIGHTLY ROUGH TO VERY ROUGH, BLOCKY TO INTACT, GOOD TO VERY GOOD SURFACE CONDITION; RQD 88%, REC 97%.<br>@46.8'; 1.25" DIAMETER VUG PARTIALLY FILLED WITH CALCITE | 556.2 | 43<br>44<br>45<br>46<br>47<br>48<br>49<br>50<br>51<br>52<br>EOB | 88 | | 97 | NQ2-1 | | | | | | | | | | | CORE | |

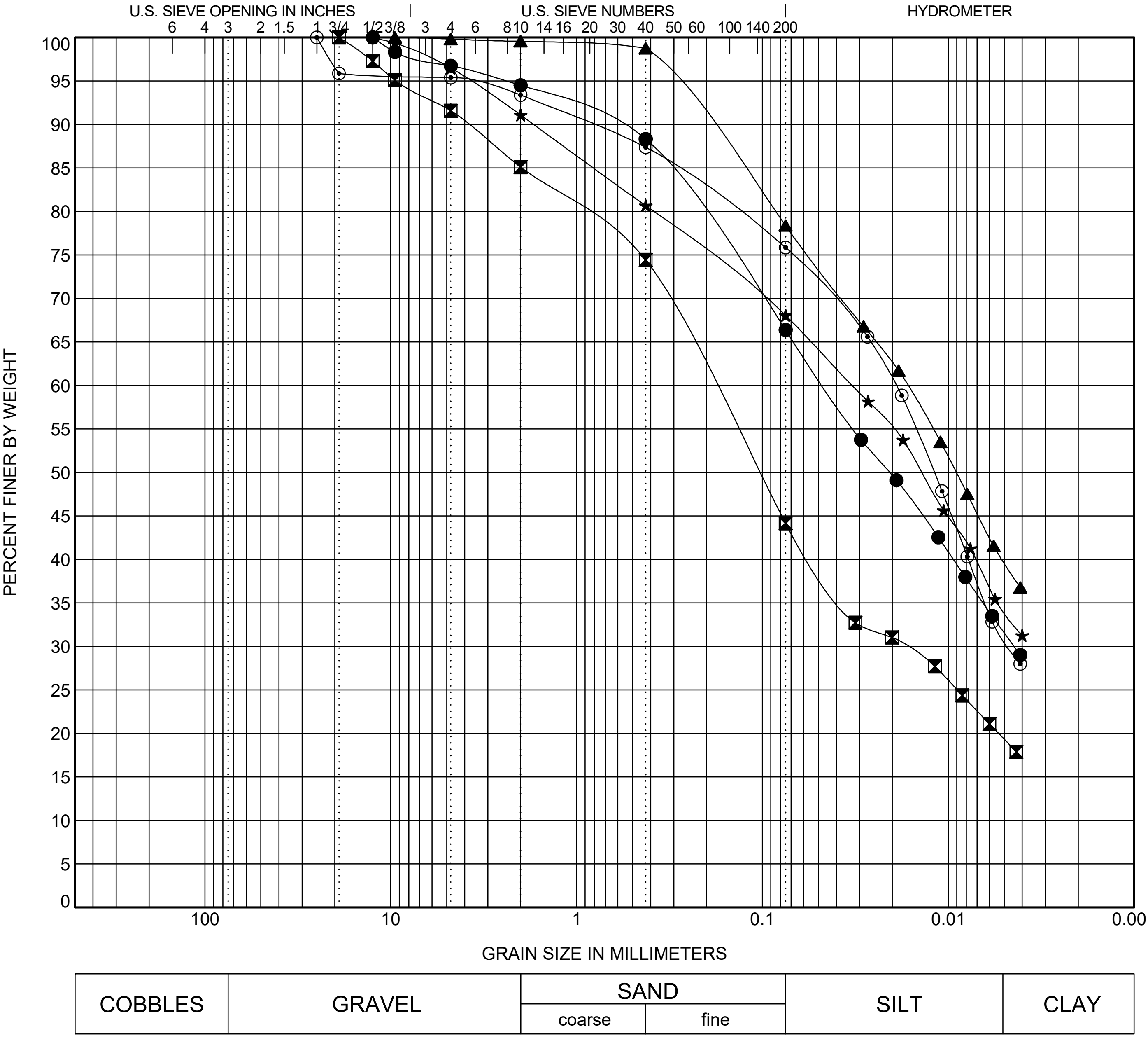
NOTES: GROUNDWATER ENCOUNTERED AT 18.0' DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; PUMPED 100 GAL. BENTONITE GROUT

# GRAIN SIZE DISTRIBUTION

**OHIO DEPARTMENT OF TRANSPORTION**
**OFFICE OF GEOTECHNICAL ENGINEERING**

**PROJECT** OTT-51-03.85
**PID** 80032
**OGE NUMBER** 0
**PROJECT TYPE** STRUCTURE FOUNDATION



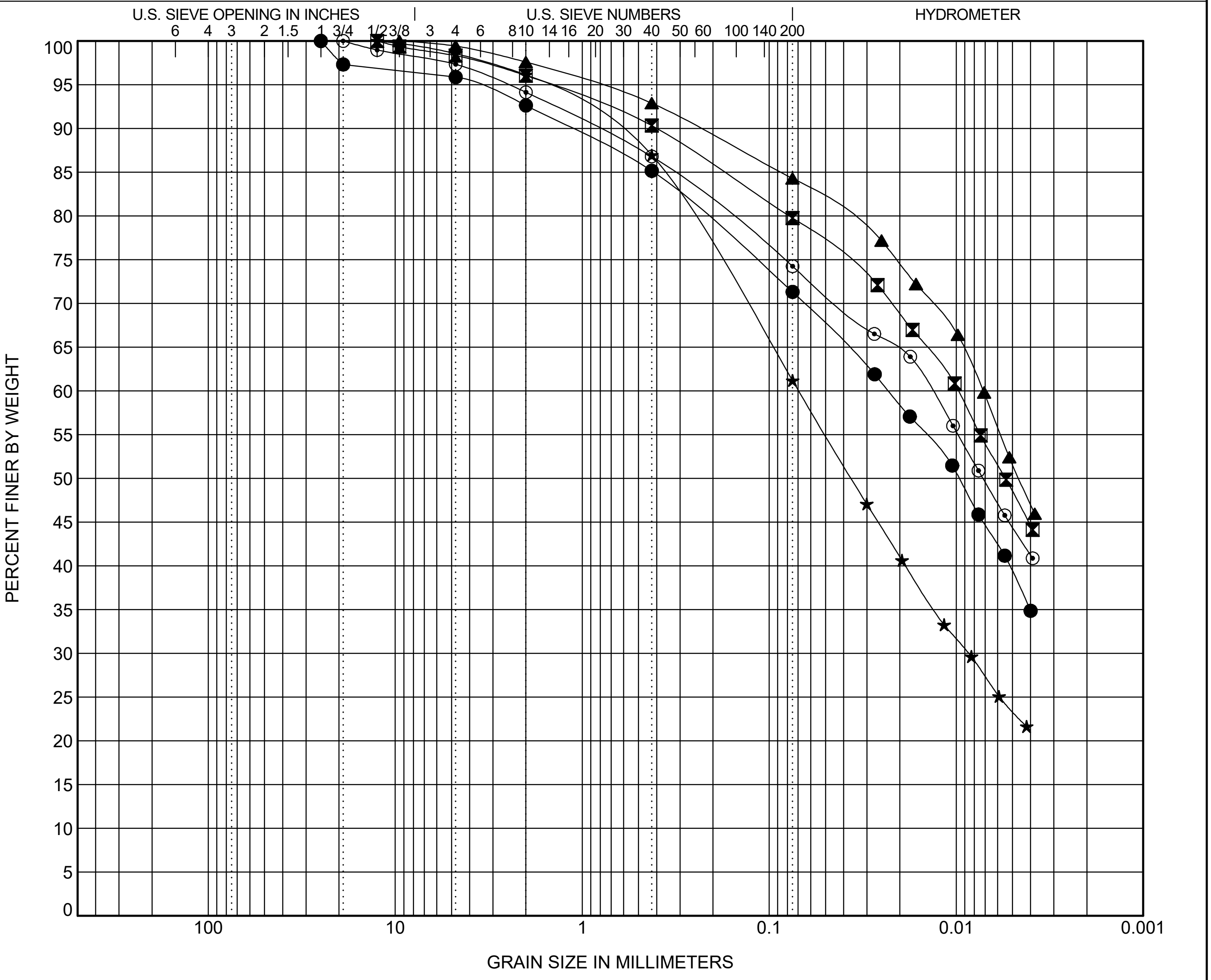
| Specimen Identification | | | ODOT (Modified AASHTO) ~ USCS Classification | LL | PL | PI |
|---|---|---|---|---|---|---|
| ● | **B-001-0-21** | **1.5** | **A-6a ~ SANDY LEAN CLAY(CL)** | **29** | **17** | **12** |
| ☒ | **B-001-0-21** | **4.5** | **A-6a ~ CLAYEY SAND(SC)** | **28** | **15** | **13** |
| ▲ | **B-001-0-21** | **13.5** | **A-7-6 ~ LEAN CLAY with SAND(CL)** | **46** | **23** | **23** |
| ★ | **B-001-0-21** | **18.0** | **A-6a ~ SANDY LEAN CLAY(CL)** | **30** | **17** | **13** |
| ⊙ | **B-001-0-21** | **20.0** | **A-4a ~ LEAN CLAY with SAND(CL)** | **23** | **15** | **8** |

| Specimen Identification | | | D90 | D50 | D30 | D10 | %G | %CS | %FS | %M | %C | Cc | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ● | **B-001-0-21** | **1.5** | **0.647** | **0.021** | **0.004** | | **6** | **6** | **22** | **34** | **32** | | |
| ☒ | **B-001-0-21** | **4.5** | **3.851** | **0.105** | **0.017** | | **15** | **11** | **30** | **25** | **19** | | |
| ▲ | **B-001-0-21** | **13.5** | **0.202** | **0.009** | | | **1** | **1** | **20** | **38** | **40** | | |
| ★ | **B-001-0-21** | **18.0** | **1.7** | **0.014** | | | **9** | **10** | **13** | **34** | **34** | | |
| ⊙ | **B-001-0-21** | **20.0** | **0.835** | **0.012** | **0.005** | | **6** | **6** | **12** | **45** | **31** | | |

# GRAIN SIZE DISTRIBUTION

**OHIO DEPARTMENT OF TRANSPORTION**
**OFFICE OF GEOTECHNICAL ENGINEERING**

**PROJECT** OTT-51-03.85
**PID** 80032
**OGE NUMBER** 0
**PROJECT TYPE** STRUCTURE FOUNDATION



| COBBLES | GRAVEL | SAND | | SILT | CLAY |
|---|---|---|---|---|---|
| | | coarse | fine | | |

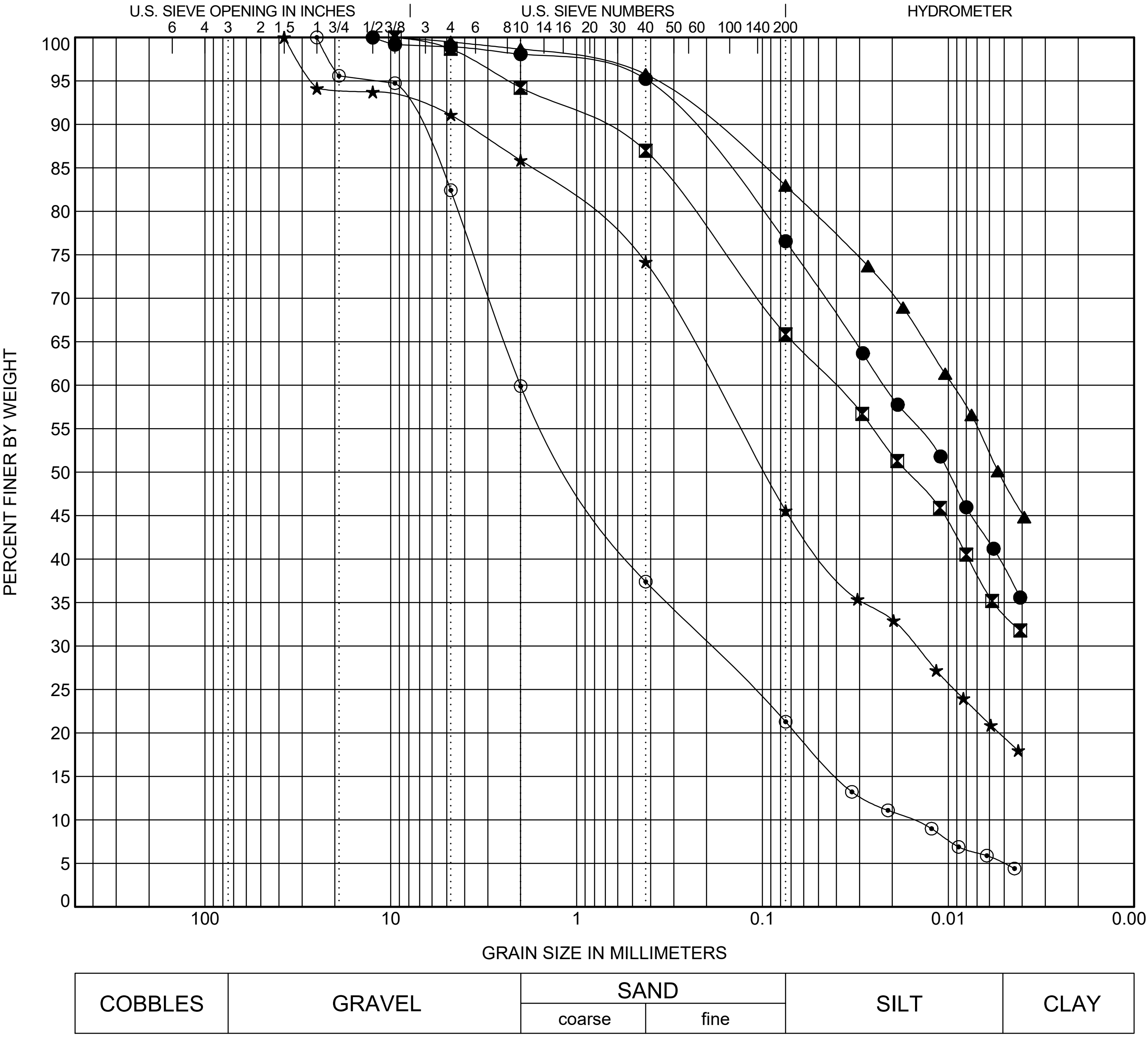
| | Specimen Identification | | ODOT (Modified AASHTO) ~ USCS Classification | LL | PL | PI |
|---|---|---|---|---|---|---|
| ● | **B-001-0-21** | **21.5** | **A-6a ~ LEAN CLAY with SAND(CL)** | **28** | **15** | **13** |
| ⧗ | **B-001-0-21** | **23.0** | **A-6a ~ LEAN CLAY with SAND(CL)** | **31** | **17** | **14** |
| ▲ | **B-001-0-21** | **25.0** | **A-6a ~ LEAN CLAY with SAND(CL)** | **31** | **16** | **15** |
| ★ | **B-001-0-21** | **27.5** | **A-4a ~ SANDY SILTY CLAY(CL-ML)** | **20** | **13** | **7** |
| ⊙ | **B-002-0-21** | **1.5** | **A-6b ~ LEAN CLAY with SAND(CL)** | **35** | **19** | **16** |

| | Specimen Identification | | D90 | D50 | D30 | D10 | %G | %CS | %FS | %M | %C | Cc | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ● | **B-001-0-21** | **21.5** | **1.159** | **0.01** | | | **8** | **7** | **14** | **32** | **39** | | |
| ⧗ | **B-001-0-21** | **23.0** | **0.403** | **0.005** | | | **3** | **6** | **11** | **32** | **48** | | |
| ▲ | **B-001-0-21** | **25.0** | **0.237** | **0.005** | | | **2** | **5** | **9** | **32** | **52** | | |
| ★ | **B-001-0-21** | **27.5** | **0.711** | **0.036** | **0.009** | | **4** | **9** | **26** | **38** | **23** | | |
| ⊙ | **B-002-0-21** | **1.5** | **0.836** | **0.007** | | | **6** | **7** | **13** | **30** | **44** | | |

# GRAIN SIZE DISTRIBUTION

**OHIO DEPARTMENT OF TRANSPORTION**
**OFFICE OF GEOTECHNICAL ENGINEERING**

**PROJECT** OTT-51-03.85 **PID** 80032
**OGE NUMBER** 0 **PROJECT TYPE** STRUCTURE FOUNDATION



| Specimen Identification | | | ODOT (Modified AASHTO) ~ USCS Classification | LL | PL | PI |
|---|---|---|---|---|---|---|
| ● | **B-002-0-21** | **3.0** | **A-6b ~ LEAN CLAY with SAND(CL)** | **37** | **17** | **20** |
| ☒ | **B-002-0-21** | **6.0** | **A-6b ~ SANDY LEAN CLAY(CL)** | **35** | **19** | **16** |
| ▲ | **B-002-0-21** | **8.5** | **A-7-6 ~ LEAN CLAY with SAND(CL)** | **42** | **19** | **23** |
| ★ | **B-002-0-21** | **11.0** | **A-6a ~ CLAYEY SAND(SC)** | **27** | **16** | **11** |
| ⊙ | **B-002-0-21** | **18.0** | **A-1-b ~ SILTY SAND with GRAVEL(SM)** | **NP** | **NP** | **NP** |

| Specimen Identification | | | D90 | D50 | D30 | D10 | %G | %CS | %FS | %M | %C | Cc | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ● | **B-002-0-21** | **3.0** | **0.261** | **0.01** | | | **1** | **3** | **19** | **38** | **39** | | |
| ☒ | **B-002-0-21** | **6.0** | **0.811** | **0.017** | | | **6** | **7** | **21** | **32** | **34** | | |
| ▲ | **B-002-0-21** | **8.5** | **0.195** | **0.005** | | | **1** | **3** | **13** | **34** | **49** | | |
| ★ | **B-002-0-21** | **11.0** | **3.961** | **0.098** | **0.015** | | **13** | **12** | **29** | **27** | **19** | | |
| ⊙ | **B-002-0-21** | **18.0** | **7.277** | **1.011** | **0.192** | **0.016** | **41** | **22** | **16** | **16** | **5** | **1.15** | **126.04** |

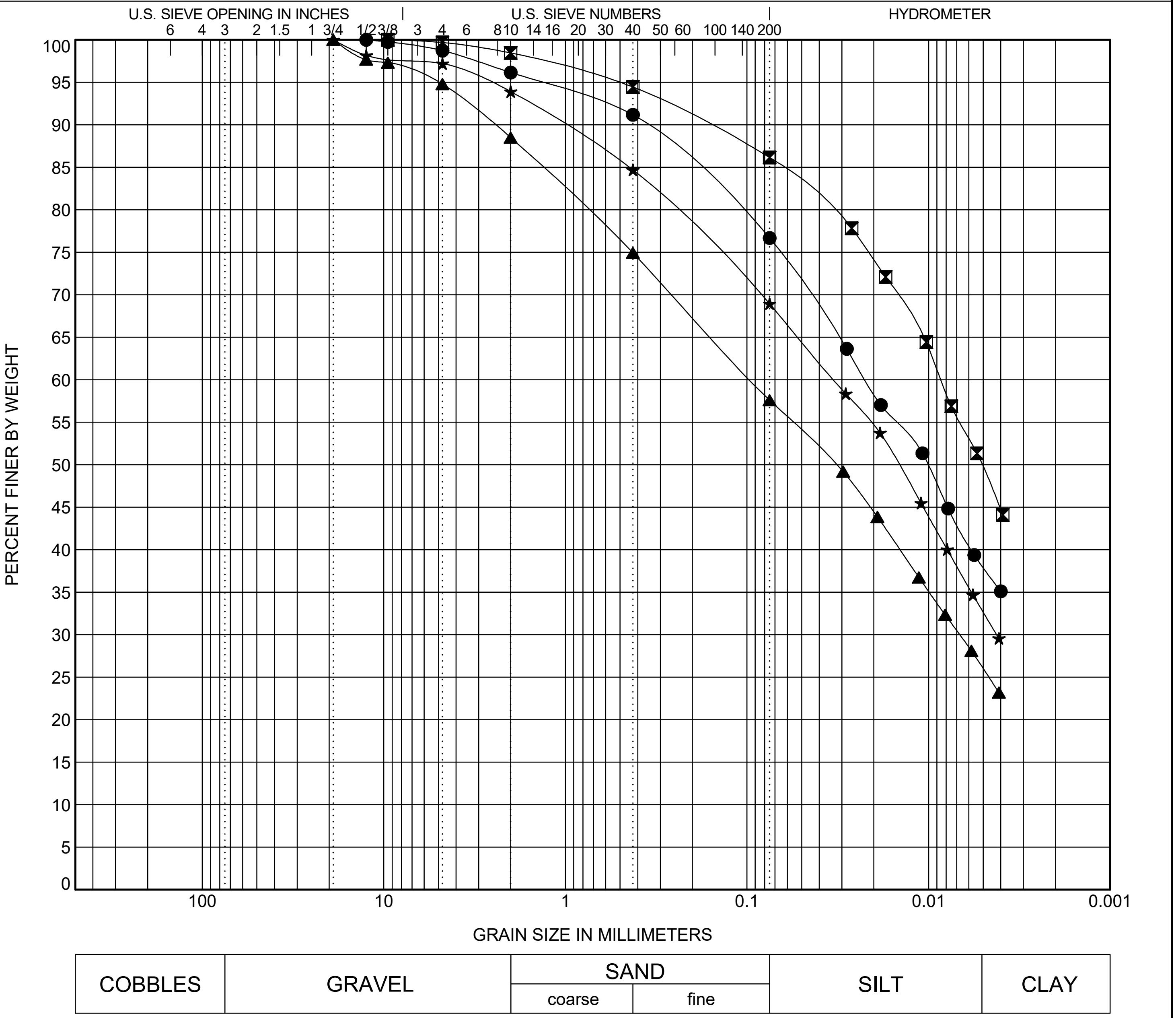
GRAIN SIZE - OH DOT.GDT - 6/14/22 16:17 - Z:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\OTT-51-3.85\GINT FILES\OTT-51-3.85.GPJ

# GRAIN SIZE DISTRIBUTION

**OHIO DEPARTMENT OF TRANSPORTION**
**OFFICE OF GEOTECHNICAL ENGINEERING**

**PROJECT** OTT-51-03.85 **PID** 80032

**OGE NUMBER** 0 **PROJECT TYPE** STRUCTURE FOUNDATION



| | Specimen Identification | | ODOT (Modified AASHTO) ~ USCS Classification | LL | PL | PI |
|---|---|---|---|---|---|---|
| ● | **B-002-0-21** | **19.5** | **A-6a ~ LEAN CLAY with SAND(CL)** | **31** | **17** | **14** |
| ⧗ | **B-002-0-21** | **21.0** | **A-6b ~ LEAN CLAY(CL)** | **35** | **18** | **17** |
| ▲ | **B-002-0-21** | **22.5** | **A-4a ~ SANDY LEAN CLAY(CL)** | **24** | **15** | **9** |
| ★ | **B-002-0-21** | **25.0** | **A-4a ~ SANDY LEAN CLAY(CL)** | **24** | **14** | **10** |
| | | | | | | |

| | Specimen Identification | | D90 | D50 | D30 | D10 | %G | %CS | %FS | %M | %C | Cc | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ● | **B-002-0-21** | **19.5** | **0.369** | **0.01** | | | **4** | **5** | **14** | **39** | **38** | | |
| ⧗ | **B-002-0-21** | **21.0** | **0.168** | **0.005** | | | **2** | **4** | **8** | **36** | **50** | | |
| ▲ | **B-002-0-21** | **22.5** | **2.46** | **0.032** | **0.007** | | **11** | **14** | **17** | **32** | **26** | | |
| ★ | **B-002-0-21** | **25.0** | **1.037** | **0.015** | **0.004** | | **6** | **9** | **16** | **36** | **33** | | |
| | | | | | | | | | | | | | |

GRAIN SIZE - OH DOT.GDT - 6/14/22 16:17 - Z:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\OTT-51-3.85\GINT FILES\OTT-51-3.85.GPJ

# B-001-0-21

| Run #: | Depth | | Recovery | | RQD | |
|---|---|---|---|---|---|---|
| NQ2-1 | 42.5’ | 52.5’ | 119/120 | 99% | 95.5/120 | 80% |
| | | | | | | |

OTT-51-03.85

# B-002-0-21

| Run #: | Depth | | Recovery | | RQD | |
|---|---|---|---|---|---|---|
| NQ2-1 | 42.5' | 52.5' | 116.25/120 | 97% | 106/120 | 88% |
| | | | | | | |
| OTT-51-03.85 | | | | | | |

# APPENDIX C

# GB1 ANALYSIS

# OHIO DEPARTMENT OF TRANSPORTATION

## OFFICE OF GEOTECHNICAL ENGINEERING

## PLAN SUBGRADES
## Geotechnical Bulletin GB1

Instructions: Enter data in the shaded cells only.
(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.)

**OTT-51-03.85**
**80032**

**Bridge Replacement: OTT-51-03.85 carrying SR-51 over Toussaint Creek**

**NEAS, INC.**

**Prepared By:** Melinda He
**Date prepared:** Friday, June 24, 2022

Chunmei (Melinda) He, Ph.D, P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH, 43231
614-714-0299
che@neasinc.com

**NO. OF BORINGS:** 2

| # | Boring ID | Alignment | Station | Offset | Dir | Drill Rig | ER | Boring EL. | Proposed Subgrade EL | Cut Fill |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B-001-0-21 | SR 51 | | | | CME 55X | 79 | 608.9 | 607.4 | 1.5 C |
| 2 | B-002-0-21 | SR 51 | | | | CME 55X | 79 | 608.7 | 607.2 | 1.5 C |

| # | Boring | Sample | Sample Depth | | Subgrade Depth | | Standard Penetration | | HP (tsf) | Physical Characteristics | | | | | | Moisture | | Ohio DOT | | Sulfate Content (ppm) | Problem | | Excavate and Replace (Item 204) | | Recommendation (Enter depth in inches) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | From | To | From | To | $N_{60}$ | $N_{60L}$ | | LL | PL | PI | % Silt | % Clay | P200 | $M_C$ | $M_{OPT}$ | Class | GI | | Unsuitable | Unstable | Unsuitable | Unstable | |
| 1 | B 001-0 21 | SS-1 | 1.5 | 3.0 | 0.0 | 1.5 | 13 | 5 | 4.25 | 29 | 17 | 12 | 34 | 32 | 66 | 17 | 14 | A-6a | 7 | | | $N_{60}$ & Mc | | 12" | |
| | | SS-2 | 3.0 | 4.5 | 1.5 | 3.0 | 13 | | 2.5 | | | | | | | 19 | 14 | A-6a | 10 | | | $N_{60}$ & Mc | | | |
| | | SS-3 | 4.5 | 6.0 | 3.0 | 4.5 | 5 | | 2.5 | 28 | 15 | 13 | 25 | 19 | 44 | 15 | 14 | A-6a | 3 | | | | | | |
| | | SS-4 | 6.0 | 7.5 | 4.5 | 6.0 | 7 | | 2.25 | | | | | | | 20 | 14 | A-6a | 10 | | | | | | |
| 2 | B 002-0 21 | SS-1 | 1.5 | 3.0 | 0.0 | 1.5 | 14 | 11 | 4.5 | 35 | 19 | 16 | 30 | 44 | 74 | 17 | 16 | A-6b | 10 | | | | | | |
| | | SS-2 | 3.0 | 4.5 | 1.5 | 3.0 | 13 | | 3.75 | 37 | 17 | 20 | 38 | 39 | 77 | 18 | 16 | A-6b | 12 | | | | | | |
| | | SS-3 | 4.5 | 6.0 | 3.0 | 4.5 | 11 | | 1 | | | | | | | 24 | 16 | A-6b | 16 | | | | | | |
| | | SS-4 | 6.0 | 7.5 | 4.5 | 6.0 | 11 | | 1.25 | | | | | | | 23 | 16 | A-6b | 16 | | | | | | |

OHIO DEPARTMENT OF TRANSPORTATION

**Subgrade Analysis**

V. 14.6 2/11/2022

**PID:** 80032

**County-Route-Section:** OTT-51-03.85
**No. of Borings:** 2

**Geotechnical Consultant:** NEAS, INC.
**Prepared By:** Melinda He
**Date prepared:** 6/24/2022

| Chemical Stabilization Options | | |
|---|---|---|
| 320 | Rubblize & Roll | No |
| 206 | Cement Stabilization | Option |
| | Lime Stabilization | No |
| 206 | Depth | 14" |

| Excavate and Replace Stabilization Options | |
|---|---|
| Global Geotextile<br>Average(N60L):<br>Average(HP): | <br>12"<br>0" |
| Global Geogrid<br>Average(N60L):<br>Average(HP): | <br>0"<br>0" |

| Design CBR | 6 |
|---|---|

| % Samples within 6 feet of subgrade | | | |
|---|---|---|---|
| $N_{60} \le 5$ | 13% | $HP \le 0.5$ | 0% |
| $N_{60} < 12$ | 50% | $0.5 < HP \le 1$ | 13% |
| $12 \le N_{60} < 15$ | 50% | $1 < HP \le 2$ | 13% |
| $N_{60} \ge 20$ | 0% | $HP > 2$ | 75% |
| M+ | 25% | | |
| Rock | 0% | | |
| Unsuitable | 0% | | |

| Excavate and Replace at Surface | |
|---|---|
| Average | 0" |
| Maximum | 0" |
| Minimum | 0" |

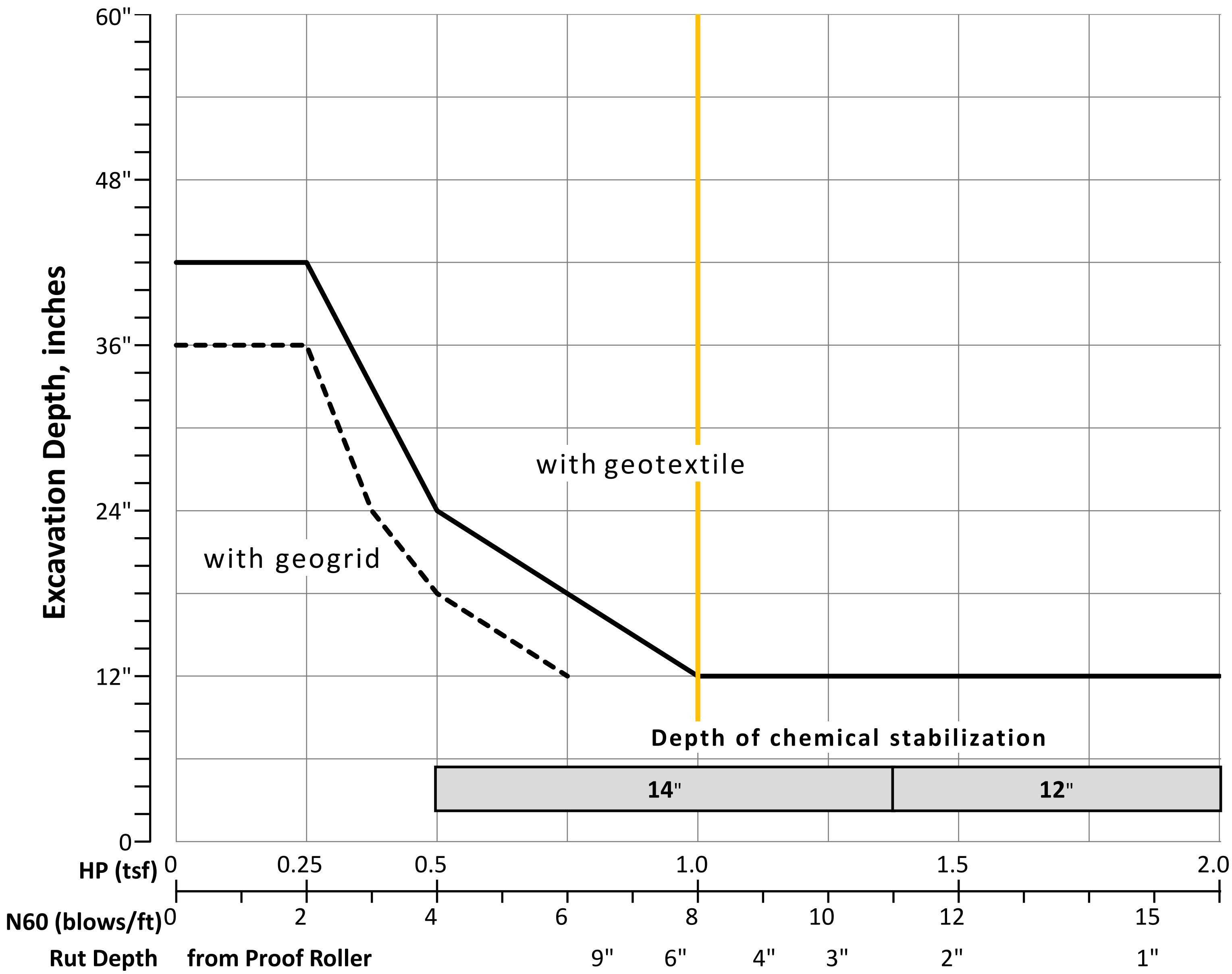
| % Proposed Subgrade Surface | |
|---|---|
| Unstable & Unsuitable | 50% |
| Unstable | 50% |
| Unsuitable | 0% |

| | $N_{60}$ | $N_{60L}$ | HP | LL | PL | PI | Silt | Clay | P 200 | $M_C$ | $M_{OPT}$ | GI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average | 11 | 8 | 2.75 | 32 | 17 | 15 | 32 | 34 | 65 | 19 | 15 | 11 |
| Maximum | 14 | 11 | 4.50 | 37 | 19 | 20 | 38 | 44 | 77 | 24 | 16 | 16 |
| Minimum | 5 | 5 | 1.00 | 28 | 15 | 12 | 25 | 19 | 44 | 15 | 14 | 3 |

## Classification Counts by Sample

| ODOT Class | Rock | A-1-a | A-1-b | A-2-4 | A-2-5 | A-2-6 | A-2-7 | A-3 | A-3a | A-4a | A-4b | A-5 | A-6a | A-6b | A-7-5 | A-7-6 | A-8a | A-8b | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Count | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 8 |
| Percent | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 50% | 50% | 0% | 0% | 0% | 0% | 100% |
| % Rock\|Granular\|Cohesive | 0% | 0% | | | | | | | | | 100% | | | | | | | | 100% |
| Surface Class Count | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 4 |
| Surface Class Percent | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 50% | 50% | 0% | 0% | 0% | 0% | 100% |

## GB1 Figure B – Subgrade Stabilization



**OVERRIDE TABLE**

| Calculated Average | New Values | Check to Override |
|---|---|---|
| 2.75 | 0.50 | ☐ HP |
| 8.00 | 6.00 | ☐ N60L |

**Average HP** 🟦

**Average $N_{60L}$** 🟨

# APPENDIX D

# SETTLEMENT ANALYSIS

# OTT-51-03.85

## PROJECT IDENTIFICATION

| | |
|---|---|
| Title: | OTT-51-03.85 |
| Project Number: | - |
| Client: | ODOT |
| Designer: | ZM |
| Station Number: | Rear Abutment STA. 103+50 |

**Description:**
B-001-0-21

**Company's information:**

| | |
|---|---|
| Name: | NEAS, Inc. |
| Street: | <br>, |
| Telephone #: | |
| Fax #: | |
| E-Mail: | |

**Original file path and name:** C:\Users\s ..... 51\OTT-51-03.85 RearAbut_STA.103+50_B-001-0-21.2ST
**Original date and time of creating this file:** 6/23/2022

**GEOMETRY:** Analysis of a 3D-Approximate geometry

## INPUT DATA – FOUNDATION LAYERS – 7 layers

| | **Wet Unit Weight, $\gamma$ [lb/ft$^3$]** | **Poisson's Ratio $\mu$** | **Description of Soil** |
|---|---|---|---|
| 1 | 108.00 | 0.35 | A-6a |
| 2 | 112.00 | 0.35 | A-7-6 |
| 3 | 112.00 | 0.35 | A-6a |
| 4 | 122.00 | 0.35 | A-4a |
| 5 | 122.00 | 0.35 | A-6a |
| 6 | 130.00 | 0.35 | A-4a |
| 7 | 140.00 | 0.30 | A-1-b |

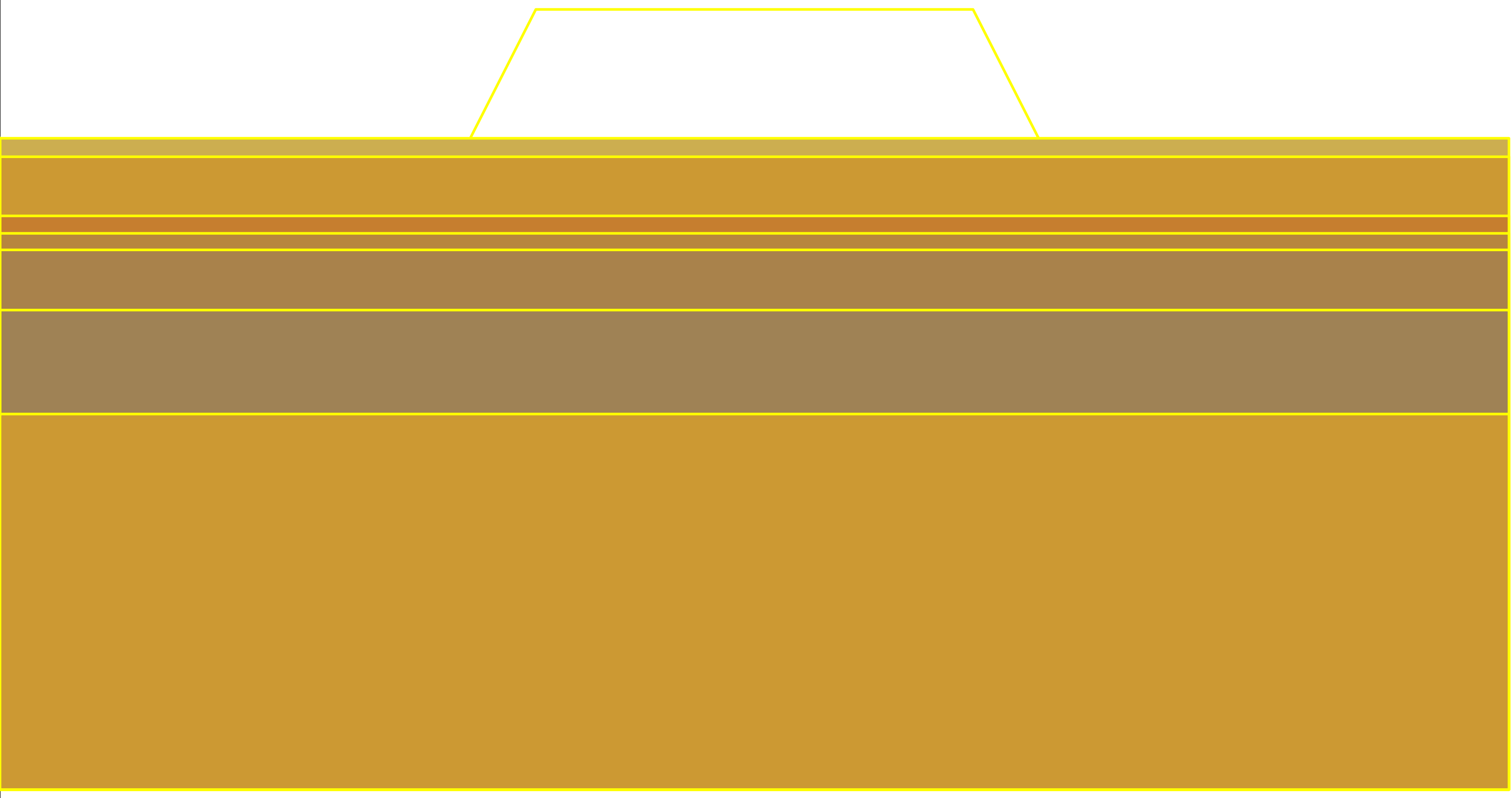
## INPUT DATA – EMBANKMENT LAYERS – 1 layers

| | **Wet Unit Weight, $\gamma$ [lb/ft$^3$]** | **Description of Soil** |
|---|---|---|
| 1 | 120.00 | Embankment Fills |

## INPUT DATA OF WATER

| **Point #** | **Coordinates (X, Z) :**<br>**(X) [ ft.]** | **(Z) [ ft.]** |
|---|---|---|
| 1 | 0.00 | 588.90 |
| 2 | 10.00 | 588.90 |
| 3 | 25.00 | 588.90 |
| 4 | 40.00 | 588.90 |

## DRAWING OF SPECIFIED GEOMETRY



## INPUT DATA FOR CONSOLIDATION –– $\alpha = 1/2$

| Layer # | Underging Consolidation [Yes/No] | OCR = Pc / Po | Cc | Cr | e0 | Cv [ft ²/day] | Drains at : | Shear Strength Data S | m | CREEP Ca/Cc |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Yes | 1.50 | 0.145 | 0.020 | 0.960 | 0.3000 | Top | 0.250 | 0.800 | 0.0500 |
| 2 | Yes | 1.50 | 0.196 | 0.036 | 0.870 | 0.2000 | Bottom | 0.250 | 0.800 | 0.0500 |
| 3 | Yes | 1.50 | 0.128 | 0.014 | 0.740 | 0.3000 | Top & Bot. | 0.250 | 0.800 | 0.0500 |
| 4 | Yes | 2.40 | 0.091 | 0.007 | 0.540 | 0.3000 | Top | 0.250 | 0.800 | 0.0500 |
| 5 | Yes | 2.40 | 0.121 | 0.016 | 0.580 | 0.3000 | Bottom | 0.250 | 0.800 | 0.0500 |
| 6 | Yes | 3.00 | 0.069 | 0.005 | 0.420 | 0.3000 | Bottom | 0.250 | 0.800 | 0.0500 |
| 7 | No | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

Secondary Comprassion (Creep) : Settlement is calculated at t2/t1 = 10.0

## IMMEDIATE SETTLEMENT, Si

| Node # | Settlement along section: X [ ft.] | Y [ ft.] | Layer (k) | Young's Modulus, E [lb/ft ²] | Poisson's Ratio, μ | Settlement of each layer, Si(k) [ ft.] | Initial Z [ ft.] | Final Z * [ ft.] | Total Settlement Sum of Si(k), [ ft.] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -26.00 | 0.00 | 1 | 40000 | 0.3500 | -0.0020 | 597.60 | 597.57 | 0.03 |
| | | | 2 | 30000 | 0.3500 | 0.0025 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0075 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0015 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0074 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0116 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0037 | | | |
| 2 | -20.80 | 0.00 | 1 | 40000 | 0.3500 | 0.0303 | 597.60 | 597.38 | 0.22 |
| | | | 2 | 30000 | 0.3500 | 0.1151 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0320 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0048 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0161 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0182 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0050 | | | |
| 3 | -15.60 | 0.00 | 1 | 40000 | 0.3500 | 0.0333 | 597.60 | 597.31 | 0.29 |
| | | | 2 | 30000 | 0.3500 | 0.1480 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0458 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0068 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0227 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0240 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0062 | | | |
| 4 | -10.40 | 0.00 | 1 | 40000 | 0.3500 | 0.0326 | 597.60 | 597.31 | 0.29 |
| | | | 2 | 30000 | 0.3500 | 0.1442 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0478 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0074 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0256 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0279 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0071 | | | |
| 5 | -5.20 | 0.00 | 1 | 40000 | 0.3500 | 0.0324 | 597.60 | 597.31 | 0.29 |
| | | | 2 | 30000 | 0.3500 | 0.1410 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0475 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0074 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0265 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0299 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0077 | | | |
| 6 | 0.00 | 0.00 | 1 | 40000 | 0.3500 | 0.0323 | 597.60 | 597.31 | 0.29 |
| | | | 2 | 30000 | 0.3500 | 0.1400 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0473 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0074 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0267 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0304 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0078 | | | |
| 7 | 5.20 | 0.00 | 1 | 40000 | 0.3500 | 0.0324 | 597.60 | 597.31 | 0.29 |
| | | | 2 | 30000 | 0.3500 | 0.1410 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0475 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0074 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0265 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0299 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0077 | | | |

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

## IMMEDIATE SETTLEMENT, Si

| Node # | Settlement along section: X [ ft.] | Y [ ft.] | Layer (k) | Young's Modulus, E [lb/ft ²] | Poisson's Ratio, μ | Settlement of each layer, Si(k) [ ft.] | Initial Z [ ft.] | Final Z * [ ft.] | Total Settlement Sum of Si(k), [ ft.] |
|---|---|---|---|---|---|---|---|---|---|
| 8 | 10.40 | 0.00 | 1 | 40000 | 0.3500 | 0.0326 | 597.60 | 597.31 | 0.29 |
| | | | 2 | 30000 | 0.3500 | 0.1442 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0478 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0074 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0256 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0279 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0071 | | | |
| 9 | 15.60 | 0.00 | 1 | 40000 | 0.3500 | 0.0333 | 597.60 | 597.31 | 0.29 |
| | | | 2 | 30000 | 0.3500 | 0.1480 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0458 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0068 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0227 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0241 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0062 | | | |
| 10 | 20.80 | 0.00 | 1 | 40000 | 0.3500 | 0.0302 | 597.60 | 597.38 | 0.22 |
| | | | 2 | 30000 | 0.3500 | 0.1150 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0320 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0048 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0161 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0182 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0050 | | | |
| 11 | 26.00 | 0.00 | 1 | 40000 | 0.3500 | -0.0020 | 597.60 | 597.57 | 0.03 |
| | | | 2 | 30000 | 0.3500 | 0.0025 | | | |
| | | | 3 | 30000 | 0.3500 | 0.0075 | | | |
| | | | 4 | 200000 | 0.3500 | 0.0015 | | | |
| | | | 5 | 200000 | 0.3500 | 0.0074 | | | |
| | | | 6 | 300000 | 0.3500 | 0.0116 | | | |
| | | | 7 | 500000 | 0.3000 | 0.0037 | | | |

*Note: Final Z is calculated assuming only 'Immediate Settlement' exists.

## ULTIMATE SETTLEMENT, Sc

| Node<br># | X<br>[ ft.] | Y<br>[ ft.] | Original<br>Z<br>[ ft.] | Settlement<br>Sc<br>[ ft.] | Final<br>Z *<br>[ ft.] |
|---|---|---|---|---|---|
| 1 | -26.00 | 0.00 | 597.60 | 0.05 | 597.55 |
| 2 | -20.80 | 0.00 | 597.60 | 0.39 | 597.21 |
| 3 | -15.60 | 0.00 | 597.60 | 0.46 | 597.14 |
| 4 | -10.40 | 0.00 | 597.60 | 0.47 | 597.13 |
| 5 | -5.20 | 0.00 | 597.60 | 0.47 | 597.13 |
| 6 | 0.00 | 0.00 | 597.60 | 0.47 | 597.13 |
| 7 | 5.20 | 0.00 | 597.60 | 0.47 | 597.13 |
| 8 | 10.40 | 0.00 | 597.60 | 0.47 | 597.13 |
| 9 | 15.60 | 0.00 | 597.60 | 0.46 | 597.14 |
| 10 | 20.80 | 0.00 | 597.60 | 0.39 | 597.21 |
| 11 | 26.00 | 0.00 | 597.60 | 0.05 | 597.55 |

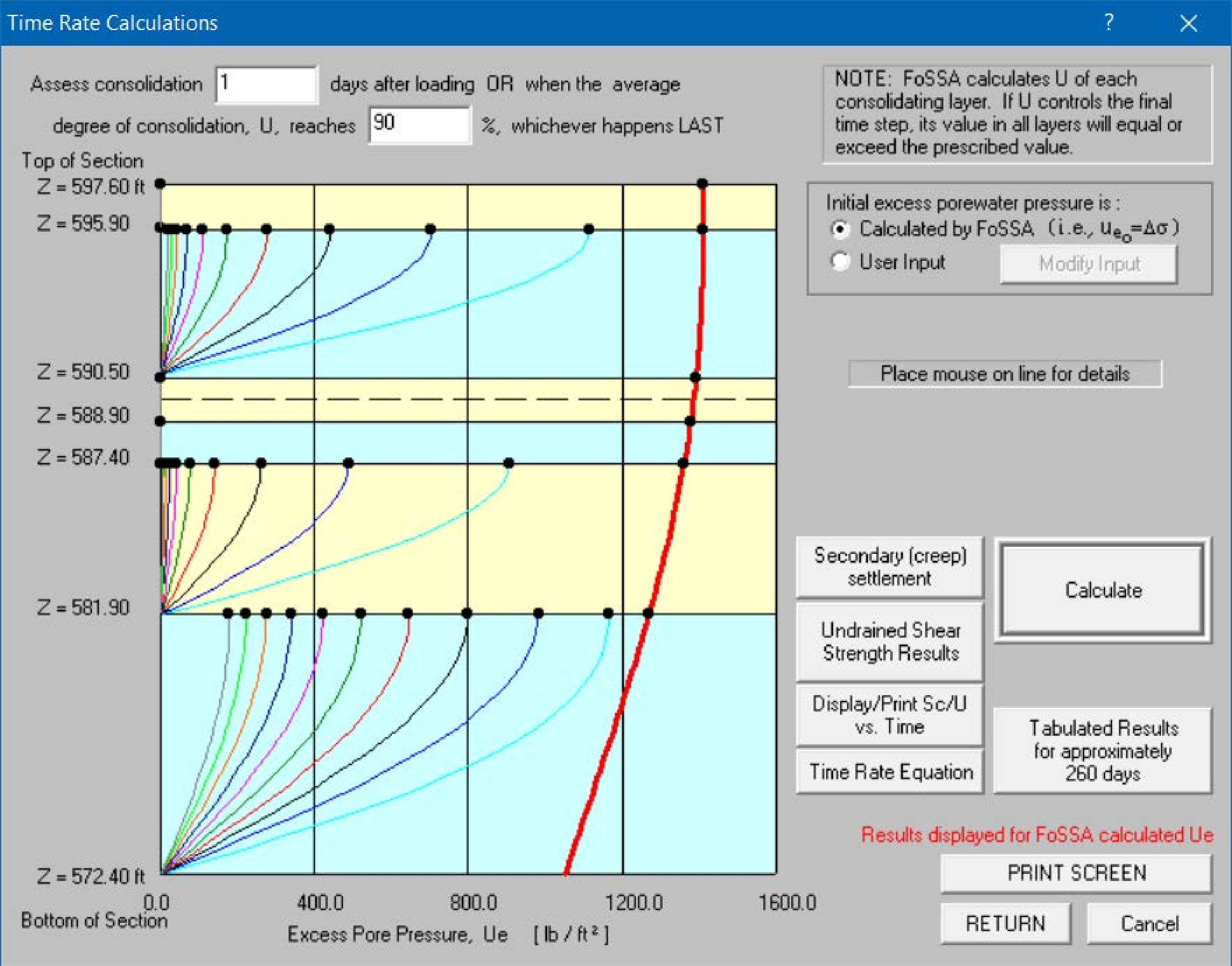
*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

## TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

| Found. Soil # | Point # | Coordinates (X, Z) : (X) [ ft.] | (Z) [ ft.] | DESCRIPTION |
|---|---|---|---|---|
| 1 | 1 | 0.00 | 597.60 | A-6a |
| 2 | 1 | 0.00 | 595.90 | A-7-6 |
| 3 | 1 | 0.00 | 590.50 | A-6a |
| 4 | 1 | 0.00 | 588.90 | A-4a |
| 5 | 1 | 0.00 | 587.40 | A-6a |
| 6 | 1 | 0.00 | 581.90 | A-4a |
| 7 | 1 | 0.00 | 572.40 | A-1-b |

## TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

| Embank. Soil # | | Point # | Coordinates (X, Z) : (X) [ ft.] | (Z) [ ft.] | DESCRIPTION |
|---|---|---|---|---|---|
| 1 | X1 = -26.00 [ft] | 1 | -20.00 | 609.37 | Embankment Fills |
| | X2 = 26.00 [ft] | 2 | 20.00 | 609.37 | |



Assess consolidation 1 days after loading OR when the average degree of consolidation, U, reaches 90 %, whichever happens LAST

NOTE: FoSSA calculates U of each consolidating layer. If U controls the final time step, its value in all layers will equal or exceed the prescribed value.

Initial excess porewater pressure is :

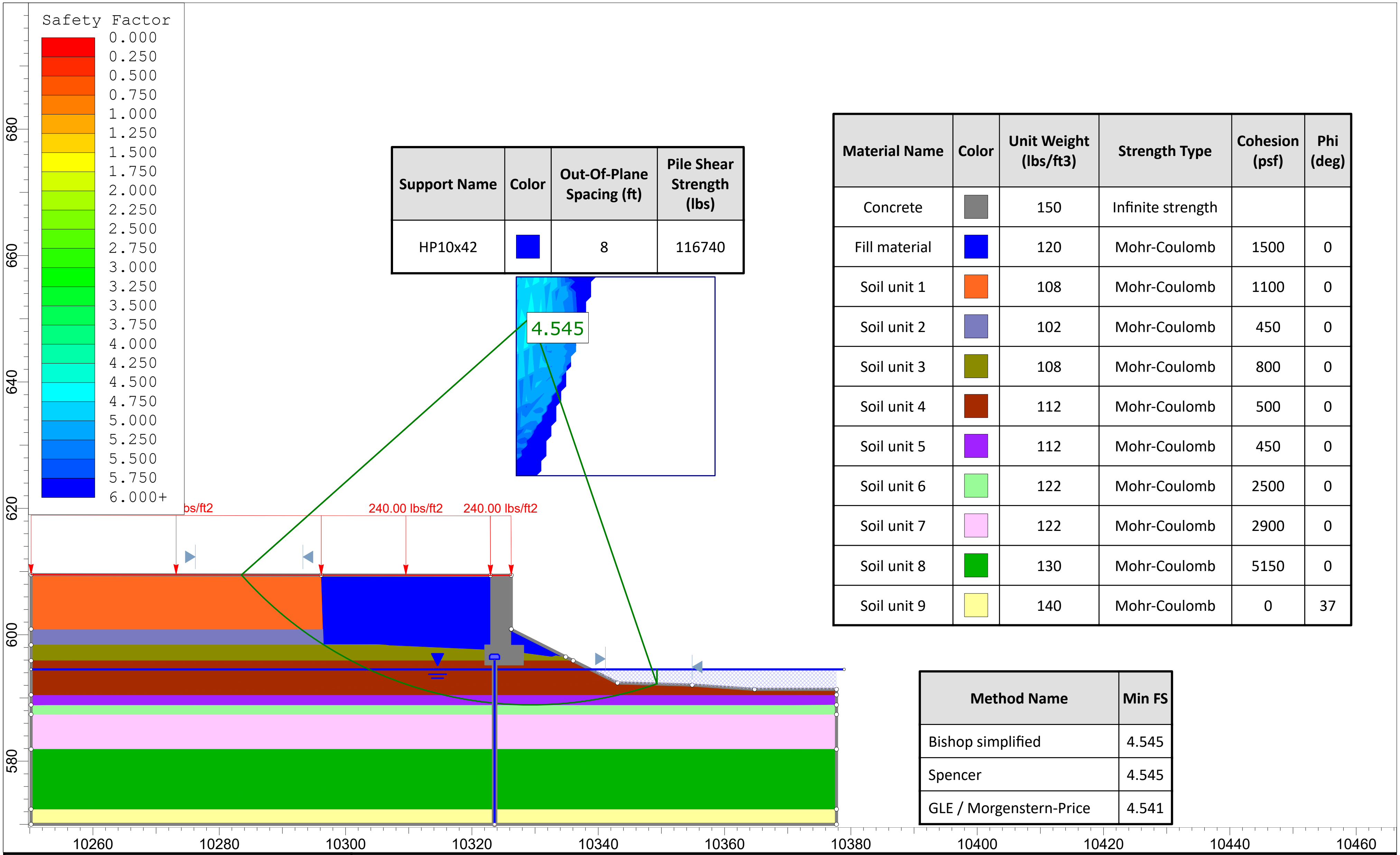
● Calculated by FoSSA (i.e., $u_{e_o}=\Delta\sigma$)

○ User Input

Results displayed for FoSSA calculated Ue

# APPENDIX E

# GLOBAL STABILITY ANALYSIS



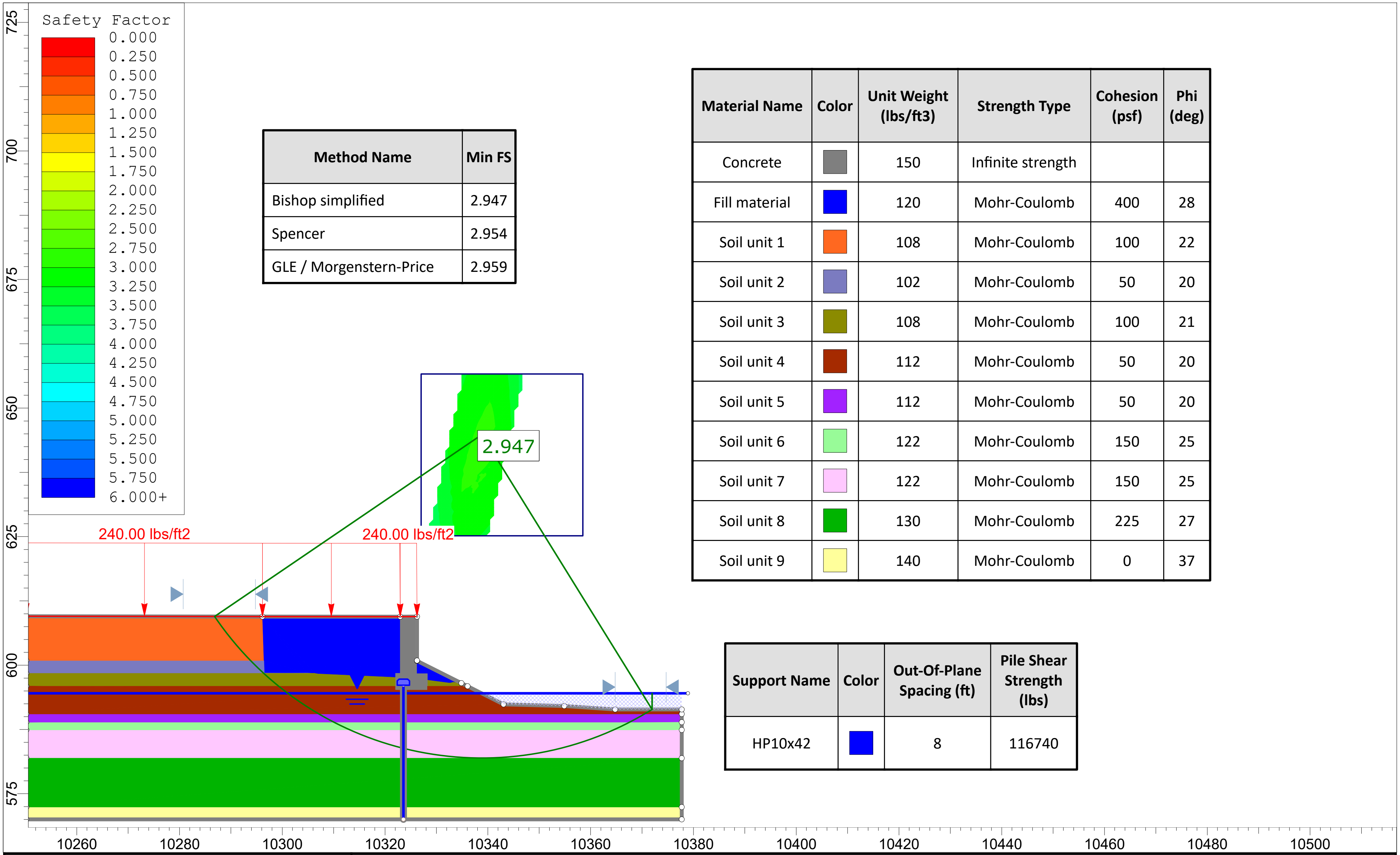
| Support Name | Color | Out-Of-Plane Spacing (ft) | Pile Shear Strength (lbs) |
|---|---|---|---|
| HP10x42 | 🟦 | 8 | 116740 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) |
|---|---|---|---|---|---|
| Concrete | ⬛ | 150 | Infinite strength | | |
| Fill material | 🟦 | 120 | Mohr-Coulomb | 1500 | 0 |
| Soil unit 1 | 🟧 | 108 | Mohr-Coulomb | 1100 | 0 |
| Soil unit 2 | 🟪 | 102 | Mohr-Coulomb | 450 | 0 |
| Soil unit 3 | 🟫 | 108 | Mohr-Coulomb | 800 | 0 |
| Soil unit 4 | 🟥 | 112 | Mohr-Coulomb | 500 | 0 |
| Soil unit 5 | 🟪 | 112 | Mohr-Coulomb | 450 | 0 |
| Soil unit 6 | 🟩 | 122 | Mohr-Coulomb | 2500 | 0 |
| Soil unit 7 | 🟪 | 122 | Mohr-Coulomb | 2900 | 0 |
| Soil unit 8 | 🟩 | 130 | Mohr-Coulomb | 5150 | 0 |
| Soil unit 9 | 🟨 | 140 | Mohr-Coulomb | 0 | 37 |

| Method Name | Min FS |
|---|---|
| Bishop simplified | 4.545 |
| Spencer | 4.545 |
| GLE / Morgenstern-Price | 4.541 |

| | | | |
|---|---|---|---|
| *Project* | OTT-51-03.85 | | |
| *Analysis Description* | Rear abutment circular failure short term (total) | | |
| *Drawn By* | M. Jasiewicz | *Scale* 1:252 | *Company* NEAS Inc. |
| *Date* | 6/27/2022, 4:43:26 PM | *File Name* | RearAbut_Circular_Short.slim |

SLIDEINTERPRET 7.037



| Method Name | Min FS |
|---|---|
| Bishop simplified | 2.947 |
| Spencer | 2.954 |
| GLE / Morgenstern-Price | 2.959 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) |
|---|---|---|---|---|---|
| Concrete | ⬛ | 150 | Infinite strength | | |
| Fill material | 🟦 | 120 | Mohr-Coulomb | 400 | 28 |
| Soil unit 1 | 🟧 | 108 | Mohr-Coulomb | 100 | 22 |
| Soil unit 2 | 🟪 | 102 | Mohr-Coulomb | 50 | 20 |
| Soil unit 3 | 🟫 | 108 | Mohr-Coulomb | 100 | 21 |
| Soil unit 4 | 🟥 | 112 | Mohr-Coulomb | 50 | 20 |
| Soil unit 5 | 🟪 | 112 | Mohr-Coulomb | 50 | 20 |
| Soil unit 6 | 🟩 | 122 | Mohr-Coulomb | 150 | 25 |
| Soil unit 7 | ⬜ | 122 | Mohr-Coulomb | 150 | 25 |
| Soil unit 8 | 🟩 | 130 | Mohr-Coulomb | 225 | 27 |
| Soil unit 9 | 🟨 | 140 | Mohr-Coulomb | 0 | 37 |

| Support Name | Color | Out-Of-Plane Spacing (ft) | Pile Shear Strength (lbs) |
|---|---|---|---|
| HP10x42 | 🟦 | 8 | 116740 |

rocscience

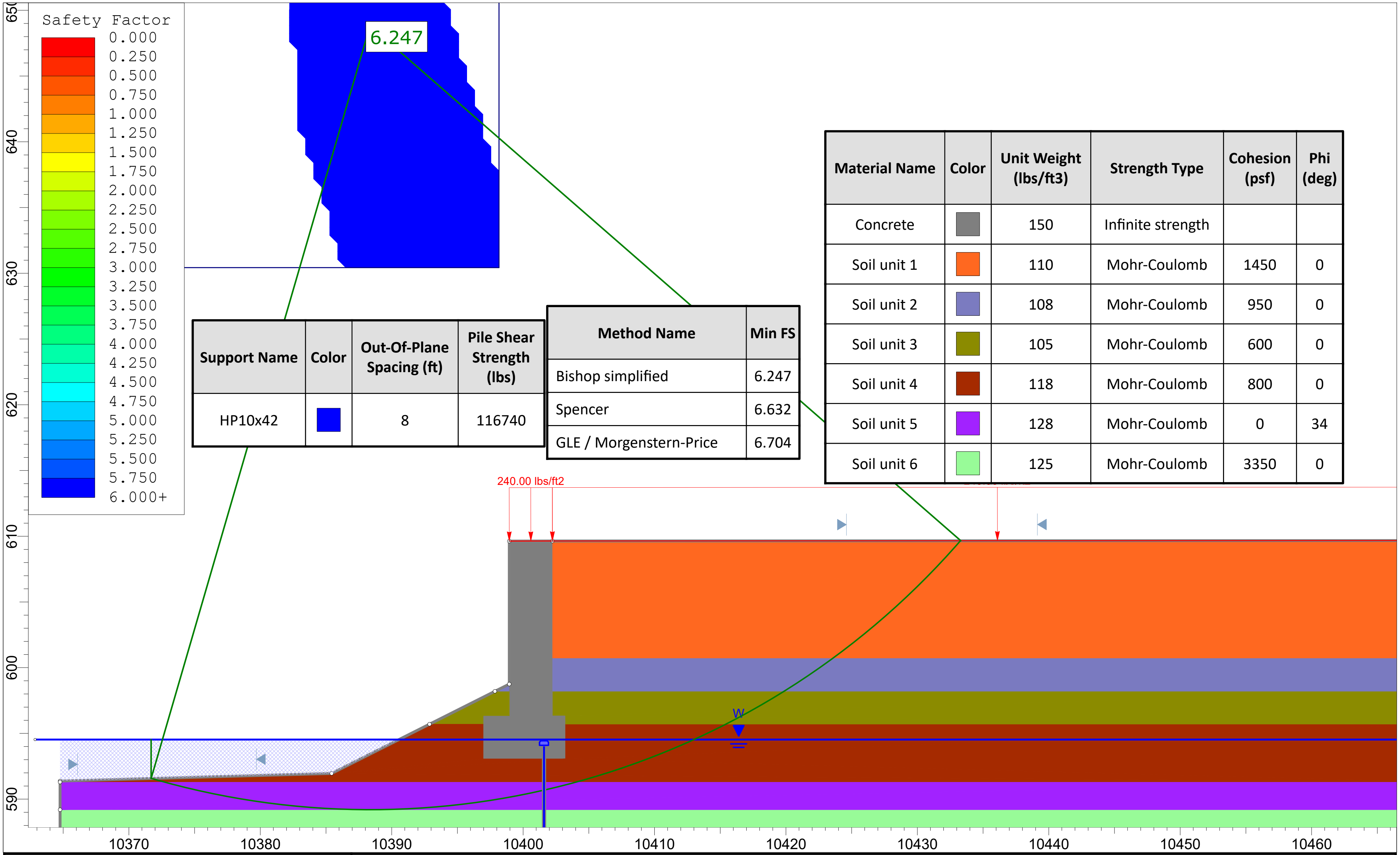
SLIDEINTERPRET 7.037

*Project* OTT-51-03.85

*Analysis Description* Rear abutment circular failure long term (effective)

*Drawn By* M. Jasiewicz
*Scale* 1:310
*Company* NEAS Inc.

*Date* 6/27/2022, 4:43:26 PM
*File Name* RearAbut_Circular_Long.slim



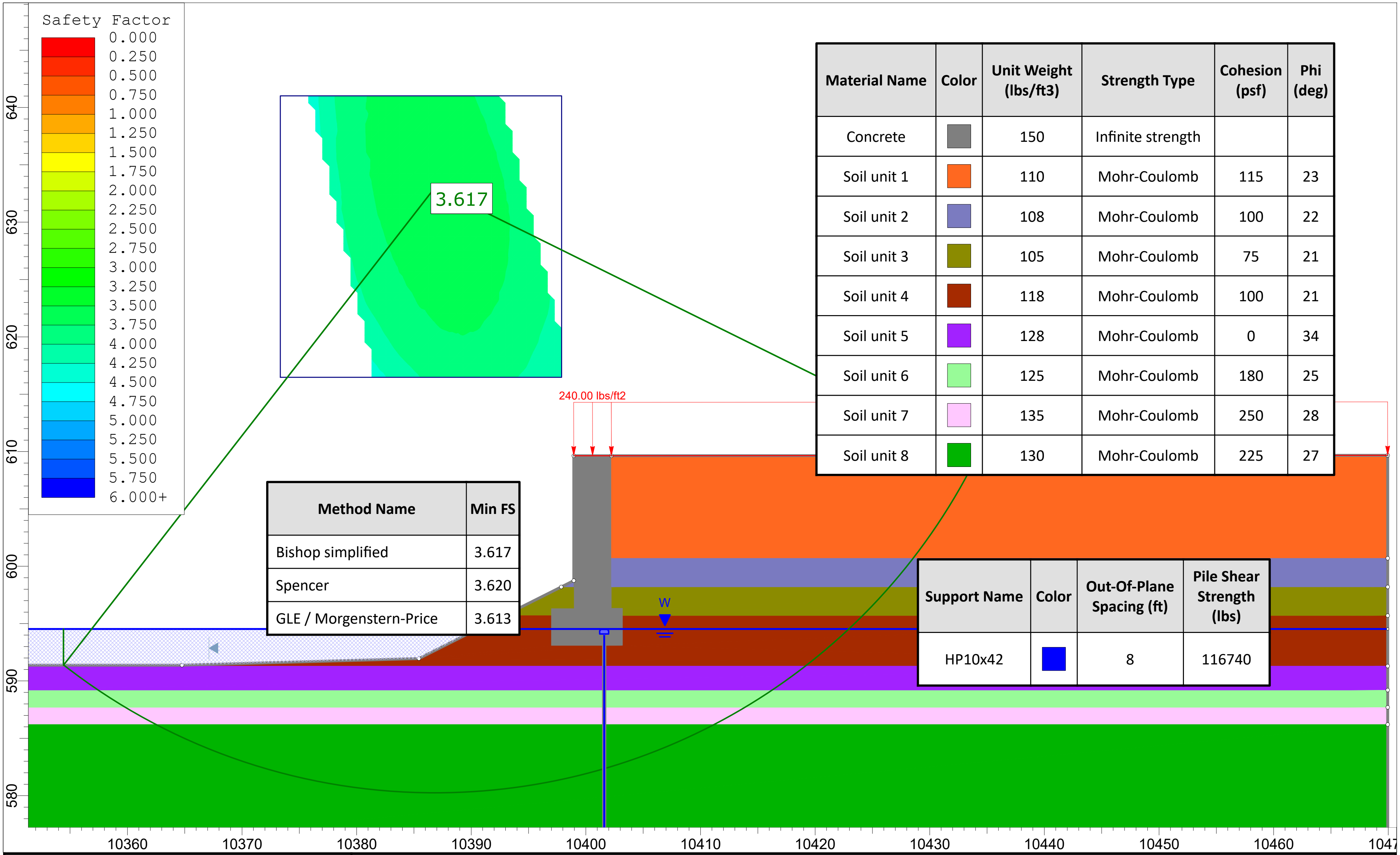
| Support Name | Color | Out-Of-Plane Spacing (ft) | Pile Shear Strength (lbs) |
|---|---|---|---|
| HP10x42 | 🟦 | 8 | 116740 |

| Method Name | Min FS |
|---|---|
| Bishop simplified | 6.247 |
| Spencer | 6.632 |
| GLE / Morgenstern-Price | 6.704 |

| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) |
|---|---|---|---|---|---|
| Concrete | ■ | 150 | Infinite strength | | |
| Soil unit 1 | 🟧 | 110 | Mohr-Coulomb | 1450 | 0 |
| Soil unit 2 | 🟦 | 108 | Mohr-Coulomb | 950 | 0 |
| Soil unit 3 | 🟨 | 105 | Mohr-Coulomb | 600 | 0 |
| Soil unit 4 | 🟥 | 118 | Mohr-Coulomb | 800 | 0 |
| Soil unit 5 | 🟪 | 128 | Mohr-Coulomb | 0 | 34 |
| Soil unit 6 | 🟩 | 125 | Mohr-Coulomb | 3350 | 0 |

| | | | |
|---|---|---|---|
| *Project* | OTT-51-03.85 | | |
| *Analysis Description* | Forward abutment circular failure short term (total) | | |
| *Drawn By* | M. Jasiewicz | *Scale* 1:121 | *Company* NEAS Inc. |
| *Date* | 6/27/2022, 4:43:26 PM | *File Name* | ForwardAbut_Circular_Short.slim |

SLIDEINTERPRET 7.037



| Material Name | Color | Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) |
|---|---|---|---|---|---|
| Concrete | ◼ | 150 | Infinite strength | | |
| Soil unit 1 | 🟧 | 110 | Mohr-Coulomb | 115 | 23 |
| Soil unit 2 | 🟦 | 108 | Mohr-Coulomb | 100 | 22 |
| Soil unit 3 | 🟨 | 105 | Mohr-Coulomb | 75 | 21 |
| Soil unit 4 | 🟥 | 118 | Mohr-Coulomb | 100 | 21 |
| Soil unit 5 | 🟪 | 128 | Mohr-Coulomb | 0 | 34 |
| Soil unit 6 | 🟩 | 125 | Mohr-Coulomb | 180 | 25 |
| Soil unit 7 | ⬜ | 135 | Mohr-Coulomb | 250 | 28 |
| Soil unit 8 | 🟩 | 130 | Mohr-Coulomb | 225 | 27 |

| Method Name | Min FS |
|---|---|
| Bishop simplified | 3.617 |
| Spencer | 3.620 |
| GLE / Morgenstern-Price | 3.613 |

| Support Name | Color | Out-Of-Plane Spacing (ft) | Pile Shear Strength (lbs) |
|---|---|---|---|
| HP10x42 | 🟦 | 8 | 116740 |

SLIDEINTERPRET 7.037

| | |
|---|---|
| *Project* | OTT-51-03.85 |
| *Analysis Description* | Forward abutment circular failure long term (effective) |
| *Drawn By* | M. Jasiewicz |
| *Scale* | 1:139 |
| *Company* | NEAS Inc. |
| *Date* | 6/27/2022, 4:43:26 PM |
| *File Name* | ForwardAbut_Circular_lONG.slim |