FINAL REPORT
GEOTECHNICAL EXPLORATION
SUBGRADE AND RETAINING WALLS
ROS-159-0.41
ROSS COUNTY, OHIO
PID#: 113013

Prepared For:

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NEAS PROJECT 22-0019

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National Engineering & Architectural Services Inc.

EXECUTIVE SUMMARY

The Ohio Department of Transportation has proposed a safety improvement project (ROS-159-0.41, PID 113013) in Ross County, Ohio. The proposed project is along SR-159 (Bridge Street) south of Riverside Street and North Pawnee Road, and the overall project objective is to improve the safety, congestion and pedestrian connectivity within the project limits. The improvements proposed to accomplish this objective consist of 1) widening of SR 159 and associated side streets; 2) construction of a roundabout at the intersection between Consumer Center Drive and Stewart Road; 3) construction of a modular block wall under US-35 Bridge (Wall 1); 4) construction of one retaining wall at Kroger parking lot (Wall 2); and 5) construction of one retaining wall at McDonald's (Wall 3).

National Engineering & Architectural Services, Inc. (NEAS) has been contracted to perform geotechnical engineering services for the project. 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 scope of work performed by NEAS as part of the referenced project included: a review of published geotechnical information; performing 31 test borings for the for the proposed construction; laboratory testing of soil samples in accordance with the SGE; performing geotechnical engineering analysis to assess subgrade stabilization requirements, pavement design parameters; assess wall design and construction considerations; and development of this summary report.

NEAS understands that the overall project objective is to improve the safety, congestion and pedestrian connectivity along SR-159 (Bridge Street) and improve safety along the US-35 EB exit Ramp. For this purpose, a subgrade exploration and subsequent analysis was completed for the referenced project. Also, NEAS understands that the proposed project improvements include construction of Wall 1 between Sta. 720+52.84 and Sta. 722+50.09 in reference to SR-159, Wall 2 between Sta. 740+40.37 and Sta. 741+80.04 in reference to SR-159 and Wall 3 between Sta. 752+24.74 and Sta. 754+25.00 in reference to SR-159. According to the retaining wall site plan, Wall 1 is a modular block wall, while Wall 2 and Wall 3 are Cast-In-Place concrete walls on spread footing. Wall 1 will be approximately 307.7 ft in length with a maximum wall height of 7.5 ft. Wall 2 will be approximately 142 ft in length with a maximum height of 10.8 ft including footing and a maximum exposed height of 4.9 ft. Wall 3 will be approximately 200 ft in length with a maximum wall height of 10.8 ft including footing.

Based on our subgrade analysis, unstable subgrade conditions, including areas of weak soils and high moisture content soils, were encountered less than 30 percent of the project area. Therefore, NEAS recommends local stabilization in the form of Item 204 Excavate and Replace to a depth of 12 inches along Merietta Connector Road between Station 15+10 and Station 17+58. NEAS believes that the subgrade soils will provide adequate pavement support assuming it is designed and constructed in accordance with the recommendations provided within this report, as well as all applicable ODOT standards and specifications.

For all three retaining walls, geotechnical analyses consisting of external stability (i.e., overall stability, bearing capacity, and sliding) and global stability evaluation were performed. Based on external stability analysis for Wall 1, the CDR ratios of overturning, undrained/drained bearing capacity and sliding check are all greater than 1.0. Based on the site plan provided by Palmer Engineering via email on November 17, 2023, 1 Horizontal: 1 Vertical (1H:1V) excavation cut was proposed for the construction of Wall 1. **Our global stability analysis under construction conditions revealed a minimum factor of safety for the short-term condition is 0.70, indicating potential instability in the excavation cut.** The Means and Methods of constructing the modular block wall can be left up to the discretion of the Contractor as long the depth of the excavation does not exceed 8 feet otherwise temporary shoring details shall be included with the plans.

Based on our external stability analyses for Wall 2 and Wall 3, the CDR ratios of overturning, undrained/drained bearing capacity and sliding check are all greater than 1.0. The minimum slope stability safety factors for both short-term and long-term conditions at the Wall 2 and Wall 3 sites exceeded the desired value of 1.5 which approximately equates to an AASHTO resistance factor of less than 0.65.

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1. INTRODUCTION

1.1. General

National Engineering & Architectural Services, Inc. (NEAS) presents our Geotechnical Exploration Report for the Ohio Department of Transportation (ODOT) for the ROS-159-0.41 project along State Route 159 (SR159) (Bridge Street) between south of Riverside Street and North of Pawnee Road in Ross County, Ohio. The overall project objective is to improve safety, congestion, pedestrian connectivity along SR 159 (Bridge Street) and improve safety along the US 35 EB exist ramp. Three walls were proposed, including Wall 1 under the US-35 bridge between Sta. 720+50 and Sta. 722+50 in reference to SR-159, Wall 2 at Kroger between Sta. 740+60 and Sta. 741+80 in reference to SR-159 and Wall 3 at McDonald's between Sta. 752+30 and Sta. 754+20 in reference to SR-159.

This report presents a summary of the encountered surficial and subsurface conditions and our recommendations for the retaining wall 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 (AASHTO LRFD, 2020), ODOT's 2023 Bridge Design Manual (BDM) (ODOT BDM, 2023), and ODOT's 2023 Geotechnical Design Manual (GDM) (ODOT, 2023). This report also presents our recommendations for subgrade stabilization and pavement design parameters for the planned improvements. The pavement subgrade analysis and recommendations presented are in accordance with ODOT's GDM (ODOT, 2023) and *Pavement Design Manual* (PDM) (ODOT, 2022).

The exploration was conducted in general accordance with NEAS's proposal to Burgess & Niple, Inc.(B&N), dated May 26, 2022, and with the provisions of ODOT's *Specifications for Geotechnical Explorations* (SGE) (ODOT, 2023).

The scope of work performed by NEAS as part of the referenced project included: a review of published geotechnical information; performing 31 test borings; laboratory testing of soil samples in accordance with the SGE; performing geotechnical engineering analysis to assess the retaining wall design and construction considerations; assess subgrade stabilization requirements, pavement design parameters and development of this summary report.

1.2. Proposed Construction

NEAS understands that the proposed project improvements include the construction of Wall 1 between Sta. 720+52.84 and Sta. 722+50.09 in reference to SR-159, Wall 2 between Sta. 740+40.37 and Sta. 741+80.04 in reference to SR-159 and Wall 3 between Sta. 752+24.74 and Sta. 754+25 in reference to SR-159. According to the retaining wall site plan, Wall 1 is a modular block wall, while Wall 2 and Wall 3 are Cast-In-Place concrete walls on spread footing. Wall 1 will be approximately 307.7 ft in length with a maximum wall height of 7.5 ft. Wall 2 will be approximately 142 ft in length with a maximum height of 10.8 ft including footing and a maximum exposed height of 4.9 ft. Wall 3 will be approximately 200 ft in length with a maximum wall height of 10.8 ft including footing.

2. GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1. Geology and Physiography

The project site is located within the Illinoian Glaciated Allegheny Plateau, part of the Glaciated Allegheny Plateaus (ODGS, 1998). This is a moderate relief, dissected, rugged hilly area comprised of loess and older drift on ridgetops, but absent on bedrock slopes. Dissection is similar to unglaciated regions of the Allegheny Plateau. Soils in this region are characteristically colluvium and Illinoian-age till over Devonian- to Pennsylvanian-age shales, siltstones, and sandstones.

Based on the Quaternary geology map of Ohio, the geology at the project site is mapped as Late Wisconsinan-age Intermediate-level outwash terraces, comprised of sand and gravel. The sand and gravel are underlain by Devonian-age shale bedrock (Pavey, et al 1999).

Based on the Bedrock Geologic Units Map of Ohio (USGS & ODGS, 2006), bedrock within the project area consists of shale, of the Ohio Shale formation. The Ohio Shale formation is comprised of Devonian-age shale. The shale in this formation is described as brownish black to greenish gray and weathers brown in color, carbonaceous to clayey, laminated to thin bedded, has fissile partings, has carbonate concretions and a petroliferous odor. The bedrock appears to not follow the natural topography of the site which slopes upward from west to east. The bedrock is relatively level throughout the project (ODGS, 2003). Based on the ODNR bedrock topography map of Ohio, bedrock elevations at the project site can be expected to be around 500 ft amsl, putting bedrock at depths of between 115 and 125 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 a mix of Mentor silt loam and Ockley loam with local concentrations of Rossburg silt loam at the southern end of the project area, and Eldean loam followed by Fitchville silt loam at the northern end of the project area. Soils in the Mentor series are characterized as very deep, well drained soils formed in stratified Wisconsinan-age glaciolacustrine or stream sediments on terraces in valleys on lake plains and outwash plains. The Mentor series is comprised of both coarse- and fine-grained soils and classifies as A-1, A-2, A-4, A-6, and A-7 type soils according to the AASHTO method of soil classification. Soils in the Ockley series are characterized as very deep, well drained soils that are deep or very deep to calcareous, stratified sandy and gravelly outwash. These soils formed in loess or silty material and in the underlying loamy outwash on stream terraces and outwash plains, and less commonly on kame moraines and eskers. The Ockley series is comprised of both coarse- and fine-grained soils and classifies as A-1, A-2, A-4, A-6, and A-7 type soils according to the AASHTO method of soil classification. Soils in the Rossburg series are characterized as very deep, well drained soils formed in loamy alluvium on flood plains. The Rossburg series is comprised of both coarse- and fine-grained soils and classifies as A-2, A-4, and A-6 type soils according to the AASHTO method of soil classification. Soils in the Eldean series are characterized as very deep, well drained soils that are moderately deep to calcareous sandy and gravelly material. These soils are formed in outwash materials dominantly of limestone origin on outwash terraces, kames, and moraines. The Eldean series is comprised of both coarse- and fine-grained soils and classifies as A-1, A-2, A-4, A-6, and A-7 type soils according to the AASHTO method of soil classification. Soils in the Fitchville series are characterized as very deep, somewhat poorly drained soils formed in stratified Wisconsinan-age glaciolacustrine sediments on terraces in valleys on till plains and lake plains. The Fitchville series is comprised of primarily fine-grained soils and classifies as A-4, A-6, and A-7 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 Scioto River as it is the most dominant hydraulic influence in the vicinity of the project's boundaries. The water level of the Scioto River 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 southern end of the project up to N Plaza Blvd. is located within a special flood hazard area (Zone A), while the portion of the project north of N Plaza Blvd and west of North Bridge Street. is located within a 0.2% annual chance flood hazard area based on available mapping by the Federal Emergency Management Agency's (FEMA) National Flood Hazard mapping program (FEMA, 2016). The rest of the project site is not located within a flood hazard zone.

2.3. Mining and Oil/Gas Production

One inactive surface mine (ID# IM-0986) is noted on ODNR's Mines of Ohio Locator about 0.43 miles east and 0.3 miles north of the intersection between US-35 and North Bridge Street. One active surface mine (ID# IM-2360) is noted on ODNR's Mines of Ohio Locator about 0.25 miles east 0.85 miles north of the aforementioned intersection. (ODNR [1], 2022).

2.4. Historical Records and Previous Phases of Project Exploration

The following report/plans were available for review and evaluation for this report:

- Project Boring Logs, and Structural Foundation Investigation Sheets for ROS-159-0043, dated March 26, 1999.
- Project Boring Logs, and Soil Profile Sheets for ROS-35-19.93, dated July 10, 1962.

No historical borings were utilized in our analyses.

2.5. Field Reconnaissance

A field reconnaissance visit for the overall project area was conducted on July 20, 2022, along North Bridge Street between Stewart Road and 0.1 miles north of Pawnee Road. Site conditions were noted and photographed during the visit. The land use of most of the project area consists of ODOT right-of-way (ROW) and commercial properties (i.e., businesses, restaurants, warehouses, etc.).

2.5.1. North Bridge Street Near US-35

In general, the pavement condition along the project section of North Bridge Street in the area around the US-35 interchange was observed to be fair to poor with signs of weathering and surface wear. Moderate severity longitudinal and transverse cracking was common along this section, as well as occasional moderate severity wheel track cracking, rutting, patching, and crack sealing deficiencies (Photograph 1). The roadway in this section is level with the surrounding land in this area and slopes downward from both the north and south to the lowest point being where US-35 crosses over N Bridge St. The roadway drained to drainage ditches in both shoulders of the roadway as well as basins in the median. The area is moderately vegetated, and signs of standing water such as heavy vegetation in the drainage ditches was observed.

Photograph 1: Overall Pavement Condition of North Bridge Street near US-35

2.5.2. North Bridge Street between North Plaza Blvd. and Pawnee Road

In general, the pavement condition along this section of North Bridge Street was observed to be good with some signs of weathering and surface wear. Light severity longitudinal and transverse cracking was common along this section, as well as crack sealing deficiencies (Photograph 2). The roadway in this section is level with the surrounding land in this area which itself is relatively flat. The roadway drains to drainage basins on both shoulders of the roadway. The area is lightly vegetated for the most part, and signs of standing water were not observed.

Photograph 2: Overall Pavement condition of N Bridge St Between N Plaza Blvd and Pawnee Rd

2.5.3. North Bridge Street between Pawnee Street and Project End

In general, the pavement condition of this portion of North Bridge Street was observed to be fair with signs of weathering and surface wear. Light severity longitudinal and transverse cracking was common along this section as well as rutting, and wheel track cracking (Photograph 3). The roadway in this section is level with the surrounding land in this area which itself is relatively flat. The roadway drains to a drainage ditch past the eastern shoulder of the roadway and drainage basins on the western shoulder of the roadway. The area is lightly vegetated for the most part, and signs of standing water were not observed.

Photograph 3: Overall Pavement condition of N Bridge St Betwee

2.5.4. Ramp US-35 EB to North Bridge Street

In general, the pavement condition of the ramp from US-35 EB to North Bridge Street was observed to be good with some signs of weathering and surface wear. Light severity longitudinal and transverse cracking was common along this section as well as crack sealing deficiencies (Photograph 4). The roadway in this section is above the surrounding land on an embankment with slopes of about 3V:1H (3 ft vertical to 1 ft horizontal) leading down to the surrounding land. The roadway itself slopes gently downwards from west to east. The roadway drains to drainage ditches past both shoulders of the roadway. The area is moderately vegetated, and signs of standing water such as cattails and heavy vegetation were observed in the southern drainage ditch. No signs of distress due to geotechnical issues were observed.

Photograph 4: Overall Pavement condition of Ramp US-35 EB

2.5.5. Parking lot East of Marriot Fairfield Inn.

In general, the pavement condition of this portion of the project. was observed to be fair with signs of weathering and surface wear. Moderate longitudinal and transverse cracking was common along this section as well as map cracking and crack sealing deficiencies (Photograph 5). The roadway in this section sits is level with the surrounding land which itself is relatively flat. The roadway drains to drainage basins in the eastern shoulder of the parking lot. The area is lightly vegetated for the most part, and signs of standing water were not observed.

Photograph 5: Overall Pavement condition of Parking Lot

2.5.6. Stewart Street

In general, the pavement condition of this portion of the project was observed to be poor with signs of weathering and surface wear. Moderate longitudinal and transverse cracking was common along this section as well as high severity patching, delamination, raveling, and crack sealing deficiencies (Photograph 6). The roadway in this section is level with the surrounding land which rises gently from south to north. The roadway drains to drainage ditches past both sides of the roadway with drainage basins interspersed at intervals in the ditches, as well as drainage basins where the curbs are raised. The area is lightly vegetated for the most part, and signs of standing water were not observed.

Photograph 6: Overall Pavement condition of Stewart Street

3. GEOTECHNICAL EXPLORATION

3.1. Field Exploration Program

ODOT performed subsurface exploration on October 10, 2021, which include 7 borings (B-001-1-21, B-004-1-21, B-005-1-21, B-007-1-21, B-010-1-21, B-025-1-21 and B-026-1-21) drilled to depths between 1.5 and 3.5 ft bgs. Each ODOT boring was incorporated with Dynamic Cone Penetration (DCP) which are included in Appendix B. In addition, another subsurface exploration was conducted by NEAS between July 26, 2022, and August 22, 2022, and included 31 boring drilled to depths between 7.5 and 41.5 ft bgs. The boring locations were selected by NEAS in general accordance with the guidelines contained in the SGE with the intent to evaluate subgrade soil and groundwater conditions without being restricted by underground utilities or dictated terrain (i.e., steep embankment slopes). Boring locations were located by NEAS prior drilling or ODOT. Each individual project boring log (included within Appendix B) includes the recorded boring latitude and longitude and the corresponding ground surface elevation, as shown on Table 1 below. The boring locations are depicted on the Boring Location Map provided in Appendix A. The boring logs and the DCP test data sheets are provided in Appendix B.

Table 1: Project Boring Information

Boring Number	Latitude	Longitude	Elevation (ft)	Depth (ft)	Boring Number	Latitude	Longitude	Elevation (ft)	Depth (ft)
B-001-0-22	39.345260	-82.976167	626.5	11.5	B-016-0-22	39.355746	-82.976310	624.3	11.5
B-001-1-21	39.346136	82.976401	624.1	3.0	B-017-0-22	39.356518	-82.976278	624.0	7.5
B-002-0-22	39.346234	-82.976354	622.5	26.5	B-018-0-22	39.357097	-82.976259	625.3	21.5
B-003-0-22	39.346753	-82.976718	621.8	7.5	B-019-0-22	39.357478	-82.976237	626.5	21.5
B-004-0-22	39.347655	-82.976470	621.3	26.5	B-020-0-22	39.345595	-82.977370	620.9	7.5
B-004-1-21	39.347298	82.976754	623.6	1.5	B-021-0-22	39.345797	-82.975503	620.1	7.5
B-005-0-22	39.348349	-82.976562	619.8	21.5	B-022-0-22	39.345571	-82.974922	617.6	11.5
B-005-1-21	39.348241	82.976615	621.4	3.5	B-023-0-22	39.344821	-82.975057	614.3	7.5
B-006-0-22	39.348564	-82.976366	638.9	41.5	B-024-0-22	39.345945	-82.974075	620.3	7.5
B-007-0-22	39.349001	-82.976696	621.2	7.5	B-025-0-22	39.347938	-82.978248	631.4	25.0
B-007-1-21	39.349168	82.976822	622.4	1.5	B-025-1-21	39.348040	82.978239	634.3	3.0
B-008-0-22	39.349349	-82.976406	617.7	11.5	B-026-0-22	39.347800	-82.976835	623.5	15.0
B-009-0-22	39.349635	-82.976829	621.4	16.5	B-026-1-21	39.347842	82.977079	626.3	2.8
B-010-0-22	39.350320	-82.976506	622.5	11.5	B-027-0-22	39.351374	-82.978031	624.1	7.5
B-011-0-22	39.351186	-82.976446	625.8	7.5	B-028-0-22	39.351932	-82.977605	624.9	7.5
B-012-0-22	39.352752	-82.976421	626.9	16.5	B-029-0-22	39.351854	-82.976898	626.0	7.5
B-013-0-22	39.353280	-82.976398	626.5	16.5	B-030-0-22	39.351722	-82.975857	625.3	7.5
B-014-0-22	39.353908	-82.976376	625.5	16.5	B-031-0-22	39.356192	-82.976760	622.9	7.5
B-015-0-22	39.354875	-82.976342	624.4	7.5					
Notes: 1. Boring locations and corresponding ground surface elevation were surveyed in the field.									

Borings drilled by NEAS were drilled using a CME 45B truck-mounted drilling rig utilizing 3.25-inch (inner diameter) hollow stem augers. Soil samples for subgrade borings were recovered continuously thereafter at 2.5 ft interval drilled to end of boring (EOB). Each boring was sampled using an 18-inch split spoon sampler (AASHTO T-206 "Standard Method for Penetration Test and Split Barrel Sampling of Soils."). The soil samples obtained from the exploration program were visually observed in the field by NEAS field representative and preserved for review by a geologist for possible laboratory testing. Standard penetration tests (SPT) were conducted using a CME auto hammer that has been calibrated to be 72.6 % efficient as indicated on the boring logs (Appendix B).

Field boring logs were prepared by drilling personnel and included pavement description, 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). After completing the borings, the boreholes were backfilled with either auger cuttings, bentonite chips, or a combination of these materials and patched accordingly with cold patch asphalt and/or cement when drilling through the roadway.

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 after Stage 2 submission.

3.2.1. Classification Testing

Representative soil samples were selected for index properties (Atterberg limits) and gradation testing for classification purposes. At each boring location, the upper two samples obtained below the proposed top of subgrade elevation were generally tested while additional samples in each boring were selected for testing with the intent of properly classifying the subsurface soil and groundwater conditions within the planned project limits. Soils not selected for testing were compared to laboratory tested samples and classified visually. Moisture content testing was conducted on all samples. The laboratory testing was performed in general accordance with applicable AASHTO specifications and ODOT Supplements.

Final classification of soil strata in accordance with AASHTO M-145 "Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes," as modified by ODOT "Classification of Soils" was made once laboratory test results became available. The results of the soil classification are presented on the boring logs 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., continuously or at 2.5-ft) in the retaining wall 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. Sulfate testing

Sulfate testing was generally performed on one sample from each subgrade/roadway boring performed for pavement/subgrade design purposes. The selected samples were tested in accordance with ODOT Supplement 1122, "Determining Sulfate Content in Soils" dated July 17, 2015. In general, the upper most sample (within 3 ft of the proposed subgrade elevation) from each boring was tested when feasible. Testing results are summarized in Table 2 below, and presented on the boring logs within Appendix B.

Table 2: Sulfate Test Summary by Boring

Boring ID	Sample	Depth (ft)	Dilution Ratio	Average Sulfate Content (ppm)	Boring ID	Sample	Depth (ft)	Dilution Ratio	Average Sulfate Content (ppm)
B-001-0-22	SS-1	2.5-4.0	20	0	B-017-0-22	SS-1	1.5-3.0	20	0
B-003-0-22	SS-1	1.5-3.0	20	100	B-020-0-22	SS-2	1.5-3.0	20	0
B-007-0-22	SS-1	1.5-3.0	20	60	B-021-0-22	SS-1	1.5-3.0	20	160
B-008-0-22	SS-1	2.5-4.0	20	0	B-022-0-22	SS-1	2.5-4.0	20	20
B-009-0-22	SS-1A	2.5-3.0	20	180	B-023-0-22	SS-1	1.5-3.0	20	0
B-010-0-22	SS-1	2.5-4.0	20	60	B-024-0-22	SS-1	1.5-3.0	20	0
B-011-0-22	SS-1	1.5-3.0	20	0	B-025-0-22	SS-1	1.5-3.0	20	180
B-012-0-22	SS-1	2.5-4.0	20	60	B-026-0-22	SS-1	1.5-3.0	20	20
B-013-0-22	SS-1	2.5-4.0	20	100	B-027-0-22	SS-1	1.5-3.0	20	673
B-014-0-22	SS-1	2.5-4.0	20	20	B-028-0-22	SS-1	0.0-1.5	20	0
B-015-0-22	SS-2	3.0-4.5	20	0	B-029-0-22	SS-1	1.5-3.0	20	40
B-016-0-22	SS-1	2.5-4.0	20	60	B-030-0-22	SS-2	3.0-4.5	20	40
					B-031-0-22	SS-1	1.5-3.0	20	60

4. GEOTECHNICAL 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. It should be noted that for the purposes of this report and our analysis the term 'subgrade' has been assumed to represent soils and/or soil conditions from 1.5 ft below proposed final pavement grades to a depth of 7.5 ft below the proposed pavement grades.

4.1. Existing Pavement

The pavement section thicknesses in terms of asphalt, concrete and granular base were measured at representative project subgrade borings during the subsurface exploration for the project and are recorded on the test boring logs provided in Appendix B. A summary of these measurements is provided in Table 3 below.

Table 3: Measured Pavement Thickness at Boring Locations

Boring ID	Proposed Alignment	Drilled Depth (ft)	Asphalt Thickness (in)	Concrete Thickness (in)	Base Thickness (in)	Total Thickness (in)	Boring ID	Proposed Alignment	Drilled Depth (ft)	Asphalt Thickness (in)	Concrete Thickness (in)	Base Thickness (in)	Total Thickness (in)
B-001-0-22	SR 159	11.5	9.5	0.0	8.5	18.0	B-016-0-22	SR 159	11.5	9.5	0.0	9.5	19.0
B-002-0-22	SR 159	26.5	12.0	0.0	6.0	18.0	B-017-0-22	SR 159	7.5	9.5	0.0	8.5	18.0
B-003-0-22	SR 159	7.5	12.0	0.0	8.0	20.0	B-018-0-22	SR 159	21.5	9.5	0.0	3.5	13.0
B-004-0-22	SR 159	26.5	3.5	9.5	6.0	19.0	B-019-0-22	SR 159	21.5	9.5	0.0	3.5	13.0
B-005-0-22	SR 159	21.5	5.0	8.0	6.0	19.0	B-021-0-22	Stewart Rd.	7.5	4.0	14.0	5.0	23.0
B-007-0-22	Ramp A1	7.5	6.0	7.0	5.0	18.0	B-023-0-22	Consumer Center Dr.	7.5	5.0	0.0	10.0	15.0
B-008-0-22	Ramp A1	11.5	9.5	0.0	8.5	18.0	B-024-0-22	River Trace	7.5	7.0	0.0	10.0	17.0
B-009-0-22	SR 159	16.5	12.0	0.0	6.0	18.0	B-025-0-22	US 35-Ramp C	25	5.0	7.0	6.0	18.0
B-010-0-22	SR 159	11.5	12.0	0.0	6.0	18.0	B-026-0-22	US 35-Ramp C	15.0	6.0	7.0	5.0	18.0
B-011-0-22	SR 159	7.5	6.0	0.0	11.0	17.0	B-027-0-22	Marietta Connector	7.5	6.0	0.0	9.0	15.0
B-012-0-22	SR 159	16.5	9.5	0.0	2.5	12.0	B-029-0-22	Marietta Connector	7.5	5.0	0.0	11.0	16.0
B-013-0-22	SR 159	16.5	9.5	0.0	2.5	12.0	B-030-0-22	Marietta Rd	7.5	9.5	0.0	8.5	18.0
B-014-0-22	SR 159	16.5	12.0	0.0	7.0	19.0	B-031-0-21	Pawnee Rd	7.5	9.5	0.0	8.5	18.0
B-015-0-22	SR 159	7.5	12.0	0.0	6.0	18.0							

4.2. Subgrade Conditions

The subgrade conditions in the project area are relatively consistent and are generally comprised of either fill soils (i.e., embankment/roadway fill) or natural soils. The fill and/or natural soils encountered within the project limits are generally classified as non-cohesive A-1-b, A-1-a, A-2-4, A-2-6, A-3a, and A-4a or cohesive A-4a, A-6a, A-6b, and A-7-6 soil. A brief summary of the subgrade conditions encountered along the project site is below.

4.2.1. SR-159

The borings performed along SR-159 included ODOT borings B-001-1-21, B-004-1-21, B-005-1-21 and B-007-1-21 as well as project borings B-001-0-22 through B-019-0-22 except B-006-0-22 through B-008-0-22.

Along SR 159, forty-nine percent (49%) of the soil samples were identified as fine-grained soils and were comprised of 1) Cohesive Sandy Silt (A-4a, 5% of samples), 2) Silt and Clay (A-6a, 31% of samples) and 3) Silty Clay (A-6b, 13% of samples). With respect to the consistency of the fine-grained soils, the descriptions varied from stiff to hard correlating to converted SPT-N values (N_{60}) between 4 and 47 blows per foot (bpf). Natural moisture contents ranged from 10 to 27 percent. Based on Atterberg Limit tests performed on representative samples of the fine-grained subgrade soils obtained along the project portions of SR-159, the liquid and plastic limits ranged from 21 to 36 percent and from 14 to 19 percent, respectively.

Fifty-one percent (51%) of the samples taken along the proposed roadway were classified as coarse-grained, non-cohesive soils and were comprised of: 1) Gravel (A-1-a, 6% of samples); 2) Gravel with Sand (A-1-b, 24% of samples); 3) Gravel and Stone Fragments with Sand and Silt (A-2-4, 3% of samples); 4) Gravel and Stone Fragments with Sand and Silt (A-2-6, 6% of samples); 5) Coarse and fine sand (A-3a, 6% of samples); and, 6) non-cohesive Sandy Silt (A-4a, 6% of samples). With respect to the relative density of the coarse-grained soils, the descriptions varied from loose to very dense correlating to N_{60} values between 5 and 56 bpf. Natural moisture contents ranged from 4 to 24 percent.

4.2.2. Connector Road

The borings performed along Connector Road included B-027-0-22 through B-029-0-22.

Along Connector Road, twenty-seven percent (27%) of the soil samples were identified as fine-grained soils and were comprised of Silty Clay (A-6b, 27% of samples). With respect to the consistency of the fine-grained soils, the descriptions varied from very stiff to hard correlating to converted SPT-N values (N_{60}) between 8 and 13 blows per foot (bpf). Natural moisture contents ranged from 15 to 18 percent. Based on Atterberg Limit tests performed on representative samples of the fine-grained subgrade soils obtained along the project portions, the liquid and plastic limits are between 32 to 34 percent and 16 to 17 percent, respectively.

Seventy-three percent (73%) of the samples taken along the proposed roadway were classified as coarse-grained, non-cohesive soils and were comprised of: 1) Gravel with Sand (A-1-b, 27% of samples); 2) Gravel and Stone Fragments with Sand and Silt (A-2-4, 1 sample); 3) Gravel and Stone Fragments with Sand and Silt (A-2-6, 17% of samples); and, 4) non-cohesive Sandy Silt (A-4a, 18% of samples). With respect to the relative density of the coarse-grained soils, the descriptions varied from loose to Medium dense correlating to N_{60} values between 7 and 24 bpf. Natural moisture contents ranged from 6 to 16 percent.

4.2.3. Marietta Road

The boring performed along Marietta Road included B-030-0-22.

Along Marietta Road, twenty-five percent (25%) of the soil samples were identified as fine-grained soils and were comprised of Silty Clay (A-6b, 1 sample). With respect to the consistency of the fine-grained soils, the description is very stiff correlating to converted SPT-N values (N_{60}) of 7 blows per foot (bpf). Natural moisture content is 16 percent. Based on Atterberg Limit tests performed on representative samples of the fine-grained subgrade soils obtained along the project portions, the liquid and plastic limits are 34 percent and 16 percent, respectively.

Seventy-five percent (75%) of the samples taken along the proposed roadway were classified as coarse-grained, non-cohesive soils and were comprised of: 1) Gravel with Sand (A-1-b, one sample); and 2) Coarse and fine sand (A-3a, 50% of samples). With respect to the relative density of the coarse-grained soils, the descriptions varied from loose to Medium dense correlating to N_{60} values between 8 and 21 bpf. Natural moisture contents ranged from 3 to 9 percent.

4.2.4. Pawnee Road

The boring performed along Pawnee Road included B-031-0-22.

One hundred percent (100%) of the samples taken along Pawnee Road were classified as coarse-grained, non-cohesive soils and were comprised of: 1) Gravel with Sand (A-1-b, 75% of samples); and Gravel and Stone Fragments with Sand and Silt (A-2-4, 1 sample). With respect to the relative density of the coarse-grained soils, the descriptions varied from loose to dense correlating to N_{60} values between 6 and 67 bpf. Natural moisture contents ranged from 8 to 11 percent.

4.2.5. Ramp A1

The borings performed along Ramp A1 included B-007-0-22 and B-008-0-22.

One hundred percent (100%) of the samples taken along Ramp A1 were classified as coarse-grained, non-cohesive soils and were comprised of: 1) Gravel with Sand (A-1-b, 50% of samples); 2) Gravel and Stone Fragments with Sand and Silt (A-2-4, 25% of samples); 3) Coarse and fine sand (A-3a, 1 sample) and 4) non-cohesive Sandy Silt (A-4a, 1 sample). With respect to the relative density of the coarse-grained soils, the descriptions varied from very loose to medium dense correlating to N_{60} values between 4 and 29 bpf. Natural moisture contents ranged from 6 to 17 percent.

4.2.6. River Trace

The boring performed along River Trace Street included B-024-0-22.

Along River Trace Street, fifty percent (50%) of the soil samples were identified as fine-grained soils and were comprised of Sandy Silt (A-4a, 50% of samples). With respect to the consistency of the fine-grained soils, the description is very stiff correlating to converted SPT-N values (N_{60}) ranged from 10 to 25 blows per foot (bpf). Natural moisture contents ranged from 11 to 13 percent. Based on Atterberg Limit tests performed on representative samples of the fine-grained subgrade soils obtained along the project portions, the liquid and plastic limits are 22 to 24 percent and 16 percent, respectively.

Fifty percent (50%) of the samples taken along the proposed roadway were classified as coarse-grained, non-cohesive soils and were comprised of Gravel and Stone Fragments with Sand and Silt (A-2-4, 50% of samples). With respect to the relative density of the coarse-grained soils, the descriptions varied from dense to very dense correlating to N_{60} values between 31 and 56 bpf. Natural moisture contents ranged from 7 to 9 percent.

4.2.7. Stewart Road

The borings performed along Stewart Road included B-020-0-22 through B-022-0-22.

Along Stewart Road, sixty-four percent (67%) of the soil samples were identified as fine-grained soils and were comprised of 1) cohesive Sandy Silt (A-4a, 33% of samples), 2)Silt and Clay (A-6a, 25% of samples) and 3) Silty Clay (A-6b, 1 sample) With respect to the consistency of the fine-grained soils, the descriptions varied from very stiff to hard correlating to converted SPT-N values (N_{60}) between 6 and 36 blows per foot (bpf). Natural moisture contents ranged from 10 to 24 percent. Based on Atterberg Limit tests performed on representative samples of the fine-grained subgrade soils obtained along the project portions, the liquid and plastic limits ranged from 26 to 40 percent and from 16 to 20 percent, respectively.

Thirty-three percent (33%) of the samples taken along the proposed roadway were classified as coarse-grained, non-cohesive soils and were comprised of: 1) Gravel with Sand (A-1-b, 17% of samples); 2) Coarse and fine sand (A-3a, 16% of samples) With respect to the relative density of the coarse-grained soils, the descriptions varied from loose to very dense correlating to N_{60} values between 5 and 56 bpf. Natural moisture contents ranged from 5 to 10 percent.

4.2.8. US-35 Ramp C

The borings performed along US-35 Ramp C included two ODOT borings B-025-1-21 and B-026-1-21 as well as project borings B-025-0-22 through B-026-0-22.

Along US-35 Ramp C, thirty-six percent (36%) of the soil samples were identified as fine-grained soils and were comprised of cohesive Silt and Clay (A-6a, 36% of samples). With respect to the consistency of the fine-grained soils, the descriptions varied from very stiff to hard correlating to converted SPT-N values (N_{60}) between 8 and 11 blows per foot (bpf). Natural moisture contents ranged from 14 to 21 percent. Based on Atterberg Limit tests performed on representative samples of the fine-grained subgrade soils obtained along the project portions, the liquid and plastic limits ranged from 20 to 32 percent and from 14 to 18 percent, respectively.

Sixty-four percent (64%) of the samples taken along the proposed roadway were classified as coarse-grained, non-cohesive soils and were comprised of: 1) Gravel with Sand (A-1-b, 27% of samples); 2) Gravel and Stone Fragments with Sand and Silt (A-2-4, 36% of samples). With respect to the relative density of the coarse-grained soils, the descriptions is medium dense correlating to N_{60} values between 24 and 46 bpf. Natural moisture contents ranged from 6 to 9 percent.

4.2.9. Consumer Center Drive

The boring performed along Consumer Center Drive included B-023-0-22.

Along Consumer Center Drive Segment, fifty percent (50%) of the soil samples were identified as fine-grained soils and were comprised of Clay (A-7-6, 50% of samples). With respect to the consistency of the fine-grained soils, the description is very stiff to hard correlating to converted SPT-N values (N_{60}) from 11 to 15 blows per foot (bpf). Natural moisture content ranged from 20 to 24 percent. Based on Atterberg Limit tests performed on representative samples of the fine-grained subgrade soils obtained along the project portions, the liquid and plastic limits are 42 percent and 21 percent, respectively.

Fifty percent (50%) of the samples taken along the proposed roadway were classified as coarse-grained, non-cohesive soils and were comprised of Gravel with Sand (A-1-b, 50% of samples). With respect to the relative density of the coarse-grained soils, the descriptions varied from loose to Medium dense correlating to N_{60} values between 8 and 11 bpf. Natural moisture contents ranged from 11 to 14 percent.

4.2.10. Groundwater

Groundwater measurements were taken during the boring drilling procedures and/or immediately following the completion of each borehole. Groundwater was not encountered during drilling performed as part of the project.

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.

4.3. Subsurface Conditions

4.3.1. Overburden Soil

The subsurface soils encountered at wall 1 can be described using B-006-0-22, while wall 2 can be described using B-014-0-22 and wall 3 can be described using B-018-0-22 and B-019-0-22. The soils encountered at both walls can be described as follows.

At the proposed Wall 1 site, the soil stratum encountered in this boring comprised of both granular and cohesive soil materials. The soil encountered below the topsoil is classified as non-cohesive Sandy Silt (A-4a) to a depth of 7 ft bgs (elevation 631.9 ft amsl) followed by 2.5 ft of cohesive Sandy Silt (A-4a) (elevation 629.4 ft amsl). Then Gravel and Stone Fragment with Sand and Silt (A-2-4) was encountered with a depth of 2.5 ft bgs (elevation 626.9 ft amsl) followed by 12.5 ft bgs of cohesive Sandy Silt (A-4a). At an elevation of 614.4 ft amsl, 5 ft bgs of Gravel and Stone Fragment with Sand and Silt (A-2-4) was encountered followed by cohesive Sandy Silt to the end of boring (EOB). The cohesive soil is described as having a consistency of hard correlating to N_{60} values ranging from 17 to 45 and unconfined compressive strengths (estimated by means of hand penetrometer) of 4.50 tons per square foot (tsf). Natural moisture content of the cohesive soil ranged from 10 to 16 percent. Based on an Atterberg Limits test performed on a representative sample of the cohesive soil material, the liquid and plastic limits values ranged from 20 to 23 percent and 15 to 17 percent, respectively. On the other hand, the non-cohesive soils are described as having a relative compactness ranging from medium dense to dense correlating to N_{60} values ranging from 25 to 52. The natural moisture content of the granular soils ranged from 7 percent to 10 percent.

At the proposed Wall 2 site, the soils encountered below the pavement section comprised of cohesive fine-grained soils to a depth of 7.6 ft bgs (elevation 617.9 ft amsl) followed by granular soils to the terminated boring depth (elevation 609.0 ft amsl). Based on laboratory testing, a visual soil review as well as soil behavior index, the cohesive material is classified as Silt and Clay (A-6a) while the non-cohesive soil is classified as Coarse and Fine Sand (A-3a) and Gravel and Stone Fragments with Sand (A-1-b). The cohesive soil is described as having a consistency of very stiff correlating to N_{60} values of 7 and unconfined compressive strengths (estimated by means of hand penetrometer) ranging from 2.50 to 3.50 tons per square foot (tsf). Natural moisture content of the cohesive soil ranged from 14 to 18 percent. Based on an Atterberg Limits test performed on a representative sample of the cohesive soil material, the liquid and plastic limits values are 31 percent and 13 percent, respectively. On the other hand, the non-cohesive soils are described as having a relative compactness ranging from loose to very loose correlating to N_{60} values ranging from 4 to 8. The natural moisture content of the granular soils ranged from 6 percent to 12 percent.

At the proposed wall 3 site, the soils encountered below the pavement section comprised of cohesive fine-grained soils to the depths of between 4.5 ft and 12.0 ft bgs (elevations between 614.5 ft and 620.5 ft amsl) following by granular soils to the terminated boring depth of 21.5 ft bgs. Based on laboratory testing, a visual soil review as well as soil behavior index, the granular material is classified as Sandy Silt (A-4a), Coarse and Fine Sand (A-3a) and Gravel and Stone Fragments with Sand (A-1-b) while the cohesive soils are classified as Silt and Clay (A-6a) and Silty Clay (A-6b). The non-cohesive soils are described as having a relative compactness ranging from loose to medium dense to loose to dense correlating to N_{60} values ranging from 6 to 41. The natural moisture content of the granular soils ranged from 5 to 14 percent. On the other hand, the cohesive soil is described as having a consistency of very stiff correlating to N_{60} values ranging from 6 to 13 and unconfined compressive strengths (estimated by means of hand penetrometer) ranging from 3.00 to 4.50 tons per square foot (tsf). Natural moisture contents of the cohesive soils are between 17 and 20 percent. Based on the Atterberg Limits test performed on a representative sample of the cohesive soil material, the liquid and plastic limits values ranged from 31 to 34 percent and 15 to 19 percent, respectively.

4.3.2. Groundwater

Groundwater measurements were taken during the boring drilling procedures and immediately following the completion of each borehole. Groundwater was not encountered during drilling in any of the structure borings.

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.

4.3.3. Bedrock

Bedrock was not encountered in any of the structure borings performed.

5. ANALYSIS AND RECOMMENDATIONS

We understand that the overall project objective is to improve the safety, congestion and pedestrian connectivity along SR-159 (Bridge Street) and improve safety along the US-35 EB exit Ramp. For this purpose, subgrade analysis was performed in accordance with ODOT's GDM criteria utilizing the ODOT provided subgrade analysis spreadsheet (SubgradeAnalysis.xls, version 14.6 dated February 11, 2022). Input information for the spreadsheet was based on the soil characteristics gathered during NEAS's exploration (i.e., SPT results, laboratory test results, etc.).

The proposed project improvements also include the construction of three retaining walls. It is our understanding that wall 1 will be a modular block wall while walls 2 and 3 will be Cast-In-Place concrete wall on spread footing. The proposed retaining walls 1, 2 and 3 will be approximately 231.05 ft, 142 ft and 200 ft in length, respectively with a design height of 7.5 ft, 10.8 ft and 10.8 ft, respectively.

The analyses performed are based on the information: 1) the soil characteristics gathered during the subsurface exploration (i.e., SPT results, laboratory test results, etc.) presented in Section 5.1 of this report; 2) the developed generalized soil profile at the proposed retaining wall locations and other design assumptions presented in subsequent sections of this report; and, 3) the basemap and site plans including the retaining wall details provided by Burgess & Niple Inc. and Palmer Engineering. Geotechnical analyses consisting of subgrade analyses, external stability (i.e., overall stability, bearing capacity, and sliding) analyses, and global stability analyses were performed for the proposed retaining walls. The geotechnical engineering analyses were performed in accordance with LRFD Bridge Design Specifications, (AASHTO LRFD, 2020), ODOT's 2020 Bridge Design Manual (BDM) (ODOT BDM, 2023) and ODOT's 2023 Geotechnical Design Manual (GDM (ODOT GDM, 2023).

5.1. Generalized Soil Profile for Analysis

For analysis purposes, each boring log was reviewed and the engineering properties for each soil strata were estimated based on their 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. Engineering soil properties were estimated for each individual classified layer per boring location. Soil layers with similar behavior (i.e., cohesive or non-cohesive/granular) and characteristics (i.e., relative compactness/consistency, moisture content, etc.) were grouped into generalized soil units (i.e., Soil Types) and weighted average values of the estimated engineering soil properties were assigned to each Soil Type to develop a generalized soil profile for analysis. The summary of the generalized soil profile including designated Soil Types, elevations, average engineering soil properties per boring location are presented within Table 4 through Table 8 below.

Table 4: Soil Profile and Estimated Engineering Properties for B-006-0-22

Wall 1: Soil Profile B-006-0-22							
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)	Setup Factor (f_{su})
Sandy Silt Depth (638.9 ft - 634.4 ft)	118	118	128	-	-	38	1.20
Sandy Silt Depth (634.4 ft - 631.9 ft)	122	122	132	-	-	40	1.20
Sandy Silt Depth (631.9 ft - 629.4 ft)	112	112	122	2100	200	25	1.20
Gravel with Sand and Silt Depth (629.4 ft - 626.9 ft)	118	118	128	-	-	35	1.20
Sandy Silt Depth (626.9 ft - 619.9 ft)	118	118	128	3550	300	27	1.50
Sandy Silt Depth (619.9 ft - 614.4 ft)	122	122	132	5000	375	28	1.50
Gravel with Sand and Silt Depth (614.4 ft - 609.4 ft)	118	118	128	-	-	35	1.20
Sandy Silt Depth (609.4 ft - 597.4 ft)	115	115	125	3300	250	27	1.50

Notes:
1. *Values interpreted from ODOT Geotechnical Design Manual (GDM) Section 405.*
2. *Values calculated from Terzaghi and Peck (1967) if N160<52, else Stroud and Butler (1975) was used.*
3. *Values interpreted from LRFD BDS Table 10.4.6.2.4-1 and ODOT GDM Table 400-3.*

Table 5: Soil Profile and Estimated Engineering Properties for B-012-0-22

Embankment Slope: Soil Profile, B-012-0-22						
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)
Gravel Elevation (626.9 ft - 622.4 ft)	110	110	120	-	-	30
Silt and Clay Elevation (622.4 ft - 619.9 ft)	108	108	118	800	100	21
Gravel Elevation (619.9 ft - 617.4 ft)	118	118	128	-	-	35
Gravel with Sand Elevation (617.4 ft - 610.4 ft)	125	125	135	-	-	37

otes:
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 for B-014-0-22

Wall 2: Soil Profile B-014-0-22							
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)	Setup Factor (f_{su})
Silt and Clay Depth (625.5 ft - 621 ft)	108	108	118	850	100	22	1.50
Silt and Clay Depth (621 ft - 617.9 ft)	108	108	118	850	100	22	1.50
Coarse and Fine Sand Depth (617.9 ft - 616 ft)	110	110	120	-	-	30	1.00
Gravel with Sand Depth (616 ft - 609 ft)	110	110	120	-	-	32	1.00

Notes:
1. *Values interpreted from ODOT Geotechnical Design Manual (GDM) Section 405.*
2. *Values calculated from Terzaghi and Peck (1967) if N160<52, else Stroud and Butler (1975) was used.*
3. *Values interpreted from LRFD BDS Table 10.4.6.2.4-1 and ODOT GDM Table 400-3.*

Table 7: Soil Profile and Estimated Engineering Properties for B-018-0-22

Wall 3: Soil Profile, B-018-0-22						
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 Elevation (625.3 ft - 620.8 ft)	108	108	118	1,200	100	23
Sandy Silt Elevation (620.8 ft - 617.5 ft)	110	110	120	-	-	29
Coarse and Fine Sand Elevation (617.5 ft - 613.3 ft)	112	112	122	-	-	30
Gravel with Sand Elevation (613.3 ft - 610.8 ft)	112	112	122	-	-	30
Gravel with Sand Elevation (610.8 ft - 605.8 ft)	120	120	130	-	-	35

es:
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 8: Soil Profile and Estimated Engineering Properties for B-019-0-22

Wall 3: Soil Profile, B-019-0-22						
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 Elevation (626.5 ft - 622 ft)	108	108	118	800	100	21
Silty Clay Elevation (622 ft - 617 ft)	108	108	118	1,200	100	23
Silt and Clay Elevation (617 ft - 614.5 ft)	105	105	115	700	75	21
Gravel with Sand Elevation (614.5 ft - 605 ft)	112	112	122	-	-	30

es:
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. Subgrade Analysis

A subgrade analysis was performed to identify the method, location, and dimensions (including depth) of required subgrade stabilization for the project. 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 subgrade analysis including pavement design parameters and unsuitable subgrade conditions identified within the project limits. The subgrade analysis spreadsheets are provided in Appendix C.

5.2.1. Pavement Design Recommendations

It is our understanding that pavement analysis and design is to be performed to determine the proposed pavement section within the project limits to improve safety. A subgrade analysis was performed using the subgrade soil data obtained during our field exploration program to evaluate the soil characteristics to develop pavement parameters for use in pavement design. The subgrade analysis parameters recommended for use in pavement design are presented in Table 9 below. Provided in the table are 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 9: Pavement Design Parameters

Segment	Maximum N_{60L}	Minimum N_{60L}	Average N_{60L}	Average PI Values	Design CBR*
SR 159	30	5	12	14	9
Consumer Center	8	8	8	21	7
Connector Road	8	5	7	16	8
Merietta Rd	7	7	7	18	12*
Pawnee Rd	6	6	6	0	13*
Ramp A1	4	4	4	0	13*
River Trace	10	10	10	7	9
Stewart Rd	15	5	9	14	7
US 35-Ramp C	10	8	9	11	10
Entire Project	**30**	**4**	**10**	**13**	**9**

Note: * NEAS recommend using a CBR value of 9 in the pavement design for the side street.

Where the CBR values for the side streets are greater than the one for the overall entire project, such as Pawnee Road, NEAS recommend using a CBR value of 9 conservatively since the limited information can be provided from only one boring performed along the side streets.

5.2.2. Unsuitable Subgrade

Per ODOT's GDM, the presence of select subgrade conditions are prohibited within the subgrade zone for new pavement construction. These prohibited subgrade conditions generally include the presence of rock, specific soil types, and soils with a liquid limit greater than 65 percent. With respect to the proposed improvement project these subgrade conditions are further discussed in the following subsections.

5.2.2.1. Rock

Rock was not encountered at or close to subgrade elevation at the boring locations performed within the project limits. Per ODOT's GDM, if rock is encountered within 24 inches of the bottom of the proposed asphalt or concrete pavement it is to be removed in accordance with 204.05 of the ODOT CMS and replaced with Item 204 Embankment.

5.2.2.2. Prohibited Soils

Prohibited soil types per the GDM, which include A-4b, A-2-5, A-5, A-7-5, A-8a, A-8b, and soils with liquid limits greater than 65, were not encountered within the subgrade of the project limits.

5.2.3. Unstable Soils

The subgrade analysis recommends subgrade stabilization for soils in which the N_{60} value of a particular soil sample (SS) at a referenced boring location is less than 12 bpf and in some cases less than 15 bpf (i.e., where moisture content is greater than optimum plus 3 percent). Based on the specific N_{60} value at the subject boring, *Figure B - Subgrade Stabilization* recommends a depth of subgrade stabilization for ODOT standard stabilization methods. For the purposes of this report the term 'weak soils' has been assumed to represent subgrade soils of these conditions. It should be noted that although a soil sample's N_{60} value may meet the criteria to be considered a weak soil, the depth in which the weak soil is encountered in relation to the proposed subgrade is considered when each individual subgrade boring is analyzed. For example, if the subgrade analysis recommends an excavate and replace of 12 inches within a weak soil underlying 18 inches of stable material, it would be unreasonable to recommend the removal of both the stable and unstable material for a total of 30 inches of excavate and replace.

Based on N_{60} values encountered within the project borings, our subgrade analysis indicated the need for 14 inches of chemical treatment or excavation and replacement to depths of 12 inches to 18 inches at selected locations. Information on the boring location where weak soils were encountered and determined to have a potential impact on subgrade performance is shown in Table 10 below. Also included is the associated subgrade analysis recommended remediation depth at that location.

Table 10: Unstable (Weak) Soils Location Summary

Boring ID	Sample ID	N_{60}	Moisture Above Optimum (%)	Depth Below Subgrade (ft)	Remediation Depth (inches)		
					Excavate and Replace (Item 204 w/ Geotextile)	Excavate and Replace (Item 204 w/ Geogrid - SS 861)	Chemical Stabilization (Item 206)
Connector							
B-028-0-22	SS-2	10	0	(-0.1)-1.4	12	-	14

It should be noted that *Figure B - Subgrade Stabilization* does not apply to soil types A-1-a, A-1-b, A-3, or A-3a, nor to soils with N_{60L} values of 15 or more. Per GDM guidance, *these soils should be reworked to stabilize the subgrade.*

5.2.3.1. High Moisture Content Soils

High moisture content soils are defined by the GDM as soils that exceed the estimated optimum moisture content (per *Figure A - Optimum Moisture Content* within the GDM) for a given classification by 3 percent or more. Per the GDM, soils determined to be above the identified moisture content levels are a likely indication of the presence of an unstable subgrade and may require some form of subgrade stabilization. Similar to our analysis of weak soils, although a soil sample's moisture content may meet the criteria to be considered high, the depth in which the high moisture soil is encountered in relation to the proposed subgrade is considered when each individual subgrade boring is analyzed for stabilization recommendations. Based on the subsurface exploration performed, a high moisture content soils within the proposed subgrade of the project were encountered in two borings as shown in Table 11 below.

Table 11: High Moisture Soils Summary

Boring ID	Sample ID	Moisture Content (%)	Optimum Moisture Content (%)	Moisture Above Optimum (%)	Depth Below Subgrade (ft)
Ramp A1					
B-007-0-22	SS-2	13	10	3	1.5-3.0
River Trace					
B-024-0-22	SS-2	13	10	3	1.5-3.0
Stewart Road					
B-020-0-22	SS-3	18	10	8	1.5-3.0
B-021-0-22	SS-2B	13	10	3	2.5-3.0

5.2.4. Stabilization Recommendations

Based on the results of our analysis, subgrade soils designated by ODOT's subgrade analysis as "unstable" were present at various locations throughout the project as mentioned in section 5.1.3 of this report. Also, Subgrade soils designated as "unstable" via high moisture content were encountered in borings described in section 5.1.3.1 in this report. Although these materials were encountered at different locations throughout the project, guidance from ODOTs GBM states that *"if it is determined that 30 percent or more of the subgrade area must be stabilized, consider stabilizing the entire project (global stabilization)"* and since less than 30 % of the soils need to be stabilized, therefore, NEAS recommend local stabilization in the form of Item 204 Excavate and Replace where the unstable subgrade materials are encountered. Excavation limits and depths for each roadway which needs stabilization are summarized in Table 12 below the proposed subgrade with the excavated material being replaced with Item 204 Granular Material Type C in accordance with Section F "Excavate and Replace (Item 204)" of the ODOT GDM. 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. From L&D3, include plan note G121 in the plans.

Table 12: Stabilization Recommendation Summary

Start Station	End Station	Excavate and Replace w/ Item 204(1) (inches)	Chemical Stabilization (inches)	Unsuitable Subgrade Conditions	Borings Considered
Merietta Connector					
15+10	17+58	12	14	-	B-028-0-22

5.3. Wall 1

Wall 1 is a modular block wall approximately 307.7 ft in length. Wall 1 has a maximum wall height of 7.5 ft (from top of wall 627.7 ft to bottom of wall 620.2 ft).

5.3.1. Modular Block Wall Design Assumptions

As the proposed Wall 1 is planned to be a modular block wall, ODOT's BDM and AASHTO's LRFD BDS dictate analysis parameters and design minimums/constraints to be used in the analysis and design process. The referenced parameters and design minimums/constraints that were significant to our analyses consist of the following:

Wall configuration: with respect to design constraints and assumptions specific to the proposed retaining wall, the geometry of the proposed wall (i.e., exposed wall height, existing ground elevation, proposed grade, bottom of wall elevation, etc.) is assumed to be consistent with that shown in the proposed Retaining Wall Plan prepared by Palmer Engineering.

Fill materials: Per the fill materials for modular block wall, retained fill soils will meet the minimum design soil parameters per Table 307-1 of the ODOT BDM as shown in Table 13 below.

Table 13: Design Soil Parameters for Fill Materials for Modular Block Wall

Type of Soil	Soil Unit Weight (pcf)	Friction Angle (°)	Cohesion (psf)
Granular Material Type B, per 703.16.C	120	30	0
Notes: *1. Per Table 307-1 of the ODOT BDM, 2020.*			

5.3.2. External Stability

Based on our estimated engineering soil properties and the retaining wall design assumptions provided in section 5.1 and 5.2.1 of this report, external stability analysis was performed for the proposed Wall1 utilizing boring B-006-0-22.

A shallow foundation bearing analyses were first performed for wall 1 under effective (drained) and total (undrained) stress conditions in general accordance with the LRFD Bridge Design Specifications, 9th Edition with 2020 interim revisions. The cross-section was then evaluated for resistance to bearing pressure, sliding force, and overturning at the Strength Limit State in accordance with the AASHTO's LRFD BDS by using the software entitled *Redi-Rock Wall+* by Redi-Rock, Inc. The capacity to demand ratios (CDRs) were calculated for the referenced cross-section with respect to bearing, sliding and overturning. The capacity to demand ratios (CDR) larger than 1.0 indicate a safe design. Based on the Wall 1 site plan provided by Palmer Engineering through email on November 17, 2023, the capacity to demand ratios (CDRs) calculated for the referenced cross-section with respect to bearing, sliding and overturning are presented in Tables 14 below for Wall 1 (External Stability and Bearing Resistance Calculation Results can be found in Appendix D).

Table 144: External Stability Summary for Wall 1

Wall 1 External Analysis	
Top of Wall (feet)	627.7
Bottom of Wall (feet)	620.2
Exposed Wall Height (feet)	6.0
Design Wall Height (feet)	7.5
Boring Log Used in Calculation	B-006-0-22
Capactiy Demand Ratio (CDR)	
Sliding	1.19
Overturning / Eccentricity	2.34
Bearing Capacity (Undrained/Drained)	5.3 / 3.4
Factored Bearing Resistance (ksf) (Undrained/Drained)	9.2 / 5.9

Notes:

1. *Bearing Resistance calculated in accordance to Section 11.10.5.4 of 2020 LRFD BDS and factored using Resistance Factor provided in Table 11.5.7-1 of 2020*

5.3.3. Global Stability

For purposes of evaluating the stability of the proposed Wall 1, NEAS developed global stability analyses. The models were developed from NEAS's interpretation of the available information which included: 1) the site plan provided by Palmer Engineering for the retaining wall site; and 2) test borings and laboratory data developed as part of this report. With respect to the soil's engineering properties, the estimated engineering properties of the Soil Profile resented 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 2.0* by Rocscience, Inc. Specifically, the Simplified Bishop, Spencer and GLE analysis methods were used to calculate a factor of safety (FOS) for circular type slope failure. The FOS is the ratio of the resisting forces to the driving forces, with the desired safety factor being more than about 1.5 which approximately equates to an AASHTO resistance factor of less than 0.65 (per AASHTO's LRFD BDS, the specified resistance factors are essentially the inverse of the FOS that should be targeted in slope stability programs). For the analysis, a resistance factor of 0.65 or lower is targeted as the slope does support a structural element.

Based on our slope stability analyses for Wall 1, the minimum slope stability safety factor for both short-term and long-term conditions exceeded the desired value of 1.5. The results of the analyses are summarized in Table 15. The graphical output of the slope stability program (cross-sectional model, calculated safety factor, and critical failure plane) is presented in Appendix D.

Table 155: Global Stability Analysis Summary for Wall 1

Global Stability Analsysis For the Modular Block Wall Structure					
Location	Boring No.	Description	Minimum Factor of Safety	Equivalent Resistance Factor	Status (OK/NG)
Wall 1	B-006-0-22	Effective Stress	1.65	0.61	OK
		Total Stress	6.72	0.15	OK

5.3.1. Global Stability under Construction Condition

Global Stability analyses were performed for the construction condition for Wall 1. Based on the site plan provided by Palmer Engineering via email on November 17, 2023, 1 Horizontal: 1 Vertical (1H:1V) cut was proposed for the construction of Wall 1. With respect to the soil's engineering properties, the estimated engineering properties of the Soil Profile presented in Section 5.1. of this report were used in our analyses.

The slope stability model at the construction condition was analyzed for short-term (Total Stress) slope stability utilizing the software entitled *Slide 2.0* by Rocscience, Inc. Specifically, the Simplified Bishop, Spencer and GLE analysis methods were used to calculate a factor of safety (FOS) for circular type slope failure**. Based on the site plan provided by Palmer Engineering via email on November 17, 2023, 1 Horizontal: 1 Vertical (1H:1V) excavation cut was proposed for the construction of Wall 1. Our global stability analysis under construction conditions revealed a minimum factor of safety for the short-term condition is 0.70, indicating potential instability in the excavation cut.** The Means and Methods of constructing the modular block wall can be left up to the discretion of the Contractor as long the depth of the excavation does not exceed 8 feet otherwise temporary shoring details shall be included with the plans. The graphical output of the slope stability program (cross-sectional model, calculated safety factor, and critical failure plane) is presented in Appendix D.

5.4. Wall 2

According to Wall 2 site plan prepared by Burgess & Niple, Inc., Wall 2 is Cast-In-Place concrete wall on spread footing. Wall 2 will be approximately 142 ft in length with a maximum height of 10.8 ft including footing and a maximum exposed height of 4.9 ft.

5.4.1. Cast-In-Place Wall Design Assumptions

For the design of the proposed retaining wall, ODOT's BDM, AASHTO's LRFD BDS, and the project conditions dictate analysis parameters and design minimums/constraints are to be used in the analysis and design process. The referenced parameters and design minimums/constraints that where significant to our analyses consist of the following:

- Porous backfill is to be placed from back of the wall extending from top of footing elevation to top of earth backfill with a width not less than 2 feet.
- Retained soils behind the porous backfill are to consist of material placed and compacted in accordance with Item 203, Roadway Excavation and Embankment, of the ODOT Construction and Material Specifications (CMS).
- Retained fill soils will meet the minimum design soil parameters per ODOT's BDM Table 307-1 as shown in Table 15 below.

Table 166: Design Soil Parameters for Fill Materials for Cast-In-Place Wall

Type of Soil	Soil Unit Weight (pcf)	Friction Angle (°)	Cohesion (psf)
On-Site soil varying from sandy lean clay to silty sand, per 703.16.A	120	30	0
Notes: *1.Per Table 307-1 of the ODOT BDM, 2020.*			

5.4.2. External Stability

Based on the site plan provided by Burgess & Niple Inc. on November 14, 2023, through email, external stability was evaluated using boring B-014-0-22. The bottom of the footings varies between elevation of 616.0 ft and 618.0 ft amsl. Wall 2 was evaluated for resistance to bearing pressure, sliding force and overturning at the Strength Limit State in accordance with Section 11.5.3 of the AASHTO's LRFD BDS.

Results are expressed in terms of Capacity to Demand Ratios (CDR) that compare the available factored resistances to the factored load. CDRs >=1 indicate a safe design. The CDRs calculated for the referenced cross sections with respect to bearing, sliding and overturning, as well as the calculated factored bearing resistances are presented in Table 17 below (External Stability Results can be found in Appendix E).

Table 177: External Stability Summary for Wall 2

CIP Retaining Wall 2	
Station in reference to Wall 2	STA. 0+50
Top of Wall (feet)	626.80
Proposed Grade Elevation (feet)	622.90
Bottom of Footing (feet)	616.00
Exposed Wall Height (feet)	3.90
Design Wall Height (feet)	10.80
Boring Log Used in Calculation	B-014-0-22
Capactiy Demand Ratio (CDR)	
Sliding (Undrained/Drained)	2.41 / 2.41
Overturning / Eccentricity	5.83
Bearing Capacity (Undrained/Drained)	3.78 / 3.78
Factored Bearing Resistance (ksf)[(1)] (Undrained/Drained)	8.1 / 8.1
Notes: 1. *Bearing Resistance calculated in accordance to Section 11.10.5.4 of 2020 LRFD BDS and factored using Resistance Factor provided in Table 11.5.7-1 of 2020 LRFD BDS.*	

5.4.3. Global Stability

The slope geometry at wall 2 site is assumed to be consistent with that shown in the site plan provided by B&N Inc. ODOT's SGE and AASHTO's LRFD BDS dictate analysis parameters to be used in the analysis process. Based on planned roadway grades and alignment, AASHTO's LRFD BDS dictates that the slopes shall be evaluated for a live load surcharge of 90 pound per square foot (psf).

For the purpose of evaluating the stability of the retaining wall, NEAS developed global stability analyses. The models were developed from NEAS's interpretation of the available information which included: 1) the site plan provided by B&N, Inc. for the retaining wall site; and 2) test borings and laboratory data developed as part of this report. With respect to the soil's engineering properties, the estimated engineering properties of the Soil Profile resented 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 Simplified Bishop, Spencer and GLE analysis methods were used to calculate a factor of safety (FOS) for circular type slope failure. The FOS is the ratio of the resisting forces to the driving forces, with the desired safety factor being more than about 1.54 which approximately equates to an AASHTO resistance factor of less than 0.65 (per AASHTO's LRFD BDS, the specified resistance factors are essentially the inverse of the FOS that should be targeted in slope stability programs). For the analysis, a resistance factor of 0.65 or lower is targeted as the slope does support a structural element.

Based on our slope stability analyses for the referenced retaining wall, the minimum slope stability safety factor for both short-term and long-term conditions exceeded the desired value of 1.5. The results of the analyses are summarized in Table 18. The graphical output of the slope stability program (cross-sectional model, calculated safety factor, and critical failure plane) is presented in Appendix E.

Table 188: Global Stability Analysis Summary at Wall 2

Global Stability Analsysis For Retaining Wall 2 at Kroger					
Location	**Boring No.**	**Description**	**Minimum Factor of Safety**	**Equivalent Resistance Factor**	**Status (OK/NG)**
Wall 2	B-014-0-22	Effective Stress	2.07	0.48	OK
		Total Stress	3.23	0.31	OK

5.5. Wall 3

According to the retaining wall justification study reports, the recommended alternative for wall 3 is Cast-In-Place concrete wall on spread footing. Wall 3 will be approximately 190 ft in length with a maximum wall height of 11 ft including footing.

5.5.1. External Stability

Based on the basemap and site plan provided by B & N on November 14, 2023, through email, external stability was evaluated using boring B-018-0-22 and B-019-0-22. The bottom of the footing at each boring location were similar at an approximate elevation of 616.1 ft amsl. The retaining wall was evaluated for resistance to bearing pressure, sliding force and overturning at the Strength Limit State in accordance with Section 11.5.3 of AASHTO's LRFD BDS.

Results are expressed in terms of Capacity to Demand Ratios (CDR) that compare the available factored resistances to the factored load. CDRs >=1 indicate a safe design. The CDRs calculated for the referenced cross sections with respect to bearing, sliding and overturning, as well as the calculated factored bearing resistances are presented in Table 19 below (External Stability Results can be found in Appendix F).

Table 1919: External Stability Summary for Wall 3

CIP Retaining Wall 3		
Station in reference to ROS-159	STA. 752+95	STA. 754+25
Top of Wall (feet)	626.40	627.60
Proposed Grade Elevation (feet)	622.00	623.30
Bottom of Footing (feet)	616.00	616.80
Exposed Wall Height (feet)	4.40	4.30
Design Wall Height (feet)	10.40	10.80
Boring Log Used in Calculation	B-018-0-22	B-019-0-22
Capactiy Demand Ratio (CDR)		
Sliding (Undrained/Drained)	2.48 / 2.48	1.61 / 2.41
Overturning / Eccentricity	6.50	5.83
Bearing Capacity (Undrained/Drained)	3.61 / 3.61	1.03 / 1.54
Factored Bearing Resistance (ksf)(1) (Undrained/Drained)	7.4 / 7.4	2.2 / 3.3

Notes:

1. *Bearing Resistance calculated in accordance to Section 11.10.5.4 of 2020 LRFD BDS and factored using Resistance Factor provided in Table 11.5.7-1 of 2020 LRFD BDS.*

5.5.2. Global Stability

The slope geometry at wall 3 site is assumed to be consistent with that shown in the site plans provided by B&N Inc. ODOT's SGE and AASHTO's LRFD BDS dictate analysis parameters to be used in the analysis process. Based on planned roadway grades and alignment, AASHTO's LRFD BDS dictates that the slopes shall be evaluated for a live load surcharge of 90 pound per square foot (psf).

For the purpose of evaluating the stability of the retaining wall, NEAS developed global stability analyses. The models were developed from NEAS's interpretation of the available information which included: 1) the site plan provided by B&N, Inc. for the retaining wall site; and 2) test borings and laboratory data developed as part of this report. With respect to the soil's engineering properties, the estimated engineering properties of the Soil Profile 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 Simplified Bishop, Spencer and GLE analysis methods were used to calculate a factor of safety (FOS) for circular type slope failure. The FOS is the ratio of the resisting forces to the driving forces, with the desired safety factor being more than about 1.5 which approximately equates to an AASHTO resistance factor of less than 0.65 (per AASHTO's LRFD BDS, the specified resistance factors are essentially the inverse of the FOS that should be targeted in slope stability programs). For the analysis, a resistance factor of 0.65 or lower is targeted as the slope does support a structural element.

Based on our slope stability analyses for the referenced retaining wall, the minimum slope stability safety factor for both short-term and long-term conditions exceeded the desired value of 1.5. The results of the analyses are summarized in Table 20. The graphical output of the slope stability program (cross-sectional model, calculated safety factor, and critical failure plane) is presented in Appendix F.

Table 200: Global Stability Analysis Summary at Wall 3

Global Stability Analsysis For Retaining Wall 3 at McDonald's					
Location	**Boring No.**	**Description**	**Minimum Factor of Safety**	**Equivalent Resistance Factor**	**Status (OK/NG)**
Wall 3	B-019-0-22	Effective Stress	2.10	0.48	OK
		Total Stress	4.81	0.21	OK

5.6. Embankment Stability Analysis

At the time of this report, embankment fills, sliver fills, or fills are required for roadway widening purposes for Lowe's parking lot. Based on the proposed cross-sections, NEAS performed overall stability (Global stability) analysis of the embankment fill along the proposed locations.

5.6.1. Global Stability

The 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 Simplified Bishop, Spencer and GLE analysis methods were used to calculate a factor of safety (FOS) for circular type slope failure. The FOS is the ratio of the resisting forces to the driving forces, with the desired safety factor being more than about 1.3 which approximately equates to an AASHTO resistance factor of less than 0.75 (per AASHTO's LRFD BDS, the specified resistance factors are essentially the inverse of the FOS that should be targeted in slope stability programs). For the analysis, a resistance factor of 0.75 or lower is targeted as the slope does support the embankment fills.

Based on our slope stability analyses for the referenced sections, the minimum slope stability safety factor for both short-term and long-term conditions exceeded the desired value of 1.3. The results of the analyses are summarized in Table 21. The graphical output of the slope stability program (cross-sectional model, calculated safety factor, and critical failure plane) is presented in Appendix G.

Table 211: Global Stability Analysis Summary for the Embankment at Lowe's

Global Stability Analsysis for Embankments					
Location	**Boring No.**	**Description**	**Minimum Factor of Safety**	**Equivalent Resistance Factor**	**Status (OK/NG)**
Lowe's Parking Lot	B-012-0-22	Effective Stress	1.92	0.52	OK
		Total Stress	2.77	0.36	OK

5.6.1.Embankment Construction Recommendations

In areas where additional embankment material is proposed along existing slopes (i.e., side-hill sliver fills) that are steeper than 8H:1V but flatter than 4H:1V, it is recommended that the proposed embankment be benched into the existing slopes in accordance with Item 203.05 "Embankment Construction Methods" of the ODOT CMS. For areas where additional embankment material is proposed along existing slopes that are steeper than 4H:1V, it is recommended that the proposed embankment be designed and constructed in accordance with ODOT's GDM. For sidehill fills planned on existing slopes steeper than 4H:1V, ODOT's GDM 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, 2023). As proposed cross-sections are not available at this time, at this stage of the project a special benching scheme similar to that shown in Figures 800-1, 800-3 or 800-4, as appropriate, of the

ODOT GDM should be used in areas where special benching is recommended. The height and width dimensions of the special benching scheme shown in these figures 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 1.75H:1V slope if the existing slope is made up of primarily granular 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 800-2 of the ODOT GDM 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.

5.7. Seismic Site Class

Based on the results of the subsurface exploration, laboratory test data, and the AASHTO Site Class Definitions indicated in Table 3.10.3.1-1 of the *LRFD Bridge Design Specifications, 9th Edition* (AASHTO LRFD, 2020), the average Standard Penetration Test blow counts for B-014-0-22, B-018-0-22, and B-019-0-22 were found to be 6 blows/ft, 12 blows/ft, and 8 blows/ft respectively. As a result, the boring locations site is classified as Site Class of E, with N< 15 blows/ft.

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 proposed retaining walls for the ROS-159-0.41 project. This report has been prepared for Burgess & Niple Inc., ODOT and their design consultants to be used solely in evaluating the soils at the proposed retaining walls 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 test results 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 culverts are 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 Burgess & Niple Inc. in performing this geotechnical exploration for the ROS-159-0.41 project. Please call if there are any questions, or if we can be of further service.

Respectfully Submitted,

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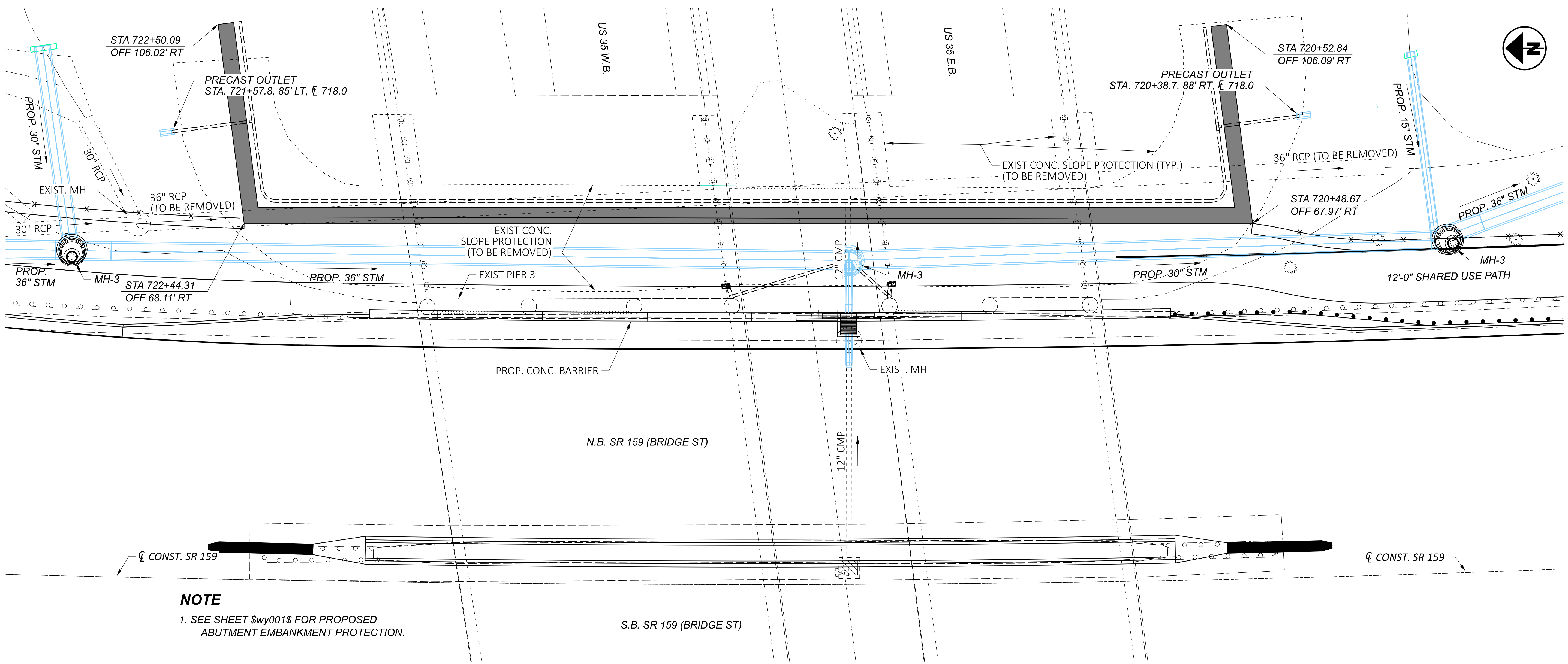
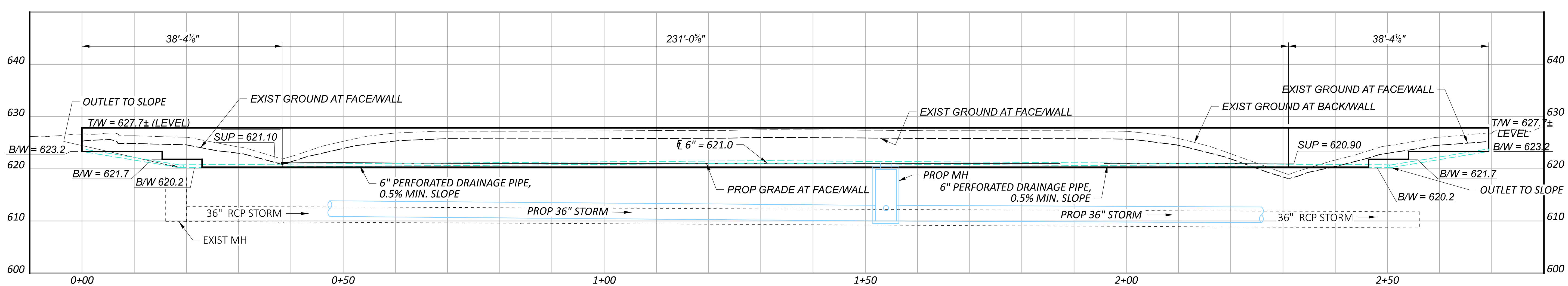
APPENDIX A

SITE PLAN



NOTE

1. SEE SHEET $wy001$ FOR PROPOSED ABUTMENT EMBANKMENT PROTECTION.



WALL ELEVATION
STATIONING ALONG FACE OF WALL

HORIZONTAL SCALE IN FEET
0 5 10 20

WALL 1
PLAN AND ELEVATION

DESIGN AGENCY
Palmer ENGINEERING
6350 EAST KEMPER ROAD
SUITE B
CINCINNATI, OH 45249
(513) 469-1600

DESIGNER
DPF
REVIEWER
BJF 11/22/23
PROJECT ID
113013
SHEET 349 TOTAL 591

ROS-159-0.41

MODEL: Sheet PAPERSIZE: 17x11 (in.) DATE: 10/2/2024 TIME: 9:20:35 PM USER: soroka
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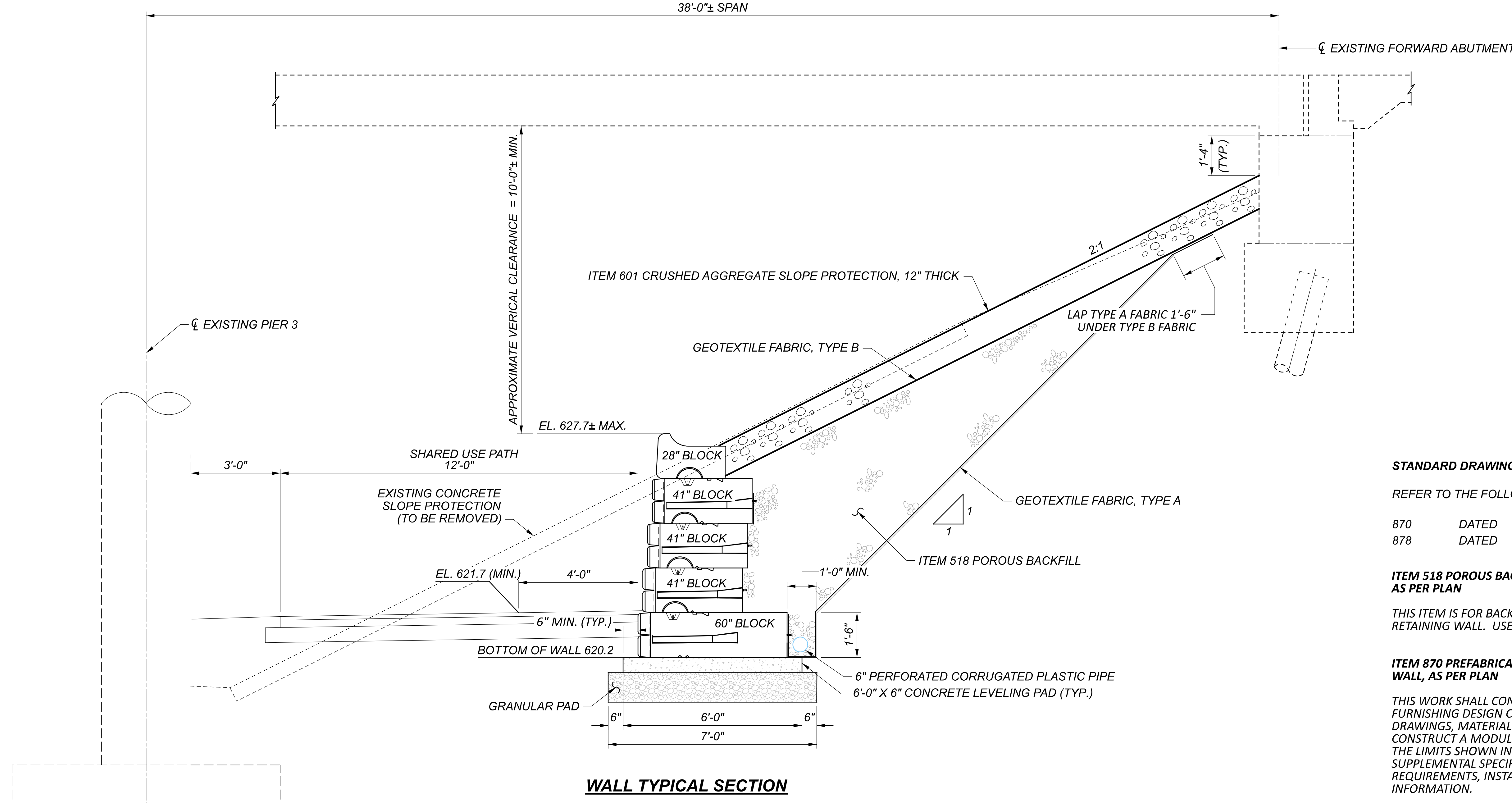
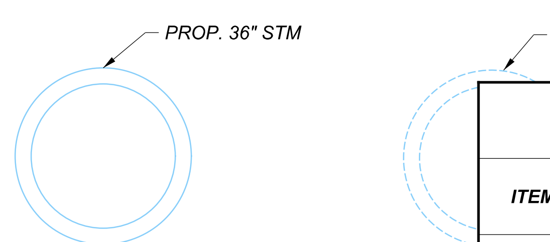


WALL TYPICAL SECTION



ESTIMATED QUANTITIES				
ITEM	ITEM EXT.	TOTAL	UNIT	DESCRIPTION
503	11100	LS	LS	COFFERDAMS AND EXCAVATION BRACING
518	21201	212	CY	POROUS BACKFILL WITH GEOTEXTILE FABRIC, AS PER PLAN
870	10001	2070	SF	PREFABRICATED MODULAR RETAINING WALL, AS PER PLAN
870	11000	350	CY	WALL EXCAVATION
870	12000	269	FT	DRAINAGE PIPE, PERFORATED
870	12100	100	FT	DRAINAGE PIPE, NON-PERFORATED
870	14000	2	DAY	ON-SITE ASSISTANCE
870	15000	LS	LS	PMRW INSPECTION AND COMPACTION TESTING

STANDARD DRAWINGS AND SUPPLEMENTAL SPECIFICATIONS

REFER TO THE FOLLOWING SUPPLEMENTAL SPECIFICATION(S):

870	DATED	7-21-23
878	DATED	1-21-22

ITEM 518 POROUS BACKFILL WITH GEOTEXTILE FABRIC, AS PER PLAN

THIS ITEM IS FOR BACKFILL OF THE MODULAR BLOCK RETAINING WALL. USE TYPE A GEOTEXTILE FABRIC.

ITEM 870 PREFABRICATED MODULAR RETAINING WALL, AS PER PLAN

THIS WORK SHALL CONSIST OF PREPARING THE DESIGN, FURNISHING DESIGN COMPUTATIONS, SHOP DRAWINGS, MATERIALS, EQUIPMENT, AND LABOR TO CONSTRUCT A MODULAR BLOCK RETAINING WALL TO THE LIMITS SHOWN IN THE PLANS. REFER TO SUPPLEMENTAL SPECIFICATION 870 FOR SUBMITTAL REQUIREMENTS, INSTALLATION DETAILS, AND OTHER INFORMATION.

INTERLOCKING BLOCKS SHALL BE WET-CAST CONCRETE BY THE MANUFACTURER LISTED BELOW, OR AN APPROVED EQUAL:

REDI-ROCK STRUCTURES
(513) 382-5822
JTURTON@REDI-ROCKSTRUCTURES.COM
BLOCK FINISH: KINGSTONE

THE FACTORED BEARING RESISTANCE TO BE USED FOR DESIGN PURPOSES IS 3600 PSF.

BACKFILL THE MODULAR BLOCK WALL WITH ITEM 518 POROUS BACKFILL ON TYPE A GEOTEXTILE FABRIC. EXTEND THE TYPE A GEOTEXTILE FABRIC UNDERNEATH THE TYPE B GEOTEXTILE FABRIC OF THE CRUSHED AGGREGATE SLOPE PROTECTION A MINIMUM OF 18". PAYMENT FOR POROUS BACKFILL AND GEOTEXTILE FABRIC IS UNDER A SEPARATE PAY ITEM.

PAYMENT FOR THE PREFABRICATED MODULAR RETAINING WALL INCLUDES MODULAR UNITS, BEARING PADS, JOINT COVERING, MODULAR WALL INFILL MATERIALS, LEVELING PADS, AESTHETIC FINISH AND OTHER ITEMS NECESSARY TO COMPLETE THE WALL INSTALLATION THAT DO NOT HAVE SEPARATE PAY ITEMS. WALL EXCAVATION, DRAINAGE PIPE, AND INSPECTION AND TESTING ARE PAID UNDER SEPARATE PAY ITEMS. INCLUDE PAYMENT FOR ANY NECESSARY EXCAVATION BRACING UNDER ITEM 503 COFFERDAMS AND EXCAVATION BRACING.

WALL 1 - NOTES AND DETAILS

DESIGN AGENCY
Palmer ENGINEERING
8350 EAST KEMPER ROAD
SUITE B
CINCINNATI, OH 45249
(513) 469-1600

DESIGNER DPF
REVIEWER BJF 11/22/23
PROJECT ID 113013
SHEET 350 TOTAL 591

ROS-159-0.41

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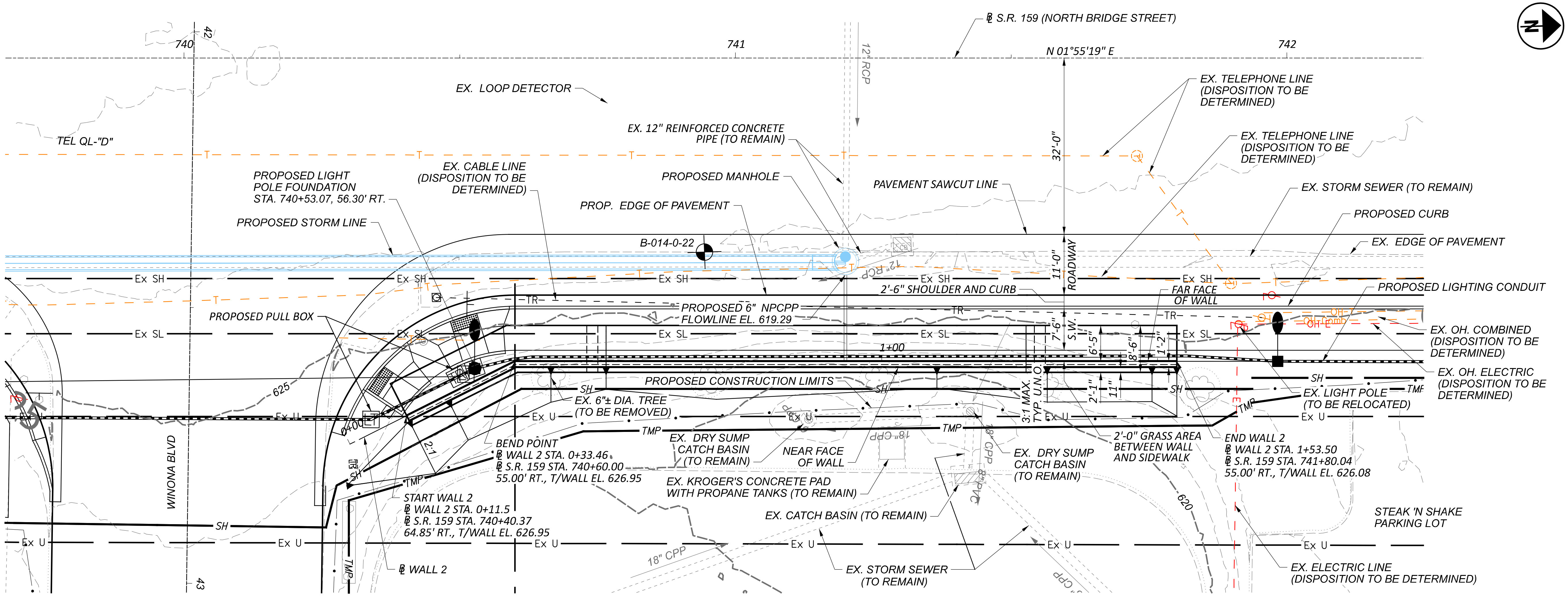
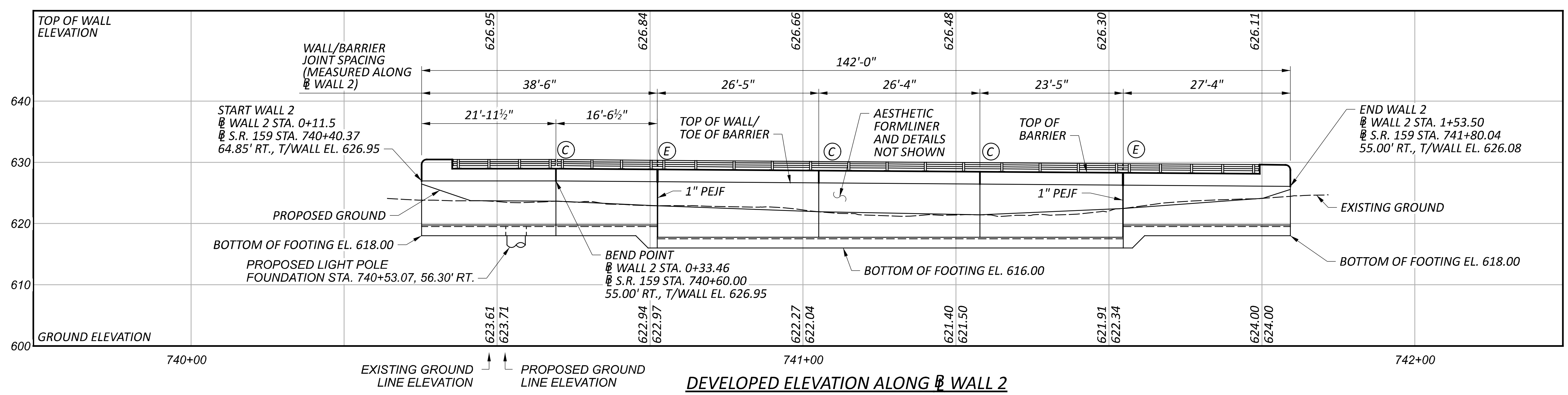


PLAN



DEVELOPED ELEVATION ALONG ℄ WALL 2

LEGEND:

- Ⓒ - CONTRACTION JOINT
- Ⓔ - EXPANSION JOINT
- ⊕ - NEW BORING LOCATION

NOTES:

1. UNLESS NOTED OTHERWISE THE GROUND SLOPE AT THE FACE OF THE WALL SHALL BE 3:1 (H:V) FOR THE FIRST THREE FEET FROM THE WALL FACE. AFTER WHICH THE GROUND SLOPE SHALL BE 2:1 (H:V) MAX. TO TIE INTO EXISTING GRADE.
2. EARTHWORK LIMITS SHOWN ARE APPROXIMATE. ACTUAL SLOPES SHALL CONFORM TO PLAN CROSS SECTIONS.

SITE PLAN
WALL NO. 2
RETAINING WALL AT KROGER

SFN	N/A
DESIGN AGENCY	B&N burgessniple.com
DESIGNER	JFM
CHECKER	JHL
REVIEWER	JCS 07/12/23
PROJECT ID	113013
SUBSET / TOTAL	1 / 15
SHEET / TOTAL	351 / 591

ROS-159-0.41

MODEL: Sheet PAPERSIZE: 17x11 (in.) DATE: 10/2/2024 TIME: 9:20:49 PM USER: soroka
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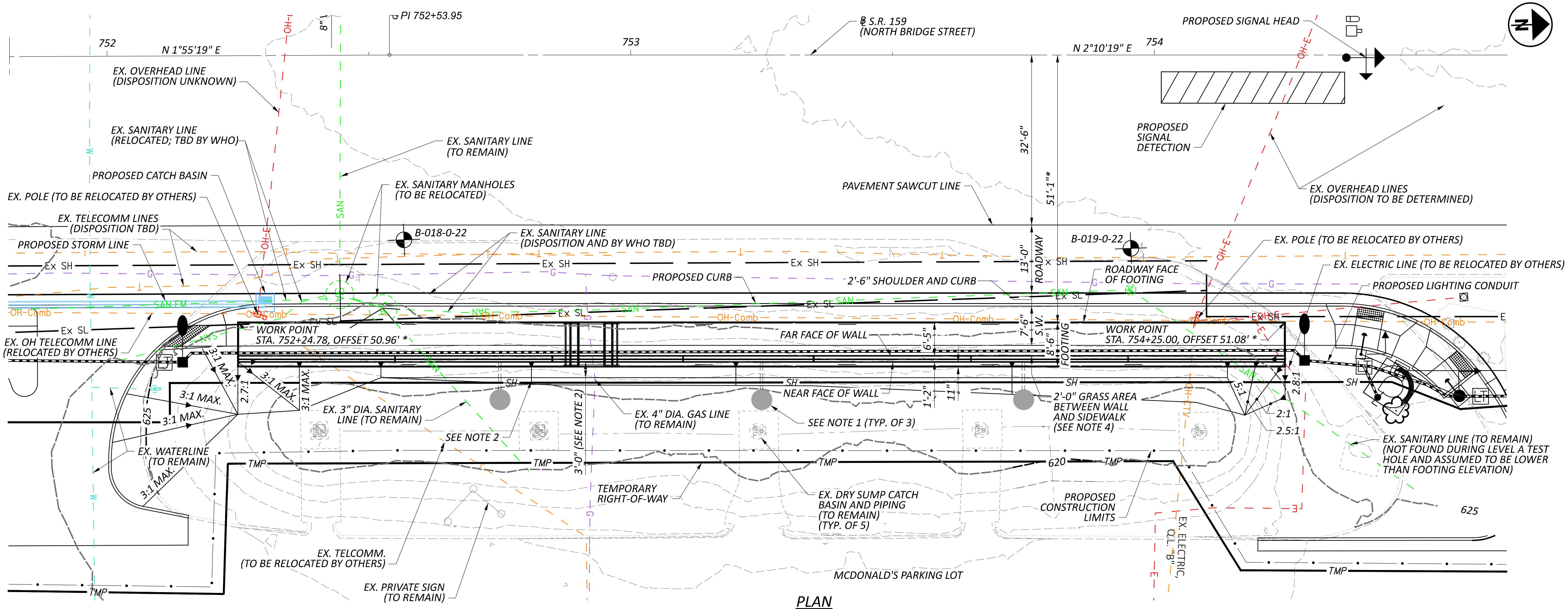
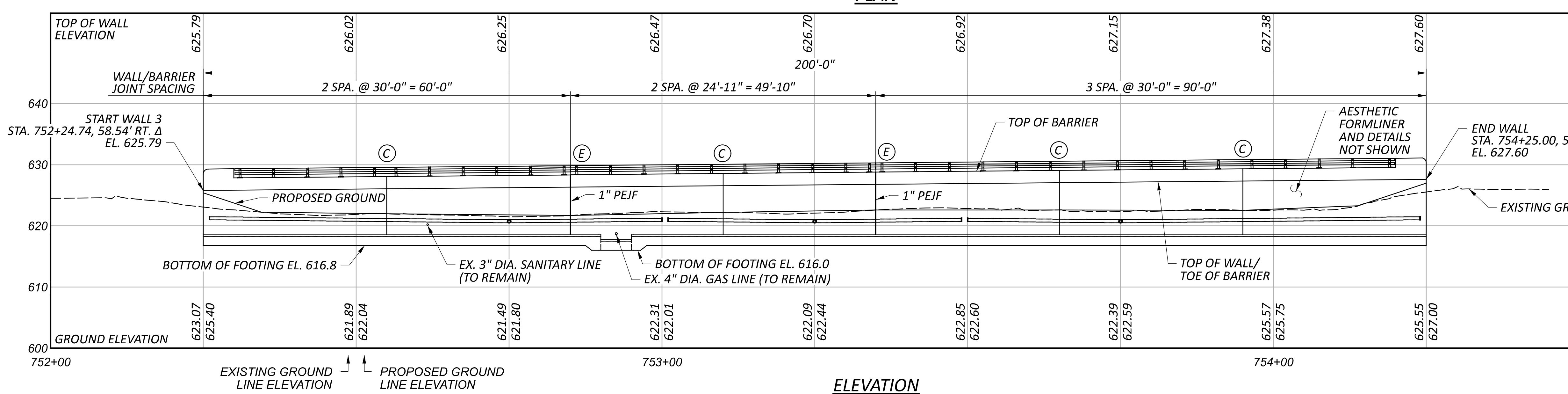


PLAN



ELEVATION

LEGEND:

- Ⓒ - CONTRACTION JOINT
- Ⓔ - EXPANSION JOINT
- ⊕ - NEW BORING LOCATION

Δ - THE OFFSET IS MEASURED TO THE NEAR FACE OF THE RETAINING WALL

* - THE 51'-1" IS MEASURED FROM THE ℄ S.R. 159 FROM STATION 752+53.95 TO STATION 754+25.00. BEFORE STATION 752+53.95 THE DIMENSION IS VARIABLE. THE RETAINING WALL SHALL BE PLACED AT A DIRECTIONAL BEARING OF N 2°10'19" E WHICH IS PARALLEL TO ℄ S.R. 159 FROM STATION 752+53.95 TO STATION 754+25.00.

NOTES:

1. 6" DIA. N.P.C.P.P. DRAINING INTO 4'-0" DIAMETER CRUSHED AGGREGATE SLOPE PROTECTION 1'-0" THICK. THE 6" DIA. N.P.C.P.P. EXITS THE WALL AT FLOWLINE OF ELEVATION 620.5 AND WILL SLOPE TO DAYLIGHT AT 1/8" PER FOOT MINIMUM.
2. UNLESS NOTED OTHERWISE THE GROUND SLOPE AT THE FACE OF THE WALL SHALL BE 3:1 (H:V) FOR THE FIRST THREE FEET FROM THE WALL FACE. AFTER WHICH THE GROUND SLOPE SHALL BE 2:1 (H:V) MAX TO TIE INTO EXISTING GRADE.
3. EARTHWORK LIMITS SHOWN ARE APPROXIMATE. ACTUAL SLOPES SHALL CONFORM TO PLAN CROSS SECTIONS.
4. THE 2'-0" DIMENSION WILL VARY BEFORE STATION 752+53.95.

SITE PLAN
WALL NO. 3
RETAINING WALL AT MCDONALD'S

SFN	N/A
DESIGN AGENCY	B&N burgessniple.com
DESIGNER	JFM
CHECKER	SRW
REVIEWER	JCS 07/10/23
PROJECT ID	113013
SUBSET / TOTAL	2 / 15
SHEET / TOTAL	352 / 591

ROS-159-0.41

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APPENDIX B

SOIL BORING LOGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 709+31, 52' RT.	EXPLORATION ID B-001-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 626.5 (MSL) EOB: 11.5 ft.	PAGE 1 OF 1
START: 8/2/22 END: 8/2/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.345260, -82.976167	

MATERIAL DESCRIPTION AND NOTES	ELEV. 626.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
9.5" ASPHALT AND 8.5" BASE (DRILLERS DESCRIPTION)	625.0	1																	
MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, SOME SILT, LITTLE CLAY, LITTLE GRAVEL, MOIST		2–3	10 13 12	30	61	SS-1	-	13	15	37	23	12	NP	NP	NP	11	A-3a (0)	0	
	622.0	4																	
MEDIUM DENSE TO DENSE, BROWN AND GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST		5–6	9 10 18	34	50	SS-2	-	33	22	20	18	7	NP	NP	NP	8	A-1-b (0)	-	
		7–8	9 10 13	28	67	SS-3	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	-	
	615.0	9–11 EOB	7 11 13	29	56	SS-4	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED .5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 712+90, 36' RT.	EXPLORATION ID B-002-0-22
TYPE: EMBANKMENT FOUNDATION	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 622.5 (MSL) EOB: 26.5 ft.	PAGE
START: 8/2/22 END: 8/2/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.346234, -82.976354	1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 622.5
12.0" ASPHALT AND 6.0" BASE (DRILLERS DESCRIPTION)	621.0
DENSE, BROWN AND GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	617.3
VERY STIFF, DARK BROWNISH GRAY, **SILT AND CLAY**, SOME SAND, SOME GRAVEL, DAMP	615.5
MEDIUM DENSE, BROWNISH GRAY, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST	613.0
VERY STIFF TO HARD, BROWNISH GRAY AND ORANGISH BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, DAMP TO MOIST	608.0
LOOSE, BROWN, **COARSE AND FINE SAND**, SOME SILT, TRACE GRAVEL, TRACE CLAY, MOIST	605.5
MEDIUM DENSE TO VERY DENSE, BROWN, **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, DAMP	596.0

EOB

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
21 21 13	41	22	SS-1	-	44	22	14	15	5	NP	NP	NP	7	A-1-b (0)	-	
3 5 5	12	56	SS-2	3.25	22	15	18	28	17	33	18	15	14	A-6a (4)	-	
5 7 2	11	72	SS-3	-	-	-	-	-	-	-	-	-	16	A-2-4 (V)	-	
5 5 6	13	67	SS-4	4.50	7	10	25	33	25	32	18	14	15	A-6a (6)	-	
3 2 4	7	83	SS-5	3.00	-	-	-	-	-	-	-	-	19	A-6a (V)	-	
1 3 4	8	100	SS-6	-	-	-	-	-	-	-	-	-	11	A-3a (V)	-	
4 5 8	16	22	SS-7	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	-	
10 13 15	34	56	SS-8	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	-	
32 31 25	68	61	SS-9	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED .5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / J. HODGES	DRILL RIG: CME 45B	STATION / OFFSET: 714+89, 46' LT.	EXPLORATION ID B-003-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / J. HODGES	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 621.8 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 7/27/22 END: 7/27/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.346753, -82.976718	

MATERIAL DESCRIPTION AND NOTES	ELEV. 621.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
12.0" ASPHALT AND 8.0" BASE (DRILLERS DESCRIPTION)	620.1	1																	
HARD, BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, DAMP TO MOIST **(FILL)**		2	14 9 8	21	78	SS-1	4.50	0	11	47	27	15	21	15	6	11	A-4a (1)	100	
	617.3	3–4	8 6 5	13	100	SS-2	4.50	-	-	-	-	-	-	-	-	17	A-4a (V)	-	
VERY STIFF, BROWNISH GRAY, **SILT AND CLAY**, "AND" SAND, LITTLE GRAVEL, CONTAINS SHELLS, DAMP **(FILL)**	615.8	5	2 6 5	13	100	SS-3	3.25	11	10	27	30	22	31	17	14	16	A-6a (5)	-	
DENSE, BLACK AND BROWNISH GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, CONTAINS ASPHALT FRAGMENTS, WET **(FILL)**	614.3	6–7, EOB	7 13 21	41	100	SS-4	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 718+09, 56' RT.	EXPLORATION ID B-004-0-22
TYPE: EMBANKMENT FOUNDATION	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 621.3 (MSL) EOB: 26.5 ft.	PAGE 1 OF 1
START: 8/2/22 END: 8/2/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.347655, -82.976470	

MATERIAL DESCRIPTION AND NOTES	ELEV. 621.3
3.5" ASPHALT AND 9.5" CONCRETE AND 6.0" BASE (DRILLERS DESCRIPTION)	619.7
DENSE TO VERY DENSE, BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	614.3
HARD, BROWN AND DARK GRAY, **SILT AND CLAY**, SOME TO "AND" SAND, TRACE GRAVEL, DAMP TO MOIST	609.3
STIFF TO HARD, BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE GRAVEL, DAMP TO MOIST	603.3
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP	601.8
LOOSE TO MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS**, SOME SAND, TRACE SILT, TRACE CLAY, DAMP TO MOIST	594.8

EOB

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm
8 26 20	56	44	SS-1	-	47	23	13	13	4	NP	NP	NP	4	A-1-b (0)	-
13 14 13	33	83	SS-2	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	-
6 5 5	12	89	SS-3	4.50	6	11	27	28	28	31	16	15	14	A-6a (6)	-
3 3 7	12	100	SS-4	4.50	-	-	-	-	-	-	-	-	23	A-6a (V)	-
2 3 5	10	100	SS-5	4.25	1	3	6	46	44	47	23	24	22	A-7-6 (15)	-
0 3 2	6	100	SS-6	2.75	-	-	-	-	-	-	-	-	25	A-7-6 (V)	-
5 6 7	16	72	SS-7A	1.25	-	-	-	-	-	-	-	-	25	A-7-6 (V)	-
			SS-7B	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	-
3 3 2	6	33	SS-8	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	-
5 5 4	11	44	SS-9	-	-	-	-	-	-	-	-	-	14	A-1-a (V)	-

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE. BORING OFFSET 60' SOUTH DUE TO OVERHEAD UTILITIES.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 720+66, 46' RT.
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 619.8 (MSL) EOB: 21.5 ft.
START: 8/2/22 END: 8/2/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.348349, -82.976562

EXPLORATION ID B-005-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 619.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
5.0" ASPHALT AND 8.0" CONCRETE AND 6.0" BASE (DRILLERS DESCRIPTION)	618.2																		
MEDIUM DENSE, BROWN AND GRAY, **GRAVEL**, LITTLE SAND, TRACE SILT, TRACE CLAY, DAMP			6 6 5	13	56	SS-1	-	76	10	5	6	3	NP	NP	NP	6	A-1-a (0)	-	
	615.3																		
STIFF TO HARD, GRAYISH BROWN AND BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, MOIST TO DAMP			2 7 3	12	67	SS-2	3.75	2	1	27	32	38	32	17	15	18	A-6a (9)	-	
			3 2 7	11	56	SS-3	3.50	-	-	-	-	-	-	-	-	14	A-6a (V)	-	
			6 6 2	10	89	SS-4	4.50	-	-	-	-	-	-	-	-	14	A-6a (V)	-	
			5 7 5	15	67	SS-5	2.00	-	-	-	-	-	-	-	-	20	A-6a (V)	-	
			5 5 4	11	94	SS-6	1.75	-	-	-	-	-	-	-	-	22	A-6a (V)	-	
			7 3 5	10	89	SS-7	2.75	-	-	-	-	-	-	-	-	13	A-6a (V)	-	
	598.3	EOB	4 7 5	15	67	SS-8	3.00	-	-	-	-	-	-	-	-	18	A-6a (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 721+45, 103' RT.	EXPLORATION ID B-006-0-22
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 638.9 (MSL) EOB: 41.5 ft.	PAGE 1 OF 2
START: 8/9/22 END: 8/9/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.348564, -82.976366	

MATERIAL DESCRIPTION AND NOTES	ELEV. 638.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
2.5" TOPSOIL (DRILLERS DESCRIPTION)	638.7																		
DENSE TO VERY DENSE, BROWN, **SANDY SILT**, SOME GRAVEL, TRACE CLAY, DAMP		3–4	12 14 13	33	89	SS-1	-	31	15	16	32	6	NP	NP	NP	7	A-4a (1)	-	
	631.9	5–6	11 20 23	52	67	SS-2	-	-	-	-	-	-	-	-	-	8	A-4a (V)	-	
HARD, BROWN, **SANDY SILT**, LITTLE GRAVEL, LITTLE CLAY, DAMP	629.4	8–9	3 4 10	17	33	SS-3	4.50	18	12	32	21	17	23	17	6	12	A-4a (1)	-	
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP	626.9	10–11	5 11 10	25	44	SS-4	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	-	
HARD, BROWN AND GRAYISH BROWN, **SANDY SILT**, LITTLE TO SOME CLAY, TRACE TO LITTLE GRAVEL, DAMP		13–14	5 10 13	28	67	SS-5	4.50	1	20	36	24	19	20	15	5	10	A-4a (2)	-	
		15–16	5 12 14	31	56	SS-6	4.50	-	-	-	-	-	-	-	-	13	A-4a (V)	-	
		18–19	5 10 12	27	72	SS-7	4.50	-	-	-	-	-	-	-	-	12	A-4a (V)	-	
SS-8 AND SS-9 BECOME SLIGHTLY ORGANIC, CONTAIN WOOD FIBERS		20–21	10 12 17	35	83	SS-8	4.50	-	-	-	-	-	-	-	-	13	A-4a (V)	-	
	614.4	23–24	12 17 20	45	83	SS-9	4.50	-	-	-	-	-	-	-	-	12	A-4a (V)	-	
MEDIUM DENSE TO DENSE, GRAYISH BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP		25–26	12 12 13	30	72	SS-10	-	-	-	-	-	-	-	-	-	7	A-2-4 (V)	-	
	609.4	28–29	10 13 17	36	83	SS-11	-	-	-	-	-	-	-	-	-	10	A-2-4 (V)	-	

PID: 113013	SFN:	PROJECT: ROS-159-0.41	STATION / OFFSET: 721+45, 103' RT.	START: 8/9/22	END: 8/9/22	PG 2 OF 2	B-006-0-22

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)	SO4 ppm	BACK FILL
HARD, BROWN, **SANDY SILT**, LITTLE TO SOME CLAY, TRACE GRAVEL, DAMP TO MOIST *(continued)*		31	11 12 14	31	83	SS-12	4.50	4	25	32	22	17	23	16	7	12	A-4a (1)	-	
		32																	
		33	10 11 11	27	67	SS-13	4.50	-	-	-	-	-	-	-	-	16	A-4a (V)	-	
		34																	
		35																	
		36	12 12 10	27	78	SS-14	4.50	-	-	-	-	-	-	-	-	12	A-4a (V)	-	
		37																	
		38	9 13 11	29	67	SS-15	4.50	-	-	-	-	-	-	-	-	17	A-4a (V)	-	
		39																	
		40																	
	597.4	41 EOB	9 7 9	19	44	SS-16	4.50	-	-	-	-	-	-	-	-	11	A-4a (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: SHOVELED SOIL CUTTINGS

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/28/22 09:30 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 400+67, 40' LT.	EXPLORATION ID B-007-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: RAMP A1	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 621.2 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 8/2/22 END: 8/2/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.349001, -82.976696	

MATERIAL DESCRIPTION AND NOTES	ELEV. 621.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
6.0" ASPHALT AND 7.0" CONCRETE AND 5.0" BASE (DRILLERS DESCRIPTION)	619.7	1																	
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP **(FILL)**	618.2	2	5 6 6	15	28	SS-1	-	30	29	17	18	6	NP	NP	NP	8	A-1-b (0)	60	
VERY LOOSE TO LOOSE, BROWN AND BLACK, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, SS-2 IS MODERATELY ORGANIC (4.0%), CONTAINS ROOTS AND BRICK FRAGMENTS, DAMP **(FILL)**		3, 4	3 2 1	4	17	SS-2	-	27	26	18	23	6	NP	NP	NP	13	A-2-4 (0)	-	
	615.2	5, 6	2 3 2	6	56	SS-3	-	-	-	-	-	-	-	-	-	6	A-2-4 (V)	-	
MEDIUM DENSE, ORANGISH BROWN, **COARSE AND FINE SAND**, LITTLE SILT, TRACE GRAVEL, MOIST	613.7	7, EOB	10 15 9	29	89	SS-4	-	-	-	-	-	-	-	-	-	16	A-3a (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/28/22 09:30 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 402+06, 14' RT.	EXPLORATION ID B-008-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: RAMP A1	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 617.7 (MSL) EOB: 11.5 ft.	PAGE 1 OF 1
START: 8/2/22 END: 8/2/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.349349, -82.976406	

MATERIAL DESCRIPTION AND NOTES	ELEV. 617.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
9.5" ASPHALT AND 8.5" BASE (DRILLERS DESCRIPTION)	616.2	0 – 1.5																	
VERY LOOSE TO MEDIUM DENSE, BROWN AND BLACK, **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, CONTAINS BRICK FRAGMENTS AND ROOTS, SS-2 BECOMES SLIGHTLY ORGANIC, DAMP **(FILL)**	610.7	3 – 4.5	5 6 6	15	28	SS-1	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	0	
		5.5 – 7	3 2 1	4	17	SS-2	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	-	
LOOSE, BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, MOIST	607.5	8 – 9.5	2 3 2	6	56	SS-3	-	1	2	61	24	12	NP	NP	NP	17	A-4a (0)	-	
MEDIUM DENSE, GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	606.2	10 – 11.5 EOB	10 15 9	29	89	SS-4	-	37	14	26	17	6	NP	NP	NP	8	A-1-b (0)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 725+34, 36' LT.	EXPLORATION ID B-009-0-22
TYPE: EMBANKMENT FOUNDATION	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 621.4 (MSL) EOB: 16.5 ft.	PAGE 1 OF 1
START: 8/2/22 END: 8/2/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.349635, -82.976829	

MATERIAL DESCRIPTION AND NOTES	ELEV. 621.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
12.0" ASPHALT AND 6.0" BASE (DRILLERS DESCRIPTION)	619.9	1																	
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, DAMP	618.4	2–3	8 8 4	15	44	SS-1A	-	49	26	10	10	5	NP	NP	NP	5	A-1-b (0)	180	
STIFF TO VERY STIFF, BROWN, **SILT AND CLAY**, "AND" SAND, LITTLE TO SOME GRAVEL, SS-2 CONTAINS NO INTACT SOIL FOR HP READINGS, DAMP		3–4				SS-1B	2.75	19	21	19	24	17	28	17	11	12	A-6a (1)	-	
	614.4	5–6	7 5 5	12	56	SS-2	-	24	18	18	22	18	27	16	11	11	A-6a (1)	-	
VERY STIFF, ORANGISH BROWN AND DARK GRAY, **SILTY CLAY**, SOME SAND, TRACE GRAVEL, CONTAINS IRON STAINING, CONTAINS NO INTACT SOIL FOR HP READINGS, DAMP	611.9	7–9	8 7 7	17	89	SS-3	-	2	3	22	38	35	35	19	16	19	A-6b (10)	-	
VERY STIFF, ORANGISH BROWN, **SILT AND CLAY**, "AND" SAND, TRACE GRAVEL, IRON STAINING, MOIST		10–11	3 5 8	16	89	SS-4	3.50	0	1	44	31	24	27	16	11	17	A-6a (4)	-	
	607.6	12–13	5 11 21	39	33	SS-5	3.00	-	-	-	-	-	-	-	-	18	A-6a (V)	-	
DENSE, LIGHT BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	604.9	14–16, EOB	7 9 18	33	56	SS-6	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 727+88, 45' RT.
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 622.5 (MSL) EOB: 11.5 ft.
START: 8/2/22 END: 8/2/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.350320, -82.976506

EXPLORATION ID B-010-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 622.5	DEPTHS
12.0" ASPHALT AND 6.0" BASE (DRILLERS DESCRIPTION)	621.0	
VERY STIFF TO HARD, BROWN, **SILTY CLAY**, SOME SAND, LITTLE TO SOME GRAVEL, SS-1 CONTAINS ROOTS, DAMP TO MOIST	611.0	EOB

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
2 2 3	6	33	SS-1	4.00	23	10	17	24	26	36	19	17	17	A-6b (5)	60	
2 2 2	5	72	SS-2	3.00	-	-	-	-	-	-	-	-	21	A-6b (V)	-	
4 4 5	11	56	SS-3	4.25	23	11	14	26	26	36	18	18	16	A-6b (6)	-	
5 4 5	11	44	SS-4	3.00	-	-	-	-	-	-	-	-	19	A-6b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE. BORING OFFSET 30' SOUTH DUE TO OVERHEAD UTILITIES.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 731+03, 48' RT.	EXPLORATION ID B-011-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 625.8 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 8/11/22 END: 8/11/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.351186, -82.976446	

MATERIAL DESCRIPTION AND NOTES	ELEV. 625.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
6.0" ASPHALT AND 11.0" BASE (DRILLERS DESCRIPTION)	624.4	1																	
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP		2	8 9 11	24	56	SS-1	-	47	24	12	12	5	NP	NP	NP	10	A-1-b (0)	0	
		3, 4	2 5 13	22	28	SS-2	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	-	
	619.8	5	4 7 4	13	56	SS-3	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	-	
VERY STIFF, BROWN, **SANDY SILT**, SOME CLAY, TRACE GRAVEL, DAMP	618.3	6, 7, EOB	5 6 4	12	44	SS-4	3.00	9	15	24	29	23	25	15	10	15	A-4a (3)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/28/22 09:30 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/28/22 09:30 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 736+73, 35' RT.	EXPLORATION ID B-012-0-22
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 626.9 (MSL) EOB: 16.5 ft.	PAGE 1 OF 1
START: 8/3/22 END: 8/3/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.352752, -82.976421	

MATERIAL DESCRIPTION AND NOTES	ELEV. 626.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
9.5" ASPHALT AND 2.5" BASE (DRILLERS DESCRIPTION)	625.4	1																	
LOOSE, BROWN, **STONE FRAGMENTS**, LITTLE SAND, TRACE SILT, TRACE CLAY, DAMP	622.4	2–4	4 2 3	6	11	SS-1	-	-	-	-	-	-	-	-	-	7	A-1-a (V)	60	
VERY STIFF, BROWN, **SILT AND CLAY**, "AND" SAND, TRACE GRAVEL, CONTAINS IRON STAINING, DAMP	619.9	5–7	2 3 3	7	56	SS-2	3.50	2	29	31	17	21	29	14	15	13	A-6a (2)	-	
DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS**, LITTLE SAND, TRACE SILT, TRACE CLAY, DAMP	617.4	8–9	3 13 14	33	33	SS-3	-	-	-	-	-	-	-	-	-	7	A-1-a (V)	-	
VERY DENSE, BROWN AND GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP		10–12	9 25 20	54	56	SS-4	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	-	
		13–14	16 27 22	59	89	SS-5	-	31	29	19	17	4	NP	NP	NP	4	A-1-b (0)	-	
	610.4	15–16 EOB	9 22 21	52	67	SS-6	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 738+66, 35' RT.	EXPLORATION ID B-013-0-22
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 626.5 (MSL) EOB: 16.5 ft.	PAGE 1 OF 1
START: 8/3/22 END: 8/3/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.353280, -82.976398	

MATERIAL DESCRIPTION AND NOTES	ELEV. 626.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
9.5" ASPHALT AND 2.5" BASE (DRILLERS DESCRIPTION)	625.0	0–1																	
HARD, BROWN, **SILT AND CLAY**, "AND" SAND, TRACE GRAVEL, SS-1 CONTAINS IRON STAINING, DAMP TO MOIST		2.5–4	4 3 5	10	100	SS-1	4.25	0	14	40	21	25	28	15	13	14	A-6a (3)	100	
		5–6.5	2 4 9	16	89	SS-2	4.50	-	-	-	-	-	-	-	-	16	A-6a (V)	-	
	618.5	7.5–9	9 20 19	47	28	SS-3A	4.25	-	-	-	-	-	-	-	-	13	A-6a (V)	-	
DENSE, BROWN AND GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE TO LITTLE SILT, TRACE CLAY, DAMP						SS-3B	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	-	
		10–11.5	13 17 14	38	56	SS-4	-	37	29	14	16	4	NP	NP	NP	4	A-1-b (0)	-	
		12.5–14	12 14 15	35	44	SS-5	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	-	
	610.0	15–16.5 EOB	12 18 18	44	56	SS-6	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41 TYPE: EMBANKMENT FOUNDATION PID: 113013 SFN: START: 8/3/22 END: 8/3/22	DRILLING FIRM / OPERATOR: NEAS / JL SAMPLING FIRM / LOGGER: NEAS / JL DRILLING METHOD: 3.25" HSA SAMPLING METHOD: SPT	DRILL RIG: CME 45B HAMMER: CME AUTOMATIC CALIBRATION DATE: 1/24/22 ENERGY RATIO (%): 72.6	STATION / OFFSET: 740+94, 35' RT. ALIGNMENT: SR 159 ELEVATION: 625.5 (MSL) EOB: 16.5 ft. LAT / LONG: 39.353908, -82.976376	EXPLORATION ID B-014-0-22 PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 625.5	DEPTHS
12.0" ASPHALT AND 7.0" BASE (DRILLERS DESCRIPTION)	623.9	
VERY STIFF, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, DAMP	621.0	
VERY STIFF, ORANGISH BROWN, **SILT AND CLAY**, "AND" SAND, TRACE GRAVEL, CONTAINS IRON STAINING, DAMP	617.9	
LOOSE, BROWN, **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE GRAVEL, DAMP	616.0	
VERY LOOSE TO LOOSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE TO LITTLE SILT, TRACE CLAY, DAMP	609.0	EOB

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm
4 3 3	7	44	SS-1	3.50	6	11	23	37	23	31	18	13	18	A-6a (6)	20
3 2 4	7	56	SS-2	2.50	-	-	-	-	-	-	-	-	14	A-6a (V)	-
3 3 2	6	89	SS-3	-	-	-	-	-	-	-	-	-	9	A-3a (V)	-
3 3 2	6	56	SS-4	-	25	34	17	17	7	NP	NP	NP	7	A-1-b (0)	-
2 1 2	4	39	SS-5	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	-
3 3 4	8	22	SS-6	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	-

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 744+47, 35' RT.	EXPLORATION ID B-015-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 624.4 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 8/3/22 END: 8/3/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.354875, -82.976342	

MATERIAL DESCRIPTION AND NOTES	ELEV. 624.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
12.0" ASPHALT AND 6.0" BASE (DRILLERS DESCRIPTION)	622.9	1																	
LOOSE TO MEDIUM DENSE, BROWN, **GRAVEL WITH SAND, SILT, AND CLAY**, CONTAINS ASPHALT FRAGMENTS, DAMP TO MOIST		2	7 6 6	15	17	SS-1	-	-	-	-	-	-	-	-	-	11	A-2-6 (V)	-	
		3, 4	4 7 5	15	28	SS-2	-	31	30	8	19	12	28	15	13	5	A-2-6 (0)	0	
	618.4	5	3 4 4	10	89	SS-3	-	-	-	-	-	-	-	-	-	24	A-2-6 (V)	-	
VERY STIFF, BROWN, **SILTY CLAY**, LITTLE SAND, TRACE GRAVEL, MOIST	616.9	6, 7 EOB	4 5 5	12	44	SS-4	3.75	0	5	7	46	42	36	19	17	20	A-6b (11)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 747+64, 35' RT.	EXPLORATION ID B-016-0-21
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 624.3 (MSL) EOB: 11.5 ft.	PAGE 1 OF 1
START: 8/3/22 END: 8/3/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.355746, -82.976310	

MATERIAL DESCRIPTION AND NOTES	ELEV. 624.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI				
9.5" ASPHALT AND 9.5" BASE (DRILLERS DESCRIPTION)	622.7																		
HARD, ORANGISH BROWN, **SILT AND CLAY**, "AND" SAND, TRACE GRAVEL, CONTAINS IRON STAINING, DAMP	619.8	3–4.5	7 5 5	12	72	SS-1	4.50	7	26	29	18	20	29	15	14	10	A-6a (2)	60	
LOOSE, ORANGISH BROWN, **COARSE AND FINE SAND**, LITTLE CLAY, LITTLE SILT, TRACE GRAVEL, CONTAINS IRON STAINING, DAMP	617.3	5.5–7	3 2 2	5	89	SS-2	-	0	35	42	11	12	NP	NP	NP	9	A-3a (0)	-	
LOOSE TO MEDIUM DENSE, BROWN, **SANDY SILT**, TRACE GRAVEL, TRACE CLAY, MOIST		7.5–9	2 3 4	8	100	SS-3	-	-	-	-	-	-	-	-	-	17	A-4a (V)	-	
	612.8	10–11.5 EOB	4 5 5	12	100	SS-4	-	-	-	-	-	-	-	-	-	19	A-4a (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 10/19/22 11:57 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 750+46, 36' RT.	EXPLORATION ID B-017-0-21
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 624.0 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 8/3/22 END: 8/3/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.356518, -82.976278	

MATERIAL DESCRIPTION AND NOTES	ELEV. 624.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
9.5" ASPHALT AND 8.5" BASE (DRILLERS DESCRIPTION)	622.5	1																	
MEDIUM DENSE, DARK BROWN, **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP	621.0	2	8 4 8	15	89	SS-1	-	34	19	15	19	13	31	19	12	12	A-2-6 (0)	0	
MEDIUM DENSE TO DENSE, DARK BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST		3–4	18 23 17	48	83	SS-2	-	44	23	13	14	6	NP	NP	NP	6	A-1-b (0)	-	
	618.5	5	10 7 3	12	56	SS-3A	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	-	
STIFF TO HARD, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, MOIST		6				SS-3B	1.50	-	-	-	-	-	-	-	-	27	A-6a (V)	-	
	616.5	7 EOB	3 7 4	13	89	SS-4	4.50	-	-	-	-	-	-	-	-	24	A-6a (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 752+57, 35' RT.	EXPLORATION ID B-018-0-22
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 625.3 (MSL) EOB: 21.5 ft.	PAGE 1 OF 1
START: 8/3/22 END: 8/3/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.357097, -82.976259	

MATERIAL DESCRIPTION AND NOTES	ELEV. 625.3
9.5" ASPHALT AND 3.5" BASE (DRILLERS DESCRIPTION)	623.7
VERY STIFF, BROWN, **SILTY CLAY**, "AND" SAND, TRACE GRAVEL, TRACE IRON STAINING, MOIST	620.8
LOOSE TO MEDIUM DENSE, BROWN, **SANDY SILT**, SOME CLAY, TRACE TO LITTLE GRAVEL, DAMP	617.5
LOOSE TO MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, LITTLE GRAVEL, TRACE SILT, TRACE CLAY, DAMP	613.3
LOOSE TO DENSE, BROWN AND GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE TO LITTLE SILT, TRACE CLAY, DAMP	603.8
	EOB

DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm
3 - 4.5	6 4 4	10	56	SS-1	3.25	0	4	39	25	32	32	15	17	17	A-6b (7)	-
5.5 - 7	3 3 2	6	56	SS-2	-	2	11	46	18	23	NP	NP	NP	13	A-4a (1)	-
8 - 9.5	6 6 6	15	11	SS-3A	-	-	-	-	-	-	-	-	-	14	A-4a (V)	-
				SS-3B	-	-	-	-	-	-	-	-	-	6	A-3a (V)	-
10.5 - 12	4 3 2	6	56	SS-4	-	-	-	-	-	-	-	-	-	7	A-3a (V)	-
13 - 14.5	5 3 5	10	44	SS-5	-	58	10	13	14	5	NP	NP	NP	9	A-1-b (0)	-
15.5 - 17	4 12 21	40	44	SS-6	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	-
18 - 19.5	16 13 11	29	39	SS-7	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	-
20.5 - 21.5	15 18 16	41	44	SS-8	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	-

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 753+96, 37' RT.	EXPLORATION ID B-019-0-22
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 626.5 (MSL) EOB: 21.5 ft.	PAGE 1 OF 1
START: 8/4/22 END: 8/4/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.357478, -82.976237	

MATERIAL DESCRIPTION AND NOTES	ELEV. 626.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
9.5" ASPHALT AND 3.5" BASE (DRILLERS DESCRIPTION)	624.9																		
VERY STIFF, BROWN, **SILT AND CLAY**, LITTLE SAND, TRACE GRAVEL, TRACE IRON STAINING, MOIST	622.0		10 3 3	7	56	SS-1	3.50	0	2	18	41	39	31	19	12	20	A-6a (9)	-	
HARD, BROWN, **SILTY CLAY**, LITTLE SAND, TRACE GRAVEL, TRACE IRON STAINING, DAMP TO MOIST			7 5 6	13	100	SS-2	4.50	2	5	10	45	38	34	17	17	17	A-6b (11)	-	
	617.0		5 3 3	7	39	SS-3	4.50	-	-	-	-	-	-	-	-	18	A-6b (V)	-	
VERY STIFF, BROWN, **SILT AND CLAY**, LITTLE SAND, TRACE GRAVEL, TRACE IRON STAINING, DAMP	614.5		7 3 2	6	33	SS-4	3.00	4	6	13	41	36	32	17	15	17	A-6a (10)	-	
LOOSE TO MEDIUM DENSE, BROWN AND GRAY, **GRAVEL WITH SAND**, TRACE TO LITTLE SILT, TRACE CLAY, DAMP			7 7 7	17	28	SS-5	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	-	
			4 3 3	7	28	SS-6	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	-	
			3 2 4	7	56	SS-7	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	-	
	605.0	EOB	4 4 4	10	56	SS-8	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / J. HODGES	DRILL RIG: CME 45B	STATION / OFFSET: 64+07, 36' RT.	EXPLORATION ID B-020-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / J. HODGES	HAMMER: CME AUTOMATIC	ALIGNMENT: STEWART RD	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 620.9 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 7/27/22 END: 7/27/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.345595, -82.977370	

MATERIAL DESCRIPTION AND NOTES	ELEV. 620.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
HARD, BROWN, **SANDY SILT**, LITTLE TO SOME CLAY, TRACE GRAVEL, SS-1 CONTAINS ROOTS, DAMP TO MOIST		1	4 9 21	36	100	SS-1	4.50	-	-	-	-	-	-	-	-	10	A-4a (V)	-	
		2	14 14 15	35	100	SS-2	4.50	1	10	39	31	19	26	16	10	12	A-4a (3)	0	
	616.4	3, 4	5 7 7	17	100	SS-3	4.50	-	-	-	-	-	-	-	-	18	A-4a (V)	-	
VERY STIFF, BROWNISH GRAY, **SILT AND CLAY**, "AND" SAND, TRACE GRAVEL, MOIST		5	2 2 3	6	100	SS-4	3.25	1	11	34	33	21	29	17	12	24	A-6a (5)	-	
	613.4	6, 7, EOB	5 5 5	12	100	SS-5	3.50	-	-	-	-	-	-	-	-	19	A-6a (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/28/22 09:30 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / J. HODGES	DRILL RIG: CME 45B	STATION / OFFSET: 69+25, 23' LT.	EXPLORATION ID B-021-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / J. HODGES	HAMMER: CME AUTOMATIC	ALIGNMENT: STEWART RD	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 620.1 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 7/28/22 END: 7/28/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.345797, -82.975503	

MATERIAL DESCRIPTION AND NOTES	ELEV. 620.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
4.0" ASPHALT AND 14.0" CONCRETE AND 5.0" BASE (DRILLERS DESCRIPTION)	618.2	1																	
MEDIUM DENSE TO VERY DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, RESEMBLES GRANULAR BASE, DAMP	616.1	2	20 21 25	56	50	SS-1	-	46	24	11	14	5	NP	NP	NP	5	A-1-b (0)	160	
		3	18 17 8	30	100	SS-2A	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	-	
HARD, BROWN, **SANDY SILT**, SOME GRAVEL, LITTLE CLAY, DAMP	615.6	4				SS-2B	4.50	-	-	-	-	-	-	-	-	13	A-4a (V)	-	
VERY STIFF, BROWN, **SILTY CLAY**, LITTLE SAND, TRACE GRAVEL, MOIST		5	4 5 7	15	100	SS-3	2.75	0	1	15	46	38	40	20	20	22	A-6b (12)	-	
	612.6	6 7 EOB	6 5 8	16	100	SS-4	2.50	-	-	-	-	-	-	-	-	27	A-6b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/28/22 09:30 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / J. HODGES	DRILL RIG: CME 45B	STATION / OFFSET: 70+96, 46' RT.	EXPLORATION ID B-022-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / J. HODGES	HAMMER: CME AUTOMATIC	ALIGNMENT: STEWART RD	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 617.6 (MSL) EOB: 11.5 ft.	PAGE 1 OF 1
START: 7/27/22 END: 7/27/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.345571, -82.974922	

MATERIAL DESCRIPTION AND NOTES	ELEV. 617.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
VERY STIFF TO HARD, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, IRON STAINING, DAMP		3	8 9 6	18	100	SS-1	4.50	9	6	24	34	27	34	19	15	16	A-6a (7)	20	
	610.6	6	2 3 2	6	100	SS-2	3.50	-	-	-	-	-	-	-	-	19	A-6a (V)	-	
LOOSE, BROWN, **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE GRAVEL, DAMP		8	3 2 2	5	100	SS-3	-	1	12	61	17	9	NP	NP	NP	10	A-3a (0)	-	
	606.1	11 (EOB)	4 3 3	7	100	SS-4	-	-	-	-	-	-	-	-	-	7	A-3a (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / J. HODGES	DRILL RIG: CME 45B	STATION / OFFSET: 9+26, 2' RT.	EXPLORATION ID B-023-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / J. HODGES	HAMMER: CME AUTOMATIC	ALIGNMENT: CONSUMER CENTER DR	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 614.3 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 7/28/22 END: 7/28/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.344821, -82.975057	

MATERIAL DESCRIPTION AND NOTES	ELEV. 614.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
5.0" ASPHALT AND 10.0" BASE (DRILLERS DESCRIPTION)	613.0	1																	
LOOSE TO MEDIUM DENSE, BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST		2	3 2 5	8	17	SS-1	-	28	27	22	15	8	NP	NP	NP	11	A-1-b (0)	0	
	609.8	3–4	2 3 6	11	33	SS-2	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	-	
VERY STIFF TO HARD, BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE GRAVEL, IRON STAINING, DAMP TO MOIST		5	3 4 5	11	100	SS-3	4.50	0	1	15	42	42	42	21	21	20	A-7-6 (13)	-	
	606.8	6–7 EOB	3 6 6	15	72	SS-4	3.00	-	-	-	-	-	-	-	-	24	A-7-6 (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41 TYPE: ROADWAY PID: 113013 SFN: START: 7/28/22 END: 7/28/22	DRILLING FIRM / OPERATOR: NEAS / J. HODGES SAMPLING FIRM / LOGGER: NEAS / J. HODGES DRILLING METHOD: 3.25" HSA SAMPLING METHOD: SPT	DRILL RIG: CME 45B HAMMER: CME AUTOMATIC CALIBRATION DATE: 1/24/22 ENERGY RATIO (%): 72.6	STATION / OFFSET: 82+06, 18' LT. ALIGNMENT: RIVERSIDE ST ELEVATION: 620.3 (MSL) EOB: 7.5 ft. LAT / LONG: 39.345945, -82.974075	EXPLORATION ID B-024-0-22 PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 620.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
7.0" ASPHALT AND 10.0" BASE (DRILLERS DESCRIPTION)	618.9	1																	
VERY STIFF, BROWN, **SANDY SILT**, LITTLE CLAY, TRACE TO LITTLE GRAVEL, TRACE IRON STAINING, DAMP		2	7 10 11	25	83	SS-1	3.75	10	18	28	30	14	22	16	6	11	A-4a (2)	0	
	615.7	3 – 4	2 3 5	10	100	SS-2	3.75	-	-	-	-	-	-	-	-	13	A-4a (V)	-	
DENSE TO VERY DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, DAMP		5	5 11 15	31	28	SS-3	-	38	15	18	18	11	24	16	8	9	A-2-4 (0)	-	
	612.8	6 – 7 EOB	9 19 27	56	39	SS-4	-	-	-	-	-	-	-	-	-	7	A-2-4 (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 108+46, 19' RT.
TYPE: EMBANKMENT FOUNDATION	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: US 35 RAMP C
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 631.4 (MSL) EOB: 25.0 ft.
START: 8/8/22 END: 8/8/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.347938, -82.978248

EXPLORATION ID B-025-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 631.4	DEPTHS	SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
5.0" ASPHALT AND 7.0" CONCRETE AND 6.0" BASE (DRILLERS DESCRIPTION)	629.9																		
MEDIUM DENSE TO DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP			25 15 20	42	44	SS-1	-	27	26	20	20	7	NP	NP	NP	6	A-2-4 (0)	180	
			9 23 15	46	89	SS-2	-	-	-	-	-	-	-	-	-	7	A-2-4 (V)	-	
	625.4		11 5 11	19	67	SS-3	-	-	-	-	-	-	-	-	-	7	A-2-4 (V)	-	
HARD, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, DAMP	623.4		2 4 4	10	67	SS-4	4.25	2	7	21	37	33	32	18	14	17	A-6a (9)	-	
VERY STIFF TO HARD, BROWN, **SANDY SILT**, LITTLE TO SOME CLAY, TRACE GRAVEL, DAMP TO MOIST			1 1 5	7	89	SS-5	3.00	-	-	-	-	-	-	-	-	17	A-4a (V)	-	
			2 5 7	15	67	SS-6	3.25	2	11	36	31	20	25	16	9	14	A-4a (3)	-	
			3 9 7	19	83	SS-7	4.50	-	-	-	-	-	-	-	-	14	A-4a (V)	-	
			4 7 10	21	72	SS-8	4.25	-	-	-	-	-	-	-	-	16	A-4a (V)	-	
	610.9		5 7 10	21	83	SS-9	4.50	-	-	-	-	-	-	-	-	15	A-4a (V)	-	
HARD, BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE GRAVEL, DAMP			5 5 6	13	78	SS-10	4.50	0	0	6	50	44	45	21	24	20	A-7-6 (15)	-	
	606.4	EOB 25	6 9 11	24	89	SS-11	4.25	-	-	-	-	-	-	-	-	20	A-7-6 (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/28/22 09:30 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 112+46, 11' RT.	EXPLORATION ID B-026-0-22
TYPE: EMBANKMENT FOUNDATION	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: US 35 RAMP C	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 623.5 (MSL) EOB: 15.0 ft.	PAGE 1 OF 1
START: 8/8/22 END: 8/8/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.347800, -82.976835	

MATERIAL DESCRIPTION AND NOTES	ELEV. 623.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
6.0" ASPHALT AND 7.0" CONCRETE AND 5.0" BASE (DRILLERS DESCRIPTION)	622.0	1																	
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, DAMP	620.5	2 – 3	10 12 8	24	67	SS-1	-	32	14	24	19	11	22	15	7	7	A-2-4 (0)	20	
VERY STIFF, DARK GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, DAMP	619.0	3 – 4	6 4 5	11	67	SS-2	4.00	12	7	24	30	27	29	16	13	14	A-6a (6)	-	
VERY STIFF, DARK BROWN AND ORANGISH BROWN, **SILT AND CLAY**, "AND" SAND, TRACE GRAVEL, IRON STAINING, DAMP TO MOIST		5 – 6	5 4 5	11	56	SS-3	3.50	-	-	-	-	-	-	-	-	21	A-6a (V)	-	
		6 – 7	4 4 3	8	83	SS-4	4.00	4	11	29	30	26	30	17	13	16	A-6a (5)	-	
		8																	
		9 – 10	2 3 7	12	89	SS-5	3.25	-	-	-	-	-	-	-	-	17	A-6a (V)	-	
		11 – 12	4 3 4	8	89	SS-6	3.00	0	4	41	29	26	28	16	12	18	A-6a (5)	-	
		13																	
	608.5	14 – 15 EOB	0 3 4	8	94	SS-7	2.75	-	-	-	-	-	-	-	-	17	A-6a (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE. BORING OFFSET UNKNOWN DISTANCE NOTHEAST OF SURVEY.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/28/22 09:30 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / J. HODGES	DRILL RIG: CME 45B	STATION / OFFSET: 13+62, 4' RT.	EXPLORATION ID B-027-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / J. HODGES	HAMMER: CME AUTOMATIC	ALIGNMENT: MARIETTA CONNECTOR	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 624.1 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 7/26/22 END: 7/26/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.351374, -82.978031	

MATERIAL DESCRIPTION AND NOTES	ELEV. 624.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
6.0" ASPHALT AND 9.0" BASE (DRILLERS DESCRIPTION)	622.8	1																	
VERY STIFF TO HARD, BROWN, **SILTY CLAY**, "AND" SAND, TRACE GRAVEL, DAMP TO MOIST		2	14 6 5	13	100	SS-1	4.25	6	7	27	31	29	32	16	16	15	A-6b (7)	673	
		3–4	4 4 3	8	100	SS-2	3.25	0	2	41	28	29	32	16	16	18	A-6b (7)	-	
	618.1	5–6	3 2 2	5	100	SS-3	2.50	-	-	-	-	-	-	-	-	17	A-6b (V)	-	
MEDIUM DENSE, BROWNISH GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, DAMP	616.6	7 EOB	4 7 13	24	100	SS-4	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / J. HODGES	DRILL RIG: CME 45B	STATION / OFFSET: 16+57, 0' LT.	EXPLORATION ID B-028-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / J. HODGES	HAMMER: CME AUTOMATIC	ALIGNMENT: MARIETTA CONNECTOR	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 624.9 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 7/26/22 END: 7/26/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.351932, -82.977605	

MATERIAL DESCRIPTION AND NOTES	ELEV. 624.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
LOOSE TO MEDIUM DENSE, BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, CONTAINS ROOTS, DAMP		1	3 5 6	13	100	SS-1	-	2	24	34	22	18	NP	NP	NP	9	A-4a (1)	0	
		2	5 4 4	10	28	SS-2	-	-	-	-	-	-	-	-	-	10	A-4a (V)	-	
	620.4	3, 4	3 3 3	7	100	SS-3	-	6	24	34	18	18	NP	NP	NP	11	A-4a (0)	-	
MEDIUM DENSE TO VERY DENSE, BROWNISH GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, DAMP		5	2 6 9	18	83	SS-4	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	-	
	617.4	6, 7, EOB	13 24 28	63	100	SS-5	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41 TYPE: ROADWAY PID: 113013 SFN: START: 7/26/22 END: 7/26/22	DRILLING FIRM / OPERATOR: NEAS / J. HODGES SAMPLING FIRM / LOGGER: NEAS / J. HODGES DRILLING METHOD: 3.25" HSA SAMPLING METHOD: SPT	DRILL RIG: CME 45B HAMMER: CME AUTOMATIC CALIBRATION DATE: 1/24/22 ENERGY RATIO (%): 72.6	STATION / OFFSET: 18+58, 21' RT. ALIGNMENT: MARIETTA CONNECTOR ELEVATION: 626.0 (MSL) EOB: 7.5 ft. LAT / LONG: 39.351854, -82.976898

EXPLORATION ID B-029-0-22

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 626.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
5.0" ASPHALT AND 11.0" BASE (DRILLERS DESCRIPTION)	624.7	1																	
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP	623.0	2	8 9 8	21	39	SS-1	-	25	27	18	21	9	NP	NP	NP	9	A-2-4 (0)	40	
LOOSE TO MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP		3–4	3 3 4	8	100	SS-2	-	5	35	26	13	21	34	17	17	15	A-2-6 (1)	-	
	620.2	5	2 5 5	12	100	SS-3	-	-	-	-	-	-	-	-	-	16	A-2-6 (V)	-	
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, DAMP	618.5	6–7, EOB	5 7 8	18	100	SS-4	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 32+18, 29' RT.	EXPLORATION ID B-030-0-22
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: MARIETTA RD	
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 625.3 (MSL) EOB: 7.5 ft.	PAGE 1 OF 1
START: 7/26/22 END: 7/26/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.351722, -82.975857	

MATERIAL DESCRIPTION AND NOTES	ELEV. 625.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
9.5" ASPHALT AND 8.5" BASE (DRILLERS DESCRIPTION)	623.8																		
LOOSE, BROWN, **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, DAMP	622.3	1–2	7 5 2	8	11	SS-1	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	-	
VERY STIFF, ORANGISH BROWN, **SILTY CLAY**, "AND" SAND, TRACE GRAVEL, CONTAINS IRON STAINING, DAMP	620.6	3–4	4 3 3	7	39	SS-2	3.00	1	24	36	16	23	34	16	18	16	A-6b (3)	40	
MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, LITTLE SILT, TRACE GRAVEL, TRACE CLAY, DAMP		4.5–6	4 5 4	11	44	SS-3	-	10	26	38	20	6	NP	NP	NP	9	A-3a (0)	-	
	617.8	6–7.5 EOB	6 9 8	21	67	SS-4	-	-	-	-	-	-	-	-	-	7	A-3a (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: NEAS / JL	DRILL RIG: CME 45B	STATION / OFFSET: 52+07, 20' RT.
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: PAWNEE RD
PID: 113013 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 622.9 (MSL) EOB: 7.5 ft.
START: 8/4/22 END: 8/4/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 72.6	LAT / LONG: 39.356192, -82.976760

EXPLORATION ID B-031-0-22

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 622.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
9.5" ASPHALT AND 8.5" BASE (DRILLERS DESCRIPTION)	621.4	1																	
LOOSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	619.9	2	5 3 2	6	33	SS-1	-	42	23	11	14	10	NP	NP	NP	10	A-1-b (0)	60	
LOOSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, DAMP	618.4	3, 4	4 3 4	8	44	SS-2	-	25	22	18	22	13	NP	NP	NP	11	A-2-4 (0)	-	
DENSE TO VERY DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP		5	7 16 24	48	56	SS-3	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	-	
	615.4	6, 7, EOB	23 25 30	67	44	SS-4	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE. BORING OFFSET 9' WEST DUE TO UTILITIES.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; SHOVELED SOIL CUTTINGS

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/28/22 09:31 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\ROS-159-0.41\GINT FILES\ROS-159-0.41.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: SIMCO	STATION / OFFSET:
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: NONE	ALIGNMENT: CL SR 159
PID: 113013 SFN:	DRILLING METHOD: 3.5" SSA	CALIBRATION DATE: N/A	ELEVATION: 624.1 (ft) EOB: 3.0 ft.
START: 10/6/21 END: 10/6/21	SAMPLING METHOD: CUTTINGS	ENERGY RATIO (%): 60	LAT / LONG: 39.346136, -82.976401

EXPLORATION ID B-001-1-21

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 624.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%)					ATTERBERG			WC	ODOT CLASS (GI)	BACK FILL
								GR	CS	FS	SI	CL	LL	PL	PI			
ASPHALT (14")	623.0	1																
GRAYISH BROWN, **GRAVEL AND STONE FRAGMENTS**, SOME SAND, TRACE SILT, TRACE CLAY, WET FROM CORING WATER	621.1	2 EOB 3			-	AS-1	-	55	23	10	9	3	NP	NP	NP	9	A-1-a (0)	

NOTES: HOLE DRY UPON COMPLETION. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP LIDAR DATA.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: SIMCO	STATION / OFFSET:
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: NONE	ALIGNMENT: CL SR 159
PID: 113013 SFN:	DRILLING METHOD: 3.5" SSA	CALIBRATION DATE: N/A	ELEVATION: 623.6 (ft) EOB: 1.5 ft.
START: 10/6/21 END: 10/6/21	SAMPLING METHOD: CUTTINGS	ENERGY RATIO (%): 60	LAT / LONG: 39.347298, -82.976754

EXPLORATION ID B-004-1-21

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 623.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (3") & CONCRETE (9")	622.6																	
BROWN, **GRAVEL**, SOME SAND, LITTLE SILT, TRACE CLAY, DAMP	622.1	1 EOB			-	AS-1	-	64	15	7	11	3	NP	NP	NP	6	A-1-a (0)	

NOTES: HOLE DRY UPON COMPLETION. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP LIDAR DATA.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: SIMCO	STATION / OFFSET:	EXPLORATION ID B-005-1-21
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: NONE	ALIGNMENT: CL SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.5" SSA	CALIBRATION DATE: N/A	ELEVATION: 621.4 (ft) EOB: 3.5 ft.	PAGE 1 OF 1
START: 10/6/21 END: 10/6/21	SAMPLING METHOD: CUTTINGS	ENERGY RATIO (%): 60	LAT / LONG: 39.348241, -82.976615	

MATERIAL DESCRIPTION AND NOTES	ELEV. 621.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (4") & CONCRETE (9.5")	620.3	1																
DARK BROWN AND GRAYISH BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, (AGGREGATE BASE), DAMP	619.9	2			-	AS-1	-	33	23	15	18	11	21	15	6	9	A-2-4 (0)	
DARK BROWN, **SILT AND CLAY**, SOME SAND, TRACE STONE FRAGMENTS, MOIST	617.9	3 EOB			-	AS-2	-	1	3	31	30	35	28	16	12	16	A-6a (7)	

NOTES: HOLE DRY UPON COMPLETION. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP LIDAR DATA.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: SIMCO	STATION / OFFSET:	EXPLORATION ID B-007-1-21
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: NONE	ALIGNMENT: CL SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.5" SSA	CALIBRATION DATE: N/A	ELEVATION: 622.4 (ft) EOB: 1.5 ft.	PAGE
START: 10/6/21 END: 10/6/21	SAMPLING METHOD: CUTTINGS	ENERGY RATIO (%): 60	LAT / LONG: 39.349168, -82.976822	1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 622.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (1.5") & CONCRETE (10.5")	621.4	1																
BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, WET FROM CORING WATER	620.9	EOB			-	AS-1	-	50	26	10	11	3	NP	NP	NP	14	A-1-b (0)	

NOTES: HOLE DRY UPON COMPLETION. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP LIDAR DATA.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH SOIL CUTTINGS

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 5/9/23 10:33 - X:\GINTPROJECTS\2021 COMPLETE\600912.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: SIMCO	STATION / OFFSET:	EXPLORATION ID B-010-1-21
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: NONE	ALIGNMENT: CL SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.5" SSA	CALIBRATION DATE: N/A	ELEVATION: 623.4 (ft) EOB: 1.2 ft.	PAGE 1 OF 1
START: 10/6/21 END: 10/6/21	SAMPLING METHOD: CUTTINGS	ENERGY RATIO (%): 60	LAT / LONG: 39.350219, -82.976579	

MATERIAL DESCRIPTION AND NOTES	ELEV. 623.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (10.5")	622.5																	
@ 0.9' - 1.2'; SHALLOW DCP REFUSAL, NO SAMPLING.	622.2	EOB 1																

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP LIDAR DATA.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH SOIL CUTTINGS

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 5/9/23 10:33 - X:\GINT\PROJECTS\2021 COMPLETE\600912.GPJ

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: SIMCO	STATION / OFFSET:	EXPLORATION ID B-025-1-21
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: NONE	ALIGNMENT: CL SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.5" SSA	CALIBRATION DATE: N/A	ELEVATION: 634.3 (ft) EOB: 3.0 ft.	PAGE
START: 10/6/21 END: 10/6/21	SAMPLING METHOD: CUTTINGS	ENERGY RATIO (%): 60	LAT / LONG: 39.348040, -82.978239	1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 634.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (5.5") & CONCRETE (9")	633.1	1																
BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, DAMP		2			-	AS-1	-	39	39	10	8	4	NP	NP	NP	8	A-1-b (0)	
@2.7'; LITTLE SILT	631.3	EOB 3			-	AS-2	-	57	12	11	12	8	20	14	6	6	A-1-b (0)	

NOTES: HOLE DRY UPON COMPLETION. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP LIDAR DATA.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH SOIL CUTTINGS

PROJECT: ROS-159-0.41	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: SIMCO	STATION / OFFSET:	EXPLORATION ID B-026-1-21
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: NONE	ALIGNMENT: CL SR 159	
PID: 113013 SFN:	DRILLING METHOD: 3.5" SSA	CALIBRATION DATE: N/A	ELEVATION: 626.3 (ft) EOB: 2.8 ft.	PAGE 1 OF 1
START: 10/6/21 END: 10/6/21	SAMPLING METHOD: CUTTINGS	ENERGY RATIO (%): 60	LAT / LONG: 39.347842, -82.977079	

MATERIAL DESCRIPTION AND NOTES	ELEV. 626.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (7") & CONCRETE (8.5")	625.0	1																
BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	623.5	2 EOB			-	AS-1	-	31	32	18	12	7	NP	NP	NP	9	A-1-b (0)	

NOTES: HOLE DRY UPON COMPLETION. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM OSIP LIDAR DATA.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: BACKFILLED WITH SOIL CUTTINGS

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 5/9/23 10:33 - X:\GINTPROJECTS\2021 COMPLETE\600912.GPJ

DCP TEST DATA

Project: ROS-159-0.41
PID: 113013
Exploration ID: D-001-2-21
Date: 10/6/2021
Surface Elevation: 624.3
Surface Materials: Asphalt (14")
Lat / Long: 39.346136, -82.976401
Test Starting Depth (ft): 1.2

Hammer
- ○ 10.1 lbs.
- ● 17.6 lbs.
- ○ Both hammers used

Office of Geotechnical Engineering
Geology, Exploration, and Laboratory Section
http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical

Soil Type
- ○ CH
- ○ CL
- ● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
3	44	1
3	81	1
3	111	1
3	136	1
3	161	1
3	180	1
3	200	1
3	216	1
3	229	1
3	240	1
3	252	1
3	264	1
3	275	1
3	286	1
3	296	1
3	307	1
3	315	1
3	325	1
3	333	1
3	341	1
3	352	1
3	364	1
3	376	1
3	388	1
3	402	1
3	415	1
3	425	1
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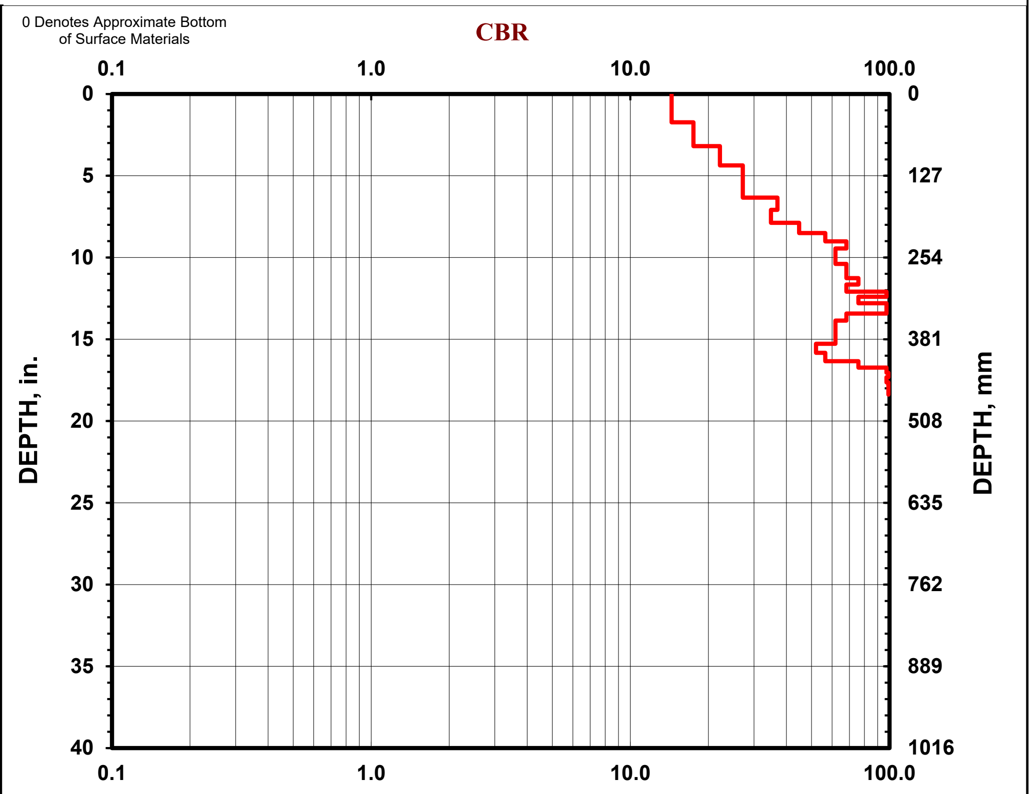
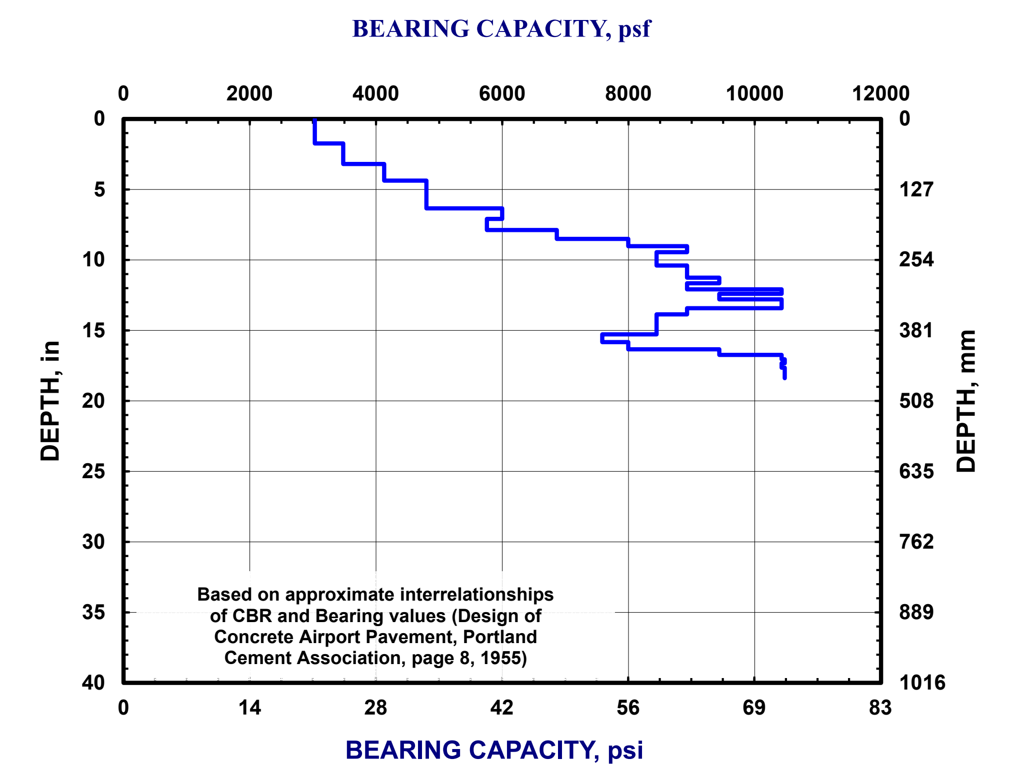
3	448	1
3	455	1
3	461	1
3	467	1





NOTES: The latitude, longitude, and elevation values are from a Trimble Geo7X handheld GPS. Sounding terminated at refusal.

DCP TEST DATA

Project:	ROS-159-0.41	PID:	113013
Exploration ID:	D-004-2-21	Date:	10/6/2021
Surface Elevation:	623.5	Surface Materials:	Asphalt (3") Concrete (9")
Lat / Long:	39.347298, -82.976754	Test Starting Depth (ft):	1.0

Hammer
- ○ 10.1 lbs.
- ● 17.6 lbs.
- ○ Both hammers used

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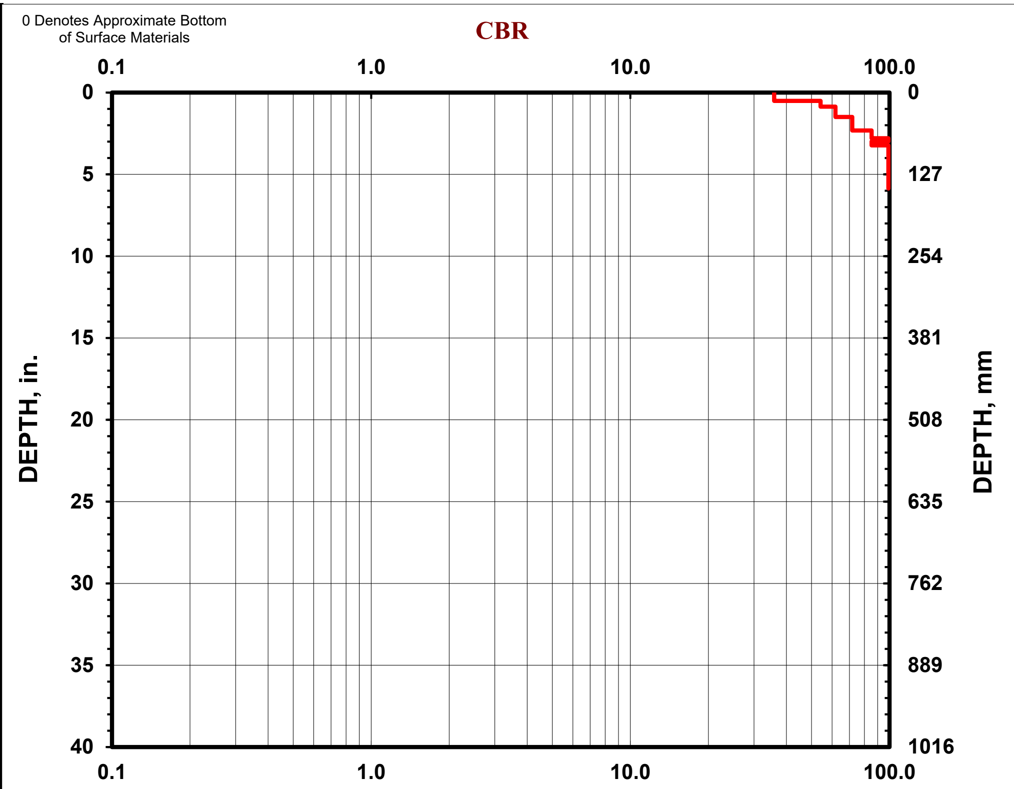
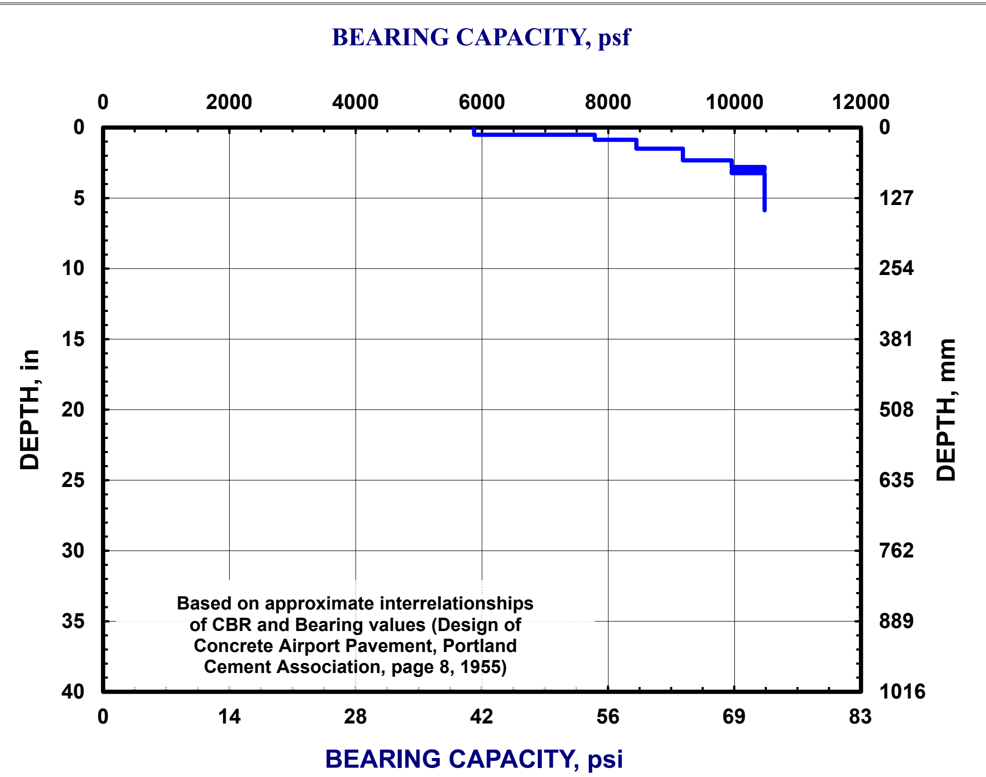
Soil Type
- ○ CH
- ○ CL
- ● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
2	13	1
2	22	1
2	30	1
2	38	1
2	45	1
2	52	1
2	59	1
2	65	1
2	71	1
2	76	1
2	82	1
2	87	1
2	92	1
2	97	1
2	102	1
2	107	1
2	112	1
2	116	1
2	121	1
2	125	1
2	129	1
2	132	1
2	136	1
2	140	1
2	145	1
2	149	1





NOTES: The latitude, longitude, and elevation values are from a Trimble Geo7X handheld GPS. Sounding terminated at refusal.

DCP TEST DATA

Project:	ROS-159-0.41	PID:	113013
Exploration ID:	D-005-2-21	Date:	10/6/2021
Surface Elevation:	621.4	Surface Materials:	Asphalt (4") Concrete (9.5")
Lat / Long:	39.348241, -82.976615	Test Starting Depth (ft):	1.1

Hammer
- ○ 10.1 lbs.
- ● 17.6 lbs.
- ○ Both hammers used

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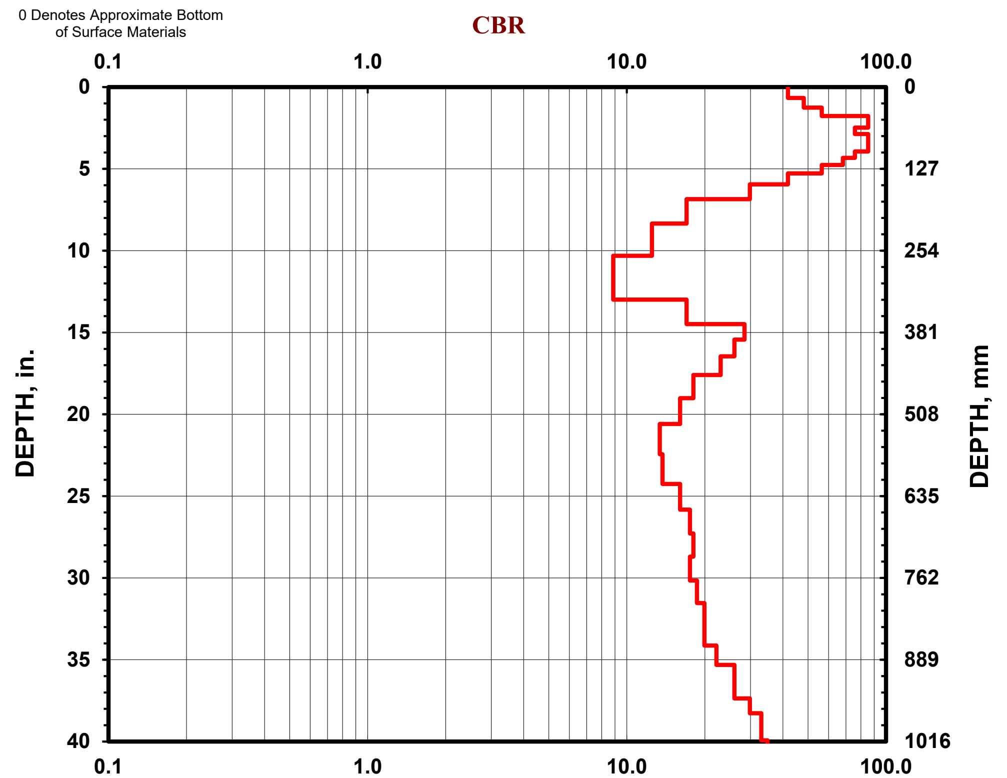
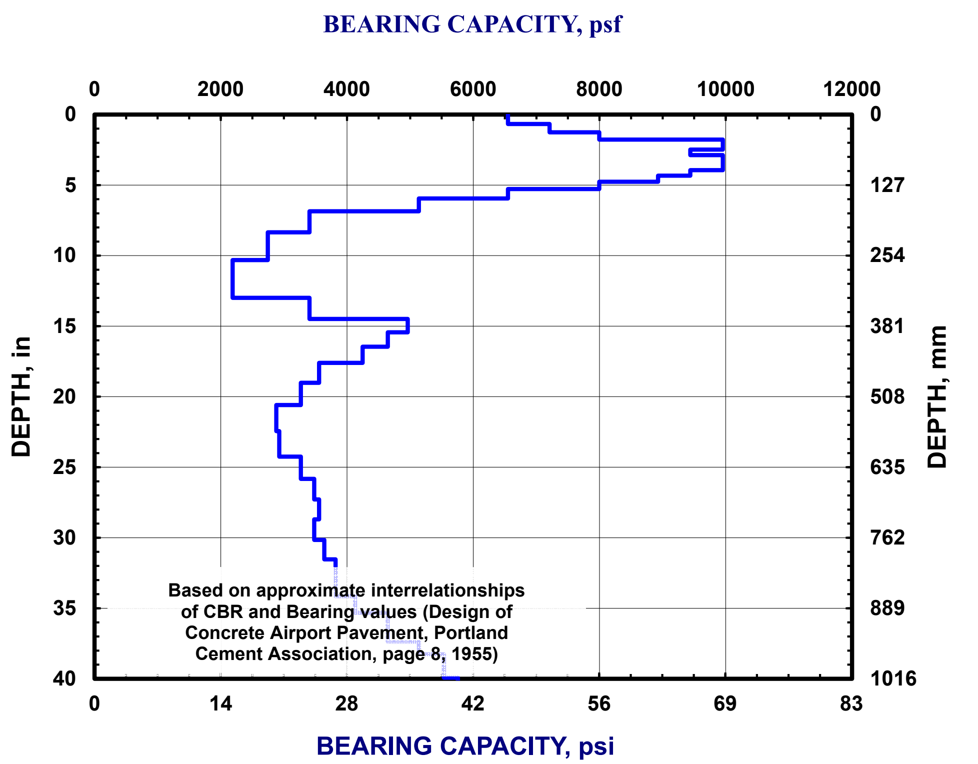
Soil Type
- ○ CH
- ○ CL
- ● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
3	17	1
3	32	1
3	45	1
3	54	1
3	63	1
3	73	1
3	82	1
3	91	1
3	100	1
3	110	1
3	121	1
3	134	1
3	151	1
3	174	1
3	212	1
3	262	1
3	330	1
3	368	1
3	392	1
3	418	1
3	447	1
3	483	1
3	523	1
3	570	1
3	616	1
3	656	1
3	693	1
3	729	1
3	766	1
3	801	1
3	834	1
3	867	1
3	897	1
3	923	1
3	949	1
3	972	1
3	993	1
3	1014	1
3	1034	1
3	1054	1
3	1072	1





NOTES: The latitude, longitude, and elevation values are from a Trimble Geo7X handheld GPS.

DCP TEST DATA

Project:	ROS-159-0.41	PID:	113013
Exploration ID:	D-007-2-21	Date:	10/6/2021
Surface Elevation:	622.1	Surface Materials:	Asphalt (1.5") Concrete (10.5")
Lat / Long:	39.349168, -82.976822	Test Starting Depth (ft):	1.1

Hammer
- ○ 10.1 lbs.
- ● 17.6 lbs.
- ○ Both hammers used

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Soil Type
- ○ CH
- ○ CL
- ● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
1	17	1
1	29	1
1	37	1
1	44	1
1	50	1
1	53	1
1	57	1
1	58	1
1	60	1
1	61	1
1	62	1
1	62	1
1	64	1
1	64	1
1	66	1
1	66	1
1	66	1
1	69	1
1	69	1
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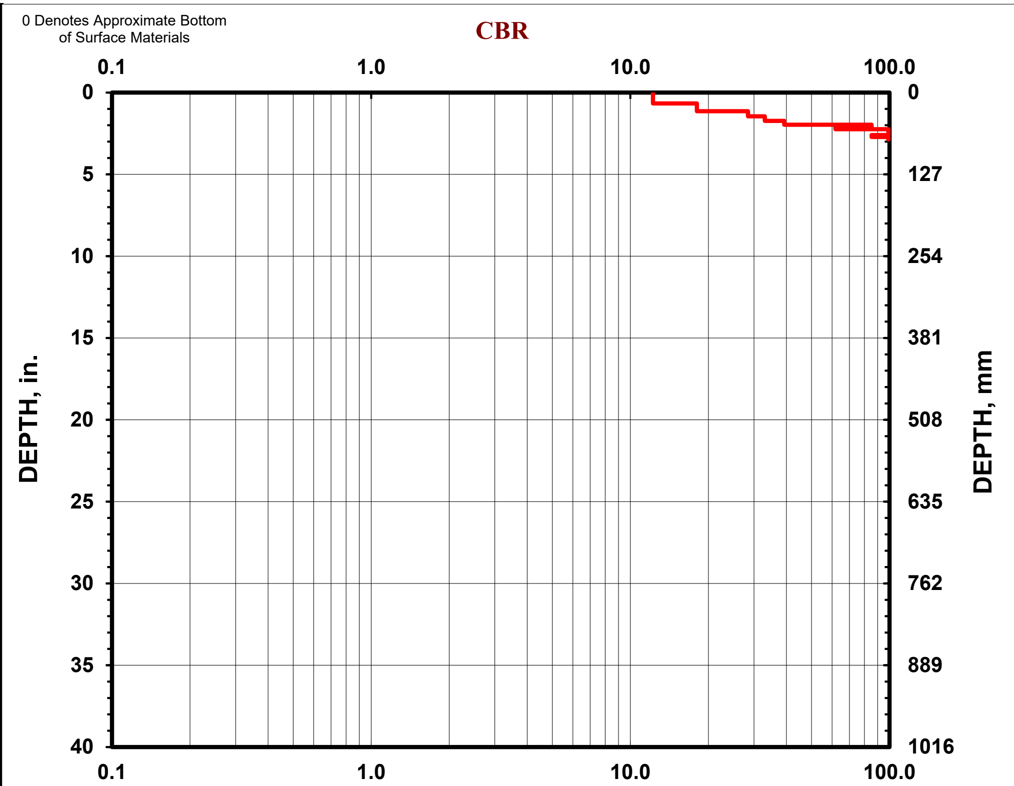
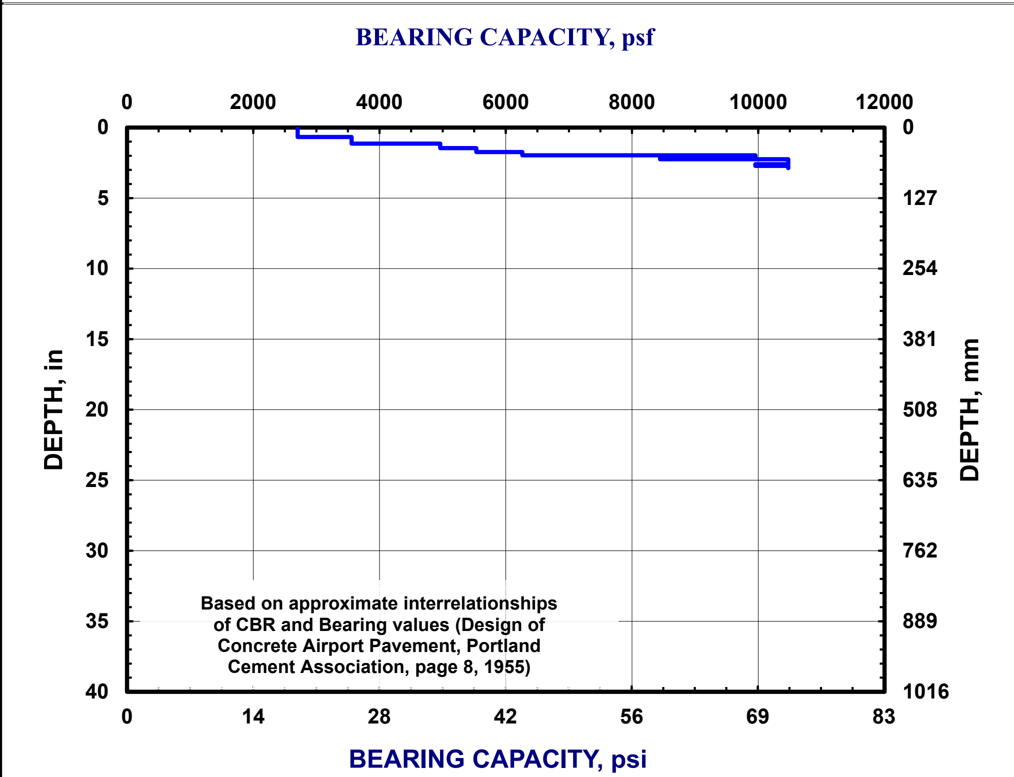
1	73	1
1	73	1





NOTES: The latitude, longitude, and elevation values are from a Trimble Geo7X handheld GPS. Sounding terminated at refusal.

DCP TEST DATA

Project:	ROS-159-0.41	PID:	113013
Exploration ID:	D-010-2-21	Date:	10/6/2021
Surface Elevation:	622.6	Surface Materials:	Asphalt (10.5")
Lat / Long:	39.350219, -82.976579	Test Starting Depth (ft):	1.1

Hammer
- ◯ 10.1 lbs.
- ◉ 17.6 lbs.
- ◯ Both hammers used

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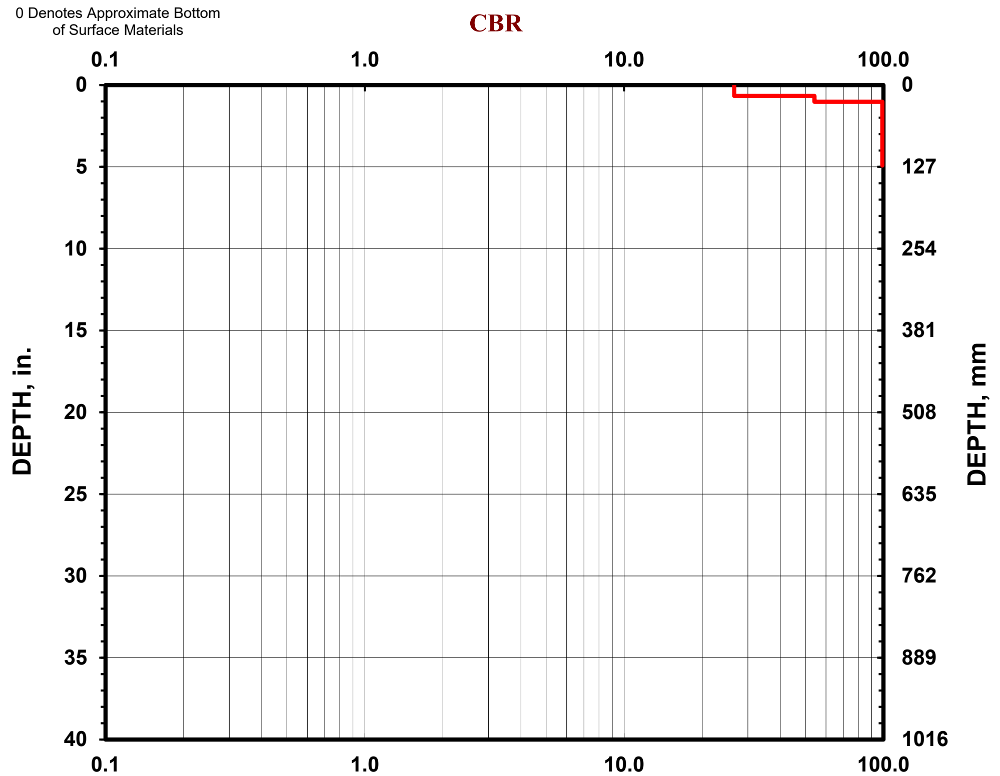
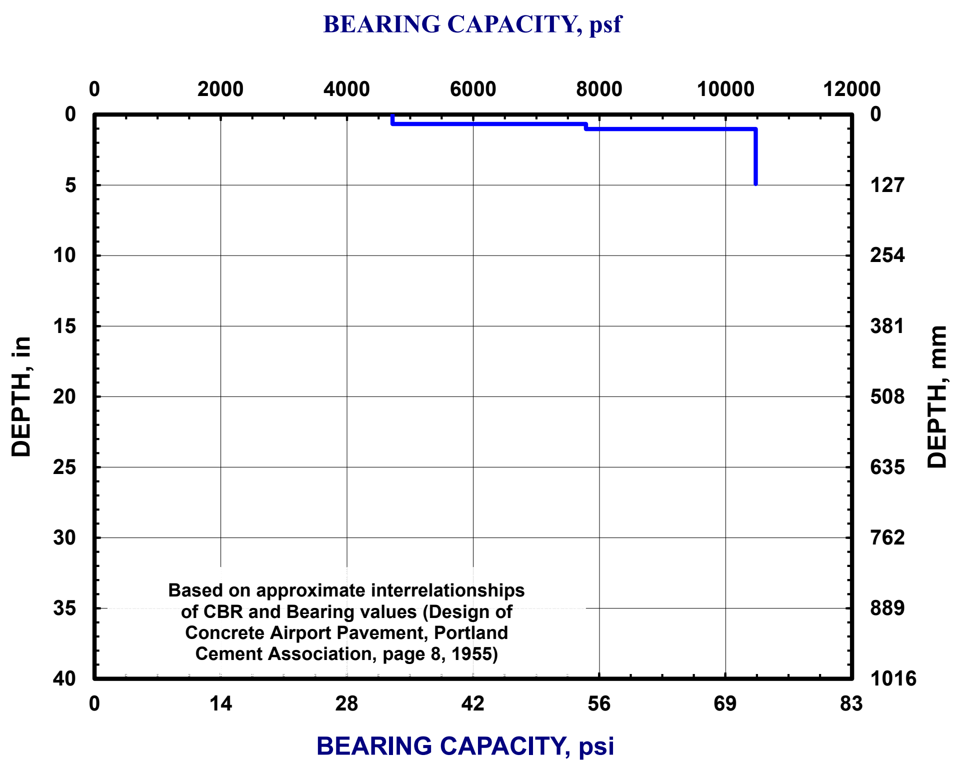
Soil Type
- ◯ CH
- ◯ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
2	17	1
2	26	1
2	30	1
2	34	1
2	37	1
2	41	1
2	44	1
2	47	1
2	51	1
2	54	1
2	58	1
2	61	1
2	65	1
2	69	1
2	73	1
2	77	1
2	80	1
2	83	1
2	87	1
2	90	1
2	94	1
2	97	1
2	101	1
2	104	1
2	107	1
2	111	1
2	114	1
2	118	1
2	121	1
2	125	1





NOTES: The latitude, longitude, and elevation values are from a Trimble Geo7X handheld GPS. Sounding terminated at refusal.

DCP TEST DATA

Project:	ROS-159-0.41	**PID:**	113013
Exploration ID:	D-025-2-21	**Date:**	10/6/2021
Surface Elevation:	634.1	**Surface Materials:**	Asphalt (5.5") Concrete (9")
Lat / Long:	39.34804, -82.978239	**Test Starting Depth (ft):**	1.3

Hammer
- ◯ 10.1 lbs.
- ◉ 17.6 lbs.
- ◯ Both hammers used

Office of Geotechnical Engineering
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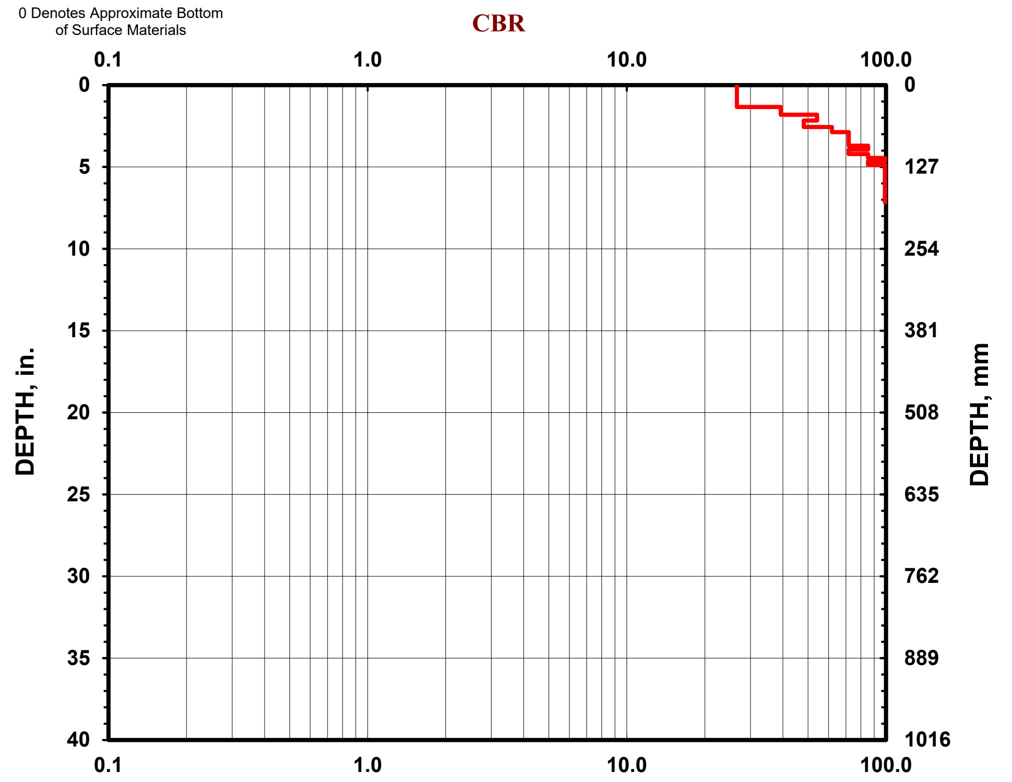
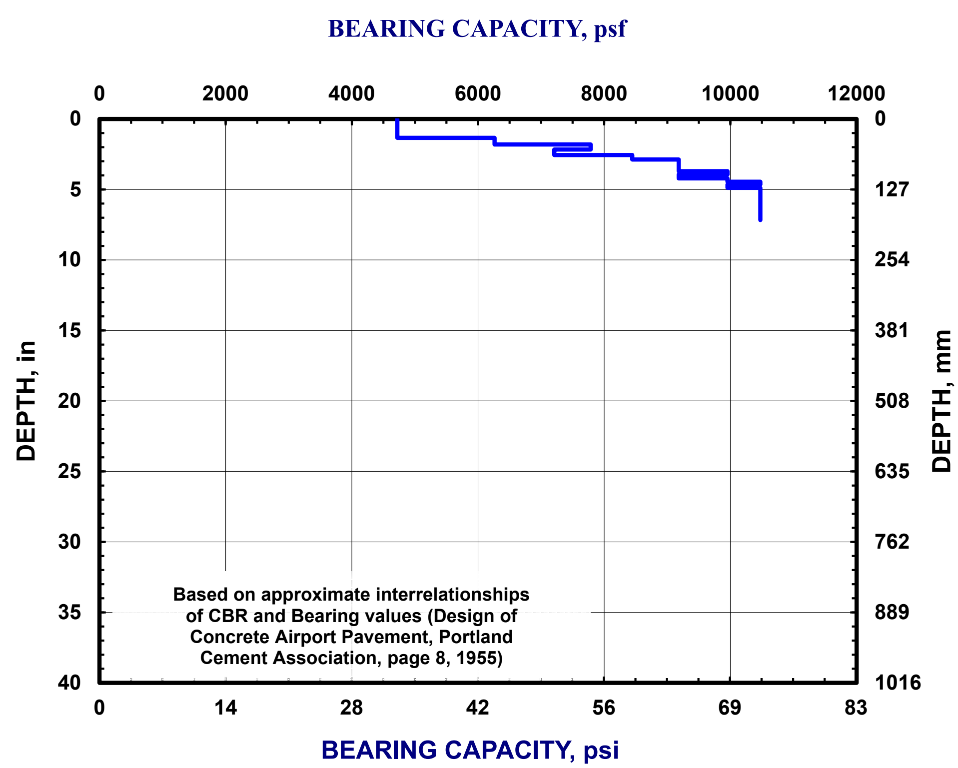
Soil Type
- ◯ CH
- ◯ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
2	17	1
2	34	1
2	46	1
2	55	1
2	65	1
2	73	1
2	80	1
2	87	1
2	94	1
2	100	1
2	107	1
2	113	1
2	118	1
2	124	1
2	129	1
2	133	1
2	138	1
2	141	1
2	145	1
2	148	1
2	151	1
2	154	1
2	156	1
2	159	1
2	161	1
2	164	1
2	167	1
2	170	1
2	174	1
2	177	1
2	181	1
1	182	1





NOTES: The latitude, longitude, and elevation values are from a Trimble Geo7X handheld GPS. Sounding terminated at refusal.

DCP TEST DATA

Project:	ROS-159-0.41	PID:	113013
Exploration ID:	D-026-2-21	Date:	10/6/2021
Surface Elevation:	625.9	Surface Materials:	Asphalt (5.5") Concrete (9")
Lat / Long:	39.347842, -82.977079	Test Starting Depth (ft):	1.4

Hammer
- ○ 10.1 lbs.
- ● 17.6 lbs.
- ○ Both hammers used

Office of Geotechnical Engineering
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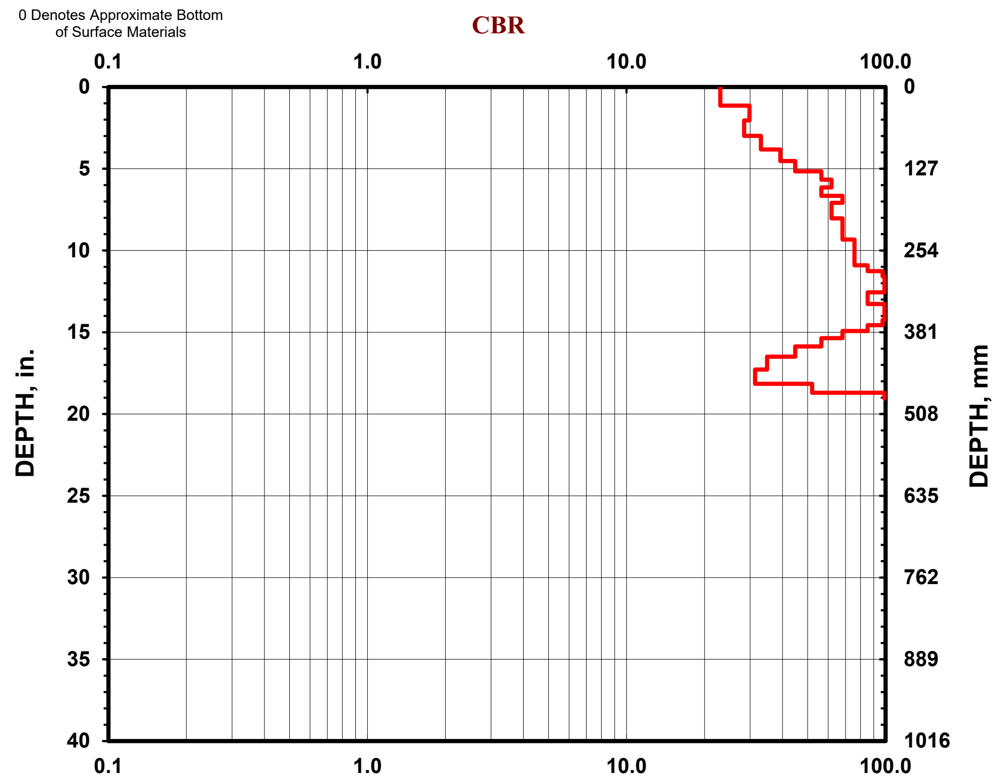
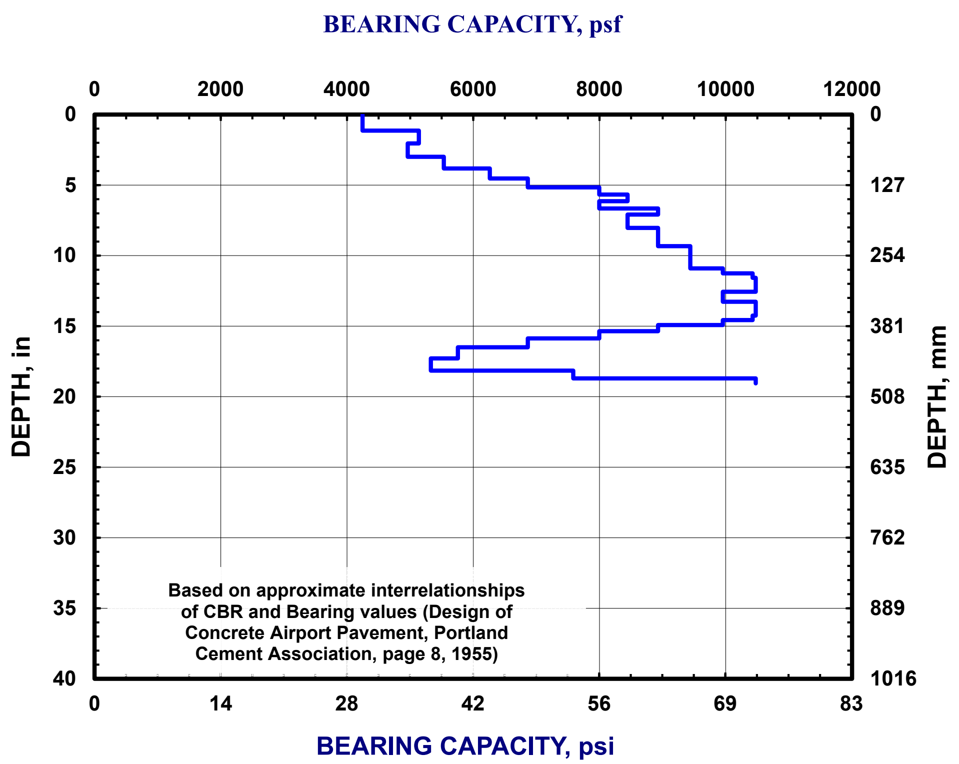
Soil Type
- ○ CH
- ○ CL
- ● All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
3	29	1
3	52	1
3	76	1
3	97	1
3	115	1
3	131	1
3	144	1
3	156	1
3	169	1
3	180	1
3	192	1
3	204	1
3	215	1
3	226	1
3	237	1
3	247	1
3	257	1
3	267	1
3	277	1
3	286	1
3	294	1
3	301	1
3	307	1
3	312	1
3	319	1
3	328	1
3	337	1
3	343	1
3	349	1
3	355	1
3	362	1
3	370	1
3	379	1
3	390	1
3	403	1
3	419	1
3	439	1
3	461	1
3	475	1
3	479	1
3	484	1
1	485	1





NOTES: The latitude, longitude, and elevation values are from a Trimble Geo7X handheld GPS. Sounding terminated at refusal.

APPENDIX C

SUBGRADE ANALYSIS

ENTIRE PROJECT

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.)

ROS-159-0.41-Entire Project
113013

SR 159 (Bridge Street) Corridor-Widening Project

NEAS, Inc.

Prepared By: Derar M. Tarawneh/ Nizar Altarawneh
Date prepared: Friday, May 12, 2023

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
che@neasinc.com

NO. OF BORINGS: 36

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-001-0-22	SR 159	709+31	52' RT	JL	CME 45B	73	626.5	625.9	0.6 C
2	B-001-1-21	SR 159			Binkley	SIMCO	60	624.1	622.6	1.5 C
3	B-002-0-22	SR 159	712+90	36' RT	JL	CME 45B	73	622.5	622.2	0.3 C
4	B-003-0-22	SR 159	714+89	46'RT	JH	CME 45B	73	621.8	621.8	0.0
5	B-004-1-21	SR 159			Binkley	SIMCO	60	623.6	622.1	1.5 C
6	B-004-0-22	SR 159	718+09	56' RT	JL	CME 45B	73	621.3	621.1	0.2 C
7	B-005-1-21	SR 159			Binkley	SIMCO	60	621.4	619.9	1.5 C
8	B-005-0-22	SR 159	720+66	46' RT	JL	CME 45B	73	619.8	620.6	0.8 F
9	B-007-0-22	Ramp A1	400+67	40' RT	JL	CME 45B	73	621.2	619.7	1.5 C
10	B-007-1-21	SR 159			Binkley	SIMCO	60	622.4	620.9	1.5 C
11	B-008-0-22	Ramp A1	402+06	14' RT	JL	CME 45B	73	617.7	616.2	1.5 C
12	B-009-0-22	SR 159	725+34	36' LT	JL	CME 45B	73	621.4	620.7	0.7 C
13	B-010-0-22	SR 159	727+88	45' RT	JL	CME 45B	73	622.5	622.1	0.4 C
14	B-011-0-22	SR 159	731+03	45' RT	JL	CME 45B	73	625.8	624.7	1.1 C
15	B-012-0-22	SR 159	736+73	35' RT	JL	CME 45B	73	626.9	626.6	0.3 C
16	B-013-0-22	SR 159	738+66	35' RT	JL	CME 45B	73	626.5	626.2	0.3 C
17	B-014-0-22	SR 159	740+94	35' RT	JL	CME 45B	73	625.5	625.1	0.4 C
18	B-015-0-22	SR 159	744+47	35' RT	JL	CME 45B	73	624.4	624.0	0.4 C
19	B-016-0-22	SR 159	747+64	35' RT	JL	CME 45B	73	624.3	623.9	0.4 C
20	B-017-0-22	SR 159	750+46	36' RT	JL	CME 45B	73	624.0	623.7	0.3 C
21	B-018-0-22	SR 159	752+57	35' RT	JL	CME 45B	73	625.3	624.8	0.5 C
22	B-019-0-22	SR 159	753+96	37' RT	JL	CME 45B	73	626.5	626.2	0.3 C
23	B-020-0-22	Stewart Rd.	64+07	36' RT	JH	CME 45B	73	620.9	619.4	1.5 C
24	B-021-0-22	Stewart Rd.	69+25	23' LT	JH	CME 45B	73	620.1	618.6	1.5 C
25	B-022-0-22	Stewart Rd.	70+96	46' RT	JH	CME 45B	73	617.6	616.1	1.5 C
26	B-023-0-22	Consumer Center Dr.	9+26	2' RT	JH	CME 45B	73	614.3	612.8	1.5 C
27	B-024-0-22	River Trace	82+06	18' LT	JH	CME 45B	73	620.3	618.8	1.5 C
28	B-025-1-21	US-35 Ramp C			Binkley	SIMCO	60	634.3	632.8	1.5 C
29	B-025-0-22	US-35 Ramp C	106+46	19' RT	JL	CME 45B	73	631.4	631.3	0.1 C
30	B-026-1-21	US-35 Ramp C			Binkley	SIMCO	60	626.3	624.8	1.5 C
31	B-026-0-22	US-35 Ramp C	112+46	11' RT	JL	CME 45B	73	623.5	622.5	1.0 C
32	B-027-0-22	Marietta Connector	13+62	4' RT	JH	CME 45B	73	624.1	623.2	0.9 C
33	B-028-0-22	Marietta Connector	16+57	0' LT	JH	CME 45B	73	624.9	623.3	1.6 C
34	B-029-0-22	Marietta Connector	18+58	21' RT	JH	CME 45B	73	626.0	625.5	0.5 C
35	B-030-0-22	Marietta Rd.	32+18	29' RT	JL	CME 45B	73	625.3	625.2	0.1 C
36	B-031-0-22	Pawnee Rd.	52+07	20' RT	JL	CME 45B	73	622.9	622.6	0.3 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	SS-1	2.5	4.0	1.9	3.4	30			NP	NP	NP	23	12	35	11	8	A-3a	0	0					
	001-0	SS-2	5.0	6.5	4.4	5.9	34			NP	NP	NP	18	7	25	8	6	A-1-b	0						
	22	SS-3	7.5	9.0	6.9	8.4	28									11	6	A-1-b							
		SS-4	10.0	11.5	9.4	10.9	29	30								10	6	A-1-b							
2	B	AS-1	2.0	3.0	0.5	1.5				NP	NP	NP	9	3	12	9	6	A-1-a	0						
	001-1																								
	21																								
								0																	
3	B	SS-1	2.5	4.0	2.2	3.7	41			NP	NP	NP	15	5	20	7	6	A-1-b	0						
	002-0	SS-2	5.0	6.5	4.7	6.2	12		3.25	33	18	15	28	17	45	14	14	A-6a	4						
	22	SS-3	7.5	9.0	7.2	8.7	11									16	10	A-2-4							
		SS-4	10.0	11.5	9.7	11.2	13	12	4.5	32	18	14	33	25	58	15	14	A-6a							
4	B	SS-1	1.5	3.0	1.5	3.0	21		4.5	21	15	6	27	15	42	11	10	A-4a	1	100					
	003-0	SS-2	3.0	4.5	3.0	4.5	13		4.5							17	10	A-4a	8						
	22	SS-3	4.5	6.0	4.5	6.0	13		3.25	31	17	14	30	22	52	16	14	A-6a	5						
		SS-4	6.0	7.5	6.0	7.5	41	13								13	6	A-1-b							
5	B	AS-1	1.0	1.5	-0.5	0.0				NP	NP	NP	11	3	14	6	6	A-1-a	0						
	004-1																								
	21																								
								0																	
6	B	SS-1	2.5	4.0	2.3	3.8	56			NP	NP	NP	13	4	17	4	6	A-1-b	0						
	004-0	SS-2	5.0	6.5	4.8	6.3	33									9	6	A-1-b	0						
	22	SS-3	7.5	9.0	7.3	8.8	12		4.5	31	16	15	28	28	56	14	14	A-6a							
		SS-4	10.0	11.5	9.8	11.3	12	30	4.5							23	14	A-6a							
7	B	AS-1	1.5	2.5	0.0	1.0				21	15	6	18	11	29	9	10	A-2-4	0			N_{60}		0''	
	005-1	AS-2	2.5	3.5	1.0	2.0				28	16	12	30	35	65	16	14	A-6a	7			N_{60}		0''	
	21																								
								0																	
8	B	SS-1	2.5	4.0	3.3	4.8	13			NP	NP	NP	6	3	9	6	6	A-1-a	0						
	005-0	SS-2	5.0	6.5	5.8	7.3	12		3.75	32	17	15	32	38	70	18	14	A-6a							
	22	SS-3	7.5	9.0	8.3	9.8	11		3.5							14	14	A-6a							
		SS-4	10.0	11.5	10.8	12.3	10	12	4.5							14	14	A-6a							
9	B	SS-1	1.5	3.0	0.0	1.5	15			NP	NP	NP	18	6	24	8	6	A-1-b	0	60					
	007-0	SS-2	3.0	4.5	1.5	3.0	4			NP	NP	NP	23	6	29	13	10	A-2-4	0			N_{60} & Mc			
	22	SS-3	4.5	6.0	3.0	4.5	6									6	10	A-2-4	0						
		SS-4	6.0	7.5	4.5	6.0	29	4		NP		NP				16	8	A-3a	0						

#	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	
10	B	AS-1	1.3	1.5	-0.2	0.0				NP	NP	NP	11	3	14	14	6	A-1-b	0						
	007-1																								
	21																								
								0																	
11	B	SS-1	2.5	4.0	1.0	2.5	15									7	6	A-1-b	0	0					
	008-0	SS-2	5.0	6.5	3.5	5.0	4									10	6	A-1-b	0						
	22	SS-3	7.5	9.0	6.0	7.5	6			NP	NP	NP	24	12	36	17	11	A-4a							
		SS-4	10.0	11.5	8.5	10.0	29	4		NP	NP	NP	17	6	23	8	6	A-1-b							
12	B	SS-1A	2.5	3.0	1.8	2.3	15			NP	NP	NP	10	5	15	5	6	A-1-b	0	180					
	009-0	SS-1B	3.0	4.0	2.3	3.3	15		2.75	28	17	11	24	17	41	12	14	A-6a	1						
	22	SS-2	5.0	6.5	4.3	5.8	12			27	16	11	22	18	40	11	14	A-6a	1						
		SS-3	7.5	9.0	6.8	8.3	17	12		35	19	16	38	35	73	19	16	A-6b							
13	B	SS-1	2.5	4.0	2.1	3.6	6		4	36	19	17	24	26	50	17	16	A-6b	5	60					
	010-0	SS-2	5.0	6.5	4.6	6.1	5		3							21	16	A-6b	16						
	22	SS-3	7.5	9.0	7.1	8.6	11		4.25	36	18	18	26	26	52	16	16	A-6b							
		SS-4	10.0	11.5	9.6	11.1	11	5	3							19	16	A-6b							
14	B	SS-1	1.5	3.0	0.4	1.9	24			NP	NP	NP	12	5	17	10	6	A-1-b	0	0					
	011-0	SS-2	3.0	4.5	1.9	3.4	22									8	6	A-1-b	0						
	22	SS-3	4.5	6.0	3.4	4.9	13									5	6	A-1-b	0						
		SS-4	6.0	7.5	4.9	6.4	12	12	3	25	15	10	29	23	52	15	10	A-4a	3						
15	B	SS-1	2.5	4.0	2.2	3.7	6									7	6	A-1-a	0	60					
	012-0	SS-2	5.0	6.5	4.7	6.2	7		3.5	29	14	15	17	21	38	13	14	A-6a	2						
	22	SS-3	7.5	9.0	7.2	8.7	33									7	6	A-1-a							
		SS-4	10.0	11.5	9.7	11.2	54	6								5	6	A-1-b							
16	B	SS-1	2.5	4.0	2.2	3.7	10		4.25	28	15	13	21	25	46	14	14	A-6a	3	100					
	013-0	SS-2	5.0	6.5	4.7	6.2	16		4.5							16	14	A-6a	10						
	22	SS-3A	7.5	8.0	7.2	7.7	47		4.25							13	14	A-6a							
		SS-3B	8.0	9.0	7.7	8.7	47	10								5	6	A-1-b							
17	B	SS-1	2.5	4.0	2.1	3.6	7		3.5	31	18	13	37	23	60	18	14	A-6a	6	20					
	014-0	SS-2	5.0	6.5	4.6	6.1	7		2.5							14	14	A-6a	10						
	22	SS-3	7.5	9.0	7.1	8.6	6									9	8	A-3a							
		SS-4	10.0	11.5	9.6	11.1	6	7					17	7	24	7	6	A-1-b							
18	B	SS-1	1.5	3.0	1.1	2.6	15									11	10	A-2-6	4						
	015-0	SS-2	3.0	4.5	2.6	4.1	15			28	15	13	19	12	31	5	10	A-2-6	0	0					
	22	SS-3	4.5	6.0	4.1	5.6	10									24	10	A-2-6	4						
		SS-4	6.0	7.5	5.6	7.1	12	10	3.75	36	19	17	46	42	88	20	16	A-6b							

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.6 2/11/2022

#	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	
19	B	SS-1	2.5	4.0	2.1	3.6	12		4.5	29	15	14	18	20	38	10	14	A-6a	2	60					
	016-0	SS-2	5.0	6.5	4.6	6.1	5			NP	NP	NP	11	12	23	9	8	A-3a	0						
	22	SS-3	7.5	9.0	7.1	8.6	8									17	10	A-4a							
		SS-4	10.0	11.5	9.6	11.1	12	5								19	10	A-4a							
20	B	SS-1	1.5	3.0	1.2	2.7	15			31	19	12	19	13	32	12	10	A-2-6	0	0					
	017-0	SS-2	3.0	4.5	2.7	4.2	48			NP	NP	NP	14	6	20	6	6	A-1-b	0						
	22	SS-3A	4.5	5.5	4.2	5.2	12									14	6	A-1-b	0						
		SS-3B	5.5	6.0	5.2	5.7	12	12	1.5							27	14	A-6a							
21	B	SS-1	2.5	4.0	2.0	3.5	10		3.25	32	15	17	25	32	57	17	16	A-6b	7			N_{60}			
	018-0	SS-2	5.0	6.5	4.5	6.0	6			NP	NP	NP	18	23	41	13	11	A-4a	1						
	22	SS-3A	7.5	8.0	7.0	7.5	15									14	10	A-4a							
		SS-3B	8.0	9.0	7.5	8.5	15	6								6	8	A-3a							
22	B	SS-1	2.5	4.0	2.2	3.7	7		3.5	31	19	12	41	39	80	20	14	A-6a	9						
	019-0	SS-2	5.0	6.5	4.7	6.2	13		4.5	34	17	17	45	38	83	17	16	A-6b	11						
	22	SS-3	7.5	9.0	7.2	8.7	7		4.5							18	16	A-6b							
		SS-4	10.0	11.5	9.7	11.2	6	7	3	32	17	15	41	36	77	17	14	A-6a							
23	B	SS-1	0.0	1.5	-1.5	0.0	36		4.5							10	10	A-4a	8						
	020-0	SS-2	1.5	3.0	0.0	1.5	35		4.5	26	16	10	31	19	50	12	11	A-4a	3						
	22	SS-3	3.0	4.5	1.5	3.0	17		4.5							18	10	A-4a	8			Mc			
		SS-4	4.5	6.0	3.0	4.5	6	6	3.25	29	17	12	33	21	54	24	14	A-6a	5						
24	B	SS-1	1.5	3.0	0.0	1.5	56			NP	NP	NP	14	5	19	5	6	A-1-b	0						
	021-0	SS-2A	3.0	4.0	1.5	2.5	30									7	6	A-1-b	0						
	22	SS-2B	4.0	4.5	2.5	3.0	30		4.5							13	10	A-4a	8			Mc			
		SS-3	4.5	6.0	3.0	4.5	15	15	2.75	40	20	20	46	38	84	22	16	A-6b	12						
25	B	SS-1	2.5	4.0	1.0	2.5	18		4.5	34	19	15	34	27	61	16	14	A-6a	7						
	022-0	SS-2	5.0	6.5	3.5	5.0	6		3.5							19	14	A-6a	10						
	22	SS-3	7.5	9.0	6.0	7.5	5			NP	NP	NP	17	9	26	10	8	A-3a							
		SS-4	10.0	11.5	8.5	10.0	7	5								7	8	A-3a							
26	B	SS-1	1.5	3.0	0.0	1.5	8			NP	NP	NP	15	8	23	11	6	A-1-b	0						
	023-0	SS-2	3.0	4.5	1.5	3.0	11									14	6	A-1-b	0						
	22	SS-3	4.5	6.0	3.0	4.5	11		4.5	42	21	21	42	42	84	20	18	A-7-6	13						
		SS-4	6.0	7.5	4.5	6.0	15	8	3							24	18	A-7-6	16						
27	B	SS-1	1.5	3.0	0.0	1.5	25		3.75	22	16	6	30	14	44	11	11	A-4a	2	0					
	024-0	SS-2	3.0	4.5	1.5	3.0	10		3.75							13	10	A-4a	8			N_{60} & Mc			
	22	SS-3	4.5	6.0	3.0	4.5	31			24	16	8	18	11	29	9	10	A-2-4	0						
		SS-4	6.0	7.5	4.5	6.0	56	10								7	10	A-2-4	0						

#	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	
28	B	AS-1	1.3	2.6	-0.3	1.1				NP	NP	NP	8	4	12	8	6	A-1-b	0						
	025-1	AS-2	2.6	3.0	1.1	1.5				20	14	6	12	8	20	6	6	A-1-b	0						
	21																								
								0																	
29	B	SS-1	1.5	3.0	1.4	2.9	42			NP	NP	NP	20	7	27	6	10	A-2-4	0	180					
	025-0	SS-2	3.0	4.5	2.9	4.4	46									7	10	A-2-4	0						
	22	SS-3	4.5	6.0	4.4	5.9	19									7	10	A-2-4	0						
		SS-4	6.0	7.5	5.9	7.4	10	10	4.25	32	18	14	37	33	70	17	14	A-6a							
30	B	AS-1	1.5	2.8	0.0	1.3				NP	NP	NP	12	7	19	9	6	A-1-b	0						
	026-1																								
	21																								
								0																	
31	B	SS-1	1.5	3.0	0.5	2.0	24			22	15	7	19	11	30	7	10	A-2-4	0	20					
	026-0	SS-2	3.0	4.5	2.0	3.5	11		4	29	16	13	30	27	57	14	14	A-6a	6			N_{60}			
	22	SS-3	4.5	6.0	3.5	5.0	11		3.5							21	14	A-6a	10						
		SS-4	6.0	7.5	5.0	6.5	8	8	4	30	17	13	30	26	56	16	14	A-6a	5						
32	B	SS-1	1.5	3.0	0.6	2.1	13		4.25	32	16	16	31	29	60	15	16	A-6b	7	673					
	027-0	SS-2	3.0	4.5	2.1	3.6	8		3.25	32	16	16	28	29	57	18	16	A-6b	7						
	22	SS-3	4.5	6.0	3.6	5.1	5		2.5							17	16	A-6b	16						
		SS-4	6.0	7.5	5.1	6.6	24	5								6	6	A-1-b							
33	B	SS-1	0.0	1.5	-1.6	-0.1	13			NP	NP	NP	22	18	40	9	11	A-4a	1	0					
	028-0	SS-2	1.5	3.0	-0.1	1.4	10									10	10	A-4a	8			N_{60}		12''	
	22	SS-3	3.0	4.5	1.4	2.9	7			NP	NP	NP	18	18	36	11	11	A-4a	0			N_{60}			
		SS-4	4.5	6.0	2.9	4.4	18	7								7	6	A-1-b	0						
34	B	SS-1	1.5	3.0	1.0	2.5	21			NP	NP	NP	21	9	30	9	10	A-2-4	0	40					
	029-0	SS-2	3.0	4.5	2.5	4.0	8			34	17	17	13	21	34	15	10	A-2-6	1						
	22	SS-3	4.5	6.0	4.0	5.5	12									16	10	A-2-6	4						
		SS-4	6.0	7.5	5.5	7.0	18	8								6	6	A-1-b							
35	B	SS-1	1.0	2.5	0.9	2.4	8									3	6	A-1-b	0						
	030-0	SS-2	3.0	4.5	2.9	4.4	7		3	34	16	18	16	23	39	16	16	A-6b	3	40					
	22	SS-3	4.5	6.0	4.4	5.9	11			NP	NP	NP	20	6	26	9	8	A-3a	0						
		SS-4	6.0	7.5	5.9	7.4	21	7								7	8	A-3a							
36	B	SS-1	1.5	3.0	1.2	2.7	6			NP	NP	NP	14	10	24	10	6	A-1-b	0	60					
	031-0	SS-2	3.0	4.5	2.7	4.2	8			NP	NP	NP	22	13	35	11	10	A-2-4	0						
	22	SS-3	4.5	6.0	4.2	5.7	48									11	6	A-1-b	0						
		SS-4	6.0	7.5	5.7	7.2	67	6								8	6	A-1-b							

PID: 113013

County-Route-Section: ROS-159-0.41-Entire Project
No. of Borings: 36

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh/ Nizar Altarawneh
Date prepared: 5/12/2023

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	12" 0"
Global Geogrid Average(N60L): Average(HP):	0" 0"

Design CBR	9

% Samples within 6 feet of subgrade			
$N_{60} \leq 5$	6%	HP ≤ 0.5	0%
$N_{60} < 12$	37%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	15%	1 < HP ≤ 2	1%
$N_{60} \geq 20$	26%	HP > 2	38%
M+	4%		
Rock	0%		
Unsuitable	0%		

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

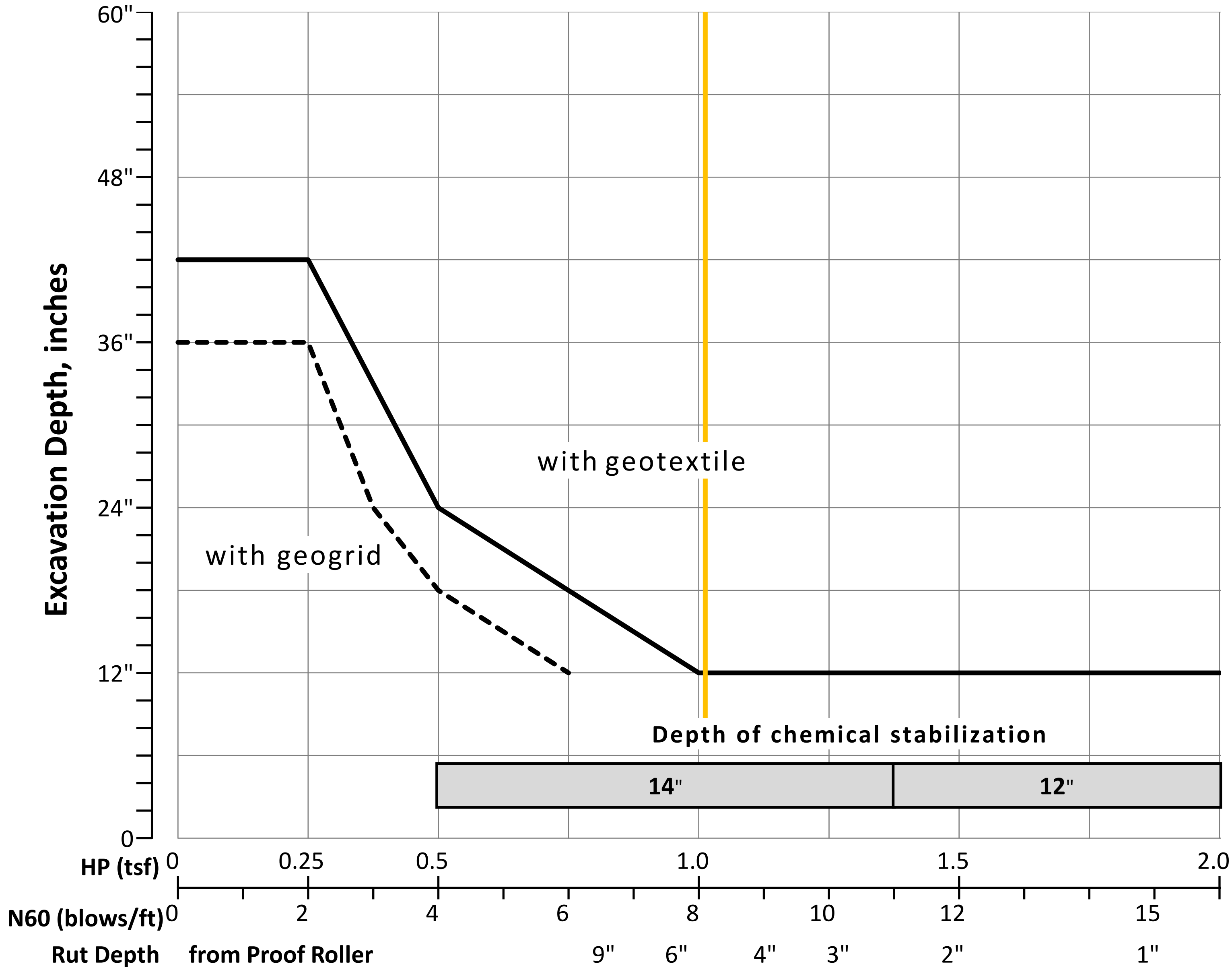
% Proposed Subgrade Surface	
Unstable & Unsuitable	19%
Unstable	19%
Unsuitable	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	18	8	3.73	30	17	13	23	18	42	12	10	3
Maximum	67	30	4.50	42	21	21	46	42	88	27	18	16
Minimum	4	0	1.50	20	14	6	6	3	9	3	6	0

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	4	34	12	0	6	0	0	9	15	0	0	28	14	0	2	0	0	124
Percent	0%	3%	27%	10%	0%	5%	0%	0%	7%	12%	0%	0%	23%	11%	0%	2%	0%	0%	100%
% Rock|Granular|Cohesive	0%	65%									35%								100%
Surface Class Count	0	3	18	6	0	4	0	0	1	10	0	0	8	4	0	0	0	0	54
Surface Class Percent	0%	6%	33%	11%	0%	7%	0%	0%	2%	19%	0%	0%	15%	7%	0%	0%	0%	0%	100%

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
3.73	0.50	☐ HP
8.11	6.00	☐ N60L

Average HP

Average N_{60L}

SR 159 SEGMENT

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.)

ROS-159-0.41-SR 159
113013

SR 159 (Bridge Street) Corridor- Widening Project

NEAS, Inc.

Prepared By: Derar M. Tarawneh/ Nizar Altarawneh
Date prepared: Friday, May 12, 2023

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
che@neasinc.com

NO. OF BORINGS: 20

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-001-0-22	SR 159	709+31	52' RT	JL	CME 45B	73	626.5	625.9	0.6 C
2	B-001-1-21	SR 159			Binkley	SIMCO	60	624.1	622.6	1.5 C
3	B-002-0-22	SR 159	712+90	36' RT	JL	CME 45B	73	622.5	622.2	0.3 C
4	B-003-0-22	SR 159	714+89	46'RT	JH	CME 45B	73	621.8	621.8	0.0
5	B-004-1-21	SR 159			Binkley	SIMCO	60	623.6	622.1	1.5 C
6	B-004-0-22	SR 159	718+09	56' RT	JL	CME 45B	73	621.3	621.1	0.2 C
7	B-005-1-21	SR 159			Binkley	SIMCO	60	621.4	619.9	1.5 C
8	B-005-0-22	SR 159	720+66	46' RT	JL	CME 45B	73	619.8	620.6	0.8 F
9	B-007-1-21	SR 159			Binkley	SIMCO	60	622.4	620.9	1.5 C
10	B-009-0-22	SR 159	725+34	36' LT	JL	CME 45B	73	621.4	620.7	0.7 C
11	B-010-0-22	SR 159	727+88	45' RT	JL	CME 45B	73	622.5	622.1	0.4 C
12	B-011-0-22	SR 159	731+03	45' RT	JL	CME 45B	73	625.8	624.7	1.1 C
13	B-012-0-22	SR 159	736+73	35' RT	JL	CME 45B	73	626.9	626.6	0.3 C
14	B-013-0-22	SR 159	738+66	35' RT	JL	CME 45B	73	626.5	626.2	0.3 C
15	B-014-0-22	SR 159	740+94	35' RT	JL	CME 45B	73	625.5	625.1	0.4 C
16	B-015-0-22	SR 159	744+47	35' RT	JL	CME 45B	73	624.4	624.0	0.4 C
17	B-016-0-22	SR 159	747+64	35' RT	JL	CME 45B	73	624.3	623.9	0.4 C
18	B-017-0-22	SR 159	750+46	36' RT	JL	CME 45B	73	624.0	623.7	0.3 C
19	B-018-0-22	SR 159	752+57	35' RT	JL	CME 45B	73	625.3	624.8	0.5 C
20	B-019-0-22	SR 159	753+96	37' RT	JL	CME 45B	73	626.5	626.2	0.3 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	SS-1	2.5	4.0	1.9	3.4	30			NP	NP	NP	23	12	35	11	8	A-3a	0	0					
	001-0	SS-2	5.0	6.5	4.4	5.9	34			NP	NP	NP	18	7	25	8	6	A-1-b	0						
	22	SS-3	7.5	9.0	6.9	8.4	28									11	6	A-1-b							
		SS-4	10.0	11.5	9.4	10.9	29	30								10	6	A-1-b							
2	B	AS-1	2.0	3.0	0.5	1.5				NP	NP	NP	9	3	12	9	6	A-1-a	0						
	001-1																								
	21																								
								0																	
3	B	SS-1	2.5	4.0	2.2	3.7	41			NP	NP	NP	15	5	20	7	6	A-1-b	0						
	002-0	SS-2	5.0	6.5	4.7	6.2	12		3.25	33	18	15	28	17	45	14	14	A-6a	4						
	22	SS-3	7.5	9.0	7.2	8.7	11									16	10	A-2-4							
		SS-4	10.0	11.5	9.7	11.2	13	12	4.5	32	18	14	33	25	58	15	14	A-6a							
4	B	SS-1	1.5	3.0	1.5	3.0	21		4.5	21	15	6	27	15	42	11	10	A-4a	1	100					
	003-0	SS-2	3.0	4.5	3.0	4.5	13		4.5							17	10	A-4a	8						
	22	SS-3	4.5	6.0	4.5	6.0	13		3.25	31	17	14	30	22	52	16	14	A-6a	5						
		SS-4	6.0	7.5	6.0	7.5	41	13								13	6	A-1-b							
5	B	AS-1	1.0	1.5	-0.5	0.0				NP	NP	NP	11	3	14	6	6	A-1-a	0						
	004-1																								
	21																								
								0																	
6	B	SS-1	2.5	4.0	2.3	3.8	56			NP	NP	NP	13	4	17	4	6	A-1-b	0						
	004-0	SS-2	5.0	6.5	4.8	6.3	33									9	6	A-1-b	0						
	22	SS-3	7.5	9.0	7.3	8.8	12		4.5	31	16	15	28	28	56	14	14	A-6a							
		SS-4	10.0	11.5	9.8	11.3	12	30	4.5							23	14	A-6a							
7	B	AS-1	1.5	2.5	0.0	1.0				21	15	6	18	11	29	9	10	A-2-4	0			N_{60}		0''	
	005-1	AS-2	2.5	3.5	1.0	2.0				28	16	12	30	35	65	16	14	A-6a	7			N_{60}		0''	
	21																								
								0																	
8	B	SS-1	2.5	4.0	3.3	4.8	13			NP	NP	NP	6	3	9	6	6	A-1-a	0						
	005-0	SS-2	5.0	6.5	5.8	7.3	12		3.75	32	17	15	32	38	70	18	14	A-6a							
	22	SS-3	7.5	9.0	8.3	9.8	11		3.5							14	14	A-6a							
		SS-4	10.0	11.5	10.8	12.3	10	12	4.5							14	14	A-6a							
9	B	AS-1	1.3	1.5	-0.2	0.0							11	3	14	14	6	A-1-b	0						
	007-1																								
	21																								
								0																	

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.6 2/11/2022

#	Boring	Sample	Sample Depth From	Sample Depth To	Subgrade Depth From	Subgrade Depth To	Standard Penetration N_{60}	Standard Penetration N_{60L}	HP (tsf)	Physical Characteristics LL	PL	PI	% Silt	% Clay	P200	Moisture M_C	M_{OPT}	Ohio DOT Class	GI	Sulfate Content (ppm)	Problem Unsuitable	Problem Unstable	Excavate and Replace (Item 204) Unsuitable	Excavate and Replace (Item 204) Unstable	Recommendation (Enter depth in inches)
10	B	SS-1A	2.5	3.0	1.8	2.3	15			NP	NP	NP	10	5	15	5	6	A-1-b	0	180					
	009-0	SS-1B	3.0	4.0	2.3	3.3	15		2.75	28	17	11	24	17	41	12	14	A-6a	1						
	22	SS-2	5.0	6.5	4.3	5.8	12						22	18	40	11	14	A-6a	6						
		SS-3	7.5	9.0	6.8	8.3	17	12					38	35	73	19	16	A-6b							
11	B	SS-1	2.5	4.0	2.1	3.6	6		4	36	19	17	24	26	50	17	16	A-6b	5	60					
	010-0	SS-2	5.0	6.5	4.6	6.1	5		3							21	16	A-6b	16						
	22	SS-3	7.5	9.0	7.1	8.6	11		4.25	36	18	18	26	26	52	16	16	A-6b							
		SS-4	10.0	11.5	9.6	11.1	11	5	3							19	16	A-6b							
12	B	SS-1	1.5	3.0	0.4	1.9	24			NP	NP	NP	12	5	17	10	6	A-1-b	0	0					
	011-0	SS-2	3.0	4.5	1.9	3.4	22									8	6	A-1-b	0						
	22	SS-3	4.5	6.0	3.4	4.9	13									5	6	A-1-b	0						
		SS-4	6.0	7.5	4.9	6.4	12	12	3	25	15	10	29	23	52	15	10	A-4a	3						
13	B	SS-1	2.5	4.0	2.2	3.7	6									7	6	A-1-a	0	60					
	012-0	SS-2	5.0	6.5	4.7	6.2	7		3.5	29	14	15	17	21	38	13	14	A-6a	2						
	22	SS-3	7.5	9.0	7.2	8.7	33									7	6	A-1-a							
		SS-4	10.0	11.5	9.7	11.2	54	6								5	6	A-1-b							
14	B	SS-1	2.5	4.0	2.2	3.7	10		4.25	28	15	13	21	25	46	14	14	A-6a	3	100					
	013-0	SS-2	5.0	6.5	4.7	6.2	16		4.5							16	14	A-6a	10						
	22	SS-3A	7.5	8.0	7.2	7.7	47		4.25							13	14	A-6a							
		SS-3B	8.0	9.0	7.7	8.7	47	10								5	6	A-1-b							
15	B	SS-1	2.5	4.0	2.1	3.6	7		3.5	31	18	13	37	23	60	18	14	A-6a	6	20					
	014-0	SS-2	5.0	6.5	4.6	6.1	7		2.5							14	14	A-6a	10						
	22	SS-3	7.5	9.0	7.1	8.6	6									9	8	A-3a							
		SS-4	10.0	11.5	9.6	11.1	6	7		NP	NP	NP	17	7	24	7	6	A-1-b							
16	B	SS-1	1.5	3.0	1.1	2.6	15									11	10	A-2-6	4						
	015-0	SS-2	3.0	4.5	2.6	4.1	15			28	15	13	19	12	31	5	10	A-2-6	0	0					
	22	SS-3	4.5	6.0	4.1	5.6	10									24	10	A-2-6	4						
		SS-4	6.0	7.5	5.6	7.1	12	10	3.75	36	19	17	46	42	88	20	16	A-6b							
17	B	SS-1	2.5	4.0	2.1	3.6	12		4.5	29	15	14	18	20	38	10	14	A-6a	2	60					
	016-0	SS-2	5.0	6.5	4.6	6.1	5			NP	NP	NP	11	12	23	9	8	A-3a	0						
	22	SS-3	7.5	9.0	7.1	8.6	8									17	10	A-4a							
		SS-4	10.0	11.5	9.6	11.1	12	5								19	10	A-4a							
18	B	SS-1	1.5	3.0	1.2	2.7	15			31	19	12	19	13	32	12	10	A-2-6	0	0					
	017-0	SS-2	3.0	4.5	2.7	4.2	48			NP	NP	NP	14	6	20	6	6	A-1-b	0						
	22	SS-3A	4.5	5.5	4.2	5.2	12									14	6	A-1-b	0						
		SS-3B	5.5	6.0	5.2	5.7	12	12	1.5							27	14	A-6a							

#	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	
19	B	SS-1	2.5	4.0	2.0	3.5	10		3.25	32	15	17	25	32	57	17	16	A-6b	7			N_{60}			
	018-0	SS-2	5.0	6.5	4.5	6.0	6			NP	NP	NP	18	23	41	13	11	A-4a	1						
	22	SS-3A	7.5	8.0	7.0	7.5	15									14	10	A-4a							
		SS-3B	8.0	9.0	7.5	8.5	15	6								6	8	A-3a							
20	B	SS-1	2.5	4.0	2.2	3.7	7		3.5	31	19	12	41	39	80	20	14	A-6a	9						
	019-0	SS-2	5.0	6.5	4.7	6.2	13		4.5	34	17	17	45	38	83	17	16	A-6b	11						
	22	SS-3	7.5	9.0	7.2	8.7	7		4.5							18	16	A-6b							
		SS-4	10.0	11.5	9.7	11.2	6	7	3	32	17	15	41	36	77	17	14	A-6a							

PID: 113013

County-Route-Section: ROS-159-0.41-SR 159
No. of Borings: 20

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh/ Nizar Altarawneh
Date prepared: 5/12/2023

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L):	12"
Average(HP):	0"
Global Geogrid Average(N60L):	0"
Average(HP):	0"

Design CBR	9

% Samples within 6 feet of subgrade			
$N_{60} \leq 5$	5%	HP ≤ 0.5	0%
$N_{60} < 12$	27%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	30%	1 < HP ≤ 2	2%
$N_{60} \geq 20$	23%	HP > 2	43%
M+	0%		
Rock	0%		
Unsuitable	0%		

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

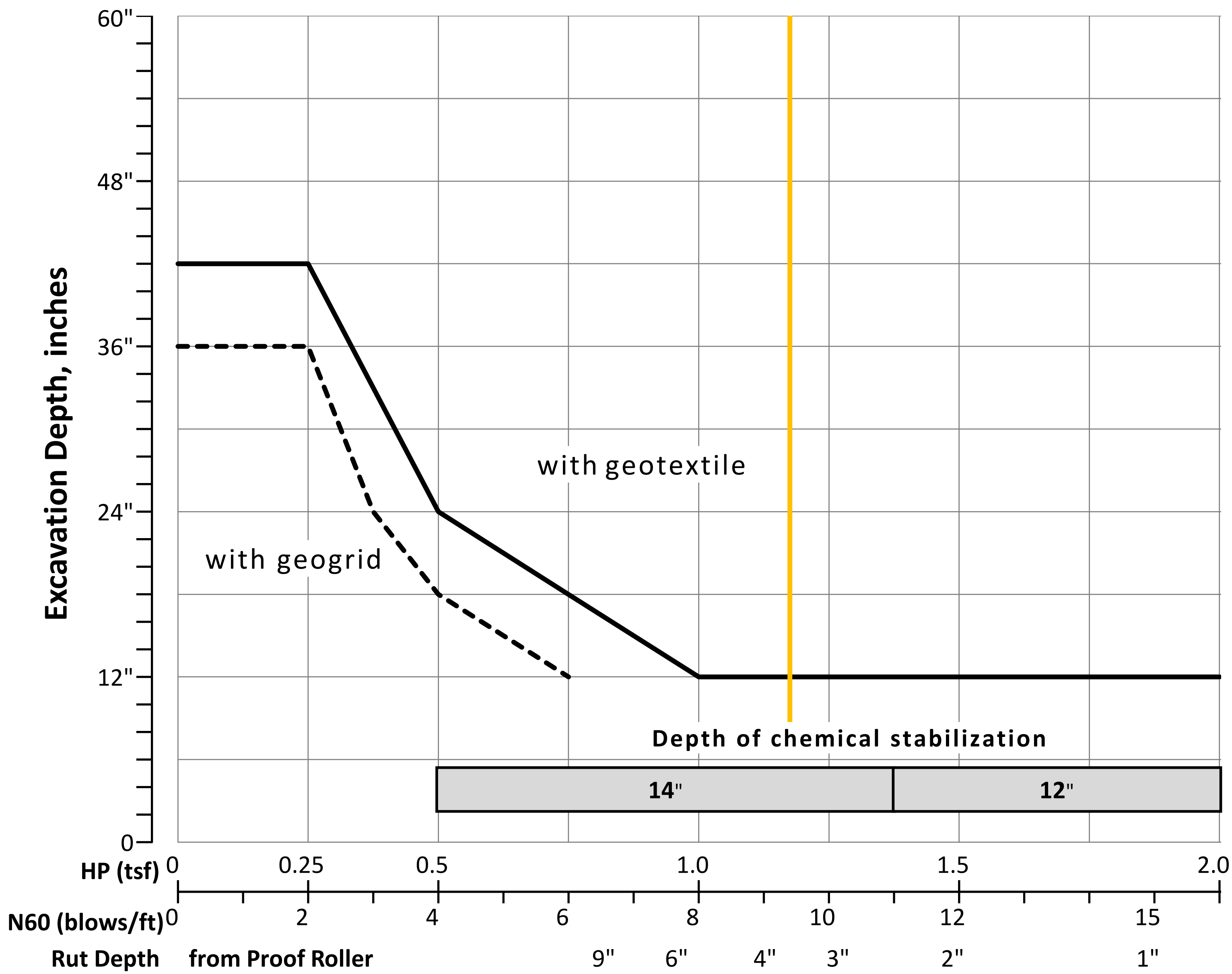
% Proposed Subgrade Surface	
Unstable & Unsuitable	13%
Unstable	13%
Unsuitable	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	17	9	3.73	30	17	14	24	20	44	13	11	3
Maximum	56	30	4.50	36	19	18	46	42	88	27	16	16
Minimum	5	0	1.50	21	14	6	6	3	9	4	6	0

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	4	16	2	0	4	0	0	4	7	0	0	21	9	0	0	0	0	67
Percent	0%	6%	24%	3%	0%	6%	0%	0%	6%	10%	0%	0%	31%	13%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	55%									45%								100%
Surface Class Count	0	3	7	1	0	3	0	0	1	1	0	0	6	2	0	0	0	0	24
Surface Class Percent	0%	13%	29%	4%	0%	13%	0%	0%	4%	4%	0%	0%	25%	8%	0%	0%	0%	0%	100%

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
3.73	0.50	☐ HP
9.45	6.00	☐ N60L

Average HP

Average N_{60L}

RAMP A1 SEGMENT

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.)

ROS-159-0.41-Ramp A1
113013

SR 159 (Bridge Street) Corridor Safety Improvement

NEAS, Inc.

Prepared By: Derar M. Tarawneh
Date prepared: Monday, September 26, 2022

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
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-007-0-22	Ramp A1	400+67	40' RT	JL	CME 45B	73	621.2	619.7	1.5 C
2	B-008-0-22	Ramp A1	402+06	14' RT	JL	CME 45B	73	617.7	616.2	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	SS-1	1.5	3.0	0.0	1.5	15						18	6	24	8	6	A-1-b	0	60					
	007-0	SS-2	3.0	4.5	1.5	3.0	4						23	6	29	13	10	A-2-4	0			N_{60} & Mc			
	22	SS-3	4.5	6.0	3.0	4.5	6									6	10	A-2-4	0						
		SS-4	6.0	7.5	4.5	6.0	29	4								16	8	A-3a	0						
2	B	SS-1	2.5	4.0	1.0	2.5	15									7	6	A-1-b	0	0					
	008-0	SS-2	5.0	6.5	3.5	5.0	4									10	6	A-1-b	0						
	22	SS-3	7.5	9.0	6.0	7.5	6						24	12	36	17	10	A-4a							
		SS-4	10.0	11.5	8.5	10.0	29	4					17	6	23	8	6	A-1-b							

PID: 113013

County-Route-Section: ROS-159-0.41-Ramp A1
No. of Borings: 2

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh
Date prepared: 9/26/2022

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L):	24"
Average(HP):	0"
Global Geogrid Average(N60L):	18"
Average(HP):	0"

Design CBR	13

% Samples within 6 feet of subgrade			
$N_{60} \leq 5$	29%	HP ≤ 0.5	0%
$N_{60} < 12$	57%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	0%	1 < HP ≤ 2	0%
$N_{60} \geq 20$	14%	HP > 2	0%
M+	14%		
Rock	0%		
Unsuitable	0%		

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

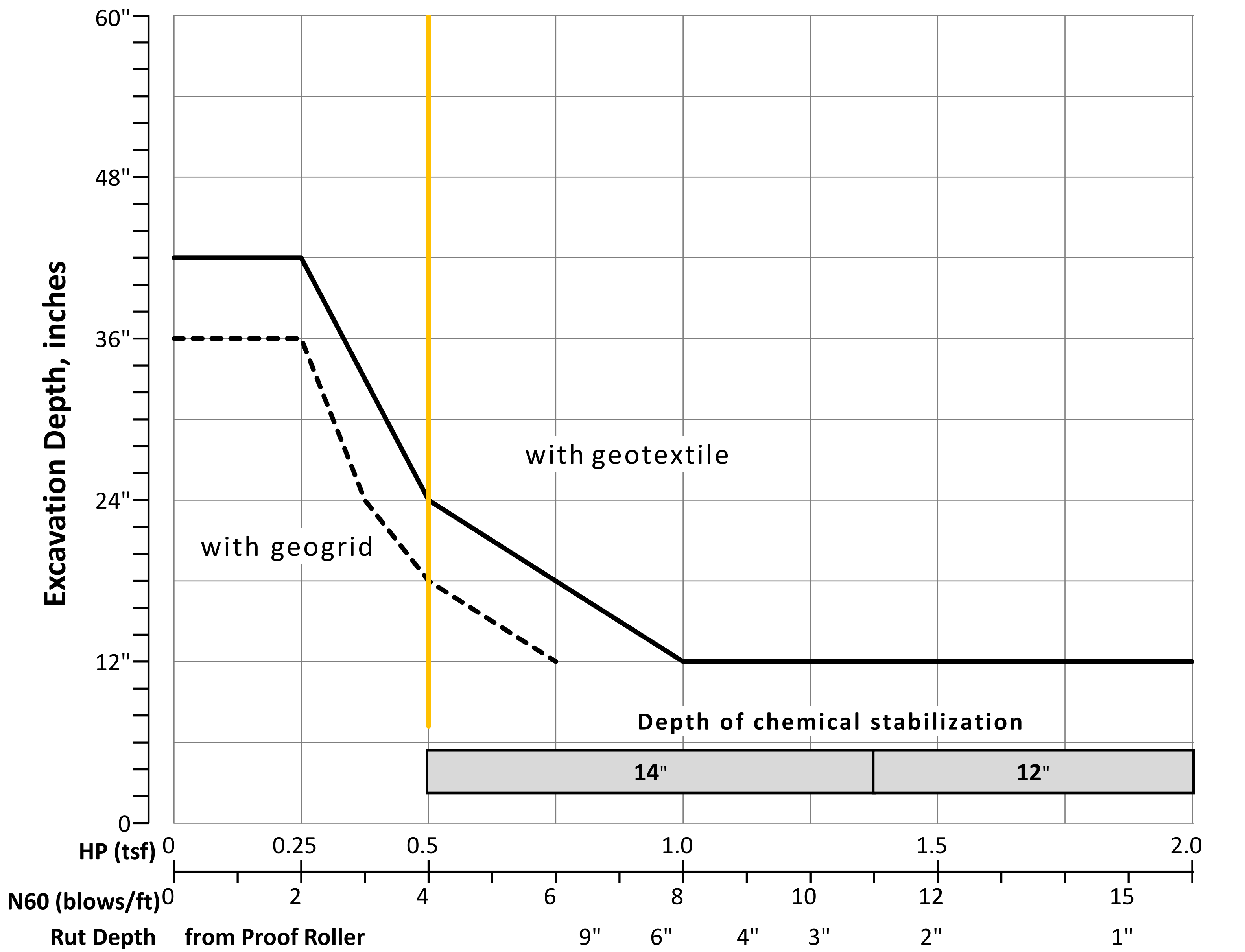
% Proposed Subgrade Surface	
Unstable & Unsuitable	33%
Unstable	33%
Unsuitable	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	14	4	NP	0	0	0	21	8	28	11	8	0
Maximum	29	4	NP	0	0	0	24	12	36	17	10	0
Minimum	4	4	NP	0	0	0	17	6	23	6	6	0

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	4	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	8
Percent	0%	0%	50%	25%	0%	0%	0%	0%	13%	13%	0%	0%	0%	0%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	100%									0%								100%
Surface Class Count	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Surface Class Percent	0%	0%	67%	33%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
NP	0.50	☐ HP
4.00	6.00	☐ N60L

STEWART ROAD SEGMENT

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.)

ROS-159-0.41-Stewart Rd
113013

SR 159 (Bridge Street) Corridor Safety Improvement

NEAS, Inc.

Prepared By: Derar M. Tarawneh
Date prepared: Monday, September 26, 2022

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
che@neasinc.com

NO. OF BORINGS: 3

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-020-0-22	Stewart Rd.	64+07	36' RT	JH	CME 45B	73	620.9	619.4	1.5 C
2	B-021-0-22	Stewart Rd.	69+25	23' LT	JH	CME 45B	73	620.1	618.6	1.5 C
3	B-022-0-22	Stewart Rd.	70+96	46' RT	JH	CME 45B	73	617.6	616.1	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	SS-1	0.0	1.5	-1.5	0.0	36		4.5							10	10	A-4a	8						
	020-0	SS-2	1.5	3.0	0.0	1.5	35		4.5	26	16	10	31	19	50	12	11	A-4a	3						
	22	SS-3	3.0	4.5	1.5	3.0	17		4.5							18	10	A-4a	8			Mc			
		SS-4	4.5	6.0	3.0	4.5	6	6	3.25	29	17	12	33	21	54	24	14	A-6a	5						
2	B	SS-1	1.5	3.0	0.0	1.5	56						14	5	19	5	6	A-1-b	0						
	021-0	SS-2A	3.0	4.0	1.5	2.5	30									7	6	A-1-b	0						
	22	SS-2B	4.0	4.5	2.5	3.0	30		4.5							13	10	A-4a	8			Mc			
		SS-3	4.5	6.0	3.0	4.5	15	15	2.75	40	20	20	46	38	84	22	16	A-6b	12						
3	B	SS-1	2.5	4.0	1.0	2.5	18		4.5	34	19	15	34	27	61	16	14	A-6a	7						
	022-0	SS-2	5.0	6.5	3.5	5.0	6		3.5							19	14	A-6a	10						
	22	SS-3	7.5	9.0	6.0	7.5	5						17	9	26	10	8	A-3a							
		SS-4	10.0	11.5	8.5	10.0	7	5								7	8	A-3a							

PID: 113013

County-Route-Section: ROS-159-0.41-Stewart Rd
No. of Borings: 3

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh
Date prepared: 9/26/2022

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	 12" 0"
Global Geogrid Average(N60L): Average(HP):	 0" 0"

Design CBR	7

% Samples within 6 feet of subgrade			
$N_{60} \leq 5$	10%	HP ≤ 0.5	0%
$N_{60} < 12$	30%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	0%	1 < HP ≤ 2	0%
$N_{60} \geq 20$	40%	HP > 2	70%
M+	20%		
Rock	0%		
Unsuitable	0%		

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

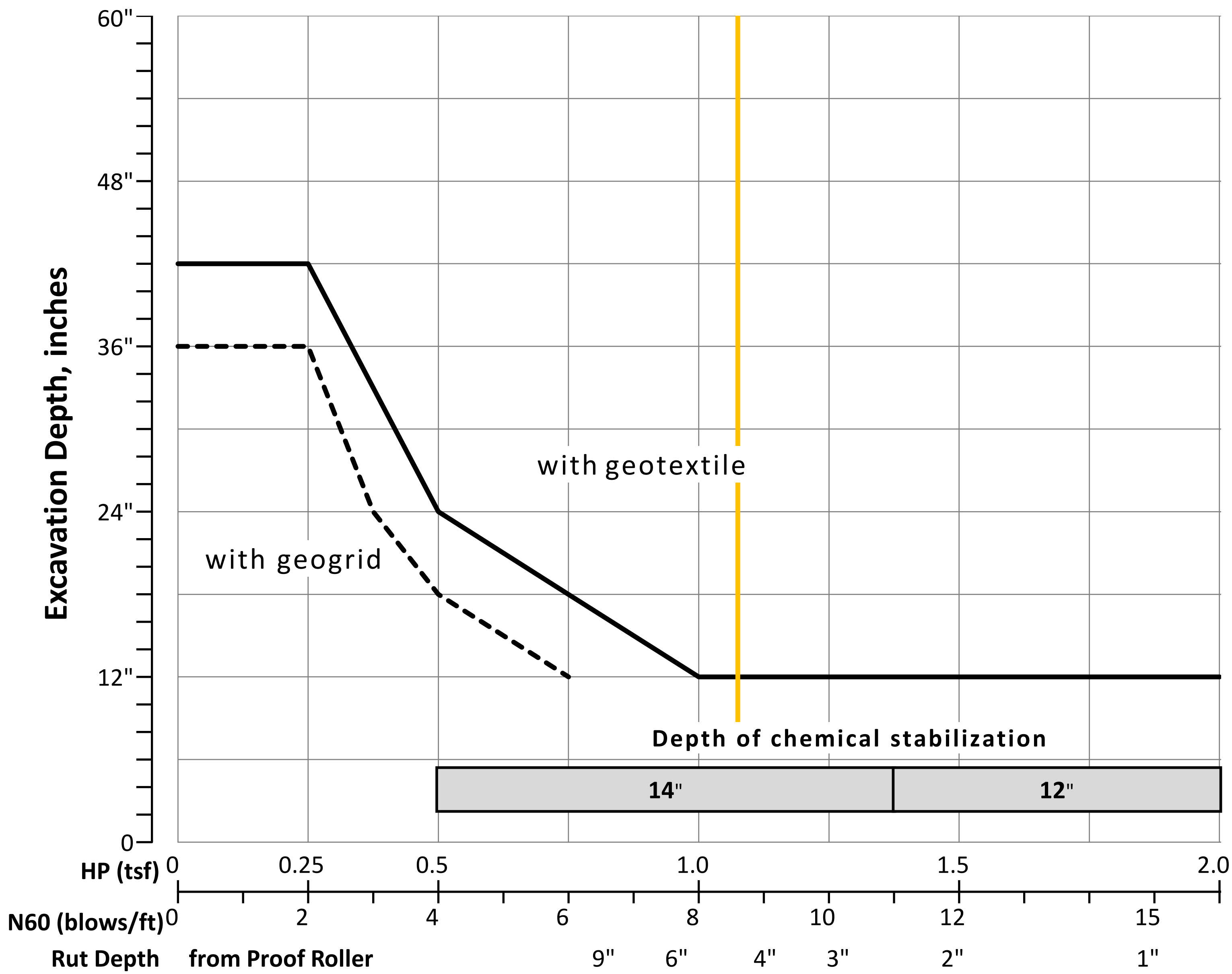
% Proposed Subgrade Surface	
Unstable & Unsuitable	29%
Unstable	29%
Unsuitable	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	20	9	3.93	32	18	14	29	20	49	14	11	6
Maximum	56	15	4.50	40	20	20	46	38	84	24	16	12
Minimum	5	5	2.75	26	16	10	14	5	19	5	6	0

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	2	0	0	0	0	0	2	3	0	0	3	1	0	0	0	0	11
Percent	0%	0%	18%	0%	0%	0%	0%	0%	18%	27%	0%	0%	27%	9%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	64%									36%								100%
Surface Class Count	0	0	2	0	0	0	0	0	0	4	0	0	1	0	0	0	0	0	7
Surface Class Percent	0%	0%	29%	0%	0%	0%	0%	0%	0%	57%	0%	0%	14%	0%	0%	0%	0%	0%	100%

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
3.93	0.50	☐ HP
8.67	6.00	☐ N60L

Average HP

Average N_{60L}

CONSUMER CENTER DRIVE SEGMENT

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.)

ROS-159-0.41-Consumer Center Dr
113013

SR 159 (Bridge Street) Corridor Safety Improvement

NEAS, Inc.

Prepared By: Derar M. Tarawneh
Date prepared: Monday, September 26, 2022

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
che@neasinc.com

NO. OF BORINGS: 1

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-023-0-22	Consumer Center Dr.	9+26	2' RT	JH	CME 45B	73	614.3	612.8	1.5 C

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.6 2/11/2022

#	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	SS-1	1.5	3.0	0.0	1.5	8						15	8	23	11	6	A-1-b	0						
	023-0	SS-2	3.0	4.5	1.5	3.0	11									14	6	A-1-b	0						
	22	SS-3	4.5	6.0	3.0	4.5	11		4.5	42	21	21	42	42	84	20	18	A-7-6	13						
		SS-4	6.0	7.5	4.5	6.0	15	8	3							24	18	A-7-6	16						

PID: 113013

County-Route-Section: ROS-159-0.41-Consumer Center Dr
No. of Borings: 1

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh
Date prepared: 9/26/2022

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	 12" 0"
Global Geogrid Average(N60L): Average(HP):	 0" 0"

Design CBR	7

% Samples within 6 feet of subgrade			
$N_{60} \leq 5$	0%	HP ≤ 0.5	0%
$N_{60} < 12$	75%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	0%	1 < HP ≤ 2	0%
$N_{60} \geq 20$	0%	HP > 2	50%
M+	0%		
Rock	0%		
Unsuitable	0%		

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

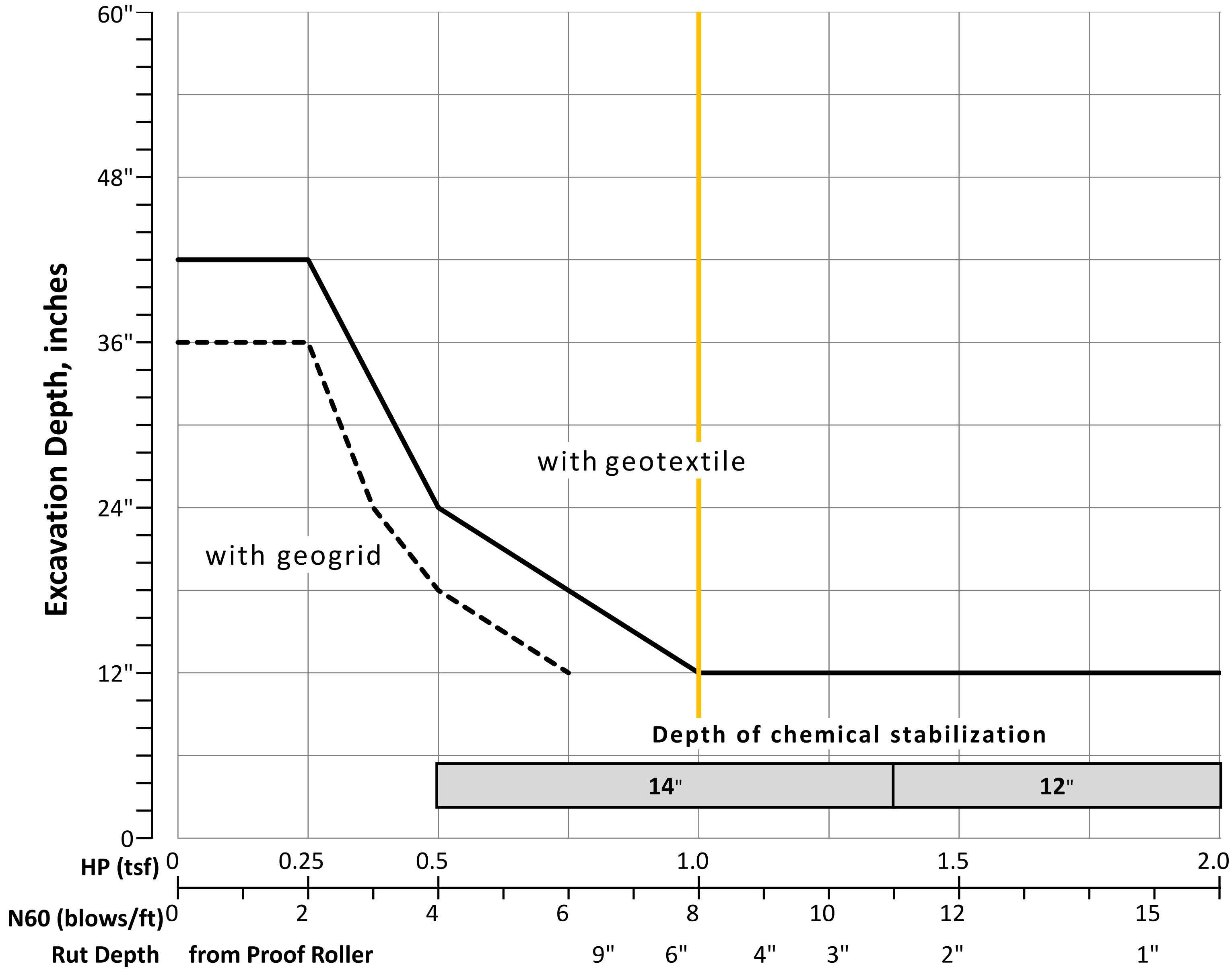
% Proposed Subgrade Surface	
Unstable & Unsuitable	0%
Unstable	0%
Unsuitable	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	11	8	3.75	42	21	21	29	25	54	17	12	7
Maximum	15	8	4.50	42	21	21	42	42	84	24	18	16
Minimum	8	8	3.00	42	21	21	15	8	23	11	6	0

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	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	4
Percent	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	0%	0%	100%
% Rock|Granular|Cohesive	0%	50%								50%									100%
Surface Class Count	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Surface Class Percent	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
3.75	0.50	☐ HP
8.00	6.00	☐ N60L

RIVER TRACE SEGMENT

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.)

ROS-159-0.41-River Trace
113013

SR 159 (Bridge Street) Corridor-Widening Project

NEAS, Inc.

Prepared By: Derar M. Tarawneh/ Nizar Altarawneh
Date prepared: Thursday, September 29, 2022

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
che@neasinc.com

NO. OF BORINGS: 1

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-024-0-22	River Trace	82+06	18' LT	JH	CME 45B	73	620.3	618.8	1.5 C

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.6 2/11/2022

#	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	SS-1	1.5	3.0	0.0	1.5	25		3.75	22	16	6	30	14	44	11	11	A-4a	2	0					
	024-0	SS-2	3.0	4.5	1.5	3.0	10		3.75							13	10	A-4a	8			N_{60} & Mc			
	22	SS-3	4.5	6.0	3.0	4.5	31			24	16	8	18	11	29	9	10	A-2-4	0						
		SS-4	6.0	7.5	4.5	6.0	56	10								7	10	A-2-4	0						

PID: 113013

County-Route-Section: ROS-159-0.41-River Trace
No. of Borings: 1

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh/ Nizar Altarawneh
Date prepared: 9/29/2022

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	12" 0"
Global Geogrid Average(N60L): Average(HP):	0" 0"

Design CBR	9

% Samples within 6 feet of subgrade			
$N_{60} \le 5$	0%	HP ≤ 0.5	0%
$N_{60} < 12$	25%	0.5 < HP ≤ 1	0%
$12 \le N_{60} < 15$	0%	1 < HP ≤ 2	0%
$N_{60} \ge 20$	75%	HP > 2	50%
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	31	10	3.75	23	16	7	24	13	37	10	10	3
Maximum	56	10	3.75	24	16	8	30	14	44	13	11	8
Minimum	10	10	3.75	22	16	6	18	11	29	7	10	0

Classification Counts by Sample

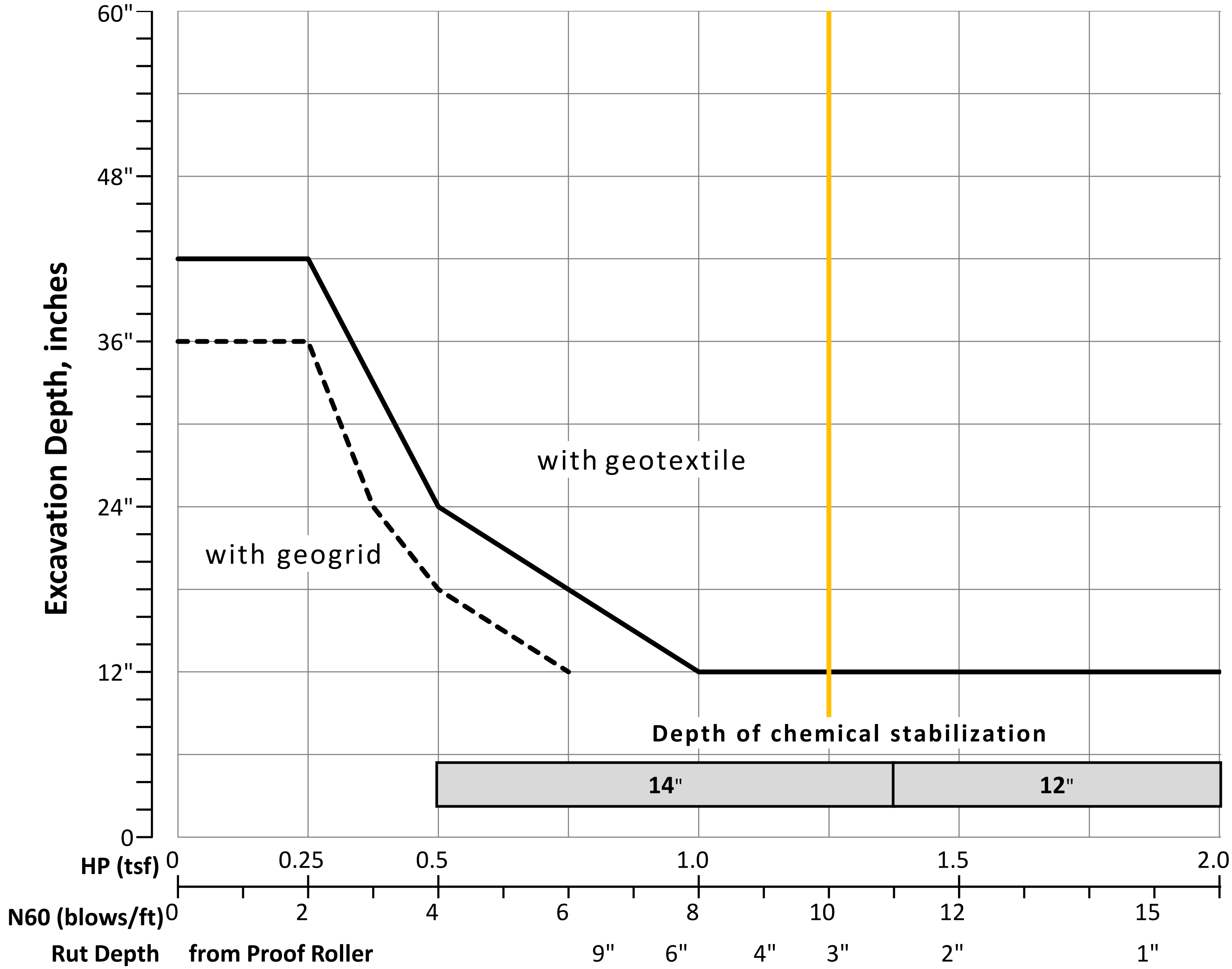
ODOT Class	Rock	A-1-a	A-1-b	A-2-4	A-2-5	A-2-6	A-2-7	A-3	A-3a	A-4a	A-4b	A-5	A-6a	A-6b	A-7-5	A-7-6	A-8a	A-8b	Totals
Count	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	4
Percent	0%	0%	0%	50%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	100%									0%								100%
Surface Class Count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

Ohio Department of Transportation

Subgrade Analysis

V. 14.6 2/11/2022

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
3.75	0.50	☐ HP
10.00	6.00	☐ N60L

Average HP

Average N_{60L}

US-35 RAMP C SEGMENT

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.)

ROS-159-0.41-US 35 Ramp C
113013

SR 159 (Bridge Street) Corridor-Widening Project

NEAS, Inc.

Prepared By: Derar M. Tarawneh/ Nizar Altarawneh
Date prepared: Friday, May 12, 2023

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
che@neasinc.com

NO. OF BORINGS: 4

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-025-1-21	US-35 Ramp C			Binkley	SIMCO	60	634.3	632.8	1.5 C
2	B-025-0-22	US-35 Ramp C	106+46	19' RT	JL	CME 45B	73	631.4	631.3	0.1 C
3	B-026-1-21	US-35 Ramp C			Binkley	SIMCO	60	626.3	624.8	1.5 C
4	B-026-0-22	US-35 Ramp C	112+46	11' RT	JL	CME 45B	73	623.5	622.5	1.0 C

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.6 2/11/2022

#	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	AS-1	1.3	2.6	-0.3	1.1				NP	NP	NP	8	4	12	8	6	A-1-b	0						
	025-1	AS-2	2.6	3.0	1.1	1.5				20	14	6	12	8	20	6	6	A-1-b	0						
	21																								
								0																	
2	B	SS-1	1.5	3.0	1.4	2.9	42			NP	NP	NP	20	7	27	6	10	A-2-4	0	180					
	025-0	SS-2	3.0	4.5	2.9	4.4	46									7	10	A-2-4	0						
	22	SS-3	4.5	6.0	4.4	5.9	19									7	10	A-2-4	0						
		SS-4	6.0	7.5	5.9	7.4	10	10	4.25	32	18	14	37	33	70	17	14	A-6a							
3	B	AS-1	1.5	2.8	0.0	1.3				NP	NP	NP	12	7	19	9	6	A-1-b	0						
	026-1																								
	21																								
								0																	
4	B	SS-1	1.5	3.0	0.5	2.0	24			22	15	7	19	11	30	7	10	A-2-4	0	20					
	026-0	SS-2	3.0	4.5	2.0	3.5	11		4	29	16	13	30	27	57	14	14	A-6a	6			N_{60}			
	22	SS-3	4.5	6.0	3.5	5.0	11		3.5							21	14	A-6a	10						
		SS-4	6.0	7.5	5.0	6.5	8	8	4	30	17	13	30	26	56	16	14	A-6a	5						

PID: 113013

County-Route-Section: ROS-159-0.41-US 35 Ramp C
No. of Borings: 4

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh/ Nizar Altarawneh
Date prepared: 5/12/2023

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	24" 0"
Global Geogrid Average(N60L): Average(HP):	18" 0"

Design CBR	10

% Samples within 6 feet of subgrade			
$N_{60} \le 5$	0%	HP ≤ 0.5	0%
$N_{60} < 12$	36%	0.5 < HP ≤ 1	0%
$12 \le N_{60} < 15$	0%	1 < HP ≤ 2	0%
$N_{60} \ge 20$	27%	HP > 2	36%
M+	0%		
Rock	0%		
Unsuitable	0%		

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

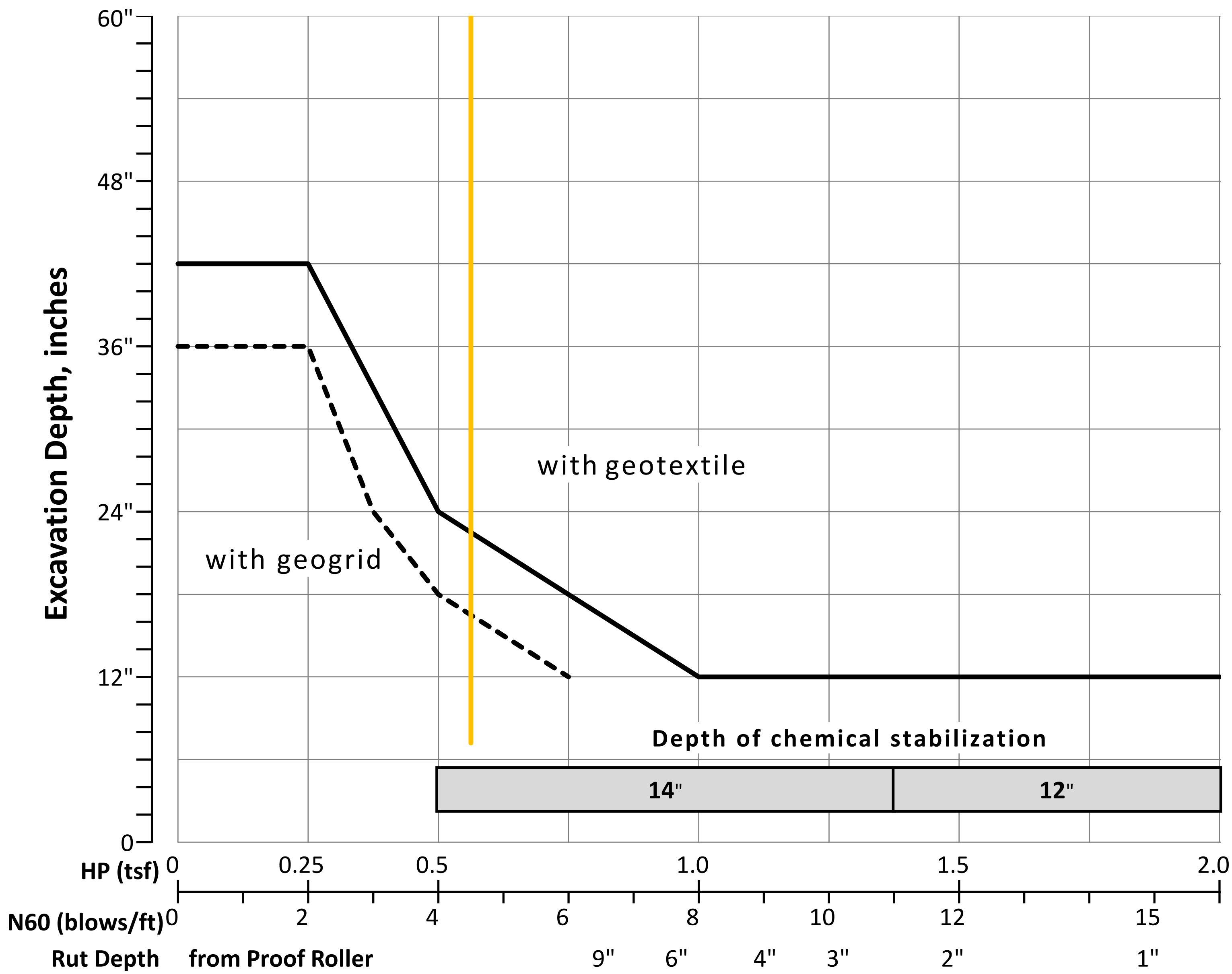
% Proposed Subgrade Surface	
Unstable & Unsuitable	17%
Unstable	17%
Unsuitable	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	21	5	3.94	27	16	11	21	15	36	11	10	2
Maximum	46	10	4.25	32	18	14	37	33	70	21	14	10
Minimum	8	0	3.50	20	14	6	8	4	12	6	6	0

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	3	4	0	0	0	0	0	0	0	0	4	0	0	0	0	0	11
Percent	0%	0%	27%	36%	0%	0%	0%	0%	0%	0%	0%	0%	36%	0%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	64%									36%								100%
Surface Class Count	0	0	3	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6
Surface Class Percent	0%	0%	50%	33%	0%	0%	0%	0%	0%	0%	0%	0%	17%	0%	0%	0%	0%	0%	100%

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
3.94	0.50	☐ HP
4.50	6.00	☐ N60L

Average HP

Average N_{60L}

MARIETTA CONNECTOR SEGMENT

OHIO DEPARTMENT OF TRANSPORTATION

OFFICE OF GEOTECHNICAL ENGINEERING

PLAN SUBGRADES
Geotechnical Bulletin GB1

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ROS-159-0.41-Marietta Connector
113013

SR 159 (Bridge Street) Corridor Safety Improvement

NEAS, Inc.

Prepared By: Derar M. Tarawneh
Date prepared: Monday, September 26, 2022

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
che@neasinc.com

NO. OF BORINGS: 3

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-027-0-22	Marietta Connector	13+62	4' RT	JH	CME 45B	73	624.1	622.6	1.5 C
2	B-028-0-22	Marietta Connector	16+57	0' LT	JH	CME 45B	73	624.9	623.4	1.5 C
3	B-029-0-22	Marietta Connector	18+58	21' RT	JH	CME 45B	73	626.0	624.5	1.5 C

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.6 2/11/2022

#	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	SS-1	1.5	3.0	0.0	1.5	13		4.25	32	16	16	31	29	60	15	16	A-6b	7	673					
	027-0	SS-2	3.0	4.5	1.5	3.0	8		3.25	32	16	16	28	29	57	18	16	A-6b	7			N_{60}			
	22	SS-3	4.5	6.0	3.0	4.5	5		2.5							17	16	A-6b	16						
		SS-4	6.0	7.5	4.5	6.0	24	5								6	6	A-1-b	0						
2	B	SS-1	0.0	1.5	-1.5	0.0	13						22	18	40	9	10	A-4a	6	0					
	028-0	SS-2	1.5	3.0	0.0	1.5	10									10	10	A-4a	8			N_{60}		12''	
	22	SS-3	3.0	4.5	1.5	3.0	7						18	18	36	11	10	A-4a	4			N_{60}			
		SS-4	4.5	6.0	3.0	4.5	18	7								7	6	A-1-b	0						
3	B	SS-1	1.5	3.0	0.0	1.5	21						21	9	30	9	10	A-2-4	0	40					
	029-0	SS-2	3.0	4.5	1.5	3.0	8			34	17	17	13	21	34	15	10	A-2-6	1			N_{60} & Mc			
	22	SS-3	4.5	6.0	3.0	4.5	12									16	10	A-2-6	4						
		SS-4	6.0	7.5	4.5	6.0	18	8								6	6	A-1-b	0						

PID: 113013

County-Route-Section: ROS-159-0.41-Marietta Connector
No. of Borings: 3

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh
Date prepared: 9/26/2022

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	 18" 0"
Global Geogrid Average(N60L): Average(HP):	 0" 0"

Design CBR	8

% Samples within 6 feet of subgrade			
$N_{60} \leq 5$	9%	HP ≤ 0.5	0%
$N_{60} < 12$	46%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	18%	1 < HP ≤ 2	0%
$N_{60} \geq 20$	18%	HP > 2	27%
M+	9%		
Rock	0%		
Unsuitable	0%		

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

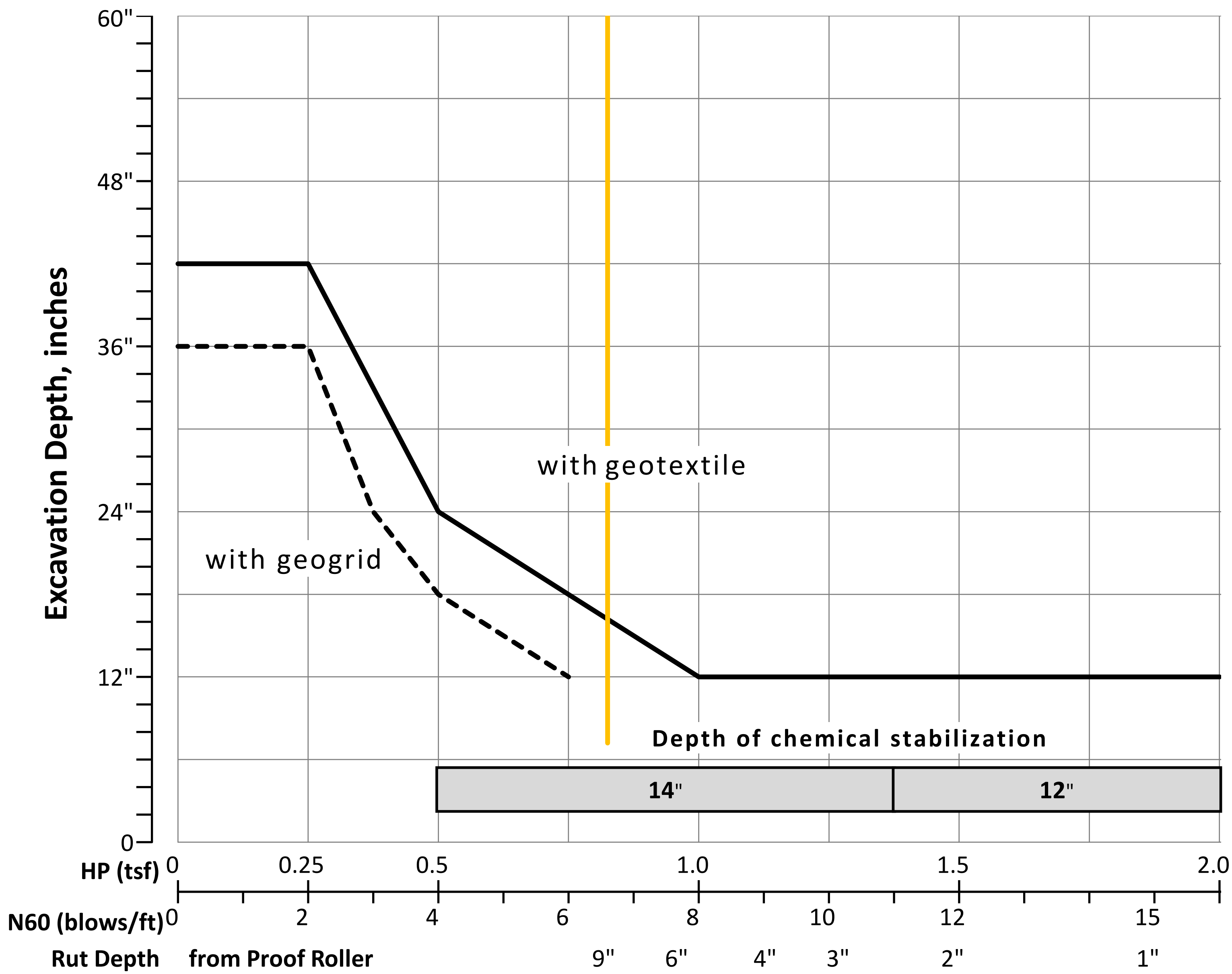
% Proposed Subgrade Surface	
Unstable & Unsuitable	57%
Unstable	57%
Unsuitable	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	13	7	3.33	33	16	16	22	21	43	12	11	4
Maximum	24	8	4.25	34	17	17	31	29	60	18	16	16
Minimum	5	5	2.50	32	16	16	13	9	30	6	6	0

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	3	1	0	2	0	0	0	2	0	0	0	3	0	0	0	0	11
Percent	0%	0%	27%	9%	0%	18%	0%	0%	0%	18%	0%	0%	0%	27%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	73%									27%								100%
Surface Class Count	0	0	0	1	0	1	0	0	0	3	0	0	0	2	0	0	0	0	7
Surface Class Percent	0%	0%	0%	14%	0%	14%	0%	0%	0%	43%	0%	0%	0%	29%	0%	0%	0%	0%	100%

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
3.33	0.50	☐ HP
6.67	6.00	☐ N60L

Average HP

Average N_{60L}

MARIETTA ROAD SEGMENT

OHIO DEPARTMENT OF TRANSPORTATION

OFFICE OF GEOTECHNICAL ENGINEERING

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Geotechnical Bulletin GB1

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ROS-159-0.41-Marietta Rd
113013

SR 159 (Bridge Street) Corridor Safety Improvement

NEAS, Inc.

Prepared By: Derar M. Tarawneh
Date prepared: Monday, September 26, 2022

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
Columbus, OH 43231
614.714.0299 Ext 111
che@neasinc.com

NO. OF BORINGS: 1

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-030-0-22	Marietta Rd.	32+18	29' RT	JL	CME 45B	73	625.3	623.8	1.5 C

OHIO DEPARTMENT OF TRANSPORTATION

Subgrade Analysis

V. 14.6 2/11/2022

#	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	SS-1	1.0	2.5	-0.5	1.0	8									3	6	A-1-b	0						
	030-0	SS-2	3.0	4.5	1.5	3.0	7		3	34	16	18	16	23	39	16	16	A-6b	3	40		N_{60}			
	22	SS-3	4.5	6.0	3.0	4.5	11						20	6	26	9	8	A-3a	0						
		SS-4	6.0	7.5	4.5	6.0	21	7								7	8	A-3a	0						

PID: 113013

County-Route-Section: ROS-159-0.41-Marietta Rd
No. of Borings: 1

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh
Date prepared: 9/26/2022

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	 15" 0"
Global Geogrid Average(N60L): Average(HP):	 0" 0"

Design CBR	12

% Samples within 6 feet of subgrade			
$N_{60} \leq 5$	0%	$HP \leq 0.5$	0%
$N_{60} < 12$	75%	$0.5 < HP \leq 1$	0%
$12 \leq N_{60} < 15$	0%	$1 < HP \leq 2$	0%
$N_{60} \geq 20$	25%	$HP > 2$	25%
M+	0%		
Rock	0%		
Unsuitable	0%		

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

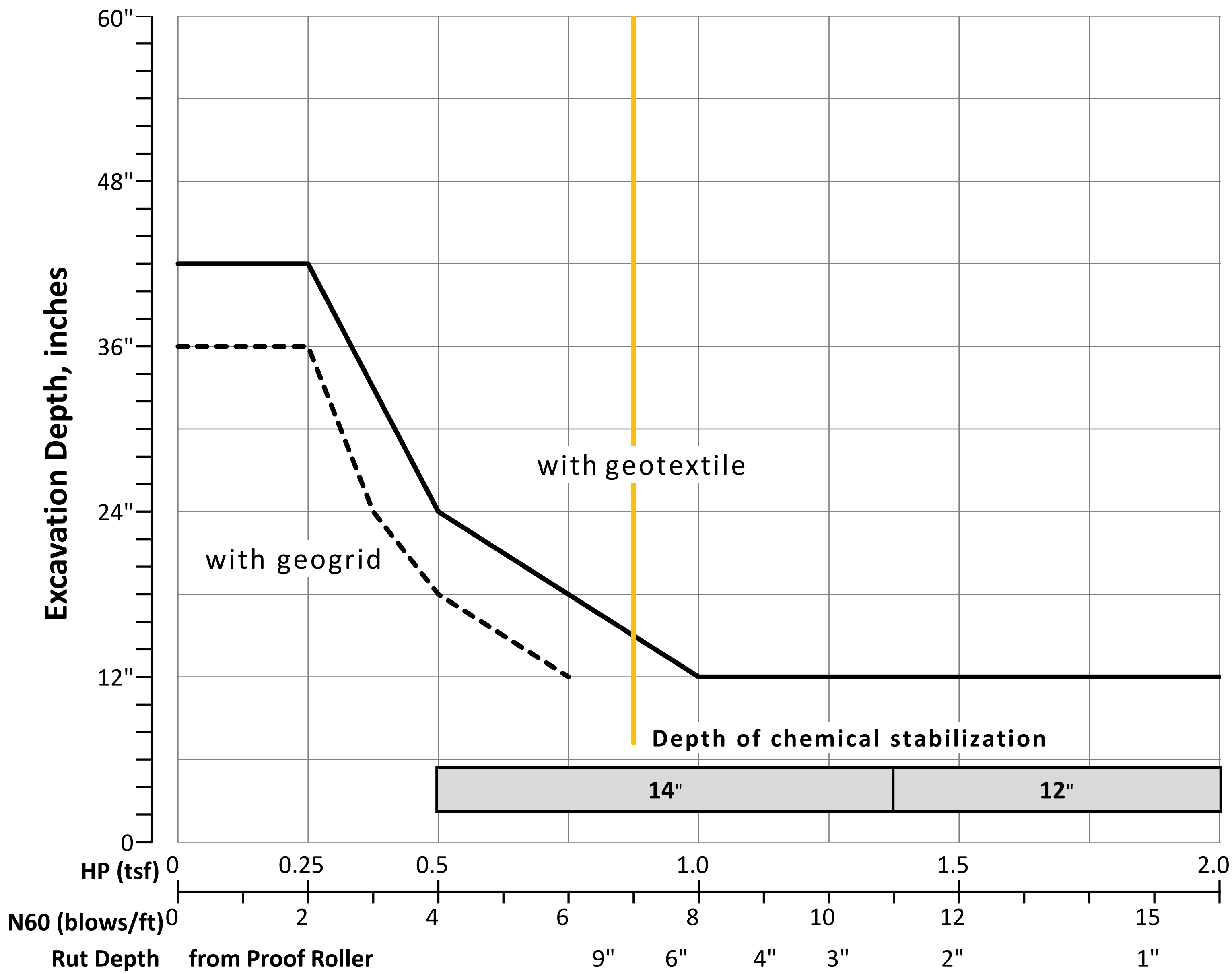
% Proposed Subgrade Surface	
Unstable & Unsuitable	50%
Unstable	50%
Unsuitable	0%

	N_{60}	N_{60L}	HP	LL	PL	PI	Silt	Clay	P 200	M_C	M_{OPT}	GI
Average	12	7	3.00	34	16	18	18	15	33	9	10	1
Maximum	21	7	3.00	34	16	18	20	23	39	16	16	3
Minimum	7	7	3.00	34	16	18	16	6	26	3	6	0

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	1	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	4
Percent	0%	0%	25%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	25%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	75%									25%								100%
Surface Class Count	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Surface Class Percent	0%	0%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	100%

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
3.00	0.50	☐ HP
7.00	6.00	☐ N60L

Average HP

Average N_{60L}

PAWNEE ROAD SEGMENT

OHIO DEPARTMENT OF TRANSPORTATION

OFFICE OF GEOTECHNICAL ENGINEERING

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ROS-159-0.41-Pawnee Rd
113013

SR 159 (Bridge Street) Corridor Safety Improvement

NEAS, Inc.

Prepared By: Derar M. Tarawneh
Date prepared: Monday, September 26, 2022

Chunmei (Melinda) He, Ph.D., P.E.
2800 Corporate Exchange Drive
Suite 240
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che@neasinc.com

NO. OF BORINGS: 1

#	Boring ID	Alignment	Station	Offset	Dir	Drill Rig	ER	Boring EL.	Proposed Subgrade EL	Cut Fill
1	B-031-0-22	Pawnee Rd.	52+07	20' RT	JL	CME 45B	73	622.9	621.4	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 031-0 22	SS-1	1.5	3.0	0.0	1.5	6						14	10	24	10	6	A-1-b	0	60					
		SS-2	3.0	4.5	1.5	3.0	8						22	13	35	11	10	A-2-4	0			N_{60}			
		SS-3	4.5	6.0	3.0	4.5	48									11	6	A-1-b	0						
		SS-4	6.0	7.5	4.5	6.0	67	6								8	6	A-1-b	0						

PID: 113013

County-Route-Section: ROS-159-0.41-Pawnee Rd
No. of Borings: 1

Geotechnical Consultant: NEAS, Inc.
Prepared By: Derar M. Tarawneh
Date prepared: 9/26/2022

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

Excavate and Replace Stabilization Options	
Global Geotextile Average(N60L): Average(HP):	 18" 0"
Global Geogrid Average(N60L): Average(HP):	 12" 0"

Design CBR	13

% Samples within 6 feet of subgrade			
$N_{60} \leq 5$	0%	HP ≤ 0.5	0%
$N_{60} < 12$	50%	0.5 < HP ≤ 1	0%
$12 \leq N_{60} < 15$	0%	1 < HP ≤ 2	0%
$N_{60} \geq 20$	50%	HP > 2	0%
M+	0%		
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	32	6	NP	0	0	0	18	12	30	10	7	0
Maximum	67	6	NP	0	0	0	22	13	35	11	10	0
Minimum	6	6	NP	0	0	0	14	10	24	8	6	0

Classification Counts by Sample

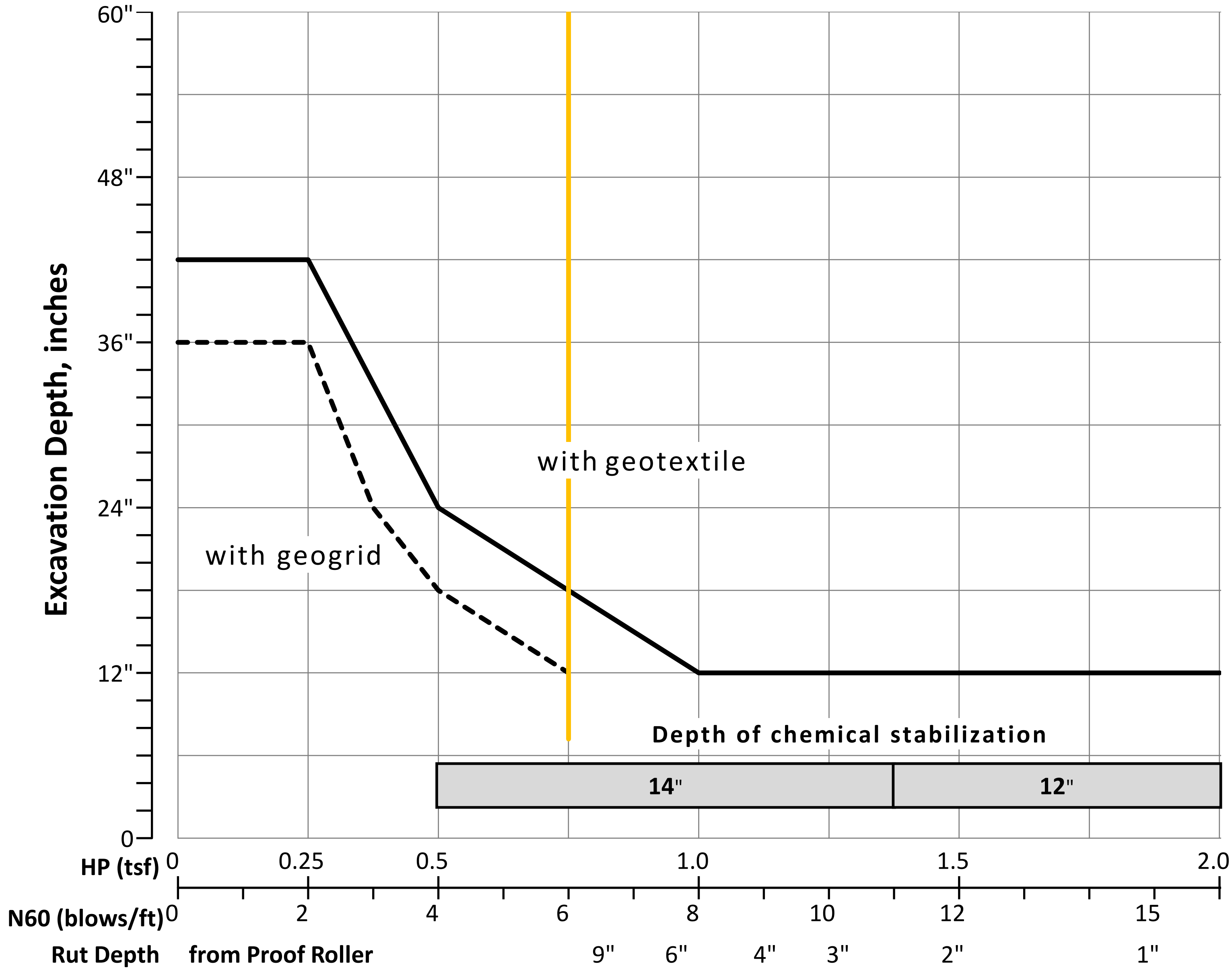
ODOT Class	Rock	A-1-a	A-1-b	A-2-4	A-2-5	A-2-6	A-2-7	A-3	A-3a	A-4a	A-4b	A-5	A-6a	A-6b	A-7-5	A-7-6	A-8a	A-8b	Totals
Count	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Percent	0%	0%	75%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
% Rock|Granular|Cohesive	0%	100%									0%								100%
Surface Class Count	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Surface Class Percent	0%	0%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%

Ohio Department of Transportation

Subgrade Analysis

V. 14.6 2/11/2022

GB1 Figure B – Subgrade Stabilization



OVERRIDE TABLE

Calculated Average	New Values	Check to Override
NP	0.50	☐ HP
6.00	6.00	☐ N60L

Average HP

Average N_{60L}

APPENDIX D

WALL 1 ANALYSES

Objective: To evaluate the bearing resistance of shallow foundation on level soil.
Method: In accordance with ODOT Bridge Design Manual, 2022 [Sect. 305.2] and LRFD Bridge Design Specifications, 9th Ed., 2020, [Sect. 10.6.3.1.2].

Givens:

Soil Design Parameters (Average Below Footing):

Drained Conditions (Effective Stress):

$\phi'_{fd} := 27\ deg$ — Effective angle of internal friction

$\gamma_{fd} := 118\ \frac{lbf}{ft^3}$ — Unit weight

$c'_{fd} := 300\ \frac{lbf}{ft^2}$ — Effective Cohesion

Undrained Conditions (Total Stress):

$\phi_{fdu} := 0\ deg$ — Angle of internal friction (Same as Drained Conditions if Sand)

$Su_{fdu} := 3550\ \frac{lbf}{ft^2}$ — Undrained Shear Strength

Undercut & Replacement Design Parameters:

$\phi_{Re} := 34\ deg$ — Angle of internal friction for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$c_{Re} := 0\ \frac{lbf}{ft^2}$ — Cohesion for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$\gamma_{Re} := 130\ \frac{lbf}{ft^3}$ — Unit Weight for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$\delta_{Re} := 0.67 \cdot \phi_{Re}$ $\quad \delta_{Re} = 22.8\ deg$ — Friction angle between Replacement soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

$D_{undercut} := 0\ ft$ — Depth of Undercut below bottom of footing

Foundation Surcharge Soil Parameters:

$\gamma_q := 110\ \frac{lbf}{ft^3}$ — Unit weight of Soil above bearing depth (Used in Bearing Resistance of Soil Calculation LRFD 10.6.3.1.2a-1)

Footing Geometry:

$D_f := 1.5\ ft$ — Footing cover at Toe
Note: Unless on rock, top of footing should be at least 1-ft from soil surface and bottom of footing at least 5-ft from nearest soil surface per BDM 202.2.3.1a

$D_F := D_f + D_{undercut}$ — Embenment Depth at bottom of Undercut

$B := 5\ ft$ — Footing base width

$B' := B$ — Footing effective base width

$L' := 269.40\ ft$ — Footing effective length

$d_w := D_f$ — Depth of groundwater below ground surface

Compute Bearing Resistance:

Drained Conditions (Effective Stress):

$$N_q := \text{if}\left(\phi'_{fd} > 0, e^{\pi \cdot \tan(\phi'_{fd})} \cdot \tan\left(45\ deg + \frac{\phi'_{fd}}{2}\right)^2, 1.0\right) \qquad N_q = 13.2$$

$$N_c := \text{if}\left(\phi'_{fd} > 0, \frac{N_q - 1}{\tan(\phi'_{fd})}, 5.14\right) \qquad N_c = 23.94$$

$$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi'_{fd}) \qquad N_\gamma = 14.5$$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$$s_c := \text{if}\left(\phi'_{fd} > 0, 1 + \left(\frac{B'}{L'}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L'}\right)\right) \qquad s_c = 1.01$$

$$s_q := \text{if}\left(\phi'_{fd} > 0, 1 + \left(\frac{B'}{L'} \cdot \tan(\phi'_{fd})\right), 1\right) \qquad s_q = 1.009$$

$$s_\gamma := \text{if}\left(\phi'_{fd} > 0, 1 - 0.4 \cdot \left(\frac{B'}{L'}\right), 1\right) \qquad s_\gamma = 0.993$$

Load inclination factors:

$i_q := 1$

$i_\gamma := 1$

$i_c := 1$

Assumed to be 1.0, see **LRFD BDS C10.6.3.1.2a**. "Most geotechnical engineers do not used the load inclination factors". If desired, use LRFD Equations [10.6.3.1.2a-5] thru [10.6.3.1.2a-9].

Compute groundwater depth correction factors per **LRFD [Table 10.6.3.1.2a-2]**:

$$C_{wq} := \text{if}(d_w \ge D_f, 1.0, 0.5) \qquad C_{wq} = 1$$

$$C_{w\gamma} := \text{if}(d_w \ge (1.5 \cdot B) + D_f, 1.0, 0.5) \qquad C_{w\gamma} = 0.5$$

Depth Correction Factor per ODOT BDM 305.2.1:

$$d_q := 1 + 2 \cdot \tan(\phi'_{fd}) \cdot (1 - \sin(\phi'_{fd}))^2 \cdot \text{atan}\left(\frac{D_F}{B'}\right)$$

$d_q = 1.09$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$$N_{cm} := N_c \cdot s_c \cdot i_c \qquad N_{cm} = 24.187$$

$$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q \qquad N_{qm} = 14.504$$

$$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma \qquad N_{\gamma m} = 14.362$$

Compute nominal bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.2a-1]:**

$$q_{nd} := c'_{fd} \cdot N_{cm} + \gamma_q \cdot D_F \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot \gamma_{fd} \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma} \qquad q_{nd} = 11767.7\ \frac{lbf}{ft^2}$$

Compute factored bearing resistance, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := 0.5$

Bearing resistance factor **LRFD Table Table 10.5.5.2.2-1**

$q_{Rd} := \phi_b \cdot q_{nd}$ $\quad q_{Rd} = 5.9\ ksf$

Factored bearing resistance Drained Conditions

Undrained Conditions (Effective Stress):

$$N_q := \text{if}\left(\phi_{fdu} > 0, e^{\pi \cdot \tan(\phi_{fdu})} \cdot \tan\left(45\ deg + \frac{\phi_{fdu}}{2}\right)^2, 1.0\right) \qquad N_q = 1$$

$$N_c := \text{if}\left(\phi_{fdu} > 0, \frac{N_q - 1}{\tan(\phi_{fdu})}, 5.14\right) \qquad N_c = 5.14$$

$$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi_{fdu}) \qquad N_\gamma = 0$$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$$s_c := \text{if}\left(\phi_{fdu} > 0, 1 + \left(\frac{B'}{L'}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L'}\right)\right) \qquad s_c = 1.004$$

$$s_q := \text{if}\left(\phi_{fdu} > 0, 1 + \left(\frac{B'}{L'} \cdot \tan(\phi_{fdu})\right), 1\right) \qquad s_q = 1$$

$$s_\gamma := \text{if}\left(\phi_{fdu} > 0, 1 - 0.4 \cdot \left(\frac{B'}{L'}\right), 1\right) \qquad s_\gamma = 1$$

Load inclination factors:

$i_q := 1$

$i_\gamma := 1$

$i_c := 1$

Assumed to be 1.0, see **LRFD BDS C10.6.3.1.2a**. "Most geotechnical engineers do not used the load inclination factors". If desired, use LRFD Equations [10.6.3.1.2a-5] thru [10.6.3.1.2a-9].

Depth Correction Factor per ODOT BDM 305.2.1:

$$d_q := 1 + 2 \cdot \tan(\phi_{fdu}) \cdot (1 - \sin(\phi_{fdu}))^2 \cdot \text{atan}\left(\frac{D_F}{B'}\right)$$

$d_q = 1$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$$N_{cm} := N_c \cdot s_c \cdot i_c \qquad N_{cm} = 5.159$$

$$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q \qquad N_{qm} = 1$$

$$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma \qquad N_{\gamma m} = 0$$

Compute nominal bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.2a-1]:**

$$q_{nu} := Su_{fdu} \cdot N_{cm} + \gamma_q \cdot D_F \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot \gamma_{fd} \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma} \qquad q_{nu} = 18479.7\ \frac{lbf}{ft^2}$$

Compute factored bearing resistance, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := 0.5$

Bearing resistance factor **LRFD Table 10.5.5.2.2-1**

$q_{Ru} := \phi_b \cdot q_{nu}$ $\quad q_{Ru} = 9.2\ \textbf{ksf}$

Factored bearing resistance Undrained Conditions

Factored Bearing Resistance Drained vs. Undrained Conditions:

Drained Conditions: $q_{Rd} = 5.9\ \textbf{ksf}$

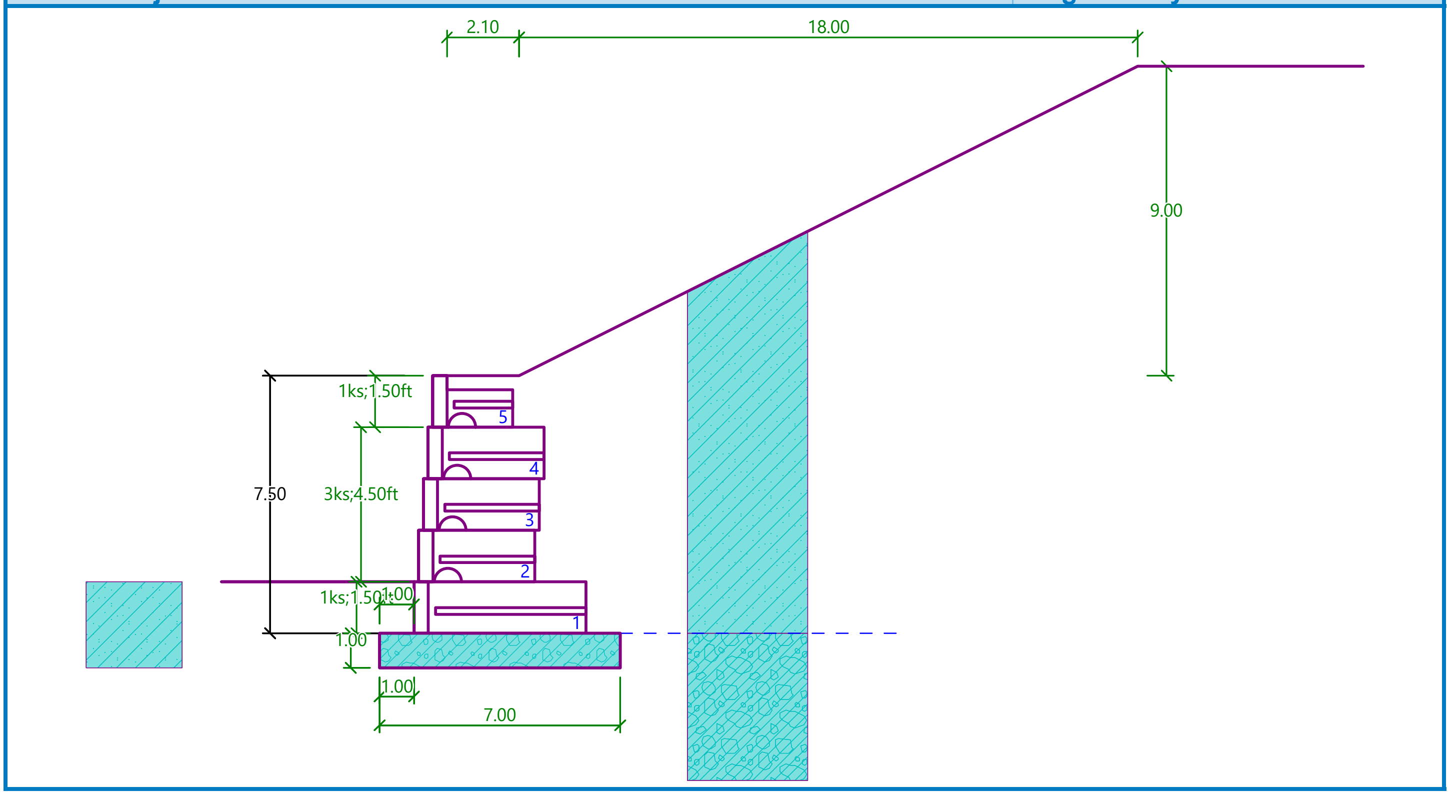
Undrained Conditions: $q_{Ru} = 9.2\ \textbf{ksf}$

Analysis of Redi Rock wall

Input data

Description : Drained Condition- Effective
Author : DT
Date : 11/20/2023
Project ID : ROS-159-0.41
Project number : Wall 1

Name : Project | **Stage - analysis : 1 - 0**



Settings

(input for current task)

Wall analysis

Verification methodology : according to LRFD
Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Coulomb
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Calculate as skew
Allowable eccentricity : 0.333
Internal stability : Standard - straight slip surface
Reduction coeff. of contact first block - base : 1.00

Load factors					
Design situation - Strength I					
		Minimum		Maximum	
Dead load of structural components :	DC =	0.90	[–]	1.25	[–]
Dead load of wearing surfaces :	DW =	0.65	[–]	1.50	[–]

DT

Load factors				
Design situation - Strength I				
Earth pressure - active :	EH_A =	0.90 [–]		1.50 [–]
Earth pressure - at rest :	EH_R =	0.90 [–]		1.35 [–]
Earth surcharge load (permanent) :	ES =	0.75 [–]		1.50 [–]
Vertical pressure of earth fill :	EV =	1.00 [–]		1.35 [–]
Live load surcharge :	LL =	0.00 [–]		1.75 [–]
Water load :	WA =	1.00 [–]		1.00 [–]

Resistance factors		
Design situation - Strength I		
Resistance factor on overturning :	ϕ_o =	0.90 [–]
Resistance factor on sliding :	ϕ_t =	0.90 [–]
Resistance factor on bearing capacity :	ϕ_b =	0.45 [–]
Resistance factor on passive pressure :	ϕ_{VE} =	0.50 [–]

Blocks

No.	Description	Height h [in]	Width w [in]	Unit weight γ [pcf]
1	Block 28	18.00	28.00	120.00
2	Block 41	18.00	40.50	120.00
3	Block 60	18.00	60.00	130.00
4	Top block 24 straight	18.00	24.00	108.00
5	Planter 41	18.00	40.50	120.00
6	Planter 60	18.00	60.00	112.00
7	Top block 28	18.00	28.00	120.00
8	Top block 41	18.00	40.50	120.00
9	Top block 24 straight garden	18.00	24.00	80.00
10	Block R-5236 HC	36.00	52.00	110.00
11	Block R-7236 HC	36.00	72.00	110.00
12	Block R-9636 HC	36.00	96.00	110.00
13	Block R-41 HC	18.00	40.50	110.00

No.	Description	Min. shear strength F_{min} [lbf/ft]	Max. shear strength F_{max} [lbf/ft]	Friction f [°]
1	Block 28	6061.00	11276.00	44.00
2	Block 41	6061.00	11276.00	44.00
3	Block 60	6061.00	11276.00	44.00
4	Top block 24 straight	6061.00	11276.00	44.00
5	Planter 41	6061.00	11276.00	44.00
6	Planter 60	6061.00	11276.00	44.00
7	Top block 28	6061.00	11276.00	44.00
8	Top block 41	6061.00	11276.00	44.00
9	Top block 24 straight garden	6061.00	11276.00	44.00
10	Block R-5236 HC	4550.00	12000.00	44.00
11	Block R-7236 HC	4550.00	12000.00	44.00

DT

No.	Description	Min. shear strength F_{min} [lbf/ft]	Max. shear strength F_{max} [lbf/ft]	Friction f [°]
12	Block R-9636 HC	4550.00	12000.00	44.00
13	Block R-41 HC	5358.00	12906.00	37.00

Setbacks

No.	Setback s [in]
1	0.010
2	0.375
3	1.625
4	9.375
5	16.625

Geometry

No. group	Description	Count	Setback s [in]
1	Block 60	1	1.62
2	Block 41	3	1.62
3	Top block 28	1	-

Base

Geometry

Upper setback a_1 = 1.00 ft
Lower setback a_2 = 1.00 ft
Height h = 1.00 ft
Width b = 7.00 ft

Material

Soil creating foundation - Leveling

Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [psf]	γ [pcf]	γ_{su} [pcf]	δ [°]
1	Soil 1		30.00	0.0	120.00	57.50	20.00
2	Bearing		27.00	300.0	118.00	65.50	18.00
3	Leveling		34.00	0.0	120.00	57.50	22.70

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

Soil 1

Unit weight : γ = 120.0 pcf
Stress-state : effective
Angle of internal friction : φ_{ef} = 30.00 °
Cohesion of soil : c_{ef} = 0.0 psf
Angle of friction struc.-soil : δ = 20.00 °
Saturated unit weight : γ_{sat} = 120.0 pcf

Bearing

Unit weight :	γ = 118.0 pcf
Stress-state :	effective
Angle of internal friction :	φ_{ef} = 27.00 °
Cohesion of soil :	c_{ef} = 300.0 psf
Angle of friction struc.-soil :	δ = 18.00 °
Saturated unit weight :	γ_{sat} = 128.0 pcf

Leveling

Unit weight :	γ = 120.0 pcf
Stress-state :	effective
Angle of internal friction :	φ_{ef} = 34.00 °
Cohesion of soil :	c_{ef} = 0.0 psf
Angle of friction struc.-soil :	δ = 22.70 °
Saturated unit weight :	γ_{sat} = 120.0 pcf

Backfill

Backfill is not considered.

Geological profile and assigned soils

No.	Thickness of layer t [ft]	Depth z [ft]	Assigned soil	Pattern
1	7.50	0.00 .. 7.50	Soil 1	
2	-	7.50 .. ∞	Bearing	

Terrain profile

No.	Coordinates x [ft]	Depth z [ft]
1	0.00	0.00
2	2.10	0.00
3	20.10	-9.00
4	21.10	-9.00

Origin [0,0] is located in upper right edge of construction.
Positive coordinate +z has downward direction.

Water influence

GWT behind the structure lies at a depth of 7.50 ft
Uplift in foot. bottom due to different pressures is not considered.

Resistance on front face of the structure

Resistance on front face of the structure: not considered
Soil on front face of the structure - Soil 1
Soil thickness in front of structure h = 2.50 ft

Terrain in front of structure is flat.

Settings of the stage of construction

Design situation : Strength I
Reduction of soil/soil friction angle : reduce to 2/3 φ (AASHTO)

DT

Verification No. 1

Forces acting on construction

Name	F_{hor} [lbf/ft]	App.Pt. z [ft]	F_{vert} [lbf/ft]	App.Pt. x [ft]	Coeff. overtur.	Coeff. sliding	Coeff. stress
Weight - wall	0.0	-3.36	3965.6	3.19	0.900	0.900	1.250
Weight - earth wedge	0.0	-4.98	1140.7	5.09	1.000	1.000	1.350
Active pressure	2788.3	-3.23	1905.1	6.28	1.500	1.500	1.500
Water pressure	31.2	-0.33	0.0	4.72	1.000	1.000	1.000
Uplift pressure	0.0	-8.50	0.0	1.96	1.000	1.000	1.000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 31619.3 lbfft/ft
Overturning moment M_{ovr} = 13512.9 lbfft/ft

Capacity demand ratio CDR = 2.34
Wall for overturning is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 5012.97 lbf/ft
Active horizontal force H_{act} = 4213.63 lbf/ft

Capacity demand ratio CDR = 1.19
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Dimensioning No. 1

Forces acting on construction

Name	F_{hor} [lbf/ft]	App.Pt. z [ft]	F_{vert} [lbf/ft]	App.Pt. x [ft]	Coeff. overtur.	Coeff. sliding	Coeff. stress
Weight - wall	0.0	-0.75	328.1	1.17	0.900	0.900	1.250
Weight - earth wedge	0.0	-1.29	89.9	1.32	1.000	1.000	1.350
Active pressure	52.2	-0.48	22.3	2.32	0.900	1.500	1.500
Water pressure	0.0	-1.50	0.0	2.10	1.000	1.000	1.000

Verification of block No. 5

Check for overturning stability

Resisting moment M_{res} = 458.6 lbfft/ft
Overturning moment M_{ovr} = 22.4 lbfft/ft

Capacity demand ratio CDR = 20.52
Joint for overturning stability is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 5818.84 lbf/ft
Active horizontal force H_{act} = 78.26 lbf/ft

Capacity demand ratio CDR = 74.36
Joint for verification is SATISFACTORY

Bearing capacity of foundation soil

Design load acting at the center of footing bottom

DT

No.	Moment [lbfft/ft]	Norm. force [lbf/ft]	Shear Force [lbf/ft]	Eccentricity [–]	Stress [psf]
1	4667.9	9354.68	4213.63	0.071	1558.6
2	4866.5	7567.45	4213.63	0.092	1324.4

Service load acting at the center of footing bottom

No.	Moment [lbfft/ft]	Norm. force [lbf/ft]	Shear Force [lbf/ft]
1	3141.8	7011.46	2819.51

Verification of foundation soil

Stress in the footing bottom : rectangle

Eccentricity verification

Max. eccentricity of normal force e = 0.092
Maximum allowable eccentricity e_{alw} = 0.333

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Bearing capacity of foundation soil R = 11767.7 psf
Partial factor on bearing capacity γ_{Rv} = 0.45
Max. stress at footing bottom σ = 1558.6 psf
Bearing capacity of foundation soil R_d = 5295.5 psf
Capacity demand ratio CDR = 3.4

Bearing capacity of foundation soil is SATISFACTORY

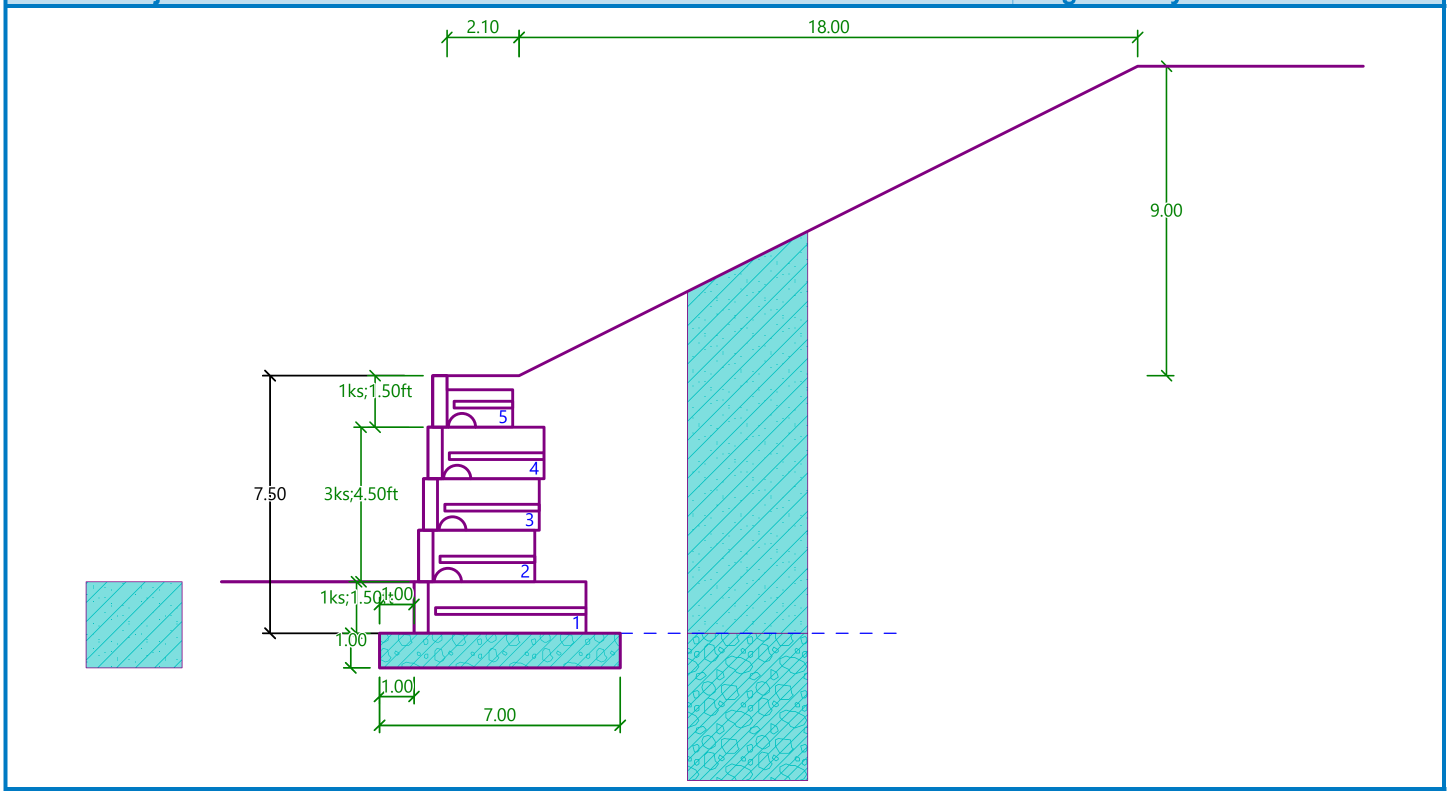
Overall verification - bearing capacity of found. soil is SATISFACTORY

Analysis of Redi Rock wall

Input data

Description : Drained Condition- Total
Author : DT
Date : 11/20/2023
Project ID : ROS-159-0.41
Project number : Wall 1

Name : Project	Stage - analysis : 1 - 0



Settings

(input for current task)

Wall analysis

Verification methodology : according to LRFD
Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Coulomb
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Calculate as skew
Allowable eccentricity : 0.333
Internal stability : Standard - straight slip surface
Reduction coeff. of contact first block - base : 1.00

Load factors					
Design situation - Strength I					
		Minimum		Maximum	
Dead load of structural components :	DC =	0.90	[–]	1.25	[–]
Dead load of wearing surfaces :	DW =	0.65	[–]	1.50	[–]

DT

Load factors					
Design situation - Strength I					
Earth pressure - active :	EH_A =	0.90	[–]	1.50	[–]
Earth pressure - at rest :	EH_R =	0.90	[–]	1.35	[–]
Earth surcharge load (permanent) :	ES =	0.75	[–]	1.50	[–]
Vertical pressure of earth fill :	EV =	1.00	[–]	1.35	[–]
Live load surcharge :	LL =	0.00	[–]	1.75	[–]
Water load :	WA =	1.00	[–]	1.00	[–]

Resistance factors			
Design situation - Strength I			
Resistance factor on overturning :	ϕ_o =	0.90	[–]
Resistance factor on sliding :	ϕ_t =	0.90	[–]
Resistance factor on bearing capacity :	ϕ_b =	0.45	[–]
Resistance factor on passive pressure :	ϕ_{VE} =	0.50	[–]

Blocks

No.	Description	Height h [in]	Width w [in]	Unit weight γ [pcf]
1	Block 28	18.00	28.00	120.00
2	Block 41	18.00	40.50	120.00
3	Block 60	18.00	60.00	130.00
4	Top block 24 straight	18.00	24.00	108.00
5	Planter 41	18.00	40.50	120.00
6	Planter 60	18.00	60.00	112.00
7	Top block 28	18.00	28.00	120.00
8	Top block 41	18.00	40.50	120.00
9	Top block 24 straight garden	18.00	24.00	80.00
10	Block R-5236 HC	36.00	52.00	110.00
11	Block R-7236 HC	36.00	72.00	110.00
12	Block R-9636 HC	36.00	96.00	110.00
13	Block R-41 HC	18.00	40.50	110.00

No.	Description	Min. shear strength F_{min} [lbf/ft]	Max. shear strength F_{max} [lbf/ft]	Friction f [°]
1	Block 28	6061.00	11276.00	44.00
2	Block 41	6061.00	11276.00	44.00
3	Block 60	6061.00	11276.00	44.00
4	Top block 24 straight	6061.00	11276.00	44.00
5	Planter 41	6061.00	11276.00	44.00
6	Planter 60	6061.00	11276.00	44.00
7	Top block 28	6061.00	11276.00	44.00
8	Top block 41	6061.00	11276.00	44.00
9	Top block 24 straight garden	6061.00	11276.00	44.00
10	Block R-5236 HC	4550.00	12000.00	44.00
11	Block R-7236 HC	4550.00	12000.00	44.00

No.	Description	Min. shear strength F_{min} [lbf/ft]	Max. shear strength F_{max} [lbf/ft]	Friction f [°]
12	Block R-9636 HC	4550.00	12000.00	44.00
13	Block R-41 HC	5358.00	12906.00	37.00

Setbacks

No.	Setback s [in]
1	0.010
2	0.375
3	1.625
4	9.375
5	16.625

Geometry

No. group	Description	Count	Setback s [in]
1	Block 60	1	1.62
2	Block 41	3	1.62
3	Top block 28	1	-

Base

Geometry

Upper setback a_1 = 1.00 ft
Lower setback a_2 = 1.00 ft
Height h = 1.00 ft
Width b = 7.00 ft

Material

Soil creating foundation - Leveling

Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [psf]	γ [pcf]	γ_{su} [pcf]	δ [°]
1	Soil 1		30.00	0.0	120.00	57.50	20.00
2	Bearing		27.00	300.0	118.00	65.50	18.00
3	Leveling		34.00	0.0	120.00	57.50	22.70

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

Soil 1

Unit weight : γ = 120.0 pcf
Stress-state : effective
Angle of internal friction : φ_{ef} = 30.00 °
Cohesion of soil : c_{ef} = 0.0 psf
Angle of friction struc.-soil : δ = 20.00 °
Saturated unit weight : γ_{sat} = 120.0 pcf

Bearing

Unit weight : γ = 118.0 pcf
Stress-state : effective
Angle of internal friction : φ_{ef} = 27.00 °
Cohesion of soil : c_{ef} = 300.0 psf
Angle of friction struc.-soil : δ = 18.00 °
Saturated unit weight : γ_{sat} = 128.0 pcf

Leveling

Unit weight : γ = 120.0 pcf
Stress-state : effective
Angle of internal friction : φ_{ef} = 34.00 °
Cohesion of soil : c_{ef} = 0.0 psf
Angle of friction struc.-soil : δ = 22.70 °
Saturated unit weight : γ_{sat} = 120.0 pcf

Backfill

Backfill is not considered.

Geological profile and assigned soils

No.	Thickness of layer t [ft]	Depth z [ft]	Assigned soil	Pattern
1	7.50	0.00 .. 7.50	Soil 1	
2	-	7.50 .. ∞	Bearing	

Terrain profile

No.	Coordinates x [ft]	Depth z [ft]
1	0.00	0.00
2	2.10	0.00
3	20.10	-9.00
4	21.10	-9.00

Origin [0,0] is located in upper right edge of construction.
Positive coordinate +z has downward direction.

Water influence

GWT behind the structure lies at a depth of 7.50 ft
Uplift in foot. bottom due to different pressures is not considered.

Resistance on front face of the structure

Resistance on front face of the structure: not considered
Soil on front face of the structure - Soil 1
Soil thickness in front of structure h = 2.50 ft

Terrain in front of structure is flat.

Settings of the stage of construction

Design situation : Strength I
Reduction of soil/soil friction angle : reduce to 2/3 φ (AASHTO)

Verification No. 1

Forces acting on construction

Name	F_{hor} [lbf/ft]	App.Pt. z [ft]	F_{vert} [lbf/ft]	App.Pt. x [ft]	Coeff. overtur.	Coeff. sliding	Coeff. stress
Weight - wall	0.0	-3.36	3965.6	3.19	0.900	0.900	1.250
Weight - earth wedge	0.0	-4.98	1140.7	5.09	1.000	1.000	1.350
Active pressure	2788.3	-3.23	1905.1	6.28	1.500	1.500	1.500
Water pressure	31.2	-0.33	0.0	4.72	1.000	1.000	1.000
Uplift pressure	0.0	-8.50	0.0	1.96	1.000	1.000	1.000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 31619.3 lbfft/ft
Overturning moment M_{ovr} = 13512.9 lbfft/ft

Capacity demand ratio CDR = 2.34
Wall for overturning is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 5012.97 lbf/ft
Active horizontal force H_{act} = 4213.63 lbf/ft

Capacity demand ratio CDR = 1.19
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Dimensioning No. 1

Forces acting on construction

Name	F_{hor} [lbf/ft]	App.Pt. z [ft]	F_{vert} [lbf/ft]	App.Pt. x [ft]	Coeff. overtur.	Coeff. sliding	Coeff. stress
Weight - wall	0.0	-0.75	328.1	1.17	0.900	0.900	1.250
Weight - earth wedge	0.0	-1.29	89.9	1.32	1.000	1.000	1.350
Active pressure	52.2	-0.48	22.3	2.32	0.900	1.500	1.500
Water pressure	0.0	-1.50	0.0	2.10	1.000	1.000	1.000

Verification of block No. 5

Check for overturning stability

Resisting moment M_{res} = 458.6 lbfft/ft
Overturning moment M_{ovr} = 22.4 lbfft/ft

Capacity demand ratio CDR = 20.52
Joint for overturning stability is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 5818.84 lbf/ft
Active horizontal force H_{act} = 78.26 lbf/ft

Capacity demand ratio CDR = 74.36
Joint for verification is SATISFACTORY

Bearing capacity of foundation soil

Design load acting at the center of footing bottom

DT

No.	Moment [lbfft/ft]	Norm. force [lbf/ft]	Shear Force [lbf/ft]	Eccentricity [–]	Stress [psf]
1	4667.9	9354.68	4213.63	0.071	1558.6
2	4866.5	7567.45	4213.63	0.092	1324.4

Service load acting at the center of footing bottom

No.	Moment [lbfft/ft]	Norm. force [lbf/ft]	Shear Force [lbf/ft]
1	3141.8	7011.46	2819.51

Verification of foundation soil

Stress in the footing bottom : rectangle

Eccentricity verification

Max. eccentricity of normal force e = 0.092
Maximum allowable eccentricity e_{alw} = 0.333

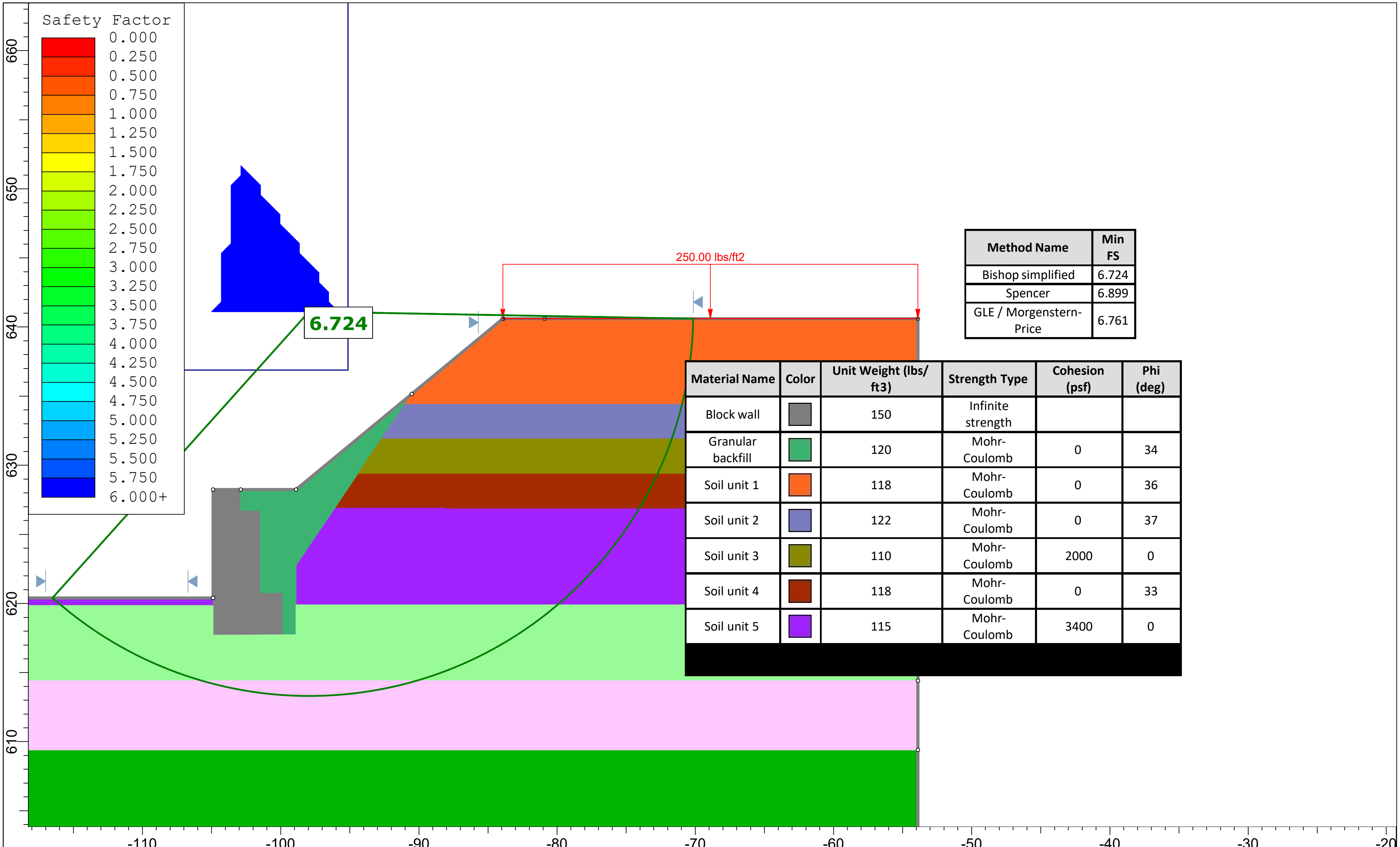
Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Bearing capacity of foundation soil R = 18479.7 psf
Partial factor on bearing capacity γ_{Rv} = 0.45
Max. stress at footing bottom σ = 1558.6 psf
Bearing capacity of foundation soil R_d = 8315.9 psf
Capacity demand ratio CDR = 5.3

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY



Method Name	Min FS
Bishop simplified	6.724
Spencer	6.899
GLE / Morgenstern-Price	6.761

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Block wall		150	Infinite strength		
Granular backfill		120	Mohr-Coulomb	0	34
Soil unit 1		118	Mohr-Coulomb	0	36
Soil unit 2		122	Mohr-Coulomb	0	37
Soil unit 3		110	Mohr-Coulomb	2000	0
Soil unit 4		118	Mohr-Coulomb	0	33
Soil unit 5		115	Mohr-Coulomb	3400	0

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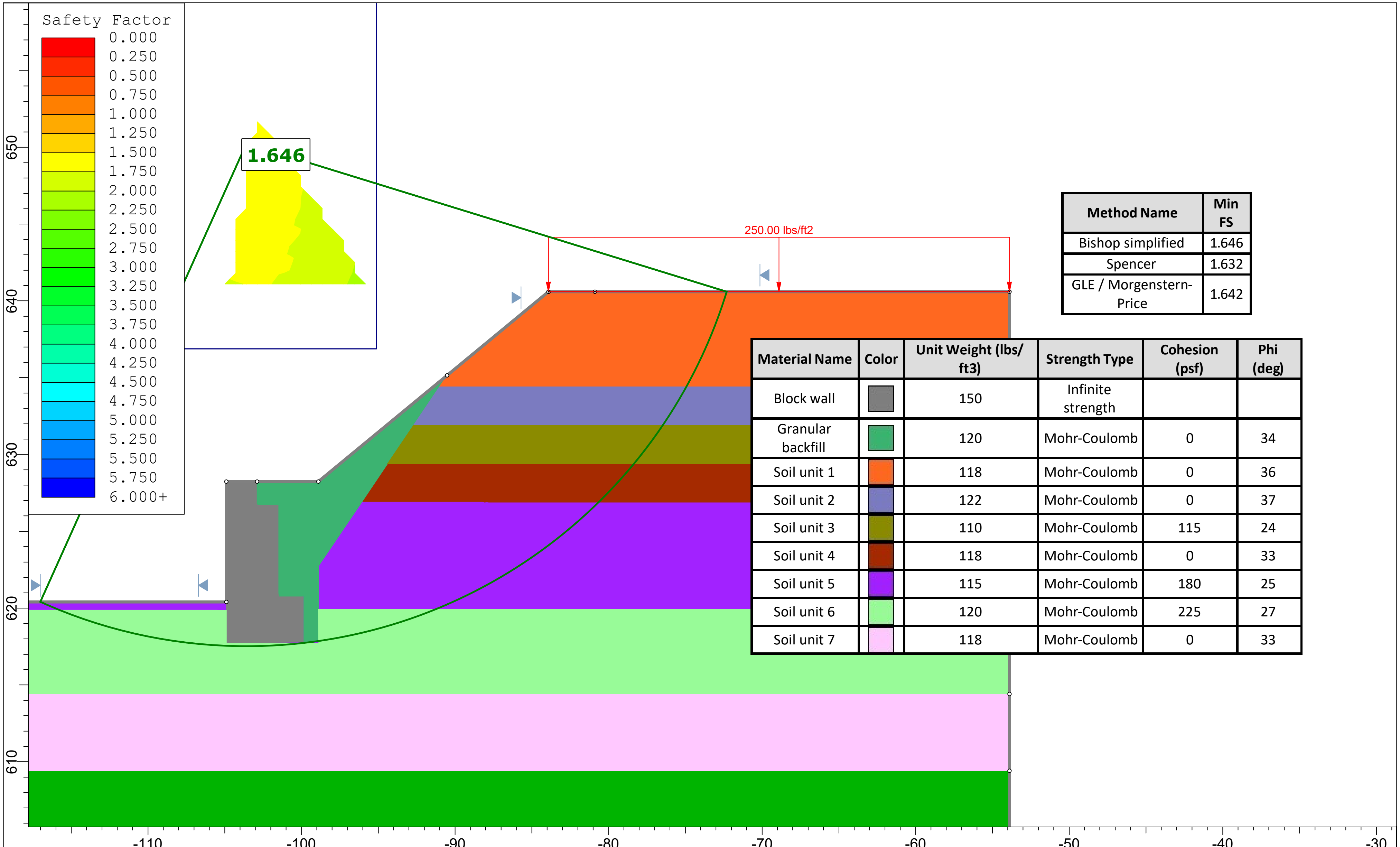
SLIDEINTERPRET 9.025

Project	ROS-159-0.41-Modular Block Wall-B-006		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	Derar Tarawneh	*Company*	NEAS Inc.
Date	01/19/2023, 10:04:20 AM	*File Name*	ROS-159-0.41_Wall_Short Term_Circular.slmd



Method Name	Min FS
Bishop simplified	1.646
Spencer	1.632
GLE / Morgenstern-Price	1.642

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Block wall		150	Infinite strength		
Granular backfill		120	Mohr-Coulomb	0	34
Soil unit 1		118	Mohr-Coulomb	0	36
Soil unit 2		122	Mohr-Coulomb	0	37
Soil unit 3		110	Mohr-Coulomb	115	24
Soil unit 4		118	Mohr-Coulomb	0	33
Soil unit 5		115	Mohr-Coulomb	180	25
Soil unit 6		120	Mohr-Coulomb	225	27
Soil unit 7		118	Mohr-Coulomb	0	33

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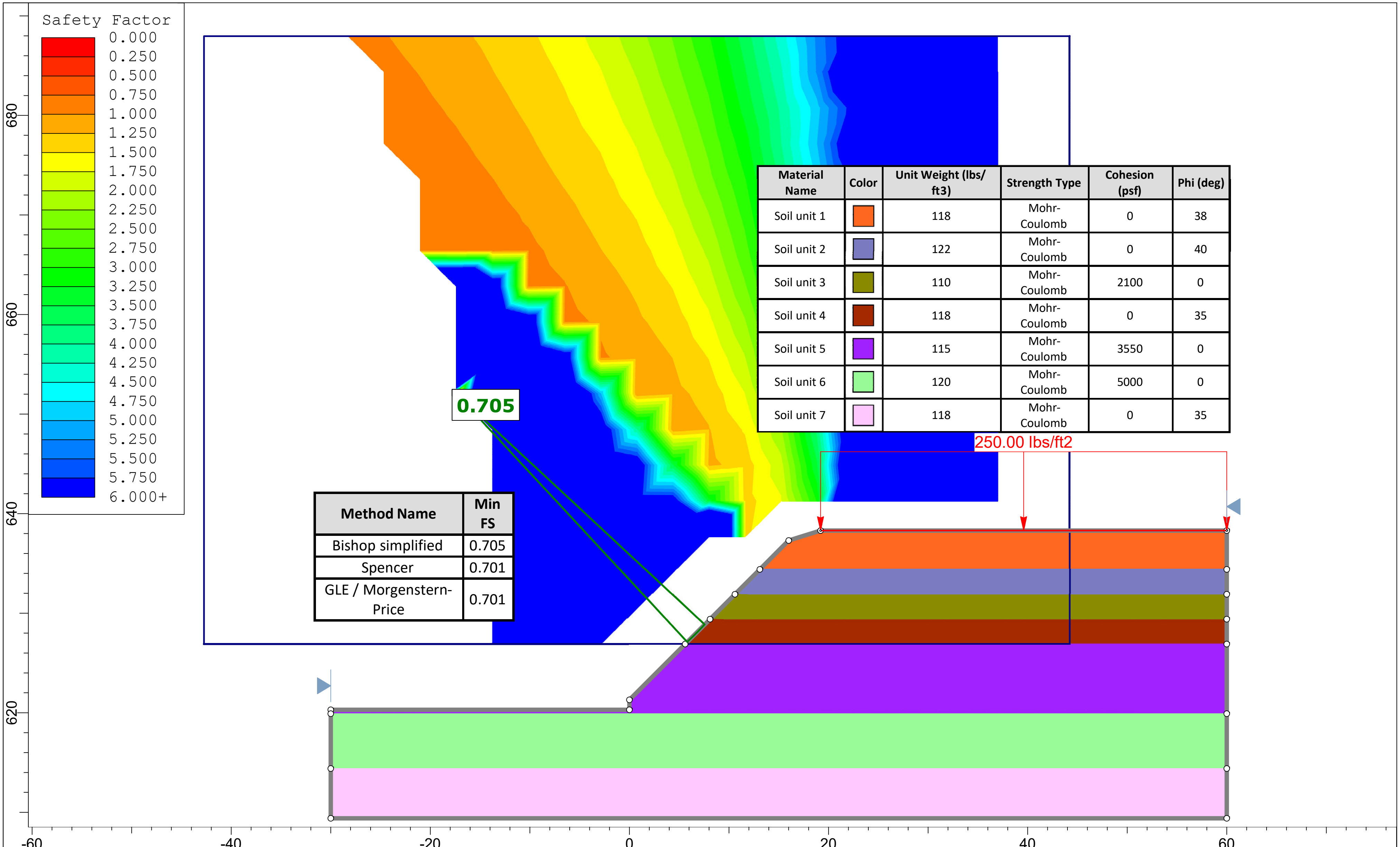
SLIDEINTERPRET 9.025

Project	ROS-159-0.41-Modular Block Wall-B-006		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	Derar Tarawneh	*Company*	NEAS Inc.
Date	01/19/2023, 10:04:20 AM	*File Name*	ROS-159-0.41_Wall_LongTerm_Circular.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Soil unit 1		118	Mohr-Coulomb	0	38
Soil unit 2		122	Mohr-Coulomb	0	40
Soil unit 3		110	Mohr-Coulomb	2100	0
Soil unit 4		118	Mohr-Coulomb	0	35
Soil unit 5		115	Mohr-Coulomb	3550	0
Soil unit 6		120	Mohr-Coulomb	5000	0
Soil unit 7		118	Mohr-Coulomb	0	35

Method Name	Min FS
Bishop simplified	0.705
Spencer	0.701
GLE / Morgenstern-Price	0.701

rocscience

SLIDEINTERPRET 9.025

Project	ROS-159-0.41-Wall 1 for Construction-B-006		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	Zhao Mankoci	*Company*	NEAS Inc.
Date	11/19/23	*File Name*	ROS-159-0.41_Wall 1_Construction_B-06.slmd

APPENDIX E

WALL 2 ANALYSES

Objective: **To evaluate the external stability of CIP wall design with broken backsloping backfill.**
Method: **In accordance with ODOT Bridge Design Manual, 2021 [Sect. 204.6.2.2] LRFD Bridge Design Specifications, 9th Ed., 2020, [Sect. 11.6.1, Sect. 11.6.2, and Sect. 11.6.3].**

Givens:

Backfill Soil Design Parameters:

$\phi'_f := 30\ deg$ — Effective angle of internal friction

$\gamma_f := 120\ \frac{lbf}{ft^3}$ — Unit weight

$c'_f := 0\ \frac{lbf}{ft^2}$ — Effective Cohesion

$\delta := 0.67 \cdot \phi'_f$ $\quad \delta = 20.1\ deg$ — Friction angle between backfill and wall taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

Foundation Soil Design Parameters:

Drained Conditions (Effective Stress):

$\phi'_{fd} := 30\ deg$ — Effective angle of internal friction

$\gamma_{fd} := 120\ \frac{lbf}{ft^3}$ — Unit weight

$c'_{fd} := 0\ \frac{lbf}{ft^2}$ — Effective Cohesion

$\delta_{fd} := 0.67 \cdot \phi'_{fd}$ $\quad \delta_{fd} = 20.1\ deg$ — Friction angle between foundation soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

Undrained Conditions (Total Stress):

$\phi_{fdu} := 30\ deg$ — Angle of internal friction (Same as Drained Conditions if granular soils)

$Su_{fdu} := 0\ \frac{lbf}{ft^2}$ — Undrained Shear Strength

$\delta_{fdu} := 0.67 \cdot \phi_{fdu}$ $\quad \delta_{fdu} = 20.1\ deg$ — Friction angle between foundation soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

Undercut & Replacement Design Parameters:

$\phi_{Re} := 34\ deg$ — Angle of internal friction for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$c_{Re} := 0\ \frac{lbf}{ft^2}$ — Cohesion for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$\gamma_{Re} := 130\ \frac{lbf}{ft^3}$ — Unit Weight for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$\delta_{Re} := 0.67 \cdot \phi_{Re}$ $\quad \delta_{Re} = 22.8\ deg$ — Friction angle between Replacement soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

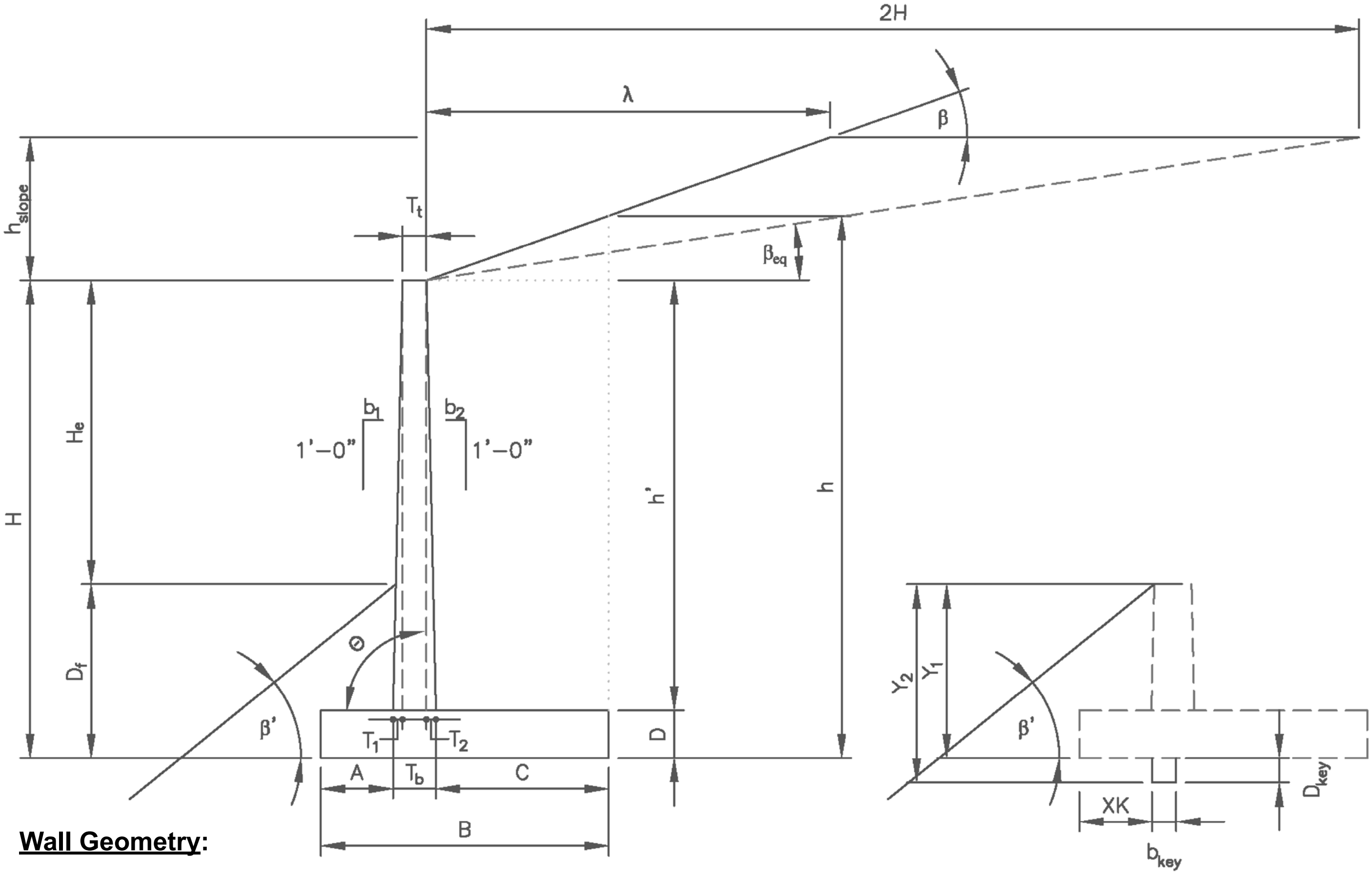
$D_{undercut} := 0\ ft$ — Depth of Undercut below bottom of footing

Foundation Surcharge Soil Parameters:

$\gamma_q := 120\ \frac{lbf}{ft^3}$ — Unit weight of Soil above bearing depth (Used in Bearing Resistance of Soil Calculation LRFD 10.6.3.1.2a-1)

Other Parameters:

$\gamma_c := 150\ \frac{lbf}{ft^3}$ — Concrete Unit weight



Wall Geometry:

$H_e := 3.9\ ft$ — Exposed wall height

$D_f := 6.9\ ft$ — Footing cover at Toe
Note: Where the potential for scour, erosion of undermining exists, spread footings shall be located to bear below the maximum depth of scour or undermining. Spread footings shall be located below the depth of potential frost. **LRFD BDS 10.6.1.2**

$H := H_e + D_f$ $\quad H = 10.8\ ft$ — Design Wall Height

$T_t := 14\ in$ — Stem thickness at top of wall

$b_1 := 0 \cdot \left(\frac{in}{ft}\right)$ — Frontwall batter, (b1H:12V)

$b_2 := 0 \cdot \left(\frac{in}{ft}\right)$ — Backwall batter, (b2H:12V)

Preliminary Wall Dimensioning:

$B := 8.5\ ft$ $\quad \frac{2}{5} \cdot H = 4.32\ ft$ to $\frac{3}{5} \cdot H = 6.48\ ft$ — Footing base width (2/5H to 3/5H)

$A := 0.917\ ft$ $\quad \frac{H}{8} = 1.35\ ft$ to $\frac{H}{5} = 2.16\ ft$ — Toe projection (H/8 to H/5)

$D := 1.5\ ft$ $\quad \frac{H}{8} = 1.35\ ft$ to $\frac{H}{5} = 2.16\ ft$ — Footing thickness (H/8 to H/5)

Shear Key Dimensioning:

$D_{key} := 0\ ft$ — Depth of shear key from bottom of footing
Note: Footings on rock typically require shear key

$b_{key} := 0\ ft$ — Width of shear key

$XK := 0\ ft$ — Distance from toe to shear key

Other Wall Dimensions:

$h' := H - D$	$h' = 9.3\ ft$	Stem height
$T_1 := b_1 \cdot h'$	$T_1 = 0\ ft$	Stem front batter width
$T_2 := b_2 \cdot h'$	$T_2 = 0\ ft$	Stem back batter width
$T_b := T_1 + T_2 + T_t$	$T_b = 1.167\ ft$	Stem thickness at bottom of wall
$C := B - A - T_b$	$C = 6.416\ ft$	Heel projection
$\theta := 90\ deg$		Angle of back face of wall to horizontal = *atan(12/b2)*
$b := 12\ in$	$b = 1\ ft$	Concrete strip width (for design)
$y_1 := D_f$	$y_1 = 6.9\ ft$	Depth to where passive pressure may begin to be utilized in front of wall.
$y_2 := D_f + D_{key}$	$y_2 = 6.9\ ft$	Bottom of shear key/footing depth i.e. depth to where passive pressure may no longer be utilized.

Site Grading and Slope Dimensions:

$\beta := 0\ deg$ — Inclination of ground slope behind face of wall. Horizontal backfill behind CIP wall, β = 0 deg

Inclination of ground slope:

- Horizontal: **0**
- 3H:1V: **18.435**
- 2H:1V: **26.565**
- 1.5H:1V: **33.690**

$\beta' := 18.435\ deg$ — Inclination of ground slope in front of wall. If it is horizontal backfill in front of CIP wall, β' = 0 deg. A negative angle (-) indicates grades slope up from front of wall. Positive angle (+) indicates grade slope down from wall as shown in above figure.

$\lambda := 0\ ft$ — Horizontal distance from the back of the wall to point of slope crest .

$L_{Traffic} := 0\ ft$ — Horizontal distance from assumed traffic surcharge load to Backface of Wall.

$2 \cdot H = 21.6\ ft$ — **IF λ IS GREATER THAN 2*H - USE INFINITE SLOPE CALCULATION SHEET**

$h_{slope} := \lambda \cdot \tan(\beta)$	$h_{slope} = 0\ ft$	Height of broken slope behind wall
$\beta_{eq} := \operatorname{atan}\left(\dfrac{h_{slope}}{2 \cdot H}\right) = 0\ deg$		Equivalent backslope angle
$h := \text{if}\left(\lambda \le T_2 + C, H + h_{slope}, H + (T_2 + C) \cdot \tan(\beta)\right) = 10.8\ ft$		Height of retained fill at back of heel

Live Load Surcharge Parameters:

$$SUR := \text{if}\left(L_{Traffic} < \frac{H}{2}, 90\ \frac{lbf}{ft^2}, 0\ \frac{lbf}{ft^2}\right) = 90\ \frac{lbf}{ft^2}$$

Live load surcharge (per LRFD BDS [3.11.6.4])
Note: ,A live load ssurcharge shall be applied where vehicular load is expected to act on the surface of the backfill within a distance equal to one-half the wall height behind the back face of the wall, see LRFD BDS Section 3.11.6.4 and Table 3.11.6.4-2 .

Calculations:

Earth Pressure Coefficients:

Backfill Active Earth:

$$\Gamma := \left(1 + \sqrt{\frac{\left(\sin\left(\phi'_f + \delta\right) \cdot \sin\left(\phi'_f - \beta_{eq}\right)\right)}{\left(\sin\left(\theta - \delta\right) \cdot \sin\left(\theta + \beta_{eq}\right)\right)}}\right)^2 \qquad \Gamma = 2.687$$

$$k_{af} := \left(\frac{\left(\sin\left(\theta + \phi'_f\right)\right)^2}{\left(\Gamma \cdot \left(\sin\left(\theta\right)\right)^2 \cdot \sin\left(\theta - \delta\right)\right)}\right) \qquad k_{af} = 0.297$$

Active Earth Pressure Coefficient (**per LRFD Sect. 3.11.5.3**)

Foundation Soil Passive Earth:

Drained Conditions assuming($\phi'_{fd} > 0$):
Input Parameters for **LRFD Figure 3.11.5.4-2**, assumes θ = 90 degrees

$$\frac{-\beta'}{\phi'_{fd}} = -0.615 \qquad \frac{-\delta_{fd}}{\phi'_{fd}} = -0.67$$

$$k'_p := 2.8$$

Passive Earth Pressure Coefficient from **LRFD Figure 3.11.5.4-2**

Determine Reduction Factor (R) by interpolation:

$$R_d := 0.878$$

Reduction Factor

$$k_{pd} := R_d \cdot k'_p \qquad k_{pd} = 2.458$$

Passive Earth Pressure Coefficient for Drained Conditions

Undrained Conditions ($\phi_{fdu} > 0$): **Note:** Expand window below to complete calculation

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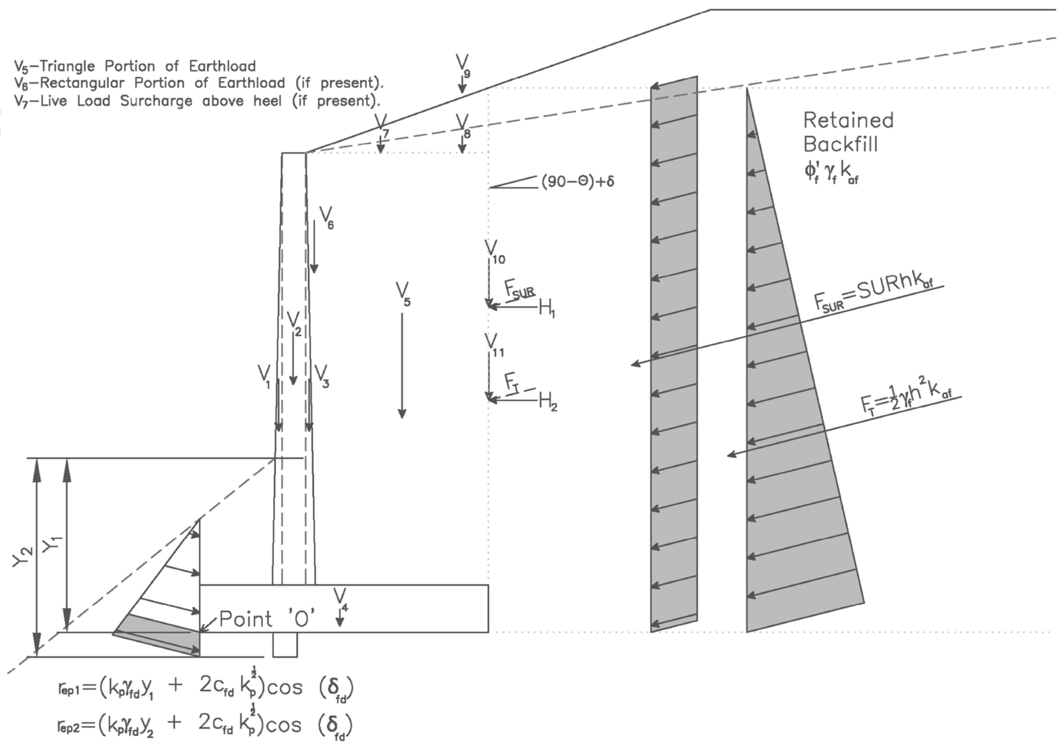
Undrained Conditions:

$$k_{pu} := \text{if}\left(\phi_{fdu} > 0, k_{pu}, 1\right) \qquad k_{pu} = 5.978$$

Passive Earth Pressure Coefficient for Resistance Undrained Conditions

Compute Unfactored Loads LRFD [Tables 3.4.1-1 and 3.4.1-2]:



$F_T := \frac{1}{2} \cdot \gamma_f \cdot h^2 \cdot k_{af}$	$F_T = 2080.3 \ \frac{lbf}{ft}$	Active Earth Force Resultant (EH)
$F_{SUR} := SUR \cdot h \cdot k_{af}$	$F_{SUR} = 288.9 \ \frac{lbf}{ft}$	Live Load Surcharge (LS)

Vertical Loads:

$V_1 := \frac{1}{2} \cdot T_1 \cdot h' \cdot \gamma_c$	$V_1 = 0 \ \frac{lbf}{ft}$	Wall stem front batter (DC)
$V_2 := T_t \cdot (h' + 3.5 \ ft) \cdot \gamma_c$	$V_2 = 2240 \ \frac{lbf}{ft}$	Wall stem (DC)
$V_3 := \frac{1}{2} \cdot T_2 \cdot h' \cdot \gamma_c$	$V_3 = 0 \ \frac{lbf}{ft}$	Wall stem back batter (DC)
$V_4 := D \cdot B \cdot \gamma_c$	$V_4 = 1912.5 \ \frac{lbf}{ft}$	Wall Footing (DC)
$V_5 := C \cdot h' \cdot \gamma_f$	$V_5 = 7160.6 \ \frac{lbf}{ft}$	Soil Backfill - Heel (EV)
$V_6 := \frac{1}{2} \cdot T_2 \cdot h' \cdot \gamma_f$	$V_6 = 0 \ \frac{lbf}{ft}$	Soil Backfill - Batter (EV)

$$V_7 := \text{if}\left(\lambda \le T_2 + C, \frac{1}{2} \cdot \lambda^2 \cdot \tan(\beta) \cdot \gamma_f, \frac{1}{2} \cdot (T_2 + C)^2 \cdot \tan(\beta) \cdot \gamma_f\right)$$

$V_7 = 0 \ \frac{lbf}{ft}$ — Soil Backfill - Backslope Triangle Portion (EV)

$$V_8 := \text{if}\left(\lambda \le T_2 + C, (T_2 + C - \lambda) \cdot h_{slope} \cdot \gamma_f, 0 \cdot \frac{lbf}{ft}\right)$$

$V_8 = 0 \ \frac{lbf}{ft}$ — Soil Backfill - Backslope Rectangular Portion (EV)

$V_9 := \text{if}\left(\lambda \le T_2 + C, (T_2 + C - \lambda) \cdot SUR, 0 \cdot \frac{lbf}{ft}\right)$

$V_9 = 577.5 \frac{lbf}{ft}$ Live Load Surcharge Above Heel - (LS)

$V_{10} := F_{SUR} \cdot \sin(90 \cdot deg - \theta + \delta)$ $V_{10} = 99.3 \frac{lbf}{ft}$ Live Load Surcharge Resultant (vertical comp. - LS)

$V_{11} := F_T \cdot \sin(90 \cdot deg - \theta + \delta)$ $V_{11} = 714.9 \frac{lbf}{ft}$ Active earth force resultant (vertical component - EH)

Moment Arm: Moment:

Moments produced from vertical loads about Point 'O'

$d_{v1} := A + \frac{2}{3} \cdot T_1 = 0.9\ ft$ $MV_1 := V_1 \cdot d_{v1} = 0\ lbf$

$d_{v2} := A + T_1 + \frac{T_t}{2} = 1.5\ ft$ $MV_2 := V_2 \cdot d_{v2} = 3360.7\ lbf$

$d_{v3} := A + T_1 + T_t + \frac{T_2}{3} = 2.1\ ft$ $MV_3 := V_3 \cdot d_{v3} = 0\ lbf$

$d_{v4} := \frac{B}{2} = 4.3\ ft$ $MV_4 := V_4 \cdot d_{v4} = 8128.1\ lbf$

$d_{v5} := B - \frac{C}{2} = 5.3\ ft$ $MV_5 := V_5 \cdot d_{v5} = 37892.8\ lbf$

$d_{v6} := A + T_1 + T_t + \frac{2\ T_2}{3} = 2.1\ ft$ $MV_6 := V_6 \cdot d_{v6} = 0\ lbf$

$d_{v7} := \text{if}\left(\lambda \le T_2 + C, A + T_1 + T_t + \left(\frac{2}{3}(\lambda)\right), A + T_1 + T_t + \left(\frac{2}{3}(T_2 + C)\right)\right) = 2.1\ ft$ $MV_7 := V_7 \cdot d_{v7} = 0\ lbf$

$d_{v8} := A + T_1 + T_t + \lambda + \left(\frac{T_2 + C - \lambda}{2}\right) = 5.3\ ft$ $MV_8 := V_8 \cdot d_{v8} = 0\ lbf$

$d_{v9} := A + T_1 + T_t + \lambda + \left(\frac{T_2 + C - \lambda}{2}\right) = 5.3\ ft$ $MV_9 := V_9 \cdot d_{v9} = 3055.9\ lbf$

$d_{v10} := B = 8.5\ ft$ $MV_{10} := V_{10} \cdot d_{v10} = 844\ lbf$

$d_{v11} := B = 8.5\ ft$ $MV_{11} := V_{11} \cdot d_{v11} = 6076.9\ lbf$

Horizontal Loads:

$H_1 := F_{SUR} \cdot \cos(90 \cdot deg - \theta + \delta)$ $H_1 = 271.3 \frac{lbf}{ft}$ Live Load Surcharge Resultant (horizontal comp. - LS)

$H_2 := F_T \cdot \cos(90 \cdot deg - \theta + \delta)$ $H_2 = 1953.6 \frac{lbf}{ft}$ Active Earth Force Resultant (horizontal comp. - EH)

Moment Arm: Moment:

$d_{h1} := \frac{h}{2}$ $d_{h1} = 5.4\ ft$ $MH_1 := H_1 \cdot d_{h1}$ $MH_1 = 1465.2 \frac{lbf \cdot ft}{ft}$

$d_{h2} := \frac{h}{3}$ $d_{h2} = 3.6\ ft$ $MH_2 := H_2 \cdot d_{h2}$ $MH_2 = 7033.1 \frac{lbf \cdot ft}{ft}$

Unfactored Loads by Load Type:

$V_{DC} := V_1 + V_2 + V_3 + V_4$ $\quad V_{DC} = 4152.5\ \frac{lbf}{ft}$ $\quad V_{EV} := V_5 + V_6 + V_7 + V_8$ $\quad V_{EV} = 7160.6\ \frac{lbf}{ft}$

$V_{LS\_Ia} := V_{10}$ $\quad V_{LS\_Ia} = 99.3\ \frac{lbf}{ft}$ $\quad V_{LS\_Ib} := V_9 + V_{10}$ $\quad V_{LS\_Ia} = 99.3\ \frac{lbf}{ft}$

$V_{EH} := V_{11}$ $\quad V_{EH} = 714.9\ \frac{lbf}{ft}$

$H_{EH} := H_2$ $\quad H_{EH} = 1953.6\ \frac{lbf}{ft}$ $\quad H_{LS} := H_1$ $\quad H_{LS} = 271.3\ \frac{lbf}{ft}$

Unfactored Moments by Load Type

$M_{DC} := MV_1 + MV_2 + MV_3 + MV_4$ $\quad M_{DC} = 11488.9\ \frac{lbf \cdot ft}{ft}$

$M_{EV} := MV_5 + MV_6 + MV_7 + MV_8$ $\quad M_{EV} = 37892.8\ \frac{lbf \cdot ft}{ft}$

$M_{LSV\_Ia} := MV_{10}$ $\quad M_{LSV\_Ia} = 844\ \frac{lbf \cdot ft}{ft}$

$M_{LSV\_Ib} := MV_9 + MV_{10}$ $\quad M_{LSV\_Ib} = 3899.9\ \frac{lbf \cdot ft}{ft}$

$M_{EH1} := MV_{11}$ $\quad M_{EH1} = 6076.9\ \frac{lbf \cdot ft}{ft}$

$M_{LSH} := MH_1$ $\quad M_{LSH} = 1465.2\ \frac{lbf \cdot ft}{ft}$

$M_{EH2} := MH_2$ $\quad M_{EH2} = 7033.1\ \frac{lbf \cdot ft}{ft}$

Load Combination Limit States:

$\eta := 1$ LRFD Load Modifier

Strength Limit State I: EV(min) = 1.00 EV(max) = 1.35
EH(min) = 0.90 EH(max) = 1.50
LS = 1.75

Strength Limit State Ia:
(Sliding and Eccentricity)
$Ia_{DC} := 0.9$ $Ia_{EV} := 1$ $Ia_{EH} := 1.5$ $Ia_{LS} := 1.75$

Strength Limit State Ib:
(Bearing Capacity)
$Ib_{DC} := 1.25$ $Ib_{EV} := 1.35$ $Ib_{EH} := 1.5$ $Ib_{LS} := 1.75$

Factored Vertical Loads by Limit State:

$V_{Ia} := \eta \cdot \left(\left(Ia_{DC} \cdot V_{DC} \right) + \left(Ia_{EV} \cdot V_{EV} \right) + \left(Ia_{EH} \cdot V_{EH} \right) + \left(Ia_{LS} \cdot V_{LS\_Ia} \right) \right)$ $V_{Ia} = 12144 \ \frac{lbf}{ft}$

$V_{Ib} := \eta \cdot \left(\left(Ib_{DC} \cdot V_{DC} \right) + \left(Ib_{EV} \cdot V_{EV} \right) + \left(Ib_{EH} \cdot V_{EH} \right) + \left(Ib_{LS} \cdot V_{LS\_Ib} \right) \right)$ $V_{Ib} = 17114.2 \ \frac{lbf}{ft}$

Factored Horizontal Loads by Limit State:

$H_{Ia} := \eta \cdot \left(\left(Ia_{LS} \cdot H_{LS} \right) + \left(Ia_{EH} \cdot H_{EH} \right) \right)$ $H_{Ia} = 3405.3 \ \frac{lbf}{ft}$

$H_{Ib} := \eta \cdot \left(\left(Ib_{LS} \cdot H_{LS} \right) + \left(Ib_{EH} \cdot H_{EH} \right) \right)$ $H_{Ib} = 3405.3 \ \frac{lbf}{ft}$

Factored Moments Produced by Vertical Loads by Limit State:

$MV_{Ia} := \eta \cdot \left(\left(Ia_{DC} \cdot M_{DC} \right) + \left(Ia_{EV} \cdot M_{EV} \right) + \left(Ia_{EH} \cdot M_{EH1} \right) + \left(Ia_{LS} \cdot M_{LSV\_Ia} \right) \right)$ $MV_{Ia} = 58825.2 \ \frac{lbf \cdot ft}{ft}$

$MV_{Ib} := \eta \cdot \left(\left(Ib_{DC} \cdot M_{DC} \right) + \left(Ib_{EV} \cdot M_{EV} \right) + \left(Ib_{EH} \cdot M_{EH1} \right) + \left(Ib_{LS} \cdot M_{LSV\_Ib} \right) \right)$ $MV_{Ib} = 81456.6 \ \frac{lbf \cdot ft}{ft}$

Factored Moments Produced by Horizontal Loads by Limit State:

$MH_{Ia} := \eta \cdot \left(\left(Ia_{LS} \cdot M_{LSH} \right) + \left(Ia_{EH} \cdot M_{EH2} \right) \right)$ $MH_{Ia} = 13113.8 \ \frac{lbf \cdot ft}{ft}$

$MH_{Ib} := \eta \cdot \left(\left(Ib_{LS} \cdot M_{LSH} \right) + \left(Ib_{EH} \cdot M_{EH2} \right) \right)$ $MH_{Ib} = 13113.8 \ \frac{lbf \cdot ft}{ft}$

Compute Bearing Resistance:

Compute the resultant location about the toe of the base length (distance from "O") Strength Ib:

$\Sigma M_R := MV_{Ib}$ — $\Sigma M_R = 81456.6\ \frac{lbf \cdot ft}{ft}$ — Sum of Resisting Moments (Strength Ib)

$\Sigma M_O := MH_{Ib}$ — $\Sigma M_O = 13113.8\ \frac{lbf \cdot ft}{ft}$ — Sum of Overturning Moments (Strength Ib)

$\Sigma V := V_{Ib}$ — $\Sigma V = 17114.2\ \frac{lbf}{ft}$ — Sum of Vertical Loads (Strength Ib)

$x := \frac{(\Sigma M_R - \Sigma M_O)}{\Sigma V}$ — $x = 4\ ft$ — Distance from Point "O" the resultant intersects the base

$e := \left|\frac{B}{2} - x\right|$ — $e = 0.26\ ft$ — Wall eccentricity, **Note:** The vertical stress is assumed to be uniformly distributed over the effective bearing width, B', since the wall is supported by a soil foundation **LRFD [11.6.3.2]**. The effective bearing width is equal to B-2e.

Foundation Layout at bottom of Undercut & Replacement:

$B' := B - 2 \cdot e + D_{undercut}$ — $B' = 8\ ft$ — Effective Footing Width, Assumed at the bottom of Undercut and Replacement

$L' := 142\ ft$ — Effective Footing Length (Assumed)

$H' := H_{Ib}$ — $H' = 3405.3\ \frac{lbf}{ft}$ — Summation of Horizontal Loads (Strength Ib)

$V' := V_{Ib}$ — $V' = 17114.2\ \frac{lbf}{ft}$ — Summation of Vertical Loads (Strength Ib)

$D_F := D_f + D_{undercut}$ — Embenment Depth at bottom of Undercut

$d_w := 0\ ft$ — Depth of Groundwater below ground surface at front of wall.

Drained Conditions (Effective Stress):

$N_q := \text{if}\left(\phi'_{fd} > 0, e^{\pi \cdot \tan(\phi'_{fd})} \cdot \tan\left(45\ deg + \frac{\phi'_{fd}}{2}\right)^2, 1.0\right)$ — $N_q = 18.4$

$N_c := \text{if}\left(\phi'_{fd} > 0, \frac{N_q - 1}{\tan(\phi'_{fd})}, 5.14\right)$ — $N_c = 30.14$

$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi'_{fd})$ — $N_\gamma = 22.4$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$s_c := \text{if}\left(\phi'_{fd} > 0, 1 + \left(\frac{B'}{L'}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L'}\right)\right)$ — $s_c = 1.034$

$s_q := \text{if}\left(\phi'_{fd} > 0, 1 + \left(\frac{B'}{L'} \cdot \tan(\phi'_{fd})\right), 1\right)$ — $s_q = 1.032$

$s_\gamma := \text{if}\left(\phi'_{fd} > 0, 1 - 0.4 \cdot \left(\frac{B'}{L'}\right), 1\right)$ — $s_\gamma = 0.978$

Load inclination factors:

$i_q := 1$

$i_\gamma := 1$

$i_c := 1$

Assumed to be 1.0, see **LRFD BDS C10.6.3.1.2a**. "Most geotechnical engineers do not used the load inclination factors". If desired, use LRFD Equations [10.6.3.1.2a-5] thru [10.6.3.1.2a-9].

Compute groundwater depth correction factors per **LRFD [Table 10.6.3.1.2a-2]**:

$C_{wq} := \text{if}\left(d_w \ge D_f, 1.0, 0.5\right)$ $\qquad C_{wq} = 0.5$

$C_{w\gamma} := \text{if}\left(d_w \ge (1.5 \cdot B) + D_f, 1.0, 0.5\right)$ $\qquad C_{w\gamma} = 0.5$

Depth Correction Factor per ODOT BDM 305.2.1:

$$d_q := 1 + 2 \cdot \tan\left(\phi'_{fd}\right) \cdot \left(1 - \sin\left(\phi'_{fd}\right)\right)^2 \cdot \operatorname{atan}\left(\frac{D_F}{B'}\right)$$

$d_q = 1.21$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $\qquad N_{cm} = 31.175$

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $\qquad N_{qm} = 22.906$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $\qquad N_{\gamma m} = 21.898$

Compute nominal bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.2a-1]:**

$q_{nd} := c'_{fd} \cdot N_{cm} + \gamma_q \cdot D_F \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot \gamma_{fd} \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma}$ $\qquad q_{nd} = 14730.2 \ \frac{lbf}{ft^2}$

Compute factored bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := .55$ $\qquad$ Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Rd} := \phi_b \cdot q_{nd}$ $\qquad q_{Rd} = 8.1 \ ksf$ $\qquad$ Factored bearing resistance Drained Conditions

Undrained Conditions (Effective Stress):

$N_q := \text{if}\left(\phi_{fdu} > 0, e^{\pi \cdot \tan\left(\phi_{fdu}\right)} \cdot \tan\left(45\ deg + \frac{\phi_{fdu}}{2}\right)^2, 1.0\right)$ $\qquad N_q = 18.4$

$N_c := \text{if}\left(\phi_{fdu} > 0, \frac{N_q - 1}{\tan\left(\phi_{fdu}\right)}, 5.14\right)$ $\qquad N_c = 30.14$

$N_\gamma := 2 \cdot \left(N_q + 1\right) \cdot \tan\left(\phi_{fdu}\right)$ $\qquad N_\gamma = 22.4$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$$s_c := \text{if}\left(\phi_{fdu} > 0, 1 + \left(\frac{B'}{L'}\right)\cdot\left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5\cdot L'}\right)\right) \qquad s_c = 1.034$$

$$s_q := \text{if}\left(\phi_{fdu} > 0, 1 + \left(\frac{B'}{L'}\cdot\tan\left(\phi_{fdu}\right)\right), 1\right) \qquad s_q = 1.032$$

$$s_\gamma := \text{if}\left(\phi_{fdu} > 0, 1 - 0.4\cdot\left(\frac{B'}{L'}\right), 1\right) \qquad s_\gamma = 0.978$$

Load inclination factors:

$i_q := 1$

$i_\gamma := 1$

$i_c := 1$

Assumed to be 1.0, see **LRFD BDS C10.6.3.1.2a**. "Most geotechnical engineers do not used the load inclination factors". If desired, use LRFD Equations [10.6.3.1.2a-5] thru [10.6.3.1.2a-9].

Depth Correction Factor per ODOT BDM 305.2.1:

$$d_q := 1 + 2\cdot\tan\left(\phi_{fdu}\right)\cdot\left(1 - \sin\left(\phi_{fdu}\right)\right)^2\cdot\text{atan}\left(\frac{D_F}{B'}\right)$$

$d_q = 1.21$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$$N_{cm} := N_c \cdot s_c \cdot i_c \qquad N_{cm} = 31.175$$

$$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q \qquad N_{qm} = 22.906$$

$$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma \qquad N_{\gamma m} = 21.898$$

Compute nominal bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.2a-1:**

$$q_{nu} := Su_{fdu}\cdot N_{cm} + \gamma_q\cdot D_F\cdot N_{qm}\cdot C_{wq} + 0.5\cdot\gamma_{fd}\cdot B'\cdot N_{\gamma m}\cdot C_{w\gamma} \qquad q_{nu} = 14730.2\ \frac{lbf}{ft^2}$$

Compute factored bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := .55$ — Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Ru} := \phi_b \cdot q_{nu}$ $\quad q_{Ru} = 8.1\ ksf$ — Factored bearing resistance Undrained Conditions

Factored Bearing Resistance Drained vs. Undrained Conditions:

Drained Conditions: $q_{Rd} = 8.1\ ksf$

Undrained Conditions: $q_{Ru} = 8.1\ ksf$

Evaluate External Stability of Wall:

Compute the factored bearing stress at bottom of Undercut & Replacement:

$e = 0.26\ ft$

$\sigma_V := \frac{\Sigma V}{B'}$ $\sigma_V = 2.143\ ksf$

Bearing Capacity at bottom of Undercut & Replacement:Demand Ratio (CDR)

Drained Conditions: $CDR_{Bearing\_D} := \frac{q_{Rd}}{\sigma_V}$ Is the CDR > or = to 1.0? $CDR_{Bearing\_D} = 3.78$

Undrained Conditions: $CDR_{Bearing\_U} := \frac{q_{Ru}}{\sigma_V}$ Is the CDR > or = to 1.0? $CDR_{Bearing\_U} = 3.78$

Limiting Eccentricity at Base of Wall (Strength Ia):

Compute the resultant location about the toe "O" of the base length (distance from Pivot):

$e_{max} := \frac{B}{3}$ $e_{max} = 2.8\ ft$ Maximum Eccentricity **LRFD [C11.6.3.3.] Equals B/3 for soil.**

$\Sigma M_R := MV_{Ia}$ $\Sigma M_R = 58825.2\ \frac{lbf \cdot ft}{ft}$ Sum of Resisting Moments (Strength Ia)

$\Sigma M_O := MH_{Ia}$ $\Sigma M_O = 13113.8\ \frac{lbf \cdot ft}{ft}$ Sum of Overturning Moments (Strength Ia)

$\Sigma V := V_{Ia}$ $\Sigma V = 12144\ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$x := \frac{(\Sigma M_R - \Sigma M_O)}{\Sigma V}$ $x = 3.8\ ft$ Distance from Point "O" the resultant intersects the base

$e := \left| \frac{B}{2} - x \right|$ $e = 0.49\ ft$ Wall eccentricity, **Note:** The vertical stress is assumed to be uniformly distributed over the effective bearing width, B', since the wall is supported by a soil foundation **LRFD [11.6.3.2]**. The effective bearing width is equal to B-2e. .

Eccentricity Capacity:Demand Ratio (CDR)

$CDR_{Eccentricity} := \frac{e_{max}}{e}$ Is the CDR > or = to 1.0? $CDR_{Eccentricity} = 5.83$

Sliding Resistance at Base of Wall LRFD [10.6.3.4]:

Factored Sliding Force (Strength Ia):

$R_u := H_{Ia}$ $\qquad R_u = 3405.3\ \frac{lbf}{ft}$

Drained/Undrained Conditions for Granular Replacement (Effective Stress):

Compute passive resistance throughout the design life of the wall **LRFD [Eq 3.11.5.4-1]**::

$r_{ep1} := \left(k_{pd} \cdot \gamma_{fd} \cdot y_1 + 2 \cdot c'_{fd} \cdot \sqrt{k_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y1

$r_{ep2} := \left(k_{pd} \cdot \gamma_{fd} \cdot y_2 + 2 \cdot c'_{fd} \cdot \sqrt{k_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y2

$R_{ep} := \frac{r_{ep1} + r_{ep2}}{2} \cdot \left(y_2 - y_1\right)$ $\qquad R_{ep} = 0\ \frac{lbf}{ft}$ Nominal passive resistance Drained Conditions

416 Note: Passive Resistance shall be neglected in stability computations, unless the base of the wall extends below the depth of maximum scour, freeze-thaw or other disturbances. In the latter case, only the embedment below the greater of these depths shall be considered effective **LRFD [11.6.3.5**].

Compute sliding resistance between soil and foundation:

$c := 1.0$ c = 1.0 for Cast-in-Place
c = 0.8 for Precast

$\Sigma V := V_{Ia}$ $\qquad \Sigma V = 12144\ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$R_\tau := c \cdot \Sigma V \cdot \tan\left(\phi_{Re}\right)$ $\qquad R_\tau = 8191.3\ \frac{lbf}{ft}$ Nominal sliding resistance Cohesionless Soils

Compute factored resistance against failure by sliding **LRFD [10.6.3.4]**:

$\phi_{ep} := 0.5$ Resistance factor for passive resistance specified in **LRFD Table 10.5.5.2.2-1**

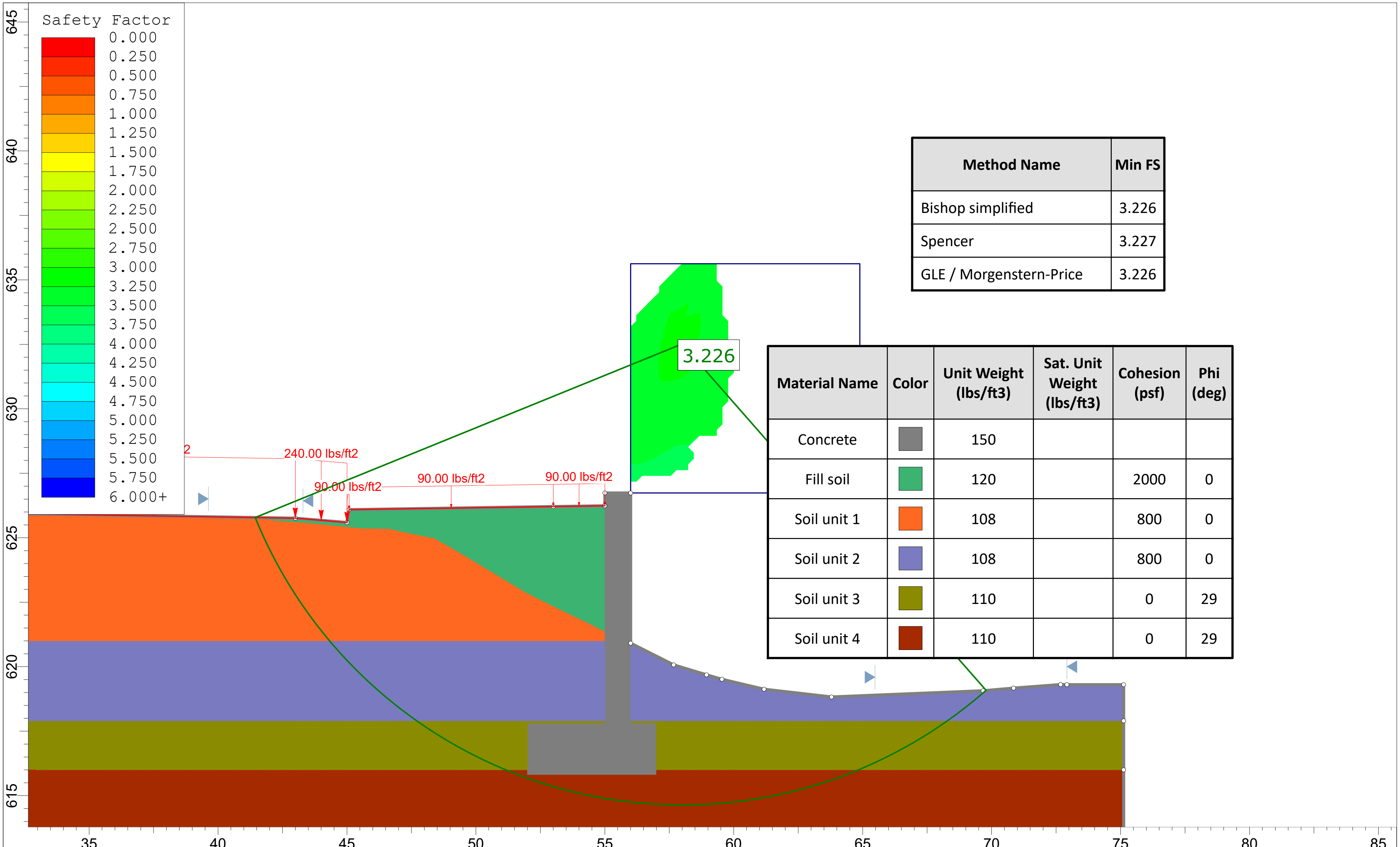
$\phi_\tau := 1.0$ Resistance factor for sliding resistance specified in **LRFD Table 11.5.7-1.**

$\phi R_n := \phi_\tau \cdot R_\tau + \phi_{ep} \cdot R_{ep}$ $\qquad R_R := \phi R_n$

Factored Sliding Resistance to be used in CDR Calculations: $R_R = 8191.26\ \frac{lbf}{ft}$

Sliding Capacity:Demand Ratio (CDR)

$CDR_{Sliding\_Base} := \frac{R_R}{R_u}$ Is the CDR > or = to 1.0? $CDR_{Sliding\_Base} = 2.41$



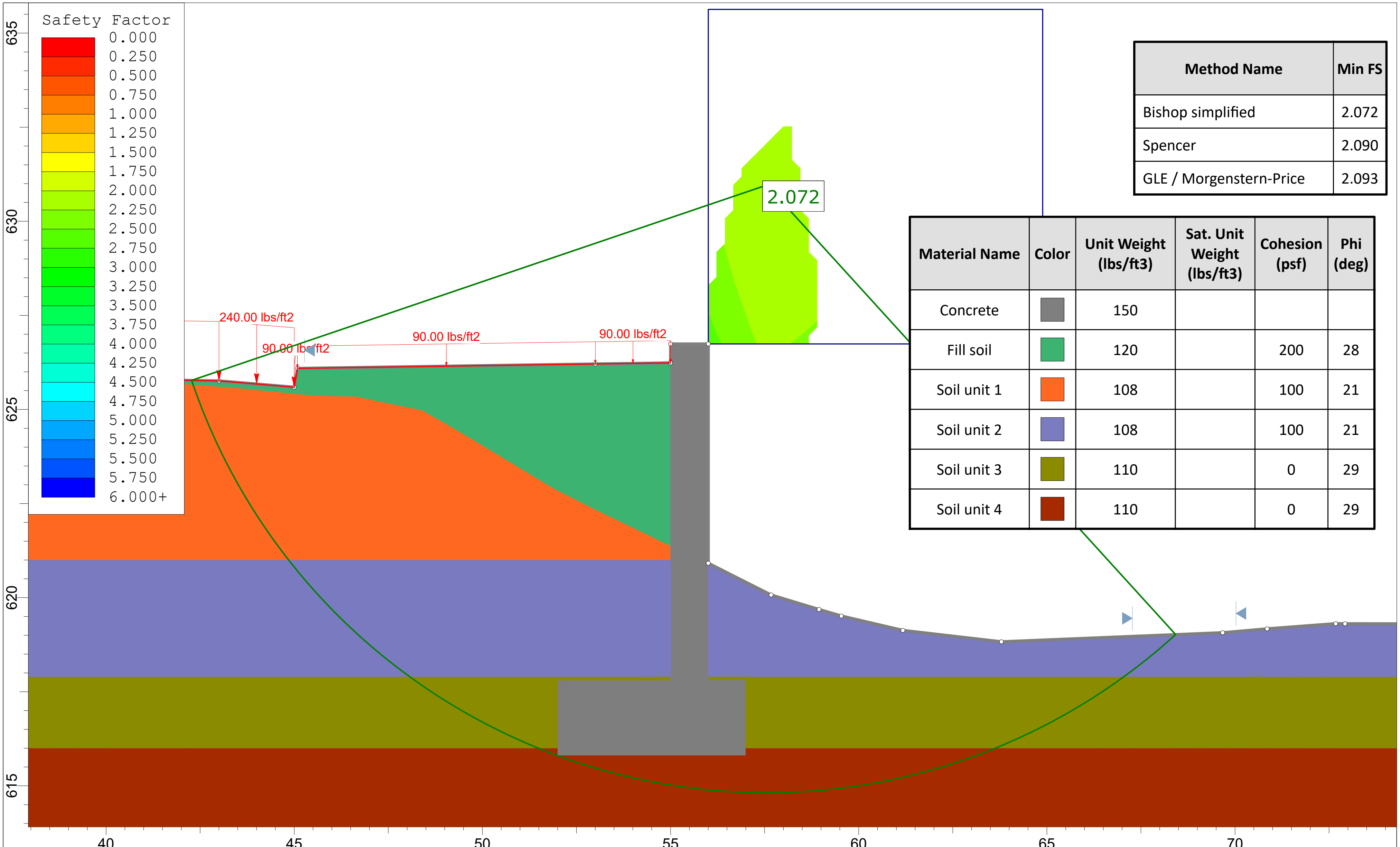
Method Name	Min FS
Bishop simplified	3.226
Spencer	3.227
GLE / Morgenstern-Price	3.226

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Concrete		150			
Fill soil		120		2000	0
Soil unit 1		108		800	0
Soil unit 2		108		800	0
Soil unit 3		110		0	29
Soil unit 4		110		0	29

rocscience

SLIDEINTERPRET 7.037

Project	ROS-159-0.41 (PID 113013)
Analysis Description	Kroger Wall Short Term (Total) Circular
Drawn By	M. Jasiewicz
Scale	1:62
Company	NEAS Inc.
Date	10/13/2022, 10:25:06 AM
File Name	KrogerWall_ShortTerm_Circular.slim



Method Name	Min FS
Bishop simplified	2.072
Spencer	2.090
GLE / Morgenstern-Price	2.093

Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Concrete		150			
Fill soil		120		200	28
Soil unit 1		108		100	21
Soil unit 2		108		100	21
Soil unit 3		110		0	29
Soil unit 4		110		0	29

rosscience

SLIDEINTERPRET 7.037

Project	ROS-159-0.41 (PID 113013)
Analysis Description	Kroger Wall Long Term (Effective) Circular
Drawn By	M. Jasiewicz
Scale	1:42
Company	NEAS Inc.
Date	10/13/2022, 10:25:06 AM
File Name	KrogerWall_LongTerm_Circular.slim

APPENDIX F

WALL 3 ANALYSES

Objective: **To evaluate the external stability of CIP wall design with broken backsloping backfill.**
Method: **In accordance with ODOT Bridge Design Manual, 2021 [Sect. 204.6.2.2] LRFD Bridge Design Specifications, 9th Ed., 2020, [Sect. 11.6.1, Sect. 11.6.2, and Sect. 11.6.3].**

Givens:

Backfill Soil Design Parameters:

$\phi'_f := 30\ deg$ — Effective angle of internal friction

$\gamma_f := 120\ \frac{lbf}{ft^3}$ — Unit weight

$c'_f := 0\ \frac{lbf}{ft^2}$ — Effective Cohesion

$\delta := 0.67 \cdot \phi'_f$ $\delta = 20.1\ deg$ — Friction angle between backfill and wall taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

Foundation Soil Design Parameters:

Drained Conditions (Effective Stress):

$\phi'_{fd} := 30\ deg$ — Effective angle of internal friction

$\gamma_{fd} := 122\ \frac{lbf}{ft^3}$ — Unit weight

$c'_{fd} := 0\ \frac{lbf}{ft^2}$ — Effective Cohesion

$\delta_{fd} := 0.67 \cdot \phi'_{fd}$ $\delta_{fd} = 20.1\ deg$ — Friction angle between foundation soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

Undrained Conditions (Total Stress):

$\phi_{fdu} := 30\ deg$ — Angle of internal friction (Same as Drained Conditions if granular soils)

$Su_{fdu} := 0\ \frac{lbf}{ft^2}$ — Undrained Shear Strength

$\delta_{fdu} := 0.67 \cdot \phi_{fdu}$ $\delta_{fdu} = 20.1\ deg$ — Friction angle between foundation soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

Undercut & Replacement Design Parameters:

$\phi_{Re} := 34\ deg$ — Angle of internal friction for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$c_{Re} := 0\ \frac{lbf}{ft^2}$ — Cohesion for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$\gamma_{Re} := 130\ \frac{lbf}{ft^3}$ — Unit Weight for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$\delta_{Re} := 0.67 \cdot \phi_{Re}$ $\delta_{Re} = 22.8\ deg$ — Friction angle between Replacement soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

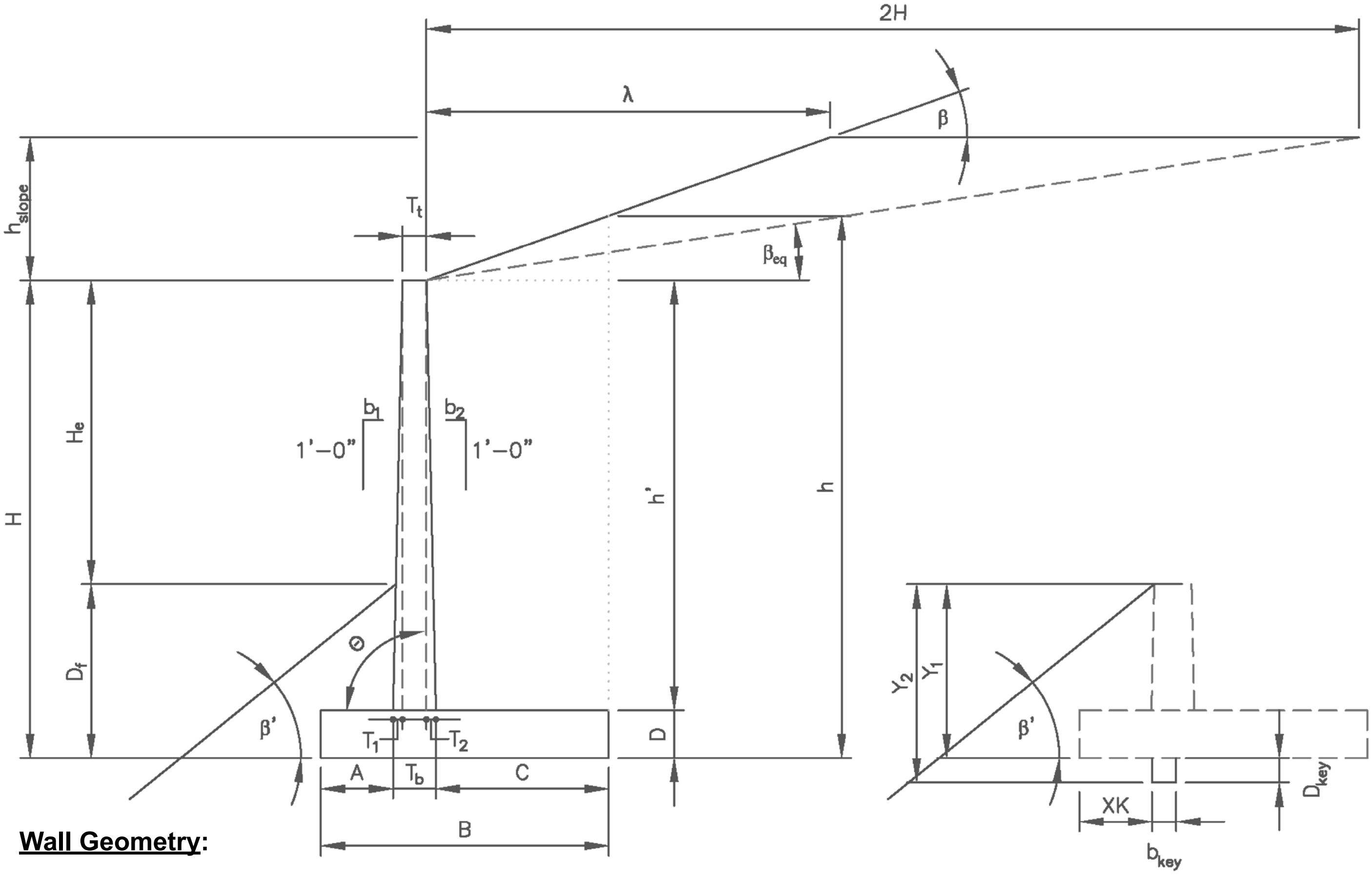
$D_{undercut} := 0\ ft$ — Depth of Undercut below bottom of footing

Foundation Surcharge Soil Parameters:

$\gamma_q := 120\ \frac{lbf}{ft^3}$ — Unit weight of Soil above bearing depth (Used in Bearing Resistance of Soil Calculation LRFD 10.6.3.1.2a-1)

Other Parameters:

$\gamma_c := 150\ \frac{lbf}{ft^3}$ — Concrete Unit weight



Wall Geometry:

$H_e := 4.4\ ft$ — Exposed wall height

$D_f := 6.0\ ft$ — Footing cover at Toe

Note: Where the potential for scour, erosion of undermining exists, spread footings shall be located to bear below the maximum depth of scour or undermining. Spread footings shall be located below the depth of potential frost. **LRFD BDS 10.6.1.2**

$H := H_e + D_f$ $\quad H = 10.4\ ft$ — Design Wall Height

$T_t := 14\ in$ — Stem thickness at top of wall

$b_1 := 0 \cdot \left(\frac{in}{ft}\right)$ — Frontwall batter, (b1H:12V)

$b_2 := 0 \cdot \left(\frac{in}{ft}\right)$ — Backwall batter, (b2H:12V)

Preliminary Wall Dimensioning:

$B := 8.5\ ft$	$\frac{2}{5} \cdot H = 4.16\ ft$	to	$\frac{3}{5} \cdot H = 6.24\ ft$	Footing base width (2/5H to 3/5H)
$A := 0.917\ ft$	$\frac{H}{8} = 1.3\ ft$	to	$\frac{H}{5} = 2.08\ ft$	Toe projection (H/8 to H/5)
$D := 1.5\ ft$	$\frac{H}{8} = 1.3\ ft$	to	$\frac{H}{5} = 2.08\ ft$	Footing thickness (H/8 to H/5)

Shear Key Dimensioning:

$D_{key} := 0\ ft$ — Depth of shear key from bottom of footing
Note: Footings on rock typically require shear key

$b_{key} := 0\ ft$ — Width of shear key

$XK := 0\ ft$ — Distance from toe to shear key

Other Wall Dimensions:

$h' := H - D$	$h' = 8.9\ ft$	Stem height
$T_1 := b_1 \cdot h'$	$T_1 = 0\ ft$	Stem front batter width
$T_2 := b_2 \cdot h'$	$T_2 = 0\ ft$	Stem back batter width
$T_b := T_1 + T_2 + T_t$	$T_b = 1.167\ ft$	Stem thickness at bottom of wall
$C := B - A - T_b$	$C = 6.416\ ft$	Heel projection
$\theta := 90\ deg$		Angle of back face of wall to horizontal = *atan(12/b2)*
$b := 12\ in$	$b = 1\ ft$	Concrete strip width (for design)
$y_1 := D_f$	$y_1 = 6\ ft$	Depth to where passive pressure may begin to be utilized in front of wall.
$y_2 := D_f + D_{key}$	$y_2 = 6\ ft$	Bottom of shear key/footing depth i.e. depth to where passive pressure may no longer be utilized.

Site Grading and Slope Dimensions:

$\beta := 0\ deg$ — Inclination of ground slope behind face of wall. Horizontal backfill behind CIP wall, β = 0 deg

Inclination of ground slope:

- Horizontal: **0**
- 3H:1V: **18.435**
- 2H:1V: **26.565**
- 1.5H:1V: **33.690**

$\beta' := 18.435\ deg$ — Inclination of ground slope in front of wall. If it is horizontal backfill in front of CIP wall, β' = 0 deg. A negative angle (-) indicates grades slope up from front of wall. Positive angle (+) indicates grade slope down from wall as shown in above figure.

$\lambda := 0\ ft$ — Horizontal distance from the back of the wall to point of slope crest .

$L_{Traffic} := 0\ ft$ — Horizontal distance from assumed traffic surcharge load to Backface of Wall.

$2 \cdot H = 20.8\ ft$

IF λ IS GREATER THAN 2*H - USE INFINITE SLOPE CALCULATION SHEET

$h_{slope} := \lambda \cdot \tan(\beta)$ $h_{slope} = 0\ ft$ — Height of broken slope behind wall

$\beta_{eq} := \operatorname{atan}\left(\frac{h_{slope}}{2 \cdot H}\right) = 0\ deg$ — Equivalent backslope angle

$h := \text{if}\left(\lambda \le T_2 + C, H + h_{slope}, H + (T_2 + C) \cdot \tan(\beta)\right) = 10.4\ ft$ — Height of retained fill at back of heel

Live Load Surcharge Parameters:

$$SUR := \text{if}\left(L_{Traffic} < \frac{H}{2}, 90\ \frac{lbf}{ft^2}, 0\ \frac{lbf}{ft^2}\right) = 90\ \frac{lbf}{ft^2}$$

Live load surcharge (per LRFD BDS [3.11.6.4])
Note: ,A live load ssurcharge shall be applied where vehicular load is expected to act on the surface of the backfill within a distance equal to one-half the wall height behind the back face of the wall, see LRFD BDS Section 3.11.6.4 and Table 3.11.6.4-2 .

Calculations:

Earth Pressure Coefficients:

Backfill Active Earth:

$$\Gamma := \left(1 + \sqrt{\frac{\left(\sin\left(\phi'_f + \delta\right) \cdot \sin\left(\phi'_f - \beta_{eq}\right)\right)}{\left(\sin\left(\theta - \delta\right) \cdot \sin\left(\theta + \beta_{eq}\right)\right)}}\right)^2 \qquad \Gamma = 2.687$$

$$k_{af} := \left(\frac{\left(\sin\left(\theta + \phi'_f\right)\right)^2}{\left(\Gamma \cdot \left(\sin(\theta)\right)^2 \cdot \sin\left(\theta - \delta\right)\right)}\right) \qquad k_{af} = 0.297$$

Active Earth Pressure Coefficient (**per LRFD Sect. 3.11.5.3**)

Foundation Soil Passive Earth:

Drained Conditions assuming($\phi'_{fd} > 0$):
Input Parameters for **LRFD Figure 3.11.5.4-2**, assumes θ = 90 degrees

$$\frac{-\beta'}{\phi'_{fd}} = -0.615 \qquad \frac{-\delta_{fd}}{\phi'_{fd}} = -0.67$$

$k'_p := 2.8$ — Passive Earth Pressure Coefficient from **LRFD Figure 3.11.5.4-2**

Determine Reduction Factor (R) by interpolation:

$R_d := 0.878$ — Reduction Factor

$k_{pd} := R_d \cdot k'_p \qquad k_{pd} = 2.458$ — Passive Earth Pressure Coefficient for Drained Conditions

Undrained Conditions ($\phi_{fdu} > 0$): **Note:** Expand window below to complete calculation

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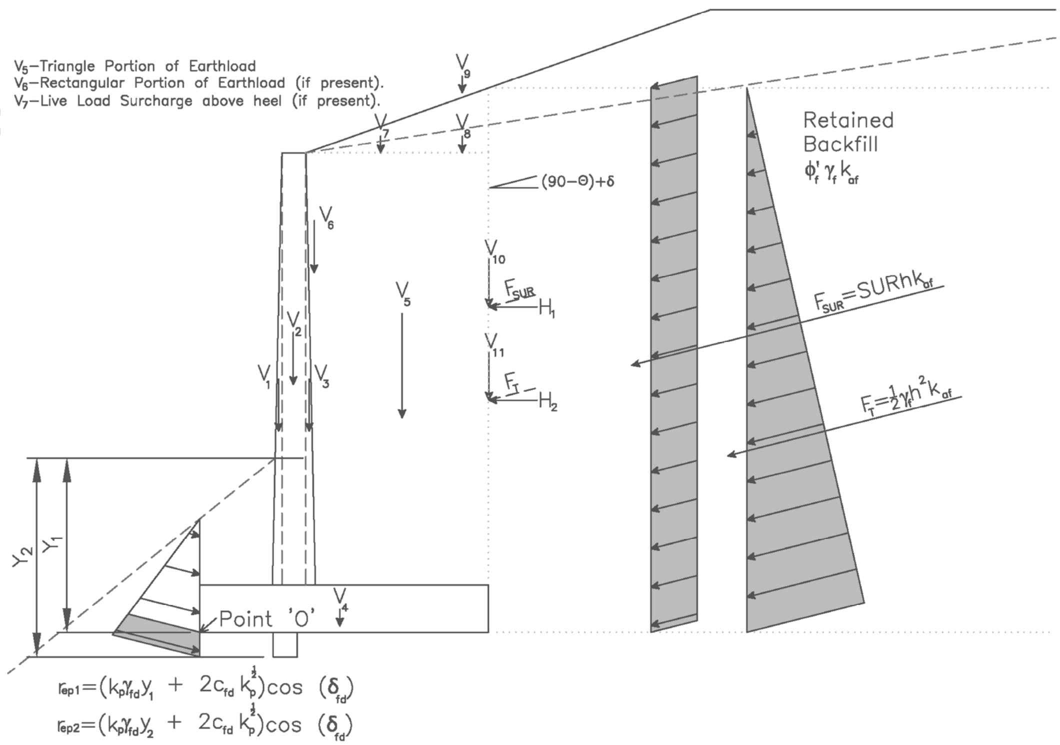
Undrained Conditions:

$k_{pu} := \text{if}\left(\phi_{fdu} > 0, k_{pu}, 1\right) \qquad k_{pu} = 5.978$ — Passive Earth Pressure Coefficient for Resistance Undrained Conditions

Compute Unfactored Loads LRFD [Tables 3.4.1-1 and 3.4.1-2]:



$F_T := \frac{1}{2} \cdot \gamma_f \cdot h^2 \cdot k_{af}$	$F_T = 1929.1\ \frac{lbf}{ft}$	Active Earth Force Resultant (EH)
$F_{SUR} := SUR \cdot h \cdot k_{af}$	$F_{SUR} = 278.2\ \frac{lbf}{ft}$	Live Load Surcharge (LS)

Vertical Loads:

$V_1 := \frac{1}{2} \cdot T_1 \cdot h' \cdot \gamma_c$	$V_1 = 0\ \frac{lbf}{ft}$	Wall stem front batter (DC)
$V_2 := T_t \cdot (h' + 3.5\ ft) \cdot \gamma_c$	$V_2 = 2170\ \frac{lbf}{ft}$	Wall stem (DC)
$V_3 := \frac{1}{2} \cdot T_2 \cdot h' \cdot \gamma_c$	$V_3 = 0\ \frac{lbf}{ft}$	Wall stem back batter (DC)
$V_4 := D \cdot B \cdot \gamma_c$	$V_4 = 1912.5\ \frac{lbf}{ft}$	Wall Footing (DC)
$V_5 := C \cdot h' \cdot \gamma_f$	$V_5 = 6852.6\ \frac{lbf}{ft}$	Soil Backfill - Heel (EV)
$V_6 := \frac{1}{2} \cdot T_2 \cdot h' \cdot \gamma_f$	$V_6 = 0\ \frac{lbf}{ft}$	Soil Backfill - Batter (EV)

$$V_7 := \text{if}\left(\lambda \le T_2 + C, \frac{1}{2} \cdot \lambda^2 \cdot \tan(\beta) \cdot \gamma_f, \frac{1}{2} \cdot (T_2 + C)^2 \cdot \tan(\beta) \cdot \gamma_f\right)$$

$V_7 = 0\ \frac{lbf}{ft}$ Soil Backfill - Backslope Triangle Portion (EV)

$$V_8 := \text{if}\left(\lambda \le T_2 + C, (T_2 + C - \lambda) \cdot h_{slope} \cdot \gamma_f, 0 \cdot \frac{lbf}{ft}\right)$$

$V_8 = 0\ \frac{lbf}{ft}$ Soil Backfill - Backslope Rectangular Portion (EV)

$V_9 := \text{if}\left(\lambda \le T_2 + C, (T_2 + C - \lambda) \cdot SUR, 0 \cdot \frac{lbf}{ft}\right)$

$V_9 = 577.5 \ \frac{lbf}{ft}$ Live Load Surcharge Above Heel - (LS)

$V_{10} := F_{SUR} \cdot \sin(90 \cdot deg - \theta + \delta)$ $V_{10} = 95.6 \ \frac{lbf}{ft}$ Live Load Surcharge Resultant (vertical comp. - LS)

$V_{11} := F_T \cdot \sin(90 \cdot deg - \theta + \delta)$ $V_{11} = 663 \ \frac{lbf}{ft}$ Active earth force resultant (vertical component - EH)

Moment Arm:

Moments produced from vertical loads about Point 'O'

Moment:

Moment Arm	Moment
$d_{v1} := A + \frac{2}{3} \cdot T_1 = 0.9 \ ft$	$MV_1 := V_1 \cdot d_{v1} = 0 \ lbf$
$d_{v2} := A + T_1 + \frac{T_t}{2} = 1.5 \ ft$	$MV_2 := V_2 \cdot d_{v2} = 3255.7 \ lbf$
$d_{v3} := A + T_1 + T_t + \frac{T_2}{3} = 2.1 \ ft$	$MV_3 := V_3 \cdot d_{v3} = 0 \ lbf$
$d_{v4} := \frac{B}{2} = 4.3 \ ft$	$MV_4 := V_4 \cdot d_{v4} = 8128.1 \ lbf$
$d_{v5} := B - \frac{C}{2} = 5.3 \ ft$	$MV_5 := V_5 \cdot d_{v5} = 36263 \ lbf$
$d_{v6} := A + T_1 + T_t + \frac{2\ T_2}{3} = 2.1 \ ft$	$MV_6 := V_6 \cdot d_{v6} = 0 \ lbf$
$d_{v7} := \text{if}\left(\lambda \le T_2 + C, A + T_1 + T_t + \left(\frac{2}{3}\ (\lambda)\right), A + T_1 + T_t + \left(\frac{2}{3}\ (T_2 + C)\right)\right) = 2.1 \ ft$	$MV_7 := V_7 \cdot d_{v7} = 0 \ lbf$
$d_{v8} := A + T_1 + T_t + \lambda + \left(\frac{T_2 + C - \lambda}{2}\right) = 5.3 \ ft$	$MV_8 := V_8 \cdot d_{v8} = 0 \ lbf$
$d_{v9} := A + T_1 + T_t + \lambda + \left(\frac{T_2 + C - \lambda}{2}\right) = 5.3 \ ft$	$MV_9 := V_9 \cdot d_{v9} = 3055.9 \ lbf$
$d_{v10} := B = 8.5 \ ft$	$MV_{10} := V_{10} \cdot d_{v10} = 812.8 \ lbf$
$d_{v11} := B = 8.5 \ ft$	$MV_{11} := V_{11} \cdot d_{v11} = 5635.1 \ lbf$

Horizontal Loads:

$H_1 := F_{SUR} \cdot \cos(90 \cdot deg - \theta + \delta)$ $H_1 = 261.3 \ \frac{lbf}{ft}$ Live Load Surcharge Resultant (horizontal comp. - LS)

$H_2 := F_T \cdot \cos(90 \cdot deg - \theta + \delta)$ $H_2 = 1811.6 \ \frac{lbf}{ft}$ Active Earth Force Resultant (horizontal comp. - EH)

Moment Arm:		Moment:	
$d_{h1} := \frac{h}{2}$	$d_{h1} = 5.2 \ ft$	$MH_1 := H_1 \cdot d_{h1}$	$MH_1 = 1358.7 \ \frac{lbf \cdot ft}{ft}$
$d_{h2} := \frac{h}{3}$	$d_{h2} = 3.5 \ ft$	$MH_2 := H_2 \cdot d_{h2}$	$MH_2 = 6280.2 \ \frac{lbf \cdot ft}{ft}$

Unfactored Loads by Load Type:

$V_{DC} := V_1 + V_2 + V_3 + V_4$ $\quad V_{DC} = 4082.5\ \frac{lbf}{ft}$ $\quad V_{EV} := V_5 + V_6 + V_7 + V_8$ $\quad V_{EV} = 6852.6\ \frac{lbf}{ft}$

$V_{LS\_Ia} := V_{10}$ $\quad V_{LS\_Ia} = 95.6\ \frac{lbf}{ft}$ $\quad V_{LS\_Ib} := V_9 + V_{10}$ $\quad V_{LS\_Ia} = 95.6\ \frac{lbf}{ft}$

$V_{EH} := V_{11}$ $\quad V_{EH} = 663\ \frac{lbf}{ft}$

$H_{EH} := H_2$ $\quad H_{EH} = 1811.6\ \frac{lbf}{ft}$ $\quad H_{LS} := H_1$ $\quad H_{LS} = 261.3\ \frac{lbf}{ft}$

Unfactored Moments by Load Type

$M_{DC} := MV_1 + MV_2 + MV_3 + MV_4$ $\quad M_{DC} = 11383.8\ \frac{lbf \cdot ft}{ft}$

$M_{EV} := MV_5 + MV_6 + MV_7 + MV_8$ $\quad M_{EV} = 36263\ \frac{lbf \cdot ft}{ft}$

$M_{LSV\_Ia} := MV_{10}$ $\quad M_{LSV\_Ia} = 812.8\ \frac{lbf \cdot ft}{ft}$

$M_{LSV\_Ib} := MV_9 + MV_{10}$ $\quad M_{LSV\_Ib} = 3868.6\ \frac{lbf \cdot ft}{ft}$

$M_{EH1} := MV_{11}$ $\quad M_{EH1} = 5635.1\ \frac{lbf \cdot ft}{ft}$

$M_{LSH} := MH_1$ $\quad M_{LSH} = 1358.7\ \frac{lbf \cdot ft}{ft}$

$M_{EH2} := MH_2$ $\quad M_{EH2} = 6280.2\ \frac{lbf \cdot ft}{ft}$

Load Combination Limit States:

$\eta := 1$ LRFD Load Modifier

Strength Limit State I: EV(min) = 1.00 EV(max) = 1.35
EH(min) = 0.90 EH(max) = 1.50
LS = 1.75

Strength Limit State Ia: (Sliding and Eccentricity) $Ia_{DC} := 0.9$ $Ia_{EV} := 1$ $Ia_{EH} := 1.5$ $Ia_{LS} := 1.75$

Strength Limit State Ib: (Bearing Capacity) $Ib_{DC} := 1.25$ $Ib_{EV} := 1.35$ $Ib_{EH} := 1.5$ $Ib_{LS} := 1.75$

Factored Vertical Loads by Limit State:

$V_{Ia} := \eta \cdot ((Ia_{DC} \cdot V_{DC}) + (Ia_{EV} \cdot V_{EV}) + (Ia_{EH} \cdot V_{EH}) + (Ia_{LS} \cdot V_{LS\_Ia}))$ $V_{Ia} = 11688.7 \frac{lbf}{ft}$

$V_{Ib} := \eta \cdot ((Ib_{DC} \cdot V_{DC}) + (Ib_{EV} \cdot V_{EV}) + (Ib_{EH} \cdot V_{EH}) + (Ib_{LS} \cdot V_{LS\_Ib}))$ $V_{Ib} = 16526.5 \frac{lbf}{ft}$

Factored Horizontal Loads by Limit State:

$H_{Ia} := \eta \cdot ((Ia_{LS} \cdot H_{LS}) + (Ia_{EH} \cdot H_{EH}))$ $H_{Ia} = 3174.7 \frac{lbf}{ft}$

$H_{Ib} := \eta \cdot ((Ib_{LS} \cdot H_{LS}) + (Ib_{EH} \cdot H_{EH}))$ $H_{Ib} = 3174.7 \frac{lbf}{ft}$

Factored Moments Produced by Vertical Loads by Limit State:

$MV_{Ia} := \eta \cdot ((Ia_{DC} \cdot M_{DC}) + (Ia_{EV} \cdot M_{EV}) + (Ia_{EH} \cdot M_{EH1}) + (Ia_{LS} \cdot M_{LSV\_Ia}))$ $MV_{Ia} = 56383.5 \frac{lbf \cdot ft}{ft}$

$MV_{Ib} := \eta \cdot ((Ib_{DC} \cdot M_{DC}) + (Ib_{EV} \cdot M_{EV}) + (Ib_{EH} \cdot M_{EH1}) + (Ib_{LS} \cdot M_{LSV\_Ib}))$ $MV_{Ib} = 78407.7 \frac{lbf \cdot ft}{ft}$

Factored Moments Produced by Horizontal Loads by Limit State:

$MH_{Ia} := \eta \cdot ((Ia_{LS} \cdot M_{LSH}) + (Ia_{EH} \cdot M_{EH2}))$ $MH_{Ia} = 11798.1 \frac{lbf \cdot ft}{ft}$

$MH_{Ib} := \eta \cdot ((Ib_{LS} \cdot M_{LSH}) + (Ib_{EH} \cdot M_{EH2}))$ $MH_{Ib} = 11798.1 \frac{lbf \cdot ft}{ft}$

Compute Bearing Resistance:

Compute the resultant location about the toe of the base length (distance from "O") Strength Ib:

$\Sigma M_R := MV_{Ib}$ $\Sigma M_R = 78407.7\ \frac{lbf \cdot ft}{ft}$ Sum of Resisting Moments (Strength Ib)

$\Sigma M_O := MH_{Ib}$ $\Sigma M_O = 11798.1\ \frac{lbf \cdot ft}{ft}$ Sum of Overturning Moments (Strength Ib)

$\Sigma V := V_{Ib}$ $\Sigma V = 16526.5\ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ib)

$x := \frac{(\Sigma M_R - \Sigma M_O)}{\Sigma V}$ $x = 4\ ft$ Distance from Point "O" the resultant intersects the base

$e := \left|\frac{B}{2} - x\right|$ $e = 0.22\ ft$ Wall eccentricity, **Note:** The vertical stress is assumed to be uniformly distributed over the effective bearing width, B', since the wall is supported by a soil foundation **LRFD [11.6.3.2]**. The effective bearing width is equal to B-2e.

Foundation Layout at bottom of Undercut & Replacement:

$B' := B - 2 \cdot e + D_{undercut}$ $B' = 8.1\ ft$ Effective Footing Width, Assumed at the bottom of Undercut and Replacement

$L' := 200\ ft$ Effective Footing Length (Assumed)

$H' := H_{Ib}$ $H' = 3174.7\ \frac{lbf}{ft}$ Summation of Horizontal Loads (Strength Ib)

$V' := V_{Ib}$ $V' = 16526.5\ \frac{lbf}{ft}$ Summation of Vertical Loads (Strength Ib)

$D_F := D_f + D_{undercut}$ Embenment Depth at bottom of Undercut

$d_w := 0\ ft$ Depth of Groundwater below ground surface at front of wall.

Drained Conditions (Effective Stress):

$N_q := \text{if}\left(\phi'_{fd} > 0, e^{\pi \cdot \tan(\phi'_{fd})} \cdot \tan\left(45\ deg + \frac{\phi'_{fd}}{2}\right)^2, 1.0\right)$ $N_q = 18.4$

$N_c := \text{if}\left(\phi'_{fd} > 0, \frac{N_q - 1}{\tan(\phi'_{fd})}, 5.14\right)$ $N_c = 30.14$

$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi'_{fd})$ $N_\gamma = 22.4$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$s_c := \text{if}\left(\phi'_{fd} > 0, 1 + \left(\frac{B'}{L'}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L'}\right)\right)$ $s_c = 1.025$

$s_q := \text{if}\left(\phi'_{fd} > 0, 1 + \left(\frac{B'}{L'} \cdot \tan(\phi'_{fd})\right), 1\right)$ $s_q = 1.023$

$s_\gamma := \text{if}\left(\phi'_{fd} > 0, 1 - 0.4 \cdot \left(\frac{B'}{L'}\right), 1\right)$ $s_\gamma = 0.984$

Load inclination factors:

$i_q := 1$

$i_\gamma := 1$

$i_c := 1$

Assumed to be 1.0, see **LRFD BDS C10.6.3.1.2a**. "Most geotechnical engineers do not used the load inclination factors". If desired, use LRFD Equations [10.6.3.1.2a-5] thru [10.6.3.1.2a-9].

Compute groundwater depth correction factors per **LRFD [Table 10.6.3.1.2a-2]**:

$C_{wq} := \text{if}\left(d_w \ge D_f, 1.0, 0.5\right)$ $\quad C_{wq} = 0.5$

$C_{w\gamma} := \text{if}\left(d_w \ge (1.5 \cdot B) + D_f, 1.0, 0.5\right)$ $\quad C_{w\gamma} = 0.5$

Depth Correction Factor per ODOT BDM 305.2.1:

$$d_q := 1 + 2 \cdot \tan\left(\phi'_{fd}\right) \cdot \left(1 - \sin\left(\phi'_{fd}\right)\right)^2 \cdot \text{atan}\left(\frac{D_F}{B'}\right)$$

$d_q = 1.18$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $\quad N_{cm} = 30.881$

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $\quad N_{qm} = 22.307$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $\quad N_{\gamma m} = 22.041$

Compute nominal bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.2a-1]:**

$q_{nd} := c'_{fd} \cdot N_{cm} + \gamma_q \cdot D_F \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot \gamma_{fd} \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma}$ $\quad q_{nd} = 13449.7 \ \frac{lbf}{ft^2}$

Compute factored bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := .55$ $\quad$ Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Rd} := \phi_b \cdot q_{nd}$ $\quad q_{Rd} = 7.4 \ ksf$ $\quad$ Factored bearing resistance Drained Conditions

Undrained Conditions (Effective Stress):

$N_q := \text{if}\left(\phi_{fdu} > 0, e^{\pi \cdot \tan\left(\phi_{fdu}\right)} \cdot \tan\left(45\ deg + \frac{\phi_{fdu}}{2}\right)^2, 1.0\right)$ $\quad N_q = 18.4$

$N_c := \text{if}\left(\phi_{fdu} > 0, \frac{N_q - 1}{\tan\left(\phi_{fdu}\right)}, 5.14\right)$ $\quad N_c = 30.14$

$N_\gamma := 2 \cdot \left(N_q + 1\right) \cdot \tan\left(\phi_{fdu}\right)$ $\quad N_\gamma = 22.4$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$$s_c := \text{if}\left(\phi_{fdu} > 0, 1 + \left(\frac{B'}{L'}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L'}\right)\right) \qquad s_c = 1.025$$

$$s_q := \text{if}\left(\phi_{fdu} > 0, 1 + \left(\frac{B'}{L'} \cdot \tan\left(\phi_{fdu}\right)\right), 1\right) \qquad s_q = 1.023$$

$$s_\gamma := \text{if}\left(\phi_{fdu} > 0, 1 - 0.4 \cdot \left(\frac{B'}{L'}\right), 1\right) \qquad s_\gamma = 0.984$$

Load inclination factors:

$i_q := 1$

$i_\gamma := 1$

$i_c := 1$

Assumed to be 1.0, see **LRFD BDS C10.6.3.1.2a**. "Most geotechnical engineers do not used the load inclination factors". If desired, use LRFD Equations [10.6.3.1.2a-5] thru [10.6.3.1.2a-9].

Depth Correction Factor per ODOT BDM 305.2.1:

$$d_q := 1 + 2 \cdot \tan\left(\phi_{fdu}\right) \cdot \left(1 - \sin\left(\phi_{fdu}\right)\right)^2 \cdot \text{atan}\left(\frac{D_F}{B'}\right)$$

$d_q = 1.18$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c \qquad N_{cm} = 30.881$

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q \qquad N_{qm} = 22.307$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma \qquad N_{\gamma m} = 22.041$

Compute nominal bearing resistance at bottom of Undercut & Replacement. **LRFD [Eq 10.6.3.1.2a-1:**

$$q_{nu} := Su_{fdu} \cdot N_{cm} + \gamma_q \cdot D_F \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot \gamma_{fd} \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma} \qquad q_{nu} = 13449.7 \ \frac{lbf}{ft^2}$$

Compute factored bearing resistance at bottom of Undercut & Replacement. **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := .55$ — Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Ru} := \phi_b \cdot q_{nu} \qquad q_{Ru} = 7.4 \ ksf$ — Factored bearing resistance Undrained Conditions

Factored Bearing Resistance Drained vs. Undrained Conditions:

Drained Conditions: $q_{Rd} = 7.4 \ ksf$

Undrained Conditions: $q_{Ru} = 7.4 \ ksf$

Evaluate External Stability of Wall:

Compute the factored bearing stress at bottom of Undercut & Replacement:

$e = 0.22\ ft$

$\sigma_V := \frac{\Sigma V}{B'}$ $\sigma_V = 2.05\ ksf$

Bearing Capacity at bottom of Undercut & Replacement:Demand Ratio (CDR)

Drained Conditions: $CDR_{Bearing\_D} := \frac{q_{Rd}}{\sigma_V}$ Is the CDR > or = to 1.0? $CDR_{Bearing\_D} = 3.61$

Undrained Conditions: $CDR_{Bearing\_U} := \frac{q_{Ru}}{\sigma_V}$ Is the CDR > or = to 1.0? $CDR_{Bearing\_U} = 3.61$

Limiting Eccentricity at Base of Wall (Strength Ia):

Compute the resultant location about the toe "O" of the base length (distance from Pivot):

$e_{max} := \frac{B}{3}$ $e_{max} = 2.8\ ft$ Maximum Eccentricity **LRFD [C11.6.3.3.] Equals B/3 for soil.**

$\Sigma M_R := MV_{Ia}$ $\Sigma M_R = 56383.5\ \frac{lbf \cdot ft}{ft}$ Sum of Resisting Moments (Strength Ia)

$\Sigma M_O := MH_{Ia}$ $\Sigma M_O = 11798.1\ \frac{lbf \cdot ft}{ft}$ Sum of Overturning Moments (Strength Ia)

$\Sigma V := V_{Ia}$ $\Sigma V = 11688.7\ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$x := \frac{(\Sigma M_R - \Sigma M_O)}{\Sigma V}$ $x = 3.8\ ft$ Distance from Point "O" the resultant intersects the base

$e := \left|\frac{B}{2} - x\right|$ $e = 0.44\ ft$ Wall eccentricity, **Note:** The vertical stress is assumed to be uniformly distributed over the effective bearing width, B', since the wall is supported by a soil foundation **LRFD [11.6.3.2**]. The effective bearing width is equal to B-2e. .

Eccentricity Capacity:Demand Ratio (CDR)

$CDR_{Eccentricity} := \frac{e_{max}}{e}$ Is the CDR > or = to 1.0? $CDR_{Eccentricity} = 6.50$

Sliding Resistance at Base of Wall LRFD [10.6.3.4]:

Factored Sliding Force (Strength Ia):

$R_u := H_{Ia}$ $\qquad R_u = 3174.7\ \frac{lbf}{ft}$

Drained/Undrained Conditions for Granular Replacement (Effective Stress):

Compute passive resistance throughout the design life of the wall **LRFD [Eq 3.11.5.4-1]**::

$r_{ep1} := \left(k_{pd} \cdot \gamma_{fd} \cdot y_1 + 2 \cdot c'_{fd} \cdot \sqrt{k_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y1

$r_{ep2} := \left(k_{pd} \cdot \gamma_{fd} \cdot y_2 + 2 \cdot c'_{fd} \cdot \sqrt{k_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y2

$R_{ep} := \frac{r_{ep1} + r_{ep2}}{2} \cdot \left(y_2 - y_1\right)$ $\qquad R_{ep} = 0\ \frac{lbf}{ft}$ Nominal passive resistance Drained Conditions

416 Note: Passive Resistance shall be neglected in stability computations, unless the base of the wall extends below the depth of maximum scour, freeze-thaw or other disturbances. In the latter case, only the embedment below the greater of these depths shall be considered effective **LRFD [11.6.3.5]**.

Compute sliding resistance between soil and foundation:

$c := 1.0$ c = 1.0 for Cast-in-Place
c = 0.8 for Precast

$\Sigma V := V_{Ia}$ $\qquad \Sigma V = 11688.7\ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$R_\tau := c \cdot \Sigma V \cdot \tan\left(\phi_{Re}\right)$ $\qquad R_\tau = 7884.1\ \frac{lbf}{ft}$ Nominal sliding resistance Cohesionless Soils

Compute factored resistance against failure by sliding **LRFD [10.6.3.4]**:

$\phi_{ep} := 0.5$ Resistance factor for passive resistance specified in **LRFD Table 10.5.5.2.2-1**

$\phi_\tau := 1.0$ Resistance factor for sliding resistance specified in **LRFD Table 11.5.7-1.**

$\phi R_n := \phi_\tau \cdot R_\tau + \phi_{ep} \cdot R_{ep}$ $\qquad R_R := \phi R_n$

Factored Sliding Resistance to be used in CDR Calculations: $R_R = 7884.098\ \frac{lbf}{ft}$

Sliding Capacity:Demand Ratio (CDR)

$CDR_{Sliding\_Base} := \frac{R_R}{R_u}$ Is the CDR > or = to 1.0? $CDR_{Sliding\_Base} = 2.48$

Objective: **To evaluate the external stability of CIP wall design with broken backsloping backfill.**
Method: **In accordance with ODOT Bridge Design Manual, 2021 [Sect. 204.6.2.2] LRFD Bridge Design Specifications, 9th Ed., 2020, [Sect. 11.6.1, Sect. 11.6.2, and Sect. 11.6.3].**

Givens:

Backfill Soil Design Parameters:

$\phi'_f := 30\ deg$ — Effective angle of internal friction

$\gamma_f := 120\ \frac{lbf}{ft^3}$ — Unit weight

$c'_f := 0\ \frac{lbf}{ft^2}$ — Effective Cohesion

$\delta := 0.67 \cdot \phi'_f$ $\quad \delta = 20.1\ deg$ — Friction angle between backfill and wall taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

Foundation Soil Design Parameters:

Drained Conditions (Effective Stress):

$\phi'_{fd} := 21\ deg$ — Effective angle of internal friction

$\gamma_{fd} := 115\ \frac{lbf}{ft^3}$ — Unit weight

$c'_{fd} := 75\ \frac{lbf}{ft^2}$ — Effective Cohesion

$\delta_{fd} := 0.67 \cdot \phi'_{fd}$ $\quad \delta_{fd} = 14.1\ deg$ — Friction angle between foundation soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

Undrained Conditions (Total Stress):

$\phi_{fdu} := 0\ deg$ — Angle of internal friction (Same as Drained Conditions if granular soils)

$Su_{fdu} := 700\ \frac{lbf}{ft^2}$ — Undrained Shear Strength

$\delta_{fdu} := 0.67 \cdot \phi_{fdu}$ $\quad \delta_{fdu} = 0\ deg$ — Friction angle between foundation soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

Undercut & Replacement Design Parameters:

$\phi_{Re} := 34\ deg$ — Angle of internal friction for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$c_{Re} := 0\ \frac{lbf}{ft^2}$ — Cohesion for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$\gamma_{Re} := 130\ \frac{lbf}{ft^3}$ — Unit Weight for Replacement soil - Item 203 Granular Material Type C, C&MS 703.16.C. ODOT BDM Table 307-1.

$\delta_{Re} := 0.67 \cdot \phi_{Re}$ $\quad \delta_{Re} = 22.8\ deg$ — Friction angle between Replacement soils and footing taken as specified in **LRFD BDS C3.11.5.3 (degrees)**

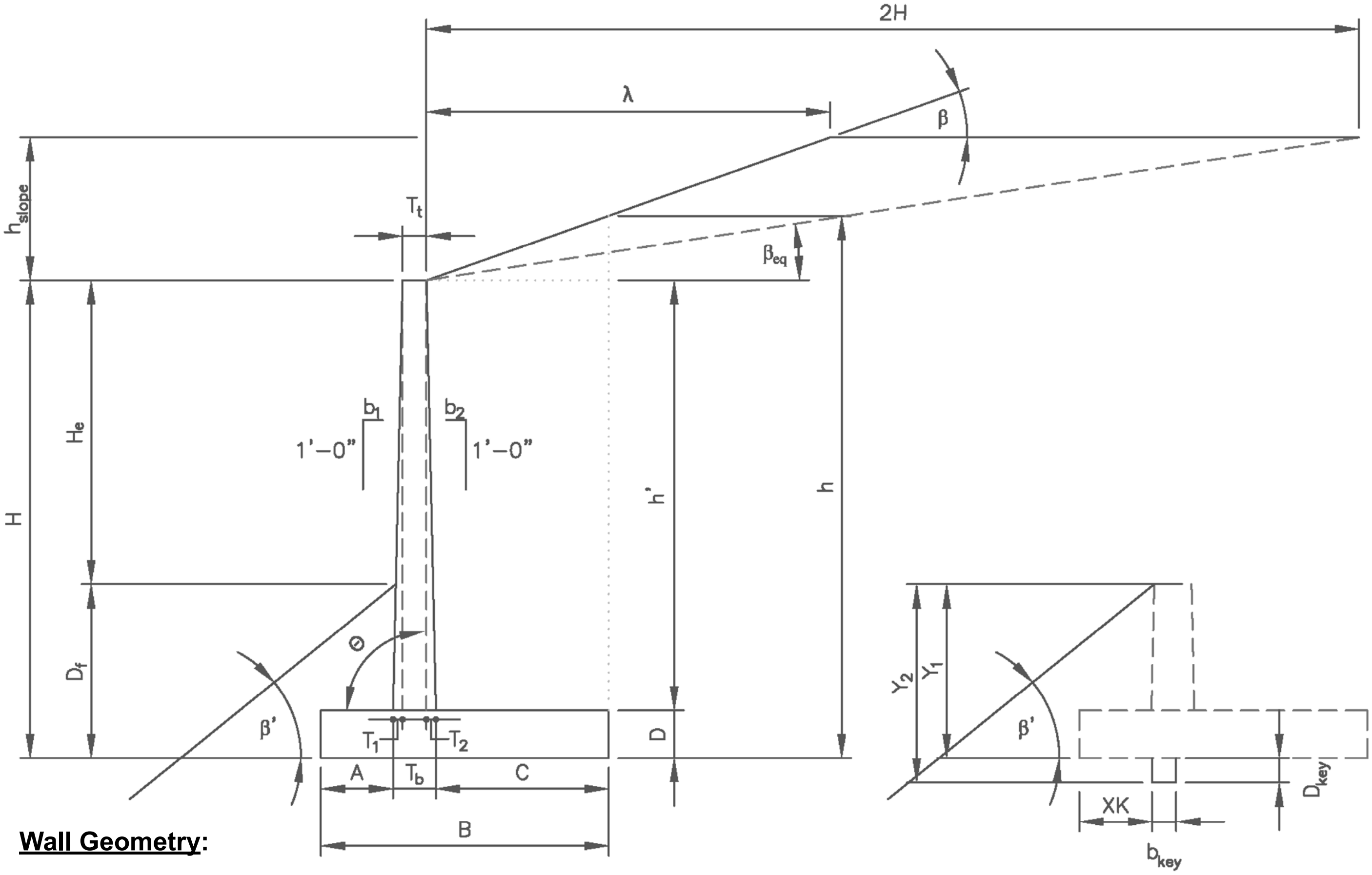
$D_{undercut} := 0\ ft$ — Depth of Undercut below bottom of footing

Foundation Surcharge Soil Parameters:

$\gamma_q := 120\ \frac{lbf}{ft^3}$ — Unit weight of Soil above bearing depth (Used in Bearing Resistance of Soil Calculation LRFD 10.6.3.1.2a-1)

Other Parameters:

$\gamma_c := 150\ \frac{lbf}{ft^3}$ — Concrete Unit weight



Wall Geometry:

$H_e := 4.3\ ft$ — Exposed wall height

$D_f := 6.5\ ft$ — Footing cover at Toe

Note: Where the potential for scour, erosion of undermining exists, spread footings shall be located to bear below the maximum depth of scour or undermining. Spread footings shall be located below the depth of potential frost. **LRFD BDS 10.6.1.2**

$H := H_e + D_f$ $\quad H = 10.8\ ft$ — Design Wall Height

$T_t := 14\ in$ — Stem thickness at top of wall

$b_1 := 0 \cdot \left(\frac{in}{ft}\right)$ — Frontwall batter, (b1H:12V)

$b_2 := 0 \cdot \left(\frac{in}{ft}\right)$ — Backwall batter, (b2H:12V)

Preliminary Wall Dimensioning:

$B := 8.5\ ft$	$\frac{2}{5} \cdot H = 4.32\ ft$	to	$\frac{3}{5} \cdot H = 6.48\ ft$	Footing base width (2/5H to 3/5H)
$A := 0.917\ ft$	$\frac{H}{8} = 1.35\ ft$	to	$\frac{H}{5} = 2.16\ ft$	Toe projection (H/8 to H/5)
$D := 1.5\ ft$	$\frac{H}{8} = 1.35\ ft$	to	$\frac{H}{5} = 2.16\ ft$	Footing thickness (H/8 to H/5)

Shear Key Dimensioning:

$D_{key} := 0\ ft$ — Depth of shear key from bottom of footing
Note: Footings on rock typically require shear key

$b_{key} := 0\ ft$ — Width of shear key

$XK := 0\ ft$ — Distance from toe to shear key

Other Wall Dimensions:

$h' := H - D$	$h' = 9.3\ ft$	Stem height
$T_1 := b_1 \cdot h'$	$T_1 = 0\ ft$	Stem front batter width
$T_2 := b_2 \cdot h'$	$T_2 = 0\ ft$	Stem back batter width
$T_b := T_1 + T_2 + T_t$	$T_b = 1.167\ ft$	Stem thickness at bottom of wall
$C := B - A - T_b$	$C = 6.416\ ft$	Heel projection
$\theta := 90\ deg$		Angle of back face of wall to horizontal = *atan(12/b2)*
$b := 12\ in$	$b = 1\ ft$	Concrete strip width (for design)
$y_1 := D_f$	$y_1 = 6.5\ ft$	Depth to where passive pressure may begin to be utilized in front of wall.
$y_2 := D_f + D_{key}$	$y_2 = 6.5\ ft$	Bottom of shear key/footing depth i.e. depth to where passive pressure may no longer be utilized.

Site Grading and Slope Dimensions:

$\beta := 0\ deg$ — Inclination of ground slope behind face of wall. Horizontal backfill behind CIP wall, β = 0 deg

Inclination of ground slope:

- Horizontal: **0**
- 3H:1V: **18.435**
- 2H:1V: **26.565**
- 1.5H:1V: **33.690**

$\beta' := 18.435\ deg$ — Inclination of ground slope in front of wall. If it is horizontal backfill in front of CIP wall, β' = 0 deg. A negative angle (-) indicates grades slope up from front of wall. Positive angle (+) indicates grade slope down from wall as shown in above figure.

$\lambda := 0\ ft$ — Horizontal distance from the back of the wall to point of slope crest .

$L_{Traffic} := 0\ ft$ — Horizontal distance from assumed traffic surcharge load to Backface of Wall.

$2 \cdot H = 21.6\ ft$ — **IF λ IS GREATER THAN 2*H - USE INFINITE SLOPE CALCULATION SHEET**

$h_{slope} := \lambda \cdot \tan(\beta)$ — $h_{slope} = 0\ ft$ — Height of broken slope behind wall

$\beta_{eq} := \operatorname{atan}\left(\frac{h_{slope}}{2 \cdot H}\right) = 0\ deg$ — Equivalent backslope angle

$h := \text{if}\left(\lambda \le T_2 + C, H + h_{slope}, H + (T_2 + C) \cdot \tan(\beta)\right) = 10.8\ ft$ — Height of retained fill at back of heel

Live Load Surcharge Parameters:

$SUR := \text{if}\left(L_{Traffic} < \frac{H}{2}, 90\ \frac{lbf}{ft^2}, 0\ \frac{lbf}{ft^2}\right) = 90\ \frac{lbf}{ft^2}$

Live load surcharge (per LRFD BDS [3.11.6.4])
Note: ,A live load ssurcharge shall be applied where vehicular load is expected to act on the surface of the backfill within a distance equal to one-half the wall height behind the back face of the wall, see LRFD BDS Section 3.11.6.4 and Table 3.11.6.4-2 .

Calculations:

Earth Pressure Coefficients:

Backfill Active Earth:

$$\Gamma := \left(1 + \sqrt{\frac{\left(\sin\left(\phi'_f + \delta\right) \cdot \sin\left(\phi'_f - \beta_{eq}\right)\right)}{\left(\sin\left(\theta - \delta\right) \cdot \sin\left(\theta + \beta_{eq}\right)\right)}}\right)^2 \qquad \Gamma = 2.687$$

$$k_{af} := \left(\frac{\left(\sin\left(\theta + \phi'_f\right)\right)^2}{\left(\Gamma \cdot \left(\sin(\theta)\right)^2 \cdot \sin\left(\theta - \delta\right)\right)}\right) \qquad k_{af} = 0.297$$

Active Earth Pressure Coefficient (**per LRFD Sect. 3.11.5.3**)

Foundation Soil Passive Earth:

Drained Conditions assuming($\phi'_{fd} > 0$):
Input Parameters for **LRFD Figure 3.11.5.4-2**, assumes θ = 90 degrees

$\frac{-\beta'}{\phi'_{fd}} = -0.878$ $\qquad$ $\frac{-\delta_{fd}}{\phi'_{fd}} = -0.67$

$k'_p := 1.35$

Passive Earth Pressure Coefficient from **LRFD Figure 3.11.5.4-2**

Determine Reduction Factor (R) by interpolation:

$R_d := 0.9$

Reduction Factor

$k_{pd} := R_d \cdot k'_p \qquad k_{pd} = 1.215$

Passive Earth Pressure Coefficient for Drained Conditions

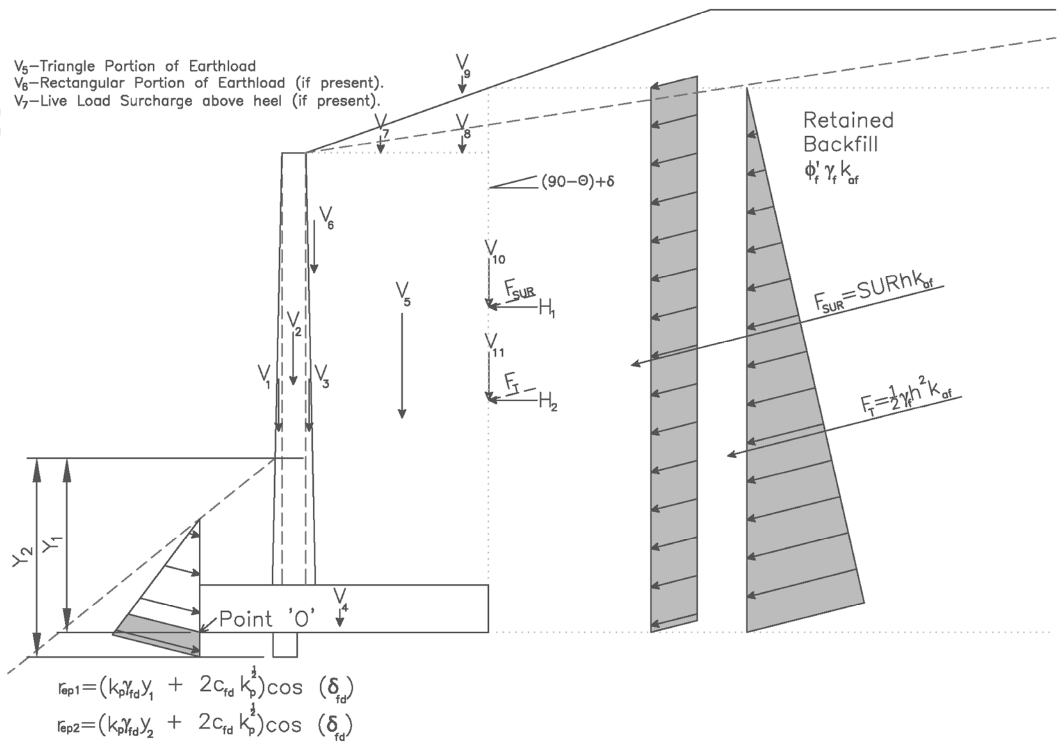
Undrained Conditions ($\phi_{fdu} > 0$): **Note:** Expand window below to complete calculation

Undrained Conditions:

$k_{pu} := \text{if}\left(\phi_{fdu} > 0, k_{pu}, 1\right) \qquad k_{pu} = 1$

Passive Earth Pressure Coefficient for Resistance Undrained Conditions

Compute Unfactored Loads LRFD [Tables 3.4.1-1 and 3.4.1-2]:



$F_T := \frac{1}{2} \cdot \gamma_f \cdot h^2 \cdot k_{af}$	$F_T = 2080.3\ \frac{lbf}{ft}$	Active Earth Force Resultant (EH)
$F_{SUR} := SUR \cdot h \cdot k_{af}$	$F_{SUR} = 288.9\ \frac{lbf}{ft}$	Live Load Surcharge (LS)

Vertical Loads:

$V_1 := \frac{1}{2} \cdot T_1 \cdot h' \cdot \gamma_c$	$V_1 = 0\ \frac{lbf}{ft}$	Wall stem front batter (DC)
$V_2 := T_t \cdot (h' + 3.5\ ft) \cdot \gamma_c$	$V_2 = 2240\ \frac{lbf}{ft}$	Wall stem (DC)
$V_3 := \frac{1}{2} \cdot T_2 \cdot h' \cdot \gamma_c$	$V_3 = 0\ \frac{lbf}{ft}$	Wall stem back batter (DC)
$V_4 := D \cdot B \cdot \gamma_c$	$V_4 = 1912.5\ \frac{lbf}{ft}$	Wall Footing (DC)
$V_5 := C \cdot h' \cdot \gamma_f$	$V_5 = 7160.6\ \frac{lbf}{ft}$	Soil Backfill - Heel (EV)
$V_6 := \frac{1}{2} \cdot T_2 \cdot h' \cdot \gamma_f$	$V_6 = 0\ \frac{lbf}{ft}$	Soil Backfill - Batter (EV)

$$V_7 := \text{if}\left(\lambda \le T_2 + C, \frac{1}{2} \cdot \lambda^2 \cdot \tan(\beta) \cdot \gamma_f, \frac{1}{2} \cdot (T_2 + C)^2 \cdot \tan(\beta) \cdot \gamma_f\right)$$

$V_7 = 0\ \frac{lbf}{ft}$ — Soil Backfill - Backslope Triangle Portion (EV)

$$V_8 := \text{if}\left(\lambda \le T_2 + C, (T_2 + C - \lambda) \cdot h_{slope} \cdot \gamma_f, 0 \cdot \frac{lbf}{ft}\right)$$

$V_8 = 0\ \frac{lbf}{ft}$ — Soil Backfill - Backslope Rectangular Portion (EV)

$V_9 := \text{if}\left(\lambda \le T_2 + C, (T_2 + C - \lambda) \cdot SUR, 0 \cdot \frac{lbf}{ft}\right)$

$V_9 = 577.5 \ \frac{lbf}{ft}$ Live Load Surcharge Above Heel - (LS)

$V_{10} := F_{SUR} \cdot \sin(90 \cdot deg - \theta + \delta)$ $V_{10} = 99.3 \ \frac{lbf}{ft}$ Live Load Surcharge Resultant (vertical comp. - LS)

$V_{11} := F_T \cdot \sin(90 \cdot deg - \theta + \delta)$ $V_{11} = 714.9 \ \frac{lbf}{ft}$ Active earth force resultant (vertical component - EH)

Moment Arm: Moment:

Moments produced from vertical loads about Point 'O'

$d_{v1} := A + \frac{2}{3} \cdot T_1 = 0.9 \ ft$ $MV_1 := V_1 \cdot d_{v1} = 0 \ lbf$

$d_{v2} := A + T_1 + \frac{T_t}{2} = 1.5 \ ft$ $MV_2 := V_2 \cdot d_{v2} = 3360.7 \ lbf$

$d_{v3} := A + T_1 + T_t + \frac{T_2}{3} = 2.1 \ ft$ $MV_3 := V_3 \cdot d_{v3} = 0 \ lbf$

$d_{v4} := \frac{B}{2} = 4.3 \ ft$ $MV_4 := V_4 \cdot d_{v4} = 8128.1 \ lbf$

$d_{v5} := B - \frac{C}{2} = 5.3 \ ft$ $MV_5 := V_5 \cdot d_{v5} = 37892.8 \ lbf$

$d_{v6} := A + T_1 + T_t + \frac{2 \ T_2}{3} = 2.1 \ ft$ $MV_6 := V_6 \cdot d_{v6} = 0 \ lbf$

$d_{v7} := \text{if}\left(\lambda \le T_2 + C, A + T_1 + T_t + \left(\frac{2}{3}(\lambda)\right), A + T_1 + T_t + \left(\frac{2}{3}(T_2 + C)\right)\right) = 2.1 \ ft$ $MV_7 := V_7 \cdot d_{v7} = 0 \ lbf$

$d_{v8} := A + T_1 + T_t + \lambda + \left(\frac{T_2 + C - \lambda}{2}\right) = 5.3 \ ft$ $MV_8 := V_8 \cdot d_{v8} = 0 \ lbf$

$d_{v9} := A + T_1 + T_t + \lambda + \left(\frac{T_2 + C - \lambda}{2}\right) = 5.3 \ ft$ $MV_9 := V_9 \cdot d_{v9} = 3055.9 \ lbf$

$d_{v10} := B = 8.5 \ ft$ $MV_{10} := V_{10} \cdot d_{v10} = 844 \ lbf$

$d_{v11} := B = 8.5 \ ft$ $MV_{11} := V_{11} \cdot d_{v11} = 6076.9 \ lbf$

Horizontal Loads:

$H_1 := F_{SUR} \cdot \cos(90 \cdot deg - \theta + \delta)$ $H_1 = 271.3 \ \frac{lbf}{ft}$ Live Load Surcharge Resultant (horizontal comp. - LS)

$H_2 := F_T \cdot \cos(90 \cdot deg - \theta + \delta)$ $H_2 = 1953.6 \ \frac{lbf}{ft}$ Active Earth Force Resultant (horizontal comp. - EH)

Moment Arm: Moment:

$d_{h1} := \frac{h}{2}$ $d_{h1} = 5.4 \ ft$ $MH_1 := H_1 \cdot d_{h1}$ $MH_1 = 1465.2 \ \frac{lbf \cdot ft}{ft}$

$d_{h2} := \frac{h}{3}$ $d_{h2} = 3.6 \ ft$ $MH_2 := H_2 \cdot d_{h2}$ $MH_2 = 7033.1 \ \frac{lbf \cdot ft}{ft}$

Unfactored Loads by Load Type:

$V_{DC} := V_1 + V_2 + V_3 + V_4$ $\quad V_{DC} = 4152.5\ \frac{lbf}{ft}$ $\quad V_{EV} := V_5 + V_6 + V_7 + V_8$ $\quad V_{EV} = 7160.6\ \frac{lbf}{ft}$

$V_{LS\_Ia} := V_{10}$ $\quad V_{LS\_Ia} = 99.3\ \frac{lbf}{ft}$ $\quad V_{LS\_Ib} := V_9 + V_{10}$ $\quad V_{LS\_Ia} = 99.3\ \frac{lbf}{ft}$

$V_{EH} := V_{11}$ $\quad V_{EH} = 714.9\ \frac{lbf}{ft}$

$H_{EH} := H_2$ $\quad H_{EH} = 1953.6\ \frac{lbf}{ft}$ $\quad H_{LS} := H_1$ $\quad H_{LS} = 271.3\ \frac{lbf}{ft}$

Unfactored Moments by Load Type

$M_{DC} := MV_1 + MV_2 + MV_3 + MV_4$ $\quad M_{DC} = 11488.9\ \frac{lbf \cdot ft}{ft}$

$M_{EV} := MV_5 + MV_6 + MV_7 + MV_8$ $\quad M_{EV} = 37892.8\ \frac{lbf \cdot ft}{ft}$

$M_{LSV\_Ia} := MV_{10}$ $\quad M_{LSV\_Ia} = 844\ \frac{lbf \cdot ft}{ft}$

$M_{LSV\_Ib} := MV_9 + MV_{10}$ $\quad M_{LSV\_Ib} = 3899.9\ \frac{lbf \cdot ft}{ft}$

$M_{EH1} := MV_{11}$ $\quad M_{EH1} = 6076.9\ \frac{lbf \cdot ft}{ft}$

$M_{LSH} := MH_1$ $\quad M_{LSH} = 1465.2\ \frac{lbf \cdot ft}{ft}$

$M_{EH2} := MH_2$ $\quad M_{EH2} = 7033.1\ \frac{lbf \cdot ft}{ft}$

Load Combination Limit States:

$\eta := 1$ LRFD Load Modifier

Strength Limit State I: EV(min) = 1.00 EV(max) = 1.35
EH(min) = 0.90 EH(max) = 1.50
LS = 1.75

Strength Limit State Ia: (Sliding and Eccentricity) $Ia_{DC} := 0.9$ $Ia_{EV} := 1$ $Ia_{EH} := 1.5$ $Ia_{LS} := 1.75$

Strength Limit State Ib: (Bearing Capacity) $Ib_{DC} := 1.25$ $Ib_{EV} := 1.35$ $Ib_{EH} := 1.5$ $Ib_{LS} := 1.75$

Factored Vertical Loads by Limit State:

$V_{Ia} := \eta \cdot ((Ia_{DC} \cdot V_{DC}) + (Ia_{EV} \cdot V_{EV}) + (Ia_{EH} \cdot V_{EH}) + (Ia_{LS} \cdot V_{LS\_Ia}))$ $V_{Ia} = 12144 \ \frac{lbf}{ft}$

$V_{Ib} := \eta \cdot ((Ib_{DC} \cdot V_{DC}) + (Ib_{EV} \cdot V_{EV}) + (Ib_{EH} \cdot V_{EH}) + (Ib_{LS} \cdot V_{LS\_Ib}))$ $V_{Ib} = 17114.2 \ \frac{lbf}{ft}$

Factored Horizontal Loads by Limit State:

$H_{Ia} := \eta \cdot ((Ia_{LS} \cdot H_{LS}) + (Ia_{EH} \cdot H_{EH}))$ $H_{Ia} = 3405.3 \ \frac{lbf}{ft}$

$H_{Ib} := \eta \cdot ((Ib_{LS} \cdot H_{LS}) + (Ib_{EH} \cdot H_{EH}))$ $H_{Ib} = 3405.3 \ \frac{lbf}{ft}$

Factored Moments Produced by Vertical Loads by Limit State:

$MV_{Ia} := \eta \cdot ((Ia_{DC} \cdot M_{DC}) + (Ia_{EV} \cdot M_{EV}) + (Ia_{EH} \cdot M_{EH1}) + (Ia_{LS} \cdot M_{LSV\_Ia}))$ $MV_{Ia} = 58825.2 \ \frac{lbf \cdot ft}{ft}$

$MV_{Ib} := \eta \cdot ((Ib_{DC} \cdot M_{DC}) + (Ib_{EV} \cdot M_{EV}) + (Ib_{EH} \cdot M_{EH1}) + (Ib_{LS} \cdot M_{LSV\_Ib}))$ $MV_{Ib} = 81456.6 \ \frac{lbf \cdot ft}{ft}$

Factored Moments Produced by Horizontal Loads by Limit State:

$MH_{Ia} := \eta \cdot ((Ia_{LS} \cdot M_{LSH}) + (Ia_{EH} \cdot M_{EH2}))$ $MH_{Ia} = 13113.8 \ \frac{lbf \cdot ft}{ft}$

$MH_{Ib} := \eta \cdot ((Ib_{LS} \cdot M_{LSH}) + (Ib_{EH} \cdot M_{EH2}))$ $MH_{Ib} = 13113.8 \ \frac{lbf \cdot ft}{ft}$

Compute Bearing Resistance:

Compute the resultant location about the toe of the base length (distance from "O") Strength Ib:

$\Sigma M_R := MV_{Ib}$ — $\Sigma M_R = 81456.6 \ \frac{lbf \cdot ft}{ft}$ — Sum of Resisting Moments (Strength Ib)

$\Sigma M_O := MH_{Ib}$ — $\Sigma M_O = 13113.8 \ \frac{lbf \cdot ft}{ft}$ — Sum of Overturning Moments (Strength Ib)

$\Sigma V := V_{Ib}$ — $\Sigma V = 17114.2 \ \frac{lbf}{ft}$ — Sum of Vertical Loads (Strength Ib)

$x := \frac{(\Sigma M_R - \Sigma M_O)}{\Sigma V}$ — $x = 4 \ ft$ — Distance from Point "O" the resultant intersects the base

$e := \left| \frac{B}{2} - x \right|$ — $e = 0.26 \ ft$ — Wall eccentricity, **Note:** The vertical stress is assumed to be uniformly distributed over the effective bearing width, B', since the wall is supported by a soil foundation **LRFD [11.6.3.2]**. The effective bearing width is equal to B-2e.

Foundation Layout at bottom of Undercut & Replacement:

$B' := B - 2 \cdot e + D_{undercut}$ — $B' = 8 \ ft$ — Effective Footing Width, Assumed at the bottom of Undercut and Replacement

$L' := 200 \ ft$ — Effective Footing Length (Assumed)

$H' := H_{Ib}$ — $H' = 3405.3 \ \frac{lbf}{ft}$ — Summation of Horizontal Loads (Strength Ib)

$V' := V_{Ib}$ — $V' = 17114.2 \ \frac{lbf}{ft}$ — Summation of Vertical Loads (Strength Ib)

$D_F := D_f + D_{undercut}$ — Embenment Depth at bottom of Undercut

$d_w := 0 \ ft$ — Depth of Groundwater below ground surface at front of wall.

Drained Conditions (Effective Stress):

$$N_q := \text{if}\left(\phi'_{fd} > 0, e^{\pi \cdot \tan(\phi'_{fd})} \cdot \tan\left(45 \ deg + \frac{\phi'_{fd}}{2}\right)^2, 1.0\right) \qquad N_q = 7.07$$

$$N_c := \text{if}\left(\phi'_{fd} > 0, \frac{N_q - 1}{\tan(\phi'_{fd})}, 5.14\right) \qquad N_c = 15.81$$

$$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi'_{fd}) \qquad N_\gamma = 6.2$$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$$s_c := \text{if}\left(\phi'_{fd} > 0, 1 + \left(\frac{B'}{L'}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L'}\right)\right) \qquad s_c = 1.018$$

$$s_q := \text{if}\left(\phi'_{fd} > 0, 1 + \left(\frac{B'}{L'} \cdot \tan(\phi'_{fd})\right), 1\right) \qquad s_q = 1.015$$

$$s_\gamma := \text{if}\left(\phi'_{fd} > 0, 1 - 0.4 \cdot \left(\frac{B'}{L'}\right), 1\right) \qquad s_\gamma = 0.984$$

Load inclination factors:

$i_q := 1$

$i_\gamma := 1$

$i_c := 1$

Assumed to be 1.0, see **LRFD BDS C10.6.3.1.2a**. "Most geotechnical engineers do not used the load inclination factors". If desired, use LRFD Equations [10.6.3.1.2a-5] thru [10.6.3.1.2a-9].

Compute groundwater depth correction factors per **LRFD [Table 10.6.3.1.2a-2]**:

$C_{wq} := \text{if}\left(d_w \ge D_f, 1.0, 0.5\right)$ $\quad C_{wq} = 0.5$

$C_{w\gamma} := \text{if}\left(d_w \ge (1.5 \cdot B) + D_f, 1.0, 0.5\right)$ $\quad C_{w\gamma} = 0.5$

Depth Correction Factor per ODOT BDM 305.2.1:

$$d_q := 1 + 2 \cdot \tan\left(\phi'_{fd}\right) \cdot \left(1 - \sin\left(\phi'_{fd}\right)\right)^2 \cdot \text{atan}\left(\frac{D_F}{B'}\right)$$

$d_q = 1.22$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $\quad N_{cm} = 16.097$

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $\quad N_{qm} = 8.729$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $\quad N_{\gamma m} = 6.097$

Compute nominal bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.2a-1]:**

$q_{nd} := c'_{fd} \cdot N_{cm} + \gamma_q \cdot D_F \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot \gamma_{fd} \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma}$ $\quad q_{nd} = 6011.7\ \frac{lbf}{ft^2}$

Compute factored bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := .55$ $\quad$ Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Rd} := \phi_b \cdot q_{nd}$ $\quad q_{Rd} = 3.3\ ksf$ $\quad$ Factored bearing resistance Drained Conditions

Undrained Conditions (Effective Stress):

$$N_q := \text{if}\left(\phi_{fdu} > 0, e^{\pi \cdot \tan\left(\phi_{fdu}\right)} \cdot \tan\left(45\ deg + \frac{\phi_{fdu}}{2}\right)^2, 1.0\right)$$ $\quad N_q = 1$

$$N_c := \text{if}\left(\phi_{fdu} > 0, \frac{N_q - 1}{\tan\left(\phi_{fdu}\right)}, 5.14\right)$$ $\quad N_c = 5.14$

$N_\gamma := 2 \cdot \left(N_q + 1\right) \cdot \tan\left(\phi_{fdu}\right)$ $\quad N_\gamma = 0$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$s_c := \text{if}\left(\phi_{fdu} > 0, 1 + \left(\frac{B'}{L'}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L'}\right)\right)$ $s_c = 1.008$

$s_q := \text{if}\left(\phi_{fdu} > 0, 1 + \left(\frac{B'}{L'} \cdot \tan(\phi_{fdu})\right), 1\right)$ $s_q = 1$

$s_\gamma := \text{if}\left(\phi_{fdu} > 0, 1 - 0.4 \cdot \left(\frac{B'}{L'}\right), 1\right)$ $s_\gamma = 1$

Load inclination factors:

$i_q := 1$

$i_\gamma := 1$

$i_c := 1$

Assumed to be 1.0, see **LRFD BDS C10.6.3.1.2a**. "Most geotechnical engineers do not used the load inclination factors". If desired, use LRFD Equations [10.6.3.1.2a-5] thru [10.6.3.1.2a-9].

Depth Correction Factor per ODOT BDM 305.2.1:

$d_q := 1 + 2 \cdot \tan(\phi_{fdu}) \cdot (1 - \sin(\phi_{fdu}))^2 \cdot \text{atan}\left(\frac{D_F}{B'}\right)$

$d_q = 1$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $N_{cm} = 5.181$

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $N_{qm} = 1$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $N_{\gamma m} = 0$

Compute nominal bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.2a-1:**

$q_{nu} := Su_{fdu} \cdot N_{cm} + \gamma_q \cdot D_F \cdot N_{qm} \cdot C_{wq} + 0.5 \cdot \gamma_{fd} \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma}$ $q_{nu} = 4016.7 \frac{lbf}{ft^2}$

Compute factored bearing resistance at bottom of Undercut & Replacement, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := .55$ Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Ru} := \phi_b \cdot q_{nu}$ $q_{Ru} = 2.2\ ksf$ Factored bearing resistance Undrained Conditions

Factored Bearing Resistance Drained vs. Undrained Conditions:

Drained Conditions: $q_{Rd} = 3.3\ ksf$

Undrained Conditions: $q_{Ru} = 2.2\ ksf$

Evaluate External Stability of Wall:

Compute the factored bearing stress at bottom of Undercut & Replacement:

$e = 0.26\ ft$

$\sigma_V := \frac{\Sigma V}{B'}$ $\sigma_V = 2.143\ ksf$

Bearing Capacity at bottom of Undercut & Replacement:Demand Ratio (CDR)

Drained Conditions: $CDR_{Bearing\_D} := \frac{q_{Rd}}{\sigma_V}$ Is the CDR > or = to 1.0? $CDR_{Bearing\_D} = 1.54$

Undrained Conditions: $CDR_{Bearing\_U} := \frac{q_{Ru}}{\sigma_V}$ Is the CDR > or = to 1.0? $CDR_{Bearing\_U} = 1.03$

Limiting Eccentricity at Base of Wall (Strength Ia):

Compute the resultant location about the toe "O" of the base length (distance from Pivot):

$e_{max} := \frac{B}{3}$	$e_{max} = 2.8\ ft$	Maximum Eccentricity **LRFD [C11.6.3.3.] Equals B/3 for soil.**
$\Sigma M_R := MV_{Ia}$	$\Sigma M_R = 58825.2\ \frac{lbf \cdot ft}{ft}$	Sum of Resisting Moments (Strength Ia)
$\Sigma M_O := MH_{Ia}$	$\Sigma M_O = 13113.8\ \frac{lbf \cdot ft}{ft}$	Sum of Overturning Moments (Strength Ia)
$\Sigma V := V_{Ia}$	$\Sigma V = 12144\ \frac{lbf}{ft}$	Sum of Vertical Loads (Strength Ia)
$x := \frac{(\Sigma M_R - \Sigma M_O)}{\Sigma V}$	$x = 3.8\ ft$	Distance from Point "O" the resultant intersects the base
$e := \left\lvert \frac{B}{2} - x \right\rvert$	$e = 0.49\ ft$	Wall eccentricity, **Note:** The vertical stress is assumed to be uniformly distributed over the effective bearing width, B', since the wall is supported by a soil foundation **LRFD [11.6.3.2**]. The effective bearing width is equal to B-2e. .

Eccentricity Capacity:Demand Ratio (CDR)

$CDR_{Eccentricity} := \frac{e_{max}}{e}$ Is the CDR > or = to 1.0? $CDR_{Eccentricity} = 5.83$

Sliding Resistance at Base of Wall LRFD [10.6.3.4]:

Factored Sliding Force (Strength Ia):

$R_u := H_{Ia}$ $\qquad R_u = 3405.3\ \frac{lbf}{ft}$

Drained/Undrained Conditions for Granular Replacement (Effective Stress):

Compute passive resistance throughout the design life of the wall **LRFD [Eq 3.11.5.4-1]:**:

$r_{ep1} := \left(k_{pd} \cdot \gamma_{fd} \cdot y_1 + 2 \cdot c'_{fd} \cdot \sqrt{k_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y1

$r_{ep2} := \left(k_{pd} \cdot \gamma_{fd} \cdot y_2 + 2 \cdot c'_{fd} \cdot \sqrt{k_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y2

$R_{ep} := \frac{r_{ep1} + r_{ep2}}{2} \cdot \left(y_2 - y_1\right)$ $\qquad R_{ep} = 0\ \frac{lbf}{ft}$ Nominal passive resistance Drained Conditions

416 Note: Passive Resistance shall be neglected in stability computations, unless the base of the wall extends below the depth of maximum scour, freeze-thaw or other disturbances. In the latter case, only the embedment below the greater of these depths shall be considered effective **LRFD [11.6.3.5**].

Compute sliding resistance between soil and foundation:

$c := 1.0$ c = 1.0 for Cast-in-Place
c = 0.8 for Precast

$\Sigma V := V_{Ia}$ $\qquad \Sigma V = 12144\ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$R_\tau := c \cdot \Sigma V \cdot \tan\left(\phi_{Re}\right)$ $\qquad R_\tau = 8191.3\ \frac{lbf}{ft}$ Nominal sliding resistance Cohesionless Soils

Compute factored resistance against failure by sliding **LRFD [10.6.3.4]**:

$\phi_{ep} := 0.5$ Resistance factor for passive resistance specified in **LRFD Table 10.5.5.2.2-1**

$\phi_\tau := 1.0$ Resistance factor for sliding resistance specified in **LRFD Table 11.5.7-1.**

$\phi R_n := \phi_\tau \cdot R_\tau + \phi_{ep} \cdot R_{ep}$ $\qquad R_R := \phi R_n$

Factored Sliding Resistance to be used in CDR Calculations: $R_R = 8191.26\ \frac{lbf}{ft}$

Sliding Capacity:Demand Ratio (CDR)

$CDR_{Sliding\_Base} := \frac{R_R}{R_u}$ Is the CDR > or = to 1.0? $CDR_{Sliding\_Base} = 2.41$

Undrained Conditions (Total Stress):

Compute passive resistance throughout the design life of the wall **LRFD [Eq 3.11.5.4-1]**::

$r_{ep1} := \left(k_{pu} \cdot \gamma_{fd} \cdot y_1 + 2 \cdot Su_{fdu} \cdot \sqrt{k_{pu}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y1

$r_{ep2} := \left(k_{pu} \cdot \gamma_{fd} \cdot y_2 + 2 \cdot Su_{fdu} \cdot \sqrt{k_{pu}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y2

$R_{ep} := \frac{r_{ep1} + r_{ep2}}{2} \cdot \left(y_2 - y_1\right)$ $R_{ep} = 0 \ \frac{lbf}{ft}$ Nominal passive resistance Drained Conditions

416 Note: Passive Resistance shall be neglected in stability computations, unless the base of the wall extends below the depth of maximum scour, freeze-thaw or other disturbances. In the latter case, only the embedment below the greater of these depths shall be considered effective **LRFD [11.6.3.5]**.

Compute sliding resistance between soil and foundation:

$c := 1.0$ c = 1.0 for Cast-in-Place
c = 0.8 for Precast

$\Sigma V := V_{Ia}$ $\Sigma V = 12144 \ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$e = 0.49 \ ft$ Wall eccentricity, Calculated in above Limiting Eccentricity at Base of Wall (Strength Ia) Section.

$B = 8.5 \ ft$ Footing base width

$\frac{B}{6} = 1.4 \ ft$ If e < B/6 the resultant is in the middle one-third

$\sigma_{vmax} := \frac{\Sigma V}{B} \cdot \left(1 + 6 \cdot \frac{e}{B}\right)$ $\sigma_{vmax} = 1918.7 \ \frac{lbf}{ft^2}$ Max vertical stress (if resultant is in the middle one-third of base) **LRFD [11.6.3.2-2]**.

$\sigma_{vmin} := \frac{\Sigma V}{B} \cdot \left(1 - 6 \cdot \frac{e}{B}\right)$ $\sigma_{vmin} = 938.7 \ \frac{lbf}{ft^2}$ Max verical stress (if resultant is in the middle one-third of base) **LRFD [11.6.3.2-2]**.

$q_{max} := \frac{1}{2} \cdot \sigma_{vmax}$ $q_{max} = 959.4 \ \frac{lbf}{ft^2}$ Max unit shear resistance as 1/2 max vertical stress **LRFD [10.6.3.4]**.

$q_{min} := \frac{1}{2} \cdot \sigma_{vmin}$ $q_{min} = 469.3 \ \frac{lbf}{ft^2}$ Minimum unit shear resistance as 1/2 minimum vertical stress **LRFD [10.6.3.4]**.

Determine which Cohesive Soil Resistance Case is Present:

$Case_1 := \text{if}\left(q_{max} > Su_{fdu} > q_{min} \geq 0, 1, 0\right)$ $Case_1 = 1$

$Case_2 := \text{if}\left(Su_{fdu} > q_{max} > q_{min} \geq 0, 1, 0\right)$ $Case_2 = 0$

$Case_3 := \text{if}\left(q_{max} > q_{min} > Su_{fdu}, 1, 0\right)$ $Case_3 = 0$

$Case_4 := \text{if}\left(q_{min} < 0, \text{if}\left(Su_{fdu} < q_{max}, 1, 0\right), 0\right)$ $Case_4 = 0$

$Case_5 := \text{if}\left(q_{min} < 0, \text{if}\left(Su_{fdu} > q_{max}, 1, 0\right), 0\right)$ $Case_5 = 0$

Unit Shear Resistance for Case 1:

$S_1 := Su_{fdu} - q_{min} = 230.7\ \frac{lbf}{ft^2}$

$S_2 := q_{min} = 469.3\ \frac{lbf}{ft^2}$

$B_1 := \frac{B \cdot (Su_{fdu} - q_{min})}{q_{max} - q_{min}} = 4\ ft$

$B_2 := \frac{B \cdot (q_{max} - Su_{fdu})}{q_{max} - q_{min}} = 4.5\ ft$

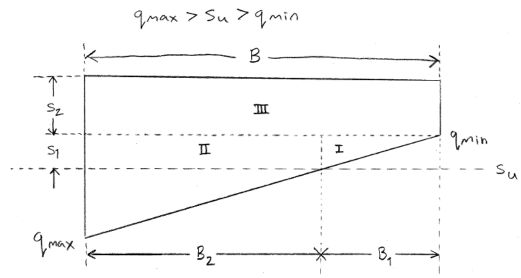
$B_3 := B = 8.5\ ft$

$I := \frac{1}{2} \cdot S_1 \cdot B_1 = 461.4\ \frac{lbf}{ft}$

$II := S_1 \cdot B_2 = 1037.7\ \frac{lbf}{ft}$

$III := S_2 \cdot B_3 = 3989.4\ \frac{lbf}{ft}$

$R_{\tau\_case1} := I + II + III = 5488.6\ \frac{lbf}{ft}$



Unit Shear Resistance for Case 2:

$S_1 := q_{max} - q_{min} = 490\ \frac{lbf}{ft^2}$

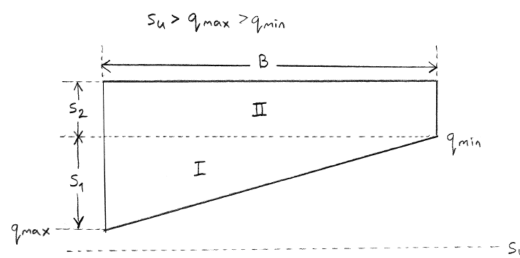
$S_2 := q_{min} = 469.3\ \frac{lbf}{ft^2}$

$B = 8.5\ ft$

$I := \frac{1}{2} \cdot S_1 \cdot B = 2082.6\ \frac{lbf}{ft}$

$II := S_2 \cdot B = 3989.4\ \frac{lbf}{ft}$

$R_{\tau\_case2} := I + II = 6072\ \frac{lbf}{ft}$



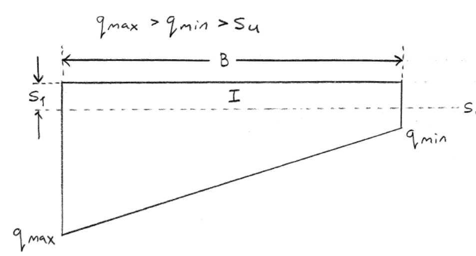
Unit Shear Resistance for Case 3:

$S_1 := Su_{fdu} = 700\ \frac{lbf}{ft^2}$

$B = 8.5\ ft$

$I := \frac{1}{2} \cdot S_1 \cdot B = 2975\ \frac{lbf}{ft}$

$R_{\tau\_case3} := I = 2975\ \frac{lbf}{ft}$



Unit Shear Resistance for Case 4:

$S_1 := Su_{fdu} = 700\ \frac{lbf}{ft^2}$

$B_3 := \frac{B \cdot (-q_{min})}{q_{max} - q_{min}} = -8.1\ ft$

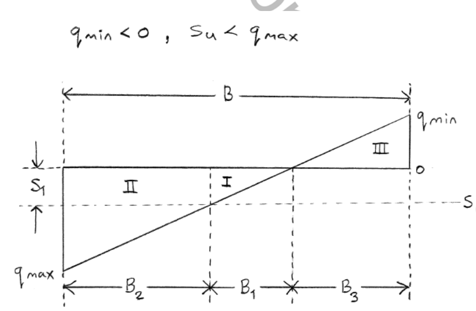
$B_1 := \left(\frac{Su_{fdu}}{q_{max}}\right) \cdot (B - B_3) = 12.1\ ft$

$B_2 := B - (B_1 + B_3) = 4.5\ ft$

$I := \frac{1}{2} \cdot S_1 \cdot B_1 = 4249.8\ \frac{lbf}{ft}$

$II := S_1 \cdot B_2 = 3149.3\ \frac{lbf}{ft}$

$R_{\tau\_case4} := I + II = 7399.1\ \frac{lbf}{ft}$



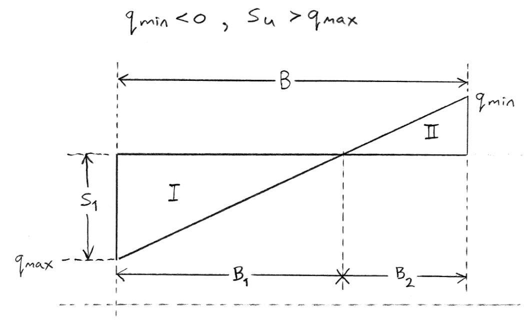
Unit Shear Resistance for Case 5:

$S_1 := q_{max} = 959.4 \ \frac{lbf}{ft^2}$

$B_1 := \frac{B \cdot q_{max}}{q_{max} - q_{min}} = 16.6 \ ft$ $\qquad B_2 := B - B_1 = -8.1 \ ft$

$I := \frac{1}{2} \cdot S_1 \cdot B_1 = 7982.5 \ \frac{lbf}{ft}$

$R_{\tau\_case5} := I = 7982.5 \ \frac{lbf}{ft}$



Define the Applicable Case:

$R_\tau := R_{\tau\_case1}$ $\qquad R_\tau = 5488.6 \ \frac{lbf}{ft}$ $\qquad$ Nominal sliding resistance Cohesive Soils

Compute factored resistance against failure by sliding **LRFD [10.6.3.4]**:

$\phi_{ep} := 0.5$ $\qquad$ Resistance factor for passive resistance specified in **LRFD Table 10.5.5.2.2-1**

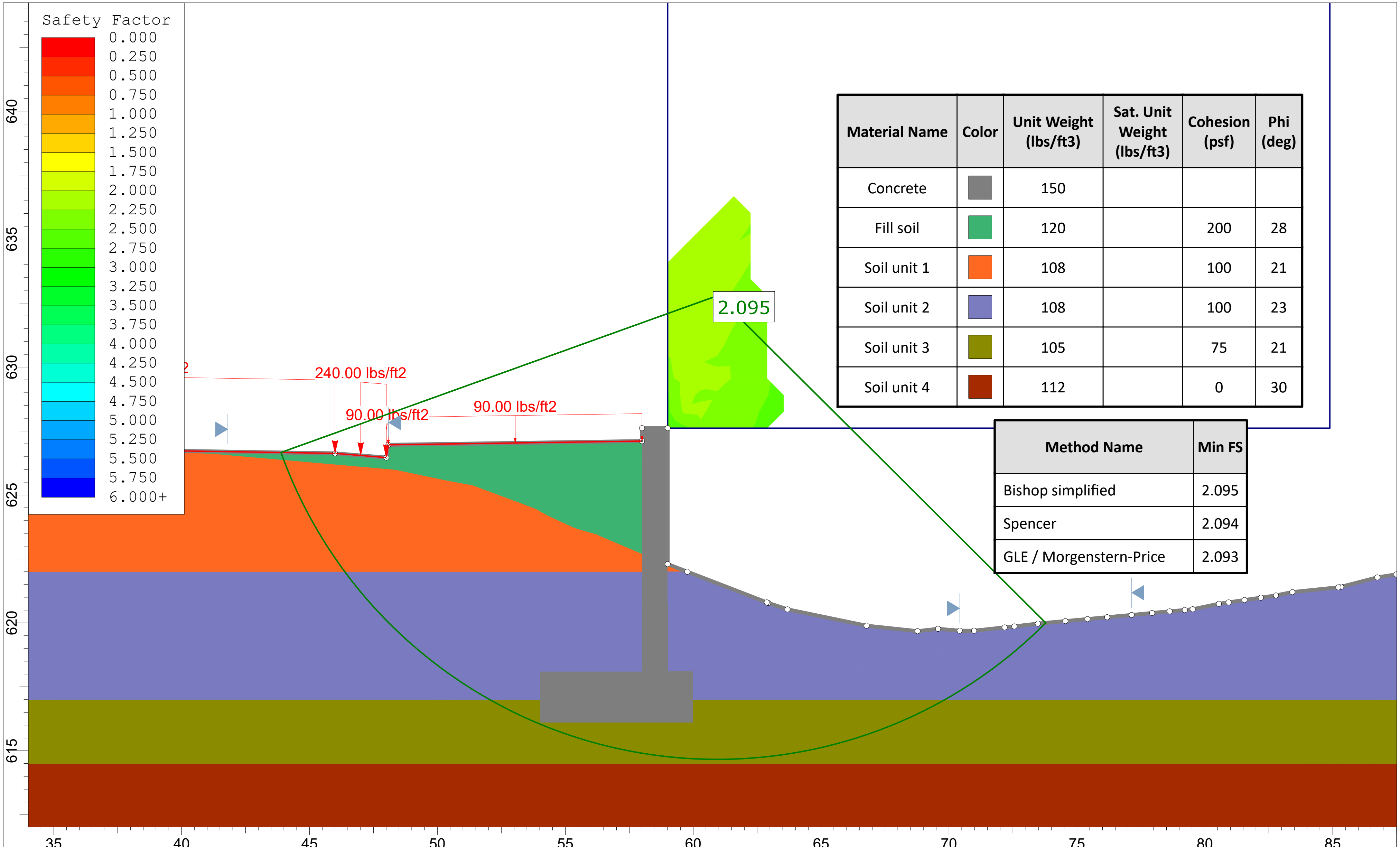
$\phi_\tau := 1.0$ $\qquad$ Resistance factor for sliding resistance specified in **LRFD Table 11.5.7-1.**

$\phi R_n := \phi_\tau \cdot R_\tau + \phi_{ep} \cdot R_{ep}$ $\qquad R_R := \phi R_n$

Factored Sliding Resistance to be used in CDR Calculations: $R_R = 5488.568 \ \frac{lbf}{ft}$

Sliding Capacity:Demand Ratio (CDR)

$CDR_{Sliding} := \frac{R_R}{R_u}$ $\qquad$ Is the CDR > or = to 1.0? $\qquad CDR_{Sliding} = 1.61$



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Concrete		150			
Fill soil		120		200	28
Soil unit 1		108		100	21
Soil unit 2		108		100	23
Soil unit 3		105		75	21
Soil unit 4		112		0	30

Method Name	Min FS
Bishop simplified	2.095
Spencer	2.094
GLE / Morgenstern-Price	2.093

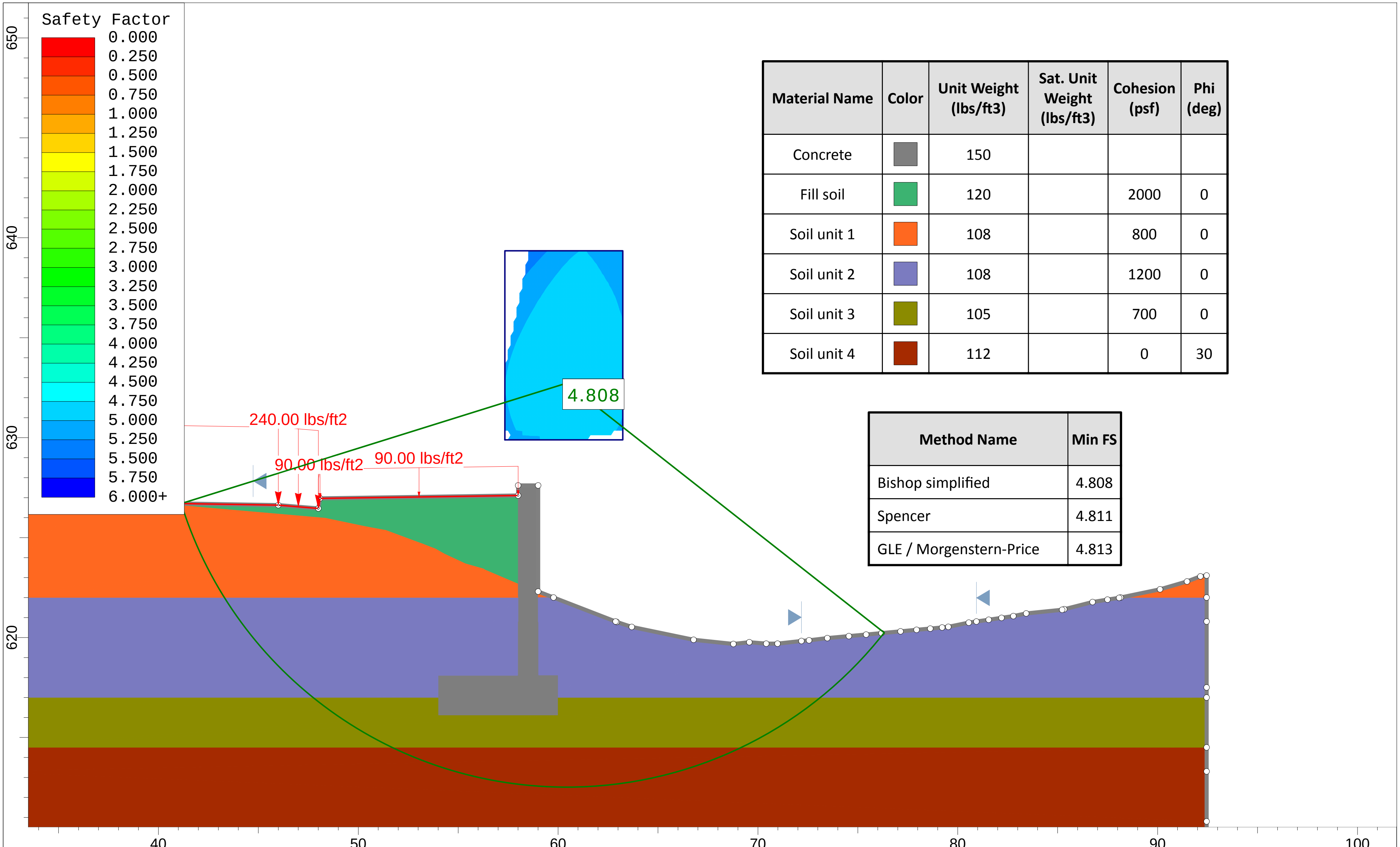
SLIDEINTERPRET 7.037

Project ROS-159-0.41 (PID 113013)

Analysis Description McDonald's Wall Long Term (Effective) Circular

Drawn By M. Jasiewicz | *Scale* 1:62 | *Company* NEAS Inc.

Date 10/13/2022, 10:25:06 AM | *File Name* McDonaldsWall_LongTerm_Circular_B019.slim



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Concrete		150			
Fill soil		120		2000	0
Soil unit 1		108		800	0
Soil unit 2		108		1200	0
Soil unit 3		105		700	0
Soil unit 4		112		0	30

Method Name	Min FS
Bishop simplified	4.808
Spencer	4.811
GLE / Morgenstern-Price	4.813

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SLIDEINTERPRET 7.038

Project ROS-159-0.41 (PID 113013)

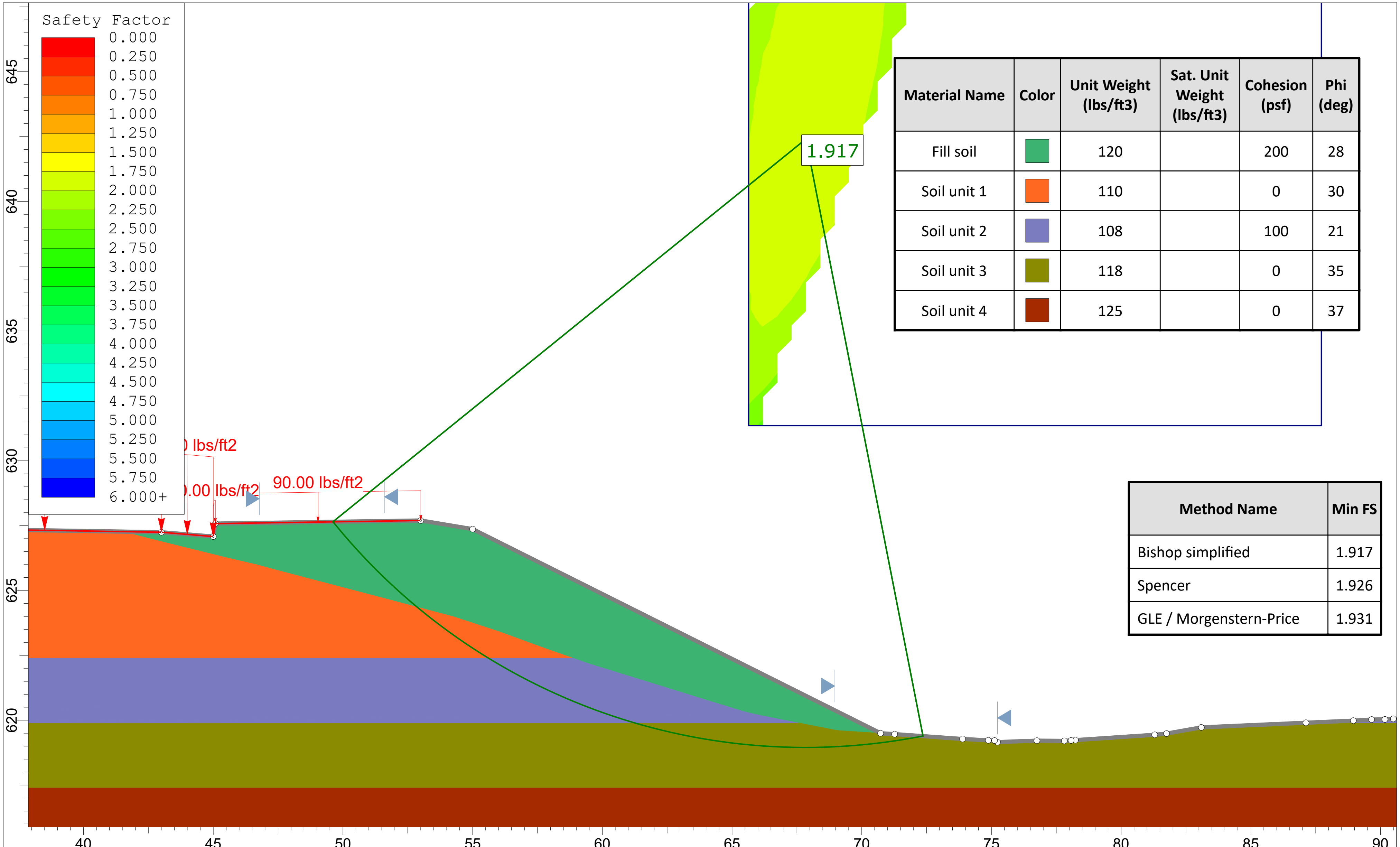
Analysis Description McDonald's Wall Short Term (Total) Circular

Drawn By M. Jasiewicz *Scale* 1:80 *Company* NEAS Inc.

Date 10/13/2022, 10:25:06 AM *File Name* McDonaldsWall_ShortTerm_Circular_B019.slim

APPENDIX F

EMBANKMENT STABILTY ANALYSIS



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Fill soil	Green	120		200	28
Soil unit 1	Orange	110		0	30
Soil unit 2	Purple	108		100	21
Soil unit 3	Olive	118		0	35
Soil unit 4	Brown	125		0	37

Method Name	Min FS
Bishop simplified	1.917
Spencer	1.926
GLE / Morgenstern-Price	1.931

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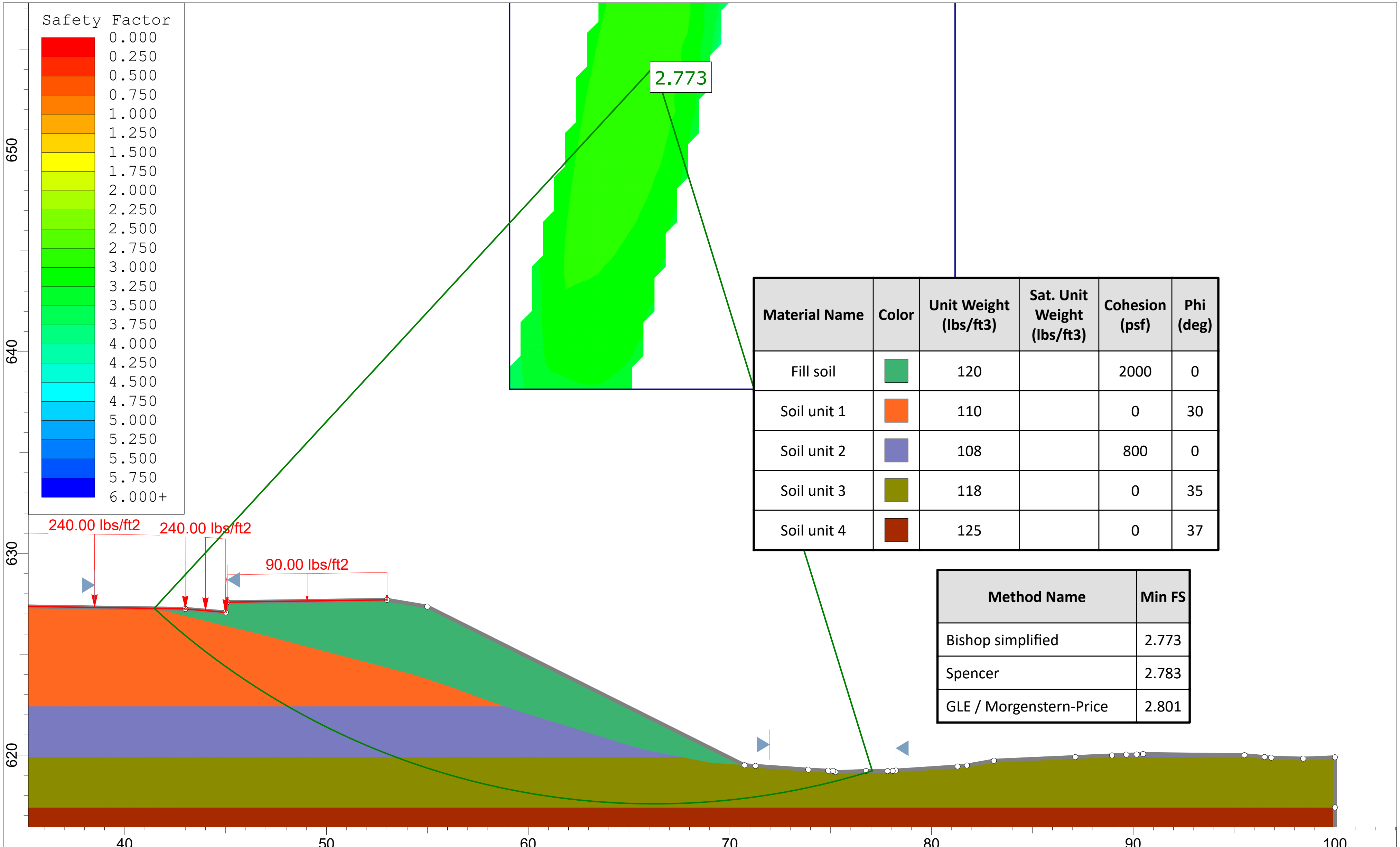
SLIDEINTERPRET 7.037

Project	ROS-159-0.41 (PID 113013)
Analysis Description	Lowe's Wall Long Term (Effective) Circular
Drawn By	M. Jasiewicz
Scale	1:61
Company	NEAS Inc.
Date	10/13/2022, 10:25:06 AM
File Name	LowesWall_LongTerm_Circular_B012.slim



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (deg)
Fill soil		120		2000	0
Soil unit 1		110		0	30
Soil unit 2		108		800	0
Soil unit 3		118		0	35
Soil unit 4		125		0	37

Method Name	Min FS
Bishop simplified	2.773
Spencer	2.783
GLE / Morgenstern-Price	2.801

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SLIDEINTERPRET 7.037

Project	ROS-159-0.41 (PID 113013)		
Analysis Description	Lowe's Wall Short Term (Total) Circular		
Drawn By M. Jasiewicz	*Scale* 1:79	*Company*	NEAS Inc.
Date	10/13/2022, 10:25:06 AM	*File Name*	LowesWall_ShortTerm_Circular_B012.slim