Stantec

REPORT OF LANDSLIDE EXPLORATION
BUT-126-2.92 (FINAL)

PID: 116204
Butler County, Ohio

January 6, 2025

Prepared for:

Ohio Department of Transportation, District 8
Lebanon, Ohio

Prepared by:
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Project Number: 173410733

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BUT-126-2.92 Geotechnical Comment Log

Geotechncial Report

Review Comment		Stantec Response
1)	Define the area or dimensions for porous backfill. Embankment fill should be considered outside of influence zone. (pg 16)	Porous backfill is recommended as total backfill behind CIP retaining wall due to construction constraints.
2)	Had difficulty obtaining PZ40 on a past construction project and used AZ38. (pg 32)	Report still recommends PZ40, but includes language stating sections with properties meeting or exceeding PZ40s may be used if approved by ODOT.
3)	Is 5 ft of scour assumbed in front of the wall? (pg 32)	The 5 feet here is to get to the CIP wall bearing elevation for the permanent sheet pile wall analysis.
4)	Show pile length on plans (pgs 33, 37, 41, and 45)	Pile length shown on structural plans.
5)	Is wall really needed as open cut is feasible? (pg 45)	Discussed with ODOT, determined open cut was not best approach for construction.

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Executive Summary

Embankment erosion has occurred along a section of State Route (SR) 126 at Straight Line Mileage (SLM) 2.90 in Butler County, Ohio. The erosion is causing slope instability along approximately 300 feet of the southern embankment of SR 126. Dry Fork Creek runs adjacent to SR 126 and is the source of the erosion occurring on the embankment. Past erosion protection measures have been installed along the alignment, including sheet piling and rock channel protection. The project site is located approximately 1.4 miles northwest of Okeana, Ohio. The Ohio Department of Transportation (ODOT) plans to protect the affected roadway from the erosion with a cast-in-place retaining wall located south of SR 126. Stantec Consulting Services Inc. (Stantec) was contracted by ODOT to perform the retaining wall design for this project.

ODOT advanced four borings along the eastbound shoulder of SR 126 road to obtain geotechnical data for the proposed landslide stabilization. The borings were advanced in accordance with the ODOT Specifications for Geotechnical Explorations (SGE).

The surface materials encountered in the borings consisted of 12 to 18 inches of asphalt followed by 6 inches of base. Below the roadway materials, granular soil typically classifying as gravel and stone fragments with sand and silt or gravel and stone fragments with sand were encountered to depths ranging from 3.0 to 3.5 feet. The remaining soils encountered were predominately fine-grained, classifying as sandy silt, silt and clay, silty clay, and clay. In borings B-001-0-22, B-002-0-22, and B-004-0-22, thin layers (1.5 to 4.5 feet) of coarse-grained soils were encountered at various depths. In B-003-0-22, coarse-grained material was encountered from a depth of 6.0 feet to 19.5 feet. These coarse-grained materials were visually described or classified as gravel and stone fragments with sand and silt, gravel and stone fragments with sand, gravel and stone fragments with sand, silt, and clay, or coarse and fine sand.

Bedrock was encountered at depth of 19.5 feet in B-001-0-22 and 31.0 feet in B-002-0-22. Bedrock was not encountered in B-003-0-22 or B-004-0-22. Bedrock was described as interbedded shale and limestone. The shale was described as brown to gray, highly to moderately weathered, very weak, thinly laminated, and calcareous. The limestone was described as medium light gray, moderately weathered, strong, thin bedded, and fossiliferous. Groundwater was not observed while drilling B-001-0-22 and B-002-0-22; however, this may have been obscured by the addition of water during rock coring. It is likely that groundwater is present within the bedrock at these two locations. Groundwater was observed during drilling at a depth of 15 feet in B-003-0-22 and 16 feet in B-004-0-23. Borings B-003-0-22 and B-004-0-22 were terminated at a depth of 49.5 feet and 45.0 feet, respectively, after encountering a natural gas pocket.

A cast-in-place (CIP) concrete retaining wall is planned throughout the project limits along SR 126 at an offset of 21 feet right of centerline to the face of the wall. The wall will be supported by a spread footing bearing at an elevation of 655.0 feet and the top of wall will range from an elevation of 680.1 feet at the start of the wall to 677.0 at the end for a wall height ranging from 22 to 25.1 feet. A permanent sheet pile wall will be designed throughout the limits of the project along Dry Fork Creek at the toe of the SR 126

embankment. The offset from centerline of SR 126 will be 23 feet right. The wall will first serve as a cofferdam to allow construction of the spread footing of the CIP concrete retaining wall. After construction of the retaining wall, the wall will be left in place to provide erosion protection and protect against undermining of the retaining wall footing. A temporary sheet pile wall will be designed throughout the limits of the project along SR 126 at an offset from centerline of SR 126 of 5 feet. The wall will retain and support SR 126 during construction of the CIP concrete wall. After construction of the retaining wall, the sheet piling will be removed after backfilling behind the permanent CIP wall is completed. Design recommendations for the CIP wall and sheet pile walls are included in this report.

Acronyms / Abbreviations

ER	Energy Ratio
GDM	Geotechnical Design Manual
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
PSI	Pounds per Square Inch
RQD	Rock Quality Designation
SGE	Specifications for Geotechnical Exploration
SLM	Straight Line Mileage
SPT	Standard Penetration Test
SR	State Route
TIMS	Traffic Information Management System
UCR	Unconfined Compression Strength for Rock Core
USDA	United States Department of Agriculture

1 INTRODUCTION

Embankment erosion has occurred along a section of State Route (SR) 126 at Straight Line Mileage (SLM) 2.90 in Butler County, Ohio. The erosion is causing slope instability along approximately 300 feet of the southern embankment of SR 126. Dry Fork Creek runs adjacent to SR 126 and is the source of the erosion occurring on the embankment. Past erosion protection measures have been installed along the alignment, including sheet piling and rock channel protection. The project site is located approximately 1.4 miles northwest of Okeana, Ohio.

The Ohio Department of Transportation (ODOT) plans to protect the affected roadway from the erosion with a cast-in-place retaining wall located south of SR 126. To facilitate this, the past remediation measures are to be removed and new sheet piling will be driven to serve as a cofferdam during construction and left in place for erosion protection along the toe of the embankment slope. Additional temporary sheet piling will be necessary to retain the SR 126 embankment during spread footing and wall construction. Stantec Consulting Services Inc. (Stantec) was contracted by ODOT to perform the retaining wall design for this project. Figure 1 shows the site vicinity.

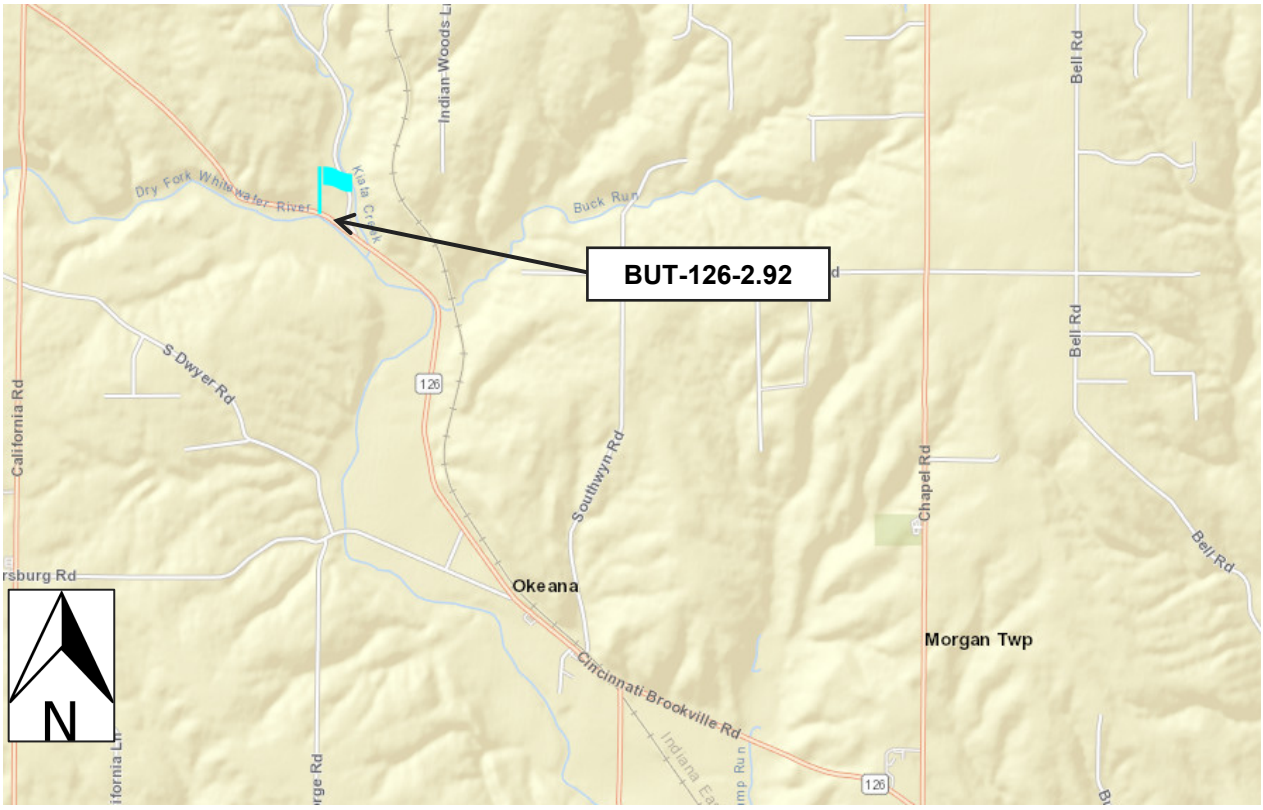


Figure 1: Site Vicinity
(ODOT Transportation Information Mapping System [TIMS] Interactive Mapping, 2024)

2 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 GENERAL

The *Physiographic Regions of Ohio Map* (Ohio Department of Natural Resources [ODNR], 1998) indicates that the project is located within the Southern Ohio Loamy Till Plain. This region is described as a surface of loamy till containing end and recessional moraines. The region is commonly associated with boulder belts and buried valleys. The geology of the Southern Ohio Loamy Till Plain contains loamy, high lime Wisconsinan-age till, outwash, and loess over Lower Paleozoic-age carbonate rocks. Moderate relief of approximately 200 feet can be observed in the regions, with elevations ranging from 530 feet to 1,150 feet.

2.2 SOIL GEOLOGY

According to the *Ohio Geology Interactive Map* (ODNR, 2024), the project site is underlain by late Wisconsinan outwash. The *Ohio Geology Interactive Map* also suggests a glacial drive thickness of approximately 70 feet. The soil survey (*Web Soil Survey of Butler County, Ohio*, United States Department of Agriculture [USDA], 2024) indicates that the project site is underlain by soils from the Ross loam and Miamian-Russell silt loam complexes. These soils primarily consist of loam with lesser amounts of silt loam and clay loam. These soils are typically well-drained with a moderately high to high capacity of transmitting water.

2.3 BEDROCK GEOLOGY

Bedrock mapping (*Ohio Geology Interactive Map*, ODNR, 2024) and *Descriptions of Geologic Map Units* (ODNR, 2011) indicates that the overburden soils at the project site are underlain primarily by sedimentary bedrock of the Kope Formation from the Ordovician group. Bedrock from the Kope Formation is comprised of interbedded shale (75%) and limestone (25%). The bedrock is described as shades of gray to bluish gray and weathering light to yellowish gray, with unit thicknesses between 200 to 260 feet.

According to the *Ohio Mine Locator* (ODNR, 2024), there are no recorded active mines within a 5-mile radius of the project footprint. Multiple inactive surface aggregate mines are located approximately 5 miles southeast of the project. The *Karst Interactive Map* (ODNR, 2024) indicates there are no known karst features in the immediate project vicinity. Four suspected karst features are located approximately 1 mile southwest of the project location and all are described as potential sinkholes. The *Ohio Oil and Gas Well Map* (ODNR, 2024) shows no wells within a 10-mile radius of the project.

2.4 HYDROLOGY AND HYDROGEOLOGY

Dry Fork Creek is located to the south of the project site and flows to the southeast into Whitewater River near White Water Park, Ohio. Whitewater River then flows south to the Great Miami River near Elizabethtown, Ohio which then flows south into the Ohio River near Lawrenceburg, Indiana.

The *Ohio Geology Interactive Map* shows that the site is underlain by the Whitewater Alluvial Aquifer, which has a yield ranging from 5 to 25 gallons per minute and a thickness between 25 and 100 feet. A search was performed using the ODNR *Ohio Water Wells Map* (2024) to determine if any water wells are located near the project site. According to the map, 13 water wells have been drilled within a 1-mile radius of the project footprint. The well logs indicate a bedrock depth ranging from 10 to 109 feet. The bedrock encountered at these wells were described as shale and limestone. The logs also indicate a considerable variation of the static water depth in the area surrounding the site, ranging from 5 to 82 feet.

2.5 SEISMIC

A review of the seismic data available in the project vicinity was completed using the ODNR *Ohio Earthquake Epicenters Map* (2024). Overall, Ohio has a relatively limited amount of seismic activity. Within a 10-mile radius of the project, there have been no recorded earthquake epicenters. The available data reviewed included events that occurred in Ohio from 1804 to present day.

2.6 SITE RECONNAISSANCE

ODOT and Stantec representatives visited the site on April 29, 2024. The land surrounding the project site can be described as agricultural with some residential homes in the vicinity. The pavement was observed to be generally in fair condition; however, the eastbound lane had cracks and the shoulder had been repaved due to settlement caused by the erosion. Ground settlement caused by the erosion was observed just off the shoulder and downslope, with some affecting the alignment of guardrail posts. Previous repairs consisting of sheet pile walls, gabion baskets, and pile lagging walls were located along the downhill slope. A rock protection blanket was recently placed by ODOT to reduce further erosion. The erosion affects approximately 300 feet of the roadway. The bank of the creek was well vegetated.

3 EXPLORATION

3.1 HISTORIC EXPLORATION PROGRAMS

The ODOT Traffic Information Management System (TIMS) provides documentation for two geotechnical explorations performed within 0.5 miles of the project site along SR 126. BUT-126-3.08 (PID 4782) was a project for a bridge crossing over Kiata Creek. The exploration consisted of three soil borings drilled in 1990. Soils at the site were variable between cohesive and granular materials. Cohesive soils were described as silt and clay (A-6a) and sandy silt (A-4a). Granular soils were described as gravel and stone

fragments (A-1-a), sandy silt (A-4a), and coarse and fine sand (A-3a). Bedrock was not encountered in these borings, which were advanced to depths ranging from 36.5 to 46.5 feet.

BUT-126-2.55 (PID 25347) was a project for a culvert. The exploration consisted of three roadway and four structure borings advanced along SR 126 in 2005. Soils encountered during this exploration were described as primarily cohesive, classifying as silty clay (A-6b), silt and clay (A-6a), and sandy silt (A-4a). Bedrock was described as interbedded limestone and shale and was encountered at depths ranging from 19.2 to 33.8 feet.

3.2 PROJECT EXPLORATION PROGRAM

ODOT advanced four borings along the project alignment from January 24 to February 8, 2022. The borings were advanced along the eastbound shoulder of the road. A summary of these borings is shown in Table 1. Boring locations are shown on the geotechnical profile in Appendix A. The locations and elevations of the borings were provided by ODOT. Boring logs for the project were also completed by ODOT and provided to Stantec.

Table 1. Boring Summary

Boring No.	Station (feet)	Offset (feet)	Ground Surface Elevation (feet)	Top of Bedrock Elevation (feet)	Bottom of Boring Elevation (feet)
B-001-0-22	11+95	7 Rt.	678.6	658.6	648.6
B-002-0-22	12+91	14 Rt.	677.0	646.0	636.0
B-003-0-22	13+87	7 Rt.	676.3	N/A	626.8
B-004-0-22	14+85	7 Rt.	676.5	N/A	631.5

The borings were advanced in accordance with the ODOT Specifications for Geotechnical Explorations (SGE). The borings were performed with a CME 55 truck-mounted drill rig using 3¼-inch inside diameter (ID) hollow stem augers to advance the borings through soil. Standard Penetration Test (SPT) sampling was performed continuously until the bedrock was encountered. The energy ratio (ER) of the drill rig automatic hammer and drill rod system were measured to be 83.6 percent on April 15, 2020. The depths and elevations of the SPTs with the corresponding N_{60}-values are shown on the boring logs in Appendix A.

Upon encountering fairly competent bedrock, approximately 10 feet of rock coring was performed using NQ2-size equipment. Recovery, core loss, and rock quality designation (RQD) values were recorded as percentages for each coring run. These values are shown on the boring logs contained in Appendix A.

The materials encountered were logged by an inspector from ODOT, with attention given to soil type, consistency, and moisture content. The borings were checked for the presence of groundwater during drilling and at its conclusion with the depth of water recorded. The borings were sealed with bentonite grout and capped with asphalt cold patch.

The soil samples obtained from the borings were returned to ODOT's geotechnical laboratory for visual classification and tested for water content. Engineering classification testing was performed on samples reflecting each of the main soil horizons. The engineering classification tests conducted on the samples were sieve and hydrometer analysis (ASTM D 422) and Atterberg limits (ASTM D 4318). The samples were classified according to the ODOT classification method. Results from classification and moisture content testing are shown on the boring logs in Appendix A.

Four rock core samples were subjected to unconfined compressive strength testing according to ASTM D 7012, Method C. Two rock core samples were also subjected to slake durability testing according to ASTM D 4644. The results of available laboratory testing are included in Appendix A.

4 FINDINGS

The surface materials encountered in the borings consisted of 12 to 18 inches of asphalt followed by 6 inches of base. Below the roadway materials, granular soil typically classifying as gravel and stone fragments with sand and silt (A-2-4) or gravel and stone fragments with sand (A-1-b) were encountered to depths ranging from 3.0 to 3.5 feet. The remaining soils encountered were predominately fine-grained, classifying as sandy silt (A-4a), silt and clay (A-6a), silty clay (A-6b), and clay (A-7-6).The fine-grained soils were described as medium stiff to hard (N_{60} values ranging from 6 to 64 with an average of 23), shades of brown to gray, damp to moist (natural moisture contents ranging from 11 to 28 with an average of 15) and slightly to moderately plastic (plasticity indices ranging from 5 to 24 with an average of 14).

In borings B-001-0-22, B-002-0-22, and B-004-0-22, thin layers (1.5 to 4.5 feet) of coarse-grained soils were encountered at various depths. In B-003-0-22, coarse-grained material was encountered from a depth of 6.0 to 19.5 feet. These coarse-grained materials were visually described or classified as gravel and stone fragments with sand and silt (A-2-4), gravel and stone fragments with sand (A-1-b), gravel and stone fragments with sand, silt, and clay (A-2-6), or coarse and fine sand (A-3a). The soils were described as loose to very dense (N_{60} values ranging from 6 to 78 with an average of 29), brown to gray, and damp to moist (natural moisture contents ranging from 3 to 14 with an average 8).

Bedrock was encountered at a depth of 19.5 feet in B-001-0-22 and 31.0 feet in B-002-0-22. Bedrock was not encountered in B-003-0-22 or B-004-0-22. Bedrock was described as interbedded shale and limestone. The shale was described as brown to gray, highly to moderately weathered, very weak, thinly laminated, and calcareous. The limestone was described as medium light gray, moderately weathered, strong, thin bedded, and fossiliferous. Ten feet of bedrock was cored in each boring prior to termination. Core recoveries ranged from 95 to 100 percent and RQD values varied from 33 to 78. Unconfined compressive testing was completed on two samples of limestone, resulting in compressive strengths of 7,724 and 12,468 pounds per square inch (psi). Testing of two samples of shale bedrock resulted in unconfined compressive strengths of 50 and 90 psi.

Groundwater was not observed while drilling B-001-0-22 and B-002-0-22; however, this may have been obscured by the addition of water during rock coring. It is likely that groundwater is present within the

bedrock at these two locations. Groundwater was observed during drilling at a depth of 15 feet in B-003-0-22 and 16 feet in B-004-0-23.

Borings B-003-0-22 and B-004-0-22 were terminated at depths of 49.5 and 45.0 feet, respectively, prior to encountering bedrock. These were terminated due to encountering a natural gas pocket.

Boring logs, photographs of the rock core, and laboratory testing results are presented in Appendix A.

5 ANALYSIS AND RECOMMENDATIONS

5.1 GENERAL

The recommendations that follow are based on the information discussed in this report and the interpretation of the subsurface conditions encountered at the site during our fieldwork. If future design changes are made, Stantec should be notified so that such changes can be reviewed, and the recommendations amended as necessary.

These conclusions and recommendations are based on data and subsurface conditions from the borings advanced during this exploration using the degree of care and skill ordinarily exercised under similar circumstances by competent members of the engineering profession. No warranties can be made regarding the continuity of conditions.

5.2 RETAINING WALL

A cast-in-place (CIP) concrete retaining wall is planned throughout the project limits along SR 126 at an offset of 21 feet right of centerline to the face of the wall. The wall will be supported by a spread footing bearing at an elevation of 655.0 feet (approximately 5 feet below the creek bed) and the top of wall will range from an elevation of 680.1 feet at the start of the wall to 677.0 at the end for a wall height ranging from 22 to 25.1 feet. Table 2 provides the recommended earth pressure and bearing capacity parameters for the CIP retaining wall design for sliding, overturning, eccentricity, and bearing capacity. The bearing capacity calculations can be found in Appendix B. From Station 11+50 to 12+21, the retaining wall will bear on interbedded shale and limestone encountered in B-001-0-22. The remainder of the wall will bear on very stiff silt and clay (A-6a) soil.

Table 2. Recommended Earth Pressure and Bearing Capacity Parameters for CIP Retaining Wall Design

Parameter	Recommended Value
Retained Soil Unit Weight (pcf)	130
Retained Soil Drained Friction Angle (degrees)	30
Active Earth Pressure Coefficient (K_a)	0.33
Nominal Bearing Resistance of Soil (ksf)	14.7
Factored Bearing Resistance of Soil (ksf)	7.4
Friction Angle between Very Stiff Clay and Concrete (degrees)	22
Nominal Bearing Resistance of Bedrock (ksf)	139.8
Factored Bearing Resistance of Bedrock (ksf)	62.9
Friction Angle between Bedrock and Concrete (degrees)	35

5.3 PERMANENT SHEET PILE WALL

A permanent sheet pile wall will be designed throughout the limits of the project along Dry Fork Creek at the toe of the SR 126 embankment. The offset from centerline of SR 126 will be 23 feet right. The wall will first serve as a cofferdam to allow construction of the spread footing of the CIP concrete retaining wall. After construction of the retaining wall, the wall will be left in place to provide erosion protection and protect against undermining of the retaining wall footing. Toe support for most of the sheeting will be provided by embedment into the underlying soil. From the beginning of the wall to Station 12+21, rock excavation will be needed to reach the retaining wall footing elevation. Within this station range, permanent sheet pile walls will not be installed. From Station 12+21 to 13+58, depth to bedrock is anticipated to not be sufficient for permanent sheet pile wall embedment. Therefore, struts and braces will need to be installed and connected with the temporary sheeting described in Section 5.4 of the report. From Station 13+58 to the end of the wall, embedment depths are sufficient for the permanent sheet pile wall to not need additional support with a minimum embedment of 17 feet. The permanent wall was modelled using the computer program SPW911. Soil parameters listed in Table 2 were used. Modelling output is presented in Appendix C. Table 3 and Table 4 provides design parameters for the permanent sheet pile wall at the toe of slope. A PZ40 steel sheet pile wall section is recommended. If PZ40 sections are not available at the time of construction, an alternate section with section parameters meeting or exceeding the PZ40 may be used if approved by ODOT. Section properties for PZ40 sheeting are provided in Appendix C. Strut load was determined using SPW911 assuming no toe support was present for the braced section of the permanent wall if embedment depths less than less than the value shown in Table 3 are encountered.

Table 3. SPW911 Model Results for Braced Permanent Sheet Pile Wall (Station 12+21 to 13+58)

Design Parameter	Model Result Value
Braced Sheet Pile Maximum Bending Moment (unfactored)	18,525.5 ft-lb/ft
Braced Sheet Pile Maximum Shear Force (unfactored)	3,815.8 lb/ft
Braced Sheet Pile Maximum Deflection (PZ40 Sheeting)	0.1 in
Required Toe Embedment (FS = 1.3)	5.3 ft
Strut Elevation	670.0 ft
Strut Load (assumes no embedment, unfactored)	7,293.6 lb/ft

Table 4. SPW911 Model Results for Unbraced Permanent Sheet Pile Wall (Station 13+58 to 16+01)

Design Parameter	Model Result Value
Braced Sheet Pile Maximum Bending Moment (unfactored)	42,935.1 ft-lb/ft
Braced Sheet Pile Maximum Shear Force (unfactored)	5,130.3 lb/ft
Braced Sheet Pile Maximum Deflection (PZ40 Sheeting)	1.2 in
Required Toe Embedment (FS = 1.3)	16.9 ft (use 17.0 ft)

5.4 TEMPORARY SHEET PILE WALL

A temporary sheet pile wall will be designed throughout the limits of the project along SR 126 at an offset from centerline of SR 126 of 5 feet. The wall will retain and support SR 126 during construction of the CIP concrete wall. After construction of the retaining wall, the sheet piling will be removed after backfilling behind the permanent CIP wall is completed. Where possible, toe support for most of the sheeting will be provided by embedment into the underlying soil. From the beginning of the wall to Station 12+91, the depth of bedrock is shallow and will not allow for enough embedment for support. Within this station range, two rows of soil anchors will be needed. From Station 12+91 to the end of the wall, one row of anchors will be needed. These sections of wall were modelled using the computer program SPW911. Soil parameters listed in Table 2 were used. Modelling output is presented in Appendix C and supporting calculations for anchor design are included in Appendix D. Table 5 and Table 6 provide design parameters for the temporary sheet pile along the top of the slope. A PZ40 steel sheet pile wall section is recommended. If PZ40 sections are not available at the time of construction, an alternate section with section parameters meeting or exceeding the PZ40 may be used if approved by ODOT. Section properties for PZ40 sheeting are provided in Appendix C.

Table 5. SPW911 Model Results for Temporary Sheet Pile Wall (Station 11+50 to 12+91)

Design Parameter	Model Result Value
Sheet Pile Maximum Bending Moment (unfactored)	28,561.1 ft-lb/ft
Sheet Pile Maximum Shear Force (unfactored)	7,376.5 lb/ft
Sheet Pile Maximum Deflection (PZ40 Sheeting)	0 in
Required Toe Embedment (FS = 1.3)	0 ft
Row 1 Anchor Elevation	672.1 ft
Row 1 Anchor Load	3,257.2 lb/ft
Row 1 Anchor Spacing	3.25 ft
Row 1 Anchor Diameter	6 in
Row 1 Anchor Inclination	15 degrees
Row 1 Required Unbonded / Bonded Length	15 ft / 10 ft
Row 2 Anchor Elevation	662.1 ft
Row 2 Anchor Load	10,361.9 lb/ft
Row 2 Anchor Spacing	3.25 ft
Row 2 Anchor Diameter	6 in
Row 2 Anchor Inclination	15 degrees
Row 2 Required Unbonded / Bonded Length	15 ft / 31 ft

Table 6. SPW911 Model Results for Temporary Sheet Pile Wall (Station 12+91 to 16+01)

Design Parameter	Model Result Value
Sheet Pile Maximum Bending Moment (unfactored)	21,975.6 ft-lb/ft
Sheet Pile Maximum Shear Force (unfactored)	7,325.1 lb/ft
Sheet Pile Maximum Deflection (PZ40 Sheeting)	0.1
Required Toe Embedment (FS ≥ 1.3)	10 ft
Row 1 Anchor Elevation	669.9 ft
Row 1 Anchor Load	6,298.5 lb/ft
Row 1 Anchor Spacing	3.25 ft
Row 1 Anchor Diameter	6 in
Row 1 Anchor Inclination	15 degrees
Row 1 Required Unbonded / Bonded Length	15 ft / 19 ft

Five-foot anchor spacing was originally analyzed for design. This spacing resulted in bonded lengths of up to 47 feet. It was determined that the anchor spacing would be reduced to 3.25 feet in order to minimize the length of anchor reaching past ODOT right-of-way at the site (30 feet from centerline) and for ease of construction.

5.5 WALL BACKFILL

To reduce lateral earth pressures applied to permanent retaining structures due to hydrostatic buildup, free drainage should be provided in accordance with ODOT Construction and Materials Specifications (CMS) Item 518. Placement of the granular backfill should be in accordance with ODOT CMS Item 518.05 “Porous Backfill”. Positive drainage of the granular backfill using weepholes or pipe drains is necessary to minimize the hydrostatic pressures against the structures.

Backfill comprised of cohesive soils and/or granular soils with significant clay content may result in high magnitudes of lateral loads due to creep and swelling pressures. These materials are not recommended for use as backfill behind permanent walls, especially within the influence zone of the wall. The use of normal embankment material outside of the zone of influence was considered, however, it was assumed that insufficient space will be available between the CIP wall and the temporary sheet pile wall for safe and proper compaction of embankment fill to occur. It is recommended that backfill material comprised of free-draining granular material, such as the material specified under ODOT CMS Item 703.11, Type 3 (No. 57 or 67 gradations per CMS Table 703.01-1), be used.

Backfill should be compacted in accordance with ODOT CMS Item 203.07 “Compaction and Moisture Requirements”. Overcompaction in areas directly behind structures should be avoided as this can cause damage to the structures. Appropriate equipment should be used to obtain the required compaction without causing damage.

APPENDIX A
GEOTECHNCIAL PROFILE DRAWINGS

PROJECT DESCRIPTION

THIS PROJECT, BUT-126-2.92, IS THE EXPLORATION FOR MULTIPLE LANDSLIDES LOCATED ALONG THE SOUTHERN EMBANKMENT OF STATE ROUTE 126 AT SLM 2.90 IN BUTLER COUNTY, OHIO. A CAST-IN-PLACE RETAILING WALL IS RECOMMENDED TO STABILIZE THE ROADWAY.

HISTORIC RECORDS

THE ODOT TRAFFIC INFORMATION MANAGEMENT SYSTEM (TIMS) PROVIDES DOCUMENTATION FOR TWO GEOTECHNICAL EXPLORATIONS PERFORMED WITHIN 0.5 MILES OF THE PROJECT. INFORMATION FROM THESE EXPLORATIONS IS NOT PRESENTED IN THESE DRAWINGS; HOWEVER, THE INFORMATION WAS USED TO UNDERSTAND THE GENERAL SUBSURFACE PROFILE OF THE PROJECT AREA.

THE BUT-126-3.08 (PID 4782) PROJECT WAS COMPLETED FOR A BRIDGE CROSSING OVER KIATA CREEK. THE EXPLORATION CONSISTED OF FOUR BORINGS DRILLED IN 1990. SOILS AT THE SITE WERE VARIABLE BETWEEN COHESIVE AND GRANULAR MATERIALS. COHESIVE SOILS WERE DESCRIBED AS SILT AND CLAY (A-6A) AND SANDY SILT (A-4A). GRANULAR SOILS WERE DESCRIBED AS GRAVEL AND STONE FRAGMENTS (A-1-A), SANDY SILT (A-4A), AND COARSE AND FINE SAND (A-3A).

THE BUT-126-2.55 (PID 25347) PROJECT WAS COMPLETED FOR A CULVERT. THE EXPLORATION CONSISTED OF THREE ROADWAY AND FOUR STRUCTURAL BORINGS ADVANCED ALONG SR 126 IN 2005. SOILS ENCOUNTERED DURING THIS EXPLORATION WERE DESCRIBED AS PRIMARILY COHESIVE, CLASSIFYING AS SILTY CLAY (A-6B), SILT AND CLAY (A-6A), AND SANDY SILT (A-4A). BEDROCK WAS DESCRIBED AS INTERBEDDED LIMESTONE AND SHALE AND WAS ENCOUNTERED AT DEPTHS RANGING FROM 19.2 TO 33.8 FEET.

GEOLOGY

THE PROJECT SITE IS LOCATED WITHIN THE SOUTHERN OHIO LOAMY TILL PLAIN PHYSIOGRAPHIC REGION. THIS REGION IS DESCRIBED AS A SURFACE OF LOAMY TILL CONTAINING END AND RECESSIONAL MORAINES, WITH BOULDER BELTS AND BURIED VALLEYS. THE REGION CONSISTS OF LOAMY, HIGH LIME WISCONSINAN-AGE TILL, OUTWASH, AND LOESS OVER LOWER PALEOZOIC-AGE CARBONATE ROCKS. THE OVERBURDEN SOILS AT THE PROJECT SITE ARE UNDERLAIN PRIMARILY BY SEDIMENTARY BEDROCK OF THE KOPE FORMATION FROM THE ORDOVICIAN GROUP. THE BEDROCK FROM THE KOPE FORMATION IS COMPRISED OF INTERBEDDED LIMESTONE AND SHALE.

RECONNAISSANCE

ODOT AND STANTEC REPRESENTATIVES VISITED THE SITE ON APRIL 29, 2024, AFTER THE EXPLORATION. THE LAND SURROUNDING THE PROJECT SITE CAN BE DESCRIBED AS AGRICULTURAL WITH SOME RESIDENTIAL BUILDINGS IN THE VICINITY. THE PAVEMENT WAS OBSERVED TO BE GENERALLY IN FAIR CONDITION; HOWEVER, THE EASTBOUND LANE HAD CRACKS AND THE SHOULDER HAD BEEN REPAVED DUE TO SETTLEMENT CAUSED BY THE LANDSLIDES. SINKHOLES CAUSED BY THE EROSION WERE OBSERVED OFF THE SHOULDER AND DOWNSLOPE, SOME WERE LARGE ENOUGH TO SWALLOW GUARDRAIL POSTS. PREVIOUS REPAIRS CONSISTING OF SHEET PILE WALLS, GABION BASKETS, AND PILE LAGGING WALLS WERE LOCATED ALONG THE DOWNHILL SLOPE. A ROCK PROTECTION BLANKET WAS RECENTLY PLACED BY ODOT TO REDUCE FURTHER EROSION. THE LANDSLIDE AFFECTS APPROXIMATELY 300 FEET OF THE ROADWAY. THE BANK OF THE CREEK WAS WELL VEGETATED.

SUBSURFACE EXPLORATION

ODOT ADVANCED FOUR BORINGS IN 2022 TO OBTAIN GEOTECHNICAL DATA FOR THE PROPOSED LANDSLIDE STABILIZATION. THE BORINGS WERE ADVANCED ALONG THE EASTBOUND SHOULDER OF THE ROAD. THE BORINGS WERE ADVANCED IN ACCORDANCE WITH THE ODOT SPECIFICATIONS FOR GEOTECHNICAL EXPLORATIONS (SGE). THE BORINGS WERE PERFORMED WITH A CME 55 TRUCK MOUNTED DRILL RIG USING 3¼-INCH INSIDE DIAMETER (ID) HOLLOW STEM AUGERS TO ADVANCE THE BORINGS THROUGH SOIL. STANDARD PENETRATION TEST (SPT) SAMPLING WAS PERFORMED CONTINUOUSLY UNTIL THE BEDROCK WAS ENCOUNTERED. 10 FEET OF BEDROCK WAS CORED PRIOR TO TERMINATION IN TWO BORINGS. THE ENERGY RATIO (ER) OF THE CME 55 AUTOMATIC HAMMER AND DRILL ROD SYSTEM WERE MEASURED TO BE 83.6 PERCENT ON APRIL 15, 2020.

EXPLORATION FINDINGS

THE SURFACE MATERIALS ENCOUNTERED IN THE BORINGS CONSISTED OF 12 TO 18 INCHES OF ASPHALT FOLLOWED BY 6 INCHES OF BASE. BELOW THE ROADWAY MATERIALS, GRANULAR SOIL TYPICALLY CLASSIFYING AS GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT (A-2-4) OR GRAVEL AND STONE FRAGMENTS WITH SAND (A-1-B) WERE ENCOUNTERED TO DEPTHS RANGING FROM 3.0 TO 3.5 FEET. THE REMAINING SOILS ENCOUNTERED WERE PREDOMINATELY FINE-GRAINED, CLASSIFYING AS SANDY SILT (A-4A), SILT AND CLAY (A-6A), SILTY CLAY (A-6B), AND CLAY (A-7-6).THE FINE-GRAINED SOILS WERE DESCRIBED AS MEDIUM STIFF TO HARD, SHADES OF BROWN TO GRAY, DAMP TO MOIST, AND SLIGHTLY TO MODERATELY PLASTIC.

IN BORINGS B-001-0-22, B-002-0-22, AND B-004-0-22, THIN LAYERS (1.5 TO 4.5 FEET) OF COARSE-GRAINED SOILS WERE ENCOUNTERED AT VARIOUS DEPTHS. IN B-003-0-22, COARSE-GRAINED MATERIAL WAS ENCOUNTERED FROM A DEPTH OF 6.0 FEET TO 19.5 FEET. THESE COARSE-GRAINED MATERIALS WERE VISUALLY DESCRIBED OR CLASSIFIED AS GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT (A-2-4), GRAVEL AND STONE FRAGMENTS WITH SAND (A-1-B), GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY (A-2-6), OR COARSE AND FINE SAND (A-3A). THE SOILS WERE DESCRIBED AS LOOSE TO VERY DENSE, BROWN TO GRAY, AND DAMP TO MOIST.

BEDROCK WAS ENCOUNTERED AT DEPTH OF 19.5 FEET IN B-001-0-22 AND 31.0 FEET IN B-002-0-22. BEDROCK WAS NOT ENCOUNTERED IN B-003-0-22 OR B-004-0-22. BEDROCK WAS DESCRIBED AS INTERBEDDED SHALE AND LIMESTONE. THE SHALE WAS DESCRIBED AS BROWN TO GRAY, HIGHLY TO MODERATELY WEATHERED, VERY WEAK, THINLY LAMINATED, AND CALCAREOUS. THE LIMESTONE WAS DESCRIBED AS MEDIUM LIGHT GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, AND FOSSILIFEROUS. TEN FEET OF BEDROCK WAS CORED IN EACH BORING PRIOR TO TERMINATION. UNCONFINED COMPRESSIVE TESTING WAS COMPLETED ON TWO SAMPLES OF LIMESTONE, RESULTING IN COMPRESSIVE STRENGTHS OF 7,724 AND 12,468 POUNDS PER SQUARE INCH (PSI). TESTING OF TWO SAMPLES OF SHALE BEDROCK RESULTED IN UNCONFINED COMPRESSIVE STRENGTHS OF 50 AND 90 PSI.

GROUNDWATER WAS NOT OBSERVED WHILE DRILLING B-001-0-22 AND B-002-0-22; HOWEVER, THIS MAY HAVE BEEN OBSCURED BY THE ADDITION OF WATER DURING ROCK CORING. IT IS LIKELY THAT GROUNDWATER IS PRESENT WITHIN THE BEDROCK AT THESE TWO LOCATIONS. GROUNDWATER WAS OBSERVED DURING DRILLING AT A DEPTH OF 15 FEET IN B-003-0-22 AND 16 FEET IN B-004-0-23.

BORINGS B-003-0-22 AND B-004-0-22 WERE TERMINATED AT A DEPTH OF 49.5 FEET AND 45.0 FEET RESPECTIVELY PRIOR TO ENCOUNTERING BEDROCK. THESE WERE TERMINATED DUE TO ENCOUNTERING A NATURAL GAS POCKET.

SPECIFICATIONS

THIS GEOTECHNICAL EXPLORATION WAS PERFORMED IN ACCORDANCE WITH THE STATE OF OHIO, DEPARTMENT OF TRANSPORTATION, OFFICE OF GEOTECHNICAL ENGINEERING, SPECIFICATIONS FOR GEOTECHNICAL EXPLORATIONS, DATED JANUARY 2024.

AVAILABLE INFORMATION

THE SOIL, BEDROCK, AND GROUNDWATER INFORMATION COLLECTED FOR THIS SUBSURFACE EXPLORATION THAT CAN BE CONVENIENTLY DISPLAYED ON THE SOIL PROFILE SHEETS HAS BEEN PRESENTED. GEOTECHNICAL REPORTS, IF PREPARED, ARE AVAILABLE FOR REVIEW ON THE OFFICE OF CONTRACT SALES WEBSITE.

LEGEND

DESCRIPTION	ODOT CLASS	CLASSIFIED MECH./VISUAL	
GRAVEL AND STONE FRAGMENTS WITH SAND	A-1-b	5	3
GRAVEL OR STONE FRAGMENTS WITH SAND AND SILT	A-2-4	5	4
GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY	A-2-6	2	4
COARSE AND FINE SAND	A-3a	1	0
SANDY SILT	A-4a	3	3
SILT AND CLAY	A-6a	22	27
SILTY CLAY	A-6b	5	3
CLAY	A-7-6	2	0
	TOTAL	45	44
BOULDERY ZONE	VISUAL		
SHALE	VISUAL		
LIMESTONE	VISUAL		
PAVEMENT AND/OR BASE = X = APPROXIMATE THICKNESS	VISUAL		

BORING LOCATION - PLAN VIEW

DRIVE SAMPLE AND/OR ROCK CORE BORING PLOTTED TO VERTICAL SCALE ONLY. HORIZONTAL BAR INDICATES A CHANGE IN STRATIGRAPHY.

N_{60} INDICATES STANDARD PENETRATION RESISTANCE NORMALIZED TO 60% DRILL ROD ENERGY RATIO.

WC INDICATES WATER CONTENT IN PERCENT.

X/Y/D" NUMBER OF BLOWS FOR STANDARD PENETRATION TEST (SPT): X= NUMBER OF BLOWS FOR 6 INCHES (UNCORRECTED). Y/D"= NUMBER OF BLOWS (UNCORRECTED) FOR D" OF PENETRATION AT REFUSAL.

ST INDICATES A SHELBY TUBE SAMPLE.

SS INDICATES A SPLIT SPOON SAMPLE, STANDARD PENETRATION TEST.

W— INDICATES FREE WATER.

TR INDICATES THE TOP OF ROCK.

LOI INDICATES ORGANIC CONTENT BY LOSS ON IGNITION, AASHTO T267.

SDI (%) SLAKE DURABILITY TEST, ASTM D4644.

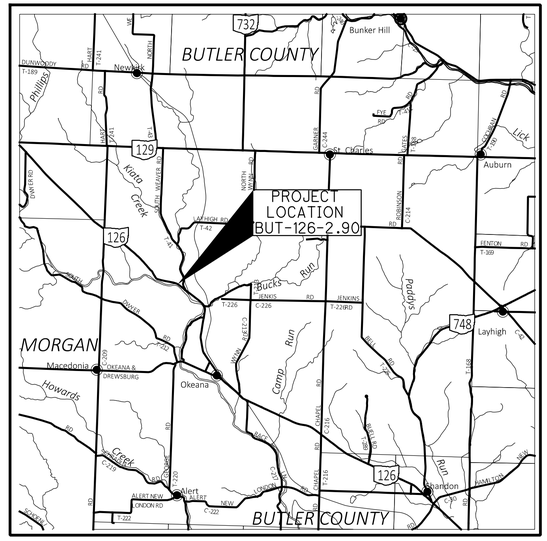
Q_u INDICATES UNCONFINED COMPRESSION TEST, (ROCK) ASTM D7012.

RECON. - EK & JS 04/29/24

DRILLING - ODOT/CARY & McLEISH 01/24/22 - 02/08/22

DRAWN - MJ 07/2024

REVIEWED - EK 11/2024



LOCATION MAP

SCALE IN MILES

0 1 2 3 4

N

PARTICLE SIZE DEFINITIONS

12"	3"	2.0 mm	0.42 mm	0.074 mm	0.005 mm
BOULDERS | COBBLES		GRAVEL	COARSE SAND	FINE SAND	SILT | CLAY
		No. 10 SIEVE	No. 40 SIEVE	No. 200 SIEVE	

BEDROCK TEST SUMMARY

EXPLOR. ID	SAMPLE ELEV. (FT.)	SAMPLE DEPTH (FT.)	QU (PSI)	LITHOLOGY
B-001-0-22	656.0'-655.6'	22.6'-23.0'	7,724	LIMESTONE
	650.0'-649.7'	28.6'-28.9'	90	SHALE
B-002-0-22	645.7'-645.3'	31.3'-31.7'	12,468	LIMESTONE
	641.5'-641.1'	35.5'-35.9'	50	SHALE

ORGANIC CONTENT BY LOSS ON IGNITION TEST

EXPLOR. ID	SAMPLE ID	SAMPLE ELEVATION	SAMPLE DEPTH	LOI (%)
B-001-0-22	SS-2	675.6'-674.1'	3.0'-4.5'	5.5
	SS-3	674.1'-672.6'	4.5'-6.0'	4.7
B-002-0-22	SS-2	674.0'-672.5'	3.0'-4.5'	5.4
	SS-13	657.5'-656.0'	19.5'-21.0'	5.5

GEOTECHNICAL PROFILE - RETAINING WALL
RETAINING WALL BUT-126-2.92

DESIGN AGENCY
Stantec
10200 Alliance Road, Suite 300
Cincinnati, OH 45242
(513) 842-8200

DESIGNER MSJ

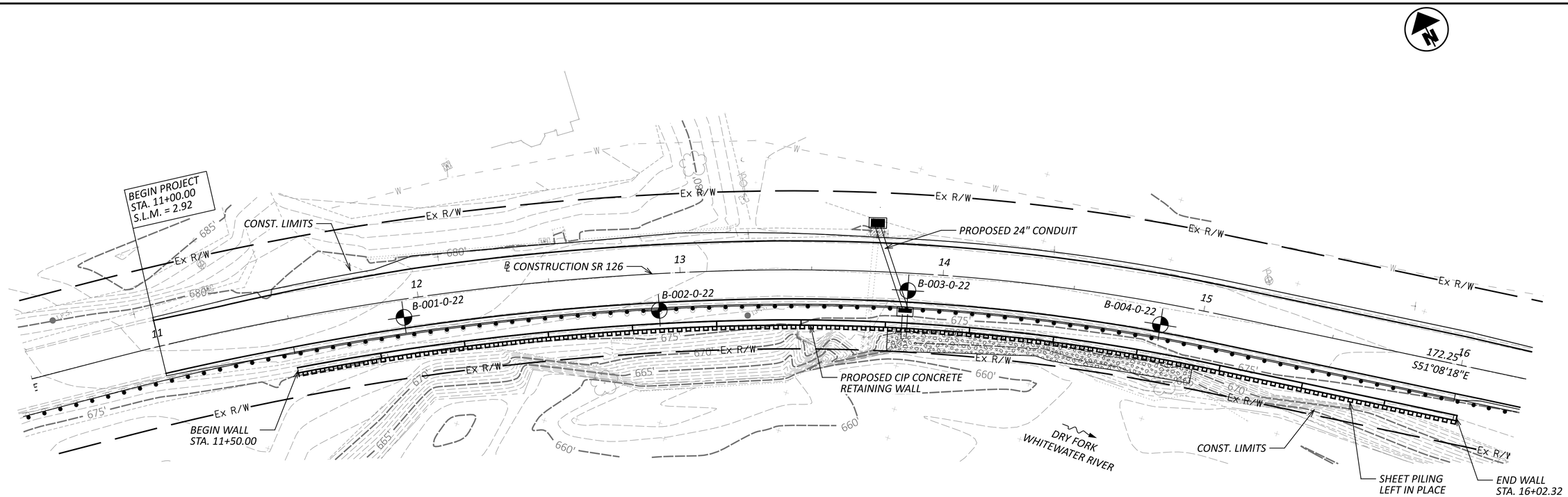
REVIEWER EMK 11/22/24

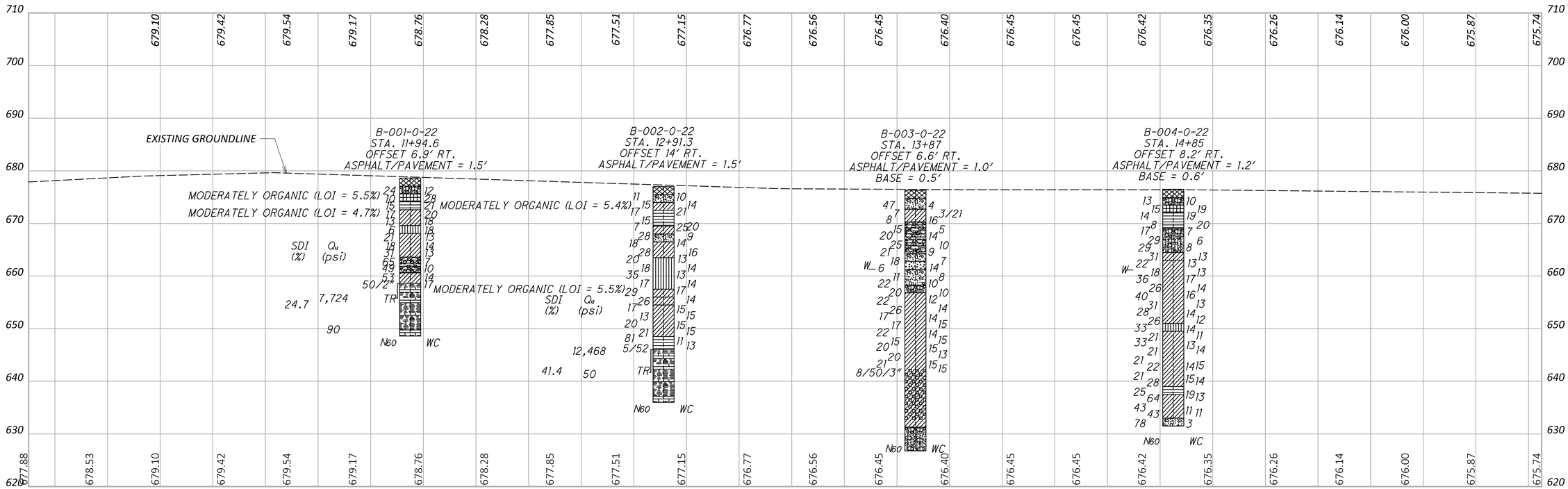
PROJECT ID 116204

SUBSET 1 TOTAL 7

SHEET P.33 TOTAL 39

BUT-126-2.92





GEOTECHNICAL PROFILE - RETAINING WALL
SR 126 STA. 10+50.00 TO STA. 16+20.00

DESIGN AGENCY
Stantec
10200 Alliance Road, Suite 300
Cincinnati, OH 45242
(513) 842-8200

DESIGNER MSJ
REVIEWER EMK 11/22/24
PROJECT ID 116204
SUBSET 2 TOTAL 7
SHEET P.34 TOTAL 39

BUT-126-2.92

MODEL: BL_P_S127 - Plan 1 [Sheet] PAPERSIZE: 34x22 (in.) DATE: 11/21/2024 TIME: 4:41:40 PM USER: MJennings
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PROJECT: BUT-126-2.92	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 11+95, 7' RT.	EXPLORATION ID B-001-0-22
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 126	
PID: 116204 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/15/20	ELEVATION: 678.6 (MSL) EOB: 30.0 ft.	PAGE 1 OF 1
START: 1/24/22 END: 1/25/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 83.6	LAT / LONG: 39.365550, -84.777010	

MATERIAL DESCRIPTION AND NOTES	ELEV.	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 (18')	678.6																	
	677.1																	
MEDIUM DENSE, BROWN AND DARK BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, DAMP	675.6		12 12 5	24	78	SS-1	-	30	22	19	17	12	20	15	5	12	A-2-4 (0)	
STIFF, DARK BROWN, **CLAY**, "AND" SILT, SOME SAND, TRACE GRAVEL AND STONE FRAGMENTS, MODERATELY ORGANIC (LOI = 5.5%), MOIST	674.1		3 3 4	10	83	SS-2	1.50	5	7	17	41	30	41	23	18	28	A-7-6 (11)	
STIFF, DARK BROWN, **SILTY CLAY**, LITTLE SAND, TRACE GRAVEL, MODERATELY ORGANIC (LOI = 4.7%), MOIST	672.6		3 4 7	15	100	SS-3	2.00	3	4	14	45	34	40	20	20	21	A-6b (12)	
STIFF, BROWN, **SILT AND CLAY**, LITTLE SAND, TRACE GRAVEL, MOIST @7.5'; VERY STIFF	669.6		4 5 7	17	100	SS-4	2.00	1	2	15	48	34	32	17	15	20	A-6a (10)	
			2 4 5	13	100	SS-5	2.50	-	-	-	-	-	-	-	-	18	A-6a (V)	
MEDIUM STIFF, BROWN, **SANDY SILT**, LITTLE CLAY, TRACE STONE FRAGMENTS, MOIST	668.1		2 2 2	6	100	SS-6	0.50	6	8	32	37	17	23	14	9	18	A-4a (4)	
VERY STIFF, BROWN, **SILT AND CLAY**, SOME SAND, SOME GRAVEL AND STONE FRAGMENTS, DAMP @12.0'; BROWN AND GRAY			5 6 9	21	100	SS-7	2.00	-	-	-	-	-	-	-	-	13	A-6a (V)	
			3 6 7	18	100	SS-8	2.50	21	8	17	29	25	26	14	12	14	A-6a (5)	
@13.5'; NO RECOVERY	663.6		7 10 12	31	0	SS-9	-	-	-	-	-	-	-	-	-	13	A-6a (V)	
VERY DENSE, BROWN AND GRAY, **STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, DAMP @16.5' - 18.0'; ENCOUNTERED LIMESTONE BOULDERS/COBBLES	660.6		6 18 29	65	44	SS-10	-	53	9	9	15	14	25	14	11	7	A-2-6 (0)	
			25 18 17	49	56	SS-11	-	-	-	-	-	-	-	-	-	10	A-2-6 (V)	
HARD, BROWN AND GRAY, **SILT AND CLAY**, SOME STONE FRAGMENTS, LITTLE SAND, DAMP @19.5'; MOIST	658.6	TR	10 20 18	53	100	SS-12	-	26	6	6	31	31	31	16	15	14	A-6a (7)	
			50/2"	-	100	SS-13	-	-	-	-	-	-	-	-	-	17	A-6a (V)	
INTERBEDDED SHALE (64%) AND LIMESTONE (36%), BLOCKY, GOOD, RQD 69%, REC. 99%; **SHALE**, GRAY AND BROWN, HIGHLY TO MODERATELY WEATHERED, VERY WEAK, THINLY LAMINATED, CALCAREOUS, RANGES IN THICKNESS FROM 1 INCH TO 17 INCHES; **LIMESTONE**, MEDIUM LIGHT GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, RANGES IN THICKNESS FROM 1 INCHE TO 16 INCHES. @ 22.6' - 23.0'; LIMESTONE, γ = 168 pcf; Qu = 7,724 psi @ 23.1' - 24.0'; SHALE, Id2 = 24.7%			60		98	NQ2-1										CORE	
@ 28.6' - 28.9'; SHALE, γ = 146 pcf; Qu = 90 psi	648.6	EOB	78		100	NQ2-2										CORE	

NOTES: HOLE DRY BEFORE CORING. LAT/LONG/ELEV FROM DISTRICT SURVEY GRADE INSTRUMENTS.
ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

SHEET	SUBSET	PROJECT ID	REVIEWER	DESIGNER	DESIGN AGENCY
P.35 / TOTAL 39	3 / TOTAL 7	116204	EMK 11/22/24	MSJ	Stantec 10200 Alliance Road, Suite 200 Cincinnati, OH 45242 (513) 842-8200

GEOTECHNICAL PROFILE - RETAINING WALL
BORING LOG B-001-0-22

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 11/21/2024 TIME: 4:32:48 PM USER: MJennings
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 08\Butler\116204\401-Engineering_Stantec\Geotechnical\Sheets\116204_ZL002.dgn

PROJECT: BUT-126-2.92	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 12+91, 14' RT.	EXPLORATION ID B-002-0-22
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 126	
PID: 116204 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/15/20	ELEVATION: 677.0 (MSL) EOB: 41.0 ft.	PAGE 1 OF 1
START: 1/25/22 END: 1/27/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 83.6	LAT / LONG: 39.365470, -84.776700	

MATERIAL DESCRIPTION AND NOTES	ELEV.	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 (18")	677.0																	
	675.5																	
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, (NOT ENOUGH MATERIAL TO TEST), DAMP	674.0		5 4 4	11	17	SS-1	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
STIFF, DARK BROWN, **SILT AND CLAY**, SOME SAND, SOME GRAVEL AND STONE FRAGMENTS, MODERATELY ORGANIC (LOI = 5.4%), DAMP	672.5		4 5 6	15	44	SS-2	2.00	22	12	13	32	21	31	17	14	14	A-6a (5)	
VERY STIFF, BROWN, **SILTY CLAY**, LITTLE SAND, MOIST	669.5		4 5 7	17	56	SS-3	3.00	0	1	10	51	38	35	17	18	21	A-6b (11)	
			3 5 6	15	100	SS-4	3.00	-	-	-	-	-	-	-	-	20	A-6b (V)	
MEDIUM STIFF, BROWN, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, MOIST	668.0		2 2 3	7	100	SS-5	1.00	16	5	18	39	22	29	14	15	25	A-6a (7)	
MEDIUM DENSE, BROWN, **STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	666.5		5 8 12	28	56	SS-6	-	51	17	12	16	4	NP	NP	NP	9	A-1-b (0)	
VERY STIFF, BROWN AND GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, MOIST			4 5 8	18	100	SS-7	3.00	14	9	19	33	25	26	13	13	14	A-6a (6)	
@12.0' - 13.5'; NO RECOVERY, AUGER CUTTINGS TAKEN	663.5		9 10 10	28	0	SS-8	-	-	-	-	-	-	-	-	-	16	A-6a (V)	
VERY STIFF, GRAY, **SANDY SILT**, SOME CLAY, LITTLE GRAVEL AND STONE FRAGMENTS, MOIST			5 6 8	20	100	SS-9	3.00	13	8	18	35	26	23	13	10	13	A-4a (5)	
			3 5 8	18	100	SS-10	3.00	-	-	-	-	-	-	-	-	14	A-4a (V)	
@16.5'; BROWN AND GRAY			12 17 8	35	67	SS-11	2.25	-	-	-	-	-	-	-	-	13	A-4a (V)	
@18.0'; GRAY	657.5		4 5 7	17	100	SS-12	3.00	-	-	-	-	-	-	-	-	14	A-4a (V)	
VERY STIFF, DARK GRAY AND GREENISH GRAY, **SILT AND CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, MODERATELY ORGANIC (LOI = 5.5%), DAMP	656.0		9 10 11	29	67	SS-13	2.25	16	4	7	42	31	31	18	13	17	A-6a (9)	
VERY STIFF, GRAY, **SILT AND CLAY**, SOME SAND, LITTLE STONE FRAGMENTS, MOIST	654.5		6 8 11	26	100	SS-14	3.50	17	7	15	34	27	25	14	11	14	A-6a (6)	
VERY STIFF, GRAYISH BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL AND STONE FRAGMENTS, MOIST			3 5 7	17	100	SS-15	2.50	9	7	16	36	32	26	13	13	15	A-6a (8)	
			2 3 6	13	100	SS-16	2.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
			3 5 9	20	100	SS-17	2.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
	648.5		6 6 9	21	100	SS-18	3.00	-	-	-	-	-	-	-	-	15	A-6a (V)	
VERY STIFF, BROWN AND GRAY, **SILTY CLAY**, SOME STONE FRAGMENTS, LITTLE SAND, DAMP @28.5' - 30.0'; ENCOUNTERED LIMESTONE BOULDERS/COBBLES	646.0	TR	19 30 28	81	11	SS-19	2.75	-	-	-	-	-	-	-	-	11	A-6b (V)	
			5 52	-	83	SS-20	3.25	26	5	5	31	33	32	16	16	13	A-6b (8)	
INTERBEDDED LIMESTONE (53%) AND SHALE (47%), BLOCKY, GOOD, RQD 43%, REC. 98%; **LIMESTONE**, MEDIUM LIGHT GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, RANGES IN THICKNESS 1" TO 21"; **SHALE**, BROWN AND GRAY, HIGHLY WEATHERED, VERY WEAK, THINLY LAMINATED, SLIGHTLY CALCAREOUS, RANGES IN THICKNESS FROM 0.5 INCHES TO 9 INCHES. @31.0' - 31.25'; CLAY WITH LIMESTONE FRAGMENTS @ 31.3' - 31.7'; LIMESTONE, γ = 168 pcf; Qu = 12,468 psi @32.7' - 33.3'; HIGH ANGLE FRACTURE @ 35.0' - 36.0'; SHALE, Id2 = 41.4% @ 35.5' - 35.9'; SHALE, γ = 146 pcf; Qu = 50 psi @36.3' - 36.8'; CLAY SEAM			52		100	NQ2-1										CORE	
			33		95	NQ2-2										CORE	
	636.0	EOB																
@40.8' - 41.0'; HIGH ANGLE FRACTURE WITH CLAY INFILLING																		

NOTES: HOLE DRY BEFORE CORING. LAT/LONG/ELEV FROM DISTRICT SURVEY GRADE INSTRUMENTS.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 20 LB. BENTONITE CHIPS

SHEET	SUBSET	PROJECT ID	REVIEWER	DESIGNER	DESIGN AGENCY
P.36 / TOTAL 39	4 / TOTAL 7	116204	EMK 11/22/24	MSJ	Stantec 10200 Alliance Road Suite 200 Cincinnati, OH 45242 (513) 842-8200

GEOTECHNICAL PROFILE - RETAINING WALL
BORING LOG B-002-0-22

BUT-126-2.92

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 11/21/2024 TIME: 4:33:31 PM USER: MJennings
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 08\Butler\116204\401-Engineering_Stantec\Geotechnical\Sheets\116204_ZL003.dgn

PROJECT: BUT-126-2.92	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 13+87, 7' RT.	EXPLORATION ID B-003-0-22
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 126	
PID: 116204 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/15/20	ELEVATION: 676.3 (MSL) EOB: 49.5 ft.	PAGE 1 OF 1
START: 1/27/22 END: 2/1/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 83.6	LAT / LONG: 39.365350, -84.776380	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASPHALT (12') & BASE (6')	676.3																	
	674.8	1																
DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRAC CLAY, DAMP		2	10 17 17	47	78	SS-1	-	48	18	15	14	5	NP	NP	NP	4	A-1-b (0)	
@3.0'; LOOSE	672.7	3	6 3 2	7	89	SS-2A	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	
STIFF, BROWN, **SILT AND CLAY**, "AND" SAND, DAMP		4				SS-2B	2.00	0	3	33	37	27	31	16	15	21	A-6a (8)	
	670.3	5	2 3 3	8	44	SS-3	2.00	-	-	-	-	-	-	-	-	16	A-6a (V)	
MEDIUM DENSE, BROWN, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP		6	4 4 7	15	33	SS-4	-	-	-	-	-	-	-	-	-	5	A-2-6 (V)	
		7	3 5 9	20	11	SS-5	-	-	-	-	-	-	-	-	-	14	A-2-6 (V)	
		8	5 8 10	25	50	SS-6	-	42	8	18	18	14	27	15	12	10	A-2-6 (0)	
	664.3	9	9 7 8	21	0	SS-7	-	-	-	-	-	-	-	-	-	9	A-2-6 (V)	
MEDIUM DENSE, BROWN, **STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP	662.8	10	6 6 7	18	44	SS-8	-	52	15	12	15	6	21	16	5	7	A-1-b (0)	
LOOSE, BROWN, **COARSE AND FINE SAND**, SOME SILT, LITTLE STONE FRAGMENTS, TRACE CLAY, MOIST	661.3	11	2 2 2	6	44	SS-9	-	15	38	18	24	5	NP	NP	NP	14	A-3a (0)	
MEDIUM DENSE, BROWN, **STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST		12	3 3 5	11	56	SS-10	-	56	15	13	12	4	NP	NP	NP	8	A-1-b (0)	
@16.5'; WET		13	5 8 8	22	61	SS-11	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
	658.3	14																
MEDIUM DENSE, BROWN AND GRAY, **STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, DAMP	656.8	15	4 5 9	20	78	SS-12	-	41	12	15	19	13	21	12	9	10	A-2-4 (0)	
VERY STIFF, GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL AND STONE FRAGMENTS, MOIST		16	4 7 9	22	56	SS-13	2.50	16	11	18	30	25	24	12	12	12	A-6a (5)	
@21.0'; STIFF		17	5 9 10	26	33	SS-14	1.00	-	-	-	-	-	-	-	-	14	A-6a (V)	
@22.5'; VERY STIFF		18	2 6 6	17	100	SS-15	2.00	12	8	17	34	29	25	13	12	14	A-6a (6)	
		19	4 5 7	17	100	SS-16	2.00	-	-	-	-	-	-	-	-	15	A-6a (V)	
		20	4 7 9	22	83	SS-17	2.50	-	-	-	-	-	-	-	-	14	A-6a (V)	
		21	3 5 6	15	100	SS-18	2.50	8	8	18	34	32	25	13	12	15	A-6a (7)	
@28.5'; CONTAINS WOOD		22	3 5 9	20	100	SS-19	2.00	-	-	-	-	-	-	-	-	15	A-6a (V)	
		23	2 6 8	20	100	SS-20	2.50	-	-	-	-	-	-	-	-	13	A-6a (V)	
		24	4 6 9	21	67	SS-21	2.50	12	8	18	33	29	23	12	11	15	A-6a (6)	
		25	8 50/3"	-	100	SS-22	2.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
@34.0' - 44.0'; ENCOUNTERED BOULDERS/COBBLES		26																
		27						-	10	15	16	32	27	26	15	11	-	A-6a (5)
		28	0		40	NQ2-1												CORE
		29																
		30																
		31																
		32																
		33																
		34	0		3	NQ2-2												CORE
		35																
		36																
		37																
		38																
		39																
		40																
		41																
		42																
		43																
		44																
	631.3	45	50/3"	-	100	SS-23	-	-	-	-	-	-	-	-	-	6	A-2-4 (V)	
VERY DENSE, GRAY, **STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP		46																
		47	43 70 64	187	83	SS-24	-	51	11	12	17	9	17	13	4	6	A-2-4 (0)	
		48	50/4"	-	75	SS-25	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
	626.8	49																
		EOB																

@49.5'; END OF BORING DUE TO ENCOUNTERING A NATURAL GAS POCKET

NOTES: LAT/LONG/ELEV FROM DISTRICT SURVEY GRADE INSTRUMENTS.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED 50 LB. BENTONITE CHIPS; TREMIED 50 LB. BENTONITE GROUT; 30 GAL. WATER

SHEET	SUBSET	PROJECT ID	REVIEWER	DESIGNER	DESIGN AGENCY
P.37 / TOTAL 39	5 / TOTAL 7	116204	EMK 11/22/24	MSJ	Stantec 10200 Alliance Road, Suite 200 Cincinnati, OH 45242 (513) 842-8200

GEOTECHNICAL PROFILE - RETAINING WALL
BORING LOG B-003-0-22

MODEL: Sheet PAPERSIZE: 34x22 (in.) DATE: 11/21/2024 TIME: 4:34:14 PM USER: MJennings
pw:\\ohiodot-pw.bentley.com:ohiodot-pw-02\Documents\01 Active Projects\District 08\Butler\116204\401-Engineering_Stantec\Geotechnical\Sheets\116204_ZL004.dgn

PROJECT: BUT-126-2.92	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 14+85, 8' RT.	EXPLORATION ID B-004-0-22
TYPE: RETAINING WALL	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 126	
PID: 116204 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/15/20	ELEVATION: 676.5 (MSL) EOB: 45.0 ft.	PAGE 1 OF 1
START: 2/1/22 END: 2/8/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 83.6	LAT / LONG: 39.365210, -84.776090	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD		REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASPHALT (14") & BASE (6")	676.5																	
	674.9	1																
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, DAMP	673.5	2	10 6 3	13	56	SS-1	-	33	19	19	18	11	20	15	5	10	A-2-4 (0)	
VERY STIFF, GRAYISH BROWN, **CLAY**, "AND" SILT, SOME SAND, TRACE GRAVEL AND STONE FRAGMENTS, DAMP	672.0	3	2 4 7	15	67	SS-2	3.75	5	5	21	37	32	43	19	24	19	A-7-6 (13)	
VERY STIFF, BROWN, **SILTY CLAY**, SOME SAND, TRACE GRAVEL AND STONE FRAGMENTS, MOIST @6.0'; STIFF	669.0	4	3 4 6	14	100	SS-3	3.00	1	1	26	38	34	33	17	16	19	A-6b (10)	
		5	2 2 4	8	100	SS-4	2.00	-	-	-	-	-	-	-	-	20	A-6b (V)	
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, DAMP	664.5	6	3 5 7	17	44	SS-5	-	55	10	12	14	9	24	15	9	7	A-2-4 (0)	
		7	8 10 11	29	67	SS-6	-	-	-	-	-	-	-	-	-	6	A-2-4 (V)	
		8	8 10 11	29	56	SS-7	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
VERY STIFF, BROWN AND GRAY, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL AND STONE FRAGMENTS, DAMP	663.0	9	3 8 14	31	78	SS-8	3.75	17	7	16	33	27	27	13	14	13	A-6a (7)	
VERY STIFF, GRAY, **SILT AND CLAY**, SOME SAND, TRACE STONE FRAGMENTS, MOIST		10	4 6 10	22	100	SS-9	3.00	9	6	17	37	31	26	13	13	13	A-6a (8)	
		11	3 5 8	18	100	SS-10	3.00	-	-	-	-	-	-	-	-	13	A-6a (V)	
@16.5'; STIFF, MOIST		12	11 11 15	36	28	SS-11	1.00	-	-	-	-	-	-	-	-	17	A-6a (V)	
@18.0'; VERY STIFF		13	6 7 12	26	83	SS-12	3.00	17	8	16	31	28	25	14	11	14	A-6a (5)	
		14	4 12 17	40	100	SS-13	3.00	-	-	-	-	-	-	-	-	16	A-6a (V)	
@21.0'; DAMP		15	6 8 14	31	100	SS-14	4.00	-	-	-	-	-	-	-	-	13	A-6a (V)	
		16	4 8 12	28	22	SS-15	2.00	-	-	-	-	-	-	-	-	14	A-6a (V)	
		17	7 9 10	26	100	SS-16	3.50	23	15	17	24	21	25	14	11	12	A-6a (2)	
	651.0																	
MEDIUM STIFF, GRAY, **SANDY SILT**, SOME GRAVEL AND STONE FRAGMENTS, LITTLE CLAY, MOIST	649.5	18	5 10 14	33	100	SS-17	0.50	24	19	18	20	19	24	14	10	14	A-4a (1)	
VERY STIFF, GRAY, **SILT AND CLAY**, SOME SAND, SOME GRAVEL AND STONE FRAGMENTS, DAMP		19	8 6 9	21	100	SS-18	3.50	-	-	-	-	-	-	-	-	11	A-6a (V)	
@28.5'; MOIST		20	3 10 14	33	83	SS-19	3.00	25	14	16	23	22	27	13	14	13	A-6a (3)	
		21	3 6 9	21	100	SS-20	3.50	-	-	-	-	-	-	-	-	14	A-6a (V)	
		22	5 7 8	21	83	SS-21	2.50	-	-	-	-	-	-	-	-	14	A-6a (V)	
		23	4 7 9	22	100	SS-22	2.50	10	8	18	33	31	26	14	12	15	A-6a (7)	
@34.5'; STIFF		24	2 6 9	21	100	SS-23	1.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
@36.0'; VERY STIFF	639.0	25	6 10 10	28	100	SS-24	2.50	-	-	-	-	-	-	-	-	14	A-6a (V)	
VERY STIFF, DARK GRAY, **SILTY CLAY**, LITTLE SAND, MOIST	637.5	26	3 7 11	25	100	SS-25	2.50	0	2	11	33	54	39	17	22	19	A-6b (13)	
HARD, GRAY, **SILT AND CLAY**, SOME SAND, SOME STONE FRAGMENTS, DAMP		27	5 11 35	64	100	SS-26	4.00	21	9	17	30	23	24	13	11	13	A-6a (4)	
		28	9 14 17	43	39	SS-27	4.5+	-	-	-	-	-	-	-	-	11	A-6a (V)	
@42.0'; VERY STIFF	633.0	29	10 12 19	43	56	SS-28	2.50	-	-	-	-	-	-	-	-	11	A-6a (V)	
VERY DENSE, GRAY, **STONE FRAGMENTS WITH SAND**, LITTLE SAND, TRACE CLAY, DAMP	631.5	30	22 28 28	78	67	SS-29	-	42	22	17	13	6	NP	NP	NP	3	A-1-b (0)	
		EOB 45																
@45.0'; END OF BORING DUE TO ENCOUNTERING A NATURAL GAS POCKET																		

NOTES: HOLE DRY UPON COMPLETION. LAT/LONG/ELEV FROM DISTRICT SURVEY GRADE INSTRUMENTS.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED 50 LB. BENTONITE CHIPS; TREMIED 50 LB. BENTONITE GROUT; 30 GAL. WATER

SHEET	SUBSET	PROJECT ID	REVIEWER	DESIGNER	DESIGN AGENCY
P.38 / TOTAL 39	6 / TOTAL 7	116204	EMK 11/22/24	MSJ	Stantec 10200 Alliance Road, Suite 200 Cincinnati, OH 45242 (513) 842-8200

GEOTECHNICAL PROFILE - RETAINING WALL
BORING LOG B-004-0-22

SLAKE DURABILITY TEST

ASTM D 4644

Office of Geotechnical Engineering

Lab No.:	
Report Date:	2/15/2022
Tech:	C. B

County	BUT	Route	126	Section	2.9
Boring Number	B-001-0-22	Distirict	8	PID	116204
Station		Offset	NA	Offsest Direction	NA
Latitude	NA	Longitude	NA	Ground Elev. (Ft)	NA
Sample Number	1	Top Depth	23.1	Bottom Depth	24.0'

Geologic Unit	
Description	Shale

NATURAL MOISTURE DETERMINATION

Pan ID	Sample Weight (g)	Tare Weight (g)		IN: 02/08/22	OUT: 02/09/22	Moisture Content (%)
1	501.31	1233.03	Time	14:10	7:15	18.63%
			Mass	1734.34	1655.62	

Start Time (mil):	End Time (mil):		First Cycle (I_{d1})					
7:20	7:30		Drum ID	Tare Weight (g)		IN: 2/9/22	OUT: 02/09/22	Final Dry Mass (g)
Start Temp (ºC):	End Temp (ºC):	Avg. Temp (ºC)	1	1233.03	Time	7:40	11:20	
21.0	20.9	20.95			Mass	1475.16	1432.21	199.18

Start Time (mil):	End Time (mil):		Second Cycle (Id2)					
12:40	12:50		Drum ID	Tare Weight (g)		IN: 2/9/22	OUT: 2/10/22	Final Dry Mass (g)
Start Temp (ºC):	End Temp (ºC):	Avg. Temp (ºC)	1	1233.03	Time	12:54	7:30	
18.4	18.3	18.35			Mass	1361.21	1337.53	104.5

Before First Cycle

After Second Cycle

Slake Durability Index

$I_{d2}=\{(W_F-C)/(B-C)\}*100$

I_{d2} = 24.7%

Retained Material Type: III (Reference Below)

WF = Drum mass + oven dried specimum after second cycle; B = Drum mass + specimen prior to test; C = Drum mass

From ASTM D4644

T 1 — Retained pieces remain virtually unchanged

T 2 — Retained material consists of large and small pieces

T 3 — Retained material is exclusively small pieces

SLAKE DURABILITY TEST

ASTM D 4644

Office of Geotechnical Engineering

Lab No.:	
Report Date:	2/15/2022
Tech:	C. B

County	BUT	Route	126	Section	2.9
Boring Number	B-002-0-22	Distirict	8	PID	116204
Station		Offset	NA	Offsest Direction	NA
Latitude	NA	Longitude	NA	Ground Elev. (Ft)	NA
Sample Number	2	Top Depth	35.0'	Bottom Depth	36.0'

Geologic Unit	
Description	Shale

NATURAL MOISTURE DETERMINATION

Pan ID	Sample Weight (g)	Tare Weight (g)		IN: 02/08/22	OUT: 02/09/22	Moisture Content (%)
2	513.63	1233.26	Time	14:10	7:15	11.84%
			Mass	1746.89	1692.50	

Start Time (mil):	End Time (mil):		First Cycle (I_{d1})					
7:20	7:30		Drum ID	Tare Weight (g)		IN: 2/9/22	OUT: 02/09/22	Final Dry Mass (g)
Start Temp (ºC):	End Temp (ºC):	Avg. Temp (ºC)	2	1233.26	Time	7:40	11:20	
20.1	21.4	20.75			Mass	1602.11	1564.41	331.15

Start Time (mil):	End Time (mil):		Second Cycle (Id2)					
12:40	12:50		Drum ID	Tare Weight (g)		IN: 2/9/22	OUT: 2/10/22	Final Dry Mass (g)
Start Temp (ºC):	End Temp (ºC):	Avg. Temp (ºC)	2	1233.26	Time	12:55	7:30	
18.3	18.4	18.35			Mass	1450.07	1423.49	190.23

Before First Cycle

After Second Cycle

Slake Durability Index

$I_{d2}=\{(W_F-C)/(B-C)\}*100$

I_{d2} = 41.4%

Retained Material Type: II (Reference Below)

WF = Drum mass + oven dried specimum after second cycle; B = Drum mass + specimen prior to test; C = Drum mass

From ASTM D4644

T 1 — Retained pieces remain virtually unchanged

T 2 — Retained material consists of large and small pieces

T 3 — Retained material is exclusively small pieces

GEOTECHNICAL PROFILE -RETAINING WALL
LABORATORY TEST DATA

DESIGN AGENCY
Stantec
10200 Alliance Road, Suite 300
Cincinnati, OH 45242
(513) 842-8200

DESIGNER MSJ

REVIEWER EMK 11/22/24

PROJECT ID 116204

SUBSET 7 TOTAL 7

SHEET P.39 TOTAL 39

BUT-126-2.92

APPENDIX B
BEARING CAPACITY ANALYSES

Undrained

cohesion (c)=	from HPs	2500	psf
friction angle=		0	degrees
γf=	115		pcf
γq=	116		pcf
Nc=	5.14	Cwq=	1
Nq=	1	Cwγ=	0.5
Nγ=	0		

Shape factors

Bearing width (B)	12	ft
Bearing length (L)	45.5	ft
Bearing Depth (D)	10	ft
Sc=	1.0527473	
Sq=	1	
Sγ=	1	
Ncm=	5.4111209	
Nqm=	1	
Nγm=	0	
qn=	14687.802	psf

Resistance factor (2020 LRFD Table 10.5.5.2.2-1):
0.5 for footings in clay

qr=	7343.9011	psf
	7.3	ksf

key

- lookup from within sheet
- pull from bearing design
- pull from logs/testing
- in sheet calculation
- from ODOT lookup
- results

Drained

cohesion (c)=		300	psf
friction angle=		30	degrees
γf=	115		pcf
γq=	116		pcf
Nc=	30.1	Cwq=	1
Nq=	18.4	Cwγ=	0.5
Nγ=	22.4		

Shape factors

Bearing width (B)	12	ft
Bearing length (L)	45.5	ft
Bearing Depth (D)	10	ft
Sc=	1.161221	
Sq=	1.152268	
Sγ=	0.894505	
Ncm=	34.95275	
Nqm=	21.20173	
Nγm=	20.03692	
qn=	41992.58	psf

Resistance factor (2020 LRFD Table 10.5.5.2.2-1):
0.5 for footings in clay

qr=	20996.29	psf
	21.0	ksf

Bearing Capacity by AASHTO 2020 LRFD 10.6.3.1.2a

$$q_n = cN_{cm} + \gamma_q D_f N_{qm} C_{wq} + 0.5\gamma_f B N_{\gamma m} C_{w\gamma} \quad (10.6.3.1.2a\text{-}1)$$

in which:

$$N_{cm} = N_c s_c i_c \quad (10.6.3.1.2a\text{-}2)$$

$$N_{qm} = N_q s_q d_q i_q \quad (10.6.3.1.2a\text{-}3)$$

$$N_\gamma m = N_\gamma s_\gamma i_\gamma \quad (10.6.3.1.2a\text{-}4)$$

Assume load inclination factors are equal to 1.0, based on commentary in Section 10.3.1.2a.

Assume depth correction factor, d_q, is 1.0 based on Section 10.6.3.1.2a.

Table 10.6.3.1.2a-1—Bearing Capacity Factors N_c (Prandtl, 1921), N_q (Reissner, 1924), and N_γ (Vesic, 1975)

ϕ_f	N_c	N_q	N_γ	ϕ_f	N_c	N_q	N_γ
0	5.14	1.0	0.0	23	18.1	8.7	8.2
1	5.4	1.1	0.1	24	19.3	9.6	9.4
2	5.6	1.2	0.2	25	20.7	10.7	10.9
3	5.9	1.3	0.2	26	22.3	11.9	12.5
4	6.2	1.4	0.3	27	23.9	13.2	14.5
5	6.5	1.6	0.5	28	25.8	14.7	16.7
6	6.8	1.7	0.6	29	27.9	16.4	19.3
7	7.2	1.9	0.7	30	30.1	18.4	22.4
8	7.5	2.1	0.9	31	32.7	20.6	26.0
9	7.9	2.3	1.0	32	35.5	23.2	30.2
10	8.4	2.5	1.2	33	38.6	26.1	35.2
11	8.8	2.7	1.4	34	42.2	29.4	41.1
12	9.3	3.0	1.7	35	46.1	33.3	48.0
13	9.8	3.3	2.0	36	50.6	37.8	56.3
14	10.4	3.6	2.3	37	55.6	42.9	66.2
15	11.0	3.9	2.7	38	61.4	48.9	78.0
16	11.6	4.3	3.1	39	67.9	56.0	92.3
17	12.3	4.8	3.5	40	75.3	64.2	109.4
18	13.1	5.3	4.1	41	83.9	73.9	130.2
19	13.9	5.8	4.7	42	93.7	85.4	155.6
20	14.8	6.4	5.4	43	105.1	99.0	186.5
21	15.8	7.1	6.2	44	118.4	115.3	224.6
22	16.9	7.8	7.1	45	133.9	134.9	271.8

Table 10.6.3.1.2a-2—Coefficients C_{wq} and $C_{w\gamma}$ for Various Groundwater Depths

D_w	C_{wq}	$C_{w\gamma}$
0.0	0.5	0.5
D_f	1.0	0.5
$>1.5B + D_f$	1.0	1.0

Assume footing is below ground water depth

Table 10.6.3.1.2a-3—Shape Correction Factors s_c, s_γ, s_q

Factor	Friction Angle	Cohesion Term (s_c)	Unit Weight Term (s_γ)	Surcharge Term (s_q)
Shape Factors s_c, s_γ, s_q	$\phi_f = 0$	$1 + \left(\frac{B}{5L}\right)$	1.0	1.0
	$\phi_f > 0$	$1 + \left(\frac{B}{L}\right)\left(\frac{N_q}{N_c}\right)$	$1 - 0.4\left(\frac{B}{L}\right)$	$1 + \left(\frac{B}{L}\tan\phi_f\right)$

Performed by: J. Samples 6/12/2024
Reviewed by: E. Kistner 6/20/2024

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BUT-126-2.92 RMR DETERMINATION FOR BEDROCK BEARING CAPACITY

BEDROCK CONDITIONS

According to B-001-0-22 and B-002-0-22, bedrock at the project site is described as highly weathered interbedded shale and limestone. Ratio of the bedrock ranged from 47 to 64 percent shale and 36 to 53 percent limestone. Four unconfined compression strength tests were completed on this bedrock, two shale samples and two limestone. From laboratory data provided by ODOT, the typical unconfined compressive strength (q_u) of rock at the site is:

$q_{u\,sh\,ale} = 50\ and\ 90\ psi \rightarrow average\ 70\ psi$

$q_{u\,li\,mestone} = 7{,}724\ and\ 12{,}468\ psi \rightarrow average\ 10{,}096\ psi$

The retaining wall will only bear on bedrock in the portion of the alignment with only B-001-0-22. A weighted average using the interbedded shale and limestone ratio of 64 to 36 at B-001-0-22 was used to determine typical compressive strength of the bedrock unit:

$q_{u,typical} = (.64 * 70\ psi) + (.36 * 10{,}096\ psi) = 3{,}679.4\ psi$
$\rightarrow 530\ ksf\ lower\ to\ 520\ ksf\ due\ to\ shale\ content\ and\ to\ use\ more\ conservative\ RMR\ strength\ value$

Average unit weight of shale samples is 146 pounds per cubic foot (pcf) and the average unit weight of limestone samples is 168 pcf. For analysis, a conservative value of 150 pcf was used due to the fracturing and weathering of bedrock observed.

According to the Ohio Department of Transportation (ODOT) Geotechnical Design Manual (GDM) section 1303.3.3, bearing capacity on bedrock can be estimated using the rock mass rating (RMR) of the bedrock unit.

Calculated by: J. Samples 6/12/2024
Reviewed by: E. Kistner 6/20/2024

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ROCK MASS RATING

From the 2012 AASHTO LRFD Bridge Design Specifications (table not available in 2020 AASHTO LRFD):

Table 10.4.6.4-1—Geomechanics Classification of Rock Masses

Parameter			Ranges of Values						
1	Strength of intact rock material	Point load strength index	>175 ksf	85–175 ksf	45–85 ksf	20–45 ksf	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength	>4320 ksf	2160–4320 ksf	1080–2160 ksf	520–1080 ksf	215–520 ksf	70–215 ksf	20–70 ksf
	Relative Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90% to 100%	75% to 90%		50% to 75%		25% to 50%	<25%
	Relative Rating		20	17		13		8	3
3	Spacing of joints		>10 ft	3–10 ft		1–3 ft		2 in.–1 ft	<2 in.
	Relative Rating		30	25		20		10	5
4	Condition of joints		• Very rough surfaces • Not continuous • No separation • Hard joint wall rock	• Slightly rough surfaces • Separation <0.05 in. • Hard joint wall rock		• Slightly rough surfaces • Separation <0.05 in. • Soft joint wall rock		• Slicken-sided surfaces or • Gouge <0.2 in. thick or • Joints open 0.05–0.2 in. • Continuous joints	• Soft gouge >0.2 in. thick or • Joints open >0.2 in. • Continuous joints
	Relative Rating		25	20		12		6	0
5	Groundwater conditions (use one of the three evaluation criteria as appropriate to the method of exploration)	Inflow per 30 ft tunnel length	None	<400 gal./hr.		400–2000 gal./hr.		>2000 gal./hr.	
		Ratio = joint water pressure/ major principal stress	0	0.0–0.2		0.2–0.5		>0.5	
		General Conditions	Completely Dry	Moist only (interstitial water)		Water under moderate pressure		Severe water problems	
	Relative Rating		10	7		4		0	

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Reviewed by: E. Kistner 6/20/2024

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Based on Table 10.4.6.4-1 and the assumptions listed below, the RMR is estimated to be 44.

- Unconfined Compressive Strength: 520 ksf
- RQD from boring logs ranges between 33 and 78 percent, average of 56 percent
- Spacing of the joints is between one foot and two inches
- Condition of the joints is slightly rough with soft joint wall rock
- Bedrock is moist only

Based on an RMR of 44, the bedrock can be described as Class No. III, Fair Rock according to Table 10.4.6.4-3 of the 2012 AASHTO LRFD Bridge Design Specifications:

Table 10.4.6.4-3—Geomechanics Rock Mass Classes Determined from Total Ratings

RMR Rating	100–81	80–61	60–41	40–21	<20
Class No.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

Calculated by: J. Samples 6/12/2024
Reviewed by: E. Kistner 6/20/2024

RMR	44	sum of relative ratings	
cohesion (c)=	104*RMR	4576	psf
friction angle=	5+(RMR/2)	27	degrees
γf=	150	pcf	
γq=	116	pcf	
Nc=	23.9	Cwq=	0.5
Nq=	13.2	Cwγ=	0.5
Nγ=	14.5		

Shape factors

Bearing width (B)	12	ft
Bearing length (L)	45.5	ft
Bearing Depth (D)	10	ft
Sc=	1.14566187	
Sq=	1.134380338	
Sγ=	0.894505495	
Ncm=	27.38131868	
Nqm=	14.97382047	
Nγm=	12.97032967	
qn=	139818.3785	psf

Resistance factor (2020 LRFD Table 10.5.5.2.2-1):

0.45 for footings on rock

qr=	62918.27033	psf
	62.9	ksf

key

- lookup from within sheet
- pull from bearing design
- pull from logs/testing
- in sheet calculation
- from ODOT lookup
- results

Bearing Capacity by AASHTO 2020 LRFD 10.6.3.1.2a

$$q_n = cN_{cm} + \gamma_q D_f N_{qm} C_{wq} + 0.5\gamma_f B N_{\gamma m} C_{w\gamma} \quad (10.6.3.1.2a\text{-}1)$$

in which:

$$N_{cm} = N_c s_c i_c \quad (10.6.3.1.2a\text{-}2)$$

$$N_{qm} = N_q s_q d_q i_q \quad (10.6.3.1.2a\text{-}3)$$

$$N_\gamma m = N_\gamma s_\gamma i_\gamma \quad (10.6.3.1.2a\text{-}4)$$

Assume load inclination factors are equal to 1.0, based on commentary in Section 10.3.1.2a.

Assume depth correction factor, d_q, is 1.0 based on Section 10.6.3.1.2a.

Table 10.6.3.1.2a-1—Bearing Capacity Factors N_c (Prandtl, 1921), N_q (Reissner, 1924), and N_γ (Vesic, 1975)

ϕ_f	N_c	N_q	N_γ	ϕ_f	N_c	N_q	N_γ
0	5.14	1.0	0.0	23	18.1	8.7	8.2
1	5.4	1.1	0.1	24	19.3	9.6	9.4
2	5.6	1.2	0.2	25	20.7	10.7	10.9
3	5.9	1.3	0.2	26	22.3	11.9	12.5
4	6.2	1.4	0.3	27	23.9	13.2	14.5
5	6.5	1.6	0.5	28	25.8	14.7	16.7
6	6.8	1.7	0.6	29	27.9	16.4	19.3
7	7.2	1.9	0.7	30	30.1	18.4	22.4
8	7.5	2.1	0.9	31	32.7	20.6	26.0
9	7.9	2.3	1.0	32	35.5	23.2	30.2
10	8.4	2.5	1.2	33	38.6	26.1	35.2
11	8.8	2.7	1.4	34	42.2	29.4	41.1
12	9.3	3.0	1.7	35	46.1	33.3	48.0
13	9.8	3.3	2.0	36	50.6	37.8	56.3
14	10.4	3.6	2.3	37	55.6	42.9	66.2
15	11.0	3.9	2.7	38	61.4	48.9	78.0
16	11.6	4.3	3.1	39	67.9	56.0	92.3
17	12.3	4.8	3.5	40	75.3	64.2	109.4
18	13.1	5.3	4.1	41	83.9	73.9	130.2
19	13.9	5.8	4.7	42	93.7	85.4	155.6
20	14.8	6.4	5.4	43	105.1	99.0	186.5
21	15.8	7.1	6.2	44	118.4	115.3	224.6
22	16.9	7.8	7.1	45	133.9	134.9	271.8

Table 10.6.3.1.2a-2—Coefficients C_{wq} and $C_{w\gamma}$ for Various Groundwater Depths

D_w	C_{wq}	$C_{w\gamma}$
0.0	0.5	0.5
D_f	1.0	0.5
$>1.5B + D_f$	1.0	1.0

Assume groundwater will be at or near the depth of the foundation.

Table 10.6.3.1.2a-3—Shape Correction Factors s_c, s_γ, s_q

Factor	Friction Angle	Cohesion Term (s_c)	Unit Weight Term (s_γ)	Surcharge Term (s_q)
Shape Factors s_c, s_γ, s_q	$\phi_f = 0$	$1 + \left(\frac{B}{5L}\right)$	1.0	1.0
	$\phi_f > 0$	$1 + \left(\frac{B}{L}\right)\left(\frac{N_q}{N_c}\right)$	$1 - 0.4\left(\frac{B}{L}\right)$	$1 + \left(\frac{B}{L}\tan\phi_f\right)$

Performed by: J. Samples 6/12/2024
Reviewed by: E. Kistner 6/20/2024

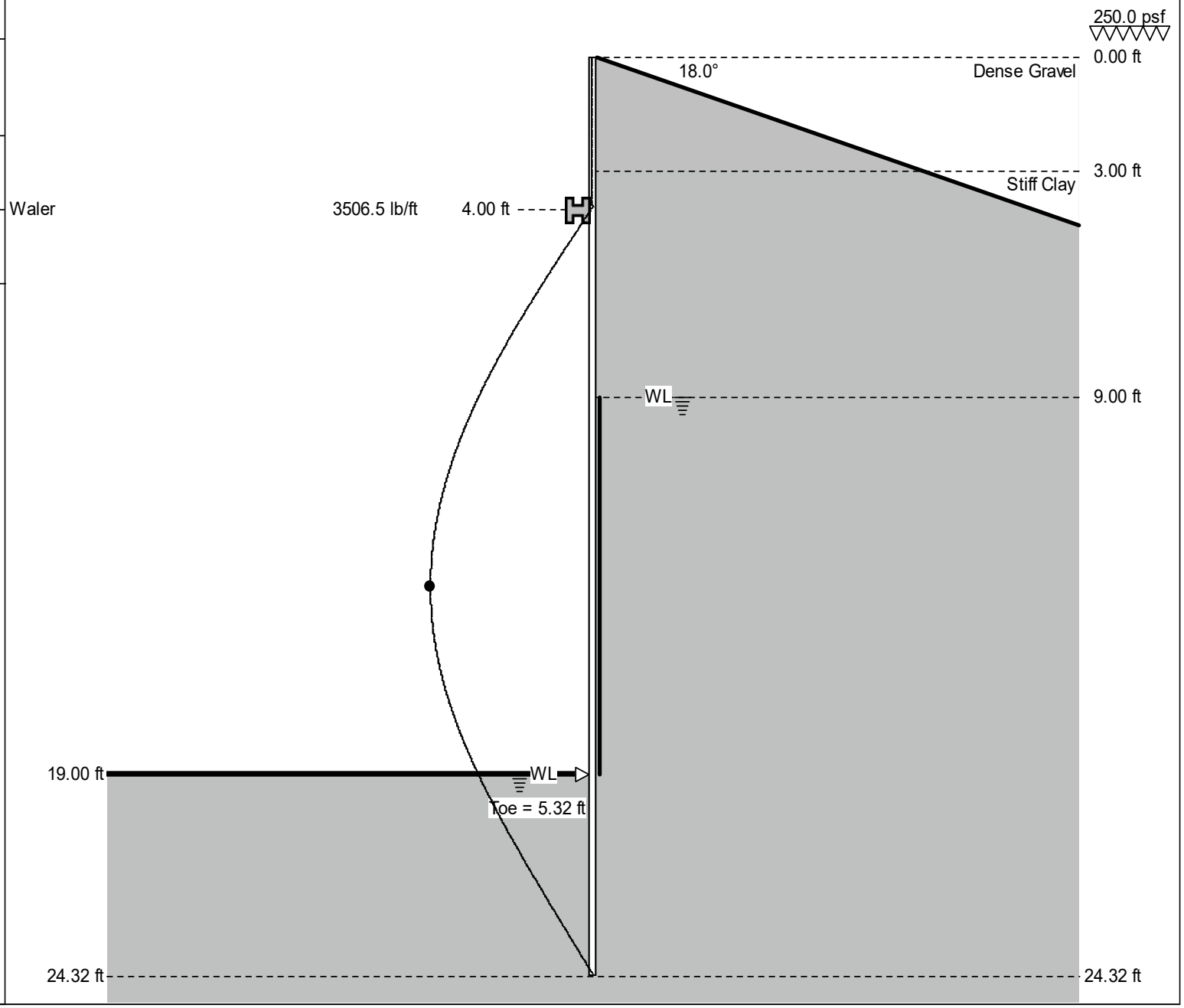
APPENDIX C
SPW 911 ANALYSES

Client: Ohio Deparment of Transportation
Site: BUT-126-2.92
Attn: Casey Carriere

Title: BUT-126-2.90 Retaining Wall
Designer: James Samples
Ref: Stantec
Date: 11.20.24

Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.

Maximum	d (ft)
● 0.1 in	14.04



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SPW911, v2.40

Client: Ohio Deparment of Transportation
Site: BUT-126-2.92
Attn: Casey Carriere

Title: BUT-126-2.90 Retaining Wall
Designer: James Samples
Ref: Stantec
Date: 11.20.24

Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.

Input Data

Depth Of Excavation = 19.00 ft Depth Of Active Water = 9.00 ft Water Density = 62.43 pcf
Surcharge = 250.0 psf Depth Of Passive Water = 19.00 ft Minimum Fluid Density = 31.82 pcf
Slope (active) = -18.0 degrees

Soil Profile — Active Side

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Dense Gravel	135.00	72.60	0.0	0.0	36.0	0.0	0.22	0.00	4.64	0.00
3.00	Stiff Clay	125.00	62.60	300.0	0.0	30.0	0.0	0.27	1.04	3.71	3.85

Soil Profile — Passive Side

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Dense Gravel	135.00	72.60	0.0	0.0	36.0	0.0	0.26	0.00	3.85	0.00
3.00	Stiff Clay	125.00	62.60	300.0	0.0	30.0	0.0	0.33	1.15	3.00	3.46

Solution

Sheet

Sheet Name	I (in⁴/ft)	E (psi)	Z (in³/ft)	f (psi)	Maximum Bending Moment (ftlb/ft)	Upstand (ft)	Toe (ft)	Pile Length (ft)
PZ40	490.85	3.04E+07	60.70	50000.0	127556.3	0.00	5.32	24.32

Load Model: Area Distribution

Supports

Depth (ft)	Type	Linear Load (lb/ft)
4.00	Waler	3506.5

Maxima

	Maximum	Depth
Bending Moment	18525.5 ftlb/ft	14.27 ft
Deflection	0.1 in	14.04 ft
Pressure	1029.2 psf	19.00 ft
Shear Force	3815.8 lb/ft	19.01 ft

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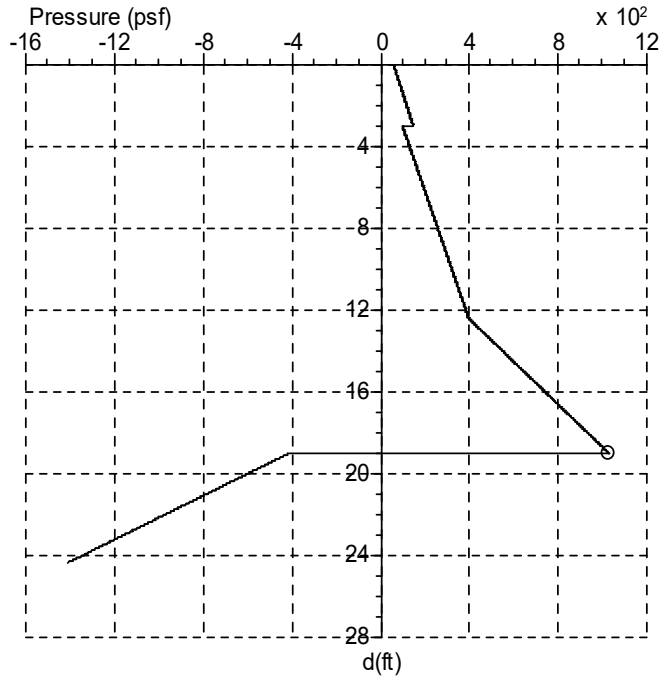
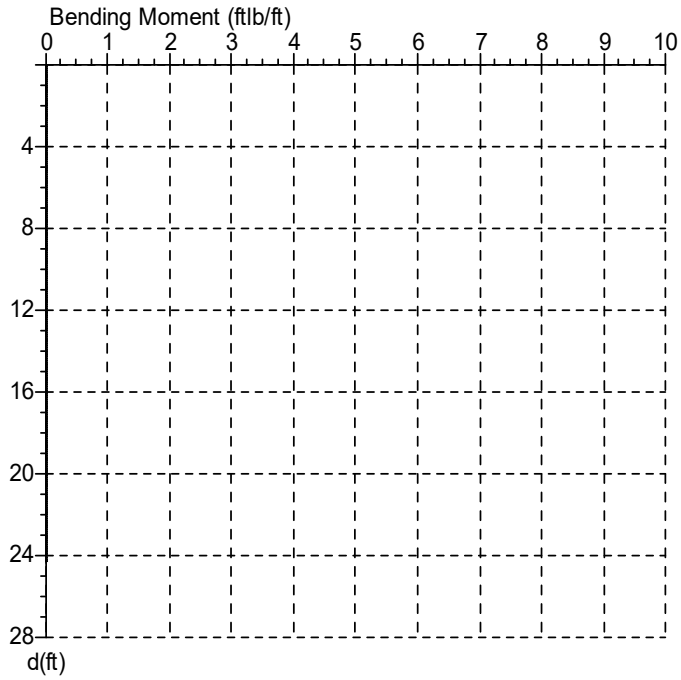
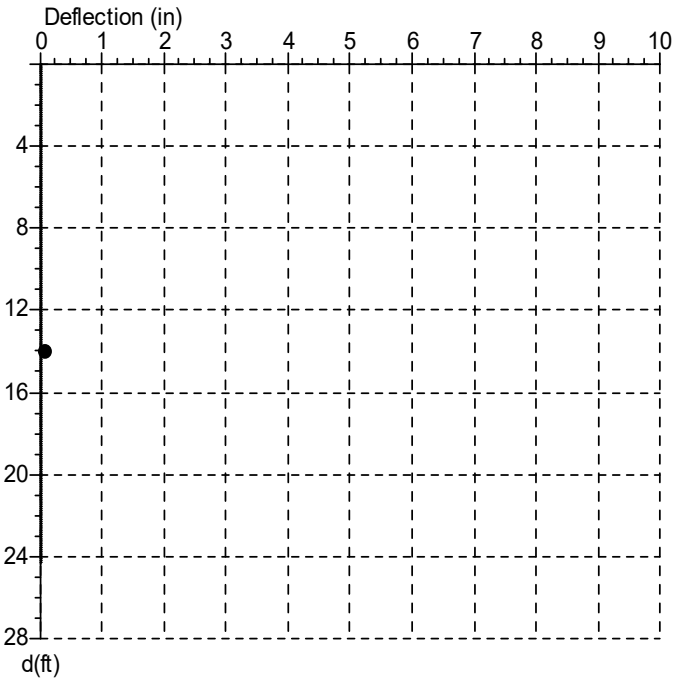
Ref: Stantec
Date: 11.20.24

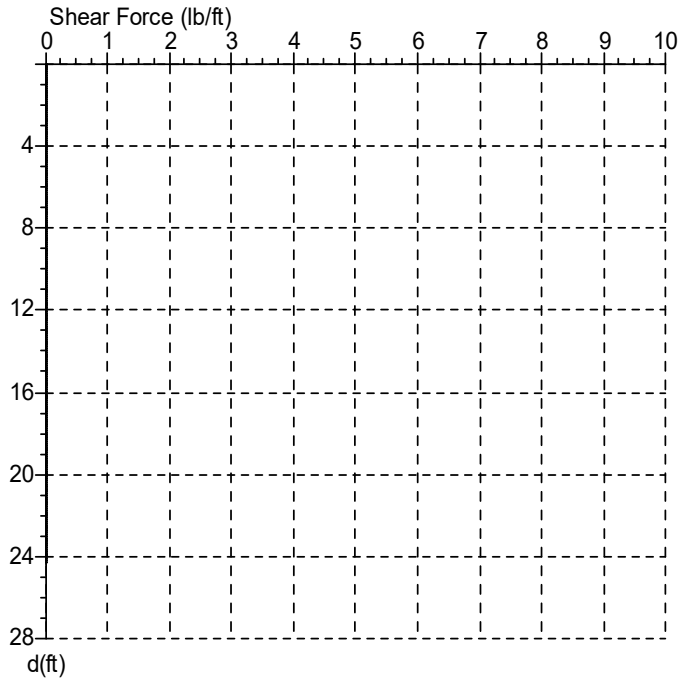
Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.

	Maximum	d (ft)
○	1029.2 psf	19.00
□	18525.5 ftlb/ft	14.27
◇	3815.8 lb/ft	19.01
●	0.1 in	14.04









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Designer: James Samples
Ref: Stantec
Date: 11.20.24

Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
0.00	55.0	0.0	0.0	0.0	8.18	260.7	0.0	0.0	0.0	16.36	774.8	0.0	0.0	0.0
0.22	61.6	0.0	0.0	0.0	8.39	267.2	0.0	0.0	0.0	16.57	796.2	0.0	0.0	0.0
0.43	67.6	0.0	0.0	0.0	8.61	274.3	0.0	0.0	0.0	16.79	815.7	0.0	0.0	0.0
0.65	74.3	0.0	0.0	0.0	8.82	280.7	0.0	0.0	0.0	17.00	837.1	0.0	0.0	0.0
0.86	80.3	0.0	0.0	0.0	9.04	287.8	0.0	0.0	0.0	17.22	858.6	0.0	0.0	0.0
1.08	86.9	0.0	0.0	0.0	9.25	294.9	0.0	0.0	0.0	17.43	878.0	0.0	0.0	0.0
1.29	93.5	0.0	0.0	0.0	9.47	301.4	0.0	0.0	0.0	17.65	899.5	0.0	0.0	0.0
1.51	99.5	0.0	0.0	0.0	9.68	308.5	0.0	0.0	0.0	17.86	919.0	0.0	0.0	0.0
1.72	106.2	0.0	0.0	0.0	9.90	314.9	0.0	0.0	0.0	18.08	940.4	0.0	0.0	0.0
1.94	112.8	0.0	0.0	0.0	10.11	322.0	0.0	0.0	0.0	18.29	961.9	0.0	0.0	0.0
2.15	118.8	0.0	0.0	0.0	10.33	329.1	0.0	0.0	0.0	18.51	981.3	0.0	0.0	0.0
2.37	125.4	0.0	0.0	0.0	10.55	335.6	0.0	0.0	0.0	18.72	1002.8	0.0	0.0	0.0
2.58	131.4	0.0	0.0	0.0	10.76	342.7	0.0	0.0	0.0	18.94	1024.2	0.0	0.0	0.0
2.80	138.1	0.0	0.0	0.0	10.98	349.8	0.0	0.0	0.0	19.15	-446.7	0.0	0.0	0.0
3.01	96.1	0.0	0.0	0.0	11.19	356.2	0.0	0.0	0.0	19.37	-488.4	0.0	0.0	0.0
3.23	102.6	0.0	0.0	0.0	11.41	363.3	0.0	0.0	0.0	19.58	-526.2	0.0	0.0	0.0
3.44	109.7	0.0	0.0	0.0	11.62	369.8	0.0	0.0	0.0	19.80	-567.9	0.0	0.0	0.0
3.66	116.8	0.0	0.0	0.0	11.84	376.9	0.0	0.0	0.0	20.01	-609.6	0.0	0.0	0.0
3.87	123.3	0.0	0.0	0.0	12.05	384.0	0.0	0.0	0.0	20.23	-647.4	0.0	0.0	0.0
4.09	130.4	0.0	0.0	0.0	12.27	390.5	0.0	0.0	0.0	20.44	-689.1	0.0	0.0	0.0
4.30	136.8	0.0	0.0	0.0	12.48	402.5	0.0	0.0	0.0	20.66	-727.0	0.0	0.0	0.0
4.52	143.9	0.0	0.0	0.0	12.70	423.9	0.0	0.0	0.0	20.87	-768.6	0.0	0.0	0.0
4.73	151.0	0.0	0.0	0.0	12.91	443.4	0.0	0.0	0.0	21.09	-810.3	0.0	0.0	0.0
4.95	157.5	0.0	0.0	0.0	13.13	464.9	0.0	0.0	0.0	21.31	-848.2	0.0	0.0	0.0
5.16	164.6	0.0	0.0	0.0	13.34	484.4	0.0	0.0	0.0	21.52	-889.8	0.0	0.0	0.0
5.38	171.0	0.0	0.0	0.0	13.56	505.8	0.0	0.0	0.0	21.74	-931.5	0.0	0.0	0.0
5.60	178.1	0.0	0.0	0.0	13.77	527.2	0.0	0.0	0.0	21.95	-969.4	0.0	0.0	0.0
5.81	185.2	0.0	0.0	0.0	13.99	546.7	0.0	0.0	0.0	22.17	-1011.0	0.0	0.0	0.0
6.03	191.7	0.0	0.0	0.0	14.20	568.2	0.0	0.0	0.0	22.38	-1048.9	0.0	0.0	0.0
6.24	198.8	0.0	0.0	0.0	14.42	589.6	0.0	0.0	0.0	22.60	-1090.6	0.0	0.0	0.0
6.46	205.9	0.0	0.0	0.0	14.63	609.1	0.0	0.0	0.0	22.81	-1132.2	0.0	0.0	0.0
6.67	212.3	0.0	0.0	0.0	14.85	630.5	0.0	0.0	0.0	23.03	-1170.1	0.0	0.0	0.0
6.89	219.4	0.0	0.0	0.0	15.06	650.0	0.0	0.0	0.0	23.24	-1211.8	0.0	0.0	0.0
7.10	225.9	0.0	0.0	0.0	15.28	671.5	0.0	0.0	0.0	23.46	-1253.4	0.0	0.0	0.0
7.32	233.0	0.0	0.0	0.0	15.49	692.9	0.0	0.0	0.0	23.67	-1291.3	0.0	0.0	0.0
7.53	240.1	0.0	0.0	0.0	15.71	712.4	0.0	0.0	0.0	23.89	-1333.0	0.0	0.0	0.0
7.75	246.5	0.0	0.0	0.0	15.93	733.8	0.0	0.0	0.0	24.10	-1370.8	0.0	0.0	0.0
7.96	253.6	0.0	0.0	0.0	16.14	753.3	0.0	0.0	0.0	24.32	-1412.5	0.0	0.0	0.0

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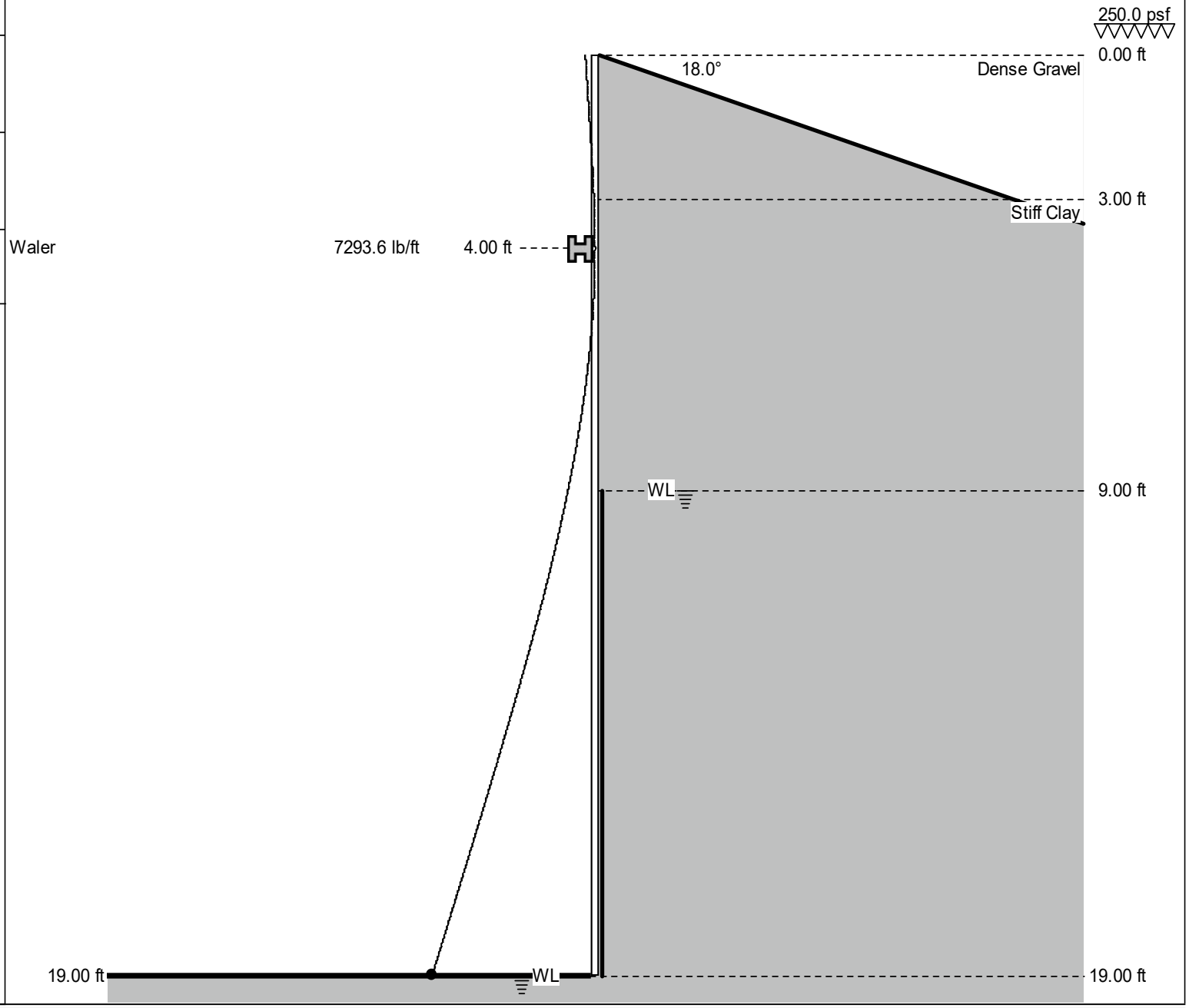
SPW911, v2.40

Client: Ohio Deparment of Transportation
Site: BUT-126-2.92
Attn: Casey Carriere

Title: BUT-126-2.90 Retaining Wall
Designer: James Samples
Ref: Stantec
Date: 11.20.24

Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.
Toe: No Earth Support

Maximum	d (ft)
● 0.5 in	18.98



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Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.
Toe: No Earth Support

Input Data

Depth Of Excavation = 19.00 ft Depth Of Active Water = 9.00 ft Water Density = 62.43 pcf
Surcharge = 250.0 psf Depth Of Passive Water = 19.00 ft Minimum Fluid Density = 31.82 pcf
Slope (active) = -18.0 degrees

Soil Profile — Active Side

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Dense Gravel	135.00	72.60	0.0	0.0	36.0	0.0	0.22	0.00	4.64	0.00
3.00	Stiff Clay	125.00	62.60	300.0	0.0	30.0	0.0	0.27	1.04	3.71	3.85

Soil Profile — Passive Side

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Dense Gravel	135.00	72.60	0.0	0.0	36.0	0.0	0.26	0.00	3.85	0.00
3.00	Stiff Clay	125.00	62.60	300.0	0.0	30.0	0.0	0.33	1.15	3.00	3.46

Solution

Sheet

Sheet Name	I (in⁴/ft)	E (psi)	Z (in³/ft)	f (psi)	Maximum Bending Moment (ftlb/ft)	Upstand (ft)	Toe (ft)	Pile Length (ft)
PZ40	490.85	3.04E+07	60.70	50000.0	127556.3	0.00	0.00	19.00

Load Model: Area Distribution (Hinge Method used for Shear Force, Bending Moment and Deflection)

Supports

Depth (ft)	Type	Linear Load (lb/ft)
4.00	Waler	7293.6

Maxima

	Maximum	Depth
Bending Moment	67876.6 ftlb/ft	4.00 ft
Deflection	0.5 in	18.98 ft
Pressure	1029.2 psf	19.00 ft
Shear Force	6881.3 lb/ft	4.00 ft

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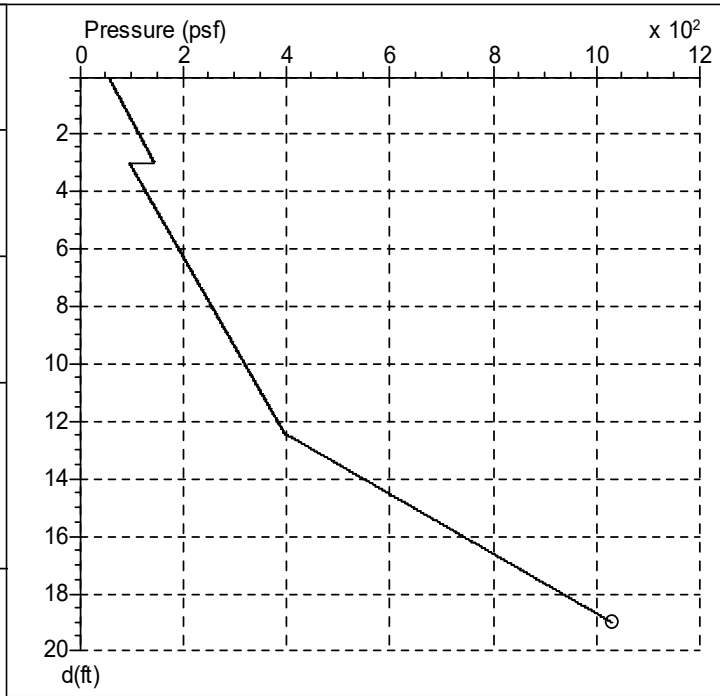
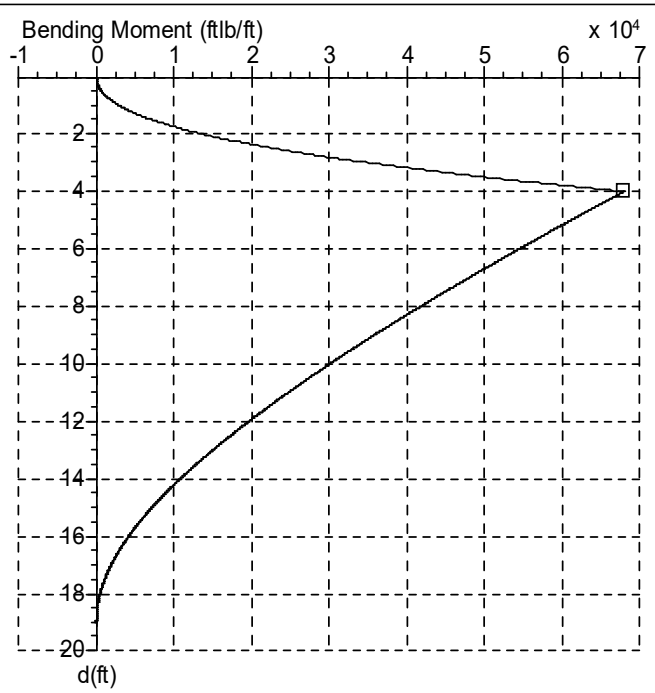
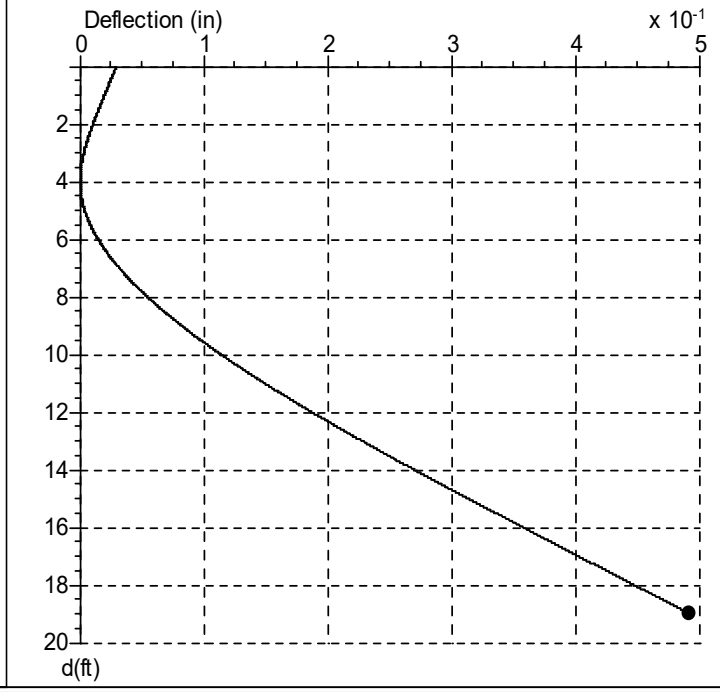
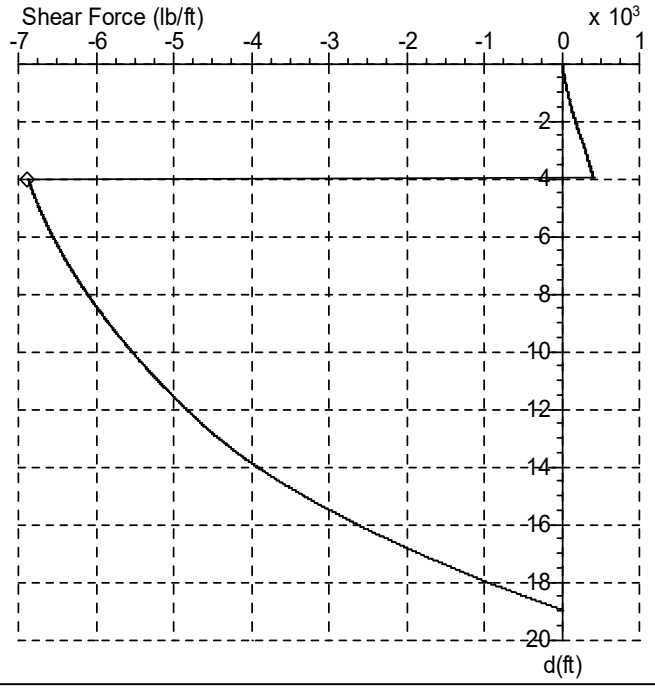
	Maximum	d (ft)
○	1029.2 psf	19.00
□	67876.6 ftlb/ft	4.00
◇	6881.3 lb/ft	4.00
●	0.5 in	18.98









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Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.
Toe: No Earth Support

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
0.00	55.0	0.2	0.0	0.0	6.39	203.7	51859.3	0.0	-6484.7	12.78	430.9	15997.7	0.2	-4530.3
0.17	60.2	73.4	0.0	10.1	6.56	208.8	50834.9	0.0	-6452.0	12.95	447.7	15214.8	0.2	-4453.6
0.34	64.9	287.4	0.0	20.0	6.73	214.3	49714.1	0.0	-6415.1	13.12	462.9	14514.7	0.2	-4381.4
0.50	70.0	698.6	0.0	31.9	6.89	219.3	48700.8	0.0	-6380.7	13.28	479.7	13758.1	0.2	-4299.2
0.67	74.8	1244.2	0.0	43.4	7.06	224.9	47592.5	0.0	-6342.0	13.45	496.4	13016.0	0.2	-4214.1
0.84	79.9	2046.7	0.0	56.9	7.23	230.4	46491.1	0.0	-6302.3	13.62	511.6	12354.4	0.3	-4134.2
1.01	85.1	3075.6	0.0	71.4	7.40	235.5	45495.8	0.0	-6265.4	13.79	528.4	11641.5	0.3	-4043.5
1.18	89.8	4219.7	0.0	85.3	7.57	241.0	44407.9	0.0	-6223.9	13.96	543.6	11007.3	0.3	-3958.5
1.35	95.0	5721.3	0.0	101.4	7.73	246.1	43425.2	0.0	-6185.3	14.12	560.3	10325.5	0.3	-3862.2
1.51	100.1	7491.8	0.0	118.5	7.90	251.6	42351.3	0.1	-6141.9	14.29	577.1	9660.6	0.3	-3763.0
1.68	104.8	9347.1	0.0	134.8	8.07	257.2	41285.1	0.1	-6097.5	14.46	592.3	9071.4	0.3	-3670.3
1.85	110.0	11671.7	0.0	153.6	8.24	262.2	40322.6	0.1	-6056.4	14.63	609.0	8440.4	0.3	-3565.6
2.02	114.7	14054.9	0.0	171.5	8.41	267.8	39271.4	0.1	-6010.2	14.80	625.8	7827.9	0.3	-3457.9
2.19	119.9	16986.9	0.0	192.0	8.58	273.3	38228.4	0.1	-5963.0	14.96	641.0	7287.5	0.3	-3357.5
2.35	125.1	20258.5	0.0	213.4	8.74	278.3	37287.3	0.1	-5919.3	15.13	657.7	6711.6	0.3	-3244.3
2.52	129.8	23539.5	0.0	233.7	8.91	283.9	36260.2	0.1	-5870.3	15.30	673.0	6205.4	0.3	-3138.8
2.69	134.9	27499.9	0.0	256.8	9.08	288.9	35334.0	0.1	-5824.9	15.47	689.7	5668.1	0.3	-3020.0
2.86	140.1	31842.3	0.0	280.9	9.25	294.5	34323.5	0.1	-5774.1	15.64	706.5	5151.7	0.3	-2898.3
3.03	96.3	36132.8	0.0	302.0	9.42	300.0	33321.9	0.1	-5722.3	15.81	721.7	4700.9	0.3	-2785.1
3.19	101.9	41158.1	0.0	319.3	9.58	305.1	32419.3	0.1	-5674.3	15.97	738.4	4225.8	0.4	-2657.9
3.36	106.9	45976.5	0.0	335.9	9.75	310.6	31435.3	0.1	-5620.7	16.14	753.6	3813.4	0.4	-2539.6
3.53	112.4	51566.1	0.0	355.1	9.92	316.2	30460.7	0.1	-5566.0	16.31	770.4	3381.5	0.4	-2406.8
3.70	118.0	57474.2	0.0	375.2	10.09	321.2	29583.0	0.1	-5515.5	16.48	787.1	2973.1	0.4	-2271.0
3.87	123.0	63134.6	0.0	394.4	10.26	326.7	28626.8	0.1	-5459.1	16.65	802.4	2622.4	0.4	-2145.1
4.04	128.6	67658.7	0.0	-6877.2	10.42	331.8	27766.2	0.1	-5406.9	16.81	819.1	2260.0	0.4	-2003.7
4.20	133.6	66571.3	0.0	-6856.4	10.59	337.3	26829.1	0.1	-5348.6	16.98	835.8	1922.4	0.4	-1859.5
4.37	139.2	65379.0	0.0	-6832.6	10.76	342.9	25902.2	0.1	-5289.3	17.15	851.1	1637.4	0.4	-1725.8
4.54	144.7	64190.9	0.0	-6807.9	10.93	347.9	25068.6	0.1	-5234.6	17.32	867.8	1348.7	0.4	-1576.0
4.71	149.8	63114.7	0.0	-6784.5	11.10	353.5	24161.7	0.2	-5173.5	17.49	883.0	1109.0	0.4	-1437.3
4.88	155.3	61935.1	0.0	-6757.9	11.27	359.0	23265.6	0.2	-5111.4	17.65	899.8	870.9	0.4	-1281.9
5.04	160.9	60760.3	0.0	-6730.3	11.43	364.1	22460.4	0.2	-5054.1	17.82	916.5	660.2	0.4	-1123.6
5.21	165.9	59696.5	0.0	-6704.4	11.60	369.6	21585.2	0.2	-4990.1	17.99	931.7	492.7	0.4	-977.1
5.38	171.4	58531.1	0.0	-6675.0	11.77	374.7	20799.3	0.2	-4931.2	18.16	948.5	335.4	0.5	-813.3
5.55	176.5	57476.2	0.0	-6647.4	11.94	380.2	19945.6	0.2	-4865.4	18.33	965.2	206.9	0.5	-646.5
5.72	182.0	56320.9	0.0	-6616.2	12.11	385.7	19103.5	0.2	-4798.7	18.50	980.5	116.0	0.5	-485.2
5.88	187.6	55171.1	0.0	-6583.9	12.27	390.8	18348.1	0.2	-4737.2	18.66	997.2	45.8	0.5	-304.0
6.05	192.6	54130.8	0.0	-6553.8	12.44	399.0	17528.4	0.2	-4668.5	18.83	1012.4	9.5	0.5	-136.5
6.22	198.2	52992.1	0.0	-6519.7	12.61	414.2	16793.8	0.2	-4604.0	19.00	1029.2	0.0	0.5	0.0

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Client: Ohio Deparment of Transportation
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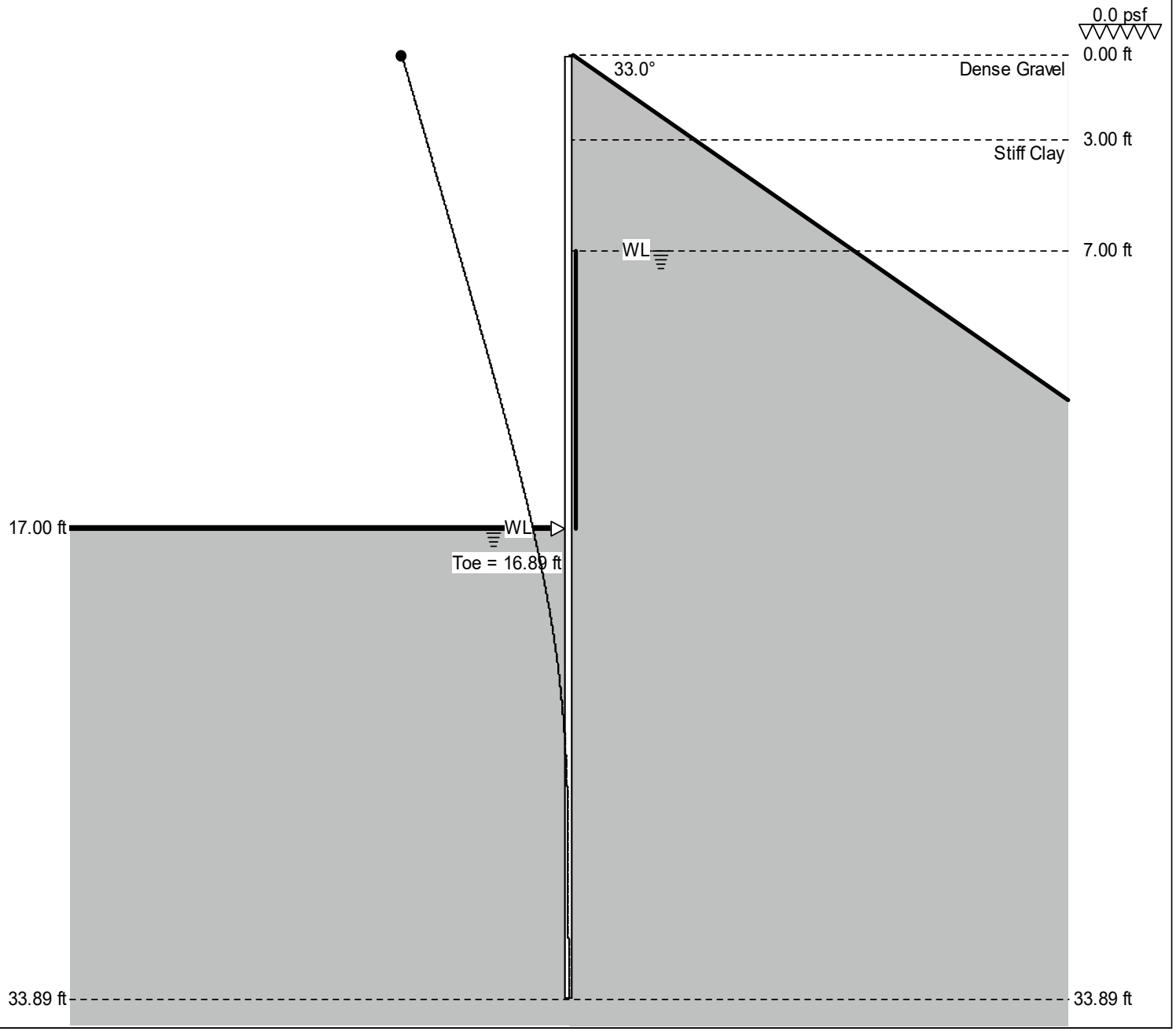
Designer: James Samples
Ref: Stantec
Date: 11.20.24

Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.
Toe: Cantilever

Maximum	d (ft)
● 1.2 in	0.00



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Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.
Toe: Cantilever

Input Data

Depth Of Excavation = 17.00 ft Depth Of Active Water = 7.00 ft Water Density = 62.43 pcf
Surcharge = 0.0 psf Depth Of Passive Water = 17.00 ft Minimum Fluid Density = 31.82 pcf
Slope (active) = -33.0 degrees

Soil Profile — Active Side

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Dense Gravel	135.00	72.60	0.0	0.0	36.0	0.0	0.16	0.00	6.26	0.00
3.00	Stiff Clay	125.00	62.60	300.0	0.0	30.0	0.0	0.20	0.88	5.13	4.53

Soil Profile — Passive Side

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Dense Gravel	135.00	72.60	0.0	0.0	36.0	0.0	0.26	0.00	3.85	0.00
3.00	Stiff Clay	125.00	62.60	300.0	0.0	30.0	0.0	0.33	1.15	3.00	3.46

Solution

Sheet

Sheet Name	I (in⁴/ft)	E (psi)	Z (in³/ft)	f (psi)	Maximum Bending Moment (ftlb/ft)	Upstand (ft)	Toe (ft)	Pile Length (ft)
PZ40	490.85	3.04E+07	60.70	50000.0	127556.3	0.00	16.89	33.89

Maxima

	Maximum	Depth
Bending Moment	42935.1 ftlb/ft	22.51 ft
Deflection	1.2 in	0.00 ft
Pressure	791.3 psf	17.00 ft
Shear Force	5130.3 lb/ft	17.00 ft

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◇	5130.3 lb/ft	17.00
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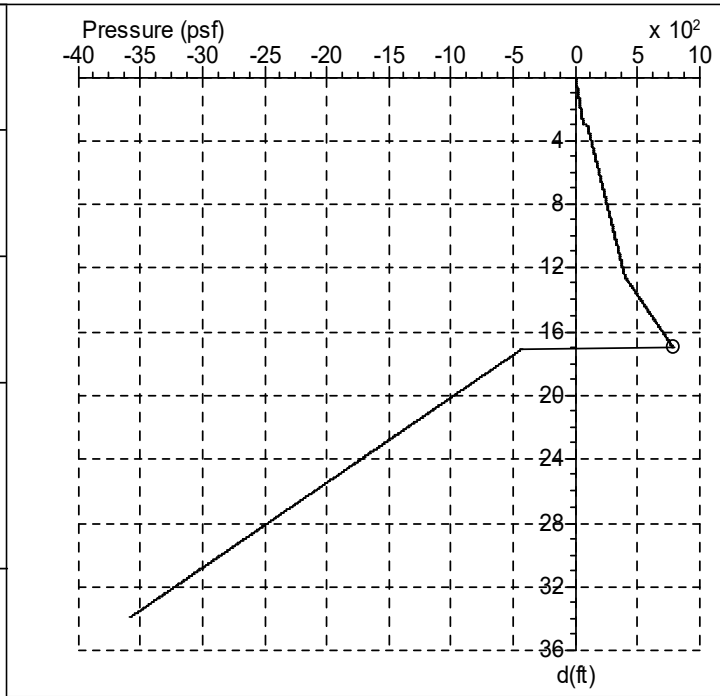

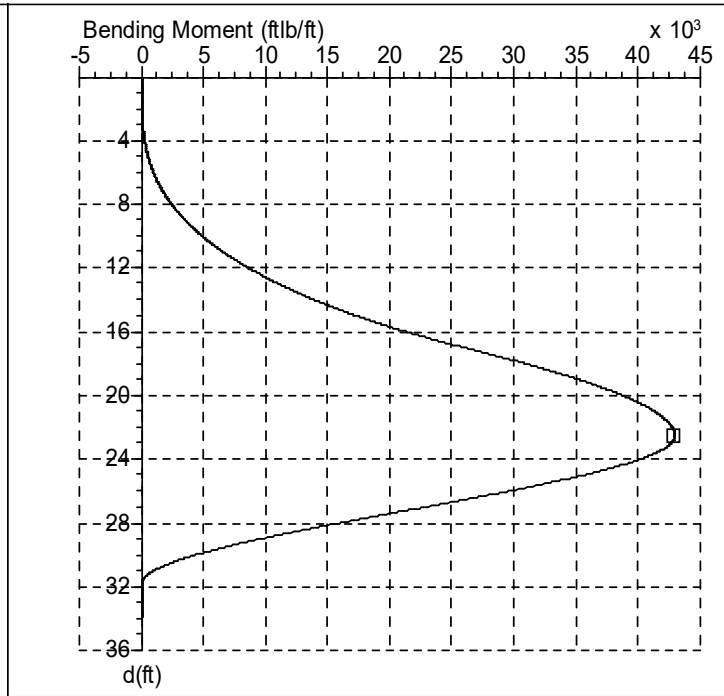

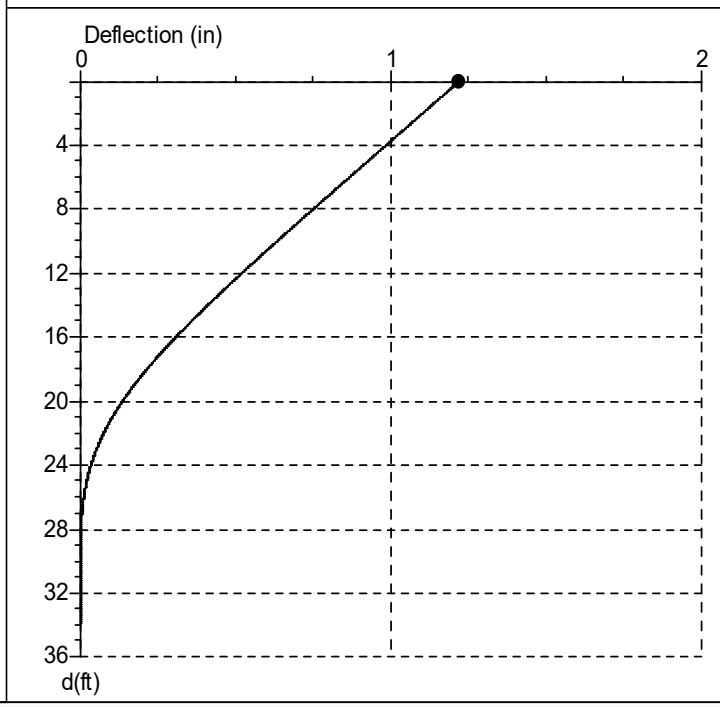

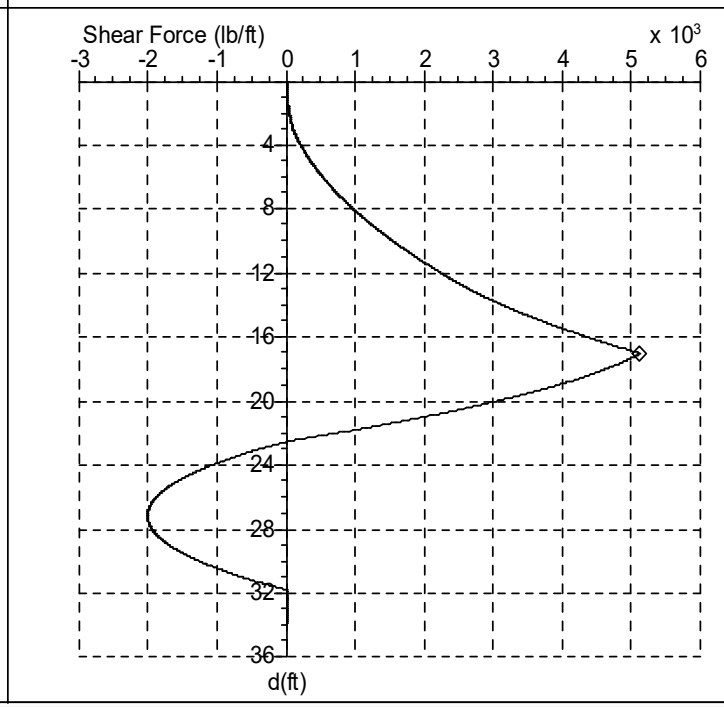

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depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
0.00	0.0	0.0	1.2	0.0	11.40	363.4	7436.9	0.6	2032.1	22.80	-1505.7	42829.5	0.1	-237.8
0.30	6.7	0.1	1.2	1.1	11.70	372.4	8022.9	0.5	2136.1	23.10	-1563.9	42453.2	0.1	-482.1
0.60	12.8	0.7	1.2	4.0	12.00	382.3	8701.9	0.5	2253.5	23.40	-1616.9	41890.7	0.0	-688.4
0.90	19.5	2.7	1.2	9.1	12.30	391.3	9351.1	0.5	2362.9	23.70	-1675.1	41047.4	0.0	-898.2
1.20	25.6	6.0	1.2	15.6	12.60	406.2	10101.2	0.5	2486.4	24.00	-1733.4	39987.6	0.0	-1089.8
1.50	32.3	12.1	1.1	24.7	12.90	433.3	10890.5	0.5	2617.2	24.30	-1786.3	38852.7	0.0	-1248.3
1.80	39.0	21.2	1.1	35.8	13.20	458.0	11644.3	0.5	2743.5	24.60	-1844.6	37433.7	0.0	-1405.4
2.10	45.1	32.8	1.1	47.8	13.50	485.2	12515.6	0.4	2890.4	24.90	-1897.5	36004.5	0.0	-1532.5
2.40	51.9	49.7	1.1	63.0	13.80	509.9	13348.3	0.4	3031.2	25.20	-1955.7	34297.1	0.0	-1655.1
2.70	58.6	71.6	1.1	80.2	14.10	537.1	14311.1	0.4	3194.2	25.50	-2014.0	32467.0	0.0	-1759.5
3.00	64.8	96.4	1.0	97.7	14.40	564.2	15325.7	0.4	3365.7	25.80	-2066.9	30713.0	0.0	-1838.8
3.30	105.2	131.1	1.0	129.0	14.70	588.9	16295.2	0.4	3528.9	26.10	-2125.2	28702.5	0.0	-1908.7
3.60	114.2	171.3	1.0	160.1	15.00	616.1	17415.9	0.4	3716.5	26.40	-2183.4	26625.6	0.0	-1960.5
3.90	124.1	226.2	1.0	197.3	15.30	643.3	18595.9	0.3	3912.5	26.70	-2236.4	24696.5	0.0	-1991.9
4.20	134.0	293.0	1.0	237.6	15.60	668.0	19722.4	0.3	4098.1	27.00	-2294.6	22547.1	0.0	-2009.2
4.50	143.0	364.9	1.0	276.8	15.90	695.1	21023.0	0.3	4310.2	27.30	-2347.6	20584.2	0.0	-2009.2
4.80	152.9	457.1	0.9	322.9	16.20	719.8	22263.5	0.3	4510.4	27.60	-2405.8	18433.2	0.0	-1991.9
5.10	162.8	564.1	0.9	372.1	16.50	747.0	23694.3	0.3	4738.6	27.90	-2464.0	16309.5	0.0	-1956.6
5.40	171.8	675.0	0.9	419.5	16.80	774.2	25197.0	0.3	4975.3	28.20	-2517.0	14419.1	0.0	-1908.7
5.70	181.7	812.8	0.9	474.6	17.10	-436.2	26624.9	0.3	5094.2	28.50	-2575.2	12401.7	0.0	-1838.8
6.00	190.7	953.2	0.9	527.3	17.40	-494.4	28185.0	0.2	4950.5	28.80	-2628.2	10640.0	0.0	-1759.6
6.30	200.6	1125.3	0.9	588.2	17.70	-552.7	29698.0	0.2	4788.7	29.10	-2686.4	8799.6	0.0	-1655.1
6.60	210.5	1316.6	0.8	652.2	18.00	-605.6	31027.8	0.2	4625.8	29.40	-2744.7	7080.3	0.0	-1532.5
6.90	219.5	1508.2	0.8	713.0	18.30	-663.9	32435.2	0.2	4429.4	29.69	-2797.6	5638.7	0.0	-1405.4
7.20	229.4	1739.1	0.8	782.9	18.60	-716.8	33659.7	0.2	4235.2	29.99	-2855.8	4204.3	0.0	-1248.3
7.50	238.4	1968.1	0.8	849.1	18.90	-775.1	34941.1	0.2	4004.3	30.29	-2914.1	2947.6	0.0	-1073.1
7.80	248.3	2242.1	0.8	924.8	19.20	-833.3	36148.3	0.2	3755.2	30.59	-2967.0	1975.5	0.0	-898.2
8.10	258.2	2539.9	0.7	1003.6	19.50	-886.2	37176.7	0.2	3513.2	30.89	-3025.3	1111.6	0.0	-688.4
8.40	267.2	2832.3	0.7	1077.9	19.80	-944.5	38226.8	0.1	3229.6	31.19	-3078.2	529.0	0.0	-482.1
8.70	277.1	3178.4	0.7	1162.6	20.10	-1002.7	39186.3	0.1	2927.9	31.49	-3136.5	128.9	0.0	-237.8
9.00	286.9	3551.3	0.7	1250.4	20.40	-1055.7	39975.4	0.1	2638.0	31.79	-3194.7	0.0	0.0	0.0
9.30	295.9	3914.2	0.7	1332.8	20.70	-1113.9	40746.6	0.1	2301.8	32.09	-3247.6	0.0	0.0	0.0
9.60	305.8	4340.7	0.7	1426.5	21.00	-1166.9	41355.1	0.1	1980.4	32.39	-3305.9	0.0	0.0	0.0
9.90	314.8	4753.9	0.6	1514.2	21.30	-1225.1	41917.5	0.1	1609.7	32.69	-3364.1	0.0	0.0	0.0
10.20	324.7	5237.5	0.6	1613.7	21.60	-1283.3	42362.3	0.1	1220.8	32.99	-3417.1	0.0	0.0	0.0
10.50	334.6	5752.4	0.6	1716.3	21.90	-1336.3	42660.0	0.1	851.6	33.29	-3475.3	0.0	0.0	0.0
10.80	343.6	6248.3	0.6	1812.2	22.20	-1394.5	42864.9	0.1	428.2	33.59	-3528.3	0.0	0.0	0.0
11.10	353.5	6825.6	0.6	1920.6	22.50	-1447.5	42934.4	0.1	27.6	33.89	-3586.5	0.0	0.0	0.0

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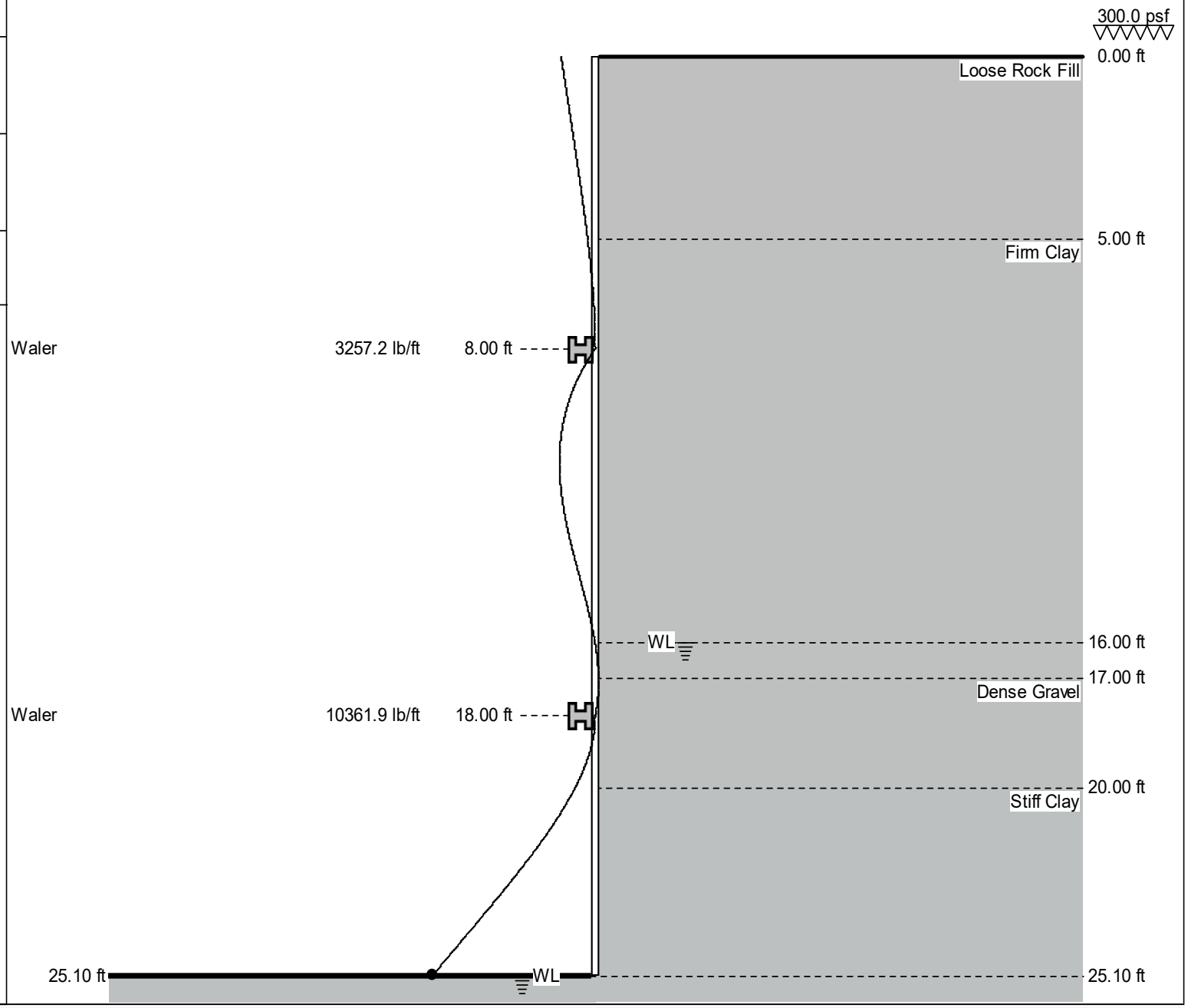
Web: www.pilebuck.com

Client: Ohio Deparment of Transportation
Site: BUT-126-2.92
Attn: Casey Carriere

Title: BUT-126-2.90 Retaining Wall
Designer: James Samples
Ref: Stantec
Date: 11.20.24

Sheet: PZ40
Pressure: Coulomb; Full hydrostatic pressure in cohesive soils.
Toe: No Earth Support

Maximum	d (ft)
● 0.0 in	25.08



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Date: 11.20.24

Sheet: PZ40
Pressure: Coulomb; Full hydrostatic pressure in cohesive soils.
Toe: No Earth Support

Input Data

Depth Of Excavation = 25.10 ft Depth Of Active Water = 16.00 ft Water Density = 62.43 pcf
Surcharge = 300.0 psf Depth Of Passive Water = 25.10 ft Minimum Fluid Density = 31.82 pcf

Soil Profile

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Loose Rock Fill	130.00	62.60	0.0	0.0	34.0	0.0	0.28	0.00	3.54	0.00
5.00	Firm Clay	125.00	62.60	200.0	0.0	28.0	0.0	0.36	1.20	2.77	3.33
17.00	Dense Gravel	135.00	72.60	0.0	0.0	36.0	0.0	0.26	0.00	3.85	0.00
20.00	Stiff Clay	125.00	62.60	300.0	0.0	30.0	0.0	0.33	1.15	3.00	3.46

Solution

Sheet

Sheet Name	I (in⁴/ft)	E (psi)	Z (in³/ft)	f (psi)	Maximum Bending Moment (ftlb/ft)	Upstand (ft)	Toe (ft)	Pile Length (ft)
PZ40	490.85	3.04E+07	60.70	50000.0	127556.3	0.00	0.00	25.10

Load Model: Area Distribution (Hinge Method used for Shear Force, Bending Moment and Deflection)

Supports

Depth (ft)	Type	Linear Load (lb/ft)
8.00	Waler	3257.2
18.00	Waler	10361.9

Maxima

	Maximum	Depth
Bending Moment	28561.2 ftlb/ft	18.00 ft
Deflection	0.0 in	25.08 ft
Pressure	1392.0 psf	25.06 ft
Shear Force	7376.5 lb/ft	18.00 ft

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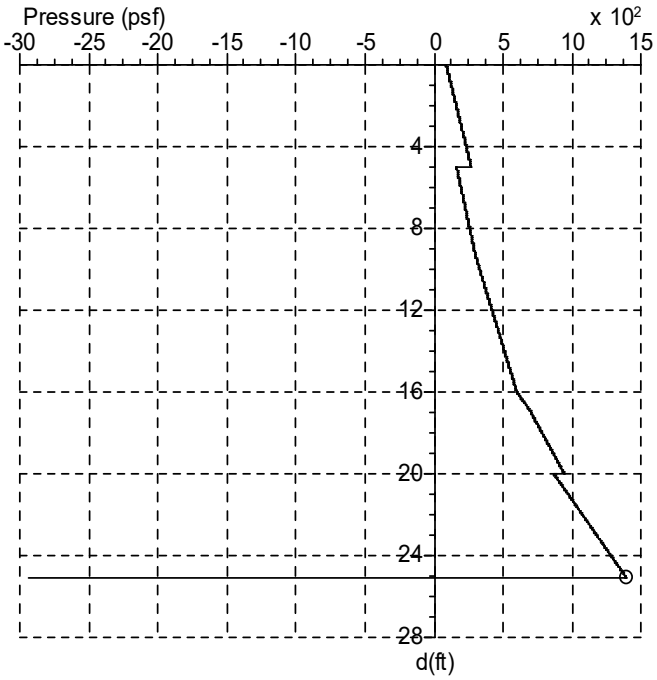
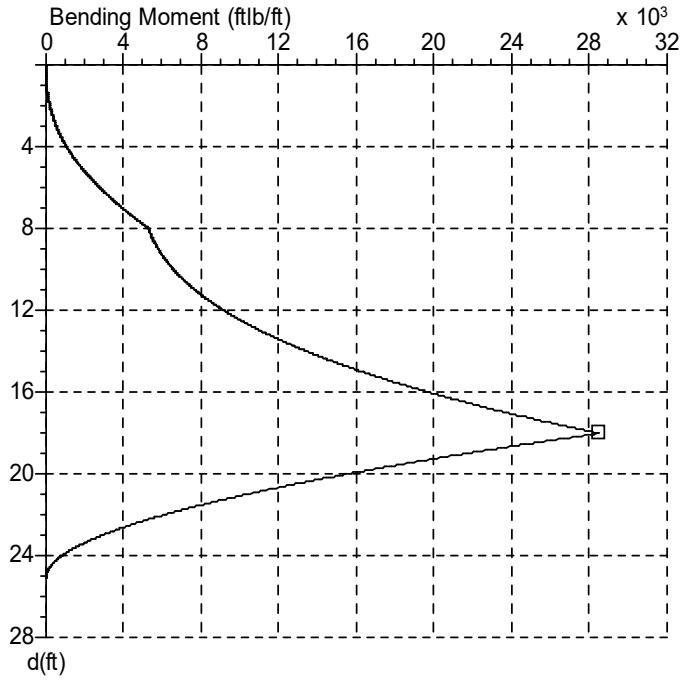
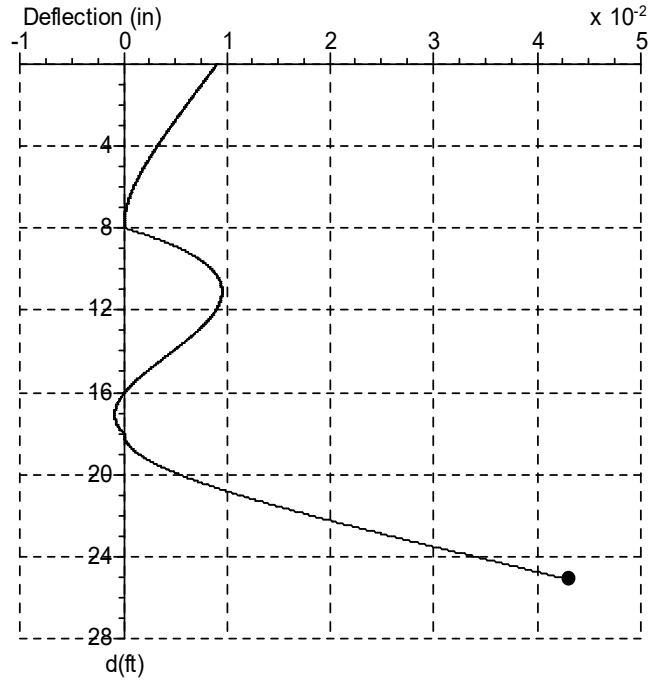
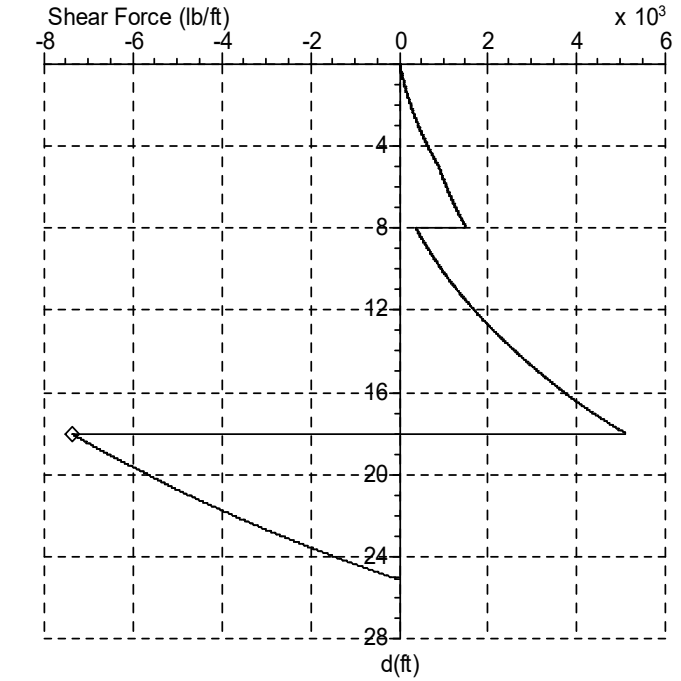
Sheet: PZ40
Pressure: Coulomb; Full hydrostatic pressure in cohesive soils.
Toe: No Earth Support

Maximum		d (ft)
○	1392.0 psf	25.06
□	28561.2 ftlb/ft	18.00
◇	7376.5 lb/ft	18.00
●	0.0 in	25.08









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Title: BUT-126-2.90 Retaining Wall
Designer: James Samples
Ref: Stantec
Date: 11.20.24

Sheet: PZ40
Pressure: Coulomb; Full hydrostatic pressure in cohesive soils.
Toe: No Earth Support

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
0.00	84.0	0.0	0.0	0.0	8.44	269.1	5487.5	0.0	482.3	16.88	691.5	23257.6	0.0	4283.5
0.22	92.4	2.1	0.0	20.4	8.66	275.8	5594.0	0.0	539.3	17.10	708.6	24262.6	0.0	4445.0
0.44	100.0	8.3	0.0	40.6	8.88	283.1	5725.2	0.0	603.7	17.33	725.6	25208.9	0.0	4595.1
0.67	108.4	20.1	0.0	64.7	9.11	289.8	5857.4	0.0	663.7	17.55	744.3	26286.6	0.0	4764.4
0.89	116.0	35.9	0.0	88.3	9.33	297.1	6017.5	0.0	731.3	17.77	763.0	27403.7	0.0	4938.0
1.11	124.4	59.1	0.0	116.0	9.55	307.2	6193.5	0.0	800.8	17.99	780.0	28454.5	0.0	5099.6
1.33	132.7	89.0	0.0	145.7	9.77	316.6	6367.6	0.0	866.2	18.21	798.7	27033.7	0.0	-7211.1
1.55	140.3	122.2	0.0	174.4	10.00	326.9	6575.1	0.0	940.3	18.44	815.6	25541.3	0.0	-7042.1
1.78	148.7	165.9	0.0	207.8	10.22	336.3	6778.8	0.0	1009.8	18.66	834.3	23940.8	0.0	-6852.1
2.00	157.1	217.5	0.0	243.1	10.44	346.7	7019.9	0.0	1088.5	18.88	853.0	22384.5	0.0	-6657.8
2.22	164.7	271.7	0.0	276.9	10.66	357.0	7279.5	0.0	1169.5	19.10	870.0	21008.8	0.0	-6477.4
2.44	173.1	339.6	0.0	315.9	10.88	366.5	7531.9	0.0	1245.3	19.32	888.7	19539.6	0.0	-6274.9
2.67	180.7	409.3	0.0	353.0	11.11	376.8	7828.1	0.0	1330.9	19.55	907.4	18117.4	0.0	-6068.1
2.89	189.1	495.2	0.0	395.7	11.33	387.2	8144.3	0.0	1418.9	19.77	924.3	16866.1	0.0	-5876.3
3.11	197.4	591.1	0.0	440.3	11.55	396.6	8449.5	0.0	1501.0	19.99	943.4	15536.5	0.0	-5661.3
3.33	205.1	687.4	0.0	482.5	11.77	406.9	8805.4	0.0	1593.5	20.21	888.8	14369.5	0.0	-5477.5
3.55	213.4	803.7	0.0	530.8	11.99	416.3	9147.7	0.0	1679.7	20.44	912.6	13130.9	0.0	-5270.0
3.78	221.8	931.4	0.0	581.0	12.22	426.7	9545.3	0.0	1776.8	20.66	936.5	11940.5	0.0	-5057.0
4.00	229.4	1057.6	0.0	628.3	12.44	437.1	9965.6	0.0	1876.3	20.88	958.2	10901.3	0.0	-4858.6
4.22	237.8	1208.2	0.0	682.2	12.66	446.5	10367.7	0.0	1968.8	21.10	982.0	9806.7	0.0	-4635.2
4.44	245.4	1356.0	0.0	732.9	12.88	456.8	10832.8	0.0	2072.8	21.32	1003.7	8856.7	0.0	-4427.3
4.66	253.8	1531.1	0.0	790.5	13.11	467.2	11322.0	0.0	2179.2	21.55	1027.6	7862.4	0.0	-4193.3
4.89	262.2	1719.6	0.0	850.0	13.33	476.6	11788.3	0.0	2278.0	21.77	1051.5	6922.5	0.0	-3953.9
5.11	162.5	1902.7	0.0	894.6	13.55	486.9	12325.4	0.0	2388.9	21.99	1073.1	6116.3	0.0	-3732.9
5.33	169.9	2113.0	0.0	932.9	13.77	496.4	12836.1	0.0	2491.9	22.21	1097.0	5282.6	0.0	-3491.0
5.55	176.5	2312.1	0.0	969.3	13.99	506.7	13423.0	0.0	2607.4	22.43	1120.9	4505.2	0.0	-3243.8
5.78	183.8	2540.0	0.0	1010.8	14.22	517.1	14036.7	0.0	2725.3	22.66	1142.5	3848.2	0.0	-3014.5
6.00	191.2	2777.7	0.0	1054.1	14.44	526.5	14618.5	0.0	2834.5	22.88	1166.4	3181.4	0.0	-2757.2
6.22	197.8	3002.5	0.0	1094.9	14.66	536.8	15285.2	0.0	2956.9	23.10	1188.1	2627.1	0.0	-2518.6
6.44	205.2	3260.0	0.0	1141.4	14.88	547.2	15980.3	0.0	3081.7	23.32	1211.9	2075.5	0.0	-2251.1
6.66	212.5	3528.3	0.0	1189.6	15.10	556.6	16637.5	0.0	3197.3	23.55	1235.8	1585.9	0.0	-1978.3
6.89	219.2	3782.0	0.0	1234.9	15.33	566.9	17388.5	0.0	3326.6	23.77	1257.5	1195.8	0.0	-1725.7
7.11	226.5	4072.2	0.0	1286.3	15.55	576.4	18097.4	0.0	3446.3	23.99	1281.3	828.3	0.0	-1442.8
7.33	233.1	4346.5	0.0	1334.4	15.77	586.7	18906.4	0.0	3580.2	24.21	1305.2	526.4	0.0	-1154.5
7.55	240.5	4660.0	0.0	1389.1	15.99	597.0	19746.6	0.0	3716.5	24.43	1326.9	309.9	0.0	-887.9
7.77	247.8	4986.3	0.0	1445.4	16.22	619.5	20537.9	0.0	3844.0	24.66	1350.8	136.7	0.0	-589.5
8.00	254.5	5294.4	0.0	361.7	16.44	644.3	21439.8	0.0	3989.6	24.88	1372.4	39.3	0.0	-313.6
8.22	261.8	5384.0	0.0	421.1	16.66	666.7	22289.3	0.0	4126.9	25.10	-2943.5	0.0	0.0	0.0

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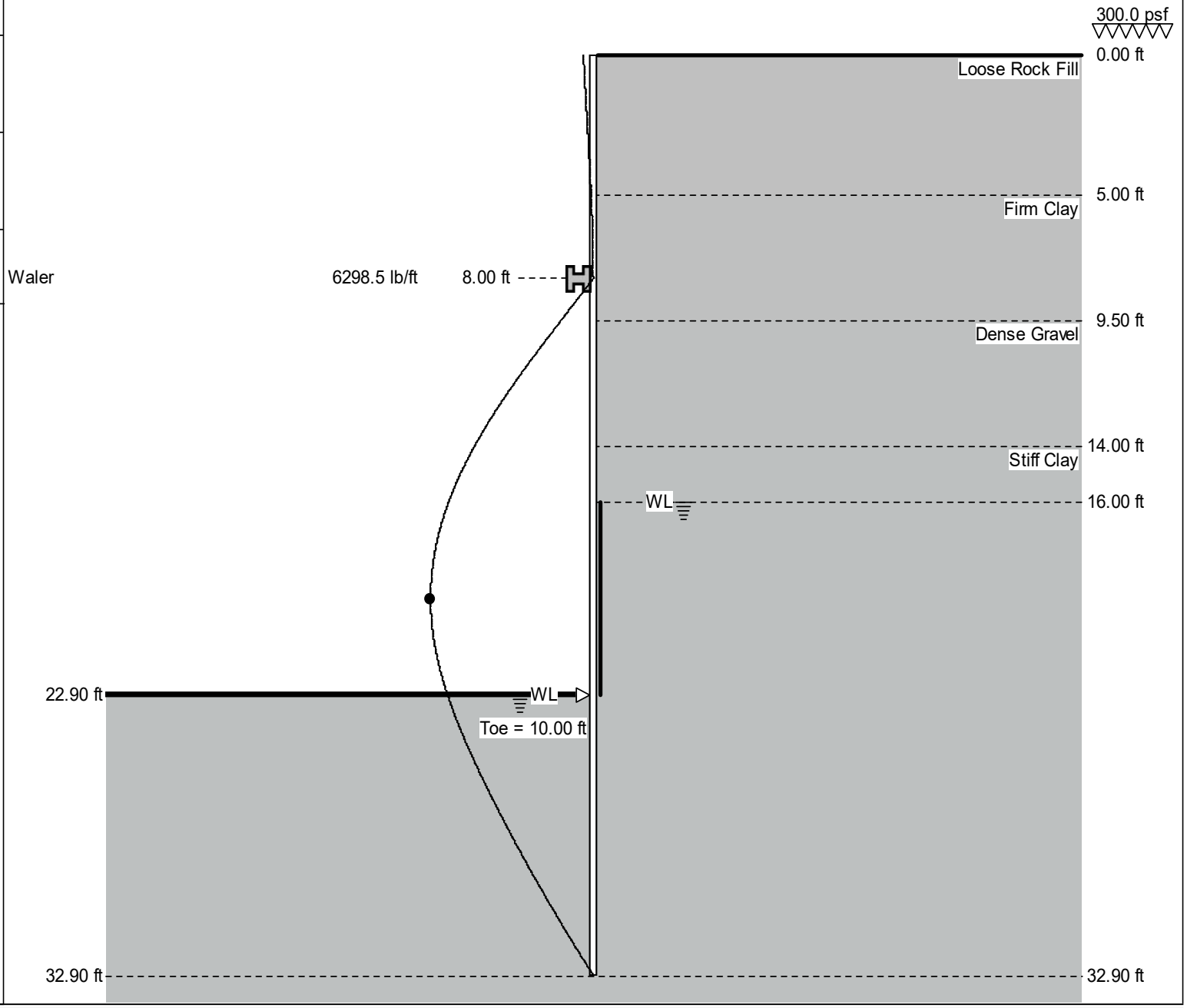
Site: BUT-126-2.92
Attn: Casey Carriere

Title: BUT-126-2.90 Retaining Wall
Designer: James Samples
Ref: Stantec
Date: 11.20.24

Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.
Toe: Free Earth Support

Maximum	d (ft)
● 0.1 in	19.44



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Date: 11.20.24

Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.
Toe: Free Earth Support

Input Data

Depth Of Excavation = 22.90 ft Depth Of Active Water = 16.00 ft Water Density = 62.43 pcf
Surcharge = 300.0 psf Depth Of Passive Water = 22.90 ft Minimum Fluid Density = 31.82 pcf

Soil Profile

Depth (ft)	Soil Name	γ (pcf)	γ' (pcf)	C (psf)	C_a (psf)	ϕ(°)	δ(°)	K_a	K_{ac}	K_p	K_{pc}
0.00	Loose Rock Fill	130.00	67.60	0.0	0.0	34.0	0.0	0.28	0.00	3.54	0.00
5.00	Firm Clay	125.00	62.60	200.0	0.0	28.0	0.0	0.36	1.20	2.77	3.33
9.50	Dense Gravel	135.00	72.60	0.0	0.0	36.0	0.0	0.26	0.00	3.85	0.00
14.00	Stiff Clay	125.00	62.60	300.0	0.0	30.0	0.0	0.33	1.15	3.00	3.46

Solution

Sheet

Sheet Name	I (in⁴/ft)	E (psi)	Z (in³/ft)	f (psi)	Maximum Bending Moment (ftlb/ft)	Upstand (ft)	Toe (ft)	Pile Length (ft)
PZ40	490.85	3.04E+07	60.70	50000.0	127556.3	0.00	10.00	32.90

Load Model: Area Distribution

Supports

Depth (ft)	Type	Linear Load (lb/ft)
8.00	Waler	6298.5

Maxima

	Maximum	Depth
Bending Moment	21975.7 ftlb/ft	18.29 ft
Deflection	0.1 in	19.44 ft
Pressure	1152.5 psf	22.90 ft
Shear Force	7325.1 lb/ft	32.00 ft

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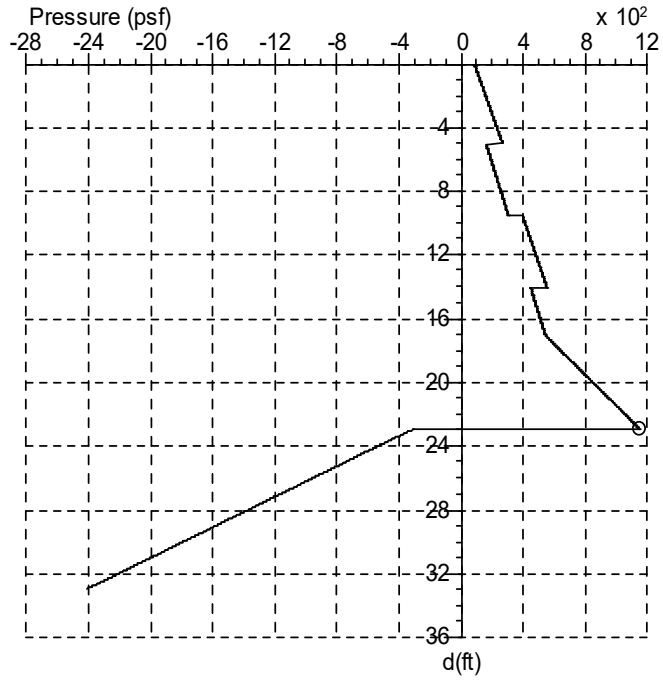
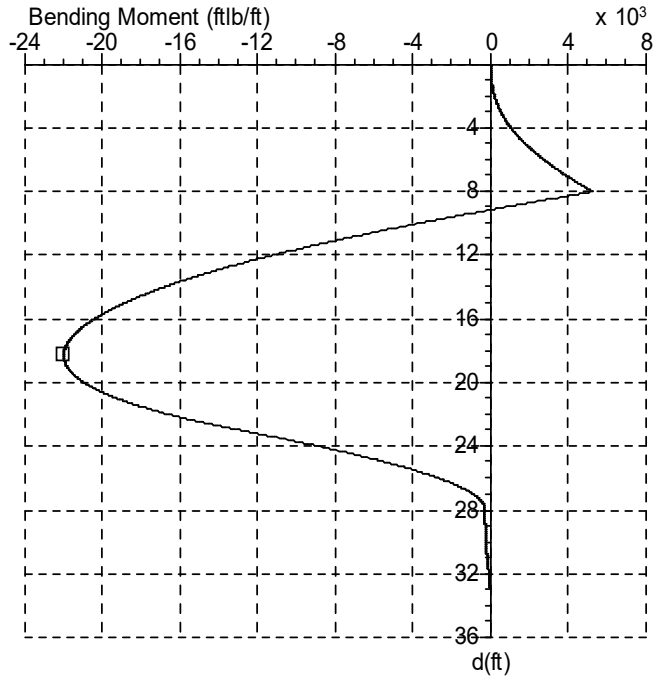
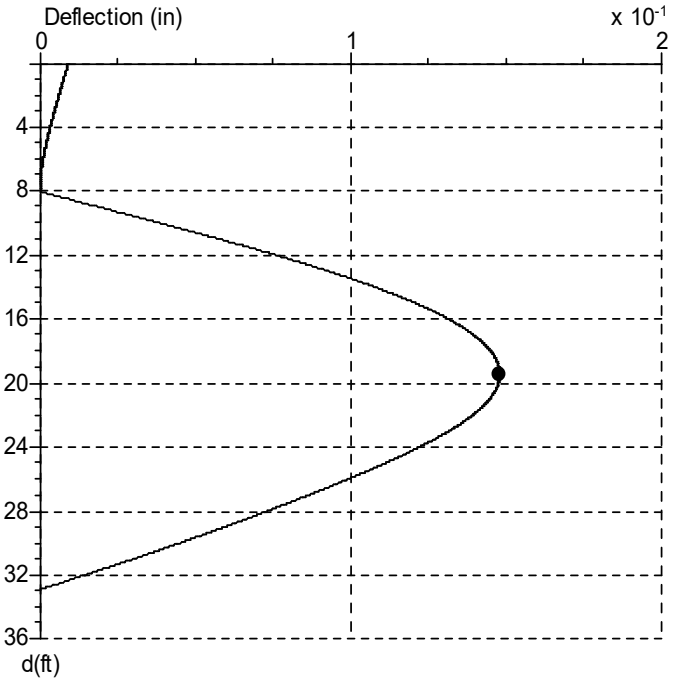
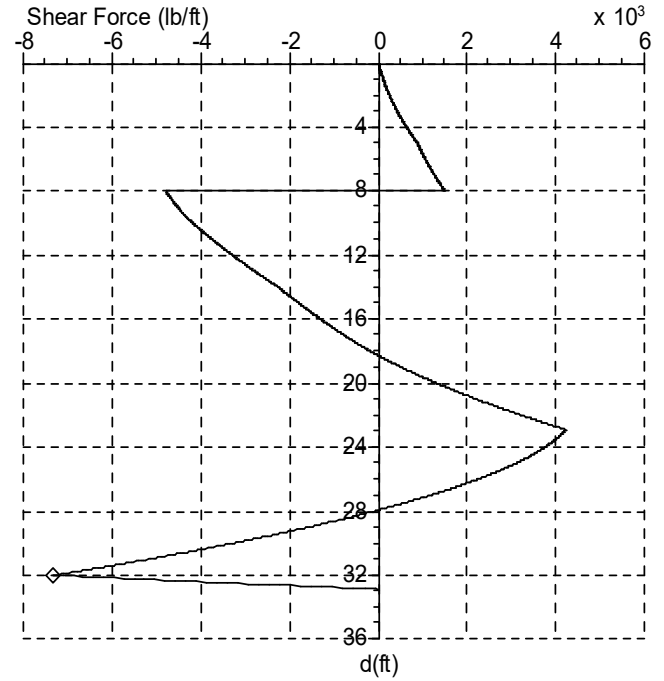
Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.
Toe: Free Earth Support

Maximum		d (ft)
○	1152.5 psf	22.90
□	21975.7 ftlb/ft	18.29
◇	7325.1 lb/ft	32.00
●	0.1 in	19.44









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SPW911, v2.40

Client: Ohio Deparment of Transportation
Site: BUT-126-2.92
Attn: Casey Carriere

Title: BUT-126-2.90 Retaining Wall
Designer: James Samples
Ref: Stantec
Date: 11.20.24

Sheet: PZ40
Pressure: Rankine; Full hydrostatic pressure in cohesive soils.
Toe: Free Earth Support

depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)	depth (ft)	P (psf)	M (ftlb/ft)	D (in)	F (lb/ft)
0.00	84.0	1.0	0.0	0.0	11.06	448.5	-7991.6	0.1	-3715.8	22.13	1071.7	-16024.8	0.1	3368.0
0.29	95.0	4.7	0.0	27.2	11.35	458.1	-8996.9	0.1	-3591.4	22.42	1103.0	-14964.9	0.1	3696.3
0.58	105.0	15.5	0.0	54.8	11.65	468.7	-10062.7	0.1	-3451.5	22.71	1131.5	-13914.3	0.1	4003.0
0.87	115.9	36.5	0.0	88.3	11.94	478.4	-10994.7	0.1	-3321.5	23.00	-331.6	-12667.1	0.1	4187.1
1.16	125.9	64.7	0.0	121.6	12.23	489.0	-11978.2	0.1	-3175.5	23.29	-397.4	-11419.6	0.1	4076.3
1.46	136.9	106.8	0.0	161.5	12.52	499.6	-12917.1	0.1	-3026.3	23.58	-457.5	-10316.8	0.1	3958.3
1.75	147.9	161.3	0.0	204.6	12.81	509.2	-13731.3	0.1	-2887.9	23.87	-521.4	-9143.4	0.1	3809.9
2.04	157.9	222.6	0.0	246.7	13.10	519.8	-14582.5	0.1	-2732.6	24.17	-578.7	-8117.8	0.1	3658.3
2.33	168.8	303.7	0.0	296.2	13.39	529.4	-15315.3	0.1	-2588.7	24.46	-641.7	-7039.9	0.1	3473.4
2.62	179.8	400.2	0.0	349.0	13.68	540.0	-16075.2	0.1	-2427.3	24.75	-704.8	-6020.3	0.1	3269.5
2.91	189.8	502.1	0.0	399.9	13.98	550.6	-16786.0	0.1	-2262.7	25.04	-762.0	-5148.9	0.1	3067.7
3.20	200.8	630.7	0.0	459.0	14.27	454.0	-17391.5	0.1	-2136.4	25.33	-825.0	-4256.7	0.1	2827.5
3.49	210.7	763.5	0.0	515.7	14.56	463.6	-18018.0	0.1	-1997.9	25.62	-888.1	-3439.4	0.1	2568.3
3.78	221.7	927.9	0.0	581.1	14.85	473.2	-18602.3	0.1	-1856.5	25.91	-945.3	-2766.3	0.1	2316.2
4.08	232.7	1112.5	0.0	649.9	15.14	482.0	-19096.0	0.1	-1725.4	26.20	-1008.4	-2108.2	0.1	2020.7
4.37	242.7	1298.7	0.0	715.3	15.43	491.6	-19597.2	0.1	-1578.5	26.49	-1065.6	-1589.2	0.1	1735.6
4.66	253.7	1524.6	0.0	790.4	15.72	500.3	-20013.9	0.1	-1442.4	26.79	-1128.7	-1111.0	0.1	1403.9
4.95	264.6	1773.6	0.0	868.8	16.01	509.1	-20428.8	0.1	-1290.0	27.08	-1191.7	-735.4	0.1	1053.2
5.24	166.8	2018.0	0.0	916.5	16.30	519.5	-20797.3	0.1	-1134.6	27.37	-1249.0	-487.8	0.1	717.8
5.53	176.4	2301.5	0.0	968.4	16.60	528.2	-21091.2	0.1	-990.9	27.66	-1312.0	-324.0	0.1	330.8
5.82	185.1	2573.1	0.0	1018.2	16.89	537.8	-21368.5	0.1	-830.0	27.95	-1369.3	-278.4	0.1	-37.5
6.11	194.7	2887.9	0.0	1075.7	17.18	559.9	-21596.8	0.1	-665.0	28.24	-1432.3	-277.3	0.1	-460.8
6.41	204.3	3220.6	0.0	1136.1	17.47	588.3	-21760.1	0.1	-507.2	28.53	-1495.3	-274.0	0.1	-903.1
6.70	213.0	3539.1	0.0	1193.5	17.76	619.6	-21888.5	0.1	-324.6	28.82	-1552.6	-269.1	0.1	-1321.7
6.99	222.6	3908.0	0.0	1259.4	18.05	648.0	-21956.3	0.1	-150.5	29.12	-1615.6	-261.5	0.1	-1800.3
7.28	231.4	4260.9	0.0	1321.9	18.34	679.3	-21974.5	0.1	50.1	29.41	-1678.6	-251.5	0.1	-2297.9
7.57	241.0	4669.3	0.0	1393.3	18.63	710.6	-21930.8	0.1	260.1	29.70	-1735.9	-240.2	0.0	-2766.7
7.86	250.6	5099.6	0.0	1467.7	18.92	739.0	-21835.2	0.1	459.2	29.99	-1798.9	-225.3	0.0	-3300.6
8.15	259.3	4646.1	0.0	-4760.8	19.22	770.3	-21665.7	0.1	687.2	30.28	-1856.2	-209.4	0.0	-3802.4
8.44	268.9	3218.7	0.0	-4681.0	19.51	801.6	-21426.3	0.1	924.7	30.57	-1919.2	-189.3	0.0	-4372.6
8.73	278.5	1815.8	0.0	-4598.3	19.80	830.0	-21145.4	0.1	1148.7	30.86	-1982.2	-166.3	0.0	-4961.7
9.03	287.3	562.4	0.0	-4520.6	20.09	861.3	-20764.4	0.1	1404.2	31.15	-2039.5	-142.9	0.0	-5513.8
9.32	296.9	-791.3	0.0	-4432.4	20.38	889.7	-20350.1	0.1	1644.6	31.44	-2102.5	-114.2	0.0	-6139.2
9.61	396.5	-1998.2	0.0	-4342.1	20.67	921.0	-19817.1	0.1	1918.1	31.74	-2165.5	-82.3	0.0	-6783.6
9.90	407.1	-3293.4	0.0	-4220.7	20.96	952.3	-19200.4	0.1	2201.0	32.03	-2218.5	-50.6	0.0	-7100.0
10.19	417.7	-4551.5	0.0	-4096.2	21.25	980.7	-18564.7	0.1	2466.4	32.32	-2285.8	-21.1	0.0	-4581.5
10.48	427.3	-5662.3	0.0	-3980.3	21.55	1012.0	-17780.3	0.1	2767.3	32.61	-2343.1	-5.2	0.0	-2230.9
10.77	437.9	-6846.9	0.1	-3849.6	21.84	1040.5	-16987.4	0.1	3049.0	32.90	-2406.1	0.0	0.0	0.0

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APPENDIX D
ANCHOR CALCULATIONS

BUT-126-2.92 Retaining Wall (PID 116204)
Double Row Wall Anchor Calculations

Assumptions and Inputs:

Assumptions

- No toe support (R=0)
- Soil is not saturated
- Anchor locations and loading (waler load) determined by SPW911 sheet pile wall analysis program
- Traffic surcharge load of 300 psf

Retained Soil Properties

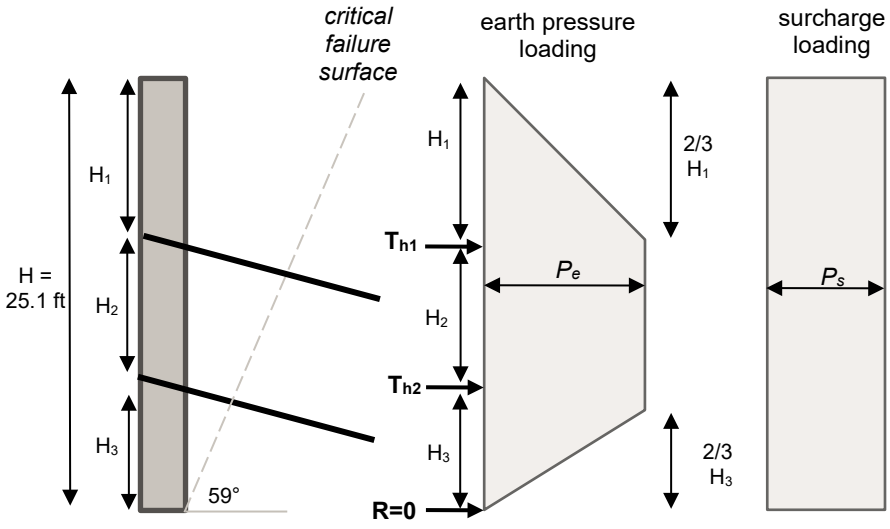
- Assume cohesive firm clay – multi layered in-situ soil, majority clays
- Moist unit weight γ = 125 pcf
- Φ = 28° (conservative lowest value of soils present)
- S_u = 2,500 psf
- K_a = 0.32 (weighted average of all soils present)

Calculations:

References

- U.S. DOT Federal Highway Administration (FHWA), Geotechnical Engineering Circular No. 4: Ground Anchors and Anchored Systems, June 1999.
- American Association of State Highway and Transportation Officials (AASHTO), LRFD Bridge Design Specifications, 9th Edition, 2020.
- Ohio Department of Transportation (ODOT), Supplemental Specification 866: Ground Anchors, April 21, 2017.
- Ohio Department of Transportation (ODOT), Bridge Design Manual (BDM), July 19, 2024.
- Ohio Department of Transportation (ODOT), Geotechnical Design Manual (GDM), July 19, 2024.

Apparent Earth Pressure Distribution (not to scale)



H_1 = 8.0 ft

H_2 = 10.0 ft

H_3 = 7.1 ft

Wall Loading – LRFD

Per AASHTO LRFD 3.11.5.7.2, the stability number, N_s, is approximately:
N_s = 110 pcf * 25.1 ft / 2,500 psf = 1.1

Total Load T_{hn} (waler load from SPW911 analysis results)

T_{h1} = 3,257.2 lb/ft of wall

T_{h2} = 10,361.9 lb/ft of wall

Anchor Load

The recommended minimum spacing Per AASHTO LRFD 11.9.4.2 is 5.0 feet. The anchor design will assume 15-degree inclination anchors at 5-foot center-to-center spacing.

$Q_{anchor1}$ = (3,257.2 lb/ft (5 ft) / cos (15°)) / 1000 = 16.9 kips

$Q_{anchor2}$ = (10,361.9 lb/ft (5 ft) / cos (15°)) / 1000 = 53.7 kips

Anchor Pullout Capacity

Per AASHTO LRFD Eqn. 11.9.4.2-1:

$$Q_R = \phi Q_n = \phi \pi D_{DH} \tau_a L_b \qquad (11.9.4.2\text{-}1)$$

where:

ϕ = resistance factor for anchor pullout (dim.)
Q_n = nominal anchor pullout resistance (kips)
D_{DH} = diameter of anchor drill hole (ft)
τ_n = nominal anchor bond stress (ksf)
L_b = anchor bond length (ft)

Φ = 0.70 for cohesive soils (AASHTO LRFD Table 11.5.7-1)

D_{DH} = 6 inches (assumed)

τ_n = 1.05 ksf for gravity grouted anchors in stiff silt-clay mixtures, for S_u = 2,500 psf (AASHTO LRFD Table C11.9.4.2-1)

Q_R = 0.70 (π) (0.5 ft) (1.05 ksf) L_b

Q_R = 1.15 L_b

$Q_{anchor1}$ = 16.9 kips = 1.15 L_b → L_b = 14.7 ft (use 15 ft)

$Q_{anchor2}$ = 53.7 kips = 1.15 L_b → L_b = 46.7 ft (use 47 ft)

Using an anchor spacing of 5 feet and an inclination angle of 15 degrees for the second row of anchors results in a bonded length requirement of 47 feet. Without considering the unbonded length, this would result in the anchor extending beyond ODOT owned right-of-way at the project site (30 feet from centerline). Inclination angles of 10 and 5 degrees lowered the bonded length to 46 and 45 feet respectively, which is still beyond the right-of-way. Due to these results, it was determined that the spacing would be reduced to 3.25 feet in order to reduce anchor lengths as well as assist in anchor placement on the sheet pile wall.

Anchor Load

$Q_{anchor1}$ = (3,257.2 lb/ft (3.25 ft) / cos (15°)) / 1000 = 11.0 kips

$Q_{anchor2}$ = (10,361.9 lb/ft (3.25 ft) / cos (15°)) / 1000 = 34.9 kips

Anchor Pullout Capacity

$Q_{anchor1}$ = 11.0 kips = 1.15 L_b → L_b = 9.5 ft (use 10 ft)

$Q_{anchor2}$ = 34.9 kips = 1.15 L_b → L_b = 30.3 ft (use 31 ft)

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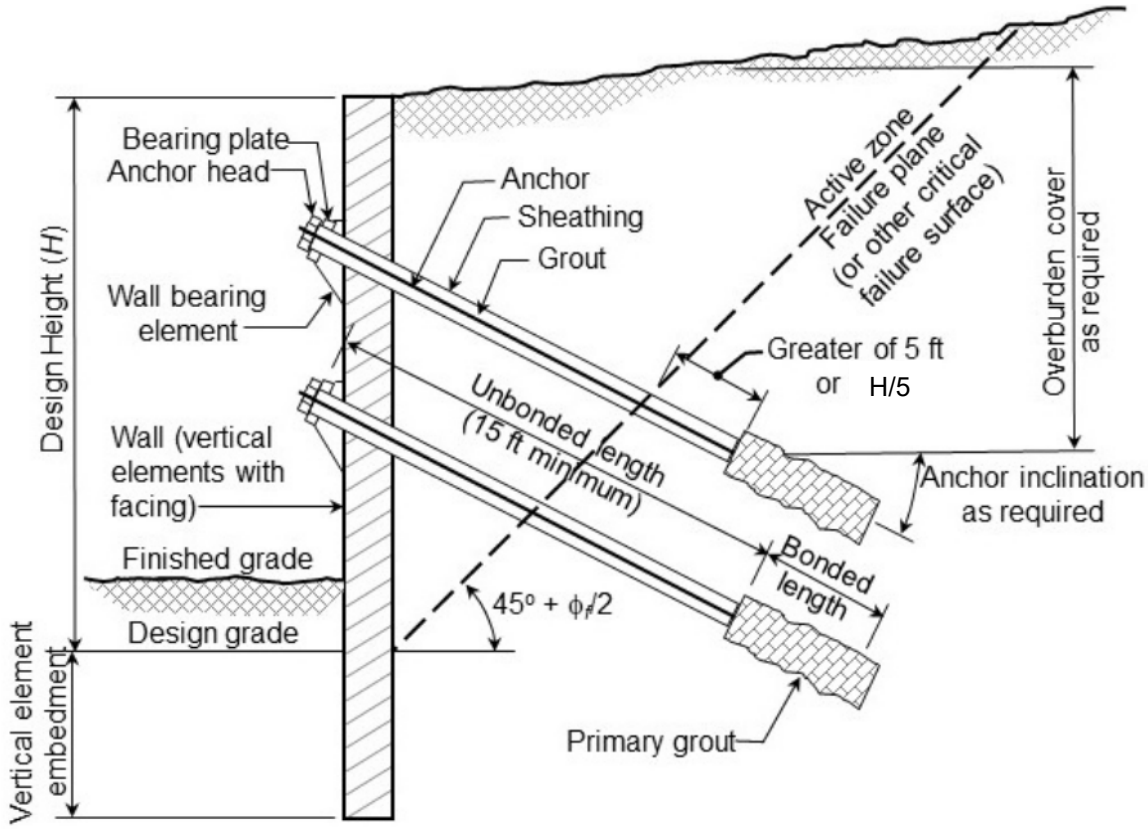
Anchor Length/Position

Based on the LRFD calculations, bonded lengths of 10 and 31 feet are recommended for the first and second rows of 15-degree inclination anchors respectively.

Per AASHTO LRFD Figure 11.9.1-1

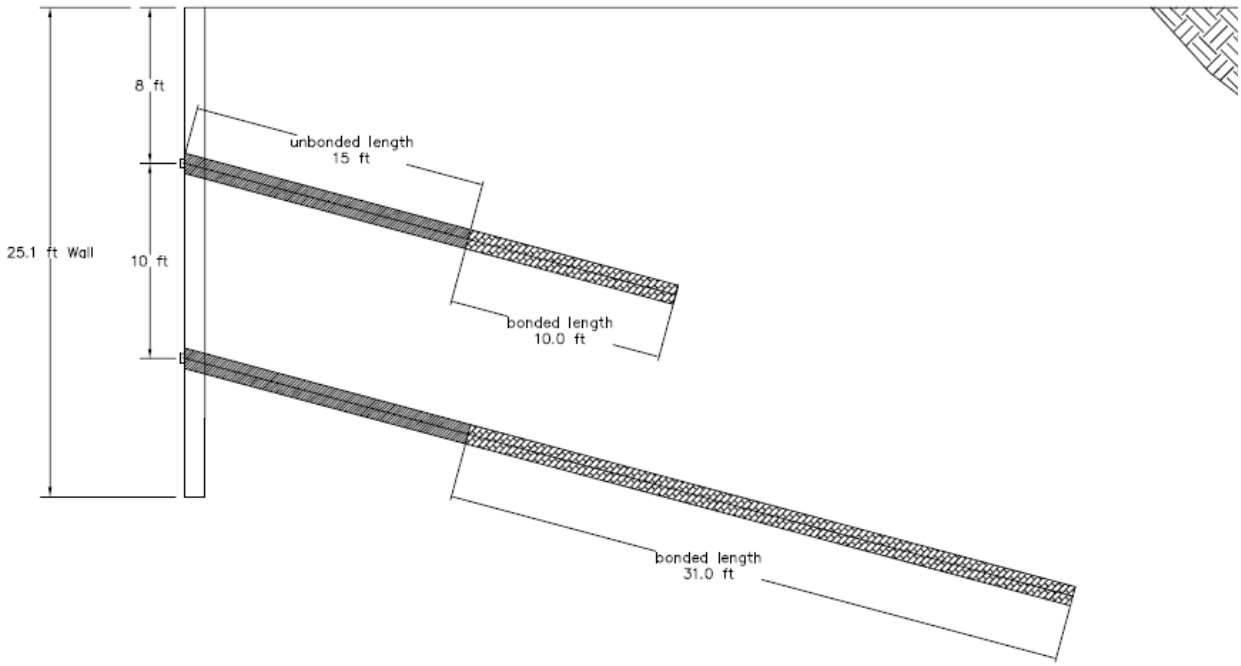


Based on geometry, the distance from the wall to the critical failure plane along the anchor location is approximately 10 feet for the upper anchor, therefore the unbonded length will be the minimum 15 ft for both anchors per AASHTO LRFD Figure 11.9.1-1. Note this is larger than FHWA GEC 4 Figure 37a.

Per AASHTO LRFD C11.9.4.2-1, for tremie-grouted anchors, a minimum overburden cover of 15.0 feet is typically required. Per FHWA GEC 4 Section 5.3.7, the minimum overburden cover for ground anchors installed in soil is 15 feet over the center of the anchor bond zone.

To meet the minimum overburden requirement for the 15-degree anchor, the anchor should be installed a minimum of 10 feet from the top of the wall. However, the location of the upper anchor was chosen based upon the deflection and moment capacity of the sheet pile wall based in the SPW911 program.

15-degree anchor geometry:



Overburden cover of 15-degree anchor = 8 ft + sin 15° (20 ft) = 13.2 ft

Overburden cover of 15-degree anchor = 18 ft + sin 15° (30.5 ft) = 25.9 ft

BUT-126-2.92 Retaining Wall (PID 116204)
Single Row Wall Anchor Calculations

Assumptions and Inputs:

Assumptions

- Soil is not saturated for entire section
- Anchor locations and loading (waler load) determined by SPW911 sheet pile wall analysis program
- Traffic surcharge load of 300 psf

Retained Soil Properties

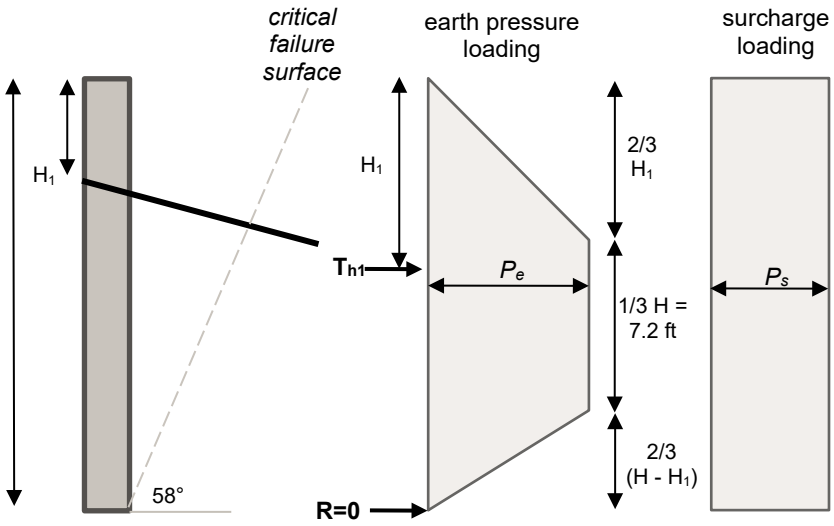
- Assume cohesive firm clay – multi layered in-situ soil, majority clays
- Moist unit weight γ = 125 pcf
- Φ = 28° (conservative lowest friction angle of all soils present)
- S_u = 2,500 psf
- K_a = 0.32 (weighted average of all soils present)

Calculations:

References

- U.S. DOT Federal Highway Administration (FHWA), Geotechnical Engineering Circular No. 4: Ground Anchors and Anchored Systems, June 1999.
- American Association of State Highway and Transportation Officials (AASHTO), LRFD Bridge Design Specifications, 9th Edition, 2020.
- Ohio Department of Transportation (ODOT), Supplemental Specification 866: Ground Anchors, April 21, 2017.
- Ohio Department of Transportation (ODOT), Bridge Design Manual (BDM), July 19, 2024.
- Ohio Department of Transportation (ODOT), Geotechnical Design Manual (GDM), July 19, 2024.

Apparent Earth Pressure Distribution (not to scale)



H_1 = 8 ft

Wall Loading – LRFD

Per AASHTO LRFD 3.11.5.7.2, the stability number, N_s, is approximately:
N_s = 110 pcf * 22.9 ft / 2,500 psf = 1.01

Total Load T_{hn} (waler load from SPW911 analysis results)

T_{h1} = 6,298.5 lb/ft of wall

Anchor Load

The recommended minimum spacing Per AASHTO LRFD 11.9.4.2 is 5.0 feet. The anchor design will assume 15-degree inclination anchors at 5-foot center-to-center spacing.

Q_{anchor} = (6,298.5 lb/ft (5 ft) / cos (15°)) / 1000 = 32.6 kips

Anchor Pullout Capacity

Per AASHTO LRFD Eqn. 11.9.4.2-1:

$$Q_R = \phi Q_n = \phi \pi D_{DH} \tau_a L_b \qquad (11.9.4.2\text{-}1)$$

where:

ϕ = resistance factor for anchor pullout (dim.)
Q_n = nominal anchor pullout resistance (kips)
D_{DH} = diameter of anchor drill hole (ft)
τ_n = nominal anchor bond stress (ksf)
L_b = anchor bond length (ft)

Φ = 0.70 for cohesive soils (AASHTO LRFD Table 11.5.7-1)

D_{DH} = 6 inches (assumed)

τ_n = 1.05 ksf for gravity grouted anchors in stiff silt-clay mixtures, for S_u = 2,500 psf (AASHTO LRFD Table C11.9.4.2-1)

Q_R = 0.70 (π) (0.5 ft) (1.05 ksf) L_b

Q_R = 1.15 L_b

$Q_{anchor1}$ = 32.6 kips = 1.15 $L_b \rightarrow L_b$ = 28.4 ft (use 29 ft)

Using an anchor spacing of 5 feet and an inclination angle of 15 degrees for the second row of anchors results in a bonded length requirement of 29 feet. Without considering the unbonded length, this would result in the anchor extending beyond ODOT owned right-of-way at the project site (30 feet from centerline). Inclination angles of 10 and 5 degrees lowered the bonded length to 28 feet, which is still beyond the right-of-way. Due to these results, it was determined that the spacing would be reduced to 3.25 feet in order to reduce anchor lengths as well as assist in anchor placement on the sheet pile wall.

Anchor Load

$Q_{anchor1}$ = (6,298.5 lb/ft (3.25 ft) / cos (15°)) / 1000 = 20.5 kips

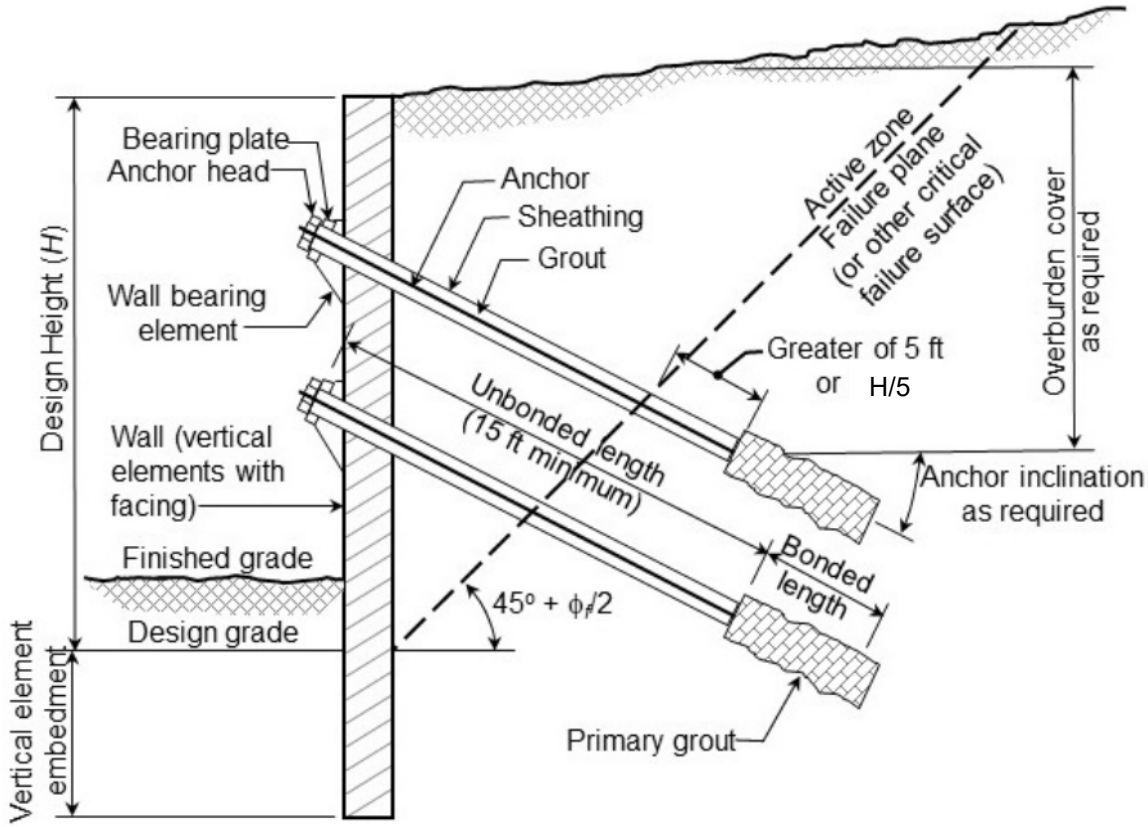
Anchor Pullout Capacity

$Q_{anchor1}$ = 20.5 kips = 1.15 $L_b \rightarrow L_b$ = 18.4 ft (use 19 ft)

Anchor Length/Position

Based on the LRFD calculations, a bonded length of 19 ft is recommended for 15-degree inclination anchors.

Per AASHTO LRFD Figure 11.9.1-1

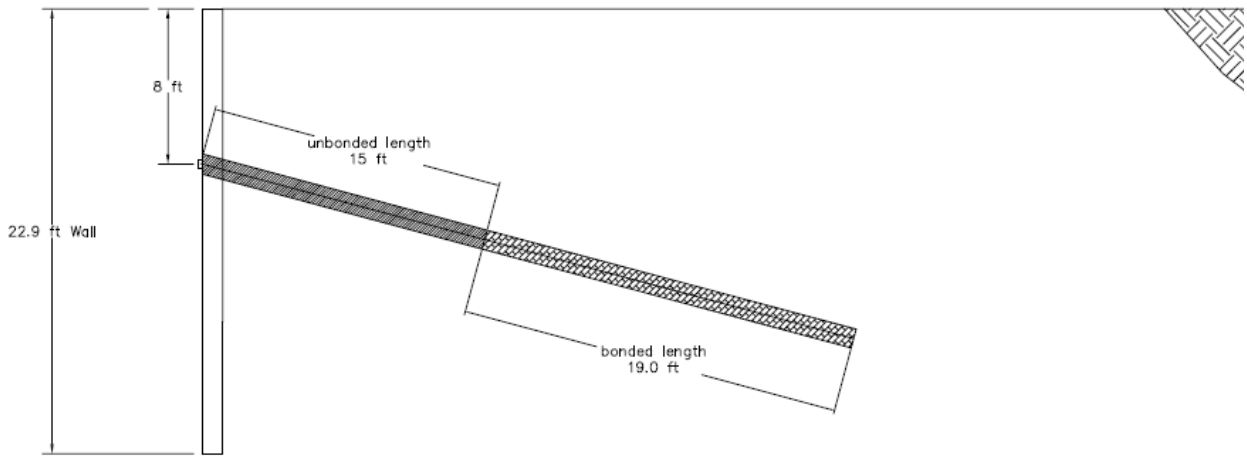


Based on geometry, the distance from the wall to the critical failure plane along the anchor location is approximately 10 feet for the anchor, therefore the unbonded length will be the minimum 15 ft per AASHTO LRFD Figure 11.9.1-1. Note this is larger than FHWA GEC 4 Figure 37a.

Per AASHTO LRFD C11.9.4.2-1, for tremie-grouted anchors, a minimum overburden cover of 15.0 feet is typically required. Per FHWA GEC 4 Section 5.3.7, the minimum overburden cover for ground anchors installed in soil is 15 feet over the center of the anchor bond zone.

To meet the minimum overburden requirement for the 15-degree anchor, the anchor should be installed a minimum of 9 feet from the top of the wall. However, the location of the upper anchor was chosen based upon the deflection and moment capacity of the sheet pile wall based in the SPW911 program.

15-degree anchor geometry:



Overburden cover of 15-degree anchor = 8 ft + sin 15° (24.5 ft) = 14.3 ft