Stantec

REPORT OF LANDSLIDE EXPLORATION
HAM-52-36.85 (FINAL)

PID: 116046
Hamilton County, Ohio

August 16, 2024

Prepared for:

Ohio Department of Transportation, District 8
Lebanon, Ohio

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Project Number: 173410733

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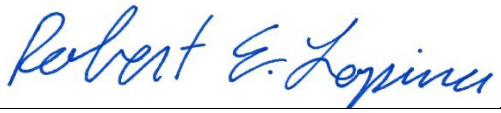
Reviewed by: 

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Executive Summary

Two landslides are located along the south side of eastbound US Route 52 between Kellogg Avenue and Asbury Road in Hamilton County, Ohio, near straight line mileage (SLM) 36.85 and 37.65. The landslide head scarps are located along the edge of roadway for approximately 175 and 100 feet of the roadway at SLM 36.85 and 37.65, respectively. The toes of the landslides were not visible but are suspected to be located downhill (south) from US 52. The project site is located approximately 3 miles south of Anderson Township, Ohio. The landslides are located where the roadway is aligned adjacent to a slight outside bend of the Ohio River. The Ohio Department of Transportation (ODOT) is planning to repair and stabilize the roadway where the landslides are located. The proposed remediation design consists of a drilled shaft walls just beyond the pavement at each slide locations. Stantec Consulting Services Inc. (Stantec) was contracted by ODOT to perform the geotechnical exploration and drilled shaft wall designs for this project.

S&ME was contracted by Stantec to advance seven borings (B-001-0-24 through B-007-0-24) along the eastbound shoulder of the 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 approximately 1 feet of roadway material (asphalt, concrete, and subbase). Below the surface materials, the soil was primarily fine-grained, typically classifying as clay (A-7-6). Thinner layers (1.5 to 3.0 feet thick) of coarse-grained materials were encountered at various depths. The fine-grained soils were described as stiff to hard, brown to gray, damp to moist, and moderately to highly plastic. The coarse-grained soils were described as loose to very dense, brown to gray, and dry to moist.

Bedrock was encountered at depths of 26.5 to 31.0 feet at SLM 36.85 and 17.5 to 20.5 feet at SLM 37.65. A layer of 1-to-6-foot weathered shale was encountered and augered through prior to coring. The bedrock was described as interbedded shale and limestone. The shale was described as weak, severely to highly weathered, and thin bedded. The limestone was described as moderately strong, moderately weathered, and medium bedded. A minimum of 10 feet of bedrock was cored prior to termination. Groundwater was encountered during drilling at a depth ranging from 23.0 to 27.0 feet in B-001-0-24 through B-003-0-24. Groundwater was not observed in the remaining borings.

Drilled shaft walls are recommended to protect the roadway at SLM 36.85 and 37.65, as summarized in the table below. It should be noted that borings were advanced outside of where the landslide failure surfaces were observed, and no borings were advanced downslope of the roadway. Therefore, the failure surfaces used in analyses were conservatively estimated based on the subsurface information, ODOT guidance, and previous project experience. The actual failure surfaces of the two landslides may differ from the failure surfaces assumed in the analyses.

Drilled Shaft Wall Detail	SLM 36.85	SLM 37.65
Starting Station	1844+25	1891+90
Ending Station	1848+00	1894+40
Wall Length	375 ft	250 ft
Reinforced Shaft Diameter	3 ft	3 ft
Reinforced Shaft Spacing (center-to-center)	5.75 ft	5.75 ft
Reinforced Shaft Steel Section	W24x162	W27x129
Reinforced Shaft Socket into Bedrock	10 ft	10 ft
Offset to C/L of Reinforced Shaft (from C/L of US 52)	47.5 ft	52.0 ft
Offset to C/L of Reinforced Shaft (from proposed sawcut)	14.5 ft	14.5 ft
Unreinforced (Plug) Shaft Diameter	3 ft	3 ft
Unreinforced (Plug) Shaft Length (from proposed ground surface)	20 ft	15 ft

Acronyms / Abbreviations

ER	Energy Ratio
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
RQD	Rock Quality Designation
SGE	Specifications for Geotechnical Exploration
SLM	Straight Line Mileage
SPT	Standard Penetration Test
TIMS	Traffic Information Management System
ER	Energy Ratio
UC	Unconfined Compression
UCR	Unconfined Compression Strength for Rock Core
USDA	United States Department of Agriculture

1 INTRODUCTION

Two landslides are located along the south side of eastbound US Route 52 between Kellogg Avenue and Asbury Road in Hamilton County, Ohio, near SLM 36.85 and 37.65. The landslide head scarps are located along the edge of roadway for approximately 175 and 100 feet of the roadway at SLM 36.85 and 37.65, respectively. The toes of the landslides were not visible but are suspected to be located downhill (south) from US 52. The project site is located approximately 3 miles south of Anderson Township, Ohio. The landslides are located where the roadway is aligned adjacent to a slight outside bend of the Ohio River.

The Ohio Department of Transportation (ODOT) is planning to repair and stabilize the roadway where the landslides are located. The proposed remediation design consists of drilled shaft walls just beyond the pavement at each slide locations. Stantec Consulting Services Inc. (Stantec) was contracted by ODOT to perform the geotechnical exploration and drilled shaft wall designs for this project. Figure 1 shows the site vicinity.

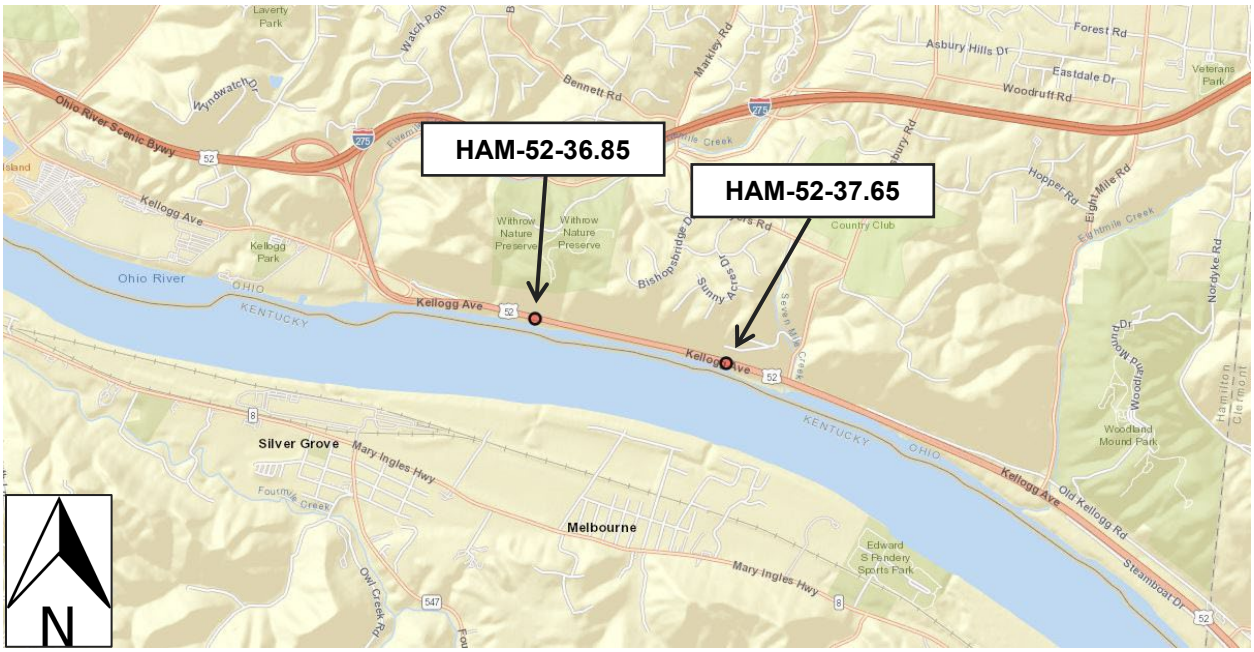


Figure 1: Site Vicinity

(Ohio Department of Natural Resources 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 Outer Bluegrass Region. The Outer Bluegrass Region is described as a dissected plateau of carbonate rocks, with caves and other karst features relatively common in portions of the region. The region consists of Ordovician and Silurian age dolomites, limestones, and calcareous shales underlaying silt-loam colluvium. The region has moderately high relief (about 300 feet) with elevations ranging from 455 to 1,120 feet.

2.2 SOIL GEOLOGY

According to the *Quaternary Geology of Ohio Map* (ODNR, 1999), the project site is underlain by silty loam till covered with 1 to 3 meters of loess from the Illinoian era. These soils are ground moraine deposits, flat and relatively continuous. The soil survey (*Web Soil Survey of Washington County, Ohio*, United States Department of Agriculture [USDA], 2023) indicates that the project site is underlain by soils from the Urban land-Udorthents complex, Eden flaggy silty clay loam complex, and Chagrin-Nelse Wheeling complex. These soils vary between clay, loam, silty clay loam, silt loam, sandy loam. These soils are typically well-drained with a low to high capacity of transmitting water. The *Drift Thickness Map of Ohio* (ODNR, 2004) suggests that the glacial drift thickness ranges from 0 to 20 feet at the project site.

2.3 BEDROCK GEOLOGY

Bedrock mapping (*Ohio Geology Interactive Map*, ODNR, 2023) 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 Point Pleasant and Kope Formations from the Ordovician group. The bedrock from the Point Pleasant Formation is comprised of interbedded limestone (60%) and shale (40%). The bedrock is described as shades of gray to bluish gray that weathers light gray, with unit thicknesses between 0 to 80 feet. The 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 weathers light to yellowish gray, with unit thicknesses between 200 to 260 feet.

According to the *Ohio Mine Locator* (ODNR, 2023), there are no recorded mines within a 5-mile radius of the project footprint. However, there are 12 mines just outside of the 5-mile radius. Out of the twelve, six are historic surface mines, three are surface-affected active industrial mines producing sand and gravels, and the other three are inactive sand and gravel mines. The closest of these mines is a historic surface mine 5.8 miles north of the site. The *Karst Interactive Map* (ODNR, 2023) indicates there are no known karst features in the project vicinity. Approximately 3 miles north of the project, two field verified karst sinks are identified on the map.

2.4 HYDROLOGY AND HYDROGEOLOGY

The Ohio River is located to the south of the project site. Surface drainage at the site is assumed to be collected in the Ohio River.

The *Ohio Geology Interactive Map* shows that the site is underlain by the Anderson Thin Upland Aquifer, which has a yield of less than 25 gallons per minute. According to the *Groundwater Resources of Washington County Map* (ODNR, 2023), the project site is in an area where wells with yields of 1 to 15 gallons per minute can be achieved. The principal aquifer in the area is sand and gravel.

A search was performed using the ODNR *Ohio Water Wells Map* (2023) to determine if any water wells are located near the project site. According to the map, 13 water wells have been drilled within a 2-mile radius of the project footprint. The well logs indicate a bedrock depth ranging from 9 to 46 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 14 to 75 feet.

2.5 SEISMIC

A review of the seismic data available in the project vicinity was completed using the ODNR *Ohio Earthquake Epicenters Map* (2023). Overall, Ohio has a relatively limited amount of seismic activity. Within a 10-mile radius of the project, there have been nine earthquake epicenters with magnitudes between 1.5 and 2.9. The available data reviewed included events that occurred in Ohio from 1804 to present day.

2.6 SITE RECONNAISSANCE

Prior to the field exploration, ODOT marked the borings and Stantec carried out desktop review to make observations and evaluate site conditions. The land surrounding the project site can be described as rural with some residential buildings in the vicinity. The pavement was observed to be generally in fair condition; however, the right eastbound lane had cracks and the shoulder had been repaved due to settlement caused by the landslide at both locations. Previous repairs consisting of drilled shafts were located at the downhill slope about 15 to 25 feet from the edge of the roadway at each location. The road surface was approximately 100 feet north of the Ohio River. The landslide affects approximately 175 feet and 100 feet of the roadway at SLM 36.85 and 37.65, respectively. The banks of the river were well vegetated.

3 EXPLORATION

3.1 HISTORIC EXPLORATION PROGRAMS

The ODOT Traffic Information Management System (TIMS) provides documentation for three geotechnical explorations performed along US 52. The HAM-52-34.84 project was for geohazard remediation that was located between the two landslides identified for this project. The exploration consisted of four borings drilled in 1973. The overburden soils predominantly classified as silt and clay (A-6a) and silty clay with stone fragments (A-6b). Bedrock was encountered at depths between 20 to 24 feet and was described as gray limestone and shale.

The HAM-52-32.60 project was for a new alignment located approximately 4 miles west of the site and consisted of 179 borings advanced along US 52 in 1960. The overburden soils predominantly classified as silty clay (A-6b) and silt and clay (A-6a). No bedrock information was available.

The HAM-52-37.88/37.99 project for structural foundation exploration (culvert) was located approximately 0.3 miles east of the site and consisted of four borings advanced along US 52 in 2009. The overburden soils predominantly classified as silty clay (A-6b), clay (A-7-6), gravel and/or stone fragments (A-1-a), and gravel and/or stone fragments with sand and silt (A-2-6). Bedrock was encountered at depths of 29.6 and 33.0 feet in two borings.

3.2 PROJECT EXPLORATION PROGRAM

S&ME was contracted by Stantec to advance seven borings to obtain geotechnical data for the proposed landslide stabilization. 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 site plan in Appendix A. The locations of the borings were surveyed by ODOT following the exploration.

Table 1. Boring Summary

Site	Boring No.	Station (feet)	Offset (feet)	Ground Surface Elevation (feet)	Top of Bedrock Elevation (feet)	Bottom of Boring Elevation (feet)
SLM 36.85	B-001-0-24	1844+23	30 Right	504.6	473.6	459.7
	B-002-0-24	1845+24	30 Right	503.7	475.7	462.7
	B-003-0-24	1846+16	29 Right	503.0	473.5	463.0
	B-004-0-24	1847+14	30 Right	502.1	475.6	462.9
SLM 37.65	B-005-0-24	1891+56	33 Right	498.4	477.9	463.9
	B-006-0-24	1893+05	34 Right	499.0	481.5	469.5
	B-007-0-24	1893+99	34 Right	499.3	481.0	470.4

Note: Station and offset values are measured from the centerline of US 52.

The borings were advanced in accordance with the ODOT Specifications for Geotechnical Explorations (SGE). The borings were performed with a CME 550X (R50) 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 CME 550X automatic hammer and drill rod system were measured to be 78.7 percent on March 31, 2021.

The SPT is performed by advancing a split-spoon sampler, 18 inches in length, with a 140-pound automatic hammer dropping 30 inches at selected depth intervals in the boring. The number of hammer blows needed to advance the sampler each 6-inch increment is recorded. The blow count from the first 6-inch increment is discarded due to ground disturbance at the bottom of the boring. The sum of the blow counts from the last two 6-inch increments is called the field N-value (N_{field}). The field N-value is corrected to an equivalent rod energy ratio of 60 percent (N_{60}) according to the equation below.

$$N_{60} = N_{field}\left(\frac{ER}{60}\right)$$

The depths and elevations of the SPTs with the corresponding N_{60}-values are shown on the boring logs in Appendix B.

Upon encountering fairly competent bedrock, approximately 10 feet of rock coring was performed in each boring using NQ2-size equipment. Recovery, core loss, and rock quality designation (RQD) values were recorded as percentages for each coring run. The recovery is a measurement of the core sample obtained from a core run. The loss is the difference between the core run and the recovery. The RQD is measured by dividing the sum of all pieces of intact rock core longer than four inches in a run by the total length of the core run. These values are shown on the boring logs contained in Appendix B.

The materials encountered were logged by an inspector from S&ME, 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 S&ME'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.

Four rock core samples were subjected to unconfined compressive strength testing. One sample was subjected to compression testing according to ASTM D 7012, Method C. Due to the soft/fragile nature of the rock samples, three samples were subjected to compression testing according to ASTM D 2166 (for soil samples).

The results of laboratory testing are included in Appendix D.

4 FINDINGS

4.1 LANDSLIDE AT SLM 36.85

Borings B-001-0-24 through B-004-0-24 were advanced to obtain subsurface information for the landslide located near SLM 36.85. The surface materials encountered in these borings consisted of 3 to 4 inches of asphalt followed by 8 inches of concrete. Below the surface materials, the encountered soil was primarily fine-grained, typically classifying as clay (A-7-6). Isolated samples classified as sandy silt (A-4a), silt and clay (A-6a), and silty clay (A-6b). The fine-grained soils were described as stiff to hard (N_{60} values ranging from 7 to 83 with an average of 23), brown to gray, damp to moist (natural moisture contents ranging from 10 to 30 with an average of 15), and moderately plastic (plasticity indices ranging from 9 to 33 with an average of 23).

Thinner layers (typically 1.5 feet thick) of coarse-grained soils were also encountered at various depths. These coarse-grained materials were visually described or classified as gravel and stone fragments with sand (A-1-b), gravel and stone fragments with sand and silt (A-2-4), and gravel and stone fragments with sand, silt, and clay (A-2-6). The soils were described as loose to very dense (N_{60} values ranging from 7 to 26 with an average of 15), brown to gray, and damp to moist (natural moisture contents ranging from 21 to 24 with an average 17).

Bedrock was encountered at depths ranging from 26.5 to 31.0 feet. A layer of highly weathered shale up to about 5 feet thick was augered prior to coring. The cored bedrock was described as interbedded gray shale and limestone. The shale was described as weak, severely to highly weathered, and thin bedded. The limestone was described as moderately strong, moderately weathered, and medium bedded. A minimum of 10 feet of bedrock was cored prior to termination. Core recoveries ranged from 81 to 100 percent and RQD values varied from 22 to 71 percent. Testing of two samples of shale bedrock resulted in unconfined compressive strengths of 8 and 499 psi. Groundwater was encountered during drilling at depths ranging between 23.0 and 27.0 feet in B-001-0-24 through B-003-0-24. Groundwater was not observed in B-004-0-24 during drilling; however, this may have been obscured by the addition of water during rock coring.

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

4.2 LANDSLIDE AT SLM 37.65

Borings B-005-0-24 through B-007-0-24 were advanced to obtain subsurface information for the landslide located near SLM 37.65. The surface materials encountered in these borings consisted of 2 inches of asphalt, 6 to 7 inches of concrete, and 3 to 4 inches of subbase. Below the surface materials, the encountered soil was primarily fine-grained, typically classifying as clay (A-7-6), with one sample classifying as silty clay (A-6b). The fine-grained soils were described as stiff to hard (N_{60} values ranging from 8 to 79 with an average of 21), brown to gray, damp to moist (natural moisture contents ranging from

12 to 31 with an average of 19) and moderately to highly plastic (plasticity indices ranging from 14 to 36 with an average of 28).

In B-006-0-24 and B-007-0-24, thinner layers (1.5 to 3.0 feet) of coarse-grained soils were encountered at various depths. These coarse-grained materials were visually described or classified as gravel and stone fragments with sand, silt, and clay (A-2-6). The soils were described as loose to very dense (N_{60} values ranging from 5 to 71 with an average of 29), brown to gray, and dry to damp (natural moisture contents ranging from 1 to 14 with an average 7).

Bedrock was encountered at depths ranging from 17.5 to 20.5 feet. A 1-to-3-foot-thick layer of weathered shale was augered prior to coring. The cored bedrock was described as interbedded gray shale and limestone. The shale was described as weak, severely to highly weathered, and thin bedded. The limestone was described as moderately strong, moderately weathered, and medium bedded. A minimum of 10 feet of bedrock was cored prior to termination. Core recoveries ranged from 29 to 100 percent and RQD values varied from 0 to 93 percent. Testing of two samples of shale bedrock resulted in unconfined compressive strengths of 26 and 42 psi. Groundwater was not observed during drilling; however, this may have been obscured by the addition of water during rock coring.

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

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.

It should be noted that borings were advanced outside of where the landslide failure surfaces were observed, and no borings were advanced downslope of the roadway. Therefore, the failure surfaces used in analyses were conservatively estimated based on the subsurface information, ODOT guidance, and previous project experience. The actual failure surfaces of the two landslides could differ from the failure surfaces assumed in the analyses.

5.2 DRILLED SHAFT WALL

It appears the two landslides are occurring along US Route 52 due to toe of slope erosion caused by the outside bend of the Ohio River. The slope instability may have propagated from the bank erosion at the toe of slope extending upward and outward into the roadway over time. ODOT has indicated that a drilled shaft wall downhill of US 52 was the preferred repair at each location. The procedure for drilled shaft wall design for landslide stabilization outlined Section 900 of the ODOT Geotechnical Design Manual (GDM) was generally followed.

To estimate the failure surfaces of the landslides, back analyses were performed at each location using conventional limit equilibrium method as implemented in GeoStudio SLOPE/W 2018 R2 software. Cross sections at Stations 1845+50 (SLM 36.85) and 1893+00 (SLM 37.65) were selected as representative of each landslides based on the field exploration and site observations. For each site, a subsurface stratigraphy consisting of cohesive soil and bedrock was modeled based on the soil and rock encountered in the borings. Failure surfaces along the soil-bedrock interfaces were assumed at each site. Therefore, a 2-foot layer of weak soil along the interface was modeled for both back analyses. The analysis cross sections are shown in Appendix E.

The foundation soils and the bedrock were given unit weight and shear strength parameters based on recommendations from the ODOT GDM and engineering judgement. For the landslide located at SLM 36.85, the friction angle of the weak layer was adjusted to 4.5 degrees, and for the landslide located at 37.65, the friction angle was adjusted to 9.5 degrees to achieve a factor of safety of 1.0. The material parameter derivations and results of the slope stability back analysis are provided in Appendix E.

The UA Slope Program was used to estimate the loading on the drilled shaft walls. The analysis cross sections and failure surfaces developed in the slope stability back analyses were modeled in the UA Slope Program. Firstly, as described in the ODOT GDM, existing conditions without the drilled shafts were analyzed. Drained friction angles in the weak zone of 9.0 degrees at SLM 36.85 and 11.0 degrees at SLM 37.65 were required to achieve a factor of safety of 1.00 in the UA Slope Program.

Using the same material parameters as to achieve the factor of safety of 1.00 in the UA Slope Program, the proposed drilled shaft wall geometry was analyzed. For the landslide located at SLM 36.85, the drilled shaft was modeled 47.5 feet right of the centerline of US 52 (14.5 feet from the proposed sawcut line), and a backfill height of 1.9 feet was assumed to be placed behind the wall to rebuild the shoulder. For the landslide located at SLM 37.65, the drilled shaft was modeled 52.0 feet right of the centerline of US 52 (14.5 feet from the proposed sawcut line), and a backfill of 1.1 feet was assumed to be placed behind the wall to rebuild the shoulder. For both the locations, fill material was assigned a cohesion of 250 psf, a friction angle of 28 degrees, and a unit weight of 125 pcf based on ODOT GDM Table 500-2 for A-6a or A-6b material.

For both sites, drilled shaft walls consisting of 3-foot diameter drilled shafts at 5.75 feet center-to-center spacing were analyzed. Unreinforced plug drilled shafts are recommended to be installed between the reinforced drilled shafts; therefore, it was assumed that the drilled shafts would take the full loading from the uphill slices without any arching or load transfer to the downhill slices. The resulting loads on the walls were 34.6 kips per shaft (SLM 36.85) and 35.3 kips per shaft (SLM 37.65). The results of UA Slope analyses are presented in Appendix F.

The loading estimated from UA Slope combined with traffic surcharge live loads of 250 psf were modelled as a trapezoidal distributed loads in drilled shaft analyses using LPile v2022 software. It was assumed that downhill soil above the assumed failure depth would provide no passive resistance because it was assumed that some movement would continue along that plane, creating a gap between the soil and the drilled shafts.

The boring and the laboratory testing results were used to estimate the soil and rock parameters used in LPile. A p-reduction factor was used in accordance with Section 903.5 of the GDM. Two layers of weak rock were modelled in the LPile software. The top 5 feet of bedrock, typically described as severely weathered shale, was modelled with an unconfined compressive strength of 8 psi, estimated based on the testing of the severely weathered shale. The lower weak rock layer was modelled with an unconfined compressive strength of 600 psi, based on the average of the testing performed on competent bedrock and the minimum unconfined compressive strength value provided in the GDM (Table 400-5). Calculations performed to estimate the bedrock parameters are provided in Appendix E.

The LPile analyses were performed considering both Service (I) and Strength (I) Limit States. A maximum deflection of 2 inches was considered at Service (I) Limit State, in accordance with ODOT GDM Section 903.8. At Strength (I) Limit State, steel sections were selected to withstand the maximum moment and shear values estimated from LPile at each site. The results of the LPile analysis are summarized in Table 2, and associated calculates are presented in Appendix G.

Table 2. Analysis Results

Site	Maximum Deflection (inches)	Maximum Moment (kip-feet)	Maximum Shear (kips)	Selected W-Section
SLM 36.85	1.95	757.2	102.3	W24x162
SLM 37.65	1.73	866.7	457.7	W27x129

5.3 RECOMMENDATIONS

The recommended details for the drilled shaft walls are presented in Table 3.

Table 3. Drilled Shaft Wall Recommendations

Drilled Shaft Wall Detail	SLM 36.85	SLM 37.65
Starting Station	1844+25	1891+90
Ending Station	1848+00	1894+40
Wall Length	375 ft	250 ft
Reinforced Shaft Diameter	3 ft	3 ft
Reinforced Shaft Spacing (center-to-center)	5.75 ft	5.75 ft
Reinforced Shaft Steel Section	W24x162	W27x129
Reinforced Shaft Socket into Bedrock	10 ft	10 ft
Offset to C/L of Reinforced Shaft (from C/L of US 52)	47.5 ft	52.0 ft
Offset to C/L of Reinforced Shaft (from proposed sawcut)	14.5 ft	14.5 ft
Unreinforced (Plug) Shaft Diameter	3 ft	3 ft
Unreinforced (Plug) Shaft Length (from proposed ground surface)	20 ft	15 ft

The starting and ending stations of the proposed drilled shaft walls were selected based on the boring locations and aerial imagery. To protect against loss of material through the drilled shaft wall, 3-foot diameter unreinforced plug drilled shafts are recommended to be installed between the reinforced drilled shafts. These shafts shall extend to depths of 20 and 15 feet from the existing ground surface for landslides located at SLM 36.85 and 37.65, respectively. It was assumed that the precast lagging would be used to build up the roadway shoulder. The precast lagging should be buried 4 feet from the proposed grade to retain the backfill.

Lengths of steel sections and drilled shafts along the length of the wall may vary based on depth to bedrock and proposed grade. The borings indicate a fairly consistent bedrock elevation along the wall alignments; however, the borings were advanced upslope of where the drilled shaft walls will be constructed, so exact bedrock elevations are unknown. The estimated top of bedrock elevations along the walls were estimated assuming a sloping bedrock surface of 1% percent toward the river. The estimated top of bedrock elevations along the walls are presented in the following table.

Table 4. Estimated Top of Bedrock Elevations along the Walls

SLM 36.85						
Station	1844+00	1844+23	1845+24	1846+16	1847+14	1848+00
Est. top of Rock Ele. (ft)	471.6	472.2	474.3	475.1	475.7	476.2

SLM 37.65					
Station	1891+40	1891+56	1893+05	1893+99	1894+60
Est. top of Rock Ele. (ft)	472.8	473.2	476.8	476.4	476.1

Note: The top of bedrock elevations were estimated assuming a sloping bedrock perpendicular to US 52.

APPENDIX A
BORING LOCATIONS

Boring Locations

HAM-52-36.85

SLM 36.85


HAM-52-36.85
SLM 36.85
B-001-0-24, B-002-0-24, B-003-0-024 & B-004-0-24
B-001-0-24
B-002-0-24
B-003-0-24
B-004-0-24
Google Earth
Image Landsat / Copernicus
N
100 ft

Boring Locations

HAM-52-36.85

SLM 37.65


HAM-52-36.85
SLM 37.65
B-005-0-24, B-006-0-24 & B-007-0-24
B-005-0-24
B-006-0-24
B-007-0-24
Google Earth
Image Landsat / Copernicus
N
100 ft

APPENDIX B
BORING LOGS

Boring Logs

HAM-52-36.85

SLM 36.85

S&ME JOB: 23780169

PROJECT: HAM-US-52-36.85	DRILLING FIRM / OPERATOR: S&ME / B. KEYNON	DRILL RIG: S&ME CME 550X (R50)	STATION / OFFSET: 1844+23, 30' RT
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: S&ME / S. MARAHATTA	HAMMER: CME AUTOMATIC	ALIGNMENT: US 52
PID: 116046 BR ID: N/A	DRILLING METHOD: 3-1/4" HSA / NQ2	CALIBRATION DATE: 3/31/21	ELEVATION: 504.6 (MSL) EOB: 44.83 ft.
START: 2/27/24 END: 2/27/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 78.7	LAT / LONG: 39.045069 N, -84.376600 W

EXPLORATION ID **B-001-0-24**

MATERIAL DESCRIPTION AND NOTES	ELEV. 504.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASPHALT (4 INCHES)	504.2																	
CONCRETE (8 INCHES)	503.6																	
VERY STIFF, BROWN AND GRAY, **CLAY**, TRACE SAND, SOME GRAVEL, SLIGHTLY ORGANIC, MOIST	502.1		4 6 6	16	67	SS-1	3.5	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
STIFF, BROWN AND GRAY, **SANDY SILT**, LITTLE CLAY, LITTLE GRAVEL, DAMP	500.6		6 7 7	18	39	SS-2		14	9	34	28	15	23	14	9	10	A-4a (2)	
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, TRACE SAND, TRACE GRAVEL, MOIST TO DAMP	494.6		3 4 7	14	56	SS-3	4.5	-	-	-	-	-	-	-	-	22	A-7-6 (V)	
			3 4 8	16	67	SS-4	4.5	10	6	2	33	49	58	26	32	21	A-7-6 (20)	
			3 4 6	13	56	SS-5	4.5	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
			4 8 9	22	44	SS-6	4.5	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
HARD TO VERY STIFF, BROWN AND GRAY, **CLAY**, SOME SILT, LITTLE LIMESTONE FRAGMENTS, TRACE SAND, MOIST TO DAMP	490.1		4 5 10	20	67	SS-7	4.5	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
			4 7 10	22	67	SS-8	4.5	13	4	2	33	48	48	22	26	20	A-7-6 (16)	
			4 8 9	22	67	SS-9	4	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
HARD TO STIFF, BROWN AND GRAY, **SILT AND CLAY**, TRACE LIMESTONE FRAGMENTS, MOIST	487.1		9 9 10	25	22	SS-10	4.5	-	-	-	-	-	-	-	-	20	A-6a (V)	
			4 7 8	20	22	SS-11		-	-	-	-	-	-	-	-	16	A-6a (V)	
VERY STIFF TO MEDIUM STIFF, BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE GRAVEL, MOIST			6 6 5	14	33	SS-12	4	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
			5 7 8	20	44	SS-13	0.75	2	5	3	44	46	46	20	26	24	A-7-6 (16)	
			5 6 8	18	22	SS-14	0.5	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
trace limestone floaters encountered from 22 to 23.5 feet	481.1		4 5 6	14	33	SS-15	0.5	-	-	-	-	-	-	-	-	28	A-7-6 (V)	
STIFF TO HARD, OLIVE BROWN AND GRAY, **CLAY**, SOME SILT, TRACE SAND, LITTLE LIMESTONE FRAGMENTS, MOIST	478.1		6 9 11	26	44	SS-16	1.75	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
			8 10 12	29	56	SS-17	4.5	-	-	-	-	-	-	-	-	22	A-7-6 (V)	
VERY STIFF TO HARD, BROWN AND GRAY, **CLAY**, "AND" LIMESTONE FRAGMENTS, SOME SILT, TRACE SAND, DAMP TO MOIST		W 477.6	8 10 10	26	67	SS-18		40	6	3	22	29	47	21	26	21	A-7-6 (10)	
			10 19 19	50	56	SS-19		-	-	-	-	-	-	-	-	25	A-7-6 (V)	
			50-4"	-	100													

PLATE 1

S&ME JOB: 23780169

PID: 116046	BR ID: N/A	PROJECT: HAM-US-52-36.85	STATION / OFFSET: 1844+23, 30' RT	START: 2/27/24	END: 2/27/24	PG 2 OF 2	**B-001-0-24**

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
	474.6																	
	473.6					SS-20		-	-	-	-	-	-	-	-	25	A-7-6 (V)	
INTERBEDDED SHALE (80%) AND LIMESTONE (20%), RQD 40%, REC. 90%; **SHALE**, GRAY, SEVERELY TO HIGHLY WEATHERED, VERY WEAK TO WEAK, FINE GRAINED, THIN BEDDED; **LIMESTONE**, GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG.		TR 31	35 50-4"	-	80	SS-21		-	-	-	-	-	-	-	-	10	Rock (V)	
		32																
		33	50-2"	-	100	SS-22		-	-	-	-	-	-	-	-	3	Rock (V)	
		34																
		35	22		83	NQ											CORE	
		36																
		37																
		38	53		100	NQ											CORE	
		39																
		40																
		41																
		42																
		43	31		81	NQ											CORE	
		44																
	459.7	EOB																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED BENTONITE GROUT

S&ME JOB: 23780169

PROJECT: HAM-US-52-36.85	DRILLING FIRM / OPERATOR: S&ME / B. KEYNON	DRILL RIG: S&ME CME 550X (R50)	STATION / OFFSET: 1845+24, 30' RT	EXPLORATION ID B-002-0-24
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: S&ME / S. MARAHATTA	HAMMER: CME AUTOMATIC	ALIGNMENT: US 52	
PID: 116046 BR ID: N/A	DRILLING METHOD: 3-1/4" HSA / NQ2	CALIBRATION DATE: 3/31/21	ELEVATION: 503.7 (MSL) EOB: 41.3 ft.	PAGE 1 OF 2
START: 2/28/24 END: 2/28/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 78.7	LAT / LONG: 39.045003 N, -84.376256 W	

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 (4 INCHES)	503.4																	
CONCRETE (8 INCHES)	502.7																	
LOOSE, GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND AND SILT**, SLIGHTLY ORGANIC, DRY	501.2		3 3 2	7	22	SS-1		-	-	-	-	-	-	-	-	7	A-2-4 (V)	
STIFF TO HARD, BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE GRAVEL, TRACE SAND, MOIST TO DAMP			3 3 3	8	56	SS-2	1.75	8	7	2	42	41	48	23	25	27	A-7-6 (16)	
			4 4 6	13	33	SS-3	1.75	-	-	-	-	-	-	-	-	22	A-7-6 (V)	
			5 7 6	17	67	SS-4	4.5	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
	495.2		3 5 6	14	100	SS-5	4.25	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, TRACE SAND, DAMP	493.7		3 5 8	17	28	SS-6	4.5	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
VERY STIFF TO HARD, BROWN AND GRAY, **CLAY**, SOME SILT, LITTLE GRAVEL, TRACE SAND, DAMP TO MOIST			8 10 11	28	33	SS-7	2.5	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
			5 8 11	25	33	SS-8	4.5	16	7	2	31	44	51	24	27	17	A-7-6 (17)	
	489.2		3 10 11	28	56	SS-9	4.5	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
VERY STIFF TO MEDIUM STIFF, BROWN AND GRAY, **CLAY**, SOME SILT, LITTLE GRAVEL, TRACE SAND, DAMP TO MOIST			3 5 5	13	56	SS-10	3.5	-	-	-	-	-	-	-	-	26	A-7-6 (V)	
			3 4 5	12	100	SS-11	2.5	-	-	-	-	-	-	-	-	27	A-7-6 (V)	
slightly organics soil from 17.5 to 19 feet			3 5 5	13	67	SS-12	1.75	-	-	-	-	-	-	-	-	26	A-7-6 (V)	
	483.2		3 5 4	12	67	SS-13	0.5	-	-	-	-	-	-	-	-	30	A-7-6 (V)	
STIFF, RED BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, TRACE ORGANICS, MOIST	481.7		3 2 3	7	67	SS-14	1.5	1	3	3	50	43	47	20	27	27	A-7-6 (16)	
STIFF, RED BROWN AND GRAY, **CLAY**, TRACE SAND, "AND" LIMESTONE FRAGMENTS, MOIST	480.2		13 32 30	81	67	SS-15	2	-	-	-	-	-	-	-	-	26	A-7-6 (V)	
HARD, BROWN AND GRAY, **SILTY CLAY**, AND LIMESTONE FRAGMENTS, LITTLE SAND, MOIST	478.7	W 479.7	18 29 34	83	67	SS-16		42	8	7	26	17	36	16	20	19	A-6b (4)	
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, TRACE SAND, SOME LIMESTONE FRAGMENTS, MOIST	477.2		29 19 13	42	67	SS-17		30	7	4	30	29	43	18	25	23	A-7-6 (11)	
VERY DENSE, BROWN AND GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, WET	475.7	TR	30 50-1"	-	57	SS-18		-	-	-	-	-	-	-	-	21	A-2-6 (V)	
			50-2"	-	100	SS-19		-	-	-	-	-	-	-	-	15	Rock (V)	
			50-2"	-	100													

S&ME ODOT LOG (8.5X11) - SGE 01/2019 - OH DOT.GDT - 4/11/24 11:23 - T:\CINCINNATI-1178\PROJECTS\2023\23780169_STANTEC_HAM-52-36.85_CINCINNATI OH\GEO\PROJEC

PLATE 3

S&ME JOB: 23780169

PID: 116046	BR ID: N/A	PROJECT: HAM-US-52-36.85	STATION / OFFSET: 1845+24, 30' RT	START: 2/28/24	END: 2/28/24	PG 2 OF 2	**B-002-0-24**

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
	473.7					SS-20		-	-	-	-	-	-	-	-	6	Rock (V)	
INTERBEDDED SHALE (68%) AND LIMESTONE (32%), RQD 55.5%, REC. 100%; **SHALE**, GRAY, SEVERELY TO HIGHLY WEATHERED, VERY WEAK TO WEAK, FINE GRAINED, THIN BEDDED; **LIMESTONE**, GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG. *(continued)*		31	61		100	NQ-RC-1												CORE
		34																
		35	60		100	NQ-RC-2												CORE
		38																
		39	42		100	NQ-RC-3												CORE
	462.4	41 EOB																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED BENTONITE GROUT

S&ME JOB: 23780169

PROJECT: HAM-US-52-36.85	DRILLING FIRM / OPERATOR: S&ME / B. KEYNON	DRILL RIG: S&ME CME 550X (R50)	STATION / OFFSET: 1846+16, 29' RT	EXPLORATION ID B-003-0-24
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: S&ME / S. MARAHATTA	HAMMER: CME AUTOMATIC	ALIGNMENT: US 52	
PID: 116046 BR ID: N/A	DRILLING METHOD: 3-1/4" HSA / NQ2	CALIBRATION DATE: 3/31/21	ELEVATION: 503.0 (MSL) EOB: 40.0 ft.	PAGE 1 OF 2
START: 2/29/24 END: 2/29/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 78.7	LAT / LONG: 39.044948 N, -84.375940 W	

MATERIAL DESCRIPTION AND NOTES	ELEV. 503.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASPHALT (4 INCHES)	502.6																	
CONCRETE (8 INCHES)	502.0																	
VERY STIFF, BROWN AND GRAY, **CLAY**, TRACE SAND, TRACE GRAVEL, SLIGHTLY ORGANIC, DAMP	500.5	1	3 5 3	10	33	SS-1	2.5	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, SOME SAND, SOME GRAVEL, DAMP	499.0	2	4 6 5	14	33	SS-2	4.5	22	21	8	23	26	52	22	30	18	A-7-6 (10)	
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, TRACE SAND, TRACE GRAVEL, DAMP	497.5	3	4 5 7	16	44	SS-3	4.5	-	-	-	-	-	-	-	-	22	A-7-6 (V)	
HARD, BROWN, **CLAY**, SOME SILT, TRACE SAND, TRACE GRAVEL, DAMP	496.0	4	7 8 9	22	22	SS-4	4.5	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
MEDIUM DENSE, BROWN AND GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP	494.5	5	9 13 7	26	44	SS-5		66	2	1	12	19	39	15	24	7	A-2-6 (2)	
STIFF, BROWN, **CLAY**, SOME SILT, SOME LIMESTONE FRAGMENTS, TRACE SAND, DAMP	488.5	6	5 8 7	20	22	SS-6	4.5	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
		7	10 6 5	14	44	SS-7	4.5	29	6	3	26	36	47	20	27	14	A-7-6 (13)	
		8	6 8 6	18	22	SS-8	4.5	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
		9	5 5 10	20	56	SS-9	4.5	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
STIFF, BROWN AND GRAY, **CLAY**, "AND" SILT, LITTLE LIMESTONE FRAGMENTS, TRACE SAND, MOIST TO DAMP	485.5	10	7 7 5	16	44	SS-10	2	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
		11	4 5 6	14	22	SS-11		13	2	3	42	40	47	22	25	22	A-7-6 (15)	
VERY STIFF TO STIFF, RED BROWN, **CLAY**, SOME SILT, TRACE LIMESTONE FRAGMENTS, TRACE SAND, MOIST	482.5	12	3 4 4	10	56	SS-12	2.25	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
		13	2 3 3	8	67	SS-13	1	-	-	-	-	-	-	-	-	27	A-7-6 (V)	
STIFF TO HARD, BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, TRACE LIMESTONE FRAGMENTS, MOIST TO WET	479.5	14	7 7 10	22	56	SS-14	1.25	2	2	4	53	39	44	20	24	27	A-7-6 (14)	
		15	20 27 35	81	67	SS-15	4.5	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
VERY DENSE, BROWN AND GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP Limestone floaters encountered	473.5	W 480.0 16	50-4"	-	75	SS-16		-	-	-	-	-	-	-	-	3	A-1-b (V)	
		17	18 50-1"	-	86	SS-17		-	-	-	-	-	-	-	-	16	A-2-6 (V)	
		18	30 38 50-2"	-	71	SS-18		-	-	-	-	-	-	-	-	11	A-1-b (V)	
		19	30 50-1"	-	86	SS-19		-	-	-	-	-	-	-	-	14	A-2-6 (V)	
		TR 29																

PLATE 5

S&ME JOB: 23780169

PID: 116046	BR ID: N/A	PROJECT: HAM-US-52-36.85	STATION / OFFSET: 1846+16, 29' RT	START: 2/29/24	END: 2/29/24	PG 2 OF 2	B-003-0-24

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
INTERBEDDED SHALE (70%) AND LIMESTONE (30%), RQD 58.7%, REC. 100%; **SHALE**, GRAY, SEVERELY TO HIGHLY WEATHERED, VERY WEAK TO WEAK, FINE GRAINED, THIN BEDDED; **LIMESTONE**, GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG. *(continued)*	473.0	31	60		100	NQ-RC-1											CORE	
		32																
		33	60		100	NQ-RC-2											CORE	
		34																
		35																
		36																
		37																
		38	57		100	NQ-RC-3											CORE	
		39																
	463.0	EOB 40																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED BENTONITE GROUT

PLATE 9

S&ME JOB: 23780169

PROJECT: HAM-US-52-36.85	DRILLING FIRM / OPERATOR: S&ME / B. KEYNON	DRILL RIG: S&ME CME 550X (R50)	STATION / OFFSET: 1847+14, 30' RT
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: S&ME / S. MARAHATTA	HAMMER: CME AUTOMATIC	ALIGNMENT: US 52
PID: 116046 BR ID: N/A	DRILLING METHOD: 3-1/4" HSA / NQ2	CALIBRATION DATE: 3/31/21	ELEVATION: 502.1 (MSL) EOB: 39.16 ft.
START: 3/1/24 END: 3/1/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 78.7	LAT / LONG: 39.044883 N, -84.375603 W

EXPLORATION ID **B-004-0-24**

PAGE 1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 502.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
ASHPHALT (3 INCHES)	501.8																	
CONCRETE (8 INCHES)	501.2																	
LOOSE, BROWN AND GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP	499.6	1	3 4 4	10	33	SS-1		-	-	-	-	-	-	-	-	21	A-2-6 (V)	
HARD, BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, DAMP TO MOIST		2	5 5 6	14	44	SS-2	4.5	0	1	2	46	51	51	24	27	22	A-7-6 (17)	
		3	3 5 8	17	89	SS-3	4.5	-	-	-	-	-	-	-	-	22	A-7-6 (V)	
		4	4 5 6	14	100	SS-4	4.5	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
		5	2 5 21	34	89	SS-5	4.5	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
	493.6	6																
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, TRACE GRAVEL, TRACE SAND, DAMP	492.1	7	4 6 7	17	78	SS-6	4	5	5	3	34	53	56	23	33	15	A-7-6 (19)	
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, TRACE GRAVEL, TRACE SAND, MOIST		8	3 5 8	17	67	SS-7	4.5	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
	489.1	9	5 7 11	24	100	SS-8	4.5	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, TRACE SAND, SOME LIMESTONE FRAGMENTS, MOIST	487.6	10	8 14 40	71	56	SS-9	4.5	-	-	-	-	-	-	-	-	12	A-7-6 (V)	
VERY STIFF, BROWN AND GRAY, **CLAY**, LITTLE SILT, TRACE SAND, "AND" LIMESTONE FRAGMENTS, DAMP	486.1	11	13 11 18	38	44	SS-10		46	6	3	19	26	51	19	32	15	A-7-6 (9)	
VERY STIFF, BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, SLIGHLTY ORGANIC, DAMP	483.1	12	9 6 7	17	89	SS-11	2.5	2	3	2	48	45	49	22	27	22	A-7-6 (17)	
		13	3 3 6	12	100	SS-12	2.75	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
STIFF, RED BROWN, **CLAY**, SOME SILT, "AND" LIMESTONE FRAGMENTS, LITTLE SAND, DAMP	481.6	14	4 6 8	18	100	SS-13		39	5	7	29	20	41	19	22	13	A-7-6 (7)	
VERY STIFF TO HARD, BROWN AND GRAY, **CLAY**, SOME LIMESTONE FRAGMENTS, MOIST TO DAMP		15	13 9 9	24	100	SS-14	2.5	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
		16	8 14 50-5"	-	24	SS-15	4.5	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
		17	30 28 50-4"	-	25	SS-16	4.5	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
	477.1	18	25 50-1"	-	14	SS-17		-	-	-	-	-	-	-	-	12	A-2-6 (V)	
VERY DENSE, BROWN AND GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, SOME LIMESTONE FRAGMENTS, DRY	475.6	TR 19	50-5"	-	80	SS-18		-	-	-	-	-	-	-	-	9	Rock (V)	
		20																
		21																
		22																
		23																
		24																
		25																
		26																
		27	71		100	NQ-RC-1											CORE	
		28																
		29																

PLATE 7

S&ME JOB: 23780169

PID: 116046	BR ID: N/A	PROJECT: HAM-US-52-36.85	STATION / OFFSET: 1847+14, 30' RT	START: 3/1/24	END: 3/1/24	PG 2 OF 2	**B-004-0-24**

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
INTERBEDDED SHALE (70%) AND LIMESTONE (30%), RQD 59.2%, REC. 100%; **SHALE**, GRAY, SEVERELY TO HIGHLY WEATHERED, VERY WEAK TO WEAK, FINE GRAINED, THIN BEDDED; **LIMESTONE**, GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG. *(continued)*	472.1	31	57		100	NQ-RC-2											CORE	
		36	58		100	NQ-RC-3											CORE	
	462.9	EOB 39																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED BENTONITE GROUT

Boring Logs

HAM-52-36.85

SLM 37.65

S&ME JOB: 23780169

PROJECT: HAM-US-52-36.85	DRILLING FIRM / OPERATOR: S&ME / B. KEYNON	DRILL RIG: S&ME CME 550X (R50)	STATION / OFFSET: 1891+56, 33' RT	EXPLORATION ID B-005-0-24
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: S&ME / S. MARAHATTA	HAMMER: CME AUTOMATIC	ALIGNMENT: US 52	
PID: 116046 BR ID: N/A	DRILLING METHOD: 3-1/4" HSA / NQ2	CALIBRATION DATE: 3/31/21	ELEVATION: 498.4 (MSL) EOB: 34.58 ft.	PAGE 1 OF 2
START: 3/4/24 END: 3/4/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 78.7	LAT / LONG: 39.042159 N, -84.360360 W	

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
	498.4																	
ASPHALT (2 INCHES)	498.3																	
CONCRETE (7 INCHES)	497.7																	
SUBBASE (3 INCHES)	497.4																	
STIFF, BROWN AND GRAY, **CLAY**, "AND" SILT, LITTLE GRAVEL, LITTLE SAND, MOIST	495.9		4 5 6	14	33	SS-1	1.25	16	12	6	36	30	45	19	26	20	A-7-6 (13)	
VERY STIFF, BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, SLIGHTLY ORGANIC, MOIST TO DAMP			5 5 3	10	33	SS-2	2	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
			2 3 5	10	67	SS-3	3.25	-	-	-	-	-	-	-	-	31	A-7-6 (V)	
			3 5 7	16	67	SS-4	3.5	0	0	2	42	56	61	25	36	25	A-7-6 (20)	
	489.9		4 5 8	17	50	SS-9	3	-	-	-	-	-	-	-	-	28	A-7-6 (V)	
HARD, BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, MOIST			3 4 8	16	78	SS-6	4.25	0	0	2	49	49	51	21	30	22	A-7-6 (18)	
			3 4 8	16	100	SS-7	4.5	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
	485.4		2 3 6	12	78	SS-8	4.5	1	0	2	61	36	47	20	27	21	A-7-6 (16)	
HARD, BROWN AND YELLOW, **CLAY**, SOME SILT, TRACE SAND, MOIST	483.9		1 3 6	12	100	SS-9	4.5	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
HARD, BROWN, **CLAY**, SOME SILT, "AND" LIMESTONE FRAGMENTS, TRACE SAND, DAMP TO MOIST			2 12 15	35	67	SS-10	4.5	44	6	4	25	21	44	18	26	13	A-7-6 (7)	
			50-4"	-	100	SS-11	4.5	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
	479.4		28 30 30	79	56	SS-12	4.5	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, "AND" LIMESTONE FRAGMENTS, LITTLE SAND, DAMP	477.9	TR	31 27 30	75	83	SS-13	4.5	-	-	-	-	-	-	-	-	12	A-7-6 (V)	
INTERBEDDED SHALE (77%) AND LIMESTONE (23%), RQD 49.6%, REC. 100%; **SHALE**, GRAY, SEVERELY TO HIGHLY WEATHERED, VERY WEAK TO WEAK, FINE GRAINED, THIN BEDDED; **LIMESTONE**, GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG.			15 43 40-3"	-	120	SS-14	4.5	-	-	-	-	-	-	-	-	12	Rock (V)	
			50-3"	-		SS-15		-	-	-	-	-	-	-	-	13	Rock (V)	
			28		100	NQ-RC-1											CORE	
			53		100	NQ-RC-2											CORE	

S&ME ODOT LOG (8.5X11) - SGE 01/2019 - OH DOT.GDT - 4/11/24 11:23 - T:\CINCINNATI-1178\PROJECTS\2023\23780169_STANTEC_HAM-52-36.85_CINCINNATI OH\GEO\PROJEC

PLATE 9

S&ME JOB: 23780169

PID: 116046	BR ID: N/A	PROJECT: HAM-US-52-36.85	STATION / OFFSET: 1891+56, 33' RT	START: 3/4/24	END: 3/4/24	PG 2 OF 2	**B-005-0-24**

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
INTERBEDDED SHALE (77%) AND LIMESTONE (23%), RQD 49.6%, REC. 100%; **SHALE**, GRAY, SEVERELY TO HIGHLY WEATHERED, VERY WEAK TO WEAK, FINE GRAINED, THIN BEDDED; **LIMESTONE**, GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG. *(continued)*	468.4	31 32 33 34	53		100	NQ-RC-3											CORE	
	463.9	EOB																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED BENTONITE GROUT

PLATE 10

S&ME JOB: 23780169

PROJECT: HAM-US-52-36.85	DRILLING FIRM / OPERATOR: S&ME / B. KEYNON	DRILL RIG: S&ME CME 550X (R50)	STATION / OFFSET: 1893+05, 34' RT
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: S&ME / S. MARAHATTA	HAMMER: CME AUTOMATIC	ALIGNMENT: US 52
PID: 116046 BR ID: N/A	DRILLING METHOD: 3-1/4" HSA / NQ2	CALIBRATION DATE: 3/31/21	ELEVATION: 499.0 (MSL) EOB: 29.5 ft.
START: 3/5/24 END: 3/5/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 78.7	LAT / LONG: 39.042054 N, -84.359854 W

EXPLORATION ID **B-006-0-24**

PAGE 1 OF 1

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
	499.0																	
ASPHALT (2 INCHES)	498.9																	
CONCRETE (6 INCHES)	498.2																	
SUBBASE (4 INCHES)	498.0																	
VERY STIFF TO HARD, BROWN AND GRAY, **CLAY**, "AND" SILT, LITTLE GRAVEL, LITTLE SAND, DAMP	495.0	1	3 4 7	14	33	SS-1	2.5	14	8	5	38	35	46	20	26	20	A-7-6 (15)	
		2																
		3	7 8 50-3"	-	20	SS-2	4.5	-	-	-	-	-	-	-	-	12	A-7-6 (V)	
VERY DENSE, BROWN AND GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DRY	493.5	4	42 50-3"	-	11	SS-3		-	-	-	-	-	-	-	-	1	A-2-6 (V)	
		5																
HARD, BROWN AND GRAY, **CLAY**, SOME SILT, LITTLE GRAVEL, TRACE SAND, MOIST	492.0	6	14 12 7	25	17	SS-4	4.5	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
VERY STIF TO HARD, BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE GRAVEL, TRACE SAND, DAMP slightly organic from 7 to 8.5 feet		7	5 5 7	16	33	SS-5	3.5	7	4	3	44	42	49	20	29	19	A-7-6 (17)	
		8	7 7 7	18	33	SS-6	4.25	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
	487.5	9	5 6 6	16	67	SS-7	3.75	1	2	2	56	39	55	23	32	22	A-7-6 (19)	
		10																
HARD, BROWN, **CLAY**, SOME SILT, TRACE SAND, LITTLE GRAVEL, MOIST	486.0	11	4 11 9	26	67	SS-8	4.5	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
HARD, RED BROWN, **CLAY**, "AND" SILT, TRACE SAND, SLIGHTLY ORGANIC, MOIST	484.5	12	3 4 7	14	83	SS-9	4.25	0	1	9	50	40	44	18	26	21	A-7-6 (15)	
		13																
VERY DENSE, BROWN AND GRAY, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP	483.0	14	4 11 50-5"	-	71	SS-10		68	10	5	10	7	-	-	-	5	A-2-6 (V)	
Limestone floaters encountered		15																
	481.5	16	50-1"	-	100	SS-11		-	-	-	-	-	-	-	-	18	A-7-6 (V)	
HARD, BROWN, **CLAY**, MOIST Limestone floaters encountered		17																
		18	16 50-2"	-		SS-12		-	-	-	-	-	-	-	-	11	Rock (V)	
INTERBEDDED SHALE (72%) AND LIMESTONE (28%), RQD 37.2%, REC. 93%; **SHALE**, GRAY, SEVERELY TO HIGHLY WEATHERED, VERY WEAK TO WEAK, FINE GRAINED, THIN BEDDED; **LIMESTONE**, GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG.		19	0		67	NQ-RC-1											CORE	
		20																
		21																
		22	35		100	NQ-RC-2											CORE	
		23																
		24																
		25																
		26																
		27	50		93	NQ-RC-3											CORE	
		28																
	469.5	29																
		EOB																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED BENTONITE GROUT

S&ME JOB: 23780169

PROJECT: HAM-US-52-36.85	DRILLING FIRM / OPERATOR: S&ME / B. KEYNON	DRILL RIG: S&ME CME 550X (R50)	STATION / OFFSET: 1893+99, 34' RT
TYPE: ROADWAY	SAMPLING FIRM / LOGGER: S&ME / S. MARAHATTA	HAMMER: CME AUTOMATIC	ALIGNMENT: US 52
PID: 116046 BR ID: N/A	DRILLING METHOD: 3-1/4" HSA / NQ2	CALIBRATION DATE: 3/31/21	ELEVATION: 499.3 (MSL) EOB: 28.83 ft.
START: 3/5/24 END: 3/5/24	SAMPLING METHOD: SPT	ENERGY RATIO (%): 78.7	LAT / LONG: 39.041982 N, -84.359535 W

EXPLORATION ID **B-007-0-24**

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 (2 INCHES)	499.1																	
CONCRETE (6 INCHES)	498.4																	
SUBBASE (4 INCHES)	498.3																	
STIFF, BROWN AND GRAY, **CLAY**, SOME SILT, TRACE GRAVEL, SLIGHTLY ORGANIC, MOIST	495.3		5 4 3	9	50	SS-1	2	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
VERY STIFF, BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, TRACE GRAVEL, MOIST	493.8		15 5 4	12	0	SS-2		-	-	-	-	-	-	-	-	-	A-7-6 (V)	
STIFF, BROWN, **CLAY**, SOME SILT, TRACE GRAVEL, MOIST	492.3		5 4 4	10	67	SS-3	2.75	6	4	3	37	50	50	20	30	20	A-7-6 (18)	
LOOSE TO VERY LOOSE, BROWN, **GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, DAMP	489.3		3 3 3	8	33	SS-4	1.75	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
VERY STIFF, RED BROWN, **CLAY**, "AND" SILT, LITTLE SAND, TRACE GRAVEL, MOIST	486.3		3 4 4	10	33	SS-5		63	14	4	12	7	29	15	14	6	A-2-6 (0)	
STIFF, RED BROWN, **SILTY CLAY**, "AND" SILT, LITTLE SAND, TRACE GRAVEL, MOIST	484.8		3 2 2	5	33	SS-6		-	-	-	-	-	-	-	-	14	A-2-6 (V)	
HARD, BROWN, **CLAY**, SOME SILT, SOME LIMESTONE FRAGMENTS, TRACE SAND, MOIST	481.0		2 3 3	8	67	SS-7	2	8	6	5	36	45	48	20	28	24	A-7-6 (17)	
			2 3 5	10	83	SS-8	2.5	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
			2 3 8	14	100	SS-9	1.5	9	3	11	48	29	36	17	19	21	A-6b (12)	
			5 23 16	51	67	SS-10	4	26	3	3	30	38	57	21	36	19	A-7-6 (17)	
			12 13 25	50	67	SS-11	4.5	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
		TR	10 50-3" 0	-	89	SS-12		-	-	-	-	-	-	-	-	17	A-7-6 (V)	
INTERBEDDED SHALE (82%) AND LIMESTONE (18%), RQD 39.4%, REC. 89%; **SHALE**, GRAY, SEVERELY TO HIGHLY WEATHERED, VERY WEAK TO WEAK, FINE GRAINED, THIN BEDDED; **LIMESTONE**, GRAY, MODERATELY WEATHERED, MODERATELY STRONG TO STRONG.					29	NQ-RC-1											CORE	
			30		85	NQ-RC-2											CORE	
			53		100	NQ-RC-3		-	-	-	-	-	-	-	-	-	CORE	
	470.4	EOB																

NOTES: NONE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: ASPHALT PATCH; TREMIED BENTONITE GROUT

PLATE 12

APPENDIX C

ROCK CORE PHOTOGRAPHS

Rock Core Photographs

HAM-52-36.85

SLM 36.85

Date: 3/8/2024

Photographer: Suman Marahatta

1	**Location / Orientation**	B-001-0-24
	Remarks	34 to 44.83 feet

Date: 3/8/2024

Photographer: Suman Marahatta

2	**Location / Orientation**	B-002-0-24
	Remarks	30.2 to 41.3 feet

Photographer: Suman Marahatta | Date: 3/8/2024

3	**Location / Orientation**	B-003-0-24
	Remarks	29.5 to 40 feet

Photographer: Suman Marahatta | Date: 3/8/2024

4	**Location / Orientation**	B-004-0-24
	Remarks	28.75 to 39.16 feet

Rock Core Photographs

HAM-52-36.85

SLM 37.65

Date: 3/8/2024

Photographer: Suman Marahatta

5	**Location / Orientation**	B-005-0-24
	Remarks	23.5 to 34.583 feet

Date: 3/8/2024

Photographer: Suman Marahatta

6	**Location / Orientation**	B-006-0-24
	Remarks	18.75 to 29.5 feet

Date: 3/8/2024

Photographer: Suman Marahatta

7	**Location / Orientation**	B-007-0-24
	Remarks	18.25 to 28.233 feet

APPENDIX D

LABORATORY TESTING RESULTS

Laboratory Testing Results

Moisture Content

HAM-52-36.85

SLM 36.85 and SLM 37.65

SUMMARY OF LABORATORY TEST RESULTS

BORING	SAMPLE (#)	Top Depth (ft)	MC %	LL %	PL %	PI %	AGGREGATE %	COARSE SAND %	FINE SAND %	SILT %	CLAY %	SILT/CLAY %	D / 50 m m	D / 95 m m	H R B ODOT CLASSIFICATION
B-001-0-24		1.00	18												A-7-6 (V)
B-001-0-24		2.50	10	23	14	9	14	9	34	28	15		0.1307	20.0407	A-4a (2)
B-001-0-24		4.00	22												A-7-6 (V)
B-001-0-24		5.50	21	58	26	32	10	6	2	33	49		0.0052	5.1076	A-7-6 (20)
B-001-0-24		7.00	24												A-7-6 (V)
B-001-0-24		8.50	23												A-7-6 (V)
B-001-0-24		10.00	21												A-7-6 (V)
B-001-0-24		11.50	20	48	22	26	13	4	2	33	48		0.0056	29.2867	A-7-6 (16)
B-001-0-24		13.00	23												A-7-6 (V)
B-001-0-24		14.50	20												A-6a (V)
B-001-0-24		16.00	16												A-6a (V)
B-001-0-24		17.50	20												A-7-6 (V)
B-001-0-24		19.00	24	46	20	26	2	5	3	44	46		0.0064	0.8139	A-7-6 (16)
B-001-0-24		20.50	24												A-7-6 (V)
B-001-0-24		22.00	28												A-7-6 (V)
B-001-0-24		23.50	25												A-7-6 (V)
B-001-0-24		25.00	22												A-7-6 (V)
B-001-0-24		26.50	21	47	21	26	40	6	3	22	29		0.0689	30.5672	A-7-6 (10)
B-001-0-24		28.00	25												A-7-6 (V)
B-001-0-24		29.50	25												A-7-6 (V)
B-001-0-24		31.00	10												Rock (V)
B-001-0-24		32.50	3												Rock (V)
B-002-0-24		1.00	7												A-2-4 (V)
B-002-0-24		2.50	27	48	23	25	8	7	2	42	41		0.0087	2.8538	A-7-6 (16)
B-002-0-24		4.00	22												A-7-6 (V)
B-002-0-24		5.50	21												A-7-6 (V)
B-002-0-24		7.00	24												A-7-6 (V)
B-002-0-24		8.50	23												A-7-6 (V)
B-002-0-24		10.00	20												A-7-6 (V)
B-002-0-24		11.50	17	51	24	27	16	7	2	31	44		0.0086	28.5802	A-7-6 (17)

PROJECT HAM-52-36.85
LOCATION HAMILTON COUNTY, OHIO
JOB NO. 23780169 **DATE** 4/1/24

SUMMARY OF LABORATORY TEST RESULTS

BORING	SAMPLE (#)	Top Depth (ft)	MC %	LL %	PL %	PI %	AGGREGATE %	COARSE SAND %	FINE SAND %	SILT %	CLAY %	SILT/CLAY %	D / 50 m m	D / 95 m m	H R B ODOT CLASSIFICATION
B-002-0-24		13.00	21												A-7-6 (V)
B-002-0-24		14.50	26												A-7-6 (V)
B-002-0-24		16.00	27												A-7-6 (V)
B-002-0-24		17.50	26												A-7-6 (V)
B-002-0-24		19.00	30												A-7-6 (V)
B-002-0-24		20.50	27	47	20	27	1	3	3	50	43		0.0073	0.1883	A-7-6 (16)
B-002-0-24		22.00	26												A-7-6 (V)
B-002-0-24		23.50	19	36	16	20	42	8	7	26	17		0.4238	23.3242	A-6b (4)
B-002-0-24		25.00	23	43	18	25	30	7	4	30	29		0.0324	28.0706	A-7-6 (11)
B-002-0-24		26.50	21												A-2-6 (V)
B-002-0-24		28.00	15												Rock (V)
B-002-0-24		29.50	6												Rock (V)
B-003-0-24		1.00	23												A-7-6 (V)
B-003-0-24		2.50	18	52	22	30	22	21	8	23	26		0.1010	22.5601	A-7-6 (10)
B-003-0-24		4.00	22												A-7-6 (V)
B-003-0-24		5.50	20												A-7-6 (V)
B-003-0-24		7.00	7	39	15	24	66	2	1	12	19		7.9885	35.0357	A-2-6 (2)
B-003-0-24		8.50	15												A-7-6 (V)
B-003-0-24		10.00	14	47	20	27	29	6	3	26	36		0.0204	28.5036	A-7-6 (13)
B-003-0-24		11.50	20												A-7-6 (V)
B-003-0-24		13.00	20												A-7-6 (V)
B-003-0-24		14.50	25												A-7-6 (V)
B-003-0-24		16.00	22	47	22	25	13	2	3	42	40		0.0098	21.7945	A-7-6 (15)
B-003-0-24		17.50	24												A-7-6 (V)
B-003-0-24		19.00	27												A-7-6 (V)
B-003-0-24		20.50	27	44	20	24	2	2	4	53	39		0.0088	0.1865	A-7-6 (14)
B-003-0-24		22.00	25												A-7-6 (V)
B-003-0-24		23.50	3												A-1-b (V)
B-003-0-24		25.00	16												A-2-6 (V)
B-003-0-24		26.50	11												A-1-b (V)

PROJECT HAM-52-36.85
LOCATION HAMILTON COUNTY, OHIO
JOB NO. 23780169 **DATE** 4/1/24

SUMMARY OF LABORATORY TEST RESULTS

BORING	SAMPLE (#)	Top Depth (ft)	MC %	LL %	PL %	PI %	AGGREGATE %	COARSE SAND %	FINE SAND %	SILT %	CLAY %	SILT/CLAY %	D / 50 mm	D / 95 mm	HRB ODOT CLASSIFICATION
B-003-0-24		28.00	14												A-2-6 (V)
B-004-0-24		1.00	21												A-2-6 (V)
B-004-0-24		2.50	22	51	24	27	0	1	2	46	51		0.0046	0.0657	A-7-6 (17)
B-004-0-24		4.00	22												A-7-6 (V)
B-004-0-24		5.50	18												A-7-6 (V)
B-004-0-24		7.00	19												A-7-6 (V)
B-004-0-24		8.50	15	56	23	33	5	5	3	34	53		0.0042	2.2517	A-7-6 (19)
B-004-0-24		10.00	20												A-7-6 (V)
B-004-0-24		11.50	19												A-7-6 (V)
B-004-0-24		13.00	12												A-7-6 (V)
B-004-0-24		14.50	15	51	19	32	46	6	3	19	26		0.8500	33.5056	A-7-6 (9)
B-004-0-24		16.00	22	49	22	27	2	3	2	48	45		0.0066	0.2120	A-7-6 (17)
B-004-0-24		17.50	25												A-7-6 (V)
B-004-0-24		19.00	13	41	19	22	39	5	7	29	20		0.0937	35.3106	A-7-6 (7)
B-004-0-24		20.50	23												A-7-6 (V)
B-004-0-24		22.00	18												A-7-6 (V)
B-004-0-24		23.50	16												A-7-6 (V)
B-004-0-24		25.00	12												A-2-6 (V)
B-004-0-24		26.50	9												Rock (V)
B-005-0-24		1.00	20	45	19	26	16	12	6	36	30		0.0226	9.4262	A-7-6 (13)
B-005-0-24		2.50	23												A-7-6 (V)
B-005-0-24		4.00	31												A-7-6 (V)
B-005-0-24		5.50	25	61	25	36	0	0	2	42	56			0.0618	A-7-6 (20)
B-005-0-24		7.00	28												A-7-6 (V)
B-005-0-24		8.50	22	51	21	30	0	0	2	49	49		0.0055	0.0637	A-7-6 (18)
B-005-0-24		10.00	21												A-7-6 (V)
B-005-0-24		11.50	21	47	20	27	1	0	2	61	36		0.0096	0.0680	A-7-6 (16)
B-005-0-24		13.00	20												A-7-6 (V)
B-005-0-24		14.50	13	44	18	26	44	6	4	25	21		0.4403	33.7796	A-7-6 (7)
B-005-0-24		16.00	17												A-7-6 (V)

PROJECT HAM-52-36.85
LOCATION HAMILTON COUNTY, OHIO
JOB NO. 23780169 **DATE** 4/1/24

SUMMARY OF LABORATORY TEST RESULTS

BORING	SAMPLE (#)	Top Depth (ft)	MC %	LL %	PL %	PI %	AGGREGATE %	COARSE SAND %	FINE SAND %	SILT %	CLAY %	SILT/CLAY %	D / 50 m m	D / 95 m m	H R B ODOT CLASSIFICATION
B-005-0-24		17.50	16												A-7-6 (V)
B-005-0-24		19.00	12												A-7-6 (V)
B-005-0-24		20.50	12												Rock (V)
B-005-0-24		22.00	13												Rock (V)
B-006-0-24		1.00	20	46	20	26	14	8	5	38	35		0.0150	6.6543	A-7-6 (15)
B-006-0-24		2.50	12												A-7-6 (V)
B-006-0-24		4.00	1												A-2-6 (V)
B-006-0-24		5.50	19												A-7-6 (V)
B-006-0-24		7.00	19	49	20	29	7	4	3	44	42		0.0083	5.2882	A-7-6 (17)
B-006-0-24		8.50	20												A-7-6 (V)
B-006-0-24		10.00	22	55	23	32	1	2	2	56	39		0.0087	0.0750	A-7-6 (19)
B-006-0-24		11.50	18												A-7-6 (V)
B-006-0-24		13.00	21	44	18	26	0	1	9	50	40		0.0090	0.1226	A-7-6 (15)
B-006-0-24		14.50	5				68	10	5	10	7		14.3722	34.7874	A-2-6 (V)
B-006-0-24		16.00	18												A-7-6 (V)
B-006-0-24		17.50	11												Rock (V)
B-007-0-24		1.00	17												A-7-6 (V)
B-007-0-24		4.00	20	50	20	30	6	4	3	37	50		0.0050	2.9924	A-7-6 (18)
B-007-0-24		5.50	24												A-7-6 (V)
B-007-0-24		7.00	6	29	15	14	63	14	4	12	7		4.8483	8.9984	A-2-6 (0)
B-007-0-24		8.50	14												A-2-6 (V)
B-007-0-24		10.00	24	48	20	28	8	6	5	36	45		0.0069	3.8082	A-7-6 (17)
B-007-0-24		11.50	21												A-7-6 (V)
B-007-0-24		13.00	21	36	17	19	9	3	11	48	29		0.0169	19.8696	A-6b (12)
B-007-0-24		14.50	19	57	21	36	26	3	3	30	38		0.0147	32.0354	A-7-6 (17)
B-007-0-24		16.00	18												A-7-6 (V)
B-007-0-24		17.50	17												A-7-6 (V)

PROJECT HAM-52-36.85
LOCATION HAMILTON COUNTY, OHIO
JOB NO. 23780169 **DATE** 4/1/24

Laboratory Testing Results

Rock Tests

HAM-52-36.85

SLM 36.85

Form No. TR-D7012C-01
Revision No. : 1LexC
Revision Date: 12/12/23

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D7012 Method C

Quality Assurance

S&ME, Inc. - Lexington: 2020 Liberty Road, Suite 105, Lexington, KY 40505

Project No.:	23780169	Report Date:	03/21/24
Project Name:	HAM-52-36.85 Landslide	Test Date(s):	04/01/24
Client Name:	Stantec		
Client Address:	10200 Alliance Rd Suite 300, Blue Ash, OH 45242	Received Date:	03/12/24
Location:	B-001-0-24	Depth, ft:	38.3 - 38.7
Sample Description:	Gray Shale		

Angle of load relative to lithology: Approximately perpendicular

Test Results

Moisture Content ***4.6*** **%** ***Dry Unit Weight*** ***144.7*** **pcf**

Compressive Strength ***499*** **psi**

Before Test

After Test

Strain rate: 0.015 in/min.

Notes / Deviations / References:

J. Folsom	Jacob Folsom	Lab Services Manager	4/1/2024
Technical Responsibility	*Signature*	*Position*	*Date*

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D2166

Quality Assurance

S&ME, Inc. - Lexington: 2020 Liberty Road, Suite 105, Lexington, KY 40505

Project No.:	23780169	Report Date:	04/01/24
Project Name:	HAM-52-36.85 Landslide	Test Date(s):	03/14/24
Client Name:	Stantec		
Client Address:	10200 Alliance Rd Suite 300, Blue Ash, OH 45242	Received Date:	03/12/24
Location:	B-003-0-24	Depth, ft:	31.9 - 32.3
Sample Description:	Gray Shale		

Angle of load relative to lithology: Approximately perpendicular

Test Results

Moisture Content ***16.7*** **%** ***Dry Unit Weight*** ***113.3*** **pcf**

Compressive Strength ***8*** **psi**

After Test

Strain rate: 0.04 in/min.

Notes / Deviations / References: **Sample was too soft to prepare and run as a rock core specimen so it was run using methods based on ASTM D2166, the test method for soil unconfined compressive strength testing.**

J. Folsom	Jacob Folsom	Lab Services Manager	4/1/2024
Technical Responsibility	*Signature*	*Position*	*Date*

Laboratory Testing Results

Rock Tests

HAM-52-36.85

SLM 37.65

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D2166

Quality Assurance

S&ME, Inc. - Lexington: 2020 Liberty Road, Suite 105, Lexington, KY 40505

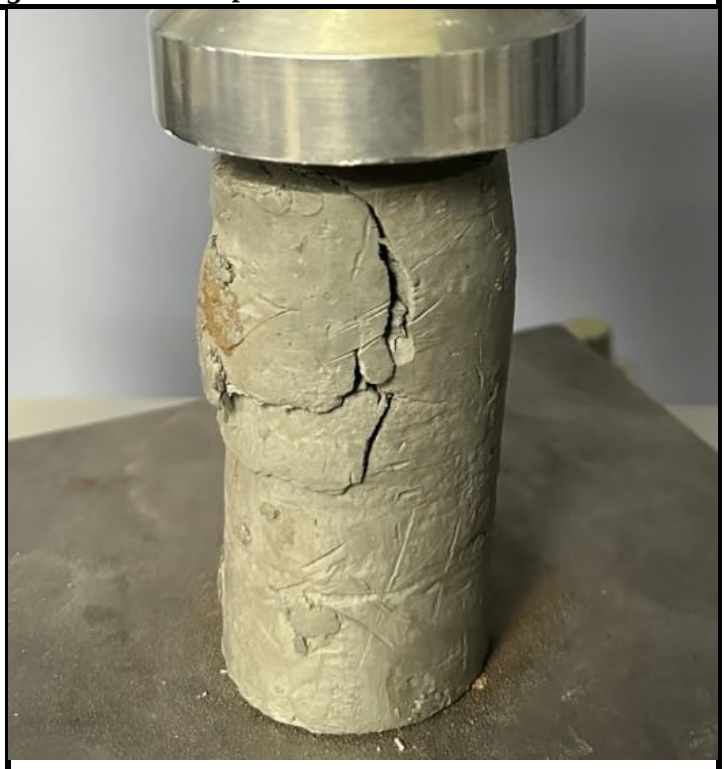
Project No.:	23780169	Report Date:	04/01/24
Project Name:	HAM-52-36.85 Landslide	Test Date(s):	03/14/24
Client Name:	Stantec		
Client Address:	10200 Alliance Rd Suite 300, Blue Ash, OH 45242	Received Date:	03/12/24
Location:	B-005-0-24	Depth, ft:	25.5 - 26.1
Sample Description:	Gray Shale		

Angle of load relative to lithology: Approximately perpendicular

Test Results

Moisture Content ***13.4*** **%** ***Dry Unit Weight*** ***125.6*** **pcf**

Compressive Strength ***26*** **psi**



After Test

Strain rate: 0.05 in/min.

Notes / Deviations / References: **Sample was too soft to prepare and run as a rock core specimen so it was run using methods based on ASTM D2166, the test method for soil unconfined compressive strength testing.**

J. Folsom	Jacob Folsom	Lab Services Manager	4/1/2024
Technical Responsibility	*Signature*	*Position*	*Date*

UNIAXIAL COMPRESSIVE STRENGTH OF ROCK

ASTM D2166

Quality Assurance

S&ME, Inc. - Lexington: 2020 Liberty Road, Suite 105, Lexington, KY 40505

Project No.:	23780169	Report Date:	04/01/24
Project Name:	HAM-52-36.85 Landslide	Test Date(s):	03/14/24
Client Name:	Stantec		
Client Address:	10200 Alliance Rd Suite 300, Blue Ash, OH 45242	Received Date:	03/12/24
Location:	B-005-0-24	Depth, ft:	35.0 - 35.5
Sample Description:	Gray Shale		

Angle of load relative to lithology: Approximately perpendicular

Test Results

Moisture Content ***21.4*** **%** ***Dry Unit Weight*** ***117.1*** **pcf**

Compressive Strength ***42*** **psi**

After Test

Strain rate: 0.05 in/min.

Notes / Deviations / References: **Sample was too soft to prepare and run as a rock core specimen so it was run using methods based on ASTM D2166, the test method for soil unconfined compressive strength testing.**

J. Folsom	Jacob Folsom	Lab Services Manager	4/1/2024
Technical Responsibility	*Signature*	*Position*	*Date*

APPENDIX E

SLOPE STABILITY ANALYSIS

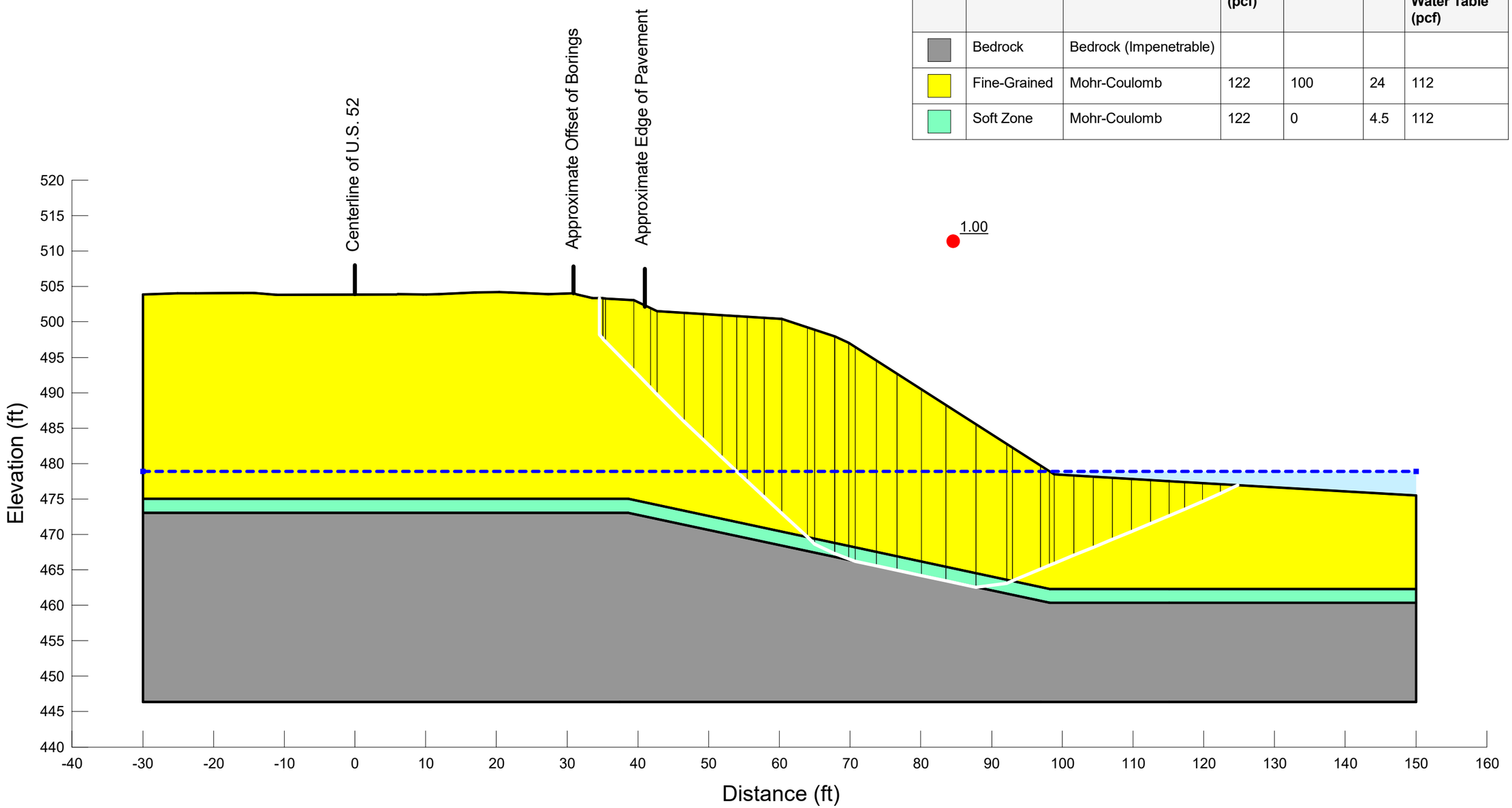
Slope Stability Analysis

HAM-52-36.85

SLM 36.85

HAM-52-36.85 Landslides	**Slope Stability Analysis - FS = 1.00**	Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.
ODOT District 8		
SLM 36.85- Back Analysis	Back Analysis - 36.85	

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Constant Unit Wt. Above Water Table (pcf)
	Bedrock	Bedrock (Impenetrable)				
	Fine-Grained	Mohr-Coulomb	122	100	24	112
	Soft Zone	Mohr-Coulomb	122	0	4.5	112



Project No. 173410733

Performed By: G. Khatri 4/8/2024
Checked By: R. Lopina 4/10/2024

04/10/2024: 08:32:11 AM

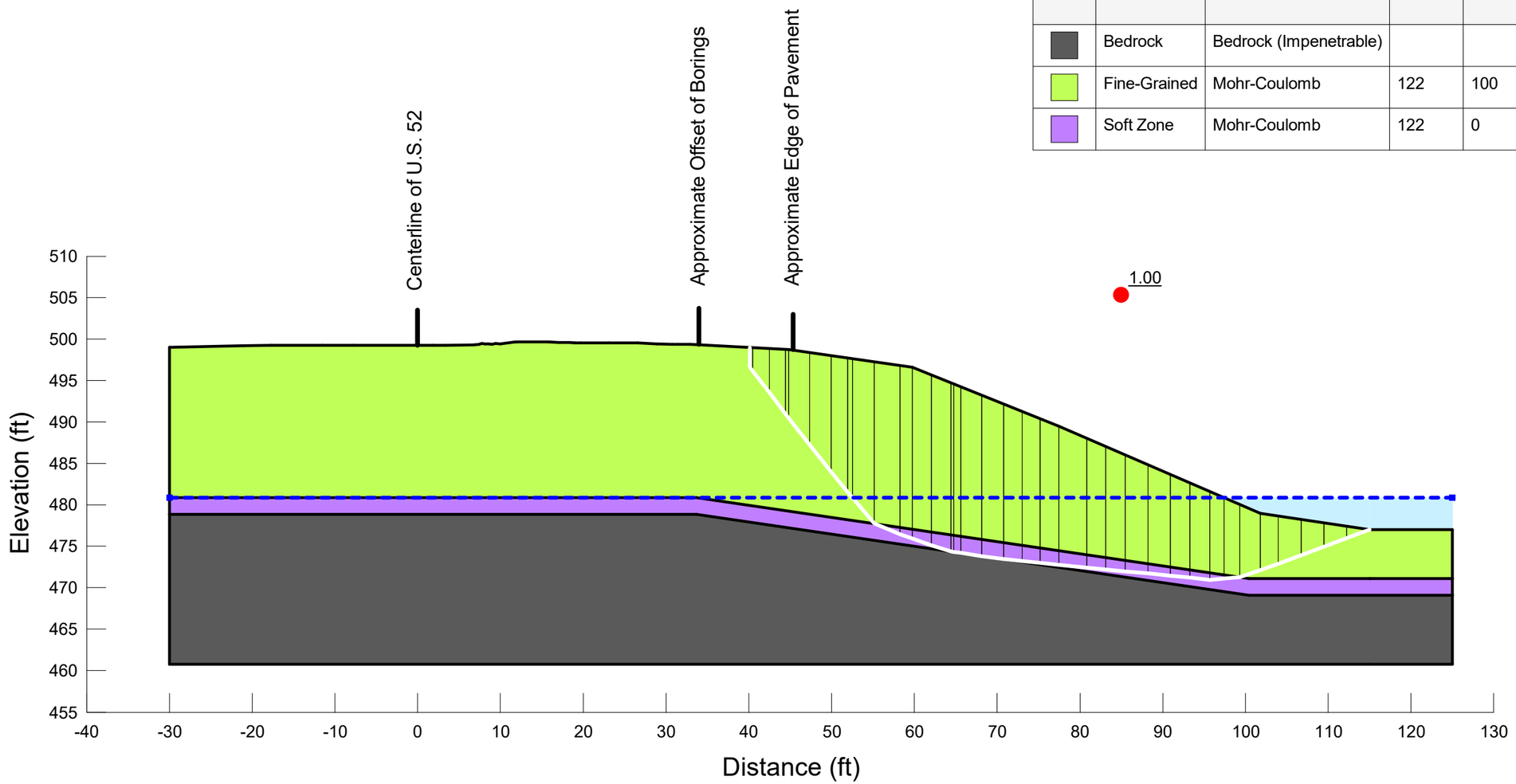
Slope Stability Analysis

HAM-52-36.85

SLM 37.65

HAM-52-36.85	**Slope Stability Analysis - FS = 1.00**	Note: The results of the analysis shown here are based on available subsurface information, laboratory test results and approximate soil properties. The drawing depicts approximate subsurface conditions based on historical drawings or specific borings at the time of drilling. No warranties can be made regarding the continuity of subsurface conditions.
ODOT District 8		
SLM 37.65 - Back Analysis	Back Analysis-37.65	

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Constant Unit Wt. Above Water Table (pcf)
	Bedrock	Bedrock (Impenetrable)				
	Fine-Grained	Mohr-Coulomb	122	100	24	112
	Soft Zone	Mohr-Coulomb	122	0	9.5	112



Project No. 173410733

Performed By: G. Khatri 4/9/2024
Checked By: R. Lopina 4/10/2024

04/10/2024: 08:36:11 AM

APPENDIX F

UA SLOPE ANALYSIS

UA Slope Analysis

HAM-52-36.85

SLM 36.85

HAM-52-36.85
PAGE 1 OF 2: UA SLOPE BACK ANALYSIS (NO DRILLED SHAFT)

File Run Options Help

Calculated Results

Factor of Safety: 1.00
Force per Shaft: 0.000 lb
Acting Point X: 0.000 ft Y: 0.000 ft

Analysis Unit System

(•) English ( ) Metric

Number of Vertical Sections and Soil Layers

Vertical Section Num: 30 Soil Layer Num: 3

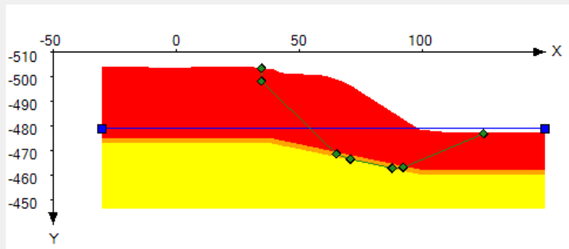
Analysis Method

( ) Total Stress (•) Effective Stress

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	100.0	24.0	112.0
Layer2	0.0	9.0	112.0
▸ Layer3	2000.0	40.0	134.0

Chart (Double-Click for More Options)



Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
▸ X (ft)	-30.00	-22.48	-15.04	-14.30	-11.08	-2.60	5.88	9.65	11.87	17.09	20.38	21.73	27.34	29.06
Y1 (ft)	-503.89	-504.08	-504.09	-504.09	-503.81	-503.80	-503.81	-503.85	-503.85	-504.19	-504.23	-504.18	-503.92	-503.92
Y2 (ft)	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03
Y3 (ft)	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03
Y4 (ft)	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33

Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	Section 21	Section 22	Section 23	Section 24	Section 25	Section 26	Section 27
30.90	31.38	33.60	35.00	35.44	39.42	42.71	47.50	53.10	60.33	67.84	70.53	98.85
-504.06	-503.88	-503.37	-503.37	-503.28	-503.06	-501.51	-501.22	-500.87	-500.42	-497.96	-496.61	-478.50
-475.03	-475.03	-475.03	-475.03	-475.03	-474.84	-474.02	-473.15	-471.95	-470.41	-468.81	-468.25	-462.33
-473.03	-473.03	-473.03	-473.03	-473.03	-472.84	-472.02	-471.15	-469.95	-468.41	-466.81	-466.25	-460.33
-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33

Section 28	Section 29	Section 30
108.85	114.35	150.00
-477.55	-477.55	-477.50
-462.33	-462.33	-462.33
-460.33	-460.33	-460.33
-446.33	-446.33	-446.33

Coordinates of Crest X: 21.73 ft Y: -504.18 ft Coordinates of Toe X: 125.14 ft Y: -477.50 ft

Drilled Shaft Information

(•) Calculate without Drilled Shaft
( ) Automatic Load Transfer Factor
( ) Manually Defined Load Transfer Factor
[ ] Anchor (On/Off)

Anchor force: 0.00 lb
Anchor angle: 0.00
Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)

[ ] Auto Save Data

Xmin 0.00 Diameter: 0.30 ft
Xmax 0.00 CTC Spacing: 0.00 ft
XDelta 0.00 X Coordinate: 0.00 ft

Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

	Point 1	Point 2
▸ X (ft)	-30.00	150.00
Y (ft)	-478.92	-478.92

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
▸ X (ft)	34.54	34.55	65.02	70.73	87.77	92.15	124.84
Y (ft)	-503.37	-498.17	-468.63	-466.49	-462.86	-463.13	-476.84

Performed By: G. Khatri 04/09/2024
Checked By: R. Lopina 04/10/2024

HAM-52-36.85
PAGE 2 OF 2: UA SLOPE ANALYSIS (3-FT SHAFTS AT 5.75-FT CENTER-TO-CENTER SPACING)

File Run Options Help

Calculated Results

Factor of Safety: 1.12
Force per Shaft: 34622.327 lb
Acting Point X: 47.500 ft Y: -491.372 ft

Analysis Unit System

(•) English ( ) Metric

Number of Vertical Sections and Soil Layers

Vertical Section Num: 31 Soil Layer Num: 4

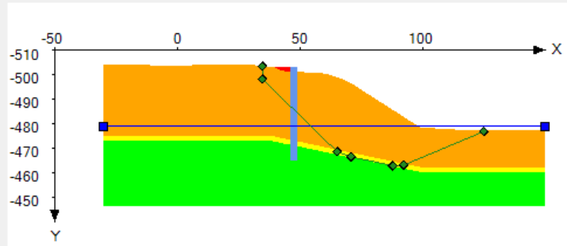
Analysis Method

( ) Total Stress (•) Effective Stress

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	250.0	28.0	125.0
Layer2	100.0	24.0	112.0
Layer3	0.0	9.0	112.0
▸ Layer4	2000.0	40.0	134.0

Chart (Double-Click for More Options)



Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
▸ X (ft)	-30.00	-22.48	-15.04	-14.30	-11.08	-2.60	5.88	9.65	11.87	17.09	20.38	21.73	27.34	29.06
Y1 (ft)	-503.89	-504.08	-504.09	-504.09	-503.81	-503.80	-503.81	-503.85	-503.85	-504.19	-504.23	-504.18	-503.92	-503.92
Y2 (ft)	-503.89	-504.08	-504.09	-504.09	-503.81	-503.80	-503.81	-503.85	-503.85	-504.19	-504.23	-504.18	-503.92	-503.92
Y3 (ft)	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03	-475.03
Y4 (ft)	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03	-473.03
Y5 (ft)	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33

Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	Section 21	Section 22	Section 23	Section 24	Section 25	Section 26	Section 27	Section 28	Section 29	Section 30	Section 31
30.90	31.38	33.60	35.00	35.44	39.42	42.71	47.50	47.50	53.10	60.33	67.84	70.53	98.85	108.85	114.35	150.00
-504.06	-503.88	-503.37	-503.37	-503.28	-503.06	-503.06	-503.06	-501.22	-500.87	-500.42	-497.96	-496.61	-478.50	-477.88	-477.55	-477.50
-504.06	-503.88	-503.37	-503.37	-503.28	-503.06	-501.51	-501.22	-501.22	-500.87	-500.42	-497.96	-496.61	-478.50	-477.88	-477.55	-477.50
-475.03	-475.03	-475.03	-475.03	-475.03	-474.84	-474.02	-473.15	-473.15	-471.95	-470.41	-468.81	-468.25	-462.33	-462.33	-462.33	-462.33
-473.03	-473.03	-473.03	-473.03	-473.03	-472.84	-472.02	-471.15	-471.15	-469.95	-468.41	-466.81	-466.25	-460.33	-460.33	-460.33	-460.33
-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33	-446.33

Coordinates of Crest X: 21.73 ft Y: -504.18 ft Coordinates of Toe X: 125.14 ft Y: -477.50 ft

Drilled Shaft Information

( ) Calculate without Drilled Shaft
( ) Automatic Load Transfer Factor
(•) Manually Defined Load Transfer Factor
[ ] Anchor (On/Off)

Anchor force: 0.00 lb
Anchor angle: 0.00
Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (η)
Xmin 0.00 Diameter: 3.00 ft
Xmax 0.00 CTC Spacing: 5.75 ft
XDelta 0.00 X Coordinate: 47.50 ft

[ ] Auto Save Data

▷ Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

	Point 1	Point 2
▸ X (ft)	-30.00	150.00
Y (ft)	-478.92	-478.92

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
▸ X (ft)	34.54	34.55	65.02	70.73	87.77	92.15	124.84
Y (ft)	-503.37	-498.17	-468.63	-466.49	-462.86	-463.13	-476.84

Performed By: G. Khatri 04/09/2024
Checked By: R. Lopina 04/10/2024

UA Slope Analysis

HAM-52-36.85

SLM 37.65

Stantec

HAM-52-36.85
PAGE 1 OF 2: UA SLOPE BACK ANALYSIS (NO DRILLED SHAFT)

File Run Options Help

Calculated Results

Factor of Safety: 1.00
Force per Shaft: 0.000 lb
Acting Point X: 0.000 ft Y: 0.000 ft

Analysis Unit System

(•) English ( ) Metric

Number of Vertical Sections and Soil Layers

Vertical Section Num: 24 Soil Layer Num: 4

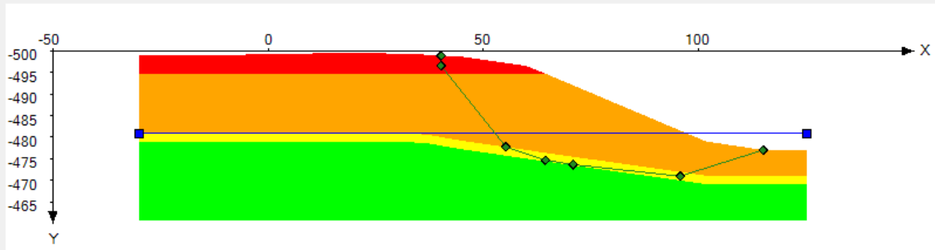
Analysis Method

( ) Total Stress (•) Effective Stress

Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	100.0	24.0	112.0
Layer2	100.0	24.0	112.0
Layer3	0.0	11.0	112.0
▸ Layer4	2000.0	40.0	134.0

Chart (Double-Click for More Options)



Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
▸ X (ft)	-30.00	-21.01	-7.74	1.88	7.47	7.76	8.60	8.97	9.40	9.97	11.81	15.75	18.34	19.71
Y1 (ft)	-499.03	-499.03	-499.18	-499.24	-499.38	-499.47	-499.40	-499.34	-499.46	-499.41	-499.67	-499.58	-499.58	-499.52
Y2 (ft)	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60
Y3 (ft)	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86
Y4 (ft)	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86
Y5 (ft)	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80

Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	Section 21	Section 22	Section 23	Section 24
23.14	28.88	32.88	37.00	44.82	59.75	64.73	101.59	114.97	124.98
-499.52	-499.44	-499.36	-499.14	-498.71	-496.60	-494.61	-479.05	-477.03	-477.03
-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.61	-479.05	-477.03	-477.03
-480.86	-480.86	-480.86	-480.58	-479.23	-477.06	-476.33	-471.12	-471.12	-471.12
-478.86	-478.86	-478.86	-478.58	-477.23	-475.06	-474.33	-469.12	-469.12	-469.12
-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80

Coordinates of Crest X: 11.81 ft Y: -499.67 ft Coordinates of Toe X: 124.98 ft Y: -494.98 ft

Drilled Shaft Information

(•) Calculate without Drilled Shaft
( ) Automatic Load Transfer Factor
( ) Manually Defined Load Transfer Factor
[ ] Anchor (On/Off)

Anchor force: 0.00 lb
Anchor angle: 0.00
Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)
Xmin 0.00 Diameter: 0.30 ft
Xmax 0.00 CTC Spacing: 0.00 ft
XDelta 0.00 X Coordinate: 0.00 ft

[ ] Auto Save Data

Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

	Point 1	Point 2
▸ X (ft)	-30.00	124.98
Y (ft)	-480.86	-480.86

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
▸ X (ft)	40.12	40.13	55.19	64.41	70.79	95.67	114.98
Y (ft)	-498.97	-496.62	-477.76	-474.68	-473.65	-470.96	-477.03

Performed By: G. Khatri 04/9/2024
Checked By: R. Lopina 04/10/2024

Stantec

HAM-52-36.85
PAGE 2 OF 2: UA SLOPE ANALYSIS (3-FT SHAFTS AT 5.75-FT CENTER-TO-CENTER SPACING)

File Run Options Help

Calculated Results

Factor of Safety: 1.24
Force per Shaft: 35330.869 lb
Acting Point X: 52.000 ft Y: -487.565 ft

Analysis Unit System

(•) English ( ) Metric

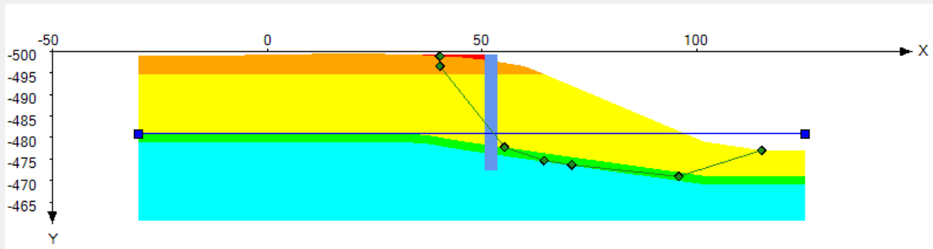
Number of Vertical Sections and Soil Layers

Vertical Section Num: 26 Soil Layer Num: 5

Analysis Method

( ) Total Stress (•) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
Layer1	250.0	28.0	125.0
Layer2	100.0	24.0	112.0
Layer3	100.0	24.0	112.0
▸ Layer4	0.0	11.0	112.0
Layer5	2000.0	40.0	134.0

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11	Section 12	Section 13	Section 14
▸ X (ft)	-30.00	-21.01	-7.74	1.88	7.47	7.76	8.60	8.97	9.40	9.97	11.81	15.75	18.34	19.71
Y1 (ft)	-499.03	-499.03	-499.18	-499.24	-499.38	-499.47	-499.40	-499.34	-499.46	-499.41	-499.67	-499.62	-499.58	-499.52
Y2 (ft)	-499.03	-499.03	-499.18	-499.24	-499.38	-499.47	-499.40	-499.34	-499.46	-499.41	-499.67	-499.62	-499.58	-499.52
Y3 (ft)	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60
Y4 (ft)	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86	-480.86
Y5 (ft)	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86	-478.86
Y6 (ft)	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80

Section 15	Section 16	Section 17	Section 18	Section 19	Section 20	Section 21	Section 22	Section 23	Section 24	Section 25	Section 26
23.14	28.88	32.88	37.00	44.82	52.00	52.00	59.75	64.73	101.59	114.97	124.98
-499.52	-499.44	-499.36	-499.36	-499.36	-499.36	-497.91	-496.60	-494.61	-479.05	-477.03	-477.03
-499.52	-499.44	-499.36	-499.14	-498.71	-497.91	-497.91	-496.60	-494.61	-479.05	-477.03	-477.03
-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.60	-494.61	-479.05	-477.03	-477.03
-480.86	-480.86	-480.86	-480.58	-479.23	-478.19	-478.19	-477.06	-476.33	-471.12	-471.12	-471.12
-478.86	-478.86	-478.86	-478.58	-477.23	-476.19	-476.19	-475.06	-474.33	-469.12	-469.12	-469.12
-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80	-460.80

Coordinates of Crest X: 11.81 ft Y: -499.67 ft Coordinates of Toe X: 124.98 ft Y: -494.98 ft

Drilled Shaft Information

( ) Calculate without Drilled Shaft
( ) Automatic Load Transfer Factor
(•) Manually Defined Load Transfer Factor
[ ] Anchor (On/Off)

Anchor force: 0.00 lb
Anchor angle: 0.00
Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)
Xmin 0.00 Diameter: 3.00 ft
Xmax 0.00 CTC Spacing: 5.75 ft
XDelta 0.00 X Coordinate: 52.00 ft

[ ] Auto Save Data

Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

	Point 1	Point 2
▸ X (ft)	-30.00	124.98
Y (ft)	-480.86	-480.86

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
▸ X (ft)	40.12	40.13	55.19	64.41	70.79	95.67	114.98
Y (ft)	-498.97	-496.62	-477.76	-474.68	-473.65	-470.96	-477.03

Performed By: G. Khatri 04/9/2024
Checked By: R. Lopina 04/10/2024

APPENDIX G

LPILE ANALYSIS

LPile Analysis

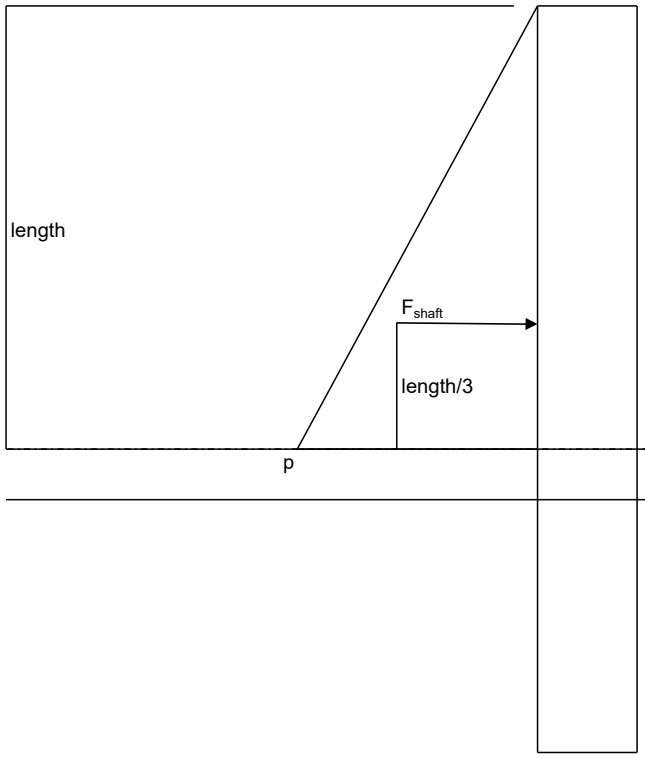
HAM-52-36.85

SLM 36.85

SUMMARY OF DRILLED SHAFT CALCULATIONS

LOADING CONDITIONS

Loading conditions were evaluated using shaft loads determined from the UA SLOPE (Version 2.3) computer program. This shaft load, combined with an assumed traffic surcharge live load, was applied to the drilled shaft above the assumed failure surface. The drilled shaft was evaluated using LPILEv2022 which is a program for the analysis of piles and drilled shafts under lateral loads. Unfactored loads (Service I Limit State) were utilized to estimate shaft head deflection and factored loads (Strength I Limit State) were used to evaluate geotechnical resistance.



Projected Ground line Depth = 0.00

Note:
x_2 represents the maximum value of the triangular distributed load that will be used in LPILE determined from F_{shaft} from the University of Akron program.

Assumed Failure Surface Depth = 18.05

Top of Rock Depth = 31.90

Bottom of Drilled Shaft Depth = 41.90

Estimated Depth to Bedrock =	31.90	feet	UA Slope Input
Estimated Depth to Failure Surface=	18.05	feet	UA Slope Input
Shaft Size =	3	feet	UA Slope Input
Center to Center Spacing =	5.75	feet	UA Slope Input
F_{shaft} =	34,622	pounds	UA Slope Output
Factor of Safety =	1.11		UA Slope Output
p = (2*Fshaft)/H * (1 ft/12 in)	320	pounds per inch	

Performed By: G. Khatri 4 /9/2024
Checked By: R. Lopina 4/10/2024

DISTRIBUTED LOAD FOR LPILE INPUT

F_{live} = assumed traffic surcharge load =	250	psf
Phi =	24.0	degrees
K_a =	0.422	
x1 = F_{live} * s * Ka * (1 ft/12 in)	51	pounds per inch
x2 = [2*Fshaft/(Depth to Failure Surface)] + x1		

Service (I) Limit State:

x1 =	51	pounds per inch
x2 =	370	pounds per inch
Total Load =	45565	pounds

Strength (I) Limit State:

x1 =	88	pounds per inch (Load Factor = 1.75)
x2 =	568	pounds per inch (Load Factor = 1.5)
Total Load =	80658	pounds

CHOOSE MATERIAL p-y CURVES for LPILE Program

Material Type	*Value*	*Units*	
Soft Clay			
γ=	60	pcf	based on tubes lab testing
c=	2,000	psf	based on ODOT GDM Section 404.1 (conservative)
Bedrock - Shale(Weak Rock)			
γ'=	51	pcf	based on lab test of B-003-0-24 with weak strength
E=	720	psi	=90 x qu
qu=	8	psi	based on lab test of B-003-0-24 with weak strength
RQD=	0	%	conservative for weak rock
Km=	0.00005		conservative for weak rock
p-y Modification Factor			
p = 0.64 (Spacing/Diameter)$^{0.34}$	0.80		
Bedrock - Shale and limestone interbed(Weak Rock)			
γ'=	72	pcf	based on average UCR from B-001-0-24 to B-007-0-24
E=	54,000	psi	=90 x qu
qu=	600	psi	average from lab test and ODOT GDM
RQD=	50	%	average from B-001-0-24 to B-004-0-24
Km=	0.00005		conservative for weak rock

SHAFT CONCRETE AND STEEL MATERIAL PROPERTIES FOR LPILE

Parameter	***Value***		***Note***
f'_c =	4,000	psi	(ODOT Class S Concrete)
E_c =	3,604,997	psi	E_c = 57,000 * SQRT(f'c)
$f_{y\ steel}$=	50,000	psi	
$E_{\ steel}$=	2.9E+07	psi	

Performed By: G. Khatri 4 /9/2024
Checked By: R. Lopina 4/10/2024

LPILE VERSION 2022 RUNS

SERVICE (I) AND STRENGTH (I) LIMIT STATES

Purpose: Achieve a shaft head deflection of 2 inches or less for Service (I) Limit State. Recommend a rock socket length by observation of the shear and moment curves. Provide shear and moment design parameters for the selection of steel beam reinforcement.

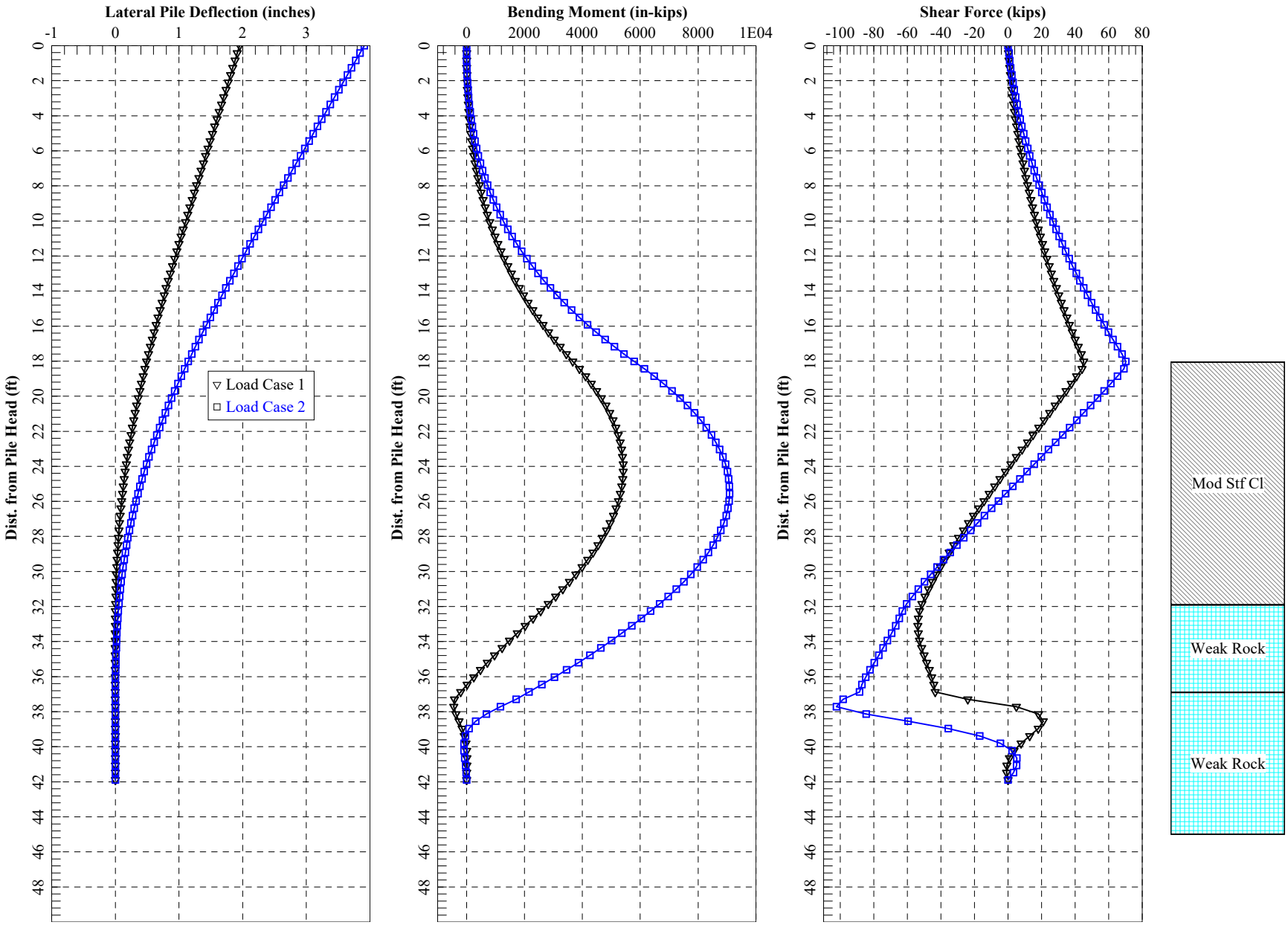
Run ID	Filename	Reinforcement Description	Deflection at Pile Head (in)	Maximum Moment (in-lbs)	Maximum Shear (lbs)
1	W24x162_3ftD_5.75ftCTC	W24X162	1.95	53,824	5,409,257
2	W24X162_3ftD_5.75ftCTC	W24X162	3.91	102,275	9,086,546

Based on the calculations and assumptions presented above, it appears a 36-inch diameter drilled shaft with a center-to-center spacing of 69 inches can provide tolerable deflections when placed approximately at 47.5 ft from centreline of the roadway. A minimum 10-foot rock socket is recommended.

PROPERTIES OF SELECTED SECTIONS

Run ID	Source	Reinforcement Description	Area of Steel (in^2)	Moment of Inertia (in^4)	Section Modulus (in^3)
1 & 2	AISC Manual of Steel Construction	W24x162	47.8	5,170	414

Performed By: G. Khatri 4 /9/2024
Checked By: R. Lopina 4/10/2024


Lateral Pile Deflection (inches)
-1
0
1
2
3
Dist. from Pile Head (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Load Case 1
Load Case 2
Bending Moment (in-kips)
0
2000
4000
6000
8000
1E04
Shear Force (kips)
-100
-80
-60
-40
-20
0
20
40
60
80
Mod Stf Cl
Weak Rock
Weak Rock

```
================================================================================

                    LPile for Windows, Version 2022-12.006

                 Analysis of Individual Piles and Drilled Shafts
                Subjected to Lateral Loading Using the p-y Method
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================================================================================

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--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\173410733\technical_production\working_report\Appendix G - LPile Analysis\

Name of input data file:
HAM-52-36.85_section 36.85 W24X162 Lpile Analysis.lp12d

Name of output report file:
HAM-52-36.85_section 36.85 W24X162 Lpile Analysis.lp12o

Name of plot output file:
```

HAM-52-36.85_section 36.85 W24X162 Lpile Analysis.lp12p

Name of runtime message file:
HAM-52-36.85_section 36.85 W24X162 Lpile Analysis.lp12r

Date and Time of Analysis

Date: April 11, 2024 Time: 10:04:40

Problem Title

Project Name: HAM-52-36.85

Job Number: 173410733

Client: Ohio Department of Transportation (ODOT)

Engineer: G. Khatri

Description: L-Pile Analsis

Program Options and Settings

Computational Options:
 - Conventional Analysis
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed = 500
 - Deflection tolerance for convergence = 1.0000E-05 in
 - Maximum allowable deflection = 100.0000 in
 - Number of pile increments = 100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Analysis uses p-y modification factors for p-y curves
 - Analysis uses layering correction (Method of Georgiadis)
 - Analysis includes loading by multiple distributed lateral loads acting on pile
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 2
Total length of pile = 41.900 ft

Depth of ground surface below top of pile = 18.0500 ft

Pile diameters used for p-y curve computations are defined using 4 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	13.0000
2	4.000	13.0000
3	4.000	36.0000
4	41.900	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is a AISC strong axis steel pile
Length of section = 4.000000 ft
AISC Section Type = W

AISC Section Name = W24X162

Pile width = 13.000000 in

Pile Section No. 2:

Section 2 is an elastic pile
Cross-sectional Shape = Circular Pile
Length of section = 37.900000 ft
Width of top of section = 36.000000 in
Width of bottom of section = 36.000000 in
Top Area = 47.800000 sq. in
Bottom Area = 47.800000 sq. in

```
   Moment of Inertia at Top                          =        5170. in^4
   Moment of Inertia at Bottom                       =        5170. in^4
   Elastic Modulus                                   =    29000000. psi



--------------------------------------------------------------------------------
                       Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 3 layers

Layer 1 is stiff clay with user-defined k-value

   Distance from top of pile to top of layer         =    18.050000 ft
   Distance from top of pile to bottom of layer      =    31.900000 ft
   Effective unit weight at top of layer             =    60.000000 pcf
   Effective unit weight at bottom of layer          =    60.000000 pcf
   Undrained cohesion at top of layer                =        2000. psf
   Undrained cohesion at bottom of layer             =        2000. psf
   Epsilon-50 at top of layer                        =       0.0000
   Epsilon-50 at bottom of layer                     =       0.0000
   Subgrade k at top of layer                        =       0.0000 pci
   Subgrade k at bottom of layer                     =       0.0000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.
   NOTE: Default values for subgrade k will be computed for this layer.

Layer 2 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer         =    31.900000 ft
   Distance from top of pile to bottom of layer      =    36.900000 ft
   Effective unit weight at top of layer             =    51.000000 pcf
   Effective unit weight at bottom of layer          =    51.000000 pcf
   Uniaxial compressive strength at top of layer     =     8.000000 psi
   Uniaxial compressive strength at bottom of layer  =     8.000000 psi
   Initial modulus of rock at top of layer           =   720.000000 psi
   Initial modulus of rock at bottom of layer        =   720.000000 psi
   RQD of rock at top of layer                       =       0.0000 %
   RQD of rock at bottom of layer                    =       0.0000 %
   k rm of rock at top of layer                      =    0.0000500
```

```
   k rm of rock at bottom of layer                    =    0.0000500


Layer 3 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer          =    36.900000 ft
   Distance from top of pile to bottom of layer       =    45.000000 ft
   Effective unit weight at top of layer              =    72.000000 pcf
   Effective unit weight at bottom of layer           =    72.000000 pcf
   Uniaxial compressive strength at top of layer      =   600.000000 psi
   Uniaxial compressive strength at bottom of layer   =   600.000000 psi
   Initial modulus of rock at top of layer            =       54000. psi
   Initial modulus of rock at bottom of layer         =       54000. psi
   RQD of rock at top of layer                        =    50.000000 %
   RQD of rock at bottom of layer                     =    50.000000 %
   k rm of rock at top of layer                       =    0.0000500
   k rm of rock at bottom of layer                    =    0.0000500


 (Depth of the lowest soil layer extends 3.100 ft below the pile tip)



--------------------------------------------------------------------------------
                        Summary of Input Soil Properties
--------------------------------------------------------------------------------

Layer         Soil Type          Layer      Effective    Cohesion     Uniaxial                    E50
     Rock Mass
 Num.           Name             Depth       Unit Wt.                    qu          RQD %         or           kpy
      Modulus
          (p-y Curve Type)        ft           pcf          psf          psi                      krm          pci
        psi
-----   -------------------   ----------   ----------   ----------   ----------   ----------   ----------
----------   ----------
  1       Stiff Clay w/o         18.0500      60.0000        2000.       --           --         default
default        --
        Free Water, using k      31.9000      60.0000        2000.       --           --         default
default        --
  2            Weak              31.9000      51.0000       --           8.0000         0.00     5.00E-05       --
     720.0000
```

	Rock	36.9000	51.0000	--	8.0000	0.00	5.00E-05	--
720.0000								
3	Weak	36.9000	72.0000	--	600.0000	50.0000	5.00E-05	--
54000.								
	Rock	45.0000	72.0000	--	600.0000	50.0000	5.00E-05	--
54000.								

Modification Factors for p-y Curves

Distribution of p-y modifiers with depth defined using 2 points

Point No.	Depth X ft	p-mult	y-mult
1	18.050	0.8000	1.0000
2	31.900	0.8000	1.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading for Individual Load Cases

Distributed lateral load intensity for Load Case 1 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	51.000

2	18.050	370.000

Distributed lateral load intensity for Load Case 2 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	88.000
2	18.050	568.000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes
2	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

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Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 2

Pile Section No. 1:

Dimensions and Properties of Steel AISC Strong Axis:

Length of Section	=	4.000000 ft
Flange Width	=	13.000000 in
Section Depth	=	25.000000 in
Flange Thickness	=	1.220000 in
Web Thickness	=	0.705000 in
Yield Stress of Pipe	=	50.000000 ksi
Elastic Modulus	=	29000. ksi
Cross-sectional Area	=	47.800000 sq. in.
Moment of Inertia	=	5170. in^4
Elastic Bending Stiffness	=	149930000. kip-in^2
Plastic Modulus, Z	=	468.000000in^3
Plastic Moment Capacity = Fy Z	=	23400.in-kip

Axial Structural Capacities:

Nom. Axial Structural Capacity = Fy As	=	2390.000 kips
Nominal Axial Tensile Capacity	=	-2390.000 kips

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	0.000

Definition of Run Messages:

Y = part of pipe section has yielded.

Axial Thrust Force = 0.000 kips

Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in2	Depth to N Axis in	Max Total Stress ksi	Run Msg
0.00000564	843.5817563	149661328.	12.5000000	2.0228366	
0.00001127	1687.	149661328.	12.5000000	4.0456731	
0.00001691	2531.	149661328.	12.5000000	6.0685097	
0.00002255	3374.	149661328.	12.5000000	8.0913462	
0.00002818	4218.	149661328.	12.5000000	10.1141828	
0.00003382	5061.	149661328.	12.5000000	12.1370193	
0.00003946	5905.	149661328.	12.5000000	14.1598559	
0.00004509	6749.	149661328.	12.5000000	16.1826924	
0.00005073	7592.	149661328.	12.5000000	18.2055290	
0.00005637	8436.	149661328.	12.5000000	20.2283655	
0.00006200	9279.	149661328.	12.5000000	22.2512021	
0.00006764	10123.	149661328.	12.5000000	24.2740387	
0.00007328	10967.	149661328.	12.5000000	26.2968752	
0.00007891	11810.	149661328.	12.5000000	28.3197118	
0.00008455	12654.	149661328.	12.5000000	30.3425483	
0.00009019	13497.	149661328.	12.5000000	32.3653849	
0.00009582	14341.	149661328.	12.5000000	34.3882214	
0.0001015	15184.	149661328.	12.5000000	36.4110580	
0.0001071	16028.	149661328.	12.5000000	38.4338945	
0.0001127	16872.	149661328.	12.5000000	40.4567311	
0.0001184	17715.	149661328.	12.5000000	42.4795677	
0.0001240	18559.	149661328.	12.5000000	44.5024042	
0.0001296	19402.	149661328.	12.5000000	46.5252408	
0.0001353	20246.	149661328.	12.5000000	48.5480773	
0.0001409	21044.	149335438.	12.5000000	50.0000000	Y
0.0001466	21568.	147167341.	12.5000000	50.0000000	Y
0.0001522	21830.	143443513.	12.5000000	50.0000000	Y
0.0001578	21936.	138990727.	12.5000000	50.0000000	Y
0.0001635	22031.	134778644.	12.5000000	50.0000000	Y
0.0001691	22117.	130792919.	12.5000000	50.0000000	Y
0.0001747	22195.	127019731.	12.5000000	50.0000000	Y

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Checked by: R. Lopina 4/10/2024

0.0001804	22265.	123438572.	12.5000000	50.0000000	Y
0.0001860	22329.	120041927.	12.5000000	50.0000000	Y
0.0001916	22387.	116816521.	12.5000000	50.0000000	Y
0.0001973	22441.	113750451.	12.5000000	50.0000000	Y
0.0002029	22490.	110832995.	12.5000000	50.0000000	Y
0.0002086	22535.	108054452.	12.5000000	50.0000000	Y
0.0002142	22577.	105406006.	12.5000000	50.0000000	Y
0.0002198	22616.	102879617.	12.5000000	50.0000000	Y
0.0002311	22684.	98157690.	12.5000000	50.0000000	Y
0.0002424	22744.	93839045.	12.5000000	50.0000000	Y
0.0002536	22795.	89870682.	12.5000000	50.0000000	Y
0.0002649	22841.	86216799.	12.5000000	50.0000000	Y
0.0002762	22880.	82841835.	12.5000000	50.0000000	Y
0.0002875	22916.	79715608.	12.5000000	50.0000000	Y
0.0002987	22947.	76812297.	12.5000000	50.0000000	Y
0.0003100	22975.	74109652.	12.5000000	50.0000000	Y
0.0003213	23000.	71588365.	12.5000000	50.0000000	Y
0.0003326	23023.	69228461.	12.5000000	50.0000000	Y
0.0003438	23043.	67017513.	12.5000000	50.0000000	Y
0.0003551	23062.	64943044.	12.5000000	50.0000000	Y
0.0003664	23078.	62989711.	12.5000000	50.0000000	Y
0.0003777	23094.	61150178.	12.5000000	50.0000000	Y
0.0003889	23108.	59413683.	12.5000000	50.0000000	Y
0.0004002	23120.	57772030.	12.5000000	50.0000000	Y
0.0004115	23132.	56217876.	12.5000000	50.0000000	Y
0.0004227	23143.	54744647.	12.5000000	50.0000000	Y
0.0004340	23153.	53345344.	12.5000000	50.0000000	Y
0.0004453	23163.	52016769.	12.5000000	50.0000000	Y
0.0004566	23171.	50750132.	12.5000000	50.0000000	Y
0.0004678	23179.	49544538.	12.5000000	50.0000000	Y
0.0004791	23186.	48394700.	12.5000000	50.0000000	Y
0.0004904	23193.	47295595.	12.5000000	50.0000000	Y
0.0005017	23200.	46245888.	12.5000000	50.0000000	Y
0.0005129	23206.	45241851.	12.5000000	50.0000000	Y
0.0005242	23211.	44278956.	12.5000000	50.0000000	Y
0.0005355	23216.	43356603.	12.5000000	50.0000000	Y
0.0005468	23222.	42472285.	12.5000000	50.0000000	Y
0.0005580	23226.	41622571.	12.5000000	50.0000000	Y
0.0005693	23231.	40805636.	12.5000000	50.0000000	Y
0.0005806	23235.	40020427.	12.5000000	50.0000000	Y
0.0005918	23239.	39265131.	12.5000000	50.0000000	Y

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0.0006031	23243.	38537591.	12.5000000	50.0000000	Y
0.0006144	23246.	37835670.	12.5000000	50.0000000	Y
0.0006257	23249.	37159043.	12.5000000	50.0000000	Y
0.0006369	23252.	36506367.	12.5000000	50.0000000	Y
0.0006482	23255.	35876394.	12.5000000	50.0000000	Y
0.0006595	23258.	35267672.	12.5000000	50.0000000	Y
0.0006708	23261.	34678509.	12.5000000	50.0000000	Y
0.0007158	23270.	32507418.	12.5000000	50.0000000	Y

Summary of Results for Nominal Moment Capacity for Section 1

Load No.	Axial Thrust kips	Nominal Moment Capacity in-kips
1	0.00000000	23270.

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

Pile Section No. 2:

Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	18.0500	0.00	N.A.	No	0.00	362899.
2	31.9000	13.8500	No	Yes	N.A.	N.A.
3	36.9000	18.8500	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection for Lateral Loading for Load Case Number 1

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	1.9507	-2.63E-05	0.00	-0.00707	3.31E-08	1.50E+11	0.00	0.00	52.8513
0.4190	1.9152	668.0607	279.6984	-0.00707	0.8399	1.50E+11	0.00	0.00	58.4050
0.8380	1.8797	2813.	591.9752	-0.00707	3.5362	1.50E+11	0.00	0.00	65.8101
1.2570	1.8441	6621.	941.4845	-0.00707	8.3242	1.50E+11	0.00	0.00	73.2151

1.6760	1.8086	12280.	1328.	-0.00707	15.4393	1.50E+11	0.00	0.00	80.6202
2.0950	1.7731	19978.	1752.	-0.00707	25.1169	1.50E+11	0.00	0.00	88.0252
2.5140	1.7375	29900.	2213.	-0.00707	37.5923	1.50E+11	0.00	0.00	95.4302
2.9330	1.7020	42236.	2712.	-0.00707	53.1009	1.50E+11	0.00	0.00	102.8353
3.3520	1.6665	57171.	3248.	-0.00706	71.8780	1.50E+11	0.00	0.00	110.2403
3.7710	1.6310	74893.	3820.	-0.00706	94.1591	1.50E+11	0.00	0.00	117.6454
4.1900	1.5955	95589.	4431.	-0.00706	332.8046	1.50E+11	0.00	0.00	125.0504
4.6090	1.5600	119446.	5078.	-0.00705	415.8676	1.50E+11	0.00	0.00	132.4555
5.0280	1.5245	146653.	5763.	-0.00705	510.5891	1.50E+11	0.00	0.00	139.8605
5.4470	1.4891	177394.	6484.	-0.00705	617.6209	1.50E+11	0.00	0.00	147.2655
5.8660	1.4537	211859.	7243.	-0.00704	737.6148	1.50E+11	0.00	0.00	154.6706
6.2850	1.4183	250234.	8040.	-0.00703	871.2225	1.50E+11	0.00	0.00	162.0756
6.7040	1.3830	292707.	8873.	-0.00702	1019.	1.50E+11	0.00	0.00	169.4807
7.1230	1.3477	339464.	9744.	-0.00701	1182.	1.50E+11	0.00	0.00	176.8857
7.5420	1.3125	390693.	10652.	-0.00700	1360.	1.50E+11	0.00	0.00	184.2907
7.9610	1.2773	446581.	11597.	-0.00698	1555.	1.50E+11	0.00	0.00	191.6958
8.3800	1.2422	507315.	12580.	-0.00697	1766.	1.50E+11	0.00	0.00	199.1008
8.7990	1.2072	573083.	13599.	-0.00695	1995.	1.50E+11	0.00	0.00	206.5059
9.2180	1.1723	644071.	14656.	-0.00693	2242.	1.50E+11	0.00	0.00	213.9109
9.6370	1.1375	720467.	15751.	-0.00691	2508.	1.50E+11	0.00	0.00	221.3160
10.0560	1.1029	802458.	16882.	-0.00688	2794.	1.50E+11	0.00	0.00	228.7210
10.4750	1.0683	890231.	18051.	-0.00685	3099.	1.50E+11	0.00	0.00	236.1260
10.8940	1.0339	983974.	19256.	-0.00682	3426.	1.50E+11	0.00	0.00	243.5311
11.3130	0.9997	1083873.	20499.	-0.00679	3774.	1.50E+11	0.00	0.00	250.9361
11.7320	0.9657	1190117.	21780.	-0.00675	4144.	1.50E+11	0.00	0.00	258.3412
12.1510	0.9319	1302891.	23097.	-0.00671	4536.	1.50E+11	0.00	0.00	265.7462
12.5700	0.8982	1422384.	24452.	-0.00666	4952.	1.50E+11	0.00	0.00	273.1512
12.9890	0.8649	1548782.	25844.	-0.00661	5392.	1.50E+11	0.00	0.00	280.5563
13.4080	0.8318	1682273.	27273.	-0.00656	5857.	1.50E+11	0.00	0.00	287.9613
13.8270	0.7989	1823043.	28740.	-0.00650	6347.	1.50E+11	0.00	0.00	295.3664
14.2460	0.7664	1971281.	30244.	-0.00644	6863.	1.50E+11	0.00	0.00	302.7714
14.6650	0.7342	2127173.	31785.	-0.00637	7406.	1.50E+11	0.00	0.00	310.1765
15.0840	0.7024	2290907.	33363.	-0.00629	7976.	1.50E+11	0.00	0.00	317.5815
15.5030	0.6709	2462669.	34978.	-0.00621	8574.	1.50E+11	0.00	0.00	324.9865
15.9220	0.6399	2642647.	36631.	-0.00613	9201.	1.50E+11	0.00	0.00	332.3916
16.3410	0.6093	2831028.	38321.	-0.00604	9857.	1.50E+11	0.00	0.00	339.7966
16.7600	0.5792	3028000.	40048.	-0.00594	10542.	1.50E+11	0.00	0.00	347.2017
17.1790	0.5496	3233749.	41812.	-0.00583	11259.	1.50E+11	0.00	0.00	354.6067
17.5980	0.5206	3448463.	43614.	-0.00572	12006.	1.50E+11	0.00	0.00	362.0117
18.0170	0.4921	3672329.	45059.	-0.00560	12786.	1.50E+11	0.00	0.00	212.9006
18.4360	0.4642	3901577.	44036.	-0.00547	13584.	1.50E+11	-619.996	6715.	0.00

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18.8550	0.4370	4115151.	40901.	-0.00534	14327.	1.50E+11	-627.071	7214.	0.00
19.2740	0.4105	4312873.	37732.	-0.00520	15016.	1.50E+11	-633.449	7758.	0.00
19.6930	0.3848	4494580.	34532.	-0.00505	15648.	1.50E+11	-639.113	8352.	0.00
20.1120	0.3598	4660130.	31306.	-0.00490	16225.	1.50E+11	-644.046	9001.	0.00
20.5310	0.3355	4809398.	28058.	-0.00474	16745.	1.50E+11	-648.233	9714.	0.00
20.9500	0.3121	4942278.	24790.	-0.00457	17207.	1.50E+11	-651.654	10498.	0.00
21.3690	0.2895	5058684.	21507.	-0.00441	17612.	1.50E+11	-654.292	11362.	0.00
21.7880	0.2678	5158548.	18212.	-0.00424	17960.	1.50E+11	-656.129	12319.	0.00
22.2070	0.2469	5241826.	14911.	-0.00406	18250.	1.50E+11	-657.145	13380.	0.00
22.6260	0.2270	5308490.	11606.	-0.00388	18482.	1.50E+11	-657.319	14562.	0.00
23.0450	0.2079	5358537.	8303.	-0.00371	18656.	1.50E+11	-656.632	15882.	0.00
23.4640	0.1897	5391983.	5005.	-0.00353	18773.	1.50E+11	-655.060	17362.	0.00
23.8830	0.1724	5408869.	1718.	-0.00334	18832.	1.50E+11	-652.581	19029.	0.00
24.3020	0.1561	5409257.	-1555.	-0.00316	18833.	1.50E+11	-649.168	20913.	0.00
24.7210	0.1406	5393234.	-4808.	-0.00298	18777.	1.50E+11	-644.797	23054.	0.00
25.1400	0.1261	5360910.	-8036.	-0.00280	18665.	1.50E+11	-639.438	25498.	0.00
25.5590	0.1125	5312420.	-11235.	-0.00262	18496.	1.50E+11	-633.059	28304.	0.00
25.9780	0.09972	5247927.	-14400.	-0.00245	18271.	1.50E+11	-625.627	31544.	0.00
26.3970	0.08787	5167616.	-17524.	-0.00227	17992.	1.50E+11	-617.104	35311.	0.00
26.8160	0.07689	5071705.	-20603.	-0.00210	17658.	1.50E+11	-607.447	39722.	0.00
27.2350	0.06677	4960437.	-23630.	-0.00193	17270.	1.50E+11	-596.608	44930.	0.00
27.6540	0.05748	4834087.	-26599.	-0.00177	16830.	1.50E+11	-584.531	51134.	0.00
28.0730	0.04900	4692959.	-29504.	-0.00161	16339.	1.50E+11	-571.150	58603.	0.00
28.4920	0.04132	4537392.	-32339.	-0.00145	15797.	1.50E+11	-556.388	67702.	0.00
28.9110	0.03440	4367759.	-35096.	-0.00130	15207.	1.50E+11	-540.147	78940.	0.00
29.3300	0.02822	4184471.	-37767.	-0.00116	14569.	1.50E+11	-522.307	93049.	0.00
29.7490	0.02275	3987978.	-40343.	-0.00102	13885.	1.50E+11	-502.709	111112.	0.00
30.1680	0.01795	3778776.	-42817.	-8.92E-04	13156.	1.50E+11	-481.139	134804.	0.00
30.5870	0.01378	3557411.	-45176.	-7.69E-04	12386.	1.50E+11	-457.292	166851.	0.00
31.0060	0.01021	3324485.	-47409.	-6.53E-04	11575.	1.50E+11	-430.712	212010.	0.00
31.4250	0.00721	3080671.	-49499.	-5.46E-04	10726.	1.50E+11	-400.652	279412.	0.00
31.8440	0.00472	2826728.	-51425.	-4.47E-04	9842.	1.50E+11	-365.750	389278.	0.00
32.2630	0.00272	2563538.	-52814.	-3.57E-04	8925.	1.50E+11	-186.637	345617.	0.00
32.6820	0.00114	2295630.	-53561.	-2.75E-04	7993.	1.50E+11	-110.460	487837.	0.00
33.1010	-5.11E-05	2024929.	-53824.	-2.03E-04	7050.	1.50E+11	5.6458	555252.	0.00
33.5200	-8.99E-04	1754371.	-53530.	-1.39E-04	6108.	1.50E+11	111.3682	622668.	0.00
33.9390	-0.00145	1486629.	-52749.	-8.49E-05	5176.	1.50E+11	199.2348	690083.	0.00
34.3580	-0.00175	1223923.	-51584.	-3.95E-05	4261.	1.50E+11	264.1480	757498.	0.00
34.7770	-0.00185	967895.	-50158.	-2.73E-06	3370.	1.50E+11	303.2923	824914.	0.00
35.1960	-0.00178	719535.	-48601.	2.56E-05	2505.	1.50E+11	316.0283	892329.	0.00
35.6150	-0.00159	479164.	-47043.	4.57E-05	1668.	1.50E+11	303.7847	959745.	0.00

Performed by: G. Khatri 4/9/2024
Checked by: R. Lopina 4/10/2024

36.0340	-0.00132	246473.	-45600.	5.78E-05	858.1275	1.50E+11	269.9612	1027160.	0.00
36.4530	-0.00101	20607.	-44369.	6.23E-05	71.7465	1.50E+11	219.8496	1094575.	0.00
36.8720	-6.95E-04	-199701.	-43413.	5.93E-05	695.2837	1.50E+11	160.5795	1161991.	0.00
37.2910	-4.13E-04	-415949.	-23948.	4.90E-05	1448.	1.50E+11	7582.	9.22E+07	0.00
37.7100	-2.02E-04	-440517.	4947.	3.46E-05	1534.	1.50E+11	3911.	9.73E+07	0.00
38.1290	-6.52E-05	-366200.	18118.	2.11E-05	1275.	1.50E+11	1328.	1.02E+08	0.00
38.5480	9.98E-06	-258320.	20920.	1.06E-05	899.3722	1.50E+11	-213.163	1.07E+08	0.00
38.9670	4.16E-05	-155829.	18043.	3.68E-06	542.5370	1.50E+11	-931.216	1.12E+08	0.00
39.3860	4.70E-05	-76880.	12939.	-2.18E-07	267.6658	1.50E+11	-1099.	1.17E+08	0.00
39.8050	3.95E-05	-25714.	7759.	-1.94E-06	89.5257	1.50E+11	-961.659	1.23E+08	0.00
40.2240	2.75E-05	1141.	3584.	-2.35E-06	3.9710	1.50E+11	-699.061	1.28E+08	0.00
40.6430	1.58E-05	10322.	776.2807	-2.16E-06	35.9377	1.50E+11	-417.581	1.33E+08	0.00
41.0620	5.85E-06	8947.	-670.550	-1.83E-06	31.1496	1.50E+11	-157.928	1.36E+08	0.00
41.4810	-2.62E-06	3579.	-889.703	-1.62E-06	12.4609	1.50E+11	70.7551	1.36E+08	0.00
41.9000	-1.05E-05	0.00	0.00	-1.56E-06	0.00	1.50E+11	283.1442	6.79E+07	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

Pile-head deflection	=	1.95074514 inches
Computed slope at pile head	=	-0.0070684 radians
Maximum bending moment	=	5409257. inch-lbs
Maximum shear force	=	-53824. lbs
Depth of maximum bending moment	=	24.30200000 feet below pile head
Depth of maximum shear force	=	33.10100000 feet below pile head
Number of iterations	=	25
Number of zero deflection points	=	3
Pile deflection at ground	=	0.48989762 inches

Pile-head Deflection vs. Pile Length for Load Case 1

Boundary Condition Type 1, Shear and Moment

Shear = 0. lbs
Moment = 0. in-lbs
Axial Load = 0. lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
41.90000	1.95074514	5409257.	-53824.
39.80500	1.92313729	5359795.	-53709.
37.71000	1.92967272	5375245.	-52059.
35.61500	5.12377707	4857890.	-59673.
33.52000	8.69539062	4687200.	-64814.
31.42500	15.45540219	4625820.	-68719.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 2

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	3.9110	-2.16E-04	0.00	-0.01331	2.71E-07	1.50E+11	0.00	0.00	90.7856
0.4190	3.8441	1148.	477.4789	-0.01331	1.4428	1.50E+11	0.00	0.00	99.1424
0.8380	3.7772	4802.	1004.	-0.01331	6.0367	1.50E+11	0.00	0.00	110.2848
1.2570	3.7102	11244.	1587.	-0.01331	14.1360	1.50E+11	0.00	0.00	121.4271
1.6760	3.6433	20755.	2225.	-0.01331	26.0948	1.50E+11	0.00	0.00	132.5695
2.0950	3.5764	33619.	2920.	-0.01331	42.2672	1.50E+11	0.00	0.00	143.7119

2.5140	3.5095	50115.	3670.	-0.01330	63.0074	1.50E+11	0.00	0.00	154.8543
2.9330	3.4426	70526.	4477.	-0.01330	88.6695	1.50E+11	0.00	0.00	165.9967
3.3520	3.3758	95134.	5339.	-0.01330	119.6078	1.50E+11	0.00	0.00	177.1391
3.7710	3.3089	124220.	6258.	-0.01330	156.1763	1.50E+11	0.00	0.00	188.2814
4.1900	3.2420	158066.	7233.	-0.01329	550.3269	1.50E+11	0.00	0.00	199.4238
4.6090	3.1752	196954.	8264.	-0.01329	685.7186	1.50E+11	0.00	0.00	210.5662
5.0280	3.1084	241164.	9350.	-0.01328	839.6439	1.50E+11	0.00	0.00	221.7086
5.4470	3.0417	290980.	10493.	-0.01327	1013.	1.50E+11	0.00	0.00	232.8510
5.8660	2.9750	346683.	11692.	-0.01326	1207.	1.50E+11	0.00	0.00	243.9934
6.2850	2.9084	408553.	12947.	-0.01325	1422.	1.50E+11	0.00	0.00	255.1357
6.7040	2.8418	476874.	14257.	-0.01323	1660.	1.50E+11	0.00	0.00	266.2781
7.1230	2.7753	551927.	15624.	-0.01321	1922.	1.50E+11	0.00	0.00	277.4205
7.5420	2.7089	633992.	17047.	-0.01319	2207.	1.50E+11	0.00	0.00	288.5629
7.9610	2.6426	723353.	18526.	-0.01317	2518.	1.50E+11	0.00	0.00	299.7053
8.3800	2.5765	820291.	20061.	-0.01315	2856.	1.50E+11	0.00	0.00	310.8476
8.7990	2.5105	925088.	21652.	-0.01312	3221.	1.50E+11	0.00	0.00	321.9900
9.2180	2.4446	1038024.	23299.	-0.01308	3614.	1.50E+11	0.00	0.00	333.1324
9.6370	2.3789	1159382.	25002.	-0.01305	4037.	1.50E+11	0.00	0.00	344.2748
10.0560	2.3134	1289444.	26761.	-0.01301	4489.	1.50E+11	0.00	0.00	355.4172
10.4750	2.2481	1428491.	28576.	-0.01296	4973.	1.50E+11	0.00	0.00	366.5596
10.8940	2.1831	1576805.	30447.	-0.01291	5490.	1.50E+11	0.00	0.00	377.7019
11.3130	2.1183	1734668.	32374.	-0.01285	6039.	1.50E+11	0.00	0.00	388.8443
11.7320	2.0538	1902360.	34357.	-0.01279	6623.	1.50E+11	0.00	0.00	399.9867
12.1510	1.9897	2080165.	36397.	-0.01273	7242.	1.50E+11	0.00	0.00	411.1291
12.5700	1.9258	2268364.	38492.	-0.01265	7898.	1.50E+11	0.00	0.00	422.2715
12.9890	1.8624	2467237.	40643.	-0.01257	8590.	1.50E+11	0.00	0.00	433.4139
13.4080	1.7994	2677068.	42850.	-0.01249	9321.	1.50E+11	0.00	0.00	444.5562
13.8270	1.7368	2898138.	45113.	-0.01239	10090.	1.50E+11	0.00	0.00	455.6986
14.2460	1.6748	3130728.	47433.	-0.01229	10900.	1.50E+11	0.00	0.00	466.8410
14.6650	1.6132	3375120.	49808.	-0.01218	11751.	1.50E+11	0.00	0.00	477.9834
15.0840	1.5523	3631596.	52239.	-0.01207	12644.	1.50E+11	0.00	0.00	489.1258
15.5030	1.4919	3900437.	54727.	-0.01194	13580.	1.50E+11	0.00	0.00	500.2681
15.9220	1.4322	4181926.	57270.	-0.01180	14560.	1.50E+11	0.00	0.00	511.4105
16.3410	1.3732	4476343.	59869.	-0.01166	15585.	1.50E+11	0.00	0.00	522.5529
16.7600	1.3149	4783971.	62525.	-0.01150	16656.	1.50E+11	0.00	0.00	533.6953
17.1790	1.2575	5105092.	65236.	-0.01134	17774.	1.50E+11	0.00	0.00	544.8377
17.5980	1.2009	5439986.	68004.	-0.01116	18940.	1.50E+11	0.00	0.00	555.9801
18.0170	1.1453	5788936.	70223.	-0.01097	20155.	1.50E+11	0.00	0.00	326.8689
18.4360	1.0906	6146149.	69115.	-0.01077	21399.	1.50E+11	-767.568	3539.	0.00
18.8550	1.0369	6483957.	65229.	-0.01056	22575.	1.50E+11	-778.255	3774.	0.00
19.2740	0.9844	6802091.	61291.	-0.01034	23682.	1.50E+11	-788.243	4026.	0.00

Performed by: G. Khatri 4/9/2024
Checked by: R. Lopina 4/10/2024

19.6930	0.9330	7100297.	57304.	-0.01011	24721.	1.50E+11	-797.521	4298.	0.00
20.1120	0.8828	7378341.	53273.	-0.00986	25689.	1.50E+11	-806.071	4591.	0.00
20.5310	0.8338	7636008.	49200.	-0.00961	26586.	1.50E+11	-813.881	4908.	0.00
20.9500	0.7861	7873098.	45090.	-0.00935	27411.	1.50E+11	-820.935	5251.	0.00
21.3690	0.7398	8089435.	40947.	-0.00908	28164.	1.50E+11	-827.219	5622.	0.00
21.7880	0.6948	8284859.	36774.	-0.00881	28845.	1.50E+11	-832.716	6026.	0.00
22.2070	0.6512	8459231.	32575.	-0.00853	29452.	1.50E+11	-837.412	6466.	0.00
22.6260	0.6090	8612433.	28355.	-0.00824	29985.	1.50E+11	-841.291	6946.	0.00
23.0450	0.5683	8744366.	24117.	-0.00795	30445.	1.50E+11	-844.336	7470.	0.00
23.4640	0.5291	8854954.	19866.	-0.00766	30830.	1.50E+11	-846.530	8045.	0.00
23.8830	0.4913	8944141.	15607.	-0.00736	31140.	1.50E+11	-847.858	8676.	0.00
24.3020	0.4551	9011894.	11342.	-0.00706	31376.	1.50E+11	-848.301	9372.	0.00
24.7210	0.4204	9058200.	7078.	-0.00675	31537.	1.50E+11	-847.842	10141.	0.00
25.1400	0.3872	9083073.	2819.	-0.00645	31624.	1.50E+11	-846.461	10992.	0.00
25.5590	0.3555	9086546.	-1431.	-0.00614	31636.	1.50E+11	-844.140	11938.	0.00
25.9780	0.3254	9068679.	-5667.	-0.00584	31574.	1.50E+11	-840.858	12992.	0.00
26.3970	0.2968	9029555.	-9885.	-0.00554	31438.	1.50E+11	-836.596	14172.	0.00
26.8160	0.2697	8969280.	-14078.	-0.00523	31228.	1.50E+11	-831.331	15496.	0.00
27.2350	0.2442	8887989.	-18242.	-0.00493	30945.	1.50E+11	-825.040	16989.	0.00
27.6540	0.2201	8785840.	-22372.	-0.00464	30589.	1.50E+11	-817.700	18678.	0.00
28.0730	0.1975	8663019.	-26462.	-0.00435	30161.	1.50E+11	-809.285	20599.	0.00
28.4920	0.1764	8519739.	-30507.	-0.00406	29663.	1.50E+11	-799.768	22794.	0.00
28.9110	0.1567	8356240.	-34502.	-0.00377	29093.	1.50E+11	-789.122	25315.	0.00
29.3300	0.1385	8172791.	-38440.	-0.00350	28455.	1.50E+11	-777.314	28228.	0.00
29.7490	0.1216	7969692.	-42315.	-0.00323	27747.	1.50E+11	-764.311	31613.	0.00
30.1680	0.1060	7747270.	-46122.	-0.00296	26973.	1.50E+11	-750.077	35576.	0.00
30.5870	0.09176	7505885.	-49855.	-0.00271	26133.	1.50E+11	-734.572	40250.	0.00
31.0060	0.07878	7245930.	-53506.	-0.00246	25228.	1.50E+11	-717.750	45809.	0.00
31.4250	0.06702	6967829.	-57069.	-0.00222	24259.	1.50E+11	-699.560	52481.	0.00
31.8440	0.05644	6672043.	-60537.	-0.00199	23230.	1.50E+11	-679.944	60576.	0.00
32.2630	0.04698	6359068.	-63093.	-0.00177	22140.	1.50E+11	-336.791	36046.	0.00
32.6820	0.03859	6037578.	-64928.	-0.00157	21021.	1.50E+11	-393.106	51217.	0.00
33.1010	0.03122	5706150.	-67046.	-0.00137	19867.	1.50E+11	-449.421	72373.	0.00
33.5200	0.02482	5363361.	-69401.	-0.00118	18673.	1.50E+11	-487.256	98724.	0.00
33.9390	0.01931	5008253.	-71905.	-0.00101	17437.	1.50E+11	-508.618	132411.	0.00
34.3580	0.01466	4640287.	-74496.	-8.49E-04	16156.	1.50E+11	-522.273	179179.	0.00
34.7770	0.01078	4259118.	-77136.	-6.99E-04	14829.	1.50E+11	-527.724	246134.	0.00
35.1960	0.00762	3864607.	-79781.	-5.63E-04	13455.	1.50E+11	-524.321	345834.	0.00
35.6150	0.00512	3456841.	-82384.	-4.40E-04	12035.	1.50E+11	-511.163	502240.	0.00
36.0340	0.00319	3036152.	-84893.	-3.32E-04	10571.	1.50E+11	-486.862	766284.	0.00
36.4530	0.00178	2603155.	-87093.	-2.37E-04	9063.	1.50E+11	-388.314	1094575.	0.00

Performed by: G. Khatri 4/9/2024
Checked by: R. Lopina 4/10/2024

36.8720	8.12E-04	2160342.	-88541.	-1.57E-04	7521.	1.50E+11	-187.625	1161991.	0.00
37.2910	2.04E-04	1712785.	-98429.	-9.21E-05	5963.	1.50E+11	-3746.	9.22E+07	0.00
37.7100	-1.15E-04	1170535.	-102275.	-4.38E-05	4075.	1.50E+11	2216.	9.73E+07	0.00
38.1290	-2.36E-04	684306.	-84631.	-1.27E-05	2382.	1.50E+11	4802.	1.02E+08	0.00
38.5480	-2.42E-04	319482.	-59564.	4.15E-06	1112.	1.50E+11	5169.	1.07E+08	0.00
38.9670	-1.94E-04	85328.	-35652.	1.09E-05	297.0785	1.50E+11	4343.	1.12E+08	0.00
39.3860	-1.32E-04	-39038.	-16980.	1.17E-05	135.9153	1.50E+11	3084.	1.17E+08	0.00
39.8050	-7.64E-05	-85426.	-4546.	9.63E-06	297.4205	1.50E+11	1861.	1.23E+08	0.00
40.2240	-3.52E-05	-84755.	2376.	6.78E-06	295.0840	1.50E+11	892.1097	1.28E+08	0.00
40.6430	-8.22E-06	-61530.	5164.	4.32E-06	214.2257	1.50E+11	216.9050	1.33E+08	0.00
41.0620	8.34E-06	-32823.	5144.	2.74E-06	114.2757	1.50E+11	-225.064	1.36E+08	0.00
41.4810	1.94E-05	-9804.	3264.	2.03E-06	34.1355	1.50E+11	-522.673	1.36E+08	0.00
41.9000	2.87E-05	0.00	0.00	1.86E-06	0.00	1.50E+11	-775.646	6.79E+07	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 2:

Pile-head deflection	=	3.91097731 inches
Computed slope at pile head	=	-0.0133079 radians
Maximum bending moment	=	9086546. inch-lbs
Maximum shear force	=	-102275. lbs
Depth of maximum bending moment	=	25.55900000 feet below pile head
Depth of maximum shear force	=	37.71000000 feet below pile head
Number of iterations	=	25
Number of zero deflection points	=	2
Pile deflection at ground	=	1.14096080 inches

Pile-head Deflection vs. Pile Length for Load Case 2

Boundary Condition Type 1, Shear and Moment

Shear   =   0. lbs
Moment   =   0. in-lbs
Axial Load =   0. lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
41.90000	3.91097731	9086546.	-102275.
39.80500	3.86017340	9012587.	-109363.
37.71000	3.94132495	8884237.	-143232.
35.61500	64.65353937	7689422.	-104672.

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	1.9507	-0.00707	-53824.	5409257.
2	V, lb	0.00	M, in-lb	0.00	0.00	3.9110	-0.01331	-102275.	9086546.

Maximum pile-head deflection = 3.9109773139 inches
Maximum pile-head rotation   = -0.0133079443 radians = -0.762489 deg.

Summary of Warning Messages

The following warning was reported 4522 times

**** Warning ****

An unreasonable input value for compressive strength has been specified
for a soil defined using the weak rock criteria. The input value is less
than 100 psi. Please check your input data for correctness.

The following warning was reported 932 times

**** Warning ****

An unreasonable input value for unconfined compressive strength has been
specified for a soil defined using the weak rock criteria. The input value
is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.

Stantec

CHECK FOR BEAM CLEARANCE

- Chosen beam size: W24X162
- d = 25.0 in
- b_f = 13.0 in
- $\sqrt{25^2+13^2}$ = 28.18 in
- 3-inch clearance for a drilled shaft size of 36 inches = 36 in - 2 (3 in) = 30 in
- 28.18 in < 30 in → **ACCEPTABLE**

CHECK FOR DEFLECTION

- Allowable Deflection – 2 inches (GDM)
- W24X162 deflection from LPILE is 1.95 inches
- 1.95 in < 2.00 in → **ACCEPTABLE**

CHECK FOR SHEAR CAPACITY OF BEAM

- Section 6 of 8th edition of LRFD Bridge Design Manual
- Chosen beam size: W24x162
    - Maximum Shear from LPILE – 102.28 kips
- $V_n = C\ V_p$

$$V_p = 0.58 F_{yw} D t_w \qquad (6.10.9.3.2\text{-}3)$$

where:

d_o = transverse stiffener spacing (in.)
V_n = nominal shear resistance of the web panel (kip)
V_p = plastic shear force (kip)
C = ratio of the shear-buckling resistance to the shear yield strength

- $V_n = 1.0\ (0.58\ F_{yw}\ D\ t_w)$
- V_n = 1.0 (0.58) (50 ksi) (25 in) (0.705 in)
- V_n = 511.13 kips > 102.28 kips → **ACCEPTABLE**

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Checked By: R. Lopina 04/10/2024

Stantec

CHECK FOR BUCKLING OF BEAM

- Chosen beam size: W24X162

- If $\frac{D}{t_w} \le 1.12\sqrt{\frac{Ek}{F_{yw}}}$, then:

$$C = 1.0 \qquad (6.10.9.3.2\text{-}4)$$

in which:

k = shear-buckling coefficient

$$= 5 + \frac{5}{\left(\frac{d_o}{D}\right)^2} \qquad (6.10.9.3.2\text{-}7)$$

- $k = 5 + \frac{5}{(\frac{69\text{in}}{25.0\text{iin}})^2} = 5.66$
- $1.12\sqrt{\frac{(29{,}000\text{ ksi})\ (5.66)}{50\text{ ksi}}} = 64.17$
- $\frac{D}{t_w} = \frac{25.0}{0.705} = 35.46 < 64.17 \rightarrow$ **ACCEPTABLE**

CHECK MOMENT CAPACITY

- Chosen beam size: W24X162
    - Beam stickup is approx. 4 feet for moment calculation (pre-cast lagging buried 4 feet)
    - Maximum moment from LPILE – 757.2 ft-kips
    - From “Steel Construction Manual”, AISC 14th Edition – an unbraced length of 4 feet for a W24x162 beam can support a moment capacity of approximately 1755 ft-kips; which is greater than 757.2 ft-kips → **ACCEPTABLE**

LPile Analysis

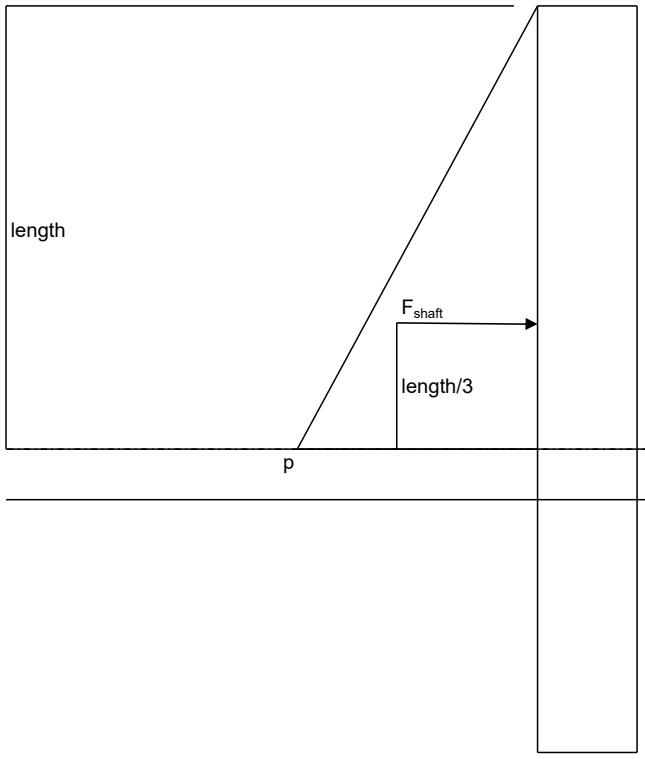
HAM-52-36.85

SLM 37.65

SUMMARY OF DRILLED SHAFT CALCULATIONS

LOADING CONDITIONS

Loading conditions were evaluated using shaft loads determined from the UA SLOPE (Version 2.3) computer program. This shaft load, combined with an assumed traffic surcharge live load, was applied to the drilled shaft above the assumed failure surface. The drilled shaft was evaluated using LPILEv2022 which is a program for the analysis of piles and drilled shafts under lateral loads. Unfactored loads (Service I Limit State) were utilized to estimate shaft head deflection and factored loads (Strength I Limit State) were used to evaluate geotechnical resistance.



Projected Ground line Depth = 0.00

Note:
x_2 represents the maximum value of the triangular distributed load that will be used in LPILE determined from F_{shaft} from the University of Akron program.

Assumed Failure Surface Depth = 17.25

Top of Rock Depth = 22.50

Bottom of Drilled Shaft Depth = 32.50

Estimated Depth to Bedrock =	22.50	feet	UA Slope Input
Estimated Depth to Failure Surface=	17.25	feet	UA Slope Input
Shaft Size =	3	feet	UA Slope Input
Center to Center Spacing =	5.75	feet	UA Slope Input
F_{shaft} =	35,331	pounds	UA Slope Output
Factor of Safety =	1.24		UA Slope Output
p = (2*Fshaft)/H * (1 ft/12 in)	341	pounds per inch	

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Checked By: R. Lopina 4/10/2024

DISTRIBUTED LOAD FOR LPILE INPUT

F_{live} = assumed traffic surcharge load =	250	psf
Phi =	24.0	degrees
K_a =	0.422	
x1 = F_{live} * s * Ka * (1 ft/12 in)	51	pounds per inch
x2 = [2*Fshaft/(Depth to Failure Surface)] + x1		

Service (I) Limit State:

x1 =	51	pounds per inch
x2 =	392	pounds per inch
Total Load =	45788	pounds

Strength (I) Limit State:

x1 =	88	pounds per inch (Load Factor = 1.75)
x2 =	600	pounds per inch (Load Factor = 1.5)
Total Load =	80447	pounds

CHOOSE MATERIAL p-y CURVES for LPILE Program

Material Type	*Value*	*Units*	
Soft Clay			
γ=	60	pcf	based on tubes lab testing
c=	1,500	psf	based on ODOT GDM Section 404.1 (conservative)
Bedrock - Shale (Weak Rock)			
γ'=	51	pcf	based on lab test of B-003-0-24 with weak strength
E=	720	psi	=90 x qu
qu=	8	psi	based on lab test pf B-003-0-24 with weak strength
RQD=	0	%	conservative for weak rock
Km=	0.00005		conservative for weak rock
Bedrock - Interbedded Shale and Sandstone (Weak Rock)			
γ'=	72	pcf	based on average UCR from B-001-0-24 to B-007-0-24
E=	54,000	psi	=90 x qu
qu=	600	psi	average from lab test and ODOT GDM values
RQD=	50	%	Based on average from B-005-0-24 to B-007-0-24
Km=	0.00005		conservative for weak rock
p-y Modification Factor			
p = 0.64 (Spacing/Diameter)$^{0.34}$	0.80		

SHAFT CONCRETE AND STEEL MATERIAL PROPERTIES FOR LPILE

Parameter	*Value*		*Note*
f'_c =	4,000	psi	(ODOT Class S Concrete)
E_c =	3,604,997	psi	E_c = 57,000 * SQRT(f'c)
$f_{y\ steel}$=	50,000	psi	
E_{steel}=	2.9E+07	psi	

Performed By: G. Khatri 4/9/2024
Checked By: R. Lopina 4/10/2024

LPILE VERSION 2022 RUNS

SERVICE (I) AND STRENGTH (I) LIMIT STATES

Purpose: Achieve a shaft head deflection of 2 inches or less for Service (I) Limit State. Recommend a rock socket length by observation of the shear and moment curves. Provide shear and moment design parameters for the selection of steel beam reinforcement.

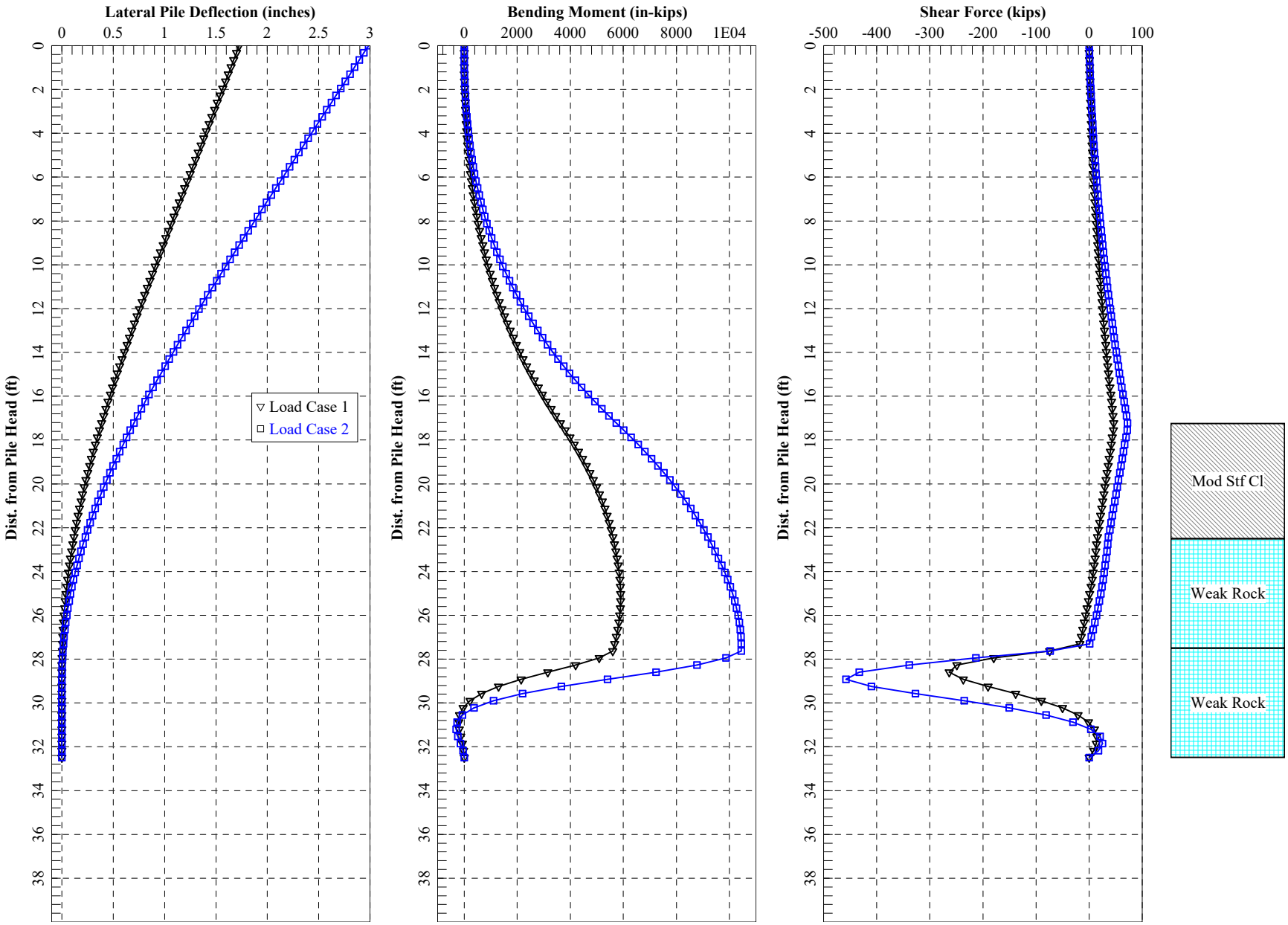
Run ID	Filename	Reinforcement Description	Deflection at Pile Head (in)	Maximum Moment (in-lbs)	Maximum Shear (lbs)
1	W27X129_3ftD_5.75ftCTC	W27X129	1.73	5,894,050	263,612
2	W27X129_3ftD_5.75ftCTC	W27X129	2.99	10,400,000	457,732

Based on the calculations and assumptions presented above, it appears a 36-inch diameter drilled shaft with a center-to-center spacing of 69 inches can provide tolerable deflections when placed approximately at 52 ft from the centreline of the roadway. A minimum 10-foot rock socket is recommended.

PROPERTIES OF SELECTED SECTIONS

Run ID	Source	Reinforcement Description	Area of Steel (in^2)	Moment of Inertia (in^4)	Section Modulus (in^3)
1 & 2	AISC Manual of Steel Construction	W27X129	37.8	4,760	345

Performed By: G. Khatri 4/9/2024
Checked By: R. Lopina 4/10/2024


Lateral Pile Deflection (inches)
0
0.5
1
1.5
2
2.5
3
Dist. from Pile Head (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Load Case 1
Load Case 2
Bending Moment (in-kips)
0
2000
4000
6000
8000
1E04
Shear Force (kips)
-500
-400
-300
-200
-100
0
100
Mod Stf Cl
Weak Rock
Weak Rock

```
================================================================================

                    LPile for Windows, Version 2022-12.006

                 Analysis of Individual Piles and Drilled Shafts
                Subjected to Lateral Loading Using the p-y Method
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================================================================================

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--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\173410733\technical_production\working_report\Appendix G - LPile Analysis\

Name of input data file:
HAM-52-36.85_section 37.65 W27X129 Lpile Analysis.lp12d

Name of output report file:
HAM-52-36.85_section 37.65 W27X129 Lpile Analysis.lp12o

Name of plot output file:
```

HAM-52-36.85_section 37.65 W27X129 Lpile Analysis.lp12p

Name of runtime message file:
HAM-52-36.85_section 37.65 W27X129 Lpile Analysis.lp12r

Date and Time of Analysis

Date: April 11, 2024 Time: 10:14:14

Problem Title

Project Name: HAM-52-36.85

Job Number: 173410733

Client: Ohio Department of Transportation (ODOT)

Engineer: G. Khatri

Description: L-Pile Analsis

Program Options and Settings

Computational Options:
 - Conventional Analysis
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed = 500
 - Deflection tolerance for convergence = 1.0000E-05 in
 - Maximum allowable deflection = 100.0000 in
 - Number of pile increments = 100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Analysis uses p-y modification factors for p-y curves
 - Analysis uses layering correction (Method of Georgiadis)
 - Analysis includes loading by multiple distributed lateral loads acting on pile
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 2
Total length of pile = 32.500 ft

Performed by: G. Khatri 4/9/2024
Checked by: R. Lopina 4/10/2024

Depth of ground surface below top of pile = 17.2500 ft

Pile diameters used for p-y curve computations are defined using 4 points.

p-y curves are computed using pile diameter values interpolated with depth over the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	10.0000
2	4.000	10.0000
3	4.000	36.0000
4	32.500	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is a AISC strong axis steel pile
Length of section = 4.000000 ft
AISC Section Type = W

AISC Section Name = W27X129

Pile width = 10.000000 in

Pile Section No. 2:

Section 2 is an elastic pile
Cross-sectional Shape = Circular Pile
Length of section = 28.500000 ft
Width of top of section = 36.000000 in
Width of bottom of section = 36.000000 in
Top Area = 37.800000 sq. in
Bottom Area = 37.800000 sq. in

```
   Moment of Inertia at Top                          =        4760. in^4
   Moment of Inertia at Bottom                       =        4760. in^4
   Elastic Modulus                                   =    29000000. psi



--------------------------------------------------------------------------------
                      Soil and Rock Layering Information
--------------------------------------------------------------------------------

The soil profile is modelled using 3 layers

Layer 1 is stiff clay with user-defined k-value

   Distance from top of pile to top of layer         =    17.250000 ft
   Distance from top of pile to bottom of layer      =    22.500000 ft
   Effective unit weight at top of layer             =    60.000000 pcf
   Effective unit weight at bottom of layer          =    60.000000 pcf
   Undrained cohesion at top of layer                =        1500. psf
   Undrained cohesion at bottom of layer             =        1500. psf
   Epsilon-50 at top of layer                        =       0.0000
   Epsilon-50 at bottom of layer                     =       0.0000
   Subgrade k at top of layer                        =       0.0000 pci
   Subgrade k at bottom of layer                     =       0.0000 pci

   NOTE: Default values for Epsilon-50 will be computed for this layer.
   NOTE: Default values for subgrade k will be computed for this layer.

Layer 2 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer         =    22.500000 ft
   Distance from top of pile to bottom of layer      =    27.500000 ft
   Effective unit weight at top of layer             =    51.000000 pcf
   Effective unit weight at bottom of layer          =    51.000000 pcf
   Uniaxial compressive strength at top of layer     =     8.000000 psi
   Uniaxial compressive strength at bottom of layer  =     8.000000 psi
   Initial modulus of rock at top of layer           =   720.000000 psi
   Initial modulus of rock at bottom of layer        =   720.000000 psi
   RQD of rock at top of layer                       =       0.0000 %
   RQD of rock at bottom of layer                    =       0.0000 %
   k rm of rock at top of layer                      =    0.0000500
```

```
   k rm of rock at bottom of layer                    =    0.0000500


Layer 3 is weak rock, p-y criteria by Reese, 1997

   Distance from top of pile to top of layer          =    27.500000 ft
   Distance from top of pile to bottom of layer       =    32.500000 ft
   Effective unit weight at top of layer              =    72.000000 pcf
   Effective unit weight at bottom of layer           =    72.000000 pcf
   Uniaxial compressive strength at top of layer      =   600.000000 psi
   Uniaxial compressive strength at bottom of layer   =   600.000000 psi
   Initial modulus of rock at top of layer            =       54000. psi
   Initial modulus of rock at bottom of layer         =       54000. psi
   RQD of rock at top of layer                        =    50.000000 %
   RQD of rock at bottom of layer                     =    50.000000 %
   k rm of rock at top of layer                       =    0.0000500
   k rm of rock at bottom of layer                    =    0.0000500


 (Depth of the lowest soil layer extends 0.000 ft below the pile tip)



--------------------------------------------------------------------------------
                        Summary of Input Soil Properties
--------------------------------------------------------------------------------

Layer         Soil Type          Layer      Effective    Cohesion     Uniaxial                    E50
     Rock Mass
 Num.           Name             Depth       Unit Wt.                    qu          RQD %         or           kpy
      Modulus
          (p-y Curve Type)        ft           pcf          psf          psi                      krm          pci
        psi
-----   ------------------   ----------   ----------   ----------   ----------   ----------   ----------
----------   ----------
  1       Stiff Clay w/o         17.2500      60.0000        1500.       --           --         default
default        --
        Free Water, using k      22.5000      60.0000        1500.       --           --         default
default        --
  2            Weak              22.5000      51.0000       --           8.0000         0.00     5.00E-05       --
      720.0000
```

	Rock	27.5000	51.0000	--	8.0000	0.00	5.00E-05	--
720.0000								
3	Weak	27.5000	72.0000	--	600.0000	50.0000	5.00E-05	--
54000.								
	Rock	32.5000	72.0000	--	600.0000	50.0000	5.00E-05	--
54000.								

Modification Factors for p-y Curves

Distribution of p-y modifiers with depth defined using 2 points

Point No.	Depth X ft	p-mult	y-mult
1	17.250	0.8000	1.0000
2	17.250	0.8000	1.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading for Individual Load Cases

Distributed lateral load intensity for Load Case 1 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	59.000

2	17.250	392.000

Distributed lateral load intensity for Load Case 2 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	103.000
2	17.250	600.000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes
2	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 2

Pile Section No. 1:

Dimensions and Properties of Steel AISC Strong Axis:

Length of Section	=	4.000000 ft
Flange Width	=	10.000000 in
Section Depth	=	27.600000 in
Flange Thickness	=	1.100000 in
Web Thickness	=	0.610000 in
Yield Stress of Pipe	=	50.000000 ksi
Elastic Modulus	=	29000. ksi
Cross-sectional Area	=	37.800000 sq. in.
Moment of Inertia	=	4760. in^4
Elastic Bending Stiffness	=	138040000. kip-in^2
Plastic Modulus, Z	=	395.000000in^3
Plastic Moment Capacity = Fy Z	=	19750.in-kip

Axial Structural Capacities:

Nom. Axial Structural Capacity = Fy As	=	1890.000 kips
Nominal Axial Tensile Capacity	=	-1890.000 kips

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	0.000

Definition of Run Messages:

Y = part of pipe section has yielded.

Axial Thrust Force = 0.000 kips

Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in2	Depth to N Axis in	Max Total Stress ksi	Run Msg
0.00000733	998.1344063	136215990.	13.8000000	2.9031750	
0.00001466	1996.	136215990.	13.8000000	5.8063500	
0.00002198	2994.	136215990.	13.8000000	8.7095251	
0.00002931	3993.	136215990.	13.8000000	11.6127001	
0.00003664	4991.	136215990.	13.8000000	14.5158751	
0.00004397	5989.	136215990.	13.8000000	17.4190501	
0.00005129	6987.	136215990.	13.8000000	20.3222251	
0.00005862	7985.	136215990.	13.8000000	23.2254002	
0.00006595	8983.	136215990.	13.8000000	26.1285752	
0.00007328	9981.	136215990.	13.8000000	29.0317502	
0.00008060	10979.	136215990.	13.8000000	31.9349252	
0.00008793	11978.	136215990.	13.8000000	34.8381003	
0.00009526	12976.	136215990.	13.8000000	37.7412753	
0.0001026	13974.	136215990.	13.8000000	40.6444503	
0.0001099	14972.	136215990.	13.8000000	43.5476253	
0.0001172	15970.	136215990.	13.8000000	46.4508003	
0.0001246	16968.	136215990.	13.8000000	49.3539754	
0.0001319	17697.	134172382.	13.8000000	50.0000000	Y
0.0001392	17934.	128816136.	13.8000000	50.0000000	Y
0.0001466	18087.	123414582.	13.8000000	50.0000000	Y
0.0001539	18217.	118388218.	13.8000000	50.0000000	Y
0.0001612	18331.	113708874.	13.8000000	50.0000000	Y
0.0001685	18429.	109351208.	13.8000000	50.0000000	Y
0.0001759	18517.	105291553.	13.8000000	50.0000000	Y
0.0001832	18593.	101495332.	13.8000000	50.0000000	Y
0.0001905	18661.	97948692.	13.8000000	50.0000000	Y
0.0001978	18722.	94628537.	13.8000000	50.0000000	Y
0.0002052	18776.	91513170.	13.8000000	50.0000000	Y
0.0002125	18825.	88586071.	13.8000000	50.0000000	Y
0.0002198	18868.	85832960.	13.8000000	50.0000000	Y
0.0002272	18908.	83239680.	13.8000000	50.0000000	Y

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Checked by: R. Lopina 4/10/2024

0.0002345	18944.	80790909.	13.8000000	50.0000000	Y
0.0002418	18977.	78477408.	13.8000000	50.0000000	Y
0.0002491	19007.	76289296.	13.8000000	50.0000000	Y
0.0002565	19034.	74217653.	13.8000000	50.0000000	Y
0.0002638	19059.	72251223.	13.8000000	50.0000000	Y
0.0002711	19082.	70383062.	13.8000000	50.0000000	Y
0.0002784	19104.	68609134.	13.8000000	50.0000000	Y
0.0002858	19123.	66917587.	13.8000000	50.0000000	Y
0.0003004	19159.	63770731.	13.8000000	50.0000000	Y
0.0003151	19189.	60901114.	13.8000000	50.0000000	Y
0.0003297	19215.	58274449.	13.8000000	50.0000000	Y
0.0003444	19239.	55862032.	13.8000000	50.0000000	Y
0.0003591	19259.	53639601.	13.8000000	50.0000000	Y
0.0003737	19277.	51583818.	13.8000000	50.0000000	Y
0.0003884	19293.	49678096.	13.8000000	50.0000000	Y
0.0004030	19308.	47908515.	13.8000000	50.0000000	Y
0.0004177	19320.	46256847.	13.8000000	50.0000000	Y
0.0004323	19332.	44716609.	13.8000000	50.0000000	Y
0.0004470	19342.	43272769.	13.8000000	50.0000000	Y
0.0004616	19352.	41920602.	13.8000000	50.0000000	Y
0.0004763	19360.	40647785.	13.8000000	50.0000000	Y
0.0004909	19368.	39450656.	13.8000000	50.0000000	Y
0.0005056	19376.	38321579.	13.8000000	50.0000000	Y
0.0005203	19382.	37254146.	13.8000000	50.0000000	Y
0.0005349	19388.	36245203.	13.8000000	50.0000000	Y
0.0005496	19394.	35288931.	13.8000000	50.0000000	Y
0.0005642	19399.	34380890.	13.8000000	50.0000000	Y
0.0005789	19403.	33518825.	13.8000000	50.0000000	Y
0.0005935	19408.	32699332.	13.8000000	50.0000000	Y
0.0006082	19412.	31917545.	13.8000000	50.0000000	Y
0.0006228	19416.	31172364.	13.8000000	50.0000000	Y
0.0006375	19419.	30461444.	13.8000000	50.0000000	Y

Summary of Results for Nominal Moment Capacity for Section 1

Load No.	Axial Thrust	Nominal Moment Capacity		

	kips	in-kips
1	0.00000000	19419.

Note that the values in the above table are not factored by a strength reduction factor for LRFD.

The value of the strength reduction factor depends on the provisions of the LRFD code being followed.

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to the LRFD structural design standard being followed.

Pile Section No. 2:

Moment-curvature properties were derived from elastic section properties

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	17.2500	0.00	N.A.	No	0.00	83809.
2	22.5000	5.2500	No	Yes	N.A.	N.A.
3	27.5000	10.2500	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals for Layer n. Layering correction equivalent depths are computed only for soil types with both shallow-depth and deep-depth expressions for peak lateral load transfer. These soil types are soft and stiff clays,

non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	1.7261	-1.05E-04	0.00	-0.00682	1.11E-07	1.36E+11	0.00	0.00	60.5685
0.3250	1.6995	460.6233	245.3927	-0.00682	0.4838	1.36E+11	0.00	0.00	65.2739
0.6500	1.6729	1914.	512.1951	-0.00682	2.0106	1.36E+11	0.00	0.00	71.5478
0.9750	1.6463	4456.	803.4657	-0.00682	4.6804	1.36E+11	0.00	0.00	77.8217
1.3000	1.6197	8181.	1119.	-0.00682	8.5936	1.36E+11	0.00	0.00	84.0957
1.6250	1.5931	13186.	1459.	-0.00682	13.8504	1.36E+11	0.00	0.00	90.3696
1.9500	1.5665	19565.	1824.	-0.00682	20.5510	1.36E+11	0.00	0.00	96.6435
2.2750	1.5399	27413.	2213.	-0.00682	28.7956	1.36E+11	0.00	0.00	102.9174
2.6000	1.5134	36828.	2627.	-0.00682	38.6846	1.36E+11	0.00	0.00	109.1913
2.9250	1.4868	47903.	3065.	-0.00681	50.3181	1.36E+11	0.00	0.00	115.4652
3.2500	1.4602	60734.	3527.	-0.00681	63.7963	1.36E+11	0.00	0.00	121.7391
3.5750	1.4336	75417.	4014.	-0.00681	79.2196	1.36E+11	0.00	0.00	128.0130
3.9000	1.4071	92047.	4526.	-0.00681	96.6881	1.36E+11	0.00	0.00	134.2870
4.2250	1.3805	110720.	5062.	-0.00681	418.6878	1.38E+11	0.00	0.00	140.5609
4.5500	1.3540	131530.	5622.	-0.00680	497.3829	1.38E+11	0.00	0.00	146.8348
4.8750	1.3275	154574.	6207.	-0.00680	584.5235	1.38E+11	0.00	0.00	153.1087
5.2000	1.3010	179947.	6817.	-0.00679	680.4703	1.38E+11	0.00	0.00	159.3826
5.5250	1.2745	207743.	7450.	-0.00679	785.5844	1.38E+11	0.00	0.00	165.6565
5.8500	1.2480	238060.	8109.	-0.00678	900.2265	1.38E+11	0.00	0.00	171.9304
6.1750	1.2216	270991.	8791.	-0.00677	1025.	1.38E+11	0.00	0.00	178.2043
6.5000	1.1952	306633.	9499.	-0.00677	1160.	1.38E+11	0.00	0.00	184.4783

6.8250	1.1688	345081.	10230.	-0.00676	1305.	1.38E+11	0.00	0.00	190.7522
7.1500	1.1425	386431.	10987.	-0.00675	1461.	1.38E+11	0.00	0.00	197.0261
7.4750	1.1162	430777.	11767.	-0.00674	1629.	1.38E+11	0.00	0.00	203.3000
7.8000	1.0899	478215.	12572.	-0.00672	1808.	1.38E+11	0.00	0.00	209.5739
8.1250	1.0637	528841.	13402.	-0.00671	2000.	1.38E+11	0.00	0.00	215.8478
8.4500	1.0376	582750.	14256.	-0.00669	2204.	1.38E+11	0.00	0.00	222.1217
8.7750	1.0115	640037.	15134.	-0.00668	2420.	1.38E+11	0.00	0.00	228.3957
9.1000	0.9855	700798.	16037.	-0.00666	2650.	1.38E+11	0.00	0.00	234.6696
9.4250	0.9596	765129.	16965.	-0.00664	2893.	1.38E+11	0.00	0.00	240.9435
9.7500	0.9338	833124.	17917.	-0.00661	3150.	1.38E+11	0.00	0.00	247.2174
10.0750	0.9080	904880.	18893.	-0.00659	3422.	1.38E+11	0.00	0.00	253.4913
10.4000	0.8824	980491.	19894.	-0.00656	3708.	1.38E+11	0.00	0.00	259.7652
10.7250	0.8568	1060053.	20919.	-0.00653	4009.	1.38E+11	0.00	0.00	266.0391
11.0500	0.8314	1143662.	21969.	-0.00650	4325.	1.38E+11	0.00	0.00	272.3130
11.3750	0.8061	1231412.	23043.	-0.00647	4657.	1.38E+11	0.00	0.00	278.5870
11.7000	0.7810	1323400.	24142.	-0.00643	5004.	1.38E+11	0.00	0.00	284.8609
12.0250	0.7560	1419720.	25265.	-0.00639	5369.	1.38E+11	0.00	0.00	291.1348
12.3500	0.7311	1520469.	26413.	-0.00635	5750.	1.38E+11	0.00	0.00	297.4087
12.6750	0.7064	1625741.	27585.	-0.00631	6148.	1.38E+11	0.00	0.00	303.6826
13.0000	0.6819	1735633.	28782.	-0.00626	6563.	1.38E+11	0.00	0.00	309.9565
13.3250	0.6576	1850238.	30003.	-0.00621	6997.	1.38E+11	0.00	0.00	316.2304
13.6500	0.6335	1969654.	31248.	-0.00616	7448.	1.38E+11	0.00	0.00	322.5043
13.9750	0.6096	2093975.	32518.	-0.00610	7918.	1.38E+11	0.00	0.00	328.7783
14.3000	0.5859	2223296.	33813.	-0.00604	8407.	1.38E+11	0.00	0.00	335.0522
14.6250	0.5625	2357714.	35132.	-0.00597	8916.	1.38E+11	0.00	0.00	341.3261
14.9500	0.5393	2497323.	36475.	-0.00590	9444.	1.38E+11	0.00	0.00	347.6000
15.2750	0.5164	2642220.	37843.	-0.00583	9992.	1.38E+11	0.00	0.00	353.8739
15.6000	0.4938	2792498.	39235.	-0.00575	10560.	1.38E+11	0.00	0.00	360.1478
15.9250	0.4715	2948255.	40652.	-0.00567	11149.	1.38E+11	0.00	0.00	366.4217
16.2500	0.4496	3109585.	42093.	-0.00559	11759.	1.38E+11	0.00	0.00	372.6957
16.5750	0.4280	3276583.	43559.	-0.00550	12390.	1.38E+11	0.00	0.00	378.9696
16.9000	0.4067	3449346.	45049.	-0.00540	13044.	1.38E+11	0.00	0.00	385.2435
17.2250	0.3858	3627968.	46240.	-0.00530	13719.	1.38E+11	0.00	0.00	225.1097
17.5500	0.3653	3810014.	45702.	-0.00520	14408.	1.38E+11	-501.009	5348.	0.00
17.8750	0.3453	3984440.	43740.	-0.00509	15067.	1.38E+11	-504.821	5702.	0.00
18.2000	0.3256	4151188.	41765.	-0.00497	15698.	1.38E+11	-508.169	6086.	0.00
18.5250	0.3065	4310206.	39777.	-0.00485	16299.	1.38E+11	-511.040	6503.	0.00
18.8500	0.2878	4461451.	37780.	-0.00473	16871.	1.38E+11	-513.418	6958.	0.00
19.1750	0.2696	4604888.	35774.	-0.00460	17413.	1.38E+11	-515.288	7454.	0.00
19.5000	0.2519	4740486.	33761.	-0.00447	17926.	1.38E+11	-516.633	7999.	0.00
19.8250	0.2347	4868227.	31745.	-0.00433	18409.	1.38E+11	-517.436	8597.	0.00

Performed by: G. Khatri 4/9/2024
Checked by: R. Lopina 4/10/2024

20.1500	0.2181	4988097.	29727.	-0.00419	18863.	1.38E+11	-517.677	9257.	0.00
20.4750	0.2020	5100094.	27708.	-0.00405	19286.	1.38E+11	-517.335	9987.	0.00
20.8000	0.1865	5204222.	25693.	-0.00391	19680.	1.38E+11	-516.389	10798.	0.00
21.1250	0.1716	5300496.	23682.	-0.00376	20044.	1.38E+11	-514.814	11703.	0.00
21.4500	0.1572	5388939.	21678.	-0.00361	20378.	1.38E+11	-512.585	12717.	0.00
21.7750	0.1434	5469586.	19685.	-0.00345	20683.	1.38E+11	-509.671	13859.	0.00
22.1000	0.1303	5542481.	17704.	-0.00330	20959.	1.38E+11	-506.041	15151.	0.00
22.4250	0.1177	5607679.	15739.	-0.00314	21206.	1.38E+11	-501.659	16622.	0.00
22.7500	0.1058	5665247.	14134.	-0.00298	21423.	1.38E+11	-321.605	11859.	0.00
23.0750	0.09445	5717923.	12794.	-0.00282	21622.	1.38E+11	-365.286	15083.	0.00
23.4000	0.08377	5765043.	11285.	-0.00266	21801.	1.38E+11	-408.967	19040.	0.00
23.7250	0.07372	5805943.	9604.	-0.00249	21955.	1.38E+11	-452.648	23946.	0.00
24.0500	0.06431	5839958.	7754.	-0.00233	22084.	1.38E+11	-496.329	30098.	0.00
24.3750	0.05555	5866424.	5733.	-0.00216	22184.	1.38E+11	-540.010	37914.	0.00
24.7000	0.04743	5884676.	3542.	-0.00200	22253.	1.38E+11	-583.692	47996.	0.00
25.0250	0.03996	5894050.	1180.	-0.00183	22288.	1.38E+11	-627.374	61233.	0.00
25.3500	0.03314	5893882.	-1352.	-0.00167	22288.	1.38E+11	-671.056	78977.	0.00
25.6750	0.02697	5883508.	-4031.	-0.00150	22249.	1.38E+11	-703.075	101682.	0.00
26.0000	0.02144	5862439.	-6776.	-0.00133	22169.	1.38E+11	-704.502	128132.	0.00
26.3250	0.01657	5830655.	-9512.	-0.00117	22049.	1.38E+11	-698.531	164448.	0.00
26.6500	0.01233	5788246.	-12208.	-0.00100	21888.	1.38E+11	-684.173	216378.	0.00
26.9750	0.00873	5735431.	-14829.	-8.41E-04	21689.	1.38E+11	-660.078	294721.	0.00
27.3000	0.00577	5672577.	-17334.	-6.80E-04	21451.	1.38E+11	-624.306	421988.	0.00
27.6250	0.00343	5600226.	-74502.	-5.21E-04	21177.	1.38E+11	-28693.	3.26E+07	0.00
27.9500	0.00171	5091458.	-179551.	-3.70E-04	19253.	1.38E+11	-25178.	5.75E+07	0.00
28.2750	5.45E-04	4199726.	-249133.	-2.39E-04	15881.	1.38E+11	-10504.	7.51E+07	0.00
28.6000	-1.54E-04	3148222.	-263612.	-1.35E-04	11905.	1.38E+11	3079.	7.82E+07	0.00
28.9250	-5.06E-04	2143550.	-237074.	-6.00E-05	8106.	1.38E+11	10530.	8.12E+07	0.00
29.2500	-6.22E-04	1299045.	-190352.	-1.14E-05	4912.	1.38E+11	13430.	8.42E+07	0.00
29.5750	-5.95E-04	658806.	-138216.	1.63E-05	2491.	1.38E+11	13306.	8.73E+07	0.00
29.9000	-4.95E-04	220957.	-89923.	2.87E-05	835.5534	1.38E+11	11460.	9.03E+07	0.00
30.2250	-3.71E-04	-42592.	-50272.	3.12E-05	161.0618	1.38E+11	8874.	9.34E+07	0.00
30.5500	-2.51E-04	-171165.	-20856.	2.82E-05	647.2634	1.38E+11	6211.	9.64E+07	0.00
30.8750	-1.51E-04	-205266.	-1250.	2.29E-05	776.2168	1.38E+11	3843.	9.95E+07	0.00
31.2000	-7.28E-05	-180917.	9972.	1.74E-05	684.1414	1.38E+11	1912.	1.02E+08	0.00
31.5250	-1.47E-05	-127487.	14477.	1.31E-05	482.0925	1.38E+11	398.1402	1.05E+08	0.00
31.8500	2.92E-05	-68000.	13715.	1.03E-05	257.1439	1.38E+11	-788.854	1.05E+08	0.00
32.1750	6.57E-05	-20512.	8718.	9.06E-06	77.5676	1.38E+11	-1774.	1.05E+08	0.00
32.5000	9.99E-05	0.00	0.00	8.77E-06	0.00	1.38E+11	-2697.	5.26E+07	0.00

* This analysis computed pile response using nonlinear moment-curvature rela-

tionships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     1.72607991 inches
Computed slope at pile head      =     -0.0068186 radians
Maximum bending moment           =       5894050. inch-lbs
Maximum shear force              =       -263612. lbs
Depth of maximum bending moment  =    25.02500000 feet below pile head
Depth of maximum shear force     =    28.60000000 feet below pile head
Number of iterations             =             15
Number of zero deflection points =              2
Pile deflection at ground        =     0.38423556 inches
```

Pile-head Deflection vs. Pile Length for Load Case 1

Boundary Condition Type 1, Shear and Moment

```
Shear      =              0. lbs
Moment     =              0. in-lbs
Axial Load =              0. lbs
```

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
32.50000	1.72607991	5894050.	-263612.
30.87500	1.75090881	5894689.	-263347.
29.25000	2.70590497	5505345.	-396905.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 2

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	2.9856	2.11E-04	0.00	-0.01159	2.21E-07	1.36E+11	0.00	0.00	105.3409
0.3250	2.9403	801.1180	424.5242	-0.01159	0.8415	1.36E+11	0.00	0.00	112.3638
0.6500	2.8951	3311.	881.0022	-0.01159	3.4782	1.36E+11	0.00	0.00	121.7275
0.9750	2.8499	7673.	1374.	-0.01159	8.0598	1.36E+11	0.00	0.00	131.0913
1.3000	2.8047	14028.	1904.	-0.01159	14.7358	1.36E+11	0.00	0.00	140.4551
1.6250	2.7595	22520.	2470.	-0.01159	23.6558	1.36E+11	0.00	0.00	149.8188
1.9500	2.7143	33291.	3072.	-0.01159	34.9695	1.36E+11	0.00	0.00	159.1826
2.2750	2.6691	46483.	3711.	-0.01159	48.8264	1.36E+11	0.00	0.00	168.5464
2.6000	2.6239	62238.	4387.	-0.01159	65.3762	1.36E+11	0.00	0.00	177.9101
2.9250	2.5787	80699.	5099.	-0.01159	84.7684	1.36E+11	0.00	0.00	187.2739
3.2500	2.5335	102009.	5847.	-0.01158	107.1526	1.36E+11	0.00	0.00	196.6377
3.5750	2.4883	126310.	6633.	-0.01158	132.6786	1.36E+11	0.00	0.00	206.0014
3.9000	2.4432	153744.	7454.	-0.01158	161.4957	1.36E+11	0.00	0.00	215.3652
4.2250	2.3980	184454.	8312.	-0.01157	697.5137	1.38E+11	0.00	0.00	224.7290
4.5500	2.3529	218581.	9207.	-0.01157	826.5683	1.38E+11	0.00	0.00	234.0928
4.8750	2.3078	256270.	10138.	-0.01156	969.0873	1.38E+11	0.00	0.00	243.4565
5.2000	2.2628	297661.	11106.	-0.01155	1126.	1.38E+11	0.00	0.00	252.8203
5.5250	2.2177	342898.	12110.	-0.01154	1297.	1.38E+11	0.00	0.00	262.1841
5.8500	2.1727	392122.	13151.	-0.01153	1483.	1.38E+11	0.00	0.00	271.5478
6.1750	2.1278	445477.	14228.	-0.01152	1685.	1.38E+11	0.00	0.00	280.9116
6.5000	2.0829	503105.	15342.	-0.01151	1902.	1.38E+11	0.00	0.00	290.2754
6.8250	2.0380	565147.	16493.	-0.01149	2137.	1.38E+11	0.00	0.00	299.6391
7.1500	1.9932	631747.	17679.	-0.01148	2389.	1.38E+11	0.00	0.00	309.0029
7.4750	1.9485	703047.	18903.	-0.01146	2659.	1.38E+11	0.00	0.00	318.3667
7.8000	1.9039	779189.	20163.	-0.01144	2947.	1.38E+11	0.00	0.00	327.7304
8.1250	1.8593	860317.	21459.	-0.01141	3253.	1.38E+11	0.00	0.00	337.0942

8.4500	1.8148	946571.	22792.	-0.01139	3579.	1.38E+11	0.00	0.00	346.4580
8.7750	1.7705	1038095.	24162.	-0.01136	3926.	1.38E+11	0.00	0.00	355.8217
9.1000	1.7263	1135031.	25567.	-0.01133	4292.	1.38E+11	0.00	0.00	365.1855
9.4250	1.6821	1237521.	27010.	-0.01129	4680.	1.38E+11	0.00	0.00	374.5493
9.7500	1.6382	1345709.	28489.	-0.01126	5089.	1.38E+11	0.00	0.00	383.9130
10.0750	1.5943	1459735.	30004.	-0.01122	5520.	1.38E+11	0.00	0.00	393.2768
10.4000	1.5507	1579744.	31557.	-0.01118	5974.	1.38E+11	0.00	0.00	402.6406
10.7250	1.5072	1705876.	33145.	-0.01113	6451.	1.38E+11	0.00	0.00	412.0043
11.0500	1.4638	1838275.	34770.	-0.01108	6951.	1.38E+11	0.00	0.00	421.3681
11.3750	1.4207	1977084.	36432.	-0.01102	7476.	1.38E+11	0.00	0.00	430.7319
11.7000	1.3779	2122443.	38130.	-0.01097	8026.	1.38E+11	0.00	0.00	440.0957
12.0250	1.3352	2274497.	39865.	-0.01090	8601.	1.38E+11	0.00	0.00	449.4594
12.3500	1.2928	2433386.	41636.	-0.01084	9202.	1.38E+11	0.00	0.00	458.8232
12.6750	1.2507	2599255.	43443.	-0.01077	9829.	1.38E+11	0.00	0.00	468.1870
13.0000	1.2088	2772244.	45288.	-0.01069	10483.	1.38E+11	0.00	0.00	477.5507
13.3250	1.1673	2952497.	47168.	-0.01061	11165.	1.38E+11	0.00	0.00	486.9145
13.6500	1.1260	3140157.	49085.	-0.01052	11875.	1.38E+11	0.00	0.00	496.2783
13.9750	1.0852	3335364.	51039.	-0.01043	12613.	1.38E+11	0.00	0.00	505.6420
14.3000	1.0447	3538262.	53029.	-0.01034	13380.	1.38E+11	0.00	0.00	515.0058
14.6250	1.0046	3748994.	55056.	-0.01023	14177.	1.38E+11	0.00	0.00	524.3696
14.9500	0.9649	3967701.	57120.	-0.01012	15004.	1.38E+11	0.00	0.00	533.7333
15.2750	0.9256	4194526.	59219.	-0.01001	15862.	1.38E+11	0.00	0.00	543.0971
15.6000	0.8868	4429612.	61356.	-0.00989	16751.	1.38E+11	0.00	0.00	552.4609
15.9250	0.8485	4673101.	63529.	-0.00976	17671.	1.38E+11	0.00	0.00	561.8246
16.2500	0.8107	4925135.	65738.	-0.00962	18624.	1.38E+11	0.00	0.00	571.1884
16.5750	0.7734	5185857.	67984.	-0.00948	19610.	1.38E+11	0.00	0.00	580.5522
16.9000	0.7367	5455409.	70266.	-0.00933	20630.	1.38E+11	0.00	0.00	589.9159
17.2250	0.7006	5733933.	72089.	-0.00917	21683.	1.38E+11	0.00	0.00	344.5955
17.5500	0.6652	6017699.	71626.	-0.00901	22756.	1.38E+11	-581.983	3412.	0.00
17.8750	0.6304	6292613.	69346.	-0.00883	23796.	1.38E+11	-586.815	3630.	0.00
18.2000	0.5963	6558602.	67049.	-0.00865	24801.	1.38E+11	-591.136	3866.	0.00
18.5250	0.5629	6815599.	64737.	-0.00846	25773.	1.38E+11	-594.930	4122.	0.00
18.8500	0.5303	7063548.	62410.	-0.00826	26711.	1.38E+11	-598.180	4399.	0.00
19.1750	0.4985	7302398.	60072.	-0.00806	27614.	1.38E+11	-600.868	4701.	0.00
19.5000	0.4674	7532109.	57724.	-0.00785	28483.	1.38E+11	-602.976	5031.	0.00
19.8250	0.4372	7752648.	55370.	-0.00764	29317.	1.38E+11	-604.483	5392.	0.00
20.1500	0.4079	7963994.	53011.	-0.00741	30116.	1.38E+11	-605.367	5789.	0.00
20.4750	0.3794	8166132.	50649.	-0.00719	30880.	1.38E+11	-605.606	6226.	0.00
20.8000	0.3518	8359058.	48288.	-0.00695	31610.	1.38E+11	-605.174	6709.	0.00
21.1250	0.3251	8542780.	45930.	-0.00671	32305.	1.38E+11	-604.043	7245.	0.00
21.4500	0.2994	8717315.	43578.	-0.00647	32965.	1.38E+11	-602.185	7843.	0.00

Performed by: G. Khatri 4/9/2024
Checked by: R. Lopina 4/10/2024

21.7750	0.2747	8882690.	41235.	-0.00622	33590.	1.38E+11	-599.567	8513.	0.00
22.1000	0.2509	9038945.	38903.	-0.00597	34181.	1.38E+11	-596.153	9267.	0.00
22.4250	0.2281	9186134.	36586.	-0.00571	34737.	1.38E+11	-591.904	10119.	0.00
22.7500	0.2064	9324319.	34805.	-0.00545	35260.	1.38E+11	-321.603	6078.	0.00
23.0750	0.1856	9457613.	33466.	-0.00518	35764.	1.38E+11	-365.284	7675.	0.00
23.4000	0.1659	9585351.	31956.	-0.00492	36247.	1.38E+11	-408.964	9613.	0.00
23.7250	0.1473	9706868.	30276.	-0.00464	36707.	1.38E+11	-452.645	11987.	0.00
24.0500	0.1297	9821501.	28425.	-0.00437	37140.	1.38E+11	-496.326	14925.	0.00
24.3750	0.1132	9928585.	26404.	-0.00409	37545.	1.38E+11	-540.007	18604.	0.00
24.7000	0.09781	1.00E+07	24213.	-0.00381	37919.	1.38E+11	-583.688	23274.	0.00
25.0250	0.08352	1.01E+07	21852.	-0.00352	38259.	1.38E+11	-627.369	29297.	0.00
25.3500	0.07034	1.02E+07	19320.	-0.00323	38563.	1.38E+11	-671.050	37207.	0.00
25.6750	0.05829	1.03E+07	16617.	-0.00295	38829.	1.38E+11	-714.732	47825.	0.00
26.0000	0.04736	1.03E+07	13745.	-0.00265	39054.	1.38E+11	-758.414	62450.	0.00
26.3250	0.03758	1.04E+07	10702.	-0.00236	39235.	1.38E+11	-802.096	83244.	0.00
26.6500	0.02894	1.04E+07	7488.	-0.00207	39369.	1.38E+11	-845.779	113990.	0.00
26.9750	0.02144	1.04E+07	4228.	-0.00177	39455.	1.38E+11	-826.226	150271.	0.00
27.3000	0.01510	1.04E+07	1068.	-0.00148	39494.	1.38E+11	-794.026	205096.	0.00
27.6250	0.00991	1.04E+07	-73416.	-0.00118	39487.	1.38E+11	-37403.	1.47E+07	0.00
27.9500	0.00586	9871323.	-213184.	-8.97E-04	37329.	1.38E+11	-34273.	2.28E+07	0.00
28.2750	0.00291	8779256.	-338502.	-6.34E-04	33199.	1.38E+11	-29992.	4.02E+07	0.00
28.6000	9.19E-04	7231010.	-432890.	-4.08E-04	27344.	1.38E+11	-18412.	7.82E+07	0.00
28.9250	-2.72E-04	5402713.	-457732.	-2.29E-04	20430.	1.38E+11	5673.	8.12E+07	0.00
29.2500	-8.68E-04	3660703.	-410091.	-1.01E-04	13843.	1.38E+11	18758.	8.42E+07	0.00
29.5750	-0.00106	2204005.	-327207.	-1.83E-05	8334.	1.38E+11	23746.	8.73E+07	0.00
29.9000	-0.00101	1108484.	-235253.	2.85E-05	4192.	1.38E+11	23410.	9.03E+07	0.00
30.2250	-8.38E-04	369028.	-150465.	4.94E-05	1395.	1.38E+11	20071.	9.34E+07	0.00
30.5500	-6.25E-04	-65143.	-81181.	5.37E-05	246.3402	1.38E+11	15459.	9.64E+07	0.00
30.8750	-4.19E-04	-264187.	-30178.	4.91E-05	999.0277	1.38E+11	10697.	9.95E+07	0.00
31.2000	-2.43E-04	-300533.	3119.	4.11E-05	1136.	1.38E+11	6379.	1.02E+08	0.00
31.5250	-9.91E-05	-239859.	20774.	3.34E-05	907.0287	1.38E+11	2675.	1.05E+08	0.00
31.8500	1.81E-05	-138498.	25035.	2.81E-05	523.7304	1.38E+11	-489.889	1.05E+08	0.00
32.1750	1.20E-04	-44588.	17756.	2.55E-05	168.6091	1.38E+11	-3243.	1.05E+08	0.00
32.5000	2.17E-04	0.00	0.00	2.49E-05	0.00	1.38E+11	-5863.	5.26E+07	0.00

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 2:

Pile-head deflection	=	2.98555829	inches
Computed slope at pile head	=	-0.0115933	radians
Maximum bending moment	=	10443965.	inch-lbs
Maximum shear force	=	-457732.	lbs
Depth of maximum bending moment	=	27.30000000	feet below pile head
Depth of maximum shear force	=	28.92500000	feet below pile head
Number of iterations	=	16	
Number of zero deflection points	=	2	
Pile deflection at ground	=	0.69791884	inches

Pile-head Deflection vs. Pile Length for Load Case 2

Boundary Condition Type 1, Shear and Moment

Shear	=	0. lbs
Moment	=	0. in-lbs
Axial Load	=	0. lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
32.50000	2.98555829	10443965.	-457732.
30.87500	3.03166893	10430329.	-468834.

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs

Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	1.7261	-0.00682	-263612.	5894050.
2	V, lb	0.00	M, in-lb	0.00	0.00	2.9856	-0.01159	-457732.	1.04E+07

Maximum pile-head deflection = 2.9855582947 inches
Maximum pile-head rotation = -0.0115932603 radians = -0.664245 deg.

Summary of Warning Messages

The following warning was reported 1685 times

**** Warning ****

An unreasonable input value for compressive strength has been specified
for a soil defined using the weak rock criteria. The input value is less
than 100 psi. Please check your input data for correctness.

The following warning was reported 1010 times

**** Warning ****

An unreasonable input value for unconfined compressive strength has been
specified for a soil defined using the weak rock criteria. The input value
is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.

Performed by: G. Khatri 4/9/2024
Checked by: R. Lopina 4/10/2024

Stantec

CHECK FOR BEAM CLEARANCE

- Chosen beam size: W27X129
- d = 27.6 in
- b_f = 10.0 in
- $\sqrt{27.6^2+10.0^2}$ = 29.4 in
- 3-inch clearance for a drilled shaft size of 36 inches = 36 in - 2 (3 in) = 30 in
- 29.4 in < 30 in → **ACCEPTABLE**

CHECK FOR DEFLECTION

- Allowable Deflection – 2 inches (GDM)
- W27X129 deflection from LPILE is 1.73 inches
- 1.73 in < 2.00 in → **ACCEPTABLE**

CHECK FOR SHEAR CAPACITY OF BEAM

- Section 6 of 8th edition of LRFD Bridge Design Manual
- Chosen beam size: W27X129
    - Maximum Shear from LPILE – 457.73 kips
- $V_n = C\ V_p$

$$V_p = 0.58 F_{yw} D t_w \qquad (6.10.9.3.2\text{-}3)$$

where:

d_o = transverse stiffener spacing (in.)
V_n = nominal shear resistance of the web panel (kip)
V_p = plastic shear force (kip)
C = ratio of the shear-buckling resistance to the shear yield strength

- $V_n = 1.0\ (0.58\ F_{yw}\ D\ t_w)$
- V_n = 1.0 (0.58) (50 ksi) (27.6 in) (0.610 in)
- V_n = 488.24 kips > 457.73 kips → **ACCEPTABLE**

Stantec

CHECK FOR BUCKLING OF BEAM

- Chosen beam size: W27X129

  - If $\frac{D}{t_w} \le 1.12\sqrt{\frac{Ek}{F_{yw}}}$, then:

$$C = 1.0 \qquad (6.10.9.3.2\text{-}4)$$

in which:

k = shear-buckling coefficient

$$= 5 + \frac{5}{\left(\frac{d_o}{D}\right)^2} \qquad (6.10.9.3.2\text{-}7)$$

- $k = 5 + \frac{5}{(\frac{69\text{in}}{27.6\text{in}})^2} = 5.8$
- $1.12\sqrt{\frac{(29{,}000\ \text{ksi})\ (5.8)}{50\ \text{ksi}}} = 64.96$
- $\frac{D}{t_w} = \frac{27.6}{0.610} = 45.25 < 64.96 \rightarrow$ **ACCEPTABLE**

CHECK MOMENT CAPACITY

- Chosen beam size: W27X129
  - Beam stickup is approx. 4 feet for moment calculation (pre-cast lagging buried 4 feet)
  - Maximum moment from LPILE – 866.7 ft-kips
  - From “Steel Construction Manual”, AISC 14th Edition – an unbraced length of 4 feet for a W27x129 beam can support a moment capacity of approximately 1481 ft-kips; which is greater than 866.7 ft-kips → **ACCEPTABLE**