Resource International, Inc.

FRA-70-13.10
FRA-70-1358L
I-70 WB OVER CSX AND NS RAILROAD
PID NO. 89464
FRANKLIN COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT (REV. 3)

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Rii Project No. W-13-072

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May 12, 2015 (Revised June 15, 2022)

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Re: Structure Foundation Exploration Report (Rev. 3)
FRA-70-13.10 Phase 6A
FRA-70-1358L – I-70 WB over CSX and NS Railroad
PID No. 89464
Rii Project No. W-13-072

Ms. Montgomery:

Resource International, Inc. (Rii) is pleased to submit this revised structure foundation exploration report for the above referenced project. Engineering logs have been prepared and are attached to this report along with the results of laboratory testing. This report includes recommendations for the design and construction of the proposed FRA-70-1358L bridge structure carrying I-70 westbound over both CSX and Norfolk Southern Railroad tracks as part of the FRA-70-13.10 Phase 6A project (PID 89464) in Columbus, Ohio.

We sincerely appreciate the opportunity to be of service to you on this project. If you have any questions regarding the structure foundation exploration or this report, please contact us.

Sincerely,

RESOURCE INTERNATIONAL, INC.

Brian R. Trenner, P.E.
Director – Geotechnical Services

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Enclosure: Structure Foundation Exploration Report (Rev. 3)

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EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration for the design and construction of the proposed FRA-70-1358L bridge structure carrying I-70 westbound over both CSX and Norfolk Southern (NS) railroad tracks. The existing structure is a four-span bridge that consists of a reinforced concrete deck on continuous steel beams with reinforced concrete substructures supported on 12-inch cast-in-place (CIP) pipe piles and has a total length of approximately 328 feet. It is understood that the existing structure will be completely removed and replaced with a two-span composite prestressed concrete I-beam superstructure with a reinforced concrete deck and semi-integral abutments behind mechanically stabilized earth (MSE) walls and wall type pier. The proposed structure will have a total length of approximately 238 feet and width of approximately 110 feet, and the alignment will be shifted approximately 60 feet north of the existing bridge alignment. In addition, the roadway profile will be elevated approximately 6.0 to 7.0 feet above the existing I-70 westbound profile grade. Please note that the analysis and recommendations for retaining wall E2 at the rear abutment and retaining wall E4, between Sta. 409+50 and 411+05 (BL Wall E4), at the forward abutment are presented under this report cover.

Exploration and Findings

Between February 6 and 26, 2014, three (3) structural borings, designated as B-017-9-13, B-018-1-13 and B-018-2-13, were drilled to completion depths ranging from 78.1 to 84.5 feet below the existing ground surface at the locations shown on the boring plan provided in Appendix I of the full report. Based on the final configuration of Retaining Wall E2, on December 2, 2020, one (1) additional boring, designated as B-019-6-19, was obtained within the abandoned Mound Street at the south end of the existing embankment and was extended to a depth of 40.0 feet below the existing ground surface. Borings B-017-3-13 and B-017-7-13, which were performed for the FRA-70-1358R bridge structure as part of the FRA-70-12.68 Phase 4A project, have also been referenced to determine the type of material that the existing embankments are comprised of, as well as the condition of the existing embankment fill, at the rear and forward abutment.

Borings B-017-3-13 and B-017-7-13 were performed in the south shoulder of I-70 eastbound and encountered 6.0 and 11.0 inches of asphalt overlying 4.0 and 6.0 inches of aggregate base, respectively, at the ground surface. Borings B-017-9-13, B-018-1-13 and B-0182-13 were advanced within the grassy area just north of the existing structure and encountered 2.0 to 12.0 inches of topsoil at the existing ground surface, as identified by the significant presence of vegetation and organic material. Boring B-019-6-19 was advanced at the west end of the existing embankment supporting the abandoned Mound Street and encountered 4.0 inches of topsoil at the ground surface.

Beneath the pavement, existing embankment fill was encountered in borings B-017-3-13 and B-017-7-13 extending to a depth of 32.0 and 39.0 feet below the existing ground surface, respectively. The embankment fill consisted of brown, gray, brownish gray and black gravel, gravel and sand, silt and clay, silty clay and clay (ODOT A-1-a, A-1-b, A-6a, A-6b, A-7-6) and did not contain any deleterious material.

Beneath the topsoil in borings B-017-9-13, B-018-1-13 and B-018-2-13, material identified as existing fill was encountered extending to depths ranging from 5.5 to 14.3 feet below the ground surface. In general, the fill materials consisted of granular soils comprised of black and brown gravel and sand, gravel with sand and silt and coarse and fine sand (ODOT A-1-b, A-2-4, A-3a) overlying cohesive soils comprised of brown and gray sandy silt and silty clay (ODOT A-4a, A-6b). The fill materials contained trash and debris, including organic material, root fibers, cinders, plastic, coal, brick and slag fragments throughout.

Beneath the topsoil in boring B-019-6-13, existing embankment fill consisting of gray, dark gray, brown and dark brown gravel with sand, gravel with sand and silt, silt and clay and silty clay (ODOT A-1-b, A-2-4, A-6a, A-6b) was encountered extending to a depth of 27.0 feet, overlying existing fill material comprised of brown gravel with sand and silt (ODOT A-2-4) extending to a depth of 32.0 feet.

Underlying the surficial topsoil and existing fill materials, natural granular soils were encountered overlying cohesive material. The granular soils were generally described as brown and gray gravel, gravel with sand, gravel with sand and silt, gravel with sand, silt and clay and coarse and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-2-6, A-3a). The cohesive soils were generally described as gray, brown and dark brown sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6). It should be noted that cobbles and rock fragments were present within the dense granular soils at the rear and forward abutments. These obstructions were encountered at depths ranging from 22.0 to 31.0 feet below the ground surface, which corresponds to elevations ranging from approximately 684 to 696 feet msl.

Top of bedrock was encountered in borings B-017-9-13, B-018-1-13 and B-018-2-13 at an elevation of 653.2, 657.7 and 656.9 feet msl, respectively. The upper portion of the bedrock consists of weathered shale which was able to be augered to competent mudstone bedrock in boring B-017-9-13 and competent limestone bedrock in borings B-018-1-13 and B-018-2-13. The cored bedrock consists of mudstone, which was encountered in boring B-017-9-13 at an elevation of 648.0 feet msl, and limestone bedrock, which was encountered an elevation of 643.5 in borings B-017-9-13 and B-018-1-13 and an elevation of 641.2 in boring B-018-2-13.

Analyses and Recommendations

Driven Pile Recommendations

Given the proposed loading at each substructure unit, friction bearing piles will not be a feasible foundation option as the required ultimate bearing value per pile exceeds the values provided in Section 305.3.4 of the 2020 ODOT Bridge Design Manual (BDM) based on the maximum factored loads per pile. Therefore, given the depth of bedrock encountered in the borings performed, it is recommended that steel H-piles (ODOT Item 507.06) driven to refusal on bedrock be employed for foundation support. Per Section 305.3.1.2 of the 2020 ODOT BDM, refusal is met during driving when the pile penetration is an inch or less after receiving at least 20 blows from the pile hammer. The following table shows the recommended pile lengths and the corresponding factored structural axial resistance ($R_{R\,max}$) of the steel H-piles.

FRA-70-1358L Driven Pile Recommendations

Substructure Reference	Ground Elevation [1] (feet msl)	Pile Size	Pile Elevation (feet msl)		Pile Length [4] (feet)	$R_{R\,max}$ [5] (kips/pile)	Sleeve Length [6] (feet)	φ [7]
			Top [2]	Tip [3]				
Rear Abutment (B-017-3-13 / B-017-9-13)	740.3 / 717.6	HP 12x53 [8]	735.0	653.2	85	380	4.1 / 21.6	N/A
		HP 14x73 [8]	735.0	653.2	85	530	4.6 / 21.6	N/A
Pier (B-018-1-13)	717.0	HP 14x73 [8]	713.0	657.7	60	530	N/A	N/A
Forward Abutment (B-017-7-13 / B-018-2-13)	715.7	HP 12x53 [8]	738.8	656.9	85	380	26.3	N/A
		HP 14x73 [8]	738.8	656.9	85	530	26.3	N/A

1. *Ground elevation listed is the ground elevation at the respective boring locations.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is considered to be 1.0-foot above the proposed bottom of footing elevation per Section 305.3.5.1 of the 2020 ODOT BDM.*
3. *The pile tip elevation is based on the top of bedrock elevation in the nearest boring per Section 305.3.5.2 of the 2020 ODOT BDM.*
4. *Per Section 305.3.5.2 of the 2020 ODOT BDM, the estimated pile length was determined as the pile cutoff elevation (top) minus the pile tip elevation, rounded up to the nearest 5.0 feet.*
5. *The factored structural axial resistance for H-piles is based on the structural limit state of the steel H-pile section per Section 305.3.3 of the 2020 ODOT BDM.*
6. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall backfill. Multiple values represent the minimum and maximum sleeve length, respectively, where the wall steps up along the existing embankment slopes.*
7. *For H-piles driven to refusal on bedrock, no geotechnical resistance factor should be applied to the factored structural axial resistance values presented, as the values presented account for the structural resistance factor, $\varphi_c = 0.50$, for H-piles subject to damage due to severe driving conditions.*
8. *A steel pile point is recommended to protect the tips of the steel H-piles during pile installation.*

The anticipated total settlement at the facing of the MSE wall at the rear abutment is 5.31 to 10.24 inches and at the forward abutment is 6.70 inches, based on traditional consolidation settlement methodology. However, it is noted that settlement results from CPT sounding C-001-1-21 yielded a total anticipated settlement that was approximately half of the predicted settlement determined using traditional methodology. Results of the settlement analysis indicate that approximately 90 percent of the primary consolidation of the cohesive layers at the rear and forward abutment will be complete within 30 days following the placement if the surcharge load based on the results from the CPT testing and correlations. Therefore, if the above noted waiting period is specified following completion of construction of the MSE walls, downdrag forces along the piles will be eliminated.

MSE Wall Recommendations

It is proposed to construct MSE walls at the rear abutment (Retaining Wall E2) and forward abutment (Retaining Wall E4 between Sta. 409+50 and 411+05, BL Wall E4) of the proposed bridge structure. Based upon the proposed plan information, the wall height at the rear abutment ranges from and 18.0 to 35.5 feet from the top of the leveling pad to the proposed profile grade of the roadway, and the wall height at the forward abutment is 42.5 feet. It should be noted that the footprint of the MSE wall at rear abutment will be within the limits of the existing embankment supporting I-70 eastbound and westbound, and that the MSE wall will be constructed full height from the existing grade at the base of the embankment to the proposed profile grade of I-70 westbound for a portion of the wall length, and will be stepped up along the existing embankment as the wall extends to the north along the length of the abutment.

The anticipated bearing materials at the rear abutment (Wall E2) from the beginning of the wall to Sta. 201+63 (BL Wall E2) and at the forward abutment (Wall E4) consist of existing fill comprised of very loose to medium dense gravel with sand, gravel with sand and silt and coarse and fine sand and medium stiff to very stiff sandy silt and silty clay (ODOT A-1-b, A-2-4, A-3a, A-4a, A-6b), which extends to an elevation of 704.8 to 701.4 feet msl and contains trash debris, plastic, cinders, brick fragments and organic material throughout. The anticipated bearing materials along the remainder of the wall at the rear abutment (Wall E2) from Sta. 201+63 (BL Wall E2) to the end of the wall alignment consist of existing embankment fill comprised of stiff to very stiff silt and clay, silty clay and clay (ODOT A-7-6) with interbedded layers of loose to dense gravel with sand and gravel with sand and silt (ODOT A-1-b, A-2-4).

As noted in Section 5.2 of the full report, it is understood that ground improvement techniques will be implemented within the footprint of Wall E2 from the beginning of the wall alignment to Sta. 201+63 (BL Wall E2) and within the entire footprint of Wall E4. As this is a proprietary design, the analysis for this wall considers the existing fill material will remain in place and will not be stabilized. MSE wall foundations bearing on existing fill material or granular embankment, placed and compacted in accordance with ODOT Item 203, may be proportioned for a factored bearing resistance as indicated in the following table. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.

FRA-70-1358L (Retaining Wall E2 and E4) MSE Wall Design Parameters

Substructure Unit (Boring)	Station Along Wall Alignment		Wall Height Analyzed (feet)	Back-slope Behind Wall	Minimum Required Reinforcement Length [1] (feet)	Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing Pressure [3] (ksf)
	From	To				Nominal	Factored [2]	
Rear Abutment / Retaining Wall E2 (B-017-3-13 / B-017-9-13 / B-019-6-19)	200+68	201+63	35.5	Level	24.9 (0.7H)	4.24	2.76	8.26
	201+63	202+03	25.5	Level	29.3 (1.15H)	8.73	5.67	5.06
Forward Abutment / Retaining Wall E4 (B-017-7-13 / B-018-2-13)	409+50	411+05	42.5	Level	29.8 (0.7H)	9.77	6.35	9.72

1. *The minimum reinforcement length is based on the maximum wall height analyzed. The value in parentheses represent the required reinforcement length expressed as a percentage of the wall height, H.*
2. *A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.*
3. *The strength limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the strength limit state.*

Based on the results of the external and global stability analysis performed for the MSE wall at the rear abutment (Wall E2) between Sta. 201+63 and 202+03, the recommended controlling strap length is 1.15 times the maximum height of the MSE wall (measured from the top of the leveling pad to the proposed profile grade of the roadway) along that segment of the wall. All external and global stability calculations indicate that adequate resistance is available for support of the MSE wall at the abutment for a strap length equal to 115 percent of the wall height for this segment of the wall.

Based on the results of the external and global stability analysis performed for the MSE wall at the rear abutment (Wall E2) between Sta. 200+68 and 201+63 and at the forward abutment (Wall E4), sliding under undrained conditions as well as bearing and global stability under both drained and undrained conditions were not satisfied at a strap length equal to 0.7 times the wall height. Increasing the width of the wall up to 1.3 times the wall height still did not satisfy all of the external and global stability requirements. Consideration was given to over excavating these soils and replacing it with granular embankment; however, given the depth of over exaction required to completely remove this material, this a very expensive and uneconomical option. Therefore, it is recommended that ground improvement techniques be implemented to increase the strength of the soil mass and reduce settlement potential within these layers.

The design of the ground improvement should result in the improved soil matrix meeting the design criteria for bearing resistance and compressibility for the MSE wall. The improved soil matrix will need to provide a factored bearing resistance greater than or equal to the factored bearing pressure at the strength limit state of 8.26 to 9.72 ksf. Additionally, the improved soil matrix will need to limit settlement to the required maximum differential settlement of 1/100 along the wall facing and to tolerable limits for maximum settlement of the wall based on the wall manufacturer's specifications or for constructability of the roadway. In the absence of specific settlement from the wall manufacturer, the ground improvement design should limit total settlement of the embankment and back of the reinforced soil mass to 5.0 inches, and total settlement at the facing of the wall to 2.5 inches.

Based on the conditions encountered, the ground improvement elements should be extended to an approximate elevation of 700 feet msl. Additionally, it is recommended that ground improvement elements be located along the length of the leveling pad if concentrated loads will be imparted along the pad to ensure that differential settlement does not occur.

Please note that this executive summary does not contain all the information presented in the report. The unabridged subsurface exploration report should be read in its entirety to obtain a more complete understanding of the information presented.

1.0 INTRODUCTION

The overall purpose of this project is to provide detailed subsurface information and recommendations for the design and construction of the FRA-70/71-13.10/14.36 (Projects 6A/6R) project in Columbus, Ohio. The projects represent the central portion of the FRA-70-8.93 (PID 77369) I-70/71 south innerbelt improvements project, which includes all improvements along I-70 westbound from the I-71/SR-315 interchange to Front Street and along I-71 southbound from I-70 to Greenlawn Avenue. The FRA-70-13.10 (Project 6A) phase will consist of all work associated with the construction of I-70 westbound from SR 315 to Front Street, including Ramps D3 and D7. This project includes the construction of one (1) new bridge structure for Ramp D3 over the Scioto River (FRA-70-1323C) and the reconstruction of three (3) bridges, including I-70 westbound over the Scioto River (FRA-70-1322L), I-70 westbound over CSX and Norfolk Southern (NS) Railroad (FRA-70-1358L) and I-70 westbound over Short Street (FRA-70-1373L), as well as the construction of five (5) new retaining walls (Walls E2, E3, E4, E7 and E9) to accommodate the new configuration.

This report is a presentation of the structure foundation exploration performed for the design and construction of the proposed FRA-70-1358L bridge structure carrying I-70 westbound over both CSX and Norfolk Southern (NS) Railroad tracks, as shown on the vicinity map and boring plan presented in Appendix I. The existing structure is a four-span bridge that consists of a reinforced concrete deck on continuous steel beams with reinforced concrete substructures supported on 12-inch cast-in-place (CIP) pipe piles and has a total length of approximately 328 feet. It is understood that the existing structure will be completely removed and replaced with a two-span composite prestressed concrete I-beam superstructure with a reinforced concrete deck and semi-integral abutments behind mechanically stabilized earth (MSE) walls and wall type pier. The proposed structure will have a total length of approximately 238 feet and width of approximately 110 feet, and the alignment will be shifted approximately 60 feet north of the existing bridge alignment. In addition, the roadway profile will be elevated approximately 6.0 to 7.0 feet above the existing I-70 westbound profile grade. Please note that the analysis and recommendations for Retaining Wall E2 at the rear abutment and Retaining Wall E4, between Sta. 409+50 and 411+05 (BL Wall E4), at the forward abutment are presented under this report cover. Design recommendations for the remaining alignment of Retaining Wall E4 is under a separate cover.

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Site Geology

Both the Illinoian and Wisconsinan glaciers advanced over two-thirds of the State of Ohio, leaving behind glacial features such as moraines, kame deposits, lacustrine deposits and outwash terraces. The glacial and non-glacial regions comprise five physiographic sections based on geological age, depositional process and geomorphic occurrence (physical features or landforms). The project area lies within the Columbus

Lowland District of the Till Plains Section. This area is characterized by flat to gently rolling ground moraine deposits from the Late Wisconsinan age. The site topography exhibits moderate to high relief. The ground moraine deposits are composed primarily of silty loam till (Darby, Bellefontaine, Centerburg, Grand Lake, Arcanum, Knightstown Tills), with smaller alluvium and outwash deposits bordering the Scioto River, its tributaries and floodplain areas. A ground moraine is the sheet of debris left after the steady retreat of glacial ice. The debris left behind ranges in composition from clay size particles to boulders (including silt, sand, and gravel). Outwash deposits consist of undifferentiated sand and gravel deposited by meltwater in front of glacial ice, and often occurs as valley terraces or low plains. Alluvium and alluvial terrace deposits range in composition from silty clay size particles to cobbles, usually deposited in present and former floodplain areas.

According to the bedrock geology and topography maps obtained from the Ohio Department of Natural Resources (ODNR), the underlying bedrock west of the Scioto River consists predominantly of the Middle to Lower Devonian-aged Columbus Limestone. This formation is further subdivided into two members in the central portion of the state, known as the Delhi and Bellepoint Members. The Delhi Member consists of light gray, finely to coarsely crystalline, irregularly bedded, fossiliferous limestone. The Bellepoint Member consists of variable brown, finely crystalline, massively bedded limey dolomite. Both of these members contain chert nodules. East of the Scioto River, the underlying bedrock consists of the Upper Devonian Ohio Shale Formation overlying the Middle Devonian-aged Delaware Limestone Formation. The Ohio Shale formation consists of brownish black to greenish gray, thinly bedded, fissile, carbonaceous shale. The Delaware Limestone consists of bluish gray, thin to medium bedded dolomitic limestone with nodules and layers of chert. Regionally, the bedrock surface forms a broad valley aligned roughly north-to-south beneath the Scioto River. According to bedrock topography mapping, the elevation of the bedrock surface ranges from approximately 600 feet mean sea level (msl) in the valley to approximately 625 feet msl near the project limits. Within the borings performed for the current investigation, shale bedrock was encountered at elevations ranging from 653.7 to 657.7 feet msl.

2.2 Existing Conditions

The existing bridge carrying I-70 westbound over CSX and NS Railroad is located approximately 800 feet west of the Short Street overpass and 1,000 feet east of the Scioto River. The existing I-70 westbound in the vicinity of the structure is a four-lane, asphalt paved roadway that is aligned east-to-west. Two pairs of railroad tracks cross under the third span of the existing bridge, with westernmost pair operated by CSX Railroad and the easternmost tracks operated by NS Railroad. An access road also crosses under the second span of the bridge, which provides access to the north side of I-70 between the highway and the Scioto River. The existing I-70 roadway profile grade is elevated approximately 25 feet above the railroad tracks and surrounding terrain. The terrain along I-70 slopes gently to the west and the surrounding area is relatively flat-lying.

3.0 EXPLORATION

Between February 6 and 26, 2014, three (3) structural borings, designated as B-017-9-13, B-018-1-13 and B-018-2-13, were drilled at the locations shown on the boring plan provided in Appendix I of this report and summarized in Table 1. The borings were advanced to completion depths ranging from 78.1 to 84.5 feet below the existing ground surface. Based on the final configuration of Retaining Wall E2, on December 2, 2020, one (1) additional boring, designated as B-019-6-19, was obtained within the abandoned Mound Street at the south end of the existing embankment and was extended to a depth of 40.0 feet below the existing ground surface.

Table 1. Test Boring Summary

Boring Number	Station [1]	Offset [1]	Latitude	Longitude	Ground Elevation (feet msl)	Boring Depth (feet)
B-017-9-13	166+64.96	18.3' Lt.	39.953423434	-83.007954336	717.6	78.1
B-018-1-13	167+31.32	54.6' Lt.	39.953550889	-83.007738627	717.0	83.5
B-018-2-13	168+63.72	22.9' Lt.	39.953512324	-83.007250705	715.7	84.5
B-019-6-19	166+09.00	108.1' Lt.	39.953639182	-83.008209871	738.1	40.0

1. *Station and offset referenced to the proposed baseline of I-70 westbound.*

The boring locations were determined and located in the field by Rii representatives. Rii utilized a handheld GPS unit to obtain northing and easting coordinates of the boring locations. Ground surface elevations at the boring locations were interpolated using topographic mapping information provided by ms consultants.

The borings were drilled using an all-terrain vehicle (ATV) mounted rotary drilling machine, utilizing a 3.25 or 4.25-inch inside diameter, hollow-stem auger to advance the holes. Standard penetration test (SPT) and split spoon sampling were performed in the borings at 2.5-foot increments of depth to 30.0 feet and at 5.0-foot increments thereafter to the top of bedrock. The SPT, per the American Society for Testing and Materials (ASTM) designation D1586, is conducted using a 140-pound hammer falling 30.0 inches to drive a 2.0-inch outside diameter split spoon sampler 18.0 inches. Rii utilized a calibrated automatic drop hammer to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of blow per 6.0-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). Standard penetration blow counts aid in determining soil properties applicable in foundation system design. Measured blow count (N) values are corrected to an equivalent (60%) energy ratio, N_{60}, by the following equation. Both values are represented on boring logs in Appendix III.

$$N_{60} = N_m*(ER/60)$$

Where:
N_m = measured N value
ER = drill rod energy ratio, expressed as a percent, for the system used

The hammer for the CME 750 drill rig used for the 2013 exploration borings was calibrated on April 26, 2013, and has a drill rod energy ratio of 82.6 percent. The hammer for the CME 750X drill rig used for the 2019 exploration boring was calibrated on September 14, 2020, and has a drill rod energy ratio of 86.2 percent.

Hand penetrometer readings, which provide a rough estimate of the unconfined compressive strength of the soil, were reported on the boring logs in units of tons per square foot (tsf) and were utilized to classify the consistency of the cohesive soil in each layer. An indirect estimate of the unconfined compressive strength of the cohesive split spoon samples can also be made from a correlation with the blow counts (N_{60}). Please note that split spoon samples are considered to be disturbed and the laboratory determination of their shear strengths may vary from undisturbed conditions.

The depth to bedrock was determined by split spoon sampler refusal. Split spoon sampler refusal is defined as exceeding 50 blows with less than 6 inches of penetration by the split spoon sampler. The borings were then extended to competent bedrock, which was defined by encountering auger refusal. Auger refusal is defined as no or insignificant observable advancement of the augers with the weight of the drill rig driving the augers.

Where borings were extended into the competent bedrock (after encountering auger refusal), an HQ-sized double-tube diamond bit core barrel (utilizing wire line equipment) was used to core the bedrock. Coring produced 2.5-inch diameter cores, from which the type of rock and geological characteristics were determined.

Rock cores were logged in the field and visually classified in the laboratory. They were analyzed to identify the type of rock, color, mineral content, bedding planes and other geological and mechanical features of interest in this project. The Rock Quality Designation (RQD) for each rock core run was calculated according to the following equation:

$$RQD = \frac{\sum \text{segments equal to or longer than 4.0 inches}}{\text{core run length}} \times 100$$

During drilling, Rii personnel prepared field logs showing the encountered subsurface conditions. Soil and rock samples obtained from the drilling operation were preserved and sealed in glass jars or rock core boxes and delivered to the soil laboratory. In the laboratory, the soil and rock samples were visually classified and select samples were tested, as noted in Table 2.

Table 2. Laboratory Test Schedule

Laboratory Test	Test Designation	Number of Tests Performed
Natural Moisture Content	ASTM D 2216	75
Plastic and Liquid Limits	AASHTO T89, T90	20
Gradation – Sieve/Hydrometer	AASHTO T88	21
One-Dimensional Consolidation	ASTM D2435	1
Unconfined Compressive Strength of Intact Rock Core Specimens	ASTM D7012	3

The tests performed are necessary to classify the existing soil and rock according to the Ohio Department of Transportation (ODOT) classification system and to estimate engineering properties of importance in determining foundation design and construction recommendations. Results of the laboratory testing are presented on the boring logs in Appendix III and also in Appendix IV. A description of the soil and rock terms used throughout this report is presented in Appendix II.

Borings B-017-3-13 and B-017-7-13, which were performed for the FRA-70-1358R bridge structure as part of the FRA-70-12.68 Phase 4A project, have also been referenced to determine the type of material that the existing embankments are comprised of, as well as the condition of the existing embankment fill, at the rear and forward abutment. A copy of these logs are also included in Appendix III. For complete details of the subsurface exploration for these borings, please reference the structure foundation exploration report dated June 29, 2020.

3.1 Supplemental Investigation by ODOT OGE

Due to the conditions encountered at the site, which were resulting in high amounts of settlement and long wait periods for time rate of consolidation, additional investigation was performed by the ODOT Office of Geotechnical Engineering (OGE). The supplemental investigation consisted of obtaining cone penetration test (CPT) soundings as well as additional soil borings to obtain undisturbed (Shelby tube) samples within layers of interest as identified from the current project borings and CPT testing.

Between March 16 and April 21, 2021, a total of eight (8) CPT soundings were performed, two each near the north and south ends of the rear and forward abutments of the existing FRA-70-1358L/R structures, which were designated as C-001-0-21 through C-004-1-21. The soundings were extended to depths ranging from 22.3 to 55.8 feet below grade. Soundings C-003-1-21 and C-004-0-21 were prebored to a depth of 46.5 and 38.05 feet, respectively, below grade prior to starting the CPT soundings at those locations. In addition, on April 19, 2021, five (5) soil borings were performed at offset locations adjacent to the CPT soundings, which were extended to depths ranging from 12.0 to 49.2 feet below grade. The CPT soundings and supplemental boring locations performed by ODOT OGE are shown on the boring plan provided in Appendix I of this report and summarized in Table 3.

Table 3. CPT Sounding and Test Boring Summary (ODOT OGE)

CPT/Boring Number	Station [1]	Offset [1]	Latitude	Longitude	Ground Elevation (feet msl)	CPT/Boring Depth (feet)
C-001-0-21	166+73.70	14' Lt.	39.953420	-83.007908	720.2	22.3
C-001-1-21	166+73.89	7' Lt.	39.953402	-83.007903	720.9	54.1
C-002-0-21	166+65.36	157' Rt.	39.952952	-83.007836	714.1	26.9
C-002-1-21	166+62.33	166' Rt.	39.952927	-83.007841	714.1	26.4
C-003-0-21	168+78.96	38' Lt.	39.953561	-83.007189	714.8	34.9
C-003-1-21	168+79.94	39' Lt.	39.953565	-83.007186	714.9	55.7
C-004-0-21	169+23.86	135' Rt.	39.953103	-83.006969	715.5	39.1
C-004-1-21	169+25.17	139' Rt.	39.953091	-83.006963	715.2	20.5
B-017-10-21	166+73.70	14' Lt.	39.953420	-83.007908	720.2	12.0
B-017-11-21	166+62.33	166' Rt.	39.952927	-83.007841	714.1	49.2
B-017-20-21	166+73.70	14' Lt.	39.953420	-83.007908	720.2	42.5
B-018-3-21	168+79.94	39' Lt.	39.953565	-83.007186	714.9	49.0
B-018-4-21	169+23.86	135' Rt.	39.953103	-83.006969	715.5	38.5

1. *Station and offset referenced to the proposed baseline of I-70 westbound.*

A summary report of the CPT soundings, include information regarding data processing and CPT sounding logs, was provided by ODOT OGE in the report titled “Cone Penetration Test Soundings Report” dated July 6, 2021, and is included in Appendix V.

The supplemental borings performed by ODOT OGE were drilled using a track-mounted rotary drilling machine, utilizing a 3.25-inch inside diameter, hollow-stem auger to advance the holes. SPT and split spoon sampling were performed in the borings at select depths to verify the soil type and consistency at the depths of interest. The hammers for the CME 850R and Acker XLS drill rigs used by ODOT OGE were calibrated on May 1, 2019, and have a drill rod energy ratios of 89 and 90 percent, respectively. Additionally, Shelby tube samples were also obtained within the supplemental borings to provide samples for consolidation and shear strength testing. Laboratory testing of the recovered split spoon and Shelby tube samples were performed by the ODOT OGE laboratory, which are included in Table 4. The borings logs and laboratory test results for the supplemental borings performed by ODOT OGE are provided in Appendix VI.

Table 4. Supplemental Boring Laboratory Test Schedule (ODOT OGE)

Laboratory Test	Test Designation	Number of Tests Performed
Natural Moisture Content	ASTM D 2216	8
Plastic and Liquid Limits	AASHTO T89, T90	8
Gradation – Sieve/Hydrometer	AASHTO T88	8
One-Dimensional Consolidation	AASHTO T216	7
Unconfined Compressive Strength of Cohesive Soil	AASHTO T208	6

4.0 FINDINGS

Interpreted engineering logs have been prepared based on the field logs, visual examination of samples and laboratory test results. Classification follows the current version of the ODOT Specifications for Geotechnical Explorations (SGE) at the time the explorations were performed. The following is a summary of what was found in the test borings and what is represented on the boring logs.

4.1 Surface Materials

Borings B-017-3-13 and B-017-7-13 were performed in the south shoulder of I-70 eastbound and encountered 6.0 and 11.0 inches of asphalt overlying 4.0 and 6.0 inches of aggregate base, respectively, at the ground surface. Borings B-017-9-13, B-018-1-13 and B-0182-13 were advanced within the grassy area just north of the existing structure and encountered 2.0 to 12.0 inches of topsoil at the existing ground surface, as identified by the significant presence of vegetation and organic material. Boring B-019-6-19 was advanced at the west end of the existing embankment supporting the abandoned Mound Street and encountered 4.0 inches of topsoil at the ground surface. Surficial material types and measurements for the supplemental borings performed by ODOT OGE were not provided on the boring logs.

4.2 Subsurface Soils

Beneath the pavement, existing embankment fill was encountered in borings B-017-3-13 and B-017-7-13 extending to a depth of 32.0 and 39.0 feet below the existing ground surface, respectively. The embankment fill consisted of brown, gray, brownish gray and black gravel, gravel and sand, silt and clay, silty clay and clay (ODOT A-1-a, A-1-b, A-6a, A-6b, A-7-6) and did not contain any deleterious material.

Beneath the topsoil in borings B-017-9-13, B-018-1-13 and B-018-2-13, material identified as existing fill was encountered extending to depths ranging from 5.5 to 14.3 feet below the ground surface. In general, the fill materials consisted of granular soils comprised of black and brown gravel and sand, gravel with sand and silt and coarse and fine sand (ODOT A-1-b, A-2-4, A-3a) overlying cohesive soils comprised of brown and gray sandy silt and silty clay (ODOT A-4a, A-6b). The fill materials contained trash and debris, including organic material, root fibers, cinders, plastic, coal, brick and slag fragments throughout.

Beneath the topsoil in boring B-019-6-13, existing embankment fill consisting of gray, dark gray, brown and dark brown gravel with sand, gravel with sand and silt, silt and clay and silty clay (ODOT A-1-b, A-2-4, A-6a, A-6b) was encountered extending to a depth of 27.0 feet, overlying existing fill material comprised of brown gravel with sand and silt (ODOT A-2-4) extending to a depth of 32.0 feet.

Underlying the surficial topsoil and existing fill materials, natural granular soils were encountered overlying cohesive material. The granular soils were generally described as brown and gray gravel, gravel with sand, gravel with sand and silt, gravel with sand, silt and clay and coarse and fine sand (ODOT A-1-a, A-1-b, A-2-4, A-2-6, A-3a). The cohesive soils were generally described as gray, brown and dark brown sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6). It should be noted that cobbles and rock fragments were present within the dense granular soils at the rear and forward abutments. These obstructions were encountered at depths ranging from 22.0 to 31.0 feet below the ground surface, which corresponds to elevations ranging from approximately 684 to 696 feet msl.

The relative density of granular soils is primarily derived from SPT blow counts (N_{60}). Based on the SPT blow counts obtained, the granular soil encountered ranged from very loose (N_{60} < 5 blows per foot [bpf]) to very dense (N_{60} > 50 bpf). Overall blow counts recorded from the SPT sampling ranged from 4 bpf to split spoon sampler refusal. The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soil encountered ranged from medium stiff ($0.5 \leq HP \leq 1.0$ tsf) to hard (HP > 4.0 tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 1.0 to over 4.5 tsf (limit of instrument).

Natural moisture contents of the soil samples tested ranged from 2 to 30 percent. A moisture content of 110 percent was obtained in sample SS-14A from boring B-017-7-13. The high moisture content is likely due to the presence of wood fragments and other organics in the sample. The natural moisture content of the cohesive soil samples tested for plasticity index ranged from 10 percent below to 7 percent above their corresponding plastic limits. In general, the soil exhibited natural moisture contents considered to be significantly below to moderately above optimum moisture levels.

In general, the soil conditions encountered in the supplemental borings performed by ODOT OGE matched the conditions encountered in the borings completed as part of the current (Rii) investigation. Results of the consolidation and unconfined compressive strength testing performed by ODOT OGE are summarized in Table 5.

Table 5. Supplemental Boring Laboratory Test Results (ODOT OGE)

Boring Number	Sample ID	Depth (feet)	ODOT Class.	MC	LL	PI	P200	σ_p' (psf)	C_c	C_r	OCR	Q_u (psf)	S_u (psf)
B-017-10-21	ST-1	11.2-11.6	A-6a	21	31	14	78	-	-	-	-	1,123	562
		11.6-11.8	A-6a	21	31	14	78	3,000	0.205	0.162	2.249	-	-
B-017-11-21	ST-1	5.2-5.7	A-6a	23	30	11	67	-	-	-	-	1,613	807
		5.7-6.0	A-6a	23	30	11	67	2,600	0.108	0.050	3.966	-	-
	ST-7	48.5-49.2	A-7-6	17	40	17	95	15,200	0.157	0.056	2.725	-	-
B-017-20-21	ST-1	40.2-40.7	A-7-6	26	46	24	100	-	-	-	-	2,635	1,318
		40.8-41.0	A-7-6	26	46	24	100	13,000	0.210	0.101	2.771	-	-
	ST-2	41.8-42.3	A-7-6	24	41	20	100	-	-	-	-	1,814	907
		42.3-42.5	A-7-6	24	41	20	100	14,400	0.180	0.079	2.960	-	-
B-018-3-21	ST-8	48.1-48.6	A-7-6	27	44	23	98	-	-	-	-	3,283	1,642
		48.6-48.8	A-7-6	27	44	23	98	17,000	0.220	0.099	3.042	-	-
B-018-4-21	ST-2B	37.5-38.0	A-4a	13	24	10	64	-	-	-	-	3,370	1,685
		38.2-38.4	A-4a	13	24	10	64	-	-	0.072	-	-	-

4.3 Bedrock

Bedrock was encountered in the borings as presented in Table 6.

Table 6. Top of Bedrock Elevations

Boring Number	Ground Surface Elevation (feet msl)	Top of Bedrock		Top of Bedrock Core	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-017-3-13	740.3	83.5	656.8	83.5	656.8
B-017-7-13	743.1	90.0	653.1	90.0	653.1
B-017-9-13	717.6	64.4	653.2	69.6	648.0
B-018-1-13	717.0	59.3	657.7	73.5	643.5
B-018-2-13	715.7	58.8	656.9	74.5	641.2
B-019-6-19	738.1	N/A	-	N/A	-

With the exception of boring B-019-6-19, shale bedrock was encountered in the remaining borings at elevations ranging from 653.1 to 657.7 feet msl. The upper portion of the bedrock in borings B-017-9-13, B-018-1-13 and B-018-2-13 consists of weathered shale which was able to be augered to competent mudstone bedrock in boring B-017-9-13 and competent limestone bedrock in borings B-018-1-13 and B-018-2-13. The cored bedrock in borings B-017-3-13 and B-017-7-13 and the upper portion of cored bedrock in boring B-017-9-13 consists of mudstone and shale. Limestone bedrock was encountered in borings B-017-9-13 and B-018-1-13 at an elevation of 643.5 feet msl and in boring B-018-2-13 at an elevation of 641.2 feet msl. The mudstone is described as brown, slightly to severely weathered, very weak to weak, thinly laminated to medium bedded, arenaceous, calcareous, friable, pyritic, fissile and fractured to highly fractured with open, rough apertures. The shale bedrock was descried as black and gray, slightly to highly weathered, very weak to slightly strong, thinly laminated to thin bedded, fissile and moderately to highly fractured with open, slightly rough to rough apertures. The limestone is described as gray and tan, unweathered to slightly weathered, strong to very strong, thick to very thick bedded, calcareous, arenaceous, argillaceous, slightly carbonaceous, fossiliferous, cherty, dolomitic, jointed and slightly to highly fractured with open, slightly rough to rough apertures.

The percent recovery, RQD values and unconfined compressive strengths of the bedrock core runs are summarized in Table 7.

Table 7. Rock Core Summary

Boring	Core No.	Depth (feet)	Recovery (%)	RQD (%)	Unconfined Compressive Strength
B-017-3-13	RC-1	83.5 to 85.0	56	0	N/A
	RC-2	85.0 to 87.0	100	46	q_u @ 86.0' = 222 psi
B-017-7-13	RC-1	90.0 to 91.0	100	79	N/A
	RC-2	91.0 to 92.0	100	66	N/A
	RC-3	92.0 to 96.7	74	15	N/A
B-017-9-13	RC-1	69.6 to 74.1	50	0	N/A
	RC-2	74.1 to 78.1	77	38	q_u @ 74.2’ = 11,707 psi
B-018-1-13	RC-1	73.5 to 78.5	98	97	q_u @ 75.6’ = 9,525 psi
	RC-2	78.5 to 83.5	88	24	N/A
B-018-2-13	RC-1	74.5 to 79.5	100	72	q_u @ 78.5’ = 10,153 psi
	RC-2	79.5 to 84.5	100	87	N/A

It should be noted that bedrock experiences mechanical breaks during the drilling and coring processes. Rii attempted to account for fresh, manmade breaks during tabulation of the RQD analysis. The quality of the cored mudstone and shale bedrock, according to the RQD values, ranged from very poor (RQD ≤ 25%) to very good (75% < RQD ≤ 90%), and the quality of the cored limestone bedrock ranged from very poor (RQD ≤ 25%) to excellent (RQD > 90%).

The borings performed as part of the supplemental investigation by ODOT OGE were not extended down to bedrock.

4.4 Groundwater

Groundwater was encountered in the borings as presented in Table 8.

Table 8. Groundwater Levels

Boring Number	Ground Surface Elevation (feet msl)	Initial Groundwater		Upon Completion	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-017-3-13	740.3	58.5	681.8	N/A [1]	N/A
B-017-7-13	743.1	57.0	686.1	N/A [1]	N/A
B-017-9-13	717.6	20.0	697.6	N/A [1]	N/A
B-018-1-13	717.0	7.0 [1]	710.0	N/A [1]	N/A
B-018-2-13	715.7	25.0	690.7	N/A [1]	N/A
B-019-6-19	738.1	Dry	-	Dry	-

1. *The groundwater level at completion could not be obtained due to the addition of water or mud as a drilling fluid.*
2. *Groundwater level indicated is representative of seepage.*

Groundwater seepage was initially encountered in boring B-018-1-13 at an elevation of 710.0 feet msl. More significant groundwater flow was encountered during drilling in borings B-017-3-13, B-017-7-13, B-017-9-13 and B-018-2-13 at elevations ranging from 681.8 to 697.6 feet msl. The groundwater levels at the completion of drilling could not be measured due to the addition of mud to counteract heaving sands and/or water as a circulating fluid during the rock coring process. Boring B-019-6-19 was observed to be dry during and at the completion of drilling. Groundwater levels were not noted on the supplemental boring logs provided by ODOT OGE.

Please note that short-term water level readings, especially in cohesive soils, are not necessarily an accurate indication of the actual groundwater level. In addition, groundwater levels or the presence of groundwater are considered to be dependent on seasonal fluctuations in precipitation.

A more comprehensive description of what was encountered during the drilling process may be found on the boring logs in Appendix III.

4.5 CPT Soundings

As noted in Section 3.1, eight (8) CPT soundings were performed by ODOT OGE, with sounding C-001-0-21 performed in close proximity to boring B-017-9-13, sounding C-002-0-21 performed in close proximity to boring B-017-3-13, sounding C-003-0-21 performed in close proximity to boring B-018-2-13 and sounding C-004-0-21 performed in close proximity to boring B-017-6-13. Offset soundings C-001-1-21, C-002-1-21, C-003-1-21 and C-004-1-21 were offset adjacent to the original, respective sounding locations. Based on a review of the CPT sounding logs provided by ODOT OGE, the following soil profile was generally observed from the soundings:

- Soft to medium stiff clay and silty clay and/or loose silty sand were observed from the ground surface to approximate elevations ranging from 700.3 to 706.9 feet msl, with isolated seams of organic soils were identified in soundings C-002-0-21 and C-002-1-21 at an approximate elevation of 707.5 to 711.2 feet msl, overlying

- Medium dense silty sand, sand and sandy silt extending to approximate elevations ranging from 697.8 to 702.4 feet msl, overlying

- Medium dense to very dense sand and sandy silt extending to approximate elevations ranging from 679.8 to 682.4 feet msl, overlying

- Very stiff to hard clay extending to the termination depths of the soundings.

Based on correlations for friction angle, undrained shear strength and SPT N-values, the conditions encountered in the CPT soundings approximately matched the soil conditions encountered in the soil borings performed by Rii for the current exploration.

5.0 ANALYSES AND RECOMMENDATIONS

Data obtained from the subsurface exploration has been used to determine the foundation support capabilities and the settlement potential for the soil encountered at the site. These parameters have been used to provide guidelines for the design of foundation systems for the subject bridge, as well as the construction specifications related to the placement of foundation systems and general earthwork recommendations, which are discussed in the following paragraphs.

Design details of the proposed structure were provided by CH2M and ms consultants. Based on the information provided, it is understood that the existing four-span bridge will be completely removed and replaced with a two-span composite prestressed concrete I-beam superstructure with a reinforced concrete deck and semi-integral abutments behind mechanically stabilized earth (MSE) walls and wall type pier supported on deep foundations consisting of driven piles. The proposed structure will have a total length of approximately 238 feet and width of approximately 110 feet, and the proposed structure alignment will be shift approximately 60 feet north of the existing bridge alignment. In addition, the roadway profile will be elevated approximately 6.0 to 7.0 feet above the existing I-70 westbound profile grade.

Retaining Wall E2 will be located at the rear abutment of the proposed structure to provide the required grade separation to support the configuration. The wall height along the alignment will range from 18.0 to 35.5 feet, and the total wall length is approximately 134 lineal feet. The wall will connect to the existing Retaining Wall 4W10 (which is part of the FRA-70-13.11 Project 4A, PID 77372) at the south side of the bridge structure. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Wall E9.

A portion of Retaining Wall E4, between Sta. 409+50 and 411+05 (BL Wall E4), will be located at the forward abutment of the proposed structure to provide the required grade separation to support the configuration. The maximum wall height at the forward abutment is 42.5 feet, and the total wall length along the abutment is approximately 148 lineal feet. The wall will connect to the existing Retaining Wall 4W8 (which is part of the FRA-70-13.11 Project 4A, PID 77372) on the south side of the structure, and turns to the east on the north side of the bridge structure and follows the alignment of Ramp D7. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Wall E7. Design recommendations for the remaining alignment of Retaining Wall E7 is presented under a separate cover.

Proposed structural data was obtained from design details provided by CH2M and ms consultants and are included in Table 9.

Table 9. Structure and Bridge Design Elevations

Substructure Unit	Structure Component [1]	Elevation [1] (feet msl)	Design Maximum Factored Load [2]
Rear Abutment / Retaining Wall E2 (B-017-3-13, B-017-9-13 and B-019-2-19)	Profile Grade	747.9	287 kips/pile
	Bottom of Footing	734.0	
	Bottom of Wall (Top of Leveling Pad)	712.4 / 729.9 [2]	
Pier (B-018-1-13)	Bottom of Footing	712.0	490 kips/pile
Forward Abutment / Retaining Wall E4 (Sta. 409+50 to 411+05) (B-017-7-13 and B-018-2-13)	Profile Grade	754.0	360 kips/pile
	Bottom of Footing	737.8	
	Bottom of Wall (Top of Leveling Pad)	711.5	

1. *Proposed foundation elevations and structural loading based on structure information provided by CH2M and ms consultants.*
2. *Multiple values represent the minimum and maximum bottom of wall elevation at the rear abutment where the wall steps up along the existing embankment slopes.*

5.1 Driven Pile Recommendations

Given the proposed loading at each substructure unit, friction bearing piles will not be a feasible foundation option as the required ultimate bearing value per pile exceeds the values provided in Section 305.3.4 of the 2020 ODOT Bridge Design Manual (BDM) based on the maximum factored loads per pile. Therefore, given the depth of bedrock encountered in the borings performed, it is recommended that steel H-piles (ODOT Item 507.06) driven to refusal on bedrock be employed for foundation support. Per Section 305.3.1.2 of the 2020 ODOT BDM, refusal is met during driving when the pile penetration is an inch or less after receiving at least 20 blows from the pile hammer. Table 10 shows the recommended pile lengths and the corresponding factored structural axial resistance ($R_{R\,max}$) of the steel H-piles.

Table 10. FRA-70-1358L Driven Pile Recommendations

Substructure Reference	Ground Elevation [1] (feet msl)	Pile Size	Pile Elevation (feet msl)		Pile Length [4] (feet)	$R_{R\ max}$ [5] (kips/pile)	Sleeve Length [6] (feet)	φ [7]
			Top [2]	Tip [3]				
Rear Abutment (B-017-3-13 / B-017-9-13)	740.3 / 717.6	HP 12x53 [8]	735.0	653.2	85	380	4.1 / 21.6	N/A
		HP 14x73 [8]	735.0	653.2	85	530	4.6 / 21.6	N/A
Pier (B-018-1-13)	717.0	HP 14x73 [8]	713.0	657.7	60	530	N/A	N/A
Forward Abutment (B-017-7-13 / B-018-2-13)	715.7	HP 12x53 [8]	738.8	656.9	85	380	26.3	N/A
		HP 14x73 [8]	738.8	656.9	85	530	26.3	N/A

1. *Ground elevation listed is the ground elevation at the respective boring locations.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is considered to be 1.0-foot above the proposed bottom of footing elevation per Section 305.3.5.1 of the 2020 ODOT BDM.*
3. *The pile tip elevation is based on the top of bedrock elevation in the nearest boring per Section 305.3.5.2 of the 2020 ODOT BDM.*
4. *Per Section 305.3.5.2 of the 2020 ODOT BDM, the estimated pile length was determined as the pile cutoff elevation (top) minus the pile tip elevation, rounded up to the nearest 5.0 feet.*
5. *The factored structural axial resistance for H-piles is based on the structural limit state of the steel H-pile section per Section 305.3.3 of the 2020 ODOT BDM.*
6. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall backfill. Multiple values represent the minimum and maximum sleeve length, respectively, where the wall steps up along the existing embankment slopes.*
7. *For H-piles driven to refusal on bedrock, no geotechnical resistance factor should be applied to the factored structural axial resistance values presented, as the values presented account for the structural resistance factor, φ_c = 0.50, for H-piles subject to damage due to severe driving conditions.*
8. *A steel pile point is recommended to protect the tips of the steel H-piles during pile installation.*

Per Section 305.3.3 of the 2020 ODOT BDM, the factored resistance of H-piles driven to refusal on bedrock is typically governed by the structural resistance of the pile element. The factored structural axial resistances listed in Table 10 consider an axially loaded pile with negligible moment, no appreciable loss of section due to deterioration throughout the life of the structure, a steel yield strength of 50 ksi, a structural resistance factor for H-piles subject to damage due to severe driving conditions (φ_c = 0.50 per Section 6.5.4.2 of the 2020 AASHTO LRFD BDS) and a pile fully braced along its length. **These bearing values should not be used for piles that are subjected to bending moments or are not supported by soil for their entire length.** Static or dynamic load testing is not required for H-piles driven to refusal on bedrock. It is anticipated that the piles will be able to be driven a short distance into the surficial bedrock before satisfying the driving conditions that meet the refusal criterion. Settlement is estimated to be less than 1.0 inch for H-piles driven to refusal on bedrock.

5.1.1 Downdrag Considerations

The anticipated total settlement at the facing of the MSE wall at the rear abutment is 5.31 to 10.24 inches and at the forward abutment is 6.70 inches, based on traditional consolidation settlement methodology. However, it is noted that settlement results from CPT sounding C-001-1-21 yielded a total anticipated settlement that was approximately half of the predicted settlement determined using traditional methodology. Regardless, given the anticipated amount of settlement at the MSE wall facing, downdrag loads may be induced on the pile elements if installed to the final tip elevation prior to construction of the wall. To reduce the amount of downdrag induced on the piles, it is recommended that the piles be pre-driven into the soil only as far as necessary to remain vertical and that the MSE wall should be constructed around the piles and then allowed to sit for a specified holding period such that a percentage of the consolidation can occur prior to driving the piles the to the design tip elevation and reduce the amount of downdrag on the piles. In order to consolidate the underlying soil to the required settlement, consideration should be given to the placement of a surcharge load in order to preload the site under the full weight of the MSE wall height (from the bottom of wall elevation to the profile grade) and left in place until approximately 90 percent of consolidation of the subsurface soils has occurred to prevent downdrag loads from developing along the pile elements. Results of the settlement analysis indicate that approximately 90 percent of the primary consolidation of the cohesive layers at the rear and forward abutment will be complete within 30 days following the placement if the surcharge load based on the results from the CPT testing and correlations. Therefore, if the above noted waiting period is specified following completion of construction of the MSE walls, downdrag forces along the piles will be eliminated.

Settlement platforms should be installed once the embankment surcharge has been placed to monitor the settlement of the embankment over time. A shorter or longer hold period than specified may be required based on the settlement platform readings as directed by the geotechnical engineer. The required hold period may be considered complete when survey monitoring of the settlement platforms indicate that the above noted settlement has occurred for the hold period or until the survey shows less than ⅛-inch of total movement per week over a two week period **following placement of the final lifts of surcharge loading.**

5.1.2 Driveability

A drivability analysis was performed in accordance with Section 10.7.8 of the 2020 AASHTO LRFD BDS using the GRLWEAP software program, and the results are provided in Appendix VII. In the driveability analysis, a Delmag 19-42 hammer with a rated energy of approximately 43,000 ft-lbs was used in conjunction with the H-pile sections. Based on the results of this analysis, driving stresses induced on the H-piles **would not exceed** 90 percent of the yield stress of the steel (f_y = 50 ksi, 0.9f_y = 45 ksi) if driven through the overburden soils to the bedrock elevation provided in Table 10. Care should be taken during pile driving operations when approaching the bedrock, and when extending the piles into the surficial bedrock material, to ensure that the driving stresses induced on the pile elements do not exceed the maximum allowable value of 90 percent of the yield stress of the steel, subsequently damaging the pile elements. Pile driving should be terminated upon achieving the required 20 blows from the pile hammer with an inch or less of penetration to reduce the possibility of damaging the pile element.

Per Section 305.3.5.6 of the 2020 ODOT BDM, although the surficial bedrock consists of weak rock with an unconfined compressive strength less than 500 psi, steel pile points **shall be used** when the piles are extended through overburden containing layers of very dense granular soils as well as boulders.

5.1.3 Lateral Design

If lateral loads or moments are expected to be applied on the foundation elements, they should be analyzed to verify the pile has enough lateral and bending resistance against these loads. A boring-by-boring tabulation of parameters that should be used for lateral loading design is provided in Appendix VIII. In order to evaluate the lateral capacity, it is recommended that a derivation of COM624, such as LPILE, be utilized to determine the proper embedment depth required to resist the lateral load for a given end condition and deflection. Table 11 lists the eleven different soil types internal to the LPILE program. These strata were utilized to define the soil strata in the soil profile for each boring provided in Appendix VIII.

Table 11. Subsurface Strata Description

Strata	Description
1	Soft Clay
2	Stiff Clay with Water
3	Stiff Clay without Free Water
4	Sand (Reese)
5	User Defined
6	Vuggy Limestone (Strong Rock)
7	Silt (with cohesion and internal friction angle)
8	API Sand
9	Weak Rock
10	Liquefiable Sand (Rollins)
11	Stiff Clay without free water with a specified initial K (Brown)

5.2 MSE Wall Recommendations

It is proposed to construct MSE walls at the rear abutment (Retaining Wall E2) and forward abutment (Retaining Wall E4 between Sta. 409+50 and 411+05, BL Wall E4) of the proposed bridge structure. MSE walls are constructed on earthen foundations at a minimum depth of 3.0 feet below grade, as defined by the top of the leveling pad to the ground surface located 4.0 feet from the face of the wall. Per Section 840.04.A of ODOT Supplemental Specification 840 (SS 840), the height of the MSE wall at the bridge abutment is defined as the elevation difference between the profile grade at the face of the wall and the top of the leveling pad, and where the wall does not cross in front of the abutment, the height of the wall is defined as the elevation difference between the top of coping and the top of the leveling pad. However, at the abutment, it is noted that the reinforced soil mass only extends from the foundation bearing elevation (top of leveling pad) to the bottom of footing elevation. Additionally, per Section 201.4.1.C.7 of the 2020 ODOT BDM, a minimum of one row of soil reinforcement straps should be attached to the backside of the abutment footing to resist horizontal forces from the bridge structure and lateral pressures along the back wall of the abutment footing, and prevent any load transfer from these forces to the coping and facing panels. The width of the MSE wall foundation (B) is defined by the length of the reinforced soil mass. Per the 307.4.A of the 2020 ODOT BDM and Section 840.04.A.2 of ODOT SS 840, the minimum length of the reinforced soil mass is equal to 70 percent of the height of the MSE wall or 8.0 feet whichever is greater. A non-structural bearing leveling pad consisting of a minimum of 6.0-inches of unreinforced concrete should be placed at the base of the wall facing for constructability purposes. Please note that the leveling pad is not a structural foundation.

Based upon the proposed plan information, the wall height at the rear abutment ranges from and 18.0 to 35.5 feet from the top of the leveling pad to the proposed profile grade of the roadway, and the wall height at the forward abutment is 42.5 feet. It should be noted that the footprint of the MSE wall at rear abutment will be within the limits of the existing embankment supporting I-70 eastbound and westbound, and that the MSE wall will be constructed full height from the existing grade at the base of the embankment to the proposed profile grade of I-70 westbound for a portion of the wall length, and will be stepped up along the existing embankment as the wall extends to the north along the length of the abutment. For the analysis, the foundation width was set at 70 percent of the maximum wall height for the rear and forward abutments, respectively, and the foundation width was increased, if required, until external and global stability requirements were satisfied.

Per Section 840.06.D of ODOT SS 840, the foundation subgrade should be inspected to verify that the subsurface conditions are the same as those anticipated in this report. Based on the plan information provided, the footprint of the wall at the rear abutment is within the limits of the existing embankment fill and the wall will step up along the existing embankment slope. Based on the conditions encountered in boring B-017-3-13, the existing I-70 embankment is comprised of stiff to very stiff clay (ODOT A-7-6). Based on the conditions encountered in boring B-019-6-19, the existing embankment supporting the abandoned Mound Street is comprised of interbedded layers of loose to dense gravel with sand and gravel with sand and silt (ODOT A-1-b, A-2-4) and stiff to very stiff silt and clay and silty clay (ODOT A-6a, A-6b). The underlying soils encountered in borings B-017-3-13 and B-019-6-19 consist of existing fill comprised of medium dense to very dense gravel with sand and gravel with sand and silt (ODOT A-1-b, A-2-4) overlying stiff to very stiff sandy silt and silty clay (ODOT A-6b) followed by thicker layers of interbedded dense to very dense gravel and gravel with sand (ODOT A-1-a, A-1-b) and very stiff to hard silt and clay and clay (ODOT A-6a, A-7-6) over shale bedrock at an elevation of 656.8 feet msl. Boring B-017-9-13, which was performed in front of the proposed rear abutment at the toe of the existing embankment, encountered existing fill at the ground surface consisting of very loose to medium dense gravel with sand and coarse and fine sand and medium stiff silty clay (ODOT A-1-b, A-3a, A-6b), which extends to an elevation of 707.1 feet msl and contains coal fragments, slag, cinders and organics throughout. The underlying natural soils consist of a thick layer of granular material comprised of medium dense to dense gravel with sand, coarse and fine sand and gravel with sand silt and clay (ODOT A-1-b, A-2-4, A-3a) overlying a thick layer very stiff to hard clay (ODOT A-7-6) over shale bedrock at an elevation of 653.2 feet msl.

Existing fill material was encountered at the proposed bearing elevation at the forward abutment (Wall E4), which extends to a depth of 10.1 feet below the proposed bearing elevation (El. 701.4 feet msl). The fill material consists of loose to medium dense gravel with sand and silt (ODOT A-2-4) and stiff to very stiff sandy silt and silty clay (ODOT A-4a, A-6b) and contained trash debris, plastic, cinders, brick fragments and organic material throughout. Underlying the fill material, natural soils were encountered consisting of a thick layer of natural medium dense to very dense gravel and gravel with sand (ODOT A-1-a, A-1-b) overlying a thick layer of very stiff to hard clay (ODOT A-7-6) over shale bedrock at an elevation of 656.9 feet msl. These soils are not considered suitable for foundation support for a wall of this size.

Given the low blow counts and hand penetrometer values as well as the presence of organics and debris observed within the existing fill material encountered at the rear abutment (Wall E2) and forward abutment (Wall E9), these soils are not considered suitable for support of the MSE walls. However, a portion of Wall E2, from Sta. 201+63 (BL Wall E2) to the end of the wall alignment, will be situated further up and back into the existing I-70 and abandoned Mound Street embankments, which are considered suitable for support of the wall in its current conditions. Consideration was given to over excavating the unsuitable existing fill soils and replacing it with granular embankment; however, given the depth of over excavation required at both walls and the fact that this material extends around the existing I-70 embankment along the remainder of the alignment of Wall E4, this option is not considered economically feasible.

A study was performed by GPD GROUP as part of the FRA-70-12.68 Project 4R (PID 105523), dated March 2, 2018, to investigate the use of ground improvement techniques (stone columns/rigid inclusions) as well as the use of lightweight fill consisting of cellular concrete to control settlement within the fill material and meet strength requirements. Analyses for both alternatives were provided in the report, as well as a cost comparison between the two alternatives. Based on the results of the study, it was understood that ground improvement techniques will be a cheaper option for that wall. It is anticipated that similar results would be obtained for these walls.

The ground improvement techniques, which will consist of stone columns or rigid inclusions, will increase the bearing resistance of the existing fill and cohesive soil deposits and also reduce settlement potential. The improved soils should also result in an increase of the shear strength within these soils, which in turn will improve the global stability of the wall/embankment system. It is recommended that the ground improvement elements be installed within the entire footprint of Wall E4 and the proposed embankment in areas outside of the existing I-70 embankment. The design of such a system is proprietary and beyond the scope of this investigation. Based on discussions with the ODOT Office of Geotechnical Engineering (OGE), the analysis for the walls was performed assuming that the existing fill and unsuitable soils will remain in place and not be stabilized. Additional considerations for the ground improvement design, including required performance criteria, are provided in Section 5.2.8.

Per Section 307.4.C of the 2020 AASHTO LRFD BDS and Section 840.06.D of ODOT SS 840, following foundation subgrade inspection and acceptance, a minimum of 12.0 inches of ODOT Item 703.16.C, Granular Material Type C, should be placed and compacted in accordance with ODOT Item 204.07.

Since the walls are located within an existing floodplain, the analyses were performed using a design groundwater level at the ground surface.

5.2.1 Strength Parameters Utilized in External and Global Stability Analyses

The shear strength parameters utilized in the external and global stability analyses for the MSE walls at the abutments are provided in Table 12.

Table 12. Shear Strength Parameters Utilized in MSE Wall Stability Analyses

Material Type	γ (pcf)	φ' (1) (°)	c' (2) (psf)	S_u (3) (psf)
MSE Wall Backfill (Select granular fill)	120	34	0	N/A
Item 203 Embankment Fill (Retained soil)	120	30	0	2,000
Existing Embankment Fill: Stiff to Very Stiff Silt and Clay (ODOT A-6a)	120	26 to 27	0	2,250 to 2,375
Existing Embankment Fill: Stiff to Very Stiff Silty Clay (ODOT A-6b)	115 to 120	25 to 26	0	1,250 to 3,125
Existing Embankment Fill: Stiff to Very Stiff Clay (ODOT A-7-6)	115	24	0	1,375
Existing Embankment Fill: Loose to Medium Dense Granular Soils (ODOT A-2-4)	125	34	0	N/A
Existing Fill: Very Dense Granular Soils (ODOT A-2-4)	135	40	0	N/A
Existing Fill: Stiff to Very Stiff Sandy Silt (ODOT A-4a)	120	28 to 29	0	1,875 to 2,875
Existing Fill: Medium Stiff to Very Stiff Silty Clay (ODOT A-6b)	115 to 120	25	0	750 to 1,875
Medium Dense to Very Dense Granular Soils (ODOT A-1-a, A-1-b, A-2-6, A-3a)	130 to 135	35 to 42	0	N/A
Very Stiff Silty Clay (ODOT A-6b)	115	27	25	1,625
Very Stiff to Hard Clay (ODOT A-7-6)	120 to 130	26	0 to 100	2,750 to 8,000

1. *Per Figure 7-45, Section 7.6.9 of FHWA GEC 5 for cohesive soils and Table 10.4.6.2.4-1 of the 2020 AASHTO LRFS BDS for granular soils.*
2. *Estimated based on overconsolidated nature of soil.*
3. *S_u = 125(N_{60}), Terzaghi and Peck (1967).*

Shear strength parameters for the reinforced soil backfill and retained embankment are provided in Table 307-1 of the 2020 ODOT BDM and Section 840.04.A.3 of ODOT SS 840. Per these specifications, the select granular backfill in the reinforced zone and the retained embankment must meet the shear strength requirements provided in Table 12. The shear strength parameters for the natural soils were assigned using correlations provided in FHWA Geotechnical Engineering Circular (GEC) No. 5 (FHWA-NHI-16-072) Evaluation of Soil and Rock Properties, the 2020 AASHTO LRFD BDS and based on past experience in the vicinity of the site with projects performed in similar subsurface profiles.

5.2.2 Bearing Stability

The anticipated bearing materials at the rear abutment (Wall E2) from the beginning of the wall to Sta. 201+63 (BL Wall E2) and at the forward abutment (Wall E4) consist of existing fill comprised of very loose to medium dense gravel with sand, gravel with sand and silt and coarse and fine sand and medium stiff to very stiff sandy silt and silty clay (ODOT A-1-b, A-2-4, A-3a, A-4a, A-6b), which extends to an elevation of 704.8 to 701.4 feet msl and contains trash debris, plastic, cinders, brick fragments and organic material throughout. The anticipated bearing materials along the remainder of the wall at the rear abutment (Wall E2) from Sta. 201+63 (BL Wall E2) to the end of the wall alignment consist of existing embankment fill comprised of stiff to very stiff silt and clay, silty clay and clay (ODOT A-7-6) with interbedded layers of loose to dense gravel with sand and gravel with sand and silt (ODOT A-1-b, A-2-4).

As noted in Section 5.2, it is understood that ground improvement techniques will be implemented within the footprint of Wall E2 from the beginning of the wall alignment to Sta. 201+63 (BL Wall E2) and within the entire footprint of Wall E4. As this is a proprietary design, the analysis for this wall considers the existing fill material will remain in place and will not be stabilized. MSE wall foundations bearing on existing fill material or granular embankment, placed and compacted in accordance with ODOT Item 203, may be proportioned for a factored bearing resistance as indicated in Table 13. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.

Table 13. FRA-70-1358L (Retaining Wall E2 and E4) MSE Wall Design Parameters

Substructure Unit (Boring)	Station Along Wall Alignment		Wall Height Analyzed (feet)	Back-slope Behind Wall	Minimum Required Reinforcement Length [1] (feet)	Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing Pressure [3] (ksf)
	From	To				Nominal	Factored [2]	
Rear Abutment / Retaining Wall E2 (B-017-3-13 / B-017-9-13 / B-019-6-19)	200+68	201+63	35.5	Level	24.9 (0.7H)	4.24	2.76	8.26
	201+63	202+03	25.5	Level	29.3 (1.15H)	8.73	5.67	5.06
Forward Abutment / Retaining Wall E4 (B-017-7-13 / B-018-2-13)	409+50	411+05	42.5	Level	29.8 (0.7H)	9.77	6.35	9.72

1. *The minimum reinforcement length is based on the maximum wall height analyzed. The value in parentheses represent the required reinforcement length expressed as a percentage of the wall height, H.*
2. *A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.*
3. *The strength limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the strength limit state.*

Rii performed a verification of the bearing pressure exerted on the subgrade material for the specified wall heights indicated in Table 13. Based on the minimum length of reinforced soil mass presented, the factored equivalent bearing pressure exerted below the wall **will exceed** the factored bearing resistance at the strength limit state, considering the wall will bear on the existing fill material and unsuitable soils for Wall E2 between Sta. 200+68 and 201+63 and for Wall E4. Based on the minimum length of reinforced soil mass presented, the factored equivalent bearing pressure exerted below the wall **will not exceed** the factored bearing resistance at the strength limit state for Wall E2 between Sta. 201+63 and 202+03.

5.2.3 Settlement Evaluation

The compressibility parameters utilized in the settlement analyses of the proposed MSE wall at the rear abutment are provided in Table 14.

Table 14. Compressibility Parameters Utilized in Settlement Analysis

Material Type	γ (pcf)	N_{60} (bpf)	$(N1)_{60}$ (1) (bpf)	S_u (2) (psf)	σ_p' (3) (psf)	PL (%)	LL (%)	C_c (4)	C_r (5)	e_o (6)	C_v (7) (ft^2/yr)	C' (8)
Existing Embankment Fill: Stiff Silty Clay (ODOT A-6b)	115	10	10	1,250	3,046	18	39	0.261	0.039	0.577	300	-
Existing Embankment Fill: Loose to Very Dense Gravel with Sand and Silt (ODOT A-2-4)	125 to 135	7 to 57	13 to 69	-	2,222 to 18,096	-	-	-	-	-	-	61 to 261
Existing Fill: Very Loose to Dense Granular Soils (ODOT A-2-4, A-3a)	120 to 125	4 to 18	7 to 36	-	2,285 to 5,715	-	-	-	-	-	-	48 to 117
Existing Fill: Stiff to Very Stiff Sandy Silt (ODOT A-4a)	120	11 to 23	11 to 23	1,375 to 2,875	4,606 to 10,155	18 to 19	25 to 28	0.135 to 0.162	0.020 to 0.024	0.467 to 0.491	800	-
Existing Fill: Medium Stiff to Very Stiff Silty Clay (ODOT A-6b)	115 to 120	10 to 21	6 to 21	750 to 2,625	1,792 to 6,583	18	40	0.270	0.041	0.585	300	-
Medium Dense to Very Dense Granular Soils (ODOT A-1-a, A-1-b, A-2-6, A-3a)	125 to 135	19 to 66	26 to 77	-	5,821 to 20,953	-	-	-	-	-	-	78 to 311
Hard Sandy Silt (ODOT A-4a)	125	39	39	4,875	17,965	18	25	0.135	0.014	0.467	800	-

Material Type	γ (pcf)	N_{60} (bpf)	$(N1)_{60}$ (1) (bpf)	S_u (2) (psf)	σ_p' (3) (psf)	PL (%)	LL (%)	C_c (4)	C_r (5)	e_o (6)	C_v (7) (ft^2/yr)	C' (8)
Very Stiff Silty Clay (ODOT A-6b)	115	13	13	1,625	3,690	18	39	0.261	0.026	0.577	300	-
Very Stiff to Hard Clay (9) (ODOT A-7-6)	120 to 130	19 to 98	19 to 98	2,375 to 4,625	7,500 to 18,200	21 to 26	45 to 58	0.203	0.093	0.645	183	-

1. *$(N1)_{60} = C_n N_{60}$, where $C_n = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS.*
2. *$S_u = 125(N_{60})$ for $N_{60} < 52$; Ref. Terzhaghi & Peck (1967); $S_u = f_1 N_{60} p_a/100$ for $N_{60} \geq 52$; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989).*
3. *Cohesive: $\sigma_p' = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$, where $\sigma_p = S_u/(0.11+0.0037(PI))$; Granular: $\sigma_p' = n(N_{60}{}^m)p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007) and Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957).*
4. *$C_c = 0.009(LL-10)$;Table 6-9, Section 6.14.1 of FHWA GEC 5.*
5. *$C_r = 0.15(C_c)$ for the existing fill and $0.10(C_c)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981.*
6. *$e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981.*
7. *Per Figure 6-37, Section 6.14.2 of FHWA GEC 5.*
8. *Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS.*
9. *For the lower A-7-6 layer, values for σ_p' were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.*

Settlement analysis was initially performed using traditional one-dimensional settlement methodology using the parameters provided in Table 14. For the upper soil layers, correlations were utilized to define the settlement parameters for each layer, which aligned well with the consolidation test results provided by ODOT OGE. For the lower clay (ODOT A-7-6) layer, values for preconsolidation stress (σ_p') were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of the compression index (C_c), recompression index (C_r) and initial void ratio (e_o) from the test results were used for this layer.

Results of the settlement analysis are tabulated in Table 15. Total settlements of 9.46 to 17.41 inches at the center of the reinforced soil mass and 5.31 to 10.24 inches at the facing of the wall are anticipated at the rear and forward abutments. Time rate of settlement values are also provided in Table 15, which indicate that 90 percent of the primary consolidation will be complete at approximately 330 and 140 days at the rear and forward abutment, respectively. It should be noted that the amount of settlement and time rate of settlement assume that the upper soils will not be stabilized. However, the time rate of settlement is still being controlled by the lower clay (ODOT A-7-6) layer, and a substantial amount of settlement (over 0.5 to 1.0 inches) is still remaining at 90 to 180 days following completion of construction. Please note that the consolidation settlement and time rate of consolidation provided in Table 15 are based on estimates using correlated or measured compressibility parameters provided in Table 14 for the underlying soils. Settlement calculations using this methodology are provided in Appendix IX.

Table 15. MSE Wall Settlement Values

Substructure Unit (Boring)	Station Along Wall Alignment		Service Limit Equivalent Bearing Pressure [1] (ksf)	Total Settlement Values (inches)		Time Rate of Consolidation (Remaining Settlement at Wall Facing After Hold Period, inches)					Time to 90% Consol. (Days)
	From	To		Center of Wall Mass	Facing of Wall	30 Days	60 Days	90 Days	120 Days	180 Days	
Rear Abutment / Retaining Wall E2 (B-017-3-13 / B-017-9-13 / B-019-6-19)	200+68	201+63	4.26	17.41	10.24	4.21	3.56	3.04	2.64	2.01	330
	201+63	202+03	3.06	9.46	5.31	2.31	1.93	1.64	1.42	1.08	300
Forward Abutment / Retaining Wall E4 (B-017-7-13 / B-018-2-13)	409+50	411+05	5.10	9.64	6.70	2.18	1.51	1.12	0.81	0.42	140

1. *The service limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the service limit state.*

Following discussion of the settlement results with ODOT OGE using the correlated parameters for the upper soils and measured values for the lower clay (ODOT A-7-6) layer, additional settlement analysis was performed using the CPT data and methodology outlined by ODOT to further evaluate the total settlement and time rate of settlement of the lower clay layer. While reasonably consistent compressibility parameters were determined from the consolidation tests provided by ODOT OGE, there is speculation regarding whether sample disturbance and transportation potentially influenced the test results, and that in-situ measurements from the CPT testing may yield more accurate results, especially within this layer.

A spreadsheet containing correlations from the raw data obtained from the CPT testing was provided by ODOT OGE for sounding C-001-1-21, which was performed adjacent to boring B-017-9-13. Within the spreadsheet, the soil type and classification as well as other physical properties of the soil were tabulated with depth. The information from boring B-017-9-13 was also tabulated within the spreadsheet to better illustrate the conditions encountered for each exploration methodology and to determine how well the exploration results line up. In general, the soil profile and properties approximately matched, except that the CPT sounding indicated the presence of either granular soils layers within the underlying clay (ODOT A-7-6) layer. It is likely that thin layers of granular material are present within this layer, which were not encountered within the 5.0-foot interval sampling performed in the soil boring, but which would likely result in accelerated time rate of consolidation.

Results of the settlement analysis using the CPT data and correlations indicates that the total settlement anticipated less than half of that calculated using the traditional method, with a total settlement at the wall facing of 3.74 inches. Time rate of settlement indicates that 90 percent of primary consolidation of the lower soil layers below the fill material will be completed in less than 30 days. It is anticipated that this will be common to both walls at the rear and forward abutments since the time rate of consolidation is being controlled by the same lower clay (ODOT A-7-6) layer. Settlement calculations using this methodology are also provided in Appendix IX.

Actual settlement and time rate of consolidation should be determined by monitoring the settlement of the wall using settlement platforms.

Per Section 307.1.6 of the 2020 ODOT BDM, the maximum allowable differential settlement in the longitudinal direction (regardless of the size of panels) is one (1) percent (1/100). Given the amount of settlement anticipated at the facing along the wall alignment, as well as the presence of existing fill material that may vary significantly over the footprint of the walls, differential settlement greater than 1/100 may occur if the existing fill material is not stabilized or over excavated and replaced with embankment fill. If either the total or differential settlement values predicted present an issue with respect to the deformation tolerances that the wall can withstand, then measures should be taken to minimize the amount of settlement that will occur. This should be considered in the final ground improvement design.

5.2.4 Eccentricity (Overturning Stability)

The resistance of the MSE walls to overturning will be dependent on the on the location of the resultant force at the bottom of the wall due to the overturning and resisting moments acting on the wall. For MSE walls, overturning stability is determined by calculating the eccentricity of the resultant force from the midpoint of the base of the wall and comparing this value to a limiting eccentricity value. Per Section 11.10.5.5 of the 2020 AASHTO LRFD BDS, for foundations bearing on soil, the location of the resultant of the reaction forces shall be within the middle two-thirds ($^{2}/_{3}$) of the base width. Therefore, the limiting eccentricity is one-third ($^{1}/_{3}$) of the base width of the wall. Rii performed a verification of the eccentricity of the resultant force for the specified wall height indicated in Table 13. Based on the minimum length of reinforced soil mass presented in Table 13 and utilizing the soil parameters listed in Section 5.2.1 for the retained embankment material, the calculated eccentricity of the resultant force **will not exceed** the limiting eccentricity at the strength limit state.

5.2.5 Sliding Stability

The resistance of the MSE walls to sliding was evaluated per Section 11.10.5.3 of the 2020 AASHTO LRFD BDS. Given that the bearing soils along both of the walls consist of cohesive material, the sliding resistance was evaluated under both drained and undrained conditions. For drained conditions, the sliding resistance is determined by multiplying a coefficient of sliding friction "f" times the total vertical force at the base of the wall. The coefficient of sliding friction is determined based on the limiting friction angle between the foundation soil and the reinforced soil backfill. Based on the soil parameters listed in Section 5.2.1 for the foundation soil and the reinforced soil backfill, a coefficient of sliding friction of 0.47 to 0.49 was utilized for design. For undrained conditions, the sliding resistance is taken as the limiting value between the undrained shear strength of the bearing soil and half of the vertical stress applied by the wall multiplied by the width of the MSE wall. Based on the soil parameters listed in Section 5.2.1, the undrained shear strength of the bearing material ranges from 0.75 to 2.0 ksf.

A geotechnical resistance factor of φ_τ=1.0 was considered in calculating the factored shear resistance between the reinforced soil mass and foundation for sliding. Based on the minimum length of reinforced soil mass presented in Table 13 and utilizing the soil parameters listed in Section 5.2.1 for the retained embankment material, the resultant horizontal forces on the back of the MSE walls **will not exceed** the factored shear resistance at the strength limit state under drained conditions for either wall. However, the resultant horizontal forces on the back of the MSE wall at the rear abutment (Wall E2) between Sta. 200+68 and 201+63 **will exceed** the factored shear resistance at the strength limit state under undrained conditions.

5.2.6 Overall (Global) Stability

A slope stability analysis was performed to check the global stability of walls at the rear and forward abutments. As per Section 11.6.2.3 of the 2020 AASHTO LRFD BDS, safety against soil failure shall be evaluated at the service limit state by assuming the reinforced soil mass to be a rigid body. Soil parameters utilized in external stability analyses are presented in Section 5.2.1. For the global stability condition, it was considered that the failure plane will not cross through the reinforced soil masses. The computer software program Slide, manufactured by Rocscience Inc., was utilized to perform the analyses.

Per Section 307.1.2 of the 2020 ODOT BDM and Section 11.6.2.3 of the 2020 AASHTO LRFD BDS, overall (global) stability for MSE walls that are integrated with or supporting structural foundations or elements is satisfied if the product of the factor of safety from the slope stability output multiplied by the resistance factor φ=0.65 is greater than 1.0. Therefore, global stability is satisfied when a minimum factor of safety of 1.5 is obtained. For an MSE wall designed with the minimum strap length listed in Table 13, the resulting factor of safety under drained conditions (long-term stability) and undrained conditions (short-term stability) at the rear abutment (Wall E2) between Sta. 201+63 and 202+03 using the Spencer's analysis method was greater than 1.5. However, the resulting factor of safety under drained conditions (long-term stability) and undrained conditions (short-term stability) at the rear abutment (Wall E2) between Sta. 200+68 and 201+63 and forward abutment (Wall E4) was less than 1.5.

5.2.7 Final MSE Wall Considerations

Based on the results of the external and global stability analysis performed for the MSE wall at the rear abutment (Wall E2) between Sta. 201+63 and 202+03, the recommended controlling strap length is 1.0 times the maximum height of the MSE wall (measured from the top of the leveling pad to the proposed profile grade of the roadway) along that segment of the wall. All external and global stability calculations indicate that adequate resistance is available for support of the MSE wall at the abutment for a strap length equal to 100 percent of the wall height for this segment of the wall.

Based on the results of the external and global stability analysis performed for the MSE wall at the rear abutment (Wall E2) between Sta. 200+68 and 201+63 and at the forward abutment (Wall E), sliding under undrained conditions as well as bearing and global stability under both drained and undrained conditions were not satisfied at a strap length equal to 0.7 times the wall height. Increasing the width of the wall up to 1.3 times the wall height still did not satisfy all of the external and global stability requirements. As noted in Section 5.2, consideration was given to over excavating these soils and replacing it with granular embankment; however, given the depth of over exaction required to completely remove this material, this a very expensive and uneconomical option. Therefore, it is recommended that ground improvement techniques be implemented to increase the strength of the soil mass and reduce settlement potential within these layers. Additional considerations for the ground improvement design, including required performance criteria, are provided in Section 5.2.8 below.

Calculations for external (bearing and sliding resistance and limiting eccentricity) and overall (global) stability of the MSE walls are provided in Appendix IX.

5.2.8 Ground Improvement Considerations

The design of the ground improvement should result in the improved soil matrix meeting the design criteria for bearing resistance and compressibility for the MSE wall. The improved soil matrix will need to provide a factored bearing resistance greater than or equal to the factored bearing pressure at the strength limit state of 8.26 to 9.72 ksf. Additionally, the improved soil matrix will need to limit settlement to the required maximum differential settlement of 1/100 along the wall facing and to tolerable limits for maximum settlement of the wall based on the wall manufacturer's specifications or for constructability of the roadway. In the absence of specific settlement from the wall manufacturer, the ground improvement design should limit total settlement of the embankment and back of the reinforced soil mass to 5.0 inches, and total settlement at the facing of the wall to 2.5 inches.

Based on the conditions encountered, the ground improvement elements should be extended to an approximate elevation of 700 feet msl. Additionally, it is recommended that ground improvement elements be located along the length of the leveling pad if concentrated loads will be imparted along the pad to ensure that differential settlement does not occur.

The design of the ground improvement should demonstrate that all external and global stability requirements will be satisfied, including sliding, eccentricity, bearing and global stability checks. Calculations showing that these stability requirements are satisfied should be provided with the shop drawings for review and acceptance.

5.3 Lateral Earth Pressure

For the soil types encountered in the borings, the "in-situ" unit weight (γ), cohesion (c), effective angle of friction (φ'), and lateral earth pressure coefficients for at-rest conditions (k_o), active conditions (k_a), and passive conditions (k_p) have been estimated and are provided in Table 16 and Table 17.

Table 16. Estimated Undrained (Short-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	*c* (psf)	φ	k_a	k_o	k_p
Soft to Stiff Cohesive Soil	115	1,500	0°	N/A	N/A	N/A
Very Stiff to Hard Cohesive Soil	125	3,000	0°	N/A	N/A	N/A
Very Loose to Loose Granular Soil	120	0	28°	0.32	0.53	5.07
Medium Dense Granular Soil	125	0	32°	0.27	0.47	6.82
Dense to Very Dense Granular Soil	130	0	36°	0.23	0.41	9.09
Compacted Cohesive Engineered Fill	120	2,000	0°	N/A	N/A	N/A
Compacted Granular Engineered Fill	120	0	32°	0.27	0.47	6.82

1. *When below groundwater table, use effective unit weight, γ' = γ - 62.4 pcf and add hydrostatic water pressure.*

Table 17. Estimated Drained (Long-term) Soil Parameters for Design

Soil Type	γ (pcf) [1]	*c* (psf)	φ'	k_a	k_o	k_p
Soft to Stiff Cohesive Soil	115	0	26°	0.35	0.56	4.53
Very Stiff to Hard Cohesive Soil	120	50	28°	0.32	0.53	5.07
Very Loose to Loose Granular Soil	120	0	28°	0.32	0.53	5.07
Medium Dense Granular Soil	125	0	32°	0.27	0.47	6.82
Dense to Very Dense Granular Soil	130	0	36°	0.23	0.41	9.09
Compacted Cohesive Engineered Fill	120	0	30°	0.30	0.50	5.58
Compacted Granular Engineered Fill	120	0	32°	0.27	0.47	6.82

1. *When below groundwater table, use effective unit weight, γ' = γ - 62.4 pcf and add hydrostatic water pressure.*

These parameters are considered appropriate for the design of all subsurface structures and any excavation support systems. Subsurface structures (where the top of the structure is restrained from movement) should be designed based on at-rest conditions (k_o). For proposed temporary retaining structures (where the top of the structure is allowed to move), earth pressure distributions should be based on active (k_a) and passive (k_p) conditions. Active earth pressure is developed as the structure moves away from the backfill or retained soil, while passive pressure is developed as the structure moves towards the backfill. A relatively small amount of lateral movement is needed to reach the active condition (≥ 0.1 percent of the height), whereas the movements required to engage the passive condition are approximately ten times greater than those required to develop active earth pressure. The values in this table have been estimated from correlation charts based on minimum standards specified for compacted engineered fill materials.

These recommendations do not take into consideration the effect of any surcharge loading or a sloped ground surface (a flat surface is assumed). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage. Surcharge loads, such as that imposed by traffic loading, will create additional lateral loading on the subsurface structures and excavation support systems. The resulting lateral earth pressure should be evaluated based on active (k_a) and at-rest (k_o) conditions and the anticipated magnitude of the loading.

Where necessary, temporary retaining structures such as sheet pile system should be designed using the undrained soil parameters provided in Table 16, and the design should follow all applicable guidelines for the type of retaining structure utilized. Permanent retaining and subsurface structures should be designed using the drained soil parameters provided in Table 17. Regardless of whether the retaining structure is temporary or permanent, the effective unit weight ($\gamma' = \gamma$ - 62.4 pcf) plus the hydrostatic water pressure ($\gamma_w * h_w$, where h_w is the height of water behind the wall above the base of the wall) should be utilized below the design groundwater level. The lateral earth pressure coefficients should only be applied to the horizontal pressure resulting from the effective overburden pressure, and should not be applied to the hydrostatic water pressure.

5.4 Construction Considerations

All site work shall conform to local codes and to the latest ODOT Construction and Materials Specifications (CMS), including that all excavation and embankment preparation and construction should follow ODOT Item 200 (Earthwork).

5.4.1 Excavation Considerations

All excavations should be shored / braced or laid back at a safe angle in accordance with Occupational Safety and Health Administration (OSHA) guidelines. During excavation, if slopes cannot be laid back to OSHA Standards due to adjacent structures or other obstructions, temporary may be required. The following table should be utilized as a general guide for implementing OSHA guidelines when estimating excavation back slopes at the various boring locations. Actual excavation back slopes must be field verified by qualified personnel at the time of excavation in strict accordance with OSHA guidelines.

Table 18. Excavation Back Slopes

Soil	Maximum Back Slope	Notes
Soft to Medium Stiff Cohesive	1.5 : 1.0	Above Ground Water Table and No Seepage
Stiff Cohesive	1.0 : 1.0	Above Ground Water Table and No Seepage
Very Stiff to Hard Cohesive	0.75 : 1.0	Above Ground Water Table and No Seepage
All Granular & Cohesive Soil Below Ground Water Table or with Seepage	1.5 : 1.0	None
Rock to 3.0' +/- below Auger Refusal	0.75 : 1.0	Above Ground Water Table and No Seepage
Stable Rock	Vertical	Above Ground Water Table and No Seepage

5.4.2 Groundwater Considerations

Based on the groundwater observations made during drilling, groundwater is not anticipated to be encountered during construction. However, where/if groundwater is encountered, proper groundwater control should be employed and maintained to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or "boiling" condition where soft silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36 inches below the deepest excavation. Any seepage or groundwater encountered at this site should be able to be controlled by pumping from temporary sumps. Additional measures may be required depending on seasonal fluctuations of the groundwater level. Note that determining and maintaining actual groundwater levels during construction is the responsibility of the contractor.

6.0 LIMITATIONS OF STUDY

The above recommendations are predicated upon construction inspection by a qualified soil technician under the direct supervision of a professional geotechnical engineer. Adequate testing and inspection during construction are considered necessary to assure an adequate foundation system and are part of these recommendations.

The recommendations for this project were developed utilizing soil and bedrock information obtained from the test borings that were made at the proposed site for the current investigation. Resource International is not responsible for the data, conclusions, opinions or recommendations made by others during previous investigations at this site. At this time we would like to point out that soil borings only depict the soil and bedrock conditions at the specific locations and time at which they were made. The conditions at other locations on the site may differ from those occurring at the boring locations.

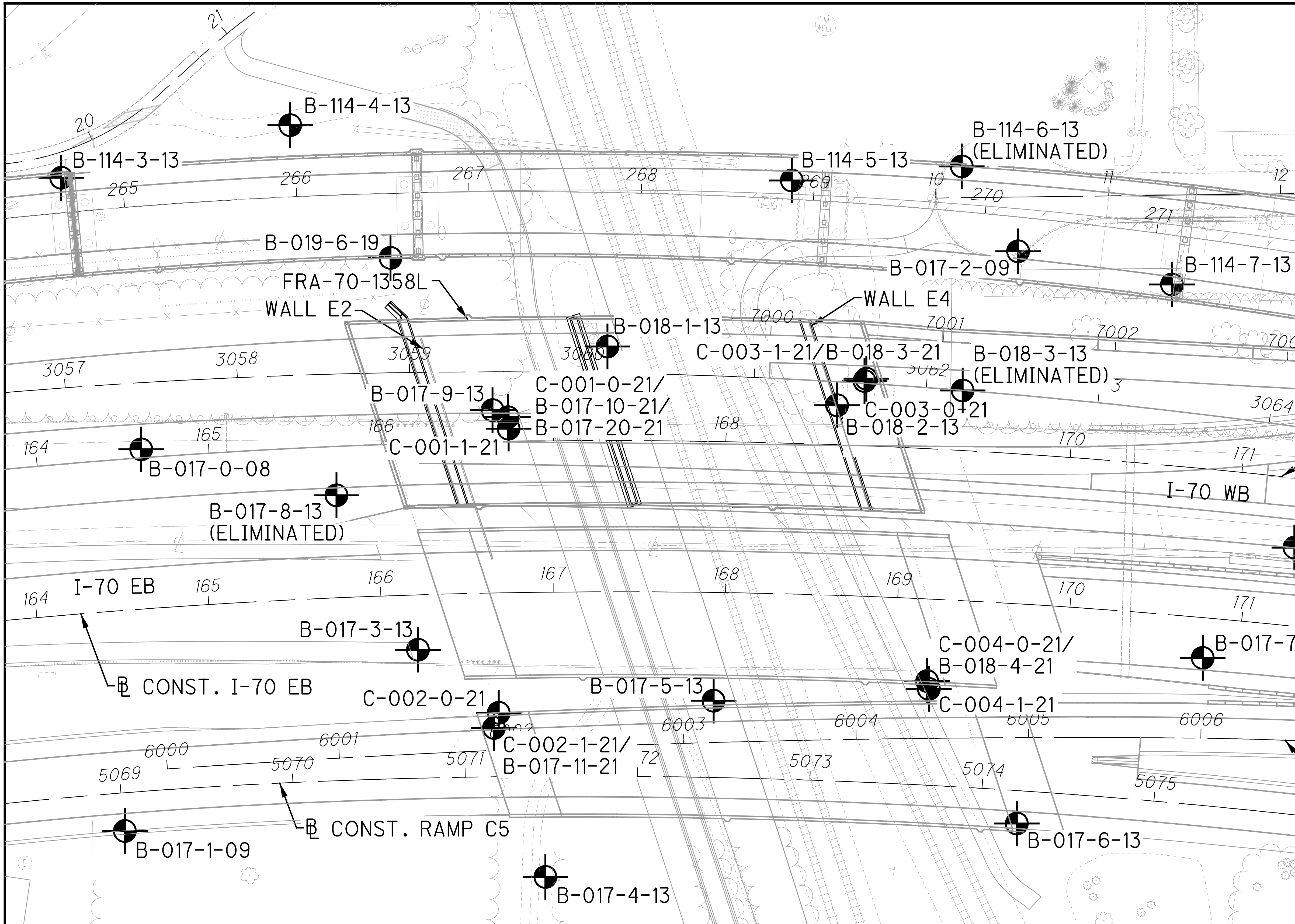
The conclusions and recommendations herein have been based upon the available soil and bedrock information and the design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be brought to the attention of the geotechnical engineer to determine whether any changes in the foundation or earthwork recommendations are necessary. If deviations from the noted subsurface conditions are encountered during construction, they should also be brought to the attention of the geotechnical engineer.

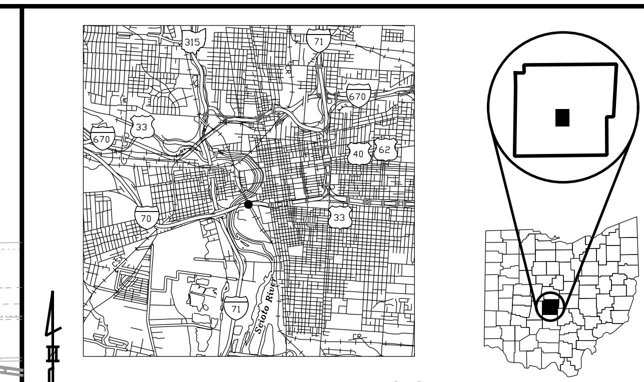
The scope of our services does not include any environmental assessment or investigation for the presence or absence of hazardous or toxic materials in the soil, groundwater or surface water within or beyond the site studied. Any statements in this report or on the test boring logs regarding odors, staining of soils or other unusual conditions observed are strictly for the information of our client.

Our professional services have been performed, our findings obtained and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. Resource International is not responsible for the conclusions, opinions or recommendations made by others based upon the data included.

APPENDIX I

VICINITY MAP AND BORING PLAN





FRANKLIN COUNTY

VICINITY MAP

BORING PLAN

FRA-70-1358L

FRANKLIN COUNTY, OHIO

PROJECT NO.
Rii W-13-072

SCALE: 1"=60'
0 30 60

DRAWN
RRM

REVIEWED
BRT

DATE
11/12/2021

RESOURCE INTERNATIONAL, INC.

APPENDIX II

DESCRIPTION OF SOIL AND ROCK TERMS

DESCRIPTION OF SOIL TERMS

The following terminology was used to describe soils throughout this report and is generally adapted from ASTM 2487/2488 and ODOT Specifications for Geotechnical Explorations.

Granular Soils – ODOT A-1, A-2, A-3, A-4 (non-plastic)
The relative compactness of granular soils is described as:

Description	Blows per foot – SPT (N_{60})		
Very Loose	Below		5
Loose	5	-	10
Medium Dense	11	-	30
Dense	31	-	50
Very Dense	Over		50

Cohesive Soils – ODOT A-4, A-5, A-6, A-7, A-8
The relative consistency of cohesive soils is described as:

Description	Unconfined Compression (tsf)		
Very Soft	Less than		0.25
Soft	0.25	-	0.5
Medium Stiff	0.5	-	1.0
Stiff	1.0	-	2.0
Very Stiff	2.0	-	4.0
Hard	Over		4.0

Gradation - The following size-related denominations are used to describe soils:

Soil Fraction		Size
Boulders		Larger than 12"
Cobbles		12" to 3"
Gravel	coarse	3" to ¾"
	fine	¾" to 2.0 mm (¾" to #10 Sieve)
Sand	coarse	2.0 mm to 0.42 mm (#10 to #40 Sieve)
	fine	0.42 mm to 0.074 mm (#40 to #200 Sieve)
Silt		0.074 mm to 0.005 mm (#200 to 0.005 mm)
Clay		Smaller than 0.005 mm

Modifiers of Components - The following modifiers indicate the range of percentages of the minor soil components:

Term	Range		
Trace	0%	-	10%
Little	10%	-	20%
Some	20%	-	35%
And	35%	-	50%

Moisture Table - The following moisture-related denominations are used to describe cohesive soils:

Term	Range - ODOT
Dry	Well below Plastic Limit
Damp	Below Plastic Limit
Moist	Above PL to 3% below LL
Wet	3% below LL to above LL

Organic Content – The following terms are used to describe organic soils:

Term	Organic Content (%)
Slightly organic	2-4
Moderately organic	4-10
Highly organic	>10

Bedrock – The following terms are used to describe the relative strength of bedrock:

Description	Field Parameter
Very Weak	Can be carved with knife and scratched by fingernail. Pieces 1 in. thick can be broken by finger pressure.
Weak	Can be grooved or gouged with knife readily. Small, thin pieces can be broken by finger pressure.
Slightly Strong	Can be grooved or gouged 0.05 in deep with knife. 1 in. size pieces from hard blows of geologist hammer.
Moderately Strong	Can be scratched with knife or pick. 1/4 in. size grooves or gouges from blows of geologist hammer.
Strong	Can be scratched with knife or pick with difficulty. Hard hammer blows to detach hand specimen.
Very Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to detach hand specimen.
Extremely Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to chip hand specimen.

DESCRIPTION OF ROCK TERMS

The following terminology was used to describe the rock throughout this report and is generally adapted from ASTM D5878 and the ODOT Specifications for Geotechnical Explorations.

Weathering – Describes the degree of weathering of the rock mass:

Description	Field Parameter
Unweathered	No evidence of any chemical or mechanical alteration of the rock mass. Mineral crystals have a right appearance with no discoloration. Fractures show little or not staining on surfaces.
Slightly Weathered	Slight discoloration of the rock surface with minor alterations along discontinuities. Less than 10% of the rock volume presents alteration.
Moderately Weathered	Portions of the rock mass are discolored as evident by a dull appearance. Surfaces may have a pitted appearance with weathering "halos" evident. Isolated zones of varying rock strengths due to alteration may be present. 10 to 15% of the rock volume presents alterations.
Highly Weathered	Entire rock mass appears discolored and dull. Some pockets of slightly to moderately weathered rock may be present and some areas of severely weathered materials may be present.
Severely Weathered	Majority of the rock mass reduced to a soil-like state with relic rock structure discernable. Zones of more resistant rock may be present but the material can generally be molded and crumbled by hand pressures.

Strength of Bedrock – The following terms are used to describe the relative strength of bedrock:

Description	Field Parameter
Very Weak	Can be carved with knife and scratched by fingernail. Pieces 1 in. thick can be broken by finger pressure.
Weak	Can be grooved or gouged with knife readily. Small, thin pieces can be broken by finger pressure.
Slightly Strong	Can be grooved or gouged 0.05 in deep with knife. 1 in. size pieces from hard blows of geologist hammer.
Moderately Strong	Can be scratched with knife or pick. 1/4 in. size grooves or gouges from blows of geologist hammer.
Strong	Can be scratched with knife or pick with difficulty. Hard hammer blows to detach hand specimen.
Very Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to detach hand specimen.
Extremely Strong	Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to chip hand specimen.

Bedding Thickness – Description of bedding thickness as the average perpendicular distances between bedding surfaces:

Description	Thickness
Very Thick	Greater than 36 inches
Thick	18 to 36 inches
Medium	10 to 18 inches
Thin	2 to 10 inches
Very Thin	0.4 to 2 inches
Laminated	0.1 to 0.4 inches
Thinly Laminated	Less than 0.1 inches

Fracturing – Describes the degree and condition of fracturing (fault, joint, or shear):

Degree of Fracturing

Description	Spacing
Unfractured	Greater than 10 feet
Intact	3 to 10 feet
Slightly Fractured	1 to 3 feet
Moderately Fractured	

Aperture Width

Description	Width
Open	Greater than 0.2 inches
Narrow	0.05 to 0.2 inches
Tight	Less than 0.05 inches

Surface Roughness

Description	Criteria
Very Rough	Near vertical steps and ridges occur on surface
Slightly Rough	Asperities on the surfaces distinguishable
Slickensided	Surface has smooth, glassy finish, evidence of Striations

RQD – Rock Quality Designation (calculation shown in report) and Rock Quality (ODOT, GB 3, January 13, 2006):

RQD %	Rock Index Property Classification (based on RQD, not slake durability index)
0 – 25%	Very Poor
26 – 50%	Poor
51 – 70%	Fair
71 – 85%	Good
86 – 100%	Very Good

CLASSIFICATION OF SOILS

Ohio Department of Transportation

(The classification of a soil is found by proceeding from top to bottom of the chart. The first classification that the test data fits is the correct classification.)

SYMBOL	DESCRIPTION	Classifcation AASHTO	Classifcation OHIO	LL_O/LL × 100*	% Pass #40	% Pass #200	Liquid Limit (LL)	Plastic Index (PI)	Group Index Max.	REMARKS
	Gravel and/or Stone Fragments	A-1-a			30 Max.	15 Max.		6 Max.	0	Min. of 50% combined gravel, cobble and boulder sizes
	Gravel and/or Stone Fragments with Sand	A-1-b			50 Max.	25 Max.		6 Max.	0	
F S	Fine Sand	A-3			51 Min.	10 Max.	NON-PLASTIC		0	
	Coarse and Fine Sand	--	A-3a			35 Max.		6 Max.	0	Min. of 50% combined coarse and fine sand sizes
	Gravel and/or Stone Fragments with Sand and Silt	A-2-4				35 Max.	40 Max.	10 Max.	0	
		A-2-5					41 Min.			
	Gravel and/or Stone Fragments with Sand, Silt and Clay	A-2-6				35 Max.	40 Max.	11 Min.	4	
		A-2-7					41 Min.			
	Sandy Silt	A-4	A-4a	76 Min.		36 Min.	40 Max.	10 Max.	8	Less than 50% silt sizes
	Silt	A-4	A-4b	76 Min.		50 Min.	40 Max.	10 Max.	8	50% or more silt sizes
	Elastic Silt and Clay	A-5		76 Min.		36 Min.	41 Min.	10 Max.	12	
	Silt and Clay	A-6	A-6a	76 Min.		36 Min.	40 Max.	11 - 15	10	
	Silty Clay	A-6	A-6b	76 Min.		36 Min.	40 Max.	16 Min.	16	
	Elastic Clay	A-7-5		76 Min.		36 Min.	41 Min.	≦LL-30	20	
	Clay	A-7-6		76 Min.		36 Min.	41 Min.	>LL-30	20	
	Organic Silt	A-8	A-8a	75 Max.		36 Min.				W/o organics would classify as A-4a or A-4b
	Organic Clay	A-8	A-8b	75 Max.		36 Min.				W/o organics would classify as A-5, A-6a, A-6b, A-7-5 or A-7-6

MATERIAL CLASSIFIED BY VISUAL INSPECTION

- Sod and Topsoil
- Pavement or Base
- Uncontrolled Fill (Describe)
- Bouldery Zone
- P Peat

* Only perform the oven-dried liquid limit test and this calculation if organic material is present in the sample.

APPENDIX III

PROJECT BORING LOGS:

B-017-3-13, B-017-7-13, B-017-9-13, B-018-1-13, B-018-2-13 and B-019-6-19

BORING LOGS

Definitions of Abbreviations

AS	=	Auger sample
GI	=	Group index as determined from the Ohio Department of Transportation classification system
HP	=	Unconfined compressive strength as determined by a hand penetrometer (tons per square foot)
LL_o	=	Oven-dried liquid limit as determined by ASTM D4318. Per ASTM D2487, if LL_o/LL is less than 75 percent, soil is classified as “organic”.
LOI	=	Percent organic content (by weight) as determined by ASTM D2974 (loss on ignition test)
PID	=	Photo-ionization detector reading (parts per million)
QR	=	Unconfined compressive strength of intact rock core sample as determined by ASTM D2938 (pounds per square inch)
QU	=	Unconfined compressive strength of soil sample as determined by ASTM D2166 (pounds per square foot)
RC	=	Rock core sample
REC	=	Ratio of total length of recovered soil or rock to the total sample length, expressed as a percentage
RQD	=	Rock quality designation – estimate of the degree of jointing or fracture in a rock mass, expressed as a percentage:

$$\frac{\sum \text{segments equal to or longer than 4.0 inches}}{\text{core run length}} \times 100$$

S	=	Sulfate content (parts per million)
SPT	=	Standard penetration test blow counts, per ASTM D1586. Driving resistance recorded in terms of blows per 6-inch interval while letting a 140-pound hammer free fall 30 inches to drive a 2-inch outer diameter (O.D.) split spoon sampler a total of 18 inches. The second and third intervals are added to obtain the number of blows per foot (N_m).
N_{60}	=	Measured blow counts corrected to an equivalent (60 percent) energy ratio (ER) by the following equation: $N_{60} = N_m*(ER/60)$
SS	=	Split spoon sample
2S	=	For instances of no recovery from standard SS interval, a 2.5 inch O.D. split spoon is driven the full length of the standard SS interval plus an additional 6.0 inches to obtain a representative sample. Only the final 6.0 inches of sample is retained. Blow counts from 2S sampling are not correlated with N_{60} values.
3S	=	Same as 2S, but using a 3.0 inch O.D. split spoon sampler.
TR	=	Top of rock
W	=	Initial water level measured during drilling
▼	=	Water level measured at completion of drilling

Classification Test Data

Gradation (as defined on Description of Soil Terms):

GR	=	% Gravel
SA	=	% Sand
SI	=	% Silt
CL	=	% Clay

Atterberg Limits:

LL	=	Liquid limit
PL	=	Plastic limit
PI	=	Plasticity Index
WC	=	Water content (%)

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / J.B.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 166+20.53 / 31.8' RT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / S.B.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-70 EB
PID: 77372 BR ID: FRA-70-1358R	DRILLING METHOD: 4.25" HSA / RC	CALIBRATION DATE: 4/26/13	ELEVATION: 740.3 (MSL) EOB: 87.0 ft.
START: 7/30/13 END: 8/2/13	SAMPLING METHOD: SPT / HQ	ENERGY RATIO (%): 77.7	LAT / LONG: 39.953028358, -83.008033736

EXPLORATION ID
B-017-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 740.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.5'- ASPHALT (6.0")	739.8																	
0.3'- AGGREGATE BASE (4.0")	739.5																	
FILL: STIFF TO VERY STIFF, BROWN **CLAY**, "AND" SILT, TRACE TO LITTLE FINE TO COARSE SAND, TRACE TO SOME FINE GRAVEL, DAMP TO MOIST.		1, 2, 3	4-4-10	18	78	SS-1	3.25	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		4, 5	5-2-4	8	50	SS-2	1.50	26	13	6	36	19	43	16	27	16	A-7-6 (11)	
		6, 7, 8	2-3-5	10	33	SS-3	2.25	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
		9, 10	3-4-5	12	44	SS-4	2.75	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
		11, 12, 13	2-3-3	8	50	SS-5	2.00	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
		14, 15	1-3-3	8	56	SS-6	1.25	21	9	5	36	29	43	17	26	19	A-7-6 (13)	
		16, 17	3-4-5	12	17	SS-7	1.25	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		18	4	-	67	3S-7A	1.25	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
		19, 20	2-7-5	16	50	SS-8	3.00	5	3	3	35	54	50	18	32	22	A-7-6 (18)	
		21, 22, 23	3-4-5	12	83	SS-9	3.00	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
		24, 25	3-3-5	10	89	SS-10	2.00	-	-	-	-	-	-	-	-	26	A-7-6 (V)	
	713.3	26, 27	3-9-10	25	83	SS-11	3.75	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
FILL: MEDIUM DENSE, BLACK **GRAVEL AND SAND**, TRACE SILT, MOIST.							-	-	-	-	-	-	-	-	-	16	A-1-b (V)	
		28, 29	3-5-9	18	33	SS-12	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 166+20.53 / 31.8 RT	START: 7/30/13	END: 8/2/13	PG 2 OF 3	B-017-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 710.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
FILL: MEDIUM DENSE, BLACK **GRAVEL AND SAND**, TRACE SILT, MOIST. *(same as above)*	708.3	31 – 32																
STIFF, BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		33 – 35	1 4 7	14	67	SS-13	1.50	5	7	12	41	35	37	17	20	20	A-6b (12)	
	703.3	36 – 37																
DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST.		38 – 40	5 13 16	38	61	SS-14	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
		41 – 45	20 25 20	58	94	SS-15	-	59	16	8	14	3	NP	NP	NP	6	A-1-b (0)	
		46 – 50 (W at ~48.5)	13 26 26	67	56	SS-16	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
		51 – 55	30 25 28	69	78	SS-17	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
	683.3	56 – 57																
VERY STIFF TO HARD, GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, DAMP.		58 – 60 (W at ~58.5)	15 22 20	54	67	SS-18	3.50	28	13	18	30	11	22	11	11	10	A-6a (1)	
		61																

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/14/15 17:34 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 166+20.53 / 31.8 RT	START: 7/30/13	END: 8/2/13	PG 3 OF 3	B-017-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 678.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
VERY STIFF TO HARD, GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, DAMP. *(same as above)*		63																
		64–65	20 25 40	84	67	SS-19	4.50	-	-	-	-	-	-	-	-	9	A-6a (V)	
	673.3	66–67																
VERY DENSE, BROWN AND GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, MOIST.		68																
		69–70	3 30 36	85	67	SS-20	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
	668.3	71–72																
HARD, BROWN TO GRAY **CLAY**, TRACE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.		73																
		74–75	4 19 19	49	72	SS-21	4.50	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		76–78																
		79–80	10 24 40	83	72	SS-22	4.5+	8	2	3	41	46	41	19	22	10	A-7-6 (13)	
		81																
AUGER REFUSAL @ 83.5'	656.8	82–83.5 TR	4 20 50/5"	-	59	SS-23	4.5+	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
SHALE : BLACK AND GRAY, SLIGHTLY TO HIGHLY WEATHERED, VERY WEAK TO SLIGHTLY STRONG, THINLY LAMINATED TO THIN BEDDED, FISSILE, HIGHLY TO MODERATELY FRACTURED, OPEN APERTURE, SLIGHTLY ROUGH; RQD 26%, REC 81%. -QU @ 86.0' = 222 PSI		84–85	0		56	RC-1											CORE	
	653.3	85–87 EOB	46		100	RC-2											CORE	

NOTES: SEEPAGE ENCOUNTERED @ 48.5'; GROUNDWATER ENCOUNTERED INITIALLY @ 58.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 100 LBS BENTONITE CHIPS AND SOIL CUTTINGS

B-017-3-13 – RC-1 and RC-2 – Depth from 83.5 to 87.0 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / J.B.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 170+79.36 / 23.3' RT	EXPLORATION ID B-017-7-13
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / S.B.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-70 EB	PAGE 1 OF 4
PID: 77372 BR ID: FRA-70-1358R	DRILLING METHOD: 4.25" HSA / RC	CALIBRATION DATE: 4/26/13	ELEVATION: 743.1 (MSL) EOB: 96.7 ft.	
START: 8/4/13 END: 8/7/13	SAMPLING METHOD: SPT / HQ	ENERGY RATIO (%): 77.7	LAT / LONG: 39.953200568, -83.006425064	

MATERIAL DESCRIPTION AND NOTES	ELEV. 743.1
0.9' - ASPHALT (11.0")	742.2
0.5' - AGGREGATE BASE (6.0")	741.7
FILL: MEDIUM DENSE, GRAY **GRAVEL**, LITTLE FINE TO COARSE SAND, TRACE SILT, TRACE CLAY, MOIST.	739.1
FILL: STIFF TO VERY STIFF, BROWNISH GRAY TO BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.	735.1
FILL: VERY DENSE, BROWN **GRAVEL**, TRACE SILT, DAMP.	732.6
FILL: STIFF TO HARD, BROWN TO DARK BROWNISH GRAY **SILTY CLAY**, SOME FINE GRAVEL, LITTLE COARSE TO FINE SAND, DRY TO MOIST.	

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

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
4 5 6	14	67	SS-1	-	69	13	5	10	3	NP	NP	NP	7	A-1-a (0)
3 3 5	10	50	SS-2	- 3.00	- -	- -	- -	- -	- -	- -	- -	- -	9 13	A-1-a (V) A-6a (V)
6 8 12	26	50	SS-3	2.00	-	-	-	-	-	-	-	-	12	A-6a (V)
18 25 25	65	44	SS-4	-	-	-	-	-	-	-	-	-	5	A-1-a (V)
3 9 10	25	50	SS-5	2.00	-	-	-	-	-	-	-	-	12	A-6b (V)
1 2 5	9	56	SS-6	1.50	31	11	8	30	20	37	18	19	19	A-6b (6)
5 15 15	39	39	SS-7	2.00	-	-	-	-	-	-	-	-	9	A-6b (V)
15 50 28	101	39	SS-8	2.00	-	-	-	-	-	-	-	-	19	A-6b (V)
6 12 9	27	56	SS-9	1.75	-	-	-	-	-	-	-	-	20	A-6b (V)
21 6 8	18	56	SS-10	4.50	24	10	9	33	24	40	20	20	18	A-6b (8)
7 8 10	23	83	SS-11	2.50	-	-	-	-	-	-	-	-	16	A-6b (V)
WOH 2 10	16	72	SS-12	2.75	-	-	-	-	-	-	-	-	18	A-6b (V)

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 170+79.36 / 23.3 RT	START: 8/4/13	END: 8/7/13	PG 2 OF 4	B-017-7-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 713.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
FILL: STIFF TO HARD, BROWN TO DARK BROWNISH GRAY **SILTY CLAY**, SOME FINE GRAVEL, LITTLE COARSE TO FINE SAND, DRY TO MOIST. *(same as above)*	711.1	31–32																
FILL: STIFF, DARK BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, DAMP.		34–35	4 4 5	12	50	SS-13	1.75	24	14	12	31	19	33	18	15	20	A-6a (5)	
-WOOD FRAGMENTS RECOVERED FROM 38.5' TO 39.0'	704.1	38.5–39	10	21	33	SS-14	-	-	-	-	-	-	-	-	-	110		
HARD, DARK BROWN **SILTY CLAY**, SOME FINE TO COARSE SAND, SOME FINE GRAVEL, MOIST.	701.1	39–40	8 8				4.50	-	-	-	-	-	-	-	-	13	A-6b (V)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, MOIST.		44–45	2 8 11	25	78	SS-15	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
		W (48.5)																
		49–50	10 14 16	39	61	SS-16	-	52	18	10	16	4	21	18	3	10	A-1-b (0)	
	686.1	54–55	20 30 45	97	72	SS-17	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
VERY DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE SILT, MOIST.		W (57)																
		59–59.8	41 21 50/4"	-	100	SS-18	-	-	-	-	-	-	-	-	-	17	A-2-4 (V)	
-COBBLES PRESENT @ 60.0'		60–61																

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/14/15 17:34 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 170+79.36 / 23.3 RT	START: 8/4/13	END: 8/7/13	PG 3 OF 4	B-017-7-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 681.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
VERY DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE SILT, MOIST. *(same as above)*		63																
		64	8 20 20	52	83	SS-19	-	-	-	-	-	-	-	-	-	17	A-2-4 (V)	
	676.1	65–67																
HARD, GRAY **CLAY**, SOME SILT, TRACE COARSE TO FINE SAND, DAMP.		68																
		69	8 9 16	32	78	SS-20	4.5+	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
		70–73																
		74	12 14 20	44	89	SS-21	4.5+	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		75–78																
		79	12 22 50	93	44	SS-22	4.5+	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		80–83																
		84	40 35 50/4"	-	81	SS-23	4.5+	0	2	5	34	59	54	25	29	15	A-7-6 (18)	
		85–88																
		89	25 50/4"	-	100	SS-24	4.5+	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
AUGER REFUSAL @ 90.0'	653.1	TR 90																
MUDSTONE : GRAY, SLIGHTLY WEATHERED, VERY WEAK, THINLY LAMINATED TO LAMINATED, FRIABLE, FISSILE, HIGHLY FRACTURED TO FRACTURED, OPEN APERTURE, ROUGH; RQD 73%, REC 100%.		90–91	79		100	RC-1											CORE	
	651.1	91–92	66		100	RC-2											CORE	
		92–94																

PID: 77372	BR ID: FRA-70-1358R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 170+79.36 / 23.3 RT	START: 8/4/13	END: 8/7/13	PG 4 OF 4	B-017-7-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 648.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
SHALE : GRAY TO BLACK, HIGHLY WEATHERED, VERY WEAK, THINLY LAMINATED TO LAMINATED, FRIABLE, MODERATELY TO HIGHLY FRACTURED, OPEN APERTURE, SLIGHTLY ROUGH TO ROUGH; RQD 15%, REC 74%. *(same as above)*	646.4	95, 96; EOB	15		74	RC-3											CORE	

NOTES: SEEPAGE ENCOUNTERED @ 48.5'; GROUNDWATER ENCOUNTERED INITIALLY @ 57.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 188 LBS PORTLAND CEMENT / 50 LBS BENTONITE POWDER / 50 GAL WATER

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/14/15 17:34 - U:\GI8\PROJECTS\2013\W-13-045.GPJ

B-017-7-13 – RC-1, RC-2, and RC-3 – Depth from 90.0 to 96.7 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: CME-750 (SN 98048)	STATION / OFFSET: 166+64.96 / 18.3' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / R.B.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-70 WB
PID: 89464 BR ID: FRA-70-1358L	DRILLING METHOD: 4.25" HSA / HQ	CALIBRATION DATE: 4/26/13	ELEVATION: 717.6 (MSL) EOB: 78.1 ft.
START: 2/25/14 END: 2/26/14	SAMPLING METHOD: SPT / RC	ENERGY RATIO (%): 82.6	LAT / LONG: 39.953423, -83.007954

EXPLORATION ID B-017-9-13

PAGE 1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 717.6
0.1' - TOPSOIL (2.0")	717.5
FILL: VERY LOOSE TO MEDIUM DENSE, BLACK TO BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST TO WET. -ORGANICS, ROOT FIBERS AND CINDERS PRESENT IN 3S-1A -CINDERS AND SLAG PRESENT IN SS-2	712.1
FILL: MEDIUM STIFF, BROWN TO GRAY **SILTY CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST.	708.9
FILL: VERY LOOSE, BROWN AND BLACK **COARSE AND FINE SAND**, SOME CLAY, LITTLE FINE GRAVEL, TRACE SILT, WET. -TRACE COAL FRAGMENTS PRESENT IN SS-4B	707.1
STIFF, DARK BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.	704.6
MEDIUM DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST.	702.1
MEDIUM DENSE, BROWN **COARSE AND FINE SAND**, LITTLE SILT, LITTLE FINE GRAVEL, TRACE CLAY, MOIST.	699.6
MEDIUM DENSE TO DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST. -INTRODUCED MUD @ 20.0' -ROCK FRAGMENTS PRESENT THROUGHOUT -COBBLES PRESENT FROM 22.0' TO 31.0'	

DEPTHS: 1–29 (W at 20)

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
2 2 1	4	0	SS-1	-	-	-	-	-	-	-	-	-	-	
3	-	67	3S-1A	-	40	20	17	16	7	35	29	6	29	A-1-b (0)
6 8 12	28	56	SS-2	-	-	-	-	-	-	-	-	-	18	A-1-b (V)
2 2 2	6	50	SS-3	1.00	11	10	12	35	32	40	18	22	19	A-6b (11)
1 1 2	4	33	SS-4	1.00	-	-	-	-	-	-	-	-	26	A-6b (V)
				-	-	-	-	-	-	-	-	-	22	A-3a (V)
WOH 1 4	7	44	SS-5	1.50	-	-	-	-	-	-	-	-	24	A-6b (V)
6 8 12	28	33	SS-6	-	51	11	10	14	14	-	-	-	17	A-2-6 (V)
6 6 8	19	44	SS-7	-	18	19	37	19	7	NP	NP	NP	15	A-3a (0)
4 6 11	23	56	SS-8	-	-	-	-	-	-	-	-	-	13	A-1-b (V)
10 13 21	47	67	SS-9	-	-	-	-	-	-	-	-	-	12	A-1-b (V)
3 7 11	25	50	SS-10	-	-	-	-	-	-	-	-	-	9	A-1-b (V)
9 10 13	32	56	SS-11	-	54	17	8	15	6	24	19	5	12	A-1-b (0)
17 15 19	47	50	SS-12	-	-	-	-	-	-	-	-	-	10	A-1-b (V)

HOLE SEALED

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 12:57 - U:\GI8\PROJECTS\2013\W-13-072.GPJ

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 166+64.96 / 18.3 LT	START: 2/25/14	END: 2/26/14	PG 2 OF 3	B-017-9-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 687.6	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
MEDIUM DENSE TO DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST. *(same as above)*	685.6	31–32																
VERY STIFF, GRAY **CLAY**, LITTLE SILT, TRACE COARSE SAND, TRACE FINE GRAVEL, MOIST.		33																
		34–35	3 7 9	22	50	SS-13	3.50	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
		36–38																
		39–40	3 6 8	19	56	SS-14	2.25	0	1	0	12	87	58	23	35	30	A-7-6 (20)	
		41–43																
		44–45	5 6 10	22	72	SS-15	2.75	-	-	-	-	-	-	-	-	27	A-7-6 (V)	
		46–48																
		49–50	4 7 11	25	78	SS-16	4.00	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
		51–53																
		54–55	6 10 16	36	78	SS-17	4.00	1	0	0	15	84	53	21	32	22	A-7-6 (19)	
	660.6	56																
HARD, GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE FINE SAND, DRY.		57–58																
		59–60	11 21 50	98	56	SS-18	4.5+	-	-	-	-	-	-	-	-	15	A-7-6 (V)	
-BECOMING SHALE @ 60.0'		61																

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 166+64.96 / 18.3 LT	START: 2/25/14	END: 2/26/14	PG 3 OF 3	B-017-9-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 655.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
HARD, GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE FINE SAND, DRY. *(same as above)*	653.2	63 64	21 50/5"	-	73	SS-19	4.5+	10	0	1	34	55	53	24	29	15	A-7-6 (18)	
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK. AUGER REFUSAL @ 69.6'	648.0	TR 65 66 67 68 69	31 42 50/1"	-	69	SS-20	-	-	-	-	-	-	-	-	-	16	Rock (V)	
MUDSTONE : BROWN, HIGHLY TO SEVERLY WEATHERED, VERY WEAK TO WEAK, MEDIUM BEDDED, ARENACEOUS, CALCAREOUS, FRIABLE, PYRITIC, FISSILE, FRACTURED TO HIGHLY FRACTURED, OPEN APERTURES, ROUGH; RQD 0%, REC 62%.	643.5	70 71 72 73	0		50	RC-1											CORE	
LIMESTONE : GRAY, SLIGHTLY WEATHERED, VERY STRONG, THICK BEDDED, ARENACEOUS, CALCAREOUS, ARGILLACEOUS, CHERT INCLUSIONS, PYRITIC, JOINTED, MODERATELY TO HIGHLY FRACTURED, OPEN APERTURES, ROUGH; RQD 57%, REC 100%. -QU @ 74.2' = 11,707 PSI	639.5	74 75 76 77 EOB 78	38		77	RC-2											CORE	

NOTES: GROUNDWATER ENCOUNTERED INTIALLY @ 20.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 376 LBS CEMENT / 50 LBS BENTONITE POWDER / 80 GAL WATER

B-017-9-13 – RC-1 and RC-2 – Depth from 69.6 to 78.1 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.B.	DRILL RIG: CME-750 (SN 98048)	STATION / OFFSET: 167+31.32 / 54.6' LT
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / TF	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-70 WB
PID: 89464 BR ID: FRA-70-1358L	DRILLING METHOD: 4.25" HSA / HQ	CALIBRATION DATE: 4/26/13	ELEVATION: 717.0 (MSL) EOB: 83.5 ft.
START: 2/6/14 END: 2/7/14	SAMPLING METHOD: SPT / RC	ENERGY RATIO (%): 82.6	LAT / LONG: 39.953551, -83.007739

EXPLORATION ID B-018-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 717.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
1.0' - TOPSOIL (12.0")	716.0																	
FILL: MEDIUM DENSE, BLACK AND BROWN **GRAVEL WITH SAND**, SOME SILT, TRACE CLAY, WET. -SLAG AND ORGANICS PRESENT IN SS-1		1 2 3	3 2 8	14	61	SS-1	-	31	28	19	20	2	NP	NP	NP	30	A-1-b (0)	
-BRICK AND COAL FRAGMENTS PRESENT IN SS-2	711.5	4 5	9 7 6	18	56	SS-2	-	-	-	-	-	-	-	-	-	19	A-1-b (V)	
MEDIUM STIFF TO VERY STIFF, GRAY TO BROWN **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, MOIST.		6 W 7 8	2 1 2	4	61	SS-3	1.00	-	-	-	-	-	-	-	-	29	A-4a (V)	
-CONSOLIDATION TEST PERFORMED @ 10.1'		9 10			75	ST-4	2.00	6	6	18	41	29	34	25	9	28	A-4a (7)	
		11 12 13	3 2 6	11	39	SS-5	1.00	-	-	-	-	-	-	-	-	21	A-4a (V)	
	701.5	14 15	2 11 13	33	44	SS-6	2.50	-	-	-	-	-	-	-	-	29	A-4a (V)	
MEDIUM DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.	699.0	16 17 18	10 9 6	21	89	SS-7	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
DENSE TO VERY DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		19 20	11 14 21	48	67	SS-8	-	68	14	7	7	4	NP	NP	NP	7	A-1-a (0)	
	694.0	21 22 23	21 26 28	74	83	SS-9	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
STIFF, BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP.	691.5	24 25	26 21 17	52	33	SS-10	2.00	16	19	14	31	20	33	21	12	20	A-6a (4)	
DENSE, GRAY **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST.	689.0	26 27 28	16 14 13	37	33	SS-11	-	-	-	-	-	-	-	-	-	20	A-2-6 (V)	
VERY DENSE, BROWN TO GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		29	17 17 20	51	61	SS-12	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 167+31.32 / 54.6 LT	START: 2/6/14	END: 2/7/14	PG 2 OF 3	B-018-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 687.0	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
VERY DENSE, BROWN TO GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. *(same as above)*		34	17 17 20	51	61	SS-13	-	-	-	-	-	-	-	-	-	7	A-1-a (V)	
		39	21 21 36	78	89	SS-14	-	61	23	7	6	3	NP	NP	NP	7	A-1-a (0)	
STIFF TO VERY STIFF, GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP TO MOIST.	675.0	44	4 4 5	12	39	SS-15	1.75	-	-	-	-	-	-	-	-	26	A-7-6 (V)	
		49	3 5 8	18	78	SS-16	2.75	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
VERY STIFF TO HARD, BROWN TO GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP.	665.0	54	12 10 16	36	50	SS-17	4.00	7	4	2	31	56	41	25	16	19	A-7-6 (11)	
		59	23 50/3"	-	89	SS-18	4.5+	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK.	657.7	TR (59)																

Depth scale: 31 – 61

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 167+31.32 / 54.6 LT	START: 2/6/14	END: 2/7/14	PG 3 OF 3	B-018-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 654.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK. *(same as above)*		63																
		64	22 32 50/5"	-	82	SS-19	-	-	-	-	-	-	-	-	-	19	Rock (V)	
		65–68																
		69	6 23 50	100	67	SS-20	-	-	-	-	-	-	-	-	-	16	Rock (V)	
AUGER REFUSAL @ 73.5'	643.5	70–73																
LIMESTONE : GRAY AND TAN, UNWEATHERED TO SLIGHTLY WEATHERED, STRONG, VERY THICK BEDDED, CALCAREOUS, SLIGHTLY CARBONACEOUS, CHERTY, CALCITE GROWTHS, DOLOMITIC, JOINTED, MODERATELY TO HIGHLY FRACTURED, OPEN APERTURES, ROUGH; RQD 60%, REC 93%. -QU @ 75.6' = 9,525 PSI -LOSS OF CIRCULATION @ 76.8'		74–78	97		98	RC-1											CORE	
-CHERT INCLUSIONS FROM 79.5' TO 80.0'	633.5	79–83 EOB	24		88	RC-2											CORE	

NOTES: SEEPAGE ENCOUNTERED @ 7.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 188 LBS CEMENT / 50 LBS BENTONITE POWDER / 40 GAL WATER

B-018-1-13 – RC-1 and RC-2 – Depth from 73.5 to 83.5 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.B.	DRILL RIG: CME-750 (SN 98048)	STATION / OFFSET: 168+63.72 / 22.9' LT	EXPLORATION ID **B-018-2-13**
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / K.S.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-70 WB	
PID: 89464 BR ID: FRA-70-1358L	DRILLING METHOD: 4.25" HSA / HQ	CALIBRATION DATE: 4/26/13	ELEVATION: 715.7 (MSL) EOB: 84.5 ft.	PAGE
START: 2/10/14 END: 2/13/14	SAMPLING METHOD: SPT / RC	ENERGY RATIO (%): 82.6	LAT / LONG: 39.953512, -83.007251	1 OF 3

MATERIAL DESCRIPTION AND NOTES	ELEV. 715.7
0.5' - TOPSOIL (6.0")	715.2
FILL: LOOSE TO MEDIUM DENSE, BROWN TO BLACK **GRAVEL WITH SAND AND SILT**, LITTLE CLAY, MOIST TO WET. -TRASH, DEBRIS, PLASTIC, CINDERS AND ROOT FIBERS PRESENT THROUGHOUT	710.2
FILL: STIFF TO VERY STIFF, BROWN **SILTY CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST. -TRACE CINDERS AND BRICK FRAGMENTS PRESENT THROUGHOUT	705.2
FILL: STIFF TO VERY STIFF, BROWN TO DARK BROWN **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, DAMP. -TRACE CINDERS PRESENT IN SS-5	701.4
MEDIUM DENSE TO DENSE, BROWN **GRAVEL WITH SAND**, TRACE CLAY, TRACE SILT, DAMP TO MOIST. -TRACE ROCK FRAGMENTS PRESENT IN SS-6B	695.2
DENSE TO VERY DENSE, GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP TO MOIST. -IRON STAINING PRESENT IN SS-11 -LIMESTONE FRAGMENTS PRESENT THROUGHOUT	

Water level symbol (W) at depth 25.

DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
1–2.5	6 4 3	10	67	SS-1	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	
3.5–5	3 5 8	18	72	SS-2	-	26	25	17	22	10	NP	NP	NP	28	A-2-4 (0)	
6–7.5	7 7 8	21	83	SS-3	2.25	-	-	-	-	-	-	-	-	26	A-6b (V)	
8.5–10	4 4 3	10	61	SS-4	1.75	-	-	-	-	-	-	-	-	23	A-6b (V)	
11–12.5	6 6 8	19	78	SS-5	2.75	9	16	8	39	28	28	19	9	16	A-4a (6)	
13.5–15	3 3 5	11	11	SS-6	1.50	-	-	-	-	-	-	-	-	18	A-4a (V)	
					-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
16–17.5	5 9 7	22	72	SS-7	-	42	37	13	1	7	NP	NP	NP	9	A-1-b (0)	
18.5–20	7 9 19	39	78	SS-8	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
21–22.5	21 25 28	73	56	SS-9	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
23.5–25	15 20 23	59	83	SS-10	-	54	29	6	6	5	NP	NP	NP	8	A-1-a (0)	
26–27.5	25 21 15	50	78	SS-11	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
28.5–30	23 20 23	59	83	SS-12	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 168+63.72 / 22.9 LT	START: 2/10/14	END: 2/13/14	PG 2 OF 3	B-018-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 685.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
DENSE TO VERY DENSE, GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP TO MOIST. *(same as above)* -COBBLES PRESENT @ 31.0'		31–33																
		34–35	48 15 18	45	56	SS-13	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
-HEAVING SAND ENCOUNTERED @ 35.0' -INTRODUCED MUD @ 35.0'	678.7	36–37																
VERY STIFF TO HARD, GRAY **CLAY**, SOME SILT, TRACE FINE GRAVEL, TRACE COARSE SAND, DRY TO DAMP.		38																
		39–40	7 9 18	37	39	SS-14	3.50	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
		41–43																
		44–45	5 8 11	26	78	SS-15	3.50	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
		46–48																
		49–50	8 11 13	33	72	SS-16	4.00	1	1	0	20	78	45	26	19	22	A-7-6 (13)	
		51–53																
		54–55	8 11 15	36	83	SS-17	4.50	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
	656.9	56–58																
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK.		TR 59	50/3"	-	100	SS-18	4.5+	-	-	-	-	-	-	-	-	11	A-7-6 (V)	
		60–61																

PID: 89464	BR ID: FRA-70-1358L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 168+63.72 / 22.9 LT	START: 2/10/14	END: 2/13/14	PG 3 OF 3	B-018-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 653.6	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
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK. *(same as above)*		63																
		64	12 50/5"	-	91	SS-19	-	-	-	-	-	-	-	-	-	11	Rock (V)	
		65–68																
		69	25 50/3"	-	100	SS-20	-	-	-	-	-	-	-	-	-	11	Rock (V)	
		70–73																
AUGER REFUSAL @ 74.5'	641.2	74	30 50/2"	-	100	SS-21	-	-	-	-	-	-	-	-	-	13	Rock (V)	
LIMESTONE : GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, STRONG, VERY THICK BEDDED, CALCAREOUS, ARGILLACEOUS, FOSSILIFEROUS, CHERTY, DOLOMITIC, JOINTED, SLIGHTLY TO HIGHLY FRACTURED, OPEN APERTURES, SLIGHTLY ROUGH; RQD 80%, REC 100%. -0.1' TO 0.2' CLAY SEAMS PRESENT FROM 74.5' TO 75.5' -QU @ 78.5' = 10,153 PSI		75–79	72		100	RC-1											CORE	
	631.2	80–84 (EOB)	87		100	RC-2											CORE	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 25.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 188 LBS CEMENT / 50 LBS BENTONITE POWDER / 40 GAL WATER; COMPACTED WITH THE AUGER 300 LB. BENTONITE CHIPS AND SOIL CUTTINGS

B-018-2-13 – RC-1 – Depth from 74.5 to 79.5 feet

B-018-2-13 – RC-2 – Depth from 79.5 to 84.5 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: CME-750X SN 310218	STATION / OFFSET: 166+09.00 / 108.1' LT	EXPLORATION ID **B-019-6-19**
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / K.C.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-70 WB	PAGE 1 OF 2
PID: 89464 BR ID: N/A	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 9/14/20	ELEVATION: 738.1 (MSL) EOB: 40.0 ft.	
START: 12/2/20 END: 12/2/20	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.2	LAT / LONG: 39.953639, -83.008210	

MATERIAL DESCRIPTION AND NOTES	ELEV. 738.1
0.4' - TOPSOIL (4.0")	737.7
FILL: MEDIUM DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST.	735.1
FILL: STIFF, DARK GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST. -CONCRETE FRAGMENTS PRESENT IN SS-2	732.6
FILL: VERY STIFF, DARK GRAY TO BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST.	727.6
FILL: DENSE, GRAY **GRAVEL WITH SAND**, TRACE SILT, DRY. -COBBLES @ 11.0'	725.1
FILL: LOOSE TO MEDIUM DENSE, BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT IN SS-7	720.1
FILL: VERY STIFF, BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST.	716.1
FILL: VERY DENSE, DARK BROWN TO BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST. -COBBLES @ 25.0'	711.1
FILL: VERY STIFF, BROWN **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP. -COBBLES @ 28.5'	

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
4 9 11	29	56	SS-1	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)
4 6 7	19	67	SS-2	2.00	-	-	-	-	-	-	-	-	16	A-6a (V)
6 2 3	7	56	SS-3	2.75	-	-	-	-	-	-	-	-	19	A-6b (V)
4 4 5	13	56	SS-4	3.50	-	-	-	-	-	-	-	-	22	A-6b (V)
25 19 7	37	44	SS-5	-	-	-	-	-	-	-	-	-	2	A-1-b (V)
8 5 7	17	50	SS-6	-	-	-	-	-	-	-	-	-	14	A-2-4 (V)
3 2 3	7	44	SS-7	-	50	11	10	19	10	26	17	9	11	A-2-4 (0)
3 3 4	10	72	SS-8	2.50	-	-	-	-	-	-	-	-	22	A-6b (V)
2 18 22	57	39	SS-9	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)
11 7 9	23	0	SS-10	-	-	-	-	-	-	-	-	-	-	

PID: 89464	BR ID: N/A	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 166+09.00 / 108.1 LT	START: 12/2/20	END: 12/2/20	PG 2 OF 2	B-019-6-19

MATERIAL DESCRIPTION AND NOTES	ELEV. 708.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
FILL: VERY STIFF, BROWN **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP. *(continued)* -BRICK FRAGMENTS PRESENT IN 2S-10A	706.1	31	12	-	100	2S-10A	3.00	-	-	-	-	-	-	-	-	12	A-4a (V)	
VERY STIFF, BROWN **SILTY CLAY**, SOME FINE TO COARSE SAND, SOME FINE GRAVEL, MOIST.	701.1	32–37	3 4 5	13	56	2S-11	2.50	32	14	13	28	13	39	18	21	18	A-6b (4)	
VERY STIFF, BROWN **SANDY SILT**, SOME FINE GRAVEL, LITTLE CLAY, DAMP.	698.1	38–40 EOB	6 10 17	39	33	SS-12	2.50	-	-	-	-	-	-	-	-	11	A-4a (V)	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING; CAVE-IN DEPTH @ 36.8'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 100 LBS BENTONITE CHIPS AND SOIL CUTTINGS .

APPENDIX IV

LABORATORY TEST RESULTS

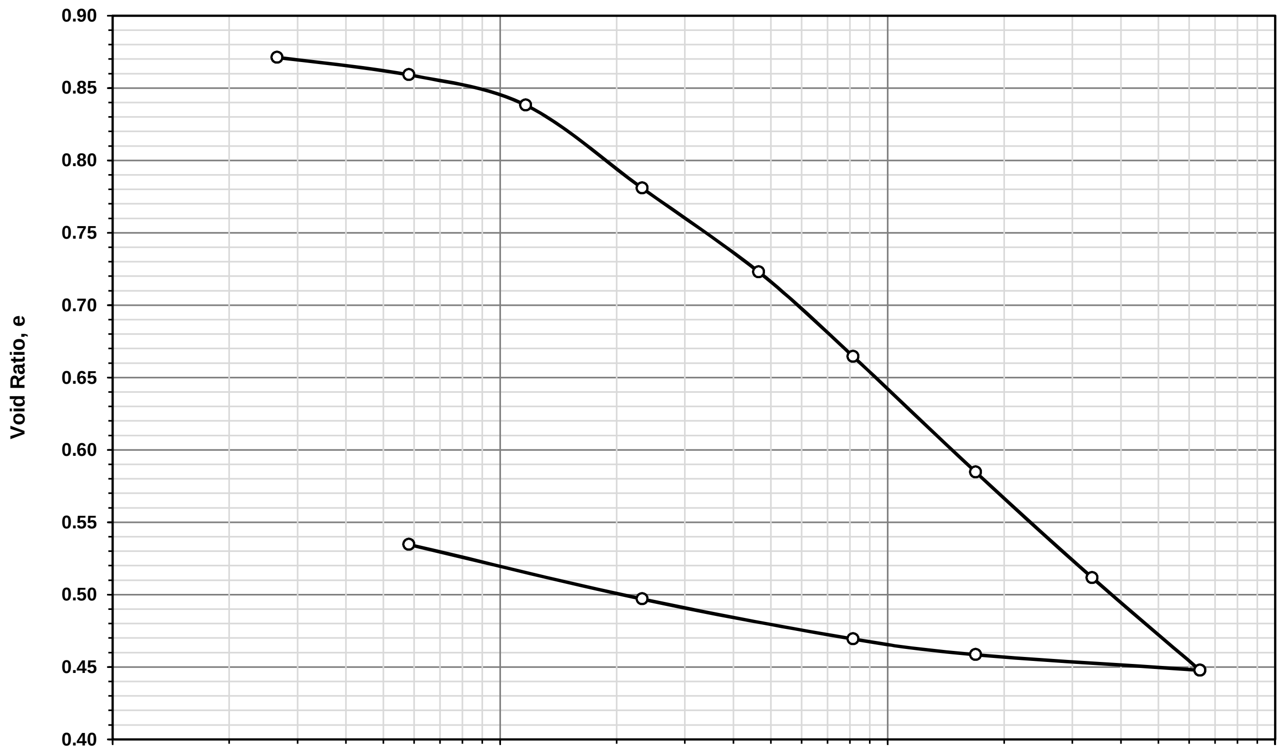
One-Dimensional Consolidation Test Report (ASTM D2435)

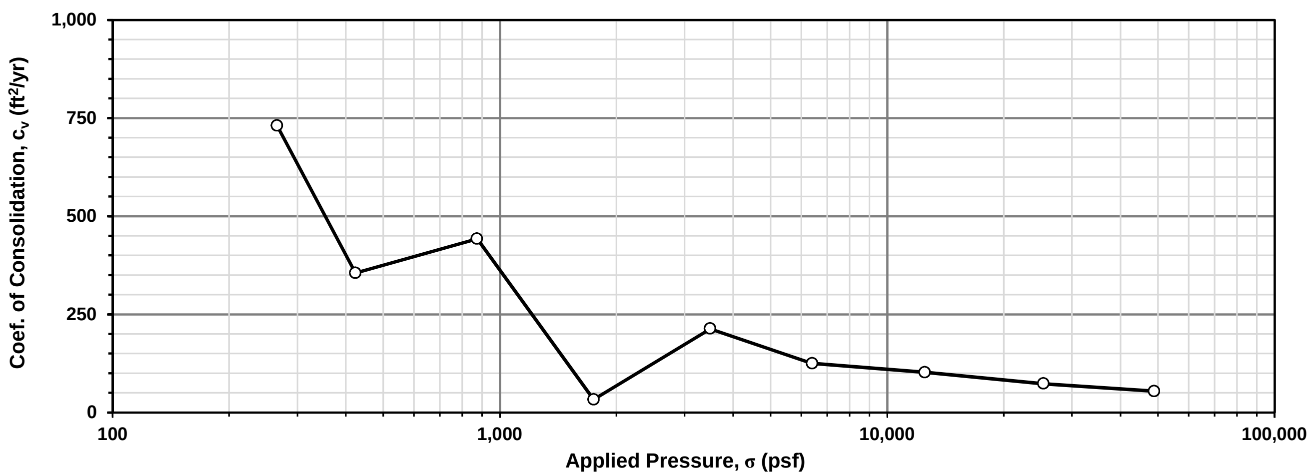
Project Number:	W-13-072	Boring Number:	B-018-1-13
Project Name:	FRA-70-13.10	Station / Offset:	167+31.32, 54.6' Lt.
Project Location:	Columbus, Ohio	Sample No. / Depth:	ST-4 / 10.1 ft
Client:	ms consultants, inc.	Date of Testing:	02/11/2014 to 02/27/2014

Soil Description: Gray SANDY SILT, some clay, trace fine gravel.
Soil Classification: ODOT A-4a

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	34	25	9	6	6	18	41	29

Natural		γ_d (pcf)	γ_{sat} (pcf)	σ_{vo}' (psf)	S_G	e_o	σ_p' (psf)	c_c	c_r
S_o	w_o								
96.7%	31.4%	88.7	116.9	1,212	2.67	0.879	1,851	0.271	0.043





RESOURCE INTERNATIONAL, INC.

Engineering Consultants

Unconfined Compressive Strength
of Intact Rock Core Specimens (ASTM D 7012-04)

6350 Presidential Gatew.
Columbus, OH 43231
Phone (614) 823-4949

9885 Rockside Road
Cleveland, OH 44125
Phone (216) 573-0955

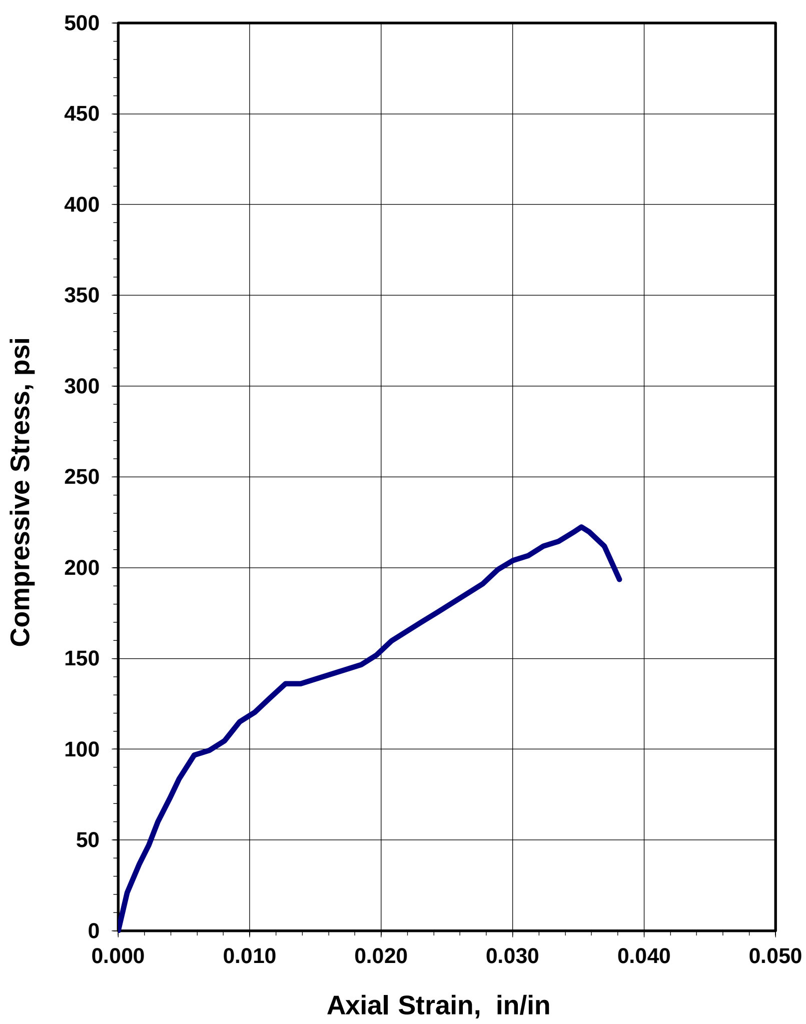
4480 Lake Forest Drive
Cincinnati, Ohio 45242
Phone (513) 769-6998

Project: FRA-70-12.68
Project No.: W-13-045
Date of Testing: 8/8/2013
Test Performed by: KR/TK

Rock Description: SHALE: Black, highly weathered, very weak.

Boring No.:	B-017-3-13	Average Length:	4.328 in
Station / Offset:	166+20.53, 31.8' Rt.	Average Diameter:	2.206 in
Sample No. / Depth:	RC-2 / 86 ft.	Length to diameter ratio:	1.962
Moisture condition:	As received	Cross Sectional Area:	3.820 in^2
Rate of Loading:	2.7 lbs/sec	Failure Load:	850 lbs
Testing Time:	310 sec	Axial Strain at Failure:	0.0352 in/in
(Rate 2-15 minutes to failure)		Stress:	222 psi

Unconfined Compression Test



Before Testing

After Failure

REMARKS:

RESOURCE INTERNATIONAL, INC.
Engineering Consultants

6350 Presidential Gatew.	9885 Rockside Road	4480 Lake Forest Drive
Columbus, OH 43231	Cleveland, OH 44125	Cincinnati, Ohio 45242
Phone (614) 823-4949	Phone (216) 573-0955	Phone (513) 769-6998

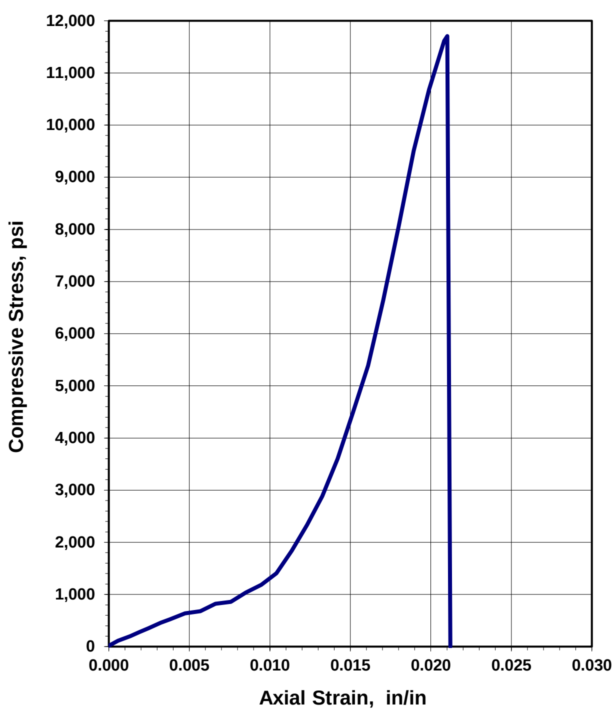
Unconfined Compressive Strength
of Intact Rock Core Specimens (ASTM D 7012-04)

Project: FRA-70-13.10 - Project 6A
Project No.: W-13-072
Date of Testing: 3/7/2014
Test Performed by: K.R./T.K.

Rock Description: Gray Limestone

Boring No.:	B-017-9-13	Average Length:	5.28 in
Sample No:	RC-2	Average Diameter:	2.399 in
Depth (ft):	74.2	Length to diameter ratio:	2.201
Moisture condition:	As received	Cross Sectional Area:	4.518 in^2
Rate of Loading:	96.0 lbs/sec	Failure Load:	52,900 lbs
Testing Time:	551 sec	Axial Strain at Failure:	0.0210 in/in
(Rate 2-15 minutes to failure)		Stress:	11,707 psi

Unconfined Compression Test



Before Testing

After Failure

REMARKS:

RESOURCE INTERNATIONAL, INC.

Engineering Consultants

Unconfined Compressive Strength
of Intact Rock Core Specimens (ASTM D 7012-04)

6350 Presidential Gatew.
Columbus, OH 43231
Phone (614) 823-4949

9885 Rockside Road
Cleveland, OH 44125
Phone (216) 573-0955

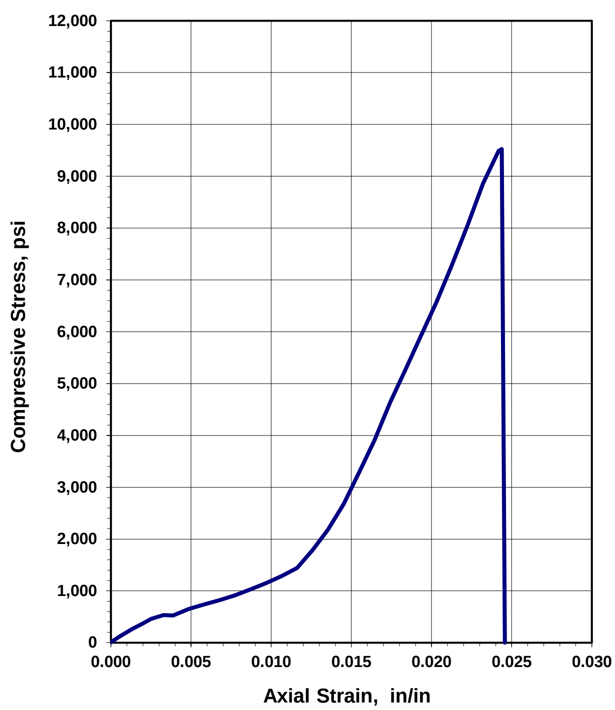
4480 Lake Forest Drive
Cincinnati, Ohio 45242
Phone (513) 769-6998

Project: FRA-70-13.10 - Project 6A
Project No.: W-13-072
Date of Testing: 2/10/2014
Test Performed by: K.R./T.K.

Rock Description: Gray Limestone

Boring No.:	B-018-1-13	Average Length:	5.168 in
Sample No:	RC-1	Average Diameter:	2.385 in
Depth (ft):	75.6	Length to diameter ratio:	2.167
Moisture condition:	As received	Cross Sectional Area:	4.465 in^2
Rate of Loading:	85.8 lbs/sec	Failure Load:	42,540 lbs
Testing Time:	496 sec	Axial Strain at Failure:	0.0244 in/in
	(Rate 2-15 minutes to failure)	Stress:	9,525 psi

Unconfined Compression Test



Before Testing

After Failure

REMARKS:

RESOURCE INTERNATIONAL, INC.
Engineering Consultants

6350 Presidential Gatew.
Columbus, OH 43231
Phone (614) 823-4949

9885 Rockside Road
Cleveland, OH 44125
Phone (216) 573-0955

4480 Lake Forest Drive
Cincinnati, Ohio 45242
Phone (513) 769-6998

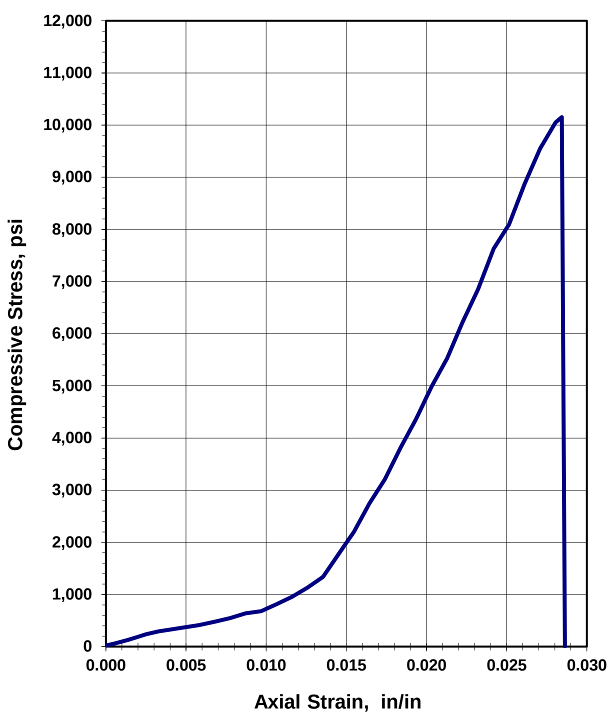
Unconfined Compressive Strength
of Intact Rock Core Specimens (ASTM D 7012-04)

Project: FRA-70-13.10 - Project 6A
Project No.: W-13-072
Date of Testing: 2/13/2014
Test Performed by: J.H./T.K.

Rock Description: Gray Limestone

Boring No.:	B-018-2-13	Average Length:	5.169 in
Sample No:	RC-1	Average Diameter:	2.4 in
Depth (ft):	78.5	Length to diameter ratio:	2.154
Moisture condition:	As received	Cross Sectional Area:	4.522 in^2
Rate of Loading:	78.5 lbs/sec	Failure Load:	45,920 lbs
Testing Time:	585 sec	Axial Strain at Failure:	0.0284 in/in
	(Rate 2-15 minutes to failure)	Stress:	10,153 psi

Unconfined Compression Test



Before Testing

After Failure

REMARKS: ______

APPENDIX V

CONE PENETRATION TEST (CPT) SOUNDINGS REPORT (ODOT OGE)

CONE PENETRATION TEST SOUNDINGS REPORT

Office of Geotechnical Engineering
Division of Engineering

Project: FRA-70-1358L

PID: 89464

Date: July 6, 2021

Number of Soundings: 8

Equipment: A.P. van den Berg, 23 Ton Crawler, Hyson 200kN

Sounding ID	Completion Date	Probe SN	Calibration Date	Elevation	Latitude	Longitude	Depth (ft.)
C-001-0-21	3/16/2021	130510	11/26/2019	720.2	39.95342	-83.007908	22.28
C-001-1-21	3/16/2021	090304	8/19/2020	720.9	39.953402	-83.007903	54.07
C-002-0-21	3/17/2021	130510	11/26/2019	714.1	39.952952	-83.007836	26.89
C-002-1-21	3/17/2021	090304	8/19/2020	714.1	39.952927	-83.007841	26.44
C-003-0-21	3/17/2021	090304	8/19/2020	714.8	39.953561	-83.007189	34.86
C-003-1-21	4/21/2021	200723	10/12/2020	714.9	39.953565	-83.007186	55.74
C-004-0-21	4/21/2021	200723	10/12/2020	715.5	39.953103	-83.006969	39.07
C-004-1-21	4/21/2021	200723	10/12/2020	715.2	39.953091	-83.006963	20.45

Project Information

Eight soundings were completed for this project. All soundings were completed off road. Sounding C-003-1-21 was predrilled to 46.5 feet and back filled with bentonite grout. Sounding C-003-1-21 was terminated due to a rod shearing off. Sounding C-004-0-21 was predrilled to 38.5 feet and back filled with sand. Sounding C-004-0-21 terminated due to excessive tip resistance. The static water levels reported on the attached logs were determined by pore pressure response. With the exception of C-001-0-21 and C-001-1-21, the latitude, longitude, and elevation values for the soundings are from a Trimble Geo7X handheld GPS with an external Trimble Tornado antenna. The locations of C-001-0-21 and C-001-1-21 are from a Trimble Geo7X handheld GPS and offset data. The elevations for both soundings are from nearby historic boring B-017-9-13.

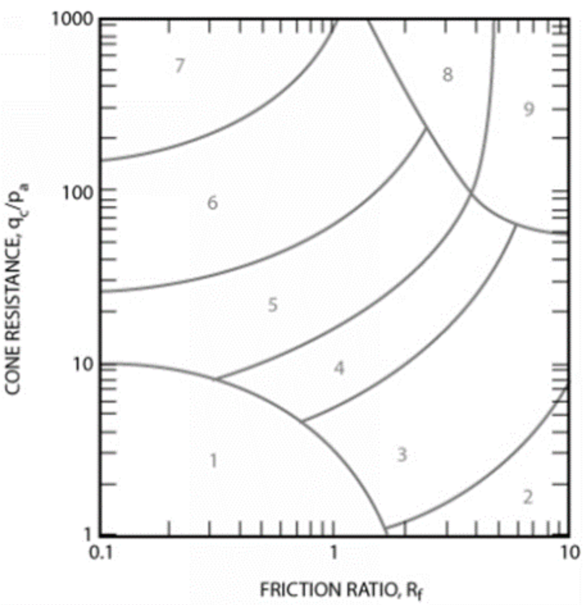
The raw CPT data is available upon request. The included CPT logs are for informational purposes only. The CPT logs have been filtered for negative values, corrected for inclination at depth, and filtered for data spikes. Additionally, for each sounding, the measured values of q_c and f_s were shifted relative to one another with a cross correlation function.

Cone Penetration Test Data and Interpretation

These Cone Penetration Test (CPT) Soundings follow ASTM D 5778 and were made by ordinary and conventional methods and with care deemed adequate for the Department's design purposes. Since subsurface conditions outside each CPT sounding are unknown, and soil, rock, and water conditions cannot be relied upon to be consistent or uniform, no warrant is made that conditions adjacent to this sounding will necessarily be the same as or similar to those shown in this report.

The CPT data collected are presented as graphical plots in the report, generated by CPeT-IT software. The plots include interpreted Soil Behavior Type (SBT) based on the method described by Robertson (2010). The interpretations are presented only as a guide for geotechnical use and should be carefully reviewed.

The department does not warrant the correctness or the applicability of any of the geotechnical parameters interpreted by the software and does not assume any liability for use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used in the software. Furthermore, the Department will not be responsible for an interpretations, assumptions, projections, or interpolations made by the contractor, or other users of this report. While the Department believes that the information as to the condition and materials reported is accurate, it does not warrant that the information is necessarily complete. Water pressure measurements and subsequent interpreted water levels shown in this report should be used with discretion since they represent dynamic conditions. Dynamic pore water pressure measurements may deviate substantially from hydrostatic conditions, especially in cohesive soils.



Zone	*Soil Behavior Type*
1	*Sensitive, fine grained*
2	*Organic soils - clay*
3	*Clay – silty clay to clay*
4	*Silt mixtures – clayey silt to silty clay*
5	*Sand mixtures – silty sand to sandy silt*
6	*Sands – clean sand to silty sand*
7	*Gravelly sand to dense sand*
8	*Very stiff sand to clayey sand**
9	*Very stiff fine grained**

** Heavily overconsolidated or cemented*

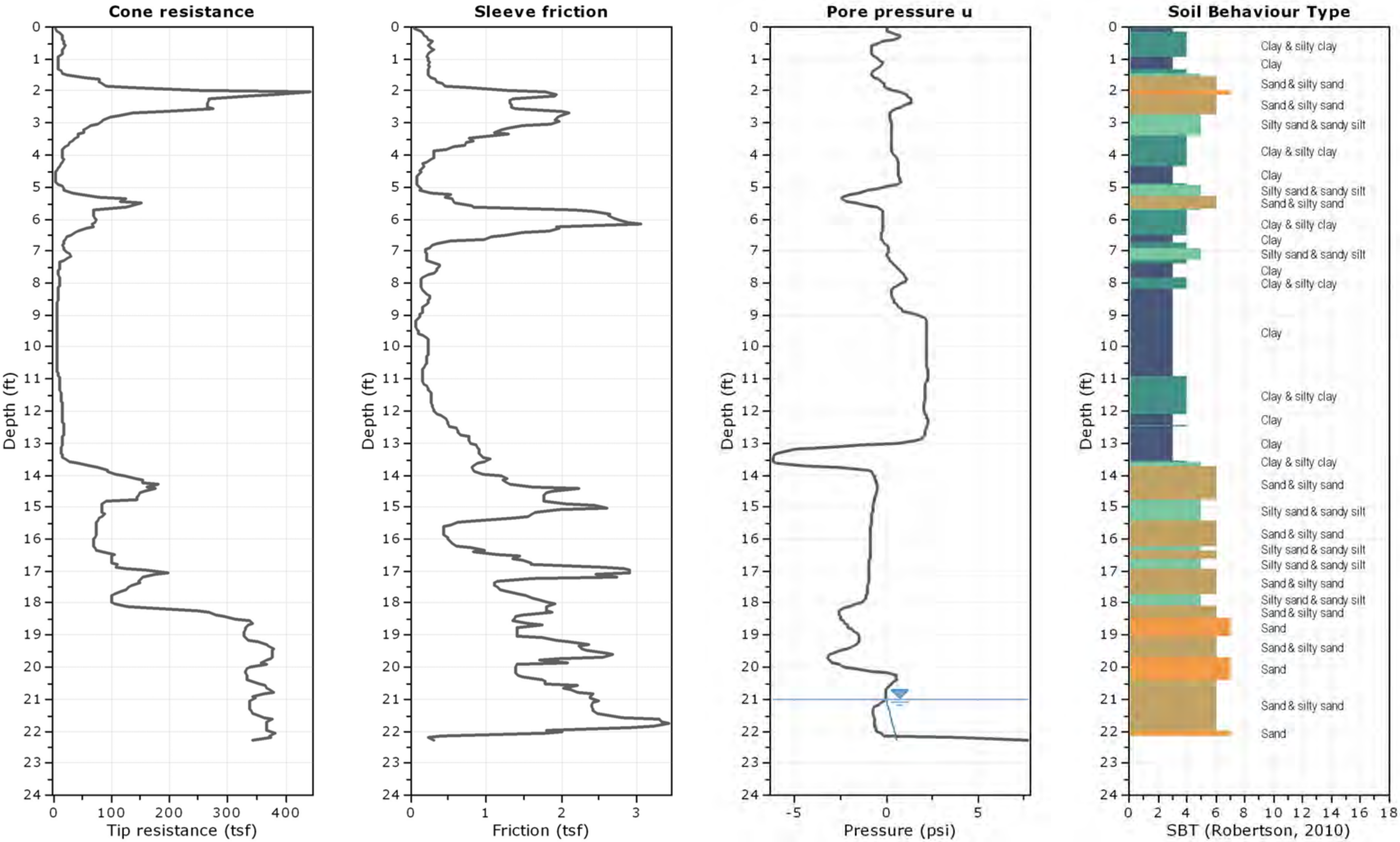
Non-normalized CPT Soil Behavior Type (SBT) chart

Robertson, P.K. and Cabal, K.L, 2016. *Guide to Cone Penetration Testing for Geotechnical Engineering, 6th Edition.* Signal Hill, California: 34.
http://www.greggdrilling.com/wp-content/uploads/2017/07/CPT-Guide-6th-Edition-2016.pdf
Accessed May 21, 2019

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

CPT: C-001-0-21
Total depth: 22.28 ft, Date: 3/16/2021
Surface Elevation: 720.2 ft
Coords: lat 39.95342° lon -83.007908°

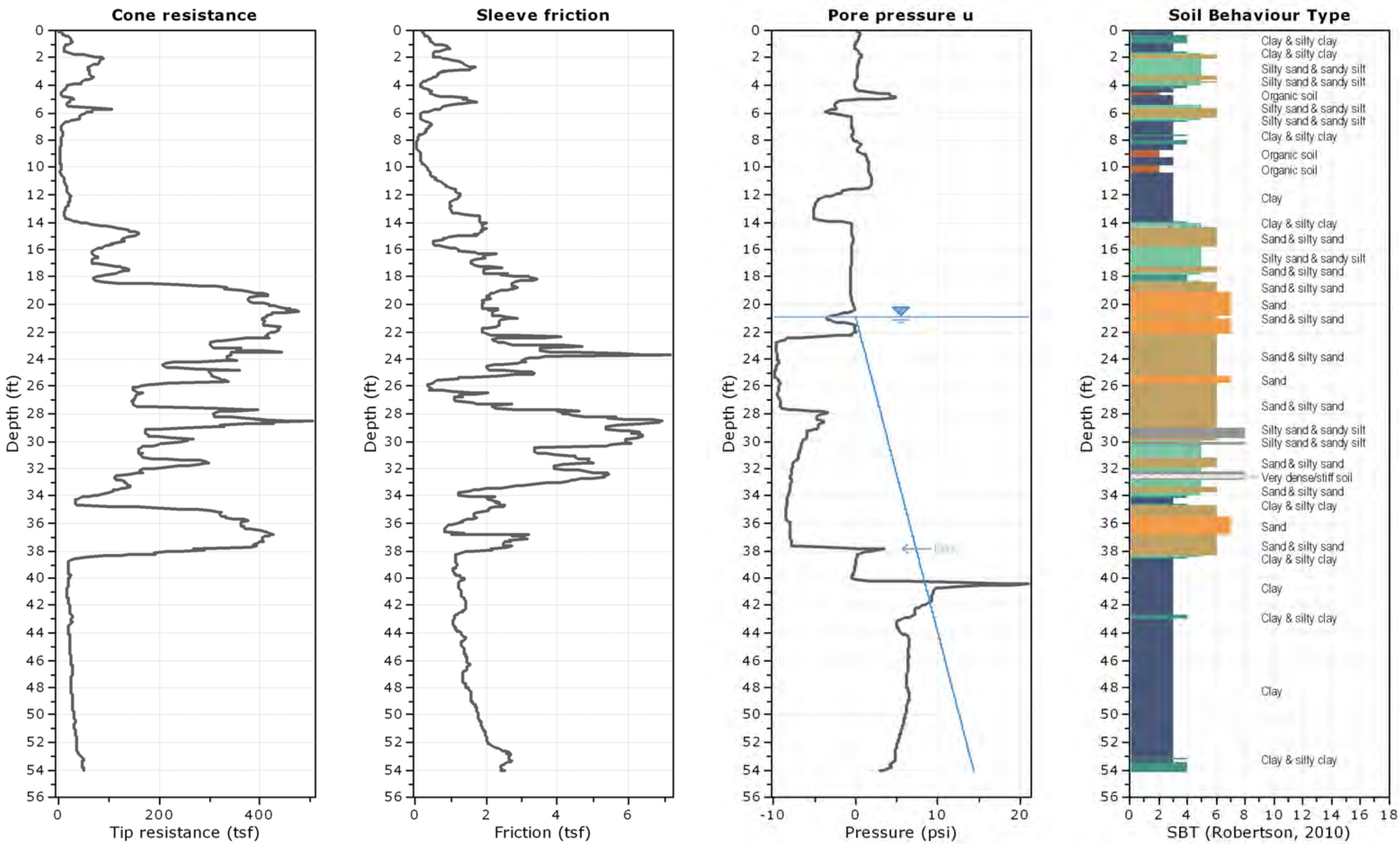
Project: FRA-70-1358L
Location: Franklin County



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

CPT: C-001-1-21
Total depth: 54.07 ft, Date: 3/16/2021
Surface Elevation: 720.9 ft
Coords: lat 39.953402° lon -83.007903°

Project: FRA-70-1358L
Location: Franklin County



Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

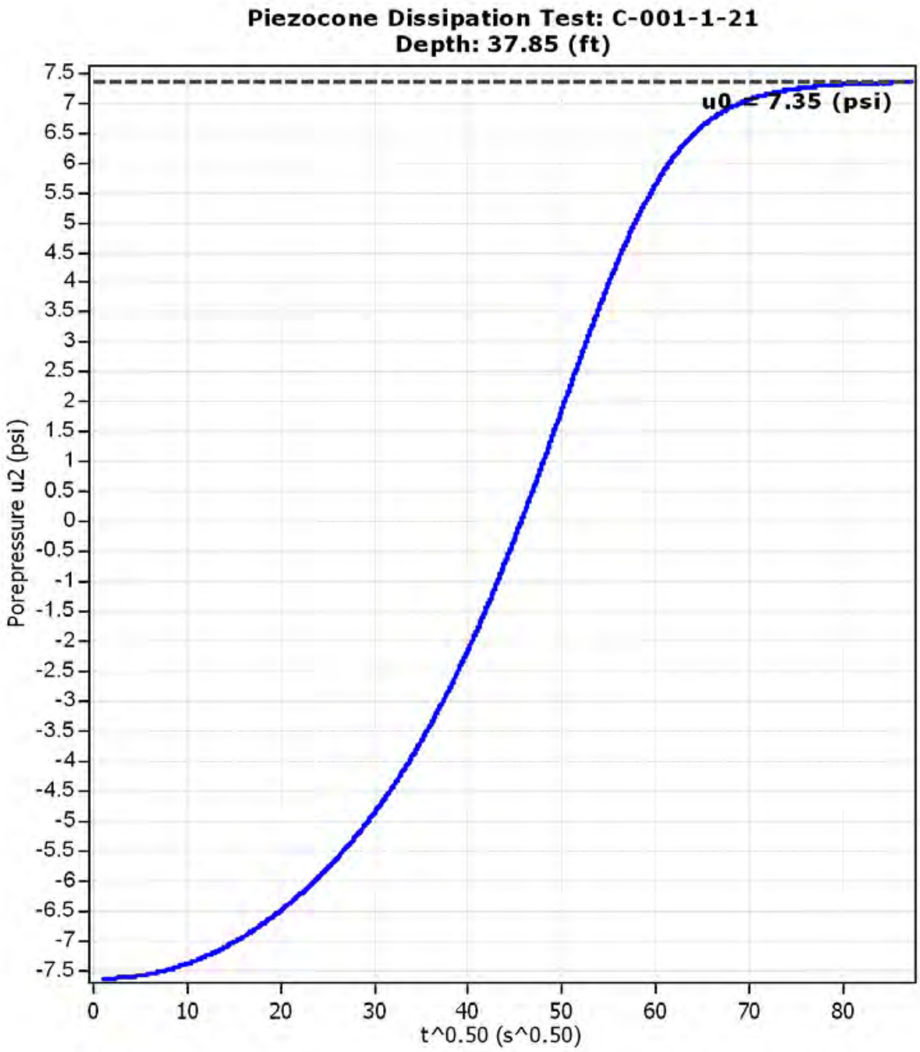
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

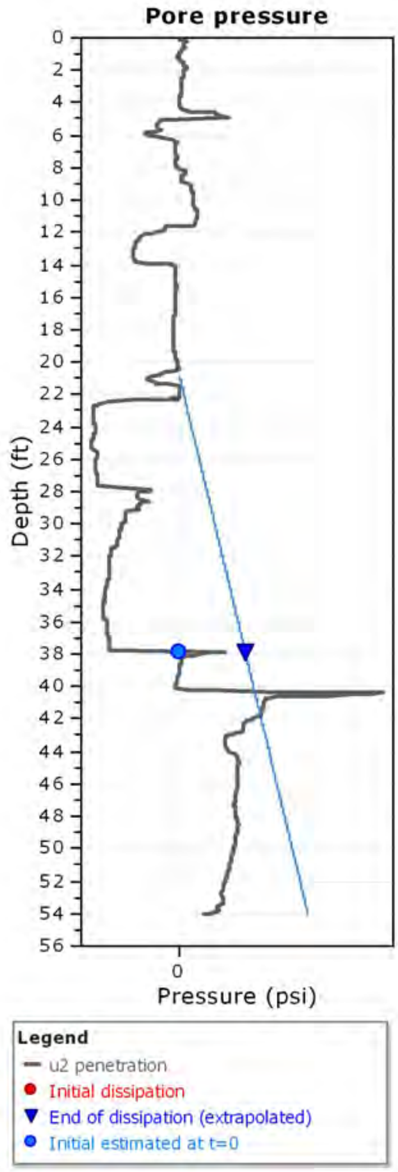
$$k_h = c_h \times \gamma_w / M$$

where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

CPTU Borehole	Depth (ft)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (ft^2/s)	c_h ($ft^2/year$)	M (tsf)	k_h (ft/s)
C-001-1-21	37.85	0.0	0	0.00E+000	100.00	0.00E+000	0	1852.95	-1.00E+004

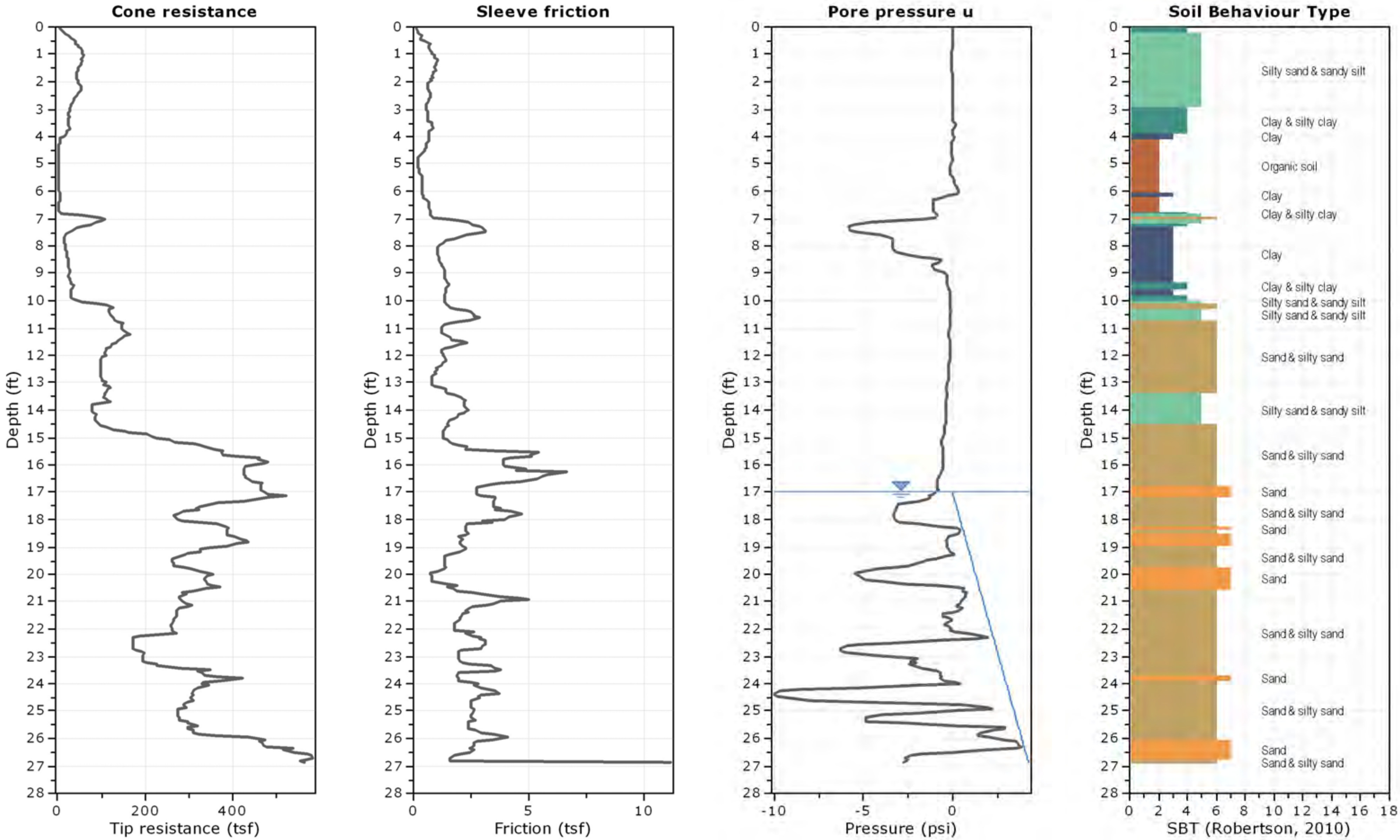

Piezocone Dissipation Test: C-001-1-21
Depth: 37.85 (ft)
u0 = 7.35 (psi)
Porepressure u2 (psi)
t^0.50 (s^0.50)


Pore pressure
Depth (ft)
Pressure (psi)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

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

CPT: C-002-0-21
Total depth: 26.89 ft, Date: 3/17/2021
Surface Elevation: 714.1 ft
Coords: lat 39.952952° lon -83.007836°

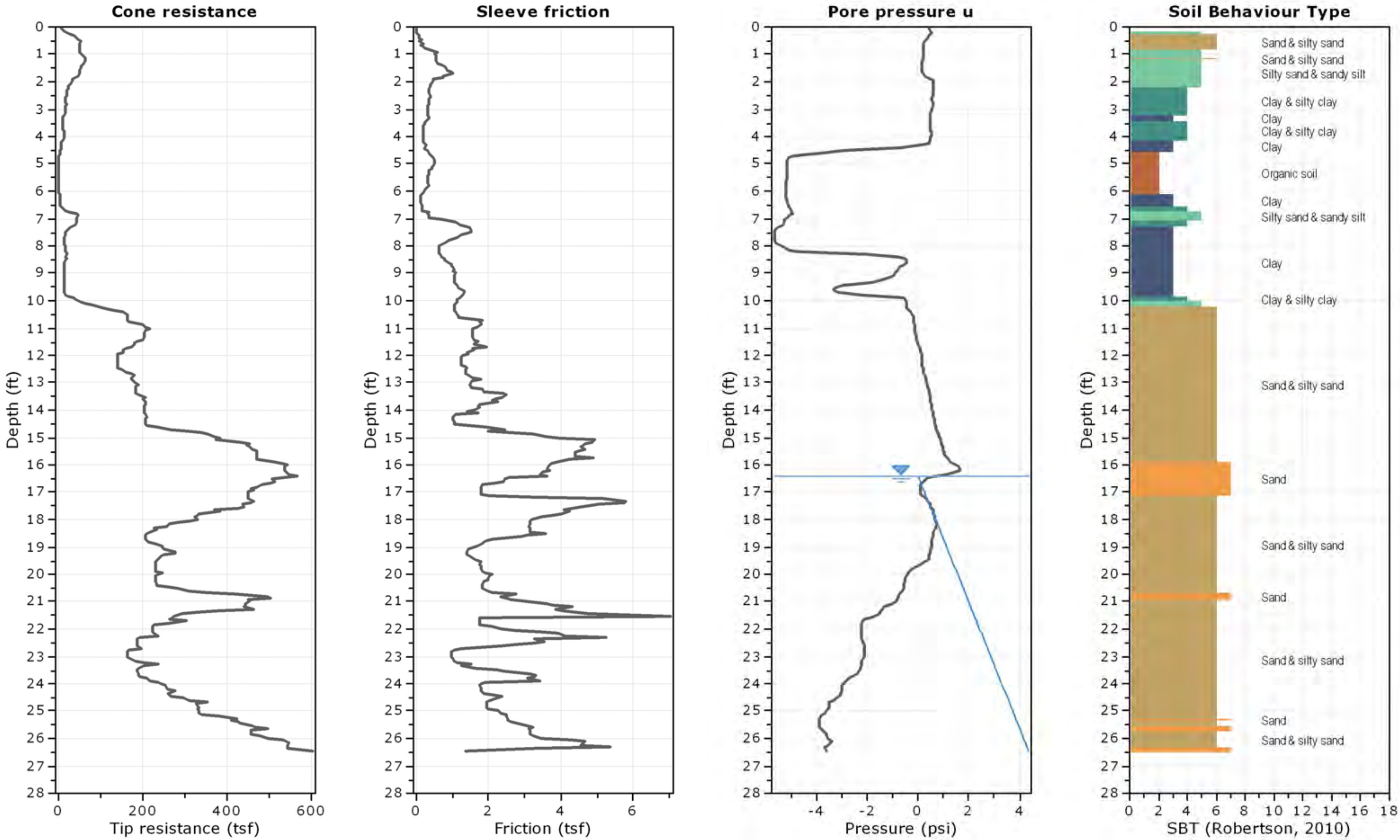
Project: FRA-70-1358L
Location: Franklin County



CPT: C-002-1-21

Total depth: 26.44 ft, Date: 3/17/2021
Surface Elevation: 714.1 ft
Coords: lat 39.952927° lon -83.007841°

Project: FRA-70-1358L
Location: Franklin County

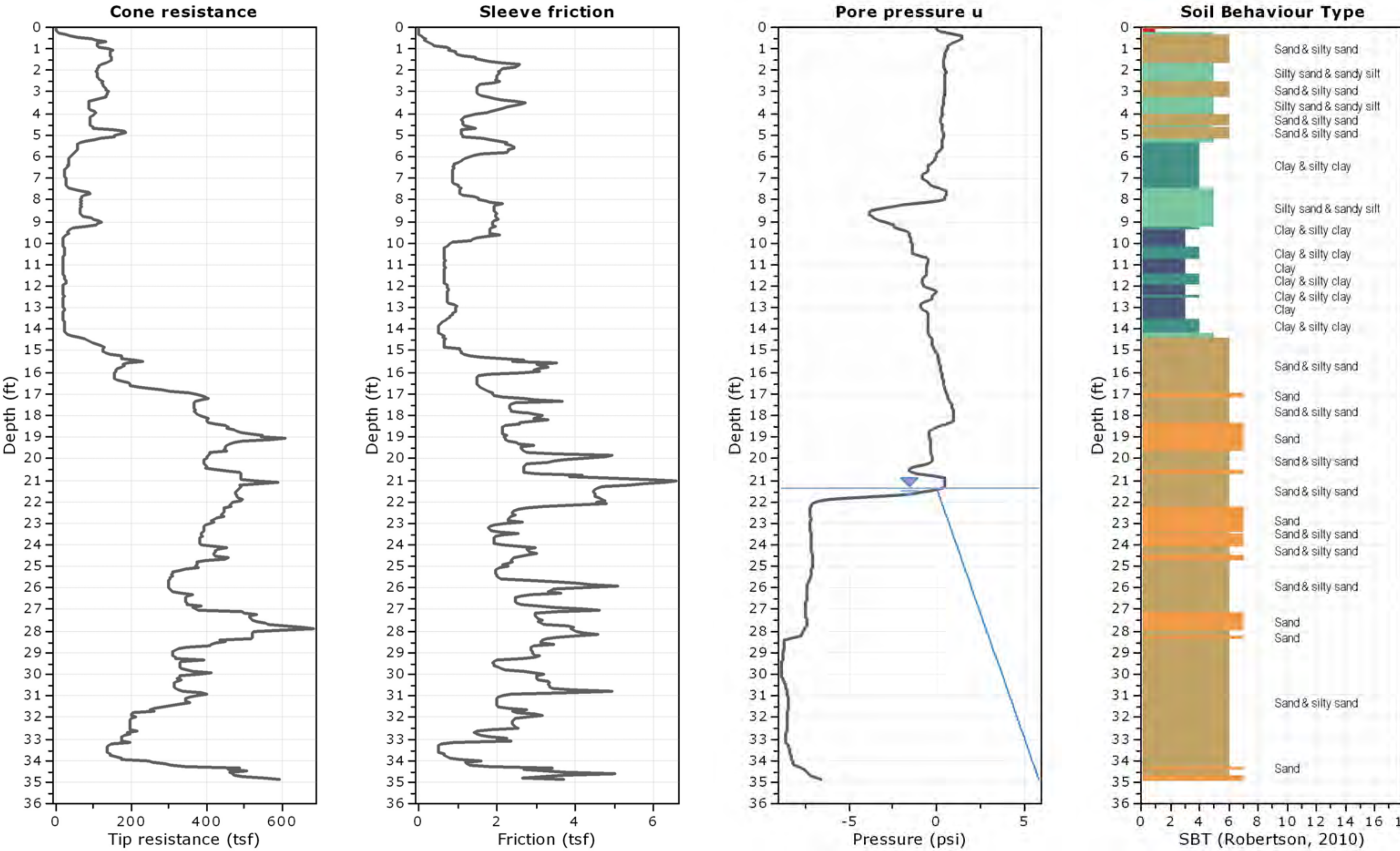


Office of Geotechnical Engineering
Geology, Exploration and, Laboratory Section
http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical

CPT: C-003-0-21

Total depth: 34.86 ft, Date: 3/17/2021
Surface Elevation: 714.8 ft
Coords: lat 39.953561° lon -83.007189°

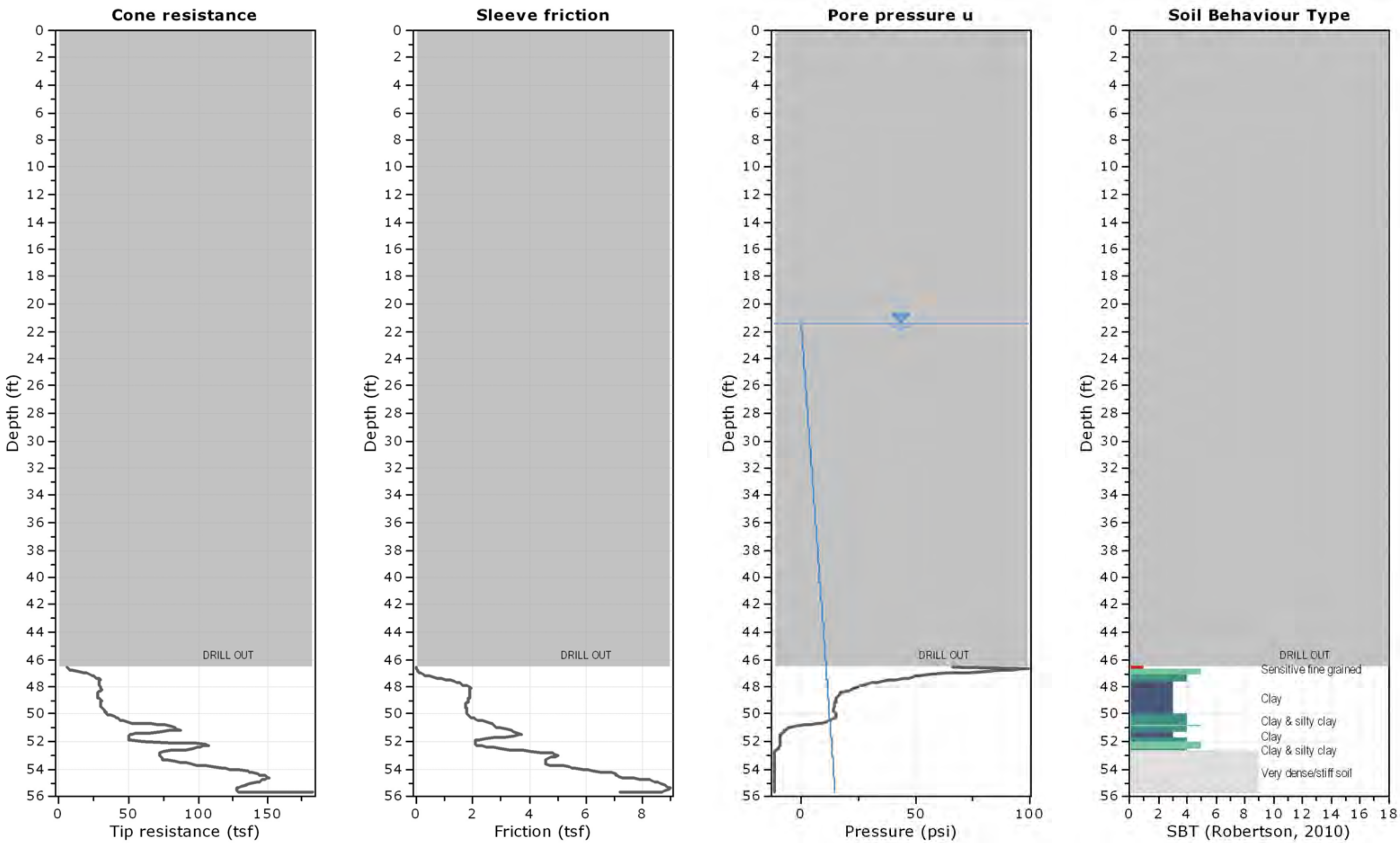
Project: FRA-70-1358L
Location: Franklin County



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

CPT: C-003-1-21
Total depth: 55.74 ft, Date: 4/21/2021
Surface Elevation: 714.9 ft
Coords: lat 39.953565° lon -83.007186°

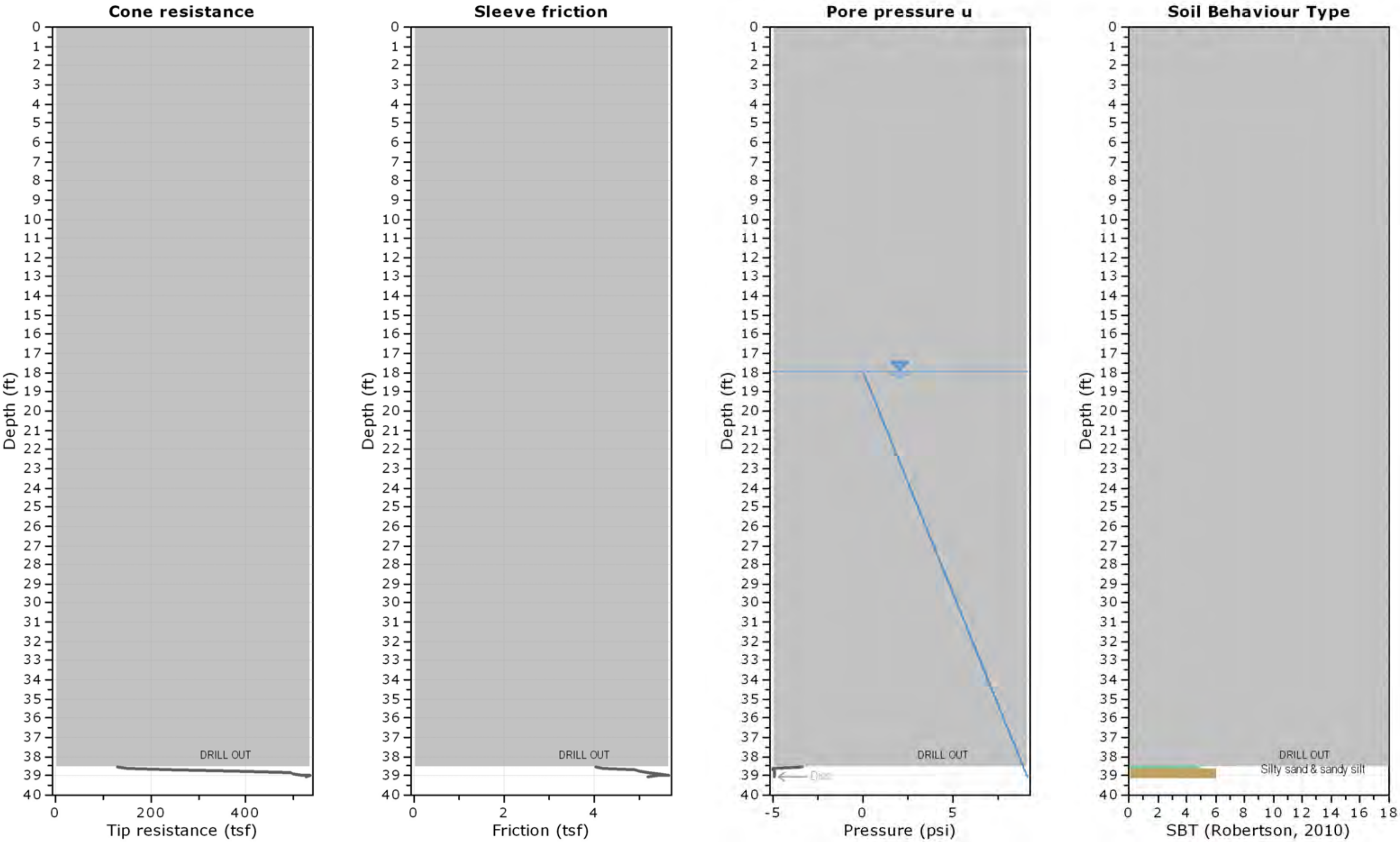
Project: FRA-70-1358L
Location: Franklin County



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

CPT: C-004-0-21
Total depth: 39.07 ft, Date: 4/21/2021
Surface Elevation: 715.5 ft
Coords: lat 39.953103° lon -83.006969°

Project: FRA-70-1358L
Location: Franklin County



Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

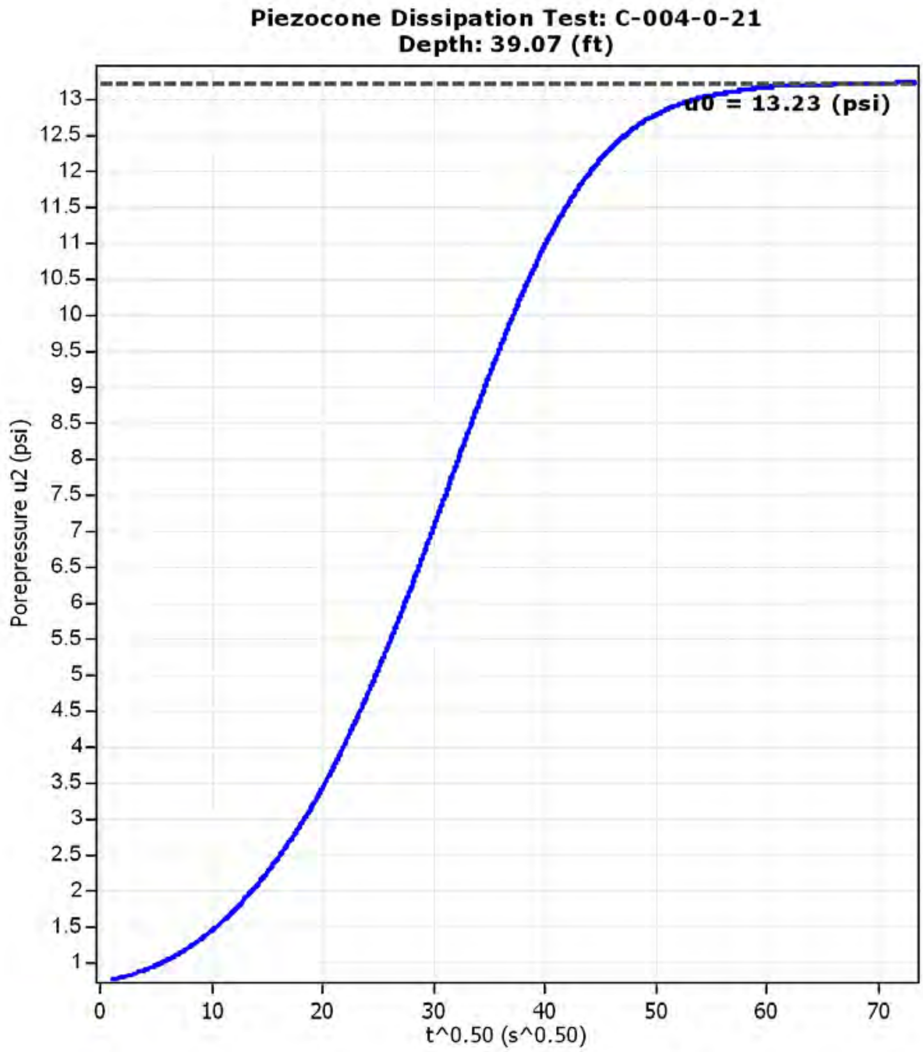
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

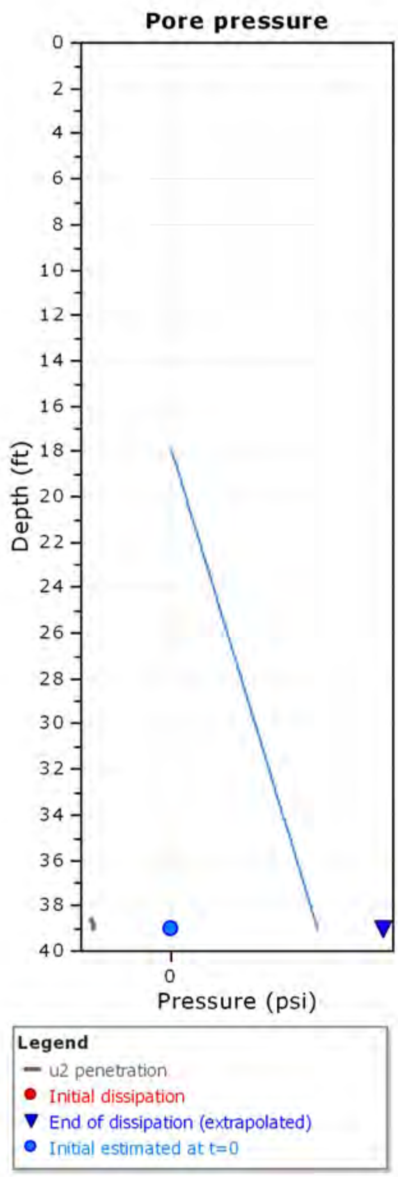
$$k_h = c_h \times \gamma_w / M$$

where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

CPTU Borehole	Depth (ft)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (ft^2/s)	c_h ($ft^2/year$)	M (tsf)	k_h (ft/s)
C-004-0-21	39.07	0.0	0	0.00E+000	100.00	0.00E+000	0	2793.83	-1.00E+004


Piezocone Dissipation Test: C-004-0-21
Depth: 39.07 (ft)
u0 = 13.23 (psi)
Porepressure u2 (psi)
t^0.50 (s^0.50)


Pore pressure
Depth (ft)
Pressure (psi)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

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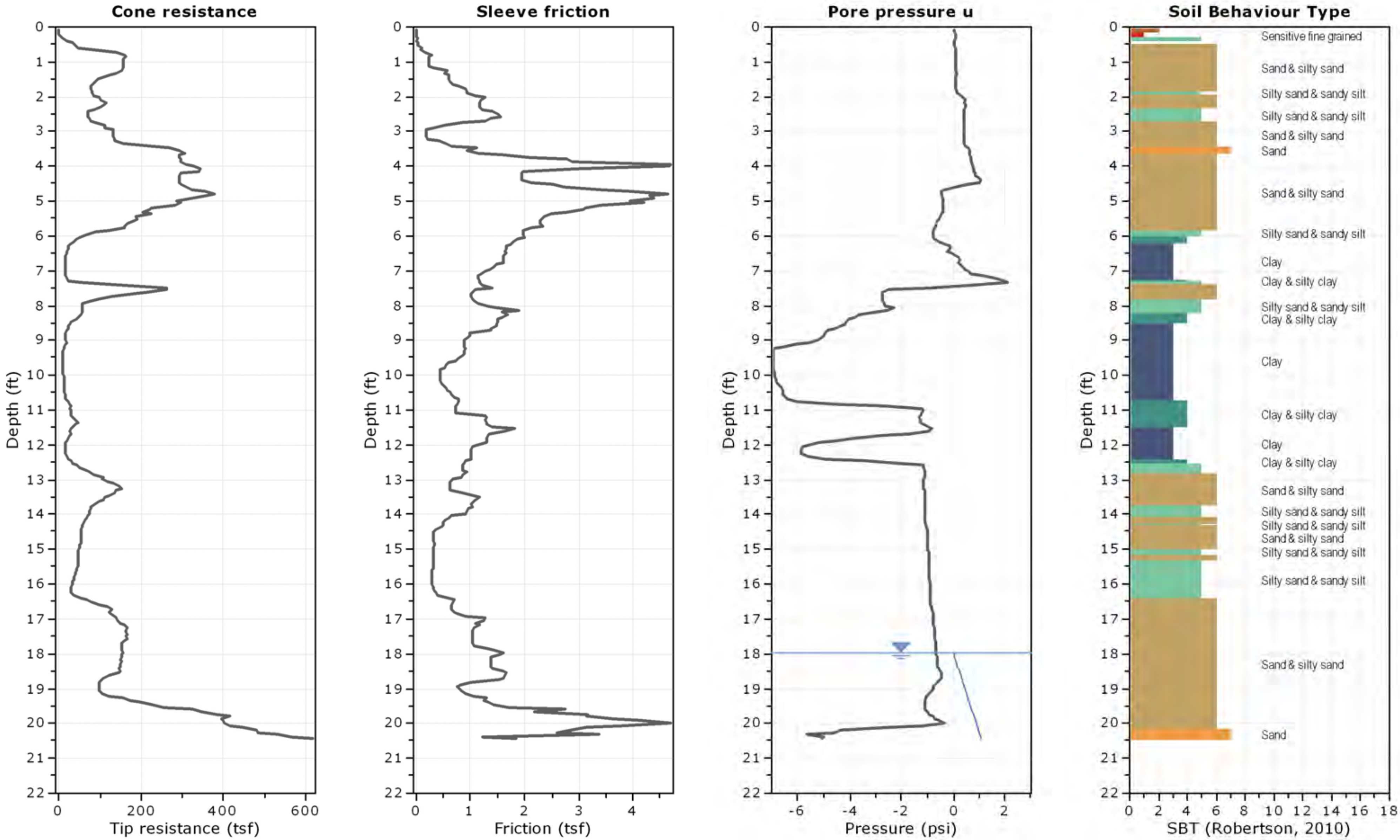
http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical

CPT: C-004-1-21

Total depth: 20.45 ft, Date: 4/21/2021
Surface Elevation: 715.2 ft
Coords: lat 39.953091° lon -83.006963°

Project: FRA-70-1358L
Location: Franklin County



APPENDIX VI

SUPPLEMENTAL BORING LOGS AND LABORATORY TEST RESULTS (ODOT OGE)

PROJECT: FRA-70-1358L	DRILLING FIRM / OPERATOR: ODOT / MCINTOSH	DRILL RIG: CME 850R TRACKED	STATION / OFFSET:
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: ODOT / LEWIS	HAMMER: CME AUTOMATIC	ALIGNMENT: CL IR 70
PID: 89464 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 5/1/19	ELEVATION: 720.2 (ft) EOB: 12.0 ft.
START: 4/19/21 END: 4/19/21	SAMPLING METHOD: ST	ENERGY RATIO (%): 89	LAT / LONG: 39.953420, -83.007908

EXPLORATION ID B-017-10-21

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 720.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
AUGERED WITHOUT SAMPLING.	710.2	0 - 10																
VERY STIFF, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, MOIST @11.2'; QU = 1,123 PSF @ 6.0% STRAIN; γ_d = 95.33 PCF	708.2	10 - 12 (EOB)			100	ST-1	2.50	1	5	16	38	40	31	17	14	21	A-6a (10)	

NOTES: BORING OFFSET FROM CPT SOUNDING C-001-0-21 TO COLLECT UNDISTURBED SAMPLES FOR TESTING. WATER LEVEL NOT RECORDED. REFER TO CPT SOUNDINGS FOR WATER LEVEL.

STANDARD ODOT SOIL BORING LOG (11 X 17) - OH DOT.GDT - 10/25/21 07:10 - X:\GINT\PROJECTS\2021 COMPLETE\600839.GPJ

NOTES: BORING ALLOWED TO COLLAPSE WITH NATUAL MATERIAL THEN CUTTINGS AND BENTONITE WERE USED TO FINISH BACKFILLING THE BORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 50 LB. BENTONITE CHIPS

PROJECT: FRA-70-1358L	DRILLING FIRM / OPERATOR: ODOT / BINKLEY	DRILL RIG: ACKER XLS TRACK	STATION / OFFSET:	EXPLORATION ID B-017-11-21
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: ODOT / AJ	HAMMER: ACKER AUTOMATIC	ALIGNMENT: CL IR 70	
PID: 89464 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 5/1/19	ELEVATION: 714.1 (ft) EOB: 49.2 ft.	PAGE
START: 4/19/21 END: 4/19/21	SAMPLING METHOD: SPT / ST	ENERGY RATIO (%): 90	LAT / LONG: 39.952927, -83.007841	1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 714.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
AUGERED WITHOUT SAMPLING.	709.6	0–4.5																
MEDIUM STIFF, BROWN, **SILT AND CLAY**, SOME SAND, LITTLE GRAVEL, MOIST @5.2'; QU = 1,613 PSF @ 14.4% STRAIN; γ_d = 105.37 PCF	704.1	4.5–10			85	ST-1	0.50	10	9	14	35	32	30	19	11	23	A-6a (7)	
MEDIUM DENSE, BROWN AND GRAY, **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP		10–11.5	8 12 13	38	100	SS-2	-	-	-	-	-	-	-	-	-	-	A-2-4 (V)	
	695.6	13.5–15	9 13 18	47	78	SS-3	4.50	-	-	-	-	-	-	-	-	-	A-2-4 (V)	
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, WET		18.5–20	4 10 11	32	56	SS-4	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
@21.0'; SPLIT SPOON BLOCKED BY STONE FRAGMENT		21–22.5	10 11 12	35	61	SS-5	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
	689.1	23.5–25	7 15 14	44	72	SS-6	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
AUGERED WITHOUT SAMPLING.	666.1	25–48																
HARD, GRAY, **SILTY CLAY**, TRACE SAND, DAMP	664.9	48–49.2 (EOB)			97	ST-7	-	0	2	3	38	57	40	23	17	17	A-6b (11)	

NOTES: BORING OFFSET FROM CPT SOUNDING C-002-1-21 TO COLLECT UNDISTURBED SAMPLES FOR TESTING. WATER LEVEL NOT RECORDED. REFER TO CPT SOUNDINGS FOR WATER LEVEL.

NOTES: BORING ALLOWED TO COLLAPSE WITH NATUAL MATERIAL THEN CUTTINGS AND BENTONITE WERE USED TO FINISH BACKFILLING THE BORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 50 LB. BENTONITE CHIPS

PROJECT: FRA-70-1358L	DRILLING FIRM / OPERATOR: ODOT / MCINTOSH	DRILL RIG: CME 850R TRACKED	STATION / OFFSET:	EXPLORATION ID B-017-20-21
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: ODOT / LEWIS	HAMMER: CME AUTOMATIC	ALIGNMENT: CL IR 70	
PID: 89464 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 5/1/19	ELEVATION: 720.2 (ft) EOB: 42.5 ft.	PAGE 1 OF 1
START: 4/19/21 END: 4/19/21	SAMPLING METHOD: ST	ENERGY RATIO (%): 89	LAT / LONG: 39.953420, -83.007908	

MATERIAL DESCRIPTION AND NOTES	ELEV. 720.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
AUGERED WITHOUT SAMPLING.	681.2	0–39																
STIFF, GRAY, **CLAY**, LITTLE SILT, MOIST @40.2'; QU = 2,635 PSF @ 8.4% STRAIN; γ_d = 99.87 PCF		40			100	ST-1	2.75	0	0	0	14	86	46	22	24	26	A-7-6 (15)	
@41.0'; MEDIUM STIFF, SOME SILT @41.8'; QU = 1,814 PSF @ 12.4% STRAIN; γ_d = 99.66 PCF	677.7	42 EOB			100	ST-2	2.75	0	0	0	25	75	41	21	20	24	A-7-6 (12)	

NOTES: BORING OFFSET FROM CPT SOUNDING C-001-0-21 TO COLLECT UNDISTURBED SAMPLES FOR TESTING. WATER LEVEL NOT RECORDED. REFER TO CPT SOUNDINGS FOR WATER LEVEL.

NOTES: BORING ALLOWED TO COLLAPSE WITH NATUAL MATERIAL THEN CUTTINGS AND BENTONITE WERE USED TO FINISH BACKFILLING THE BORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 50 LB. BENTONITE CHIPS

PROJECT: FRA-70-1358L TYPE: BRIDGE PID: 89464 SFN: START: 4/19/21 END: 4/19/21	DRILLING FIRM / OPERATOR: ODOT / MCINTOSH SAMPLING FIRM / LOGGER: ODOT / LEWIS DRILLING METHOD: 3.25" HSA SAMPLING METHOD: SPT / ST	DRILL RIG: CME 850R TRACKED HAMMER: CME AUTOMATIC CALIBRATION DATE: 5/1/19 ENERGY RATIO (%): 89	STATION / OFFSET: ALIGNMENT: CL IR 70 ELEVATION: 714.9 (ft) EOB: 49.0 ft. LAT / LONG: 39.953565, -83.007186	EXPLORATION ID B-018-3-21 PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 714.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
AUGERED WITHOUT SAMPLING.	679.4	0 – 35																
DENSE, GRAY, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET		35 – 37	7 10 14	36	56	SS-1	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
@38.0'; MEDIUM DENSE	675.4	38 – 39.5	5 8 8	24	39	SS-2	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
DENSE, GRAYISH BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST		39.5 – 41	10 11 16	40	56	SS-3	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
		41 – 42.5	20 24 26	74	78	SS-4	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
		42.5 – 44	27 25 2	40	72	SS-5	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
		44 – 45.5	15 15 12	40	67	SS-6	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
	668.4	45.5 – 46.5	15 10 9	28	67	SS-7A	-	-	-	-	-	-	-	-	-	-	A-1-a (V)	
MEDIUM DENSE, GRAY, **GRAVEL AND STONE FRAGMENTS**, LITTLE SAND, TRACE SILT, TRACE CLAY, MOIST	667.9	46.5 – 47				SS-7B	3.50	-	-	-	-	-	-	-	-	-	A-7-6 (V)	
VERY STIFF, GRAY, **CLAY**, LITTLE SILT, TRACE SAND, MOIST @48.1'; QU = 3,283 PSF @ 7.3% STRAIN; γ_d = 100.30 PCF	665.9	47 – 49 EOB			83	ST-8	3.50	0	1	1	18	80	44	21	23	27	A-7-6 (14)	

NOTES: BORING OFFSET FROM CPT SOUNDING C-003-1-21 TO COLLECT UNDISTURBED SAMPLES FOR TESTING. WATER LEVEL NOT RECORDED. REFER TO CPT SOUNDINGS FOR WATER LEVEL.

NOTES: BORING ALLOWED TO COLLAPSE WITH NATUAL MATERIAL THEN CUTTINGS AND BENTONITE WERE USED TO FINISH BACKFILLING THE BORING.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 50 LB. BENTONITE CHIPS

PROJECT: FRA-70-1358L	DRILLING FIRM / OPERATOR: ODOT / MCINTOSH	DRILL RIG: CME 850R TRACKED	STATION / OFFSET:	EXPLORATION ID B-018-4-21
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: ODOT / LEWIS	HAMMER: CME AUTOMATIC	ALIGNMENT: CL IR 70	
PID: 89464 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 5/1/19	ELEVATION: 715.5 (ft) EOB: 38.5 ft.	PAGE
START: 4/19/21 END: 4/19/21	SAMPLING METHOD: SPT / ST	ENERGY RATIO (%): 89	LAT / LONG: 39.953103, -83.006969	1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 715.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
AUGERED WITHOUT SAMPLING.	680.0	1–35																
VERY DENSE, GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, MOIST	678.0	36–37	9 27 20	70	72	SS-1	-	-	-	-	-	-	-	-	-	-	A-1-b (V)	
					89	ST-2A	-	42	26	23	7	2	NP	NP	NP	9	A-1-b (0)	
VERY STIFF, GRAY, **SANDY SILT**, SOME CLAY, LITTLE GRAVEL, DAMP	677.0	38 EOB				ST-2B	2.50	16	7	13	32	32	24	14	10	13	A-4a (6)	

@37.5'; QU = 3,370 PSF @ 15.0% STRAIN; γ_d = 127.26 PCF

NOTES: BORING OFFSET FROM CPT SOUNDING C-004-0-21 TO COLLECT UNDISTURBED SAMPLES FOR TESTING. WATER LEVEL NOT RECORDED. REFER TO CPT SOUNDINGS FOR WATER LEVEL.

NOTES: BORING ALLOWED TO COLLAPSE WITH NATUAL MATERIAL THEN CUTTINGS AND BENTONITE WERE USED TO FINISH BACKFILLING THE BORING.

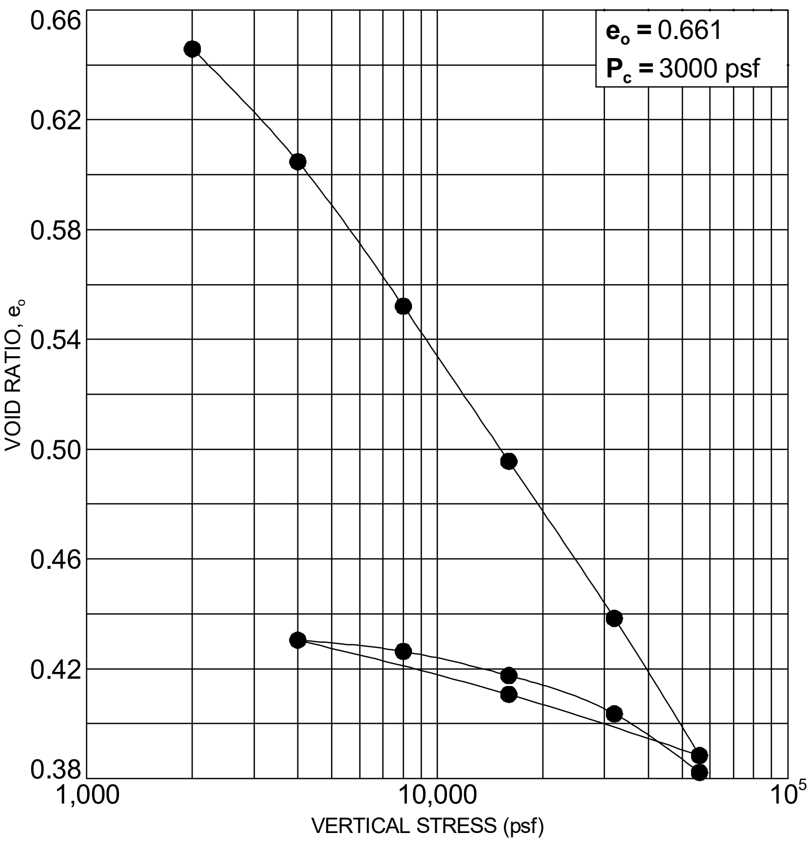
ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 50 LB. BENTONITE CHIPS

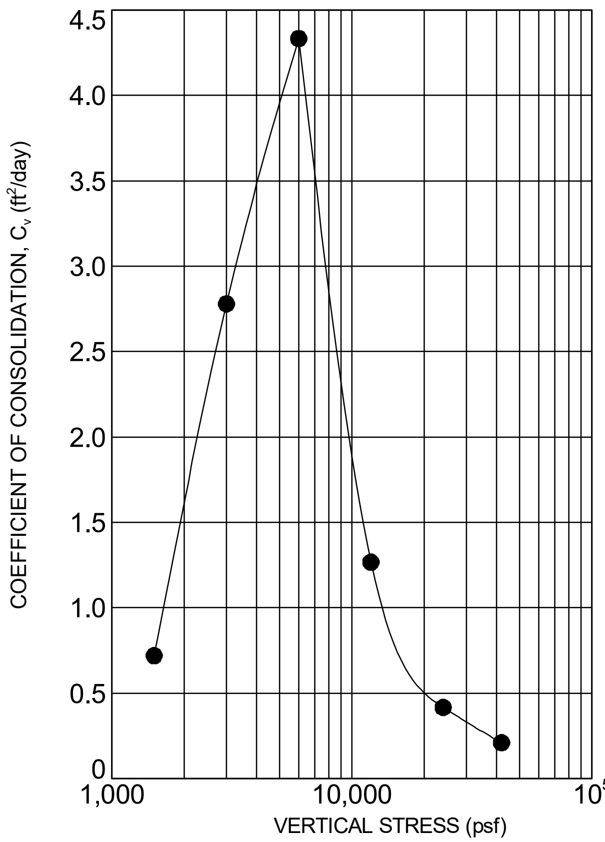
ONE-DIMENSIONAL CONSOLIDATION
AASHTO T - 216
(Page 1 of 2)

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-10-21 SAMPLE ID: ST-1
STATION: NOT RECORDED DEPTH: 11.6 - 11.8 feet





SPECIMEN DETAILS

Initial Height, H_o =	1.001 in
Ring Diameter, D =	2.500 in
Initial Volume, V_o =	4.915 in^3
Initial (Total) Weight, W_{tot} =	0.339 lb
Dry Weight, W_{dry} =	0.278 lb
Initial Water Content, WC_o =	21.9 %
Wet (Total) Unit Weight, γ_{tot} =	119.07 pcf
Dry Unit Weight, γ_{dry} =	97.71 pcf
Volume of Solids, V_s =	2.957 in^3
Initial Saturation, S_o =	85.9 %
Final Water Content, WC_f =	17.3 %
Final Wet Weight, $W_{wet,f}$ =	0.326 lb
Final Dry Unit Weight, $\gamma_{dry,f}$ =	117.40 pcf
Final Saturation, S_f =	117.7 %
Final Void Ratio, e_f =	0.383

C_c = 0.205 C_r = 0.162
P_o = 1334 psf OCR = 2.249

TEST DETAILS

METHOD OF TESTING: "Method B"
CONDITION OF TEST: "Natural Moisture Content"
SPECIFIC GRAVITY: 2.60 (Actual)
NOTES:

TESTED BY: AW 6/9/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
1	5	16	38	40

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
31	17	14	21

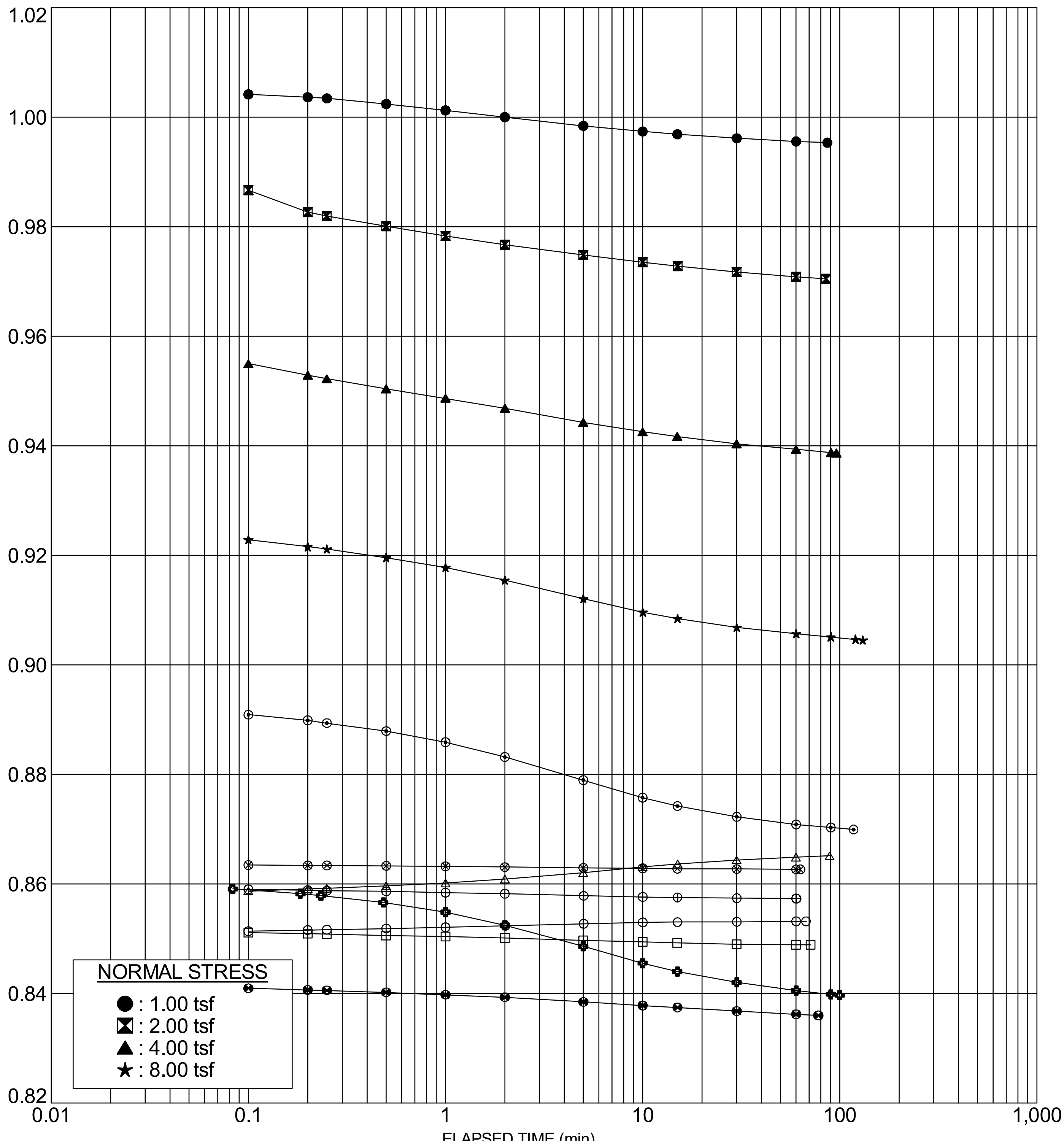
ODOT CLASS: A-6a HP (tsf): 2.50
DESCRIPTION: Medium Stiff, Brown, **SILT AND CLAY**, Some Sand, Trace Gravel, Moist

ONE-DIMENSIONAL CONSOLIDATION
AASHTO T - 216
(Page 2 of 2)

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-10-21 SAMPLE ID: ST-1
STATION: NOT RECORDED DEPTH: 11.6 - 11.8 feet



TESTED BY: AW 6/9/2021

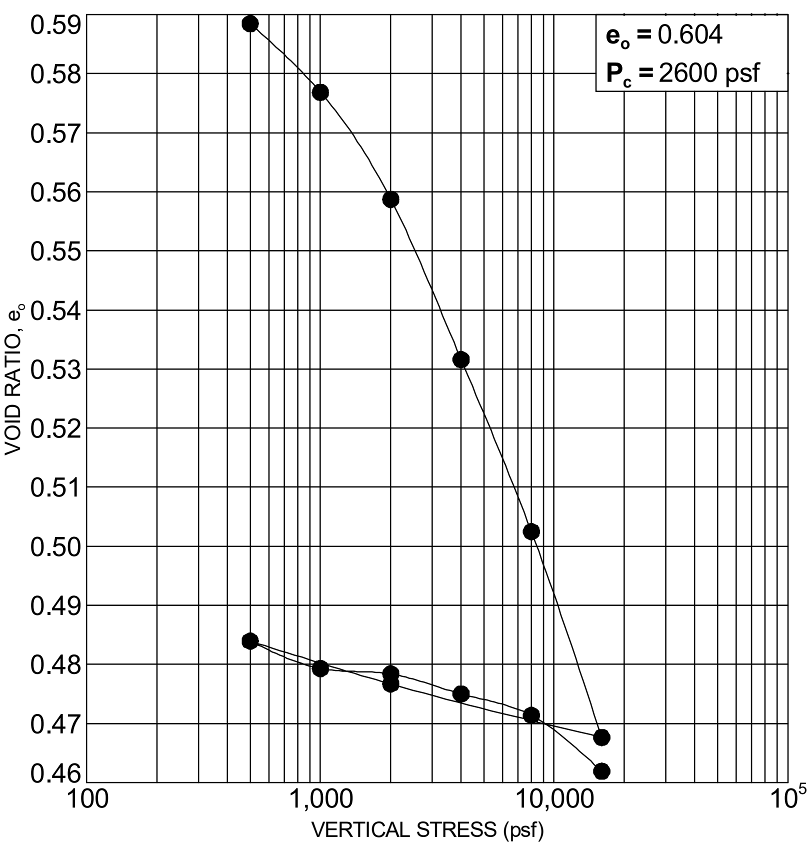
ONE-DIMENSIONAL CONSOLIDATION
AASHTO T - 216

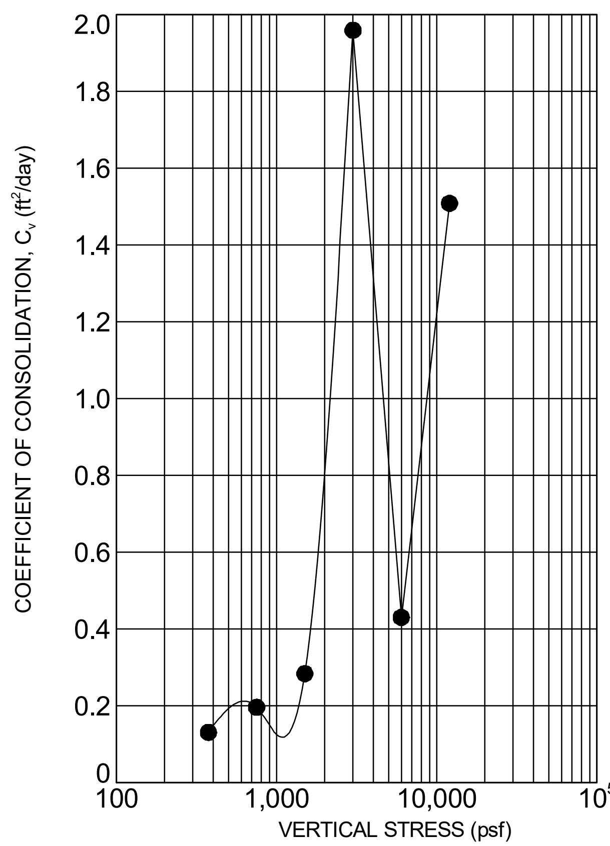
OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-11-21 SAMPLE ID: ST-1
STATION: NOT RECORDED DEPTH: 5.7 - 6.0 feet





SPECIMEN DETAILS

Initial Height, H_o =	0.996 in
Ring Diameter, D =	2.500 in
Initial Volume, V_o =	4.888 in^3
Initial (Total) Weight, W_{tot} =	0.361 lb
Dry Weight, W_{dry} =	0.294 lb
Initial Water Content, WC_o =	22.7 %
Wet (Total) Unit Weight, γ_{tot} =	127.50 pcf
Dry Unit Weight, γ_{dry} =	103.94 pcf
Volume of Solids, V_s =	3.048 in^3
Initial Saturation, S_o =	100.3 %
Final Water Content, WC_f =	18.0 %
Final Wet Weight, $W_{wet,f}$ =	0.347 lb
Final Dry Unit Weight, $\gamma_{dry,f}$ =	114.00 pcf
Final Saturation, S_f =	104.1 %
Final Void Ratio, e_f =	0.462

C_c = 0.108 C_r = 0.050
P_o = 656 psf OCR = 3.966

TEST DETAILS

METHOD OF TESTING: "Method B"
CONDITION OF TEST: Inundated
SPECIFIC GRAVITY: 2.67 (Assumed)
NOTES:

TESTED BY: AW 6/9/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
10	9	14	35	32

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
30	19	11	23

ODOT CLASS: A-6a HP (tsf): 0.50
DESCRIPTION: Medium Stiff, Brown, **SILT AND CLAY**, Some Sand, Little Gravel, Moist

ONE-DIMENSIONAL CONSOLIDATION
AASHTO T - 216
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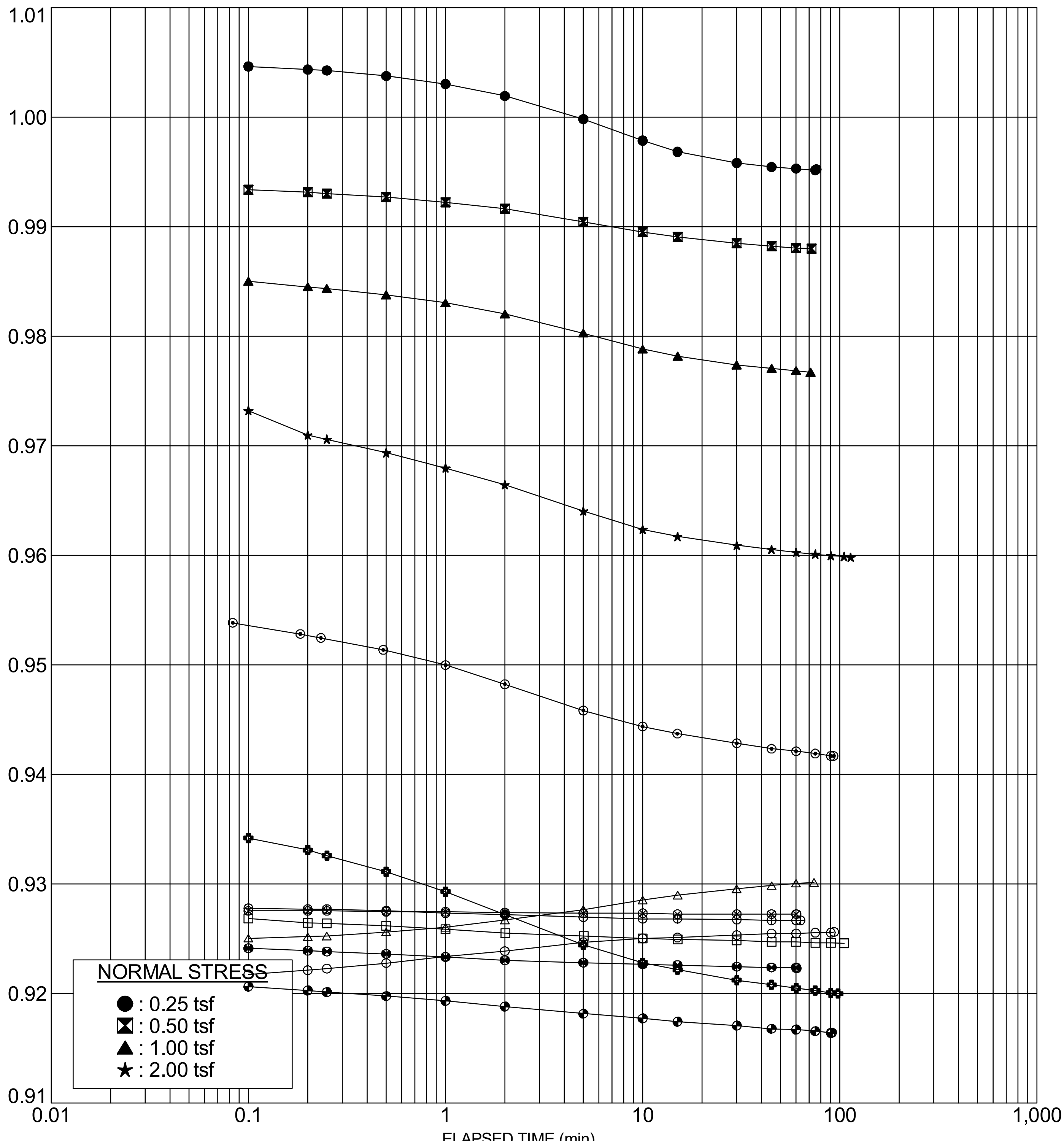
OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

PROJECT FRA-70-1358L
PID 89464
OGE NUMBER 600839
PROJECT TYPE STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-11-21
SAMPLE ID: ST-1
STATION: NOT RECORDED
DEPTH: 5.7 - 6.0 feet



TESTED BY: AW 6/9/2021

OHDOT CONSOLIDATION - PAGE 2 - OH DOT.GDT - 7/7/21 12:13 - X:\GINT\PROJECTS\600839.GPJ

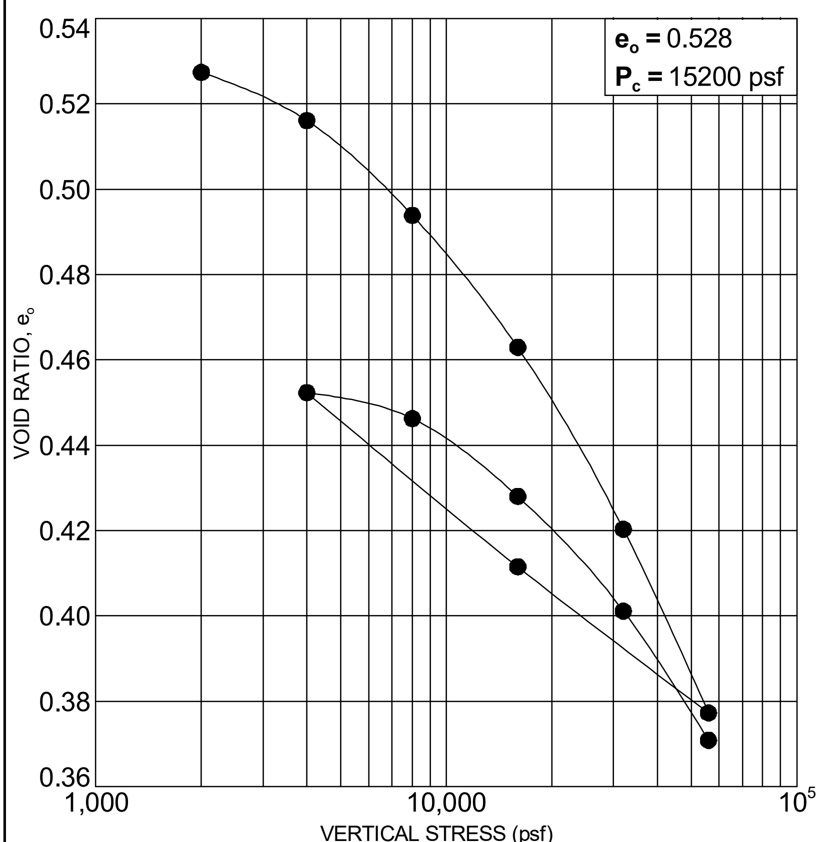
ONE-DIMENSIONAL CONSOLIDATION AASHTO T - 216 (Page 1 of 2)

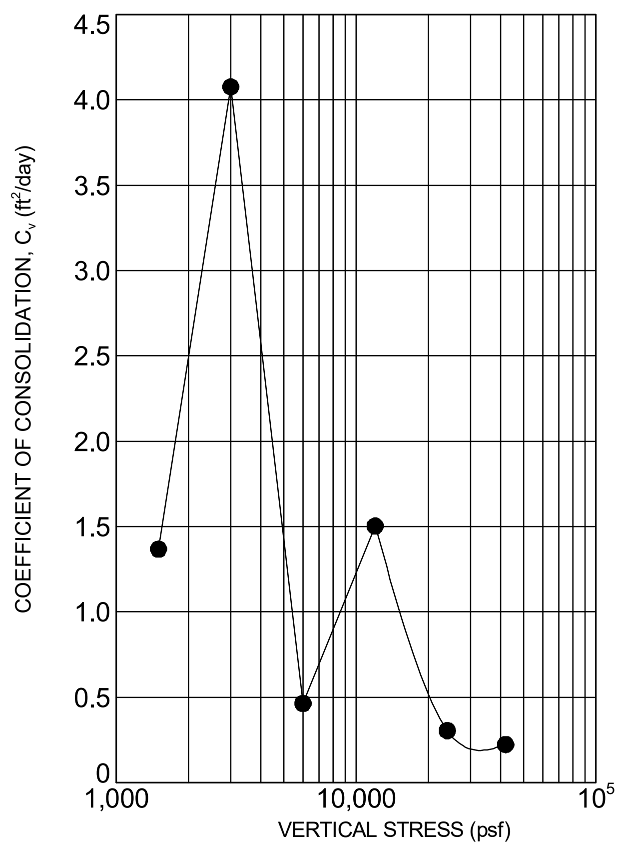
OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

PROJECT FRA-70-1358L　　**PID** 89464
OGE NUMBER 600839　　**PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-11-21　　SAMPLE ID: ST-7
STATION: NOT RECORDED　　DEPTH: 48.5 - 49.2 feet





SPECIMEN DETAILS

Initial Height, H_o =	0.993 in
Ring Diameter, D =	2.500 in
Initial Volume, V_o =	4.873 in^3
Initial (Total) Weight, W_{tot} =	0.367 lb
Dry Weight, W_{dry} =	0.309 lb
Initial Water Content, WC_o =	18.8 %
Wet (Total) Unit Weight, γ_{tot} =	130.12 pcf
Dry Unit Weight, γ_{dry} =	109.49 pcf
Volume of Solids, V_s =	3.184 in^3
Initial Saturation, S_o =	95.4 %
Final Water Content, WC_f =	19.7 %
Final Wet Weight, $W_{wet,f}$ =	0.370 lb
Final Dry Unit Weight, $\gamma_{dry,f}$ =	122.00 pcf
Final Saturation, S_f =	141.6 %
Final Void Ratio, e_f =	0.373

C_c = 0.157　　C_r = 0.056
P_o = 5578 psf　　OCR = 2.725

TEST DETAILS

METHOD OF TESTING: "Method B"
CONDITION OF TEST: Inundated
SPECIFIC GRAVITY: 2.68 (Actual)
NOTES:

TESTED BY: AW 6/8/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
0	2	3	38	57

ATTERBERG LIMITS　MOISTURE

LL	PL	PI	WC
40	23	17	17

ODOT CLASS: A-6b　　HP (tsf): -
DESCRIPTION: Hard, Gray, **SILTY CLAY**, Trace Sand, Damp

OHDOT CONSOLIDATION - PAGE 1 - OH DOT.GDT - 7/9/21 07:09 - X:\GINT\PROJECTS\600839.GPJ

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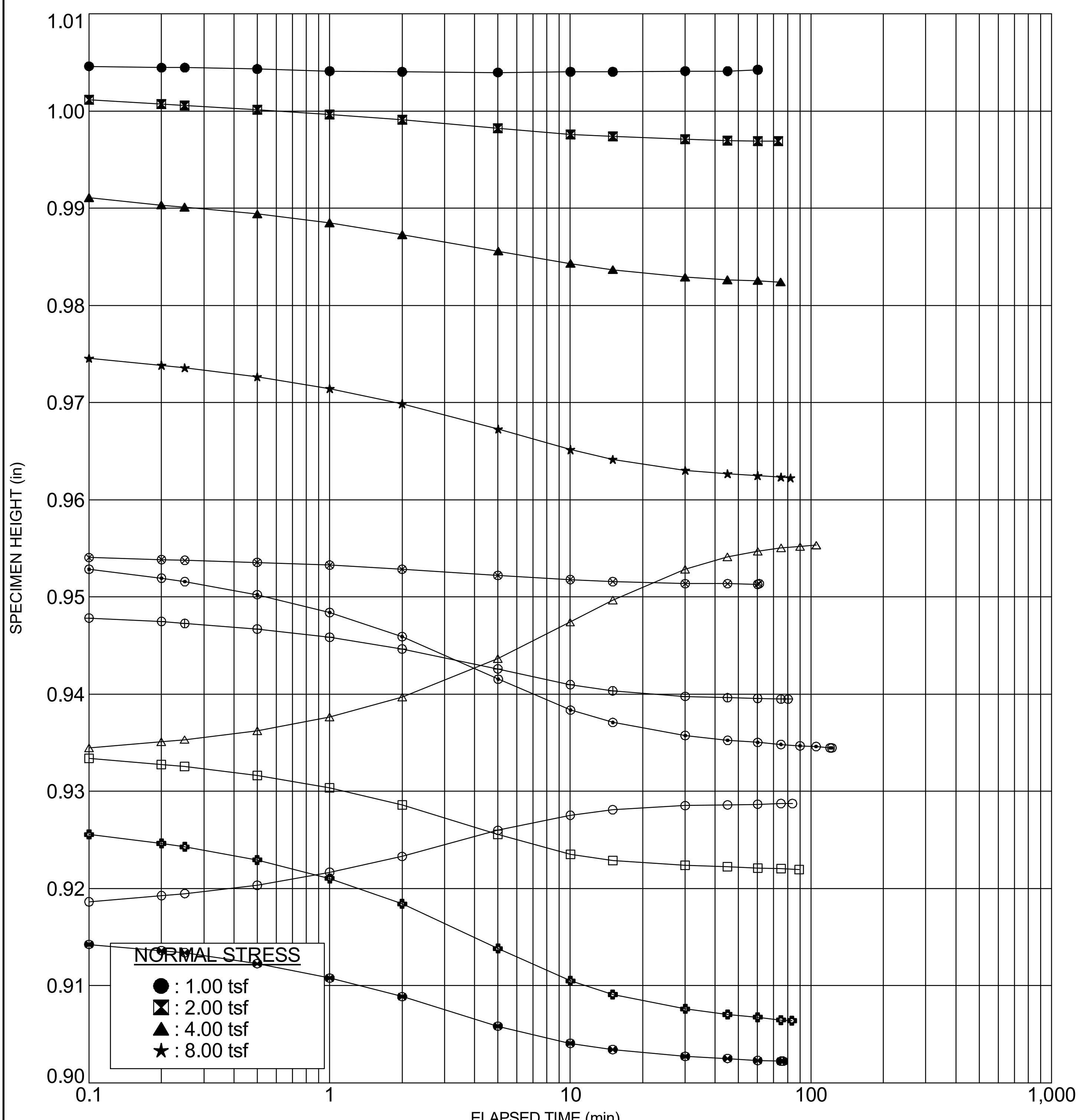
ONE-DIMENSIONAL CONSOLIDATION
AASHTO T - 216

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-11-21 SAMPLE ID: ST-7
STATION: NOT RECORDED DEPTH: 48.5 - 49.2 feet



TESTED BY: AW 6/8/2021

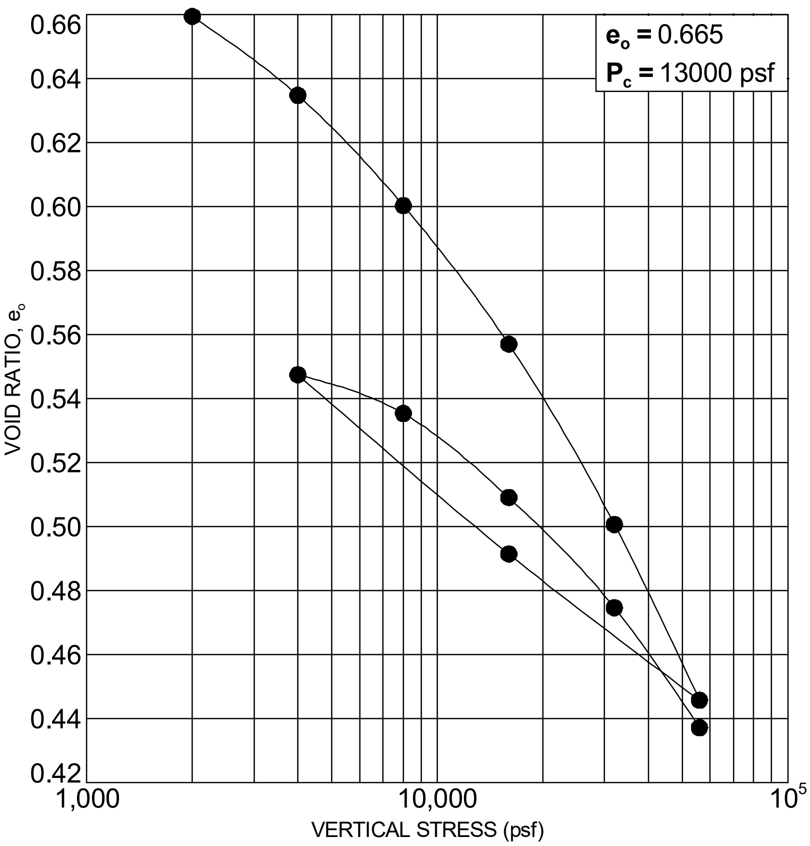
OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

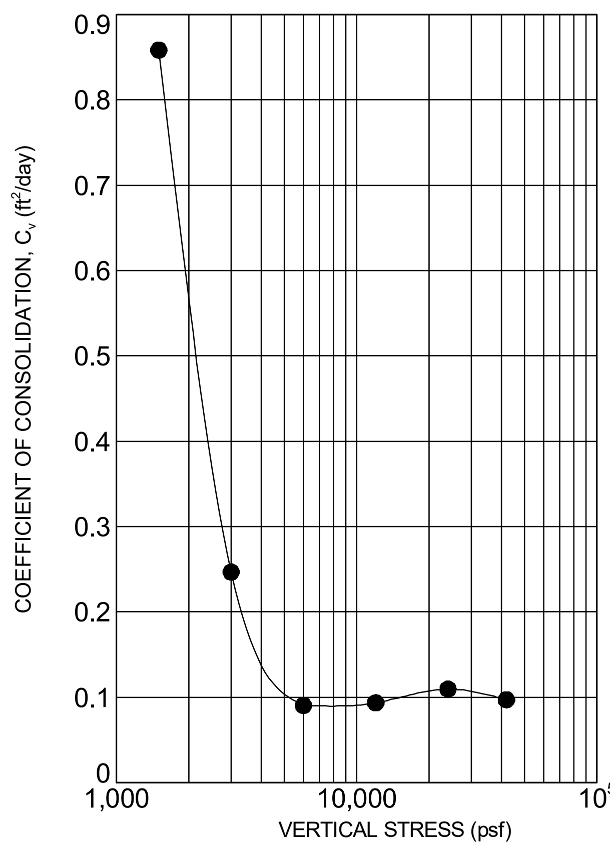
ONE-DIMENSIONAL CONSOLIDATION AASHTO T - 216 (Page 1 of 2)

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-20-21 SAMPLE ID: ST-1
STATION: NOT RECORDED DEPTH: 40.8 - 41.0 feet





SPECIMEN DETAILS

Initial Height, H_o =	1.000 in
Ring Diameter, D =	2.500 in
Initial Volume, V_o =	4.908 in^3
Initial (Total) Weight, W_{tot} =	0.354 lb
Dry Weight, W_{dry} =	0.283 lb
Initial Water Content, WC_o =	25.1 %
Wet (Total) Unit Weight, γ_{tot} =	124.73 pcf
Dry Unit Weight, γ_{dry} =	99.74 pcf
Volume of Solids, V_s =	2.945 in^3
Initial Saturation, S_o =	100.1 %
Final Water Content, WC_f =	20.4 %
Final Wet Weight, $W_{wet,f}$ =	0.341 lb
Final Dry Unit Weight, $\gamma_{dry,f}$ =	115.50 pcf
Final Saturation, S_f =	124.2 %
Final Void Ratio, e_f =	0.438

C_c = 0.210 C_r = 0.101
P_o = 4692 psf OCR = 2.771

TEST DETAILS

METHOD OF TESTING: "Method B"
CONDITION OF TEST: "Natural Moisture Content"
SPECIFIC GRAVITY: 2.66 (Actual)
NOTES:

TESTED BY: AW 6/8/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
0	0	0	14	86

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
46	22	24	26

ODOT CLASS: A-7-6 HP (tsf): 2.75
DESCRIPTION: Stiff, Gray, **CLAY**, Little Silt, Moist

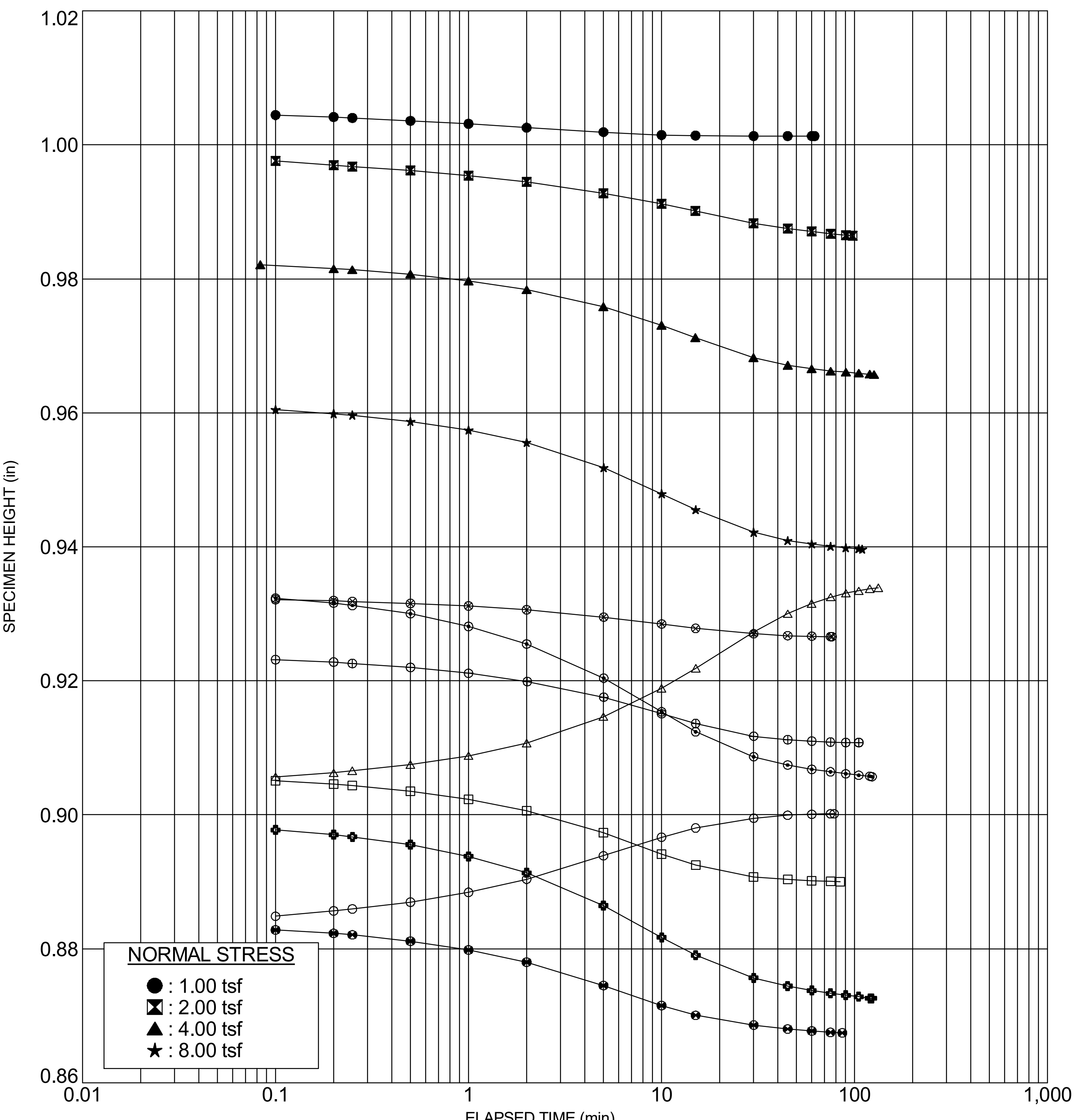
OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

ONE-DIMENSIONAL CONSOLIDATION AASHTO T - 216 (Page 2 of 2)

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-20-21 SAMPLE ID: ST-1
STATION: NOT RECORDED DEPTH: 40.8 - 41.0 feet



TESTED BY: AW 6/8/2021

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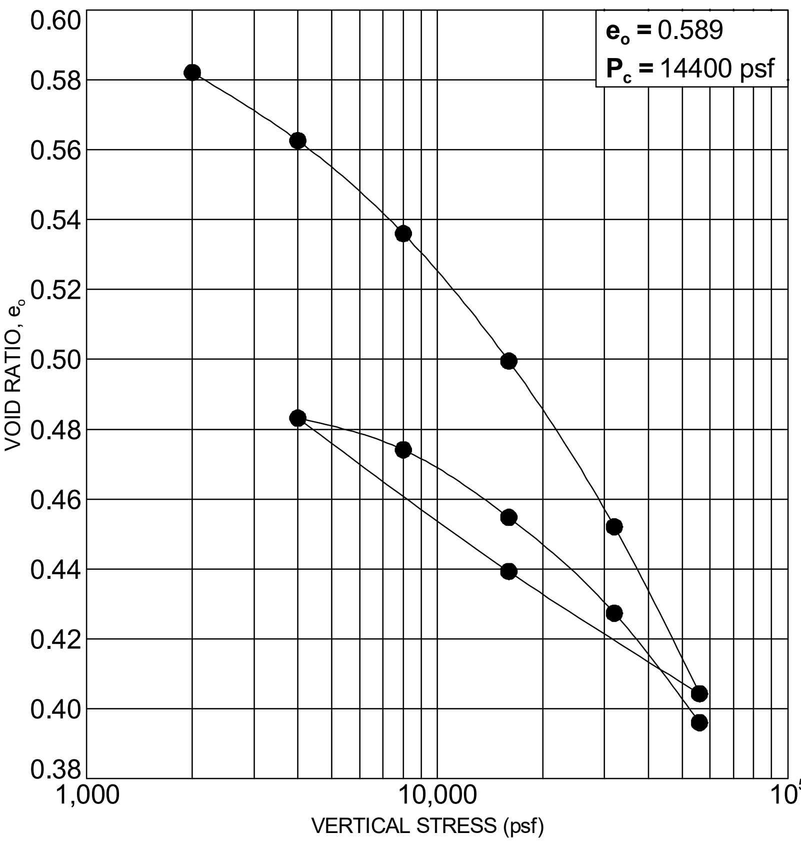
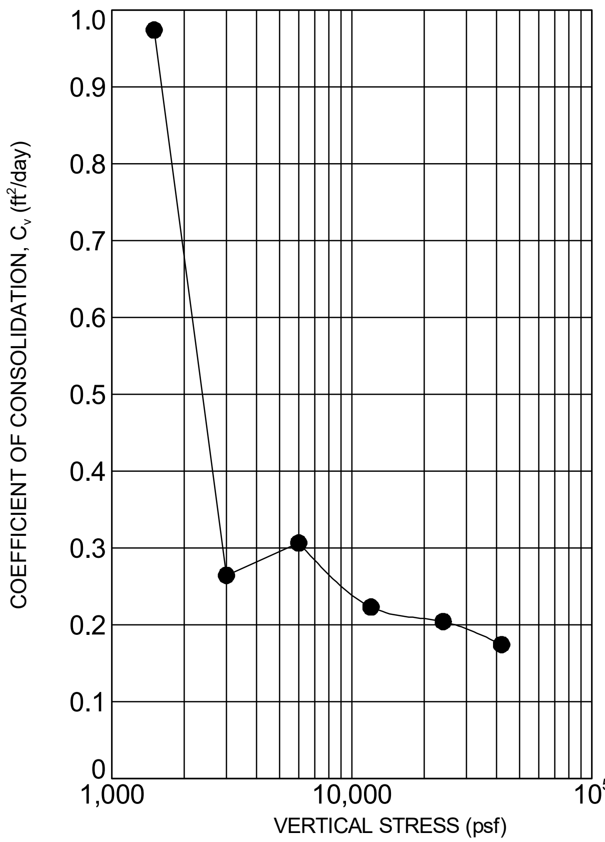
ONE-DIMENSIONAL CONSOLIDATION AASHTO T - 216 (Page 1 of 2)

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-20-21 SAMPLE ID: ST-2
STATION: NOT RECORDED DEPTH: 42.3 - 42.5 feet





SPECIMEN DETAILS

Initial Height, H_o =	1.001 in
Ring Diameter, D =	2.500 in
Initial Volume, V_o =	4.914 in^3
Initial (Total) Weight, W_{tot} =	0.365 lb
Dry Weight, W_{dry} =	0.297 lb
Initial Water Content, WC_o =	22.9 %
Wet (Total) Unit Weight, γ_{tot} =	128.38 pcf
Dry Unit Weight, γ_{dry} =	104.49 pcf
Volume of Solids, V_s =	3.089 in^3
Initial Saturation, S_o =	103.0 %
Final Water Content, WC_f =	21.3 %
Final Wet Weight, $W_{wet,f}$ =	0.360 lb
Final Dry Unit Weight, $\gamma_{dry,f}$ =	119.00 pcf
Final Saturation, S_f =	142.5 %
Final Void Ratio, e_f =	0.397

C_c = 0.180 C_r = 0.079
P_o = 4865 psf OCR = 2.960

TEST DETAILS

METHOD OF TESTING: "Method B"
CONDITION OF TEST: "Natural Moisture Content"
SPECIFIC GRAVITY: 2.66 (Actual)
NOTES:

TESTED BY: AW 6/9/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
0	0	0	25	75

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
41	21	20	24

ODOT CLASS: A-7-6 HP (tsf): 2.75

DESCRIPTION: Medium Stiff, Gray, **CLAY**, Some Silt, Moist

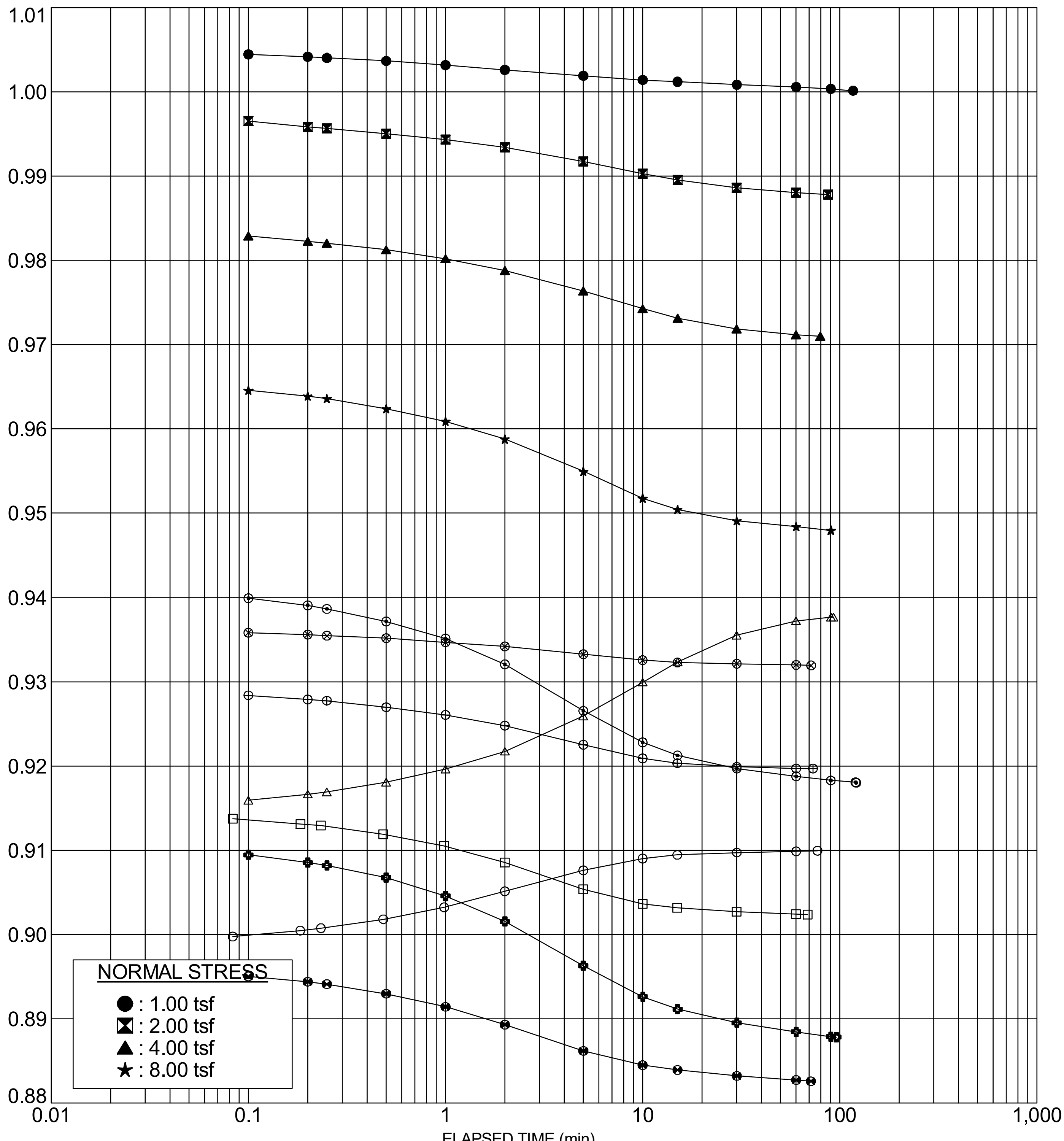
OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

ONE-DIMENSIONAL CONSOLIDATION AASHTO T - 216 (Page 2 of 2)

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-20-21 SAMPLE ID: ST-2
STATION: NOT RECORDED DEPTH: 42.3 - 42.5 feet



TESTED BY: AW 6/9/2021

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

ONE-DIMENSIONAL CONSOLIDATION AASHTO T - 216

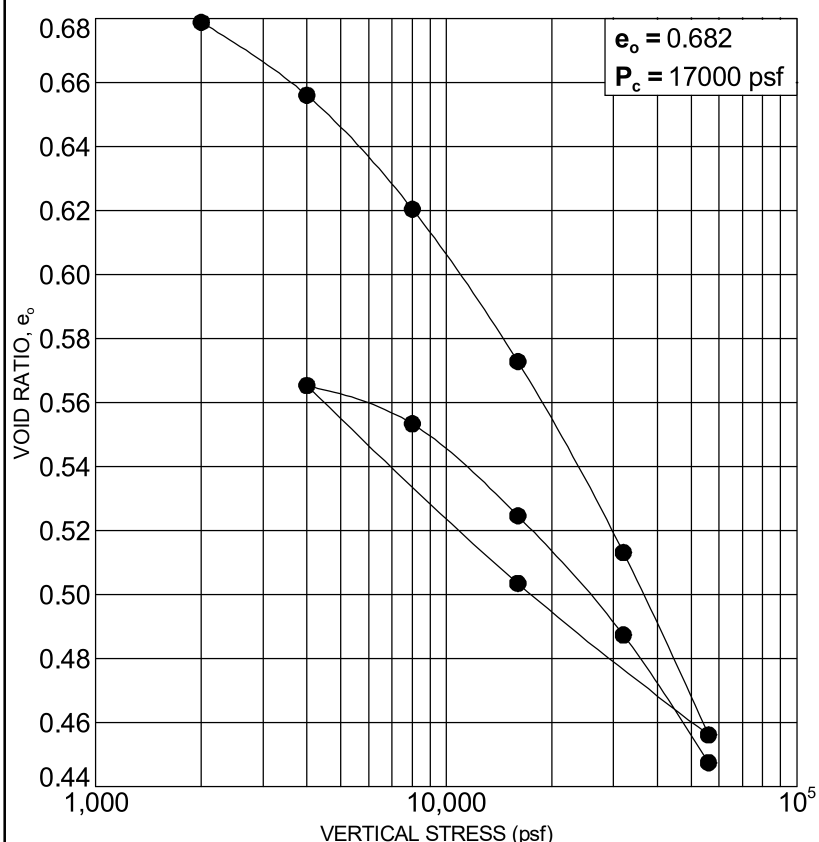
PROJECT FRA-70-1358L **PID** 89464

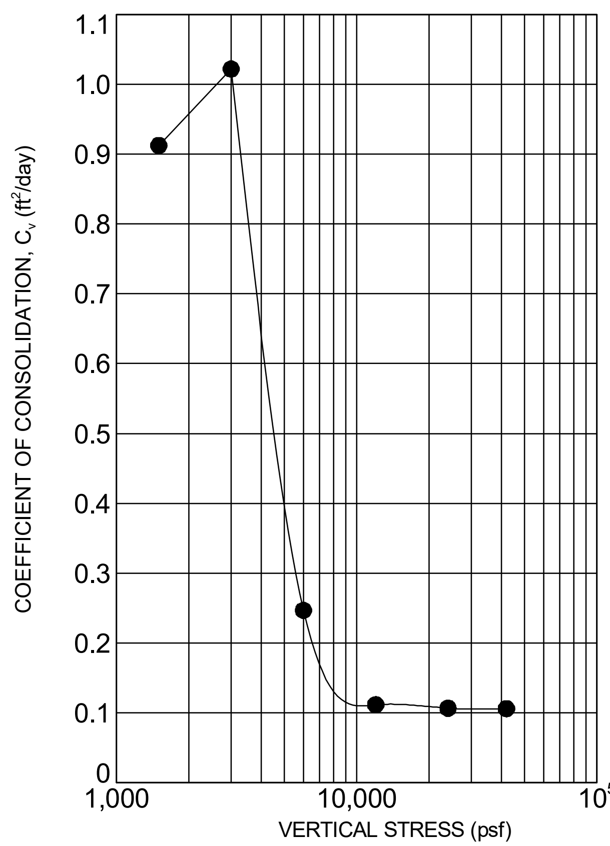
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-018-3-21 SAMPLE ID: ST-8

STATION: NOT RECORDED DEPTH: 48.6 - 48.8 feet





SPECIMEN DETAILS

Initial Height, H_o =	0.999 in
Ring Diameter, D =	2.500 in
Initial Volume, V_o =	4.904 in^3
Initial (Total) Weight, W_{tot} =	0.355 lb
Dry Weight, W_{dry} =	0.283 lb
Initial Water Content, WC_o =	25.2 %
Wet (Total) Unit Weight, γ_{tot} =	125.01 pcf
Dry Unit Weight, γ_{dry} =	99.81 pcf
Volume of Solids, V_s =	2.914 in^3
Initial Saturation, S_o =	99.5 %
Final Water Content, WC_f =	22.5 %
Final Wet Weight, $W_{wet,f}$ =	0.347 lb
Final Dry Unit Weight, $\gamma_{dry,f}$ =	116.00 pcf
Final Saturation, S_f =	135.5 %
Final Void Ratio, e_f =	0.448

C_c = 0.220 C_r = 0.099

P_o = 5589 psf OCR = 3.042

TEST DETAILS

METHOD OF TESTING: "Method B"

CONDITION OF TEST: "Natural Moisture Content"

SPECIFIC GRAVITY: 2.69 (Actual)

NOTES:

TESTED BY: AW 6/10/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
0	1	1	18	80

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
44	21	23	27

ODOT CLASS: A-7-6 HP (tsf): 3.50

DESCRIPTION: Stiff, Gray, **CLAY**, Little Silt, Trace Sand, Moist

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

ONE-DIMENSIONAL CONSOLIDATION
AASHTO T - 216
(Page 2 of 2)

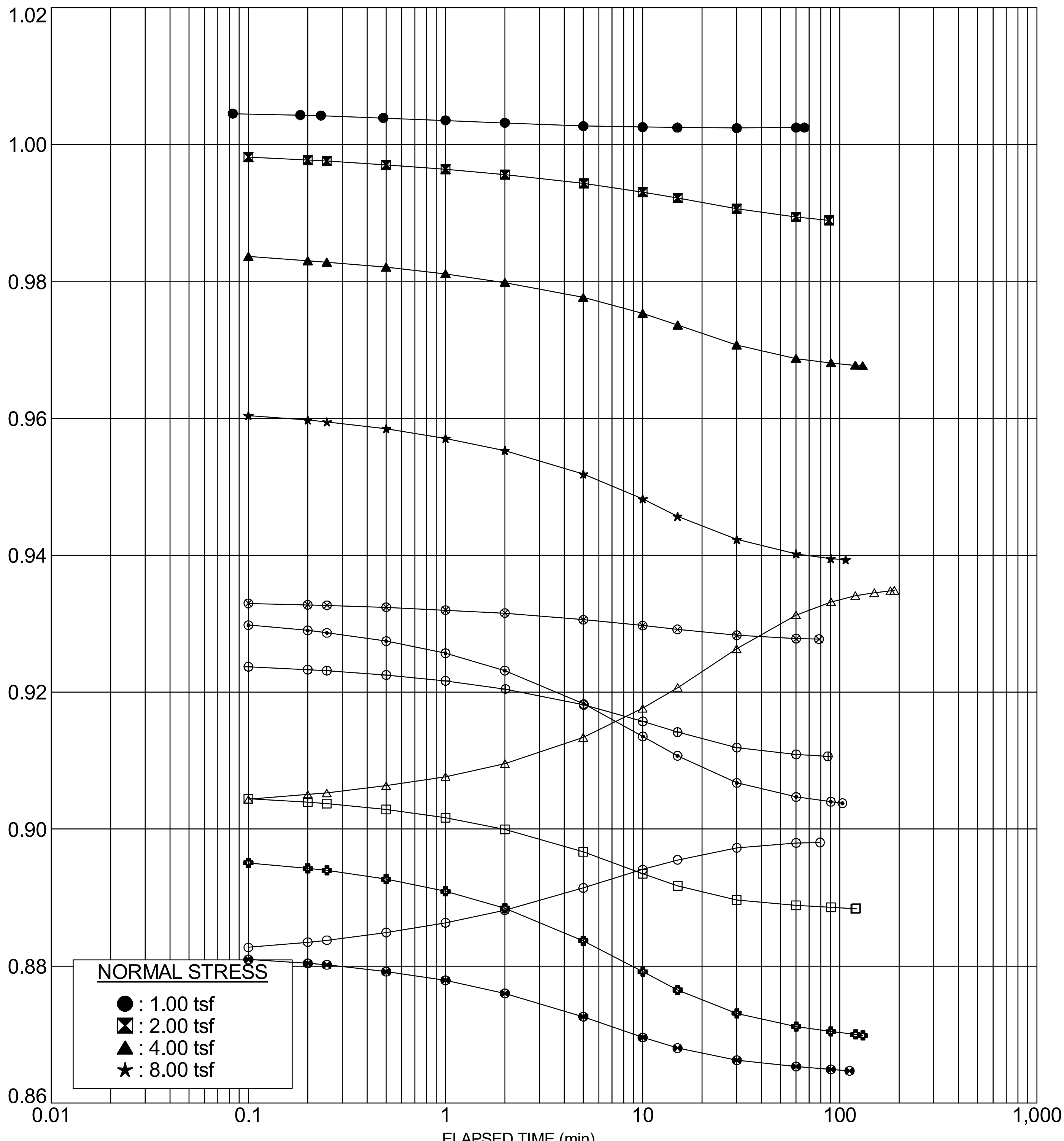
PROJECT FRA-70-1358L **PID** 89464

OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-018-3-21 SAMPLE ID: ST-8

STATION: NOT RECORDED DEPTH: 48.6 - 48.8 feet



TESTED BY: AW 6/10/2021

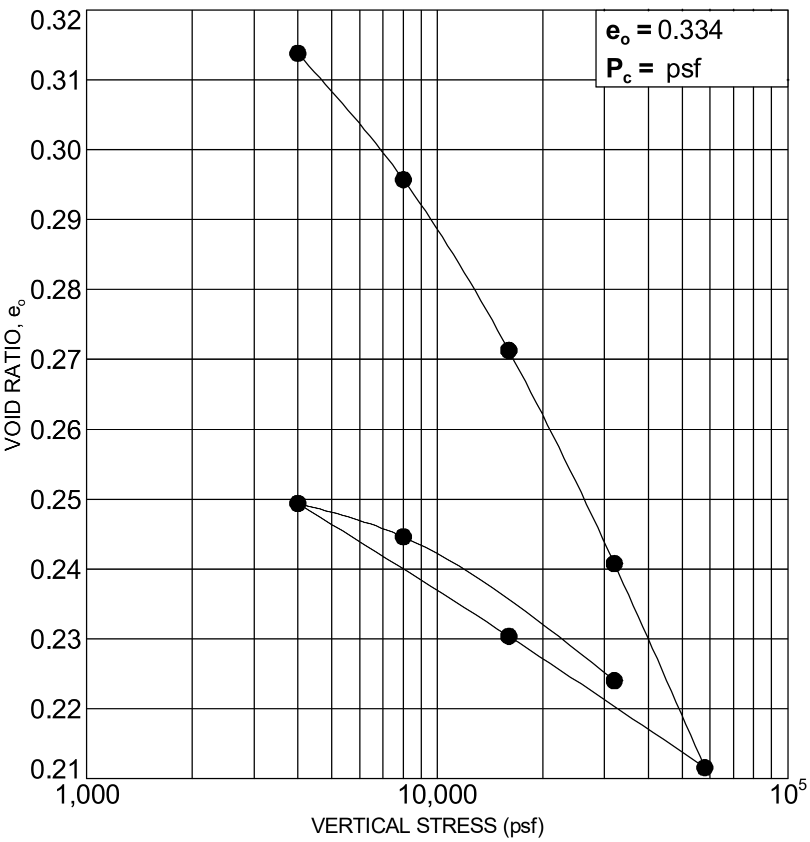
OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

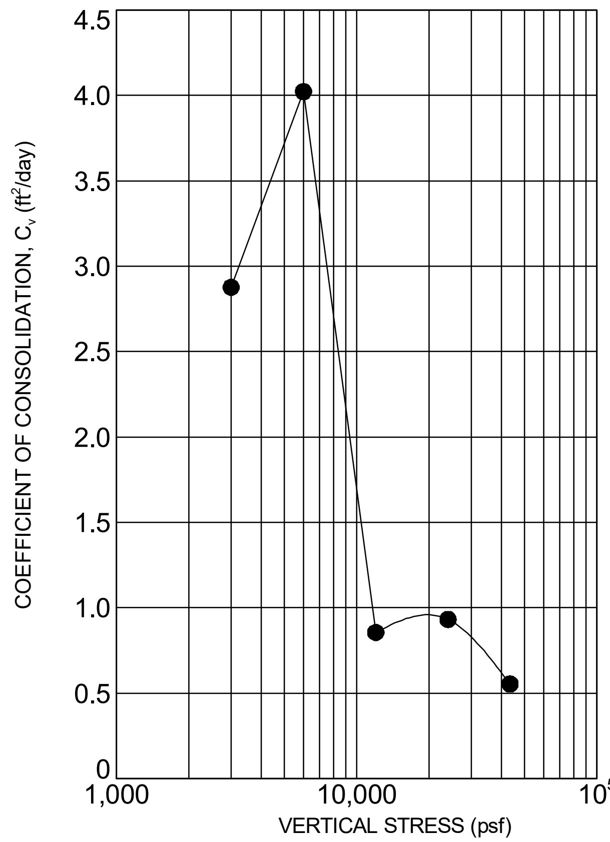
ONE-DIMENSIONAL CONSOLIDATION
AASHTO T - 216

PROJECT FRA-70-1358L
PID 89464
OGE NUMBER 600839
PROJECT TYPE STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-018-4-21
SAMPLE ID: ST-2b
STATION: NOT RECORDED
DEPTH: 38.2 - 38.4 feet





SPECIMEN DETAILS

Initial Height, H_o =	1.004 in
Ring Diameter, D =	2.500 in
Initial Volume, V_o =	4.930 in^3
Initial (Total) Weight, W_{tot} =	0.400 lb
Dry Weight, W_{dry} =	0.356 lb
Initial Water Content, WC_o =	12.3 %
Wet (Total) Unit Weight, γ_{tot} =	140.33 pcf
Dry Unit Weight, γ_{dry} =	124.92 pcf
Volume of Solids, V_s =	3.695 in^3
Initial Saturation, S_o =	98.5 %
Final Water Content, WC_f =	11.0 %
Final Wet Weight, $W_{wet,f}$ =	0.396 lb
Final Dry Unit Weight, $\gamma_{dry,f}$ =	136.20 pcf
Final Saturation, S_f =	130.7 %
Final Void Ratio, e_f =	0.224

C_c =		C_r =	0.072
P_o =	4393 psf	OCR =	

TEST DETAILS

METHOD OF TESTING: "Method B"
CONDITION OF TEST: "Natural Moisture Content"
SPECIFIC GRAVITY: 2.67 (Assumed)
NOTES: Pc and Cc are indeterminate

TESTED BY: AW 5/17/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
16	7	13	32	32

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
24	14	10	13

ODOT CLASS: A-4a
HP (tsf): 2.50

DESCRIPTION: Very Stiff, Gray, **SANDY SILT**, Some Clay, Little Gravel, Damp

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

ONE-DIMENSIONAL CONSOLIDATION AASHTO T - 216 (Page 2 of 2)

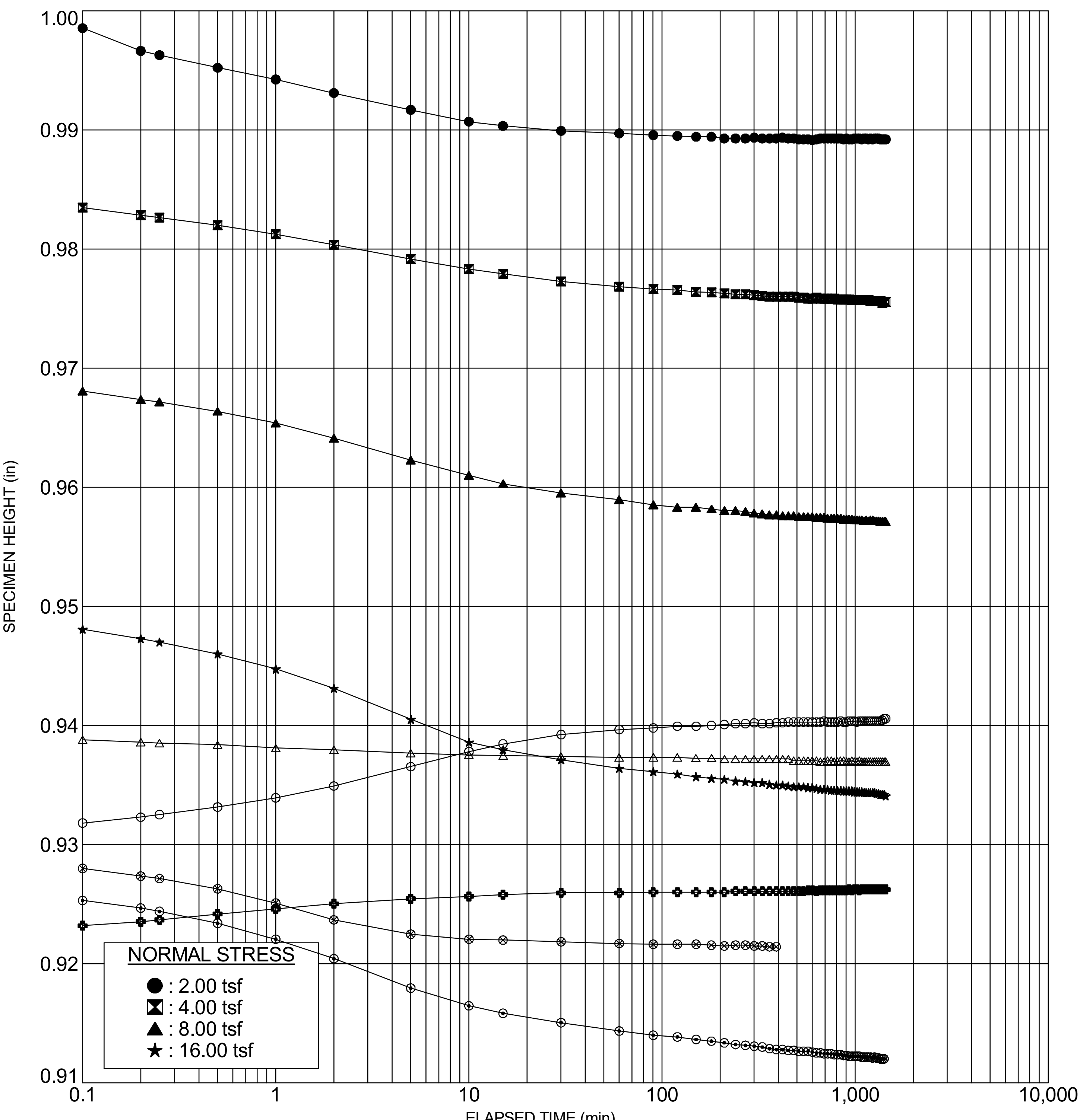
PROJECT FRA-70-1358L **PID** 89464

OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-018-4-21 SAMPLE ID: ST-2b

STATION: NOT RECORDED DEPTH: 38.2 - 38.4 feet



TESTED BY: AW 5/17/2021

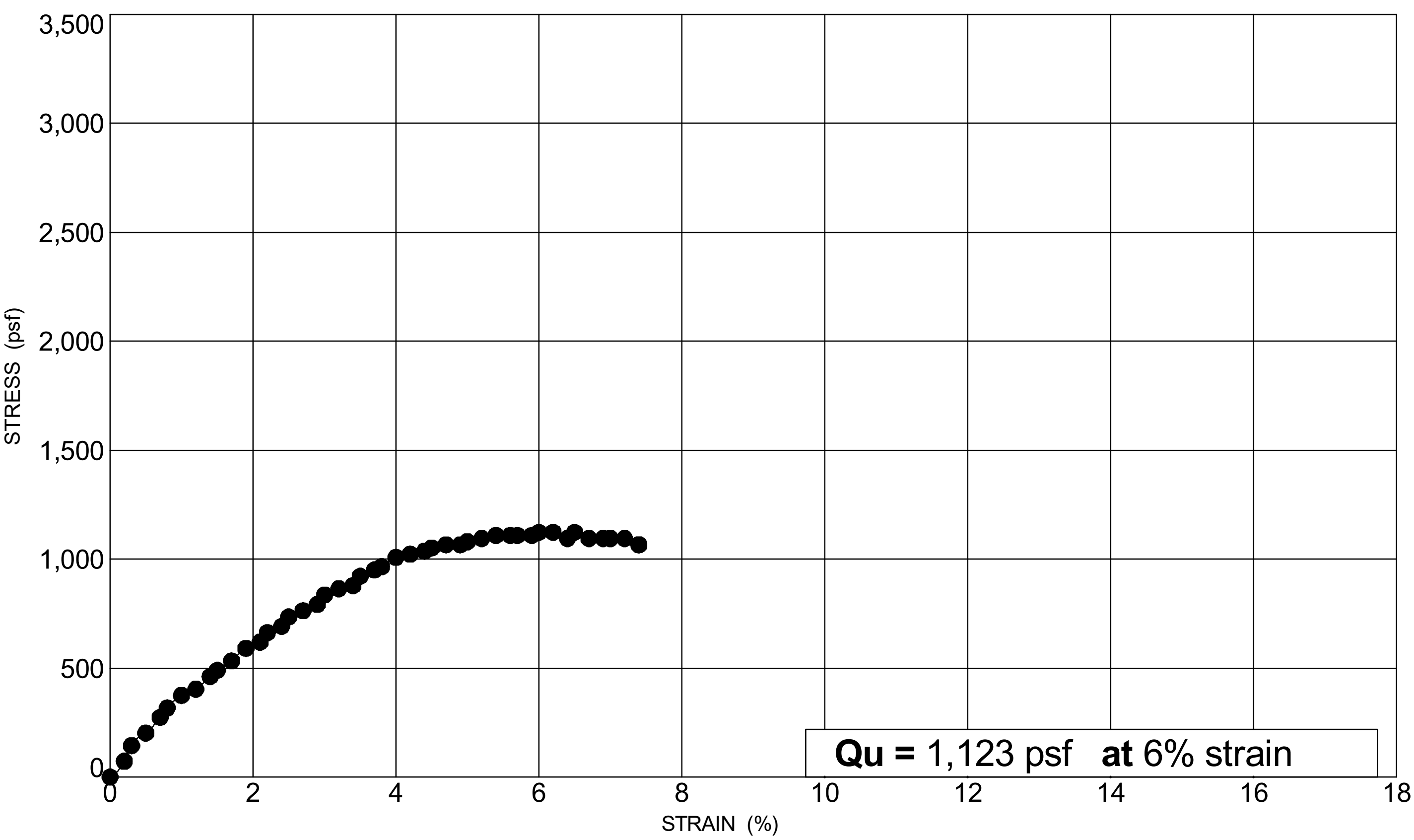
UNCONFINED COMPRESSION TEST
AASHTO T - 208

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-10-21 SAMPLE ID: ST-1
STATION: NOT RECORDED DEPTH: 11.2 - 11.6 feet



SPECIMEN FAILURE SKETCHES OR PHOTOGRAPHS

FRONT VIEW

SIDE VIEW

SPECIMEN DETAILS

HEIGHT: 5.76 inches
DIAMETER: 2.85 inches
WET UNIT WT: 121.71 pcf
DRY UNIT WT: 95.33 pcf

TESTED BY: AW 6/30/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
1	5	16	38	40

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
31	17	14	21

ODOT CLASS: A-6a HP (tsf): 2.50

DESCRIPTION: Medium Stiff, Brown, **SILT AND CLAY**, Some Sand, Trace Gravel, Moist

OHDOT UNCONFINED COMPRESSION - OH DOT.GDT - 7/9/21 06:54 - X:\GINT\PROJECTS\600839.GPJ

UNCONFINED COMPRESSION TEST
AASHTO T - 208

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

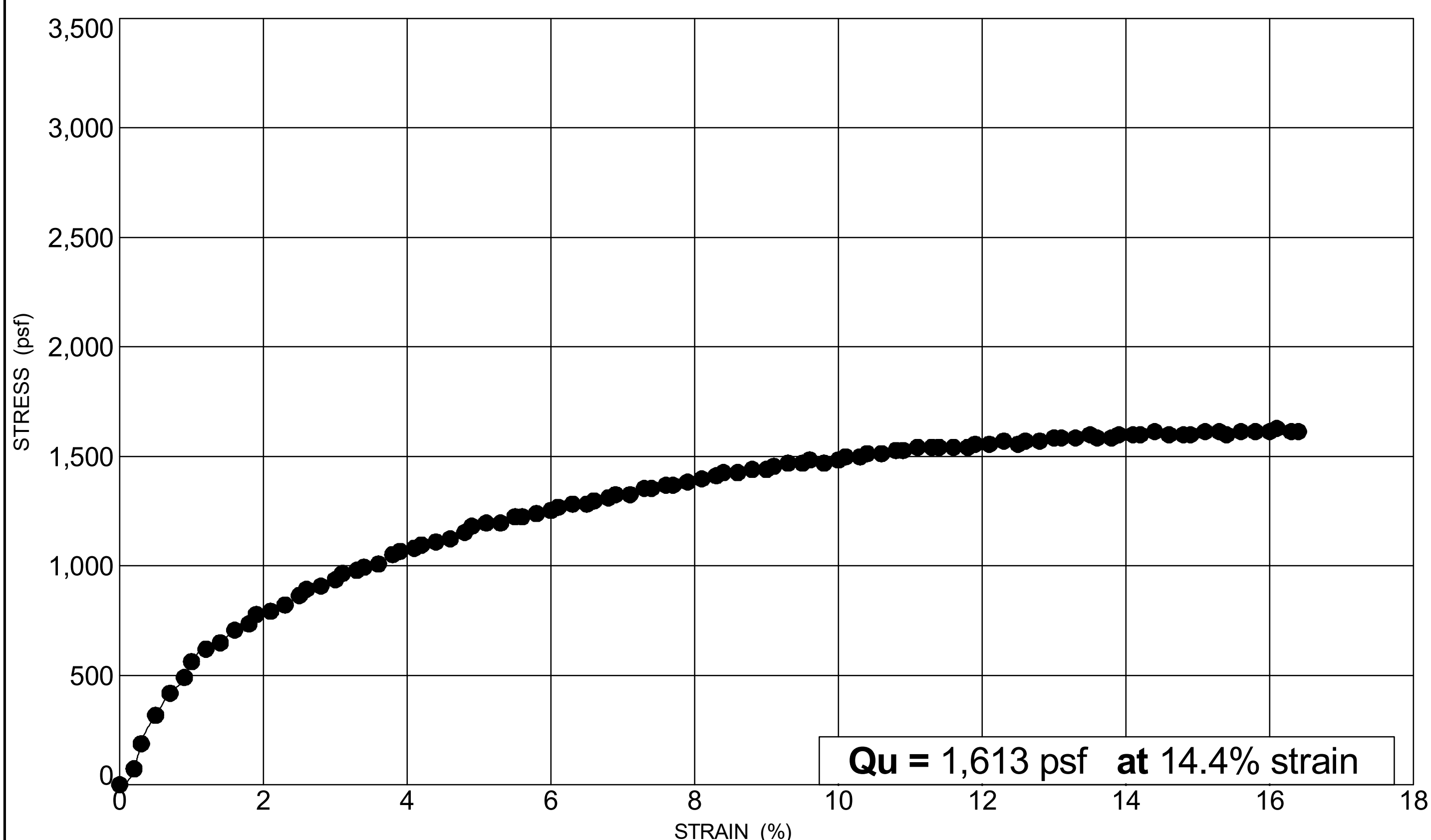
PROJECT FRA-70-1358L | **PID** 89464

OGE NUMBER 600839 | **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-11-21 | SAMPLE ID: ST-1

STATION: NOT RECORDED | DEPTH: 5.2 - 5.65 feet



SPECIMEN FAILURE SKETCHES OR PHOTOGRAPHS


FRONT VIEW


SIDE VIEW

SPECIMEN DETAILS

HEIGHT: 5.75 inches

DIAMETER: 2.84 inches

WET UNIT WT: 129.14 pcf

DRY UNIT WT: 105.37 pcf

TESTED BY: AW 6/30/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
10	9	14	35	32

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
30	19	11	23

ODOT CLASS: A-6a HP (tsf): 0.50

DESCRIPTION: Medium Stiff, Brown, **SILT AND CLAY**, Some Sand, Little Gravel, Moist

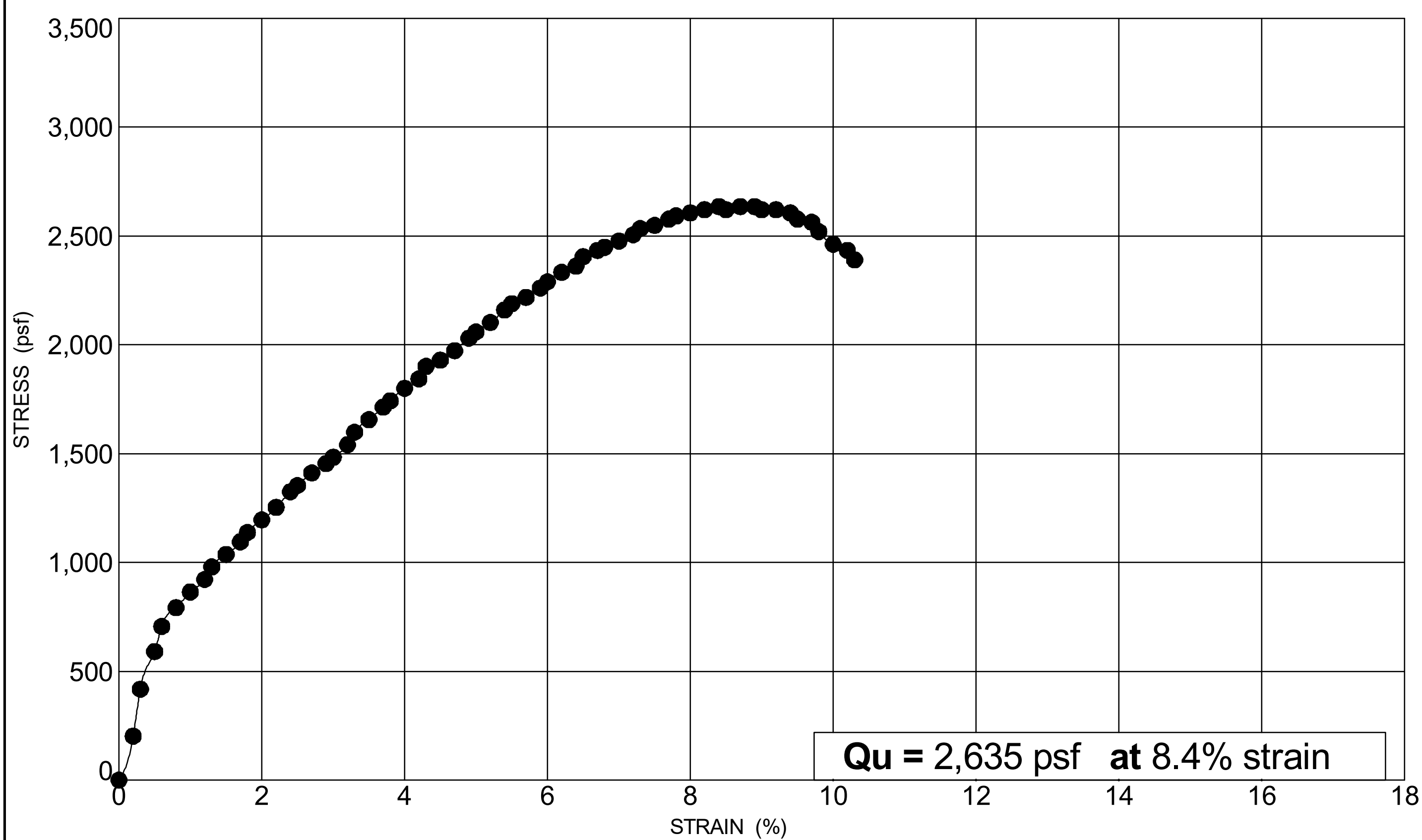
OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

UNCONFINED COMPRESSION TEST
AASHTO T - 208

PROJECT FRA-70-1358L | **PID** 89464
OGE NUMBER 600839 | **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-20-21 | SAMPLE ID: ST-1
STATION: NOT RECORDED | DEPTH: 40.2 - 40.7 feet



SPECIMEN FAILURE SKETCHES OR PHOTOGRAPHS


FRONT VIEW


SIDE VIEW

SPECIMEN DETAILS

HEIGHT: 5.74 inches
DIAMETER: 2.86 inches
WET UNIT WT: 125.50 pcf
DRY UNIT WT: 99.87 pcf

TESTED BY: AW 6/30/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
0	0	0	14	86

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
46	22	24	26

ODOT CLASS: A-7-6 HP (tsf): 2.75
DESCRIPTION: Stiff, Gray, **CLAY**, Little Silt, Moist

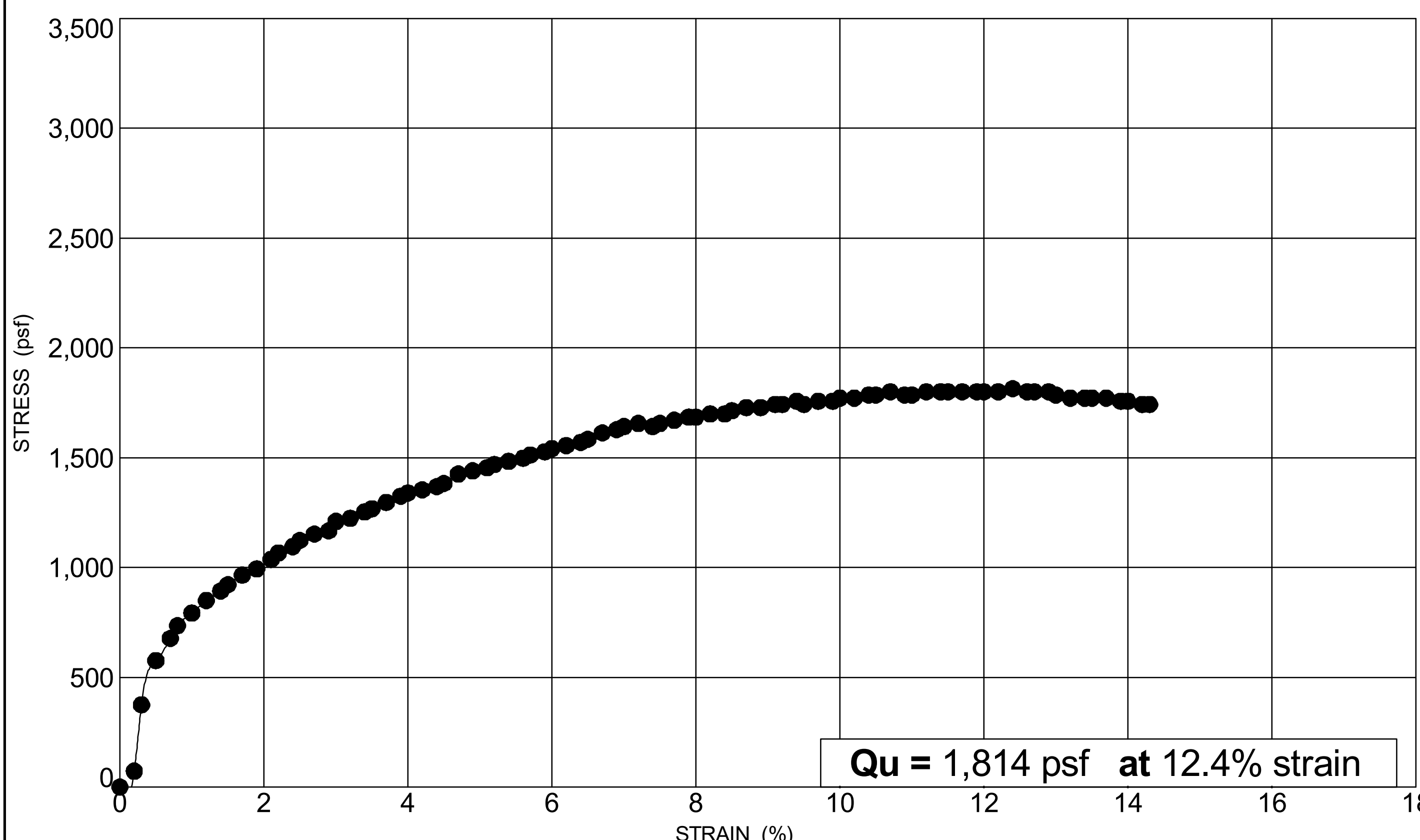
UNCONFINED COMPRESSION TEST
AASHTO T - 208

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

PROJECT FRA-70-1358L **PID** 89464
OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-017-20-21 SAMPLE ID: ST-2
STATION: NOT RECORDED DEPTH: 41.8 - 42.25 feet



SPECIMEN FAILURE SKETCHES OR PHOTOGRAPHS

FRONT VIEW

SIDE VIEW

SPECIMEN DETAILS

HEIGHT: 5.75 inches
DIAMETER: 2.82 inches
WET UNIT WT: 125.55 pcf
DRY UNIT WT: 99.66 pcf

TESTED BY: AW 6/30/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
0	0	0	25	75

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
41	21	20	24

ODOT CLASS: A-7-6 HP (tsf): 2.75

DESCRIPTION: Medium Stiff, Gray, **CLAY**, Some Silt, Moist

OHDOT UNCONFINED COMPRESSION - OH DOT.GDT - 7/9/21 06:54 - X:\GINT\PROJECTS\600839.GPJ

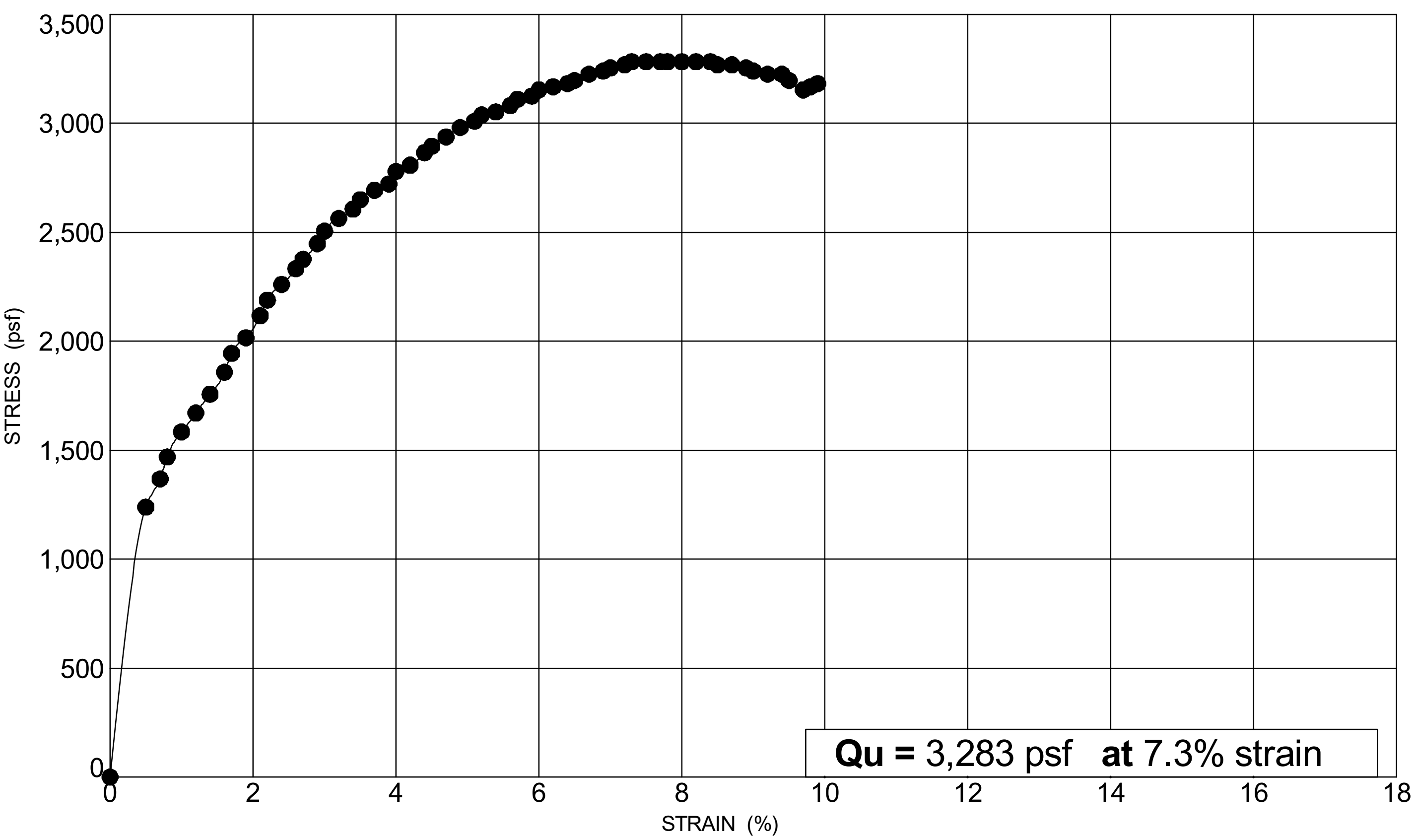
OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

UNCONFINED COMPRESSION TEST
AASHTO T - 208

PROJECT FRA-70-1358L
PID 89464
OGE NUMBER 600839
PROJECT TYPE STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-018-3-21
SAMPLE ID: ST-8
STATION: NOT RECORDED
DEPTH: 48.1 - 48.6 feet



SPECIMEN FAILURE SKETCHES OR PHOTOGRAPHS

FRONT VIEW

SIDE VIEW

SPECIMEN DETAILS

HEIGHT: 5.75 inches
DIAMETER: 2.79 inches
WET UNIT WT: 127.48 pcf
DRY UNIT WT: 100.30 pcf

TESTED BY: AW 6/30/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
0	1	1	18	80

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
44	21	23	27

ODOT CLASS: A-7-6
HP (tsf): 3.50

DESCRIPTION: Stiff, Gray, **CLAY**, Little Silt, Trace Sand, Moist

UNCONFINED COMPRESSION TEST
AASHTO T - 208

OHIO DEPARTMENT OF TRANSPORTION
OFFICE OF GEOTECHNICAL ENGINEERING

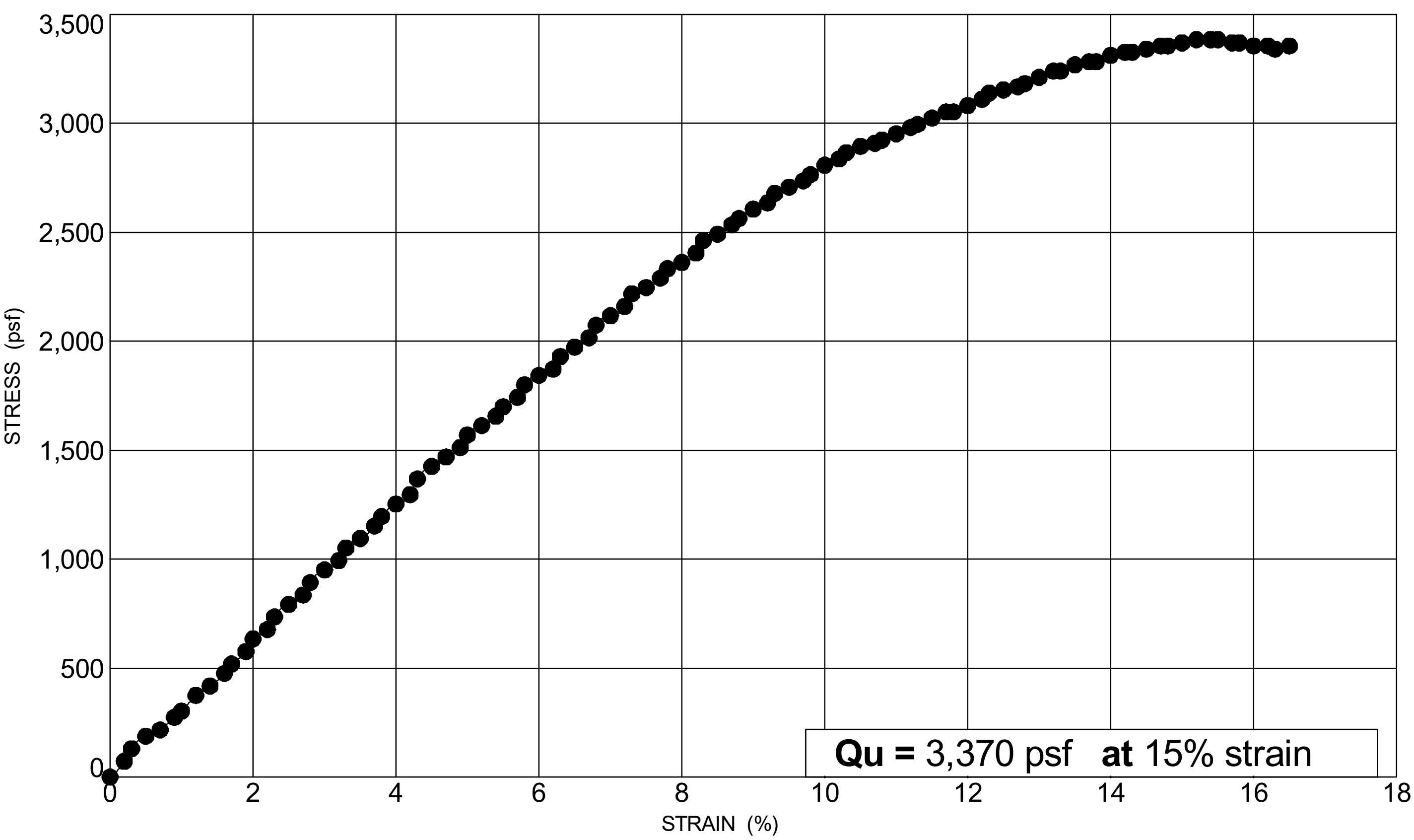
PROJECT FRA-70-1358L **PID** 89464

OGE NUMBER 600839 **PROJECT TYPE** STRUCTURE

SAMPLE IDENTIFICATION

BORING ID: B-018-4-21 SAMPLE ID: ST-2b

STATION: NOT RECORDED DEPTH: 37.5 - 38.0 feet



SPECIMEN FAILURE SKETCHES OR PHOTOGRAPHS

FRONT VIEW

SIDE VIEW

SPECIMEN DETAILS

HEIGHT: 5.73 inches

DIAMETER: 2.87 inches

WET UNIT WT: 144.11 pcf

DRY UNIT WT: 127.26 pcf

TESTED BY: AW 6/23/2021

CLASSIFICATION RESULTS

GRADATION (%)

GR	CS	FS	SI	CL
16	7	13	32	32

ATTERBERG LIMITS / MOISTURE

LL	PL	PI	WC
24	14	10	13

ODOT CLASS: A-4a HP (tsf): 2.50

DESCRIPTION: Very Stiff, Gray, **SANDY SILT**, Some Clay, Little Gravel, Damp

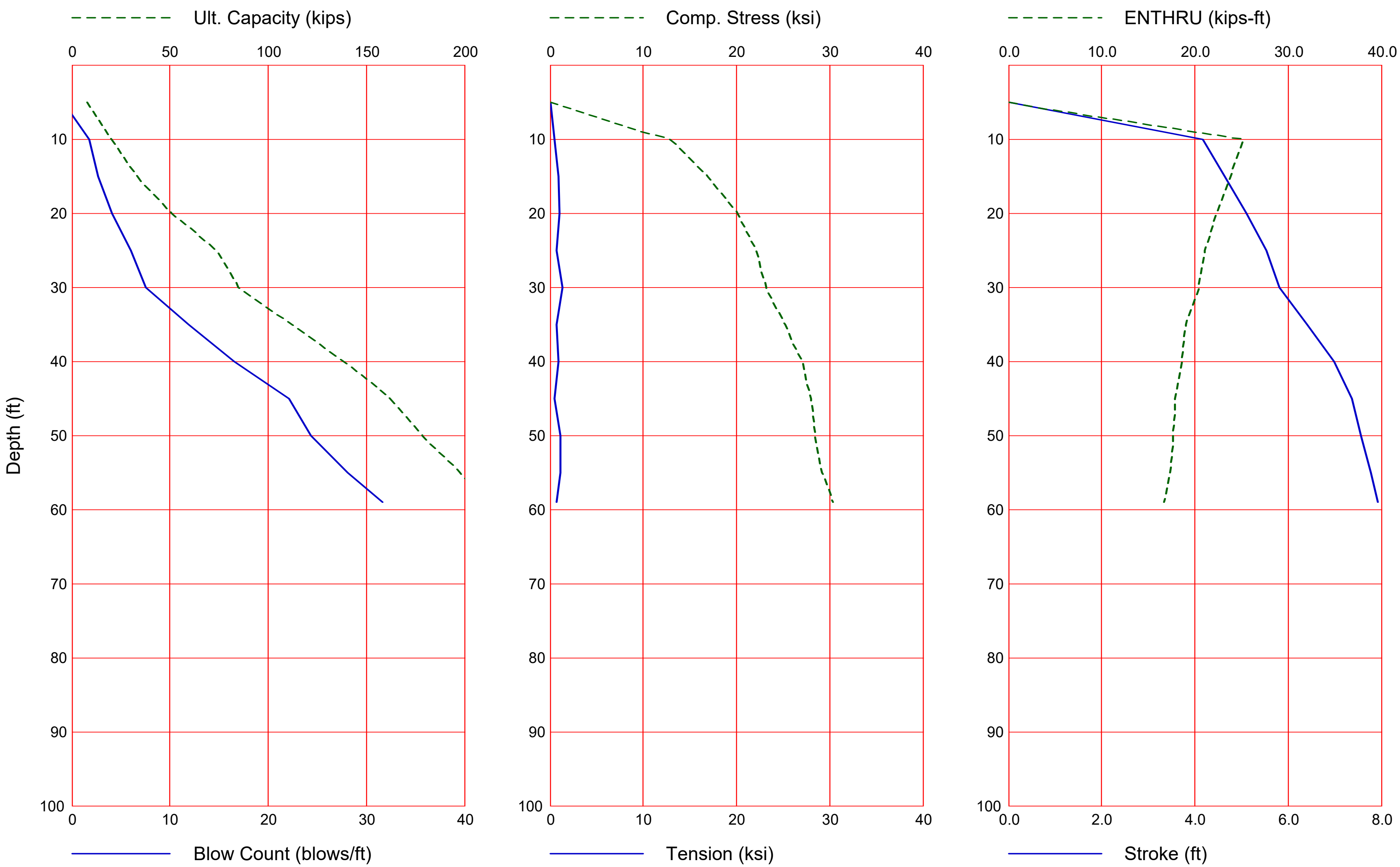
APPENDIX VII

GRLWEAP DRIVEABILITY ANALYSIS OUTPUTS

Resource International Inc
FRA-70-1358L - RA - B-017-9-13 - HP12x53

Jun 06 2022
GRLWEAP Version 2010

Gain/Loss 3 at Shaft and Toe 0.500 / 1.000



Gain/Loss 3 at Shaft and Toe 0.500 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Stroke ft	ENTHRU kips-ft
5.0	7.6	7.1	0.5	-1.0	0.000	0.000	0.00	0.0
10.0	20.2	15.3	4.9	1.8	13.010	-0.441	4.16	25.2
15.0	33.2	23.6	9.6	2.7	16.889	-0.893	4.64	23.8
20.0	51.1	37.9	13.2	4.1	20.126	-1.063	5.10	22.3
25.0	73.5	56.7	16.8	6.0	22.091	-0.730	5.53	21.1
30.0	84.8	82.1	2.7	7.5	23.244	-1.364	5.81	20.4
35.0	112.1	109.4	2.7	11.9	25.250	-0.720	6.41	19.0
40.0	138.4	135.8	2.7	16.6	27.007	-0.947	6.99	18.6
45.0	162.2	159.5	2.7	22.1	27.997	-0.452	7.36	17.9
50.0	178.6	174.2	4.4	24.4	28.440	-1.111	7.57	17.6
55.0	197.9	190.1	7.8	28.1	29.200	-1.068	7.78	17.3
59.0	213.0	205.2	7.8	31.6	30.349	-0.709	7.93	16.7

Total Continuous Driving Time 15.00 minutes; Total Number of Blows 673 (starting at penetration 5.0 ft)

GRLWEAP - Version 2010
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS

written by GRL Engineers, Inc. (formerly Goble Rausche Likins
and Associates, Inc.) with cooperation from Pile Dynamics, Inc.

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

The GRLWEAP program simulates the behavior of a preformed pile driven by either an impact hammer or a vibratory hammer. The program is based on mathematical models, which describe motion and forces of hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate, often complex, dynamic situations.

A wave equation analysis generally relies on input data, which represents normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. All of the input data selected by the user may be the best available information at the time when the analysis is performed. However, input data and therefore results may significantly differ from actual field conditions.

Therefore, the program authors recommend prudent use of the GRLWEAP results. Soil response and hammer performance should be verified by static and/or dynamic testing and measurements. Estimates of bending or other local stresses (e.g., helmet or clamp contact, uneven rock surfaces etc.), prestress effects and others must also be accounted for by the user.

The calculated capacity - blow count relationship, i.e. the bearing graph, should be used in conjunction with observed blow counts for the capacity assessment of a driven pile. Soil setup occurring after pile installation may produce bearing capacity values that differ substantially from those expected from a wave equation analysis due to soil setup or relaxation. This is particularly true for pile driven with vibratory hammers. The GRLWEAP user must estimate such effects and should also use proper care when applying blow counts from restrike because of the variability of hammer energy, soil resistance and blow count during early restriking.

Finally, the GRLWEAP capacities are ultimate values. They MUST be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of building and other factors.

```
 Input  File: J:\GEOTECH\PROJECTS\2013\W-13-072 FRA-70-13.10 PROJECT 6A\ANALYSIS\FRA-70-1358L\DRIVEABILITY\B-017-9-13\HP
12X53\B-017-9.GWW
 Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2010.GW
 Hammer File Version:  2003 (12/4/2018)

                       Input File Contents
     FRA-70-1358L - RA - B-017-9-13 - HP12x53
 OUT OSG HAM STR FUL PEL  N SPL N-U P-D %SK ISM  0 PHI RSA ITR H-D MXT     DEx
-100   0  41   0   0   0  0   0   0   1   0   0  0   0   0   0   0   0   0.000
    Pile g  Hammer g  Toe Area Pile Size           Pile Type
    32.170    32.170   144.000    12.000             Unknown
      W Cp      A Cp      E Cp      T Cp       CoR      ROut      StCp
     1.900   227.000     530.0     2.000     0.800     0.010       0.0
      A Cu      E Cu      T Cu       CoR      ROut      StCu
     0.000       0.0     0.000     0.000     0.000       0.0
      LPle      APle      EPle      WPle      Peri        CI       CoR      ROut
    59.000     15.50   29000.0   492.000     3.970         0     0.850     0.010
  FFatigue        F0  0-Bottom
         0     0.000     0.000
 Manufac  Hmr Name  HmrType No Seg-s
 DELMAG   D 19-42         1       5
    Ram Wt     Ram L   Ram Dia   MaxStrk   RtdStrk    Efficy
      4.00    129.10     12.60     11.86     10.81      0.80
    IB. Wt     IB. L    IB.Dia    IB CoR     IB RO
      0.75     25.30     12.60     0.900     0.010
  CompStrk A Chamber V Chamber   C Delay  C Duratn Exp Coeff VolCStart  Vol CEnd
     16.65    124.70    157.70    0.0020    0.0020     1.250      0.00      0.00
     P atm        P1        P2        P3        P4        P5
     14.70   1600.00   1440.00   1295.00   1165.00      0.00
    Stroke    Effic.  Pressure  R-Weight   T-Delay Exp-Coeff   Eps-Str  Total-AW
```

10.8100	0.8000	1600.0000	0.0000	0.0000	0.0000	0.0100	0.0000
Qs	Qt	Js	Jt	Qx	Jx	Rati	Dept
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Research Soil Model: Atoe, Plug, Gap, Q-fac
0.000 0.000 0.000 0.000
Research Soil Model: RD-skn: m, d, toe: m, d
0.000 0.000 0.000 0.000
Research Toe Plug: Res-int, Q-int, D-int, Res-plug, Q-plug, D-plug
0.000 0.000 0.000 0.000 0.000 0.000
Research Toe Plug: RD plug toe: m, d
0.000 0.000
Research Toe Plug: New Toe Plug Model is NOT applied
Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimL	TSf0
0.01	0.71	0.73	0.10	0.10	0.20	0.15	1.49	6.00	168.000
3.49	0.71	0.73	0.10	0.10	0.20	0.15	1.49	6.00	168.000
3.51	0.06	0.35	0.10	0.10	0.05	0.15	1.00	6.00	1.000
5.29	0.09	0.54	0.10	0.10	0.05	0.15	1.00	6.00	1.000
5.31	0.82	0.85	0.10	0.10	0.20	0.15	1.49	6.00	168.000
7.79	0.82	0.85	0.10	0.10	0.20	0.15	1.49	6.00	168.000
7.81	0.26	3.60	0.10	0.10	0.05	0.15	1.00	6.00	1.000
10.29	0.37	5.04	0.10	0.10	0.05	0.15	1.00	6.00	1.000
10.31	0.27	2.76	0.10	0.10	0.05	0.15	1.00	6.00	1.000
12.79	0.34	3.49	0.10	0.10	0.05	0.15	1.00	6.00	1.000
12.81	0.50	7.98	0.10	0.10	0.05	0.15	1.00	6.00	1.000
21.81	0.92	14.50	0.10	0.10	0.05	0.15	1.00	6.00	1.000
26.79	1.14	18.11	0.10	0.10	0.05	0.15	1.00	6.00	1.000
26.81	2.75	2.66	0.10	0.10	0.20	0.15	2.00	6.00	168.000
35.81	2.75	2.66	0.10	0.10	0.20	0.15	2.00	6.00	168.000
44.81	2.27	2.66	0.10	0.10	0.20	0.15	2.00	6.00	168.000
46.79	2.15	2.66	0.10	0.10	0.20	0.15	2.00	6.00	168.000
46.81	1.07	4.36	0.10	0.10	0.20	0.15	2.00	6.00	168.000
51.79	1.07	4.36	0.10	0.10	0.20	0.15	2.00	6.00	168.000
51.81	1.90	7.75	0.10	0.10	0.20	0.15	2.00	6.00	168.000
59.00	1.90	7.75	0.10	0.10	0.20	0.15	2.00	6.00	168.000

Gain/Loss factors: shaft and toe
0.40000 0.45000 0.50000 0.55000 0.60000
1.00000 1.00000 1.00000 1.00000 1.00000

Dpth	L	Wait	Strk	Pmx%	Eff.	Stff	CoR
5.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
55.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
59.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
Version 2010
English Units

FRA-70-1358L - RA - B-017-9-13 - HP12x53

Hammer Model: D 19-42 Made by: DELMAG

No.	Weight kips	Stiffn k/inch	CoR	C-Slk ft	Dampg k/ft/s
1	0.800				
2	0.800	140046.6	1.000	0.0000	
3	0.800	140046.6	1.000	0.0000	
4	0.800	140046.6	1.000	0.0000	
5	0.800	140046.6	1.000	0.0000	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		11428.0			

HAMMER OPTIONS:

Hammer File ID No.	41	Hammer Type	OE Diesel
Stroke Option	FxdP-VarS	Stroke Convergence Crit.	0.010
Fuel Pump Setting	Maximum		

```
HAMMER DATA:
  Ram Weight          (kips)      4.00  Ram Length          (inch)    129.10
  Maximum Stroke        (ft)     11.86
  Rated Stroke          (ft)     10.81  Efficiency                     0.800

  Maximum Pressure     (psi)   1600.00  Actual Pressure      (psi)   1600.00
  Compression Exponent           1.350  Expansion Exponent             1.250
  Ram Diameter        (inch)     12.60
  Combustion Delay       (s)   0.00200  Ignition Duration      (s)   0.00200

          The Hammer Data Includes Estimated (NON-MEASURED) Quantities
          ____________________________________________________________



  HAMMER CUSHION                        PILE CUSHION
  Cross Sect. Area     (in2)    227.00  Cross Sect. Area     (in2)      0.00
  Elastic-Modulus      (ksi)     530.0  Elastic-Modulus      (ksi)       0.0
  Thickness           (inch)      2.00  Thickness           (inch)      0.00
  Coeff of Restitution             0.8  Coeff of Restitution             1.0
  RoundOut              (ft)       0.0  RoundOut              (ft)       0.0
  Stiffness        (kips/in)   60155.0  Stiffness        (kips/in)       0.0
```



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  Depth                 (ft)       5.0  Standard Soil Setup
  Shaft Gain/Loss Factor         0.400  Toe Gain/Loss Factor           1.000

  PILE PROFILE:
  Toe Area             (in2)   144.000  Pile Type                    Unknown
  Pile Size           (inch)    12.000

   L b Top     Area    E-Mod  Spec Wt    Perim  C Index  Wave Sp      EA/c
        ft      in2      ksi   lb/ft3       ft             ft/s    k/ft/s
       0.0    15.50   29000.    492.0      4.0        0    16524.     27.2
      59.0    15.50   29000.    492.0      4.0        0    16524.     27.2

  Wave Travel Time 2L/c (ms)     7.141

         Pile and Soil Model            Total Capacity Rut  (kips)       6.9
 No. Weight   Stiffn C-Slk T-Slk  CoR  Soil-S  Soil-D Quake  LbTop Perim    Area
       kips     k/in    ft    ft         kips    s/ft  inch     ft    ft     in2
   1  0.174    11428 0.010 0.000 0.85     0.0   0.000 0.100   3.28   4.0    15.5
   2  0.174    11428 0.000 0.000 1.00     0.0   0.000 0.100   6.56   4.0    15.5
  17  0.174    11428 0.000 0.000 1.00     2.9   0.200 0.100  55.72   4.0    15.5
  18  0.174    11428 0.000 0.000 1.00     3.5   0.188 0.100  59.00   4.0    15.5
 Toe                                      0.5   0.150 0.100

      3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
      3.125 kips total reduced pile weight   (g= 32.17 ft/s2)

  PILE, SOIL, ANALYSIS OPTIONS:
  Uniform pile                          Pile Segments: Automatic
  No. of Slacks/Splices              0  Pile Damping           (%)         1
                                        Pile Damping Fact.(k/ft/s)     0.544
  Driveability Analysis
  Soil Damping Option            Smith
  Max No Analysis Iterations         0  Time Increment/Critical          160
  Output Time Interval               1  Analysis Time-Input   (ms)         0
  Output Level: Normal
  Gravity Mass, Pile, Hammer:   32.170    32.170    32.170
  Output Segment Generation: Automatic

     Depth    Stroke  Pressure    Efficy
        ft        ft     Ratio
      5.00     10.81      1.00     0.800
```



```
     Rut   Bl Ct   Stroke (ft) Ten Str   i   t Comp Str   i   t ENTHRU   Bl Rt
    kips    b/ft   down     up     ksi              ksi         kip-ft   b/min
     6.9  Hammer did not run
     7.2  Hammer did not run
     7.6  Hammer did not run
```

7.9 Hammer did not run
8.2 Hammer did not run

FRA-70-1358L - RA - B-017-9-13 - HP12x53   06/06/2022
Resource International Inc   GRLWEAP Version 2010

Depth	(ft)	10.0	Standard Soil Setup	
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor	1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	12.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms)   7.141

Pile and Soil Model   Total Capacity Rut (kips)   19.0

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	0.3	0.200	0.100	49.17	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	5.6	0.200	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	3.4	0.185	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	4.8	0.135	0.100	59.00	4.0	15.5
Toe						4.9	0.150	0.100			

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight   (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
10.00	10.81	1.00	0.800

FRA-70-1358L - RA - B-017-9-13 - HP12x53   06/06/2022
Resource International Inc   GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
19.0	1.7	4.16	4.13	-0.45	4	11	12.82	1	2	25.6	58.3
19.6	1.7	4.16	4.16	-0.46	4	11	12.90	1	2	25.4	58.1
20.2	1.8	4.16	4.20	-0.44	4	11	13.01	1	2	25.2	57.9
20.8	1.8	4.24	4.21	-0.43	3	11	13.52	1	2	25.3	57.6
21.4	1.9	4.27	4.24	-0.42	3	11	13.76	1	2	25.2	57.4

FRA-70-1358L - RA - B-017-9-13 - HP12x53   06/06/2022
Resource International Inc   GRLWEAP Version 2010

Depth	(ft)	15.0	Standard Soil Setup	
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor	1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	12.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms)   7.141

Pile and Soil Model   Total Capacity Rut (kips)   32.0

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	3.2	0.200	0.100	45.89	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	3.2	0.186	0.100	49.17	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	5.7	0.187	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	4.0	0.050	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	6.2	0.050	0.100	59.00	4.0	15.5

Toe	9.6	0.150	0.100	

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
15.00	10.81	1.00	0.800

↑

FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
32.0	2.6	4.59	4.57	-0.87	2	9	16.58	1	2	24.0	55.4
32.6	2.6	4.62	4.60	-0.90	2	9	16.75	1	2	23.9	55.2
33.2	2.7	4.64	4.62	-0.89	2	9	16.89	1	2	23.8	55.1
33.8	2.8	4.67	4.64	-0.90	2	9	17.05	2	2	23.7	54.9
34.4	2.8	4.69	4.67	-0.90	2	9	17.17	3	2	23.6	54.8

↑

FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

Depth (ft) 20.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model Total Capacity Rut (kips) 49.9

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.0	15.5
12	0.174	11428	0.000	0.000	1.00	0.6	0.200	0.100	39.33	4.0	15.5
13	0.174	11428	0.000	0.000	1.00	5.5	0.199	0.100	42.61	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	3.6	0.187	0.100	45.89	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	4.7	0.126	0.100	49.17	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	4.5	0.050	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	7.9	0.050	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	9.9	0.050	0.100	59.00	4.0	15.5
Toe						13.2	0.150	0.100			

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
20.00	10.81	1.00	0.800

↑

FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
49.9	4.0	5.06	5.02	-1.10	2	9	19.81	13	4	22.5	52.8
50.5	4.1	5.08	5.05	-1.06	2	9	19.96	13	4	22.3	52.6
51.1	4.1	5.10	5.06	-1.06	2	9	20.13	13	4	22.3	52.5
51.7	4.2	5.12	5.08	-1.03	2	9	20.24	13	4	22.2	52.4
52.3	4.3	5.14	5.10	-1.01	2	9	20.36	13	4	22.2	52.4

↑

FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

Depth (ft) 25.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	12.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 72.3

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.0	15.5
11	0.174	11428	0.000	0.000	1.00	3.5	0.200	0.100	36.06	4.0	15.5
12	0.174	11428	0.000	0.000	1.00	3.1	0.183	0.100	39.33	4.0	15.5
13	0.174	11428	0.000	0.000	1.00	5.8	0.185	0.100	42.61	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	4.0	0.050	0.100	45.89	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	6.4	0.050	0.100	49.17	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	9.0	0.050	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	10.9	0.050	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	12.9	0.050	0.100	59.00	4.0	15.5
Toe						16.8	0.150	0.100			

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
25.00	10.81	1.00	0.800

FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
72.3	5.9	5.49	5.46	-0.46	11	50	21.92	11	4	21.2	50.5
72.9	6.0	5.51	5.48	-0.59	11	50	22.01	11	4	21.1	50.4
73.5	6.0	5.53	5.49	-0.73	11	50	22.09	11	4	21.1	50.3
74.1	6.1	5.54	5.51	-0.78	11	50	22.19	11	4	21.0	50.2
74.7	6.2	5.55	5.53	-0.91	11	50	22.25	11	4	20.9	50.1

FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

Depth	(ft)	30.0	Standard Soil Setup	
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor	1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	12.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 80.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.0	15.5
9	0.174	11428	0.000	0.000	1.00	0.8	0.200	0.100	29.50	4.0	15.5
10	0.174	11428	0.000	0.000	1.00	5.2	0.199	0.100	32.78	4.0	15.5
11	0.174	11428	0.000	0.000	1.00	3.9	0.189	0.100	36.06	4.0	15.5
12	0.174	11428	0.000	0.000	1.00	4.6	0.115	0.100	39.33	4.0	15.5
13	0.174	11428	0.000	0.000	1.00	4.7	0.050	0.100	42.61	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	8.0	0.050	0.100	45.89	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	10.0	0.050	0.100	49.17	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	11.9	0.050	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	13.9	0.050	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	14.3	0.198	0.100	59.00	4.0	15.5

Toe						2.7	0.150	0.100		

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
30.00	10.81	1.00	0.800

Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
80.1	6.8	5.69	5.66	-1.11	12	50	22.70	10	4	20.7	49.6
82.4	7.1	5.75	5.73	-1.22	12	50	22.95	10	4	20.5	49.2
84.8	7.5	5.81	5.79	-1.36	9	44	23.24	10	4	20.4	49.0
87.1	7.9	5.87	5.86	-1.50	9	44	23.50	10	4	20.2	48.7
89.4	8.3	5.88	5.93	-1.54	9	44	23.55	10	4	20.0	48.5

Depth (ft) 35.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 101.9

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.0	15.5
8	0.174	11428	0.000	0.000	1.00	3.8	0.200	0.100	26.22	4.0	15.5
9	0.174	11428	0.000	0.000	1.00	3.1	0.183	0.100	29.50	4.0	15.5
10	0.174	11428	0.000	0.000	1.00	5.6	0.181	0.100	32.78	4.0	15.5
11	0.174	11428	0.000	0.000	1.00	4.1	0.050	0.100	36.06	4.0	15.5
12	0.174	11428	0.000	0.000	1.00	6.6	0.050	0.100	39.33	4.0	15.5
13	0.174	11428	0.000	0.000	1.00	9.1	0.050	0.100	42.61	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	11.0	0.050	0.100	45.89	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	13.0	0.050	0.100	49.17	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	14.4	0.157	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	59.00	4.0	15.5
Toe						2.7	0.150	0.100			

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
35.00	10.81	1.00	0.800

Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
101.9	10.4	6.22	6.25	-0.67	8	43	24.53	8	3	19.4	47.2
107.0	11.1	6.32	6.34	-0.64	6	40	24.91	8	3	19.2	46.9
112.1	11.9	6.41	6.43	-0.72	10	39	25.25	8	3	19.0	46.5
117.1	12.7	6.51	6.53	-0.66	10	38	25.58	8	3	18.8	46.2
122.2	13.6	6.61	6.62	-0.60	8	37	25.93	8	3	18.8	45.9

Depth (ft) 40.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model Total Capacity Rut (kips) 123.0

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.0	15.5
6	0.174	11428	0.000	0.000	1.00	1.1	0.200	0.100	19.67	4.0	15.5
7	0.174	11428	0.000	0.000	1.00	5.0	0.198	0.100	22.94	4.0	15.5
8	0.174	11428	0.000	0.000	1.00	4.2	0.191	0.100	26.22	4.0	15.5
9	0.174	11428	0.000	0.000	1.00	4.5	0.104	0.100	29.50	4.0	15.5
10	0.174	11428	0.000	0.000	1.00	4.8	0.050	0.100	32.78	4.0	15.5
11	0.174	11428	0.000	0.000	1.00	8.1	0.050	0.100	36.06	4.0	15.5
12	0.174	11428	0.000	0.000	1.00	10.1	0.050	0.100	39.33	4.0	15.5
13	0.174	11428	0.000	0.000	1.00	12.0	0.050	0.100	42.61	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	14.0	0.060	0.100	45.89	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	49.17	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	13.6	0.200	0.100	59.00	4.0	15.5
Toe						2.7	0.150	0.100			

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
40.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
123.0	13.7	6.63	6.65	-0.49	6	33	25.84	7	3	18.6	45.8
130.7	15.1	6.79	6.80	-0.81	6	33	26.37	7	3	18.5	45.2
138.4	16.6	6.99	6.93	-0.95	6	33	27.01	7	3	18.6	44.7
146.1	18.3	7.11	7.07	-0.93	6	33	27.41	7	3	18.4	44.3
153.8	19.9	7.22	7.19	-0.72	6	33	27.77	7	3	18.4	43.9

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Depth (ft) 45.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model Total Capacity Rut (kips) 142.0

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.0	15.5
5	0.174	11428	0.000	0.000	1.00	4.1	0.200	0.100	16.39	4.0	15.5
6	0.174	11428	0.000	0.000	1.00	3.1	0.183	0.100	19.67	4.0	15.5

7	0.174	11428	0.000	0.000	1.00	5.5	0.176	0.100	22.94	4.0	15.5
8	0.174	11428	0.000	0.000	1.00	4.1	0.050	0.100	26.22	4.0	15.5
9	0.174	11428	0.000	0.000	1.00	6.8	0.050	0.100	29.50	4.0	15.5
10	0.174	11428	0.000	0.000	1.00	9.2	0.050	0.100	32.78	4.0	15.5
11	0.174	11428	0.000	0.000	1.00	11.1	0.050	0.100	36.06	4.0	15.5
12	0.174	11428	0.000	0.000	1.00	13.1	0.050	0.100	39.33	4.0	15.5
13	0.174	11428	0.000	0.000	1.00	14.4	0.163	0.100	42.61	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	45.89	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	14.0	0.200	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	13.1	0.200	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	12.2	0.200	0.100	59.00	4.0	15.5
Toe						2.7	0.150	0.100			

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
45.00	10.81	1.00	0.800

↑
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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
142.0	17.7	7.09	7.04	-1.05	5	33	27.13	5	3	18.3	44.4
152.1	20.0	7.24	7.21	-0.90	5	33	27.63	5	3	18.2	43.9
162.2	22.1	7.36	7.36	-0.45	5	33	28.00	5	3	17.9	43.5
172.3	23.6	7.48	7.47	-0.08	18	12	28.36	5	3	17.8	43.2
182.3	25.1	7.59	7.57	-0.29	5	49	28.72	5	3	17.8	42.9

↑
FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

Depth (ft) 50.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 155.5

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.0	15.5
3	0.174	11428	0.000	0.000	1.00	1.4	0.200	0.100	9.83	4.0	15.5
4	0.174	11428	0.000	0.000	1.00	4.7	0.197	0.100	13.11	4.0	15.5
5	0.174	11428	0.000	0.000	1.00	4.5	0.192	0.100	16.39	4.0	15.5
6	0.174	11428	0.000	0.000	1.00	4.3	0.091	0.100	19.67	4.0	15.5
7	0.174	11428	0.000	0.000	1.00	5.0	0.050	0.100	22.94	4.0	15.5
8	0.174	11428	0.000	0.000	1.00	8.2	0.050	0.100	26.22	4.0	15.5
9	0.174	11428	0.000	0.000	1.00	10.2	0.050	0.100	29.50	4.0	15.5
10	0.174	11428	0.000	0.000	1.00	12.1	0.050	0.100	32.78	4.0	15.5
11	0.174	11428	0.000	0.000	1.00	14.0	0.076	0.100	36.06	4.0	15.5
12	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	39.33	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	45.89	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	13.6	0.200	0.100	49.17	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	12.7	0.200	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	11.7	0.200	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	5.7	0.200	0.100	59.00	4.0	15.5
Toe						4.4	0.150	0.100			

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy

50.00	10.81	1.00	0.800

↑
FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
155.5	20.9	7.31	7.29	-1.56	16	12	27.65	4	2	18.0	43.7
167.0	22.7	7.45	7.43	-1.28	16	12	28.06	4	2	17.7	43.3
178.6	24.4	7.57	7.56	-1.11	17	12	28.44	4	3	17.6	42.9
190.1	26.3	7.69	7.68	-0.93	17	12	28.79	4	2	17.6	42.6
201.7	28.5	7.79	7.78	-0.74	17	12	29.09	4	2	17.6	42.3

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FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

Depth (ft) 55.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model Total Capacity Rut (kips) 171.6

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.174	11428	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	4.4	0.200	0.100	6.56	4.0	15.5
3	0.174	11428	0.000	0.000	1.00	3.2	0.184	0.100	9.83	4.0	15.5
4	0.174	11428	0.000	0.000	1.00	5.4	0.171	0.100	13.11	4.0	15.5
5	0.174	11428	0.000	0.000	1.00	4.1	0.050	0.100	16.39	4.0	15.5
6	0.174	11428	0.000	0.000	1.00	7.0	0.050	0.100	19.67	4.0	15.5
7	0.174	11428	0.000	0.000	1.00	9.2	0.050	0.100	22.94	4.0	15.5
8	0.174	11428	0.000	0.000	1.00	11.2	0.050	0.100	26.22	4.0	15.5
9	0.174	11428	0.000	0.000	1.00	13.2	0.050	0.100	29.50	4.0	15.5
10	0.174	11428	0.000	0.000	1.00	14.4	0.168	0.100	32.78	4.0	15.5
11	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	36.06	4.0	15.5
13	0.174	11428	0.000	0.000	1.00	14.0	0.200	0.100	42.61	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	13.1	0.200	0.100	45.89	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	12.2	0.200	0.100	49.17	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	8.5	0.200	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	5.6	0.200	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	9.8	0.200	0.100	59.00	4.0	15.5
Toe						7.8	0.150	0.100			

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
55.00	10.81	1.00	0.800

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Resource International Inc GRLWEAP Version 2010

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
171.6	23.6	7.54	7.52	-1.57	16	12	28.46	2	2	17.5	43.0
184.7	25.7	7.67	7.67	-1.33	16	12	28.87	2	2	17.3	42.6
197.9	28.1	7.78	7.78	-1.07	16	12	29.20	2	2	17.3	42.4
211.0	30.8	7.89	7.89	-0.80	16	12	29.57	2	2	17.3	42.1
224.2	33.9	7.92	7.99	-0.53	16	12	29.68	2	2	17.3	41.9

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Depth (ft) 59.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	12.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
59.0	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 183.7

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.174	11428	0.010	0.000	0.85	5.6	0.200	0.100	3.28	4.0	15.5
2	0.174	11428	0.000	0.000	1.00	3.4	0.185	0.100	6.56	4.0	15.5
3	0.174	11428	0.000	0.000	1.00	4.9	0.143	0.100	9.83	4.0	15.5
4	0.174	11428	0.000	0.000	1.00	4.3	0.050	0.100	13.11	4.0	15.5
5	0.174	11428	0.000	0.000	1.00	7.7	0.050	0.100	16.39	4.0	15.5
6	0.174	11428	0.000	0.000	1.00	9.7	0.050	0.100	19.67	4.0	15.5
7	0.174	11428	0.000	0.000	1.00	11.6	0.050	0.100	22.94	4.0	15.5
8	0.174	11428	0.000	0.000	1.00	13.6	0.050	0.100	26.22	4.0	15.5
9	0.174	11428	0.000	0.000	1.00	14.4	0.188	0.100	29.50	4.0	15.5
10	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	32.78	4.0	15.5
11	0.174	11428	0.000	0.000	1.00	14.3	0.200	0.100	36.06	4.0	15.5
12	0.174	11428	0.000	0.000	1.00	13.8	0.200	0.100	39.33	4.0	15.5
13	0.174	11428	0.000	0.000	1.00	12.9	0.200	0.100	42.61	4.0	15.5
14	0.174	11428	0.000	0.000	1.00	12.0	0.200	0.100	45.89	4.0	15.5
15	0.174	11428	0.000	0.000	1.00	7.2	0.200	0.100	49.17	4.0	15.5
16	0.174	11428	0.000	0.000	1.00	6.4	0.200	0.100	52.44	4.0	15.5
17	0.174	11428	0.000	0.000	1.00	9.9	0.200	0.100	55.72	4.0	15.5
18	0.174	11428	0.000	0.000	1.00	9.9	0.200	0.100	59.00	4.0	15.5
Toe						7.8	0.150	0.100			

3.125 kips total unreduced pile weight (g= 32.17 ft/s2)
3.125 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
59.00	10.81	1.00	0.800

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
183.7	25.8	7.70	7.68	-1.38	15	12	29.51	1	2	16.9	42.6
198.3	28.6	7.83	7.82	-1.01	15	12	29.97	1	2	16.7	42.3
213.0	31.6	7.93	7.94	-0.71	16	12	30.35	1	2	16.7	42.0
227.6	35.1	7.99	8.04	-0.42	16	12	30.59	1	2	16.7	41.8
242.3	38.8	8.12	8.15	-0.15	16	12	31.02	1	2	16.7	41.5

FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.400 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	6.9	6.4	0.5	Hammer did not run				
10.0	19.0	14.1	4.9	1.7	12.818	-0.454	4.16	25.6
15.0	32.0	22.4	9.6	2.6	16.578	-0.872	4.59	24.0
20.0	49.9	36.7	13.2	4.0	19.808	-1.097	5.06	22.5
25.0	72.3	55.5	16.8	5.9	21.921	-0.459	5.49	21.2
30.0	80.1	77.4	2.7	6.8	22.704	-1.112	5.69	20.7
35.0	101.9	99.3	2.7	10.4	24.527	-0.671	6.22	19.4
40.0	123.0	120.3	2.7	13.7	25.842	-0.494	6.63	18.6
45.0	142.0	139.4	2.7	17.7	27.128	-1.050	7.09	18.3
50.0	155.5	151.1	4.4	20.9	27.645	-1.564	7.31	18.0
55.0	171.6	163.8	7.8	23.6	28.461	-1.568	7.54	17.5
59.0	183.7	175.9	7.8	25.8	29.509	-1.385	7.70	16.9

Total Driving Time 13 minutes; Total No. of Blows 573
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.450 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	7.2	6.7	0.5	Hammer did not run				
10.0	19.6	14.7	4.9	1.7	12.903	-0.455	4.16	25.4
15.0	32.6	23.0	9.6	2.6	16.746	-0.897	4.62	23.9
20.0	50.5	37.3	13.2	4.1	19.957	-1.058	5.08	22.3
25.0	72.9	56.1	16.8	6.0	22.009	-0.586	5.51	21.1
30.0	82.4	79.8	2.7	7.1	22.954	-1.218	5.75	20.5
35.0	107.0	104.3	2.7	11.1	24.913	-0.644	6.32	19.2
40.0	130.7	128.1	2.7	15.1	26.369	-0.805	6.79	18.5
45.0	152.1	149.4	2.7	20.0	27.626	-0.900	7.24	18.2
50.0	167.0	162.6	4.4	22.7	28.064	-1.284	7.45	17.7
55.0	184.7	177.0	7.8	25.7	28.869	-1.330	7.67	17.3
59.0	198.3	190.6	7.8	28.6	29.972	-1.010	7.83	16.7

Total Driving Time 14 minutes; Total No. of Blows 625
Starting at penetration 5.0 ft

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.500 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	7.6	7.1	0.5	Hammer did not run				
10.0	20.2	15.3	4.9	1.8	13.010	-0.441	4.16	25.2
15.0	33.2	23.6	9.6	2.7	16.889	-0.893	4.64	23.8
20.0	51.1	37.9	13.2	4.1	20.126	-1.063	5.10	22.3
25.0	73.5	56.7	16.8	6.0	22.091	-0.730	5.53	21.1
30.0	84.8	82.1	2.7	7.5	23.244	-1.364	5.81	20.4
35.0	112.1	109.4	2.7	11.9	25.250	-0.720	6.41	19.0
40.0	138.4	135.8	2.7	16.6	27.007	-0.947	6.99	18.6
45.0	162.2	159.5	2.7	22.1	27.997	-0.452	7.36	17.9
50.0	178.6	174.2	4.4	24.4	28.440	-1.111	7.57	17.6
55.0	197.9	190.1	7.8	28.1	29.200	-1.068	7.78	17.3
59.0	213.0	205.2	7.8	31.6	30.349	-0.709	7.93	16.7

Total Driving Time 15 minutes; Total No. of Blows 673
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.550 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	7.9	7.4	0.5	Hammer did not run				
10.0	20.8	15.9	4.9	1.8	13.522	-0.435	4.24	25.3
15.0	33.8	24.2	9.6	2.8	17.045	-0.898	4.67	23.7
20.0	51.7	38.5	13.2	4.2	20.238	-1.028	5.12	22.2
25.0	74.1	57.3	16.8	6.1	22.194	-0.778	5.54	21.0
30.0	87.1	84.4	2.7	7.9	23.498	-1.503	5.87	20.2
35.0	117.1	114.5	2.7	12.7	25.579	-0.657	6.51	18.8
40.0	146.1	143.5	2.7	18.3	27.410	-0.926	7.11	18.4
45.0	172.3	169.6	2.7	23.6	28.356	-0.085	7.48	17.8
50.0	190.1	185.8	4.4	26.3	28.791	-0.932	7.69	17.6
55.0	211.0	203.3	7.8	30.8	29.565	-0.804	7.89	17.3
59.0	227.6	219.9	7.8	35.1	30.587	-0.419	7.99	16.7

Total Driving Time 16 minutes; Total No. of Blows 727
Starting at penetration 5.0 ft

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.600 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	8.2	7.7	0.5	Hammer did not run				
10.0	21.4	16.5	4.9	1.9	13.756	-0.421	4.27	25.2
15.0	34.4	24.8	9.6	2.8	17.169	-0.899	4.69	23.6
20.0	52.3	39.1	13.2	4.3	20.363	-1.009	5.14	22.2
25.0	74.7	57.9	16.8	6.2	22.252	-0.914	5.55	20.9
30.0	89.4	86.8	2.7	8.3	23.552	-1.545	5.88	20.0
35.0	122.2	119.5	2.7	13.6	25.933	-0.596	6.61	18.8

40.0	153.8	151.2	2.7	19.9	27.767	-0.723	7.22	18.4
45.0	182.3	179.7	2.7	25.1	28.719	-0.289	7.59	17.8
50.0	201.7	197.3	4.4	28.5	29.094	-0.743	7.79	17.6
55.0	224.2	216.4	7.8	33.9	29.678	-0.526	7.92	17.3
59.0	242.3	234.6	7.8	38.8	31.020	-0.147	8.12	16.7

Total Driving Time 18 minutes; Total No. of Blows 780
Starting at penetration 5.0 ft

FRA-70-1358L - RA - B-017-9-13 - HP12x53 06/06/2022
Resource International Inc GRLWEAP Version 2010

Table of Depths Analyzed with Driving System Modifiers

Depth ft	Temp. Length ft	Wait Time hr	Equivalent Stroke ft	Pressure Ratio	Efficy.	Stiffn. Factor	Cushion CoR
5.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
10.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
15.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
20.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
25.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
30.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
35.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
40.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
45.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
50.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
55.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
59.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00

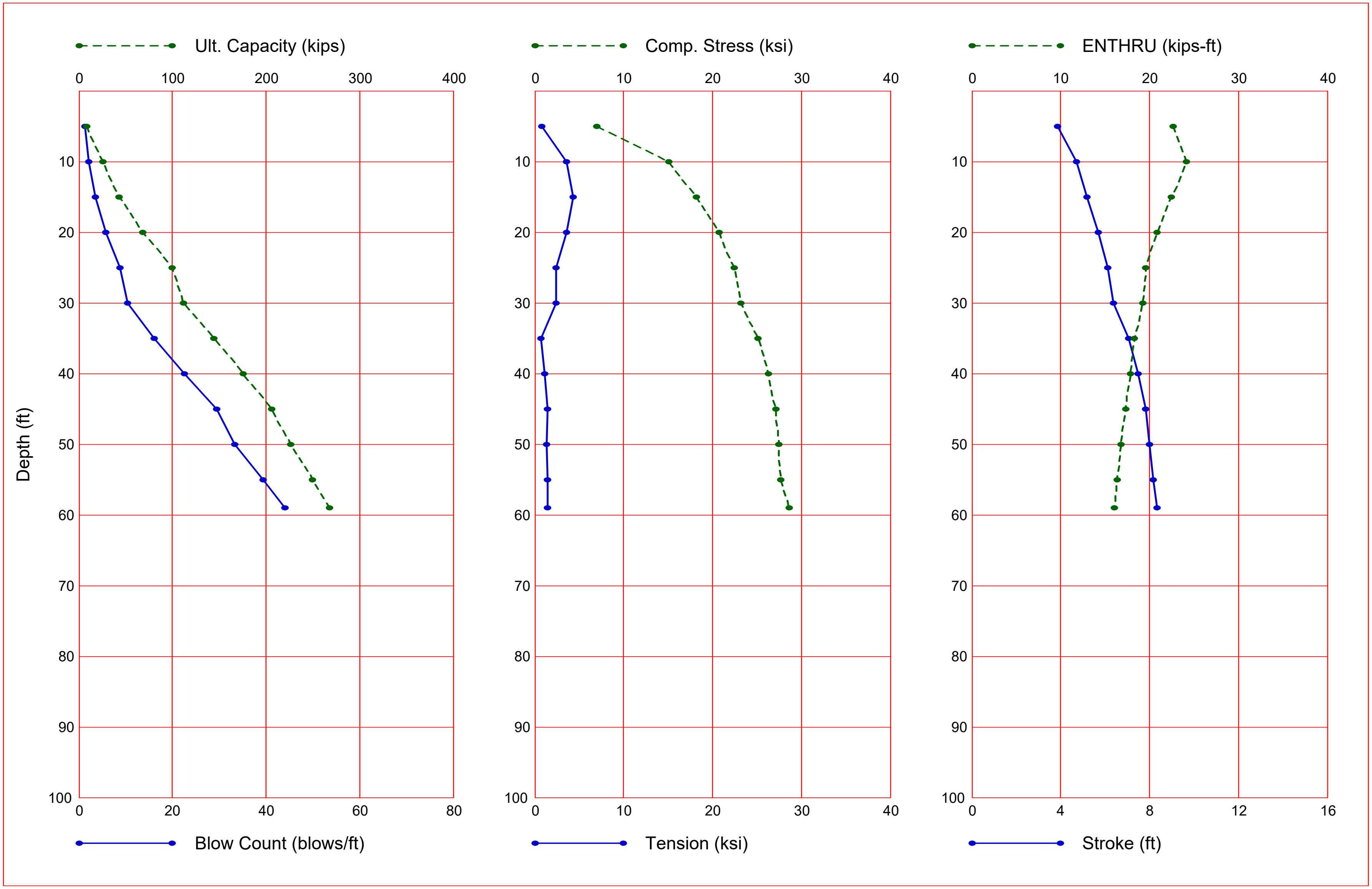
Soil Layer Resistance Values

Depth ft	Shaft Res. k/ft2	End Bearing kips	Shaft Quake inch	Toe Quake inch	Shaft Damping s/ft	Toe Damping s/ft	Soil Setup Normlzd	Limit Distance ft	Setup Time hrs
0.01	0.71	0.73	0.100	0.100	0.200	0.150	0.660	6.000	168.000
3.49	0.71	0.73	0.100	0.100	0.200	0.150	0.660	6.000	168.000
3.51	0.06	0.35	0.100	0.100	0.050	0.150	0.000	6.000	1.000
5.29	0.09	0.54	0.100	0.100	0.050	0.150	0.000	6.000	1.000
5.31	0.82	0.85	0.100	0.100	0.200	0.150	0.660	6.000	168.000
7.79	0.82	0.85	0.100	0.100	0.200	0.150	0.660	6.000	168.000
7.81	0.26	3.60	0.100	0.100	0.050	0.150	0.000	6.000	1.000
10.29	0.37	5.04	0.100	0.100	0.050	0.150	0.000	6.000	1.000
10.31	0.27	2.76	0.100	0.100	0.050	0.150	0.000	6.000	1.000
12.79	0.34	3.49	0.100	0.100	0.050	0.150	0.000	6.000	1.000
12.81	0.50	7.98	0.100	0.100	0.050	0.150	0.000	6.000	1.000
21.81	0.92	14.50	0.100	0.100	0.050	0.150	0.000	6.000	1.000
26.79	1.14	18.11	0.100	0.100	0.050	0.150	0.000	6.000	1.000
26.81	2.75	2.66	0.100	0.100	0.200	0.150	1.000	6.000	168.000
35.81	2.75	2.66	0.100	0.100	0.200	0.150	1.000	6.000	168.000
44.81	2.27	2.66	0.100	0.100	0.200	0.150	1.000	6.000	168.000
46.79	2.15	2.66	0.100	0.100	0.200	0.150	1.000	6.000	168.000
46.81	1.07	4.36	0.100	0.100	0.200	0.150	1.000	6.000	168.000
51.79	1.07	4.36	0.100	0.100	0.200	0.150	1.000	6.000	168.000
51.81	1.90	7.75	0.100	0.100	0.200	0.150	1.000	6.000	168.000
59.00	1.90	7.75	0.100	0.100	0.200	0.150	1.000	6.000	168.000

Resource International Inc
FRA-70-1358L - RA - B-017-9-13 - HP14x73

Feb 27 2021
GRLWEAP Version 2010

Gain/Loss 3 at Shaft and Toe 0.500 / 1.000



Gain/Loss 3 at Shaft and Toe 0.500 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Stroke ft	ENTHRU kips-ft
5.0	9.1	8.4	0.7	1.3	6.949	-0.813	3.87	22.7
10.0	25.5	18.8	6.7	2.2	15.130	-3.587	4.70	24.2
15.0	43.5	30.3	13.2	3.6	18.137	-4.364	5.20	22.4
20.0	68.5	50.3	18.2	5.8	20.727	-3.552	5.68	20.9
25.0	99.9	76.7	23.2	8.8	22.410	-2.450	6.14	19.6
30.0	112.1	108.4	3.7	10.5	23.244	-2.377	6.39	19.2
35.0	144.4	140.8	3.7	16.0	25.119	-0.678	7.04	18.3
40.0	176.1	172.4	3.7	22.6	26.346	-1.130	7.48	17.9
45.0	205.9	202.2	3.7	29.4	27.150	-1.413	7.84	17.3
50.0	226.4	220.4	6.0	33.3	27.437	-1.341	8.02	16.8
55.0	250.0	239.3	10.7	39.3	27.712	-1.406	8.16	16.4
59.0	267.9	257.2	10.7	44.1	28.635	-1.436	8.33	16.1

Total Continuous Driving Time 22.00 minutes; Total Number of Blows 928 (starting at penetration 5.0 ft)

GRLWEAP - Version 2010
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS

written by GRL Engineers, Inc. (formerly Goble Rausche Likins and Associates, Inc.) with cooperation from Pile Dynamics, Inc.

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

The GRLWEAP program simulates the behavior of a preformed pile driven by either an impact hammer or a vibratory hammer. The program is based on mathematical models, which describe motion and forces of hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate, often complex, dynamic situations.

A wave equation analysis generally relies on input data, which represents normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. All of the input data selected by the user may be the best available information at the time when the analysis is performed. However, input data and therefore results may significantly differ from actual field conditions.

Therefore, the program authors recommend prudent use of the GRLWEAP results. Soil response and hammer performance should be verified by static and/or dynamic testing and measurements. Estimates of bending or other local stresses (e.g., helmet or clamp contact, uneven rock surfaces etc.), prestress effects and others must also be accounted for by the user.

The calculated capacity - blow count relationship, i.e. the bearing graph, should be used in conjunction with observed blow counts for the capacity assessment of a driven pile. Soil setup occurring after pile installation may produce bearing capacity values that differ substantially from those expected from a wave equation analysis due to soil setup or relaxation. This is particularly true for pile driven with vibratory hammers. The GRLWEAP user must estimate such effects and should also use proper care when applying blow counts from restrike because of the variability of hammer energy, soil resistance and blow count during early restriking.

Finally, the GRLWEAP capacities are ultimate values. They MUST be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of building and other factors.

```
 Input  File: J:\GEOTECH\PROJECTS\2013\W-13-072 FRA-70-13.10 PROJECT 6A\ANALYSIS\FRA-70-1358L\DRIVEABILITY\B-017-9-13\B-017-9.GWW
 Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2010.GW
 Hammer File Version:  2003 (12/4/2018)

                       Input File Contents
     FRA-70-1358L - RA - B-017-9-13 - HP14x73
 OUT OSG HAM STR FUL PEL   N SPL N-U P-D %SK ISM   0 PHI RSA ITR H-D MXT     DEx
-100   0  41   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0.000
    Pile g  Hammer g  Toe Area Pile Size           Pile Type
    32.170    32.170   144.000    14.000             Unknown
      W Cp      A Cp      E Cp      T Cp       CoR      ROut      StCp
     1.900   227.000     530.0     2.000     0.800     0.010       0.0
      A Cu      E Cu      T Cu       CoR      ROut      StCu
     0.000       0.0     0.000     0.000     0.000       0.0
      LPle      APle      EPle      WPle      Peri        CI       CoR      ROut
    59.000     21.40   29000.0   492.000     4.700         0     0.850     0.010
  FFatigue        F0  0-Bottom
         0     0.000     0.000
 Manufac  Hmr Name  HmrType No Seg-s
 DELMAG   D 19-42         1        5
    Ram Wt     Ram L   Ram Dia   MaxStrk   RtdStrk    Efficy
      4.00    129.10     12.60     11.86     10.81      0.80
    IB. Wt     IB. L    IB.Dia    IB CoR     IB RO
      0.75     25.30     12.60     0.900     0.010
  CompStrk A Chamber V Chamber   C Delay  C Duratn Exp Coeff VolCStart  Vol CEnd
     16.65    124.70    157.70    0.0020    0.0020     1.250      0.00      0.00
     P atm        P1        P2        P3        P4        P5
     14.70   1600.00   1440.00   1295.00   1165.00      0.00
    Stroke    Effic.  Pressure  R-Weight   T-Delay Exp-Coeff   Eps-Str  Total-AW
   10.8100    0.8000 1600.0000    0.0000    0.0000    0.0000    0.0100    0.0000
        Qs        Qt        Js        Jt        Qx        Jx      Rati      Dept
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  Research Soil Model: Atoe, Plug,  Gap, Q-fac
     0.000     0.000     0.000     0.000
```

Research Soil Model: RD-skn: m, d, toe: m, d
0.000 0.000 0.000 0.000
Research Toe Plug: Res-int, Q-int, D-int, Res-plug, Q-plug, D-plug
0.000 0.000 0.000 0.000 0.000 0.000
Research Toe Plug: RD plug toe: m, d
0.000 0.000
Research Toe Plug: New Toe Plug Model is NOT applied
Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimL	TSf0
0.01	0.71	1.00	0.10	0.10	0.20	0.15	1.49	6.00	168.000
3.49	0.71	1.00	0.10	0.10	0.20	0.15	1.49	6.00	168.000
3.51	0.06	0.48	0.10	0.10	0.05	0.15	1.00	6.00	1.000
5.29	0.10	0.74	0.10	0.10	0.05	0.15	1.00	6.00	1.000
5.31	0.82	1.17	0.10	0.10	0.20	0.15	1.49	6.00	168.000
7.79	0.82	1.17	0.10	0.10	0.20	0.15	1.49	6.00	168.000
7.81	0.31	4.97	0.10	0.10	0.05	0.15	1.00	6.00	1.000
10.29	0.43	6.96	0.10	0.10	0.05	0.15	1.00	6.00	1.000
10.31	0.31	3.81	0.10	0.10	0.05	0.15	1.00	6.00	1.000
12.79	0.39	4.81	0.10	0.10	0.05	0.15	1.00	6.00	1.000
12.81	0.60	11.02	0.10	0.10	0.05	0.15	1.00	6.00	1.000
21.81	1.09	20.02	0.10	0.10	0.05	0.15	1.00	6.00	1.000
26.79	1.36	25.00	0.10	0.10	0.05	0.15	1.00	6.00	1.000
26.81	2.75	3.68	0.10	0.10	0.20	0.15	2.00	6.00	168.000
35.81	2.75	3.68	0.10	0.10	0.20	0.15	2.00	6.00	168.000
44.81	2.46	3.68	0.10	0.10	0.20	0.15	2.00	6.00	168.000
46.79	2.36	3.68	0.10	0.10	0.20	0.15	2.00	6.00	168.000
46.81	1.07	6.02	0.10	0.10	0.20	0.15	2.00	6.00	168.000
51.79	1.07	6.02	0.10	0.10	0.20	0.15	2.00	6.00	168.000
51.81	1.90	10.70	0.10	0.10	0.20	0.15	2.00	6.00	168.000
59.00	1.90	10.70	0.10	0.10	0.20	0.15	2.00	6.00	168.000

Gain/Loss factors: shaft and toe
0.40000 0.45000 0.50000 0.55000 0.60000
1.00000 1.00000 1.00000 1.00000 1.00000

Dpth	L	Wait	Strk	Pmx%	Eff.	Stff	CoR
5.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
55.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
59.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
Version 2010
English Units

FRA-70-1358L - RA - B-017-9-13 - HP14x73

Hammer Model: D 19-42 Made by: DELMAG

No.	Weight kips	Stiffn k/inch	CoR	C-Slk ft	Dampg k/ft/s
1	0.800				
2	0.800	140046.6	1.000	0.0000	
3	0.800	140046.6	1.000	0.0000	
4	0.800	140046.6	1.000	0.0000	
5	0.800	140046.6	1.000	0.0000	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		15778.0			

HAMMER OPTIONS:

Hammer File ID No.	41	Hammer Type	OE Diesel
Stroke Option	FxdP-VarS	Stroke Convergence Crit.	0.010
Fuel Pump Setting	Maximum		

HAMMER DATA:

Ram Weight	(kips)	4.00	Ram Length	(inch)	129.10
Maximum Stroke	(ft)	11.86			
Rated Stroke	(ft)	10.81	Efficiency		0.800
Maximum Pressure	(psi)	1600.00	Actual Pressure	(psi)	1600.00
Compression Exponent		1.350	Expansion Exponent		1.250
Ram Diameter	(inch)	12.60			
Combustion Delay	(s)	0.00200	Ignition Duration	(s)	0.00200

The Hammer Data Includes Estimated (NON-MEASURED) Quantities

HAMMER CUSHION			PILE CUSHION		
Cross Sect. Area	(in2)	227.00	Cross Sect. Area	(in2)	0.00
Elastic-Modulus	(ksi)	530.0	Elastic-Modulus	(ksi)	0.0
Thickness	(inch)	2.00	Thickness	(inch)	0.00
Coeff of Restitution		0.8	Coeff of Restitution		1.0
RoundOut	(ft)	0.0	RoundOut	(ft)	0.0
Stiffness	(kips/in)	60155.0	Stiffness	(kips/in)	0.0

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Depth	(ft)	5.0	Standard Soil Setup		
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor		1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type		Unknown
Pile Size	(inch)	14.000			

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 8.3

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	3.5	0.200	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	4.1	0.187	0.100	59.00	4.7	21.4
Toe						0.7	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

PILE, SOIL, ANALYSIS OPTIONS:

Uniform pile		Pile Segments: Automatic	
No. of Slacks/Splices	0	Pile Damping (%)	1
		Pile Damping Fact.(k/ft/s)	0.751
Driveability Analysis			
Soil Damping Option	Smith		
Max No Analysis Iterations	0	Time Increment/Critical	160
Output Time Interval	1	Analysis Time-Input (ms)	0
Output Level: Normal			

Gravity Mass, Pile, Hammer: 32.170 32.170 32.170
Output Segment Generation: Automatic

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
5.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft			ksi			ksi			kip-ft	b/min
8.3	1.3	3.79	3.78	-0.49	7	35	6.84	1	7	22.4	60.8
8.7	1.3	3.83	3.82	-0.70	6	35	6.90	1	7	22.5	60.5
9.1	1.3	3.87	3.85	-0.81	6	34	6.95	1	6	22.7	60.2
9.5	1.3	3.90	3.89	-0.79	6	35	7.42	1	2	23.0	60.0
9.9	1.3	3.89	3.93	-0.76	5	34	7.63	1	2	22.9	59.8

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Depth	(ft)	10.0	Standard Soil Setup		
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor		1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type		Unknown
Pile Size	(inch)	14.000			

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L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model   Total Capacity Rut (kips) 24.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
15	0.240	15778	0.000	0.000	1.00	0.3	0.200	0.100	49.17	4.7	21.4
16	0.240	15778	0.000	0.000	1.00	6.7	0.200	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	4.1	0.183	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	6.3	0.129	0.100	59.00	4.7	21.4
Toe						6.7	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
10.00	10.81	1.00	0.800

Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
24.1	2.1	4.59	4.63	-3.24	5	9	14.51	1	2	24.1	55.2
24.8	2.1	4.67	4.66	-3.52	5	9	14.94	1	2	24.2	54.9
25.5	2.2	4.70	4.69	-3.59	5	9	15.13	1	2	24.2	54.8
26.2	2.2	4.73	4.72	-3.64	5	9	15.30	1	2	24.1	54.6
26.9	2.3	4.76	4.75	-3.68	5	9	15.48	1	2	24.0	54.4

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Depth (ft) 15.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model   Total Capacity Rut (kips) 42.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	3.8	0.200	0.100	45.89	4.7	21.4
15	0.240	15778	0.000	0.000	1.00	3.9	0.184	0.100	49.17	4.7	21.4
16	0.240	15778	0.000	0.000	1.00	6.9	0.185	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	5.6	0.050	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	8.7	0.050	0.100	59.00	4.7	21.4
Toe						13.2	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
15.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
42.1	3.4	5.15	5.13	-4.38	5	8	17.86	9	4	22.6	52.3
42.8	3.5	5.18	5.15	-4.38	5	8	17.98	9	4	22.5	52.2

43.5	3.6	5.20	5.17	-4.36	5	8	18.14	14	5	22.4	52.1
44.2	3.7	5.22	5.19	-4.33	5	8	18.29	14	5	22.3	51.9
44.9	3.8	5.24	5.22	-4.29	5	8	18.41	14	5	22.2	51.8

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Depth (ft) 20.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 67.1

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
12	0.240	15778	0.000	0.000	1.00	0.7	0.200	0.100	39.33	4.7	21.4
13	0.240	15778	0.000	0.000	1.00	6.5	0.199	0.100	42.61	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	4.4	0.186	0.100	45.89	4.7	21.4
15	0.240	15778	0.000	0.000	1.00	6.2	0.119	0.100	49.17	4.7	21.4
16	0.240	15778	0.000	0.000	1.00	6.2	0.050	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	11.1	0.050	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	13.8	0.050	0.100	59.00	4.7	21.4
Toe						18.2	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
20.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
67.1	5.6	5.64	5.62	-3.64	5	8	20.52	13	4	21.0	49.9
67.8	5.7	5.66	5.64	-3.59	5	8	20.60	13	4	20.9	49.8
68.5	5.8	5.68	5.66	-3.55	5	8	20.73	13	4	20.9	49.7
69.2	5.9	5.69	5.68	-3.49	5	8	20.82	13	4	20.8	49.6
69.9	5.9	5.71	5.70	-3.45	5	8	20.90	13	4	20.8	49.5

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Depth (ft) 25.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 98.5

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
11	0.240	15778	0.000	0.000	1.00	4.2	0.200	0.100	36.06	4.7	21.4
12	0.240	15778	0.000	0.000	1.00	3.7	0.181	0.100	39.33	4.7	21.4
13	0.240	15778	0.000	0.000	1.00	7.0	0.183	0.100	42.61	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	5.6	0.050	0.100	45.89	4.7	21.4
15	0.240	15778	0.000	0.000	1.00	9.0	0.050	0.100	49.17	4.7	21.4

16	0.240	15778	0.000	0.000	1.00	12.6	0.050	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	15.3	0.050	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	18.0	0.050	0.100	59.00	4.7	21.4
Toe						23.2	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
25.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
98.5	8.5	6.10	6.15	-2.51	3	9	22.25	11	4	19.7	47.7
99.2	8.6	6.12	6.16	-2.49	3	9	22.33	11	4	19.7	47.6
99.9	8.8	6.14	6.18	-2.45	3	9	22.41	11	4	19.6	47.5
100.6	8.9	6.16	6.20	-2.41	3	9	22.49	11	4	19.6	47.5
101.3	9.0	6.17	6.21	-2.38	3	9	22.54	11	4	19.6	47.4

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Depth (ft) 30.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 106.6

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
9	0.240	15778	0.000	0.000	1.00	1.0	0.200	0.100	29.50	4.7	21.4
10	0.240	15778	0.000	0.000	1.00	6.2	0.199	0.100	32.78	4.7	21.4
11	0.240	15778	0.000	0.000	1.00	4.7	0.188	0.100	36.06	4.7	21.4
12	0.240	15778	0.000	0.000	1.00	6.1	0.109	0.100	39.33	4.7	21.4
13	0.240	15778	0.000	0.000	1.00	6.4	0.050	0.100	42.61	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	11.3	0.050	0.100	45.89	4.7	21.4
15	0.240	15778	0.000	0.000	1.00	14.0	0.050	0.100	49.17	4.7	21.4
16	0.240	15778	0.000	0.000	1.00	16.7	0.050	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	19.5	0.050	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	17.1	0.198	0.100	59.00	4.7	21.4
Toe						3.7	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
30.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
106.6	9.6	6.27	6.31	-2.38	9	42	22.82	10	4	19.4	47.1
109.4	10.1	6.33	6.36	-2.42	7	42	23.05	10	4	19.3	46.9
112.1	10.5	6.39	6.42	-2.38	7	41	23.24	10	4	19.2	46.6
114.9	10.9	6.44	6.47	-2.23	6	41	23.45	10	4	19.1	46.5
117.7	11.3	6.49	6.52	-2.22	9	40	23.67	10	4	19.0	46.3

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Depth (ft) 35.0 Standard Soil Setup

Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model   Total Capacity Rut (kips) 132.4

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
8	0.240	15778	0.000	0.000	1.00	4.5	0.200	0.100	26.22	4.7	21.4
9	0.240	15778	0.000	0.000	1.00	3.7	0.182	0.100	29.50	4.7	21.4
10	0.240	15778	0.000	0.000	1.00	6.9	0.178	0.100	32.78	4.7	21.4
11	0.240	15778	0.000	0.000	1.00	5.6	0.050	0.100	36.06	4.7	21.4
12	0.240	15778	0.000	0.000	1.00	9.3	0.050	0.100	39.33	4.7	21.4
13	0.240	15778	0.000	0.000	1.00	12.7	0.050	0.100	42.61	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	15.4	0.050	0.100	45.89	4.7	21.4
15	0.240	15778	0.000	0.000	1.00	18.2	0.050	0.100	49.17	4.7	21.4
16	0.240	15778	0.000	0.000	1.00	18.6	0.152	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	59.00	4.7	21.4
Toe						3.7	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
35.00	10.81	1.00	0.800

Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft			ksi			ksi			kip-ft	b/min
132.4	13.9	6.78	6.80	-1.20	17	13	24.34	8	3	18.4	45.3
138.4	14.9	6.95	6.88	-0.77	6	40	24.84	8	3	18.5	44.9
144.4	16.0	7.04	6.99	-0.68	9	34	25.12	8	3	18.3	44.6
150.4	17.2	7.12	7.08	-0.78	8	34	25.42	8	3	18.3	44.3
156.4	18.4	7.21	7.17	-0.89	8	34	25.71	8	3	18.2	44.0

Depth (ft) 40.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model   Total Capacity Rut (kips) 157.7

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
6	0.240	15778	0.000	0.000	1.00	1.3	0.200	0.100	19.67	4.7	21.4
7	0.240	15778	0.000	0.000	1.00	5.9	0.198	0.100	22.94	4.7	21.4
8	0.240	15778	0.000	0.000	1.00	5.0	0.190	0.100	26.22	4.7	21.4
9	0.240	15778	0.000	0.000	1.00	6.0	0.099	0.100	29.50	4.7	21.4
10	0.240	15778	0.000	0.000	1.00	6.7	0.050	0.100	32.78	4.7	21.4
11	0.240	15778	0.000	0.000	1.00	11.4	0.050	0.100	36.06	4.7	21.4
12	0.240	15778	0.000	0.000	1.00	14.1	0.050	0.100	39.33	4.7	21.4
13	0.240	15778	0.000	0.000	1.00	16.9	0.050	0.100	42.61	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	19.5	0.058	0.100	45.89	4.7	21.4

15	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	49.17	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	16.4	0.200	0.100	59.00	4.7	21.4
Toe						3.7	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
40.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
157.7	18.6	7.25	7.22	-0.96	5	34	25.63	7	3	18.1	43.9
166.9	20.6	7.37	7.34	-1.01	5	34	26.02	7	3	18.0	43.5
176.1	22.6	7.48	7.47	-1.13	8	27	26.35	7	3	17.9	43.2
185.3	24.9	7.59	7.59	-1.33	7	27	26.69	7	3	17.8	42.9
194.4	27.1	7.70	7.69	-1.45	7	27	26.98	7	3	17.7	42.6

FRA-70-1358L - RA - B-017-9-13 - HP14x73 02/27/2021
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Depth (ft) 45.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 181.6

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
5	0.240	15778	0.000	0.000	1.00	4.8	0.200	0.100	16.39	4.7	21.4
6	0.240	15778	0.000	0.000	1.00	3.8	0.182	0.100	19.67	4.7	21.4
7	0.240	15778	0.000	0.000	1.00	6.8	0.173	0.100	22.94	4.7	21.4
8	0.240	15778	0.000	0.000	1.00	5.6	0.050	0.100	26.22	4.7	21.4
9	0.240	15778	0.000	0.000	1.00	9.5	0.050	0.100	29.50	4.7	21.4
10	0.240	15778	0.000	0.000	1.00	12.8	0.050	0.100	32.78	4.7	21.4
11	0.240	15778	0.000	0.000	1.00	15.6	0.050	0.100	36.06	4.7	21.4
12	0.240	15778	0.000	0.000	1.00	18.3	0.050	0.100	39.33	4.7	21.4
13	0.240	15778	0.000	0.000	1.00	18.5	0.158	0.100	42.61	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	45.89	4.7	21.4
16	0.240	15778	0.000	0.000	1.00	16.7	0.200	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	16.1	0.200	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	15.4	0.200	0.100	59.00	4.7	21.4
Toe						3.7	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
45.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
181.6	24.5	7.60	7.58	-1.39	8	27	26.47	5	3	17.7	42.9
193.7	27.3	7.73	7.73	-1.54	7	27	26.85	5	3	17.5	42.5
205.9	29.4	7.84	7.84	-1.41	7	27	27.15	5	3	17.3	42.2
218.0	31.6	7.93	7.93	-0.99	7	27	27.44	5	3	17.1	42.0
230.2	33.7	8.03	8.01	-0.49	17	12	27.73	5	3	17.2	41.7

FRA-70-1358L - RA - B-017-9-13 - HP14x73 02/27/2021

Depth (ft) 50.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model Total Capacity Rut (kips) 198.5

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	0.0	0.000	0.100	6.56	4.7	21.4
3	0.240	15778	0.000	0.000	1.00	1.7	0.200	0.100	9.83	4.7	21.4
4	0.240	15778	0.000	0.000	1.00	5.6	0.197	0.100	13.11	4.7	21.4
5	0.240	15778	0.000	0.000	1.00	5.4	0.191	0.100	16.39	4.7	21.4
6	0.240	15778	0.000	0.000	1.00	5.8	0.087	0.100	19.67	4.7	21.4
7	0.240	15778	0.000	0.000	1.00	6.9	0.050	0.100	22.94	4.7	21.4
8	0.240	15778	0.000	0.000	1.00	11.5	0.050	0.100	26.22	4.7	21.4
9	0.240	15778	0.000	0.000	1.00	14.3	0.050	0.100	29.50	4.7	21.4
10	0.240	15778	0.000	0.000	1.00	17.0	0.050	0.100	32.78	4.7	21.4
11	0.240	15778	0.000	0.000	1.00	19.4	0.073	0.100	36.06	4.7	21.4
12	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	39.33	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	45.89	4.7	21.4
15	0.240	15778	0.000	0.000	1.00	16.4	0.200	0.100	49.17	4.7	21.4
16	0.240	15778	0.000	0.000	1.00	15.8	0.200	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	15.0	0.200	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	6.8	0.200	0.100	59.00	4.7	21.4
Toe						6.0	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
50.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
198.5	28.2	7.80	7.79	-2.16	16	6	26.82	4	2	17.4	42.3
212.5	30.6	7.93	7.92	-1.71	17	6	27.18	4	2	17.1	42.0
226.4	33.3	8.02	8.02	-1.34	17	6	27.44	4	2	16.8	41.8
240.4	36.2	8.11	8.11	-1.17	16	12	27.70	4	2	16.9	41.5
254.4	39.6	8.14	8.20	-1.03	16	12	27.79	4	2	16.8	41.4

FRA-70-1358L - RA - B-017-9-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Depth (ft) 55.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model Total Capacity Rut (kips) 218.3

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.240	15778	0.010	0.000	0.85	0.0	0.000	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	5.2	0.200	0.100	6.56	4.7	21.4
3	0.240	15778	0.000	0.000	1.00	3.8	0.182	0.100	9.83	4.7	21.4
4	0.240	15778	0.000	0.000	1.00	6.7	0.168	0.100	13.11	4.7	21.4

5	0.240	15778	0.000	0.000	1.00	5.6	0.050	0.100	16.39	4.7	21.4
6	0.240	15778	0.000	0.000	1.00	9.8	0.050	0.100	19.67	4.7	21.4
7	0.240	15778	0.000	0.000	1.00	13.0	0.050	0.100	22.94	4.7	21.4
8	0.240	15778	0.000	0.000	1.00	15.7	0.050	0.100	26.22	4.7	21.4
9	0.240	15778	0.000	0.000	1.00	18.4	0.050	0.100	29.50	4.7	21.4
10	0.240	15778	0.000	0.000	1.00	18.3	0.164	0.100	32.78	4.7	21.4
11	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	36.06	4.7	21.4
13	0.240	15778	0.000	0.000	1.00	16.7	0.200	0.100	42.61	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	16.1	0.200	0.100	45.89	4.7	21.4
15	0.240	15778	0.000	0.000	1.00	15.4	0.200	0.100	49.17	4.7	21.4
16	0.240	15778	0.000	0.000	1.00	10.7	0.200	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	6.6	0.200	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	11.6	0.200	0.100	59.00	4.7	21.4
Toe						10.7	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
55.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
218.3	32.5	7.93	8.00	-2.40	16	6	27.09	2	2	16.7	41.9
234.1	35.8	8.05	8.12	-1.92	16	6	27.40	2	2	16.4	41.6
250.0	39.3	8.16	8.21	-1.41	16	6	27.71	2	2	16.4	41.3
265.8	43.1	8.27	8.31	-1.05	16	12	28.03	2	2	16.6	41.1
281.7	47.3	8.39	8.41	-0.95	16	12	28.35	2	2	16.8	40.8

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Depth (ft) 59.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
59.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 7.141

Pile and Soil Model — Total Capacity Rut (kips) 232.6

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.240	15778	0.010	0.000	0.85	6.6	0.200	0.100	3.28	4.7	21.4
2	0.240	15778	0.000	0.000	1.00	4.1	0.183	0.100	6.56	4.7	21.4
3	0.240	15778	0.000	0.000	1.00	6.3	0.138	0.100	9.83	4.7	21.4
4	0.240	15778	0.000	0.000	1.00	5.9	0.050	0.100	13.11	4.7	21.4
5	0.240	15778	0.000	0.000	1.00	10.8	0.050	0.100	16.39	4.7	21.4
6	0.240	15778	0.000	0.000	1.00	13.6	0.050	0.100	19.67	4.7	21.4
7	0.240	15778	0.000	0.000	1.00	16.3	0.050	0.100	22.94	4.7	21.4
8	0.240	15778	0.000	0.000	1.00	19.0	0.050	0.100	26.22	4.7	21.4
9	0.240	15778	0.000	0.000	1.00	17.6	0.186	0.100	29.50	4.7	21.4
10	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	32.78	4.7	21.4
11	0.240	15778	0.000	0.000	1.00	16.9	0.200	0.100	36.06	4.7	21.4
12	0.240	15778	0.000	0.000	1.00	16.6	0.200	0.100	39.33	4.7	21.4
13	0.240	15778	0.000	0.000	1.00	15.9	0.200	0.100	42.61	4.7	21.4
14	0.240	15778	0.000	0.000	1.00	15.3	0.200	0.100	45.89	4.7	21.4
15	0.240	15778	0.000	0.000	1.00	8.8	0.200	0.100	49.17	4.7	21.4
16	0.240	15778	0.000	0.000	1.00	7.6	0.200	0.100	52.44	4.7	21.4
17	0.240	15778	0.000	0.000	1.00	11.7	0.200	0.100	55.72	4.7	21.4
18	0.240	15778	0.000	0.000	1.00	11.7	0.200	0.100	59.00	4.7	21.4
Toe						10.7	0.150	0.100			

4.314 kips total unreduced pile weight (g= 32.17 ft/s2)
4.314 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
59.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
232.6	35.8	8.09	8.14	-2.47	15	6	27.93	1	2	16.1	41.5
250.2	39.7	8.21	8.25	-1.90	15	6	28.28	1	2	15.9	41.2
267.9	44.1	8.33	8.36	-1.44	15	6	28.63	1	2	16.1	41.0
285.5	49.0	8.45	8.47	-0.97	15	6	29.00	1	2	16.3	40.7
303.1	54.4	8.56	8.57	-0.69	15	12	29.34	1	2	16.5	40.4

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SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.400 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	8.3	7.6	0.7	1.3	6.839	-0.489	3.79	22.4
10.0	24.1	17.4	6.7	2.1	14.513	-3.244	4.59	24.1
15.0	42.1	28.8	13.2	3.4	17.864	-4.380	5.15	22.6
20.0	67.1	48.9	18.2	5.6	20.521	-3.638	5.64	21.0
25.0	98.5	75.3	23.2	8.5	22.251	-2.512	6.10	19.7
30.0	106.6	102.9	3.7	9.6	22.819	-2.377	6.27	19.4
35.0	132.4	128.7	3.7	13.9	24.339	-1.203	6.78	18.4
40.0	157.7	154.1	3.7	18.6	25.630	-0.965	7.25	18.1
45.0	181.6	177.9	3.7	24.5	26.468	-1.387	7.60	17.7
50.0	198.5	192.5	6.0	28.2	26.820	-2.159	7.80	17.4
55.0	218.3	207.6	10.7	32.5	27.087	-2.404	7.93	16.7
59.0	232.6	221.9	10.7	35.8	27.927	-2.472	8.09	16.1

Total Driving Time 18 minutes; Total No. of Blows 793
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.450 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	8.7	8.0	0.7	1.3	6.899	-0.702	3.83	22.5
10.0	24.8	18.1	6.7	2.1	14.942	-3.521	4.67	24.2
15.0	42.8	29.5	13.2	3.5	17.981	-4.380	5.18	22.5
20.0	67.8	49.6	18.2	5.7	20.599	-3.589	5.66	20.9
25.0	99.2	76.0	23.2	8.6	22.328	-2.486	6.12	19.7
30.0	109.4	105.7	3.7	10.1	23.047	-2.423	6.33	19.3
35.0	138.4	134.8	3.7	14.9	24.843	-0.774	6.95	18.5
40.0	166.9	163.2	3.7	20.6	26.018	-1.013	7.37	18.0
45.0	193.7	190.0	3.7	27.3	26.851	-1.544	7.73	17.5
50.0	212.5	206.4	6.0	30.6	27.180	-1.715	7.93	17.1
55.0	234.1	223.4	10.7	35.8	27.400	-1.924	8.05	16.4
59.0	250.2	239.5	10.7	39.7	28.278	-1.904	8.21	15.9

Total Driving Time 20 minutes; Total No. of Blows 862
Starting at penetration 5.0 ft

FRA-70-1358L - RA - B-017-9-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.500 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	9.1	8.4	0.7	1.3	6.949	-0.813	3.87	22.7
10.0	25.5	18.8	6.7	2.2	15.130	-3.587	4.70	24.2
15.0	43.5	30.3	13.2	3.6	18.137	-4.364	5.20	22.4
20.0	68.5	50.3	18.2	5.8	20.727	-3.552	5.68	20.9
25.0	99.9	76.7	23.2	8.8	22.410	-2.450	6.14	19.6
30.0	112.1	108.4	3.7	10.5	23.244	-2.377	6.39	19.2
35.0	144.4	140.8	3.7	16.0	25.119	-0.678	7.04	18.3
40.0	176.1	172.4	3.7	22.6	26.346	-1.130	7.48	17.9
45.0	205.9	202.2	3.7	29.4	27.150	-1.413	7.84	17.3
50.0	226.4	220.4	6.0	33.3	27.437	-1.341	8.02	16.8
55.0	250.0	239.3	10.7	39.3	27.712	-1.406	8.16	16.4
59.0	267.9	257.2	10.7	44.1	28.635	-1.436	8.33	16.1

Total Driving Time 22 minutes; Total No. of Blows 928
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.550 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU

ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	9.5	8.8	0.7	1.3	7.419	-0.789	3.90	23.0
10.0	26.2	19.5	6.7	2.2	15.303	-3.637	4.73	24.1
15.0	44.2	31.0	13.2	3.7	18.285	-4.334	5.22	22.3
20.0	69.2	51.0	18.2	5.9	20.815	-3.495	5.69	20.8
25.0	100.6	77.4	23.2	8.9	22.488	-2.408	6.16	19.6
30.0	114.9	111.2	3.7	10.9	23.451	-2.229	6.44	19.1
35.0	150.4	146.8	3.7	17.2	25.423	-0.783	7.12	18.3
40.0	185.3	181.6	3.7	24.9	26.691	-1.330	7.59	17.8
45.0	218.0	214.3	3.7	31.6	27.445	-0.993	7.93	17.1
50.0	240.4	234.4	6.0	36.2	27.700	-1.174	8.11	16.9
55.0	265.8	255.1	10.7	43.1	28.031	-1.052	8.27	16.6
59.0	285.5	274.8	10.7	49.0	28.997	-0.965	8.45	16.3

Total Driving Time 23 minutes; Total No. of Blows 1001
Starting at penetration 5.0 ft

FRA-70-1358L - RA - B-017-9-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.600 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	9.9	9.2	0.7	1.3	7.627	-0.761	3.89	22.9
10.0	26.9	20.2	6.7	2.3	15.482	-3.677	4.76	24.0
15.0	44.9	31.7	13.2	3.8	18.408	-4.292	5.24	22.2
20.0	69.9	51.7	18.2	5.9	20.900	-3.452	5.71	20.8
25.0	101.3	78.1	23.2	9.0	22.535	-2.385	6.17	19.6
30.0	117.7	114.0	3.7	11.3	23.671	-2.220	6.49	19.0
35.0	156.4	152.8	3.7	18.4	25.705	-0.886	7.21	18.2
40.0	194.4	190.7	3.7	27.1	26.985	-1.450	7.70	17.7
45.0	230.2	226.5	3.7	33.7	27.729	-0.495	8.03	17.2
50.0	254.4	248.3	6.0	39.6	27.788	-1.027	8.14	16.8
55.0	281.7	271.0	10.7	47.3	28.350	-0.953	8.39	16.8
59.0	303.1	292.4	10.7	54.4	29.345	-0.691	8.56	16.5

Total Driving Time 25 minutes; Total No. of Blows 1079
Starting at penetration 5.0 ft

FRA-70-1358L - RA - B-017-9-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Table of Depths Analyzed with Driving System Modifiers

Depth	Temp. Length	Wait Time	Equivalent Stroke	Pressure Ratio	Efficy.	Stiffn. Factor	Cushion CoR
ft	ft	hr	ft				
5.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
10.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
15.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
20.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
25.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
30.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
35.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
40.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
45.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
50.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
55.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00
59.00	59.00	0.00	10.81	1.00	0.80	1.00	1.00

Soil Layer Resistance Values

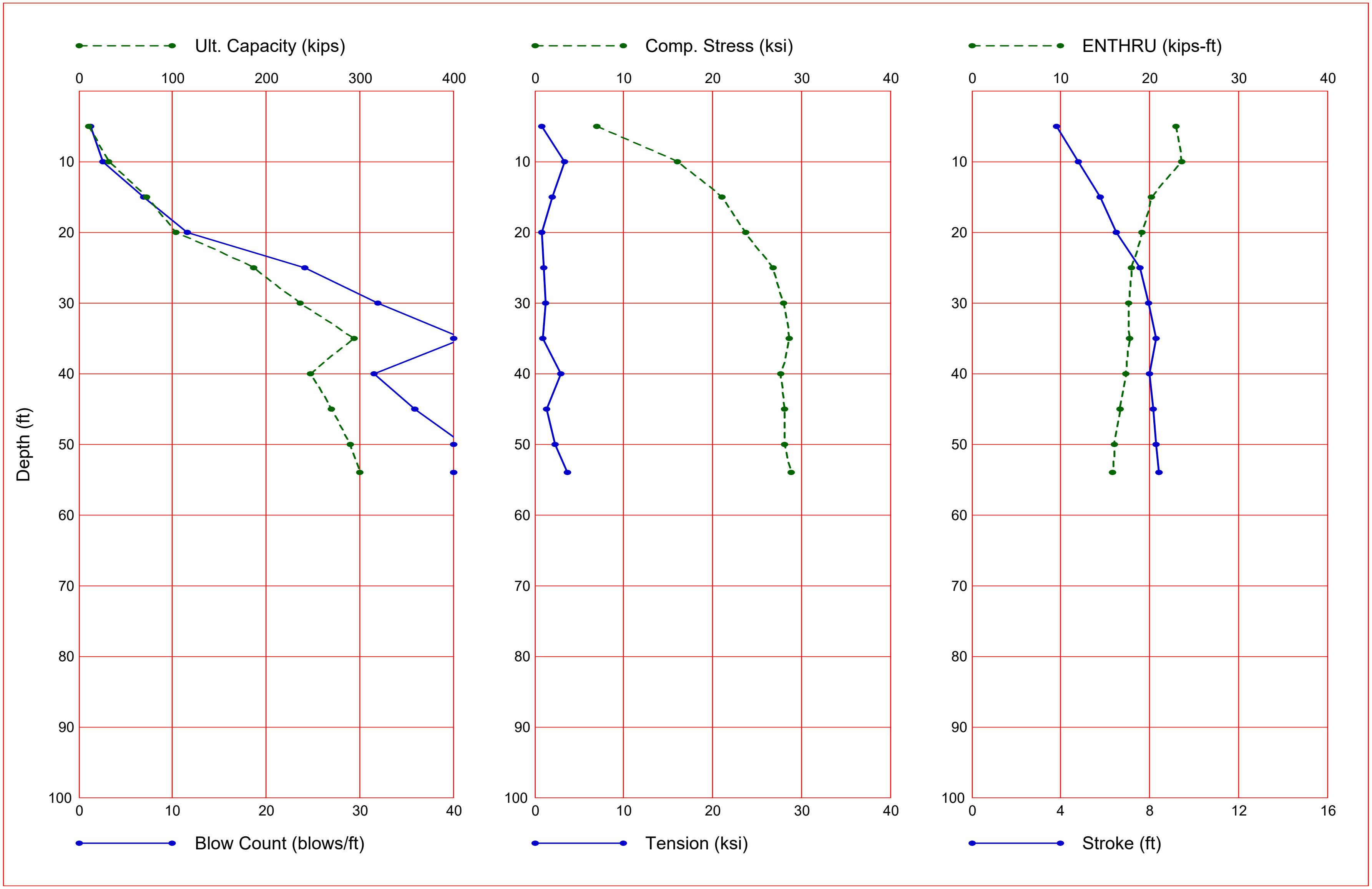
Depth	Shaft Res.	End Bearing	Shaft Quake	Toe Quake	Shaft Damping	Toe Damping	Soil Setup	Limit Distance	Setup Time
ft	k/ft2	kips	inch	inch	s/ft	s/ft	Normlzd	ft	hrs
0.01	0.71	1.00	0.100	0.100	0.200	0.150	0.660	6.000	168.000
3.49	0.71	1.00	0.100	0.100	0.200	0.150	0.660	6.000	168.000
3.51	0.06	0.48	0.100	0.100	0.050	0.150	0.000	6.000	1.000
5.29	0.10	0.74	0.100	0.100	0.050	0.150	0.000	6.000	1.000
5.31	0.82	1.17	0.100	0.100	0.200	0.150	0.660	6.000	168.000
7.79	0.82	1.17	0.100	0.100	0.200	0.150	0.660	6.000	168.000
7.81	0.31	4.97	0.100	0.100	0.050	0.150	0.000	6.000	1.000
10.29	0.43	6.96	0.100	0.100	0.050	0.150	0.000	6.000	1.000
10.31	0.31	3.81	0.100	0.100	0.050	0.150	0.000	6.000	1.000
12.79	0.39	4.81	0.100	0.100	0.050	0.150	0.000	6.000	1.000
12.81	0.60	11.02	0.100	0.100	0.050	0.150	0.000	6.000	1.000
21.81	1.09	20.02	0.100	0.100	0.050	0.150	0.000	6.000	1.000
26.79	1.36	25.00	0.100	0.100	0.050	0.150	0.000	6.000	1.000

26.81	2.75	3.68	0.100	0.100	0.200	0.150	1.000	6.000	168.000
35.81	2.75	3.68	0.100	0.100	0.200	0.150	1.000	6.000	168.000
44.81	2.46	3.68	0.100	0.100	0.200	0.150	1.000	6.000	168.000
46.79	2.36	3.68	0.100	0.100	0.200	0.150	1.000	6.000	168.000
46.81	1.07	6.02	0.100	0.100	0.200	0.150	1.000	6.000	168.000
51.79	1.07	6.02	0.100	0.100	0.200	0.150	1.000	6.000	168.000
51.81	1.90	10.70	0.100	0.100	0.200	0.150	1.000	6.000	168.000
59.00	1.90	10.70	0.100	0.100	0.200	0.150	1.000	6.000	168.000

Resource International Inc
FRA-70-1358L - P1 - B-018-1-13 - HP14x73

Feb 27 2021
GRLWEAP Version 2010

Gain/Loss 3 at Shaft and Toe 0.500 / 1.000



Gain/Loss 3 at Shaft and Toe 0.500 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Stroke ft	ENTHRU kips-ft
5.0	10.2	9.6	0.7	1.3	6.964	-0.799	3.83	23.0
10.0	31.6	27.9	3.7	2.6	16.029	-3.389	4.82	23.6
15.0	72.9	42.4	30.5	6.9	21.024	-1.925	5.77	20.2
20.0	104.3	95.6	8.7	11.6	23.713	-0.827	6.50	19.1
25.0	186.5	130.9	55.5	24.2	26.818	-1.019	7.56	18.0
30.0	236.3	167.8	68.5	31.9	27.958	-1.243	7.96	17.7
35.0	293.8	212.3	81.5	41.1	28.604	-0.926	8.29	17.8
40.0	248.0	245.5	2.5	31.5	27.716	-2.893	7.98	17.3
45.0	270.1	267.6	2.5	35.9	28.136	-1.315	8.17	16.7
50.0	289.9	283.9	6.0	41.2	28.103	-2.281	8.29	16.1
54.0	300.0	294.0	6.0	42.9	28.822	-3.637	8.41	15.8

Total Continuous Driving Time 29.00 minutes; Total Number of Blows 1202 (starting at penetration 5.0 ft)

GRLWEAP - Version 2010
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS

written by GRL Engineers, Inc. (formerly Goble Rausche Likins and Associates, Inc.) with cooperation from Pile Dynamics, Inc.

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

The GRLWEAP program simulates the behavior of a preformed pile driven by either an impact hammer or a vibratory hammer. The program is based on mathematical models, which describe motion and forces of hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate, often complex, dynamic situations.

A wave equation analysis generally relies on input data, which represents normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. All of the input data selected by the user may be the best available information at the time when the analysis is performed. However, input data and therefore results may significantly differ from actual field conditions.

Therefore, the program authors recommend prudent use of the GRLWEAP results. Soil response and hammer performance should be verified by static and/or dynamic testing and measurements. Estimates of bending or other local stresses (e.g., helmet or clamp contact, uneven rock surfaces etc.), prestress effects and others must also be accounted for by the user.

The calculated capacity - blow count relationship, i.e. the bearing graph, should be used in conjunction with observed blow counts for the capacity assessment of a driven pile. Soil setup occurring after pile installation may produce bearing capacity values that differ substantially from those expected from a wave equation analysis due to soil setup or relaxation. This is particularly true for pile driven with vibratory hammers. The GRLWEAP user must estimate such effects and should also use proper care when applying blow counts from restrike because of the variability of hammer energy, soil resistance and blow count during early restriking.

Finally, the GRLWEAP capacities are ultimate values. They MUST be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of building and other factors.

```
 Input  File: J:\GEOTECH\PROJECTS\2013\W-13-072 FRA-70-13.10 PROJECT 6A\ANALYSIS\FRA-70-1358L\DRIVEABILITY\B-018-1-13\B-018-1.GWW
 Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2010.GW
 Hammer File Version:  2003 (12/4/2018)

                        Input File Contents
     FRA-70-1358L - P1 - B-018-1-13 - HP14x73
 OUT OSG HAM STR FUL PEL  N SPL N-U P-D %SK ISM  0 PHI RSA ITR H-D MXT     DEx
-100   0  41   0   0   0  0   0   0   1   0   0  0   0   0   0   0   0   0.000
    Pile g  Hammer g  Toe Area Pile Size           Pile Type
    32.170    32.170   144.000    14.000             Unknown
      W Cp      A Cp      E Cp      T Cp       CoR      ROut      StCp
     1.900   227.000     530.0     2.000     0.800     0.010       0.0
      A Cu      E Cu      T Cu       CoR      ROut      StCu
     0.000       0.0     0.000     0.000     0.000       0.0
      LPle      APle      EPle      WPle      Peri        CI       CoR      ROut
    54.000     21.40   29000.0   492.000     4.700         0     0.850     0.010
  FFatigue        F0  0-Bottom
         0     0.000     0.000
 Manufac  Hmr Name  HmrType No Seg-s
 DELMAG   D 19-42         1       5
    Ram Wt     Ram L   Ram Dia   MaxStrk   RtdStrk    Efficy
      4.00    129.10     12.60     11.86     10.81      0.80
    IB. Wt     IB. L    IB.Dia    IB CoR     IB RO
      0.75     25.30     12.60     0.900     0.010
  CompStrk A Chamber V Chamber   C Delay  C Duratn Exp Coeff VolCStart  Vol CEnd
     16.65    124.70    157.70    0.0020    0.0020     1.250      0.00      0.00
     P atm        P1        P2        P3        P4        P5
     14.70   1600.00   1440.00   1295.00   1165.00      0.00
    Stroke    Effic.  Pressure  R-Weight   T-Delay Exp-Coeff   Eps-Str  Total-AW
   10.8100    0.8000 1600.0000    0.0000    0.0000    0.0000    0.0100    0.0000
        Qs        Qt        Js        Jt        Qx        Jx      Rati      Dept
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  Research Soil Model: Atoe, Plug,  Gap, Q-fac
     0.000     0.000     0.000     0.000
```

Research Soil Model: RD-skn: m, d, toe: m, d
0.000 0.000 0.000 0.000
Research Toe Plug: Res-int, Q-int, D-int, Res-plug, Q-plug, D-plug
0.000 0.000 0.000 0.000 0.000 0.000
Research Toe Plug: RD plug toe: m, d
0.000 0.000
Research Toe Plug: New Toe Plug Model is NOT applied
Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimL	TSf0
0.01	0.49	0.67	0.10	0.10	0.15	0.15	1.21	6.00	24.000
5.49	0.49	0.67	0.10	0.10	0.15	0.15	1.21	6.00	24.000
5.51	0.99	3.68	0.10	0.10	0.15	0.15	1.21	6.00	24.000
10.49	0.99	3.68	0.10	0.10	0.15	0.15	1.21	6.00	24.000
10.51	0.44	8.14	0.10	0.10	0.05	0.15	1.00	6.00	1.000
12.99	0.57	10.44	0.10	0.10	0.05	0.15	1.00	6.00	1.000
13.01	0.64	25.29	0.10	0.10	0.05	0.15	1.00	6.00	1.000
17.99	0.97	38.22	0.10	0.10	0.05	0.15	1.00	6.00	1.000
18.01	6.50	8.69	0.10	0.10	0.20	0.15	1.49	6.00	168.000
20.49	6.50	8.69	0.10	0.10	0.20	0.15	1.49	6.00	168.000
20.51	0.99	18.32	0.10	0.10	0.05	0.15	1.00	6.00	1.000
22.99	1.13	20.80	0.10	0.10	0.05	0.15	1.00	6.00	1.000
23.01	1.27	50.36	0.10	0.10	0.05	0.15	1.00	6.00	1.000
32.01	1.86	73.73	0.10	0.10	0.05	0.15	1.00	6.00	1.000
36.99	2.19	86.67	0.10	0.10	0.05	0.15	1.00	6.00	1.000
37.01	1.88	2.51	0.10	0.10	0.20	0.15	2.00	6.00	168.000
46.01	1.88	2.51	0.10	0.10	0.20	0.15	2.00	6.00	168.000
46.99	1.88	2.51	0.10	0.10	0.20	0.15	2.00	6.00	168.000
47.01	1.07	6.02	0.10	0.10	0.20	0.15	2.00	6.00	168.000
54.00	1.07	6.02	0.10	0.10	0.20	0.15	2.00	6.00	168.000

Gain/Loss factors: shaft and toe
0.40000 0.45000 0.50000 0.55000 0.60000
1.00000 1.00000 1.00000 1.00000 1.00000

Dpth	L	Wait	Strk	Pmx%	Eff.	Stff	CoR
5.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
54.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
Version 2010
English Units

FRA-70-1358L - P1 - B-018-1-13 - HP14x73

Hammer Model: D 19-42 Made by: DELMAG

No.	Weight kips	Stiffn k/inch	CoR	C-Slk ft	Dampg k/ft/s
1	0.800				
2	0.800	140046.6	1.000	0.0000	
3	0.800	140046.6	1.000	0.0000	
4	0.800	140046.6	1.000	0.0000	
5	0.800	140046.6	1.000	0.0000	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		15323.5			

HAMMER OPTIONS:

Hammer File ID No.	41	Hammer Type	OE Diesel
Stroke Option	FxdP-VarS	Stroke Convergence Crit.	0.010
Fuel Pump Setting	Maximum		

HAMMER DATA:

Ram Weight	(kips)	4.00	Ram Length	(inch)	129.10
Maximum Stroke	(ft)	11.86			
Rated Stroke	(ft)	10.81	Efficiency		0.800
Maximum Pressure	(psi)	1600.00	Actual Pressure	(psi)	1600.00
Compression Exponent		1.350	Expansion Exponent		1.250
Ram Diameter	(inch)	12.60			
Combustion Delay	(s)	0.00200	Ignition Duration	(s)	0.00200

The Hammer Data Includes Estimated (NON-MEASURED) Quantities

HAMMER CUSHION			PILE CUSHION		
Cross Sect. Area	(in2)	227.00	Cross Sect. Area	(in2)	0.00
Elastic-Modulus	(ksi)	530.0	Elastic-Modulus	(ksi)	0.0
Thickness	(inch)	2.00	Thickness	(inch)	0.00
Coeff of Restitution		0.8	Coeff of Restitution		1.0
RoundOut	(ft)	0.0	RoundOut	(ft)	0.0
Stiffness	(kips/in)	60155.0	Stiffness	(kips/in)	0.0

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Depth	(ft)	5.0	Standard Soil Setup	
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor	1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	14.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model — Total Capacity Rut (kips) 9.8

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	0.0	0.000	0.100	6.75	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	3.0	0.150	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	6.2	0.150	0.100	54.00	4.7	21.4
Toe						0.7	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

PILE, SOIL, ANALYSIS OPTIONS:

Uniform pile		Pile Segments: Automatic	
No. of Slacks/Splices	0	Pile Damping (%)	1
		Pile Damping Fact.(k/ft/s)	0.751
Driveability Analysis			
Soil Damping Option	Smith		
Max No Analysis Iterations	0	Time Increment/Critical	160
Output Time Interval	1	Analysis Time-Input (ms)	0

Output Level: Normal
Gravity Mass, Pile, Hammer: 32.170 32.170 32.170
Output Segment Generation: Automatic

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
5.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
9.8	1.3	3.79	3.78	-0.64	6	32	6.86	1	6	22.9	60.9
10.0	1.3	3.81	3.80	-0.71	6	32	6.86	1	6	23.0	60.7
10.2	1.3	3.83	3.81	-0.80	6	32	6.96	1	2	23.0	60.6
10.4	1.3	3.85	3.82	-0.84	6	32	7.23	1	2	23.1	60.5
10.6	1.3	3.86	3.84	-0.86	6	32	7.43	1	2	23.0	60.4

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Depth	(ft)	10.0	Standard Soil Setup	
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor	1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	14.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s

0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model — Total Capacity Rut (kips) 30.5

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	0.0	0.000	0.100	6.75	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	6.0	0.150	0.100	47.25	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	8.3	0.150	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	12.5	0.150	0.100	54.00	4.7	21.4
Toe						3.7	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
10.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
30.5	2.5	4.78	4.76	-3.30	4	8	15.75	1	2	23.8	54.3
31.0	2.6	4.80	4.78	-3.35	4	8	15.90	1	2	23.7	54.2
31.6	2.6	4.82	4.80	-3.39	4	8	16.03	1	2	23.6	54.1
32.2	2.7	4.85	4.82	-3.42	4	8	16.19	1	2	23.6	53.9
32.8	2.8	4.86	4.84	-3.40	4	8	16.26	1	2	23.4	53.8

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Depth (ft) 15.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model — Total Capacity Rut (kips) 71.6

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	0.0	0.000	0.100	6.75	4.7	21.4
12	0.247	15323	0.000	0.000	1.00	2.7	0.150	0.100	40.50	4.7	21.4
13	0.247	15323	0.000	0.000	1.00	6.2	0.150	0.100	43.88	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	11.4	0.150	0.100	47.25	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	10.8	0.131	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	10.1	0.050	0.100	54.00	4.7	21.4
Toe						30.5	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
15.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
71.6	6.8	5.75	5.80	-2.00	3	8	20.91	12	4	20.3	49.2
72.3	6.9	5.76	5.82	-1.95	3	8	20.94	12	4	20.3	49.1
72.9	6.9	5.77	5.83	-1.93	3	8	21.02	12	4	20.2	49.0
73.5	7.0	5.79	5.84	-1.89	3	8	21.09	12	4	20.2	49.0
74.1	7.1	5.80	5.85	-1.86	3	8	21.16	12	4	20.2	48.9

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Depth (ft) 20.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model — Total Capacity Rut (kips) 99.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	0.0	0.000	0.100	6.75	4.7	21.4
11	0.247	15323	0.000	0.000	1.00	5.7	0.150	0.100	37.12	4.7	21.4
12	0.247	15323	0.000	0.000	1.00	8.1	0.150	0.100	40.50	4.7	21.4
13	0.247	15323	0.000	0.000	1.00	12.5	0.150	0.100	43.88	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	9.0	0.080	0.100	47.25	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	12.1	0.050	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	42.9	0.186	0.100	54.00	4.7	21.4
Toe						8.7	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
20.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft			ksi			ksi			kip-ft	b/min
99.1	10.8	6.39	6.41	-0.73	11	43	23.34	11	4	19.2	46.6
101.7	11.2	6.45	6.46	-0.78	11	42	23.54	11	4	19.2	46.5
104.3	11.6	6.50	6.50	-0.83	11	40	23.71	11	4	19.1	46.3
106.9	12.0	6.54	6.55	-0.90	11	40	23.88	11	4	19.0	46.1
109.6	12.4	6.58	6.59	-0.88	11	40	24.01	11	4	19.0	46.0

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Depth (ft) 25.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model — Total Capacity Rut (kips) 180.2

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	0.0	0.000	0.100	6.75	4.7	21.4
9	0.247	15323	0.000	0.000	1.00	2.5	0.150	0.100	30.38	4.7	21.4
10	0.247	15323	0.000	0.000	1.00	6.2	0.150	0.100	33.75	4.7	21.4
11	0.247	15323	0.000	0.000	1.00	11.1	0.150	0.100	37.12	4.7	21.4
12	0.247	15323	0.000	0.000	1.00	11.0	0.133	0.100	40.50	4.7	21.4
13	0.247	15323	0.000	0.000	1.00	9.9	0.050	0.100	43.88	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	17.4	0.105	0.100	47.25	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	47.0	0.189	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	19.6	0.050	0.100	54.00	4.7	21.4
Toe						55.5	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
25.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
180.2	22.9	7.50	7.47	-1.08	9	30	26.67	10	4	18.1	43.2
183.3	23.5	7.53	7.51	-1.06	9	30	26.74	10	4	18.1	43.1
186.5	24.2	7.56	7.55	-1.02	9	30	26.82	10	4	18.0	43.0
189.6	24.8	7.60	7.59	-0.97	9	30	26.96	10	4	18.0	42.9
192.7	25.5	7.63	7.62	-0.92	9	30	27.04	10	4	18.0	42.8

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Depth (ft) 30.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model — Total Capacity Rut (kips) 230.0

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	0.0	0.000	0.100	6.75	4.7	21.4
8	0.247	15323	0.000	0.000	1.00	5.5	0.150	0.100	27.00	4.7	21.4
9	0.247	15323	0.000	0.000	1.00	7.8	0.150	0.100	30.38	4.7	21.4
10	0.247	15323	0.000	0.000	1.00	12.5	0.150	0.100	33.75	4.7	21.4
11	0.247	15323	0.000	0.000	1.00	9.1	0.086	0.100	37.12	4.7	21.4
12	0.247	15323	0.000	0.000	1.00	12.0	0.050	0.100	40.50	4.7	21.4
13	0.247	15323	0.000	0.000	1.00	41.1	0.184	0.100	43.88	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	25.6	0.136	0.100	47.25	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	22.2	0.050	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	25.7	0.050	0.100	54.00	4.7	21.4
Toe						68.5	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
30.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
230.0	30.8	7.91	7.89	-1.33	8	25	27.80	8	3	17.8	42.0
233.2	31.5	7.93	7.93	-1.28	8	25	27.87	8	3	17.7	42.0
236.3	31.9	7.96	7.94	-1.24	8	25	27.96	8	3	17.7	41.9
239.4	32.5	7.98	7.97	-1.18	8	25	27.99	8	3	17.7	41.8
242.5	33.1	7.99	8.00	-1.10	8	25	28.04	8	3	17.6	41.8

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Depth (ft) 35.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model   Total Capacity Rut (kips) 287.6

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	0.0	0.000	0.100	6.75	4.7	21.4
6	0.247	15323	0.000	0.000	1.00	2.3	0.150	0.100	20.25	4.7	21.4
7	0.247	15323	0.000	0.000	1.00	6.2	0.150	0.100	23.62	4.7	21.4
8	0.247	15323	0.000	0.000	1.00	10.9	0.150	0.100	27.00	4.7	21.4
9	0.247	15323	0.000	0.000	1.00	11.2	0.136	0.100	30.38	4.7	21.4
10	0.247	15323	0.000	0.000	1.00	9.7	0.050	0.100	33.75	4.7	21.4
11	0.247	15323	0.000	0.000	1.00	15.5	0.083	0.100	37.12	4.7	21.4
12	0.247	15323	0.000	0.000	1.00	48.7	0.190	0.100	40.50	4.7	21.4
13	0.247	15323	0.000	0.000	1.00	19.4	0.050	0.100	43.88	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	23.9	0.050	0.100	47.25	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	27.4	0.050	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	30.9	0.050	0.100	54.00	4.7	21.4
Toe						81.5	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
35.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
287.6	39.8	8.24	8.24	-1.02	7	43	28.50	7	3	17.7	41.2
290.7	40.7	8.18	8.25	-0.97	7	43	28.37	7	3	17.6	41.3
293.8	41.1	8.29	8.28	-0.93	7	42	28.60	7	3	17.8	41.1
297.0	42.3	8.23	8.30	-0.88	7	42	28.51	7	3	17.6	41.1
300.1	42.5	8.33	8.32	-0.83	7	42	28.77	7	3	17.8	41.0

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Depth (ft) 40.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model   Total Capacity Rut (kips) 239.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	0.0	0.000	0.100	6.75	4.7	21.4
5	0.247	15323	0.000	0.000	1.00	5.3	0.150	0.100	16.88	4.7	21.4
6	0.247	15323	0.000	0.000	1.00	7.6	0.150	0.100	20.25	4.7	21.4
7	0.247	15323	0.000	0.000	1.00	12.5	0.150	0.100	23.62	4.7	21.4
8	0.247	15323	0.000	0.000	1.00	9.2	0.091	0.100	27.00	4.7	21.4
9	0.247	15323	0.000	0.000	1.00	11.9	0.050	0.100	30.38	4.7	21.4
10	0.247	15323	0.000	0.000	1.00	39.3	0.182	0.100	33.75	4.7	21.4
11	0.247	15323	0.000	0.000	1.00	27.1	0.145	0.100	37.12	4.7	21.4
12	0.247	15323	0.000	0.000	1.00	22.1	0.050	0.100	40.50	4.7	21.4
13	0.247	15323	0.000	0.000	1.00	25.6	0.050	0.100	43.88	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	29.1	0.050	0.100	47.25	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	32.6	0.050	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	14.4	0.181	0.100	54.00	4.7	21.4
Toe						2.5	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
40.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
239.1	30.1	7.91	7.91	-3.31	7	25	27.53	5	3	17.4	42.0
243.6	30.9	7.94	7.94	-3.11	7	25	27.61	5	3	17.3	41.9
248.0	31.5	7.98	7.97	-2.89	7	25	27.72	5	3	17.3	41.8
252.5	32.3	8.01	8.00	-2.64	7	25	27.81	5	3	17.2	41.8
256.9	33.0	8.04	8.04	-2.38	7	25	27.90	5	3	17.1	41.7

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Depth (ft) 45.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model Total Capacity Rut (kips) 256.8

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	0.0	0.000	0.100	6.75	4.7	21.4
3	0.247	15323	0.000	0.000	1.00	2.1	0.150	0.100	10.12	4.7	21.4
4	0.247	15323	0.000	0.000	1.00	6.2	0.150	0.100	13.50	4.7	21.4
5	0.247	15323	0.000	0.000	1.00	10.6	0.150	0.100	16.88	4.7	21.4
6	0.247	15323	0.000	0.000	1.00	11.4	0.138	0.100	20.25	4.7	21.4
7	0.247	15323	0.000	0.000	1.00	9.6	0.050	0.100	23.62	4.7	21.4
8	0.247	15323	0.000	0.000	1.00	13.6	0.050	0.100	27.00	4.7	21.4
9	0.247	15323	0.000	0.000	1.00	50.3	0.192	0.100	30.38	4.7	21.4
10	0.247	15323	0.000	0.000	1.00	19.2	0.050	0.100	33.75	4.7	21.4
11	0.247	15323	0.000	0.000	1.00	23.8	0.050	0.100	37.12	4.7	21.4
12	0.247	15323	0.000	0.000	1.00	27.3	0.050	0.100	40.50	4.7	21.4
13	0.247	15323	0.000	0.000	1.00	30.8	0.050	0.100	43.88	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	25.6	0.101	0.100	47.25	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	11.9	0.200	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	11.9	0.200	0.100	54.00	4.7	21.4
Toe						2.5	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
45.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
256.8	33.4	8.09	8.08	-2.30	14	6	27.79	4	2	16.9	41.6
263.4	34.5	8.14	8.12	-1.82	7	25	27.96	9	4	16.9	41.5
270.1	35.9	8.17	8.16	-1.31	15	12	28.14	9	4	16.7	41.4
276.7	37.4	8.21	8.21	-1.19	15	12	28.30	9	4	16.6	41.3
283.4	39.3	8.17	8.25	-1.05	15	12	28.32	9	4	16.4	41.3

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Depth (ft) 50.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	14.000		

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model — Total Capacity Rut (kips) 273.4

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.247	15323	0.010	0.000	0.85	0.0	0.000	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	5.0	0.150	0.100	6.75	4.7	21.4
3	0.247	15323	0.000	0.000	1.00	7.4	0.150	0.100	10.12	4.7	21.4
4	0.247	15323	0.000	0.000	1.00	12.5	0.150	0.100	13.50	4.7	21.4
5	0.247	15323	0.000	0.000	1.00	9.3	0.095	0.100	16.88	4.7	21.4
6	0.247	15323	0.000	0.000	1.00	11.7	0.050	0.100	20.25	4.7	21.4
7	0.247	15323	0.000	0.000	1.00	37.5	0.180	0.100	23.62	4.7	21.4
8	0.247	15323	0.000	0.000	1.00	28.7	0.152	0.100	27.00	4.7	21.4
9	0.247	15323	0.000	0.000	1.00	21.9	0.050	0.100	30.38	4.7	21.4
10	0.247	15323	0.000	0.000	1.00	25.5	0.050	0.100	33.75	4.7	21.4
11	0.247	15323	0.000	0.000	1.00	29.0	0.050	0.100	37.12	4.7	21.4
12	0.247	15323	0.000	0.000	1.00	32.5	0.050	0.100	40.50	4.7	21.4
13	0.247	15323	0.000	0.000	1.00	15.2	0.175	0.100	43.88	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	11.9	0.200	0.100	47.25	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	7.4	0.200	0.100	54.00	4.7	21.4
Toe						6.0	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
50.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
273.4	37.4	8.19	8.24	-3.30	14	6	27.85	2	2	16.2	41.3
281.7	39.2	8.23	8.29	-2.77	14	6	27.97	2	2	16.1	41.2
289.9	41.2	8.29	8.34	-2.28	14	6	28.10	2	2	16.1	41.0
298.2	43.5	8.35	8.40	-1.86	14	6	28.28	2	2	16.2	40.9
306.5	45.3	8.41	8.44	-1.37	14	6	28.45	7	3	16.4	40.8

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Depth	(ft)	54.0	Standard Soil Setup	
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor	1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	14.000		

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.0	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.536

Pile and Soil Model — Total Capacity Rut (kips) 281.4

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.247	15323	0.010	0.000	0.85	6.2	0.150	0.100	3.38	4.7	21.4
2	0.247	15323	0.000	0.000	1.00	8.5	0.150	0.100	6.75	4.7	21.4
3	0.247	15323	0.000	0.000	1.00	12.5	0.150	0.100	10.12	4.7	21.4
4	0.247	15323	0.000	0.000	1.00	8.9	0.069	0.100	13.50	4.7	21.4
5	0.247	15323	0.000	0.000	1.00	12.4	0.050	0.100	16.88	4.7	21.4
6	0.247	15323	0.000	0.000	1.00	46.5	0.190	0.100	20.25	4.7	21.4
7	0.247	15323	0.000	0.000	1.00	20.9	0.097	0.100	23.62	4.7	21.4
8	0.247	15323	0.000	0.000	1.00	22.6	0.050	0.100	27.00	4.7	21.4
9	0.247	15323	0.000	0.000	1.00	26.1	0.050	0.100	30.38	4.7	21.4
10	0.247	15323	0.000	0.000	1.00	29.6	0.050	0.100	33.75	4.7	21.4

11	0.247	15323	0.000	0.000	1.00	32.3	0.055	0.100	37.12	4.7	21.4
12	0.247	15323	0.000	0.000	1.00	11.9	0.200	0.100	40.50	4.7	21.4
14	0.247	15323	0.000	0.000	1.00	11.5	0.200	0.100	47.25	4.7	21.4
15	0.247	15323	0.000	0.000	1.00	6.8	0.200	0.100	50.62	4.7	21.4
16	0.247	15323	0.000	0.000	1.00	6.8	0.200	0.100	54.00	4.7	21.4
Toe						6.0	0.150	0.100			

3.948 kips total unreduced pile weight (g= 32.17 ft/s2)
3.948 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
54.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
281.4	38.4	8.30	8.33	-4.41	14	6	28.49	1	2	15.8	41.0
290.7	40.4	8.37	8.39	-4.01	14	6	28.67	1	2	15.8	40.9
300.0	42.9	8.41	8.45	-3.64	14	6	28.82	6	3	15.8	40.8
309.3	45.1	8.47	8.50	-3.27	14	6	29.10	6	3	15.9	40.6
318.6	47.6	8.54	8.55	-2.96	14	6	29.32	6	3	16.0	40.5

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SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.400 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	9.8	9.2	0.7	1.3	6.856	-0.644	3.79	22.9
10.0	30.5	26.8	3.7	2.5	15.747	-3.302	4.78	23.8
15.0	71.6	41.2	30.5	6.8	20.913	-2.002	5.75	20.3
20.0	99.1	90.4	8.7	10.8	23.343	-0.728	6.39	19.2
25.0	180.2	124.7	55.5	22.9	26.668	-1.083	7.50	18.1
30.0	230.0	161.5	68.5	30.8	27.805	-1.329	7.91	17.8
35.0	287.6	206.1	81.5	39.8	28.495	-1.016	8.24	17.7
40.0	239.1	236.6	2.5	30.1	27.528	-3.315	7.91	17.4
45.0	256.8	254.2	2.5	33.4	27.787	-2.297	8.09	16.9
50.0	273.4	267.3	6.0	37.4	27.852	-3.297	8.19	16.2
54.0	281.4	275.4	6.0	38.4	28.494	-4.408	8.30	15.8

Total Driving Time 27 minutes; Total No. of Blows 1134
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.450 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	10.0	9.4	0.7	1.3	6.860	-0.715	3.81	23.0
10.0	31.0	27.4	3.7	2.6	15.903	-3.351	4.80	23.7
15.0	72.3	41.8	30.5	6.9	20.943	-1.946	5.76	20.3
20.0	101.7	93.0	8.7	11.2	23.538	-0.778	6.45	19.2
25.0	183.3	127.8	55.5	23.5	26.740	-1.057	7.53	18.1
30.0	233.2	164.7	68.5	31.5	27.871	-1.283	7.93	17.7
35.0	290.7	209.2	81.5	40.7	28.369	-0.968	8.18	17.6
40.0	243.6	241.1	2.5	30.9	27.606	-3.105	7.94	17.3
45.0	263.4	260.9	2.5	34.5	27.957	-1.816	8.14	16.9
50.0	281.7	275.6	6.0	39.2	27.972	-2.766	8.23	16.1
54.0	290.7	284.7	6.0	40.4	28.667	-4.010	8.37	15.8

Total Driving Time 28 minutes; Total No. of Blows 1169
Starting at penetration 5.0 ft

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SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.500 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	10.2	9.6	0.7	1.3	6.964	-0.799	3.83	23.0
10.0	31.6	27.9	3.7	2.6	16.029	-3.389	4.82	23.6
15.0	72.9	42.4	30.5	6.9	21.024	-1.925	5.77	20.2
20.0	104.3	95.6	8.7	11.6	23.713	-0.827	6.50	19.1
25.0	186.5	130.9	55.5	24.2	26.818	-1.019	7.56	18.0
30.0	236.3	167.8	68.5	31.9	27.958	-1.243	7.96	17.7

35.0	293.8	212.3	81.5	41.1	28.604	-0.926	8.29	17.8
40.0	248.0	245.5	2.5	31.5	27.716	-2.893	7.98	17.3
45.0	270.1	267.6	2.5	35.9	28.136	-1.315	8.17	16.7
50.0	289.9	283.9	6.0	41.2	28.103	-2.281	8.29	16.1
54.0	300.0	294.0	6.0	42.9	28.822	-3.637	8.41	15.8

Total Driving Time 29 minutes; Total No. of Blows 1202
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.550 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	10.4	9.8	0.7	1.3	7.231	-0.839	3.85	23.1
10.0	32.2	28.5	3.7	2.7	16.189	-3.417	4.85	23.6
15.0	73.5	43.0	30.5	7.0	21.090	-1.888	5.79	20.2
20.0	106.9	98.2	8.7	12.0	23.878	-0.901	6.54	19.0
25.0	189.6	134.1	55.5	24.8	26.960	-0.975	7.60	18.0
30.0	239.4	170.9	68.5	32.5	27.988	-1.177	7.98	17.7
35.0	297.0	215.5	81.5	42.3	28.514	-0.879	8.23	17.6
40.0	252.5	250.0	2.5	32.3	27.807	-2.641	8.01	17.2
45.0	276.7	274.2	2.5	37.4	28.304	-1.187	8.21	16.6
50.0	298.2	292.2	6.0	43.5	28.278	-1.858	8.35	16.2
54.0	309.3	303.3	6.0	45.1	29.099	-3.266	8.47	15.9

Total Driving Time 30 minutes; Total No. of Blows 1243
Starting at penetration 5.0 ft

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SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.600 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	10.6	10.0	0.7	1.3	7.434	-0.858	3.86	23.0
10.0	32.8	29.1	3.7	2.8	16.257	-3.402	4.86	23.4
15.0	74.1	43.6	30.5	7.1	21.158	-1.858	5.80	20.2
20.0	109.6	100.9	8.7	12.4	24.007	-0.884	6.58	19.0
25.0	192.7	137.2	55.5	25.5	27.035	-0.924	7.63	18.0
30.0	242.5	174.0	68.5	33.1	28.038	-1.102	7.99	17.6
35.0	300.1	218.6	81.5	42.5	28.769	-0.829	8.33	17.8
40.0	256.9	254.4	2.5	33.0	27.903	-2.384	8.04	17.1
45.0	283.4	280.9	2.5	39.3	28.318	-1.054	8.17	16.4
50.0	306.5	300.5	6.0	45.3	28.449	-1.369	8.41	16.4
54.0	318.6	312.6	6.0	47.6	29.322	-2.959	8.54	16.0

Total Driving Time 31 minutes; Total No. of Blows 1282
Starting at penetration 5.0 ft

FRA-70-1358L - P1 - B-018-1-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Table of Depths Analyzed with Driving System Modifiers

Depth	Temp. Length	Wait Time	Equivalent Stroke	Pressure Ratio	Efficy.	Stiffn. Factor	Cushion CoR
ft	ft	hr	ft				
5.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
10.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
15.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
20.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
25.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
30.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
35.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
40.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
45.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
50.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00
54.00	54.00	0.00	10.81	1.00	0.80	1.00	1.00

Soil Layer Resistance Values

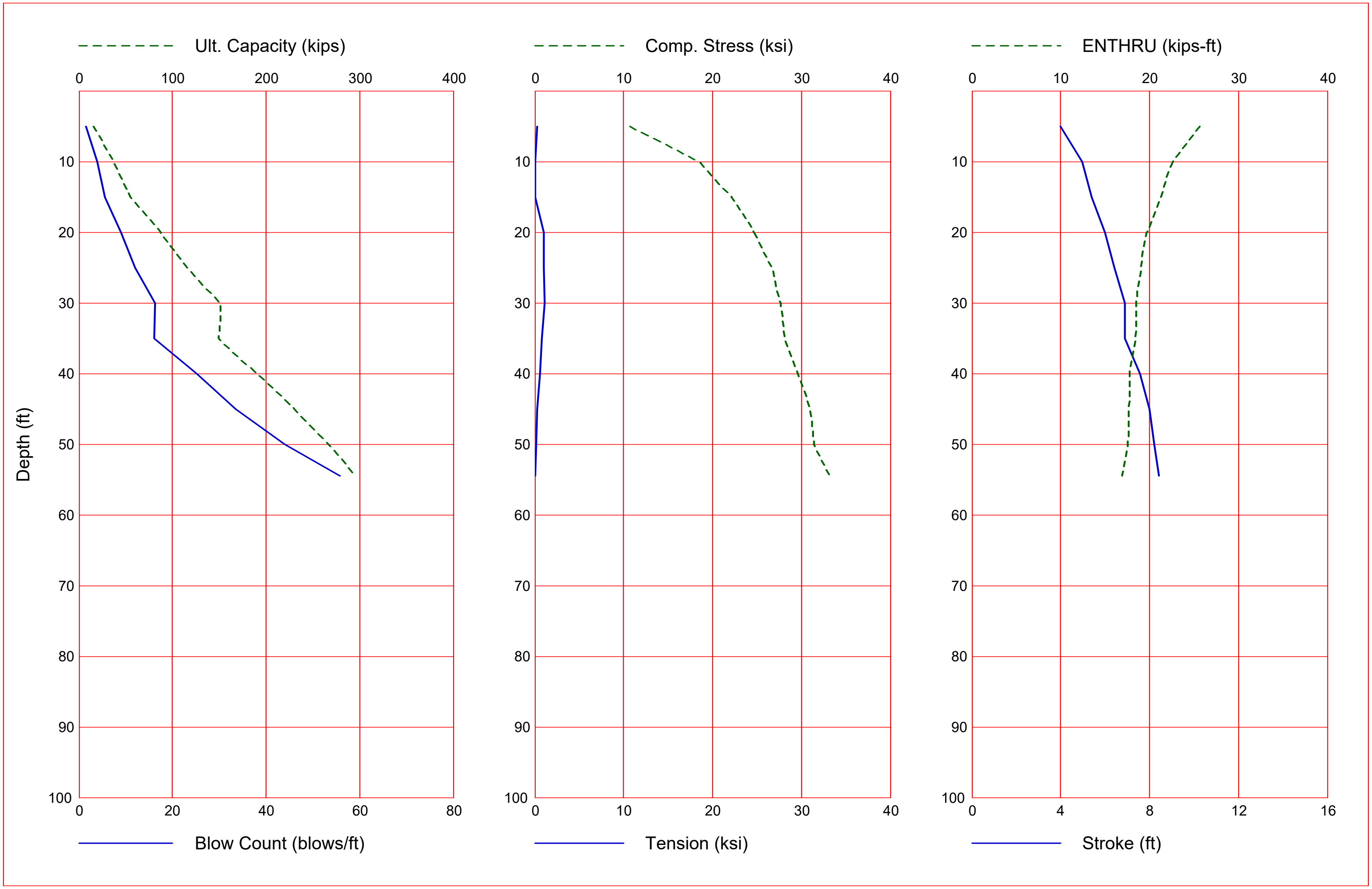
Depth	Shaft Res.	End Bearing	Shaft Quake	Toe Quake	Shaft Damping	Toe Damping	Soil Setup	Limit Distance	Setup Time
ft	k/ft2	kips	inch	inch	s/ft	s/ft	Normlzd	ft	hrs
0.01	0.49	0.67	0.100	0.100	0.150	0.150	0.340	6.000	24.000
5.49	0.49	0.67	0.100	0.100	0.150	0.150	0.340	6.000	24.000
5.51	0.99	3.68	0.100	0.100	0.150	0.150	0.340	6.000	24.000
10.49	0.99	3.68	0.100	0.100	0.150	0.150	0.340	6.000	24.000
10.51	0.44	8.14	0.100	0.100	0.050	0.150	0.000	6.000	1.000

12.99	0.57	10.44	0.100	0.100	0.050	0.150	0.000	6.000	1.000
13.01	0.64	25.29	0.100	0.100	0.050	0.150	0.000	6.000	1.000
17.99	0.97	38.22	0.100	0.100	0.050	0.150	0.000	6.000	1.000
18.01	6.50	8.69	0.100	0.100	0.200	0.150	0.660	6.000	168.000
20.49	6.50	8.69	0.100	0.100	0.200	0.150	0.660	6.000	168.000
20.51	0.99	18.32	0.100	0.100	0.050	0.150	0.000	6.000	1.000
22.99	1.13	20.80	0.100	0.100	0.050	0.150	0.000	6.000	1.000
23.01	1.27	50.36	0.100	0.100	0.050	0.150	0.000	6.000	1.000
32.01	1.86	73.73	0.100	0.100	0.050	0.150	0.000	6.000	1.000
36.99	2.19	86.67	0.100	0.100	0.050	0.150	0.000	6.000	1.000
37.01	1.88	2.51	0.100	0.100	0.200	0.150	1.000	6.000	168.000
46.01	1.88	2.51	0.100	0.100	0.200	0.150	1.000	6.000	168.000
46.99	1.88	2.51	0.100	0.100	0.200	0.150	1.000	6.000	168.000
47.01	1.07	6.02	0.100	0.100	0.200	0.150	1.000	6.000	168.000
54.00	1.07	6.02	0.100	0.100	0.200	0.150	1.000	6.000	168.000

Resource International Inc
FRA-70-1358L - FA - B-018-2-13 - HP12x53

Jun 07 2022
GRLWEAP Version 2010

Gain/Loss 3 at Shaft and Toe 0.500 / 1.000



Gain/Loss 3 at Shaft and Toe 0.500 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Stroke ft	ENTHRU kips-ft
5.0	15.4	13.6	1.8	1.6	10.740	-0.214	3.97	25.7
10.0	36.9	35.1	1.8	3.9	18.534	0.000	4.97	22.6
15.0	55.3	45.5	9.8	5.6	22.137	0.000	5.41	21.3
20.0	87.4	61.4	25.9	9.1	24.655	-1.032	5.99	19.7
25.0	116.4	83.1	33.3	12.1	26.716	-1.019	6.43	19.0
30.0	150.9	110.2	40.7	16.4	27.649	-1.146	6.91	18.5
35.0	149.8	145.8	4.0	16.0	28.073	-0.786	6.89	18.4
40.0	190.7	186.7	4.0	25.2	29.571	-0.587	7.58	17.8
45.0	230.8	226.8	4.0	33.6	30.947	-0.275	7.98	17.6
50.0	266.6	262.6	4.0	44.1	31.452	-0.117	8.21	17.5
54.5	294.9	290.9	4.0	55.8	33.179	0.000	8.44	16.9

Total Continuous Driving Time 22.00 minutes; Total Number of Blows 949 (starting at penetration 5.0 ft)

GRLWEAP - Version 2010
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS

written by GRL Engineers, Inc. (formerly Goble Rausche Likins
and Associates, Inc.) with cooperation from Pile Dynamics, Inc.

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

The GRLWEAP program simulates the behavior of a preformed pile driven by either an impact hammer or a vibratory hammer. The program is based on mathematical models, which describe motion and forces of hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate, often complex, dynamic situations.

A wave equation analysis generally relies on input data, which represents normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. All of the input data selected by the user may be the best available information at the time when the analysis is performed. However, input data and therefore results may significantly differ from actual field conditions.

Therefore, the program authors recommend prudent use of the GRLWEAP results. Soil response and hammer performance should be verified by static and/or dynamic testing and measurements. Estimates of bending or other local stresses (e.g., helmet or clamp contact, uneven rock surfaces etc.), prestress effects and others must also be accounted for by the user.

The calculated capacity - blow count relationship, i.e. the bearing graph, should be used in conjunction with observed blow counts for the capacity assessment of a driven pile. Soil setup occurring after pile installation may produce bearing capacity values that differ substantially from those expected from a wave equation analysis due to soil setup or relaxation. This is particularly true for pile driven with vibratory hammers. The GRLWEAP user must estimate such effects and should also use proper care when applying blow counts from restrike because of the variability of hammer energy, soil resistance and blow count during early restriking.

Finally, the GRLWEAP capacities are ultimate values. They MUST be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of building and other factors.

```
 Input  File: J:\GEOTECH\PROJECTS\2013\W-13-072 FRA-70-13.10 PROJECT 6A\ANALYSIS\FRA-70-1358L\DRIVEABILITY\B-018-2-13\HP
12X53\B-018-2.GWW
 Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2010.GW
 Hammer File Version:  2003 (12/4/2018)

                        Input File Contents
     FRA-70-1358L - FA - B-018-2-13 - HP12x53
 OUT OSG HAM STR FUL PEL  N SPL N-U P-D %SK ISM  0 PHI RSA ITR H-D MXT     DEx
-100   0  41   0   0   0  0   0   0   1   0   0  0   0   0   0   0   0   0.000
    Pile g  Hammer g  Toe Area Pile Size          Pile Type
    32.170    32.170   144.000    12.000            Unknown
      W Cp      A Cp      E Cp      T Cp       CoR      ROut      StCp
     1.900   227.000     530.0     2.000     0.800     0.010       0.0
      A Cu      E Cu      T Cu       CoR      ROut      StCu
     0.000       0.0     0.000     0.000     0.000       0.0
      LPle      APle      EPle      WPle      Peri        CI       CoR      ROut
    54.500     15.50   29000.0   492.000     3.970         0     0.850     0.010
  FFatigue        F0  0-Bottom
         0     0.000     0.000
 Manufac  Hmr Name  HmrType No Seg-s
 DELMAG   D 19-42         1       5
    Ram Wt     Ram L   Ram Dia   MaxStrk   RtdStrk    Efficy
      4.00    129.10     12.60     11.86     10.81      0.80
    IB. Wt     IB. L    IB.Dia    IB CoR     IB RO
      0.75     25.30     12.60     0.900     0.010
  CompStrk A Chamber V Chamber   C Delay  C Duratn Exp Coeff VolCStart  Vol CEnd
     16.65    124.70    157.70    0.0020    0.0020     1.250      0.00      0.00
     P atm        P1        P2        P3        P4        P5
     14.70   1600.00   1440.00   1295.00   1165.00      0.00
    Stroke    Effic.  Pressure  R-Weight   T-Delay Exp-Coeff   Eps-Str  Total-AW
```

10.8100	0.8000	1600.0000	0.0000	0.0000	0.0000	0.0100	0.0000
Qs	Qt	Js	Jt	Qx	Jx	Rati	Dept
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Research Soil Model: Atoe, Plug, Gap, Q-fac
0.000 0.000 0.000 0.000
Research Soil Model: RD-skn: m, d, toe: m, d
0.000 0.000 0.000 0.000
Research Toe Plug: Res-int, Q-int, D-int, Res-plug, Q-plug, D-plug
0.000 0.000 0.000 0.000 0.000 0.000
Research Toe Plug: RD plug toe: m, d
0.000 0.000
Research Toe Plug: New Toe Plug Model is NOT applied
Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimL	TSf0
0.01	0.00	0.00	0.10	0.10	0.05	0.15	1.00	6.00	1.000
1.29	0.05	0.56	0.10	0.10	0.05	0.15	1.00	6.00	1.000
1.31	1.37	1.82	0.10	0.10	0.20	0.15	1.49	6.00	168.000
6.29	1.37	1.82	0.10	0.10	0.20	0.15	1.49	6.00	168.000
6.31	1.37	1.82	0.10	0.10	0.20	0.15	1.21	6.00	24.000
10.09	1.37	1.82	0.10	0.10	0.20	0.15	1.21	6.00	24.000
10.11	0.40	6.31	0.10	0.10	0.05	0.15	1.00	6.00	1.000
16.29	0.68	10.78	0.10	0.10	0.05	0.15	1.00	6.00	1.000
16.31	0.76	20.49	0.10	0.10	0.05	0.15	1.00	6.00	1.000
25.31	1.25	33.78	0.10	0.10	0.05	0.15	1.00	6.00	1.000
32.79	1.65	44.81	0.10	0.10	0.05	0.15	1.00	6.00	1.000
32.81	4.12	4.00	0.10	0.10	0.20	0.15	2.00	6.00	168.000
41.81	4.12	4.00	0.10	0.10	0.20	0.15	2.00	6.00	168.000
50.81	3.31	4.00	0.10	0.10	0.20	0.15	2.00	6.00	168.000
54.50	2.97	4.00	0.10	0.10	0.20	0.15	2.00	6.00	168.000

Gain/Loss factors: shaft and toe
0.40000 0.45000 0.50000 0.55000 0.60000
1.00000 1.00000 1.00000 1.00000 1.00000

Dpth	L	Wait	Strk	Pmx%	Eff.	Stff	CoR
5.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
54.50	0.00	0.00	0.000	0.0	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
Version 2010
English Units

FRA-70-1358L - FA - B-018-2-13 - HP12x53

Hammer Model: D 19-42 Made by: DELMAG

No.	Weight kips	Stiffn k/inch	CoR	C-Slk ft	Dampg k/ft/s
1	0.800				
2	0.800	140046.6	1.000	0.0000	
3	0.800	140046.6	1.000	0.0000	
4	0.800	140046.6	1.000	0.0000	
5	0.800	140046.6	1.000	0.0000	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		10996.9			

HAMMER OPTIONS:

Hammer File ID No.	41	Hammer Type	OE Diesel
Stroke Option	FxdP-VarS	Stroke Convergence Crit.	0.010
Fuel Pump Setting	Maximum		

HAMMER DATA:

Ram Weight	(kips)	4.00	Ram Length	(inch)	129.10
Maximum Stroke	(ft)	11.86			
Rated Stroke	(ft)	10.81	Efficiency		0.800
Maximum Pressure	(psi)	1600.00	Actual Pressure	(psi)	1600.00
Compression Exponent		1.350	Expansion Exponent		1.250

Ram Diameter (inch) 12.60
Combustion Delay (s) 0.00200 Ignition Duration (s) 0.00200

The Hammer Data Includes Estimated (NON-MEASURED) Quantities

HAMMER CUSHION			PILE CUSHION		
Cross Sect. Area	(in2)	227.00	Cross Sect. Area	(in2)	0.00
Elastic-Modulus	(ksi)	530.0	Elastic-Modulus	(ksi)	0.0
Thickness	(inch)	2.00	Thickness	(inch)	0.00
Coeff of Restitution		0.8	Coeff of Restitution		1.0
RoundOut	(ft)	0.0	RoundOut	(ft)	0.0
Stiffness	(kips/in)	60155.0	Stiffness	(kips/in)	0.0

FRA-70-1358L - FA - B-018-2-13 - HP12x53 06/07/2022
Resource International Inc GRLWEAP Version 2010

Depth (ft) 5.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model Total Capacity Rut (kips) 14.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	1.1	0.187	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	11.2	0.200	0.100	54.50	4.0	15.5
Toe						1.8	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

PILE, SOIL, ANALYSIS OPTIONS:
Uniform pile Pile Segments: Automatic
No. of Slacks/Splices 0 Pile Damping (%) 1
Pile Damping Fact.(k/ft/s) 0.544
Driveability Analysis
Soil Damping Option Smith
Max No Analysis Iterations 0 Time Increment/Critical 160
Output Time Interval 1 Analysis Time-Input (ms) 0
Output Level: Normal
Gravity Mass, Pile, Hammer: 32.170 32.170 32.170
Output Segment Generation: Automatic

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
5.00	10.81	1.00	0.800

FRA-70-1358L - FA - B-018-2-13 - HP12x53 06/07/2022
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
14.1	1.5	3.85	3.87	-0.07	9	11	9.47	1	2	25.5	60.2
14.8	1.5	3.93	3.90	-0.21	9	11	10.27	1	2	25.6	59.8
15.4	1.6	3.97	3.94	-0.21	9	12	10.74	1	2	25.7	59.6
16.1	1.6	4.00	3.98	-0.20	9	12	11.16	1	2	25.7	59.3
16.8	1.6	4.04	4.01	-0.20	5	11	11.58	1	2	25.7	59.0

FRA-70-1358L - FA - B-018-2-13 - HP12x53 06/07/2022
Resource International Inc GRLWEAP Version 2010

Depth (ft) 10.0 Standard Soil Setup

Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model Total Capacity Rut (kips) 34.4

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	6.3	0.198	0.100	47.69	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	11.5	0.200	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	14.8	0.200	0.100	54.50	4.0	15.5
Toe						1.8	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
10.00	10.81	1.00	0.800

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
34.4	3.5	4.87	4.85	0.00	1	0	17.96	3	2	22.9	53.7
35.7	3.7	4.92	4.89	0.00	1	0	18.24	4	3	22.8	53.5
36.9	3.9	4.97	4.94	0.00	1	0	18.53	6	3	22.6	53.2
38.2	4.0	5.01	4.99	0.00	1	0	18.78	7	3	22.4	53.0
39.4	4.2	5.06	5.03	0.00	1	0	19.04	7	3	22.3	52.7

Depth (ft) 15.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model Total Capacity Rut (kips) 52.8

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.0	15.5
12	0.180	10997	0.000	0.000	1.00	0.4	0.159	0.100	40.88	4.0	15.5
13	0.180	10997	0.000	0.000	1.00	11.2	0.200	0.100	44.28	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	13.2	0.200	0.100	47.69	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	10.9	0.170	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	7.4	0.050	0.100	54.50	4.0	15.5
Toe						9.8	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	

15.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
52.8	5.3	5.34	5.31	-0.10	3	11	21.63	13	5	21.5	51.2
54.1	5.5	5.38	5.35	0.00	1	0	21.90	13	4	21.4	51.0
55.3	5.6	5.41	5.39	0.00	1	0	22.14	13	4	21.3	50.8
56.6	5.8	5.45	5.43	0.00	1	0	22.36	13	5	21.2	50.6
57.8	6.0	5.48	5.47	0.00	1	0	22.61	13	4	21.1	50.4

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Depth (ft) 20.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 84.9

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.0	15.5
11	0.180	10997	0.000	0.000	1.00	5.6	0.198	0.100	37.47	4.0	15.5
12	0.180	10997	0.000	0.000	1.00	11.3	0.200	0.100	40.88	4.0	15.5
13	0.180	10997	0.000	0.000	1.00	14.8	0.200	0.100	44.28	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	7.1	0.084	0.100	47.69	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	8.4	0.050	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	11.7	0.050	0.100	54.50	4.0	15.5
Toe						25.9	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
20.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
84.9	8.7	5.93	5.97	-0.94	9	47	24.31	11	4	19.8	48.3
86.1	8.9	5.97	6.00	-0.92	9	47	24.53	11	4	19.8	48.2
87.4	9.1	5.99	6.04	-1.03	11	41	24.65	11	4	19.7	48.1
88.6	9.3	6.03	6.07	-1.16	11	41	24.85	11	4	19.7	47.9
89.9	9.5	6.07	6.10	-1.25	10	41	25.05	11	4	19.6	47.8

FRA-70-1358L - FA - B-018-2-13 - HP12x53 06/07/2022
Resource International Inc GRLWEAP Version 2010

Depth (ft) 25.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 113.9

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.0	15.5
9	0.180	10997	0.000	0.000	1.00	0.1	0.050	0.100	30.66	4.0	15.5
10	0.180	10997	0.000	0.000	1.00	10.8	0.200	0.100	34.06	4.0	15.5
11	0.180	10997	0.000	0.000	1.00	12.9	0.200	0.100	37.47	4.0	15.5
12	0.180	10997	0.000	0.000	1.00	11.4	0.176	0.100	40.88	4.0	15.5
13	0.180	10997	0.000	0.000	1.00	7.2	0.050	0.100	44.28	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	10.0	0.050	0.100	47.69	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	12.9	0.050	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	15.4	0.050	0.100	54.50	4.0	15.5
Toe						33.3	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
25.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft			ksi			ksi			kip-ft	b/min
113.9	11.8	6.38	6.40	-0.89	7	41	26.40	10	4	19.0	46.7
115.2	12.0	6.41	6.43	-0.93	10	36	26.55	10	4	19.0	46.6
116.4	12.1	6.43	6.45	-1.02	10	36	26.72	10	4	19.0	46.5
117.7	12.3	6.45	6.47	-1.10	10	36	26.87	10	4	18.9	46.4
118.9	12.5	6.48	6.50	-1.18	10	35	27.05	10	4	18.8	46.3

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Depth (ft) 30.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 148.4

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.0	15.5
8	0.180	10997	0.000	0.000	1.00	4.9	0.197	0.100	27.25	4.0	15.5
9	0.180	10997	0.000	0.000	1.00	11.2	0.200	0.100	30.66	4.0	15.5
10	0.180	10997	0.000	0.000	1.00	14.6	0.200	0.100	34.06	4.0	15.5
11	0.180	10997	0.000	0.000	1.00	7.6	0.103	0.100	37.47	4.0	15.5
12	0.180	10997	0.000	0.000	1.00	8.2	0.050	0.100	40.88	4.0	15.5
13	0.180	10997	0.000	0.000	1.00	11.5	0.050	0.100	44.28	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	14.0	0.050	0.100	47.69	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	16.5	0.050	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	19.0	0.050	0.100	54.50	4.0	15.5
Toe						40.7	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
30.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
148.4	15.8	6.86	6.86	-0.99	8	30	27.41	9	4	18.6	45.0
149.7	16.1	6.89	6.89	-1.06	8	30	27.56	9	4	18.6	44.9
150.9	16.4	6.91	6.92	-1.15	8	30	27.65	9	4	18.5	44.9
152.2	16.7	6.93	6.94	-1.21	8	30	27.79	9	4	18.5	44.8
153.4	16.9	6.96	6.97	-1.28	8	30	27.89	9	4	18.5	44.7

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Depth (ft) 35.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model Total Capacity Rut (kips) 143.7

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.0	15.5
6	0.180	10997	0.000	0.000	1.00	0.1	0.050	0.100	20.44	4.0	15.5
7	0.180	10997	0.000	0.000	1.00	10.1	0.199	0.100	23.84	4.0	15.5
8	0.180	10997	0.000	0.000	1.00	12.7	0.200	0.100	27.25	4.0	15.5
9	0.180	10997	0.000	0.000	1.00	12.0	0.182	0.100	30.66	4.0	15.5
10	0.180	10997	0.000	0.000	1.00	7.1	0.050	0.100	34.06	4.0	15.5
11	0.180	10997	0.000	0.000	1.00	9.7	0.050	0.100	37.47	4.0	15.5
12	0.180	10997	0.000	0.000	1.00	12.7	0.050	0.100	40.88	4.0	15.5
13	0.180	10997	0.000	0.000	1.00	15.2	0.050	0.100	44.28	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	17.7	0.050	0.100	47.69	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	20.2	0.050	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	22.2	0.173	0.100	54.50	4.0	15.5
Toe						4.0	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
35.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
143.7	14.8	6.77	6.79	-0.51	7	30	27.55	7	3	18.5	45.3
146.7	15.3	6.84	6.85	-0.67	7	30	27.81	7	3	18.5	45.1
149.8	16.0	6.89	6.91	-0.79	7	30	28.07	7	3	18.4	44.9
152.8	16.6	6.95	6.97	-0.88	7	30	28.33	7	3	18.4	44.7
155.9	17.2	7.08	7.02	-0.94	7	30	28.79	7	3	18.5	44.4

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Depth (ft) 40.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s

0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 176.5

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.0	15.5
5	0.180	10997	0.000	0.000	1.00	4.2	0.197	0.100	17.03	4.0	15.5
6	0.180	10997	0.000	0.000	1.00	11.2	0.200	0.100	20.44	4.0	15.5
7	0.180	10997	0.000	0.000	1.00	14.4	0.200	0.100	23.84	4.0	15.5
8	0.180	10997	0.000	0.000	1.00	8.1	0.119	0.100	27.25	4.0	15.5
9	0.180	10997	0.000	0.000	1.00	8.1	0.050	0.100	30.66	4.0	15.5
10	0.180	10997	0.000	0.000	1.00	11.3	0.050	0.100	34.06	4.0	15.5
11	0.180	10997	0.000	0.000	1.00	13.9	0.050	0.100	37.47	4.0	15.5
12	0.180	10997	0.000	0.000	1.00	16.4	0.050	0.100	40.88	4.0	15.5
13	0.180	10997	0.000	0.000	1.00	18.9	0.050	0.100	44.28	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	21.4	0.088	0.100	47.69	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	22.3	0.200	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	22.3	0.200	0.100	54.50	4.0	15.5
Toe						4.0	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
40.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
176.5	22.6	7.43	7.40	-0.90	5	28	29.03	6	3	18.1	43.3
183.6	24.0	7.51	7.49	-0.69	5	28	29.32	6	3	17.9	43.1
190.7	25.2	7.58	7.57	-0.59	5	48	29.57	6	3	17.8	42.9
197.9	26.5	7.65	7.65	-0.51	5	48	29.83	6	3	17.7	42.7
205.0	27.8	7.73	7.72	-0.43	5	46	30.11	6	3	17.7	42.5

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Depth (ft) 45.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 208.5

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.0	15.5
3	0.180	10997	0.000	0.000	1.00	0.0	0.050	0.100	10.22	4.0	15.5
4	0.180	10997	0.000	0.000	1.00	9.4	0.199	0.100	13.62	4.0	15.5
5	0.180	10997	0.000	0.000	1.00	12.5	0.200	0.100	17.03	4.0	15.5
6	0.180	10997	0.000	0.000	1.00	12.5	0.186	0.100	20.44	4.0	15.5
7	0.180	10997	0.000	0.000	1.00	7.0	0.050	0.100	23.84	4.0	15.5
8	0.180	10997	0.000	0.000	1.00	9.5	0.050	0.100	27.25	4.0	15.5
9	0.180	10997	0.000	0.000	1.00	12.5	0.050	0.100	30.66	4.0	15.5
10	0.180	10997	0.000	0.000	1.00	15.0	0.050	0.100	34.06	4.0	15.5
11	0.180	10997	0.000	0.000	1.00	17.6	0.050	0.100	37.47	4.0	15.5
12	0.180	10997	0.000	0.000	1.00	20.1	0.050	0.100	40.88	4.0	15.5
13	0.180	10997	0.000	0.000	1.00	22.1	0.167	0.100	44.28	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	22.3	0.200	0.100	47.69	4.0	15.5

16	0.180	10997	0.000	0.000	1.00	21.6	0.200	0.100	54.50	4.0	15.5
Toe						4.0	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
45.00	10.81	1.00	0.800

↑
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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
208.5	28.6	7.79	7.77	-0.40	4	45	30.25	4	3	17.5	42.3
219.6	31.0	7.89	7.88	-0.23	4	45	30.61	4	3	17.5	42.1
230.8	33.6	7.98	7.97	-0.28	4	43	30.95	4	3	17.6	41.9
241.9	36.5	8.06	8.06	-0.33	4	41	31.26	4	3	17.7	41.6
253.0	40.0	8.08	8.16	-0.46	4	39	31.40	4	3	17.6	41.5

↑
FRA-70-1358L - FA - B-018-2-13 - HP12x53 06/07/2022
Resource International Inc GRLWEAP Version 2010

Depth (ft) 50.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model Total Capacity Rut (kips) 237.1

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.180	10997	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	3.5	0.196	0.100	6.81	4.0	15.5
3	0.180	10997	0.000	0.000	1.00	11.2	0.200	0.100	10.22	4.0	15.5
4	0.180	10997	0.000	0.000	1.00	14.2	0.200	0.100	13.62	4.0	15.5
5	0.180	10997	0.000	0.000	1.00	8.6	0.132	0.100	17.03	4.0	15.5
6	0.180	10997	0.000	0.000	1.00	7.9	0.050	0.100	20.44	4.0	15.5
7	0.180	10997	0.000	0.000	1.00	11.1	0.050	0.100	23.84	4.0	15.5
8	0.180	10997	0.000	0.000	1.00	13.7	0.050	0.100	27.25	4.0	15.5
9	0.180	10997	0.000	0.000	1.00	16.2	0.050	0.100	30.66	4.0	15.5
10	0.180	10997	0.000	0.000	1.00	18.7	0.050	0.100	34.06	4.0	15.5
11	0.180	10997	0.000	0.000	1.00	21.3	0.068	0.100	37.47	4.0	15.5
12	0.180	10997	0.000	0.000	1.00	22.3	0.200	0.100	40.88	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	22.2	0.200	0.100	47.69	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	20.8	0.200	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	19.1	0.200	0.100	54.50	4.0	15.5
Toe						4.0	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
50.00	10.81	1.00	0.800

↑
FRA-70-1358L - FA - B-018-2-13 - HP12x53 06/07/2022
Resource International Inc GRLWEAP Version 2010

Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
237.1	35.2	8.03	8.02	0.00	1	0	30.82	3	2	17.4	41.7
251.8	39.6	8.08	8.13	-0.08	2	39	31.04	3	2	17.3	41.5
266.6	44.1	8.21	8.24	-0.12	2	37	31.45	3	2	17.5	41.2
281.3	49.5	8.33	8.35	-0.17	2	36	31.84	3	2	17.6	41.0
296.0	55.8	8.44	8.45	-0.19	2	35	32.19	3	2	17.7	40.7

FRA-70-1358L - FA - B-018-2-13 - HP12x53 06/07/2022
Resource International Inc GRLWEAP Version 2010

Depth (ft) 54.5 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 12.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	15.50	29000.	492.0	4.0	0	16524.	27.2
54.5	15.50	29000.	492.0	4.0	0	16524.	27.2

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 259.8

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.180	10997	0.010	0.000	0.85	7.1	0.198	0.100	3.41	4.0	15.5
2	0.180	10997	0.000	0.000	1.00	11.7	0.200	0.100	6.81	4.0	15.5
3	0.180	10997	0.000	0.000	1.00	14.4	0.198	0.100	10.22	4.0	15.5
4	0.180	10997	0.000	0.000	1.00	6.5	0.050	0.100	13.62	4.0	15.5
5	0.180	10997	0.000	0.000	1.00	8.8	0.050	0.100	17.03	4.0	15.5
6	0.180	10997	0.000	0.000	1.00	12.0	0.050	0.100	20.44	4.0	15.5
7	0.180	10997	0.000	0.000	1.00	14.5	0.050	0.100	23.84	4.0	15.5
8	0.180	10997	0.000	0.000	1.00	17.0	0.050	0.100	27.25	4.0	15.5
9	0.180	10997	0.000	0.000	1.00	19.5	0.050	0.100	30.66	4.0	15.5
10	0.180	10997	0.000	0.000	1.00	21.9	0.140	0.100	34.06	4.0	15.5
11	0.180	10997	0.000	0.000	1.00	22.3	0.200	0.100	37.47	4.0	15.5
13	0.180	10997	0.000	0.000	1.00	21.9	0.200	0.100	44.28	4.0	15.5
14	0.180	10997	0.000	0.000	1.00	20.3	0.200	0.100	47.69	4.0	15.5
15	0.180	10997	0.000	0.000	1.00	18.6	0.200	0.100	51.09	4.0	15.5
16	0.180	10997	0.000	0.000	1.00	16.9	0.200	0.100	54.50	4.0	15.5
Toe						4.0	0.150	0.100			

2.886 kips total unreduced pile weight (g= 32.17 ft/s2)
2.886 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
54.50	10.81	1.00	0.800

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
259.8	42.5	8.19	8.22	0.00	1	0	32.21	1	2	16.7	41.3
277.4	48.7	8.31	8.35	0.00	1	0	32.66	1	2	16.7	41.0
294.9	55.8	8.44	8.46	0.00	1	0	33.18	1	2	16.9	40.7
312.5	64.7	8.57	8.57	0.00	1	0	33.66	1	2	17.0	40.4
330.1	75.4	8.70	8.68	0.00	1	0	34.16	1	2	17.3	40.1

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.400 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	14.1	12.3	1.8	1.5	9.465	-0.071	3.85	25.5
10.0	34.4	32.6	1.8	3.5	17.964	0.000	4.87	22.9
15.0	52.8	43.0	9.8	5.3	21.632	-0.096	5.34	21.5
20.0	84.9	58.9	25.9	8.7	24.308	-0.938	5.93	19.8
25.0	113.9	80.6	33.3	11.8	26.396	-0.886	6.38	19.0
30.0	148.4	107.7	40.7	15.8	27.414	-0.989	6.86	18.6
35.0	143.7	139.7	4.0	14.8	27.545	-0.513	6.77	18.5
40.0	176.5	172.5	4.0	22.6	29.030	-0.899	7.43	18.1
45.0	208.5	204.5	4.0	28.6	30.253	-0.403	7.79	17.5
50.0	237.1	233.1	4.0	35.2	30.824	0.000	8.03	17.4
54.5	259.8	255.8	4.0	42.5	32.211	0.000	8.19	16.7

Total Driving Time 19 minutes; Total No. of Blows 822
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.450 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	14.8	13.0	1.8	1.5	10.267	-0.207	3.93	25.6
10.0	35.7	33.9	1.8	3.7	18.240	0.000	4.92	22.8
15.0	54.1	44.2	9.8	5.5	21.896	0.000	5.38	21.4
20.0	86.1	60.2	25.9	8.9	24.527	-0.924	5.97	19.8
25.0	115.2	81.9	33.3	12.0	26.552	-0.929	6.41	19.0
30.0	149.7	109.0	40.7	16.1	27.562	-1.060	6.89	18.6
35.0	146.7	142.7	4.0	15.3	27.809	-0.669	6.84	18.5
40.0	183.6	179.6	4.0	24.0	29.323	-0.693	7.51	17.9
45.0	219.6	215.6	4.0	31.0	30.613	-0.231	7.89	17.5
50.0	251.8	247.8	4.0	39.6	31.036	-0.075	8.08	17.3
54.5	277.4	273.4	4.0	48.7	32.663	0.000	8.31	16.7

Total Driving Time 20 minutes; Total No. of Blows 883
Starting at penetration 5.0 ft

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.500 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	15.4	13.6	1.8	1.6	10.740	-0.214	3.97	25.7
10.0	36.9	35.1	1.8	3.9	18.534	0.000	4.97	22.6
15.0	55.3	45.5	9.8	5.6	22.137	0.000	5.41	21.3
20.0	87.4	61.4	25.9	9.1	24.655	-1.032	5.99	19.7
25.0	116.4	83.1	33.3	12.1	26.716	-1.019	6.43	19.0
30.0	150.9	110.2	40.7	16.4	27.649	-1.146	6.91	18.5
35.0	149.8	145.8	4.0	16.0	28.073	-0.786	6.89	18.4
40.0	190.7	186.7	4.0	25.2	29.571	-0.587	7.58	17.8
45.0	230.8	226.8	4.0	33.6	30.947	-0.275	7.98	17.6
50.0	266.6	262.6	4.0	44.1	31.452	-0.117	8.21	17.5
54.5	294.9	290.9	4.0	55.8	33.179	0.000	8.44	16.9

Total Driving Time 22 minutes; Total No. of Blows 949
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.550 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	16.1	14.3	1.8	1.6	11.156	-0.201	4.00	25.7
10.0	38.2	36.3	1.8	4.0	18.781	0.000	5.01	22.4
15.0	56.6	46.7	9.8	5.8	22.365	0.000	5.45	21.2
20.0	88.6	62.7	25.9	9.3	24.849	-1.159	6.03	19.7
25.0	117.7	84.4	33.3	12.3	26.867	-1.103	6.45	18.9
30.0	152.2	111.5	40.7	16.7	27.786	-1.212	6.93	18.5
35.0	152.8	148.8	4.0	16.6	28.333	-0.883	6.95	18.4
40.0	197.9	193.9	4.0	26.5	29.830	-0.508	7.65	17.7
45.0	241.9	237.9	4.0	36.5	31.264	-0.333	8.06	17.7
50.0	281.3	277.3	4.0	49.5	31.835	-0.166	8.33	17.6
54.5	312.5	308.5	4.0	64.7	33.664	0.000	8.57	17.0

Total Driving Time 24 minutes; Total No. of Blows 1023
Starting at penetration 5.0 ft

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.600 1.000

Depth ft	Rut kips	Frictn kips	End Bg kips	Bl Ct bl/ft	Com Str ksi	Ten Str ksi	Stroke ft	ENTHRU kip-ft
5.0	16.8	15.0	1.8	1.6	11.577	-0.195	4.04	25.7
10.0	39.4	37.6	1.8	4.2	19.041	0.000	5.06	22.3
15.0	57.8	48.0	9.8	6.0	22.613	0.000	5.48	21.1
20.0	89.9	63.9	25.9	9.5	25.045	-1.252	6.07	19.6
25.0	118.9	85.6	33.3	12.5	27.047	-1.179	6.48	18.8
30.0	153.4	112.7	40.7	16.9	27.892	-1.282	6.96	18.5
35.0	155.9	151.9	4.0	17.2	28.795	-0.942	7.08	18.5

40.0	205.0	201.0	4.0	27.8	30.114	-0.429	7.73	17.7
45.0	253.0	249.0	4.0	40.0	31.400	-0.459	8.08	17.6
50.0	296.0	292.0	4.0	55.8	32.194	-0.190	8.44	17.7
54.5	330.1	326.1	4.0	75.4	34.164	0.000	8.70	17.3

Total Driving Time 26 minutes; Total No. of Blows 1111
Starting at penetration 5.0 ft

Table of Depths Analyzed with Driving System Modifiers

Depth ft	Temp. Length ft	Wait Time hr	Equivalent Stroke ft	Pressure Ratio	Efficy.	Stiffn. Factor	Cushion CoR
5.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
10.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
15.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
20.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
25.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
30.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
35.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
40.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
45.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
50.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
54.50	54.50	0.00	10.81	1.00	0.80	1.00	1.00

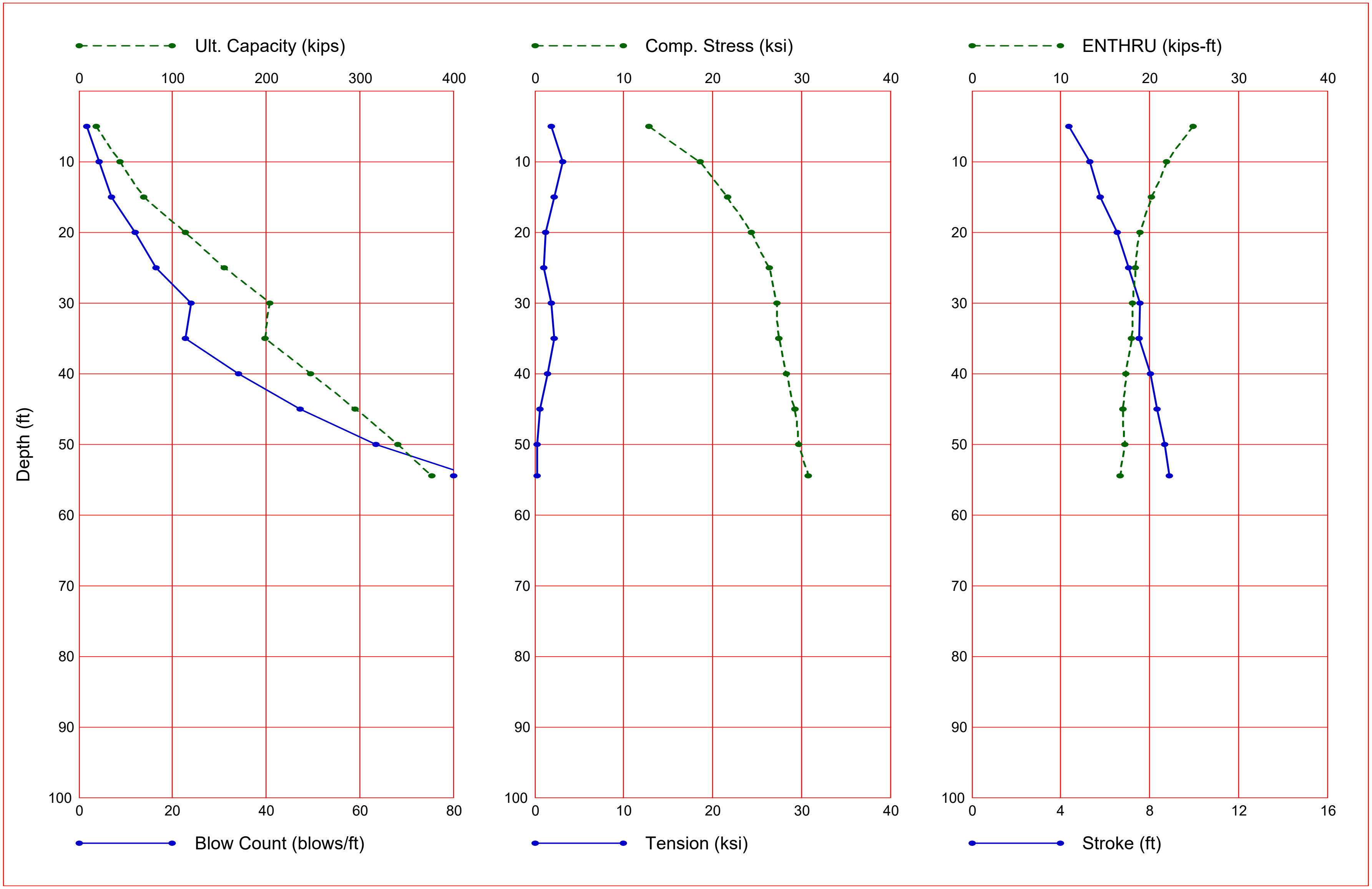
Soil Layer Resistance Values

Depth ft	Shaft Res. k/ft2	End Bearing kips	Shaft Quake inch	Toe Quake inch	Shaft Damping s/ft	Toe Damping s/ft	Soil Setup Normlzd	Limit Distance ft	Setup Time hrs
0.01	0.00	0.00	0.100	0.100	0.050	0.150	0.000	6.000	1.000
1.29	0.05	0.56	0.100	0.100	0.050	0.150	0.000	6.000	1.000
1.31	1.37	1.82	0.100	0.100	0.200	0.150	0.660	6.000	168.000
6.29	1.37	1.82	0.100	0.100	0.200	0.150	0.660	6.000	168.000
6.31	1.37	1.82	0.100	0.100	0.200	0.150	0.340	6.000	24.000
10.09	1.37	1.82	0.100	0.100	0.200	0.150	0.340	6.000	24.000
10.11	0.40	6.31	0.100	0.100	0.050	0.150	0.000	6.000	1.000
16.29	0.68	10.78	0.100	0.100	0.050	0.150	0.000	6.000	1.000
16.31	0.76	20.49	0.100	0.100	0.050	0.150	0.000	6.000	1.000
25.31	1.25	33.78	0.100	0.100	0.050	0.150	0.000	6.000	1.000
32.79	1.65	44.81	0.100	0.100	0.050	0.150	0.000	6.000	1.000
32.81	4.12	4.00	0.100	0.100	0.200	0.150	1.000	6.000	168.000
41.81	4.12	4.00	0.100	0.100	0.200	0.150	1.000	6.000	168.000
50.81	3.31	4.00	0.100	0.100	0.200	0.150	1.000	6.000	168.000
54.50	2.97	4.00	0.100	0.100	0.200	0.150	1.000	6.000	168.000

Resource International Inc
FRA-70-1358L - FA - B-018-2-13 - HP14x73

Feb 27 2021
GRLWEAP Version 2010

Gain/Loss 3 at Shaft and Toe 0.500 / 1.000



Gain/Loss 3 at Shaft and Toe 0.500 / 1.000

Depth ft	Ultimate Capacity kips	Friction kips	End Bearing kips	Blow Count blows/ft	Comp. Stress ksi	Tension Stress ksi	Stroke ft	ENTHRU kips-ft
5.0	18.7	16.2	2.5	1.8	12.856	-1.853	4.37	24.9
10.0	44.1	41.6	2.5	4.3	18.596	-3.115	5.32	21.9
15.0	69.6	56.0	13.6	6.9	21.659	-2.155	5.79	20.2
20.0	114.4	78.5	35.8	12.0	24.350	-1.180	6.55	18.9
25.0	155.2	109.2	46.0	16.6	26.412	-0.968	7.08	18.4
30.0	203.8	147.6	56.2	23.9	27.255	-1.833	7.58	18.1
35.0	199.3	193.7	5.5	22.8	27.482	-2.179	7.53	18.0
40.0	247.7	242.2	5.5	34.2	28.369	-1.429	8.05	17.3
45.0	295.5	290.0	5.5	47.2	29.269	-0.624	8.34	17.0
50.0	340.3	334.8	5.5	63.4	29.687	-0.223	8.68	17.2
54.5	377.4	371.8	5.5	84.0	30.785	-0.219	8.89	16.7

Total Continuous Driving Time 32.00 minutes; Total Number of Blows 1332 (starting at penetration 5.0 ft)

GRLWEAP - Version 2010
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS

written by GRL Engineers, Inc. (formerly Goble Rausche Likins and Associates, Inc.) with cooperation from Pile Dynamics, Inc.

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

The GRLWEAP program simulates the behavior of a preformed pile driven by either an impact hammer or a vibratory hammer. The program is based on mathematical models, which describe motion and forces of hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate, often complex, dynamic situations.

A wave equation analysis generally relies on input data, which represents normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. All of the input data selected by the user may be the best available information at the time when the analysis is performed. However, input data and therefore results may significantly differ from actual field conditions.

Therefore, the program authors recommend prudent use of the GRLWEAP results. Soil response and hammer performance should be verified by static and/or dynamic testing and measurements. Estimates of bending or other local stresses (e.g., helmet or clamp contact, uneven rock surfaces etc.), prestress effects and others must also be accounted for by the user.

The calculated capacity - blow count relationship, i.e. the bearing graph, should be used in conjunction with observed blow counts for the capacity assessment of a driven pile. Soil setup occurring after pile installation may produce bearing capacity values that differ substantially from those expected from a wave equation analysis due to soil setup or relaxation. This is particularly true for pile driven with vibratory hammers. The GRLWEAP user must estimate such effects and should also use proper care when applying blow counts from restrike because of the variability of hammer energy, soil resistance and blow count during early restriking.

Finally, the GRLWEAP capacities are ultimate values. They MUST be reduced by means of an appropriate factor of safety to yield a design or working load. The selection of a factor of safety should consider the quality of the construction control, the variability of the site conditions, uncertainties in the loads, the importance of building and other factors.

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 Input  File: J:\GEOTECH\PROJECTS\2013\W-13-072 FRA-70-13.10 PROJECT 6A\ANALYSIS\FRA-70-1358L\DRIVEABILITY\B-018-2-13\B-018-2.GWW
 Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2010.GW
 Hammer File Version:  2003 (12/4/2018)

                        Input File Contents
     FRA-70-1358L - FA - B-018-2-13 - HP14x73
 OUT OSG HAM STR FUL PEL  N SPL N-U P-D %SK ISM  0 PHI RSA ITR H-D MXT     DEx
-100   0  41   0   0   0  0   0   0   1   0   0  0   0   0   0   0   0   0.000
    Pile g  Hammer g  Toe Area Pile Size          Pile Type
    32.170    32.170   144.000    14.000            Unknown
      W Cp      A Cp      E Cp      T Cp       CoR      ROut      StCp
     1.900   227.000     530.0     2.000     0.800     0.010       0.0
      A Cu      E Cu      T Cu       CoR      ROut      StCu
     0.000       0.0     0.000     0.000     0.000       0.0
      LPle      APle      EPle      WPle      Peri        CI       CoR      ROut
    54.500     21.40   29000.0   492.000     4.700         0     0.850     0.010
  FFatigue        F0  0-Bottom
         0     0.000     0.000
 Manufac  Hmr Name  HmrType No Seg-s
 DELMAG   D 19-42         1       5
    Ram Wt     Ram L   Ram Dia   MaxStrk   RtdStrk    Efficy
      4.00    129.10     12.60     11.86     10.81      0.80
    IB. Wt     IB. L    IB.Dia    IB CoR     IB RO
      0.75     25.30     12.60     0.900     0.010
  CompStrk A Chamber V Chamber   C Delay  C Duratn Exp Coeff VolCStart  Vol CEnd
     16.65    124.70    157.70    0.0020    0.0020     1.250      0.00      0.00
     P atm        P1        P2        P3        P4        P5
     14.70   1600.00   1440.00   1295.00   1165.00      0.00
    Stroke    Effic.  Pressure  R-Weight   T-Delay Exp-Coeff   Eps-Str  Total-AW
   10.8100    0.8000 1600.0000    0.0000    0.0000    0.0000    0.0100    0.0000
        Qs        Qt        Js        Jt        Qx        Jx      Rati      Dept
     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  Research Soil Model: Atoe, Plug,  Gap, Q-fac
     0.000     0.000     0.000     0.000
```

Research Soil Model: RD-skn: m, d, toe: m, d
0.000 0.000 0.000 0.000
Research Toe Plug: Res-int, Q-int, D-int, Res-plug, Q-plug, D-plug
0.000 0.000 0.000 0.000 0.000 0.000
Research Toe Plug: RD plug toe: m, d
0.000 0.000
Research Toe Plug: New Toe Plug Model is NOT applied
Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimL	TSf0
0.01	0.00	0.01	0.10	0.10	0.05	0.15	1.00	6.00	1.000
1.29	0.05	0.77	0.10	0.10	0.05	0.15	1.00	6.00	1.000
1.31	1.37	2.51	0.10	0.10	0.20	0.15	1.49	6.00	168.000
6.29	1.37	2.51	0.10	0.10	0.20	0.15	1.49	6.00	168.000
6.31	1.37	2.51	0.10	0.10	0.15	0.15	1.21	6.00	24.000
10.09	1.37	2.51	0.10	0.10	0.15	0.15	1.21	6.00	24.000
10.11	0.47	8.71	0.10	0.10	0.05	0.15	1.00	6.00	1.000
16.29	0.81	14.89	0.10	0.10	0.05	0.15	1.00	6.00	1.000
16.31	0.90	28.29	0.10	0.10	0.05	0.15	1.00	6.00	1.000
25.31	1.49	46.63	0.10	0.10	0.05	0.15	1.00	6.00	1.000
32.79	1.98	61.87	0.10	0.10	0.05	0.15	1.00	6.00	1.000
32.81	4.12	5.52	0.10	0.10	0.20	0.15	2.00	6.00	168.000
41.81	4.12	5.52	0.10	0.10	0.20	0.15	2.00	6.00	168.000
50.81	3.63	5.52	0.10	0.10	0.20	0.15	2.00	6.00	168.000
54.50	3.32	5.52	0.10	0.10	0.20	0.15	2.00	6.00	168.000

Gain/Loss factors: shaft and toe
0.40000 0.45000 0.50000 0.55000 0.60000
1.00000 1.00000 1.00000 1.00000 1.00000

Dpth	L	Wait	Strk	Pmx%	Eff.	Stff	CoR
5.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000
54.50	0.00	0.00	0.000	0.0	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.0	0.000	0.000	0.000

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
Version 2010
English Units

FRA-70-1358L - FA - B-018-2-13 - HP14x73

Hammer Model: D 19-42 Made by: DELMAG

No.	Weight (kips)	Stiffn (k/inch)	CoR	C-Slk (ft)	Dampg (k/ft/s)
1	0.800				
2	0.800	140046.6	1.000	0.0000	
3	0.800	140046.6	1.000	0.0000	
4	0.800	140046.6	1.000	0.0000	
5	0.800	140046.6	1.000	0.0000	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		15182.9			

HAMMER OPTIONS:

Hammer File ID No.	41	Hammer Type	OE Diesel
Stroke Option	FxdP-VarS	Stroke Convergence Crit.	0.010
Fuel Pump Setting	Maximum		

HAMMER DATA:

Ram Weight	(kips)	4.00	Ram Length	(inch)	129.10
Maximum Stroke	(ft)	11.86			
Rated Stroke	(ft)	10.81	Efficiency		0.800
Maximum Pressure	(psi)	1600.00	Actual Pressure	(psi)	1600.00
Compression Exponent		1.350	Expansion Exponent		1.250
Ram Diameter	(inch)	12.60			
Combustion Delay	(s)	0.00200	Ignition Duration	(s)	0.00200

The Hammer Data Includes Estimated (NON-MEASURED) Quantities

HAMMER CUSHION PILE CUSHION

Cross Sect. Area	(in2)	227.00	Cross Sect. Area	(in2)	0.00
Elastic-Modulus	(ksi)	530.0	Elastic-Modulus	(ksi)	0.0
Thickness	(inch)	2.00	Thickness	(inch)	0.00
Coeff of Restitution		0.8	Coeff of Restitution		1.0
RoundOut	(ft)	0.0	RoundOut	(ft)	0.0
Stiffness	(kips/in)	60155.0	Stiffness	(kips/in)	0.0

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Depth	(ft)	5.0	Standard Soil Setup		
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor		1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	14.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 17.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	1.3	0.186	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	13.3	0.200	0.100	54.50	4.7	21.4
Toe						2.5	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

PILE, SOIL, ANALYSIS OPTIONS:

Uniform pile		Pile Segments: Automatic	
No. of Slacks/Splices	0	Pile Damping (%)	1
		Pile Damping Fact.(k/ft/s)	0.751
Driveability Analysis			
Soil Damping Option	Smith		
Max No Analysis Iterations	0	Time Increment/Critical	160
Output Time Interval	1	Analysis Time-Input (ms)	0
Output Level: Normal			

Gravity Mass, Pile, Hammer: 32.170 32.170 32.170
Output Segment Generation: Automatic

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
5.00	10.81	1.00	0.800

FRA-70-1358L - FA - B-018-2-13 - HP14x73 02/27/2021
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Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft			ksi			ksi			kip-ft	b/min
17.1	1.7	4.29	4.31	-1.55	4	8	12.24	1	2	24.8	57.2
17.9	1.8	4.33	4.36	-1.71	4	8	12.57	1	2	24.9	56.9
18.7	1.8	4.37	4.39	-1.85	4	8	12.86	1	2	24.9	56.7
19.4	1.9	4.41	4.43	-2.00	4	8	13.16	1	2	24.9	56.4
20.2	1.9	4.45	4.47	-2.09	4	8	13.40	1	2	24.7	56.2

FRA-70-1358L - FA - B-018-2-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Depth	(ft)	10.0	Standard Soil Setup		
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor		1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	14.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 41.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	7.5	0.198	0.100	47.69	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	13.6	0.196	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	17.5	0.150	0.100	54.50	4.7	21.4
Toe						2.5	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
10.00	10.81	1.00	0.800

↑
FRA-70-1358L - FA - B-018-2-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft) down	up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft			ksi			ksi			kip-ft	b/min
41.1	3.9	5.23	5.21	-3.24	4	8	18.13	8	3	22.2	51.9
42.6	4.1	5.27	5.25	-3.16	4	8	18.37	9	4	22.1	51.6
44.1	4.3	5.32	5.30	-3.11	4	8	18.60	9	4	21.9	51.4
45.5	4.5	5.36	5.34	-3.02	4	8	18.81	10	4	21.8	51.2
47.0	4.7	5.40	5.38	-2.93	4	8	19.03	10	4	21.7	51.0

↑
FRA-70-1358L - FA - B-018-2-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Depth (ft) 15.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 66.7

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.7	21.4
12	0.249	15183	0.000	0.000	1.00	0.5	0.155	0.100	40.88	4.7	21.4
13	0.249	15183	0.000	0.000	1.00	13.3	0.200	0.100	44.28	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	15.6	0.172	0.100	47.69	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	13.4	0.127	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	10.3	0.050	0.100	54.50	4.7	21.4
Toe						13.6	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
15.00	10.81	1.00	0.800

↑
FRA-70-1358L - FA - B-018-2-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft) down	up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft			ksi			ksi			kip-ft	b/min
66.7	6.5	5.71	5.76	-2.37	4	8	21.25	13	4	20.4	49.4
68.2	6.7	5.75	5.80	-2.27	4	8	21.47	13	4	20.3	49.2
69.6	6.9	5.79	5.83	-2.15	3	8	21.66	13	4	20.2	49.0
71.1	7.1	5.82	5.87	-2.04	3	8	21.84	13	4	20.1	48.9
72.6	7.2	5.86	5.90	-1.91	3	8	22.02	13	4	20.0	48.7

↑
FRA-70-1358L - FA - B-018-2-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Depth (ft) 20.0 Standard Soil Setup

Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor	1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	14.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 111.4

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.7	21.4
11	0.249	15183	0.000	0.000	1.00	6.7	0.197	0.100	37.47	4.7	21.4
12	0.249	15183	0.000	0.000	1.00	13.4	0.199	0.100	40.88	4.7	21.4
13	0.249	15183	0.000	0.000	1.00	17.5	0.150	0.100	44.28	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	9.7	0.070	0.100	47.69	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	11.8	0.050	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	16.5	0.050	0.100	54.50	4.7	21.4
Toe						35.8	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
20.00	10.81	1.00	0.800

FRA-70-1358L - FA - B-018-2-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
111.4	11.6	6.49	6.51	-1.09	11	43	24.05	11	4	19.0	46.3
112.9	11.8	6.52	6.54	-1.11	11	43	24.20	11	4	19.0	46.2
114.4	12.0	6.55	6.57	-1.18	10	37	24.35	11	4	18.9	46.1
115.8	12.2	6.58	6.59	-1.22	10	37	24.47	11	4	18.9	46.0
117.3	12.4	6.60	6.61	-1.25	10	37	24.57	11	4	18.8	45.9

FRA-70-1358L - FA - B-018-2-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Depth	(ft)	25.0	Standard Soil Setup	
Shaft Gain/Loss Factor		0.400	Toe Gain/Loss Factor	1.000

PILE PROFILE:

Toe Area	(in2)	144.000	Pile Type	Unknown
Pile Size	(inch)	14.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 152.3

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.7	21.4
9	0.249	15183	0.000	0.000	1.00	0.1	0.050	0.100	30.66	4.7	21.4
10	0.249	15183	0.000	0.000	1.00	12.7	0.200	0.100	34.06	4.7	21.4
11	0.249	15183	0.000	0.000	1.00	15.3	0.176	0.100	37.47	4.7	21.4
12	0.249	15183	0.000	0.000	1.00	14.0	0.132	0.100	40.88	4.7	21.4
13	0.249	15183	0.000	0.000	1.00	10.1	0.050	0.100	44.28	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	14.0	0.050	0.100	47.69	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	18.2	0.050	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	21.7	0.050	0.100	54.50	4.7	21.4
Toe						46.0	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
25.00	10.81	1.00	0.800

FRA-70-1358L - FA - B-018-2-13 - HP14x73 02/27/2021
Resource International Inc GRLWEAP Version 2010

Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
152.3	16.0	7.04	6.98	-0.83	10	32	26.18	10	4	18.5	44.6
153.8	16.3	7.06	7.00	-0.90	10	32	26.32	10	4	18.4	44.5
155.2	16.6	7.08	7.02	-0.97	10	32	26.41	10	4	18.4	44.4
156.7	16.9	7.11	7.05	-1.02	10	32	26.57	10	4	18.3	44.4
158.2	17.2	7.13	7.07	-1.08	10	32	26.70	10	4	18.3	44.3

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Depth (ft) 30.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model Total Capacity Rut (kips) 200.8

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.7	21.4
8	0.249	15183	0.000	0.000	1.00	5.8	0.197	0.100	27.25	4.7	21.4
9	0.249	15183	0.000	0.000	1.00	13.3	0.200	0.100	30.66	4.7	21.4
10	0.249	15183	0.000	0.000	1.00	17.3	0.152	0.100	34.06	4.7	21.4
11	0.249	15183	0.000	0.000	1.00	10.2	0.082	0.100	37.47	4.7	21.4
12	0.249	15183	0.000	0.000	1.00	11.6	0.050	0.100	40.88	4.7	21.4
13	0.249	15183	0.000	0.000	1.00	16.3	0.050	0.100	44.28	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	19.9	0.050	0.100	47.69	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	23.4	0.050	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	27.0	0.050	0.100	54.50	4.7	21.4
Toe						56.2	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
30.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
200.8	23.2	7.54	7.50	-1.72	8	26	27.08	9	4	18.2	43.1
202.3	23.6	7.56	7.53	-1.76	8	26	27.18	9	3	18.1	43.0
203.8	23.9	7.58	7.54	-1.83	8	26	27.26	9	4	18.1	43.0
205.2	24.3	7.59	7.57	-1.88	8	26	27.32	8	3	18.1	42.9
206.7	24.6	7.61	7.59	-1.92	8	25	27.41	8	3	18.1	42.8

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Depth (ft) 35.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 192.0

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.7	21.4
6	0.249	15183	0.000	0.000	1.00	0.1	0.050	0.100	20.44	4.7	21.4
7	0.249	15183	0.000	0.000	1.00	11.9	0.199	0.100	23.84	4.7	21.4
8	0.249	15183	0.000	0.000	1.00	15.1	0.179	0.100	27.25	4.7	21.4
9	0.249	15183	0.000	0.000	1.00	14.5	0.136	0.100	30.66	4.7	21.4
10	0.249	15183	0.000	0.000	1.00	9.9	0.050	0.100	34.06	4.7	21.4
11	0.249	15183	0.000	0.000	1.00	13.7	0.050	0.100	37.47	4.7	21.4
12	0.249	15183	0.000	0.000	1.00	18.0	0.050	0.100	40.88	4.7	21.4
13	0.249	15183	0.000	0.000	1.00	21.5	0.050	0.100	44.28	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	25.1	0.050	0.100	47.69	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	28.6	0.050	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	28.1	0.169	0.100	54.50	4.7	21.4
Toe						5.5	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth ft	Stroke ft	Pressure Ratio	Efficy
35.00	10.81	1.00	0.800

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Rut kips	Bl Ct b/ft	Stroke (ft) down	up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
192.0	21.1	7.44	7.40	-1.85	8	26	27.15	7	3	18.1	43.4
195.7	21.9	7.48	7.44	-2.05	7	26	27.33	7	3	18.1	43.2
199.3	22.8	7.53	7.50	-2.18	7	26	27.48	7	3	18.0	43.1
202.9	23.7	7.57	7.55	-2.26	7	26	27.70	7	3	17.9	42.9
206.5	24.6	7.62	7.60	-2.34	7	26	27.88	7	3	17.9	42.8

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Depth (ft) 40.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top ft	Area in2	E-Mod ksi	Spec Wt lb/ft3	Perim ft	C Index	Wave Sp ft/s	EA/c k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 230.8

No.	Weight kips	Stiffn k/in	C-Slk ft	T-Slk ft	CoR	Soil-S kips	Soil-D s/ft	Quake inch	LbTop ft	Perim ft	Area in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.7	21.4
5	0.249	15183	0.000	0.000	1.00	5.0	0.196	0.100	17.03	4.7	21.4
6	0.249	15183	0.000	0.000	1.00	13.3	0.200	0.100	20.44	4.7	21.4
7	0.249	15183	0.000	0.000	1.00	17.0	0.155	0.100	23.84	4.7	21.4
8	0.249	15183	0.000	0.000	1.00	10.7	0.092	0.100	27.25	4.7	21.4
9	0.249	15183	0.000	0.000	1.00	11.3	0.050	0.100	30.66	4.7	21.4
10	0.249	15183	0.000	0.000	1.00	16.0	0.050	0.100	34.06	4.7	21.4
11	0.249	15183	0.000	0.000	1.00	19.6	0.050	0.100	37.47	4.7	21.4
12	0.249	15183	0.000	0.000	1.00	23.2	0.050	0.100	40.88	4.7	21.4
13	0.249	15183	0.000	0.000	1.00	26.7	0.050	0.100	44.28	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	29.7	0.083	0.100	47.69	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	26.4	0.200	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	26.4	0.200	0.100	54.50	4.7	21.4
Toe						5.5	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth Stroke Pressure Efficy

ft	ft	Ratio	
40.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
230.8	30.7	7.90	7.90	-2.12	6	25	27.94	6	3	17.5	42.0
239.3	32.5	7.98	7.98	-1.81	5	25	28.16	6	3	17.3	41.8
247.7	34.2	8.05	8.04	-1.43	5	25	28.37	6	3	17.3	41.7
256.2	36.1	8.11	8.10	-0.98	5	25	28.58	6	3	17.2	41.5
264.6	38.3	8.17	8.17	-0.54	5	43	28.75	6	3	17.2	41.4

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Depth (ft) 45.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model Total Capacity Rut (kips) 269.1

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	0.0	0.000	0.100	6.81	4.7	21.4
3	0.249	15183	0.000	0.000	1.00	0.0	0.050	0.100	10.22	4.7	21.4
4	0.249	15183	0.000	0.000	1.00	11.1	0.199	0.100	13.62	4.7	21.4
5	0.249	15183	0.000	0.000	1.00	14.8	0.182	0.100	17.03	4.7	21.4
6	0.249	15183	0.000	0.000	1.00	15.1	0.139	0.100	20.44	4.7	21.4
7	0.249	15183	0.000	0.000	1.00	9.8	0.050	0.100	23.84	4.7	21.4
8	0.249	15183	0.000	0.000	1.00	13.4	0.050	0.100	27.25	4.7	21.4
9	0.249	15183	0.000	0.000	1.00	17.7	0.050	0.100	30.66	4.7	21.4
10	0.249	15183	0.000	0.000	1.00	21.3	0.050	0.100	34.06	4.7	21.4
11	0.249	15183	0.000	0.000	1.00	24.8	0.050	0.100	37.47	4.7	21.4
12	0.249	15183	0.000	0.000	1.00	28.4	0.050	0.100	40.88	4.7	21.4
13	0.249	15183	0.000	0.000	1.00	28.3	0.162	0.100	44.28	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	26.4	0.200	0.100	47.69	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	25.9	0.200	0.100	54.50	4.7	21.4
Toe						5.5	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
45.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
269.1	39.7	8.23	8.22	-0.37	15	12	28.86	4	2	16.9	41.3
282.3	43.6	8.24	8.30	-0.51	4	40	28.97	4	2	16.9	41.1
295.5	47.2	8.34	8.38	-0.62	4	39	29.27	4	2	17.0	40.9
308.8	51.2	8.44	8.47	-0.47	4	37	29.59	4	2	17.1	40.7
322.0	55.5	8.54	8.55	-0.54	4	37	29.90	4	2	17.3	40.5

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Depth (ft) 50.0 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c

ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 304.9

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.249	15183	0.010	0.000	0.85	0.0	0.000	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	4.1	0.196	0.100	6.81	4.7	21.4
3	0.249	15183	0.000	0.000	1.00	13.3	0.200	0.100	10.22	4.7	21.4
4	0.249	15183	0.000	0.000	1.00	16.8	0.159	0.100	13.62	4.7	21.4
5	0.249	15183	0.000	0.000	1.00	11.2	0.100	0.100	17.03	4.7	21.4
6	0.249	15183	0.000	0.000	1.00	11.1	0.050	0.100	20.44	4.7	21.4
7	0.249	15183	0.000	0.000	1.00	15.7	0.050	0.100	23.84	4.7	21.4
8	0.249	15183	0.000	0.000	1.00	19.4	0.050	0.100	27.25	4.7	21.4
9	0.249	15183	0.000	0.000	1.00	22.9	0.050	0.100	30.66	4.7	21.4
10	0.249	15183	0.000	0.000	1.00	26.5	0.050	0.100	34.06	4.7	21.4
11	0.249	15183	0.000	0.000	1.00	29.8	0.065	0.100	37.47	4.7	21.4
12	0.249	15183	0.000	0.000	1.00	26.4	0.200	0.100	40.88	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	26.3	0.200	0.100	47.69	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	25.3	0.200	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	24.1	0.200	0.100	54.50	4.7	21.4
Toe						5.5	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
50.00	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft) down	Stroke (ft) up	Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft			ksi			ksi			kip-ft	b/min
304.9	50.1	8.43	8.47	-0.49	15	12	29.02	3	2	16.6	40.7
322.6	56.5	8.56	8.58	-0.27	15	11	29.37	3	2	16.9	40.4
340.3	63.4	8.68	8.67	-0.22	2	33	29.69	3	2	17.2	40.2
358.0	71.7	8.79	8.78	-0.25	2	33	30.01	3	2	17.4	39.9
375.7	79.8	8.90	8.87	-0.23	2	33	30.30	3	2	17.6	39.7

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Depth (ft) 54.5 Standard Soil Setup
Shaft Gain/Loss Factor 0.400 Toe Gain/Loss Factor 1.000

PILE PROFILE:
Toe Area (in2) 144.000 Pile Type Unknown
Pile Size (inch) 14.000

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	21.40	29000.	492.0	4.7	0	16524.	37.6
54.5	21.40	29000.	492.0	4.7	0	16524.	37.6

Wave Travel Time 2L/c (ms) 6.596

Pile and Soil Model — Total Capacity Rut (kips) 334.5

No.	Weight	Stiffn	C-Slk	T-Slk	CoR	Soil-S	Soil-D	Quake	LbTop	Perim	Area
	kips	k/in	ft	ft		kips	s/ft	inch	ft	ft	in2
1	0.249	15183	0.010	0.000	0.85	8.4	0.198	0.100	3.41	4.7	21.4
2	0.249	15183	0.000	0.000	1.00	13.9	0.192	0.100	6.81	4.7	21.4
3	0.249	15183	0.000	0.000	1.00	17.1	0.149	0.100	10.22	4.7	21.4
4	0.249	15183	0.000	0.000	1.00	9.1	0.050	0.100	13.62	4.7	21.4
5	0.249	15183	0.000	0.000	1.00	12.4	0.050	0.100	17.03	4.7	21.4
6	0.249	15183	0.000	0.000	1.00	17.0	0.050	0.100	20.44	4.7	21.4
7	0.249	15183	0.000	0.000	1.00	20.5	0.050	0.100	23.84	4.7	21.4
8	0.249	15183	0.000	0.000	1.00	24.1	0.050	0.100	27.25	4.7	21.4
9	0.249	15183	0.000	0.000	1.00	27.6	0.050	0.100	30.66	4.7	21.4
10	0.249	15183	0.000	0.000	1.00	29.0	0.134	0.100	34.06	4.7	21.4
11	0.249	15183	0.000	0.000	1.00	26.4	0.200	0.100	37.47	4.7	21.4
13	0.249	15183	0.000	0.000	1.00	26.1	0.200	0.100	44.28	4.7	21.4
14	0.249	15183	0.000	0.000	1.00	24.9	0.200	0.100	47.69	4.7	21.4
15	0.249	15183	0.000	0.000	1.00	23.7	0.200	0.100	51.09	4.7	21.4
16	0.249	15183	0.000	0.000	1.00	22.2	0.200	0.100	54.50	4.7	21.4
Toe						5.5	0.150	0.100			

3.985 kips total unreduced pile weight (g= 32.17 ft/s2)
3.985 kips total reduced pile weight (g= 32.17 ft/s2)

Depth	Stroke	Pressure	Efficy
ft	ft	Ratio	
54.50	10.81	1.00	0.800

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Rut	Bl Ct	Stroke (ft)		Ten Str	i	t	Comp Str	i	t	ENTHRU	Bl Rt
kips	b/ft	down	up	ksi			ksi			kip-ft	b/min
334.5	62.3	8.66	8.66	-0.54	15	11	30.04	1	2	16.4	40.2
355.9	72.3	8.78	8.76	-0.36	15	11	30.44	1	2	16.6	40.0
377.4	84.0	8.89	8.87	-0.22	15	11	30.78	1	2	16.7	39.7
398.8	96.8	9.00	8.97	-0.14	16	11	31.15	1	2	16.9	39.5
420.2	112.9	9.10	9.06	-0.09	16	11	31.48	1	2	17.1	39.3

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SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.400 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	17.1	14.6	2.5	1.7	12.237	-1.547	4.29	24.8
10.0	41.1	38.6	2.5	3.9	18.132	-3.239	5.23	22.2
15.0	66.7	53.1	13.6	6.5	21.254	-2.374	5.71	20.4
20.0	111.4	75.6	35.8	11.6	24.049	-1.085	6.49	19.0
25.0	152.3	106.3	46.0	16.0	26.185	-0.832	7.04	18.5
30.0	200.8	144.6	56.2	23.2	27.077	-1.719	7.54	18.2
35.0	192.0	186.5	5.5	21.1	27.151	-1.849	7.44	18.1
40.0	230.8	225.3	5.5	30.7	27.942	-2.122	7.90	17.5
45.0	269.1	263.5	5.5	39.7	28.861	-0.371	8.23	16.9
50.0	304.9	299.4	5.5	50.1	29.018	-0.488	8.43	16.6
54.5	334.5	329.0	5.5	62.3	30.044	-0.537	8.66	16.4

Total Driving Time 27 minutes; Total No. of Blows 1145
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.450 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	17.9	15.4	2.5	1.8	12.572	-1.715	4.33	24.9
10.0	42.6	40.1	2.5	4.1	18.371	-3.161	5.27	22.1
15.0	68.2	54.6	13.6	6.7	21.471	-2.270	5.75	20.3
20.0	112.9	77.1	35.8	11.8	24.204	-1.106	6.52	19.0
25.0	153.8	107.8	46.0	16.3	26.317	-0.899	7.06	18.4
30.0	202.3	146.1	56.2	23.6	27.176	-1.759	7.56	18.1
35.0	195.7	190.1	5.5	21.9	27.333	-2.049	7.48	18.1
40.0	239.3	233.8	5.5	32.5	28.164	-1.813	7.98	17.3
45.0	282.3	276.8	5.5	43.6	28.971	-0.508	8.24	16.9
50.0	322.6	317.1	5.5	56.5	29.372	-0.268	8.56	16.9
54.5	355.9	350.4	5.5	72.3	30.441	-0.359	8.78	16.6

Total Driving Time 29 minutes; Total No. of Blows 1238
Starting at penetration 5.0 ft

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SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.500 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	18.7	16.2	2.5	1.8	12.856	-1.853	4.37	24.9
10.0	44.1	41.6	2.5	4.3	18.596	-3.115	5.32	21.9
15.0	69.6	56.0	13.6	6.9	21.659	-2.155	5.79	20.2
20.0	114.4	78.5	35.8	12.0	24.350	-1.180	6.55	18.9
25.0	155.2	109.2	46.0	16.6	26.412	-0.968	7.08	18.4
30.0	203.8	147.6	56.2	23.9	27.255	-1.833	7.58	18.1
35.0	199.3	193.7	5.5	22.8	27.482	-2.179	7.53	18.0
40.0	247.7	242.2	5.5	34.2	28.369	-1.429	8.05	17.3
45.0	295.5	290.0	5.5	47.2	29.269	-0.624	8.34	17.0
50.0	340.3	334.8	5.5	63.4	29.687	-0.223	8.68	17.2
54.5	377.4	371.8	5.5	84.0	30.785	-0.219	8.89	16.7

Total Driving Time 32 minutes; Total No. of Blows 1332
Starting at penetration 5.0 ft

G/L at Shaft and Toe: 0.550 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	19.4	16.9	2.5	1.9	13.156	-2.003	4.41	24.9
10.0	45.5	43.0	2.5	4.5	18.806	-3.025	5.36	21.8
15.0	71.1	57.5	13.6	7.1	21.837	-2.039	5.82	20.1
20.0	115.8	80.0	35.8	12.2	24.465	-1.221	6.58	18.9
25.0	156.7	110.7	46.0	16.9	26.566	-1.021	7.11	18.3
30.0	205.2	149.1	56.2	24.3	27.323	-1.881	7.59	18.1
35.0	202.9	197.4	5.5	23.7	27.695	-2.263	7.57	17.9
40.0	256.2	250.7	5.5	36.1	28.580	-0.978	8.11	17.2
45.0	308.8	303.3	5.5	51.2	29.585	-0.468	8.44	17.1
50.0	358.0	352.5	5.5	71.7	30.009	-0.253	8.79	17.4
54.5	398.8	393.3	5.5	96.8	31.146	-0.140	9.00	16.9

Total Driving Time 35 minutes; Total No. of Blows 1442
Starting at penetration 5.0 ft

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SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.600 1.000

Depth	Rut	Frictn	End Bg	Bl Ct	Com Str	Ten Str	Stroke	ENTHRU
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft
5.0	20.2	17.7	2.5	1.9	13.402	-2.092	4.45	24.7
10.0	47.0	44.5	2.5	4.7	19.030	-2.929	5.40	21.7
15.0	72.6	59.0	13.6	7.2	22.015	-1.909	5.86	20.0
20.0	117.3	81.5	35.8	12.4	24.568	-1.254	6.60	18.8
25.0	158.2	112.2	46.0	17.2	26.701	-1.076	7.13	18.3
30.0	206.7	150.5	56.2	24.6	27.410	-1.922	7.61	18.1
35.0	206.5	201.0	5.5	24.6	27.881	-2.336	7.62	17.9
40.0	264.6	259.1	5.5	38.3	28.751	-0.537	8.17	17.2
45.0	322.0	316.5	5.5	55.5	29.897	-0.541	8.54	17.3
50.0	375.7	370.2	5.5	79.8	30.295	-0.227	8.90	17.6
54.5	420.2	414.7	5.5	112.9	31.481	-0.087	9.10	17.1

Total Driving Time 38 minutes; Total No. of Blows 1561
Starting at penetration 5.0 ft

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Table of Depths Analyzed with Driving System Modifiers

Depth	Temp. Length	Wait Time	Equivalent Stroke	Pressure Ratio	Efficy.	Stiffn. Factor	Cushion CoR
ft	ft	hr	ft				
5.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
10.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
15.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
20.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
25.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
30.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
35.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
40.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
45.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
50.00	54.50	0.00	10.81	1.00	0.80	1.00	1.00
54.50	54.50	0.00	10.81	1.00	0.80	1.00	1.00

Soil Layer Resistance Values

Depth	Shaft Res.	End Bearing	Shaft Quake	Toe Quake	Shaft Damping	Toe Damping	Soil Setup	Limit Distance	Setup Time
ft	k/ft2	kips	inch	inch	s/ft	s/ft	Normlzd	ft	hrs
0.01	0.00	0.01	0.100	0.100	0.050	0.150	0.000	6.000	1.000
1.29	0.05	0.77	0.100	0.100	0.050	0.150	0.000	6.000	1.000
1.31	1.37	2.51	0.100	0.100	0.200	0.150	0.660	6.000	168.000
6.29	1.37	2.51	0.100	0.100	0.200	0.150	0.660	6.000	168.000
6.31	1.37	2.51	0.100	0.100	0.150	0.150	0.340	6.000	24.000
10.09	1.37	2.51	0.100	0.100	0.150	0.150	0.340	6.000	24.000
10.11	0.47	8.71	0.100	0.100	0.050	0.150	0.000	6.000	1.000
16.29	0.81	14.89	0.100	0.100	0.050	0.150	0.000	6.000	1.000
16.31	0.90	28.29	0.100	0.100	0.050	0.150	0.000	6.000	1.000
25.31	1.49	46.63	0.100	0.100	0.050	0.150	0.000	6.000	1.000
32.79	1.98	61.87	0.100	0.100	0.050	0.150	0.000	6.000	1.000

32.81	4.12	5.52	0.100	0.100	0.200	0.150	1.000	6.000	168.000
41.81	4.12	5.52	0.100	0.100	0.200	0.150	1.000	6.000	168.000
50.81	3.63	5.52	0.100	0.100	0.200	0.150	1.000	6.000	168.000
54.50	3.32	5.52	0.100	0.100	0.200	0.150	1.000	6.000	168.000

APPENDIX VII

LATERAL DESIGN PARAMETERS

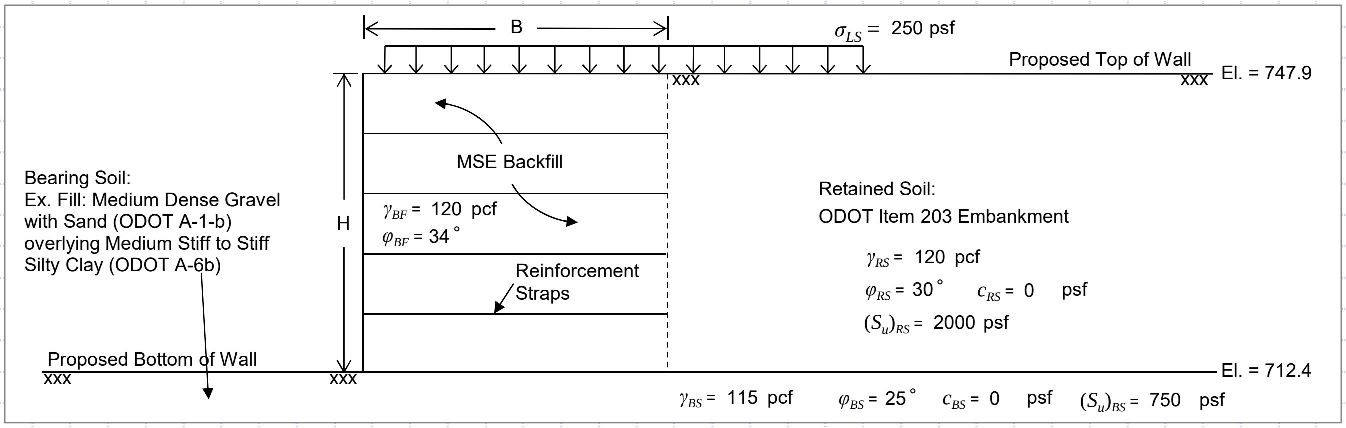
FRA-70-1358L I-70 WB over CSX and NS Railroad
Lateral Design Parameters

Boring No.	Elevation (feet msl)	Soil Class.	Soil Type	Strata	N_{60}	$N1_{60}$	γ (pcf)	γ' (pcf)	Strength Parameter	k (soil) k_{rm} (rock)	$ε_{50}$ (soil) E_r (rock)	RQD (rock)
B-017-3-13	740.3 to 713.3	A-7-6	C	3	11	11	115 psf	115 psf	Su = 1,375 psf	435 pci	0.0075	-
	713.3 to 708.3	A-1-b	G	4	18	15	125 psf	125 psf	φ = 36°	160 pci	-	-
	708.3 to 703.3	A-6b	C	3	14	14	120 psf	120 psf	Su = 1,750 psf	585 pci	0.0067	-
	703.3 to 698.3	A-1-b	G	4	38	27	130 psf	130 psf	φ = 39°	250 pci	-	-
	698.3 to 683.3	A-1-b	G	4	63	40	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	683.3 to 673.3	A-6a	C	2	69	69	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	673.3 to 668.3	A-1-a	G	4	85	48	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	668.3 to 656.8	A-7-6	C	2	66	66	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	656.8 to 653.3	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 750 psi	0.00025	68,000 psi	26
B-017-7-13	743.1 to 739.1	A-1-a	G	4	14	24	120 psf	120 psf	φ = 39°	250 pci	-	-
	739.1 to 735.1	A-6a	C	3	18	18	120 psf	120 psf	Su = 2,250 psf	750 pci	0.0060	-
	735.1 to 732.6	A-1-a	G	4	65	78	135 psf	135 psf	φ = 43°	395 pci	-	-
	732.6 to 711.1	A-6b	C	3	25	25	120 psf	120 psf	Su = 3,125 psf	1,040 pci	0.0050	-
	711.1 to 704.1	A-6a	C	3	12	12	115 psf	115 psf	Su = 1,500 psf	500 pci	0.0070	-
	704.1 to 701.1	A-6b	C	3	21	21	120 psf	120 psf	Su = 2,625 psf	875 pci	0.0055	-
	701.1 to 691.1	A-1-b	G	4	32	21	130 psf	130 psf	φ = 38°	215 pci	-	-
	691.1 to 686.1	A-1-b	G	4	97	58	135 psf	135 psf	φ = 42°	355 pci	-	-
	686.1 to 676.1	A-2-4	G	4	86	49	135 psf	72.6 psf	φ = 40°	155 pci	-	-
	676.1 to 666.1	A-7-6	C	2	38	38	125 psf	62.6 psf	Su = 4,750 psf	1,585 pci	0.0044	-
	666.1 to 653.1	A-7-6	C	2	111	111	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	653.1 to 646.4	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 360 psi	0.0005	32,000 psi	15
B-017-9-13	717.6 to 712.1	A-1-b	G	4	16	25	125 psf	125 psf	φ = 38°	215 pci	-	-
	712.1 to 708.9	A-6b	C	1	6	6	115 psf	115 psf	Su = 750 psf	100 pci	0.0100	-
	708.9 to 707.1	A-3a	G	4	4	5	120 psf	120 psf	φ = 30°	45 pci	-	-
	707.1 to 704.6	A-6b	C	1	7	7	115 psf	115 psf	Su = 875 psf	165 pci	0.0095	-
	704.6 to 702.1	A-2-6	G	4	28	29	130 psf	130 psf	φ = 38°	215 pci	-	-
	702.1 to 699.6	A-3a	G	4	19	19	125 psf	125 psf	φ = 35°	135 pci	-	-
	699.6 to 685.6	A-1-b	G	4	35	31	130 psf	67.6 psf	φ = 39°	140 pci	-	-
	685.6 to 665.6	A-7-6	C	2	22	22	120 psf	57.6 psf	Su = 2,750 psf	915 pci	0.0053	-
	665.6 to 660.6	A-7-6	C	2	36	36	125 psf	62.6 psf	Su = 4,500 psf	1,500 pci	0.0045	-
	660.6 to 653.2	A-7-6	C	2	98	98	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	653.2 to 648.0	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	20
	648.0 to 643.5	Mudstone	R	9	-	-	150 psf	87.6 psf	Qu = 360 psi	0.0005	32,000 psi	0
	643.5 to 639.5	Limestone	R	9	-	-	165 psf	102.6 psf	Qu = 10,000 psi	0.0005	1,000,000 psi	57
B-018-1-13	717.0 to 711.5	A-1-b	G	4	16	25	125 psf	125 psf	φ = 38°	215 pci	-	-
	711.5 to 706.5	A-4a	C	1	4	4	110 psf	47.6 psf	Su = 500 psf	65 pci	0.0150	-
	706.5 to 701.5	A-4a	C	2	22	22	120 psf	57.6 psf	Su = 2,750 psf	915 pci	0.0053	-
	701.5 to 699.0	A-1-a	G	4	21	24	125 psf	62.6 psf	φ = 39°	140 pci	-	-
	699.0 to 694.0	A-1-a	G	4	61	65	135 psf	72.6 psf	φ = 43°	215 pci	-	-
	694.0 to 691.5	A-6a	C	2	52	52	130 psf	67.6 psf	Su = 6,500 psf	2,165 pci	0.0038	-
	691.5 to 689.0	A-2-6	G	4	37	37	130 psf	67.6 psf	φ = 39°	140 pci	-	-
	689.0 to 675.0	A-1-a	G	4	60	54	135 psf	72.6 psf	φ = 43°	215 pci	-	-
	675.0 to 665.0	A-7-6	C	2	15	15	120 psf	57.6 psf	Su = 1,875 psf	625 pci	0.0065	-
	665.0 to 657.7	A-7-6	C	2	36	36	125 psf	62.6 psf	Su = 4,500 psf	1,500 pci	0.0045	-
	657.7 to 643.5	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	20
	643.5 to 633.5	Limestone	R	9	-	-	165 psf	102.6 psf	Qu = 10,000 psi	0.0005	1,000,000 psi	60
B-018-2-13	715.7 to 710.2	A-2-4	G	4	14	22	125 psf	125 psf	φ = 37°	190 pci	-	-
	710.2 to 705.2	A-6b	C	3	15	15	120 psf	120 psf	Su = 1,875 psf	625 pci	0.0065	-
	705.2 to 701.4	A-4a	C	3	15	15	120 psf	120 psf	Su = 1,875 psf	625 pci	0.0065	-
	701.4 to 695.2	A-1-b	G	4	30	29	130 psf	130 psf	φ = 39°	250 pci	-	-
	695.2 to 678.7	A-1-a	G	4	57	47	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	678.7 to 656.9	A-7-6	C	2	33	33	125 psf	62.6 psf	Su = 4,125 psf	1,375 pci	0.0046	-
	656.9 to 641.2	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	20
	641.2 to 631.2	Limestone	R	9	-	-	165 psf	102.6 psf	Qu = 10,000 psi	0.0005	1,000,000 psi	80
B-019-6-19	738.1 to 735.1	A-2-4	G	4	29	52	130 psf	130 psf	φ = 41°	315 pci	-	-
	735.1 to 732.6	A-6a	C	3	19	19	120 psf	120 psf	Su = 2,375 psf	790 pci	0.0058	-
	732.6 to 727.6	A-6b	C	3	10	10	115 psf	115 psf	Su = 1,250 psf	365 pci	0.0080	-
	727.6 to 725.1	A-1-b	G	4	37	41	130 psf	130 psf	φ = 41°	315 pci	-	-
	725.1 to 720.1	A-2-4	G	4	12	12	125 psf	125 psf	φ = 34°	115 pci	-	-
	720.1 to 716.1	A-6b	C	3	10	10	115 psf	115 psf	Su = 1,250 psf	365 pci	0.0080	-
	716.1 to 711.1	A-2-4	G	4	57	49	135 psf	135 psf	φ = 40°	280 pci	-	-
	711.1 to 706.1	A-4a	C	3	23	23	120 psf	120 psf	Su = 2,875 psf	960 pci	0.0052	-
	706.1 to 701.1	A-6b	C	3	13	13	115 psf	115 psf	Su = 1,625 psf	540 pci	0.0068	-
	701.1 to 698.1	A-4a	C	3	39	39	125 psf	125 psf	Su = 4,875 psf	1,625 pci	0.0044	-

APPENDIX IX

MSE WALL CALCULATIONS

FRA-70-1358L - Retaining Wall E2 (Sta. 200+68 to 201+63) - MSE Wall - Rear Abutment - B-017-3-13 and B-017-9-13 - 35.5 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	35.5	ft
MSE Wall Width (Reinforcement Length), (B) =	24.9	ft
MSE Wall Length, (L) =	95	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(S_u)_{BS}]$ =	750	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_w) =	0.0	ft

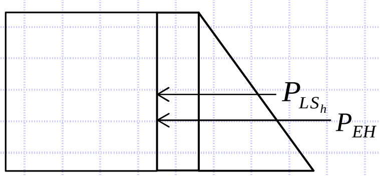
LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3

Sliding Force: $P_H = P_{EH} + P_{LS_h}$



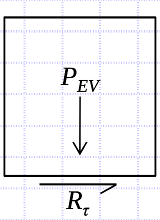
$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(35.5 ft)²(0.297)(1.5) = 33.69 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(35.5 ft)(0.297)(1.75) = 4.61 kip/ft

P_H = 33.69 kip/ft + 4.61 kip/ft = 38.30 kip/ft

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance: $R_\tau = P_{EV} \cdot \tan\delta$



$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(35.5 ft)(24.9 ft)(1.00) = 106.07 kip/ft

$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$

$\tan\delta =$ tan(25) ≤ tan(34) ⟶ 0.47 ≤ 0.67 ⟶ $\tan\delta =$ 0.47

R_τ = (106.07 kip/ft)(0.47) = 49.85 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 38.30 kip/ft ≤ (49.85 kip/ft)(1.0) = 49.85 kip/ft ⟶ 38.30 kip/ft ≤ 49.85 kip/ft **OK**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	35.5	ft
MSE Wall Width (Reinforcement Length), (B) =	24.9	ft
MSE Wall Length, (L) =	95	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	750	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

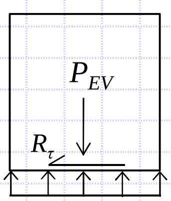
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 ***(Continued)***

Check Sliding Resistance - Undrained Condition

Nominal Sliding Resisting: $R_\tau = ((S_u)_{BS} \leq q_s) \cdot B$



$(S_u)_{BS} =$ 0.75 ksf

$q_s = \sigma_v / 2$ = (4.26 ksf) / 2 = 2.13 ksf

$\sigma_v = P_{EV} / B$ = (106.07 kip/ft) / (24.9 ft) = 4.26 ksf

R_τ = (0.75 ksf ≤ 2.13 ksf)(24.9 ft) = 18.68 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \leq R_\tau \cdot \phi_\tau$ ⟶ 38.30 kip/ft ≤ (18.68 kip/ft)(1.0) = 18.68 kip/ft ⟶ 38.30 kip/ft ≤ 18.68 kip/ft **ERROR!!**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	3	OF	6
CALCULATED BY	BRT	DATE	11/22/2021
CHECKED BY	JPS	DATE	11/23/2021

FRA-70-1358L - Rear Abutment - Wall E2

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	35.5	ft
MSE Wall Width (Reinforcement Length), (B) =	24.9	ft
MSE Wall Length, (L) =	95	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

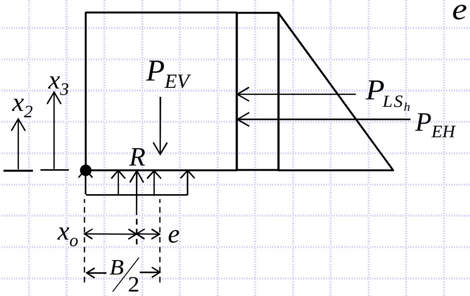
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	750	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.5



$$e = B/2 - x_o$$

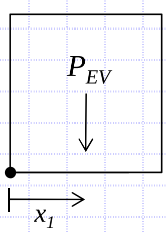
$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (1320.57 kip·ft/ft - 480.38 kip·ft/ft) / (106.07 kip/ft) = 7.92 ft

M_{EV} = 1320.57 kip·ft/ft
M_H = 480.38 kip·ft/ft
P_{EV} = 106.07 kip/ft
Defined below

$e =$ (24.9 ft)/2 - 7.92 ft = 4.53 ft

Resisting Moment, M_{EV}:

$$M_{EV} = P_{EV}(x_1)$$



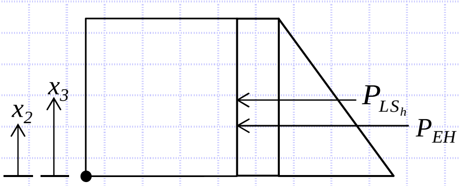
$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(35.5 ft)(24.9 ft)(1.00) = 106.07 kip/ft

$x_1 = B/2$ = (24.9 ft) / 2 = 12.45 ft

$M_{EV} =$ (106.07 kip/ft)(12.45 ft) = 1320.57 kip·ft/ft

Overturning Moment, M_H:

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$$



$P_{EH} = ½\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(35.5 ft)²(0.297)(1.5) = 33.69 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(35.5 ft)(0.297)(1.75) = 4.61 kip/ft

$x_2 = H/3$ = (35.5 ft) / 3 = 11.83 ft

$x_3 = H/2$ = (35.5 ft) / 2 = 17.75 ft

$M_H =$ (33.69 kip/ft)(11.83 ft) + (4.61 kip/ft)(17.75 ft) = 480.38 kip·ft/ft

Check Eccentricity

$e < e_{max} \longrightarrow$ 4.53 ft < 8.30 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (24.9 ft) / 3 = 8.30 ft

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	35.5	ft
MSE Wall Width (Reinforcement Length), (B) =	24.9	ft
MSE Wall Length, (L) =	95	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

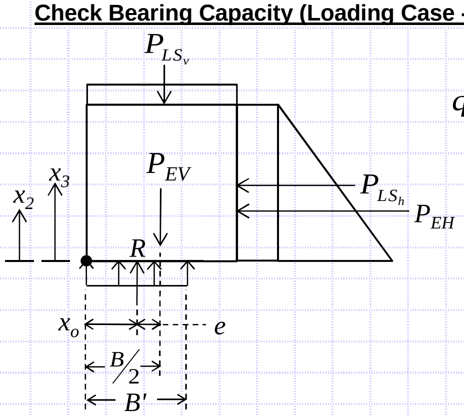
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	750	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 24.9 ft - 2(3.12 ft) = 18.66 ft

$e = B/2 - x_o$ = (24.9 ft) / 2 - 9.33 ft = 3.12 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (1918.47 kip·ft/ft - 480.39 kip·ft/ft) / 154.09 kip/ft = 9.33 ft

q_{eq} = (154.09 kip/ft) / (18.66 ft) = 8.26 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

M_V = [(120 pcf)(35.5 ft)(24.9 ft)(1.35)](12.45 ft) + [(250 psf)(24.9 ft)(1.75)](12.45 ft) = 1918.47 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

M_H = [½(120 pcf)(35.5 ft)²(0.297)(1.5)](11.83 ft) + [(250 psf)(35.5 ft)(0.297)(1.75)](17.75 ft) = 480.39 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

P_V = (120 pcf)(35.5 ft)(24.9 ft)(1.35) + (250 psf)(24.9 ft)(1.75) = 154.09 kip/ft

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 22.81

- N_c = 20.72
- s_c = 1+(18.66 ft/95 ft)(10.66/20.72)
- = 1.101
- i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 12.41

- N_q = 10.66
- s_q = 1.092
- d_q = 1+2tan(25°)[1-sin(25°)]²tan⁻¹(4.0 ft/18.66 ft)
- 1.066
- i_q = 1.000 (Assumed)
- C_{wq} = 0.0 ft > 4.0 ft = 0.500

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 10.02

- N_γ = 10.88
- s_γ = 0.921
- i_γ = 1.000 (Assumed)
- $C_{w\gamma}$ = 0.0 ft < 1.5(18.66 ft) + 4.0 ft = 0.500

q_n = (0 psf)(22.813) + (115 pcf)(4.0 ft)(12.409)(0.500) + ½(115 pcf)(18.7 ft)(10.020)(0.500) = 8.23 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 8.26 ksf ≤ (8.23 ksf)(0.65) = 5.35 ksf ⟶ 8.26 ksf ≤ 5.35 ksf **ERROR!!**

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	35.5	ft
MSE Wall Width (Reinforcement Length), (B) =	24.9	ft
MSE Wall Length, (L) =	95	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	750	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 *(Continued)*

Check Bearing Resistance - Undrained Condition

Nominal Bearing Resistance: $$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$

$N_{cm} = N_c s_c i_c$ = 5.340

- N_c = 5.140
- s_c = 1+(18.66 ft/[(5)(95 ft)]) = 1.039
- i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 1.000

- N_q = 1.000
- s_q = 1.000
- d_q = 1+2tan(0°)[1-sin(0°)]²tan⁻¹(4.0 ft/18.66 ft) = 1.000
- i_q = 1.000 (Assumed)
- C_{wq} = 0.0 ft > 4.0 ft = 0.500

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

- N_γ = 0.000
- s_γ = 1.000
- i_γ = 1.000 (Assumed)
- $C_{w\gamma}$ = 0.0 ft < 1.5(18.66 ft) + 4.0 ft = 0.500

$q_n =$ (750 psf)(5.340) + (115 pcf)(4.0 ft)(1.000)(0.500) + ½(115 pcf)(18.7 ft)(0.000)(0.500) = 4.24 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \leq q_n \cdot \phi_b$ ⟶ 8.26 ksf ≤ (4.24 ksf)(0.65) = 2.76 ksf ⟶ 8.26 ksf ≤ 2.76 ksf **ERROR!!**

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	35.5	ft
MSE Wall Width (Reinforcement Length), (B) =	24.9	ft
MSE Wall Length, (L) =	95	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

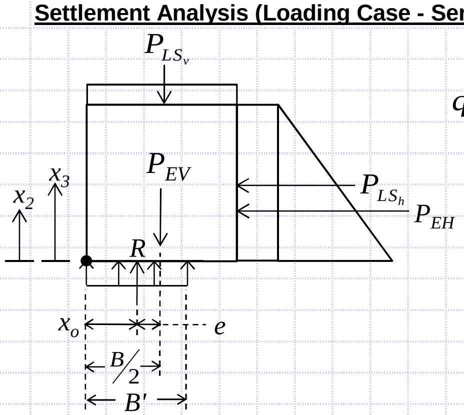
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	750	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



$$q_{eq} = P_V / B'$$

$$B' = B - 2e \quad = \quad 24.9 \text{ ft} - 2(2.78 \text{ ft}) \quad = \quad 19.34 \quad \text{ft}$$

$$e = B/2 - x_o \quad = \quad (24.9 \text{ ft}) / 2 - 9.67 \text{ ft} \quad = \quad 2.78 \quad \text{ft}$$

$$x_o = \frac{M_V - M_H}{P_V} \quad = \quad (1398.12 \text{ kip·ft/ft} - 312.46 \text{ kip·ft/ft}) / 112.3 \text{ kip/ft} \quad = \quad 9.67 \quad \text{ft}$$

$$q_{eq} = \quad (112.3 \text{ kip/ft}) / (19.34 \text{ ft}) \quad = \quad 5.81 \quad \text{ksf}$$

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

$$M_V = [(120 \text{ pcf})(35.5 \text{ ft})(24.9 \text{ ft})(1.00)](12.5 \text{ ft}) + [(250 \text{ psf})(24.9 \text{ ft})(1.00)](12.5 \text{ ft}) \quad = \quad 1398.12 \quad \text{kip·ft/ft}$$

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

$$M_H = [\tfrac{1}{2}(120 \text{ pcf})(35.5 \text{ ft})^2(0.297)(1.00)](11.83 \text{ ft}) + [(250 \text{ psf})(35.5 \text{ ft})(0.297)(1.00)](17.75 \text{ ft}) \quad = \quad 312.46 \quad \text{kip·ft/ft}$$

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

$$P_V = (120 \text{ pcf})(35.5 \text{ ft})(24.9 \text{ ft})(1.00) + (250 \text{ psf})(24.9 \text{ ft})(1.00) \quad = \quad 112.3 \quad \text{kip/ft}$$

Settlement:

		B-017-9-13	
Total Settlement at Center of Reinforced Soil Mass:	S_t =	17.410	in
Total Settlement at Wall Facing:	S_t =	10.244	in

Time Rate of Consolidation and Downdrag Depths and Loads:

Boring	Hold Period	Degree of Consolidation	Settlement Remaining at Completion of Hold Period	Depth of Downdrag
B-017-9-13	30 days	59 %	4.212 in	52.3 ft
	60 days	65 %	3.559 in	51.8 ft
	90 days	70 %	3.043 in	51.0 ft
	120 days	74 %	2.641 in	50.5 ft
	180 days	80 %	2.009 in	48.5 ft

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 200+68 to 201+63)

Calculated By: BRT Date: 10/18/2021

Checked By: JPS Date: 10/20/2021

Boring B-017-9-13

H =	35.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	4,260	psf	Bearing pressure at bottom of wall

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,13) (psf)	σ_p' (4,13) (psf)	C_c (5,13)	C_r (6,13)	e_o (7,13)	C' (8)	Z_f/B	Total Settlement at Center of Reinforced Soil Mass: I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Total Settlement at Facing of Wall: I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)
1	A-6b	C	0.0	1.5	1.5	0.8	115	6	6	750	18	40	173	86	39	3,918	1,792	0.270	0.041	0.585		0.01	1.000	4,260	4,299	0.161	1.928	0.500	2,130	2,169	0.085	1.017
	A-6b	C	1.5	3.5	2.0	2.5	115	6	6	750	18	40	403	288	132	3,918	1,792	0.270	0.041	0.585		0.02	1.000	4,260	4,391	0.191	2.287	0.500	2,130	2,261	0.092	1.109
2	A-3a	G	3.5	5.3	1.8	4.4	120	4	7				619	511	236	511	2,285				48	0.03	1.000	4,259	4,495	0.048	0.576	0.500	2,130	2,366	0.038	0.450
3	A-6b	C	5.3	7.8	2.5	6.6	115	7	7	875	18	40	906	762	354	4,572	2,091	0.270	0.041	0.585		0.05	1.000	4,258	4,612	0.196	2.348	0.500	2,130	2,483	0.081	0.974
4	A-2-6	G	7.8	10.3	2.5	9.1	130	28	41				1,231	1,069	504	1,069	8,889				134	0.07	0.999	4,256	4,759	0.018	0.218	0.500	2,130	2,634	0.013	0.161
5	A-3a	G	10.3	12.8	2.5	11.6	125	19	26				1,544	1,387	667	1,387	5,821				78	0.09	0.998	4,251	4,918	0.028	0.332	0.500	2,129	2,796	0.020	0.238
6	A-1-b	G	12.8	19.8	7.0	16.3	130	35	43				2,454	1,999	981	1,999	11,112				143	0.12	0.994	4,236	5,217	0.036	0.426	0.500	2,128	3,110	0.025	0.294
	A-1-b	G	19.8	26.8	7.0	23.3	130	35	39				3,364	2,909	1,455	2,909	11,112				126	0.17	0.985	4,194	5,649	0.033	0.392	0.499	2,125	3,580	0.022	0.260
7	A-7-6	C	26.8	31.8	5.0	29.3	120	22	22	2,750	23	58	3,964	3,664	1,835	-	7,500	0.203	0.093	0.645		0.22	0.971	4,138	5,973	0.145	1.738	0.498	2,121	3,956	0.094	1.131
	A-7-6	C	31.8	36.8	5.0	34.3	120	19	19	2,375	23	58	4,564	4,264	2,123	-	10,000	0.203	0.093	0.645		0.26	0.957	4,078	6,201	0.132	1.579	0.497	2,116	4,239	0.085	1.018
	A-7-6	C	36.8	41.8	5.0	39.3	120	22	22	2,750	23	58	5,164	4,864	2,411	-	12,400	0.203	0.093	0.645		0.29	0.940	4,006	6,417	0.120	1.442	0.495	2,109	4,521	0.077	0.926
	A-7-6	C	41.8	46.8	5.0	44.3	120	25	25	3,125	23	58	5,764	5,464	2,699	-	14,800	0.203	0.093	0.645		0.33	0.921	3,925	6,624	0.110	1.322	0.493	2,101	4,801	0.071	0.848
8	A-7-6	C	46.8	51.8	5.0	49.3	125	36	36	4,500	21	53	6,389	6,076	3,000	-	17,200	0.203	0.093	0.645		0.37	0.901	3,836	6,836	0.101	1.213	0.491	2,092	5,091	0.065	0.779
	A-7-6	C	51.8	59.2	7.4	55.5	130	98	98	10,744	21	53	7,351	6,870	3,406	-	20,400	0.203	0.093	0.645		0.41	0.873	3,719	7,125	0.134	1.609	0.488	2,077	5,484	0.086	1.038
																									Total Settlement:		17.410 in			Total Settlement:		10.244 in

1. $(N1)_{60} = C_n N_{60}$, where $C_n = [0.77\log(40/\sigma_{vo}')] \le 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for $N_{60} \ge 52$; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \le \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \le \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 200+68 to 201+63)

Calculated By: BRT — Date: 10/18/2021

Checked By: JPS — Date: 10/20/2021

Boring B-017-9-13

H =	35.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	4,260	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-6b (Lower)	A-7-6		
c_v =	300	300	183	ft^2/yr	Coefficient of consolidation
t =	30	30	30	days	Time following completion of construction
H_{dr} =	3.5	2.5	16.2	ft	Length of longest drainage path considered
T_v =	2.013	3.945	0.057		Time factor
U =	99	100	27	%	Degree of consolidation

$(S_c)_t$ = 6.032 in — Settlement complete at 59% of primary consolidation

																										Total Settlement at Facing of Wall			Settlement Complete at 59% of Primary Consolidation		Remaining Settlement at 59% of Primary Consolidation	
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-6b	C	0.0	1.5	1.5	0.8	115	6	6	750	18	40	173	86	39	3,918	1,792	0.270	0.041	0.585		0.01	0.500	2,130	2,169	0.085	1.017	2.125	1.007	2.104	0.010	4.202
	A-6b	C	1.5	3.5	2.0	2.5	115	6	6	750	18	40	403	288	132	3,918	1,792	0.270	0.041	0.585		0.02	0.500	2,130	2,261	0.092	1.109		1.098		0.011	4.191
2	A-3a	G	3.5	5.3	1.8	4.4	120	4	7				619	511	236	511	2,285				48	0.03	0.500	2,130	2,366	0.038	0.450	0.450	0.450	0.450	0.000	4.191
3	A-6b	C	5.3	7.8	2.5	6.6	115	7	7	875	18	40	906	762	354	4,572	2,091	0.270	0.041	0.585		0.05	0.500	2,130	2,483	0.081	0.974	0.974	0.974	0.974	0.000	4.191
4	A-2-6	G	7.8	10.3	2.5	9.1	130	28	41				1,231	1,069	504	1,069	8,889				134	0.07	0.500	2,130	2,634	0.013	0.161	0.161	0.161	0.161	0.000	4.191
5	A-3a	G	10.3	12.8	2.5	11.6	125	19	26				1,544	1,387	667	1,387	5,821				78	0.09	0.500	2,129	2,796	0.020	0.238	0.238	0.238	0.238	0.000	4.191
6	A-1-b	G	12.8	19.8	7.0	16.3	130	35	43				2,454	1,999	981	1,999	11,112				143	0.12	0.500	2,128	3,110	0.025	0.294	0.554	0.294	0.554	0.000	4.191
	A-1-b	G	19.8	26.8	7.0	23.3	130	35	39				3,364	2,909	1,455	2,909	11,112				126	0.17	0.499	2,125	3,580	0.022	0.260		0.260		0.000	4.191
7	A-7-6	C	26.8	31.8	5.0	29.3	120	22	22	2,750	23	58	3,964	3,664	1,835	-	7,500	0.203	0.093	0.645		0.22	0.498	2,121	3,956	0.094	1.131	3.924	0.305	1.059	0.826	3.365
	A-7-6	C	31.8	36.8	5.0	34.3	120	19	19	2,375	23	58	4,564	4,264	2,123	-	10,000	0.203	0.093	0.645		0.26	0.497	2,116	4,239	0.085	1.018		0.275		0.743	2.621
	A-7-6	C	36.8	41.8	5.0	39.3	120	22	22	2,750	23	58	5,164	4,864	2,411	-	12,400	0.203	0.093	0.645		0.29	0.495	2,109	4,521	0.077	0.926		0.250		0.676	1.946
	A-7-6	C	41.8	46.8	5.0	44.3	120	25	25	3,125	23	58	5,764	5,464	2,699	-	14,800	0.203	0.093	0.645		0.33	0.493	2,101	4,801	0.071	0.848		0.229		0.619	1.326
8	A-7-6	C	46.8	51.8	5.0	49.3	125	36	36	4,500	21	53	6,389	6,076	3,000	-	17,200	0.203	0.093	0.645		0.37	0.491	2,092	5,091	0.065	0.779	1.817	0.210	0.491	0.569	0.758
	A-7-6	C	51.8	59.2	7.4	55.5	130	98	98	10,744	21	53	7,351	6,870	3,406	-	20,400	0.203	0.093	0.645		0.41	0.488	2,077	5,484	0.086	1.038		0.280		0.758	0.000

Settlement Remaining After Hold Period: 4.212 in

Depth of Downdrag: 52.3 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 200+68 to 201+63)

Calculated By: BRT Date: 10/18/2021

Checked By: JPS Date: 10/20/2021

Boring B-017-9-13

H =	35.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	4,260	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-6b (Lower)	A-7-6		
c_v =	300	300	183	ft^2/yr	Coefficient of consolidation
t =	60	60	60	days	Time following completion of construction
H_{dr} =	3.5	2.5	16.2	ft	Length of longest drainage path considered
T_v =	4.026	7.890	0.115		Time factor
U =	100	100	38	%	Degree of consolidation

$(S_c)_t$ = 6.685 in Settlement complete at 65% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (11,12) (ft)	Total Settlement at Facing of Wall: S_c (in)	Total Settlement at Facing of Wall: Layer Settlement (in)	Settlement Complete at 65% of Primary Consolidation: $(S_c)_t$ (13) (in)	Settlement Complete at 65% of Primary Consolidation: Layer Settlement (in)	Remaining Settlement at 65% of Primary Consolidation: $S_c - (S_c)_t$ (in)	Remaining Settlement at 65% of Primary Consolidation: Relative Movement (in)
1	A-6b	C	0.0	1.5	1.5	0.8	115	6	6	750	18	40	173	86	39	3,918	1,792	0.270	0.041	0.585		0.01	0.500	2,130	2,169	0.085	1.017	2.125	1.017	2.125	0.000	3.559
	A-6b	C	1.5	3.5	2.0	2.5	115	6	6	750	18	40	403	288	132	3,918	1,792	0.270	0.041	0.585		0.02	0.500	2,130	2,261	0.092	1.109		1.109		0.000	3.559
2	A-3a	G	3.5	5.3	1.8	4.4	120	4	7				619	511	236	511	2,285				48	0.03	0.500	2,130	2,366	0.038	0.450	0.450	0.450	0.450	0.000	3.559
3	A-6b	C	5.3	7.8	2.5	6.6	115	7	7	875	18	40	906	762	354	4,572	2,091	0.270	0.041	0.585		0.05	0.500	2,130	2,483	0.081	0.974	0.974	0.974	0.974	0.000	3.559
4	A-2-6	G	7.8	10.3	2.5	9.1	130	28	41				1,231	1,069	504	1,069	8,889				134	0.07	0.500	2,130	2,634	0.013	0.161	0.161	0.161	0.161	0.000	3.559
5	A-3a	G	10.3	12.8	2.5	11.6	125	19	26				1,544	1,387	667	1,387	5,821				78	0.09	0.500	2,129	2,796	0.020	0.238	0.238	0.238	0.238	0.000	3.559
6	A-1-b	G	12.8	19.8	7.0	16.3	130	35	43				2,454	1,999	981	1,999	11,112				143	0.12	0.500	2,128	3,110	0.025	0.294	0.554	0.294	0.554	0.000	3.559
	A-1-b	G	19.8	26.8	7.0	23.3	130	35	39				3,364	2,909	1,455	2,909	11,112				126	0.17	0.499	2,125	3,580	0.022	0.260		0.260		0.000	3.559
7	A-7-6	C	26.8	31.8	5.0	29.3	120	22	22	2,750	23	58	3,964	3,664	1,835	-	7,500	0.203	0.093	0.645		0.22	0.498	2,121	3,956	0.094	1.131	3.924	0.430	1.491	0.701	2.858
	A-7-6	C	31.8	36.8	5.0	34.3	120	19	19	2,375	23	58	4,564	4,264	2,123	-	10,000	0.203	0.093	0.645		0.26	0.497	2,116	4,239	0.085	1.018		0.387		0.631	2.226
	A-7-6	C	36.8	41.8	5.0	39.3	120	22	22	2,750	23	58	5,164	4,864	2,411	-	12,400	0.203	0.093	0.645		0.29	0.495	2,109	4,521	0.077	0.926		0.352		0.574	1.652
	A-7-6	C	41.8	46.8	5.0	44.3	120	25	25	3,125	23	58	5,764	5,464	2,699	-	14,800	0.203	0.093	0.645		0.33	0.493	2,101	4,801	0.071	0.848		0.322		0.526	1.127
8	A-7-6	C	46.8	51.8	5.0	49.3	125	36	36	4,500	21	53	6,389	6,076	3,000	-	17,200	0.203	0.093	0.645		0.37	0.491	2,092	5,091	0.065	0.779	1.817	0.296	0.690	0.483	0.643
	A-7-6	C	51.8	59.2	7.4	55.5	130	98	98	10,744	21	53	7,351	6,870	3,406	-	20,400	0.203	0.093	0.645		0.41	0.488	2,077	5,484	0.086	1.038		0.394		0.643	0.000

Settlement Remaining After Hold Period: 3.559 in

Depth of Downdrag: 51.8 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}{}^m\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 200+68 to 201+63)

Calculated By: BRT Date: 10/18/2021

Checked By: JPS Date: 10/20/2021

Boring B-017-9-13

H =	35.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	4,260	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-6b (Lower)	A-7-6		
c_v =	300	300	183	ft^2/yr	Coefficient of consolidation
t =	90	90	90	days	Time following completion of construction
H_{dr} =	3.5	2.5	16.2	ft	Length of longest drainage path considered
T_v =	6.039	11.836	0.172		Time factor
U =	100	100	47	%	Degree of consolidation

$(S_c)_t$ = 7.201 in Settlement complete at 70% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)
1	A-6b	C	0.0	1.5	1.5	0.8	115	6	6	750	18	40	173	86	39	3,918	1,792
	A-6b	C	1.5	3.5	2.0	2.5	115	6	6	750	18	40	403	288	132	3,918	1,792
2	A-3a	G	3.5	5.3	1.8	4.4	120	4	7				619	511	236	511	2,285
3	A-6b	C	5.3	7.8	2.5	6.6	115	7	7	875	18	40	906	762	354	4,572	2,091
4	A-2-6	G	7.8	10.3	2.5	9.1	130	28	41				1,231	1,069	504	1,069	8,889
5	A-3a	G	10.3	12.8	2.5	11.6	125	19	26				1,544	1,387	667	1,387	5,821
6	A-1-b	G	12.8	19.8	7.0	16.3	130	35	43				2,454	1,999	981	1,999	11,112
	A-1-b	G	19.8	26.8	7.0	23.3	130	35	39				3,364	2,909	1,455	2,909	11,112
7	A-7-6	C	26.8	31.8	5.0	29.3	120	22	22	2,750	23	58	3,964	3,664	1,835	-	7,500
	A-7-6	C	31.8	36.8	5.0	34.3	120	19	19	2,375	23	58	4,564	4,264	2,123	-	10,000
	A-7-6	C	36.8	41.8	5.0	39.3	120	22	22	2,750	23	58	5,164	4,864	2,411	-	12,400
	A-7-6	C	41.8	46.8	5.0	44.3	120	25	25	3,125	23	58	5,764	5,464	2,699	-	14,800
8	A-7-6	C	46.8	51.8	5.0	49.3	125	36	36	4,500	21	53	6,389	6,076	3,000	-	17,200
	A-7-6	C	51.8	59.2	7.4	55.5	130	98	98	10,744	21	53	7,351	6,870	3,406	-	20,400

										Total Settlement at Facing of Wall			Settlement Complete at 70% of Primary Consolidation		Remaining Settlement at 70% of Primary Consolidation	
Layer	Soil Class.	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-6b	0.270	0.041	0.585		0.01	0.500	2,130	2,169	0.085	1.017	2.125	1.017	2.125	0.000	3.043
	A-6b	0.270	0.041	0.585		0.02	0.500	2,130	2,261	0.092	1.109		1.109		0.000	3.043
2	A-3a				48	0.03	0.500	2,130	2,366	0.038	0.450	0.450	0.450	0.450	0.000	3.043
3	A-6b	0.270	0.041	0.585		0.05	0.500	2,130	2,483	0.081	0.974	0.974	0.974	0.974	0.000	3.043
4	A-2-6				134	0.07	0.500	2,130	2,634	0.013	0.161	0.161	0.161	0.161	0.000	3.043
5	A-3a				78	0.09	0.500	2,129	2,796	0.020	0.238	0.238	0.238	0.238	0.000	3.043
6	A-1-b				143	0.12	0.500	2,128	3,110	0.025	0.294	0.554	0.294	0.554	0.000	3.043
	A-1-b				126	0.17	0.499	2,125	3,580	0.022	0.260		0.260		0.000	3.043
7	A-7-6	0.203	0.093	0.645		0.22	0.498	2,121	3,956	0.094	1.131	3.924	0.532	1.844	0.600	2.443
	A-7-6	0.203	0.093	0.645		0.26	0.497	2,116	4,239	0.085	1.018		0.479		0.540	1.903
	A-7-6	0.203	0.093	0.645		0.29	0.495	2,109	4,521	0.077	0.926		0.435		0.491	1.413
	A-7-6	0.203	0.093	0.645		0.33	0.493	2,101	4,801	0.071	0.848		0.399		0.449	0.963
8	A-7-6	0.203	0.093	0.645		0.37	0.491	2,092	5,091	0.065	0.779	1.817	0.366	0.854	0.413	0.550
	A-7-6	0.203	0.093	0.645		0.41	0.488	2,077	5,484	0.086	1.038		0.488		0.550	0.000

Settlement Remaining After Hold Period: 3.043 in

Depth of Downdrag: 51.0 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{\ m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 200+68 to 201+63)

Calculated By: BRT Date: 10/18/2021

Checked By: JPS Date: 10/20/2021

Boring B-017-9-13

H =	35.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	4,260	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-6b (Lower)	A-7-6		
c_v =	300	300	183	ft^2/yr	Coefficient of consolidation
t =	120	120	120	days	Time following completion of construction
H_{dr} =	3.5	2.5	16.2	ft	Length of longest drainage path considered
T_v =	8.051	15.781	0.229		Time factor
U =	100	100	54	%	Degree of consolidation

$(S_c)_t$ = 7.603 in Settlement complete at 74% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (11,12) (ft)	Total Settlement at Facing of Wall: S_c (in)	Total Settlement at Facing of Wall: Layer Settlement (in)	Settlement Complete at 74% of Primary Consolidation: $(S_c)_t$ (13) (in)	Settlement Complete at 74% of Primary Consolidation: Layer Settlement (in)	Remaining Settlement at 74% of Primary Consolidation: S_c - $(S_c)_t$ (in)	Remaining Settlement at 74% of Primary Consolidation: Relative Movement (in)
1	A-6b	C	0.0	1.5	1.5	0.8	115	6	6	750	18	40	173	86	39	3,918	1,792	0.270	0.041	0.585		0.01	0.500	2,130	2,169	0.085	1.017	2.125	1.017	2.125	0.000	2.641
	A-6b	C	1.5	3.5	2.0	2.5	115	6	6	750	18	40	403	288	132	3,918	1,792	0.270	0.041	0.585		0.02	0.500	2,130	2,261	0.092	1.109		1.109		0.000	2.641
2	A-3a	G	3.5	5.3	1.8	4.4	120	4	7				619	511	236	511	2,285				48	0.03	0.500	2,130	2,366	0.038	0.450	0.450	0.450	0.450	0.000	2.641
3	A-6b	C	5.3	7.8	2.5	6.6	115	7	7	875	18	40	906	762	354	4,572	2,091	0.270	0.041	0.585		0.05	0.500	2,130	2,483	0.081	0.974	0.974	0.974	0.974	0.000	2.641
4	A-2-6	G	7.8	10.3	2.5	9.1	130	28	41				1,231	1,069	504	1,069	8,889				134	0.07	0.500	2,130	2,634	0.013	0.161	0.161	0.161	0.161	0.000	2.641
5	A-3a	G	10.3	12.8	2.5	11.6	125	19	26				1,544	1,387	667	1,387	5,821				78	0.09	0.500	2,129	2,796	0.020	0.238	0.238	0.238	0.238	0.000	2.641
6	A-1-b	G	12.8	19.8	7.0	16.3	130	35	43				2,454	1,999	981	1,999	11,112				143	0.12	0.500	2,128	3,110	0.025	0.294	0.554	0.294	0.554	0.000	2.641
	A-1-b	G	19.8	26.8	7.0	23.3	130	35	39				3,364	2,909	1,455	2,909	11,112				126	0.17	0.499	2,125	3,580	0.022	0.260		0.260		0.000	2.641
7	A-7-6	C	26.8	31.8	5.0	29.3	120	22	22	2,750	23	58	3,964	3,664	1,835	-	7,500	0.203	0.093	0.645		0.22	0.498	2,121	3,956	0.094	1.131	3.924	0.611	2.119	0.520	2.120
	A-7-6	C	31.8	36.8	5.0	34.3	120	19	19	2,375	23	58	4,564	4,264	2,123	-	10,000	0.203	0.093	0.645		0.26	0.497	2,116	4,239	0.085	1.018		0.550		0.468	1.652
	A-7-6	C	36.8	41.8	5.0	39.3	120	22	22	2,750	23	58	5,164	4,864	2,411	-	12,400	0.203	0.093	0.645		0.29	0.495	2,109	4,521	0.077	0.926		0.500		0.426	1.226
	A-7-6	C	41.8	46.8	5.0	44.3	120	25	25	3,125	23	58	5,764	5,464	2,699	-	14,800	0.203	0.093	0.645		0.33	0.493	2,101	4,801	0.071	0.848		0.458		0.390	0.836
8	A-7-6	C	46.8	51.8	5.0	49.3	125	36	36	4,500	21	53	6,389	6,076	3,000	-	17,200	0.203	0.093	0.645		0.37	0.491	2,092	5,091	0.065	0.779	1.817	0.421	0.981	0.358	0.477
	A-7-6	C	51.8	59.2	7.4	55.5	130	98	98	10,744	21	53	7,351	6,870	3,406	-	20,400	0.203	0.093	0.645		0.41	0.488	2,077	5,484	0.086	1.038		0.560		0.477	0.000

Settlement Remaining After Hold Period: 2.641 in

Depth of Downdrag: 50.5 ft

1. $(N1)_{60} = C_nN_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1N_{60}p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{\;m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
6. C_r = 0.15(Cc) for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 200+68 to 201+63)

Calculated By: BRT   Date: 10/18/2021

Checked By: JPS   Date: 10/20/2021

Boring B-017-9-13

H =	35.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	4,260	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-6b (Lower)	A-7-6		
c_v =	300	300	183	ft^2/yr	Coefficient of consolidation
t =	180	180	180	days	Time following completion of construction
H_{dr} =	3.5	2.5	16.2	ft	Length of longest drainage path considered
T_v =	12.077	23.671	0.344		Time factor
U =	100	100	65	%	Degree of consolidation

$(S_c)_t$ = 8.235 in   Settlement complete at 80% of primary consolidation

																										Total Settlement at Facing of Wall			Settlement Complete at 80% of Primary Consolidation		Remaining Settlement at 80% of Primary Consolidation	
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-6b	C	0.0	1.5	1.5	0.8	115	6	6	750	18	40	173	86	39	3,918	1,792	0.270	0.041	0.585		0.01	0.500	2,130	2,169	0.085	1.017	2.125	1.017	2.125	0.000	2.009
	A-6b	C	1.5	3.5	2.0	2.5	115	6	6	750	18	40	403	288	132	3,918	1,792	0.270	0.041	0.585		0.02	0.500	2,130	2,261	0.092	1.109		1.109		0.000	2.009
2	A-3a	G	3.5	5.3	1.8	4.4	120	4	7				619	511	236	511	2,285				48	0.03	0.500	2,130	2,366	0.038	0.450	0.450	0.450	0.450	0.000	2.009
3	A-6b	C	5.3	7.8	2.5	6.6	115	7	7	875	18	40	906	762	354	4,572	2,091	0.270	0.041	0.585		0.05	0.500	2,130	2,483	0.081	0.974	0.974	0.974	0.974	0.000	2.009
4	A-2-6	G	7.8	10.3	2.5	9.1	130	28	41				1,231	1,069	504	1,069	8,889				134	0.07	0.500	2,130	2,634	0.013	0.161	0.161	0.161	0.161	0.000	2.009
5	A-3a	G	10.3	12.8	2.5	11.6	125	19	26				1,544	1,387	667	1,387	5,821				78	0.09	0.500	2,129	2,796	0.020	0.238	0.238	0.238	0.238	0.000	2.009
6	A-1-b	G	12.8	19.8	7.0	16.3	130	35	43				2,454	1,999	981	1,999	11,112				143	0.12	0.500	2,128	3,110	0.025	0.294	0.554	0.294	0.554	0.000	2.009
	A-1-b	G	19.8	26.8	7.0	23.3	130	35	39				3,364	2,909	1,455	2,909	11,112				126	0.17	0.499	2,125	3,580	0.022	0.260		0.260		0.000	2.009
7	A-7-6	C	26.8	31.8	5.0	29.3	120	22	22	2,750	23	58	3,964	3,664	1,835	-	7,500	0.203	0.093	0.645		0.22	0.498	2,121	3,956	0.094	1.131	3.924	0.735	2.550	0.396	1.613
	A-7-6	C	31.8	36.8	5.0	34.3	120	19	19	2,375	23	58	4,564	4,264	2,123	-	10,000	0.203	0.093	0.645		0.26	0.497	2,116	4,239	0.085	1.018		0.662		0.356	1.257
	A-7-6	C	36.8	41.8	5.0	39.3	120	22	22	2,750	23	58	5,164	4,864	2,411	-	12,400	0.203	0.093	0.645		0.29	0.495	2,109	4,521	0.077	0.926		0.602		0.324	0.933
	A-7-6	C	41.8	46.8	5.0	44.3	120	25	25	3,125	23	58	5,764	5,464	2,699	-	14,800	0.203	0.093	0.645		0.33	0.493	2,101	4,801	0.071	0.848		0.551		0.297	0.636
8	A-7-6	C	46.8	51.8	5.0	49.3	125	36	36	4,500	21	53	6,389	6,076	3,000	-	17,200	0.203	0.093	0.645		0.37	0.491	2,092	5,091	0.065	0.779	1.817	0.506	1.181	0.273	0.363
	A-7-6	C	51.8	59.2	7.4	55.5	130	98	98	10,744	21	53	7,351	6,870	3,406	-	20,400	0.203	0.093	0.645		0.41	0.488	2,077	5,484	0.086	1.038		0.675		0.363	0.000

Settlement Remaining After Hold Period: 2.009 in

Depth of Downdrag: 48.5 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
6. C_r = 0.15(Cc) for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 200+68 to 201+63)

Calculated By: BRT Date: 10/18/2021

Checked By: JPS Date: 10/20/2021

Boring B-017-9-13

H =	35.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	4,260	psf	Bearing pressure at bottom of wall

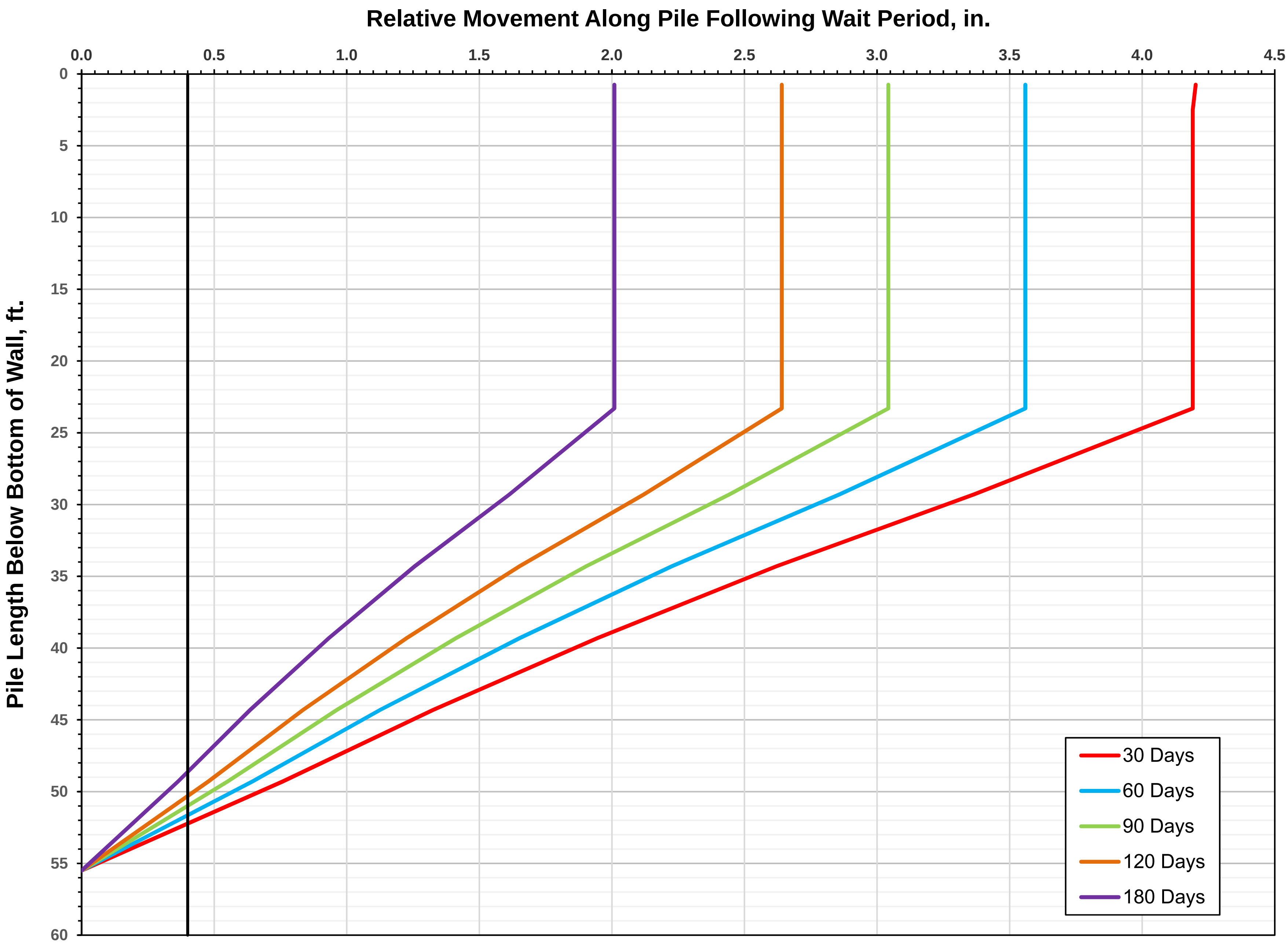
	A-6b (Upper)	A-6b (Lower)	A-7-6		
c_v =	300	300	183	ft^2/yr	Coefficient of consolidation
t =	330	330	330	days	Time following completion of construction
H_{dr} =	3.5	2.5	16.2	ft	Length of longest drainage path considered
T_v =	22.141	43.397	0.630		Time factor
U =	100	100	83	%	Degree of consolidation

$(S_c)_t$ = 9.268 in Settlement complete at 90% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (11,12) (ft)	Total Settlement at Facing of Wall: S_c (in)	Total Settlement at Facing of Wall: Layer Settlement (in)	Settlement Complete at 90% of Primary Consolidation: $(S_c)_t$ (13) (in)	Settlement Complete at 90% of Primary Consolidation: Layer Settlement (in)	Remaining Settlement at 90% of Primary Consolidation: $S_c - (S_c)_t$ (in)	Remaining Settlement at 90% of Primary Consolidation: Relative Movement (in)
1	A-6b	C	0.0	1.5	1.5	0.8	115	6	6	750	18	40	173	86	39	3,918	1,792	0.270	0.041	0.585		0.01	0.500	2,130	2,169	0.085	1.017	2.125	1.017	2.125	0.000	0.976
	A-6b	C	1.5	3.5	2.0	2.5	115	6	6	750	18	40	403	288	132	3,918	1,792	0.270	0.041	0.585		0.02	0.500	2,130	2,261	0.092	1.109		1.109		0.000	0.976
2	A-3a	G	3.5	5.3	1.8	4.4	120	4	7				619	511	236	511	2,285				48	0.03	0.500	2,130	2,366	0.038	0.450	0.450	0.450	0.450	0.000	0.976
3	A-6b	C	5.3	7.8	2.5	6.6	115	7	7	875	18	40	906	762	354	4,572	2,091	0.270	0.041	0.585		0.05	0.500	2,130	2,483	0.081	0.974	0.974	0.974	0.974	0.000	0.976
4	A-2-6	G	7.8	10.3	2.5	9.1	130	28	41				1,231	1,069	504	1,069	8,889				134	0.07	0.500	2,130	2,634	0.013	0.161	0.161	0.161	0.161	0.000	0.976
5	A-3a	G	10.3	12.8	2.5	11.6	125	19	26				1,544	1,387	667	1,387	5,821				78	0.09	0.500	2,129	2,796	0.020	0.238	0.238	0.238	0.238	0.000	0.976
6	A-1-b	G	12.8	19.8	7.0	16.3	130	35	43				2,454	1,999	981	1,999	11,112				143	0.12	0.500	2,128	3,110	0.025	0.294	0.554	0.294	0.554	0.000	0.976
	A-1-b	G	19.8	26.8	7.0	23.3	130	35	39				3,364	2,909	1,455	2,909	11,112				126	0.17	0.499	2,125	3,580	0.022	0.260		0.260		0.000	0.976
7	A-7-6	C	26.8	31.8	5.0	29.3	120	22	22	2,750	23	58	3,964	3,664	1,835	-	7,500	0.203	0.093	0.645		0.22	0.498	2,121	3,956	0.094	1.131	3.924	0.939	3.257	0.192	0.784
	A-7-6	C	31.8	36.8	5.0	34.3	120	19	19	2,375	23	58	4,564	4,264	2,123	-	10,000	0.203	0.093	0.645		0.26	0.497	2,116	4,239	0.085	1.018		0.845		0.173	0.610
	A-7-6	C	36.8	41.8	5.0	39.3	120	22	22	2,750	23	58	5,164	4,864	2,411	-	12,400	0.203	0.093	0.645		0.29	0.495	2,109	4,521	0.077	0.926		0.768		0.157	0.453
	A-7-6	C	41.8	46.8	5.0	44.3	120	25	25	3,125	23	58	5,764	5,464	2,699	-	14,800	0.203	0.093	0.645		0.33	0.493	2,101	4,801	0.071	0.848		0.704		0.144	0.309
8	A-7-6	C	46.8	51.8	5.0	49.3	125	36	36	4,500	21	53	6,389	6,076	3,000	-	17,200	0.203	0.093	0.645		0.37	0.491	2,092	5,091	0.065	0.779	1.817	0.647	1.508	0.132	0.176
	A-7-6	C	51.8	59.2	7.4	55.5	130	98	98	10,744	21	53	7,351	6,870	3,406	-	20,400	0.203	0.093	0.645		0.41	0.488	2,077	5,484	0.086	1.038		0.861		0.176	0.000

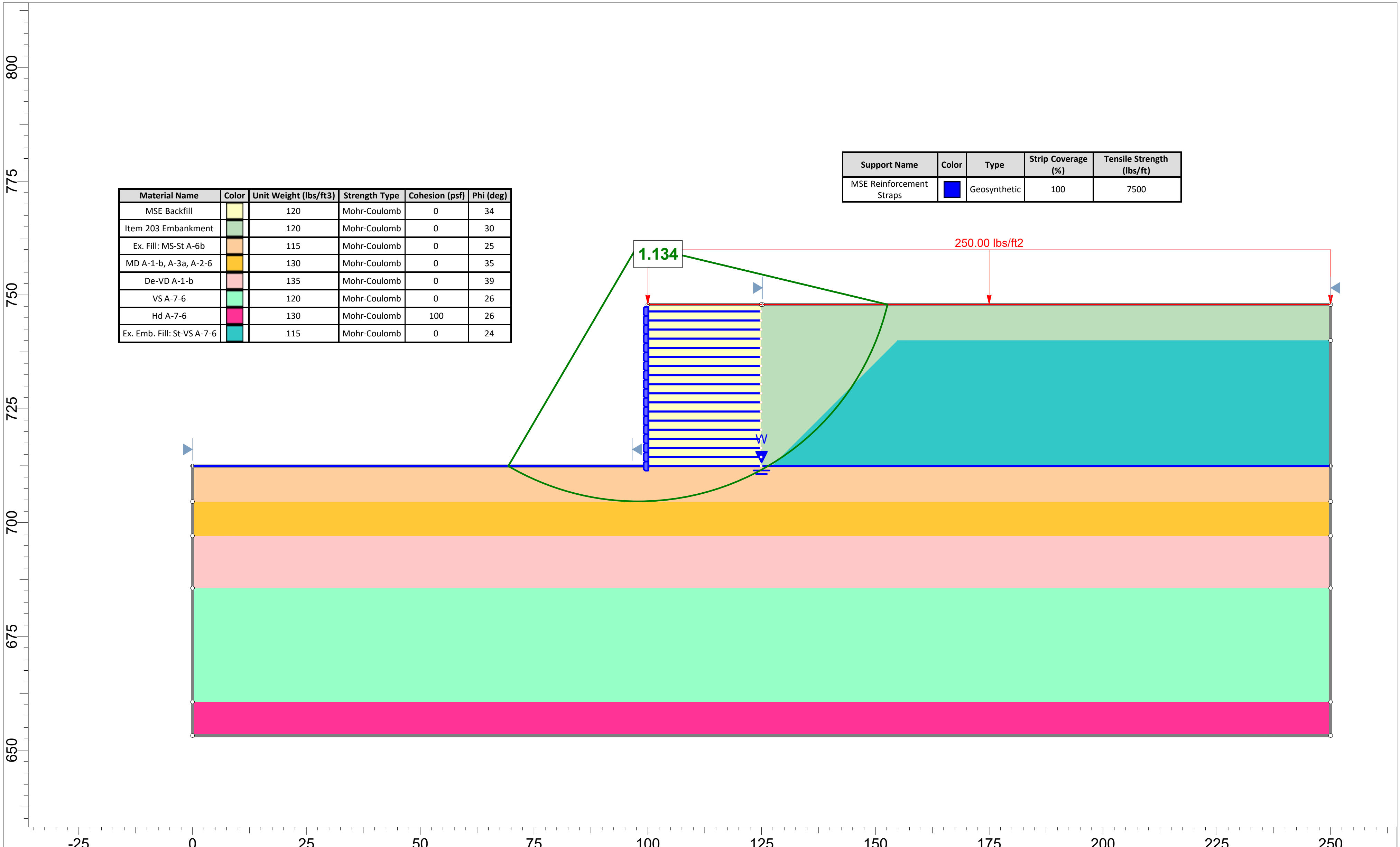
Settlement Remaining After Hold Period: 0.976 in

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\ N_{60}^m\ p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
6. C_r = 0.15(Cc) for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.


Relative Movement Along Pile Following Wait Period, in.
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Pile Length Below Bottom of Wall, ft.
0
5
10
15
20
25
30
35
40
45
50
55
60
30 Days
60 Days
90 Days
120 Days
180 Days

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Ex. Fill: MS-St A-6b		115	Mohr-Coulomb	0	25
MD A-1-b, A-3a, A-2-6		130	Mohr-Coulomb	0	35
De-VD A-1-b		135	Mohr-Coulomb	0	39
VS A-7-6		120	Mohr-Coulomb	0	26
Hd A-7-6		130	Mohr-Coulomb	100	26
Ex. Emb. Fill: St-VS A-7-6		115	Mohr-Coulomb	0	24

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		Geosynthetic	100	7500



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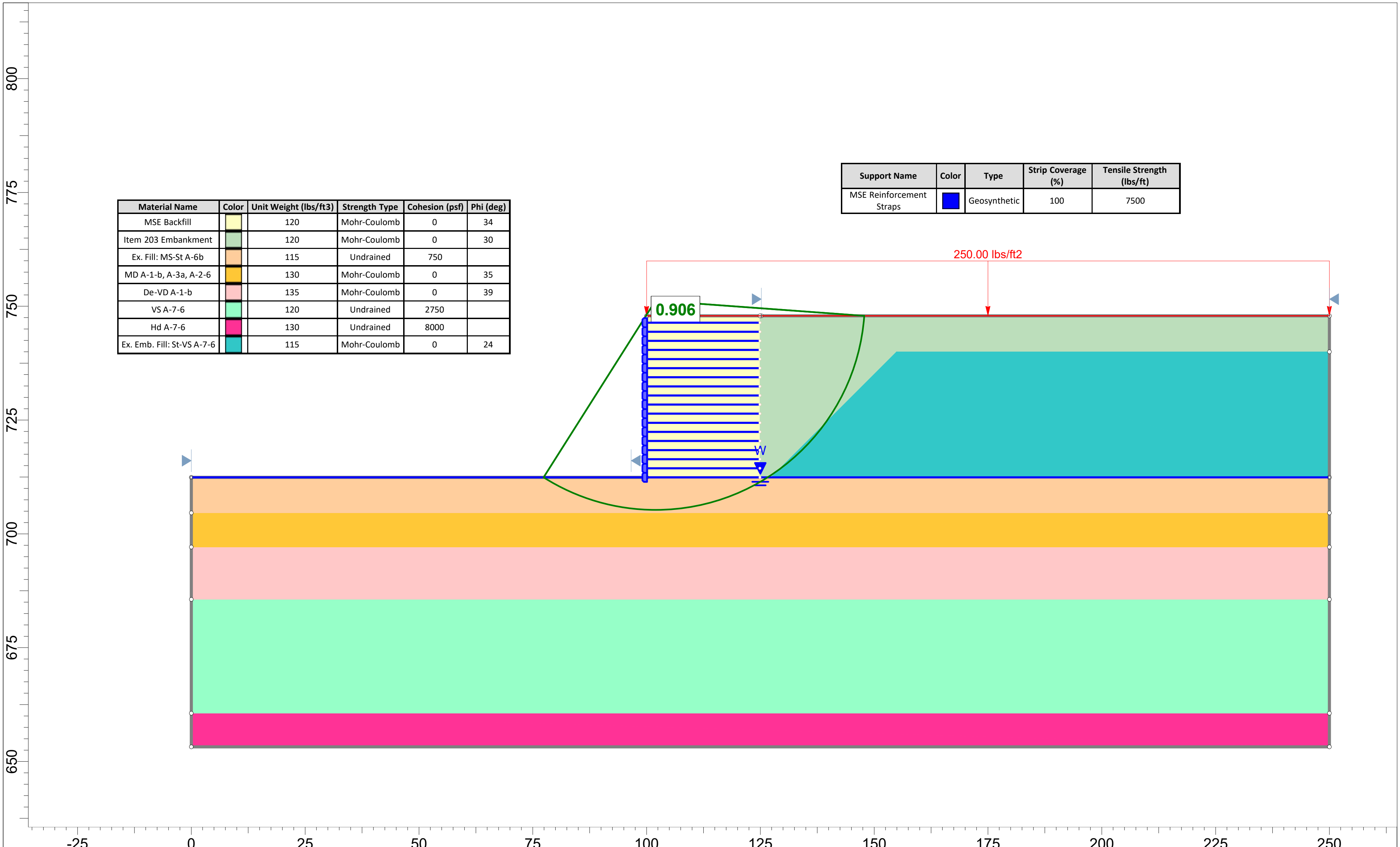
SLIDEINTERPRET 9.012

Project	FRA-70-13.10 - FRA-70-1358L - Rear Abutment - Retaining Wall E2 - Global Stability
Analysis Description	Sta. 200+68 to 201+63 - 35.5 ft Wall Height - Drained - Circular - Spencer's
Drawn By	BRT
Scale	1:350
Company	Resource International, Inc.
Date	5/22/2021
File Name	FRA-70-1358L - Global Stability - RA - Sta. 200+68 to 201+63.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Ex. Fill: MS-St A-6b		115	Undrained	750	
MD A-1-b, A-3a, A-2-6		130	Mohr-Coulomb	0	35
De-VD A-1-b		135	Mohr-Coulomb	0	39
VS A-7-6		120	Undrained	2750	
Hd A-7-6		130	Undrained	8000	
Ex. Emb. Fill: St-VS A-7-6		115	Mohr-Coulomb	0	24

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		Geosynthetic	100	7500

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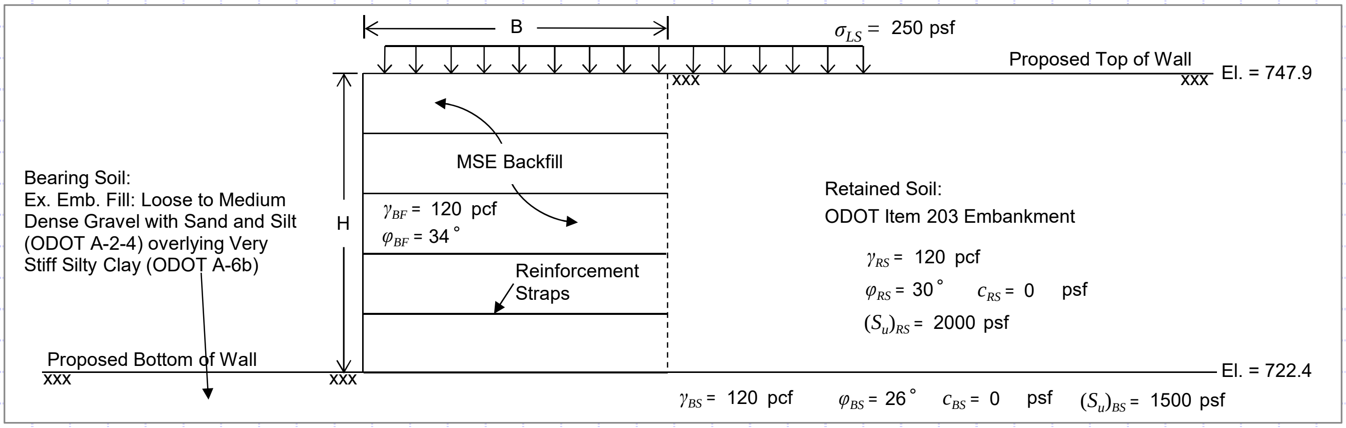
SLIDEINTERPRET 9.012

Project	FRA-70-13.10 - FRA-70-1358L - Rear Abutment - Retaining Wall E2 - Global Stability		
Analysis Description	Sta. 200+68 to 201+63 - 35.5 ft Wall Height - Undrained - Circular - Spencer's		
Drawn By BRT	*Scale* 1:350	*Company* Resource International, Inc.	
Date 5/22/2021	*File Name* FRA-70-1358L - Global Stability - RA - Sta. 200+68 to 201+63.slim		

FRA-70-1358L - Retaining Wall E2 (Sta. 201+63 to 202+03) - MSE Wall - Rear Abutment - B-017-9-13 and B-019-6-19 - 25.5 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.3	ft
MSE Wall Length, (L) =	40	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(S_u)_{BS}$] =	1500	psf
Embedment Depth, (D_f) =	0.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_w) =	10.0	ft

LRFD Load Factors

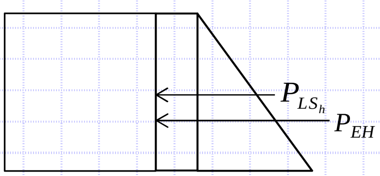
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3

Sliding Force:

$$P_H = P_{EH} + P_{LS_h}$$



$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \text{½(120 pcf)(25.5 ft)²(0.297)(1.5)} = 17.38 \text{ kip/ft}$$

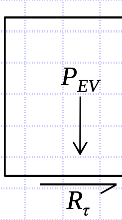
$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = \text{(250 psf)(25.5 ft)(0.297)(1.75)} = 3.31 \text{ kip/ft}$$

$$P_H = \text{17.38 kip/ft + 3.31 kip/ft} = 20.69 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:

$$R_\tau = P_{EV} \cdot \tan\delta$$



$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(25.5 ft)(29.3 ft)(1.00)} = 89.66 \text{ kip/ft}$$

$$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$$

$$\tan\delta = \tan(26) \le \tan(34) \longrightarrow 0.49 \le 0.67 \longrightarrow \tan\delta = 0.49$$

$$R_\tau = \text{(89.66 kip/ft)(0.49)} = 43.93 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$$P_H \le R_\tau \cdot \phi_\tau \longrightarrow \text{20.69 kip/ft} \le \text{(43.93 kip/ft)(1.0) = 43.93 kip/ft} \longrightarrow \text{20.69 kip/ft} \le \text{43.93 kip/ft}$$

OK

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.3	ft
MSE Wall Length, (L) =	40	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	1500	psf
Embedment Depth, (D_f) =	0.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0	ft

LRFD Load Factors

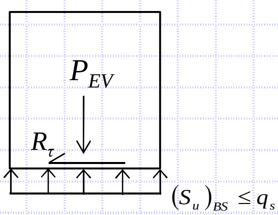
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 *(Continued)*

Check Sliding Resistance - Undrained Condition

Nominal Sliding Resisting: $R_\tau = ((S_u)_{BS} \leq q_s) \cdot B$



$(S_u)_{BS} =$ 1.50 ksf

$q_s = \sigma_v / 2$ = (3.06 ksf) / 2 = 1.53 ksf

$\sigma_v = P_{EV} / B$ = (89.66 kip/ft) / (29.3 ft) = 3.06 ksf

R_τ = (1.50 ksf ≤ 1.53 ksf)(29.3 ft) = 43.95 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \leq R_\tau \cdot \phi_\tau$ ⟶ 20.69 kip/ft ≤ (43.95 kip/ft)(1.0) = 43.95 kip/ft ⟶ 20.69 kip/ft ≤ 43.95 kip/ft **OK**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.3	ft
MSE Wall Length, (L) =	40	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

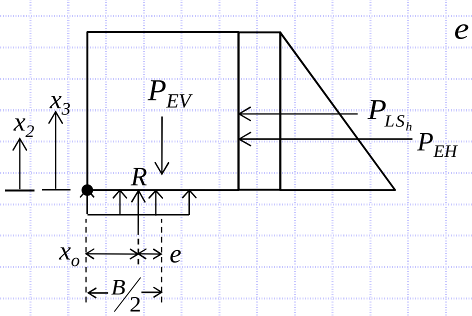
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1500	psf
Embedment Depth, (D_f) =	0.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.5



$$e = B/2 - x_o$$

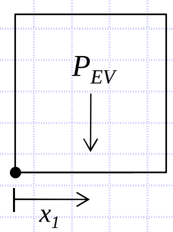
$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (1313.52 kip·ft/ft - 189.93 kip·ft/ft) / (89.66 kip/ft) = 12.53 ft

M_{EV}	=	1313.52	kip·ft/ft
M_H	=	189.93	kip·ft/ft
P_{EV}	=	89.66	kip/ft

Defined below

$e =$ (29.3 ft)/2 - 12.53 ft = 2.12 ft

Resisting Moment, M_{EV}:



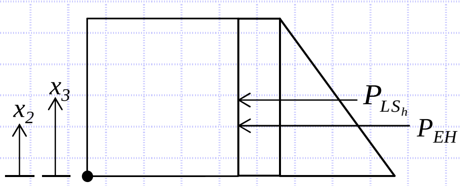
$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(25.5 ft)(29.3 ft)(1.00) = 89.66 kip/ft

$x_1 = B/2$ = (29.3 ft) / 2 = 14.65 ft

$M_{EV} =$ (89.66 kip/ft)(14.65 ft) = 1313.52 kip·ft/ft

Overturning Moment, M_H:



$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$$

$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(25.5 ft)²(0.297)(1.5) = 17.38 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(25.5 ft)(0.297)(1.75) = 3.31 kip/ft

$x_2 = H/3$ = (25.5 ft) / 3 = 8.50 ft

$x_3 = H/2$ = (25.5 ft) / 2 = 12.75 ft

$M_H =$ (17.38 kip/ft)(8.5 ft) + (3.31 kip/ft)(12.75 ft) = 189.93 kip·ft/ft

Check Eccentricity

$e < e_{max} \longrightarrow$ 2.12 ft < 9.77 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (29.3 ft) / 3 = 9.77 ft

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	4	OF	6
CALCULATED BY	BRT	DATE	11/22/2021
CHECKED BY	JPS	DATE	11/23/2021

FRA-70-1358L - Rear Abutment - Wall E2

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.3	ft
MSE Wall Length, (L) =	40	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

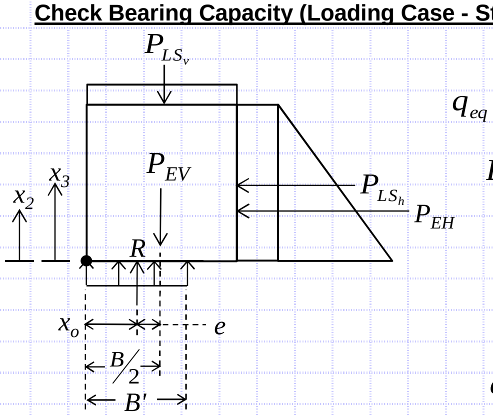
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1500	psf
Embedment Depth, (D_f) =	0.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 29.3 ft - 2(1.42 ft) = 26.46 ft

$e = B/2 - x_o$ = (29.3 ft) / 2 - 13.23 ft = 1.42 ft

$x_o = \frac{M_V - M_H}{P_V}$ = (1961.01 kip·ft/ft - 189.99 kip·ft/ft) / 133.86 kip/ft = 13.23 ft

q_{eq} = (133.86 kip/ft) / (26.46 ft) = 5.06 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

M_V = [(120 pcf)(25.5 ft)(29.3 ft)(1.35)](14.65 ft) + [(250 psf)(29.3 ft)(1.75)](14.65 ft) = 1961.01 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

M_H = [½(120 pcf)(25.5 ft)²(0.297)(1.5)](8.5 ft) + [(250 psf)(25.5 ft)(0.297)(1.75)](12.75 ft) = 189.99 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

P_V = (120 pcf)(25.5 ft)(29.3 ft)(1.35) + (250 psf)(29.3 ft)(1.75) = 133.86 kip/ft

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 30.08

N_c = 22.25
s_c = 1+(26.46 ft/40 ft)(11.85/22.25)
= 1.352
i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 15.68

N_q = 11.85
s_q = 1.323
d_q = 1+2tan(26°)[1-sin(26°)]²tan⁻¹(0.0 ft/26.46 ft)
1.000
i_q = 1.000 (Assumed)
C_{wq} = 10.0 ft > 0.0 ft = 1.000

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 9.22

N_γ = 12.54
s_γ = 0.735
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 10.0 ft < 1.5(26.46 ft) + 0.0 ft = 0.626

q_n = (0 psf)(30.082) + (120 pcf)(0.0 ft)(15.678)(1.000) + ½(120 pcf)(26.5 ft)(9.217)(0.626) = 9.16 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

$q_{eq} \leq q_n \cdot \phi_b$ ⟶ 5.06 ksf ≤ (9.16 ksf)(0.65) = 5.95 ksf ⟶ 5.06 ksf ≤ 5.95 ksf **OK**

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.3	ft
MSE Wall Length, (L) =	40	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1500	psf
Embedment Depth, (D_f) =	0.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 *(Continued)*

Check Bearing Resistance - Undrained Condition

Nominal Bearing Resistance: $$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$

$N_{cm} = N_c s_c i_c$ = 5.820

- N_c = 5.140
- s_c = 1+(26.46 ft/[(5)(40 ft)]) = 1.132
- i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 1.000

- N_q = 1.000
- s_q = 1.000
- d_q = 1+2tan(0°)[1-sin(0°)]²tan⁻¹(0.0 ft/26.46 ft)
  1.000
- i_q = 1.000 (Assumed)
- C_{wq} = 10.0 ft > 0.0 ft = 1.000

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

- N_γ = 0.000
- s_γ = 1.000
- i_γ = 1.000 (Assumed)
- $C_{w\gamma}$ = 10.0 ft < 1.5(26.46 ft) + 0.0 ft = 0.626

q_n = (1500 psf)(5.820) + (120 pcf)(0.0 ft)(1.000)(1.000) + ½(120 pcf)(26.5 ft)(0.000)(0.626) = 8.73 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 5.06 ksf ≤ (8.73 ksf)(0.65) = 5.67 ksf ⟶ 5.06 ksf ≤ 5.67 ksf **OK**

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	25.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.3	ft
MSE Wall Length, (L) =	40	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

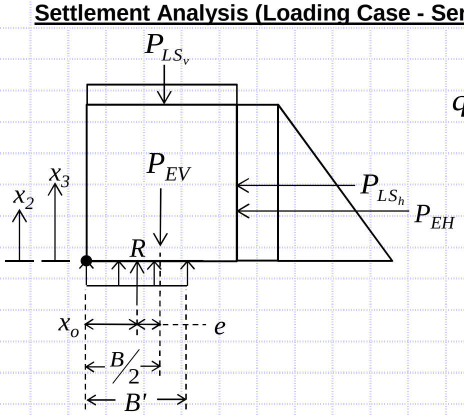
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	1500	psf
Embedment Depth, (D_f) =	0.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 29.3 ft - 2(1.26 ft) = 26.78 ft

$e = B/2 - x_o$ = (29.3 ft) / 2 - 13.39 ft = 1.26 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (1420.80 kip·ft/ft - 122.63 kip·ft/ft) / 96.98 kip/ft = 13.39 ft

q_{eq} = (96.98 kip/ft) / (26.78 ft) = 3.62 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

M_V = [(120 pcf)(25.5 ft)(29.3 ft)(1.00)](14.7 ft) + [(250 psf)(29.3 ft)(1.00)](14.7 ft) = 1420.80 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

M_H = [½(120 pcf)(25.5 ft)²(0.297)(1.00)](8.5 ft) + [(250 psf)(25.5 ft)(0.297)(1.00)](12.75 ft) = 122.63 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

P_V = (120 pcf)(25.5 ft)(29.3 ft)(1.00) + (250 psf)(29.3 ft)(1.00) = 96.98 kip/ft

Settlement:

		B-019-6-19	
Total Settlement at Center of Reinforced Soil Mass:	S_t =	9.456	in
Total Settlement at Wall Facing:	S_t =	5.309	in

Time Rate of Consolidation and Downdrag Depths and Loads:

Boring	Hold Period	Degree of Consolidation	Settlement Remaining at Completion of Hold Period	Depth of Downdrag
B-019-6-19	30 days	57 %	2.306 in	61.2 ft
	60 days	64 %	1.928 in	60.1 ft
	90 days	69 %	1.639 in	58.9 ft
	120 days	73 %	1.421 in	57.7 ft
	180 days	80 %	1.081 in	54.5 ft

W-13-072 - FRA-70-13.10 - FRA-70-1358L
MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 201+63 to 202+03)

Calculated By: BRT Date: 10/18/2021
Checked By: JPS Date: 10/20/2021

Boring B-019-6-19

H =	25.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	10.0	ft	Depth below bottom of footing
q =	3,060	psf	Bearing pressure at bottom of wall

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,13) (psf)	σ_p' (4,13) (psf)	C_c (5,13)	C_r (6,13)	e_o (7,13)	C' (8)	Z_f/B	Total Settlement at Center of Reinforced Soil Mass: I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Total Settlement at Facing of Wall: I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)
1	A-2-4	G	0.0	2.3	2.3	1.2	125	7	13				288	144	144	144	2,222				61	0.01	1.000	3,060	3,204	0.050	0.605	0.500	1,530	1,674	0.040	0.479
2	A-6b	C	2.3	4.3	2.0	3.3	115	10	10	1,250	18	39	518	403	403	6,660	3,046	0.261	0.039	0.577		0.02	1.000	3,060	3,462	0.062	0.745	0.500	1,530	1,932	0.034	0.406
	A-6b	C	4.3	6.3	2.0	5.3	115	10	10	1,250	18	39	748	633	633	6,660	3,046	0.261	0.039	0.577		0.04	1.000	3,059	3,692	0.062	0.738	0.500	1,530	2,162	0.027	0.318
3	A-2-4	G	6.3	11.3	5.0	8.8	135	57	69				1,423	1,085	1,085	1,085	18,096				261	0.07	0.999	3,057	4,142	0.011	0.134	0.500	1,530	2,615	0.007	0.088
4	A-4a	C	11.3	16.3	5.0	13.8	120	23	23	2,875	18	25	2,023	1,723	1,485	21,155	10,155	0.135	0.020	0.467		0.10	0.996	3,049	4,535	0.033	0.401	0.500	1,529	3,015	0.021	0.255
5	A-6b	C	16.3	21.3	5.0	18.8	115	13	13	1,625	18	39	2,598	2,310	1,761	8,657	3,960	0.261	0.026	0.577		0.14	0.991	3,034	4,795	0.098	1.175	0.499	1,528	3,289	0.022	0.269
6	A-4a	C	21.3	24.3	3.0	22.8	125	39	39	4,875	18	25	2,973	2,785	1,986	35,872	17,965	0.135	0.014	0.467		0.17	0.985	3,015	5,002	0.011	0.133	0.499	1,527	3,513	0.007	0.082
7	A-1-b	G	24.3	31.3	7.0	27.8	130	35	33				3,883	3,428	2,317	3,428	11,112				109	0.21	0.975	2,984	5,301	0.023	0.278	0.498	1,525	3,841	0.014	0.170
	A-1-b	G	31.3	38.3	7.0	34.8	130	35	31				4,793	4,338	2,790	4,338	11,112				102	0.26	0.956	2,924	5,714	0.021	0.256	0.497	1,520	4,310	0.013	0.155
8	A-7-6	C	38.3	43.3	5.0	40.8	120	22	22	2,750	23	58	5,393	5,093	3,171	-	13,100	0.203	0.093	0.645		0.30	0.935	2,861	6,031	0.079	0.947	0.495	1,514	4,684	0.048	0.575
	A-7-6	C	43.3	48.3	5.0	45.8	120	19	19	2,375	23	58	5,993	5,693	3,459	-	15,500	0.203	0.093	0.645		0.34	0.915	2,801	6,259	0.073	0.874	0.493	1,507	4,966	0.044	0.533
	A-7-6	C	48.3	53.3	5.0	50.8	120	22	22	2,750	23	58	6,593	6,293	3,747	-	17,900	0.203	0.093	0.645		0.38	0.894	2,736	6,482	0.067	0.807	0.490	1,500	5,247	0.041	0.496
	A-7-6	C	53.3	58.3	5.0	55.8	120	25	25	3,125	23	58	7,193	6,893	4,035	-	20,400	0.203	0.093	0.645		0.42	0.872	2,667	6,701	0.062	0.747	0.487	1,492	5,526	0.039	0.463
9	A-7-6	C	58.3	63.3	5.0	60.8	125	36	36	4,500	21	53	7,818	7,505	4,335	-	22,800	0.203	0.093	0.645		0.45	0.848	2,596	6,931	0.058	0.691	0.484	1,482	5,817	0.036	0.433
	A-7-6	C	63.3	70.7	7.4	67.0	130	98	98	10,744	21	53	8,780	8,299	4,742	-	25,900	0.203	0.093	0.645		0.50	0.819	2,506	7,248	0.077	0.925	0.480	1,468	6,210	0.049	0.588
																									Total Settlement:		9.456 in			Total Settlement:		5.309 in

1. $(N1)_{60} = C_n N_{60}$, where $C_n = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for $N_{60} \geq 52$; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{\ m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 201+63 to 202+03)

Calculated By:	BRT	Date:	10/18/2021
Checked By:	JPS	Date:	10/20/2021

Boring B-019-6-19

H =	25.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	10.0	ft	Depth below bottom of footing
q =	3,060	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-4a	A-6b (Lower)	A-7-6		
c_v =	300	800	300	183	ft^2/yr	Coefficient of consolitation
t =	30	30	30	30	days	Time following completion of construction
H_{dr} =	2.0	5.0	6.5	16.2	ft	Length of longest drainage path considered
T_v =	6.164	2.630	0.584	0.057		Time factor
U =	100	100	81	27	%	Degree of consolidation

$(S_c)_t$ = 3.004 in — Settlement complete at 57% of primary consolidation

																										Total Settlement at Facing of Wall			Settlement Complete at 57% of Primary Consolidation		Remaining Settlement at 57% of Primary Consolidation	
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-2-4	G	0.0	2.3	2.3	1.2	125	7	13				288	144	144	144	2,222				61	0.01	0.500	1,530	1,674	0.040	0.479	0.479	0.479	0.479	0.000	2.306
2	A-6b	C	2.3	4.3	2.0	3.3	115	10	10	1,250	18	39	518	403	403	6,660	3,046	0.261	0.039	0.577		0.02	0.500	1,530	1,932	0.034	0.406	0.724	0.406	0.724	0.000	2.306
	A-6b	C	4.3	6.3	2.0	5.3	115	10	10	1,250	18	39	748	633	633	6,660	3,046	0.261	0.039	0.577		0.04	0.500	1,530	2,162	0.027	0.318		0.318		0.000	2.306
3	A-2-4	G	6.3	11.3	5.0	8.8	135	57	69				1,423	1,085	1,085	1,085	18,096				261	0.07	0.500	1,530	2,615	0.007	0.088	0.088	0.088	0.088	0.000	2.306
4	A-4a	C	11.3	16.3	5.0	13.8	120	23	23	2,875	18	25	2,023	1,723	1,485	21,155	10,155	0.135	0.020	0.467		0.10	0.500	1,529	3,015	0.021	0.255	0.255	0.255	0.255	0.000	2.306
5	A-6b	C	16.3	21.3	5.0	18.8	115	13	13	1,625	18	39	2,598	2,310	1,761	8,657	3,960	0.261	0.026	0.577		0.14	0.499	1,528	3,289	0.022	0.269	0.269	0.218	0.218	0.051	2.254
6	A-4a	C	21.3	24.3	3.0	22.8	125	39	39	4,875	18	25	2,973	2,785	1,986	35,872	17,965	0.135	0.014	0.467		0.17	0.499	1,527	3,513	0.007	0.082	0.082	0.082	0.082	0.000	2.254
7	A-1-b	G	24.3	31.3	7.0	27.8	130	35	33				3,883	3,428	2,317	3,428	11,112				109	0.21	0.498	1,525	3,841	0.014	0.170	0.325	0.170	0.325	0.000	2.254
	A-1-b	G	31.3	38.3	7.0	34.8	130	35	31				4,793	4,338	2,790	4,338	11,112				102	0.26	0.497	1,520	4,310	0.013	0.155		0.155		0.000	2.254
8	A-7-6	C	38.3	43.3	5.0	40.8	120	22	22	2,750	23	58	5,393	5,093	3,171	-	13,100	0.203	0.093	0.645		0.30	0.495	1,514	4,684	0.048	0.575	2.067	0.155	0.558	0.420	1.835
	A-7-6	C	43.3	48.3	5.0	45.8	120	19	19	2,375	23	58	5,993	5,693	3,459	-	15,500	0.203	0.093	0.645		0.34	0.493	1,507	4,966	0.044	0.533		0.144		0.389	1.446
	A-7-6	C	48.3	53.3	5.0	50.8	120	22	22	2,750	23	58	6,593	6,293	3,747	-	17,900	0.203	0.093	0.645		0.38	0.490	1,500	5,247	0.041	0.496		0.134		0.362	1.084
	A-7-6	C	53.3	58.3	5.0	55.8	120	25	25	3,125	23	58	7,193	6,893	4,035	-	20,400	0.203	0.093	0.645		0.42	0.487	1,492	5,526	0.039	0.463		0.125		0.338	0.745
9	A-7-6	C	58.3	63.3	5.0	60.8	125	36	36	4,500	21	53	7,818	7,505	4,335	-	22,800	0.203	0.093	0.645		0.45	0.484	1,482	5,817	0.036	0.433	1.021	0.117	0.276	0.316	0.429
	A-7-6	C	63.3	70.7	7.4	67.0	130	98	98	10,744	21	53	8,780	8,299	4,742	-	25,900	0.203	0.093	0.645		0.50	0.480	1,468	6,210	0.049	0.588		0.159		0.429	0.000

Settlement Remaining After Hold Period: 2.306 in

Depth of Downdrag: 61.2 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for N_{60}<52; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{\ m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
6. C_r = 0.15(Cc) for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 201+63 to 202+03)

Calculated By: BRT Date: 10/18/2021

Checked By: JPS Date: 10/20/2021

Boring B-019-6-19

H =	25.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	10.0	ft	Depth below bottom of footing
q =	3,060	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-4a	A-6b (Lower)	A-7-6		
c_v =	300	800	300	183	ft^2/yr	Coefficient of consolitation
t =	60	60	60	60	days	Time following completion of construction
H_{dr} =	2.0	5.0	6.5	16.2	ft	Length of longest drainage path considered
T_v =	12.329	5.260	1.167	0.115		Time factor
U =	100	100	95	38	%	Degree of consolidation

$(S_c)_t$ = 3.381 in Settlement complete at 64% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	Settlement Complete at 64% of Primary Consolidation: $(S_c)_t$ (13) (in)	Layer Settlement (in)	Remaining Settlement at 64% of Primary Consolidation: $S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-2-4	G	0.0	2.3	2.3	1.2	125	7	13				288	144	144	144	2,222				61	0.01	0.500	1,530	1,674	0.040	0.479	0.479	0.479	0.479	0.000	1.928
2	A-6b	C	2.3	4.3	2.0	3.3	115	10	10	1,250	18	39	518	403	403	6,660	3,046	0.261	0.039	0.577		0.02	0.500	1,530	1,932	0.034	0.406	0.724	0.406	0.724	0.000	1.928
	A-6b	C	4.3	6.3	2.0	5.3	115	10	10	1,250	18	39	748	633	633	6,660	3,046	0.261	0.039	0.577		0.04	0.500	1,530	2,162	0.027	0.318		0.318		0.000	1.928
3	A-2-4	G	6.3	11.3	5.0	8.8	135	57	69				1,423	1,085	1,085	1,085	18,096				261	0.07	0.500	1,530	2,615	0.007	0.088	0.088	0.088	0.088	0.000	1.928
4	A-4a	C	11.3	16.3	5.0	13.8	120	23	23	2,875	18	25	2,023	1,723	1,485	21,155	10,155	0.135	0.020	0.467		0.10	0.500	1,529	3,015	0.021	0.255	0.255	0.255	0.255	0.000	1.928
5	A-6b	C	16.3	21.3	5.0	18.8	115	13	13	1,625	18	39	2,598	2,310	1,761	8,657	3,960	0.261	0.026	0.577		0.14	0.499	1,528	3,289	0.022	0.269	0.269	0.256	0.256	0.013	1.915
6	A-4a	C	21.3	24.3	3.0	22.8	125	39	39	4,875	18	25	2,973	2,785	1,986	35,872	17,965	0.135	0.014	0.467		0.17	0.499	1,527	3,513	0.007	0.082	0.082	0.082	0.082	0.000	1.915
7	A-1-b	G	24.3	31.3	7.0	27.8	130	35	33				3,883	3,428	2,317	3,428	11,112				109	0.21	0.498	1,525	3,841	0.014	0.170	0.325	0.170	0.325	0.000	1.915
	A-1-b	G	31.3	38.3	7.0	34.8	130	35	31				4,793	4,338	2,790	4,338	11,112				102	0.26	0.497	1,520	4,310	0.013	0.155		0.155		0.000	1.915
8	A-7-6	C	38.3	43.3	5.0	40.8	120	22	22	2,750	23	58	5,393	5,093	3,171	-	13,100	0.203	0.093	0.645		0.30	0.495	1,514	4,684	0.048	0.575	2.067	0.218	0.785	0.356	1.558
	A-7-6	C	43.3	48.3	5.0	45.8	120	19	19	2,375	23	58	5,993	5,693	3,459	-	15,500	0.203	0.093	0.645		0.34	0.493	1,507	4,966	0.044	0.533		0.202		0.330	1.228
	A-7-6	C	48.3	53.3	5.0	50.8	120	22	22	2,750	23	58	6,593	6,293	3,747	-	17,900	0.203	0.093	0.645		0.38	0.490	1,500	5,247	0.041	0.496		0.188		0.308	0.920
	A-7-6	C	53.3	58.3	5.0	55.8	120	25	25	3,125	23	58	7,193	6,893	4,035	-	20,400	0.203	0.093	0.645		0.42	0.487	1,492	5,526	0.039	0.463		0.176		0.287	0.633
9	A-7-6	C	58.3	63.3	5.0	60.8	125	36	36	4,500	21	53	7,818	7,505	4,335	-	22,800	0.203	0.093	0.645		0.45	0.484	1,482	5,817	0.036	0.433	1.021	0.165	0.388	0.269	0.365
	A-7-6	C	63.3	70.7	7.4	67.0	130	98	98	10,744	21	53	8,780	8,299	4,742	-	25,900	0.203	0.093	0.645		0.50	0.480	1,468	6,210	0.049	0.588		0.223		0.365	0.000

Settlement Remaining After Hold Period: 1.928 in

Depth of Downdrag: 60.1 ft

1. $(N1)_{60} = C_N N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
6. C_r = 0.15(Cc) for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 201+63 to 202+03)

Calculated By: BRT   Date: 10/18/2021

Checked By: JPS   Date: 10/20/2021

Boring B-019-6-19

H =	25.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	10.0	ft	Depth below bottom of footing
q =	3,060	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-4a	A-6b (Lower)	A-7-6		
c_v =	300	800	300	183	ft^2/yr	Coefficient of consolitation
t =	90	90	90	90	days	Time following completion of construction
H_{dr} =	2.0	5.0	6.5	16.2	ft	Length of longest drainage path considered
T_v =	18.493	7.890	1.751	0.172		Time factor
U =	100	100	99	47	%	Degree of consolidation

$(S_c)_t$ = 3.670 in   Settlement complete at 69% of primary consolidation

																										Total Settlement at Facing of Wall			Settlement Complete at 69% of Primary Consolidation		Remaining Settlement at 69% of Primary Consolidation	
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-2-4	G	0.0	2.3	2.3	1.2	125	7	13				288	144	144	144	2,222				61	0.01	0.500	1,530	1,674	0.040	0.479	0.479	0.479	0.479	0.000	1.639
2	A-6b	C	2.3	4.3	2.0	3.3	115	10	10	1,250	18	39	518	403	403	6,660	3,046	0.261	0.039	0.577		0.02	0.500	1,530	1,932	0.034	0.406	0.724	0.406	0.724	0.000	1.639
	A-6b	C	4.3	6.3	2.0	5.3	115	10	10	1,250	18	39	748	633	633	6,660	3,046	0.261	0.039	0.577		0.04	0.500	1,530	2,162	0.027	0.318		0.318		0.000	1.639
3	A-2-4	G	6.3	11.3	5.0	8.8	135	57	69				1,423	1,085	1,085	1,085	18,096				261	0.07	0.500	1,530	2,615	0.007	0.088	0.088	0.088	0.088	0.000	1.639
4	A-4a	C	11.3	16.3	5.0	13.8	120	23	23	2,875	18	25	2,023	1,723	1,485	21,155	10,155	0.135	0.020	0.467		0.10	0.500	1,529	3,015	0.021	0.255	0.255	0.255	0.255	0.000	1.639
5	A-6b	C	16.3	21.3	5.0	18.8	115	13	13	1,625	18	39	2,598	2,310	1,761	8,657	3,960	0.261	0.026	0.577		0.14	0.499	1,528	3,289	0.022	0.269	0.269	0.267	0.267	0.003	1.637
6	A-4a	C	21.3	24.3	3.0	22.8	125	39	39	4,875	18	25	2,973	2,785	1,986	35,872	17,965	0.135	0.014	0.467		0.17	0.499	1,527	3,513	0.007	0.082	0.082	0.082	0.082	0.000	1.637
7	A-1-b	G	24.3	31.3	7.0	27.8	130	35	33				3,883	3,428	2,317	3,428	11,112				109	0.21	0.498	1,525	3,841	0.014	0.170	0.325	0.170	0.325	0.000	1.637
	A-1-b	G	31.3	38.3	7.0	34.8	130	35	31				4,793	4,338	2,790	4,338	11,112				102	0.26	0.497	1,520	4,310	0.013	0.155		0.155		0.000	1.637
8	A-7-6	C	38.3	43.3	5.0	40.8	120	22	22	2,750	23	58	5,393	5,093	3,171	-	13,100	0.203	0.093	0.645		0.30	0.495	1,514	4,684	0.048	0.575	2.067	0.270	0.971	0.305	1.332
	A-7-6	C	43.3	48.3	5.0	45.8	120	19	19	2,375	23	58	5,993	5,693	3,459	-	15,500	0.203	0.093	0.645		0.34	0.493	1,507	4,966	0.044	0.533		0.250		0.282	1.050
	A-7-6	C	48.3	53.3	5.0	50.8	120	22	22	2,750	23	58	6,593	6,293	3,747	-	17,900	0.203	0.093	0.645		0.38	0.490	1,500	5,247	0.041	0.496		0.233		0.263	0.787
	A-7-6	C	53.3	58.3	5.0	55.8	120	25	25	3,125	23	58	7,193	6,893	4,035	-	20,400	0.203	0.093	0.645		0.42	0.487	1,492	5,526	0.039	0.463		0.218		0.246	0.541
9	A-7-6	C	58.3	63.3	5.0	60.8	125	36	36	4,500	21	53	7,818	7,505	4,335	-	22,800	0.203	0.093	0.645		0.45	0.484	1,482	5,817	0.036	0.433	1.021	0.204	0.480	0.230	0.312
	A-7-6	C	63.3	70.7	7.4	67.0	130	98	98	10,744	21	53	8,780	8,299	4,742	-	25,900	0.203	0.093	0.645		0.50	0.480	1,468	6,210	0.049	0.588		0.276		0.312	0.000

Settlement Remaining After Hold Period: 1.639 in

Depth of Downdrag: 58.9 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{\,m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 201+63 to 202+03)

Calculated By: BRT   Date: 10/18/2021

Checked By: JPS   Date: 10/20/2021

Boring B-019-6-19

H =	25.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	10.0	ft	Depth below bottom of footing
q =	3,060	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-4a	A-6b (Lower)	A-7-6		
c_v =	300	800	300	183	ft^2/yr	Coefficient of consolitation
t =	120	120	120	120	days	Time following completion of construction
H_{dr} =	2.0	5.0	6.5	16.2	ft	Length of longest drainage path considered
T_v =	24.658	10.521	2.334	0.229		Time factor
U =	100	100	100	54	%	Degree of consolidation

$(S_c)_t$ = 3.889 in   Settlement complete at 73% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	Settlement Complete at 73% of Primary Consolidation: $(S_c)_t$ (13) (in)	Layer Settlement (in)	Remaining Settlement at 73% of Primary Consolidation: $S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-2-4	G	0.0	2.3	2.3	1.2	125	7	13				288	144	144	144	2,222				61	0.01	0.500	1,530	1,674	0.040	0.479	0.479	0.479	0.479	0.000	1.421
2	A-6b	C	2.3	4.3	2.0	3.3	115	10	10	1,250	18	39	518	403	403	6,660	3,046	0.261	0.039	0.577		0.02	0.500	1,530	1,932	0.034	0.406	0.724	0.406	0.724	0.000	1.421
	A-6b	C	4.3	6.3	2.0	5.3	115	10	10	1,250	18	39	748	633	633	6,660	3,046	0.261	0.039	0.577		0.04	0.500	1,530	2,162	0.027	0.318		0.318		0.000	1.421
3	A-2-4	G	6.3	11.3	5.0	8.8	135	57	69				1,423	1,085	1,085	1,085	18,096				261	0.07	0.500	1,530	2,615	0.007	0.088	0.088	0.088	0.088	0.000	1.421
4	A-4a	C	11.3	16.3	5.0	13.8	120	23	23	2,875	18	25	2,023	1,723	1,485	21,155	10,155	0.135	0.020	0.467		0.10	0.500	1,529	3,015	0.021	0.255	0.255	0.255	0.255	0.000	1.421
5	A-6b	C	16.3	21.3	5.0	18.8	115	13	13	1,625	18	39	2,598	2,310	1,761	8,657	3,960	0.261	0.026	0.577		0.14	0.499	1,528	3,289	0.022	0.269	0.269	0.269	0.269	0.000	1.421
6	A-4a	C	21.3	24.3	3.0	22.8	125	39	39	4,875	18	25	2,973	2,785	1,986	35,872	17,965	0.135	0.014	0.467		0.17	0.499	1,527	3,513	0.007	0.082	0.082	0.082	0.082	0.000	1.421
7	A-1-b	G	24.3	31.3	7.0	27.8	130	35	33				3,883	3,428	2,317	3,428	11,112				109	0.21	0.498	1,525	3,841	0.014	0.170	0.325	0.170	0.325	0.000	1.421
	A-1-b	G	31.3	38.3	7.0	34.8	130	35	31				4,793	4,338	2,790	4,338	11,112				102	0.26	0.497	1,520	4,310	0.013	0.155		0.155		0.000	1.421
8	A-7-6	C	38.3	43.3	5.0	40.8	120	22	22	2,750	23	58	5,393	5,093	3,171	-	13,100	0.203	0.093	0.645		0.30	0.495	1,514	4,684	0.048	0.575	2.067	0.310	1.116	0.264	1.156
	A-7-6	C	43.3	48.3	5.0	45.8	120	19	19	2,375	23	58	5,993	5,693	3,459	-	15,500	0.203	0.093	0.645		0.34	0.493	1,507	4,966	0.044	0.533		0.288		0.245	0.911
	A-7-6	C	48.3	53.3	5.0	50.8	120	22	22	2,750	23	58	6,593	6,293	3,747	-	17,900	0.203	0.093	0.645		0.38	0.490	1,500	5,247	0.041	0.496		0.268		0.228	0.683
	A-7-6	C	53.3	58.3	5.0	55.8	120	25	25	3,125	23	58	7,193	6,893	4,035	-	20,400	0.203	0.093	0.645		0.42	0.487	1,492	5,526	0.039	0.463		0.250		0.213	0.470
9	A-7-6	C	58.3	63.3	5.0	60.8	125	36	36	4,500	21	53	7,818	7,505	4,335	-	22,800	0.203	0.093	0.645		0.45	0.484	1,482	5,817	0.036	0.433	1.021	0.234	0.551	0.199	0.271
	A-7-6	C	63.3	70.7	7.4	67.0	130	98	98	10,744	21	53	8,780	8,299	4,742	-	25,900	0.203	0.093	0.645		0.50	0.480	1,468	6,210	0.049	0.588		0.318		0.271	0.000

Settlement Remaining After Hold Period: 1.421 in

Depth of Downdrag: 57.7 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^m\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 201+63 to 202+03)

Calculated By: BRT Date: 10/18/2021

Checked By: JPS Date: 10/20/2021

Boring B-019-6-19

H =	25.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	10.0	ft	Depth below bottom of footing
q =	3,060	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-4a	A-6b (Lower)	A-7-6		
c_v =	300	800	300	183	ft^2/yr	Coefficient of consolitation
t =	180	180	180	180	days	Time following completion of construction
H_{dr} =	2.0	5.0	6.5	16.2	ft	Length of longest drainage path considered
T_v =	36.986	15.781	3.502	0.344		Time factor
U =	100	100	100	65	%	Degree of consolidation

$(S_c)_t$ = 4.229 in Settlement complete at 80% of primary consolidation

																										Total Settlement at Facing of Wall			Settlement Complete at 80% of Primary Consolidation		Remaining Settlement at 80% of Primary Consolidation	
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-2-4	G	0.0	2.3	2.3	1.2	125	7	13				288	144	144	144	2,222				61	0.01	0.500	1,530	1,674	0.040	0.479	0.479	0.479	0.479	0.000	1.081
2	A-6b	C	2.3	4.3	2.0	3.3	115	10	10	1,250	18	39	518	403	403	6,660	3,046	0.261	0.039	0.577		0.02	0.500	1,530	1,932	0.034	0.406	0.724	0.406	0.724	0.000	1.081
	A-6b	C	4.3	6.3	2.0	5.3	115	10	10	1,250	18	39	748	633	633	6,660	3,046	0.261	0.039	0.577		0.04	0.500	1,530	2,162	0.027	0.318		0.318		0.000	1.081
3	A-2-4	G	6.3	11.3	5.0	8.8	135	57	69				1,423	1,085	1,085	1,085	18,096				261	0.07	0.500	1,530	2,615	0.007	0.088	0.088	0.088	0.088	0.000	1.081
4	A-4a	C	11.3	16.3	5.0	13.8	120	23	23	2,875	18	25	2,023	1,723	1,485	21,155	10,155	0.135	0.020	0.467		0.10	0.500	1,529	3,015	0.021	0.255	0.255	0.255	0.255	0.000	1.081
5	A-6b	C	16.3	21.3	5.0	18.8	115	13	13	1,625	18	39	2,598	2,310	1,761	8,657	3,960	0.261	0.026	0.577		0.14	0.499	1,528	3,289	0.022	0.269	0.269	0.269	0.269	0.000	1.081
6	A-4a	C	21.3	24.3	3.0	22.8	125	39	39	4,875	18	25	2,973	2,785	1,986	35,872	17,965	0.135	0.014	0.467		0.17	0.499	1,527	3,513	0.007	0.082	0.082	0.082	0.082	0.000	1.081
7	A-1-b	G	24.3	31.3	7.0	27.8	130	35	33				3,883	3,428	2,317	3,428	11,112				109	0.21	0.498	1,525	3,841	0.014	0.170	0.325	0.170	0.325	0.000	1.081
	A-1-b	G	31.3	38.3	7.0	34.8	130	35	31				4,793	4,338	2,790	4,338	11,112				102	0.26	0.497	1,520	4,310	0.013	0.155		0.155		0.000	1.081
8	A-7-6	C	38.3	43.3	5.0	40.8	120	22	22	2,750	23	58	5,393	5,093	3,171	-	13,100	0.203	0.093	0.645		0.30	0.495	1,514	4,684	0.048	0.575	2.067	0.374	1.344	0.201	0.880
	A-7-6	C	43.3	48.3	5.0	45.8	120	19	19	2,375	23	58	5,993	5,693	3,459	-	15,500	0.203	0.093	0.645		0.34	0.493	1,507	4,966	0.044	0.533		0.346		0.186	0.693
	A-7-6	C	48.3	53.3	5.0	50.8	120	22	22	2,750	23	58	6,593	6,293	3,747	-	17,900	0.203	0.093	0.645		0.38	0.490	1,500	5,247	0.041	0.496		0.322		0.174	0.520
	A-7-6	C	53.3	58.3	5.0	55.8	120	25	25	3,125	23	58	7,193	6,893	4,035	-	20,400	0.203	0.093	0.645		0.42	0.487	1,492	5,526	0.039	0.463		0.301		0.162	0.357
9	A-7-6	C	58.3	63.3	5.0	60.8	125	36	36	4,500	21	53	7,818	7,505	4,335	-	22,800	0.203	0.093	0.645		0.45	0.484	1,482	5,817	0.036	0.433	1.021	0.282	0.664	0.152	0.206
	A-7-6	C	63.3	70.7	7.4	67.0	130	98	98	10,744	21	53	8,780	8,299	4,742	-	25,900	0.203	0.093	0.645		0.50	0.480	1,468	6,210	0.049	0.588		0.382		0.206	0.000

Settlement Remaining After Hold Period: 1.081 in

Depth of Downdrag: 54.5 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for $N60 \geq 52$; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{\ m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E2 (Sta. 201+63 to 202+03)

Calculated By: BRT Date: 10/18/2021

Checked By: JPS Date: 10/20/2021

Boring B-019-6-19

H =	25.5	ft	Total wall height
B =	134.3	ft	Width of embankment (length of wall along abutment face)
D_w =	10.0	ft	Depth below bottom of footing
q =	3,060	psf	Bearing pressure at bottom of wall

	A-6b (Upper)	A-4a	A-6b (Lower)	A-7-6		
c_v =	300	800	300	183	ft^2/yr	Coefficient of consolitation
t =	330	330	330	330	days	Time following completion of construction
H_{dr} =	2.0	5.0	6.5	16.2	ft	Length of longest drainage path considered
T_v =	67.808	28.932	6.420	0.630		Time factor
U =	100	100	100	83	%	Degree of consolidation

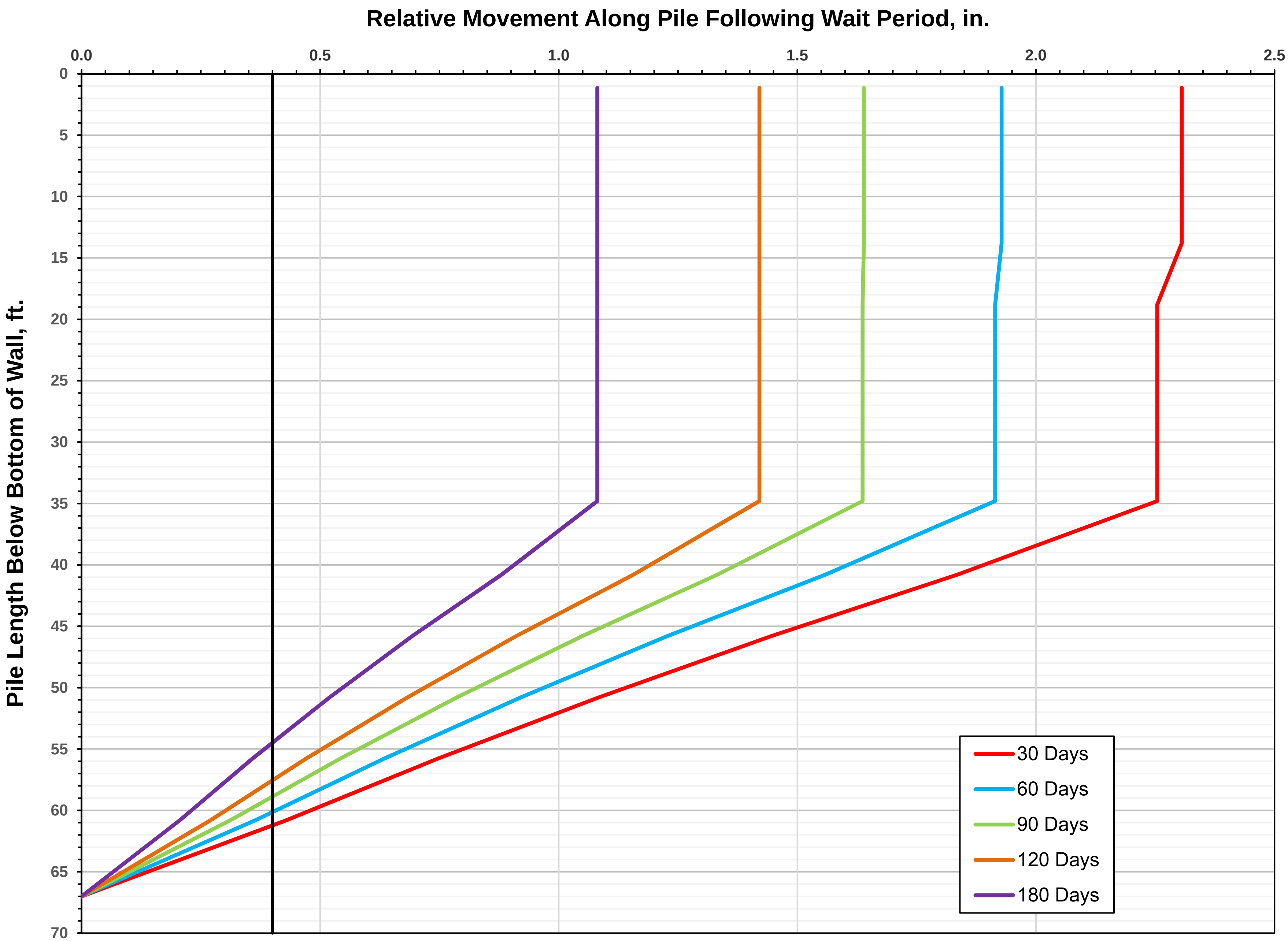
$(S_c)_t$ = 4.785 in Settlement complete at 90% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)
1	A-2-4	G	0.0	2.3	2.3	1.2	125	7	13				288	144	144	144	2,222
2	A-6b	C	2.3	4.3	2.0	3.3	115	10	10	1,250	18	39	518	403	403	6,660	3,046
	A-6b	C	4.3	6.3	2.0	5.3	115	10	10	1,250	18	39	748	633	633	6,660	3,046
3	A-2-4	G	6.3	11.3	5.0	8.8	135	57	69				1,423	1,085	1,085	1,085	18,096
4	A-4a	C	11.3	16.3	5.0	13.8	120	23	23	2,875	18	25	2,023	1,723	1,485	21,155	10,155
5	A-6b	C	16.3	21.3	5.0	18.8	115	13	13	1,625	18	39	2,598	2,310	1,761	8,657	3,960
6	A-4a	C	21.3	24.3	3.0	22.8	125	39	39	4,875	18	25	2,973	2,785	1,986	35,872	17,965
7	A-1-b	G	24.3	31.3	7.0	27.8	130	35	33				3,883	3,428	2,317	3,428	11,112
	A-1-b	G	31.3	38.3	7.0	34.8	130	35	31				4,793	4,338	2,790	4,338	11,112
8	A-7-6	C	38.3	43.3	5.0	40.8	120	22	22	2,750	23	58	5,393	5,093	3,171	-	13,100
	A-7-6	C	43.3	48.3	5.0	45.8	120	19	19	2,375	23	58	5,993	5,693	3,459	-	15,500
	A-7-6	C	48.3	53.3	5.0	50.8	120	22	22	2,750	23	58	6,593	6,293	3,747	-	17,900
	A-7-6	C	53.3	58.3	5.0	55.8	120	25	25	3,125	23	58	7,193	6,893	4,035	-	20,400
9	A-7-6	C	58.3	63.3	5.0	60.8	125	36	36	4,500	21	53	7,818	7,505	4,335	-	22,800
	A-7-6	C	63.3	70.7	7.4	67.0	130	98	98	10,744	21	53	8,780	8,299	4,742	-	25,900

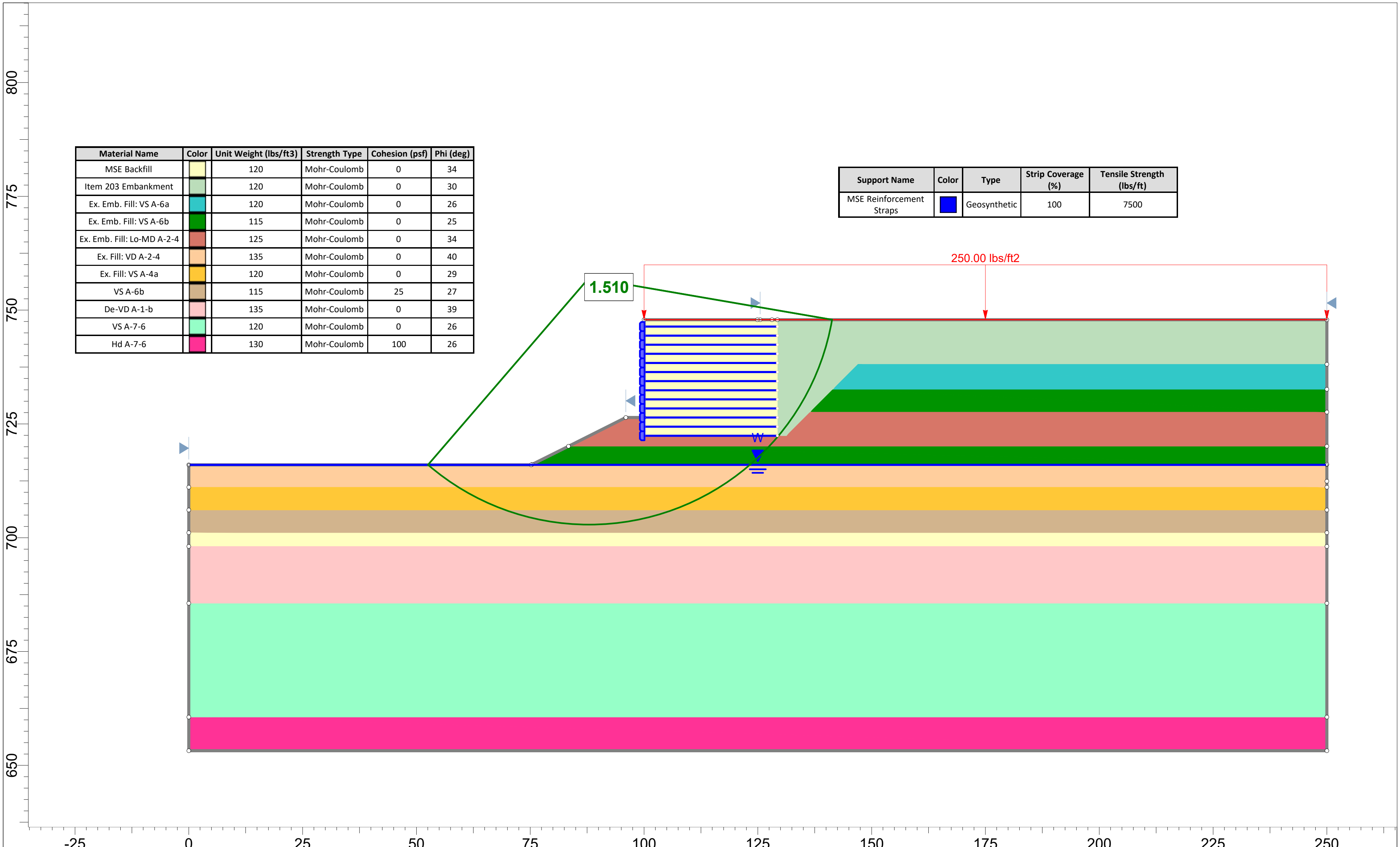
									Total Settlement at Facing of Wall			Settlement Complete at 90% of Primary Consolidation		Remaining Settlement at 90% of Primary Consolidation	
Layer	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1				61	0.01	0.500	1,530	1,674	0.040	0.479	0.479	0.479	0.479	0.000	0.525
2	0.261	0.039	0.577		0.02	0.500	1,530	1,932	0.034	0.406	0.724	0.406	0.724	0.000	0.525
	0.261	0.039	0.577		0.04	0.500	1,530	2,162	0.027	0.318		0.318		0.000	0.525
3				261	0.07	0.500	1,530	2,615	0.007	0.088	0.088	0.088	0.088	0.000	0.525
4	0.135	0.020	0.467		0.10	0.500	1,529	3,015	0.021	0.255	0.255	0.255	0.255	0.000	0.525
5	0.261	0.026	0.577		0.14	0.499	1,528	3,289	0.022	0.269	0.269	0.269	0.269	0.000	0.525
6	0.135	0.014	0.467		0.17	0.499	1,527	3,513	0.007	0.082	0.082	0.082	0.082	0.000	0.525
7				109	0.21	0.498	1,525	3,841	0.014	0.170	0.325	0.170	0.325	0.000	0.525
				102	0.26	0.497	1,520	4,310	0.013	0.155		0.155		0.000	0.525
8	0.203	0.093	0.645		0.30	0.495	1,514	4,684	0.048	0.575	2.067	0.477	1.716	0.098	0.427
	0.203	0.093	0.645		0.34	0.493	1,507	4,966	0.044	0.533		0.442		0.091	0.337
	0.203	0.093	0.645		0.38	0.490	1,500	5,247	0.041	0.496		0.412		0.084	0.252
	0.203	0.093	0.645		0.42	0.487	1,492	5,526	0.039	0.463		0.385		0.079	0.174
9	0.203	0.093	0.645		0.45	0.484	1,482	5,817	0.036	0.433	1.021	0.359	0.848	0.074	0.100
	0.203	0.093	0.645		0.50	0.480	1,468	6,210	0.049	0.588		0.488		0.100	0.000

Settlement Remaining After Hold Period: 0.525 in

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{\,m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.



Relative Movement Along Pile Following Wait Period, in.
0.0
0.5
1.0
1.5
2.0
2.5
Pile Length Below Bottom of Wall, ft.
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
30 Days
60 Days
90 Days
120 Days
180 Days



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Ex. Emb. Fill: VS A-6a		120	Mohr-Coulomb	0	26
Ex. Emb. Fill: VS A-6b		115	Mohr-Coulomb	0	25
Ex. Emb. Fill: Lo-MD A-2-4		125	Mohr-Coulomb	0	34
Ex. Fill: VD A-2-4		135	Mohr-Coulomb	0	40
Ex. Fill: VS A-4a		120	Mohr-Coulomb	0	29
VS A-6b		115	Mohr-Coulomb	25	27
De-VD A-1-b		135	Mohr-Coulomb	0	39
VS A-7-6		120	Mohr-Coulomb	0	26
Hd A-7-6		130	Mohr-Coulomb	100	26

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		Geosynthetic	100	7500

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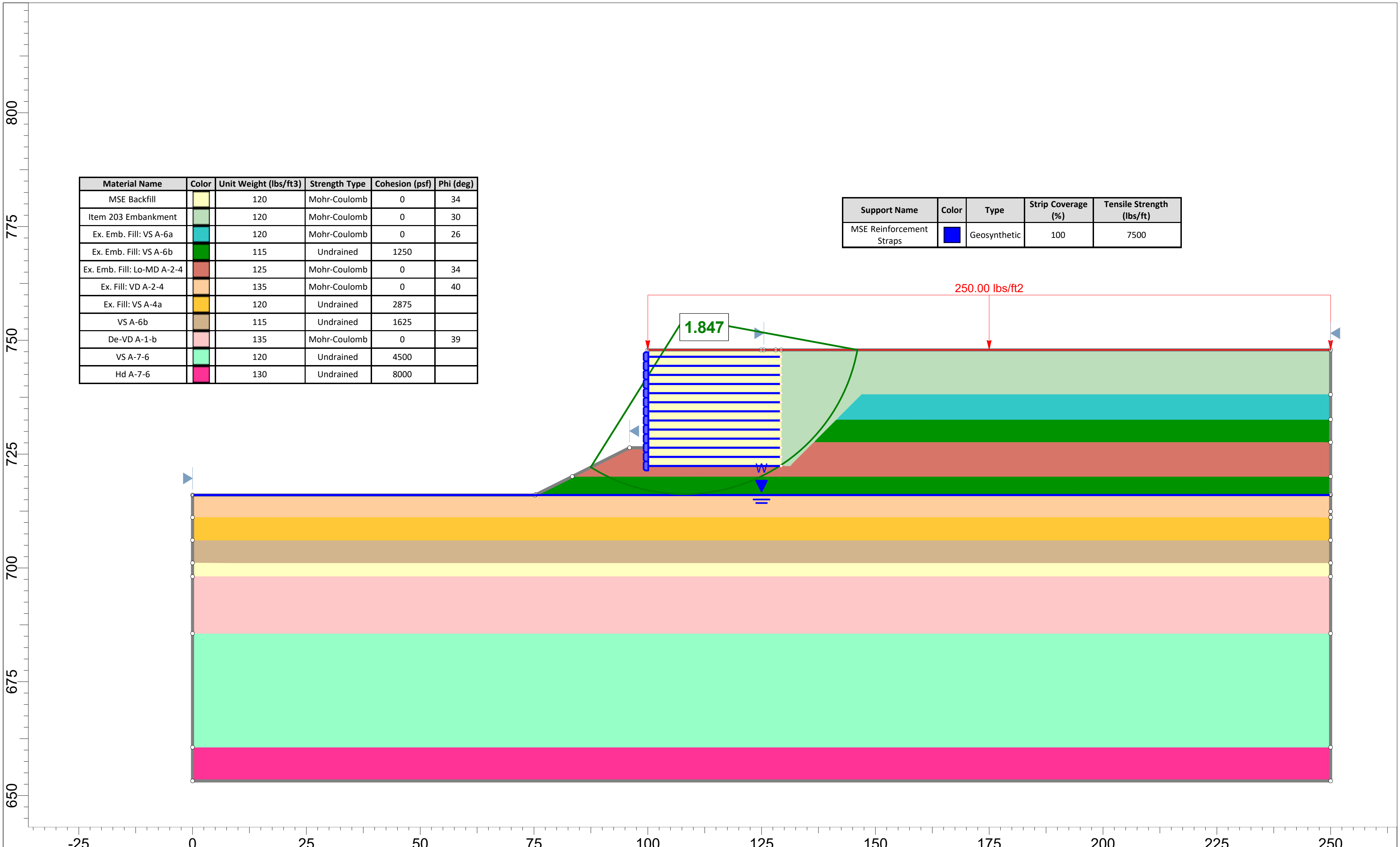
SLIDEINTERPRET 9.012

Project	FRA-70-13.10 - FRA-70-1358L - Rear Abutment - Retaining Wall E2 - Global Stability		
Analysis Description	Sta. 201+63 to 202+03 - 25.5 ft Wall Height - Drained - Circular - Spencer's		
Drawn By BRT	*Scale* 1:350	*Company*	Resource International, Inc.
Date	5/22/2021	*File Name*	FRA-70-1358L - Global Stability - RA - Sta. 201+63 to 202+03.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Ex. Emb. Fill: VS A-6a		120	Mohr-Coulomb	0	26
Ex. Emb. Fill: VS A-6b		115	Undrained	1250	
Ex. Emb. Fill: Lo-MD A-2-4		125	Mohr-Coulomb	0	34
Ex. Fill: VD A-2-4		135	Mohr-Coulomb	0	40
Ex. Fill: VS A-4a		120	Undrained	2875	
VS A-6b		115	Undrained	1625	
De-VD A-1-b		135	Mohr-Coulomb	0	39
VS A-7-6		120	Undrained	4500	
Hd A-7-6		130	Undrained	8000	

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		Geosynthetic	100	7500

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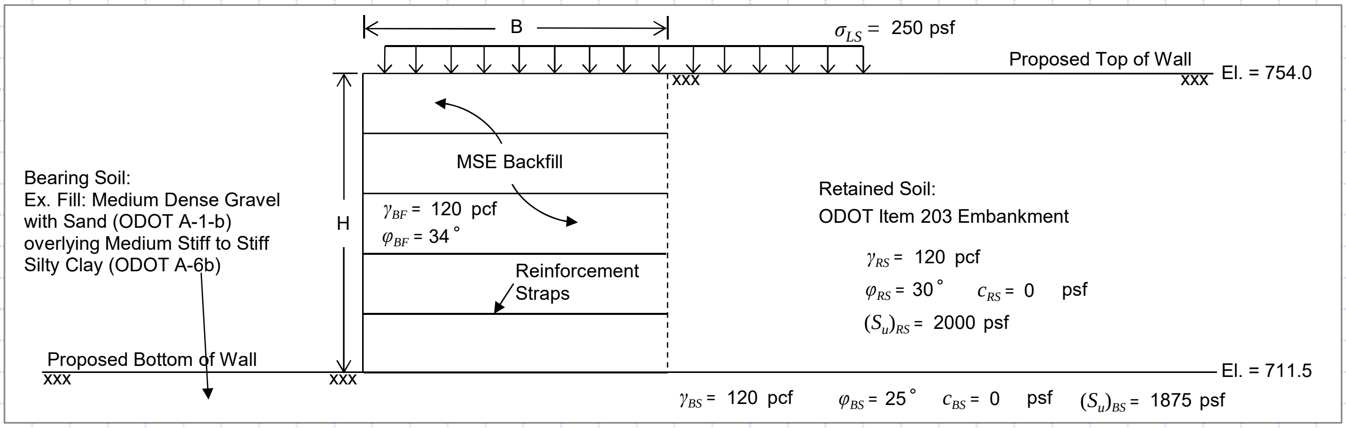
SLIDEINTERPRET 9.012

Project	FRA-70-13.10 - FRA-70-1358L - Rear Abutment - Retaining Wall E2 - Global Stability		
Analysis Description	Sta. 201+63 to 202+03 - 25.5 ft Wall Height - Undrained - Circular - Spencer's		
Drawn By BRT	*Scale* 1:350	*Company* Resource International, Inc.	
Date 5/22/2021	*File Name* FRA-70-1358L - Global Stability - RA - Sta. 201+63 to 202+03.slim		

FRA-70-1358L - Retaining Wall E4 - MSE Wall - Forward Abutment - B-017-7-13 and B-018-2-13 - 42.5 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	42.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.8	ft
MSE Wall Length, (L) =	148	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(S_u)_{BS}]$ =	1875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_w) =	0.0	ft

LRFD Load Factors

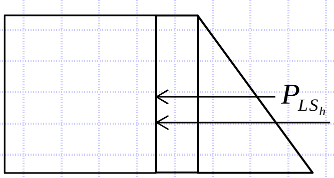
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3

Sliding Force:

$$P_H = P_{EH} + P_{LS_h}$$



$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \text{½(120 pcf)(42.5 ft)²(0.297)(1.5)} = 48.28 \text{ kip/ft}$$

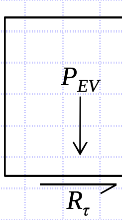
$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = \text{(250 psf)(42.5 ft)(0.297)(1.75)} = 5.52 \text{ kip/ft}$$

$$P_H = \text{48.28 kip/ft + 5.52 kip/ft} = 53.80 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:

$$R_\tau = P_{EV} \cdot \tan\delta$$



$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(42.5 ft)(29.8 ft)(1.00)} = 151.98 \text{ kip/ft}$$

$$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$$

$$\tan\delta = \tan(25) \le \tan(34) \longrightarrow 0.47 \le 0.67 \longrightarrow \tan\delta = 0.47$$

$$R_\tau = \text{(151.98 kip/ft)(0.47)} = 71.43 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$$P_H \le R_\tau \cdot \phi_\tau \longrightarrow \text{53.80 kip/ft} \le \text{(71.43 kip/ft)(1.0) = 71.43 kip/ft} \longrightarrow \text{53.80 kip/ft} \le \text{71.43 kip/ft}$$ **OK**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	42.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.8	ft
MSE Wall Length, (L) =	148	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

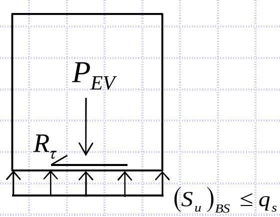
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 *(Continued)*

Check Sliding Resistance - Undrained Condition

Nominal Sliding Resisting: $R_\tau = ((S_u)_{BS} \le q_s) \cdot B$



$(S_u)_{BS}$ = 1.88 ksf

$q_s = \sigma_v / 2$ = (5.10 ksf) / 2 = 2.55 ksf

$\sigma_v = P_{EV} / B$ = (151.98 kip/ft) / (29.8 ft) = 5.10 ksf

R_τ = (1.88 ksf ≤ 2.55 ksf)(29.8 ft) = 55.88 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 53.80 kip/ft ≤ (55.88 kip/ft)(1.0) = 55.88 kip/ft ⟶ 53.80 kip/ft ≤ 55.88 kip/ft **OK**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	42.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.8	ft
MSE Wall Length, (L) =	148	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

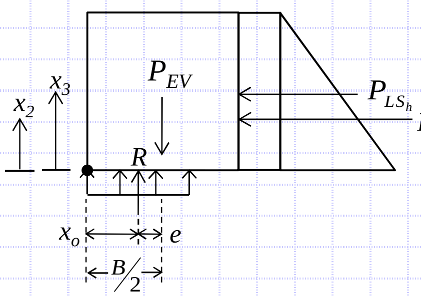
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.5



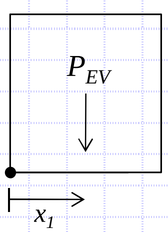
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (2264.5 kip·ft/ft - 801.43 kip·ft/ft) / (151.98 kip/ft) = 9.63 ft

M_{EV} =	2264.50	kip·ft/ft	Defined below
M_H =	801.43	kip·ft/ft	
P_{EV} =	151.98	kip/ft	

$e =$ (29.8 ft)/2 - 9.63 ft = 5.27 ft

Resisting Moment, M_{EV}:



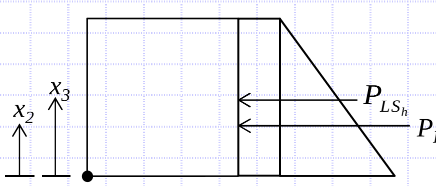
$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(42.5 ft)(29.8 ft)(1.00) = 151.98 kip/ft

$x_1 = B/2$ = (29.8 ft) / 2 = 14.90 ft

$M_{EV} =$ (151.98 kip/ft)(14.90 ft) = 2264.50 kip·ft/ft

Overturning Moment, M_H:



$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$$

$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(120 pcf)(42.5 ft)²(0.297)(1.5) = 48.28 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(42.5 ft)(0.297)(1.75) = 5.52 kip/ft

$x_2 = H/3$ = (42.5 ft) / 3 = 14.17 ft

$x_3 = H/2$ = (42.5 ft) / 2 = 21.25 ft

$M_H =$ (48.28 kip/ft)(14.17 ft) + (5.52 kip/ft)(21.25 ft) = 801.43 kip·ft/ft

Check Eccentricity

$e < e_{max} \longrightarrow$ 5.27 ft < 9.93 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (29.8 ft) / 3 = 9.93 ft

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	42.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.8	ft
MSE Wall Length, (L) =	148	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

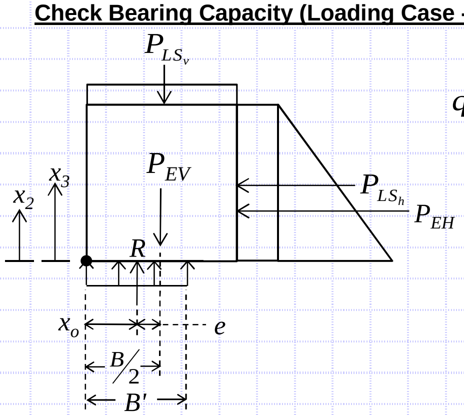
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 29.8 ft - 2(3.67 ft) = 22.46 ft

$e = B/2 - x_o$ = (29.8 ft) / 2 - 11.23 ft = 3.67 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (3251.34 kip·ft/ft - 801.49 kip·ft/ft) / 218.21 kip/ft = 11.23 ft

q_{eq} = (218.21 kip/ft) / (22.46 ft) = 9.72 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

M_V = [(120 pcf)(42.5 ft)(29.8 ft)(1.35)](14.9 ft) + [(250 psf)(29.8 ft)(1.75)](14.9 ft) = 3251.34 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

M_H = [½(120 pcf)(42.5 ft)²(0.297)(1.5)](14.17 ft) + [(250 psf)(42.5 ft)(0.297)(1.75)](21.25 ft) = 801.49 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

P_V = (120 pcf)(42.5 ft)(29.8 ft)(1.35) + (250 psf)(29.8 ft)(1.75) = 218.21 kip/ft

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 22.34

N_c = 20.72
s_c = 1+(22.46 ft/148 ft)(10.66/20.72)
= 1.078
i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 12.04

N_q = 10.66
s_q = 1.071
d_q = 1+2tan(25°)[1-sin(25°)]²tan⁻¹(4.0 ft/22.46 ft)
1.055
i_q = 1.000 (Assumed)
C_{wq} = 0.0 ft > 4.0 ft = 0.500

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 10.22

N_γ = 10.88
s_γ = 0.939
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 0.0 ft < 1.5(22.46 ft) + 4.0 ft = 0.500

q_n = (0 psf)(22.336) + (120 pcf)(4.0 ft)(12.045)(0.500) + ½(120 pcf)(22.5 ft)(10.216)(0.500) = 9.77 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 9.72 ksf ≤ (9.77 ksf)(0.65) = 6.35 ksf ⟶ 9.72 ksf ≤ 6.35 ksf **ERROR!!**

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	42.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.8	ft
MSE Wall Length, (L) =	148	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 ***(Continued)***

Check Bearing Resistance - Undrained Condition

Nominal Bearing Resistance: $$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$

$N_{cm} = N_c s_c i_c$ = 5.290

- N_c = 5.140
- s_c = 1+(22.46 ft/[(5)(148 ft)]) = 1.030
- i_c = 1.000 (Assumed)

$N_{qm} = N_q s_q d_q i_q$ = 1.000

- N_q = 1.000
- s_q = 1.000
- d_q = 1+2tan(0°)[1-sin(0°)]²tan⁻¹(4.0 ft/22.46 ft) = 1.000
- i_q = 1.000 (Assumed)
- C_{wq} = 0.0 ft > 4.0 ft = 0.500

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

- N_γ = 0.000
- s_γ = 1.000
- i_γ = 1.000 (Assumed)
- $C_{w\gamma}$ = 0.0 ft < 1.5(22.46 ft) + 4.0 ft = 0.500

$q_n =$ (1875 psf)(5.290) + (120 pcf)(4.0 ft)(1.000)(0.500) + ½(120 pcf)(22.5 ft)(0.000)(0.500) = 10.16 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \leq q_n \cdot \phi_b$ ⟶ 9.72 ksf ≤ (10.16 ksf)(0.65) = 6.60 ksf ⟶ 9.72 ksf ≤ 6.60 ksf **ERROR!!**

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	42.5	ft
MSE Wall Width (Reinforcement Length), (B) =	29.8	ft
MSE Wall Length, (L) =	148	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

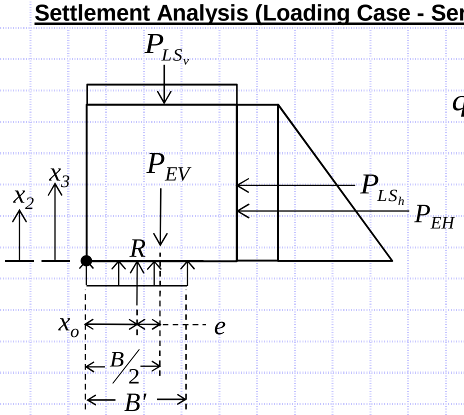
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	1875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 29.8 ft - 2(3.28 ft) = 23.24 ft

$e = B/2 - x_o$ = (29.8 ft) / 2 - 11.62 ft = 3.28 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (2375.51 kip·ft/ft - 523.15 kip·ft/ft) / 159.43 kip/ft = 11.62 ft

$q_{eq} =$ (159.43 kip/ft) / (23.24 ft) = 6.86 ksf

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

$M_V =$ [(120 pcf)(42.5 ft)(29.8 ft)(1.00)](14.9 ft) + [(250 psf)(29.8 ft)(1.00)](14.9 ft) = 2375.51 kip·ft/ft

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

$M_H =$ [½(120 pcf)(42.5 ft)²(0.297)(1.00)](14.17 ft) + [(250 psf)(42.5 ft)(0.297)(1.00)](21.25 ft) = 523.15 kip·ft/ft

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

$P_V =$ (120 pcf)(42.5 ft)(29.8 ft)(1.00) + (250 psf)(29.8 ft)(1.00) = 159.43 kip/ft

Settlement:

		B-018-2-13	
Total Settlement at Center of Reinforced Soil Mass:	S_t =	17.410	in
Total Settlement at Wall Facing:	S_t =	10.244	in

Time Rate of Consolidation and Downdrag Depths and Loads:

Boring	Hold Period	Degree of Consolidation	Settlement Remaining at Completion of Hold Period	Depth of Downdrag
B-017-9-13	30 days	68 %	2.175 in	46.8 ft
	60 days	77 %	1.510 in	45.2 ft
	90 days	83 %	1.123 in	43.1 ft
	120 days	88 %	0.807 in	39.9 ft
	180 days	94 %	0.421 in	31.1 ft

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E4

Calculated By: BRT Date: 10/18/221

Checked By: JPS Date: 10/20/2021

Boring B-018-2-13

H =	42.5	ft	Total wall height
B =	42.5	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	5,100	psf	Bearing pressure at bottom of wall

																							Total Settlement at Center of Reinforced Soil Mass					Total Settlement at Facing of Wall				
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,13) (psf)	σ_p' (4,13) (psf)	C_c (5,13)	C_r (6,13)	e_o (7,13)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)
1	A-2-4	G	0.0	1.3	1.3	0.7	125	18	36				163	81	41	81	5,715				117	0.02	1.000	5,100	5,141	0.023	0.280	0.500	2,550	2,591	0.020	0.240
2	A-6b	C	1.3	3.8	2.5	2.6	120	21	21	2,625	18	40	463	313	153	13,715	6,583	0.270	0.041	0.585		0.06	0.999	5,096	5,250	0.098	1.176	0.500	2,550	2,703	0.080	0.955
	A-6b	C	3.8	6.3	2.5	5.1	120	10	10	1,250	18	40	763	613	297	6,531	3,135	0.270	0.041	0.585		0.12	0.995	5,073	5,370	0.165	1.979	0.500	2,548	2,846	0.063	0.752
3	A-4a	C	6.3	8.2	1.9	7.3	120	19	19	2,375	19	28	991	877	424	16,574	7,955	0.162	0.024	0.491		0.17	0.985	5,025	5,449	0.034	0.412	0.499	2,545	2,969	0.026	0.314
	A-4a	C	8.2	10.1	1.9	9.2	120	11	11	1,375	19	28	1,219	1,105	534	9,595	4,606	0.162	0.016	0.491		0.22	0.972	4,959	5,493	0.035	0.421	0.498	2,540	3,073	0.016	0.188
4	A-1-b	G	10.1	16.3	6.2	13.2	130	30	39				2,025	1,622	798	1,622	9,524				128	0.31	0.931	4,751	5,548	0.041	0.489	0.494	2,521	3,319	0.030	0.360
5	A-1-a	G	16.3	21.8	5.5	19.1	135	66	77				2,767	2,396	1,207	2,396	20,953				311	0.45	0.851	4,341	5,548	0.012	0.141	0.485	2,472	3,679	0.009	0.103
	A-1-a	G	21.8	27.3	5.5	24.6	135	55	59				3,510	3,138	1,606	3,138	17,461				211	0.58	0.769	3,923	5,529	0.014	0.168	0.471	2,403	4,009	0.010	0.124
	A-1-a	G	27.3	32.8	5.5	30.1	135	45	45				4,252	3,881	2,006	3,881	14,286				149	0.71	0.692	3,529	5,535	0.016	0.195	0.454	2,316	4,322	0.012	0.147
6	A-7-6	C	32.8	37.8	5.0	35.3	125	37	37	4,625	26	45	4,877	4,565	2,362	-	10,400	0.203	0.093	0.645		0.83	0.626	3,194	5,556	0.105	1.260	0.436	2,223	4,584	0.081	0.977
	A-7-6	C	37.8	42.8	5.0	40.3	125	26	26	3,250	26	45	5,502	5,190	2,675	-	12,900	0.203	0.093	0.645		0.95	0.572	2,915	5,590	0.090	1.086	0.417	2,129	4,803	0.072	0.862
	A-7-6	C	42.8	47.8	5.0	45.3	125	33	33	4,125	26	45	6,127	5,815	2,988	-	15,300	0.203	0.093	0.645		1.07	0.524	2,672	5,660	0.078	0.941	0.399	2,033	5,021	0.064	0.765
	A-7-6	C	47.8	54.6	6.8	51.2	125	36	36	4,500	26	45	6,977	6,552	3,357	-	18,200	0.203	0.093	0.645		1.20	0.476	2,427	5,784	0.091	1.090	0.377	1,923	5,280	0.076	0.907
																							Total Settlement:			9.638 in		Total Settlement:			6.695 in	

1. $(N1)_{60} = C_nN_{60}$, where $C_n = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1N_{60}p_a/100$ for for $N_{60}\geq52$; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\ N_{60}^{\ m}\ p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
6. C_r = 0.15(Cc) for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E4

Calculated By: BRT   Date: 10/18/221

Checked By: JPS   Date: 10/20/2021

Boring B-018-2-13

H =	42.5	ft	Total wall height
B =	42.5	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	5,100	psf	Bearing pressure at bottom of wall

	A-6b	A-4a	A-7-6		
c_v =	300	800	183	ft^2/yr	Coefficient of consolidation
t =	30	30	30	days	Time following completion of construction
H_{dr} =	4.5	3.8	10.9	ft	Length of longest drainage path considered
T_v =	1.218	4.554	0.127		Time factor
U =	96	100	40	%	Degree of consolidation

$(S_c)_t$ = 4.615 in   Settlement complete at 68% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (11,12) (ft)	Total Settlement at Facing of Wall: S_c (in)	Total Settlement at Facing of Wall: Layer Settlement (in)	Settlement Complete at 68% of Primary Consolidation: $(S_c)_t$ (13) (in)	Settlement Complete at 68% of Primary Consolidation: Layer Settlement (in)	Remaining Settlement at 68% of Primary Consolidation: $S_c - (S_c)_t$ (in)	Remaining Settlement at 68% of Primary Consolidation: Relative Movement (in)
1	A-2-4	G	0.0	1.3	1.3	0.7	125	18	36				163	81	41	81	5,715				117	0.02	0.500	2,550	2,591	0.020	0.240	0.240	0.240	0.240	0.000	2.175
2	A-6b	C	1.3	3.8	2.5	2.6	120	21	21	2,625	18	40	463	313	153	13,715	6,583	0.270	0.041	0.585		0.06	0.500	2,550	2,703	0.080	0.955	1.707	0.917	1.639	0.038	2.137
	A-6b	C	3.8	6.3	2.5	5.1	120	10	10	1,250	18	40	763	613	297	6,531	3,135	0.270	0.041	0.585		0.12	0.500	2,548	2,846	0.063	0.752		0.722		0.030	2.106
3	A-4a	C	6.3	8.2	1.9	7.3	120	19	19	2,375	19	28	991	877	424	16,574	7,955	0.162	0.024	0.491		0.17	0.499	2,545	2,969	0.026	0.314	0.597	0.314	0.597	0.000	2.106
	A-4a	C	8.2	10.1	1.9	9.2	120	11	11	1,375	19	28	1,219	1,105	534	9,595	4,606	0.162	0.024	0.491		0.22	0.498	2,540	3,073	0.024	0.283		0.283		0.000	2.106
4	A-1-b	G	10.1	16.3	6.2	13.2	130	30	39				2,025	1,622	798	1,622	9,524				128	0.31	0.494	2,521	3,319	0.030	0.360	0.360	0.360	0.360	0.000	2.106
5	A-1-a	G	16.3	21.8	5.5	19.1	135	66	77				2,767	2,396	1,207	2,396	20,953				311	0.45	0.485	2,472	3,679	0.009	0.103	0.375	0.103	0.375	0.000	2.106
	A-1-a	G	21.8	27.3	5.5	24.6	135	55	59				3,510	3,138	1,606	3,138	17,461				211	0.58	0.471	2,403	4,009	0.010	0.124		0.124		0.000	2.106
	A-1-a	G	27.3	32.8	5.5	30.1	135	45	45				4,252	3,881	2,006	3,881	14,286				149	0.71	0.454	2,316	4,322	0.012	0.147		0.147		0.000	2.106
6	A-7-6	C	32.8	37.8	5.0	35.3	125	37	37	4,625	26	45	4,877	4,565	2,362	-	10,400	0.203	0.093	0.645		0.83	0.436	2,223	4,584	0.081	0.977	3.511	0.391	1.404	0.586	1.520
	A-7-6	C	37.8	42.8	5.0	40.3	125	26	26	3,250	26	45	5,502	5,190	2,675	-	12,900	0.203	0.093	0.645		0.95	0.417	2,129	4,803	0.072	0.862		0.345		0.517	1.003
	A-7-6	C	42.8	47.8	5.0	45.3	125	33	33	4,125	26	45	6,127	5,815	2,988	-	15,300	0.203	0.093	0.645		1.07	0.399	2,033	5,021	0.064	0.765		0.306		0.459	0.544
	A-7-6	C	47.8	54.6	6.8	51.2	125	36	36	4,500	26	45	6,977	6,552	3,357	-	18,200	0.203	0.093	0.645		1.20	0.377	1,923	5,280	0.076	0.907		0.363		0.544	0.000

Settlement Remaining After Hold Period: 2.175 in

Depth of Downdrag: 46.8 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E4

Calculated By: BRT   Date: 10/18/221

Checked By: JPS   Date: 10/20/2021

Boring B-018-2-13

H =	42.5	ft	Total wall height
B =	42.5	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	5,100	psf	Bearing pressure at bottom of wall

	A-6b	A-4a	A-7-6		
c_v =	300	800	183	ft^2/yr	Coefficient of consolidation
t =	60	60	60	days	Time following completion of construction
H_{dr} =	4.5	3.8	10.9	ft	Length of longest drainage path considered
T_v =	2.435	9.107	0.253		Time factor
U =	100	100	57	%	Degree of consolidation

$(S_c)_t$ = 5.186 in   Settlement complete at 77% of primary consolidation

																										Total Settlement at Facing of Wall			Settlement Complete at 77% of Primary Consolidation		Remaining Settlement at 77% of Primary Consolidation	
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-2-4	G	0.0	1.3	1.3	0.7	125	18	36				163	81	41	81	5,715				117	0.02	0.500	2,550	2,591	0.020	0.240	0.240	0.240	0.240	0.000	1.510
2	A-6b	C	1.3	3.8	2.5	2.6	120	21	21	2,625	18	40	463	313	153	13,715	6,583	0.270	0.041	0.585		0.06	0.500	2,550	2,703	0.080	0.955	1.707	0.955	1.707	0.000	1.510
	A-6b	C	3.8	6.3	2.5	5.1	120	10	10	1,250	18	40	763	613	297	6,531	3,135	0.270	0.041	0.585		0.12	0.500	2,548	2,846	0.063	0.752		0.752		0.000	1.510
3	A-4a	C	6.3	8.2	1.9	7.3	120	19	19	2,375	19	28	991	877	424	16,574	7,955	0.162	0.024	0.491		0.17	0.499	2,545	2,969	0.026	0.314	0.502	0.314	0.502	0.000	1.510
	A-4a	C	8.2	10.1	1.9	9.2	120	11	11	1,375	19	28	1,219	1,105	534	9,595	4,606	0.162	0.016	0.491		0.22	0.498	2,540	3,073	0.016	0.188		0.188		0.000	1.510
4	A-1-b	G	10.1	16.3	6.2	13.2	130	30	39				2,025	1,622	798	1,622	9,524				128	0.31	0.494	2,521	3,319	0.030	0.360	0.360	0.360	0.360	0.000	1.510
5	A-1-a	G	16.3	21.8	5.5	19.1	135	66	77				2,767	2,396	1,207	2,396	20,953				311	0.45	0.485	2,472	3,679	0.009	0.103	0.375	0.103	0.375	0.000	1.510
	A-1-a	G	21.8	27.3	5.5	24.6	135	55	59				3,510	3,138	1,606	3,138	17,461				211	0.58	0.471	2,403	4,009	0.010	0.124		0.124		0.000	1.510
	A-1-a	G	27.3	32.8	5.5	30.1	135	45	45				4,252	3,881	2,006	3,881	14,286				149	0.71	0.454	2,316	4,322	0.012	0.147		0.147		0.000	1.510
6	A-7-6	C	32.8	37.8	5.0	35.3	125	37	37	4,625	26	45	4,877	4,565	2,362	-	10,400	0.203	0.093	0.645		0.83	0.436	2,223	4,584	0.081	0.977	3.511	0.557	2.001	0.420	1.090
	A-7-6	C	37.8	42.8	5.0	40.3	125	26	26	3,250	26	45	5,502	5,190	2,675	-	12,900	0.203	0.093	0.645		0.95	0.417	2,129	4,803	0.072	0.862		0.492		0.371	0.719
	A-7-6	C	42.8	47.8	5.0	45.3	125	33	33	4,125	26	45	6,127	5,815	2,988	-	15,300	0.203	0.093	0.645		1.07	0.399	2,033	5,021	0.064	0.765		0.436		0.329	0.390
	A-7-6	C	47.8	54.6	6.8	51.2	125	36	36	4,500	26	45	6,977	6,552	3,357	-	18,200	0.203	0.093	0.645		1.20	0.377	1,923	5,280	0.076	0.907		0.517		0.390	0.000

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}{}^m\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

Settlement Remaining After Hold Period: 1.510 in

Depth of Downdrag: 45.2 ft

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E4

Calculated By: BRT Date: 10/18/221

Checked By: JPS Date: 10/20/2021

Boring B-018-2-13

H =	42.5	ft	Total wall height
B =	42.5	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	5,100	psf	Bearing pressure at bottom of wall

	A-6b	A-4a	A-7-6		
c_v =	300	800	183	ft^2/yr	Coefficient of consolidation
t =	90	90	90	days	Time following completion of construction
H_{dr} =	4.5	3.8	10.9	ft	Length of longest drainage path considered
T_v =	3.653	13.661	0.380		Time factor
U =	100	100	68	%	Degree of consolidation

$(S_c)_t$ = 5.572 in Settlement complete at 83% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (11,12) (ft)	Total Settlement at Facing of Wall: S_c (in)	Total Settlement at Facing of Wall: Layer Settlement (in)	Settlement Complete at 83% of Primary Consolidation: $(S_c)_t$ (13) (in)	Settlement Complete at 83% of Primary Consolidation: Layer Settlement (in)	Remaining Settlement at 83% of Primary Consolidation: $S_c - (S_c)_t$ (in)	Remaining Settlement at 83% of Primary Consolidation: Relative Movement (in)
1	A-2-4	G	0.0	1.3	1.3	0.7	125	18	36				163	81	41	81	5,715				117	0.02	0.500	2,550	2,591	0.020	0.240	0.240	0.240	0.240	0.000	1.123
2	A-6b	C	1.3	3.8	2.5	2.6	120	21	21	2,625	18	40	463	313	153	13,715	6,583	0.270	0.041	0.585		0.06	0.500	2,550	2,703	0.080	0.955	1.707	0.955	1.707	0.000	1.123
	A-6b	C	3.8	6.3	2.5	5.1	120	10	10	1,250	18	40	763	613	297	6,531	3,135	0.270	0.041	0.585		0.12	0.500	2,548	2,846	0.063	0.752		0.752		0.000	1.123
3	A-4a	C	6.3	8.2	1.9	7.3	120	19	19	2,375	19	28	991	877	424	16,574	7,955	0.162	0.024	0.491		0.17	0.499	2,545	2,969	0.026	0.314	0.502	0.314	0.502	0.000	1.123
	A-4a	C	8.2	10.1	1.9	9.2	120	11	11	1,375	19	28	1,219	1,105	534	9,595	4,606	0.162	0.016	0.491		0.22	0.498	2,540	3,073	0.016	0.188		0.188		0.000	1.123
4	A-1-b	G	10.1	16.3	6.2	13.2	130	30	39				2,025	1,622	798	1,622	9,524				128	0.31	0.494	2,521	3,319	0.030	0.360	0.360	0.360	0.360	0.000	1.123
5	A-1-a	G	16.3	21.8	5.5	19.1	135	66	77				2,767	2,396	1,207	2,396	20,953				311	0.45	0.485	2,472	3,679	0.009	0.103	0.375	0.103	0.375	0.000	1.123
	A-1-a	G	21.8	27.3	5.5	24.6	135	55	59				3,510	3,138	1,606	3,138	17,461				211	0.58	0.471	2,403	4,009	0.010	0.124		0.124		0.000	1.123
	A-1-a	G	27.3	32.8	5.5	30.1	135	45	45				4,252	3,881	2,006	3,881	14,286				149	0.71	0.454	2,316	4,322	0.012	0.147		0.147		0.000	1.123
6	A-7-6	C	32.8	37.8	5.0	35.3	125	37	37	4,625	26	45	4,877	4,565	2,362	-	10,400	0.203	0.093	0.645		0.83	0.436	2,223	4,584	0.081	0.977	3.511	0.664	2.387	0.313	0.811
	A-7-6	C	37.8	42.8	5.0	40.3	125	26	26	3,250	26	45	5,502	5,190	2,675	-	12,900	0.203	0.093	0.645		0.95	0.417	2,129	4,803	0.072	0.862		0.586		0.276	0.535
	A-7-6	C	42.8	47.8	5.0	45.3	125	33	33	4,125	26	45	6,127	5,815	2,988	-	15,300	0.203	0.093	0.645		1.07	0.399	2,033	5,021	0.064	0.765		0.520		0.245	0.290
	A-7-6	C	47.8	54.6	6.8	51.2	125	36	36	4,500	26	45	6,977	6,552	3,357	-	18,200	0.203	0.093	0.645		1.20	0.377	1,923	5,280	0.076	0.907		0.617		0.290	0.000

Settlement Remaining After Hold Period: 1.123 in

Depth of Downdrag: 43.1 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{\ m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_r/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E4

Calculated By: BRT Date: 10/18/221

Checked By: JPS Date: 10/20/2021

Boring B-018-2-13

H =	42.5	ft	Total wall height
B =	42.5	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	5,100	psf	Bearing pressure at bottom of wall

	A-6b	A-4a	A-7-6		
c_v =	300	800	183	ft^2/yr	Coefficient of consolidation
t =	120	120	120	days	Time following completion of construction
H_{dr} =	4.5	3.8	10.9	ft	Length of longest drainage path considered
T_v =	4.871	18.214	0.506		Time factor
U =	100	100	77	%	Degree of consolidation

$(S_c)_t$ = 5.888 in Settlement complete at 88% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	Settlement Complete at 88% of Primary Consolidation: $(S_c)_t$ (13) (in)	Layer Settlement (in)	Remaining Settlement at 88% of Primary Consolidation: $S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-2-4	G	0.0	1.3	1.3	0.7	125	18	36				163	81	41	81	5,715				117	0.02	0.500	2,550	2,591	0.020	0.240	0.240	0.240	0.240	0.000	0.807
2	A-6b	C	1.3	3.8	2.5	2.6	120	21	21	2,625	18	40	463	313	153	13,715	6,583	0.270	0.041	0.585		0.06	0.500	2,550	2,703	0.080	0.955	1.707	0.955	1.707	0.000	0.807
	A-6b	C	3.8	6.3	2.5	5.1	120	10	10	1,250	18	40	763	613	297	6,531	3,135	0.270	0.041	0.585		0.12	0.500	2,548	2,846	0.063	0.752		0.752		0.000	0.807
3	A-4a	C	6.3	8.2	1.9	7.3	120	19	19	2,375	19	28	991	877	424	16,574	7,955	0.162	0.024	0.491		0.17	0.499	2,545	2,969	0.026	0.314	0.502	0.314	0.502	0.000	0.807
	A-4a	C	8.2	10.1	1.9	9.2	120	11	11	1,375	19	28	1,219	1,105	534	9,595	4,606	0.162	0.016	0.491		0.22	0.498	2,540	3,073	0.016	0.188		0.188		0.000	0.807
4	A-1-b	G	10.1	16.3	6.2	13.2	130	30	39				2,025	1,622	798	1,622	9,524				128	0.31	0.494	2,521	3,319	0.030	0.360	0.360	0.360	0.360	0.000	0.807
5	A-1-a	G	16.3	21.8	5.5	19.1	135	66	77				2,767	2,396	1,207	2,396	20,953				311	0.45	0.485	2,472	3,679	0.009	0.103	0.375	0.103	0.375	0.000	0.807
	A-1-a	G	21.8	27.3	5.5	24.6	135	55	59				3,510	3,138	1,606	3,138	17,461				211	0.58	0.471	2,403	4,009	0.010	0.124		0.124		0.000	0.807
	A-1-a	G	27.3	32.8	5.5	30.1	135	45	45				4,252	3,881	2,006	3,881	14,286				149	0.71	0.454	2,316	4,322	0.012	0.147		0.147		0.000	0.807
6	A-7-6	C	32.8	37.8	5.0	35.3	125	37	37	4,625	26	45	4,877	4,565	2,362	-	10,400	0.203	0.093	0.645		0.83	0.436	2,223	4,584	0.081	0.977	3.511	0.752	2.703	0.225	0.583
	A-7-6	C	37.8	42.8	5.0	40.3	125	26	26	3,250	26	45	5,502	5,190	2,675	-	12,900	0.203	0.093	0.645		0.95	0.417	2,129	4,803	0.072	0.862		0.664		0.198	0.384
	A-7-6	C	42.8	47.8	5.0	45.3	125	33	33	4,125	26	45	6,127	5,815	2,988	-	15,300	0.203	0.093	0.645		1.07	0.399	2,033	5,021	0.064	0.765		0.589		0.176	0.209
	A-7-6	C	47.8	54.6	6.8	51.2	125	36	36	4,500	26	45	6,977	6,552	3,357	-	18,200	0.203	0.093	0.645		1.20	0.377	1,923	5,280	0.076	0.907		0.698		0.209	0.000

Settlement Remaining After Hold Period: 0.807 in

Depth of Downdrag: 39.9 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}^{\ m}\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
6. C_r = 0.15(Cc) for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L

MSE Wall Settlement - Rear Abutment - Retaining Wall E4

Calculated By: BRT Date: 10/18/221

Checked By: JPS Date: 10/20/2021

Boring B-018-2-13

H =	42.5	ft	Total wall height
B =	42.5	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	5,100	psf	Bearing pressure at bottom of wall

	A-6b	A-4a	A-7-6		
c_v =	300	800	183	ft^2/yr	Coefficient of consolidation
t =	180	180	180	days	Time following completion of construction
H_{dr} =	4.5	3.8	10.9	ft	Length of longest drainage path considered
T_v =	7.306	27.321	0.760		Time factor
U =	100	100	88	%	Degree of consolidation

$(S_c)_t$ = 6.274 in Settlement complete at 94% of primary consolidation

Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)
1	A-2-4	G	0.0	1.3	1.3	0.7	125	18	36				163	81	41	81	5,715
2	A-6b	C	1.3	3.8	2.5	2.6	120	21	21	2,625	18	40	463	313	153	13,715	6,583
	A-6b	C	3.8	6.3	2.5	5.1	120	10	10	1,250	18	40	763	613	297	6,531	3,135
3	A-4a	C	6.3	8.2	1.9	7.3	120	19	19	2,375	19	28	991	877	424	16,574	7,955
	A-4a	C	8.2	10.1	1.9	9.2	120	11	11	1,375	19	28	1,219	1,105	534	9,595	4,606
4	A-1-b	G	10.1	16.3	6.2	13.2	130	30	39				2,025	1,622	798	1,622	9,524
5	A-1-a	G	16.3	21.8	5.5	19.1	135	66	77				2,767	2,396	1,207	2,396	20,953
	A-1-a	G	21.8	27.3	5.5	24.6	135	55	59				3,510	3,138	1,606	3,138	17,461
	A-1-a	G	27.3	32.8	5.5	30.1	135	45	45				4,252	3,881	2,006	3,881	14,286
6	A-7-6	C	32.8	37.8	5.0	35.3	125	37	37	4,625	26	45	4,877	4,565	2,362	-	10,400
	A-7-6	C	37.8	42.8	5.0	40.3	125	26	26	3,250	26	45	5,502	5,190	2,675	-	12,900
	A-7-6	C	42.8	47.8	5.0	45.3	125	33	33	4,125	26	45	6,127	5,815	2,988	-	15,300
	A-7-6	C	47.8	54.6	6.8	51.2	125	36	36	4,500	26	45	6,977	6,552	3,357	-	18,200

										Total Settlement at Facing of Wall			Settlement Complete at 94% of Primary Consolidation		Remaining Settlement at 94% of Primary Consolidation	
Layer	Soil Class.	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-2-4				117	0.02	0.500	2,550	2,591	0.020	0.240	0.240	0.240	0.240	0.000	0.421
2	A-6b	0.270	0.041	0.585		0.06	0.500	2,550	2,703	0.080	0.955	1.707	0.955	1.707	0.000	0.421
	A-6b	0.270	0.041	0.585		0.12	0.500	2,548	2,846	0.063	0.752		0.752		0.000	0.421
3	A-4a	0.162	0.024	0.491		0.17	0.499	2,545	2,969	0.026	0.314	0.502	0.314	0.502	0.000	0.421
	A-4a	0.162	0.016	0.491		0.22	0.498	2,540	3,073	0.016	0.188		0.188		0.000	0.421
4	A-1-b				128	0.31	0.494	2,521	3,319	0.030	0.360	0.360	0.360	0.360	0.000	0.421
5	A-1-a				311	0.45	0.485	2,472	3,679	0.009	0.103	0.375	0.103	0.375	0.000	0.421
	A-1-a				211	0.58	0.471	2,403	4,009	0.010	0.124		0.124		0.000	0.421
	A-1-a				149	0.71	0.454	2,316	4,322	0.012	0.147		0.147		0.000	0.421
6	A-7-6	0.203	0.093	0.645		0.83	0.436	2,223	4,584	0.081	0.977	3.511	0.860	3.089	0.117	0.304
	A-7-6	0.203	0.093	0.645		0.95	0.417	2,129	4,803	0.072	0.862		0.759		0.103	0.201
	A-7-6	0.203	0.093	0.645		1.07	0.399	2,033	5,021	0.064	0.765		0.673		0.092	0.109
	A-7-6	0.203	0.093	0.645		1.20	0.377	1,923	5,280	0.076	0.907		0.798		0.109	0.000

Settlement Remaining After Hold Period: 0.421 in

Depth of Downdrag: 31.1 ft

1. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1 N_{60} p_a/100$ for for $N60\geq52$; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\, N_{60}{}^m\, p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.

W-13-072 - FRA-70-13.10 - FRA-70-1358L
MSE Wall Settlement - Rear Abutment - Retaining Wall E4

Calculated By: BRT Date: 10/18/221
Checked By: JPS Date: 10/20/2021

Boring B-018-2-13

H =	42.5	ft	Total wall height
B =	42.5	ft	Width of embankment (length of wall along abutment face)
D_w =	0.0	ft	Depth below bottom of footing
q =	5,100	psf	Bearing pressure at bottom of wall

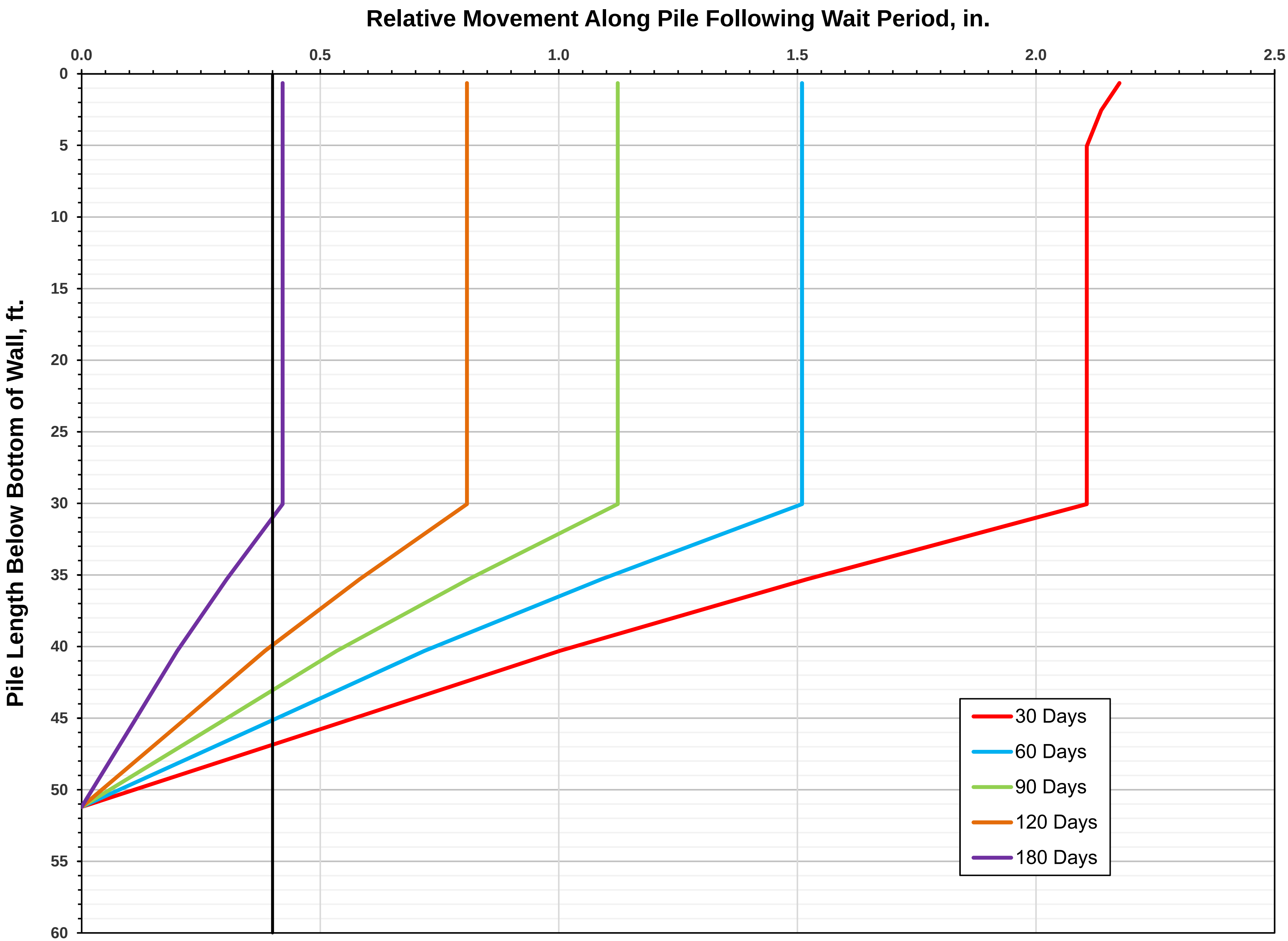
	A-6b	A-4a	A-7-6		
c_v =	300	800	183	ft^2/yr	Coefficient of consolidation
t =	140	140	140	days	Time following completion of construction
H_{dr} =	4.5	3.8	10.9	ft	Length of longest drainage path considered
T_v =	5.682	21.250	0.591		Time factor
U =	100	100	81	%	Degree of consolidation

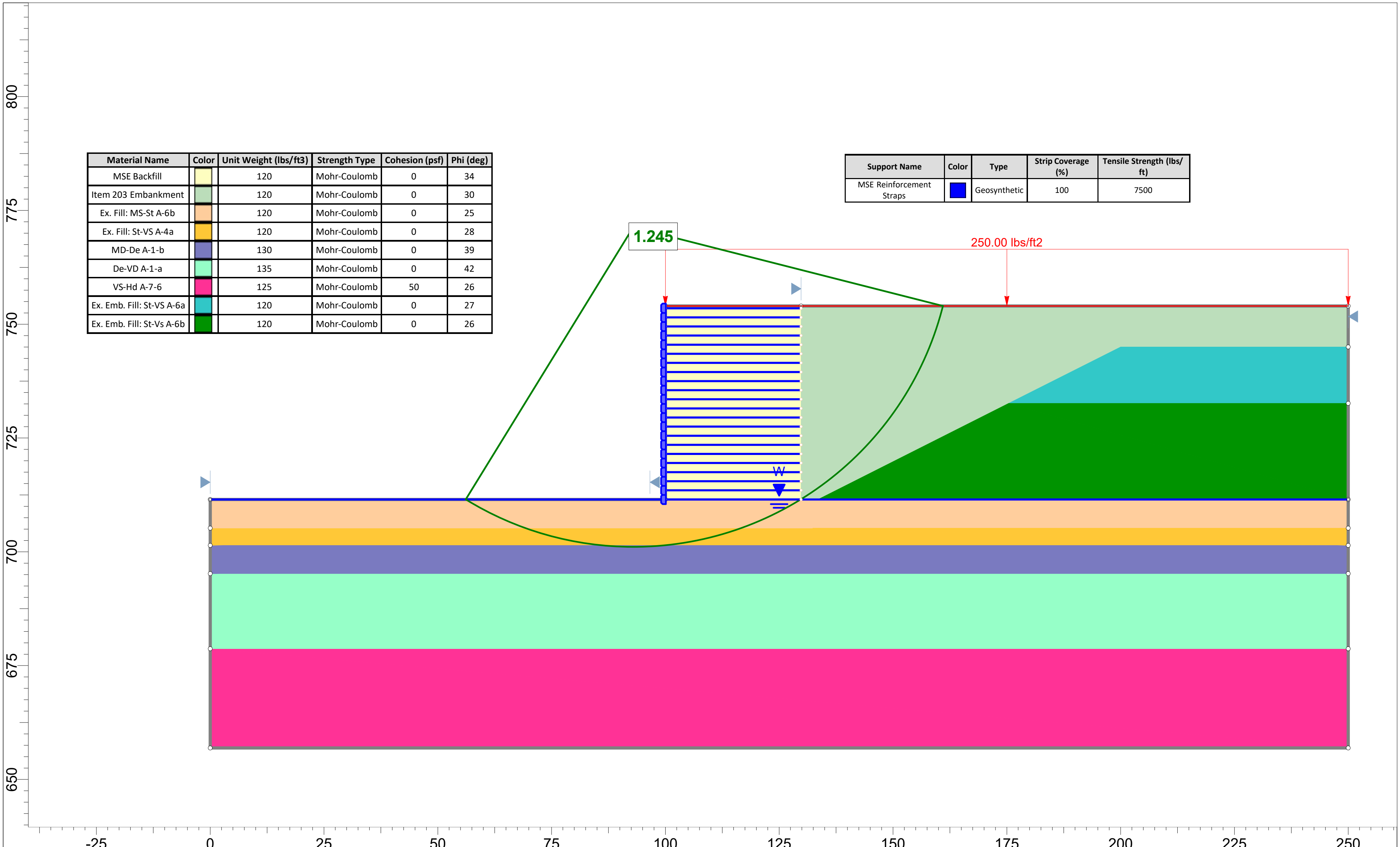
$(S_c)_t$ = 6.028 in Settlement complete at 90% of primary consolidation

																										Total Settlement at Facing of Wall			Settlement Complete at 90% of Primary Consolidation		Remaining Settlement at 90% of Primary Consolidation	
Layer	Soil Class.	Soil Type	Layer Depth (ft)		Layer Thickness H (ft)	Depth to Midpoint (ft)	γ (pcf)	N_{60}	$(N1)_{60}$ (1)	S_u (2) (psf)	PL	LL	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p (3,14) (psf)	σ_p' (4,14) (psf)	C_c (5,14)	C_r (6,14)	e_o (7,14)	C' (8)	Z_f/B	I (9)	$\Delta\sigma_v$ (10) (psf)	σ_{vf}' Midpoint (psf)	S_c (11,12) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (13) (in)	Layer Settlement (in)	$S_c - (S_c)_t$ (in)	Relative Movement (in)
1	A-2-4	G	0.0	1.3	1.3	0.7	125	18	36				163	81	41	81	5,715				117	0.02	0.500	2,550	2,591	0.020	0.240	0.240	0.240	0.240	0.000	0.667
2	A-6b	C	1.3	3.8	2.5	2.6	120	21	21	2,625	18	40	463	313	153	13,715	6,583	0.270	0.041	0.585		0.06	0.500	2,550	2,703	0.080	0.955	1.707	0.955	1.707	0.000	0.667
	A-6b	C	3.8	6.3	2.5	5.1	120	10	10	1,250	18	40	763	613	297	6,531	3,135	0.270	0.041	0.585		0.12	0.500	2,548	2,846	0.063	0.752		0.752		0.000	0.667
3	A-4a	C	6.3	8.2	1.9	7.3	120	19	19	2,375	19	28	991	877	424	16,574	7,955	0.162	0.024	0.491		0.17	0.499	2,545	2,969	0.026	0.314	0.502	0.314	0.502	0.000	0.667
	A-4a	C	8.2	10.1	1.9	9.2	120	11	11	1,375	19	28	1,219	1,105	534	9,595	4,606	0.162	0.016	0.491		0.22	0.498	2,540	3,073	0.016	0.188		0.188		0.000	0.667
4	A-1-b	G	10.1	16.3	6.2	13.2	130	30	39				2,025	1,622	798	1,622	9,524				128	0.31	0.494	2,521	3,319	0.030	0.360	0.360	0.360	0.360	0.000	0.667
5	A-1-a	G	16.3	21.8	5.5	19.1	135	66	77				2,767	2,396	1,207	2,396	20,953				311	0.45	0.485	2,472	3,679	0.009	0.103	0.375	0.103	0.375	0.000	0.667
	A-1-a	G	21.8	27.3	5.5	24.6	135	55	59				3,510	3,138	1,606	3,138	17,461				211	0.58	0.471	2,403	4,009	0.010	0.124		0.124		0.000	0.667
	A-1-a	G	27.3	32.8	5.5	30.1	135	45	45				4,252	3,881	2,006	3,881	14,286				149	0.71	0.454	2,316	4,322	0.012	0.147		0.147		0.000	0.667
6	A-7-6	C	32.8	37.8	5.0	35.3	125	37	37	4,625	26	45	4,877	4,565	2,362	-	10,400	0.203	0.093	0.645		0.83	0.436	2,223	4,584	0.081	0.977	3.511	0.791	2.844	0.186	0.481
	A-7-6	C	37.8	42.8	5.0	40.3	125	26	26	3,250	26	45	5,502	5,190	2,675	-	12,900	0.203	0.093	0.645		0.95	0.417	2,129	4,803	0.072	0.862		0.698		0.164	0.318
	A-7-6	C	42.8	47.8	5.0	45.3	125	33	33	4,125	26	45	6,127	5,815	2,988	-	15,300	0.203	0.093	0.645		1.07	0.399	2,033	5,021	0.064	0.765		0.619		0.145	0.172
	A-7-6	C	47.8	54.6	6.8	51.2	125	36	36	4,500	26	45	6,977	6,552	3,357	-	18,200	0.203	0.093	0.645		1.20	0.377	1,923	5,280	0.076	0.907		0.735		0.172	0.000

Settlement Remaining After Hold Period: 0.667 in

1. $(N1)_{60} = C_nN_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
2. $S_u = 125(N_{60})$ for $N_{60}<52$; Ref. Terzhaghi & Peck (1967) ; $S_u = f_1N_{60}p_a/100$ for for N60≥52; Ref. FHWA-NHI-16-072 (GEC 5), Equation 7.19, per Stroud (1974, 1989)
3. $\sigma_p = S_u/(0.11+0.0037(PI))$; Ref. NAVFAC DM-7.1 "Soil Mechanics," Skempton (1957)
4. Cohesive: $\sigma'_p = \sigma_p - [(\sigma_p/\gamma_{tot})\gamma_w]$; Granular: $\sigma'_p = n\,N_{60}^{\;m}\,p_a$; Ref. FHWA-NHI-10-016 (GEC 10) " Drilled Shafts: Construction Procedures and LRFD Design Methods," Eqn. 3-17, 3-18, Mayne (2007), Kulhawy and Chen (2007)
5. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
6. $C_r = 0.15(Cc)$ for the existing fill and 0.10(Cc) for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
7. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
8. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
9. Influence factor for strip loaded footing
10. $\Delta\sigma_v = q_e(I)$
11. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_{p}'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
12. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
13. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0
14. For the lower A-7-6 layer, values for σ'_p were determined using a best fit interpolation based on measured values obtained from consolidation test results performed on the material, and the average value of C_c, C_r and e_o were used for this layer.


Relative Movement Along Pile Following Wait Period, in.
0.0
0.5
1.0
1.5
2.0
2.5
Pile Length Below Bottom of Wall, ft.
0
5
10
15
20
25
30
35
40
45
50
55
60
30 Days
60 Days
90 Days
120 Days
180 Days



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Ex. Fill: MS-St A-6b		120	Mohr-Coulomb	0	25
Ex. Fill: St-VS A-4a		120	Mohr-Coulomb	0	28
MD-De A-1-b		130	Mohr-Coulomb	0	39
De-VD A-1-a		135	Mohr-Coulomb	0	42
VS-Hd A-7-6		125	Mohr-Coulomb	50	26
Ex. Emb. Fill: St-VS A-6a		120	Mohr-Coulomb	0	27
Ex. Emb. Fill: St-Vs A-6b		120	Mohr-Coulomb	0	26

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		Geosynthetic	100	7500

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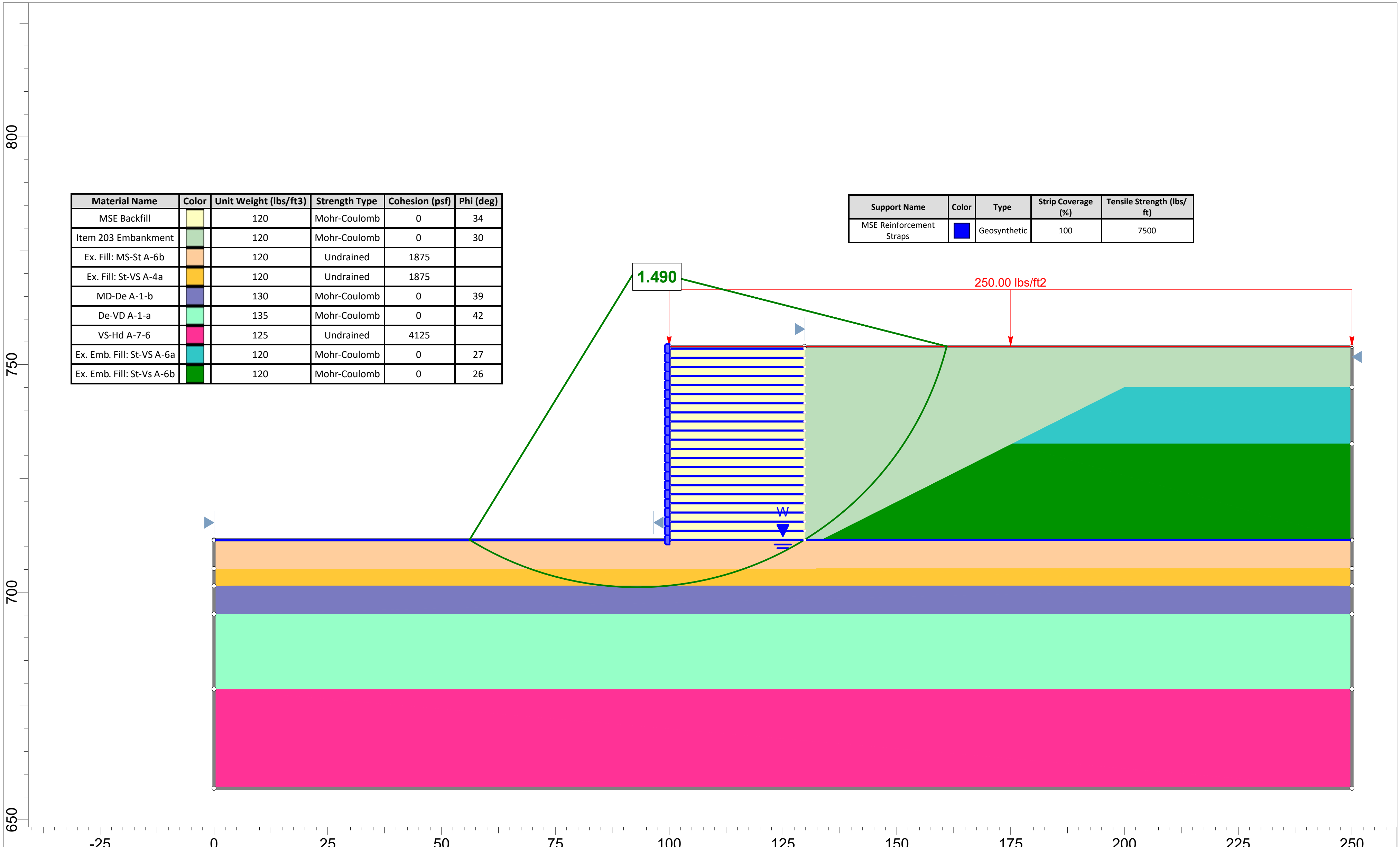
SLIDEINTERPRET 9.012

Project FRA-70-13.10 - FRA-70-1358L - Forward Abutment - Retaining Wall E4 (Sta. 409+50 to 410+98) - Global Stability

Analysis Description 42.5 ft Wall Height - Drained - Circular - Spencer's

Drawn By BRT | *Scale* 1:350 | *Company* Resource International, Inc.

Date 2/22/2021 | *File Name* FRA-70-1358L - Global Stability - Forward Abutment.slim



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Ex. Fill: MS-St A-6b		120	Undrained	1875	
Ex. Fill: St-VS A-4a		120	Undrained	1875	
MD-De A-1-b		130	Mohr-Coulomb	0	39
De-VD A-1-a		135	Mohr-Coulomb	0	42
VS-Hd A-7-6		125	Undrained	4125	
Ex. Emb. Fill: St-VS A-6a		120	Mohr-Coulomb	0	27
Ex. Emb. Fill: St-Vs A-6b		120	Mohr-Coulomb	0	26

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		Geosynthetic	100	7500

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SLIDEINTERPRET 9.012

Project	FRA-70-13.10 - FRA-70-1358L - Forward Abutment - Retaining Wall E4 (Sta. 409+50 to 410+98) - Global Stability
Analysis Description	42.5 ft Wall Height - Undrained - Circular - Spencer's
Drawn By	BRT
Scale	1:350
Company	Resource International, Inc.
Date	2/22/2021
File Name	FRA-70-1358L - Global Stability - Forward Abutment.slim