Resource International, Inc.

FRA-70-12.68 PROJECT 4R
FRA-70-1373A AND R
RAMP C5/I-70 EB OVER SHORT STREET
PID NO. 105523
FRANKLIN COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT

Prepared For:
GPD GROUP
1801 Watermark Drive, Suite 210
Columbus, OH 43215

Prepared By:
Resource International, Inc.
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Columbus, Ohio 43231

Rii Project No. W-13-045

January 2019

RESOURCE INTERNATIONAL, INC.
ISO 9001:2008
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Planning

Engineering

Construction Management

Technology

July 14, 2018 (Revised January 30, 2019)

Mr. Christopher W. Luzier, P.E.
Project Manager
GPD GROUP
1801 Watermark Drive, Suite 210
Columbus, OH 43215

Re: Structure Foundation Exploration Report
FRA-70-12.68 Project 4R
FRA-70-1373A and R – Ramp C5 and I-70 EB over Short Street
PID No. 105523
Rii Project No. W-13-045

Mr. Luzier:

Resource International, Inc. (Rii) is pleased to submit this 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-70-1373A and R bridge structures carrying Ramp C5 and I-70 eastbound over Short Street as part of the FRA-70-12.68 Project 4R 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 Programming

Jonathan P. Sterenberg, P.E.
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Enclosure: Structure Foundation Exploration Report

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EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration for the FRA-70-1373A and R bridge structures carrying the proposed Ramp C5 and I-70 eastbound over Short Street. Based on information provided by Burgess and Niple, it is understood that the proposed FRA-70-1373A and R bridges will consist of single span prestressed concrete I-beam structures with composite reinforced concrete decks and pile supported semi-integral stub abutments behind mechanically stabilized earth (MSE) walls. The existing FRA-70-1358R structure will be completely removed and replaced. In addition, the roadway profile I-70 eastbound will be elevated approximately 15 feet above the existing I-70 eastbound grade as well as approximately 35 feet above the ground surface grade where the bridge will be widened to the south, and the grade along Ramp C5 will be elevated approximately 40 feet above the ground surface grade.

Additionally, please note that the analysis and recommendations for the portion of Retaining Wall 4W8, between Sta. 5080+60, 22.4' Rt. (BL Ramp C5) and 175+91, 38.2' Lt. (BL I-70 EB), at the rear abutment, and Retaining Wall 4W5, between Sta. 179+66, 39.8' Lt. (BL I-70 EB) and 5081+38, 24.3' Rt. (BL Ramp C5), at the forward abutment, are presented under this report cover. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Wall 4W8. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Wall 4W5. However, given the presence of existing fill material to significant depths, as well as the significant amount of existing utilities within the footprint of this wall, it is understood that lightweight fill material consisting of cellular concrete will be utilized along the length of the wall that crosses in front of the abutments.

Exploration and Findings

Between July 1 and March 17, 2015, four (4) structural borings, designated as B-020-1-13 through B-020-3-13 and B-020-9-15, were drilled to completion depths ranging from 49.8 to 86.0 feet below the existing ground surface as part of the current exploration. In addition, borings B-020-5-13 and B-020-7-13, which were performed as part of the FRA-70-13.10 Project 6A for the proposed FRA-70-1373L bridge structure, were also utilized for subsurface evaluation and foundation analysis for the FRA-70-1373R structure. The borings were performed between February 18, 2014, and January 29, 2015, and were advanced to a depth of 90.0 and 80.4 feet below existing grade, respectively. In addition to the borings performed by Rii for the current exploration, one (1) boring, designated as B-021-0-08, was performed in the vicinity of the structure by DLZ as part of the FRA-70-8.93 preliminary exploration and their findings were published in a report dated March 2010. The boring was performed between July 29 and 31, 2008, and was advanced to a completion depth of 90.0 feet below the existing ground surface.

Boring B-020-1-13 was on the property located at the southwest corner of Short Street and an access drive that extends west of Short Street along the south side of I-70 to the existing railroad tracks and encountered 6.0 inches of topsoil overlying 4.0 inches of brick pavers at the ground surface. Boring B-020-2-13 was drilled through existing pavement at the entry of the access drive and encountered 4.0 inches of asphalt overlying 6.0 inches of aggregate base. Borings B-020-3-13 and B-020-9-13 were drilled through the existing pavement of Short Street and encountered 4.0 inches of asphalt overlaying 4.0 inches of brick pavers in each boring followed by 9.0 and 3.0 inches of aggregate base, respectively, at the ground surface. Boring B-020-5-13 was drilled in the median shoulder of I-70 westbound and encountered 6.0 inches of concrete overlying 6.0 inches of aggregate base at the ground surface. Boring B-020-7-13 was drilled through the existing sidewalk along the east side of Short Street, below the existing structure and between the curb and pier columns, and encountered 8.0 inches of concrete at the ground surface. Boring B-021-0-08 was drilled on the property located at the southeast corner of W. Fulton Street and Short Street and encountered 3.0 inches of gravel at the ground surface.

Beneath the surface materials in borings B-020-1-13, B-020-2-13, B-020-3-13, B-020-7-13, B-020-9-15 and B-021-0-08, material identified as existing fill was encountered extending to depths ranging from 10.5 to 21.5 feet below existing grade, which corresponds to elevations ranging from 690.9 to 702.5 feet msl. The fill material consisted of dark brown, brown, black and gray gravel and sand, gravel with sand and silt, sandy silt, silt and clay, silty clay and clay (ODOT A-1-b, A-2-4, A-6a, A-6b, A--7-6). The fill material was placed within the limits of the abandoned canal and contains construction debris and organics throughout. Additionally, the SPT blow counts were significantly lower and more variable within the fill depth of the borings where fill was encountered. Boring B-020-5-13 encountered existing embankment fill consisting of brown silt and clay (ODOT A-6a) extending to a depth of 25.5 feet below the existing ground surface. The fill contained wood and brick fragments.

Underlying the surficial materials and existing fill, natural granular and cohesive soils were encountered. The granular soils were generally described as brown, gray, brownish gray, dark brown and black gravel, gravel and sand, gravel with sand and silt, gravel with sand, silt and clay, fine sand and sandy silt (ODOT A-1-a, A-1-b, A-2-4, A-2-6, A-3, A-4a). The cohesive soils were described as gray, brown, brownish gray sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6). Granite boulders were encountered in boring B-020-3-13 at an elevation of 686.3 feet msl and again at an elevation of 662.5 feet msl. Auger refusal was encountered at these elevations, and rock coring was performed for a 5.0-foot interval at both instances, which small boulder pieces were recovered from the core runs. Granite boulders were also encountered in borings B-020-5-13 and B-020-7-13 at an elevation of 657 feet msl, and rock coring was performed below this elevation.

Top of bedrock was encountered in borings B-020-1-13, B-020-2-13, B-020-5-13, B-020-7-13, B-020-9-13 and B-021-0-08 at elevations ranging from 647.1 to 660.9 feet msl. The upper portion of the bedrock consists of weak shale which was able to be

augered to competent shale or mudstone bedrock in borings B-020-2-13, B-020-5-13 and B-021-0-08 and competent limestone bedrock in boring B-020-1-13. The cored bedrock consists of shale and mudstone, which was encountered in borings B-020-2-13, B-020-5-13, B-020-7-13, B-020-9-13, B-021-0-08 and B-024-0-08 at elevations ranging from 641.9 to 657.9 feet msl, and limestone bedrock, which was encountered in borings B-020-1-13 and B-020-2-13 an elevation of 632.3 and 631.9 feet msl, respectively.

Analyses and Recommendations

Driven Pile Recommendations

Given the depth to bedrock encountered in the borings, it is recommended that steel H-piles (ODOT Item 507.06) driven to refusal on bedrock be employed for foundation support of the proposed substructure elements. Per Section 202.2.3.2a of the 2007 ODOT Bridge Design Manual, 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 7 shows the recommended pile lengths and the corresponding factored structural axial resistance ($R_{R\ max}$) of steel H-piles.

FRA-70-1373A and R Driven Pile Recommendations

Structure Reference	Substructure Reference (Boring)	Ground Elevation [1]	Pile Size	Pile Elevation		Pile Length [3] (feet)	$R_{R\ max}$ [4] (kips/pile)	Sleeve Length [5]	φ [6]
				Top [2]	Tip				
FRA-70-1373A	Rear Abutment (B-020-1-13)	712.8	HP 10x42	738.0	647.8	95	310	30.5	N/A
	Forward Abutment (B-020-9-15)	713.0	HP 10x42	741.4	652.5	90	310	31.1	N/A
FRA-70-1373R	Rear Abutment (B-020-2-13)	711.4	HP 10x42	732.1	641.9	95	310	24.6	N/A
	Forward Abutment (B-020-7-13)	713.5	HP 10x42	731.3	648.1	85	310	22.3	N/A

1. *Ground elevation listed is the ground elevation at the respective boring location.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is 1.0-foot above the proposed bottom of footing elevation.*
3. *Per Section 202.3.2 of the 2007 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.*
4. *The factored structural axial resistance for H-piles is based on the structural limit state of the steel H-pile section per Section 202.2.3.2.a of the 2007 ODOT BDM.*
5. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall backfill, including the foundation preparation.*
6. *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.*

Consideration was given to the use of friction piles using cast-in-place (CIP) pipe piles; however, given the required pile reactions provided by Burgess and Niple, additional piles would be required to support the proposed substructure units, which would result in additional costs. Existing fill consisting primarily of soft to stiff silt and clay, silty clay and clay with interbedded layers of very loose to loose granular soil was encountered extending to elevations ranging from 690.9 to 702.5 feet msl. The fill material contained debris and organics throughout. Below the fill material medium dense to very dense granular soils consisting of gravel and gravel and sand were encountered which extended to approximate elevations of 660 to 665 feet msl. Analyses indicate that 16-inch CIP piles would only be able to be driven a short distance into this material before reaching the maximum capacity and overstressing the piles. Given the weak and variable nature of the overlying fill material, the capacity would need to be carried almost solely in the end bearing of the pile. Additionally, as the bridge site is situated in a flood plain area, it is anticipated that the site will be inundated during the design life. Therefore, if a critical design groundwater elevation at the finished grade of the roadway is considered, there will be a significant reduction in the capacity of the piles, which would likely result in significant settlement or complete failure of the piles. Therefore, CIP pipe piles were not considered for foundation support of the proposed substructures.

The anticipated total settlement along the facing of Wall 4W8 at the rear abutment of the two structures is approximately 9.5 inches, and total settlements along the facing of Wall 4W5 at the forward abutment of the two structures is approximately 2.5 inches. 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 20 to 55 days following the placement of the surcharge load. However, even at 90 percent consolidation, the remaining settlement still exceeds 0.4 inches along Wall 4W8 at the rear abutment of both structures, which is the relative movement that results in full mobilization of the side resistance, and thus generating downdrag loads. Since the majority of the settlement is occurring within the upper fill material, if this material is stabilized, then the total amount of settlement will be reduced, resulting in the elimination of the downdrag loading.

MSE Wall Recommendations

Based on proposed plan and profile information provided by Dynotec, the maximum wall heights along Retaining Wall 4W8 where it crosses in front of the rear abutment of the FRA-70-1373A and FRA-70-1373R structures is 43.3 and 39.8 feet, respectively, from the top of the leveling pad to the proposed profile grade of the roadway. Therefore, it is considered that the minimum reinforcement length and the effective foundation width (B) of the rear and forward abutment MSE walls for external and global stability calculations will be 30.3 and 27.9 feet, respectively. Since the wall is located within an existing floodplain, the analysis was performed using a design groundwater level at the ground surface.

The anticipated bearing materials at the proposed bearing elevation along Retaining Wall 4W8, along the rear abutment of both structures, consists of existing fill comprised of soft to stiff silt and clay, silty clay and clay (ODOT A-6a, A-6b, A-7-6) with seams of vey loos to medium dense gravel and sand and gravel with sand and silt (ODOT A-1-b, A-2-4) and contained slag, cinders and organic material. As noted in Section 5.2 of the full report, it is understood that ground improvement techniques will be implemented along the alignment of Retaining Wall 4W8, including where the wall crosses the rear abutment of both structures. As this is a proprietary design, the analysis for this wall considers the existing fill material will remain in place. MSE wall foundations bearing on the existing fill material may be proportioned for a nominal bearing resistance as indicated in the following table. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored nominal bearing resistance at the strength limit state.

Retaining Wall 4W8 MSE Wall Design Parameters

Structure Reference / Substructure Unit (Boring)	Wall Height Analyzed (feet)	Backslope Behind Wall	Minimum Required Reinforcement Length [1] (feet)	Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing Pressure [3] (ksf)
				Nominal	Factored [2]	
FRA-70-1373A Rear Abutment / Retaining Wall 4W8 (B-020-1-13)	43.3	Level	30.3 (0.7H)	5.10	3.32	9.74
FRA-70-1373R Rear Abutment / Retaining Wall 4W8 (B-020-2-13)	39.8	Level	27.9 (0.7H)	8.94	5.81	9.01

1. *The required foundation width is 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.*

Total settlements of approximately 15.5 inches at the center of the reinforced soil mass and 9.5 inches at the facing of the wall are anticipated along Wall 4W8 where is crosses in front of the rear abutment of the two structures. Based on the results of the analysis, 90 percent of the total settlement is anticipated to occur over a period of approximately 20 to 55 days.

Based on the results of the external and global stability analysis performed for the MSE wall, 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 1.0 times the wall height still did not satisfy all of the external and global stability requirements. As noted in Section 5.2 of the full report, consideration was given to over excavating these soils and

replacing it with granular embankment; however, similar conditions are anticipated along the remainder of the alignment of Retaining Wall 4W8, which makes this a very expensive and uneconomical option. Recommendations have been provided in the structure foundation exploration report for Retaining Wall 4W8 to incorporate the use of ground improvement techniques to stabilize the existing fill and underlying cohesive soils. The recommendations for this alternative should govern the design of this portion of the wall as well.

Lightweight (Cellular Concrete) Wall Recommendations

Given the presence of existing fill material to significant depths, as well as the significant amount of existing utilities present along the east side of Short Street, it is understood that lightweight fill material consisting of cellular concrete will be utilized as the backfill along the length of Wall 4W5 that crosses in front of the forward abutment of both structures. The use of the lightweight cellular concrete will eliminate the need for undercut or ground improvement to stabilize the underlying existing fill material and control settlement to tolerable limits. Based on information provided by GPD GROUP, two types of lightweight cellular concrete will be utilized in lieu of typical embankment fill and select granular fill, which is typically used for MSE wall applications. The wall facing will be connected to geosynthetic straps that are embedded into the cellular concrete and supported on a leveling pad, similar to traditional MSE walls. Since the wall is located within an existing floodplain, the analysis was performed using a design groundwater level at the ground surface.

It is recommended that the reinforcement extend the minimum length of 70 percent of the wall height into the cellular concrete backfill, similar to traditional MSE walls.

Based on the plan information provided, it is understood that the cellular concrete fill will be placed the full height of the embankment within the limits of Ramp C5 as well as I-70 eastbound to the east side of the Franklin main, which is approximately 400 feet east of Short Street. As such, external and global stability calculations will not be required for this section of Wall 4W5. However, if bearing resistance must be checked, then a factored bearing resistance of 3.0 ksf should be utilized for design at the strength limit state.

Total settlements of 3.14 to 3.68 inches at the center of the wall mass and 2.33 to 2.69 inches at the facing of the wall are anticipated along Wall 4W5 where is crosses in front of the forward abutment of the two structures. Based on the results of the analysis, 90 percent of the total settlement is anticipated to occur over a period of approximately 0 to 55 days.

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-70-12.68/13.11/14.05C (Project 4R/4H/4A) projects in Columbus, Ohio. The projects represent the central portion of FRA-70-8.93 (PID 77369) I-70/71 south innerbelt improvements project. The FRA-70-12.68 (Project 4R) phase will consist of all work associated with the construction of Ramp C5, starting at the bridge over Souder Avenue and extending east to Front Street. The proposed Ramp C5 will be a two-lane to four-lane ramp that will collect and direct traffic from I-71 northbound and SR-315 southbound as well as I-70 eastbound to exit in downtown at the intersection of Front Street and W. Fulton Avenue. This project includes the construction of six (6) new bridge structures for the proposed Ramp C5 alignment and replacement of three (3) bridge structures, two along I-70 and the Front Street Structure over I-70, as well as the construction of fourteen (14) new retaining walls and a culvert structure to accommodate the new configuration.

This report is a presentation of the structure foundation exploration performed for the FRA-70-1373A and R bridge structures carrying the proposed Ramp C5 and I-70 eastbound over Short Street, as shown on the vicinity map and boring plan presented in Appendix I. Based on information provided by Burgess and Niple, it is understood that the proposed FRA-70-1373A bridge will consist of a single span prestressed concrete I-beam structure with a composite reinforced concrete deck with pile supported semi-integral stub abutments behind mechanically stabilized earth (MSE) walls. The proposed structure will have a total length of approximately 93 feet and width of approximately 41.5 feet. In addition, the roadway profile will be elevated approximately 40 feet above the existing ground surface grade.

The existing FRA-70-1373R structure is a three-span bridge with a total length of approximately 118 feet. It is understood that the existing structure will be completely removed and replaced with a single span prestressed concrete I-beam structure with a composite reinforced concrete deck with pile supported semi-integral stub abutments behind mechanically stabilized earth (MSE) walls. The proposed structure will have a total length of approximately 94 feet and will be widened to the south approximately 60 to 65 feet, for an overall width of approximately 100 feet. In addition, the roadway profile will be elevated approximately 15 feet above the existing I-70 eastbound grade as well as approximately 35 feet above the ground surface grade where the bridge will be widened to the south.

Additionally, please note that the analysis and recommendations for the portions of Retaining Wall 4W8, between Sta. 5080+60, 22.4’ Rt. (BL Ramp C5) and 175+91, 38.2’ Lt. (BL I-70 EB), at the rear abutment, and Retaining Wall 4W5, between Sta. 179+66, 39.8’ Lt. (BL I-70 EB) and 5081+38, 24.3’ Rt. (BL Ramp C5), at the forward abutment, are presented under this report cover. Design recommendations for the remaining alignment of Retaining Walls 4W5 and 4W8 are presented under separate covers.

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 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 limy dolomite. Both of these members contain chert nodules. Just 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. Shale bedrock was encountered in several of the borings utilized for this project at elevations ranging from 647.1 to 660.9 msl.

2.2 Existing Conditions

The proposed FRA-70-1373A and R structures are located at the existing I-70 over Short Street overpass, approximately 200 feet south of the intersection of Short Street and Mound Street and approximately 1,100 feet west of the Front Street overpass. The existing I-70 eastbound in the vicinity of the structures is a three-lane, asphalt paved roadway that is aligned east-to-west. The existing I-70 roadway profile grade is elevated approximately 26 feet above the Short Street profile grade, and is supported by an existing cast-in-place (CIP) retaining wall along the south side of the alignment between the highway and W. Fulton Street. Based on utility plans provided by GPD GROUP, there are many buried utilities within the Short Street and W. Fulton Street roadways and also beneath the surrounding sidewalks, including the Olentangy Scioto Interceptor Sewer (OSIS), which runs north to south within the roadway of Short Street. Additionally, based on information provided by ODOT and GPD GROUP, it is understood that a canal was formerly located in the area of the Short Street and W. Fulton Street intersection, which was abandoned and filled in prior to construction of the original US 40 / I-70 roadways. The terrain along I-70 slopes down gently to the east and along W. Fulton Street slopes up moderately to the east from Short Street, and the surrounding area in the vicinity of the intersection of Short Street and W. Fulton Street is relatively flat-lying.

3.0 EXPLORATION

Between July 1 and August 21, 2013, three (3) structural borings, designated as B-020-1-13 through B-020-3-13, were drilled to completion depths ranging from 49.8 to 86.0 feet below the existing ground surface. Auger refusal was encountered at a depth of 26.0 feet below the ground surface in boring B-020-3-13, and a 5.0-foot rock core run recovered a 1.5-foot thick granite boulder at this depth overlying natural soils. The boring was continued below this depth following the rock core through the boulder, and another boulder was encountered at a depth of 49.8 feet below existing grade. The boring could not be advanced beyond this depth using the hollow-stem augers or a casing advancer with a tri-cone bit. Therefore, the boring was terminated at this depth. On March 16 and 17, 2015, boring B-020-9-15 was performed within Short Street approximately 45 feet closer to the bridge structure and extended to a depth of 75.5 feet below grade.

In addition, borings B-020-5-13 and B-020-7-13, which were performed as part of the FRA-70-13.10 Project 6A for the proposed FRA-70-1373L bridge structure, were also utilized for subsurface evaluation and foundation analysis for the FRA-70-1373R structure. These borings were performed between February 18, 2014, and January 29, 2015, and were advanced to a depth of 90.0 and 80.4 feet below existing grade, respectively. On February 23, 2014, auger refusal was encountered in boring B-020-5-13 at a depth of 75.5 feet below the ground surface, and a 1.1-foot rock core run recovered 9.0-inches of granite from a boulder. The boring could not be advanced beyond this depth using the hollow-stem augers, and due to time restrictions for the

traffic control, the boring was terminated at this depth. On January 22, 2015, boring B-020-5-13 was extended to bedrock and cored to the depth noted above in accordance with ODOT SGE requirements and per the comment provided for the Stage 1 preliminary report. Boring B-020-7-13 was located within the eastern sidewalk underneath of the existing bridge structure due to the inability to perform the boring from the roadway grade above. Due to the limited overhead clearance, the drilling for this boring was performed by Stock Drilling using a low-head clearance rig.

In addition to the borings performed by Rii for the current exploration, one (1) boring, designated as B-021-0-08, was performed in the vicinity of the structure by DLZ as part of the FRA-70-8.93 preliminary exploration and their findings were published in a report dated March 2010. The boring was performed between July 29 and 31, 2008, and was advanced to a completion depth of 90.0 feet below the existing ground surface. The current project boring locations are shown on the boring plan provided in Appendix I of this report and summarized in Table 1 below.

Table 1. Test Boring Summary

Boring Number	Reference Alignment	Station	Offset	Latitude	Longitude	Ground Elevation (feet msl)	Boring Depth (feet)
B-020-1-13	BL Ramp C5	5080+09.80	30.9' Rt.	39.952922218	-83.004665587	712.8	86.0
B-020-2-13	BL I-70 EB	176+13.92	34.0' Rt.	39.953155708	-83.004534664	711.4	84.5
B-020-3-13	BL Ramp C5	5081+15.55	85.3' Rt.	39.952760425	-83.004309070	712.3	49.8
B-020-5-13	BL I-70 WB	175+57.74	11.8' Rt.	39.953452196	-83.004773258	733.4	90.0
B-020-7-13	BL I-70 WB	176+68.64	1.8' Rt.	39.953451540	-83.004376859	713.5	80.4
B-020-9-15	BL Ramp C5	5081+05.25	39.8' Rt.	39.952886963	-83.004333117	713.0	75.5
B-021-0-08	BL Ramp C5	5082+48.43	39.8' Rt.	39.952847911	-83.003831990	727.9	90.0

With the exception of B-021-0-08, 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 GPD GROUP.

The borings were drilled using a truck or all-terrain vehicle (ATV) mounted rotary drilling machine, utilizing a 3.25-inch or 4.25-inch inside diameter, continuous hollow-stem auger to advance the holes. In general, 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 boring termination depth or top of bedrock. For boring B-020-5-13, split spoon sampling was performed at 5.0-foot increments to a depth of 20.0 feet, at 2.5-foot intervals for the next 30.0 feet and then at 5.0-foot intervals 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 hammers for the Mobile B-53 and CME 750 drill rigs operated by Rii were calibrated on April 26, 2013, and have drill rod energy ratios of 77.7 and 82.6 percent, respectively. The hammer for the CME 55 drill rig operated by Rii was calibrated on October 20, 2014, and has a drill rod energy ratio of 92.0 percent. The hammers for the CME 750X and CME 55-LC drill rigs operated by Stock Drilling were calibrated on March 28, 2013, and have a drill rod energy ratios of 78.6 and 73.2 percent, respectively. The hammer for the CME 75 drill rig used by DLZ has a drill rod energy ratio of 61.2 percent.

During drilling for the borings performed by Rii and Stock Drilling, field logs were prepared by Rii personnel showing the encountered subsurface conditions. Soil samples obtained from the drilling operation were preserved and sealed in glass jars and delivered to the soil laboratory. In the laboratory, the soil 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	113
Plastic and Liquid Limits	AASHTO T89, T90	39
Gradation – Sieve/Hydrometer	AASHTO T88	39
One-Dimensional Consolidation	ASTM D2435	2
Consolidated Undrained (CU) Triaxial Test	ASTM D4767	2
Point Load Strength Index of Rock Specimens	ASTM D5731	1
Unconfined Compressive Strength of Intact Rock	ASTM D7012	1

The tests performed are necessary to classify existing soil 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 in Appendix V and in part, on the boring logs in Appendix III. A description of the soil terms used throughout this report is presented in Appendix II.

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 or auger refusal, or by visual inspection of the very weak to weak shale and mudstone samples in conjunction with the blow counts obtained from the SPT testing. Split spoon sampler refusal is defined as exceeding 50 blows from the hammer with less than 6.0 inches of penetration by the split spoon sampler. 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 bedrock (after encountering auger refusal), an NQ or HQ-sized double-tube diamond bit core barrel (utilizing wire line equipment) was used to core the bedrock. Coring produced 1.85 or 2.45 inch diameter cores, for NQ and HQ-sized cores, respectively, 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:

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

In addition to the project borings, historic borings performed in 1959 by the Department of Highways as part of the FRA-40-12.89 project were also obtained from the construction documents on record. One (1) boring, designated as B-001-A-59, was obtained along the alignment of the existing CIP wall separating I-70 eastbound and W. Fulton Street. The boring was extended to a depth of 51.0 feet below the existing grade at the time of the exploration. Please note that the elevations provided on the historic boring logs were referenced to the North American Datum (NAD) 27. The

current design survey is referenced to NAD 83. The NAD 27 datum is 0.6 feet lower than the NAD 83 datum. **Therefore, all elevations noted in this report with respect to the historic borings are adjusted to the current NAD 83 datum.** The historic boring location is shown on the boring plan provided in Appendix I, and the historic boring log is provided in Appendix IV.

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 respective version of the ODOT Specifications for Geotechnical Explorations (SGE) at the time the exploration borings were performed. The following is a summary of what was found in the test borings performed as part of the preliminary engineering phase and current exploration and what is represented on the boring logs.

4.1 Surface Materials

Boring B-020-1-13 was performed on the property located at the southwest corner of Short Street and an access drive that extends west of Short Street along the south side of I-70 to the existing railroad tracks and encountered 6.0 inches of topsoil overlying 4.0 inches of brick pavers at the ground surface. Boring B-020-2-13 was drilled through existing pavement at the entry of the access drive and encountered 4.0 inches of asphalt overlying 6.0 inches of aggregate base. Borings B-020-3-13 and B-020-9-13 were drilled through the existing pavement of Short Street and encountered 4.0 inches of asphalt overlaying 4.0 inches of brick pavers in each boring followed by 9.0 and 3.0 inches of aggregate base, respectively, at the ground surface. Boring B-020-5-13 was drilled in the median shoulder of I-70 westbound and encountered 6.0 inches of concrete overlying 6.0 inches of aggregate base at the ground surface. Boring B-020-7-13 was drilled through the existing sidewalk along the east side of Short Street, below the existing structure and between the curb and pier columns, and encountered 8.0 inches of concrete at the ground surface. Boring B-021-0-08 was drilled on the property located at the southeast corner of W. Fulton Street and Short Street and encountered 3.0 inches of gravel at the ground surface.

4.2 Subsurface Soils

Beneath the surface materials in borings B-020-1-13, B-020-2-13, B-020-3-13, B-020-7-13, B-020-9-15 and B-021-0-08, material identified as existing fill was encountered extending to depths ranging from 10.5 to 21.5 feet below existing grade, which corresponds to elevations ranging from 690.9 to 702.5 feet msl. The fill material consisted of dark brown, brown, black and gray gravel and sand, gravel with sand and silt, sandy silt, silt and clay, silty clay and clay (ODOT A-1-b, A-2-4, A-6a, A-6b, A--7-6). The fill material was placed within the limits of the abandoned canal and was observed to contain debris and organics throughout. Additionally, the SPT blow counts were

significantly lower and more variable within the fill depth of the borings where fill was encountered.

Boring B-020-5-13 encountered existing embankment fill consisting of brown silt and clay (ODOT A-6a) extending to a depth of 25.5 feet below the existing ground surface. The fill contained wood and brick fragments.

Underlying the surficial materials and existing fill, natural granular and cohesive soils were encountered. The granular soils were generally described as brown, gray, brownish gray, dark brown and black gravel, gravel and sand, gravel with sand and silt, gravel with sand, silt and clay, fine sand and sandy silt (ODOT A-1-a, A-1-b, A-2-4, A-2-6, A-3, A-4a). The cohesive soils were described as gray, brown, brownish gray sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6). Granite boulders were encountered in boring B-020-3-13 at an elevation of 686.3 feet msl and again at an elevation of 662.5 feet msl. Auger refusal was encountered at these elevations, and rock coring was performed for a 5.0-foot interval at both instances, which small boulder pieces were recovered from the core runs. Granite boulders were also encountered in borings B-020-5-13 and B-020-7-13 at an elevation of 657 feet msl, and rock coring was performed below this elevation. Based on the lack of recovery and observation of the soil washout in the circulation fluid in core runs RC-1 through RC-3, it is anticipated that this material is a hard cohesive soil rather than highly weathered bedrock.

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} < 6 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 soils encountered ranged from very soft (HP $\leq$ 0.25 tsf) to hard (HP > 4.0 tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from less than 0.25 to over 4.5 tsf (limit of instrument).

Natural moisture contents of the soil samples tested ranged from 4 to 37 percent. The natural moisture content of the cohesive soil samples tested for plasticity index ranged from 7 percent below to 7 percent above their corresponding plastic limits. In general, the soils exhibited natural moisture contents considered to be moderately below to moderately above optimum moisture levels.

4.3 Bedrock

Bedrock was encountered in all of the borings as presented in Table 3.

Table 3. Top of Bedrock Elevations

Boring Number	Ground Surface Elevation (feet msl)	Top of Bedrock (Sampler Refusal)		Top of Bedrock Core (Auger Refusal)	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-020-1-13	712.8	64.2	648.6	80.5	632.3
B-020-2-13	711.4	64.3	647.1	69.5	641.9
B-020-3-13	712.3	N/A	N/A	N/A	N/A
B-020-5-13	733.4	76.6	656.8	80.0	653.4
B-020-7-13	713.5	65.4	648.1	65.4	648.1
B-020-9-15	713.0	60.5	652.5	60.5	652.5
B-021-0-08	727.9	67.0	660.9	70.0	657.9

Top of bedrock was encountered in borings B-020-1-13, B-020-2-13, B-020-5-13, B-020-7-13, B-020-9-13 and B-021-0-08 at elevations ranging from 647.1 to 660.9 feet msl. The upper portion of the bedrock consists of weak shale which was able to be augered to competent shale or mudstone bedrock in borings B-020-2-13, B-020-5-13 and B-021-0-08 and competent limestone bedrock in boring B-020-1-13. The cored bedrock consists of shale and mudstone, which was encountered in borings B-020-2-13, B-020-5-13, B-020-7-13, B-020-9-13, B-021-0-08 and B-024-0-08 at elevations ranging from 641.9 to 657.9 feet msl, and limestone bedrock, which was encountered in borings B-020-1-13 and B-020-2-13 an elevation of 632.3 and 631.9 feet msl, respectively.

The mudstone is described as gray, slightly to highly weathered, very weak to weak, thinly laminated to thick bedded, arenaceous, calcareous, fissile, friable and slightly to highly fractured with tight to open, slightly rough to very rough apertures. The shale is described as dark gray, bluish gray and black, unweathered to highly weathered, very weak to slightly strong, laminated to thick bedded, arenaceous, calcareous, fissile, friable, pyritic, jointed and moderately to highly fractured with tight to open, slightly rough to very rough apertures. The limestone is described as gray and tan, unweathered to slightly weathered, moderately strong to strong, very thin to medium bedded, calcareous, crystalline, dolomitic, pyritic and slightly fractured to fractured with narrow to open, slightly rough to very rough apertures.

The percent recovery, RQD values and unconfined compressive strengths of the bedrock core runs are summarized in Table 4.

Table 4. Rock Core Summary

Boring	Core No.	Elevation (feet msl)	Recovery (%)	RQD (%)	Unconfined Compressive Strength
B-020-1-13	RC-2	632.3 to 626.8	99	49	q_u @ 80.7' = 9,465 psi
B-020-2-13	RC-1	641.9 to 636.9	40	8	N/A
	RC-2	636.9 to 631.9	20	0	N/A
	RC-3	631.9 to 626.9	97	97	N/A
B-020-5-13	RC-2	653.4 to 648.4	80	63	N/A
	RC-3	648.4 to 643.4	100	72	N/A
B-020-7-13	RC-4	648.1 to 638.1	97	89	q_u @ 69.4' = 224 psi [1]
	RC-5	638.1 to 633.1	100	45	N/A
B-020-9-13	RC-1	652.5 to 647.5	52	17	N/A
	RC-2	647.5 to 642.5	75	48	N/A
	RC-3	642.5 to 637.5	100	80	N/A
B-021-0-08	R1	657.9 to 652.9	100	82	N/A
	R2	652.9 to 647.9	100	90	N/A
	R3	647.9 to 642.9	100	75	N/A
	R4	642.9 to 637.9	100	87	q_u @ 82.8' = 1,536 psi

1. *Represents the mean unconfined compressive strength based on correlations with the mean point load strength index.*

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 zones where boulders were encountered that required rock coring techniques to advance through these zones are not included in the RQD tabulation above. The quality of the cored mudstone and shale bedrock, according to the RQD values of the bedrock units, ranged from very poor (RQD ≤ 25%) to good (75% < RQD ≤ 90%), and the quality of the cored limestone bedrock ranged from fair (50% < RQD ≤ 75%) to excellent (RQD > 90%).

4.4 Groundwater

Groundwater was encountered in the borings as presented in Table 5.

Table 5. Groundwater

Boring Number	Ground Elevation (feet msl)	Initial Groundwater		Upon Completion	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-020-1-13	712.8	23.0	689.8	N/A [1]	N/A
B-020-2-13	711.4	18.5	692.9	N/A [1]	N/A
B-020-3-13	712.3	15.0	697.3	N/A [1]	N/A
B-020-5-13	733.4	43.5	689.9	N/A [1]	N/A
B-020-7-13	713.5	N/A [2]	N/A	N/A [1]	N/A
B-020-9-15	713.0	24.5	688.5	N/A [1]	N/A
B-021-0-08	727.9	28.0	699.9	26.9	701.0

1. *The groundwater level at completion could not be obtained due to the addition of water or mud as a drilling fluid.*
2. *Groundwater was not encountered in boring B-020-7-13 prior to introducing water to the borehole.*

Groundwater was encountered initially during drilling in all of the borings, with the exception of boring B-020-7-13, at depths ranging from 15.0 to 43.5 feet below the existing ground surface, which corresponds to elevations ranging from 689.8 to 699.9 feet msl. Groundwater was not encountered in boring B-020-7-13 prior to introducing water to the borehole. At the completion of drilling and prior to beginning rock coring operations in boring B-021-0-08, groundwater accumulated in the auger stems to a depth of 26.9 feet below the ground surface, which corresponds to an elevation of 701.0 feet msl. The groundwater levels at the completion of drilling could not be measured in the remainder of the borings due to the addition of mud to counteract heaving sands as well as water as a circulating fluid during the rock coring process.

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

4.5 Historic Borings

Historic boring B-001-A-59 encountered existing fill consisting of loose to medium dense, gray, dark gray and brown gravel with sand and silt and sandy silt (ODOT A-2-4, A-4a) extending to a depth of 17.0 feet below existing grade at the time the boring was performed, which corresponds to an elevation of 696.4 feet msl. In general, the natural soils encountered below the fill consisted of medium dense to very dense granular soils with a thin layer of cohesive soil at the bottom of the boring. The granular soils were generally described as brown and gray gravel, gravel and sand and gravel with sand and silt (ODOT A-1-a, A-1-b, A-2-4), and the thin layer of cohesive soil at the bottom of the boring was described as gray sandy silt (ODOT A-4a). Boulders were noted throughout the natural granular soil deposits encountered below the fill beginning at elevation 696.4 feet msl. Bedrock was not encountered in the boring prior to the termination depth. Groundwater levels were not noted on the boring log. In general, the subsurface conditions encountered in the historic boring matched relatively closely with the subsurface conditions encountered in the current and preliminary engineering exploration borings.

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 bridge structure were provided by Burgess and Niple. Based on information provided, it is understood that the proposed FRA-70-1373A bridge will consist of a single span prestressed concrete I-beam structure with a composite reinforced concrete deck with pile supported semi-integral stub abutments behind mechanically stabilized earth (MSE) walls. The proposed structure will have a total length of approximately 93 feet and width of approximately 41.5 feet. In addition, the roadway profile will be elevated approximately 40 feet above the existing ground surface grade.

The existing FRA-70-1373R structure is a three-span bridge with a total length of approximately 118 feet. It is understood that the existing structure will be completely removed and replaced with a single span prestressed concrete I-beam structure with a composite reinforced concrete deck with pile supported semi-integral stub abutments behind mechanically stabilized earth (MSE) walls. The proposed structure will have a total length of approximately 94 feet and will be widened to the south approximately 60 to 65 feet, for an overall width of approximately 100 feet. In addition, the roadway profile will be elevated approximately 15 feet above the existing I-70 eastbound grade as well

as approximately 35 feet above the ground surface grade where the bridge will be widened to the south.

A portion of Retaining Wall 4W8, between Sta. 5080+60, 22.4' Rt. (BL Ramp C5) and Sta. 175+91, 38.2' Lt. (BL I-70 EB), will be located along the rear abutment of the proposed structures to provide the required grade separation to support the configuration. The maximum wall height at the rear abutment for the FRA-70-1373A and R structures is 43.3 and 39.8 feet, respectively, and the total wall length along both abutments is approximately 150 lineal feet. The wall alignment will turn west on the south side of the FRA-70-1373A structure and continue to the FRA-70-1358A bridge over CSX and Norfolk Southern Railroad. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Wall 4W8. Design recommendations for the remaining alignment of Retaining Wall 4W8 west of the bend at Sta. 5080+60, 22.4' Rt. (BL Ramp C5) is presented under a separate cover.

Additionally, a portion of Retaining Wall 4W5, between Sta. 179+66, 39.8' Lt. (BL I-70 EB) and Sta. 5081+38, 24.3' Rt. (BL Ramp C5), will be located along the forward abutment of the proposed structures to provide the required grade separation to support the configuration. The maximum wall height at the forward abutment for the FRA-70-1373A and R structures is 44.1 and 37.1 feet, respectively, and the total wall length along both abutments is approximately 157 lineal feet. The wall alignment will turn east on the south side of the FRA-70-1373A structure and continue to the FRA-70-1390C bridge over I-70/71. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for Retaining Wall 4W5. However, given the presence of existing fill material to significant depths, as well as the significant amount of existing utilities within the footprint of this wall, it is understood that lightweight fill material consisting of cellular concrete will be utilized along the length of the wall that crosses in front of the abutments. Design recommendations for the remaining alignment of Retaining Wall 4W5 east of the bend at Sta. 5081+38, 24.3' Rt. (BL Ramp C5) is presented under a separate cover.

Proposed structural data was obtained from design details provided by Burgess and Niple, Dynotec and GPD GROUP and are included in Table 6.

Table 6. Bridge and Retaining Wall Design Elevations and Structure Loading

Structure Reference	Substructure Reference (Borings)	Structure Component [1]	Elevation [1] (feet msl)	Design Maximum Factored Load
FRA-70-1373A	Rear Abutment (B-020-1-13 / B-020-9-15)	Profile Grade	751.3	290 kips/pile
		Bottom of Footing	737.0	
		Bottom of Wall (Top of Leveling Pad)	708.0	
	Forward Abutment (B-020-9-15 / B-021-0-08)	Profile Grade	754.6	290 kips/pile
		Bottom of Footing	740.4	
		Bottom of Wall (Top of Leveling Pad)	710.8	
FRA-70-1373R	Rear Abutment (B-020-2-13 / B-020-5-13)	Profile Grade	747.8	290 kips/pile
		Bottom of Footing	731.1	
		Bottom of Wall (Top of Leveling Pad)	708.0	
	Forward Abutment (B-020-2-13 / B-020-7-13 / B-001-A-59)	Profile Grade	746.6	290 kips/pile
		Bottom of Footing	730.3	
		Bottom of Wall (Top of Leveling Pad)	709.5	

1. *Proposed foundation elevations and structural loading based on structure information provided by Burgess and Niple, Dynotec and GPD GROUP.*

5.1 Driven Pile Recommendations

Given the depth to bedrock encountered in the borings, it is recommended that steel H-piles (ODOT Item 507.06) driven to refusal on bedrock be employed for foundation support of the proposed substructure elements. Per Section 202.2.3.2a of the 2007 ODOT Bridge Design Manual, 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 7 shows the recommended pile lengths and the corresponding factored structural axial resistance ($R_{R\,max}$) of steel H-piles. 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.

Table 7. FRA-70-1373A and R Driven Pile Recommendations

Structure Reference	Substructure Reference (Boring)	Ground Elevation [1]	Pile Size	Pile Elevation		Pile Length [3] (feet)	$R_{R\ max}$ [4] (kips/pile)	Sleeve Length [5]	φ [6]
				Top [2]	Tip				
FRA-70-1373A	Rear Abutment (B-020-1-13)	712.8	HP 10x42	738.0	647.8	95	310	30.5	N/A
	Forward Abutment (B-020-9-15)	713.0	HP 10x42	741.4	652.5	90	310	31.1	N/A
FRA-70-1373R	Rear Abutment (B-020-2-13)	711.4	HP 10x42	732.1	641.9	95	310	24.6	N/A
	Forward Abutment (B-020-7-13)	713.5	HP 10x42	731.3	648.1	85	310	22.3	N/A

1. *Ground elevation listed is the ground elevation at the respective boring location.*
2. *The top of pile elevation corresponds to the pile cutoff elevation, which is 1.0-foot above the proposed bottom of footing elevation.*
3. *Per Section 202.3.2 of the 2007 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.*
4. *The factored structural axial resistance for H-piles is based on the structural limit state of the steel H-pile section per Section 202.2.3.2.a of the 2007 ODOT BDM.*
5. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall or cellular concrete backfill, including the foundation preparation.*
6. *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.*

As per Section 202.2.3.2.a of the 2007 ODOT BDM, the factored resistance for 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 7 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 (LRFD 6.5.4.2: $\varphi_c = 0.50$) and a pile fully braced along its length. **The factored structural axial resistance 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. Due to the weathered, variable nature of the upper portion of the bedrock, it is estimated that refusal will be met within the upper 3.0 to 5.0 feet of the surficial bedrock. Therefore, the recommended pile tip elevation at the forward abutment is based on a penetration of 4.0 feet into the weathered shale bedrock. Settlement is estimated to be less than 1.0 inch for H-piles driven to refusal on bedrock.

Consideration was given to the use of friction piles using cast-in-place (CIP) pipe piles; however, given the required pile reactions provided by Burgess and Niple, additional piles would be required to support the proposed substructure units, which would result in additional costs. As noted in Section 4.2, existing fill consisting primarily of soft to stiff silt and clay, silty clay and clay with interbedded layers of very loose to loose granular soil was encountered extending to elevations ranging from 690.9 to 702.5 feet msl. The fill material contained debris and organics throughout. Below the fill material medium dense to very dense granular soils consisting of gravel and gravel and sand were encountered which extended to approximate elevations of 660 to 665 feet msl. Analyses indicate that 16-inch CIP piles would only be able to be driven a short distance into this material before reaching the maximum capacity and overstressing the piles. Given the weak and variable nature of the overlying fill material, the capacity would need to be carried almost solely in the end bearing of the pile. Additionally, as the bridge site is situated in a flood plain area, it is anticipated that the site will be inundated during the design life. Therefore, if a critical design groundwater elevation at the finished grade of the roadway is considered, there will be a significant reduction in the capacity of the piles, which would likely result in significant settlement or complete failure of the piles. Therefore, CIP pipe piles were not considered for foundation support of the proposed substructures.

5.1.1 Downdrag Considerations

The anticipated total settlement along the facing of Wall 4W8 at the rear abutment of the two structures is approximately 9.5 inches, and total settlements along the facing of Wall 4W5 at the forward abutment of the two structures is approximately 2.5 inches. Given the anticipated amount of settlement following construction of the embankment, downdrag loads may be induced on the pile elements if installed to the final tip elevation prior to placement of the embankment fill. 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). The surcharge should remain 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 20 to 55 days following the placement of the surcharge load. However, even at 90 percent consolidation, the remaining settlement still exceeds 0.4 inches along Wall 4W8 at the rear abutment of both structures, which is the relative movement that results in full mobilization of the side resistance, and thus generating downdrag loads. Since the majority of the settlement is

occurring within the upper fill material, if this material is stabilized as discussed in Section 5.2, then the total amount of settlement will be reduced, resulting in the elimination of the downdrag loading.

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 2018 AASHTO LRFD Bridge Design Specifications (BDS) using the GRLWEAP software program, and the results are provided in Appendix VI. 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 depths provided in Table 7. Care should be taken during pile driving operations when approaching the bedrock elevations noted above, 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 202.2.3.2.a of the 2007 ODOT BDM, steel pile points should not be used when the piles are driven to bear on shale. However, it should be noted that dense granular soils and cobbles and boulders were encountered throughout the surficial deposits. If there is difficulty in driving the piles to bear on the bedrock due to the dense granular soils or obstructions, then consideration should be given to the use of a pile point to aid in penetrating beyond these layers or obstructions. If a pile point is utilized, the piles may penetrate further into the shale bedrock prior to encountering refusal.

5.1.3 Lateral Design Considerations

If lateral loads or moments are expected to be applied on the foundation elements, they should be analyzed to verify the shaft or 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 VII. 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 and cross section (for drilled shafts) required to resist the lateral load for a given end condition and deflection. Table 8 lists the 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 VII.

Table 8. 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 an MSE wall at the rear abutment (Retaining Wall 4W10 between Sta. 5080+60, 22.4' Rt., BL Ramp C5, and Sta. 175+91, 38.2' Lt., BL I-70 EB) and forward abutment (Retaining Wall 4W5 between Sta. 179+66, 39.8' Lt., BL I-70 EB, and Sta. 5081+38, 24.3' Rt., BL Ramp C5) of the proposed bridge structure. As previously discussed, given the presence of existing fill material to significant depths, as well as the significant amount and critical nature of existing utilities within the footprint of Retaining Wall 4W5, it is understood that lightweight fill material consisting of cellular concrete will be utilized along the length of the wall that crosses in front of the forward abutment of both structures. While it is understood that the wall facing will be connected to geosynthetic straps that will be embedded in the cellular concrete backfill, the analysis approach for this type of system differs from that of a traditional MSE wall. Therefore, the recommendations for this system are presented in Section 5.3.

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 204.6.2.1 of the 2007 ODOT BDM, the height of the MSE wall at the bridge abutments is defined as the elevation difference between the profile grade at the face of the wall and the top of the leveling pad. However, 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 303.5.1 of the 2007 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 backwall of the abutment footing, and prevent any load transfer from these forces to the coping and facing panels. For portions of the wall outside the limits of the bridge abutments, the straps should be installed the full height of the wall. The width of the MSE wall foundation (B) is defined by the length of the reinforced soil mass. Per the Section 204.6.2.1 of the 2007 ODOT BDM and Supplemental Specification (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 on proposed plan and profile information provided by Dynotec, the maximum wall heights along Retaining Wall 4W8 where it crosses in front of the rear abutment of the FRA-70-1373A and FRA-70-1373R structures is 43.3 and 39.8 feet, respectively, from the top of the leveling pad to the proposed profile grade of the roadway. Therefore, it is considered that the minimum reinforcement length and the effective foundation width (B) of the rear and forward abutment MSE walls for external and global stability calculations will be 30.3 and 27.9 feet, respectively.

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. Existing fill material was encountered at the proposed bearing elevation at the rear abutment (Wall 4W8), which extends to depths ranging from 5.5 feet (El. to 702.5 feet msl) to 17.1 feet (El. 690.9 feet msl) below the proposed bearing elevation. The fill material consisted of primarily of soft to stiff silt and clay, silty clay and clay (ODOT A-6a, A-6b, A-7-6) with seams of vey loos to medium dense gravel and sand and gravel with sand and silt (ODOT A-1-b, A-2-4) and contained slag, cinders and organic material. These soils are not considered suitable for foundation support for a wall of this size. Consideration was given to over excavating these soils and replacing it with granular embankment; however, similar conditions are anticipated along the remainder of the alignment of Retaining Wall 4W8, which makes this a very expensive and uneconomical option. Recommendations have been provided in the structure foundation exploration report for Retaining Wall 4W8 to incorporate the use of ground improvement techniques to stabilize the existing fill and underlying cohesive soils. The recommendations for this alternative should govern the design of this portion of the wall as well. For this report, the analysis this section of Wall 4W8 has been conducted using the soil profile as encountered in the borings.

Per 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 wall is located within an existing floodplain, the analysis was 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 9.

Table 9. 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 at 4W10)	120	30	0	2,000
Existing Fill: Medium Stiff to Stiff Silt and Clay (ODOT A-6a)	115	25 to 26	0	875 to 1,625
Existing Fill: Medium Stiff to Stiff Silty Clay (ODOT A-6b)	115	24	0	1,000 to 1,250
Existing Fill: Soft Clay (ODOT A-7-6)	115	23	0	500
Existing Fill: Very Loose to Loose Granular Soils (ODOT A-1-b, A-2-4)	120	31 to 33	0	N/A
Medium Dense to Very Dense Gravel and Sand (ODOT A-1-b)	125 to 135	36 to 42	0	N/A
Hard Sandy Silt (ODOT A-4a)	130	32	50	7,000
Hard Silty Clay (ODOT A-6b)	130	27	50	8,000
Hard Clay (ODOT A-7-6)	130	26	50	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 2018 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 are provided in ODOT SS 840. Per SS 840, the select granular backfill in the reinforced zone must meet the shear strength requirements provided in Table 9. Based on the design plans provided by GPD Group and Dynotec, it is understood that Item 203 granular embankment will be utilized where any new embankment will be placed behind the reinforced soil backfill at both

MSE walls. Therefore, the shear strength parameters for the retained fill will be modeled using a friction angle of 33 degrees since granular embankment is being specified, instead of using the shear strength parameters provided in ODOT SS 840.

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 and based on past experience in the vicinity of the site with projects performed in similar subsurface profiles. However, the friction angle for the existing fill that consisted of medium dense gravel with sand and silt was conservatively assigned since there no records of the material origin or how it was placed.

5.2.2 Bearing Stability

The anticipated bearing materials at the proposed bearing elevation along Retaining Wall 4W8, along the rear abutment of both structures, consists of existing fill comprised of soft to stiff silt and clay, silty clay and clay (ODOT A-6a, A-6b, A-7-6) with seams of vey loos to medium dense gravel and sand and gravel with sand and silt (ODOT A-1-b, A-2-4) and contained slag, cinders and organic material. As noted in Section 5.2, it is understood that ground improvement techniques will be implemented along the alignment of Retaining Wall 4W8, including where the wall crosses the rear abutment of both structures. As this is a proprietary design, the analysis for this wall considers the existing fill material will remain in place. MSE wall foundations bearing on engineered fill, placed and compacted in accordance with ODOT Item 203, or existing fill material may be proportioned for a nominal bearing resistance as indicated in Table 10. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored nominal bearing resistance at the strength limit state.

Table 10. Retaining Wall 4W8 MSE Wall Design Parameters

Structure Reference / Substructure Unit (Boring)	Wall Height Analyzed (feet)	Backslope Behind Wall	Minimum Required Reinforcement Length [1] (feet)	Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing Pressure [3] (ksf)
				Nominal	Factored [2]	
FRA-70-1373A Rear Abutment / Retaining Wall 4W8 (B-020-1-13)	43.3	Level	30.3 (0.7H)	5.10	3.32	9.74
FRA-70-1373R Rear Abutment / Retaining Wall 4W8 (B-020-2-13)	39.8	Level	27.9 (0.7H)	8.94	5.81	9.01

1. *The required foundation width is 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 soils for the maximum specified wall heights indicated in Table 10. 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 for Wall 4W8, considering the wall will bear on the existing fill material.

5.2.3 Settlement Evaluation

The compressibility parameters utilized in the settlement analysis of the proposed MSE walls are provided in Table 11.

Table 11. Compressibility Parameters Utilized in Settlement Analysis

Material Type	γ (pcf)	LL (%)	C_c (1)	C_r (2)	e_o (3)	C_v (4) (ft²/yr)	N_{60}	C' (5)
Existing Fill: Medium Stiff to Stiff Silt and Clay (ODOT A-6a)	115	35	0.225	0.034	0.546	600	N/A	N/A
Existing Fill: Medium Stiff to Stiff Silty Clay (ODOT A-6b)	115	39 to 40	0.261 to 0.270	0.039 to 0.041	0.577 to 0.585	300	N/A	N/A
Existing Fill: Soft Clay (ODOT A-7-6)	115	41	0.279	0.042	0.593	150	N/A	N/A
Existing Fill: Very Loose to Loose Granular Soils (ODOT A-1-b, A-2-4)	120	N/A	N/A	N/A	N/A	N/A	4 to 8	51 to 57
Medium Dense to Very Dense Gravel and Sand (ODOT A-1-b)	125 to 135	N/A	N/A	N/A	N/A	N/A	17 to 100	74 to 439
Hard Sandy Silt (ODOT A-4a)	130	22	0.108	0.011	0.444	800	N/A	N/A
Hard Silty Clay (ODOT A-6b)	130	38	0.252	0.025	0.569	150	N/A	N/A
Hard Clay (ODOT A-7-6)	130	44	0.306	0.031	0.616	150	N/A	N/A

1. *Per Table 6-9, Section 6.14.1 of FHWA GEC 5.*
2. *Estimated at 10% of C_c for natural soils and 15% C_c for existing fill per Section 8.11 of Holtz and Kovacs (1981).*
3. *Per Table 8-2 of Holtz and Kovacs (1981).*
4. *Per Figure 6-37, Section 6.14.2 of FHWA GEC 5.*
5. *Per Figure 10.6.2.4.2-1 of 2018 AASHTO LRFD BDS.*

Results of the settlement analysis are tabulated in Table 12. Total settlements of approximately 15.5 inches at the center of the reinforced soil mass and 9.5 inches at the facing of the wall are anticipated along Wall 4W8 where is crosses in front of the rear abutment of the two structures. Based on the results of the analysis, 90 percent of the total settlement is anticipated to occur over a period of approximately 20 to 55 days. Please note that the consolidation settlement and time rate of consolidation are based

on estimates using correlated compressibility parameters provided in Table 11 for the underlying soils. Actual settlement and time rate of consolidation should be determined by monitoring the settlement of the wall using settlement platforms.

Table 12. Retaining Wall 4W8 MSE Wall Settlement Results

Structure Reference / Substructure Unit (Boring)	Wall Height Analyzed (feet)	Backslope Behind Wall in Analysis	Service Limit Equivalent Bearing Pressure [1] (ksf)	Total Settlement Values (inches)		Time for 90% Consolidation (Days)
				Center of Wall Mass	Facing of Wall	
FRA-70-1373A Rear Abutment / Retaining Wall 4W8 (B-020-1-13)	43.3	Level	6.90	15.03	9.31	22
FRA-70-1373R Rear Abutment / Retaining Wall 4W8 (B-020-2-13)	39.8	Level	6.37	15.25	9.18	55

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.*

Per Section 204.6.2.1 of the ODOT BDM, "the maximum allowable differential settlement in the longitudinal direction (regardless of the size of panels) is one (1) percent." Given the amount of settlement anticipated at the facing along Wall 4W8 where is crosses in front of the rear abutment of the two structures, as well as the presence of existing fill material that may vary significantly over the footprint of the wall, differential settlement greater than 1/100 may occur if the fill material is not stabilized or over excavated and replaced with embankment fill. If either the total or differential settlement predicted presents an issue with respect to the deformation tolerances that the walls can withstand, then measures should be taken to minimize the amount of settlement that will occur. This can be achieved by preloading the site and consolidating the underlying soils prior to constructing the wall. If preloading the site is not a desired option, then consideration could be given to ground improvement through the use of stone columns. Settlement calculations are provided in Appendix VIII.

5.2.4 Eccentricity (Overturning Stability)

The resistance of the MSE walls to overturning will be dependent 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 2018 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 maximum specified wall

heights indicated in Table 10. Based on the minimum length of reinforced soil mass presented in Table 10 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 for either wall.

5.2.5 Sliding Stability

The resistance of the MSE walls to sliding was evaluated per Section 11.10.5.3 of the 2018 AASHTO LRFD BDS. 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 and reinforced soil backfill, a coefficient of sliding friction of 0.47 and 0.49 was utilized for design. The sliding resistance at was also evaluated under undrained conditions as well. 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 existing silt and clay fill material encountered at the proposed bearing elevation is estimated to be 875 to 1,625 psf. A geotechnical resistance factor of φ_τ=1.0 was considered in calculating the factored shear resistance between the reinforced backfill material and foundation for sliding. Based on the minimum length of reinforced soil mass presented in Table 10 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. However, the resultant horizontal forces on the back of the MSE wall **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 the wall. As per the 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 the global 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 mass. The computer software program Slide 6.0 manufactured by Rocscience Inc. was utilized to perform the analyses.

Per Section 11.6.2.3 of the 2018 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. Given that the subsurface conditions are similar along the alignment of Wall 4W8 at the rear abutment of both

structures, one global stability analysis was performed using the wall configuration at the FRA-70-1373A rear abutment, since this represents the tallest section of the wall. For an MSE wall designed with the minimum strap lengths listed in Table 10, the resulting factor of safety under drained conditions (long-term stability) was less than 1.5, and under undrained conditions (short-term stability) was less than 1.0.

5.2.7 Final MSE Wall Considerations

Based on the results of the external and global stability analysis performed for the MSE wall, 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 1.0 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, similar conditions are anticipated along the remainder of the alignment of Retaining Wall 4W8, which makes this a very expensive and uneconomical option. Recommendations have been provided in the structure foundation exploration report for Retaining Wall 4W8 to incorporate the use of ground improvement techniques to stabilize the existing fill and underlying cohesive soils. The recommendations for this alternative should govern the design of this portion of the wall as well.

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

5.3 Lightweight (Cellular Concrete) Wall Recommendations

Given the presence of existing fill material to significant depths, as well as the significant amount of existing utilities present along the east side of Short Street, it is understood that lightweight fill material consisting of cellular concrete is being considered to be utilized as the backfill along the length of Wall 4W5 that crosses in front of the forward abutment of both structures. The use of the lightweight cellular concrete will eliminate the need for undercut or ground improvement to stabilize the underlying existing fill material and control settlement to tolerable limits. Based on information provided by GPD GROUP, two types of lightweight cellular concrete will be utilized in lieu of typical embankment fill and select granular fill, which is typically used for MSE wall applications. The wall facing will be connected to geosynthetic straps that are embedded into the cellular concrete and supported on a leveling pad, similar to traditional MSE walls.

A typical section of the proposed cellular concrete wall system was provided by GPD GROUP. Based on the information provided, the typical section will consist of an approximate 3.0-foot thick pavement section, including asphalt and/or concrete and aggregate base, overlying 2.0 feet of Class III cellular concrete, followed by Class II cellular concrete to the bottom of the embankment/wall elevation. A composite unit

weight of 130 pcf was considered for the entire pavement section, and the unit weight of the Class III cellular concrete is 36 pcf and the Class II cellular concrete is 30 pcf. The pressure at the bottom of the embankment was calculated as follows:

$$\Delta\sigma = (130\ pcf)(3.0\ ft) + (36\ pcf)(2.0\ ft) + (H - 5\ ft)(30\ pcf)$$

Where,

$\Delta\sigma$ = induced pressure at the bottom of embankment/wall (psf)

H = height of embankment/wall from existing ground surface to profile grade of roadway (ft)

Since the wall is located within an existing floodplain, the analysis was performed using a design groundwater level at the ground surface.

Following placement of the cellular concrete, the material will cure and harden similar to concrete and will become a rigid mass. The concept of active earth pressure within this mass is not valid, as it cannot substantially deform, develop an active wedge, and mobilize active earth pressure. Therefore, the entire cellular concrete mass must be treated as a solid block. The “reinforced zone” is not the same as a traditional MSE wall reinforced zone, as the reinforcement straps only need to extend back into the cellular mass far enough to fully develop resistance in tension as if it were a reinforcing bar embedded in reinforced concrete. However, it is recommended that the reinforcement extend the minimum length of 70 percent of the wall height into the cellular concrete backfill, similar to traditional MSE walls.

Considering the above commentary in regards to the external stability of the cellular concrete backfilled MSE walls, sliding, overturning, bearing and overall (global) stability of the wall must be performed for the entire mass as a single block. Therefore, consideration must be given to the effect of the backfill material behind the cellular concrete if it is only utilized within the reinforced zone of the wall.

The active earth pressure coefficient, and consequently the active pressure on the back of the cellular concrete mass, will greatly reduce as the slope of the backfill soil flattens. Once the slope of the backfill flattens more than the internal friction angle of the backfill soil, the active earth pressure coefficient will go to zero. Therefore, if the backslope of any backfill is reduced to the internal friction angle of the backfill material, analysis of external stability is not required, with the exception of bearing and overall (global) stability. Based on the plan information provided, it is understood that the cellular concrete fill will be placed the full height of the embankment within the limits of Ramp C5 as well as I-70 eastbound to the east side of the Franklin main, which is approximately 400 feet east of Short Street. As such, external and global stability calculations will not be required for this section of Wall 4W5. However, if bearing resistance must be checked, then a factored bearing resistance of 3.0 ksf should be utilized for design at the strength limit state.

The compressibility parameters utilized in the settlement analysis of the proposed cellular concrete backfilled MSE wall along Wall 4W5 at the forward abutment of both structures are provided in Table 11.

Table 13. Compressibility Parameters Utilized in Settlement Analysis

Material Type	γ (pcf)	LL (%)	C_c [1]	C_r [2]	e_o [3]	C_v [4] (ft²/yr)	N_{60}	C' [5]
Existing Fill: Medium Stiff to Stiff Silt and Clay (ODOT A-6a)	115	35	0.225	0.034	0.546	600	N/A	N/A
Existing Fill: Medium Stiff to Stiff Silty Clay (ODOT A-6b)	115	34 to 38	0.216 to 0.252	0.032 to 0.038	0.538 to 0.569	300	N/A	N/A
Existing Fill: Soft Clay (ODOT A-7-6)	115	43	0.297	0.045	0.608	150	N/A	N/A
Existing Fill: Loose Sandy Silt (ODOT A-4a)	115	N/A	N/A	N/A	N/A	N/A	9	30 to 34
Existing Fill: Very Loose to Loose Granular Soils (ODOT A-1-b, A-2-4)	120	N/A	N/A	N/A	N/A	N/A	5 to 13	57 to 71
Medium Dense to Very Dense Granular Soils (ODOT A-1-a, A-1-b, A-2-4, A-2-6)	125 to 135	N/A	N/A	N/A	N/A	N/A	25 to 120	77 to 560
Hard Silt and Clay (ODOT A-6a)	125 to 130	27	0.153	0.015	0.483	600	N/A	N/A
Hard Clay (ODOT A-7-6)	130	42	0.288	0.029	0.600	150	N/A	N/A

1. *Per Table 6-9, Section 6.14.1 of FHWA GEC 5.*
2. *Estimated at 10% of C_c for natural soils and 15% C_c for existing fill per Section 8.11 of Holtz and Kovacs (1981).*
3. *Per Table 8-2 of Holtz and Kovacs (1981).*
4. *Per Figure 6-37, Section 6.14.2 of FHWA GEC 5.*
5. *Per Figure 10.6.2.4.2-1 of 2018 AASHTO LRFD BDS.*

Results of the settlement analysis are tabulated in Table 12. Total settlements of 3.14 to 3.68 inches at the center of the wall mass and 2.33 to 2.69 inches at the facing of the wall are anticipated along Wall 4W5 where is crosses in front of the forward abutment of the two structures. Based on the results of the analysis, 90 percent of the total settlement is anticipated to occur over a period of approximately 0 to 55 days. Please note that the consolidation settlement and time rate of consolidation are based on estimates using correlated compressibility parameters provided in Table 11 for the underlying soils. Actual settlement and time rate of consolidation should be determined by monitoring the settlement of the wall using settlement platforms.

Table 14. Retaining Wall 4W5 Settlement Results

Structure Reference / Substructure Unit (Boring)	Wall / Embankment Height (feet)	Pressure at Bottom of Wall / Embankment [1] (ksf)	Total Settlement Values (inches)		Time for 90% Consolidation (Days)
			Center of Wall Mass	Facing of Wall	
FRA-70-1373A Forward Abutment / Retaining Wall 4W5 (B-020-9-15)	43.8	1.69	3.14	2.33	10
FRA-70-1373R Forward Abutment / Retaining Wall 4W5 (B-020-7-13 / B-001-A-59)	37.1	1.49	3.50 to 3.68	2.55 to 2.69	0 to 55

1. $\Delta\sigma$ = (130 pcf)(3.0 ft) + (36 pcf)(2.0 ft) + (H - 5 ft)(30 pcf).

Per Section 204.6.2.1 of the ODOT BDM, for traditional MSE walls "the maximum allowable differential settlement in the longitudinal direction (regardless of the size of panels) is one (1) percent." Based on the total anticipated settlement at the facing of the walls, maximum differential settlements in the longitudinal directions are anticipated to be less than 1/1000, which is within the tolerable limit of 1/100. If localized bearing pressures exerted on the leveling pad from the wall facing panels will be higher than the pressure exerted by the wall mass, then there is a potential for differential settlement to occur given the variability in the fill material.

Results of the settlement analysis and bearing resistance for the cellular concrete MSE wall are provided in Appendix IX.

5.4 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 15 and Table 16.

Table 15. 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
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	130	0	33°	0.26	0.46	7.41

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

Table 16. 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	125	50	28°	0.32	0.53	5.07
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	130	0	33°	0.26	0.46	7.41

1. *When below groundwater table, use effective unit weight, $\gamma' = \gamma - 62.4$ 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. 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 considered). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage.

5.5 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).

Given the proximity to existing utilities, including the including the Olentangy Scioto Interceptor Sewer (OSIS), it is recommended that vibration monitoring be performed for any utilities that can be potentially damaged due to the vibrations associated with the installation of the driven piles or any temporary shoring that will need to be driven or vibrated into place. The threshold limits for the amount of tolerable vibration will need to be determined by the entity that owns the utility or in accordance with local code requirements. If levels of vibration exceed the threshold limits, then corrective measures will need to be implemented, or evaluation of the effect of the vibration on the existing utilities will need to be performed. Since the piles will be point bearing on bedrock, corrective measures could include pre-boring the piles to a depth below the existing utilities such that the vibration from driving them from the depth of the bored hole will not exceed the threshold values. With respect to temporary shoring, if required, the type of shoring may be limited to soldier pile and lagging systems or pre-boring the sheeting into place.

5.5.1 Excavation Considerations

All excavations should be shored / braced or laid back at a safe angle in accordance to 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 shoring 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 17. 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

5.5.2 Groundwater Considerations

Based on the groundwater observations made during drilling, groundwater is not anticipated to be encountered during construction. 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.

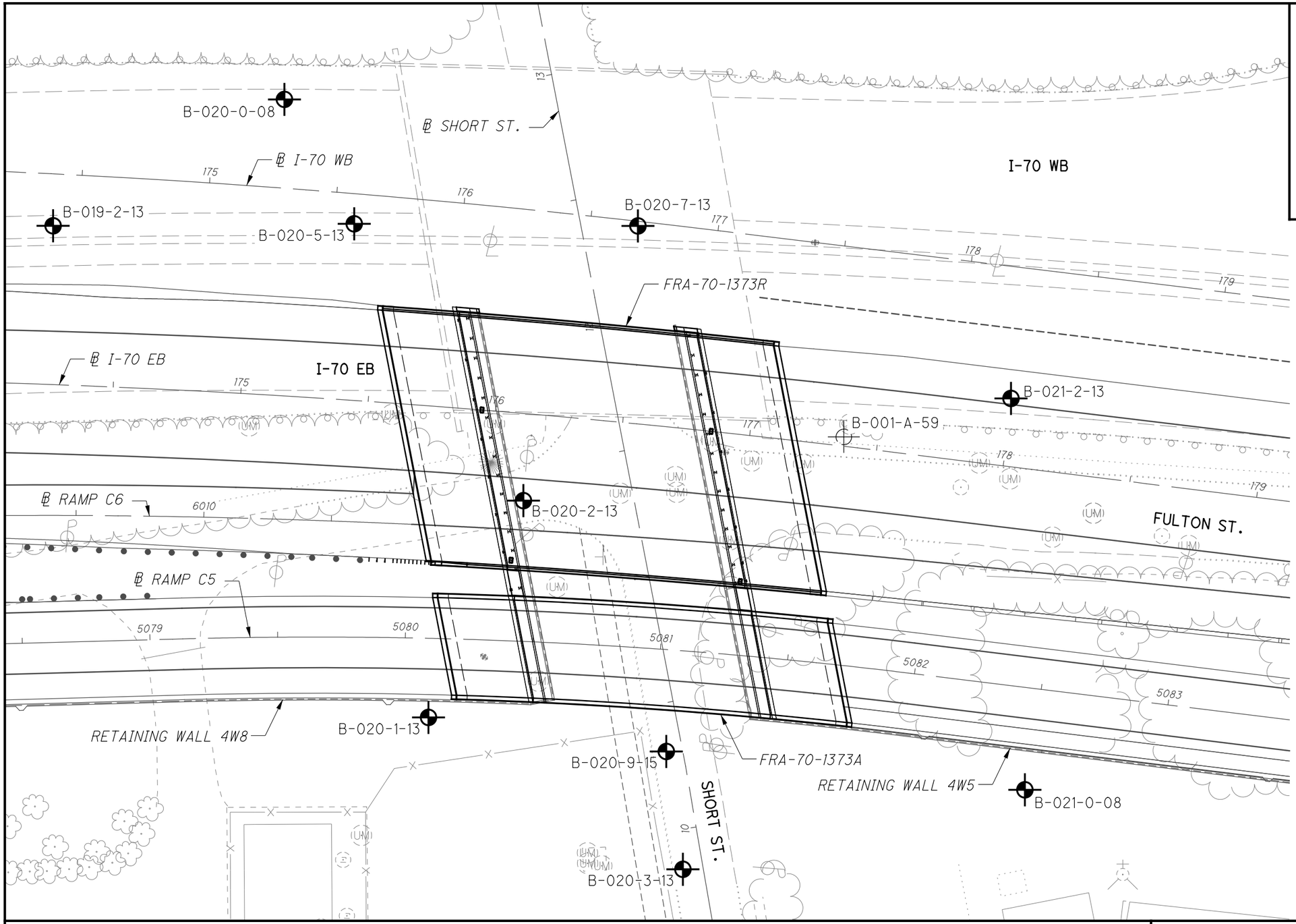
The conclusions and recommendations herein have been based upon the available soil and bedrock information and the design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be 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.

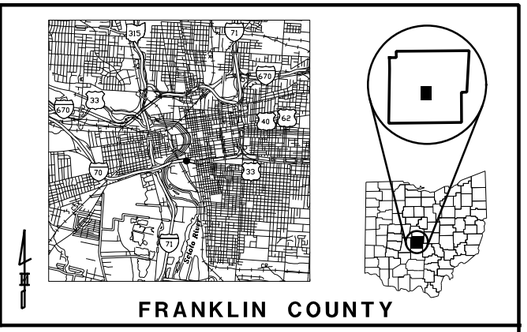
The scope of our services does not include any environmental assessment or investigation for the presence or absence of hazardous or toxic materials in the soil, groundwater or surface water within or beyond the site studied. Any statements in this report or on the test boring logs regarding odors, staining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





VICINITY MAP

BORING PLAN

FRA-70-1373A AND FRA-70-1373R

FRANKLIN COUNTY, OHIO

RII PROJECT NO. W-13-045		DRAWN RRM
SCALE: 1"=40' 0 20 40	N	REVIEWED BRT
		DATE 7-13-18

RESOURCE INTERNATIONAL, INC.

APPENDIX II

DESCRIPTION OF SOIL 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.

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		LL_O/LL x 100*	% Pass #40	% Pass #200	Liquid Limit (LL)	Plastic Index (PI)	Group Index Max.	REMARKS
		AASHTO	OHIO							
	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	
	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.	$\leq$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

Peat

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

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

APPENDIX III

PROJECT BORING LOGS:

B-020-1-13 through B-020-3-13, B-020-5-13, B-020-7-13 and B-020-9-15

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: STOCK / A/M	DRILL RIG: CME 750X (SN 375128)	STATION / OFFSET: 5080+09.80 / 30.9' RT	**EXPLORATION ID B-020-1-13**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / K.R.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C5		
PID: 77372 BR ID: FRA-70-1373A	DRILLING METHOD: 4.25" HSA / RC	CALIBRATION DATE: 3/28/13	ELEVATION: 712.8 (MSL) EOB: 86.0 ft.		PAGE 1 OF 3
START: 7/1/13 END: 7/3/13	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 78.6	LAT / LONG: 39.952922218, -83.004665587		

MATERIAL DESCRIPTION AND NOTES	ELEV. 712.8	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
0.5' - TOPSOIL (6.0")	712.3																	
0.3' - BRICK (4.0")	712.0																	
FILL: HARD, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP. -ROOT AND GRASS FIBERS PRESENT IN SS-1	709.8	1	6 50/5"	-	55	SS-1	-	-	-	-	-	-	-	-	-	11	A-6a (V)	
POSSIBLE FILL: MEDIUM DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST.	707.3	4	15 11 5	21	81	SS-2	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	
POSSIBLE FILL: SOFT TO STIFF, DARK BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP TO MOIST. -STONE FRAGMENTS PRESENT IN SS-4	702.3	7	2 1 2	4	64	SS-3	0.50	20	13	13	22	32	35	20	15	20	A-6a (6)	
		9	2 5 3	10	33	SS-4	-	-	-	-	-	-	-	-	-	12	A-6a (V)	
POSSIBLE FILL: STIFF TO VERY STIFF, DARK BROWNISH GRAY TO BROWN **SILTY CLAY**, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.	697.3	12	1 2 4	8	56	SS-5	2.75	-	-	-	-	-	-	-	-	23	A-6b (V)	
		14	2 3 3	8	78	SS-6	2.00	6	9	12	23	50	40	17	23	19	A-6b (13)	
POSSIBLE FILL: VERY LOOSE, DARK BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, WET.	694.8	17	1 1 2	4	67	SS-7	-	-	-	-	-	-	-	-	-	21	A-1-b (V)	
MEDIUM DENSE, DARK BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST. -STONE FRAGMENTS PRESENT IN SS-8	692.3	19	5 9 6	20	39	SS-8	-	-	-	-	-	-	-	-	-	15	A-2-6 (V)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, LITTLE CLAY, TRACE SILT, MOIST. -COBBLES PRESENT @ 22.0'		22	10 7 5	16	39	SS-9	-	-	-	-	-	-	-	-	-	17	A-1-b (V)	
		W 23																
		24	3 6 8	18	53	SS-10	-	-	-	-	-	-	-	-	-	15	A-1-b (V)	
		27	5 4 8	16	56	SS-11	-	36	30	12	9	13	NP	NP	NP	15	A-1-b (0)	
		29	8 16 16	42	83	SS-12	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/31/15 08:54 - U:\GI\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1373A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5080+09.80 / 30.9 RT	START: 7/1/13	END: 7/3/13	PG 2 OF 3	B-020-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM DENSE TO DENSE, BROWN **GRAVEL AND SAND**, LITTLE CLAY, TRACE SILT, MOIST. *(same as above)*	682.8	31																
	680.8	32																
HARD, GRAY **SANDY SILT**, SOME CLAY, LITTLE FINE GRAVEL, DAMP.		33																
		34	15 18 25	56	100	SS-13	4.5+	20	13	17	21	29	22	13	9	10	A-4a (3)	
-HEAVING SANDS ENCOUNTERED @ 35.0'		35																
	675.8	36																
VERY DENSE, GRAY TO BROWNISH GRAY **GRAVEL AND SAND**, TRACE SILT, DAMP TO MOIST.		37																
		38																
		39	7 13 34	62	100	SS-14	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	
-INTRODUCED WATER @ 40.0'		40																
		41																
		42																
		43																
		44	20 43 50/5"	-	100	SS-15	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
		45																
		46																
		47																
		48																
		49	17 41 50/3"	-	100	SS-16	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
		50																
		51																
	660.8	52																
HARD, GRAY **CLAY**, LITTLE SILT, TRACE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.		53																
		54	18 30 25	72	100	SS-17	-	-	-	-	-	-	-	-	-	14	A-7-6 (V)	
-SHALE FRAGMENTS PRESENT IN SS-17		55																
		56																
		57																
		58																
		59	30 26 33	77	78	SS-18	4.5+	6	1	8	18	67	44	21	23	14	A-7-6 (14)	
		60																
		61																

PID: 77372	BR ID: FRA-70-1373A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5080+09.80 / 30.9 RT	START: 7/1/13	END: 7/3/13	PG 3 OF 3	B-020-1-13

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
HARD, GRAY **CLAY**, LITTLE SILT, TRACE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP. *(same as above)*	650.7	63																
	648.6	TR 64	24 50/2"	-	100	SS-19	4.50	-	-	-	-	-	-	-	-	14	A-7-6 (V)	
SHALE: GRAY, VERY WEAK, HIGHLY WEATHERED. -AUGER REFUSAL @ 65.0'. ATTEMPTED 10.0' ROCK CORE RUN. NO RECOVERY FROM CORE RUN. MAY HAVE WASHED OUT HIGHLY WEATHERED SHALE MATERIAL DURING THE CORING OPERATION. CONTINUED SPT SAMPLING @ 75.0'.		65 66 67 68 69 70	0		0	RC-1											CORE	
		71 72 73 74 75	50/4"	-	100	SS-20	-	-	-	-	-	-	-	-	-	15	Rock (V)	
AUGER REFUSAL @ 80.5'	632.3	76 77 78 79 80	50/1"	-	0	SS-21	-	-	-	-	-	-	-	-	-	-		
LIMESTONE : LIGHT AND DARK GRAY, UNWEATHERED, STRONG, VERY THIN TO THIN BEDDED, CRYSTALLINE, DOLOMITIC, MODERATELY FRACTURED TO FRACTURED, OPEN APERTURE, VERY ROUGH; RQD 49%, REC 99%. -QU @ 80.7' = 9,465 PSI -CHERT NODULES PRESENT THROUGHOUT		81 82 83 84 85	49		99	RC-2											CORE	
	626.8	EOB 86																

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 23.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 376 PORTLAND CEMENT / 200 LBS BENTONITE POWDER / 150 GAL WATER

B-020-1-13 – RC-1 – Depth from 65.0 to 75.0 feet

B-020-1-13 – RC-2 – Depth from 81.0 to 86.0 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / S.M.	DRILL RIG: CME-750 (SN 98048)	STATION / OFFSET: 176+13.92 / 34' RT	**EXPLORATION ID B-020-2-13**
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / C.H.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-70 EB	
PID: 77372 BR ID: FRA-70-1373R	DRILLING METHOD: 3.25" HSA / RC	CALIBRATION DATE: 4/26/13	ELEVATION: 711.4 (MSL) EOB: 84.5 ft.	PAGE 1 OF 3
START: 7/16/13 END: 7/17/13	SAMPLING METHOD: SPT / NQ	ENERGY RATIO (%): 82.6	LAT / LONG: 39.953155708, -83.004534664	

MATERIAL DESCRIPTION AND NOTES	ELEV. 711.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.3' - ASPHALT (4.0")	711.1																	
0.5' - AGGREGATE BASE (6.0")	710.6																	
FILL: STIFF, BLACK AND BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP. -ROCK FRAGMENTS PRESENT	708.4	1	4 8 6	19	72	SS-1	1.75	-	-	-	-	-	-	-	-	16	A-6a (V)	
FILL: VERY LOOSE, BLACK AND BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST.	705.9	4	2 2 1	4	33	SS-2	-	47	16	12	19	6	26	23	3	15	A-1-b (0)	
POSSIBLE FILL: STIFF, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.	703.4	7	3 4 7	15	33	SS-3	2.00	-	-	-	-	-	-	-	-	15	A-6a (V)	
POSSIBLE FILL: MEDIUM STIFF TO STIFF, BROWN **SILTY CLAY**, TRACE COARSE TO FINE SAND, MOIST.	698.4	10	2 2 3	7	83	SS-4	1.00	0	1	8	54	37	39	20	19	25	A-6b (12)	
		12	3 4 6	14	83	SS-5	1.75	-	-	-	-	-	-	-	-	27	A-6b (V)	
POSSIBLE FILL: MEDIUM STIFF, BROWN **CLAY**, SOME SILT, AND FINE TO COARSE SAND, LITTLE FINE GRAVEL, MOIST. -CONSOLIDATION TEST PERFORMED @ 14.7'	693.4	15			83	ST-6	0.75	17	31	13	24	15	41	16	25	22	A-7-6 (4)	
		17	1 1 2	4	33	SS-7	0.75	-	-	-	-	-	-	-	-	25	A-7-6 (V)	
POSSIBLE FILL: LOOSE, BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, WET. -HEAVING SANDS ENCOUNTERED @ 18.5' -COBBLES PRESENT @ 19.5'	690.9	W 19	WOH 2 4	8	33	SS-8	-	33	21	13	26	7	31	25	6	30	A-2-4 (0)	
DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST.		22	4 13 10	32	67	SS-9	-	-	-	-	-	-	-	-	-	16	A-1-b (V)	
		24	50/5"	-	80	SS-10	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
		27	9 12 14	36	33	SS-11	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
		29	9 24 32	77	39	SS-12	-	47	27	10	12	4	21	18	3	7	A-1-b (0)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/31/15 08:54 - U:\GI\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1373R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 176+13.92 / 34 RT	START: 7/16/13	END: 7/17/13	PG 2 OF 3	B-020-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST. *(same as above)*	681.4	31																
		32																
		33																
		34	14 29 33	85	61	SS-13	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
		35																
		36																
		37																
		38																
		39	22 48 50/5"	-	71	SS-14	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
		40																
		41																
		42																
		43																
		44	15 31 29	83	94	SS-15	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
HARD, BROWN **SILT AND CLAY**, LITTLE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP.	666.9	45					4.5+	11	1	4	46	38	32	18	14	17	A-6a (10)	
	664.4	46																
HARD, BROWN **SILTY CLAY**, LITTLE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP.		47																
		48																
		49	29 27 25	72	22	SS-16	-	-	-	-	-	-	-	-	-	18	A-6b (V)	
		50																
		51																
		52																
		53																
		54	11 20 20	55	56	SS-17	4.50	-	-	-	-	-	-	-	-	17	A-6b (V)	
		55																
		56																
		57																
		58																
		59	14 50/3"	-	89	SS-18	-	19	3	4	36	38	38	20	18	16	A-6b (11)	
		60																
		61																
	649.4																	

PID: 77372	BR ID: FRA-70-1373R	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 176+13.92 / 34 RT	START: 7/16/13	END: 7/17/13	PG 3 OF 3	B-020-2-13

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
HARD, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP. *(same as above)*	649.3	63																
	647.1	TR 64	35 50/3"	-	100	SS-19	-	-	-	-	-	-	-	-	-	11	A-6a (V)	
SHALE: GRAY, VERY WEAK, HIGHLY WEATHERED.		65																
		66																
		67																
		68																
	641.9	69	49 50/2"	-	100	SS-20	-	-	-	-	-	-	-	-	-	9	Rock (V)	
SHALE : GRAY AND BLACK, SLIGHTLY TO MODERATELY WEATHERED, WEAK AND STRONG, THINLY LAMINATED TO MEDIUM BEDDED, CALCAREOUS, PYRITIC, FISSILE, FRACTURED TO HIGHLY FRACTURED, NARROW TO OPEN APERTURE, SMOOTH TO SLIGHTLY ROUGH; RQD 4%, REC 30%.		70																
		71																
		72	8		40	RC-1											CORE	
		73																
		74																
		75																
		76																
		77	0		20	RC-2											CORE	
		78																
	631.9	79																
LIMESTONE : GRAY AND TAN, SLIGHTLY WEATHERED, MODERATELY STRONG, VERY THIN TO MEDIUM BEDDED, CALCAREOUS, PYRITIC, DOLOMITIC, CHERT NODULES, FRACTURED TO SLIGHTLY FRACTURED, NARROW APERTURE, SMOOTH; RQD 97%, REC 97%.		80																
		81																
		82	97		97	RC-3											CORE	
		83																
	626.9	EOB 84																

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 18.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 94 LBS PORTLAND CEMENT / 100 LBS BENTONITE POWDER / 50 GAL WATER

B-020-2-13 – RC-1, RC-2, and RC-3 – Depth from 69.5 to 84.5 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: 5081+15.55 / 85.3' RT	**EXPLORATION ID B-020-3-13**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / S.B.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C5		
PID: 77372 BR ID: FRA-70-1373A	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 712.3 (MSL) EOB: 49.8 ft.		PAGE 1 OF 2
START: 8/15/13 END: 8/21/13	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.952760425, -83.004309070		

MATERIAL DESCRIPTION AND NOTES	ELEV. 712.3	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
0.3' - ASPHALT (4.0")	712.0																	
0.3' - BRICK (4.0")	711.7																	
0.8' - AGGREGSTE BASE (9.0")	710.9																	
POSSIBLE FILL: STIFF, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP. -TRACE ORGANICS IN SS-1	709.3	1	3 3 6	12	72	SS-1	2.00	-	-	-	-	-	-	-	-	13	A-6a (V)	
POSSIBLE FILL: STIFF TO VERY STIFF, GRAY TO BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		2																
		3	3 2 3	6	61	SS-2	1.25	4	4	8	47	37	38	18	20	22	A-6b (12)	
		4																
		5	1 2 4	8	83	SS-3	2.25	-	-	-	-	-	-	-	-	31	A-6b (V)	
		6																
		7																
		8	4 3 5	10	78	SS-4	2.50	0	0	14	54	32	35	15	20	22	A-6b (12)	
		9																
		10																
		11	1 2 3	6	44	SS-5	1.75	-	-	-	-	-	-	-	-	18	A-6b (V)	
	699.3	12																
POSSIBLE FILL: MEDIUM STIFF, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		13																
		14	WOH 2 4	8	44	SS-6	1.00	-	-	-	-	-	-	-	-	23	A-6a (V)	
	696.8	15	W															
MEDIUM DENSE TO VERY DENSE, BROWN AND GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		16																
		17	14 22 20	54	39	SS-7	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
-COBBLES PRESENT THROUGHOUT		18																
		19	WOH 8 10	23	50	SS-8	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
	691.8	20																
LOOSE TO VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, MOIST.		21																
		22	2 3 4	9	50	SS-9	1.75	50	21	9	17	3	24	18	6	13	A-1-b (0)	
-COBBLES PRESENT THROUGHOUT		23																
		24	5 15 40	71	67	SS-10	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
		25																
-AUGER REFUSAL ENCOUNTERED @ 26.0'. ATTEMPTED 5.0' CORE RUN. GRANITE BOULDER PIECE RECOVERED IN CORE RUN. REMAINING SOIL WAS WASHED OUT DURING CORING OPERATION. CONTINUED SPT SAMPLING @ 31.3'.		26	50/3"	-	0	SS-11	-	-	-	-	-	-	-	-	-	-	
		27																
		28																
		29	7		17	RC-1											CORE	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/28/15 11:04 - U:\GI\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1373A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5081+15.55 / 85.3 RT	START: 8/15/13	END: 8/21/13	PG 2 OF 2	B-020-3-13

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
LOOSE TO VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, MOIST. *(same as above)*	682.3	31																
	680.3	32																
VERY STIFF TO HARD, GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP TO MOIST.		33																
		34																
		35	10 30 50/5"	-	100	SS-12	4.5+	20	8	11	29	32	34	16	18	14	A-6b (8)	
		36																
		37																
		38																
	672.8	39	10 40 50/4"	-	100	SS-13	4.00	-	-	-	-	-	-	-	-	19	A-6b (V)	
VERY DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP TO MOIST.		40					-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
		41																
		42																
		43																
		44	19 50/2"	-	38	SS-14	-	-	-	-	-	-	-	-	-	5	A-1-a (V)	
	665.3	45																
		46																
		47																
		48																
VERY DENSE, BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP. -AUGER REFUSAL ENCOUNTERED @ 49.8'. ATTEMPTED ROCK CORE RUN AT 49.8' AND RECOVERED GRANITE BOULDER PIECE. SOIL WAS OBSERVED TO BE WASHING OUT WITH THE CIRCULATION FUILD BELOW THE BOULDER. BORING TERMINATED AT 49.8' PRIOR TO ENCOUNTERING BEDROCK.	662.5	49 EOB	25 36 50/3"	-	60	SS-15	-	47	20	12	14	7	22	14	8	10	A-2-4 (0)	

NOTES: SEEPAGE ENCOUNTERED @ 15.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 50 LBS BENTONITE CHIPS AND SOIL CUTTINGS

B-020-3-13 – RC-1 – Depth from 26.0 to 29.0 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.B./J.K.	DRILL RIG: CME-750 (SN 98048)	STATION / OFFSET: 175+57.74 / 11.8' RT	**EXPLORATION ID B-020-5-13**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / S.B./N.A.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-70 WB		
PID: 89464 BR ID: FRA-70-1373L	DRILLING METHOD: 4.25" HSA / HQ	CALIBRATION DATE: 4/26/13	ELEVATION: 733.4 (MSL) EOB: 90.0 ft.		PAGE 1 OF 3
START: 2/18/14 END: 1/29/15	SAMPLING METHOD: SPT / RC	ENERGY RATIO (%): 82.6	LAT / LONG: 39.953452196, -83.004773258		

MATERIAL DESCRIPTION AND NOTES	ELEV. 733.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
0.5' - CONCRETE (6.0")	732.9																	
0.5' - AGGREGATE BASE (6.0")	732.4																	
FILL: VERY STIFF TO HARD, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP TO MOIST.		1 2 3																
-WOOD FRAGMENTS PRESENT IN SS-1		4 5	8 9 10	26	50	SS-1	3.50	-	-	-	-	-	-	-	-	17	A-6a (V)	
		6 7 8																
-IRON STAINING PRESENT IN SS-2		9 10	4 7 8	21	44	SS-2	3.75	-	-	-	-	-	-	-	-	20	A-6a (V)	
-ROCK FRAGMENTS PRESENT THROUGHOUT		11 12 13																
		14 15	5 7 11	25	67	SS-3	4.25	11	8	16	36	29	32	17	15	15	A-6a (8)	
		16 17 18																
-IRON STAINING PRESENT IN SS-4		19 20	4 9 12	29	78	SS-4	4.00	-	-	-	-	-	-	-	-	17	A-6a (V)	
-BRICK FRAGMENTS PRESENT IN SS-5		21 22	12 15 15	41	89	SS-5	4.50	-	-	-	-	-	-	-	-	17	A-6a (V)	
		23																
-LIMESTONE FRAGMENTS PRESENT IN SS-6		24 25	15 8 13	29	44	SS-6	4.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
	707.9																	
HARD, BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST. -IRON STAINING PRESENT IN SS-7		26 27	6 8 12	28	56	SS-7	4.50	13	13	15	29	30	33	16	17	18	A-6b (8)	
		28 29																
			4 6 10	22	89	SS-8	4.50	-	-	-	-	-	-	-	-	23	A-6b (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 4/21/15 08:35 - U:\GI\PROJECTS\2013\W-13-072.GPJ

PID: 89464	BR ID: FRA-70-1373L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 175+57.74 / 11.8 RT	START: 2/18/14	END: 1/29/15	PG 2 OF 3	B-020-5-13

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
HARD, BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST. *(same as above)*	703.4	31	9 14 15	40	72	SS-9	4.50	-	-	-	-	-	-	-	-	19	A-6b (V)	
	700.4	32																
MEDIUM DENSE TO VERY DENSE, BROWN TO REDDISH BROWN **GRAVEL WITH SAND AND SILT**, LITTLE CLAY, MOIST.		33																
		34	5 6 6	17	56	SS-10	-	-	-	-	-	-	-	-	-	14	A-2-4 (V)	
		35																
		36																
		37	10 8 10	25	100	SS-11	-	33	21	12	25	9	24	19	5	13	A-2-4 (0)	
		38																
		39	15 20 30	69	83	SS-12	-	-	-	-	-	-	-	-	-	13	A-2-4 (V)	
	692.9	40																
MEDIUM DENSE TO VERY DENSE, BROWN TO GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DAMP TO MOIST.		41																
		42	19 19 17	50	78	SS-13	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
-INTRODUCED MUD @ 43.0'		43	W															
		44	18 19 24	59	56	SS-14	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
		45																
		46																
		47	11 7 10	23	100	SS-15	-	23	46	18	9	4	NP	NP	NP	14	A-1-b (0)	
-ROCK FRAGMENTS PRESENT THROUGHOUT		48																
		49	15 23 27	69	56	SS-16	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
		50																
		51																
		52																
		53																
		54	50/5"	-	100	SS-17	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
-STRONG PETROLEUM ODOR PRESENT IN SS-17		55																
		56																
	676.4	57																
HARD, GRAY **SANDY SILT**, SOME CLAY, TRACE FINE GRAVEL, MOIST.		58																
		59	15 30 50/5"	-	59	SS-18	4.50	5	9	18	45	23	25	15	10	17	A-4a (7)	
		60																
		61																
	671.4																	

PID: 89464	BR ID: FRA-70-1373L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 175+57.74 / 11.8 RT	START: 2/18/14	END: 1/29/15	PG 3 OF 3	B-020-5-13

MATERIAL DESCRIPTION AND NOTES	ELEV. 671.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, DAMP. *(same as above)*	669.2	63																
		64	8 30 45	103	61	SS-19	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
HARD, BROWN **SILT AND CLAY**, "AND" COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP.		65					4.50	-	-	-	-	-	-	-	-	9	A-6a (V)	
		66																
		67																
		68																
-ROCK FRAGMENTS PRESENT IN SS-20		69	25 30 50	110	78	SS-20	4.50	20	13	23	24	20	25	12	13	10	A-6a (3)	
	661.4	70																
		71																
HARD, BROWN **SILTY CLAY**, LITTLE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP.		72																
		73																
		74	24 17 30	65	89	SS-21	4.50	-	-	-	-	-	-	-	-	17	A-6b (V)	
AUGER REFUSAL @ 75.5'	657.9	75																
GRANITE BOULDER	656.8	76			62	RC-1	-	-	-	-	-	-	-	-	-	-		
-BORING TERMINATED @ 76.6' ON 2-23-14. RESUMED DRILLING ON 1-22-15 AND CONTINUED SAMPLING @ 78.5'.		TR																
		77																
		78																
SHALE : GRAY, HIGHLY WEATHERED, VERY WEAK.		79	49 29 37	91	17	SS-22	-	-	-	-	-	-	-	-	-	13	Rock (V)	
	653.4	80																
MUDSTONE : GRAY, SLIGHTLY WEATHERED, VERY WEAK TO WEAK, VERY THIN TO THICK BEDDED, ARENACEOUS, CALCAREOUS, FRIABLE, FISSILE, PYRITIC, SLIGHTLY TO HIGHLY FRACTURED, TIGHT TO OPEN APERTURES, ROUGH TO VERY ROUGH; RQD 73%, REC 88%.		81																
		82	63		80	RC-2											CORE	
-0.3' GRANITE BOULDER @ 80.0'		83																
-0.3' LIMESTONE SEAM @ 82.6'		84																
		85																
		86																
	645.4	87	72		100	RC-3											CORE	
SHALE : BLACK AND GRAY, UNWEATHERED TO SLIGHTLY WEATHERED, VERY WEAK TO SLIGHTLY STRONG, LAMINATED TO THICK BEDDED, ARENACEOUS, CALCAREOUS, FRIABLE, FISSILE, MODERATELY TO HIGHLY FRACTURED, TIGHT TO OPEN APERTURES, ROUGH TO VERY ROUGH; RQD 46%, REC 100%.	643.4	88																
		89																
		EOB 90																

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 43.5'

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

B-020-5-13 – RC-1 – Depth from 75.5 to 76.6 feet

B-020-5-13 – RC-2 and RC-3 – Depth from 80.0 to 90.0 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: STOCK / J/M	DRILL RIG: CME 55-LC (SN 360485)	STATION / OFFSET: 176+68.64 / 1.8' RT	**EXPLORATION ID B-020-7-13**
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / K.R.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-70 WB	
PID: 89464 BR ID: FRA-70-1373L	DRILLING METHOD: 4.25" HSA / NQ	CALIBRATION DATE: 3/28/13	ELEVATION: 713.5 (MSL) EOB: 80.4 ft.	PAGE 1 OF 3
START: 1/19/15 END: 1/22/15	SAMPLING METHOD: SPT / RC	ENERGY RATIO (%): 73.2	LAT / LONG: 39.953451540, -83.004376859	

MATERIAL DESCRIPTION AND NOTES	ELEV. 713.5	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
0.7' - CONCRETE (8.0")	712.8																	
POSSIBBLE FILL: LOOSE TO MEDIUM DENSE, BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST.		1	5 4 4	10	83	SS-1	-	-	-	-	-	-	-	-	-	12	A-2-4 (V)	
		2																
		3																
		4	WOH 2 3	6	67	SS-2	-	25	31	17	19	8	NP	NP	NP	13	A-2-4 (0)	
	706.5	5																
		6																
POSSIBBLE FILL: STIFF, DARK BROWN **CLAY**, "AND" SILT, TRACE COARSE TO FINE SAND, MOIST.		7																
		8																
		9	2 4 6	12	11	SS-3	-	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
-SWITCHED TO ROTARY DRILLING TECHNIQUES WITH WATER AND CASING ADVANCER @ 10.0'		10																
		11																
-CONSOLIDATION TEST PERFORMED @ 11.8' -CU TRIAXIAL COMPRESSION TEST PERFORMED @ 12.0'		12			71	ST-4	1.50	0	2	7	45	46	43	19	24	23	A-7-6 (14)	
	700.5	13																
POSSIBBLE FILL: MEDIUM STIFF TO STIFF, BROWN **SILTY CLAY**, TRACE FINE SAND, TRACE FINE GRAVEL, MOIST.		14	2 3 4	9	81	S-5	1.25	1	0	8	49	42	38	19	19	26	A-6b (12)	
		15																
		16																
	696.4	17			63	ST-6	0.75	-	-	-	-	-	-	-	-	-	A-6b (V)	
POSSIBBLE FILL: HARD, REDDISH BROWN **SANDY SILT**, LITTLE FINE GRAVEL, LITTLE CLAY, MOIST.	695.5						4.50	19	14	12	40	15	26	21	5	21	A-4a (4)	
		18																
POSSIBBLE FILL: MEDIUM STIFF, BROWN **CLAY**, "AND" SILT, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		19	1 2 3	6	33	SS-7	-	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
	693.0	20																
VERY DENSE, BLACK **GRAVEL**, LITTLE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		21																
		22			0	ST-8	-	-	-	-	-	-	-	-	-	-		
		23																
-COBBLES PRESENT @ 24.0'		24	7 19 20	48	61	SS-9	-	78	11	5	4	2	NP	NP	NP	11	A-1-a (0)	
	686.5	25																
		26																
DENSE, BROWN AND BLACK **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST.		27																
		28																
-HEAVING SANDS ENCOUNTERED @ 28.5'		29	5 13 14	33	100	SS-10	-	-	-	-	-	-	-	-	-	15	A-1-b (V)	

PID: 89464	BR ID: FRA-70-1373L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 176+68.64 / 1.8 RT	START: 1/19/15	END: 1/22/15	PG 2 OF 3	B-020-7-13

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
DENSE, BROWN AND BLACK **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST. *(same as above)*	683.5	31																
	681.5	32																
HARD, BROWNISH GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, MOIST.		33																
	679.5	34	11 20 33	65	72	SS-11	4.5+	11	11	19	33	26	27	15	12	13	A-6a (6)	
VERY DENSE, BLACK **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST.		35					-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
		36																
		37																
		38																
		39	6 20 38	71	94	SS-12	-	54	14	22	7	3	NP	NP	NP	14	A-1-b (0)	
-COBBLES PRESENT @ 40.0'		40																
	671.5	41																
HARD, GRAY **SILT AND CLAY**, SOME COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP.		42																
		43																
		44	4 6 21	33	44	SS-13	4.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
		45																
	666.5	46																
VERY DENSE, GRAY AND BLACK **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		47																
		48																
		49	9 32 41	89	100	SS-14	-	70	13	9	5	3	NP	NP	NP	10	A-1-a (0)	
		50																
		51																
		52																
		53																
	659.5	54	5 20 39	72	78	SS-15	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	
HARD, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		55					4.5+	-	-	-	-	-	-	-	-	13	A-6a (V)	
AUGER REFUSAL @ 55.0'		56			25	RC-1	-	-	-	-	-	-	-	-	-	-	A-6a (V)	
-0.8' GRANITE BOULDER @ 56.5'		57																
		58																
		59			33	RC-2	-	-	-	-	-	-	-	-	-	-	A-6a (V)	
		60																
-0.8' MUDSTONE SEAM @ 60.7'		61																

PID: 89464	BR ID: FRA-70-1373L	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 176+68.64 / 1.8 RT	START: 1/19/15	END: 1/22/15	PG 3 OF 3	B-020-7-13

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
HARD, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST. *(same as above)* -0.1' THICK PIECE OF GRANITE RECOVERED IN RC-3. REMAINING SOIL WASHED OUT DURING CORING.	651.4	63 64 65			2	RC-3	-	-	-	-	-	-	-	-	-	-	A-6a (V)	
	648.1	TR																
MUDSTONE : GRAY, HIGHLY WEATHERED, VERY WEAK, THINLY LAMINATED TO THIN BEDDED, ARENACEOUS, CALCAREOUS, FRIABLE, FISSILE, SLIGHTLY TO HIGHLY FRACTURED, THIGHT APERTURES, SLIGHTLY ROUGH; RQD 74%, REC 98%.		66 67 68 69 70	89		97	RC-4											CORE	
-POINT LOAD STRENGTH @ 69.4' to 74.8' -MEAN QU = 224 PSI		71 72 73 74 75																
		76 77 78	45		100	RC-5											CORE	
	633.1	EOB 79 80																

NOTES: GROUNDWATER NOT ENCOUNTERED PRIOR TO INTORDUCTION OF WATER AS A DRILLING FLUID

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 150 LBS BENTONITE CHIPS AND SOIL CUTTINGS

B-020-7-13 – RC-1, RC-2, RC-3 and RC-4 – Depth from 55.0 to 73.5 feet

B-020-7-13 – RC-4 (cont.) and RC-5 – Depth from 73.5 to 80.4 feet

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-12.68 - PHASE 4A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: CME 55 (SN 386345)	STATION / OFFSET: 5081+05.25 / 39.8' RT	**EXPLORATION ID B-020-9-15**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / C.D.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL RAMP C5		
PID: 77372 BR ID: FRA-70-1373A	DRILLING METHOD: 4.25" HSA / RC	CALIBRATION DATE: 10/20/14	ELEVATION: 713.0 (MSL) EOB: 75.5 ft.		PAGE 1 OF 3
START: 3/16/15 END: 3/17/15	SAMPLING METHOD: SPT / HQ	ENERGY RATIO (%): 92	LAT / LONG: 39.952886963, -83.004333117		

MATERIAL DESCRIPTION AND NOTES	ELEV. 713.0	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
0.3'- ASPHALT (4.0")	712.7																	
0.4' - BRICK (4.0")	712.3																	
0.3' - AGGREGATE BASE (3.0")	712.0																	
POSSIBLE FILL: STIFF, DARK BROWN **SILT AND CLAY**, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP TO MOIST.		1	5 4 3	11	56	SS-1	1.25	-	-	-	-	-	-	-	-	22	A-6a (V)	
		2																
		3																
		4	4 4 4	12	100	SS-2	1.50	10	10	14	37	29	35	20	15	18	A-6a (8)	
	707.5	5																
POSSIBLE FILL: STIFF, DARK BROWN AND BLACK TO BROWNISH GRAY **SILTY CLAY**, LITTLE COARSE TO FINE SAND, MOIST.		6	3 2 4	9	61	SS-3	2.00	-	-	-	-	-	-	-	-	37	A-6b (V)	
		7																
		8																
		9	4 4 6	15	100	SS-4	2.00	0	1	13	50	36	34	18	16	21	A-6b (10)	
	702.5	10																
DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DAMP. -ROCK FRAGMENTS PRESENT IN SS-5		11	7 11 12	35	39	SS-5	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	
	700.0	12																
MEDIUM DENSE, BROWN **SANDY SILT**, "AND" FINE GRAVEL, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT IN SS-6		13																
		14	6 5 13	28	100	SS-6	-	38	15	10	29	8	22	19	3	14	A-4a (0)	
	697.5	15																
VERY DENSE, BROWNISH GRAY **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT IN SS-7		16																
		17	20 14 24	58	89	SS-7	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
	695.0	18																
MEDIUM DENSE, BROWNISH GRAY **SANDY SILT**, SOME FINE GRAVEL, TRACE CLAY, MOIST.		19	13 9 9	28	100	SS-8	-	34	18	12	26	10	NP	NP	NP	10	A-4a (0)	
	692.5	20																
MEDIUM DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, LITTLE SILT, TRACE CLAY, MOIST.		21																
		22	14 43 17	92	50	SS-9	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
		23																
-ROCK FRAGMENTS PRESENT THROUGHOUT	W	24	13 4 8	18	33	SS-10	-	33	38	9	13	7	NP	NP	NP	16	A-1-b (0)	
		25																
		26																
-PETROLEUM ODOR PRESENT IN SS-11		27	23 25 50/4"	-	88	SS-11	-	47	21	14	12	6	NP	NP	NP	11	A-1-b (0)	
	685.0	28																
VERY DENSE, BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST. -INTRODUCED MUD @ 30.0'		29	7 14 19	51	100	SS-12	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 3/28/15 13:40 - U:\GI\PROJECTS\2013\W-13-045.GPJ

PID: 77372	BR ID: FRA-70-1373A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5081+05.25 / 39.8 RT	START: 3/16/15	END: 3/17/15	PG 2 OF 3	B-020-9-15

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
VERY DENSE, BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST. *(same as above)*	683.0	31																
		32																
		33																
		34	5 30 42	110	100	SS-13	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	
		35																
		36																
	676.0	37																
VERY DENSE, GRAY **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST.		38																
		39	34 37 50/5"	-	82	SS-14	-	35	18	14	15	18	26	13	13	9	A-2-6 (1)	
		40																
		41																
	671.0	42																
VERY DENSE, BROWNISH GRAY TO GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST.		43																
		44	17 32 15	72	100	SS-15	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
		45																
		46																
		47																
		48																
		49	17 50/5"	-	73	SS-16	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
-ROCK FRAGMENTS PRESENT IN SS-16		50																
		51																
	661.0	52																
VERY STIFF TO HARD, GRAY **CLAY**, SOME SILT, LITTLE FINE GRAVEL, TRACE COARSE TO FINE SAND, DAMP.		53																
		54	12 24 39	97	100	SS-17	4.5+	11	3	3	34	49	42	19	23	14	A-7-6 (14)	
		55																
-BECOMING SHALE WITH DEPTH		56																
		57																
		58																
		59	23 50/4"	-	100	SS-18	3.75	-	-	-	-	-	-	-	-	16	A-7-6 (V)	
	652.5	60																
	TR	61																

PID: 77372	BR ID: FRA-70-1373A	PROJECT: FRA-70-12.68 - PHASE 4A	STATION / OFFSET: 5081+05.25 / 39.8 RT	START: 3/16/15	END: 3/17/15	PG 3 OF 3	B-020-9-15

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
SHALE : DARK GRAY TO BLACK, HIGHLY WEATHERED, VERY WEAK TO WEAK, THINLY LAMINATED TO MEDIUM BEDDED, ARENACEOUS, CALCAREOUS, FRIABLE, FISSILE, JOINTED, MODERATELY TO HIGHLY FRACTURED, THIGHT TO OPEN APERTURES, SLIGHTLY TO VERY ROUGH; RQD 48%, REC 75%. *(same as above)* -0.4' GRANITE BOULDER @ 60.5' -0.2' CLAY SEAM @ 60.9' -0.4' LIMESTONE SEAM @ 61.5' -0.5' LIMESTONE SEAM @ 64.5'	650.9	63 64 65	17		52	RC-1											CORE	
		66 67 68 69 70	48		75	RC-2											CORE	
-SLIGHTLY WEATHERED AND SLIGHTLY FRACTURED IN RC-3		71 72 73 74 75	80		100	RC-3											CORE	
	637.5	EOB																

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 24.5'

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

B-020-9-13 ALT – RC-1 and RC-2 – Depth from 60.5 to 70.5 feet

B-020-9-13 ALT – RC-3 – Depth from 70.5 to 75.5 feet

APPNDIX IV

HISTORIC BORING LOGS:

B-001-A-59

B-001-A-59

STATE OF OHIO
DEPARTMENT OF HIGHWAYS
TESTING LABORATORY

SHEET 4

LOG OF BORING

CO., RT. NO., SEC. FRA-40-12.82 BRIDGE NO.
RETAINING WALL-A SOUTH-EAST INNERBELT

LOCATION: T.H 1-ABA STA. 51+16 OFFSET 72'RT FED. NO.

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
714.5	0			
	2			
	4			
709.5	6	2/3	19687	Brown Silty Gravelly Sand
707.0	8	3/5	19688	Dk.Gr.Gravelly Sand Silt W/Coal Fragments
704.5	10			
	12	3/6	19689	Dk.Gr.Gravelly Sandy Silt
702.0	14	3/7	19690	Gr.Gravelly Sandy Silt Trace of Organic
699.5	16	4/9	19691	Dk.Gray Silty Sandy Gravel
697.0	18	10/13	19692	Brown Gravel W/Limestone Fragments
694.5	20			
	22	8/14	19693	Brown Sandy Gravel
692.0	24	12/18	19694	Brown Silty Sandy Gravel
689.5	26	10/16	19695	Brown Silty Sandy Gravel
	28			
684.5	30			
	32	19/32	19696	Gray Silty Gravelly Sand
	34			
679.5	36	30/55	19697	Gray Sandy Gravel

FILL

Boulders

MB
A. 26. 59

B-001-A-59

LOG OF BORING (CONTINUED) SHEET 5

BRIDGE NO. _____ T.H. 1-A B

ELEV.	DEPTH	NO. BLOWS	SAMPLE NO.	DESCRIPTION
	38			
674.5	40			
		45/75	19698	Gray Silty Sandy Gravel
	42			
	44			
669.5				
	46	37/95	19699	Gray Silty Sandy Gravel
	48			
664.5	50			
663.5		31/40	19700	Gray Sandy Silt
	52			BOTTOM OF BORING
	54			
	56			
	58			
	60			
	62			
	64			
	66			
	68			
	70			
	72			
	74			
	76			
	78			
	80			
	82			

Boulders

APPENDIX V

LABORATORY TEST RESULTS

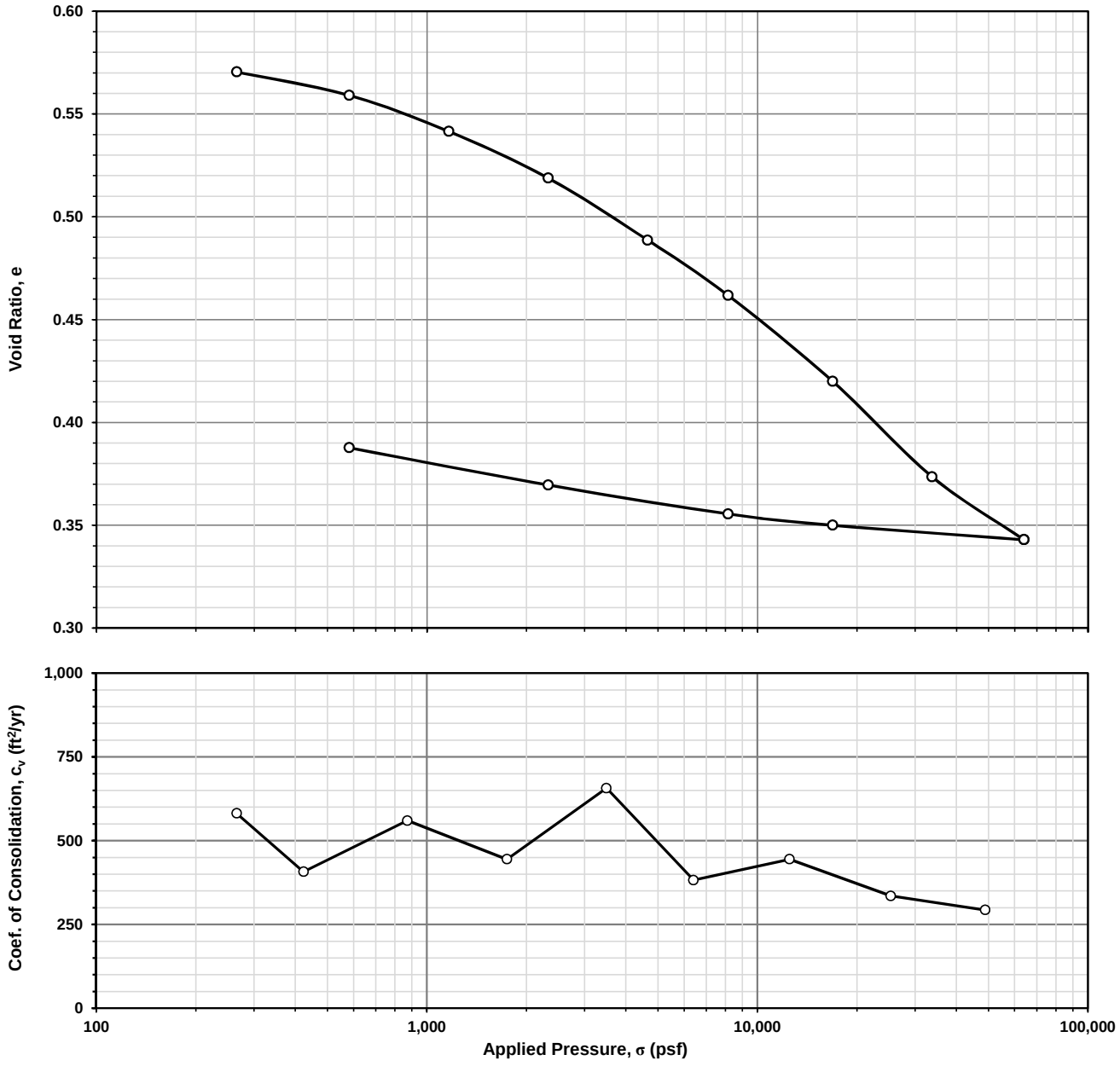
One-Dimensional Consolidation Test Report (ASTM D2435)

Project Number:	W-13-045	Boring Number:	B-020-2-13
Project Name:	FRA-70-12.68	Station / Offset:	176+13.62, 34.0' Rt.
Project Location:	Columbus, Ohio	Sample No. / Depth:	ST-6 / 14.7 ft
Client:	GPD GROUP	Date of Testing:	08/13/2013 to 08/30/2013

Soil Description: Brown CLAY, and coarse to fine sand, some silt, little fine gravel.
Soil Classification: ODOT A-7-6

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	41	16	25	17	31	13	24	15

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								
101.6%	19.9%	105.6	128.9	1,617	2.67	0.578	2,470	0.154	0.022



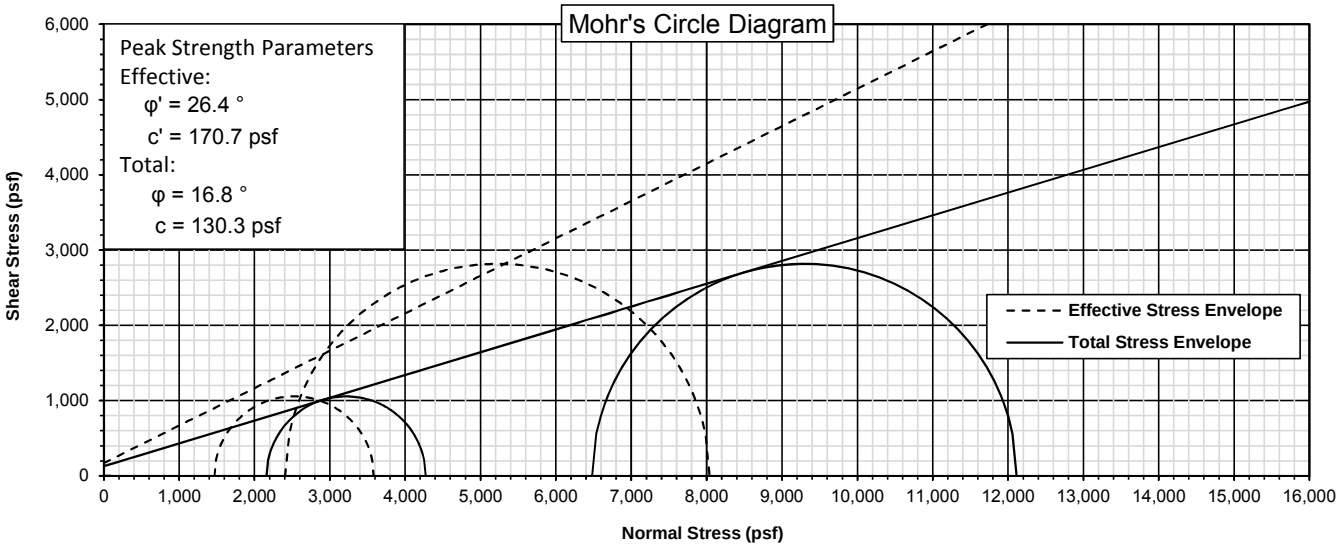
Consolidated, Undrained Triaxial Compression Test Report (ASTM D4767)

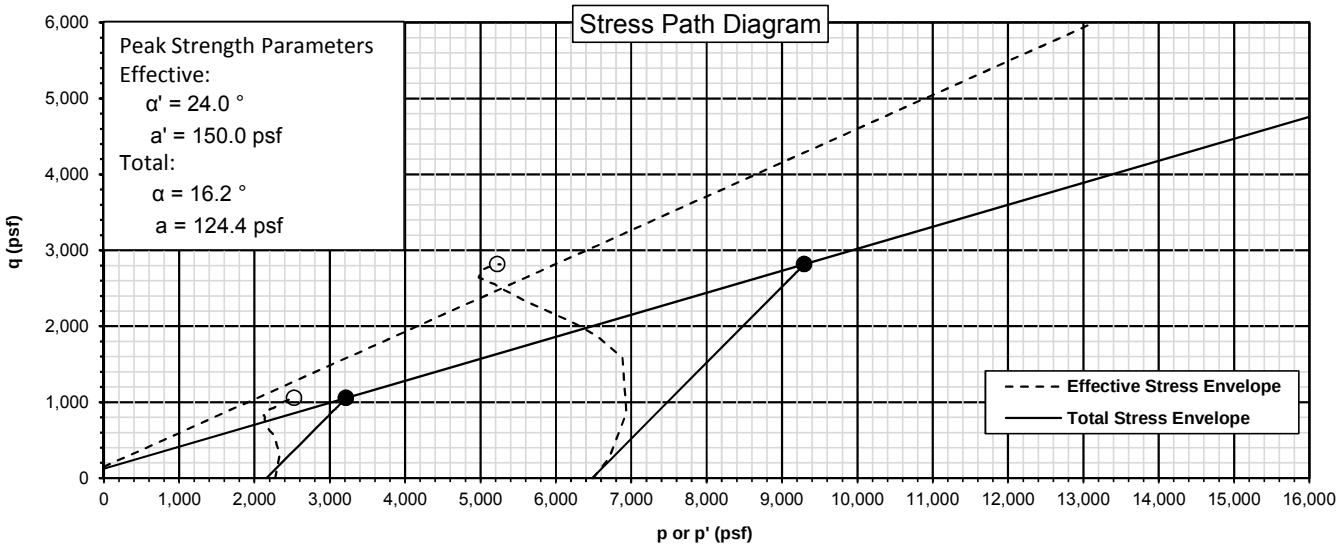
Project Number:	W-13-045	Boring Number:	B-020-2-13
Project Name:	FRA-70-12.68	Station / Offset:	176+13.92, 34.0' Rt.
Project Location:	Columbus, Ohio	Sample No. / Depth:	ST-6 / 13.5 ft to 14.0 ft
Client:	GPD GROUP	Date of Testing:	08/14/2013 to 08/21/2013

Soil Description: Brown CLAY, "and" coarse to fine sand, some silt, little fine gravel.
Soil Classification: ODOT A-7-6

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	41	16	25	17	31	13	24	15

Stage	Boring No.	Sample No.	Depth (ft)	$(\sigma_3)_f$ (psf)	$(\sigma_1)_f$ (psf)	$(\sigma_3')_f$ (psf)	$(\sigma_1')_f$ (psf)	p'_f (psf)	q_f (psf)
1	B-020-2-13	ST-6	13.5	2,160.0	4,271.8	1,468.8	3,580.6	2,524.7	1,055.9
2	B-020-2-13	ST-6	14	6,480.0	12,114.6	2,404.8	8,039.4	5,222.1	2,817.3
3									





Notes:

Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

Project Number:	W-13-045	Boring Number:	B-020-2-13
Project Name:	FRA-70-12.68	Station / Offset:	176+13.92, 34.0' Rt.
Project Location:	Columbus, Ohio	Sample No. / Depth:	ST-6 / 13.5 ft
Client:	GPD GROUP	Date of Testing:	6/21/2013

Data for Specimen No. 1

Soil Description: Brown CLAY, "and" coarse to fine sand, some silt, little fine gravel.
Soil Classification: ODOT A-7-6

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	41	16	25	17	31	13	24	15

Diameter, D_0	2.854	in	Volume of Solids , V_s :	21.813	in^3
Area, A_0	6.396	in^2	Initial Volume of Voids, V_v :	14.805	in^3
Height, L_0	5.725	in	Initial Void Ratio, e_o :	0.679	
Volume, V_0	36.618	in^3	Initial Degree of Saturation, S_0 :	88.2	%

Water Content BEFORE Test

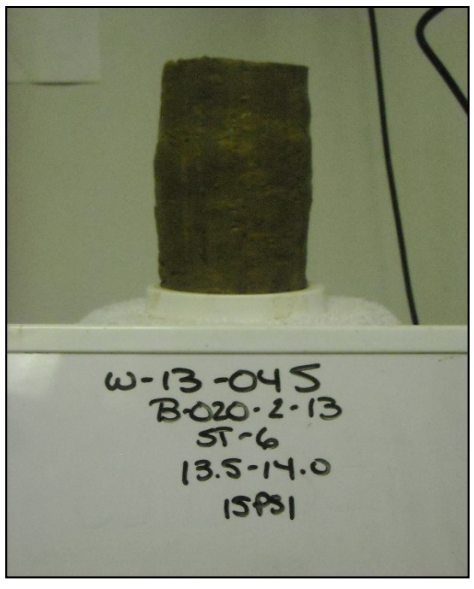
Tin No.:	M-74	g
Wet Soil + Tin :	146.25	g
Dry Soil + Tin :	124.58	g
Tin Weight :	27.9	g
Dry Mass :	96.68	g
Weight of water :	21.67	g
Moisture :	22.41	%

Water Content AFTER Test (Total Specimen)

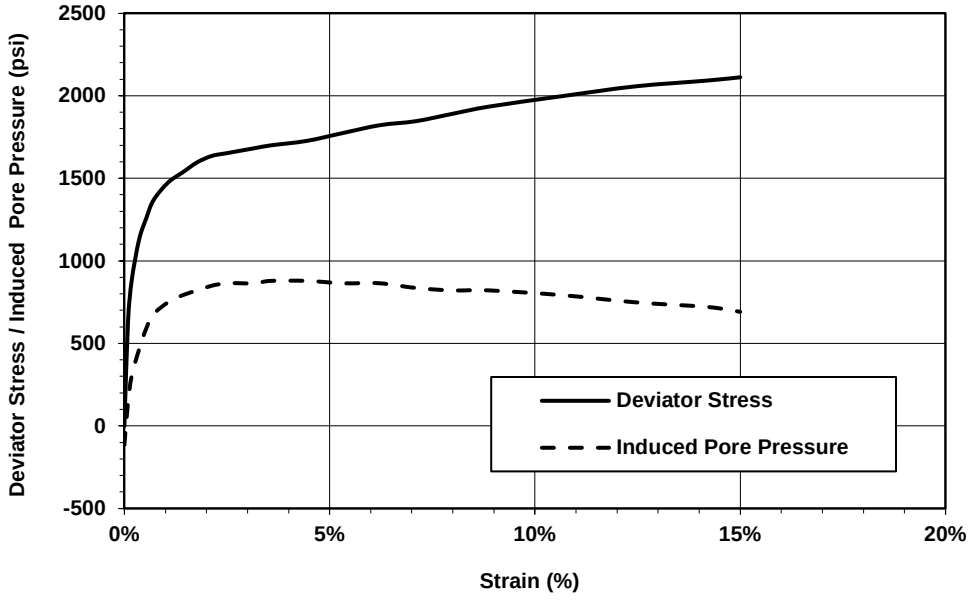
Tin No.:	KDW	g
Wet Soil + Tin :	1262.80	g
Dry Soil + Tin :	1032.30	g
Tin Weight :	77.90	g
Dry Mass :	954.40	g
Weight of water :	230.50	g
Moisture :	24.15	%
Wet Density :	123.27	pcf
Dry Density :	99.29	pcf

Consolidation Cell Pressure:	140.0	psi	Deviator Stress @ Failure, Ds:	2,112	psf
Consolidation Back Pressure:	125.0	psi	Axial Strain @ Failure:	15.0	%
Effective Confining Stress, σ_3:	15.0	psi	Major Principal Stress @ Failure, σ_1:	4,272	psf
	2,160	psf	Induced Pore Pressure @ Failure:	691	psf
Strain Rate:	0.0030	in/min	Effective Minor Principal Stress,σ'_3:	1,469	psf
			Effective Major Principal Stress, σ'_1:	3,581	psf

Failure Sketch



CU Compressive Strength and Induced Pore Pressure



Notes:

Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

Project Number:	W-13-045	Boring Number:	B-020-2-13
Project Name:	FRA-70-12.68	Station / Offset:	176+13.92, 34.0' Rt.
Project Location:	Columbus, Ohio	Sample No. / Depth:	ST-6 / 14.0 ft
Client:	GPD GROUP	Date of Testing:	8/21/2013

Data for Specimen No. 2

Soil Description: Brown CLAY, "and" coarse to fine sand, some silt, little fine gravel.
Soil Classification: ODOT A-7-6

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	41	16	25	17	31	13	24	15

Diameter, D_0	2.849	in	Volume of Solids , V_s :	23.322	in^3
Area, A_0	6.376	in^2	Initial Volume of Voids, V_v :	13.698	in^3
Height, L_0	5.806	in	Initial Void Ratio, e_o :	0.587	
Volume, V_0	37.019	in^3	Initial Degree of Saturation, S_0 :	101.89	%

Water Content BEFORE Test

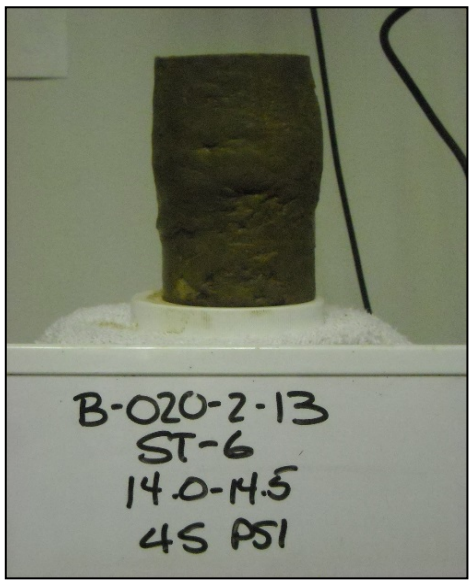
Tin No.:	M-74	g
Wet Soil + Tin :	146.25	g
Dry Soil + Tin :	124.58	g
Tin Weight :	27.9	g
Dry Mass :	96.68	g
Weight of water :	21.67	g
Moisture :	22.41	%

Water Content AFTER Test (Total Specimen)

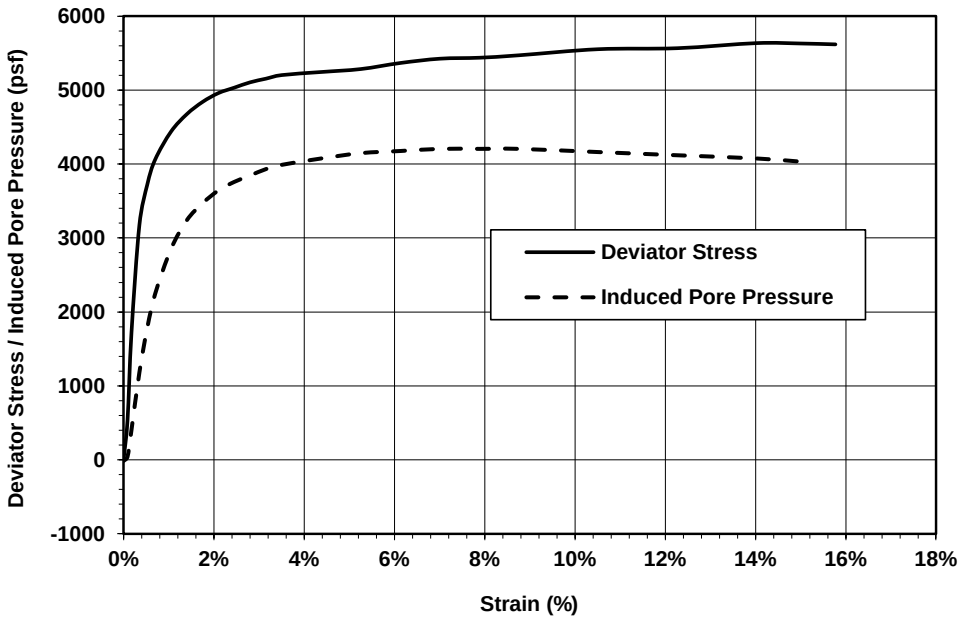
Tin No.:	BC	g
Wet Soil + Tin :	1307.40	g
Dry Soil + Tin :	1110.10	g
Tin Weight :	89.70	g
Dry Mass :	1020.40	g
Weight of water :	197.30	g
Moisture :	19.34	%
Wet Density :	125.31	pcf
Dry Density :	105.01	pcf

Consolidation Cell Pressure:	133.0	psi	Deviator Stress @ Failure, Ds:	5,635	psf
Consolidation Back Pressure:	88.0	psi	Axial Strain @ Failure:	14.0	%
Effective Confining Stress, σ_3:	45.0	psi	Major Principal Stress @ Failure, σ_1:	12,115	psf
	6,480	psf	Induced Pore Pressure @ Failure:	4,075	psf
Strain Rate:	0.0030	in/min	Effective Minor Principal Stress,σ'_3:	2,405	psf
			Effective Major Principal Stress, σ'_1:	8,039	psf

Failure Sketch



CU Compressive Strength and Induced Pore Pressure



Notes:

One-Dimensional Consolidation Test Report (ASTM D2435)

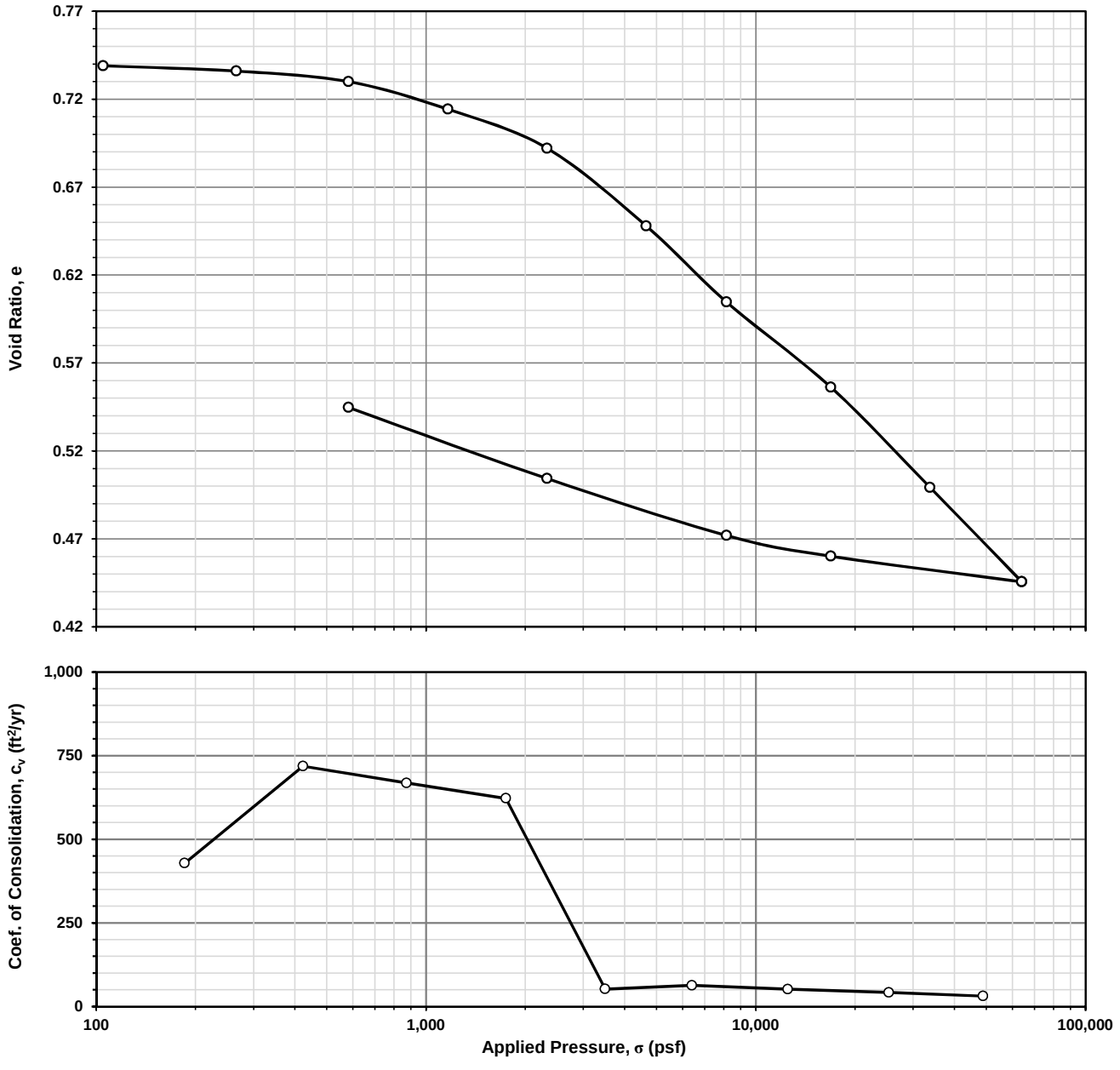
Project Number:	W-13-072	Boring Number:	B-020-7-13
Project Name:	FRA-70-13.10	Station / Offset:	176+68.64, 1.8' Rt.
Project Location:	Columbus, Ohio	Sample No. / Depth:	ST-4 / 11.8 ft
Client:	ms consultants, inc.	Date of Testing:	01/27/2015 to 02/12/2015

Soil Description: Dark brown CLAY, "and" silt, trace coarse to fine sand

Soil Classification: ODOT A-7-6

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	43	19	24	0	2	7	45	46

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								
99.6%	23.3%	95.5	122.0	1,357	2.67	0.745	3,449	0.210	0.049



Consolidated, Undrained Triaxial Compression Test Report (ASTM D4767)

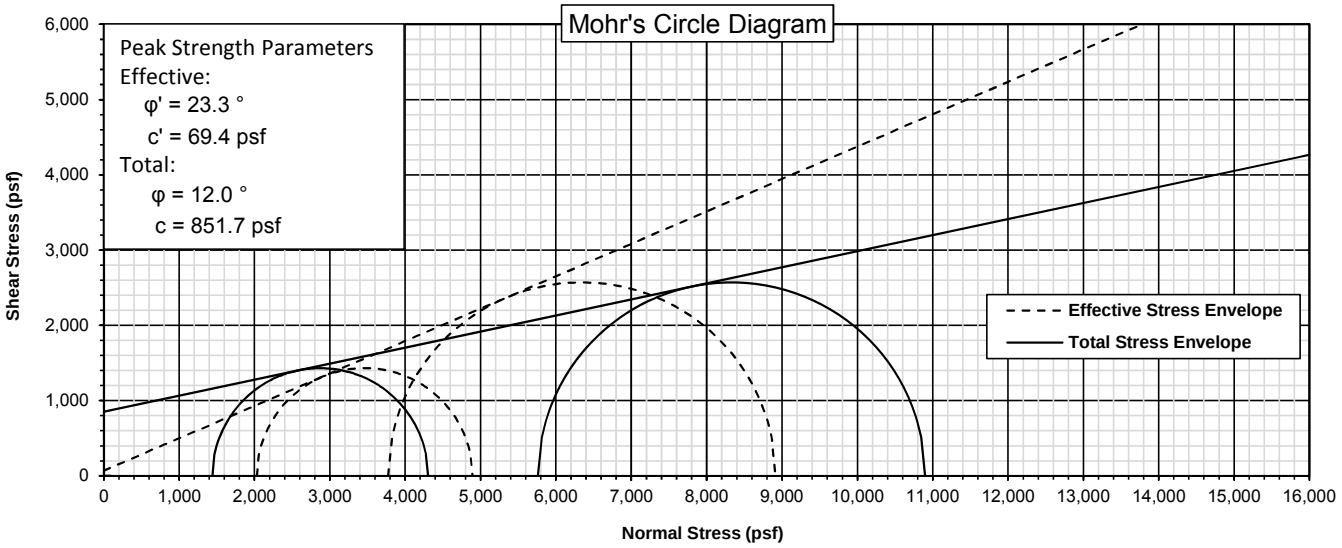
Project Number:	W-13-072	Boring Number:	B-020-7-13
Project Name:	FRA-70-13.10	Station / Offset:	176+68.64, 1.8' Rt.
Project Location:	Franklin County, Ohio	Sample No. / Depth:	ST-4 / 12.0 ft to 13.0 ft
Client:	ms consultants	Date of Testing:	01/28/2015 to 02/10/2015

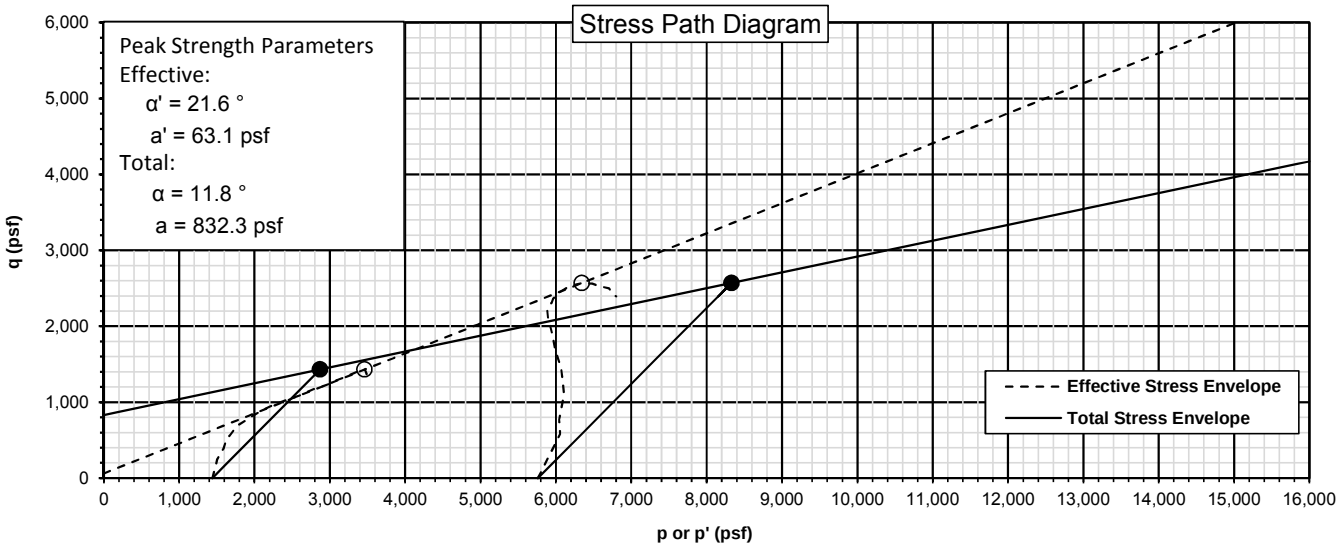
Soil Description: Dark brown CLAY, "and" silt, trace coarse to fine sand

Soil Classification: ODOT A-7-6

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	43	19	24	0	2	7	45	46

Stage	Boring No.	Sample No.	Depth (ft)	$(\sigma_3)_f$ (psf)	$(\sigma_1)_f$ (psf)	$(\sigma_3')_f$ (psf)	$(\sigma_1')_f$ (psf)	p'_f (psf)	q_f (psf)
1	B-020-7-13	ST-4	12.0-12.5	1,440.0	4,302.7	2,030.4	4,893.1	3,461.8	1,431.4
2	B-020-7-13	ST-4	12.5-13.0	5,760.0	10,900.3	3,772.8	8,913.1	6,343.0	2,570.2
3									





Notes:

Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

Project Number:	W-13-072	Boring Number:	B-020-7-13
Project Name:	FRA-70-13.10	Station / Offset:	176+68.64, 1.8' Rt.
Project Location:	Franklin County, Ohio	Sample No. / Depth:	ST-4 / 12.0-12.5 ft
Client:	ms consultants	Date of Testing:	2/10/2015

Data for Specimen No. 1

Soil Description: Dark brown CLAY, "and" silt, trace coarse to fine sand
Soil Classification: ODOT A-7-6

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	43	19	24	0	2	7	45	46

Diameter, D_0	2.872	in	Volume of Solids , V_s :	23.242	in^3
Area, A_0	6.478	in^2	Initial Volume of Voids, V_v :	15.246	in^3
Height, L_0	5.941	in	Initial Void Ratio, e_o :	0.656	
Volume, V_0	38.487	in^3	Initial Degree of Saturation, S_0 :	94.7	%

Water Content BEFORE Test

Tin No.:	X-16	g
Wet Soil + Tin :	113.18	g
Dry Soil + Tin :	97.47	g
Tin Weight :	29.97	g
Dry Mass :	67.5	g
Weight of water :	15.71	g
Moisture :	23.27	%

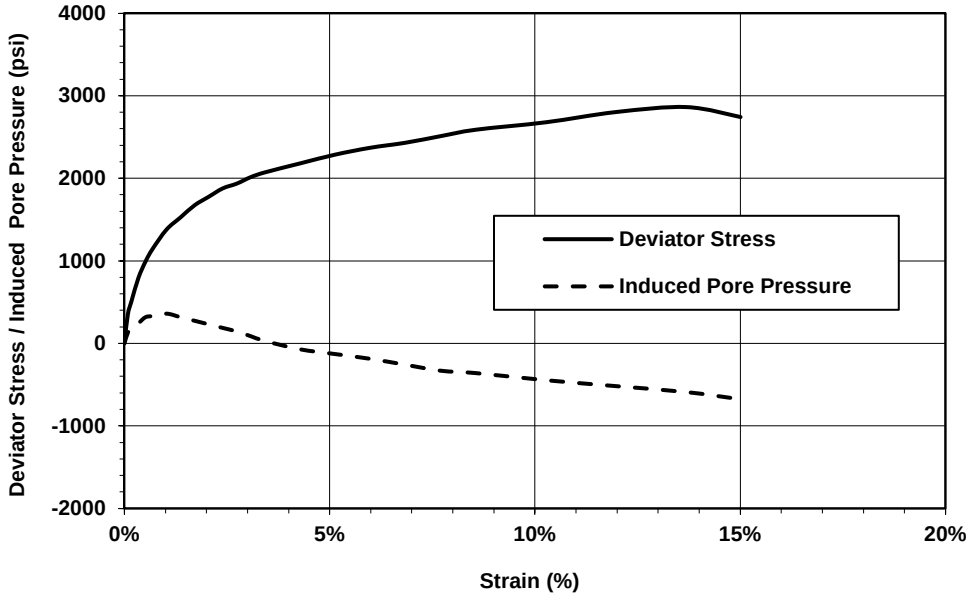
Water Content AFTER Test (Total Specimen)

Tin No.:	FUNKY	g
Wet Soil + Tin :	1316.50	g
Dry Soil + Tin :	1073.70	g
Tin Weight :	56.80	g
Dry Mass :	1016.90	g
Weight of water :	242.80	g
Moisture :	23.88	%
Wet Density :	124.69	pcf
Dry Density :	100.65	pcf

Consolidation Cell Pressure:	140.0	psi	Deviator Stress @ Failure, Ds:	2,863	psf
Consolidation Back Pressure:	130.0	psi	Axial Strain @ Failure:	13.7	%
Effective Confining Stress, σ_3:	10.0	psi	Major Principal Stress @ Failure, σ_1:	4,303	psf
	1,440	psf	Induced Pore Pressure @ Failure:	-590	psf
Strain Rate:	0.0030	in/min	Effective Minor Principal Stress,σ'_3:	2,030	psf
			Effective Major Principal Stress, σ'_1:	4,893	psf

Failure Sketch

CU Compressive Strength and Induced Pore Pressure



Notes:

Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

Project Number:	W-13-072	Boring Number:	B-020-7-13
Project Name:	FRA-70-13.10	Station / Offset:	176+68.64, 1.8' Rt.
Project Location:	Franklin County, Ohio	Sample No. / Depth:	ST-4 / 12.5-13.0 ft
Client:	ms consultants	Date of Testing:	10/11/2014

Data for Specimen No. 2

Soil Description: Dark brown CLAY, "and" silt, trace coarse to fine sand
Soil Classification: ODOT A-7-6

Physical Characteristics	L.L.	P.L.	P.I.	Gravel%	C. Sand%	F. Sand%	Silt%	Clay%
	43	19	24	0	2	7	45	46

Diameter, D_0	2.875	in	Volume of Solids , V_s :	23.795	in^3
Area, A_0	6.492	in^2	Initial Volume of Voids, V_v :	14.946	in^3
Height, L_0	5.968	in	Initial Void Ratio, e_o :	0.628	
Volume, V_0	38.741	in^3	Initial Degree of Saturation, S_0 :	98.93	%

Water Content BEFORE Test

Tin No.:	X-16	g
Wet Soil + Tin :	113.18	g
Dry Soil + Tin :	97.47	g
Tin Weight :	29.97	g
Dry Mass :	67.5	g
Weight of water :	15.71	g
Moisture :	23.27	%

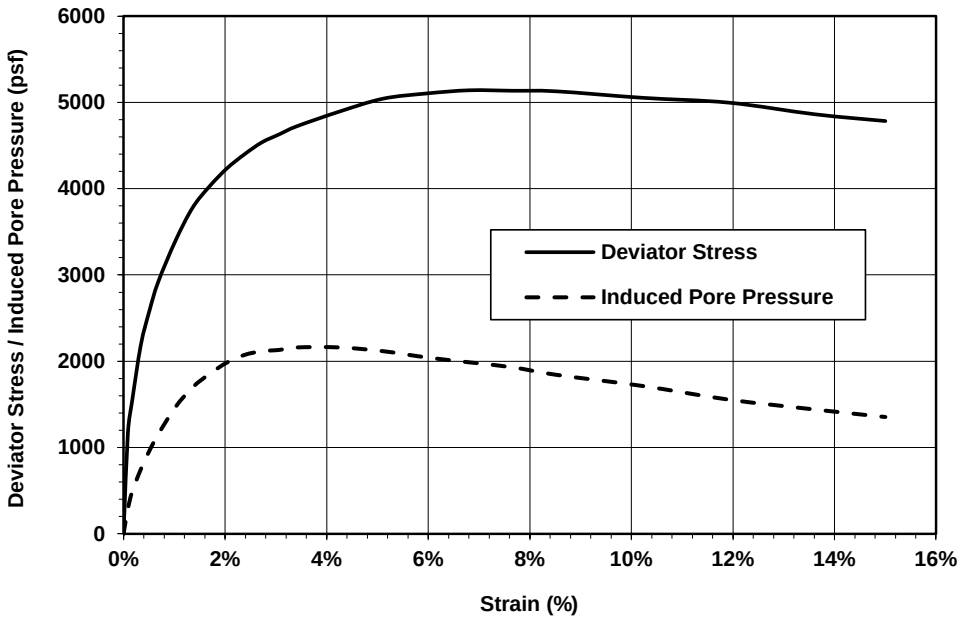
Water Content AFTER Test (Total Specimen)

Tin No.:	FUNKY	g
Wet Soil + Tin :	1325.30	g
Dry Soil + Tin :	1097.20	g
Tin Weight :	56.10	g
Dry Mass :	1041.10	g
Weight of water :	228.10	g
Moisture :	21.91	%
Wet Density :	124.80	pcf
Dry Density :	102.37	pcf

Consolidation Cell Pressure:	143.0	psi	Deviator Stress @ Failure, Ds:	5,140	psf
Consolidation Back Pressure:	103.0	psi	Axial Strain @ Failure:	6.8	%
Effective Confining Stress, σ_3:	40.0	psi	Major Principal Stress @ Failure, σ_1:	10,900	psf
	5,760	psf	Induced Pore Pressure @ Failure:	1,987	psf
Strain Rate:	0.0030	in/min	Effective Minor Principal Stress,σ'_3:	3,773	psf
			Effective Major Principal Stress, σ'_1:	8,913	psf

Failure Sketch

CU Compressive Strength and Induced Pore Pressure



Notes:

RESOURCE INTERNATIONAL, INC.

Engineering Consultants

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Columbus, OH 43231
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Cleveland, OH 44125
Phone (216) 573-0955

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

Point Load Strength Index of Rock Specimens

(ASTM D 5731-08)

Project: FRA-70-13.10
Project No.: W-13-072
Date of Testing: 2/2/2015
Test Performed by: E.M.

Rock Description: Gray Mudstone

Boring No.: B-020-7-13
Station / Offset: 176+68.64, 1.8' Rt.
Sample No. / Depth: RC-4 / 69.4' to 74.8'

Test Apparatus: Forney-LA 0080
Serial Number: A125/AZ/0014
Date of Calibration: 8/9/2014

Sample No.	Test Type	Depth (ft)	Width (mm)	Diameter (mm)	Load (N)	D_e^2 (mm^2)	D_e (mm)	F	Is (MPa)	$Is_{(50)}$ (MPa)	σ_c (MPa)
1	a ⊥	69.4	37.0	46.5	70	2,192	46.8	0.97	0.03	0.03	0.38
2	a ⊥	70.6	37.1	46.0	185	2,174	46.6	0.97	0.09	0.08	1.02
3	a ⊥	70.9	35.8	45.5	195	2,078	45.6	0.96	0.09	0.09	1.13
4	a ⊥	73.8	36.7	45.9	105	2,143	46.3	0.97	0.05	0.05	0.59
5	a ⊥	74.8	34.2	45.6	110	1,983	44.5	0.95	0.06	0.05	0.67
6											
7											
8											
9											
10											

STATISTICS	
Mean $Is_{(50)}$ ⊥	0.06 MPa (9 psi)
Mean $Is_{(50)}$ ‖	
$Ia_{(50)}$	

Specific Specimen Shape:

d = diametrical
a = axial
b = block
i = irregular lump
⊥ = perpendicular to bedding plane
‖ = parallel to bedding plane

Estimated Unaxial Compression, σ_c = K*Is

K = 12
*Per Section 206.1.3 of 2011 ODOT Rock Slope Design Guide

Mean σ_c = 0.76 MPa (110 psi)

Remarks:

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

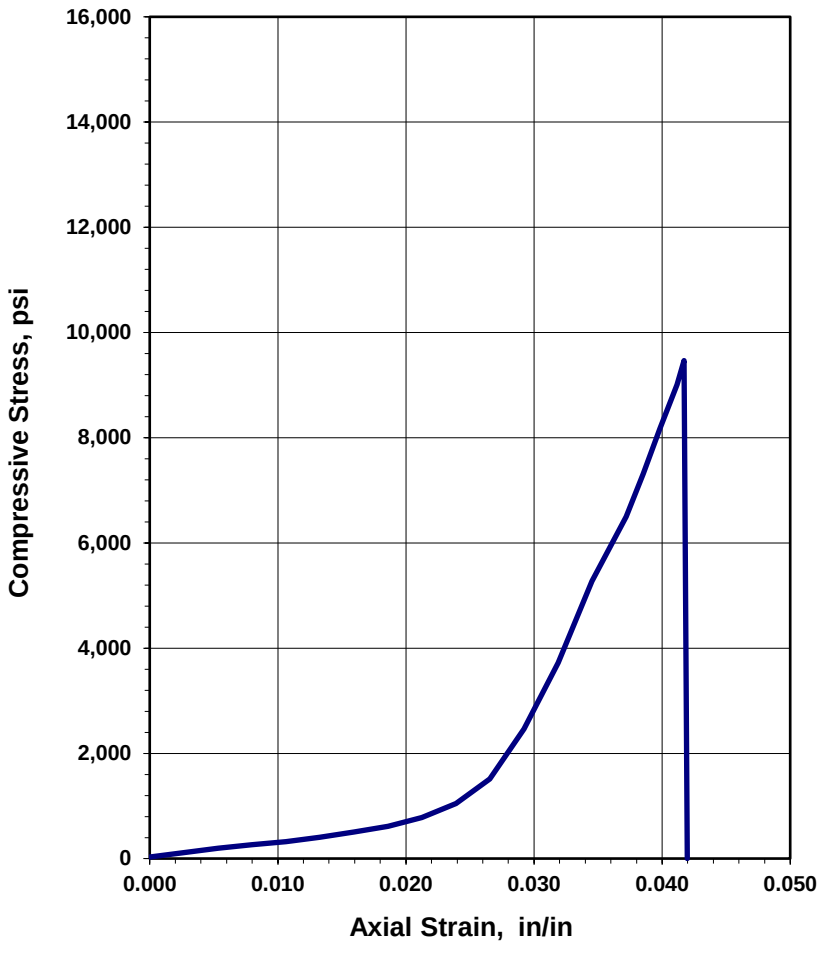
Project: FRA-70-12.68
Project No.: W-13-045
Date of Testing: 7/26/2013
Test Performed by: KR/TK

Rock Description: LIMESTONE: Light gray, unweathered, strong.

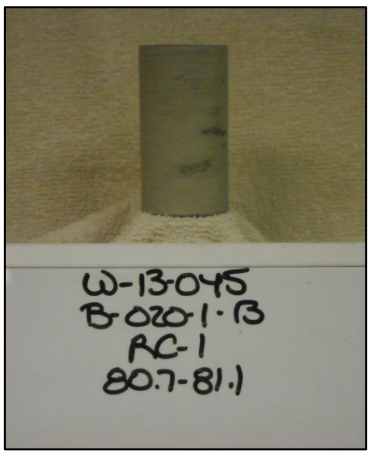
Boring No.:	B-020-1-13	Average Length:	3.765 in
Station / Offset:	5080+09.80, 30.9' Rt.	Average Diameter:	1.863 in
Sample No. / Depth:	RC-1 / 80.7 ft.	Length to diameter ratio:	2.021
Moisture condition:	As received	Cross Sectional Area:	2.725 in^2
		Failure Load:	25,800 lbs
Rate of Loading:	55.0 lbs/sec	Axial Strain at Failure:	0.0417 in/in
Testing Time:	469 sec	Stress:	9,465 psi

(Rate 2-15 minutes to failure)

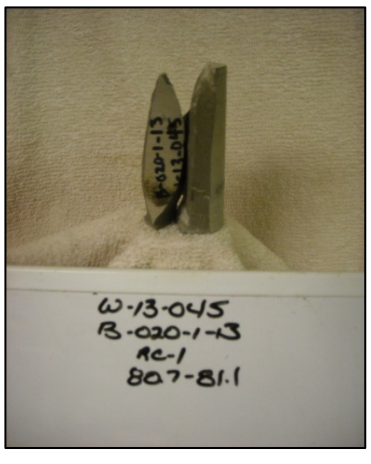
Unconfined Compression Test



Before Testing



After Failure



REMARKS:

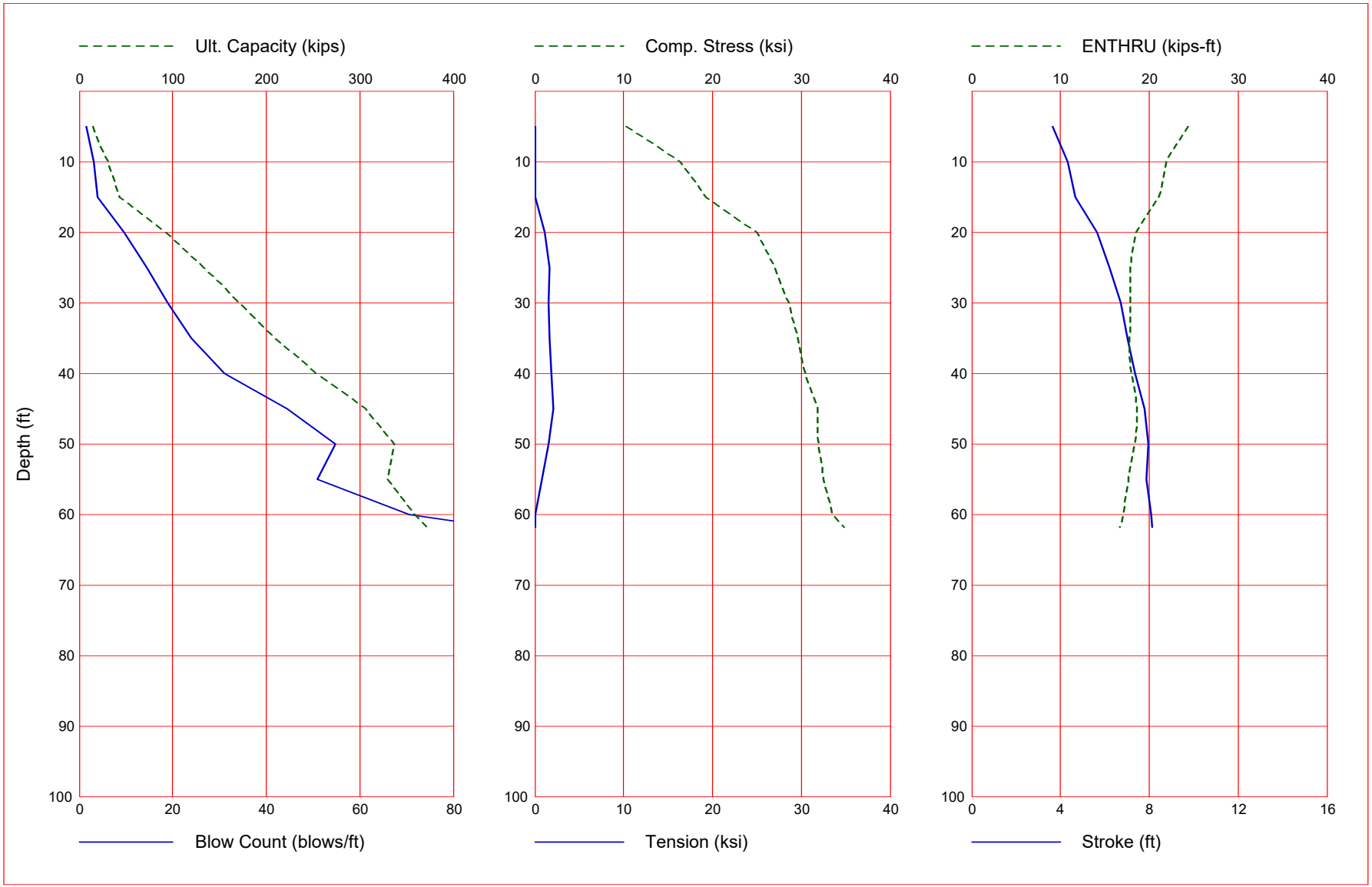
APPENDIX VI

GRLWEAP DRIVEABILITY ANALYSIS OUTPUTS

Resource International Inc
FRA-70-1373A - FA - B-020-9-15 - HP10x42

Jul 12 2018
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	14.4	13.2	1.2	1.5	10.263	0.000	3.66	24.4
10.0	30.4	25.0	5.4	3.1	16.404	0.000	4.35	21.9
15.0	43.2	34.8	8.4	4.0	19.270	-0.020	4.68	21.1
20.0	92.7	52.4	40.3	9.7	25.003	-1.145	5.67	18.5
25.0	133.1	84.3	48.8	14.5	27.061	-1.699	6.22	17.9
30.0	171.3	120.8	50.4	19.0	28.630	-1.545	6.71	17.9
35.0	208.7	161.5	47.2	24.0	29.642	-1.604	7.02	17.8
40.0	253.2	206.0	47.2	31.0	30.489	-1.858	7.38	18.0
45.0	306.0	255.0	51.0	44.5	31.842	-2.097	7.80	18.6
50.0	336.8	308.2	28.6	54.7	31.909	-1.581	7.95	18.4
55.0	330.1	323.9	6.2	50.9	32.468	-0.787	7.87	17.6
60.0	357.7	350.0	7.8	70.6	33.583	0.000	8.08	17.1
61.8	371.9	364.1	7.8	89.2	34.819	0.000	8.14	16.7

Total Continuous Driving Time 37.00 minutes; Total Number of Blows 1604

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-13-045 FRA-70-13.54 PROJECT 4A\ANALYSIS\FRA-70-1373A AND R\DRIVEABILITY\FRA-70-1373A - FA\B-020-9.GWW
Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2003.GW
Hammer File Version: 2003 (2/22/2013)

Input File Contents

FRA-70-1373A - FA - B-020-9-15 - HP10x42

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	10.070	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
61.800	12.40	29000.0	492.000	3.300	0	0.850	0.010

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	0.002	0.002	1.250	0.00	0.00

P atm	P1	P2	P3	P4	P5
14.70	1520.00	1368.00	1231.00	1108.00	0.00

Stroke	Effic.	Pressure	R-Weight	T-Delay	Exp-Coeff	Eps-Str	Total-AW

10.8100	0.8000	1520.0000	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

Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimD	SU T
0.01	1.18	1.07	0.10	0.10	0.20	0.15	1.49	0.00	0.0
3.49	1.18	1.07	0.10	0.10	0.20	0.15	1.49	0.00	0.0
3.51	1.24	1.16	0.10	0.10	0.20	0.15	1.49	0.00	0.0
8.49	1.24	1.16	0.10	0.10	0.20	0.15	1.49	0.00	0.0
8.51	0.47	4.53	0.10	0.10	0.01	0.15	1.21	0.00	0.0
17.51	1.03	9.95	0.10	0.10	0.01	0.15	1.21	0.00	0.0
18.49	1.09	10.54	0.10	0.10	0.01	0.15	1.21	0.00	0.0
18.51	1.59	37.06	0.10	0.10	0.05	0.15	1.00	0.00	0.0
22.49	1.96	45.80	0.10	0.10	0.05	0.15	1.00	0.00	0.0
22.51	1.96	45.83	0.10	0.10	0.05	0.15	1.00	0.00	0.0
25.99	2.14	49.94	0.10	0.10	0.05	0.15	1.00	0.00	0.0
26.01	2.14	49.96	0.10	0.10	0.05	0.15	1.00	0.00	0.0
34.99	2.59	51.03	0.10	0.10	0.05	0.15	1.00	0.00	0.0
35.01	2.57	43.36	0.10	0.10	0.05	0.15	1.00	0.00	0.0
39.99	2.82	43.36	0.10	0.10	0.05	0.15	1.00	0.00	0.0
40.01	2.85	51.03	0.10	0.10	0.05	0.15	1.00	0.00	0.0
49.01	3.30	51.03	0.10	0.10	0.05	0.15	1.00	0.00	0.0
49.99	3.35	51.03	0.10	0.10	0.05	0.15	1.00	0.00	0.0
50.01	1.90	6.20	0.10	0.10	0.20	0.15	2.00	0.00	0.0
57.79	1.90	6.20	0.10	0.10	0.20	0.15	2.00	0.00	0.0
57.81	2.38	7.75	0.10	0.10	0.20	0.15	1.00	0.00	0.0
61.80	2.39	7.75	0.10	0.10	0.20	0.15	1.00	0.00	0.0

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	0.000	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
55.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
60.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
61.80	0.00	0.00	0.000	0.000	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000

1	0	10.81000	11.86000	

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

FRA-70-1373A - FA - B-020-9-15 - HP10x42

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	140046.7	1.000	0.0100	
3	0.800	140046.7	1.000	0.0100	
4	0.800	140046.7	1.000	0.0100	
5	0.800	140046.7	1.000	0.0100	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		9213.1			

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)	1520.00	Actual Pressure	(psi)	1520.00
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

Depth	(ft)	5.0			
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)	10.070			

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model — Total Capacity Rut (kips) 13.1

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	4.1	0.200	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	7.8	0.200	0.100	61.80	3.3	12.4
Toe						1.2	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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)	0.435
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 ft	Stroke ft	Pressure Ratio	Efficy
5.00	10.81	1.00	0.800

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
13.1	1.4	3.55	3.57	0.00	1	0	9.82	1	7	24.1	62.6

13.7	1.5	3.62	3.60	0.00	1	0	10.07	1	7	24.3	62.2
14.4	1.5	3.66	3.64	0.00	1	0	10.26	1	7	24.4	61.9
15.0	1.6	3.70	3.68	0.00	1	0	10.45	1	7	24.4	61.6
15.7	1.6	3.70	3.73	0.00	1	0	10.53	1	7	24.2	61.3
1		0	10.81000		11.86000						

FRA-70-1373A - FA - B-020-9-15 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 10.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 28.1

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	0.6	0.200	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	7.6	0.200	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	8.1	0.200	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	6.4	0.150	0.100	61.80	3.3	12.4
Toe						5.4	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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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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
28.1	2.8	4.27	4.28	0.00	1	0	15.64	1	2	22.3	57.3
29.2	2.9	4.31	4.34	0.00	1	0	16.01	1	2	22.1	56.9
30.4	3.1	4.35	4.38	0.00	1	0	16.40	1	2	21.9	56.6
31.6	3.2	4.39	4.43	0.00	1	0	16.76	1	2	21.7	56.3
32.7	3.4	4.48	4.47	0.00	1	0	17.28	1	2	21.7	55.9
1		0	10.81000		11.86000						

FRA-70-1373A - FA - B-020-9-15 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 15.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 40.5

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4

2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	4.7	0.200	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	7.9	0.200	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	8.1	0.200	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	4.9	0.010	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	6.6	0.010	0.100	61.80	3.3	12.4
Toe						8.4	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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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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
40.5	3.7	4.59	4.57	-0.06	4	12	18.51	15	5	21.3	55.3
41.9	3.9	4.64	4.62	-0.04	4	11	18.91	15	5	21.2	55.0
43.2	4.0	4.68	4.66	-0.02	4	11	19.27	15	5	21.1	54.7
44.6	4.2	4.73	4.70	0.00	4	11	19.62	15	5	21.0	54.5
46.0	4.4	4.77	4.74	0.00	1	0	19.98	15	5	20.8	54.2
1		0	10.81000		11.86000						

FRA-70-1373A - FA - B-020-9-15 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 20.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 89.6

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	1.1	0.200	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	7.7	0.200	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	8.1	0.200	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	6.1	0.138	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	5.8	0.010	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	7.5	0.010	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	13.0	0.033	0.100	61.80	3.3	12.4
Toe						40.3	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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-70-1373A - FA - B-020-9-15 - HP10x42 07/12/2018
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
89.6	9.3	5.60	5.65	-1.26	13	45	24.60	14	5	18.6	49.6
91.2	9.5	5.64	5.68	-1.20	13	44	24.81	14	5	18.6	49.4
92.7	9.7	5.67	5.71	-1.15	13	44	25.00	14	5	18.5	49.3

94.3	9.9	5.70	5.74	-1.10	14	43	25.20	14	5	18.5	49.2
95.9	10.1	5.73	5.77	-1.05	14	43	25.35	14	5	18.4	49.0

1 0 10.81000 11.86000

FRA-70-1373A - FA - B-020-9-15 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 25.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 129.9

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
12	0.138	9213	0.000	0.000	1.00	5.2	0.200	0.100	39.03	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	7.9	0.200	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	7.8	0.194	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	5.0	0.010	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	6.7	0.010	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	8.5	0.010	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	18.6	0.050	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	21.5	0.050	0.100	61.80	3.3	12.4
Toe						48.8	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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
129.9	13.9	6.17	6.19	-1.56	12	35	26.73	12	4	17.9	47.4
131.5	14.2	6.20	6.22	-1.63	12	35	26.90	12	4	17.9	47.2
133.1	14.5	6.22	6.24	-1.70	12	35	27.06	12	4	17.9	47.1
134.6	14.8	6.25	6.28	-1.74	12	35	27.23	12	4	17.8	47.0
136.2	15.1	6.29	6.30	-1.79	12	35	27.40	12	4	17.8	46.9

1 0 10.81000 11.86000

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Depth (ft) 30.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 168.1

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
10	0.138	9213	0.000	0.000	1.00	1.7	0.200	0.100	32.53	3.3	12.4
11	0.138	9213	0.000	0.000	1.00	7.7	0.200	0.100	35.78	3.3	12.4
12	0.138	9213	0.000	0.000	1.00	8.1	0.200	0.100	39.03	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	5.9	0.124	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	5.9	0.010	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	7.6	0.010	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	13.7	0.036	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	20.3	0.050	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	22.5	0.050	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	24.2	0.050	0.100	61.80	3.3	12.4
Toe						50.4	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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
168.1	18.4	6.66	6.61	-1.58	10	31	28.35	11	4	17.9	45.7
169.7	18.7	6.68	6.63	-1.56	10	31	28.49	11	4	17.9	45.6
171.3	19.0	6.71	6.65	-1.55	10	31	28.63	11	4	17.9	45.5
172.8	19.3	6.73	6.68	-1.52	10	30	28.77	11	4	17.9	45.5
174.4	19.6	6.74	6.70	-1.49	10	30	28.88	11	4	17.8	45.4
1		0	10.81000		11.86000						

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Resource International Inc GRLWEAP Version 2010

Depth (ft) 35.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 205.6

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
9	0.138	9213	0.000	0.000	1.00	5.8	0.200	0.100	29.27	3.3	12.4
10	0.138	9213	0.000	0.000	1.00	7.9	0.200	0.100	32.53	3.3	12.4
11	0.138	9213	0.000	0.000	1.00	7.5	0.188	0.100	35.78	3.3	12.4
12	0.138	9213	0.000	0.000	1.00	5.1	0.010	0.100	39.03	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	6.8	0.010	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	9.1	0.014	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	18.9	0.050	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	21.6	0.050	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	23.4	0.050	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	25.2	0.050	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	26.9	0.050	0.100	61.80	3.3	12.4
Toe						47.2	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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 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
205.6	23.3	6.99	6.95	-1.63	9	28	29.38	9	3	17.8	44.6
207.1	23.7	7.00	6.97	-1.62	9	28	29.49	9	3	17.7	44.5
208.7	24.0	7.02	6.99	-1.60	9	28	29.64	9	3	17.8	44.5
210.3	24.2	7.04	7.00	-1.59	9	28	29.78	9	3	17.8	44.5
211.8	24.7	7.06	7.03	-1.56	9	28	29.91	9	3	17.7	44.4
1		0	10.81000		11.86000						

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Depth (ft) 40.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 250.0

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
7	0.138	9213	0.000	0.000	1.00	2.3	0.200	0.100	22.77	3.3	12.4
8	0.138	9213	0.000	0.000	1.00	7.7	0.200	0.100	26.02	3.3	12.4
9	0.138	9213	0.000	0.000	1.00	8.1	0.200	0.100	29.27	3.3	12.4
10	0.138	9213	0.000	0.000	1.00	5.7	0.108	0.100	32.53	3.3	12.4
11	0.138	9213	0.000	0.000	1.00	6.0	0.010	0.100	35.78	3.3	12.4
12	0.138	9213	0.000	0.000	1.00	7.8	0.010	0.100	39.03	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	14.5	0.039	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	20.5	0.050	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	22.6	0.050	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	24.4	0.050	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	26.1	0.050	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	27.8	0.050	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	29.4	0.050	0.100	61.80	3.3	12.4
Toe						47.2	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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
250.0	30.3	7.34	7.33	-1.81	8	48	30.26	8	3	17.9	43.5
251.6	30.5	7.37	7.33	-1.83	8	48	30.41	8	3	18.1	43.5
253.2	31.0	7.38	7.36	-1.86	7	47	30.49	8	3	18.0	43.4
254.7	31.5	7.39	7.38	-1.90	7	47	30.61	8	3	17.9	43.4
256.3	32.0	7.41	7.39	-1.93	7	47	30.70	8	3	18.0	43.3
1		0	10.81000		11.86000						

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Depth (ft) 45.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model — Total Capacity Rut (kips) 302.9

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
6	0.138	9213	0.000	0.000	1.00	6.4	0.200	0.100	19.52	3.3	12.4
7	0.138	9213	0.000	0.000	1.00	8.0	0.200	0.100	22.77	3.3	12.4
8	0.138	9213	0.000	0.000	1.00	7.2	0.181	0.100	26.02	3.3	12.4
9	0.138	9213	0.000	0.000	1.00	5.2	0.010	0.100	29.27	3.3	12.4
10	0.138	9213	0.000	0.000	1.00	7.0	0.010	0.100	32.53	3.3	12.4
11	0.138	9213	0.000	0.000	1.00	9.9	0.019	0.100	35.78	3.3	12.4
12	0.138	9213	0.000	0.000	1.00	19.1	0.050	0.100	39.03	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	21.8	0.050	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	23.5	0.050	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	25.3	0.050	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	27.1	0.050	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	28.6	0.050	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	30.5	0.050	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	32.4	0.050	0.100	61.80	3.3	12.4
Toe						51.0	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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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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
302.9	43.1	7.75	7.74	-2.13	6	45	31.55	6	3	18.5	42.4
304.5	44.1	7.78	7.77	-2.10	6	44	31.70	6	3	18.5	42.3
306.0	44.5	7.80	7.77	-2.10	6	44	31.84	6	3	18.6	42.3
307.6	45.5	7.80	7.79	-2.07	6	44	31.93	6	3	18.5	42.2
309.1	46.5	7.82	7.81	-2.03	6	44	32.07	6	3	18.5	42.2
	1	0	10.81000		11.86000						

↑
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Depth (ft) 50.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model — Total Capacity Rut (kips) 333.6

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
4	0.138	9213	0.000	0.000	1.00	2.8	0.200	0.100	13.01	3.3	12.4
5	0.138	9213	0.000	0.000	1.00	7.8	0.200	0.100	16.26	3.3	12.4
6	0.138	9213	0.000	0.000	1.00	8.1	0.200	0.100	19.52	3.3	12.4
7	0.138	9213	0.000	0.000	1.00	5.5	0.089	0.100	22.77	3.3	12.4
8	0.138	9213	0.000	0.000	1.00	6.2	0.010	0.100	26.02	3.3	12.4
9	0.138	9213	0.000	0.000	1.00	7.9	0.010	0.100	29.27	3.3	12.4
10	0.138	9213	0.000	0.000	1.00	15.3	0.041	0.100	32.53	3.3	12.4
11	0.138	9213	0.000	0.000	1.00	20.7	0.050	0.100	35.78	3.3	12.4
12	0.138	9213	0.000	0.000	1.00	22.7	0.050	0.100	39.03	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	24.5	0.050	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	26.3	0.050	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	27.9	0.050	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	29.5	0.050	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	31.6	0.050	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	33.3	0.050	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	35.1	0.050	0.100	61.80	3.3	12.4
Toe						28.6	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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

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
333.6	52.5	7.93	7.91	-1.59	4	20	31.68	5	3	18.4	41.9
335.2	53.8	7.95	7.93	-1.58	4	20	31.82	5	3	18.4	41.9
336.8	54.7	7.95	7.94	-1.58	4	20	31.91	5	3	18.4	41.9
338.3	56.0	7.97	7.96	-1.56	4	20	32.03	5	3	18.4	41.8
339.9	57.0	7.98	7.96	-1.55	4	20	32.14	4	3	18.4	41.8
1		0	10.81000		11.86000						

Depth (ft) 55.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 323.8

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	0.138	9213	0.010	0.000	0.85	0.0	0.000	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	0.0	0.000	0.100	6.51	3.3	12.4
3	0.138	9213	0.000	0.000	1.00	6.9	0.200	0.100	9.76	3.3	12.4
4	0.138	9213	0.000	0.000	1.00	8.0	0.200	0.100	13.01	3.3	12.4
5	0.138	9213	0.000	0.000	1.00	6.9	0.172	0.100	16.26	3.3	12.4
6	0.138	9213	0.000	0.000	1.00	5.4	0.010	0.100	19.52	3.3	12.4
7	0.138	9213	0.000	0.000	1.00	7.1	0.010	0.100	22.77	3.3	12.4
8	0.138	9213	0.000	0.000	1.00	10.6	0.022	0.100	26.02	3.3	12.4
9	0.138	9213	0.000	0.000	1.00	19.4	0.050	0.100	29.27	3.3	12.4
10	0.138	9213	0.000	0.000	1.00	21.9	0.050	0.100	32.53	3.3	12.4
11	0.138	9213	0.000	0.000	1.00	23.7	0.050	0.100	35.78	3.3	12.4
12	0.138	9213	0.000	0.000	1.00	25.4	0.050	0.100	39.03	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	27.2	0.050	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	28.7	0.050	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	30.6	0.050	0.100	48.79	3.3	12.4

16	0.138	9213	0.000	0.000	1.00	32.5	0.050	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	34.3	0.050	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	20.8	0.110	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	8.2	0.200	0.100	61.80	3.3	12.4
Toe						6.2	0.150	0.100			

2.618 kips total unreduced pile weight (g= 32.17 ft/s2)
2.618 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

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
323.8	46.7	7.82	7.79	-0.86	3	38	32.11	3	3	17.6	42.2
326.9	48.5	7.85	7.82	-0.83	3	38	32.31	3	3	17.6	42.2
330.1	50.9	7.87	7.86	-0.79	3	38	32.47	3	3	17.6	42.1
333.2	52.9	7.91	7.89	-0.75	3	37	32.66	3	3	17.6	42.0
336.3	55.3	7.93	7.92	-0.73	3	37	32.83	3	3	17.5	41.9
1		0	10.81000		11.86000						

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Depth (ft) 60.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 349.7

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	0.138	9213	0.010	0.000	0.85	3.4	0.200	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	7.8	0.200	0.100	6.51	3.3	12.4
3	0.138	9213	0.000	0.000	1.00	8.1	0.200	0.100	9.76	3.3	12.4
4	0.138	9213	0.000	0.000	1.00	5.3	0.069	0.100	13.01	3.3	12.4
5	0.138	9213	0.000	0.000	1.00	6.3	0.010	0.100	16.26	3.3	12.4
6	0.138	9213	0.000	0.000	1.00	8.0	0.010	0.100	19.52	3.3	12.4
7	0.138	9213	0.000	0.000	1.00	16.1	0.043	0.100	22.77	3.3	12.4
8	0.138	9213	0.000	0.000	1.00	20.9	0.050	0.100	26.02	3.3	12.4
9	0.138	9213	0.000	0.000	1.00	22.9	0.050	0.100	29.27	3.3	12.4
10	0.138	9213	0.000	0.000	1.00	24.6	0.050	0.100	32.53	3.3	12.4
11	0.138	9213	0.000	0.000	1.00	26.4	0.050	0.100	35.78	3.3	12.4
12	0.138	9213	0.000	0.000	1.00	28.0	0.050	0.100	39.03	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	29.7	0.050	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	31.7	0.050	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	33.4	0.050	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	33.1	0.057	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	8.2	0.200	0.100	55.29	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	19.9	0.200	0.100	61.80	3.3	12.4
Toe						7.8	0.150	0.100			

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

Depth ft	Stroke ft	Pressure Ratio	Efficy
60.00	10.81	1.00	0.800

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
349.7	63.3	8.03	8.03	-0.21	17	12	33.13	1	2	17.0	41.7
353.7	66.9	8.06	8.06	0.00	2	37	33.35	1	2	17.1	41.6
357.7	70.6	8.08	8.08	0.00	1	0	33.58	1	2	17.1	41.6
361.7	75.1	8.12	8.12	0.00	1	0	33.82	1	2	17.1	41.5
365.7	81.7	8.07	8.14	0.00	1	0	33.82	1	2	16.9	41.5
	1	0	10.81000		11.86000						

Depth (ft) 61.8
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.8	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.480

Pile and Soil Model Total Capacity Rut (kips) 363.8

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	0.138	9213	0.010	0.000	0.85	7.6	0.200	0.100	3.25	3.3	12.4
2	0.138	9213	0.000	0.000	1.00	8.0	0.200	0.100	6.51	3.3	12.4
3	0.138	9213	0.000	0.000	1.00	6.6	0.161	0.100	9.76	3.3	12.4
4	0.138	9213	0.000	0.000	1.00	5.5	0.010	0.100	13.01	3.3	12.4
5	0.138	9213	0.000	0.000	1.00	7.3	0.010	0.100	16.26	3.3	12.4
6	0.138	9213	0.000	0.000	1.00	11.5	0.027	0.100	19.52	3.3	12.4
7	0.138	9213	0.000	0.000	1.00	19.7	0.050	0.100	22.77	3.3	12.4
8	0.138	9213	0.000	0.000	1.00	22.1	0.050	0.100	26.02	3.3	12.4
9	0.138	9213	0.000	0.000	1.00	23.8	0.050	0.100	29.27	3.3	12.4
10	0.138	9213	0.000	0.000	1.00	25.6	0.050	0.100	32.53	3.3	12.4
11	0.138	9213	0.000	0.000	1.00	27.3	0.050	0.100	35.78	3.3	12.4
12	0.138	9213	0.000	0.000	1.00	28.9	0.050	0.100	39.03	3.3	12.4
13	0.138	9213	0.000	0.000	1.00	30.8	0.050	0.100	42.28	3.3	12.4
14	0.138	9213	0.000	0.000	1.00	32.7	0.050	0.100	45.54	3.3	12.4
15	0.138	9213	0.000	0.000	1.00	34.4	0.050	0.100	48.79	3.3	12.4
16	0.138	9213	0.000	0.000	1.00	18.4	0.124	0.100	52.04	3.3	12.4
17	0.138	9213	0.000	0.000	1.00	8.2	0.200	0.100	55.29	3.3	12.4
18	0.138	9213	0.000	0.000	1.00	12.2	0.200	0.100	58.55	3.3	12.4
19	0.138	9213	0.000	0.000	1.00	25.6	0.200	0.100	61.80	3.3	12.4
Toe						7.8	0.150	0.100			

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

Depth ft	Stroke ft	Pressure Ratio	Efficy
61.80	10.81	1.00	0.800

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
363.8	78.7	8.07	8.14	0.00	1	0	34.25	1	2	16.7	41.5
367.9	83.9	8.10	8.17	0.00	1	0	34.54	1	2	16.7	41.4
371.9	89.2	8.14	8.19	0.00	1	0	34.82	1	2	16.7	41.3
375.9	95.1	8.17	8.21	0.00	1	0	35.09	1	2	16.7	41.3
379.9	101.4	8.20	8.23	0.00	1	0	35.36	1	2	16.7	41.2

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	13.1	11.9	1.2	1.4	9.821	0.000	3.55	24.1
10.0	28.1	22.6	5.4	2.8	15.639	0.000	4.27	22.3
15.0	40.5	32.0	8.4	3.7	18.511	-0.065	4.59	21.3
20.0	89.6	49.3	40.3	9.3	24.600	-1.259	5.60	18.6
25.0	129.9	81.2	48.8	13.9	26.734	-1.557	6.17	17.9
30.0	168.1	117.7	50.4	18.4	28.350	-1.575	6.66	17.9
35.0	205.6	158.4	47.2	23.3	29.376	-1.634	6.99	17.8
40.0	250.0	202.8	47.2	30.3	30.264	-1.812	7.34	17.9
45.0	302.9	251.9	51.0	43.1	31.549	-2.126	7.75	18.5
50.0	333.6	305.0	28.6	52.5	31.682	-1.592	7.93	18.4
55.0	323.8	317.6	6.2	46.7	32.112	-0.856	7.82	17.6
60.0	349.7	341.9	7.8	63.3	33.125	-0.206	8.03	17.0
61.8	363.8	356.1	7.8	78.7	34.246	0.000	8.07	16.7

Total Driving Time 35 minutes; Total No. of Blows 1513

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	13.7	12.6	1.2	1.5	10.074	0.000	3.62	24.3
10.0	29.2	23.8	5.4	2.9	16.011	0.000	4.31	22.1
15.0	41.9	33.4	8.4	3.9	18.906	-0.041	4.64	21.2
20.0	91.2	50.8	40.3	9.5	24.806	-1.203	5.64	18.6
25.0	131.5	82.7	48.8	14.2	26.905	-1.629	6.20	17.9
30.0	169.7	119.3	50.4	18.7	28.491	-1.563	6.68	17.9
35.0	207.1	159.9	47.2	23.7	29.491	-1.618	7.00	17.7
40.0	251.6	204.4	47.2	30.5	30.414	-1.829	7.37	18.1
45.0	304.5	253.4	51.0	44.1	31.696	-2.101	7.78	18.5
50.0	335.2	306.6	28.6	53.8	31.819	-1.576	7.95	18.4
55.0	326.9	320.7	6.2	48.5	32.307	-0.832	7.85	17.6
60.0	353.7	345.9	7.8	66.9	33.350	-0.005	8.06	17.1
61.8	367.9	360.1	7.8	83.9	34.538	0.000	8.10	16.7

Total Driving Time 36 minutes; Total No. of Blows 1559

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	14.4	13.2	1.2	1.5	10.263	0.000	3.66	24.4
10.0	30.4	25.0	5.4	3.1	16.404	0.000	4.35	21.9
15.0	43.2	34.8	8.4	4.0	19.270	-0.020	4.68	21.1
20.0	92.7	52.4	40.3	9.7	25.003	-1.145	5.67	18.5
25.0	133.1	84.3	48.8	14.5	27.061	-1.699	6.22	17.9
30.0	171.3	120.8	50.4	19.0	28.630	-1.545	6.71	17.9
35.0	208.7	161.5	47.2	24.0	29.642	-1.604	7.02	17.8
40.0	253.2	206.0	47.2	31.0	30.489	-1.858	7.38	18.0
45.0	306.0	255.0	51.0	44.5	31.842	-2.097	7.80	18.6
50.0	336.8	308.2	28.6	54.7	31.909	-1.581	7.95	18.4
55.0	330.1	323.9	6.2	50.9	32.468	-0.787	7.87	17.6
60.0	357.7	350.0	7.8	70.6	33.583	0.000	8.08	17.1
61.8	371.9	364.1	7.8	89.2	34.819	0.000	8.14	16.7

Total Driving Time 37 minutes; Total No. of Blows 1604

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	15.0	13.9	1.2	1.6	10.452	0.000	3.70	24.4
10.0	31.6	26.1	5.4	3.2	16.759	0.000	4.39	21.7
15.0	44.6	36.2	8.4	4.2	19.623	-0.004	4.73	21.0
20.0	94.3	54.0	40.3	9.9	25.197	-1.099	5.70	18.5
25.0	134.6	85.9	48.8	14.8	27.227	-1.743	6.25	17.8
30.0	172.8	122.4	50.4	19.3	28.772	-1.520	6.73	17.9
35.0	210.3	163.1	47.2	24.2	29.777	-1.592	7.04	17.8
40.0	254.7	207.5	47.2	31.5	30.612	-1.900	7.39	17.9
45.0	307.6	256.5	51.0	45.5	31.934	-2.069	7.80	18.5

50.0	338.3	309.7	28.6	56.0	32.025	-1.564	7.97	18.4
55.0	333.2	327.0	6.2	52.9	32.665	-0.748	7.91	17.6
60.0	361.7	354.0	7.8	75.1	33.821	0.000	8.12	17.1
61.8	375.9	368.1	7.8	95.1	35.090	0.000	8.17	16.7

Total Driving Time 38 minutes; Total No. of Blows 1657

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	15.7	14.5	1.2	1.6	10.527	0.000	3.70	24.2
10.0	32.7	27.3	5.4	3.4	17.275	0.000	4.48	21.7
15.0	46.0	37.5	8.4	4.4	19.978	0.000	4.77	20.8
20.0	95.9	55.5	40.3	10.1	25.352	-1.048	5.73	18.4
25.0	136.2	87.4	48.8	15.1	27.398	-1.795	6.29	17.8
30.0	174.4	123.9	50.4	19.6	28.877	-1.490	6.74	17.8
35.0	211.8	164.6	47.2	24.7	29.911	-1.560	7.06	17.7
40.0	256.3	209.1	47.2	32.0	30.700	-1.928	7.41	18.0
45.0	309.1	258.1	51.0	46.5	32.072	-2.032	7.82	18.5
50.0	339.9	311.3	28.6	57.0	32.141	-1.551	7.98	18.4
55.0	336.3	330.1	6.2	55.3	32.825	-0.735	7.93	17.5
60.0	365.7	358.0	7.8	81.7	33.818	0.000	8.07	16.9
61.8	379.9	372.2	7.8	101.4	35.365	0.000	8.20	16.7

Total Driving Time 40 minutes; Total No. of Blows 1717

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Table of Depths Analyzed with Driving System Modifiers

Depth ft	Temp. Length ft	Wait Time hr	Equivalent Pressure Stroke ft	Ratio	Efficy.	Stiffn. Factor	Cushion CoR
5.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
10.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
15.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
20.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
25.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
30.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
35.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
40.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
45.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
50.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
55.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
60.00	61.80	0.00	10.81	1.00	0.80	1.00	1.00
61.80	61.80	0.00	10.81	1.00	0.80	1.00	1.00

Soil Layer Resistance Values

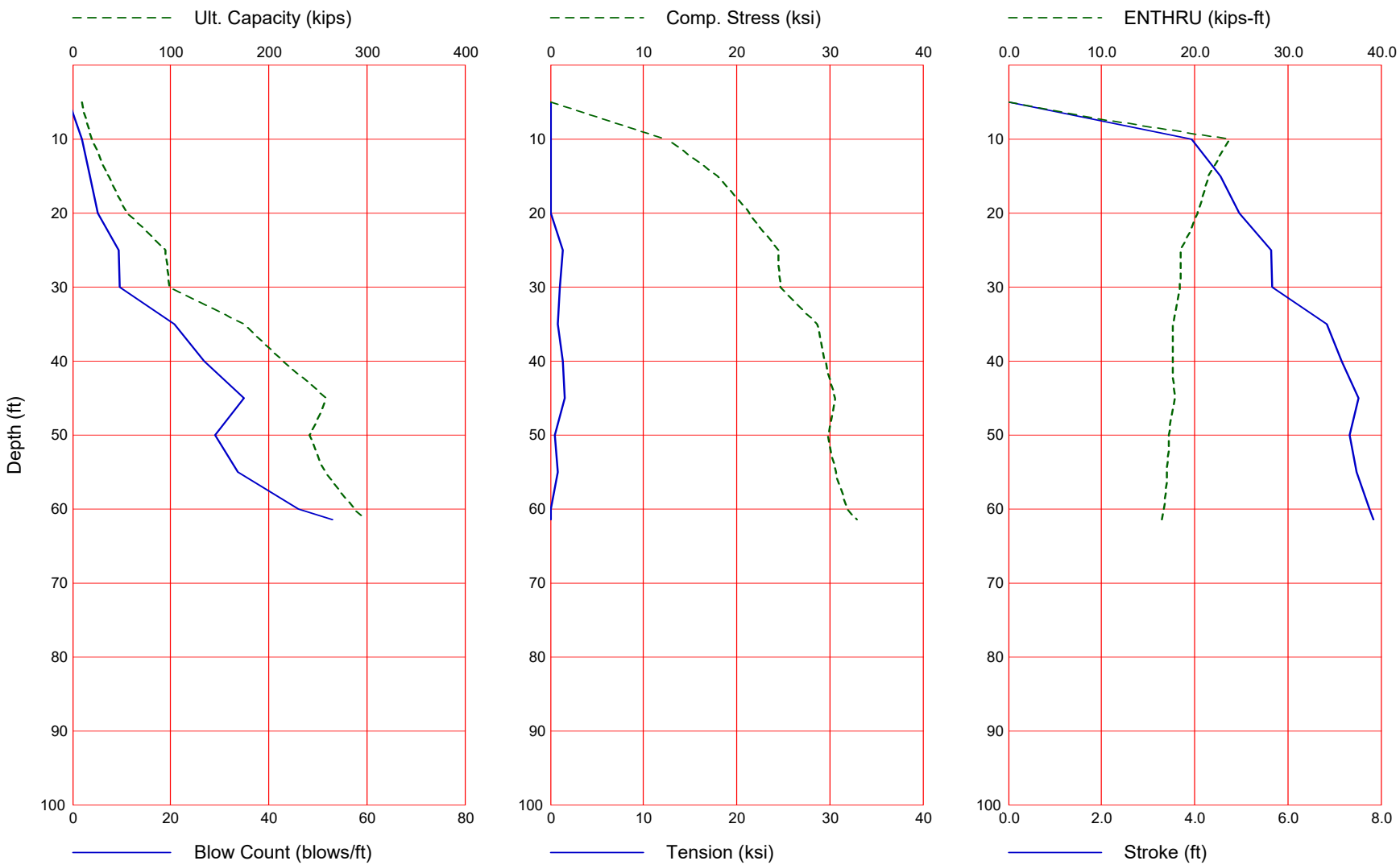
Depth ft	Shaft Res. k/ft2	End Bearing kips	Shaft Quake inch	Toe Quake inch	Shaft Damping s/ft	Toe Damping s/ft	Soil Setup Normlzd	Limit Distance ft	Setup Time hrs
0.01	1.18	1.07	0.100	0.100	0.200	0.150	0.660	0.000	0.000
3.49	1.18	1.07	0.100	0.100	0.200	0.150	0.660	0.000	0.000
3.51	1.24	1.16	0.100	0.100	0.200	0.150	0.660	0.000	0.000
8.49	1.24	1.16	0.100	0.100	0.200	0.150	0.660	0.000	0.000
8.51	0.47	4.53	0.100	0.100	0.010	0.150	0.340	0.000	0.000
17.51	1.03	9.95	0.100	0.100	0.010	0.150	0.340	0.000	0.000
18.49	1.09	10.54	0.100	0.100	0.010	0.150	0.340	0.000	0.000
18.51	1.59	37.06	0.100	0.100	0.050	0.150	0.000	0.000	0.000
22.49	1.96	45.80	0.100	0.100	0.050	0.150	0.000	0.000	0.000
22.51	1.96	45.83	0.100	0.100	0.050	0.150	0.000	0.000	0.000
25.99	2.14	49.94	0.100	0.100	0.050	0.150	0.000	0.000	0.000
26.01	2.14	49.96	0.100	0.100	0.050	0.150	0.000	0.000	0.000
34.99	2.59	51.03	0.100	0.100	0.050	0.150	0.000	0.000	0.000
35.01	2.57	43.36	0.100	0.100	0.050	0.150	0.000	0.000	0.000
39.99	2.82	43.36	0.100	0.100	0.050	0.150	0.000	0.000	0.000
40.01	2.85	51.03	0.100	0.100	0.050	0.150	0.000	0.000	0.000

49.01	3.30	51.03	0.100	0.100	0.050	0.150	0.000	0.000	0.000
49.99	3.35	51.03	0.100	0.100	0.050	0.150	0.000	0.000	0.000
50.01	1.90	6.20	0.100	0.100	0.200	0.150	1.000	0.000	0.000
57.79	1.90	6.20	0.100	0.100	0.200	0.150	1.000	0.000	0.000
57.81	2.38	7.75	0.100	0.100	0.200	0.150	0.000	0.000	0.000
61.80	2.39	7.75	0.100	0.100	0.200	0.150	0.000	0.000	0.000

Resource International Inc
FRA-70-1373A - RA - B-020-1-13 - HP10x42

Jul 12 2018
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	9.8	9.1	0.7	-1.0	0.000	0.000	0.00	0.0
10.0	20.0	19.2	0.8	2.0	12.503	0.000	3.94	23.7
15.0	37.0	28.9	8.1	3.6	17.938	0.000	4.55	21.5
20.0	55.5	45.0	10.4	5.2	21.424	0.000	4.96	20.3
25.0	94.2	67.5	26.7	9.5	24.443	-1.296	5.64	18.5
30.0	98.5	93.1	5.4	9.6	24.694	-1.049	5.66	18.4
35.0	174.2	124.0	50.1	20.7	28.640	-0.835	6.83	17.7
40.0	214.6	163.7	50.9	26.8	29.521	-1.316	7.15	17.7
45.0	258.6	207.5	51.0	34.9	30.590	-1.523	7.51	17.9
50.0	241.8	235.6	6.2	29.1	29.798	-0.472	7.32	17.2
55.0	257.6	251.4	6.2	33.7	30.642	-0.832	7.48	17.0
60.0	286.8	279.0	7.8	46.0	31.874	0.000	7.75	16.7
61.5	298.6	290.8	7.8	52.9	32.885	0.000	7.85	16.5

Total Continuous Driving Time 24.00 minutes; Total Number of Blows 1060

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-13-045 FRA-70-13.54 PROJECT 4A\ANALYSIS\FRA-70-1373A AND R\DRIVEABILITY\FRA-70-1373A - RA\B-020-1-13.GWW
Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2003.GW
Hammer File Version: 2003 (2/22/2013)

Input File Contents

FRA-70-1373A - RA - B-020-1-13 - HP10x42

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	10.070	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
61.500	12.40	29000.0	492.000	3.300	0	0.850	0.010

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	0.002	0.002	1.250	0.00	0.00

P atm	P1	P2	P3	P4	P5
14.70	1520.00	1368.00	1231.00	1108.00	0.00

Stroke	Effic.	Pressure	R-Weight	T-Delay	Exp-Coeff	Eps-Str	Total-AW

10.8100	0.8000	1520.0000	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

Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimD	SU T
0.01	0.82	0.68	0.10	0.10	0.20	0.15	1.49	0.00	0.0
5.49	0.82	0.68	0.10	0.10	0.20	0.15	1.49	0.00	0.0
5.51	0.92	0.77	0.10	0.10	0.20	0.15	1.49	0.00	0.0
10.49	0.92	0.77	0.10	0.10	0.20	0.15	1.49	0.00	0.0
10.51	0.38	1.78	0.10	0.10	0.05	0.15	1.00	0.00	0.0
12.99	0.47	1.78	0.10	0.10	0.05	0.15	1.00	0.00	0.0
13.01	0.72	6.99	0.10	0.10	0.05	0.15	1.00	0.00	0.0
17.99	1.02	9.87	0.10	0.10	0.05	0.15	1.00	0.00	0.0
18.01	1.02	9.88	0.10	0.10	0.05	0.15	1.00	0.00	0.0
22.99	1.17	11.29	0.10	0.10	0.05	0.15	1.00	0.00	0.0
23.01	1.67	25.28	0.10	0.10	0.05	0.15	1.00	0.00	0.0
26.99	1.85	28.06	0.10	0.10	0.05	0.15	1.00	0.00	0.0
27.01	1.67	5.42	0.10	0.10	0.15	0.15	1.21	0.00	0.0
31.99	1.67	5.42	0.10	0.10	0.15	0.15	1.21	0.00	0.0
32.01	2.13	49.68	0.10	0.10	0.05	0.15	1.00	0.00	0.0
41.01	2.58	51.03	0.10	0.10	0.05	0.15	1.00	0.00	0.0
46.99	2.88	51.03	0.10	0.10	0.05	0.15	1.00	0.00	0.0
47.01	1.90	6.20	0.10	0.10	0.20	0.15	2.00	0.00	0.0
56.01	1.92	6.20	0.10	0.10	0.20	0.15	2.00	0.00	0.0
57.49	1.95	6.20	0.10	0.10	0.20	0.15	2.00	0.00	0.0
57.51	2.38	7.75	0.10	0.10	0.20	0.15	1.00	0.00	0.0
61.50	2.39	7.75	0.10	0.10	0.20	0.15	1.00	0.00	0.0

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	0.000	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
55.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
60.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
61.50	0.00	0.00	0.000	0.000	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000

1 0 10.81000 11.86000

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

FRA-70-1373A - RA - B-020-1-13 - HP10x42

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	140046.7	1.000	0.0100	
3	0.800	140046.7	1.000	0.0100	
4	0.800	140046.7	1.000	0.0100	
5	0.800	140046.7	1.000	0.0100	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		8770.7			

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)	1520.00	Actual Pressure	(psi)	1520.00
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

Depth	(ft)	5.0			
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)	10.070			

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model — Total Capacity Rut (kips) 8.9

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	0.145	8771	0.010	0.000	0.85	0.0	0.000	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	0.0	0.000	0.100	6.83	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	2.6	0.200	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	5.6	0.200	0.100	61.50	3.3	12.4
Toe						0.7	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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)	0.435
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 ft	Stroke ft	Pressure Ratio	Efficy
5.00	10.81	1.00	0.800

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
8.9	Hammer did not run										

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    9.3  Hammer did not run
    9.8  Hammer did not run
   10.2  Hammer did not run
   10.7  Hammer did not run
         1           0   10.81000       11.86000
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FRA-70-1373A - RA - B-020-1-13 - HP10x42                          07/12/2018
Resource International Inc                                GRLWEAP Version 2010

 Depth                 (ft)      10.0
 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)    10.070

  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    12.40   29000.    492.0      3.3        0    16524.     21.8
    61.5    12.40   29000.    492.0      3.3        0    16524.     21.8

 Wave Travel Time 2L/c (ms)     7.444

        Pile and Soil Model            Total Capacity Rut  (kips)      18.1
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  0.145     8771 0.010 0.000 0.85     0.0   0.000 0.100   3.42   3.3    12.4
  2  0.145     8771 0.000 0.000 1.00     0.0   0.000 0.100   6.83   3.3    12.4
 16  0.145     8771 0.000 0.000 1.00     5.2   0.200 0.100  54.67   3.3    12.4
 17  0.145     8771 0.000 0.000 1.00     5.8   0.200 0.100  58.08   3.3    12.4
 18  0.145     8771 0.000 0.000 1.00     6.3   0.200 0.100  61.50   3.3    12.4
Toe                                      0.8   0.150 0.100

     2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
     2.606 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
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FRA-70-1373A - RA - B-020-1-13 - HP10x42                          07/12/2018
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
   18.1     1.8   3.84   3.86    0.00   1   0    11.45   1   2   24.0    60.3
   19.0     1.9   3.90   3.91    0.00   1   0    12.03   1   2   23.8    59.9
   20.0     2.0   3.94   3.96    0.00   1   0    12.50   1   2   23.7    59.5
   20.9     2.1   4.02   4.00    0.00   1   0    13.17   1   2   23.6    59.1
   21.9     2.2   4.07   4.05    0.00   1   0    13.62   1   2   23.3    58.8
         1           0   10.81000       11.86000
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FRA-70-1373A - RA - B-020-1-13 - HP10x42                          07/12/2018
Resource International Inc                                GRLWEAP Version 2010

 Depth                 (ft)      15.0
 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)    10.070

  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    12.40   29000.    492.0      3.3        0    16524.     21.8
    61.5    12.40   29000.    492.0      3.3        0    16524.     21.8

 Wave Travel Time 2L/c (ms)     7.444

        Pile and Soil Model            Total Capacity Rut  (kips)      35.0
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  0.145     8771 0.010 0.000 0.85     0.0   0.000 0.100   3.42   3.3    12.4
  2  0.145     8771 0.000 0.000 1.00     0.0   0.000 0.100   6.83   3.3    12.4
```

14	0.145	8771	0.000	0.000	1.00	2.2	0.200	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	5.6	0.200	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	6.1	0.200	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	5.7	0.175	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	7.2	0.050	0.100	61.50	3.3	12.4
Toe						8.1	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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-70-1373A - RA - B-020-1-13 - HP10x42 07/12/2018
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
35.0	3.3	4.43	4.47	0.00	1	0	17.18	4	3	21.6	56.1
36.0	3.5	4.51	4.50	0.00	1	0	17.62	4	3	21.6	55.8
37.0	3.6	4.55	4.53	0.00	1	0	17.94	14	5	21.5	55.5
38.0	3.7	4.59	4.57	0.00	1	0	18.25	14	5	21.4	55.3
39.0	3.8	4.62	4.61	0.00	1	0	18.53	14	5	21.2	55.1
	1		0	10.81000			11.86000				

FRA-70-1373A - RA - B-020-1-13 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 20.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model Total Capacity Rut (kips) 53.5

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	0.145	8771	0.010	0.000	0.85	0.0	0.000	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	0.0	0.000	0.100	6.83	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	4.8	0.200	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	5.8	0.200	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	6.3	0.200	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	5.3	0.105	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	9.4	0.050	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	11.5	0.050	0.100	61.50	3.3	12.4
Toe						10.4	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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
53.5	4.9	4.89	4.87	0.00	1	0	21.00	13	5	20.5	53.4
54.5	5.1	4.92	4.89	0.00	1	0	21.20	13	5	20.4	53.2
55.5	5.2	4.96	4.93	0.00	1	0	21.42	13	5	20.3	53.0
56.5	5.3	4.99	4.96	0.00	1	0	21.60	13	5	20.2	52.9
57.5	5.5	5.02	4.99	0.00	1	0	21.82	13	5	20.1	52.7

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Depth (ft) 25.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model Total Capacity Rut (kips) 92.2

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	0.145	8771	0.010	0.000	0.85	0.0	0.000	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	0.0	0.000	0.100	6.83	3.3	12.4
11	0.145	8771	0.000	0.000	1.00	1.8	0.200	0.100	37.58	3.3	12.4
12	0.145	8771	0.000	0.000	1.00	5.6	0.200	0.100	41.00	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	6.1	0.200	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	5.8	0.182	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	6.9	0.050	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	10.5	0.050	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	12.1	0.050	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	16.7	0.050	0.100	61.50	3.3	12.4
Toe						26.7	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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
92.2	9.1	5.64	5.62	-1.48	11	44	24.37	12	4	18.8	49.5
93.2	9.3	5.61	5.66	-1.39	11	44	24.31	12	4	18.6	49.5
94.2	9.5	5.64	5.69	-1.30	11	44	24.44	12	4	18.5	49.4
95.2	9.6	5.67	5.71	-1.19	11	44	24.58	12	4	18.5	49.3
96.2	9.8	5.69	5.73	-1.08	12	44	24.72	12	4	18.4	49.2

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Depth (ft) 30.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model Total Capacity Rut (kips) 96.0

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	0.145	8771	0.010	0.000	0.85	0.0	0.000	0.100	3.42	3.3	12.4

2	0.145	8771	0.000	0.000	1.00	0.0	0.000	0.100	6.83	3.3	12.4
10	0.145	8771	0.000	0.000	1.00	4.4	0.200	0.100	34.17	3.3	12.4
11	0.145	8771	0.000	0.000	1.00	5.7	0.200	0.100	37.58	3.3	12.4
12	0.145	8771	0.000	0.000	1.00	6.3	0.200	0.100	41.00	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	5.2	0.121	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	9.2	0.050	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	11.4	0.050	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	13.0	0.050	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	19.8	0.050	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	15.7	0.137	0.100	61.50	3.3	12.4
Toe						5.4	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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
96.0	9.2	5.66	5.64	-1.30	9	45	24.54	10	4	18.7	49.5
97.3	9.4	5.63	5.69	-1.15	8	45	24.52	10	4	18.5	49.4
98.5	9.6	5.66	5.72	-1.05	8	45	24.69	10	4	18.4	49.3
99.8	9.8	5.69	5.74	-1.10	10	40	24.85	10	4	18.4	49.2
101.1	10.0	5.72	5.77	-1.22	10	40	25.02	10	4	18.3	49.1
1		0	10.81000		11.86000						

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Depth (ft) 35.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model Total Capacity Rut (kips) 171.2

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	0.145	8771	0.010	0.000	0.85	0.0	0.000	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	0.0	0.000	0.100	6.83	3.3	12.4
8	0.145	8771	0.000	0.000	1.00	1.4	0.200	0.100	27.33	3.3	12.4
9	0.145	8771	0.000	0.000	1.00	5.6	0.200	0.100	30.75	3.3	12.4
10	0.145	8771	0.000	0.000	1.00	6.0	0.200	0.100	34.17	3.3	12.4
11	0.145	8771	0.000	0.000	1.00	6.0	0.188	0.100	37.58	3.3	12.4
12	0.145	8771	0.000	0.000	1.00	6.6	0.050	0.100	41.00	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	10.3	0.050	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	12.1	0.050	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	16.2	0.050	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	18.5	0.082	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	14.9	0.150	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	23.6	0.060	0.100	61.50	3.3	12.4
Toe						50.1	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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

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
171.2	20.2	6.79	6.75	-0.92	8	30	28.43	9	4	17.6	45.2
172.7	20.5	6.81	6.77	-0.88	8	30	28.52	9	4	17.7	45.2
174.2	20.7	6.83	6.79	-0.84	8	30	28.64	9	4	17.7	45.1
175.6	21.1	6.85	6.81	-0.78	8	30	28.73	9	4	17.6	45.0
177.1	21.4	6.86	6.83	-0.72	8	30	28.83	9	4	17.6	45.0

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Depth (ft) 40.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model Total Capacity Rut (kips) 211.6

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	0.145	8771	0.010	0.000	0.85	0.0	0.000	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	0.0	0.000	0.100	6.83	3.3	12.4
7	0.145	8771	0.000	0.000	1.00	4.0	0.200	0.100	23.92	3.3	12.4
8	0.145	8771	0.000	0.000	1.00	5.7	0.200	0.100	27.33	3.3	12.4
9	0.145	8771	0.000	0.000	1.00	6.3	0.200	0.100	30.75	3.3	12.4
10	0.145	8771	0.000	0.000	1.00	5.3	0.134	0.100	34.17	3.3	12.4
11	0.145	8771	0.000	0.000	1.00	8.8	0.050	0.100	37.58	3.3	12.4
12	0.145	8771	0.000	0.000	1.00	11.3	0.050	0.100	41.00	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	12.6	0.050	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	19.5	0.050	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	16.1	0.129	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	18.1	0.110	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	25.6	0.050	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	27.6	0.050	0.100	61.50	3.3	12.4
Toe						50.9	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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
211.6	26.0	7.12	7.10	-1.27	7	50	29.33	7	3	17.7	44.2
213.1	26.4	7.14	7.12	-1.29	7	50	29.43	7	3	17.7	44.1
214.6	26.8	7.15	7.14	-1.32	7	49	29.52	7	3	17.7	44.1
216.0	27.1	7.18	7.16	-1.34	7	49	29.65	7	3	17.7	44.0
217.5	27.5	7.20	7.17	-1.37	7	49	29.75	7	3	17.6	44.0

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Depth (ft) 45.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model — Total Capacity Rut (kips) 255.6

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	0.145	8771	0.010	0.000	0.85	0.0	0.000	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	0.0	0.000	0.100	6.83	3.3	12.4
5	0.145	8771	0.000	0.000	1.00	0.9	0.200	0.100	17.08	3.3	12.4
6	0.145	8771	0.000	0.000	1.00	5.6	0.200	0.100	20.50	3.3	12.4
7	0.145	8771	0.000	0.000	1.00	6.0	0.200	0.100	23.92	3.3	12.4
8	0.145	8771	0.000	0.000	1.00	6.1	0.193	0.100	27.33	3.3	12.4
9	0.145	8771	0.000	0.000	1.00	6.2	0.050	0.100	30.75	3.3	12.4
10	0.145	8771	0.000	0.000	1.00	10.1	0.050	0.100	34.17	3.3	12.4
11	0.145	8771	0.000	0.000	1.00	12.0	0.050	0.100	37.58	3.3	12.4
12	0.145	8771	0.000	0.000	1.00	15.7	0.050	0.100	41.00	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	18.8	0.075	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	14.9	0.150	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	22.8	0.066	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	26.5	0.050	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	28.5	0.050	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	30.4	0.050	0.100	61.50	3.3	12.4
Toe						51.0	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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

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
255.6	33.8	7.48	7.46	-1.56	6	46	30.38	6	3	17.9	43.1
257.1	34.2	7.48	7.47	-1.54	6	46	30.47	6	3	18.0	43.1
258.6	34.9	7.51	7.49	-1.52	6	45	30.59	6	3	17.9	43.0
260.0	35.2	7.53	7.50	-1.50	6	45	30.70	6	3	18.0	43.0
261.5	35.8	7.54	7.52	-1.48	6	45	30.80	6	3	18.0	43.0

1 0 10.81000 11.86000

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Depth (ft) 50.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model — Total Capacity Rut (kips) 237.0

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	0.145	8771	0.010	0.000	0.85	0.0	0.000	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	0.0	0.000	0.100	6.83	3.3	12.4
4	0.145	8771	0.000	0.000	1.00	3.5	0.200	0.100	13.67	3.3	12.4
5	0.145	8771	0.000	0.000	1.00	5.6	0.200	0.100	17.08	3.3	12.4

6	0.145	8771	0.000	0.000	1.00	6.3	0.200	0.100	20.50	3.3	12.4
7	0.145	8771	0.000	0.000	1.00	5.4	0.145	0.100	23.92	3.3	12.4
8	0.145	8771	0.000	0.000	1.00	8.4	0.050	0.100	27.33	3.3	12.4
9	0.145	8771	0.000	0.000	1.00	11.1	0.050	0.100	30.75	3.3	12.4
10	0.145	8771	0.000	0.000	1.00	12.5	0.050	0.100	34.17	3.3	12.4
11	0.145	8771	0.000	0.000	1.00	19.0	0.050	0.100	37.58	3.3	12.4
12	0.145	8771	0.000	0.000	1.00	16.5	0.121	0.100	41.00	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	17.4	0.118	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	25.5	0.050	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	27.4	0.050	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	29.4	0.050	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	31.3	0.050	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	11.5	0.174	0.100	61.50	3.3	12.4
Toe						6.2	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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

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
237.0	27.6	7.27	7.23	-0.58	4	47	29.55	4	3	17.2	43.8
239.4	28.2	7.30	7.26	-0.52	4	47	29.68	4	3	17.2	43.7
241.8	29.1	7.32	7.30	-0.47	4	46	29.80	4	3	17.2	43.6
244.3	29.6	7.35	7.31	-0.48	4	43	29.96	4	3	17.3	43.5
246.7	30.3	7.37	7.34	-0.60	4	43	30.05	4	3	17.3	43.5
1		0	10.81000		11.86000						

Depth (ft) 55.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model Total Capacity Rut (kips) 249.6

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	0.145	8771	0.010	0.000	0.85	0.0	0.000	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	0.5	0.200	0.100	6.83	3.3	12.4
3	0.145	8771	0.000	0.000	1.00	5.6	0.200	0.100	10.25	3.3	12.4
4	0.145	8771	0.000	0.000	1.00	5.9	0.200	0.100	13.67	3.3	12.4
5	0.145	8771	0.000	0.000	1.00	6.2	0.198	0.100	17.08	3.3	12.4
6	0.145	8771	0.000	0.000	1.00	5.9	0.050	0.100	20.50	3.3	12.4
7	0.145	8771	0.000	0.000	1.00	10.0	0.050	0.100	23.92	3.3	12.4
8	0.145	8771	0.000	0.000	1.00	11.9	0.050	0.100	27.33	3.3	12.4
9	0.145	8771	0.000	0.000	1.00	15.1	0.050	0.100	30.75	3.3	12.4
10	0.145	8771	0.000	0.000	1.00	19.2	0.068	0.100	34.17	3.3	12.4
11	0.145	8771	0.000	0.000	1.00	14.9	0.150	0.100	37.58	3.3	12.4
12	0.145	8771	0.000	0.000	1.00	22.1	0.072	0.100	41.00	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	26.4	0.050	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	28.3	0.050	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	30.3	0.050	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	23.9	0.089	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	8.6	0.200	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	8.6	0.200	0.100	61.50	3.3	12.4
Toe						6.2	0.150	0.100			

2.606 kips total unreduced pile weight (g= 32.17 ft/s2)
2.606 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

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
249.6	31.0	7.41	7.38	-1.34	17	13	30.28	3	3	17.0	43.4
253.6	32.5	7.44	7.43	-1.08	17	12	30.45	3	2	16.9	43.3
257.6	33.7	7.48	7.47	-0.83	17	13	30.64	3	3	17.0	43.2
261.6	35.2	7.53	7.51	-0.59	17	12	30.85	3	2	17.0	43.0
265.6	36.5	7.56	7.54	-0.46	3	40	31.04	3	3	17.1	42.9
1		0	10.81000		11.86000						

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Depth (ft) 60.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model Total Capacity Rut (kips) 277.2

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	0.145	8771	0.010	0.000	0.85	3.1	0.200	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	5.6	0.200	0.100	6.83	3.3	12.4
3	0.145	8771	0.000	0.000	1.00	6.3	0.200	0.100	10.25	3.3	12.4
4	0.145	8771	0.000	0.000	1.00	5.5	0.155	0.100	13.67	3.3	12.4
5	0.145	8771	0.000	0.000	1.00	8.1	0.050	0.100	17.08	3.3	12.4
6	0.145	8771	0.000	0.000	1.00	11.0	0.050	0.100	20.50	3.3	12.4
7	0.145	8771	0.000	0.000	1.00	12.4	0.050	0.100	23.92	3.3	12.4
8	0.145	8771	0.000	0.000	1.00	18.5	0.050	0.100	27.33	3.3	12.4
9	0.145	8771	0.000	0.000	1.00	16.9	0.114	0.100	30.75	3.3	12.4
10	0.145	8771	0.000	0.000	1.00	16.7	0.126	0.100	34.17	3.3	12.4
11	0.145	8771	0.000	0.000	1.00	25.3	0.050	0.100	37.58	3.3	12.4
12	0.145	8771	0.000	0.000	1.00	27.3	0.050	0.100	41.00	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	29.2	0.050	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	31.2	0.050	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	13.2	0.160	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	8.6	0.200	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	8.6	0.200	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	22.0	0.200	0.100	61.50	3.3	12.4
Toe						7.8	0.150	0.100			

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

Depth ft	Stroke ft	Pressure Ratio	Efficy
60.00	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
277.2	41.3	7.67	7.65	0.00	1	0	31.46	1	2	16.7	42.6
282.0	43.8	7.71	7.70	0.00	1	0	31.66	1	2	16.6	42.5

286.8	46.0	7.75	7.74	0.00	1	0	31.87	1	2	16.7	42.4
291.5	48.6	7.80	7.78	0.00	1	0	32.10	1	2	16.7	42.3
296.3	51.5	7.83	7.83	0.00	1	0	32.31	1	2	16.7	42.2

1 0 10.81000 11.86000

Depth (ft) 61.5
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
61.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.444

Pile and Soil Model Total Capacity Rut (kips) 289.0

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	0.145	8771	0.010	0.000	0.85	5.6	0.200	0.100	3.42	3.3	12.4
2	0.145	8771	0.000	0.000	1.00	5.9	0.200	0.100	6.83	3.3	12.4
3	0.145	8771	0.000	0.000	1.00	6.3	0.200	0.100	10.25	3.3	12.4
4	0.145	8771	0.000	0.000	1.00	5.6	0.069	0.100	13.67	3.3	12.4
5	0.145	8771	0.000	0.000	1.00	9.7	0.050	0.100	17.08	3.3	12.4
6	0.145	8771	0.000	0.000	1.00	11.7	0.050	0.100	20.50	3.3	12.4
7	0.145	8771	0.000	0.000	1.00	14.5	0.050	0.100	23.92	3.3	12.4
8	0.145	8771	0.000	0.000	1.00	19.6	0.059	0.100	27.33	3.3	12.4
9	0.145	8771	0.000	0.000	1.00	14.9	0.150	0.100	30.75	3.3	12.4
10	0.145	8771	0.000	0.000	1.00	21.1	0.081	0.100	34.17	3.3	12.4
11	0.145	8771	0.000	0.000	1.00	26.2	0.050	0.100	37.58	3.3	12.4
12	0.145	8771	0.000	0.000	1.00	28.1	0.050	0.100	41.00	3.3	12.4
13	0.145	8771	0.000	0.000	1.00	30.1	0.050	0.100	44.42	3.3	12.4
14	0.145	8771	0.000	0.000	1.00	26.1	0.077	0.100	47.83	3.3	12.4
15	0.145	8771	0.000	0.000	1.00	8.6	0.200	0.100	51.25	3.3	12.4
16	0.145	8771	0.000	0.000	1.00	8.6	0.200	0.100	54.67	3.3	12.4
17	0.145	8771	0.000	0.000	1.00	11.8	0.200	0.100	58.08	3.3	12.4
18	0.145	8771	0.000	0.000	1.00	26.9	0.200	0.100	61.50	3.3	12.4
Toe						7.8	0.150	0.100			

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

Depth ft	Stroke ft	Pressure Ratio	Efficy
61.50	10.81	1.00	0.800

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
289.0	47.3	7.77	7.76	0.00	1	0	32.39	1	2	16.5	42.4
293.8	49.7	7.80	7.79	0.00	1	0	32.62	1	2	16.5	42.3
298.6	52.9	7.85	7.84	0.00	1	0	32.88	1	2	16.5	42.2
303.3	56.1	7.88	7.88	0.00	1	0	33.12	1	2	16.5	42.1
308.1	60.4	7.84	7.92	0.00	1	0	33.12	1	2	16.3	42.1

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	8.9	8.2	0.7	Hammer did not run				
10.0	18.1	17.3	0.8	1.8	11.449	0.000	3.84	24.0
15.0	35.0	26.9	8.1	3.3	17.180	0.000	4.43	21.6

20.0	53.5	43.0	10.4	4.9	20.998	0.000	4.89	20.5
25.0	92.2	65.5	26.7	9.1	24.367	-1.481	5.64	18.8
30.0	96.0	90.6	5.4	9.2	24.542	-1.303	5.66	18.7
35.0	171.2	121.1	50.1	20.2	28.426	-0.921	6.79	17.6
40.0	211.6	160.8	50.9	26.0	29.335	-1.270	7.12	17.7
45.0	255.6	204.6	51.0	33.8	30.375	-1.560	7.48	17.9
50.0	237.0	230.8	6.2	27.6	29.553	-0.584	7.27	17.2
55.0	249.6	243.4	6.2	31.0	30.276	-1.342	7.41	17.0
60.0	277.2	269.4	7.8	41.3	31.465	0.000	7.67	16.7
61.5	289.0	281.3	7.8	47.3	32.389	0.000	7.77	16.5

Total Driving Time 22 minutes; Total No. of Blows 1003

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	9.3	8.6	0.7	Hammer did not run				
10.0	19.0	18.2	0.8	1.9	12.029	0.000	3.90	23.8
15.0	36.0	27.9	8.1	3.5	17.625	0.000	4.51	21.6
20.0	54.5	44.0	10.4	5.1	21.203	0.000	4.92	20.4
25.0	93.2	66.5	26.7	9.3	24.306	-1.391	5.61	18.6
30.0	97.3	91.8	5.4	9.4	24.520	-1.147	5.63	18.5
35.0	172.7	122.6	50.1	20.5	28.520	-0.883	6.81	17.7
40.0	213.1	162.2	50.9	26.4	29.428	-1.291	7.14	17.7
45.0	257.1	206.1	51.0	34.2	30.471	-1.544	7.48	18.0
50.0	239.4	233.2	6.2	28.2	29.677	-0.521	7.30	17.2
55.0	253.6	247.4	6.2	32.5	30.451	-1.076	7.44	16.9
60.0	282.0	274.2	7.8	43.8	31.659	0.000	7.71	16.6
61.5	293.8	286.0	7.8	49.7	32.625	0.000	7.80	16.5

Total Driving Time 23 minutes; Total No. of Blows 1029

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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	9.8	9.1	0.7	Hammer did not run				
10.0	20.0	19.2	0.8	2.0	12.503	0.000	3.94	23.7
15.0	37.0	28.9	8.1	3.6	17.938	0.000	4.55	21.5
20.0	55.5	45.0	10.4	5.2	21.424	0.000	4.96	20.3
25.0	94.2	67.5	26.7	9.5	24.443	-1.296	5.64	18.5
30.0	98.5	93.1	5.4	9.6	24.694	-1.049	5.66	18.4
35.0	174.2	124.0	50.1	20.7	28.640	-0.835	6.83	17.7
40.0	214.6	163.7	50.9	26.8	29.521	-1.316	7.15	17.7
45.0	258.6	207.5	51.0	34.9	30.590	-1.523	7.51	17.9
50.0	241.8	235.6	6.2	29.1	29.798	-0.472	7.32	17.2
55.0	257.6	251.4	6.2	33.7	30.642	-0.832	7.48	17.0
60.0	286.8	279.0	7.8	46.0	31.874	0.000	7.75	16.7
61.5	298.6	290.8	7.8	52.9	32.885	0.000	7.85	16.5

Total Driving Time 24 minutes; Total No. of Blows 1060

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	10.2	9.5	0.7	Hammer did not run				
10.0	20.9	20.1	0.8	2.1	13.166	0.000	4.02	23.6
15.0	38.0	29.9	8.1	3.7	18.247	0.000	4.59	21.4
20.0	56.5	46.0	10.4	5.3	21.605	0.000	4.99	20.2
25.0	95.2	68.5	26.7	9.6	24.577	-1.193	5.67	18.5
30.0	99.8	94.4	5.4	9.8	24.847	-1.101	5.69	18.4
35.0	175.6	125.5	50.1	21.1	28.734	-0.781	6.85	17.6
40.0	216.0	165.2	50.9	27.1	29.647	-1.344	7.18	17.7
45.0	260.0	209.0	51.0	35.2	30.703	-1.501	7.53	18.0
50.0	244.3	238.1	6.2	29.6	29.956	-0.483	7.35	17.3
55.0	261.6	255.4	6.2	35.2	30.845	-0.592	7.53	17.0
60.0	291.5	283.8	7.8	48.6	32.098	0.000	7.80	16.7
61.5	303.3	295.6	7.8	56.1	33.116	0.000	7.88	16.5

Total Driving Time 25 minutes; Total No. of Blows 1090

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	10.7	10.0	0.7	Hammer did not run				
10.0	21.9	21.1	0.8	2.2	13.615	0.000	4.07	23.3
15.0	39.0	30.9	8.1	3.8	18.526	0.000	4.62	21.2
20.0	57.5	47.0	10.4	5.5	21.824	0.000	5.02	20.1
25.0	96.2	69.5	26.7	9.8	24.716	-1.081	5.69	18.4
30.0	101.1	95.7	5.4	10.0	25.023	-1.216	5.72	18.3
35.0	177.1	127.0	50.1	21.4	28.833	-0.724	6.86	17.6
40.0	217.5	166.6	50.9	27.5	29.748	-1.374	7.20	17.6
45.0	261.5	210.5	51.0	35.8	30.800	-1.477	7.54	18.0
50.0	246.7	240.5	6.2	30.3	30.053	-0.600	7.37	17.3
55.0	265.6	259.4	6.2	36.5	31.036	-0.461	7.56	17.1
60.0	296.3	288.6	7.8	51.5	32.306	0.000	7.83	16.7
61.5	308.1	300.4	7.8	60.4	33.123	0.000	7.84	16.3

Total Driving Time 25 minutes; Total No. of Blows 1120

FRA-70-1373A - RA - B-020-1-13 - HP10x42 07/12/2018
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	61.50	0.00	10.81	1.00	0.80	1.00	1.00
10.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
15.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
20.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
25.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
30.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
35.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
40.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
45.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
50.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
55.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
60.00	61.50	0.00	10.81	1.00	0.80	1.00	1.00
61.50	61.50	0.00	10.81	1.00	0.80	1.00	1.00

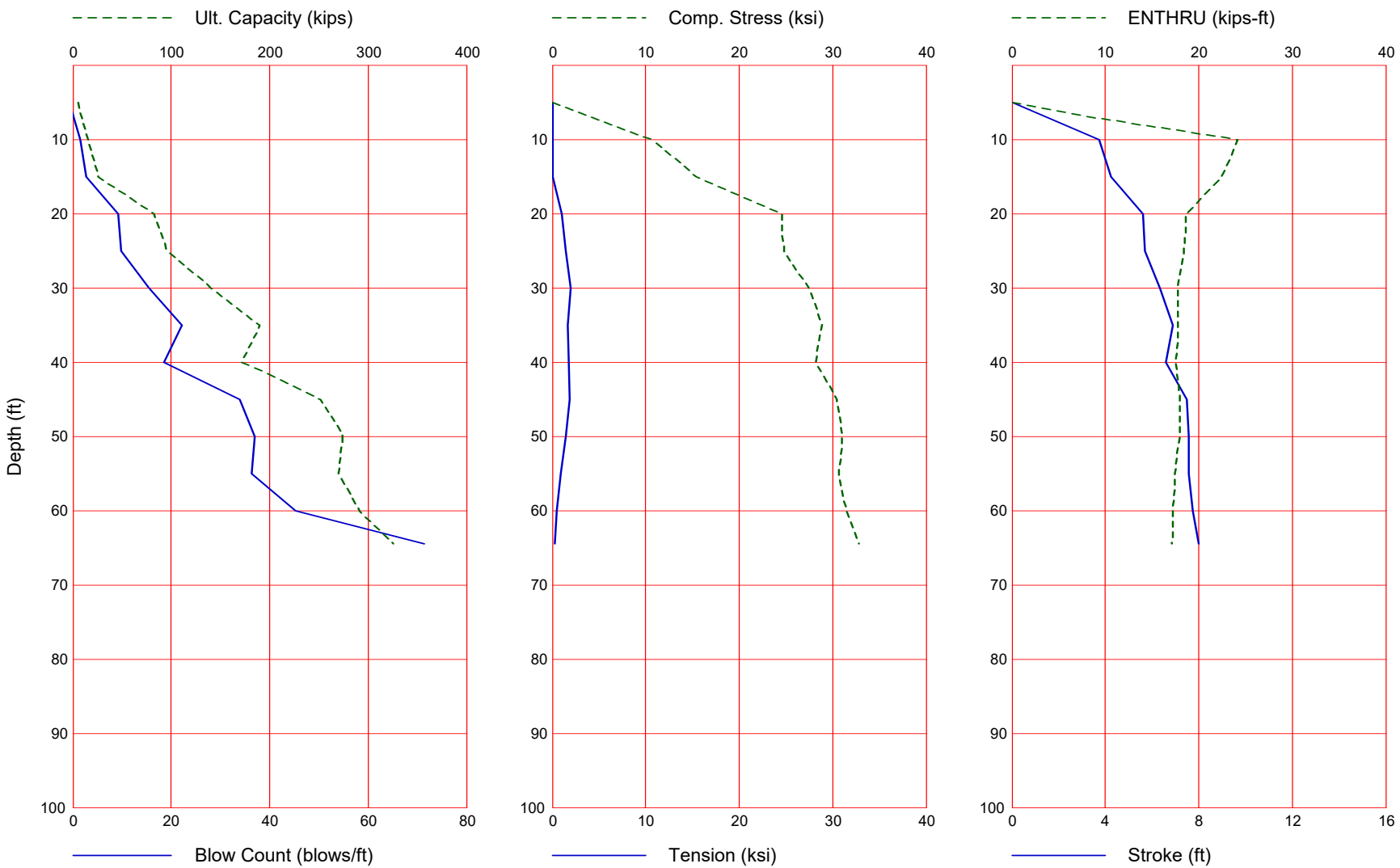
Soil Layer Resistance Values

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	0.82	0.68	0.100	0.100	0.200	0.150	0.660	0.000	0.000
5.49	0.82	0.68	0.100	0.100	0.200	0.150	0.660	0.000	0.000
5.51	0.92	0.77	0.100	0.100	0.200	0.150	0.660	0.000	0.000
10.49	0.92	0.77	0.100	0.100	0.200	0.150	0.660	0.000	0.000
10.51	0.38	1.78	0.100	0.100	0.050	0.150	0.000	0.000	0.000
12.99	0.47	1.78	0.100	0.100	0.050	0.150	0.000	0.000	0.000
13.01	0.72	6.99	0.100	0.100	0.050	0.150	0.000	0.000	0.000
17.99	1.02	9.87	0.100	0.100	0.050	0.150	0.000	0.000	0.000
18.01	1.02	9.88	0.100	0.100	0.050	0.150	0.000	0.000	0.000
22.99	1.17	11.29	0.100	0.100	0.050	0.150	0.000	0.000	0.000
23.01	1.67	25.28	0.100	0.100	0.050	0.150	0.000	0.000	0.000
26.99	1.85	28.06	0.100	0.100	0.050	0.150	0.000	0.000	0.000
27.01	1.67	5.42	0.100	0.100	0.150	0.150	0.340	0.000	0.000
31.99	1.67	5.42	0.100	0.100	0.150	0.150	0.340	0.000	0.000
32.01	2.13	49.68	0.100	0.100	0.050	0.150	0.000	0.000	0.000
41.01	2.58	51.03	0.100	0.100	0.050	0.150	0.000	0.000	0.000
46.99	2.88	51.03	0.100	0.100	0.050	0.150	0.000	0.000	0.000
47.01	1.90	6.20	0.100	0.100	0.200	0.150	1.000	0.000	0.000
56.01	1.92	6.20	0.100	0.100	0.200	0.150	1.000	0.000	0.000
57.49	1.95	6.20	0.100	0.100	0.200	0.150	1.000	0.000	0.000
57.51	2.38	7.75	0.100	0.100	0.200	0.150	0.000	0.000	0.000
61.50	2.39	7.75	0.100	0.100	0.200	0.150	0.000	0.000	0.000

Resource International Inc
FRA-70-1373R - FA - B-020-7-13 - HP10x42

Jul 12 2018
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	6.0	4.8	1.2	-1.0	0.000	0.000	0.00	0.0
10.0	16.1	15.3	0.9	1.6	10.715	0.000	3.75	24.2
15.0	26.0	25.4	0.6	2.7	15.369	0.000	4.25	22.4
20.0	82.7	44.4	38.3	9.2	24.633	-1.053	5.60	18.6
25.0	95.6	72.4	23.2	9.9	24.838	-1.489	5.70	18.4
30.0	140.2	102.4	37.8	15.5	27.428	-1.985	6.33	17.8
35.0	189.9	139.4	50.5	22.1	28.888	-1.607	6.90	17.8
40.0	171.2	168.0	3.2	18.5	28.262	-1.747	6.61	17.5
45.0	251.4	193.0	58.3	33.9	30.488	-1.827	7.47	18.0
50.0	274.6	242.4	32.3	37.0	31.022	-1.408	7.58	18.0
55.0	269.7	263.5	6.2	36.3	30.685	-0.924	7.57	17.4
60.0	290.8	284.6	6.2	45.2	31.526	-0.514	7.76	17.2
64.5	326.0	318.2	7.8	71.3	32.802	-0.241	8.00	17.1

Total Continuous Driving Time 30.00 minutes; Total Number of Blows 1304

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-13-045 FRA-70-13.54 PROJECT 4A\ANALYSIS\FRA-70-1373A AND R\DRIVEABILITY\FRA-70-1373R - FA\B-020-7-13.GWW
Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2003.GW
Hammer File Version: 2003 (2/22/2013)

Input File Contents

FRA-70-1373R - FA - B-020-7-13 - HP10x42

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	10.070	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
64.500	12.40	29000.0	492.000	3.300	0	0.850	0.010

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	0.002	0.002	1.250	0.00	0.00

P atm	P1	P2	P3	P4	P5
14.70	1520.00	1368.00	1231.00	1108.00	0.00

Stroke	Effic.	Pressure	R-Weight	T-Delay	Exp-Coeff	Eps-Str	Total-AW

10.8100	0.8000	1520.0000	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

Res. Distribution

Dpth	Rskn	Rtoe	Qs	Qt	Js	Jt	SU F	LimD	SU T
0.01	0.00	0.00	0.10	0.10	0.05	0.15	1.00	0.00	0.0
2.99	0.14	1.14	0.10	0.10	0.05	0.15	1.00	0.00	0.0
3.01	1.24	1.16	0.10	0.10	0.20	0.15	2.00	0.00	0.0
8.99	1.24	1.16	0.10	0.10	0.20	0.15	2.00	0.00	0.0
9.01	1.02	0.87	0.10	0.10	0.20	0.15	1.49	0.00	0.0
13.99	1.02	0.87	0.10	0.10	0.20	0.15	1.49	0.00	0.0
14.01	0.71	0.58	0.10	0.10	0.20	0.15	2.00	0.00	0.0
16.49	0.71	0.58	0.10	0.10	0.20	0.15	2.00	0.00	0.0
16.51	1.33	31.12	0.10	0.10	0.05	0.15	1.00	0.00	0.0
19.49	1.61	37.67	0.10	0.10	0.05	0.15	1.00	0.00	0.0
19.51	1.61	37.70	0.10	0.10	0.05	0.15	1.00	0.00	0.0
22.99	1.79	41.81	0.10	0.10	0.05	0.15	1.00	0.00	0.0
23.01	1.62	22.04	0.10	0.10	0.05	0.15	1.00	0.00	0.0
29.99	1.92	26.08	0.10	0.10	0.05	0.15	1.00	0.00	0.0
30.01	2.12	49.53	0.10	0.10	0.05	0.15	1.00	0.00	0.0
37.99	2.52	51.03	0.10	0.10	0.05	0.15	1.00	0.00	0.0
38.01	0.98	3.20	0.10	0.10	0.20	0.15	1.49	0.00	0.0
42.99	0.98	3.20	0.10	0.10	0.20	0.15	1.49	0.00	0.0
43.01	2.76	58.35	0.10	0.10	0.05	0.15	1.00	0.00	0.0
49.99	3.12	58.35	0.10	0.10	0.05	0.15	1.00	0.00	0.0
50.01	1.90	6.20	0.10	0.10	0.20	0.15	1.49	0.00	0.0
59.01	1.92	6.20	0.10	0.10	0.20	0.15	1.49	0.00	0.0
60.49	1.95	6.20	0.10	0.10	0.20	0.15	1.49	0.00	0.0
60.51	2.38	7.75	0.10	0.10	0.20	0.15	1.00	0.00	0.0
64.50	2.39	7.75	0.10	0.10	0.20	0.15	1.00	0.00	0.0

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	0.000	0.000	0.000	0.000
10.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
15.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
20.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
25.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
30.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
35.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
40.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
45.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
50.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
55.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
60.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000
64.50	0.00	0.00	0.000	0.000	0.000	0.000	0.000
0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000

1 0 10.81000 11.86000

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

FRA-70-1373R - FA - B-020-7-13 - HP10x42

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	140046.7	1.000	0.0100	
3	0.800	140046.7	1.000	0.0100	
4	0.800	140046.7	1.000	0.0100	
5	0.800	140046.7	1.000	0.0100	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		8827.4			

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)	1520.00	Actual Pressure (psi)	1520.00
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

Depth (ft)	5.0		
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)	10.070					

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	12.40	29000.	492.0	3.3	0	16524.	21.8
64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model — Total Capacity Rut (kips) 5.2

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	0.2	0.050	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	3.8	0.191	0.100	64.50	3.3	12.4
Toe						1.2	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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)	0.435

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 ft	Stroke ft	Pressure Ratio	Efficy
5.00	10.81	1.00	0.800

INITIAL STATIC ANALYSIS: Total Wt, Sum(R) 5.4 5.2
Hammer+Pile Weight > Rult: Pile Runs

FRA-70-1373R - FA - B-020-7-13 - HP10x42 07/12/2018
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
5.2	0.0	10.81	0.00	0.00	1	0	0.00	1	0	0.0	78.4
5.6	Hammer did not run										
6.0	Hammer did not run										
6.4	Hammer did not run										
6.8	Hammer did not run										

1 0 10.81000 11.86000

FRA-70-1373R - FA - B-020-7-13 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 10.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model Total Capacity Rut (kips) 13.5

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	1.1	0.131	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	5.6	0.200	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	6.0	0.200	0.100	64.50	3.3	12.4
Toe						0.9	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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

FRA-70-1373R - FA - B-020-7-13 - HP10x42 07/12/2018
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
13.5	1.5	3.58	3.61	0.00	1	0	10.02	1	7	23.9	62.3
14.8	1.5	3.67	3.70	0.00	1	0	10.43	1	7	24.2	61.7
16.1	1.6	3.75	3.77	0.00	1	0	10.72	1	7	24.2	61.0
17.5	1.7	3.82	3.84	0.00	1	0	11.23	1	2	24.1	60.5
18.8	1.8	3.89	3.91	0.00	1	0	12.01	1	2	23.9	59.9

1 0 10.81000 11.86000

FRA-70-1373R - FA - B-020-7-13 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

Depth (ft) 15.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model					Total Capacity Rut (kips)			22.2		
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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	0.2	0.050	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	3.5	0.189	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	5.6	0.200	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	6.6	0.200	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	5.8	0.200	0.100	64.50	3.3	12.4
Toe						0.6	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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

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
22.2	2.2	4.10	4.08	-0.02	5	12	13.91	1	2	23.2	58.6
24.1	2.5	4.16	4.18	0.00	5	12	14.62	1	2	22.8	58.0
26.0	2.7	4.25	4.26	0.00	1	0	15.37	1	2	22.4	57.4
27.9	2.9	4.32	4.35	0.00	1	0	16.00	1	2	22.1	56.8
29.8	3.2	4.40	4.44	0.00	1	0	16.61	1	2	21.7	56.3

1 0 10.81000 11.86000

Depth (ft) 20.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model					Total Capacity Rut (kips)			78.6		
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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
14	0.144	8827	0.000	0.000	1.00	0.8	0.067	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	5.6	0.200	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	5.9	0.200	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	6.9	0.200	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	4.4	0.192	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	16.8	0.050	0.100	64.50	3.3	12.4
Toe						38.3	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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

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
78.6	8.5	5.50	5.55	-1.11	15	48	23.99	15	5	18.8	50.0
80.6	8.8	5.55	5.59	-1.11	15	48	24.32	15	5	18.7	49.8
82.7	9.2	5.60	5.64	-1.05	15	48	24.63	15	5	18.6	49.6
84.8	9.5	5.65	5.69	-1.05	15	45	24.94	15	5	18.5	49.4
86.9	9.8	5.69	5.74	-1.06	15	45	25.24	15	5	18.4	49.2
1		0	10.81000		11.86000						

Depth (ft) 25.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model Total Capacity Rut (kips) 91.4

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
12	0.144	8827	0.000	0.000	1.00	0.1	0.050	0.100	40.74	3.3	12.4
13	0.144	8827	0.000	0.000	1.00	3.3	0.187	0.100	44.13	3.3	12.4
14	0.144	8827	0.000	0.000	1.00	5.6	0.200	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	6.5	0.200	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	6.0	0.200	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	9.6	0.100	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	18.2	0.050	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	19.1	0.050	0.100	64.50	3.3	12.4
Toe						23.2	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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
91.4	9.3	5.60	5.66	-1.33	13	45	24.29	13	4	18.5	49.6
93.5	9.6	5.65	5.70	-1.29	13	41	24.58	13	4	18.4	49.4
95.6	9.9	5.70	5.75	-1.49	13	41	24.84	13	4	18.4	49.2
97.7	10.2	5.74	5.79	-1.60	13	41	25.12	13	5	18.3	49.0
99.8	10.5	5.79	5.83	-1.67	13	41	25.36	13	5	18.2	48.8
1		0	10.81000		11.86000						

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Depth (ft) 30.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model — Total Capacity Rut (kips) 136.0

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
11	0.144	8827	0.000	0.000	1.00	0.6	0.050	0.100	37.34	3.3	12.4
12	0.144	8827	0.000	0.000	1.00	5.4	0.199	0.100	40.74	3.3	12.4
13	0.144	8827	0.000	0.000	1.00	5.8	0.200	0.100	44.13	3.3	12.4
14	0.144	8827	0.000	0.000	1.00	6.9	0.200	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	4.3	0.200	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	16.3	0.052	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	19.1	0.050	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	19.1	0.050	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	20.7	0.050	0.100	64.50	3.3	12.4
Toe						37.8	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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

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
136.0	14.7	6.25	6.27	-1.92	12	34	26.93	12	4	17.9	47.0
138.1	15.1	6.30	6.30	-1.98	12	34	27.20	12	4	17.9	46.9
140.2	15.5	6.33	6.34	-1.98	12	34	27.43	12	4	17.8	46.8
142.3	15.9	6.36	6.38	-1.96	12	34	27.67	12	4	17.7	46.6
144.3	16.3	6.40	6.41	-1.91	12	34	27.91	12	4	17.8	46.5

1 0 10.81000 11.86000

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Depth (ft) 35.0
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) 10.070

L ft	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		12.40	29000.	492.0	3.3	0	16524.	21.8
64.5		12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model — Total Capacity Rut (kips) 185.7

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
9	0.144	8827	0.000	0.000	1.00	0.1	0.050	0.100	30.55	3.3	12.4
10	0.144	8827	0.000	0.000	1.00	3.0	0.185	0.100	33.95	3.3	12.4
11	0.144	8827	0.000	0.000	1.00	5.6	0.200	0.100	37.34	3.3	12.4
12	0.144	8827	0.000	0.000	1.00	6.4	0.200	0.100	40.74	3.3	12.4
13	0.144	8827	0.000	0.000	1.00	6.2	0.200	0.100	44.13	3.3	12.4
14	0.144	8827	0.000	0.000	1.00	8.8	0.108	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	18.0	0.050	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	19.1	0.050	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	19.9	0.050	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	22.6	0.050	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	25.6	0.050	0.100	64.50	3.3	12.4
Toe						50.5	0.150	0.100			

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

2.733 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
185.7	21.2	6.84	6.81	-1.58	10	29	28.53	10	4	17.8	45.1
187.8	21.7	6.86	6.84	-1.58	10	29	28.69	10	4	17.8	45.0
189.9	22.1	6.90	6.86	-1.61	10	29	28.89	10	4	17.8	44.9
192.0	22.5	6.93	6.89	-1.61	10	29	29.10	10	4	17.9	44.8
194.1	23.0	6.96	6.93	-1.61	10	29	29.26	10	4	17.8	44.7

1 0 10.81000 11.86000

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Depth (ft) 40.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model Total Capacity Rut (kips) 166.6

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
8	0.144	8827	0.000	0.000	1.00	0.6	0.050	0.100	27.16	3.3	12.4
9	0.144	8827	0.000	0.000	1.00	5.2	0.198	0.100	30.55	3.3	12.4
10	0.144	8827	0.000	0.000	1.00	5.7	0.200	0.100	33.95	3.3	12.4
11	0.144	8827	0.000	0.000	1.00	6.9	0.200	0.100	37.34	3.3	12.4
12	0.144	8827	0.000	0.000	1.00	4.5	0.200	0.100	40.74	3.3	12.4
13	0.144	8827	0.000	0.000	1.00	15.5	0.056	0.100	44.13	3.3	12.4
14	0.144	8827	0.000	0.000	1.00	19.1	0.050	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	19.0	0.050	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	20.6	0.050	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	24.5	0.050	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	26.5	0.050	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	15.4	0.104	0.100	64.50	3.3	12.4
Toe						3.2	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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
166.6	17.6	6.52	6.54	-1.65	9	29	27.75	9	4	17.7	46.1
168.9	18.1	6.57	6.57	-1.71	9	29	28.02	9	4	17.6	45.9
171.2	18.5	6.61	6.62	-1.75	9	29	28.26	9	4	17.5	45.8
173.5	18.6	6.71	6.64	-1.76	9	29	28.71	9	4	17.7	45.6
175.8	19.0	6.74	6.67	-1.76	9	29	28.92	9	4	17.6	45.5

1 0 10.81000 11.86000

Depth (ft) 45.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model Total Capacity Rut (kips) 246.2

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
6	0.144	8827	0.000	0.000	1.00	0.1	0.050	0.100	20.37	3.3	12.4
7	0.144	8827	0.000	0.000	1.00	2.7	0.183	0.100	23.76	3.3	12.4
8	0.144	8827	0.000	0.000	1.00	5.6	0.200	0.100	27.16	3.3	12.4
9	0.144	8827	0.000	0.000	1.00	6.4	0.200	0.100	30.55	3.3	12.4
10	0.144	8827	0.000	0.000	1.00	6.4	0.200	0.100	33.95	3.3	12.4
11	0.144	8827	0.000	0.000	1.00	8.1	0.116	0.100	37.34	3.3	12.4
12	0.144	8827	0.000	0.000	1.00	17.9	0.050	0.100	40.74	3.3	12.4
13	0.144	8827	0.000	0.000	1.00	19.1	0.050	0.100	44.13	3.3	12.4
14	0.144	8827	0.000	0.000	1.00	19.8	0.050	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	22.4	0.050	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	25.5	0.050	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	26.1	0.054	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	6.6	0.200	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	21.3	0.080	0.100	64.50	3.3	12.4
Toe						58.3	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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
246.2	32.1	7.41	7.40	-1.90	8	48	30.15	8	3	18.0	43.3
248.8	32.8	7.44	7.42	-1.87	8	48	30.35	8	3	18.1	43.2
251.4	33.9	7.47	7.47	-1.83	7	48	30.49	8	3	18.0	43.1
254.0	34.4	7.51	7.48	-1.81	7	48	30.72	8	3	18.2	43.0
256.6	35.6	7.54	7.53	-1.78	7	47	30.87	8	3	18.1	42.9
1		0	10.81000		11.86000						

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Depth (ft) 50.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model Total Capacity Rut (kips) 269.4

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
5	0.144	8827	0.000	0.000	1.00	0.5	0.050	0.100	16.97	3.3	12.4
6	0.144	8827	0.000	0.000	1.00	4.9	0.197	0.100	20.37	3.3	12.4
7	0.144	8827	0.000	0.000	1.00	5.7	0.200	0.100	23.76	3.3	12.4
8	0.144	8827	0.000	0.000	1.00	6.9	0.200	0.100	27.16	3.3	12.4
9	0.144	8827	0.000	0.000	1.00	4.7	0.200	0.100	30.55	3.3	12.4
10	0.144	8827	0.000	0.000	1.00	14.7	0.060	0.100	33.95	3.3	12.4
11	0.144	8827	0.000	0.000	1.00	19.0	0.050	0.100	37.34	3.3	12.4
12	0.144	8827	0.000	0.000	1.00	19.0	0.050	0.100	40.74	3.3	12.4
13	0.144	8827	0.000	0.000	1.00	20.5	0.050	0.100	44.13	3.3	12.4
14	0.144	8827	0.000	0.000	1.00	24.3	0.050	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	26.4	0.050	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	16.5	0.097	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	8.1	0.177	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	32.0	0.050	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	33.9	0.050	0.100	64.50	3.3	12.4
Toe						32.3	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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

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
269.4	34.9	7.53	7.49	-1.35	6	44	30.60	6	3	18.0	43.0
272.0	36.2	7.55	7.54	-1.39	6	44	30.80	6	3	17.9	42.9
274.6	37.0	7.58	7.56	-1.41	6	44	31.02	6	3	18.0	42.9
277.3	38.3	7.60	7.59	-1.43	6	43	31.19	6	3	17.9	42.8
279.9	39.3	7.64	7.62	-1.46	6	43	31.44	6	3	18.0	42.7
1		0	10.81000		11.86000						

Depth (ft) 55.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model Total Capacity Rut (kips) 262.3

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.0	0.000	0.100	6.79	3.3	12.4
3	0.144	8827	0.000	0.000	1.00	0.0	0.050	0.100	10.18	3.3	12.4
4	0.144	8827	0.000	0.000	1.00	2.5	0.180	0.100	13.58	3.3	12.4
5	0.144	8827	0.000	0.000	1.00	5.6	0.200	0.100	16.97	3.3	12.4
6	0.144	8827	0.000	0.000	1.00	6.3	0.200	0.100	20.37	3.3	12.4
7	0.144	8827	0.000	0.000	1.00	6.6	0.200	0.100	23.76	3.3	12.4
8	0.144	8827	0.000	0.000	1.00	7.4	0.125	0.100	27.16	3.3	12.4
9	0.144	8827	0.000	0.000	1.00	17.7	0.050	0.100	30.55	3.3	12.4
10	0.144	8827	0.000	0.000	1.00	19.1	0.050	0.100	33.95	3.3	12.4
11	0.144	8827	0.000	0.000	1.00	19.7	0.050	0.100	37.34	3.3	12.4
12	0.144	8827	0.000	0.000	1.00	22.1	0.050	0.100	40.74	3.3	12.4
13	0.144	8827	0.000	0.000	1.00	25.4	0.050	0.100	44.13	3.3	12.4

14	0.144	8827	0.000	0.000	1.00	27.1	0.051	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	6.6	0.200	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	19.9	0.085	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	32.9	0.050	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	24.2	0.104	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	12.9	0.200	0.100	64.50	3.3	12.4
Toe						6.2	0.150	0.100			

2.733 kips total unreduced pile weight (g= 32.17 ft/s2)
2.733 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

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
262.3	33.7	7.49	7.48	-0.76	4	42	30.24	5	3	17.3	43.1
266.0	34.9	7.53	7.51	-0.86	4	42	30.46	5	3	17.4	43.0
269.7	36.3	7.57	7.56	-0.92	4	42	30.68	5	3	17.4	42.9
273.3	37.5	7.60	7.58	-0.96	4	41	30.89	5	3	17.4	42.8
277.0	39.5	7.63	7.64	-0.95	4	41	31.06	5	3	17.3	42.7
1		0	10.81000		11.86000						

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Depth (ft) 60.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

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	0.144	8827	0.010	0.000	0.85	0.0	0.000	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	0.4	0.050	0.100	6.79	3.3	12.4
3	0.144	8827	0.000	0.000	1.00	4.7	0.196	0.100	10.18	3.3	12.4
4	0.144	8827	0.000	0.000	1.00	5.6	0.200	0.100	13.58	3.3	12.4
5	0.144	8827	0.000	0.000	1.00	6.9	0.200	0.100	16.97	3.3	12.4
6	0.144	8827	0.000	0.000	1.00	4.9	0.200	0.100	20.37	3.3	12.4
7	0.144	8827	0.000	0.000	1.00	13.9	0.065	0.100	23.76	3.3	12.4
8	0.144	8827	0.000	0.000	1.00	18.9	0.050	0.100	27.16	3.3	12.4
9	0.144	8827	0.000	0.000	1.00	19.0	0.050	0.100	30.55	3.3	12.4
10	0.144	8827	0.000	0.000	1.00	20.5	0.050	0.100	33.95	3.3	12.4
11	0.144	8827	0.000	0.000	1.00	24.0	0.050	0.100	37.34	3.3	12.4
12	0.144	8827	0.000	0.000	1.00	26.3	0.050	0.100	40.74	3.3	12.4
13	0.144	8827	0.000	0.000	1.00	17.6	0.090	0.100	44.13	3.3	12.4
14	0.144	8827	0.000	0.000	1.00	6.8	0.197	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	31.9	0.050	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	33.8	0.050	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	14.1	0.187	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	12.9	0.200	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	13.0	0.200	0.100	64.50	3.3	12.4
Toe						6.2	0.150	0.100			

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

Depth ft	Stroke ft	Pressure Ratio

60.00	10.81	1.00	0.800

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	40.3	7.68	7.66	-0.43	3	40	31.00	3	3	17.2	42.6
286.1	42.7	7.73	7.71	-0.44	3	38	31.28	3	3	17.2	42.5
290.8	45.2	7.76	7.76	-0.51	3	38	31.53	3	3	17.2	42.4
295.5	47.9	7.80	7.80	-0.53	3	38	31.81	3	3	17.2	42.3
300.2	50.6	7.84	7.84	-0.54	3	37	32.10	3	3	17.2	42.2

1 0 10.81000 11.86000

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Depth (ft) 64.5
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
64.5	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.807

Pile and Soil Model Total Capacity Rut (kips) 316.4

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	0.144	8827	0.010	0.000	0.85	1.4	0.153	0.100	3.39	3.3	12.4
2	0.144	8827	0.000	0.000	1.00	5.6	0.200	0.100	6.79	3.3	12.4
3	0.144	8827	0.000	0.000	1.00	6.0	0.200	0.100	10.18	3.3	12.4
4	0.144	8827	0.000	0.000	1.00	6.9	0.200	0.100	13.58	3.3	12.4
5	0.144	8827	0.000	0.000	1.00	5.3	0.166	0.100	16.97	3.3	12.4
6	0.144	8827	0.000	0.000	1.00	17.1	0.050	0.100	20.37	3.3	12.4
7	0.144	8827	0.000	0.000	1.00	19.1	0.050	0.100	23.76	3.3	12.4
8	0.144	8827	0.000	0.000	1.00	19.4	0.050	0.100	27.16	3.3	12.4
9	0.144	8827	0.000	0.000	1.00	21.4	0.050	0.100	30.55	3.3	12.4
10	0.144	8827	0.000	0.000	1.00	25.0	0.050	0.100	33.95	3.3	12.4
11	0.144	8827	0.000	0.000	1.00	26.9	0.050	0.100	37.34	3.3	12.4
12	0.144	8827	0.000	0.000	1.00	10.8	0.143	0.100	40.74	3.3	12.4
13	0.144	8827	0.000	0.000	1.00	14.8	0.112	0.100	44.13	3.3	12.4
14	0.144	8827	0.000	0.000	1.00	32.5	0.050	0.100	47.53	3.3	12.4
15	0.144	8827	0.000	0.000	1.00	28.4	0.078	0.100	50.92	3.3	12.4
16	0.144	8827	0.000	0.000	1.00	12.9	0.200	0.100	54.32	3.3	12.4
17	0.144	8827	0.000	0.000	1.00	12.9	0.200	0.100	57.71	3.3	12.4
18	0.144	8827	0.000	0.000	1.00	15.4	0.200	0.100	61.11	3.3	12.4
19	0.144	8827	0.000	0.000	1.00	26.7	0.200	0.100	64.50	3.3	12.4
Toe						7.8	0.150	0.100			

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

Depth ft	Stroke ft	Pressure Ratio	Efficy
64.50	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
316.4	62.6	7.92	7.97	-0.25	2	36	32.14	2	2	17.1	41.9
321.2	66.4	7.96	8.00	-0.25	2	35	32.47	2	2	17.1	41.8
326.0	71.3	8.00	8.05	-0.24	2	35	32.80	2	2	17.1	41.7
330.8	75.8	8.05	8.08	-0.25	2	35	33.12	2	2	17.1	41.6
335.6	80.4	8.09	8.10	-0.26	2	35	33.43	2	2	17.2	41.5

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	5.2	4.0	1.2	0.0	0.000	0.000	10.81	0.0
10.0	13.5	12.6	0.9	1.5	10.019	0.000	3.58	23.9
15.0	22.2	21.6	0.6	2.2	13.911	-0.024	4.10	23.2
20.0	78.6	40.3	38.3	8.5	23.991	-1.108	5.50	18.8
25.0	91.4	68.3	23.2	9.3	24.292	-1.333	5.60	18.5
30.0	136.0	98.2	37.8	14.7	26.930	-1.916	6.25	17.9
35.0	185.7	135.3	50.5	21.2	28.526	-1.576	6.84	17.8
40.0	166.6	163.4	3.2	17.6	27.755	-1.651	6.52	17.7
45.0	246.2	187.8	58.3	32.1	30.151	-1.900	7.41	18.0
50.0	269.4	237.1	32.3	34.9	30.595	-1.347	7.53	18.0
55.0	262.3	256.1	6.2	33.7	30.241	-0.763	7.49	17.3
60.0	281.4	275.2	6.2	40.3	30.999	-0.430	7.68	17.2
64.5	316.4	308.6	7.8	62.6	32.144	-0.251	7.92	17.1

Total Driving Time 27 minutes; Total No. of Blows 1211

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	5.6	4.4	1.2	Hammer did not run				
10.0	14.8	13.9	0.9	1.5	10.432	0.000	3.67	24.2
15.0	24.1	23.5	0.6	2.5	14.624	-0.003	4.16	22.8
20.0	80.6	42.4	38.3	8.8	24.320	-1.112	5.55	18.7
25.0	93.5	70.3	23.2	9.6	24.578	-1.291	5.65	18.4
30.0	138.1	100.3	37.8	15.1	27.196	-1.977	6.30	17.9
35.0	187.8	137.3	50.5	21.7	28.688	-1.582	6.86	17.8
40.0	168.9	165.7	3.2	18.1	28.022	-1.712	6.57	17.6
45.0	248.8	190.4	58.3	32.8	30.351	-1.869	7.44	18.1
50.0	272.0	239.7	32.3	36.2	30.804	-1.388	7.55	17.9
55.0	266.0	259.8	6.2	34.9	30.461	-0.859	7.53	17.4
60.0	286.1	279.9	6.2	42.7	31.279	-0.440	7.73	17.2
64.5	321.2	313.4	7.8	66.4	32.471	-0.247	7.96	17.1

Total Driving Time 29 minutes; Total No. of Blows 1254

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	6.0	4.8	1.2	Hammer did not run				
10.0	16.1	15.3	0.9	1.6	10.715	0.000	3.75	24.2
15.0	26.0	25.4	0.6	2.7	15.369	0.000	4.25	22.4
20.0	82.7	44.4	38.3	9.2	24.633	-1.053	5.60	18.6
25.0	95.6	72.4	23.2	9.9	24.838	-1.489	5.70	18.4
30.0	140.2	102.4	37.8	15.5	27.428	-1.985	6.33	17.8
35.0	189.9	139.4	50.5	22.1	28.888	-1.607	6.90	17.8
40.0	171.2	168.0	3.2	18.5	28.262	-1.747	6.61	17.5
45.0	251.4	193.0	58.3	33.9	30.488	-1.827	7.47	18.0
50.0	274.6	242.4	32.3	37.0	31.022	-1.408	7.58	18.0
55.0	269.7	263.5	6.2	36.3	30.685	-0.924	7.57	17.4
60.0	290.8	284.6	6.2	45.2	31.526	-0.514	7.76	17.2
64.5	326.0	318.2	7.8	71.3	32.802	-0.241	8.00	17.1

Total Driving Time 30 minutes; Total No. of Blows 1304

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	6.4	5.2	1.2	Hammer did not run				
10.0	17.5	16.6	0.9	1.7	11.227	0.000	3.82	24.1
15.0	27.9	27.3	0.6	2.9	16.004	0.000	4.32	22.1
20.0	84.8	46.5	38.3	9.5	24.937	-1.049	5.65	18.5
25.0	97.7	74.5	23.2	10.2	25.116	-1.603	5.74	18.3
30.0	142.3	104.5	37.8	15.9	27.675	-1.958	6.36	17.7

35.0	192.0	141.5	50.5	22.5	29.096	-1.612	6.93	17.9
40.0	173.5	170.3	3.2	18.6	28.707	-1.763	6.71	17.7
45.0	254.0	195.7	58.3	34.4	30.720	-1.809	7.51	18.2
50.0	277.3	245.0	32.3	38.3	31.190	-1.435	7.60	17.9
55.0	273.3	267.1	6.2	37.5	30.885	-0.963	7.60	17.4
60.0	295.5	289.3	6.2	47.9	31.815	-0.534	7.80	17.2
64.5	330.8	323.0	7.8	75.8	33.118	-0.251	8.05	17.1

Total Driving Time 31 minutes; Total No. of Blows 1353

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	6.8	5.6	1.2	Hammer did not run				
10.0	18.8	17.9	0.9	1.8	12.008	0.000	3.89	23.9
15.0	29.8	29.2	0.6	3.2	16.614	0.000	4.40	21.7
20.0	86.9	48.6	38.3	9.8	25.241	-1.057	5.69	18.4
25.0	99.8	76.6	23.2	10.5	25.356	-1.674	5.79	18.2
30.0	144.3	106.5	37.8	16.3	27.913	-1.910	6.40	17.8
35.0	194.1	143.6	50.5	23.0	29.260	-1.606	6.96	17.8
40.0	175.8	172.6	3.2	19.0	28.919	-1.758	6.74	17.6
45.0	256.6	198.3	58.3	35.6	30.866	-1.776	7.54	18.1
50.0	279.9	247.6	32.3	39.3	31.442	-1.462	7.64	18.0
55.0	277.0	270.8	6.2	39.5	31.065	-0.949	7.63	17.3
60.0	300.2	294.0	6.2	50.6	32.097	-0.538	7.84	17.2
64.5	335.6	327.8	7.8	80.4	33.435	-0.264	8.09	17.2

Total Driving Time 32 minutes; Total No. of Blows 1406

FRA-70-1373R - FA - B-020-7-13 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

Table of Depths Analyzed with Driving System Modifiers

Depth ft	Temp. Length ft	Wait Time hr	Equivalent Pressure Stroke ft	Ratio	Efficy.	Stiffn. Factor	Cushion CoR
5.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
10.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
15.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
20.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
25.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
30.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
35.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
40.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
45.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
50.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
55.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
60.00	64.50	0.00	10.81	1.00	0.80	1.00	1.00
64.50	64.50	0.00	10.81	1.00	0.80	1.00	1.00

Soil Layer Resistance Values

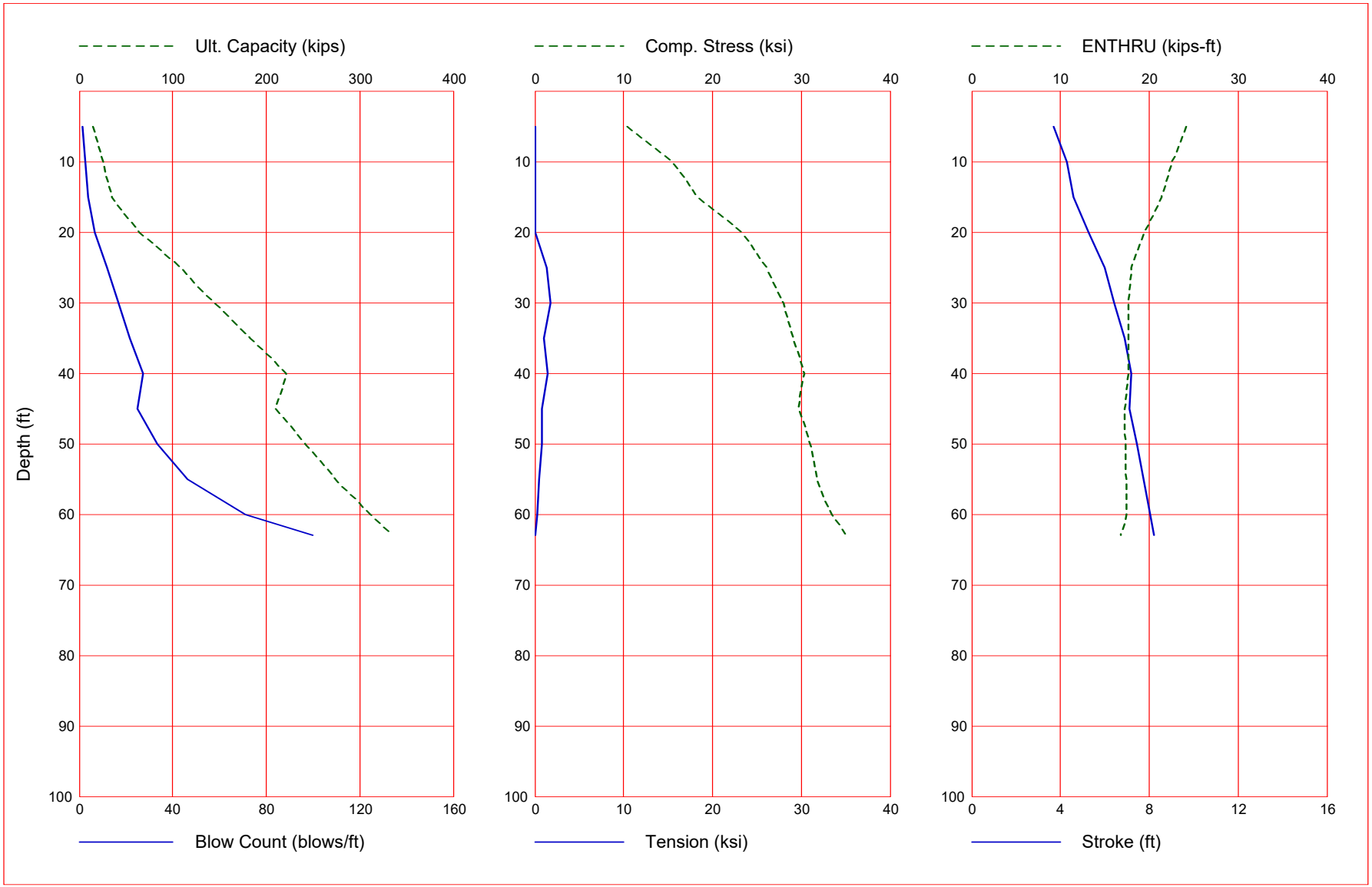
Depth ft	Shaft Res. k/ft2	End Bearing kips	Shaft Quake inch	Toe Quake inch	Shaft Damping s/ft	Toe Damping s/ft	Soil Setup Normlzd	Limit Distance ft	Setup Time hrs
0.01	0.00	0.00	0.100	0.100	0.050	0.150	0.000	0.000	0.000
2.99	0.14	1.14	0.100	0.100	0.050	0.150	0.000	0.000	0.000
3.01	1.24	1.16	0.100	0.100	0.200	0.150	1.000	0.000	0.000
8.99	1.24	1.16	0.100	0.100	0.200	0.150	1.000	0.000	0.000
9.01	1.02	0.87	0.100	0.100	0.200	0.150	0.660	0.000	0.000
13.99	1.02	0.87	0.100	0.100	0.200	0.150	0.660	0.000	0.000
14.01	0.71	0.58	0.100	0.100	0.200	0.150	1.000	0.000	0.000
16.49	0.71	0.58	0.100	0.100	0.200	0.150	1.000	0.000	0.000
16.51	1.33	31.12	0.100	0.100	0.050	0.150	0.000	0.000	0.000
19.49	1.61	37.67	0.100	0.100	0.050	0.150	0.000	0.000	0.000
19.51	1.61	37.70	0.100	0.100	0.050	0.150	0.000	0.000	0.000
22.99	1.79	41.81	0.100	0.100	0.050	0.150	0.000	0.000	0.000
23.01	1.62	22.04	0.100	0.100	0.050	0.150	0.000	0.000	0.000

29.99	1.92	26.08	0.100	0.100	0.050	0.150	0.000	0.000	0.000
30.01	2.12	49.53	0.100	0.100	0.050	0.150	0.000	0.000	0.000
37.99	2.52	51.03	0.100	0.100	0.050	0.150	0.000	0.000	0.000
38.01	0.98	3.20	0.100	0.100	0.200	0.150	0.660	0.000	0.000
42.99	0.98	3.20	0.100	0.100	0.200	0.150	0.660	0.000	0.000
43.01	2.76	58.35	0.100	0.100	0.050	0.150	0.000	0.000	0.000
49.99	3.12	58.35	0.100	0.100	0.050	0.150	0.000	0.000	0.000
50.01	1.90	6.20	0.100	0.100	0.200	0.150	0.660	0.000	0.000
59.01	1.92	6.20	0.100	0.100	0.200	0.150	0.660	0.000	0.000
60.49	1.95	6.20	0.100	0.100	0.200	0.150	0.660	0.000	0.000
60.51	2.38	7.75	0.100	0.100	0.200	0.150	0.000	0.000	0.000
64.50	2.39	7.75	0.100	0.100	0.200	0.150	0.000	0.000	0.000

Resource International Inc
FRA-70-1373R - RA - B-020-2-13 - HP10x42

Jul 12 2018
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	15.1	14.1	1.0	1.6	10.405	0.000	3.68	24.2
10.0	25.9	25.5	0.4	2.7	15.503	0.000	4.29	22.6
15.0	34.5	30.2	4.3	3.7	18.334	-0.070	4.60	21.4
20.0	64.2	46.7	17.5	6.7	23.324	-0.068	5.28	19.5
25.0	108.8	70.0	38.8	12.0	26.130	-1.377	5.98	18.0
30.0	144.2	99.5	44.7	16.7	28.020	-1.761	6.43	17.6
35.0	182.5	133.2	49.3	21.5	29.025	-0.965	6.87	17.7
40.0	221.7	171.0	50.7	27.5	30.320	-1.460	7.18	17.6
45.0	210.4	204.2	6.2	25.1	29.656	-0.811	7.11	17.2
50.0	242.0	235.8	6.2	33.6	30.991	-0.814	7.46	17.3
55.0	274.4	268.2	6.2	46.5	31.777	-0.517	7.76	17.4
60.0	310.9	303.1	7.8	71.1	33.450	-0.290	8.03	17.4
63.0	334.5	326.7	7.8	99.8	35.082	0.000	8.20	16.8

Total Continuous Driving Time 33.00 minutes; Total Number of Blows 1424

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-13-045 FRA-70-13.54 PROJECT 4A\ANALYSIS\FRA-70-1373A AND R\DRIVEABILITY\FRA-70-1373R - RA\B-020-2-13.GWW
Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2003.GW
Hammer File Version: 2003 (2/22/2013)

Input File Contents

FRA-70-1373R - RA - B-020-2-13 - HP10x42

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	10.070	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
63.000	12.40	29000.0	492.000	3.300	0	0.850	0.010

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	0.002	0.002	1.250	0.00	0.00

P atm	P1	P2	P3	P4	P5
14.70	1520.00	1368.00	1231.00	1108.00	0.00

Stroke	Effic.	Pressure	R-Weight	T-Delay	Exp-Coeff	Eps-Str	Total-AW

```
  10.8100    0.8000 1520.0000    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
 Res. Distribution
   Dpth    Rskn      Rtoe      Qs      Qt      Js      Jt   SU F    LimD   SU T
   0.01    1.30      1.26    0.10    0.10    0.20    0.15   1.49    0.00    0.0
   4.49    1.30      1.26    0.10    0.10    0.20    0.15   1.49    0.00    0.0
   4.51    1.10      0.97    0.10    0.10    0.20    0.15   1.49    0.00    0.0
   9.49    1.10      0.97    0.10    0.10    0.20    0.15   1.49    0.00    0.0
   9.51    0.49      0.39    0.10    0.10    0.20    0.15   2.00    0.00    0.0
  14.49    0.49      0.39    0.10    0.10    0.20    0.15   2.00    0.00    0.0
  14.51    0.62      4.31    0.10    0.10    0.05    0.15   1.00    0.00    0.0
  14.99    0.64      4.31    0.10    0.10    0.05    0.15   1.00    0.00    0.0
  15.01    0.64      4.31    0.10    0.10    0.05    0.15   1.00    0.00    0.0
  16.99    0.68      4.31    0.10    0.10    0.05    0.15   1.00    0.00    0.0
  17.01    1.16     15.80    0.10    0.10    0.05    0.15   1.00    0.00    0.0
  24.49    1.48     20.13    0.10    0.10    0.05    0.15   1.00    0.00    0.0
  24.51    1.64     38.22    0.10    0.10    0.05    0.15   1.00    0.00    0.0
  33.51    2.09     48.85    0.10    0.10    0.05    0.15   1.00    0.00    0.0
  40.99    2.47     51.03    0.10    0.10    0.05    0.15   1.00    0.00    0.0
  41.01    1.90      6.20    0.10    0.10    0.20    0.15   1.00    0.00    0.0
  50.01    1.92      6.20    0.10    0.10    0.20    0.15   1.00    0.00    0.0
  58.99    2.09      6.20    0.10    0.10    0.20    0.15   1.00    0.00    0.0
  59.01    2.38      7.75    0.10    0.10    0.20    0.15   1.00    0.00    0.0
  63.00    2.39      7.75    0.10    0.10    0.20    0.15   1.00    0.00    0.0
 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     0.000     0.000     0.000     0.000
    10.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    15.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    20.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    25.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    30.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    35.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    40.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    45.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    50.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    55.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    60.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
    63.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
     0.00      0.00      0.00     0.000     0.000     0.000     0.000     0.000
          1           0   10.81000       11.86000
```

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

FRA-70-1373R - RA - B-020-2-13 - HP10x42

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	140046.7	1.000	0.0100	
3	0.800	140046.7	1.000	0.0100	
4	0.800	140046.7	1.000	0.0100	
5	0.800	140046.7	1.000	0.0100	
Imp Block	0.753	70735.6	0.900	0.0100	
Helmet	1.900	60155.0	0.800	0.0100	5.8
Combined Pile Top		9037.6			

```
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)	1520.00	Actual Pressure	(psi)	1520.00
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

Depth	(ft)	5.0			
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)	10.070			

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model — Total Capacity Rut (kips) 13.7

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	4.3	0.200	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	8.4	0.200	0.100	63.00	3.3	12.4
Toe						1.0	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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)		0.435
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 ft	Stroke ft	Pressure Ratio	Efficy
5.00	10.81	1.00	0.800

Rut kips	Bl Ct b/ft	Stroke (ft) down	Stroke (ft) up	Ten Str ksi	i	t	Comp Str ksi	i	t	ENTHRU kip-ft	Bl Rt b/min
13.7	1.5	3.60	3.63	0.00	1	0	10.06	1	7	24.1	62.2
14.4	1.5	3.67	3.66	0.00	1	0	10.32	1	7	24.4	61.8
15.1	1.6	3.68	3.71	0.00	1	0	10.40	1	7	24.2	61.6

15.8	1.6	3.73	3.75	0.00	1	0	10.56	1	7	24.2	61.2
16.5	1.7	3.76	3.79	0.00	1	0	10.73	1	7	24.2	60.9

1 0 10.81000 11.86000

Depth (ft) 10.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 23.3

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	0.1	0.200	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	8.6	0.200	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	7.7	0.200	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	6.5	0.200	0.100	63.00	3.3	12.4
Toe						0.4	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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

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
23.3	2.4	4.16	4.12	0.00	1	0	14.46	1	2	23.0	58.2
24.6	2.5	4.21	4.19	0.00	1	0	14.89	1	2	22.7	57.8
25.9	2.7	4.29	4.25	0.00	1	0	15.50	1	2	22.6	57.3
27.2	2.9	4.29	4.32	0.00	1	0	15.71	1	2	22.2	57.0
28.4	3.0	4.34	4.37	0.00	1	0	16.17	1	2	22.0	56.7

1 0 10.81000 11.86000

Depth (ft) 15.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 31.2

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	4.5	0.200	0.100	49.74	3.3	12.4

16	0.140	9038	0.000	0.000	1.00	8.4	0.200	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	7.3	0.200	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	3.9	0.200	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	2.9	0.172	0.100	63.00	3.3	12.4
Toe						4.3	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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

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
31.2	3.3	4.43	4.47	-0.14	18	14	17.01	15	5	21.6	56.1
32.8	3.5	4.49	4.53	-0.09	18	14	17.56	15	5	21.4	55.7
34.5	3.7	4.60	4.58	-0.07	18	14	18.33	15	5	21.4	55.2
36.1	3.9	4.66	4.64	-0.06	18	14	18.78	15	5	21.1	54.9
37.8	4.1	4.72	4.70	-0.05	18	14	19.26	15	5	21.0	54.5

1 0 10.81000 11.86000

Depth (ft) 20.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 60.9

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	0.3	0.200	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	8.6	0.200	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	7.7	0.200	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	6.4	0.200	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	2.1	0.200	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	5.4	0.092	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	12.9	0.050	0.100	63.00	3.3	12.4
Toe						17.5	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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

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
60.9	6.3	5.19	5.16	0.00	1	0	22.75	14	5	19.7	51.8
62.6	6.5	5.23	5.21	0.00	1	0	23.02	14	5	19.5	51.5
64.2	6.7	5.28	5.25	-0.07	14	50	23.32	14	5	19.5	51.3
65.9	7.0	5.32	5.30	-0.32	14	50	23.61	14	5	19.4	51.1
67.5	7.2	5.36	5.35	-0.49	14	50	23.86	14	5	19.2	50.9

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Depth (ft) 25.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 105.5

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
12	0.140	9038	0.000	0.000	1.00	4.6	0.200	0.100	39.79	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	8.3	0.200	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	7.3	0.200	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	3.8	0.200	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	2.9	0.169	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	9.6	0.050	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	14.1	0.050	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	15.9	0.050	0.100	63.00	3.3	12.4
Toe						38.8	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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
105.5	11.5	5.91	5.95	-1.44	12	40	25.72	12	4	18.1	48.3
107.2	11.7	5.94	5.98	-1.42	12	40	25.90	12	4	18.0	48.2
108.8	12.0	5.98	6.00	-1.38	12	40	26.13	12	4	18.0	48.1
110.5	12.3	6.01	6.04	-1.30	12	40	26.30	12	4	18.0	47.9
112.1	12.6	6.05	6.07	-1.20	12	40	26.50	12	4	17.9	47.8

1 0 10.81000 11.86000

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Depth (ft) 30.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 140.9

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4

2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
10	0.140	9038	0.000	0.000	1.00	0.4	0.200	0.100	33.16	3.3	12.4
11	0.140	9038	0.000	0.000	1.00	8.6	0.200	0.100	36.47	3.3	12.4
12	0.140	9038	0.000	0.000	1.00	7.7	0.200	0.100	39.79	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	6.4	0.200	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	2.1	0.200	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	5.5	0.090	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	13.0	0.050	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	14.9	0.050	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	17.6	0.050	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	20.0	0.050	0.100	63.00	3.3	12.4
Toe						44.7	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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
140.9	16.1	6.38	6.39	-1.80	11	33	27.67	11	4	17.7	46.6
142.6	16.4	6.40	6.42	-1.79	11	33	27.82	11	4	17.6	46.5
144.2	16.7	6.43	6.44	-1.76	11	33	28.02	11	4	17.6	46.4
145.9	17.0	6.46	6.47	-1.71	11	33	28.21	11	4	17.6	46.3
147.5	17.3	6.49	6.51	-1.65	11	33	28.39	11	4	17.5	46.2
1		0	10.81000		11.86000						

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Depth (ft) 35.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 179.2

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
9	0.140	9038	0.000	0.000	1.00	4.8	0.200	0.100	29.84	3.3	12.4
10	0.140	9038	0.000	0.000	1.00	8.3	0.200	0.100	33.16	3.3	12.4
11	0.140	9038	0.000	0.000	1.00	7.3	0.200	0.100	36.47	3.3	12.4
12	0.140	9038	0.000	0.000	1.00	3.7	0.200	0.100	39.79	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	3.0	0.167	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	9.7	0.050	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	14.2	0.050	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	16.0	0.050	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	19.1	0.050	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	21.0	0.050	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	22.8	0.050	0.100	63.00	3.3	12.4
Toe						49.3	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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
179.2	20.9	6.81	6.79	-1.08	9	30	28.70	9	4	17.6	45.1
180.8	21.2	6.85	6.81	-1.00	9	30	28.89	9	4	17.7	45.0
182.5	21.5	6.87	6.83	-0.97	9	28	29.02	9	4	17.7	45.0
184.1	21.9	6.89	6.85	-0.96	9	28	29.16	9	4	17.6	44.9
185.7	22.3	6.91	6.88	-0.94	9	28	29.29	9	4	17.6	44.8

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Depth (ft) 40.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 218.5

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
7	0.140	9038	0.000	0.000	1.00	0.5	0.200	0.100	23.21	3.3	12.4
8	0.140	9038	0.000	0.000	1.00	8.6	0.200	0.100	26.53	3.3	12.4
9	0.140	9038	0.000	0.000	1.00	7.7	0.200	0.100	29.84	3.3	12.4
10	0.140	9038	0.000	0.000	1.00	6.3	0.200	0.100	33.16	3.3	12.4
11	0.140	9038	0.000	0.000	1.00	2.1	0.200	0.100	36.47	3.3	12.4
12	0.140	9038	0.000	0.000	1.00	5.6	0.088	0.100	39.79	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	13.1	0.050	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	15.0	0.050	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	17.7	0.050	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	20.1	0.050	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	21.9	0.050	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	23.7	0.050	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	25.6	0.050	0.100	63.00	3.3	12.4
Toe						50.7	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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
218.5	26.5	7.15	7.11	-1.39	8	50	30.04	8	3	17.8	44.1
220.1	27.1	7.16	7.15	-1.43	8	50	30.15	8	3	17.6	44.0
221.7	27.5	7.18	7.16	-1.46	8	49	30.32	8	3	17.6	44.0
223.4	27.9	7.20	7.18	-1.48	8	49	30.49	8	3	17.7	43.9
225.0	28.4	7.22	7.21	-1.49	8	49	30.62	8	3	17.6	43.9

1 0 10.81000 11.86000

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Depth (ft) 45.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 207.1

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
6	0.140	9038	0.000	0.000	1.00	4.9	0.200	0.100	19.89	3.3	12.4
7	0.140	9038	0.000	0.000	1.00	8.3	0.200	0.100	23.21	3.3	12.4
8	0.140	9038	0.000	0.000	1.00	7.3	0.200	0.100	26.53	3.3	12.4
9	0.140	9038	0.000	0.000	1.00	3.7	0.200	0.100	29.84	3.3	12.4
10	0.140	9038	0.000	0.000	1.00	3.1	0.164	0.100	33.16	3.3	12.4
11	0.140	9038	0.000	0.000	1.00	9.8	0.050	0.100	36.47	3.3	12.4
12	0.140	9038	0.000	0.000	1.00	14.2	0.050	0.100	39.79	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	16.0	0.050	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	19.1	0.050	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	21.0	0.050	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	22.8	0.050	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	24.6	0.050	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	25.2	0.076	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	20.9	0.200	0.100	63.00	3.3	12.4
Toe						6.2	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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

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
207.1	24.3	7.07	7.04	-0.74	6	50	29.38	6	3	17.2	44.4
208.8	24.7	7.10	7.06	-0.76	6	49	29.55	6	3	17.2	44.3
210.4	25.1	7.11	7.08	-0.81	6	49	29.66	6	3	17.2	44.2
212.1	25.4	7.14	7.10	-0.86	6	48	29.81	6	3	17.2	44.2
213.7	25.8	7.16	7.12	-0.89	6	48	29.95	6	3	17.2	44.1

1 0 10.81000 11.86000

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Depth (ft) 50.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 238.7

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4

4	0.140	9038	0.000	0.000	1.00	0.7	0.200	0.100	13.26	3.3	12.4
5	0.140	9038	0.000	0.000	1.00	8.6	0.200	0.100	16.58	3.3	12.4
6	0.140	9038	0.000	0.000	1.00	7.6	0.200	0.100	19.89	3.3	12.4
7	0.140	9038	0.000	0.000	1.00	6.2	0.200	0.100	23.21	3.3	12.4
8	0.140	9038	0.000	0.000	1.00	2.1	0.200	0.100	26.53	3.3	12.4
9	0.140	9038	0.000	0.000	1.00	5.7	0.086	0.100	29.84	3.3	12.4
10	0.140	9038	0.000	0.000	1.00	13.2	0.050	0.100	33.16	3.3	12.4
11	0.140	9038	0.000	0.000	1.00	15.0	0.050	0.100	36.47	3.3	12.4
12	0.140	9038	0.000	0.000	1.00	17.7	0.050	0.100	39.79	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	20.1	0.050	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	21.9	0.050	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	23.7	0.050	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	25.6	0.050	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	22.5	0.149	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	20.9	0.200	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	20.9	0.200	0.100	63.00	3.3	12.4
Toe						6.2	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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
238.7	32.5	7.42	7.42	-0.82	5	44	30.68	5	3	17.3	43.3
240.3	32.8	7.45	7.42	-0.83	5	44	30.86	5	3	17.5	43.2
242.0	33.6	7.46	7.45	-0.81	5	43	30.99	5	3	17.3	43.2
243.6	34.2	7.47	7.47	-0.79	5	43	31.13	5	3	17.3	43.1
245.3	34.6	7.49	7.48	-0.77	5	43	31.29	5	3	17.4	43.1

1 0 10.81000 11.86000

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Depth (ft) 55.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
	63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 271.1

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	0.140	9038	0.010	0.000	0.85	0.0	0.000	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	0.0	0.000	0.100	6.63	3.3	12.4
3	0.140	9038	0.000	0.000	1.00	5.0	0.200	0.100	9.95	3.3	12.4
4	0.140	9038	0.000	0.000	1.00	8.3	0.200	0.100	13.26	3.3	12.4
5	0.140	9038	0.000	0.000	1.00	7.3	0.200	0.100	16.58	3.3	12.4
6	0.140	9038	0.000	0.000	1.00	3.6	0.200	0.100	19.89	3.3	12.4
7	0.140	9038	0.000	0.000	1.00	3.2	0.161	0.100	23.21	3.3	12.4
8	0.140	9038	0.000	0.000	1.00	9.9	0.050	0.100	26.53	3.3	12.4
9	0.140	9038	0.000	0.000	1.00	14.2	0.050	0.100	29.84	3.3	12.4
10	0.140	9038	0.000	0.000	1.00	16.1	0.050	0.100	33.16	3.3	12.4
11	0.140	9038	0.000	0.000	1.00	19.2	0.050	0.100	36.47	3.3	12.4
12	0.140	9038	0.000	0.000	1.00	21.0	0.050	0.100	39.79	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	22.8	0.050	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	24.7	0.050	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	25.1	0.078	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	20.9	0.200	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	20.9	0.200	0.100	56.37	3.3	12.4

18	0.140	9038	0.000	0.000	1.00	21.0	0.200	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	21.7	0.200	0.100	63.00	3.3	12.4
Toe						6.2	0.150	0.100			

2.669 kips total unreduced pile weight (g= 32.17 ft/s2)
2.669 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

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
271.1	44.4	7.73	7.73	-0.53	3	40	31.46	3	3	17.5	42.4
272.8	45.1	7.75	7.74	-0.53	3	39	31.62	3	3	17.5	42.4
274.4	46.5	7.76	7.76	-0.52	3	39	31.78	3	3	17.4	42.3
276.0	47.2	7.78	7.77	-0.52	3	39	31.94	3	3	17.5	42.3
277.7	48.4	7.78	7.78	-0.51	3	39	32.04	3	3	17.4	42.3
1		0	10.81000		11.86000						

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Depth (ft) 60.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 307.6

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	0.140	9038	0.010	0.000	0.85	0.8	0.200	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	8.6	0.200	0.100	6.63	3.3	12.4
3	0.140	9038	0.000	0.000	1.00	7.6	0.200	0.100	9.95	3.3	12.4
4	0.140	9038	0.000	0.000	1.00	6.1	0.200	0.100	13.26	3.3	12.4
5	0.140	9038	0.000	0.000	1.00	2.1	0.200	0.100	16.58	3.3	12.4
6	0.140	9038	0.000	0.000	1.00	5.8	0.084	0.100	19.89	3.3	12.4
7	0.140	9038	0.000	0.000	1.00	13.3	0.050	0.100	23.21	3.3	12.4
8	0.140	9038	0.000	0.000	1.00	15.0	0.050	0.100	26.53	3.3	12.4
9	0.140	9038	0.000	0.000	1.00	17.8	0.050	0.100	29.84	3.3	12.4
10	0.140	9038	0.000	0.000	1.00	20.1	0.050	0.100	33.16	3.3	12.4
11	0.140	9038	0.000	0.000	1.00	21.9	0.050	0.100	36.47	3.3	12.4
12	0.140	9038	0.000	0.000	1.00	23.8	0.050	0.100	39.79	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	25.6	0.050	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	22.4	0.152	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	20.9	0.200	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	20.9	0.200	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	21.3	0.200	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	22.0	0.200	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	23.7	0.200	0.100	63.00	3.3	12.4
Toe						7.8	0.150	0.100			

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

Depth ft	Stroke ft	Pressure Ratio	Efficy
60.00	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
307.6	67.3	8.00	8.02	-0.30	2	36	33.07	2	2	17.4	41.7
309.2	69.1	8.01	8.03	-0.30	2	36	33.25	2	2	17.4	41.7
310.9	71.1	8.03	8.04	-0.29	2	36	33.45	2	2	17.4	41.7
312.5	72.8	8.04	8.04	-0.29	2	36	33.64	2	2	17.4	41.6
314.2	75.8	8.05	8.06	-0.27	2	36	33.82	2	2	17.3	41.6
1		0	10.81000		11.86000						

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Depth (ft) 63.0
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) 10.070

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	12.40	29000.	492.0	3.3	0	16524.	21.8
63.0	12.40	29000.	492.0	3.3	0	16524.	21.8

Wave Travel Time 2L/c (ms) 7.625

Pile and Soil Model Total Capacity Rut (kips) 331.2

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	0.140	9038	0.010	0.000	0.85	8.6	0.200	0.100	3.32	3.3	12.4
2	0.140	9038	0.000	0.000	1.00	7.8	0.200	0.100	6.63	3.3	12.4
3	0.140	9038	0.000	0.000	1.00	6.6	0.200	0.100	9.95	3.3	12.4
4	0.140	9038	0.000	0.000	1.00	2.1	0.200	0.100	13.26	3.3	12.4
5	0.140	9038	0.000	0.000	1.00	5.3	0.097	0.100	16.58	3.3	12.4
6	0.140	9038	0.000	0.000	1.00	12.6	0.050	0.100	19.89	3.3	12.4
7	0.140	9038	0.000	0.000	1.00	14.9	0.050	0.100	23.21	3.3	12.4
8	0.140	9038	0.000	0.000	1.00	17.5	0.050	0.100	26.53	3.3	12.4
9	0.140	9038	0.000	0.000	1.00	19.9	0.050	0.100	29.84	3.3	12.4
10	0.140	9038	0.000	0.000	1.00	21.8	0.050	0.100	33.16	3.3	12.4
11	0.140	9038	0.000	0.000	1.00	23.6	0.050	0.100	36.47	3.3	12.4
12	0.140	9038	0.000	0.000	1.00	25.4	0.050	0.100	39.79	3.3	12.4
13	0.140	9038	0.000	0.000	1.00	23.0	0.136	0.100	43.11	3.3	12.4
14	0.140	9038	0.000	0.000	1.00	20.9	0.200	0.100	46.42	3.3	12.4
15	0.140	9038	0.000	0.000	1.00	20.9	0.200	0.100	49.74	3.3	12.4
16	0.140	9038	0.000	0.000	1.00	21.3	0.200	0.100	53.05	3.3	12.4
17	0.140	9038	0.000	0.000	1.00	22.0	0.200	0.100	56.37	3.3	12.4
18	0.140	9038	0.000	0.000	1.00	23.3	0.200	0.100	59.68	3.3	12.4
19	0.140	9038	0.000	0.000	1.00	26.1	0.200	0.100	63.00	3.3	12.4
Toe						7.8	0.150	0.100			

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

Depth ft	Stroke ft	Pressure Ratio	Efficy
63.00	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
331.2	91.6	8.18	8.15	0.00	1	0	34.62	1	2	17.0	41.3
332.8	95.7	8.19	8.17	0.00	1	0	34.86	1	2	16.9	41.3
334.5	99.8	8.20	8.17	0.00	1	0	35.08	1	2	16.8	41.3
336.1	102.9	8.20	8.17	0.00	1	0	35.29	1	2	16.8	41.3
337.8	107.4	8.21	8.18	0.00	1	0	35.53	1	2	16.7	41.3

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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	13.7	12.7	1.0	1.5	10.064	0.000	3.60	24.1
10.0	23.3	22.9	0.4	2.4	14.460	0.000	4.16	23.0
15.0	31.2	26.9	4.3	3.3	17.010	-0.139	4.43	21.6
20.0	60.9	43.4	17.5	6.3	22.748	0.000	5.19	19.7
25.0	105.5	66.7	38.8	11.5	25.718	-1.436	5.91	18.1
30.0	140.9	96.2	44.7	16.1	27.665	-1.798	6.38	17.7
35.0	179.2	129.9	49.3	20.9	28.703	-1.080	6.81	17.6
40.0	218.5	167.7	50.7	26.5	30.045	-1.395	7.15	17.8
45.0	207.1	200.9	6.2	24.3	29.384	-0.742	7.07	17.2
50.0	238.7	232.5	6.2	32.5	30.682	-0.821	7.42	17.3
55.0	271.1	264.9	6.2	44.4	31.457	-0.526	7.73	17.5
60.0	307.6	299.8	7.8	67.3	33.074	-0.300	8.00	17.4
63.0	331.2	323.5	7.8	91.6	34.617	0.000	8.18	17.0

Total Driving Time 31 minutes; Total No. of Blows 1354

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	14.4	13.4	1.0	1.5	10.325	0.000	3.67	24.4
10.0	24.6	24.2	0.4	2.5	14.893	0.000	4.21	22.7
15.0	32.8	28.5	4.3	3.5	17.562	-0.093	4.49	21.4
20.0	62.6	45.1	17.5	6.5	23.020	0.000	5.23	19.5
25.0	107.2	68.4	38.8	11.7	25.903	-1.420	5.94	18.0
30.0	142.6	97.9	44.7	16.4	27.824	-1.788	6.40	17.6
35.0	180.8	131.5	49.3	21.2	28.892	-0.999	6.85	17.7
40.0	220.1	169.4	50.7	27.1	30.146	-1.428	7.16	17.6
45.0	208.8	202.6	6.2	24.7	29.546	-0.761	7.10	17.2
50.0	240.3	234.1	6.2	32.8	30.864	-0.832	7.45	17.5
55.0	272.8	266.6	6.2	45.1	31.623	-0.531	7.75	17.5
60.0	309.2	301.5	7.8	69.1	33.245	-0.296	8.01	17.4
63.0	332.8	325.1	7.8	95.7	34.857	0.000	8.19	16.9

Total Driving Time 32 minutes; Total No. of Blows 1386

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	15.1	14.1	1.0	1.6	10.405	0.000	3.68	24.2
10.0	25.9	25.5	0.4	2.7	15.503	0.000	4.29	22.6
15.0	34.5	30.2	4.3	3.7	18.334	-0.070	4.60	21.4
20.0	64.2	46.7	17.5	6.7	23.324	-0.068	5.28	19.5
25.0	108.8	70.0	38.8	12.0	26.130	-1.377	5.98	18.0
30.0	144.2	99.5	44.7	16.7	28.020	-1.761	6.43	17.6
35.0	182.5	133.2	49.3	21.5	29.025	-0.965	6.87	17.7
40.0	221.7	171.0	50.7	27.5	30.320	-1.460	7.18	17.6
45.0	210.4	204.2	6.2	25.1	29.656	-0.811	7.11	17.2
50.0	242.0	235.8	6.2	33.6	30.991	-0.814	7.46	17.3
55.0	274.4	268.2	6.2	46.5	31.777	-0.517	7.76	17.4
60.0	310.9	303.1	7.8	71.1	33.450	-0.290	8.03	17.4
63.0	334.5	326.7	7.8	99.8	35.082	0.000	8.20	16.8

Total Driving Time 33 minutes; Total No. of Blows 1424

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	15.8	14.8	1.0	1.6	10.560	0.000	3.73	24.2
10.0	27.2	26.8	0.4	2.9	15.710	0.000	4.29	22.2
15.0	36.1	31.8	4.3	3.9	18.781	-0.060	4.66	21.1
20.0	65.9	48.3	17.5	7.0	23.607	-0.315	5.32	19.4
25.0	110.5	71.7	38.8	12.3	26.302	-1.305	6.01	18.0
30.0	145.9	101.2	44.7	17.0	28.212	-1.713	6.46	17.6
35.0	184.1	134.8	49.3	21.9	29.165	-0.959	6.89	17.6
40.0	223.4	172.6	50.7	27.9	30.490	-1.481	7.20	17.7
45.0	212.1	205.9	6.2	25.4	29.807	-0.857	7.14	17.2
50.0	243.6	237.4	6.2	34.2	31.132	-0.793	7.47	17.3

55.0	276.0	269.8	6.2	47.2	31.935	-0.521	7.78	17.5
60.0	312.5	304.8	7.8	72.8	33.641	-0.289	8.04	17.4
63.0	336.1	328.4	7.8	102.9	35.286	0.000	8.20	16.8

Total Driving Time 33 minutes; Total No. of Blows 1452

FRA-70-1373R - RA - B-020-2-13 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

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	16.5	15.5	1.0	1.7	10.731	0.000	3.76	24.2
10.0	28.4	28.1	0.4	3.0	16.174	0.000	4.34	22.0
15.0	37.8	33.5	4.3	4.1	19.263	-0.052	4.72	21.0
20.0	67.5	50.0	17.5	7.2	23.860	-0.489	5.36	19.2
25.0	112.1	73.3	38.8	12.6	26.503	-1.197	6.05	17.9
30.0	147.5	102.8	44.7	17.3	28.393	-1.646	6.49	17.5
35.0	185.7	136.5	49.3	22.3	29.291	-0.944	6.91	17.6
40.0	225.0	174.3	50.7	28.4	30.619	-1.495	7.22	17.6
45.0	213.7	207.5	6.2	25.8	29.950	-0.891	7.16	17.2
50.0	245.3	239.1	6.2	34.6	31.286	-0.770	7.49	17.4
55.0	277.7	271.5	6.2	48.4	32.043	-0.515	7.78	17.4
60.0	314.2	306.4	7.8	75.8	33.816	-0.273	8.05	17.3
63.0	337.8	330.0	7.8	107.4	35.535	0.000	8.21	16.7

Total Driving Time 34 minutes; Total No. of Blows 1492

FRA-70-1373R - RA - B-020-2-13 - HP10x42 07/12/2018
Resource International Inc GRLWEAP Version 2010

Table of Depths Analyzed with Driving System Modifiers

Depth ft	Temp. Length ft	Wait Time hr	Equivalent Pressure Stroke ft	Ratio	Efficy.	Stiffn. Factor	Cushion CoR
5.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
10.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
15.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
20.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
25.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
30.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
35.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
40.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
45.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
50.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
55.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
60.00	63.00	0.00	10.81	1.00	0.80	1.00	1.00
63.00	63.00	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	1.30	1.26	0.100	0.100	0.200	0.150	0.660	0.000	0.000
4.49	1.30	1.26	0.100	0.100	0.200	0.150	0.660	0.000	0.000
4.51	1.10	0.97	0.100	0.100	0.200	0.150	0.660	0.000	0.000
9.49	1.10	0.97	0.100	0.100	0.200	0.150	0.660	0.000	0.000
9.51	0.49	0.39	0.100	0.100	0.200	0.150	1.000	0.000	0.000
14.49	0.49	0.39	0.100	0.100	0.200	0.150	1.000	0.000	0.000
14.51	0.62	4.31	0.100	0.100	0.050	0.150	0.000	0.000	0.000
14.99	0.64	4.31	0.100	0.100	0.050	0.150	0.000	0.000	0.000
15.01	0.64	4.31	0.100	0.100	0.050	0.150	0.000	0.000	0.000
16.99	0.68	4.31	0.100	0.100	0.050	0.150	0.000	0.000	0.000
17.01	1.16	15.80	0.100	0.100	0.050	0.150	0.000	0.000	0.000
24.49	1.48	20.13	0.100	0.100	0.050	0.150	0.000	0.000	0.000
24.51	1.64	38.22	0.100	0.100	0.050	0.150	0.000	0.000	0.000
33.51	2.09	48.85	0.100	0.100	0.050	0.150	0.000	0.000	0.000
40.99	2.47	51.03	0.100	0.100	0.050	0.150	0.000	0.000	0.000
41.01	1.90	6.20	0.100	0.100	0.200	0.150	0.000	0.000	0.000
50.01	1.92	6.20	0.100	0.100	0.200	0.150	0.000	0.000	0.000

58.99	2.09	6.20	0.100	0.100	0.200	0.150	0.000	0.000	0.000
59.01	2.38	7.75	0.100	0.100	0.200	0.150	0.000	0.000	0.000
63.00	2.39	7.75	0.100	0.100	0.200	0.150	0.000	0.000	0.000

APPENIX VII

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-020-1-13	712.8 to 707.3	A-2-4	G	4	21	33	125 psf	125 psf	φ = 39°	250 pci	-	-
	707.3 to 702.3	A-6a	C	1	7	7	115 psf	115 psf	Su = 875 psf	165 pci	0.0095	-
	702.3 to 697.3	A-6b	C	3	8	8	115 psf	115 psf	Su = 1,000 psf	235 pci	0.0090	-
	697.3 to 694.8	A-1-b	G	4	4	4	120 psf	120 psf	φ = 31°	60 pci	-	-
	694.8 to 684.8	A-1-b	G	4	17	15	125 psf	62.6 psf	φ = 36°	95 pci	-	-
	684.8 to 680.8	A-1-b	G	4	42	35	130 psf	67.6 psf	φ = 40°	155 pci	-	-
	680.8 to 675.8	A-4a	C	2	56	56	130 psf	67.6 psf	Su = 7,000 psf	2,335 pci	0.0037	-
	675.8 to 660.8	A-1-b	G	4	100	75	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	660.8 to 648.6	A-7-6	C	2	75	75	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	648.6 to 632.3	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	0
	632.3 to 626.8	Limestone	R	9	-	-	165 psf	102.6 psf	Qu = 10,000 psi	0.00005	1,000,000 psi	49
B-020-2-13	711.4 to 703.4	A-6a	C	3	13	13	115 psf	115 psf	Su = 1,625 psf	540 pci	0.0068	-
	703.4 to 698.4	A-6b	C	3	10	10	115 psf	115 psf	Su = 1,250 psf	365 pci	0.0080	-
	698.4 to 693.4	A-7-6	C	1	4	4	115 psf	115 psf	Su = 500 psf	65 pci	0.0150	-
	693.4 to 690.9	A-2-4	G	4	8	8	120 psf	57.6 psf	φ = 33°	60 pci	-	-
	690.9 to 683.4	A-1-b	G	4	34	32	130 psf	67.6 psf	φ = 39°	140 pci	-	-
	683.4 to 666.9	A-1-b	G	4	91	75	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	666.9 to 647.1	A-6b	C	2	82	82	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	647.1 to 641.9	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	20
	641.9 to 631.9	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 750 psi	0.00025	68,000 psi	4
	631.9 to 626.9	Limestone	R	9	-	-	165 psf	102.6 psf	Qu = 10,000 psi	0.00005	1,000,000 psi	97
B-020-3-13	712.3 to 696.8	A-6b	C	3	8	8	115 psf	115 psf	Su = 1,000 psf	235 pci	0.0090	-
	696.8 to 691.8	A-1-a	G	4	32	32	130 psf	67.6 psf	φ = 40°	155 pci	-	-
	691.8 to 689.3	A-1-b	G	4	9	9	120 psf	57.6 psf	φ = 34°	70 pci	-	-
	689.3 to 680.3	A-1-b	G	4	120	110	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	680.3 to 672.8	A-6b	C	2	120	120	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	672.8 to 665.3	A-1-a	G	4	120	96	135 psf	72.6 psf	φ = 43°	215 pci	-	-
	665.3 to 662.5	A-2-4	G	4	120	92	135 psf	72.6 psf	φ = 41°	175 pci	-	-

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-020-5-13	733.4 to 716.4	A-6a	C	3	24	24	120 psf	120 psf	Su = 3,000 psf	1,000 pci	0.0050	-
	716.4 to 707.9	A-6a	C	3	33	33	125 psf	125 psf	Su = 4,125 psf	1,375 pci	0.0046	-
	707.9 to 700.4	A-6b	C	3	30	30	125 psf	125 psf	Su = 3,750 psf	1,250 pci	0.0048	-
	700.4 to 695.4	A-2-4	G	4	21	16	125 psf	125 psf	φ = 35°	135 pci	-	-
	695.4 to 676.4	A-1-b	G	4	65	42	135 psf	72.6 psf	φ = 41°	175 pci	-	-
	676.4 to 669.2	A-4a	C	2	120	120	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	669.2 to 661.4	A-6a	C	2	106	106	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	661.4 to 656.8	A-6b	C	2	65	65	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	656.8 to 653.4	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	20
	653.4 to 645.4	Mudstone	R	9	-	-	150 psf	87.6 psf	Qu = 360 psi	0.0005	32,000 psi	73
	645.4 to 643.4	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 1,125 psi	0.00015	100,000 psi	46
B-020-7-13	713.5 to 706.5	A-2-4	G	4	8	12	120 psf	120 psf	φ = 34°	115 pci	-	-
	706.5 to 700.5	A-7-6	C	3	12	12	115 psf	115 psf	Su = 1,500 psf	500 pci	0.0070	-
	700.5 to 695.5	A-6b	C	3	9	9	115 psf	115 psf	Su = 1,125 psf	300 pci	0.0085	-
	695.5 to 693.0	A-7-6	C	1	6	6	115 psf	115 psf	Su = 750 psf	100 pci	0.0100	-
	693.0 to 686.5	A-1-a	G	4	48	43	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	686.5 to 679.5	A-1-b	G	4	33	28	130 psf	67.6 psf	φ = 39°	140 pci	-	-
	679.5 to 671.5	A-1-b	G	4	67	53	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	671.5 to 666.5	A-6a	C	2	33	33	125 psf	62.6 psf	Su = 4,125 psf	1,375 pci	0.0046	-
	666.5 to 659.5	A-1-a	G	4	89	64	135 psf	72.6 psf	φ = 43°	215 pci	-	-
	659.5 to 648.1	A-6a	C	2	120	120	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	648.1 to 633.1	Mudstone	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	74
B-020-9-15	713.0 to 707.5	A-6a	C	3	11	11	115 psf	115 psf	Su = 1,375 psf	435 pci	0.0075	-
	707.5 to 702.5	A-6b	C	3	12	12	115 psf	115 psf	Su = 1,500 psf	500 pci	0.0070	-
	702.5 to 692.5	A-4a	G	4	37	38	130 psf	130 psf	φ = 36°	160 pci	-	-
	692.5 to 685.0	A-1-b	G	4	77	67	135 psf	135 psf	φ = 42°	355 pci	-	-
	685.0 to 676.0	A-2-4	G	4	80	64	135 psf	72.6 psf	φ = 41°	175 pci	-	-
	676.0 to 671.0	A-2-6	G	4	120	91	135 psf	72.6 psf	φ = 41°	175 pci	-	-
	671.0 to 661.0	A-1-b	G	4	96	69	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	661.0 to 652.5	A-7-6	C	2	108	108	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	652.5 to 637.5	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 360 psi	0.0005	32,000 psi	48

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-021-0-08	727.9 to 719.9	A-1-b	G	4	11	16	120 psf	120 psf	φ = 36°	160 pci	-	-
	719.9 to 709.9	A-6b	C	3	14	14	115 psf	115 psf	Su = 1,750 psf	585 pci	0.0067	-
	709.9 to 704.9	A-1-a	G	4	37	35	130 psf	130 psf	φ = 41°	315 pci	-	-
	704.9 to 699.9	A-4a	C	3	9	9	115 psf	115 psf	Su = 1,125 psf	300 pci	0.0085	-
	699.9 to 695.9	A-1-b	G	4	21	17	125 psf	62.6 psf	φ = 37°	110 pci	-	-
	695.9 to 685.9	A-1-b	G	4	106	83	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	685.9 to 670.9	A-3	G	4	71	50	135 psf	72.6 psf	φ = 39°	140 pci	-	-
	670.9 to 660.9	A-6b	C	2	85	85	130 psf	67.6 psf	Su = 8,000 psf	2,665 pci	0.0033	-
	660.9 to 656.7	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 200 psi	0.0005	20,000 psi	20
	656.7 to 637.9	Shale	R	9	-	-	150 psf	87.6 psf	Qu = 750 psi	0.00025	68,000 psi	83
B-001-A-59	713.9 to 706.9	A-1-b	G	4	5	8	120 psf	120 psf	φ = 34°	115 pci	-	-
	706.9 to 699.4	A-4a	G	4	9	10	115 psf	115 psf	φ = 30°	45 pci	-	-
	699.4 to 696.9	A-2-4	G	4	13	13	120 psf	120 psf	φ = 35°	135 pci	-	-
	696.9 to 685.9	A-1-a	G	4	25	23	125 psf	125 psf	φ = 39°	250 pci	-	-
	685.9 to 665.9	A-1-b	G	4	94	74	135 psf	72.6 psf	φ = 42°	195 pci	-	-
	665.9 to 662.9	A-4a	G	4	71	51	135 psf	72.6 psf	φ = 38°	125 pci	-	-

APPENDIX VIII

MSE WALL CALCULATIONS

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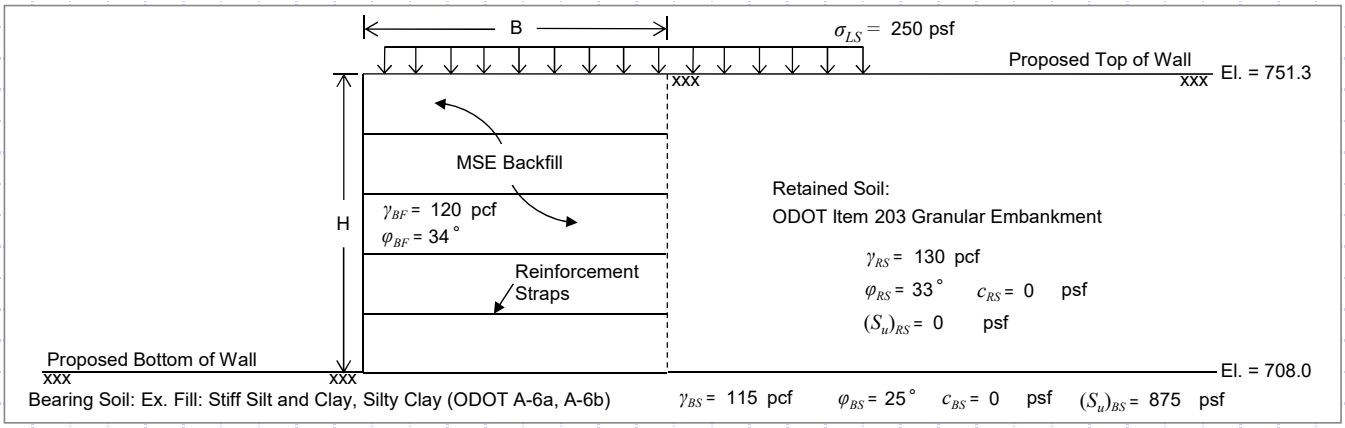
FRA-70-1373A - Rear Abutment - Wall 4W8

FRA-70-1373A - Retaining Wall 4W8 - MSE Wall - Rear Abutment - B-020-1-13 - 43.3 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	43.3	ft
MSE Wall Width (Reinforcement Length), (B) =	30.3	ft
MSE Wall Length, (L) =	56	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
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, [$(S_u)_{BS}$] =	875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

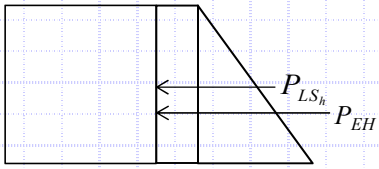
LRFD Load Factors

	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:



$$P_H = P_{EH} + P_{LS_h}$$

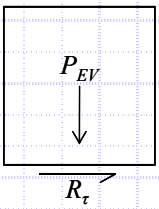
$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \text{½(130 pcf)(43.3 ft)²(0.264)(1.5)} = 48.26 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = \text{(250 psf)(43.3 ft)(0.264)(1.75)} = 5 \text{ kip/ft}$$

$$P_H = \text{48.26 kip/ft + 5 kip/ft} = 53.26 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:



$$R_\tau = P_{EV} \cdot \tan\delta$$

$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(43.3 ft)(30.3 ft)(1.00)} = 157.44 \text{ kip/ft}$$

$$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$$

$$\tan\delta = \tan(25) \le \tan(34) \longrightarrow 0.47 \le 0.67 \longrightarrow \tan\delta = 0.47$$

$$R_\tau = \text{(157.44 kip/ft)(0.47)} = 74.00 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$$P_H \le R_\tau \cdot \phi_\tau \longrightarrow \text{53.26 kip/ft} \le \text{(74.00 kip/ft)(1.0) = 74.00 kip/ft} \longrightarrow \text{53.26 kip/ft} \le \text{74.00 kip/ft}$$ **OK**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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FRA-70-1373A - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	43.3	ft
MSE Wall Width (Reinforcement Length), (B) =	30.3	ft
MSE Wall Length, (L) =	56	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
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)$_{BS}$] =	875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

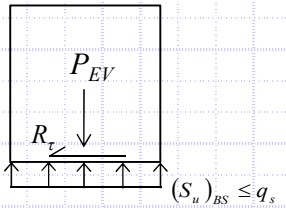
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(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: $R_\tau = \left((S_u)_{BS} \le q_s\right) \cdot B$



$(S_u)_{BS}$ = 0.88 ksf

$q_s = \sigma_v / 2$ = (5.20 ksf) / 2 = 2.60 ksf

$\sigma_v = P_{EV} / B$ = (157.44 kip/ft) / (30.3 ft) = 5.20 ksf

R_τ = (0.88 ksf ≤ 2.60 ksf)(30.3 ft) = 26.51 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 53.26 kip/ft ≤ (26.51 kip/ft)(1.0) = 26.51 kip/ft ⟶ 53.26 kip/ft ≤ 26.51 kip/ft **ERROR!!**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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FRA-70-1373A - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	43.3	ft
MSE Wall Width (Reinforcement Length), (B) =	30.3	ft
MSE Wall Length, (L) =	56	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

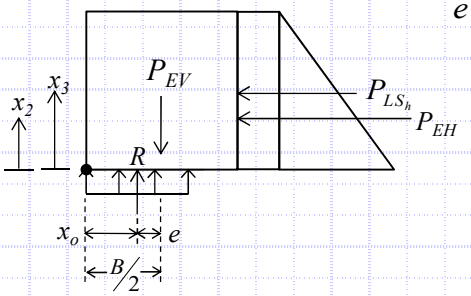
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

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



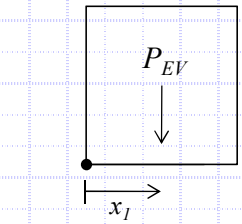
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}} = (2385.22 \text{ kip·ft/ft} - 804.64 \text{ kip·ft/ft}) / (157.44 \text{ kip/ft}) = 10.04 \text{ ft}$$

M_{EV} = 2385.22 kip·ft/ft
M_H = 804.64 kip·ft/ft
P_{EV} = 157.44 kip/ft
} Defined below

e = (30.3 ft)/2 - 10.04 ft = 5.11 ft

Resisting Moment, M_{EV}:



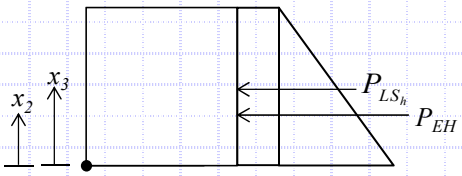
$$M_{EV} = P_{EV}(x_1)$$

$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(43.3 \text{ ft})(30.3 \text{ ft})(1.00) = 157.44 \text{ kip/ft}$$

$$x_1 = B/2 = (30.3 \text{ ft}) / 2 = 15.15 \text{ ft}$$

$$M_{EV} = (157.44 \text{ kip/ft})(15.15 \text{ ft}) = 2385.22 \text{ kip·ft/ft}$$

Overturning Moment, M_H:



$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$$

$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \tfrac{1}{2}(130 \text{ pcf})(43.3 \text{ ft})^2(0.264)(1.5) = 48.26 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf})(43.3 \text{ ft})(0.264)(1.75) = 5 \text{ kip/ft}$$

$$x_2 = H/3 = (43.3 \text{ ft}) / 3 = 14.43 \text{ ft}$$

$$x_3 = H/2 = (43.3 \text{ ft}) / 2 = 21.65 \text{ ft}$$

$$M_H = (48.26 \text{ kip/ft})(14.43 \text{ ft}) + (5 \text{ kip/ft})(21.65 \text{ ft}) = 804.64 \text{ kip·ft/ft}$$

Check Eccentricity

$e < e_{max} \longrightarrow$ 5.11 ft < 10.10 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} = (30.3 \text{ ft}) / 3 = 10.10 \text{ ft}$

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FRA-70-1373A - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	43.3	ft
MSE Wall Width (Reinforcement Length), (B) =	30.3	ft
MSE Wall Length, (L) =	56	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

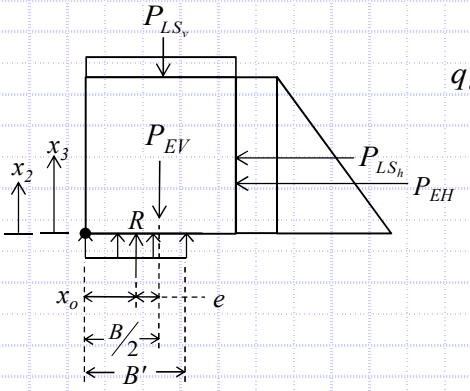
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

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



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 30.3 ft - 2(3.56 ft) = 23.18 ft

$e = B/2 - x_o$ = (30.3 ft) / 2 - 11.59 ft = 3.56 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (3420.85 kip·ft/ft - 804.66 kip·ft/ft) / 225.8 kip/ft = 11.59 ft

q_{eq} = (225.8 kip/ft) / (23.18 ft) = 9.74 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)(43.3 ft)(30.3 ft)(1.35)](15.15 ft) + [(250 psf)(30.3 ft)(1.75)](15.15 ft) = 3420.85 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(130 pcf)(43.3 ft)²(0.264)(1.5)](14.43 ft) + [(250 psf)(43.3 ft)(0.264)(1.75)](21.65 ft) = 804.66 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)(43.3 ft)(30.3 ft)(1.35) + (250 psf)(30.3 ft)(1.75) = 225.8 kip/ft

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 25.13 $\quad N_{qm} = N_q s_q d_q i_q$ = 13.39 $\quad N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 9.07

N_c = 20.72
s_c = 1+(23.18 ft/56 ft)(10.66/20.72) = 1.213
i_c = 1.000 (Assumed)

N_q = 10.66
s_q = 1.193
d_q = 1+2tan(25°)[1-sin(25°)]²tan⁻¹(4.0 ft/23.18 ft) = 1.053
i_q = 1.000 (Assumed)
C_{wq} = 0.0 ft > 4.0 ft = 0.500

N_γ = 10.88
s_γ = 0.834
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 0.0 ft < 1.5(23.18 ft) + 4.0 ft = 0.500

q_n = (0 psf)(25.133) + (115 pcf)(4.0 ft)(13.391)(0.500) + ½(115 pcf)(23.2 ft)(9.074)(0.500) = 9.13 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 9.74 ksf ≤ (9.13 ksf)(0.65) = 5.93 ksf ⟶ 9.74 ksf ≤ 5.93 ksf **ERROR!!**

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FRA-70-1373A - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	43.3	ft
MSE Wall Width (Reinforcement Length), (B) =	30.3	ft
MSE Wall Length, (L) =	56	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
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)$_{BS}$] =	875	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: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 5.570 $N_{qm} = N_q s_q d_q i_q$ = 1.000 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

N_c = 5.140
s_c = 1+(23.18 ft/[(5)(56 ft)]) = 1.083
i_c = 1.000 (Assumed)

N_q = 1.000
s_q = 1.000
d_q = $1+2\tan(0°)[1-\sin(0°)]^2\tan^{-1}(4.0\text{ ft}/23.18\text{ ft})$ = 1.000
i_q = 1.000 (Assumed)
C_{wq} = 0.0 ft > 4.0 ft = 0.500

N_γ = 0.000
s_γ = 1.000
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 0.0 ft < 1.5(23.18 ft) + 4.0 ft = 0.500

q_n = (875 psf)(5.570) + (115 pcf)(4.0 ft)(1.000)(0.500) + ½(115 pcf)(23.2 ft)(0.000)(0.500) = 5.10 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 9.74 ksf ≤ (5.10 ksf)(0.65) = 3.32 ksf ⟶ 9.74 ksf ≤ 3.32 ksf **ERROR!!**

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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FRA-70-1373A - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	43.3	ft
MSE Wall Width (Reinforcement Length), (B) =	30.3	ft
MSE Wall Length, (L) =	56	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

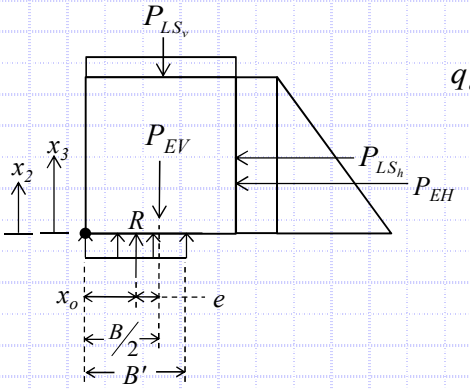
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	25	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	875	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

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



$$q_{eq} = P_V / B'$$

$$B' = B - 2e = 30.3 \text{ ft} - 2(3.19 \text{ ft}) = 23.92 \text{ ft}$$

$$e = B/2 - x_o = (30.3 \text{ ft})/2 - 11.96 \text{ ft} = 3.19 \text{ ft}$$

$$x_o = \frac{M_V - M_H}{P_V} = (2499.96 \text{ kip·ft/ft} - 526.13 \text{ kip·ft/ft}) / 165.01 \text{ kip/ft} = 11.96 \text{ ft}$$

$$q_{eq} = (165.01 \text{ kip/ft}) / (23.92 \text{ ft}) = 6.90 \text{ ksf}$$

$$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

$$M_V = [(120 \text{ pcf})(43.3 \text{ ft})(30.3 \text{ ft})(1.00)](15.2 \text{ ft}) + [(250 \text{ psf})(30.3 \text{ ft})(1.00)](15.2 \text{ ft}) = 2499.96 \text{ kip·ft/ft}$$

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

$$M_H = [\tfrac{1}{2}(130 \text{ pcf})(43.3 \text{ ft})^2(0.264)(1.00)](14.43 \text{ ft}) + [(250 \text{ psf})(43.3 \text{ ft})(0.264)(1.00)](21.65 \text{ ft}) = 526.13 \text{ kip·ft/ft}$$

$$P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$$

$$P_V = (120 \text{ pcf})(43.3 \text{ ft})(30.3 \text{ ft})(1.00) + (250 \text{ psf})(30.3 \text{ ft})(1.00) = 165.01 \text{ kip/ft}$$

Settlement (To be calculated at Stage 2 Detailed Design):

Total Settlement at Center of Reinforced Soil Mass: S_t = **15.026** in

Total Settlement at Wall Facing: S_t = **9.310** in

Time Rate of Consolidation and Downdrag Depths and Loads:

Hold Period	Degree of Consolidation	Settlement Remaining at Completion of Hold Period	Depth of Downdrag
22 days	90 %	0.942 in	

W-13-045 - FRA-70-12.68 - FRA-70-1373A

MSE Wall Settlement - Rear Abutment - Retaining Wall 4W8

Calculated By: BRT Date: 7/13/2018

Checked By: JPS Date: 7/13/2018

Boring B-020-1-13

H=	43.3	ft	Total wall height
B'=	23.9	ft	Effective footing width due to eccentricity
D_w =	0.0	ft	Depth below bottom of footing
q_e =	6,900	psf	Equivalent 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)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (psf) [1]	LL	C_c [2]	C_r [3]	e_o [4]	N_{60}	$(N1)_{60}$ [5]	C' [6]	Z_f/B	I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)	I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)
1	A-6a	C	0.0	2.5	2.5	1.3	120	300	150	72	2,072	35	0.225	0.034	0.546				0.05	1.000	6,897	6,969	0.271	3.256	0.500	3,450	3,522	0.163	1.962
	A-6a	C	2.5	5.5	3.0	4.0	120	660	480	230	2,230	35	0.225	0.034	0.546				0.17	0.986	6,803	7,034	0.282	3.389	0.499	3,443	3,674	0.159	1.911
2	A-6b	C	5.5	8.0	2.5	6.8	120	960	810	389	2,389	40	0.270	0.041	0.585				0.28	0.945	6,522	6,911	0.247	2.963	0.496	3,420	3,809	0.137	1.640
	A-6b	C	8.0	10.5	2.5	9.3	120	1,260	1,110	533	2,533	40	0.270	0.041	0.585				0.39	0.889	6,133	6,665	0.222	2.667	0.490	3,378	3,911	0.124	1.483
3	A-1-b	G	10.5	13.0	2.5	11.8	120	1,560	1,410	677	2,677					4	5	51	0.49	0.824	5,683	6,360	0.048	0.573	0.481	3,316	3,993	0.038	0.454
4	A-1-b	G	13.0	18.0	5.0	15.5	125	2,185	1,873	905	4,905					17	22	78	0.65	0.726	5,009	5,914	0.053	0.630	0.462	3,189	4,094	0.042	0.507
	A-1-b	G	18.0	23.0	5.0	20.5	125	2,810	2,498	1,218	5,218					17	20	74	0.86	0.613	4,230	5,448	0.044	0.528	0.432	2,978	4,197	0.036	0.436
5	A-1-b	G	23.0	27.0	4.0	25.0	130	3,330	3,070	1,510	5,510					42	46	153	1.05	0.532	3,668	5,178	0.014	0.168	0.402	2,773	4,283	0.012	0.142
6	A-4a	C	27.0	32.0	5.0	29.5	130	3,980	3,655	1,814	5,814	22	0.108	0.011	0.444				1.23	0.467	3,219	5,033	0.017	0.199	0.372	2,570	4,384	0.014	0.172
7	A-1-b	G	32.0	39.5	7.5	35.8	135	4,993	4,486	2,255	6,255					100	96	439	1.50	0.397	2,738	4,993	0.006	0.071	0.335	2,309	4,565	0.005	0.063
	A-1-b	G	39.5	47.0	7.5	43.3	135	6,005	5,499	2,800	6,800					100	89	387	1.81	0.335	2,312	5,112	0.005	0.061	0.295	2,039	4,839	0.005	0.055
8	A-7-6	C	47.0	53.0	6.0	50.0	130	6,785	6,395	3,275	7,275	44	0.306	0.031	0.616				2.09	0.293	2,024	5,299	0.024	0.285	0.266	1,834	5,109	0.022	0.263
	A-7-6	C	53.0	59.0	6.0	56.0	130	7,565	7,175	3,681	7,681	44	0.306	0.031	0.616				2.34	0.264	1,820	5,501	0.020	0.238	0.243	1,679	5,359	0.019	0.222
																						Total Settlement:		15.026 in			Total Settlement:		9.310 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$, Estimate σ_m of 2,000 psf in existing fill material and 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$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)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-045 - FRA-70-12.68 - FRA-70-1373A
MSE Wall Settlement - Rear Abutment - Retaining Wall 4W8

Calculated By: BRT Date: 07/13/2018
Checked By: JPS Date: 07/13/2018

Boring B-020-1-13

H=	43.3	ft	Total wall height
B'=	23.9	ft	Effective footing width due to eccentricity
D_w =	0.0	ft	Depth below bottom of footing
q_e =	6,900	psf	Equivalent bearing pressure at bottom of wall

	A-6a	A-6b	A-4a	A-7-6		
c_v =	600	300	800	150	ft^2/yr	Coefficient of consolitation
t =	22	22	22	22	days	Time following completion of construction
H_{dr} =	5.5	5	2.5	12	ft	Length of longest drainage path considered
T_v =	1.196	0.723	7.715	0.063		Time factor
U =	96	86	100	28	%	Degree of consolidation

$(S_c)_t$ = 8.368 in Settlement complete at 90% of primary consolidation

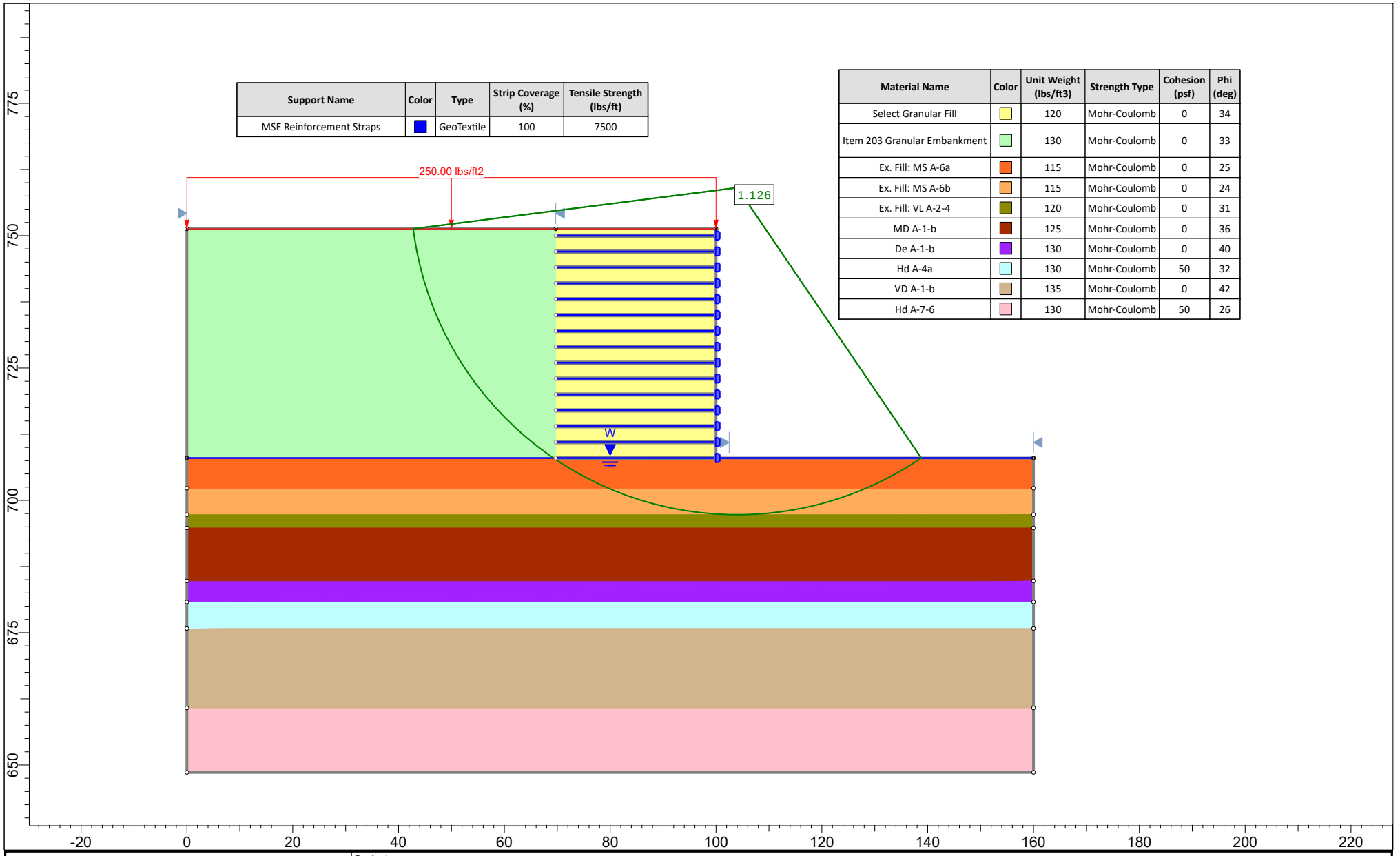
Layer	Soil Type	Soil Type	Layer Depth (ft)		Layer Thickness (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (9,10) (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: $(S_c)_t$ (11) (in)	Settlement Complete at 90% of Primary Consolidation: Layer Settlement (in)
1	A-6a	C	0.0	2.5	2.5	1.3	120	300	150	72	2,072	35	0.225	0.034	0.546				0.05	0.500	3,450	3,522	0.163	1.962	3.873	1.883	3.718
	A-6a	C	2.5	5.5	3.0	4.0	120	660	480	230	2,230	35	0.225	0.034	0.546				0.17	0.499	3,443	3,674	0.159	1.911		1.834	
2	A-6b	C	5.5	8.0	2.5	6.8	120	960	810	389	2,389	40	0.270	0.041	0.585				0.28	0.496	3,420	3,809	0.137	1.640	3.123	1.410	2.686
	A-6b	C	8.0	10.5	2.5	9.3	120	1,260	1,110	533	2,533	40	0.270	0.041	0.585				0.39	0.490	3,378	3,911	0.124	1.483		1.276	
3	A-1-b	G	10.5	13.0	2.5	11.8	120	1,560	1,410	677	2,677					4	5	51	0.49	0.481	3,316	3,993	0.038	0.454	0.454	0.454	0.454
4	A-1-b	G	13.0	18.0	5.0	15.5	125	2,185	1,873	905	4,905					17	22	78	0.65	0.462	3,189	4,094	0.042	0.507	0.943	0.507	0.943
	A-1-b	G	18.0	23.0	5.0	20.5	125	2,810	2,498	1,218	5,218					17	20	74	0.86	0.432	2,978	4,197	0.036	0.436		0.436	
5	A-1-b	G	23.0	27.0	4.0	25.0	130	3,330	3,070	1,510	5,510					42	46	153	1.05	0.402	2,773	4,283	0.012	0.142	0.142	0.142	0.142
6	A-4a	C	27.0	32.0	5.0	29.5	130	3,980	3,655	1,814	5,814	22	0.108	0.011	0.444				1.23	0.372	2,570	4,384	0.014	0.172	0.172	0.172	0.172
7	A-1-b	G	32.0	39.5	7.5	35.8	135	4,993	4,486	2,255	6,255					100	96	439	1.50	0.335	2,309	4,565	0.005	0.063	0.118	0.063	0.118
	A-1-b	G	39.5	47.0	7.5	43.3	135	6,005	5,499	2,800	6,800					100	89	387	1.81	0.295	2,039	4,839	0.005	0.055		0.055	
8	A-7-6	C	47.0	53.0	6.0	50.0	130	6,785	6,395	3,275	7,275	44	0.306	0.031	0.616				2.09	0.266	1,834	5,109	0.022	0.263	0.486	0.074	0.136
	A-7-6	C	53.0	59.0	6.0	56.0	130	7,565	7,175	3,681	7,681	44	0.306	0.031	0.616				2.34	0.243	1,679	5,359	0.019	0.222		0.062	

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 psf in existing fill material and 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$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)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

Settlement Remaining After Hold Period: 0.942 in

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		GeoTextile	100	7500

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Select Granular Fill		120	Mohr-Coulomb	0	34
Item 203 Granular Embankment		130	Mohr-Coulomb	0	33
Ex. Fill: MS A-6a		115	Mohr-Coulomb	0	25
Ex. Fill: MS A-6b		115	Mohr-Coulomb	0	24
Ex. Fill: VL A-2-4		120	Mohr-Coulomb	0	31
MD A-1-b		125	Mohr-Coulomb	0	36
De A-1-b		130	Mohr-Coulomb	0	40
Hd A-4a		130	Mohr-Coulomb	50	32
VD A-1-b		135	Mohr-Coulomb	0	42
Hd A-7-6		130	Mohr-Coulomb	50	26



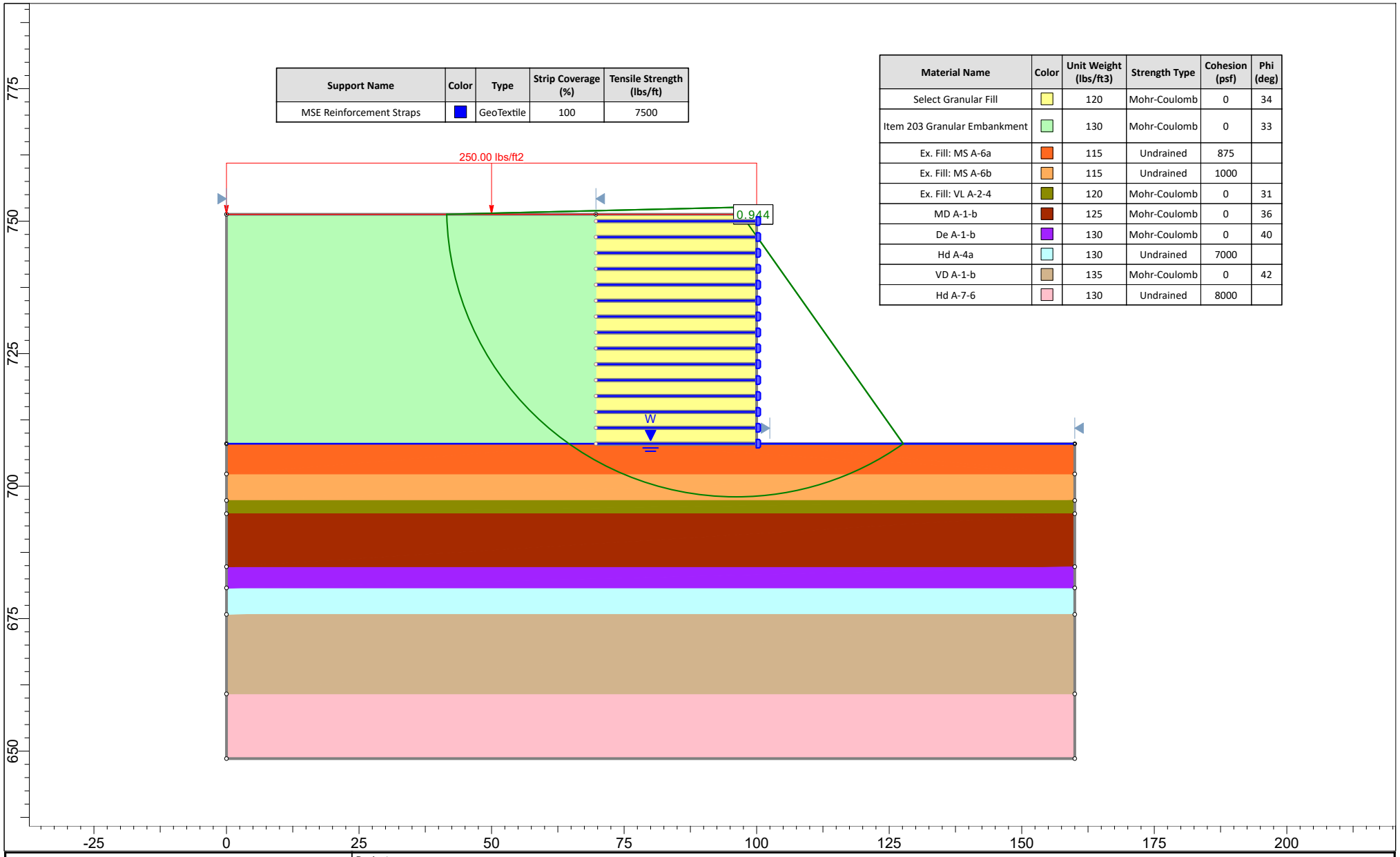
rocscience

SLIDEINTERPRET 7.020

Project	FRA-70-12.68 - FRA-70-1373A - Retaining Wall 4W8 - MSE Wall Global Stability		
Analysis Description	Rear Abutment - 43.3 ft Wall Height - Drained - Circular - Spencer		
Drawn By	BRT	Scale 1:300	Company Resource International, Inc.
Date	7/14/2018, 5:46:56 PM		File Name FRA-70-1373A - Rear Abutment - Global Stability.slim

Support Name	Color	Type	Strip Coverage (%)	Tensile Strength (lbs/ft)
MSE Reinforcement Straps		GeoTextile	100	7500

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Select Granular Fill		120	Mohr-Coulomb	0	34
Item 203 Granular Embankment		130	Mohr-Coulomb	0	33
Ex. Fill: MS A-6a		115	Undrained	875	
Ex. Fill: MS A-6b		115	Undrained	1000	
Ex. Fill: VL A-2-4		120	Mohr-Coulomb	0	31
MD A-1-b		125	Mohr-Coulomb	0	36
De A-1-b		130	Mohr-Coulomb	0	40
Hd A-4a		130	Undrained	7000	
VD A-1-b		135	Mohr-Coulomb	0	42
Hd A-7-6		130	Undrained	8000	



SLIDEINTERPRET 7.020

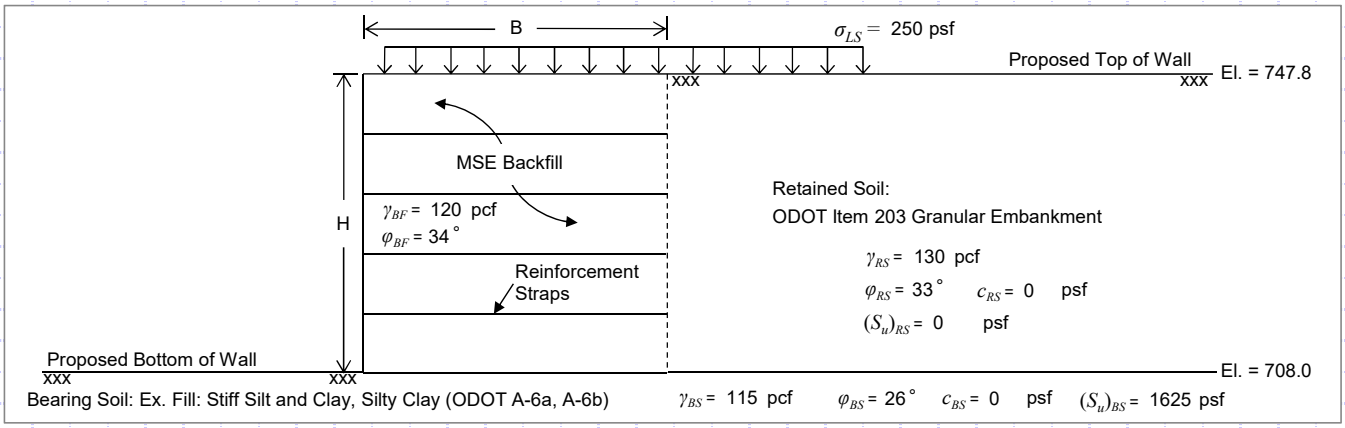
Project	FRA-70-12.68 - FRA-70-1373A - Retaining Wall 4W8 - MSE Wall Global Stability		
Analysis Description	Rear Abutment - 43.3 ft Wall Height - Undrained - Circular - Spencer		
Drawn By	BRT	*Scale* 1:300	*Company* Resource International, Inc.
Date	7/14/2018, 5:46:56 PM		*File Name* FRA-70-1373A - Rear Abutment - Global Stability.slim

RESOURCE INTERNATIONAL, INC.
6350 PRESIDENTIAL GATEWAY
COLUMBUS, OHIO 43231
PHONE: (614) 823-4949
FAX: (614) 823-4990
WWW.RESOURCEINTERATIONAL.COM

JOB	FRA-70-12.68	NO.	W-13-045
SHEET NO.	1	OF	6
CALCULATED BY	BRT	DATE	7/7/2018
CHECKED BY	JPS	DATE	7/9/2018

FRA-70-1373R - Rear Abutment - Wall 4W8

FRA-70-1373R - Retaining Wall 4W8 - MSE Wall - Rear Abutment - B-020-2-13 - 39.8 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	39.8	ft
MSE Wall Width (Reinforcement Length), (B) =	27.9	ft
MSE Wall Length, (L) =	102	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
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}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(S_u)_{BS}$] =	1625	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

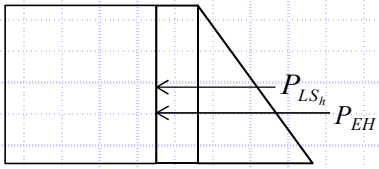
LRFD Load Factors

	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:



$$P_H = P_{EH} + P_{LS_h}$$

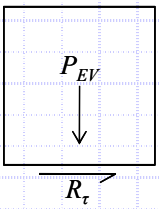
$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(130 pcf)(39.8 ft)²(0.264)(1.5) = 40.77 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (250 psf)(39.8 ft)(0.264)(1.75) = 4.6 kip/ft

P_H = 40.77 kip/ft + 4.6 kip/ft = 45.37 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)(39.8 ft)(27.9 ft)(1.00) = 133.25 kip/ft

$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF})$

$\tan\delta$ = tan(26) ≤ tan(34) ⟶ 0.49 ≤ 0.67 ⟶ $\tan\delta$ = 0.49

R_τ = (133.25 kip/ft)(0.49) = 65.29 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 45.37 kip/ft ≤ (65.29 kip/ft)(1.0) = 65.29 kip/ft ⟶ 45.37 kip/ft ≤ 65.29 kip/ft **OK**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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JOB	FRA-70-12.68	NO.	W-13-045
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FRA-70-1373R - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	39.8	ft
MSE Wall Width (Reinforcement Length), (B) =	27.9	ft
MSE Wall Length, (L) =	102	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
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}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	1625	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

LRFD Load Factors

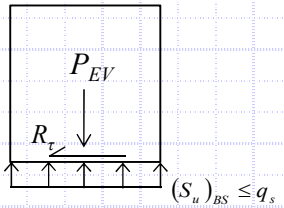
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(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: $R_\tau = \left((S_u)_{BS} \le q_s\right) \cdot B$



$(S_u)_{BS}$ = 1.63 ksf

$q_s = \sigma_v / 2$ = (4.78 ksf) / 2 = 2.39 ksf

$\sigma_v = P_{EV} / B$ = (133.25 kip/ft) / (27.9 ft) = 4.78 ksf

R_τ = (1.63 ksf ≤ 2.39 ksf)(27.9 ft) = 45.34 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 45.37 kip/ft ≤ (45.34 kip/ft)(1.0) = 45.34 kip/ft ⟶ 45.37 kip/ft ≤ 45.34 kip/ft **ERROR!!**

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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FRA-70-1373R - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	39.8	ft
MSE Wall Width (Reinforcement Length), (B) =	27.9	ft
MSE Wall Length, (L) =	102	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

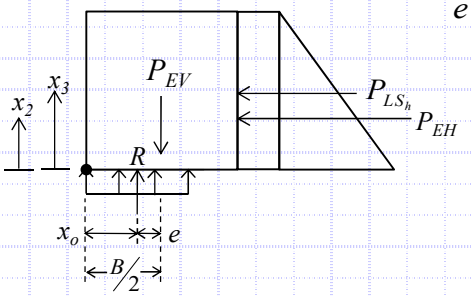
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	1625	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

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



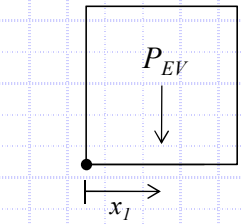
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}} = (1858.84 \text{ kip·ft/ft} - 632.56 \text{ kip·ft/ft}) / (133.25 \text{ kip/ft}) = 9.20 \text{ ft}$$

M_{EV} = 1858.84 kip·ft/ft
M_H = 632.56 kip·ft/ft
P_{EV} = 133.25 kip/ft
} Defined below

$e =$ (27.9 ft)/2 - 9.2 ft = 4.75 ft

Resisting Moment, M_{EV}:



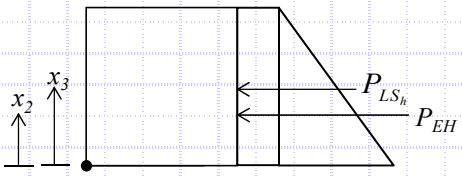
$$M_{EV} = P_{EV}(x_1)$$

$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(39.8 \text{ ft})(27.9 \text{ ft})(1.00) = 133.25 \text{ kip/ft}$$

$$x_1 = B/2 = (27.9 \text{ ft}) / 2 = 13.95 \text{ ft}$$

$$M_{EV} = (133.25 \text{ kip/ft})(13.95 \text{ ft}) = 1858.84 \text{ kip·ft/ft}$$

Overturning Moment, M_H:



$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$$

$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \tfrac{1}{2}(130 \text{ pcf})(39.8 \text{ ft})^2(0.264)(1.5) = 40.77 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf})(39.8 \text{ ft})(0.264)(1.75) = 4.6 \text{ kip/ft}$$

$$x_2 = H/3 = (39.8 \text{ ft}) / 3 = 13.27 \text{ ft}$$

$$x_3 = H/2 = (39.8 \text{ ft}) / 2 = 19.90 \text{ ft}$$

$$M_H = (40.77 \text{ kip/ft})(13.27 \text{ ft}) + (4.6 \text{ kip/ft})(19.90 \text{ ft}) = 632.56 \text{ kip·ft/ft}$$

Check Eccentricity

$e < e_{max} \longrightarrow$ 4.75 ft < 9.30 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} = (27.9 \text{ ft}) / 3 = 9.30 \text{ ft}$

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FRA-70-1373R - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	39.8	ft
MSE Wall Width (Reinforcement Length), (B) =	27.9	ft
MSE Wall Length, (L) =	102	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

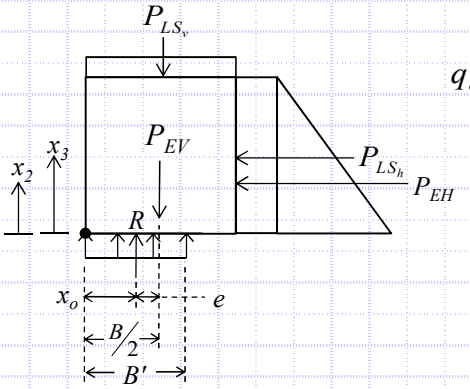
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	1625	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

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



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 27.9 ft - 2(3.29 ft) = 21.32 ft

$e = B/2 - x_o$ = (27.9 ft) / 2 - 10.66 ft = 3.29 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (2679.72 kip·ft/ft - 632.54 kip·ft/ft) / 192.09 kip/ft = 10.66 ft

q_{eq} = (192.09 kip/ft) / (21.32 ft) = 9.01 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)(39.8 ft)(27.9 ft)(1.35)](13.95 ft) + [(250 psf)(27.9 ft)(1.75)](13.95 ft) = 2679.72 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(130 pcf)(39.8 ft)²(0.264)(1.5)](13.27 ft) + [(250 psf)(39.8 ft)(0.264)(1.75)](19.9 ft) = 632.54 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)(39.8 ft)(27.9 ft)(1.35) + (250 psf)(27.9 ft)(1.75) = 192.09 kip/ft

Check Bearing Resistance - Drained Condition

Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 24.72 $\quad N_{qm} = N_q s_q d_q i_q$ = 13.80 $\quad N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 11.49

N_c = 22.25
s_c = 1+(21.32 ft/102 ft)(11.85/22.25) = 1.111
i_c = 1.000 (Assumed)

N_q = 11.85
s_q = 1.102
d_q = 1+2tan(26°)[1-sin(26°)]²tan⁻¹(4.0 ft/21.32 ft) = 1.057
i_q = 1.000 (Assumed)
C_{wq} = 0.0 ft > 4.0 ft = 0.500

N_γ = 12.54
s_γ = 0.916
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 0.0 ft < 1.5(21.32 ft) + 4.0 ft = 0.500

q_n = (0 psf)(24.720) + (115 pcf)(4.0 ft)(13.803)(0.500) + ½(115 pcf)(21.3 ft)(11.487)(0.500) = 10.22 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 9.01 ksf ≤ (10.22 ksf)(0.65) = 6.64 ksf ⟶ 9.01 ksf ≤ 6.64 ksf **ERROR!!**

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JOB	FRA-70-12.68	NO.	W-13-045
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CHECKED BY	JPS	DATE	7/9/2018

FRA-70-1373R - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	39.8	ft
MSE Wall Width (Reinforcement Length), (B) =	27.9	ft
MSE Wall Length, (L) =	102	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
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}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	1625	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: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 5.360 $N_{qm} = N_q s_q d_q i_q$ = 1.000 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

N_c = 5.140
s_c = 1+(21.32 ft/[(5)(102 ft)]) = 1.042
i_c = 1.000 (Assumed)

N_q = 1.000
s_q = 1.000
d_q = 1+2tan(0°)[1-sin(0°)]^{2}tan^{-1}(4.0 ft/21.32 ft) = 1.000
i_q = 1.000 (Assumed)
C_{wq} = 0.0 ft > 4.0 ft = 0.500

N_γ = 0.000
s_γ = 1.000
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 0.0 ft < 1.5(21.32 ft) + 4.0 ft = 0.500

q_n = (1625 psf)(5.360) + (115 pcf)(4.0 ft)(1.000)(0.500) + ½(115 pcf)(21.3 ft)(0.000)(0.500) = 8.94 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 9.01 ksf ≤ (8.94 ksf)(0.65) = 5.81 ksf ⟶ 9.01 ksf ≤ 5.81 ksf **ERROR!!**

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.7-1)*

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FRA-70-1373R - Rear Abutment - Wall 4W8

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	39.8	ft
MSE Wall Width (Reinforcement Length), (B) =	27.9	ft
MSE Wall Length, (L) =	102	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	130	pcf
Retained Soil Friction Angle, (φ_{RS}) =	33	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	0	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.264	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

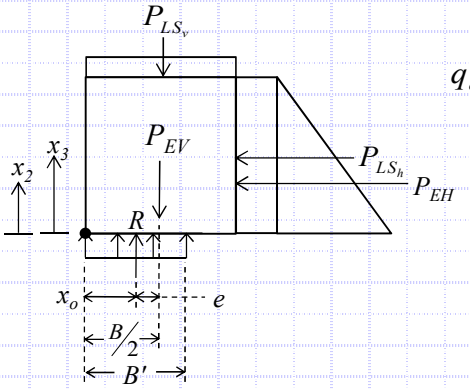
Bearing Soil Unit Weight, (γ_{BS}) =	115	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	1625	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	0.0	ft

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



$$q_{eq} = P_V / B'$$

$B' = B - 2e$ = 27.9 ft - 2(2.95 ft) = 22.00 ft

$e = B/2 - x_o$ = (27.9 ft) / 2 - 11 ft = 2.95 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (1956.14 kip·ft/ft - 412.98 kip·ft/ft) / 140.23 kip/ft = 11 ft

q_{eq} = (140.23 kip/ft) / (22 ft) = 6.37 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)(39.8 ft)(27.9 ft)(1.00)](14.0 ft) + [(250 psf)(27.9 ft)(1.00)](14.0 ft) = 1956.14 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(130 pcf)(39.8 ft)²(0.264)(1.00)](13.27 ft) + [(250 psf)(39.8 ft)(0.264)(1.00)](19.9 ft) = 412.98 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)(39.8 ft)(27.9 ft)(1.00) + (250 psf)(27.9 ft)(1.00) = 140.23 kip/ft

Settlement (To be calculated at Stage 2 Detailed Design):

Total Settlement at Center of Reinforced Soil Mass: S_t = **15.253** in

Total Settlement at Wall Facing: S_t = **9.178** in

Time Rate of Consolidation and Downdrag Depths and Loads:

Hold Period	Degree of Consolidation	Settlement Remaining at Completion of Hold Period	Depth of Downdrag
55 days	90 %	0.893 in	

W-13-045 - FRA-70-12.68 - FRA-70-1373R

MSE Wall Settlement - Rear Abutment - Retaining Wall 4W8

Calculated By: BRT Date: 7/13/2018

Checked By: JPS Date: 7/13/2018

Boring B-020-2-13

H=	39.8	ft	Total wall height
B'=	22.0	ft	Effective footing width due to eccentricity
D_w =	0.0	ft	Depth below bottom of footing
q_e =	6,370	psf	Equivalent 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)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)
1	A-1-b	G	0.0	2.0	2.0	1.0	120	240	120	58	2,058					4	8	54	0.05	1.000	6,368	6,426	0.076	0.910	0.500	3,185	3,242	0.065	0.778
2	A-6a	C	2.0	4.5	2.5	3.3	115	528	384	181	2,181	35	0.225	0.034	0.546				0.15	0.990	6,307	6,488	0.231	2.776	0.499	3,181	3,362	0.127	1.529
3	A-6b	C	4.5	7.0	2.5	5.8	115	815	671	312	2,312	39	0.261	0.039	0.577				0.26	0.955	6,082	6,394	0.237	2.841	0.497	3,163	3,475	0.127	1.526
	A-6b	C	7.0	9.5	2.5	8.3	115	1,103	959	444	2,444	39	0.261	0.039	0.577				0.38	0.896	5,707	6,151	0.212	2.542	0.490	3,124	3,568	0.114	1.368
4	A-7-6	C	9.5	12.0	2.5	10.8	115	1,390	1,246	575	2,575	41	0.279	0.042	0.593				0.49	0.826	5,259	5,834	0.198	2.379	0.481	3,063	3,639	0.108	1.302
	A-7-6	C	12.0	14.5	2.5	13.3	115	1,678	1,534	707	2,707	41	0.279	0.042	0.593				0.60	0.754	4,803	5,510	0.173	2.082	0.468	2,982	3,689	0.097	1.166
5	A-2-4	G	14.5	17.0	2.5	15.8	120	1,978	1,828	845	2,845					8	10	57	0.72	0.687	4,376	5,221	0.035	0.416	0.453	2,885	3,730	0.028	0.339
6	A-1-b	G	17.0	24.5	7.5	20.8	130	2,953	2,465	1,170	5,170					34	40	131	0.94	0.574	3,655	4,825	0.035	0.422	0.418	2,664	3,834	0.029	0.354
7	A-1-b	G	24.5	32.5	8.0	28.5	135	4,033	3,493	1,714	5,714					91	96	437	1.30	0.448	2,856	4,570	0.008	0.094	0.363	2,314	4,028	0.007	0.081
	A-1-b	G	32.5	41.0	8.5	36.8	135	5,180	4,606	2,313	6,313					91	87	372	1.67	0.360	2,293	4,606	0.007	0.082	0.312	1,987	4,300	0.006	0.074
8	A-6b	C	41.0	47.0	6.0	44.0	130	5,960	5,570	2,824	6,824	38	0.252	0.025	0.569				2.00	0.306	1,948	4,772	0.022	0.263	0.275	1,751	4,576	0.020	0.242
	A-6b	C	47.0	53.0	6.0	50.0	130	6,740	6,350	3,230	7,230	38	0.252	0.025	0.569				2.27	0.271	1,729	4,959	0.018	0.215	0.249	1,588	4,818	0.017	0.201
	A-6b	C	53.0	61.0	8.0	57.0	130	7,780	7,260	3,703	7,703	38	0.252	0.025	0.569				2.59	0.240	1,528	5,231	0.019	0.231	0.224	1,428	5,131	0.018	0.218
																					Total Settlement:		15.253 in			Total Settlement:		9.178 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 psf in existing fill material and 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
2. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
3. 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
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$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)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-045 - FRA-70-12.68 - FRA-70-1373R
MSE Wall Settlement - Rear Abutment - Retaining Wall 4W8

Calculated By: BRT Date: 07/13/2018
Checked By: JPS Date: 07/13/2018

Boring B-020-2-13

H=	39.8	ft	Total wall height
B'=	22.0	ft	Effective footing width due to eccentricity
D_w =	0.0	ft	Depth below bottom of footing
q_e =	6,370	psf	Equivalent bearing pressure at bottom of wall

	A-6a	A-6b (Upper)	A-7-6	A-6b (Lower)		
c_v =	600	300	150	300	ft^2/yr	Coefficient of consolitation
t =	55	55	55	55	days	Time following completion of construction
H_{dr} =	2.5	5	5	20	ft	Length of longest drainage path considered
T_v =	14.466	1.808	0.904	0.113		Time factor
U =	100	99	91	38	%	Degree of consolidation

$(S_c)_t$ = 8.285 in Settlement complete at 90% of primary consolidation

Layer	Soil Type	Soil Type	Layer Depth (ft)		Layer Thickness (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall: S_c (9,10) (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: $(S_c)_t$ (11) (in)	Settlement Complete at 90% of Primary Consolidation: Layer Settlement (in)
1	A-1-b	G	0.0	2.0	2.0	1.0	120	240	120	58	2,058					4	8	54	0.05	0.500	3,185	3,242	0.065	0.778	0.778	0.778	0.778
2	A-6a	C	2.0	4.5	2.5	3.3	115	528	384	181	2,181	35	0.225	0.034	0.546				0.15	0.499	3,181	3,362	0.127	1.529	1.529	1.529	
3	A-6b	C	4.5	7.0	2.5	5.8	115	815	671	312	2,312	39	0.261	0.039	0.577				0.26	0.497	3,163	3,475	0.127	1.526	2.894	1.388	4.162
	A-6b	C	7.0	9.5	2.5	8.3	115	1,103	959	444	2,444	39	0.261	0.039	0.577				0.38	0.490	3,124	3,568	0.114	1.368		1.245	
4	A-7-6	C	9.5	12.0	2.5	10.8	115	1,390	1,246	575	2,575	41	0.279	0.042	0.593				0.49	0.481	3,063	3,639	0.108	1.302	2.468	1.185	1.185
	A-7-6	C	12.0	14.5	2.5	13.3	115	1,678	1,534	707	2,707	41	0.279	0.042	0.593				0.60	0.468	2,982	3,689	0.097	1.166		1.061	1.061
5	A-2-4	G	14.5	17.0	2.5	15.8	120	1,978	1,828	845	2,845					8	10	57	0.72	0.453	2,885	3,730	0.028	0.339	0.339	0.339	0.693
6	A-1-b	G	17.0	24.5	7.5	20.8	130	2,953	2,465	1,170	5,170					34	40	131	0.94	0.418	2,664	3,834	0.029	0.354	0.354	0.354	
7	A-1-b	G	24.5	32.5	8.0	28.5	135	4,033	3,493	1,714	5,714					91	96	437	1.30	0.363	2,314	4,028	0.007	0.081	0.155	0.081	0.155
	A-1-b	G	32.5	41.0	8.5	36.8	135	5,180	4,606	2,313	6,313					91	87	372	1.67	0.312	1,987	4,300	0.006	0.074		0.074	
8	A-6b	C	41.0	47.0	6.0	44.0	130	5,960	5,570	2,824	6,824	38	0.252	0.025	0.569				2.00	0.275	1,751	4,576	0.020	0.242	0.661	0.092	0.168
	A-6b	C	47.0	53.0	6.0	50.0	130	6,740	6,350	3,230	7,230	38	0.252	0.025	0.569				2.27	0.249	1,588	4,818	0.017	0.201		0.076	
	A-6b	C	53.0	61.0	8.0	57.0	130	7,780	7,260	3,703	7,703	38	0.252	0.025	0.569				2.59	0.224	1,428	5,131	0.018	0.218		0.083	0.083

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 psf in existing fill material and 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$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)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

Settlement Remaining After Hold Period: 0.893 in

APPENDIX IX

CELLULAR CONCRETE WALL CALCULATIONS

W-13-045 - FRA-70-12.68 - FRA-70-1373A and R

MSE Wall with Cellular Concrete Backfill - Forward Abutment - Wall 4W5

Boring	Boring Elevation	Top of Wall / Profile Elevation (ft msl)	Bottom of Wall / Embankment Elevation (ft msl)	Wall / Embankment Height (ft)	Pressure at Bottom of Wall / Embankment [1] (psf)	Total Settlement at Center of Wall / Embankment (in)	Total Settlement at Wall Facing (in)
B-020-7-13	713.5	746.6	709.5	37.1	1,485	3.68	2.69
B-001-A-59	735.5	746.6	709.5	37.1	1,485	3.50	2.55
B-020-9-15	732.4	754.6	710.8	43.8	1,686	3.14	2.33

1. $\Delta\sigma$ = (130 pcf)(3.0 ft) + (36 pcf)(2.0 ft) + (H - 5 ft)(30 pcf)

W-13-045 - FRA-70-12.68 - FRA-70-1373R

MSE Wall with Cellular Concrete Backfill Settlement - Forward Abutment - Wall 4W5

Calculated By: BRT Date: 7/14/2018

Checked By: JPS Date: 7/15/2018

Boring B-020-7-13

H =	37.1	ft	Total wall/embankment height from profile grade to top of leveling pad
B =	26.0	ft	Wall/embankment width considered in analysis, equal to 70% of the wall height
D_w =	0.0	ft	Depth below bottom of wall/embankment
q =	1,485	psf	Bearing pressure at bottom of wall/embankment (see summary sheet)

																			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)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' [1] (psf)	LL	C_c [2]	C_r [3]	e_o [4]	N_{60}	$(N1)_{60}$ [5]	C' [6]	Z_f/B	I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)	I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)
1	A-2-4	G	0.0	3.0	3.0	1.5	120	360	180	86	2,086					6	12	60	0.06	0.999	1,484	1,570	0.063	0.761	0.500	742	829	0.049	0.593
2	A-7-6	C	3.0	5.0	2.0	4.0	115	590	475	225	2,225	43	0.297	0.045	0.608				0.15	0.989	1,469	1,694	0.049	0.582	0.499	741	967	0.035	0.420
	A-7-6	C	5.0	7.0	2.0	6.0	115	820	705	331	2,331	43	0.297	0.045	0.608				0.23	0.967	1,436	1,767	0.040	0.484	0.498	739	1,069	0.028	0.339
	A-7-6	C	7.0	9.0	2.0	8.0	115	1,050	935	436	2,436	43	0.297	0.045	0.608				0.31	0.933	1,385	1,821	0.034	0.413	0.494	734	1,170	0.024	0.285
3	A-6b	C	9.0	11.5	2.5	10.3	115	1,338	1,194	554	2,554	38	0.252	0.038	0.569				0.39	0.884	1,313	1,868	0.032	0.381	0.489	726	1,280	0.022	0.263
	A-6b	C	11.5	14.0	2.5	12.8	115	1,625	1,481	686	2,686	38	0.252	0.038	0.569				0.49	0.824	1,224	1,910	0.027	0.322	0.481	714	1,400	0.019	0.224
4	A-7-6	C	14.0	16.5	2.5	15.3	115	1,913	1,769	817	2,817	43	0.297	0.045	0.608				0.59	0.764	1,134	1,951	0.026	0.314	0.470	698	1,515	0.019	0.223
5	A-1-a	G	16.5	23.0	6.5	19.8	135	2,790	2,351	1,119	5,119					48	57	203	0.76	0.663	985	2,103	0.009	0.106	0.447	663	1,782	0.006	0.078
6	A-1-b	G	23.0	30.0	7.0	26.5	130	3,700	3,245	1,591	5,591					33	36	116	1.02	0.542	805	2,396	0.011	0.129	0.406	603	2,194	0.008	0.101
7	A-1-b	G	30.0	38.0	8.0	34.0	135	4,780	4,240	2,118	6,118					68	67	250	1.31	0.445	661	2,779	0.004	0.045	0.361	537	2,655	0.003	0.038
8	A-6a	C	38.0	43.0	5.0	40.5	125	5,405	5,093	2,565	6,565	27	0.153	0.015	0.483				1.56	0.383	569	3,134	0.004	0.054	0.326	485	3,050	0.004	0.047
9	A-1-a	G	43.0	50.0	7.0	46.5	135	6,350	5,878	2,976	6,976					89	77	311	1.79	0.339	503	3,479	0.002	0.018	0.298	442	3,418	0.001	0.016
10	A-6a	C	50.0	55.0	5.0	52.5	130	7,000	6,675	3,399	7,399	27	0.153	0.015	0.483				2.02	0.303	450	3,849	0.003	0.033	0.273	405	3,804	0.003	0.030
	A-6a	C	55.0	61.5	6.5	58.3	130	7,845	7,423	3,788	7,788	27	0.153	0.015	0.483				2.24	0.275	409	4,196	0.003	0.036	0.252	374	4,162	0.003	0.033
																						Total Settlement:	3.678 in				Total Settlement:	2.690 in	

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 psf in existing fill material and 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$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)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-045 - FRA-70-12.68 - FRA-70-1373R

MSE Wall with Cellular Concrete Backfill Settlement - Forward Abutment - Wall 4W5

Calculated By: BRT Date: 7/14/2018

Checked By: JPS Date: 7/15/2018

Boring B-020-7-13

H =	37.1	ft	Total wall/embankment height from profile grade to top of leveling pad
B =	26.0	ft	Wall/embankment width considered in analysis, equal to 70% of the wall height
D_w =	0.0	ft	Depth below bottom of wall/embankment
q =	1,485	psf	Bearing pressure at bottom of wall/embankment (see summary sheet)

	A-7-6	A-6b	A-6a (Upper)	A-6a (Lower)		
c_v =	150	300	600	600	ft^2/yr	Coefficient of consolitation
t =	55	55	55	55	days	Time following completion of construction
H_{dr} =	7	7	2.5	11.5	ft	Length of longest drainage path considered
T_v =	0.461	0.923	14.466	0.684		Time factor
U =	74	92	100	85	%	Degree of consolidation

$(S_c)_t$ = 2.312 in Settlement complete at 86% of primary consolidation

Layer	Soil Type	Soil Type	Layer Depth (ft)		Layer Thickness (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	Total Settlement at Facing of Wall			Settlement Complete at 86% of Primary Consolidation	
																							S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-2-4	G	0.0	3.0	3.0	1.5	120	360	180	86	2,086					6	12	60	0.06	0.500	742	829	0.049	0.593	0.593	0.593	0.593
2	A-7-6	C	3.0	5.0	2.0	4.0	115	590	475	225	2,225	43	0.297	0.045	0.608				0.15	0.499	741	967	0.035	0.420	1.045	0.311	0.773
	A-7-6	C	5.0	7.0	2.0	6.0	115	820	705	331	2,331	43	0.297	0.045	0.608				0.23	0.498	739	1,069	0.028	0.339		0.251	
	A-7-6	C	7.0	9.0	2.0	8.0	115	1,050	935	436	2,436	43	0.297	0.045	0.608				0.31	0.494	734	1,170	0.024	0.285		0.211	
3	A-6b	C	9.0	11.5	2.5	10.3	115	1,338	1,194	554	2,554	38	0.252	0.038	0.569				0.39	0.489	726	1,280	0.022	0.263	0.487	0.242	0.448
	A-6b	C	11.5	14.0	2.5	12.8	115	1,625	1,481	686	4,686	38	0.252	0.038	0.569				0.49	0.481	714	1,400	0.019	0.224		0.206	
4	A-7-6	C	14.0	16.5	2.5	15.3	115	1,913	1,769	817	4,817	43	0.297	0.045	0.608				0.59	0.470	698	1,515	0.019	0.223	0.223	0.165	0.165
5	A-1-a	G	16.5	23.0	6.5	19.8	135	2,790	2,351	1,119	5,119					48	57	203	0.76	0.447	663	1,782	0.006	0.078	0.078	0.078	0.078
6	A-1-b	G	23.0	30.0	7.0	26.5	130	3,700	3,245	1,591	5,591					33	36	116	1.02	0.406	603	2,194	0.008	0.101	0.101	0.101	0.101
7	A-1-b	G	30.0	38.0	8.0	34.0	135	4,780	4,240	2,118	6,118					68	67	250	1.31	0.361	537	2,655	0.003	0.038	0.038	0.038	0.038
8	A-6a	C	38.0	43.0	5.0	40.5	125	5,405	5,093	2,565	6,565	27	0.153	0.015	0.483				1.56	0.326	485	3,050	0.004	0.047	0.047	0.047	0.047
9	A-1-a	G	43.0	50.0	7.0	46.5	135	6,350	5,878	2,976	6,976					89	77	311	1.79	0.298	442	3,418	0.001	0.016	0.016	0.016	0.016
10	A-6a	C	50.0	55.0	5.0	52.5	130	7,000	6,675	3,399	7,399	27	0.153	0.015	0.483				2.02	0.273	405	3,804	0.003	0.030	0.063	0.026	0.054
	A-6a	C	55.0	61.5	6.5	58.3	130	7,845	7,423	3,788	7,788	27	0.153	0.015	0.483				2.24	0.252	374	4,162	0.003	0.033		0.028	

1. $\sigma_p' = \sigma_{vo}'+\sigma_{m;}$ Estimate σ_m of 2,000 psf in existing fill material and 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
2. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
3. 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
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_nN_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$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)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

Settlement Remaining After Hold Period: 0.378 in

W-13-045 - FRA-70-12.68 - FRA-70-1373R

MSE Wall with Cellular Concrete Backfill Settlement - Forward Abutment - Wall 4W5

Calculated By: BRT Date: 7/14/2018

Checked By: JPS Date: 7/15/2018

Boring B-020-7-13

H =	37.1	ft	Total wall/embankment height from profile grade to top of leveling pad
B =	26.0	ft	Wall/embankment width considered in analysis, equal to 70% of the wall height
D_w =	0.0	ft	Depth below bottom of wall/embankment
q =	1,485	psf	Bearing pressure at bottom of wall/embankment (see summary sheet)

																			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)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' [1] (psf)	LL	C_c [2]	C_r [3]	e_o [4]	N_{60}	$(N1)_{60}$ [5]	C' [6]	Z_f/B	I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)	I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)
1	A-1-b	G	0.0	2.5	2.5	1.3	120	300	150	72	2,072					5	10	57	0.05	1.000	1,484	1,556	0.059	0.707	0.500	742	814	0.046	0.558
2	A-4a	G	2.5	5.0	2.5	3.8	115	588	444	210	2,210					9	16	34	0.14	0.991	1,471	1,681	0.067	0.808	0.499	742	951	0.049	0.587
	A-4a	G	5.0	7.5	2.5	6.3	115	875	731	341	2,341					9	14	31	0.24	0.963	1,431	1,772	0.057	0.684	0.497	738	1,080	0.040	0.479
	A-4a	G	7.5	10.0	2.5	8.8	115	1,163	1,019	473	2,473					9	13	30	0.34	0.918	1,363	1,836	0.049	0.591	0.493	732	1,205	0.034	0.408
3	A-2-4	G	10.0	12.5	2.5	11.3	120	1,463	1,313	611	2,611					13	18	71	0.43	0.861	1,278	1,889	0.017	0.209	0.486	722	1,332	0.012	0.144
4	A-1-a	G	12.5	18.0	5.5	15.3	125	2,150	1,806	855	4,855					25	32	105	0.59	0.764	1,134	1,989	0.019	0.230	0.470	698	1,553	0.014	0.163
	A-1-a	G	18.0	23.5	5.5	20.8	125	2,838	2,494	1,199	5,199					25	29	97	0.80	0.643	954	2,153	0.014	0.173	0.441	655	1,854	0.011	0.129
5	A-1-b	G	23.5	28.5	5.0	26.0	135	3,513	3,175	1,553	5,553					94	102	485	1.00	0.550	816	2,369	0.002	0.023	0.409	608	2,160	0.001	0.018
	A-1-b	G	28.5	33.5	5.0	31.0	135	4,188	3,850	1,916	5,916					94	96	435	1.19	0.480	713	2,628	0.002	0.019	0.379	563	2,478	0.001	0.015
	A-1-b	G	33.5	38.5	5.0	36.0	135	4,863	4,525	2,279	6,279					94	90	395	1.38	0.424	630	2,908	0.001	0.016	0.350	520	2,799	0.001	0.014
	A-1-b	G	38.5	43.5	5.0	41.0	135	5,538	5,200	2,642	6,642					94	85	363	1.58	0.379	563	3,204	0.001	0.014	0.324	481	3,123	0.001	0.012
6	A-4a	G	43.5	46.5	3.0	45.0	135	5,943	5,740	2,932	6,932					71	62	103	1.73	0.349	518	3,450	0.002	0.025	0.305	452	3,384	0.002	0.022
																						Total Settlement:		3.499 in			Total Settlement:		2.548 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 psf in existing fill material and 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$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)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-045 - FRA-70-12.68 - FRA-70-1373A

MSE Wall with Cellular Concrete Backfill Settlement - Forward Abutment - Wall 4W5

Calculated By: BRT Date: 7/14/2018

Checked By: JPS Date: 7/15/2018

Boring B-020-9-15

H =	43.8	ft	Total wall/embankment height from profile grade to top of leveling pad
B =	30.7	ft	Wall/embankment width considered in analysis, equal to 70% of the wall height
D_w =	0.0	ft	Depth below bottom of wall/embankment
q =	1,686	psf	Bearing pressure at bottom of wall/embankment (see summary sheet)

																			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)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' [1] (psf)	LL	C_c [2]	C_r [3]	e_o [4]	N_{60}	$(N1)_{60}$ [5]	C' [6]	Z_f/B	I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)	I [7]	$\Delta\sigma_v$ [8] (psf)	σ_{vf}' Midpoint (psf)	S_c [9,10] (ft)	S_c (in)
1	A-6a	C	0.0	3.5	3.5	1.8	115	403	201	92	2,092	35	0.225	0.034	0.546				0.06	0.999	1,685	1,777	0.098	1.179	0.500	843	935	0.077	0.923
2	A-6b	C	3.5	6.0	2.5	4.8	115	690	546	250	2,250	34	0.216	0.032	0.538				0.15	0.989	1,667	1,917	0.047	0.559	0.499	842	1,092	0.034	0.405
	A-6b	C	6.0	8.5	2.5	7.3	115	978	834	381	2,381	34	0.216	0.032	0.538				0.24	0.965	1,627	2,008	0.038	0.456	0.497	839	1,220	0.027	0.319
3	A-4a	G	8.5	11.0	2.5	9.8	130	1,303	1,140	532	4,532					37	53	90	0.32	0.928	1,564	2,096	0.017	0.199	0.494	833	1,364	0.011	0.137
	A-4a	G	11.0	13.5	2.5	12.3	130	1,628	1,465	701	4,701					37	50	85	0.40	0.882	1,486	2,187	0.015	0.175	0.489	824	1,525	0.010	0.120
	A-4a	G	13.5	16.0	2.5	14.8	130	1,953	1,790	870	4,870					37	47	81	0.48	0.831	1,401	2,270	0.013	0.155	0.482	812	1,682	0.009	0.107
	A-4a	G	16.0	18.5	2.5	17.3	130	2,278	2,115	1,039	5,039					37	45	77	0.56	0.779	1,314	2,352	0.011	0.138	0.473	797	1,836	0.008	0.096
4	A-1-b	G	18.5	26.0	7.5	22.3	135	3,290	2,784	1,395	5,395					77	86	370	0.72	0.682	1,150	2,545	0.005	0.064	0.452	761	2,157	0.004	0.046
5	A-2-4	G	26.0	30.5	4.5	28.3	135	3,898	3,594	1,831	5,831					80	83	344	0.92	0.584	985	2,815	0.002	0.029	0.422	711	2,542	0.002	0.022
	A-2-4	G	30.5	35.0	4.5	32.8	135	4,505	4,201	2,158	6,158					80	78	316	1.07	0.524	883	3,041	0.002	0.025	0.399	672	2,830	0.002	0.020
6	A-2-6	G	35.0	40.0	5.0	37.5	135	5,180	4,843	2,503	6,503					120	111	560	1.22	0.471	793	3,296	0.001	0.013	0.374	631	3,134	0.001	0.010
7	A-1-b	G	40.0	45.0	5.0	42.5	135	5,855	5,518	2,866	6,866					96	85	358	1.38	0.424	715	3,580	0.001	0.016	0.350	590	3,456	0.001	0.014
	A-1-b	G	45.0	50.0	5.0	47.5	135	6,530	6,193	3,229	7,229					96	81	333	1.55	0.385	650	3,878	0.001	0.014	0.328	553	3,781	0.001	0.012
8	A-7-6	C	50.0	58.5	8.5	54.3	130	7,635	7,083	3,697	7,697	42	0.288	0.029	0.600				1.77	0.342	577	4,274	0.010	0.116	0.300	506	4,204	0.009	0.102
																				Total Settlement:			3.139 in		Total Settlement:			2.334 in	

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 psf in existing fill material and 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$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)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-045 - FRA-70-12.68 - FRA-70-1373A

MSE Wall with Cellular Concrete Backfill Settlement - Forward Abutment - Wall 4W5

Calculated By: BRT Date: 7/14/2018

Checked By: JPS Date: 7/15/2018

Boring B-020-9-15

H =	43.8	ft	Total wall/embankment height from profile grade to top of leveling pad
B =	30.7	ft	Wall/embankment width considered in analysis, equal to 70% of the wall height
D_w =	0.0	ft	Depth below bottom of wall/embankment
q =	1,686	psf	Bearing pressure at bottom of wall/embankment (see summary sheet)

	A-6a	A-6b	A-7-6		
c_v =	600	300	150	ft^2/yr	Coefficient of consolitation
t =	10	10	10	days	Time following completion of construction
H_{dr} =	3.5	4	8.5	ft	Length of longest drainage path considered
T_v =	1.342	0.514	0.057		Time factor
U =	97	77	27	%	Degree of consolidation

$(S_c)_t$ = 2.065 in Settlement complete at 88% of primary consolidation

																					Total Settlement at Facing of Wall			Settlement Complete at 88% of Primary Consolidation	
Layer	Soil Type	Soil Type	Layer Depth (ft)		Layer Thickness (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	S_c (9,10) (ft)	S_c (in)	Layer Settlement (in)	$(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-6a	C	0.0	3.5	3.5	1.8	115	403	201	92	2,092	35	0.225	0.034	0.546				0.06	0.500	843	935	0.077	0.923	0.923	0.896	0.896
2	A-6b	C	3.5	6.0	2.5	4.8	115	690	546	250	2,250	34	0.216	0.032	0.538				0.15	0.499	842	1,092	0.034	0.405	0.724	0.312	0.557
	A-6b	C	6.0	8.5	2.5	7.3	115	978	834	381	2,381	34	0.216	0.032	0.538				0.24	0.497	839	1,220	0.027	0.319		0.246	
3	A-4a	G	8.5	11.0	2.5	9.8	130	1,303	1,140	532	4,532					37	53	90	0.32	0.494	833	1,364	0.011	0.137	0.459	0.137	0.459
	A-4a	G	11.0	13.5	2.5	12.3	130	1,628	1,465	701	4,701					37	50	85	0.40	0.489	824	1,525	0.010	0.120		0.120	
	A-4a	G	13.5	16.0	2.5	14.8	130	1,953	1,790	870	4,870					37	47	81	0.48	0.482	812	1,682	0.009	0.107		0.107	
	A-4a	G	16.0	18.5	2.5	17.3	130	2,278	2,115	1,039	5,039					37	45	77	0.56	0.473	797	1,836	0.008	0.096		0.096	
4	A-1-b	G	18.5	26.0	7.5	22.3	135	3,290	2,784	1,395	5,395					77	86	370	0.72	0.452	761	2,157	0.004	0.046	0.046	0.046	0.046
5	A-2-4	G	26.0	30.5	4.5	28.3	135	3,898	3,594	1,831	5,831					80	83	344	0.92	0.422	711	2,542	0.002	0.022	0.043	0.022	0.043
	A-2-4	G	30.5	35.0	4.5	32.8	135	4,505	4,201	2,158	6,158					80	78	316	1.07	0.399	672	2,830	0.002	0.020		0.020	
6	A-2-6	G	35.0	40.0	5.0	37.5	135	5,180	4,843	2,503	6,503					120	111	560	1.22	0.374	631	3,134	0.001	0.010	0.010	0.010	0.010
7	A-1-b	G	40.0	45.0	5.0	42.5	135	5,855	5,518	2,866	6,866					96	85	358	1.38	0.350	590	3,456	0.001	0.014	0.026	0.014	0.026
	A-1-b	G	45.0	50.0	5.0	47.5	135	6,530	6,193	3,229	7,229					96	81	333	1.55	0.328	553	3,781	0.001	0.012		0.012	
8	A-7-6	C	50.0	58.5	8.5	54.3	130	7,635	7,083	3,697	7,697	42	0.288	0.029	0.600				1.77	0.300	506	4,204	0.009	0.102	0.102	0.028	0.028

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 2,000 psf in existing fill material and 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.15(Cc)$ for the existing fill and $0.10(Cc)$ for the natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$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)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)
11. $(S_c)_t = S_c(U/100)$; U = 100 for all granular soils at time t = 0

Settlement Remaining After Hold Period: 0.269 in

W-13-045 - FRA-70-12.68 - FRA-70-1373A and R

MSE Wall with Cellular Concrete Backfill - Bearing Resistance - Forward Abutment - Wall 4W5

Calculated By: BRT Date: 7/14/2018

Checked By: JPS Date: 7/15/2018

B =	26.0	ft	
L =	105	ft	
c =	1,125	psf	
γ =	115	pcf	
D_f =	3.0	ft	
φ =	0	deg	
D_w =	0.0	ft	Below ground surface

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma} = 6.23 \text{ ksf}$$

$$N_{cm} = N_c s_c i_c = 5.39 \qquad N_{qm} = N_q s_q d_q i_q = 1.00 \qquad N_{\gamma m} = N_\gamma s_\gamma i_\gamma = 0.00$$

N_c =	5.14	s_c =	1+(26 ft/105 ft)(1/5.14) =	1.048	i_c =	1.000	d_q =	1+2tan(0°)[1-sin(0°)]²tan⁻¹(3 ft/26 ft) = 1.000
N_q =	1.00	s_q =	1+(26 ft/105 ft)tan(0°) =	1.000	i_q =	1.000	C_{wq} =	0.0 ft < 3.0 ft = 0.500
N_γ =	0.00	s_γ =	1-0.4(26 ft/105 ft) =	0.901	i_γ =	1.000	$C_{w\gamma}$ =	0.0 ft < 1.5(26 ft) + 3 ft = 0.500

$$q_R = q_n \cdot \phi_b = 3.12 \text{ ksf}$$

φ_b = 0.5