Resource International, Inc.

FRA-71-14.36 PHASE 6R
RETAINING WALL W2
PID NO. 105588
FRANKLIN COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT (REV. 1)

Prepared For:
ms consultants, inc.
2221 Schrock Road
Columbus, OH 43229-1547

Prepared By:
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Columbus, Ohio 43231

Rii Project No. W-13-072

July 2019

RESOURCE INTERNATIONAL, INC.
ISO 9001:2015
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Planning

Engineering

Construction Management

Technology

June 18, 2015 (Revised July 19, 2019)

Mr. Gary Gardner, P.E.
ms consultants, inc.
2221 Schrock Road
Columbus, OH 43229-1547

Re: Structure Foundation Exploration Report (Rev. 1)
FRA-71-14.36 Phase 6R
Retaining Wall W2
PID No. 105588
Rii Project No. W-13-072

Mr. Gardner:

Resource International, Inc. (Rii) is pleased to submit this revised structure foundation exploration report for the above referenced project. Engineering logs have been prepared and are attached to this report along with the results of laboratory testing. This report includes recommendations for the design and construction of proposed Retaining Wall W2 as part of the FRA-71-14.36 Phase 6R project 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 (Rev. 1)

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EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration for the design and construction of the proposed Retaining Wall W2. Based on plan information provided by the Rii design team and ms consultants, Retaining Wall W2 will be located along the west side of I-71 southbound and Ramp C3 and will provide the required grade separation to avoid right-of-way take that would be associated with graded embankments. The wall begins at Sta. 216+75, BL I-71 SB, and extends north along the west side of I-71 southbound to Sta. 228+70, BL I-71 SB, where it continues north along the west side of Ramp C3 between Sta. 3010+20 and 3017+52, BL Ramp C3. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for the entire alignment of Retaining Wall W2. The wall heights along the wall alignment will range from 7.7 feet at Sta. 219+39 to 39.4 feet at Sta. 212+25 (BL Wall W2), and the total wall length is approximately 1,940 lineal feet.

Exploration and Findings

Between January 16, 2014, and March 27, 2015, fifteen (15) structural borings, designated as B-098-2-13 through B-107-4-14, were advanced to completion depths ranging from 15.0 to 54.3 feet below the existing ground surface. In addition to the borings performed by Rii as part of the current exploration, two (2) borings, designated as B-099-1-09 and B-101-0-09, were advanced to a completion depth of 12.5 and 10.0 feet below the existing ground surface, respectively, by DLZ as part of the FRA-70-8.93 preliminary exploration.

Borings B-099-2-13, B-099-3-13 and B-099-5-14 were performed in the existing MJS Carriers parking lot. Borings B-099-2-13 and B-099-3-13 encountered 2.0 inches of asphalt each at the ground surface overlying 4.0 inches of aggregate base in boring B-099-2-13, and boring B-099-5-14 encountered 8.0 inches of crushed gravel and asphalt at the ground surface. Boring B-102-2-14 was performed within the existing pavement behind the loading dock for LifeCare Alliance and encountered 4.0 inches of asphalt overlying 12.0 inches of concrete followed by 3.0 inches of aggregate base. Boring B-105-6-14 was performed within the existing parking lot of R.W. Setterlin Building Company and encountered 4.0 inches of asphalt overlying 8.0 inches of fill material. The remaining borings were performed within the grass areas adjacent to the parking lots or along the embankment supporting I-71/SR-315 southbound and encountered 1.0 to 10.0 inches of topsoil at the ground surface, as identified by the significant presence of vegetation and organic material.

Beneath the topsoil in borings B-098-2-13, B-102-4-14 and B-107-3-14, material identified as existing fill was encountered extending to a depth of 3.0 feet below the ground surface at the respective boring locations, which corresponds to elevations ranging from 701.3 to 712.0 feet msl. The fill material consisted of dark brown and brown gravel with sand, silt and clay and clay (ODOT A-2-6, A-7-6) and contained root fibers and brick fragments throughout.

Underlying the surficial materials and existing fill in borings B-098-2-13, B-102-4-14 and B-107-3-14, natural granular soils were encountered with intermittent seams of cohesive material. The granular soils were generally described as brown, gray, brownish gray and black gravel, gravel and sand, gravel with sand and silt, gravel with sand, silt and clay and sandy silt (ODOT A-1-a, A-1-b, A-2-4, A-2-6, A-4a). The cohesive soils were generally described as brown, dark brown, gray, brownish gray, dark gray and reddish brown sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6).

Analyses and Recommendations

Design details of the proposed retaining wall were provided by the Rii design team. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for the entire alignment of Retaining Wall W2. The will be located along the west side of I-71 southbound and Ramp C3 and will provide the required grade separation to avoid right-of-way take that would be associated with graded embankments. The wall heights along the wall alignment will range from 7.7 feet at Sta. 219+39 to 39.4 feet at Sta. 212+25 (BL Wall W2), and the total wall length is approximately 1,940 lineal feet.

MSE Wall Recommendations

Based on the proposed plan and profile information, wall heights along the southern portion of the proposed wall alignment, between Sta. 200+00 and 211+08 (BL Wall W2), range from 8.5 to 37.7 feet, as measured from the top of the leveling pad to the top of the coping, and will directly support the roadway on top and behind the wall. Wall heights along the northern portion of the proposed wall alignment, between Sta. 211+08 and 219+39, range from 7.7 to 38.6 feet, and will support graded embankments with 2:1 (H:V) backslopes that extend up to the proposed Ramp C3 roadway.

The anticipated bearing materials along the wall alignment consist of loose to very dense gravel, gravel and sand and gravel with sand, silt and clay (ODOT A-1-a, A-1-b, A-2-6), and stiff to very stiff silty clay and clay (ODOT A-6b, A-7-6) was encountered in several of the borings extending to depths up to 5.0 feet below the proposed bottom of wall elevation. As noted in Section 5.1 of the full report, it is recommended that the clay (ODOT A-7-6) soil, where encountered, be completely over excavated to expose the underlying competent granular soils and replaced ODOT Item 203 granular embankment. MSE wall foundations bearing on these competent natural soils or granular embankment, placed and compacted in accordance with ODOT Item 203, may be proportioned for a factored bearing resistance as indicated in the following table. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.

Retaining Wall W2 MSE Wall Design Parameters

From Station [1]	To Station [1]	Wall Height Analyzed (feet)	Backslope Behind Wall in Analysis	Minimum Required Reinforcement Length [2] (feet)	Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing Pressure [4] (ksf)
					Nominal	Factored [3]	
200+00	203+00	18.5	Level	13.0 (0.70H ≥ 8.0)	13.09	8.51	4.71
203+00	212+25	38.1	Level	26.7 (0.70H)	77.33	50.26	8.81
212+25	216+50	38.9	2:1 (Broken-back)	27.2 (0.70H)	27.50	17.88	11.64
216+50	219+39	30.2	2:1 (Infinite)	21.1 (0.70H ≥ 8.0)	41.25	26.81	9.62

1. *Station referenced to the baseline of Retaining Wall W2.*
2. *The required foundation width is expressed as a percentage of the wall height, H.*
3. *A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.*
4. *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 up to 3.14 inches at the center of the reinforced soil mass and 2.57 inches at the facing of the wall are anticipated along the alignment of Retaining Wall W2. Based on the results of the analysis, 100 percent of the total settlement at the facing of the wall is anticipated to occur during construction of the wall or within 35 days following the completion of construction of the wall.

Based on the results of the external and global stability analysis performed for Retaining Wall W2, the recommended controlling strap length is 0.70 times the height of the MSE wall (measured from the top of the leveling pad to the proposed profile grade of the roadway or top of coping) for the entire wall alignment.

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

1.0 INTRODUCTION

The overall purpose of this project is to provide detailed subsurface information and recommendations for the design and construction of the FRA-70/71-13.10/14.36 (Projects 6A/6R) project in Columbus, Ohio. The projects represent the central portion of FRA-70-8.93 (PID 77369) I-70/71 south innerbelt improvements project, which includes all improvements along I-70 westbound from the I-71/SR-315 interchange to Front Street and along I-71 southbound from I-70 to Greenlawn Avenue. The FRA-71-14.36 (Project 6R) phase will consist of all work associated with the reconfiguration and construction of I-71 southbound from downtown (Front Street) to Greenlawn Avenue, including Ramps C3, D6 and D7. This project includes the construction of two (2) new bridge structures, one (1) for I-71 southbound over Short Street, NS/CXS Railroad and the Scioto River (FRA-71-1503L) and one (1) for Ramp D7 over Short Street (FRA-70-1373B), as well as the construction of five (5) new retaining walls (Walls E4, E5, E7, W2 and W5) to accommodate the new configuration.

This report is a presentation of the structure foundation exploration performed for the design and construction of the proposed Retaining Wall W2, as shown on the vicinity map and boring plan presented in Appendix I. Retaining Wall W2 will be located along the west side of I-71 southbound and Ramp C3 and will provide the required grade separation to avoid right-of-way take that would be associated with graded embankments. The wall begins at Sta. 216+75, BL I-71 SB, and extends north along the west side of I-71 southbound to Sta. 228+70, BL I-71 SB, where it continues north along the west side of Ramp C3 between Sta. 3010+20 and 3017+52, BL Ramp C3. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for the entire alignment of Retaining Wall W2. The wall heights along the wall alignment will range from 7.7 feet at Sta. 219+39 to 39.4 feet at Sta. 212+25 (BL Wall W2), and the total wall length is approximately 1,940 lineal feet.

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Site Geology

Both the Illinoian and Wisconsinan glaciers advanced over two-thirds of the State of Ohio, leaving behind glacial features such as moraines, kame deposits, lacustrine deposits and outwash terraces. The glacial and non-glacial regions comprise five physiographic sections based on geological age, depositional process and geomorphic occurrence (physical features or landforms). The project area lies within the Columbus Lowland District of the Till Plains Section. This area is characterized by flat to gently rolling ground moraine deposits from the Late Wisconsinan age. The site topography exhibits moderate to high relief. The ground moraine deposits are composed primarily of silty loam till (Darby, Bellefontaine, Centerburg, Grand Lake, Arcanum, Knightstown Tills), with smaller alluvium and outwash deposits bordering the Scioto River, its tributaries and floodplain areas. A ground moraine is the sheet of debris left after the steady retreat of glacial ice. The debris left behind ranges in composition from clay size

particles to boulders (including silt, sand, and gravel). Outwash deposits consist of undifferentiated sand and gravel deposited by meltwater in front of glacial ice, and often occurs as valley terraces or low plains. Alluvium and alluvial terrace deposits range in composition from silty clay size particles to cobbles, usually deposited in present and former floodplain areas.

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

2.2 Existing Conditions

The proposed Retaining Wall W2 is located along the west side of the existing ramp carrying I-70 eastbound and I-71 southbound to SR-315 southbound. The existing I-70 eastbound and I-71 southbound ramps are single-lane, asphalt paved roadways with full width shoulders, and the existing SR-315 southbound roadway is a two-lane, asphalt paved roadway with full width inside and outside shoulders. The profile grade of the ramps and highway are elevated on engineered embankments approximately 35 feet above the surrounding terrain along north end of the proposed wall alignment adjacent to the I-70 eastbound ramp to approximately 5 feet above surrounding terrain along the south side of the proposed wall alignment adjacent to I-71/SR-315 southbound. The existing embankments are covered with dense vegetation and show no visible signs of instability. Commercial properties are situated along the west side of the I-70 eastbound and I-71/SR-315 roadways, and the Scioto River is situated along the west side of I-71/SR-315. The terrain along I-71/SR-315 southbound slopes down gently to the south, and the surrounding area is relatively flat-lying.

3.0 EXPLORATION

Between January 16, 2014, and March 27, 2015, fifteen (15) structural borings, designated as B-098-2-13, B-098-3-14, B-099-2-13, B-099-3-13, B-099-5-14, B-100-1-14, B-100-3-14, B-102-2-14, B-102-4-14, B-102-6-14, B-103-1-14, B-105-4-14, B-105-6-14, B-107-3-14 and B-107-4-14, were advanced to completion depths ranging from 15.0 to 54.3 feet below the existing ground surface. The borings were drilled at the toe of the existing embankment supporting I-71/SR-315 southbound and the ramp from I-70 eastbound to I-71/SR-315 southbound. In addition to the borings performed by Rii as part of the current exploration, two (2) borings, designated as B-099-1-09 and B-101-0-09, were performed DLZ in the vicinity of the bridge structure as part of the FRA-70-8.93 preliminary exploration, and their findings were published in a report dated March 18, 2010. The borings were advanced to a completion depth of 12.5 and 10.0 feet below the existing ground surface, respectively. 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-098-2-13	BL I-71 SB	217+50.17	29.4' Lt.	39.944646825	-83.013554525	715.0	47.9
B-098-3-14	BL I-71 SB	216+00.00	23.8' Lt.	39.944287341	-83.013291632	716.3	15.0
B-099-1-09	BL I-71 SB	221+80.40	63.9' Lt.	39.945653478	-83.014366412	704.5	12.5
B-099-2-13	BL I-71 SB	219+00.12	52.5' Lt.	39.944983752	-83.013872625	705.1	25.0
B-099-3-13	BL I-71 SB	220+36.69	56.8' Lt.	39.945311743	-83.014109060	705.0	25.0
B-099-5-14	BL I-71 SB	222+00.00	69.6' Lt.	39.945694161	-83.014416489	704.2	30.0
B-100-1-14	BL I-71 SB	223+51.27	54.9' Lt.	39.946081913	-83.014616606	705.6	45.0
B-100-3-14	BL I-71 SB	225+01.50	55.6' Lt.	39.946438290	-83.014870081	706.0	30.0
B-101-0-09	BL I-71 SB	226+52.84	34.1' Lt.	39.946821934	-83.015076772	706.9	10.0
B-102-2-14	BL I-71 SB	226+56.20	52.9' Lt.	39.946802907	-83.015140045	706.1	45.0
B-102-4-14	BL I-71 SB	228+05.59	58.8' Lt.	39.947144182	-83.015436296	705.2	49.4
B-102-6-14	BL Ramp C3	3016+76.27	75.2' Rt.	39.947404459	-83.015822670	700.5	44.0
B-103-1-14	BL Ramp C3	3015+16.32	74.2' Rt.	39.947764221	-83.016136629	703.3	54.3
B-105-4-14	BL Ramp C3	3013+70.11	102.6' Rt.	39.948055710	-83.016519556	700.0	45.0
B-105-6-14	BL Ramp C3	3012+25.98	120.3' Rt.	39.948372985	-83.016857114	703.0	35.0
B-107-3-14	BL Ramp C3	3010+61.70	149.1' Rt.	39.948726068	-83.017248056	704.3	25.0
B-107-4-14	BL Ramp C3	3009+90.45	162.2' Rt.	39.948867841	-83.017410893	705.1	20.0

The locations for the current exploration borings performed by Rii were determined and located in the field by Rii representatives. Rii utilized a handheld GPS unit to obtain geographic latitude and longitude coordinates of the boring locations. Ground surface elevations at the boring locations were interpolated using topographic mapping information provided by ms consultants.

The borings performed by Rii for the current exploration were drilled using a truck or an all-terrain vehicle (ATV) mounted rotary drilling machine, utilizing either 3.25 or 4.25-inch inside diameter, hollow stem auger or a 4.5-inch outside diameter, solid flight auger to advance the holes. Standard penetration test (SPT) and split spoon sampling were performed in the borings at 2.5-foot increments of depth to 10.0 or 20.0 feet, and at 5.0-foot increments thereafter to the boring termination depth. 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 blows 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, CME 750 and CME 750X drill rigs operated by Rii were calibrated on April 26, 2013, and have drill rod energy ratios of 77.7, 82.6 and 86.8 percent, respectively. The hammers for the CME 750, CME 750X and CME 55 drill rigs operated by Rii were calibrated again on October 20, 2014, and have drill rod energy ratios of 92.9, 85.7 and 92.0 percent, respectively. The updated energy ratios for the CME 750 and CME 750X drill rigs were utilized for borings performed after the recalibration date for those rigs. The hammers for the two CME 75 drill rigs operated by DLZ have drill rod energy ratios of 61.2 and 62.0 percent. No calibration date is available for the DLZ rig calibrations.

During drilling for the borings performed by Rii, 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	165
Plastic and Liquid Limits	AASHTO T89, T90	64
Gradation – Sieve/Hydrometer	AASHTO T88	64

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 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.

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

Borings B-099-2-13, B-099-3-13 and B-099-5-14 were performed in the existing MJS Carriers parking lot. Borings B-099-2-13 and B-099-3-13 encountered 2.0 inches of asphalt each at the ground surface overlying 4.0 inches of aggregate base in boring B-099-2-13, and boring B-099-5-14 encountered 8.0 inches of crushed gravel and asphalt at the ground surface. Boring B-102-2-14 was performed within the existing pavement behind the loading dock for LifeCare Alliance and encountered 4.0 inches of asphalt overlying 12.0 inches of concrete followed by 3.0 inches of aggregate base. Boring B-105-6-14 was performed within the existing parking lot of R.W. Setterlin Building Company and encountered 4.0 inches of asphalt overlying 8.0 inches of fill material. The remaining borings were performed within the grass areas adjacent to the

parking lots or along the embankment supporting I-71/SR-315 southbound and encountered 1.0 to 10.0 inches of topsoil at the ground surface, as identified by the significant presence of vegetation and organic material.

4.2 Subsurface Soils

Beneath the topsoil in borings B-098-2-13, B-102-4-14 and B-107-3-14, material identified as existing fill was encountered extending to a depth of 3.0 feet below the ground surface at the respective boring locations, which corresponds to elevations ranging from 701.3 to 712.0 feet msl. The fill material consisted of dark brown and brown gravel with sand, silt and clay and clay (ODOT A-2-6, A-7-6) and contained root fibers and brick fragments throughout.

Underlying the surficial materials and existing fill in borings B-098-2-13, B-102-4-14 and B-107-3-14, natural granular soils were encountered with intermittent seams of cohesive material. The granular soils were generally described as brown, gray, brownish gray and black gravel, gravel and sand, gravel with sand and silt, gravel with sand, silt and clay and sandy silt (ODOT A-1-a, A-1-b, A-2-4, A-2-6, A-4a). The cohesive soils were generally described as brown, dark brown, gray, brownish gray, dark gray and reddish brown sandy silt, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6).

The relative density of the granular soils is derived from the SPT blow counts (N_{60}). The relative density of the granular soil encountered ranged from loose ($5 \leq N_{60} \leq 10$ blows per foot [bpf]) to very dense ($N_{60} > 50$ bpf). Overall blow counts recorded from the SPT sampling ranged from 5 bpf to split spoon sampler refusal. 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. The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soil encountered ranged from stiff ($1.0 < HP \leq 2.0$ tsf) to hard ($HP > 4.0$ tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 1.5 to over 4.5 tsf (limit of instrument).

Natural moisture contents of the soil samples tested ranged from 2 to 31 percent. The natural moisture content of the cohesive soil samples tested for plasticity index ranged from 7 percent below to 7 percent above the corresponding plastic limits. In general, the soil exhibited natural moisture contents considered to be significantly below to significantly above the optimum moisture levels.

4.3 Bedrock

Bedrock was not encountered in the borings performed for this structure exploration.

4.4 Groundwater

Groundwater was encountered in the borings as presented in Table 3.

Table 3. Groundwater Levels

Boring Number	Ground Elevation (feet msl)	Initial Groundwater		Upon Completion [1]	
		Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)
B-098-2-13	715.0	24.0	691.0	N/A	N/A
B-098-3-14	716.3	Dry	Dry	Dry	Dry
B-099-1-09	704.5	Dry	Dry	Dry	Dry
B-099-2-13	705.1	17.0	688.1	N/A	N/A
B-099-3-13	705.0	17.5	687.5	22.6	682.4
B-099-5-14	704.2	17.5	686.7	24.3	679.9
B-100-1-14	705.6	18.5	687.1	N/A	N/A
B-100-3-14	706.0	19.0	687.0	23.4	682.6
B-101-0-09	706.9	Dry	Dry	Dry	Dry
B-102-2-14	706.1	17.5	688.6	N/A	N/A
B-102-4-14	705.2	18.0	687.2	N/A	N/A
B-102-6-14	700.5	11.0	689.5	N/A	N/A
B-103-1-14	703.3	15.5	687.8	N/A	N/A
B-105-4-14	700.0	11.0	689.0	N/A	N/A
B-105-6-14	703.0	13.5	689.5	N/A	N/A
B-107-3-14	704.3	16.0	688.3	N/A	N/A
B-107-4-14	705.1	13.5	691.6	15.0	690.1

1. *N/A indicates that the groundwater level at the completion of drilling could not be obtained due to the addition of water or mud to the boreholes to counteract heaving sands.*

With the exception of borings B-098-3-14, B-099-1-09 and B-101-0-09, groundwater was encountered initially during the drilling process in the remaining borings at depths ranging from 11.0 to 24.0 feet below existing grade, which corresponds to elevations ranging from 686.7 to 691.6 feet msl. At the completion of drilling and prior to removing the augers in borings B-099-3-13, B-099-5-14, B-100-3-14 and B-107-4-14, groundwater accumulated in the auger stems to depths ranging from 15.0 to 24.3 feet below existing grade, which corresponds to elevations ranging from 679.9 to 690.1 feet

msl. The groundwater level at the completion of drilling could not be obtained in several of the borings due to the addition of water or mud to the boreholes to counteract heaving sands.

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

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

5.0 ANALYSES AND RECOMMENDATIONS

Data obtained from the drilling and testing programs have 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 retaining wall, 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 retaining wall were provided by the Rii design team. It is understood that a mechanically stabilized earth (MSE) wall type is being considered as the preferred wall type for the entire alignment of Retaining Wall W2. The will be located along the west side of I-71 southbound and Ramp C3 and will provide the required grade separation to avoid right-of-way take that would be associated with graded embankments. The wall heights along the wall alignment will range from 7.7 feet at Sta. 219+39 to 39.4 feet at Sta. 212+25 (BL Wall W2), and the total wall length is approximately 1,940 lineal feet.

5.1 MSE Wall Recommendations

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 2019 ODOT BDM, the height of the MSE wall is defined as the elevation difference between the top of coping 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 roadway subgrade elevation where the roadway is supported on the top of the wall, and the reinforced soil mass extends to the top of the coping where the roadway is not supported on top 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 2019 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 the proposed plan and profile information, wall heights along the southern portion of the proposed wall alignment, between Sta. 200+00 and 211+08 (BL Wall W2), range from 8.5 to 37.7 feet, as measured from the top of the leveling pad to the top of the coping, and will directly support the roadway on top and behind the wall. Wall heights along the northern portion of the proposed wall alignment, between Sta. 211+08 and 219+39, range from 7.7 to 38.6 feet, and will support graded embankments with 2:1 (H:V) backslopes that extend up to the proposed Ramp C3 roadway. For the analysis, the foundation width was set at 70 percent of the wall height and the foundation width was increased, if required, until external and global stability requirements were satisfied.

Per Section 840.06.D of ODOT SS 840, the foundation subgrade should be inspected to verify that the subsurface conditions are the same as those anticipated in this report. The anticipated soils at the proposed bearing elevation along the majority of the wall alignment consist of loose to very dense gravel, gravel with sand and gravel with sand, silt and clay (ODOT A-1-a, A-1-b, A-2-6). Cohesive soil deposits consisting of stiff to very stiff silty clay and clay (ODOT A-6b, A-7-6) were encountered at the proposed bearing elevation in borings B-098-3-14, B-099-2-13, B-099-3-13, B-099-5-14, B-100-1-14, B-103-1-14, B-105-4-14 and B-107-3-14. At borings B-098-3-14, B-099-3-13, B-099-5-14, B-100-1-14 and B-107-3-14, these deposits only extend to depths of 1.0 to 1.5 feet below the bottom of wall elevation and will likely be removed during the foundation preparation. At borings B-099-2-13, B-103-1-14 and B-105-4-14, the cohesive soils extended to a depth of 3.5, 5.0 and 2.0 feet (elevation 697.1, 692.8 and 694.5 feet msl), respectively, below the bottom of wall.

Given the high plasticity of the clay (ODOT A-7-6) soils encountered in borings B-103-1-14 and B-105-4-14, along with the reduced shear strength and increased compressibility of these soil types, it is recommended that this material, where encountered, be completely over excavated to expose the underlying competent granular soils and replaced ODOT Item 203 granular embankment. Over excavation depths on the order of 2.0 to 5.0 feet are anticipated between approximately Sta. 213+50 and 216+50 (BL Wall W2) based on the elevation of the bottom of the cohesive soil deposits encountered in borings B-103-1-14 and B-105-4-14. The actual limits and depth of over excavation will need to be determined during the construction of the wall based on observation of the subgrade condition by a qualified soil technician or geotechnical engineer.

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.

5.1.1 Strength Parameters Utilized in External and Global Stability Analyses

The shear strength parameters utilized in the external and global stability analyses for the MSE wall are provided in Table 4.

Table 4. 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 backfill)	120	34	0	N/A
Item 203 Embankment Fill (Retained soil)	120	30	0	2,000
Item 203 Granular Embankment (Over excavation backfill)	120	32	0	N/A
Loose to Very Dense Granular Soils (ODOT A-1-a, A-1-b, A-2-6, A-4a)	120 to 135	34 to 42	0	N/A
Very Stiff Silty Clay (ODOT A-6b)	120	26	0	2,500
Stiff Clay (ODOT A-7-6)	115	25	0	1,750
Hard Sandy Silt (ODOT A-4a)	130	33	100	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 and retained embankment are provided in ODOT SS 840. Per SS 840, the select granular backfill in the reinforced zone and the retained embankment must meet the shear strength requirements provided in Table 4. 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.

5.1.2 Bearing Stability

The anticipated bearing materials along the wall alignment consist of loose to very dense gravel, gravel and sand and gravel with sand, silt and clay (ODOT A-1-a, A-1-b, A-2-6), and stiff to very stiff silty clay and clay (ODOT A-6b, A-7-6) was encountered in several of the borings extending to depths up to 5.0 feet below the proposed bottom of wall elevation. As noted in Section 5.1, it is recommended that the clay (ODOT A-7-6) soil, where encountered, be completely over excavated to expose the underlying

competent granular soils and replaced ODOT Item 203 granular embankment. MSE wall foundations bearing on these competent natural soils or granular embankment, placed and compacted in accordance with ODOT Item 203, may be proportioned for a factored bearing resistance as indicated in Table 5. A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state. The reinforcement lengths presented in the following table represent the minimum foundation widths required to satisfy external and global stability requirements, expressed as a percentage of the wall height.

Table 5. Retaining Wall W2 MSE Wall Design Parameters

From Station [1]	To Station [1]	Wall Height Analyzed (feet)	Backslope Behind Wall in Analysis	Minimum Required Reinforcement Length [2] (feet)	Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing Pressure [4] (ksf)
					Nominal	Factored [3]	
200+00	203+00	18.5	Level	13.0 (0.70H ≥ 8.0)	13.09	8.51	4.71
203+00	212+25	38.1	Level	26.7 (0.70H)	77.33	50.26	8.81
212+25	216+50	38.9	2:1 (Broken-back)	27.2 (0.70H)	27.50	17.88	11.64
216+50	219+39	30.2	2:1 (Infinite)	21.1 (0.70H ≥ 8.0)	41.25	26.81	9.62

1. *Stationing referenced to the baseline of Retaining Wall W2.*
2. *The required foundation width is expressed as a percentage of the wall height, H.*
3. *A geotechnical resistance factor of φ_b=0.65 was considered in calculating the factored bearing resistance at the strength limit state.*
4. *The strength limit equivalent bearing pressure is the uniformly distributed pressure asserted by the wall over an effective base width based on the eccentricity of the wall system at the strength limit state.*

Rii performed a verification of the bearing pressure exerted on the subgrade material for the specified wall heights indicated in Table 5. Based on the minimum length of reinforced soil mass presented, the factored equivalent bearing pressure exerted below the wall **will not exceed** the factored bearing resistance at the strength limit state.

5.1.3 Settlement Evaluation

The compressibility parameters utilized in the settlement analyses of the proposed MSE wall are provided in Table 6.

Table 6. 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]
Item 203 Granular Embankment (Over excavation backfill)	120	N/A	N/A	N/A	N/A	N/A	30	149 to 207
Loose to Very Dense Granular Soils (ODOT A-1-a, A-1-b, A-2-6, A-4a)	120 to 135	N/A	N/A	N/A	N/A	N/A	8 to 120	40 to 736
Very Stiff Silty Clay (ODOT A-6b)	120	37 to 40	0.243 to 0.270	0.024 to 0.027	0.561 to 0.585	300	N/A	N/A
Hard Sandy Silt (ODOT A-4a)	130	20 to 22	0.090 to 0.108	0.009 to 0.011	0.428 to 0.444	1,000	N/A	N/A

1. *Per Table 6-9, Section 6.14.1 of FHWA GEC 5.*
2. *Estimated at 10% of C_c 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 7. Total settlements of up to 3.14 inches at the center of the reinforced soil mass and 2.57 inches at the facing of the wall are anticipated along the alignment of Retaining Wall W2. Based on the results of the analysis, 100 percent of the total settlement at the facing of the wall is anticipated to occur during construction of the wall or within 35 days following the completion of construction of the wall. Please note that the consolidation settlement and time rate of consolidation are based on estimates using correlated compressibility parameters provided in Table 6 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 7. Retaining Wall W2 MSE Wall Settlement Values

From Station [1]	To Station [1]	Service Limit Equivalent Bearing Pressure [2] (ksf)	Total Settlement Values (inches)		Time for 100% Consolidation (Days)
			Center of Wall Mass	Facing of Wall	
200+00	203+00	1.88 to 3.26	0.49 to 1.64	0.44 to 1.31	0 to 35
203+00	212+25	3.23 to 6.20	0.65 to 2.40	0.52 to 1.90	0 to 15
212+25	216+50	7.57 to 8.03	2.61 to 3.14	2.20 to 2.57	0 to 5
216+50	219+39	1.12 to 6.73	0.62 to 2.25	0.46 to 1.81	0 to 5

1. *Stationing referenced to the baseline of Retaining Wall W2.*
2. *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.” 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 1/1,000, which is within the tolerable limit of 1/100. If the total or differential settlement values predicted for the proposed wall present 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 walls. 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 IV.

5.1.4 Eccentricity (Overturning Stability)

The resistance of the MSE wall to overturning will be dependent on the on the location of the resultant force at the bottom of the wall due to the overturning and resisting moments acting on the wall. For MSE walls, overturning stability is determined by calculating the eccentricity of the resultant force from the midpoint of the base of the wall and comparing this value to a limiting eccentricity value. Per Section 11.10.5.5 of the 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 specified wall heights indicated in Table 5. Based on the minimum length of reinforced soil mass presented in Table 5 and utilizing the soil parameters listed in Section 5.1.1 for the retained embankment material, the calculated eccentricity of the resultant force **will not exceed** the limiting eccentricity at the strength limit state.

5.1.5 Sliding Stability

The resistance of the MSE wall 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 5.1.1 for the foundation and reinforced soil backfill material, a coefficient of sliding friction of 0.49 to 0.67 was utilized for design. For the section of wall at boring B-099-2-13, sliding was also evaluated using undrained conditions. 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 5.1.1, the undrained shear strength of the silty clay (ODOT A-6b) encountered at the proposed bearing elevation at boring B-099-3-13 is estimated to be 2,500 psf.

A geotechnical resistance factor of φ_τ=1.0 was considered in calculating the factored shear resistance. Based on the minimum length of reinforced soil mass presented in Table 5 and utilizing the soil parameters listed in Section 5.1.1 for the retained embankment material, the resultant horizontal forces on the back of the MSE wall **will not exceed** the factored shear resistance at the strength limit state for drained or undrained conditions.

5.1.6 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 Table 4. 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 2018 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 not integrated with or supporting structural foundations or elements, global stability is satisfied if the product of the factor of safety from the slope stability output multiplied by the resistance factor φ=0.75 is greater than 1.0. Therefore, global stability is satisfied when a minimum factor of safety of 1.3 is obtained. For MSE walls designed with a minimum strap length listed in Table 5, the resulting factor of safety under drained conditions (long-term stability) was greater than or equal to 1.3. Given the granular nature of the subsurface profile, an undrained analysis was not performed.

5.1.7 Final MSE Wall Considerations

Based on the results of the external and global stability analysis performed for Retaining Wall W2, the recommended controlling strap length is 0.70 times the height of the MSE wall (measured from the top of the leveling pad to the proposed profile grade of the roadway or top of coping) for the entire wall alignment.

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

5.2 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 8 and Table 9.

Table 8. 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	120	0	32°	0.27	0.47	6.82

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

Table 9. 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	0	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	120	0	32°	0.27	0.47	6.82

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

These parameters are considered appropriate for the design of all subsurface structures and any excavation support systems. Subsurface structures (where the top of the structure is restrained from movement) should be designed based on at-rest conditions (k_o). For proposed temporary retaining structures (where the top of the structure is allowed to move), earth pressure distributions should be based on active (k_a) and passive (k_p) conditions. 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.

5.3 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) and MSE Wall Construction and foundation preparation follows Supplemental Specification 840.

5.3.1 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 10. 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

5.3.2 Groundwater Considerations

Based on the groundwater observations made during drilling, little to no groundwater seepage is anticipated during construction. However, where/if groundwater is encountered, proper groundwater control should be employed and maintained to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or "boiling" condition where soft silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36.0 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

BORINGS B-098-2-13, B-099-2-13, B-099-3-13, B-099-5-14, B-100-1-14, B-100-3-14, B-102-2-14, B-102-4-14, B-102-6-14, B-103-1-14, B-105-4-14, B-105-6-14, B-107-3-14 AND B-107-4-14 WERE PERFORMED FOR WALL W2.

BORINGS B-099-4-14, B-100-2-14, B-100-4-14, B-102-3-14, B-102-5-14, B-105-3-14, B-105-5-13, B-107-2-14 AND B-108-7-13 WERE PERFORMED FOR WALL W5.

BORINGS B-104-1-13, B-105-2-13, B-107-1-13 AND B-108-4-13 WERE PERFORMED FOR THE FRA-71-1503L STRUCTURE.

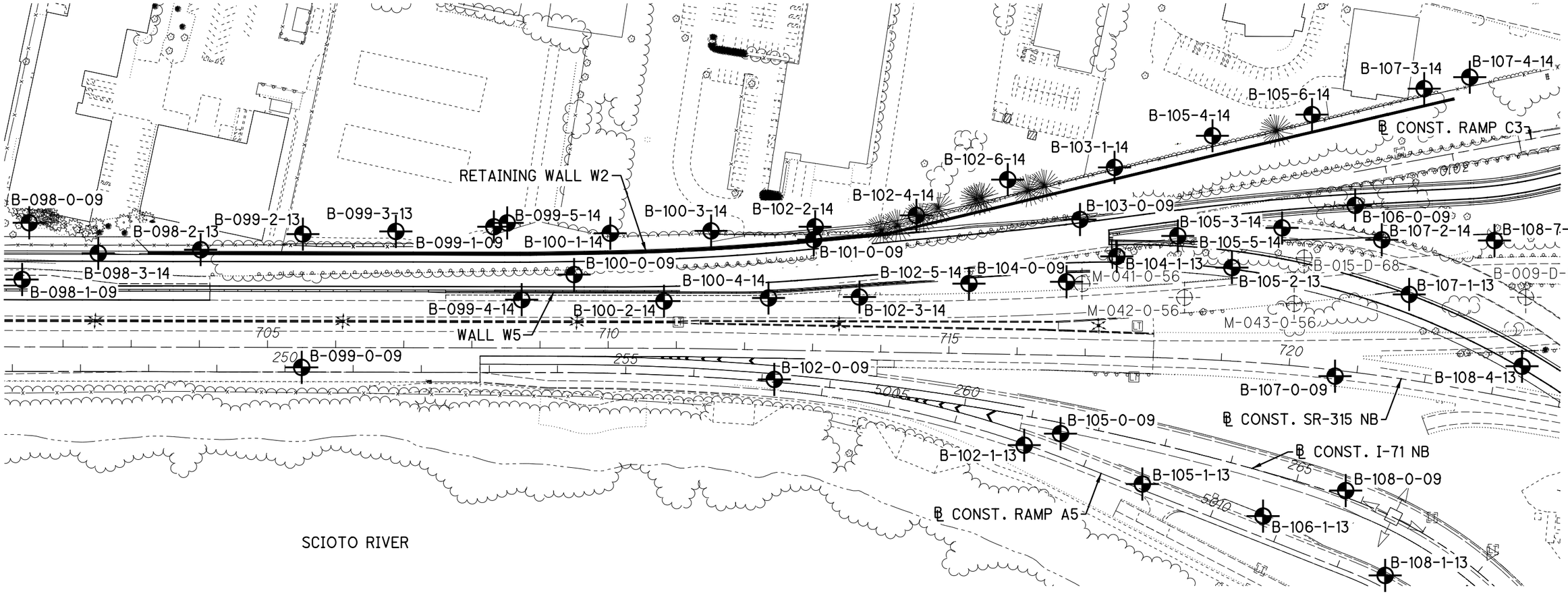
BORINGS B-102-1-13, B-105-1-13, B-106-1-13 AND B-108-1-13 WERE PERFORMED AS PART OF THE FRA-70-12.68 PROJECT 4A/4R.

BORINGS B-098-0-09, B-098-1-09, B-099-0-09, B-100-0-09, B-101-0-09, B-102-0-09, B-103-0-09, B-104-0-09, B-105-0-09, B-106-0-09, B-107-0-09 AND B-108-0-09 WERE DRILLED AS PART OF THE FRA-70-8.93 PRELIMINARY EXPLORATION.

LEGEND

PROJECT BORING

HISTORIC BORING



BORING PLAN

FRA-70-13.10 - RETAINING WALL W2

FRANKLIN COUNTY, OHIO

PROJECT NO. Rii W-13-072	DRAWN RRM
SCALE: 1"=150' (0, 75, 150)	REVIEWED BRT
	DATE 7-17-19

RESOURCE INTERNATIONAL Rii

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 - The relative compactness of granular soils is described as:
ODOT A-1, A-2, A-3, A-4 (non-plastic) or USCS GW, GP, GM, GC, SW, SP, SM, SC, ML (non-plastic)

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 - The relative consistency of cohesive soils is described as:
ODOT A-4, A-5, A-6, A-7, A-8 or USCS ML, CL, OL, MH, CH, OH, PT

Description	Blows per foot – SPT (N_{60})			Unconfined Compression (tsf)
Very Soft	Below		2	UCS ≤ 0.25
Soft	2	-	4	0.25 < UCS ≤ 0.5
Medium Stiff	5	-	8	0.5 < UCS ≤ 1.0
Stiff	9	-	15	1.0 < UCS ≤ 2.0
Very Stiff	16	-	30	2.0 < UCS ≤ 4.0
Hard	Over		30	UCS > 4.0

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

Soil Fraction		USCS Size	ODOT Size
Boulders		Larger than 12”	Larger than 12”
Cobbles		12” to 3”	12” to 3”
Gravel	coarse	3” to ¾”	3” to ¾“
	fine	¾” to 4.75 mm (¾” to #4 Sieve)	¾” to 2.0 mm (¾” to #10 Sieve)
Sand	coarse	4.75 mm to 2.0 mm (#4 to #10 Sieve)	2.0 mm to 0.42 mm (#10 to #40 Sieve)
	medium	2.0 mm to 0.42 mm (#10 to #40 Sieve)	-
	fine	0.42 mm to 0.074 mm (#40 to #200 Sieve)	0.42 mm to 0.074 mm (#40 to #200 Sieve)
Silt		0.074 mm to 0.005 mm (#200 to 0.005 mm)	0.074 mm to 0.005 mm (#200 to 0.005 mm)
Clay		Smaller than 0.005 mm	Smaller than 0.005 mm

Modifiers of Components - Modifiers of components are as follows:

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 - USCS	Range - ODOT
Dry	0% to 10%	Well below Plastic Limit
Damp	>2% below Plastic Limit	Below Plastic Limit
Moist	2% below to 2% above Plastic Limit	Above PL to 3% below LL
Very Moist	>2% above Plastic Limit	
Wet	[3] Liquid Limit	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 bedrock hardness:

Term		Blows per foot – SPT (N)		
Very Soft		Below		50
Soft		50/5”	–	50/6”
Medium Hard		50/3”	–	50/4”
Hard		50/1”	–	50/2”
Very Hard	50/0”			

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		$LL_0/LL \times 100$*	% 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	
F S	Fine Sand	A-3			51 Min.	10 Max.	NON-PLASTIC		0	
	Coarse and Fine Sand	--	A-3a			35 Max.		6 Max.	0	Min. of 50% combined coarse and fine sand sizes
	Gravel and/or Stone Fragments with Sand and Silt	A-2-4				35 Max.	40 Max.	10 Max.	0	
		A-2-5					41 Min.			
	Gravel and/or Stone Fragments with Sand, Silt and Clay	A-2-6				35 Max.	40 Max.	11 Min.	4	
		A-2-7					41 Min.			
	Sandy Silt	A-4	A-4a	76 Min.		36 Min.	40 Max.	10 Max.	8	Less than 50% silt sizes
	Silt	A-4	A-4b	76 Min.		50 Min.	40 Max.	10 Max.	8	50% or more silt sizes
	Elastic Silt and Clay	A-5		76 Min.		36 Min.	41 Min.	10 Max.	12	
	Silt and Clay	A-6	A-6a	76 Min.		36 Min.	40 Max.	11 - 15	10	
	Silty Clay	A-6	A-6b	76 Min.		36 Min.	40 Max.	16 Min.	16	
	Elastic Clay	A-7-5		76 Min.		36 Min.	41 Min.	≦LL-30	20	
	Clay	A-7-6		76 Min.		36 Min.	41 Min.	>LL-30	20	
	Organic Silt	A-8	A-8a	75 Max.		36 Min.				W/o organics would classify as A-4a or A-4b
	Organic Clay	A-8	A-8b	75 Max.		36 Min.				W/o organics would classify as A-5, A-6a, A-6b, A-7-5 or A-7-6

MATERIAL CLASSIFIED BY VISUAL INSPECTION

- Sod and Topsoil
- Pavement or Base
- Uncontrolled Fill (Describe)
- Bouldery Zone
- Peat, S-Sedimentary W-Woody F-Fibrous L-Loamy & etc

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

APPENDIX III

PROJECT BORING LOGS:

B-098-2-13 through B-107-4-14

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-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.B.	DRILL RIG: CME-750X (SN 310218)	STATION / OFFSET: 217+50.17 / 29.4' LT	**EXPLORATION ID B-098-2-13**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / J.S.	HAMMER: CME AUTOMATIC	ALIGNMENT: BL I-71 SB		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 715.0 (MSL) EOB: 47.9 ft.		PAGE 1 OF 2
START: 1/16/14 END: 1/16/14	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.8	LAT / LONG: 39.944647, -83.013555		

MATERIAL DESCRIPTION AND NOTES	ELEV. 715.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.8' - TOPSOIL (10.0")	714.2																	
FILL: HARD, DARK BROWN **CLAY**, 'AND" SILT, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST. -ROOT FIBERS PRESENT IN SS-1	712.0	1 2 3	4 9 20	42	28	SS-1	4.25	-	-	-	-	-	-	-	-	23	A-7-6 (V)	
DENSE TO VERY DENSE, BROWNISH GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT THROUGHOUT	707.0	4 5 6 7	7 19 14	48	67	SS-2	-	60	13	7	14	6	24	18	6	8	A-1-b (0)	
			16 19 29	69	67	SS-3	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	
DENSE TO VERY DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. -LIMESTONE FRAGMENTS PRESENT THROUGHOUT	702.0	8 9 10 11 12	17 18 20	55	67	SS-4	-	-	-	-	-	-	-	-	-	5	A-1-a (V)	
			24 15 15	43	72	SS-5	-	55	24	8	10	3	NP	NP	NP	8	A-1-a (0)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST.	693.0	13 14 15 16 17 18	3 10 9	27	33	SS-6	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
			5 3 7	14	50	SS-7	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
			4 6 11	25	67	SS-8	-	31	44	8	14	3	NP	NP	NP	7	A-1-b (0)	
MEDIUM DENSE TO DENSE, BROWN TO GRAY **GRAVEL**, SOME FINE TO COARSE SAND, LITTLE SILT, TRACE CLAY, MOIST. -INTRODUCED MUD @ 23.5'		W 19 20 21 22 23 24 25 26 27 28 29	5 14 8	32	61	SS-9	-	65	16	5	11	3	NP	NP	NP	13	A-1-a (0)	
			26 12 8	29	39	SS-10	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 12:59 - U:\GI\PROJECTS\2013\W-13-072.GPJ

PID: 89464	BR ID: N/A	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 217+50.17 / 29.4 LT	START: 1/16/14	END: 1/16/14	PG 2 OF 2	B-098-2-13

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
MEDIUM DENSE TO DENSE, BROWN TO GRAY **GRAVEL**, SOME FINE TO COARSE SAND, LITTLE SILT, TRACE CLAY, MOIST. *(same as above)*	685.0	31																
	683.0	32																
LOOSE, GRAY **GRAVEL**, LITTLE TO SOME COARSE TO FINE SAND, TRACE TO LITTLE SILT, TRACE CLAY, MOIST.		33																
		34	14 4 3	10	50	SS-11	-	-	-	-	-	-	-	-	-	14	A-1-a (V)	
		35																
		36																
		37																
		38																
		39	3 3 3	9	22	SS-12	-	-	-	-	-	-	-	-	-	17	A-1-a (V)	
	673.0	40																
DENSE TO VERY DENSE, BROWN **GRAVEL**, LITTLE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		41																
		42																
		43																
		44	12 12 14	38	50	SS-13	-	76	10	4	7	3	NP	NP	NP	11	A-1-a (0)	
		45																
		46																
		47																
	667.1	EOB	50/5"	-	100	SS-14	-	-	-	-	-	-	-	-	-	13	A-1-a (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 24.0'; CAVE-IN DEPTH @ 25.0'

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

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: CME 750 (SN 98048)	STATION / OFFSET: 216+00.00 / 23.8' LT	**EXPLORATION ID B-098-3-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / N.A.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-71 SB		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.5" CFA	CALIBRATION DATE: 10/20/14	ELEVATION: 716.3 (MSL) EOB: 15.0 ft.		PAGE 1 OF 1
START: 2/4/15 END: 2/4/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 92.9	LAT / LONG: 39.944287, -83.013292		

MATERIAL DESCRIPTION AND NOTES	ELEV. 716.3	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
0.4' - TOPSOIL (5.0")	715.9																	
VERY STIFF, DARK BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP.	713.3	1	3 3 4	11	50	SS-1	3.00	-	-	-	-	-	-	-	-	21	A-6b (V)	
DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, DAMP.	710.8	4	15 13 12	38	100	SS-2	-	62	13	6	19	0	23	20	3	8	A-1-b (0)	
DENSE TO VERY DENSE, BROWN **GRAVEL**, LITTLE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP. -ROCK FRAGMENTS PRESENT IN SS-3		6	1 20 15	53	72	SS-3	-	-	-	-	-	-	-	-	-	4	A-1-a (V)	
		9	16 24 18	63	89	SS-4	-	78	9	4	6	3	18	15	3	3	A-1-a (0)	
	701.3	14	16 16 14	45	56	SS-5	-	-	-	-	-	-	-	-	-	3	A-1-a (V)	
	EOB	15																

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER SOIL CUTTINGS

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 12:59 - U:\GI\PROJECTS\2013\W-13-072.GPJ

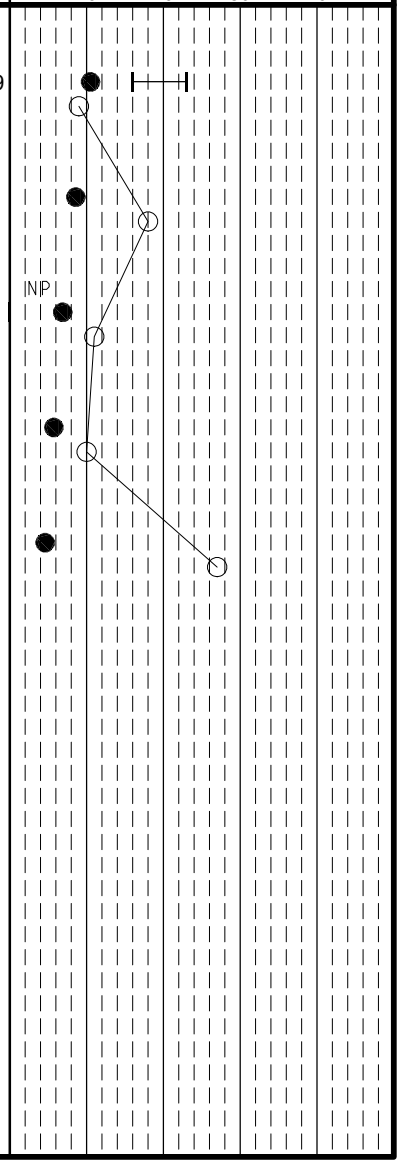
DLZ Ohio, Inc. * 6121 Huntley Road, Columbus, Ohio 43229 * (614) 888-0040

Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-099-1-09 | *Location:* Sta. 221+80.40, 63.9' LT., BL I-71 SB | *Date Drilled:* 9/25/2009

WATER OBSERVATIONS:
Water seepage at: None
Water level at completion: None
FIELD NOTES:

Depth (ft)	Elev. (ft) 704.5	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	Graphic Log	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0.5	704.0						Topsoil - 6"							
		12 4 5	11	1			Loose brown SANDY SILT (A-4a), little gravel; damp.		19	21	---	15	26	19
3.5	701.0													
		8 8 9	11	2			Medium dense brown GRAVEL (A-1-a), little to some fine to coarse sand, trace silt; damp.							
5														
		13 7 4	12	3					74	15	---	5	--6--	
		8 4 6	9	4										
10														
		26 13 13	16	5										
12.5	692.0													
							Bottom of Boring - 12.5'							
15														
20														
25														



RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 219+00.12 / 52.5' LT	**EXPLORATION ID B-099-2-13**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / C.D.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-71 SB		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.5" CFA	CALIBRATION DATE: 4/26/13	ELEVATION: 705.1 (MSL) EOB: 25.0 ft.		PAGE 1 OF 1
START: 2/5/15 END: 2/5/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.944984, -83.013873		

MATERIAL DESCRIPTION AND NOTES	ELEV. 705.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.2' - ASPHALT (2.0")	704.9																	
0.3' - AGGREGATE BASE (4.0")	704.6																	
STIFF TO HARD, BROWN **SILTY CLAY**, LITTLE COARSE TO FINE SAND, TRACE TO SOME FINE GRAVEL, DAMP TO MOIST. -ORGANICS PRESENT IN SS-1 -ROOT FIBERS PRESENT IN SS-2 -ROCK FRAGMENTS PRESENT IN SS-3	697.1		8 3 4	9	100	SS-1	1.50	7	5	13	46	29	39	21	18	14	A-6b (11)	
			3 6 8	18	72	SS-2	4.50	-	-	-	-	-	-	-	-	25	A-6b (V)	
			5 8 9	22	67	SS-3	2.25	34	6	11	28	21	40	19	21	16	A-6b (7)	
DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST.	694.6		12 11 14	32	61	SS-4	-	-	-	-	-	-	-	-	-	17	A-2-6 (V)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST. -LIMESTONE AND CHERT FRAGMENTS PRESENT IN SS-5	689.6		11 15 20	45	50	SS-5	-	64	15	4	12	5	NP	NP	NP	7	A-1-b (0)	
			13 9 12	27	89	SS-6	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
MEDIUM DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, LITTLE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT THROUGHOUT	680.1	W	6 5 4	12	39	SS-7	-	-	-	-	-	-	-	-	-	10	A-1-a (V)	
			6 5 6	14	33	SS-8	-	-	-	-	-	-	-	-	-	14	A-1-a (V)	
		EOB	4 5 6	14	100	SS-9	-	54	26	5	12	3	23	18	5	14	A-1-a (0)	

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 17.0'; CAVE-IN DEPTH @ 17.0'

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

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 12:59 - U:\GI\PROJECTS\2013\W-13-072.GPJ

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 220+36.69 / 56.8' LT	**EXPLORATION ID B-099-3-13**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / C.D.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-71 SB		
PID: 89464 BR ID: N/A	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 705.0 (MSL) EOB: 25.0 ft.		PAGE 1 OF 1
START: 2/5/15 END: 2/5/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.945312, -83.014109		

MATERIAL DESCRIPTION AND NOTES	ELEV. 705.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.2' - ASPHALT (2.0")	704.8																	
STIFF, REDDISH BROWN **SILTY CLAY**, "AND" COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP.	702.0		4 3 3	8	39	SS-1	2.00	18	17	27	20	18	32	15	17	12	A-6b (2)	
VERY STIFF, REDDISH BROWN **CLAY**, SOME SILT, SOME COARSE TO FINE SAND, LITTLE FINE GRVAEL, MOIST.	699.5				46	ST-2	3.00	14	12	15	28	31	46	19	27	26	A-7-6 (12)	
DENSE, GRAY **GRAVEL**, TRACE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.	694.5		7 14 12	34	39	SS-3	-	-	-	-	-	-	-	-	-	4	A-1-a (V)	
			20 19 19	49	33	SS-4	-	-	-	-	-	-	-	-	-	4	A-1-a (V)	
DENSE, BROWN **GRAVEL WITH SAND AND SILT**, LITTLE CLAY, MOIST. -ROCK FRAGMENTS PRESENT IN SS-5	692.0		15 12 13	32	89	SS-5	-	65	5	3	7	20	NP	NP	NP	12	A-2-4 (0)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP TO WET.			17 14 16	39	56	SS-6	-	-	-	-	-	-	-	-	-	4	A-1-b (V)	
		W	14 15 11	34	44	SS-7	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
			5 4 6	13	50	SS-8	-	60	17	6	12	5	26	20	6	21	A-1-b (0)	
-ROCK FRAGMENTS PRESENT IN SS-9	680.0	EOB	11 5 6	14	89	SS-9	-	-	-	-	-	-	-	-	-	16	A-1-b (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 17.5' AND AT COMPLETION @ 22.6'

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

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 12:59 - U:\GI\PROJECTS\2013\W-13-072.GPJ

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 222+00.00 / 69.6' LT	**EXPLORATION ID B-099-5-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / C.D.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-71 SB		
PID: 89464 BR ID: N/A	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 704.2 (MSL) EOB: 30.0 ft.		PAGE 1 OF 1
START: 2/5/15 END: 2/5/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.945694, -83.014416		

MATERIAL DESCRIPTION AND NOTES	ELEV. 704.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.7' - GRAVEL AND ASPHALT (8.0")	703.5																	
VERY STIFF, GRAY **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP. -ROCK FRAGMENTS PRESENT IN SS-1	701.2	1 2	10 5 10	19	67	SS-1	3.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
VERY STIFF, DARK BROWN **SILTY CLAY**, SOME COARSE TO FINE SAND, SOME FINE GRAVEL, DAMP. -IRON STAINING PRESENT IN SS-2	698.7	3 4 5	4 5 8	17	89	SS-2	3.75	24	12	12	26	26	37	19	18	16	A-6b (6)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND AND SILT**, LITTLE CLAY, DAMP TO MOIST. -ROCK FRAGMENTS PRESENT THROUGHOUT	693.7	6 7 8 9 10	7 8 11	25	39	SS-3	-	-	-	-	-	-	-	-	-	13	A-2-4 (V)	
			7 9 9	23	50	SS-4	-	56	9	7	17	11	27	17	10	8	A-2-4 (0)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST. -ROCK FRAGMENTS PRESENT THROUGHOUT	686.2	11 12 13 14 15 16 17	6 5 5	13	39	SS-5	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	
			10 7 8	19	39	SS-6	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
			14 12 13	32	61	SS-7	-	58	17	9	12	4	NP	NP	NP	9	A-1-b (0)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT IN SS-10		W 18 19 20 21 22 23 24 25 26 27 28 29 EOB	3 4 7	14	33	SS-8	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
			4 5 8	17	33	SS-9	-	-	-	-	-	-	-	-	-	14	A-1-a (V)	
			9 14 13	35	44	SS-10	-	63	19	6	7	5	NP	NP	NP	13	A-1-a (0)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 17.5' AND AT COMPLETION @ 24.3'

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

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 12:59 - U:\GI\PROJECTS\2013\W-13-072.GPJ

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 223+51.27 / 54.9' LT	**EXPLORATION ID B-100-1-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / C.D.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-71 SB		
PID: 89464 BR ID: N/A	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 705.6 (MSL) EOB: 45.0 ft.		PAGE 1 OF 2
START: 2/6/15 END: 2/6/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.946082, -83.014617		

MATERIAL DESCRIPTION AND NOTES	ELEV. 705.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.2' - TOPSOIL (2.0")	705.4																	
VERY STIFF, BROWN **CLAY**, SOME FINE GRAVEL, SOME COARSE TO FINE SAND, LITTLE SILT, MOIST. -ROCK FRAGMENTS PRESENT IN SS-1	702.6	1 2 3	3 5 7	16	100	SS-1	2.75	25	13	9	18	35	42	20	22	23	A-7-6 (8)	
MEDIUM DENSE TO DENSE, GRAYISH BROWN **GRAVEL**, LITTLE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.		4 5	12 13 11	31	50	SS-2	-	-	-	-	-	-	-	-	-	5	A-1-a (V)	
-ROCK FRAGMENTS PRESENT IN SS-3		6 7	6 8 9	22	50	SS-3	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
		8 9	10 11 11	28	56	SS-4	-	71	9	5	9	6	NP	NP	NP	5	A-1-a (0)	
	692.6	10 11	7 8 7	19	33	SS-5	-	-	-	-	-	-	-	-	-	2	A-1-a (V)	
DENSE TO VERY DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.		12 13	17 19 18	48	100	SS-6	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
		14 15	15 33 21	70	100	SS-7	-	66	14	6	9	5	NP	NP	NP	4	A-1-a (0)	
		16 17																
		W 18	33 19 13	41	44	SS-8	-	-	-	-	-	-	-	-	-	7	A-1-a (V)	
	683.6	19 20																
VERY DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST. -HEAVING SANDS ENCOUNTERED @ 23.5' -INTRODUCED MUD @ 23.5'		21 22 23	33 25 23	62	100	SS-9	-	55	23	6	11	5	20	16	4	9	A-1-b (0)	
	678.6	24 25																
MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST TO WET.		26 27 28 29	6 8 7	19	100	SS-10	-	-	-	-	-	-	-	-	-	19	A-1-b (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 12:59 - U:\GI\PROJECTS\2013\W-13-072.GPJ

PID: 89464	BR ID: N/A	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 223+51.27 / 54.9 LT	START: 2/6/15	END: 2/6/15	PG 2 OF 2	B-100-1-14

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, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST TO WET. *(same as above)*	675.6	31																
		32																
		33																
		34	5 6 10	21	44	SS-11	-	29	44	14	9	4	NP	NP	NP	17	A-1-b (0)	
		35																
		36																
		37																
		38																
		39	4 9 9	23	83	SS-12	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
		40																
		41																
	663.6	42																
VERY DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET.		43																
	661.2	44	23 43 32	97	94	SS-13	-	-	-	-	-	-	-	-	-	21	A-1-b (V)	
HARD, GRAY **SILT AND CLAY**, SOME FINE GRAVEL, LITTLE COARSE TO FINE SAND, DAMP. -ROCK FRAGMENTS PRESENT IN SS-13B	660.6	45 EOB					4.5+	-	-	-	-	-	-	-	-	11	A-6a (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 18.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 300 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 225+01.50 / 55.6' LT	**EXPLORATION ID B-100-3-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / C.D.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-71 SB		
PID: 89464 BR ID: N/A	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 706.0 (MSL) EOB: 30.0 ft.		PAGE 1 OF 1
START: 2/6/15 END: 2/6/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.946438, -83.014870		

MATERIAL DESCRIPTION AND NOTES	ELEV. 706.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.3' - TOPSOIL (3.0")	705.7																	
HARD, REDDISH BROWN **CLAY**, SOME SILT, LITTLE COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP. -ROOT FIBERS PRESENT IN SS-1	703.0	1 2 3	7 5 7	16	67	SS-1	4.5+	15	7	10	31	37	43	20	23	16	A-7-6 (12)	
DENSE TO VERY DENSE, BROWN **GRAVEL**, LITTLE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, DAMP.	698.0	4 5 6 7	31 24 21	58	39	SS-2	-	-	-	-	-	-	-	-	-	3	A-1-a (V)	
			18 21 15	47	100	SS-3	-	71	10	5	10	4	20	17	3	5	A-1-a (0)	
DENSE TO VERY DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP.	693.0	8 9 10	12 15 13	36	100	SS-4	-	-	-	-	-	-	-	-	-	3	A-1-b (V)	
		11 12 13	17 20 29	63	100	SS-5	-	62	15	7	14	2	NP	NP	NP	3	A-1-b (0)	
VERY DENSE, GRAY **GRAVEL**, TRACE COARSE TO FINE SAND, TRACE SILT, DAMP.		14	50/2"	-	50	SS-6	-	-	-	-	-	-	-	-	-	3	A-1-a (V)	
-ROCK FRAGMENTS PRESENT IN SS-6	684.0	16 17 18 19 20 21 22	37 50/5"	-	36	SS-7	-	-	-	-	-	-	-	-	-	3	A-1-a (V)	
		W	42 50/5"	-	18	SS-8	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
MEDIUM DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, LITTLE SILT, TRACE CLAY, MOIST TO WET.		23 24 25 26 27 28	7 7 9	21	100	SS-9	-	58	22	6	12	2	NP	NP	NP	11	A-1-a (0)	
-ROCK FRAGMENTS PRESENT IN SS-10		29 EOB	8 8 8	21	100	SS-10	-	-	-	-	-	-	-	-	-	22	A-1-a (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 19.0' AND AT COMPLETION @ 23.4'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 200 LBS BENTONITE CHIPS AND SOIL CUTTINGS

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 12:59 - U:\GI\PROJECTS\2013\W-13-072.GPJ

DLZ Ohio, Inc. * 6121 Huntley Road, Columbus, Ohio 43229 * (614) 888-0040

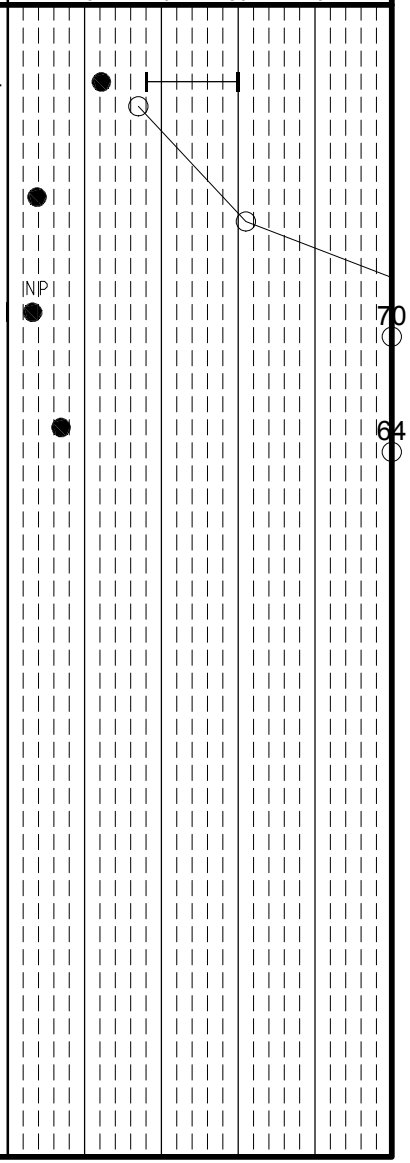
Client: ms consultants | *Project:* FRA-70-8.93 | *Job No.* 0221-1004.01

LOG OF: Boring B-101-0-09 | *Location:* Sta. 226+52.84, 34.1' LT., BL I-71 SB | *Date Drilled:* 8/21/2009

WATER OBSERVATIONS:
Water seepage at: None
Water level at completion: None
FIELD NOTES:

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	Graphic Log	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0.3	706.6						Topsoil - 3"							
		12 9 8	11	1		4.5+	POSSIBLE FILL: Hard brown SILT AND CLAY (A-6a), little fine to coarse sand, trace gravel; damp.		5	6	---	12	43	34
3.5	703.4													
5		24 15 15	9	2			POSSIBLE FILL: Dense to very dense brown GRAVEL (A-1-a), little fine to coarse sand, trace to little silt; damp.							
		5 34 35	11	3					75	9	---	6	--10--	
10.0	696.9	17 35 28	12	4										
							Bottom of Boring - 10.0'							

STANDARD PENETRATION (N60)
Natural Moisture Content, % -
PL — LL
Blows per foot - ○ / Non-Plastic - NP
10 20 30 40



RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: CME-55 (SN 386345)	STATION / OFFSET: 226+56.20 / 52.9' LT	**EXPLORATION ID B-102-2-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / N.A.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-71 SB		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 10/20/14	ELEVATION: 706.1 (MSL) EOB: 45.0 ft.		PAGE 1 OF 2
START: 2/26/15 END: 2/26/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 92	LAT / LONG: 39.946803, -83.015140		

MATERIAL DESCRIPTION AND NOTES	ELEV. 706.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.3' - ASPHALT (4.0")	705.8																	
1.0' - CONCRETE (12.0")	704.8																	
0.3' - AGGREGATE BASE (3.0")	704.5																	
MEDIUM DENSE, BROWNISH GRAY **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP.	703.1		5 5 7	18	56	SS-1	-	-	-	-	-	-	-	-	-	10	A-2-6 (V)	
VERY DENSE, BROWNISH GRAY **GRAVEL**, "AND" COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT THROUGHOUT			6 17 19	54	100	SS-2	-	53	18	15	10	4	NP	NP	NP	4	A-1-a (0)	
	698.1		14 24 20	66	100	SS-3	-	-	-	-	-	-	-	-	-	5	A-1-a (V)	
MEDIUM DENSE TO DENSE, BROWNISH GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST.			10 10 7	26	100	SS-4	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
			4 7 3	15	56	SS-5	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
	690.6		11 13 11	36	78	SS-6	-	66	13	4	12	5	23	19	4	6	A-1-b (0)	
DENSE, GRAY **GRAVEL**, LITTLE COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		W	11 14 17	47	0	SS-7	-	-	-	-	-	-	-	-	-	-		
			14	-	100	2S-7A	-	73	12	4	7	4	NP	NP	NP	11	A-1-a (0)	
-ROCK FRAGMENTS PRESENT IN SS-8			11 17 14	47	44	SS-8	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
	684.1																	
MEDIUM DENSE TO DENSE, GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST TO WET.			6 11 13	36	100	SS-9	-	-	-	-	-	-	-	-	-	19	A-1-b (V)	
-ROCK FRAGMENTS PRESENT THROUGHOUT			4 7 7	21	100	SS-10	-	59	15	6	14	6	24	19	5	12	A-1-b (0)	

PID: 89464	BR ID: N/A	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 226+56.20 / 52.9 LT	START: 2/26/15	END: 2/26/15	PG 2 OF 2	B-102-2-14

MATERIAL DESCRIPTION AND NOTES	ELEV. 676.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
MEDIUM DENSE TO DENSE, GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST TO WET. *(same as above)*	674.1	31																
DENSE TO VERY DENSE, GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST TO WET.		32																
		33																
		34	16 27 11	57	100	SS-11	-	-	-	-	-	-	-	-	-	14	A-1-b (V)	
		35																
		36																
		37																
		38																
-ROCK FRAGMENTS PRESENT THROUGHOUT		39	8 14 15	44	100	SS-12	-	32	36	13	13	6	NP	NP	NP	24	A-1-b (0)	
		40																
		41																
		42																
		43																
	661.1	44	14 28 37	98	100	SS-13	-	-	-	-	-	-	-	-	-	18	A-1-b (V)	
EOB		45																

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 17.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 275 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / J.K.	DRILL RIG: MOBILE B-53 (SN 624400)	STATION / OFFSET: 228+05.59 / 58.8' LT	**EXPLORATION ID B-102-4-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / C.D.	HAMMER: AUTOMATIC	ALIGNMENT: BL I-71 SB		
PID: 89464 BR ID: N/A	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 4/26/13	ELEVATION: 705.2 (MSL) EOB: 49.4 ft.		PAGE 1 OF 2
START: 2/4/15 END: 2/4/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 77.7	LAT / LONG: 39.947144, -83.015436		

MATERIAL DESCRIPTION AND NOTES	ELEV. 705.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.2' - TOPSOIL (2.0")	705.0																	
FILL: VERY DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST. -ROOT FIBERS AND IRON STAINING PRESENT IN SS-1	702.2	1	9 50/2"	-	88	SS-1	-	-	-	-	-	-	-	-	-	10	A-2-6 (V)	
DENSE TO VERY DENSE, BROWN **GRAVEL**, LITTLE COARSE TO FINE SAND, LITTLE SILT, TRACE CLAY, DAMP.		4	15 13 23	47	100	SS-2	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	
	697.2	7	8 32 25	74	78	SS-3	-	71	10	5	11	3	NP	NP	NP	4	A-1-a (0)	
LOOSE TO MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP TO WET.		9	18 11 9	26	83	SS-4	-	-	-	-	-	-	-	-	-	5	A-1-b (V)	
		12	20 11 9	26	94	SS-5	-	56	14	7	17	6	20	17	3	6	A-1-b (0)	
		14	6 7 10	22	50	SS-6	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
		17	4 5 5	13	39	SS-7	-	64	9	6	16	5	25	19	6	12	A-1-b (0)	
-ROCK FRAGMENTS PRESENT IN SS-7 AND SS-8	683.2	W 18																
		19	6 5 3	10	67	SS-8	-	-	-	-	-	-	-	-	-	23	A-1-b (V)	
VERY DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST.		24	19 28 40	88	100	SS-9	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
	678.2																	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		29	7 8 11	25	100	SS-10	-	-	-	-	-	-	-	-	-	11	A-1-a (V)	

PID: 89464	BR ID: N/A	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 228+05.59 / 58.8 LT	START: 2/4/15	END: 2/4/15	PG 2 OF 2	B-102-4-14

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**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. *(same as above)*	675.2	31																
-HEAVING SANDS ENCOUNTERED @ 32.0'		32																
		33																
		34	14 12 12	31	100	SS-11	-	69	20	4	5	2	NP	NP	NP	12	A-1-a (0)	
-INTRODUCED WATER @ 35.0'		35																
		36																
	668.2	37																
VERY DENSE, GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		38																
		39	17 21 25	60	100	SS-12	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
		40																
	663.2	41																
DENSE, BROWN AND BLACK **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST.		42																
		43																
		44	12 21 14	45	94	SS-13	-	-	-	-	-	-	-	-	-	17	A-1-b (V)	
	658.2	45																
HARD, GRAY **SANDY SILT**, "AND" FINE GRAVEL, LITTLE CLAY, DAMP.		46																
		47																
		48																
	655.8	49	24 50/5"	-	100	SS-14	4.5+	37	10	13	24	16	22	13	9	9	A-4a (1)	
EOB																		

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 18.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 200 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: CME 750 (SN 98048)	STATION / OFFSET: 3016+76.27 / 75.2' RT	**EXPLORATION ID B-102-6-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / N.A.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C3		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 10/20/14	ELEVATION: 700.5 (MSL) EOB: 44.0 ft.		PAGE 1 OF 2
START: 2/6/15 END: 2/6/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 92.9	LAT / LONG: 39.947404, -83.015823		

MATERIAL DESCRIPTION AND NOTES	ELEV. 700.5	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
0.2' - TOPSOIL (2.0")	700.3																	
MEDIUM DENSE, GRAY **GRAVEL**, LITTLE COARSE TO FINE SAND, LITTLE SILT, TRACE CLAY, MOIST.		1	10 8 3	17	39	SS-1	-	76	7	3	11	3	NP	NP	NP	8	A-1-a (0)	
-COBBLES PRESENT @ 4.0'		2																
		3																
		4	10 5 5	15	33	SS-2	-	-	-	-	-	-	-	-	-	10	A-1-a (V)	
		5																
		6	6 6 4	15	22	SS-3	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	
	692.5	7																
LOOSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP.		8																
	690.0	9	2 3 5	12	33	SS-4	-	64	6	5	17	8	30	19	11	14	A-2-6 (0)	
LOOSE TO MEDIUM DENSE, BROWN **GRAVEL**, LITTLE COARSE TO FINE SAND, LITTLE SILT, TRACE CLAY, MOIST TO WET.		10																
		11 W																
		12	1 1 2	5	44	SS-5	-	-	-	-	-	-	-	-	-	14	A-1-a (V)	
		13																
-INTRODUCED MUD @ 15.0'		14	2 3 4	11	33	SS-6	-	-	-	-	-	-	-	-	-	19	A-1-a (V)	
	685.0	15																
DENSE TO VERY DENSE, BROWN **GRAVEL**, LITTLE COARSE TO FINE SAND, LITTLE SILT, TRACE CLAY, MOIST.		16																
-ROCK FRAGMENTS PRESENT IN SS-7		17	13 15 17	48	100	SS-7	-	68	12	5	13	2	NP	NP	NP	13	A-1-a (0)	
		18																
		19	13 15 23	57	50	SS-8	-	-	-	-	-	-	-	-	-	10	A-1-a (V)	
		20																
		21																
		22																
		23																
		24	15 17 23	60	56	SS-9	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	
	673.5	25																
MEDIUM DENSE, GRAY **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST.		26																
		27																
		28																
		29	18 10 9	29	50	SS-10	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	

PID: 89464	BR ID: N/A	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 3016+76.27 / 75.2 RT	START: 2/6/15	END: 2/6/15	PG 2 OF 2	B-102-6-14

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, GRAY **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST. *(same as above)*	670.5	31																
	668.5	32																
VERY DENSE, GRAY **GRAVEL WITH SAND AND SILT**, TRACE CLAY, MOIST.		33																
-ROCK FRAGMENTS PRESENT IN SS-11		34	19 13 45	87	100	SS-11	-	21	3	45	29	2	NP	NP	NP	17	A-2-4 (0)	
	663.5	35																
VERY DENSE, GRAY AND BLACK **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST.		36																
		37																
-HEAVING SANDS ENCOUNTERED @ 38.5'		38																
		39	25 25 26	77	100	SS-12	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
		40																
		41																
		42																
-ROCK FRAGMENTS PRESENT IN SS-13		43																
AUGER REFUSAL @ 44.0'	656.5 EOB	44	50/2"	-	100	SS-13	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 11.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: CME 750 (SN 98048)	STATION / OFFSET: 3015+16.32 / 74.2' RT	**EXPLORATION ID B-103-1-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / N.A.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C3		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 10/20/14	ELEVATION: 703.3 (MSL) EOB: 54.3 ft.		PAGE 1 OF 2
START: 3/26/15 END: 3/27/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 92.9	LAT / LONG: 39.947764, -83.016137		

MATERIAL DESCRIPTION AND NOTES	ELEV. 703.3	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
0.1' - TOPSOIL (1.0")	703.2																	
STIFF TO VERY STIFF, DARK GRAY TO DARK GRAYISH BROWN **CLAY**, LITTLE TO "AND" SILT, TRACE TO SOME COARSE TO FINE SAND, TRACE TO SOME FINE GRAVEL, DAMP TO MOIST.		1	5 4 3	11	33	SS-1	1.50	-	-	-	-	-	-	-	-	28	A-7-6 (V)	
		2																
		3																
		4	1 6 7	20	100	SS-2	3.50	5	3	3	58	31	54	25	29	23	A-7-6 (18)	
		5																
		6																
		7	2 4 6	15	100	SS-3	3.50	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
		8																
-ROCK FRAGMENTS PRESENT IN SS-4		9	1 4 4	12	78	SS-4	1.50	33	21	7	15	24	43	21	22	18	A-7-6 (4)	
	692.8	10																
MEDIUM DENSE TO DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		11	5 8 7	23	33	SS-5	-	-	-	-	-	-	-	-	-	4	A-1-a (V)	
-COBBLES PRESENT @ 13.0'		12																
		13																
		14	7 14 10	36	0	SS-6	-	-	-	-	-	-	-	-	-	-		
		15	4	-	100	3S-6A	-	69	19	5	6	1	NP	NP	NP	14	A-1-a (0)	
		16																
		17	7 4 5	14	0	SS-7	-	-	-	-	-	-	-	-	-	-		
	685.3	18	6	-	100	3S-7A	-	-	-	-	-	-	-	-	-	11	A-1-a (V)	
DENSE TO VERY DENSE, GRAY **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST.		19	8 9 12	32	100	SS-8	-	-	-	-	-	-	-	-	-	17	A-1-b (V)	
-HEAVING SANDS ENCOUNTERED @ 18.5'		20																
-INTRODUCED MUD @ 20.0'		21																
		22																
		23																
		24	7 10 10	30	100	SS-9	-	37	51	4	5	3	NP	NP	NP	13	A-1-b (0)	
		25																
		26																
		27																
		28																
		29	6 18 16	51	100	SS-10	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	

W

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 13:00 - U:\GI\PROJECTS\2013\W-13-072.GPJ

PID: 89464	BR ID: N/A	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 3015+16.32 / 74.2 RT	START: 3/26/15	END: 3/27/15	PG 2 OF 2	B-103-1-14

MATERIAL DESCRIPTION AND NOTES	ELEV. 673.3	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
DENSE TO VERY DENSE, GRAY **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST. *(same as above)*		31																
		32																
		33																
		34	7 16 16	48	100	SS-11	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
		35																
		36																
		37																
		38																
		39	21 10 12	33	67	SS-12	-	-	-	-	-	-	-	-	-	10	A-1-b (V)	
		40																
		41																
	661.3	42																
HARD, GRAY **SANDY SILT**, SOME CLAY, SOME FINE GRAVEL, DAMP.		43																
		44	10 34 45	119	100	SS-13	4.5+	23	13	17	25	22	22	12	10	10	A-4a (2)	
		45																
		46																
	656.3	47																
VERY DENSE, GRAY **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST.		48																
		49	17 27 30	86	100	SS-14	-	-	-	-	-	-	-	-	-	16	A-1-b (V)	
		50																
		51																
		52																
		53																
-ROCK FRAGMENTS PRESENT IN SS-15	649.0	54 EOB	30 50/4"	-	100	SS-15	-	34	39	13	8	6	NP	NP	NP	13	A-1-b (0)	

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 15.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 250 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: CME 750X (SN 310218)	STATION / OFFSET: 3013+70.11 / 102.6' RT	**EXPLORATION ID B-105-4-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / N.A.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C3		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 10/20/14	ELEVATION: 700.0 (MSL) EOB: 45.0 ft.		PAGE 1 OF 2
START: 2/17/15 END: 2/18/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 85.7	LAT / LONG: 39.948056, -83.016520		

MATERIAL DESCRIPTION AND NOTES	ELEV. 700.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.3' - TOPSOIL (4.0")	699.7																	
VERY STIFF TO HARD, BROWN **CLAY**, "AND" SILT, TRACE COARSE TO FINE SAND, DAMP TO MOIST. -ROOT FIBERS PRESENT IN SS-1		1 2 3 4 5	4 7 7	20	100	SS-1	4.25	0	1	5	40	54	54	22	32	24	A-7-6 (19)	
	694.5		2 3 3	9	33	SS-2	2.75	-	-	-	-	-	-	-	-	20	A-7-6 (V)	
LOOSE TO MEDIUM DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, DAMP TO MOIST. -IRON STAINING PRESENT IN SS-3		6 7 8	2 3 2	7	39	SS-3	-	-	-	-	-	-	-	-	-	9	A-2-6 (V)	
	689.5	W 9 10	2 3 5	11	44	SS-4	-	-	-	-	-	-	-	-	-	13	A-2-6 (V)	
VERY DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS AND PETROLEUM ODOR PRESENT IN SS-6 -COBBLES ENCOUNTERED @ 14.0'		W 11 12 13 14 15	9 20 30	71	100	SS-5	-	66	12	10	9	3	NP	NP	NP	14	A-1-a (0)	
	684.5		22 23 25	69	100	SS-6	-	-	-	-	-	-	-	-	-	10	A-1-a (V)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, WET. -HEAVING SANDS ENCOUNTERED @ 16.0' -INTRODUCED MUD @ 16.0'		16 17 18 19 20	3 5 7	17	100	SS-7	-	22	37	25	12	4	NP	NP	NP	21	A-1-b (0)	
			5 6 7	19	100	SS-8	-	-	-	-	-	-	-	-	-	25	A-1-b (V)	
	678.0	21 22 23																
MEDIUM DENSE, BROWN **SANDY SILT**, LITTLE FINE GRAVEL, TRACE CLAY, MOIST. -IRON STAINING PRESENT IN SS-9		24 25 26 27 28	3 7 7	20	100	SS-9	-	20	11	30	33	6	NP	NP	NP	19	A-4a (1)	
	673.0																	
DENSE TO VERY DENSE, GRAY **GRAVEL**, "AND" COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		29	13 15 12	39	100	SS-10	-	-	-	-	-	-	-	-	-	11	A-1-a (V)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 13:00 - U:\GI\PROJECTS\2013\W-13-072.GPJ

PID: 89464	BR ID: N/A	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 3013+70.11 / 102.6 RT	START: 2/17/15	END: 2/18/15	PG 2 OF 2	B-105-4-14

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, GRAY **GRAVEL**, "AND" COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. *(same as above)*	670.0	31																
		32																
		33																
		34	21 19 31	71	100	SS-11	-	55	29	7	6	3	NP	NP	NP	11	A-1-a (0)	
		35																
		36																
		37																
		38																
		39	19 28 29	81	78	SS-12	-	-	-	-	-	-	-	-	-	18	A-1-a (V)	
		40																
	658.0	41																
VERY DENSE, GRAY **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST.		42																
		43																
-ROCK FRAGMENTS PRESENT IN SS-13		44	20 28 31	84	100	SS-13	-	-	-	-	-	-	-	-	-	8	A-1-b (V)	
	655.0 EOB	45																

NOTES: SEEPAGE ENCOUNTERED @ 8.5'; GROUNDWATER ENCOUNTERED INITIALLY @ 11.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 200 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: CME 750 (SN 98048)	STATION / OFFSET: 3012+25.98 / 120.3' RT	**EXPLORATION ID B-105-6-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / N.A.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C3		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 10/20/14	ELEVATION: 703.0 (MSL) EOB: 35.0 ft.		PAGE 1 OF 2
START: 3/25/15 END: 3/25/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 92.9	LAT / LONG: 39.948373, -83.016857		

MATERIAL DESCRIPTION AND NOTES	ELEV. 703.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.3' - ASPHALT (4.0")	702.7																	
0.7' - FILL MATERIAL (8.0")	702.0																	
VERY STIFF, DARK GRAY TO DARK BROWNISH GRAY **CLAY**, "AND" SILT, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, MOIST.		1	3 5 6	17	89	SS-1	2.75	2	7	3	62	26	43	26	17	31	A-7-6 (11)	
		2																
		3																
		4	3 3 6	14	50	SS-2	-	-	-	-	-	-	-	-	-	24	A-7-6 (V)	
	697.5	5																
MEDIUM DENSE, BROWN **GRAVEL WITH SAND, SILT, AND CLAY**, MOIST.		6	1 5 6	17	33	SS-3	-	-	-	-	-	-	-	-	-	15	A-2-6 (V)	
	695.0	7																
MEDIUM DENSE TO DENSE, BROWN TO GRAY **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.		8 W																
		9	2 6 6	18	39	SS-4	-	60	25	7	5	3	NP	NP	NP	12	A-1-a (0)	
		10																
		11	2 6 8	21	44	SS-5	-	-	-	-	-	-	-	-	-	17	A-1-a (V)	
		12																
		13 W																
		14	4 5 4	14	56	SS-6	-	-	-	-	-	-	-	-	-	12	A-1-a (V)	
-PETROLEUM ODOR PRESENT IN SS-6 AND SS-7		15																
		16	6 7 4	17	100	SS-7	-	-	-	-	-	-	-	-	-	11	A-1-a (V)	
		17																
		18																
		19	11 17 14	47	100	SS-8	-	65	26	0	7	2	NP	NP	NP	10	A-1-a (0)	
-HEAVING SANDS ENCOUNTERED @ 20.0'		20																
		21																
		22																
		23																
		24	10 17 14	47	56	SS-9	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
		25																
		26																
	676.0	27																
VERY DENSE, GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST.		28																
		29	7 14 21	53	100	SS-10	-	38	32	7	13	10	NP	NP	NP	11	A-1-b (0)	

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 13:00 - U:\GI\PROJECTS\2013\W-13-072.GPJ

PID: 89464	BR ID: N/A	PROJECT: FRA-70-13.10 - PHASE 6A	STATION / OFFSET: 3012+25.98 / 120.3 RT	START: 3/25/15	END: 3/25/15	PG 2 OF 2	B-105-6-14

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
VERY DENSE, GRAY **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, MOIST. *(same as above)*	673.0	31 32 33																
-ROCK FRAGMENTS PRESENT IN SS-11	668.0	34 35 EOB	12 22 17	59	56	SS-11	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	

NOTES: SEEPAGE ENCOUNTERED @ 8.5'; GROUNDWATER INITIALLY ENCOUNTERED @ 13.5'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER 200 LBS BENTONITE CHIPS AND SOIL CUTTINGS

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: CME 750 (SN 98048)	STATION / OFFSET: 3010+61.70 / 149.1' RT	**EXPLORATION ID B-107-3-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / N.A.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C3		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.25" HSA	CALIBRATION DATE: 10/20/14	ELEVATION: 704.3 (MSL) EOB: 25.0 ft.		PAGE 1 OF 1
START: 2/4/15 END: 2/4/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 92.9	LAT / LONG: 39.948726, -83.017248		

MATERIAL DESCRIPTION AND NOTES	ELEV. 704.3	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' - TOPSOIL (3.0")	704.0																	
FILL: HARD, BROWN **CLAY**, "AND" SILT, TRACE COARSE TO FINE SAND, DAMP. -BRICK AND ROCK FRAGMENTS PRESENT IN SS-1	701.3		2 2 3	8	6	SS-1	4.5+	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
VERY STIFF, BROWN **CLAY**, "AND" SILT, TRACE COARSE TO FINE SAND, DAMP TO MOIST. -ROOT FIBERS PRESENT IN SS-2 AND SS-3	696.3		2 4 5	14	100	SS-2	3.75	0	1	3	48	48	55	24	31	27	A-7-6 (19)	
			3 3 8	17	100	SS-3	4.00	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND AND SILT**, TRACE CLAY, DAMP.	693.8		4 5 6	17	44	SS-4	-	44	14	9	24	9	26	18	8	7	A-2-4 (0)	
DENSE TO VERY DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST. -ROCK FRAGMENTS PRESENT THROUGHOUT			14 19 23	63	67	SS-5	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
-COBBLES PRESENT @ 15.0'	688.8		6 15 16	47	67	SS-6	-	-	-	-	-	-	-	-	-	9	A-1-b (V)	
MEDIUM DENSE TO DENSE, BROWN **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT IN SS-7		W	4 5 7	18	56	SS-7	-	72	16	4	6	2	NP	NP	NP	13	A-1-a (0)	
-HEAVING SANDS ENCOUNTERED @ 20.0'	682.3		14 13 16	44	100	SS-8	-	-	-	-	-	-	-	-	-	9	A-1-a (V)	
HARD, GRAY **SANDY SILT**, LITTLE FINE GRAVEL, LITTLE CLAY, DAMP.	679.3	EOB	21 27 29	84	39	SS-9	4.5+	16	15	21	34	14	20	13	7	8	A-4a (3)	

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 16.0'

ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER SOIL CUTTINGS

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 13:01 - U:\GI\PROJECTS\2013\W-13-072.GPJ

RESOURCE INTERNATIONAL, INC.

PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / OPERATOR: RII / S.B.	DRILL RIG: CME 750 (SN 98048)	STATION / OFFSET: 3009+90.45 / 162.2' RT	**EXPLORATION ID B-107-4-14**	
TYPE: STRUCTURE	SAMPLING FIRM / LOGGER: RII / N.A.	HAMMER: AUTOMATIC	ALIGNMENT: BL RAMP C3		
PID: 89464 BR ID: N/A	DRILLING METHOD: 4.5" CFA	CALIBRATION DATE: 10/20/14	ELEVATION: 705.1 (MSL) EOB: 20.0 ft.		PAGE 1 OF 1
START: 2/4/15 END: 2/4/15	SAMPLING METHOD: SPT	ENERGY RATIO (%): 92.9	LAT / LONG: 39.948868, -83.017411		

MATERIAL DESCRIPTION AND NOTES	ELEV. 705.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
0.4' - TOPSOIL (5.0")	704.7																	
VERY STIFF, BROWN **SILT AND CLAY**, LITTLE COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP. -ROOT FIBERS PRESENT IN SS-1	702.1		3 7 8	23	33	SS-1	-	-	-	-	-	-	-	-	-	12	A-6a (V)	
VERY STIFF, DARK BROWN **CLAY**, "AND" SILT, TRACE FINE SAND, TRACE FINE GRAVEL, MOIST. -ROOT FIBERS PRESENT IN SS-2	699.6		5 6 7	20	100	SS-2	3.50	1	0	10	45	44	47	22	25	24	A-7-6 (15)	
MEDIUM DENSE, BROWN **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP TO MOIST. -WOOD FRAGMENTS PRESENT IN SS-4			2 4 5	14	67	SS-3	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
			3 6 11	26	100	SS-4	-	37	21	18	19	5	NP	NP	NP	6	A-1-b (0)	
-ROCK FRAGMENTS PRESENT IN SS-5	688.1	W	7 4 3	11	50	SS-5	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	
VERY DENSE, BROWN **GRAVEL**, SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT IN SS-6	685.1	EOB	12 21 24	68	100	SS-6	-	66	16	6	10	2	NP	NP	NP	10	A-1-a (0)	

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 13.5' AND AT COMPLETION @ 15.0'

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

2014 ODOT BORING LOG-RII NE BRIDGE ID - OH DOT.GDT - 7/12/19 13:01 - U:\GI\PROJECTS\2013\W-13-072.GPJ

APPENDIX IV

MSE WALL CALCULATIONS

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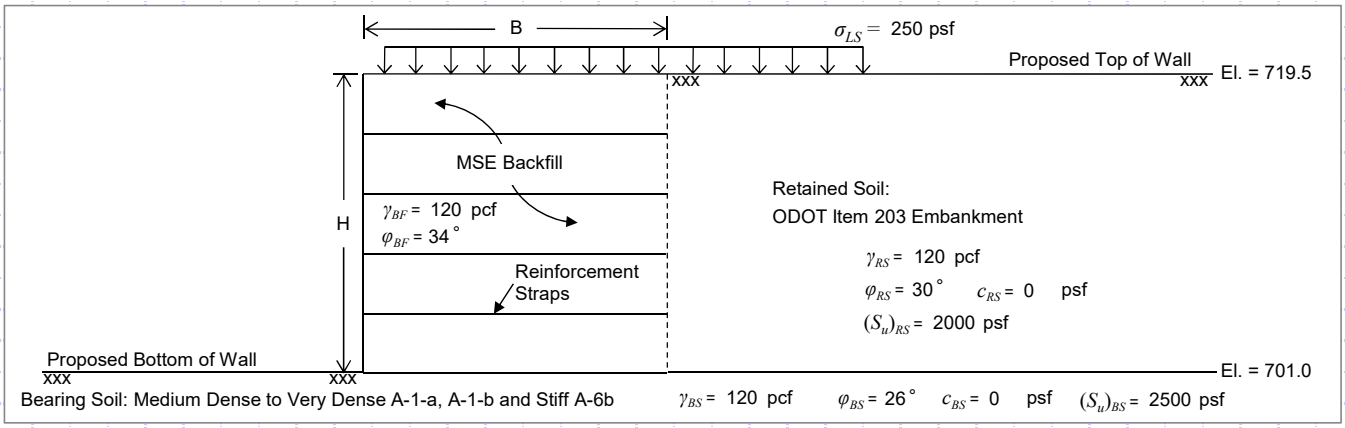
JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	1	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 200+00 to 203+00

Retaining Wall W2 - Sta. 200+00 to 203+00 - B-098-2-13 and B-099-2-13 - 38.1 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.5	ft
MSE Wall Width (Reinforcement Length), (B) =	13.0	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(S_u)_{BS}$] =	2500	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	12.5	ft

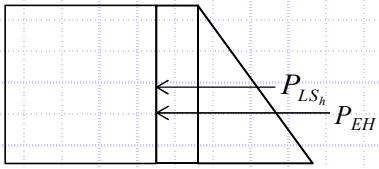
LRFD Load Factors

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

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3

Sliding Force:



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

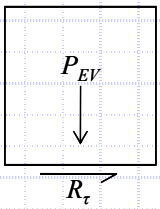
$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \text{½(120 pcf)(18.5 ft)²(0.297)(1.5)} = 9.15 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = \text{(250 psf)(18.5 ft)(0.297)(1.75)} = 2.4 \text{ kip/ft}$$

$$P_H = \text{9.15 kip/ft + 2.4 kip/ft} = 11.55 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:



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

$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(18.5 ft)(13.0 ft)(1.00)} = 28.86 \text{ kip/ft}$$

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

$$\tan\delta = \text{tan(26) ≤ tan(34)} \longrightarrow \text{0.49 ≤ 0.67} \longrightarrow \tan\delta = 0.49$$

$$R_\tau = \text{(28.86 kip/ft)(0.49)} = 14.14 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$$P_H \le R_\tau \cdot \phi_\tau \longrightarrow \text{11.55 kip/ft ≤ (14.14 kip/ft)(1.0) = 14.14 kip/ft} \longrightarrow \text{11.55 kip/ft ≤ 14.14 kip/ft}$$ **OK**

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

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	2	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 200+00 to 203+00

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.5	ft
MSE Wall Width (Reinforcement Length), (B) =	13.0	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] =	2500	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	12.5	ft

LRFD Load Factors

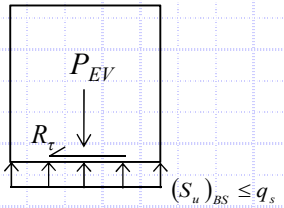
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

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



$(S_u)_{BS}$ = 2.50 ksf

$q_s = \sigma_v / 2$ = (2.22 ksf) / 2 = 1.11 ksf

$\sigma_v = P_{EV} / B$ = (28.86 kip/ft) / (13 ft) = 2.22 ksf

R_τ = (2.50 ksf ≤ 1.11 ksf)(13.0 ft) = 14.43 kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 11.55 kip/ft ≤ (14.43 kip/ft)(1.0) = 14.43 kip/ft ⟶ 11.55 kip/ft ≤ 14.43 kip/ft **OK**

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

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	3	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 200+00 to 203+00

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.5	ft
MSE Wall Width (Reinforcement Length), (B) =	13.0	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

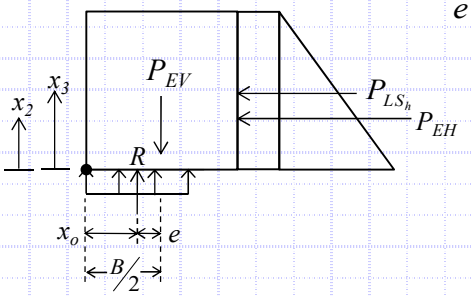
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	2500	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	12.5	ft

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



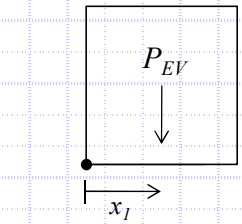
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}} = (187.59 \text{ kip·ft/ft} - 78.66 \text{ kip·ft/ft}) / (28.86 \text{ kip/ft}) = 3.77 \text{ ft}$$

M_{EV} = 187.59 kip·ft/ft
M_H = 78.66 kip·ft/ft
P_{EV} = 28.86 kip/ft
} Defined below

$e =$ (13 ft)/2 - 3.77 ft = 2.73 ft

Resisting Moment, M_{EV}:



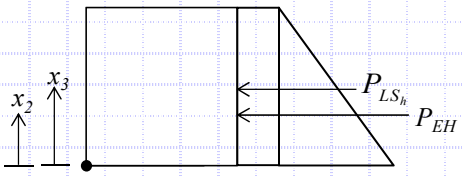
$$M_{EV} = P_{EV}(x_1)$$

$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(18.5 \text{ ft})(13.0 \text{ ft})(1.00) = 28.86 \text{ kip/ft}$$

$$x_1 = B/2 = (13.0 \text{ ft}) / 2 = 6.50 \text{ ft}$$

$$M_{EV} = (28.86 \text{ kip/ft})(6.50 \text{ ft}) = 187.59 \text{ kip·ft/ft}$$

Overturning Moment, M_H:



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

$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \tfrac{1}{2}(120 \text{ pcf})(18.5 \text{ ft})^2(0.297)(1.5) = 9.15 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf})(18.5 \text{ ft})(0.297)(1.75) = 2.4 \text{ kip/ft}$$

$$x_2 = H/3 = (18.5 \text{ ft}) / 3 = 6.17 \text{ ft}$$

$$x_3 = H/2 = (18.5 \text{ ft}) / 2 = 9.25 \text{ ft}$$

$$M_H = (9.15 \text{ kip/ft})(6.17 \text{ ft}) + (2.4 \text{ kip/ft})(9.25 \text{ ft}) = 78.66 \text{ kip·ft/ft}$$

Check Eccentricity

$e < e_{max} \longrightarrow$ 2.73 ft < 4.33 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} = (13.0 \text{ ft}) / 3 = 4.33 \text{ ft}$

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	4	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 200+00 to 203+00

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.5	ft
MSE Wall Width (Reinforcement Length), (B) =	13.0	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

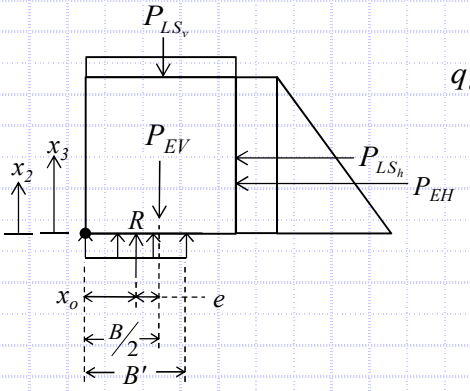
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	2500	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	12.5	ft

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



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

$B' = B - 2e$ = 13.0 ft - 2(1.76 ft) = 9.48 ft

$e = B/2 - x_o$ = (13.0 ft) / 2 - 4.74 ft = 1.76 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (290.22 kip·ft/ft - 78.68 kip·ft/ft) / 44.65 kip/ft = 4.74 ft

q_{eq} = (44.65 kip/ft) / (9.48 ft) = 4.71 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)(18.5 ft)(13.0 ft)(1.35)](6.5 ft) + [(250 psf)(13.0 ft)(1.75)](6.5 ft) = 290.22 kip·ft/ft

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

M_H = [½(120 pcf)(18.5 ft)²(0.297)(1.5)](6.17 ft) + [(250 psf)(18.5 ft)(0.297)(1.75)](9.25 ft) = 78.68 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)(18.5 ft)(13.0 ft)(1.35) + (250 psf)(13.0 ft)(1.75) = 44.65 kip/ft

Check Bearing Resistance - Drained Condition

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

$N_{cm} = N_c s_c i_c$ = 22.32 $\quad N_{qm} = N_q s_q d_q i_q$ = 13.33 $\quad N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 12.51

N_c = 22.25
s_c = 1+(9.48 ft/1939 ft)(11.85/22.25) = 1.003
i_c = 1.000 (Assumed)

N_q = 11.85
s_q = 1.002
d_q = 1+2tan(26°)[1-sin(26°)]²tan⁻¹(4.0 ft/9.48 ft) = 1.123
i_q = 1.000 (Assumed)
C_{wq} = 12.5 ft > 4.0 ft = 1.000

N_γ = 12.54
s_γ = 0.998
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 12.5 ft < 1.5(9.48 ft) + 4.0 ft = 0.940

q_n = (0 psf)(22.317) + (120 pcf)(4.0 ft)(13.334)(1.000) + ½(120 pcf)(9.5 ft)(12.515)(0.940) = 13.09 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

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

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 4.71 ksf ≤ (13.09 ksf)(0.65) = 8.51 ksf ⟶ 4.71 ksf ≤ 8.51 ksf **OK**

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	5	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 200+00 to 203+00

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.5	ft
MSE Wall Width (Reinforcement Length), (B) =	13.0	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	2500	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	12.5	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: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 5.150 $N_{qm} = N_q s_q d_q i_q$ = 1.000 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

N_c = 5.140
s_c = 1+(9.48 ft/[(5)(1939 ft)]) = 1.001
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/9.48 ft) = 1.000
i_q = 1.000 (Assumed)
C_{wq} = 12.5 ft > 4.0 ft = 1.000

N_γ = 0.000
s_γ = 1.000
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 12.5 ft < 1.5(9.48 ft) + 4.0 ft = 0.940

q_n = (2500 psf)(5.150) + (120 pcf)(4.0 ft)(1.000)(1.000) + ½(120 pcf)(9.5 ft)(0.000)(0.940) = 13.36 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 4.71 ksf ≤ (13.36 ksf)(0.65) = 8.68 ksf ⟶ 4.71 ksf ≤ 8.68 ksf **OK**

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

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	6	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 200+00 to 203+00

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	18.5	ft
MSE Wall Width (Reinforcement Length), (B) =	13.0	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

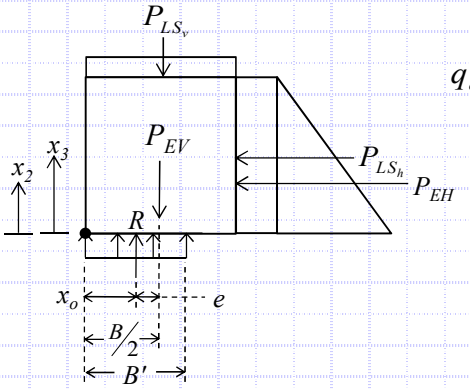
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	26	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	2500	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	12.5	ft

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



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

$B' = B - 2e$ = 13.0 ft - 2(1.57 ft) = 9.86 ft

$e = B/2 - x_o$ = (13.0 ft) / 2 - 4.93 ft = 1.57 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (208.72 kip·ft/ft - 50.34 kip·ft/ft) / 32.11 kip/ft = 4.93 ft

q_{eq} = (32.11 kip/ft) / (9.86 ft) = 3.26 ksf

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

M_V = [(120 pcf)(18.5 ft)(13.0 ft)(1.00)](6.5 ft) + [(250 psf)(13.0 ft)(1.00)](6.5 ft) = 208.72 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(120 pcf)(18.5 ft)²(0.297)(1.00)](6.17 ft) + [(250 psf)(18.5 ft)(0.297)(1.00)](9.25 ft) = 50.34 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)(18.5 ft)(13.0 ft)(1.00) + (250 psf)(13.0 ft)(1.00) = 32.11 kip/ft

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 100% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Along Wall Facing
B-098-2-13	0.492 in	0.437 in	0 days		
B-099-2-13	1.635 in	1.314 in	35 days	165 ft	1/2260

W-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 200+00 to 203+00

Calculated By: BRT Date: 6/23/2019
Checked By: JPS Date: 6/24/2019

Boring B-098-2-13

H=	10.2	ft	Total wall height
B'=	6.3	ft	Effective footing width due to eccentricity
D_w =	12.5	ft	Depth below bottom of footing
q_e =	1,880	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	2.5	2.5	1.3	135	338	169	169	4,169					58	106	517	0.20	0.978	1,838	2,007	0.005	0.062	0.498	937	1,106	0.004	0.047
	A-1-b	G	2.5	5.0	2.5	3.8	135	675	506	506	4,506					58	85	359	0.60	0.758	1,426	1,932	0.004	0.049	0.469	882	1,388	0.003	0.037
2	A-1-a	G	5.0	7.5	2.5	6.3	135	1,013	844	844	4,844					49	63	231	0.99	0.553	1,040	1,884	0.004	0.045	0.410	772	1,615	0.003	0.037
	A-1-a	G	7.5	10.0	2.5	8.8	135	1,350	1,181	1,181	5,181					49	58	204	1.39	0.423	795	1,976	0.003	0.033	0.350	657	1,838	0.002	0.028
3	A-1-b	G	10.0	13.0	3.0	11.5	125	1,725	1,538	1,538	5,538					22	24	83	1.83	0.332	625	2,162	0.005	0.064	0.294	552	2,090	0.005	0.058
	A-1-b	G	13.0	16.0	3.0	14.5	125	2,100	1,913	1,788	5,788					22	23	81	2.30	0.268	504	2,292	0.004	0.048	0.247	464	2,252	0.004	0.045
	A-1-b	G	16.0	19.0	3.0	17.5	125	2,475	2,288	1,976	5,976					22	22	79	2.78	0.224	422	2,397	0.003	0.038	0.211	398	2,373	0.003	0.036
4	A-1-a	G	19.0	24.0	5.0	21.5	130	3,125	2,800	2,238	6,238					30	29	96	3.41	0.184	346	2,584	0.003	0.039	0.177	332	2,570	0.003	0.038
	A-1-a	G	24.0	29.0	5.0	26.5	130	3,775	3,450	2,576	6,576					30	28	92	4.21	0.150	282	2,858	0.002	0.029	0.146	274	2,851	0.002	0.029
5	A-1-a	G	29.0	34.0	5.0	31.5	120	4,375	4,075	2,889	6,889					9	8	54	5.00	0.126	238	3,127	0.003	0.038	0.124	233	3,123	0.003	0.038
	A-1-a	G	34.0	39.0	5.0	36.5	120	4,975	4,675	3,177	7,177					9	8	54	5.79	0.109	206	3,383	0.003	0.031	0.108	203	3,380	0.003	0.030
6	A-1-a	G	39.0	45.0	6.0	42.0	130	5,755	5,365	3,524	7,524					38	31	101	6.67	0.095	179	3,703	0.001	0.015	0.094	177	3,701	0.001	0.015
																						Total Settlement:		0.492 in			Total Settlement:		0.437 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$, Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 200+00 to 203+00

Calculated By: BRT Date: 6/23/2019
Checked By: JPS Date: 6/24/2019

Boring B-099-2-13

H=	18.5	ft	Total wall height
B'=	9.9	ft	Effective footing width due to eccentricity
D_w =	12.5	ft	Depth below bottom of footing
q_e =	3,260	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-6b	C	0.0	3.5	3.5	1.8	120	420	210	210	4,210	40	0.270	0.027	0.585				0.18	0.984	3,207	3,417	0.072	0.867	0.499	1,626	1,836	0.056	0.674
2	A-2-6	G	3.5	6.0	2.5	4.8	130	745	583	583	4,583					32	45	150	0.48	0.831	2,710	3,292	0.013	0.150	0.482	1,570	2,153	0.009	0.113
3	A-1-b	G	6.0	8.5	2.5	7.3	130	1,070	908	908	4,908					36	46	151	0.73	0.678	2,210	3,117	0.009	0.106	0.451	1,469	2,376	0.007	0.083
	A-1-b	G	8.5	11.0	2.5	9.8	130	1,395	1,233	1,233	5,233					36	42	137	0.98	0.556	1,813	3,045	0.007	0.086	0.412	1,342	2,574	0.006	0.070
4	A-1-a	G	11.0	14.0	3.0	12.5	125	1,770	1,583	1,583	5,583					13	14	63	1.26	0.458	1,493	3,075	0.014	0.165	0.368	1,200	2,783	0.012	0.140
	A-1-a	G	14.0	17.0	3.0	15.5	125	2,145	1,958	1,770	5,770					13	14	62	1.57	0.381	1,243	3,013	0.011	0.134	0.325	1,061	2,831	0.010	0.118
	A-1-a	G	17.0	20.5	3.5	18.8	125	2,583	2,364	1,974	5,974					13	13	61	1.89	0.321	1,048	3,022	0.011	0.127	0.286	933	2,906	0.010	0.115
																					Total Settlement:		1.635 in			Total Settlement:		1.314 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(C_c)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 200+00 to 203+00

Calculated By: BRT Date: 06/23/2019
Checked By: JPS Date: 06/24/2019

Boring B-099-2-13

H=	18.5	ft	Total wall height
B'=	9.9	ft	Effective footing width due to eccentricity
D_w =	12.5	ft	Depth below bottom of footing
q_e =	3,260	psf	Equivalent bearing pressure at bottom of wall

	A-6b				
c_v =	300			ft^2/yr	Coefficient of consolitation
t =	35			days	Time following completion of construction
H_{dr} =	3.5			ft	Length of longest drainage path considered
T_v =	2.348				Time factor
U =	100			%	Degree of consolidation

$(S_c)_t$ = 1.314 in Settlement complete at 100% of primary consolidation

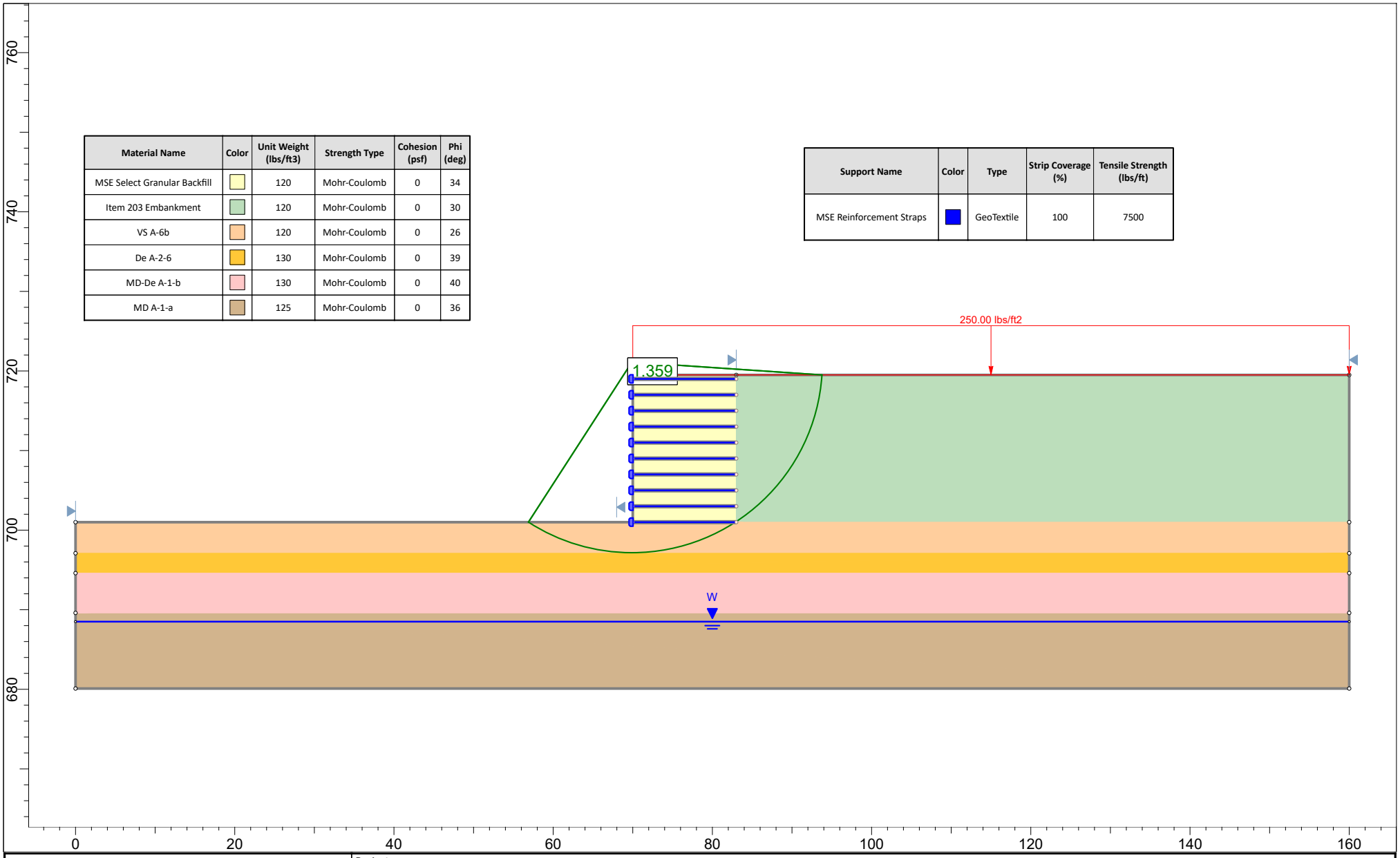
																					Total Settlement at Facing of Wall			Settlement Complete at 100% of Primary Consolidation	
Layer	Soil Type	Soil Type	Layer Depth (ft)		Layer Thickness (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (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-6b	C	0.0	3.5	3.5	1.8	120	420	210	210	4,210	40	0.270	0.027	0.585				0.18	0.499	1,626	1,836	0.056	0.674	0.674	0.674	0.674
2	A-2-6	G	3.5	6.0	2.5	4.8	130	745	583	583	4,583					32	45	150	0.48	0.482	1,570	2,153	0.009	0.113	0.113	0.113	0.113
3	A-1-b	G	6.0	8.5	2.5	7.3	130	1,070	908	908	4,908					36	46	151	0.73	0.451	1,469	2,376	0.007	0.083	0.153	0.083	0.153
	A-1-b	G	8.5	11.0	2.5	9.8	130	1,395	1,233	1,233	5,233					36	42	137	0.98	0.412	1,342	2,574	0.006	0.070		0.070	
4	A-1-a	G	11.0	14.0	3.0	12.5	125	1,770	1,583	1,583	5,583					13	14	63	1.26	0.368	1,200	2,783	0.012	0.140	0.374	0.140	0.374
	A-1-a	G	14.0	17.0	3.0	15.5	125	2,145	1,958	1,770	5,770					13	14	62	1.57	0.325	1,061	2,831	0.010	0.118		0.118	
	A-1-a	G	17.0	20.5	3.5	18.8	125	2,583	2,364	1,974	5,974					13	13	61	1.89	0.286	933	2,906	0.010	0.115		0.115	

1. $\sigma_p' = \sigma_{vo}'+\sigma_m$; Estimate σ_m of 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 = 0.10(Cc) for 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 (Cohesive 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: 0.000 in

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Select Granular Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
VS A-6b		120	Mohr-Coulomb	0	26
De A-2-6		130	Mohr-Coulomb	0	39
MD-De A-1-b		130	Mohr-Coulomb	0	40
MD A-1-a		125	Mohr-Coulomb	0	36

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



Resource International, Inc.
Planning | Engineering | Construction Management | Technology

SLIDEINTERPRET 8.020

Project	Retaining Wall W2 - Sta. 200+00 to 203+00 - MSE Wall Global Stability		
Analysis Description	18.5 ft Wall Height - Drained - Circular - Spencer		
Drawn By	BRT	*Scale* 1:200	*Company* Resource International, Inc.
Date	6/23/2019		*File Name* Retaining Wall W2 - Sta. 200+00 to 203+00 - Global Stability.slim

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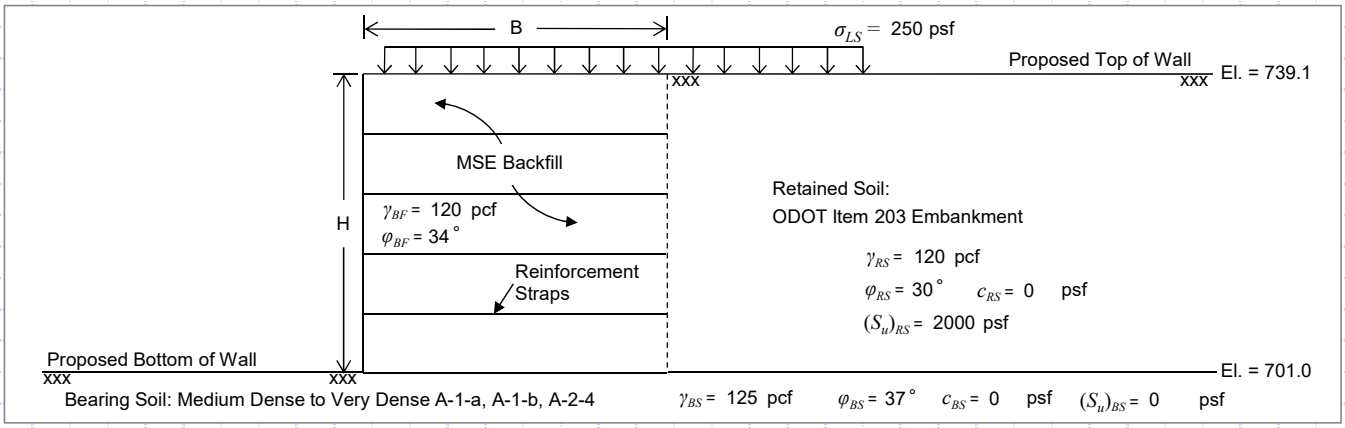
JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	1	OF	6
CALCULATED BY	BRT	DATE	6/22/2019
CHECKED BY	JPS	DATE	6/23/2019

Retaining Wall W2 - Sta. 203+00 to 212+25

Retaining Wall W2 - Sta. 203+00 to 212+25 - B-099-3-13, B-099-5-14, B-100-1-14, B-100-3-14, B-102-2-14 and B-102-4-14 - 38.1 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.1	ft
MSE Wall Width (Reinforcement Length), (B) =	26.7	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion [1], (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	37	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [$(S_u)_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	14.0	ft

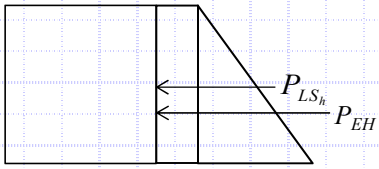
LRFD Load Factors

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

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3

Sliding Force:



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

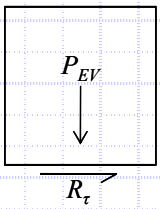
$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \text{½(120 pcf)(38.1 ft)²(0.297)(1.5)} = 38.8 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = \text{(250 psf)(38.1 ft)(0.297)(1.75)} = 4.95 \text{ kip/ft}$$

$$P_H = \text{38.8 kip/ft + 4.95 kip/ft} = 43.75 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:



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

$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(38.1 ft)(26.7 ft)(1.00)} = 122.07 \text{ kip/ft}$$

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

$$\tan\delta = \text{tan(37) ≤ tan(34)} \longrightarrow \text{0.75 ≤ 0.67} \longrightarrow \tan\delta = 0.67$$

$$R_\tau = \text{(122.07 kip/ft)(0.67)} = 81.79 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$$P_H \le R_\tau \cdot \phi_\tau \longrightarrow \text{43.75 kip/ft ≤ (81.79 kip/ft)(1.0) = 81.79 kip/ft} \longrightarrow \text{43.75 kip/ft ≤ 81.79 kip/ft}$$ **OK**

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

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JOB	FRA-70-13.10	NO.	W-13-072
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Retaining Wall W2 - Sta. 203+00 to 212+25

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.1	ft
MSE Wall Width (Reinforcement Length), (B) =	26.7	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	37	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	14.0	ft

LRFD Load Factors

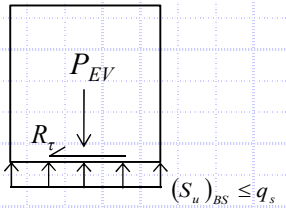
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

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



$(S_u)_{BS}$ = N/A ksf

$q_s = \sigma_v / 2$ = (4.57 ksf) / 2 = 2.29 ksf

$\sigma_v = P_{EV} / B$ = (122.07 kip/ft) / (26.7 ft) = 4.57 ksf

R_τ = (N/A ksf ≤ 2.29 ksf)(26.7 ft) = N/A kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ N/A ⟶ N/A

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

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Retaining Wall W2 - Sta. 203+00 to 212+25

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.1	ft
MSE Wall Width (Reinforcement Length), (B) =	26.7	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

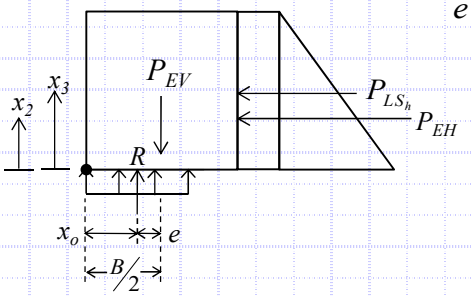
Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	37	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	14.0	ft

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



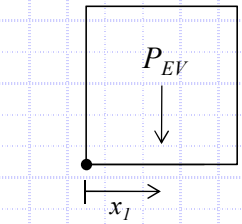
$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}} = (1629.63 \text{ kip·ft/ft} - 587.06 \text{ kip·ft/ft}) / (122.07 \text{ kip/ft}) = 8.54 \text{ ft}$$

M_{EV} = 1629.63 kip·ft/ft
M_H = 587.06 kip·ft/ft
P_{EV} = 122.07 kip/ft
} Defined below

$e =$ (26.7 ft)/2 - 8.54 ft = 4.81 ft

Resisting Moment, M_{EV}:



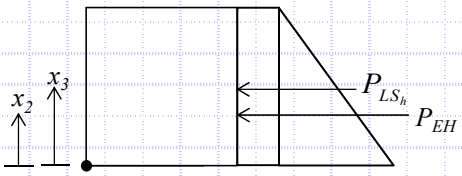
$$M_{EV} = P_{EV}(x_1)$$

$$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(38.1 \text{ ft})(26.7 \text{ ft})(1.00) = 122.07 \text{ kip/ft}$$

$$x_1 = B/2 = (26.7 \text{ ft}) / 2 = 13.35 \text{ ft}$$

$$M_{EV} = (122.07 \text{ kip/ft})(13.35 \text{ ft}) = 1629.63 \text{ kip·ft/ft}$$

Overturning Moment, M_H:



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

$$P_{EH} = \tfrac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH} = \tfrac{1}{2}(120 \text{ pcf})(38.1 \text{ ft})^2(0.297)(1.5) = 38.80 \text{ kip/ft}$$

$$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf})(38.1 \text{ ft})(0.297)(1.75) = 4.95 \text{ kip/ft}$$

$$x_2 = H/3 = (38.1 \text{ ft}) / 3 = 12.70 \text{ ft}$$

$$x_3 = H/2 = (38.1 \text{ ft}) / 2 = 19.05 \text{ ft}$$

$$M_H = (38.8 \text{ kip/ft})(12.7 \text{ ft}) + (4.95 \text{ kip/ft})(19.05 \text{ ft}) = 587.06 \text{ kip·ft/ft}$$

Check Eccentricity

$e < e_{max} \longrightarrow$ 4.81 ft < 8.90 ft **OK**

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (26.7 ft) / 3 = 8.90 ft

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Retaining Wall W2 - Sta. 203+00 to 212+25

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.1	ft
MSE Wall Width (Reinforcement Length), (B) =	26.7	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

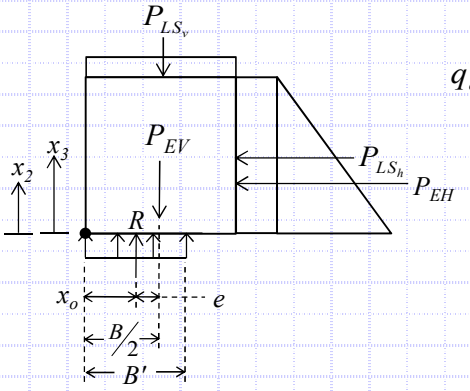
Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	37	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	14.0	ft

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



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

$B' = B - 2e$ = 26.7 ft - 2(3.33 ft) = 20.04 ft

$e = B/2 - x_o$ = (26.7 ft) / 2 - 10.02 ft = 3.33 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (2355.99 kip·ft/ft - 587.09 kip·ft/ft) / 176.48 kip/ft = 10.02 ft

q_{eq} = (176.48 kip/ft) / (20.04 ft) = 8.81 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)(38.1 ft)(26.7 ft)(1.35)](13.35 ft) + [(250 psf)(26.7 ft)(1.75)](13.35 ft) = 2355.99 kip·ft/ft

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

M_H = [½(120 pcf)(38.1 ft)²(0.297)(1.5)](12.7 ft) + [(250 psf)(38.1 ft)(0.297)(1.75)](19.05 ft) = 587.09 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)(38.1 ft)(26.7 ft)(1.35) + (250 psf)(26.7 ft)(1.75) = 176.48 kip/ft

Check Bearing Resistance - Drained Condition

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

$N_{cm} = N_c s_c i_c$ = 56.08 $N_{qm} = N_q s_q d_q i_q$ = 44.82 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 65.93

N_c = 55.63
s_c = 1+(20.04 ft/1939 ft)(42.92/55.63) = 1.008
i_c = 1.000 (Assumed)

N_q = 42.92
s_q = 1.008
d_q = 1+2tan(37°)[1-sin(37°)]²tan⁻¹(3.0 ft/20.04 ft) = 1.036
i_q = 1.000 (Assumed)
C_{wq} = 14.0 ft > 3.0 ft = 1.000

N_γ = 66.19
s_γ = 0.996
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 14.0 ft < 1.5(20.04 ft) + 3.0 ft = 0.733

q_n = (0 psf)(56.075) + (125 pcf)(3.0 ft)(44.821)(1.000) + ½(125 pcf)(20.0 ft)(65.925)(0.733) = 77.33 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

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

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 8.81 ksf ≤ (77.33 ksf)(0.65) = 50.26 ksf ⟶ 8.81 ksf ≤ 50.26 ksf **OK**

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Retaining Wall W2 - Sta. 203+00 to 212+25

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.1	ft
MSE Wall Width (Reinforcement Length), (B) =	26.7	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	37	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	14.0	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: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$

$N_{cm} = N_c s_c i_c$ = 5.150 $N_{qm} = N_q s_q d_q i_q$ = 1.000 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

N_c = 5.140
s_c = 1+(20.04 ft/[(5)(1939 ft)]) = 1.002
i_c = 1.000 (Assumed)

N_q = 1.000
s_q = 1.000
d_q = 1+2tan(0°)[1-sin(0°)]²tan⁻¹(3.0 ft/20.04 ft)
= 1.000
i_q = 1.000 (Assumed)
C_{wq} = 14.0 ft > 3.0 ft = 1.000

N_γ = 0.000
s_γ = 1.000
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 14.0 ft < 1.5(20.04 ft) + 3.0 ft = 0.733

q_n = (0 psf)(5.150) + (125 pcf)(3.0 ft)(1.000)(1.000) + ½(125 pcf)(20.0 ft)(0.000)(0.733) = N/A ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 8.81 ksf ≤ (N/A ksf)(0.65) = N/A ksf ⟶ N/A

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

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Retaining Wall W2 - Sta. 203+00 to 212+25

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.1	ft
MSE Wall Width (Reinforcement Length), (B) =	26.7	ft
MSE Wall Length, (L) =	1939	ft
Live Surcharge Load, (σ_{LS}) =	250	psf
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{BS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°

Bearing Soil Properties:

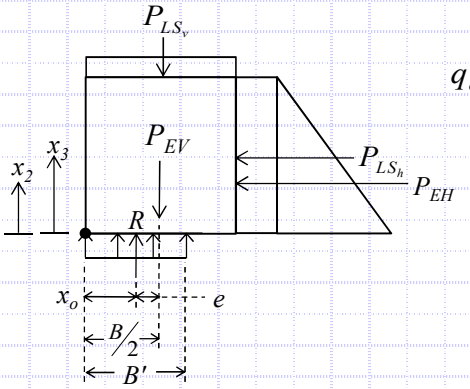
Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	37	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	3.0	ft
Depth to Grounwater (Below Bot. of Wall), (D_W) =	14.0	ft

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



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

$$B' = B - 2e = 26.7 \text{ ft} - 2(2.97 \text{ ft}) = 20.76 \text{ ft}$$

$$e = B/2 - x_o = (26.7 \text{ ft})/2 - 10.38 \text{ ft} = 2.97 \text{ ft}$$

$$x_o = \frac{M_V - M_H}{P_V} = (1718.78 \text{ kip·ft/ft} - 382.41 \text{ kip·ft/ft}) / 128.75 \text{ kip/ft} = 10.38 \text{ ft}$$

$$q_{eq} = (128.75 \text{ kip/ft}) / (20.76 \text{ ft}) = 6.20 \text{ ksf}$$

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

$$M_V = [(120 \text{ pcf})(38.1 \text{ ft})(26.7 \text{ ft})(1.00)](13.4 \text{ ft}) + [(250 \text{ psf})(26.7 \text{ ft})(1.00)](13.4 \text{ ft}) = 1718.78 \text{ kip·ft/ft}$$

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

$$M_H = [\tfrac{1}{2}(120 \text{ pcf})(38.1 \text{ ft})^2(0.297)(1.00)](12.7 \text{ ft}) + [(250 \text{ psf})(38.1 \text{ ft})(0.297)(1.00)](19.05 \text{ ft}) = 382.41 \text{ kip·ft/ft}$$

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

$$P_V = (120 \text{ pcf})(38.1 \text{ ft})(26.7 \text{ ft})(1.00) + (250 \text{ psf})(26.7 \text{ ft})(1.00) = 128.75 \text{ kip/ft}$$

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 100% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Along Wall Facing
B-099-3-13	0.830 in	0.683 in	0 days		
B-099-5-14	1.757 in	1.437 in	15 days	150 ft	1/2390
B-100-1-14	1.189 in	0.981 in	0 days	165 ft	1/4340
B-100-3-14	0.625 in	0.515 in	0 days	150 ft	1/3860
B-102-2-14	1.353 in	1.102 in	0 days	155 ft	1/3170
B-102-4-14	2.396 in	1.904 in	6 days	155 ft	1/2320

W-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 203+00 to 212+25

Calculated By: BRT Date: 6/22/2019
Checked By: JPS Date: 6/23/2019

Boring B-099-3-13

H=	18.3	ft	Total wall height
B'=	9.7	ft	Effective footing width due to eccentricity
D_w =	13.0	ft	Depth below bottom of footing
q_e =	3,230	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-a	G	0.0	2.0	2.0	1.0	130	260	130	130	4,130					41	79	319	0.10	0.996	3,219	3,349	0.009	0.106	0.500	1,614	1,744	0.007	0.085
	A-1-a	G	2.0	4.0	2.0	3.0	130	520	390	390	4,390					41	63	233	0.31	0.932	3,011	3,401	0.008	0.097	0.494	1,597	1,987	0.006	0.073
	A-1-a	G	4.0	6.0	2.0	5.0	130	780	650	650	4,650					41	56	198	0.52	0.808	2,611	3,261	0.007	0.085	0.478	1,544	2,194	0.005	0.064
2	A-2-4	G	6.0	8.5	2.5	7.3	130	1,105	943	943	4,943					32	40	131	0.75	0.670	2,163	3,105	0.010	0.119	0.448	1,448	2,391	0.008	0.093
3	A-1-b	G	8.5	11.0	2.5	9.8	130	1,430	1,268	1,268	5,268					36	42	136	1.01	0.548	1,769	3,037	0.007	0.084	0.408	1,319	2,586	0.006	0.068
	A-1-b	G	11.0	13.5	2.5	12.3	130	1,755	1,593	1,593	5,593					36	39	126	1.26	0.458	1,479	3,071	0.006	0.068	0.368	1,189	2,781	0.005	0.057
4	A-1-b	G	13.5	16.5	3.0	15.0	125	2,130	1,943	1,818	5,818					13	13	62	1.55	0.385	1,245	3,063	0.011	0.132	0.328	1,059	2,877	0.010	0.116
	A-1-b	G	16.5	20.5	4.0	18.5	125	2,630	2,380	2,037	6,037					13	13	61	1.91	0.319	1,032	3,068	0.012	0.140	0.285	919	2,956	0.011	0.127
																				Total Settlement:			0.830 in			Total Settlement:		0.683 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$, Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 203+00 to 212+25

Calculated By: BRT Date: 6/22/2019
Checked By: JPS Date: 6/23/2019

Boring B-099-5-14

H=	19.0	ft	Total wall height
B'=	10.1	ft	Effective footing width due to eccentricity
D_w =	14.0	ft	Depth below bottom of footing
q_e =	3,340	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-6b	C	0.0	2.0	2.0	1.0	120	240	120	120	4,120	37	0.243	0.024	0.561				0.10	0.997	3,329	3,449	0.045	0.545	0.500	1,669	1,789	0.037	0.438
2	A-2-4	G	2.0	4.5	2.5	3.3	125	553	396	396	4,396					24	37	120	0.32	0.926	3,092	3,488	0.020	0.235	0.494	1,649	2,045	0.015	0.178
	A-2-4	G	4.5	7.0	2.5	5.8	125	865	709	709	4,709					24	32	106	0.57	0.774	2,587	3,295	0.016	0.189	0.472	1,577	2,286	0.012	0.144
3	A-1-b	G	7.0	9.5	2.5	8.3	125	1,178	1,021	1,021	5,021					19	23	82	0.82	0.633	2,115	3,136	0.015	0.179	0.438	1,463	2,484	0.012	0.142
	A-1-b	G	9.5	12.0	2.5	10.8	125	1,490	1,334	1,334	5,334					19	22	78	1.06	0.525	1,752	3,086	0.012	0.141	0.399	1,332	2,666	0.010	0.116
	A-1-b	G	12.0	14.5	2.5	13.3	125	1,803	1,646	1,646	5,646					19	20	75	1.31	0.444	1,482	3,128	0.009	0.112	0.361	1,205	2,851	0.008	0.096
4	A-1-a	G	14.5	17.5	3.0	16.0	125	2,178	1,990	1,865	5,865					15	15	65	1.58	0.377	1,260	3,126	0.010	0.124	0.323	1,079	2,944	0.009	0.109
	A-1-a	G	17.5	20.5	3.0	19.0	125	2,553	2,365	2,053	6,053					15	15	64	1.88	0.323	1,080	3,133	0.009	0.103	0.287	960	3,013	0.008	0.093
	A-1-a	G	20.5	23.5	3.0	22.0	125	2,928	2,740	2,241	6,241					15	14	64	2.18	0.282	943	3,184	0.007	0.086	0.258	861	3,101	0.007	0.080
5	A-1-a	G	23.5	26.5	3.0	25.0	130	3,318	3,123	2,436	6,436					35	33	107	2.48	0.250	836	3,273	0.004	0.043	0.233	777	3,214	0.003	0.040
																						Total Settlement:		1.757 in			Total Settlement:		1.437 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 203+00 to 212+25

Calculated By: BRT Date: 06/22/2019
Checked By: JPS Date: 06/23/2019

Boring B-099-5-14

H=	19.0	ft	Total wall height
B'=	10.1	ft	Effective footing width due to eccentricity
D_w =	14.0	ft	Depth below bottom of footing
q_e =	3,340	psf	Equivalent bearing pressure at bottom of wall

	A-6b				
c_v =	300			ft^2/yr	Coefficient of consolitation
t =	15			days	Time following completion of construction
H_{dr} =	2			ft	Length of longest drainage path considered
T_v =	3.082				Time factor
U =	100			%	Degree of consolidation

$(S_c)_t$ = 1.437 in Settlement complete at 100% of primary consolidation

																						Total Settlement at Facing of Wall			Settlement Complete at 100% 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-6b	C	0.0	2.0	2.0	1.0	120	240	120	120	4,120	37	0.243	0.024	0.561				0.10	0.500	1,669	1,789	0.037	0.438	0.438	0.438	0.438
2	A-2-4	G	2.0	4.5	2.5	3.3	125	553	396	396	4,396					24	37	120	0.32	0.494	1,649	2,045	0.015	0.178	0.322	0.178	0.322
	A-2-4	G	4.5	7.0	2.5	5.8	125	865	709	709	4,709					24	32	106	0.57	0.472	1,577	2,286	0.012	0.144		0.144	
3	A-1-b	G	7.0	9.5	2.5	8.3	125	1,178	1,021	1,021	5,021					19	23	82	0.82	0.438	1,463	2,484	0.012	0.142	0.354	0.142	0.354
	A-1-b	G	9.5	12.0	2.5	10.8	125	1,490	1,334	1,334	5,334					19	22	78	1.06	0.399	1,332	2,666	0.010	0.116		0.116	
	A-1-b	G	12.0	14.5	2.5	13.3	125	1,803	1,646	1,646	5,646					19	20	75	1.31	0.361	1,205	2,851	0.008	0.096		0.096	
4	A-1-a	G	14.5	17.5	3.0	16.0	125	2,178	1,990	1,865	5,865					15	15	65	1.58	0.323	1,079	2,944	0.009	0.109	0.282	0.109	0.282
	A-1-a	G	17.5	20.5	3.0	19.0	125	2,553	2,365	2,053	6,053					15	15	64	1.88	0.287	960	3,013	0.008	0.093		0.093	
	A-1-a	G	20.5	23.5	3.0	22.0	125	2,928	2,740	2,241	6,241					15	14	64	2.18	0.258	861	3,101	0.007	0.080		0.080	
5	A-1-a	G	23.5	26.5	3.0	25.0	130	3,318	3,123	2,436	6,436					35	33	107	2.48	0.233	777	3,214	0.003	0.040	0.040	0.040	0.040

1. $\sigma_p' = \sigma_{vo}' + \sigma_{m;}$ Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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: 0.000 in

W-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 203+00 to 212+25

Calculated By: BRT Date: 6/22/2019
Checked By: JPS Date: 6/23/2019

Boring B-100-1-14

H=	18.6	ft	Total wall height
B'=	9.8	ft	Effective footing width due to eccentricity
D_w =	16.0	ft	Depth below bottom of footing
q_e =	3,280	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-a	G	0.0	2.5	2.5	1.3	130	325	163	163	4,163					25	46	153	0.13	0.993	3,259	3,421	0.022	0.259	0.500	1,639	1,801	0.017	0.205
	A-1-a	G	2.5	5.0	2.5	3.8	130	650	488	488	4,488					25	37	120	0.38	0.891	2,924	3,411	0.018	0.212	0.490	1,607	2,094	0.013	0.158
	A-1-a	G	5.0	7.5	2.5	6.3	130	975	813	813	4,813					25	33	106	0.64	0.732	2,402	3,215	0.014	0.168	0.464	1,521	2,333	0.011	0.129
	A-1-a	G	7.5	10.5	3.0	9.0	130	1,365	1,170	1,170	5,170					25	30	98	0.92	0.585	1,918	3,088	0.013	0.155	0.422	1,385	2,555	0.010	0.125
2	A-1-a	G	10.5	13.5	3.0	12.0	135	1,770	1,568	1,568	5,568					48	52	178	1.22	0.470	1,540	3,108	0.005	0.060	0.374	1,226	2,794	0.004	0.051
	A-1-a	G	13.5	16.5	3.0	15.0	135	2,175	1,973	1,973	5,973					48	48	162	1.53	0.389	1,276	3,248	0.004	0.048	0.330	1,082	3,055	0.004	0.042
	A-1-a	G	16.5	19.5	3.0	18.0	135	2,580	2,378	2,253	6,253					48	46	154	1.84	0.331	1,084	3,337	0.003	0.040	0.292	959	3,212	0.003	0.036
3	A-1-b	G	19.5	24.5	5.0	22.0	135	3,255	2,918	2,543	6,543					62	57	201	2.24	0.275	901	3,444	0.003	0.039	0.252	826	3,369	0.003	0.036
4	A-1-b	G	24.5	29.5	5.0	27.0	125	3,880	3,568	2,881	6,881					21	18	71	2.76	0.226	742	3,623	0.007	0.084	0.213	698	3,579	0.007	0.080
	A-1-b	G	29.5	34.5	5.0	32.0	125	4,505	4,193	3,194	7,194					21	18	70	3.27	0.192	630	3,824	0.006	0.067	0.184	603	3,797	0.005	0.065
	A-1-b	G	34.5	39.5	5.0	37.0	125	5,130	4,818	3,507	7,507					21	17	68	3.78	0.167	547	4,054	0.005	0.055	0.161	529	4,036	0.004	0.053
																						Total Settlement:		1.189 in			Total Settlement:		0.981 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 203+00 to 212+25

Calculated By: BRT Date: 6/22/2019
Checked By: JPS Date: 6/23/2019

Boring B-100-3-14

H=	22.3	ft	Total wall height
B'=	11.9	ft	Effective footing width due to eccentricity
D_w =	13.0	ft	Depth below bottom of footing
q_e =	3,840	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-a	G	0.0	2.5	2.5	1.3	135	338	169	169	4,169					52	95	431	0.11	0.996	3,826	3,994	0.008	0.096	0.500	1,919	2,088	0.006	0.076
	A-1-a	G	2.5	5.0	2.5	3.8	135	675	506	506	4,506					52	76	303	0.32	0.929	3,568	4,074	0.007	0.090	0.494	1,897	2,403	0.006	0.067
2	A-1-b	G	5.0	7.5	2.5	6.3	135	1,013	844	844	4,844					49	63	231	0.53	0.802	3,081	3,924	0.007	0.087	0.477	1,832	2,676	0.005	0.065
	A-1-b	G	7.5	10.0	2.5	8.8	135	1,350	1,181	1,181	5,181					49	58	204	0.74	0.676	2,597	3,778	0.006	0.074	0.450	1,728	2,910	0.005	0.058
3	A-1-a	G	10.0	13.0	3.0	11.5	135	1,755	1,553	1,553	5,553					120	130	736	0.97	0.564	2,165	3,717	0.002	0.019	0.415	1,592	3,144	0.001	0.015
	A-1-a	G	13.0	16.0	3.0	14.5	135	2,160	1,958	1,864	5,864					120	123	666	1.22	0.471	1,810	3,674	0.001	0.016	0.375	1,439	3,303	0.001	0.013
	A-1-a	G	16.0	19.0	3.0	17.5	135	2,565	2,363	2,082	6,082					120	119	625	1.47	0.403	1,546	3,628	0.001	0.014	0.338	1,298	3,380	0.001	0.012
4	A-1-a	G	19.0	23.0	4.0	21.0	125	3,065	2,815	2,316	6,316					21	20	74	1.76	0.343	1,316	3,632	0.011	0.126	0.301	1,154	3,470	0.009	0.114
	A-1-a	G	23.0	27.0	4.0	25.0	125	3,565	3,315	2,566	6,566					21	19	73	2.10	0.292	1,122	3,688	0.009	0.104	0.265	1,017	3,584	0.008	0.096
																						Total Settlement:		0.625 in			Total Settlement:		0.515 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$. Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 203+00 to 212+25

Calculated By: BRT Date: 6/22/2019
Checked By: JPS Date: 6/23/2019

Boring B-102-2-14

H=	28.5	ft	Total wall height
B'=	15.4	ft	Effective footing width due to eccentricity
D_w =	14.5	ft	Depth below bottom of footing
q_e =	4,750	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-a	G	0.0	2.5	2.5	1.3	135	338	169	169	4,169					61	112	563	0.08	0.998	4,742	4,910	0.007	0.078	0.500	2,374	2,543	0.005	0.063
	A-1-a	G	2.5	5.0	2.5	3.8	135	675	506	506	4,506					61	89	389	0.24	0.962	4,570	5,076	0.006	0.077	0.497	2,361	2,868	0.005	0.058
2	A-1-b	G	5.0	7.5	2.5	6.3	130	1,000	838	838	4,838					26	34	110	0.41	0.877	4,168	5,005	0.018	0.213	0.488	2,319	3,156	0.013	0.158
	A-1-b	G	7.5	10.0	2.5	8.8	130	1,325	1,163	1,163	5,163					26	31	101	0.57	0.775	3,682	4,844	0.015	0.184	0.472	2,243	3,406	0.012	0.139
	A-1-b	G	10.0	12.5	2.5	11.3	130	1,650	1,488	1,488	5,488					26	29	95	0.73	0.679	3,224	4,712	0.013	0.158	0.451	2,141	3,629	0.010	0.122
3	A-1-a	G	12.5	15.5	3.0	14.0	135	2,055	1,853	1,853	5,853					48	49	166	0.91	0.589	2,797	4,650	0.007	0.086	0.424	2,012	3,865	0.006	0.069
	A-1-a	G	15.5	19.0	3.5	17.3	135	2,528	2,291	2,120	6,120					48	47	158	1.12	0.504	2,395	4,515	0.007	0.088	0.390	1,853	3,973	0.006	0.073
4	A-1-b	G	19.0	24.0	5.0	21.5	130	3,178	2,853	2,416	6,416					29	27	91	1.40	0.421	2,000	4,416	0.014	0.172	0.349	1,656	4,071	0.012	0.149
	A-1-b	G	24.0	29.0	5.0	26.5	130	3,828	3,503	2,754	6,754					29	26	88	1.72	0.351	1,665	4,419	0.012	0.140	0.306	1,453	4,206	0.010	0.125
5	A-1-b	G	29.0	35.5	6.5	32.3	135	4,705	4,266	3,159	7,159					51	43	143	2.09	0.293	1,392	4,550	0.007	0.087	0.266	1,262	4,420	0.007	0.080
	A-1-b	G	35.5	42.0	6.5	38.8	135	5,583	5,144	3,631	7,631					51	41	134	2.52	0.247	1,171	4,802	0.006	0.071	0.230	1,091	4,721	0.006	0.066
																						Total Settlement:		1.353 in			Total Settlement:		1.102 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 203+00 to 212+25

Calculated By: BRT Date: 6/22/2019
Checked By: JPS Date: 6/23/2019

Boring B-102-4-14

H=	38.1	ft	Total wall height
B'=	20.8	ft	Effective footing width due to eccentricity
D_w =	13.0	ft	Depth below bottom of footing
q_e =	6,200	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-a	G	0.0	3.0	3.0	1.5	135	405	203	203	4,203					47	83	348	0.07	0.999	6,192	6,395	0.013	0.155	0.500	3,100	3,302	0.010	0.126
2	A-1-b	G	3.0	5.5	2.5	4.3	125	718	561	561	4,561					25	36	116	0.20	0.976	6,051	6,612	0.023	0.277	0.498	3,089	3,651	0.018	0.210
	A-1-b	G	5.5	8.0	2.5	6.8	125	1,030	874	874	4,874					25	32	105	0.32	0.924	5,730	6,604	0.021	0.252	0.494	3,060	3,934	0.016	0.187
	A-1-b	G	8.0	10.5	2.5	9.3	125	1,343	1,186	1,186	5,186					25	29	97	0.44	0.853	5,291	6,477	0.019	0.227	0.485	3,007	4,193	0.014	0.169
3	A-1-b	G	10.5	13.5	3.0	12.0	120	1,703	1,523	1,523	5,523					11	12	60	0.58	0.770	4,772	6,295	0.031	0.372	0.471	2,922	4,444	0.023	0.281
	A-1-b	G	13.5	17.0	3.5	15.3	120	2,123	1,913	1,772	5,772					11	11	59	0.73	0.677	4,200	5,972	0.031	0.377	0.450	2,793	4,565	0.024	0.294
4	A-1-b	G	17.0	19.5	2.5	18.3	135	2,460	2,291	1,964	5,964					88	89	386	0.88	0.604	3,742	5,706	0.003	0.036	0.429	2,657	4,621	0.002	0.029
	A-1-b	G	19.5	22.0	2.5	20.8	135	2,798	2,629	2,145	6,145					88	86	368	1.00	0.551	3,415	5,560	0.003	0.034	0.410	2,539	4,684	0.002	0.028
5	A-1-a	G	22.0	25.0	3.0	23.5	130	3,188	2,993	2,337	6,337					28	27	90	1.13	0.501	3,105	5,443	0.012	0.147	0.389	2,409	4,747	0.010	0.123
	A-1-a	G	25.0	28.5	3.5	26.8	130	3,643	3,415	2,557	6,557					28	26	88	1.29	0.451	2,797	5,354	0.013	0.154	0.365	2,261	4,818	0.011	0.132
	A-1-a	G	28.5	32.0	3.5	30.3	130	4,098	3,870	2,794	6,794					28	25	86	1.45	0.407	2,521	5,314	0.011	0.137	0.340	2,110	4,904	0.010	0.120
6	A-1-a	G	32.0	37.0	5.0	34.5	135	4,773	4,435	3,093	7,093					60	51	175	1.66	0.362	2,246	5,340	0.007	0.081	0.313	1,943	5,037	0.006	0.073
7	A-1-b	G	37.0	42.0	5.0	39.5	130	5,423	5,098	3,444	7,444					45	37	120	1.90	0.321	1,988	5,432	0.008	0.099	0.286	1,770	5,214	0.008	0.090
8	A-4a	C	42.0	45.0	3.0	43.5	130	5,813	5,618	3,714	7,714	22	0.108	0.011	0.444				2.09	0.293	1,819	5,533	0.004	0.047	0.266	1,648	5,363	0.004	0.043
																						Total Settlement:		2.396 in			Total Settlement:		1.904 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 203+00 to 212+25

Calculated By: BRT Date: 06/22/2019
Checked By: JPS Date: 06/23/2019

Boring B-102-4-14

H=	38.1	ft	Total wall height
B'=	20.8	ft	Effective footing width due to eccentricity
D_w =	13.0	ft	Depth below bottom of footing
q_e =	6,200	psf	Equivalent bearing pressure at bottom of wall

	A-4a			
c_v =	1,000		ft^2/yr	Coefficient of consolitation
t =	6		days	Time following completion of construction
H_{dr} =	3		ft	Length of longest drainage path considered
T_v =	1.826			Time factor
U =	99		%	Degree of consolidation

$(S_c)_t$ = 1.904 in Settlement complete at 100% of primary consolidation

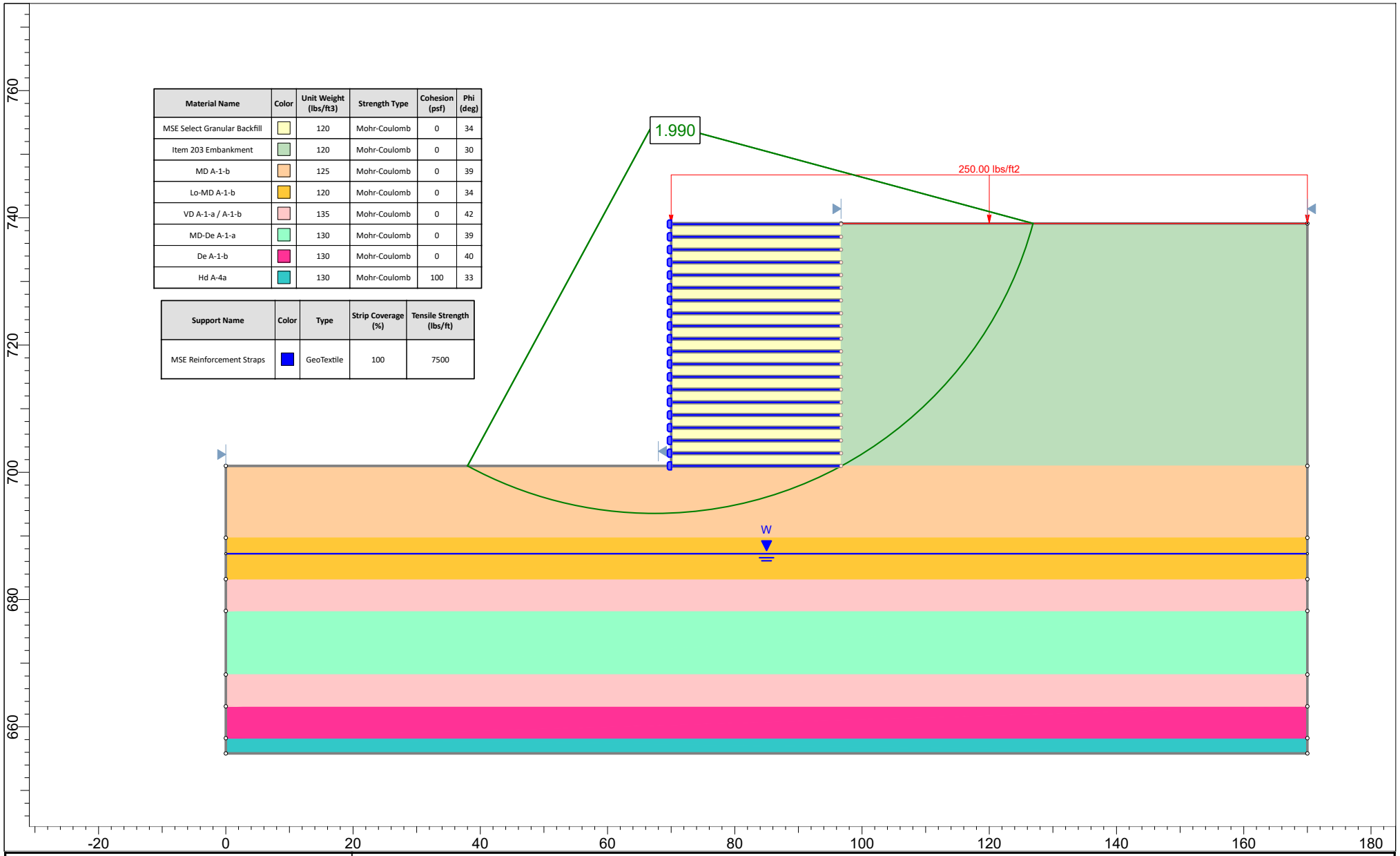
Layer	Soil Type	Soil Type	Layer Depth (ft)		Layer Thickness (ft)	Depth to Midpoint (ft)	γ (pcf)	σ_{vo} Bottom (psf)	σ_{vo} Midpoint (psf)	σ_{vo}' Midpoint (psf)	σ_p' (1) (psf)	LL	C_c (2)	C_r (3)	e_o (4)	N_{60}	$(N1)_{60}$ (5)	C' (6)	Z_f/B	I (7)	$\Delta\sigma_v$ (8) (psf)	σ_{vf}' Midpoint (psf)	Total 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 100% of Primary Consolidation: $(S_c)_t$ (11) (in)	Settlement Complete at 100% of Primary Consolidation: Layer Settlement (in)
1	A-1-a	G	0.0	3.0	3.0	1.5	135	405	203	203	4,203					47	83	348	0.07	0.500	3,100	3,302	0.010	0.126	0.126	0.126	
2	A-1-b	G	3.0	5.5	2.5	4.3	125	718	561	561	4,561					25	36	116	0.20	0.498	3,089	3,651	0.018	0.210		0.210	0.692
	A-1-b	G	5.5	8.0	2.5	6.8	125	1,030	874	874	4,874					25	32	105	0.32	0.494	3,060	3,934	0.016	0.187	0.567	0.187	
	A-1-b	G	8.0	10.5	2.5	9.3	125	1,343	1,186	1,186	5,186					25	29	97	0.44	0.485	3,007	4,193	0.014	0.169		0.169	
3	A-1-b	G	10.5	13.5	3.0	12.0	120	1,703	1,523	1,523	5,523					11	12	60	0.58	0.471	2,922	4,444	0.023	0.281		0.281	0.574
	A-1-b	G	13.5	17.0	3.5	15.3	120	2,123	1,913	1,772	5,772					11	11	59	0.73	0.450	2,793	4,565	0.024	0.294	0.574	0.294	
4	A-1-b	G	17.0	19.5	2.5	18.3	135	2,460	2,291	1,964	5,964					88	89	386	0.88	0.429	2,657	4,621	0.002	0.029		0.029	0.057
	A-1-b	G	19.5	22.0	2.5	20.8	135	2,798	2,629	2,145	6,145					88	86	368	1.00	0.410	2,539	4,684	0.002	0.028	0.057	0.028	
5	A-1-a	G	22.0	25.0	3.0	23.5	130	3,188	2,993	2,337	6,337					28	27	90	1.13	0.389	2,409	4,747	0.010	0.123		0.123	
	A-1-a	G	25.0	28.5	3.5	26.8	130	3,643	3,415	2,557	6,557					28	26	88	1.29	0.365	2,261	4,818	0.011	0.132	0.375	0.132	0.375
	A-1-a	G	28.5	32.0	3.5	30.3	130	4,098	3,870	2,794	6,794					28	25	86	1.45	0.340	2,110	4,904	0.010	0.120		0.120	
6	A-1-a	G	32.0	37.0	5.0	34.5	135	4,773	4,435	3,093	7,093					60	51	175	1.66	0.313	1,943	5,037	0.006	0.073	0.073	0.073	0.073
7	A-1-b	G	37.0	42.0	5.0	39.5	130	5,423	5,098	3,444	7,444					45	37	120	1.90	0.286	1,770	5,214	0.008	0.090	0.090	0.090	0.090
8	A-4a	C	42.0	45.0	3.0	43.5	130	5,813	5,618	3,714	7,714	22	0.108	0.011	0.444				2.09	0.266	1,648	5,363	0.004	0.043	0.043	0.043	0.043

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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: 0.000 in

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Select Granular Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
MD A-1-b		125	Mohr-Coulomb	0	39
Lo-MD A-1-b		120	Mohr-Coulomb	0	34
VD A-1-a / A-1-b		135	Mohr-Coulomb	0	42
MD-De A-1-a		130	Mohr-Coulomb	0	39
De A-1-b		130	Mohr-Coulomb	0	40
Hd A-4a		130	Mohr-Coulomb	100	33

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



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SLIDEINTERPRET 8.020

Project	Retaining Wall W2 - Sta. 203+00 to 212+25 - MSE Wall Global Stability		
Analysis Description	38.1 ft Wall Height - Drained - Circular - Spencer		
Drawn By	BRT	*Scale* 1:250	*Company* Resource International, Inc.
Date	6/23/2019		*File Name* Retaining Wall W2 - Sta. 203+00 to 212+25 - Global Stability.slim

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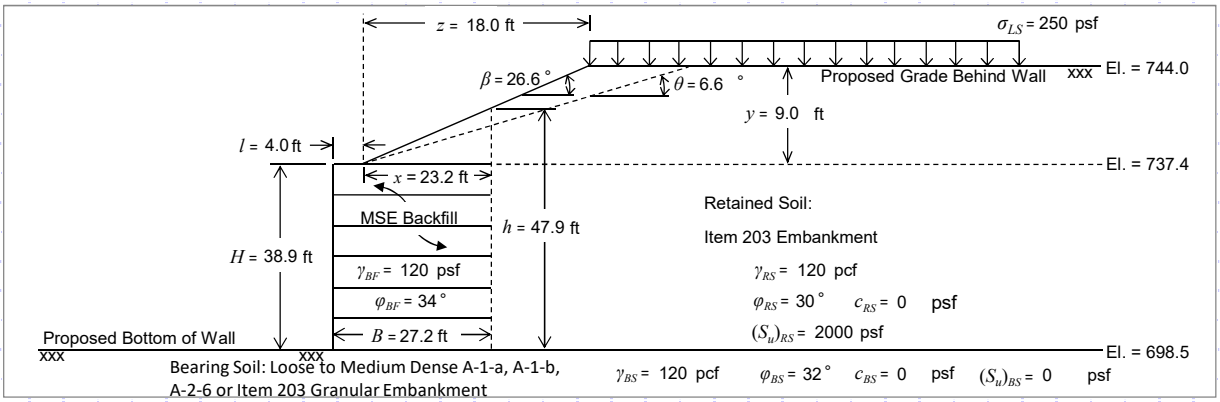
JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	1	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 212+25 to 216+50

Retaining Wall W2 - Sta. 212+25 to 216+50 - B-102-6-14, B-103-1-14, B-105-4-14 - 2:1 Broken Backslope - 38.9 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.9	ft
MSE Wall Width (Reinforcement Length), (B) =	27.2	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	47.9	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	6.6	°
Distance from Toe to Top of Backslope, (z) =	18.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.323	
Live Surcharge Load, (σ_{LS}) =	250	psf

MSE Backfill and Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(S_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	7.5	ft

LRFD Load Factors

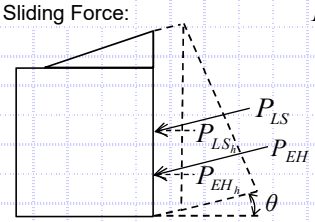
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

1. *Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.*

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Sections 11.6.3.6 and 11.10.5.3

Sliding Force:



$$P_H = (P_{EH} + P_{LS})\cos\theta$$

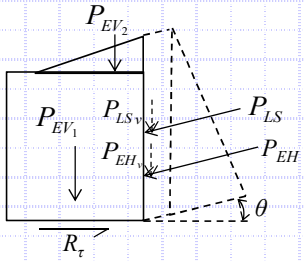
$$P_{EH} = \tfrac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH} = \text{½(120 pcf)(47.9 ft)²(0.323)(1.50)} = 66.74 \text{ kip/ft}$$

$$P_{LS} = \sigma_{LS} h K_a \gamma_{LS} = \text{(250 psf)(47.9 ft)(0.323)(1.75)} = 6.05 \text{ kip/ft}$$

$$P_H = \text{(66.74 kip/ft + 6.05 kip/ft)cos(6.6°)} = 72.31 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:



$$R_\tau = (P_{EV_1} + P_{EV_2} + P_{EH}\sin\theta)\tan\delta \quad \text{(Neglect } P_{LS_v} \text{ for conservatism)}$$

$$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = \text{(120 pcf)(38.9 ft)(27.2 ft)(1.00)} = 126.97 \text{ kip/ft}$$

$$P_{EV_2} = \tfrac{1}{2}\gamma_{RS}(h-H)(B-l)\gamma_{EV} = \text{½(120 pcf)(47.9 ft - 38.9 ft)(27.2 ft - 4.0 ft)(1.00)} = 12.55 \text{ kip/ft}$$

$$P_{EH} = \tfrac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH} = \text{½(120 pcf)(47.9 ft)²(0.323)(1.50)} = 66.74 \text{ kip/ft}$$

$$\tan\delta = (\tan\varphi_{BS} \le \tan\varphi_{BF}) \longrightarrow \tan(32) \le \tan(34) \longrightarrow 0.62 \le 0.67 = 0.62$$

$$R_\tau = \text{[126.97 kip/ft + 12.55 kip/ft + (66.74 kip/ft)sin(6.6°)](0.62)} = 91.26 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$$P_H \le R_\tau \cdot \phi_\tau \longrightarrow \text{72.31 kip/ft} \le \text{(91.26 kip/ft)(1.0) = 91.26 kip/ft} \longrightarrow \text{72.31 kip/ft} \le \text{91.26 kip/ft} \quad \textbf{OK}$$

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	2	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 212+25 to 216+50

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.9	ft
MSE Wall Width (Reinforcement Length), (B) =	27.2	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	47.9	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	6.6	°
Distance from Toe to Top of Backslope, (z) =	18.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.323	
Live Surcharge Load, (σ_{LS}) =	250	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	7.5	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

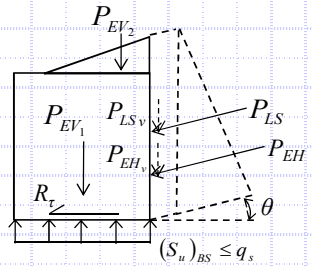
(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 ***(Continued)***

Check Sliding Resistance - Undrained Condition

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



(Neglect P_{LSv} for conservatism)

$(S_u)_{BS}$ = N/A ksf

$q_s = \sigma_v / 2$

$\sigma_v = P_V / B$

$P_V = P_{EV_1} + P_{EV_2} + P_{EH} \sin\theta$

$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(38.9 ft)(27.2 ft)(1.00) = 127 kip/ft

$P_{EV_2} = \frac{1}{2} \gamma_{RS} (h - H)(B - l) \gamma_{EV}$

P_{EV_2} = ½(120 pcf)(47.9 ft - 38.9 ft)(27.2 ft - 4.0 ft)(1.00) = 12.55 kip/ft

$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH}$ = ½(120 pcf)(47.9 ft)²(0.323)(1.50) = 66.74 kip/ft

P_V = 126.97 kip/ft + 12.55 kip/ft + (66.74 kip/ft)sin(6.6°) = 147.19 kip/ft

σ_v = (147.19 kip/ft) / (27.2 ft) = 5.41 ksf

q_s = (5.41 ksf) / 2 = 2.71 ksf

R_τ = (N/A ksf ≤ 2.71 ksf)(27.2 ft) = N/A kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ N/A ⟶ N/A

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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JOB	FRA-70-13.10	NO.	W-13-072
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Retaining Wall W2 - Sta. 212+25 to 216+50

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.9	ft
MSE Wall Width (Reinforcement Length), (B) =	27.2	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	47.9	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	6.6	°
Distance from Toe to Top of Backslope, (z) =	18.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.323	
Live Surcharge Load, (σ_{LS}) =	250	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	7.5	ft

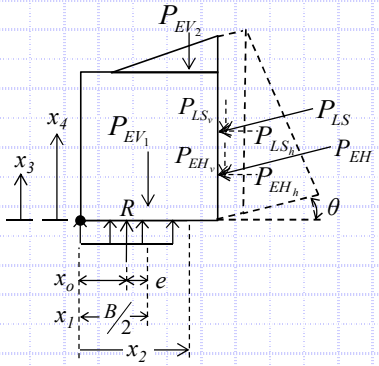
LRFD Load Factors

	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)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.6.3.3



$$e = B/2 - x_o$$

$$x_o = \frac{M_V - M_H}{P_V} = 2179.79 \text{ kip·ft/ft} - 1219.91 \text{ kip·ft/ft}) / (147.19 \text{ kip/f} = 6.52 \text{ ft}$$

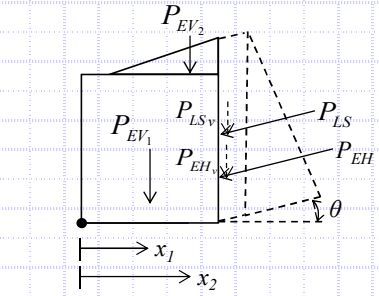
M_V = 2179.79 kip·ft/ft
M_H = 1219.91 kip·ft/ft
} Defined below

$P_V = P_{EV_1} + P_{EV_2} + P_{EH} \sin\theta$ = 126.97 kip/ft + 12.55 kip/ft + (66.74 kip/ft)sin(6.6°) = 147.19 kip/ft

$e =$ (27.2 ft/ 2) - 6.52 ft = 7.08 ft

Resisting Moment, M_V:

$$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) + P_{EH} \sin\theta(B)$$ (Neglect P_{LS_v} for conservatism)



$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(38.9 ft)(27.2 ft)(1.00) = 126.97 kip/ft

$P_{EV_2} = ½\gamma_{RS}(h - H)(B - l)\gamma_{EV}$ = ½(120 pcf)(47.9 ft - 38.9 ft)(27.2 ft - 4.0 ft)(1.00) = 12.55 kip/ft

$P_{EH} = ½\gamma_{RS}h^2K_a\gamma_{EH}$ = ½(120 pcf)(47.9 ft)²(0.323)(1.50) = 66.74 kip/ft

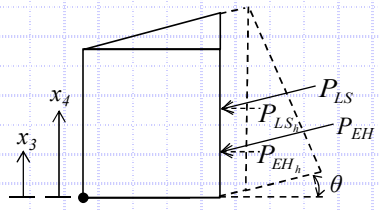
$x_1 = B/2$ = (27.2 ft) / 2 = 13.60 ft

$x_2 = l + ⅔(B - l)$ = 4.0 ft + ⅔(27.2 ft - 4.0 ft) = 19.47 ft

M_V = (126.97 kip/ft)(13.60 ft) + (12.55 kip/ft)(19.47 ft) + (66.74 kip/ft)sin(6.6°)(27.2 ft) = 2179.79 kip·ft/ft

Overturning Moment, M_H:

$$M_H = P_{EH} \cos\theta(x_3) + P_{LS} \cos\theta(x_4)$$



$P_{EH} = ½\gamma_{RS}h^2K_a\gamma_{EH}$ = ½(120 pcf)(47.9 ft)²(0.323)(1.50) = 66.74 kip/ft

$P_{LS} = \sigma_{LS}hK_a\gamma_{LS}$ = (250 psf)(47.9 ft)(0.323)(1.75) = 6.77 kip/ft

$x_3 = h/3$ = (47.9 ft) / 3 = 15.97 ft

$x_4 = h/2$ = (47.9 ft) / 2 = 23.96 ft

M_H = (66.74 kip/ft)cos(6.6°)(15.97 ft) + (6.77 kip/ft)cos(6.6°)(23.96 ft) = 1219.91 kip·ft/ft

Check Eccentricity Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (27.2 ft) / 3 = 9.07 ft

$e < e_{max} \longrightarrow$ 7.08 ft < 9.07 ft **OK**

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JOB	FRA-70-13.10	NO.	W-13-072
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Retaining Wall W2 - Sta. 212+25 to 216+50

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.9	ft
MSE Wall Width (Reinforcement Length), (B) =	27.2	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	47.9	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	6.6	°
Distance from Toe to Top of Backslope, (z) =	18.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.323	
Live Surcharge Load, (σ_{LS}) =	250	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	7.5	ft

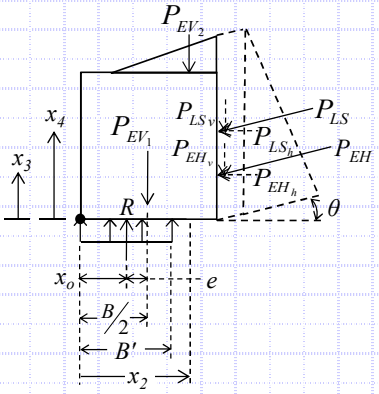
LRFD Load Factors

	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)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.6.3.2



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

$$B' = B - 2e = 27.2 \text{ ft} - 2(5.18 \text{ ft}) = 16.84 \text{ ft}$$

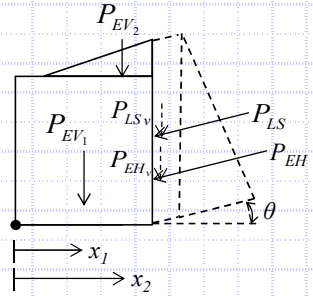
$$e = B/2 - x_o = (27.2 \text{ ft} / 2) - 8.42 \text{ ft} = 5.18 \text{ ft}$$

$$x_o = \frac{M_V - M_H}{P_V} = (2869.65 \text{ kip·ft/ft} - 1219.91 \text{ kip·ft/ft}) / 196.02 \text{ kip/f} = 8.42 \text{ ft}$$

$$q_{eq} = (196.02 \text{ kip/ft}) / (16.84 \text{ ft}) = 11.64 \text{ ksf}$$

Resisting Moment, M_V:

$$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) + P_{EH} \sin\theta(B)$$



$$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(38.9 \text{ ft})(27.2 \text{ ft})(1.35) = 171.41 \text{ kip/ft}$$

$$P_{EV_2} = \tfrac{1}{2}\gamma_{RS}(h - H)(B - l)\gamma_{EV} = \tfrac{1}{2}(120 \text{ pcf})(47.9 \text{ ft} - 38.9 \text{ ft})(27.2 \text{ ft} - 4.0 \text{ ft})(1.35) = 16.94 \text{ kip/ft}$$

$$P_{EH} = \tfrac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH} = \tfrac{1}{2}(120 \text{ pcf})(47.9 \text{ ft})^2(0.323)(1.50) = 66.74 \text{ kip/ft}$$

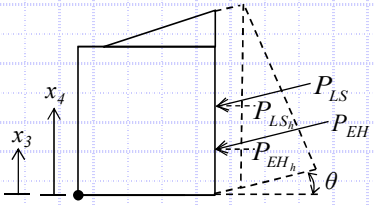
$$x_1 = B/2 = (27.2 \text{ ft}) / 2 = 13.60 \text{ ft}$$

$$x_2 = l + \tfrac{2}{3}(B - l) = 4.0 \text{ ft} + \tfrac{2}{3}(27.2 \text{ ft} - 4.0 \text{ ft}) = 19.47 \text{ ft}$$

$$M_V = (171.41 \text{ kip/ft})(13.60 \text{ ft}) + (16.94 \text{ kip/ft})(19.5 \text{ ft}) + (66.74 \text{ kip/ft})\sin(6.6°)(27.2 \text{ ft}) = 2869.65 \text{ kip·ft/ft}$$

Overturning Moment, M_H:

$$M_H = P_{EH} \cos\theta(x_3) + P_{LS} \cos\theta(x_4)$$



$$P_{EH} = \tfrac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH} = \tfrac{1}{2}(120 \text{ pcf})(47.9 \text{ ft})^2(0.323)(1.50) = 66.74 \text{ kip/ft}$$

$$P_{LS} = \sigma_{LS} h K_a \gamma_{LS} = (250 \text{ psf})(47.9 \text{ ft})(0.323)(1.75) = 6.77 \text{ kip/ft}$$

$$x_3 = h/3 = (47.9 \text{ ft}) / 3 = 15.97 \text{ ft}$$

$$x_4 = h/2 = (47.9 \text{ ft}) / 2 = 23.96 \text{ ft}$$

$$M_H = (66.74 \text{ kip/ft})\cos(6.6°)(15.97 \text{ ft}) + (6.77 \text{ kip/ft})\cos(6.6°)(23.96 \text{ ft}) = 1219.91 \text{ kip·ft/ft}$$

Vertical Forces, P_V:

$$P_V = P_{EV_1} + P_{EV_2} + P_{EH} \sin\theta$$

$$P_V = 171.41 \text{ kip/ft} + 16.94 \text{ kip/ft} + (66.74 \text{ kip/ft})\sin(6.6°) = 196.02 \text{ kip/ft}$$

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	5	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 212+25 to 216+50

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.9	ft
MSE Wall Width (Reinforcement Length), (B) =	27.2	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	47.9	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	6.6	°
Distance from Toe to Top of Backslope, (z) =	18.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.323	
Live Surcharge Load, (σ_{LS}) =	250	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	7.9	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)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 ***(Continued)***

Check Bearing Resistance - Drained Condition

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

$N_{cm} = N_c s_c i_c$ = 35.49 $N_{qm} = N_q s_q d_q i_q$ = 25.5 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 30.2

N_c = 35.49
s_c = 1+(16.84 ft/1939 ft)(23.18/35.49) = 1.000
i_c = 1.000 (Assumed)

N_q = 23.18
s_q = 1+(16.84 ft/1939 ft)tan(32°) = 1.000
d_q = 1+2tan(32°)[1-sin(32°)]^{2}tan^{-1}(4.0 ft/16.84 ft) = 1.100
i_q = 1.000 (Assumed)
C_{wq} = 7.9 ft > 4.0 ft = 1.000

N_γ = 30.21
s_γ = 1-0.4(16.84 ft/1939 ft) = 1.000
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 7.9 ft < 1.5(16.84 ft) + 4.0 ft = 0.500

q_n = (0 psf)(35.49) + (120 pcf)(4.0 ft)(25.5)(1.0) + ½(120 pcf)(16.8 ft)(30.2)(0.5) = 27.50 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 11.64 ksf ≤ (27.50 ksf)(0.65) = 17.88 ksf ⟶ 11.64 ksf ≤ 17.88 ksf **OK**

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

Check Bearing Resistance - Undrained Condition

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

$N_{cm} = N_c s_c i_c$ = 5.140 $N_{qm} = N_q s_q d_q i_q$ = 1.000 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

N_c = 5.140
s_c = 1+(16.84 ft/[(5)(1939 ft)] = 1.000
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/16.84 ft) = 1.000
i_q = 1.000 (Assumed)
C_{wq} = 7.9 ft > 4.0 ft = 1.000

N_γ = 0.000
s_γ = 1.000
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 7.9 ft < 1.5(16.84 ft) + 4.0 ft = 0.500

q_n = (0 psf)(5.14) + (120 pcf)(4.0 ft)(1.0)(1.0) + ½(120 pcf)(16.8 ft)(0.0)(0.5) = N/A ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ N/A ⟶ N/A

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	6	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 212+25 to 216+50

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	38.9	ft
MSE Wall Width (Reinforcement Length), (B) =	27.2	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	47.9	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	6.6	°
Distance from Toe to Top of Backslope, (z) =	18.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.323	
Live Surcharge Load, (σ_{LS}) =	250	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	32	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	7.5	ft

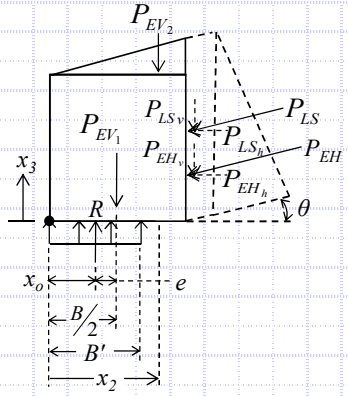
LRFD Load Factors

	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)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



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

$B' = B - 2e$ = 27.2 ft - 2(4.53 ft) = 18.14 ft

$e = B/2 - x_o$ = (27.2 ft / 2) - 9.07 ft = 4.53 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (2110.13 kip·ft/ft - 797.95 kip·ft/ft) / 144.63 kip/ft = 9.07 ft

q_{eq} = (144.63 kip/ft) / (18.14 ft) = 7.97 ksf

$$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) + P_{EH}\sin\theta(B) = (\gamma_{BF} HB\gamma_{EV})(\tfrac{1}{2}B) + (\tfrac{1}{2}\gamma_{RS}(h-H)(B-l)\gamma_{EV})(l + \tfrac{2}{3}(B-l)) + (\tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\sin\theta)(B)$$

M_V = [(120 pcf)(38.9 ft)(27.2 ft)(1.00)][½(27.2 ft)] + [½(120 pcf)(47.9 ft - 38.9 ft)(27.2 ft - 4.0 ft)(1.00)][4.0 ft + ⅔(27.2 ft - 4.0 ft)] + [½(120 pcf)(47.9 ft)²(0.323)(1.00)sin(6.6°)](27.2 ft) = 2110.13 kip·ft/ft

$$M_H = P_{EH}\cos\theta(x_3) + P_{LS}\cos\theta(x_4) = (\tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\cos\theta)(h/3) + (\sigma_{LS}hK_a\gamma_{LS}\cos\theta)(h/2)$$

M_H = ½[(120 pcf)(47.9 ft)²(0.323)(1.00)cos(6.6°)](47.9 ft /3) + [(250 psf)(47.9 ft)(0.323)(1.00)cos(6.6°)](47.9 ft /2) = 797.95 kip·ft/ft

$$P_V = P_{EV_1} + P_{EV_2} + P_{EH}\sin\theta = (\gamma_{BF} HB\gamma_{EV}) + (\tfrac{1}{2}\gamma_{RS}(h-H)(B-l)\gamma_{EV}) + (\tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\sin\theta)$$

P_V = (120 pcf)(38.9 ft)(27.2 ft)(1.00) + ½(120 pcf)(47.9 ft - 38.9 ft)(27.2 ft - 4.0 ft)(1.00) + ½(120 pcf)(47.9 ft)²(0.323)(1.00)sin(6.6°) = 144.63 kip/ft

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 100% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Along Wall Facing
B-102-6-14	3.143 in	2.547 in	0 days		
B-103-1-14	2.607 in	2.202 in	5 days	160 ft	1/5570
B-105-4-14	3.074 in	2.569 in	0 days	145 ft	1/4740

W-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 212+25 to 216+50

Calculated By: BRT Date: 6/23/2019
Checked By: JPS Date: 6/24/2019

Boring B-102-6-14

H=	38.9	ft	Total wall height
B'=	18.1	ft	Effective footing width due to eccentricity
D_w =	7.5	ft	Depth below bottom of footing
q_e =	7,970	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-a	G	0.0	2.5	2.5	1.3	125	313	156	156	4,156					15	28	93	0.07	0.999	7,961	8,118	0.046	0.554	0.500	3,984	4,141	0.038	0.460
	A-1-a	G	2.5	5.5	3.0	4.0	125	688	500	500	4,500					15	22	79	0.22	0.970	7,734	8,234	0.046	0.557	0.498	3,968	4,468	0.036	0.436
2	A-2-6	G	5.5	8.0	2.5	6.8	120	988	838	838	4,838					12	16	65	0.37	0.897	7,150	7,988	0.037	0.449	0.491	3,910	4,748	0.029	0.345
3	A-1-a	G	8.0	10.5	2.5	9.3	120	1,288	1,138	1,028	5,028					8	10	56	0.51	0.811	6,466	7,494	0.038	0.459	0.479	3,814	4,843	0.030	0.358
	A-1-a	G	10.5	13.0	2.5	11.8	120	1,588	1,438	1,172	5,172					8	9	56	0.65	0.726	5,783	6,955	0.035	0.415	0.462	3,683	4,855	0.028	0.331
4	A-1-a	G	13.0	16.5	3.5	14.8	135	2,060	1,824	1,371	5,371					57	64	237	0.81	0.634	5,054	6,425	0.010	0.119	0.438	3,493	4,864	0.008	0.097
	A-1-a	G	16.5	20.5	4.0	18.5	135	2,600	2,330	1,644	5,644					57	61	219	1.02	0.541	4,311	5,955	0.010	0.122	0.406	3,233	4,877	0.009	0.103
	A-1-a	G	20.5	24.5	4.0	22.5	135	3,140	2,870	1,934	5,934					57	58	204	1.24	0.464	3,697	5,631	0.009	0.109	0.371	2,958	4,892	0.008	0.095
5	A-1-b	G	24.5	29.5	5.0	27.0	130	3,790	3,465	2,248	6,248					29	28	93	1.49	0.398	3,170	5,418	0.020	0.246	0.335	2,672	4,920	0.018	0.219
6	A-2-4	G	29.5	34.5	5.0	32.0	135	4,465	4,128	2,599	6,599					90	82	342	1.77	0.342	2,727	5,326	0.005	0.055	0.300	2,393	4,992	0.004	0.050
7	A-1-b	G	34.5	41.5	7.0	38.0	135	5,410	4,938	3,034	7,034					99	85	363	2.10	0.292	2,330	5,364	0.005	0.057	0.265	2,113	5,147	0.004	0.053
																						Total Settlement:		3.143 in			Total Settlement:		2.547 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 212+25 to 216+50

Calculated By: BRT Date: 6/23/2019
Checked By: JPS Date: 6/24/2019

Boring B-103-1-14

H=	34.9	ft	Total wall height
B'=	16.1	ft	Effective footing width due to eccentricity
D_w =	7.5	ft	Depth below bottom of footing
q_e =	8,030	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 (Gr. Emb.)	A-1-b	G	0.0	2.5	2.5	1.3	120	300	150	150	4,150					30	56	196	0.08	0.998	8,018	8,168	0.022	0.266	0.500	4,014	4,164	0.018	0.221
	A-1-b	G	2.5	5.0	2.5	3.8	120	600	450	450	4,450					30	45	149	0.23	0.966	7,758	8,208	0.021	0.254	0.497	3,995	4,445	0.017	0.200
2	A-1-a	G	5.0	7.5	2.5	6.3	125	913	756	756	4,756					25	33	108	0.39	0.888	7,131	7,888	0.024	0.282	0.490	3,931	4,687	0.018	0.220
	A-1-a	G	7.5	10.0	2.5	8.8	125	1,225	1,069	991	4,991					25	31	102	0.54	0.791	6,349	7,340	0.021	0.257	0.475	3,815	4,806	0.017	0.203
	A-1-a	G	10.0	12.5	2.5	11.3	125	1,538	1,381	1,147	5,147					25	30	98	0.70	0.697	5,594	6,742	0.020	0.235	0.455	3,656	4,803	0.016	0.190
3	A-1-b	G	12.5	15.5	3.0	14.0	130	1,928	1,733	1,327	5,327					31	35	115	0.87	0.607	4,877	6,204	0.017	0.210	0.430	3,451	4,778	0.015	0.174
	A-1-b	G	15.5	18.5	3.0	17.0	130	2,318	2,123	1,530	5,530					31	34	110	1.06	0.528	4,238	5,768	0.016	0.188	0.400	3,214	4,744	0.013	0.161
	A-1-b	G	18.5	21.5	3.0	20.0	130	2,708	2,513	1,733	5,733					31	33	106	1.24	0.464	3,727	5,459	0.014	0.169	0.371	2,981	4,713	0.012	0.147
4	A-1-b	G	21.5	26.5	5.0	24.0	135	3,383	3,045	2,015	6,015					45	45	149	1.49	0.398	3,196	5,211	0.014	0.166	0.335	2,693	4,708	0.012	0.148
5	A-1-b	G	26.5	31.5	5.0	29.0	130	4,033	3,708	2,366	6,366					28	26	89	1.80	0.336	2,702	5,068	0.018	0.222	0.296	2,380	4,746	0.017	0.203
	A-1-b	G	31.5	36.5	5.0	34.0	130	4,683	4,358	2,704	6,704					28	25	86	2.11	0.291	2,335	5,038	0.016	0.188	0.264	2,119	4,823	0.015	0.175
6	A-4a	C	36.5	41.5	5.0	39.0	130	5,333	5,008	3,042	7,042	22	0.108	0.011	0.444				2.42	0.256	2,053	5,095	0.008	0.101	0.237	1,902	4,944	0.008	0.095
7	A-1-b	G	41.5	49.0	7.5	45.3	135	6,345	5,839	3,483	7,483					78	64	234	2.81	0.222	1,782	5,265	0.006	0.069	0.209	1,681	5,164	0.005	0.066
																						Total Settlement:		2.607 in			Total Settlement:		2.202 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$, Estimate σ_m of 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 = 0.10(Cc) for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 212+25 to 216+50

Calculated By: BRT Date: 06/23/2019
Checked By: JPS Date: 06/24/2019

Boring B-103-1-14

H=	34.9	ft	Total wall height
B'=	16.1	ft	Effective footing width due to eccentricity
D_w =	7.5	ft	Depth below bottom of footing
q_e =	8,030	psf	Equivalent bearing pressure at bottom of wall

	A-4a				
c_v =	1,000			ft^2/yr	Coefficient of consolitation
t =	5			days	Time following completion of construction
H_{dr} =	2.5			ft	Length of longest drainage path considered
T_v =	2.192				Time factor
U =	100			%	Degree of consolidation

$(S_c)_t$ = 1.368 in Settlement complete at 100% of primary consolidation

																					Total Settlement at Facing of Wall			Settlement Complete at 100% 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-1-b	G	0.0	2.5	2.5	1.3	120	300	150	150	4,150					30	56	196	0.08	0.500	4,014	4,164	0.018	0.221	0.421	0.221	0.421
	A-1-b	G	2.5	5.0	2.5	3.8	120	600	450	450	4,450					30	45	149	0.23	0.497	3,995	4,445	0.017	0.200		0.200	
2	A-1-a	G	5.0	7.5	2.5	6.3	125	913	756	756	4,756					25	33	108	0.39	0.490	3,931	4,687	0.018	0.220	0.613	0.220	0.613
	A-1-a	G	7.5	10.0	2.5	8.8	125	1,225	1,069	991	4,991					25	31	102	0.54	0.475	3,815	4,806	0.017	0.203		0.203	
	A-1-a	G	10.0	12.5	2.5	11.3	125	1,538	1,381	1,147	5,147					25	30	98	0.70	0.455	3,656	4,803	0.016	0.190		0.190	
3	A-1-b	G	12.5	15.5	3.0	14.0	130	1,928	1,733	1,327	5,327					31	35	115	0.87	0.430	3,451	4,778	0.015	0.174	0.482	0.174	0.482
	A-1-b	G	15.5	18.5	3.0	17.0	130	2,318	2,123	1,530	5,530					31	34	110	1.06	0.400	3,214	4,744	0.013	0.161		0.161	
	A-1-b	G	18.5	21.5	3.0	20.0	130	2,708	2,513	1,733	5,733					31	33	106	1.24	0.371	2,981	4,713	0.012	0.147		0.147	
4	A-1-b	G	21.5	26.5	5.0	24.0	135	3,383	3,045	2,015	6,015					45	45	149	1.49	0.335	2,693	4,708	0.012	0.148	0.148	0.148	0.148
5	A-1-b	G	26.5	31.5	5.0	29.0	130	4,033	3,708	2,366	6,366					28	26	89	1.80	0.296	2,380	4,746	0.017	0.203	0.378	0.203	0.378
	A-1-b	G	31.5	36.5	5.0	34.0	130	4,683	4,358	2,704	6,704					28	25	86	2.11	0.264	2,119	4,823	0.015	0.175		0.175	
6	A-4a	C	36.5	41.5	5.0	39.0	130	5,333	5,008	3,042	7,042	22	0.108	0.011	0.444				2.42	0.237	1,902	4,944	0.008	0.095	0.095	0.095	0.095
7	A-1-b	G	41.5	49.0	7.5	45.3	135	6,345	5,839	3,483	7,483					78	64	234	2.81	0.209	1,681	5,164	0.005	0.066	0.066	0.066	0.066

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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: 0.000 in

W-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 212+25 to 216+50

Calculated By: BRT Date: 6/23/2019
Checked By: JPS Date: 6/24/2019

Boring B-102-6-14

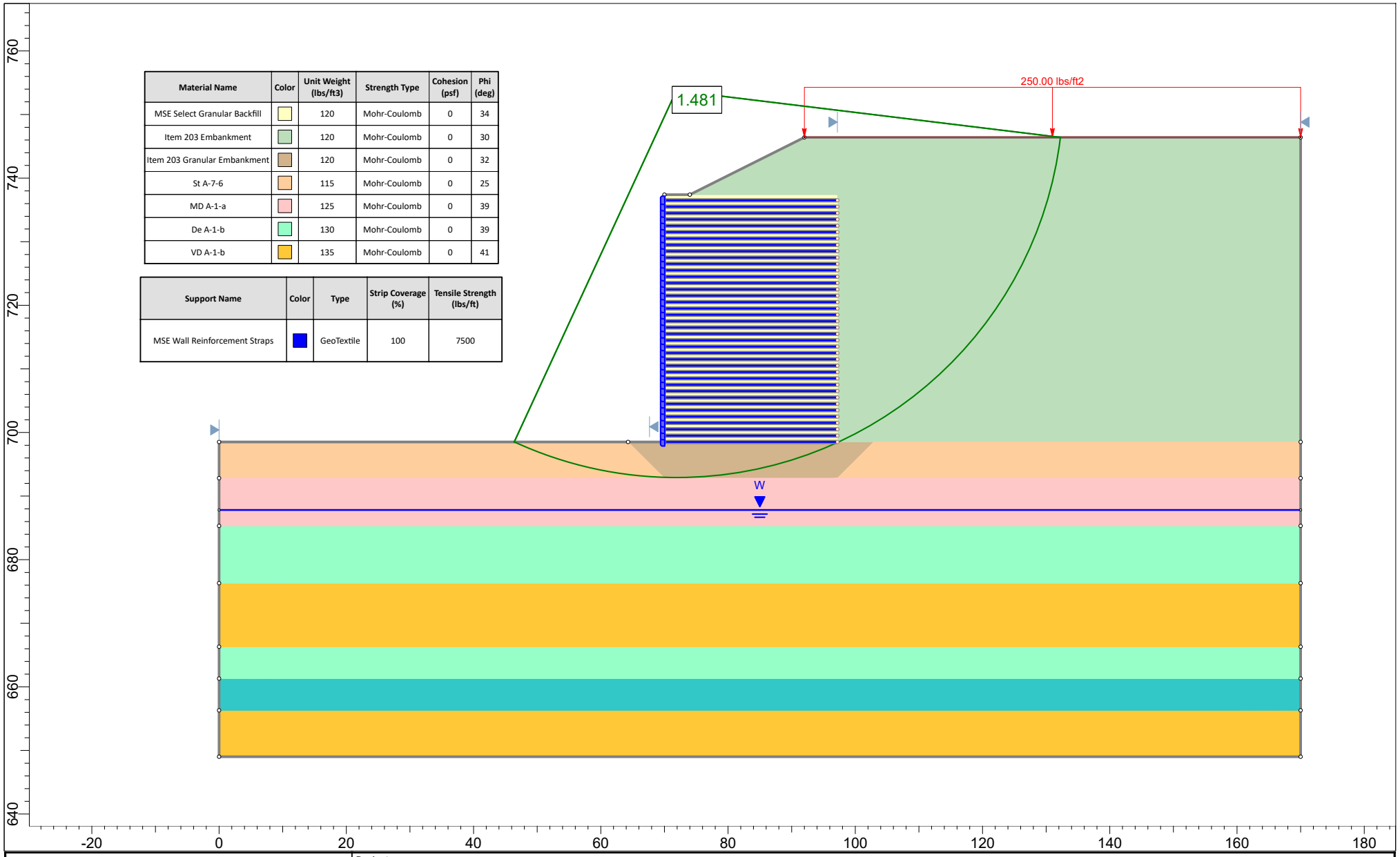
H=	32.5	ft	Total wall height
B'=	15.3	ft	Effective footing width due to eccentricity
D_w =	7.5	ft	Depth below bottom of footing
q_e =	7,570	psf	Equivalent bearing pressure at bottom of wall

																				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 (Gr. Emb.)	A-1-b	G	0.0	2.0	2.0	1.0	120	240	120	120	4,120					30	58	207	0.07	0.999	7,563	7,683	0.017	0.210	0.500	3,785	3,905	0.015	0.176
2	A-2-6	G	2.0	4.5	2.5	3.3	120	540	390	390	4,390					9	14	63	0.21	0.973	7,368	7,758	0.052	0.621	0.498	3,770	4,160	0.041	0.492
	A-2-6	G	4.5	7.0	2.5	5.8	120	840	690	690	4,690					9	12	60	0.38	0.895	6,778	7,468	0.043	0.518	0.490	3,712	4,402	0.034	0.403
3	A-1-a	G	7.0	9.5	2.5	8.3	135	1,178	1,009	962	4,962					70	87	376	0.54	0.793	6,006	6,968	0.006	0.069	0.476	3,600	4,562	0.004	0.054
	A-1-a	G	9.5	12.0	2.5	10.8	135	1,515	1,346	1,143	5,143					70	83	348	0.70	0.694	5,257	6,401	0.005	0.064	0.455	3,443	4,586	0.004	0.052
4	A-1-b	G	12.0	14.0	2.0	13.0	125	1,765	1,640	1,297	5,297					18	21	76	0.85	0.617	4,670	5,967	0.018	0.210	0.433	3,277	4,574	0.014	0.174
	A-1-b	G	14.0	16.0	2.0	15.0	125	2,015	1,890	1,422	5,422					18	20	74	0.98	0.558	4,223	5,645	0.016	0.193	0.412	3,121	4,543	0.014	0.163
	A-1-b	G	16.0	18.5	2.5	17.3	125	2,328	2,171	1,563	5,563					18	20	73	1.13	0.502	3,798	5,360	0.018	0.219	0.389	2,945	4,507	0.016	0.188
5	A-4a	G	18.5	21.0	2.5	19.8	125	2,640	2,484	1,719	5,719					20	21	41	1.29	0.450	3,404	5,123	0.029	0.344	0.364	2,755	4,474	0.025	0.301
	A-4a	G	21.0	23.5	2.5	22.3	125	2,953	2,796	1,876	5,876					20	20	40	1.45	0.407	3,078	4,954	0.026	0.312	0.340	2,576	4,452	0.023	0.278
6	A-1-a	G	23.5	28.5	5.0	26.0	130	3,603	3,278	2,123	6,123					39	38	125	1.70	0.355	2,684	4,807	0.014	0.171	0.308	2,335	4,458	0.013	0.155
7	A-1-a	G	28.5	33.5	5.0	31.0	135	4,278	3,940	2,474	6,474					76	71	272	2.03	0.302	2,287	4,761	0.005	0.063	0.272	2,061	4,535	0.005	0.058
	A-1-a	G	33.5	38.5	5.0	36.0	135	4,953	4,615	2,837	6,837					76	67	253	2.35	0.263	1,989	4,826	0.005	0.055	0.243	1,836	4,672	0.004	0.051
8	A-1-b	G	38.5	41.5	3.0	40.0	135	5,358	5,155	3,127	7,127					84	72	277	2.61	0.238	1,800	4,927	0.002	0.026	0.223	1,684	4,811	0.002	0.024
																						Total Settlement:		3.074 in			Total Settlement:		2.569 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$, Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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)

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Select Granular Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
Item 203 Granular Embankment		120	Mohr-Coulomb	0	32
St A-7-6		115	Mohr-Coulomb	0	25
MD A-1-a		125	Mohr-Coulomb	0	39
De A-1-b		130	Mohr-Coulomb	0	39
VD A-1-b		135	Mohr-Coulomb	0	41

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



Resource International, Inc.
Planning | Engineering | Construction Management | Technology

SLIDEINTERPRET 8.020

Project	Retaining Wall W2 - Sta. 212+25 to 216+50 - MSE Wall Global Stability		
Analysis Description	38.9 ft Wall Height - Drained - Circular - Spencer		
Drawn By	BRT	*Scale* 1:250	*Company* Resource International, Inc.
Date	6/23/2019		*File Name* Retaining Wall W2 - Sta. 212+25 to 216+50 - Global Stability.slim

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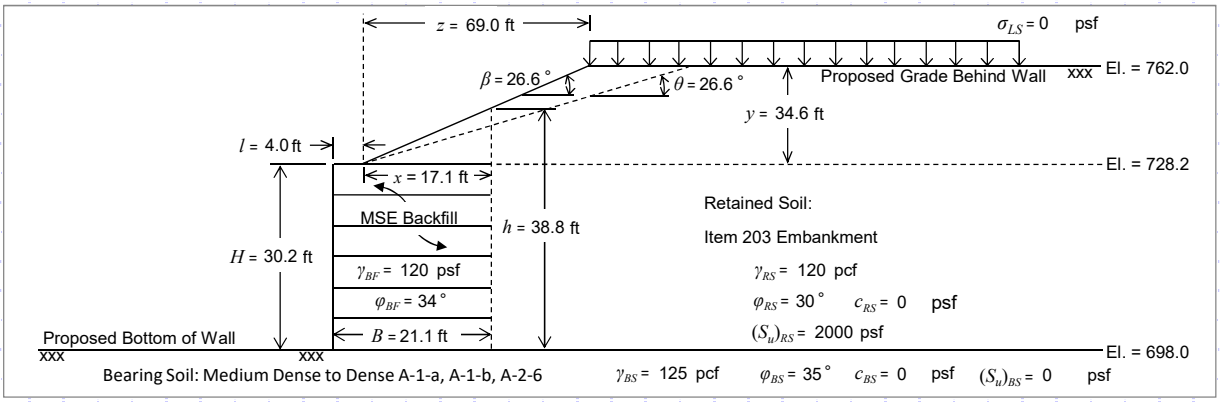
JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	1	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 216+50 to 219+39

Retaining Wall W2 - Sta. 216+50 to 219+39 - B-105-6-14, B-107-3-14, B-107-4-14 - 2:1 Backslope - 30.2 ft. Wall Height



MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	30.2	ft
MSE Wall Width (Reinforcement Length), (B) =	21.1	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	38.8	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	26.6	°
Distance from Toe to Top of Backslope, (z) =	69.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.526	
Live Surcharge Load, (σ_{LS}) =	0	psf

MSE Backfill and Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	35	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(S_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	8.0	ft

LRFD Load Factors

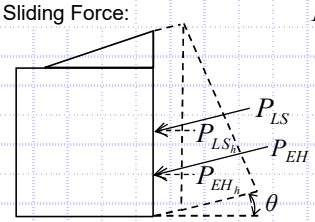
	EV	EH	LS
Strength Ia	1.00	1.50	1.75
Strength Ib	1.35	1.50	1.75
Service I	1.00	1.00	1.00

(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

1. *Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.*

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Sections 11.6.3.6 and 11.10.5.3

Sliding Force:



$$P_H = \left(P_{EH} + P_{LS}\right)\cos\theta$$

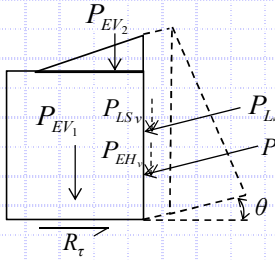
$$P_{EH} = \tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH} = \text{½(120 pcf)(38.8 ft)²(0.526)(1.50)} = 71.13 \text{ kip/ft}$$

$$P_{LS} = \sigma_{LS}hK_a\gamma_{LS} = \text{(0 psf)(38.8 ft)(0.526)(1.75)} = 0.00 \text{ kip/ft}$$

$$P_H = \text{(71.13 kip/ft + 0.00 kip/ft)cos(26.6°)} = 63.60 \text{ kip/ft}$$

Check Sliding Resistance - Drained Condition

Nominal Sliding Resistance:



$$R_\tau = \left(P_{EV_1} + P_{EV_2} + P_{EH}\sin\theta\right)\tan\delta \qquad \text{(Neglect } P_{LS_v} \text{ for conservatism)}$$

$$P_{EV_1} = \gamma_{BF}\cdot H\cdot B\cdot\gamma_{EV} = \text{(120 pcf)(30.2 ft)(21.1 ft)(1.00)} = 76.47 \text{ kip/ft}$$

$$P_{EV_2} = \tfrac{1}{2}\gamma_{RS}\left(h-H\right)\left(B-l\right)\gamma_{EV} = \text{½(120 pcf)(38.8 ft - 30.2 ft)(21.1 ft - 4.0 ft)(1.00)} = 8.79 \text{ kip/ft}$$

$$P_{EH} = \tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH} = \text{½(120 pcf)(38.8 ft)²(0.526)(1.50)} = 71.13 \text{ kip/ft}$$

$$\tan\delta = \left(\tan\varphi_{BS} \le \tan\varphi_{BF}\right) \longrightarrow \tan(35) \le \tan(34) \longrightarrow 0.70 \le 0.67 = 0.67$$

$$R_\tau = \text{[76.47 kip/ft + 8.79 kip/ft + (71.13 kip/ft)sin(26.6°)](0.67)} = 78.46 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

$$P_H \le R_\tau\cdot\phi_\tau \longrightarrow \text{63.60 kip/ft} \le \text{(78.46 kip/ft)(1.0) = 78.46 kip/ft} \longrightarrow \text{63.60 kip/ft} \le \text{78.46 kip/ft} \quad \textbf{OK}$$

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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JOB	FRA-70-13.10	NO.	W-13-072
SHEET NO.	2	OF	6
CALCULATED BY	BRT	DATE	6/23/2019
CHECKED BY	JPS	DATE	6/24/2019

Retaining Wall W2 - Sta. 216+50 to 219+39

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	30.2	ft
MSE Wall Width (Reinforcement Length), (B) =	21.1	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	38.8	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	26.6	°
Distance from Toe to Top of Backslope, (z) =	69.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.526	
Live Surcharge Load, (σ_{LS}) =	0	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	35	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	8.0	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

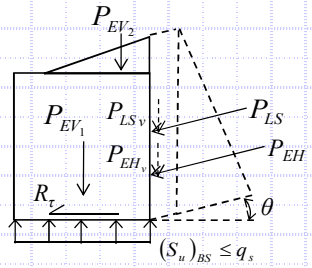
(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 ***(Continued)***

Check Sliding Resistance - Undrained Condition

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



(Neglect P_{LSv} for conservatism)

$(S_u)_{BS}$ = N/A ksf

$q_s = \sigma_v / 2$

$\sigma_v = P_V / B$

$P_V = P_{EV_1} + P_{EV_2} + P_{EH} \sin\theta$

$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(30.2 ft)(21.1 ft)(1.00) = 76.47 kip/ft

$P_{EV_2} = \frac{1}{2} \gamma_{RS} (h - H)(B - l) \gamma_{EV}$

P_{EV_2} = ½(120 pcf)(38.8 ft - 30.2 ft)(21.1 ft - 4.0 ft)(1.00) = 8.79 kip/ft

$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH}$ = ½(120 pcf)(38.8 ft)²(0.526)(1.50) = 71.13 kip/ft

P_V = 76.47 kip/ft + 8.79 kip/ft + (71.13 kip/ft)sin(26.6°) = 117.11 kip/ft

σ_v = (117.11 kip/ft) / (21.1 ft) = 5.55 ksf

q_s = (5.55 ksf) / 2 = 2.78 ksf

R_τ = (N/A ksf ≤ 2.78 ksf)(21.1 ft) = N/A kip/ft

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ N/A ⟶ N/A

Use φ_τ = **1.0** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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JOB	FRA-70-13.10	NO.	W-13-072
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Retaining Wall W2 - Sta. 216+50 to 219+39

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	30.2	ft
MSE Wall Width (Reinforcement Length), (B) =	21.1	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	38.8	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	26.6	°
Distance from Toe to Top of Backslope, (z) =	69.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.526	
Live Surcharge Load, (σ_{LS}) =	0	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	35	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	8.0	ft

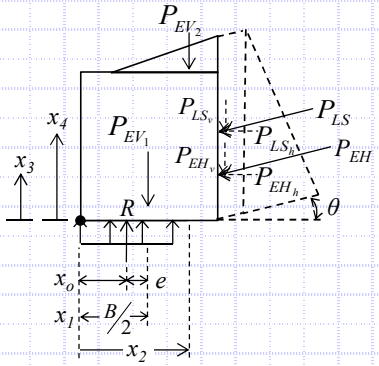
LRFD Load Factors

	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)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.6.3.3



$$e = B/2 - x_o$$

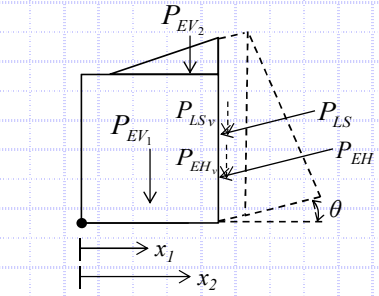
$$x_o = \frac{M_V - M_H}{P_V} = (1614.14 \text{ kip·ft/ft} - 821.73 \text{ kip·ft/ft}) / (117.11 \text{ kip/ft} = 6.77 \text{ ft}$$

M_V = 1614.14 kip·ft/ft
M_H = 821.73 kip·ft/ft
} Defined below

$P_V = P_{EV_1} + P_{EV_2} + P_{EH} \sin\theta$ = 76.47 kip/ft + 8.79 kip/ft + (71.13 kip/ft)sin(26.6°) = 117.11 kip/ft

$e =$ (21.1 ft/ 2) - 6.77 ft = 3.78 ft

Resisting Moment, M_V:



$$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) + P_{EH}\sin\theta(B)$$ (Neglect P_{LS_v} for conservatism)

$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(30.2 ft)(21.1 ft)(1.00) = 76.47 kip/ft

$P_{EV_2} = ½\gamma_{RS}(h - H)(B - l)\gamma_{EV}$ = ½(120 pcf)(38.8 ft - 30.2 ft)(21.1 ft - 4.0 ft)(1.00) = 8.79 kip/ft

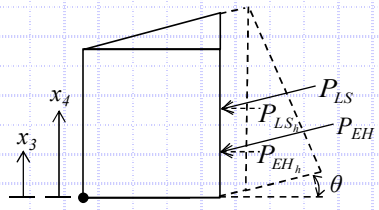
$P_{EH} = ½\gamma_{RS}h^2K_a\gamma_{EH}$ = ½(120 pcf)(38.8 ft)²(0.526)(1.50) = 71.13 kip/ft

$x_1 = B/2$ = (21.1 ft) / 2 = 10.55 ft

$x_2 = l + ⅔(B - l)$ = 4.0 ft + ⅔(21.1 ft - 4.0 ft) = 15.40 ft

M_V = (76.47 kip/ft)(10.55 ft) + (8.79 kip/ft)(15.4 ft) + (71.13 kip/ft)sin(26.6°)(21.1 ft) = 1614.14 kip·ft/ft

Overturning Moment, M_H:



$$M_H = P_{EH}\cos\theta(x_3) + P_{LS}\cos\theta(x_4)$$

$P_{EH} = ½\gamma_{RS}h^2K_a\gamma_{EH}$ = ½(120 pcf)(38.8 ft)²(0.526)(1.50) = 71.13 kip/ft

$P_{LS} = \sigma_{LS}hK_a\gamma_{LS}$ = (0 psf)(38.8 ft)(0.526)(1.75) = 0.00 kip/ft

$x_3 = h/3$ = (38.8 ft) / 3 = 12.92 ft

$x_4 = h/2$ = (38.8 ft) / 2 = 19.38 ft

M_H = (71.13 kip/ft)cos(26.6°)(12.92 ft) + (0 kip/ft)cos(26.6°)(19.38 ft) = 821.73 kip·ft/ft

Check Eccentricity

Limiting Eccentricity: $e_{max} = B/3 \longrightarrow e_{max} =$ (21.1 ft) / 3 = 7.03 ft

$e < e_{max} \longrightarrow$ 3.78 ft < 7.03 ft **OK**

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JOB	FRA-70-13.10	NO.	W-13-072
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Retaining Wall W2 - Sta. 216+50 to 219+39

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	30.2	ft
MSE Wall Width (Reinforcement Length), (B) =	21.1	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	38.8	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	26.6	°
Distance from Toe to Top of Backslope, (z) =	69.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.526	
Live Surcharge Load, (σ_{LS}) =	0	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	35	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	8.0	ft

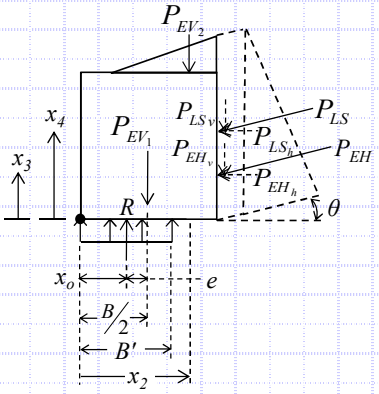
LRFD Load Factors

	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)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.6.3.2



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

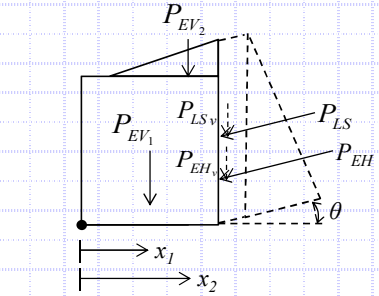
$$B' = B - 2e = 21.1 \text{ ft} - 2(2.91 \text{ ft}) = 15.28 \text{ ft}$$

$$e = B/2 - x_o = (21.1 \text{ ft} / 2) - 7.64 \text{ ft} = 2.91 \text{ ft}$$

$$x_o = \frac{M_V - M_H}{P_V} = (1943.74 \text{ kip·ft/ft} - 821.73 \text{ kip·ft/ft}) / 146.94 \text{ kip/ft} = 7.64 \text{ ft}$$

$$q_{eq} = (146.94 \text{ kip/ft}) / (15.28 \text{ ft}) = 9.62 \text{ ksf}$$

Resisting Moment, M_V:



$$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) + P_{EH}\sin\theta(B)$$

$$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(30.2 \text{ ft})(21.1 \text{ ft})(1.35) = 103.23 \text{ kip/ft}$$

$$P_{EV_2} = \tfrac{1}{2}\gamma_{RS}(h - H)(B - l)\gamma_{EV} = \tfrac{1}{2}(120 \text{ pcf})(38.8 \text{ ft} - 30.2 \text{ ft})(21.1 \text{ ft} - 4.0 \text{ ft})(1.35) = 11.86 \text{ kip/ft}$$

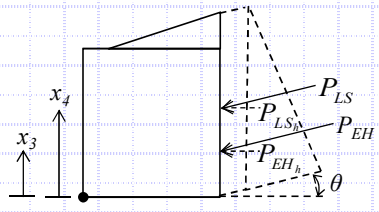
$$P_{EH} = \tfrac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH} = \tfrac{1}{2}(120 \text{ pcf})(38.8 \text{ ft})^2(0.526)(1.50) = 71.13 \text{ kip/ft}$$

$$x_1 = B/2 = (21.1 \text{ ft}) / 2 = 10.55 \text{ ft}$$

$$x_2 = l + \tfrac{2}{3}(B - l) = 4.0 \text{ ft} + \tfrac{2}{3}(21.1 \text{ ft} - 4.0 \text{ ft}) = 15.40 \text{ ft}$$

$$M_V = (103.23 \text{ kip/ft})(10.55 \text{ ft}) + (11.86 \text{ kip/ft})(15.4 \text{ ft}) + (71.13 \text{ kip/ft})\sin(26.6°)(21.1 \text{ ft}) = 1943.74 \text{ kip·ft/ft}$$

Overturning Moment, M_H:



$$M_H = P_{EH}\cos\theta(x_3) + P_{LS}\cos\theta(x_4)$$

$$P_{EH} = \tfrac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH} = \tfrac{1}{2}(120 \text{ pcf})(38.8 \text{ ft})^2(0.526)(1.50) = 71.13 \text{ kip/ft}$$

$$P_{LS} = \sigma_{LS} h K_a \gamma_{LS} = (0 \text{ psf})(38.8 \text{ ft})(0.526)(1.75) = 0.00 \text{ kip/ft}$$

$$x_3 = h/3 = (38.8 \text{ ft}) / 3 = 12.92 \text{ ft}$$

$$x_4 = h/2 = (38.8 \text{ ft}) / 2 = 19.38 \text{ ft}$$

$$M_H = (71.13 \text{ kip/ft})\cos(26.6°)(12.92 \text{ ft}) + (0 \text{ kip/ft})\cos(26.6°)(19.38 \text{ ft}) = 821.73 \text{ kip·ft/ft}$$

Vertical Forces, P_V:

$$P_V = P_{EV_1} + P_{EV_2} + P_{EH}\sin\theta$$

$$P_V = 103.23 \text{ kip/ft} + 11.86 \text{ kip/ft} + (71.13 \text{ kip/ft})\sin(26.6°) = 146.94 \text{ kip/ft}$$

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Retaining Wall W2 - Sta. 216+50 to 219+39

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	30.2	ft
MSE Wall Width (Reinforcement Length), (B) =	21.1	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	38.8	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	26.6	°
Distance from Toe to Top of Backslope, (z) =	69.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.526	
Live Surcharge Load, (σ_{LS}) =	0	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	35	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	7.9	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)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 11.10.5.4 ***(Continued)***

Check Bearing Resistance - Drained Condition

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

$N_{cm} = N_c s_c i_c$ = 46.12 $N_{qm} = N_q s_q d_q i_q$ = 36.6 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 48.0

N_c = 46.12
s_c = 1+(15.28 ft/1939 ft)(33.3/46.12) = 1.000
i_c = 1.000 (Assumed)

N_q = 33.30
s_q = 1+(15.28 ft/1939 ft)tan(35°) = 1.000
d_q = 1+2tan(35°)[1-sin(35°)]²tan⁻¹(4.0 ft/15.28 ft) = 1.100
i_q = 1.000 (Assumed)
C_{wq} = 7.9 ft > 4.0 ft = 1.000

N_γ = 48.03
s_γ = 1-0.4(15.28 ft/1939 ft) = 1.000
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 7.9 ft < 1.5(15.28 ft) + 4.0 ft = 0.500

q_n = (0 psf)(46.12) + (125 pcf)(4.0 ft)(36.6)(1.0) + ½(125 pcf)(15.3 ft)(48.0)(0.5) = 41.25 ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ 9.62 ksf ≤ (41.25 ksf)(0.65) = 26.81 ksf ⟶ 9.62 ksf ≤ 26.81 ksf **OK**

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

Check Bearing Resistance - Undrained Condition

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

$N_{cm} = N_c s_c i_c$ = 5.140 $N_{qm} = N_q s_q d_q i_q$ = 1.000 $N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.000

N_c = 5.140
s_c = 1+(15.28 ft/[(5)(1939 ft)] = 1.000
i_c = 1.000 (Assumed)

N_q = 1.000
s_q = 1.000
d_q = 1+2tan(0°)[1-sin(0°)]²tan⁻¹(4.0 ft/15.28 ft) = 1.000
i_q = 1.000 (Assumed)
C_{wq} = 7.9 ft > 4.0 ft = 1.000

N_γ = 0.000
s_γ = 1.000
i_γ = 1.000 (Assumed)
$C_{w\gamma}$ = 7.9 ft < 1.5(15.28 ft) + 4.0 ft = 0.500

q_n = (0 psf)(5.14) + (125 pcf)(4.0 ft)(1.0)(1.0) + ½(125 pcf)(15.3 ft)(0.0)(0.5) = N/A ksf

Verify Equivalent Pressure Less Than Factored Bearing Resistance

$q_{eq} \le q_n \cdot \phi_b$ ⟶ N/A ⟶ N/A

Use φ_b = **0.65** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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Retaining Wall W2 - Sta. 216+50 to 219+39

MSE Wall Dimensions and Retained Soil Parameters

MSE Wall Height, (H) =	30.2	ft
MSE Wall Width (Reinforcement Length), (B) =	21.1	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (L) =	1939	ft
MSE Wall Effective Height, (h) =	38.8	ft
Retained Soil Backslope, (β) =	26.6	°
Effective Retained Soil Backslope, (θ) =	26.6	°
Distance from Toe to Top of Backslope, (z) =	69.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	°
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf
Retained Soil Undrained Shear Strength, [(S_u)$_{RS}$] =	2000	psf
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.526	
Live Surcharge Load, (σ_{LS}) =	0	psf

Bearing Soil Properties:

MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	°
Bearing Soil Unit Weight, (γ_{BS}) =	125	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	35	°
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, [(s_u)$_{BS}$] =	0	psf
Embedment Depth, (D_f) =	4.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	8.0	ft

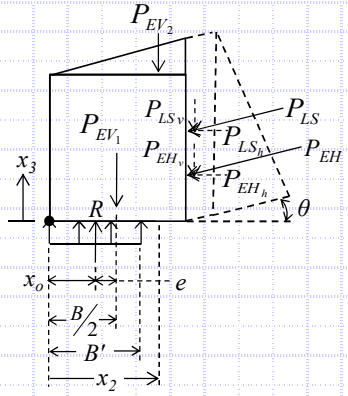
LRFD Load Factors

	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)

1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analysis.

Settlement Analysis (Loading Case - Service I) - AASHTO LRFD BDM Section 11.10.4.1



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

$B' = B - 2e$ = 21.1 ft - 2(2.64 ft) = 15.82 ft

$e = B/2 - x_o$ = (21.1 ft / 2) - 7.91 ft = 2.64 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (1390.04 kip·ft/ft - 547.88 kip·ft/ft) / 106.49 kip/ft = 7.91 ft

q_{eq} = (106.49 kip/ft) / (15.82 ft) = 6.73 ksf

$$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) + P_{EH}\sin\theta(B) = (\gamma_{BF} HB\gamma_{EV})(\tfrac{1}{2}B) + (\tfrac{1}{2}\gamma_{RS}(h-H)(B-l)\gamma_{EV})(l + \tfrac{2}{3}(B-l)) + (\tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\sin\theta)(B)$$

M_V = [(120 pcf)(30.2 ft)(21.1 ft)(1.00)][½(21.1 ft)] + [½(120 pcf)(38.8 ft - 30.2 ft)(21.1 ft - 4.0 ft)(1.00)][4.0 ft + ⅔(21.1 ft - 4.0 ft)] + [½(120 pcf)(38.8 ft)²(0.526)(1.00)sin(26.6°)](21.1 ft) = 1390.04 kip·ft/ft

$$M_H = P_{EH}\cos\theta(x_3) + P_{LS}\cos\theta(x_4) = (\tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\cos\theta)(h/3) + (\sigma_{LS}hK_a\gamma_{LS}\cos\theta)(h/2)$$

M_H = ½[(120 pcf)(38.8 ft)²(0.526)(1.00)cos(26.6°)](38.8 ft /3) + [(0 psf)(38.8 ft)(0.526)(1.00)cos(26.6°)](38.8 ft /2) = 547.88 kip·ft/ft

$$P_V = P_{EV_1} + P_{EV_2} + P_{EH}\sin\theta = (\gamma_{BF} HB\gamma_{EV}) + (\tfrac{1}{2}\gamma_{RS}(h-H)(B-l)\gamma_{EV}) + (\tfrac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\sin\theta)$$

P_V = (120 pcf)(30.2 ft)(21.1 ft)(1.00) + ½(120 pcf)(38.8 ft - 30.2 ft)(21.1 ft - 4.0 ft)(1.00) + ½(120 pcf)(38.8 ft)²(0.526)(1.00)sin(26.6°) = 106.49 kip/ft

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 100% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Along Wall Facing
B-105-6-14	2.248 in	1.812 in	0 days		
B-107-3-14	0.642 in	0.506 in	5 days	165 ft	1/1520
B-107-4-14	0.623 in	0.464 in	0 days	40 ft	1/11430

W-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 216+50 to 219+39

Calculated By: BRT Date: 6/23/2019
Checked By: JPS Date: 6/24/2019

Boring B-105-6-14

H=	30.2	ft	Total wall height
B'=	15.8	ft	Effective footing width due to eccentricity
D_w =	8.0	ft	Depth below bottom of footing
q_e =	6,730	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-2-6	G	0.0	2.5	2.5	1.3	125	313	156	156	4,156					17	32	103	0.08	0.998	6,719	6,875	0.040	0.477	0.500	3,364	3,521	0.033	0.393
2	A-1-a	G	2.5	5.0	2.5	3.8	125	625	469	469	4,469					18	27	90	0.24	0.964	6,491	6,960	0.032	0.390	0.497	3,347	3,816	0.025	0.303
	A-1-a	G	5.0	7.5	2.5	6.3	125	938	781	781	4,781					18	24	83	0.40	0.884	5,947	6,728	0.028	0.340	0.489	3,291	4,072	0.022	0.261
	A-1-a	G	7.5	10.0	2.5	8.8	125	1,250	1,094	1,047	5,047					18	22	78	0.55	0.784	5,278	6,325	0.025	0.299	0.474	3,189	4,236	0.019	0.232
	A-1-a	G	10.0	12.5	2.5	11.3	125	1,563	1,406	1,203	5,203					18	21	77	0.71	0.689	4,638	5,841	0.022	0.269	0.453	3,052	4,255	0.018	0.215
3	A-1-a	G	12.5	15.5	3.0	14.0	135	1,968	1,765	1,391	5,391					48	54	186	0.89	0.600	4,035	5,425	0.010	0.114	0.427	2,875	4,266	0.008	0.094
	A-1-a	G	15.5	18.5	3.0	17.0	135	2,373	2,170	1,608	5,608					48	52	176	1.08	0.520	3,501	5,110	0.009	0.103	0.397	2,672	4,281	0.007	0.087
	A-1-a	G	18.5	21.5	3.0	20.0	135	2,778	2,575	1,826	5,826					48	50	167	1.27	0.457	3,076	4,902	0.008	0.092	0.368	2,474	4,301	0.007	0.080
4	A-1-b	G	21.5	25.5	4.0	23.5	135	3,318	3,048	2,080	6,080					57	56	198	1.49	0.399	2,684	4,764	0.007	0.087	0.336	2,260	4,340	0.006	0.078
	A-1-b	G	25.5	29.5	4.0	27.5	135	3,858	3,588	2,371	6,371					57	54	186	1.74	0.347	2,336	4,706	0.006	0.077	0.303	2,043	4,413	0.006	0.070
																						Total Settlement:		2.248 in			Total Settlement:		1.812 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$, Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 216+50 to 219+39

Calculated By: BRT Date: 6/23/2019
Checked By: JPS Date: 6/24/2019

Boring B-107-3-14

H=	10.5	ft	Total wall height
B'=	6.7	ft	Effective footing width due to eccentricity
D_w =	8.0	ft	Depth below bottom of footing
q_e =	1,910	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-2-6	G	0.0	3.5	3.5	1.8	125	438	219	219	4,219					17	30	98	0.26	0.955	1,824	2,042	0.035	0.417	0.497	948	1,167	0.026	0.312
2	A-1-b	G	3.5	6.0	2.5	4.8	135	775	606	606	4,606					56	78	318	0.71	0.691	1,320	1,926	0.004	0.047	0.454	867	1,473	0.003	0.036
	A-1-b	G	6.0	8.5	2.5	7.3	135	1,113	944	944	4,944					56	70	269	1.08	0.518	989	1,933	0.003	0.035	0.396	757	1,700	0.002	0.029
3	A-1-a	G	8.5	11.5	3.0	10.0	130	1,503	1,308	1,183	5,183					32	38	123	1.49	0.398	759	1,942	0.005	0.063	0.335	640	1,823	0.005	0.055
	A-1-a	G	11.5	15.0	3.5	13.3	130	1,958	1,730	1,402	5,402					32	36	117	1.98	0.309	590	1,992	0.005	0.055	0.277	529	1,932	0.004	0.050
4	A-4a	C	15.0	18.0	3.0	16.5	130	2,348	2,153	1,622	5,622	20	0.090	0.009	0.428				2.46	0.252	481	2,103	0.002	0.026	0.234	446	2,069	0.002	0.024
																						Total Settlement:		0.642 in			Total Settlement:		0.506 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 216+50 to 219+39

Calculated By: BRT Date: 06/23/2019
Checked By: JPS Date: 06/24/2019

Boring B-107-3-14

H=	10.5	ft	Total wall height
B'=	6.7	ft	Effective footing width due to eccentricity
D_w =	8.0	ft	Depth below bottom of footing
q_e =	1,910	psf	Equivalent bearing pressure at bottom of wall

	A-4a				
c_v =	1,000			ft^2/yr	Coefficient of consolitation
t =	5			days	Time following completion of construction
H_{dr} =	3			ft	Length of longest drainage path considered
T_v =	1.522				Time factor
U =	98			%	Degree of consolidation

$(S_c)_t$ = 0.506 in Settlement complete at 100% 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)	S_c (in)	Layer Settlement (in)	Settlement Complete at 100% of Primary Consolidation: $(S_c)_t$ (11) (in)	Layer Settlement (in)
1	A-2-6	G	0.0	3.5	3.5	1.8	125	438	219	219	4,219					17	30	98	0.26	0.497	948	1,167	0.026	0.312	0.312	0.312	0.312
2	A-1-b	G	3.5	6.0	2.5	4.8	135	775	606	606	4,606					56	78	318	0.71	0.454	867	1,473	0.003	0.036	0.065	0.036	0.065
	A-1-b	G	6.0	8.5	2.5	7.3	135	1,113	944	944	4,944					56	70	269	1.08	0.396	757	1,700	0.002	0.029		0.029	
3	A-1-a	G	8.5	11.5	3.0	10.0	130	1,503	1,308	1,183	5,183					32	38	123	1.49	0.335	640	1,823	0.005	0.055	0.105	0.055	0.105
	A-1-a	G	11.5	15.0	3.5	13.3	130	1,958	1,730	1,402	5,402					32	36	117	1.98	0.277	529	1,932	0.004	0.050		0.050	
4	A-4a	C	15.0	18.0	3.0	16.5	130	2,348	2,153	1,622	5,622	20	0.090	0.009	0.428				2.46	0.234	446	2,069	0.002	0.024	0.024	0.023	0.023

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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: 0.000 in

W-13-072 - FRA-70-13.10 - Retaining Wall W2
MSE Wall Settlement - Sta. 216+50 to 219+39

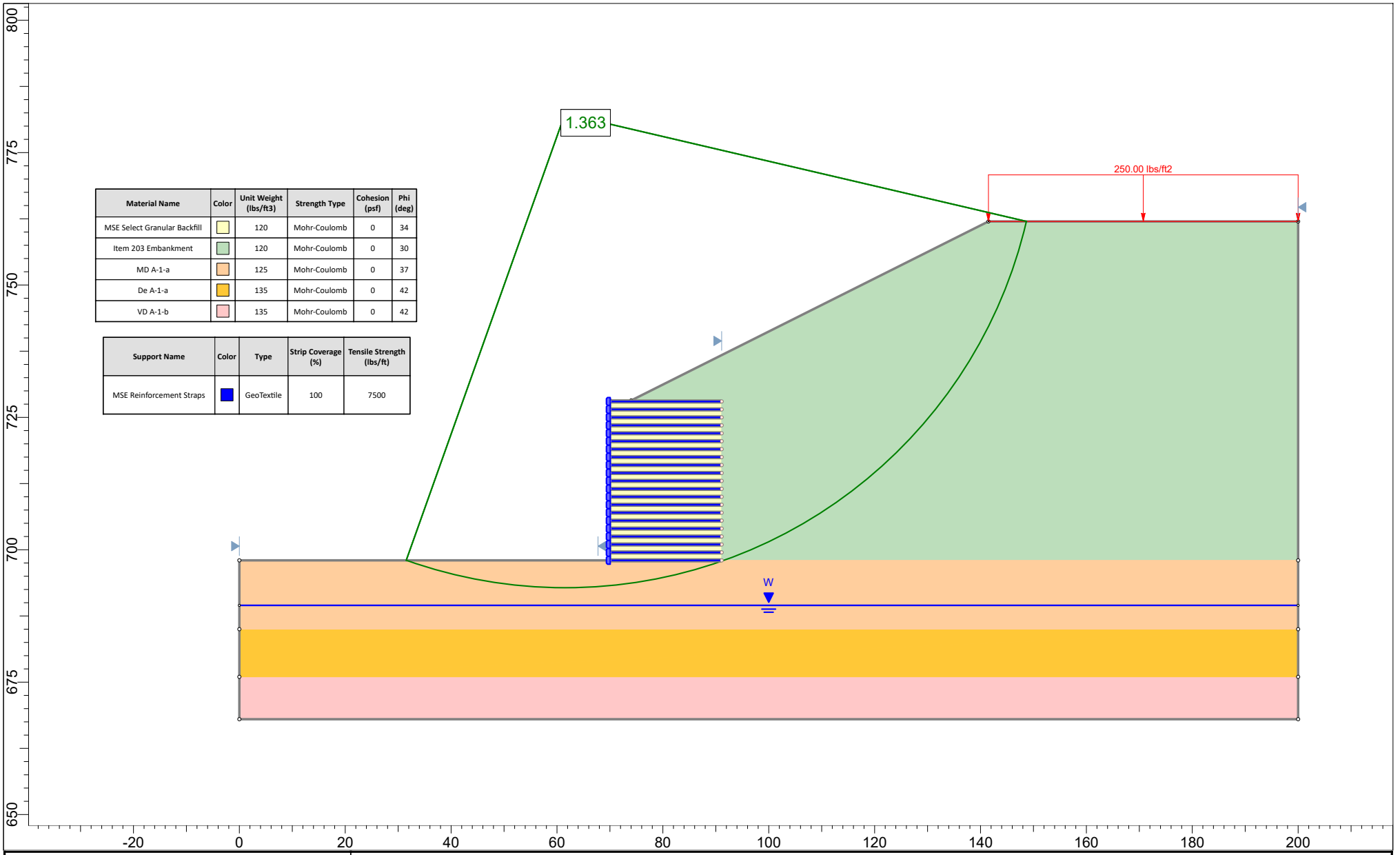
Calculated By: BRT Date: 6/23/2019
Checked By: JPS Date: 6/24/2019

Boring B-107-4-14

H=	7.2	ft	Total wall height
B'=	7.7	ft	Effective footing width due to eccentricity
D_w =	8.0	ft	Depth below bottom of footing
q_e =	1,120	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	125	250	125	125	4,125					20	39	126	0.13	0.993	1,112	1,237	0.016	0.190	0.500	559	684	0.012	0.141
	A-1-b	G	2.0	4.5	2.5	3.3	125	563	406	406	4,406					20	31	101	0.42	0.867	972	1,378	0.013	0.158	0.487	545	952	0.009	0.110
2	A-1-b	G	4.5	7.0	2.5	5.8	120	863	713	713	4,713					11	15	64	0.75	0.670	750	1,463	0.012	0.146	0.448	502	1,215	0.009	0.108
	A-1-b	G	7.0	10.0	3.0	8.5	120	1,223	1,043	1,011	5,011					11	14	62	1.10	0.510	571	1,583	0.009	0.113	0.393	440	1,451	0.008	0.091
3	A-1-a	G	10.0	13.5	3.5	11.8	135	1,695	1,459	1,225	5,225					70	82	338	1.53	0.390	437	1,661	0.001	0.016	0.331	370	1,595	0.001	0.014
																					Total Settlement:		0.623 in			Total Settlement:		0.464 in

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate σ_m of 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. $C_r = 0.10(Cc)$ for 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 (Cohesive 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)



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
MSE Select Granular Backfill		120	Mohr-Coulomb	0	34
Item 203 Embankment		120	Mohr-Coulomb	0	30
MD A-1-a		125	Mohr-Coulomb	0	37
De A-1-a		135	Mohr-Coulomb	0	42
VD A-1-b		135	Mohr-Coulomb	0	42

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

Resource International, Inc.
Planning | Engineering | Construction Management | Technology

SLIDEINTERPRET 8.020

Project	Retaining Wall W2 - Sta. 216+50 to 219+39 - MSE Wall Global Stability		
Analysis Description	30.2 ft Wall Height - Drained - Circular - Spencer		
Drawn By	BRT	*Scale* 1:300	*Company* Resource International, Inc.
Date	5/29/2015		*File Name* Retaining Wall W2 - Sta. 216+50 to 219+39 - Global Stability.slim