

FRA-71-14.36 PHASE 6R RETAINING WALL W5 PID NO. 105588 FRANKLIN COUNTY, OHIO

STRUCTURE FOUNDATION EXPLORATION REPORT (REV. 1)

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Rii Project No. W-13-072

July 2019

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June 19, 2015 (Revised July 19, 2019)

Mr. Gary Gardner, P.E., P.S. 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 W5 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 the proposed Retaining Wall W5 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. Director – Geotechnical Planning

Enclosure: Structure Foundation Exploration Report (Rev. 1)

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Engineering

Construction Management

Technology

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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 W5. It is understood that this wall will be located along the east side of I-71 southbound and Ramp C3, providing the required grade separation between the I-71/Ramp C3 roadways and the adjacent SR-315 SB roadway. The subject wall begins at Sta. 221+10 (BL I-71 SB), and extends northward along the east side of I-71 southbound to Sta. 230+94 (BL I-71 SB), where it crosses under the rear abutment of the FRA-71-1503L bridge structure and continues north along the east side of Ramp C3 from Sta. 3015+50 to 3008+14 (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 W5. Wall heights along the proposed alignment are anticipated to range from 6.8 feet at the southern terminus to a maximum height of 49.2 feet near Sta. 509+81 (BL Wall W5). The total anticipated wall length is on the order of 1,777 lineal feet.

Exploration and Findings

Between June 4, 2014, and April 28, 2015 a total of eleven (11) structural borings, designated as B-099-4-14, B-100-2-14, B-100-4-14, B-102-3-14, B-102-5-14, B-104-1-13, B-105-3-14, B-105-5-14, B-107-2-14, B-108-7-14 and B-108-8-14, were advanced to completion depths ranging from 15.0 to 70.5 feet below the existing ground surface. The borings were drilled in the shoulder of SR-315 southbound and along the toe of the existing embankment supporting I-71 southbound and the ramp from I-70 eastbound to I-71 southbound along the west side of SR-315 southbound. In addition to the borings performed by Rii as part of the current exploration, two (2) historic borings, designated as B-100-0-09 and B-104-0-09, were performed by DLZ in the vicinity of the proposed structure as part of the FRA-70-8.93 Preliminary Engineering project (PID No. 77369) with their findings published in a report dated March 18, 2010. The historic borings were advanced to completion depths of 15.0 and 30.0 feet below the existing ground surface, respectively.

All borings performed as part of the current exploration were located within the existing pavement of I-71 southbound, the existing shoulder pavement of SR-315 southbound, or along the toe of the supporting embankment of I-71 southbound. Borings located within the existing pavement generally encountered either 2.0 to 5.0 inches of asphalt overlying 6.0 to 10.0 inches of concrete, or 9.0 to 12.0 inches of concrete at the ground surface. Aggregate base material was encountered underlying the surficial pavement materials in three (3) of the borings, ranging in thickness from 5.0 to 6.0 inches. Borings located outside the limits of the existing pavement generally encountered 4.0 to 8.0 inches of topsoil at the existing ground surface, as identified by the significant presence of organics and vegetation.

Beneath the surficial materials detailed in the previous section, existing fill and/or possible fill materials were encountered in a total of six (6) of the thirteen (13) borings analyzed as part of this exploration. The fill materials extended to depths ranging from as shallow as 5.5 feet to as deep as 25.5 feet beneath the existing ground surface. In general, the existing and possible fill materials consisted of brown, dark brown, gray and dark gray gravel, gravel with sand, gravel with sand and silt, sandy silt, silt and clay, and silty clay (ODOT A-1-a, A-1-b, A-2-4, A-4a, A-6a, and A-6b). While a majority of the fill materials that were encountered in the borings is considered to be existing embankment fill and suitable for foundation support, it should be noted that asphalt and coal fragments were noted within the fill materials encountered in borings B-105-5-14, B-107-2-14, and B-108-7-14. The presence of organic and chemical odors was also noted within the fill materials encountered in boring B-105-5-14 between El. 703.4 and 698.4 feet msl.

Beneath the surficial and fill materials, natural soils were encountered consisting of both cohesive and granular soils. In general, the borings primarily encountered cohesive natural soils overlying deep granular deposits. The cohesive soils were generally described as black, brown, dark brown, gray, and dark gray sandy silt, silt, silt and clay, silty clay, and clay (ODOT A-4a, A-4b, A-6a, A-6b, and A-7-6). The granular soils were generally described as black, brown, gray and dark gray gravel, gravel with sand, gravel with sand and silt, gravel with sand, silt and clay, coarse and fine sand, sandy silt, and silt (ODOT A-1-a, A-1-b, A-2-4, A-2-6, A-3a, A-4a, A-4b).

Bedrock was encountered in boring B-104-1-13 at a depth of 60.5 feet beneath the ground surface. Upon encountering competent bedrock, as defined by auger refusal, a changeover to rock coring techniques was made and 10.0 feet of rock core was attempted. The cored bedrock consisted of gray limestone, described as being unweathered, very strong, very thickly bedded, calcareous, siliceous, cherty, dolomitic, crystalline, and slightly to moderately fractured, with open apertures and a slightly rough to very rough surface.

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 W5. Wall heights along the proposed alignment are anticipated to range from 6.8 feet at the southern terminus to a maximum height of 49.2 feet near Sta. 509+81 (BL Wall W5). The total anticipated wall length is on the order of 1,777 lineal feet.

MSE Wall Recommendations

Wall heights on the order of 6.8 to 49.2 feet are anticipated along the wall alignment, with the bottom of wall proposed to bear at a minimum depth of 4.0 feet beneath the proposed ground surface.

The anticipated soils at the proposed bearing elevation along a majority of the proposed wall alignment are anticipated to consist of natural cohesive soils and existing embankment fill comprised of stiff to hard silty sand, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6) overlying medium dense to very dense granular soils comprised primarily of gravel and gravel and sand (ODOT A-1-a, A-1-b). MSE wall foundations bearing on these competent natural soils , existing embankment fill or new 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 nominal bearing resistance at the strength limit state.

Retaining Wall W5 MSE Wall Design Parameters

From Station ¹	To Station ¹	Wall Height Analyzed	Backslope Behind Wall	Minimum Required Reinforcement Longth 2 Bearing Resistance at Strength Limit (ksf)		Strength Limit Equivalent Bearing	
		(feet)	in Analysis	Length ² (feet)	Nominal	Factored ³	Pressure ⁴ (ksf)
500+00	507+00	28.3	Level	19.8 (0.70H ≥ 8.0)	13.38	8.70	6.76
507+00	508+50	40.2	Level	32.2 (0.80H)	13.41	8.72	8.58
508+50	509+85	48.5	Level	38.8 (0.80H)	15.99	10.39	10.20
600+19	601+83	36.3	2:1 (Broken-Back)	47.1 (1.30H)	15.42	8.12 ⁽⁵⁾	6.92
601+83	605+50	33.7	2:1 (Broken-Back)	47.2 (1.40H)	14.14	7.81 ⁽⁵⁾	7.76
605+50	607+00	33.8	2:1 (Broken-Back)	23.7 (0.70H)	29.65	19.27	10.10
607+00	607+65	10.1	2:1 (Infinite)	13.0 (1.30H ≥ 8.0)	6.75	4.39	2.27

- 1. Stationing is referenced to the baseline of Retaining Wall W5.
- 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.
- 5. The factored bearing resistance includes a reduction factor applied to the nominal resistance to account for the fore slope in front of the wall per Section 10.6.3.1.2c of the 2018 AASHTO LRFD BDM.

Total settlements ranging from 0.97 to 9.02 inches at the center of the reinforced soil mass and 0.76 to 3.61 inches at the facing of the wall are anticipated along the alignment of Retaining Wall W5 between Sta. 500+00 and 510+30. It should be noted that the high settlement values of 9.02 at the center of the reinforced soil mass and 3.61 inches at the facing of the wall were observed at boring B-102-5-14, which represents the segment of wall between Sta. 507+00 and 508+50. Total settlements ranging from

0.95 to 4.46 inches at the center of the reinforced soil mass and 0.69 to 2.41 inches at the facing of the wall are anticipated along the alignment of Retaining Wall W5 between Sta. 600+19 and 607+65. Based on the results of the analysis, 90 percent of the total settlement is anticipated to occur over a period of approximately 1 to 70 days.

Based on the results of the external and global stability analysis performed for Retaining Wall W5, 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 top of wall) between Sta. 500+00 and 507+00, 0.80 times the height of the MSE wall between Sta. 507+00 and 509+85, and 1.3 times the height of the MSE wall between Sta. 600+19 and 607+65.

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 W5, as shown on the vicinity map and boring plan presented in Appendix I. Retaining Wall W5 will be located along the east side of I-71 southbound and Ramp C3, providing the required grade separation between the I-71/Ramp C3 roadways and the adjacent SR-315 SB roadway. The subject wall begins at Sta. 221+10 (BL I-71 SB), and extends northward along the east side of I-71 southbound to Sta. 230+94 (BL I-71 SB), where it crosses under the rear abutment of the FRA-71-1503L bridge structure and continues north along the east side of Ramp C3 from Sta. 3015+50 to 3008+14 (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 W5. Wall heights along the proposed alignment are anticipated to range from 6.8 feet at the southern terminus to a maximum height of 49.2 feet near Sta. 509+81 (BL Wall W5). The total anticipated wall length is on the order of 1,777 lineal feet. Please note that the recommendations for the portion of the retaining wall where it crosses in front of the rear abutment of the FRA-71-1503L structure are provided in the bridge structure foundation exploration report for that structure, which are presented under a separate cover.

2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1 Site Geology

Both the Illinoian and Wisconsinan glaciers advanced over two-thirds of the State of Ohio, leaving behind glacial features such as moraines, kame deposits, lacustrine deposits and outwash terraces. The glacial and non-glacial regions comprise five physiographic sections based on geological age, depositional process and geomorphic occurrence (physical features or landforms). The project area lies within the Columbus Lowland District of the Till Plains Section. This area is characterized by flat to gently rolling ground moraine deposits from the Late Wisconsinan age. The site topography

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

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

2.2 Existing Conditions

The proposed Retaining Wall W5 is situated between the southbound lanes of I-71 and SR-315 and crosses under I-71 southbound at the rear abutment of the proposed FRA-71-1503L bridge structure, and continues north along the east side of Ramp C3 where it terminates on the south side of the proposed Ramp C5. 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 ranging from 5 to 35 feet above the surrounding terrain. 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, with the Scioto River situated along the west side of I-71/SR-315. The terrain along I-71/SR-315 southbound gently slopes downward to the south, and the surrounding area is relatively flat-lying.

3.0 EXPLORATION

Between June 4, 2014, and April 28, 2015 a total of eleven (11) structural borings, designated as B-099-4-14, B-100-2-14, B-100-4-14, B-102-3-14, B-102-5-14, B-104-1-13, B-105-3-14, B-105-5-14, B-107-2-14, B-108-7-14 and B-108-8-14, were advanced to completion depths ranging from 15.0 to 70.5 feet below the existing ground surface. The borings were drilled in the shoulder of SR-315 southbound and along the toe of the existing embankment supporting I-71 southbound and the ramp from I-70 eastbound to I-71 southbound along the west side of SR-315 southbound. In addition to the borings performed by Rii as part of the current exploration, two (2) historic borings, designated as B-100-0-09 and B-104-0-09, were performed by DLZ in the vicinity of the proposed structure as part of the FRA-70-8.93 Preliminary Engineering project (PID No. 77369) with their findings published in a report dated March 18, 2010. The historic borings were advanced to completion depths of 15.0 and 30.0 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 are 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-099-4-14	BL I-71 SB	221+70.29	44.7' Rt.	39.945765348	-83.014005413	717.0	15.0
B-100-0-09	BL I-71 SB	222+98.38	5.9' Rt.	39.946029204	-83.014337557	716.6	15.0
B-100-2-14	BL I-71 SB	224+29.33	45.6' Rt.	39.946399914	-83.014429916	716.9	15.0
B-100-4-14	BL I-71 SB	225+81.07	46.9' Rt.	39.946768298	-83.014696343	716.3	25.0
B-102-3-14	BL I-71 SB	227+13.65	54.8' Rt.	39.947091789	-83.014919601	715.6	30.0
B-102-5-14	BL I-71 SB	228+75.36	46.6' Rt.	39.947458593	-83.015245752	713.6	45.0
B-104-0-09	BL I-71 SB	230+19.87	52.9' Rt.	39.947804392	-83.015488523	710.2	30.0
B-104-1-13	BL I-71 SB	230+95.90	17.5' Rt.	39.947937268	-83.015727886	714.5	70.5
B-105-3-14	BL Ramp C3	3014+37.27	37.7' Lt.	39.948117531	-83.015969846	719.4	55.0
B-105-5-14	BL Ramp C3	3012+82.16	42.1' Lt.	39.948475867	-83.016258220	723.9	50.0
B-107-2-14	BL Ramp C3	3011+35.50	67.0' Lt.	39.948851596	-83.016450128	727.5	45.0
B-108-7-14	BL Ramp C3	3009+74.31	79.9' Lt.	39.949258997	-83.016710746	703.6	30.0
B-108-8-14	BL Ramp C3	3008+52.04	89.6' Lt.	39.949572208	-83.016991873	703.4	15.0

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 with both truck and all-terrain vehicle (ATV) mounted rotary drilling machines, utilizing either a 3.25 or 4.25-inch inside diameter, hollow stem auger to advance the holes between sampling attempts. Standard penetration test (SPT) and split spoon sampling were generally performed in the borings at 2.5-foot increments to depths ranging from 20.0 to 40.0 feet beneath the existing ground surface, and at 5.0-foot increments thereafter to the boring termination depth or top of bedrock. The SPT, per the American Society for Testing and Materials (ASTM) designation D1586, is conducted using a 140-pound hammer falling 30.0 inches to drive a 2.0-inch outside diameter split spoon sampler 18.0 inches. Rii utilized a calibrated automatic drop hammer to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of 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, N₆₀, by the following equation. Both values are represented on boring logs in Appendix III.

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

Where:

 N_m = measured N value

ER = drill rod energy ratio, expressed as a percent, for the system used

The hammers for the Mobile B-53 and CME 750X drill rigs operated by Rii were calibrated on April 26, 2013, and have drill rod energy ratios of 77.7 and 86.8 percent, respectively. The hammer for the CME 750X and the CME 55 drill rigs operated by Rii were also calibrated on October 20, 2014, with drill rod energy ratios of 85.7 and 92.0 percent, respectively. The updated energy ratio for the CME 750X drill rig utilized for borings performed as part of this project has been reported on the boring logs. 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

Additionally, a total of five (5) borings included in this investigation were performed by our subcontractor, Stock Drilling, to ensure that all of the subject borings were completed in a timely and efficient manner. Stock utilized a BK-81 HD truck mounted drill rig to advance the borings, for which the hammer system was calibrated on March 28, 2013 with a drill rod energy ratio of 72.3 percent. The hammers for the two CME 75 drill rigs operated by DLZ for the performance of the historic borings have drill rod energy ratios of 61.2 and 62.0 percent. No calibration date was available for these rig calibrations at the time of this report.

For instances of little to no recovery from the standard split spoon interval, a 3.0-inch outside diameter split spoon was driven the full length of the standard split spoon interval plus an additional 6.0 inches to obtain a representative sample. Only the final 6.0 inches of sample was retained for classification. Blow counts from the 3S sampling are not correlated with N_{60} values.

In addition to the SPT samples, one (1) undisturbed (Shelby tube) sample was attempted within boring B-100-2-14. This sample was obtained by hydraulically pushing a 2.75-inch outer diameter thin-walled seamless steel tube into the soil at a constant rate of penetration. The recovered Shelby tube sample was cleaned of soil cuttings and preserved within the tube by sealing the ends with wax.

During drilling, heaving sands were encountered in six (6) of the eleven (11) borings performed by Rii for the current exploration. The heaving sand conditions were encountered in the borings at depths ranging from 23.5 to 48.5 feet beneath the ground surface. Where these conditions were encountered, drilling fluid consisting of either water or a mixture of bentonite gel and water was introduced to the borings to counteract the water pressure and prevent the sands from heaving into the augers. Depths at which heaving sands were encountered and where drilling fluid was introduced to the boreholes is presented on the boring logs included in Appendix III.

The depth to bedrock in boring B-104-0-09 was determined by auger refusal on the bedrock surface. Auger refusal is defined as no or insignificant observable advancement of the augers with the weight of the drill rig driving the augers. An NQ-sized double-tube diamond bit core barrel (utilizing wire line equipment) was used to core the bedrock. Coring produced 1.85 inch diameter cores, from which the type of rock and its geological characteristics were determined.

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

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

The RQD value aids in estimating the general quality of the rock and is used in conjunction with other parameters to designate the quality of the rock mass.

Upon completion of drilling, the borings were backfilled in accordance with the ODOT policy for sealing boreholes, utilizing either a mixture of bentonite chips and soil cuttings or cement-bentonite grout. Where borings penetrated the existing pavement, an equivalent thickness of quickset concrete was used to repair the pavement surface.

During drilling for the borings performed as part of the current exploration, 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	116
Plastic and Liquid Limits	AASHTO T89, T90	47
Gradation – Sieve/Hydrometer	AASHTO T88	47
Unconfined Compressive Strength of Intact Rock	ASTM D7012	1

The tests performed are necessary to classify existing soil according to the Ohio Department of Transportation (ODOT) classification system and to estimate engineering properties of importance in determining foundation design and construction recommendations. Results of the laboratory testing are presented on the boring logs in Appendix III and in Appendix IV. 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

All borings performed as part of the current exploration were located within the existing pavement of I-71 southbound, the existing shoulder pavement of SR-315 southbound, or along the toe of the supporting embankment of I-71 southbound. Borings located within the existing pavement generally encountered either 2.0 to 5.0 inches of asphalt overlying 6.0 to 10.0 inches of concrete, or 9.0 to 12.0 inches of concrete at the ground surface. Aggregate base material was encountered underlying the surficial pavement materials in three (3) of the borings, ranging in thickness from 5.0 to 6.0 inches. Borings located outside the limits of the existing pavement generally encountered 4.0 to 8.0 inches of topsoil at the existing ground surface, as identified by the significant presence of organics and vegetation. A summary of the surficial materials encountered in the borings is provided in Table 3.

Table 3. Summary of Surficial Pavement Materials

Acabalt Concrete Aggregate Cravel Tonge								
Boring Number	Asphalt Thickness (in)	Concrete Thickness (in)	Base Thickness (in)	Gravel Thickness (in)	Topsoil Thickness (in)			
B-099-4-14	3.0	9.0	-	-	-			
B-100-0-09	5.0	-	5.0	-	-			
B-100-2-14	2.0	10.0	-	-	-			
B-100-4-14	-	12.0	-	-	-			
B-102-3-14	-	9.0	6.0	-	-			
B-102-5-14	-	-	-	-	6.0			
B-104-0-09	-	-	-	-	4.0			
B-104-1-13	-	-	-	-	4.0			
B-105-3-14	4.0	9.5	-	-	6.0			
B-105-5-14	3.0	6.0	6.0	-	-			
B-107-2-14	3.0	9.0	-	-	-			
B-108-7-14	-	-	-	-	8.0			
B-108-8-14	-	-	-	-	6.0			

4.2 Subsurface Soils

Beneath the surficial materials detailed in the previous section, existing fill and/or possible fill materials were encountered in a total of six (6) of the thirteen (13) borings analyzed as part of this exploration. The fill materials extended to depths ranging from as shallow as 5.5 feet to as deep as 25.5 feet beneath the existing ground surface. In general, the existing and possible fill materials consisted of brown, dark brown, gray and dark gray gravel, gravel with sand, gravel with sand and silt, sandy silt, silt and clay, and silty clay (ODOT A-1-a, A-1-b, A-2-4, A-4a, A-6a, and A-6b). While a majority of the fill materials that were encountered in the borings is considered to be existing embankment fill and suitable for foundation support, it should be noted that asphalt and coal fragments were noted within the fill materials encountered in borings B-105-5-14, B-107-2-14, and B-108-7-14. The presence of organic and chemical odors was also noted within the fill materials encountered in boring B-105-5-14 between El. 703.4 and 698.4 feet msl.

Beneath the surficial and fill materials, natural soils were encountered consisting of both cohesive and granular soils. In general, the borings primarily encountered cohesive natural soils overlying deep granular deposits. The cohesive soils were generally described as black, brown, dark brown, gray, and dark gray sandy silt, silt, silt and clay, silty clay, and clay (ODOT A-4a, A-4b, A-6a, A-6b, and A-7-6). The granular soils were generally described as black, brown, gray and dark gray gravel, gravel with sand, gravel with sand and silt, gravel with sand, silt and clay, coarse and fine sand, sandy silt, and silt (ODOT A-1-a, A-1-b, A-2-4, A-2-6, A-3a, A-4a, A-4b).

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 $(1.0 < \text{HP} \le 2.0 \text{ tsf})$ to hard (HP > 4.0 tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 1.0 to over 4.5 tsf (limit of instrument). The relative density of the granular soils is derived from the SPT blow counts (N₆₀). The relative density of the granular soil encountered ranged from very loose (N₆₀ < 5 blows per foot [bpf]) to very dense (N₆₀ > 50 bpf). Overall blow counts recorded from the SPT sampling ranged from 3 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.

Natural moisture contents of the soil samples tested ranged from 2 to 32 percent. The natural moisture content of the cohesive soil samples tested for plasticity index ranged from 9 percent below to 6 percent above the corresponding plastic limits. In general, the soil exhibited natural moisture contents considered to be significantly below to moderately above the optimum moisture levels.

4.3 Bedrock

Bedrock was encountered in boring B-104-1-13 at a depth of 60.5 feet beneath the ground surface. Upon encountering competent bedrock, as defined by auger refusal, a changeover to rock coring techniques was made and 10.0 feet of rock core was attempted. The cored bedrock consisted of gray limestone, described as being unweathered, very strong, very thickly bedded, calcareous, siliceous, cherty, dolomitic, crystalline, and slightly to moderately fractured, with open apertures and a slightly rough to very rough surface. A summary of the depth and elevation at which bedrock was encountered is presented in Table 4. It should be noted that auger refusal was initially encountered in boring B-104-1-13 at a depth of 51.0 feet beneath the ground surface. Upon encountering auger refusal, a changeover to rock coring techniques was made, and 3.0 feet of rock coring was performed. Upon inspection of the recovered sample, it was determined that auger refusal had been encountered on granite and limestone boulders. As a result, the boring was offset 5.0 feet north of its original location, and soil sampling was continued until competent bedrock was encountered.

Table 4. Top of Bedrock Elevations

Boring	Ground Surface	Top of	Bedrock	Top of Bedrock Core		
Number	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)	
B-104-1-13	714.5	60.5	654.0	60.5	654.0	

The percent recovery and RQD values of the bedrock core runs in boring B-104-1-13 is summarized in Table 5, along with the results of the unconfined compressive strength testing that was performed.

Table 5. Rock Core Summary

Boring Number	Core No.	Elevation (feet msl)	Recovery (%)	RQD (%)	Unconfined Compressive Strength
B-104-1-13	RC-1	654.0 to 649.0	100	75	N/A
D-104-1-13	RC-2	649.0 to 644.0	90	70	q _u @ 65.5' = 8,783 psi

It should be noted that bedrock experiences mechanical breaks during the drilling and coring processes. Rii attempted to account for fresh, manmade breaks during tabulation of the RQD analysis. The quality of the cored bedrock, according to the RQD values, was good ($70 < RQD \le 85\%$).

4.4 Groundwater

Groundwater was encountered in a total of ten (10) of the thirteen (13) borings analyzed as part of this investigation. A summary of the depths where groundwater was encountered in provided in Table 6. Groundwater was initially encountered in the borings at depths ranging from 3.0 to 35.0 feet beneath the ground surface, corresponding to elevations ranging from 685.1 to 713.6 feet msl. At the completion of drilling, groundwater had accumulated within the historic borings B-100-0-09 and B-104-0-09 to depths of 13.4 and 19.4 feet beneath the ground surface, corresponding to elevations of 703.2 and 690.8 feet msl, respectively. The borings performed by Rii as part of the current investigation were either dry at the completion of drilling, or accurate groundwater levels could not be obtained due to the addition of drilling fluids during the drilling process to counteract the water pressure causing sands to heave into the augers.

Table 6. Groundwater Level Readings in Borings

Table 6. Groundwater Level Readings III Borings									
Boring	Ground	Initial Gr	oundwater	Upon Co	mpletion				
Number	Elevation (feet msl)	Depth (feet)	Elevation (feet msl)	Depth ¹ (feet)	Elevation (feet msl)				
B-099-4-14	717.0	Dry	N/A	Dry	N/A				
B-100-0-09	716.6	3.0	713.6	13.4	703.2				
B-100-2-14	716.9	Dry	N/A	Dry	N/A				
B-100-4-14	716.3	Dry	N/A	Dry	N/A				
B-102-3-14	715.6	28.5	687.1	Dry	N/A				
B-102-5-14	713.6	28.5	685.1	N/A	N/A				
B-104-0-09	710.2	22.5	687.7	19.4	690.8				
B-104-1-13	714.5	21.0	693.5	N/A	N/A				
B-105-3-14	719.4	28.5	690.9	N/A	N/A				
B-105-5-14	723.9	33.5	690.4	N/A	N/A				
B-107-2-14	727.5	35.0	692.5	N/A	N/A				
B-108-7-14	703.6	16.0	687.6	N/A	N/A				
B-108-8-14	703.4	13.5	689.9	Dry	N/A				

^{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.

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 W5. The Wall will be located along the east side of I-71 southbound and Ramp C3, providing the required grade separation between the I-71/Ramp C3 roadways and the adjacent SR-315 SB roadway. The subject wall begins at Sta. 221+10 (BL I-71 SB), and extends northward along the east side of I-71 southbound to Sta. 230+94.01 (BL I-71 SB), where it continues north along the east side of Ramp C3 between Sta. 3015+50 and 3008+13.61 (BL Ramp C3). Wall heights along the proposed alignment are anticipated to range from 6.8 feet at the southern terminus to a maximum height of 49.2 feet near Sta. 509+81 (BL Wall W5). The total anticipated wall length is on the order of 1,777 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 2007 ODOT BDM and Supplemental Specification (SS) 840, the minimum length of the reinforced soil mass is equal to 70 percent of the height of the MSE wall or 8.0 feet whichever is greater. A non-structural bearing leveling pad consisting of a minimum of 6.0-inches of unreinforced concrete should be placed at the base of the wall facing for constructability purposes. Please note that the leveling pad is not a structural foundation.

As stated, information available at the time of this report indicates wall heights on the order of 6.8 to 49.2 feet are anticipated along the wall alignment, with the bottom of wall proposed to bear at a minimum depth of 4.0 feet beneath the proposed ground surface. For the analysis, the foundation width was set at 70 percent of the wall height, or a minimum width of 8.0 feet, 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 a majority of the proposed wall alignment will consist of stiff to hard silty sand, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6) overlying medium dense to very dense granular soils comprised primarily of gravel and gravel and sand (ODOT A-1-a, A-1-b). Existing embankment fill comprised of very stiff to hard sandy silt and silt and clay (ODOT A-4a, A-6a) overlying gravel with sand and gravel with sand and silt (ODOT A 1 b, A-2-4) was encountered in borings B-104-1-13, B-105-3-14, B-105-5-14 and B-107-2-14 extending to depths ranging from 6.0 to 13.0 feet below the bearing elevation. Based on the SPT N-values and hand penetrometer values within the existing embankment fill, this material is considered suitable for foundation support.

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 7.

Table 7. Shear Strength Parameters Utilized in MSE Wall Stability Analyses

Material Type	γ (pcf)	φ' (1) (°)	c' (2) (psf)	$S_u^{(3)}$ (psf)
MSE Wall Backfill (Select granular fill)	120	34	0	N/A
Item 203 Embankment Fill (Retained soil)	120	30	0	2,000
Very Stiff Silt (ODOT A-4b)	120	29	0	2,250
Stiff to Hard Silt and Clay (ODOT A-6a)	120	27 to 28	0 to 50	2,750 to 8,000
Stiff to Hard Silty Clay (ODOT A-6b)	120 to 125	26	0	2,500 to 3,000
Very Stiff to Hard Clay (ODOT A-7-6)	120	25	0	2,500
Very Loose to Medium Dense Granular Soil (ODOT A-1-a, A-1-b, A-3a)	115 to 125	29 to 39	0	N/A
Dense to Very Dense Granular Soil (ODOT A-1-a, A-1-b, A-2-4)	130 to 135	37 to 43	0	N/A

^{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.

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 7. 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 soils at the proposed bearing elevation along a majority of the proposed wall alignment are anticipated to consist of natural cohesive soils and existing embankment fill comprised of stiff to hard silty sand, silt and clay, silty clay and clay (ODOT A-4a, A-6a, A-6b, A-7-6) overlying medium dense to very dense granular soils comprised primarily of gravel and gravel and sand (ODOT A-1-a, A-1-b). MSE wall foundations bearing on these competent natural soils, existing embankment fill or new embankment, placed and compacted in accordance with ODOT Item 203, may be proportioned for a factored bearing resistance as indicated in Table 8. 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.

^{2.} Estimated based on overconsolidated nature of soil.

^{3.} $S_u = 125(N_{60})$, Terzaghi and Peck (1967).

Table 8. Retaining Wall W5 MSE Wall Design Parameters

From Station ¹	To Station ¹	Wall Height Analyzed	Backslope Behind Wall	Minimum Required Reinforcement	Streng	esistance at th Limit sf)	Strength Limit Equivalent Bearing
Otation	Otation	(feet)	in Analysis	Length ² (feet)	Nominal	Factored ³	Pressure ⁴ (ksf)
500+00	507+00	28.3	Level	19.8 (0.70H ≥ 8.0)	13.38	8.70	6.76
507+00	508+50	40.2	Level	32.2 (0.80H)	13.41	8.72	8.58
508+50	509+85	48.5	Level	38.8 (0.80H)	15.99	10.39	10.20
600+19	601+83	36.3	2:1 (Broken-Back)	47.1 (1.30H)	15.42	8.12 ⁽⁵⁾	6.92
601+83	605+50	33.7	2:1 (Broken-Back)	47.2 (1.40H)	14.14	7.81 ⁽⁵⁾	7.76
605+50	607+00	33.8	2:1 (Broken-Back)	23.7 (0.70H)	29.65	19.27	10.10
607+00	607+65	10.1	2:1 (Infinite)	13.0 (1.30H ≥ 8.0)	6.75	4.39	2.27

- 1. Stationing is referenced to the baseline of Retaining Wall W5.
- 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.
- 5. The factored bearing resistance includes a reduction factor applied to the nominal resistance to account for the fore slope in front of the wall per Section 10.6.3.1.2c of the 2018 AASHTO LRFD BDM.

For analysis of the wall sections between Sta. 600+19 and 605+50, the calculated factored bearing resistance includes a reduction factor applied to the nominal resistance to account for the fore slope in front of the wall per Section 10.6.3.1.2c of the 2018 AASHTO LRFD BDM. The bearing resistance for the remainder of this portion of the wall alignment, between Sta. 605+50 and 607+65, was calculated assuming no embedment depth below grade since there is just a small wedge of soil that will be placed in front of the wall.

Rii performed a verification of the bearing pressure exerted on the subgrade material for the specified wall heights indicated in Table 8. 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 9.

Table 9. Compressibility Parameters Utilized in Settlement Analysis

Material Type	γ (pcf)	<i>LL</i> (%)	C_c (1)	$C_r^{(2)}$	e _o (3)	$C_{v}^{(4)}$ (ft²/yr)	N_{60}	C' (5)
Very Stiff to Hard Sandy Silt and Silt (ODOT A-4a, A-4b)	120 to 125	22 to 25	0.108 to 0.144	0.011 to 0.014	0.444 to 0.475	1,000	N/A	N/A
Stiff to Hard Silt and Clay (ODOT A-6a)	120 to 125	25 to 34	0.135 to 0.216	0.014 to 0.022	0.467 to 0.538	600	N/A	N/A
Stiff to Hard Silty Clay (ODOT A-6b)	115 to 125	33 to 40	0.207 to 0.270	0.021 to 0.027	0.530 to 0.585	300	N/A	N/A
Very Stiff to Hard Clay (ODOT A-7-6)	120 to 125	43 to 56	0.297 to 0.414	0.030 to 0.041	0.608 to 0.710	150	N/A	N/A
Very Loose to Medium Dense Granular Soil (ODOT A-1-a, A-1-b, A-2-6, A-3a)	115 to 130	N/A	N/A	N/A	N/A	N/A	3 to 28	47 to 105
Dense to Very Dense Granular Soil (ODOT A-1-a, A-1-b, A-2-4, A-3a, A-4a)	130 to 135	N/A	N/A	N/A	N/A	N/A	33 to 120	75 to 851

- 1. Per Table 6-9, Section 6.14.1 of FHWA GEC 5.
- 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 10. Total settlements ranging from 0.97 to 9.02 inches at the center of the reinforced soil mass and 0.76 to 3.61 inches at the facing of the wall are anticipated along the alignment of Retaining Wall W5 between Sta. 500+00 and 510+30. It should be noted that the high settlement values of 9.02 at the center of the reinforced soil mass and 3.61 inches at the facing of the wall were observed at boring B-102-5-14, which represents the segment of wall between Sta. 507+00 and 508+50. Total settlements ranging from 0.95 to 4.46 inches at the center of the reinforced soil mass and 0.69 to 2.41 inches at the facing of the wall are anticipated along the alignment of Retaining Wall W5 between Sta. 600+19 and 607+65.

Based on the results of the analysis, 90 percent of the total settlement is anticipated to occur over a period of approximately 1 to 70 days. Please note that the consolidation settlement and time rate of consolidation are based on estimates using correlated compressibility parameters provided in Table 9 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 10. Retaining Wall W5 MSE Wall Settlement Values

From	То	Service Limit Equivalent		ment Values hes)	Time for 90%
Station ¹	Station ¹	Bearing Pressure ³ (ksf)	Center of Wall Mass	Facing of Wall	Consolidation (Days)
500+00	507+00	1.25 to 4.74	0.97 to 2.62	0.76 to 1.96	13 to 70
507+00	508+50	6.11	9.02	3.61	95
508+50	509+85	6.86 to 7.29	4.18 to 5.43	2.54 to 2.63	1 to 5
600+19	601+83	5.05 to 5.30	3.52 to 4.46	1.87 to 2.41	3 to 15
601+83	605+50	5.61 to 6.10	2.95 to 3.51	1.32 to 1.54	1 to 5
605+50	607+00	7.06	2.40	1.34	1
607+00	607+65	1.65	0.95	0.69	3

^{1.} Station referenced to the baseline of Retaining Wall W5.

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 1/500, which is within the tolerable limit of 1/100.

If the total or differential settlement values predicted for the proposed walls 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. Guidelines for the implementation of ground improvement, if utilized for any segment along this wall, are provided in the structure foundation exploration report for Retaining Wall E4. Settlement calculations are provided in Appendix IV.

^{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.

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 8. Based on the minimum length of reinforced soil mass presented in Table 8 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. Given that the bearing soils consist of both cohesive and granular materials, the sliding resistance was evaluated for both drained and undrained conditions. For drained conditions, the sliding resistance is determined by multiplying a coefficient of sliding friction "f" times the total vertical force at the base of the wall. The coefficient of sliding friction is determined based on the limiting friction angle between the foundation soil and the reinforced soil backfill. Based on the soil parameters listed in Section 5.1.1 for the foundation and reinforced soil backfill material, a coefficient of sliding friction of 0.47 to 0.67 was utilized for design. For undrained conditions, the sliding resistance is taken as the limiting value between the undrained shear strength of the bearing soil and half of the vertical stress applied by the wall multiplied by the width of the MSE wall. Based on the soil parameters listed in Section 5.1.1, the undrained shear strength of the cohesive bearing material ranges from 2.5 to 4.0 ksf.

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 8 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 <u>will</u> 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 7. 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 8, the resulting factor of safety under drained conditions (long-term stability) was greater than or equal to 1.3. The wall was also evaluated under undrained conditions (short-term stability) to verify the stability of the wall during and immediately following construction. The resulting factor of safety under undrained conditions was also greater than 1.3.

5.1.7 Final MSE Wall Considerations

Based on the results of the external and global stability analysis performed for Retaining Wall W5, 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 top of wall) between Sta. 500+00 and 507+00, 0.80 times the height of the MSE wall between Sta. 507+00 and 509+85, and 1.3 times the height of the MSE wall between Sta. 600+19 and 607+65. Bearing resistance and global stability were the controlling factors in the determination of the recommended strap length in the areas where the recommended strap length was 80 to 130 percent of the wall height.

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 11 and Table 12.

Table 11. 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, $\gamma' = \gamma$ - 62.4 pcf and add hydrostatic water pressure.

Table 12. 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, $\gamma' = \gamma$ - 62.4 pcf and add hydrostatic water pressure.

These parameters are considered appropriate for the design of all subsurface structures and any excavation support systems. Subsurface structures (where the top of the structure is restrained from movement) should be designed based on at-rest conditions (k_o) . For proposed temporary retaining structures (where the top of the structure is allowed to move), earth pressure distributions should be based on active (k_a) and passive (k_p) conditions. The values in this table have been estimated from correlation charts based on minimum standards specified for compacted engineered fill materials. These recommendations do not take into consideration the effect of any surcharge loading or a sloped ground surface (a flat surface is considered). Earth pressures on excavation support systems will be dependent on the type of sheeting and method of bracing or anchorage.

5.3 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 13. Excavation Back Slopes

Table 15: Excavation back clopes							
Soil	Soil Maximum Back Slope						
Soft to Medium Stiff Cohesive	1.5 : 1.0	Above Ground Water Table and No Seepage					
Stiff Cohesive	1.0 : 1.0	Above Ground Water Table and No Seepage					
Very Stiff to Hard Cohesive	0.75 : 1.0	Above Ground Water Table and No Seepage					
All Granular & Cohesive Soil Below Ground Water Table or with Seepage	1.5 : 1.0	None					
Rock to 3.0' +/- below Auger Refusal	0.75 : 1.0	Above Ground Water Table and No Seepage					
Stable Rock	Vertical	Above Ground Water Table and No Seepage					

5.3.2 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

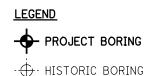
BORINGS B-099-4-14, B-100-2-14, B-100-4-14, B-102-3-14, B-102-5-14, B-105-3-14, B-105-5-13, B-107-2-14, B-108-7-14 AND B-108-8-13 WERE PERFORMED FOR WALL W5.

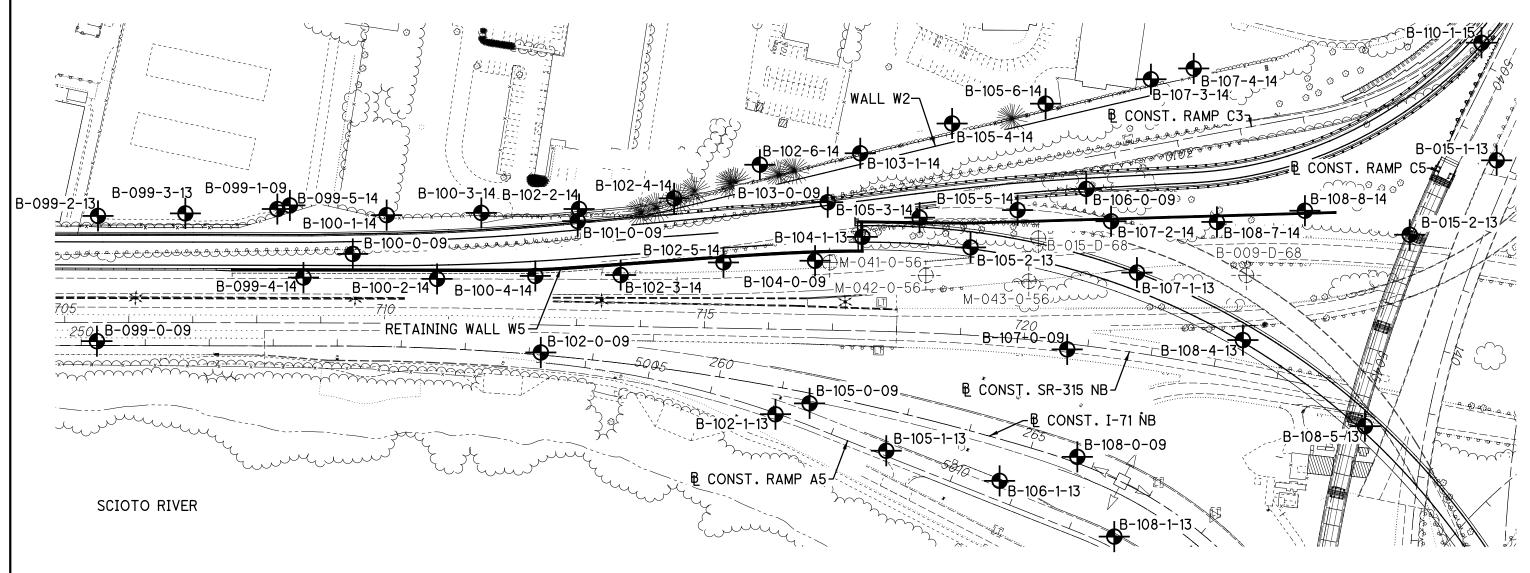
BORINGS B-099-2-13, B-099-3-13, B-099-5-14, B-100-1-14, B-100-3-14, B-102-2-14, B-102-4-14, B-102-6-14, B-103-1-14, B-105-4-14, B-105-5-14, B-107-3-14 AND B-107-4-14 WERE PÉRFORMED FOR WALL W2.

BORINGS B-104-1-13, B-105-2-13, B-107-1-13, B-108-4-13 AND B-108-5-13 WERÉ PERFORMED FOR THE FRA-71-1503L STRUCTURE.

BORINGS B-015-1-13, B-015-2-13, B-102-1-13. B-105-1-13. B-106-1-13. B-108-1-13 AND B-110-1-15 WERE PERFORMED AS PART OF THE FRA-70-12.68 PROJECT 4A/4R.

BORINGS 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.





BORING PLAN FRA-70-13.10 - RETAINING WALL W5 FRANKLIN COUNTY, OHIO

PROJECT NO. Rii W-13-072

SCALE: 1"=150' 75 150



DRAWN RRM REVIEWED BRT DATE 7-17-19



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)

<u>Description</u>	Blows per foot – SPT (N ₆₀)					
Very Loose	Below		5			
Loose	5	-	10			
Medium Dense	11	-	30			
Dense	31	-	50			
Very Dense	Over		50			

<u>Cohesive Soils</u> - 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

	, ,		, ,	Unconfined
<u>Description</u>	Blows per foot - SPT (N ₆₀)			Compression (tsf)
Very Soft	Below		2	UCS ≤ 0.25
Soft	2	-	4	$0.25 < UCS \le 0.5$
Medium Stiff	5	-	8	0.5 < UCS ≤ 1.0
Stiff	9	-	15	1.0 < UCS ≤ 2.0
Very Stiff	16	-	30	$2.0 < UCS \le 4.0$
Hard	Over		30	UCS > 4.0

<u>Gradation</u> - 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 3/4"
fine	3/4" to 4.75 mm (3/4" to #4 Sieve)	3/4" to 2.0 mm (3/4" 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)	<u>-</u>
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:

<u>Term</u>	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:

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

Bedrock – The following terms are used to describe bedrock hardness:

<u>Term</u>		Blows per	foot - S	PT (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"			

DESCRIPTION OF ROCK TERMS

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

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

Description Field Parameter

Unweathered No evidence of any chemical or mechanical alteration of the rock mass. Mineral crystals have a

right appearance with no discoloration. Fractures show little or not staining on surfaces.

Slight discoloration of the rock surface with minor alterations along discontinuities. Less than 10% Slightly Weathered

of the rock volume presents alteration.

Portions of the rock mass are discolored as evident by a dull appearance. Surfaces may have a Moderately Weathered

pitted appearance with weathering "halos" evident. Isolated zones of varying rock strengths due to

alteration may be present. 10 to 15% of the rock volume presents alterations.

Highly Weathered Entire rock mass appears discolored and dull. Some pockets of slightly to moderately weathered

rock may be present and some areas of severely weathered materials may be present.

Severely Weathered Majority of the rock mass reduced to a soil-like state with relic rock structure discernable. Zones of

more resistant rock may be present but the material can generally be molded and crumbled by

hand pressures.

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

Description Field Parameter

Very Weak Can be carved with knife and scratched by fingernail. Pieces 1 in. thick can be broken by finger

Can be grooved or gouged with knife readily. Small, thin pieces can be broken by finger pressure. Weak Slightly Strong

Can be grooved or gouged 0.05 in deep with knife. 1 in. size pieces from hard blows of geologist

hammer.

Moderately Strong Can be scratched with knife or pick. 1/4 in. size grooves or gouges from blows of geologist

hammer.

Can be scratched with knife or pick with difficulty. Hard hammer blows to detach hand specimen. Strong Very Strong

Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to detach hand

Extremely Strong Cannot be scratched by knife or pick. Hard repeated blows of geologist hammer to chip hand

specimen.

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

Description Thickness

Very Thick Greater than 36 inches 18 to 36 inches Thick 10 to 18 inches Medium Thin 2 to 10 inches

Very Thin 0.4 to 2 inches Laminated 0.1 to 0.4 inches Thinly Laminated Less than 0.1 inches

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

Degree of Fracturing

Description Spacing

Greater than 10 feet Unfractured

Intact 3 to 10 feet Slightly Fractured 1 to 3 feet

Moderately Fractured

Condition of Fractures

Aperature Width Surface Roughness

Description Width Description Criteria

Open Greater than 0.2 inches Very Rough Near vertical steps and ridges occur on surface 0.05 to 0.2 inches Slightly Rough Asperities on the surfaces distinguishable Narrow Less than 0.05 inches Slickensided Surface has smooth, glassy finish, evidence of Tight

Striations

RQD – Rock Quality Designation:

Rock Index Property Classification RQD %

0 - 25%Very Poor 26 - 50% Poor 51 - 70% Fair 71 - 85%Good 86 - 100%Very Good



CLASSIFICATION OF SOILS Online 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.)

C		Classif	cation	LL _O /LL	*	*	Liquid	Plastic	Group	T
SYMBOL	DESCRIPTION	AASHTO	OHIO	× 100*	Pass #40	Pass #200	Liquid Limit (LL)	Index (PI)	Index Max.	REMARKS
0000	Gravel and/or Stone Fragments	Α-	1-a		30 Max.	15 Max.	-	6 Max.	0	Min. of 50% combined grave cobble and boulder sizes
0.000	Gravel and/or Stone Fragments with Sand	Α-	1-b		50 Max.	25 Max.		6 Max.	0	
F.S	Fine Sand	А	-3		51 Min.	10 Max.	NON-P	LASTIC	0	
	Coarse and Fine Sand		A-3a			35 Max.		6 Max.	0	Min. of 50% combined coars and fine sand sizes
	Gravel and/or Stone Fragments with Sand and Silt		2-4			35 Max.	40 Max. 41 Min.	10 Max.	0	
	Gravel and/or Stone Fragments with Sand, Silt and Clay	-	2-6 2-7			35 Max.	40 Max. 41 Min.	11 Min.	4	
	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	Α-	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 a A-5, A-6a, A-6b A-7-5 or A-7-6

MATERIAL CLASSIFIED BY VISUAL INSPECTION

Sod and Topsoil XXXX 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)
LLo	=	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:
		\sum segments equal to or longer than 4.0 inches
		core run length
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: $N_{60} = N_m^*(ER/60)$
		equation. Not - Num (Livot)
SS	=	Split spoon sample
SS 2S	=	·
		Split spoon sample 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
28	=	Split spoon sample 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.

Classification Test Data

=

Gradation (as defined on Description of Soil Terms):

Water level measured at completion of drilling

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.																			
I	PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM /	OPERATOR	R: STOCK / T.B./B.Z	Z. DI	RILL RIG	3: _BK	81 HD (SN 8	310792.	.111)	STAT	ION /	OFFS	SET:	221	+70.2	9 / 44.	7' RT		RATION ID
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l	PID: <u>89464</u> BR ID: <u>N/A</u>	DRILLING METHO		4.25" HSA		ALIBRAT			3/28/13	i	ELEV			717.0				-	5.0 ft.	PAGE 1 OF 1
ļ	START: <u>4/14/15</u> END: <u>4/14/15</u>	SAMPLING METH		SPT	_	NERGY F			72.3		LAT /				_			.014005	,	T
l	MATERIAL DESCRIPTION		ELEV.	DEPTHS	SPT			SAMPLE			GRAD			,	_	ERBI			ODOT CLASS (GI)	BACK
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3	FINE SAND, TRACE SILT, TRACE CLAY, MOIST.	RSE TO PO	1	14	4	100	<u>├</u> .,			\dagger	+									1>11>
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NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING

Client	: ms c	onsu	Itants	6			Project: FRA-70-8.93						Job	No. 02	21-10	04.01	
LOG	DF: Bo	ring	B-10	0-0-0	9	Lo	cation: Sta. 222+98.38, 5.9' RT., BL I-71 SB		D	ate	Dril	led: 9	/1/200	9			
Depth (ft)	Elev. (ft)	Blows per 6"	Recovery	Sam No Prive		Hand Penetro- meter (tsf)	WATER OBSERVATIONS: Water seepage at: 3.0' Water level at completion: 13.4' FIELD NOTES: DESCRIPTION	Grapine Log	GF pues 3 %		F. Sand	% Silt NO % Clay	Natu Flows	ral Mo L ⊢	isture	TRATIO Content, Non-Plas	% - ● LL
0.8 - - - - 5	715.8	9 5 4 5 2 5 3	10	1 2 3			Aggregate Base - 5" POSSIBLE FILL: Loose brown GRAVEL (A-1-a), some fine to coarse sand, trace to little silt; damp to moist.	6	8 17	7		9					
7.5 - 9.0	710.6	5 4 23 32 17 28 8 3 6 5	12 12 6	4 5 6		1.0	Stiff gray SANDY SILT (A-4a), some fine to coarse sand, some gravel; moist. Very dense gray GRAVEL WITH SAND (A-1-b), little silt; damp. Stiff brown SILTY CLAY (A-6b), little to some fine to coarse sand, little gravel; contains rock fragments; damp to moist.	2	1 1 2:	1	15	30 23 16 27 30	 NP • 				
- - - 15.0 15	701.6	6 18 12 8 13 24	10	7		1.0)		
- - 20 - - - - - - -							Bottom of Boring - 15.0'										

RESOURCE INTERNATIONAL, INC.																			
PROJECT:FRA-70-13.10 - PHASE 6A	DRILLING FIRM /	OPERATOR	E: STOCK / T.B./B.Z	Z. DRI	LL RIG	: <u>BK</u> 8	B1 HD (SN	810792.	111)	STAT	ION /	OFFS	ET: _	224	+29.3	3 / 45.	6' RT		RATION I
Rii TYPE: STRUCTURE	SAMPLING FIRM	/ LOGGER:	RII / D.M.	HAN	MER:		AUTOM	ATIC		ALIGI	NMEN	IT:		BL	. I-71	SB		B-10	0-2-14
PID: <u>89464</u> BR ID: <u>N/A</u>	DRILLING METHO	DD:	4.25" HSA	CAL	IBRAT	ION DA	TE:	3/28/13		ELEV	/ATIOI	N:	716.9	(MSL	.)	EOB:		15.0 ft.	PAGE
START: <u>4/13/15</u> END: <u>4/13/15</u>	SAMPLING METH	IOD:	SPT	ENE	RGY F	RATIO (%):	72.3		LAT /	LONG	G:		39.9	94640	0, -83.	.014430)	1 OF 1
MATERIAL DESCRIPTION	•	ELEV.	DEDTUG	SPT/		REC	SAMPLE	HP	G	RAD	ATIO	N (%)	ATT	ERB	ERG		ODOT	BACK
AND NOTES		716.9	DEPTHS	RQD	N ₆₀	(%)	ID	(tsf)			FS	SI	CL	LL	PL	PI	wc	CLASS (GI)	FILL
∖0.2' - ASPHALT (2.0")	/ X X	716.7/	L _			,													
0.8' - CONCRETE (10.0")		715.9	<u></u> 1 ¬	6															_×××××××××××××××××××××××××××××××××××××
VERY STIFF, BROWN SILTY CLAY, LITTLE COARS	SE TO	1	- 2 -	ິ 9	31	67	SS-1	2.50	-	-	-	_	-	-	_	-	20	A-6b (V)	\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
FINE SAND, LITTLE FINE GRAVEL, MOIST.		1	F 4 T	17														` '	1 × ×
-ROCK FRAGMENTS PRESENT IN SS-1			- 3 -																1>11
			<u> </u>	5							_								15LV 5
		1		5 10	18	78	SS-2	2.25	12	11	8	34	35	40	18	22	19	A-6b (12)	1>17
		711.4	_ 5 _	- 10															1 × × 1
VERY STIFF, BROWN SILT AND CLAY , LITTLE CO.	ARSE ////	1	− 6 −	7															- 1 LV 1
TO FINE SAND, TRACE FINE GRAVEL, DAMP.]		15	41	78	SS-3	2.50	-	-	-	_	-	-	_	_	12	A-6a (V)	1>11
-ROCK FRAGMENTS PRESENT IN SS-3		7000	<u></u> 7	19														()	JLV J
VERY STIFF, BROWN SILTY CLAY , SOME FINE GF	RAVEL ///	708.9	- 8 -																1>11
	WAVLL,		9 -																<1>/ 1 / 1 / 1 / 1 / 1 / 1 / 1 / 1 / 1 /
,			<u> </u>																1 LV 1
			- 10 																1 > 1 1
			- 11 -			67	ST-4	3.25	25	9	6	30	30	35	17	18	20	A-6b (8)	JLV J
-ROCK FRAGMENTS PRESENT THROUGHOUT			- 40															,	1> \ 1 1 \ \ 1
			- 12 - -																7>17
		1	 13																JYLV J
		1	- 14	5	0.5		20.												1>11
		701.9	EOB	11 18	35	83	SS-5	2.75	-	-	-	-	-	-	-	-	17	A-6b (V)	1LV 1
-ROCK FRAGMENTS PRESENT THROUGHOUT																			
NOTES: GROUNDWATER NOT ENCOUNTERED DURING DE ABANDONMENT METHODS, MATERIALS, QUANTITIES: CO		THE AUGEF	R SOIL CUTTINGS																

RESOURCE INTERNATIONAL, INC.																			EVDI OF	
PROJECT: FRA-70-13.10 - PHASE 6A	DRILLING FIRM / (81 HD (SN 8		.111)				:T: _				9' RT		RATION ID 0-4-14
RII TYPE: STRUCTURE	SAMPLING FIRM /			/ D.M.		MMER:		AUTOMA			ALIGN					I-71 S			- 🖵	PAGE
PID: <u>89464</u> BR ID: <u>N/A</u>	DRILLING METHO		4.25" HS	6A		LIBRAT			3/28/13		ELEV			16.3					5.0 ft.	1 OF 1
START: <u>4/14/15</u> END: <u>4/14/15</u>	SAMPLING METH		SPT		=	ERGY F			72.3	_	LAT /		_					014696	i	1
MATERIAL DESCRIPTION		ELEV.	DEPT	HS	SPT/ RQD			SAMPLE			RAD				ATTE				ODOT CLASS (GI)	BACK
AND NOTES	NV.	716.3			RQD	- 00	(%)	ID	(tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	CLASS (GI)	FILL
1.0' - CONCRETE (12.0")		715.3		- - 1 -																_
VERY STIFF, BROWN AND BLACK SILTY CLAY , S	OME			- '	3 6	17	56	SS-1	2.50		_	_	_	_	_	_	_	15	A-6b (V)	1 LV T
COARSE TO FINE SAND, LITTLE TO SOME FINE (DAMP TO MOIST.	JRAVEL,			_ 2 _	8		50	33-1	2.50	_	_	-	-	_	-	-	_	2	A-00 (V)	1 > V <
DAMI TO MOIOT.				— 3 —																12/1
I				L 4 I	3															1LV 5
I				- '	6 10	19	56	SS-2	2.50	20	12	8	31	29	39	18	21	16	A-6b (9)	1>11:
				_ 5 _	10															17/7/
I				− 6 −	4															1 × × ×
ı				7	16	31	78	SS-3	3.00	-	-	-	-	-	-	-	-	23	A-6b (V)	1>11
				- ' 4	10							\dashv		_						1527
				<u> </u>																1 > V > 1
				− 9 −	5 6	25	72	SS-4	3.00	28	14	8	29	21	38	19	19	16	A-6b (6)	12/1
				L 10 L	15		12	30-4	3.00	20	14	٥	23	_	30	19	19	10	A-00 (0)	1 LV 7
				- '-																1 > N <
				<u> </u>	9															12/7
				— 12 —	9 19	34	89	SS-5	3.00	-	-	-	-	-	-	-	-	21	A-6b (V)	1 LV 7
		703.3		- - 13 -	13															1>11
DENSE TO VERY DENSE, GRAY TO BROWNISH O	SRAY				11									_						12/1
GRAVEL WITH SAND , LITTLE SILT, TRACE CLAY, MOIST.				14	12	33	94	SS-6	-	65	11	7	12	5	NP	NP	NP	10	A-1-b (0)	1 LV 5
Wolo I.				<u> </u>	15															1>11:
-ROCK FRAGMENTS PRESENT THROUGHOUT	lo Ca			- - 16 -																12/1
DENSE TO VERY DENSE, GRAY TO BROWNISH OF GRAVEL WITH SAND, LITTLE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT THROUGHOUT MEDIUM DENSE, BROWNISH GRAY GRAVEL WITH SAND, LITTLE SILT, TRACE CLAY, MOIST. -ROCK FRAGMENTS PRESENT THROUGHOUT	0.0			- 1	25 32	80	67	SS-7	_	l _	_	_	_	_	_	_	_	6	A-1-b (V)	< \ \ < \ \ < \ \ \ <
				17	34		01											_	A-1-0 (V)	1>11
MEDIUM DENSE, BROWNISH GRAY GRAVEL WIT		698.3		— 18 —																1 LV T
SAND, LITTLE SILT, TRACE CLAY, MOIST.				19	21													_		< . v <
	6.0			- '	11	18	44	SS-8	-	37	34	9	16	4	NP	NP	NP	6	A-1-b (0)	1>11
				_ 20 _																JLV 5
				<u> </u>																1>11
-ROCK FRAGMENTS PRESENT THROUGHOUT				- - 22 -																12/1
	ا ر د ا			-																1 LV S
	6 0			_ 23 _																1>11:
				<u> </u>	ნ 6	18	50	SS-9	_	_	_	_	_		_		_	15	A-1-b (V)	TLYT
	K.C.	691.3	— ЕОВ		6 9		- 50									·		.0	, , , D (V)	< · ^ <
			-	_0																
NOTES. CONTINUATED NOT ENGOUNTEDED SUBMO	DDILLING.																			
NOTES: GROUNDWATER NOT ENCOUNTERED DURING I ABANDONMENT METHODS, MATERIALS, QUANTITIES: C			2 601 011	TTINICS																
ADANDONIVIENT IVIETHODO, IVIATERIALO, QUANTITIES: U	OIVIFACTED WITH I	I IE AUGE	\ SOIL CU	LINGS																

PROJECT: FRA-70-13.10 - PHASE 6A TYPE: STRUCTURE	DRILLING FIRM /				.L RIG: IMER:		BILE B-53 (S		400)	STAT			_		′+13.6 _ I-71 \$		8' RT	EXPLOR B-10	RATION 2-3-14
PID: 89464 BR ID: N/A	DRILLING METH	OD:	3.25" HSA	CALI	BRATI	ON DA	TE:4	1/26/13		ELEV	'ATIOI	N:	715.6	6 (MSL	_)	EOB:	3	0.0 ft.	PAG
START: <u>2/26/15</u> END: <u>2/26/15</u>	SAMPLING METH	HOD:	SPT	ENE	RGY R	ATIO (%):	77.7		LAT /	LONG	G:		39.	94709	2, -83.	.014920		1 OF
MATERIAL DESCRIPTION AND NOTES		ELEV. 715.6		SPT/ RQD	N ₆₀	REC (%)	SAMPLE ID	HP (tsf)	GR	cs		N (% sı	,	ATT LL	ERBI PL	ERG PI	wc	ODOT CLASS (GI)	BAC FILI
8' - CONCRETE (9.0")	\bowtie	714.8																	
5' - AGGREGATE BASE (6.0")		714.3	<u> </u>																
TIFF TO VERY STIFF, BROWNISH GRAY SILTY OME FINE GRAVEL, SOME COARSE TO FINE S RY TO DAMP.			_ 2 _ 1	1 9 9	23	67	SS-1	3.00	-	1	-	-	1	-	-	-	5	A-6b (V)	
ROCK FRAGMENTS PRESENT IN SS-2			4 1	0 12 6	23	72	SS-2	1.50	27	14	9	46	4	34	17	17	16	A-6b (5)	
ENSE, BROWN GRAVEL , SOME COARSE TO FI AND, TRACE SILT, TRACE CLAY, DAMP TO MO	ıst. ¦°∪	1	6 3	32 15	34	33	SS-3	_	_	_	_	_		_	_	_	2	A-1-a (V)	
			- 7 - 8 -	11	01	00												74-1-a (v)	
		705.1	_ 9 _ 8 _ 10 _	15 14	38	56	SS-4	-	-	-	-	-	1	-	-	-	5	A-1-a (V)	
ERY STIFF, DARK BROWNISH GRAY SILTY CLA OME FINE GRAVEL, LITTLE COARSE TO FINE S AMP.	AY,	700.1	- - 11 - 8 - 12 -	12	31	50	SS-5	3.50	34	14	6	24	22	40	18	22	12	A-6b (6)	
ROCK FRAGMENTS PRESENT IN SS-5 ERY STIFF TO HARD, DARK GRAYISH BROWN	CLAY,	702.6	- 13 -	12															
OME COARSE TO FINE SAND, SOME FINE GRATTLE SILT, DAMP TO MOIST.	AVEL,		- 14 - 5 - 15	11 14	32	100	SS-6	4.50	-	-	-	-	-	-	-	-	32	A-7-6 (V)	
			16 6	8	18	89	SS-7	4.00	23	15	9	19	34	56	23	33	20	A-7-6 (13)	
EDIUM DENSE, BROWN GRAVEL WITH SAND , I	-ITTLE	697.6	- 17 - - 18 -	6	10	09	33-7	4.00	20	13	9	13	34	30	25	33	20	A-7-0 (13)	
ILT, TRACE CLAY, MOIST.			- 19 - 5 - 20 -	8 4	16	50	SS-8	-	-	-	-	-	-	-	-	-	12	A-1-b (V)	
			- - 21 -																
	ă		- 22 - - 23 -																
			24 - 3 - 25 - 3	6	12	0	SS-9	-	-	-	-	-	-	-	-	-	-		X
			- 26 -	24	-	0	3S-9A	-	-	-	-	-	-	-	-	-	-		
			W - 27 -																
			_ 29 _ 7	10	27	100	SS-10	_	64	12	5	17	2	NP	NP	NP	15	A-1-b (0)	

	TYPE:		STRUCTUF	o⊏	SAMI	DI ING FIRM	/ LOGGER:	RII /	S.B.		MER:		ME 750X (S AUTOMA		10)	STATI					. I-71 S		J 111	B-10	RATI()2-5 -
	PID: 8	9464	BR ID:	N/A			7	3.25" HSA		_		ON DA		0/20/14		ELEVA		_	713 6					5.0 ft.	F
	START:	2/2/15		2/3/15		PLING METH		SPT		_		RATIO (85.7		LAT /			10.0				.015246		1
	START				SAIVII	LING WET		3F I		ऱ—					_			_					013240	<u>) </u>	
			RIAL DESCH				ELEV.	DEPTH		SPT/	N ₆₀		SAMPLE			RADA			-		ERBE		1 '	ODOT	В
			AND NOTE	<u>s</u>			713.6			RQD	00	(%)	ID	(tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	CLASS (GI)	
0.5' - TOP						- 20	713.1	-	4														1 '		7 4
			GRAVEL W	VITH SAND), SILT,	0./	a	-	- 1 1 3	;															-4>
AND CLAY	•						3		- 2 -	8 _	19	28	SS-1	-	-	-	-	-	-	-	-	-	10	A-2-6 (V)	1 4 7 1
	RAGME	NTS AN	D ROOT FIE	3ERS PRE	ESENT IN		710.6	-	4	5												-			- 4
SS-1							7 10.0	-	- 3 -														l '		17 /
			ROWNISH				∃		- 4 🗐 5	,							_								7
DRY TO D		EL, LII	TLE COARS	E IO FIN	E SAND,		1	-	_ H	21	43	56	SS-2	4.5+	26	9	6	29	30	39	21	18	13	A-6b (8)	12
		ITS PR	ESENT IN S	35-2			<u> </u>	-	- 5 🕂	-												-			- 51
ROOKI	TOTOME	••••	LOLIVI IIV	<i>7</i> 0 <i>L</i>			╡		- 6																7>
								-	° 13	3	11	56	SS-3	3.00									18	A 65 () ()	7 4
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							705.6		- 8 -																77
			ROWN AND							\longrightarrow													<u> </u>		-\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
			"AND" SILT				-	-	- 9 - 9	9	20	33	SS-4	2.50	_	_	_	_	_	_	_		28	A-7-6 (V)	
			NE GRAVE	L, MOIST.					- 10	5		55	00-4	2.50		_		_		_		·		/-1-0 (V)	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \
-ROCK F	RAGIVIEI	412 IN	55-4				1		- 10 🖵																12:
]	-	- 11 													-			
-ORGAN	ICS PRE	SENT IN	N SS-5				-	-		4	13	67	SS-5	4.5+	0	1	4	47	48	46	26	20	29	A-7-6 (13)	1/1:
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							1	-	- 13 —														l '		4>
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]	_	- 17 🕌	6 _	19	100	SS-7	3.00	-	-	-	-	-	-	-	-	26	A-7-6 (V)) 5
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							1		- 19 - 2		14	100	00.0	0.50			_	20			24	7.		A 7 0 (40)	14>
]	-	- 8	5	14	100	SS-8	2.50	1	3	4	38	54	52	21	31	27	A-7-6 (18)) { / / /
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							‡		- 21 -														1 '		7 1
							691.6	-	-														1 '		\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \
MEDILIM	DENSE I	ROWN	GRAVEL W	VITH SANI) TT =	a.J.	331.0	-	- 22 —													i l	l '		7
SILT, TRA				OANL	•, LIIILL	0.0	<u> </u>		- 23 -														1 '		< 1
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						\circ		-	- 24 - 5	7	23	78	SS-9	_	_	_	_	_	_	_	_	!	10	A-1-b (V)	1 5
						\triangleright \bigcirc	.		- ₂₅ 👢	′ 9		. 5													
						0.1			23]			T					T		I	7	J	i T	1		7 /
						βQ		-	- 26 —													i l	l '		7 < 7
							686.6		- 27 —													i l	l '		7
			COARSE AN						21													i l	l '		7 47
LITTLE FI	NE GRAV	/EL, TR	ACE SILT, 7	FRACE CL	LAY, WET	- -	<u>.</u>	., -	- 28 -													i l	l '		14:
							∄ ⊢	<i>\</i>	- 29 - 4									_							- 2

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

Client:	ms c	onsu	Itants	3			Project: FRA-70-8.93								Job i	No.()22′	1-10	04.0	1	
LOG C	F: Bo	ring	B-10	4-0-0	9	Loc	cation: Sta. 222+98.38, 5.9' RT., BL I-71 SB			Dat	e E	Drill	ed:	9/4	/200	9					
(ft)	Elev. (ft)	Blows per 6"	Recovery	Samp No Prive		Hand Penetro- meter (tsf)	WATER OBSERVATIONS: Water seepage at: 22.5' Water level at completion: 19.4' FIELD NOTES: DESCRIPTION	Graphic Log	a)	R. C. Sand			ON 3ilt	Clay	Natu	ral M L ⊢	loisti	ure (Conte	ent, % ⊣ L	L
0.3 / - -	709.9/	13 10 9	18	1			Topsoil - 4" Medium dense gray SANDY SILT (A-4a), some fine to coarse sand, little gravel; damp.									11					
3.5 - - <u>5</u>	706.7	11 10 8	12	2		3.0	Stiff to very stiff brown SILT AND CLAY (A-6a), some fine to coarse sand, little to some gravel; damp.		20	15		13	25 2						 		
-		3 4 7	12	3		2.0	@ 6.0'-7.5', dark brown, contains trace organic material.														
10 11.0		10 8 8	3	4		1.5										\ 					
13.5	696.7	6 7 8	13	5		4.0	Very stiff to hard brown SILTY CLAY (A-6b), little to some fine to coarse sand; damp.		0	2		18	37 4			 		 		 	
15.5 - 15		13 11 14	12	6			Medium dense brown GRAVEL (A-1-a). some fine to coarse sand, little silt; damp.	000													
-		12 10 8	12	7				000								 					
<u>20</u> 21.0	1	15 11 12	12	8				000	57	18		10	15	j				(
- 23.5	686.7	3 6 12	10	9			Medium dense brown COARSE AND FINE SAND (A-3a), little silt, little gravel; wet.	· · · ·													
25	685.2	5 5 5	9	10			Medium dense to dense brown GRAVEL (A-1-a), little fine to coarse sand, trace silt; wet.	000						Ì	 (

Client:	ms c	onsu	Itants	3			Project: FRA-70-8.93								Job No.0	221-1	004.01	
LOG C	F: Bo	oring	B-10)4-0-0	9	Loc	cation: Sta. 222+98.38, 5.9' RT., BL I-71 SB			Da	ite i	Dril	led.	: 9/4	4/2009			
Depth (ft)	Elev. (ft)	Blows per 6"	Recovery	Sam No		Hand Penetro- meter (tsf)	WATER OBSERVATIONS: Water seepage at: 22.5' Water level at completion: 19.4' FIELD NOTES: DESCRIPTION	Graphic Log	% Aggregate		Sand		% Sitt		STANDAR Natural Me PL ⊢ Blows per fo 10	oisture	Conten	t, % - ● LL
- - -		8 5 12 18 20	6	11			Medium dense to dense brown GRAVEL (A-1-a), little fine to coarse sand, trace silt; wet.	0000										
30.0 30 - - -	680.2		8	12			Bottom of Boring - 30.0'	0 /										
3 <u>5</u> - -																		
- 4 <u>0</u> -																		
- - <u>45</u>																		
- - - 50																		

D::	\	OJECT: PE:	F		'0-13.1 TRUCT		HASE 6A					ERATOI		RII / J.K. ' S.B./J.			L RIG MER:		BILE B-53 (400)	1	TION /		SET:)+95.9 _ I-71	0 / 17. SB	5' RT	EXPLO B-10	
KII		: 8	9464				A-71-1503L			NG MET			3.25" HS					ION DA		4/26/13				_	714 !			EOB:	-	 70.5 ft.	
		. <u> </u>	6/4/1	_	END:		6/26/14			ING ME			SPT /					RATIO (77.7		LAT			7 1 1.0				.01572		1
						_	PTION					ELEV.				DT/			SAMPLE		(SRAD			5)	_		ERG			1
					D NO							714.5	DEP	THS		QD	N ₆₀	(%)	ID	(tsf)		_		SI	CL	LL	PL	PI	wc	ODOT CLASS (GI)	s
).3' - TO	PSC	II (4)")									714.2 /						(70)	1.0	(101)	0.1			0.							X
				RD	DARK	(BR	ROWN TO	GRA	ΔΥ	- 1/	// \\	1 14.2		F 1	1																
							NE SAND							-	Ho	9	28	67	SS-1	4.25	_	_	_	_	_	_	_	_	11	A-6a (V)	K
O SOM	ΛΕ FI	NE GF	RAVEL,	DAI	MP TO	OM C	DIST.							_ 2		13		<u> </u>		0										7.00(1)	_\\
														⊢ 3	-																K
														_ 4	11	_											١	١			
														- '	H	9	25	67	SS-2	4.25	16	12	14	29	29	25	14	11	15	A-6a (5)	K
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## Commonstrate Section Section	ID: 89464 BR ID: FRA-71-1503L PROJECT: FRA-70-13.10			STATION		<u> </u>		5.90 / 17.										3 2 OI	<u> </u>
MEDIUM DENSE TO VERY DENSE. BROWN TO ASSOCIATE TO SAME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST, (same above) MEDIUM DENSE TO VERY DENSE. DARK BROWNISH READ TO SAME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST, (same above) MEDIUM DENSE TO VERY DENSE. DARK BROWNISH RACE SILT, TRACE CLAY, MOIST, (same above) ACOBBLES PRESENT FROM 35.0' TO 38.5' COBBLES PRESENT FROM 35.0' TO 38.5' ASSOCIATED AND CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. DARK BROWNISH RACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. DARK BROWNISH RACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. DARK BROWNISH RACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. DARK BROWNISH RACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. BROWNI GRAVEL WITH SAND, TRACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, TRACE CLAY, MOIST, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GRAVEL WITH SAND, TRACE SILT, (same above) MERIUM DENSE TO VERY DENSE. GROWNI GR	MATERIAL DESCRIPTION	I		EPTHS	SPT/	N ₆₀												wo	ODOT CLASS (GI)
SRAY GRAVEL WITH SAND, TRACE SILT, TRACE CLAY, MOIST. -COBBLES PRESENT FROM 35.0' TO 38.5' -COBBLES PRESENT THROUGHOUT -COBB	MEDIUM DENSE TO VERY DENSE, BROWN TO BROWNISH GRAY GRAVEL , TRACE TO SOME COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST. (same as above)	39		H	RQD	33	(%)	ID	(tst)	GR	CS	FS	SI	CL	LL	PL	Ы	wc	SEASO (CI) SI
-COBBLES PRESENT FROM 35.0' TO 38.5' -36 -37 -38 -39 -30 -37 -38 -39 -30 -41 -40 -40 -41 -42 -42 -41 -42 -42 -43 -43 -44 -43 -43 -44 -43 -43 -44 -43 -43	GRAY GRAVEL WITH SAND , TRACE SILT, TRACE CLAY, 💎 🔀			_ 34 -	11	28	100	SS-13	-	-	-	-	-	-	-	-	-	12	A-1-b (V)
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VERY LOOSE, BROWN GRAVEL WITH SAND, TRACE SILT, TRACE CLAY, MOIST. 42 43 44 43 44 47 TRACE CLAY, MOIST. 48 47 TRACE CLAY, MOIST. 48 47 TRACE CLAY, MOIST. 48 49 47 TRACE CLAY, MOIST. 48 49 49 40 41 41 42 41 42 43 43 40 47 48 47 48 48 49 48 49 48 49 48 49 48 49 49	0.	79		-	50/2" /	/	0	SS-14	-		<u> </u>					-			
## 1672.5 SILT, TRACE CLAY, MOIST. ## 1672.5 SILT, TRACE CLAY, MOIST. ## 1672.5 SILT, TRACE CLAY, MOIST. ## 1 3 1 00 SS-15 - 39 43 6 2 10 NP NP NP 12 A-1-b (0) ## 4 4 3 1 1 3 100 SS-15 - 39 43 6 2 10 NP NP NP 12 A-1-b (0) ## 4 5 4 - 46 - 47 - 47 - 48 - 48 - 48 - 48 - 48 - 48		2.7 29		-	<u>-</u> -														
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/ERY DENSE, GRAY GRAVEL WITH SAND , TRACE SILT, TRACE CLAY, MOIST. -HEAVING SANDS ENCOUNTERED @ 48.5' -INTRODUCED MUD @ 48.5' -INTRODUCED MUD @ 48.5' -BORING TERMINATED @ 54.0' ON 6-5-14. OFFSET BORING 5.0' NORTH AND CONTINUED SAMPLING @ 58.5' -SON 6-26-14. -ARAP, BROWN SILT AND CLAY , SOME COARSE TO TINE SAND, TRACE FINE GRAVEL, DAMP. -COBBLES PRESENT THROUGHOUT -COBBLES PRESENT THROUGHOUT -AB - 44 - 48 - 49 - 16		5 5 5 667.5		- 45 - 46 -	1 1	3	100	SS-15 	-	39	43	6	2	10	NP	NP	NP	12	A-1-b (0)
AUGER REFUSAL @ 51.0' GRANITE AND LIMESTONE BOULDERS. -BORING TERMINATED @ 54.0' ON 6-5-14. OFFSET BORING 5.0' NORTH AND CONTINUED SAMPLING @ 58.5' ON 6-26-14. HARD, BROWN SILT AND CLAY, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP. -COBBLES PRESENT THROUGHOUT 663.5 660.5 -50 -51 -52 0 25 RC-1 CORE -53 -54 -56 -57 -56 -57 -58 -56 -57 -58 -59 -50 -50 -50 -50 -50 -50 -50		3		-	=														
AUGER REFUSAL @ 51.0' GRANITE AND LIMESTONE BOULDERS. -BORING TERMINATED @ 54.0' ON 6-5-14. OFFSET BORING 5.0' NORTH AND CONTINUED SAMPLING @ 58.5' -BORING 5.0' NORTH AND CONTINUED SAMPLING @ 58.5' -ARD, BROWN SILT AND CLAY, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP. -COBBLES PRESENT THROUGHOUT -55 -56 -57 -58 -59 -50 -50 -57 -58 -59 -50 -57 -58 -50 -57 -58 -50 -57 -58 -50 -57 -58 -50 -57 -58 -50 -57 -58 -50 -57 -58 -50 -57 -58 -59 -50 -50 -57 -58 -50 -50 -57 -58 -50 -50 -57 -58 -50 -50 -57 -58 -50 -50 -50 -50 -50 -50 -50) () (-	16 25 50/2"	-	100	SS-16	-	-	-	-	-	-	-	-	-	11	A-1-b (V)
## CORE	AUGER REFUSAL @ 51.0'	663.5	<u>. </u>	-															
-BORING 1ERMINATED @ 54.0 ON 6-5-14. OFFSET BORING 50 NORTH AND CONTINUED SAMPLING @ 58.5 ON 6-26-14. OFFSET BORING 5.0 NORTH AND CLAY, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP. OFFSET BORING 1.53 ON 6-56 ON 6-56 ON 6-57 ON 6-56 ON 6-57 ON 6-56 ON 6-57 ON 6-58 ON 6-50/3" ON 6-	l ■			-															
- COBBLES PRESENT THROUGHOUT - 58	BORING 5.0' NORTH AND CONTINUED SAMPLING @ 58.5'		;	- 53 -	0		25	RC-1											CORE
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B-104-1-13 - RC-1 - Depth from 60.5 to 65.5 feet



B-104-1-13 - RC-2 - Depth from 65.5 to 70.5 feet

Dii	PROJE		FR	A-70-13. STRUC		HASE 6A				/ OPERATOR:		/ S.B.		LL RIG /IMER:		ME-55 (SN AUTOM		5)	STATI		DFFSET Γ:)14+37 L RAM		7.7' LT	EXPLOR B-10	
MII		8946	1	BR ID:		N/A				HOD:	4.25" HS		_		ION DA		10/20/14	1			l: 71					55.0 ft.	F
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		(4.00)		ND NC	IES				N/A	719.4			RQD		(%)	ID	(tsf)	GR	CS	FS	SI CI	. LL	. PL	PI	WC	OLAGO (GI)	XXX
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0.5' - AG				,					/ 	117.8		L 2 - □															7 4
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ABANDONMENT METHODS, MATERIALS, QUANTITIES: COMPACTED WITH THE AUGER SOIL CUTTINGS

D	PROJECT TYPE:	:	RA-70-13.10 - STRUCTU				OPERATOR: / LOGGER:	STOC	K / C/T		LL RIG MMER:		31 HD (SN)		.111)	STAT			ET: _		+82.16 AMP (1' LT	EXPLOR B-10
KIII		39464	BR ID:	N/A			7 LOGGLIK DD:	4.25" HS/		_				3/28/13				_	722.0	(MSL)				.0 ft.
						NG METH		4.25 HS/ SPT	١			RATIO (_	LAT /			123.9					.U IL.
	START: _	4/17/		4/17/15	SAMPLII	NG METE		3P1						72.3					. 1				16258	
		MATE	RIAL DESC				ELEV.	DEPTH	ıs İ	SPT/	N ₆₀		SAMPLE	1		RAD			_	ATTE				ODOT
			AND NOTE	ES		K // //	723.9			RQD	60	(%)	ID	(tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	CLASS (GI)
0.3' - AS	SPHALT (3	.0")				_/ 💥	723.6	-	- 4															
0.5' - CC	ONCRETE	(6.0")					723.1/		- 1 -															
).5' - AG	GREGATI	BASE	(6.0")			-/ <i>\///</i>	722.6		- - 2 -															
FILL: VE	RY STIFF	TO HA	RD. BROW	NISH GRAY	TO	_ ////	1																	
GRAY S	SILT AND C	LAY, L	ITTĹE TO S	OME COARS	SE TO		1	-	- 3 -															
	AND, LITTL	E TO S	OME FINE	GRAVEL, DA	AMP TO		1		· , 🖠	3														
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				BROWN GI	RAVEL	H.A.			- 16 -	q														
WITH SA	AND AND	SILI, LI	TTLE CLAY	, DAMP.			, l		- 17 -	ັ 29	88	100	SS-5	-	25	22	25	17	11	NP	NP	NP	7	A-2-4 (0)
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-ROCK	FRAGME	N I S PI	KESENI IH	ROUGHOUT			,		- ₄, ■	5 0/3"∕	- <	100	SS-6	 - /	- /	- 1	-	- 🗼	-)	- 🖈	- +	- 1	7 1	A-2-4 (V)
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=11 1 · N/E	EDILIM DE	NSE B	POWN CPA	VEL WITH S	AND		703.4																	
	SILT, TRA			WEL WITH 3	AND,	0 (702.2		- 21 	33				-	-	_	-	-	-	_	-	-	6	A-1-b (V)
			SENT IN SS	S-7A					– 22 –	9	23	100	SS-7	4.5+	t _	_	_	_	_	_	_	_		A-6b (V)
				BROWN SIL	_TY	~ 		}	- 4	10				7.51		_	-	-	_	-	-	-	20	, (OD (V)
,				ND, TRACE				ŀ	_ 23 _															
GRAVEI	L, MOIST.			•					_ 24 _	6	00	460	00.0	T									40	A 01 0 0
-ORGA	ANICS PRE	SENT	THROUGHO	DUT				}		7 10	20	100	SS-8	4.5+	-	-	-	-	-	-	-	-	19	A-6b (V)
							698.4	ŀ	– 25 –	10												\dashv		
/ERY S	TIFF, BRC	WN SI	LT, LITTLE (COARSE TO	FINE	++++	Ĥ l		- - 26 -															
SAND, L	LITTLÉ CL	AY, LIT	TLE FINE G	RAVEL, MO		++++	H I		- H		10	100	00.0	2.50	14		4.7	F.C.	47	22	47		20	
-ROCK	FRAGME	NTS P	RESENT IN	SS-9		++++	<u> </u>	}	− 27 −	5 10	18	100	SS-9	2.50	11	3	13	56	17	22	17	5	20	A-4b (8)
						++++	695.9	ļ	=									$\overline{}$			\dashv	\neg		
JEDIUN	I DENSE,	BROW	N GRAVEL,	SOME COAL	RSE TO	####			_ 28 _															
FINE SA	AND, TRAC	E SILT	, TRACE ĆI	AY, MOIST.		600	1	-	– 29 –	4	20	67	CC 10										10	A-1-a (V)
						000	l k	-	- 1	11 12	28	67	SS-10	-	I - I	-	-	-	-	-	-	-	10	4-1-a(V)

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

	LING FIRM / OPERATOR:			_	BK 81 HD (SN									.0' LT	EXPLORAT B-107-2
	PLING FIRM / LOGGER: _	RII / D.M. 4.25" HSA	HAMMI		AUTOM			ALIGNM	-			RAMP		4	. —
	LING METHOD:					3/28/13		ELEVAT	_	121.					5.0 ft.
	PLING METHOD:	SPT	ENERG		_ , ,	72.3	_							016450	
MATERIAL DESCRIPTION	ELEV.		SPT/ N		SAMPLE			RADAT				ERBI			ODOT E
AND NOTES	727.5	I	RQD	60 (%	6) ID	(tst)	GR	CS F	S SI	CL	LL	PL	PI	WC	CLASS (GI)
0.3' - ASPHALT (3.0")	727.2	⊢ . ⊢													₩
0.7' - CONCRETE (9.0")	726.5														~~
FILL: STIFF, GRAY SANDY SILT , LITTLE FINE GRAVEL,		<u> </u>													1
TRACE CLAY, DAMP.		F 4													1
		_ 3 _													1
		- 4 - 4													
-ROCK FRAGMENTS PRESENT IN SS-1				2 7	2 SS-1	1.50	-	_ _	. _	-	l -	_	_	10	A-4a (V)
NOOK TWOMENTO TRECENT IN GO T		5	5								1			-	77
		- 6 -													\ \frac{<}{7}
	720.5	F 7 -													1
FILL: VERY STIFF, GRAY SILTY CLAY, SOME COARSE		F . 4													7
TO FINE SAND, TRACE FINE GRAVEL, DAMP.		- 8 -													1
-ASPHALT FRAGMENTS PRESENT IN SS-2		_ 9 _ 5		7 78	000	0.50								40	A Ch () ()
			6 1	7 78	8 SS-2	3.50	-	- -	-	-	-	-	-	13	A-6b (V)
		_ 10													7
		<u></u> 11 −													7
		├ 40													1
		<u> </u>													7 7
		- 13 -													<
		14 7													7
		- ' "	7 1	9 94	4 SS-3	3.00	10	12 1	5 33	30	33	16	17	14	A-6b (8)
		<u> </u>	9												7
		- 16 -													77
	710.5	F 4													1
FILL: VERY STIFF, GRAY SILT AND CLAY, SOME	///	_ 17 _													7
COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP.	. [///	- 18 -													1
		10 17									1				1
-ROCK FRAGMENTS PRESENT IN SS-4		<u></u> 19		4 83	3 SS-4	3.50	-	- -	- -	-	-	-	-	9	A-6a (V)
	707.0	20	17								+				
FILL: VERY DENSE, GRAY GRAVEL WITH SAND, LITTLE	1	21													7
SILT, TRACE CLAY, DAMP TO MOIST.		2	0/3"	<u>- 4_0</u>	SS-5	<u> </u>				 -	↓ -	 - -		<u> </u>	
		- 22 - 3	81 -	- 10	00 SS-6	-	42	20 1	8 14	6	NP	NP	NP	5	A-1-b (0)
		23	50/2"								1				77
			9								+				
-ASPHALT FRAGMENTS PRESENT IN SS-7		24 - 24		0 50	0 SS-7	-	-	- -	-	-	-	-	-	9	A-1-b (V)
	702.0	- 25	4				\vdash		-		1				
/ERY STIFF, DARK BROWN SILTY CLAY, "AND"	102.0	1									1				1
COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP.	. 🗐 📗	26 3		, ,	1 00 0	2.00	10	24 2	2 24	40		40	40	44	A Ch (2)
,		- 27 -	4 3 8	3 6 ⁻	1 SS-8	3.00	18	21 2	2 21	18	37	18	19	14	A-6b (3)
	699.5	- 28 -									1				7
MEDIUM DENSE, BROWNISH GRAY GRAVEL WITH	a	<u></u>	_								1				
SAND, LITTLE SILT, TRACE CLAY, MOIST.		− 29 − 1	5 14 2	8 83	3 SS-9			_ _	. _	_	1 -	_	_	7	Δ_1_h (\/ \)
	19		· 9 -	- 0										'	7-1-0 (V)

0.7' - TOPSO FILL: DENSE BROWN GR.	PE:		RE N/A	SAMPLI	IG FIRM / NG FIRM	OPERATO			RILL RIG									3009	+/43	1//9	9' LT	EXPLO	VALIO.
91D ST/ 0.7' - TOPSC FILL: DENSE BROWN GR	0: 89464 ART: 1/30/1 MATE	_ BR ID: 5 END: _	N/A	_	NG FIRM		DU / N / A				ME 750X (S		10)				-'' —					− B-10	8-7-1
0.7' - TOPSC FILL: DENSE BROWN GR	MATE OIL (8.0")	5 END: _							AMMER:		AUTOMA				NMEN	_			RAMP			_ —	PAG
0.7' - TOPSC FILL: DENSE BROWN GR	MATE DIL (8.0")			_	IG METH		3.25" HSA		ALIBRA1			0/20/14				N:	703.6 (0.0 ft.	10
FILL: DENSE BROWN GR	OIL (8.0")	DIAL DESCR	1/30/15	_SAMPLI	NG METH	10D:	SPT	E	NERGY			85.7			LONG						016711		10
FILL: DENSE BROWN GR	<u> </u>	KIAL DESCR	RIPTION			ELEV.	DEPTHS	SPT			SAMPLE	HP	G		ATIO	N (%)) <i>A</i>	ATTE	RBE	RG		ODOT	BAC
FILL: DENSE BROWN GR	<u> </u>	AND NOTE	S			703.6	DEI IIIO	RQE) 1460	(%)	ID	(tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	CLASS (GI)	FIL
BROWN GR						702.9	_	_															7 LV
TDACE OILT	AVEL, LITTLE	COARSE T	WNISH GRAY O FINE SAND		60		- 1 - - - 2 -	3 13	39	61	SS-1	-	-	_	_	-	-	_	-	_	15	A-1-a (V)	12 L
-COAL FRA	T, TRACE CLA AGMENTS PR ENCOUNTER	EŚENT IN S			000		- 3 -	1	4								+					` ′	1/2/
-COBBLES	LINCOUNTER	NED TIROU	GHOOT				- 4 -	7 19	54	78	SS-2	-	81	7	4	6	2 1	NP	NP	NP	10	A-1-a (0)	177
DENSE TO V	/ERY DENSE	BROWNIS	H GRAY GRA	WEL		698.1	- 5 -	-	9														12/
	RSE TO FINE				000	2	- 6 - - 7 -	10 12 2		89	SS-3	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	777
					00		- 8 -																177
0000150	ENOO!	NED TURS!	OLIOLI T		000		- 9 - - - 10 -	19 30 2		67	SS-4	-	-	-	-	-	-	-	-	-	8	A-1-a (V)	12/
-COBBLES	ENCOUNTER	RED THROU	GHOUT				- - 11 -	40		83	SS-5	_	87	5	3	4	1 1	NP	NP	NP	10	A-1-a (0)	12/
					000)	- 12 - -	50/6	<u>'</u>				01			1	Ť			-	-10	7(10(0)	17/
-ROCK FRA	AGMENTS PR	ESENT IN S	S-6		60		13 - 14 -	31 50/5	, -	100	SS-6	-	-	-	-	-	-	-	-	-	6	A-1-a (V)	772
MEDIUM DE	NSE, GRAY (RAVEL WIT		TLE	000	688.6	- 15 -																12/
SILT, TRACE	E CLAY, MOIS	01.					16 - - - 17 -	33 10	21	100	SS-7	-	52	22	7	14	5 1	NP	NP	NP	14	A-1-b (0)	17 X Z
							- 18 -		5														12/
							- 19 - - - 20 -	3 4	13 5	100	SS-8	-	-	-	-	-	-	-	-	-	13	A-1-b (V)	7 \ 7 \ 7 \ 7 \ 7 \ 7 \ 7 \ 7 \ 7 \ 7 \
					00. 00.		_ 21 -	-															7 2
	SE, BROWNIS , TRACE CLA		AVEL WITH S	SAND,		681.6	_ 22 -	-															777
	SANDS ENC	·	@ 23.5'				23 - - 24 -	22 34	107	100	SS-9		33	32	20	11	4	NP	NP	NP	12	A-1-b (0)	-12 172 172
							- 25 -	4	1 107	100			- 55	02	20	11	- -	- 1	. 🗤	1 11	14	73-130 (0)	1 > 1 × 1
							26 27 -	_															7 < 7 >
							- 28 -	_															1 × ×
						•		17 19	61	100	SS-10	-	-	-	-	-	-	-	-	-	15	A-1-b (V)	1 1 2 1 X

	DRILLING FIRM /						ИЕ 750X (SI		8)				_			9.6' LT	EXPLO	
	SAMPLING FIRM		RII / N.A.		MMER:		AUTOMA				NMENT			BL RAI				PA
	DRILLING METHO		3.25" HSA	_	LIBRAT			0/20/14						MSL)	_		15.0 ft.	10
START:1/30/15 END:1/30/15	SAMPLING METH	IOD:	SPT	EN	IERGY F	<u>`</u>		85.7			LONG	_				3.01699	2	, ,
MATERIAL DESCRIPTION		ELEV.	DEPTHS	SPT/			SAMPLE				OITA	۱ (%)	Α	TTER	BERG	3	ODOT	BA
AND NOTES		703.4	DEI IIIO	RQD	1 60	(%)	ID	(tsf)	GR	CS	FS	SI (CL I	LL P	. PI	WC	CLASS (GI)	
5' - TOPSOIL (6.0")	\longrightarrow	702.9																12
ARD, DARK BROWN SILT AND CLAY , SOME COA	RSE ////	1	├ 1 	9														1 > 1
FINE SAND, TRACE FINE GRAVEL, DAMP.	V///	1	_ 2 	12	26	50	SS-1	4.25	-	-	-	-	-	- -	-	12	A-6a (V)	7 2
ROCK FRAGMENTS PRESENT IN SS-1 COBBLES PRESENT @ 1.0'		700.4		- 6	-													- 1 L
INSE, BROWNISH GRAY SANDY SILT , SOME FIN			_ 3 _															1>
RAVEL, LITTLE CLAY, DAMP.	' -		⊢ 4 −	4	33	44	SS-2		32	16	11	30	₁₁ N	ום או	NP	8	A 40 (1)	1 L
,			-	11 12		44	33-2	-	32	10	11	30	1 1 I r	אף וא	INP	°	A-4a (1)	1 > 1
		697.9	5 -															1 / L
INSE TO VERY DENSE, BROWN GRAVEL , TRAC	E 600		- 6 -	3									+		_			- 1 × 1
DARSE TO FINE SAND, TRACE SILT, MOIST.	200			13	43	56	SS-3	-	-	-	-	-	-	- -	-	6	A-1-a (V)	1 >
	000]	⊢ ′ □	17												-		- 5 L
	[0 0 0	1	- 8 -															1>
	00	1	<u> </u>	11,		400					,							7 2
	₽Ŏ (1	- H	19 20	56	100	SS-4	-	96	2	1	1	0 1	N PI	PNP	6	A-1-a (0)	12/
	ŀ. ()°	1	_ 10 _		1													7 2 1
	000		- 11															1 L
	60(691.4																1 > 1
DIUM DENSE, BROWN GRAVEL WITH SAND , TR	RACE		_ 12															J'L
LT, TRACE CLAY, MOIST.		١,	L 13 —															1 > 1
	0.0	!	14	10														12/
ROCK FRAGMENTS PRESENT IN SS-5	p ~ 1	688.4	14	9	27	39	SS-5	-	-	-	-	-	-	- -	-	12	A-1-b (V)	1 L
		J JJJJ.+	—EOB —15—	1(<u> </u>												1	1, -

NOTES: GROUNDWATER INITIALLY ENCOUNTERED @ 13.5'

APPENDIX IV

LABORATORY TEST RESULTS



Engineering Consultants

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

6350 Presidential Gatew. Columbus, OH 43231

Phone (614) 823-4949

9885 Rockside Road Cleveland, OH 44125 Phone (216) 573-0955 4480 Lake Forest Drive Cincinnati, Ohio 45242 Phone (513) 769-6998

Project No.: <u>W-13-072</u>

Date of Testing: <u>7/3/2014</u>

Test Performed by: K.R./T.K.

Rock Description: Dolomitic Limestone

 Boring No.:
 B-104-1-13

 Sample No:
 RC-2

 Depth (ft):
 65.5

 Moisture condition:
 As received

Rate of Loading: 55.1 lbs/sec
Testing Time: 432 sec

(Rate 2-15 minutes to failure)

 Average Length:
 4.185 in

 Average Diameter:
 1.858 in

 Length to diameter ratio:
 2.252

 Cross Sectional Area:
 2.710 in²

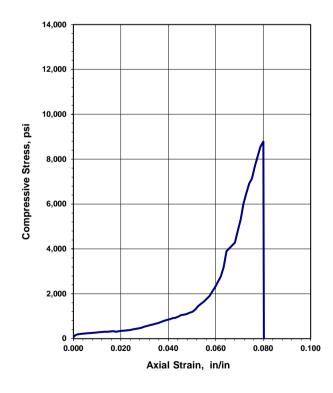
Project: FRA-70-13.10 - Project 6A

 Failure Load:
 23,820 lbs

 Axial Strain at Failure:
 0.0800 in/in

 Stress:
 8,783 psi

Unconfined Compression Test



Before Testing



After Failure



REMARKS:

APPENDIX V

MSE WALL CALCULATIONS



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

Use $\varphi_{\tau} = 1.0$ (Per AASHTO LRFD BDM Table 11.5.7-1)

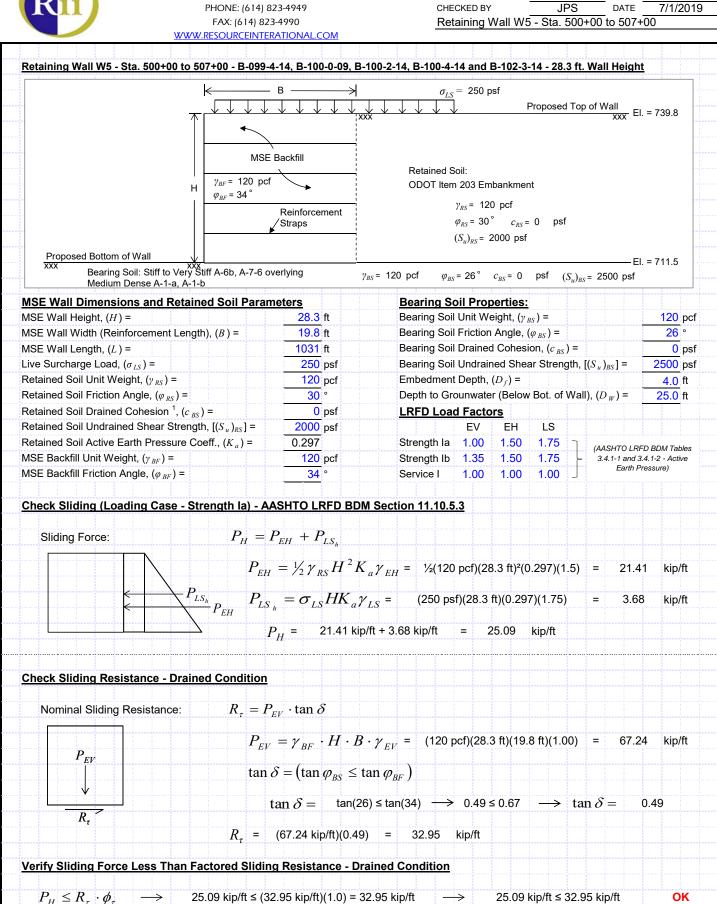
 JOB
 FRA-70-13.10
 NO.
 W-13-072

 SHEET NO.
 1
 OF
 6

 CALCULATED BY
 BRT
 DATE
 6/29/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta. 500+00 to 507+00





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

FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF 6 CALCULATED BY BRT DATE 6/29/2019 CHECKED BY JPS DATE 7/1/2019 Retaining Wall W5 - Sta. 500+00 to 507+00

FAX: (614) 823-4990	
WWW.RESOURCEINTERATIONAL.COM	1

MSE Wall Dimensions and Retai	ined Soil Parameters	Bearing Soil Properties:		
ISE Wall Height, (H) =	28.3 ft	Bearing Soil Unit Weight, (γ_{BS})	=	120 pc
ISE Wall Width (Reinforcement Leng		Bearing Soil Friction Angle, (φ_B)		26 °
ISE Wall Length, (<i>L</i>) =	1031 ft	Bearing Soil Drained Cohesion		0 ps
ive Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil Undrained Shear S		2500 ps
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment Depth, (D_f) =		4.0 ft
Retained Soil Friction Angle, (φ_{RS}) =	30°	Depth to Grounwater (Below Bo	ot. of Wall), (D_W) =	25.0 ft
tetained Soil Drained Cohesion, (c_{BS}		LRFD Load Factors		
tetained Soil Undrained Shear Streng			LS	
Retained Soil Active Earth Pressure C		Strength Ia 1.00 1.50 1	.75 7 (448470) PE	TO DOM Tables
MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf		.75 - 3.4.1-1 and 3	D BDM Tables .4.1-2 - Active
ISE Backfill Friction Angle, (φ_{BF}) =	34 °		.00 Earth Pi	ressure)
	Strength Ia) - AASHTO LRFD BDM	M Section 11.10.5.3 (Continued)		
heck Sliding Resistance - Undr	rained Condition			
Nominal Sliding Resisting:	$R_{\tau} = ((S_u)_{BS} \le q_s) \cdot B$			
	$\left(S_{u}\right)_{BS} = 2.50$	ksf		
$\mid P_{EV} \mid$	4.123			
ا م	$q_s = v/2 =$	(3.40 ksf) / 2 = 1.70 ksf		
	n /			
	$\sigma_{\cdot \cdot} = \frac{P_{EV}}{R}$	= (67.24 kip/ft) / (19.8 ft) =	3.40 ksf	
	7 1			
	$R_{\tau} = (2.50 \text{ ksf} \le 1.70)$) ksf)(19.8 ft) = 33.66 kip/ft		
	Factored Sliding Resistance - Un	drained Condition		
		drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \Longrightarrow Z$	Factored Sliding Resistance - Un	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \Longrightarrow Z$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \Longrightarrow Z$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	ok
$P_H \leq R_{\tau} \cdot \phi_{\tau} \Longrightarrow Z$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \Longrightarrow Z$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \Longrightarrow Z$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	ok
$P_H \leq R_{\tau} \cdot \phi_{\tau} \Longrightarrow Z$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_\tau \cdot \phi_\tau \longrightarrow Z$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	ok
$P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 2$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	ok
$P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 2$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 2$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 2$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 2$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 2$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK
$P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 2$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	ok
$P_H \leq R_\tau \cdot \phi_\tau \longrightarrow Z$	Factored Sliding Resistance - Un 25.09 kip/ft ≤ (33.66 kip/ft)(1.0) = 3	drained Condition	/ft ≤ 33.66 kip/ft	OK



W-13-072 JOB FRA-70-13.10 NO.

•					
6350 PRESIDENTIAL GATEWAY	SHEET NO.	3	OF	6	
COLUMBUS, OHIO 43231	CALCULATED BY	BRT	DATE	6/29/2019	
PHONE: (614) 823-4949	CHECKED BY	JPS	DATE	7/1/2019	
FAX: (614) 823-4990	Retaining Wall W5	- Sta. 500+00	to 507+	00	

$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	FAX: (614) 8 WWW.RESOURCEINT		<u>M</u>	Retaining V	Wall W5 - Sta. 500	+00 to 507+0	JU
MSE Wall Height, (II) = 23.3 n Bearing Soil Unit Weight, (P_{SS}) = 10.8 n Bearing Soil Total No. (P_{SS}) = 250 pst Bearing Soil Unit Weight, (P_{SS}) = 250 pst Bearing Soil Unit Weight, (P_{SS}) = 250 pst Bearing Soil Unit Weight, (P_{SS}) = 250 pst Bearing Soil Unit Weight, (P_{SS}) = 250 pst Bearing Soil Unit Weight, (P_{SS}) = 250 pst Bearing Soil Unit Weight, (P_{SS}) = 250 pst Psteined Soil Unit Weight, (P_{SS}) = 30 pst Psteined Soil Unit Weight, (P_{SS}) = 30 pst Psteined Soil Unit Weight, (P_{SS}) = 30 pst Psteined Soil Unit Weight, (P_{SS}) = 2000 pst Psteined Soil Unit Weight, ($P_$			_				
MSE Wall Worth (Reinforcement Length), (θ) =							400
							120 pcf
Live Surcharge Load, $(x_{12}) = $ $\frac{250}{120}$ pof Bearing Soil Undrained Shear Strength, $[(s_+)_{15}] = \frac{250}{30}$ $\frac{120}{30}$ Depth to Grourwater (Below Bot. of Wall), $(D_w) = \frac{250}{250}$ Retained Soil Unit Weight, $(y_{12}) = \frac{1}{30}$ $\frac{1}{30}$ Depth to Grourwater (Below Bot. of Wall), $(D_w) = \frac{250}{250}$ Retained Soil Christon Angle, $(c_{15}) = \frac{1}{30}$ $\frac{1}{2000}$ Depth to Grourwater (Below Bot. of Wall), $(D_w) = \frac{250}{250}$ Retained Soil Active Earth Pressure Coeff., $(K_+) = \frac{1}{30}$ $\frac{1}{2000}$ $\frac{1}{30}$							
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$						<u> </u>	0 psf
Retained Soil Priction Angle, $(o_{RF}) = Retained Soil Undrained Schession, (c_{RS}) = Retained Soil Undrained Shear Strength, (s_{LS}) = 2000 per Retained Soil Undrained Shear Strength, (s_{LS}) = 2000 per Retained Soil Undrained Shear Strength, (s_{LS}) = 2000 per Retained Soil Undrained Shear Strength, (s_{LS}) = 2000 Strength in 1.00 1.50 1.76 MSE Backfull Weight (s_{PF}) = 34 Service in 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.0$						$[(s_u)_{BS}] =$	2500 psf
Retained Soil Dariened Cohesion, (c_B) = $\frac{0}{2000}$ psf $\frac{1}{2000}$ psf $\frac{1}{2000}$ Per Retained Soil Undrained Shear Strength, $[S_A]_{S_B}$ = $\frac{1}{200}$ pcf $\frac{1}{200}$ Strength $[a \ 1.00 \ 1.50 \ 1.75]$ $\frac{1}{200}$ MSE Backfill Unit Weight, $(c_{B'})$ = $\frac{1}{200}$ pcf $\frac{1}{200}$ pcf Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ MSE Backfill Friction Angle, $(c_{B'})$ = $\frac{1}{200}$ pcf Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc Strength $[a \ 1.00 \ 1.00 \ 1.00 \ 1.00]$ $\frac{1}{200}$ Pc S	<u> 18</u>					II) (D)	4.0 ft
Retained Soil Undrained Shear Strength, $[(S)_{AB}] = 2000$ psf Retained Soil Active Earth Pressure Coeff., $(K_a) = 0.297$ Strength in 1.35 1.50 1.75 $\frac{1}{2.45 + 1.49 \times 1.2} = \frac{1.20}{34}$ Strength in 1.35 1.50 1.75 $\frac{1}{2.45 + 1.49 \times 1.2} = \frac{1.20}{34}$ Strength in 1.35 1.50 1.75 $\frac{1}{2.45 + 1.49 \times 1.2} = \frac{1.20}{34}$ Service 1 1.00 1.00 1.00 1.00 $\frac{1}{1.00}$ Service 1 1.00 1.00 1.00 1.00 $\frac{1}{1.00}$ Service 1 1.00 1.00 1.00 1.00 $\frac{1}{1.00}$ Service 1 1.00 1.00 1.00 1.00 1.00 $\frac{1}{1.00}$ Service 1 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1				•	analong mangrana garang mangrana	II), $(D_W) =$	25.0 ft
Retained Soil Active Earth Pressure Coeff. (K_s) = $\frac{0.297}{120}$ pcf Strength Ia 1.00 1.50 1.75 Is (K_s) = $($							
MSE Backfill Unit Weight, $(y_{IR}) = \frac{120 \text{ pcf}}{34 \text{ service } 1 \cdot 1.00 \cdot 1.00 \cdot 1.00}$ Strength ib 1.35 \ 1.50 \ 1.75 \ 2.4 in art 3.4 to 3.4		·e					
MSE Backfill Friction Angle (φ_{BF}) = 34° Service I 1.00 1.00 1.00 1.00 $\frac{1}{1.00}$ Check Eccentricity (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.5 $e = B/2 - x_o$ $e = B/2 - x$							
Selectification (Loading Case - Strength la) - AASHTO LRFD BDM Section 11.10.5.5 $e = \frac{B}{2} - x_o$ $e = \frac{B}{2} - x_o$ $e = \frac{B}{2} - x_o$ $e = \frac{A_{EV} - M_H}{P_{EV}} = (665.68 \text{ kip-ft/ft} - 253.97 \text{ kip-ft/ft}) / (67.24 \text{ kip/ft}) = 6.12$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $e = (67.24 \text{ kip/ft}) = 665.68 \text{ kip-ft/ft}$ $e = (67.24 \text{ kip/ft}) = 9.90 \text{ ft}$ $e = (67.24 \text{ kip/ft}) = 665.68 \text{ kip-ft/ft}$ $e = (67.24 \text{ kip/ft}) = 665.68 \text{ kip-ft/ft}$ $e = (67.24 \text{ kip/ft}) = 67.24 \text{ kip/ft}$ $e = (67.24 $.E	ı&			Ammonia amin'ny fivondronana amin'ny faritr'olona a		
$e = \frac{B}{2} - x_o$ $e = $	MSE Backfill Friction Angle, (φ_{BF}) =	34 °	Se	rvice I 1.00	1.00 1.00 🗸		
$P_{EV} = \frac{M_{EV} - M_H}{P_{EV}} = (665.68 \text{ kip-ft/ft} - 253.97 \text{ kip-ft/ft}) / (67.24 \text{ kip/ft}) = 6.12$ $M_{EV} = 665.68 \text{ kip-ft/ft} - 253.97 kip-f$	Check Eccentricity (Loading Case - Strength	la) - AASHT() LRFD BDM Se	ction 11.10.5.5			
$x_o = \frac{BE_{EV} - IM_H}{P_{EIV}} = (665.68 \text{ kip-ft/ft} - 253.97 \text{ kip-ft/ft}) / (67.24 \text{ kip/ft}) = 6.12$ $M_{EV} = 665.68 \text{ kip-ft/ft}$ $M_H = 253.97 \text{ kip-ft/ft}$ $P_{EV} = 67.24 \text{ kip/ft}$ $P_{EV} = 7.24 \text{ kip/ft}$ $P_{EV} =$	e = I	$\frac{3}{2} - x_o$					
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	P_{EV}	$M_{\scriptscriptstyle FV}$ –	M_H				
$P_{EV} = 67.24 \text{ kip/ft} - \frac{1}{2} + \frac{1}{2$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$=\frac{P_{EV}}{P_{EV}}$	-11 = (665.6	38 kip·ft/ft - 253.	.97 kip·ft/ft) / (67.2	4 kip/ft) =	6.12 ft
$P_{EV} = 67.24 \text{ kip/ft} $ $e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $Resisting Moment, M_{EV}: M_{EV} = P_{EV}(x_1)$ $P_{EV} = Y_{BF} \cdot H \cdot B \cdot Y_{EV} = (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.00) = 67.24 \text{ kip.}$ $X_1 = B_2 / 2 = (19.8 \text{ ft})/2 = 9.90 \text{ ft}$ $M_{EV} = (67.24 \text{ kip/ft})(9.90 \text{ ft}) = 665.68 \text{ kip-ft/ft}$ $M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$ $P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(28.3 \text{ ft})^2 (0.297)(1.5) = 21.41 \text{ kip.}$ $X_2 = H_3 = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $X_3 = H_2 = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ $Check Eccentricity$ $e < e_{max} \implies 3.78 \text{ ft} < 6.60 \text{ ft}$ OK		<i>M</i> _{EV} =	665 68 kin·ft/f	t ¬			
$P_{EV} = 67.24 \text{ kip/ft} - \frac{1}{2} + \frac{1}{2$	7 4 4 4 3 6	$M_{II} =$	253.97 kin-ft/f	t – Defined	l helow		
$e = (19.8 \text{ ft})/2 - 6.12 \text{ ft} = 3.78 \text{ ft}$ $M_{EV} = P_{EV} \left(x_1 \right)$ $P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.00) = 67.24 \text{ kip.}$ $x_1 = B/2 = (19.8 \text{ ft})/2 = 9.90 \text{ ft}$ $M_{EV} = (67.24 \text{ kip/ft})(9.90 \text{ ft}) = 665.68 \text{ kip-ft/ft}$ $M_H = P_{EH} \left(x_2 \right) + P_{LS_h} \left(x_3 \right)$ $P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} \gamma_{e} (120 \text{ pcf})(28.3 \text{ ft})^2 (0.297)(1.5) = 21.41 \text{ kip.}$ $x_2 = H/3 = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $x_3 = H/2 = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ $\frac{Check Eccentricity}{e < e_{max}} \Rightarrow 3.78 \text{ ft} < 6.60 \text{ ft}$ OK	10 T 12 E	<i>P</i> –	67.24 kin/ft	Defined	i bolow		
Resisting Moment, M_{EV} : $M_{EV} = P_{EV}(x_1)$ $P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.00) = 67.24 \text{ kip,}$ $x_1 = B/2 = (19.8 \text{ ft})/2 = 9.90 \text{ ft}$ $M_{EV} = (67.24 \text{ kip/ft})(9.90 \text{ ft}) = 665.68 \text{ kip-ft/ft}$ Overturning Moment, M_H : $M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$ $P_{EH} = \frac{1}{2}\gamma_{RS}H^2K_a\gamma_{EH} = \frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^2(0.297)(1.5) = 21.41 \text{ kip,}$ $\gamma_{LS_h} = \gamma_{LS_h} =$	+B/2	1 EV -	01.24 Kip/it				
$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.00) = 67.24 \text{ kip.}$ $x_1 = B/2 = (19.8 \text{ ft})/2 = 9.90 \text{ ft}$ $M_{EV} = (67.24 \text{ kip/ft})(9.90 \text{ ft}) = 665.68 \text{ kip-ft/ft}$ $P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(28.3 \text{ ft})^2 (0.297)(1.5) = 21.41 \text{ kip.}$ $P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} (250 \text{ psf})(28.3 \text{ ft})(0.297)(1.5) = 3.68 \text{ kip/ft}$ $x_2 = \frac{1}{3} = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $x_3 = \frac{1}{2} = (28.3 \text{ ft})/2 = 14.15 \text{ ft}$ $M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ $\frac{\text{Check Eccentricity}}{e < e_{\text{max}}} \rightarrow 3.78 \text{ ft} < 6.60 \text{ ft}$ OK	-	= (19.8 f	:)/2 - 6.12 ft =	3.78 ft			
$x_1 = B/2 = (19.8 \text{ ft})/2 = 9.90 \text{ ft}$ $M_{EV} = (67.24 \text{ kip/ft})(9.90 \text{ ft}) = 665.68 \text{ kip-ft/ft}$ $M_{H} = P_{EH}(x_2) + P_{LS_h}(x_3)$ $P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} \gamma_{RS} (120 \text{ pcf})(28.3 \text{ ft})^2 (0.297)(1.5) = 21.41 \text{ kip.}$ $x_2 = H/3 = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $x_3 = H/2 = (28.3 \text{ ft})/2 = 14.15 \text{ ft}$ $M_{H} = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ $\frac{\text{Check Eccentricity}}{\text{Check Eccentricity}}$	Resisting Moment, $M_{\scriptscriptstyle EV}$: $M_{\scriptscriptstyle EV}$	$= P_{EV}(x_1)$)				
$x_1 = B/2 = (19.8 \text{ ft})/2 = 9.90 \text{ ft}$ $M_{EV} = (67.24 \text{ kip/ft})(9.90 \text{ ft}) = 665.68 \text{ kip-ft/ft}$ $M_H = P_{EH}(x_2) + P_{LS_h}(x_3)$ $P_{EH} = \frac{1}{2}\gamma_{RS}H^2K_a\gamma_{EH} = \frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^2(0.297)(1.5) = 21.41 \text{ kip.}$ $P_{LS_h} = \sigma_{LS}HK_a\gamma_{LS} = (250 \text{ psf})(28.3 \text{ ft})(0.297)(1.75) = 3.68 \text{ kip/ft}$ $x_2 = H/3 = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $x_3 = H/2 = (28.3 \text{ ft})/2 = 14.15 \text{ ft}$ $M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ $\frac{\text{Check Eccentricity}}{e < e_{\text{max}}} \rightarrow 3.78 \text{ ft} < 6.60 \text{ ft}$ OK	P_r	$\gamma_V = \gamma_{RE}$:	$H \cdot B \cdot \gamma_{FV} =$	(120 pcf)(28.	3 ft)(19.8 ft)(1.00)	= 67.24	l kip/ft
$M_{EV} = (67.24 \text{ kip/ft})(9.90 \text{ ft}) = 665.68 \text{ kip-ft/ft}$ $M_{H} = P_{EH} \left(x_{2} \right) + P_{LS_{h}} \left(x_{3} \right)$ $P_{EH} = \frac{1}{2} \gamma_{RS} H^{2} K_{a} \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(28.3 \text{ ft})^{2}(0.297)(1.5) = 21.41 \text{ kip.}$ $P_{LS_{h}} = \sigma_{LS} H K_{a} \gamma_{LS} = (250 \text{ psf})(28.3 \text{ ft})(0.297)(1.75) = 3.68 \text{ kip/ft}$ $x_{2} = \frac{1}{3} = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $x_{3} = \frac{1}{2} = (28.3 \text{ ft})/2 = 14.15 \text{ ft}$ $M_{H} = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ $\frac{\text{Check Eccentricity}}{e < e_{\text{max}}} \rightarrow 3.78 \text{ ft} < 6.60 \text{ ft} \qquad \text{OK}$	$ P_{EV} $						
Overturning Moment, M_H : $M_H = P_{EH} \left(x_2 \right) + P_{LS_h} \left(x_3 \right)$ $P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(28.3 \text{ ft})^2 (0.297)(1.5) = 21.41 \text{ kip,}$ $P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf})(28.3 \text{ ft})(0.297)(1.75) = 3.68 \text{ kip/ft}$ $x_2 = \frac{H}{3} = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $x_3 = \frac{H}{2} = (28.3 \text{ ft})/2 = 14.15 \text{ ft}$ $M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ Check Eccentricity $P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (28.3 \text{ ft})/2 = 14.15 \text{ ft}$ $M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$	x_1	$=\frac{D}{2}$:	= (19.8 ft) / 2	= 9.90	ft		
Overturning Moment, M_H : $M_H = P_{EH} \left(x_2 \right) + P_{LS_h} \left(x_3 \right)$ $P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(28.3 \text{ ft})^2 (0.297)(1.5) = 21.41 \text{ kip,}$ $P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf})(28.3 \text{ ft})(0.297)(1.75) = 3.68 \text{ kip/ft}$ $x_2 = \frac{H}{3} = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $x_3 = \frac{H}{2} = (28.3 \text{ ft})/2 = 14.15 \text{ ft}$ $M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ Check Eccentricity $P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (28.3 \text{ ft})/2 = 14.15 \text{ ft}$ $M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$	<u> </u>						
$P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf}) (28.3 \text{ ft})^2 (0.297) (1.5) = 21.41 \text{ kip/ft}}{21.41 \text{ kip/ft}}$ $P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf}) (28.3 \text{ ft}) (0.297) (1.75) = 3.68 \text{ kip/ft}}$ $x_2 = \frac{H}{3} = (28.3 \text{ ft}) / 3 = 9.43 \text{ ft}}{21.41 \text{ kip/ft}}$ $x_3 = \frac{H}{2} = (28.3 \text{ ft}) / 2 = 14.15 \text{ ft}}{21.41 \text{ kip/ft}}$ $M_H = (21.41 \text{ kip/ft}) (9.43 \text{ ft}) + (3.68 \text{ kip/ft}) (14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}}$ $\frac{\text{Check Eccentricity}}{21.41 \text{ kip/ft}}$		$M_{EV} =$	(67.24 kip/ft)(9.	.90 ft) = 6	65.68 kip·ft/ft		
$P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf}) (28.3 \text{ ft})^2 (0.297) (1.5) = 21.41 \text{ kip/ft}}{21.41 \text{ kip/ft}}$ $P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf}) (28.3 \text{ ft}) (0.297) (1.75) = 3.68 \text{ kip/ft}}$ $x_2 = \frac{H}{3} = (28.3 \text{ ft}) / 3 = 9.43 \text{ ft}}{21.41 \text{ kip/ft}}$ $x_3 = \frac{H}{2} = (28.3 \text{ ft}) / 2 = 14.15 \text{ ft}}{21.41 \text{ kip/ft}}$ $M_H = (21.41 \text{ kip/ft}) (9.43 \text{ ft}) + (3.68 \text{ kip/ft}) (14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}}$ $\frac{\text{Check Eccentricity}}{21.41 \text{ kip/ft}}$							
$P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf}) (28.3 \text{ ft})^2 (0.297) (1.5) = 21.41 \text{ kip/ft}$ $P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf}) (28.3 \text{ ft}) (0.297) (1.75) = 3.68 \text{ kip/ft}$ $x_2 = \frac{H}{3} = (28.3 \text{ ft}) / 3 = 9.43 \text{ ft}$ $x_3 = \frac{H}{2} = (28.3 \text{ ft}) / 2 = 14.15 \text{ ft}$ $M_H = (21.41 \text{ kip/ft}) (9.43 \text{ ft}) + (3.68 \text{ kip/ft}) (14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ $\frac{\text{Check Eccentricity}}{\text{Check Eccentricity}}$							
$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS} = (250 \text{ psf})(28.3 \text{ ft})(0.297)(1.75) = 3.68 \text{ kip/ft}$ $x_2 = H/3 = (28.3 \text{ ft})/3 = 9.43 \text{ ft}$ $x_3 = H/2 = (28.3 \text{ ft})/2 = 14.15 \text{ ft}$ $M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ $\frac{\text{Check Eccentricity}}{e < e_{\text{max}}} \rightarrow 3.78 \text{ ft} < 6.60 \text{ ft} \qquad \text{OK}$	Overturning Moment, M_H : M_H	$=P_{EH}(x_2)$	$+P_{LS_h}(x_3)$				
							kip/ft
$x_2 = \frac{H}{3} = \frac{(28.3 \text{ ft})}{3} = 9.43 \text{ ft}$ $x_3 = \frac{H}{2} = \frac{(28.3 \text{ ft})}{2} = 14.15 \text{ ft}$ $M_H = \frac{(21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft})}{253.97 \text{ kip-ft/ft}}$ $e < e_{\text{max}} \rightarrow 3.78 \text{ ft} < 6.60 \text{ ft}$ OK	P_{LS_h}	$_{S_h} = \sigma_{LS} F$	$HK_a \gamma_{LS} = 0$	250 psf)(28.3 ft))(0.297)(1.75) =	3.68	kip/ft
$M_H = (21.41 \text{ kip/ft})(9.43 \text{ ft}) + (3.68 \text{ kip/ft})(14.15 \text{ ft}) = 253.97 \text{ kip-ft/ft}$ $\frac{\text{Check Eccentricity}}{e < e_{\text{max}} \longrightarrow 3.78 \text{ ft} < 6.60 \text{ ft}} \text{ OK}$	x_2	$_{2}=H_{3}$	= (28.3 ft) / 3	= 9.43	ft		
Check Eccentricity $e < e_{\text{max}} \longrightarrow 3.78 \text{ ft} < 6.60 \text{ ft}$ OK	x_3	$=\frac{H}{2}$	= (28.3 ft) / 2	= 14.15	ft		
e < $e_{ m max}$ \longrightarrow 3.78 ft < 6.60 ft $ m OK$		$M_H =$	(21.41 kip/ft)(9.	43 ft) + (3.68 ki _l	p/ft)(14.15 ft) =	253.97	kip∙ft/ft
	Check Eccentricity						
	$e < e_{\dots} \rightarrow 3.78 \text{ ft} < 6.60 \text{ ft}$	OK					
\mathbf{p}_{1}							
Limiting Eccentricity: $e_{\text{max}} = B/3 \rightarrow e_{\text{max}} = (19.8 \text{ ft})/3 = 6.60 \text{ ft}$	Limiting Eccentricity: $e_{max} = B/2$ –	$ ightarrow$ $e_{ ext{\tiny max}}$:	= (19.8 ft) / 3	= 6.60	ft		



 $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$

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

JOB FRA-70-13.10 NO. SHEET NO. OF CALCULATED BY BRT DATE JPS CHECKED BY DATE

6 6/29/2019 7/1/2019

W-13-072

Retaining Wall W5 - Sta. 500+00 to 507+00

6.76 ksf ≤ 11.65 ksf

OK

ISE Wall Dimensions and Retained Soil Para	<u>ameters</u>	Bearing Soil F	Properties:	
/ISE Wall Height, (H) =	28.3 ft		t Weight, (γ_{BS}) =	120 pcf
ISE Wall Width (Reinforcement Length), (B) =	19.8 ft		tion Angle, (φ_{BS}) =	26 °
/ISE Wall Length, (<i>L</i>) =	1031 ft		ined Cohesion, $(c_{BS}) =$	0 psf
ive Surcharge Load, (σ_{LS}) =	250 psf		drained Shear Strength, $[(s_u)_{BS}]$ =	ş
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment De		4.0 ft
Retained Soil Friction Angle, (φ_{RS}) =	30°		vater (Below Bot. of Wall), (D_W)	= 25.0 ft
Retained Soil Drained Cohesion, (c_{BS}) =	0 psf	LRFD Load Fa		
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}] =$	2000 psf		V EH LS	
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	Strength la 1.	(AASHT)	O LRFD BDM Tables
ASE Backfill Unit Weight, $(\gamma_{BF}) =$	120 pcf	Strength lb 1.	manangananananganananangan 🕞 🕞	and 3.4.1-2 - Active arth Pressure)
/ISE Backfill Friction Angle, (φ_{BF}) =	34°	Service I 1.	00 1.00 1.00 🗸 🗀	
Check Bearing Capacity (Loading Case - Stre	ength lb) - AASHTO	LRFD BDM Section	<u>11.10.5.4</u>	
P_{LS_y}	5			
$q_{eq} =$	P_V / R'			
D				
X_{3} P_{EV} $P_{LS_{h}}$ $P_{LS_{h}}$	=B-2e=19	0.8 ft - 2(2.55 ft) = = (19.8 ft) / 2 - 7.35	14.70 π	
P_{EH}	$e = B/2 - x_0$	= (19.8 ft) / 2 - 7.35	ft = 2.55 ft	
	/			
	$x_{o} = \frac{M_{V} - M_{H}}{-}$	= (984.43 kip·f	t/ft - 253.91 kip·ft/ft) / 99.44 kiµ	p/ft = 7.35
$x_o \leftarrow \times \rightarrow -1 - e$	$P_{\scriptscriptstyle V}$			
$\stackrel{B}{\leftarrow}$				
Q_{ei}	$_{q} = (99.44 \text{ kip/ft})$) / (14.7 ft) =	6.76 ksf	
$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF} \cdot M_V)$ $M_V = [(120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.38 $				
		$+(\sigma_{IS}HK_{a}\gamma_{IS})$	(x_3)	
$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\frac{1}{2}\gamma_{RS})$	$H^2K_a\gamma_{EH}(x_2)$			
	$H^2K_a\gamma_{EH}(x_2)$			kip-ft/ft
$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\frac{1}{2}\gamma_{RS})$	$(H^2K_a\gamma_{EH})(x_2)$ 5)](9.43 ft) + [(250 ps	sf)(28.3 ft)(0.297)(1.7		kip-ft/ft
$M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{RS})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^{2}(0.297)(1.5)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{E}$	$(H^2K_a\gamma_{EH})(x_2)$ 5)](9.43 ft) + [(250 pt) $V_V + \sigma_{LS} \cdot B \cdot \gamma_{LS}$	sf)(28.3 ft)(0.297)(1.7	5)](14.15 ft) = 253.91	kip-ft/ft
$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\frac{1}{2}\gamma_{RS})$ $M_H = [\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^2(0.297)(1.000)$	$(H^2K_a\gamma_{EH})(x_2)$ 5)](9.43 ft) + [(250 pt) $V_V + \sigma_{LS} \cdot B \cdot \gamma_{LS}$	sf)(28.3 ft)(0.297)(1.7	5)](14.15 ft) = 253.91	kip-ft/ft
$M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{RS})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^{2}(0.297)(1.5)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{E}$	$(H^2 K_a \gamma_{EH})(x_2)$ 5)](9.43 ft) + [(250 pt) $V + \sigma_{LS} \cdot B \cdot \gamma_{LS}$ + (250 psf)(19.8 ft)(1	sf)(28.3 ft)(0.297)(1.7	5)](14.15 ft) = 253.91	kip-ft/ft
$\begin{split} M_{H} &= P_{EH}\left(x_{2}\right) + P_{LS_{h}}\left(x_{3}\right) = \left(\frac{1}{2}\gamma_{RS}\right) \\ M_{H} &= \left[\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^{2}(0.297)(1.000) \\ P_{V} &= P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{ES} \\ P_{V} &= (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.35) \\ \end{split}$ Check Bearing Resistance - Drained Condition	$(H^2 K_a \gamma_{EH})(x_2)$ 5)](9.43 ft) + [(250 pt) $V + \sigma_{LS} \cdot B \cdot \gamma_{LS}$ + (250 psf)(19.8 ft)(1	sf)(28.3 ft)(0.297)(1.7 s .75) = 99.44	5)](14.15 ft) = 253.91	kip-ft/ft
$\begin{split} M_{H} &= P_{EH}\left(x_{2}\right) + P_{LS_{h}}\left(x_{3}\right) = \left(\frac{1}{2}\gamma_{RS}\right) \\ M_{H} &= \left[\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^{2}(0.297)(1.000) \\ P_{V} &= P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{ES} \\ P_{V} &= (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.35) \\ \end{split}$ Check Bearing Resistance - Drained Condition	$(H^2 K_a \gamma_{EH})(x_2)$ 5)](9.43 ft) + [(250 pt) $V + \sigma_{LS} \cdot B \cdot \gamma_{LS}$ + (250 psf)(19.8 ft)(1	sf)(28.3 ft)(0.297)(1.7 s .75) = 99.44	5)](14.15 ft) = 253.91	kip-ft/ft
$M_H=P_{EH}\left(x_2\right)+P_{LS_h}\left(x_3\right)=\left(\frac{1}{2}\gamma_{RS}\right)$ $M_H=\left(\frac{1}{2}(120\ \mathrm{pcf})(28.3\ \mathrm{ft})^2(0.297)(1.1)$ $P_V=P_{EV}+P_{LS}=\gamma_{BF}\cdot H\cdot B\cdot \gamma_{ES}$ $P_V=\left(120\ \mathrm{pcf}\right)(28.3\ \mathrm{ft})(19.8\ \mathrm{ft})(1.35)$ Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: $q_n=cN_{cm}$	$(H^2 K_a \gamma_{EH})(x_2)$ 5)](9.43 ft) + [(250 pt) $V + \sigma_{LS} \cdot B \cdot \gamma_{LS}$ + (250 psf)(19.8 ft)(1	sf)(28.3 ft)(0.297)(1.7) $S = 99.44$ $+ \frac{1}{2} \gamma B N_{\gamma m} C_{w\gamma}$	5)](14.15 ft) = 253.91	
$M_H=P_{EH}\left(x_2\right)+P_{LS_h}\left(x_3\right)=\left(\frac{1}{2}\gamma_{RS}\right)$ $M_H=\left(\frac{1}{2}(120\ \mathrm{pcf})(28.3\ \mathrm{ft})^2(0.297)(1.1)$ $P_V=P_{EV}+P_{LS}=\gamma_{BF}\cdot H\cdot B\cdot \gamma_{ES}$ $P_V=\left(120\ \mathrm{pcf}\right)(28.3\ \mathrm{ft})(19.8\ \mathrm{ft})(1.35)$ Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: $q_n=cN_{cm}$	$(B_{A})^{2}K_{a}\gamma_{EH}(x_{2})$ (5)](9.43 ft) + [(250 pt) $V_{A} + \sigma_{LS} \cdot B \cdot \gamma_{LS}$ + (250 psf)(19.8 ft)(1	sf)(28.3 ft)(0.297)(1.7) $S = 99.44$ $+ \frac{1}{2} \gamma B N_{\gamma m} C_{w\gamma}$	$N_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma} = 12$	
$M_H=P_{EH}\left(x_2\right)+P_{LS_h}\left(x_3\right)=\left(rac{1}{2}\gamma_{RS}\right)$ $M_H=[\frac{1}{2}(120\ \mathrm{pcf})(28.3\ \mathrm{ft})^2(0.297)(1.1)$ $P_V=P_{EV}+P_{LS}=\gamma_{BF}\cdot H\cdot B\cdot \gamma_E$ $P_V=(120\ \mathrm{pcf})(28.3\ \mathrm{ft})(19.8\ \mathrm{ft})(1.35)$ Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: $q_n=cN_{cm}$ $N_{cm}=N_cs_ci_c=22.43$	$SH^{2}K_{a}\gamma_{EH}(x_{2})$ $SH^{2}K_{a}\gamma_{EH}(x$	sf)(28.3 ft)(0.297)(1.7) $S = 99.44$ $+ \frac{1}{2} \gamma B N_{\gamma m} C_{w\gamma}$	$S_{\rm pm} = N_{\gamma} S_{\gamma} i_{\gamma} = 12$	
$M_H=P_{EH}\left(x_2\right)+P_{LS_h}\left(x_3\right)=\left(rac{1}{2}\gamma_{RS} ight)$ $M_H=[rac{1}{2}(120\ \mathrm{pcf})(28.3\ \mathrm{ft})^2(0.297)(1.1)$ $P_V=P_{EV}+P_{LS}=\gamma_{BF}\cdot H\cdot B\cdot \gamma_E$ $P_V=(120\ \mathrm{pcf})(28.3\ \mathrm{ft})(19.8\ \mathrm{ft})(1.35)$ Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: $q_n=cN_{cm}$ $N_{cm}=N_cs_ci_c=22.43$ $N_c=22.25$	$(H^2K_a\gamma_{EH})(x_2)$ 5)](9.43 ft) + [(250 ps) $V + \sigma_{LS} \cdot B \cdot \gamma_{LS}$ + (250 psf)(19.8 ft)(1 $V + \gamma D_f N_{qm} C_{wq} + \gamma D_f N_{qm} C_{wq}$ $V + \gamma D_f N_{qm} C_{wq} + \gamma D_f N_{qm} C_{wq}$ $N_{qm} = N_q S_q d_{qq}$ $N_q = 11.85$ $S_q = 1.007$	sf)(28.3 ft)(0.297)(1.7) $S = 99.44$ $+ \frac{1}{2} \gamma B N_{\gamma m} C_{w\gamma}$	$N_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma} = 12$ $N_{\gamma} = 12.54$ $S_{\gamma} = 0.994$ ft) $i_{\gamma} = 1.000$ (Assume	.46
$M_H = P_{EH} \left(x_2 \right) + P_{LS_h} \left(x_3 \right) = \left(\frac{1}{2} \gamma_{RS} \right)$ $M_H = [\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^2(0.297)(1.12)$ $P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{E}$ $P_V = (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.35)$ Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 22.43$ $N_c = 22.25$ $s_c = 1 + (14.7 \text{ ft/1031 ft})(11.85/22.25)$	$SH^{2}K_{a}\gamma_{EH}(x_{2})$ $SH^{2}K_{a}\gamma_{EH}(x$	sf)(28.3 ft)(0.297)(1.7. s $.75) = 99.44$ $+ \frac{1}{2} \gamma B N_{yn} C_{wy}$ $i_q = 12.91$ s° [1-sin(26°)] ² tan ⁻¹ (4.0 ft/14.7	$N_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma} = 12$ $N_{\gamma} = 12.54$ $S_{\gamma} = 0.994$.46
$M_{H} = P_{EH}\left(x_{2}\right) + P_{LS_{h}}\left(x_{3}\right) = \left(\frac{1}{2}\gamma_{RS}\right)$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^{2}(0.297)(1.5)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{E}$ $P_{V} = (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.35)$ Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: $q_{n} = cN_{cm}$ $N_{cm} = N_{c}s_{c}i_{c} = 22.43$ $N_{c} = 22.25$ $s_{c} = 1+(14.7 \text{ ft}/1031 \text{ ft})(11.85/22.25)$ $= 1.008$	$SH^{2}K_{a}\gamma_{EH}(x_{2})$ $SH^{2}K_{a}\gamma_{EH}(x$	sf)(28.3 ft)(0.297)(1.7. ss	$N_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma} = 12$ $N_{\gamma} = 12.54$ $S_{\gamma} = 0.994$ ft) $i_{\gamma} = 1.000$ (Assume	.46
$M_{H} = P_{EH}\left(x_{2}\right) + P_{LS_{h}}\left(x_{3}\right) = \left(\frac{1}{2}\gamma_{RS}\right)$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^{2}(0.297)(1.5)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{E}$ $P_{V} = (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.35)$ Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: $q_{n} = cN_{cm}$ $N_{cm} = N_{c}s_{c}i_{c} = 22.43$ $N_{c} = 22.25$ $s_{c} = 1+(14.7 \text{ ft}/1031 \text{ ft})(11.85/22.25)$ $= 1.008$	$SH^{2}K_{a}\gamma_{EH}(x_{2})$ $SH^{2}K_{a}\gamma_{EH}(x$	sf)(28.3 ft)(0.297)(1.7. s $.75) = 99.44$ $+ \frac{1}{2} \gamma B N_{yn} C_{wy}$ $i_q = 12.91$ s° [1-sin(26°)] ² tan ⁻¹ (4.0 ft/14.7	$N_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma} = 12$ $N_{\gamma} = 12.54$ $S_{\gamma} = 0.994$ ft) $i_{\gamma} = 1.000$ (Assume	.46
$M_{H} = P_{EH}\left(x_{2}\right) + P_{LS_{h}}\left(x_{3}\right) = \left(\frac{1}{2}\gamma_{RS}\right)$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^{2}(0.297)(1.5)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{E}$ $P_{V} = (120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.35)$ Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: $q_{n} = cN_{cm}$ $N_{cm} = N_{c}s_{c}i_{c} = 22.43$ $N_{c} = 22.25$ $s_{c} = 1+(14.7 \text{ ft}/1031 \text{ ft})(11.85/22.25)$ $= 1.008$	$SH^{2}K_{a}\gamma_{EH}(x_{2})$ $SH^{2}K_{a}\gamma_{EH}(x$	sf)(28.3 ft)(0.297)(1.7.5) s .75) = 99.44 $i_q = 12.91$ Assumed) 4.0 ft = 1.000	$N_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma} = 12$ $N_{\gamma} = 12.54$ $S_{\gamma} = 0.994$ ft) $i_{\gamma} = 1.000$ (Assume $C_{w\gamma} = 25.0 \text{ft} < 1.5(14.7 \text{ft})$.46

 $6.76 \text{ ksf} \le (17.93 \text{ ksf})(0.65) = 11.65 \text{ ksf}$



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FRA-70-13.10 JOB NO. W-13-072 SHEET NO. OF 6 CALCULATED BY BRT DATE 6/29/2019 CHECKED BY JPS DATE 7/1/2019 Retaining Wall W5 - Sta. 500+00 to 507+00

PHONE: (614) 823-4949

FAX: (614) 823-4990

WWW.RESOURCEINTERATIONAL.COM

MSE Wall Dimensions and Retained Soil Paran	<u>neters</u>	Bearing Soil Prope	rues.		
MSE Wall Height, (H) =	28.3 ft	Bearing Soil Unit Weig	ght, $(\gamma_{BS}) =$		20 pcf
#ISE Wall Width (Reinforcement Length), (B) =	19.8 ft	Bearing Soil Friction A	$\operatorname{Ingle}_{(\varphi_{BS})} =$		26 °
/ISE Wall Length, (L) =	1031 ft	Bearing Soil Drained (Cohesion, $(c_{BS}) =$		0 psf
ive Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil Undraine		$(s_u)_{BS}] = 25$	00 psf
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment Depth, (L			4.0 ft
Retained Soil Friction Angle, (φ_{RS}) =	30°	Depth to Grounwater ((Below Bot. of Wall), $(D_W) = 2$	5.0 ft
Retained Soil Drained Cohesion, (c_{BS}) =	0 psf	LRFD Load Factors			
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}] =$	2000 psf	EV	EH LS		
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	Y	1.50 1.75	(AASHTO LRFD BDN	/I Tables
/ISE Backfill Unit Weight, (γ_{BF}) =	120 pcf		1.50 1.75 -	3.4.1-1 and 3.4.1-2 Earth Pressure	
/ISE Backfill Friction Angle, (φ_{BF}) =	34 °	Service I 1.00	1.00 1.00 🗸	24.07770004.	·
Check Bearing Capacity (Loading Case - Stren	gth lb) - AASHTO	LRFD BDM Section 11.10	.5.4 (Continued)		
Check Bearing Resistance - Undrained Conditi	<u>ion</u>				
Nominal Bearing Resistance: $q_{n}=cN_{cm}$ +	- $\gamma D_f N_{qm} C_{wq}$ +	$-\frac{1}{2}\gamma BN_{\gamma m}C_{w\gamma}$			
$N_{cm} = N_c s_c i_c = 5.160$	$N_{qm} = N_q s_q d_q i$	$t_q = 1.000$	$V_{ym} = N_{\gamma} s_{\gamma} i_{\gamma}$	= 0.000	
N _c = 5.140	$N_q = 1.000$		$N_{\nu} = 0.000$		
$S_{c} = 1+(14.7 \text{ ft/}[(5)(1031 \text{ ft})]) = 1.003$			$S_{y} = 1.000$		
		o°)[1-sin(0°)]²tan⁻¹(4.0 ft/14.7 ft)	$i_{\gamma} = 1.000$	(Assumed)	
	1.000		rangan and an arrangan area area.	1.5(14.7 ft) + 4.0 ft	= 1.0
				.,,	
	$i_a = 1.000$ (A	Assumed)			
$q_n=\hspace{0.2cm}$ (2500 psf)(5.160) + (120 pcf)(4.0 fi		4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1		3.38 ksf	
erify Equivalent Pressure Less Than Factored	$C_{wq} = 25.0 \text{ft} >$ t)(1.000)(1.000) + ½	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
Verify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100		3.38 ksf	
erify Equivalent Pressure Less Than Factored	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
'erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
'erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
'erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
'erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
'erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
Verify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
Verify Equivalent Pressure Less Than Factored $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_{_n} \cdot \phi_b \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_{_{n}} \cdot \phi_{_{b}} \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_{_{n}} \cdot \phi_{_{b}} \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
/erify Equivalent Pressure Less Than Factored $q_{eq} \leq q_{_{n}} \cdot \phi_{_{b}} \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	
Verify Equivalent Pressure Less Than Factored $q_{eq} \leq q_{_{n}} \cdot \phi_{_{b}} \longrightarrow 6.76 ext{ ksf} \leq$	$C_{wq} = 25.0 \text{ ft} >$ t)(1.000)(1.000) + ½ d Bearing Resistar (13.38 ksf)(0.65) =	4.0 ft = 1.000 2(120 pcf)(14.7 ft)(0.000)(1 100	.067) = 1	3.38 ksf	



RESOURCE INTERNATIONAL, INC. 6350 PRESIDENTIAL GATEWAY COLUMBUS, OHIO 43231

FRA-70-13.10 SHEET NO. CALCULATED BY DATE CHECKED BY JPS

W-13-072 6/29/2019 DATE 7/1/2019

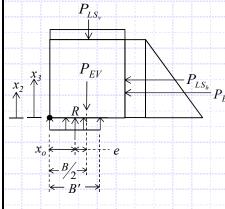
Retaining Wall W5 - Sta. 500+00 to 507+00

PHONE: (614) 823-4949
FAX: (614) 823-4990
WWW.RESOURCEINTERATIONAL.COM

MSE Wall Dimensions and Retained Soil Para	<u>meters</u>	Bearing Soil Properties:	
MSE Wall Height, (H) =	28.3 ft	Bearing Soil Unit Weight, (γ_{BS}) =	120 pcf
MSE Wall Width (Reinforcement Length), (<i>B</i>) =	19.8 ft	Bearing Soil Friction Angle, (φ_{BS}) =	26 °
MSE Wall Length, (L) =	1031 ft	Bearing Soil Drained Cohesion, (c_{BS}) =	0 psf
Live Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	2500 psf
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment Depth, (D_f) =	4.0 ft
Retained Soil Friction Angle, (φ_{RS}) =	30 °	Depth to Grounwater (Below Bot. of Wall), (D_W) =	25.0 ft
Retained Soil Drained Cohesion, (c_{BS}) =	0 psf	LRFD Load Factors	
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	EV EH LS	
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	Strength la 1.00 1.50 1.75 7	RFD BDM Tables
MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf	Strength lb 1.35 1.50 1.75 - 3.4.1-1 and	1 3.4.1-2 - Active
MSE Backfill Friction Angle, (φ_{BF}) =	34 °	Service I 1.00 1.00 1.00 J	Pressure)

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

 $q_{eq} = \frac{P_V}{R'}$



$$R' - R - 2a = 19.8 \text{ ft} - 2(2.28 \text{ ft}) = 15.24 \text{ ft}$$

$$P_{LS_h}$$
 P_{EH} $B' = B - 2e$ = 19.8 ft - 2(2.28 ft) = 15.24 ft
 $e = B/2 - x_o$ = (19.8 ft) / 2 - 7.62 ft = 2.28 ft
 $x_o = \frac{M_V - M_H}{P_V}$ = (714.69 kip·ft/ft - 164.32 kip·ft/ft) / 72.19 kip/ft =

$$q_{eq} = (72.19 \text{ kip/ft}) / (15.24 \text{ ft}) = 4.74 \text{ ksf}$$

$$M_{V} = P_{EV}(x_1) + P_{LS_{V}}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

$$M_V = [(120 \text{ pcf})(28.3 \text{ ft})(19.8 \text{ ft})(1.00)](9.9 \text{ ft}) + [(250 \text{ psf})(19.8 \text{ ft})(1.00)](9.9 \text{ ft}) = 714.69 \text{ kip-ft/ft}$$

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (V_2 \gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

$$M_H = [\frac{1}{2}(120 \text{ pcf})(28.3 \text{ ft})^2(0.297)(1.00)](9.43 \text{ ft}) + [(250 \text{ psf})(28.3 \text{ ft})(0.297)(1.00)](14.15 \text{ ft})$$
 = 164.32 kip·ft/ft

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

$$P_{V} = (120 \, {\rm pcf})(28.3 \, {\rm ft})(19.8 \, {\rm ft})(1.00) + (250 \, {\rm psf})(19.8 \, {\rm ft})(1.00) = 72.19 \, {\rm kip/ft}$$

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Along Wall Facing
B-099-4-14	1.080 in	0.811 in	50 days		
B-100-0-09	0.967 in	0.758 in	13 days	120 ft	1/27170
B-100-2-14	1.108 in	0.872 in	70 days	125 ft	1/13160
B-100-4-14	1.884 in	1.496 in	14 days	140 ft	1/2690
B-102-3-14	2.617 in	1.957 in	22 days	130 ft	1/3380

W-13-072 - FRA-70-13.10 - Retaining Wall W5

Calculated By: BRT Date: 6/29/2019 MSE Wall Settlement - Sta. 500+00 to 507+00 Checked By: Date: 7/1/2019

Boring B-099-4-14

7.1 ft Total wall height 7.1 B'= Effective footing width due to eccentricity 25.0 Depth below bottom of footing 1,250 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of R	einforced So	il Mass	Total Settlement at Facing of Wall					
Layer	Soil Class.	Soil Type	Layer (Depth	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	1 ⁽⁷⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	
1	A-7-6	С	0.0	2.0	2.0	1.0	120	240	120	120	4,120	43	0.297	0.030	0.608				0.14	0.991	1,239	1,359	0.039	0.467	0.499	624	744	0.029	0.351	
2	A-7-6	С	2.0	4.5	2.5	3.3	125	553	396	396	4,396	43	0.297	0.030	0.608				0.46	0.845	1,056	1,453	0.026	0.313	0.484	605	1,001	0.019	0.223	
2	A-7-6	С	4.5	7.0	2.5	5.8	125	865	709	709	4,709	43	0.297	0.030	0.608				0.81	0.637	796	1,505	0.015	0.181	0.439	549	1,257	0.011	0.138	
3	A-6a	С	7.0	9.5	2.5	8.3	120	1,165	1,015	1,015	5,015	34	0.216	0.022	0.538				1.16	0.490	612	1,627	0.007	0.086	0.384	479	1,494	0.006	0.071	
4	A-1-a	G	9.5	11.5	2.0	10.5	130	1,425	1,295	1,295	5,295					28	32	105	1.48	0.401	501	1,796	0.003	0.032	0.337	421	1,716	0.002	0.028	
1. $\sigma_p' = \sigma_v$	$\sigma_{vo}' + \sigma_{m}$; Estimate σ_{m} of 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003												Total Settlement: 1.080 ii					O in Total Settlement: 0.811 in												

^{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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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.} $\Delta \sigma_v = q_e(I)$

 $^{9. \ \} S_c = [C_{c'}(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_i}'; \ [C_{f'}(1+e_o)](H) \log(\sigma_p'/\sigma_{v_o}') + [C_{c'}(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_p') \\ \text{for } \sigma_{v_o}' < \sigma_p' < \sigma_{v_i}'; \ \text{Ref. Section } 10.6.2.4.3, \ \text{AASHTO LRFD BDS (Cohesive soil layers)} \\ \text{In the layer } S_c = [C_{c'}(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_{v_o}' < \sigma_{v_o$

^{10.} S_c = H(1/C')log(σ_{vf} '/ σ_{vo} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-072 - FRA-70-13.10 - Retaining Wall W5 MSE Wall Settlement - Sta. 500+00 to 507+00
 Calculated By:
 BRT
 Date:
 6/29/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Boring B-099-4-14

H=	7.1	ft	Total wall height		A-7-6	A-6a		
B'=	7.1	ft	Effective footing width due to eccentricity	c _v =	150	600	ft²/yr	Coefficient of consolitation
$D_w =$	25.0	ft	Depth below bottom of footing	t =	50	50	days	Time following completion of construction
q _e =	1,250	psf	Equivalent bearing pressure at bottom of wall	H _{dr} =	5	2.5	ft	Length of longest drainage path considered
				$T_v =$	0.822	13.151		Time factor
				U =	89	100	%	Degree of consolidation
				$(S_c)_t =$	0.733	in	Settlement complete a	at 90% of primary consolidation

																							Total Settlement at Facing of Wall			Settlement Complete at 90% of Primary Consolidation	
Layer	Soil Type	Soil Type	Layer (f	Depth t)	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⁾	Δσ _ν ⁽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-7-6	С	0.0	2.0	2.0	1.0	120	240	120	120	4,120	43	0.297	0.030	0.608				0.14	0.499	624	744	0.029	0.351	0.351	0.313	0.313
2	A-7-6	С	2.0	4.5	2.5	3.3	125	553	396	396	4,396	43	0.297	0.030	0.608				0.46	0.484	605	1,001	0.019	0.223	0.361	0.198	0.321
2	A-7-6	С	4.5	7.0	2.5	5.8	125	865	709	709	4,709	43	0.297	0.030	0.608				0.81	0.439	549	1,257	0.011	0.138	0.301	0.123	0.321
3	A-6a	С	7.0	9.5	2.5	8.3	120	1,165	1,015	1,015	5,015	34	0.216	0.022	0.538				1.16	0.384	479	1,494	0.006	0.071	0.071	0.071	0.071
4	A-1-a	G	9.5	11.5	2.0	10.5	130	1,425	1,295	1,295	5,295	•				28	32	105	1.48	0.337	421	1,716	0.002	0.028	0.028	0.028	0.028

- 1. σ_0 ' = σ_{vo} '+ σ_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 $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v_o}')$ for $\sigma_p' \leq \sigma_{v_o'}' < \sigma_{v'}'$; $[C_t/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_v'/\sigma_p')$ for $\sigma_{v_o'} < \sigma_{v'}' < \sigma_{v'}'$; $[C_t/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}')$
- 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:

0.078 in

W-13-072 - FRA-70-13.10 - Retaining Wall W5 MSE Wall Settlement - Sta. 500+00 to 507+00

 Calculated By:
 BRT
 Date:
 6/29/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Boring B-100-0-09

H= 10.2 ft Total wall height

B'= 6.3 ft Effective footing width due to eccentricity

D_w = 25.0 ft Depth below bottom of footing

 q_e = 1,880 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	t Center of R	einforced Sc	oil Mass	Total Settlement at Facing of Wall					
Layer	Soil Class.	Soil Type	Layer (t		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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	1 ⁽⁷⁾	Δσ _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	120	360	180	180	4,180					8	14	64	0.24	0.964	1,813	1,993	0.049	0.591	0.497	935	1,115	0.037	0.448	
2	A-4a	С	3.0	4.5	1.5	3.8	125	548	454	454	4,454	24	0.126	0.013	0.460				0.60	0.758	1,426	1,879	0.008	0.096	0.469	882	1,335	0.006	0.073	
3	A-1-b	G	4.5	6.0	1.5	5.3	130	743	645	645	4,645					37	51	174	0.83	0.625	1,175	1,820	0.004	0.047	0.435	819	1,464	0.003	0.037	
	A-6b	С	6.0	8.0	2.0	7.0	125	993	868	868	4,868	33	0.207	0.021	0.530				1.11	0.507	954	1,821	0.009	0.105	0.392	736	1,604	0.007	0.087	
4	A-6b	С	8.0	10.0	2.0	9.0	125	1,243	1,118	1,118	5,118	33	0.207	0.021	0.530				1.43	0.413	776	1,894	0.006	0.074	0.344	647	1,764	0.005	0.064	
	A-6b	С	10.0	12.0	2.0	11.0	125	1,493	1,368	1,368	5,368	33	0.207	0.021	0.530				1.75	0.346	651	2,018	0.005	0.055	0.303	569	1,937	0.004	0.049	
1. $\sigma_p' = \sigma_v$	= σ_{vo} '+ σ_{m} ; Estimate σ_{m} of 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003													Tota	Settlement:		0.967 in	in Total Settlement: 0.758 in												

^{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.} $e_0 = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981

^{5.} $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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.} $\Delta \sigma_v = q_e(I)$

 $^{9. \ \} S_c = [C_c/(1+e_o)](H) log(\sigma_{v_i}'/\sigma_{v_o}') for \ \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_i}'; \ [C_r/(1+e_o)](H) log(\sigma_p'/\sigma_{v_o}') + [C_c/(1+e_o)](H) log(\sigma_{v_i}'/\sigma_p') \ for \ \sigma_{v_o}' < \sigma_p' < \sigma_{v_i}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO LRFD \ BDS \ (Cohesive soil layers)$

^{10.} S_c = H(1/C')log(σ_{v_i} '/ σ_{v_o} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-072 - FRA-70-13.10 - Retaining Wall W5

MSE Wall Settlement - Sta. 500+00 to 507+00

Boring B-100-0-09

H=	10.2	ft	Total wall height		A-6b		
B'=	6.3	ft	Effective footing width due to eccentricity	c _v =	300	ft²/yr	Coefficient of consolitation
$D_w =$	25.0	ft	Depth below bottom of footing	t =	13	days	Time following completion of construction
q _e =	1,880	psf	Equivalent bearing pressure at bottom of wall	$H_{dr} =$	6	ft	Length of longest drainage path considered
				$T_v =$	0.297		Time factor
				U =	61	%	Degree of consolidation
				(S _c) _t =	0.680 in	Settlement complete	at 90% of primary consolidation

																							Total Se	ttlement at F			mplete at 90% of onsolidation
Layer	Soil Type	Soil Type	Layer (f	Depth t)	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⁾	$\Delta\sigma_{\rm v}^{~(8)}$ (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-a	G	0.0	3.0	3.0	1.5	120	360	180	180	4,180					8	14	64	0.24	0.497	935	1,115	0.037	0.448	0.448	0.448	0.448
2	A-4a	С	3.0	4.5	1.5	3.8	125	548	454	454	4,454	24	0.126	0.013	0.460				0.60	0.469	882	1,335	0.006	0.073	0.073	0.073	0.073
3	A-1-b	G	4.5	6.0	1.5	5.3	130	743	645	645	4,645					37	51	174	0.83	0.435	819	1,464	0.003	0.037	0.037	0.037	0.037
	A-6b	О	6.0	8.0	2.0	7.0	125	993	868	868	4,868	33	0.207	0.021	0.530				1.11	0.392	736	1,604	0.007	0.087		0.053	
4	A-6b	С	8.0	10.0	2.0	9.0	125	1,243	1,118	1,118	5,118	33	0.207	0.021	0.530				1.43	0.344	647	1,764	0.005	0.064	0.200	0.039	0.122
	A-6b	С	10.0	12.0	2.0	11.0	125	1,493	1,368	1,368	5,368	33	0.207	0.021	0.530				1.75	0.303	569	1,937	0.004	0.049		0.030	

- 1. $\sigma_n' = \sigma_{vo}' + \sigma_m$. 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 $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v_o}')$ for $\sigma_p' \leq \sigma_{v_o'}' < \sigma_{v'}'$; $[C_t/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_v'/\sigma_p')$ for $\sigma_{v_o'} < \sigma_{v'}' < \sigma_{v'}'$; $[C_t/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}')$
- 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

Calculated By: Date: 6/29/2019 Date: 7/1/2019 Checked By:

Settlement Remaining After Hold Period: 0.078 in

MSE Wall Settlement - Sta. 500+00 to 507+00

Boring B-100-2-14

13.4 ft Total wall height

7.0 ft Effective footing width due to eccentricity

 $D_w =$ 25.0 ft Depth below bottom of footing

2,500 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of Re	einforced Soi	I Mass		Total Sett	lement at Fa	acing of Wall	
Layer	Soil Class.	Soil Type	,	Depth	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⁾	$\Delta\sigma_{\rm v}^{~(8)}$ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	Δσ _ν ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
1	A-6a	С	0.0	2.5	2.5	1.3	125	313	156	156	4,156	32	0.198	0.020	0.522				0.18	0.983	2,458	2,614	0.040	0.477	0.499	1,247	1,403	0.031	0.372
	A-6b	С	2.5	4.5	2.0	3.5	125	563	438	438	4,438	35	0.225	0.023	0.546				0.50	0.818	2,046	2,483	0.022	0.263	0.480	1,199	1,637	0.017	0.200
2	A-6b	С	4.5	7.0	2.5	5.8	125	875	719	719	4,719	35	0.225	0.023	0.546				0.82	0.631	1,577	2,296	0.018	0.220	0.437	1,093	1,812	0.015	0.175
	A-6b	С	7.0	9.5	2.5	8.3	125	1,188	1,031	1,031	5,031	35	0.225	0.023	0.546				1.18	0.484	1,211	2,242	0.012	0.147	0.381	952	1,984	0.010	0.124
1. σ _p ' = σ _ν	₀'+σ _{m;} Estima	te $\sigma_{\rm m}$ of 4,00	00 psf (mode	erately over	consolidated)	for natural s	oil deposits;	Ref. Table 1	1.2, Coduto 2	2003	•								•		Total	Settlement:		1.108 in	•	Total	Settlement:	·	0.872 in

^{2.} $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5

Calculated By: BRT Date: 6/29/2019 Checked By: JPS

Date: 7/1/2019

^{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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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.} $\Delta \sigma_v = q_e(I)$

 $^{9. \ \} S_c = [C_{c'}(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_i}'; \ [C_{f'}(1+e_o)](H) \log(\sigma_p'/\sigma_{v_o}') + [C_{c'}(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_p') \\ \text{for } \sigma_{v_o}' < \sigma_p' < \sigma_{v_i}'; \ \text{Ref. Section } 10.6.2.4.3, \ \text{AASHTO LRFD BDS (Cohesive soil layers)} \\ \text{In the layer } S_c = [C_{c'}(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_{v_o}' < \sigma_{v_o$

^{10.} S_c = H(1/C')log(σ_{vf}/σ_{vo} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

MSE Wall Settlement - Sta. 500+00 to 507+00

BRT Date: 6/29/2019 Calculated By: Checked By: JPS Date: 7/1/2019

Boring B-100-2-14

H=	13.4	ft	Total wall height		A-6a	A-6b		
B'=	7.0	ft	Effective footing width due to eccentricity	c _v =	600	300	ft ² /yr	Coefficient of consolitation
$D_w =$	25.0	ft	Depth below bottom of footing	t =	70	70	days	Time following completion of construction
q _e =	2,500	psf	Equivalent bearing pressure at bottom of wall	$H_{dr} =$	2.5	9.5	ft	Length of longest drainage path considered
				$T_v =$	18.411	0.637		Time factor
				U =	100	83	%	Degree of consolidation
				(S _c) _t =	0.787	in	Settlement complete a	at 90% of primary consolidation

																						Total Se	ettlement at f	acing of Wall	Settlement Com Primary Co	nplete at 90% of onsolidation
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⁾	Δσ _ν ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	Layer Settlement (in)	(S _c) _t ⁽¹¹⁾ (in)	Layer Settlement (in)
1	A-6a	С	0.0 2.5	2.5	1.3	125	313	156	156	4,156	32	0.198	0.020	0.522				0.18	0.499	1,247	1,403	0.031	0.372	0.372	0.372	0.372
	A-6b	С	2.5 4.5	2.0	3.5	125	563	438	438	4,438	35	0.225	0.023	0.546				0.50	0.480	1,199	1,637	0.017	0.200		0.166	
2	A-6b	С	4.5 7.0	2.5	5.8	125	875	719	719	4,719	35	0.225	0.023	0.546				0.82	0.437	1,093	1,812	0.015	0.175	0.500	0.146	0.415
	A-6b	С	7.0 9.5	2.5	8.3	125	1,188	1,031	1,031	5,031	35	0.225	0.023	0.546				1.18	0.381	952	1,984	0.010	0.124		0.103	1

- 1. $\sigma_{\rm o}' = \sigma_{\rm vo}' + \sigma_{\rm m}$ Estimate $\sigma_{\rm m}$ 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 $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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. $S_c = [C_o/(1+e_o)](H)log(\sigma_{v_f}/\sigma_{v_o}')$ for $\sigma_p' \le \sigma_{v_o}' < \sigma_{v_f}'$; $[C_r/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}')$ for $\sigma_{v_o}' < \sigma_{v_f}'$; $[C_r/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}')$ for $\sigma_{v_o}' < \sigma_{v_f}'$; 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: 0.085 in

Settlement Complete at 90% of

W-13-072 - FRA-70-13.10 - Retaining Wall W5 MSE Wall Settlement - Sta. 500+00 to 507+00

Boring B-100-4-14

19.5 ft Total wall height H=

B'= 10.4 ft Effective footing width due to eccentricity

 $D_w =$ 25.0 ft Depth below bottom of footing

3,400 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of Re	einforced So	l Mass		Total Sett	tlement at Fa	acing of Wall	
Layer	Soil Class.	Soil Type	,	r 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⁾	$\Delta\sigma_{_{_{ m V}}}^{(8)}$ (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)
	A-6b	С	0.0	2.0	2.0	1.0	125	250	125	125	4,125	38	0.252	0.025	0.569				0.10	0.997	3,390	3,515	0.047	0.559	0.500	1,699	1,824	0.037	0.449
4	A-6b	С	2.0	4.0	2.0	3.0	125	500	375	375	4,375	38	0.252	0.025	0.569				0.29	0.942	3,204	3,579	0.031	0.378	0.495	1,684	2,059	0.024	0.285
1	A-6b	С	4.0	6.0	2.0	5.0	125	750	625	625	4,625	38	0.252	0.025	0.569				0.48	0.831	2,824	3,449	0.024	0.286	0.482	1,638	2,263	0.018	0.215
	A-6b	С	6.0	8.0	2.0	7.0	125	1,000	875	875	4,875	38	0.252	0.025	0.569				0.67	0.711	2,419	3,294	0.018	0.222	0.459	1,560	2,435	0.014	0.171
2	A-1-b	G	8.0	13.0	5.0	10.5	130	1,650	1,325	1,325	5,325					33	38	122	1.01	0.546	1,856	3,181	0.016	0.187	0.408	1,386	2,711	0.013	0.152
	A-1-b	G	13.0	16.5	3.5	14.8	125	2,088	1,869	1,869	5,869					18	18	71	1.42	0.415	1,412	3,281	0.012	0.145	0.345	1,174	3,043	0.010	0.125
3	A-1-b	G	16.5	20.0	3.5	18.3	125	2,525	2,306	2,306	6,306					18	17	69	1.75	0.344	1,171	3,477	0.009	0.109	0.302	1,026	3,332	0.008	0.098
1. $\sigma_n' = \sigma_n$, _o '+σ _m . Estima	ate σ _m of 4,0	00 psf (mod	lerately over	consolidated)	for natural so	oil deposits;	Ref. Table 1	1.2, Coduto 2	2003					<u> </u>			•			Total	Settlement:		1.884 in		Total	Settlement:	·	1.496 in

Calculated By: BRT

Checked By: JPS

Date: 6/29/2019

Date: 7/1/2019

^{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 $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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.} $S_c = [C_c/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{vo})$ for $\sigma_{p'} \leq \sigma_{vo'} < \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{p'}/\sigma_{vo'}) + [C_c/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{p'})$ for $\sigma_{vo'} < \sigma_{p'} < \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{p'})$ for $\sigma_{vo'} < \sigma_{p'} < \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{p'})$ for $\sigma_{vo'} < \sigma_{p'} < \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{p'})$ for $\sigma_{vo'} < \sigma_{p'} < \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{vo'} < \sigma_{p'} < \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{vo'} < \sigma_{p'} < \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{vo'} < \sigma_{v'} < \sigma_{v'}$ for $\sigma_{vo'} < \sigma_{v'}$ for $\sigma_{vo'} < \sigma_{v'} < \sigma_{v'}$ fo

^{10.} S_c = H(1/C')log(σ_{v_1} '/ σ_{v_0} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-072 - FRA-70-13.10 - Retaining Wall W5
MSE Wall Settlement - Sta. 500+00 to 507+00

 Calculated By:
 BRT
 Date:
 6/29/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Total Settlement at Facing of Wall

Settlement Remaining After Hold Period: 0.157 in

Settlement Complete at 90% of

Boring B-100-4-14

H=	19.5	ft	Total wall height		A-6b			
B'=	10.4	ft	Effective footing width due to eccentricity	c _v =	300		ft²/yr	Coefficient of consolitation
$D_w =$	25.0	ft	Depth below bottom of footing	t =	14		days	Time following completion of construction
q _e =	3,400	psf	Equivalent bearing pressure at bottom of wall	$H_{dr} =$	4		ft	Length of longest drainage path considered
				$T_v =$	0.719			Time factor
				U =	86		%	Degree of consolidation
				$(S_c)_t =$	1.339	in	Settlement complete	at 90% of primary consolidation

																							Total Se	ttlement at F	acing of Wall		onsolidation
Layer	Soil Type	Soil Type	Layer (f	Depth it)	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⁾	$\Delta\sigma_{\rm v}^{~(8)}$ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	Layer Settlement (in)	(S _c) _t ⁽¹¹⁾ (in)	Layer Settlement (in)
	A-6b	С	0.0	2.0	2.0	1.0	125	250	125	125	4,125	38	0.252	0.025	0.569				0.10	0.500	1,699	1,824	0.037	0.449		0.386	
1	A-6b	С	2.0	4.0	2.0	3.0	125	500	375	375	4,375	38	0.252	0.025	0.569				0.29	0.495	1,684	2,059	0.024	0.285	1.121	0.245	0.964
'	A-6b	С	4.0	6.0	2.0	5.0	125	750	625	625	4,625	38	0.252	0.025	0.569				0.48	0.482	1,638	2,263	0.018	0.215	1.121	0.185	0.904
	A-6b	С	6.0	8.0	2.0	7.0	125	1,000	875	875	4,875	38	0.252	0.025	0.569				0.67	0.459	1,560	2,435	0.014	0.171		0.147	
2	A-1-b	G	8.0	13.0	5.0	10.5	130	1,650	1,325	1,325	5,325					33	38	122	1.01	0.408	1,386	2,711	0.013	0.152	0.152	0.152	0.152
3	A-1-b	G	13.0	16.5	3.5	14.8	125	2,088	1,869	1,869	5,869					18	18	71	1.42	0.345	1,174	3,043	0.010	0.125	0.223	0.125	0.223
3	A-1-b	G	16.5	20.0	3.5	18.3	125	2,525	2,306	2,306	6,306					18	17	69	1.75	0.302	1,026	3,332	0.008	0.098	0.223	0.098	0.223

- 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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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. $\Delta \sigma_v = q_e(I)$
- $9. \ \ S_c = [C_o/(1+e_o)](H)log(\sigma_{v_f}/\sigma_{v_o}')for \ \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_f}'; \ [C_r/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H)log(\sigma_{v_f}/\sigma_p') \ for \ \sigma_{v_o}' < \sigma_{v_f}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO \ LRFD \ BDS \ (Cohesive soil \ layers)$
- 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

W-13-072 - FRA-70-13.10 - Retaining Wall W5 MSE Wall Settlement - Sta. 500+00 to 507+00

Date: 6/29/2019 Calculated By: BRT Checked By: JPS Date: 7/1/2019

Boring B-102-3-14

28.3 ft Total wall height

B'= 15.2 ft Effective footing width due to eccentricity

> 25.0 ft Depth below bottom of footing

4,740 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of R	einforced So	il Mass		Total Set	tlement at Fa	acing of Wall	
Layer	Soil Class.	Soil Type	Layer (i	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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
1	A-6b	С	0.0	1.5	1.5	0.8	120	180	90	90	4,090	34	0.216	0.022	0.538				0.05	1.000	4,738	4,828	0.050	0.601	0.500	2,370	2,460	0.030	0.363
2	A-1-a	G	1.5	4.0	2.5	2.8	130	505	343	343	4,343					36	57	202	0.18	0.983	4,658	5,000	0.014	0.173	0.499	2,364	2,707	0.011	0.133
2	A-1-a	G	4.0	6.5	2.5	5.3	130	830	668	668	4,668					36	49	166	0.35	0.913	4,327	4,994	0.013	0.158	0.492	2,334	3,001	0.010	0.118
3	A-6b	С	6.5	9.0	2.5	7.8	125	1,143	986	986	4,986	40	0.270	0.027	0.585				0.51	0.812	3,849	4,835	0.029	0.353	0.479	2,269	3,255	0.022	0.265
4	A-7-6	С	9.0	11.5	2.5	10.3	120	1,443	1,293	1,293	5,293	56	0.414	0.041	0.710				0.67	0.711	3,369	4,661	0.034	0.405	0.459	2,174	3,467	0.026	0.311
4	A-7-6	С	11.5	14.0	2.5	12.8	120	1,743	1,593	1,593	5,593	56	0.414	0.041	0.710				0.84	0.622	2,949	4,542	0.028	0.331	0.435	2,060	3,652	0.022	0.262
-	A-1-b	G	14.0	18.0	4.0	16.0	125	2,243	1,993	1,993	5,993					14	14	63	1.05	0.529	2,508	4,500	0.022	0.270	0.401	1,900	3,892	0.018	0.222
5	A-1-b	G	18.0	22.0	4.0	20.0	125	2,743	2,493	2,493	6,493					14	13	61	1.32	0.443	2,098	4,590	0.017	0.208	0.360	1,707	4,200	0.015	0.178
6	A-1-b	G	22.0	26.0	4.0	24.0	130	3,263	3,003	3,003	7,003					27	23	82	1.58	0.378	1,794	4,796	0.010	0.119	0.324	1,534	4,536	0.009	0.105
1. $\sigma_p' = \sigma_v$	-'+σ _{m;} Estima	te $\sigma_{\rm m}$ of 4,00	00 psf (mode	erately overc	onsolidated)	for natural s	oil deposits;	Ref. Table 1	1.2, Coduto	2003	•		•	•			•		•		Total	Settlement:		2.617 in		Total	Settlement:	1	1.957 in

^{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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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

^{9.} $S_c = [C_{c'}(1+e_o)](H)\log(\sigma_{v_i}'/\sigma_{v_o}')$ for $\sigma_p' \leq \sigma_{v_o'}' < \sigma_{v_i}'$; $[C_{r'}(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o'}')$ for $\sigma_{v_o}' < \sigma_p'$; $[C_{r'}(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o'}')$ for $\sigma_{v_o}' < \sigma_p' < \sigma_{v_o'}'$; 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)

MSE Wall Settlement - Sta. 500+00 to 507+00

28.3 ft

Boring B-102-3-14

B'= 15.2 ft Effective footing width due to eccentricity $D_w =$ 25.0 ft Depth below bottom of footing

4,740 psf Equivalent bearing pressure at bottom of wall

Total wall height

A-6b A-7-6 150 ft²/yr 300 22 22 t = days $H_{dr} =$

1.5 5 $T_v =$ 0.362 8.037 67 U = 100

1.768 in

 $(S_c)_t =$

Settlement complete at 90% of primary consolidation

Time factor

Coefficient of consolitation

Degree of consolidation

Time following completion of construction

Length of longest drainage path considered

																							Total Se	ettlement at l	acing of Wall		onsolidation
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)	Δσ _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	С	0.0	1.5	1.5	0.8	120	180	90	90	4,090	34	0.216	0.022	0.538				0.05	0.500	2,370	2,460	0.030	0.363	0.363	0.363	0.363
2	A-1-a	G	1.5	4.0	2.5	2.8	130	505	343	343	4,343					36	57	202	0.18	0.499	2,364	2,707	0.011	0.133	0.251	0.133	0.251
	A-1-a	G	4.0	6.5	2.5	5.3	130	830	668	668	4,668					36	49	166	0.35	0.492	2,334	3,001	0.010	0.118	0.251	0.118	0.251
3	A-6b	С	6.5	9.0	2.5	7.8	125	1,143	986	986	4,986	40	0.270	0.027	0.585				0.51	0.479	2,269	3,255	0.022	0.265	0.265	0.265	0.265
4	A-7-6	С	9.0	11.5	2.5	10.3	120	1,443	1,293	1,293	5,293	56	0.414	0.041	0.710				0.67	0.459	2,174	3,467	0.026	0.311	0.573	0.209	0.384
4	A-7-6	С	11.5	14.0	2.5	12.8	120	1,743	1,593	1,593	5,593	56	0.414	0.041	0.710				0.84	0.435	2,060	3,652	0.022	0.262	0.373	0.175	0.364
5	A-1-b	G	14.0	18.0	4.0	16.0	125	2,243	1,993	1,993	5,993					14	14	63	1.05	0.401	1,900	3,892	0.018	0.222	0.400	0.222	0.400
5	A-1-b	G	18.0	22.0	4.0	20.0	125	2,743	2,493	2,493	6,493					14	13	61	1.32	0.360	1,707	4,200	0.015	0.178	0.400	0.178	0.400
6	A-1-b	G	22.0	26.0	4.0	24.0	130	3,263	3,003	3,003	7,003					27	23	82	1.58	0.324	1,534	4,536	0.009	0.105	0.105	0.105	0.105

^{1.} $\sigma_{\rm p}' = \sigma_{\rm vo}' + \sigma_{\rm m}$. Estimate $\sigma_{\rm m}$ of 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003

Calculated By: Date: 6/29/2019 JPS Date: 7/1/2019 Checked By:

Settlement Remaining After Hold Period: 0.189

Total Settlement at Facing of Wall

Settlement Complete at 90% of

^{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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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

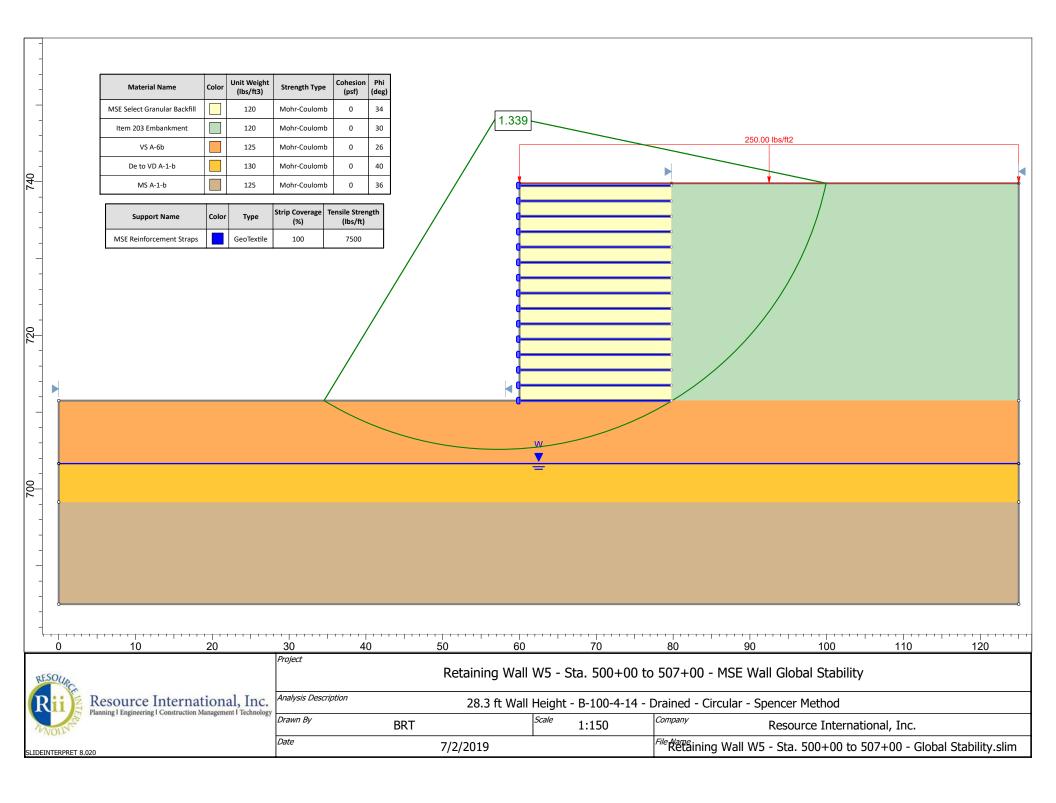
^{7.} Influence factor for strip loaded footing

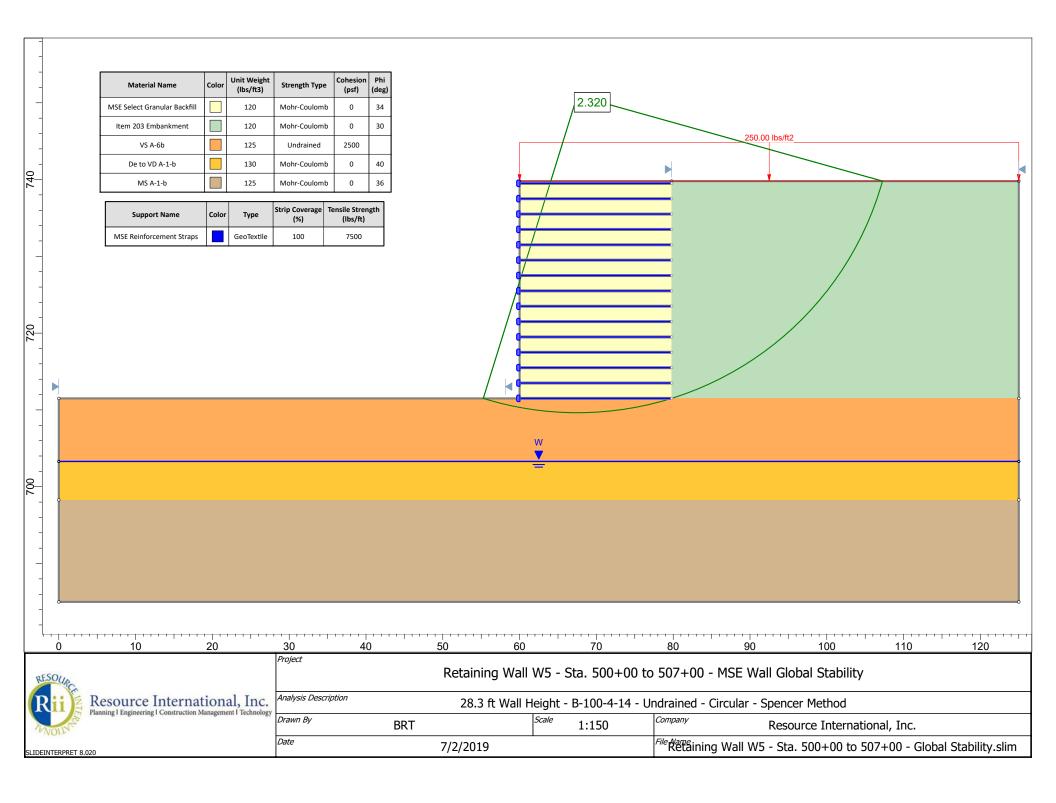
^{8.} $\Delta \sigma_v = q_e(I)$

^{9.} $S_c = [C_o/(1+e_o)](H)\log(\sigma_{v_f}/\sigma_{v_o}')$ for $\sigma_p' \leq \sigma_{v_o}' < \sigma_{v_f}'$; $[C_f/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}')$ for $\sigma_{v_o}' < \sigma_{v_f}' < \sigma_{v_f}'$; 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

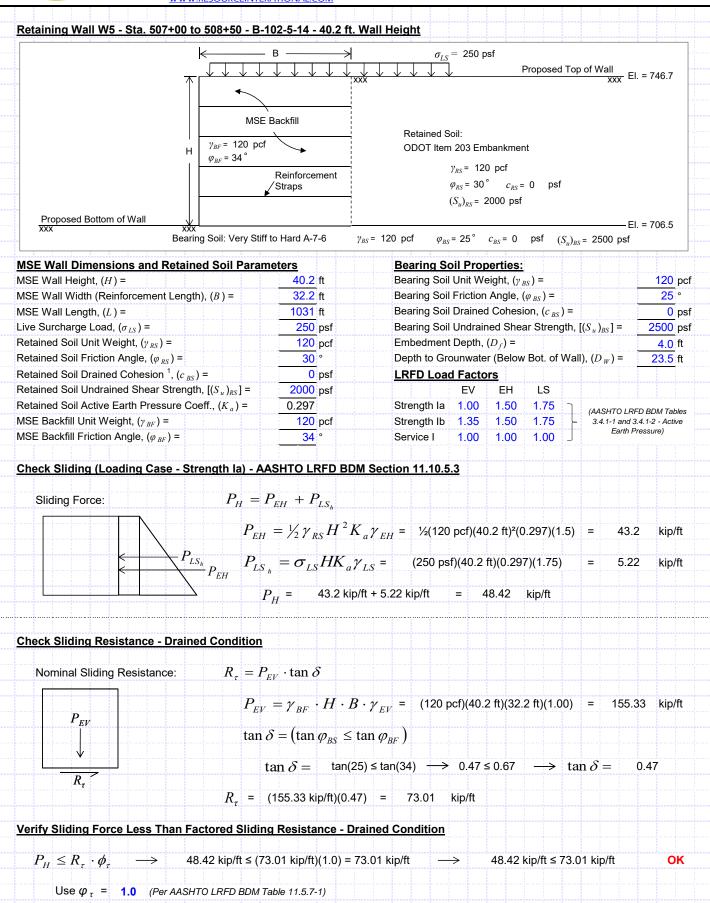






JOB FRA-70-13.10 W-13-072 SHEET NO. 6 CALCULATED BY DATE 6/30/2019 JPS CHECKED BY DATE 7/1/2019 Retaining Wall W5 - Sta. 507+00 to 508+50







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

FRA-70-13.10 JOB NO. SHEET NO. CALCULATED BY BRT CHECKED BY JPS

W-13-072 OF DATE DATE

6 6/30/2019 7/1/2019

Retaining Wall W5 - Sta. 507+00 to 508+50

$\frac{n}{S_u}\Big)_{BS} \leq q_s\Big)$	Bearin Bearin Bearin Embe Depth LRFL Streng Streng Service BDM Section 1	ng Soil ng Soil ng Soil edment n to Gro D Load gth Ia gth Ib ce I	Friction Drained Undrain Depth, (bunwater Fractor EV 1.00 1.35 1.00	r (Below <u>rs</u> EH 1.50 1.50 1.00	φ_{BS}) = on, (c_{BS}) = on, (c_{BS}) = Bot. of LS 1.75	gth, [(, (D_W) = (AASHTO LRF 3.4.1-1 and 3.	120 pc 25 ° 0 ps 2500 ps 4.0 ft 23.5 ft
	Bearin Bearin Bearin Embe Depth LRFC Streng Streng Servic	ng Soil ng Soil edment n to Gro D Load gth Ia gth Ib	Drained Undrain Depth, (cunwater Factor EV 1.00 1.35	I Cohesia led Shear (D_f) = r (Below rs EH 1.50 1.00	on, (c _{BS} ar Streng Bot. of LS 1.75	gth, [(, (D_W) = (AASHTO LRF 3.4.1-1 and 3.	0 ps 2500 ps 4.0 ft 23.5 ft
$ \begin{array}{c c} \hline 250 \text{ psf} \\ \hline 120 \text{ pcf} \\ \hline 30 ^{\circ} \\ \hline 0 \text{ psf} \\ \hline 2000 \text{ psf} \\ \hline 0.297 \\ \hline 120 \text{ pcf} \\ \hline 34 ^{\circ} \\ \hline ASHTO LRFD E$	Bearin Embe Depth LRFC Streng Streng Servic BDM Section 1*	ng Soil edment n to Gro D Load gth Ia gth Ib ce I	Undrain Depth, (punwater I Factor EV 1.00 1.35 1.00	ned Shea $(D_f) = r$ (Below FS EH 1.50 1.00	Bot. of LS 1.75	gth, [(, (D_W) = (AASHTO LRF 3.4.1-1 and 3.	2500 ps 4.0 ft 23.5 ft DBDM Tables 4.1-2 - Active
$\begin{array}{c c} \hline 120 \text{ pcf} \\ \hline 30 ^{\circ} \\ \hline 0 ^{\circ} \\ \hline 2000 ^{\circ} \\ \hline 0.297 \\ \hline 120 ^{\circ} \\ \hline 34 ^{\circ} \\ \hline \\ ASHTO LRFD E \\ \hline \\ S_u \Big)_{BS} \leq q_s \Big)$	Embe Depth LRFC Streng Streng Service BDM Section 1*	edment n to Gro D Load gth la gth lb	Depth, (bunwater if Factor EV 1.00 1.35 1.00	(D _f) = r (Below rs EH 1.50 1.50	Bot. of LS 1.75 1.75	Wall),	, (D_W) = (AASHTO LRF 3.4.1-1 and 3.	23.5 ft FD BDM Tables 4.1-2 - Active
$\begin{array}{c c} \hline 120 \text{ pcf} \\ \hline 30 ^{\circ} \\ \hline 0 ^{\circ} \\ \hline 2000 ^{\circ} \\ \hline 0.297 \\ \hline 120 ^{\circ} \\ \hline 34 ^{\circ} \\ \hline \\ ASHTO LRFD E \\ \hline \\ S_u \Big)_{BS} \leq q_s \Big)$	Depth LRFE Streng Streng Service BDM Section 1*	n to Gro D Load gth Ia gth Ib ce I	EV 1.00 1.35 1.00	r (Below <u>rs</u> EH 1.50 1.50 1.00	LS 1.75 1.75	7	(AASHTO LRF 3.4.1-1 and 3.	4.0 ft 23.5 ft D BDM Tables 4.1-2 - Active
$\begin{array}{c} 30 \\ \hline 0 \\ \hline 2000 \\ \hline 2000 \\ \hline 9sf \\ \hline 0.297 \\ \hline 120 \\ \hline 34 \\ \end{array}$	Depth LRFE Streng Streng Service BDM Section 1*	n to Gro D Load gth Ia gth Ib ce I	EV 1.00 1.35 1.00	r (Below <u>rs</u> EH 1.50 1.50 1.00	LS 1.75 1.75	7	(AASHTO LRF 3.4.1-1 and 3.	FD BDM Tables .4.1-2 - Active
$\begin{array}{c} \hline 0 \text{ psf} \\ \hline 2000 \text{ psf} \\ \hline 0.297 \\ \hline 120 \text{ pcf} \\ \hline 34 \\ ^{\circ} \\ \hline \\ \text{ASHTO LRFD E} \\ \hline \\ S_u \Big)_{BS} \leq q_s \Big)$	Streng Streng Service BDM Section 1*	gth la gth lb	EV 1.00 1.35 1.00	EH 1.50 1.50 1.00	LS 1.75 1.75	7	(AASHTO LRF 3.4.1-1 and 3.	.4.1-2 - Active
$ \begin{array}{c} \hline 2000 \text{ psf} \\ \hline 0.297 \\ \hline 120 \text{ pcf} \\ \hline 34 \\ \end{array} $ $ \begin{array}{c} ASHTO LRFD E \\ \hline Su \\ DBS \\ \end{array} $	Streng Streng Service BDM Section 1:	gth Ia gth Ib ce I	EV 1.00 1.35 1.00	EH 1.50 1.50 1.00	1.75 1.75	-	3.4.1-1 and 3.	.4.1-2 - Active
$ \begin{array}{c c} \hline 0.297 \\ \hline 120 \text{ pcf} \\ \hline 34 \\ \circ \end{array} $ ASHTO LRFD E	Strenç Service BDM Section 1	gth Ib	1.35 1.00	1.50 1.00	1.75	-	3.4.1-1 and 3.	.4.1-2 - Active
$\frac{120 \text{ pcf}}{34} \circ$ ASHTO LRFD E	Service BDM Section 1 ^r). B	ce I	1.00	1.00		nëmmo moë	3.4.1-1 and 3.	.4.1-2 - Active
34° ASHTO LRFD E on $S_u^{\circ}_{BS} \leq q_s^{\circ}$	Service BDM Section 1 ^r). B	ce I	1.00	1.00	1.00		Earth Pr	ressure)
$\frac{n}{S_u}\Big)_{BS} \leq q_s\Big)$) · B	1.10.5.	3 (Conti	inued)				
$(S_{\mu})_{RS} = 2.$								
~ 11 1 RX	50 ksf							
, <u>D</u> D								
$u = \frac{\sigma_v}{2} = \frac{\sigma_v}{2}$	= (4.82 ksf)/2	2 =	2.41	ksf				
/	· · · · · ·							
$\sigma = P_{EV}$	= (155.3	રેઽ kin/f	+) / (32.	2 ft)	=	4 82	ksf	
υ, –	'B - \)U Mp,.	t) / (U	٠٧ ١٠٠		7.52	NO.	
= (2.50 ksf ≤ 2	2.41 ksf)(32.2 ft	i) =	77.60	0 kip/	ft			
g Resistance -	- Undrained Co	nditio	<u>n</u>					
'.60 kip/ft)(1.0)	= 77.60 kip/ft		>	48.42 k	(ip/ft ≤	77.60) kip/ft	OK
able 11.5.7-1)								
<u> </u>	$\sigma_{s} = \frac{\sigma_{v}}{2}$ $\sigma_{v} = \frac{P_{EV}}{2}$ $\sigma_{v} = \frac{(2.50 \text{ ksf} \le 1.00 \text{ ksf} \le 1.00 \text{ ksf}}{2.60 \text{ kip/ft}}$	$\sigma_{v} = \frac{P_{EV}}{B} = (155.3)$ = (2.50 ksf ≤ 2.41 ksf)(32.2 ft) (3.60 kip/ft)(1.0) = 77.60 kip/ft	$\sigma_s = \frac{\sigma_v}{2} = (4.82 \text{ ksf})/2 = \frac{\sigma_v}{2} = (4.82 \text{ ksf})/2 = \frac{\sigma_v}{2} = (155.33 \text{ kip/f})$ $\sigma_v = \frac{P_{EV}}{B} = (155.33 \text{ kip/f})$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{1}{2} = \frac{1}$	$\sigma_{s} = \frac{\sigma_{v}}{2} = (4.82 \text{ ksf})/2 = 2.41$ $\sigma_{v} = \frac{P_{EV}}{B} = (155.33 \text{ kip/ft})/(32.2 \text{ ksf}) = 77.60$ $\sigma_{s} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{(32.2 \text{ ksf})} = 77.60$ $\sigma_{s} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{(32.2 \text{ ksf})} = 77.60$ $\sigma_{s} = \frac{(3.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{(32.2 \text{ ksf})} = 77.60$ $\sigma_{s} = \frac{(3.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{(32.2 \text{ ksf})} = 77.60$	$\sigma_s = \frac{\sigma_v}{2} = (4.82 \text{ ksf}) / 2 = 2.41 \text{ ksf}$ $\sigma_v = \frac{P_{EV}}{B} = (155.33 \text{ kip/ft}) / (32.2 \text{ ft})$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{77.60 \text{ kip/ft}}{B}$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{77.60 \text{ kip/ft}}{B}$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{77.60 \text{ kip/ft}}{B}$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{77.60 \text{ kip/ft}}{B}$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{77.60 \text{ kip/ft}}{B}$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{77.60 \text{ kip/ft}}{B}$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{77.60 \text{ kip/ft}}{B}$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B}$ $\sigma_v = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})}{B} = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf})($	$G_s = \frac{\sigma_v}{2} = (4.82 \text{ ksf}) / 2 = 2.41 \text{ ksf}$ $G_v = \frac{P_{EV}}{B} = (155.33 \text{ kip/ft}) / (32.2 \text{ ft}) = 8$ $G_s = (2.50 \text{ ksf} \le 2.41 \text{ ksf}) (32.2 \text{ ft}) = 77.60 \text{ kip/ft}$ $G_s = \frac{Resistance - Undrained Condition}{(60 \text{ kip/ft})(1.0)} = 77.60 \text{ kip/ft}$	$G_s = \frac{\sigma_v}{2} = (4.82 \text{ ksf}) / 2 = 2.41 \text{ ksf}$ $G_v = \frac{P_{EV}}{B} = (155.33 \text{ kip/ft}) / (32.2 \text{ ft}) = 4.82$ $G_s = (2.50 \text{ ksf} \le 2.41 \text{ ksf}) (32.2 \text{ ft}) = 77.60 \text{ kip/ft}$ $G_s = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf}) (32.2 \text{ ft})}{(32.2 \text{ ft})} = \frac{1.82}{48.42 \text{ kip/ft}} = \frac{1.82}{48.42 \text{ kip/ft}}$ $G_s = \frac{(2.50 \text{ ksf} \le 2.41 \text{ ksf}) (32.2 \text{ ft})}{(32.2 \text{ ft})} = \frac{1.82}{48.42 \text{ kip/ft}} = 1.8$	$G_s = \frac{\sigma_v}{2} = (4.82 \text{ ksf})/2 = 2.41 \text{ ksf}$ $G_v = \frac{P_{EV}}{B} = (155.33 \text{ kip/ft})/(32.2 \text{ ft}) = 4.82 \text{ ksf}$ $G_s = (2.50 \text{ ksf} \le 2.41 \text{ ksf})(32.2 \text{ ft}) = 77.60 \text{ kip/ft}$ $G_s = \frac{1}{2} \frac{1}$



RESOURCE INTERNATIONAL INC

FRA-70-13.10 JOB NO. SHEET NO. OF CALCULATED BY BRT DATE CHECKED BY JPS

W-13-072 6 6/30/2019 DATE 7/1/2019

Retaining Wall W5 - Sta. 507+00 to 508+50

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

ISE Wall Dimensions and Retained Soil Par	rameters	Bearing Soil Properties:	
ISE Wall Height, (H) =	40.2 ft	Bearing Soil Unit Weight, (γ_{BS}) =	120 pc
ISE Wall Width (Reinforcement Length), (B) =	32.2 ft	Bearing Soil Friction Angle, (φ_{BS}) =	25 °
ISE Wall Length, (L) =	1031 ft	Bearing Soil Drained Cohesion, (c_{BS}) =	0 ps
ive Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	2500 ps
etained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment Depth, (D_f) =	4.0 ft
etained Soil Friction Angle, (φ_{RS}) =	30 °	Depth to Grounwater (Below Bot. of Wall), (D_W) =	23.5 ft
etained Soil Drained Cohesion, (c_{BS}) =	0 psf	LRFD Load Factors	
etained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	EV EH LS	
etained Soil Active Earth Pressure Coeff., (K_a) =	0.297	Strength la 1.00 1.50 1.75	RFD BDM Tables
ISE Backfill Unit Weight, (γ_{BF}) =	120 pcf	Strength lb 1.35 1.50 1.75 - 3.4.1-1 and	3.4.1-2 - Active
ISE Backfill Friction Angle, (φ_{BF}) =	34 °	Service I 1.00 1.00 1.00 J Earth	Pressure)
Sheck Eccentricity (Loading Case - Strength $e=$	$\frac{B}{2} = x_o$	9 BDM Section 11.10.5.5	
P_{EV}	M - M		
P_{LS_h}	$P_{ev} = rac{1VI EV}{P_{EV}} rac{1VI H}{P_{EV}}$	= (2500.81 kip·ft/ft - 683.8 kip·ft/ft) / (155.33 kip/ft) =	11.70 ft
RV			
7.141,1	$M_{EV} = 2500.8$	1 kip·ft/ft ¬	
χ. × × , ρ	$M_{EV} = 2500.8$ $M_H = 683.8$	kip·ft/ft - Defined below	
$x_o \longleftrightarrow e$	$P_{EV} = 155.33$	kip/ft	
	e = (32.2 ft)/2 - 11	.7 ft = 4.40 ft	
PEV	$c_1 = B_2 = (32)$	$\gamma_{EV} = (120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.00) = 155$ 2.2 ft / 2 = 16.10 ft 3 kip/ft)(16.10 ft) = 2500.81 kip-ft/ft	33 kip/ft
Overturning Moment, M_H : M_H	$= P_{EH}(x_2) + P_1$	$L_{S_{\mu}}(X_3)$	
		$_{a}\gamma_{EH} = \frac{1}{2}(120 \text{ pcf})(40.2 \text{ ft})^{2}(0.297)(1.5) = 43.$	
P_{LS_h}	$P_{LS_h} = \sigma_{LS} H K_a \gamma_h$	$L_{LS} = (250 \text{ psf})(40.2 \text{ ft})(0.297)(1.75) = 5.22$	kip/ft
	$G_2 = \frac{H}{3} = (40)$	0.2 ft) / 3 = 13.40 ft	
		0.2 ft) / 2 = 20.10 ft	
	$M_H = (43.2)$	kip/ft)(13.4 ft) + (5.22 kip/ft)(20.10 ft) = 683.8	kip·ft/ft
heck Eccentricity			



JOB W-13-072 SHEET NO. CALCULATED BY BRT DATE 6/30/2019 CHECKED BY JPS DATE 7/1/2019 Retaining Wall W5 - Sta. 507+00 to 508+50

MSE Wall Dimensions and Retained Soil Parar	<u>neters</u>	Bearing Soil Pro	erties:			
MSE Wall Height, (H) =	40.2 ft	Bearing Soil Unit W	eight, (γ_{BS})	=		120 pcf
MSE Wall Width (Reinforcement Length), (B) =	32.2 ft	Bearing Soil Friction	Angle, (φ_B	_S)=		25 °
MSE Wall Length, (<i>L</i>) =	1031 ft	Bearing Soil Draine	d Cohesion,	$(c_{BS}) =$		0 psf
Live Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil Undrai	ned Shear S	Strength,	$[(s_u)_{BS}] =$	2500 psf
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment Depth,				4.0 ft
Retained Soil Friction Angle, (φ_{RS}) =	30°	Depth to Grounwate	r (Below Bo	ot. of Wa	II), (D_W) =	23.5 ft
Retained Soil Drained Cohesion, (c_{BS}) =	0 psf	LRFD Load Facto	,,,,,, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	EV		LS		
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	Strength Ia 1.00		.75	(AASHTO LI	RFD BDM Tables
MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf	Strength lb 1.35		.75		l 3.4.1-2 - Active Pressure)
MSE Backfill Friction Angle, (φ_{BF}) =	34 °	Service I 1.00	1.00 1	ا 00.	_a, a,	
$P_{LS_{r}}$	D /					
$q_{eq} =$	$P_{V/_{\mathbf{D}}}$					
Y eq —	/ <i>B</i> '					
P	- D Oo - 22	2 ft 2/2 06 ft\ - '	06 00 f			
$\begin{bmatrix} x_3 \\ A \end{bmatrix}$ P_{EV} P_{LS} $B'=$	$= \mathbf{b} - 2\mathbf{e} = 32.$.2 ft - 2(3.06 ft) = 2	זו סט.ט:			
$\frac{1}{2}$	~ /					
	a - B/	- (22.2.ft) / 2. 42.04.ft	_	بر م		
$R \lor R \lor$	$e = \frac{B}{2} - x_o =$	= (32.2 ft) / 2 - 13.04 ft	= 3.0)6 ft		
$\begin{array}{c c} & & & \\ \hline & & \\ \hline & & \\ \hline \end{array}$	$e = \frac{B}{2} - x_o = M_V - M_H$	= (32.2 ft) / 2 - 13.04 ft $= (32.2 ft) / 2 - 13.04 ft$	= 3.0)6 ft	000 70 1	[6 _ 40 04
	$e = \frac{B_2 - x_o}{2 - x_o} = \frac{M_V - M_H}{P_{co}}$	= $(32.2 \text{ ft}) / 2 - 13.04 \text{ ft}$ = $(3602.97 \text{ kip} \cdot \text{ft/ft})$	= 3.0 · 683.83 ki	06 ft p∙ft/ft) /	223.79 kip/	/ft = 13.04
<i>x_o</i> ← ×> e	$e = \frac{B_{2} - x_{o}}{2} = \frac{M_{V} - M_{H}}{P_{V}}$	= (32.2 ft) / 2 - 13.04 ft = (3602.97 kip·ft/ft	= 3.0 · 683.83 ki	06 ft p-ft/ft) /	223.79 kip/	/ft = 13.04
<i>x_o</i> ← ×> e	$x_o = r - r$	= (3602.97 kip·ft/ft	· 683.83 ki	p·ft/ft) /	223.79 kip/	/ft = 13.04
$x_o \leftarrow x_o \leftarrow c$	$x_o = r - r$	= (32.2 ft) / 2 - 13.04 ft = (3602.97 kip·ft/ft - 12.04 ft) / (26.08 ft) = 8.58	· 683.83 ki	06 ft p-ft/ft) /	223.79 kip/	/ft = 13.04
$x_{o} \xleftarrow{B} \xrightarrow{C} e$ $x_{o} \xleftarrow{B} \xrightarrow{A} \qquad q_{eq}$	$x_o = \frac{r}{P_V}$ $= (223.79 \text{ kip/ft})$	= (3602.97 kip·ft/ft / (26.08 ft) = 8.58	· 683.83 ki B ksf	06 ft p-ft/ft) /	223.79 kip/	/ft = 13.04
<i>x_o</i> ← ×> e	$x_o = \frac{r}{P_V}$ $= (223.79 \text{ kip/ft})$	= (3602.97 kip·ft/ft / (26.08 ft) = 8.58	· 683.83 ki B ksf	06 ft p-ft/ft) /	223.79 kip/	/ft = 13.04
$X_{o} \overset{\longrightarrow}{\longleftarrow} P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot F)$	$x_o = \frac{r}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV}(x_1)$	= (3602.97 kip·ft/ft \cdot / (26.08 ft) = 8.58 + $(\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$	· 683.83 ki	p-ft/ft) /		/ft = 13.04
$x_{o} \xleftarrow{B/2} \qquad \qquad q_{eq}$	$x_o = \frac{r}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV}(x_1)$	= (3602.97 kip·ft/ft \cdot / (26.08 ft) = 8.58 + $(\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$	· 683.83 ki	p-ft/ft) /		/ft = 13.04
$x_{o} \stackrel{B}{\longleftarrow} e$ $\downarrow B_{2} \stackrel{B}{\longrightarrow} e$ $M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot F)$ $M_{V} = [(120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35)]$	$x_o = \frac{r}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV} (x_1)$ $(16.1 \text{ ft}) + [(250 \text{ psf})]$	= (3602.97 kip·ft/ft $/$ (26.08 ft) = 8.58 + $(\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ (32.2 ft)(1.75)](16.1 ft)	683.83 ki	p-ft/ft) /		/ft = 13.04
$X_{o} \xrightarrow{B'_{2}} P_{EV} e$ $A = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot F)$	$x_o = \frac{r}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV} (x_1)$ $(16.1 \text{ ft}) + [(250 \text{ psf})]$	= (3602.97 kip·ft/ft $/$ (26.08 ft) = 8.58 + $(\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ (32.2 ft)(1.75)](16.1 ft)	683.83 ki	p-ft/ft) /		/ft = 13.04
$X_{o} \stackrel{E}{\longleftarrow} W_{eq}$ $M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot F)$ $M_{V} = [(120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{RS})$	$x_o = \frac{r}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV} (x_1)$ $(16.1 \text{ ft}) + [(250 \text{ psf})]$ $H^2 K_a \gamma_{EH} (x_2)$	= (3602.97 kip·ft/ft $/$ (26.08 ft) = 8.58 $+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ (32.2 ft)(1.75)](16.1 ft) $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$	683.83 ki	p·ft/ft) /)-ft/ft	
$x_{o} \stackrel{B}{\longleftarrow} e$ $\downarrow B_{2} \stackrel{B}{\longrightarrow} q_{eq}$ $M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot F)$ $M_{V} = [(120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35)]$	$x_o = \frac{r}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV} (x_1)$ $(16.1 \text{ ft}) + [(250 \text{ psf})]$ $H^2 K_a \gamma_{EH} (x_2)$	= (3602.97 kip·ft/ft $/$ (26.08 ft) = 8.58 $+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ (32.2 ft)(1.75)](16.1 ft) $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$	683.83 ki	p·ft/ft) /		
$X_{o} \stackrel{B}{\longleftarrow} P_{e} \stackrel{B}{\longrightarrow} P_{e} \qquad q_{eq}$ $M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot H)$ $M_{V} = [(120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{RS} H)$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(40.2 \text{ ft})^{2}(0.297)(1.5 \text{ ft})$	$x_o = \frac{r}{P_V}$ = (223.79 kip/ft) $H \cdot B \cdot \gamma_{EV} (x_1)$ (16.1 ft) + [(250 psf) $H^2 K_a \gamma_{EH} (x_2)$ 5)](13.4 ft) + [(250 p	= $(3602.97 \text{ kip-ft/ft} \cdot / (26.08 \text{ ft}))$ = $8.58 \cdot (3602.97 \cdot / (26.08 \text{ ft}))$	683.83 ki	p·ft/ft) /)-ft/ft	
$X_{o} \xrightarrow{B'_{2}} P_{EV} = Q_{eq}$ $M_{V} = P_{EV}(x_{1}) + P_{LS_{V}}(x_{1}) = (\gamma_{BF} \cdot F)$ $M_{V} = [(120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{RS})$	$x_o = \frac{r}{P_V}$ = (223.79 kip/ft) $H \cdot B \cdot \gamma_{EV} (x_1)$ (16.1 ft) + [(250 psf) $H^2 K_a \gamma_{EH} (x_2)$ 5)](13.4 ft) + [(250 p	= $(3602.97 \text{ kip-ft/ft} \cdot / (26.08 \text{ ft}))$ = $8.58 \cdot (3602.97 \cdot / (26.08 \text{ ft}))$	683.83 ki	p·ft/ft) /)-ft/ft	
$x_{o} \xrightarrow{B/2} e$ $M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot H)$ $M_{V} = [(120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{RS}H)$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(40.2 \text{ ft})^{2}(0.297)(1.5 \text{ ft})^{2}$	$x_o = \frac{\gamma}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV}(x_1)$ $(16.1 \text{ ft}) + [(250 \text{ psf})]$ $H^2 K_a \gamma_{EH}(x_2)$ $(5)](13.4 \text{ ft}) + [(250 \text{ psf})]$ $L + \sigma_{LS} \cdot B \cdot \gamma_{LS}$	= $(3602.97 \text{ kip-ft/ft} \cdot / (26.08 \text{ ft}))$ = $8.58 \cdot (3602.97 \cdot / (26.08 \text{ ft}))$	683.83 ki 8 ksf = 3602) 20.1 ft)	p·ft/ft) /)-ft/ft	
$x_{o} \xrightarrow{B/2} P_{EV} = e$ $M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot P_{EV}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot P_{$	$x_o = \frac{\gamma}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV} (x_1)$ $(16.1 \text{ ft}) + [(250 \text{ psf})]$ $H^2 K_a \gamma_{EH} (x_2)$ $(5)](13.4 \text{ ft}) + [(250 \text{ psf})]$ $(250 \text{ psf})(32.2 \text{ ft})(1)$	= $(3602.97 \text{ kip-ft/ft} \cdot / (26.08 \text{ ft}))$ = $8.58 \cdot (3602.97 \cdot / (26.08 \text{ ft}))$	683.83 ki 8 ksf = 3602) 20.1 ft)	p·ft/ft) /)-ft/ft	
$x_{o} \xrightarrow{B/2} P_{EV} = Q_{eq}$ $M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot H)$ $M_{V} = [(120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{RS} I)$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(40.2 \text{ ft})^{2}(0.297)(1.5)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ $P_{V} = (120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35) + C$ Check Bearing Resistance - Drained Condition	$x_o = \frac{\gamma}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV} (x_1)$ $(16.1 \text{ ft}) + [(250 \text{ psf})]$ $H^2 K_a \gamma_{EH} (x_2)$ $(5)](13.4 \text{ ft}) + [(250 \text{ psf})]$ $(250 \text{ psf})(32.2 \text{ ft})(1)$	= $(3602.97 \text{ kip-ft/ft} \cdot / (26.08 \text{ ft}))$ = $8.58 \cdot \gamma_{LS} \cdot (x_1) \cdot (x_2 \cdot B \cdot \gamma_{LS}) \cdot (x_3 \cdot B \cdot \gamma_{LS})$	683.83 ki 8 ksf = 3602) 20.1 ft)	p·ft/ft) /)-ft/ft	
$x_{o} \xrightarrow{B/2} P_{EV} = q_{eq}$ $M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF} \cdot H)$ $M_{V} = [(120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{RS})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(40.2 \text{ ft})^{2}(0.297)(1.5)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ $P_{V} = (120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.35) + Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: q_{n} = cN_{cm} + CN_$	$x_o = \frac{\gamma}{P_V}$ $= (223.79 \text{ kip/ft})$ $H \cdot B \cdot \gamma_{EV} (x_1)$ $(16.1 \text{ ft}) + [(250 \text{ psf})]$ $H^2 K_a \gamma_{EH} (x_2)$ $(5)](13.4 \text{ ft}) + [(250 \text{ psf})]$ $(250 \text{ psf})(32.2 \text{ ft})(1.1 \text{ psf})$	= $(3602.97 \text{ kip-ft/ft} \cdot 1/(26.08 \text{ ft}))$ = $8.58 \cdot (26.08 \text{ ft})$ = $8.58 \cdot (26.08 ft$	683.83 ki 8 ksf 20.1 ft)	p·ft/ft) / 2.97 kip)-ft/ft	p-ft/ft

		1				
$N_c =$	20.72	$N_q =$	10.66	N_{γ} =	10.88	
$s_c =$	1+(26.08 ft/1031 ft)(10.66/20.72)	$s_q =$	1.012	$s_{\gamma} =$	0.990	
=	1.013	$d_q =$	1+2tan(25°)[1-sin(25°)]²tan⁻¹(4.0 ft/26.08 ft)	$i_{\gamma} =$	1.000 (Assumed)	
$i_c =$	1.000 (Assumed)		1.047	$C_{wy} =$	23.5 ft < 1.5(26.08 ft) + 4.0 ft	= 0.800
		$i_q =$	1.000 (Assumed)			
		$C_{wq} =$	23.5 ft > 4.0 ft = 1.000			
$q_{n} =$	(0 psf)(20.989) + (120 pcf)(4.0 ft	t)(11.295)(1.0	000) + ½(120 pcf)(26.1 ft)(10.771)(0	0.800)	= 18.91 ksf	

Use $\varphi_b = 0.65$ (Per AASHTO LRFD BDM Table 11.5.7-1) Verify Equivalent Pressure Less Than Factored Bearing Resistance $q_{eq} \leq q_n \cdot \phi_b$ $8.58 \text{ ksf} \le (18.91 \text{ ksf})(0.65) = 12.29 \text{ ksf}$ 8.58 ksf ≤ 12.29 ksf OK



 JOB
 FRA-70-13.10
 NO.
 W-13-072

 SHEET NO.
 5
 0F
 6

 CALCULATED BY
 BRT
 DATE
 6/30/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta 507+00 to 508+50

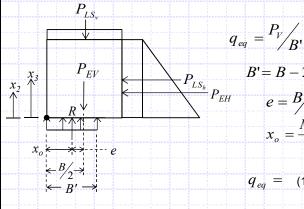
PHO	X: (614) 823-4990	Retaining \	Mall W5	- Sta 50	07+00 to 5	08+50
	OURCEINTERATIONAL.COM	- Notalining	VVali VVO	- Ota. 0	01 100 10 0	00.00
ISE Wall Dimensions and Retained S	oil Parameters	Bearing Soil Prop	<u>oerties:</u>			
/ISE Wall Height, (H) =	40.2 ft	Bearing Soil Unit W	eight, (γ_{BS}	.)=		120 pc
\emph{MSE} Wall Width (Reinforcement Length), (\emph{B}	32.2 ft	Bearing Soil Friction				25 °
ISE Wall Length, (L) =	1031 ft	Bearing Soil Drained				0 ps
ive Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil Undrair		r Strengt	h, $[(s_u)_{BS}] =$	
Retained Soil Unit Weight, (γ _{RS}) =	120 pcf	Embedment Depth,				4.0 ft
Retained Soil Friction Angle, (φ_{RS}) =	<u>30</u> °	Depth to Grounwate		Bot. of W	/all), (D_W) =	= 23.5 ft
Retained Soil Drained Cohesion, (c_{BS}) =	0 psf	LRFD Load Facto				
Retained Soil Undrained Shear Strength, [(S		EV	EH	LS		
Retained Soil Active Earth Pressure Coeff., (Strength Ia 1.00		1.75) LRFD BDM Tables
ASE Backfill Unit Weight, $(\gamma_{BF}) =$	120 pcf	Strength lb 1.35	1.50	1.75		and 3.4.1-2 - Active orth Pressure)
ASE Backfill Friction Angle, (φ_{BF}) =	34 °	Service I 1.00	1.00	1.00		Turr rossurs,
Check Bearing Capacity (Loading Cas Check Bearing Resistance - Undrained		RFD BDM Section 11.	10.5.4 <i>(</i> Ca	ontinued)		
Nominal Bearing Resistance: $q_{\scriptscriptstyle n}=$	$cN_{cm} + \gamma D_f N_{qm} C_{wq} +$	$Y_2 \gamma BN_{\gamma m} C_{w\gamma}$				
$N_{cm} = N_c s_c i_c = 5.170$	$N_{qm} = N_q s_q d_q i_q$, = 1.000	$N_{ym} =$	$N_{\gamma}s_{\gamma}$	$i_{\gamma} = 0$	0.000
$N_c = 5.140$	N_q = 1.000		N_{ν}	= 0.00	00	
	1.005 $S_q = 1.000$		Entertain Description	= 1.00		
		[1-sin(0°)]²tan⁻¹(4.0 ft/26.08 ft)			0 (Assume	d)
i_c = 1.000 (Assumed)	u a 1. Ztan(o)	11-511(0) tall (4.0 1020.00 II)	- · ·		``	
$i_c = 1.000$ (Assumed)	1.000	[1-511(0)] tall (4.01020.00 it)	B	= 23.5	ft < 1.5(26.08 f	t + 4.0 ft = 0.
$I_c = 1.000$ (Assumed)	1.000		B	= 23.5	ft < 1.5(26.08 f	t) + 4.0 ft = 0
		ssumed) .0 ft = 1.000	$C_{w_{\!\scriptscriptstyle y}}$	= 23.5 t		t) + 4.0 ft = 0
$q_n = (2500 ext{psf})(5.170) + (120$ Verify Equivalent Pressure Less Than	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $Pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ Factored Bearing Resistance})$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf
$q_n = (2500 ext{psf})(5.170) + (120 ext{Verify Equivalent Pressure Less Than}$	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	$C_{w_{\!\scriptscriptstyle y}}$		13.41	
$q_n=$ (2500 psf)(5.170) + (120 /erify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 8$	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf
$q_n = (2500 ext{psf})(5.170) + (120$ Verify Equivalent Pressure Less Than	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 /erify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 8$	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 /erify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 8$	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 /erify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 8$	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 /erify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 8$	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	
$q_n=$ (2500 psf)(5.170) + (120 /erify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 8$	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) 0 ft = 1.000 (120 pcf)(26.1 ft)(0.000)	(0.800)		13.41	ksf
$q_n=$ (2500 psf)(5.170) + (120 Verify Equivalent Pressure Less Than $q_{eq} \leq q_n \cdot \phi_b \longrightarrow$ 8	$i_{q} = 1.000$ $i_{q} = 1.000 \text{ (As}$ $C_{wq} = 23.5 \text{ ft} > 4.$ $pcf)(4.0 \text{ ft})(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000) 1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.000)(1.000)(1.000)(1.000) + \frac{1}{2}(4.0 \text{ ft})(1.000)(1.00$	ssumed) .0 ft = 1.000 (120 pcf)(26.1 ft)(0.000) Ce	(0.800)		13.41	ksf



RESOURCE INTERNATIONAL, INC. 6350 PRESIDENTIAL GATEWAY COLUMBUS, OHIO 43231 PHONE: (614) 823-4949 FAX: (614) 823-4990 WWW.RESOURCEINTERATIONAL.COM JOB FRA-70-13.10 W-13-072 SHEET NO. CALCULATED BY 6/30/2019 DATE CHECKED BY JPS DATE 7/1/2019 Retaining Wall W5 - Sta. 507+00 to 508+50

MSE Wall Dimensions and Retained Soil Param	<u>neters</u>	Bearing Soil Properties:
MSE Wall Height, (H) =	40.2 ft	Bearing Soil Unit Weight, (γ_{BS}) = 120
MSE Wall Width (Reinforcement Length), (<i>B</i>) =	32.2 ft	Bearing Soil Friction Angle, (φ_{BS}) = 25
MSE Wall Length, (<i>L</i>) =	1031 ft	Bearing Soil Drained Cohesion, $(c_{BS}) = 0$
Live Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}] = 2500$
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment Depth, (D_f) = 4.0
Retained Soil Friction Angle, (φ_{RS}) =	30 °	Depth to Grounwater (Below Bot. of Wall), (D_W) = 23.5
Retained Soil Drained Cohesion, (c_{BS}) =	0 psf	LRFD Load Factors
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	EV EH LS
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	Strength la 1.00 1.50 1.75] (AASHTO LRFD BDM Tal
MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf	Strength lb 1.35 1.50 1.75 - 3.4.1-1 and 3.4.1-2 - Acti
MSE Backfill Friction Angle, (φ_{BF}) =	34 °	Service I 1.00 1.00 1.00 Earth Pressure)

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



$$R' - R - 2a = 32.2 \text{ ft} - 2(2.73 \text{ ft}) = 26.74 \text{ ft}$$

$$P_{LS_h} P_{EH} = B - 2e = 32.2 \text{ ft} - 2(2.73 \text{ ft}) = 26.74 \text{ ft}$$

$$e = B/2 - x_o = (32.2 \text{ ft}) / 2 - 13.37 \text{ ft} = 2.73 \text{ ft}$$

$$x_o = \frac{M_V - M_H}{P_V} = (2630.46 \text{ kip·ft/ft} - 445.89 \text{ kip·ft/ft}) / 163.38 \text{ kip/ft} = 13.37 \text{ ft}$$

 $q_{eq} = (163.38 \text{ kip/ft}) / (26.74 \text{ ft}) = 6.11$

$$M_{V} = P_{EV}(x_1) + P_{LS_{V}}(x_1) = (\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV})(x_1) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$$

 $M_V = [(120 \text{ pcf})(40.2 \text{ ft})(32.2 \text{ ft})(1.00)](16.1 \text{ ft}) + [(250 \text{ psf})(32.2 \text{ ft})(1.00)](16.1 \text{ ft}) = 2630.46 \text{ kip-ft/ft}$

$$M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (V_2 \gamma_{RS} H^2 K_a \gamma_{EH})(x_2) + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$$

 $M_H = [\frac{1}{2}(120 \text{ pcf})(40.2 \text{ ft})^2(0.297)(1.00)](13.4 \text{ ft}) + [(250 \text{ psf})(40.2 \text{ ft})(0.297)(1.00)](20.1 \text{ ft})$ = 445.89 kip·ft/ft

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

 $P_{\scriptscriptstyle V} = (120~{
m pcf})(40.2~{
m ft})(32.2~{
m ft})(1.00) + (250~{
m psf})(32.2~{
m ft})(1.00) = 163.38~{
m kip/ft}$

Settlement, Time Rate of Consolidation and Differential Settlement:

 Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Along Wall Facing
B-102-3-14	2.617 in	1.957 in	22 days		
 B-102-5-14	9.024 in	3.611 in	95 days	150 ft	1/1090

MSE Wall Settlement - Sta. 507+00 to 508+50

Boring B-102-5-14

40.2 ft Total wall height

26.7 ft B'= Effective footing width due to eccentricity

 $D_w =$ 23.5 ft Depth below bottom of footing

6,110 Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of R	einforced Soi	l Mass		Total Sett	tlement at Fa	cing of Wall	
Layer	Soil Class.	Soil Type	٠,	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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	1 (7)	$\Delta\sigma_{v}^{(8)}$ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
1	A-6a	С	0.0	1.0	1.0	0.5	120	120	60	60	4,060	39	0.261	0.026	0.577				0.02	1.000	6,110	6,170	0.060	0.725	0.500	3,055	3,115	0.028	0.341
	A-7-6	С	1.0	2.5	1.5	1.8	120	300	210	210	4,210	49	0.351	0.035	0.655				0.07	0.999	6,104	6,314	0.097	1.169	0.500	3,055	3,265	0.038	0.455
	A-7-6	С	2.5	5.0	2.5	3.8	120	600	450	450	4,450	49	0.351	0.035	0.655				0.14	0.991	6,058	6,508	0.140	1.683	0.499	3,051	3,501	0.047	0.567
2	A-7-6	С	5.0	7.5	2.5	6.3	120	900	750	750	4,750	49	0.351	0.035	0.655				0.23	0.966	5,901	6,651	0.120	1.440	0.497	3,039	3,789	0.037	0.448
2	A-7-6	С	7.5	10.0	2.5	8.8	120	1,200	1,050	1,050	5,050	49	0.351	0.035	0.655				0.33	0.923	5,637	6,687	0.101	1.210	0.493	3,015	4,065	0.031	0.374
	A-7-6	С	10.0	12.5	2.5	11.3	120	1,500	1,350	1,350	5,350	49	0.351	0.035	0.655				0.42	0.868	5,303	6,653	0.082	0.983	0.487	2,975	4,325	0.027	0.322
	A-7-6	С	12.5	15.0	2.5	13.8	120	1,800	1,650	1,650	5,650	49	0.351	0.035	0.655				0.51	0.809	4,942	6,592	0.064	0.766	0.478	2,922	4,572	0.023	0.282
4	A-1-b	G	15.0	20.0	5.0	17.5	125	2,425	2,113	2,113	6,113					23	23	80	0.66	0.722	4,411	6,523	0.031	0.367	0.461	2,818	4,931	0.023	0.276
5	A-3a	G	20.0	25.0	5.0	22.5	125	3,050	2,738	2,738	6,738					23	21	68	0.84	0.620	3,790	6,527	0.028	0.332	0.434	2,651	5,389	0.022	0.259
6	A-1-a	G	25.0	30.0	5.0	27.5	130	3,700	3,375	3,125	7,125					36	31	101	1.03	0.538	3,286	6,412	0.015	0.186	0.404	2,471	5,596	0.013	0.150
7	A-1-a	G	30.0	35.0	5.0	32.5	135	4,375	4,038	3,476	7,476					50	41	134	1.22	0.472	2,883	6,359	0.010	0.118	0.375	2,292	5,767	0.008	0.099
8	A-1-b	G	35.0	38.0	3.0	36.5	135	4,780	4,578	3,766	7,766					66	52	179	1.37	0.429	2,619	6,385	0.004	0.046	0.353	2,155	5,921	0.003	0.040
1. $\sigma_p' = \sigma_p$	_o '+σ _{m;} Estima	ate $\sigma_{\rm m}$ of 4,0	00 psf (mode	erately overc	onsolidated)	for natural so	oil deposits; l	Ref. Table 1	1.2, Coduto 2	2003											Total	Settlement:		9.024 in		Total	Settlement:		3.611 in

^{2.} C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5

Calculated By: BRT Date: 6/30/2019 Checked By: Date: 7/1/2019

^{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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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.} $\Delta \sigma_v = q_e(I)$

 $^{9. \ \} S_c = [C_o/(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_i}'; \ [C_r/(1+e_o)](H) \log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H) \\ \log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H) \\ \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_{v_o}' < \sigma_{v_i}'; \ \text{Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)} \\ \text{for } \sigma_{v_o}' \leq \sigma_$

^{10.} S_c = H(1/C')log(σ_{vf} '/ σ_{vo} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

MSE Wall Settlement - Sta. 507+00 to 508+50

Boring B-102-5-14

H=	40.2	ft	Total wall height		A-6b	A-7-6		
B'=	26.7	ft	Effective footing width due to eccentricity	c _v =	300	150	ft²/yr	Coefficient of consolitation
$D_w =$	23.5	ft	Depth below bottom of footing	t =	95	95	days	Time following completion of construction
q _e =	6,110	psf	Equivalent bearing pressure at bottom of wall	H _{dr} =	1.0	7.5	ft	Length of longest drainage path considered
				$T_v =$	78.082	0.694		Time factor
				U =	100	85	%	Degree of consolidation

3.244 in

																							Total Se	ettlement at	Facing of Wall		mplete at 90% of onsolidation
Layer	Soil Type	Soil Type	,	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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	Layer Settlement (in)	(S _c) _t ⁽¹¹⁾ (in)	Layer Settlement (in)
1	A-6a	С	0.0	1.0	1.0	0.5	120	120	60	60	4,060	39	0.261	0.026	0.577				0.02	0.500	3,055	3,115	0.028	0.341	0.341	0.341	0.341
	A-7-6	С	1.0	2.5	1.5	1.8	120	300	210	210	4,210	49	0.351	0.035	0.655				0.07	0.500	3,055	3,265	0.038	0.455		0.387	
	A-7-6	С	2.5	5.0	2.5	3.8	120	600	450	450	4,450	49	0.351	0.035	0.655				0.14	0.499	3,051	3,501	0.047	0.567		0.482	
2	A-7-6	С	5.0	7.5	2.5	6.3	120	900	750	750	4,750	49	0.351	0.035	0.655				0.23	0.497	3,039	3,789	0.037	0.448	2.446	0.380	2.080
2	A-7-6	С	7.5	10.0	2.5	8.8	120	1,200	1,050	1,050	5,050	49	0.351	0.035	0.655				0.33	0.493	3,015	4,065	0.031	0.374	2.440	0.318	2.000
	A-7-6	С	10.0	12.5	2.5	11.3	120	1,500	1,350	1,350	5,350	49	0.351	0.035	0.655				0.42	0.487	2,975	4,325	0.027	0.322		0.273	
	A-7-6	С	12.5	15.0	2.5	13.8	120	1,800	1,650	1,650	5,650	49	0.351	0.035	0.655				0.51	0.478	2,922	4,572	0.023	0.282		0.239	
4	A-1-b	G	15.0	20.0	5.0	17.5	125	2,425	2,113	2,113	6,113					23	23	80	0.66	0.461	2,818	4,931	0.023	0.276	0.276	0.276	0.276
5	A-3a	G	20.0	25.0	5.0	22.5	125	3,050	2,738	2,738	6,738					23	21	68	0.84	0.434	2,651	5,389	0.022	0.259	0.259	0.259	0.259
6	A-1-a	G	25.0	30.0	5.0	27.5	130	3,700	3,375	3,125	7,125					36	31	101	1.03	0.404	2,471	5,596	0.013	0.150	0.150	0.150	0.150
7	A-1-a	G	30.0	35.0	5.0	32.5	135	4,375	4,038	3,476	7,476		-	-	-	50	41	134	1.22	0.375	2,292	5,767	0.008	0.099	0.099	0.099	0.099
8	A-1-b	G	35.0	38.0	3.0	36.5	135	4,780	4,578	3,766	7,766	·				66	52	179	1.37	0.353	2,155	5,921	0.003	0.040	0.040	0.040	0.040

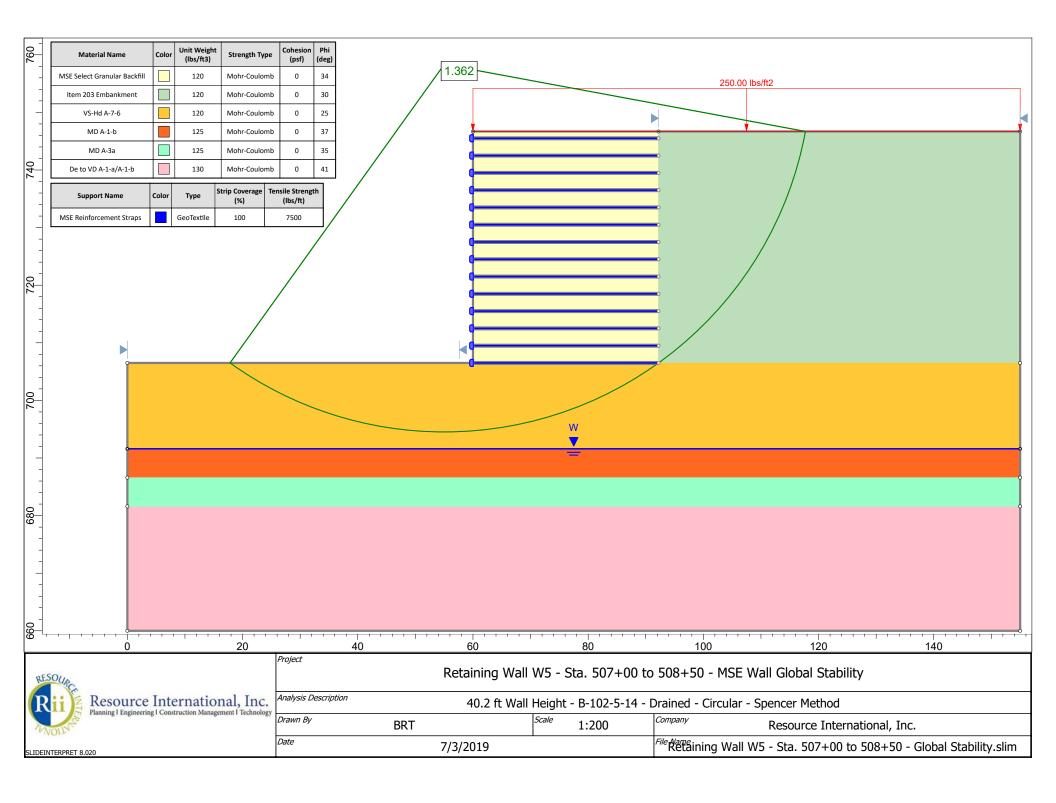
Settlement complete at 90% of primary consolidation

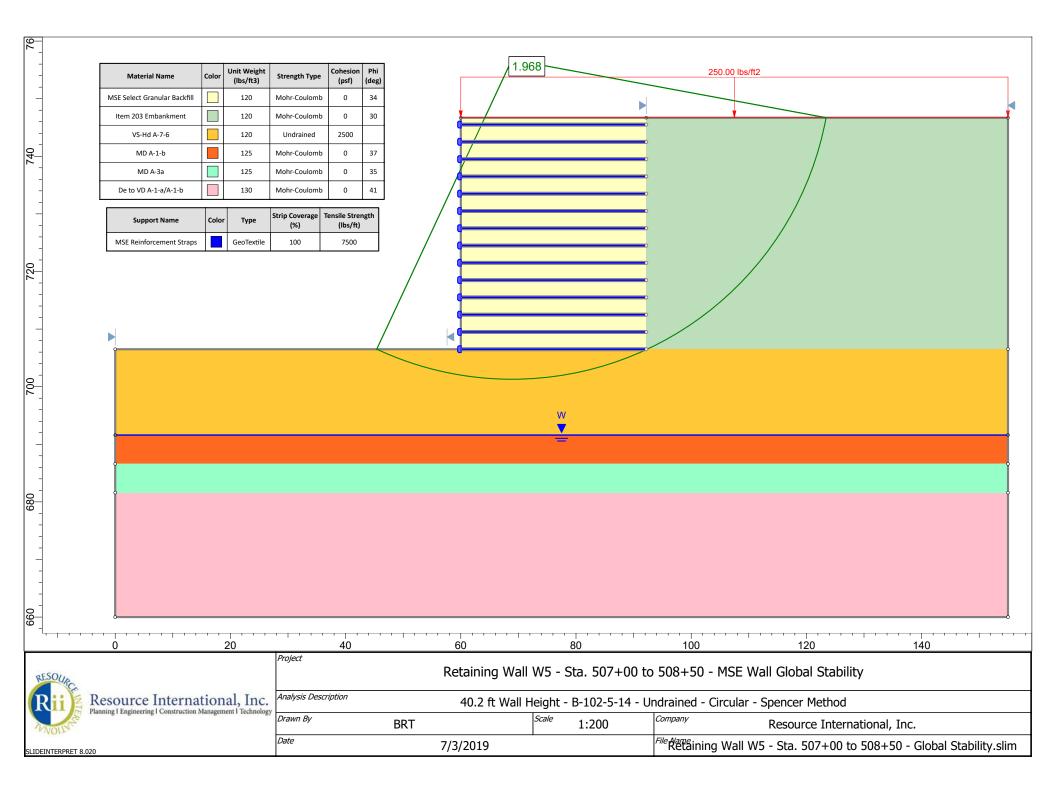
- 1. $\sigma_p' = \sigma_{vo}' + \sigma_{m}$; Estimate σ_m of 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
- 2. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
- 3. $C_r = 0.10(Cc)$ for natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
- 4. $e_0 = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
- 5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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. $\Delta \sigma_v = q_e(I)$
- $9. \ \ S_c = [C_c/(1+e_o)](H)log(\sigma_{v_f}/\sigma_{v_o}') \\ for \ \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_f}'; \ [C_r/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}') \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_p'; \ [C_r/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}') \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_p'; \ [C_r/(1+e_o)](H)log(\sigma_{v_f}/\sigma_p') \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_{v_f}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO \ LRFD \ BDS \ (Cohesive \ soil \ layers) \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_{v_f}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO \ LRFD \ BDS \ (Cohesive \ soil \ layers) \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_{v_f}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO \ LRFD \ BDS \ (Cohesive \ soil \ layers) \\ for \ \sigma_{v_o}' < \sigma_{v_f}' < \sigma_{v$
- 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

Calculated By: Date: 6/30/2019 Date: 7/1/2019 Checked By:

Settlement Remaining After Hold Period: 0.367 in

Settlement Complete at 90% of

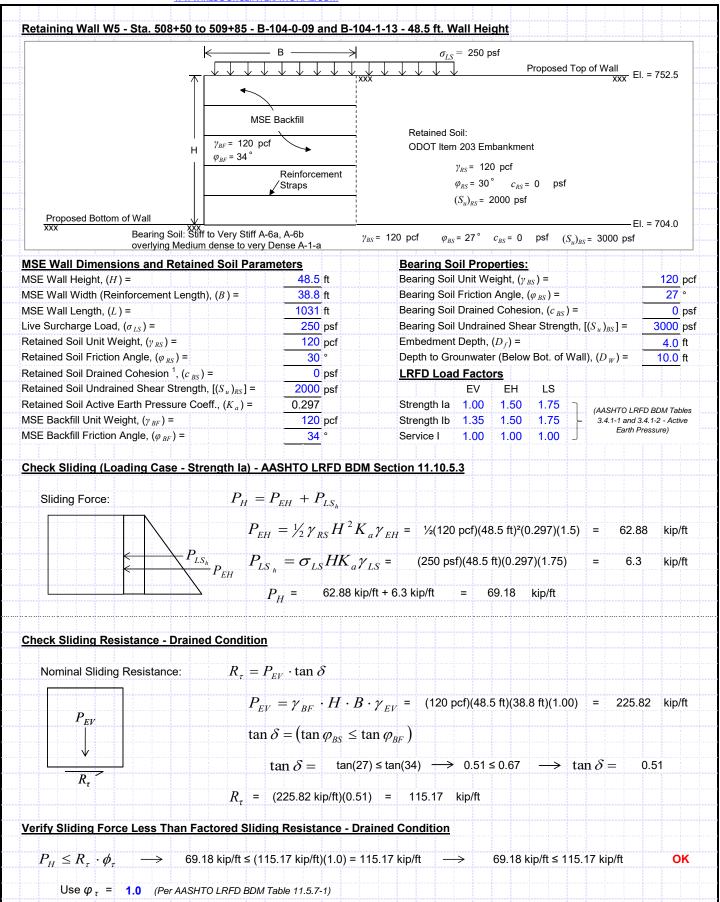






JOB FRA-70-13.10 W-13-072 SHEET NO. 6 CALCULATED BY DATE 6/30/2019 JPS CHECKED BY DATE 7/1/2019 Retaining Wall W5 - Sta. 508+50 to 509+85

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 JOB
 FRA-70-13.10
 NO.
 W-13-072

 SHEET NO.
 2
 OF
 6

 CALCULATED BY
 BRT
 DATE
 6/30/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta 508+50 to 509+85

MSE Backfill Unit Weight, (γ_{BF}) = 120 pcf Strength lb 1.35 1.50 1.75 \vdash 3.4.1-1 and	Soil Unit Weight, (γ_{BS}) = 120 pcf Soil Friction Angle, (φ_{BS}) = 27 ° Soil Drained Cohesion, (c_{BS}) = 0 psf Soil Undrained Shear Strength, $[(s_u)_{BS}]$ = 3000 psf		
MSE Wall Width (Reinforcement Length), $(B) = \frac{38.8 \text{ ft}}{1031 \text{ ft}}$ Bearing Soil Friction Angle, $(\varphi_{RS}) = \frac{1031 \text{ ft}}{1031 \text{ ft}}$ Bearing Soil Drained Cohesion, $(c_{RS}) = \frac{250 \text{ psf}}{120 \text{ pof}}$ Bearing Soil Undrained Shear Strength, $\{(s_w)_{RS}\} = \frac{250 \text{ psf}}{120 \text{ pof}}$ Bearing Soil Undrained Shear Strength, $\{(s_w)_{RS}\} = \frac{250 \text{ psf}}{120 \text{ pof}}$ Bearing Soil Undrained Shear Strength, $\{(s_w)_{RS}\} = \frac{30 \text{ o}}{120 \text{ pof}}$ Depth to Grounwater (Below Bot. of Wall), $(D_w) = \frac{120 \text{ pof}}{120 \text{ pof}}$ Bearing Soil Orained Cohesion, $(c_{RS}) = \frac{30 \text{ o}}{120 \text{ pof}}$ Depth to Grounwater (Below Bot. of Wall), $(D_w) = \frac{120 \text{ pof}}{120 \text{ pof}}$ Strength Ia 1.00 1.50 1.75 Beatained Soil Active Earth Pressure Coeff., $(K_w) = \frac{120 \text{ pof}}{120 \text{ pof}}$ Strength Ib 1.35 1.50 1.75 Strength Ib 1.35 1.50 1.75 Beatained Soil Active Earth Pressure Coeff., $(K_w) = \frac{120 \text{ pof}}{34 \text{ o}}$ Service I 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.	Soil Friction Angle, (φ_{BS}) = $\frac{27}{\circ}$ ° Soil Drained Cohesion, (c_{BS}) = $\frac{0}{\circ}$ psf Soil Undrained Shear Strength, $[(s_u)_{BS}]$ = $\frac{3000}{\circ}$ psf		
MSE Wall Length, (L) = $0.0000000000000000000000000000000000$	Soil Drained Cohesion, $(c_{BS}) = 0$ psf Soil Undrained Shear Strength, $[(s_u)_{BS}] = 0$ psf	38 8 ft	
Leve Surcharge Load, (σ_{LS}) = $\frac{250}{120}$ psf Bearing Soil Undrained Shear Strength, $[(s_u)_{RS}]$ = $\frac{250}{120}$ psf Embedment Depth, (D_r) = Retained Soil Unit Weight, (γ_{RS}) = $\frac{30}{0}$ ° Depth to Grounwater (Below Bot. of Wall), (D_W) = Retained Soil Drained Cohesion, (c_{RS}) = $\frac{30}{0}$ psf LRFD Load Factors Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ = $\frac{2000}{0}$ psf LRFD Load Factors Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ = $\frac{2000}{120}$ psf Strength la 1.00 1.50 1.75 LS0	Soil Undrained Shear Strength, $[(s_u)_{BS}] = 3000$ psf		
Retained Soil Unit Weight, (γ_{RS}) = 30° Depth to Grounwater (Below Bot. of Wall), (D_{W}) = Retained Soil Friction Angle, (φ_{RS}) = 0 psf Pateianed Soil Undrained Shear Strength, $[(S_{u})_{RS}]$ = 0 psf Retained Soil Undrained Shear Strength, $[(S_{u})_{RS}]$ = 0 psf Retained Soil Undrained Shear Strength, $[(S_{u})_{RS}]$ = 0 psf Retained Soil Undrained Shear Strength, $[(S_{u})_{RS}]$ = 0 psf Retained Soil Undrained Shear Strength, $[(S_{u})_{RS}]$ = 0 psf Retained Soil Active Earth Pressure Coeff., (K_{u}) = 0 2007 Strength la 0 1.50 1.75 Strength la 0 1.50 1.75 Strength lb 0 1.35 1.50 1.75 Strength lb 0 1.35 1.50 1.75 Service 0 1.00 Indicated Shear Strength la) - AASHTO LRFD BDM Section 11.10.5.3 (Continued) Check Sliding (Loading Case - Strength la) - AASHTO LRFD BDM Section 11.10.5.3 (Continued) Check Sliding Resistance - Undrained Condition Nominal Sliding Resistance - Undrained Condition $R_{r} = ((S_{u})_{BS} \le q_{s}) \cdot B$ $R_{r} = (3.00 \text{ ksf} \le 2.91 \text{ ksf})(38.8 \text{ ft}) = 112.91 \text{ kip/ft}$ Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition $R_{r} = (3.00 \text{ ksf} \le 2.91 \text{ kip/ft})(1.0) = 112.91 \text{ kip/ft} \longrightarrow 69.18 \text{ kip/ft} \le 112.91 \text{ kip/ft}$			
Retained Soil Friction Angle, $(\varphi_{gs}) = \frac{30}{0}$ Depth to Grounwater (Below Bot. of Wall), $(D_W) = \frac{30}{0}$ Retained Soil Drained Cohesion, $(c_{BS}) = \frac{0}{0}$ psf LRFD Load Factors Retained Soil Undrained Shear Strength, $[(S_w)_{BS}] = \frac{0}{2000}$ psf EV EH LS Retained Soil Active Earth Pressure Coeff., $(K_a) = \frac{0.297}{120}$ Strength la 1.00 1.50 1.75 MSE Backfill Unit Weight, $(\gamma_{BF}) = \frac{0.297}{34}$ Service 1 1.00 1.00 1.00 $\frac{1.00}{1.00}$ Strength lib 1.35 1.50 1.75 MSE Backfill Friction Angle, $(\varphi_{BF}) = \frac{34}{34}$ Service 1 1.00 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + \text{and}}$ Service 1 1.00 1.00 $\frac{3.41 + \text{and}}{5.41 + $	ent Depth, (D_f) = 4.0 ft		
Retained Soil Drained Cohesion, $(c_{BS}) = \frac{0}{2000} \text{ psf}$ Retained Soil Undrained Shear Strength, $[(S_u)_{BS}] = \frac{0}{2000} \text{ psf}$ Retained Soil Undrained Shear Strength, $[(S_u)_{BS}] = \frac{0}{2000} \text{ psf}$ Retained Soil Undrained Shear Strength, $[(S_u)_{BS}] = \frac{0}{2000} \text{ psf}$ Retained Soil Undrained Shear Strength, $[(S_u)_{BS}] = \frac{0}{2000} \text{ psf}$ Retained Soil Undrained Shear Strength In the			
Retained Soil Undrained Shear Strength, $[(S_u)_{BS}] = 2000$ psf Retained Soil Active Earth Pressure Coeff., $(K_a) = 0.297$ MSE Backfill Unit Weight, $(y_{BF}) = 120$ pcf MSE Backfill Unit Weight, $(y_{BF}) = 120$ pcf MSE Backfill Friction Angle, $(\varphi_{BF}) = 34$ ° Service I 1.00 1.00 1.00 1.00 Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 (Continued) Check Sliding Resistance - Undrained Condition Nominal Sliding Resistance - Undrained Condition $(S_u)_{BS} = 3.00 \text{ ksf}$ $Q_s = \frac{\sigma_v}{2} = (5.82 \text{ ksf})/2 = 2.91 \text{ ksf}$ $R_\tau = (3.00 \text{ ksf} \le 2.91 \text{ ksf})(38.8 \text{ ft}) = 112.91 \text{ kip/ft}$ Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition $P_H \le R_\tau \cdot \phi_\tau \implies 69.18 \text{ kip/ft} \le (112.91 \text{ kip/ft})(1.0) = 112.91 \text{ kip/ft} \implies 69.18 \text{ kip/ft} \le 112.91 \text{ kip/ft}$			
Retained Soil Active Earth Pressure Coeff., $(K_a) = \frac{0.297}{120 \text{ pcf}}$ Strength la 1.00 1.50 1.75 MSE Backfill Unit Weight, $(\gamma_{BF}) = \frac{0.297}{120 \text{ pcf}}$ Strength lb 1.35 1.50 1.75 MSE Backfill Friction Angle, $(\varphi_{BF}) = \frac{34}{34}$ Service l 1.00 1.00 1.00 1.00 $\frac{1.00}{3.4.1-1 \text{ and}}$ Service l 1.00 1.00 1.00 1			
MSE Backfill Unit Weight, $(y_{BF}) = \frac{120}{34} \text{ pcf}$ Strength Ib 1.35 1.50 1.75 MSE Backfill Friction Angle, $(\varphi_{BF}) = \frac{120}{34} \text{ service I}$ 1.00 1.00 1.00 1.00 $\frac{3.4.1-1}{6} \text{ and } \frac{3.4.1-1}{6} \text{ and } 3.4.1-1$	la 100 150 175 ¬		
MSE Backfill Friction Angle, (φ_{BF}) = 34° Service 1.00 1.00 1.00 Earth I Check Sliding (Loading Case - Strength Ia) - AASHTO LRFD BDM Section 11.10.5.3 (Continued) Check Sliding Resistance - Undrained Condition Nominal Sliding Resisting: $R_{\tau} = ((S_u)_{BS} \leq q_s) \cdot B$ $(S_u)_{BS} = 3.00 \text{ ksf}$ $q_s = \sigma_{v/2} = (5.82 \text{ ksf}) / 2 = 2.91 \text{ ksf}$ $R_{\tau} = (3.00 \text{ ksf} \leq 2.91 \text{ ksf}) / 38.8 \text{ ft}) = 5.82 \text{ ksf}$ $R_{\tau} = (3.00 \text{ ksf} \leq 2.91 \text{ ksf}) / 38.8 \text{ ft}) = 112.91 \text{ kip/ft}$ Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition $P_H \leq R_{\tau} \cdot \phi_{\tau} \implies 69.18 \text{ kip/ft} \leq (112.91 \text{ kip/ft}) / (1.0) = 112.91 \text{ kip/ft} \implies 69.18 \text{ kip/ft} \leq 112.91 \text{ kip/ft}$	(AASHTU LRFD BDM Tables		
Check Sliding Resistance - Undrained Condition Nominal Sliding Resisting: $R_{\tau} = ((S_u)_{BS} \leq q_s) \cdot B$ $(S_u)_{BS} = 3.00 \text{ksf}$ $q_s = \frac{\sigma_v}{2} = (5.82 \text{ ksf})/2 = 2.91 \text{ksf}$ $R_{\tau} = (3.00 \text{ ksf} \leq 2.91 \text{ ksf})/38.8 \text{ ft}) = 5.82 \text{ksf}$ $R_{\tau} = (3.00 \text{ ksf} \leq 2.91 \text{ ksf})/38.8 \text{ ft}) = 112.91 \text{kip/ft}$ Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition $P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 69.18 \text{ kip/ft} \leq (112.91 \text{ kip/ft})/(1.0) = 112.91 \text{ kip/ft} \longrightarrow 69.18 \text{ kip/ft} \leq 112.91 \text{ kip/ft}$	Earth Proseura)		
Nominal Sliding Resisting: $R_{\tau} = \left(\left(S_u \right)_{BS} \leq q_s \right) \cdot B$ $\left(S_u \right)_{BS} = 3.00 \text{ksf}$ $q_s = \frac{\sigma_v}{2} = (5.82 \text{ ksf}) / 2 = 2.91 \text{ksf}$ $\sigma_v = \frac{P_{EV}}{B} = (225.82 \text{ kip/ft}) / (38.8 \text{ ft}) = 5.82 \text{ksf}$ $R_{\tau} = (3.00 \text{ ksf} \leq 2.91 \text{ ksf}) (38.8 \text{ ft}) = 112.91 \text{kip/ft}$ $P_H \leq R_{\tau} \cdot \phi_{\tau} \implies 69.18 \text{ kip/ft} \leq (112.91 \text{ kip/ft}) (1.0) = 112.91 \text{ kip/ft} \implies 69.18 \text{ kip/ft} \leq 112.91 \text{ kip/ft}$	0.5.3 (Continued)	ASHTO LRFD BDM	Check Sliding (Loading Case - Strength I
$(S_u)_{BS} = 3.00 \text{ ksf}$ $q_s = \sigma_v/2 = (5.82 \text{ ksf})/2 = 2.91 \text{ ksf}$ $\sigma_v = P_{EV}/B = (225.82 \text{ kip/ft})/(38.8 \text{ ft}) = 5.82 \text{ ksf}$ $R_\tau = (3.00 \text{ ksf} \le 2.91 \text{ ksf})(38.8 \text{ ft}) = 112.91 \text{ kip/ft}$ $\text{Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition}$ $P_H \le R_\tau \cdot \phi_\tau \implies 69.18 \text{ kip/ft} \le (112.91 \text{ kip/ft})(1.0) = 112.91 \text{ kip/ft} \implies 69.18 \text{ kip/ft} \le 112.91 \text{ kip/ft}$			
$q_s = \sigma_v /_2 = (5.82 \text{ ksf}) / 2 = 2.91 \text{ ksf}$ $q_s = P_{EV} /_B = (225.82 \text{ kip/ft}) / (38.8 \text{ ft}) = 5.82 \text{ ksf}$ $R_\tau = (3.00 \text{ ksf} \le 2.91 \text{ ksf}) / (38.8 \text{ ft}) = 112.91 \text{ kip/ft}$ $P_H \le R_\tau \cdot \phi_\tau \implies 69.18 \text{ kip/ft} \le (112.91 \text{ kip/ft}) / (1.0) = 112.91 \text{ kip/ft} \implies 69.18 \text{ kip/ft} \le 112.91 \text{ kip/ft}$		$(S_u)_{BS} \leq q_s \cdot B$	Nominal Sliding Resisting: R
$q_s = \sqrt[3]{2} = (5.82 \text{ ksf})/2 = 2.91 \text{ ksf}$ $R_{\tau} = \sqrt[3]{8} + \sqrt[3]{8$			P.L.
$R_{\tau} = (3.00 \text{ ksf} \le 2.91 \text{ ksf})(38.8 \text{ ft}) = 112.91 \text{ kip/ft}$ $\textit{Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition}$ $P_{H} \le R_{\tau} \cdot \phi_{\tau} \implies 69.18 \text{ kip/ft} \le (112.91 \text{ kip/ft})(1.0) = 112.91 \text{ kip/ft} \implies 69.18 \text{ kip/ft} \le 112.91 \text{ kip/ft}$	= 2.91 ksf	$q_s = \frac{\sigma_v}{2} = 0$	R
/erify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition $P_{H} \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 69.18 \text{ kip/ft} \leq (112.91 \text{ kip/ft})(1.0) = 112.91 \text{ kip/ft} \longrightarrow 69.18 \text{ kip/ft} \leq 112.91 \text{ kip/ft}$	ip/ft) / (38.8 ft) = 5.82 ksf	$\sigma_{_{\scriptscriptstyle \mathcal{V}}} = P_{_{EV}} / B$	$ \begin{array}{ccc} & & & \\ & & & \\ & & & \\ & & & \\ \end{array} $ $ \begin{array}{ccc} & & & \\ & & & \\ \end{array} $ $ \begin{array}{cccc} & & & \\ & & & \\ \end{array} $ $ \begin{array}{cccc} & & & \\ & & & \\ \end{array} $
$P_H \le R_\tau \cdot \phi_\tau \longrightarrow 69.18 \text{ kip/ft} \le (112.91 \text{ kip/ft})(1.0) = 112.91 \text{ kip/ft} \longrightarrow 69.18 \text{ kip/ft} \le 112.91 \text{ kip/ft}$	= 112.91 kip/ft	= (3.00 ksf ≤ 2.91	
	tion	g Resistance - Un	/erify Sliding Force Less Than Factored
Use $arphi_{ au}$ = 1.0 (Per AASHTO LRFD BDM Table 11.5.7-1)	—> 69.18 kip/ft ≤ 112.91 kip/ft OK	2.91 kip/ft)(1.0) = 1 ⁻	$P_H \leq R_ au \cdot \phi_ au$ 69.18 kip/ff
		able 11.5.7-1)	Use $arphi_{ au}=$ 1.0 (Per AASHTO LRFC



JOB FRA-70-13.10 NO. SHEET NO. CALCULATED BY BRT CHECKED BY JPS

W-13-072 OF DATE 6/30/2019 DATE 7/1/2019

6

Retaining Wall W5 - Sta. 508+50 to 509+85

FAX: (614) 823-4990
WWW.RESOURCEINTERATIONAL.COM

ISE Wall Dimensions and Retained Soil P	<u>arameters</u>	Bearing Soil Properties:	
ISE Wall Height, (H) =	48.5 ft	Bearing Soil Unit Weight, (γ_{BS}) =	120 pc
ISE Wall Width (Reinforcement Length), (<i>B</i>) =	38.8 ft	Bearing Soil Friction Angle, (φ_{BS}) =	27 °
ISE Wall Length, (L) =	1031 ft	Bearing Soil Drained Cohesion, (c_{BS}) =	0 ps
ive Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	3000 ps
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment Depth, (D_f) =	4.0 ft
Retained Soil Friction Angle, (φ_{RS}) =	30 °	Depth to Grounwater (Below Bot. of Wall), (D_W) =	10.0 ft
tetained Soil Drained Cohesion, (c_{RS}) =	0 psf	LRFD Load Factors	
tetained Soil Undrained Shear Strength, $[(S_u)_{RS}]$		EV EH LS	
Letained Soil Active Earth Pressure Coeff., (K_a) :		Strength la 1.00 1.50 1.75	
ISE Backfill Unit Weight, (γ_{BE}) =	120 pcf	(AASHIOLR	FD BDM Tables 3.4.1-2 - Active
ISE Backfill Friction Angle, (φ_{BF}) =	34 °		Pressure)
Check Eccentricity (Loading Case - Streng	th la) - AASHTO LRFD	BDM Section 11.10.5.5	
	$=B/2-x_o$		
	12		
\uparrow^3 P_{LS_h}	$x_{\circ} = \frac{M_{EV} - M_{H}}{2}$	= 4380.91 kip·ft/ft - 1169.54 kip·ft/ft) / (225.82 kip/ft =	14.22 ft
P_{EH}	$P_{\!\scriptscriptstyle EV}$		
	$M_{EV} = 4380.9^{\circ}$	1 kip·ft/ft ¬	
$x_{\circ} \leftarrow x_{\circ} e$	$M_H = 1169.54$	this in the state of the state	
$x_0 \leftarrow \Rightarrow e$	$P_{EV} = 225.82$	kip/ft - kip/ft	
1-72-1		22 ft = 5.18 ft	
Resisting Moment, $M_{\it EV}$: M	$_{EV}=P_{EV}(x_1)$		
P_{EV}	$P_{EV} = \gamma_{BF} \cdot H \cdot B$	γ_{EV} = (120 pcf)(48.5 ft)(38.8 ft)(1.00) = 225.	82 kip/ft
	$x_1 = B/2 = (38)$.8 ft) / 2 = 19.40 ft	
	M (005.00	1000 04 Lings	
	$M_{EV} = (225.82)$	2 kip/ft)(19.40 ft) = 4380.91 kip-ft/ft	
Overturning Moment, M_H : M	$H = P_{EH}(x_2) + P_1$	(x_3, x_3)	
	$P_{EH} = \frac{1}{2} \gamma_{RS} H^2 K$	$_{a}\gamma_{EH} = \frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(1.5) = 62.8$	38 kip/ft
P_{LS_h}	$P_{LS_h} = \sigma_{LS} H K_a \gamma_L$	$_{LS}$ = (250 psf)(48.5 ft)(0.297)(1.75) = 6.3	kip/ft
	$x_2 = H_3 = (48)$.5 ft) / 3 = 16.17 ft	
	$x_3 = \frac{H}{2} = (48)$.5 ft) / 2 = 24.25 ft	
	$M_{H} = (62.88)$	kip/ft)(16.17 ft) + (6.3 kip/ft)(24.25 ft) = 1169.54	kip·ft/ft
Sheck Eccentricity			
MECK Eccentificity			
$e < e_{\rm max} \longrightarrow 5.18 {\rm ft} < 12.93 {\rm ft}$	OK		



 JOB
 FRA-70-13.10
 NO.

 SHEET NO.
 4
 OF

 CALCULATED BY
 BRT
 DATE

6 6 6/30/2019 7/1/2019

	14) 823-4949	CHECKED BY	JPS DATE	7/1/2019
	823-4990	Retaining Wall V	V5 - Sta. 508+50 to 509	+85
<u>WWW.RESOURCEII</u>	NTERATIONAL.COM			
MSE Wall Dimensions and Retained Soil Pa	ramotore	Bearing Soil Propertie	61	
MSE Wall Height, (H) =	48.5 ft	Bearing Soil Unit Weight,	man anananakananangananangananatananangana	120 pcf
MSE Wall Width (Reinforcement Length), (B) =	38.8 ft	Bearing Soil Friction Angle		27 °
MSE Wall Length, (L) =	1031 ft	Bearing Soil Drained Cohe		0 psf
Live Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil Undrained Sh		3000 psf
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment Depth, (D_f) =		4.0 ft
Retained Soil Friction Angle, (φ_{RS}) =	30 °	Depth to Grounwater (Bel		10.0 ft
Retained Soil Drained Cohesion, (c_{BS}) =	0 psf	LRFD Load Factors		
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =		EV EH	LS	
Retained Soil Active Earth Pressure Coeff., (K_a) =	nannigaranan garanga garanga	Strength la 1.00 1.50) 175 ¬	
MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf	Strength lb 1.35 1.50	(AASHIO LE	RFD BDM Tables 3.4.1-2 - Active
MSE Backfill Friction Angle, (φ_{BF}) =	34 °	Service I 1.00 1.00	Farth	Pressure)
			, 1.00 -	
Check Bearing Capacity (Loading Case - St	renath lh) - AASHTO	I RFD RDM Section 11 10 5 4		
	rengui ib) - AAOITIO	ERI D DDM Oction 11.10.0.4		
$P_{LS_{v}}$	D /			
	$=\frac{P_V}{R'}$			
	/ B			
X_3 P_{EV} P_{EV}	B' = B - 2e = 38	3.8 ft - 2(3.63 ft) = 31.54	ft	
P_{LS_h}				
P_{LS_h}	$\rho = B/$ $- r$	= (38.8 ft) / 2 - 15.77 ft =	3.63 ft	
R^{\vee}				
	$_{r}$ $_{-}$ M_{V} $-M_{H}$	- = (6243.44 kip·ft/ft - 1169	52 kin.ft/ft\ / 321 83 kin	/ft = 15.77 f
	P_{ν}	- (0243.44 Kip livit - 1109	.52 KIP 1010) / 521.65 KIP	/10.77
$x_o \leftarrow x_{o-1} - e$	- V			
$\vdash B / \rightarrow \downarrow$				
$1^{11}/2^{11}$	a — (224.02 kim/ft			
$\stackrel{\longleftarrow}{\models} \stackrel{B/2}{\rightarrow} \stackrel{\longrightarrow}{\mapsto} \qquad	$q_{eq} = (321.83 \text{ kip/ft})$) / (31.54 ft) = 10.20 k	sf	
 	4		sf	
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$	4		sf	
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$	$\cdot H \cdot B \cdot \gamma_{EV})(x_1)$	$+(\sigma_{LS}\cdot B\cdot \gamma_{LS})(x_1)$		
<u> </u>	$\cdot H \cdot B \cdot \gamma_{EV})(x_1)$	$+\left(\sigma_{LS}\cdot B\cdot \gamma_{LS}\right)\!(x_1)$	sf 6243.44 kip-ft/ft	
$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF})$ $M_V = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3 \text{ ft})(1.$	$H \cdot B \cdot \gamma_{EV}(x_1)$	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$)(38.8 ft)(1.75)](19.4 ft) =		
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$	$H \cdot B \cdot \gamma_{EV}(x_1)$	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$)(38.8 ft)(1.75)](19.4 ft) =		
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\gamma_{2} \gamma_{2})$	$H \cdot B \cdot \gamma_{EV}(x_1)$ $(35)](19.4 \text{ ft}) + [(250 \text{ psf})](x_2)$ $(35)](19.4 \text{ ft}) + [(250 \text{ psf})](x_2)$	+ $(\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$)(38.8 ft)(1.75)](19.4 ft) = + $(\sigma_{LS}HK_a\gamma_{LS})(x_3)$	6243.44 kip-ft/ft	
$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF})$ $M_V = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3 \text{ ft})(1.$	$H \cdot B \cdot \gamma_{EV}(x_1)$ $(35)](19.4 \text{ ft}) + [(250 \text{ psf})](x_2)$ $(35)](19.4 \text{ ft}) + [(250 \text{ psf})](x_2)$	+ $(\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$)(38.8 ft)(1.75)](19.4 ft) = + $(\sigma_{LS}HK_a\gamma_{LS})(x_3)$	6243.44 kip-ft/ft	p-ft/ft
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{2})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(70.297)]$	$H \cdot B \cdot \gamma_{EV}(x_1)$ (85)](19.4 ft) + [(250 psf $H_{RS}H^2K_a\gamma_{EH}(x_2)$ (1.5)](16.17 ft) + [(250 psf	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) =$ $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $)(38.8 \text{ ft})(1.75)](24.25)$ $(38.8 \text{ ft})(1.75)](24.25)$	6243.44 kip-ft/ft	o-ft/ft
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\gamma_{2} \gamma_{2})$	$H \cdot B \cdot \gamma_{EV}(x_1)$ (85)](19.4 ft) + [(250 psf $H_{RS}H^2K_a\gamma_{EH}(x_2)$ (1.5)](16.17 ft) + [(250 psf	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) =$ $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $)(38.8 \text{ ft})(1.75)](24.25)$ $(38.8 \text{ ft})(1.75)](24.25)$	6243.44 kip-ft/ft	o-ft/ft
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\gamma_{2}\gamma_{2})$ $M_{H} = [\gamma_{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(1.20 \text{ pcf})(48.5 \text{ ft})^{2}(0.29$	$H \cdot B \cdot \gamma_{EV} (x_1)$ (35)](19.4 ft) + [(250 psf $x_{RS} H^2 K_a \gamma_{EH})(x_2)$ (1.5)](16.17 ft) + [(250 psf $x_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS})$	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$)(38.8 ft)(1.75)](19.4 ft) = $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ osf)(48.5 ft)(0.297)(1.75)](24.25	6243.44 kip-ft/ft	o-ft/ft
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{2})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(70.297)]$	$H \cdot B \cdot \gamma_{EV} (x_1)$ (35)](19.4 ft) + [(250 psf $x_{RS} H^2 K_a \gamma_{EH})(x_2)$ (1.5)](16.17 ft) + [(250 psf $x_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS})$	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$)(38.8 ft)(1.75)](19.4 ft) = $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ osf)(48.5 ft)(0.297)(1.75)](24.25	6243.44 kip-ft/ft	p-ft/ft
$ \begin{array}{l} $	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ 35)](19.4 ft) + [(250 psf $x_{RS} H^2 K_a \gamma_{EH})(x_2)$ 1.5)](16.17 ft) + [(250 psf $x_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS})$ 5) + (250 psf)(38.8 ft)(1	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$)(38.8 ft)(1.75)](19.4 ft) = $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ osf)(48.5 ft)(0.297)(1.75)](24.25	6243.44 kip-ft/ft	p-ft/ft
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\gamma_{2} \gamma_{2})$ $M_{H} = [\gamma_{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(1.20 \text{ pcf})(1.20 \text{ pcf}$	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ 35)](19.4 ft) + [(250 psf $x_{RS} H^2 K_a \gamma_{EH})(x_2)$ 1.5)](16.17 ft) + [(250 psf $x_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS})$ 5) + (250 psf)(38.8 ft)(1	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$)(38.8 ft)(1.75)](19.4 ft) = $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ osf)(48.5 ft)(0.297)(1.75)](24.25	6243.44 kip-ft/ft	o-ft/ft
$\begin{array}{c} \longleftarrow B' \rightarrow \\ M_V = P_{EV}\left(x_1\right) + P_{LS_v}\left(x_1\right) = \left(\gamma_{BF}\right) \\ M_V = & [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.38)] \\ M_H = & P_{EH}\left(x_2\right) + P_{LS_h}\left(x_3\right) = \left(\frac{1}{2}\gamma_{EF}\right) \\ M_H = & [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^2(0.297)(100) \\ P_V = & P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EF} \\ P_V = & (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.38) \\ \hline \text{Check Bearing Resistance - Drained Conditions} \end{array}$	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ 35)](19.4 ft) + [(250 psf $x_{RS} H^2 K_a \gamma_{EH})(x_2)$ 1.5)](16.17 ft) + [(250 psf $x_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS})$ 5) + (250 psf)(38.8 ft)(4)	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) =$ $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $osf)(48.5 \text{ ft})(0.297)(1.75)](24.25)$ S $1.75) = 321.83 \text{ kip/ft}$	6243.44 kip-ft/ft	D-ft/ft
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.38)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{E})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(7)]$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{E}$ $P_{V} = (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.38)$ Check Bearing Resistance - Drained Condition	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ 35)](19.4 ft) + [(250 psf $x_{RS} H^2 K_a \gamma_{EH})(x_2)$ 1.5)](16.17 ft) + [(250 psf $x_{EV} + \sigma_{LS} \cdot B \cdot \gamma_{LS})$ 5) + (250 psf)(38.8 ft)(1	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) =$ $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $osf)(48.5 \text{ ft})(0.297)(1.75)](24.25)$ S $1.75) = 321.83 \text{ kip/ft}$	6243.44 kip-ft/ft	p-ft/ft
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{2})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{F}$ $P_{V} = (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ Check Bearing Resistance - Drained Condition	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ (35)](19.4 ft) + [(250 psf)] (19.4 ft) + [(250 psf	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) = 0$ $+ (\sigma_{LS}HK_a\gamma_{LS})(x_3)$ $)(38.5 \text{ ft})(0.297)(1.75)](24.25)$ $(38.5 \text{ ft})(0.297)(1.75)](24.25)$ $(48.5 \text{ ft})(0.297)(1.75)](24.25)$ $(58.5 \text{ ft})(0.297)(1.75)](24.25)$ $(58.5 \text{ ft})(0.297)(1.75)](24.25)$ $(59.5 \text{ ft})(0.297)(1.75)$ $(79.5 \text{ ft})(0.297)(1.75)$	6243.44 kip-ft/ft ift) = 1,169.52 kip	
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.38)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{E})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(7)]$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{E}$ $P_{V} = (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.38)$ Check Bearing Resistance - Drained Condition	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ (35)](19.4 ft) + [(250 psf)] (19.4 ft) + [(250 psf	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) = 0$ $+ (\sigma_{LS}HK_a\gamma_{LS})(x_3)$ $)(38.5 \text{ ft})(0.297)(1.75)](24.25)$ $(38.5 \text{ ft})(0.297)(1.75)](24.25)$ $(48.5 \text{ ft})(0.297)(1.75)](24.25)$ $(58.5 \text{ ft})(0.297)(1.75)](24.25)$ $(58.5 \text{ ft})(0.297)(1.75)](24.25)$ $(59.5 \text{ ft})(0.297)(1.75)$ $(79.5 \text{ ft})(0.297)(1.75)$	6243.44 kip-ft/ft ift) = 1,169.52 kip	
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\gamma_{2}\gamma_{2})$ $M_{H} = [\gamma_{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(1.20 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(1.20 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{F}$ $P_{V} = (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ $Check Bearing Resistance - Drained Conditation Nominal Bearing Resistance: q_{n} = cN_{ch} N_{cm} = N_{c}s_{c}i_{c} = 24.35$	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ (35)](19.4 ft) + [(250 psf)] (18.8) $H^2 K_a \gamma_{EH} (x_2) $ (1.5)](16.17 ft) + [(250 psf)] (250 psf)(38.8 ft)(4) (35) + (250 psf)(38.8 ft)(4) (47) $H^2 M_{gm} C_{gm} C_{g$	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) = 1 + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $)(38.5 \text{ ft})(0.297)(1.75)](24.25)$ S $(38.5 \text{ ft})(0.297)(1.75)](24.25)$ S $(48.5 \text{ ft})(0.297)(1.75)$ S	6243.44 kip-ft/ft 617 ft) = 1,169.52 kip $S_{ij} = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$	
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{2})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{F}$ $P_{V} = (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ Check Bearing Resistance - Drained Condition	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ (35)](19.4 ft) + [(250 psf)] (19.4 ft) + [(250 psf	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) = 1 + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $)(38.5 \text{ ft})(0.297)(1.75)](24.25)$ S $(38.5 \text{ ft})(48.5 \text{ ft})(0.297)(1.75)](24.25)$ S $(48.5 \text{ ft})(0.297)(1.75)](24.25)$ S $(58.75) = 321.83 \text{ kip/ft}$ $(69.75) + \frac{1}{2} \gamma B N_{ym} C_{wy}$	6243.44 kip-ft/ft 67ft) = 1,169.52 kip $j_{ij} = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$ $j_{ij} = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$	
$\begin{array}{l} \longleftarrow B' \rightarrow \\ M_V = P_{EV}\left(x_1\right) + P_{LS_v}\left(x_1\right) = \left(\gamma_{BF}\right) \\ M_V = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)] \\ M_H = P_{EH}\left(x_2\right) + P_{LS_h}\left(x_3\right) = \left(\gamma_2\gamma_1\right) \\ M_H = [\%(120 \text{ pcf})(48.5 \text{ ft})^2(0.297)(1.297)] \\ P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_1 \\ P_V = (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35) \\ \hline \text{Check Bearing Resistance - Drained Condit} \\ \text{Nominal Bearing Resistance:} \qquad q_n = cN_{ch} \\ N_{cm} = N_c s_c i_c = 24.35 \\ \hline \end{array}$	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ (35)](19.4 ft) + [(250 psf)] (18.8) $H^2 K_a \gamma_{EH} (x_2) $ (1.5)](16.17 ft) + [(250 psf)] (250 psf)(38.8 ft)(4) (35) + (250 psf)(38.8 ft)(4) (47) $H^2 M_{gm} C_{gm} C_{g$	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) = 1 + (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $)(38.5 \text{ ft})(0.297)(1.75)](24.25)$ S $(38.5 \text{ ft})(48.5 \text{ ft})(0.297)(1.75)](24.25)$ S $(48.5 \text{ ft})(0.297)(1.75)](24.25)$ S $(58.75) = 321.83 \text{ kip/ft}$ $(69.75) + \frac{1}{2} \gamma B N_{ym} C_{wy}$	6243.44 kip-ft/ft 617 ft) = 1,169.52 kip $S_{ij} = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$	
$M_V = P_{EV}(x_1) + P_{LS_v}(x_1) = (\gamma_{BF})$ $M_V = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_H = P_{EH}(x_2) + P_{LS_h}(x_3) = (\frac{1}{2}\gamma_{ES_h})(1.20 \text{ pcf})(48.5 \text{ ft})^2(0.297)(1.20 \text{ pcf})(48.5 \text{ ft})^2(0.297)(1.20 \text{ pcf})(48.5 \text{ ft})^2(0.297)(1.20 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ $P_V = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{ES_v}$ $P_V = (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ Check Bearing Resistance - Drained Conditation Nominal Bearing Resistance: $q_n = cN_{CR_v}$ $N_{CR_v} = N_c s_c i_c = 24.35$ $N_C = 23.94$	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ (35)](19.4 ft) + [(250 psf X_S H^2 K_a \gamma_{EH})(x_2)] (1.5)](16.17 ft) + [(250 psf X_E Y_E Y_E Y_E Y_E Y_E Y_E Y_E Y_E Y_E Y	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) =$ $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $)(38.8 \text{ ft})(1.75)](24.25)$ $(38.8 \text{ ft})(1.75)](24.25)$ $(38.8 \text{ ft})(1.75)](24.25)$ $(48.5 \text{ ft})(0.297)(1.75)](24.25)$ $(48.5 \text{ ft})(0.297)(1.75)[(24.25)(1.75)(1.75)[(24.25)(1.75)(1.75)[(24.25)(1.75)(1.75)[(24.25)(1.75)(1.75)[(24.25)(1.75)(1.75)[(24.25)(1.75)(1.75)[(24.25)(1.75)(1.75)[(24.25)(1.75)(1.75)[(24.25)(1.75)[(24.25)(1.75)(1.75)[(24.25)[(24.25)(1.75)[(24.25)(1.75)[(24.25)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75)[(24.25)(1.75$	6243.44 kip-ft/ft 67ft) = 1,169.52 kip $j_{ij} = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$ $j_{ij} = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$	
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{E})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(1.3)]$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ $P_{V} = (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ $Check Bearing Resistance - Drained Condition $ Nominal Bearing Resistance: $q_{n} = cN_{CR}$ $N_{CM} = N_{CS_{e}}i_{C} = 24.35$ $N_{C} = 23.94$ $S_{C} = 1+(31.54 \text{ ft}/1031 \text{ ft})(13.2/23.94)$	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ (35)](19.4 ft) + [(250 psf X_S H^2 K_a \gamma_{EH})(x_2)] (1.5)](16.17 ft) + [(250 psf X_E Y_E Y_E Y_E Y_E Y_E Y_E Y_E Y_E Y_E Y	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) =$ $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $)(38.8 \text{ ft})(1.75)](24.25)$ $(38.8 \text{ ft})(1.75)](24.25)$ $(38.8 \text{ ft})(0.297)(1.75)](24.25)$ $(38.8 \text{ ft})(1.75)] = 321.83 \text{ kip/ft}$ $+ \frac{1}{2} \gamma B N_{ym} C_{wy}$ $i_q = 13.92 \qquad N_{ym}$ $i_q = 13.92 \qquad N_{ym}$	6243.44 kip-ft/ft 61ft) = 1,169.52 kip $a = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$ $N_{\gamma} = 14.47$ $S_{\gamma} = 0.988$	
$M_{V} = P_{EV}(x_{1}) + P_{LS_{v}}(x_{1}) = (\gamma_{BF})$ $M_{V} = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.3)]$ $M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{E})$ $M_{H} = [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^{2}(0.297)(1.3)]$ $P_{V} = P_{EV} + P_{LS} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ $P_{V} = (120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.35)$ $Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: \qquad q_{n} = cN_{CR}$ $N_{CM} = N_{C}S_{c}i_{C} = 24.35$ $N_{C} = 23.94$ $S_{C} = 1+(31.54 \text{ ft}/1031 \text{ ft})(13.2/23.94)$ $= 1.017$	$ \cdot H \cdot B \cdot \gamma_{EV})(x_1) $ (35)](19.4 ft) + [(250 psf X_EY	$+ (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_1)$ $)(38.8 \text{ ft})(1.75)](19.4 \text{ ft}) =$ $+ (\sigma_{LS} H K_a \gamma_{LS})(x_3)$ $)(38.8 \text{ ft})(1.75)](24.25)$ $(38.5 \text{ ft})(0.297)(1.75)](24.25)$ $(48.5 \text{ ft})(0.297)(1.75)](24.25)$ $(58.5 \text{ ft})(0.297)(1.75)](24.25)$ $(68.5 \text{ ft})(0.297)(1.75)](24.25)$ $(79.5 \text{ ft})(0.297)(1.75)[(1.75)(1.75)](24.25)$ $(79.5 \text{ ft})(0.297)(1.75)[(1.75)(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)(1.75)[(1.75)(1.75)[(1.75)(1.75)(1.75)[$	6243.44 kip-ft/ft ift) = 1,169.52 kip $i = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$ $i = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$ $i = N_{\gamma} S_{\gamma} i_{\gamma} = 14.30$ $i = 1.000$ (Assumed)	

<u>Verify Equivalent Pressure Less Than Factored Bearing Resistance</u>
Use $φ_b = 0.65$ (Per AASHTO LRFD BDM Table 11.5.7-1)

(0 psf)(24.347) + (120 pcf)(4.0 ft)(13.921)(1.000) + ½(120 pcf)(31.5 ft)(14.296)(0.606)

 $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 10.20 \text{ ksf} \leq (23.08 \text{ ksf})(0.65) = 15.00 \text{ ksf} \longrightarrow 10.20 \text{ ksf} \leq 15.00 \text{ ksf}$



FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF 6 CALCULATED BY BRT DATE 6/30/2019 CHECKED BY JPS DATE 7/1/2019 Retaining Wall W5 - Sta. 508+50 to 509+85

ISE Wall Dimensions and Ret	ained Soil Param	<u>neters</u>	Bearing Soil I	Properties:			
/ISE Wall Height, (<i>H</i>) =		48.5 ft	Bearing Soil Un	it Weight, (γ_{BS})	ı =		120 pcf
ISE Wall Width (Reinforcement Le	ength), (B) =	38.8 ft	Bearing Soil Fri	ction Angle, (φ	_{BS}) =		27 °
/ISE Wall Length, (<i>L</i>) =		1031 ft	Bearing Soil Dra	ained Cohesion	$(c_{BS}) =$		0 psf
ive Surcharge Load, (σ_{LS}) =		250 psf	Bearing Soil Un	drained Shear	Strength, [(.	$(s_u)_{BS}] =$	3000 psf
etained Soil Unit Weight, (γ_{RS}) =		120 pcf	Embedment De	pth, (D_f) =			4.0 ft
etained Soil Friction Angle, (φ_{RS}) =	=	30 °	Depth to Groun	water (Below B	ot. of Wall)	$, (D_{W}) =$	10.0 ft
etained Soil Drained Cohesion, (c	_{BS}) =	0 psf	LRFD Load Fa	actors			
etained Soil Undrained Shear Stre	ength, $[(S_u)_{RS}] =$	2000 psf	E	V EH	LS		
etained Soil Active Earth Pressure	e Coeff., (K_a) =	0.297	Strength la 1.	00 1.50	1.75 기	(AASHTO LRFL	DOM Tables
ISE Backfill Unit Weight, (γ_{BF}) =		120 pcf	Strength lb 1.	35 1.50	1.75 -	3.4.1-1 and 3.4	1.1-2 - Active
SE Backfill Friction Angle, (φ_{BF}) =		34 °	Service I 1.	00 1.00	1.00	Earth Pre	essure)
heck Bearing Capacity (Load			RFD BDM Section	11.10.5.4 (Co	ntinued)		
heck Bearing Resistance - Ur							
ominal Bearing Resistance:		$\gamma D_f N_{qm} C_{wq} +$					
$N_{cm} = N_c s_c i_c = 5.17$	70 <i>1</i>	$V_{qm} = N_q s_q d_q i_q$, = 1.000		$N_{\gamma}s_{\gamma}i_{\gamma}$	= 0.000	
$N_c = 5.140$		N_q = 1.000			= 0.000		
$S_c = 1+(31.54 \text{ ft/}[(5)(1031)]$	ft)]) = 1.006	$s_{g} = 1.000$			= 1.000		
i_c = 1.000 (Assumed)		d_q = 1+2tan(0°)	[1-sin(0°)]²tan⁻¹(4.0 ft/31.54		1.000 (
		1.000		C_{wy} :	= 10.0 ft < 1	.5(31.54 ft) + 4.0	oft = 0
		$i = 1.000 (\Delta s)$	ssumed)				
a = (3000 psf)(5.170)) + (120 pcf)(4.0 ft	$i_q = 1.000 \text{ (As}$ $C_{wq} = 10.0 \text{ ft} > 4.$ $C_{(1.000)(1.000) + \frac{1}{2}(1.000)$.0 ft = 1.000	000)(0.606)	= 15	5.99 ksf	
$q_n= \hspace{1.5cm} ext{(3000 psf)(5.170)}$ erify Equivalent Pressure Les		$C_{wq} = 10.0 \text{ft} > 4.$ $C_{wq} = 10.0 \text{ft} > 4.$ $C_{wq} = 10.0 \text{ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0	000)(0.606)	= 15	5.99 ksf	
	ss Than Factored	$C_{wq} = 10.0 \text{ft} > 4.$ (1.000)(1.000) + $\frac{1}{2}$ (1.000)	.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce	000)(0.606) 10.20 ksf s			
erify Equivalent Pressure Les	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{\it eq} \leq q_{\it n} \cdot \phi_b ightarrow$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{\it eq} \leq q_{\it n} \cdot \phi_b ightarrow$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{\it eq} \leq q_{\it n} \cdot \phi_b ightarrow$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{\it eq} \leq q_{\it n} \cdot \phi_b ightarrow$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{\it eq} \leq q_{\it n} \cdot \phi_b ightarrow$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{\it eq} \leq q_{\it n} \cdot \phi_b ightarrow$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{\it eq} \leq q_{\it n} \cdot \phi_b ightarrow$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{eq} \leq q_{n} \cdot \phi_{b} o$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{eq} \leq q_n \cdot \phi_b o$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				
erify Equivalent Pressure Les $q_{eq} \leq q_n \cdot \phi_b o$	ss Than Factored	$C_{wq} = 10.0 \text{ ft} > 4.$.0 ft = 1.000 (120 pcf)(31.5 ft)(0.0 ce				



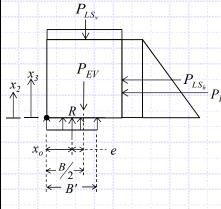
RESOURCE INTERNATIONAL, INC. 6350 PRESIDENTIAL GATEWAY COLUMBUS, OHIO 43231 PHONE: (614) 823-4949 FAX: (614) 823-4990 WWW.RESOURCEINTERATIONAL.COM

FRA-70-13.10 JOB W-13-072 SHEET NO. CALCULATED BY DATE 6/30/2019 CHECKED BY JPS DATE 7/1/2019 Retaining Wall W5 - Sta. 508+50 to 509+85

MSE Wall Dimensions and Retained Soil Param	<u>ieters</u>	Bearing So	oil Prop	erties:				
MSE Wall Height, (H) =	48.5 ft	Bearing Soil	Unit We	eight, (γ _{./}	_{BS}) =			120 pc
MSE Wall Width (Reinforcement Length), (B) =	38.8 ft	Bearing Soil	Friction	Angle, ($(\varphi_{BS}) =$			27 °
MSE Wall Length, (L) =	1031 ft	Bearing Soil	Drained	d Cohesi	on, (c_{BS}) =		0 ps
Live Surcharge Load, (σ_{LS}) =	250 psf	Bearing Soil	Undrair	ned Shea	ar Stren	gth,	$[(s_u)_{BS}] =$	3000 ps
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	Embedment	Depth,	$(D_f) =$				4.0 ft
Retained Soil Friction Angle, (φ_{RS}) =	30 °	Depth to Gro	ounwate	r (Below	Bot. of	Wal	$ (D_W) = $	10.0 ft
Retained Soil Drained Cohesion, (c_{BS}) =	0 psf	LRFD Load	d Facto	<u>rs</u>				
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}] =$	2000 psf		EV	EH	LS			
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.297	Strength la	1.00	1.50	1.75	٦	(AASHTO I PI	FD BDM Tables
MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf	Strength Ib	1.35	1.50	1.75	F	3.4.1-1 and 3	3.4.1-2 - Active
MSE Backfill Friction Angle, (φ_{BF}) =	34 °	Service I	1.00	1.00	1.00	J	Earth P	Pressure)

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

 $q_{eq} = \frac{P_V}{R'}$



$$B' = B - 2e = 38.8 \text{ ft} - 2(3.25 \text{ ft}) = 32.30 \text{ ft}$$

$$P_{LS_h} P_{EH} = B - 2e = 38.8 \text{ ft} - 2(3.25 \text{ ft}) = 32.30 \text{ ft}$$

$$e = B/2 - x_o = (38.8 \text{ ft}) / 2 - 16.15 \text{ ft} = 3.25 \text{ ft}$$

$$x_o = \frac{M_V - M_H}{P_V} = (4569.01 \text{ kip·ft/ft} - 765.13 \text{ kip·ft/ft}) / 235.52 \text{ kip/ft} = 16.15 \text{ ft}$$

 $q_{eq} = (235.52 \text{ kip/ft}) / (32.3 \text{ ft}) = 7.29$

$$M_{V} = P_{EV}(x_{1}) + P_{LS}(x_{1}) = (\gamma_{BE} \cdot H \cdot B \cdot \gamma_{EV})(x_{1}) + (\sigma_{LS} \cdot B \cdot \gamma_{LS})(x_{1})$$

 $M_V = [(120 \text{ pcf})(48.5 \text{ ft})(38.8 \text{ ft})(1.00)](19.4 \text{ ft}) + [(250 \text{ psf})(38.8 \text{ ft})(1.00)](19.4 \text{ ft}) = 4569.01 \text{ kip-ft/ft}$

$$M_{H} = P_{EH}(x_{2}) + P_{LS_{h}}(x_{3}) = (\frac{1}{2}\gamma_{RS}H^{2}K_{a}\gamma_{EH})(x_{2}) + (\sigma_{LS}HK_{a}\gamma_{LS})(x_{3})$$

 $M_H = [\frac{1}{2}(120 \text{ pcf})(48.5 \text{ ft})^2(0.297)(1.00)](16.17 \text{ ft}) + [(250 \text{ psf})(48.5 \text{ ft})(0.297)(1.00)](24.25 \text{ ft}) = 765.13 \text{ kip-ft/ft}$

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

 $P_{V} = (120 \, \mathrm{pcf})(48.5 \, \mathrm{ft})(38.8 \, \mathrm{ft})(1.00) + (250 \, \mathrm{psf})(38.8 \, \mathrm{ft})(1.00) = 235.52 \, \mathrm{kip/ft}$

Settlement, Time Rate of Consolidation and Differential Settlement:

 Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Along Wall Facing
B-102-5-14	9.024 in	3.611 in	105 days		
B-104-0-09	5.429 in	2.542 in	5 days	135 ft	1/1520
B-104-1-13	4.181 in	2.631 in	1 days	70 ft	1/9440

W-13-072 - FRA-70-13.10 - Retaining Wall W5
MSE Wall Settlement - Sta. 508+50 to 509+85

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Boring B-104-0-09

 $D_w =$

H= 45.5 ft Total wall height

B'= 30.3 ft Effective footing width due to eccentricity

10.0 ft Depth below bottom of footing

 q_e = 6,860 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of R	einforced So	il Mass		Total Set	tlement at Fa	cing of Wall	
Layer	Soil Class.	Soil Type		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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
1	A-6a	С	0.0	2.0	2.0	1.0	120	240	120	120	4,120	31	0.189	0.019	0.514				0.03	1.000	6,859	6,979	0.095	1.146	0.500	3,430	3,550	0.037	0.441
'	A-6a	С	2.0	4.5	2.5	3.3	120	540	390	390	4,390	31	0.189	0.019	0.514				0.11	0.996	6,833	7,223	0.100	1.203	0.500	3,428	3,818	0.031	0.371
2	A-6b	С	4.5	7.0	2.5	5.8	120	840	690	690	4,690	39	0.261	0.026	0.577				0.19	0.980	6,725	7,415	0.117	1.401	0.499	3,420	4,110	0.032	0.385
	A-1-a	G	7.0	9.5	2.5	8.3	125	1,153	996	996	4,996					23	28	94	0.27	0.950	6,517	7,513	0.023	0.279	0.496	3,403	4,399	0.017	0.205
3	A-1-a	G	9.5	12.0	2.5	10.8	125	1,465	1,309	1,262	5,262					23	27	90	0.35	0.908	6,226	7,488	0.022	0.259	0.492	3,374	4,636	0.016	0.189
	A-1-a	G	12.0	14.5	2.5	13.3	125	1,778	1,621	1,418	5,418					23	26	87	0.44	0.858	5,886	7,304	0.020	0.244	0.486	3,331	4,750	0.015	0.180
4	A-3a	G	14.5	17.0	2.5	15.8	125	2,090	1,934	1,575	5,575					18	19	66	0.52	0.806	5,527	7,102	0.025	0.297	0.478	3,277	4,852	0.018	0.222
5	A-1-a	G	17.0	21.5	4.5	19.3	125	2,653	2,371	1,794	5,794					13	13	62	0.64	0.734	5,034	6,828	0.042	0.506	0.464	3,182	4,977	0.032	0.386
6	A-1-a	G	21.5	23.5	2.0	22.5	130	2,913	2,783	2,003	6,003					40	40	131	0.74	0.672	4,611	6,614	0.008	0.095	0.449	3,080	5,083	0.006	0.074
1. σ _p ' = σ _v	o'+σ _{m;} Estima	ate $\sigma_{\rm m}$ of 4,00	00 psf (mode	erately overc	consolidated)	for natural s	oil deposits;	Ref. Table 1	1.2, Coduto	2003			•				•				Total	Settlement:		5.429 in		Total	Settlement:		2.452 in

^{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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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.} $\Delta \sigma_v = q_e$

 $^{9. \ \} S_c = [C_c/(1+e_o)](H)\log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_i}'; \ [C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') \\ \text{for } \sigma_{v_o}' < \sigma_p'; \ [C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') \\ \text{for } \sigma_{v_o}' < \sigma_p' < \sigma_{v_i}'; \ \text{Ref. Section } 10.6.2.4.3, \ \text{AASHTO LRFD BDS (Cohesive soil layers)} \\ \text{for } \sigma_{v_o}' < \sigma_{v_o}'$

^{10.} S_c = H(1/C')log(σ_{vf} // σ_{vo} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

MSE Wall Settlement - Sta. 508+50 to 509+85

Boring B-104-0-09

H=	45.5	ft	Total wall height		A-6a	A-6b		
B'=	30.3	ft	Effective footing width due to eccentricity	c _v =	600	300	ft²/yr	Coefficient of consolitation
$D_w =$	10.0	ft	Depth below bottom of footing	t =	5	5	days	Time following completion of construction
q _e =	6,860	psf	Equivalent bearing pressure at bottom of wall	H _{dr} =	3.5	2.5	ft	Length of longest drainage path considered
				$T_v =$	0.671	0.658		Time factor
				U =	85	84	%	Degree of consolidation
				$(S_c)_t =$	2.269	in	Settlement complete at	93% of primary consolidation

																										Filliary C	orisolidation
Layer	Soil Type	Soil Type	Layer (Depth	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⁾	Δσ _ν ⁽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)
4	A-6a	С	0.0	2.0	2.0	1.0	120	240	120	120	4,120	31	0.189	0.019	0.514				0.03	0.500	3,430	3,550	0.037	0.441	0.812	0.375	0.690
'	A-6a	С	2.0	4.5	2.5	3.3	120	540	390	390	4,390	31	0.189	0.019	0.514				0.11	0.500	3,428	3,818	0.031	0.371	0.612	0.315	0.690
2	A-6b	С	4.5	7.0	2.5	5.8	120	840	690	690	4,690	39	0.261	0.026	0.577				0.19	0.499	3,420	4,110	0.032	0.385	0.385	0.323	0.323
	A-1-a	G	7.0	9.5	2.5	8.3	125	1,153	996	996	4,996					23	28	94	0.27	0.496	3,403	4,399	0.017	0.205		0.205	
3	A-1-a	G	9.5	12.0	2.5	10.8	125	1,465	1,309	1,262	5,262					23	27	90	0.35	0.492	3,374	4,636	0.016	0.189	0.574	0.189	0.574
	A-1-a	G	12.0	14.5	2.5	13.3	125	1,778	1,621	1,418	5,418					23	26	87	0.44	0.486	3,331	4,750	0.015	0.180		0.180	
4	A-3a	G	14.5	17.0	2.5	15.8	125	2,090	1,934	1,575	5,575					18	19	66	0.52	0.478	3,277	4,852	0.018	0.222	0.222	0.222	0.222
5	A-1-a	G	17.0	21.5	4.5	19.3	125	2,653	2,371	1,794	5,794					13	13	62	0.64	0.464	3,182	4,977	0.032	0.386	0.386	0.386	0.386
6	A-1-a	G	21.5	23.5	2.0	22.5	130	2,913	2,783	2,003	6,003					40	40	131	0.74	0.449	3.080	5,083	0.006	0.074	0.074	0.074	0.074

- 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. $e_0 = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
- 5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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. $S_c = [C_o/(1+e_o)](H)\log(\sigma_{v_f}/\sigma_{v_o}')$ for $\sigma_p' \leq \sigma_{v_o}' < \sigma_{v_f}'$; $[C_f/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}')$ for $\sigma_{v_o}' < \sigma_{v_f}' < \sigma_{v_f}'$; $[C_f/(1+e_o)](H)\log(\sigma_{v_f}/\sigma_{v_o}')$ for $\sigma_{v_o}' < \sigma_{v_o}' < \sigma_{v_o}' < \sigma_{v_o}'$; 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

Calculated By: Date: 6/30/2019 JPS Checked By: Date: 7/1/2019

Settlement Remaining After Hold Period: 0.183 in

Total Settlement at Facing of Wall

Settlement Complete at 93% of

W-13-072 - FRA-70-13.10 - Retaining Wall W5
MSE Wall Settlement - Sta. 507+00 to 508+50

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Boring B-104-1-13

H= 48.5 ft Total wall height

B'= 32.3 ft Effective footing width due to eccentricity

D_w = 10.0 ft Depth below bottom of footing

q_e = 7,290 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of Re	einforced So	il Mass		Total Set	tlement at Fa	icing of Wall	
Layer	Soil Class.	Soil Type		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	1 ⁽⁷⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
1	A-6a	С	0.0	2.5	2.5	1.3	120	300	150	150	4,150	31	0.189	0.019	0.514				0.04	1.000	7,289	7,439	0.124	1.489	0.500	3,645	3,795	0.044	0.525
2	A-3a	G	2.5	5.0	2.5	3.8	120	600	450	450	4,450					12	18	64	0.12	0.995	7,254	7,704	0.048	0.582	0.500	3,643	4,093	0.038	0.452
	A-1-a	G	5.0	7.5	2.5	6.3	130	925	763	763	4,763					35	46	154	0.19	0.979	7,138	7,901	0.016	0.197	0.499	3,634	4,397	0.012	0.148
3	A-1-a	G	7.5	10.0	2.5	8.8	130	1,250	1,088	1,088	5,088					35	42	138	0.27	0.951	6,930	8,017	0.016	0.188	0.496	3,617	4,704	0.011	0.138
3	A-1-a	G	10.0	12.5	2.5	11.3	130	1,575	1,413	1,335	5,335					35	40	130	0.35	0.911	6,643	7,977	0.015	0.179	0.492	3,588	4,923	0.011	0.131
	A-1-a	G	12.5	15.0	2.5	13.8	130	1,900	1,738	1,504	5,504					35	38	125	0.43	0.865	6,307	7,811	0.014	0.172	0.487	3,547	5,051	0.011	0.126
1	A-1-a	G	15.0	18.0	3.0	16.5	135	2,305	2,103	1,697	5,697					54	57	201	0.51	0.811	5,915	7,612	0.010	0.117	0.479	3,489	5,186	0.007	0.087
7	A-1-a	G	18.0	21.5	3.5	19.8	135	2,778	2,541	1,933	5,933					54	55	190	0.61	0.748	5,455	7,388	0.011	0.129	0.467	3,404	5,337	0.008	0.098
5	A-1-b	G	21.5	26.5	5.0	24.0	130	3,428	3,103	2,229	6,229					28	27	91	0.74	0.672	4,899	7,127	0.028	0.333	0.449	3,273	5,502	0.022	0.259
6	A-1-b	G	26.5	31.5	5.0	29.0	135	4,103	3,765	2,579	6,579					120	110	550	0.90	0.594	4,331	6,910	0.004	0.047	0.425	3,101	5,680	0.003	0.037
7	A-1-b	G	31.5	36.5	5.0	34.0	115	4,678	4,390	2,892	6,892					3	3	48	1.05	0.529	3,857	6,749	0.038	0.458	0.401	2,922	5,814	0.031	0.378
8	A-1-b	G	36.5	40.5	4.0	38.5	135	5,218	4,948	3,169	7,169					120	102	482	1.19	0.480	3,499	6,668	0.003	0.032	0.379	2,762	5,931	0.002	0.027
9	A-1-a	G	40.5	43.5	3.0	42.0	140	5,638	5,428	3,431	7,431					120	99	457	1.30	0.447	3,258	6,689	0.002	0.023	0.362	2,643	6,073	0.002	0.020
10	A-6a	С	43.5	50.0	6.5	46.8	130	6,483	6,060	3,767	7,767	30	0.180	0.018	0.507				1.45	0.408	2,976	6,743	0.020	0.236	0.341	2,488	6,255	0.017	0.205
1. σ _p ' = σ _v	, _o '+σ _{m;} Estima	te $\sigma_{\rm m}$ of 4,0	00 psf (mode	erately over	consolidated)	for natural so	il deposits;	Ref. Table	11.2, Coduto	2003											Tota	Settlement:		4.181 in		Tota	l Settlement:		2.631 in

^{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 $C_N = [0.77 log(40/\sigma_{vo})] \le 2.0$ 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_{v'}/\sigma_{vo}) \\ \text{for } \sigma_p' \leq \sigma_{vo}' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for }$

^{10.} S_c = H(1/C')log(σ_{v_i} '/ σ_{v_o} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

MSE Wall Settlement - Sta. 507+00 to 508+50

Boring B-104-1-13

A-6a A-6a H= 48.5 ft Total wall height (Upper) (Lower) B'= 32.3 ft Effective footing width due to eccentricity 600 ft²/yr Coefficient of consolitation $c_v =$ 600 10.0 Depth below bottom of footing 1 1 days Time following completion of construction 7,290 Equivalent bearing pressure at bottom of wall $H_{dr} =$ 1.3 6.5 Length of longest drainage path considered $q_e =$ psf $T_v =$ 1.052 0.039 Time factor 22 Degree of consolidation U = 94 $(S_c)_t =$ 2.439 in Settlement complete at 93% of primary consolidation

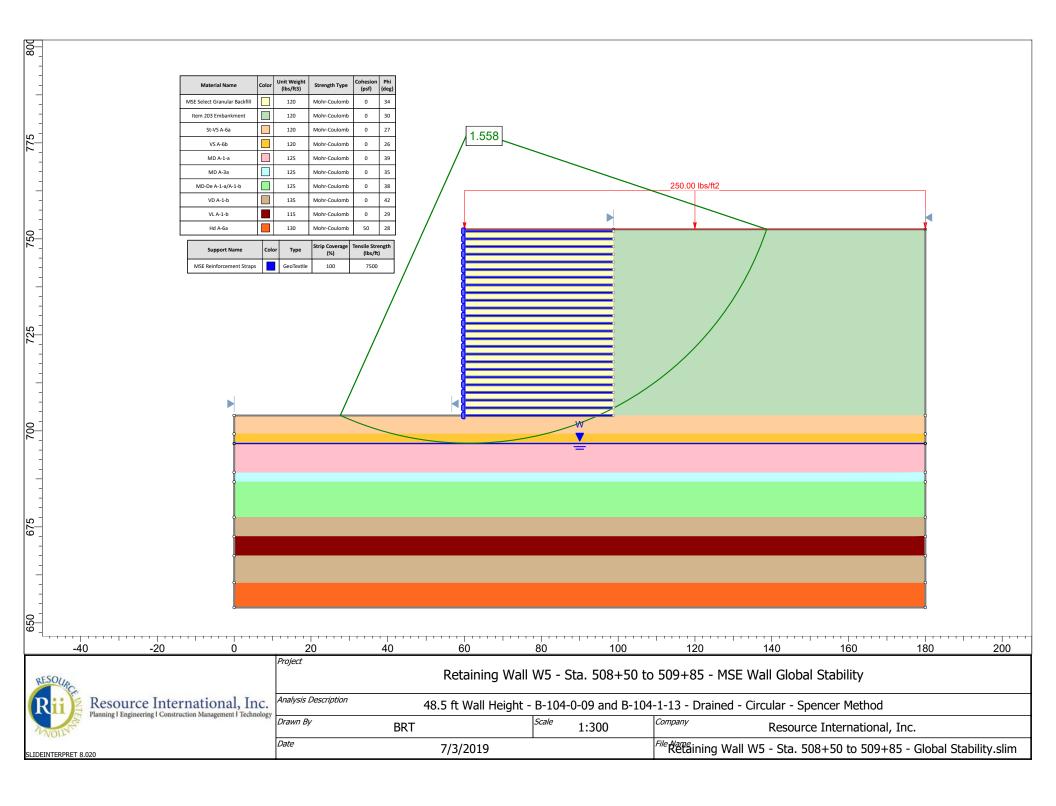
																							Total Se	ettlement at F	Facing of Wall		mplete at 93% of onsolidation
Layer	Soil Type	Soil Type	Layer (f	Depth ft)	Layer Thickness (ft)	Depth to Midpoint (ft)	γ (pcf)	σ _{vo} Bottom (psf)	σ _{vo} Midpoint (psf)	σ _{vo} ' Midpoint (psf)	$\sigma_p'^{(1)}$ (psf)	LL	C _c ⁽²⁾	C _r ⁽³⁾	e _o ⁽⁴⁾	N ₆₀	(N1) ₆₀ (5)	C' (6)	Z_f /B	I ⁽⁷⁾	Δσ _ν ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	Layer Settlement (in)	(S _c) _t ⁽¹¹⁾ (in)	Layer Settlement (in)
1	A-6a	С	0.0	2.5	2.5	1.3	120	300	150	150	4,150	31	0.189	0.019	0.514				0.04	0.500	3,645	3,795	0.044	0.525	0.525	0.494	0.494
2	A-3a	G	2.5	5.0	2.5	3.8	120	600	450	450	4,450					12	18	64	0.12	0.500	3,643	4,093	0.038	0.452		0.452	
	A-1-a	G	5.0	7.5	2.5	6.3	130	925	763	763	4,763					35	46	154	0.19	0.499	3,634	4,397	0.012	0.148		0.148	
2	A-1-a	G	7.5	10.0	2.5	8.8	130	1,250	1,088	1,088	5,088					35	42	138	0.27	0.496	3,617	4,704	0.011	0.138	1.082	0.138	1.082
3	A-1-a	G	10.0	12.5	2.5	11.3	130	1,575	1,413	1,335	5,335					35	40	130	0.35	0.492	3,588	4,923	0.011	0.131	1.002	0.131	1.002
	A-1-a	G	12.5	15.0	2.5	13.8	130	1,900	1,738	1,504	5,504					35	38	125	0.43	0.487	3,547	5,051	0.011	0.126		0.126	
1	A-1-a	G	15.0	18.0	3.0	16.5	135	2,305	2,103	1,697	5,697					54	57	201	0.51	0.479	3,489	5,186	0.007	0.087		0.087	
4	A-1-a	G	18.0	21.5	3.5	19.8	135	2,778	2,541	1,933	5,933					54	55	190	0.61	0.467	3,404	5,337	0.008	0.098	0.098	0.098	0.098
5	A-1-b	G	21.5	26.5	5.0	24.0	130	3,428	3,103	2,229	6,229					28	27	91	0.74	0.449	3,273	5,502	0.022	0.259	0.259	0.259	0.259
6	A-1-b	G	26.5	31.5	5.0	29.0	135	4,103	3,765	2,579	6,579					120	110	550	0.90	0.425	3,101	5,680	0.003	0.037	0.037	0.037	0.037
7	A-1-b	G	31.5	36.5	5.0	34.0	115	4,678	4,390	2,892	6,892					3	3	48	1.05	0.401	2,922	5,814	0.031	0.378	0.378	0.378	0.378
8	A-1-b	G	36.5	40.5	4.0	38.5	135	5,218	4,948	3,169	7,169					120	102	482	1.19	0.379	2,762	5,931	0.002	0.027	0.027	0.027	0.027
9	A-1-a	G	40.5	43.5	3.0	42.0	140	5,638	5,428	3,431	7,431					120	99	457	1.30	0.362	2,643	6,073	0.002	0.020	0.020	0.020	0.020
10	A-6a	С	43.5	50.0	6.5	46.8	130	6,483	6,060	3,767	7,767	30	0.180	0.018	0.507				1.45	0.341	2,488	6,255	0.017	0.205	0.205	0.045	0.045

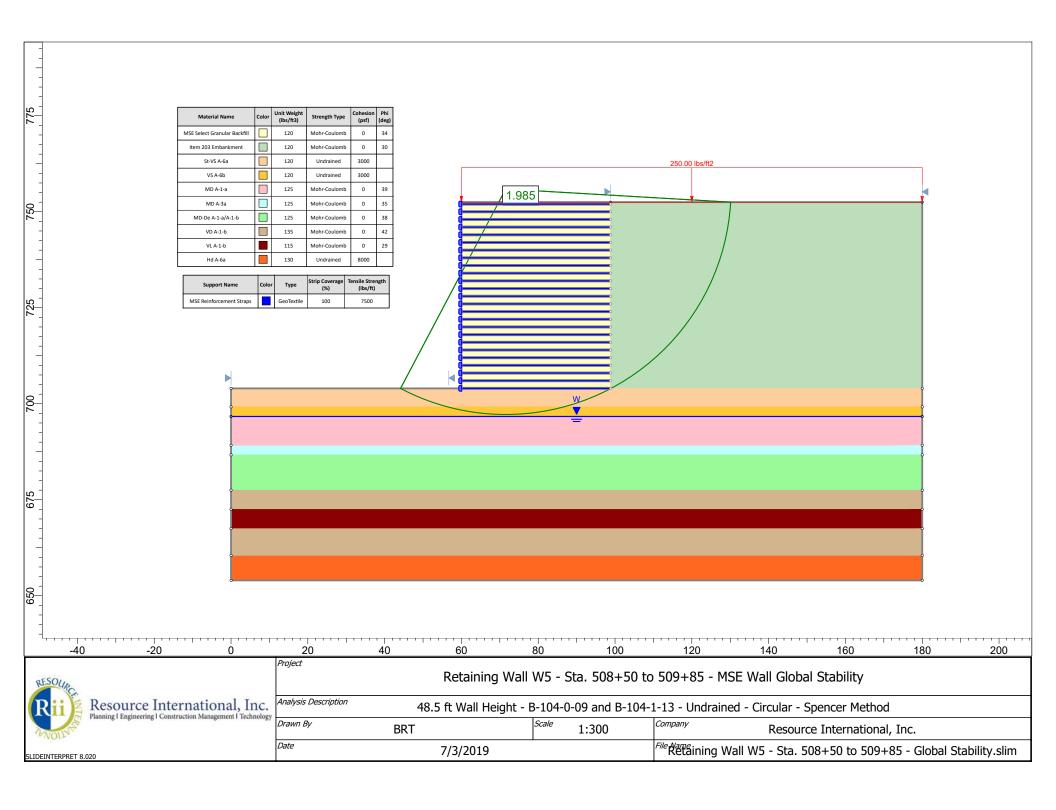
- 1. $\sigma_p' = \sigma_{vo}' + \sigma_{m}$; Estimate σ_m of 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
- 2. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
- 3. C_r = 0.10(Cc) for natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
- 4. e_o = (C_c/1.15)+0.35; Ref. Table 8-2, Holtz and Kovacs 1981
- 5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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. $S_c = [C_o/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v_o}')$ for $\sigma_p' \le \sigma_{v_o'}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}')$ for $\sigma_{v_o'}' \le \sigma_p'$ is $\sigma_{v_o'}' \le \sigma_{v_o'}' \le \sigma_{v_o'}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}')$ for $\sigma_{v_o'}' \le \sigma_{v_o'}' \le \sigma_{v_o'}' \le \sigma_{v_o'}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}')$ for $\sigma_{v_o'}' \le \sigma_{v_o'}'
- 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

Calculated By: BRT Date: 6/30/2019 Checked By: Date: 7/1/2019

Settlement Remaining After Hold Period: 0.192 in

Settlement Complete at 93% of







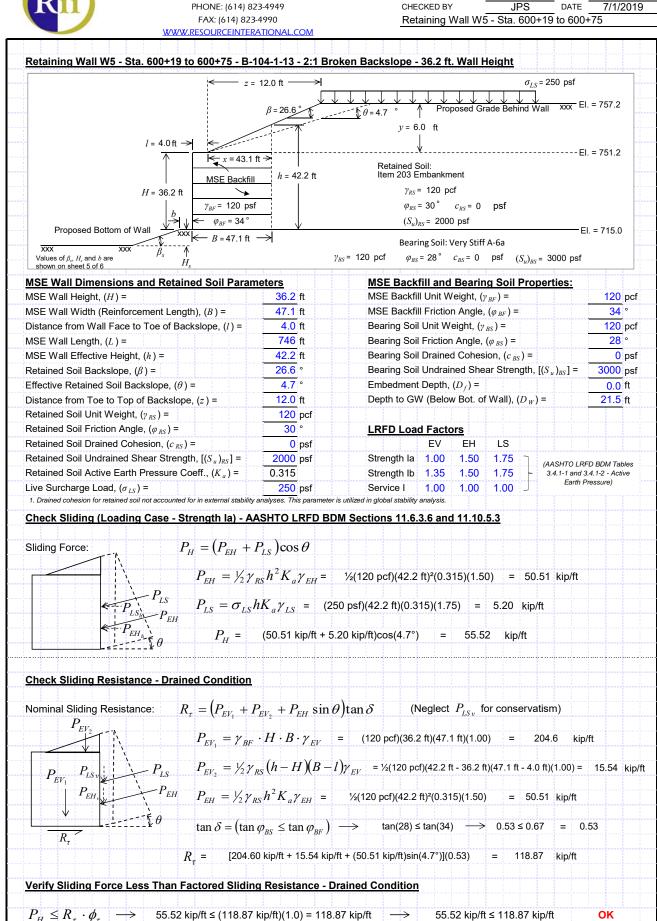
 JOB
 FRA-70-13.10
 NO.
 W-13-072

 SHEET NO.
 1
 OF
 6

 CALCULATED BY
 BRT
 DATE
 6/29/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta. 600+19 to 600+75



Use φ_{τ} = 1.0 (Per AASHTO LRFD BDM Table 11.5.6-1)



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FRA-70-13.10 JOB SHEET NO. CALCULATED BY DATE CHECKED BY

DATE 7/1/2019

W-13-072

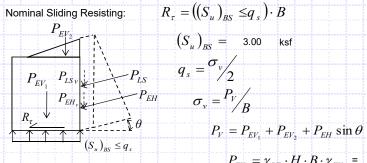
Retaining Wall W5 - Sta. 600+19 to 600+75

RESOURCE INTERNATIONAL, INC.
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MSE Wall Dimensions and Retained Soil Paran	neters	Bearing Soil Properties:	
MSE Wall Height, (H) =	36.2 ft	MSE Backfill Unit Weight, (γ_{BF}) =	l20 pcf
MSE Wall Width (Reinforcement Length), (B) =	47.1 ft	MSE Backfill Friction Angle, (φ_{BF}) =	34 °
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft	Bearing Soil Unit Weight, (γ_{BS}) =	20 pcf
MSE Wall Length, (L) =	746 ft	Bearing Soil Friction Angle, (φ_{BS}) =	28 °
MSE Wall Effective Height, (h) =	42.2 ft	Bearing Soil Drained Cohesion, (c_{BS}) =	0 psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}] = 30$	000 psf
Effective Retained Soil Backslope, (θ) =	4.7 °	Embedment Depth, (D_f) =	0.0 ft
Distance from Toe to Top of Backslope, (z) =	12.0 ft	Depth to GW (Below Bot. of Wall), (D_W) = 2	1.5 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf		
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Factors	
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV EH LS	
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	Strength la 1.00 1.50 1.75 7 (AASHTO LRED BD)	A Tables
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.315	Strength lb 1.35 1.50 1.75 - 3.4.1-1 and 3.4.1-2	- Active
Live Surcharge Load, (σ_{IS}) =	250 psf	Service I 1.00 1.00 1.00	e)

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

Check Sliding Resistance - Undrained Condition



$$\left(S_u^{}
ight)_{BS}^{}=$$
 3.00 ksf

$$q_s = \frac{\sigma_v}{2}$$

$$\sigma_v = \frac{P_V}{B}$$

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

(Neglect $P_{LS_{\nu}}$ for conservatism)

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

$$P_{EV_2}$$
 = ½(120 pcf)(42.2 ft - 36.2 ft)(47.1 ft - 4.0 ft)(1.00) = 15.54 kip/ft

 $P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(36.2 ft)(47.1 ft)(1.00) = 204.6 kip/ft

$$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(42.2 \text{ ft})^2 (0.315)(1.50) = 50.51 \text{ kip/ft}$$

$$P_V = 204.6 \text{ kip/ft} + 15.54 \text{ kip/ft} + (50.51 \text{ kip/ft}) \sin(4.7^\circ) = 224.28 \text{ kip/ft}$$

$$\sigma_{v} = (224.28 \text{ kip/ft}) / (47.1 \text{ ft}) = 4.76 \text{ ksf}$$

$$q_s = (4.76 \text{ ksf})/2 = 2.38 \text{ ksf}$$

$$R_{\tau} = (3.00 \text{ ksf} \le 2.38 \text{ ksf})(47.1 \text{ ft}) = 141.30 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

 $P_H \le R_\tau \cdot \phi_\tau \longrightarrow 55.52 \text{ kip/ft} \le (141.30 \text{ kip/ft})(1.0) = 141.30 \text{ kip/ft} \longrightarrow$ 55.52 kip/ft ≤ 141.30 kip/ft OK

Use $\varphi_{\tau} = 1.0$ (Per AASHTO LRFD BDM Table 11.5.6-1)



FRA-70-13.10 JOB SHEET NO. OF CALCULATED BY BRT DATE JPS CHECKED BY DATE

Retaining Wall W5 - Sta. 600+19 to 600+75

W-13-072

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MSE Wall Dimensions and Retained Soil Param	<u>neters</u>	Bearing Soil Prope	rties:	
MSE Wall Height, (H) =	36.2 ft	MSE Backfill Unit Wei	ght, (γ_{BF}) =	120 pcf
MSE Wall Width (Reinforcement Length), (B) =	47.1 ft	MSE Backfill Friction A	Angle, (φ_{BF}) =	34 °
Distance from Wall Face to Toe of Backslope, (I) =	4.0 ft	Bearing Soil Unit Weig	ght, (γ_{BS}) =	120 pcf
MSE Wall Length, (L) =	746 ft	Bearing Soil Friction A	$ngle, (\varphi_{BS}) =$	28 °
MSE Wall Effective Height, (h) =	42.2 ft	Bearing Soil Drained C	Cohesion, (c_{BS}) =	0 psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained	d Shear Strength,	$[(s_u)_{BS}] = 3000 \text{ psf}$
Effective Retained Soil Backslope, (θ) =	4.7 °	Embedment Depth, (D	$O_f) =$	0.0 ft
Distance from Toe to Top of Backslope, (z) =	12.0 ft	Depth to GW (Below E	Bot. of Wall), (D_W) = 21.5 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf			
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Factors	3	
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV	EH LS	
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}] =$	2000 psf	Strength la 1.00 1	1.50 1.75 🧵	(440,000,000,000,000,000,000,000,000,000
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.315		1.50 1.75 -	(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active
Live Surcharge Load, (σ_{IS}) =	250 psf		1.00 1.00	Earth Pressure)
Drained cohesion for retained soil not accounted for in external stability				
Check Eccentricity (Loading Case - Strength la) - AASHTO I RED	BDM Section 11 6 3 3		
P_{EV_2}	v			
$e = \frac{B}{2} -$	λ_o			
$ \begin{array}{c c} X_4 & P_{EV_1} & P_{LS} & P_{LS} \\ P_{EH} & P_{EH} & P_{EH} & P_{EH} \end{array} $	$_{V}-M_{H}$		0) / (004 001 : /6	
	$\frac{r}{D} = 5521.$	89 kip·ft/ft - 830.68 kip·ft/fi	t) / (224.28 kip/ft	. = 20.92 ft
$P_{EH_{\nu}}$	r_V			
D EII E C				
$\frac{1}{\sqrt{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1}{1+\frac{1+\frac{1+\frac{1}{1+1+\frac{1+\frac{1+\frac{1+\frac{1+\frac{1+\frac{1+\frac{1+\frac{1+\frac$	= 5521.89 ki	o·ft/ft	,	
	= 830.68 ki	ο∙π/π		
$x_o \not\models \qquad \Rightarrow e$	$= P_{EV_1} + P_{EV_2} + I$	$P_{EH} \sin \theta = 204.6 \text{ kip/ft} + 15.5$	54 kip/ft + (50.51 kip	o/ft)sin(4.7°) = 224.28 kip/
$x_{I} \leftarrow B/2 \rightarrow 1$	A			
$\rho - 1$	47.1 ft/ 2) - 20.92 ft	: = 2.63 ft		
Resisting Moment, M_V : $M_V = P_{rv}$	$(x_{-}) + P_{}(x_{-}) +$	$P_{EH} \sin \theta(B)$	(Nealect P_{is} f	or conservatism)
$P_{\scriptscriptstyle EV_2}$	(\mathcal{N}_1) (\mathcal{N}_2)	1 EH SIN O(D)	ν - 5 Ls ν	
P = 1	, .H.R. ₁ ,	= (120 pcf)(36.2 ft)(47	7 1 ft)(1 00) =	204.60 kip/ft
LEV ₁	$^{\prime}_{BF}$ 11 $^{\prime}$ $^{\prime}_{EV}$	- (120 pci)(30.2 it)(47	.111)(1.00) –	204.00 kip/it
P = 1	$\langle \chi (h H) \rangle R$	$I_{\text{out}} = \frac{1}{(120 \text{ pof})(42.2 \text{ ft})}$	36 2 ft\//47 1 ft //	0 ft)(1 00) = 15 54 kin/
$P_{EV_1} P_{LS} \bigvee_{D} P_{EV_2} = 1/2$	$_{2}\gamma_{RS}(n-11)(D-$	$l)\gamma_{EV}$ = ½(120 pcf)(42.2 ft -	30.2 11)(47.1 11 - 4.1	0 II)(1.00) – 13.34 KIP/
1 71 1 1 7	/ 12 **	1//100 5/10 0 5/2/0 0	245)(4.50)	50.54 1. 6
$P_{EH} = 1$	$\gamma_2 \gamma_{RS} h^2 K_a \gamma_{EH} =$	½(120 pcf)(42.2 ft)²(0.3	315)(1.50) =	50.51 kip/ft
V L				
$\bullet \qquad \qquad \downarrow \bullet \qquad \qquad \downarrow \bullet \qquad \qquad \downarrow \bullet \qquad \qquad \downarrow \qquad \qquad \qquad \downarrow \qquad \qquad \qquad \downarrow \qquad \qquad \qquad \downarrow \qquad \qquad \downarrow \qquad \qquad \qquad \downarrow \qquad \qquad \qquad \downarrow \qquad \qquad \qquad \downarrow \qquad \qquad \qquad \qquad \downarrow \qquad \qquad \qquad \downarrow \qquad \qquad \qquad \qquad \qquad \downarrow \qquad \qquad \qquad \qquad \qquad \downarrow \qquad \qquad \qquad \qquad \qquad \downarrow \qquad $	2 = (47.1 ft) / 2	= 23.55 ft		
$\longrightarrow x_I$	7			
$x_2 = l$	$+\frac{2}{3}(B-l) = 4$	4.0 ft + ⅔(47.1 ft - 4.0 ft) =	= 32.73 ft	
$M_{V} = (204.$	6 kip/ft)(23.55 ft) + (1	5.54 kip/ft)(32.73 ft) + (50.51 l	kip/ft)sin(4.7°)(47.	1 ft) = 5521.89 kip·
Overturning Moment, $M_{\scriptscriptstyle H}$: $M_{\scriptscriptstyle H}=P_{\scriptscriptstyle FH}$	$\cos\theta(x_3) + P_I$	$\cos\theta(x_4)$		
H EH		S		
-7% $P-1$	$/ v h^2 K v =$	½(120 pcf)(42.2 ft)²(0.3	315)(1 50) =	50.51 kin/ft
EH	$2 f_{RS} n K_a f_{EH}$	72(120 poi)(12.2 it) (0.0	310)(1.00)	00.01 кір/п
	- <i>l.V</i>	(250 psf)(42.2 ft)(0.315)(1.7 = 14.07 ft	75) – 500	lein/ft
χ_4 $P_{LS} = 0$	$\sigma_{LS} n \kappa_a \gamma_{LS} =$	(250 psr)(42.2 it)(0.515)(1.7	(5) = 5.62	кір/ії
$\uparrow \mid P_{LS} \mid P_{FH} \mid h$	/40.050.40	44.07 6		
$x_3 = h$	$3 = (42.2 \pi)/3$	= 14.07 π		
$\frac{1-EH_h}{h}$	/			
$x_4 = y$	2 = (42.2 ft) / 2	= 21.1 ft		
$M_{H} = (50.5)$	1 kip/ft)cos(4.7°)(14.	07 ft) + (5.82 kip/ft)cos(4.7°)	(21.10 ft) = 8	30.68 kip-ft/ft
	5 /			
Check Eccentricity Limiting Eccentricity:	$e_{\text{max}} = B/2$	$\rightarrow e_{\rm max} = (47.$	1 ft) / 3 =	15.70 ft
		11100		
$e < e_{\rm max} \longrightarrow 2.63 {\rm ft} < 15.70 {\rm ft}$	OK			
max				



FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF 6 CALCULATED BY BRT DATE 6/29/2019 JPS 7/1/2019 CHECKED BY DATE Retaining Wall W5 - Sta. 600+19 to 600+75

	(: (614) 823-4990	Retaining Wall W5 - Sta. 600)+19 to 600+75
WWW.RESOL	<u>URCEINTERATIONAL.COM</u>		
MSE Wall Dimensions and Retained S	oil Parameters	Bearing Soil Properties:	
MSE Wall Height, (H) =	36.2 ft	MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf
MSE Wall Width (Reinforcement Length), (B	r) = 47.1 ft	MSE Backfill Friction Angle, (φ_{BF}) =	34 °
Distance from Wall Face to Toe of Backslop	e, (<i>l</i>) = 4.0 ft	Bearing Soil Unit Weight, (γ_{BS}) =	120 pcf
MSE Wall Length, (L) =	746 ft	Bearing Soil Friction Angle, (φ_{BS}) =	28 °
MSE Wall Effective Height, (h) =	42.2 ft	Bearing Soil Drained Cohesion, (c_{BS}) =	0 psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained Shear Strength	$[(s_u)_{BS}] = 3000 \text{ psf}$
Effective Retained Soil Backslope, (θ) =	4.7 °	Embedment Depth, (D_f) =	0.0 ft
Distance from Toe to Top of Backslope, (z)	= 12.0 ft	Depth to GW (Below Bot. of Wall), (D_W) = 21.5 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf		
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Factors	
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV EH LS	
Retained Soil Undrained Shear Strength, [(S		Strength la 1.00 1.50 1.75	
Retained Soil Active Earth Pressure Coeff.,	ກັກກຳກັກການກອ້ານການເອົາ	Strength lb 1.35 1.50 1.75	(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active
Live Surcharge Load, (σ_{IS}) =	250 psf	Service I 1.00 1.00 1.00	Earth Pressure)
Drained cohesion for retained soil not accounted for in ex			
Check Bearing Capacity (Loading Cas	e - Strength lb) - AASHTC	LRFD BDM Section 11.6.3.2	
P_{EV_2}			
	D /		
	$q_{eq} = \frac{P_V}{R'}$		
and an armedia and an armedia and armedia arme	1 eq / B		
X_4 P_{EV_1} P_{LS}	B' = B - 2e = 47	7.1 ft - 2(1.79 ft) = 43.52 ft	
X_3 P_{EH} P_{EH}	$D = D - 2\epsilon$		
\bigwedge^3	$\rho = B/_{-} r$	= (47.1 ft / 2) - 21.76 ft = 1.79 ft	
R^{\vee}	/ 2		
	$M_V - M_H$	- = (7386.35 kip·ft/ft - 830.68 kip·ft/ft) / 3	201 22 kip/ft = 21 76 ft
	$\lambda_o = \frac{1}{P_{cc}}$	$= (7380.33 \text{ Kip}^{-1})/(1-830.08 \text{ Kip}^{-1})/(13)$	001.33 KIP/IL = 21.70 II
X ₀ + +>	- <i>V</i>		
$ \leftarrow B_2 \rightarrow \downarrow $	(004 00 L; (fi)) //40 = 0 50	
<i>← B'</i> →	$q_{eq} = (301.33 \text{KIP/TI})$) / (43.52 ft) = 6.92 ksf	
$ x_2 \rightarrow 1$			
Resisting Moment, $M_{_{I\!\!\!/}}$: $M_{_{I\!\!\!/}}$	$P_{EV_1}(x_1) + P_{EV_2}(x_2)$	$+P_{EH}\sin\theta(B)$	
D			0-004
P_{EV_2}	$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$	= (120 pcf)(36.2 ft)(47.1 ft)(1.35) =	276.21 kip/ft
	$P_{EV_2} = \frac{1}{2} \gamma_{RS} (h - H) (B -$	$(-l)\gamma_{EV} = \frac{1}{2}(120 \text{ pcf})(42.2 \text{ ft - } 36.2 \text{ ft})(47.1 \text{ ft - } 4.2 \text{ ft})$	0 ft(1.35) = 20.98 kip/ft
$P_{\scriptscriptstyle LS}$			
E' \ D	$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH}$	$= \frac{1}{2}(120 \text{ pcf})(42.2 \text{ ft})^2(0.315)(1.50) =$	50.51 kip/ft
م نے ۔ ۔ ۔ ا ا	$x_1 = B/2 = (47.1 \text{ ft})/2$	2 = 23.55 ft	
$\rightarrow x_I$	$x_2 = l + \frac{2}{3}(B - l) =$	$4.0 \text{ ft} + \frac{2}{3}(47.1 \text{ ft} - 4.0 \text{ ft}) = 32.73 \text{ ft}$	
$\rightarrow x_2$			
$M_{ u}$	= (276.21 kip/ft)(23.55 ft) +	$(20.98 \text{ kip/ft})(32.7 \text{ ft}) + (50.51 \text{ kip/ft})\sin(4.7^{\circ})(47.8 \text{ kip/ft})\sin(4.7^{\circ})$	1 ft) = 7386.35 kip⋅ft/
Overturning Moment, $M_{\scriptscriptstyle H}$: M	$P_{EH} = P_{EH} \cos \theta(x_3) + P$	$P_{IS}\cos\theta(x_4)$	
	$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_{R} \gamma_{EH}$	= $\frac{1}{2}(120 \text{ pcf})(42.2 \text{ ft})^2(0.315)(1.50)$ =	50.51 kip/ft
	EH /2/KS d/EH		
x_4 P_{LS}	$P_{rg} = \sigma_{rg} h K \gamma_{rg} =$	(250 psf)(42.2 ft)(0.315)(1.75) = 5.82	kip/ft
1.4 LS			
x_3 P_{EH}	$x_2 = h/2 = (42.2 \text{ ft})/3$	3 = 14.07 ft	
X_3	$x_3 = h/3 = (42.2 \text{ ft})/3$		
<u></u>	$x_4 = h/2 = (42.2 \text{ ft})/2$	2 = 21.1 ft	
	4 /2 - (72.211)/2		
A.A.	$_{-} = (50.51 \text{kin/ft}) \cos(4.7^{\circ})(4.4)$	4.07 ft) + (5.82 kip/ft)cos(4.7°)(21.10 ft) = 8	330.68 kip·ft/ft
M_{H}	7 – (30.3 i Kip/it)COS(4.7)(14	τ.σ. τις τ (σ.σ. κιμ/π./ουδ(4.7.)(21.10 π.) = - δ	סט.טט אוףיועונ
Vertical Forces, P_V : P_V	_ D D D =:	20	
P_{V}	$= P_{EV_1} + P_{EV_2} + P_{EH} \operatorname{si}$	110	
	D = 276 24 kin/# + 20 00	8 kin/ft + (50.51 kin/ft)sin/4.7% = 204.22	kin/ft
	$r_V = 270.21 \text{ kip/it} + 20.98$	8 kip/ft + (50.51 kip/ft)sin(4.7°) = 301.33	kip/ft



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FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF 6 CALCULATED BY BRT DATE 6/29/2019 JPS 7/1/2019 CHECKED BY DATE Retaining Wall W5 - Sta. 600+19 to 600+75

ISE Wall Dimensions and Retained Soil Par	<u>ameters</u>	Bearing Soil Proper	<u>ties:</u>		
/ISE Wall Height, (H) =	36.2 ft	MSE Backfill Unit Weiç	ght, (γ_{BF}) =		120 pcf
ISE Wall Width (Reinforcement Length), (B) =	47.1 ft	MSE Backfill Friction A	$\log (\varphi_{BF}) =$		34 °
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft	Bearing Soil Unit Weig	ht, (γ_{BS}) =		120 pcf
ISE Wall Length, (<i>L</i>) =	746 ft	Bearing Soil Friction A	ngle, (φ_{BS}) =		28 °
ISE Wall Effective Height, (h) =	42.2 ft	Bearing Soil Drained C	Cohesion, (c_{BS}) =		0 psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained	d Shear Strength,	$[(s_u)_{BS}] =$	3000 psf
ffective Retained Soil Backslope, (θ) =	4.7 °	Embedment Depth, (D	_f) =		0.0 ft
Distance from Toe to Top of Backslope, (z) =	12.0 ft	Depth to GW (Below B	Sot. of Wall), $(D_{\it W})$		21.5 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf				
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Factors			
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV I	EH LS		
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	Strength la 1.00 1	.50 1.75	(AASHTO LRFD	BDM Tables
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.315	Strength lb 1.35 1	.50 1.75 -	3.4.1-1 and 3.4.	.1-2 - Active
ive Surcharge Load, (σ_{LS}) = 1. Drained cohesion for retained soil not accounted for in external stab	250 psf		.00 1.00	Earth Pres	ssure)
Check Bearing Capacity (Loading Case - Stro Check Bearing Resistance - Drained Condition		RFD BDM Section 11.10).5.4 (Continued)		
lominal Bearing Resistance: $q_{_{n}}=cN_{_{cm}}$	$+ \gamma D_f N_{qm} C_{wq} + \frac{1}{2}$	$_{2}^{\prime}\gamma B^{\prime}N_{_{eta m}}C_{_{w\gamma}}$			
$N_{cm} = N_c s_c i_c = 25.8$	$N_{qm} = N_q s_q d_q i_q$	= 14.7 \(\lambda\)	$V_{\gamma m} = N_{\gamma} s_{\gamma} i_{\gamma}$	= 16.7	
N - 25 200	N - 44700		N = 40.700		
$N_c = 25.800$	$N_q = 14.720$	40.60	$N_{\gamma} = 16.720$	EO #/740 #\	- 1000
S _c = 1+(43.52 ft/746 ft)(14.72/25.8) = 1.000	rannonation de la company	46 ft)tan(28°) = 1.000	$s_{\gamma} = 1-0.4(43)$ $i_{\gamma} = 1.000$		- 1.000
	rānum ratum ratum ratum ratum tien ratum tie	-sin(28°)]²tan ⁻¹ (0.0 ft/43.52 ft)	aagaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa		0f - 05
i_c = 1.000 (Assumed)	= 1.000		$C_{wy} = 21.5 \text{ft} < 1$.5(43.52 ft) + 0.0	υπ – 0.5
	; - 4000 4				
$q_n = (0 \text{ psf})(25.8) + (120 \text{ pcf})(0.0 \text{ ft})(10.0 \text{ ft})$		ft = 1.000 43.5 ft)(16.7)(0.5) =			
erify Equivalent Pressure Less Than Factor	$C_{wq} = 21.5 \text{ft} > 0.0$ 4.7)(1.0) + ½(120 pcf)(ft = 1.000 43.5 ft)(16.7)(0.5) =	21.83 ksf	.24 ksf	OK
	$C_{wq} = 21.5 \text{ ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{ pcf})(120 \text$	ft = 1.000 43.5 ft)(16.7)(0.5) = <u>ee</u> .65) = 7.24 ksf>	21.83 ksf 6.92 ksf ≤ 7		
/erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92$ k	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(120 $	ft = 1.000 43.5 ft)(16.7)(0.5) = <u>ee</u> .65) = 7.24 ksf>	21.83 ksf 6.92 ksf ≤ 7		
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 ext{ (Per AASHTO LRFD BDM Use } \varphi_b = 0.65 ext{ (Per AASHTO LRFD BDM Check Bearing Resistance - Undrained Concessions)}$	$C_{wq} = 21.5 \text{ft} > 0.0$ 4.7)(1.0) + ½(120 pcf)(red Bearing Resistance sf \leq (21.83 ksf)(0.51)(0.44 Section 10.6.3.1.2c) 11 Table 11.5.6-1) Sittion	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{18.6}{10.00}$.65) = 7.24 ksf \rightarrow \rightarrow Use $\beta_s = \frac{18.6}{10.00}$	21.83 ksf 6.92 ksf ≤ 7		
The second density of	$C_{wq} = 21.5 \text{ft} > 0.0$ 4.7)(1.0) + $\frac{1}{2}$ (120 pcf)(red Bearing Resistance sf \leq (21.83 ksf)(0.51)(0.0) 4 Section 10.6.3.1.2c) — 4 Table 11.5.6-1) littion $+ \gamma D_f N_{qm} C_{wq} + \frac{1}{2}$	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{18.6}{10.00}$.65) = 7.24 ksf \rightarrow \rightarrow Use $\beta_s = \frac{18.6}{10.00}$ $\frac{18.6}{2} \gamma B' N_{\gamma m} C_{w\gamma}$	21.83 ksf 6.92 ksf ≤ 7 0 $H_s = 1$	0.0 ft b	= 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 (Per AASHTO LRFD BDM Use \varphi_b = 0.65 (Per AASHTO LRFD BDM eleck Bearing Resistance - Undrained Conclusioninal Bearing Resistance: q_n = cN_{cm} N_{cm} = N_c s_c i_c = 5.140$	$C_{wq} = 21.5 \text{ft} > 0.0$ 4.7)(1.0) + ½(120 pcf)(red Bearing Resistance sf ≤ (21.83 ksf)(0.51)(0 4 Section 10.6.3.1.2c) — 4 Table 11.5.6-1) Sition + $\gamma D_f N_{qm} C_{wq} + \frac{1}{2}$ $N_{qm} = N_q s_q d_q i_q$	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{18.6}{10.00}$.65) = 7.24 ksf \rightarrow \rightarrow Use $\beta_s = \frac{18.6}{10.00}$ $\frac{18.6}{2} \gamma B' N_{\gamma m} C_{w\gamma}$	21.83 ksf $6.92 \text{ ksf} \le 7$ $0^{\circ} H_s = 1$ $I_{ym} = N_{\gamma} s_{\gamma} i_{\gamma}$	0.0 ft b	= 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 (Per AASHTO LRFD BDM Use \varphi_b = 0.65 (Per AASHTO LRFD BDM eleck Bearing Resistance - Undrained Conclusioninal Bearing Resistance: q_n = cN_{cm} N_{cm} = N_c s_c i_c = 5.140 N_c = 5.140$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(120 $	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{18.6}{10.00}$.65) = 7.24 ksf \rightarrow \rightarrow Use $\beta_s = \frac{18.6}{10.00}$ $\frac{18.6}{2} \gamma B' N_{\gamma m} C_{w\gamma}$	21.83 ksf $6.92 \text{ ksf} \le 7$ $0^{\circ} H_s = 1$ $I_{ym} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$	0.0 ft b	= 0.0
Perify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 \text{(Per AASHTO LRFD BDM)}$ Use $\varphi_b = 0.65 \text{(Per AASHTO LRFD BDM)}$ Check Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(43.52 \text{ft/[(5)(746 \text{ft)]}} = 1.000$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(120 $	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{180}{1000}$.65) = 7.24 ksf \rightarrow \rightarrow Use β_s = 18.0 $\frac{1}{2} \gamma B' N_{\gamma m} C_{w\gamma}$ = 1.000 Λ	21.83 ksf $6.92 \text{ ksf} \le 7$ $0^{\circ} H_s = 1$ $N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$	0.0 ft b	= 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 (Per AASHTO LRFD BDN Use \varphi_b = 0.65 (Per AASHTO LRFD BDN Check Bearing Resistance - Undrained Conclusioninal Bearing Resistance: q_n = cN_{cm} N_{cm} = N_c s_c i_c = 5.140 N_c = 5.140$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(120 $	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{18.6}{10.00}$.65) = 7.24 ksf \rightarrow \rightarrow Use $\beta_s = \frac{18.6}{10.00}$ $\frac{18.6}{2} \gamma B' N_{\gamma m} C_{w\gamma}$	21.83 ksf $6.92 \text{ ksf} \le 7$ $0^{\circ} H_s = 1$ $N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	0.0 ft b = 0.000 (Assumed)	= 0.0
Perify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 \text{(Per AASHTO LRFD BDM)}$ Use $\varphi_b = 0.65 \text{(Per AASHTO LRFD BDM)}$ Check Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(43.52 \text{ft/[(5)(746 \text{ft)]}} = 1.000$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(120 $	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{100}{100}$.65) = 7.24 ksf \rightarrow $\frac{1000}{100}$ $\frac{1000}{100}$ $\frac{1000}{100}$ -sin(0°)] ² tan ⁻¹ (0.0 ft/43.52 ft)	21.83 ksf $6.92 \text{ ksf} \le 7$ $0^{\circ} H_s = 1$ $N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$	0.0 ft b = 0.000 (Assumed)	= 0.0
Perify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 \text{(Per AASHTO LRFD BDM)}$ Use $\varphi_b = 0.65 \text{(Per AASHTO LRFD BDM)}$ Check Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(43.52 \text{ft/[(5)(746 \text{ft)]}} = 1.000$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(1.0) + \frac$	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{120}{100}$.65) = 7.24 ksf \longrightarrow \implies Use $\beta_s = \frac{18.0}{100}$ $\frac{1}{2} \gamma B' N_{\gamma m} C_{wy}$ = 1.000 Λ -sin(0°)] ² tan ⁻¹ (0.0 ft/43.52 ft)	21.83 ksf $6.92 \text{ ksf} \le 7$ $0^{\circ} H_s = 1$ $N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	0.0 ft b = 0.000 (Assumed)	= 0.0
Perify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 \text{(Per AASHTO LRFD BDM)}$ Use $\varphi_b = 0.65 \text{(Per AASHTO LRFD BDM)}$ Check Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(43.52 \text{ft/[(5)(746 \text{ft)]}} = 1.000$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(120 $	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{120}{100}$.65) = 7.24 ksf \longrightarrow \implies Use $\beta_s = \frac{18.0}{100}$ $\frac{1}{2} \gamma B' N_{\gamma m} C_{wy}$ = 1.000 Λ -sin(0°)] ² tan ⁻¹ (0.0 ft/43.52 ft)	21.83 ksf $6.92 \text{ ksf} \le 7$ $0^{\circ} H_s = 1$ $N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	0.0 ft b = 0.000 (Assumed)	= 0.0
Perify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 \text{(Per AASHTO LRFD BDM)}$ Use $\varphi_b = 0.65 \text{(Per AASHTO LRFD BDM)}$ Check Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(43.52 \text{ft/[(5)(746 \text{ft)]}} = 1.000$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(1.0) + \frac$	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{120}{100}$.65) = 7.24 ksf \rightarrow \rightarrow Use $\beta_s = \frac{18.0}{100}$ $\frac{1}{2} \frac{\gamma B^{\dagger} N_{\gamma m} C_{w\gamma}}{100}$ = 1.000 Λ -sin(0°)] ² tan ⁻¹ (0.0 ft/43.52 ft)	21.83 ksf $6.92 \text{ ksf} \le 7$ $0^{\circ} H_s = 1$ $N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	0.0 ft b = 0.000 (Assumed)	= 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 (Per AASHTO LRFD BDM)$ Use $\varphi_b = 0.65 (Per AASHTO LRFD BDM)$ Check Bearing Resistance - Undrained Concombinal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(43.52 \mathrm{ft/[(5)(746 ft)]} = 1.000$ $i_c = 1.000 (Assumed)$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(1.0) + \frac$	ft = 1.000 43.5 ft)(16.7)(0.5) = $\frac{18.6}{10.00}$.65) = 7.24 ksf \rightarrow \rightarrow Use β_s = 18.0 $\frac{1}{2} \gamma B' N_{\gamma m} C_{w\gamma}$ = 1.000 Λ .sin(0°)] ² tan ⁻¹ (0.0 ft/43.52 ft) .sumed) ft = 1.000	21.83 ksf 6.92 ksf \leq 7 O° $H_{s} = 1$ $N_{\gamma} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$ $C_{w\gamma} = 21.5 \text{ft} < 1$	0.0 ft b = 0.000 (Assumed)	= 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \rightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 (Per AASHTO LRFD BDM)$ Use $\varphi_b = 0.65 (Per AASHTO LRFD BDM)$ Check Bearing Resistance - Undrained Concombinated Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(43.52 \mathrm{ft}/[(5)(746 \mathrm{ft})] = 1.000$ $i_c = 1.000 (Assumed)$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(1.0) + \frac$	ft = 1.000 43.5 ft)(16.7)(0.5) = 69 .65) = 7.24 ksf \longrightarrow Where β_s = 18.0 2 $\gamma B' N_{\gamma m} C_{wy}$ = 1.000 Λ -sin(0°)] ² tan ⁻¹ (0.0 ft/43.52 ft) sumed) ft = 1.000 f)(43.5 ft)(0.0)(0.5) = 69	21.83 ksf 6.92 ksf \leq 7 0° $H_s = 1$ $N_y = N_y S_y i_y$ $N_y = 0.000$ $S_y = 1.000$ $i_y = 1.000$ $C_{wy} = 21.5 \text{ft} < 1$ 15.42 ksf	= 0.000 (Assumed) .5(43.52 ft) + 0.0	= 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 6.92 \mathrm{k}$ $RC_{BC} = 0.51 (Per AASHTO LRFD BDM)$ Use $\varphi_b = 0.65 (Per AASHTO LRFD BDM)$ Check Bearing Resistance - Undrained Concombinal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(43.52 ft/(5)(746 ft)) = 1.000$ $i_c = 1.000 (Assumed)$ $q_n = (3000 \mathrm{psf})(5.14) + (120 \mathrm{pcf})(0.0 ft)$ $N_c = 1 t(43.52 t/(5)(746 ft)) = 1.000$	$C_{wq} = 21.5 \text{ft} > 0.0$ $4.7)(1.0) + \frac{1}{2}(120 \text{pcf})(1.0) + \frac$	ft = 1.000 43.5 ft)(16.7)(0.5) = 69 .65) = 7.24 ksf \longrightarrow Where β_s = 18.0 2 $\gamma B' N_{\gamma m} C_{wy}$ = 1.000 Λ -sin(0°)] ² tan ⁻¹ (0.0 ft/43.52 ft) sumed) ft = 1.000 f)(43.5 ft)(0.0)(0.5) = 69	21.83 ksf 6.92 ksf \leq 7 0° $H_s = 1$ $N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$ $C_{w\gamma} = 21.5 \text{ft} < 1$ 15.42 ksf 6.92 ksf \leq 8	0.0 ft b = 0.000 (Assumed) .5(43.52 ft) + 0.1	= 0.0



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

FRA-70-13.10 JOB SHEET NO. CALCULATED BY DATE JPS CHECKED BY DATE

W-13-072 6/29/2019 7/1/2019

Retaining Wall W5 - Sta. 600+19 to 600+75

MSE Wall Dimensions and Retained Soil Paran	neters
MSE Wall Height, (H) =	36.2 ft
MSE Wall Width (Reinforcement Length), (B) =	47.1 ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft
MSE Wall Length, (L) =	746 ft
MSE Wall Effective Height, (h) =	42.2 ft
Retained Soil Backslope, (β) =	26.6 °
Effective Retained Soil Backslope, (θ) =	4.7 °
Distance from Toe to Top of Backslope, (z) =	12.0 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) =	0.315
Live Surcharge Load, (σ_{LS}) =	250 psf

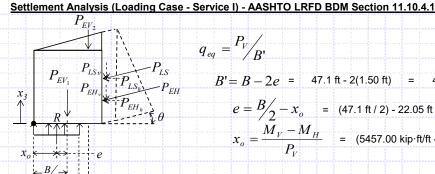
Bearing Soil Properties:		
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	0
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	0
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	3000	psf
Embedment Depth, (D_f) =	0.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	21.5	ft

LRFD Load Factors

	LV	LII	LO	
Strength la	1.00	1.50	1.75	٦
Strength lb	1.35	1.50	1.75	}
Service I	1.00	1.00	1.00	J

(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.



 $q_{eq} = \frac{P_V}{B'}$

$$B' = B - 2e = 47.1 \text{ ft} - 2(1.50 \text{ ft}) = 44.10 \text{ ft}$$

$$e = \frac{B}{2} - x_o = (47.1 \text{ ft / 2}) - 22.05 \text{ ft} = 1.50$$

$$x_o = \frac{M_V - M_H}{P_V}$$
 = (5457.00 kip·ft/ft - 542.08 kip·ft/ft) / 222.90 kip/ft = 22.05 ft

$$q_{eq} = (222.9 \, \text{kip/ft}) \, / \, (44.1 \, \text{ft}) = 5.05 \, \text{ksf}$$

$$M_{V} = P_{EV_{1}}(x_{1}) + P_{EV_{2}}(x_{2}) + P_{EH} \sin \theta(B) = (\gamma_{BF} H B \gamma_{EV})(\gamma_{2} B) + (\gamma_{2} \gamma_{RS} (h - H)(B - I)\gamma_{EV})(I + \gamma_{3} (B - I)) + (\gamma_{2} \gamma_{RS} h^{2} K_{a} \gamma_{EH} \sin \theta)(B)$$

 $M_V =$ [(120 pcf)(36.2 ft)(47.1 ft)(1.00)][½(47.1 ft)] + [½(120 pcf)(42.2 ft - 36.2 ft)(47.1 ft - 4.0 ft)(1.00)][4.0 ft + ¾(47.1 ft - 4.0 ft)] 5457 kip·ft/ft + [1/2(120 pcf)(42.2 ft)2(0.315)(1.00)sin(4.7°)](47.1 ft)

$$M_{H} = P_{EH} \cos \theta(x_3) + P_{LS} \cos \theta(x_4) = \left(\frac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH} \cos \theta\right)\left(\frac{h}{3}\right) + \left(\sigma_{LS}hK_a\gamma_{LS} \cos \theta\right)\left(\frac{h}{3}\right)$$

= 542.08 kip·ft/ft ½[(120 pcf)(42.2 ft)²(0.315)(1.00)cos(4.7°)](42.2 ft /3) + [(250 psf)(42.2 ft)(0.315)(1.00)cos(4.7°)](42.2 ft /2)

$$P_{V} = P_{EV_{1}} + P_{EV_{2}} + P_{EH} \sin \theta = (\gamma_{BF} H B \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} (h - H)(B - l) \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} h^{2} K_{a} \gamma_{EH} \sin \theta)$$

 $P_V = (120 \text{ pcf})(36.2 \text{ ft})(47.1 \text{ ft})(1.00) + \frac{1}{2}(120 \text{ pcf})(42.2 \text{ ft} - 36.2 \text{ ft})(47.1 \text{ ft} - 4.0 \text{ ft})(1.00) = 222.9 \text{ kip/ft}$ + ½(120 pcf)(42.2 ft)²(0.315)(1.00)sin(4.7°)

Settlement, Time Rate of Consolidation and Differential Settlement:

B-104-1-13	2.412 in 1.872 in	15 days 3 days	85 ft	
B-105-5-14 3.512 in		3 davs	0E #	
			00 11	1/1890
	1.535 in	5 days	145 ft	1/5160
B-107-2-14 2.946 in	1.321 in	1 days	135 ft	1/7570
B-108-7-14 2.403 in	1.341 in	1 days	160 ft	1/96000
B-108-8-14 0.950 in	0.694 in	3 days	130 ft	1/2410

W-13-072 - FRA-70-13.10 - Retaining Wall W5
MSE Wall Settlement - Sta. 600+19 to 600+75

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Boring B-104-1-13

H= 36.2 ft Total wall height

B'= 44.1 ft Effective footing width due to eccentricity

D_w = 21.5 ft Depth below bottom of footing

q_e = 5,050 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of Re	einforced So	il Mass		Total Sett	tlement at Fa	acing of Wall	
Layer	Soil Class.	Soil Type	· .	Depth	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)	$\Delta\sigma_{_{_{ m V}}}^{(8)}$ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	$\Delta\sigma_{_{_{ m V}}}^{(8)}$ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
	A-6a	С	0.0	2.5	2.5	1.3	120	300	150	150	4,150	25	0.135	0.014	0.467				0.03	1.000	5,050	5,200	0.056	0.668	0.500	2,525	2,675	0.029	0.345
1	A-6a	С	2.5	5.5	3.0	4.0	120	660	480	480	4,480	25	0.135	0.014	0.467				0.09	0.998	5,038	5,518	0.052	0.621	0.500	2,524	3,004	0.022	0.264
	A-6a	С	5.5	8.5	3.0	7.0	120	1,020	840	840	4,840	25	0.135	0.014	0.467				0.16	0.988	4,989	5,829	0.043	0.519	0.499	2,521	3,361	0.017	0.199
2	A-6a	С	8.5	11.0	2.5	9.8	120	1,320	1,170	1,170	5,170	31	0.189	0.019	0.514				0.22	0.970	4,901	6,071	0.042	0.503	0.498	2,514	3,684	0.016	0.187
2	A-6a	С	11.0	13.5	2.5	12.3	120	1,620	1,470	1,470	5,470	31	0.189	0.019	0.514				0.28	0.947	4,785	6,255	0.036	0.432	0.496	2,504	3,974	0.013	0.162
3	A-3	G	13.5	16.0	2.5	14.8	120	1,920	1,770	1,770	5,770					12	13	47	0.33	0.919	4,640	6,410	0.030	0.359	0.493	2,490	4,260	0.020	0.245
4	A-1-a	G	16.0	26.0	10.0	21.0	130	3,220	2,570	2,570	6,570					35	32	105	0.48	0.833	4,209	6,779	0.040	0.481	0.482	2,435	5,005	0.028	0.331
5	A-1-a	G	26.0	32.5	6.5	29.3	135	4,098	3,659	3,175	7,175					54	46	152	0.66	0.717	3,622	6,797	0.014	0.170	0.460	2,324	5,499	0.010	0.122
6	A-1-b	G	32.5	37.5	5.0	35.0	130	4,748	4,423	3,580	7,580					28	23	80	0.79	0.645	3,257	6,837	0.018	0.211	0.441	2,229	5,809	0.013	0.158
7	A-1-b	G	37.5	42.5	5.0	40.0	135	5,423	5,085	3,931	7,931					120	93	417	0.91	0.590	2,979	6,909	0.003	0.035	0.424	2,141	6,071	0.002	0.027
8	A-1-b	G	42.5	47.5	5.0	45.0	115	5,998	5,710	4,244	8,244					3	2	48	1.02	0.542	2,735	6,979	0.023	0.271	0.406	2,050	6,293	0.018	0.215
9	A-1-b	G	47.5	51.5	4.0	49.5	135	6,538	6,268	4,520	8,520					120	87	377	1.12	0.503	2,542	7,063	0.002	0.025	0.390	1,968	6,489	0.002	0.020
10	A-1-a	G	51.5	54.5	3.0	53.0	140	6,958	6,748	4,782	8,782					120	85	362	1.20	0.477	2,408	7,190	0.001	0.018	0.377	1,906	6,688	0.001	0.014
11	A-6a	С	54.5	61.0	6.5	57.8	130	7,803	7,380	5,118	9,118	30	0.180	0.018	0.507				1.31	0.444	2,244	7,362	0.012	0.147	0.361	1,824	6,942	0.010	0.123
1. σ _p ' = σ	_{νο} '+σ _{m;} Estima	ate $\sigma_{\rm m}$ of 4,0	00 psf (mode	erately overc	consolidated)	for natural so	oil deposits;	Ref. Table 1	1.2, Coduto	2003	•			•	•	•	•	•	•		Total	Settlement:		4.459 in		Total	Settlement:	1	2.412 in

^{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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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.} $\Delta \sigma_v = q_e(I)$

 $^{9. \ \} S_c = [C_c/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{vo}) \\ \text{for } \sigma_p' \leq \sigma_{vo}' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_p' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'} < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{vo}' < \sigma_{v'}; \ [C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_p') \\ \text{for } \sigma_{$

^{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 W5

MSE Wall Settlement - Sta. 600+19 to 600+75

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Total Settlement at Facing of Wall

Settlement Remaining After Hold Period: 0.243 in

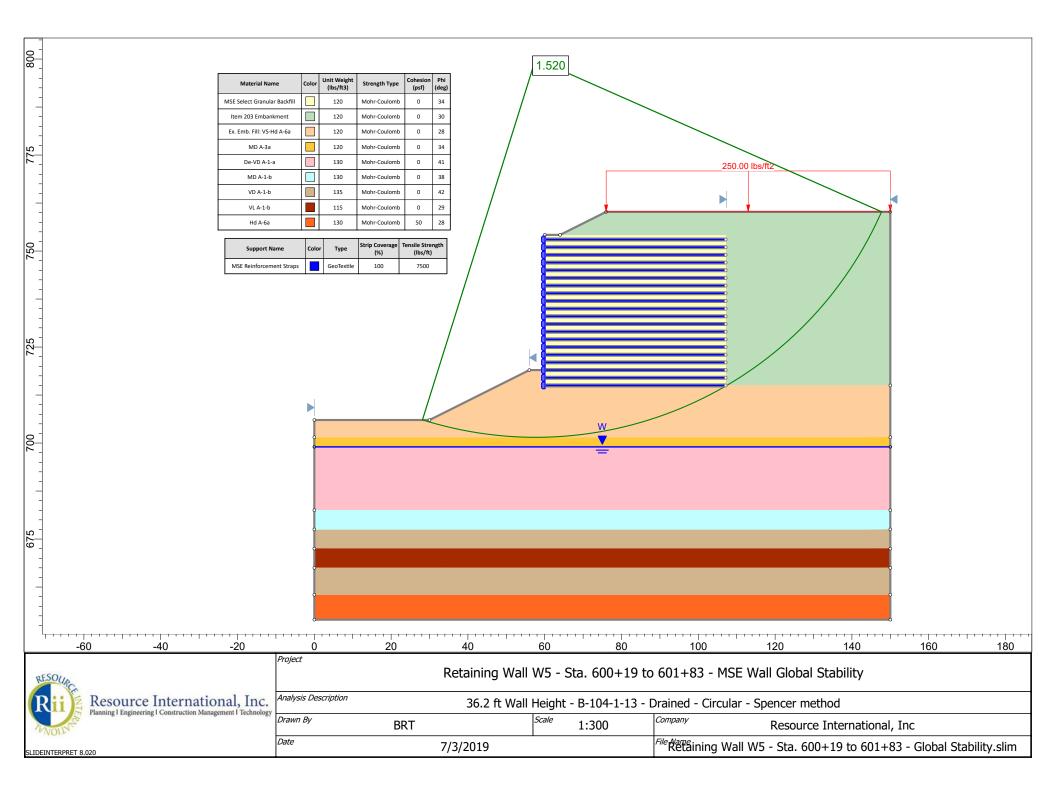
Settlement Complete at 90% of

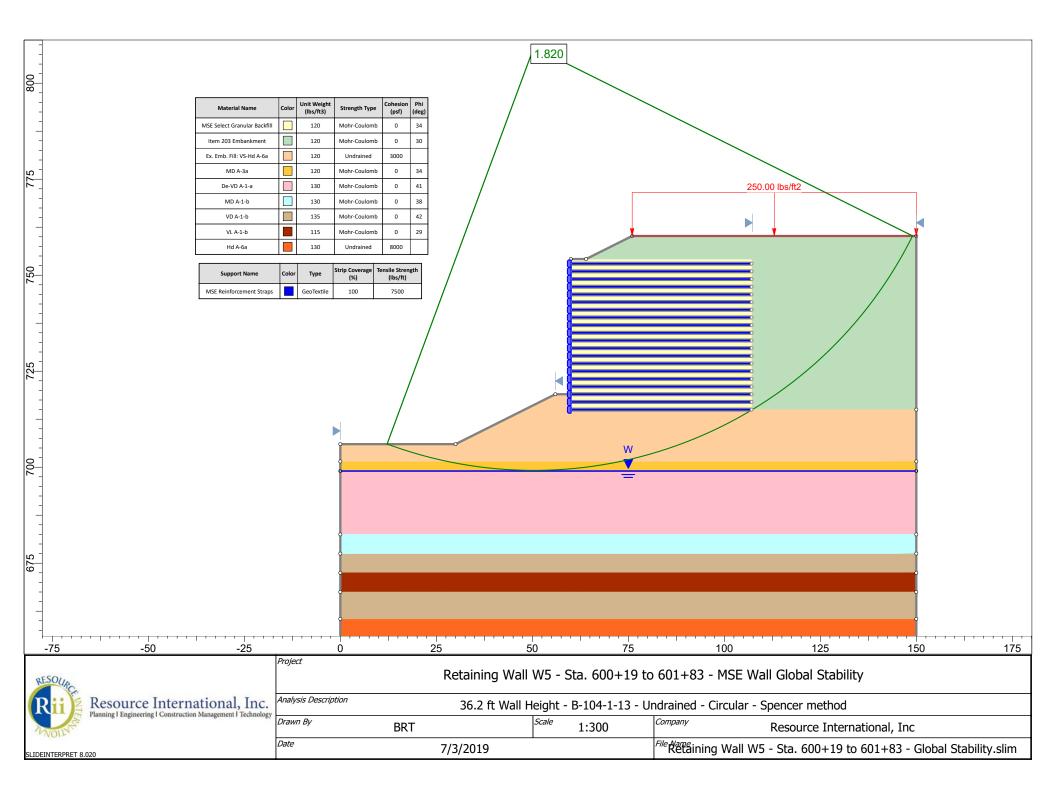
Boring B-104-1-13

				(S _c) _t =	2.169		t 90% of primary consolidation
				U =	81	%	Degree of consolidation
				$T_v =$	0.584		Time factor
q _e =	5,050	psf	Equivalent bearing pressure at bottom of wall	$H_{dr} =$	6.5	ft	Length of longest drainage path considered
$D_w =$	21.5	ft	Depth below bottom of footing	t =	15	days	Time following completion of construction
B'=	44.1	ft	Effective footing width due to eccentricity	c _v =	600	ft²/yr	Coefficient of consolitation
H=	36.2	ft	Total wall height		A-6a		

																									g	Primary Co	onsolidation
Layer	Soil Type	Soil Type	Laye	r 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⁾	Δσ _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)
	A-6a	С	0.0	2.5	2.5	1.3	120	300	150	150	4,150	25	0.135	0.014	0.467				0.03	0.500	2,525	2,675	0.029	0.345		0.280	
1	A-6a	С	2.5	5.5	3.0	4.0	120	660	480	480	4,480	25	0.135	0.014	0.467				0.09	0.500	2,524	3,004	0.022	0.264	0.809	0.214	0.655
	A-6a	С	5.5	8.5	3.0	7.0	120	1,020	840	840	4,840	25	0.135	0.014	0.467				0.16	0.499	2,521	3,361	0.017	0.199		0.162	
2	A-6a	С	8.5	11.0	2.5	9.8	120	1,320	1,170	1,170	5,170	31	0.189	0.019	0.514				0.22	0.498	2,514	3,684	0.016	0.187	0.348	0.151	0.282
۷	A-6a	С	11.0	13.5	2.5	12.3	120	1,620	1,470	1,470	5,470	31	0.189	0.019	0.514				0.28	0.496	2,504	3,974	0.013	0.162	0.346	0.131	0.202
3	A-3	G	13.5	16.0	2.5	14.8	120	1,920	1,770	1,770	5,770					12	13	47	0.33	0.493	2,490	4,260	0.020	0.245	0.245	0.245	0.245
4	A-1-a	G	16.0	26.0	10.0	21.0	130	3,220	2,570	2,570	6,570					35	32	105	0.48	0.482	2,435	5,005	0.028	0.331	0.331	0.331	0.331
5	A-1-a	G	26.0	32.5	6.5	29.3	135	4,098	3,659	3,175	7,175					54	46	152	0.66	0.460	2,324	5,499	0.010	0.122	0.122	0.122	0.122
6	A-1-b	G	32.5	37.5	5.0	35.0	130	4,748	4,423	3,580	7,580					28	23	80	0.79	0.441	2,229	5,809	0.013	0.158	0.158	0.158	0.158
7	A-1-b	G	37.5	42.5	5.0	40.0	135	5,423	5,085	3,931	7,931					120	93	417	0.91	0.424	2,141	6,071	0.002	0.027	0.027	0.027	0.027
8	A-1-b	G	42.5	47.5	5.0	45.0	115	5,998	5,710	4,244	8,244					3	2	48	1.02	0.406	2,050	6,293	0.018	0.215	0.215	0.215	0.215
9	A-1-b	G	47.5	51.5	4.0	49.5	135	6,538	6,268	4,520	8,520					120	87	377	1.12	0.390	1,968	6,489	0.002	0.020	0.020	0.020	0.020
10	A-1-a	G	51.5	54.5	3.0	53.0	140	6,958	6,748	4,782	8,782					120	85	362	1.20	0.377	1,906	6,688	0.001	0.014	0.014	0.014	0.014
11	A-6a	С	54.5	61.0	6.5	57.8	130	7,803	7,380	5,118	9,118	30	0.180	0.018	0.507				1.31	0.361	1,824	6,942	0.010	0.123	0.123	0.100	0.100

- 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_o/1.15)+0.35; Ref. Table 8-2, Holtz and Kovacs 1981
- 5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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. $S_c = [C_o/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v_o}')$ for $\sigma_p' \le \sigma_{v_o'}'$; $[C_t/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}')$ for $\sigma_{v_o'}' \le \sigma_p'$; $[C_t/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}')$ for $\sigma_{v_o'}' \le \sigma_{v_o'}'$; $[C_t/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}')]$
- 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







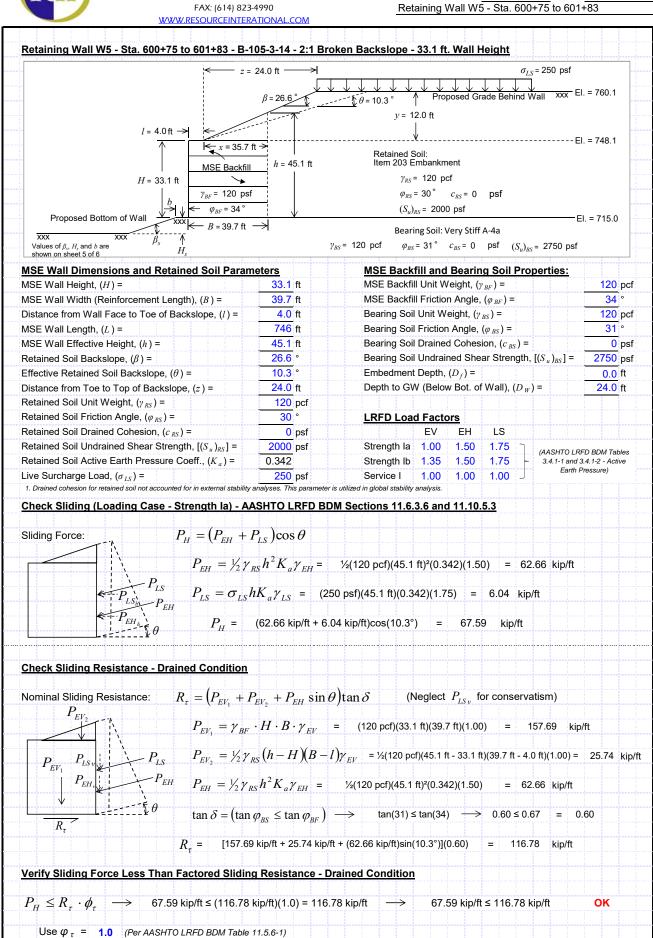
 JOB
 FRA-70-13.10
 No.
 W-13-072

 SHEET NO.
 1
 OF
 6

 CALCULATED BY
 BRT
 DATE
 6/29/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta. 600+75 to 601+83





FRA-70-13.10 JOB SHEET NO. CALCULATED BY DATE CHECKED BY DATE

7/1/2019

Retaining Wall W5 - Sta. 600+75 to 601+83

MSF Wall Dimension	ons and Retained Soil Parameters
	WWW.RESOURCEINTERATIONAL.CO
	FAX: (614) 823-4990
	PHONE: (614) 823-4949
	COLUMBUS, OHIO 43231
	6350 PRESIDENTIAL GATEWAY
	RESOURCE INTERNATIONAL, INC.

MSE Wall Dimensions and Retained Soil Paran	<u>neters</u>	Bearing Soil F	Properties 2	<u>:</u>		
MSE Wall Height, (H) =	33.1 ft	MSE Backfill Ur	nit Weight, ($(\gamma_{BF}) =$		120 pcf
MSE Wall Width (Reinforcement Length), (B) =	39.7 ft	MSE Backfill Fr	iction Angle	$(\varphi_{BF}) =$		34 °
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft	Bearing Soil Un	it Weight, (₂	γ_{BS}) =		120 pcf
MSE Wall Length, (L) =	746 ft	Bearing Soil Fri	ction Angle,	$(\varphi_{BS}) =$		31 °
MSE Wall Effective Height, (h) =	45.1 ft	Bearing Soil Dra	ained Cohe	sion, (c_{BS}) :	=	0 psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Un	drained She	ear Strengtl	h, $[(s_u)_{BS}] =$	2750 psf
Effective Retained Soil Backslope, (θ) =	10.3 °	Embedment De	pth, (D_f) =			0.0 ft
Distance from Toe to Top of Backslope, (z) =	24.0 ft	Depth to GW (E	Below Bot. c	of Wall), (D	_w) =	24.0 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf					
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load F	actors			
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	E	V EH	LS		
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	Strength la 1.	00 1.50	1.75	(AASHTO I RI	FD BDM Tables
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.342	Strength lb 1.	35 1.50	1.75	- 3.4.1-1 and 3	3.4.1-2 - Active
Live Surcharge Load, (σ_{LS}) =	250 psf	Service I 1.	00 1.00	1.00 _	Earth F	Pressure)

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

Check Sliding Resistance - Undrained Condition

 $q_{s} = \frac{\sigma_{v}}{2}$ $P_{EH} \qquad \sigma_{v} = \frac{P_{v}}{B}$ $P_{V} = P_{EV_{1}} + P_{EV_{2}} + P_{EH} \sin \theta$

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

$$\left(S_u^{}\right)_{B\!S}=$$
 2.75 ksf

$$q_s = \frac{\sigma_v}{2}$$

$$\sigma_v = \frac{P_V}{B}$$

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

(Neglect $P_{LS_{\nu}}$ for conservatism)

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

$$P_{EV_2}$$
 = ½(120 pcf)(45.1 ft - 33.1 ft)(39.7 ft - 4.0 ft)(1.00) = 25.74 kip/ft

 $P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(33.1 ft)(39.7 ft)(1.00) = 157.7 kip/ft

$$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(45.1 \text{ ft})^2 (0.342)(1.50) = 62.66 \text{ kip/ft}$$

$$P_V$$
 = 157.69 kip/ft + 25.74 kip/ft + (62.66 kip/ft)sin(10.3°) = 194.63 kip/ft

$$\sigma_{v} = (194.63 \text{ kip/ft}) / (39.7 \text{ ft}) = 4.90 \text{ ksf}$$

$$q_s = (4.90 \text{ ksf})/2 = 2.45 \text{ ksf}$$

$$R_{\tau} = (2.75 \text{ ksf} \le 2.45 \text{ ksf})(39.7 \text{ ft}) = 109.18 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

 $P_H \le R_\tau \cdot \phi_\tau \quad \longrightarrow \quad$ 67.59 kip/ft \le (109.18 kip/ft)(1.0) = 109.18 kip/ft $\quad \longrightarrow \quad$ 67.59 kip/ft ≤ 109.18 kip/ft OK

Use $arphi_{ au}$ = 1.0 (Per AASHTO LRFD BDM Table 11.5.6-1)



 $e < e_{\max} \longrightarrow$

3.34 ft < 13.23 ft

OK

RESOURCE INTERNATIONAL, INC. 6350 PRESIDENTIAL GATEWAY COLUMBUS, OHIO 43231 PHONE: (614) 823-4949 FAX: (614) 823-4990
 JOB
 FRA-70-13.10
 NO.
 W-13-072

 SHEET NO.
 3
 OF
 6

 CALCULATED BY
 BRT
 DATE
 6/29/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

PHONE: (614)		CHECKED BY JPS DAT	
FAX: (614) 8. WWW.RESOURCEINTI		Retaining Wall W5 - Sta. 600+75 to 60	71+83
MSE Wall Dimensions and Retained Soil Para	ameters	Bearing Soil Properties:	
MSE Wall Height, (H) =	33.1 ft	MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf
MSE Wall Width (Reinforcement Length), (B) =	39.7 ft	MSE Backfill Friction Angle, (φ_{BF}) =	34 °
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft	Bearing Soil Unit Weight, (γ_{BS}) =	120 pcf
MSE Wall Length, (<i>L</i>) =	746 ft	Bearing Soil Friction Angle, (φ_{BS}) =	31 °
MSE Wall Effective Height, (h) =	45.1 ft	Bearing Soil Drained Cohesion, (c_{BS}) =	0 psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	2750 psf
Effective Retained Soil Backslope, (θ) =	10.3 °	Embedment Depth, (D_f) =	0.0 ft
Distance from Toe to Top of Backslope, (z) =	24.0 ft	Depth to GW (Below Bot. of Wall), (D_W) =	24.0 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf		
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Factors	
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV EH LS	
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	Strength la 1.00 1.50 1.75	LRFD BDM Tables
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.342	Strength lb 1.35 1.50 1.75 - 3.4.1-1 an	nd 3.4.1-2 - Active
Live Surcharge Load, (σ_{LS}) =	250 psf	Service I 1.00 1.00 1.00 Eart	th Pressure)
Drained cohesion for retained soil not accounted for in external stabil	lity analyses. This parameter is	utilized in global stability analysis.	
Check Eccentricity (Loading Case - Strength	la) - AASHTO LRFD	BDM Section 11.6.3.3	
P_{EV_2}			
e = B/2	$-x_o$		
x_4 P P_{LS_v} P_{LS} P_{LS}	$\mathcal{A} = \mathcal{M}$		
P_{EV_1} P_{EV_1} P_{EH} P_{EH} P_{EH} P_{EH} P_{EH}	$\frac{M_V - M_H}{M} = 4290.5$	51 kip·ft/ft - 1077.05 kip·ft/ft) / (194.63 kip/f = 16.5	51 ft
$R_3 \mid P_{EH_y} \mid P_{EH} \mid P_{EH}$	P_{V}		
P_{EH_h}			
R^*	v = 4290.51 kip	o·ft/ft 1	
M	$_{H} = 1077.05 \text{ kij}$	p·ft/ft Defined below	
		$\theta_{EH} \sin \theta$ = 157.69 kip/ft + 25.74 kip/ft + (62.66 kip/ft)sin(10.3°) = 194.63 kip/ft
$x_1 \leftarrow B_2 \rightarrow$	r Eri Erz		
2-	(39.7 ft/ 2) - 16.51 ft	t = 3.34 ft	
Resisting Moment, M_V : $M_V = P_r$	$P_{rv}(x_1) + P_{rv}(x_2) +$	$-P_{\!E\!H}\sin heta(\!B)$ (Neglect $P_{\!L\!S_{_{oldsymbol{v}}}}$ for conser	rvatism)
$P_{\scriptscriptstyle EV_2}$	V ₁ (31) = EV ₂ (32)	EH STATE OF THE ST	
$P_{} =$	$\gamma_{} \cdot H \cdot B \cdot \gamma_{}$	= (120 pcf)(33.1 ft)(39.7 ft)(1.00) = 157.69) kip/ft
L L	I BF 11 1 EV		
$P_{} = P_{}$	$\frac{1}{2} \gamma_{ng} (h - H) (B -$	$l)\gamma_{EV}$ = ½(120 pcf)(45.1 ft - 33.1 ft)(39.7 ft - 4.0 ft)(1.00)	= 25.74 kip/ft
$\mid P_{EV} \mid \stackrel{LS}{\searrow} \mid \qquad \downarrow \qquad$	/2/ RS (** 11)(2		
	$1/v h^2 K v =$: ½(120 pcf)(45.1 ft)²(0.342)(1.50) = 62.66 k	(in/ft
TEH T	$/2/RS^{\prime\prime}$ R_a/EH		up/it
$\begin{array}{c c} & & & \\ & & & \\ & & & \\ \end{array}$	B/2 = (39.7 ft)/2	= 19.85 ft	
$\vdash \rightarrow x_{\tau}$	$/2^{-(65.716)72}$	- 10.00 It	
$\Rightarrow x_2$	I + 2/(D - I) = I	4.0 ft + 3/(39.7 ft - 4.0 ft) = 27.80 ft	
$x_2 = 0$	$(+7_3(D-i)-$	1.0 It 1 /3(05.7 It - 4.0 It) = 27.00 It	
M - (15)	7 60 kin/ft)/10 95 ft) ± /3	05 74 kin/#\\27 9 ft\ + /62 66 kin/#\\sin/40 2°\/20 7 ft\	4200 E1 Isin #/
ТИ у − (13	7.09 KIP/II)(19.00 II) + (2	25.74 kip/ft)(27.8 ft) + (62.66 kip/ft)sin(10.3°)(39.7 ft) =	4290.51 KIP·II/I
Overturning Memont M : M D	0() . D	0()	
Overturning Moment, M_H : $M_H = P_H$	$_{EH}\cos\theta(x_3)+P_L$	$S \cos \theta(x_4)$	
	1/ 12-5		
$P_{EH} =$	$\frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} =$	$= \frac{1}{2}(120 \text{ pcf})(45.1 \text{ ft})^2(0.342)(1.50) = 62.66 \text{ k}$	ip/ft
$R_{LS} = P_{LS}$	$\sigma_{LS}hK_a\gamma_{LS} =$	(250 psf)(45.1 ft)(0.342)(1.75) = 6.75 kip/ft	
\uparrow P_{LS} P_{EH}	h /		
x_3	$\frac{7}{3} = \frac{45.1 \text{ ft}}{3}$	(250 psf)(45.1 ft)(0.342)(1.75) = 6.75 kip/ft = 15.04 ft	
	$\frac{h}{2} = (45.1 \text{ ft}) / 2$		
$x_4 = 1$	$\frac{1}{2} = \frac{(45.1 \text{ ft})}{2}$	= 22.56 ft	
$M_H = (62.6)$	66 kip/ft)cos(10.3°)(15.	04 ft) + (6.75 kip/ft)cos(10.3°)(22.56 ft = 1077.05 k	tip·ft/ft
	D /		
<u>Check Eccentricity</u> Limiting Eccentrici	ty: $e_{\text{max}} = \frac{D}{3}$	$\rightarrow e_{\text{max}} = (39.7 \text{ ft})/3 = 13.23 \text{ f}$	t
	, ,		



FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF 6 CALCULATED BY BRT DATE 6/29/2019 JPS 7/1/2019 CHECKED BY DATE Retaining Wall W5 - Sta. 600+75 to 601+83

	FAX: (614) 823-4990 WWW.RESOURCEINTERATIONAL.CC		aining Wall W	5 - Sta.	600+75 to	601+83	
	W W.R.E.SOORCEINTER (HOLV.E.C.C.						
MSE Wall Dimensions and F	Retained Soil Parameters	Bearing So	oil Properties	<u>:</u>			
MSE Wall Height, (H) =	33.1 ft	MSE Backfill	l Unit Weight, ($(\gamma_{BF}) =$		120) pcf
MSE Wall Width (Reinforcement	Length), (B) = 39.7 ft	MSE Backfill	l Friction Angle	$(\varphi_{BF}) =$		34	ļ°
Distance from Wall Face to Toe	of Backslope, $(l) = 4.0$ ft	Bearing Soil	Unit Weight, (γ_{BS}) =		120	pcf
MSE Wall Length, (L) =	746 ft	Bearing Soil	Friction Angle	$, (\varphi_{BS}) =$		31	٥
MSE Wall Effective Height, (h) =	: 45.1 ft	Bearing Soil	Drained Cohe	sion, (c_B	_s) =	0) psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil	Undrained Sh	ear Strer	$gth, [(s_u)_{BS}]$] = 2750) psf
Effective Retained Soil Backslop	e, (θ) = 10.3 °	Embedment	Depth, (D_f) =			0.0) ft
Distance from Toe to Top of Bac	kslope, $(z) = 24.0$ ft	Depth to GW	V (Below Bot. o	of Wall),	(D_W) =	24.0) ft
Retained Soil Unit Weight, (γ_{RS})	= 120 p	cf					
Retained Soil Friction Angle, (φ_R	s) = 30 °	LRFD Load	d Factors				
Retained Soil Drained Cohesion,	$(c_{RS}) = 0$	sf	EV EH	LS			
Retained Soil Undrained Shear S	Strength, $[(S_u)_{RS}] = 2000 \text{ p}$	sf Strength la	1.00 1.50	1.75	7 (4464)	O I DED DOM To	abloo
Retained Soil Active Earth Press	sure Coeff., $(K_a) = 0.342$	Strength lb		1.75		O LRFD BDM Ta and 3.4.1-2 - Ac	
Live Surcharge Load, (σ_{IS}) =	250 p		1.00 1.00	1.00	E	arth Pressure)	
- ,,	counted for in external stability analyses. This						
Check Bearing Capacity (Lo	ading Case - Strength lb) - A	ASHTO LRFD BDM Sect	tion 11.6.3.2				
P_{EV_2}							
							
	$q_{eq} = \frac{P_{V}}{R'}$						
	n 1eq /B						
A_4 P_{EV} P_{LS_v}	P_{LS} $P' - P$ Q_{C}	= 39.7 ft - 2(2.23 ft)	- 35.24	ft			
\uparrow $P_{EH_{\nu}}$ $P_{EH_{\nu}}$	$-P_{EH}$ $B=B-2e$	- 33.7 11 - 2(2.23 11)	- 33.24				
P_{FH}	\ a = B/	$x_o = (39.7 \text{ ft / 2}) - 17$	760ff -	2.23	ft		
R^{\vee}	$\dot{\mathbb{R}}_{ heta}$	$x_o = (39.7 \text{ it}/2) - 1$	7.62 II =	2.23	π		
	$M_{_{V}}$	$-M_H$	6/6 4077	<u>.</u>			7.00
	$x_o = \frac{1}{1}$	$\frac{-M_{H}}{2}$ = (5636.51 kip	ο∙π/π - 1077.0	ъ кір∙π/і	1) / 258.83	KIP/T = I/I	.02
$x_o \longleftrightarrow + - \dagger - \vdots - e$	4	V					
$\leftarrow B/2 \rightarrow$							
$\leftarrow B' \Rightarrow$	$q_{eq} = (258.8)$	3 kip/ft) / (35.24 ft) =	7.34 ks	f			
$x_2 \rightarrow$							
Resisting Moment, $M_{\scriptscriptstyle V}$:	$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2)$	$P_{EH} \sin \theta(B)$					
$P_{\scriptscriptstyle EV_2}$	$P_{\scriptscriptstyle FV.}=\gamma_{\scriptscriptstyle RF}\cdot H\cdot$	$B \cdot \gamma_{EV} = (120 \text{ pcf})$	33.1 ft)(39.7 ft))(1.35)	= 212.	88 kip/ft	
1 11							
	$P_{\rm EV} = \frac{1}{2} \gamma_{\rm ng} (h -$	$H(B-l)\gamma_{EV} = \frac{1}{2}(120 \text{ pct})$	f)(45.1 ft - 33.1	ft)(39.7 ft	t - 4.0 ft)(1.3	5) = 34.75	kip/f
P. ! ! '\	$-P_{LS}$	JA EK					
P_{EV_1} P_{LS_V}		$\gamma_{11} = \frac{1}{2}(120 \text{ pcf})(4$	5.1 ft)2(0.342)(1.50)	= 62.66	kip/ft	
P_{EH}	$-P_{EH}$ EH 727 RS $^{\prime\prime}$ 13	al EH					
	$P_{EH} = \frac{1}{2} \gamma_{RS} h K$ $x_1 = \frac{B}{2} = (39)$	7 ft)/2 = 19.85 ft	ft				
	$\delta \theta$ $^{-1}$ $^{-}$ $^{\prime}2$., ,,,,					
$\rightarrow x_I$	$v = 1 \pm 2/(R \pm$	l) = 4.0 ft + ¾(39.7 ft - 4	40ft) =	27.80	ft		
$\longrightarrow x_2$	$x_2 - \iota + \lambda_3 B$	1) - 4.011 /3(09.711-1	4.011) –	27.00	14		
1 2 2	M _ (212.88 kin/ft)/10	85 ft) + (34.75 kip/ft)(27.8 ft)	+ (62 66 kin/ft)	cin/10 3°)(30 7 ft) —	5636 51	kin i
	$M_V = (212.00 \text{ kip/it})(19.00 \text{ kip/it})$	00 it) + (04.70 kip/it)(27.0 it)	+ (02.00 kip/it)	5111(10.5)(39.7 II) —	3030.31	Kib.
Overturning Moment, $M_{\scriptscriptstyle H}$	· N/ D - 20(-)					
Overturning Moment, M _H	$M_H = P_{EH} \cos \theta (x)$	$_3) + P_{LS} \cos \theta(x_4)$					
		1//100 0//	5 4 6)2(0 0 40)	(4.50)			
	$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K$	$T_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(4)$	5.1 π)²(0.342)((1.50)	= 62.66	Kip/ft	
x_a	$-P_{LS} \qquad P_{LS} = \sigma_{LS} h K_a \gamma$	_{LS} = (250 psf)(45.1 ft)(u.342)(1.75)	= 6	./5 kip/ft		
\bigwedge^{7}	P_{-}						
3 	$x_3 = \frac{n}{3} = 45$	1.1 ft / 3 = 15.04 ft	ft				
I EHh	ξ _θ (_k)						
	$rac{P_{EH}}{\sqrt{P_{EH}}} x_3 = \frac{h}{3} = (45)$ $rac{1}{\sqrt{2}}\theta x_4 = \frac{h}{2} = (45)$	1.1 ft / 2 = 22.56 t	ft				
	M_H = (62.66 kip/ft)cos(1	0.3°)(15.04 ft) + (6.75 kip/ft)cos(10.3°)(22	.56 ft =	1077.05	kip·ft/ft	
Vertical Forces, P_{ν} :	$P_{V} = P_{EV_1} + P_{EV_2} + \dots$	$P_{ru} \sin \theta$					
	EV ₁ = EK ₂	EΠ					
	$P_{vv} = 212.88 \text{kin/ft}$	+ 34.75 kip/ft + (62.66 kip/ft	t)sin(10.3°) =	258 8	33 kip/ft		
	- L		· · · · · · · · · · · · · · · · · · ·				



 JOB
 FRA-70-13.10
 NO.
 W-13-072

 SHEET NO.
 5
 OF
 6

 CALCULATED BY
 BRT
 DATE
 6/29/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta. 600+75 to 601+83

ISE Wall Dimensions and Retained Soil P	<u>arameters</u>	Bearing Soil Proper	rties:		
ISE Wall Height, (H) =	33.1 ft	MSE Backfill Unit Wei	ght, $(\gamma_{BF}) =$		120 pcf
ISE Wall Width (Reinforcement Length), (B) =	39.7 ft	MSE Backfill Friction A	Angle, (φ_{RE}) =		34 °
Distance from Wall Face to Toe of Backslope, (<i>l</i>)		Bearing Soil Unit Weig		-	120 pcf
ISE Wall Length, (L) =	746 ft	Bearing Soil Friction A			31 °
ISE Wall Effective Height, (h) =	45.1 ft	Bearing Soil Drained C	, (7 B57	<u> </u>	0 psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained		.â	2750 psf
	10.3 °	Embedment Depth, (D		, [(3 u JBS] —	0.0 ft
Iffective Retained Soil Backslope, (θ) =		Depth to GW (Below E		\	
Distance from Toe to Top of Backslope, (z) =	24.0 ft	Depui to Gw (Below E	out. Of Wall), $(D_W$, - <u> </u>	24.0 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	I DED I and England			
Retained Soil Friction Angle, (φ_{RS}) =	30°	LRFD Load Factors			
Retained Soil Drained Cohesion, (c _{RS}) =	0 psf		EH LS		
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$			1.50 1.75	(AASHTO LRFD E	
Retained Soil Active Earth Pressure Coeff., (K_a) :			1.50 1.75 -	3.4.1-1 and 3.4.1 Earth Press	
ive Surcharge Load, (σ_{LS}) = 1. Drained cohesion for retained soil not accounted for in external s	250 psf		1.00 1.00 🗵		
Check Bearing Capacity (Loading Case - S	trength lb) - AASHTO L	RFD BDM Section 11.10	0.5.4 (Continued)		
Check Bearing Resistance - Drained Cond	<u>ition</u>				
		/ 5. T			
lominal Bearing Resistance: $q_{_n} = c N_{_{CI}}$	$_{n}+\gamma D_{f}N_{qm}C_{wq}+\gamma$	$_{2}\gamma B'N_{pm}C_{w\gamma}$			
	X7	<u> </u>	7		
$N_{cm} = N_c s_c i_c$ = 32.67	$N_{qm} = N_q s_q d_q i_q$	= 20.6 1	$V_{\gamma m} = N_{\gamma} s_{\gamma} i_{\gamma}$, = 26.0	
$N_c = 32.670$	$N_q = 20.630$		$N_{\gamma} = 25.990$		
$S_c = 1 + (35.24 \text{ ft}/746 \text{ ft})(20.63/32.67)$	anna da mana da maria an mana an	46 ft)tan(31°) = 1.000	$s_{\gamma} = 1-0.4(3)$: 1.000
= 1.000		-sin(31°)]²tan⁻¹(0.0 ft/35.24 ft)	$i_{\gamma} = 1.000$		
i = 1,000 (A					
i_c = 1.000 (Assumed)	= 1.000		$C_{wy} = 24.0 \text{ft} <$	1.5(35.24 ft) + 0.0	ft = 0.5
t _c - 1.000 (Assumed)	$i_q = 1.000$ (Ass	sumed)	$C_{wy} = 24.0 \text{ ft} <$	1.5(35.24 ft) + 0.0	ft = 0.5
$q_n = (0 \text{ psf})(32.67) + (120 \text{ pcf})(0.0 \text{ fi})$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	of = 1.000 o(35.2 ft)(26.0)(0.5) =			ft = 0.5
	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	0ft = 1.000 0(35.2 ft)(26.0)(0.5) =	= 27.48 ksf		6 = 0.5
$q_n= ($ 0 psf)(32.67) + (120 pcf)(0.0 fiverify Equivalent Pressure Less Than Fact	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $c)(20.6)(1.0) + \frac{1}{2}(120 \text{ pcf})$	oft = 1.000 0(35.2 ft)(26.0)(0.5) = 020 065) = 10.54 ksf →	= 27.48 ksf - 7.34 ksf ≤ 1	10.54 ksf	OK
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Verify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD B)	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $c)(20.6)(1.0) + \frac{1}{2}(120 \text{ pcf})$	oft = 1.000 0(35.2 ft)(26.0)(0.5) = 020 065) = 10.54 ksf →	= 27.48 ksf - 7.34 ksf ≤ 1	10.54 ksf	OK
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Verify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD B)	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	oft = 1.000 0(35.2 ft)(26.0)(0.5) = 020 065) = 10.54 ksf →	= 27.48 ksf - 7.34 ksf ≤ 1	10.54 ksf	OK
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Verify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BILL Use $\phi_b = 0.65$ (Per AASHTO LRFD BILL) Check Bearing Resistance - Undrained Control of the con	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $C_{wq} = 24.0 \text{ ft}$	$\beta_{s} = 1.000$ $\beta_{s} = 1.000$ $\beta_{s} = 10.54 \text{ ksf}$ $\beta_{s} = 15.000$	= 27.48 ksf - 7.34 ksf ≤ 1	10.54 ksf	OK
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Verify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BILL Use $\phi_b = 0.65$ (Per AASHTO LRFD BILL) Check Bearing Resistance - Undrained Control of the con	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	$\beta_{s} = 1.000$ $\beta_{s} = 1.000$ $\beta_{s} = 10.54 \text{ ksf}$ $\beta_{s} = 15.000$	= 27.48 ksf - 7.34 ksf ≤ 1	10.54 ksf	OK
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Verify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BILL Use $\phi_b = 0.65$ (Per AASHTO LRFD BILL Check Bearing Resistance - Undrained Collinary Resistance - Undrained Collinary Resistance: $q_n = cN_{CO}$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf \sim 7.34 ksf \leq 1 \sim 10 \sim \sim \sim 1	9.0 ft b	OK
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Verify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BILL Use $\phi_b = 0.65$ (Per AASHTO LRFD BILL) Check Bearing Resistance - Undrained Control of the con	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $C_{wq} = 24.0 \text{ ft}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf - 7.34 ksf ≤ 1	9.0 ft b	OK
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Verify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59 \ (Per\ AASHTO\ LRFD\ Bl)$ Use $\varphi_b = 0.65 \ (Per\ AASHTO\ LRFD\ Bl)$ Check Bearing Resistance - Undrained Collominal Bearing Resistance: $q_n = cN_{cr}$ $N_{cm} = N_c s_c i_c = 5.140$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $c)(20.6)(1.0) + \frac{1}{2}(120 \text{ pcf})$ $c)($	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf = 7.34 ksf \le 1 0 \circ H_s = $V_{\gamma S_{\gamma}} i_{\gamma}$	9.0 ft b	OK
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Werify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BITUSE $\phi_b = 0.65$ (Per AASHTO LRFD	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $c)(20.6)(1.0) + \frac{1}{2}(120 \text{ pcf})$ $c)($	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$= 27.48 \text{ ksf}$ $= 7.34 \text{ ksf} \le 1$ $0 \circ H_s =$ $V_{jm} = N_{\gamma} s_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$	9.0 ft b	OK
$q_n=$ $(0 \text{ psf})(32.67)+(120 \text{ pcf})(0.0 \text{ fit})$ $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC}=$ 0.59 (Per AASHTO LRFD BIT) Use $\varphi_b=$ 0.65 (Per AASHTO LRFD BIT) Check Bearing Resistance - Undrained Companies Resistance: $q_n=cN_{cl}$ $N_{cm}=N_c s_c i_c=5.140$ $N_c=5.140$ $s_c=1+(35.24 \text{ fit}[(5)(746 \text{ fit})]=1.000$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $c)(20.6)(1.0) + \frac{1}{2}(120 \text{ pcf})$ $c)($	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$= 27.48 \text{ ksf}$ $= 7.34 \text{ ksf} \le 1$ $0 \circ H_s = $ $V_{jm} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$	9.0 ft b	OK
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Werify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BITUSE $\phi_b = 0.65$ (Per AASHTO LRFD	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $c)(20.6)(1.0) + \frac{1}{2}(120 \text{ pcf})$ $c)($	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf = 7.34 ksf \le 1 0 \circ H_s = \frac{1}{2} $N_{ym} = N_{y}S_{y}i_{y}$ $N_{y} = 0.000$ $S_{y} = 1.000$ $i_{y} = 1.000$	9.0 ft b	OK = 0.0
$q_n=$ $(0 \text{ psf})(32.67)+(120 \text{ pcf})(0.0 \text{ fit})$ $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC}=$ 0.59 (Per AASHTO LRFD BIT) Use $\varphi_b=$ 0.65 (Per AASHTO LRFD BIT) Check Bearing Resistance - Undrained Companies Resistance: $q_n=cN_{cl}$ $N_{cm}=N_c s_c i_c=5.140$ $N_c=5.140$ $s_c=1+(35.24 \text{ fit}[(5)(746 \text{ fit})]=1.000$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $c)(20.6)(1.0) + \frac{1}{2}(120 \text{ pcf})$ $c)($	$\begin{array}{cccc} 0. & \text{ft} & = & 1.000 \\ & & & & & & & & \\ 0. & & & & & & \\ 0. & & & & & \\ 0. & & & & & \\ 0. & & & & & \\ 0. & & & & \\ 0. & & & & \\ 0. & & & & \\ 0. & & & & \\ 0. & & & & \\ 0. & & & \\ 0. & & & & \\ 0. & & \\ 0. & & $	$= 27.48 \text{ ksf}$ $= 7.34 \text{ ksf} \le 1$ $0 \circ H_s = $ $V_{jm} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$	9.0 ft b	OK = 0.0
$q_n=$ $(0 \text{ psf})(32.67)+(120 \text{ pcf})(0.0 \text{ fit})$ $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC}=$ 0.59 (Per AASHTO LRFD BIT) Use $\varphi_b=$ 0.65 (Per AASHTO LRFD BIT) Check Bearing Resistance - Undrained Companies Resistance: $q_n=cN_{cl}$ $N_{cm}=N_c s_c i_c=5.140$ $N_c=5.140$ $s_c=1+(35.24 \text{ fit}[(5)(746 \text{ fit})]=1.000$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $c)(20.6)(1.0) + \frac{1}{2}(120 \text{ pcf})$ $c)($	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	= 27.48 ksf = 7.34 ksf \le 1 0 \circ H_s = \frac{1}{2} $N_{ym} = N_{y}S_{y}i_{y}$ $N_{y} = 0.000$ $S_{y} = 1.000$ $i_{y} = 1.000$	9.0 ft b	OK = 0.0
$q_n=$ $(0 \text{ psf})(32.67)+(120 \text{ pcf})(0.0 \text{ fit})$ $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC}=$ 0.59 (Per AASHTO LRFD BIT) Use $\varphi_b=$ 0.65 (Per AASHTO LRFD BIT) Check Bearing Resistance - Undrained Companies Resistance: $q_n=cN_{cl}$ $N_{cm}=N_c s_c i_c=5.140$ $N_c=5.140$ $s_c=1+(35.24 \text{ fit}[(5)(746 \text{ fit})]=1.000$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $c)(20.6)(1.0) + \frac{1}{2}(120 \text{ pcf})$ $c)($	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	= 27.48 ksf = 7.34 ksf \le 1 0 \circ H_s = \frac{1}{2} $N_{ym} = N_{y}S_{y}i_{y}$ $N_{y} = 0.000$ $S_{y} = 1.000$ $i_{y} = 1.000$	9.0 ft b	OK = 0.0
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) [erify Equivalent Pressure Less Than Fact] $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BI) Use $\varphi_b = 0.65$ (Per AASHTO LRFD BI) [Check Bearing Resistance - Undrained Coolominal Bearing Resistance: $q_n = cN_{cl}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(35.24 \text{ft/[(5)(746 \text{ft)}]} = 1.000$ $i_c = 1.000 \text{(Assumed)}$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf = 7.34 ksf \le 1 0 \circ H_s = \frac{1}{2} \frac{1}	10.54 ksf 9.0 ft b = 0.000 (Assumed) 1.5(35.24 ft) + 0.0	OK = 0.0
$q_n=$ $(0 \text{ psf})(32.67)+(120 \text{ pcf})(0.0 \text{ fit})$ $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC}=$ 0.59 (Per AASHTO LRFD BIT) Use $\varphi_b=$ 0.65 (Per AASHTO LRFD BIT) Check Bearing Resistance - Undrained Companies Resistance: $q_n=cN_{cl}$ $N_{cm}=N_c s_c i_c=5.140$ $N_c=5.140$ $s_c=1+(35.24 \text{ fit}[(5)(746 \text{ fit})]=1.000$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf = 7.34 ksf \le 1 0 \circ H_s = \frac{1}{2} $N_{ym} = N_{y}S_{y}i_{y}$ $N_{y} = 0.000$ $S_{y} = 1.000$ $i_{y} = 1.000$	10.54 ksf 9.0 ft b = 0.000 (Assumed) 1.5(35.24 ft) + 0.0	OK = 0.0
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) [erify Equivalent Pressure Less Than Fact] $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BI) Use $\varphi_b = 0.65$ (Per AASHTO LRFD BI) [Check Bearing Resistance - Undrained Coolominal Bearing Resistance: $q_n = cN_{cl}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(35.24 \text{ft/[(5)(746 \text{ft)}]} = 1.000$ $i_c = 1.000 \text{(Assumed)}$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf = 7.34 ksf \le 1 0 \circ H_s = \frac{1}{2} \frac{1}	10.54 ksf 9.0 ft b = 0.000 (Assumed) 1.5(35.24 ft) + 0.0	OK = 0.0
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) [erify Equivalent Pressure Less Than Fact] $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BI) Use $\varphi_b = 0.65$ (Per AASHTO LRFD BI) [Check Bearing Resistance - Undrained Coolominal Bearing Resistance: $q_n = cN_{cl}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(35.24 \text{ft/[(5)(746 \text{ft)}]} = 1.000$ $i_c = 1.000 \text{(Assumed)}$	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $C_{wq} = 1.000$ $C_{wq} = 1.000$ $C_{wq} = 1.000$ $C_{wq} = 1.000$ $C_{wq} = 24.0 \text{ ft} > 0.0$ $C_{wq} = 24.0 \text{ ft} > 0.0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf = 7.34 ksf \le 1 0 \circ H_s = \frac{1}{2} \frac{1}	10.54 ksf 9.0 ft b = 0.000 (Assumed) 1.5(35.24 ft) + 0.0	OK = 0.0
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Verify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BILL Use $\varphi_b = 0.65$ (Per AASHTO LRFD BILL Use $\varphi_b $	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf 7.34 ksf \leq 1 0° H_s = $V_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$ $C_{w\gamma} = 24.0 \text{ ft} <$	10.54 ksf 9.0 ft b = 0.000 (Assumed) 1.5(35.24 ft) + 0.0	OK = 0.0
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) $q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) $q_{eq}\leq q_n\cdot RC_{BC}\cdot \phi_b \longrightarrow 7.34$ $RC_{BC}=$ 0.59 (Per AASHTO LRFD BIOLET Use $\varphi_b=$ 0.65 (Per AASHTO LRFD BIOLET Use $\varphi_b=$ 0.65 (Per AASHTO LRFD BIOLET Use $q_n=$ 0.65 (Per AASHTO LRFD BIOLET Use q	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf 7.34 ksf \leq 1 0° H_s = $V_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$ $C_{w\gamma} = 24.0 \text{ ft} <$	10.54 ksf 9.0 ft b = 0.000 (Assumed) 1.5(35.24 ft) + 0.0	OK = 0.0
$q_n=$ (0 psf)(32.67) + (120 pcf)(0.0 ft) Verify Equivalent Pressure Less Than Fact $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.34$ $RC_{BC} = 0.59$ (Per AASHTO LRFD BILL Use $\varphi_b = 0.65$ (Per AASHTO LRFD BILL Use $\varphi_b $	$i_q = 1.000 \text{ (Ass}$ $C_{wq} = 24.0 \text{ ft} > 0.0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	= 27.48 ksf 7.34 ksf \leq 1 0° H_s = $V_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$ $C_{w\gamma} = 24.0 \text{ ft} <$	10.54 ksf 9.0 ft b = 0.000 (Assumed) 1.5(35.24 ft) + 0.0	OK = 0.0



 JOB
 FRA-70-13.10
 NO.

 SHEET NO.
 6
 OF

 CALCULATED BY
 BRT
 DATE

 CHECKED BY
 JPS
 DATE

W-13-072 6 6 6/29/2019 F 7/1/2019

Retaining Wall W5 - Sta. 600+75 to 601+83

MSE Wall Dimensions and Retained Soil Param	<u>ieters</u>
MSE Wall Height, (H) =	33.1 ft
MSE Wall Width (Reinforcement Length), (B) =	39.7 ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft
MSE Wall Length, (<i>L</i>) =	746 ft
MSE Wall Effective Height, (h) =	45.1 ft
Retained Soil Backslope, (β) =	26.6 °
Effective Retained Soil Backslope, (θ) =	10.3 °
Distance from Toe to Top of Backslope, (z) =	24.0 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) =	0.342

Bearing Soil Properties:		
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	0
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	31	0
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	2750	psf
Embedment Depth, (D_f) =	0.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	24.0	ft

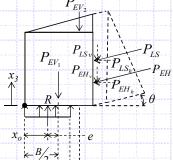
LRFD Load Factors

	L V	L'''	LO	
Strength la	1.00	1.50	1.75	٦
Strength lb	1.35	1.50	1.75	}
Service I	1.00	1.00	1.00	J

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

250 psf





Live Surcharge Load, (σ_{LS}) =

$$q_{eq} = \frac{P_V}{B'}$$
 $B' = B - 2e = 39.7 \text{ ft} - 2(1.84 \text{ ft}) = 36.02 \text{ ft}$

$$e = \frac{B}{2} - x_o = (39.7 \text{ ft/2}) - 18.01 \text{ ft} = 1.84 \text{ ft}$$

$$x_o = \frac{M_V - M_H}{P_V}$$
 = (4142.29 kip·ft/ft - 703.72 kip·ft/ft) / 190.90 kip/ft = 18.01 ft

$$q_{eq} = (190.9 \, \text{kip/ft}) \, / \, (36.02 \, \text{ft}) = 5.30 \, \text{ksf}$$

$$M_{V} = P_{EV_{1}}(x_{1}) + P_{EV_{2}}(x_{2}) + P_{EH} \sin \theta(B) = (\gamma_{BF} HB\gamma_{EV})(1/2B) + (1/2\gamma_{RS}(h-H)(B-l)\gamma_{EV})(1+1/2(B-l)) + (1/2\gamma_{RS}(h-H)(B-l)\gamma_{EV})(1+1/2(B-l)\gamma_{EV})(1+1/2(B-l)\gamma_{EV})($$

$$M_{H} = P_{EH} \cos \theta(x_3) + P_{LS} \cos \theta(x_4) = \left(\frac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}\cos\theta\right)\left(\frac{h}{3}\right) + \left(\sigma_{LS}hK_a\gamma_{LS}\cos\theta\right)\left(\frac{h}{3}\right)$$

 $M_H = \frac{1}{2}[(120 \text{ pcf})(45.1 \text{ ft})^2(0.342)(1.00)\cos(10.3^\circ)](45.1 \text{ ft}/3) = 703.72 \text{ kip-ft/ft}$ + $[(250 \text{ psf})(45.1 \text{ ft})(0.342)(1.00)\cos(10.3^\circ)](45.1 \text{ ft}/2)$

$$P_{V} = P_{EV_{1}} + P_{EV_{2}} + P_{EH} \sin \theta = (\gamma_{BF} H B \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} (h - H)(B - l) \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} h^{2} K_{a} \gamma_{EH} \sin \theta)$$

 $P_V = (120 \text{ pcf})(33.1 \text{ ft})(39.7 \text{ ft})(1.00) + \frac{1}{2}(120 \text{ pcf})(45.1 \text{ ft} - 33.1 \text{ ft})(39.7 \text{ ft} - 4.0 \text{ ft})(1.00) = 190.9 \text{ kip/ft} + \frac{1}{2}(120 \text{ pcf})(45.1 \text{ ft})^2(0.342)(1.00)\sin(10.3^\circ)$

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Alon Wall Facing
B-104-1-13	4.459 in	2.412 in	15 days		
B-105-3-14	3.519 in	1.872 in	3 days	85 ft	1/1890
B-105-5-14	3.512 in	1.535 in	5 days	145 ft	1/5160
B-107-2-14	2.946 in	1.321 in	1 days	135 ft	1/7570
B-108-7-14	2.403 in	1.341 in	1 days	160 ft	1/96000
B-108-8-14	0.950 in	0.694 in	3 days	130 ft	1/2410
			,		

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

W-13-072 - FRA-70-13.10 - Retaining Wall W5 MSE Wall Settlement - Sta. 600+75 to 601+83

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Boring B-105-3-14

H= 33.1 ft Total wall height

B'= 36.0 ft Effective footing width due to eccentricity

 D_w = 24.0 ft Depth below bottom of footing

q_e = 5,300 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of Re	einforced So	l Mass		Total Sett	tlement at Fa	cing of Wall	
Layer	Soil Class.	Soil Type		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	1 (7)	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	$\Delta\sigma_{_{_{ m V}}}^{(8)}$ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
4	A-4a	С	0.0	3.0	3.0	1.5	120	360	180	180	4,180	26	0.144	0.014	0.475				0.04	1.000	5,299	5,479	0.074	0.893	0.500	2,650	2,830	0.035	0.420
'	A-4a	С	3.0	6.0	3.0	4.5	120	720	540	540	4,540	26	0.144	0.014	0.475				0.13	0.994	5,267	5,807	0.058	0.701	0.500	2,648	3,188	0.023	0.271
2	A-3a	G	6.0	8.5	2.5	7.3	135	1,058	889	889	4,889					67	85	278	0.20	0.977	5,177	6,066	0.007	0.090	0.498	2,641	3,530	0.005	0.065
2	A-2-4	G	8.5	11.0	2.5	9.8	135	1,395	1,226	1,226	5,226					85	99	461	0.27	0.951	5,038	6,264	0.004	0.046	0.496	2,629	3,856	0.003	0.032
3	A-2-4	G	11.0	13.5	2.5	12.3	135	1,733	1,564	1,564	5,564					85	92	410	0.34	0.916	4,853	6,417	0.004	0.045	0.493	2,611	4,175	0.003	0.031
4	A-7-6	С	13.5	15.5	2.0	14.5	125	1,983	1,858	1,858	5,858	43	0.297	0.030	0.608				0.40	0.879	4,660	6,518	0.036	0.427	0.488	2,589	4,446	0.014	0.168
4	A-7-6	С	15.5	17.5	2.0	16.5	125	2,233	2,108	2,108	6,108	43	0.297	0.030	0.608				0.46	0.845	4,477	6,585	0.029	0.350	0.484	2,564	4,671	0.013	0.153
_	A-2-6	G	17.5	22.5	5.0	20.0	130	2,883	2,558	2,558	6,558					28	26	88	0.56	0.783	4,150	6,708	0.024	0.287	0.474	2,511	5,068	0.017	0.204
5	A-2-6	G	22.5	27.5	5.0	25.0	130	3,533	3,208	3,145	7,145					28	24	83	0.69	0.699	3,705	6,851	0.020	0.245	0.456	2,416	5,561	0.015	0.179
6	A-1-a	G	27.5	32.5	5.0	30.0	135	4,208	3,870	3,496	7,496					71	58	205	0.83	0.625	3,312	6,808	0.007	0.085	0.435	2,308	5,803	0.005	0.065
7	A-1-a	G	32.5	37.5	5.0	35.0	130	4,858	4,533	3,846	7,846					39	31	100	0.97	0.561	2,975	6,821	0.012	0.149	0.414	2,192	6,038	0.010	0.117
'	A-1-a	G	37.5	42.5	5.0	40.0	130	5,508	5,183	4,184	8,184					39	29	97	1.11	0.507	2,689	6,873	0.011	0.133	0.392	2,075	6,259	0.009	0.108
8	A-1-a	G	42.5	50.5	8.0	46.5	135	6,588	6,048	4,644	8,644					92	66	247	1.29	0.449	2,382	7,026	0.006	0.070	0.364	1,928	6,572	0.005	0.059
1. σ _p ' = σ,	_{′o} '+σ _{m;} Estima	ate $\sigma_{\rm m}$ of 4,0	00 psf (mode	erately overc	onsolidated)	for natural so	oil deposits;	Ref. Table 1	1.2, Coduto 2	2003											Total	Settlement:		3.519 in		Total	Settlement:		1.872 in

^{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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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.} $\Delta \sigma_v = q_e$

^{9.} $S_c = [C_c/(1+e_o)](H)[\log(\sigma_{v'}/\sigma_{v'})'$ for $\sigma_p' \leq \sigma_{v'}$; $[C_r/(1+e_o)](H)[\log(\sigma_p'/\sigma_{v'})'$ for $\sigma_{v'} < \sigma_p'$; $[C_r/(1+e_o)](H)[\log(\sigma_{v'}/\sigma_p')'$ for $\sigma_{v'} < \sigma_p' < \sigma_{v'}$; $[C_r/(1+e_o)](H)[\log(\sigma_{v'}/\sigma_p')']$ for $\sigma_{v'} < \sigma_{v'} < \sigma_{v'} < \sigma_{v'}$; $[C_r/(1+e_o)](H)[\log(\sigma_{v'}/\sigma_p')']$ for $\sigma_{v'} < \sigma_{v'} < \sigma_$

^{10.} S_c = H(1/C')log(σ_{vf} / σ_{vo} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-072 - FRA-70-13.10 - Retaining Wall W5

MSE Wall Settlement - Sta. 600+75 to 601+83

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Total Settlement at Facing of Wall

Settlement Remaining After Hold Period: 0.181 in

Settlement Complete at 90% of

Boring B-105-3-14

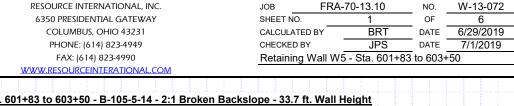
H=	33.1	ft	Total wall height		A-4a	A-7-6		
B'=	36.0	ft	Effective footing width due to eccentricity	c _v =	1,000	150	ft²/yr	Coefficient of consolitation
$D_w =$	24.0	ft	Depth below bottom of footing	t =	3	3	days	Time following completion of construction
q _e =	5,300	psf	Equivalent bearing pressure at bottom of wall	$H_{dr} =$	2.5	2.5	ft	Length of longest drainage path considered
				$T_v =$	1.315	0.197		Time factor
				U =	97	50	%	Degree of consolidation
				$(S_c)_t =$	1.690	in	Settlement complete a	t 90% of primary consolidation

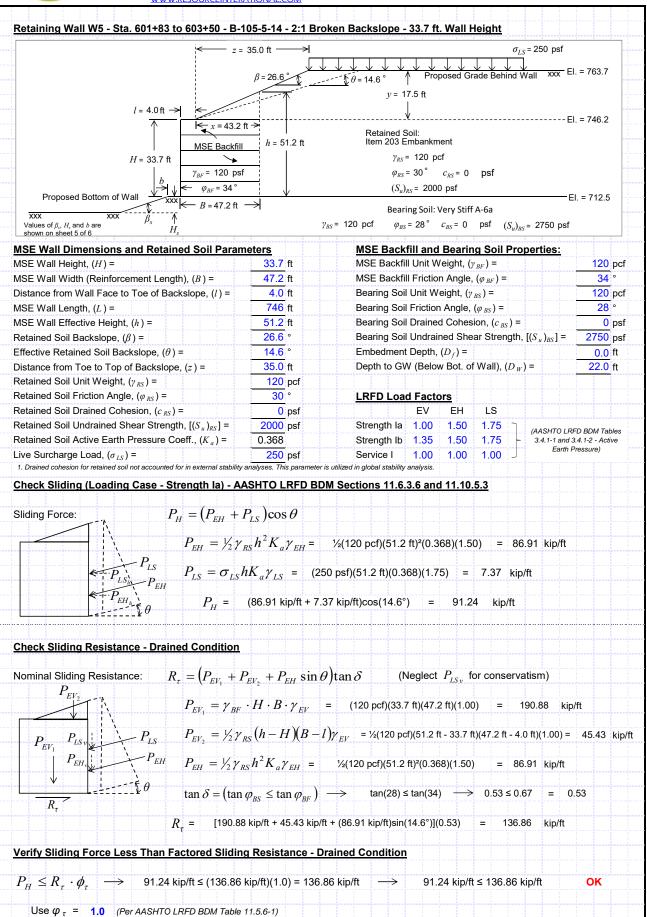
																									J	Primary Co	onsolidation
Layer	Soil Type	Soil Type	Layer (f		Layer Thickness (ft)	Depth to Midpoint (ft)	γ (pcf)	σ _{vo} Bottom (psf)	σ _{vo} Midpoint (psf)	σ _{vo} ' Midpoint (psf)	σ _p ' ⁽¹⁾ (psf)	LL	C _c (2)	C _r ⁽³⁾	e _o ⁽⁴⁾	N ₆₀	(N1) ₆₀ (5)	C' ⁽⁶⁾	Z_f/B	I ⁽⁷⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	Layer Settlement (in)	(S _c) _t ⁽¹¹⁾ (in)	Layer Settlement (in)
1	A-4a	С	0.0	3.0	3.0	1.5	120	360	180	180	4,180	26	0.144	0.014	0.475				0.04	0.500	2,650	2,830	0.035	0.420	0.691	0.408	0.671
ı	A-4a	С	3.0	6.0	3.0	4.5	120	720	540	540	4,540	26	0.144	0.014	0.475				0.13	0.500	2,648	3,188	0.023	0.271	0.091	0.263	0.071
2	A-3a	G	6.0	8.5	2.5	7.3	135	1,058	889	889	4,889					67	85	278	0.20	0.498	2,641	3,530	0.005	0.065	0.065	0.065	0.065
2	A-2-4	G	8.5	11.0	2.5	9.8	135	1,395	1,226	1,226	5,226					85	99	461	0.27	0.496	2,629	3,856	0.003	0.032	0.064	0.032	0.064
3	A-2-4	G	11.0	13.5	2.5	12.3	135	1,733	1,564	1,564	5,564					85	92	410	0.34	0.493	2,611	4,175	0.003	0.031	0.004	0.031	0.004
4	A-7-6	С	13.5	15.5	2.0	14.5	125	1,983	1,858	1,858	5,858	43	0.297	0.030	0.608				0.40	0.488	2,589	4,446	0.014	0.168	0.321	0.084	0.161
4	A-7-6	С	15.5	17.5	2.0	16.5	125	2,233	2,108	2,108	6,108	43	0.297	0.030	0.608				0.46	0.484	2,564	4,671	0.013	0.153	0.321	0.077	7 0.101
5	A-2-6	G	17.5	22.5	5.0	20.0	130	2,883	2,558	2,558	6,558					28	26	88	0.56	0.474	2,511	5,068	0.017	0.204	0.383	0.204	0.383
5	A-2-6	G	22.5	27.5	5.0	25.0	130	3,533	3,208	3,145	7,145					28	24	83	0.69	0.456	2,416	5,561	0.015	0.179	0.363	0.179	0.363
6	A-1-a	G	27.5	32.5	5.0	30.0	135	4,208	3,870	3,496	7,496					71	58	205	0.83	0.435	2,308	5,803	0.005	0.065	0.065	0.065	0.065
7	A-1-a	G	32.5	37.5	5.0	35.0	130	4,858	4,533	3,846	7,846					39	31	100	0.97	0.414	2,192	6,038	0.010	0.117	0.225	0.117	0.225
,	A-1-a	G	37.5	42.5	5.0	40.0	130	5,508	5,183	4,184	8,184					39	29	97	1.11	0.392	2,075	6,259	0.009	0.108	0.225	0.108	0.225
8	A-1-a	G	42.5	50.5	8.0	46.5	135	6,588	6,048	4,644	8,644					92	66	247	1.29	0.364	1,928	6,572	0.005	0.059	0.059	0.059	0.059

- 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. $e_0 = (C_c/1.15) + 0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
- 5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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. $\Delta \sigma_v = q_e$
- $9. \ \ S_c = [C_o/(1+e_o)](H) log(\sigma_{v_f}/\sigma_{v_o}') for \ \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_f}'; \ [C_r/(1+e_o)](H) log(\sigma_p'/\sigma_{v_o}') for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_p'; \ [C_r/(1+e_o)](H) log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H) log(\sigma_{v_f}/\sigma_p') for \ \sigma_{v_o}' < \sigma_{v_f}' < \sigma_{v_f}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO \ LRFD \ BDS \ (Cohesive soil layers)$
- 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



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DATE

6/29/2019 7/1/2019

Retaining Wall W5 - Sta. 601+83 to 603+50

MSE Wall Dimensions and Retained Soil Paran	neters	
MSE Wall Height, (H) =	33.7	ft
MSE Wall Width (Reinforcement Length), (B) =	47.2	ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft
MSE Wall Length, (<i>L</i>) =	746	ft
MSE Wall Effective Height, (h) =	51.2	ft
Retained Soil Backslope, (β) =	26.6	0
Effective Retained Soil Backslope, (θ) =	14.6	0
Distance from Toe to Top of Backslope, (z) =	35.0	ft
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf
Retained Soil Friction Angle, (φ_{RS}) =	30	0
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) =	0.368	
Live Surcharge Load, (σ_{LS}) =	250	psf
Drained cohesion for retained soil not accounted for in external stability	analyses, Thi	s paramet

Bearing Soil Properties:		
MSE Backfill Unit Weight, (γ_{BF}) =	120	pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34	0
Bearing Soil Unit Weight, (γ_{BS}) =	120	pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28	0
Bearing Soil Drained Cohesion, (c_{BS}) =	0	psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	2750	psf
Embedment Depth, (D_f) =	0.0	ft
Depth to GW (Below Bot. of Wall), (D_W) =	22.0	ft

LRFD Load Factors

	ΕV	ΕH	LS	
Strength la	1.00	1.50	1.75	٦
Strength lb	1.35	1.50	1.75	}
Service I	1.00	1.00	1.00	J

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

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

Check Sliding Resistance - Undrained Condition

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

$$\left(S_u
ight)_{BS}=$$
 2.75 ksf

$$q_s = \frac{\sigma_v}{2}$$

$$\sigma_v = \frac{P_V}{B}$$

$$P_{LS} \qquad q_s = \sigma_v / 2$$

$$P_{EH} \qquad \sigma_v = P_v / B$$

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

(Neglect $P_{LS_{\nu}}$ for conservatism)

$$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$$
 = (120 pcf)(33.7 ft)(47.2 ft)(1.00) = 190.9 kip/ft

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

$$P_{EV_2}$$
 = ½(120 pcf)(51.2 ft - 33.7 ft)(47.2 ft - 4.0 ft)(1.00) = 45.43 kip/ft

$$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(51.2 \text{ ft})^2 (0.368)(1.50) = 86.91 \text{ kip/ft}$$

$$P_V$$
 = 190.88 kip/ft + 45.43 kip/ft + (86.91 kip/ft)sin(14.6°) = 258.22 kip/ft

$$\sigma_{v}$$
 = (258.22 kip/ft) / (47.2 ft) = 5.47 ksf

$$q_s = (5.47 \text{ ksf})/2 = 2.74 \text{ ksf}$$

$$R_{\tau} = (2.75 \text{ ksf} \le 2.74 \text{ ksf})(47.2 \text{ ft}) = 129.80 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

 $P_H \leq R_{\tau} \cdot \phi_{\tau} \quad \longrightarrow \quad$ 91.24 kip/ft \leq (129.80 kip/ft)(1.0) = 129.80 kip/ft 91.24 kip/ft ≤ 129.80 kip/ft OK

Use $arphi_{ au}$ = 1.0 (Per AASHTO LRFD BDM Table 11.5.6-1)



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 Retaining Wall W5 - Sta. 601+83 to 603+50

6/29/2019 7/1/2019

W-13-072

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	resource international, inc.
	6350 PRESIDENTIAL GATEWAY
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<u>WWW.RESOL</u>	JRCEINTERATIONAL.COM		
MSE Wall Dimensions and Retained S	oil Parameters	Bearing Soil Properties:	
MSE Wall Height, (H) =	33.7 ft	MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf
MSE Wall Width (Reinforcement Length), (B) = 47.2 ft	MSE Backfill Friction Angle, (φ_{BF}) =	34 °
Distance from Wall Face to Toe of Backslop	· · · · · · · · · · · · · · · · · · ·	Bearing Soil Unit Weight, (γ_{BS}) =	120 pcf
MSE Wall Length, (L) =	746 ft	Bearing Soil Friction Angle, (φ_{BS}) =	28 °
MSE Wall Effective Height, (h) =	51.2 ft	Bearing Soil Drained Cohesion, (c_{BS}) =	0 psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained Shear Strength,	
Effective Retained Soil Backslope, (θ) =	14.6 °	Embedment Depth, (D_f) =	0.0 ft
Distance from Toe to Top of Backslope, (z)		Depth to GW (Below Bot. of Wall), (D_W)	anno di manganan i di d
Retained Soil Unit Weight, $(\gamma_{RS}) =$	120 pcf		
Retained Soil Friction Angle, (φ_{RS}) =	30 °	<u>LRFD Load Factors</u>	
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV EH LS	
Retained Soil Undrained Shear Strength, [(S		Strength la 1.00 1.50 1.75	
Retained Soil Active Earth Pressure Coeff., (ininninnumiämmiämmämmämmämmämmämmä	Strength lb 1.35 1.50 1.75	(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active
			Earth Pressure)
Live Surcharge Load, (σ_{LS}) = 1. Drained cohesion for retained soil not accounted for in exi	250 psf ternal stability analyses. This parameter is	Service I 1.00 1.00 1.00 J	
Check Eccentricity (Loading Case - St			
P_{EV_2}			
$\frac{E}{2}$	$=B/2-x_o$		
	/ 2		
P	1.6 1.6		
$\begin{array}{c c} x_4 \\ \uparrow \\ \end{array}$ $\begin{array}{c c} P_{EV_1} \\ \hline \end{array}$ $\begin{array}{c c} P_{LS} \\ \hline \end{array}$ $\begin{array}{c c} P_{LS} \\ \hline \end{array}$	$x = \frac{M_V - M_H}{1} = 7028$.9 kip-ft/ft - 1640.95 kip-ft/ft) / (258.22 kip/ft	= 20.87 ft
x_3 P_{EH} P_{EH}	P_{V}		
\uparrow			
R	M_{V} = 7028.90 ki	ip·ft/ft	
	$M_H = 1640.95 \text{ ki}$		
$x_0 \leftarrow * \Rightarrow e$		$P_{E\!H} \sin \theta$ = 190.88 kip/ft + 45.43 kip/ft + (86.91 kip/f	t)sin(14.6°) = 258.22 kin/ft
	EV ₁ EV ₂	- EH	
$x_1 \leftarrow B_2 \rightarrow$	e = (47.2 ft/ 2) - 20.87 f	ft = 2.73 ft	
Resisting Moment, $M_{\scriptscriptstyle V}$: $M_{\scriptscriptstyle \bullet}$	$P_{-1} = P_{-1}(x_1) + P_{-1}(x_2) + P_{-1}(x_3)$	$+P_{\!E\!H}\sin heta(B)$ (Neglect $P_{\!L\!S_{_{oldsymbol{V}}}}$ for	or conservatism)
$P_{\scriptscriptstyle EV_2}$	$EV_1 \times I J = EV_2 \times 2 J$	LSV.	
	$P_{rrr} = \gamma_{rrr} \cdot H \cdot B \cdot \gamma_{rrr}$	= (120 pcf)(33.7 ft)(47.2 ft)(1.00) =	190.88 kip/ft
	EK,		
P	$P_{EV} = \frac{1}{2} \gamma_{RS} (h - H)(B -$	$-l)\gamma_{EV}$ = ½(120 pcf)(51.2 ft - 33.7 ft)(47.2 ft - 4.0) ft)(1.00) = 45.43 kip/ft
$P_{rrr} \stackrel{LSV}{\searrow} \stackrel{LS}{\searrow} $	EV2 /4 / / / / / / / / / / / / / / / / / /		
P_{EH}	$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} =$	= ½(120 pcf)(51.2 ft)²(0.368)(1.50) =	86.91 kip/ft
	EH 727 RSW 1 a7 EH		
<u> </u>	$x_1 = B/2 = (47.2 \text{ ft})/2$	= 23.60 ft	
\vdash x_I	$x_1 - /2$		
$\rightarrow x_2$	$r_{-} = 1 + \frac{2}{3}(R - 1) = \frac{1}{3}$	$4.0 \text{ ft} + \frac{2}{3}(47.2 \text{ ft} - 4.0 \text{ ft}) = 32.80 \text{ ft}$	
	3 2 - 1 / 3 (B 1)		
$M_ u$	= (190.88 kip/ft)(23.60 ft) + (4	45.43 kip/ft)(32.8 ft) + (86.91 kip/ft)sin(14.6°)(47.	2 ft) = 7028.90 kip-ft/ft
Overturning Moment, $M_{\scriptscriptstyle H}$: $M_{\scriptscriptstyle H}$	$H = P_{EH} \cos \theta(x_3) + P_L$	$_{S}\cos\theta(x_{4})$	
	-5 1/ 12 tr		0004
		= ½(120 pcf)(51.2 ft)²(0.368)(1.50) =	
, i			
χ_4	$P_{LS} = \sigma_{LS} h K_a \gamma_{LS} =$	(250 pst)(51.2 ft)(0.368)(1.75) = 8.25	kıp/tt
\uparrow	h/ (54.05) (0	(250 psf)(51.2 ft)(0.368)(1.75) = 8.25 = 17.08 ft = 25.61 ft	
X_3	$x_3 = \frac{1}{3} = \frac{1}{3} = \frac{1}{3}$	= 17.08 π	
Enh	n = h/ (51.05); =	0.04	
	$x_4 = \frac{1}{2} = \frac{(51.2 \text{ tt})}{2}$	= 25.61 ft	
$M_{\dot{H}}$	$r = (60.91 \text{ kip/it})\cos(14.6^{\circ})(17.6^{\circ})$.08 ft) + $(8.25 \text{ kip/ft})\cos(14.6^{\circ})(25.61 \text{ ft}) = 16$	94∪.95 кір∙π/π
	n /		

Limiting Eccentricity: $e_{\text{max}} = B/3 \implies e_{\text{max}} = (47.2 \text{ ft})/3 = 15.73 \text{ ft}$ Check Eccentricity $e < e_{\text{max}} \longrightarrow$ 2.73 ft < 15.73 ft OK



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www	FAX: (614) 823 W.RESOURCEINTER		Ret	aining Wall W	5 - Sta. 601	+83 to 603+	+50
MSE Wall Dimensions and Retai	ined Soil Paran	<u>neters</u>	<u>-</u>	oil Properties	***************************************		
MSE Wall Height, (H) =		33.7 ft	MSE Backfil	ll Unit Weight, (γ_{BF}) =		120 pcf
MSE Wall Width (Reinforcement Leng	gth), (<i>B</i>) =	47.2 ft	MSE Backfil	I Friction Angle	$, (\varphi_{BF}) =$		34 °
Distance from Wall Face to Toe of Ba	ackslope, (l) =	4.0 ft	Bearing Soil	Unit Weight, ()	_{BS}) =		120 pcf
MSE Wall Length, (L) =		746 ft	Bearing Soil	Friction Angle,	$(\varphi_{BS}) =$		28 °
MSE Wall Effective Height, (h) =		51.2 ft	Bearing Soil	Drained Cohes	sion, $(c_{BS}) =$		0 psf
Retained Soil Backslope, (β) =		26.6 °	Bearing Soil	Undrained She	ear Strength,	$[(s_u)_{BS}] =$	2750 psf
Effective Retained Soil Backslope, (θ) =	14.6 °	Embedment	Depth, (D_f) =			0.0 ft
Distance from Toe to Top of Backslop	oe, (z) =	35.0 ft	Depth to GV	V (Below Bot. o	f Wall), ($D_{\it W}$) =	22.0 ft
Retained Soil Unit Weight, (γ_{RS}) =		120 pcf					
Retained Soil Friction Angle, (φ_{RS}) =		30 °	LRFD Load	d Factors			
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf		EV EH	LS		
Retained Soil Undrained Shear Streng	gth, $[(S_u)_{RS}] =$	2000 psf	Strength la	1.00 1.50	1.75	(AACUTO LDE	D DDM Tables
Retained Soil Active Earth Pressure (Coeff., (K_a) =	0.368	Strength lb		1.75 -	(AASHTO LRF 3.4.1-1 and 3.	-D BDM Tables .4.1-2 - Active
Live Surcharge Load, (σ_{IS}) =		250 psf	Service I	1.00 1.00	1.00	Earth Pi	ressure)
Drained cohesion for retained soil not accounted	d for in external stability						
Check Bearing Capacity (Loadin	g Case - Stren	nath lb) - AASHTC	LRFD BDM Sec	tion 11.6.3.2			
P_{EV}			<u> </u>				
		D /					
	$q_{eq} = I$	r _V / _D ,					
	1 eq	/ B					
X_{4} $P_{EV_{1}}$ $P_{LS_{1}}$ $P_{LS_{2}}$	' ₽'_	B-2e = 47	' 2 ft - 2(1 64 ft)	= 43.92	ff		
$X_3 \cap P$	EH —	B-2e-7	.2 11 - 2(1.04 11)	- 40.02	11		
\uparrow^3		$e = B/2 - x_o$	- (47.2 ft / 2) 2	106 ft _	1.64 ft		
$A = \frac{1}{2} \sum_{i=1}^{n} \frac{1}{i} \sum_{j=1}^{n} \frac{1}{i} \frac{1}{i} \frac{1}{i}$	e	$z=-/2-x_o$	= (41.21(12)-2	1.90 11 =	1.04 [[
		$M_V - M_H$	- (0406 00 ki	- #/# 1640 O	E kim #/#\ / '	240 02 kim/f	_ 21.06 ff
	X	$arepsilon_o = rac{{M_V - {M_H }}}{{P_U }}$	· = (9126.90 ki)	J·11/11 - 1040.9	o kipilili) / .	340.92 KIP/I	= 21.90 11
$x_o \leftarrow x_{i-1-1}e$		- γ					
$ \leftarrow B/2 $. , , , , , , , , , , , , , , , , , , ,				
<i>← B'</i> →	$q_{\it eq}$	= (340.92 kip/ft)) / (43.92 ft) =	7.76 kst			
$\downarrow x_2 \rightarrow \downarrow$							
Resisting Moment, $M_{\scriptscriptstyle{V}}$:	$M_V = P_{EV_1}$	$(x_1) + P_{EV_2}(x_2)$	$+ P_{EH} \sin \theta(B)$				
$P_{\scriptscriptstyle EV_2}$	$P_{EV_1} = 2$	$\gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$, = (120 pcf)((33.7 ft)(47.2 ft)	(1.35) =	257.68	kip/ft
	- '						
	$P_{\nu\nu} = 1$	$\gamma_2 \gamma_{RS} (h-H)(B-H)$	_ <i>l</i>) _{γ _{EV} = ½(120 pc}	f)(51.2 ft - 33.7	ft)(47.2 ft - 4.	0 ft)(1.35) =	61.33 kip/ft
P_{EV} P_{LS}	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	2 / N3 \	JA 228				
P_{EV_1}		$\frac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}$	= ½(120 pcf)(5	51.2 ft)2(0.368)(1.50) =	86.91 kip/	′ft
P_{EH}	EH Z	$\frac{\gamma_2 \gamma_{RS} n K_a \gamma_{EH}}{2} = (47.2 \text{ ft})/2$					
	$x_{\cdot} \equiv B$	$\sqrt{} = (47.2 \text{ ft})/2$	2 = 23.60	ft			
$-\frac{1}{2} = \frac{1}{2} - \frac{1}{2} \sqrt{\frac{1}{2}} \theta$	/	2					
$\rightarrow x_{I}$	$\mathbf{r}_{-} = 1$	$+ \frac{2}{3}(B-l) =$	4 0 ft + ² / ₃ (47 2 ft -	4 0 ft) =	32.80 ft		
$\Rightarrow x_2$	~2 - •	1.73 (B 1)			V=.VV		
	M., - (257)	68 kip/ft)(23.60 ft) +	(61.33 kin/ft)(32.8 ft)	+ (86 91 kin/ft)	sin(14 6°)(47	2 ft) = 9°	126.90 kip.ft
	W = (25).	00 Kip/it/(20.00 it/)	(01.00 kip/it/(02.0 it)	· (00.01 kip/it)	ың т т.о д <i>т</i> т.	210 - 31	120.00 Kip-it
Overturning Moment, $M_{\scriptscriptstyle H}$:	M - D	202 O(24) D	2 222 0(11)				
Overturning Moment, M_H .	$M_H = P_{EH}$	$_{I}\cos\theta(x_{3})+P$	$_{LS}\cos\theta(x_4)$				
		727-	1//100 5/5		1 = 0	0004	
	$P_{EH} = \frac{1}{2}$	$\frac{1}{2}\gamma_{RS}h^2K_a\gamma_{EH}$	$= \frac{1}{2}(120 \text{ pcf})(5$	o1.2 ft)²(0.368)(1.50) =	86.91 kip/	π
x_{a} \downarrow P_{LS}	$P_{LS} = \epsilon$	$\sigma_{LS} h K_a \gamma_{LS} =$	(250 psf)(51.2 ft)	(0.368)(1.75)	= 8.25	kip/ft	
7 K-1-D '	, ,	/					
X_3	$x_3 = n$	$\sqrt{3} = (51.2 \text{ ft}) / 3$	3 = 17.08	ft			
		_					
<u> </u>	$x_4 = h$	2 = (51.2 ft)/2	2 = 25.61	ft			
		_					
	$M_H = (86.91)$	1 kip/ft)cos(14.6°)(17	7.08 ft) + (8.25 kip/ft	c)cos(14.6°)(25.	61 ft = 1	640.95 kip-	ft/ft
Vertical Forces, P_{V} :	$P_{\nu} = P_{r\nu}$	$+P_{EV_2}+P_{EH}$ si	n $ heta$				
	EV.	EK2 EH					
	$P_{v_{i}} = 2$	257.68 kip/ft + 61.33	kip/ft + (86.91 kip/f	t)sin(14.6°) =	340.92	kip/ft	
	- · · · · · · · · · · ·	1/	, , , , , , , , , , , , , , , , , , ,			1-1-	



FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF 6 CALCULATED BY BRT DATE 6/29/2019 JPS 7/1/2019 CHECKED BY DATE Retaining Wall W5 - Sta. 601+83 to 603+50

	ameters	Bearing Soil P	roperties			
/ISE Wall Height, (H) =	33.7 ft	MSE Backfill Uni	it Weight, (, _{BF}) =		120 pc
#ISE Wall Width (Reinforcement Length), (B) =	47.2 ft	MSE Backfill Frid	ction Angle,	$(\varphi_{BF}) =$		34 °
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft	Bearing Soil Unit				120 pc
/ISE Wall Length, (L) =	746 ft	Bearing Soil Fric	tion Angle,	$(\varphi_{BS}) =$		28 °
#ISE Wall Effective Height, (h) =	51.2 ft	Bearing Soil Dra	ined Cohes	ion, $(c_{BS}) =$		0 ps
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Und	Irained She	ar Strength	$, [(s_u)_{BS}] =$	2750 ps
Effective Retained Soil Backslope, (θ) =	14.6 °	Embedment Dep	oth, (D_f) =			0.0 ft
Distance from Toe to Top of Backslope, (z) =	35.0 ft	Depth to GW (Be	elow Bot. of	f Wall), (D ⊮	,) =	22.0 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf					
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Fa	ctors			
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	E\	/ EH	LS		
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	Strength la 1.0	0 1.50	1.75	(AASHTO LRF	D BDM Tables
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.368	Strength lb 1.3	5 1.50	1.75	3.4.1-1 and 3	3.4.1-2 - Active
ive Surcharge Load, (σ_{LS}) = 1. Drained cohesion for retained soil not accounted for in external stabi	250 psf	Service I 1.0		1.00	∟ artn P	Pressure)
Check Bearing Capacity (Loading Case - Stre	ength lb) - AASHTO L			(Continued)		
Check Bearing Resistance - Drained Condition						
	$+ \gamma D_f N_{qm} C_{wq} + \gamma D_f N_{qm} C_{wq}$.		
	$N_{qm} = N_q s_q d_q i_q$	= 14.7			, = 16.7	
$N_c = 25.800$	$N_q = 14.720$, = 16.720		
$S_c = 1+(43.92 \text{ ft}/746 \text{ ft})(14.72/25.8)$		46 ft)tan(28°) = 1.00			43.92 ft/746 ft)	= 1.000
= 1.000	ānamainama ķirama jaramani aramana aramani a	-sin(28°)]²tan⁻¹(0.0 ft/43.92	aaaaa gaaaaaaa gaaaaa b		(Assumed)	
i_c = 1.000 (Assumed)	= 1.000		$C_{\scriptscriptstyle N}$	_γ = 22.0 ft <	1.5(43.92 ft) +	0.0 ft = 0
	$i_q = 1.000$ (Ass					
	$C_{wq} = 22.0 \text{ ft} > 0.0$	ft = 1.000				
$q_n = (0 \text{ psf})(25.8) + (120 \text{ pcf})(0.0 \text{ ft})(1$ Verify Equivalent Pressure Less Than Factor			= 2	22.03 ks	Γ	
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b $ 7.76 ks		.65) = 7.88 ksf	->	7.76 ksf ≤	7.88 ksf	OK
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 ext{ ks}$ $RC_{BC} = 0.55 ext{ (Per AASHTO LRFD BDM Use } \phi_b = 0.65 ext{ (Per AASHTO LRFD BDM Check Bearing Resistance - Undrained Conditions}$	sf ≤ (22.03 ksf)(0.55)(0 1 Section 10.6.3.1.2c) — 1 Table 11.5.6-1)	\rightarrow Use $\beta_s = $				OK <i>b</i> = 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 \text{ ks}$ $RC_{BC} = 0.55 \text{ (Per AASHTO LRFD BDM Use } \phi_b = 0.65 \text{ (Per AASHTO LRFD BDM Check Bearing Resistance - Undrained Condem Resistance - Undrained Condem Resistance - Undrained Condem Resistance - q_n = cN_{cm}$	sf ≤ (22.03 ksf)(0.55)(0 1 Section 10.6.3.1.2c) — 1 Table 11.5.6-1)	$\rightarrow \text{ Use } \beta_s = \frac{1}{2} 1$	15.0 °		7.0 ft	b = 0.1
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 ext{ ks}$ $RC_{BC} = 0.55 ext{ (Per AASHTO LRFD BDM}$ Use $\varphi_b = 0.65 ext{ (Per AASHTO LRFD BDM}$ Check Bearing Resistance - Undrained Conditional Bearing Resistance: $q_n = cN_{cm} \cdot N_{cm} = N_c s_c i_c = 5.140$	sf \leq (22.03 ksf)(0.55)(0 I Section 10.6.3.1.2c) — I Table 11.5.6-1) Illition $+ \gamma D_f N_{qm} C_{wq} + \gamma D_f$	$\rightarrow \text{ Use } \beta_s = \frac{1}{2} 1$	15.0°	$H_s = \phantom{aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa$	7.0 ft	b = 0.1
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 \mathrm{ks}$ $RC_{BC} = 0.55 ext{ (Per AASHTO LRFD BDM Use } \varphi_b = 0.65 ext{ (Per AASHTO LRFD BDM Boundary Resistance - Undrained Conditions)}$ $Check Bearing Resistance - Undrained Conditions)$	sf \leq (22.03 ksf)(0.55)(0 1 Section 10.6.3.1.2c) — 1 Table 11.5.6-1) Section $V_{qm} = V_{qm} C_{wq} + V_{q$	$\rightarrow \text{ Use } \beta_s = \frac{1}{2} 1$	15.0° N _{ym} =	$H_s = \phantom{aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa$	7.0 ft	b = 0.1
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 \mathrm{ks}$ $RC_{BC} = 0.55 ext{ (Per AASHTO LRFD BDM Use } \varphi_b = 0.65 ext{ (Per AASHTO LRFD BDM Boundary Resistance - Undrained Conditions)}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $N_c = 5.140$ $N_c = 1+(43.92 \mathrm{ft/[(5)(746 ft)]} = 1.000$	sf \leq (22.03 ksf)(0.55)(0 1 Section 10.6.3.1.2c) — 1 Table 11.5.6-1) Section 10.6.3.1.2c) — 1 Table 11.5.6-1) Section 10.6.3.1.2c) — Name Name Name Name Name Name Name Name	$\rightarrow \text{ Use } \beta_s = \frac{1}{2}$ $\frac{1}{2} \frac{\partial^2 N_{yn} C_{wy}}{\partial x^2}$ $= 1.000$	15.0° N _{jm} = N,	$H_s = \frac{1}{2}$ $= N_y s_y i_y$ $= 0.000$ $= 1.000$	7.0 ft	b = 0.1
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 \mathrm{ks}$ $RC_{BC} = 0.55 ext{ (Per AASHTO LRFD BDM Use } \varphi_b = 0.65 ext{ (Per AASHTO LRFD BDM Boundary Resistance - Undrained Conditions)}$ $Check Bearing Resistance - Undrained Conditions)$	sf \leq (22.03 ksf)(0.55)(0 1 Section 10.6.3.1.2c) — 1 Table 11.5.6-1) Ilition $ + \gamma D_f N_{qm} C_{wq} + \gamma D_f N_{qm} = N_q s_q d_q i_q $ $ N_q = 1.000 $ $ s_q = 1.000 $ $ d_q = 1.24 $ $ d_q = 1.24 $	$\rightarrow \text{ Use } \beta_s = \frac{1}{2} 1$	15.0° N _{jm} = N S ₁ i) i,	$H_s = \frac{1}{2}$ $= N_{\gamma} S_{\gamma} i_{\gamma}$ $= 0.000$ $= 1.000$ $= 1.000$	7.0 ft = 0.00 (Assumed)	b = 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 \mathrm{ks}$ $RC_{BC} = 0.55 (Per AASHTO LRFD BDM Use \varphi_b = 0.65 (Per AASHTO LRFD BDM Check Bearing Resistance - Undrained Cond Cominal Bearing Resistance: \qquad q_n = cN_{cm} \cdot N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $S_c = 1+(43.92 \mathrm{ft/[(5)(746 \mathrm{ft)]}} = 1.000$	sf \leq (22.03 ksf)(0.55)(0 1 Section 10.6.3.1.2c) — 1 Table 11.5.6-1) Section 10.6.3.1.2c) — 1 Table 11.5.6-1) Section 10.6.3.1.2c) — Name Name Name Name Name Name Name Name	$\Rightarrow \text{ Use } \beta_s = \frac{1}{2}$ $\frac{1}{2} \frac{\partial^2 N_{ym} C_{wy}}{\partial y^m} = \frac{1.000}{1.000}$ $\frac{1.000}{1.000}$ $\frac{1.000}{1.000}$ sumed)	15.0° N _{jm} = N S ₁ i) i,	$H_s = \frac{1}{2}$ $= N_{\gamma} S_{\gamma} i_{\gamma}$ $= 0.000$ $= 1.000$ $= 1.000$	7.0 ft	b = 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 \mathrm{ks}$ $RC_{BC} = 0.55 (Per AASHTO LRFD BDM Use \varphi_b = 0.65 (Per AASHTO LRFD BDM Check Bearing Resistance - Undrained Cond Cominal Bearing Resistance: \qquad q_n = cN_{cm} \cdot N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $S_c = 1+(43.92 \mathrm{ft/[(5)(746 \mathrm{ft)]}} = 1.000$	sf \leq (22.03 ksf)(0.55)(0 1 Section 10.6.3.1.2c) — 1 Table 11.5.6-1) Section 10.6.3.1.2c) — 1 Table 11.5.6-1) Section 10.6.3.1.2c) — $N_q = 1.5.6$ $N_q = N_q S_q d_q i_q$ $N_q = 1.000$ $S_q = 1.000$ $d_q = 1.2 tan(0^\circ)[1]$ = 1.000 $i_q = 1.000$ (Ass $C_{wq} = 22.0 \text{ ft} > 0.00$	ightarrow Use	$N_{jm} = N_{jm}$	$H_s = \frac{1}{2}$ $= N_{\gamma} S_{\gamma} i_{\gamma}$ $= 0.000$ $= 1.000$ $= 1.000$	7.0 ft = 0.00 (Assumed) 1.5(43.92 ft) +	b = 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 \text{ ks}$ $RC_{BC} = 0.55 \text{ (Per AASHTO LRFD BDM Use } \phi_b = 0.65 \text{ (Per AASHTO LRFD BDM Deck Bearing Resistance - Undrained Condense}$ Nominal Bearing Resistance: $q_n = cN_{cm} \cdot N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $N_c = 5.140$ $N_c = 1.000 \text{ (Assumed)}$	sf \leq (22.03 ksf)(0.55)(0 1 Section 10.6.3.1.2c) — 1 Table 11.5.6-1) Ilition	$\Rightarrow \text{ Use } \beta_s = \frac{1}{2} \text{ Wyn } C_{wy}$ $= 1.000$ $-\sin(0^{\circ})]^{2} \tan^{-1}(0.0 \text{ ft/43.92 ft})$ sumed $\text{ft} = 1.000$ $\text{ft/(43.9 ft)(0.0)(0.5)}$	$N_{jm} = N_{jm}$	$H_{s} = \frac{1}{2} = N_{\gamma} S_{\gamma} i_{\gamma}$ $V_{\gamma} = 0.000$ $V_{\gamma} = 1.000$ $V_{\gamma} = 22.0 \text{ ft} < 0.000$	7.0 ft = 0.00 (Assumed) 1.5(43.92 ft) +	b = 0.0
$q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 7.76 \text{ ks}$ $RC_{BC} = 0.55 \text{ (Per AASHTO LRFD BDM}$ Use $\varphi_b = 0.65 \text{ (Per AASHTO LRFD BDM}$ Check Bearing Resistance - Undrained Condition of the Conditio	sf \leq (22.03 ksf)(0.55)(0 I Section 10.6.3.1.2c) — I Table 11.5.6-1) Section 10.6.3.1.2c) — I Table 11.5.6-1) Section 10.6.3.1.2c) — I Table 11.5.6-1) N _q = 1.5.6.1 N _q = N _q S _q d _q i _q N _q = 1.000 Section 10.00 (Associated Constitution (Associated Const	$\Rightarrow \text{ Use } \beta_s = \frac{1}{2} \text{ Wy}$ $= 1.000$ $= 1.000$ $\text{Sin}(0^\circ)]^2 \text{tan}^{-1}(0.0 \text{ ft/43.92 ft})$ $\text{Sumed}(0)$ $\text{ft} = 1.000$ $\text{ft}(43.9 \text{ ft})(0.0)(0.5)$	$N_{jm} = N_{jm}$ $N_{jm} = N$	$H_{s} = \frac{1}{2} = N_{\gamma} S_{\gamma} i_{\gamma}$ $V_{\gamma} = 0.000$ $V_{\gamma} = 1.000$ $V_{\gamma} = 22.0 \text{ ft} < 0.000$	7.0 ft 7.0 ft (Assumed) 1.5(43.92 ft) +	b = 0.0



FRA-70-13.10 JOB SHEET NO. CALCULATED BY DATE JPS CHECKED BY DATE

6/29/2019 7/1/2019

W-13-072

Retaining Wall W5 - Sta. 601+83 to 603+50

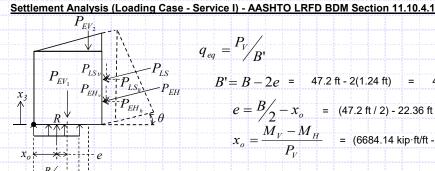
MSE Wall Dimensions and Retained Soil Paran	<u>neters</u>
MSE Wall Height, (<i>H</i>) =	33.7 ft
MSE Wall Width (Reinforcement Length), (B) =	47.2 ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft
MSE Wall Length, (L) =	746 ft
MSE Wall Effective Height, (h) =	51.2 ft
Retained Soil Backslope, (β) =	26.6 °
Effective Retained Soil Backslope, (θ) =	14.6 °
Distance from Toe to Top of Backslope, (z) =	35.0 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) =	0.368
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}) =	28 °
Bearing Soil Drained Cohesion, (c_{BS}) =	0 psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	2750 psf
Embedment Depth, (D_f) =	0.0 ft
Depth to GW (Below Bot. of Wall), (D_W) =	22.0 ft

LRFD Load Factors

	∟v	LII	LO	
Strength la	1.00	1.50	1.75	٦
Strength lb	1.35	1.50	1.75	}
Service I	1.00	1.00	1.00	ل

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



$$q_{eq} = \frac{P_V}{B'}$$

$$B' = B - 2e = 47.2 \text{ ft} - 2(1.24 \text{ ft}) = 44.72 \text{ ft}$$

$$e = \frac{B}{2} - x_o$$
 = (47.2 ft/2) - 22.36 ft = 1.24 f

$$x_o = \frac{M_V - M_H}{P_V}$$
 = (6684.14 kip·ft/ft - 1074.25 kip·ft/ft) / 250.91 kip/ft = 22.36 ft

$$q_{eq} = (250.91 \text{ kip/ft}) / (44.72 \text{ ft}) = 5.61 \text{ ksf}$$

$$M_{V} = P_{EV_{1}}(x_{1}) + P_{EV_{2}}(x_{2}) + P_{EH} \sin \theta(B) = (\gamma_{BF} HB\gamma_{EV})(1/2B) + (1/2\gamma_{RS}(h-H)(B-l)\gamma_{EV})(1+1/2(B-l)) + (1/2\gamma_{RS}(h-H)(B-l)\gamma_{EV})(1+1/2(B-l)\gamma_{EV})(1+1/2(B-l)\gamma_{EV})($$

 $M_V =$ $[(120 \text{ pcf})(33.7 \text{ ft})(47.2 \text{ ft})(1.00)][\frac{1}{2}(47.2 \text{ ft})] + [\frac{1}{2}(120 \text{ pcf})(51.2 \text{ ft} - 33.7 \text{ ft})(47.2 \text{ ft} - 4.0 \text{ ft})(1.00)][4.0 \text{ ft} + \frac{3}{2}(47.2 \text{ ft} - 4.0 \text{ ft})]$ = 6684.14 kip·ft/ft + [1/2(120 pcf)(51.2 ft)2(0.368)(1.00)sin(14.6°)](47.2 ft)

$$M_{H} = P_{EH} \cos \theta(x_3) + P_{LS} \cos \theta(x_4) = \left(\frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} \cos \theta\right) \left(\frac{h}{3}\right) + \left(\sigma_{LS} h K_a \gamma_{LS} \cos \theta\right) \left(\frac{h}{3}\right)$$

 $M_H = \frac{1}{2}[(120 \text{ pcf})(51.2 \text{ ft})^2(0.368)(1.00)\cos(14.6^\circ)](51.2 \text{ ft}/3) = 1,074.25 \text{ kip-ft/ft}$ + [(250 psf)(51.2 ft)(0.368)(1.00)cos(14.6°)](51.2 ft /2)

$$P_{V} = P_{EV_{1}} + P_{EV_{2}} + P_{EH} \sin \theta = (\gamma_{BF} H B \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} (h - H)(B - l) \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} h^{2} K_{a} \gamma_{EH} \sin \theta)$$

 $P_V = (120 \text{ pcf})(33.7 \text{ ft})(47.2 \text{ ft})(1.00) + \frac{1}{2}(120 \text{ pcf})(51.2 \text{ ft} - 33.7 \text{ ft})(47.2 \text{ ft} - 4.0 \text{ ft})(1.00) = 250.91 \text{ kip/ft}$ + ½(120 pcf)(51.2 ft)²(0.368)(1.00)sin(14.6°)

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Along Wall Facing
B-104-1-13	4.459 in	2.412 in	15 days		
B-105-3-14	3.519 in	1.872 in	3 days	85 ft	1/1890
B-105-5-14	3.512 in	1.535 in	5 days	145 ft	1/5160
B-107-2-14	2.946 in	1.321 in	1 days	135 ft	1/7570
B-108-7-14	2.403 in	1.341 in	1 days	160 ft	1/96000
B-108-8-14	0.950 in	0.694 in	3 days	130 ft	1/2410

W-13-072 - FRA-70-13.10 - Retaining Wall W5

MSE Wall Settlement - Sta. 601+83 to 603+50

Boring B-105-5-14

H= 33.7 ft Total wall height

44.7 ft B'= Effective footing width due to eccentricity

 $D_w =$ 22.0 ft Depth below bottom of footing

5,610 Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of R	einforced Soi	il Mass		Total Sett	tlement at Fa	acing of Wall	
Layer	Soil Class.	Soil Type		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⁾	$\Delta\sigma_{\rm v}^{~(8)}$ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	$\Delta\sigma_{\rm v}^{~(8)}$ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
1	A-6a	С	0.0	2.0	2.0	1.0	120	240	120	120	4,120	27	0.153	0.015	0.483				0.02	1.000	5,610	5,730	0.061	0.735	0.500	2,805	2,925	0.029	0.343
	A-6a	С	2.0	4.0	2.0	3.0	120	480	360	360	4,360	27	0.153	0.015	0.483				0.07	0.999	5,604	5,964	0.050	0.605	0.500	2,805	3,165	0.019	0.234
2	A-2-4	G	4.0	7.0	3.0	5.5	135	885	683	683	4,683					104	142	851	0.12	0.994	5,577	6,259	0.003	0.041	0.500	2,803	3,485	0.002	0.030
	A-2-4	G	7.0	10.0	3.0	8.5	135	1,290	1,088	1,088	5,088					104	125	688	0.19	0.980	5,499	6,586	0.003	0.041	0.499	2,797	3,885	0.002	0.029
2	A-6b	С	10.0	12.0	2.0	11.0	120	1,530	1,410	1,410	5,410	38	0.252	0.025	0.569				0.25	0.961	5,392	6,802	0.051	0.608	0.497	2,788	4,198	0.015	0.183
3	A-6b	С	12.0	14.0	2.0	13.0	120	1,770	1,650	1,650	5,650	38	0.252	0.025	0.569				0.29	0.941	5,281	6,931	0.046	0.548	0.495	2,778	4,428	0.014	0.165
4	A-4b	С	14.0	16.5	2.5	15.3	120	2,070	1,920	1,920	5,920	22	0.108	0.011	0.444				0.34	0.915	5,134	7,054	0.023	0.281	0.493	2,764	4,684	0.007	0.087
5	A-1-a	G	16.5	20.5	4.0	18.5	130	2,590	2,330	2,330	6,330					28	27	90	0.41	0.873	4,895	7,225	0.022	0.263	0.488	2,735	5,065	0.015	0.180
	A-1-a	G	20.5	25.5	5.0	23.0	135	3,265	2,928	2,865	6,865					74	65	242	0.51	0.809	4,539	7,404	0.009	0.102	0.478	2,683	5,548	0.006	0.071
6	A-1-a	G	25.5	30.5	5.0	28.0	135	3,940	3,603	3,228	7,228					74	62	227	0.63	0.739	4,147	7,375	0.008	0.095	0.465	2,609	5,837	0.006	0.068
	A-1-a	G	30.5	35.5	5.0	33.0	135	4,615	4,278	3,591	7,591					74	60	213	0.74	0.675	3,784	7,375	0.007	0.088	0.450	2,523	6,114	0.005	0.065
7	A-1-b	G	35.5	38.5	3.0	37.0	130	5,005	4,810	3,874	7,874					37	29	96	0.83	0.628	3,521	7,395	0.009	0.106	0.436	2,447	6,321	0.007	0.080
1. $\sigma_p' = \sigma_v$	_o '+σ _{m;} Estima	ate $\sigma_{\rm m}$ of 4,0	00 psf (mode	erately overc	onsolidated)	for natural so	oil deposits;	Ref. Table 1	1.2, Coduto 2	2003	•		•				•	•			Total	Settlement:		3.512 in		Total	Settlement:		1.535 in

^{2.} C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5

Calculated By: BRT Date: 6/30/2019 Checked By: Date: 7/1/2019

^{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 $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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.} $\Delta \sigma_v = q_e(I)$

 $^{9. \ \} S_c = [C_o/(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_i}'; \ [C_r/(1+e_o)](H) \log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H) \\ \log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H) \\ \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_{v_o}' < \sigma_{v_i}'; \ \text{Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesive soil layers)} \\ \text{for } \sigma_{v_o}' \leq \sigma_$

^{10.} S_c = H(1/C')log(σ_{vf} '/ σ_{vo} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-072 - FRA-70-13.10 - Retaining Wall W5

MSE Wall Settlement - Sta. 601+83 to 603+50

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Settlement Remaining After Hold Period:

Settlement Complete at 90% of

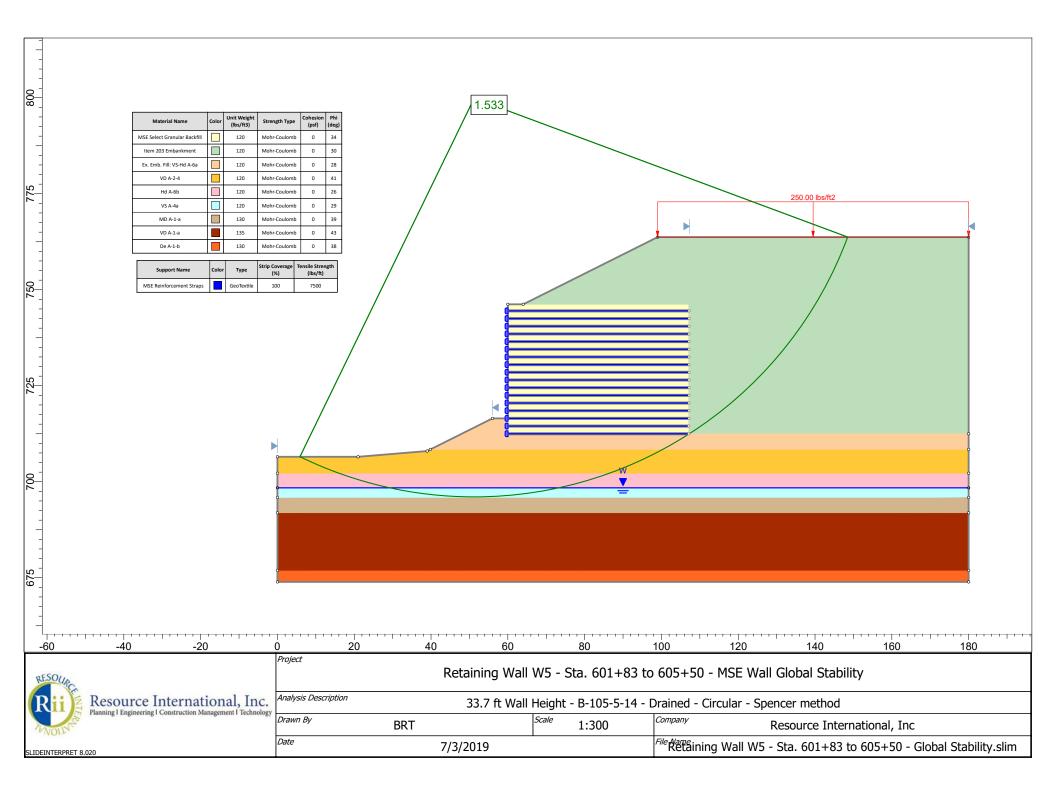
0.155

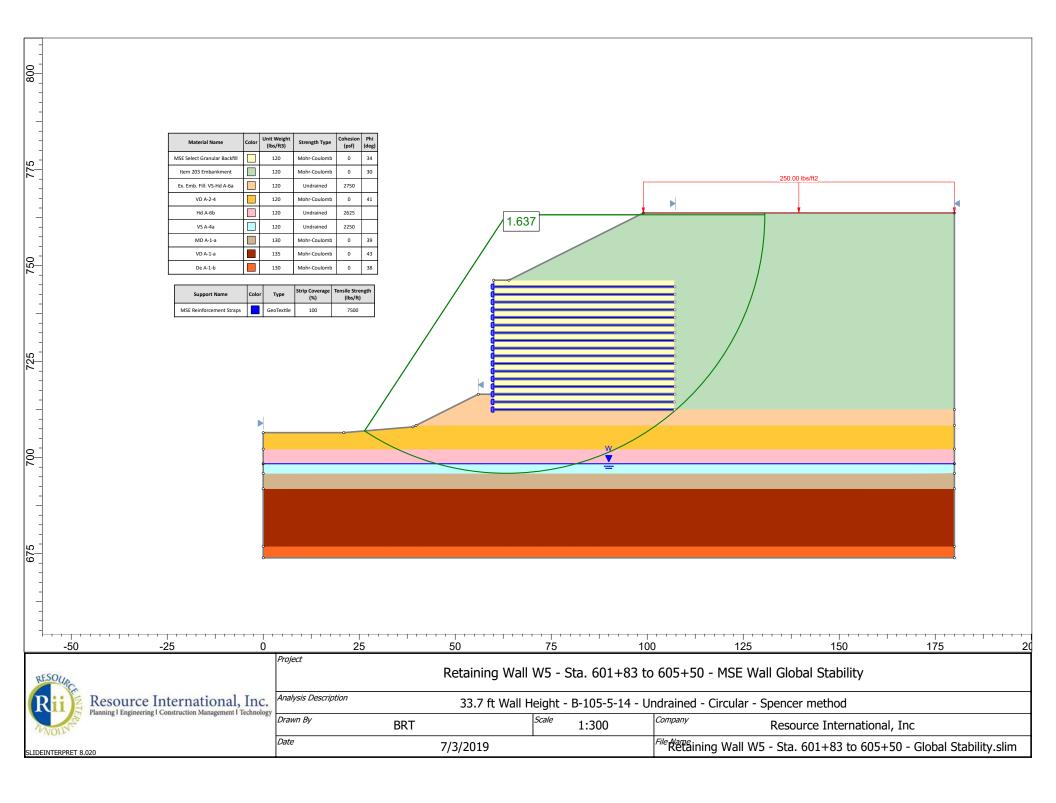
Boring B-105-5-14

H=	33.7	ft	Total wall height		A-6a	A-6b	A-4b		
B'=	44.7	ft	Effective footing width due to eccentricity	c _v =	600	300	1000	ft²/yr	Coefficient of consolitation
$D_w =$	22.0	ft	Depth below bottom of footing	t =	5	5	5	days	Time following completion of construction
q _e =	5,610	psf	Equivalent bearing pressure at bottom of wall	H _{dr} =	2.0	4	2.5	ft	Length of longest drainage path considered
				$T_v =$	2.055	0.257	2.192		Time factor
				U =	99	57	100	%	Degree of consolidation
				$(S_c)_t =$	1.380	in	Settlement	t complete	at 90% of primary consolidation

																							Total Se	illement at r	acing or vvali	Primary Co	onsolidation
Layer	Soil Type	Soil Type	Layer (f	•	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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	Layer Settlement (in)	(S _c) _t ⁽¹¹⁾ (in)	Layer Settlement (in)
1	A-6a	С	0.0	2.0	2.0	1.0	120	240	120	120	4,120	27	0.153	0.015	0.483				0.02	0.500	2,805	2,925	0.029	0.343	0.577	0.340	0.571
ļ	A-6a	С	2.0	4.0	2.0	3.0	120	480	360	360	4,360	27	0.153	0.015	0.483				0.07	0.500	2,805	3,165	0.019	0.234	0.577	0.231	0.571
2	A-2-4	G	4.0	7.0	3.0	5.5	135	885	683	683	4,683					104	142	851	0.12	0.500	2,803	3,485	0.002	0.030	0.059	0.030	0.059
2	A-2-4	G	7.0	10.0	3.0	8.5	135	1,290	1,088	1,088	5,088					104	125	688	0.19	0.499	2,797	3,885	0.002	0.029	0.039	0.029	0.059
3	A-6b	С	10.0	12.0	2.0	11.0	120	1,530	1,410	1,410	5,410	38	0.252	0.025	0.569				0.25	0.497	2,788	4,198	0.015	0.183	0.348	0.104	0.198
3	A-6b	С	12.0	14.0	2.0	13.0	120	1,770	1,650	1,650	5,650	38	0.252	0.025	0.569				0.29	0.495	2,778	4,428	0.014	0.165	0.346	0.094	0.196
4	A-4b	С	14.0	16.5	2.5	15.3	120	2,070	1,920	1,920	5,920	22	0.108	0.011	0.444				0.34	0.493	2,764	4,684	0.007	0.087	0.087	0.087	0.087
5	A-1-a	G	16.5	20.5	4.0	18.5	130	2,590	2,330	2,330	6,330					28	27	90	0.41	0.488	2,735	5,065	0.015	0.180	0.180	0.180	0.180
	A-1-a	G	20.5	25.5	5.0	23.0	135	3,265	2,928	2,865	6,865					74	65	242	0.51	0.478	2,683	5,548	0.006	0.071		0.071	
6	A-1-a	G	25.5	30.5	5.0	28.0	135	3,940	3,603	3,228	7,228					74	62	227	0.63	0.465	2,609	5,837	0.006	0.068	0.204	0.068	0.204
	A-1-a	G	30.5	35.5	5.0	33.0	135	4,615	4,278	3,591	7,591					74	60	213	0.74	0.450	2,523	6,114	0.005	0.065		0.065	
7	A-1-b	G	35.5	38.5	3.0	37.0	130	5,005	4,810	3,874	7,874					37	29	96	0.83	0.436	2,447	6,321	0.007	0.080	0.080	0.080	0.080

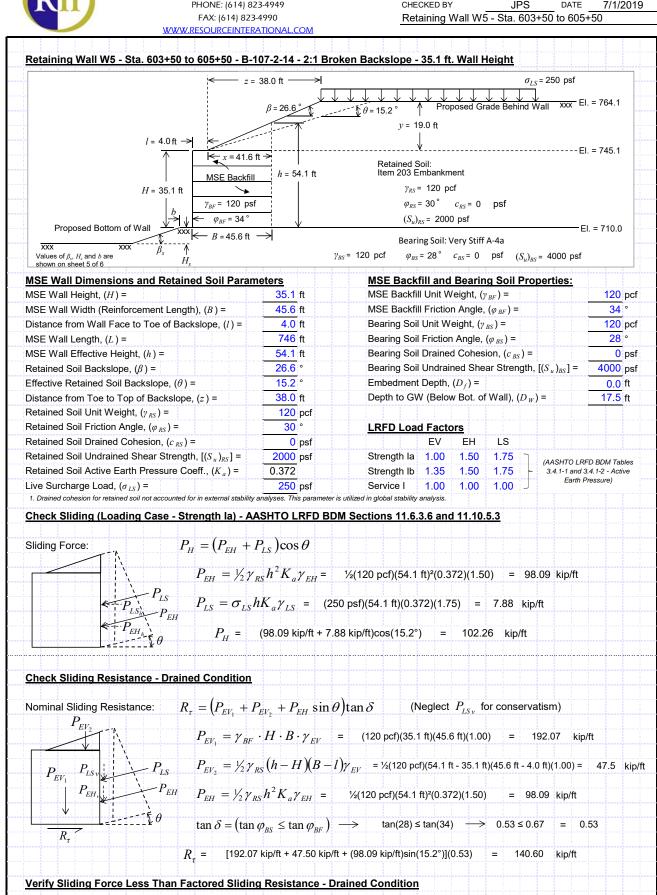
- 1. σ_p ' = σ_{vo} '+ σ_m ; Estimate σ_m of 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
- 2. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
- 3. $C_r = 0.10(Cc)$ for natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
- 4. $e_0 = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
- 5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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. $\Delta \sigma_v = q_e(I)$
- $9. \ \ S_c = [C_c/(1+e_o)](H)log(\sigma_{v_f}/\sigma_{v_o}') \\ for \ \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_f}'; \ [C_r/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}') \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_p'; \ [C_r/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}') \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_p'; \ [C_r/(1+e_o)](H)log(\sigma_{v_f}/\sigma_p') \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_{v_f}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO \ LRFD \ BDS \ (Cohesive \ soil \ layers) \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_{v_f}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO \ LRFD \ BDS \ (Cohesive \ soil \ layers) \\ for \ \sigma_{v_o}' < \sigma_{v_f}' \leq \sigma_{v_f}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO \ LRFD \ BDS \ (Cohesive \ soil \ layers) \\ for \ \sigma_{v_o}' < \sigma_{v_f}' < \sigma_{v$
- 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







JOB FRA-70-13.10 W-13-072 SHEET NO. CALCULATED BY DATE 6/29/2019 CHECKED BY JPS DATE 7/1/2019



 $P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 102.26 \text{ kip/ft} \leq (140.60 \text{ kip/ft})(1.0) = 140.60 \text{ kip/ft} \longrightarrow$ 102.26 kip/ft ≤ 140.60 kip/ft OK Use φ_{τ} = 1.0 (Per AASHTO LRFD BDM Table 11.5.6-1)



FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF CALCULATED BY BRT DATE 6/29/2019 JPS 7/1/2019 CHECKED BY DATE

6

Retaining Wall W5 - Sta. 603+50 to 605+50

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TATT	
	1707

roperties: It Weight, (γ_{BF}) = 120 pcf ction Angle, (φ_{BF}) = 34 ° It Weight, (γ_{BS}) = 120 pcf tion Angle, (φ_{BS}) = 28 ° Ition Angle, (φ_{BS}) = 0 psf tined Cohesion, (c_{BS}) = 0 psf trained Shear Strength, $[(s_u)_{BS}]$ = 4000 psf oth, (D_f) = 0.0 ft telow Bot. of Wall), (D_W) = 17.5 ft Indicates Indicates the second of t
It Weight, $(\gamma_{BF}) = 120 \text{ pcf}$ stion Angle, $(\varphi_{BF}) = 34 \text{ °}$ st Weight, $(\gamma_{BS}) = 120 \text{ pcf}$ tion Angle, $(\varphi_{BS}) = 28 \text{ °}$ sined Cohesion, $(c_{BS}) = 0 \text{ pcf}$ drained Shear Strength, $[(s_u)_{BS}] = 4000 \text{ pcf}$ sth, $(D_f) = 0.0 \text{ ft}$ selow Bot. of Wall), $(D_W) = 17.5 \text{ ft}$ strength LS $(D_f) = D_f = 0.0 \text{ ft}$ so $(D_f) = 0.0 \text{ ft}$ selow Bot. of Wall), $(D_W) = 0.0 \text{ ft}$ strength LS $(D_f) = D_f = 0.0 \text{ ft}$ so $(D_f) = D_f = 0.0 \text{ ft}$ size $(D_f) = D_f = 0.0 \text{ ft}$ so $(D_f) = D_f = 0.0 \text{ ft}$ size $(D_f) = D_f = 0.0 \text{ ft}$ si
tion Angle, (φ_{BF}) = 34 ° tweight, (γ_{BS}) = 120 pcf tion Angle, (φ_{BS}) = 28 ° ined Cohesion, (c_{BS}) = 0 psf drained Shear Strength, $[(s_u)_{BS}]$ = 4000 psf oth, (D_f) = 0.0 ft elow Bot. of Wall), (D_W) = 17.5 ft $\frac{1}{1}$ = 150 1.75 $\frac{1}{1}$ = 150 1.75 $\frac{1}{1}$ = 150 1.75 $\frac{1}{1}$ = 150 1.00 1.00 1.00 $\frac{1}{1}$ = 160 $\frac{1}{1}$ = 170 $\frac{1}$
t Weight, $(y_{BS}) = $ 28 ° tion Angle, $(\varphi_{BS}) = $ 28 ° ined Cohesion, $(c_{BS}) = $ 0 psf drained Shear Strength, $[(s_u)_{BS}] = $ 4000 psf oth, $(D_f) = $ 0.0 ft elow Bot. of Wall), $(D_W) = $ 17.5 ft inctors Cotors (AASHTO LRFD BDM Tables 15.5 1.50 1.75 (AASHTO LRFD BDM Tables 15.5 1.50 1.00 1.00 (ABSHTO LRFD BDM Tables 15.5 1.50 1.75 (AASHTO LRFD BDM Tables 15.5 1.50 1.75 (AASHTO LRFD BDM Tables 15.5 1.50 1.00 (ABSHTO LRFD BDM Tables 15.5 1.50 (ABSHTO LR
tion Angle, (φ_{BS}) = 28 ° inted Cohesion, (c_{BS}) = 0 psf drained Shear Strength, $[(s_u)_{BS}]$ = 4000 psf oth, (D_f) = 0.0 ft elow Bot. of Wall), (D_W) = 17.5 ft $\frac{\text{cctors}}{\text{cctors}}$ / EH LS (AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)
ined Cohesion, $(c_{BS}) = 0$ psf drained Shear Strength, $[(s_u)_{BS}] = 4000$ psf oth, $(D_f) = 0.0$ ft elow Bot. of Wall), $(D_W) = 0.0$ ft 0.0 ft $0.$
$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{array}{ccc} \text{oth, } (D_f) = & & & & & & & \\ \text{elow Bot. of Wall), } (D_W) = & & & & & \\ 17.5 \text{ ft} \\ & & & & & \\ \text{octors} \\ & & & & \\ 00 & 1.50 & 1.75 \\ & & & & \\ 1.50 & 1.75 \\ & & & & \\ 00 & 1.00 & 1.00 \\ & & & \\ \end{array}$
elow Bot. of Wall), (D_W) = $\begin{array}{c c} 17.5 \text{ ft} \\ \hline & 17.5 f$
CCTOTS / EH LS 10 1.50 1.75 (AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure) Sis.
/ EH LS 90 1.50 1.75 15 1.50 1.75 10 1.00 1.00 (AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure) Earth Pressure)
/ EH LS 90 1.50 1.75 15 1.50 1.75 10 1.00 1.00 (AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure) Earth Pressure)
00 1.50 1.75 (AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)
(ASSH10 LR-D BUM Tables 1.55 1.50 1.75 - 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)
15 1.50 1.75 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)
10 1.00 1.00 J
Continued)
ocf)(35.1 ft)(45.6 ft)(1.00) = 192.1 kip/ft
)(45.6 ft - 4.0 ft)(1.00) = 47.5 kip/ft
pcf)(54.1 ft) ² (0.372)(1.50) = 98.09 kip/ft
por)(04.11t) (0.072)(1.00) = 30.00 kip/it
ip/ft)sin(15.2°) = 265.29 kip/ft
ip/ft)sin(15.2°) = 265.29 kip/ft
ksf
O kip/ft
)



JOB FRA-70-13.10 SHEET NO. CALCULATED BY DATE JPS CHECKED BY DATE

6/29/2019 7/1/2019

Retaining Wall W5 - Sta. 603+50 to 605+50

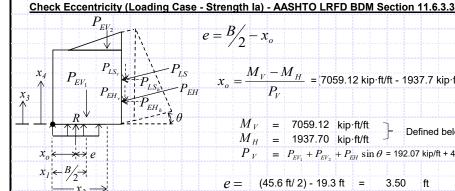
WWW.C50 OKCENTIEN	TITOT W TELE	<u> </u>	
MSE Wall Dimensions and Retained Soil Param	eters		
MSE Wall Height, (H) =	35.1	ft	
MSE Wall Width (Reinforcement Length), (B) =	45.6	ft	
Distance from Wall Face to Toe of Backslope, (<i>l</i>) =	4.0	ft	
MSE Wall Length, (<i>L</i>) =	746	ft	
MSE Wall Effective Height, (h) =	54.1	ft	
Retained Soil Backslope, (β) =	26.6	0	
Effective Retained Soil Backslope, (θ) =	15.2	0	
Distance from Toe to Top of Backslope, (z) =	38.0	ft	
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf	
Retained Soil Friction Angle, (φ_{RS}) =	30	0	
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) =	0.372		
Live Surcharge Load $(\sigma_{ro}) =$	250	nef	

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}) =	28 °
Bearing Soil Drained Cohesion, (c_{BS}) =	0 psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	4000 psf
Embedment Depth, (D_f) =	0.0 ft
Depth to GW (Below Bot. of Wall), (D_W) =	17.5 ft

LRFD Load Factors

	ΕV	ΕH	LS		
Strength la	1.00	1.50	1.75	٦	(AASH
Strength lb	1.35	1.50	1.75	}	3.4.1
Service I	1.00	1.00	1.00	J	

HTO LRFD BDM Tables -1 and 3.4.1-2 - Active



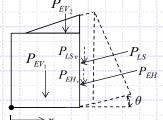
$$x_o = \frac{M_V - M_H}{P_V} = 7059.12 \text{ kip·ft/ft} - 1937.7 \text{ kip·ft/ft}) / (265.29 \text{ kip/ft}) = 19.30 \text{ ft}$$

 $M_V = 7059.12 \text{ kip-ft/ft}$ Defined below $M_H = 1937.70 \text{ kip-ft/ft}$ P Defined below $P_V = P_{EV_1} + P_{EV_2} + P_{EH} \sin \theta = 192.07 \text{ kip/ft} + 47.5 \text{ kip/ft} + (98.09 \text{ kip/ft}) \sin(15.2^\circ) = 265.29 \text{ kip/ft}$

$$e = (45.6 \text{ ft/ 2}) - 19.3 \text{ ft} = 3.50 \text{ ft}$$



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



$$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(35.1 \text{ ft})(45.6 \text{ ft})(1.00) = 192.07 \text{ kip/ft}$$

 $P_{LS} = \frac{1}{2} \gamma_{RS} (h - H) (B - l) \gamma_{EV} = \frac{1}{2} (120 \text{ pcf}) (54.1 \text{ ft} - 35.1 \text{ ft}) (45.6 \text{ ft} - 4.0 \text{ ft}) (1.00) = 47.5 \text{ kip/ft}$ $P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf}) (54.1 \text{ ft})^2 (0.372) (1.50) = 98.09 \text{ kip/ft}$

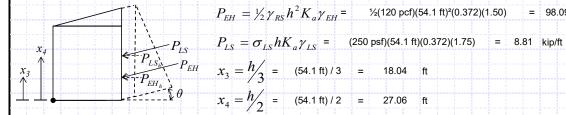
 $x_1 = B/2 = (45.6 \text{ ft})/2 = 22.80 \text{ ft}$

 $x_2 = l + \frac{2}{3}(B - l) = 4.0 \text{ ft} + \frac{2}{3}(45.6 \text{ ft} - 4.0 \text{ ft}) = 31.73 \text{ ft}$

 M_V = (192.07 kip/ft)(22.80 ft) + (47.5 kip/ft)(31.73 ft) + (98.09 kip/ft)sin(15.2°)(45.6 ft) = 7059.12 kip-ft/ft

Overturning Moment, $M_{\scriptscriptstyle H}$:

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



$$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(54.1 \text{ ft})^2 (0.372)(1.50) = 98.09 \text{ kip/ft}$$

$$P_{LS} = \sigma_{LS} h K_a \gamma_{LS}$$
 = (250 psf)(54.1 ft)(0.372)(1.75) = 8.81 kip/ft

$$x_3 = h/3 = (54.1 \text{ ft})/3 = 18.04 \text{ ft}$$

$$x_4 = \frac{h}{2} = (54.1 \text{ ft})/2 = 27.06 \text{ ft}$$

 M_H = (98.09 kip/ft)cos(15.2°)(18.04 ft) + (8.81 kip/ft)cos(15.2°)(27.06 ft) = 1937.70 kip-ft/ft

Check Eccentricity

Limiting Eccentricity:
$$e_{\text{max}} = \frac{B}{3} \rightarrow e_{\text{max}} = (45.6 \text{ ft})/3 =$$

15.20 ft

 $e < e_{\text{max}} \longrightarrow$

3.50 ft < 15.20 ft

OK



FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF 6 CALCULATED BY BRT DATE 6/29/2019 JPS 7/1/2019 CHECKED BY DATE Retaining Wall W5 - Sta. 603+50 to 605+50

	ł) 823-4990 NTERATIONAL.COM	Retaining Wall W5 - Sta. 603+50 to 605	5+50
MCF Well Dimensions and Datained Sail D		Doodles C. II December	
MSE Wall Dimensions and Retained Soil P		Bearing Soil Properties:	100 f
MSE Wall Height, (H) =	35.1 ft	MSE Backfill Unit Weight, $(\gamma_{BF}) =$	120 pcf 34 °
MSE Wall Width (Reinforcement Length), (B) =	45.6 ft	MSE Backfill Friction Angle, $(\varphi_{BF}) =$	
Distance from Wall Face to Toe of Backslope, (<i>l</i>)	= 4.0 ft 746 ft	Bearing Soil Unit Weight, (γ_{BS}) = Bearing Soil Friction Angle, (φ_{BS}) =	120 pcf 28 °
MSE Wall Length, (L) =	54.1 ft	Bearing Soil Priction Angle, $(\psi_{BS}) =$ Bearing Soil Drained Cohesion, $(c_{RS}) =$	
MSE Wall Effective Height, (h) =	26.6°		0 psf
Retained Soil Backslope, (β) =	15.2 °	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}] =$	4000 psf 0.0 ft
Effective Retained Soil Backslope, (θ) =		Embedment Depth, (D_f) =	
Distance from Toe to Top of Backslope, (z) =	38.0 ft	Depth to GW (Below Bot. of Wall), (D_W) =	17.5 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf 30 °	I DED Lood Footogo	
Retained Soil Friction Angle, (φ_{RS}) =		LRFD Load Factors EV EH LS	
Retained Soil Undrained Shear Strength ((C.))	0 psf		
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$			RFD BDM Tables
Retained Soil Active Earth Pressure Coeff., (K_a) :		Farth	I 3.4.1-2 - Active Pressure)
Live Surcharge Load, (σ_{LS}) = 1. Drained cohesion for retained soil not accounted for in external s	250 psf	Service I 1.00 1.00 1.00 J	
Check Bearing Capacity (Loading Case - S	trength lb) - AASHTO	LRFD BDM Section 11.6.3.2	
P_{EV_2}			
	$=P_{V_{R'}}$		
q_{eq}	= '/B'		
$x_4 \mid P_{LS} \mid P_{LS} \mid P_{LS} \mid$			
$\left \begin{array}{c} X_4 \\ \uparrow \\ \downarrow \end{array} \right \left \begin{array}{c} P_{EV_1} \\ P_{EH_2} \\ \downarrow \end{array} \right \left \begin{array}{c} P_{LS} \\ P_{EH_2} \\ \downarrow \end{array} \right \left \begin{array}{c} P_{LS} \\ P_{EH} \\ \downarrow \end{array} \right \left \begin{array}{c} P_{LS} \\ P_{EH} \\ \downarrow \end{array} \right $	B' = B - 2e = 45	.6 ft - 2(2.23 ft) = 41.14 ft	
$B = \frac{EH_v}{P}$	<i>R</i> /		
R \downarrow $\stackrel{i}{\sim}$ $\stackrel{EH}{\sim}$ $\stackrel{i}{\sim}$ $\stackrel{i}{\sim}$ $\stackrel{i}{\sim}$	$e = \frac{D}{2} - x_o$:	= (45.6 ft / 2) - 20.57 ft = 2.23 ft	
+ A A A A A A A A A A A A A A A A A A A	$M_{\nu}-M_{\nu}$		
	$x_o = \frac{1}{1000} \frac{V_o}{R}$	= (9119.09 kip·ft/ft - 1937.70 kip·ft/ft) / 349.13 kip.	f = 20.57 ft
$x_o \leftarrow + -1 - 1 - e$	P_V		
$E \to B/2 \to 0$			
$\leftarrow \stackrel{/}{p_!} \rightarrow \qquad $	$q_{ea} = (349.13 \text{ kip/ft})$	/ (41.14 ft) = 8.49 ksf	
$ \begin{array}{ccc} & B_2 \\ & B_1 \\ & & x_2 \\ \end{array} $			
**2			
Resisting Moment, M_V : $M_V = M_V$	$P_{EV_1}(x_1) + P_{EV_2}(x_2)$	$+P_{ru}\sin\theta(B)$	
	Ev ₁ \ 1.7 Ev ₂ \ 2.7	En	
$P_{\scriptscriptstyle EV_2}$ $P_{\scriptscriptstyle EV_2}$	$= \gamma_{BF} \cdot H \cdot B \cdot \gamma_{FV}$	= (120 pcf)(35.1 ft)(45.6 ft)(1.35) = 259.29	kip/ft
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			
!\\ P	$= \frac{1}{2} \sqrt{(h-H)(R-H)}$	$I_{V_{EV}} = \frac{1}{2}(120 \text{ pcf})(54.1 \text{ ft} - 35.1 \text{ ft})(45.6 \text{ ft} - 4.0 \text{ ft})(1.35) =$: 64.12 kip/ft
$p \mid \cdot \mid \cdot \mid \cdot \mid D$	/21 RS (11 11)(D	THE EVEN THE STATE OF THE STATE	
P_{EV_1}	$= \frac{1}{2} v h^2 K v$	= ½(120 pcf)(54.1 ft)²(0.372)(1.50) = 98.09 kij	p/ft
P_{EH}	$-$ /2 / RS $^{\prime\prime}$ $^{\prime\prime}$ A / EH	7-1,-20 10,000 10,	F'
	=B/2 = (45.6 ft)/2	= 22.80 ft	
$\theta = \frac{1}{2} \left(\frac{1}{2} \left(\frac{1}{2} \right) \right)$	$-\frac{1}{2}$		
$X_{2} = X_{1}$	=1+2/(R-1)	4.0 ft + ² / ₃ (45.6 ft - 4.0 ft) = 31.73 ft	
X_2	- · 1/3(D - i) -	73(10.0 K 1.0 K) = 01.70 K	
	(259 29 kin/ft)/22 80 ft) + /	64.12 kip/ft)(31.7 ft) + (98.09 kip/ft)sin(15.2°)(45.6 ft) =	9119 09 - kin.ft/f
$M_{\rm M} = 1$	(200.20 Rip/II)(22.00 II) T (отть мульдотт ту · (оо.оо мртдэнц то.с. д-о.о н) — - 3	5.10.00 KIP-1(/II
Overturning Moment, M_H : $M_{II} =$	$P = e_{OS} A(r) + D$	$\cos \theta(\mathbf{r})$	
Overturning Montent, M_H . $M_H =$	$P_{EH}\cos\theta(x_3)+P_I$	$s\cos\theta(x_4)$	
	1/ 72 ==	1//400 = 0//44 f 1/2/0 0/70/44 f 10/	
P_{EH}	$= \frac{1}{2} \gamma_{RS} h^* K_a \gamma_{EH} :$	$= \frac{1}{2}(120 \text{ pcf})(54.1 \text{ ft})^2(0.372)(1.50) = 98.09 \text{ kip}$	ρ/π
$x_{_{\mathcal{I}}}$ $P_{_{LS}}$ $P_{_{LS}}$	$= \sigma_{LS} h K_a \gamma_{LS} =$	(250 psf)(54.1 ft)(0.372)(1.75) = 8.81 kip/ft	
$\frac{1}{2}$ EH $X_3 =$	$=\frac{h}{3} = \frac{(54.1 \text{ ft})}{3}$	= 18.04 ft	
	<i>h</i> /		
$x_4 = x_4 = x_4$	$=\frac{h}{2} = (54.1 \text{ ft})/2$	= 27.06 ft	
$M_H = \langle \S \rangle$	98.09 kip/ft)cos(15.2°)(18	.04 ft) + (8.81 kip/ft)cos(15.2°)(27.06 ft) = 1937.70 kip	p·ft/ft
Vertical Forces, P_V : $P_V = P$	$P_{EV_1} + P_{EV_2} + P_{EH} \sin \theta$	1 $ heta$	
	y		
$P_{ u}$	= 259.29 kip/ft + 64.12	kip/ft + (98.09 kip/ft)sin(15.2°) = 349.13 kip/ft	



FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF 6 CALCULATED BY BRT DATE 6/29/2019 JPS 7/1/2019 CHECKED BY DATE Retaining Wall W5 - Sta. 603+50 to 605+50

MSE Wall Height, (H) = 35.1 ft MSE Backfill ASE Wall Width (Reinforcement Length), (B) = 45.6 ft MSE Backfill ASE Wall Length, (L) = 746 ft Bearing Soil ASE Wall Length, (L) = 746 ft Bearing Soil ASE Wall Length, (L) = 54.1 ft Bearing Soil ASE Wall Effective Height, (h) = 54.1 ft Bearing Soil ASE Wall Effective Network (h) = 15.2 ° Embedment 17.2	[Below Bot. of Wall), $(D_W) = 17.5 \text{ f}$ Factors EV EH LS 1.00 1.50 1.75 1.35 1.50 1.75 1.00 1.00 1.00 $\frac{1}{100} = \frac{(AASHTO LRFD BDM Table}{S.A.1.1 and 3.4.12 - Active}$ Earth Pressure) alysis. Dn 11.10.5.4 (Continued) $N_{ym} = N_{\gamma} S_{\gamma} i_{\gamma} = 16.7$ $N_{\gamma} = 16.720$ $S_{\gamma} = 1.0.4(41.14 \text{ ft/746 ft}) = 1.00$ $C_{w\gamma} = 17.5 \text{ ft} < 1.5(41.14 \text{ ft}) + 0.0 \text{ ft} = 1.00$ 1.000 $S_{\gamma} = 1.000 \text{ (Assumed)}$
ASE Wall Width (Reinforcement Length), (B) = 45.6 ft MSE Backfill Distance from Wall Face to Toe of Backslope, (I) = 4.0 ft Bearing Soil ASE Wall Length, (I) = 746 ft Bearing Soil ASE Wall Effective Height, (I) = 54.1 ft Bearing Soil ASE Wall Effective Height, (I) = 54.1 ft Bearing Soil ASE Wall Effective Height, (I) = 54.1 ft Bearing Soil ASE Wall Effective Height, (I) = 54.1 ft Bearing Soil ASE Wall Effective Retained Soil Backslope, (I) = 26.6 ° Bearing Soil Effective Retained Soil Backslope, (I) = 15.2 ° Embedment Distance from Toe to Top of Backslope, (I) = 15.2 ° Embedment Retained Soil Unit Weight, (I) I 2 I 2 I 2 I 2 I 2 I 2 I 3 I 4 Retained Soil Unit Weight, (I 2 I 3 I 3 I 4 I 2 I 5 I 4 Retained Soil Undrained Shear Strength, (I 3 I 3 I 4 I 5 I 7 I 8 Retained Soil Undrained Shear Strength, (I 3 I 3 I 4 I 7 I 7 I 8 Retained Soil Active Earth Pressure Coeff., (I 4 I 7 I 8 I 9 I 9 I 1 I 8 I 9 I 9 I 1	Friction Angle, $(\varphi_{BF}) = 34^{\circ}$ Init Weight, $(\gamma_{BS}) = 120^{\circ}$ priction Angle, $(\varphi_{BS}) = 28^{\circ}$ prained Cohesion, $(c_{BS}) = 00^{\circ}$ Inderined Shear Strength, $[(s_u)_{BS}] = 00^{\circ}$ [Modrained Shea
MSE Wall Length, (L) = $\frac{746}{MSE}$ ft Bearing Soil MSE Wall Effective Height, (h) = $\frac{746}{S4.1}$ ft Bearing Soil Retained Soil Backslope, (β) = $\frac{26.6}{S}$ ° Embedment $\frac{7}{15.2}$ ° Evaluated Soil Unit Weight, (r_{RS}) = $\frac{7}{15.2}$ ° $\frac{7}{15.2}$ ° Evaluated Soil Unit Weight, (r_{RS}) = $\frac{7}{15.2}$ ° $\frac{7}{15.2}$ ° $\frac{7}{15.2}$ ° Evaluated Soil Undrained Shear Strength, $\frac{7}{15.2}$ ° $\frac{7}{15.2}$ ° $\frac{7}{15.2}$ ° Strength $\frac{7}{15.2}$ ° Evaluated Soil Active Earth Pressure Coeff., (K_a) = $\frac{7}{15.2}$ ° $\frac{7}{15.2}$ ° Strength $\frac{7}{15.2}$ ° Strength $\frac{7}{15.2}$ ° Evaluated Soil Active Earth Pressure Coeff., $\frac{7}{15.2}$ ° $\frac{7}{15.2}$ ° Strength $\frac{7}{15.2}$ ° Service $\frac{7}{15.2}$ ° Evaluated Soil Active Earth Pressure Coeff., $\frac{7}{15.2}$ ° $\frac{7}{15.2}$ ° Strength $\frac{7}{15.2}$ ° Service $\frac{7}{15.2}$ ° Strength $\frac{7}{15.$	riction Angle, (φ_{BS}) = 28° prained Cohesion, (c_{BS}) = 0 prained Cohesion, (c_{BS}) = 0 prained Shear Strength, $[(s_u)_{BS}]$ = 0 prepth, (D_f) = 0 0.0 ft (Below Bot. of Wall), (D_W) = 0 17.5 ft (Below Bot. of Wall), (D_W) = 0 17.5 ft (Below Bot. of Wall), (D_W) = 0 17.5 ft (AASHTO LRFD BDM Table. 1.00 1.50 1.75 a.4.1-1 and 3.4.1-2 - Active. Earth Pressure) (Below 1.00 1.00 1.00 1.00 1.00 alysis. (Below 1.00 1.00 1.00 1.00 1.00 alysis. (Below 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.0
MSE Wall Effective Height, (h) = $\frac{54.1}{54.1}$ ft Bearing Soil Retained Soil Backslope, (β) = $\frac{54.1}{15.2}$ ° Embedment: Distance from Toe to Top of Backslope, (ε) = $\frac{38.0}{15.2}$ ° Embedment: Distance from Toe to Top of Backslope, (ε) = $\frac{38.0}{15.2}$ ° Depth to GW Retained Soil Unit Weight, (γ _{RS}) = $\frac{30}{120}$ pcf Retained Soil Unit Weight, (γ _{RS}) = $\frac{30}{120}$ pcf Retained Soil Drained Cohesion, (ε _{RS}) = $\frac{30}{120}$ pcf Retained Soil Undrained Shear Strength, [(S _u) _{RS}) = $\frac{0}{120}$ pcf Retained Soil Undrained Shear Strength, [(S _u) _{RS}) = $\frac{0}{120}$ pcf Retained Soil Undrained Shear Strength, [(S _u) _{RS}) = $\frac{0}{120}$ pcf Retained Soil Undrained Shear Strength, [(S _u) _{RS}) = $\frac{0}{120}$ pcf Strength la Retained Soil Active Earth Pressure Coeff., ($\frac{1}{120}$ = $\frac{0.372}{1.00}$ Strength la Retained Soil Active Earth Pressure Coeff., ($\frac{1}{120}$ = $\frac{0.372}{1.00}$ Strength la Retained Soil Active Earth Pressure Coeff., ($\frac{1}{120}$ = $\frac{0.372}{1.00}$ psf Strength lb Individual Strength Individual Strengt	Prained Cohesion, $(c_{BS}) = 0$ prindrained Shear Strength, $[(s_u)_{BS}] = 4000$ prepth, $(D_f) = 0.0$ f (Below Bot. of Wall), $(D_W) = 17.5$ f (Below Bot. of Wall), $(D_W) = 17.5$ f (Below Bot. of Wall), $(D_W) = 17.5$ f (AASHTO LRFD BDM Table 1.00 1.50 1.75 a.4.1-1 and 3.4.1-2 - Active Earth Pressure) (Below 1.00 1.00 1.00 1.00 alysis. Por 11.10.5.4 (Continued) (Continu
Retained Soil Backslope, (β) = 26.6° Bearing Soil Effective Retained Soil Backslope, (θ) = 15.2° Embedment: Distance from Toe to Top of Backslope, (z) = 38.0° ft Depth to GW Retained Soil Unit Weight, (y_{RS}) = 120° pcf Retained Soil Drained Cohesion, (c_{RS}) = 0° psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}]$ = 0° psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}]$ = 0° psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}]$ = 0° psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}]$ = 0° psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}]$ = 0° psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}]$ = 0° Strength ib Service I . Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses. This parameter is utili	Indrained Shear Strength, $[(s_u)_{BS}] = \frac{4000 \text{ p}}{0.0 \text{ f}}$ (Below Bot. of Wall), $(D_W) = \frac{17.5 \text{ f}}{17.5 \text{ f}}$ (Below Bot. of Wall), $(D_W) = \frac{17.5 \text{ f}}{17.5 \text{ f}}$ (AASHTO LRFD BDM Table 3.4.1-2 - Active Earth Pressure) alysis. Do 1.50 1.75 $\frac{1}{1.00} = \frac{(AASHTO LRFD BDM Table 3.4.1-2 - Active Earth Pressure)}{1.00 1.00 1.00 1.00}$ N _{ym} = N _y S _y i _y = 16.7 N _y = 16.720 1.000 S _y = 1-0.4(41.14 ft/746 ft) = 1.00 1.14 ft) i _y = 1.000 (Assumed) C _{wy} = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 1.000
Effective Retained Soil Backslope, $(\theta) = \frac{15.2}{38.0}$ c Embedment Distance from Toe to Top of Backslope, $(z) = \frac{38.0}{38.0}$ ft Depth to GW Retained Soil Unit Weight, $(\gamma_{RS}) = \frac{120}{120}$ pcf Retained Soil Unit Weight, $(\gamma_{RS}) = \frac{120}{9}$ pcf Retained Soil Drained Cohesion, $(c_{RS}) = \frac{12000}{9}$ psf Retained Soil Undrained Shear Strength, $[(S_u)_{RS}] = \frac{2000}{200}$ psf Strength la Retained Soil Active Earth Pressure Coeff., $(K_a) = \frac{250}{250}$ psf Strength la Scheck Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Section 10. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses. This parameter is utilize	Pepth, (D_f) = $0.0 \mathrm{f}$ (Below Bot. of Wall), (D_W) = $17.5 \mathrm{f}$ (Below Bot. of Wall), (D_W) = $17.5 \mathrm{f}$ (AASHTO LRFD BDM Table 1.35 1.50 1.75 1.00 1.00 1.00 1.00 $1.00 \mathrm{f}$ (AASHTO LRFD BDM Table 2 advises. Do 11.10.5.4 (Continued) $N_{ym} = N_{\gamma} s_{\gamma} i_{\gamma} = 16.7$ $N_{\gamma} = 16.720$ $N_{\gamma} = 16.720$ $N_{\gamma} = 10.00 \mathrm{f}$ (Assumed) $N_{\gamma} = 1.000 \mathrm{f}$ = $1.000 \mathrm{f}$ =
Distance from Toe to Top of Backslope, $(z) = \frac{38.0}{120}$ ft Retained Soil Unit Weight, $(\gamma_{RS}) = \frac{38.0}{120}$ pcf Retained Soil Friction Angle, $(\varphi_{RS}) = \frac{30}{30}$ scalained Soil Unit Weight, $(\varphi_{RS}) = \frac{30}{30}$ scalained Soil Unit Weight, $(\varphi_{RS}) = \frac{30}{30}$ scalained Soil Undrained Schear Strength, $[(S_u)_{RS}] = \frac{9}{2000}$ psf Retained Soil Undrained Shear Strength, $[(S_u)_{RS}] = \frac{9}{2000}$ psf Retained Soil Active Earth Pressure Coeff., $(K_u) = \frac{3.72}{250}$ psf Retained Soil Active Earth Pressure Coeff., $(K_u) = \frac{3.72}{250}$ psf Retained Soil Active Earth Pressure Coeff., $(K_u) = \frac{3.72}{250}$ psf Retained Soil Active Earth Pressure Coeff., $(K_u) = \frac{3.72}{250}$ psf Retained Soil Active Earth Pressure Coeff., $(K_u) = \frac{3.72}{250}$ psf Retained Soil Active Earth Pressure Coeff., $(K_u) = \frac{3.72}{250}$ psf Service I 1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses. This parameter is	[Below Bot. of Wall), $(D_W) = 17.5 \text{ f}$ Factors EV EH LS 1.00 1.50 1.75 1.35 1.50 1.75 1.00 1.00 1.00 $\frac{1}{100} = \frac{(AASHTO LRFD BDM Table}{S.A.1.1 and 3.4.12 - Active}$ Earth Pressure) alysis. Dn 11.10.5.4 (Continued) $N_{ym} = N_{\gamma} S_{\gamma} i_{\gamma} = 16.7$ $N_{\gamma} = 16.720$ $S_{\gamma} = 1.0.4(41.14 \text{ ft/746 ft}) = 1.00$ $C_{w\gamma} = 17.5 \text{ ft} < 1.5(41.14 \text{ ft}) + 0.0 \text{ ft} = 1.00$ 1.000 $S_{\gamma} = 1.000 \text{ (Assumed)}$
Retained Soil Unit Weight, $(\gamma_{RS}) = \frac{120}{30}$ pcf Retained Soil Friction Angle, $(\varphi_{RS}) = \frac{30}{30}$ on the setting of Soil Friction Angle, $(\varphi_{RS}) = \frac{30}{30}$ on the setting of Soil Drained Cohesion, $(c_{RS}) = \frac{2000}{2000}$ pcf Retained Soil Undrained Shear Strength, $[(S_u)_{RS}] = \frac{2000}{2000}$ pcf Strength Ia Retained Soil Active Earth Pressure Coeff., $(K_u) = \frac{250}{372}$ pcf Service I 1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses. The parameter is utilized in global	Factors EV EH LS 1.00 1.50 1.75 1.35 1.50 1.75 1.00 1.00 1.00 $\frac{1}{1}$ By although the state of the st
Retained Soil Friction Angle, $(\varphi_{RS}) = \frac{30}{0}$ Retained Soil Drained Cohesion, $(c_{RS}) = \frac{0}{0}$ psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}] = \frac{0}{2000}$ psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}] = \frac{0}{2000}$ psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}] = \frac{0}{250}$ psf Strength Ial Retained Soil Active Earth Pressure Coeff., $(K_a) = \frac{0.372}{250}$ Strength Ial Size Survivage Load, $(\sigma_{LS}) = \frac{250}{10}$ psf Service I 1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses. This parameter is utilized in global stability analyses. This parameter is utilized in global stability and the stability analyses. This parameter is utilized in global stability and the stability analyses. This parameter is utilized in global stability and the stability analyses. This parameter is utilized in global stability and the stability analyses. This parameter is utilized in global sta	EV EH LS $1.00 1.50 1.75$ $1.35 1.50 1.75$ $1.00 1.00 1.00$ $1.00 1.00$
Retained Soil Drained Cohesion, $(c_{RS}) = \frac{0}{2000}$ psf Retained Soil Undrained Shear Strength, $[(S_w)_{RS}] = \frac{0}{2000}$ psf Strength la Retained Soil Undrained Shear Strength, $[(S_w)_{RS}] = \frac{0}{250}$ psf Strength la Retained Soil Active Earth Pressure Coeff., $(K_w) = \frac{0.372}{250}$ psf Service I strength lb involved Surface Soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses.	EV EH LS $1.00 1.50 1.75$ $1.35 1.50 1.75$ $1.00 1.00 1.00$ $1.00 1.00$
Retained Soil Undrained Shear Strength, $[(s_w)_{RS}] = 2000$ psf Strength la Retained Soil Active Earth Pressure Coeff., $(K_a) = 0.372$ Strength Ib Service I 1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses. This parameter is utilized in	1.00 1.50 1.75 (AASHTO LRFD BDM Table 1.35 1.50 1.75 3.4.1-1 and 3.4.1-2 - Active Earth Pressure) alysis. On 11.10.5.4 (Continued) $N_{\gamma m} = N_{\gamma} S_{\gamma} i_{\gamma} = 16.7$ $N_{\gamma} = 16.720$ $N_{\gamma} = 10.00$ $N_{\gamma} = 10.$
Retained Soil Active Earth Pressure Coeff., $(K_a) = \frac{0.372}{250}$ Strength Ib Service I 1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses. The parameter is utilized in global stability analyses. The parameter is utilized in global stabilit	1.35 1.50 1.75 3.4.1-1 and 3.4.1-2 Active Earth Pressure) 1.00 1.00 1.00 $\frac{1}{1.00}$ N _{jm} = N _j S _j i _j = 16.7 N _j = 16.720 1.000 S _j = 1-0.4(41.14 ft/746 ft) = 1.00 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft < 1.5(41.14 ft) + 0.0 ft = 17.5 ft <
inve Surcharge Load, (σ_{LS}) = 250 psf Service 1 1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses. This parameter is util	1.00 1.00 1.00 Earth Pressure) alysis: on 11.10.5.4 (Continued) $N_{ym} = N_{\gamma} S_{\gamma} i_{\gamma} = 16.7$ $N_{\gamma} = 16.720$.000 $S_{\gamma} = 1-0.4(41.14 \text{ft}/746 \text{ft}) = 1.00$.14 ft) $i_{\gamma} = 1.000 \text{(Assumed)}$ $C_{w\gamma} = 17.5 \text{ft} < 1.5(41.14 \text{ft}) + 0.0 \text{ft} = 1.00 \text{ft}$ 1.00 C C C C C C C C C
1. Drained cohesion for retained soil not accounted for in external stability analyses. This parameter is utilized in global stability analyses. This parameter is u	alysis. $N_{jm} = N_{\gamma} S_{\gamma} i_{\gamma} = 16.7$ $N_{\gamma} = 16.720$ $0.000 S_{\gamma} = 10.4(41.14 \text{ ft/746 ft}) = 1.000$ $1.4 \text{ ft} i_{\gamma} = 1.000 \text{ (Assumed)}$ $C_{w\gamma} = 17.5 \text{ ft} < 1.5(41.14 \text{ ft}) + 0.0 \text{ ft} = 10.00 \text{ (Assumed)}$ $C_{w\gamma} = 17.5 \text{ ft} < 1.5(41.14 \text{ ft}) + 0.0 \text{ ft} = 10.00 \text{ (Assumed)}$
Check Bearing Capacity (Loading Case - Strength Ib) - AASHTO LRFD BDM Sect Check Bearing Resistance - Drained Condition Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2} \gamma B' N_{jm} C_{wy}$ $N_{cm} = N_c s_c i_c = 25.8$ $N_{qm} = N_q s_q d_q i_q = 14.7$ $N_c = 25.800$ $S_c = 1+(41.14 \text{ ft/746 ft})(14.72/25.8)$ $S_q = 1+(41.14 \text{ ft/746 ft})(1$	$N_{jm} = N_{\gamma} S_{\gamma} i_{\gamma} = 16.7$ $N_{\gamma} = 16.720$ $.000 S_{\gamma} = 1-0.4(41.14 \text{ ft/746 ft}) = 1.00$ $.14 \text{ ft}) i_{\gamma} = 1.000 \text{ (Assumed)}$ $C_{w\gamma} = 17.5 \text{ ft} < 1.5(41.14 \text{ ft}) + 0.0 \text{ ft} = 1.00 \text{ (Assumed)}$ $C_{w\gamma} = 17.5 \text{ ft} < 1.5(41.14 \text{ ft}) + 0.0 \text{ ft} = 1.00 \text{ (Assumed)}$
$N_{cm} = N_c s_c i_c = 25.8 \qquad N_{qm} = N_q s_q d_q i_q = 14.7 $ $N_c = 25.800 \qquad N_q = 14.720 $ $s_c = 1+(41.14 \text{ ft/746 ft})(14.72/25.8) \qquad s_q = 1+(41.14 \text{ ft/746 ft})(28^\circ) = 1.000 $ $i_c = 1.000 \qquad d_q = 1.000 \text{ (Assumed)} $ $i_c = 1.000 \qquad (Assumed) \qquad i_q = 1.000 \text{ (Assumed)} $ $C_{wq} = 17.5 \text{ ft} > 0.0 \text{ ft} = 1.000 $ $Q_n = (0 \text{ psf})(25.8) + (120 \text{ pcf})(0.0 \text{ ft})(14.7)(1.0) + \frac{1}{2}(120 \text{ pcf})(41.1 \text{ ft})(16.7)(0.0 \text{ ft}) $ $Q_{eq} \leq Q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 8.49 \text{ ksf} \leq (20.64 \text{ ksf})(0.64)(0.65) = 8.59 \text{ ksf} $ $RC_{BC} = 0.64 (Per AASHTO LRFD BDM Section 10.6.3.12c) \longrightarrow \text{Use } \beta_s $ $\text{Use } \varphi_b = 0.65 (Per AASHTO LRFD BDM Table 11.5.6-1) $ $Q_{eq} = 0.65 (Per A$	$N_{y} = 16.720$ $s_{y} = 1-0.4(41.14 \text{ ft/746 ft}) = 1.00$ $i_{y} = 1.000 \text{ (Assumed)}$ $C_{wy} = 17.5 \text{ ft} < 1.5(41.14 \text{ ft}) + 0.0 \text{ ft} = 10.00 \text{ (Assumed)}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$N_{y} = 16.720$ $s_{y} = 1-0.4(41.14 \text{ ft/746 ft}) = 1.00$ $i_{y} = 1.000 \text{ (Assumed)}$ $C_{wy} = 17.5 \text{ ft} < 1.5(41.14 \text{ ft}) + 0.0 \text{ ft} = 10.00 \text{ (Assumed)}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{llllllllllllllllllllllllllllllllllll$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1.14 ft) $i_{\gamma} = 1.000 \text{ (Assumed)}$ $C_{w\gamma} = 17.5 \text{ ft} < 1.5 (41.14 \text{ ft}) + 0.0 \text{ ft} = 10.00 \text{ (Assumed)}$) $= 20.64 \text{ ksf}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$C_{W7} = 17.5 \text{ft} < 1.5 (41.14 \text{ft}) + 0.0 \text{ft} =$ $) = 20.64 \text{ksf}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$) = 20.64 kst
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	
$q_n = (0 \text{ psf})(25.8) + (120 \text{ pcf})(0.0 \text{ ft})(14.7)(1.0) + \frac{1}{2}(120 \text{ pcf})(41.1 \text{ ft})(16.7)(0.0 \text{ perify Equivalent Pressure Less Than Factored Bearing Resistance})$ $q_{eq} \leq q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 8.49 \text{ ksf} \leq (20.64 \text{ ksf})(0.64)(0.65) = 8.59 \text{ ksf}$ $RC_{BC} = \textbf{0.64} \text{ (Per AASHTO LRFD BDM Section 10.6.3.1.2c)} \longrightarrow \text{Use } \beta_s$ $\text{Use } \phi_b = \textbf{0.65} \text{ (Per AASHTO LRFD BDM Table 11.5.6-1)}$ $\text{Check Bearing Resistance} \cdot \text{Undrained Condition}$ $\text{Nominal Bearing Resistance:} q_n = cN_{cm} + \gamma D_f N_{qm}C_{wq} + \frac{1}{2}\gamma B' N_{\gamma m}C_{w\gamma}$ $N_{cm} = N_c s_c i_c = 5.140 \qquad N_{qm} = N_q s_q d_q i_q = 1.000$ $N_c = 5.140 \qquad N_q = 1.000$ $S_c = 1 + (41.14 \text{ ft/[5)(746 \text{ ft)]}} = 1.000 \qquad s_q = 1.000$ $i_c = 1.000 \text{ (Assumed)} \qquad d_q = 1 + 2 \text{tan(0°)[1-sin(0°)]} $	
Use $\varphi_b = 0.65$ (Per AASHTO LRFD BDM Table 11.5.6-1) Check Bearing Resistance - Undrained Condition Nominal Bearing Resistance: $q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \frac{1}{2} \gamma B' N_{\gamma m} C_{w\gamma}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_{qm} = N_q s_q d_q i_q = 1.000$ $S_c = 1.441.14 \text{ ft/[(5)(746 \text{ ft)]}} = 1.000$ $S_q = 1.000$ $S_c = 1.000 \text{ (Assumed)}$ $S_q = 1.000$	
$N_{cm} = N_c s_c i_c = 5.140$ $N_{qm} = N_q s_q d_q i_q = 1.000$ $N_c = 5.140$ $N_q = 1.000$ $S_c = 1+(41.14 \text{ft/[(5)(746 \text{ft)]}} = 1.000$ $S_q = 1.000$	$=$ 10.0° $H_s =$ 4.0 ft $b =$ 0
$N_c = 5.140$ $N_q = 1.000$ $s_c = 1+(41.14 \text{ft/[(5)(746 \text{ft)}]} = 1.000$ $s_q = 1.000$ $d_q = 1+2 \text{tan(0^\circ)[1-sin(0^\circ)]^2 tan^{-1}(0.0 \text{ft/41})}$	
$s_c = 1 + (41.14 \text{ ft/}[(5)(746 \text{ ft)}] = 1.000$ $s_q = 1.000$ $d_q = 1 + 2 \tan(0^\circ)[1 - \sin(0^\circ)]^2 \tan^{-1}(0.0 \text{ ft/41})$	$N_{jm} = N_{\gamma} s_{\gamma} i_{\gamma} = 0.000$
$i_c = 1.000$ (Assumed) $d_q = 1+2\tan(0^\circ)[1-\sin(0^\circ)]^2\tan^{-1}(0.0 \text{ ft}/41)$	$N_{\gamma} = 0.000$
	$s_{\gamma} = 1.000$
= 1.000	C_{wy} = 17.5 ft < 1.5(41.14 ft) + 0.0 ft =
$i_q = 1.000$ (Assumed)	
$C_{wg} = 17.5 \text{ft} > 0.0 \text{ft} = 1.000$	
$q_n = (4000 \text{ psf})(5.14) + (120 \text{ pcf})(0.0 \text{ ft})(1.0)(1.0) + \frac{1}{2}(120 \text{ pcf})(41.1 \text{ ft})(0.0)(0.0 \text{ ft})$	5) = 20.56 ksf
/erify Equivalent Pressure Less Than Factored Bearing Resistance	
$q_{eq} \le q_n \cdot RC_{BC} \cdot \phi_b \longrightarrow 8.49 \text{ ksf} \le (20.56 \text{ ksf})(0.86)(0.65) = 11.49 \text{ ksf}$	



 JOB
 FRA-70-13.10
 NO.
 W-13-072

 SHEET NO.
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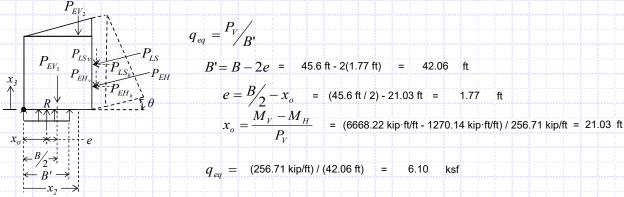
 CALCULATED BY
 BRT
 DATE
 6/29/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta. 603+50 to 605+50

MSE Wall Dimensions and Retained Soil Paran	<u>neters</u>	Bearing Soil Properties:
MSE Wall Height, (H) =	35.1 ft	MSE Backfill Unit Weight, (γ_{BF}) = 120
MSE Wall Width (Reinforcement Length), (B) =	45.6 ft	MSE Backfill Friction Angle, (φ_{BF}) = 34
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft	Bearing Soil Unit Weight, $(\gamma_{BS}) = \frac{120}{120}$
MSE Wall Length, (L) =	746 ft	Bearing Soil Friction Angle, (φ_{BS}) = 28
MSE Wall Effective Height, (h) =	54.1 ft	Bearing Soil Drained Cohesion, $(c_{BS}) = 0$
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}] = 4000$
Effective Retained Soil Backslope, (θ) =	15.2 °	Embedment Depth, (D_f) = 0.0
Distance from Toe to Top of Backslope, (z) =	38.0 ft	Depth to GW (Below Bot. of Wall), (D_W) = 17.5
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Factors
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV EH LS
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	Strength la 1.00 1.50 1.75 7 (AASHTO LRFD BDM Tab.
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.372	Strength lb 1.35 1.50 1.75 - 3.4.1-1 and 3.4.1-2 - Activ
Live Surcharge Load, (σ_{LS}) =	250 psf	Service I 1.00 1.00 1.00 Earth Pressure)

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



$$M_{V} = P_{EV_{1}}(x_{1}) + P_{EV_{2}}(x_{2}) + P_{EH} \sin \theta(B) = (\gamma_{BF} H B \gamma_{EV})(\gamma_{2} B) + (\gamma_{2} \gamma_{RS} (h - H)(B - I)\gamma_{EV})(I + \gamma_{3} (B - I)) + (\gamma_{2} \gamma_{RS} h^{2} K_{a} \gamma_{EH} \sin \theta)(B)$$

$$M_{H} = P_{EH} \cos \theta(x_{3}) + P_{LS} \cos \theta(x_{4}) = \left(\frac{1}{2}\gamma_{RS}h^{2}K_{a}\gamma_{EH} \cos \theta\right)\left(\frac{h}{3}\right) + \left(\sigma_{LS}hK_{a}\gamma_{LS} \cos \theta\right)\left(\frac{h}{2}\right)$$

 $M_H = \frac{1}{2}[(120 \text{ pcf})(54.1 \text{ ft})^2(0.372)(1.00)\cos(15.2^\circ)](54.1 \text{ ft}/3) = 1,270.14 \text{ kip-ft/ft}$ + $[(250 \text{ psf})(54.1 \text{ ft})(0.372)(1.00)\cos(15.2^\circ)](54.1 \text{ ft}/2)$

$$P_{V} = P_{EV_1} + P_{EV_2} + P_{EH} \sin \theta = \left(\gamma_{BF} H B \gamma_{EV}\right) + \left(\frac{1}{2}\gamma_{RS} \left(h - H\right) \left(B - l\right)\gamma_{EV}\right) + \left(\frac{1}{2}\gamma_{RS} h^2 K_a \gamma_{EH} \sin \theta\right)$$

 $P_V = (120 \text{ pcf})(35.1 \text{ ft})(45.6 \text{ ft})(1.00) + \frac{1}{2}(120 \text{ pcf})(54.1 \text{ ft} - 35.1 \text{ ft})(45.6 \text{ ft} - 4.0 \text{ ft})(1.00) = 256.71 \text{ kip/ft} + \frac{1}{2}(120 \text{ pcf})(54.1 \text{ ft})^2(0.372)(1.00)\sin(15.2^\circ)$

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Alon Wall Facing
B-104-1-13	4.459 in	2.412 in	15 days		
B-105-3-14	3.519 in	1.872 in	3 days	85 ft	1/1890
B-105-5-14	3.512 in	1.535 in	5 days	145 ft	1/5160
B-107-2-14	2.946 in	1.321 in	1 days	135 ft	1/7570
B-108-7-14	2.403 in	1.341 in	1 days	160 ft	1/96000
B-108-8-14	0.950 in	0.694 in	3 days	130 ft	1/2410

W-13-072 - FRA-70-13.10 - Retaining Wall W5

MSE Wall Settlement - Sta. 603+50 to 605+50

Boring B-107-2-14

H= 35.1 ft Total wall height

B'= 42.1 ft Effective footing width due to eccentricity

 D_w = 17.5 ft Depth below bottom of footing

q_e = 6,100 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	t Center of R	einforced Soi	l Mass		Total Sett	tlement at Fa	cing of Wall	
Layer	Soil Class.	Soil Type	٠,	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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	$\Delta\sigma_{v}^{(8)}$ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
1	A-6a	С	0.0	3.0	3.0	1.5	125	375	188	188	4,188	27	0.153	0.015	0.483				0.04	1.000	6,099	6,287	0.096	1.156	0.500	3,050	3,237	0.038	0.459
2	A-1-b	G	3.0	5.5	2.5	4.3	135	713	544	544	4,544					90	129	726	0.10	0.997	6,080	6,623	0.004	0.045	0.500	3,049	3,592	0.003	0.034
	A-1-b	G	5.5	8.0	2.5	6.8	135	1,050	881	881	4,881					90	115	591	0.16	0.988	6,024	6,905	0.004	0.045	0.499	3,045	3,926	0.003	0.033
3	A-6b	С	8.0	10.5	2.5	9.3	115	1,338	1,194	1,194	5,194	37	0.243	0.024	0.561				0.22	0.971	5,922	7,116	0.078	0.937	0.498	3,037	4,231	0.021	0.257
4	A-1-b	G	10.5	13.0	2.5	11.8	130	1,663	1,500	1,500	5,500					28	31	101	0.28	0.947	5,776	7,276	0.017	0.204	0.496	3,024	4,524	0.012	0.142
	A-1-b	G	13.0	15.5	2.5	14.3	135	2,000	1,831	1,831	5,831					55	57	199	0.34	0.917	5,592	7,423	0.008	0.091	0.493	3,006	4,837	0.005	0.063
5	A-1-b	G	15.5	18.5	3.0	17.0	135	2,405	2,203	2,203	6,203					55	53	184	0.40	0.879	5,360	7,562	0.009	0.105	0.488	2,979	5,181	0.006	0.073
3	A-1-b	G	18.5	21.5	3.0	20.0	135	2,810	2,608	2,452	6,452					55	51	175	0.48	0.834	5,088	7,540	0.008	0.100	0.482	2,941	5,393	0.006	0.070
	A-1-b	G	21.5	24.5	3.0	23.0	135	3,215	3,013	2,669	6,669					55	50	168	0.55	0.789	4,812	7,482	0.008	0.096	0.475	2,896	5,565	0.006	0.068
6	A-3	G	24.5	27.5	3.0	26.0	130	3,605	3,410	2,880	6,880					42	37	89	0.62	0.745	4,542	7,422	0.014	0.167	0.466	2,844	5,723	0.010	0.121
1. σ _p ' = σ,	_o '+σ _{m;} Estima	te $\sigma_{\rm m}$ of 4,00	00 psf (mode	erately overc	consolidated)	for natural so	oil deposits;	Ref. Table 1	1.2, Coduto 2	2003				•	•	•	•		•		Tota	l Settlement:		2.946 in		Total	Settlement:	•	1.321 in

^{2.} C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

^{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 $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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.} $\Delta \sigma_v = q_e(I)$

 $^{9. \ \} S_c = [C_c/(1+e_o)](H) log(\sigma_{v_i}'/\sigma_{v_o}') for \ \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_i}'; \ [C_r/(1+e_o)](H) log(\sigma_p'/\sigma_{v_o}') + [C_c/(1+e_o)](H) log(\sigma_{v_i}'/\sigma_p') \ for \ \sigma_{v_o}' < \sigma_p' < \sigma_{v_i}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO LRFD \ BDS \ (Cohesive soil layers)$

^{10.} S_c = H(1/C')log(σ_{v_l} '/ σ_{vo} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-072 - FRA-70-13.10 - Retaining Wall W5

MSE Wall Settlement - Sta. 603+50 to 605+50

Boring B-107-2-14

H=	35.1	ft	Total wall height		A-6a	A-6b		
B'=	42.1	ft	Effective footing width due to eccentricity	c _v =	600	300	ft ² /yr	Coefficient of consolitation
$D_w =$	17.5	ft	Depth below bottom of footing	t =	1	1	days	Time following completion of construction
q _e =	6,100	psf	Equivalent bearing pressure at bottom of wall	H _{dr} =	1.5	1.25	ft	Length of longest drainage path considered
				$T_v =$	0.731	0.526		Time factor
				U =	87	78	%	Degree of consolidation
				(S.), =	1 205	in	Settlement complete at	91% of primary consolidation

																							Total Se	ettlement at l	Facing of Wall		mplete at 91% of Consolidation
Layer	Soil Type	Soil Type	_	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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	Layer Settlement (in)	(S _c) _t ⁽¹¹⁾ (in)	Layer Settlement (in)
1	A-6a	С	0.0	3.0	3.0	1.5	125	375	188	188	4,188	27	0.153	0.015	0.483				0.04	0.500	3,050	3,237	0.038	0.459	0.459	0.400	0.400
2	A-1-b	G	3.0	5.5	2.5	4.3	135	713	544	544	4,544					90	129	726	0.10	0.500	3,049	3,592	0.003	0.034	0.067	0.034	0.067
2	A-1-b	G	5.5	8.0	2.5	6.8	135	1,050	881	881	4,881					90	115	591	0.16	0.499	3,045	3,926	0.003	0.033	0.007	0.033	0.007
3	A-6b	С	8.0	10.5	2.5	9.3	115	1,338	1,194	1,194	5,194	37	0.243	0.024	0.561				0.22	0.498	3,037	4,231	0.021	0.257	0.257	0.200	0.200
4	A-1-b	G	10.5	13.0	2.5	11.8	130	1,663	1,500	1,500	5,500					28	31	101	0.28	0.496	3,024	4,524	0.012	0.142	0.142	0.142	0.142
	A-1-b	G	13.0	15.5	2.5	14.3	135	2,000	1,831	1,831	5,831					55	57	199	0.34	0.493	3,006	4,837	0.005	0.063		0.063	
5	A-1-b	G	15.5	18.5	3.0	17.0	135	2,405	2,203	2,203	6,203					55	53	184	0.40	0.488	2,979	5,181	0.006	0.073	0.275	0.073	0.275
3	A-1-b	G	18.5	21.5	3.0	20.0	135	2,810	2,608	2,452	6,452					55	51	175	0.48	0.482	2,941	5,393	0.006	0.070	0.273	0.070	0.275
	A-1-b	G	21.5	24.5	3.0	23.0	135	3,215	3,013	2,669	6,669					55	50	168	0.55	0.475	2,896	5,565	0.006	0.068		0.068	
6	A-3	G	24.5	27.5	3.0	26.0	130	3,605	3,410	2,880	6,880					42	37	89	0.62	0.466	2,844	5,723	0.010	0.121	0.121	0.121	0.121

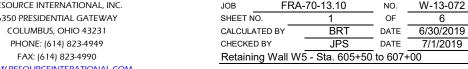
- 1. σ_p ' = σ_{vo} '+ σ_m ; Estimate σ_m of 4,000 psf (moderately overconsolidated) for natural soil deposits; Ref. Table 11.2, Coduto 2003
- 2. C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
- 3. C_r = 0.10(Cc) for natural soil deposits; Ref. Section 8.11, Holtz and Kovacs 1981
- 4. $e_o = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
- 5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo}')] \le 2.0$ 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
- $9. \quad S_c = [C_o/(1+e_o)](H)log(\sigma_{v_f}/\sigma_{v_o}')for \ \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_f}'; \ [C_r/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H)log(\sigma_p'/\sigma_{v_o}') + [C_o/(1+e_o)](H)log(\sigma_{v_f}/\sigma_p') \ for \ \sigma_{v_o}' < \sigma_{v_f}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO \ LRFD \ BDS \ (Cohesive soil layers)$
- 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

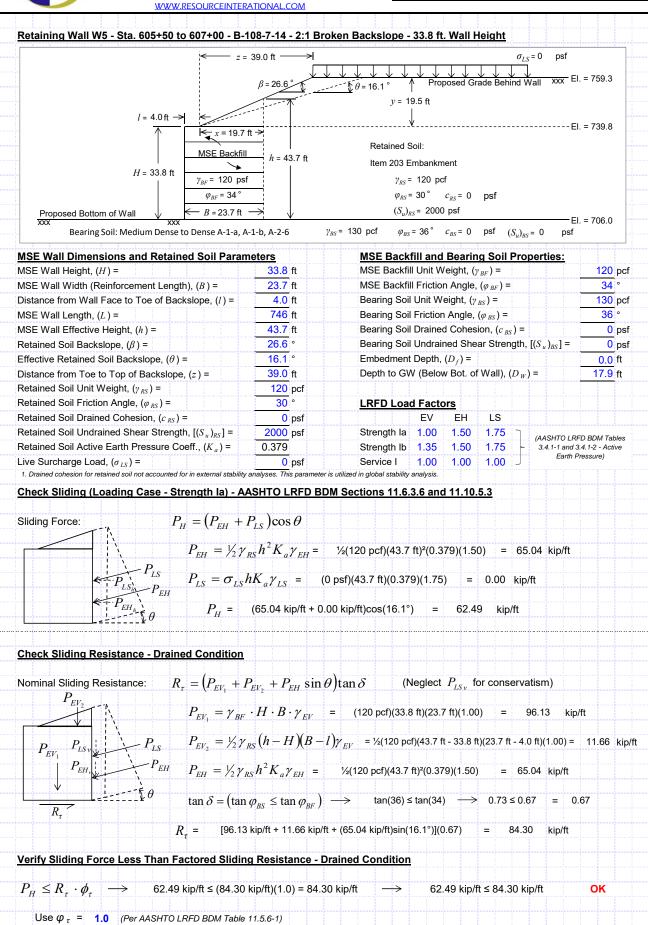
Calculated By: Date: 6/30/2019 Checked By: Date: 7/1/2019

Settlement Remaining After Hold Period: 0.116 in



JOB SHEET NO. CALCULATED BY DATE 6/30/2019 CHECKED BY JPS DATE 7/1/2019







RESOURCE INTERNATIONAL, INC. 6350 PRESIDENTIAL GATEWAY

FRA-70-13.10 W-13-072 JOB SHEET NO. 2 BRT JPS OF 6 6/30/2019 7/1/2019 CALCULATED BY DATE DATE CHECKED BY Retaining Wall W5 - Sta. 605+50 to 607+00

COLUMBUS, OHIO 43231	
PHONE: (614) 823-4949	
FAX: (614) 823-4990	
WWW.RESOURCEINTERATIONAL.COM	

SE Wall Dimensions and Retaine	ed Soil Par	rameters	Bearing S	oil Pror	nerties			
SE Wall Height, (H) =	<u> </u>	33.8 ft	MSE Backfi					120 pc
SE Wall Width (Reinforcement Length	-\ /D\=	33.8 π 23.7 ft	MSE Backfi					120 pc
			Bearing Soi				1	130 pc
istance from Wall Face to Toe of Back	«slope, (ι) –							
SE Wall Length, (L) =		746 ft	Bearing Soi					36°
SE Wall Effective Height, (h) =		43.7 ft	Bearing Soi				iii ii	0 ps
etained Soil Backslope, (β) =		26.6°	Bearing Soi			ar Sue	ıgtn, _L ı	
ffective Retained Soil Backslope, (θ) =		16.1 °	Embedmen				1	0.0 ft
istance from Toe to Top of Backslope,	, (z) =	39.0 ft	Depth to G\	N (Below	√ Bot. oi	f Wali),	(D_W) .	= <u>17.9</u> ft
etained Soil Unit Weight, (γ_{RS}) =		120 pcf						
etained Soil Friction Angle, (φ_{RS}) =		30°	<u>LRFD Loa</u>	uémmummumi	 			
etained Soil Drained Cohesion, (c_{RS}) =		0 psf		EV	EH	LS		
etained Soil Undrained Shear Strength		2000 psf	Strength la		1.50	1.75		(AASHTO LRFD BDM Tables
etained Soil Active Earth Pressure Co	$_{e}$ eff., (K_{a}) =	0.379	Strength lb		1.50	1.75	F	3.4.1-1 and 3.4.1-2 - Active
ve Surcharge Load, (σ_{LS}) =		0 psf	Service I	1.00	1.00	1.00		Earth Pressure)
. Drained cohesion for retained soil not accounted fo	or in external stat:							
heck Sliding (Loading Case - Str	ength <u>la) -</u>	AASHTO LRFD ΒΓ	OM Section 11.10	1.5.3 (Cor	ntinue <u>d)</u>			
heck Sliding Resistance - Undrai	ined Cond	ition						
Nominal Sliding Resisting:	R = ((5)	$(S_u)_{BS} \leq q_s \cdot B$						
	n_{τ} . W~	u JBS -4 s) -						
P_{EV_2}	(2)	$_{ m RS}=$ N/A ksf						
	$(\mathcal{O}_u)_E$	$_{\rm BS}=$ N/A ksf						
	<u> </u>	σ /						
P_{EV} , P_{LS}	$q_s =$	σ_{v_2}						
		, -						
P_{EH}	σ ,	$v = \frac{P_V}{R}$						
$R \vee \Gamma \Gamma$	Ammunamum	/ <i>B</i>						
$A_{\overline{\iota}}$		$P_{V} = P_{EV_{s}} + P_{EV_{s}}$	$\perp P_{-}$ $\sin \theta$					
$(S_u)_{RS} \leq q_s$		1 V - 1 EV ₁ Lx ₂	T I EH Sale					
_ u / b\s - 4 s		$D = \nu \cdot \dot{I}$	$H \cdot B \cdot \gamma_{EV} = ($	(120 ncf)	[,] (33 ႘ ft)	\'ንጻ 7 ftነ	·/1 NO`) = 96.13 kip/ft
for conservatism)		F _{EV1} - 1 BF	$I \cdot D \cdot \gamma_{EV}$,	120 pc.,,	(33.0,	(20.1,	(1.00,	= 00.10 n.p
(Neglect $P_{LS_{\nu}}$ for conservatism)		D 1/2	(
		$P_{EV_2} = \gamma_2 \gamma_{RS} \chi$	$(h-H)(B-l)\gamma_B$	EV				
		D 1/	2/1078 0	2 50/00		20/4 /	Ļ	
		P_{EV_2} = $^{\prime\prime}$ 2((120 pcf)(43.7 ft - 33	3.8 ft)(23	.7 ft - 4.	.0 ft)(1.u	ا(0ر	= 11.66 kip/ft
		$P_{\scriptscriptstyle FH} = \frac{1}{2} \gamma_{\scriptscriptstyle RS} h$	$h^2 K_a \gamma_{EH} = \frac{1}{2}$	₂(120 pcf ⁾	,)(43.7 ft`	ι)²(0.379	ı)(1.50	0) = 65.04 kip/ft
		232	4. 22.2					
		$P_V = 96.13 \text{kip/ft}$	+ 11.66 kip/ft + (65	04 kip/ft.ذ	t)sin(16	.1°) =	12	25.83 kip/ft
	σ_{i}	, = (125.83 kip/ft)	/(23.7 ft) =	5.31	ksf			
				3.0	NO.			
	a. =	(5.31 ksf) / 2 =	2.66 ksf					
	75	(J.J 1 KJ), L	Z.00 No.					
	_ מ	(NVA leaf < 2.66 kef)((20.7.E) _	N1/A	!-!∽./f4			
	$K_{\tau} =$	(N/A ksf ≤ 2.66 ksf)(2	(23.7 ft) =	N/A I	kip/ft			
erify Sliding Force Less Than Fa	ctored Slic	<u> Jing Resistance - U</u>	Indrained Condit	<u>ion)،</u>				
$P_H \leq R_{\tau} \cdot \phi_{\tau} \Longrightarrow $		N/A	->			N/A		
Use φ_{τ} = 1.0 (Per AASHTO LF	RFD BDM Tal	ble 11.5.6-1)						



 $e < e_{\text{max}} \longrightarrow$

5.04 ft < 7.90 ft

ок

 JOB
 FRA-70-13.10
 NO.
 W-13-072

 SHEET NO.
 3
 OF
 6

 CALCULATED BY
 BRT
 DATE
 6/30/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta. 605+50
 to 607+00

WWW.RESOURCEINTERATIONAL.COM
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·
COLUMBUS, OHIO 43231
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RESOURCE INTERNATIONAL, INC.

	WWW.RESOURCEINTERA	ATIONAL.COM		
MSE Wall Dimensions and	Detained Sail Daram		Pagging Sail Branaction	
MSE Wall Bloods (U) =	Retained Soil Param	33.8 ft	Bearing Soil Properties: MSE Backfill Unit Weight, (γ _{BF}) =	120 pcf
MSE Wall Height, (H) = MSE Wall Width (Reinforceme	unt Length) (P) =	23.7 ft	MSE Backfill Friction Angle, (φ_{BF}) =	34 °
Distance from Wall Face to To		4.0 ft	Bearing Soil Unit Weight, (γ_{BS}) =	130 pcf
MSE Wall Length, (L) =	e oi backsiope, (i) –	746 ft	Bearing Soil Friction Angle, $(\varphi_{RS}) =$	36°
MSE Wall Effective Height, (h)		43.7 ft	Bearing Soil Prained Cohesion, $(c_{BS}) =$	0 psf
Retained Soil Backslope, (β)		26.6 °	Bearing Soil Undrained Shear Strength, $[(s_n)_n]$	
Effective Retained Soil Backslo		16.1 °	Embedment Depth, (D_f) =	0.0 ft
Distance from Toe to Top of B		39.0 ft	Depth to GW (Below Bot. of Wall), (D_W) =	17.9 ft
Retained Soil Unit Weight, (γ_R)		120 pcf	Deput to GW (Below Bot. of Wall), (D_{ψ}) –	17.911
Retained Soil Friction Angle, (ໃນໃນການການເຂົາການການອັນການການຊົນການການຊົນການການອັນການກ	30 °	LRFD Load Factors	
Retained Soil Drained Cohesic		0 psf	EV EH LS	
Retained Soil Undrained Shea		2000 psf	Strength la 1 00 1 50 1 75 ¬	
Retained Soil Active Earth Pre		0.379	mā (AASI	HTO LRFD BDM Tables -1 and 3.4.1-2 - Active
Live Surcharge Load, (σ_{LS}) =	ssure Coen., (K _a) –	0.579 0 psf	Service I 1.00 1.00 1.00	Earth Pressure)
1. Drained cohesion for retained soil not	accounted for in external stability a			
Check Eccentricity (Loading	-			
	ng Jase - Strength la	, - AAJIII O ERFD	, Dun Occuon I I.O.J.J	
P_{EV}	$e = \frac{B}{2}$	Y		
	· - /2 - ·	^ 0		
B	D			
$X_4 \mid P_{EV_1} \mid P_{LS_v} \mid P_{LS_v}$	$P_{LS} = M_1$	$_{V}-M_{H}$ -1766	.34 kip·ft/ft - 909.84 kip·ft/ft) / (125.83 kip/ft =	6.81 ft
$L_{\mathcal{S}_{i}}$	P_{EH} $N_o = -$	$P_{\scriptscriptstyle V}$.04 KIP 1011 - 300.04 KIP 1011 / (120.00 KIP/II) -	0.01
X_3				
R^{\vee}	$\mathring{\mathbb{Z}}\theta$ M	= 1766.34 ki	p. 4/4	
	M_V	= 1766.34 ki = 909.84 ki	p·ft/ft Defined below	
$x_0 \leftarrow \times e$	$oldsymbol{D}^{I\!M}$	= 909.04 KI	$P^{-1}(I)$ = $\frac{1}{2} \sin \theta = 0.6.13 \text{ kin/ft} + 11.66 \text{ kin/ft} + (65.04 \text{ kin/ft}) \sin(4)$	6 1°) = 125 92 kin/ft
	1 V	$= P_{EV_1} + P_{EV_2} + I$	$P_{EH} \sin \theta$ = 96.13 kip/ft + 11.66 kip/ft + (65.04 kip/ft)sin(1	6.1) = 125.63 KIP/II
$x_1 \leftarrow B/2 \rightarrow$	e= ((23.7 ft/ 2) - 6.81 ft	= 5.04 ft	
$x_2 \rightarrow x_2$	e- (23.7 14 2) - 0.01 11	- 3.04 II	
Resisting Moment, $M_{\scriptscriptstyle V}$:	M = P ($(r)_{\perp}P_{\parallel}(r)_{\perp}$	- $P_{E\!H} \sin heta(B)$ (Neglect $P_{L\!S_{_{oldsymbol{V}}}}$ for cor	nservatism)
	$IVI_V - I_{EV_1}$	$(x_1) + 1_{EV_2} (x_2)$	$= I_{EH} \operatorname{SIH} \mathcal{O}(B)$ (regieer I_{LS_y} for each	isci valisiii)
P_{EV_2}	$D - \alpha$	H . R . v	= (120 pcf)(33.8 ft)(23.7 ft)(1.00) = 96	.13 kip/ft
	$I_{EV_1} - I$	$_{BF}$ '11 ' D ' γ_{EV}	- (120 pci)(33.8 ft)(23.7 ft)(1.00) - 90	. 13 KIP/II
	P = P - 1	'v (h_H)(R_	$l)\gamma_{EV} = \frac{1}{2}(120 \text{ pcf})(43.7 \text{ ft} - 33.8 \text{ ft})(23.7 \text{ ft} - 4.0 \text{ ft})(1.1 \text{ ft})$	00) = 11.66 kin/ft
P_{EV_1}	P_{LS} $P_{EV_2} - P_2$	$_{2}$ γ_{RS} $(n-11)(D-11)$	t = 72(120 pci)(43.7 it - 33.0 it)(23.7 it - 4.0 it)(1.0 it)	00) - 11.00 kip/it
$P_{EH_{v}}$	P_{EH} $D = 1$	$(\gamma_{RS}h^2K_a\gamma_{EH})$ =	= $\frac{1}{2}(120 \text{ pcf})(43.7 \text{ ft})^2(0.379)(1.50)$ = 65.0	Λ kin/ft
En	$I_{EH} = \gamma$	$2/_{RS}$ ^{n} $K_a/_{EH}$	72(120 por)(40.7 ft) (0.070)(1.30) = 00.0	T KIP/II
	$\int \Phi = r - B r$	– (23.7 ft) / 2	= 11.85 ft	
$\longrightarrow x$,		$\frac{2}{2} = (23.7 \text{ ft}) / 2$		
$x_1 \rightarrow x_2$	v = 1 :	2/(B - 1) = 4	$4.0 \text{ ft} + \frac{2}{3}(23.7 \text{ ft} - 4.0 \text{ ft}) = 17.13 \text{ ft}$	
	$\lambda_2 - \iota$	$\Gamma/3(D-i)$		
	$M_{-} = (96.13)$	kin/ft)(11 85 ft) + (11	1.66 kip/ft)(17.13 ft) + (65.04 kip/ft)sin(16.1°)(23.7 ft)	= 1766.34 kin.ft/ft
	1/1/	(1.00 1.00 1.00		- 1100.01 KIP IUK
Overturning Moment, M	$_{\scriptscriptstyle H}$: $M=P$	$\cos\theta(x_3) + P_I$	$-\cos\theta(x_i)$	
2	H = 1 EH	$U_{3}U_{1}U_{3}U_{1}U_{1}U_{1}U_{2}U_{3}U_{1}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{1}U_{2}U_{3}U_{2}U_{3}U_{1}U_{2}U_{3}U_{2}U_{3}U_{2}U_{3}U_{2}U_{3}U_{2}U_{3}U_{2}U_{3}U_{2}U_{3}U_{2}U_{3}U_{2}U_{3}U_{3}U_{2}U_{3}U_{3}U_{3}U_{3}U_{3}U_{3}U_{3}U_{3$	S SSS VV41	
X	P = 1	$/ v h^2 K v =$	= $\frac{1}{2}(120 \text{ pcf})(43.7 \text{ ft})^2(0.379)(1.50)$ = 65.0	4 kin/ft
	$p P = \sigma$	- hK ν =	(0 psf)(43.7 ft)(0.379)(1.75) = 0.00 kip/ft	
χ_4	P_{LS} $I_{LS} = 0$	LS'' al LS	(- FV	
x_3	P_{EH} $r_{*} = h/2$	= (43.7 ft) / 3	= 14.56 ft	
\uparrow	$P_{EH} \qquad x_3 = h/2$ $x_4 = h/2$	3		
	$\sum \theta \qquad x_{\perp} \equiv h/2$	= (43.7 ft)/2	= 21.83 ft	
	~4 /2	2,, 2		
	$M_{rr} = (65.04)$	4 kip/ft)cos(16.1°)(14	4.56 ft) + (0 kip/ft)cos(16.1°)(21.83 ft) = 909.84	kip-ft/ft
	H (30.0	F75(1011)(1		
Check Eccentricity	Limiting Eccentricity	e = B/	$\rightarrow e_{\text{max}} = (23.7 \text{ ft})/3 = 7.90$	ft
Shook Ecochinolty	Emiliary Ecocitations.	$\sim_{\text{max}} - /3$	max = (20.7 16)70 = 7.90	



FRA-70-13.10 W-13-072 JOB NO. SHEET NO. OF 6 CALCULATED BY BRT DATE 6/30/2019 JPS 7/1/2019 CHECKED BY DATE Retaining Wall W5 - Sta. 605+50 to 607+00

	FAX: (614) 823-4990 SOURCEINTERATIONAL.COM	Retaining Wall W5 - Sta. 605	+50 to 607+00
MSE Wall Dimensions and Retained	Soil Parameters	Bearing Soil Properties:	
MSE Wall Height, (H) =	33.8 ft	MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf
MSE Wall Width (Reinforcement Length),	(B) = 23.7 ft	MSE Backfill Friction Angle, (φ_{BF}) =	34 °
Distance from Wall Face to Toe of Backsl	ope, (<i>l</i>) = 4.0 ft	Bearing Soil Unit Weight, (γ_{BS}) =	130 pcf
MSE Wall Length, (L) =	746 ft	Bearing Soil Friction Angle, (φ_{BS}) =	36 °
MSE Wall Effective Height, (h) =	<u>43.7</u> ft	Bearing Soil Drained Cohesion, (c_{BS}) =	0 psf
Retained Soil Backslope, (β) =	26.6°	Bearing Soil Undrained Shear Strength,	$[(s_u)_{BS}] = 0 \text{ psf}$
Effective Retained Soil Backslope, (θ) =	16.1°	Embedment Depth, (D_f) =	0.0 ft
Distance from Toe to Top of Backslope, (a	z) = <u>39.0</u> ft	Depth to GW (Below Bot. of Wall), (D_{W})) = <u>17.9</u> ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf		
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Factors	
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV EH LS	
Retained Soil Undrained Shear Strength,	$[(S_u)_{RS}] = 2000 \text{ psf}$	Strength la 1.00 1.50 1.75	(AASHTO LRFD BDM Tables
Retained Soil Active Earth Pressure Coeff	$f_{.,}(K_a) = 0.379$	Strength lb 1.35 1.50 1.75 -	3.4.1-1 and 3.4.1-2 - Active
Live Surcharge Load, (σ_{LS}) =	0 psf	Service I 1.00 1.00 1.00	Earth Pressure)
Drained cohesion for retained soil not accounted for in		utilized in global stability analysis.	
Check Bearing Capacity (Loading C	ase - Strength lb) - AASHTO	LRFD BDM Section 11.6.3.2	
P_{EV_2}			
EV ₂	D /		
	$q_{eq} = \frac{P_V}{R'}$		
D I I	/ D		
$X_4 \mid P_{EV_1} \mid P_{LS} \mid P_$	R' = R - 2e = 23.	7 ft - 2(3.75 ft) = 16.20 ft	
$R_{X_3} \cap P_{EH} \cap P_{EH} \cap P_{EH}$			
\uparrow	$\rho = B/-r$	= (23.7 ft / 2) - 8.1 ft = 3.75 ft	
R^{\vee}			
	$_{\mathbf{r}} = M_{V} - M_{H}$	= (2234.87 kip·ft/ft - 909.84 kip·ft/ft) / 1	63.55 kip/ft = 8.10 ft
$x_0 \longleftrightarrow -1 - 1 - e$	P_{ν}	- (2234.07 kip lutt - 909.04 kip lutt) / 1	00.00 Kip/it = 0.10 it
$\leftarrow B/2 \Rightarrow$	(400 FF 15 - (ff)	(///COF)	
$\leftarrow B' \rightarrow \Box$	$q_{\it eq}=$ (163.55 kip/ft)	/ (16.2 ft) = 10.10 ksf	
$\vdash x_2 \rightarrow$			
Resisting Moment, $M_{_{I\!\!\!/}}$:	$M_V = P_{EV_1}(x_1) + P_{EV_2}(x_2) +$	$+P_{EH}\sin\theta(B)$	
$P_{\scriptscriptstyle EV_2}$	$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$	= (120 pcf)(33.8 ft)(23.7 ft)(1.35) =	129.77 kip/ft
Y 13	$P_{EV_2} = \frac{1}{2} \gamma_{RS} (h - H) (B -$	$(l)\gamma_{EV} = \frac{1}{2}(120 \text{ pcf})(43.7 \text{ ft} - 33.8 \text{ ft})(23.7 \text{ ft} - 4.0)$	0 ft)(1.35) = 15.74 kip/ft
P_{LS}			
	$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} =$	= $\frac{1}{2}(120 \text{ pcf})(43.7 \text{ ft})^2(0.379)(1.50)$ =	65.04 kip/ft
P_{EH}	$P_{EH} = \frac{1}{2} \gamma_{RS} h K_a \gamma_{EH} =$ $x_1 = \frac{B}{2} = \frac{(23.7 \text{ ft})}{2}$		
V 1 - 2	$x_1 = B/2 = (23.7 \text{ ft})/2$	= 11.85 ft	
J==\v2	1 / 2		
$\rightarrow x_I$	$x_2 = l + \frac{2}{2}(B - l) = 0$	$4.0 \text{ ft} + \frac{2}{3}(23.7 \text{ ft} - 4.0 \text{ ft}) = 17.13 \text{ ft}$	
$\rightarrow x_2$			
The state of the s	$I_{xx} = (129.77 \text{ kip/ft})(11.85 \text{ ft}) + (129.77 \text{ kip/ft})(11.85 \text{ ft})$	15.74 kip/ft)(17.1 ft) + (65.04 kip/ft)sin(16.1°)(23.	7 ft) = 2234.87 kin-ft/
			, === Mp
Overturning Moment, $M_{\scriptscriptstyle H}$: $M_{\scriptscriptstyle H}$:	$M_H = P_{EH} \cos \theta(x_3) + P_L$	$\cos \theta(\mathbf{r})$	
	$I_H - I_{EH} \cos \theta(x_3) + I_L$	$s\cos\theta(x_4)$	
	D 1/- 1.2 V	1//120 pot//2 7 th2/0 270//1 50)	65 04 Lin/f4
	$P_{EH} = \frac{1}{2} \gamma_{RS} h^{-} K_{a} \gamma_{EH}$	= $\frac{1}{2}(120 \text{ pcf})(43.7 \text{ ft})^2(0.379)(1.50)$ =	οο.υ4 κιρ/π
x_4 \downarrow P_{LS}	$P_{LS} = \sigma_{LS} h K_a \gamma_{LS} =$	(0 psf)(43.7 ft)(0.379)(1.75) = 0.00	kip/ft
\bigwedge			
X_3	$x_3 = h/3 = (43.7 \text{ ft})/3$	= 14.56 ft	
$\bigcap_{i=1}^{n} \bigcap_{j=1}^{n} \bigcap_{i=1}^{n} \bigcap_{j=1}^{n} \bigcap_{j=1}^{n} \bigcap_{i=1}^{n} \bigcap_{j=1}^{n} \bigcap_{j$			
<u> </u>	$x_4 = h_2 = (43.7 \text{ ft})/2$	= 21.83 ft	
	$M_H = (65.04 \text{ kip/ft})\cos(16.1^\circ)(16.1^\circ)$	4.56 ft) + (0 kip/ft)cos(16.1°)(21.83 ft) = 9	09.84 kip⋅ft/ft
Vertical Forces, P_{ν} :	$P_V = P_{EV_1} + P_{EV_2} + P_{EH} \sin \theta$	$\mathbf{n}oldsymbol{ heta}$	
	EV.		
	$P_{v} = 129.77 \text{ kip/ft} + 15.74$	kip/ft + (65.04 kip/ft)sin(16.1°) = 163.55	kip/ft
	- K		



FRA-70-13.10 JOB NO. SHEET NO. OF
 SHEET NO.
 5
 OF
 6

 CALCULATED BY
 BRT
 DATE
 6/30/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta. 605+50 to 607+00

W-13-072 6

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SE Wall Dimensions and Retained Soil F	Parameters Parameters	Bearing Soil Prop	erties:	
SE Wall Height, (H) =	33.8 ft	MSE Backfill Unit W	eight, (γ_{BF}) =	120 pcf
SE Wall Width (Reinforcement Length), (B) =	23.7 ft	MSE Backfill Friction	Angle, (φ_{BF}) =	34 °
istance from Wall Face to Toe of Backslope, (<i>l</i>) = 4.0 ft	Bearing Soil Unit We	eight, (γ_{BS}) =	130 pcf
SE Wall Length, (<i>L</i>) =	746 ft	Bearing Soil Friction	Angle, (φ_{BS}) =	36°
SE Wall Effective Height, (h) =	43.7 ft	Bearing Soil Drained	Cohesion, (c_{BS}) =	0 psf
etained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrair	ed Shear Strength	$[(s_u)_{BS}] = 0$ psf
ffective Retained Soil Backslope, (θ) =	16.1 °	Embedment Depth,	(D_f) =	0.0 ft
istance from Toe to Top of Backslope, (z) =	39.0 ft	Depth to GW (Below	Bot. of Wall), ($D_{\it W}$) = 17.9 ft
etained Soil Unit Weight, (γ_{RS}) =	120 pcf			
etained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Facto	<u>rs</u>	
etained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV	EH LS	
etained Soil Undrained Shear Strength, [$(S_u)_{RS}$]] = <u>2000</u> psf	Strength la 1.00	1.50 1.75	(AASHTO LRFD BDM Tables
etained Soil Active Earth Pressure Coeff., (K_a)	= 0.379	Strength lb 1.35	1.50 1.75 -	3.4.1-1 and 3.4.1-2 - Active Earth Pressure)
ve Surcharge Load, (σ_{LS}) =	0 psf	Service I 1.00	1.00 1.00 🗸	Latui Fiessure)
Drained cohesion for retained soil not accounted for in external				
heck Bearing Capacity (Loading Case - S	Strength ID) - AASH I O	CRFD BDM Section 11.	10.5.4 (Continued)	
heck Bearing Resistance - Drained Conc	<u>dition</u>			
ominal Bearing Resistance: $q_{_{\it n}}=cN_{_{\it c}}$	$_{cm}+\gamma\!D_{f}N_{qm}C_{wq}+$	- $\frac{1}{2}\gamma B'N_{ym}C_{w\gamma}$		
$N_{cm} = N_c s_c i_c = 50.59$	$N_{qm} = N_q s_q d_q t$	i _a = 37.8	$N_{ym} = N_{\gamma} s_{\gamma} i_{\gamma}$, = 56.3
		7		
$N_c = 50.59$	$N_q = 37.75$		$N_{\gamma} = 56.31$	
$S_c = 1 + (16.2 \text{ ft}/746 \text{ ft})(37.75/50.59)$		t/746 ft)tan(36°) = 1.000		
= 1.000	$d_q = 1 + 2 \tan(36)$	s°)[1-sin(36°)]²tan⁻¹(0.0 ft/16.2 ft)		
i_c = 1.000 (Assumed)	= 1.000		$C_{wy} = 17.9 \text{ft} <$	< 1.5(16.2 ft) + 0.0 ft = 0.5
	i = 1000 (a)	∆esumed)		
$q_n = (0 \text{ psf})(50.59) + (130 \text{ pcf})(0.01)$	$i_{q} = 1.000 \text{ (}i_{q} = 1.000 \text{ (}i_{q} = 17.9 \text{ ft})$ $C_{wq} = 17.9 \text{ ft})$ $\text{ft})(37.8)(1.0) + \frac{1}{2}(130 \text{ pc})$	0.0 ft = 1.000	= 29.65 ksi	
	$C_{wq} = 17.9 \text{ ft} > $ ft)(37.8)(1.0) + ½(130 p	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5)	= 29.65 ksi	
erify Equivalent Pressure Less Than Fac	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + ½(130 postored Bearing Resista	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) unce		
	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + ½(130 postored Bearing Resista	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) unce	= 29.65 ksi 0.10 ksf ≤ 19.27 k	
erify Equivalent Pressure Less Than Fac $q_{eq} \leq q_n \cdot \phi_b o $ 10.10 k	$C_{wg} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + ½(130 postored Bearing Resistance Sectored Sector Resistance Sector Resistance	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) unce		
erify Equivalent Pressure Less Than Fac	$C_{wg} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + ½(130 postored Bearing Resistance Sectored Sector Resistance Sector Resistance	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) unce		
erify Equivalent Pressure Less Than Fac $q_{eq} \leq q_n \cdot \phi_b o $ 10.10 k	$C_{wg} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + ½(130 postored Bearing Resistance Sectored Sector Resistance Sector Resistance	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) unce		
erify Equivalent Pressure Less Than Fac $q_{eq} \leq q_n \cdot \phi_b o $ 10.10 k	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 postored Bearing Resistants and Sectored Sect	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) unce		
erify Equivalent Pressure Less Than Fac $q_{eq} \leq q_n \cdot \phi_b \implies$ 10.10 k Use $\varphi_b = 0.65$ (Per AASHTO LRFD E	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 points and the second Bearing Resistants and the second second Bearing Resistants and the second Bearing Resistant and the second Bea	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) ince 19.27 ksf -> 1		
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD Expectation of the Bearing Resistance - Undrained Comminal Bearing Resistance: $q_n = cN_d$	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 points and the second Bearing Resistant Sectored Bearing Resistant Secto	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) cnce 19.27 ksf \rightarrow 10 cm 1	0.10 ksf ≤ 19.27 k	sf OK
erify Equivalent Pressure Less Than Fac $q_{eq} \leq q_n \cdot \phi_b \implies$ 10.10 k Use $\varphi_b = 0.65$ (Per AASHTO LRFD E	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 postored Bearing Resistants and Sectored Search 1.5.6-1) and Table 11.5.6-1) condition	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) cnce 19.27 ksf \rightarrow 10 cm 1		sf OK
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD Expectation of the Bearing Resistance - Undrained Comminal Bearing Resistance: $q_n = cN_d$	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 points and the second Bearing Resistant Sectored Bearing Resistant Secto	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) cnce 19.27 ksf \rightarrow 10 cm 1	0.10 ksf ≤ 19.27 k	sf OK
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD Expendence) heck Bearing Resistance - Undrained Comminal Bearing Resistance: $q_n = cN_c$ $N_{cm} = N_c s_c i_c = 5.140$	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 points of the second Bearing Resistants of the second Bearing Resistant of the	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) cnce 19.27 ksf \rightarrow 10 cm 1	0.10 ksf \leq 19.27 k $N_{jm}=N_{\gamma}s_{\gamma}i_{\gamma}$	sf OK
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD Expendence of the Lagrange Resistance - Undrained Comminal Bearing Resistance: $q_n = cN_c$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 points of the second Bearing Resistants of the second Bearing Resistant of the	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) cnce 19.27 ksf \rightarrow 10 cm 1	0.10 ksf \leq 19.27 k $N_{jm} = N_{\gamma} s_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$	sf OK = 0.000
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD Expendence of the Lagrange Resistance - Undrained Companied Bearing Resistance: $q_n = cN_c$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(16.2 \mathrm{ft/[(5)(746 ft)]} = 1.000$	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 points) ctored Bearing Resistants csf \(\leq (29.65 \text{ ksf})(0.65) = BDM Table 11.5.6-1) Dondition $C_{cm} + \gamma D_f N_{qm} C_{wq} +$ $N_{qm} = N_q s_q d_q i$ $N_q = 1.000$ $s_q = 1.000$	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) Ince 19.27 ksf \rightarrow 11 $-\frac{1}{2}\gamma B' N_{ym} C_{wy}$ $i_q = 1.000$	$N_{jm} = N_{\gamma} s_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $s_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	sf OK = 0.000
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD Expendence of the Lagrange Resistance - Undrained Companied Bearing Resistance: $q_n = cN_c$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(16.2 \mathrm{ft/[(5)(746 ft)]} = 1.000$	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 pc) stored Bearing Resista ssf \(\leq (29.65 \text{ ksf})(0.65) = BDM Table 11.5.6-1) Dondition $C_{m} + \gamma D_{f} N_{qm} C_{wq} +$ $N_{qm} = N_{q} S_{q} d_{q} i$ $N_{q} = 1.000$ $S_{q} = 1.000$ $d_{q} = 1.2 tan(0.00)$	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) Ince 19.27 ksf \longrightarrow 10 $-\frac{1}{2}\gamma B^{\dagger}N_{ym}C_{wy}$ $i_q = 1.000$	$N_{jm} = N_{\gamma} s_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $s_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	= 0.000 (Assumed)
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD Expendence of the Lagrange Resistance - Undrained Companied Bearing Resistance: $q_n = cN_c$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(16.2 \mathrm{ft/[(5)(746 ft)]} = 1.000$	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + ½(130 pc) stored Bearing Resista ssf \(\leq (29.65 \text{ ksf})(0.65) = BDM Table 11.5.6-1) Dondition $C_{m} + \gamma D_{f} N_{qm} C_{wq} +$ $N_{qm} = N_{q} S_{q} d_{q} i$ $N_{q} = 1.000$ $S_{q} = 1.000$ $d_{q} = 1+2 \tan(0)$ $d_{q} = 1.000$	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) Ince 19.27 ksf \longrightarrow 11 19.27 ksf \longrightarrow 11 $\frac{1}{q} = 1.000$ Assumed)	$N_{jm} = N_{\gamma} s_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $s_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	= 0.000 (Assumed)
erify Equivalent Pressure Less Than Face $q_{eq} \leq q_n \cdot \phi_b \implies 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD EXAMPLE OF LASHTO LASHT	$C_{wq} = 17.9 \text{ ft} >$ $C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 pc) ctored Bearing Resista ass $\leq (29.65 \text{ ksf})(0.65) =$ BDM Table 11.5.6-1) Dondition $C_{m} + \frac{\gamma}{D_{f}} N_{qm} C_{wq} +$ $N_{qm} = N_{q} s_{q} d_{q} i$ $N_{q} = 1.000$ $s_{q} = 1.000$ $d_{q} = 1.2 \text{tan(0)}$ $i_{q} = 1.000 (i_{q} = 1.000)$ $C_{wq} = 17.9 \text{ ft} >$	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) ince 19.27 ksf \longrightarrow 1 19.27 ksf \longrightarrow 1 $\frac{1}{q} = 1.000$ Assumed) 0.0 ft = 1.000	$N_{jm} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$ $C_{w\gamma} = 17.9 \text{ft} < 0.000$	= 0.000 (Assumed) c1.5(16.2 ft) + 0.0 ft = 0.5
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD Expendence of the Lagrange Resistance - Undrained Companied Bearing Resistance: $q_n = cN_c$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(16.2 \mathrm{ft/[(5)(746 ft)]} = 1.000$	$C_{wq} = 17.9 \text{ ft} >$ $C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 pc) ctored Bearing Resista ass $\leq (29.65 \text{ ksf})(0.65) =$ BDM Table 11.5.6-1) Dondition $C_{m} + \frac{\gamma}{D_{f}} N_{qm} C_{wq} +$ $N_{qm} = N_{q} s_{q} d_{q} i$ $N_{q} = 1.000$ $s_{q} = 1.000$ $d_{q} = 1.2 \text{tan(0)}$ $i_{q} = 1.000 (i_{q} = 1.000)$ $C_{wq} = 17.9 \text{ ft} >$	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) ince 19.27 ksf \longrightarrow 1 19.27 ksf \longrightarrow 1 $\frac{1}{q} = 1.000$ Assumed) 0.0 ft = 1.000	$N_{jm} = N_{\gamma} s_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $s_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	= 0.000 (Assumed) c1.5(16.2 ft) + 0.0 ft = 0.5
erify Equivalent Pressure Less Than Face $q_{eq} \leq q_n \cdot \phi_b \implies 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD EXAMPLE OF LASHTO LASHT	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 points ft)(1.0)(1.0) 1.0) + $\frac{1}{2}$ (130 points ft)(1.0)(1.0)(1.0)(1.0)(1.0)(1.0)(1.0)(1.0	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) cf)(16.2 ft)(56.3)(0.5) cf) $\frac{100}{1}$ cf)(16.2 ft)(16.2 ft)($N_{jm} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$ $C_{w\gamma} = 17.9 \text{ft} < 0.000$	= 0.000 (Assumed) c1.5(16.2 ft) + 0.0 ft = 0.5
erify Equivalent Pressure Less Than Face $q_{eq} \leq q_n \cdot \phi_b \implies 10.10 \mathrm{k}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD Expression of the latter of the	$C_{wq} = 17.9 \text{ ft} >$ ft)(37.8)(1.0) + $\frac{1}{2}$ (130 points ft)(1.0)(1.0) 1.0) + $\frac{1}{2}$ (130 points ft)(1.0)(1.0)(1.0)(1.0)(1.0)(1.0)(1.0)(1.0	0.0 ft = 1.000 cf)(16.2 ft)(56.3)(0.5) cf)(16.2 ft)(56.3)(0.5) cf) $\frac{100}{1}$ cf)(16.2 ft)(16.2 ft)($N_{jm} = N_{\gamma} S_{\gamma} i_{\gamma}$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$ $C_{w\gamma} = 17.9 \text{ft} < 0.000$	= 0.000 (Assumed) c1.5(16.2 ft) + 0.0 ft = 0.5



RESOURCE INTERNATIONAL, INC.

FRA-70-13.10 JOB SHEET NO. CALCULATED BY JPS CHECKED BY DATE

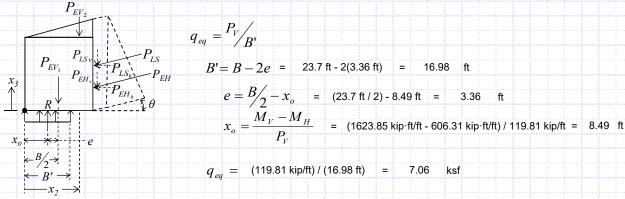
W-13-072 6/30/2019 7/1/2019

Retaining Wall W5 - Sta. 605+50 to 607+00

Rii)	6350 PRESIDENTIAL GATEWAY COLUMBUS, OHIO 43231 PHONE: (614) 823-4949 FAX: (614) 823-4990								٩Y	
	<u>WWW.RESOURCEINTERATIONAL.CO</u>									

MSE Wall Dimensions and Retained Soil Param	<u>ıeters</u>	Bearing Soil Properties:
MSE Wall Height, (H) =	33.8 ft	MSE Backfill Unit Weight, (γ_{BF}) = 120 pc
MSE Wall Width (Reinforcement Length), (B) =	23.7 ft	MSE Backfill Friction Angle, (φ_{BF}) = 34 °
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft	Bearing Soil Unit Weight, $(\gamma_{BS}) = \frac{130}{1}$
MSE Wall Length, (<i>L</i>) =	746 ft	Bearing Soil Friction Angle, (φ_{BS}) = 36 °
MSE Wall Effective Height, (h) =	43.7 ft	Bearing Soil Drained Cohesion, $(c_{BS}) = 0$ ps
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}] = 0$ ps
Effective Retained Soil Backslope, (θ) =	16.1 °	Embedment Depth, (D_f) = 0.0 ft
Distance from Toe to Top of Backslope, (z) =	39.0 ft	Depth to GW (Below Bot. of Wall), (D_W) = 17.9 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Factors
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV EH LS
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	Strength la 1.00 1.50 1.75 CAASHTO LRFD BDM Tables
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.379	Strength lb 1.35 1.50 1.75 - 3.4.1-1 and 3.4.1-2 - Active
Live Surcharge Load, (σ_{LS}) =	0 psf	Service I 1.00 1.00 1.00
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



$$M_{V} = P_{EV_{1}}(x_{1}) + P_{EV_{2}}(x_{2}) + P_{EH} \sin \theta(B) = (\gamma_{BF} H B \gamma_{EV})(\gamma_{2} B) + (\gamma_{2} \gamma_{RS} (h - H)(B - I)\gamma_{EV})(I + \gamma_{3} (B - I)) + (\gamma_{2} \gamma_{RS} h^{2} K_{a} \gamma_{EH} \sin \theta)(B)$$

 $M_V =$ [(120 pcf)(33.8 ft)(23.7 ft)(1.00)][½(23.7 ft)] + [½(120 pcf)(43.7 ft - 33.8 ft)(23.7 ft - 4.0 ft)(1.00)][4.0 ft + ¾(23.7 ft - 4.0 ft)] = 1623.85 kip·ft/ft + [½(120 pcf)(43.7 ft)²(0.379)(1.00)sin(16.1°)](23.7 ft)

$$M_{H} = P_{EH} \cos \theta(x_{3}) + P_{LS} \cos \theta(x_{4}) = \left(\frac{1}{2}\gamma_{RS}h^{2}K_{a}\gamma_{EH} \cos \theta\right)\left(\frac{h}{3}\right) + \left(\sigma_{LS}hK_{a}\gamma_{LS} \cos \theta\right)\left(\frac{h}{2}\right)$$

 $M_H = \frac{1}{2}[(120 \text{ pcf})(43.7 \text{ ft})^2(0.379)(1.00)\cos(16.1^\circ)](43.7 \text{ ft}/3) = 606.31 \text{ kip-ft/ft}$ + [(0 psf)(43.7 ft)(0.379)(1.00)cos(16.1°)](43.7 ft /2)

$$P_{V} = P_{EV} + P_{EV} + P_{EH} \sin \theta = (\gamma_{BF} H B \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} (h - H)(B - l) \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} h^{2} K_{a} \gamma_{EH} \sin \theta)$$

 $P_{\nu} = (120 \text{ pcf})(33.8 \text{ ft})(23.7 \text{ ft})(1.00) + \frac{1}{2}(120 \text{ pcf})(43.7 \text{ ft} - 33.8 \text{ ft})(23.7 \text{ ft} - 4.0 \text{ ft})(1.00) = 119.81 \text{ kip/ft}$ + ½(120 pcf)(43.7 ft)²(0.379)(1.00)sin(16.1°)

Settlement, Time Rate of Consolidation and Differential Settlement:

Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Alon Wall Facing
B-104-1-13	4.459 in	2.412 in	15 days		
B-105-3-14	3.519 in	1.872 in	3 days	85 ft	1/1890
B-105-5-14	3.512 in	1.535 in	5 days	145 ft	1/5160
B-107-2-14	2.946 in	1.321 in	1 days	135 ft	1/7570
B-108-7-14	2.403 in	1.341 in	1 days	160 ft	1/96000
B-108-8-14	0.950 in	0.694 in	3 days	130 ft	1/2410
· · · · · · · · · · · · · · · · · · ·					

W-13-072 - FRA-70-13.10 - Retaining Wall W5

MSE Wall Settlement - Sta. 605+50 to 607+00

Boring B-108-7-14

H= 33.8 ft Total wall height

B'= 17.0 ft Effective footing width due to eccentricity

 D_w = 17.9 ft Depth below bottom of footing

q_e = 7,060 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement a	t Center of Re	einforced So	il Mass		Total Se	ttlement at Fa	cing of Wall	
Layer	Soil Class.	Soil Type	Layer (1	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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)
1 (Emb.)	A-6a	С	0.0	2.5	2.5	1.3	120	300	150	150	4,150	30	0.180	0.018	0.507				0.07	0.999	7,051	7,201	0.115	1.375	0.500	3,529	3,679	0.042	0.498
	A-1-a	G	2.5	5.0	2.5	3.8	135	638	469	469	4,469					47	70	267	0.22	0.971	6,852	7,321	0.011	0.134	0.498	3,515	3,984	0.009	0.104
2	A-1-a	G	5.0	7.5	2.5	6.3	135	975	806	806	4,806					47	61	222	0.37	0.900	6,355	7,162	0.011	0.128	0.491	3,466	4,272	0.008	0.098
	A-1-a	G	7.5	10.0	2.5	8.8	135	1,313	1,144	1,144	5,144					47	56	195	0.51	0.809	5,711	6,855	0.010	0.119	0.478	3,376	4,520	0.008	0.092
2	A-1-a	G	10.0	13.5	3.5	11.8	135	1,785	1,549	1,549	5,549					104	113	576	0.69	0.701	4,949	6,498	0.004	0.045	0.456	3,222	4,771	0.003	0.036
3	A-1-a	G	13.5	17.0	3.5	15.3	135	2,258	2,021	2,021	6,021					104	104	499	0.90	0.594	4,197	6,218	0.003	0.041	0.425	3,004	5,025	0.003	0.033
4	A-1-b	G	17.0	20.5	3.5	18.8	125	2,695	2,476	2,423	6,423					17	16	66	1.10	0.510	3,603	6,026	0.021	0.251	0.393	2,773	5,197	0.018	0.210
4	A-1-b	G	20.5	24.0	3.5	22.3	125	3,133	2,914	2,642	6,642					17	15	65	1.31	0.445	3,138	5,781	0.018	0.218	0.361	2,550	5,193	0.016	0.189
-	A-1-b	G	24.0	28.0	4.0	26.0	135	3,673	3,403	2,897	6,897					84	74	289	1.53	0.389	2,748	5,645	0.004	0.048	0.330	2,331	5,228	0.004	0.043
5	A-1-b	G	28.0	32.0	4.0	30.0	135	4,213	3,943	3,187	7,187					84	71	274	1.76	0.343	2,420	5,607	0.004	0.043	0.301	2,123	5,310	0.003	0.039
1. $\sigma_p' = \sigma_{v_0}$	-'+σ _{m;} Estima	ite $\sigma_{\rm m}$ of 4,00	00 psf (mode	erately over	consolidated)	for natural so	il deposits;	Ref. Table 1	11.2, Coduto	2003			•				•		-		Tota	l Settlement:		2.403 in		Tota	al Settlement:	1	1.341 in

^{2.} C_c = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

^{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 $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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.} $\Delta \sigma_v = q_e(I)$

 $^{9. \ \} S_c = [C_c/(1+e_o)](H) log(\sigma_{v_i}'/\sigma_{v_o}') for \ \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_i}'; \ [C_r/(1+e_o)](H) log(\sigma_p'/\sigma_{v_o}') + [C_c/(1+e_o)](H) log(\sigma_{v_i}'/\sigma_p') \ for \ \sigma_{v_o}' < \sigma_p' < \sigma_{v_i}'; \ Ref. \ Section \ 10.6.2.4.3, \ AASHTO LRFD \ BDS \ (Cohesive soil layers)$

^{10.} S_c = H(1/C')log($\sigma_{v'}$ / σ_{vo} '); Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

W-13-072 - FRA-70-13.10 - Retaining Wall W5

MSE Wall Settlement - Sta. 605+50 to 607+00

33.8 ft

ft

ft

17.0

17.9

7,060

Boring B-108-7-14

B'=

 $D_w =$

Total wall height A-6a Effective footing width due to eccentricity 600 ft²/yr Coefficient of consolitation $c_v =$ Depth below bottom of footing t = 1 Time following completion of construction days Equivalent bearing pressure at bottom of wall $H_{dr} =$ 1.3 Length of longest drainage path considered $T_v =$ 1.052 Time factor U = 94 Degree of consolidation $(S_c)_t =$ 1.311 in Settlement complete at 98% of primary consolidation

																									aomig or rrain	Primary C	Consolidation
Layer	Soil Type	Soil Type	_	r 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)	Δσ _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 (Emb.)	A-6a	С	0.0	2.5	2.5	1.3	120	300	150	150	4,150	30	0.180	0.018	0.507				0.07	0.500	3,529	3,679	0.042	0.498	0.498	0.468	0.468
	A-1-a	G	2.5	5.0	2.5	3.8	135	638	469	469	4,469					47	70	267	0.22	0.498	3,515	3,984	0.009	0.104		0.104	
2	A-1-a	G	5.0	7.5	2.5	6.3	135	975	806	806	4,806					47	61	222	0.37	0.491	3,466	4,272	0.008	0.098	0.294	0.098	0.294
	A-1-a	G	7.5	10.0	2.5	8.8	135	1,313	1,144	1,144	5,144					47	56	195	0.51	0.478	3,376	4,520	0.008	0.092		0.092	
2	A-1-a	G	10.0	13.5	3.5	11.8	135	1,785	1,549	1,549	5,549					104	113	576	0.69	0.456	3,222	4,771	0.003	0.036	0.069	0.036	0.069
3	A-1-a	G	13.5	17.0	3.5	15.3	135	2,258	2,021	2,021	6,021					104	104	499	0.90	0.425	3,004	5,025	0.003	0.033	0.009	0.033	0.069
4	A-1-b	G	17.0	20.5	3.5	18.8	125	2,695	2,476	2,423	6,423					17	16	66	1.10	0.393	2,773	5,197	0.018	0.210	0.399	0.210	0.399
4	A-1-b	G	20.5	24.0	3.5	22.3	125	3,133	2,914	2,642	6,642					17	15	65	1.31	0.361	2,550	5,193	0.016	0.189	0.399	0.189	0.399
-	A-1-b	G	24.0	28.0	4.0	26.0	135	3,673	3,403	2,897	6,897					84	74	289	1.53	0.330	2,331	5,228	0.004	0.043	0.081	0.043	0.081
5	A-1-b	G	28.0	32.0	4.0	30.0	135	4,213	3,943	3,187	7,187					84	71	274	1.76	0.301	2,123	5,310	0.003	0.039	0.081	0.039	0.081

- 1. σ_p ' = σ_{vo} '+ σ_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. $e_0 = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981
- 5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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
- 9. $S_c = [C_o/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{vo}')$ for $\sigma_p' \le \sigma_{vo}' < \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}') + [C_o/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{v'}' \le \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{vo}' < \sigma_{v'}' \le \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{vo}' < \sigma_{v'}' \le \sigma_{v'}$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{vo}' < \sigma_{v'}' \le \sigma_{v'}'$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{vo}' < \sigma_{v'} \le \sigma_{v'}'$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{vo}' < \sigma_{v'} \le \sigma_{v'}'$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{vo}' < \sigma_{v'} \le \sigma_{v'}'$; $[C_r/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v'})$ for $\sigma_{v'} < \sigma_{v'} \le \sigma_{v'}$ for $\sigma_{v'} < \sigma_{v'} \le \sigma_{v'}$ for $\sigma_{v'} < \sigma_{v'} < \sigma_{v'} \le \sigma_{v'}$ for $\sigma_{v'} < \sigma_{v'} < \sigma$
- 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

Calculated By: BRT Date: 6/30/2019 Checked By: JPS Date: 7/1/2019

Settlement Remaining After Hold Period: 0.030

Total Settlement at Facing of Wall

Settlement Complete at 98% of



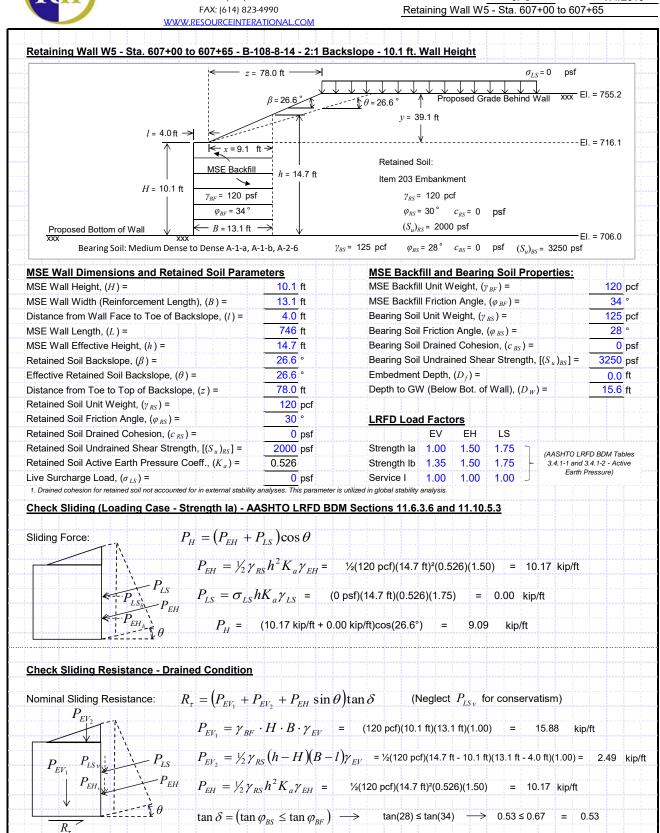
RESOURCE INTERNATIONAL, INC. 6350 PRESIDENTIAL GATEWAY COLUMBUS, OHIO 43231 PHONE: (614) 823-4949 FAX: (614) 823-4990
 JOB
 FRA-70-13.10
 NO.
 W-13-072

 SHEET NO.
 1
 OF
 6

 CALCULATED BY
 BRT
 DATE
 6/30/2019

 CHECKED BY
 JPS
 DATE
 7/1/2019

 Retaining Wall W5 - Sta. 607+00 to 607+65



Verify Sliding Force Less Than Factored Sliding Resistance - Drained Condition

 $P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow 9.09 \text{ kip/ft} \leq (12.15 \text{ kip/ft})(1.0) = 12.15 \text{ kip/ft} \longrightarrow 9.09 \text{ kip/ft} \leq 12.15 \text{ kip/ft}$ OK

Use $\varphi_{\tau} = 1.0$ (Per AASHTO LRFD BDM Table 11.5.6-1)

 $R_{\tau} = [15.88 \text{ kip/ft} + 2.49 \text{ kip/ft} + (10.17 \text{ kip/ft}) \sin(26.6^{\circ})](0.53)$



FRA-70-13.10 JOB SHEET NO. CALCULATED BY JPS CHECKED BY

DATE DATE

6/30/2019 7/1/2019

W-13-072

Retaining Wall W5 - Sta. 607+00 to 607+65

MSE Wall Dimensions and Retained Soil Paran	<u>neters</u>		Bearing So	oil Pro
MSE Wall Height, (H) =	10.1	ft	MSE Backfil	ا Unit ۱
MSE Wall Width (Reinforcement Length), (B) =	13.1	ft	MSE Backfil	I Friction
Distance from Wall Face to Toe of Backslope, (l) =	4.0	ft	Bearing Soil	Unit V
MSE Wall Length, (L) =	746	ft	Bearing Soil	Frictio
MSE Wall Effective Height, (h) =	14.7	ft	Bearing Soil	Draine
Retained Soil Backslope, (β) =	26.6	0	Bearing Soil	Undra
Effective Retained Soil Backslope, (θ) =	26.6	0	Embedment	Depth
Distance from Toe to Top of Backslope, (z) =	78.0	ft	Depth to GV	V (Belo
Retained Soil Unit Weight, (γ_{RS}) =	120	pcf		
Retained Soil Friction Angle, (φ_{RS}) =	30	0	LRFD Load	d Fact
Retained Soil Drained Cohesion, (c_{RS}) =	0	psf		EV
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000	psf	Strength la	1.00
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.526		Strength lb	1.35
Live Surcharge Load, (σ_{LS}) =	0	psf	Service I	1.00

roperties: Weight, (γ_{BF}) = 120 pcf tion Angle, (φ_{BF}) = 34 ° Weight, (γ_{BS}) = 125 pcf ion Angle, (φ_{BS}) = 28° ned Cohesion, (c_{BS}) = 0 psf rained Shear Strength, $[(s_u)_{BS}]$ = 3250 psf th, $(D_f) =$ 0.0 ft elow Bot. of Wall), (D_W) = 15.6 ft

ctors

	LV	L11	LO	
Strength la	1.00	1.50	1.75	٦
Strength lb	1.35	1.50	1.75	-
Service I	1.00	1.00	1.00	J

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

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

Check Sliding Resistance - Undrained Condition

Nominal Sliding Resisting: $P_{LS} \qquad q_s = \frac{\sigma_v}{2}$ $P_{EH} \qquad \sigma_v = \frac{P_v}{B}$

 $R_{\tau} = ((S_u)_{BS} \leq q_s) \cdot B$

$$\left(S_u^{}\right)_{B\!S}=$$
 3.25 ksf

$$q_s = \frac{\sigma_v}{2}$$

$$\sigma_v = \frac{P_V}{B}$$

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

(Neglect $P_{LS_{\nu}}$ for conservatism)

$$P_{EV_1} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV} = (120 \text{ pcf})(10.1 \text{ ft})(13.1 \text{ ft})(1.00) = 15.88 \text{ kip/ft}$$

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

$$P_{EV}$$
 = ½(120 pcf)(14.7 ft - 10.1 ft)(13.1 ft - 4.0 ft)(1.00) = 2.49 kip/ft

$$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(14.7 \text{ ft})^2 (0.526)(1.50) = 10.17 \text{ kip/ft}$$

$$P_V = 15.88 \text{ kip/ft} + 2.49 \text{ kip/ft} + (10.17 \text{ kip/ft}) \sin(26.6^\circ) = 22.92 \text{ kip/ft}$$

$$\sigma_{v} = (22.92 \text{ kip/ft}) / (13.1 \text{ ft}) = 1.75 \text{ ksf}$$

$$q_s = (1.75 \, \text{ksf}) / 2 = 0.88 \, \text{ksf}$$

$$R_{\tau} = (3.25 \text{ ksf} \le 0.88 \text{ ksf})(13.1 \text{ ft}) = 42.58 \text{ kip/ft}$$

Verify Sliding Force Less Than Factored Sliding Resistance - Undrained Condition

 $P_H \leq R_{\tau} \cdot \phi_{\tau} \longrightarrow$ $9.09 \text{ kip/ft} \le (42.58 \text{ kip/ft})(1.0) = 42.58 \text{ kip/ft}$

9.09 kip/ft ≤ 42.58 kip/ft

OK

Use $\varphi_{\tau} = 1.0$ (Per AASHTO LRFD BDM Table 11.5.6-1)



FRA-70-13.10 JOB SHEET NO. CALCULATED BY DATE JPS CHECKED BY DATE

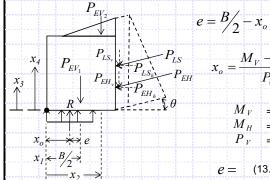
6/30/2019 7/1/2019

W-13-072

Retaining Wall W5 - Sta. 607+00 to 607+65

MSE Wall Dimensions and Retained Soil Paran	<u>neters</u>	Bearing So	oil Pro	perties:				
MSE Wall Height, (H) =	10.1 ft	MSE Backfi	ll Unit W	/eight, (₂	_{BF}) =			120 pc
MSE Wall Width (Reinforcement Length), (B) =	13.1 ft	MSE Backfi	II Frictio	n Angle,	$(\varphi_{BF}) =$:		34 °
Distance from Wall Face to Toe of Backslope, (/) =	4.0 ft	Bearing Soil	l Unit W	eight, (γ	_{BS}) =			125 pc
MSE Wall Length, (L) =	746 ft	Bearing Soil	I Friction	n Angle,	$(\varphi_{BS}) =$			28 °
MSE Wall Effective Height, (h) =	14.7 ft	Bearing Soil	l Draine	d Cohes	ion, (c_B	s) =		0 ps
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil	l Undrai	ned She	ar Strer	ngth,	$[(s_u)_{BS}] =$	3250 ps
Effective Retained Soil Backslope, (θ) =	26.6 °	Embedment	Depth,	$(D_f) =$				0.0 ft
Distance from Toe to Top of Backslope, (z) =	78.0 ft	Depth to GV	۷ (Belov	w Bot. of	f Wall),	(D_W)) =	15.6 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf							
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Loa	d Facto	ors				
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf		EV	EH	LS			
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	2000 psf	Strength la	1.00	1.50	1.75	٦	(AASUTO I DI	FD BDM Tables
Retained Soil Active Earth Pressure Coeff., (K_a) =	0.526	Strength lb	1.35	1.50	1.75	-	3.4.1-1 and 3	3.4.1-2 - Active
Live Surcharge Load, (σ_{LS}) =	0 psf	Service I	1.00	1.00	1.00	J	Earth F	Pressure)
Drained cohesion for retained soil not accounted for in external stability	analyses. This parameter is	s utilized in global stability	analysis.					

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

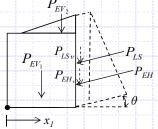


$$P_{LS} = P_{LS} = P_{EH} = (188.74 \text{ kip·ft/ft} - 44.47 \text{ kip·ft/ft}) / (22.92 \text{ kip/ft}) = 6.29 \text{ ft}$$

 $M_V = 188.74 \text{ kip·ft/ft}$ Defined below $M_H = 44.47 \text{ kip·ft/ft}$ $P_V = P_{EV_1} + P_{EV_2} + P_{EH} \sin \theta = 15.88 \text{ kip/ft} + 2.49 \text{ kip/ft} + (10.17 \text{ kip/ft}) \sin(26.6^\circ) = 22.92 \text{ kip/ft}$

$$e = (13.1 \text{ ft/ 2}) - 6.29 \text{ ft} = 0.26 \text{ ft}$$

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)(10.1 ft)(13.1 ft)(1.00) = 15.88 kip/ft

 $P_{LS} = \frac{1}{2} \gamma_{RS} (h - H) (B - l) \gamma_{EV} = \frac{1}{2} (120 \text{ pcf}) (14.7 \text{ ft} - 10.1 \text{ ft}) (13.1 \text{ ft} - 4.0 \text{ ft}) (1.00) = 2.49 \text{ kip/ft}$ $P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf}) (14.7 \text{ ft})^2 (0.526) (1.50) = 10.17 \text{ kip/ft}$

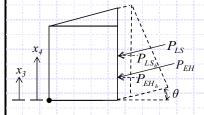
 $x_1 = B_2 = (13.1 \text{ ft})/2 = 6.55 \text{ ft}$

 $x_2 = l + \frac{2}{3}(B - l) = 4.0 \text{ ft} + \frac{2}{3}(13.1 \text{ ft} - 4.0 \text{ ft}) = 10.07 \text{ ft}$

 M_V = (15.88 kip/ft)(6.55 ft) + (2.49 kip/ft)(10.07 ft) + (10.17 kip/ft)sin(26.6°)(13.1 ft) = 188.74 kip-ft/ft

Overturning Moment, $M_{\scriptscriptstyle H}$:

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



$$P_{EH} = \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} = \frac{1}{2} (120 \text{ pcf})(14.7 \text{ ft})^2 (0.526)(1.50) = 10.17 \text{ kip/ft}$$

 $x_4 = h/2 = (14.7 \text{ ft})/2 = 7.33 \text{ ft}$

 $M_H = (10.17 \text{ kip/ft})\cos(26.6^\circ)(4.89 \text{ ft}) + (0 \text{ kip/ft})\cos(26.6^\circ)(7.33 \text{ ft}) = 44.47$

Limiting Eccentricity: $e_{\text{max}} = \frac{B}{3} \rightarrow e_{\text{max}} = \frac{(13.1 \text{ ft})}{3} =$ **Check Eccentricity** 4.37 $e < e_{\text{max}} \longrightarrow$ 0.26 ft < 4.37 ft OK



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JOB FRA-70-13.10 W-13-072 NO. SHEET NO. OF 6 6/30/2019 7/1/2019 CALCULATED BY BRT DATE CHECKED BY JPS DATE Retaining Wall W5 - Sta. 607+00 to 607+65

MSE Wall Dimensions and Retained Soil Pa	rameters	Bearing Soil Properties:
MSE Wall Height, (<i>H</i>) =	10.1 ft	MSE Backfill Unit Weight, (γ_{BF}) = 120 pcf
MSE Wall Width (Reinforcement Length), (<i>B</i>) =	13.1 ft	MSE Backfill Friction Angle, (φ_{BF}) = 34 °
Distance from Wall Face to Toe of Backslope, (l)	= 4.0 ft	Bearing Soil Unit Weight, (γ_{BS}) = 125 pcf
MSE Wall Length, (<i>L</i>) =	746 ft	Bearing Soil Friction Angle, (φ_{BS}) = 28 °
MSE Wall Effective Height, (h) =	14.7 ft	Bearing Soil Drained Cohesion, $(c_{BS}) = 0$ psf
Retained Soil Backslope, (β) =	26.6 °	Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}] = 3250$ psf
Effective Retained Soil Backslope, (θ) =	26.6 °	Embedment Depth, (D_f) = 0.0 ft
Distance from Toe to Top of Backslope, (z) =	78.0 ft	Depth to GW (Below Bot. of Wall), (D_W) = 15.6 ft
Retained Soil Unit Weight, (γ_{RS}) =	120 pcf	
Retained Soil Friction Angle, (φ_{RS}) =	30 °	LRFD Load Factors
Retained Soil Drained Cohesion, (c_{RS}) =	0 psf	EV EH LS
Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ =	= 2000 psf	Strength la 1.00 1.50 1.75 7 (440/75) (550 554 7-1/4)
Retained Soil Active Earth Pressure Coeff., (K_a) =	ē	(AASHTO LRFD BDM Tables Strength b 1.35 1.50 1.75 3.4.1-1 and 3.4.1-2 - Active
Live Surcharge Load, $(\sigma_{IS}) =$	0 psf	Service I 1.00 1.00 1.00 Earth Pressure)
Drained cohesion for retained soil not accounted for in external state.		
Check Bearing Capacity (Loading Case - St	renath lb) - AASHTO	LRFD BDM Section 11.6.3.2
P_{EV_2} .		
	n /	
	$=\frac{P_{V}}{R'}$	
ה וייי או ה	7 2	
$A_{\downarrow\downarrow}$ P_{EV_1} P_{LS} P_{LS} P_{LS} P_{LS} P_{LS} P_{LS}	'=B-2e=13.	1 ft - 2(0.09 ft) = 12.92 ft
EH _v EH		
P_{EH_h}	e = B/2 - x	= (13.1 ft / 2) - 6.46 ft = 0.09 ft
R^{\vee}	/ 4	
	$r = \frac{M_V - M_H}{M_V}$	= (233.86 kip·ft/ft - 44.47 kip·ft/ft) / 29.34 kip/ft = 6.46
x _o + ×>- 1-1-e	P_{ν}	- (200.00 KIP IUT - 14.47 KIP IUT / 20.04 KIPIT - 0.40
ការបន្តិភ័យសេច្និការបស់ខ្ញុំការបស់ខ្ញុំការបស់ខ្ញុំការបស់ខ្ញុំការបស់ខ្ញុំការបស់ខ្ញុំការបស់ខ្ញុំការបស់ការបស់ការប		
$ \begin{array}{c c} & B'_2 \\ & B'_1 \\ & & x_2 \\ \end{array} $	(00 04 Lin (ft) /	(40.00 %)
$\leftarrow_{B'} \rightarrow$	$_{eq} = (29.34 \text{ kip/ft}) /$	(12.92 ft) = 2.27 ksf
$\perp \perp x_2 \Rightarrow \downarrow$		
Resisting Moment, $M_{_{V}}$: $M_{_{V}}=F$	$P_{EV_1}(x_1) + P_{EV_2}(x_2) +$	$+P_{EH}\sin\theta(B)$
$P_{\scriptscriptstyle EV_2}$, $P_{\scriptscriptstyle EV_1}$	$= \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$	= (120 pcf)(10.1 ft)(13.1 ft)(1.35) = 21.43 kip/ft
P_{EV}	$= \frac{1}{2} \gamma_{RS} (h - H) (B -$	$l)\gamma_{EV} = \frac{1}{2}(120 \text{ pcf})(14.7 \text{ ft} - 10.1 \text{ ft})(13.1 \text{ ft} - 4.0 \text{ ft})(1.35) = 3.36 \text{ kip/}$
$P \mid \cdot \mid \cdot \mid \cdot \mid D$		
1 Er 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	$= \frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{FH} =$	= ½(120 pcf)(14.7 ft)²(0.526)(1.50) = 10.17 kip/ft
$P_{EH} = P_{EH}$		
\downarrow	B/2 = (13.1 ft)/2	= 6.55 ft
♦ ———•===¥°		
$ \longrightarrow x_1 $ $ x_2 $	$= l + \frac{2}{3}(B - l) = -1$	4.0 ft + 3/3(13.1 ft - 4.0 ft) = 10.07 ft
$M_{\nu} = 0$	21.43 kip/ft)(6.55 ft) + (3.	36 kip/ft)(10.1 ft) + (10.17 kip/ft)sin(26.6°)(13.1 ft) = 233.86 kip-
Overturning Moment, $M_{\scriptscriptstyle H}$: $M_{\scriptscriptstyle H}=M_{\scriptscriptstyle $	$P_{EH}\cos\theta(x_3) + P_L$	$-\cos\theta(x_1)$
	EH 555 (13) 1 L	S = = = = = = = = = = = = = = = = = = =
ATT.	$-1/v h^2 K v =$	= $\frac{10.17 \text{ kip/ft}}{120 \text{ pcf}}$
D	hV ~ _	(0 pefV14 7 ft)(0 526)(1 75) = 0.00 kin/ft
x_4 P_{LS} P_{LS}	$-o_{LS}n\mathbf{K}_{a}\gamma_{LS} =$	(0 psf)(14.7 ft)(0.526)(1.75) = 0.00 kip/ft
\uparrow \uparrow P_{LS_N} P_{FH}	$h_3 = (14.7 \text{ ft})/3$	
$P_{FH} \sim x_3 =$	-/3 = (14.7 m)/3	- 4.09 IL
	= h/2 = (14.7 ft)/2	
$x_4 =$	$\frac{1}{2} = \frac{(14.7 \pi)/2}{2}$	= 1.33 It
	// / / / / / / / / / / / / / / / / / / /	
M_H =	(10.17 kip/ft)cos(26.6°)(4.89 ft) + $(0 \text{ kip/ft})\cos(26.6^{\circ})(7.33 \text{ ft}) = 44.47 \text{ kip-ft/ft}$
Vertical Forces, $P_{_{V}}$: $P_{_{V}}=P_{_{L}}$	$r_{EV_1} + P_{EV_2} + P_{EH} \sin \theta$	1 heta



 JOB
 FRA-70-13.10
 NO.

 SHEET NO.
 5
 OF

 CALCULATED BY
 BRT
 DATE

 CHECKED BY
 JPS
 DATE

NO. W-13-072
OF 6
DATE 6/30/2019
DATE 7/1/2019

Retaining Wall W5 - Sta. 607+00 to 607+65

ISE Wall Dimensions and Retained Soil Par	ameters	Bearing Soil Pro	perties:		
ISE Wall Height, (<i>H</i>) =	10.1 ft	MSE Backfill Unit V	$Neight, (\gamma_{BF}) =$		120 pcf
SE Wall Width (Reinforcement Length), (B) =	<u>13.1</u> ft	MSE Backfill Friction	on Angle, (φ_{BF}) =	_	34 °
istance from Wall Face to Toe of Backslope, (l) =	·ē.·	Bearing Soil Unit W	Veight, (γ_{BS}) =		125 pcf
SE Wall Length, (L) =	<u>746</u> ft	Bearing Soil Frictio		_	28°
SE Wall Effective Height, (h) =	14.7 ft		ed Cohesion, (c_{BS}) =		0 psf
etained Soil Backslope, (β) =	26.6°		ined Shear Strength	$n,[(s_u)_{BS}]=$	3250 psf
ffective Retained Soil Backslope, (θ) =	26.6 °	Embedment Depth			0.0 ft
istance from Toe to Top of Backslope, (z) =	78.0 ft	Depth to GVV (Beio	ow Bot. of Wall), (D_1	_v) =	15.6 ft
etained Soil Unit Weight, (γ_{RS}) =	120 pcf 30 °	I DED Land Foot			
etained Soil Friction Angle, (φ_{RS}) = etained Soil Drained Cohesion, (\mathcal{C}_{RS}) =	0 psf	LRFD Load Fact	<u>iors</u> EH LS		
etained Soil Undrained Shear Strength, $[(S_u)_{RS}] =$	2000 psf	Strength la 1.00			
etained Soil Active Earth Pressure Coeff., (K_a) =	0.526	Strength lb 1.35		(AASHTO LRFD E - 3.4.1-1 and 3.4.1	
ve Surcharge Load, (σ_{IS}) =	0 psf	Service I 1.00		Earth Press	
. Drained cohesion for retained soil not accounted for in external stab					
heck Bearing Capacity (Loading Case - Str		LRFD BDM Section 1	1.10.5.4 (Continued)		
	+ $\gamma D_f N_{qm} C_{wq}$ +	- ½ γΒ' N _m C _w			
$N_{cm} = N_c s_c i_c = 25.8$	$N_{qm} = N_q s_q d_q t$		$N_{ym} = N_{\gamma} s_{\gamma} i$	_γ = 16.7	
$N_c = 25.80$	$N_q = 14.72$		N_{γ} = 16.72		
$S_c = 1+(12.92 \text{ ft/}746 \text{ ft})(14.72/25.8)$	rannonalininkan minima makama mana mana mana mana mana mana	ft/746 ft)tan(28°) = 1.000		12.92 ft/746 ft) =	1.000
= 1.000		°)[1-sin(28°)]²tan⁻¹(0.0 ft/12.92 ft)			^-
i_c = 1.000 (Assumed)	= 1.000		$C_{wy} = 15.6 \text{ft} \cdot$	< 1.5(12.92 ft) + 0.0	ft = 0.5
$q_n = (0 \text{ psf})(25.8) + (125 \text{ pcf})(0.0 \text{ ft})(1)$	$i_q = 1.000 \text{ (}/\text{4}$ $C_{wq} = 15.6 \text{ ft} > 14.7 \text{)} (1.0) + \frac{1}{2} (125 \text{ pc})$	0.0 ft = 1.000	= 6.75 ks	f	
erify Equivalent Pressure Less Than Factor	$C_{wq} = 15.6 \text{ ft} >$ 14.7)(1.0) + $\frac{1}{2}$ (125 pc) 14.7 red Bearing Resista	0.0 ft = 1.000 of)(12.9 ft)(16.7)(0.5)	= 6.75 ks		
	$C_{wq} = 15.6 \text{ ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{ pc})$ $14.7 + \frac{1}{$	0.0 ft = 1.000 of)(12.9 ft)(16.7)(0.5)	= 6.75 ks 2.27 ksf ≤ 4.39 k		
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_{_{n}} \cdot \phi_{_{b}} o $ 2.27 ksf	$C_{wq} = 15.6 \text{ ft} >$ $(4.7)(1.0) + \frac{1}{2}(125 \text{ pc})$	0.0 ft = 1.000 of)(12.9 ft)(16.7)(0.5)			
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \longrightarrow 2.27 \text{ ksf}$ Use $\varphi_b = \textbf{0.65}$ (Per AASHTO LRFD BDM	$C_{wq} = 15.6 \text{ ft} >$ $(4.7)(1.0) + \frac{1}{2}(125 \text{ pc})$	0.0 ft = 1.000 sf)(12.9 ft)(16.7)(0.5) since 4.39 ksf			
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = \textbf{0.65}$ (Per AASHTO LRFD BDA heck Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c S_c i_c = 5.140$	$C_{wq} = 15.6 \text{ ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{ pc})$ $15.6 + \frac{1}{2}(125 \text{ pc})$ $16.75 \text{ ksf})(0.65) = 4$ $17.5 + \frac{1}{2}(125 \text{ pc})$ $17.5 + \frac{1}{2}(125 \text{ pc}$	0.0 ft = 1.000 sf)(12.9 ft)(16.7)(0.5) since 4.39 ksf \longrightarrow	2.27 ksf \leq 4.39 ks $N_{ym} = N_{\gamma} S_{\gamma} i$	sf OK	
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = \textbf{0.65}$ (Per AASHTO LRFD BDM heck Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$	$C_{wq} = 15.6 \text{ ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{ pc})$ $15.6 \text{ ft} >$ $16.7 \text{ pc} >$ $16.7 \text{ pc} >$ $17.7 $	0.0 ft = 1.000 sf)(12.9 ft)(16.7)(0.5) since 4.39 ksf \longrightarrow	2.27 ksf \leq 4.39 ks $N_{jm} = N_{y} S_{y} i$ $N_{y} = 0.000$	sf OK γ = 0.000	
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD BDM heck Bearing Resistance - Undrained Condominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(12.92 \text{ ft/[5)}(746 \text{ ft)]} = 1.000$	$C_{wq} = 15.6 \text{ft} >$ $C_{wq} = 15.6 \text{ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) +$	0.0 ft = 1.000 $ \frac{1,000}{1,000} = 1.000 $ $ \frac{1,000}{1,000} = 1.000 $ $ \frac{1,000}{1,000} = 1.000 $ $ \frac{1,000}{1,000} = 1.000 $	$N_{jm} = N_{\gamma} s_{\gamma} i$ $N_{\gamma} = 0.000$ $s_{\gamma} = 1.000$	ef OK	
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = \textbf{0.65}$ (Per AASHTO LRFD BDM heck Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$	$C_{wq} = 15.6 \text{ft} >$ $C_{wq} = 15.6 \text{ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $15.6 \text{ft} >$ 16.6ft	0.0 ft = 1.000 sf)(12.9 ft)(16.7)(0.5) since 4.39 ksf \longrightarrow	$N_{jm} = N_{\gamma} S_{\gamma} i$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	sf OK $y = 0.000$ (Assumed)	
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD BDM heck Bearing Resistance - Undrained Condominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(12.92 \text{ ft/[5)}(746 \text{ ft)]} = 1.000$	$C_{wq} = 15.6 \text{ft} >$ $C_{wq} = 15.6 \text{ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $15.6 \text{ft} >$ 16.6ft	0.0 ft = 1.000 $ \frac{1.000}{1.000} = 1.000 $ $ \frac{1.000}{1.000} = 1.000 $ $ \frac{1.000}{1.000} = 1.000 $ $ \frac{1.000}{1.000} = 1.000 $	$N_{jm} = N_{\gamma} S_{\gamma} i$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	ef OK	
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD BDM heck Bearing Resistance - Undrained Condominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(12.92 \text{ ft/[5)}(746 \text{ ft)]} = 1.000$	$C_{wq} = 15.6 \text{ft} >$ $C_{wq} = 15.6 \text{ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $15.6 \text{ft} >$ 15.6ft	0.0 ft = 1.000 ince 4.39 ksf \rightarrow - $\frac{1}{2} \gamma B' N_{yy} C_{wy}$ i.q = 1.000 Assumed)	$N_{jm} = N_{\gamma} S_{\gamma} i$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	sf OK $y = 0.000$ (Assumed)	
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD BDM heck Bearing Resistance - Undrained Condominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(12.92 \text{ ft/[5)}(746 \text{ ft)]} = 1.000$	$C_{wq} = 15.6 \text{ft} >$ $C_{wq} = 15.6 \text{ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $15.6 \text{ft} >$ 16.6ft	0.0 ft = 1.000 ince 4.39 ksf \rightarrow - $\frac{1}{2} \gamma B' N_{yy} C_{wy}$ i.q = 1.000 Assumed)	$N_{jm} = N_{\gamma} S_{\gamma} i$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	sf OK $y = 0.000$ (Assumed)	
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = 0.65$ (Per AASHTO LRFD BDM heck Bearing Resistance - Undrained Condominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(12.92 \text{ ft/[5)}(746 \text{ ft)]} = 1.000$	$C_{wq} = 15.6 \text{ft} >$ $C_{wq} = 15.6 \text{ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $15.6 \text{ft} >$ $15.6 \text{ft} >$	0.0 ft = 1.000 ince 4.39 ksf \rightarrow - $\frac{1}{2} \frac{\gamma B'}{N_{pm}} C_{wy}$ $\frac{1}{q} = 1.000$ *)[1-sin(0°)] ² tan ⁻¹ (0.0 ft/12.92 ft) Assumed) 0.0 ft = 1.000	$N_{jm} = N_{\gamma} S_{\gamma} i$ $N_{\gamma} = 0.000$ $S_{\gamma} = 1.000$ $i_{\gamma} = 1.000$	y = 0.000 $y = 0.000$	
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = \textbf{0.65}$ (Per AASHTO LRFD BDA heck Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1 + (12.92 \text{ ft/}[(5)(746 \text{ ft)}] = 1.000$ $i_c = 1.000 \text{ (Assumed)}$	$C_{wq} = 15.6 \text{ft} >$ $C_{wq} = 15.6 \text{ft} >$ 14.7)(1.0) + ½(125 pc) red Bearing Resista $\leq (6.75 \text{ksf})(0.65) = 4$ M Table 11.5.6-1) Sittion $+ 2D_f N_{qm} C_{wq} +$ $N_{qm} = N_q S_q d_q i$ $N_q = 1.000$ $s_q = 1.000$ $d_q = 1+2 \tan(0)$ $= 1.000$ $i_q = 1.000 (4$ $C_{wq} = 15.6 \text{ft} >$ ft)(1.0)(1.0) + ½(125	0.0 ft = 1.000 ince 4.39 ksf \longrightarrow $-\frac{1}{2}\gamma B' N_{\gamma m} C_{w\gamma}$ $i_q = 1.000$ Assumed) 0.0 ft = 1.000 pcf)(12.9 ft)(0.0)(0.5)	$N_{jm} = N_{y} s_{y} i$ $N_{y} = 0.000$ $s_{y} = 1.000$ $i_{y} = 15.6 \text{ft}$	y = 0.000 $y = 0.000$	
erify Equivalent Pressure Less Than Factor $q_{eq} \leq q_n \cdot \phi_b \implies 2.27 \text{ ksf}$ Use $\varphi_b = \textbf{0.65}$ (Per AASHTO LRFD BDA Meck Bearing Resistance - Undrained Concominal Bearing Resistance: $q_n = cN_{cm}$ $N_{cm} = N_c s_c i_c = 5.140$ $N_c = 5.140$ $s_c = 1+(12.92 \text{ ft/[(5)(746 \text{ ft)]}} = 1.000$ $i_c = 1.000 \text{ (Assumed)}$	$C_{wq} = 15.6 \text{ft} >$ $C_{wq} = 15.6 \text{ft} >$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0) + \frac{1}{2}(125 \text{pc})$ $14.7)(1.0)(1.0) + \frac{1}{2}(125 \text{pc})$ $15.6 \text{ft} >$	0.0 ft = 1.000 ince 4.39 ksf \longrightarrow $-\frac{1}{2}\gamma B' N_{\gamma m} C_{w\gamma}$ $i_q = 1.000$ *)[1-sin(0°)] ² tan ⁻¹ (0.0 ft/12.92 ft) Assumed) 0.0 ft = 1.000 pcf)(12.9 ft)(0.0)(0.5)	$N_{jm} = N_{y} s_{y} i$ $N_{y} = 0.000$ $s_{y} = 1.000$ $i_{y} = 15.6 \text{ft}$	sf OK (x) = 0.000 (Assumed) < 1.5(12.92 ft) + 0.0	ft = 0.5



FRA-70-13.10 JOB SHEET NO. CALCULATED BY DATE CHECKED BY JPS DATE

W-13-072 6/30/2019 7/1/2019

Retaining Wall W5 - Sta. 607+00 to 607+65

MSE Wall Dimensions and Retained Soil Param	notore
MSE Wall Height, (H) =	10.1 ft
MSE Wall Width (Reinforcement Length), (B) =	13.1 ft
Distance from Wall Face to Toe of Backslope, (l) =	4.0 ft
MSE Wall Length, (L) =	746 ft
MSE Wall Effective Height, (h) =	14.7 ft
Retained Soil Backslope, (β) =	26.6 °
Effective Retained Soil Backslope, (θ) =	26.6 °
Distance from Toe to Top of Backslope, (z) =	78.0 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

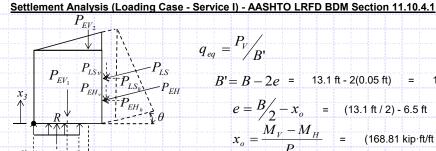
Bearing Soil Properties:	
MSE Backfill Unit Weight, (γ_{BF}) =	120 pcf
MSE Backfill Friction Angle, (φ_{BF}) =	34 °
Bearing Soil Unit Weight, (γ_{BS}) =	125 pcf
Bearing Soil Friction Angle, (φ_{BS}) =	28 °
Bearing Soil Drained Cohesion, (c_{BS}) =	0 psf
Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ =	3250 psf
Embedment Depth, (D_f) =	0.0 ft
Depth to GW (Below Bot. of Wall), (D_W) =	15.6 ft

LRFD Load Factors

	L V	L'''	LO	
Strength la	1.00	1.50	1.75	٦
Strength lb	1.35	1.50	1.75	}
Service I	1.00	1.00	1.00	J

(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.



$$q_{eq} = \frac{P_V}{B'}$$

$$B' = B - 2e$$
 = 13.1 ft - 2(0.05 ft) = 13.00 ft

$$e = B/2 - x_o = (13.1 \text{ ft/2}) - 6.5 \text{ ft} = 0.05$$

$$x_o = \frac{M_V - M_H}{P_V}$$
 = (168.81 kip·ft/ft - 29.62 kip·ft/ft) / 21.40 kip/ft = 6.50 ft

$$q_{eq} = (21.4 \text{ kip/ft}) / (13 \text{ ft}) = 1.65 \text{ ksf}$$

$$M_{V} = P_{EV_{1}}(x_{1}) + P_{EV_{2}}(x_{2}) + P_{EH} \sin \theta(B) = (\gamma_{BF} H B \gamma_{EV})(\gamma_{2} B) + (\gamma_{2} \gamma_{RS} (h - H)(B - I)\gamma_{EV})(I + \gamma_{3} (B - I)) + (\gamma_{2} \gamma_{RS} h^{2} K_{a} \gamma_{EH} \sin \theta)(B)$$

 $M_V =$ $[(120 \text{ pcf})(10.1 \text{ ft})(13.1 \text{ ft})(1.00)][\frac{1}{2}(13.1 \text{ ft})] + [\frac{1}{2}(120 \text{ pcf})(14.7 \text{ ft} - 10.1 \text{ ft})(13.1 \text{ ft} - 4.0 \text{ ft})(1.00)][4.0 \text{ ft} + \frac{3}{2}(13.1 \text{ ft} - 4.0 \text{ ft})]$ 168.81 kip-ft/ft + [1/2(120 pcf)(14.7 ft)2(0.526)(1.00)sin(26.6°)](13.1 ft)

$$M_{H} = P_{EH} \cos \theta(x_3) + P_{LS} \cos \theta(x_4) = \left(\frac{1}{2} \gamma_{RS} h^2 K_a \gamma_{EH} \cos \theta\right) \left(\frac{h}{3}\right) + \left(\sigma_{LS} h K_a \gamma_{LS} \cos \theta\right) \left(\frac{h}{3}\right)$$

 $M_H = \frac{1}{2}[(120 \text{ pcf})(14.7 \text{ ft})^2(0.526)(1.00)\cos(26.6^\circ)](14.7 \text{ ft}/3) = 29.62 \text{ kip-ft/ft}$ + [(0 psf)(14.7 ft)(0.526)(1.00)cos(26.6°)](14.7 ft /2)

$$P_{V} = P_{EV_{1}} + P_{EV_{2}} + P_{EH} \sin \theta = (\gamma_{BF} H B \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} (h - H)(B - l) \gamma_{EV}) + (\frac{1}{2} \gamma_{RS} h^{2} K_{a} \gamma_{EH} \sin \theta)$$

 $P_V = (120 \text{ pcf})(10.1 \text{ ft})(13.1 \text{ ft})(1.00) + \frac{1}{2}(120 \text{ pcf})(14.7 \text{ ft} - 10.1 \text{ ft})(13.1 \text{ ft} - 4.0 \text{ ft})(1.00) = 21.4$ + ½(120 pcf)(14.7 ft)²(0.526)(1.00)sin(26.6°)

Settlement, Time Rate of Consolidation and Differential Settlement:

 Boring	Total Settlement at Center of Reinforced Soil Mass	Total Settlement at Wall Facing	Time for 90% Consolidation	Distance Between Borings Along Wall Facing	Differential Settlement Along Wall Facing
 B-104-1-13	4.459 in	2.412 in	15 days		
 B-105-3-14	3.519 in	1.872 in	3 days	85 ft	1/1890
 B-105-5-14	3.512 in	1.535 in	5 days	145 ft	1/5160
B-107-2-14	2.946 in	1.321 in	1 days	135 ft	1/7570
 B-108-7-14	2.403 in	1.341 in	1 days	160 ft	1/96000
 B-108-8-14	0.950 in	0.694 in	3 days	130 ft	1/2410

W-13-072 - FRA-70-13.10 - Retaining Wall W5 MSE Wall Settlement - Sta. 607+00 to 607+65

 Calculated By:
 BRT
 Date:
 6/30/2019

 Checked By:
 JPS
 Date:
 7/1/2019

Boring B-108-8-14

H= 10.1 ft Total wall height

B'= 13.0 ft Effective footing width due to eccentricity

D_w = 15.6 ft Depth below bottom of footing

 q_e = 1,650 psf Equivalent bearing pressure at bottom of wall

																				Total S	Settlement at	Center of Ro	einforced So	il Mass	Total Settlement at Facing of Wall					
Layer	Soil Class.	Soil Type	,	r 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⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	I ⁽⁷⁾	Δσ _v ⁽⁸⁾ (psf)	σ _{vf} ' Midpoint (psf)	S _c ^(9,10) (ft)	S _c (in)	
1 (Emb.)	A-6a	С	0.0	2.5	2.5	1.3	120	300	150	150	4,150	30	0.180	0.018	0.507				0.10	0.997	1,645	1,795	0.032	0.386	0.500	825	975	0.024	0.291	
2	A-6a	С	2.5	5.0	2.5	3.8	120	600	450	450	4,450	30	0.180	0.018	0.507				0.29	0.942	1,555	2,005	0.019	0.233	0.495	817	1,267	0.013	0.161	
3	A-4a	G	5.0	7.5	2.5	6.3	130	925	763	763	4,763					33	44	75	0.48	0.831	1,370	2,133	0.015	0.178	0.482	795	1,557	0.010	0.124	
4	A-1-a	G	7.5	10.5	3.0	9.0	135	1,330	1,128	1,128	5,128					51	61	219	0.69	0.700	1,156	2,283	0.004	0.050	0.456	753	1,880	0.003	0.036	
4	A-1-a	G	10.5	14.0	3.5	12.3	135	1,803	1,566	1,566	5,566					51	55	193	0.94	0.574	947	2,514	0.004	0.045	0.418	690	2,256	0.003	0.035	
5	A-1-b	G	14.0	17.0	3.0	15.5	130	2,193	1,998	1,998	5,998					27	27	91	1.19	0.480	792	2,789	0.005	0.057	0.379	625	2,623	0.004	0.047	
1. $\sigma_p' = \sigma_v$	'+σ _{m;} Estima	te σ_m of 4,0	00 psf (mod	erately over	consolidated)	for natural s	oil deposits;	Ref. Table 1	1.2, Coduto 2	2003											Total	Settlement:		0.950 in		Total	Settlement:	 	0.694 in	

^{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.} $e_0 = (C_c/1.15)+0.35$; Ref. Table 8-2, Holtz and Kovacs 1981

^{5.} $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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.} $\Delta \sigma_v = q_e(I)$

 $^{9. \ \} S_c = [C_{c'}(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_p' \leq \sigma_{v_o}' < \sigma_{v_i}'; \ [C_{f'}(1+e_o)](H) \log(\sigma_p'/\sigma_{v_o}') + [C_{c'}(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_p') \\ \text{for } \sigma_{v_o}' < \sigma_p' < \sigma_{v_i}'; \ \text{Ref. Section } 10.6.2.4.3, \ \text{AASHTO LRFD BDS (Cohesive soil layers)} \\ \text{In the layer } S_c = [C_{c'}(1+e_o)](H) \log(\sigma_{v_i}'/\sigma_{v_o}') \\ \text{for } \sigma_{v_o}' < \sigma_{v_o$

^{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 W5

MSE Wall Settlement - Sta. 607+00 to 607+65

Boring B-108-8-14

H=	10.1	ft	Total wall height		A-6a		
B'=	13.0	ft	Effective footing width due to eccentricity	c _v =	600	ft²/yr	Coefficient of consolitation
$D_w =$	15.6	ft	Depth below bottom of footing	t =	3	days	Time following completion of construction
q _e =	1,650	psf	Equivalent bearing pressure at bottom of wall	H _{dr} =	2.5	ft	Length of longest drainage path considered
				$T_v =$	0.789		Time factor
				U =	88	%	Degree of consolidation
				(S _c) _t =	0.640 in	Settlement complete at	92% of primary consolidation

																							Total Settlement at Fa		acing of Wall		mplete at 92% of onsolidation
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	1 ⁽⁷⁾	Δσ _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 (Emb.)	A-6a	С	0.0	2.5	2.5	1.3	120	300	150	150	4,150	30	0.180	0.018	0.507				0.10	0.500	825	975	0.024	0.291	0.291	0.256	0.256
2	A-6a	С	2.5	5.0	2.5	3.8	120	600	450	450	4,450	30	0.180	0.018	0.507				0.29	0.495	817	1,267	0.013	0.161	0.161	0.142	0.142
3	A-4a	G	5.0	7.5	2.5	6.3	130	925	763	763	4,763					33	44	75	0.48	0.482	795	1,557	0.010	0.124	0.124	0.124	0.124
4	A-1-a	G	7.5	10.5	3.0	9.0	135	1,330	1,128	1,128	5,128					51	61	219	0.69	0.456	753	1,880	0.003	0.036	0.071	0.036	0.071
4	A-1-a	G	10.5	14.0	3.5	12.3	135	1,803	1,566	1,566	5,566					51	55	193	0.94	0.418	690	2,256	0.003	0.035		0.035	
5	A-1-b	G	14.0	17.0	3.0	15.5	130	2,193	1,998	1,998	5,998					27	27	91	1.19	0.379	625	2,623	0.004	0.047	0.047	0.047	0.047

- 1. $\sigma_{\rm p}' = \sigma_{\rm vo}' + \sigma_{\rm m}$ Estimate $\sigma_{\rm m}$ 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 $C_N = [0.77log(40/\sigma_{vo})] \le 2.0$ 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. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{v'}/\sigma_{v_o}')$ for $\sigma_p' \leq \sigma_{v_o'}' < \sigma_{v'}'$; $[C_t/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_p'/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_v'/\sigma_p')$ for $\sigma_{v_o'} < \sigma_{v'}' < \sigma_{v'}'$; $[C_t/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}') + [C_c/(1+e_o)](H)\log(\sigma_{v_o'}/\sigma_{v_o}')$
- 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

Calculated By: Date: 6/30/2019 Date: 7/1/2019 Checked By:

Settlement Remaining After Hold Period:

0.054

Settlement Complete at 92% of

