Resource International, Inc.

# FRA-70-14.05 PROJECT 4B
# RETAINING WALL 4W14
# PID NO. 96053
# FRANKLIN COUNTY, OHIO

# STRUCTURE FOUNDATION EXPLORATION REPORT

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

*Prepared By:*
**Resource International, Inc.**
**6350 Presidential Gateway**
**Columbus, Ohio 43231**

**Rii Project No. W-15-126**

**June 2022**

Planning, Engineering, Construction Management, Technology
6350 Presidential Gateway, Columbus, Ohio 43231
P 614.823.4949 F 614.823.4990

**RESOURCE INTERNATIONAL, INC.**
6350 Presidential Gateway
Columbus, Ohio 43231
T: 614.823.4949



June 27, 2022

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

**Re: Structure Foundation Exploration Report**
**FRA-70-14.05 Project 4B**
**Retaining Wall 4W14**
**PID No. 96053**
**Rii Project No. W-15-126**

Mr. Luzier:

Resource International, Inc. (Rii) is pleased to submit this structure foundation exploration report for the above referenced project. Engineering logs have been prepared and are attached to this report along with the results of laboratory testing. This report includes recommendations for the design and construction of proposed Retaining Wall 4W14 as part of the FRA-70-14.05 Project 4B in Columbus, Ohio.

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

Sincerely,

**RESOURCE INTERNATIONAL, INC.**

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

Jonathan P. Sterenberg, P.E.
Vice President – Geotechnical Services

Enclosure: Structure Foundation Exploration Report

## TABLE OF CONTENTS

## APPENDICIES

| | |
|---|---|
| **Appendix I** | **Vicinity Map and Boring Plan** |
| **Appendix II** | **Description of Soil Terms** |
| **Appendix III** | **Project Boring Logs: B-033-1-15, B-033-3-15** |
| **Appendix IV** | **Historic Boring Log: B-001-3-59** |
| **Appendix V** | **Bearing Resistance Charts** |
| **Appendix VI** | **Shallow Foundation Calculations** |
| **Appendix VII** | **External Stability Analysis Calculations by GPD GROUP** |
| **Appendix VIII** | **Global Stability Analysis Output** |

## EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration for retaining wall 4W14 as part of the FRA-70-14.05 (Project 4B) project. Retaining wall 4W14 measures approximately 300.0 lineal feet in length, with a proposed stem height above the footing varying from 32.4 to 34.2 feet. The retaining wall is proposed to be constructed as a cast-in-place (CIP) wall, and in the interim condition, the wall will have an extended stem designed to support the future engineered fill and roadway under design project FRA-70-14.05.

*Shallow Foundation Recommendations*

It is understood that the shallow spread foundations will be utilized for the retaining wall 4W14. The bearing soils are anticipated to consist both granular and cohesive material. The granular soils were generally described as, brown, brown to gray and gray gravel, gravel and sand, coarse and fine sand, fine sand, and sandy silt and silt (ODOT A-1-a, A-1-b, A-3, A-3a, A-4a, A-4b). The cohesive soils were generally described as very stiff to hard, gray sandy silt, silt and silt and clay (ODOT A-4a, A-4b, A-6a). Shallow spread foundations bearing on these competent natural soils may be proportioned for a nominal bearing resistance as presented in Table 4 in Section 5.1 of the full report.

Based on the service limit bearing pressures provided, total settlements of 0.996 to 1.167 inches are anticipated along the wall alignment. Differential settlement along the wall alignment is anticipated to be less than 1/1000. Additionally, the maximum factored bearing pressure will not exceed the factored bearing resistance at the strength limit for either retaining wall.

For concrete footing that rest on cohesionless soil, a coefficient “f” of 0.87 times the total vertical force on the base should be taken as the sliding resistance. A geotechnical resistance factor of $\varphi_\tau = 1.0$ should be considered when calculating the factored shear resistance between the soil and foundation for sliding.

## 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-70-14.05 Project 4B in Columbus, Ohio. The project represents the central portion of FRA-70-8.93 (PID 77369) I-70/71 south innerbelt improvements project. The FRA-70-14.05 Project 4B phase will consist of all work associated with the construction of the I-70/I-71 corridor from just east of S. High Street to just west of Grant Avenue, as well as a minimal amount of work Fulton Street and at the intersections of S. Third Street and S. Fourth Street with Livingston Avenue. This project includes the replacement of the FRA-33-1747 (S. Third Street) and FRA-23-1075 (S. Fourth Street) bridge structures over I-70/71, as well as the construction of three (3) new retaining walls along the north side and two (2) new retaining walls along the south side of I-70/71 to accommodate the new configuration.

This report is a presentation of the structure foundation exploration performed for the design and construction of proposed Retaining Wall 4W14 located along the south side of I-70 eastbound between the S. Third Street bridge (FRA-33-1747) and the S. Fourth Street bridge (FRA-23-1075) over I-70/I-71, as shown on the vicinity map and boring plan presented in Appendix I. Based on design information provided by GPD GROUP, it is understood that the proposed structure will consist of a cast-in-place (CIP) retaining wall type, which will connect the rear abutment of the FRA-33-1747 bridge structure at Sta. 200+56.26 (BL I-70 WB) and extend east to connect to the rear abutment of the FRA-23-1072 bridge structure at Sta. 203+60.76 (BL I-70 WB). The wall measures approximately 300 feet in length, with a proposed stem height above the footing varying from 32.4 to 34.2 feet.

## 2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

### 2.1 Site Geology

Several episodes of ice advanced throughout Ohio during the Pleistocene Epoch. Both the Illinoian and Wisconsinan glaciers advanced over two-thirds of the state, leaving behind glacial features such as moraines, kame deposits, lacustrine deposits and outwash terraces. The glacial and non-glacial regions comprise five physiographic sections grouped by age, depositional process and geomorphic occurrence (physical features or landforms). The project area lies within the Columbus Lowland District of the Till Plains Section. The project area is characterized by flat to gently rolling ground moraine deposits of the Late Wisconsinan age with large alluvium and outwash deposits bordering the Scioto River, its tributaries and floodplain areas. Ground moraines are deposited during the retreat of a glacier, which results in an undifferentiated mixture of clay, silt, sand and gravel. Alluvium and alluvial terrace deposits range from silty clay to cobble sized deposits, usually deposited in present and former floodplain areas. Outwash deposits consist of undifferentiated sand and gravel deposited by meltwater in front of glacial ice.

Based on bedrock geology and topography maps obtained from Ohio Department of Natural Resources (ODNR), the bedrock beneath the project site consists of three formations. The project alignment extends east from the top of the eastern slope of a bedrock valley that generally follows the Scioto River valley, with the youngest formation at the top of the slope and the oldest formation within the bedrock valley. The youngest formation consists of the Upper Devonian-aged Ohio Shale Formation, which consists of three members, from youngest to oldest: the Cleveland, Chagrin, and Huron Members. These members consist of primarily shale with siltstone and very fine-grained sandstone, varying in color from brownish black to greenish gray. The bedding ranges from laminated to thinly bedded and the overall formation ranges between 250 to over 500 feet thick. The Middle Devonian-aged Delaware Limestone formation, which can be present along the slopes of the bedrock valley, consists of bluish-gray, dolomitic limestone, with thin to medium bedding, and contains nodules and layers of chert. The formation ranges between 0 to 45 feet thick and is not present south of Franklin County. The oldest unit, which present within the bedrock valley, is the Middle to Lower Devonian-aged Columbus Limestone Formation, which is further subdivided into four members, two of which are predominant in the central portion of the state, known as the Delhi and Bellepoint Members. The Delhi Member consists of light gray, finely to coarsely crystalline, irregularly bedded, fossiliferous limestone. The Bellepoint Member consists of variable brown, finely crystalline, massively bedded, limy dolomite. Both of these members contain chert nodules, and the entire formation ranges between 0 to 105 feet thick.

The bedrock surface in the vicinity of the site forms a broad valley which roughly follows the present day Scioto River valley. The site lies on a slight plateaued area and slope along the east side of the valley where the underlying bedrock surface lies at an approximate elevation of 625 to 630 feet mean sea level and slopes down toward the west to an approximate elevation of 600 feet msl in the bedrock valley. According to bedrock topography mapping, the depth to the bedrock surface below the site ranges between approximately 105 to 135 feet below existing grade. Shale bedrock was encountered in several of the borings performed along the corridor at elevations ranging from 630 to 650 feet msl, increasing in elevation from west to east across the project alignment. Bedrock was not encountered within the borings performed for this current investigation.

## 2.2 Existing Conditions

As stated, the proposed Retaining Wall 4W14 will be located on the south side of eastbound I-70 between S. Third Street and S. Fourth Street, approximately 0.95 miles east of the Scioto River. The existing I-70/I-71 in the vicinity of the structure is a six-lane, bi-directional, composite asphalt and concrete paved roadway that is generally east-west aligned through downtown Columbus, Ohio. The existing I-70 profile is lowered from the surrounding terrain, as the existing corridor was cut approximately 25 to 30 feet below the existing grade of S. Third Street and S. Fourth Street as well as the surrounding downtown area. The proposed wall alignment is situated along the top of the grass covered graded slope that extends down from the north side of Livingston

Avenue and the eastbound entrance ramp from S. Third Street to I-70 eastbound. The traffic volume along the project alignment is very high, and the alignment traverses primarily commercial and government properties. The regional topography generally slopes downward to the west and south toward the Scioto River.

## 3.0 EXPLORATION

Between October 7 and 12, 2015, two (2) structural borings, designated as B-033-1-15, and B-033-3-15, were drilled to completion depths of 60.0 and 69.0 feet below the existing ground surface, respectively, along the proposed wall alignment. The current project boring locations are shown on the boring plan provided in Appendix I of this report and summarized in Table 1 below.

**Table 1. Test Boring Summary**

| Boring Number | Reference Alignment | Station | Offset | Latitude | Longitude | Ground Elevation (feet msl) [2] | Boring Depth (feet) |
|---|---|---|---|---|---|---|---|
| B-033-1-15 | BL I-70 EB | 201+68.14 | 47.8' Rt. | 39.953222 | -82.995459 | 729.7 | 60.0 |
| B-033-3-15 | BL I-70 EB | 203+36.15 | 47.7' Rt. | 39.953302 | -82.994869 | 731.2 | 69.0 |
| B-001-3-59 | BL I-70 EB | 200+00.00 [1] | 82.3' Rt. [1] | 39.953064 [1] | -82.996033 [1] | 751.2 | 56.0 |

1. *The stationing, offset, latitude and longitude for boring B-001-3-59 were estimated using historic boring plan information in conjunction with the project basemapping provided by GPD GROUP.*
2. *Ground surface elevations at the boring locations were interpolated using topographic mapping information provided by GPD GROUP.*

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. The ground surface elevation at the boring locations were interpolated using topographic mapping information provided by GPD GROUP.

The borings performed by Rii for the current exploration were drilled using a truck or an all-terrain vehicle (ATV) mounted rotary drilling machine, utilizing a 3.25-inch inside diameter, hollow-stem auger to advance the holes. In boring B-033-1-15, Standard penetration test (SPT) and split spoon sampling were performed at 5.0-foot for the first two samples and then at 2.5-foot increments of depth to 30 feet followed by the sampling performed at 5.0-foot increments thereafter to the boring termination depth. In boring B-033-3-15, the SPT and split spoon sampling were performed at 2.5-foot increments of depth to 30 feet followed by the sampling performed at 5.0-foot increments thereafter to the boring termination depth. Due to the presence of granular material in the borings, mud-drilling was introduced at depths of 8.5 and 18.5 feet below the existing grade in borings B-033-1-15 and B-033-3-15, respectively, to advance the borings to the desired sampling and termination depths. The SPT, per the American Society for Testing and Materials (ASTM) designation D1586, is conducted using a

140-pound hammer falling 30.0 inches to drive a 2.0-inch outside diameter split spoon sampler 18.0 inches. Rii utilized a calibrated automatic drop hammer to generate consistent energy transfer to the sampler. Driving resistance is recorded on the boring logs in terms of blow per 6.0-inch interval of the driving distance. The second and third intervals are added to obtain the number of blows per foot (N). Standard penetration blow counts aid in determining soil properties applicable in foundation system design. Measured blow count (N) values are corrected to an equivalent (60%) energy ratio, $N_{60}$, by the following equation. Both values are represented on boring logs in Appendix III.

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

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

The hammers for the Mobile CME 55 and the CME 750X drill rigs used by Rii were calibrated on October 20, 2014, and have drill rod energy ratios of 92.0 and 85.7 percent, respectively. The hammer for the CME 750X drill rig used by DLZ for the preliminary exploration borings had a drill rod energy ratio of 63.1 percent.

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

**Table 2. Laboratory Test Schedule**

| Laboratory Test | Test Designation | Number of Tests Performed |
|---|---|---|
| Natural Moisture Content | ASTM D 2216 | 36 |
| Plastic and Liquid Limits | AASHTO T89, T90 | 14 |
| Gradation – Sieve/Hydrometer | AASHTO T88 | 14 |

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

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

In addition to the borings performed as part of the current exploration, historic borings performed in 1959 by the Department of Highways as part of the original FRA-40-12.82 project for the existing S. Third Street bridge structure were obtained from the construction documents on record. One (1) boring, designated as B-001-3-59, was obtained at the southeast side of the existing S. Third Street bridge alignment, near the west end of the proposed Retaining Wall 4W14 alignment, on the east side of the S. Third Street bridge south abutment. Based on the elevation provided on the boring log, it is anticipated that the boring was performed from the then-existing ground surface and that the profile for the then-proposed US 40 (existing I-70/71) was lowered to provide sufficient clearance for the bridge to be constructed at the then-existing ground surface. The boring was extended to a termination depth of 56.0 feet below the ground surface at the time the boring was obtained (to an approximate elevation 695.2 feet-msl).

## 4.0 FINDINGS

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

### 4.1 Surface Materials

Borings B-033-1-15 and B-033-2-15 were drilled through the I-70 eastbound end grass berm, and encountered 3.0 inches of topsoil at the ground surface.

### 4.2 Subsurface Soils

Underlying the surficial materials, natural soils were encountered consisting of both granular and cohesive material. The granular soils were generally described as, brown, brown to gray and gray gravel, gravel and sand, coarse and fine sand, fine sand, and sandy silt and silt (ODOT A-1-a, A-1-b, A-3, A-3a, A-4a, A-4b). The cohesive soils were generally described as very stiff to hard, gray sandy silt, silt and silt and clay (ODOT A-4a, A-4b, A-6a).

The relative density of granular soils is primarily derived from SPT blow counts ($N_{60}$). Based on the SPT blow counts obtained, the granular soil encountered ranged from dense ($30 \leq N_{60} \leq 50$ blows per foot [bpf]) to very dense ($N_{60} > 50$ bpf). Overall blow counts recorded from the SPT sampling ranged from 39 bpf to split spoon sampler refusal. The shear strength and consistency of the cohesive soils are primarily derived from the hand penetrometer values (HP). The cohesive soil encountered ranged from very stiff ($2.0 \leq HP \leq 4.0$ tsf) to hard ($HP > 4.0$ tsf). The unconfined compressive strength of the cohesive soil samples tested, obtained from the hand penetrometer, ranged from 4.0 tsf to over 4.5 tsf (limit of instrument).

Natural moisture contents of the soil samples tested ranged from 4 to 23 percent. The natural moisture content of the cohesive soil samples tested for plasticity index ranged from 1 percent below to 9 percent above their corresponding plastic limits. In general, the soil exhibited natural moisture contents considered to be moderately below to significantly above optimum moisture levels.

### 4.3 Bedrock

Bedrock was not encountered in any of the borings performed during this investigation.

### 4.4 Groundwater

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

**Table 3. Groundwater**

| Boring Number | Ground Surface Elevation (feet msl) | Initial Groundwater | | Upon Completion | |
|---|---|---|---|---|---|
| | | Depth (feet) | Elevation (feet msl) | Depth (feet) | Elevation (feet msl) |
| B-033-1-15 | 729.7 | 8.5 | 721.2 | N/A [1] | - |
| B-033-3-15 | 731.2 | 11.0 | 720.2 | N/A [1] | - |

1. *The groundwater level at completion could not be obtained due to the wash boring method adopted to counter sand heave.*

Groundwater was encountered initially during the drilling process in both B-033-1-15 and B-033-3-15 at depths ranging from 8.5 to 11.0 feet below existing grade, which corresponds to elevations ranging from 720.2 to 721.2 feet msl, respectively. The groundwater level at the completion of drilling in the borings was not recorded due to the mud wash boring method adopted to advance the borings after sand heave was encountered.

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

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

## 5.0 ANALYSES AND RECOMMENDATIONS

Data obtained from the current and historic subsurface explorations 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 structure, 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 GPD GROUP. Based on the information provided, it is understood that Retaining Wall 4W14 will connect the rear abutments of the existing bridge structures FRA-33-1747 and FRA-23-1075 along the south side of I-70 eastbound. Based on plan information provided by GPD GROUP, the retaining wall is proposed to be constructed as a cast-in-place (CIP) wall type with a proposed height ranging from 32.4 to 34.2 feet. Based on design calculations provided by GPD GROUP, the footings for retaining wall 4W14 have been designed to produce a maximum service limit bearing pressure of 5.72 ksf and a maximum factored bearing pressure of 8.26 ksf at the strength limit state.

The stability analysis for bearing, eccentricity (overturning), sliding and final CIP wall dimensions and design considerations were performed by GPD GROUP and the calculations are presented in Appendix VII.

### 5.1 Shallow Foundation Recommendations

Based on plan information provided by GPD GROUP, the foundations for the proposed retaining walls will bear at Elevation 719.3 feet msl, corresponding to a depth of approximately 10.0 feet below the existing grade of I-70. At this elevation, the bearing soils for wall 4W14 are anticipated to consist of dense to very dense gravel and sand, gravel with sand and silt and coarse and fine sand (ODOT A-1-b, A-2-4, A-3a) with intermittent seams of hard sandy silt and silt (ODOT A-4a, A-4b). Shallow foundations bearing on these competent natural soils may be proportioned using the nominal bearing resistance values presented in Table 4. It is understood that the external stability calculations for this wall are being performed by the wall designer, GPD GROUP. Therefore, Rii has provided a graphical plot and tabulated the nominal and factored bearing resistance, as well as the anticipated settlement resulting from the service limit bearing pressure, as a function of the base width for use in final design of the wall systems.

## Table 4. Shallow Foundation Analysis – Retaining Wall 4W14

| Boring Number | Effective Footing Width (feet) | Service Limit Bearing Pressure (ksf) [1] | | | Nominal Bearing Resistance (ksf) | Factored Bearing Resistance [2] (ksf) |
|---|---|---|---|---|---|---|
| | | 0.5-inch | 1.0-inch | 1.5-inch | | |
| B-001-03-59 | 5 | 2.95 | 7.70 | 19.65 | 20.89 | 11.49 |
| | 7 | 2.64 | 6.33 | 15.54 | 23.56 | 12.96 |
| | 9 | 2.48 | 5.59 | 13.33 | 26.36 | 14.50 |
| | 11 | 2.38 | 5.13 | 11.97 | 29.23 | 16.07 |
| | 13 | 2.31 | 4.83 | 11.06 | 32.13 | 17.67 |
| | 15 | 2.26 | 4.62 | 10.42 | 35.07 | 19.29 |
| | 17 | 2.22 | 4.46 | 9.95 | 38.01 | 20.90 |
| | 19 | 2.20 | 4.34 | 9.60 | 40.95 | 22.52 |
| | 21 | 2.18 | 4.25 | 9.32 | 43.89 | 24.14 |
| | 23 | 2.16 | 4.18 | 9.11 | 46.83 | 25.75 |
| | 25 | 2.15 | 4.12 | 8.93 | 49.75 | 27.36 |
| B-033-1-15 | 5 | 3.47 | 8.78 | 16.96 | 41.58 | 22.87 |
| | 7 | 2.98 | 6.94 | 12.90 | 41.63 | 22.90 |
| | 9 | 2.71 | 5.93 | 10.69 | 41.69 | 22.93 |
| | 11 | 2.54 | 5.28 | 9.31 | 41.74 | 22.96 |
| | 13 | 2.42 | 4.84 | 8.39 | 41.79 | 22.99 |
| | 15 | 2.33 | 4.52 | 7.73 | 41.85 | 23.01 |
| | 17 | 2.26 | 4.27 | 7.24 | 41.90 | 23.04 |
| | 19 | 2.21 | 4.08 | 6.86 | 41.95 | 23.07 |
| | 21 | 2.17 | 3.92 | 6.57 | 42.01 | 23.10 |
| | 23 | 2.13 | 3.79 | 6.33 | 42.06 | 23.13 |
| | 25 | 2.10 | 3.69 | 6.14 | 42.11 | 23.16 |

| Boring Number | Effective Footing Width (feet) | Service Limit Bearing Pressure (ksf) [1] | | | Nominal Bearing Resistance (ksf) | Factored Bearing Resistance [2] (ksf) |
|---|---|---|---|---|---|---|
| | | 0.5-inch | 1.0-inch | 1.5-inch | | |
| B-033-3-15 | 5 | 4.25 | 11.42 | 24.25 | 44.01 | 24.20 |
| | 7 | 3.65 | 9.00 | 18.47 | 50.63 | 27.85 |
| | 9 | 3.32 | 7.65 | 15.26 | 57.46 | 31.60 |
| | 11 | 3.10 | 6.80 | 13.22 | 64.40 | 35.42 |
| | 13 | 2.95 | 6.20 | 11.75 | 71.39 | 39.27 |
| | 15 | 2.84 | 5.77 | 10.66 | 78.41 | 43.13 |
| | 17 | 2.76 | 5.44 | 9.83 | 85.44 | 46.99 |
| | 19 | 2.69 | 5.18 | 9.19 | 92.46 | 50.85 |
| | 21 | 2.64 | 4.96 | 8.68 | 99.46 | 54.70 |
| | 23 | 2.59 | 4.79 | 8.27 | 106.44 | 58.54 |
| | 25 | 2.55 | 4.64 | 7.92 | 113.40 | 62.37 |

1. *Service limit bearing pressure was calculated at total settlement values of 0.5, 1.0 and 1.5 inches.*
2. *Resistance factor of $\varphi_b$ = 0.55 was utilized in calculating the factored nominal bearing resistance at the strength limit state.*

The service limit bearing pressure that results in a maximum total settlement of 0.5, 1.0 and 1.5 inches was calculated and presented in Table 4 for retaining wall 4W14. A geotechnical resistance factor of $\varphi_b$ = 0.55 has been considered in calculating the factored bearing resistance at the strength limit state. Based on the bearing pressures provided in Table 4, and applying the geotechnical resistance factor provided to the nominal bearing resistance at the strength limit state, the service limit state should control the minimum footing dimensions for all effective footing widths analyzed for the total settlement values considered in the analysis. A graphical representation of the service limit bearing pressures and factored bearing resistance at the strength limit state is presented in Appendix V. Calculations for settlement and nominal and factored bearing resistance for the shallow spread foundations are provided in Appendix VI.

Based on the maximum service limit bearing pressures provided in the design documents and noted in Section 5.0, total settlements ranging from 0.996 to 1.167 inches are anticipated along the alignment of retaining wall 4W14. Additionally, the maximum factored bearing pressure will not exceed the factored bearing resistance at the strength limit for either retaining wall.

### 5.1.1 *Sliding Resistance*

The resistance of the footings to sliding will be dependent on the friction between the concrete footing and bearing surface. The bearing soils consist of cohesionless soil along the entire wall alignment. Therefore, it is recommended to consider the sliding resisting for both drained conditions. For drained conditions, Rii recommends using a friction angle of 40 degrees and a coefficient of sliding friction “f” of 0.87 to calculate the total vertical force on the base. A geotechnical resistance factor of $\varphi_\tau$ = 1.0 should be considered when calculating the factored shear resistance between the soil and foundation for sliding.

### 5.1.2 *Overall (Global) Stability*

A slope stability analysis was performed to check the global stability of the walls along the alignments. As per AASHTO LRFD BDS, safety against global stability failure shall be evaluated at the service limit state. Soil parameters utilized in external stability analyses are presented in Table 5. For the global stability condition, it was considered that the failure plane will not cross through any portion of the supported soil mass above the concrete or through the concrete footing itself.

**Table 5. Shear Strength Parameters Utilized in Stability Analyses**

| Material Type | Unit Weight, $\gamma$ (pcf) | Effective Friction Angle, $\varphi$' (°) | Effective Cohesion, $c$' (psf) | Undrained Shear Strength, $S_u$ (psf) |
|---|---|---|---|---|
| Item 203 Embankment Fill | 120 | 30 | 0 | 2,000 |
| Compacted Granular Engineered Fill | 120 | 30 | 0 | N/A |
| Stiff to Hard Cohesive Soils | 120 to 130 | 28 to 32 | 0 | 2,000 to 4,000 |
| Loose to Very Dense Granular Soils | 120 to 135 | 32 to 42 | 0 | N/A |

Per Section 11.6.2.3 of the 2012 AASHTO LRFD BDS, overall (global) stability for CIP walls not supporting structural foundations on spread footings is satisfied if the product of the factor of safety from the slope stability output multiplied by the resistance factor $\varphi$=0.75 is greater than 1.0. Therefore, global stability is satisfied when a minimum factor of safety of 1.33 is obtained. For retaining wall 4W14, global stability was evaluated considering the final configuration (post construction for FRA-70-14.05 Phase 4B). Based on the footing dimensions provided in the proposed design documents, the resulting factor of safety under drained conditions (long-term stability) and undrained (short-term stability) along the alignment or retaining wall 4W14 was greater than 1.33. Calculations for overall (global) stability of the CIP Wall 4W14 is provided in Appendix VIII.

## 5.2 Lateral Earth Pressure

For the soil types encountered in the borings, the "in-situ" unit weight ($\gamma$), cohesion ($c$), effective angle of friction ($\varphi'$), 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 6 and.

**Table 6. Estimated Undrained (Short-term) Soil Parameters for Design**

| Soil Type | $\gamma$ (pcf) [1] | $c$ (psf) | $\varphi$ | $k_a$ | $k_o$ | $k_p$ |
|---|---|---|---|---|---|---|
| Very Stiff to Hard Cohesive Soil | 125 | 3,000 | 0° | N/A | N/A | N/A |
| Dense to Very Dense Granular Soil | 130 | 0 | 36° | 0.23 | 0.41 | 9.09 |
| Compacted Cohesive Engineered Fill | 120 | 2,000 | 0° | N/A | N/A | N/A |
| Compacted Granular Engineered Fill | 130 | 0 | 33° | 0.30 | 0.46 | 3.39 |

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

**Table 7. Estimated Drained (Long-term) Soil Parameters for Design**

| Soil Type | $\gamma$ (pcf) [1] | $c$ (psf) | $\varphi'$ | $k_a$ | $k_o$ | $k_p$ |
|---|---|---|---|---|---|---|
| Very Stiff to Hard Cohesive Soil | 125 | 50 | 28° | 0.32 | 0.53 | 5.07 |
| Dense to Very Dense Granular Soil | 130 | 0 | 36° | 0.23 | 0.41 | 9.09 |
| Compacted Cohesive Engineered Fill | 120 | 0 | 30° | 0.30 | 0.50 | 5.58 |
| Compacted Granular Engineered Fill | 130 | 0 | 33° | 0.26 | 0.46 | 7.41 |

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

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

### *5.2.1 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 8. Excavation Back Slopes**

| Soil | Maximum Back Slope | Notes |
|---|---|---|
| Soft to Medium Stiff Cohesive | 1.5 : 1.0 | Above Ground Water Table and No Seepage |
| Stiff Cohesive | 1.0 : 1.0 | Above Ground Water Table and No Seepage |
| Very Stiff to Hard Cohesive | 0.75 : 1.0 | Above Ground Water Table and No Seepage |
| All Granular & Cohesive Soil Below Ground Water Table or with Seepage | 1.5 : 1.0 | None |

## 5.3 Groundwater Considerations

Based on the groundwater observations made during drilling, groundwater may be encountered during excavation of the foundation for retaining wall 4W14. Where/if groundwater is encountered, proper groundwater control should be employed and maintained to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or "boiling" condition where soft silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36 inches below the deepest excavation. Any seepage or groundwater encountered at this site should be able to be controlled by pumping from temporary sumps. Additional measures may be required depending on seasonal fluctuations of the groundwater level. Note that determining and maintaining actual groundwater levels during construction is the responsibility of the contractor.

## 6.0 LIMITATIONS OF STUDY

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

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

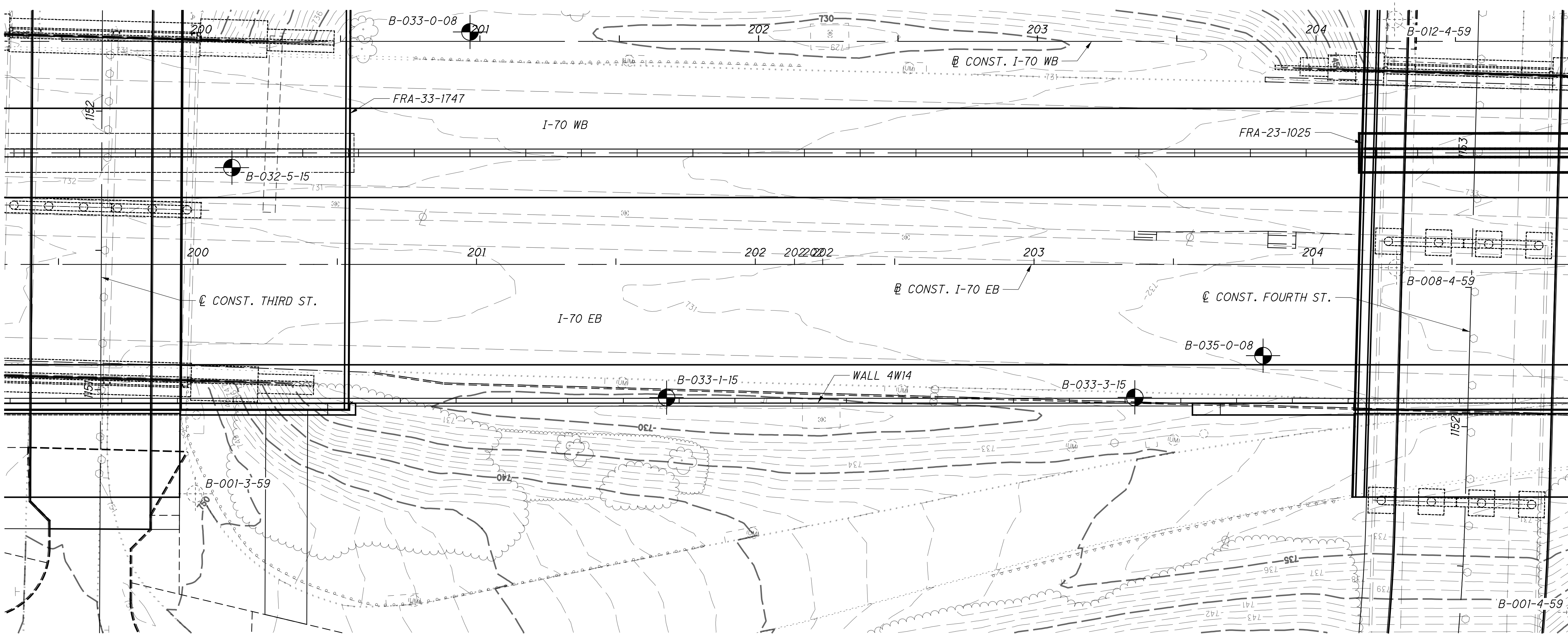
The conclusions and recommendations herein have been based upon the available soil and bedrock information and the design details furnished by a representative of the owner of the proposed project. Any revision in the plans for the proposed construction from those anticipated in this report should be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

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

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

# APPENDIX I

# VICINITY MAP AND BORING PLAN




# BORING PLAN - WALL 4W14 1-70 EB

## FRA-70-14.05

## FRANKLIN COUNTY, OHIO

| RII PROJECT NO. W-15-126 | DRAWN JAS |
|---|---|
| SCALE: 1"=20' (0 10 20) | REVIEWED BRT |
| N | DATE 11-27-18 |

RESOURCE INTERNATIONAL Rii

# APPENDIX II

# DESCRIPTION OF SOIL TERMS

## DESCRIPTION OF SOIL TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

# CLASSIFICATION OF SOILS

Ohio Department of Transportation

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

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

MATERIAL CLASSIFIED BY VISUAL INSPECTION

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

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

## DESCRIPTION OF ROCK TERMS

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

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

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

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

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

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

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

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

**Degree of Fracturing**

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

**Aperture Width**

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

**Surface Roughness**

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

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

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

## APPENDIX III

## PROJECT BORING LOGS:

## B-033-1-15 and B-033-3-15

# BORING LOGS

## Definitions of Abbreviations

| | | |
|---|---|---|
| AS | = | Auger sample |
| GI | = | Group index as determined from the Ohio Department of Transportation classification system |
| HP | = | Unconfined compressive strength as determined by a hand penetrometer (tons per square foot) |
| $LL_o$ | = | Oven-dried liquid limit as determined by ASTM D4318. Per ASTM D2487, if $LL_o$/LL is less than 75 percent, soil is classified as "organic". |
| LOI | = | Percent organic content (by weight) as determined by ASTM D2974 (loss on ignition test) |
| PID | = | Photo-ionization detector reading (parts per million) |
| QR | = | Unconfined compressive strength of intact rock core sample as determined by ASTM D2938 (pounds per square inch) |
| QU | = | Unconfined compressive strength of soil sample as determined by ASTM D2166 (pounds per square foot) |
| RC | = | Rock core sample |
| REC | = | Ratio of total length of recovered soil or rock to the total sample length, expressed as a percentage |
| RQD | = | Rock quality designation – estimate of the degree of jointing or fracture in a rock mass, expressed as a percentage: $$\frac{\sum \text{segments equal to or longer than 4.0 inches}}{\text{core run length}} \times 100$$ |
| S | = | Sulfate content (parts per million) |
| SPT | = | Standard penetration test blow counts, per ASTM D1586. Driving resistance recorded in terms of blows per 6-inch interval while letting a 140-pound hammer free fall 30 inches to drive a 2-inch outer diameter (O.D.) split spoon sampler a total of 18 inches. The second and third intervals are added to obtain the number of blows per foot ($N_m$). |
| $N_{60}$ | = | Measured blow counts corrected to an equivalent (60 percent) energy ratio (ER) by the following equation: $N_{60} = N_m*(ER/60)$ |
| SS | = | Split spoon sample |
| 2S | = | For instances of no recovery from standard SS interval, a 2.5 inch O.D. split spoon is driven the full length of the standard SS interval plus an additional 6.0 inches to obtain a representative sample. Only the final 6.0 inches of sample is retained. Blow counts from 2S sampling are not correlated with $N_{60}$ values. |
| 3S | = | Same as 2S, but using a 3.0 inch O.D. split spoon sampler. |
| TR | = | Top of rock |
| W | = | Initial water level measured during drilling |
| ▼ | = | Water level measured at completion of drilling |

<u>Classification Test Data</u>

Gradation (as defined on Description of Soil Terms):

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

Atterberg Limits:

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

RESOURCE INTERNATIONAL, INC.

| | | | |
|---|---|---|---|
| PROJECT: FRA-70-14.05 PROJECT 4B | DRILLING FIRM / OPERATOR: RII / S.B. | DRILL RIG: CME 750X (SN 310218) | STATION / OFFSET: 201+68.14 / 47.8" RT |
| TYPE: ROADWAY | SAMPLING FIRM / LOGGER: RII / C.D. | HAMMER: CME AUTOMATIC | ALIGNMENT: BL CONST. I-70 EB |
| PID: 96053 BR ID: NA | DRILLING METHOD: 3.25" - HSA | CALIBRATION DATE: 10/20/14 | ELEVATION: 729.7 (MSL) EOB: 60.0 ft. |
| START: 10/12/15 END: 10/12/15 | SAMPLING METHOD: SPT | ENERGY RATIO (%): 85.7 | COORD: 39.953222, -82.995459 |

EXPLORATION ID **B-033-1-15**

PAGE 1 OF 2

| ***MATERIAL DESCRIPTION AND NOTES*** | ELEV. 729.7 | DEPTHS | SPT/ RQD | $N_{60}$ | REC (%) | SAMPLE ID | HP (tsf) | GRADATION (%) GR | CS | FS | SI | CL | ATTERBERG LL | PL | PI | WC | ODOT CLASS (GI) | BACK FILL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.3' - TOPSOIL (3.0") | 729.4 | | | | | | | | | | | | | | | | | |
| DENSE TO VERY DENSE, BROWN **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, DAMP. | | | 9 15 21 | 51 | 100 | SS-1 | - | - | - | - | - | - | - | - | - | 4 | A-1-b (V) | |
| -INTRODUCED MUD @ 8.5' | | W | 8 16 19 | 50 | 100 | SS-2 | - | - | - | - | - | - | - | - | - | 12 | A-1-b (V) | |
| | 717.6 | | 11 17 20 | 53 | 100 | SS-3A | - | 28 | 31 | 28 | 10 | 3 | NP | NP | NP | 14 | A-1-b (0) | |
| VERY DENSE, BROWN TO GRAY **COARSE AND FINE SAND**, SOME FINE GRAVEL, LITTLE SILT, TRACE CLAY, MOIST. | | | | | | SS-3B | - | - | - | - | - | - | - | - | - | 21 | A-3a (V) | |
| | | | 10 18 26 | 63 | 100 | SS-4 | - | - | - | - | - | - | - | - | - | 13 | A-3a (V) | |
| | 711.7 | | 5 16 21 | 53 | 100 | SS-5 | - | 26 | 20 | 33 | 16 | 5 | NP | NP | NP | 14 | A-3a (0) | |
| VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST. | 709.2 | | 12 21 30 | 73 | 100 | SS-6 | - | - | - | - | - | - | - | - | - | 10 | A-1-b (V) | |
| HARD, GRAY **SANDY SILT**, LITTLE CLAY, LITTLE FINE GRAVEL, DAMP. | | | 20 50/5" | - | 100 | SS-7 | 4.5+ | 13 | 13 | 22 | 32 | 20 | 23 | 14 | 9 | 11 | A-4a (3) | |
| | 704.2 | | 11 42 50/4" | - | 100 | SS-8 | 4.5+ | - | - | - | - | - | - | - | - | 12 | A-4a (V) | |
| VERY DENSE, GRAY **FINE SAND**, TRACE SILT, TRACE CLAY, TRACE FINE GRAVEL, WET. | | | 6 22 42 | 91 | 100 | SS-9 | - | 3 | 10 | 78 | 6 | 3 | NP | NP | NP | 18 | A-3 (0) | |
| | | | 18 24 35 | 84 | 100 | SS-10 | - | - | - | - | - | - | - | - | - | 21 | A-3 (V) | |

PID: 96053 | BR ID: NA | PROJECT: FRA-70-14.05 PROJECT 4B | STATION / OFFSET: 201+68.14 / 47.8' RT | START: 10/12/15 | END: 10/12/15 |  | B-033-1-15

| MATERIAL DESCRIPTION AND NOTES | ELEV. (top 699.7) | DEPTHS |
|---|---|---|
| VERY DENSE, GRAY **FINE SAND**, TRACE SILT, TRACE CLAY, TRACE FINE GRAVEL, WET. *(same as above)* | 697.7 | 30–32 |
| HARD, GRAY **SANDY SILT**, LITTLE CLAY, TRACE FINE GRAVEL, DAMP. | 692.7 | 32–37 |
| DENSE, GRAY **COARSE AND FINE SAND**, LITTLE FINE GRAVEL, TRACE SILT, TRACE CLAY, MOIST.<br>-HEAVING SANDS ENCOUNTERED @ 38.5' | 687.7 | 37–42 |
| VERY DENSE, GRAY **GRAVEL**, "AND" COARSE TO FINE SAND, TRACE SILT, TRACE CLAY, MOIST.<br>-HEAVING SANDS ENCOUNTERED @ 43.5' | 682.7 | 42–47 |
| DENSE, GRAY **COARSE AND FINE SAND**, LITTLE FINE GRAVEL, TRACE SILT, TRACE CLAY, MOIST. | 677.7 | 47–52 |
| DENSE, GRAY **GRAVEL AND SAND**, TRACE CLAY, TRACE SILT, WET.<br>-HEAVING SANDS ENCOUNTERED THROUGHOUT | 669.7 | 52–60 (EOB) |

| DEPTH (ft) | SPT/RQD | $N_{60}$ | REC (%) | SAMPLE ID | HP (tsf) | GR | CS | FS | SI | CL | LL | PL | PI | WC | ODOT CLASS (GI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33.5–35 | 20-40-50/5" | - | 100 | SS-11 | 4.5+ | 6 | 8 | 35 | 33 | 18 | 17 | 14 | 3 | 12 | A-4a (3) |
| 38.5–40 | 8-25-38 | 90 | 83 | SS-12 | - | - | - | - | - | - | - | - | - | 17 | A-3a (V) |
| 43.5–45 | 9-28-41 | 99 | 100 | SS-13 | - | 53 | 21 | 15 | 8 | 3 | NP | NP | NP | 12 | A-1-a (0) |
| 48.5–50 | 8-11-17 | 40 | 100 | SS-14 | - | - | - | - | - | - | - | - | - | 8 | A-1-b (V) |
| 53.5–55 | 9-12-20 | 46 | 100 | SS-15 | - | - | - | - | - | - | - | - | - | 23 | A-1-b (V) |
| 58.5–60 | 7-10-17 | 39 | 100 | SS-16 | - | 1 | 52 | 43 | 1 | 3 | NP | NP | NP | 21 | A-1-b (0) |

EOB

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 8.5'

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

RESOURCE INTERNATIONAL, INC.

| | | | | |
|---|---|---|---|---|
| PROJECT: FRA-70-14.05 PROJECT 4B | DRILLING FIRM / OPERATOR: RII / M.W. | DRILL RIG: CME 55 (SN 386345) | STATION / OFFSET: 203+36.15 / 47.7" RT | EXPLORATION ID **B-033-3-15** |
| TYPE: ROADWAY | SAMPLING FIRM / LOGGER: RII / N.A. | HAMMER: CME AUTOMATIC | ALIGNMENT: BL CONST. I-70 EB | PAGE |
| PID: 96053 BR ID: NA | DRILLING METHOD: 3.25" - HSA | CALIBRATION DATE: 10/20/14 | ELEVATION: 731.2 (MSL) EOB: 69.0 ft. | 1 OF 3 |
| START: 10/7/15 END: 10/7/15 | SAMPLING METHOD: SPT | ENERGY RATIO (%): 92 | COORD: 39.953302, -82.994869 | |

| MATERIAL DESCRIPTION AND NOTES | ELEV. 731.2 |
|---|---|
| 0.3' - TOPSOIL (3.0") | 730.9 |
| VERY STIFF, BROWN **SANDY SILT**, SOME CLAY, LITTLE FINE GRAVEL, DAMP.<br>-ORGANICS PRESENT IN SS-1 | 728.2 |
| DENSE, BROWN **COARSE AND FINE SAND**, LITTLE FINE GRAVEL, TRACE SILT, TRACE CLAY, DAMP. | 725.7 |
| DENSE TO VERY DENSE, BROWN AND BROWNISH GRAY **GRAVEL AND SAND**, TRACE TO LITTLE SILT, TRACE CLAY, MOIST.<br>-SS-3 SULFATE CONTENT = 87 PPM<br>-HEAVING SANDS ENCOUNTERED @ 18.5'<br>-INTRODUCED MUD @ 18.5' | 701.5 |

Water level (W) noted at approx. 11 ft depth.

| DEPTHS | SPT/RQD | $N_{60}$ | REC (%) | SAMPLE ID | HP (tsf) | GR | CS | FS | SI | CL | LL | PL | PI | WC | ODOT CLASS (GI) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1–2 | 6 10 6 | 24 | 94 | SS-1 | 4.00 | - | - | - | - | - | - | - | - | 10 | A-4a (V) |
| 3.5–5 | 11 15 16 | 47 | 78 | SS-2 | - | 11 | 29 | 48 | 9 | 3 | NP | NP | NP | 4 | A-3a (0) |
| 6–7.5 | 11 15 19 | 51 | 100 | SS-3 | - | - | - | - | - | - | - | - | - | 7 | A-1-b (V) |
| 8.5–10 | 6 17 17 | 51 | 100 | SS-4 | - | 34 | 30 | 26 | 7 | 3 | NP | NP | NP | 7 | A-1-b (0) |
| 11–12.5 | 3 17 20 | 56 | 100 | SS-5 | - | - | - | - | - | - | - | - | - | 13 | A-1-b (V) |
| 13.5–15 | 12 15 18 | 50 | 100 | SS-6 | - | - | - | - | - | - | - | - | - | 13 | A-1-b (V) |
| 16–17.5 | 11 17 21 | 57 | 100 | SS-7 | - | 35 | 33 | 19 | 11 | 2 | NP | NP | NP | 14 | A-1-b (0) |
| 18.5–20 | 19 20 29 | 74 | 100 | SS-8 | - | - | - | - | - | - | - | - | - | 12 | A-1-b (V) |
| 23.5–25 | 19 23 28 | 77 | 100 | SS-9 | - | 23 | 29 | 33 | 13 | 2 | NP | NP | NP | 12 | A-1-b (0) |
| 28.5–30 | 21 28 27 | 83 | 78 | SS-10A | - | - | - | - | - | - | - | - | - | 10 | A-1-b (V) |

| PID: 96053 | BR ID: NA | PROJECT: FRA-70-14.05 PROJECT 4B | STATION / OFFSET: 203+36.15 / 47.7' RT | START: 10/7/15 | END: 10/7/15 | PG 2 OF 3 | B-033-3-15 |
|---|---|---|---|---|---|---|---|

| MATERIAL DESCRIPTION AND NOTES | ELEV. 701.2 | DEPTHS | SPT/ RQD | $N_{60}$ | REC (%) | SAMPLE ID | HP (tsf) | GRADATION (%) GR | CS | FS | SI | CL | ATTERBERG LL | PL | PI | WC | ODOT CLASS (GI) | BACK FILL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HARD, GRAY **SILT**, SOME COARSE TO FINE SAND, TRACE FINE GRAVEL, DAMP TO MOIST. *(same as above)* | | | | | | SS-10B | 4.5+ | - | - | - | - | - | - | - | - | 10 | A-4b (V) | |
| | | 34 | 29 30 41 | 107 | 100 | SS-11 | 4.50 | 3 | 5 | 22 | 59 | 11 | 19 | 11 | 8 | 13 | A-4b (7) | |
| | 694.2 | 37 | | | | | | | | | | | | | | | | |
| VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST. | | 39 | 13 39 43 | 123 | 100 | SS-12 | - | - | - | - | - | - | - | - | - | 16 | A-1-b (V) | |
| | | 44 | 20 34 35 | 104 | 83 | SS-13 | - | 42 | 39 | 12 | 6 | 1 | NP | NP | NP | 11 | A-1-b (0) | |
| -HEAVING SANDS ENCOUNTERED @ 48.5' | | 49 | 43 50/4" | - | 100 | SS-14 | - | - | - | - | - | - | - | - | - | 8 | A-1-b (V) | |
| | | 54 | 50/5" | - | 100 | SS-15 | - | - | - | - | - | - | - | - | - | 13 | A-1-b (V) | |
| | 674.2 | 57 | | | | | | | | | | | | | | | | |
| HARD, GRAY **SILT AND CLAY**, "AND" COARSE TO FINE SAND, LITTLE FINE GRAVEL, DAMP. | | 59 | 37 50/1" | - | 100 | SS-16 | 4.5+ | 17 | 15 | 22 | 30 | 16 | 24 | 13 | 11 | 10 | A-6a (3) | |
| | 669.2 | 62 | | | | | | | | | | | | | | | | |

| PID: 96053 | BR ID: NA | PROJECT: FRA-70-14.05 PROJECT 4B | STATION / OFFSET: 203+36.15 / 47.7' RT | START: 10/7/15 | END: 10/7/15 | PG 3 OF 3 | B-033-3-15 |
|---|---|---|---|---|---|---|---|

| MATERIAL DESCRIPTION AND NOTES | ELEV. 669.1 | DEPTHS | SPT/ RQD | $N_{60}$ | REC (%) | SAMPLE ID | HP (tsf) | GRADATION (%) GR | CS | FS | SI | CL | ATTERBERG LL | PL | PI | WC | ODOT CLASS (GI) | BACK FILL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VERY DENSE, GRAY **SANDY SILT**, LITTLE FINE GRAVEL, TRACE CLAY, MOIST. *(same as above)* | | 63 | | | | | | | | | | | | | | | | |
| | | 64 – 65 | 20 35 40 | 113 | 100 | SS-17 | - | - | - | - | - | - | - | - | - | 11 | A-4a (V) | |
| | 664.2 | 66 – 67 | | | | | | | | | | | | | | | | |
| VERY DENSE, GRAY **GRAVEL AND SAND**, TRACE SILT, TRACE CLAY, MOIST. | | 68 | | | | | | | | | | | | | | | | |
| | 662.2 | EOB 69 | 50/6" | - | 100 | SS-18 | - | - | - | - | - | - | - | - | - | 13 | A-1-b (V) | |

NOTES: GROUNDWATER ENCOUNTERED INITIALLY @ 11.0'

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

## APPENDIX IV

## HISTORIC BORING LOG:

## B-001-3-59

STATE OF OHIO
DEPARTMENT OF HIGHWAYS
TESTING LABORATORY

# LOG OF BORING

CO., RT. NO., SEC. FRA-40- REAR ABUTMENT BRIDGE NO. FRA-40- SOUTH INNERBELT UNDER S. THIRD ST.

LOCATION: T.H. 1 B STA. 50+63 OFFSET 33' RT. FED. NO.

| ELEV. | DEPTH | NO. BLOWS | SAMPLE NO. | DESCRIPTION |
|---|---|---|---|---|
| 751.2 | 0 | | | |
| | 2 | | | |
| | 4 | | | |
| 746.2 | 6 | 4/4 | 20641 | Brown Clayey Sandy Gravel |
| | 8 | | | |
| 741.2 | 10 | 9/5 | ----- | Brown Clayey Sandy Gravel |
| 738.7 | 12 | 5/6 | 20642 | Brown Clayey Sandy Gravel |
| 736.2 | 14 | 5/5 | 20643 | Brown Silty Sandy Gravel |
| 733.7 | 16 18 | 13/25 | 20644 | Brown Silty Sandy Gravel |
| 731.2 | 20 | 10/6 | 20645 | Brown Silty Sandy Gravel |
| 730.7 | 22 | 17/12 | 20646 | Gray Silty Sandy Gravel |
| 726.2 | 24 26 | 10/13 | 20647 | Gray Silty Sandy Gravel |
| 723.7 | 28 | 12/12 | 20648 | Gray Silty Sandy Gravel |
| 721.2 | 30 | 18/18 | 20649 | Gray Silty Sandy Gravel |
| | 32 | | | |
| | 34 | | | |
| 716.2 | 36 | 16/19 | 20650 | Gray Silty Sandy Gravel |

BS
7·7·59

B-001-3-59

# LOG OF BORING (CONTINUED)

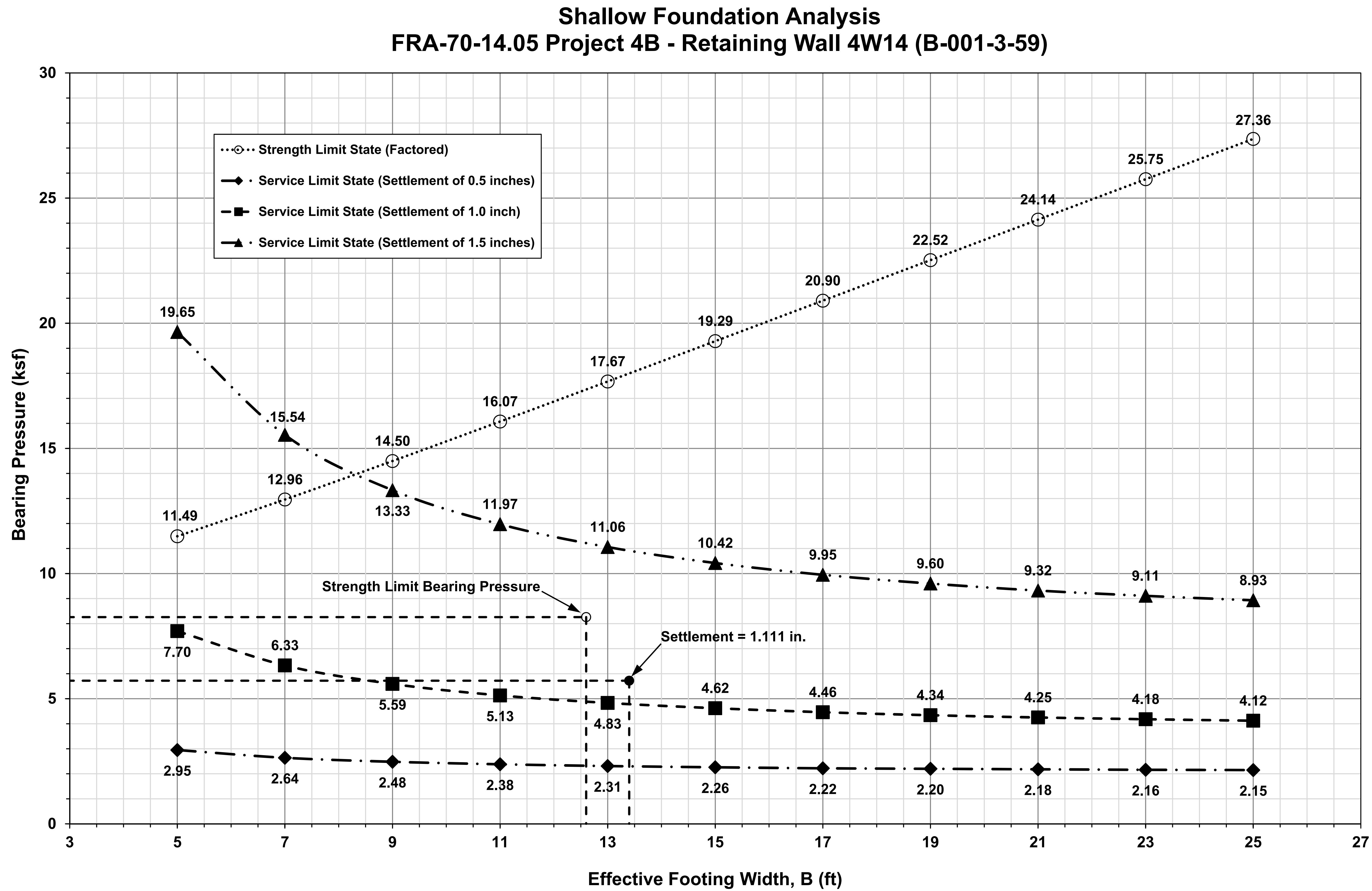
SHEET 4

BRIDGE NO. FRA-40- T.H. 1B

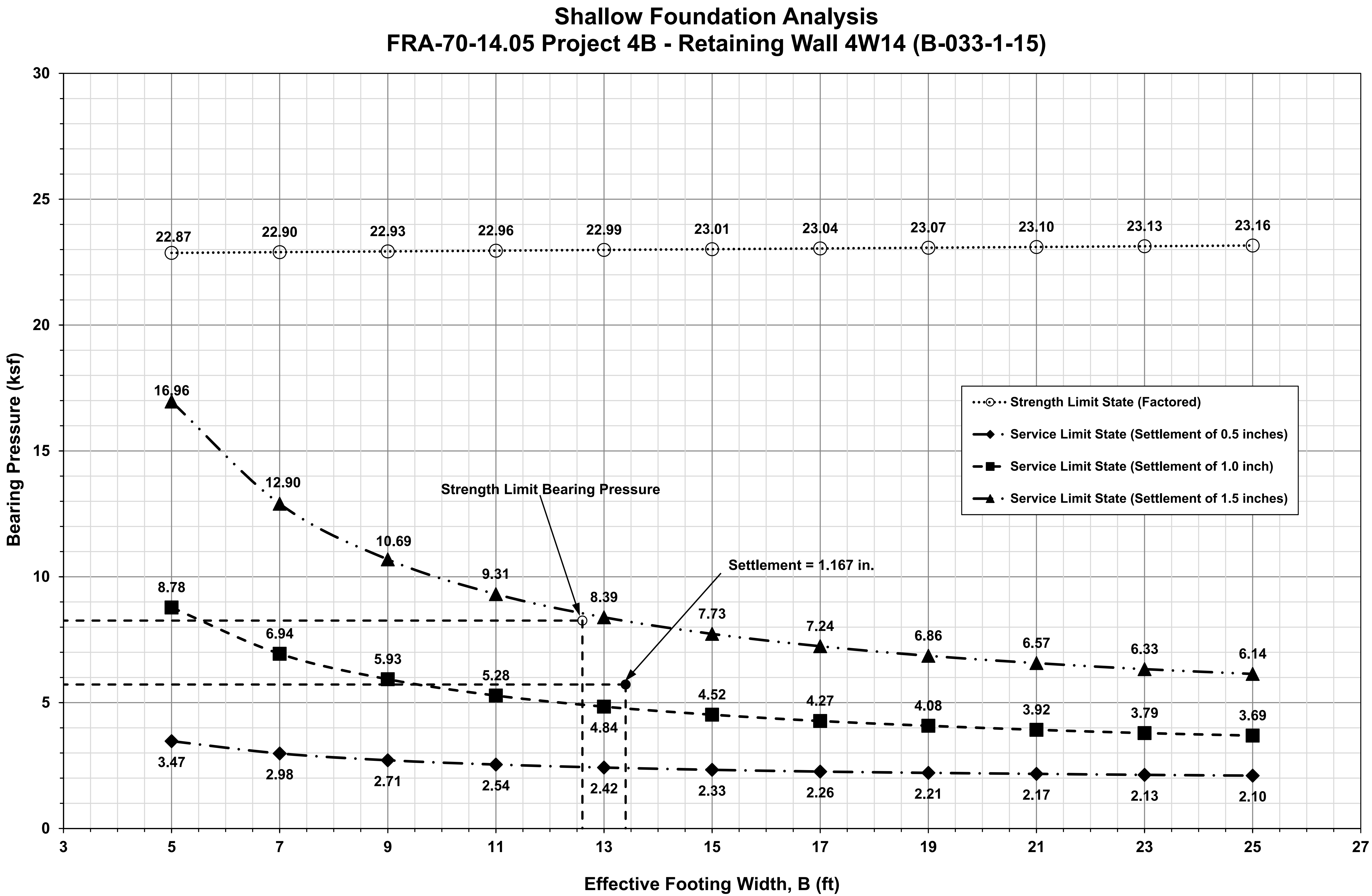
| ELEV. | DEPTH | NO. BLOWS | SAMPLE NO. | DESCRIPTION |
|---|---|---|---|---|
| | 38 | | | |
| 711.2 | 40 | | | |
| | | 11/16 | 20651 | Gray Silty Gravelly Sand |
| | 42 | | | |
| | 44 | | | |
| 706.2 | 46 | 24/40 | 20652 | Gray Silty Sandy Gravel |
| | 48 | | | |
| 701.2 | 50 | | | |
| | | 32/50 | 20653 | Gray Silty Sandy Gravel |
| | 52 | | | |
| | 54 | | | |
| 696.2 | | | | |
| 695.2 | 56 | 33/55 | 20654 | Gray Sandy Gravel |
| | | | | BOTTOM OF BORING |
| | 58 | | | |
| | 60 | | | |
| | 62 | | | |
| | 64 | | | |
| | 66 | | | |
| | 68 | | | |
| | 70 | | | |
| | 72 | | | |
| | 74 | | | |
| | 76 | | | |
| | 78 | | | |
| | 80 | | | |
| | 82 | | | |

# APPENDIX V

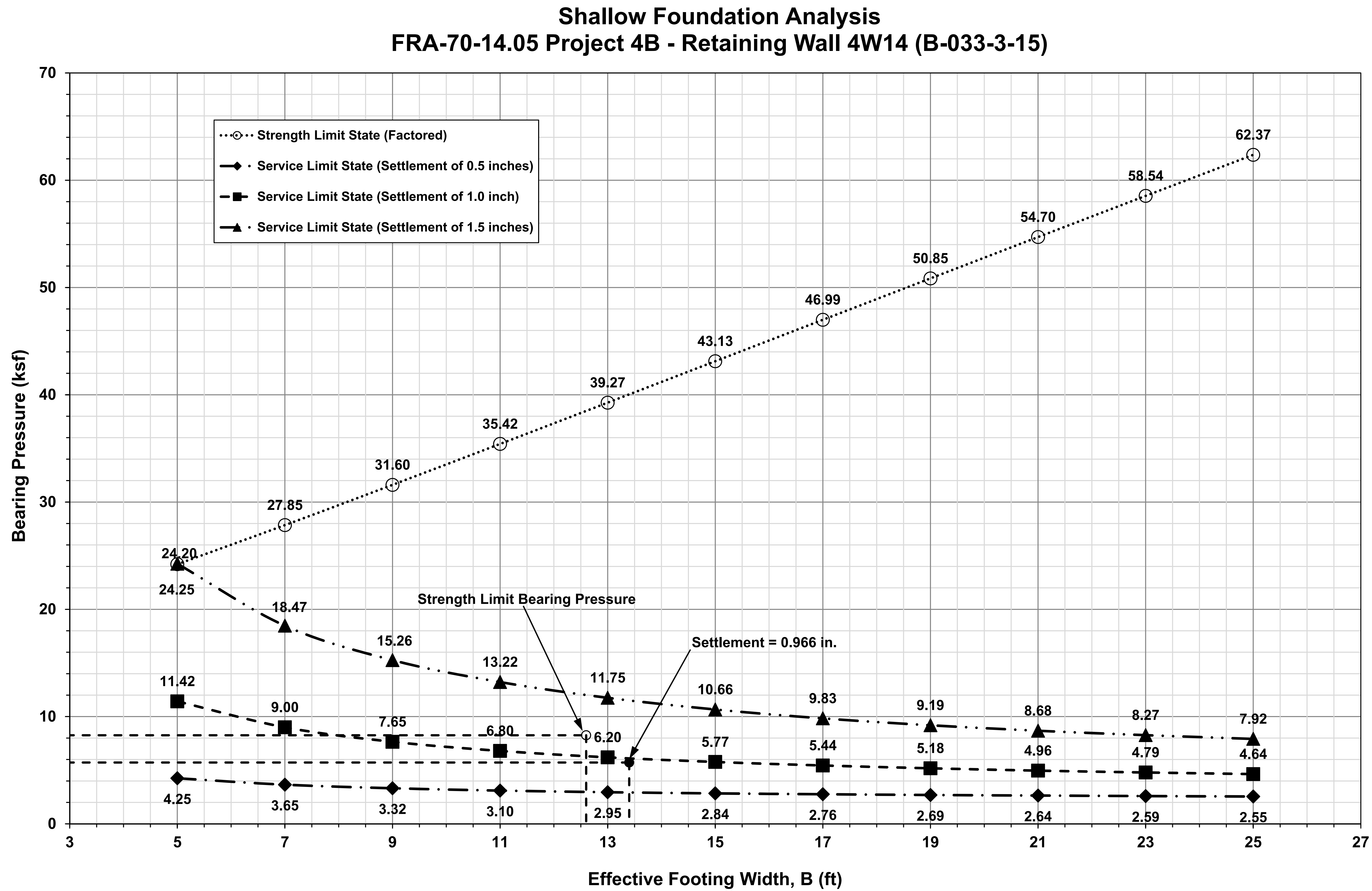
# BEARING RESISTANCE CHARTS



Shallow Foundation Analysis
FRA-70-14.05 Project 4B - Retaining Wall 4W14 (B-001-3-59)
Strength Limit State (Factored)
Service Limit State (Settlement of 0.5 inches)
Service Limit State (Settlement of 1.0 inch)
Service Limit State (Settlement of 1.5 inches)
Strength Limit Bearing Pressure
Settlement = 1.111 in.
Bearing Pressure (ksf)
Effective Footing Width, B (ft)
11.49
12.96
14.50
16.07
17.67
19.29
20.90
22.52
24.14
25.75
27.36
19.65
15.54
13.33
11.97
11.06
10.42
9.95
9.60
9.32
9.11
8.93
7.70
6.33
5.59
5.13
4.83
4.62
4.46
4.34
4.25
4.18
4.12
2.95
2.64
2.48
2.38
2.31
2.26
2.22
2.20
2.18
2.16
2.15



Shallow Foundation Analysis
FRA-70-14.05 Project 4B - Retaining Wall 4W14 (B-033-1-15)
Bearing Pressure (ksf)
Effective Footing Width, B (ft)
0
5
10
15
20
25
30
3
5
7
9
11
13
15
17
19
21
23
25
27
22.87
22.90
22.93
22.96
22.99
23.01
23.04
23.07
23.10
23.13
23.16
16.96
12.90
10.69
9.31
8.39
7.73
7.24
6.86
6.57
6.33
6.14
8.78
6.94
5.93
5.28
4.84
4.52
4.27
4.08
3.92
3.79
3.69
3.47
2.98
2.71
2.54
2.42
2.33
2.26
2.21
2.17
2.13
2.10
Strength Limit Bearing Pressure
Settlement = 1.167 in.
Strength Limit State (Factored)
Service Limit State (Settlement of 0.5 inches)
Service Limit State (Settlement of 1.0 inch)
Service Limit State (Settlement of 1.5 inches)



Shallow Foundation Analysis
FRA-70-14.05 Project 4B - Retaining Wall 4W14 (B-033-3-15)
Strength Limit State (Factored)
Service Limit State (Settlement of 0.5 inches)
Service Limit State (Settlement of 1.0 inch)
Service Limit State (Settlement of 1.5 inches)
Bearing Pressure (ksf)
Effective Footing Width, B (ft)
Strength Limit Bearing Pressure
Settlement = 0.966 in.
24.20
27.85
31.60
35.42
39.27
43.13
46.99
50.85
54.70
58.54
62.37
24.25
18.47
15.26
13.22
11.75
10.66
9.83
9.19
8.68
8.27
7.92
11.42
9.00
7.65
6.80
6.20
5.77
5.44
5.18
4.96
4.79
4.64
4.25
3.65
3.32
3.10
2.95
2.84
2.76
2.69
2.64
2.59
2.55
0
10
20
30
40
50
60
70
3
5
7
9
11
13
15
17
19
21
23
25
27

# APPENDIX VI

# SHALLOW FOUNDATION CALCULATIONS

W-15-126 - FRA-70-14.05 Project 4B - Retaining Wall 4W14
Shallow Foundation Analysis - Settlement

Calculated By: BRT  Date: 6/26/2022
Checked By: JPS  Date: 6/27/2022

Boring B-001-3-59

| | | | |
|---|---|---|---|
| B = | 13.4 | ft | Effective Footing width |
| $D_w$ = | 0.0 | ft | Depth below bottom of footing |
| q = | 5,720 | psf | Service limit bearing pressure at bottom of wall |
| $q_{net}$ = | 4,290 | psf | Net bearing pressure at bottom of wall (considers initial overburden stress of 1,430 psf from 11-foot cut to bottom of footing elevation) |

| Soil Class. | Soil Type | Layer Depth (ft) | | Layer Thickness H (ft) | Depth to Midpoint (ft) | $N_{60}$ | $\gamma$ (pcf) | $\sigma_{vo}$ Bottom (psf) | $\sigma_{vo}$ Midpoint (psf) | $\sigma_{vo}'$ Midpoint (psf) | $\sigma_m$ (1) (psf) | $\sigma_p'$ (1) (psf) | LL | $C_c$ (2) | $C_r$ (3) | $e_o$ (4) | $(N1)_{60}$ (5) | C' (6) | $Z_f$/B | I (7) | $\Delta\sigma_v$ (8) (psf) | $\sigma_{vf}'$ Midpoint (psf) | $S_c$ (9,10) (ft) | $S_c$ (in) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1-b | G | 0.0 | 0.5 | 0.5 | 0.3 | 35 | 130 | 65 | 33 | 17 | | | | | | | 70 | 268 | 0.02 | 1.000 | 4,290 | 4,307 | 0.004 | 0.054 |
| A-1-b | G | 0.5 | 1.0 | 0.5 | 0.8 | 35 | 130 | 130 | 98 | 51 | | | | | | | 70 | 268 | 0.06 | 0.999 | 4,287 | 4,338 | 0.004 | 0.043 |
| A-1-b | G | 1.0 | 1.5 | 0.5 | 1.3 | 35 | 130 | 195 | 163 | 85 | | | | | | | 70 | 268 | 0.09 | 0.997 | 4,279 | 4,363 | 0.003 | 0.038 |
| A-1-b | G | 1.5 | 2.0 | 0.5 | 1.8 | 35 | 130 | 260 | 228 | 118 | | | | | | | 68 | 258 | 0.13 | 0.993 | 4,260 | 4,378 | 0.003 | 0.037 |
| A-1-b | G | 2.0 | 2.5 | 0.5 | 2.3 | 35 | 130 | 325 | 293 | 152 | | | | | | | 65 | 242 | 0.17 | 0.986 | 4,229 | 4,381 | 0.003 | 0.036 |
| A-1-b | G | 2.5 | 3.0 | 0.5 | 2.8 | 35 | 130 | 390 | 358 | 186 | | | | | | | 63 | 230 | 0.21 | 0.976 | 4,186 | 4,372 | 0.003 | 0.036 |
| A-1-b | G | 3.0 | 4.5 | 1.5 | 3.8 | 35 | 130 | 585 | 488 | 254 | | | | | | | 59 | 211 | 0.28 | 0.946 | 4,060 | 4,314 | 0.009 | 0.105 |
| A-1-b | G | 4.5 | 6.1 | 1.6 | 5.3 | 35 | 130 | 793 | 689 | 358 | | | | | | | 55 | 192 | 0.40 | 0.884 | 3,791 | 4,149 | 0.009 | 0.106 |
| A-3a | G | 6.1 | 7.6 | 1.5 | 6.9 | 27 | 125 | 981 | 887 | 459 | | | | | | | 40 | 112 | 0.51 | 0.811 | 3,480 | 3,939 | 0.013 | 0.150 |
| A-3a | G | 7.6 | 9.1 | 1.5 | 8.4 | 27 | 125 | 1,168 | 1,074 | 553 | | | | | | | 39 | 108 | 0.62 | 0.741 | 3,180 | 3,733 | 0.012 | 0.139 |
| A-3a | G | 9.1 | 11.1 | 2.0 | 10.1 | 27 | 125 | 1,418 | 1,293 | 663 | | | | | | | 37 | 103 | 0.75 | 0.666 | 2,858 | 3,520 | 0.014 | 0.168 |
| A-1-b | G | 11.1 | 12.6 | 1.5 | 11.9 | 64 | 140 | 1,628 | 1,523 | 784 | | | | | | | 84 | 300 | 0.88 | 0.600 | 2,576 | 3,359 | 0.003 | 0.038 |
| A-1-b | G | 12.6 | 14.1 | 1.5 | 13.4 | 64 | 140 | 1,838 | 1,733 | 900 | | | | | | | 81 | 300 | 1.00 | 0.551 | 2,365 | 3,265 | 0.003 | 0.034 |
| A-2-4 | G | 14.1 | 15.6 | 1.5 | 14.9 | 64 | 140 | 2,048 | 1,943 | 1,016 | | | | | | | 79 | 300 | 1.11 | 0.508 | 2,181 | 3,198 | 0.002 | 0.030 |
| A-2-4 | G | 15.6 | 18.1 | 2.5 | 16.9 | 84 | 140 | 2,398 | 2,223 | 1,172 | | | | | | | 99 | 300 | 1.26 | 0.460 | 1,971 | 3,143 | 0.004 | 0.043 |
| A-1-a | G | 18.1 | 21.1 | 3.0 | 19.6 | 84 | 140 | 2,818 | 2,608 | 1,385 | | | | | | | 94 | 300 | 1.46 | 0.405 | 1,735 | 3,120 | 0.004 | 0.042 |
| A-1-a | G | 21.1 | 22.1 | 1.0 | 21.6 | 84 | 140 | 2,958 | 2,888 | 1,540 | | | | | | | 91 | 300 | 1.61 | 0.372 | 1,594 | 3,134 | 0.001 | 0.012 |
| | | | | | | | | | | | | | | | | | | | | | Total Settlement: | | | 1.111 in |

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate $\sigma_m$ of 4,000 psf for moderately overconsolidated soil deposit; Ref. Table 11.2, Coduto 2003
2. $C_c$ = 0.009(LL-10); Ref. Table 6-9, FHWA GEC 5
3. $C_r$ = 0.10($C_c$); Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o$ = ($C_c$/0.54)+0.35; Ref. Table 6-11, FHWA GEC 5
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

Boring B-001-3-59

| | | | |
|---|---|---|---|
| B = | 12.6 | ft | |
| L = | 300 | ft | |
| c = | 0 | psf | |
| $\gamma$ = | 130 | pcf | |
| $D_f$ = | 5.0 | ft | |
| $\varphi$ = | 35 | deg | |
| $D_w$ = | 0.0 | ft | Below ground surface |

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$ = 31.55 ksf

$N_{cm} = N_c s_c i_c$ = 47.52

$N_{qm} = N_q s_q d_q i_q$ = 37.58

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 47.22

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $N_c$ = | 46.12 | $s_c$ = | 1+(12.6 ft/300 ft)(33.3/46.12) = | 1.030 | $i_c$ = | 1.000 | $d_q$ = | 1+2tan(35°)[1-sin(35°)]²tan⁻¹(5 ft/12.6 ft) = | 1.096 |
| $N_q$ = | 33.30 | $s_q$ = | 1+(12.6 ft/300 ft)tan(35°) = | 1.029 | $i_q$ = | 1.000 | $C_{wq}$ = | 0.0 ft < 5.0 ft = | 0.500 |
| $N_\gamma$ = | 48.03 | $s_\gamma$ = | 1-0.4(12.6 ft/300 ft) = | 0.983 | $i_\gamma$ = | 1.000 | $C_{w\gamma}$ = | 0.0 ft < 1.5(12.6 ft) + 5 ft = | 0.500 |

$q_R = q_n \cdot \phi_b$ = 17.35 ksf

$\varphi_b$ = 0.55 (Per Table 11.5.7-1, AASHTO LRFD BDS) Semigravity Wall

W-15-126 - FRA-70-14.05 Project 4B - Retaining Wall 4W14

Shallow Foundation Analysis - Settlement

Calculated By: BRT Date: 6/26/2022

Checked By: JPS Date: 6/27/2022

Boring B-033-1-15

| | | | |
|---|---|---|---|
| B = | 13.4 | ft | Effective Footing width |
| $D_w$ = | 0.0 | ft | Depth below bottom of footing |
| q = | 5,720 | psf | Service limit bearing pressure at bottom of wall |
| $q_{net}$ = | 4,420 | psf | Net bearing pressure at bottom of wall (considers initial overburden stress of 1,300 psf from 10-foot cut to bottom of footing elevation) |

| Soil Class. | Soil Type | Layer Depth (ft) | | Layer Thickness H (ft) | Depth to Midpoint (ft) | $N_{60}$ | γ (pcf) | $\sigma_{vo}$ Bottom (psf) | $\sigma_{vo}$ Midpoint (psf) | $\sigma_{vo}'$ Midpoint (psf) | $\sigma_m$ (1) (psf) | $\sigma_p'$ (1) (psf) | LL | $C_c$ (2) | $C_r$ (3) | $e_o$ (4) | $(N1)_{60}$ (5) | C' (6) | $Z_f$/B | I (7) | $\Delta\sigma_v$ (8) (psf) | $\sigma_{vf}'$ Midpoint (psf) | $S_c$ (9,10) (ft) | $S_c$ (in) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1-b | G | 0.0 | 0.7 | 0.7 | 0.4 | 51 | 135 | 95 | 47 | 25 | | | | | | | 102 | 300 | 0.03 | 1.000 | 4,420 | 4,445 | 0.005 | 0.063 |
| A-1-b | G | 0.7 | 1.7 | 1.0 | 1.2 | 51 | 135 | 230 | 162 | 87 | | | | | | | 102 | 300 | 0.09 | 0.998 | 4,410 | 4,497 | 0.006 | 0.069 |
| A-3a | G | 1.7 | 4.7 | 3.0 | 3.2 | 58 | 135 | 628 | 429 | 231 | | | | | | | 100 | 300 | 0.24 | 0.965 | 4,264 | 4,494 | 0.013 | 0.152 |
| A-3a | G | 4.7 | 7.6 | 3.0 | 6.1 | 58 | 135 | 1,026 | 827 | 445 | | | | | | | 87 | 288 | 0.46 | 0.846 | 3,737 | 4,182 | 0.010 | 0.120 |
| A-1-b | G | 7.6 | 10.1 | 2.5 | 8.9 | 73 | 135 | 1,364 | 1,195 | 643 | | | | | | | 101 | 300 | 0.66 | 0.719 | 3,178 | 3,820 | 0.006 | 0.077 |
| A-4a | C | 10.1 | 12.6 | 2.5 | 11.4 | 50 | 135 | 1,701 | 1,532 | 824 | 4,000 | 4,824 | 23 | 0.117 | 0.012 | 0.452 | | | 0.85 | 0.618 | 2,732 | 3,556 | 0.013 | 0.154 |
| A-4a | C | 12.6 | 15.1 | 2.5 | 13.9 | 50 | 135 | 2,039 | 1,870 | 1,006 | 4,000 | 5,006 | 23 | 0.117 | 0.012 | 0.452 | | | 1.03 | 0.536 | 2,371 | 3,376 | 0.011 | 0.127 |
| A-3 | G | 15.1 | 18.4 | 3.3 | 16.7 | 87 | 140 | 2,494 | 2,266 | 1,222 | | | | | | | 101 | 256 | 1.25 | 0.462 | 2,043 | 3,266 | 0.005 | 0.065 |
| A-3 | G | 18.4 | 21.6 | 3.3 | 20.0 | 87 | 140 | 2,949 | 2,721 | 1,475 | | | | | | | 96 | 239 | 1.49 | 0.398 | 1,759 | 3,234 | 0.005 | 0.056 |
| A-4a | C | 21.6 | 24.1 | 2.5 | 22.9 | 50 | 140 | 3,299 | 3,124 | 1,698 | 4,000 | 5,698 | 17 | 0.063 | 0.006 | 0.405 | | | 1.71 | 0.353 | 1,562 | 3,260 | 0.003 | 0.038 |
| A-4a | C | 24.1 | 26.6 | 2.5 | 25.4 | 50 | 140 | 3,649 | 3,474 | 1,892 | 4,000 | 5,892 | 17 | 0.063 | 0.006 | 0.405 | | | 1.89 | 0.322 | 1,422 | 3,314 | 0.003 | 0.033 |
| A-3a | G | 26.6 | 29.1 | 2.5 | 27.9 | 90 | 140 | 3,999 | 3,824 | 2,086 | | | | | | | 89 | 296 | 2.08 | 0.295 | 1,304 | 3,390 | 0.002 | 0.021 |
| A-3a | G | 29.1 | 31.6 | 2.5 | 30.4 | 90 | 140 | 4,349 | 4,174 | 2,280 | | | | | | | 86 | 283 | 2.26 | 0.272 | 1,204 | 3,483 | 0.002 | 0.020 |
| A-1-a | G | 31.6 | 36.6 | 5.0 | 34.1 | 99 | 140 | 5,049 | 4,699 | 2,571 | | | | | | | 91 | 300 | 2.54 | 0.244 | 1,078 | 3,649 | 0.003 | 0.030 |
| A-1-b | G | 36.6 | 41.6 | 5.0 | 39.1 | 40 | 140 | 5,749 | 5,399 | 2,959 | | | | | | | 35 | 113 | 2.92 | 0.214 | 946 | 3,905 | 0.005 | 0.064 |
| A-1-b | G | 41.6 | 46.6 | 5.0 | 44.1 | 42 | 140 | 6,449 | 6,099 | 3,347 | | | | | | | 35 | 113 | 3.29 | 0.191 | 842 | 4,189 | 0.004 | 0.052 |
| A-1-b | G | 46.6 | 49.6 | 3.0 | 48.1 | 42 | 140 | 6,869 | 6,659 | 3,657 | | | | | | | 34 | 109 | 3.59 | 0.175 | 774 | 4,431 | 0.002 | 0.027 |
| | | | | | | | | | | | | | | | | | | | | | Total Settlement: | | | 1.167 in |

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate $\sigma_m$ of 4,000 psf for moderately overconsolidated soil deposit; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.10(C_c)$; Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
5. $(N1)_{60} = C_n N_{60}$, where $C_N = [0.77\log(40/\sigma_{vo}')] \leq 2.0$ ksf; Ref. Section 10.4.6.2.4, AASHTO LRFD BDS
6. Bearing capacity index; Ref. Figure 10.6.2.4.2-1, AASHTO LRFD BDS
7. Influence factor for strip loaded footing; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \leq \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \leq \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

| | | | |
|---|---|---|---|
| Calculated By: | BRT | Date: | 6/26/2022 |
| Checked By: | JPS | Date: | 6/27/2022 |

Boring B-033-1-15

| | | | |
|---|---|---|---|
| $B$ = | 12.6 | ft | |
| $L$ = | 300 | ft | |
| $c$ = | 8,000 | psf | |
| $\gamma$ = | 130 | pcf | |
| $D_f$ = | 5.0 | ft | |
| $\varphi$ = | 0 | deg | |
| $D_w$ = | 0.0 | ft | Below ground surface |

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$ = 41.78 ksf

$N_{cm} = N_c s_c i_c$ = 5.18

$N_{qm} = N_q s_q d_q i_q$ = 1.00

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 0.00

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_c$ = | 5.14 | $s_c$ = | 1+(12.6 ft/300 ft)(1/5.14) = | 1.008 | $i_c$ = | 1.000 | $d_q$ = | 1+2tan(0°)[1-sin(0°)]²tan⁻¹(5 ft/12.6 ft) = | 1.000 |
| $N_q$ = | 1.00 | $s_q$ = | 1+(12.6 ft/300 ft)tan(0°) = | 1.000 | $i_q$ = | 1.000 | $C_{wq}$ = | 0.0 ft < 5.0 ft = | 0.500 |
| $N_\gamma$ = | 0.00 | $s_\gamma$ = | 1-0.4(12.6 ft/300 ft) = | 0.983 | $i_\gamma$ = | 1.000 | $C_{w\gamma}$ = | 0.0 ft < 1.5(12.6 ft) + 5 ft = | 0.500 |

$q_R = q_n \cdot \phi_b$ = 22.98 ksf

$\varphi_b$ = 0.55 (Per Table 11.5.7-1, AASHTO LRFD BDS) Semigravity Wall

W-15-126 - FRA-70-14.05 Project 4B - Retaining Wall 4W14
Shallow Foundation Analysis - Settlement

Calculated By: BRT Date: 6/26/2022
Checked By: JPS Date: 6/27/2022

Boring B-033-3-15

| | | | |
|---|---|---|---|
| B = | 13.4 | ft | Effective Footing width |
| $D_w$ = | 0.0 | ft | Depth below bottom of footing |
| q = | 5,720 | psf | Service limit bearing pressure at bottom of wall |
| $q_{net}$ = | 4,160 | psf | Net bearing pressure at bottom of wall (considers initial overburden stress of 1,560 psf from 12-foot cut to bottom of footing elevation) |

| Soil Class. | Soil Type | Layer Depth (ft) | | Layer Thickness H (ft) | Depth to Midpoint (ft) | $N_{60}$ | γ (pcf) | $\sigma_{vo}$ Bottom (psf) | $\sigma_{vo}$ Midpoint (psf) | $\sigma_{vo}'$ Midpoint (psf) | $\sigma_m$ (1) (psf) | $\sigma_p'$ (1) (psf) | LL | $C_c$ (2) | $C_r$ (3) | $e_o$ (4) | $(N1)_{60}$ (5) | C' (6) | $Z_f$/B | I (7) | $\Delta\sigma_v$ (8) (psf) | $\sigma_{vf}'$ Midpoint (psf) | $S_c$ (9,10) (ft) | $S_c$ (in) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1-b | G | 0.0 | 1.4 | 1.4 | 0.7 | 56 | 135 | 189 | 95 | 51 | | | | | | | 112 | 300 | 0.05 | 1.000 | 4,158 | 4,209 | 0.009 | 0.107 |
| A-1-b | G | 1.4 | 2.8 | 1.4 | 2.1 | 56 | 135 | 378 | 284 | 152 | | | | | | | 104 | 300 | 0.16 | 0.988 | 4,111 | 4,264 | 0.007 | 0.081 |
| A-1-b | G | 2.8 | 5.3 | 2.5 | 4.1 | 56 | 135 | 716 | 547 | 294 | | | | | | | 92 | 300 | 0.30 | 0.936 | 3,893 | 4,187 | 0.010 | 0.115 |
| A-1-b | G | 5.3 | 7.8 | 2.5 | 6.6 | 56 | 135 | 1,053 | 884 | 476 | | | | | | | 83 | 300 | 0.49 | 0.825 | 3,434 | 3,909 | 0.008 | 0.091 |
| A-1-b | G | 7.8 | 10.3 | 2.5 | 9.1 | 78 | 135 | 1,391 | 1,222 | 657 | | | | | | | 107 | 300 | 0.68 | 0.710 | 2,954 | 3,611 | 0.006 | 0.074 |
| A-1-b | G | 10.3 | 12.8 | 2.5 | 11.6 | 78 | 140 | 1,741 | 1,566 | 845 | | | | | | | 101 | 300 | 0.86 | 0.611 | 2,542 | 3,386 | 0.005 | 0.060 |
| A-1-b | G | 12.8 | 15.3 | 2.5 | 14.1 | 78 | 140 | 2,091 | 1,916 | 1,039 | | | | | | | 95 | 300 | 1.05 | 0.531 | 2,207 | 3,246 | 0.004 | 0.049 |
| A-1-b | G | 15.3 | 17.8 | 2.5 | 16.6 | 78 | 140 | 2,441 | 2,266 | 1,233 | | | | | | | 91 | 300 | 1.24 | 0.466 | 1,940 | 3,173 | 0.003 | 0.041 |
| A-4b | C | 17.8 | 21.3 | 3.5 | 19.6 | 107 | 135 | 2,913 | 2,677 | 1,457 | 4,000 | 5,457 | 19 | 0.081 | 0.008 | 0.420 | | | 1.46 | 0.405 | 1,687 | 3,143 | 0.007 | 0.080 |
| A-4b | C | 21.3 | 25.1 | 3.8 | 23.2 | 107 | 140 | 3,445 | 3,179 | 1,731 | 4,000 | 5,731 | 19 | 0.081 | 0.008 | 0.420 | | | 1.73 | 0.349 | 1,451 | 3,182 | 0.006 | 0.069 |
| A-1-b | G | 25.1 | 30.1 | 5.0 | 27.6 | 96 | 140 | 4,145 | 3,795 | 2,073 | | | | | | | 95 | 300 | 2.06 | 0.298 | 1,238 | 3,311 | 0.003 | 0.041 |
| A-1-b | G | 30.1 | 35.1 | 5.0 | 32.6 | 96 | 140 | 4,845 | 4,495 | 2,461 | | | | | | | 90 | 300 | 2.43 | 0.255 | 1,059 | 3,520 | 0.003 | 0.031 |
| A-1-b | G | 35.1 | 40.1 | 5.0 | 37.6 | 96 | 140 | 5,545 | 5,195 | 2,849 | | | | | | | 85 | 300 | 2.81 | 0.222 | 924 | 3,773 | 0.002 | 0.024 |
| A-1-b | G | 40.1 | 44.6 | 4.5 | 42.4 | 96 | 140 | 6,175 | 5,860 | 3,217 | | | | | | | 81 | 300 | 3.16 | 0.198 | 824 | 4,042 | 0.001 | 0.018 |
| A-6a | C | 44.6 | 50.1 | 5.5 | 47.4 | 50 | 140 | 6,945 | 6,560 | 3,605 | 4,000 | 7,605 | 24 | 0.126 | 0.013 | 0.460 | | | 3.53 | 0.178 | 740 | 4,345 | 0.004 | 0.046 |
| A-4a | C | 50.1 | 55.1 | 5.0 | 52.6 | 113 | 140 | 7,645 | 7,295 | 4,013 | 4,000 | 8,013 | 20 | 0.090 | 0.009 | 0.428 | | | 3.93 | 0.160 | 667 | 4,680 | 0.002 | 0.025 |
| A-1-b | G | 55.1 | 57.1 | 2.0 | 56.1 | 50 | 140 | 7,925 | 7,785 | 4,284 | | | | | | | 37 | 122 | 4.19 | 0.151 | 627 | 4,911 | 0.001 | 0.012 |
| | | | | | | | | | | | | | | | | | | | | | | Total Settlement: | | 0.966 in |

1. $\sigma_p' = \sigma_{vo}' + \sigma_m$; Estimate $\sigma_m$ of 4,000 psf for moderately overconsolidated soil deposit; Ref. Table 11.2, Coduto 2003
2. $C_c = 0.009(LL-10)$; Ref. Table 6-9, FHWA GEC 5
3. $C_r = 0.10(C_c)$; Ref. Chapter 8.11, Holtz and Kovacs 1981
4. $e_o = (C_c/0.54)+0.35$; Ref. Table 6-11, FHWA GEC 5
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; $I = [\beta+\sin(\beta)\cos(\beta+2\delta)]/\pi$, where $\beta = \tan^{-1}[(x+B/2)/Z_f]-\delta$, $\delta = \tan^{-1}[(x-B/2)/Z_f]$ and x = horizontal distance from center of footing; Ref. Figure 6.13 and Equation 6.24, Das 2005
8. $\Delta\sigma_v = q_e(I)$
9. $S_c = [C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_{vo}')$ for $\sigma_p' \le \sigma_{vo}' < \sigma_{vf}'$; $[C_r/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')$ for $\sigma_{vo}' < \sigma_{vf}' \le \sigma_p'$; $[Cr/(1+e_o)](H)\log(\sigma_p'/\sigma_{vo}')+[C_c/(1+e_o)](H)\log(\sigma_{vf}'/\sigma_p')$ for $\sigma_{vo}' < \sigma_p' < \sigma_{vf}'$; Ref. Section 10.6.2.4.3, AASHTO LRFD BDS (Cohesiv soil layers)
10. $S_c = H(1/C')\log(\sigma_{vf}'/\sigma_{vo}')$; Ref. Section 10.6.2.4.2, AASHTO LRFD BDS (Granular soil layers)

Boring B-033-3-15

| | | | |
|---|---|---|---|
| B = | 12.6 | ft | |
| L = | 300 | ft | |
| c = | 0 | psf | |
| $\gamma$ = | 135 | pcf | |
| $D_f$ = | 5.0 | ft | |
| $\varphi$ = | 40 | deg | |
| $D_w$ = | 0.0 | ft | Below ground surface |

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + \tfrac{1}{2}\gamma B N_{\gamma m} C_{w\gamma}$$ = 69.99 ksf

$N_{cm} = N_c s_c i_c$ = 78.01

$N_{qm} = N_q s_q d_q i_q$ = 71.84

$N_{\gamma m} = N_\gamma s_\gamma i_\gamma$ = 107.57

2.5

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $N_c$ = | 75.31 | $s_c$ = | 1+(12.6 ft/300 ft)(64.2/75.31) = | 1.036 | $i_c$ = | 1.000 | $d_q$ = | 1+2tan(40°)[1-sin(40°)]²tan⁻¹(5 ft/12.6 ft) = | 1.081 |
| $N_q$ = | 64.20 | $s_q$ = | 1+(12.6 ft/300 ft)tan(40°) = | 1.035 | $i_q$ = | 1.000 | $C_{wq}$ = | 0.0 ft < 5.0 ft = | 0.500 |
| $N_\gamma$ = | 109.41 | $s_\gamma$ = | 1-0.4(12.6 ft/300 ft) = | 0.983 | $i_\gamma$ = | 1.000 | $C_{w\gamma}$ = | 0.0 ft < 1.5(12.6 ft) + 5 ft = | 0.500 |

$q_R = q_n \cdot \phi_b$ = 38.49 ksf

$\varphi_b$ = 0.55 (Per Table 11.5.7-1, AASHTO LRFD BDS) Semigravity Wall

# APPENDIX VII

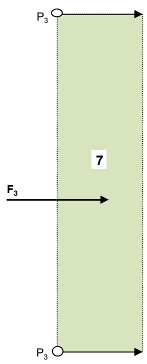
# EXTERNAL STABILITY ANALYSIS CALCULATIONS BY GPD GROUP

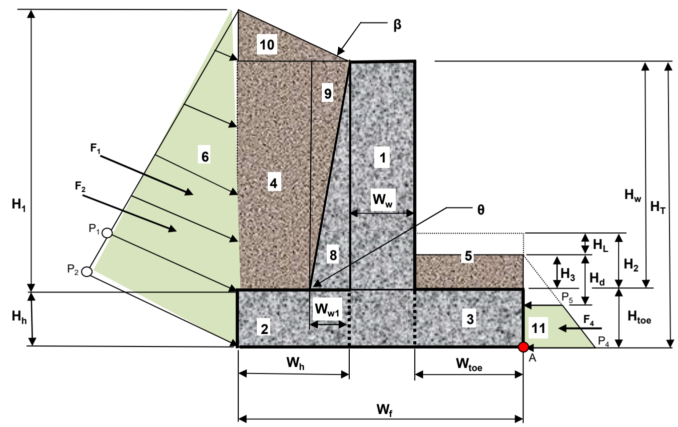
## Spread Footing Retaining Wall Design

*Based on AASHTO LRFD Bridge Design Specifications (9th edition) and the 2020 ODOT BDM.*

### Wall Data:

| | | | |
|---|---|---|---|
| Concrete Unit Weight, $\gamma_c$ = | 0.150 | kcf | |
| Toe Height, $H_{toe}$ = | 4.25 | ft | |
| Heel Height, $H_h$ = | 4.00 | ft | |
| Wall Height, $H_w$ = | 29.50 | ft | |
| Total Height, $H_T = H_w + H_{toe}$ = | 33.75 | ft | |
| Soil Height over Heel, $H_1 = H_T - H_h + (W_h * S_e)$ = | 29.75 | ft | |
| Max. Soil Height over Toe, $H_2$ = | 5.00 | ft | |
| Future Loss of Soil over Toe, $H_L$ = | 0.00 | ft | |
| Min. Soil Height over Toe, $H_3 = \max(0, H_2 - H_L)$ = | 5.00 | ft | |
| Depth of Disturbance, $H_d$ = | 2.67 | ft | |
| Wall Width, $W_w$ = | 1.50 | ft | |
| Toe Width, $W_{toe}$ = | 4.00 | ft | |
| Heel Width, $W_h$ = | 12.00 | ft | |
| Additional Wall Width, $W_{w1}$ = | 2.50 | ft | |
| Theta, $\theta$ = | 85.20 | deg. | |
| Footing Width, $W_f$ = | 17.50 | ft | |




### Soil Data:

| | | | |
|---|---|---|---|
| Is Retained Soil Sloped? | No | | |
| Slope of Embankment, $S_e$ = | 0.00 | | |
| Beta, $\beta$ = | 0.00 | deg. | |
| Include Surcharge over Heel? | Yes | | |
| Include Surcharge over Toe? | Yes | | |
| Is traffic < $H_T$ / 2 from back of wall? | Yes | | *HT / 2 = 16.88 ft* |
| Dist. from back of wall to edge of traffic = | 0.00 | ft | *LRFD 3.11.6.4* |
| Minimum Soil Unit Weight for LLS, $\gamma_{soil\ LLS}$ = | 0.125 | kcf | *BDM 307.1.1* |
| Surcharge Height behind Wall, $H_s$ = | 2.00 | ft | *LRFD Table 3.11.6.4-1* |
| Surcharge Height in front of Wall, $H_{sf}$ = | 3.73 | ft | |
| $P_{soil\ LLS} = \gamma_{soil\ LLS} * (k_a \text{ or } k_0)$ = | 41.67 | pcf | |
| Active or At Rest Pressure? | Active | | |
| Retained Soil Unit Weight, $\gamma_{soil}$ = | 0.120 | kcf | *BDM Table 307-1* |
| Footing Resting On? | Granular | | |
| Internal Friction Angle of Soil, $\delta$ = | 40.00 | deg. | *@ Base of the Footer* |
| Internal Friction Angle of Fill, $\phi'_{fill}$ = | 30.00 | deg. | |
| Friction Angle between Fill & Wall, $\delta$ = | 20.00 | deg. | *LRFD 3.11.5.3* |
| Active Lateral Earth Press. Coefficient, ka = | 0.33 | | *LRFD 3.11.5.3-1 (Coulomb)* |
| $P_{soil} = \gamma_{soil} * (k_a \text{ or } k_0)$ = | 40.00 | pcf | |
| Bearing on soil or rock? | Soil | | *LRFD 10.6.1.4* |
| Factor Bearing Resistance (Strength) = | 29.095 | ksf | |
| Bearing Capacity (Service) = | 7.414 | ksf | *To Check Settlement* |
| Consider Passive Force on Toe? | No | | |
| Passive Lat. Earth Pressure Coeff., $k_p$ = | 3.00 | | $k_p = \tan^2(45° + \phi'_f/2)$ |

**Horizontal Sliding Resistance:**
*LRFD 10.6.3.4*

For cohesionless soils:

| | | |
|---|---|---|
| $V_{min}$ = | 73.36 | kips |
| Resistance, $R_\tau = V_{min} * \tan(\delta)$ = | 61.56 | kips |

For cohesive soils:

| | | |
|---|---|---|
| *The lesser of:* $C_u$ = | N.A. | ksf |
| $0.5 * \sigma'_v$ = | N.A. | ksf |
| Unit Shear Resistance: Use = | N.A. | ksf |
| Resistance, $R\tau$ = | N.A. | kips |

Manual Override:

| | | |
|---|---|---|
| Override Friction Factor = | | |
| Resistance, $R\tau$ = | N.A. | kips |

**Typical values for friction factor:**
*LRFD Table C3.11.5.3-1*

rock = 0.70
course grained soil w/out silt = 0.55
course grained soil w/silt = 0.45

*Additional friction factors for other common substrates*
shale = 0.55
silt = 0.35

Soil Pressure Calculations:

| | | |
|---|---|---|
| $P_1 = P_{soil} * H_1 / 1000$ = | 1.19 | ksf |
| $P_2 = P_{soil} * (H_1 + H_h) / 1000$ = | 1.35 | ksf |
| $P_3 = H_s * P_{soil\ LLS} / 1000$ = | 0.08 | ksf |
| $P_4 = \gamma_{soil} * k_p * (H_{toe} + H_2 - H_L)$ = | 3.33 | ksf |
| $P_5 = \gamma_{soil} * k_p * H_d$ = | 0.96 | ksf |

Soil Sliding Force Calculations:

| | | |
|---|---|---|
| $F_1 = P_1 * H_1 * 0.5$ = | 17.70 | kips |
| $F_2 = P_2 * (H_1 + H_h) * 0.5$ = | 22.78 | kips |
| $F_3 = P_3 * H_1$ = | 2.81 | kips |
| $F_4$ (Trapezoid 11) = | 0.00 | kips |

| | | | |
|---|---|---|---|
| Additional Dead Load = | 0.70 | kips | *Assumes 1.25 max. & 0.90 min. load factors.* |
| Moment Arm for Additional Dead Load = | 4.71 | ft | *from Point A* |

**Force and Moment Arm Calculations:**

| | | | | | | |
|---|---|---|---|---|---|---|
| Area 1 = $\gamma_c$ x $W_w$ x $H_T$ = | 0.150 kcf x | 1.50 ft. x | 33.75 ft. x | 1.00 ft. = | | **7.59 kips** |
| Arm 1 = $W_{toe}$ + $W_w$ / 2 = | 4.00 ft. + | 1.50 ft. | / 2.00 = | | | **4.75 ft.** |
| Area 2 = $\gamma_c$ x $W_h$ x $H_h$ = | 0.150 kcf x | 12.00 ft. x | 4.00 ft. x | 1.00 ft. = | | **7.20 kips** |
| Arm 2 = $W_{toe}$ + $W_w$ + $W_h$ / 2 = | 4.00 ft. + | 1.50 ft. + | 12.00 ft. | / 2.00 = | | **11.50 ft.** |
| Area 3 = $\gamma_c$ x $W_{toe}$ x $H_{toe}$ = | 0.150 kcf x | 4.00 ft. x | 4.25 ft. x | 1.00 ft. = | | **2.55 kips** |
| Arm 3 = $W_{toe}$ / 2 = | 4.00 ft. | / 2.00 = | | | | **2.00 ft.** |
| Area 4 = $\gamma_s$ x ($W_h$ - $W_{w1}$) x $H_W$ = | 0.120 kcf x | ( 12.00 ft. - | 2.50 ft. ) x | 29.50 ft. x | 1.00 ft. = | **33.63 kips** |
| Arm 4 = $W_{toe}$ + $W_w$ + $W_{w1}$ + ($W_h$ - $W_{w1}$) / 2 = | 4.00 ft. + | 1.50 ft. + | 2.50 ft. + | ( 12.00 ft. - | 2.50 ft. ) / 2 = | **12.75 ft.** |
| Area 5 **(Max.)** = $\gamma_s$ x $W_{toe}$ x $H_2$ = | 0.120 kcf x | 4.00 ft. x | 5.00 ft. x | 1.00 ft. = | | **2.40 kips** |
| Area 5 **(Min.)** = $\gamma_s$ x $W_{toe}$ x $H_3$ = | 0.120 kcf x | 4.00 ft. x | 5.00 ft. x | 1.00 ft. = | | **2.40 kips** |
| Arm 5 = $W_{toe}$ / 2 = | 4.00 ft. | / 2.00 = | | | | **2.00 ft.** |
| Area 6 **(Horiz. Comp.)** = $F_2$ x cos($\delta$) = | 22.78 kips x | cos ( | 20.00 deg. ) | = | | **21.41 kips** |
| Arm 6 = ($H_1$ + $H_h$) / 3 = | ( 29.75 ft. + | 4.00 ft. ) | / 3.00 = | | | **11.25 ft.** |
| Area 6 **(Vertical Comp.)** = $F_2$ x sin($\delta$) = | 22.78 kips x | sin ( | 20.00 deg. ) | = | | **7.79 kips** |
| Arm 6 = Wf = | 17.50 ft. | | | | | **17.50 ft.** |
| Area 7 = $F_3$ = | 2.81 kips | | | | | **2.81 kips** |
| Arm 7 = ($H_1$ + $H_h$) / 2 = | ( 29.75 ft. + | 4.00 ft. ) | / 2.00 = | | | **16.88 ft.** |
| Area 8 = 0.5 x $\gamma_c$ x $W_{w1}$ x $H_W$ = | 0.5 x 0.150 kcf x | 2.50 ft. x | 29.50 ft. x | 1.00 ft. = | | **5.53 kips** |
| Arm 8 = $W_{toe}$ + $W_w$ + $W_{w1}$ / 3 = | 4.00 ft. + | 1.50 ft. + | 2.50 ft. | / 3.00 = | | **6.33 ft.** |

**Force and Moment Arm Calculations (Continued):**

| | | | | | | |
|---|---|---|---|---|---|---|
| Area 9 = 0.5 x $\gamma_s$ x $W_{w1}$ x $H_W$ = | 0.5 x 0.120 kcf x | 2.50 ft. x | 29.50 ft. x | 1.00 ft. = | | **4.43 kips** |
| Arm 9 = $W_{toe}$ + $W_w$ + $W_{w1}$ x 2/3 = | 4.00 ft. + | 1.50 ft. + | 2.50 ft. | x 2.00 | / 3.00 = | **7.17 ft.** |
| Area 10 = 0.5 x $\gamma_s$ x ($S_e$ x $W_h$) x $W_h$ = | 0.5 x 0.120 kcf x | ( 0.00 x | 12.00 ft. ) x | 12.00 ft. x | 1.00 ft. = | **0.00 kips** |
| Arm 10 = $W_F$ - $W_h$ / 3 = | 17.50 ft. - | 12.00 ft. | / 3.00 = | | | **13.50 ft.** |
| Area 11 = $F_4$ = | 0.00 kips | | | | | **0.00 kips** |
| Surcharge on Heel = $\gamma_{soil\ LLS}$ x $W_h$ x $H_s$ = | 0.125 kcf x | 12.00 ft. x | 2.00 ft. x | 1.00 ft. = | | **3.00 kips** |
| Arm for Heel Surcharge = $W_F$ - $W_h$ / 2 = | 17.50 ft. - | 12.00 ft. | / 2.00 = | | | **11.50 ft.** |
| Surcharge on Toe = $\gamma_{soil\ LLS}$ x $W_{toe}$ x $H_{sf}$ = | 0.125 kcf x | 4.00 ft. x | 3.73 ft. x | 1.00 ft. = | | **1.86 kips** |
| Arm for Toe Surcharge = $W_{toe}$ / 2 = | 4.00 ft. | / 2.00 = | | | | **2.00 ft.** |

**Check Bearing Pressure:**
*per BDM 307.1.5 and LRFD 11.6.3.2.*

Factored Bearing Resistance = **29.10 ksf**

Maximum Strength Load Pressures:
Bearing pressure at Toe = **8.26 ksf** OK
Bearing pressure at Heel = **8.26 ksf** OK

**Check Eccentricity:**
*per BDM 307.1.4 and LRFD 11.6.3.3.*

Maximum Allowable e = B/3 = **5.83 ft**
Controlling Eccentricity = **3.68 ft** OK

**Check Sliding:**
*per BDM 307.1.3 and LRFD 11.6.3.6.*

Resistance factor, $\phi_\tau$ (Sliding) = 1.00 *LRFD Table 11.5.7-1*
Resistance factor, $\phi_{ep}$ (Passive pressure) = 0.50 *LRFD Table 10.5.5.2.2-1*

Sliding Resistance:
Unfactored Horizontal Sliding Resistance = 61.56 kips
Factored Horizontal Sliding Resistance = 61.56 kips

Passive Resistance on Footing Toe:
Unfactored Passive Resistance = 0.00 kips
Factored Passive Resistance = 0.00 kips

Passive Resistance on Footing Key or Sheet Piling (Below bottom of Footing):
Vertical Projection Below Footing = 0.00 ft

Pressure at Bottom of Footing ($P_4$) = 3.33 ksf
Pressure at Bottom of Disturbance ($P_5$) = 0.96 ksf
Pressure at Bottom of Key or Sheeting = 3.33 ksf

Unfactored Passive Resistance = 0.00 kips
Factored Passive Resistance = 0.00 kips

Total Factored Resisting Force = **61.56 kips**
Driving Force = **37.03 kips** OK

**Check Settlement:**

Service Bearing Capacity = **7.41 ksf**
Service Bearing Pressure at Toe = **5.72 ksf** OK
Service Bearing Pressure at Heel = **5.72 ksf** OK

**Summary of Load Effects:**

| | MAX. BEARING PRESSURE | MIN. BEARING PRESSURE | ECCENTRICITY MAX. LF | ECCENTRICITY MIN. LF | SLIDING FORCES MAX. LF | VERTICAL FORCES MIN. LF |
|---|---|---|---|---|---|---|
| STRENGTH I | 8.26 | 8.26 | 2.71 | 3.68 | 37.03 | 73.36 |
| SERVICE I | 5.72 | 5.72 | 2.24 | N/A | 24.22 | 71.83 |

**Load Modification Factors:**
*LRFD 1.3.3, LRFD 1.3.4, LRFD 1.3.5, & BDM 1001*

Ductility $\eta_D$ = 1.00 *(use 1.00 for all limit states)*
Redundancy $\eta_R$ = 1.00 *(use 1.00 for redundant structures and 1.05 for non-redundant structures)*
Operational importance $\eta_I$ = 1.00 *(use 1.00 for all limit states)*

| | | | | | |
|---|---|---|---|---|---|
| Client: | ODOT/District 6 | Job No.: | 2015370 | | |
| Project: | FRA-70 Project 4B | Page No.: | 1 | Of | 3 |
| Subject: | Wall 4W14 Design | Designed: | RFV | Date: | 3/18/2019 |
| | Sections up to 29.50 feet tall. | Checked: | MOJ | Date: | 6/1/2022 |

## STRENGTH I Load Combination

**Sliding Forces & Overturning Moments**

*1.50*EH+1.75*LS(H). Ignores resisting moments from passive force on toe/key/sheeting, which is conservative.*

*ΣM about point "A"*

| Area/Force | Unfactored Load | Load Factor | Force (k) | Moment Arm (ft) | Moment (k-ft) Max. Load Factor | |
|---|---|---|---|---|---|---|
| 6 (Horizontal comp.) | 21.41 | 1.50 | 32.11 | 11.25 | 361.27 | Horiz. Forces |
| 7 | 2.81 | 1.75 | 4.92 | 16.88 | 83.06 | |
| | | Σ Sliding Forces, $F_s$ = | 37.03 kips | Σ Overturning Moments = | 444.33 k*ft. | |

**Vertical Forces & Resisting Moments**

*1.5*DC+1.35*EV+1.75*LS $_V$ (Max.)* *0.9*DC+1.0*EV (Min.)*

*ΣM about point "A"*

| Area/Force | Force (k) Unfactored Load | Max. Load Factor | Force (k) Max. Load Factor | Min. Load Factor | Force (k) Min. Load Factor (*This column is for stability*) | Moment Arm (ft) | Moment (k-ft) Max. Load Factor | Moment (k-ft) Min. Load Factor (*This column is for stability*) | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 7.59 | 1.25 | 9.49 | 0.90 | 6.83 | 4.75 | 45.09 | 32.46 | |
| 2 | 7.20 | 1.25 | 9.00 | 0.90 | 6.48 | 11.50 | 103.50 | 74.52 | Dead Loads |
| 3 | 2.55 | 1.25 | 3.19 | 0.90 | 2.30 | 2.00 | 6.38 | 4.59 | From Concrete |
| 8 | 5.53 | 1.25 | 6.91 | 0.90 | 4.98 | 6.33 | 43.79 | 31.53 | |
| 4 | 33.63 | 1.35 | 45.40 | 1.00 | 33.63 | 12.75 | 578.86 | 428.78 | Dead Loads |
| 5 (Max.) | 2.40 | 1.35 | 3.24 | 1.00 | 2.40 | 2.00 | 6.48 | 4.80 | From Soil *(Do* |
| 5 (Min.) | 2.40 | 1.35 | 3.24 | 1.00 | 2.40 | 2.00 | 6.48 | 4.80 | *not include 5* |
| 6 (Vertical comp.) | 7.79 | 1.50 | 11.69 | 1.50 | 11.69 | 17.50 | 204.54 | 204.54 | *(Min.) and 5* |
| 9 | 4.43 | 1.35 | 5.97 | 1.00 | 4.43 | 7.17 | 42.81 | 31.71 | *(Max.)* |
| 10 | 0.00 | 1.35 | 0.00 | 1.00 | 0.00 | 13.50 | 0.00 | 0.00 | *simultaneously)* |
| Surcharge on Heel | 3.00 | 1.75 | 5.25 | 0.00 | 0.00 | 11.50 | 60.38 | 0.00 | |
| Surcharge on Toe | 1.86 | 1.75 | 3.26 | 0.00 | 0.00 | 2.00 | 6.52 | 0.00 | External Loads |
| DC | 0.70 | 1.25 | 0.88 | 0.90 | 0.63 | 4.71 | 4.14 | 2.98 | |
| | | Σ Vert. Forces = | 104.29 kips | Σ Vert. Forces = | 73.36 kips | Σ Resist. Moments = | 1102.48 k*ft. | 815.92 k*ft. | |

*Note: Calculations for each controlling load case are not necessarily shown below, but have been included in the design checks.*

| *Max. Load Factor Calculations (Worst case bearing pressure shown.)* | |
|---|---|
| Overturning Moment = Σ Overturning Moments = | 444.33 k-ft. |
| Resisting Moment = Σ Max. Resisting Moments = | 1102.48 k-ft. |
| Net Moment = Resisting Moment - Overturning Moment = | 658.15 k-ft. |
| Total Vertical Force (TVF) = Σ Vert. Forces = | 104.29 kips |
| Dist. from Point A (Ā) = Net. Moment / TVF = | 6.31 ft. |
| Eccentricity "e" = (0.5*$W_f$) - Ā = | 2.44 ft. |
| Maximum Bearing Pressure = TVF/(Wf-2*e) = | 8.26 ksf |
| Minimum Bearing Pressure = TVF/(Wf-2*e) = | 8.26 ksf |

| *Min. Load Factor Calculations (Worst case eccentricity shown.)* | |
|---|---|
| Overturning Moment = Σ Overturning Moments = | 444.33 k-ft. |
| Resisting Moment = Σ Min. Resisting Moments = | 815.92 k-ft. |
| Net Moment = Resisting Moment - Overturning Moment = | 371.59 k-ft. |
| Total Vertical Force (TVF) = Σ Vert. Forces = | 73.36 kips |
| Dist. from Point A (Ā) = Net. Moment / TVF = | 5.07 ft. |
| Eccentricity "e" = (0.5*$W_f$) - Ā = | 3.68 ft. |

## SERVICE I Load Combination

**Sliding Forces & Overturning Moments**

*1.0*EH+1.0*LS $_H$. Ignores resisting moments from passive force on toe/key/sheeting, which is conservative.*

*ΣM about point "A"*

| Area/Force | Unfactored Load | Load Factor | Force (k) | Moment Arm (ft) | Moment (k-ft) Max. Load Factor | |
|---|---|---|---|---|---|---|
| 6 (Horizontal comp.) | 21.41 | 1.00 | 21.41 | 11.25 | 240.84 | Horiz. Forces |
| 7 | 2.81 | 1.00 | 2.81 | 16.88 | 47.46 | |
| | | Σ Sliding Forces, $F_s$ = | 24.22 kips | Σ Overturning Moments = | 288.31 k*ft. | |

**Vertical Forces & Resisting Moments**

*1.0*DC+1.0*EV+1.0*LS $_V$*

*ΣM about point "A"*

| Area/Force | Force (k) Unfactored Load | Load Factor | Force (k) | Moment Arm (ft) | Moment (k-ft) | |
|---|---|---|---|---|---|---|
| 1 | 7.59 | 1.00 | 7.59 | 4.75 | 36.07 | |
| 2 | 7.20 | 1.00 | 7.20 | 11.50 | 82.80 | Dead Loads From |
| 3 | 2.55 | 1.00 | 2.55 | 2.00 | 5.10 | Concrete |
| 8 | 5.53 | 1.00 | 5.53 | 6.33 | 35.03 | |
| 4 | 33.63 | 1.00 | 33.63 | 12.75 | 428.78 | Dead Loads |
| 5 (Max.) | 2.40 | 1.00 | 2.40 | 2.00 | 4.80 | From Soil (Do not |
| 5 (Min.) | 2.40 | 1.00 | 2.40 | 2.00 | 4.80 | include 5 (Min.) and |
| 6 (Vertical comp.) | 7.79 | 1.00 | 7.79 | 17.50 | 136.36 | 5 (Max.) |
| 9 | 4.43 | 1.00 | 4.43 | 7.17 | 31.71 | simultaneously) |
| 10 | 0.00 | 1.00 | 0.00 | 13.50 | 0.00 | |
| Surcharge on Heel | 3.00 | 1.00 | 3.00 | 11.50 | 34.50 | |
| Surcharge on Toe | 1.86 | 1.00 | 1.86 | 2.00 | 3.73 | External Loads |
| DC | 0.70 | 1.00 | 0.70 | 4.71 | 3.32 | |
| | | Σ Vert. Forces = | 76.69 kips | Σ Resisting Moments = | 802.20 k*ft. | |

*Note: Calculations for each controlling load case are not necessarily shown below, but have been included in the design checks.*

| *Calculations for worst case bearing pressure shown.* | |
|---|---|
| Overturning Moment = Σ Overturning Moments = | 288.31 k-ft. |
| Resisting Moment = Σ Max. Resisting Moments = | 802.20 k-ft. |
| Net Moment = Resisting Moment - Overturning Moment = | 513.89 k-ft. |
| Total Vertical Force (TVF) = Σ Vert. Forces = | 76.69 kips |
| Dist. from Point A (Ā) = Net. Moment / TVF = | 6.70 ft. |
| Eccentricity "e" = (0.5*$W_f$) - Ā = | 2.05 ft. |
| Maximum Bearing Pressure = TVF/(Wf-2*e) = | 5.72 ksf |
| Minimum Bearing Pressure = TVF/(Wf-2*e) = | 5.72 ksf |

- Where the wall is supported by a soil foundation:

the vertical stress shall be calculated assuming a uniformly distributed pressure over an effective base area as shown in Figure 11.6.3.2-1.

The vertical stress shall be calculated as follows:

$$\sigma_v = \frac{\Sigma V}{B - 2e} \qquad (11.6.3.2\text{-}1)$$

- Where the wall is supported by a rock foundation:

the vertical stress shall be calculated assuming a linearly distributed pressure over an effective base area as shown in Figure 11.6.3.2-2. If the resultant is within the middle one-third of the base:

$$\sigma_{vmax} = \frac{\Sigma V}{B}\left(1 + 6\frac{e}{B}\right) \qquad (11.6.3.2\text{-}2)$$

$$\sigma_{vmin} = \frac{\Sigma V}{B}\left(1 - 6\frac{e}{B}\right) \qquad (11.6.3.2\text{-}3)$$

where the variables are as defined in Figure 11.6.3.2-2. If the resultant is outside the middle one-third of the base:

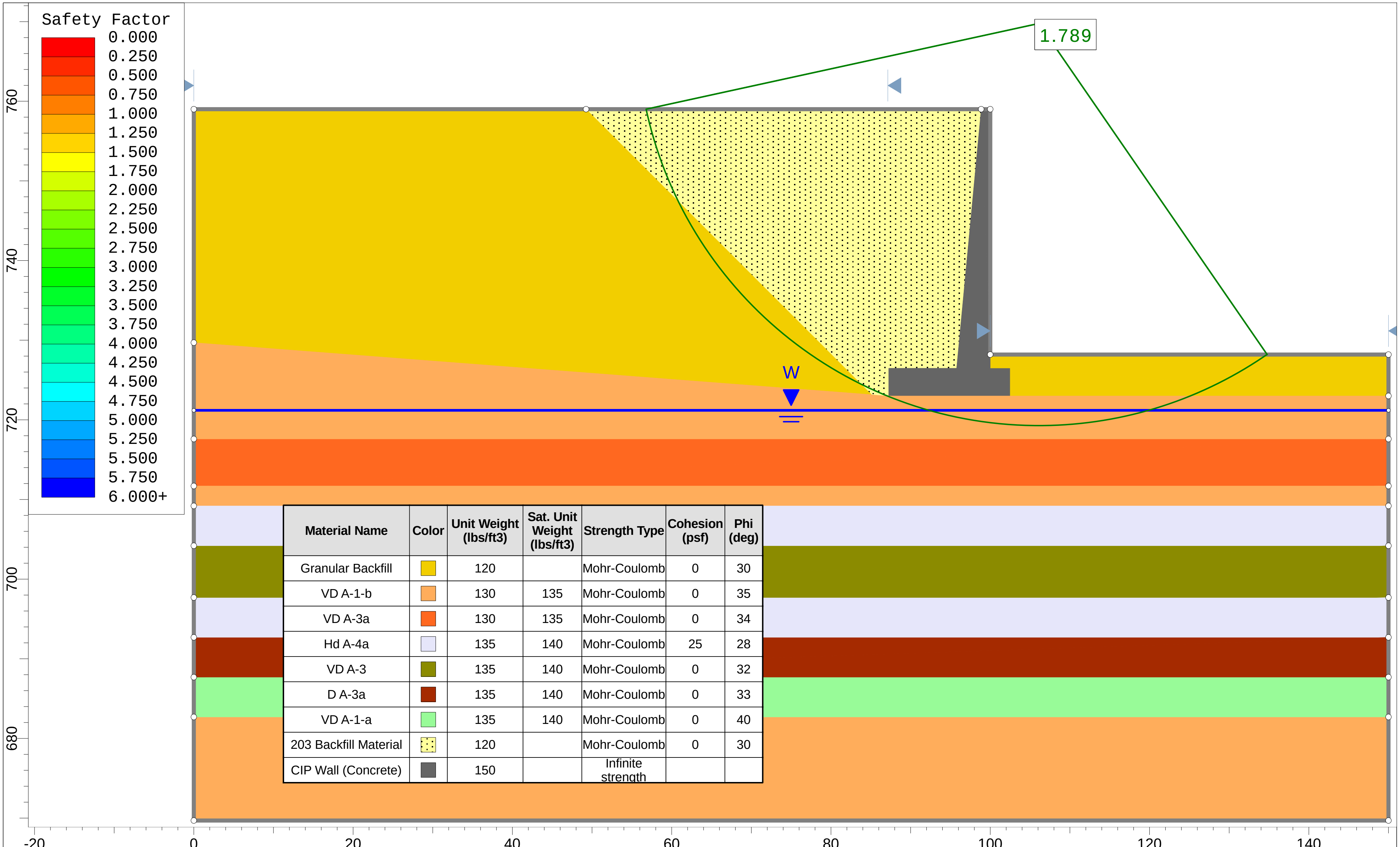
$$\sigma_{vmax} = \frac{2\Sigma V}{3[(B/2) - e)]} \qquad (11.6.3.2\text{-}4)$$

$$\sigma_{vmin} = 0 \qquad (11.6.3.2\text{-}5)$$

where the variables are as defined in Figure 11.6.3.2-2.

# APPENDIX VIII

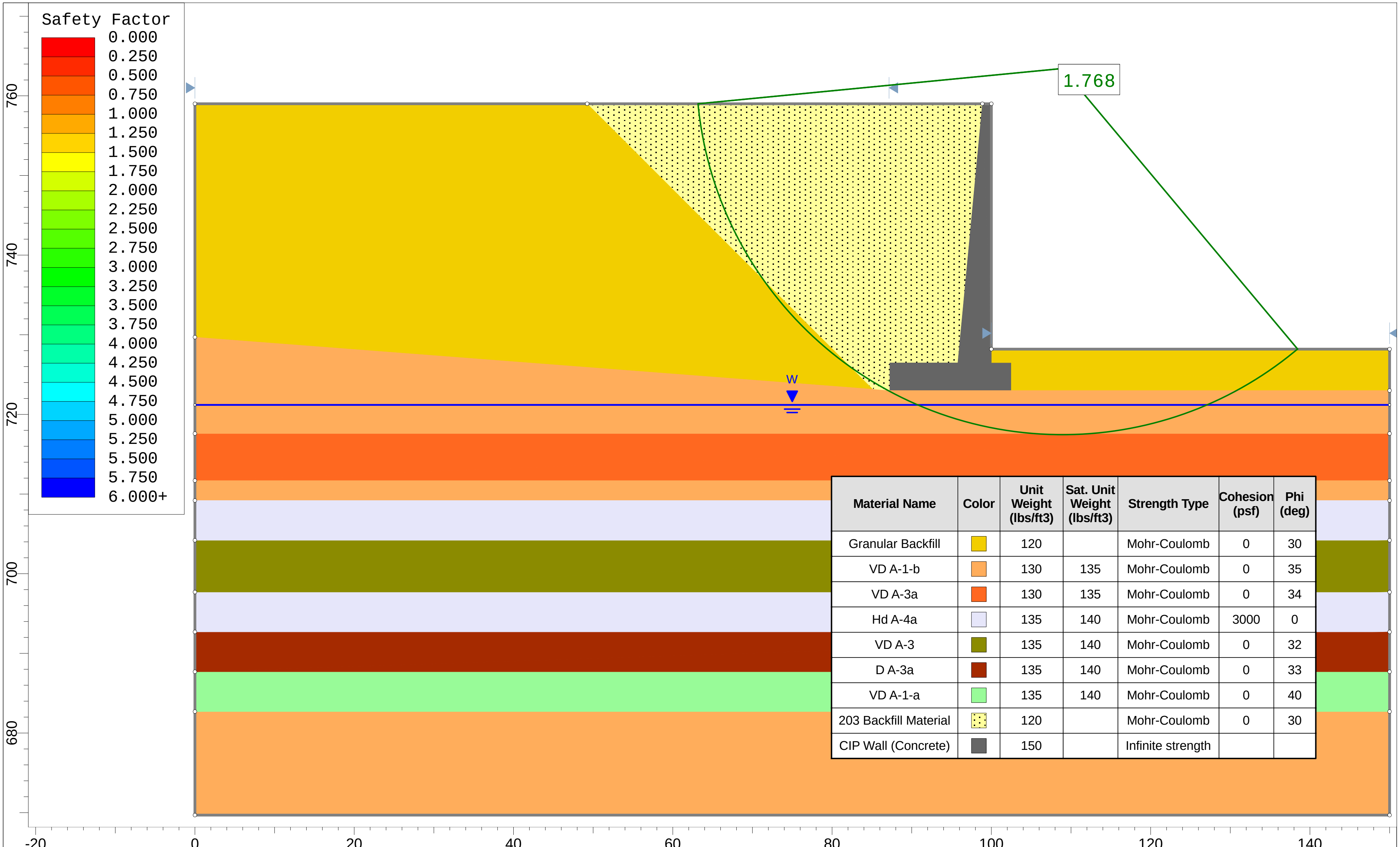
# GLOBAL STABILITY ANALYSIS OUTPUT




| Material Name | Color | Unit Weight (lbs/ft3) | Sat. Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) |
|---|---|---|---|---|---|---|
| Granular Backfill | | 120 | | Mohr-Coulomb | 0 | 30 |
| VD A-1-b | | 130 | 135 | Mohr-Coulomb | 0 | 35 |
| VD A-3a | | 130 | 135 | Mohr-Coulomb | 0 | 34 |
| Hd A-4a | | 135 | 140 | Mohr-Coulomb | 25 | 28 |
| VD A-3 | | 135 | 140 | Mohr-Coulomb | 0 | 32 |
| D A-3a | | 135 | 140 | Mohr-Coulomb | 0 | 33 |
| VD A-1-a | | 135 | 140 | Mohr-Coulomb | 0 | 40 |
| 203 Backfill Material | | 120 | | Mohr-Coulomb | 0 | 30 |
| CIP Wall (Concrete) | | 150 | | Infinite strength | | |

| | |
|---|---|
| *Project* | FRA-70-14.05 Project 4B ¦ PID No. 96053 |
| *Analysis Description* | B-033-1-15 - Spenser's - Overall Global Stability Retaining Wall 4W14 |
| *Drawn By* | HSK |
| *Scale* | 1:200 |
| *Company* | Resource International, Inc. |
| *Date* | 11/27/2018 4:25:50 PM |
| *File Name* | W-15-126 4W14-Run1.slim |

SLIDEINTERPRET 7.036




| Material Name | Color | Unit Weight (lbs/ft3) | Sat. Unit Weight (lbs/ft3) | Strength Type | Cohesion (psf) | Phi (deg) |
|---|---|---|---|---|---|---|
| Granular Backfill | | 120 | | Mohr-Coulomb | 0 | 30 |
| VD A-1-b | | 130 | 135 | Mohr-Coulomb | 0 | 35 |
| VD A-3a | | 130 | 135 | Mohr-Coulomb | 0 | 34 |
| Hd A-4a | | 135 | 140 | Mohr-Coulomb | 3000 | 0 |
| VD A-3 | | 135 | 140 | Mohr-Coulomb | 0 | 32 |
| D A-3a | | 135 | 140 | Mohr-Coulomb | 0 | 33 |
| VD A-1-a | | 135 | 140 | Mohr-Coulomb | 0 | 40 |
| 203 Backfill Material | | 120 | | Mohr-Coulomb | 0 | 30 |
| CIP Wall (Concrete) | | 150 | | Infinite strength | | |

| | |
|---|---|
| *Project* | FRA-70-14.05 Project 4B ¦ PID No. 96053 |
| *Analysis Description* | B-033-1-15 - Spenser's - Undrained - Overall Global Stability Retaining Wall 4W14 |
| *Drawn By* | HSK |
| *Scale* | 1:200 |
| *Company* | Resource International, Inc. |
| *Date* | 11/27/2018 4:39:43 PM |
| *File Name* | W-15-126 4W14-Run1-Undrained.slim |

SLIDEINTERPRET 7.036