Resource International, Inc.

# HAM-75-7.85
# HAM-562-0004
# RAMP M SR-562 OVER I-75
# PID NO. 77889
# HAMILTON COUNTY, OHIO

# STRUCTURE FOUNDATION EXPLORATION REPORT

*Prepared For:*
EMH&T
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Rii Project No. B-10-020

June 2023

RESOURCE INTERNATIONAL, INC.
ISO 9001:2015 Certified QMS
An ISO 9001:2015 QMS Certified Firm

Planning

Engineering

Construction Management

Technology

June 20, 2023

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**Re: Structure Foundation Exploration**
**HAM-75-7.85**
**HAM-562-0004 – Ramp M SR-562 over I-75**
**PID No. 77889**
**Rii Project No. B-10-020**

Ms. Cueva:

Resource International, Inc. (Rii) is pleased to submit this structure foundation exploration report for the 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 proposed replacement of the HAM-562-0004 bridge carrying Ramp M of State Route 562 over Interstate 75 as part of the HAM-75-7.85 project. The proposed bridge is located approximately 2.6 miles south of the Lockland Split on the north side of Cincinnati, in Hamilton County, 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.
Vice President – Geotechnical Planning

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Vice President – Geotechnical Services

Enclosure: Structure Foundation Exploration Report

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## EXECUTIVE SUMMARY

Resource International, Inc. (Rii) has completed a structure foundation exploration performed for the HAM-562-0004 bridge structure carrying the Ramp M of SR-562 over I-75. The existing structure is four-span bridge with a total length of approximately 235 feet. It is understood that the existing structure will be completely removed and that the proposed structure will be located approximately 40 feet south of the existing structure and will consist of a four-span steel beam structure with a reinforced concrete deck and a total length of approximately 380 feet.

A preliminary structure foundation exploration was performed by CTL Engineering for this bridge structure replacement as part of the HAM-75-2.30 Step 7 Preliminary Engineering (PID No. 76257) and their findings are presented in the report dated December 17, 2007. No additional borings were obtained at this structure for the current exploration. Therefore, all recommendations contained herein are based on information obtained from the preliminary exploration. For a complete summary of the field operations and findings for the borings performed by CTL Engineering, please reference the December 2007 report.

### Exploration and Findings

Two borings, designated as B-161-0-07 and B-163-0-07, were performed for this bridge, one each near the proposed abutment locations, as part of a preliminary geotechnical exploration performed by CTL Engineering. Based on the proposed configuration of the new alignments for the interchange, one boring, designated as B-062-0-07, from the HAM-75-0791 exploration performed by CTL Engineering as part of the HAM-75-2.30 project was also utilized in the analysis for the HAM-562-0004 structure for the proposed Pier 1 location. The borings were advanced to depths ranging from 95.0 to 120.0 feet below the existing ground surface.

In general, the borings performed by CTL encountered primarily cohesive soils with intermittent seams of granular material. The cohesive soils were generally described as soft to hard, gray, brown, brownish gray and dark brown sandy silt, silt, silt and clay, silty clay and clay (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6). The granular soils were generally described as loose to very dense granular soil generally described as brown, gray and dark gray gravel, gravel with sand, silt and clay, fine sand and coarse and fine sand (ODOT A-1-a, A-2-6, A-3, A-3a). Groundwater was encountered in all three borings at elevations ranging from 476.5 to 511.7 feet msl.

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

## Analyses and Recommendations

*Bridge Foundation Recommendations*

Design details of the structure proposed were provided to Rii by EMH&T. It is understood that the new structure will consist of a four-span steel beam structure with a semi-integral on MSE wall rear abutment, full height cast-in-place (CIP) wall-type forward abutment, and reinforced concrete piers supported on deep foundation systems comprised of driven piles. It is understood that the proposed structure will be located approximately 40 feet south of the existing structure, and that the existing structure will be completely removed.

It is recommended that a deep foundation system consisting of driven piles be employed for support of the proposed bridge foundation elements. Based on the soil encountered at this site, it is recommended that 16.0-inch CIP pipe piles (ODOT Item 507.06) be employed for foundation support. The following table shows recommended pile lengths of the CIP pipe piles, and the corresponding ultimate bearing value ($R_{ndr}$) and LRFD reduction factors (φ).

## Pile Recommendations

| Boring No. | Ground Elevation [1] (feet msl) | Pile Size [2] | Elevations (feet msl) | | Embedment Depth [5] (feet) | $R_{ndr}$ [6,7] (kips/pile) | Sleeve Length [8] (feet) | φ [9] |
|---|---|---|---|---|---|---|---|---|
| | | | Top [3] | Tip [4] | | | | |
| B-161 (Rear Abutment) | 551.1 | 16" CIP | 544.3 | 467.0 / 467.5 | 65 / 67 | 265 / 375 | 12.3 / 9.8 | 0.7 |
| B-162 (Pier 1) | 516.2 | 16" CIP | 525.9 | 445.8 | 65 | 246 / 336 | 21.7 | 0.7 |
| B-163 (Pier 2) | 555.0 | 16" CIP | 510.0 | 447.0 | 63 | 285 / 385 | N/A | 0.7 |
| B-163 (Forward Abutment) | 555.0 | 16" CIP | 533.3 / 542.3 | 474.3 / 478.3 | 59 / 64 | 225 / 325 | N/A | 0.7 |

1. *Ground elevation listed is the ground elevation at the boring location.*
2. *The pile wall thickness utilized in the analysis was determined in accordance with the equation provided in ODOT Item 507.06 and was rounded up to the nearest 1/16-inch increment.*
3. *Pile top elevation is at the proposed bottom of footing elevation. The bottom of footing at the forward abutment steps up along the length of the abutment. The elevations shown are the maximum and minimum elevations of the bottom of the footing.*
4. *Where multiple values are listed, the first elevation listed is the tip elevation for piles driven from the lowest bottom of footing/wall elevation, and the second value is the tip elevation for piles driven from the highest bottom of footing/wall elevation. The tip elevation for intermediate piles driven along the abutments may be linearly interpolated between the tip elevations provided for the lowest and highest bottom of footing/wall elevation.*
5. *Embedment depths represent the length of pile in contact with the soil. Where multiple values are listed, the first value is the embedment depth required to obtain the capacity listed for piles driven from the lowest bottom of footing/wall elevation, and the second value is the required embedment depth for piles driven from the highest bottom of footing/wall elevation.*
6. *The embedment depth and corresponding ultimate bearing value listed above are based on the maximum driving depth that can be achieved based on driveability requirements for the pile wall thickness required per ODOT Item 506.07.*
7. *The ultimate bearing value listed does not include capacity reduction due to downdrag loads at the rear abutment and pier 1. Downdrag loads and considerations are presented in Section 5.1.2. The first value listed is the ultimate bearing value during the driven condition (immediately after driving the pile). The second value listed is the ultimate bearing value after soil setup has occurred following **a minimum waiting period of 5 days after the initial drive** (at the time of restrike on the pile). Please note that the ultimate bearing value listed is valid for piles driven from both the lowest and highest bottom of footing/wall elevation. Note that the values provided are based on the static analysis performed and represent the anticipated resistance available. The design plans should list the required UBV based on the pile loading.*
8. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall backfill. Multiple values represent the length of pile to be sleeved through the MSE wall backfill as the bottom of wall elevation steps up along the abutment length. For Pier 1, the sleeve length also includes the 6.5-foot undercut depth below the bottom of wall elevation.*
9. *The resistance factor listed considers dynamic testing of the pile elements will be performed per Section 303.4.2.7 of the ODOT BDM. Alternate resistance factors may be applied based on the type and frequency of field testing specified.*

**NOTE**: The top of pile elevation coincides with the bottom of footing elevations, and the estimated pile lengths reflect exclusively the length of the pile in contact with the soil. **Embedment length of the pile into the footing is not included.** Estimated pile lengths are rounded up to the nearest foot.

The total anticipated settlement at the rear abutment at the face of the wall is 0.66 inches. Based on the total anticipated settlement at the face of the wall, downdrag loads are anticipated to develop if the piles are driven to the design tip elevation prior to construction of the MSE walls. If it is considered that the settlement of the granular material will take place during and immediately following construction of the MSE wall, the total anticipated settlement at the face of the wall will be reduced to 0.37 inches. Therefore, provided that piles are installed to the design tip elevation following completion of the MSE wall, downdrag loads are not anticipated to develop.

The anticipated total settlement at the center of the MSE wall at the rear abutment of the HAM-75-0791 bridge structure is 6.77 inches. Given the anticipated amount of settlement, downdrag loads may be induced on the pile elements if installed to the final tip elevation prior to construction of the wall/embankment. Based on the results of the settlement analysis, the time rate of consolidation to achieve 0.4 inches of total settlement is 395 days, which is well beyond a reasonable timeframe for a hold period. Therefore, pier 1 will need to be designed to accommodate the estimated drag load.

The depth of the neutral plane is 28.0 feet below the bottom of wall elevation at pier 1, and the calculated drag load based on the depth of the neutral plane is 78 kips. Per Section 305.3.2.2 of the 2020 ODOT BDM, the factored structural axial resistance of the pile at the strength limit state shall equal or exceed the combined effect of the factored drag load and the maximum factored load per pile. Based on a maximum factored load of 234 kips/pile and a drag load of 82 kips at pier 1, the combined factored load of 316 kips/pile at pier 1 is less than the factored structural pile resistance.

In addition to resisting the factored drag load on the piles, the bridge design will need to accommodate the anticipated soil settlement and elastic compression of the pile due to the combined structure load and drag load under service (unfactored) loading conditions within the depth to the neutral plane. Based on a combined service load of 221 kips at pier 1, the resulting elastic compression is 0.139 inches.

The total settlements noted in the last column in the following table will need to be accommodated in the bridge design, provided the piles are driven to the final pile tip elevation following completion of construction of the MSE wall (including placement of a surcharge up to the roadway profile grade) or specified hold period at pier 1.

**Summary of Settlement Analysis at Rear Abutment [1]**

| Duration Following Completion of Construction (days) | Settlement within Depth of Neutral Plane (inches) | Elastic Compression of Pile within Depth of Neutral Plane (inches) | Total Settlement within Depth of Neutral Plane (inches) |
|---|---|---|---|
| 0 | 3.590 | 0.139 | 4.533 |
| 30 | 1.284 | 0.139 | 1.535 |
| 45 | 1.002 | 0.139 | 1.187 |
| 60 | 0.806 | 0.139 | 0.949 |
| 75 | 0.676 | 0.139 | 0.794 |
| 90 | 0.569 | 0.139 | 0.670 |

1. *The analysis assumes the placement of a surcharge load in order to preload the site under the full weight of the MSE wall height (from the bottom of wall elevation to the profile grade of the roadway).*

*MSE Wall Recommendations*

Based upon the proposed plan information, the MSE wall at the rear abutment will have a stepped geometry along the length of the abutment as it crosses the existing slope. The top of leveling pad elevation will range from 532.0 to 534.5 ft msl and profile grade will be at an approximate elevation of 559.5 ft msl. For the analysis of external and global stability, a maximum wall height of 27.5 feet from the top of the leveling pad to the proposed profile grade of the roadway is anticipated along the abutment length.

The anticipated bearing materials at the rear abutment consist of dense to very dense sandy silt (ODOT A-4a). MSE wall foundations bearing on this soil or engineered fill, placed and compacted as described in Section 5.4 of the full report, may be proportioned for a nominal bearing resistance as indicated in the following table. A geotechnical resistance factor of $\varphi_b$=0.65 was considered in calculating the factored nominal bearing resistance at the strength limit state. Based on the minimum length of reinforced soil mass presented in the table below and utilizing the soil parameters listed in Section 5.2.1 of the full report, the bearing pressure on the front portion of the wall **will not exceed** the factored nominal bearing resistance at the strength limit state at the rear abutment.

**HAM-562-0004 MSE Wall Spread Footing Design Parameters**

| Boring No. | Maximum Wall Height (feet) | Minimum Reinforcement Length [1] | Nominal Bearing Resistance (ksf) | | Total Settlement [3] (inches) |
|---|---|---|---|---|---|
| | | | Service | Strength [2] | |
| B-161 (Rear Abutment) | 27.5 | 0.70(H) | 7.7 | 23.2 | 0.97 / 0.66 |

1. *The minimum reinforcement length is expressed as a percentage of the wall height, H, at the respective location.*
2. *The nominal bearing resistance at the strength limit state is unfactored. Rii recommends that a resistance factor of $\varphi_b$=0.65 be considered when calculating the factored nominal bearing resistance at the strength limit state.*
3. *The first value represents the anticipated total settlement at the center of the reinforced soil mass, and the second values represents the anticipated total settlement at the facing of the wall.*

For MSE walls bearing on soil, the limiting eccentricity is one-fourth of the base width of the wall. Based on the soil parameters listed in Section 5.2.1 of the full report, for an MSE wall designed with a minimum strap length as noted above, the calculated eccentricity of the resultant force **will not exceed** the limiting eccentricity at the strength limit state.

Based on the soil parameters listed in Section 5.2.1 of the full report for the foundation and retained material, a coefficient of sliding friction of 0.60 was utilized for design. A geotechnical resistance factor of $\varphi_\tau$=1.0 was considered when calculating the factored shear resistance between the soil and foundation for sliding. Based on the soil parameters listed in Section 5.2.1 of the full report, for an MSE wall designed with minimum a strap length as noted above, the resultant horizontal forces on the back of the MSE wall **will not exceed** the factored shear resistance at the strength limit state.

Overall (global) stability for MSE walls supporting structural elements is satisfied when a minimum factor of safety of 1.54 is obtained under loading conditions at the service limit state. Based on the soil parameters listed in Section 5.2.1 of the full report, for MSE walls designed with minimum strap lengths as noted above, the resulting factor of safety under drained and undrained conditions was greater than 1.54.

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

## 1.0 INTRODUCTION

The overall purpose of this project is to provide detailed subsurface information and recommendations for the design and construction of the HAM-75-7.85 project in Hamilton County, Ohio. This project represents the northern portion of HAM-75-2.30 Mill Creek Expressway improvements. The overall project will consist of roadway improvements, several new retaining walls and bridge replacements along I-75 from Vine Street to State Route 126. The project site is located in the community limits of St. Bernard, Elmwood Place, Roselawn, and Cincinnati, in Hamilton County, Ohio.

This report is a presentation of the structure foundation exploration performed for the HAM-562-0004 bridge structure carrying the Ramp M of SR-562 over I-75, as shown on the Vicinity Map and Boring Plan presented in Appendix II. The existing structure is four-span bridge with a total length of approximately 235 feet. It is understood that the existing structure will be completely removed and that the proposed structure will be located approximately 40 feet south of the existing structure and will consist of a four-span steel beam structure with a reinforced concrete deck and a total length of approximately 380 feet.

A preliminary structure foundation exploration was performed by CTL Engineering for this bridge structure replacement as part of the HAM-75-2.30 Step 7 Preliminary Engineering (PID No. 76257) and their findings are presented in the report dated December 17, 2007. No additional borings were obtained at this structure for the current exploration. Therefore, all recommendations contained herein are based on information obtained from the preliminary exploration. For a complete summary of the field operations and findings for the borings performed by CTL Engineering, please reference the December 2007 report.

## 2.0 GEOLOGY AND OBSERVATIONS OF THE PROJECT

### 2.1 Site Geology

Both the Illinoian and Wisconsinan glaciers advanced over two-thirds of the State of Ohio, leaving behind glacial features such as moraines, kame deposits, lacustrine deposits and outwash terraces. The glacial and non-glacial regions comprise five physiographic sections grouped by age, depositional process and geomorphic occurrence. Physiographically, the site lies within the Illinoian Till Plain of the Till Plains Section. This area is characterized by rolling ground moraine deposits with many buried valleys alternating between broad floodplains and bedrock gorges. The site area contains silty loam till deposited as ground moraine covered with loess and dissected by the modern day Mill Creek. Ground moraines are deposited during the retreat of a glacier which results in an undifferentiated mixture of clay, silt, sand and gravel. The valley area also contains outwash and alluvium which eroded from hills and valleys with moderate relief. Outwash deposits consist of undifferentiated sand and gravel deposited by meltwater in front of glacial ice and often occurs as valley terraces or low plains.

Alluvium and alluvial terrace deposits range in composition from silty clay particles to cobbles, usually deposited in present and former floodplain areas.

Based on Bedrock Geology and Topography Maps of the area, from the Ohio Department of Natural Resources (ODNR), the underlying bedrock consists of the Ordovician-aged Point Pleasant Formation. The Point Pleasant Formation, encountered in the bedrock valleys, is comprised of interbedded limestone and shale, averaging 60 percent limestone and 40 percent shale, and ranges from 0 to 80 feet thick. The bedrock surface forms a narrow valley roughly beneath, and following, SR 562 and is aligned northwest to southeast in the vicinity of the site. The bedrock valley continues crossing under I-75 to the west of the site where the alignment of the valley changes to northeast to southwest, roughly following the existing Mill Creek Valley. The bedrock surface at the bottom of this valley is at an approximate elevation of 350 feet mean sea level (msl). According to bedrock topography mapping, the overburden soil in the vicinity of the site is approximately 170 feet thick. An illustration of the general geology of Ohio is presented in Appendix I.

## 2.2 Existing Conditions

The site for the proposed HAM-562-0004 structure is located approximately 40 feet south of the existing overpass of SR-562 Ramp M over I-75, approximately 2.6 miles south of the Lockland Split. The existing structure is a four-span bridge that is approximately 21 feet wide and 235 feet long and carries single lane of traffic from SR-562 westbound to I-75 southbound. Ramp M also crosses over the existing HAM-75-0791 bridge structure that carries I-75 over Ramp J of SR-562. I-75 underneath Ramp M is a six-lane asphalt paved roadway, and Ramp J is a single lane asphalt paved roadway that carries traffic from I-75 southbound to SR-562 eastbound. The terrain in the vicinity of the structure is undulated due to the presence of the existing embankments that support the roadway and abutments of the bridge structures at the interchange.

# 3.0 EXPLORATION

A preliminary geotechnical exploration was performed within this project study area by CTL Engineering for the HAM-75-2.30 project (PID No. 76257). Their findings were published in a report dated December 17, 2007. Two borings, designated as B-161-0-07 and B-163-0-07, were performed for this bridge, one each near the proposed abutment locations. Based on the proposed configuration of the new alignments for the interchange, one boring, designated as B-062-0-07, from the HAM-75-0791 exploration performed by CTL Engineering as part of the HAM-75-2.30 project was also utilized in the analysis for the HAM-562-0004 structure for the proposed Pier 2 location. The borings were advanced to depths ranging from 95.0 to 120.0 feet below the existing ground surface, and SPT sampling was performed at a maximum of 5.0-foot intervals to obtain representative soil samples for laboratory classification testing. Rii has included a plan showing the soil borings performed in the project area in Appendix II.

An automatic drop hammer was utilized by CTL Engineering to generate consistent energy transfer to the sampler. No calibration data is available for the hammer used during the SPT testing for the borings performed for this project. Therefore, an estimated drill rod energy ratio of 80 percent was utilized to determine the energy corrected ($N_{60}$) blow counts.

## 4.0 FINDINGS

In general, the borings performed by CTL encountered primarily cohesive soils with intermittent seams of granular material. The cohesive soils were generally described as soft to hard, gray, brown, brownish gray and dark brown sandy silt, silt, silt and clay, silty clay and clay (ODOT A-4a, A-4b, A-6a, A-6b, A-7-6). The granular soils were generally described as loose to very dense granular soil generally described as brown, gray and dark gray gravel, gravel with sand, silt and clay, fine sand and coarse and fine sand (ODOT A-1-a, A-2-6, A-3, A-3a). Groundwater was encountered in all three borings at elevations ranging from 476.5 to 511.7 feet msl.

## 5.0 ANALYSES AND RECOMMENDATIONS

Data obtained from the drilling and testing program have been used to determine 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 the structure foundation systems, 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 structure proposed were provided to Rii by EMH&T. It is understood that the new structure will consist of a four-span steel beam structure with a semi-integral on MSE wall rear abutment, full height cast-in-place (CIP) wall-type forward abutment, and reinforced concrete piers supported on deep foundation systems comprised of driven piles. It is understood that the proposed structure will be located approximately 40 feet south of the existing structure, and that the existing structure will be completely removed.

Based on the design plans provided by EMH&T, the majority of the footprint of the footing at Pier 1 is within the MSE wall mass at the rear abutment for the HAM-75-0791 bridge structure over SR-562 Ramp J. Since the majority of the footing overlaps the MSE wall mass, the design for the Pier 1 foundation will have a bottom of footing elevation that matches the bottom of footing elevation for the rear abutment of the HAM-75-0791 bridge structure. Further, the piles will be sleeved through the MSE wall mass to the bottom of the wall elevation to match the design for the rear abutment of the HAM-75-0791 bridge structure. Additionally, per the structure foundation exploration report prepared for the HAM-75-0791 bridge structure, it has been recommended that a layer of soft to medium stiff clay (ODOT A-7-6) be stabilized via a 6.5-foot undercut below the bottom of wall elevation and replacement with suitable embankment material.

It is recommended that this stabilization measure extend over the entire footprint of the Pier 1 foundation such that a uniform working platform is created.

Proposed structural data was obtained from design details provided by EMH&T and are included in Table 1:

**Table 1. Structure & Bridge Design Elevations**

| Reference | Reference Boring | Structure Component | Elevation [1] (feet msl) |
|---|---|---|---|
| Rear Abutment | B-161-0-07 | Profile Grade | 559.5 |
| | | Bottom of Footing | 544.3 |
| | | Bottom of Wall (Leveling Pad) | 532.0 / 534.5 |
| Pier 1 | B-162-0-07 | Bottom of Footing | 525.9 |
| | | Bottom of MSE Wall Mass | 510.8 |
| Pier 2 | B-163-0-07 | Bottom of Footing | 510.0 |
| Forward Abutment | B-163-0-07 | Bottom of Footing | 533.3 / 542.3 |

1. *Elevations based on structure information provided by EMH&T. Multiple values indicated that the bottom of footing / bottom of wall elevation steps up along the length of the abutment. The elevations listed indicate the lowest and highest elevations along the abutments.*

In addition to the design elevations, proposed structural loading information was provided by EMH&T for each substructure unit and are included in Table 2:

**Table 2. Structural Loading Details**

| Substructure Reference | Maximum Factored Load per Pile (kips) | Required $R_{ndr}$ per Pile [1] (kips) |
|---|---|---|
| Rear Abutment | 260 | 371 |
| Pier 1 | 234 | 334 |
| Pier 2 | 262 | 374 |
| Forward Abutment | 225 | 322 |

1. *Required $R_{ndr}$ based on a resistance factor of 0.7.*

## 5.1 Foundation Recommendations

It is recommended that a deep foundation system consisting of driven piles be employed for support of the proposed bridge foundation elements. Based on the soil encountered at this site, it is recommended that 16.0-inch CIP pipe piles (ODOT Item 507.06) be employed for foundation support. Table 3 shows recommended pile lengths of the CIP pipe piles, and the corresponding ultimate bearing value ($R_{ndr}$) and LRFD reduction factors ($\varphi$).

## Table 3. Pile Recommendations

| Boring No. | Ground Elevation [1] (feet msl) | Pile Size [2] | Elevations (feet msl) | | Embedment Depth [5] (feet) | $R_{ndr}$ [6,7] (kips/pile) | Sleeve Length [8] (feet) | φ [9] |
|---|---|---|---|---|---|---|---|---|
| | | | Top [3] | Tip [4] | | | | |
| B-161 (Rear Abutment) | 551.1 | 16” CIP | 544.3 | 467.0 / 467.5 | 65 / 67 | 265 / 375 | 12.3 / 9.8 | 0.7 |
| B-162 (Pier 1) | 516.2 | 16” CIP | 525.9 | 445.8 | 65 | 246 / 336 | 21.7 | 0.7 |
| B-163 (Pier 2) | 555.0 | 16” CIP | 510.0 | 447.0 | 63 | 285 / 385 | N/A | 0.7 |
| B-163 (Forward Abutment) | 555.0 | 16” CIP | 533.3 / 542.3 | 474.3 / 478.3 | 59 / 64 | 225 / 325 | N/A | 0.7 |

1. *Ground elevation listed is the ground elevation at the boring location.*
2. *The pile wall thickness utilized in the analysis was determined in accordance with the equation provided in ODOT Item 507.06 and was rounded up to the nearest 1/16-inch increment.*
3. *Pile top elevation is at the proposed bottom of footing elevation. The bottom of footing at the forward abutment steps up along the length of the abutment. The elevations shown are the maximum and minimum elevations of the bottom of the footing.*
4. *Where multiple values are listed, the first elevation listed is the tip elevation for piles driven from the lowest bottom of footing/wall elevation, and the second value is the tip elevation for piles driven from the highest bottom of footing/wall elevation. The tip elevation for intermediate piles driven along the abutments may be linearly interpolated between the tip elevations provided for the lowest and highest bottom of footing/wall elevation.*
5. *Embedment depths represent the length of pile in contact with the soil. Where multiple values are listed, the first value is the embedment depth required to obtain the capacity listed for piles driven from the lowest bottom of footing/wall elevation, and the second value is the required embedment depth for piles driven from the highest bottom of footing/wall elevation.*
6. *The embedment depth and corresponding ultimate bearing value listed above are based on the maximum driving depth that can be achieved based on driveability requirements for the pile wall thickness required per ODOT Item 506.07.*
7. *The ultimate bearing value listed does not include capacity reduction due to downdrag loads at the rear abutment and pier 1. Downdrag loads and considerations are presented in Section 5.1.2. The first value listed is the ultimate bearing value during the driven condition (immediately after driving the pile). The second value listed is the ultimate bearing value after soil setup has occurred following* ***a minimum waiting period of 5 days after the initial drive*** *(at the time of restrike on the pile). Please note that the ultimate bearing value listed is valid for piles driven from both the lowest and highest bottom of footing/wall elevation. Note that the values provided are based on the static analysis performed and represent the anticipated resistance available. The design plans should list the required UBV based on the pile loading.*
8. *Sleeve length represents the required length of pile that should be sleeved within the MSE wall backfill. Multiple values represent the length of pile to be sleeved through the MSE wall backfill as the bottom of wall elevation steps up along the abutment length. For Pier 1, the sleeve length also includes the 6.5-foot undercut depth below the bottom of wall elevation.*
9. *The resistance factor listed considers dynamic testing of the pile elements will be performed per Section 303.4.2.7 of the ODOT BDM. Alternate resistance factors may be applied based on the type and frequency of field testing specified.*

**NOTE**: The top of pile elevation coincides with the bottom of footing elevations, and the estimated pile lengths reflect exclusively the length of the pile in contact with the soil. **Embedment length of the pile into the footing is not included.** Estimated pile lengths are rounded up to the nearest foot.

The piles were analyzed utilizing DRIVEN software (Appendix V). The ultimate bearing values listed represents the calculated ultimate capacity at the end of driving the pile (driven condition) and at after soil setup has occurred following a specified waiting period (at restrike), respectively. If it is not intended to verify the pile capacity after a specified waiting period has passed through dynamic testing (restrike of the driven pile), then the ultimate bearing value for the driven condition should be specified in the design documents and utilized in the foundation design. If a dynamic restrike of the pile is specified, then the ultimate bearing value at restrike should be specified in the design documents and utilized in the foundation design. Based on the subsurface conditions encountered, it is recommended that a minimum waiting period of five (5) days be specified between the end of driving the pile and the time of restrike to allow adequate soil setup to occur. Note that the values provided in Table 3 are based on the static analysis performed and represent the anticipated resistance available. The design plans should list the required UBV based on the pile loading. Settlement is estimated to be less than 1.0 inch for CIP piles driven to the frictional resistance values listed in Table 3.

Please note that variable pile tip elevations have been provided at the abutment locations. These represent the estimated pile tip elevation required to achieve the ultimate bearing value listed from the lowest and highest bottom of footing/wall elevations along the abutments.

A drivability analysis in accordance with Section 10.7.8 of the 2010 AASHTO LRFD Bridge Design Specifications (BDS) was also performed using the GRLWEAP program, and results of this analysis are presented in Section 5.1.1 of this report. Please note that the embedment depth and corresponding ultimate bearing value for CIP piles presented in Table 3 are based on the maximum embedment depth that can be achieved for the required pile wall thickness as determined below based on driveability requirements for the respective pile size. The minimum wall thickness utilized in the driveability analysis for CIP piles was determined from the following equation per ODOT Item 507.06 for the ultimate bearing value listed in Table 3.

$$t = UBV / 900{,}000$$

Where:
$t$ = pile wall thickness in inches
$UBV$ = design ultimate bearing value in pounds

We emphasize that the pile lengths and ultimate bearing values presented in Table 3 are estimates using empirical equations based on the derived characteristics of the soils encountered in the subject borings drilled. The most accurate method for determining pile capacities and lengths is to drive test piling at the site and perform static load testing in accordance with the ASTM D1143 procedure. Dynamic pile load testing should be performed in accordance with ASTM D4945. The actual pile capacities should be verified using static or dynamic pile load testing as detailed in the 2007 ODOT Bridge Design Manual (BDM). Further installation considerations are presented in Section 5.1.3.

The geotechnical resistance factor listed in Table 3 represents the recommended value based on the performance of a minimum of two dynamic pile load tests at the site as specified in Section 303.4.2.7 of the 2007 ODOT BDM. A higher resistance factor may be utilized if alternate or additional field load testing of the pile elements is performed. The 2010 AASHTO LRFD BDS provides alternate resistance factors for use in design based on the type and frequency of field load testing. Figure 1 presents the various testing types and frequency of testing, and lists the corresponding resistance factor that may be selected. ***If no field load testing of the piles (static or dynamic) is performed, then a geotechnical resistance factor of 0.35 should be used for design.***

**Figure 1. AASHTO Resistance Factors for Driven Pile Foundations**

**Table 10.5.5.2.3-1—Resistance Factors for Driven Piles**

| Condition/Resistance Determination Method | | Resistance Factor |
|---|---|---|
| Nominal Bearing Resistance of Single Pile—Dynamic Analysis and Static Load Test Methods, $\varphi_{dyn}$ | Driving criteria established by successful static load test of at least one pile per site condition and dynamic testing* of at least two piles per site condition, but no less than 2% of the production piles | 0.80 |
| | Driving criteria established by successful static load test of at least one pile per site condition without dynamic testing | 0.75 |
| | Driving criteria established by dynamic testing* conducted on 100% of production piles | 0.75 |
| | Driving criteria established by dynamic testing,* quality control by dynamic testing* of at least two piles per site condition, but no less than 2% of the production piles | 0.65 |
| | Wave equation analysis, without pile dynamic measurements or load test but with field confirmation of hammer performance | 0.50 |
| | FHWA-modified Gates dynamic pile formula (End of Drive condition only) | 0.40 |
| | Engineering News (as defined in Article 10.7.3.8.5) dynamic pile formula (End of Drive condition only) | 0.10 |

* Dynamic testing requires signal matching, and best estimates of nominal resistance are made from a restrike. Dynamic tests are calibrated to the static load test, when available.

### *5.1.1 Driveability*

Rii performed a driveability analysis using GRLWEAP (Appendix VI). In the driveability analysis, a Delmag 19-42 hammer with a rated energy of approximately 43,000 ft-lbs was used in conjunction with the CIP pipe piles. Based on the results of this analysis using a wall thickness as determined from ODOT Item 507.06, it appears that the driving stresses induced on the CIP pipe piles **would not exceed** 90 percent of the yield stress for A252, Grade 2 steel ($f_y$ = 35 ksi, 0.9$f_y$ = 31.5 ksi) if driven to the depths provided in Table 3. Please note that the required pile wall thickness was determined using the equation provided in ODOT Item 507.06, and that the pile wall thickness utilized in the driveability analysis was rounded up to the near 1/16-inch increment unless otherwise noted in Table 3.

Due to the distance of the borings performed for this structure with respect to the substructure units, actual driving conditions during pile installation may differ from the conditions predicted in the analysis.

### *5.1.2 Downdrag Considerations*

#### *5.1.2.1 Rear Abutment Considerations*

Downdrag was evaluated using the traditional method to determine the depth of downdrag. Per the traditional method for calculating the depth of downdrag, downdrag loads will develop along the portion of the pile above the interface where the relative soil movement from consolidation with respect to the pile is greater than 0.40 inches. The total anticipated settlement at the rear abutment at the face of the wall is 0.66 inches. Based on the total anticipated settlement at the face of the wall, downdrag loads are anticipated to develop if the piles are driven to the design tip elevation prior to construction of the MSE walls.

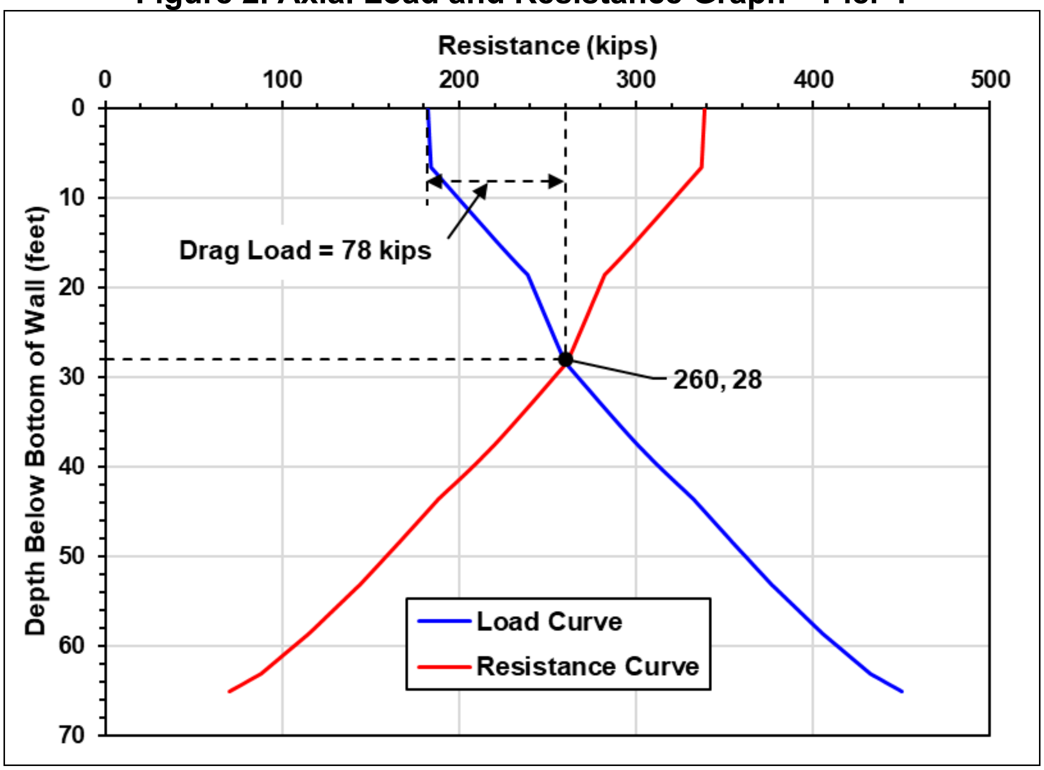
It is anticipated that the settlement of the granular material will take place during and immediately following construction of the MSE wall. Since the upper 24.0 feet of the subsurface profile consists of granular material comprised of gravel, coarse and fine sand and non-plastic sandy silt (ODOT A-1-a, A-3a, A-4a), it is anticipated that a significant amount of the anticipated settlement predicted will be complete at the end of the construction of the MSE wall. If it is considered that the settlement of the granular material will take place during and immediately following construction of the MSE wall, the total anticipated settlement at the face of the wall will be reduced to 0.37 inches. Therefore, provided that piles are installed to the design tip elevation following completion of the MSE wall, downdrag loads are not anticipated to develop. Prior to construction of the MSE wall, it is recommended that the piles be pre-driven into the soil only as far as necessary to remain vertical and that the MSE wall should be constructed around the piles. If the piles are not pre-driven, then the MSE wall should be constructed with pile sleeves, and the piles should be driven through these sleeves following completion of the MSE wall.

#### *5.1.2.2 Pier 1 Considerations*

The anticipated total settlement at the center of the MSE wall at the rear abutment of the HAM-75-0791 bridge structure is 6.77 inches. Given the anticipated amount of settlement, downdrag loads may be induced on the pile elements driven at pier 1 of the HAM-75-0004 bridge structure if installed to the final tip elevation prior to construction of the MSE wall. To reduce the amount of downdrag induced on the piles, it is recommended that the piles be pre-driven into the soil only as far as necessary to remain vertical and that the MSE wall should be constructed around the piles and then allowed to sit for a specified holding period such that settlement of the underlying foundation soils can occur prior to driving the piles the to the design tip elevation and reduce or eliminate the amount of downdrag on the piles. Downdrag loads will fully develop when then relative movement of the soil surrounding the piles exceeds 0.4 inches. Per Section 305.3.2.2 of the 2020 ODOT BDM, downdrag should be evaluated using the neutral plane method as outlined in Section 7.3.5.7 and 7.3.6.1 of FHWA Geotechnical Engineering Circular 12 (GEC 12) "Design and Construction of Driven Pile Foundations" (FHWA-NHI-16-009/010). Per the neutral plane methodology, drag loads will develop along the length of the pile above the neutral plane.

Based on the results of the settlement analysis, the time rate of consolidation to achieve 0.4 inches of total settlement is 395 days, which is well beyond a reasonable timeframe for a hold period. Therefore, pier 1 will need to be designed to accommodate the estimated drag load. Figure 2 is a plot of the axial load and resistance based on the bearing resistance from the DRIVEN analysis included in Appendix V and service load on the piles (182 kips), which indicates the neutral plane depth below the bottom of footing based on fully mobilized toe resistance in accordance with Section 305.3.2.2 of the 2020 ODOT BDM.

**Figure 2. Axial Load and Resistance Graph – Pier 1**




Based on the results of the bearing plot, the depth of the neutral plane is 28.0 feet below the bottom of wall elevation at pier 1, and the calculated drag load based on the depth of the neutral plane is 78 kips.

Per Section 305.3.2.2 of the 2020 ODOT BDM, the factored structural axial resistance of the pile at the strength limit state shall equal or exceed the combined effect of the factored drag load and the maximum factored load per pile. For piles subject to downdrag loads, the factored structural resistance of the pile shall consider a resistance factor of 0.7, which results in a factored structural resistance of 886 kips for a 16-inch pipe pile with a pile wall thickness of 0.375 (3/8) inches. A load factor of 1.05 should be applied to the unfactored downdrag load when determining the factored downdrag load per pile at the strength limit state and should be added to the factored load per pile from the superstructure. Based on a maximum factored load of 234 kips/pile and a drag load of 82 kips at pier 1, the combined factored load of 316 kips/pile at pier 1 is less than the factored structural pile resistance.

In addition to resisting the factored drag load on the piles, the bridge design will need to accommodate the anticipated soil settlement and elastic compression of the pile due to the combined structure load and drag load under service (unfactored) loading conditions within the depth to the neutral plane. For the elastic compression of the pile, since the drag load increases with depth from 0 kips at the top of the pile and bottom of wall elevation to the maximum drag load at the depth of the neutral plane, the average drag load was used in the calculation. Based on a combined service load of 221 kips at pier 1, the resulting elastic compression is 0.139 inches.

For the soil settlement within the depth of the neutral plane, consideration can be given to either driving the piles to the design pile tip elevation immediately following construction of the MSE wall, or a hold period can be specified following the completion of construction to drive the piles to the required pile tip elevation in an effort to reduce the amount of settlement that will need to be accommodated within the depth of the neutral plane. In order to consolidate the underlying soil to the required settlement, consideration should be given to the placement of a surcharge load in order to preload the site under the full weight of the MSE wall height (from the bottom of wall elevation to the profile grade of the roadway) and left in place until the end of the specified hold period in order to reduce the settlement along the pile length to the neutral plane.

To determine the estimated settlement remaining following completion of a specified hold period, the time rate of settlement will need to be evaluated. The remaining settlement will depend on the degree of consolidation, which represents the amount of primary consolidation that has occurred during the hold period expressed as a percentage of the total settlement that is anticipated and is calculated using the following equations:

$$U = \sqrt{\frac{4T_v}{\pi}} \times 100\%$$ for $T_v \leq 0.217$;

$$U = \left[1 + 10^{-\left(\frac{0.085 + T_v}{0.933}\right)}\right] \times 100\%$$ for $T_v > 0.217$;

$$T_v = \frac{c_v t}{H_{dr}{}^2}$$

Where:
$U$ = the degree of consolidation
$T_v$ = time factor
$c_v$ = coefficient of consolidation
$t$ = hold period
$H_{dr}$ = length of longest drainage path (half the thickness of the compressible stratum)

Results of the settlement analysis and time rate of consolidation at pier 1 are summarized in Table 4 below. The total settlements noted in the last column in Table 4 will need to be accommodated in the bridge design, provided the piles are driven to the final pile tip elevation following completion of construction of the MSE wall (including placement of a surcharge up to the roadway profile grade, as outlined in the previous paragraph) or specified hold period at pier 1.

**Table 4. Summary of Settlement Analysis at Pier 1 [1]**

| Duration Following Completion of Construction (days) | Settlement within Depth of Neutral Plane (inches) | Elastic Compression of Pile within Depth of Neutral Plane (inches) | Total Settlement within Depth of Neutral Plane (inches) |
|---|---|---|---|
| 0 | 4.394 | 0.139 | 4.533 |
| 30 | 1.396 | 0.139 | 1.535 |
| 45 | 1.048 | 0.139 | 1.187 |
| 60 | 0.810 | 0.139 | 0.949 |
| 75 | 0.655 | 0.139 | 0.794 |
| 90 | 0.531 | 0.139 | 0.670 |

1. *The analysis assumes the placement of a surcharge load in order to preload the site under the full weight of the MSE wall height (from the bottom of wall elevation to the profile grade of the roadway).*

It is recommended to install settlement platforms within the MSE wall mass as close to the pier footing as possible, with a minimum of one (1) settlement platform installed on each side of the pier footing. Settlement platforms should be installed once the embankment surcharge has been placed to monitor the settlement of the embankment over time. A shorter or longer hold period than specified may be required based on the settlement platform readings as directed by the geotechnical engineer.

Settlement calculations for the MSE wall at the rear abutment of the HAM-75-0791 bridge structure are provided in the structure foundation exploration report for that bridge.

### *5.1.3 Driven Pile Considerations*

Proper pile installation is as important as pile design in order to obtain a cost effective and safe product. Driven piles must be installed to develop adequate soil resistance without structural damage. Because piles cannot be visually inspected after installation, direct quality control of the finished product is impossible. Consequently, substantial control must be exercised over peripheral operations leading to the pile placement within the foundation. It is essential that installation be considered during the design stage to ensure that piles shown on the plans can be installed. Construction monitoring should be employed in (1) pile materials, (2) installation equipment, and (3) the estimation of the static load capacity.

It is recommended that the contractor submit a wave equation analysis (bearing graph) of his driving equipment, or the necessary pile driving and equipment data to perform the wave equation analysis, for hammer approval. A constant capacity wave equation analysis (inspector’s chart) should also be performed to assist field personnel during inspection in accordance with the 2007 ODOT BDM.

As noted in Section 5.1.1, due to the distance of the borings performed for this structure with respect to the substructure units, actual driving conditions during pile installation may differ from the conditions predicted in the analysis. Therefore, it is recommended that pile load testing be performed at each substructure unit to determine the actual pile driving criteria for construction. In addition, consideration could also be given to performing multiple pile load tests at the abutment locations, at the extreme ends of the footings, to determine how the driving criteria may vary along the length of the stepped abutments.

### *5.1.4 Lateral Design*

If lateral loads or moments are expected to be applied on the foundation elements, they should be analyzed to verify the pile has enough lateral and bending resistance against these loads. A boring-by-boring tabulation of parameters that should be used for lateral loading design is provided in Appendix VII. In order to evaluate the lateral capacity, it is recommended that a derivation of COM624, such as LPILE, be utilized to determine the proper embedment depth required to resist the lateral load for a given end condition and deflection. Table 5 lists the different soil types internal to the LPILE program. These strata were utilized to define the soil strata in the soil profile for each boring provided in Appendix VII.

**Table 5. Subsurface Strata Description**

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

## 5.2 MSE Wall Recommendations

It is proposed to construct an MSE wall at the rear abutment of the proposed structure. MSE walls are constructed on earthen foundations at a minimum depth of 3.0 feet below grade, as defined by the top of the leveling pad to the ground surface located 4.0 feet from the face of the wall. Note that the reinforced soil mass extends from the foundation bearing elevation to the top of MSE wall. The width of the MSE wall foundation (B) is defined by the length of the reinforced soil mass. Per the ODOT BDM (October 2007) and Supplemental Specification (SS) 840, the minimum length of the reinforced soil mass is equal to 70 percent the height of the MSE wall or 8 feet whichever is greater. A non-structural bearing leveling pad consisting of a minimum of 6-inches of unreinforced concrete should be placed at the base of the wall for constructability purposes. Please note that the leveling pad is not a structural foundation.

Based upon the proposed plan information, the MSE wall at the rear abutment will have a stepped geometry along the length of the abutment as it crosses the existing slope. The top of leveling pad elevation will range from 532.0 to 534.5 ft msl and profile grade will be at an approximate elevation of 559.5 ft msl. For the analysis of external and global stability, a maximum wall height of 27.5 feet from the top of the leveling pad to the proposed profile grade of the roadway is anticipated along the abutment length. Therefore, it is considered that the minimum reinforcement length and the effective foundation width (B) of the MSE wall for external and global stability calculations will be approximately 19.3 feet. For the analysis, the foundation width was set at 70 percent of the wall height and the foundation width was increased, if required, until external and global stability requirements were satisfied.

It is recommended that the foundation subgrade (beneath the reinforced soil mass) for the MSE wall be critically proof-rolled and stabilized to create a workable subgrade for the MSE wall reinforced soil mass. Unstable soils, primarily those containing silt (A-4a/A-4b), if encountered, may be stabilized as noted below:

- Undercut 24 inches +/- pending results of proof-roll;
- Place ODOT Item 712.09 Type D Geotextile Fabric;
- Placement of 24 inches of 703. 02A Granular Fill.

Material identified as sandy silt (ODOT A-4a) was encountered near the proposed bearing elevation at the rear abutment. However, based on the grading and consistency of the soil, this material should not require stabilization as noted above.

Please note that this recommendation for stabilization of unsuitable soils, as identified during the proof roll of the subgrade, are in addition to the foundation preparation measures provided in ODOT SS 840.

Please note that the bearing soils present at the proposed bearing elevation along the length of the rear abutment may vary from that encountered in the boring performed for this exploration. The entire bearing surface should be closely observed to verify that adequate bearing soils are present at the proposed bearing elevation.

For MSE walls, Rii recommends that consideration be given to driving the piles prior to the placement of fill and sleeving the piles extending above the existing ground surface with a plastic pipe casing as noted in Section 5.1.2. The MSE wall may then be constructed around the pile sleeves to full height.

### 5.2.1 Strength Parameters Utilized in External and Global Stability Analyses

The shear strength parameters utilized in the external and global stability analyses for the MSE walls at the abutments are provided in Table 6.

**Table 6. 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) |
|---|---|---|---|---|
| MSE Wall Backfill (Select granular fill) | 125 | 34 | 0 | N/A |
| Embankment Fill (Fill material derived from onsite soils) | 120 | 30 | 400 | 2,000 |
| Dense to Very Dense Sandy Silt [1] (ODOT A-4a) | 130 | 31 | 0 | N/A |
| Stiff to Very Stiff Silt and Clay and Silty Clay [2] (ODOT A-6a, A-6b) | 120 | 27 | 235 | 3,000 |
| Loose Coarse and Fine Sand (ODOT A-3a) | 120 | 28 | 0 | N/A |

1. *Based on laboratory consolidated undrained triaxial testing performed on an undisturbed samples from the adjacent HAM-75-11.09 project.*
2. *Based on laboratory consolidated undrained triaxial testing performed on an undisturbed sample from boring B-016-0-11 performed for Retaining Wall H.*

Shear strength parameters for the reinforced soil backfill are provided in ODOT SS 840. Per SS 840, the select granular backfill in the reinforced zone must meet the shear strength requirements provided in Table 6.

Shear strength parameters for new embankment fill were determined using ODOT Geotechnical Bulletin 6 (GB-6) as a guide. The shear strength parameters for the embankment fill listed in Table 6 above are the limiting values based on the assumption that the embankment fill utilized will consist of silt and clay, sandy silt (ODOT A-6a, A-4a) or granular material.

The long term shear strength parameters (drained/effective stress) for the natural cohesive soils were determined from consolidated undrained (CU) triaxial compression tests performed on undisturbed samples from boring B-016 (for Retaining Wall H of the HAM-75-7.85 project) and from a CU triaxial compression test performed on undisturbed samples from the HAM-75-11.09 project that is adjacent to this project location to the north. The undrained shear strength for the cohesive soils is based on indirect correlations with SPT blow counts of the soil. The friction angle for the natural granular soil encountered was determined based on correlations with the $N_{60}$ value from the SPT testing of the soil. The laboratory test results referenced above are provided in Appendix V.

### *5.2.2 Bearing Stability*

The anticipated bearing materials at the rear abutment consist of dense to very dense sandy silt (ODOT A-4a). MSE wall foundations bearing on this soil or engineered fill, placed and compacted as described in Section 5.4, may be proportioned for a nominal bearing resistance as indicated in Table 7. A geotechnical resistance factor of $\varphi_b$=0.65 was considered in calculating the factored nominal bearing resistance at the strength limit state. The reinforcement length presented in the following table represents the minimum foundation width required to satisfy external and global stability requirements, expressed as a percentage of the wall height.

**Table 7. HAM-562-0004 MSE Wall Spread Footing Design Parameters**

| Boring No. | Maximum Wall Height (ft) | Minimum Reinforcement Length [1] | Nominal Bearing Resistance (ksf) | | Total Settlement [3] (in) |
|---|---|---|---|---|---|
| | | | Service | Strength [2] | |
| B-161 (Rear Abutment) | 27.5 | 0.70(H) | 7.7 | 23.2 | 0.97 / 0.66 |

1. *The minimum reinforcement length is expressed as a percentage of the wall height, H, at the respective location.*
2. *The nominal bearing resistance at the strength limit state is unfactored. Rii recommends that a resistance factor of $\varphi_b$=0.65 be considered when calculating the factored nominal bearing resistance at the strength limit state.*
3. *The first value represents the anticipated total settlement at the center of the reinforced soil mass, and the second values represents the anticipated total settlement at the facing of the wall.*

Rii performed a verification of the bearing pressure exerted on the subgrade soils for the maximum specified wall height indicated in Table 7. Based on the minimum length of reinforced soil mass presented in Table 7 and utilizing the soil parameters listed in Section 5.2.1, the bearing pressure on the front portion of the wall **will not exceed** the factored nominal bearing resistance at the strength limit state at the rear abutment provided the subgrade is prepared as noted above.

Based profile information provided by EMH&T, it is anticipated that approximately 12.0 feet of cut will be required achieve the proposed bottom of wall elevation at the rear abutment. Therefore, the net embankment height (embankment height above existing grade up to the proposed profile grade) considered in the settlement calculations is 15.5 feet. Differential settlement of 0.31 inches is expected between the center of the reinforced soil mass and the wall facing at the rear abutment. Per Section 204.6.2.1 of the ODOT BDM, “the maximum allowable differential settlement in the longitudinal direction (regardless of the size of panels) is one (1) percent." Based on the total anticipated settlement at the facing of the wall, maximum differential settlement in the longitudinal direction is anticipated to be less than 1/1000, which is within the tolerable limit of 1/100. If either the total or differential settlement predicted presents an issue with respect to the deformation tolerances that the wall can withstand, then measures should be taken to minimize the amount of settlement that will occur. This can be achieved by preloading the site and consolidating the underlying soils prior to constructing the wall. Settlement calculations are provided in Appendix VIII.

### *5.2.3 Eccentricity (Overturning Stability)*

The resistance of the MSE wall to overturning will be dependent on the on the location of the resultant force at the bottom of the wall due to the overturning and resisting moments acting on the wall. For MSE walls, overturning stability is determined by calculating the eccentricity of the resultant force from the midpoint of the base of the wall and comparing this value to a limiting eccentricity value. Per Section 11.10.5.5 of the 2010 AASHTO LRFD BDS, for foundations bearing on soil or bedrock, the location of the resultant of the reaction forces shall be within the middle one-half of the base width. Therefore, the limiting eccentricity is one-fourth of the base width of the wall. Rii performed a verification of the eccentricity of the resultant force for the maximum specified wall height indicated in Table 7. Based on the minimum length of reinforced soil mass presented in Table 7 and utilizing the soil parameters listed in Section 5.2.1 for the retained embankment material, the calculated eccentricity of the resultant force **will not exceed** the limiting eccentricity at the strength limit state.

### *5.2.4 Sliding Stability*

The resistance of the MSE wall to sliding will be dependent on the friction between the reinforced soil backfill and bearing soils per Section 11.10.5.3 of the 2010 AASHTO LRFD BDS. For MSE walls, sliding resistance is determined by multiplying a coefficient of sliding friction "f" times the total vertical force at the base of the wall. The coefficient of sliding friction is determined based on the limiting friction angle between the foundation soil and the reinforced soil backfill. Based on the soil parameters listed in Section 5.2.1 for the foundation and reinforced soil backfill, a coefficient of sliding friction of 0.60 was utilized for design at the rear abutment. A geotechnical resistance factor of $\varphi_{\tau}$=1.0 was considered when calculating the factored shear resistance between the soil and foundation for sliding. Based on the minimum length of reinforced soil mass presented in Table 7 and utilizing the soil parameters listed in Section 5.2.1 for the for the foundation and reinforced soil backfill, the resultant horizontal forces on the back of the MSE wall **will not exceed** the factored shear resistance at the strength limit state.

### 5.2.5 *Overall (Global) Stability*

A slope stability analysis was performed to check the global stability of the wall. As per AASHTO LRFD BDS, safety against soil failure shall be evaluated at the service limit state by assuming the reinforced soil mass to be a rigid body. Soil parameters utilized in external stability analyses are presented in Section 5.2.1. For the global stability condition, it was considered that the failure plane will not cross through the reinforced soil mass.

Per Section 11.6.2.3 of the 2010 AASHTO LRFD BDS, overall (global) stability for MSE walls supporting structural elements is satisfied if the product of the factor of safety from the slope stability output multiplied by the resistance factor $\varphi$=0.65 is greater than 1.0. Therefore, global stability is satisfied when a minimum factor of safety of 1.54 is obtained. For MSE walls designed with minimum strap lengths listed in Table 7, the resulting factor of safety under drained conditions (long-term stability) greater than 1.54. The wall was also evaluated under undrained conditions (short-term stability) to verify the stability of the wall during and immediately following construction. The resulting factor of safety under undrained conditions was also greater than 1.54.

### 5.2.6 *Final MSE Wall Considerations*

Based on the results of the external and global stability analysis performed for the MSE wall, the recommended controlling strap length is 0.7 times the height of the MSE wall (measured from the top of the leveling pad to the proposed profile grade of the roadway) at the rear abutment. All of the external and global stability calculations indicate that adequate resistance is available for support of the MSE wall at the rear abutment for a strap length equal to 70 percent of the wall height.

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

## 5.3 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 8 and Table 9.

## Table 8. Estimated Undrained (Short-term) Soil Parameters for Design

| Soil Type | γ (pcf) [1] | *c* (psf) | φ' | $k_a$ | $k_o$ | $k_p$ |
|---|---|---|---|---|---|---|
| Soft to Medium Stiff Cohesive Soil | 110 | 750 | 0° | 1.0 | 1.0 | 1.0 |
| Stiff Cohesive Soil | 115 | 1,500 | 0° | 1.0 | 1.0 | 1.0 |
| Very Stiff to Hard Cohesive Soil | 120 | 3,000 | 0° | 1.0 | 1.0 | 1.0 |
| Loose Granular Soil | 120 | 0 | 28° | 0.36 | 0.53 | 2.77 |
| Medium Dense Granular Soil | 125 | 0 | 30° | 0.33 | 0.50 | 3.00 |
| Dense to Very Dense Granular Soil | 130 | 0 | 33° | 0.30 | 0.46 | 3.39 |
| Compacted Cohesive Engineered Fill | 125 | 1,500 | 0° | 1.0 | 1.0 | 1.0 |
| Compacted Granular Engineered Fill | 135 | 0 | 33° | 0.30 | 0.46 | 3.39 |

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

## Table 9. Estimated Drained (Long-term) Soil Parameters for Design

| Soil Type | γ (pcf) [1] | *c* (psf) | φ' | $k_a$ | $k_o$ | $k_p$ |
|---|---|---|---|---|---|---|
| Natural Cohesive Soil | 115 | 0 | 26° | 0.39 | 0..56 | 2.56 |
| Loose Granular Soil | 120 | 0 | 28° | 0.36 | 0.53 | 2.77 |
| Medium Dense Granular Soil | 125 | 0 | 30° | 0.33 | 0.50 | 3.00 |
| Dense to Very Dense Granular Soil | 130 | 0 | 33° | 0.30 | 0.46 | 3.39 |
| Compacted Cohesive Engineered Fill | 125 | 0 | 28° | 0.36 | 0.53 | 2.77 |
| Compacted Granular Engineered Fill | 135 | 0 | 33° | 0.30 | 0.46 | 3.39 |

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

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

## 5.4 Construction Considerations

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

### *5.4.1 Excavation Considerations*

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

**Table 10. Excavation Back Slopes**

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

### *5.4.2 Groundwater Considerations*

Based on the groundwater observations made during drilling, little to no groundwater seepage is anticipated during construction. However, where/if groundwater is encountered, proper groundwater control should be employed and maintained to prevent disturbance to excavation bottoms consisting of cohesive soil, and to prevent the possible development of a quick or "boiling" condition where soft silts and/or fine sands are encountered. It is preferable that the groundwater level, if encountered, be maintained at least 36 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 our recommendations.

Our 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 preliminary 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

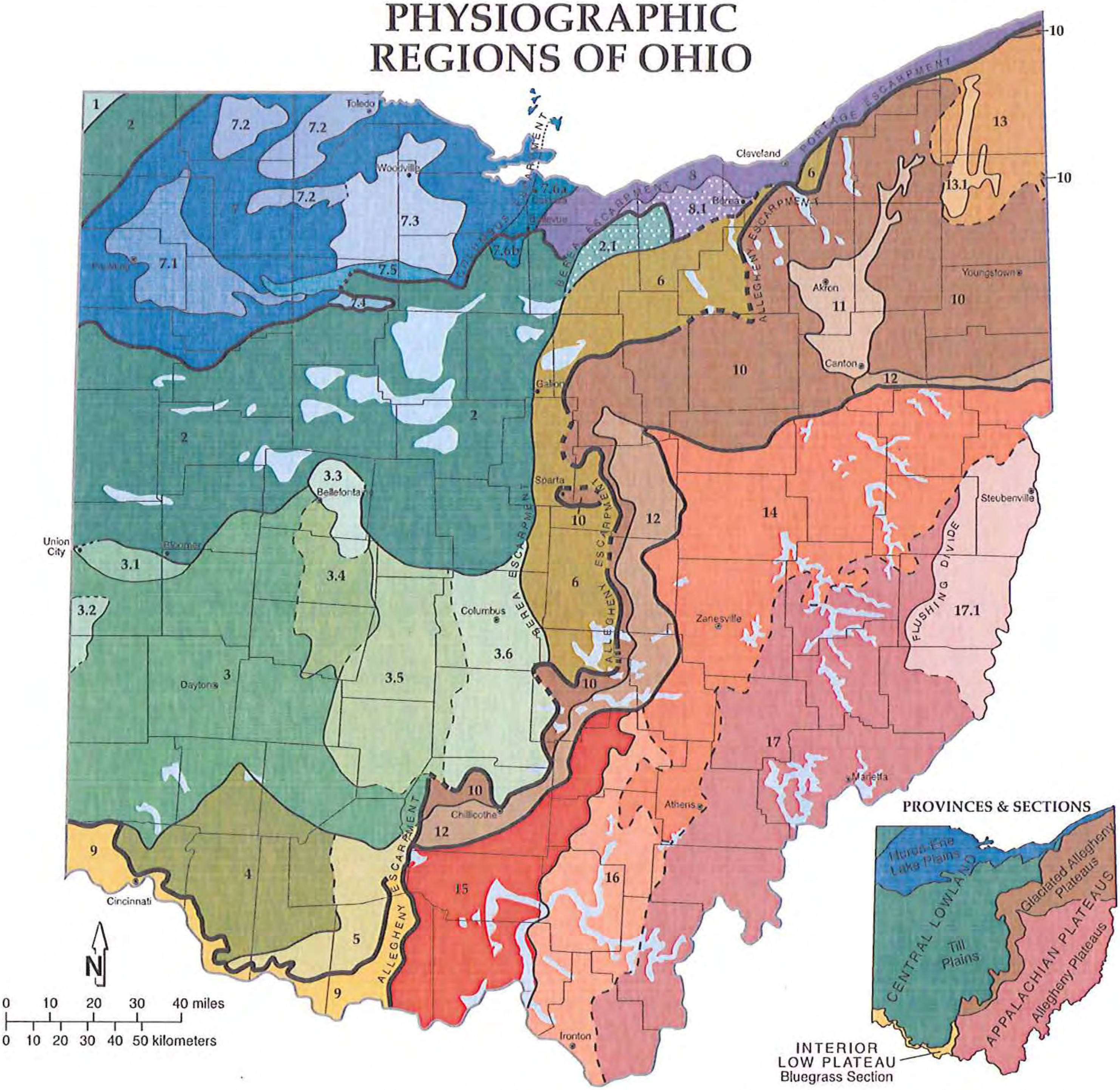
# STATE GEOLOGY

STATE OF OHIO
Ted Strickland, Governor

DEPARTMENT OF NATURAL RESOURCES
Sean D. Logan, Director

DIVISION OF GEOLOGICAL SURVEY
Lawrence H. Wickstrom, Chief

# PHYSIOGRAPHIC REGIONS OF OHIO




Transitional boundary

Lake basin/deposits outside Huron-Erie Lake Plains

**Till Plains**

1. Steuben Till Plain
2. Central Ohio Clayey Till Plain
   - 2.1. Berea Headlands of the Till Plain
3. Southern Ohio Loamy Till Plain
   - 3.1. Union City-Bloomer Transitional Terrain
   - 3.2. Whitewater Interlobate Plain
   - 3.3. Bellefontaine Upland
   - 3.4. Mad River Interlobate Plain
   - 3.5. Darby Plain
   - 3.6. Columbus Lowland
4. Illinoian Till Plain
5. Dissected Illinoian Till Plain
6. Galion Glaciated Low Plateau

**Huron-Erie Lake Plains**

7. Maumee Lake Plains
   - 7.1. Paulding Clay Basin
   - 7.2. Maumee Sand Plains
   - 7.3. Woodville Lake-Plain Reefs
   - 7.4. Findlay Embayment
   - 7.5. Fostoria Lake-Plain Shoals
   - 7.6a and 7.6b. Bellevue-Castalia Karst Plain
8. Erie Lake Plain
   - 8.1. Berea Headlands of the Erie Lake Plain

**Bluegrass Section**

9. Outer Bluegrass Region

**Glaciated Allegheny Plateaus**

10. Killbuck-Glaciated Pittsburgh Plateau
11. Akron-Canton Interlobate Plateau
12. Illinoian Glaciated Allegheny Plateau
13. Grand River Low Plateau
   - 13.1 Grand River Finger-Lake Plain

**Allegheny Plateaus**

14. Muskingum-Pittsburgh Plateau
15. Shawnee-Mississippian Plateau
16. Ironton Plateau
17. Marietta Plateau
   - 17.1. Little Switzerland Plateau

4/98

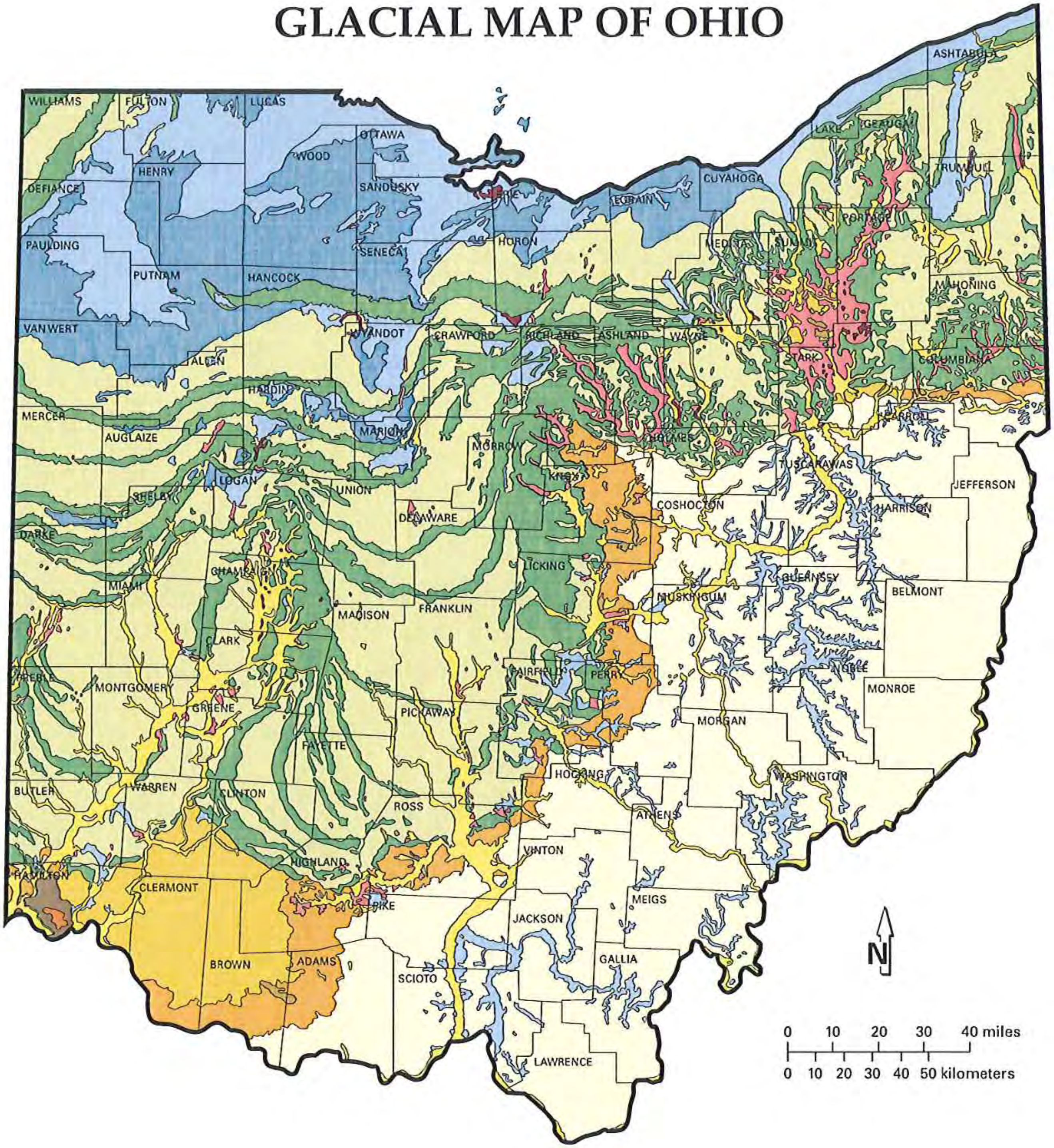
**Recommended citation:** Ohio Division of Geological Survey, 1998, Physiographic regions of Ohio: Ohio Department of Natural Resources, Division of Geological Survey, page-size map with text, 2 p., scale 1:2,100,00.

STATE OF OHIO
Bob Taft, Governor

DEPARTMENT OF NATURAL RESOURCES
Samuel W. Speck, Director

DIVISION OF GEOLOGICAL SURVEY
Thomas M. Berg, Chief

# GLACIAL MAP OF OHIO




**WISCONSINAN**
(14,000 to 24,000 years old)

- Ground moraine
- Wave-planed ground moraine
- End moraine

**ILLINOIAN**
(130,000 to 300,000 years old)

- Ground moraine
- Dissected ground moraine
- Hummocky moraine

**PRE-ILLINOIAN**
(older than 300,000 years)

- Ground moraine
- Dissected ground moraine

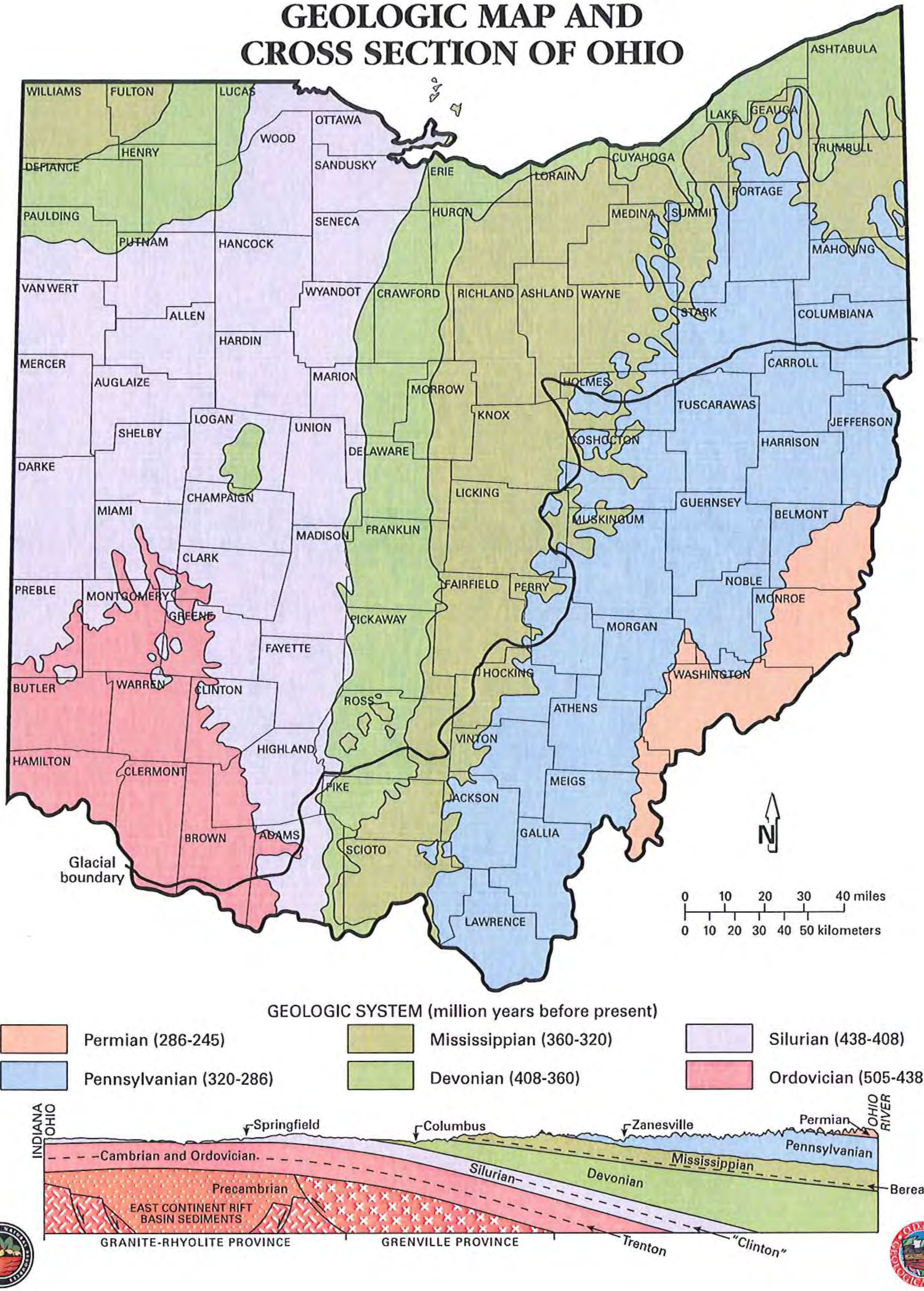
- Kames and eskers
- Outwash
- Lake deposits
- Peat
- Colluvium

STATE OF OHIO
Bob Taft, Governor

DEPARTMENT OF NATURAL RESOURCES
Samuel W. Speck, Director

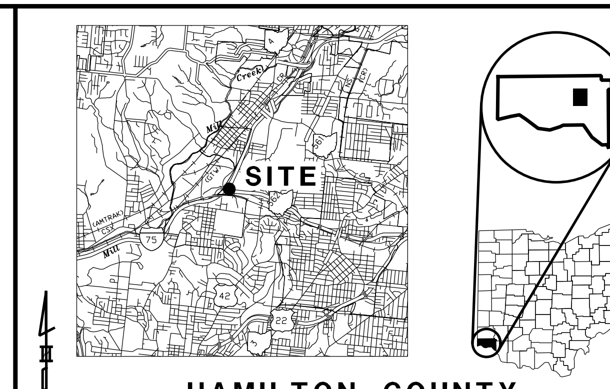
DIVISION OF GEOLOGICAL SURVEY
Thomas M. Berg, Chief

# GEOLOGIC MAP AND CROSS SECTION OF OHIO



# APPENDIX II

# VICINITY MAP AND BORING PLAN


HAMILTON COUNTY

VICINITY MAP

2007 CTL BORINGS

HISTORIC BORINGS

# BORING PLAN

## HAM-562-0004 - RAMP M SR 562 OVER I-75
## HAMILTON COUNTY, OHIO

| | |
|---|---|
| PROJECT NO. Rii B-10-020 | DRAWN RRM |
| SCALE: 1"=50' (0 25 50) | REVIEWED BRT |
| | DATE 06-12-12 |

RESOURCE INTERNATIONAL, INC.

# APPENDIX III

# 2007 CTL ENGINEERING BORING LOGS

# LOG OF BORING



Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Date Started 8/1/07 Sampler: Type SS Dia. 1.375"
Date Completed 8/1/07 Casing: Length 105.5ft Dia. 3.25"

Water Elev. 505.1ft
Boring No. B-161 Station & Offset 416+87.3, 90.6 LT Surface Elev. 551.1ft CTL Project No. 04120070g

| Elev. (ft) | Depth (ft) | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | Strata depth | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 551.1 | 0 | | | | | | | | | | | | | | | |
| 551.1 | | AUGERED | | | 0.5' | TOPSOIL (.5') | | | | | | | | | | VISUAL |
| 550.6 | 2 | 3/3/4 | | | | MEDIUM STIFF TO STIFF, DARK BROWN SANDY SILT, LITTLE CLAY, TRACE GRAVEL, MOIST | 1 | | | | | | | | 14 | VISUAL |
| 548.1 | 4 | 6/4/8 | | | 5.0' | | 2 | 2 | 10 | 34 | 38 | 16 | 24 | 10 | 17 | A-4a |
| 545.6 | 6, 8 | 6/10/13 | | | 8.0' | VERY STIFF, BROWN SANDY SILT, TRACE CLAY, DAMP | 3 | | | | | | | | 10 | VISUAL |
| 542.6 | 10 | 8/15/23 | | | | VERY STIFF TO HARD, BROWNISH GRAY SILT AND CLAY, AND SAND, LITTLE GRAVEL, DAMP | 4 | 12 | 18 | 21 | 30 | 19 | 26 | 11 | 10 | A-6a |
| 540.1 | 12 | 12/16/14 | | | 13.5' | | 5 | | | | | | | | 8 | VISUAL |
| 537.6 | 14 | 13/14/18 | | | 16.0' | DENSE, BROWN AND DARK GRAY COARSE AND FINE SAND, LITTLE GRAVEL, LITTLE SILT, TRACE CLAY, DAMP | 6 | 20 | 27 | 34 | 17 | 2 | NP | NP | 10 | A-3a |
| 535.1 | 16, 18 | 16/9/5 | | | 18.0' | STIFF, BROWN SILTY CLAY, SOME SAND, LITTLE GRAVEL, MOIST | 7 | | | | | | | | 15 | VISUAL |
| 532.6 | 20, 22 | 50-5" | | | 23.0' | VERY DENSE, BROWN GRAVEL AND/ OR STONE FRAGMENTS, SOME SAND, DRY | 8 | 65 | 10 | 21 | 4 | 0 | NP | NP | 3 | A-1-a |
| 527.6 | 24, 26, 28 | 18/27/25 | | | | HARD, GRAY SANDY SILT, SOME GRAVEL, LITTLE CLAY, DAMP TO MOIST | 9 | | | | | | | | 7 | VISUAL |
| 522.6 | 30, 32 | 16/16/17 | | | 33.5' | | 10 | 27 | 5 | 17 | 38 | 13 | NP | NP | 13 | A-4a |
| 517.6 | 34 | 6/10/38 | | | | HARD, BROWN SILTY SAND, AND GRAVEL, MOIST | 11 | | | | | | | | 9 | VISUAL |

Particle Sizes: Agg => 2.00mm, Coarse Sand = 2.00-0.42mm, Fine Sand = 0.42-0.074mm, Silt = 0.074-0.005mm, Clay =< 0.005mm.

Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Boring No. B-161

| Elev. (ft) 516.1 | Depth (ft) | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 512.6 | 38.0' | 3/2/4 | | | | LOOSE, GRAY COARSE AND FINE SAND, TRACE CLAY, LITTLE SILT, MOIST | 12 | 0 | 8 | 62 | 21 | 9 | NP | NP | 22 | A-3a |
| 507.6 | 43.5' | 6/8/11 | | | | VERY STIFF, GRAY SILT AND CLAY, TRACE SAND, TRACE GRAVEL, MOIST | 13 | | | | | | | | 17 | VISUAL |
| 502.6 | 48.5' | 2/2/3 | | | | MEDIUM STIFF, GRAY SILT AND CLAY, TRACE SAND, WET | 14 | 0 | 1 | 1 | 55 | 43 | 33 | 14 | 33 | A-6a |
| 497.6 | 53.5' | 3/9/11 | | | | VERY STIFF, GRAY SILT AND CLAY, TRACE SAND, TRACE GRAVEL, WET TO MOIST | 15 | | | | | | | | 22 | VISUAL |
| 492.6 | | 7/7/10 | | | | | 16 | | | | | | | | 23 | VISUAL |
| 487.6 | 62.0' | 3/4/7 | | | | STIFF TO VERY STIFF, GRAY SILTY CLAY, MOIST | 17 | 0 | 0 | 0 | 39 | 61 | 40 | 19 | 25 | A-6b |
| 482.6 | | 6/8/12 | | | | | 18 | | | | | | | | 24 | VISUAL |

Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Boring No. B-161

| Elev. (ft) 480.0 | Depth (ft) | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | Strata Depth | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 477.6 | 72–74 | 6/8/10 | | | | | 19 | | | | | | | | 24 | VISUAL |
| 472.6 | 78 | 10/11/12 | | | 78.5' | VERY STIFF TO HARD, GRAY SANDY SILT, TRACE CLAY, MOIST | 20 | 0 | 11 | 35 | 44 | 10 | 21 | 5 | 16 | A-4a |
| 468.1 | 82–84 | 7/8/12 | | | | | 21 | | | | | | | | 14 | VISUAL |
| 462.6 | 88–90 | 8/16/19 | | | | | 22 | | | | | | | | 15 | VISUAL |
| 457.6 | 92–94 | 14/16/20 | | | 93.5' | DENSE, GRAY COARSE AND FINE SAND, SOME SILT, TRACE GRAVEL, TRACE CLAY, MOIST | 23 | 1 | 14 | 59 | 25 | 1 | NP | NP | 16 | A-3a |
| 452.6 | 98–100 | 16/15/17 | | | | | 24 | | | | | | | | 19 | VISUAL |
| 447.6 | 102–104 | 8/10/12 | | | 103.5' | MEDIUM DENSE, GRAY AND BROWN FINE SAND, TRACE GRAVEL, TRACE SILT, WET | 25 | 2 | 30 | 59 | 9 | 0 | NP | NP | 20 | A-3 |
| 446.1 | | | | | 105.0' | BOTTOM OF BORING = 105.0' | | | | | | | | | | |

FS

# LOG OF BORING



Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Date Started 7/31/07 Sampler: Type SS Dia. 1.375"
Date Completed 7/31/07 Casing: Length 95.0ft Dia. 3.25"

Water Elev. 511.7ft
Surface Elev. 516.2ft

Boring No. B-162 Station & Offset 418+30.5, 45.6 LT

CTL Project No. 04120070g

| Elev. (ft) | Depth (ft) | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 516.2 | 0 | | | | | | | | | | | | | | | |
| 515.2 | | 4/7/6 | | | | MEDIUM DENSE, BROWN COARSE AND FINE SAND, SOME SILT, TRACE CLAY, TRACE GRAVEL, DAMP -FILL | 1 | 9 | 27 | 31 | 26 | 7 | NP | NP | 8 | A-3a |
| 512.7 | 4 | 5/4/4 | | | 3.5' | MEDIUM STIFF, BROWN SANDY SILT, AND GRAVEL, TRACE CLAY, MOIST | 2A | | | | | | | | 13 | VISUAL |
| 511.7 | | | | | 4.5' | MEDIUM STIFF, GRAY TO BROWN SILT AND CLAY, TRACE SAND, MOIST | 2B | | | | | | | | 24 | VISUAL |
| 510.2 | 6 | 3/1/3 | | | 6.0' | SOFT TO MEDIUM STIFF, GRAY TO BROWN CLAY, AND SILT,TRACE SAND, MOIST | 3 | 0 | 0 | 0 | 45 | 55 | 46 | 24 | 28 | A-7-6 |
| 507.7 | | 1/2/4 | | | | | 4 | | | | | | | | 29 | VISUAL |
| 502.7 | 14 | 2/4/6 | | | 13.5' | STIFF, GRAY TO BROWN CLAY, SOME SILT, TRACE SAND, MOIST | 5 | 0 | 0 | 0 | 27 | 73 | 49 | 26 | 30 | A-7-6 |
| 497.7 | | 4/4/5 | | | | | 6A | | | | | | | | 28 | VISUAL |
| 496.7 | 20 | | | | | -SILT LAYERS ARE INTERBEDDED | 6B | | | | | | | | 32 | VISUAL |
| 492.7 | 24 | 4/7/11 | | | 23.5' | STIFF TO VERY STIFF, GRAY TO BROWN SILT, SOME CLAY, TRACE SAND, MOIST | 7 | 0 | 0 | 1 | 71 | 28 | 30 | 9 | 25 | A-4b |
| 487.7 | | 5/6/6 | | | | | 8 | | | | | | | | 26 | VISUAL |
| 482.7 | 34 | 5/10/12 | | | 33.5' | VERY STIFF, GRAY TO BROWN SILTY CLAY, TRACE SAND, MOIST | 9 | 0 | 0 | 0 | 55 | 45 | 40 | 17 | 28 | A-6b |

Particle Sizes: Agg => 2.00mm, Coarse Sand = 2.00-0.42mm, Fine Sand = 0.42-0.074mm, Silt = 0.074-0.005mm, Clay =< 0.005mm.

Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Boring No. B-162

| Elev. (ft) 481.2 | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | Depth to layer | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 477.7 | 6/10/14 | | | | | 10 | | | | | | | | 29 | VISUAL |
| 472.7 | 4/7/10 | | | | | 11 | | | | | | | | 25 | VISUAL |
| 467.7 | 4/6/8 | | | 48.5' | MEDIUM STIFF TO STIFF, GRAY SILT, LITTLE CLAY, LITTLE SAND, TRACE GRAVEL, MOIST | 12 | 0 | 7 | 13 | 63 | 17 | 25 | 8 | 18 | A-4b |
| 462.7 | 3/3/5 | | | | | 13A | | | | | | | | 23 | VISUAL |
| 461.7 | | | | 54.5' | MEDIUM STIFF TO VERY STIFF, GRAY SILTY CLAY, SOME SAND, TRACE GRAVEL, MOIST<br>-SAND LAYERS ARE INTERBEDDED | 13B | | | | | | | | 19 | VISUAL |
| 457.7 | 7/9/11 | | | | | 14 | 0 | 8 | 19 | 28 | 45 | 38 | 18 | 22 | A-6b |
| 452.7 | 9/8/8 | | | 63.5' | VERY STIFF TO HARD, GRAY SANDY SILT, TRACE GRAVEL, TRACE CLAY, WET | 15 | 3 | 16 | 41 | 31 | 9 | 18 | 5 | 22 | A-4a |
| 447.7 | 9/16/15 | | | | | 16 | | | | | | | | 26 | VISUAL |

Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Boring No. B-162

| Elev. (ft) 445.1 | Depth (ft) | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | | | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 442.7 | 74 | 7/11/14 | | | | | | 17 | | | | | | | | 25 | VISUAL |
| 437.7 | 78.5 | 4/5/8 | | | | 78.5' | STIFF, GRAY SILT AND CLAY, SOME SAND, TRACE GRAVEL, MOIST | 18 | 0 | 2 | 23 | 50 | 25 | 31 | 13 | 30 | A-6a |
| 432.7 | 84 | 8/8/5 | | | | | | 19 | | | | | | | | 18 | VISUAL |
| 426.7 | 89.5 | 3/8/13 | | | | 89.5' | MEDIUM DENSE, GRAY TO BROWN COARSE AND FINE SAND, LITTLE SILT, TRACE GRAVEL, TRACE CLAY, MOIST | 20 | 0 | 11 | 78 | 11 | 0 | NP | NP | 20 | A-3a |
| 422.7 | 94 | 7/10/7 | | | | | | 21 | | | | | | | | 26 | VISUAL |
| 421.2 | 95 | | | | | 95.0' | | | | | | | | | | | |

BOTTOM OF BORING = 95.0'

# LOG OF BORING

Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Date Started 8/3/07 Sampler: Type SS Dia. 1.375"
Date Completed 8/7/07 Casing: Length 120.0ft Dia. 3.25"

Water Elev. 476.5ft
Boring No. B-163 Station & Offset 418+60.8, 165.1 RT Surface Elev. 555.0ft CTL Project No. 04120070g

| Elev. (ft) | Depth (ft) | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | Layer Depth | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 555.0 | 0 | | | | | | | | | | | | | | | |
| 555.0 / 554.6 | | AUGERED | | | 0.4' | TOPSOIL (0.4") | | | | | | | | | | VISUAL |
| 554.5 | | 7/9/11 | | | 3.0' | MEDIUM DENSE, BROWN GRAVEL AND/OR STONE FRAGMENTS WITH SAND, SILT, AND CLAY, DRY | 1 | | | | | | | | 5 | VISUAL |
| 552.0 | | 7/7/9 | | | 5.5' | VERY STIFF, BROWN SANDY SILT, LITTLE CLAY, LITTLE GRAVEL, DAMP | 2 | | | | | | | | 10 | VISUAL |
| 549.5 | | 9/11/12 | | | 8.5' | VERY STIFF, BROWN, LIGHT BROWN, AND GRAY, MOTTLED SILT AND CLAY, SOME SAND, TRACE GRAVEL, DAMP | 3 | 4 | 7 | 28 | 46 | 15 | 29 | 14 | 14 | A-6a |
| 546.5 | | 4/5/4 | | | 11.0' | STIFF, BROWN SANDY SILT, AND CLAY, TRACE GRAVEL, MOIST | 4 | | | | | | | | 15 | VISUAL |
| 544.0 | | 3/4/3 | | | 13.5' | MEDIUM STIFF, BROWN SILT AND CLAY, SOME SAND, TRACE GRAVEL, MOIST | 5 | 1 | 4 | 23 | 52 | 20 | 35 | 15 | 21 | A-6a |
| 541.5 | | 4/5/6 | | | 16.0' | STIFF, BROWN SANDY SILT, SOME CLAY, TRACE GRAVEL, DAMP | 6 | | | | | | | | 11 | VISUAL |
| 539.0 | | 4/5/7 | | | 18.5' | STIFF, BROWN SILT AND CLAY, SOME GRAVEL, SOME SAND, MOIST | 7 | 26 | 4 | 25 | 31 | 14 | 29 | 14 | 18 | A-6a |
| 536.5 | | 3/4/6 | | | 23.5' | STIFF, DARK BROWN SANDY SILT, SOME CLAY, LITTLE GRAVEL, DAMP | 8 | | | | | | | | 9 | VISUAL |
| 531.5 | | 4/3/4 | | | 28.5' | MEDIUM STIFF, LIGHT BROWN SILT AND CLAY, LITTLE GRAVEL, AND SAND, MOIST | 9 | 12 | 17 | 32 | 13 | 26 | 27 | 11 | 15 | A-6a |
| 526.5 | | 3/4/5 | | | | STIFF, LIGHT BROWN SILTY CLAY, LITTLE SAND, TRACE TO LITTLE GRAVEL, DAMP TO MOIST | 10 | | | | | | | | 21 | VISUAL |
| 521.5 | | 4/5/8 | | | | | 11 | 15 | 6 | 11 | 40 | 28 | 34 | 16 | 14 | A-6b |

Depth scale (ft): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34

Particle Sizes: Agg => 2.00mm, Coarse Sand = 2.00-0.42mm, Fine Sand = 0.42-0.074mm, Silt = 0.074-0.005mm, Clay =< 0.005mm.

Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Boring No. B-163

| Elev. (ft) 520.0 | Depth (ft) | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 516.5 | | 4/5/7 | | | | 12 | | | | | | | | 17 | VISUAL |
| 511.5 | 43.5' | 2/2/3 | | | MEDIUM STIFF, GRAY SILT, SOME CLAY, TRACE SAND, MOIST | 13 | 0 | 0 | 0 | 73 | 27 | 26 | 5 | 23 | A-4b |
| 506.5 | | 3/4/4 | | | | 14 | | | | | | | | 25 | VISUAL |
| 501.5 | | 2/3/5 | | | | 15 | | | | | | | | 23 | VISUAL |
| 496.5 | 58.5' | 5/6/8 | | | MEDIUM STIFF TO STIFF, GRAY SILTY CLAY, TRACE SAND, DAMP | 16 | 0 | 0 | 0 | 58 | 42 | 39 | 16 | 22 | A-6b |
| 491.5 | | 3/4/5 | | | | 17 | | | | | | | | 23 | VISUAL |
| 486.5 | | 3/3/4 | | | | 18 | | | | | | | | 23 | VISUAL |

Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Boring No. B-163

| Elev. (ft) 483.9 | Depth (ft) | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | Layer Depth | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 481.5 | 74 | 3/4/4 | | | | NO RECOVERY | 19 | | | | | | | | | |
| 479.0 | 76 | | | | 76.0' | | | | | | | | | | | |
| 476.5 | 78 | 4/5/5 | | | | LOOSE, GRAY COARSE AND FINE SAND, LITTLE CLAY, TRACE SILT, TRACE GRAVEL, WET | 20 | 4 | 21 | 47 | 8 | 20 | NP | NP | 19 | A-3a |
| 473.0 | 82 | | | | 82.0' | | | | | | | | | | | |
| 471.5 | 84 | 6/8/9 | | | | VERY STIFF, GRAY CLAY, SOME SAND, TRACE SILT, MOIST -SAND LAYERS ARE INTERBEDDED | 21 | | | | | | | | 15 | VISUAL |
| 468.0 | 87 | | | | 87.0' | | | | | | | | | | | |
| 466.5 | 88 | 4/5/6 | | | | STIFF, GRAY SILT AND CLAY, LITTLE SAND, TRACE GRAVEL, MOIST | 22 | | | | | | | | 20 | VISUAL |
| 461.5 | 94 | 4/5/7 | | | | | 23 | 1 | 2 | 10 | 44 | 43 | 33 | 12 | 23 | A-6a |
| 456.5 | 98.5 | 9/11/12 | | | 98.5' | MEDIUM DENSE, BROWN TO GRAY COARSE AND FINE SAND, TRACE CLAY, TRACE SILT, TRACE GRAVEL, WET | 24 | | | | | | | | 15 | VISUAL |
| 451.5 | 104 | 7/9/11 | | | | | 25 | 0 | 22 | 66 | 9 | 3 | NP | NP | 16 | A-3a |

Project Identification: HAM-75-2.30 PID 76257
Hamilton County, Ohio

Boring No. B-163

| Elev. (ft) 447.9 | Depth (ft) | Std. Pen./ RQD | Rec. (ft) | Loss (ft) | | | Description | Sample No. | % Agg | % C.S. | % F.S. | % Silt | % Clay | L.L. | P.I. | W.C. | ODOT Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 108 | | | | | | | | | | | | | | | | |
| 446.5 | | 5/7/8 | | | | | | 26 | | | | | | | | 16 | VISUAL |
| | 110 | | | | | | | | | | | | | | | | |
| | 112 | | | | | | | | | | | | | | | | |
| 441.5 | 114 | 9/11/12 | | | | | | 27 | | | | | | | | 20 | VISUAL |
| | 116 | | | | | | | | | | | | | | | | |
| | 118 | | | | | | | | | | | | | | | | |
| 436.5 | | 8/10/13 | | | | | | 28 | 4 | 26 | 60 | 5 | 5 | NP | NP | 15 | A-3a |
| 435.0 | 120 | | | | | 120.0' | | | | | | | | | | | |

BOTTOM OF BORING = 120.0'

# APPENDIX IV

# RII LABORATORY TEST RESULTS

6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

# CONSOLIDATED, UNDRAINED TRIAXIAL

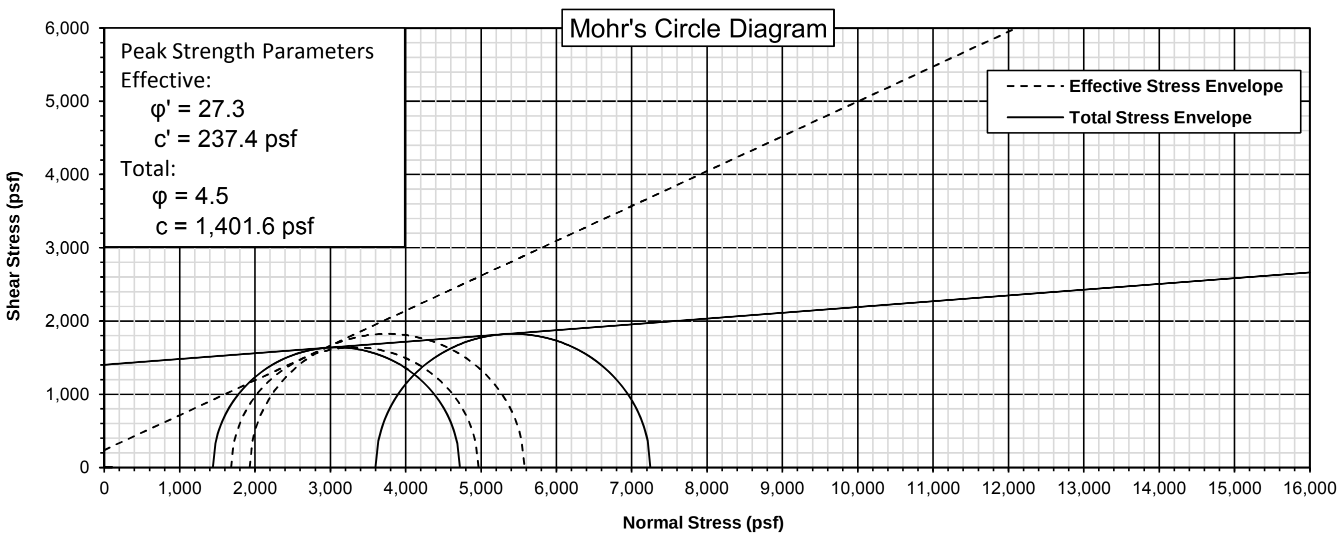
**ASTM D-4767**

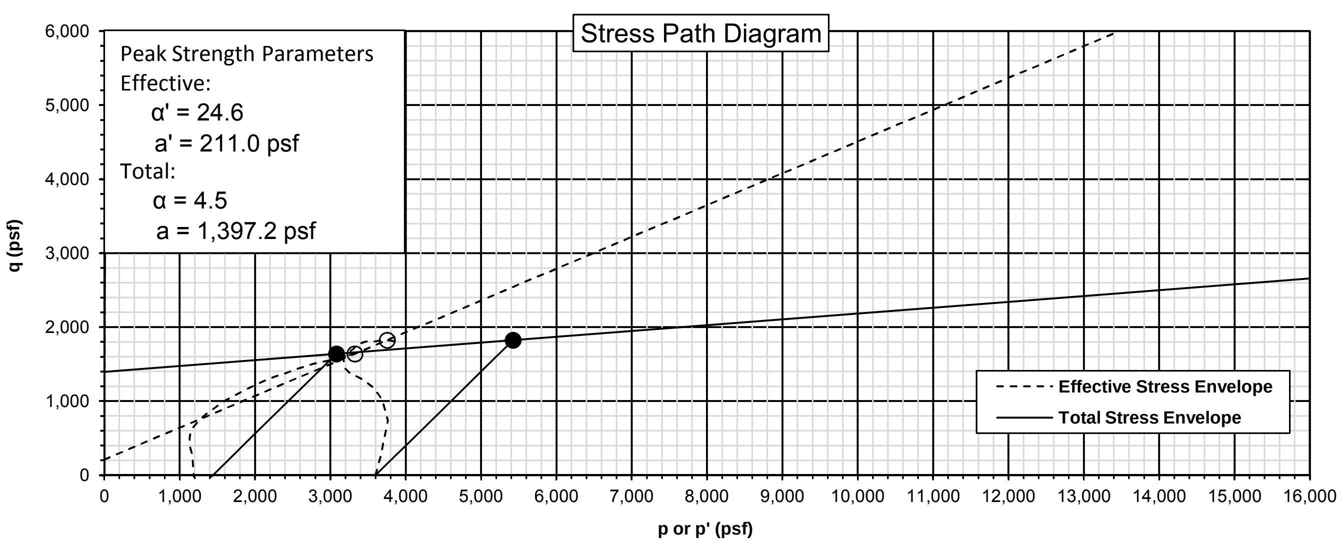
| | |
|---|---|
| PROJECT NAME: | HAM-75-7.85 |
| JOB NUMBER: | B-10-020 |
| BORING NUMBER: | B-016-0-11A |
| SAMPLE NUMBER: | ST-3 |
| SAMPLE DEPTH: | 6.5 to 7.0 feet |
| DATE OF TESTING: | 12/12/2011-12/28/11 |
| TESTED BY: | Hoyt |

Soil Description: Brown SILT and CLAY, and coarse to fine sand, trace fine gravel.
Soil Classification: ODOT A-6a

| Physical Characteristics | L.L. | P.L. | P.I. | Gravel% | C. Sand% | F. Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|
| | 29 | 14 | 15 | 7 | 9 | 32 | 29 | 23 |

| Stage | Boring No. | Sample No. | Depth (ft) | $(\sigma_3)_f$ (psf) | $(\sigma_1)_f$ (psf) | $(\sigma_3')_f$ (psf) | $(\sigma_1')_f$ (psf) | $p'_f$ (psf) | $q_f$ (psf) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B-016-0-11A | ST-3 | 7.0 | 1,440.0 | 4,719.1 | 1,684.8 | 4,963.9 | 3,324.3 | 1,639.5 |
| 2 | B-016-0-11A | ST-3 | 6.5 | 3,600.0 | 7,248.0 | 1,929.6 | 5,577.6 | 3,753.6 | 1,824.0 |
| | | | | | | | | | |



6350 Presidential Gateway
Columbus, Ohio 43231
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# CONSOLIDATED, UNDRAINED TRIAXIAL

**ASTM D-4767**

| | |
|---|---|
| PROJECT NAME: | HAM-75-7.85 |
| JOB NUMBER: | B-10-020 |
| BORING NUMBER: | B-016-0-11A |
| SAMPLE NUMBER: | ST-3 |
| SAMPLE DEPTH: | 7.0 |
| DATE OF TESTING: | 12/28/2011 |
| TESTED BY: | Hoyt |

## Data for Specimen No. 1

Soil Description: Brown SILT and CLAY, and coarse to fine sand, trace fine gravel.
Soil Classification: ODOT A-6a

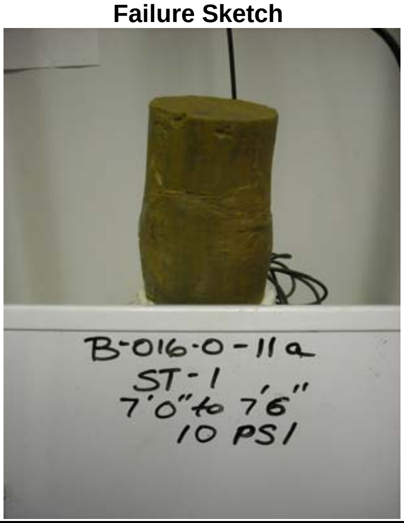
| Physical Characteristics | L.L. | P.L. | P.I. | Gravel% | C.Sand% | F.Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|
| | 29 | 14 | 15 | 7 | 9 | 32 | 29 | 23 |

| | | | | | |
|---|---|---|---|---|---|
| Diameter, $D_0$ | 2.861 | in | Volume of Solids , $V_s$ : | 25.349 | $in^3$ |
| Area, $A_0$ | 6.429 | $in^2$ | Initial Volume of Voids, $V_v$ : | 11.766 | $in^3$ |
| Height, $L_0$ | 5.773 | in | Initial Void Ratio, $e_o$ : | 0.464 | |
| Volume, $V_0$ | 37.115 | $in^3$ | Initial Degree of Saturation, $S_0$ : | 111.729 | % |

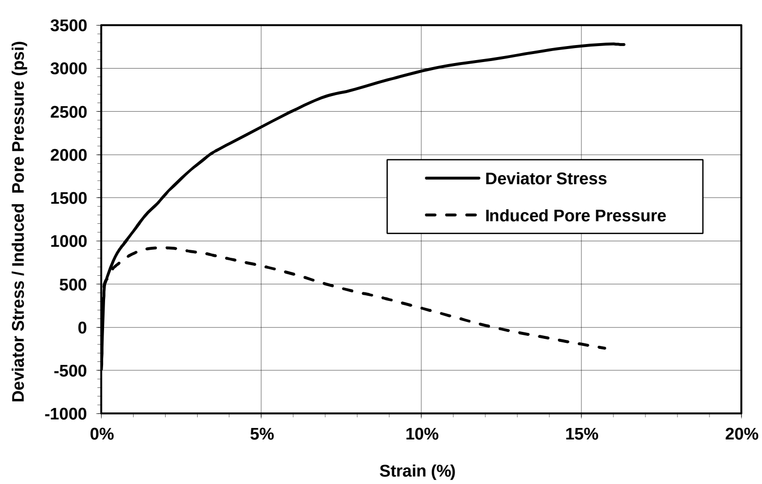
| Water Content BEFORE Test | | | Water Content AFTER Test (Total Specimen) | | |
|---|---|---|---|---|---|
| Tin No.: | WC-32 | g | Tin No.: | BIG CAT | g |
| Wet Soil + Tin : | 105.78 | g | Wet Soil + Tin : | 1393.10 | g |
| Dry Soil + Tin : | 94.18 | g | Dry Soil + Tin : | 1198.10 | g |
| Tin Weight : | 34.46 | g | Tin Weight : | 89.00 | g |
| Dry Mass : | 59.72 | g | Dry Mass : | 1109.10 | g |
| Weight of water : | 11.6 | g | Weight of water : | 195.00 | g |
| Moisture : | 19.42 | % | Moisture : | 17.58 | % |
| | | | Wet Density : | 133.85 | pcf |
| | | | Dry Density : | 113.84 | pcf |

| | | | | | |
|---|---|---|---|---|---|
| Consolidation Cell Pressure: | 145.0 | psi | Deviator Stress @ Failure, Ds: | 3279.09 | psf |
| Consolidation Back Pressure: | 135.0 | psi | Axial Strain @ Failure: | 15.74 | % |
| Effective Confining Stress, $\sigma_3$: | 10.0 | psi | Major Principal Stress @ Failure, $\sigma_1$: | 4719.09 | psf |
| | 1440.00 | psf | Induced Pore Pressure @ Failure: | -244.80 | psf |
| Strain Rate: | 0.0040 | in/min | Effective Minor Principal Stress,$\sigma'_3$: | 1684.80 | psf |
| | | | Effective Major Principal Stress, $\sigma'_1$: | 4963.89 | psf |

**Failure Sketch**




**CU Compressive Strength and Induced Pore Pressure**



6350 Presidential Gateway
Columbus, Ohio 43231
Telephone: (614) 823-4949
Fax Number: (614) 823-4990

# CONSOLIDATED, UNDRAINED TRIAXIAL

**ASTM D-4767**

| | |
|---|---|
| PROJECT NAME: | HAM-75-7.85 |
| JOB NUMBER: | B-10-020 |
| BORING NUMBER: | B-016-0-11A |
| SAMPLE NUMBER: | ST-3 |
| SAMPLE DEPTH: | 6.5 |
| DATE OF TESTING: | 12/23/2011 |
| TESTED BY: | Hoyt |

## Data for Specimen No. 2

Soil Description: Brown SILT and CLAY, and coarse to fine sand, trace fine gravel.
Soil Classification: ODOT A-6a

| Physical Characteristics | L.L. | P.L. | P.I. | Gravel% | C.Sand% | F.Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|
| | 29 | 14 | 15 | 7 | 9 | 32 | 29 | 23 |

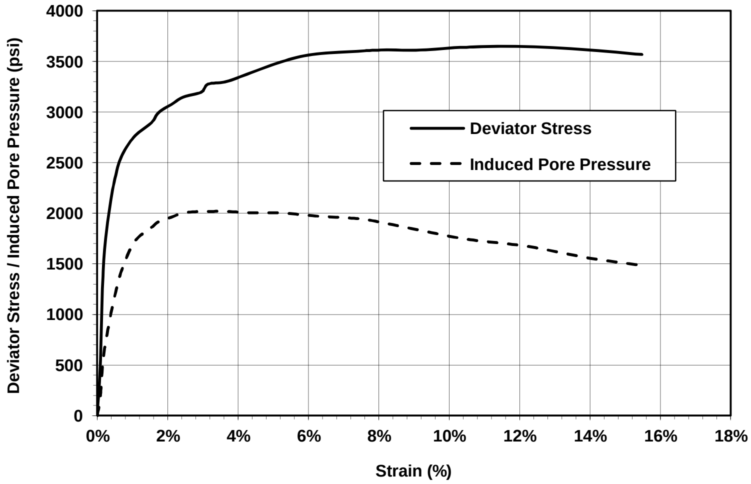
| | | | | | |
|---|---|---|---|---|---|
| Diameter, $D_0$ | 2.843 | in | Volume of Solids , $V_s$ : | 26.099 | $in^3$ |
| Area, $A_0$ | 6.350 | $in^2$ | Initial Volume of Voids, $V_v$ : | 11.933 | $in^3$ |
| Height, $L_0$ | 5.990 | in | Initial Void Ratio, $e_o$ : | 0.457 | |
| Volume, $V_0$ | 38.032 | $in^3$ | Initial Degree of Saturation, $S_0$ : | 106.30 | % |

| Water Content BEFORE Test | | | Water Content AFTER Test (Total Specimen) | | |
|---|---|---|---|---|---|
| Tin No.: | WC-32 | g | Tin No.: | OHIO | g |
| Wet Soil + Tin : | 105.78 | g | Wet Soil + Tin : | 1445.60 | g |
| Dry Soil + Tin : | 94.18 | g | Dry Soil + Tin : | 1268.90 | g |
| Tin Weight : | 30.46 | g | Tin Weight : | 127.00 | g |
| Dry Mass : | 63.72 | g | Dry Mass : | 1141.90 | g |
| Weight of water : | 11.6 | g | Weight of water : | 176.70 | g |
| Moisture : | 18.20 | % | Moisture : | 15.47 | % |
| | | | Wet Density : | 132.08 | pcf |
| | | | Dry Density : | 114.38 | pcf |

| | | | | | |
|---|---|---|---|---|---|
| Consolidation Cell Pressure: | 118.0 | psi | Deviator Stress @ Failure, Ds: | 3648.02 | psf |
| Consolidation Back Pressure: | 93.0 | psi | Axial Strain @ Failure: | 12.24 | % |
| Effective Confining Stress, $\sigma_3$: | 25.0 | psi | Major Principal Stress @ Failure, $\sigma_1$: | 7248.02 | psf |
| | 3600.00 | psf | Induced Pore Pressure @ Failure: | 1670.40 | psf |
| Strain Rate: | 0.0030 | in/min | Effective Minor Principal Stress,$\sigma'_3$: | 1929.60 | psf |
| | | | Effective Major Principal Stress, $\sigma'_1$: | 5577.62 | psf |

**Failure Sketch**


**CU Compressive Strength and Induced Pore Pressure**



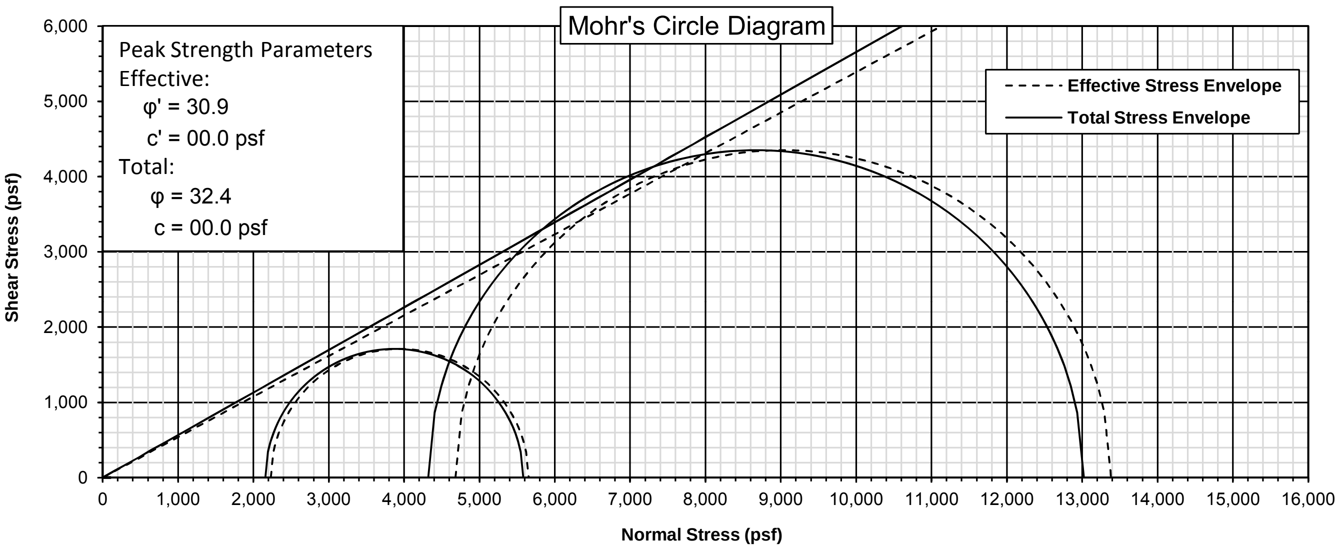
# Consolidated, Undrained Triaxial Compression Test Report (ASTM D4767)

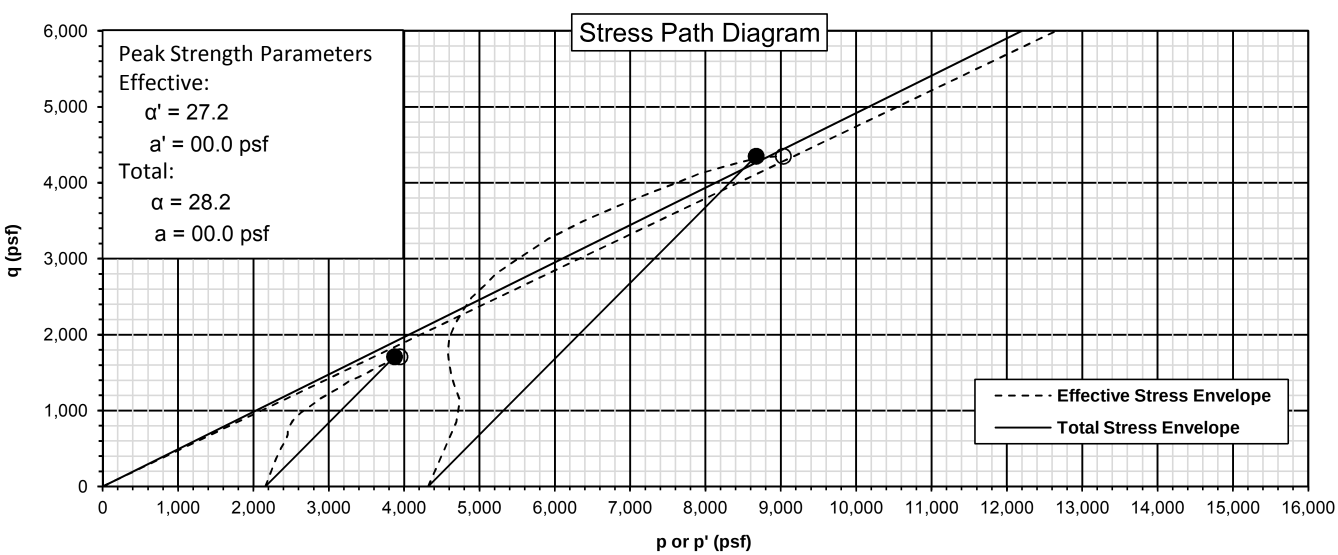
| | | | |
|---|---|---|---|
| Project Number: | B-11-010 | Boring Number: | B-004-0-11 |
| Project Name: | HAM-75-11.09 | Sample No. / Depth: | ST-2 and ST-3 / 9.5 ft to 11.4 ft |
| Project Location: | Hamilton County, Ohio | Date of Testing: | 05/11/2012 to 05/17/2012 |
| Client: | M•E Companies, Inc. | Technician: | JJH |

Soil Description: Brown SILT, some clay, trace coarse to fine sand.
Soil Classification: ODOT A-4b

| Physical Characteristics | L.L. | P.L. | P.I. | Gravel% | C. Sand% | F. Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|
| | 26 | 17 | 9 | 0 | 1 | 6 | 61 | 32 |

| Stage | Boring No. | Sample No. | Depth (ft) | $(\sigma_3)_f$ (psf) | $(\sigma_1)_f$ (psf) | $(\sigma_3')_f$ (psf) | $(\sigma_1')_f$ (psf) | $p'_f$ (psf) | $q_f$ (psf) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | B-004-0-11 | ST-2 | 9.5 | 2,160.0 | 5,580.9 | 2,232.0 | 5,652.9 | 3,942.5 | 1,710.5 |
| 2 | B-004-0-11 | ST-3 | 11.4 | 4,320.0 | 13,022.3 | 4,680.0 | 13,382.3 | 9,031.2 | 4,351.2 |
| | | | | | | | | | |




Notes: Third point of test eliminated from final results. Physical properties listed based on testing performed on cuttings when samples were trimmed.

# Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

| | | | |
|---|---|---|---|
| Project Number: | B-11-010 | Boring Number: | B-004-0-11 |
| Project Name: | HAM-75-11.09 | Sample No. / Depth: | ST-2 / 9.5 ft |
| Project Location: | Hamilton County, Ohio | Date of Testing: | 5/11/2012 |
| Client: | M•E Companies, Inc. | Technician: | JJH |

## Data for Specimen No. 1

Soil Description: Brown SILT, little clay, little fine sand, trace fine gravel.
Soil Classification: ODOT A-4b

| Physical Characteristics | L.L. | P.L. | P.I. | Gravel% | C. Sand% | F. Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|
| | 25 | 18 | 7 | 1 | 0 | 17 | 63 | 19 |

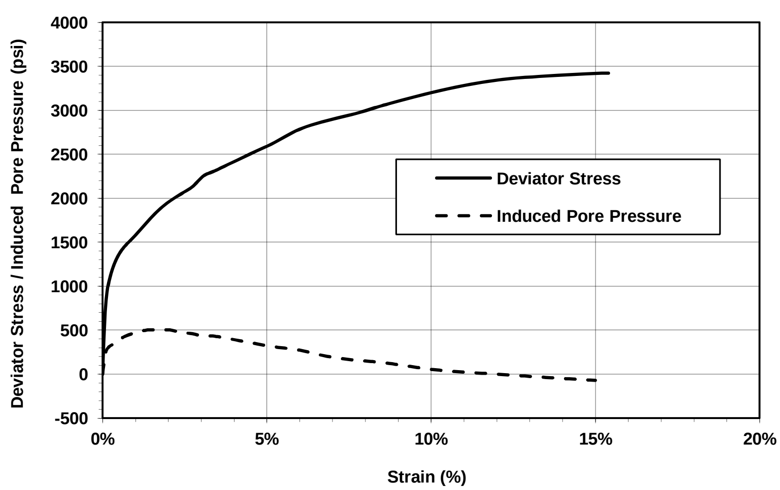
| | | | | | |
|---|---|---|---|---|---|
| Diameter, $D_0$ | 2.836 | in | Volume of Solids , $V_s$ : | 22.844 | $in^3$ |
| Area, $A_0$ | 6.315 | $in^2$ | Initial Volume of Voids, $V_v$ : | 14.495 | $in^3$ |
| Height, $L_0$ | 5.912 | in | Initial Void Ratio, $e_o$ : | 0.635 | |
| Volume, $V_0$ | 37.339 | $in^3$ | Initial Degree of Saturation, $S_0$ : | 106.037 | % |

| Water Content BEFORE Test | | | Water Content AFTER Test (Total Specimen) | | |
|---|---|---|---|---|---|
| Tin No.: | R-68 | g | Tin No.: | ST | g |
| Wet Soil + Tin : | 90.64 | g | Wet Soil + Tin : | 1399.80 | g |
| Dry Soil + Tin : | 77.67 | g | Dry Soil + Tin : | 1163.40 | g |
| Tin Weight : | 26.2 | g | Tin Weight : | 163.90 | g |
| Dry Mass : | 51.47 | g | Dry Mass : | 999.50 | g |
| Weight of water : | 12.97 | g | Weight of water : | 236.40 | g |
| Moisture : | 25.20 | % | Moisture : | 23.65 | % |
| | | | Wet Density : | 126.09 | pcf |
| | | | Dry Density : | 101.98 | pcf |

| | | | | | |
|---|---|---|---|---|---|
| Consolidation Cell Pressure: | 130.0 | psi | Deviator Stress @ Failure, Ds: | 3420.90 | psf |
| Consolidation Back Pressure: | 115.0 | psi | Axial Strain @ Failure: | 15.39 | % |
| Effective Confining Stress, $\sigma_3$: | 15.0 | psi | Major Principal Stress @ Failure, $\sigma_1$: | 5580.90 | psf |
| | 2160.00 | psf | Induced Pore Pressure @ Failure: | -72.00 | psf |
| Strain Rate: | 0.0030 | in/min | Effective Minor Principal Stress,$\sigma'_3$: | 2232.00 | psf |
| | | | Effective Major Principal Stress, $\sigma'_1$: | 5652.90 | psf |

### Failure Sketch


### CU Compressive Strength and Induced Pore Pressure




Notes:

## Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

| | | | |
|---|---|---|---|
| Project Number: | B-11-010 | Boring Number: | B-004-0-11 |
| Project Name: | HAM-75-11.09 | Sample No. / Depth: | ST-3 / 11.4 ft |
| Project Location: | Hamilton County, Ohio | Date of Testing: | 5/17/2012 |
| Client: | M•E Companies, Inc. | Technician: | JJH |

# Data for Specimen No. 2

Soil Description: Brown SILT, and clay, trace coarse to fine sand.
Soil Classification: ODOT A-4b

| Physical Characteristics | L.L. | P.L. | P.I. | Gravel% | C. Sand% | F. Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|
| | 25 | 16 | 9 | 0 | 1 | 1 | 52 | 46 |

| | | | | | |
|---|---|---|---|---|---|
| Diameter, $D_0$ | 2.843 | in | Volume of Solids , $V_s$ : | 27.218 | $in^3$ |
| Area, $A_0$ | 6.347 | $in^2$ | Initial Volume of Voids, $V_v$ : | 10.265 | $in^3$ |
| Height, $L_0$ | 5.906 | in | Initial Void Ratio, $e_o$ : | 0.377 | |
| Volume, $V_0$ | 37.483 | $in^3$ | Initial Degree of Saturation, $S_0$ : | 92.53 | % |

**Water Content BEFORE Test**

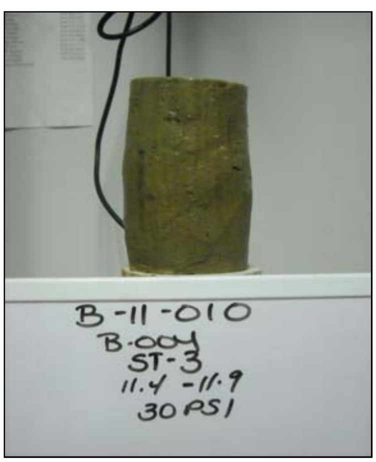
| | | |
|---|---|---|
| Tin No.: | T-26 | g |
| Wet Soil + Tin : | 123.78 | g |
| Dry Soil + Tin : | 112.71 | g |
| Tin Weight : | 28.01 | g |
| Dry Mass : | 84.7 | g |
| Weight of water : | 11.07 | g |
| Moisture : | 13.07 | % |

**Water Content AFTER Test (Total Specimen)**

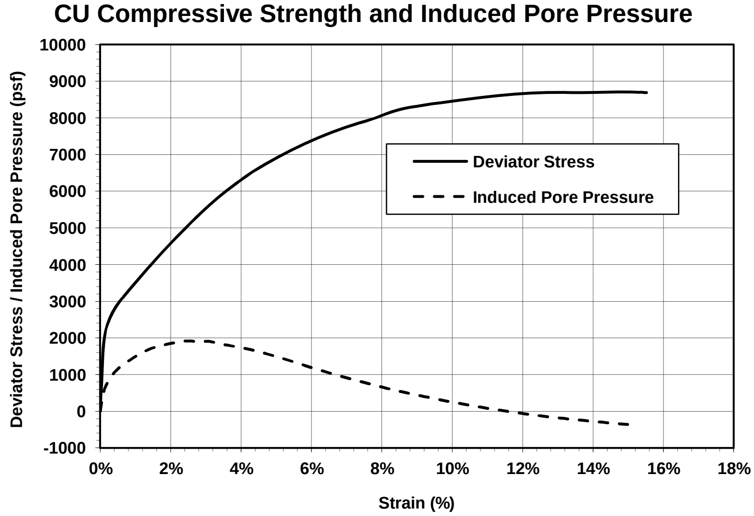
| | | |
|---|---|---|
| Tin No.: | ST | g |
| Wet Soil + Tin : | 1473.90 | g |
| Dry Soil + Tin : | 1309.00 | g |
| Tin Weight : | 118.10 | g |
| Dry Mass : | 1190.90 | g |
| Weight of water : | 164.90 | g |
| Moisture : | 13.85 | % |
| Wet Density : | 137.79 | pcf |
| Dry Density : | 121.03 | pcf |

| | | | | | |
|---|---|---|---|---|---|
| Consolidation Cell Pressure: | 143.0 | psi | Deviator Stress @ Failure, Ds: | 8702.33 | psf |
| Consolidation Back Pressure: | 113.0 | psi | Axial Strain @ Failure: | 14.99 | % |
| Effective Confining Stress, $\sigma_3$: | 30.0 | psi | Major Principal Stress @ Failure, $\sigma_1$: | 13022.33 | psf |
| | 4320.00 | psf | Induced Pore Pressure @ Failure: | -360.00 | psf |
| Strain Rate: | 0.0036 | in/min | Effective Minor Principal Stress,$\sigma'_3$: | 4680.00 | psf |
| | | | Effective Major Principal Stress, $\sigma'_1$: | 13382.33 | psf |

**Failure Sketch**




**CU Compressive Strength and Induced Pore Pressure**




Notes:

## Consolidated, Undrained Triaxial Compression Test (ASTM D4767)

| | | | |
|---|---|---|---|
| Project Number: | B-11-010 | Boring Number: | B-004-0-11 |
| Project Name: | HAM-75-11.09 | Sample No. / Depth: | ST-2 / 9.0 ft |
| Project Location: | Hamilton County, Ohio | Date of Testing: | 5/15/2012 |
| Client: | M•E Companies, Inc. | Technician: | JJH |

# Data for Specimen No. 3

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

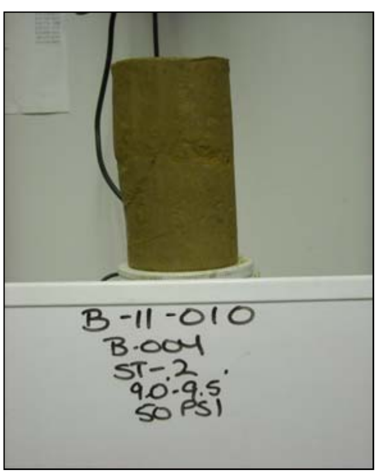
| Physical Characteristics | L.L. | P.L. | P.I. | Gravel% | C. Sand% | F. Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|
| | 27 | 15 | 12 | 11 | 9 | 14 | 38 | 28 |

| | | | | | |
|---|---|---|---|---|---|
| Diameter, $D_0$ | 2.837 | in | Volume of Solids , $V_s$ : | 22.794 | $in^3$ |
| Area, $A_0$ | 6.320 | $in^2$ | Initial Volume of Voids, $V_v$ : | 14.563 | $in^3$ |
| Height, $L_0$ | 5.911 | in | Initial Void Ratio, $e_o$ : | 0.639 | |
| Volume, $V_0$ | 37.357 | $in^3$ | Initial Degree of Saturation, $S_0$ : | 99.713 | % |

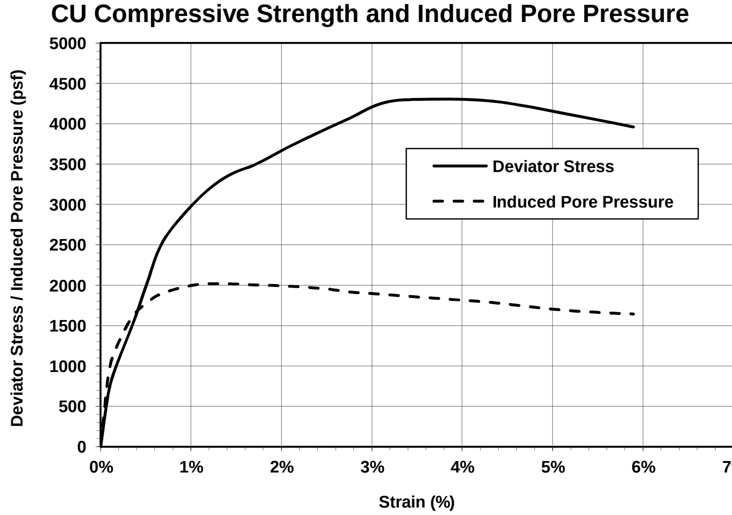
| Water Content BEFORE Test | | | Water Content AFTER Test (Total Specimen) | | |
|---|---|---|---|---|---|
| Tin No.: | T-33 | g | Tin No.: | S | g |
| Wet Soil + Tin : | 85.25 | g | Wet Soil + Tin : | 1356.80 | g |
| Dry Soil + Tin : | 74.1 | g | Dry Soil + Tin : | 1115.30 | g |
| Tin Weight : | 27.37 | g | Tin Weight : | 118.00 | g |
| Dry Mass : | 46.73 | g | Dry Mass : | 997.30 | g |
| Weight of water : | 11.15 | g | Weight of water : | 241.50 | g |
| Moisture : | 23.86047507 | % | Moisture : | 24.22 | % |
| | | | Wet Density : | 126.33 | pcf |
| | | | Dry Density : | 101.70 | pcf |

| | | | | | |
|---|---|---|---|---|---|
| Consolidation Cell Pressure: | 140.0 | psi | Deviator Stress @ Failure, Ds: | 4298.80 | psf |
| Consolidation Back Pressure: | 90.0 | psi | Axial Strain @ Failure: | 5.89 | % |
| Effective Confining Stress, $\sigma_3$: | 50.0 | psi | Major Principal Stress @ Failure, $\sigma_1$: | 11498.80 | psf |
| | 7200.00 | psf | Induced Pore Pressure @ Failure: | 1641.60 | psf |
| Strain Rate: | 0.0030 | in/min | Effective Minor Principal Stress,$\sigma'_3$: | 5558.40 | psf |
| | | | Effective Major Principal Stress, $\sigma'_1$: | 9857.20 | psf |

### Failure Sketch




### CU Compressive Strength and Induced Pore Pressure




Notes: Point classified as A-6a material type, which is different than the first two points of the test. Results of this point do not line up with remainder of points. Therefore, the results of this point are not utilized in the final results of the test.

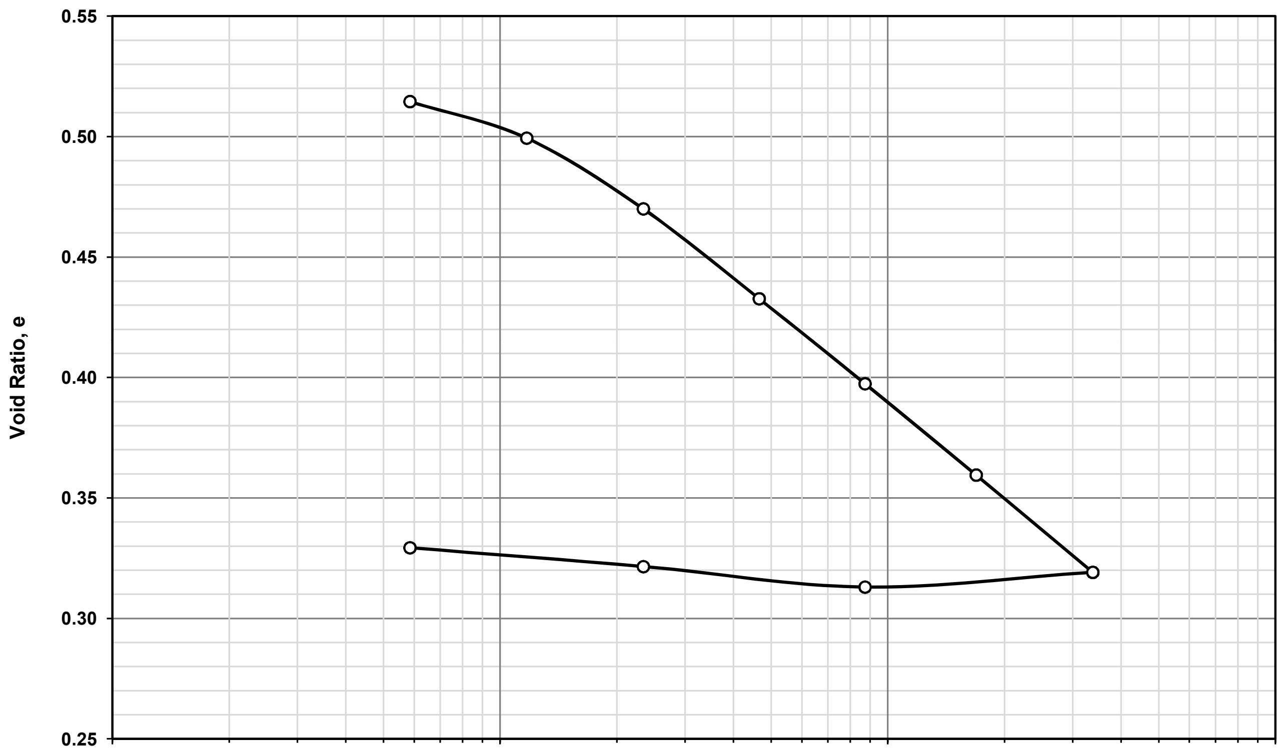
# One-Dimensional Consolidation Test Report (ASTM D2435)

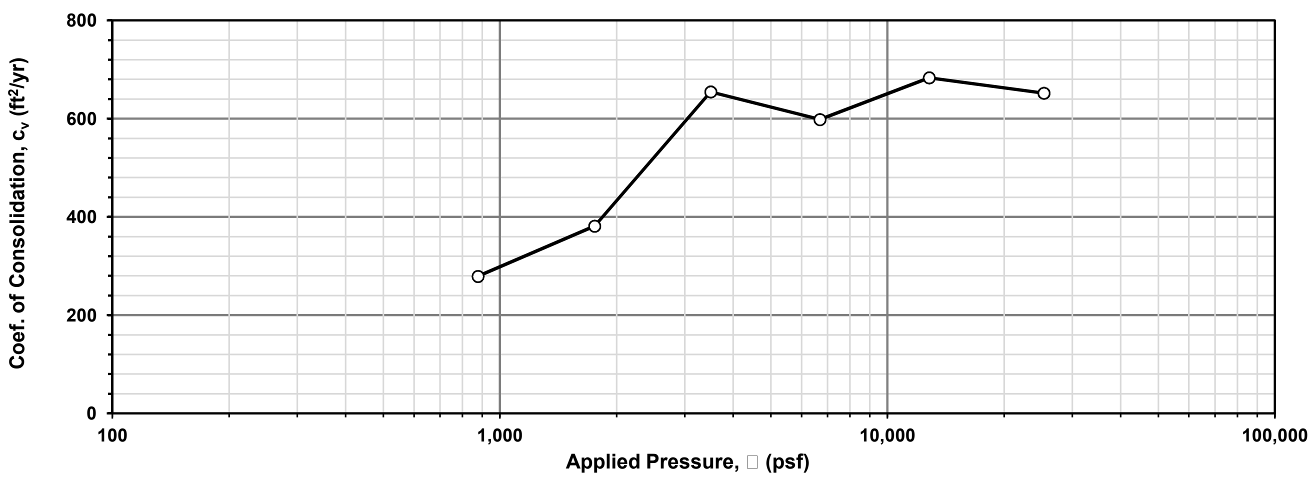
| | | | |
|---|---|---|---|
| Project Number: | B-10-020 | Boring Number: | B-015-0-11 |
| Project Name: | HAM-75-7.85 | Sample No. / Depth: | ST-8 / 20.3 ft |
| Project Location: | Hamilton County, Ohio | Date of Testing: | 10/14/2011 to 10/28/2011 |
| Client: | EMH&T | Technician: | JJH |

Soil Description: Brownish gray SANDY SILT, little clay, trace fine gravel
Soil Classification: ODOT A-4a

| Physical Characteristics | L.L. | P.L. | P.I. | Gravel% | C. Sand% | F. Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|
| | 24 | 15 | 9 | 7 | 6 | 31 | 37 | 19 |

| Natural | | $\gamma_d$ (pcf) | $\gamma_{sat}$ (pcf) | $\sigma_{vo}'$ (psf) | $S_G$ | $e_o$ | $\sigma_p'$ (psf) | $c_c$ | $c_r$ |
|---|---|---|---|---|---|---|---|---|---|
| $S_o$ | $w_o$ | | | | | | | | |
| 85.1% | 15.0% | 108.6 | 127.1 | 2,556 | 2.67 | 0.535 | 1,857 | 0.134 | 0.014 |



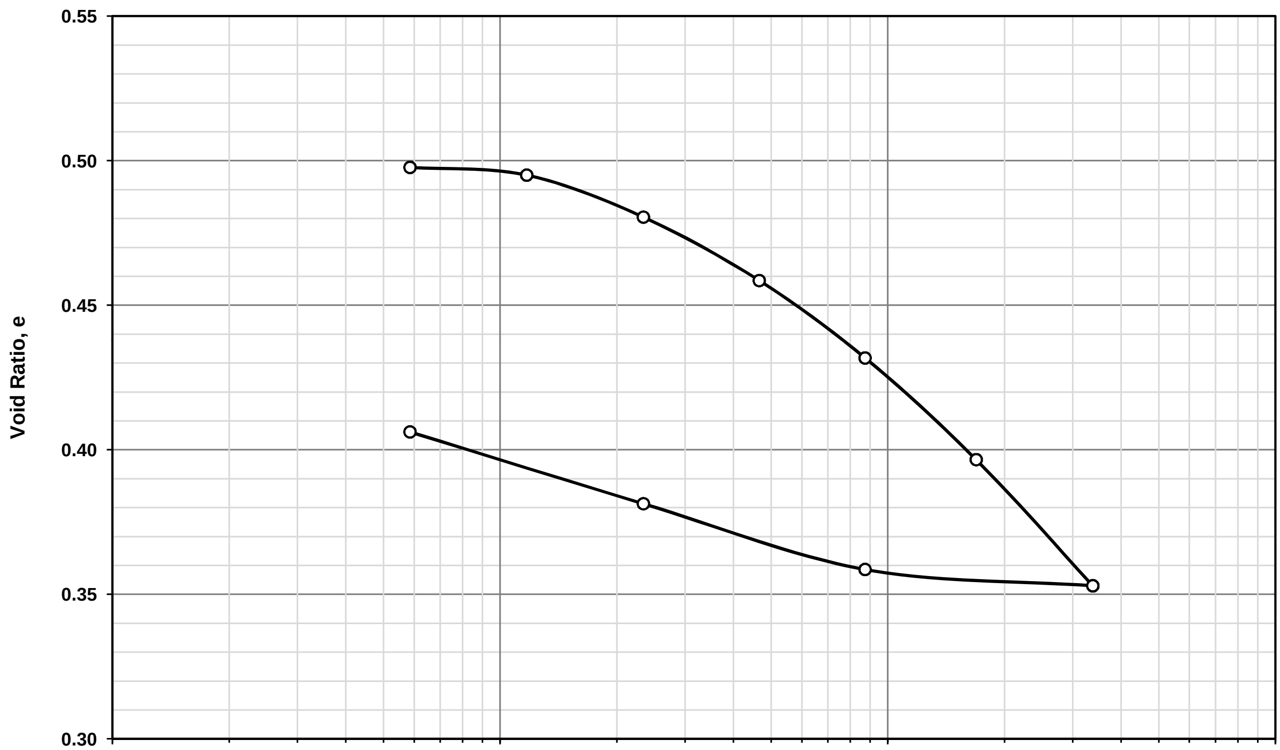
# One-Dimensional Consolidation Test Report (ASTM D2435)

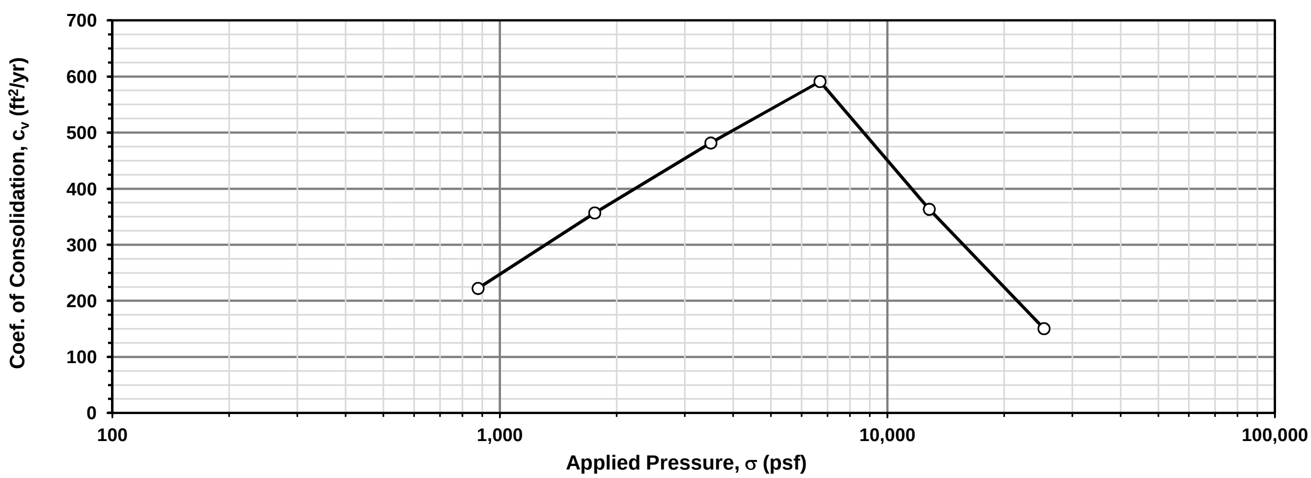
| | | | |
|---|---|---|---|
| Project Number: | B-10-020 | Boring Number: | B-053-0-11 |
| Project Name: | HAM-75-7.85 | Sample No. / Depth: | ST-4 / 8.5 ft |
| Project Location: | Hamilton County, Ohio | Date of Testing: | 11/18/2011 to 12/2/2011 |
| Client: | EMH&T | Technician: | JJH |

Soil Description: Brown SILTY CLAY, little coarse to fine sand, trace fine gravel
Soil Classification: ODOT A-6b

| Physical Characteristics | L.L. | P.L. | P.I. | Gravel% | C. Sand% | F. Sand% | Silt% | Clay% |
|---|---|---|---|---|---|---|---|---|
| | 35 | 16 | 19 | 1 | 3 | 17 | 37 | 42 |

| Natural | | $\gamma_d$ | $\gamma_{sat}$ | $\sigma_{vo}'$ | $S_G$ | $e_o$ | $\sigma_p'$ | $c_c$ | $c_r$ |
|---|---|---|---|---|---|---|---|---|---|
| $S_o$ | $w_o$ | (pcf) | (pcf) | (psf) | | | (psf) | | |
| 98.4% | 19.3% | 110.1 | 130.6 | 1,020 | 2.65 | 0.503 | 4,645 | 0.145 | 0.041 |



# APPENDIX V

# DRIVEN ANALYSIS OUTPUT

# DRIVEN 1.2

## GENERAL PROJECT INFORMATION

Filename: J:\GEOTECH\ANALYSIS\D2BZEP~U.2\B-161.DVN
Project Name: HAM-562-0004- B-161-0-07 Project Date: 05/11/2012
Project Client: EMHT
Computed By: Brian Trenner
Project Manager: Jonathan Sterenberg

## PILE INFORMATION

Pile Type: Pipe Pile - Closed End
Top of Pile: 0.00 ft
Diameter of Pile: 16.00 in

## ULTIMATE CONSIDERATIONS

| | | |
|---|---|---|
| Water Table Depth At Time Of: | - Drilling: | 27.00 ft |
| | - Driving/Restrike | 27.00 ft |
| | - Ultimate: | 27.00 ft |
| Ultimate Considerations: | - Local Scour: | 0.00 ft |
| | - Long Term Scour: | 0.00 ft |
| | - Soft Soil: | 0.00 ft |

## ULTIMATE PROFILE

| Layer | Type | Thickness | Driving Loss | Unit Weight | Strength | Ultimate Curve |
|---|---|---|---|---|---|---|
| 1 | Cohesionless | 19.00 ft | 17.00% | 135.00 pcf | 35.0/35.0 | Nordlund |
| 2 | Cohesionless | 5.50 ft | 17.00% | 120.00 pcf | 28.0/28.0 | Nordlund |
| 3 | Cohesive | 5.00 ft | 33.00% | 120.00 pcf | 3500.00 psf | T-79 Steel |
| 4 | Cohesive | 5.00 ft | 33.00% | 115.00 pcf | 750.00 psf | T-79 Steel |
| 5 | Cohesive | 25.00 ft | 50.00% | 120.00 pcf | 3000.00 psf | T-79 Steel |
| 6 | Cohesionless | 5.50 ft | 17.00% | 130.00 pcf | 32.0/32.0 | Nordlund |
| 7 | Cohesionless | 2.50 ft | 17.00% | 130.00 pcf | 32.0/32.0 | Nordlund |
| 8 | Cohesionless | 3.50 ft | 17.00% | 130.00 pcf | 35.0/35.0 | Nordlund |
| 9 | Cohesionless | 13.50 ft | 17.00% | 130.00 pcf | 35.0/35.0 | Nordlund |
| 10 | Cohesionless | 1.50 ft | 17.00% | 130.00 pcf | 32.0/32.0 | Nordlund |

# RESTRIKE - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.68 psf | 25.63 | N/A | 0.00 Kips |
| 9.01 ft | Cohesionless | 608.17 psf | 25.63 | N/A | 15.72 Kips |
| 18.01 ft | Cohesionless | 1215.68 psf | 25.63 | N/A | 62.81 Kips |
| 18.99 ft | Cohesionless | 1281.82 psf | 25.63 | N/A | 69.83 Kips |
| 19.01 ft | Cohesionless | 2565.60 psf | 20.51 | N/A | 69.94 Kips |
| 24.49 ft | Cohesionless | 2894.40 psf | 20.51 | N/A | 92.44 Kips |
| 24.51 ft | Cohesive | N/A | N/A | 906.91 psf | 92.53 Kips |
| 29.49 ft | Cohesive | N/A | N/A | 967.92 psf | 112.72 Kips |
| 29.51 ft | Cohesive | N/A | N/A | 674.06 psf | 112.79 Kips |
| 34.49 ft | Cohesive | N/A | N/A | 689.94 psf | 127.19 Kips |
| 34.51 ft | Cohesive | N/A | N/A | 1060.00 psf | 127.26 Kips |
| 43.51 ft | Cohesive | N/A | N/A | 1174.75 psf | 171.55 Kips |
| 52.51 ft | Cohesive | N/A | N/A | 1289.50 psf | 224.50 Kips |
| 59.49 ft | Cohesive | N/A | N/A | 1300.00 psf | 263.30 Kips |
| 59.51 ft | Cohesionless | 5372.34 psf | 23.44 | N/A | 263.47 Kips |
| 64.99 ft | Cohesionless | 5557.56 psf | 23.44 | N/A | 328.57 Kips |
| 65.01 ft | Cohesionless | 5744.14 psf | 23.44 | N/A | 328.82 Kips |
| 67.49 ft | Cohesionless | 5827.96 psf | 23.44 | N/A | 359.72 Kips |
| 67.51 ft | Cohesionless | 5913.14 psf | 25.63 | N/A | 360.02 Kips |
| 70.99 ft | Cohesionless | 6030.76 psf | 25.63 | N/A | 420.23 Kips |
| 71.01 ft | Cohesionless | 6149.74 psf | 25.63 | N/A | 420.58 Kips |
| 80.01 ft | Cohesionless | 6453.94 psf | 25.63 | N/A | 587.22 Kips |
| 84.49 ft | Cohesionless | 6605.36 psf | 25.63 | N/A | 676.02 Kips |
| 84.51 ft | Cohesionless | 7062.34 psf | 23.44 | N/A | 676.38 Kips |
| 85.99 ft | Cohesionless | 7112.36 psf | 23.44 | N/A | 698.88 Kips |

# RESTRIKE - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 1.35 psf | 64.00 | 150.24 Kips | 0.08 Kips |
| 9.01 ft | Cohesionless | 1216.35 psf | 64.00 | 150.24 Kips | 73.91 Kips |
| 18.01 ft | Cohesionless | 2431.35 psf | 64.00 | 150.24 Kips | 147.74 Kips |
| 18.99 ft | Cohesionless | 2563.65 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 19.01 ft | Cohesionless | 2566.20 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 24.49 ft | Cohesionless | 3223.80 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 24.51 ft | Cohesive | N/A | N/A | N/A | 43.98 Kips |
| 29.49 ft | Cohesive | N/A | N/A | N/A | 43.98 Kips |
| 29.51 ft | Cohesive | N/A | N/A | N/A | 9.42 Kips |
| 34.49 ft | Cohesive | N/A | N/A | N/A | 9.42 Kips |
| 34.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 43.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 52.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 59.49 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 59.51 ft | Cohesionless | 5372.68 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 64.99 ft | Cohesionless | 5743.12 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 65.01 ft | Cohesionless | 5744.48 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 67.49 ft | Cohesionless | 5912.12 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 67.51 ft | Cohesionless | 5913.48 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 70.99 ft | Cohesionless | 6148.72 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 71.01 ft | Cohesionless | 6150.08 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 80.01 ft | Cohesionless | 6758.48 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 84.49 ft | Cohesionless | 7061.32 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 84.51 ft | Cohesionless | 7062.68 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 85.99 ft | Cohesionless | 7162.72 psf | 40.40 | 46.08 Kips | 46.08 Kips |

# RESTRIKE - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.08 Kips | 0.08 Kips |
| 9.01 ft | 15.72 Kips | 73.91 Kips | 89.63 Kips |
| 18.01 ft | 62.81 Kips | 147.74 Kips | 210.55 Kips |
| 18.99 ft | 69.83 Kips | 150.24 Kips | 220.07 Kips |
| 19.01 ft | 69.94 Kips | 18.60 Kips | 88.54 Kips |
| 24.49 ft | 92.44 Kips | 18.60 Kips | 111.04 Kips |
| 24.51 ft | 92.53 Kips | 43.98 Kips | 136.51 Kips |
| 29.49 ft | 112.72 Kips | 43.98 Kips | 156.70 Kips |
| 29.51 ft | 112.79 Kips | 9.42 Kips | 122.22 Kips |
| 34.49 ft | 127.19 Kips | 9.42 Kips | 136.61 Kips |
| 34.51 ft | 127.26 Kips | 37.70 Kips | 164.96 Kips |
| 43.51 ft | 171.55 Kips | 37.70 Kips | 209.25 Kips |
| 52.51 ft | 224.50 Kips | 37.70 Kips | 262.19 Kips |
| 59.49 ft | 263.30 Kips | 37.70 Kips | 301.00 Kips |
| 59.51 ft | 263.47 Kips | 46.08 Kips | 309.54 Kips |
| 64.99 ft | 328.57 Kips | 46.08 Kips | 374.65 Kips |
| 65.01 ft | 328.82 Kips | 46.08 Kips | 374.90 Kips |
| 67.49 ft | 359.72 Kips | 46.08 Kips | 405.80 Kips |
| 67.51 ft | 360.02 Kips | 150.24 Kips | 510.25 Kips |
| 70.99 ft | 420.23 Kips | 150.24 Kips | 570.46 Kips |
| 71.01 ft | 420.58 Kips | 150.24 Kips | 570.82 Kips |
| 80.01 ft | 587.22 Kips | 150.24 Kips | 737.46 Kips |
| 84.49 ft | 676.02 Kips | 150.24 Kips | 826.26 Kips |
| 84.51 ft | 676.38 Kips | 46.08 Kips | 722.45 Kips |
| 85.99 ft | 698.88 Kips | 46.08 Kips | 744.96 Kips |

# DRIVING - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.68 psf | 25.63 | N/A | 0.00 Kips |
| 9.01 ft | Cohesionless | 608.17 psf | 25.63 | N/A | 13.05 Kips |
| 18.01 ft | Cohesionless | 1215.68 psf | 25.63 | N/A | 52.13 Kips |
| 18.99 ft | Cohesionless | 1281.82 psf | 25.63 | N/A | 57.96 Kips |
| 19.01 ft | Cohesionless | 2565.60 psf | 20.51 | N/A | 58.05 Kips |
| 24.49 ft | Cohesionless | 2894.40 psf | 20.51 | N/A | 76.73 Kips |
| 24.51 ft | Cohesive | N/A | N/A | 906.91 psf | 76.78 Kips |
| 29.49 ft | Cohesive | N/A | N/A | 967.92 psf | 90.31 Kips |
| 29.51 ft | Cohesive | N/A | N/A | 674.06 psf | 90.36 Kips |
| 34.49 ft | Cohesive | N/A | N/A | 689.94 psf | 100.01 Kips |
| 34.51 ft | Cohesive | N/A | N/A | 1060.00 psf | 100.04 Kips |
| 43.51 ft | Cohesive | N/A | N/A | 1174.75 psf | 122.19 Kips |
| 52.51 ft | Cohesive | N/A | N/A | 1289.50 psf | 148.66 Kips |
| 59.49 ft | Cohesive | N/A | N/A | 1300.00 psf | 168.06 Kips |
| 59.51 ft | Cohesionless | 5372.34 psf | 23.44 | N/A | 168.20 Kips |
| 64.99 ft | Cohesionless | 5557.56 psf | 23.44 | N/A | 222.24 Kips |
| 65.01 ft | Cohesionless | 5744.14 psf | 23.44 | N/A | 222.45 Kips |
| 67.49 ft | Cohesionless | 5827.96 psf | 23.44 | N/A | 248.09 Kips |
| 67.51 ft | Cohesionless | 5913.14 psf | 25.63 | N/A | 248.34 Kips |
| 70.99 ft | Cohesionless | 6030.76 psf | 25.63 | N/A | 298.31 Kips |
| 71.01 ft | Cohesionless | 6149.74 psf | 25.63 | N/A | 298.60 Kips |
| 80.01 ft | Cohesionless | 6453.94 psf | 25.63 | N/A | 436.92 Kips |
| 84.49 ft | Cohesionless | 6605.36 psf | 25.63 | N/A | 510.63 Kips |
| 84.51 ft | Cohesionless | 7062.34 psf | 23.44 | N/A | 510.92 Kips |
| 85.99 ft | Cohesionless | 7112.36 psf | 23.44 | N/A | 529.60 Kips |

# DRIVING - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 1.35 psf | 64.00 | 150.24 Kips | 0.08 Kips |
| 9.01 ft | Cohesionless | 1216.35 psf | 64.00 | 150.24 Kips | 73.91 Kips |
| 18.01 ft | Cohesionless | 2431.35 psf | 64.00 | 150.24 Kips | 147.74 Kips |
| 18.99 ft | Cohesionless | 2563.65 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 19.01 ft | Cohesionless | 2566.20 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 24.49 ft | Cohesionless | 3223.80 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 24.51 ft | Cohesive | N/A | N/A | N/A | 43.98 Kips |
| 29.49 ft | Cohesive | N/A | N/A | N/A | 43.98 Kips |
| 29.51 ft | Cohesive | N/A | N/A | N/A | 9.42 Kips |
| 34.49 ft | Cohesive | N/A | N/A | N/A | 9.42 Kips |
| 34.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 43.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 52.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 59.49 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 59.51 ft | Cohesionless | 5372.68 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 64.99 ft | Cohesionless | 5743.12 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 65.01 ft | Cohesionless | 5744.48 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 67.49 ft | Cohesionless | 5912.12 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 67.51 ft | Cohesionless | 5913.48 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 70.99 ft | Cohesionless | 6148.72 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 71.01 ft | Cohesionless | 6150.08 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 80.01 ft | Cohesionless | 6758.48 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 84.49 ft | Cohesionless | 7061.32 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 84.51 ft | Cohesionless | 7062.68 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 85.99 ft | Cohesionless | 7162.72 psf | 40.40 | 46.08 Kips | 46.08 Kips |

## DRIVING - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.08 Kips | 0.08 Kips |
| 9.01 ft | 13.05 Kips | 73.91 Kips | 86.96 Kips |
| 18.01 ft | 52.13 Kips | 147.74 Kips | 199.87 Kips |
| 18.99 ft | 57.96 Kips | 150.24 Kips | 208.20 Kips |
| 19.01 ft | 58.05 Kips | 18.60 Kips | 76.65 Kips |
| 24.49 ft | 76.73 Kips | 18.60 Kips | 95.33 Kips |
| 24.51 ft | 76.78 Kips | 43.98 Kips | 120.77 Kips |
| 29.49 ft | 90.31 Kips | 43.98 Kips | 134.30 Kips |
| 29.51 ft | 90.36 Kips | 9.42 Kips | 99.79 Kips |
| 34.49 ft | 100.01 Kips | 9.42 Kips | 109.43 Kips |
| 34.51 ft | 100.04 Kips | 37.70 Kips | 137.74 Kips |
| 43.51 ft | 122.19 Kips | 37.70 Kips | 159.89 Kips |
| 52.51 ft | 148.66 Kips | 37.70 Kips | 186.36 Kips |
| 59.49 ft | 168.06 Kips | 37.70 Kips | 205.76 Kips |
| 59.51 ft | 168.20 Kips | 46.08 Kips | 214.28 Kips |
| 64.99 ft | 222.24 Kips | 46.08 Kips | 268.32 Kips |
| 65.01 ft | 222.45 Kips | 46.08 Kips | 268.52 Kips |
| 67.49 ft | 248.09 Kips | 46.08 Kips | 294.17 Kips |
| 67.51 ft | 248.34 Kips | 150.24 Kips | 398.58 Kips |
| 70.99 ft | 298.31 Kips | 150.24 Kips | 448.55 Kips |
| 71.01 ft | 298.60 Kips | 150.24 Kips | 448.84 Kips |
| 80.01 ft | 436.92 Kips | 150.24 Kips | 587.15 Kips |
| 84.49 ft | 510.63 Kips | 150.24 Kips | 660.86 Kips |
| 84.51 ft | 510.92 Kips | 46.08 Kips | 557.00 Kips |
| 85.99 ft | 529.60 Kips | 46.08 Kips | 575.67 Kips |

# <u>ULTIMATE - SKIN FRICTION</u>

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.68 psf | 25.63 | N/A | 0.00 Kips |
| 9.01 ft | Cohesionless | 608.17 psf | 25.63 | N/A | 15.72 Kips |
| 18.01 ft | Cohesionless | 1215.68 psf | 25.63 | N/A | 62.81 Kips |
| 18.99 ft | Cohesionless | 1281.82 psf | 25.63 | N/A | 69.83 Kips |
| 19.01 ft | Cohesionless | 2565.60 psf | 20.51 | N/A | 69.94 Kips |
| 24.49 ft | Cohesionless | 2894.40 psf | 20.51 | N/A | 92.44 Kips |
| 24.51 ft | Cohesive | N/A | N/A | 906.91 psf | 92.53 Kips |
| 29.49 ft | Cohesive | N/A | N/A | 967.92 psf | 112.72 Kips |
| 29.51 ft | Cohesive | N/A | N/A | 674.06 psf | 112.79 Kips |
| 34.49 ft | Cohesive | N/A | N/A | 689.94 psf | 127.19 Kips |
| 34.51 ft | Cohesive | N/A | N/A | 1060.00 psf | 127.26 Kips |
| 43.51 ft | Cohesive | N/A | N/A | 1174.75 psf | 171.55 Kips |
| 52.51 ft | Cohesive | N/A | N/A | 1289.50 psf | 224.50 Kips |
| 59.49 ft | Cohesive | N/A | N/A | 1300.00 psf | 263.30 Kips |
| 59.51 ft | Cohesionless | 5372.34 psf | 23.44 | N/A | 263.47 Kips |
| 64.99 ft | Cohesionless | 5557.56 psf | 23.44 | N/A | 328.57 Kips |
| 65.01 ft | Cohesionless | 5744.14 psf | 23.44 | N/A | 328.82 Kips |
| 67.49 ft | Cohesionless | 5827.96 psf | 23.44 | N/A | 359.72 Kips |
| 67.51 ft | Cohesionless | 5913.14 psf | 25.63 | N/A | 360.02 Kips |
| 70.99 ft | Cohesionless | 6030.76 psf | 25.63 | N/A | 420.23 Kips |
| 71.01 ft | Cohesionless | 6149.74 psf | 25.63 | N/A | 420.58 Kips |
| 80.01 ft | Cohesionless | 6453.94 psf | 25.63 | N/A | 587.22 Kips |
| 84.49 ft | Cohesionless | 6605.36 psf | 25.63 | N/A | 676.02 Kips |
| 84.51 ft | Cohesionless | 7062.34 psf | 23.44 | N/A | 676.38 Kips |
| 85.99 ft | Cohesionless | 7112.36 psf | 23.44 | N/A | 698.88 Kips |

# ULTIMATE - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 1.35 psf | 64.00 | 150.24 Kips | 0.08 Kips |
| 9.01 ft | Cohesionless | 1216.35 psf | 64.00 | 150.24 Kips | 73.91 Kips |
| 18.01 ft | Cohesionless | 2431.35 psf | 64.00 | 150.24 Kips | 147.74 Kips |
| 18.99 ft | Cohesionless | 2563.65 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 19.01 ft | Cohesionless | 2566.20 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 24.49 ft | Cohesionless | 3223.80 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 24.51 ft | Cohesive | N/A | N/A | N/A | 43.98 Kips |
| 29.49 ft | Cohesive | N/A | N/A | N/A | 43.98 Kips |
| 29.51 ft | Cohesive | N/A | N/A | N/A | 9.42 Kips |
| 34.49 ft | Cohesive | N/A | N/A | N/A | 9.42 Kips |
| 34.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 43.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 52.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 59.49 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 59.51 ft | Cohesionless | 5372.68 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 64.99 ft | Cohesionless | 5743.12 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 65.01 ft | Cohesionless | 5744.48 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 67.49 ft | Cohesionless | 5912.12 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 67.51 ft | Cohesionless | 5913.48 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 70.99 ft | Cohesionless | 6148.72 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 71.01 ft | Cohesionless | 6150.08 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 80.01 ft | Cohesionless | 6758.48 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 84.49 ft | Cohesionless | 7061.32 psf | 64.00 | 150.24 Kips | 150.24 Kips |
| 84.51 ft | Cohesionless | 7062.68 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 85.99 ft | Cohesionless | 7162.72 psf | 40.40 | 46.08 Kips | 46.08 Kips |

# ULTIMATE - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.08 Kips | 0.08 Kips |
| 9.01 ft | 15.72 Kips | 73.91 Kips | 89.63 Kips |
| 18.01 ft | 62.81 Kips | 147.74 Kips | 210.55 Kips |
| 18.99 ft | 69.83 Kips | 150.24 Kips | 220.07 Kips |
| 19.01 ft | 69.94 Kips | 18.60 Kips | 88.54 Kips |
| 24.49 ft | 92.44 Kips | 18.60 Kips | 111.04 Kips |
| 24.51 ft | 92.53 Kips | 43.98 Kips | 136.51 Kips |
| 29.49 ft | 112.72 Kips | 43.98 Kips | 156.70 Kips |
| 29.51 ft | 112.79 Kips | 9.42 Kips | 122.22 Kips |
| 34.49 ft | 127.19 Kips | 9.42 Kips | 136.61 Kips |
| 34.51 ft | 127.26 Kips | 37.70 Kips | 164.96 Kips |
| 43.51 ft | 171.55 Kips | 37.70 Kips | 209.25 Kips |
| 52.51 ft | 224.50 Kips | 37.70 Kips | 262.19 Kips |
| 59.49 ft | 263.30 Kips | 37.70 Kips | 301.00 Kips |
| 59.51 ft | 263.47 Kips | 46.08 Kips | 309.54 Kips |
| 64.99 ft | 328.57 Kips | 46.08 Kips | 374.65 Kips |
| 65.01 ft | 328.82 Kips | 46.08 Kips | 374.90 Kips |
| 67.49 ft | 359.72 Kips | 46.08 Kips | 405.80 Kips |
| 67.51 ft | 360.02 Kips | 150.24 Kips | 510.25 Kips |
| 70.99 ft | 420.23 Kips | 150.24 Kips | 570.46 Kips |
| 71.01 ft | 420.58 Kips | 150.24 Kips | 570.82 Kips |
| 80.01 ft | 587.22 Kips | 150.24 Kips | 737.46 Kips |
| 84.49 ft | 676.02 Kips | 150.24 Kips | 826.26 Kips |
| 84.51 ft | 676.38 Kips | 46.08 Kips | 722.45 Kips |
| 85.99 ft | 698.88 Kips | 46.08 Kips | 744.96 Kips |

# DRIVEN 1.2

## GENERAL PROJECT INFORMATION

Filename: C:\DOCUME~1\LEGACY\DESKTOP\B-162.DVN
Project Name: HAM-75-0004 - B-162-0-07 Project Date: 11/28/2022
Project Client: EMHT
Computed By: Brian Trenner
Project Manager: Jonathan Sterenberg

## PILE INFORMATION

Pile Type: Pipe Pile - Closed End
Top of Pile: 6.50 ft
Diameter of Pile: 16.00 in

## ULTIMATE CONSIDERATIONS

| | | |
|---|---|---|
| Water Table Depth At Time Of: | - Drilling: | 0.00 ft |
| | - Driving/Restrike | 0.00 ft |
| | - Ultimate: | 0.00 ft |
| Ultimate Considerations: | - Local Scour: | 0.00 ft |
| | - Long Term Scour: | 0.00 ft |
| | - Soft Soil: | 0.00 ft |

## ULTIMATE PROFILE

| Layer | Type | Thickness | Driving Loss | Unit Weight | Strength | Ultimate Curve |
|---|---|---|---|---|---|---|
| 1 | Cohesionless | 6.50 ft | 0.00% | 120.00 pcf | 28.0/28.0 | Nordlund |
| 2 | Cohesive | 12.00 ft | 50.00% | 115.00 pcf | 1500.00 psf | T-79 Steel |
| 3 | Cohesionless | 10.00 ft | 33.00% | 125.00 pcf | 30.0/30.0 | Nordlund |
| 4 | Cohesive | 15.00 ft | 33.00% | 125.00 pcf | 3750.00 psf | T-79 Steel |
| 5 | Cohesionless | 5.00 ft | 33.00% | 125.00 pcf | 30.0/30.0 | Nordlund |
| 6 | Cohesive | 4.50 ft | 33.00% | 115.00 pcf | 1250.00 psf | T-79 Steel |
| 7 | Cohesive | 5.50 ft | 33.00% | 120.00 pcf | 3250.00 psf | T-79 Steel |
| 8 | Cohesionless | 4.50 ft | 17.00% | 125.00 pcf | 30.0/30.0 | Nordlund |
| 9 | Cohesionless | 2.00 ft | 17.00% | 130.00 pcf | 33.0/33.0 | Nordlund |
| 10 | Cohesionless | 5.00 ft | 17.00% | 130.00 pcf | 33.0/33.0 | Nordlund |
| 11 | Cohesionless | 3.50 ft | 17.00% | 130.00 pcf | 33.0/33.0 | Nordlund |
| 12 | Cohesive | 11.00 ft | 33.00% | 120.00 pcf | 2000.00 psf | T-79 Steel |
| 13 | Cohesionless | 6.50 ft | 0.00% | 125.00 pcf | 31.0/31.0 | Nordlund |

# RESTRIKE - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.00 psf | 0.00 | N/A | 0.00 Kips |
| 6.49 ft | Cohesionless | 0.00 psf | 0.00 | N/A | 0.00 Kips |
| 6.49 ft | Cohesive | N/A | N/A | 0.00 psf | 0.00 Kips |
| 6.50 ft | Cohesive | N/A | N/A | 0.00 psf | 0.00 Kips |
| 6.51 ft | Cohesive | N/A | N/A | 1060.00 psf | 0.04 Kips |
| 15.51 ft | Cohesive | N/A | N/A | 1072.79 psf | 40.49 Kips |
| 18.49 ft | Cohesive | N/A | N/A | 1090.30 psf | 54.76 Kips |
| 18.51 ft | Cohesionless | 1005.91 psf | 21.97 | N/A | 54.82 Kips |
| 27.51 ft | Cohesionless | 1287.61 psf | 21.97 | N/A | 74.33 Kips |
| 28.49 ft | Cohesionless | 1318.29 psf | 21.97 | N/A | 76.96 Kips |
| 28.51 ft | Cohesive | N/A | N/A | 955.91 psf | 77.03 Kips |
| 37.51 ft | Cohesive | N/A | N/A | 1066.16 psf | 117.23 Kips |
| 43.49 ft | Cohesive | N/A | N/A | 1139.42 psf | 148.54 Kips |
| 43.51 ft | Cohesionless | 2570.91 psf | 21.97 | N/A | 148.63 Kips |
| 48.49 ft | Cohesionless | 2726.79 psf | 21.97 | N/A | 171.48 Kips |
| 48.51 ft | Cohesive | N/A | N/A | 1099.29 psf | 171.58 Kips |
| 52.99 ft | Cohesive | N/A | N/A | 1120.85 psf | 192.61 Kips |
| 53.01 ft | Cohesive | N/A | N/A | 1256.04 psf | 192.71 Kips |
| 58.49 ft | Cohesive | N/A | N/A | 1260.00 psf | 221.64 Kips |
| 58.51 ft | Cohesionless | 3437.41 psf | 21.97 | N/A | 221.75 Kips |
| 62.99 ft | Cohesionless | 3577.64 psf | 21.97 | N/A | 248.71 Kips |
| 63.01 ft | Cohesionless | 3719.14 psf | 24.17 | N/A | 248.86 Kips |
| 64.99 ft | Cohesionless | 3786.06 psf | 24.17 | N/A | 266.67 Kips |
| 65.01 ft | Cohesionless | 3854.34 psf | 24.17 | N/A | 266.86 Kips |
| 69.99 ft | Cohesionless | 4022.66 psf | 24.17 | N/A | 314.45 Kips |
| 70.01 ft | Cohesionless | 4192.34 psf | 24.17 | N/A | 314.64 Kips |
| 73.49 ft | Cohesionless | 4309.96 psf | 24.17 | N/A | 350.27 Kips |
| 73.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 350.44 Kips |
| 82.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 407.56 Kips |
| 84.49 ft | Cohesive | N/A | N/A | 1515.00 psf | 420.12 Kips |
| 84.51 ft | Cohesionless | 5062.51 psf | 22.70 | N/A | 420.28 Kips |
| 90.99 ft | Cohesionless | 5265.34 psf | 22.70 | N/A | 485.34 Kips |

# RESTRIKE - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.00 psf | 22.80 | 18.60 Kips | 0.00 Kips |
| 6.49 ft | Cohesionless | 0.00 psf | 22.80 | 18.60 Kips | 0.00 Kips |
| 6.49 ft | Cohesive | N/A | N/A | N/A | 0.00 Kips |
| 6.50 ft | Cohesive | N/A | N/A | N/A | 6.39 Kips |
| 6.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 15.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 18.49 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 18.51 ft | Cohesionless | 1006.23 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 27.51 ft | Cohesionless | 1569.63 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 28.49 ft | Cohesionless | 1630.97 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 28.51 ft | Cohesive | N/A | N/A | N/A | 47.12 Kips |
| 37.51 ft | Cohesive | N/A | N/A | N/A | 47.12 Kips |
| 43.49 ft | Cohesive | N/A | N/A | N/A | 47.12 Kips |
| 43.51 ft | Cohesionless | 2571.23 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 48.49 ft | Cohesionless | 2882.97 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 48.51 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 52.99 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 53.01 ft | Cohesive | N/A | N/A | N/A | 40.84 Kips |
| 58.49 ft | Cohesive | N/A | N/A | N/A | 40.84 Kips |
| 58.51 ft | Cohesionless | 3437.73 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 62.99 ft | Cohesionless | 3718.17 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 63.01 ft | Cohesionless | 3719.48 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 64.99 ft | Cohesionless | 3853.32 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 65.01 ft | Cohesionless | 3854.68 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 69.99 ft | Cohesionless | 4191.32 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 70.01 ft | Cohesionless | 4192.68 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 73.49 ft | Cohesionless | 4427.92 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 73.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 82.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 84.49 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 84.51 ft | Cohesionless | 5062.83 psf | 35.20 | 28.85 Kips | 28.85 Kips |
| 90.99 ft | Cohesionless | 5468.47 psf | 35.20 | 28.85 Kips | 28.85 Kips |

# RESTRIKE - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.00 Kips | 0.00 Kips |
| 6.49 ft | 0.00 Kips | 0.00 Kips | 0.00 Kips |
| 6.49 ft | 0.00 Kips | 0.00 Kips | 0.00 Kips |
| 6.50 ft | 0.00 Kips | 6.39 Kips | 6.39 Kips |
| 6.51 ft | 0.04 Kips | 18.85 Kips | 18.89 Kips |
| 15.51 ft | 40.49 Kips | 18.85 Kips | 59.34 Kips |
| 18.49 ft | 54.76 Kips | 18.85 Kips | 73.61 Kips |
| 18.51 ft | 54.82 Kips | 18.60 Kips | 73.42 Kips |
| 27.51 ft | 74.33 Kips | 18.60 Kips | 92.92 Kips |
| 28.49 ft | 76.96 Kips | 18.60 Kips | 95.56 Kips |
| 28.51 ft | 77.03 Kips | 47.12 Kips | 124.16 Kips |
| 37.51 ft | 117.23 Kips | 47.12 Kips | 164.35 Kips |
| 43.49 ft | 148.54 Kips | 47.12 Kips | 195.66 Kips |
| 43.51 ft | 148.63 Kips | 18.60 Kips | 167.23 Kips |
| 48.49 ft | 171.48 Kips | 18.60 Kips | 190.08 Kips |
| 48.51 ft | 171.58 Kips | 15.71 Kips | 187.29 Kips |
| 52.99 ft | 192.61 Kips | 15.71 Kips | 208.32 Kips |
| 53.01 ft | 192.71 Kips | 40.84 Kips | 233.55 Kips |
| 58.49 ft | 221.64 Kips | 40.84 Kips | 262.48 Kips |
| 58.51 ft | 221.75 Kips | 18.60 Kips | 240.34 Kips |
| 62.99 ft | 248.71 Kips | 18.60 Kips | 267.31 Kips |
| 63.01 ft | 248.86 Kips | 69.81 Kips | 318.68 Kips |
| 64.99 ft | 266.67 Kips | 69.81 Kips | 336.49 Kips |
| 65.01 ft | 266.86 Kips | 69.81 Kips | 336.67 Kips |
| 69.99 ft | 314.45 Kips | 69.81 Kips | 384.26 Kips |
| 70.01 ft | 314.64 Kips | 69.81 Kips | 384.46 Kips |
| 73.49 ft | 350.27 Kips | 69.81 Kips | 420.09 Kips |
| 73.51 ft | 350.44 Kips | 25.13 Kips | 375.58 Kips |
| 82.51 ft | 407.56 Kips | 25.13 Kips | 432.69 Kips |
| 84.49 ft | 420.12 Kips | 25.13 Kips | 445.26 Kips |
| 84.51 ft | 420.28 Kips | 28.85 Kips | 449.14 Kips |
| 90.99 ft | 485.34 Kips | 28.85 Kips | 514.19 Kips |

# DRIVING - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.00 psf | 0.00 | N/A | 0.00 Kips |
| 6.49 ft | Cohesionless | 0.00 psf | 0.00 | N/A | 0.00 Kips |
| 6.49 ft | Cohesive | N/A | N/A | 0.00 psf | 0.00 Kips |
| 6.50 ft | Cohesive | N/A | N/A | 0.00 psf | 0.00 Kips |
| 6.51 ft | Cohesive | N/A | N/A | 1060.00 psf | 0.02 Kips |
| 15.51 ft | Cohesive | N/A | N/A | 1072.79 psf | 20.24 Kips |
| 18.49 ft | Cohesive | N/A | N/A | 1090.30 psf | 27.38 Kips |
| 18.51 ft | Cohesionless | 1005.91 psf | 21.97 | N/A | 27.42 Kips |
| 27.51 ft | Cohesionless | 1287.61 psf | 21.97 | N/A | 40.49 Kips |
| 28.49 ft | Cohesionless | 1318.29 psf | 21.97 | N/A | 42.26 Kips |
| 28.51 ft | Cohesive | N/A | N/A | 955.91 psf | 42.30 Kips |
| 37.51 ft | Cohesive | N/A | N/A | 1066.16 psf | 69.23 Kips |
| 43.49 ft | Cohesive | N/A | N/A | 1139.42 psf | 90.21 Kips |
| 43.51 ft | Cohesionless | 2570.91 psf | 21.97 | N/A | 90.28 Kips |
| 48.49 ft | Cohesionless | 2726.79 psf | 21.97 | N/A | 105.58 Kips |
| 48.51 ft | Cohesive | N/A | N/A | 1099.29 psf | 105.65 Kips |
| 52.99 ft | Cohesive | N/A | N/A | 1120.85 psf | 119.74 Kips |
| 53.01 ft | Cohesive | N/A | N/A | 1256.04 psf | 119.81 Kips |
| 58.49 ft | Cohesive | N/A | N/A | 1260.00 psf | 139.19 Kips |
| 58.51 ft | Cohesionless | 3437.41 psf | 21.97 | N/A | 139.28 Kips |
| 62.99 ft | Cohesionless | 3577.64 psf | 21.97 | N/A | 161.66 Kips |
| 63.01 ft | Cohesionless | 3719.14 psf | 24.17 | N/A | 161.79 Kips |
| 64.99 ft | Cohesionless | 3786.06 psf | 24.17 | N/A | 176.57 Kips |
| 65.01 ft | Cohesionless | 3854.34 psf | 24.17 | N/A | 176.72 Kips |
| 69.99 ft | Cohesionless | 4022.66 psf | 24.17 | N/A | 216.22 Kips |
| 70.01 ft | Cohesionless | 4192.34 psf | 24.17 | N/A | 216.38 Kips |
| 73.49 ft | Cohesionless | 4309.96 psf | 24.17 | N/A | 245.96 Kips |
| 73.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 246.07 Kips |
| 82.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 284.34 Kips |
| 84.49 ft | Cohesive | N/A | N/A | 1515.00 psf | 292.76 Kips |
| 84.51 ft | Cohesionless | 5062.51 psf | 22.70 | N/A | 292.92 Kips |
| 90.99 ft | Cohesionless | 5265.34 psf | 22.70 | N/A | 357.97 Kips |

# DRIVING - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.00 psf | 22.80 | 18.60 Kips | 0.00 Kips |
| 6.49 ft | Cohesionless | 0.00 psf | 22.80 | 18.60 Kips | 0.00 Kips |
| 6.49 ft | Cohesive | N/A | N/A | N/A | 0.00 Kips |
| 6.50 ft | Cohesive | N/A | N/A | N/A | 6.39 Kips |
| 6.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 15.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 18.49 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 18.51 ft | Cohesionless | 1006.23 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 27.51 ft | Cohesionless | 1569.63 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 28.49 ft | Cohesionless | 1630.97 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 28.51 ft | Cohesive | N/A | N/A | N/A | 47.12 Kips |
| 37.51 ft | Cohesive | N/A | N/A | N/A | 47.12 Kips |
| 43.49 ft | Cohesive | N/A | N/A | N/A | 47.12 Kips |
| 43.51 ft | Cohesionless | 2571.23 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 48.49 ft | Cohesionless | 2882.97 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 48.51 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 52.99 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 53.01 ft | Cohesive | N/A | N/A | N/A | 40.84 Kips |
| 58.49 ft | Cohesive | N/A | N/A | N/A | 40.84 Kips |
| 58.51 ft | Cohesionless | 3437.73 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 62.99 ft | Cohesionless | 3718.17 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 63.01 ft | Cohesionless | 3719.48 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 64.99 ft | Cohesionless | 3853.32 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 65.01 ft | Cohesionless | 3854.68 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 69.99 ft | Cohesionless | 4191.32 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 70.01 ft | Cohesionless | 4192.68 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 73.49 ft | Cohesionless | 4427.92 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 73.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 82.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 84.49 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 84.51 ft | Cohesionless | 5062.83 psf | 35.20 | 28.85 Kips | 28.85 Kips |
| 90.99 ft | Cohesionless | 5468.47 psf | 35.20 | 28.85 Kips | 28.85 Kips |

# DRIVING - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.00 Kips | 0.00 Kips |
| 6.49 ft | 0.00 Kips | 0.00 Kips | 0.00 Kips |
| 6.49 ft | 0.00 Kips | 0.00 Kips | 0.00 Kips |
| 6.50 ft | 0.00 Kips | 6.39 Kips | 6.39 Kips |
| 6.51 ft | 0.02 Kips | 18.85 Kips | 18.87 Kips |
| 15.51 ft | 20.24 Kips | 18.85 Kips | 39.09 Kips |
| 18.49 ft | 27.38 Kips | 18.85 Kips | 46.23 Kips |
| 18.51 ft | 27.42 Kips | 18.60 Kips | 46.02 Kips |
| 27.51 ft | 40.49 Kips | 18.60 Kips | 59.09 Kips |
| 28.49 ft | 42.26 Kips | 18.60 Kips | 60.86 Kips |
| 28.51 ft | 42.30 Kips | 47.12 Kips | 89.43 Kips |
| 37.51 ft | 69.23 Kips | 47.12 Kips | 116.36 Kips |
| 43.49 ft | 90.21 Kips | 47.12 Kips | 137.33 Kips |
| 43.51 ft | 90.28 Kips | 18.60 Kips | 108.87 Kips |
| 48.49 ft | 105.58 Kips | 18.60 Kips | 124.18 Kips |
| 48.51 ft | 105.65 Kips | 15.71 Kips | 121.36 Kips |
| 52.99 ft | 119.74 Kips | 15.71 Kips | 135.45 Kips |
| 53.01 ft | 119.81 Kips | 40.84 Kips | 160.65 Kips |
| 58.49 ft | 139.19 Kips | 40.84 Kips | 180.03 Kips |
| 58.51 ft | 139.28 Kips | 18.60 Kips | 157.88 Kips |
| 62.99 ft | 161.66 Kips | 18.60 Kips | 180.26 Kips |
| 63.01 ft | 161.79 Kips | 69.81 Kips | 231.60 Kips |
| 64.99 ft | 176.57 Kips | 69.81 Kips | 246.38 Kips |
| 65.01 ft | 176.72 Kips | 69.81 Kips | 246.53 Kips |
| 69.99 ft | 216.22 Kips | 69.81 Kips | 286.03 Kips |
| 70.01 ft | 216.38 Kips | 69.81 Kips | 286.20 Kips |
| 73.49 ft | 245.96 Kips | 69.81 Kips | 315.77 Kips |
| 73.51 ft | 246.07 Kips | 25.13 Kips | 271.20 Kips |
| 82.51 ft | 284.34 Kips | 25.13 Kips | 309.47 Kips |
| 84.49 ft | 292.76 Kips | 25.13 Kips | 317.89 Kips |
| 84.51 ft | 292.92 Kips | 28.85 Kips | 321.77 Kips |
| 90.99 ft | 357.97 Kips | 28.85 Kips | 386.82 Kips |

# ULTIMATE - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.00 psf | 0.00 | N/A | 0.00 Kips |
| 6.49 ft | Cohesionless | 0.00 psf | 0.00 | N/A | 0.00 Kips |
| 6.49 ft | Cohesive | N/A | N/A | 0.00 psf | 0.00 Kips |
| 6.50 ft | Cohesive | N/A | N/A | 0.00 psf | 0.00 Kips |
| 6.51 ft | Cohesive | N/A | N/A | 1060.00 psf | 0.04 Kips |
| 15.51 ft | Cohesive | N/A | N/A | 1072.79 psf | 40.49 Kips |
| 18.49 ft | Cohesive | N/A | N/A | 1090.30 psf | 54.76 Kips |
| 18.51 ft | Cohesionless | 1005.91 psf | 21.97 | N/A | 54.82 Kips |
| 27.51 ft | Cohesionless | 1287.61 psf | 21.97 | N/A | 74.33 Kips |
| 28.49 ft | Cohesionless | 1318.29 psf | 21.97 | N/A | 76.96 Kips |
| 28.51 ft | Cohesive | N/A | N/A | 955.91 psf | 77.03 Kips |
| 37.51 ft | Cohesive | N/A | N/A | 1066.16 psf | 117.23 Kips |
| 43.49 ft | Cohesive | N/A | N/A | 1139.42 psf | 148.54 Kips |
| 43.51 ft | Cohesionless | 2570.91 psf | 21.97 | N/A | 148.63 Kips |
| 48.49 ft | Cohesionless | 2726.79 psf | 21.97 | N/A | 171.48 Kips |
| 48.51 ft | Cohesive | N/A | N/A | 1099.29 psf | 171.58 Kips |
| 52.99 ft | Cohesive | N/A | N/A | 1120.85 psf | 192.61 Kips |
| 53.01 ft | Cohesive | N/A | N/A | 1256.04 psf | 192.71 Kips |
| 58.49 ft | Cohesive | N/A | N/A | 1260.00 psf | 221.64 Kips |
| 58.51 ft | Cohesionless | 3437.41 psf | 21.97 | N/A | 221.75 Kips |
| 62.99 ft | Cohesionless | 3577.64 psf | 21.97 | N/A | 248.71 Kips |
| 63.01 ft | Cohesionless | 3719.14 psf | 24.17 | N/A | 248.86 Kips |
| 64.99 ft | Cohesionless | 3786.06 psf | 24.17 | N/A | 266.67 Kips |
| 65.01 ft | Cohesionless | 3854.34 psf | 24.17 | N/A | 266.86 Kips |
| 69.99 ft | Cohesionless | 4022.66 psf | 24.17 | N/A | 314.45 Kips |
| 70.01 ft | Cohesionless | 4192.34 psf | 24.17 | N/A | 314.64 Kips |
| 73.49 ft | Cohesionless | 4309.96 psf | 24.17 | N/A | 350.27 Kips |
| 73.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 350.44 Kips |
| 82.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 407.56 Kips |
| 84.49 ft | Cohesive | N/A | N/A | 1515.00 psf | 420.12 Kips |
| 84.51 ft | Cohesionless | 5062.51 psf | 22.70 | N/A | 420.28 Kips |
| 90.99 ft | Cohesionless | 5265.34 psf | 22.70 | N/A | 485.34 Kips |

# ULTIMATE - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.00 psf | 22.80 | 18.60 Kips | 0.00 Kips |
| 6.49 ft | Cohesionless | 0.00 psf | 22.80 | 18.60 Kips | 0.00 Kips |
| 6.49 ft | Cohesive | N/A | N/A | N/A | 0.00 Kips |
| 6.50 ft | Cohesive | N/A | N/A | N/A | 6.39 Kips |
| 6.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 15.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 18.49 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 18.51 ft | Cohesionless | 1006.23 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 27.51 ft | Cohesionless | 1569.63 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 28.49 ft | Cohesionless | 1630.97 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 28.51 ft | Cohesive | N/A | N/A | N/A | 47.12 Kips |
| 37.51 ft | Cohesive | N/A | N/A | N/A | 47.12 Kips |
| 43.49 ft | Cohesive | N/A | N/A | N/A | 47.12 Kips |
| 43.51 ft | Cohesionless | 2571.23 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 48.49 ft | Cohesionless | 2882.97 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 48.51 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 52.99 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 53.01 ft | Cohesive | N/A | N/A | N/A | 40.84 Kips |
| 58.49 ft | Cohesive | N/A | N/A | N/A | 40.84 Kips |
| 58.51 ft | Cohesionless | 3437.73 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 62.99 ft | Cohesionless | 3718.17 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 63.01 ft | Cohesionless | 3719.48 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 64.99 ft | Cohesionless | 3853.32 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 65.01 ft | Cohesionless | 3854.68 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 69.99 ft | Cohesionless | 4191.32 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 70.01 ft | Cohesionless | 4192.68 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 73.49 ft | Cohesionless | 4427.92 psf | 47.20 | 69.81 Kips | 69.81 Kips |
| 73.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 82.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 84.49 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 84.51 ft | Cohesionless | 5062.83 psf | 35.20 | 28.85 Kips | 28.85 Kips |
| 90.99 ft | Cohesionless | 5468.47 psf | 35.20 | 28.85 Kips | 28.85 Kips |

# ULTIMATE - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.00 Kips | 0.00 Kips |
| 6.49 ft | 0.00 Kips | 0.00 Kips | 0.00 Kips |
| 6.49 ft | 0.00 Kips | 0.00 Kips | 0.00 Kips |
| 6.50 ft | 0.00 Kips | 6.39 Kips | 6.39 Kips |
| 6.51 ft | 0.04 Kips | 18.85 Kips | 18.89 Kips |
| 15.51 ft | 40.49 Kips | 18.85 Kips | 59.34 Kips |
| 18.49 ft | 54.76 Kips | 18.85 Kips | 73.61 Kips |
| 18.51 ft | 54.82 Kips | 18.60 Kips | 73.42 Kips |
| 27.51 ft | 74.33 Kips | 18.60 Kips | 92.92 Kips |
| 28.49 ft | 76.96 Kips | 18.60 Kips | 95.56 Kips |
| 28.51 ft | 77.03 Kips | 47.12 Kips | 124.16 Kips |
| 37.51 ft | 117.23 Kips | 47.12 Kips | 164.35 Kips |
| 43.49 ft | 148.54 Kips | 47.12 Kips | 195.66 Kips |
| 43.51 ft | 148.63 Kips | 18.60 Kips | 167.23 Kips |
| 48.49 ft | 171.48 Kips | 18.60 Kips | 190.08 Kips |
| 48.51 ft | 171.58 Kips | 15.71 Kips | 187.29 Kips |
| 52.99 ft | 192.61 Kips | 15.71 Kips | 208.32 Kips |
| 53.01 ft | 192.71 Kips | 40.84 Kips | 233.55 Kips |
| 58.49 ft | 221.64 Kips | 40.84 Kips | 262.48 Kips |
| 58.51 ft | 221.75 Kips | 18.60 Kips | 240.34 Kips |
| 62.99 ft | 248.71 Kips | 18.60 Kips | 267.31 Kips |
| 63.01 ft | 248.86 Kips | 69.81 Kips | 318.68 Kips |
| 64.99 ft | 266.67 Kips | 69.81 Kips | 336.49 Kips |
| 65.01 ft | 266.86 Kips | 69.81 Kips | 336.67 Kips |
| 69.99 ft | 314.45 Kips | 69.81 Kips | 384.26 Kips |
| 70.01 ft | 314.64 Kips | 69.81 Kips | 384.46 Kips |
| 73.49 ft | 350.27 Kips | 69.81 Kips | 420.09 Kips |
| 73.51 ft | 350.44 Kips | 25.13 Kips | 375.58 Kips |
| 82.51 ft | 407.56 Kips | 25.13 Kips | 432.69 Kips |
| 84.49 ft | 420.12 Kips | 25.13 Kips | 445.26 Kips |
| 84.51 ft | 420.28 Kips | 28.85 Kips | 449.14 Kips |
| 90.99 ft | 485.34 Kips | 28.85 Kips | 514.19 Kips |

# DRIVEN 1.2

## GENERAL PROJECT INFORMATION

Filename: J:\GEOTECH\ANALYSIS\D2BZEP~U.2\B-163-P.DVN
Project Name: HAM-75-0004- B-163 - Abut Project Date: 05/11/2012
Project Client: EMHT
Computed By: Brian Trener
Project Manager: Jonathan Sterenberg

## PILE INFORMATION

Pile Type: Pipe Pile - Closed End
Top of Pile: 0.00 ft
Diameter of Pile: 16.00 in

## ULTIMATE CONSIDERATIONS

| | | |
|---|---|---|
| Water Table Depth At Time Of: | - Drilling: | 71.00 ft |
| | - Driving/Restrike | 71.00 ft |
| | - Ultimate: | 71.00 ft |
| Ultimate Considerations: | - Local Scour: | 0.00 ft |
| | - Long Term Scour: | 0.00 ft |
| | - Soft Soil: | 0.00 ft |

## ULTIMATE PROFILE

| Layer | Type | Thickness | Driving Loss | Unit Weight | Strength | Ultimate Curve |
|---|---|---|---|---|---|---|
| 1 | Cohesionless | 13.50 ft | 33.00% | 120.00 pcf | 28.0/28.0 | Nordlund |
| 2 | Cohesive | 5.00 ft | 33.00% | 120.00 pcf | 2750.00 psf | T-79 Steel |
| 3 | Cohesive | 12.50 ft | 33.00% | 115.00 pcf | 1500.00 psf | T-79 Steel |
| 4 | Cohesionless | 6.00 ft | 17.00% | 120.00 pcf | 29.0/29.0 | Nordlund |
| 5 | Cohesive | 5.00 ft | 50.00% | 120.00 pcf | 3000.00 psf | T-79 Steel |
| 6 | Cohesive | 11.50 ft | 33.00% | 120.00 pcf | 2000.00 psf | T-79 Steel |
| 7 | Cohesionless | 8.00 ft | 17.00% | 130.00 pcf | 32.0/32.0 | Nordlund |
| 8 | Cohesionless | 1.50 ft | 17.00% | 125.00 pcf | 30.0/30.0 | Nordlund |
| 9 | Cohesionless | 6.50 ft | 17.00% | 125.00 pcf | 30.0/30.0 | Nordlund |
| 10 | Cohesionless | 5.50 ft | 17.00% | 130.00 pcf | 32.0/32.0 | Nordlund |

# RESTRIKE - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.60 psf | 20.51 | N/A | 0.00 Kips |
| 9.01 ft | Cohesionless | 540.60 psf | 20.51 | N/A | 6.91 Kips |
| 13.49 ft | Cohesionless | 809.40 psf | 20.51 | N/A | 15.49 Kips |
| 13.51 ft | Cohesive | N/A | N/A | 881.18 psf | 15.55 Kips |
| 18.49 ft | Cohesive | N/A | N/A | 949.82 psf | 35.36 Kips |
| 18.51 ft | Cohesive | N/A | N/A | 1090.41 psf | 35.45 Kips |
| 27.51 ft | Cohesive | N/A | N/A | 1143.29 psf | 78.56 Kips |
| 30.99 ft | Cohesive | N/A | N/A | 1163.73 psf | 96.29 Kips |
| 31.01 ft | Cohesionless | 3658.10 psf | 21.24 | N/A | 96.40 Kips |
| 36.99 ft | Cohesionless | 4016.90 psf | 21.24 | N/A | 133.60 Kips |
| 37.01 ft | Cohesive | N/A | N/A | 1091.88 psf | 133.71 Kips |
| 41.99 ft | Cohesive | N/A | N/A | 1155.37 psf | 157.81 Kips |
| 42.01 ft | Cohesive | N/A | N/A | 1415.92 psf | 157.93 Kips |
| 51.01 ft | Cohesive | N/A | N/A | 1494.67 psf | 214.28 Kips |
| 53.49 ft | Cohesive | N/A | N/A | 1515.00 psf | 230.78 Kips |
| 53.51 ft | Cohesionless | 6358.15 psf | 23.44 | N/A | 230.98 Kips |
| 61.49 ft | Cohesionless | 6876.85 psf | 23.44 | N/A | 348.30 Kips |
| 61.51 ft | Cohesionless | 7398.12 psf | 21.97 | N/A | 348.59 Kips |
| 62.99 ft | Cohesionless | 7490.63 psf | 21.97 | N/A | 367.24 Kips |
| 63.01 ft | Cohesionless | 7585.62 psf | 21.97 | N/A | 367.50 Kips |
| 69.49 ft | Cohesionless | 7990.62 psf | 21.97 | N/A | 454.62 Kips |
| 69.51 ft | Cohesionless | 8398.15 psf | 23.44 | N/A | 454.94 Kips |
| 70.99 ft | Cohesionless | 8494.35 psf | 23.44 | N/A | 481.81 Kips |
| 71.01 ft | Cohesionless | 8592.84 psf | 23.44 | N/A | 482.18 Kips |
| 74.99 ft | Cohesionless | 8727.36 psf | 23.44 | N/A | 556.44 Kips |

# RESTRIKE - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 1.20 psf | 22.80 | 18.60 Kips | 0.02 Kips |
| 9.01 ft | Cohesionless | 1081.20 psf | 22.80 | 18.60 Kips | 18.45 Kips |
| 13.49 ft | Cohesionless | 1618.80 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 13.51 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 18.49 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 18.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 27.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 30.99 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 31.01 ft | Cohesionless | 3658.70 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 36.99 ft | Cohesionless | 4376.30 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 37.01 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 41.99 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 42.01 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 51.01 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 53.49 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 53.51 ft | Cohesionless | 6358.80 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 61.49 ft | Cohesionless | 7396.20 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 61.51 ft | Cohesionless | 7398.75 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 62.99 ft | Cohesionless | 7583.75 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 63.01 ft | Cohesionless | 7586.25 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 69.49 ft | Cohesionless | 8396.25 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 69.51 ft | Cohesionless | 8398.80 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 70.99 ft | Cohesionless | 8591.20 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 71.01 ft | Cohesionless | 8593.18 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 74.99 ft | Cohesionless | 8862.22 psf | 40.40 | 46.08 Kips | 46.08 Kips |

# RESTRIKE - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.02 Kips | 0.02 Kips |
| 9.01 ft | 6.91 Kips | 18.45 Kips | 25.36 Kips |
| 13.49 ft | 15.49 Kips | 18.60 Kips | 34.09 Kips |
| 13.51 ft | 15.55 Kips | 34.56 Kips | 50.11 Kips |
| 18.49 ft | 35.36 Kips | 34.56 Kips | 69.92 Kips |
| 18.51 ft | 35.45 Kips | 18.85 Kips | 54.30 Kips |
| 27.51 ft | 78.56 Kips | 18.85 Kips | 97.41 Kips |
| 30.99 ft | 96.29 Kips | 18.85 Kips | 115.14 Kips |
| 31.01 ft | 96.40 Kips | 18.60 Kips | 115.00 Kips |
| 36.99 ft | 133.60 Kips | 18.60 Kips | 152.20 Kips |
| 37.01 ft | 133.71 Kips | 37.70 Kips | 171.41 Kips |
| 41.99 ft | 157.81 Kips | 37.70 Kips | 195.51 Kips |
| 42.01 ft | 157.93 Kips | 25.13 Kips | 183.06 Kips |
| 51.01 ft | 214.28 Kips | 25.13 Kips | 239.41 Kips |
| 53.49 ft | 230.78 Kips | 25.13 Kips | 255.91 Kips |
| 53.51 ft | 230.98 Kips | 46.08 Kips | 277.06 Kips |
| 61.49 ft | 348.30 Kips | 46.08 Kips | 394.38 Kips |
| 61.51 ft | 348.59 Kips | 18.60 Kips | 367.19 Kips |
| 62.99 ft | 367.24 Kips | 18.60 Kips | 385.84 Kips |
| 63.01 ft | 367.50 Kips | 18.60 Kips | 386.09 Kips |
| 69.49 ft | 454.62 Kips | 18.60 Kips | 473.21 Kips |
| 69.51 ft | 454.94 Kips | 46.08 Kips | 501.01 Kips |
| 70.99 ft | 481.81 Kips | 46.08 Kips | 527.89 Kips |
| 71.01 ft | 482.18 Kips | 46.08 Kips | 528.26 Kips |
| 74.99 ft | 556.44 Kips | 46.08 Kips | 602.51 Kips |

# DRIVING - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.60 psf | 20.51 | N/A | 0.00 Kips |
| 9.01 ft | Cohesionless | 540.60 psf | 20.51 | N/A | 4.63 Kips |
| 13.49 ft | Cohesionless | 809.40 psf | 20.51 | N/A | 10.38 Kips |
| 13.51 ft | Cohesive | N/A | N/A | 881.18 psf | 10.42 Kips |
| 18.49 ft | Cohesive | N/A | N/A | 949.82 psf | 23.69 Kips |
| 18.51 ft | Cohesive | N/A | N/A | 1090.41 psf | 23.75 Kips |
| 27.51 ft | Cohesive | N/A | N/A | 1143.29 psf | 52.63 Kips |
| 30.99 ft | Cohesive | N/A | N/A | 1163.73 psf | 64.51 Kips |
| 31.01 ft | Cohesionless | 3658.10 psf | 21.24 | N/A | 64.61 Kips |
| 36.99 ft | Cohesionless | 4016.90 psf | 21.24 | N/A | 95.48 Kips |
| 37.01 ft | Cohesive | N/A | N/A | 1091.88 psf | 95.54 Kips |
| 41.99 ft | Cohesive | N/A | N/A | 1155.37 psf | 107.59 Kips |
| 42.01 ft | Cohesive | N/A | N/A | 1415.92 psf | 107.66 Kips |
| 51.01 ft | Cohesive | N/A | N/A | 1494.67 psf | 145.42 Kips |
| 53.49 ft | Cohesive | N/A | N/A | 1515.00 psf | 156.48 Kips |
| 53.51 ft | Cohesionless | 6358.15 psf | 23.44 | N/A | 156.64 Kips |
| 61.49 ft | Cohesionless | 6876.85 psf | 23.44 | N/A | 254.02 Kips |
| 61.51 ft | Cohesionless | 7398.12 psf | 21.97 | N/A | 254.25 Kips |
| 62.99 ft | Cohesionless | 7490.63 psf | 21.97 | N/A | 269.74 Kips |
| 63.01 ft | Cohesionless | 7585.62 psf | 21.97 | N/A | 269.95 Kips |
| 69.49 ft | Cohesionless | 7990.62 psf | 21.97 | N/A | 342.26 Kips |
| 69.51 ft | Cohesionless | 8398.15 psf | 23.44 | N/A | 342.52 Kips |
| 70.99 ft | Cohesionless | 8494.35 psf | 23.44 | N/A | 364.83 Kips |
| 71.01 ft | Cohesionless | 8592.84 psf | 23.44 | N/A | 365.14 Kips |
| 74.99 ft | Cohesionless | 8727.36 psf | 23.44 | N/A | 426.77 Kips |

# DRIVING - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 1.20 psf | 22.80 | 18.60 Kips | 0.02 Kips |
| 9.01 ft | Cohesionless | 1081.20 psf | 22.80 | 18.60 Kips | 18.45 Kips |
| 13.49 ft | Cohesionless | 1618.80 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 13.51 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 18.49 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 18.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 27.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 30.99 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 31.01 ft | Cohesionless | 3658.70 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 36.99 ft | Cohesionless | 4376.30 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 37.01 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 41.99 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 42.01 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 51.01 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 53.49 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 53.51 ft | Cohesionless | 6358.80 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 61.49 ft | Cohesionless | 7396.20 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 61.51 ft | Cohesionless | 7398.75 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 62.99 ft | Cohesionless | 7583.75 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 63.01 ft | Cohesionless | 7586.25 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 69.49 ft | Cohesionless | 8396.25 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 69.51 ft | Cohesionless | 8398.80 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 70.99 ft | Cohesionless | 8591.20 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 71.01 ft | Cohesionless | 8593.18 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 74.99 ft | Cohesionless | 8862.22 psf | 40.40 | 46.08 Kips | 46.08 Kips |

## DRIVING - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.02 Kips | 0.02 Kips |
| 9.01 ft | 4.63 Kips | 18.45 Kips | 23.08 Kips |
| 13.49 ft | 10.38 Kips | 18.60 Kips | 28.98 Kips |
| 13.51 ft | 10.42 Kips | 34.56 Kips | 44.97 Kips |
| 18.49 ft | 23.69 Kips | 34.56 Kips | 58.25 Kips |
| 18.51 ft | 23.75 Kips | 18.85 Kips | 42.60 Kips |
| 27.51 ft | 52.63 Kips | 18.85 Kips | 71.48 Kips |
| 30.99 ft | 64.51 Kips | 18.85 Kips | 83.36 Kips |
| 31.01 ft | 64.61 Kips | 18.60 Kips | 83.20 Kips |
| 36.99 ft | 95.48 Kips | 18.60 Kips | 114.08 Kips |
| 37.01 ft | 95.54 Kips | 37.70 Kips | 133.23 Kips |
| 41.99 ft | 107.59 Kips | 37.70 Kips | 145.29 Kips |
| 42.01 ft | 107.66 Kips | 25.13 Kips | 132.79 Kips |
| 51.01 ft | 145.42 Kips | 25.13 Kips | 170.55 Kips |
| 53.49 ft | 156.48 Kips | 25.13 Kips | 181.61 Kips |
| 53.51 ft | 156.64 Kips | 46.08 Kips | 202.72 Kips |
| 61.49 ft | 254.02 Kips | 46.08 Kips | 300.10 Kips |
| 61.51 ft | 254.25 Kips | 18.60 Kips | 272.85 Kips |
| 62.99 ft | 269.74 Kips | 18.60 Kips | 288.33 Kips |
| 63.01 ft | 269.95 Kips | 18.60 Kips | 288.55 Kips |
| 69.49 ft | 342.26 Kips | 18.60 Kips | 360.86 Kips |
| 69.51 ft | 342.52 Kips | 46.08 Kips | 388.60 Kips |
| 70.99 ft | 364.83 Kips | 46.08 Kips | 410.91 Kips |
| 71.01 ft | 365.14 Kips | 46.08 Kips | 411.21 Kips |
| 74.99 ft | 426.77 Kips | 46.08 Kips | 472.85 Kips |

# ULTIMATE - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.60 psf | 20.51 | N/A | 0.00 Kips |
| 9.01 ft | Cohesionless | 540.60 psf | 20.51 | N/A | 6.91 Kips |
| 13.49 ft | Cohesionless | 809.40 psf | 20.51 | N/A | 15.49 Kips |
| 13.51 ft | Cohesive | N/A | N/A | 881.18 psf | 15.55 Kips |
| 18.49 ft | Cohesive | N/A | N/A | 949.82 psf | 35.36 Kips |
| 18.51 ft | Cohesive | N/A | N/A | 1090.41 psf | 35.45 Kips |
| 27.51 ft | Cohesive | N/A | N/A | 1143.29 psf | 78.56 Kips |
| 30.99 ft | Cohesive | N/A | N/A | 1163.73 psf | 96.29 Kips |
| 31.01 ft | Cohesionless | 3658.10 psf | 21.24 | N/A | 96.40 Kips |
| 36.99 ft | Cohesionless | 4016.90 psf | 21.24 | N/A | 133.60 Kips |
| 37.01 ft | Cohesive | N/A | N/A | 1091.88 psf | 133.71 Kips |
| 41.99 ft | Cohesive | N/A | N/A | 1155.37 psf | 157.81 Kips |
| 42.01 ft | Cohesive | N/A | N/A | 1415.92 psf | 157.93 Kips |
| 51.01 ft | Cohesive | N/A | N/A | 1494.67 psf | 214.28 Kips |
| 53.49 ft | Cohesive | N/A | N/A | 1515.00 psf | 230.78 Kips |
| 53.51 ft | Cohesionless | 6358.15 psf | 23.44 | N/A | 230.98 Kips |
| 61.49 ft | Cohesionless | 6876.85 psf | 23.44 | N/A | 348.30 Kips |
| 61.51 ft | Cohesionless | 7398.12 psf | 21.97 | N/A | 348.59 Kips |
| 62.99 ft | Cohesionless | 7490.63 psf | 21.97 | N/A | 367.24 Kips |
| 63.01 ft | Cohesionless | 7585.62 psf | 21.97 | N/A | 367.50 Kips |
| 69.49 ft | Cohesionless | 7990.62 psf | 21.97 | N/A | 454.62 Kips |
| 69.51 ft | Cohesionless | 8398.15 psf | 23.44 | N/A | 454.94 Kips |
| 70.99 ft | Cohesionless | 8494.35 psf | 23.44 | N/A | 481.81 Kips |
| 71.01 ft | Cohesionless | 8592.84 psf | 23.44 | N/A | 482.18 Kips |
| 74.99 ft | Cohesionless | 8727.36 psf | 23.44 | N/A | 556.44 Kips |

# ULTIMATE - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 1.20 psf | 22.80 | 18.60 Kips | 0.02 Kips |
| 9.01 ft | Cohesionless | 1081.20 psf | 22.80 | 18.60 Kips | 18.45 Kips |
| 13.49 ft | Cohesionless | 1618.80 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 13.51 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 18.49 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 18.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 27.51 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 30.99 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 31.01 ft | Cohesionless | 3658.70 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 36.99 ft | Cohesionless | 4376.30 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 37.01 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 41.99 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 42.01 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 51.01 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 53.49 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 53.51 ft | Cohesionless | 6358.80 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 61.49 ft | Cohesionless | 7396.20 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 61.51 ft | Cohesionless | 7398.75 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 62.99 ft | Cohesionless | 7583.75 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 63.01 ft | Cohesionless | 7586.25 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 69.49 ft | Cohesionless | 8396.25 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 69.51 ft | Cohesionless | 8398.80 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 70.99 ft | Cohesionless | 8591.20 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 71.01 ft | Cohesionless | 8593.18 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 74.99 ft | Cohesionless | 8862.22 psf | 40.40 | 46.08 Kips | 46.08 Kips |

# ULTIMATE - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.02 Kips | 0.02 Kips |
| 9.01 ft | 6.91 Kips | 18.45 Kips | 25.36 Kips |
| 13.49 ft | 15.49 Kips | 18.60 Kips | 34.09 Kips |
| 13.51 ft | 15.55 Kips | 34.56 Kips | 50.11 Kips |
| 18.49 ft | 35.36 Kips | 34.56 Kips | 69.92 Kips |
| 18.51 ft | 35.45 Kips | 18.85 Kips | 54.30 Kips |
| 27.51 ft | 78.56 Kips | 18.85 Kips | 97.41 Kips |
| 30.99 ft | 96.29 Kips | 18.85 Kips | 115.14 Kips |
| 31.01 ft | 96.40 Kips | 18.60 Kips | 115.00 Kips |
| 36.99 ft | 133.60 Kips | 18.60 Kips | 152.20 Kips |
| 37.01 ft | 133.71 Kips | 37.70 Kips | 171.41 Kips |
| 41.99 ft | 157.81 Kips | 37.70 Kips | 195.51 Kips |
| 42.01 ft | 157.93 Kips | 25.13 Kips | 183.06 Kips |
| 51.01 ft | 214.28 Kips | 25.13 Kips | 239.41 Kips |
| 53.49 ft | 230.78 Kips | 25.13 Kips | 255.91 Kips |
| 53.51 ft | 230.98 Kips | 46.08 Kips | 277.06 Kips |
| 61.49 ft | 348.30 Kips | 46.08 Kips | 394.38 Kips |
| 61.51 ft | 348.59 Kips | 18.60 Kips | 367.19 Kips |
| 62.99 ft | 367.24 Kips | 18.60 Kips | 385.84 Kips |
| 63.01 ft | 367.50 Kips | 18.60 Kips | 386.09 Kips |
| 69.49 ft | 454.62 Kips | 18.60 Kips | 473.21 Kips |
| 69.51 ft | 454.94 Kips | 46.08 Kips | 501.01 Kips |
| 70.99 ft | 481.81 Kips | 46.08 Kips | 527.89 Kips |
| 71.01 ft | 482.18 Kips | 46.08 Kips | 528.26 Kips |
| 74.99 ft | 556.44 Kips | 46.08 Kips | 602.51 Kips |

# DRIVEN 1.2

## GENERAL PROJECT INFORMATION

Filename: J:\GEOTECH\ANALYSIS\D2BZEP~U.2\B-163-A.DVN
Project Name: HAM-75-0004- B-163 - Abut    Project Date: 05/11/2012
Project Client: EMHT
Computed By: Brian Trener
Project Manager: Jonathan Sterenberg

## PILE INFORMATION

Pile Type: Pipe Pile - Closed End
Top of Pile: 0.00 ft
Diameter of Pile: 16.00 in

## ULTIMATE CONSIDERATIONS

| | | |
|---|---|---|
| Water Table Depth At Time Of: | - Drilling: | 66.00 ft |
| | - Driving/Restrike | 66.00 ft |
| | - Ultimate: | 66.00 ft |
| Ultimate Considerations: | - Local Scour: | 0.00 ft |
| | - Long Term Scour: | 0.00 ft |
| | - Soft Soil: | 0.00 ft |

## ULTIMATE PROFILE

| Layer | Type | Thickness | Driving Loss | Unit Weight | Strength | Ultimate Curve |
|---|---|---|---|---|---|---|
| 1 | Cohesionless | 11.00 ft | 17.00% | 125.00 pcf | 29.0/29.0 | Nordlund |
| 2 | Cohesive | 8.00 ft | 33.00% | 115.00 pcf | 1250.00 psf | T-79 Steel |
| 3 | Cohesive | 12.00 ft | 33.00% | 120.00 pcf | 2250.00 psf | T-79 Steel |
| 4 | Cohesionless | 15.00 ft | 33.00% | 120.00 pcf | 28.0/28.0 | Nordlund |
| 5 | Cohesive | 5.00 ft | 33.00% | 120.00 pcf | 2750.00 psf | T-79 Steel |
| 6 | Cohesive | 12.50 ft | 33.00% | 115.00 pcf | 1500.00 psf | T-79 Steel |
| 7 | Cohesionless | 6.00 ft | 17.00% | 120.00 pcf | 29.0/29.0 | Nordlund |
| 8 | Cohesive | 5.00 ft | 50.00% | 120.00 pcf | 3000.00 psf | T-79 Steel |
| 9 | Cohesive | 11.50 ft | 33.00% | 120.00 pcf | 2000.00 psf | T-79 Steel |
| 10 | Cohesionless | 8.00 ft | 17.00% | 130.00 pcf | 32.0/32.0 | Nordlund |
| 11 | Cohesionless | 5.00 ft | 17.00% | 125.00 pcf | 30.0/30.0 | Nordlund |
| 12 | Cohesionless | 8.50 ft | 17.00% | 130.00 pcf | 32.0/32.0 | Nordlund |

# RESTRIKE - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.62 psf | 21.24 | N/A | 0.00 Kips |
| 9.01 ft | Cohesionless | 563.12 psf | 21.24 | N/A | 7.86 Kips |
| 10.99 ft | Cohesionless | 686.88 psf | 21.24 | N/A | 11.69 Kips |
| 11.01 ft | Cohesive | N/A | N/A | 930.00 psf | 11.75 Kips |
| 18.99 ft | Cohesive | N/A | N/A | 957.22 psf | 43.75 Kips |
| 19.01 ft | Cohesive | N/A | N/A | 1173.14 psf | 43.84 Kips |
| 28.01 ft | Cohesive | N/A | N/A | 1277.20 psf | 91.99 Kips |
| 30.99 ft | Cohesive | N/A | N/A | 1311.66 psf | 109.66 Kips |
| 31.01 ft | Cohesionless | 3735.60 psf | 20.51 | N/A | 109.78 Kips |
| 40.01 ft | Cohesionless | 4275.60 psf | 20.51 | N/A | 164.37 Kips |
| 45.99 ft | Cohesionless | 4634.40 psf | 20.51 | N/A | 208.27 Kips |
| 46.01 ft | Cohesive | N/A | N/A | 1329.08 psf | 208.40 Kips |
| 50.99 ft | Cohesive | N/A | N/A | 1397.71 psf | 237.56 Kips |
| 51.01 ft | Cohesive | N/A | N/A | 1281.35 psf | 237.67 Kips |
| 60.01 ft | Cohesive | N/A | N/A | 1295.00 psf | 286.50 Kips |
| 63.49 ft | Cohesive | N/A | N/A | 1295.00 psf | 305.37 Kips |
| 63.51 ft | Cohesionless | 7573.10 psf | 21.24 | N/A | 305.54 Kips |
| 65.99 ft | Cohesionless | 7721.90 psf | 21.24 | N/A | 335.20 Kips |
| 66.01 ft | Cohesionless | 7872.79 psf | 21.24 | N/A | 335.44 Kips |
| 69.49 ft | Cohesionless | 7973.01 psf | 21.24 | N/A | 378.40 Kips |
| 69.51 ft | Cohesive | N/A | N/A | 1300.00 psf | 378.58 Kips |
| 74.49 ft | Cohesive | N/A | N/A | 1300.00 psf | 405.70 Kips |
| 74.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 405.82 Kips |
| 83.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 462.93 Kips |
| 85.99 ft | Cohesive | N/A | N/A | 1515.00 psf | 478.67 Kips |
| 86.01 ft | Cohesionless | 9024.84 psf | 23.44 | N/A | 478.93 Kips |
| 93.99 ft | Cohesionless | 9294.56 psf | 23.44 | N/A | 637.49 Kips |
| 94.01 ft | Cohesionless | 9565.61 psf | 21.97 | N/A | 637.85 Kips |
| 98.99 ft | Cohesionless | 9721.49 psf | 21.97 | N/A | 719.31 Kips |
| 99.01 ft | Cohesionless | 9878.64 psf | 23.44 | N/A | 719.68 Kips |
| 107.49 ft | Cohesionless | 10165.26 psf | 23.44 | N/A | 903.97 Kips |

## RESTRIKE - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 1.25 psf | 26.40 | 18.60 Kips | 0.03 Kips |
| 9.01 ft | Cohesionless | 1126.25 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 10.99 ft | Cohesionless | 1373.75 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 11.01 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 18.99 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 19.01 ft | Cohesive | N/A | N/A | N/A | 28.27 Kips |
| 28.01 ft | Cohesive | N/A | N/A | N/A | 28.27 Kips |
| 30.99 ft | Cohesive | N/A | N/A | N/A | 28.27 Kips |
| 31.01 ft | Cohesionless | 3736.20 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 40.01 ft | Cohesionless | 4816.20 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 45.99 ft | Cohesionless | 5533.80 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 46.01 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 50.99 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 51.01 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 60.01 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 63.49 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 63.51 ft | Cohesionless | 7573.70 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 65.99 ft | Cohesionless | 7871.30 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 66.01 ft | Cohesionless | 7873.08 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 69.49 ft | Cohesionless | 8073.52 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 69.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 74.49 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 74.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 83.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 85.99 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 86.01 ft | Cohesionless | 9025.18 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 93.99 ft | Cohesionless | 9564.62 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 94.01 ft | Cohesionless | 9565.93 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 98.99 ft | Cohesionless | 9877.67 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 99.01 ft | Cohesionless | 9878.98 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 107.49 ft | Cohesionless | 10452.22 psf | 40.40 | 46.08 Kips | 46.08 Kips |

# RESTRIKE - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.03 Kips | 0.03 Kips |
| 9.01 ft | 7.86 Kips | 18.60 Kips | 26.45 Kips |
| 10.99 ft | 11.69 Kips | 18.60 Kips | 30.29 Kips |
| 11.01 ft | 11.75 Kips | 15.71 Kips | 27.46 Kips |
| 18.99 ft | 43.75 Kips | 15.71 Kips | 59.45 Kips |
| 19.01 ft | 43.84 Kips | 28.27 Kips | 72.11 Kips |
| 28.01 ft | 91.99 Kips | 28.27 Kips | 120.26 Kips |
| 30.99 ft | 109.66 Kips | 28.27 Kips | 137.94 Kips |
| 31.01 ft | 109.78 Kips | 18.60 Kips | 128.38 Kips |
| 40.01 ft | 164.37 Kips | 18.60 Kips | 182.97 Kips |
| 45.99 ft | 208.27 Kips | 18.60 Kips | 226.86 Kips |
| 46.01 ft | 208.40 Kips | 34.56 Kips | 242.96 Kips |
| 50.99 ft | 237.56 Kips | 34.56 Kips | 272.12 Kips |
| 51.01 ft | 237.67 Kips | 18.85 Kips | 256.52 Kips |
| 60.01 ft | 286.50 Kips | 18.85 Kips | 305.35 Kips |
| 63.49 ft | 305.37 Kips | 18.85 Kips | 324.22 Kips |
| 63.51 ft | 305.54 Kips | 18.60 Kips | 324.14 Kips |
| 65.99 ft | 335.20 Kips | 18.60 Kips | 353.80 Kips |
| 66.01 ft | 335.44 Kips | 18.60 Kips | 354.04 Kips |
| 69.49 ft | 378.40 Kips | 18.60 Kips | 397.00 Kips |
| 69.51 ft | 378.58 Kips | 37.70 Kips | 416.28 Kips |
| 74.49 ft | 405.70 Kips | 37.70 Kips | 443.40 Kips |
| 74.51 ft | 405.82 Kips | 25.13 Kips | 430.95 Kips |
| 83.51 ft | 462.93 Kips | 25.13 Kips | 488.06 Kips |
| 85.99 ft | 478.67 Kips | 25.13 Kips | 503.80 Kips |
| 86.01 ft | 478.93 Kips | 46.08 Kips | 525.00 Kips |
| 93.99 ft | 637.49 Kips | 46.08 Kips | 683.57 Kips |
| 94.01 ft | 637.85 Kips | 18.60 Kips | 656.45 Kips |
| 98.99 ft | 719.31 Kips | 18.60 Kips | 737.91 Kips |
| 99.01 ft | 719.68 Kips | 46.08 Kips | 765.76 Kips |
| 107.49 ft | 903.97 Kips | 46.08 Kips | 950.04 Kips |

# DRIVING - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.62 psf | 21.24 | N/A | 0.00 Kips |
| 9.01 ft | Cohesionless | 563.12 psf | 21.24 | N/A | 6.52 Kips |
| 10.99 ft | Cohesionless | 686.88 psf | 21.24 | N/A | 9.70 Kips |
| 11.01 ft | Cohesive | N/A | N/A | 930.00 psf | 9.74 Kips |
| 18.99 ft | Cohesive | N/A | N/A | 957.22 psf | 31.18 Kips |
| 19.01 ft | Cohesive | N/A | N/A | 1173.14 psf | 31.24 Kips |
| 28.01 ft | Cohesive | N/A | N/A | 1277.20 psf | 63.50 Kips |
| 30.99 ft | Cohesive | N/A | N/A | 1311.66 psf | 75.34 Kips |
| 31.01 ft | Cohesionless | 3735.60 psf | 20.51 | N/A | 75.42 Kips |
| 40.01 ft | Cohesionless | 4275.60 psf | 20.51 | N/A | 112.00 Kips |
| 45.99 ft | Cohesionless | 4634.40 psf | 20.51 | N/A | 141.41 Kips |
| 46.01 ft | Cohesive | N/A | N/A | 1329.08 psf | 141.50 Kips |
| 50.99 ft | Cohesive | N/A | N/A | 1397.71 psf | 161.03 Kips |
| 51.01 ft | Cohesive | N/A | N/A | 1281.35 psf | 161.11 Kips |
| 60.01 ft | Cohesive | N/A | N/A | 1295.00 psf | 193.82 Kips |
| 63.49 ft | Cohesive | N/A | N/A | 1295.00 psf | 206.47 Kips |
| 63.51 ft | Cohesionless | 7573.10 psf | 21.24 | N/A | 206.61 Kips |
| 65.99 ft | Cohesionless | 7721.90 psf | 21.24 | N/A | 231.22 Kips |
| 66.01 ft | Cohesionless | 7872.79 psf | 21.24 | N/A | 231.43 Kips |
| 69.49 ft | Cohesionless | 7973.01 psf | 21.24 | N/A | 267.08 Kips |
| 69.51 ft | Cohesive | N/A | N/A | 1300.00 psf | 267.17 Kips |
| 74.49 ft | Cohesive | N/A | N/A | 1300.00 psf | 280.73 Kips |
| 74.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 280.81 Kips |
| 83.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 319.08 Kips |
| 85.99 ft | Cohesive | N/A | N/A | 1515.00 psf | 329.62 Kips |
| 86.01 ft | Cohesionless | 9024.84 psf | 23.44 | N/A | 329.84 Kips |
| 93.99 ft | Cohesionless | 9294.56 psf | 23.44 | N/A | 461.44 Kips |
| 94.01 ft | Cohesionless | 9565.61 psf | 21.97 | N/A | 461.75 Kips |
| 98.99 ft | Cohesionless | 9721.49 psf | 21.97 | N/A | 529.35 Kips |
| 99.01 ft | Cohesionless | 9878.64 psf | 23.44 | N/A | 529.67 Kips |
| 107.49 ft | Cohesionless | 10165.26 psf | 23.44 | N/A | 682.62 Kips |

## DRIVING - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 1.25 psf | 26.40 | 18.60 Kips | 0.03 Kips |
| 9.01 ft | Cohesionless | 1126.25 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 10.99 ft | Cohesionless | 1373.75 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 11.01 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 18.99 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 19.01 ft | Cohesive | N/A | N/A | N/A | 28.27 Kips |
| 28.01 ft | Cohesive | N/A | N/A | N/A | 28.27 Kips |
| 30.99 ft | Cohesive | N/A | N/A | N/A | 28.27 Kips |
| 31.01 ft | Cohesionless | 3736.20 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 40.01 ft | Cohesionless | 4816.20 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 45.99 ft | Cohesionless | 5533.80 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 46.01 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 50.99 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 51.01 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 60.01 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 63.49 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 63.51 ft | Cohesionless | 7573.70 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 65.99 ft | Cohesionless | 7871.30 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 66.01 ft | Cohesionless | 7873.08 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 69.49 ft | Cohesionless | 8073.52 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 69.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 74.49 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 74.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 83.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 85.99 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 86.01 ft | Cohesionless | 9025.18 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 93.99 ft | Cohesionless | 9564.62 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 94.01 ft | Cohesionless | 9565.93 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 98.99 ft | Cohesionless | 9877.67 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 99.01 ft | Cohesionless | 9878.98 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 107.49 ft | Cohesionless | 10452.22 psf | 40.40 | 46.08 Kips | 46.08 Kips |

# DRIVING - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.03 Kips | 0.03 Kips |
| 9.01 ft | 6.52 Kips | 18.60 Kips | 25.12 Kips |
| 10.99 ft | 9.70 Kips | 18.60 Kips | 28.30 Kips |
| 11.01 ft | 9.74 Kips | 15.71 Kips | 25.45 Kips |
| 18.99 ft | 31.18 Kips | 15.71 Kips | 46.89 Kips |
| 19.01 ft | 31.24 Kips | 28.27 Kips | 59.51 Kips |
| 28.01 ft | 63.50 Kips | 28.27 Kips | 91.78 Kips |
| 30.99 ft | 75.34 Kips | 28.27 Kips | 103.62 Kips |
| 31.01 ft | 75.42 Kips | 18.60 Kips | 94.02 Kips |
| 40.01 ft | 112.00 Kips | 18.60 Kips | 130.60 Kips |
| 45.99 ft | 141.41 Kips | 18.60 Kips | 160.01 Kips |
| 46.01 ft | 141.50 Kips | 34.56 Kips | 176.06 Kips |
| 50.99 ft | 161.03 Kips | 34.56 Kips | 195.59 Kips |
| 51.01 ft | 161.11 Kips | 18.85 Kips | 179.96 Kips |
| 60.01 ft | 193.82 Kips | 18.85 Kips | 212.67 Kips |
| 63.49 ft | 206.47 Kips | 18.85 Kips | 225.32 Kips |
| 63.51 ft | 206.61 Kips | 18.60 Kips | 225.21 Kips |
| 65.99 ft | 231.22 Kips | 18.60 Kips | 249.82 Kips |
| 66.01 ft | 231.43 Kips | 18.60 Kips | 250.02 Kips |
| 69.49 ft | 267.08 Kips | 18.60 Kips | 285.68 Kips |
| 69.51 ft | 267.17 Kips | 37.70 Kips | 304.87 Kips |
| 74.49 ft | 280.73 Kips | 37.70 Kips | 318.43 Kips |
| 74.51 ft | 280.81 Kips | 25.13 Kips | 305.94 Kips |
| 83.51 ft | 319.08 Kips | 25.13 Kips | 344.21 Kips |
| 85.99 ft | 329.62 Kips | 25.13 Kips | 354.76 Kips |
| 86.01 ft | 329.84 Kips | 46.08 Kips | 375.91 Kips |
| 93.99 ft | 461.44 Kips | 46.08 Kips | 507.52 Kips |
| 94.01 ft | 461.75 Kips | 18.60 Kips | 480.34 Kips |
| 98.99 ft | 529.35 Kips | 18.60 Kips | 547.95 Kips |
| 99.01 ft | 529.67 Kips | 46.08 Kips | 575.74 Kips |
| 107.49 ft | 682.62 Kips | 46.08 Kips | 728.70 Kips |

# ULTIMATE - SKIN FRICTION

| Depth | Soil Type | Effective Stress At Midpoint | Sliding Friction Angle | Adhesion | Skin Friction |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 0.62 psf | 21.24 | N/A | 0.00 Kips |
| 9.01 ft | Cohesionless | 563.12 psf | 21.24 | N/A | 7.86 Kips |
| 10.99 ft | Cohesionless | 686.88 psf | 21.24 | N/A | 11.69 Kips |
| 11.01 ft | Cohesive | N/A | N/A | 930.00 psf | 11.75 Kips |
| 18.99 ft | Cohesive | N/A | N/A | 957.22 psf | 43.75 Kips |
| 19.01 ft | Cohesive | N/A | N/A | 1173.14 psf | 43.84 Kips |
| 28.01 ft | Cohesive | N/A | N/A | 1277.20 psf | 91.99 Kips |
| 30.99 ft | Cohesive | N/A | N/A | 1311.66 psf | 109.66 Kips |
| 31.01 ft | Cohesionless | 3735.60 psf | 20.51 | N/A | 109.78 Kips |
| 40.01 ft | Cohesionless | 4275.60 psf | 20.51 | N/A | 164.37 Kips |
| 45.99 ft | Cohesionless | 4634.40 psf | 20.51 | N/A | 208.27 Kips |
| 46.01 ft | Cohesive | N/A | N/A | 1329.08 psf | 208.40 Kips |
| 50.99 ft | Cohesive | N/A | N/A | 1397.71 psf | 237.56 Kips |
| 51.01 ft | Cohesive | N/A | N/A | 1281.35 psf | 237.67 Kips |
| 60.01 ft | Cohesive | N/A | N/A | 1295.00 psf | 286.50 Kips |
| 63.49 ft | Cohesive | N/A | N/A | 1295.00 psf | 305.37 Kips |
| 63.51 ft | Cohesionless | 7573.10 psf | 21.24 | N/A | 305.54 Kips |
| 65.99 ft | Cohesionless | 7721.90 psf | 21.24 | N/A | 335.20 Kips |
| 66.01 ft | Cohesionless | 7872.79 psf | 21.24 | N/A | 335.44 Kips |
| 69.49 ft | Cohesionless | 7973.01 psf | 21.24 | N/A | 378.40 Kips |
| 69.51 ft | Cohesive | N/A | N/A | 1300.00 psf | 378.58 Kips |
| 74.49 ft | Cohesive | N/A | N/A | 1300.00 psf | 405.70 Kips |
| 74.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 405.82 Kips |
| 83.51 ft | Cohesive | N/A | N/A | 1515.00 psf | 462.93 Kips |
| 85.99 ft | Cohesive | N/A | N/A | 1515.00 psf | 478.67 Kips |
| 86.01 ft | Cohesionless | 9024.84 psf | 23.44 | N/A | 478.93 Kips |
| 93.99 ft | Cohesionless | 9294.56 psf | 23.44 | N/A | 637.49 Kips |
| 94.01 ft | Cohesionless | 9565.61 psf | 21.97 | N/A | 637.85 Kips |
| 98.99 ft | Cohesionless | 9721.49 psf | 21.97 | N/A | 719.31 Kips |
| 99.01 ft | Cohesionless | 9878.64 psf | 23.44 | N/A | 719.68 Kips |
| 107.49 ft | Cohesionless | 10165.26 psf | 23.44 | N/A | 903.97 Kips |

# ULTIMATE - END BEARING

| Depth | Soil Type | Effective Stress At Tip | Bearing Cap. Factor | Limiting End Bearing | End Bearing |
|---|---|---|---|---|---|
| 0.01 ft | Cohesionless | 1.25 psf | 26.40 | 18.60 Kips | 0.03 Kips |
| 9.01 ft | Cohesionless | 1126.25 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 10.99 ft | Cohesionless | 1373.75 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 11.01 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 18.99 ft | Cohesive | N/A | N/A | N/A | 15.71 Kips |
| 19.01 ft | Cohesive | N/A | N/A | N/A | 28.27 Kips |
| 28.01 ft | Cohesive | N/A | N/A | N/A | 28.27 Kips |
| 30.99 ft | Cohesive | N/A | N/A | N/A | 28.27 Kips |
| 31.01 ft | Cohesionless | 3736.20 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 40.01 ft | Cohesionless | 4816.20 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 45.99 ft | Cohesionless | 5533.80 psf | 22.80 | 18.60 Kips | 18.60 Kips |
| 46.01 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 50.99 ft | Cohesive | N/A | N/A | N/A | 34.56 Kips |
| 51.01 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 60.01 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 63.49 ft | Cohesive | N/A | N/A | N/A | 18.85 Kips |
| 63.51 ft | Cohesionless | 7573.70 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 65.99 ft | Cohesionless | 7871.30 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 66.01 ft | Cohesionless | 7873.08 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 69.49 ft | Cohesionless | 8073.52 psf | 26.40 | 18.60 Kips | 18.60 Kips |
| 69.51 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 74.49 ft | Cohesive | N/A | N/A | N/A | 37.70 Kips |
| 74.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 83.51 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 85.99 ft | Cohesive | N/A | N/A | N/A | 25.13 Kips |
| 86.01 ft | Cohesionless | 9025.18 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 93.99 ft | Cohesionless | 9564.62 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 94.01 ft | Cohesionless | 9565.93 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 98.99 ft | Cohesionless | 9877.67 psf | 30.00 | 18.60 Kips | 18.60 Kips |
| 99.01 ft | Cohesionless | 9878.98 psf | 40.40 | 46.08 Kips | 46.08 Kips |
| 107.49 ft | Cohesionless | 10452.22 psf | 40.40 | 46.08 Kips | 46.08 Kips |

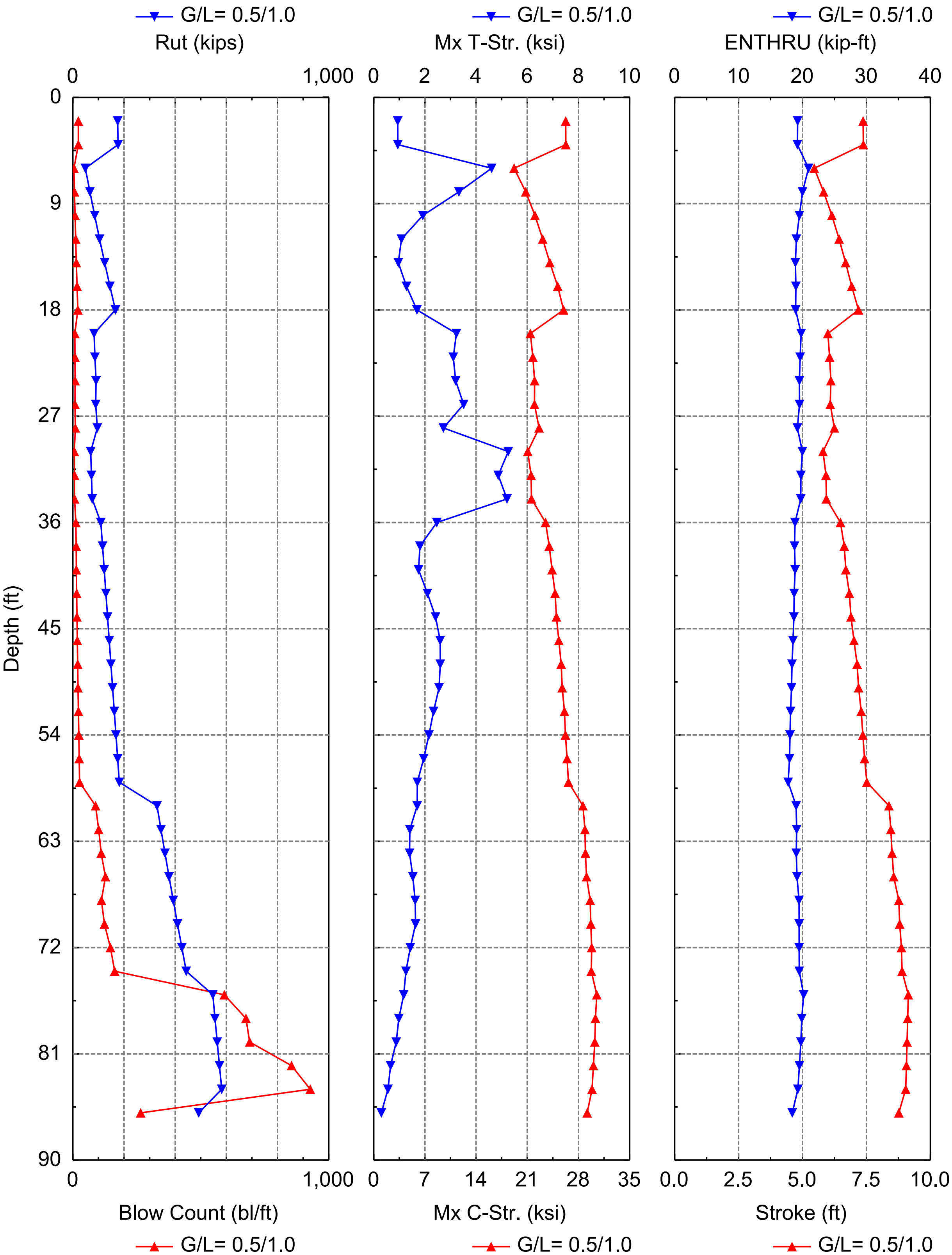
# ULTIMATE - SUMMARY OF CAPACITIES

| Depth | Skin Friction | End Bearing | Total Capacity |
|---|---|---|---|
| 0.01 ft | 0.00 Kips | 0.03 Kips | 0.03 Kips |
| 9.01 ft | 7.86 Kips | 18.60 Kips | 26.45 Kips |
| 10.99 ft | 11.69 Kips | 18.60 Kips | 30.29 Kips |
| 11.01 ft | 11.75 Kips | 15.71 Kips | 27.46 Kips |
| 18.99 ft | 43.75 Kips | 15.71 Kips | 59.45 Kips |
| 19.01 ft | 43.84 Kips | 28.27 Kips | 72.11 Kips |
| 28.01 ft | 91.99 Kips | 28.27 Kips | 120.26 Kips |
| 30.99 ft | 109.66 Kips | 28.27 Kips | 137.94 Kips |
| 31.01 ft | 109.78 Kips | 18.60 Kips | 128.38 Kips |
| 40.01 ft | 164.37 Kips | 18.60 Kips | 182.97 Kips |
| 45.99 ft | 208.27 Kips | 18.60 Kips | 226.86 Kips |
| 46.01 ft | 208.40 Kips | 34.56 Kips | 242.96 Kips |
| 50.99 ft | 237.56 Kips | 34.56 Kips | 272.12 Kips |
| 51.01 ft | 237.67 Kips | 18.85 Kips | 256.52 Kips |
| 60.01 ft | 286.50 Kips | 18.85 Kips | 305.35 Kips |
| 63.49 ft | 305.37 Kips | 18.85 Kips | 324.22 Kips |
| 63.51 ft | 305.54 Kips | 18.60 Kips | 324.14 Kips |
| 65.99 ft | 335.20 Kips | 18.60 Kips | 353.80 Kips |
| 66.01 ft | 335.44 Kips | 18.60 Kips | 354.04 Kips |
| 69.49 ft | 378.40 Kips | 18.60 Kips | 397.00 Kips |
| 69.51 ft | 378.58 Kips | 37.70 Kips | 416.28 Kips |
| 74.49 ft | 405.70 Kips | 37.70 Kips | 443.40 Kips |
| 74.51 ft | 405.82 Kips | 25.13 Kips | 430.95 Kips |
| 83.51 ft | 462.93 Kips | 25.13 Kips | 488.06 Kips |
| 85.99 ft | 478.67 Kips | 25.13 Kips | 503.80 Kips |
| 86.01 ft | 478.93 Kips | 46.08 Kips | 525.00 Kips |
| 93.99 ft | 637.49 Kips | 46.08 Kips | 683.57 Kips |
| 94.01 ft | 637.85 Kips | 18.60 Kips | 656.45 Kips |
| 98.99 ft | 719.31 Kips | 18.60 Kips | 737.91 Kips |
| 99.01 ft | 719.68 Kips | 46.08 Kips | 765.76 Kips |
| 107.49 ft | 903.97 Kips | 46.08 Kips | 950.04 Kips |

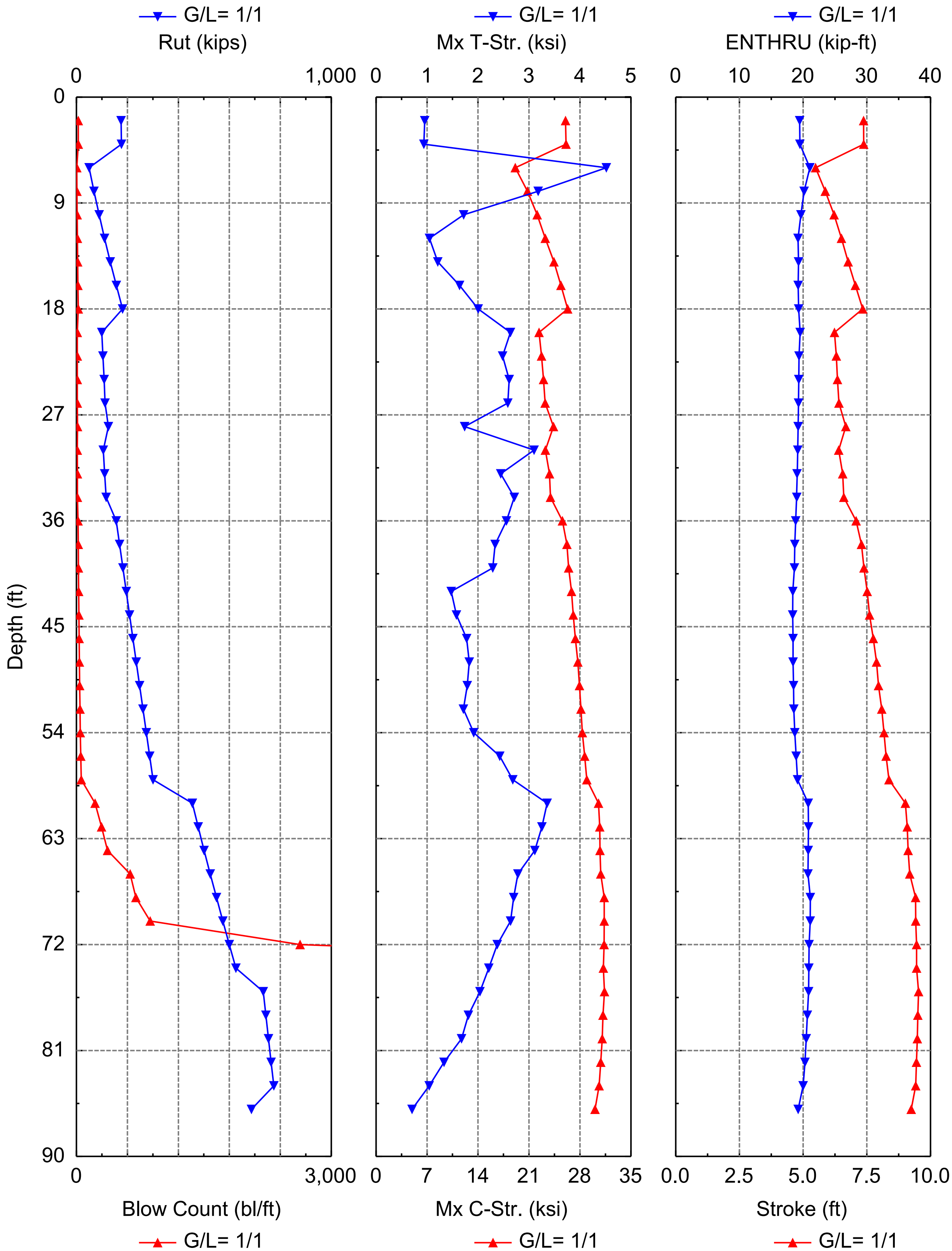
# APPENDIX VI

# GRLWEAP DRIVEABILITY ANALYSIS

Driveability Analysis Summary



Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.500/1.000

| Depth | Rut | Rshaft | Rtoe | Blow Ct | Mx C-Str | Mx T-Str. | Stroke | ENTHRU | Hammer |
|---|---|---|---|---|---|---|---|---|---|
| ft | kips | kips | kips | bl/ft | ksi | ksi | ft | kip-ft | - |
| 2.0 | 175.5 | 0.5 | 175.0 | 21.5 | 26.267 | 0.938 | 7.37 | 19.2 | D 19-42 |
| 4.0 | 176.9 | 1.9 | 175.0 | 21.7 | 26.271 | 0.942 | 7.38 | 19.2 | D 19-42 |
| 6.0 | 49.0 | 3.8 | 45.2 | 4.3 | 19.204 | 4.609 | 5.46 | 20.9 | D 19-42 |
| 8.0 | 66.8 | 6.4 | 60.3 | 6.4 | 20.797 | 3.328 | 5.82 | 20.0 | D 19-42 |
| 10.0 | 85.2 | 9.8 | 75.4 | 8.6 | 22.052 | 1.920 | 6.14 | 19.5 | D 19-42 |
| 12.0 | 104.5 | 14.0 | 90.5 | 11.1 | 23.123 | 1.083 | 6.43 | 19.0 | D 19-42 |
| 14.0 | 124.4 | 18.9 | 105.6 | 13.6 | 24.082 | 0.964 | 6.68 | 18.9 | D 19-42 |
| 16.0 | 145.2 | 24.5 | 120.6 | 16.4 | 25.159 | 1.280 | 6.92 | 19.0 | D 19-42 |
| 18.0 | 166.7 | 31.0 | 135.7 | 19.7 | 25.973 | 1.692 | 7.19 | 18.9 | D 19-42 |
| 20.0 | 82.8 | 36.2 | 46.7 | 7.8 | 21.419 | 3.232 | 5.99 | 19.8 | D 19-42 |
| 22.0 | 86.6 | 39.9 | 46.7 | 8.3 | 21.762 | 3.112 | 6.06 | 19.6 | D 19-42 |
| 24.0 | 90.6 | 44.0 | 46.7 | 8.7 | 22.002 | 3.202 | 6.11 | 19.5 | D 19-42 |
| 26.0 | 89.3 | 49.9 | 39.4 | 8.4 | 21.988 | 3.516 | 6.08 | 19.5 | D 19-42 |
| 28.0 | 95.8 | 56.5 | 39.4 | 9.7 | 22.622 | 2.726 | 6.24 | 19.2 | D 19-42 |
| 30.0 | 69.9 | 62.1 | 7.9 | 6.0 | 21.070 | 5.258 | 5.80 | 20.0 | D 19-42 |
| 32.0 | 72.7 | 64.8 | 7.9 | 6.7 | 21.524 | 4.867 | 5.92 | 19.7 | D 19-42 |
| 34.0 | 75.6 | 67.7 | 7.9 | 6.8 | 21.571 | 5.208 | 5.93 | 19.7 | D 19-42 |
| 36.0 | 109.5 | 73.3 | 36.2 | 11.6 | 23.518 | 2.464 | 6.48 | 18.8 | D 19-42 |
| 38.0 | 116.1 | 79.8 | 36.2 | 13.0 | 24.007 | 1.805 | 6.63 | 18.7 | D 19-42 |
| 40.0 | 122.6 | 86.4 | 36.2 | 13.6 | 24.397 | 1.753 | 6.69 | 18.8 | D 19-42 |
| 42.0 | 129.2 | 93.0 | 36.2 | 15.2 | 24.815 | 2.099 | 6.83 | 18.7 | D 19-42 |
| 44.0 | 135.8 | 99.5 | 36.2 | 16.0 | 25.002 | 2.417 | 6.89 | 18.7 | D 19-42 |
| 46.0 | 142.3 | 106.1 | 36.2 | 17.4 | 25.322 | 2.595 | 7.01 | 18.5 | D 19-42 |
| 48.0 | 148.9 | 112.7 | 36.2 | 19.2 | 25.637 | 2.601 | 7.13 | 18.4 | D 19-42 |
| 50.0 | 155.4 | 119.2 | 36.2 | 20.2 | 25.788 | 2.553 | 7.19 | 18.3 | D 19-42 |
| 52.0 | 162.0 | 125.8 | 36.2 | 22.2 | 26.081 | 2.340 | 7.30 | 18.1 | D 19-42 |
| 54.0 | 168.6 | 132.3 | 36.2 | 23.3 | 26.221 | 2.158 | 7.36 | 18.0 | D 19-42 |
| 56.0 | 175.1 | 138.9 | 36.2 | 24.9 | 26.445 | 1.954 | 7.43 | 18.0 | D 19-42 |
| 58.0 | 181.7 | 145.5 | 36.2 | 26.6 | 26.638 | 1.703 | 7.51 | 17.7 | D 19-42 |
| 60.0 | 329.1 | 154.1 | 175.0 | 88.9 | 28.624 | 1.699 | 8.38 | 19.0 | D 19-42 |
| 62.0 | 344.4 | 169.4 | 175.0 | 101.0 | 28.898 | 1.409 | 8.45 | 19.1 | D 19-42 |
| 64.0 | 360.0 | 185.0 | 175.0 | 110.7 | 28.958 | 1.401 | 8.50 | 19.0 | D 19-42 |
| 66.0 | 375.9 | 201.0 | 175.0 | 127.3 | 29.106 | 1.527 | 8.56 | 19.1 | D 19-42 |
| 68.0 | 392.2 | 217.3 | 175.0 | 111.9 | 29.602 | 1.624 | 8.76 | 19.5 | D 19-42 |
| 70.0 | 408.9 | 233.9 | 175.0 | 123.6 | 29.701 | 1.636 | 8.80 | 19.5 | D 19-42 |
| 72.0 | 425.9 | 250.9 | 175.0 | 146.9 | 29.816 | 1.430 | 8.86 | 19.5 | D 19-42 |
| 74.0 | 443.3 | 268.3 | 175.0 | 163.6 | 29.765 | 1.262 | 8.89 | 19.5 | D 19-42 |
| 76.0 | 547.1 | 278.8 | 268.3 | 592.1 | 30.511 | 1.174 | 9.14 | 20.2 | D 19-42 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 78.0 | 555.5 | 287.2 | 268.3 | 676.3 | 30.327 | 0.984 | 9.11 | 19.9 | D 19-42 |
| 80.0 | 564.1 | 295.8 | 268.3 | 691.1 | 30.236 | 0.881 | 9.08 | 19.8 | D 19-42 |
| 82.0 | 572.8 | 304.5 | 268.3 | 854.7 | 30.044 | 0.661 | 9.06 | 19.5 | D 19-42 |
| 84.0 | 581.8 | 313.5 | 268.3 | 928.0 | 29.857 | 0.556 | 9.03 | 19.3 | D 19-42 |
| 86.0 | 491.9 | 322.7 | 169.1 | 265.0 | 29.191 | 0.297 | 8.76 | 18.4 | D 19-42 |

Summary_Total driving time: 264 minutes; Total Number of Blows: 10494 (starting at penetration 2.0

Gain/Loss Factor at Shaft/Toe = 1.000/1.000

| Depth ft | Rut kips | Rshaft kips | Rtoe kips | Blow Ct bl/ft | Mx C-Str ksi | Mx T-Str. ksi | Stroke ft | ENTHRU kip-ft | Hammer - |
|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 175.5 | 0.5 | 175.0 | 21.3 | 26.029 | 0.954 | 7.37 | 19.4 | D 19-42 |
| 4.0 | 176.9 | 1.9 | 175.0 | 21.4 | 26.082 | 0.938 | 7.38 | 19.5 | D 19-42 |
| 6.0 | 50.0 | 4.7 | 45.2 | 4.4 | 19.116 | 4.519 | 5.49 | 21.1 | D 19-42 |
| 8.0 | 69.0 | 8.7 | 60.3 | 6.6 | 20.788 | 3.181 | 5.87 | 20.2 | D 19-42 |
| 10.0 | 89.2 | 13.8 | 75.4 | 9.0 | 22.128 | 1.720 | 6.21 | 19.7 | D 19-42 |
| 12.0 | 110.5 | 20.0 | 90.5 | 11.6 | 23.237 | 1.048 | 6.51 | 19.2 | D 19-42 |
| 14.0 | 132.9 | 27.4 | 105.6 | 14.5 | 24.429 | 1.210 | 6.77 | 19.3 | D 19-42 |
| 16.0 | 156.5 | 35.9 | 120.6 | 17.8 | 25.384 | 1.638 | 7.05 | 19.2 | D 19-42 |
| 18.0 | 181.2 | 45.5 | 135.7 | 21.6 | 26.303 | 2.005 | 7.34 | 19.3 | D 19-42 |
| 20.0 | 99.5 | 52.8 | 46.7 | 9.6 | 22.380 | 2.637 | 6.23 | 19.5 | D 19-42 |
| 22.0 | 103.9 | 57.3 | 46.7 | 10.2 | 22.720 | 2.481 | 6.30 | 19.4 | D 19-42 |
| 24.0 | 108.8 | 62.1 | 46.7 | 10.6 | 22.998 | 2.613 | 6.35 | 19.3 | D 19-42 |
| 26.0 | 112.5 | 73.1 | 39.4 | 11.0 | 23.216 | 2.585 | 6.40 | 19.3 | D 19-42 |
| 28.0 | 125.6 | 86.3 | 39.4 | 13.5 | 24.355 | 1.738 | 6.67 | 19.2 | D 19-42 |
| 30.0 | 105.3 | 97.5 | 7.9 | 10.2 | 23.259 | 3.100 | 6.39 | 19.2 | D 19-42 |
| 32.0 | 110.9 | 103.0 | 7.9 | 11.5 | 23.822 | 2.447 | 6.55 | 19.0 | D 19-42 |
| 34.0 | 116.6 | 108.7 | 7.9 | 11.9 | 23.958 | 2.711 | 6.59 | 19.0 | D 19-42 |
| 36.0 | 156.1 | 119.9 | 36.2 | 18.7 | 25.597 | 2.559 | 7.08 | 18.8 | D 19-42 |
| 38.0 | 169.3 | 133.0 | 36.2 | 22.1 | 26.203 | 2.336 | 7.29 | 18.7 | D 19-42 |
| 40.0 | 182.4 | 146.2 | 36.2 | 23.8 | 26.452 | 2.290 | 7.38 | 18.6 | D 19-42 |
| 42.0 | 195.5 | 159.3 | 36.2 | 26.6 | 26.844 | 1.475 | 7.51 | 18.4 | D 19-42 |
| 44.0 | 208.6 | 172.4 | 36.2 | 28.6 | 27.083 | 1.578 | 7.60 | 18.4 | D 19-42 |
| 46.0 | 221.7 | 185.5 | 36.2 | 31.6 | 27.375 | 1.776 | 7.75 | 18.4 | D 19-42 |
| 48.0 | 234.9 | 198.7 | 36.2 | 35.4 | 27.713 | 1.829 | 7.88 | 18.4 | D 19-42 |
| 50.0 | 248.0 | 211.8 | 36.2 | 38.0 | 27.938 | 1.789 | 7.96 | 18.5 | D 19-42 |
| 52.0 | 261.1 | 224.9 | 36.2 | 42.9 | 28.132 | 1.712 | 8.08 | 18.5 | D 19-42 |
| 54.0 | 274.2 | 238.0 | 36.2 | 46.0 | 28.328 | 1.915 | 8.17 | 18.7 | D 19-42 |
| 56.0 | 287.4 | 251.1 | 36.2 | 50.7 | 28.651 | 2.426 | 8.26 | 18.9 | D 19-42 |
| 58.0 | 300.5 | 264.3 | 36.2 | 56.8 | 28.948 | 2.681 | 8.37 | 19.1 | D 19-42 |
| 60.0 | 454.7 | 279.7 | 175.0 | 219.5 | 30.549 | 3.356 | 9.01 | 20.8 | D 19-42 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 62.0 | 477.6 | 302.6 | 175.0 | 295.1 | 30.723 | 3.255 | 9.09 | 20.8 | D 19-42 |
| 64.0 | 501.0 | 326.0 | 175.0 | 365.7 | 30.757 | 3.115 | 9.12 | 20.8 | D 19-42 |
| 66.0 | 525.0 | 350.0 | 175.0 | 632.0 | 30.848 | 2.784 | 9.18 | 20.8 | D 19-42 |
| 68.0 | 549.4 | 374.4 | 175.0 | 699.7 | 31.336 | 2.700 | 9.41 | 21.1 | D 19-42 |
| 70.0 | 574.4 | 399.4 | 175.0 | 868.4 | 31.336 | 2.638 | 9.42 | 21.1 | D 19-42 |
| 72.0 | 599.9 | 424.9 | 175.0 | 2632.9 | 31.318 | 2.378 | 9.45 | 20.9 | D 19-42 |
| 74.0 | 625.9 | 451.0 | 175.0 | 9999.0 | 31.211 | 2.212 | 9.45 | 20.9 | D 19-42 |
| 76.0 | 733.2 | 465.0 | 268.3 | 9999.0 | 31.370 | 2.039 | 9.53 | 20.9 | D 19-42 |
| 78.0 | 743.3 | 475.0 | 268.3 | 9999.0 | 31.160 | 1.811 | 9.50 | 20.7 | D 19-42 |
| 80.0 | 753.6 | 485.3 | 268.3 | 9999.0 | 31.053 | 1.677 | 9.48 | 20.5 | D 19-42 |
| 82.0 | 764.1 | 495.8 | 268.3 | 9999.0 | 30.854 | 1.332 | 9.44 | 20.3 | D 19-42 |
| 84.0 | 774.8 | 506.5 | 268.3 | 9999.0 | 30.636 | 1.044 | 9.42 | 20.0 | D 19-42 |
| 86.0 | 686.7 | 517.6 | 169.1 | 9999.0 | 30.069 | 0.705 | 9.24 | 19.2 | D 19-42 |

Summary_Refusal occurred; no driving time output possible.

GRLWEAP: Wave Equation Analysis of Pile Foundations

HAM-562-0004 - B-161-0-07 - 16" CIP 6/20/2023
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

## ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

| Depth | Soil Type | Spec. Wt | Su | Phi | Unit Rs | Unit Rt |
|---|---|---|---|---|---|---|
| ft | - | lb/ft³ | ksf | ° | ksf | ksf |
| 0.0 | Gravel | 135.0 | 0.0 | 46.0 | 0.00 | 125.31 |
| 4.0 | Gravel | 135.0 | 0.0 | 46.0 | 0.23 | 125.31 |
| 4.0 | Silt | 135.0 | 0.0 | 46.0 | 0.27 | 21.60 |
| 19.0 | Silt | 135.0 | 0.0 | 46.0 | 1.28 | 102.60 |
| 19.0 | Sand | 120.0 | 0.0 | 34.1 | 0.49 | 33.42 |
| 24.5 | Sand | 120.0 | 0.0 | 33.7 | 0.62 | 33.42 |
| 24.5 | Clay | 120.0 | 0.0 | 29.5 | 1.53 | 28.20 |
| 29.5 | Clay | 120.0 | 0.0 | 29.5 | 1.57 | 28.20 |
| 29.5 | Clay | 115.0 | 0.0 | 19.5 | 0.65 | 5.64 |
| 34.5 | Clay | 115.0 | 0.0 | 19.5 | 0.70 | 5.64 |
| 34.5 | Clay | 120.0 | 0.0 | 28.5 | 1.54 | 25.94 |
| 59.5 | Clay | 120.0 | 0.0 | 28.5 | 1.57 | 25.94 |
| 59.5 | Silt | 125.0 | 0.0 | 43.4 | 2.69 | 125.31 |
| 67.5 | Silt | 125.0 | 0.0 | 43.2 | 2.94 | 125.31 |
| 67.5 | Silt | 125.0 | 0.0 | 44.3 | 2.94 | 125.31 |
| 74.5 | Silt | 125.0 | 0.0 | 44.2 | 3.15 | 125.31 |
| 74.5 | Sand | 135.0 | 0.0 | 38.8 | 1.17 | 192.15 |
| 84.5 | Sand | 135.0 | 0.0 | 38.4 | 1.30 | 192.15 |
| 84.5 | Sand | 130.0 | 0.0 | 36.7 | 1.32 | 121.14 |
| 86.0 | Sand | 130.0 | 0.0 | 36.7 | 1.34 | 121.14 |

PILE INPUT

| | | | |
|---|---|---|---|
| Uniform Pile | | Pile Type: | Pipe |
| Pile Length: (ft) | 86.000 | Pile Penetration: (ft) | 86.000 |
| Pile Size: (ft) | 1.33 | Toe Area: (in²) | 201.06 |

Pile Profile

| Lb Top | X-Area | E-Modulus | Spec. Wt | Perim. | Crit. Index |
|---|---|---|---|---|---|
| ft | in² | ksi | lb/ft³ | ft | - |
| 0.0 | 21.4 | 30,000.0 | 492.0 | 4.2 | 0 |
| 86.0 | 21.4 | 30,000.0 | 492.0 | 4.2 | 0 |

HAMMER INPUT

| | | | |
|---|---|---|---|
| ID | 41 | Made By: | DELMAG |
| Model | D 19-42 | Type: | OED |

Hammer Data

| ID | Ram Wt | Ram L. | Ram Ar. | Rtd. Stk | Effic. | Rtd. Energy |
|---|---|---|---|---|---|---|

| - | kips | in | in² | ft | - | kip-ft |
|---|---|---|---|---|---|---|
| 41 | 4.000 | 129.1 | 124.7 | 10.8 | 0.80 | 43.2 |

DRIVE SYSTEM FOR DELMAG D 19-42-OED

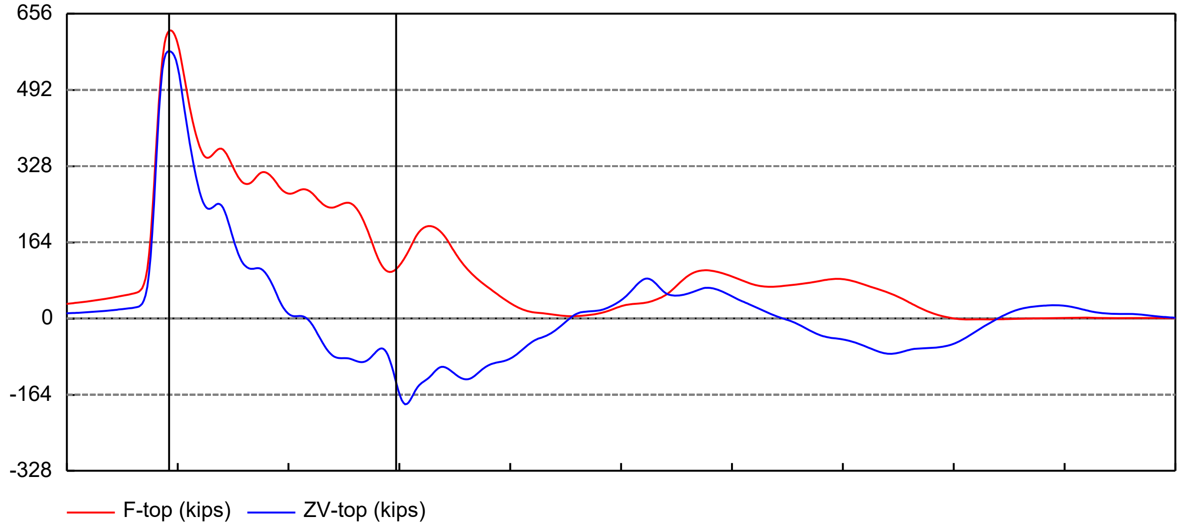
| Type | X-Area | E-Modulus | Thickness | COR | Round-out | Stiffness |
|---|---|---|---|---|---|---|
| - | in² | ksi | in | - | in | kips/in |
| Hammer C. | 227.000 | 530.000 | 2.000 | 0.800 | 0.120 | 60155.563 |
| Helmet Wt. | 1.900 | kips | | | | |

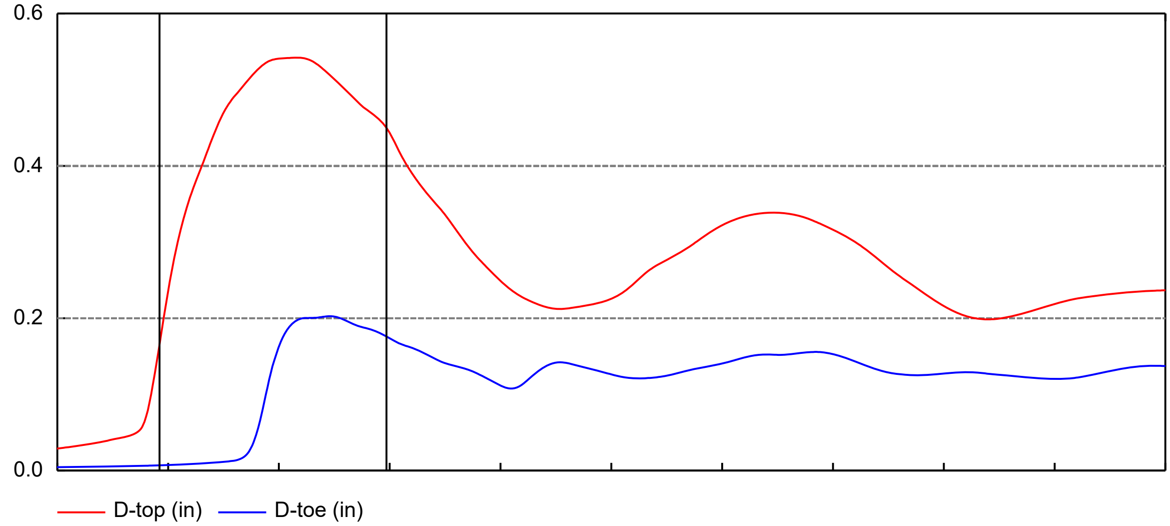
SOIL RESISTANCE DISTRIBUTION

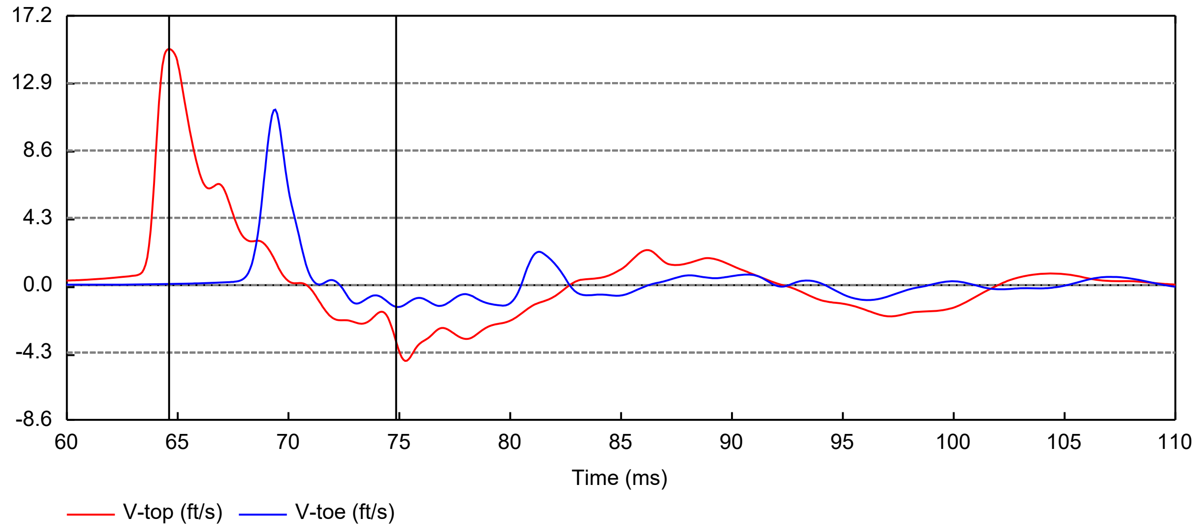
| Depth | Unit Rs | Unit Rt | Qs | Qt | Js | Jt | Set. F. | Limit D. | Set. T. | EB Area |
|---|---|---|---|---|---|---|---|---|---|---|
| ft | ksf | ksf | in | in | s/ft | s/ft | - | ft | Hours | in² |
| 0.0 | 0.0 | 125.3 | 0.10 | 0.13 | 0.05 | 0.15 | 1.0 | 6.6 | 1.0 | 201.1 |
| 2.0 | 0.1 | 125.3 | 0.10 | 0.13 | 0.05 | 0.15 | 1.0 | 6.6 | 1.0 | 201.1 |
| 4.0 | 0.2 | 125.3 | 0.10 | 0.13 | 0.05 | 0.15 | 1.0 | 6.6 | 1.0 | 201.1 |
| 4.0 | 0.3 | 21.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 5.7 | 0.4 | 30.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 7.3 | 0.5 | 39.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 9.0 | 0.6 | 48.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 10.7 | 0.7 | 57.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 12.3 | 0.8 | 66.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 14.0 | 0.9 | 75.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 15.7 | 1.1 | 84.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 17.3 | 1.2 | 93.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 19.0 | 1.3 | 102.6 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 19.0 | 0.5 | 33.4 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 20.8 | 0.5 | 33.4 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 22.7 | 0.6 | 33.4 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 24.5 | 0.6 | 33.4 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 24.5 | 1.5 | 28.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 26.2 | 1.6 | 28.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 27.8 | 1.6 | 28.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 29.5 | 1.6 | 28.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 29.5 | 0.6 | 5.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 31.2 | 0.7 | 5.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 32.8 | 0.7 | 5.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 34.5 | 0.7 | 5.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 34.5 | 1.5 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 36.2 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 37.8 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 39.5 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 41.2 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 42.8 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 44.5 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 46.2 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 47.8 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 49.5 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 51.2 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 52.8 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 54.5 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 56.2 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 57.8 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 59.5 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 59.5 | 2.7 | 125.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 61.5 | 2.7 | 125.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 63.5 | 2.8 | 125.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 65.5 | 2.9 | 125.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 67.5 | 2.9 | 125.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 67.5 | 2.9 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 69.3 | 3.0 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 71.0 | 3.0 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 72.8 | 3.1 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 74.5 | 3.2 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 74.5 | 1.2 | 192.1 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 76.2 | 1.2 | 192.1 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 77.8 | 1.2 | 192.1 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 79.5 | 1.2 | 192.1 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 81.2 | 1.3 | 192.1 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 82.8 | 1.3 | 192.1 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 84.5 | 1.3 | 192.1 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 84.5 | 1.3 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 86.0 | 1.3 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |

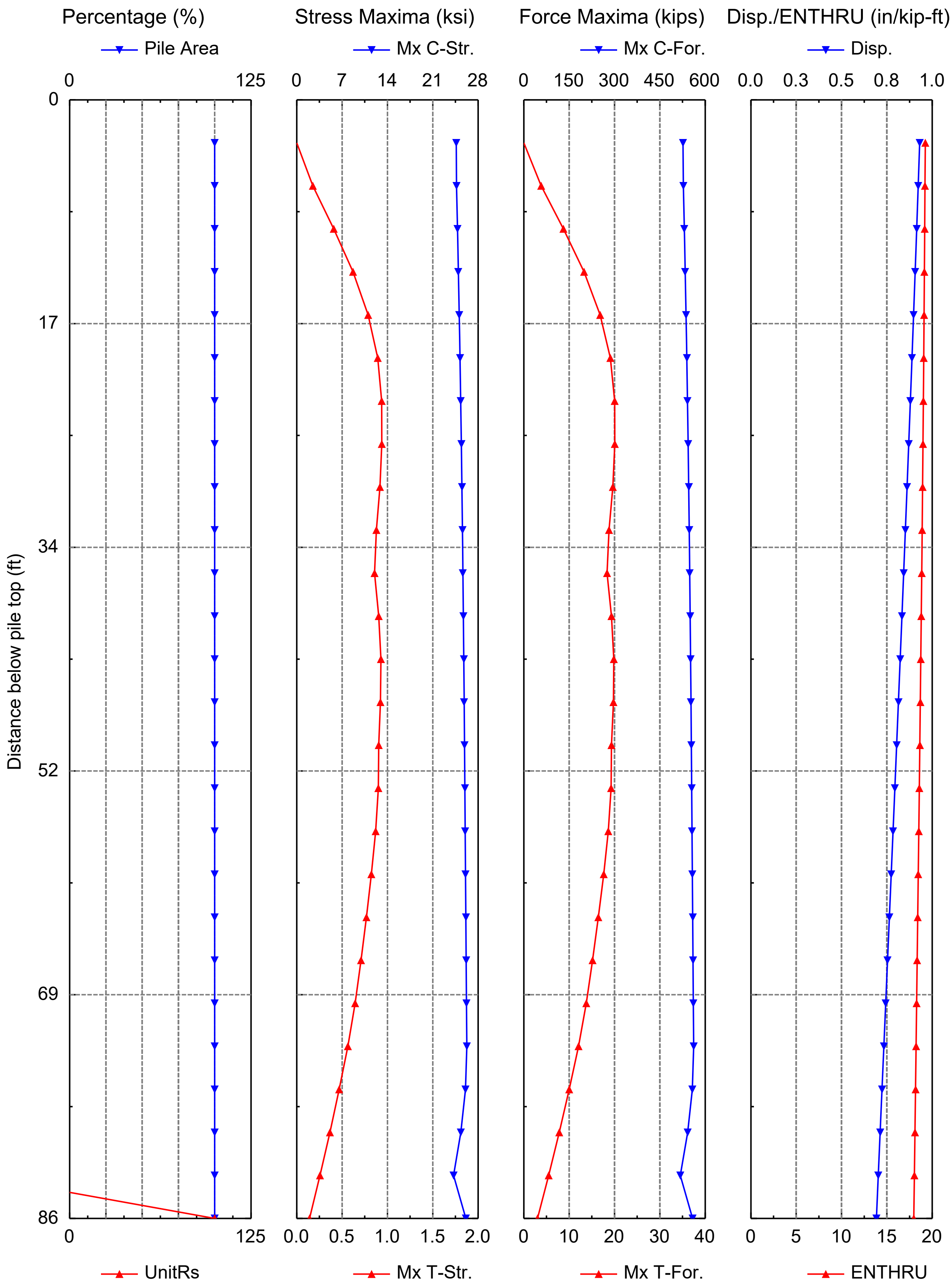
Variable Time Hisotry with DELMAG D 19-42; Depth = 86.00ft; Shaft/Toe G/L = 0.500/1.000



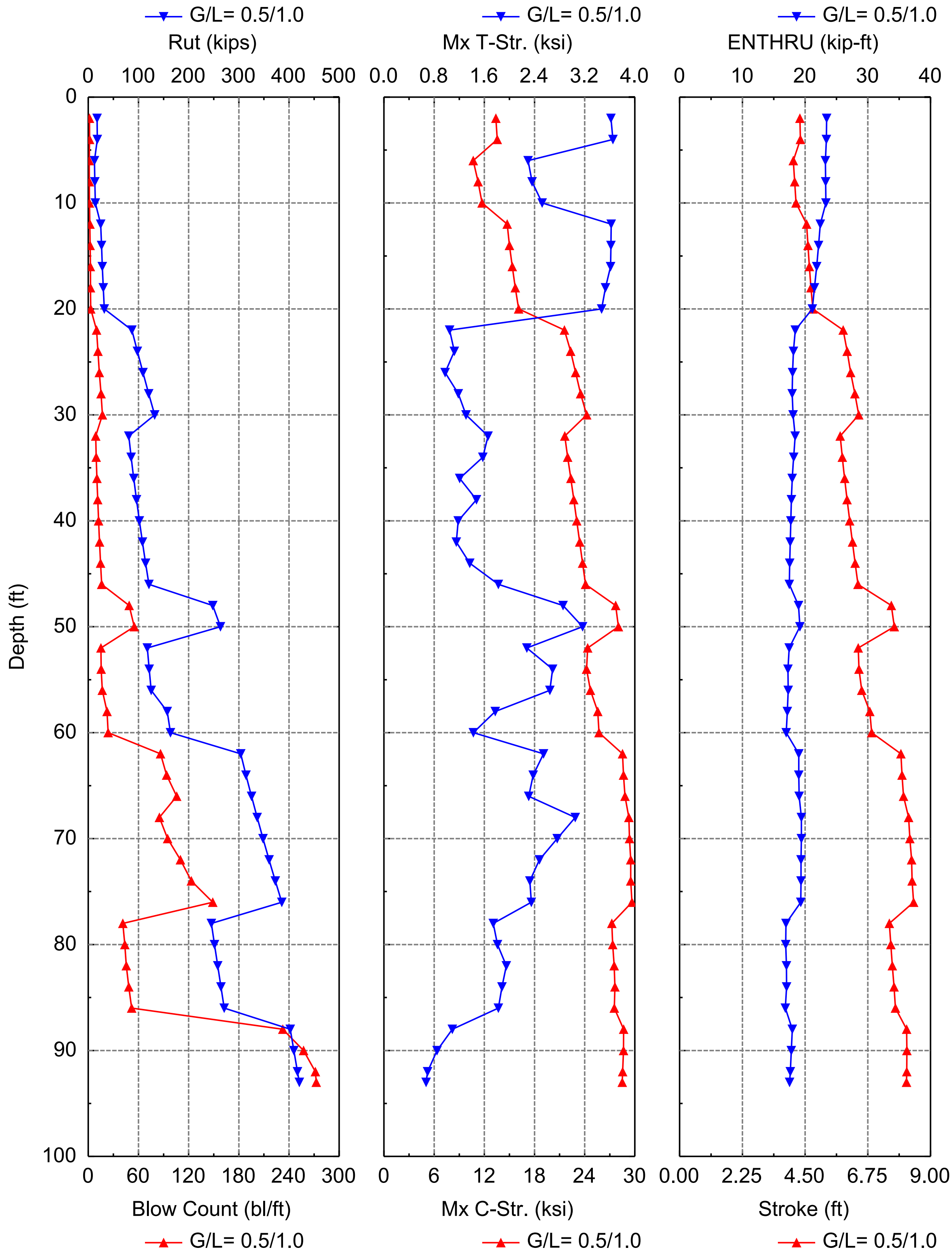



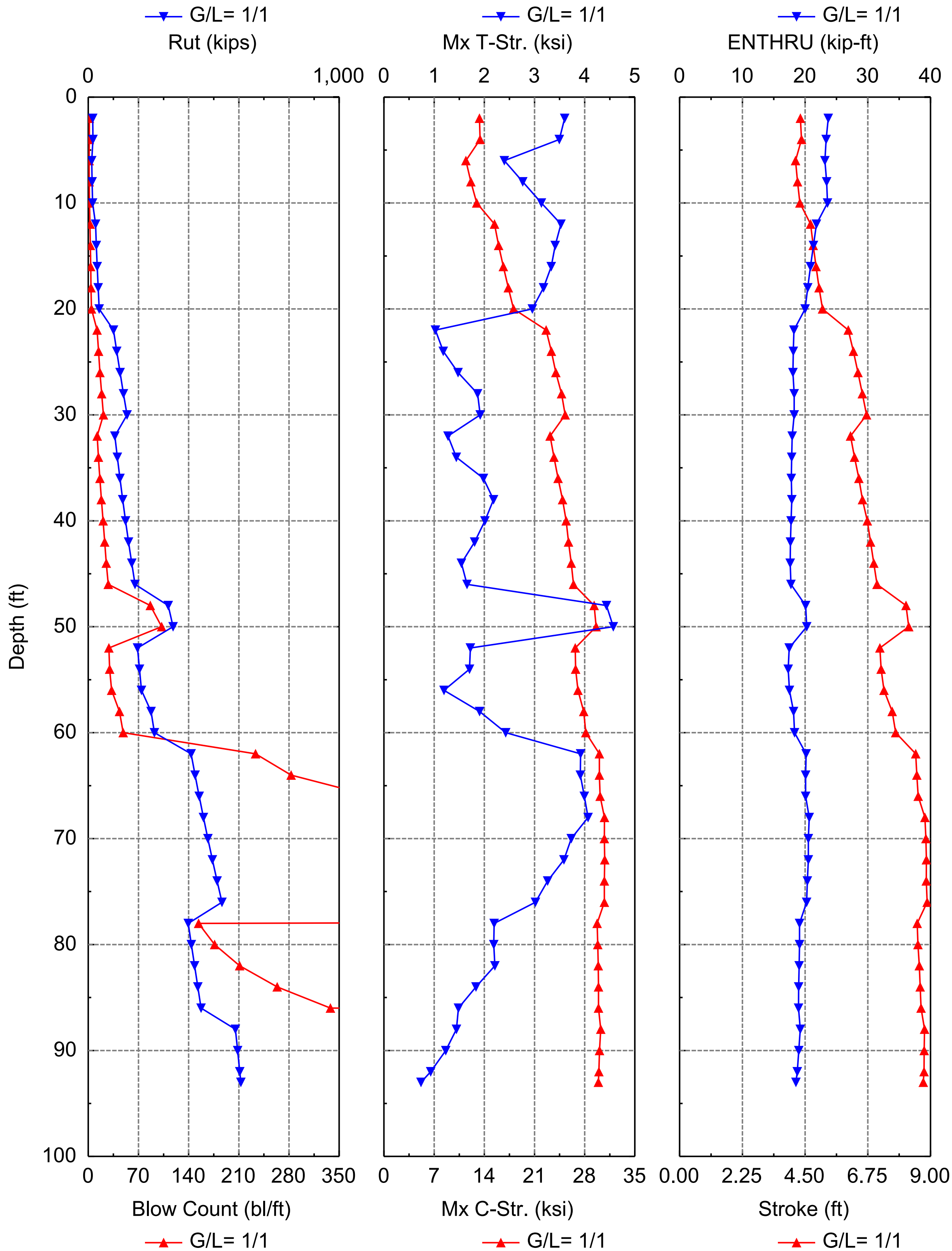
Extrema Results of Gain/Loss at Shaft/Toe = 0.500/1.000 and Depth = 2.00 ft



Driveability Analysis Summary



Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.500/1.000

| Depth | Rut | Rshaft | Rtoe | Blow Ct | Mx C-Str | Mx T-Str. | Stroke | ENTHRU | Hammer |
|---|---|---|---|---|---|---|---|---|---|
| ft | kips | kips | kips | bl/ft | ksi | ksi | ft | kip-ft | - |
| 2.0 | 17.5 | 0.2 | 17.3 | 1.4 | 13.383 | 3.617 | 4.31 | 23.4 | D 19-42 |
| 4.0 | 17.9 | 0.6 | 17.3 | 1.5 | 13.538 | 3.651 | 4.33 | 23.4 | D 19-42 |
| 6.0 | 12.3 | 1.3 | 11.0 | 1.1 | 10.679 | 2.297 | 4.08 | 23.2 | D 19-42 |
| 8.0 | 13.1 | 2.1 | 11.0 | 1.2 | 11.252 | 2.362 | 4.13 | 23.3 | D 19-42 |
| 10.0 | 14.0 | 3.0 | 11.0 | 1.3 | 11.722 | 2.521 | 4.18 | 23.3 | D 19-42 |
| 12.0 | 24.8 | 4.3 | 20.5 | 2.0 | 14.729 | 3.622 | 4.55 | 22.4 | D 19-42 |
| 14.0 | 26.3 | 5.8 | 20.5 | 2.2 | 14.998 | 3.618 | 4.60 | 22.1 | D 19-42 |
| 16.0 | 28.0 | 7.5 | 20.5 | 2.4 | 15.338 | 3.612 | 4.65 | 21.8 | D 19-42 |
| 18.0 | 29.9 | 9.4 | 20.5 | 2.6 | 15.701 | 3.531 | 4.71 | 21.5 | D 19-42 |
| 20.0 | 32.0 | 11.5 | 20.5 | 2.9 | 16.107 | 3.469 | 4.78 | 21.2 | D 19-42 |
| 22.0 | 87.0 | 14.1 | 72.9 | 9.9 | 21.576 | 1.046 | 5.86 | 18.4 | D 19-42 |
| 24.0 | 97.8 | 17.9 | 79.9 | 11.6 | 22.322 | 1.122 | 6.01 | 18.1 | D 19-42 |
| 26.0 | 108.9 | 22.1 | 86.8 | 13.2 | 22.914 | 0.975 | 6.13 | 18.0 | D 19-42 |
| 28.0 | 120.4 | 26.6 | 93.8 | 15.2 | 23.513 | 1.186 | 6.29 | 17.9 | D 19-42 |
| 30.0 | 132.3 | 31.5 | 100.8 | 16.9 | 24.238 | 1.308 | 6.42 | 18.1 | D 19-42 |
| 32.0 | 80.6 | 36.5 | 44.1 | 8.8 | 21.624 | 1.658 | 5.76 | 18.4 | D 19-42 |
| 34.0 | 85.4 | 41.4 | 44.1 | 9.5 | 21.963 | 1.575 | 5.83 | 18.2 | D 19-42 |
| 36.0 | 90.6 | 46.5 | 44.1 | 10.4 | 22.343 | 1.206 | 5.92 | 17.9 | D 19-42 |
| 38.0 | 96.1 | 52.0 | 44.1 | 11.3 | 22.690 | 1.475 | 6.00 | 17.8 | D 19-42 |
| 40.0 | 101.8 | 57.7 | 44.1 | 12.3 | 23.045 | 1.183 | 6.10 | 17.7 | D 19-42 |
| 42.0 | 107.9 | 63.8 | 44.1 | 13.5 | 23.403 | 1.154 | 6.20 | 17.6 | D 19-42 |
| 44.0 | 114.3 | 70.2 | 44.1 | 14.6 | 23.744 | 1.368 | 6.30 | 17.6 | D 19-42 |
| 46.0 | 120.8 | 76.7 | 44.1 | 16.0 | 24.098 | 1.823 | 6.40 | 17.5 | D 19-42 |
| 48.0 | 248.1 | 84.4 | 163.7 | 48.8 | 27.708 | 2.855 | 7.59 | 19.0 | D 19-42 |
| 50.0 | 263.3 | 92.7 | 170.6 | 55.0 | 28.027 | 3.167 | 7.70 | 19.2 | D 19-42 |
| 52.0 | 117.5 | 100.2 | 17.3 | 15.1 | 24.353 | 2.277 | 6.40 | 17.5 | D 19-42 |
| 54.0 | 121.4 | 104.1 | 17.3 | 15.4 | 24.215 | 2.689 | 6.43 | 17.3 | D 19-42 |
| 56.0 | 125.4 | 108.1 | 17.3 | 16.8 | 24.690 | 2.644 | 6.53 | 17.3 | D 19-42 |
| 58.0 | 157.2 | 114.7 | 42.5 | 22.4 | 25.558 | 1.774 | 6.82 | 17.2 | D 19-42 |
| 60.0 | 163.8 | 121.2 | 42.5 | 23.7 | 25.703 | 1.425 | 6.89 | 17.0 | D 19-42 |
| 62.0 | 303.7 | 128.8 | 175.0 | 86.3 | 28.521 | 2.543 | 7.94 | 19.0 | D 19-42 |
| 64.0 | 314.3 | 139.4 | 175.0 | 93.7 | 28.641 | 2.379 | 7.98 | 19.0 | D 19-42 |
| 66.0 | 325.3 | 150.3 | 175.0 | 105.7 | 28.819 | 2.308 | 8.03 | 19.1 | D 19-42 |
| 68.0 | 336.6 | 161.6 | 175.0 | 85.0 | 29.276 | 3.049 | 8.21 | 19.4 | D 19-42 |
| 70.0 | 348.3 | 173.3 | 175.0 | 94.9 | 29.355 | 2.762 | 8.26 | 19.4 | D 19-42 |
| 72.0 | 360.4 | 185.4 | 175.0 | 110.1 | 29.501 | 2.477 | 8.32 | 19.3 | D 19-42 |
| 74.0 | 372.8 | 197.8 | 175.0 | 123.3 | 29.505 | 2.325 | 8.34 | 19.3 | D 19-42 |
| 76.0 | 385.6 | 210.7 | 175.0 | 148.8 | 29.652 | 2.348 | 8.39 | 19.3 | D 19-42 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 78.0 | 245.3 | 218.5 | 26.8 | 41.3 | 27.246 | 1.742 | 7.52 | 16.9 | D 19-42 |
| 80.0 | 251.5 | 224.7 | 26.8 | 43.6 | 27.353 | 1.810 | 7.57 | 16.9 | D 19-42 |
| 82.0 | 257.9 | 231.1 | 26.8 | 45.4 | 27.518 | 1.951 | 7.63 | 17.0 | D 19-42 |
| 84.0 | 264.4 | 237.6 | 26.8 | 48.4 | 27.615 | 1.882 | 7.69 | 17.1 | D 19-42 |
| 86.0 | 270.9 | 244.2 | 26.8 | 51.8 | 27.540 | 1.823 | 7.74 | 16.9 | D 19-42 |
| 88.0 | 402.5 | 250.8 | 151.6 | 232.6 | 28.650 | 1.090 | 8.14 | 17.9 | D 19-42 |
| 90.0 | 409.6 | 257.9 | 151.6 | 257.4 | 28.642 | 0.846 | 8.15 | 17.8 | D 19-42 |
| 92.0 | 416.8 | 265.2 | 151.6 | 271.5 | 28.538 | 0.696 | 8.14 | 17.6 | D 19-42 |
| 93.0 | 420.5 | 268.9 | 151.6 | 272.5 | 28.496 | 0.671 | 8.14 | 17.5 | D 19-42 |

Summary_Total driving time: 105 minutes; Total Number of Blows: 4437 (starting at penetration 2.0 f

Gain/Loss Factor at Shaft/Toe = 1.000/1.000

| Depth | Rut | Rshaft | Rtoe | Blow Ct | Mx C-Str | Mx T-Str. | Stroke | ENTHRU | Hammer |
|---|---|---|---|---|---|---|---|---|---|
| ft | kips | kips | kips | bl/ft | ksi | ksi | ft | kip-ft | - |
| 2.0 | 17.6 | 0.3 | 17.3 | 1.4 | 13.312 | 3.601 | 4.33 | 23.7 | D 19-42 |
| 4.0 | 18.5 | 1.2 | 17.3 | 1.5 | 13.397 | 3.493 | 4.37 | 23.3 | D 19-42 |
| 6.0 | 13.5 | 2.5 | 11.0 | 1.2 | 11.426 | 2.399 | 4.16 | 23.2 | D 19-42 |
| 8.0 | 15.1 | 4.1 | 11.0 | 1.3 | 12.115 | 2.766 | 4.23 | 23.4 | D 19-42 |
| 10.0 | 17.1 | 6.0 | 11.0 | 1.5 | 12.934 | 3.137 | 4.31 | 23.6 | D 19-42 |
| 12.0 | 29.1 | 8.7 | 20.5 | 2.5 | 15.417 | 3.526 | 4.70 | 21.8 | D 19-42 |
| 14.0 | 32.1 | 11.7 | 20.5 | 2.9 | 15.994 | 3.413 | 4.79 | 21.3 | D 19-42 |
| 16.0 | 35.5 | 15.1 | 20.5 | 3.3 | 16.643 | 3.334 | 4.89 | 20.8 | D 19-42 |
| 18.0 | 39.3 | 18.8 | 20.5 | 3.8 | 17.349 | 3.179 | 5.00 | 20.4 | D 19-42 |
| 20.0 | 43.5 | 23.0 | 20.5 | 4.4 | 18.065 | 2.957 | 5.12 | 20.0 | D 19-42 |
| 22.0 | 100.6 | 27.7 | 72.9 | 12.2 | 22.617 | 1.025 | 6.05 | 18.2 | D 19-42 |
| 24.0 | 113.3 | 33.5 | 79.9 | 14.3 | 23.347 | 1.181 | 6.23 | 18.1 | D 19-42 |
| 26.0 | 126.6 | 39.7 | 86.8 | 16.2 | 23.978 | 1.477 | 6.40 | 18.1 | D 19-42 |
| 28.0 | 140.3 | 46.5 | 93.8 | 18.7 | 24.763 | 1.865 | 6.55 | 18.3 | D 19-42 |
| 30.0 | 154.6 | 53.8 | 100.8 | 21.1 | 25.273 | 1.917 | 6.70 | 18.3 | D 19-42 |
| 32.0 | 106.0 | 61.9 | 44.1 | 12.5 | 23.180 | 1.277 | 6.13 | 17.9 | D 19-42 |
| 34.0 | 115.7 | 71.6 | 44.1 | 14.1 | 23.713 | 1.443 | 6.27 | 17.9 | D 19-42 |
| 36.0 | 126.0 | 81.9 | 44.1 | 16.2 | 24.286 | 1.981 | 6.43 | 17.8 | D 19-42 |
| 38.0 | 137.0 | 92.9 | 44.1 | 18.2 | 24.913 | 2.183 | 6.56 | 17.9 | D 19-42 |
| 40.0 | 148.5 | 104.4 | 44.1 | 20.7 | 25.412 | 2.011 | 6.73 | 17.8 | D 19-42 |
| 42.0 | 160.6 | 116.5 | 44.1 | 22.8 | 25.749 | 1.805 | 6.85 | 17.7 | D 19-42 |
| 44.0 | 173.3 | 129.3 | 44.1 | 25.0 | 26.122 | 1.544 | 6.96 | 17.6 | D 19-42 |
| 46.0 | 186.4 | 142.3 | 44.1 | 27.8 | 26.444 | 1.655 | 7.08 | 17.7 | D 19-42 |
| 48.0 | 318.4 | 154.7 | 163.7 | 86.6 | 29.326 | 4.434 | 8.12 | 20.1 | D 19-42 |
| 50.0 | 337.8 | 167.2 | 170.6 | 102.3 | 29.598 | 4.570 | 8.22 | 20.3 | D 19-42 |
| 52.0 | 196.2 | 178.9 | 17.3 | 28.8 | 26.679 | 1.722 | 7.18 | 17.5 | D 19-42 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 54.0 | 204.0 | 186.7 | 17.3 | 29.7 | 26.734 | 1.705 | 7.23 | 17.3 | D 19-42 |
| 56.0 | 212.0 | 194.7 | 17.3 | 32.6 | 27.060 | 1.195 | 7.33 | 17.5 | D 19-42 |
| 58.0 | 250.3 | 207.8 | 42.5 | 43.4 | 27.863 | 1.906 | 7.62 | 18.2 | D 19-42 |
| 60.0 | 263.5 | 220.9 | 42.5 | 48.6 | 28.150 | 2.426 | 7.75 | 18.3 | D 19-42 |
| 62.0 | 409.6 | 234.7 | 175.0 | 233.3 | 30.041 | 3.918 | 8.47 | 20.2 | D 19-42 |
| 64.0 | 425.6 | 250.6 | 175.0 | 283.0 | 30.055 | 3.912 | 8.51 | 20.1 | D 19-42 |
| 66.0 | 442.0 | 267.0 | 175.0 | 396.8 | 30.156 | 3.992 | 8.56 | 20.1 | D 19-42 |
| 68.0 | 459.0 | 284.0 | 175.0 | 412.5 | 30.762 | 4.066 | 8.80 | 20.7 | D 19-42 |
| 70.0 | 476.5 | 301.5 | 175.0 | 666.7 | 30.745 | 3.732 | 8.83 | 20.5 | D 19-42 |
| 72.0 | 494.6 | 319.6 | 175.0 | 1144.5 | 30.792 | 3.585 | 8.85 | 20.5 | D 19-42 |
| 74.0 | 513.3 | 338.3 | 175.0 | 2173.9 | 30.747 | 3.261 | 8.85 | 20.4 | D 19-42 |
| 76.0 | 532.5 | 357.5 | 175.0 | 9999.0 | 30.747 | 3.019 | 8.88 | 20.2 | D 19-42 |
| 78.0 | 398.3 | 371.6 | 26.8 | 153.8 | 29.735 | 2.194 | 8.52 | 19.1 | D 19-42 |
| 80.0 | 410.8 | 384.0 | 26.8 | 176.2 | 29.819 | 2.188 | 8.55 | 19.1 | D 19-42 |
| 82.0 | 423.5 | 396.8 | 26.8 | 211.1 | 29.886 | 2.210 | 8.60 | 19.0 | D 19-42 |
| 84.0 | 436.6 | 409.8 | 26.8 | 263.5 | 29.919 | 1.833 | 8.63 | 19.0 | D 19-42 |
| 86.0 | 449.7 | 422.9 | 26.8 | 337.7 | 29.925 | 1.483 | 8.66 | 19.0 | D 19-42 |
| 88.0 | 586.5 | 434.9 | 151.6 | 9999.0 | 30.246 | 1.444 | 8.78 | 19.2 | D 19-42 |
| 90.0 | 595.0 | 443.4 | 151.6 | 9999.0 | 30.066 | 1.232 | 8.77 | 19.0 | D 19-42 |
| 92.0 | 603.7 | 452.1 | 151.6 | 9999.0 | 29.983 | 0.931 | 8.76 | 18.8 | D 19-42 |
| 93.0 | 608.1 | 456.5 | 151.6 | 9999.0 | 29.912 | 0.738 | 8.74 | 18.5 | D 19-42 |

Summary_Refusal occurred; no driving time output possible.

GRLWEAP: Wave Equation Analysis of Pile Foundations

HAM-562-0004 - B-162-0-07 - 16" CIP 6/20/2023
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

| Depth<br>ft | Soil Type<br>- | Spec. Wt<br>lb/ft³ | Su<br>ksf | Phi<br>° | Unit Rs<br>ksf | Unit Rt<br>ksf |
|---|---|---|---|---|---|---|
| 0.0 | Clay | 115.0 | 0.0 | 22.5 | 0.00 | 12.41 |
| 4.0 | Clay | 115.0 | 0.0 | 22.5 | 0.15 | 12.41 |
| 4.0 | Clay | 115.0 | 0.0 | 20.5 | 0.13 | 7.89 |
| 10.0 | Clay | 115.0 | 0.0 | 20.5 | 0.25 | 7.89 |
| 10.0 | Clay | 115.0 | 0.0 | 23.5 | 0.29 | 14.66 |
| 21.5 | Clay | 115.0 | 0.0 | 23.5 | 0.55 | 14.66 |
| 21.5 | Silt | 125.0 | 0.0 | 44.4 | 0.64 | 50.94 |
| 31.5 | Silt | 125.0 | 0.0 | 44.0 | 0.95 | 75.96 |
| 31.5 | Clay | 125.0 | 0.0 | 31.0 | 1.10 | 31.58 |
| 46.5 | Clay | 125.0 | 0.0 | 31.0 | 1.57 | 31.58 |
| 46.5 | Silt | 125.0 | 0.0 | 43.3 | 1.42 | 113.49 |
| 51.5 | Silt | 125.0 | 0.0 | 43.2 | 1.57 | 125.31 |
| 51.5 | Clay | 115.0 | 0.0 | 22.5 | 0.91 | 12.41 |
| 56.0 | Clay | 115.0 | 0.0 | 22.5 | 0.97 | 12.41 |
| 56.0 | Clay | 120.0 | 0.0 | 30.5 | 1.57 | 30.45 |
| 61.5 | Clay | 120.0 | 0.0 | 30.5 | 1.57 | 30.45 |
| 61.5 | Silt | 125.0 | 0.0 | 43.2 | 1.85 | 125.31 |
| 66.0 | Silt | 125.0 | 0.0 | 43.1 | 1.99 | 125.31 |
| 66.0 | Silt | 130.0 | 0.0 | 44.4 | 1.99 | 125.31 |
| 76.5 | Silt | 130.0 | 0.0 | 44.1 | 2.35 | 125.31 |
| 76.5 | Clay | 120.0 | 0.0 | 25.5 | 1.44 | 19.17 |
| 87.5 | Clay | 120.0 | 0.0 | 25.5 | 1.57 | 19.17 |
| 87.5 | Sand | 125.0 | 0.0 | 37.0 | 1.00 | 108.60 |
| 93.0 | Sand | 125.0 | 0.0 | 36.9 | 1.06 | 108.60 |

PILE INPUT

| | | | |
|---|---|---|---|
| Uniform Pile | | Pile Type: | Pipe |
| Pile Length: (ft) | 93.000 | Pile Penetration: (ft) | 93.000 |
| Pile Size: (ft) | 1.33 | Toe Area: (in²) | 201.06 |

Pile Profile

| Lb Top<br>ft | X-Area<br>in² | E-Modulus<br>ksi | Spec. Wt<br>lb/ft³ | Perim.<br>ft | Crit. Index<br>- |
|---|---|---|---|---|---|
| 0.0 | 18.4 | 30,000.0 | 492.0 | 4.2 | 0 |
| 93.0 | 18.4 | 30,000.0 | 492.0 | 4.2 | 0 |

HAMMER INPUT

| | | | |
|---|---|---|---|
| ID | 41 | Made By: | DELMAG |

| Model | D 19-42 | Type: | OED |
|---|---|---|---|

Hammer Data

| ID | Ram Wt | Ram L. | Ram Ar. | Rtd. Stk | Effic. | Rtd. Energy |
|---|---|---|---|---|---|---|
| - | kips | in | in² | ft | - | kip-ft |
| 41 | 4.000 | 129.1 | 124.7 | 10.8 | 0.80 | 43.2 |

DRIVE SYSTEM FOR DELMAG D 19-42-OED

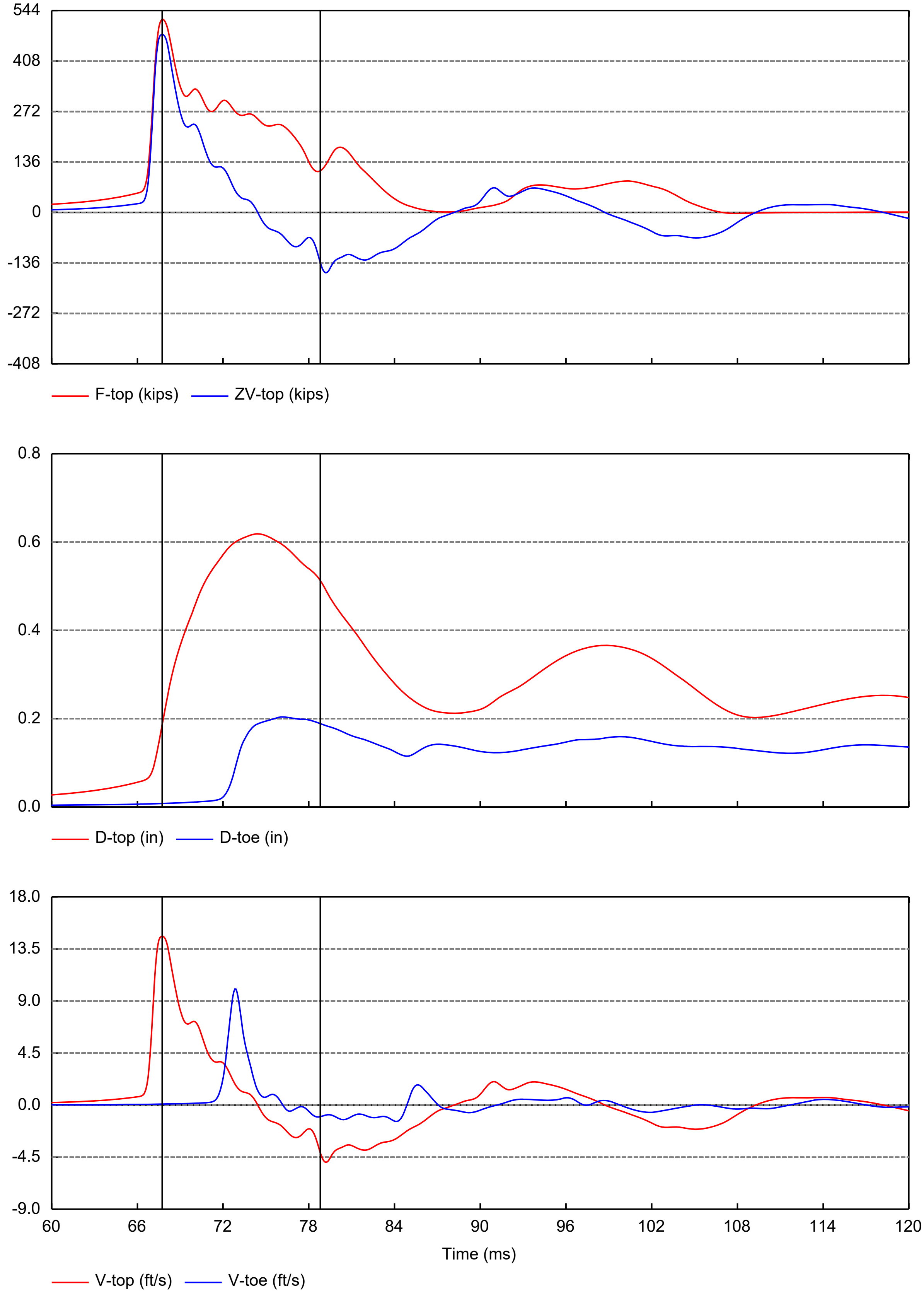
| Type | X-Area | E-Modulus | Thickness | COR | Round-out | Stiffness |
|---|---|---|---|---|---|---|
| - | in² | ksi | in | - | in | kips/in |
| Hammer C. | 227.000 | 530.000 | 2.000 | 0.800 | 0.120 | 60155.563 |
| Helmet Wt. | 1.900 | kips | | | | |

SOIL RESISTANCE DISTRIBUTION

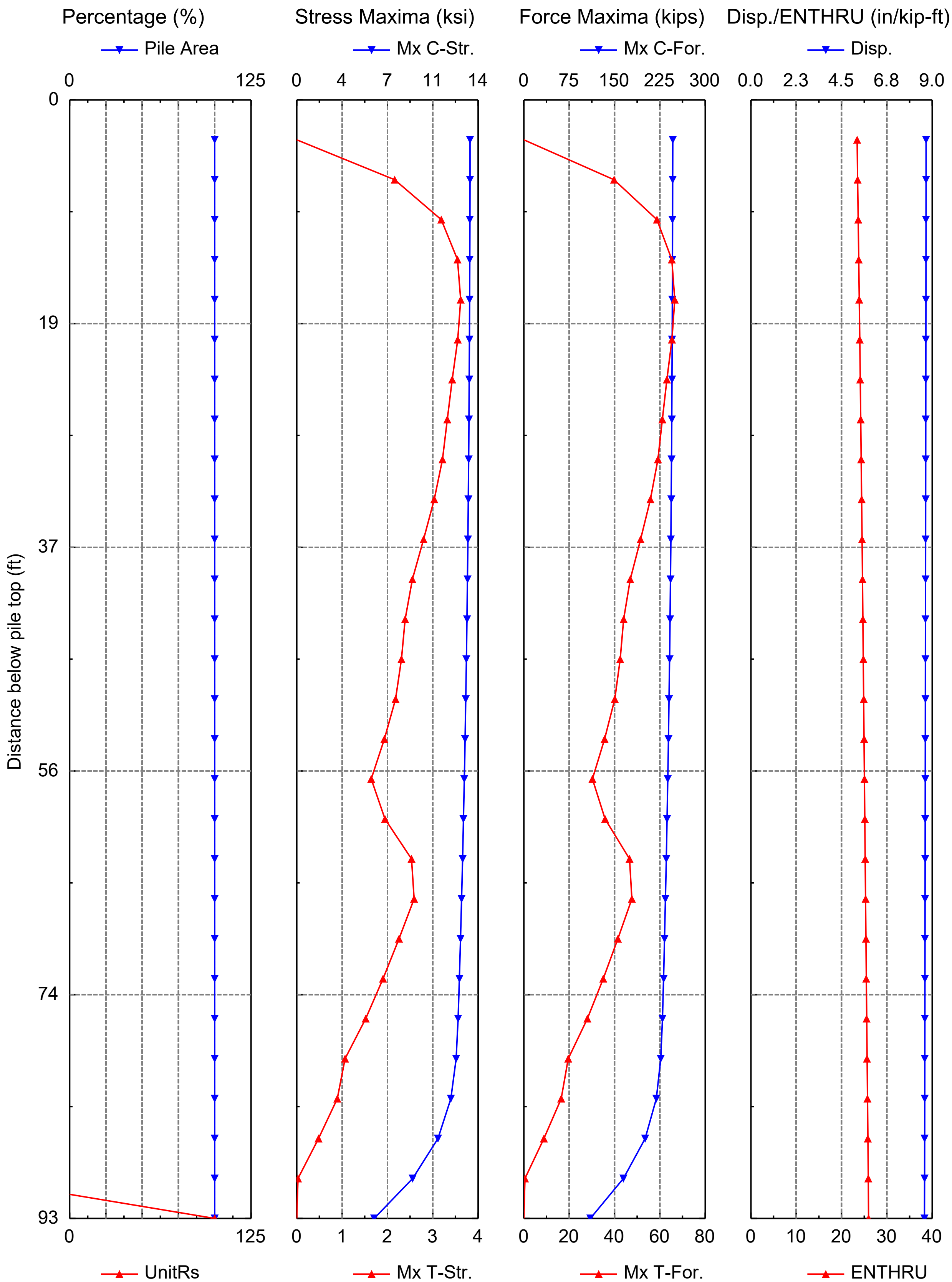
| Depth | Unit Rs | Unit Rt | Qs | Qt | Js | Jt | Set. F. | Limit D. | Set. T. | EB Area |
|---|---|---|---|---|---|---|---|---|---|---|
| ft | ksf | ksf | in | in | s/ft | s/ft | - | ft | Hours | in² |
| 0.0 | 0.0 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 2.0 | 0.1 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 4.0 | 0.1 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 4.0 | 0.1 | 7.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 6.0 | 0.2 | 7.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 8.0 | 0.2 | 7.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 10.0 | 0.3 | 7.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 10.0 | 0.3 | 14.7 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 11.6 | 0.3 | 14.7 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 13.3 | 0.4 | 14.7 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 14.9 | 0.4 | 14.7 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 16.6 | 0.4 | 14.7 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 18.2 | 0.5 | 14.7 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 19.9 | 0.5 | 14.7 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 21.5 | 0.6 | 14.7 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 21.5 | 0.6 | 50.9 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 23.2 | 0.7 | 55.1 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 24.8 | 0.7 | 59.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 26.5 | 0.8 | 63.4 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 28.2 | 0.8 | 67.6 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 29.8 | 0.9 | 71.8 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 31.5 | 0.9 | 76.0 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 31.5 | 1.1 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 33.2 | 1.2 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 34.8 | 1.2 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 36.5 | 1.3 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 38.2 | 1.3 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 39.8 | 1.4 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 41.5 | 1.5 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 43.2 | 1.5 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 44.8 | 1.6 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 46.5 | 1.6 | 31.6 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 46.5 | 1.4 | 113.5 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 48.2 | 1.5 | 117.7 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 49.8 | 1.5 | 121.8 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 51.5 | 1.6 | 125.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 51.5 | 0.9 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 53.8 | 0.9 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 56.0 | 1.0 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 56.0 | 1.6 | 30.5 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 57.8 | 1.6 | 30.5 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 59.7 | 1.6 | 30.5 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 61.5 | 1.6 | 30.5 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 61.5 | 1.9 | 125.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 63.8 | 1.9 | 125.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 66.0 | 2.0 | 125.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 66.0 | 2.0 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 67.8 | 2.1 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 69.5 | 2.1 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 71.3 | 2.2 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 73.0 | 2.2 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 74.8 | 2.3 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 76.5 | 2.3 | 125.3 | 0.10 | 0.13 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 76.5 | 1.4 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 78.3 | 1.5 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 80.2 | 1.5 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 82.0 | 1.5 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 83.8 | 1.6 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 85.7 | 1.6 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 87.5 | 1.6 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 87.5 | 1.0 | 108.6 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 89.3 | 1.0 | 108.6 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 91.2 | 1.0 | 108.6 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 93.0 | 1.1 | 108.6 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |

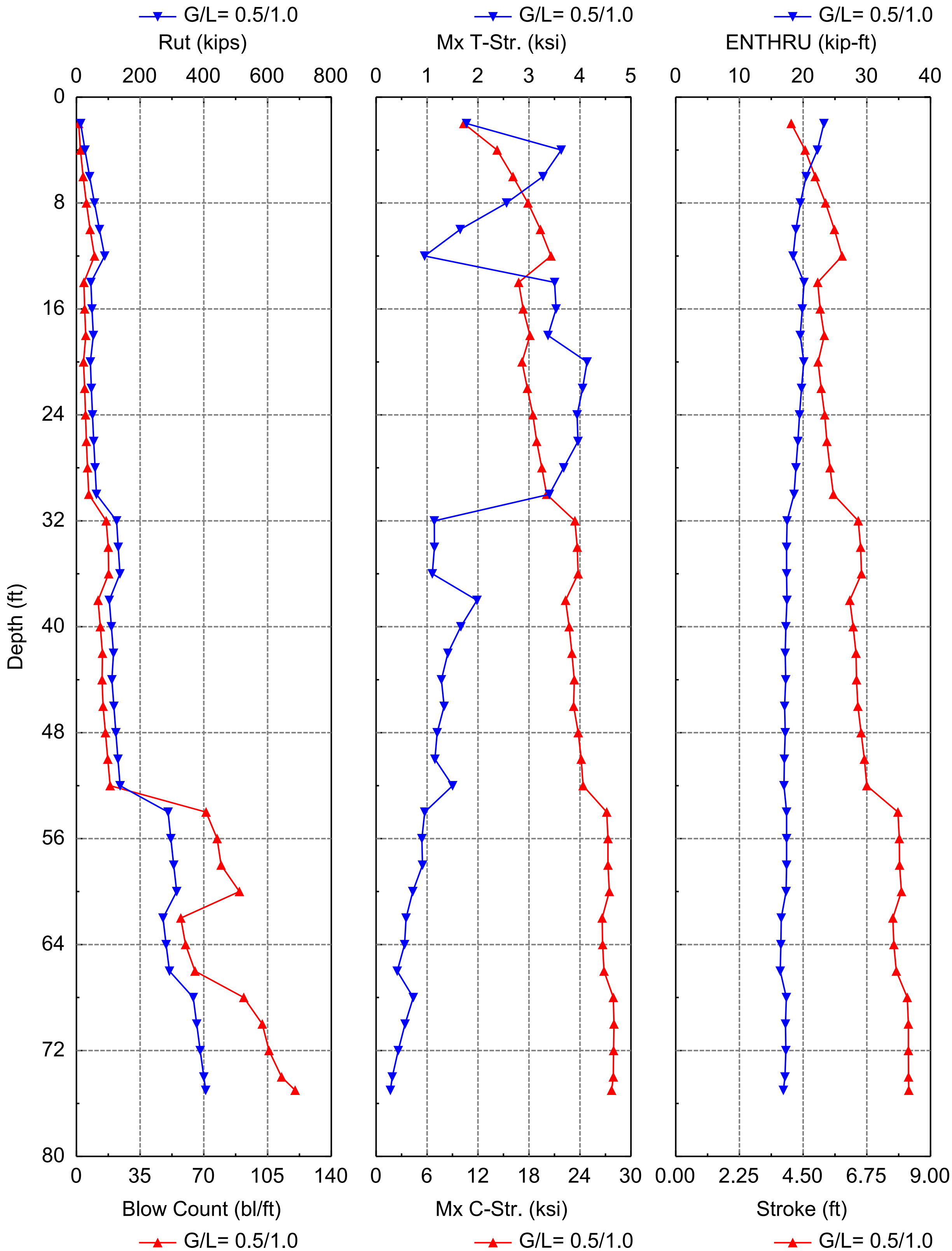
Variable Time Hisotry with DELMAG D 19-42; Depth = 93.00ft; Shaft/Toe G/L = 0.500/1.000



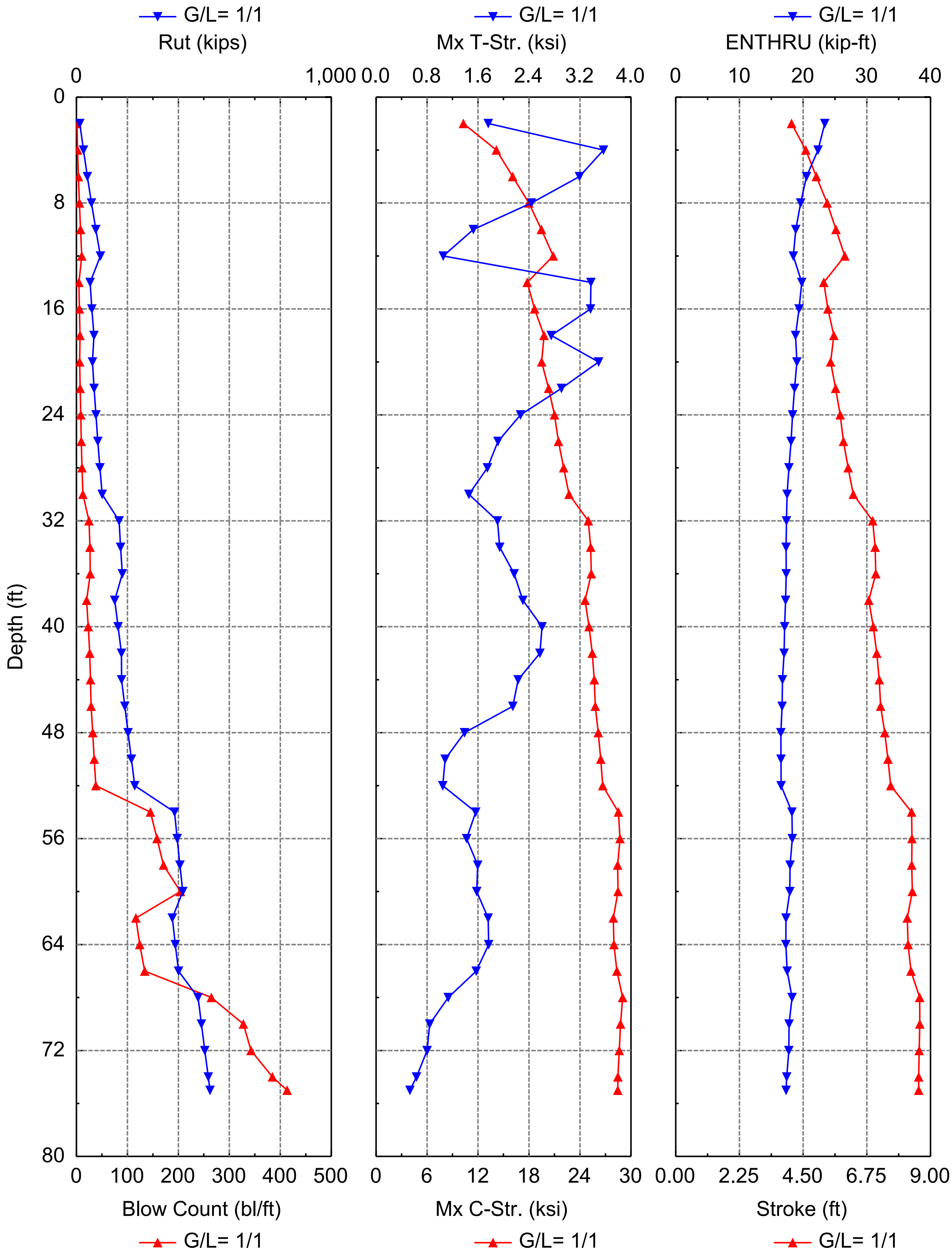
Extrema Results of Gain/Loss at Shaft/Toe = 0.500/1.000 and Depth = 2.00 ft



Driveability Analysis Summary



Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.500/1.000

| Depth | Rut | Rshaft | Rtoe | Blow Ct | Mx C-Str | Mx T-Str. | Stroke | ENTHRU | Hammer |
|---|---|---|---|---|---|---|---|---|---|
| ft | kips | kips | kips | bl/ft | ksi | ksi | ft | kip-ft | - |
| 2.0 | 13.2 | 0.3 | 12.8 | 1.2 | 10.323 | 1.774 | 4.08 | 23.3 | D 19-42 |
| 4.0 | 27.0 | 1.3 | 25.7 | 2.2 | 14.256 | 3.631 | 4.57 | 22.3 | D 19-42 |
| 6.0 | 41.4 | 2.9 | 38.5 | 3.7 | 16.116 | 3.274 | 4.93 | 20.5 | D 19-42 |
| 8.0 | 56.5 | 5.1 | 51.4 | 5.5 | 17.884 | 2.561 | 5.29 | 19.6 | D 19-42 |
| 10.0 | 72.3 | 8.0 | 64.2 | 7.5 | 19.348 | 1.651 | 5.60 | 18.9 | D 19-42 |
| 12.0 | 88.6 | 11.6 | 77.1 | 9.9 | 20.586 | 0.952 | 5.88 | 18.4 | D 19-42 |
| 14.0 | 45.4 | 15.5 | 29.9 | 4.1 | 16.781 | 3.501 | 5.02 | 20.1 | D 19-42 |
| 16.0 | 49.0 | 19.1 | 29.9 | 4.5 | 17.316 | 3.531 | 5.10 | 19.9 | D 19-42 |
| 18.0 | 53.1 | 23.2 | 29.9 | 5.1 | 18.111 | 3.373 | 5.25 | 19.6 | D 19-42 |
| 20.0 | 43.8 | 26.5 | 17.3 | 3.9 | 17.186 | 4.139 | 5.03 | 20.1 | D 19-42 |
| 22.0 | 47.1 | 29.7 | 17.3 | 4.5 | 17.807 | 4.052 | 5.14 | 19.7 | D 19-42 |
| 24.0 | 50.6 | 33.2 | 17.3 | 5.0 | 18.450 | 3.943 | 5.26 | 19.4 | D 19-42 |
| 26.0 | 54.4 | 37.1 | 17.3 | 5.5 | 18.904 | 3.961 | 5.34 | 19.2 | D 19-42 |
| 28.0 | 58.5 | 41.2 | 17.3 | 6.1 | 19.501 | 3.681 | 5.45 | 18.9 | D 19-42 |
| 30.0 | 62.9 | 45.6 | 17.3 | 6.8 | 20.082 | 3.400 | 5.57 | 18.6 | D 19-42 |
| 32.0 | 126.2 | 50.4 | 75.8 | 16.3 | 23.408 | 1.142 | 6.44 | 17.5 | D 19-42 |
| 34.0 | 131.3 | 55.4 | 75.8 | 17.5 | 23.677 | 1.145 | 6.53 | 17.4 | D 19-42 |
| 36.0 | 136.7 | 60.9 | 75.8 | 17.7 | 23.779 | 1.103 | 6.56 | 17.4 | D 19-42 |
| 38.0 | 103.2 | 67.0 | 36.2 | 11.9 | 22.299 | 1.980 | 6.15 | 17.5 | D 19-42 |
| 40.0 | 109.7 | 73.5 | 36.2 | 13.1 | 22.734 | 1.662 | 6.27 | 17.3 | D 19-42 |
| 42.0 | 116.3 | 80.1 | 36.2 | 14.3 | 23.056 | 1.409 | 6.37 | 17.2 | D 19-42 |
| 44.0 | 111.2 | 86.0 | 25.2 | 14.1 | 23.324 | 1.283 | 6.38 | 17.3 | D 19-42 |
| 46.0 | 117.4 | 92.2 | 25.2 | 14.6 | 23.248 | 1.335 | 6.43 | 17.1 | D 19-42 |
| 48.0 | 123.9 | 98.7 | 25.2 | 15.9 | 23.802 | 1.199 | 6.55 | 17.2 | D 19-42 |
| 50.0 | 130.5 | 105.3 | 25.2 | 17.2 | 24.149 | 1.154 | 6.66 | 17.1 | D 19-42 |
| 52.0 | 137.0 | 111.8 | 25.2 | 18.5 | 24.368 | 1.502 | 6.75 | 17.0 | D 19-42 |
| 54.0 | 288.0 | 118.8 | 169.1 | 71.2 | 27.148 | 0.955 | 7.85 | 17.4 | D 19-42 |
| 56.0 | 296.5 | 127.4 | 169.1 | 77.3 | 27.303 | 0.898 | 7.89 | 17.4 | D 19-42 |
| 58.0 | 305.4 | 136.2 | 169.1 | 79.5 | 27.301 | 0.910 | 7.90 | 17.4 | D 19-42 |
| 60.0 | 314.6 | 145.4 | 169.1 | 89.5 | 27.456 | 0.722 | 7.97 | 17.3 | D 19-42 |
| 62.0 | 271.7 | 155.0 | 116.6 | 57.3 | 26.612 | 0.588 | 7.67 | 16.6 | D 19-42 |
| 64.0 | 281.7 | 165.0 | 116.6 | 59.9 | 26.668 | 0.560 | 7.70 | 16.5 | D 19-42 |
| 66.0 | 292.0 | 175.3 | 116.6 | 65.1 | 26.823 | 0.416 | 7.79 | 16.4 | D 19-42 |
| 68.0 | 366.7 | 185.9 | 180.8 | 91.9 | 27.932 | 0.729 | 8.18 | 17.4 | D 19-42 |
| 70.0 | 377.5 | 196.7 | 180.8 | 102.1 | 27.993 | 0.568 | 8.21 | 17.2 | D 19-42 |
| 72.0 | 388.6 | 207.8 | 180.8 | 105.8 | 27.959 | 0.434 | 8.21 | 17.3 | D 19-42 |
| 74.0 | 399.9 | 219.1 | 180.8 | 112.7 | 27.931 | 0.317 | 8.22 | 17.1 | D 19-42 |
| 75.0 | 405.7 | 224.9 | 180.8 | 120.1 | 27.714 | 0.280 | 8.23 | 16.9 | D 19-42 |

Summary_Total driving time: 54 minutes; Total Number of Blows: 2320 (starting at penetration 2.0 ft)

Gain/Loss Factor at Shaft/Toe = 1.000/1.000

| Depth | Rut | Rshaft | Rtoe | Blow Ct | Mx C-Str | Mx T-Str. | Stroke | ENTHRU | Hammer |
|---|---|---|---|---|---|---|---|---|---|
| ft | kips | kips | kips | bl/ft | ksi | ksi | ft | kip-ft | - |
| 2.0 | 13.3 | 0.5 | 12.8 | 1.2 | 10.289 | 1.761 | 4.09 | 23.4 | D 19-42 |
| 4.0 | 27.6 | 1.9 | 25.7 | 2.2 | 14.159 | 3.570 | 4.59 | 22.3 | D 19-42 |
| 6.0 | 42.9 | 4.3 | 38.5 | 3.8 | 16.087 | 3.193 | 4.97 | 20.5 | D 19-42 |
| 8.0 | 59.1 | 7.7 | 51.4 | 5.8 | 17.977 | 2.439 | 5.35 | 19.6 | D 19-42 |
| 10.0 | 76.3 | 12.0 | 64.2 | 8.0 | 19.470 | 1.526 | 5.66 | 18.9 | D 19-42 |
| 12.0 | 94.4 | 17.3 | 77.1 | 10.6 | 20.847 | 1.055 | 5.97 | 18.5 | D 19-42 |
| 14.0 | 53.5 | 23.6 | 29.9 | 5.0 | 17.792 | 3.372 | 5.23 | 19.8 | D 19-42 |
| 16.0 | 60.8 | 30.8 | 29.9 | 5.8 | 18.659 | 3.367 | 5.38 | 19.4 | D 19-42 |
| 18.0 | 69.0 | 39.1 | 29.9 | 7.2 | 19.773 | 2.749 | 5.59 | 18.8 | D 19-42 |
| 20.0 | 63.0 | 45.7 | 17.3 | 6.3 | 19.486 | 3.492 | 5.47 | 19.0 | D 19-42 |
| 22.0 | 69.5 | 52.1 | 17.3 | 7.4 | 20.316 | 2.910 | 5.65 | 18.7 | D 19-42 |
| 24.0 | 76.5 | 59.2 | 17.3 | 8.6 | 21.001 | 2.267 | 5.81 | 18.3 | D 19-42 |
| 26.0 | 84.1 | 66.8 | 17.3 | 9.6 | 21.472 | 1.913 | 5.92 | 18.1 | D 19-42 |
| 28.0 | 92.4 | 75.1 | 17.3 | 11.1 | 22.089 | 1.747 | 6.09 | 17.8 | D 19-42 |
| 30.0 | 101.2 | 83.9 | 17.3 | 12.7 | 22.716 | 1.457 | 6.27 | 17.5 | D 19-42 |
| 32.0 | 167.3 | 91.5 | 75.8 | 24.6 | 24.977 | 1.905 | 6.96 | 17.4 | D 19-42 |
| 34.0 | 173.4 | 97.6 | 75.8 | 26.7 | 25.267 | 1.942 | 7.05 | 17.3 | D 19-42 |
| 36.0 | 179.9 | 104.1 | 75.8 | 27.0 | 25.332 | 2.168 | 7.07 | 17.3 | D 19-42 |
| 38.0 | 150.2 | 114.0 | 36.2 | 20.1 | 24.608 | 2.304 | 6.82 | 17.3 | D 19-42 |
| 40.0 | 163.4 | 127.1 | 36.2 | 23.2 | 25.078 | 2.606 | 6.98 | 17.1 | D 19-42 |
| 42.0 | 176.5 | 140.3 | 36.2 | 26.2 | 25.456 | 2.572 | 7.10 | 17.0 | D 19-42 |
| 44.0 | 177.3 | 152.1 | 25.2 | 27.6 | 25.693 | 2.231 | 7.19 | 16.8 | D 19-42 |
| 46.0 | 189.8 | 164.6 | 25.2 | 28.8 | 25.798 | 2.145 | 7.24 | 16.7 | D 19-42 |
| 48.0 | 202.7 | 177.5 | 25.2 | 31.9 | 26.158 | 1.388 | 7.38 | 16.5 | D 19-42 |
| 50.0 | 215.8 | 190.6 | 25.2 | 34.9 | 26.444 | 1.084 | 7.49 | 16.5 | D 19-42 |
| 52.0 | 228.9 | 203.7 | 25.2 | 38.0 | 26.679 | 1.047 | 7.59 | 16.6 | D 19-42 |
| 54.0 | 385.2 | 216.1 | 169.1 | 145.1 | 28.520 | 1.565 | 8.33 | 18.2 | D 19-42 |
| 56.0 | 395.4 | 226.3 | 169.1 | 158.2 | 28.719 | 1.422 | 8.34 | 18.3 | D 19-42 |
| 58.0 | 406.1 | 237.0 | 169.1 | 170.8 | 28.444 | 1.595 | 8.33 | 17.9 | D 19-42 |
| 60.0 | 417.2 | 248.0 | 169.1 | 204.0 | 28.486 | 1.580 | 8.36 | 17.9 | D 19-42 |
| 62.0 | 376.2 | 259.5 | 116.6 | 116.7 | 27.927 | 1.759 | 8.18 | 17.3 | D 19-42 |
| 64.0 | 388.2 | 271.5 | 116.6 | 124.3 | 28.004 | 1.768 | 8.21 | 17.3 | D 19-42 |
| 66.0 | 400.5 | 283.9 | 116.6 | 134.0 | 28.346 | 1.572 | 8.31 | 17.5 | D 19-42 |
| 68.0 | 477.4 | 296.6 | 180.8 | 264.8 | 29.023 | 1.132 | 8.62 | 18.3 | D 19-42 |
| 70.0 | 490.4 | 309.6 | 180.8 | 327.4 | 28.769 | 0.843 | 8.62 | 17.8 | D 19-42 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 72.0 | 503.6 | 322.8 | 180.8 | 342.7 | 28.623 | 0.800 | 8.60 | 17.7 | D 19-42 |
| 74.0 | 517.3 | 336.5 | 180.8 | 384.7 | 28.471 | 0.635 | 8.58 | 17.4 | D 19-42 |
| 75.0 | 524.2 | 343.4 | 180.8 | 413.3 | 28.452 | 0.532 | 8.58 | 17.3 | D 19-42 |

Summary_Total driving time: 135 minutes; Total Number of Blows: 5586 (starting at penetration 2.0 f

GRLWEAP: Wave Equation Analysis of Pile Foundations

HAM-562-0004 - B-163 - Pier - 16" CIP 6/20/2023
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

## SOIL PROFILE

| Depth ft | Soil Type - | Spec. Wt lb/ft³ | Su ksf | Phi ° | Unit Rs ksf | Unit Rt ksf |
|---|---|---|---|---|---|---|
| 0.0 | Silt | 115.0 | 0.0 | 43.9 | 0.00 | 0.00 |
| 13.5 | Silt | 115.0 | 0.0 | 42.6 | 0.78 | 62.10 |
| 13.5 | Clay | 120.0 | 0.0 | 26.5 | 0.77 | 21.43 |
| 18.5 | Clay | 120.0 | 0.0 | 26.5 | 1.07 | 21.43 |
| 18.5 | Clay | 115.0 | 0.0 | 22.5 | 0.68 | 12.41 |
| 31.0 | Clay | 115.0 | 0.0 | 22.5 | 1.13 | 12.41 |
| 31.0 | Sand | 125.0 | 0.0 | 35.4 | 0.68 | 54.30 |
| 37.0 | Sand | 125.0 | 0.0 | 34.9 | 0.82 | 54.30 |
| 37.0 | Clay | 120.0 | 0.0 | 28.5 | 1.57 | 25.94 |
| 42.0 | Clay | 120.0 | 0.0 | 28.5 | 1.57 | 25.94 |
| 42.0 | Clay | 120.0 | 0.0 | 25.0 | 1.38 | 18.04 |
| 53.5 | Clay | 120.0 | 0.0 | 25.0 | 1.57 | 18.04 |
| 53.5 | Sand | 130.0 | 0.0 | 37.0 | 1.19 | 121.14 |
| 61.5 | Sand | 130.0 | 0.0 | 36.6 | 1.38 | 121.14 |
| 61.5 | Sand | 125.0 | 0.0 | 35.2 | 1.40 | 83.54 |
| 66.5 | Sand | 125.0 | 0.0 | 35.0 | 1.51 | 83.54 |
| 66.5 | Sand | 130.0 | 0.0 | 36.6 | 1.50 | 129.49 |
| 75.0 | Sand | 130.0 | 0.0 | 36.3 | 1.66 | 129.49 |

## PILE INPUT

| | | | |
|---|---|---|---|
| Uniform Pile | | Pile Type: | Pipe |
| Pile Length: (ft) | 75.000 | Pile Penetration: (ft) | 75.000 |
| Pile Size: (ft) | 1.33 | Toe Area: (in²) | 201.06 |

## Pile Profile

| Lb Top ft | X-Area in² | E-Modulus ksi | Spec. Wt lb/ft³ | Perim. ft | Crit. Index - |
|---|---|---|---|---|---|
| 0.0 | 21.4 | 30,000.0 | 492.0 | 4.2 | 0 |
| 75.0 | 21.4 | 30,000.0 | 492.0 | 4.2 | 0 |

## HAMMER INPUT

| | | | |
|---|---|---|---|
| ID | 41 | Made By: | DELMAG |
| Model | D 19-42 | Type: | OED |

## Hammer Data

| ID - | Ram Wt kips | Ram L. in | Ram Ar. in² | Rtd. Stk ft | Effic. - | Rtd. Energy kip-ft |
|---|---|---|---|---|---|---|
| 41 | 4.000 | 129.1 | 124.7 | 10.8 | 0.80 | 43.2 |

DRIVE SYSTEM FOR DELMAG D 19-42-OED

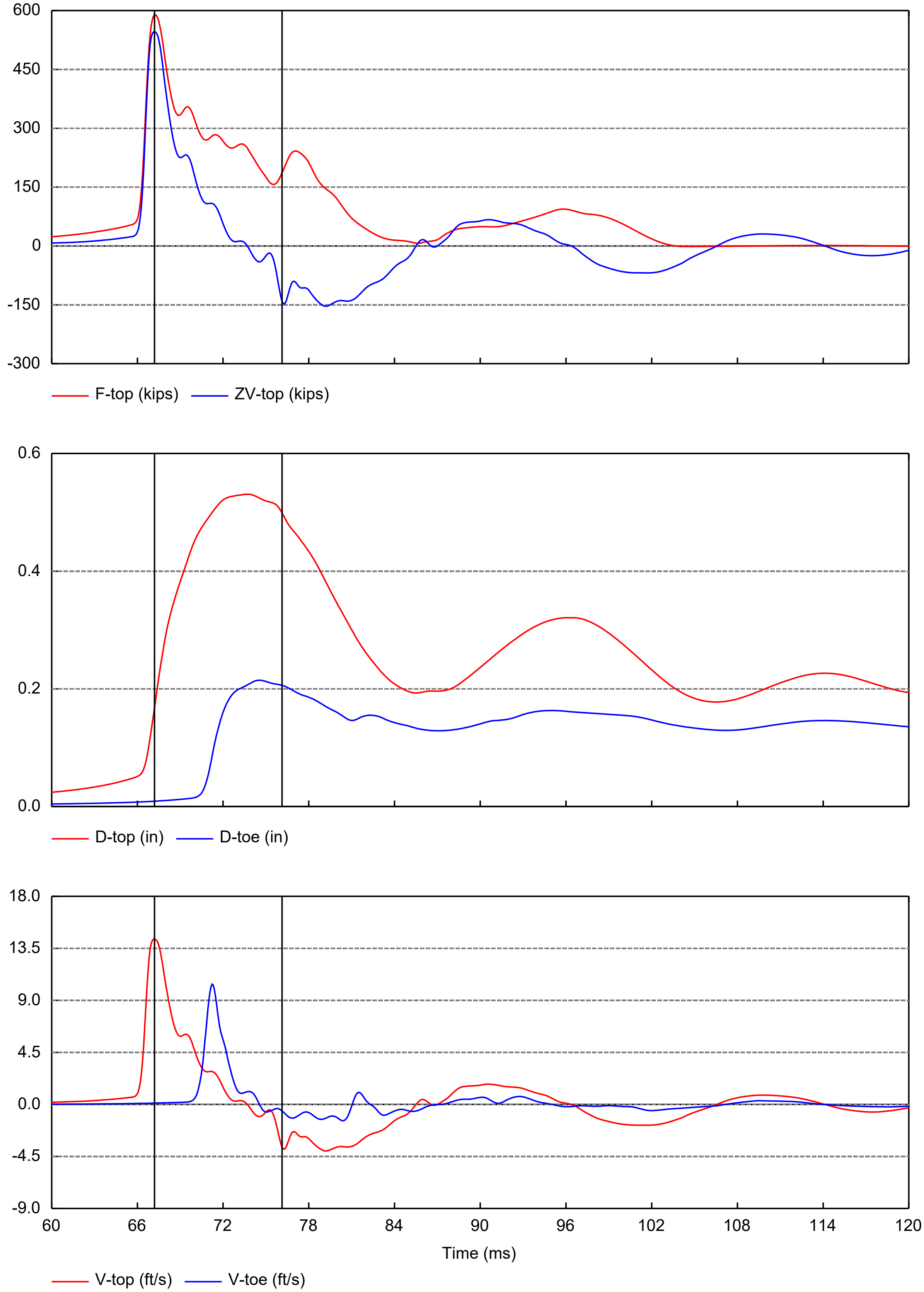
| Type | X-Area | E-Modulus | Thickness | COR | Round-out | Stiffness |
|---|---|---|---|---|---|---|
| - | in² | ksi | in | - | in | kips/in |
| Hammer C. | 227.000 | 530.000 | 2.000 | 0.800 | 0.120 | 60155.563 |
| Helmet Wt. | 1.900 | kips | | | | |

SOIL RESISTANCE DISTRIBUTION

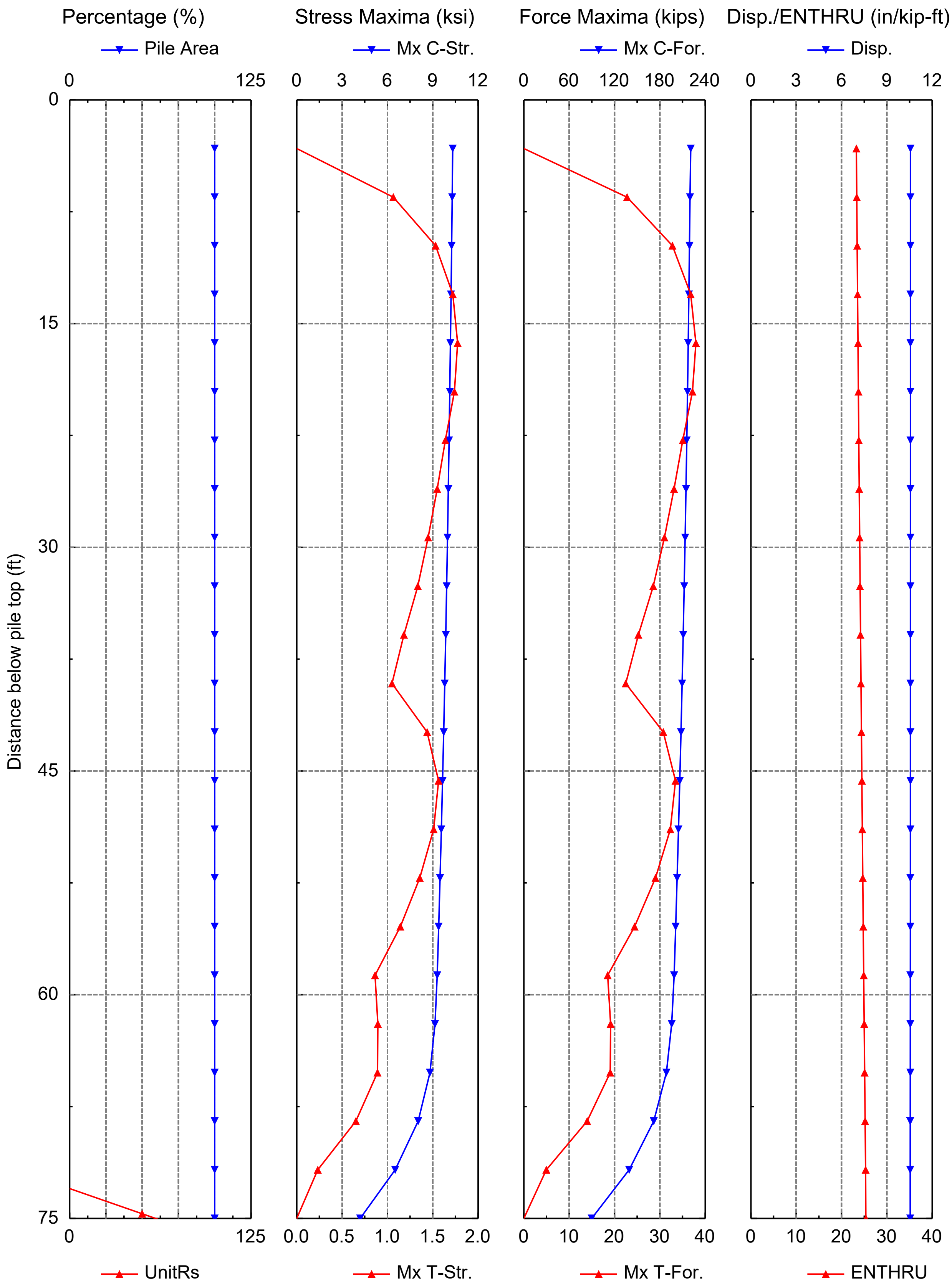
| Depth | Unit Rs | Unit Rt | Qs | Qt | Js | Jt | Set. F. | Limit D. | Set. T. | EB Area |
|---|---|---|---|---|---|---|---|---|---|---|
| ft | ksf | ksf | in | in | s/ft | s/ft | - | ft | Hours | in² |
| 0.0 | 0.0 | 0.0 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 1.7 | 0.1 | 7.8 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 3.4 | 0.2 | 15.5 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 5.1 | 0.3 | 23.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 6.8 | 0.4 | 31.0 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 8.4 | 0.5 | 38.8 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 10.1 | 0.6 | 46.6 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 11.8 | 0.7 | 54.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 13.5 | 0.8 | 62.1 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 13.5 | 0.8 | 21.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 15.2 | 0.9 | 21.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 16.8 | 1.0 | 21.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 18.5 | 1.1 | 21.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 18.5 | 0.7 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 20.3 | 0.7 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 22.1 | 0.8 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 23.9 | 0.9 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 25.6 | 0.9 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 27.4 | 1.0 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 29.2 | 1.1 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 31.0 | 1.1 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 31.0 | 0.7 | 54.3 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 33.0 | 0.7 | 54.3 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 35.0 | 0.8 | 54.3 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 37.0 | 0.8 | 54.3 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 37.0 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 38.7 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 40.3 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 42.0 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 42.0 | 1.4 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 43.6 | 1.4 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 45.3 | 1.5 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 46.9 | 1.5 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 48.6 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 50.2 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 51.9 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 53.5 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 53.5 | 1.2 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 55.5 | 1.2 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 57.5 | 1.3 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 59.5 | 1.3 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 61.5 | 1.4 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 61.5 | 1.4 | 83.5 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 63.2 | 1.4 | 83.5 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 64.8 | 1.5 | 83.5 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 66.5 | 1.5 | 83.5 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 66.5 | 1.5 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 68.2 | 1.5 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 69.9 | 1.6 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 71.6 | 1.6 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 73.3 | 1.6 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 75.0 | 1.7 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |

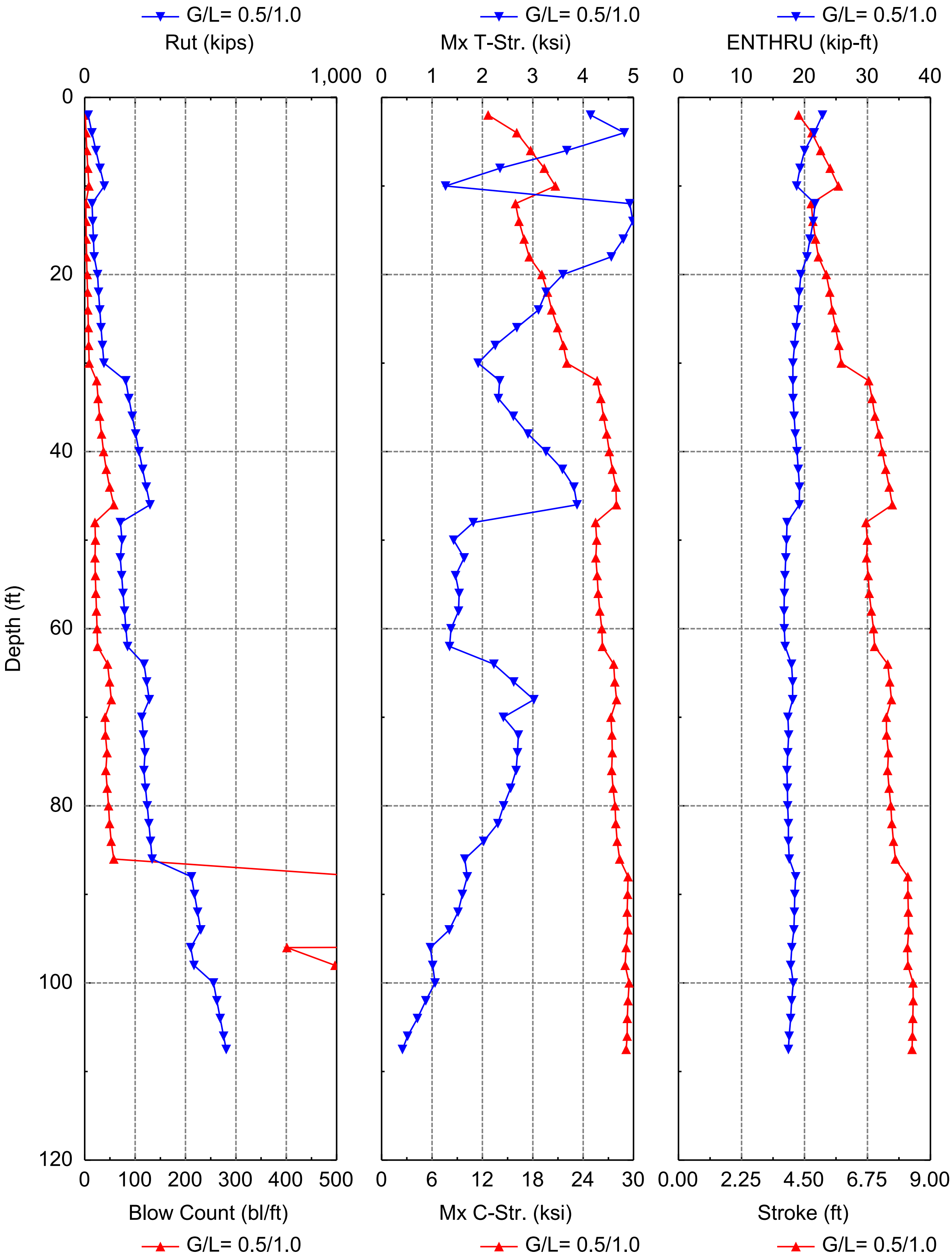
Variable Time Hisotry with DELMAG D 19-42; Depth = 75.00ft; Shaft/Toe G/L = 0.500/1.000



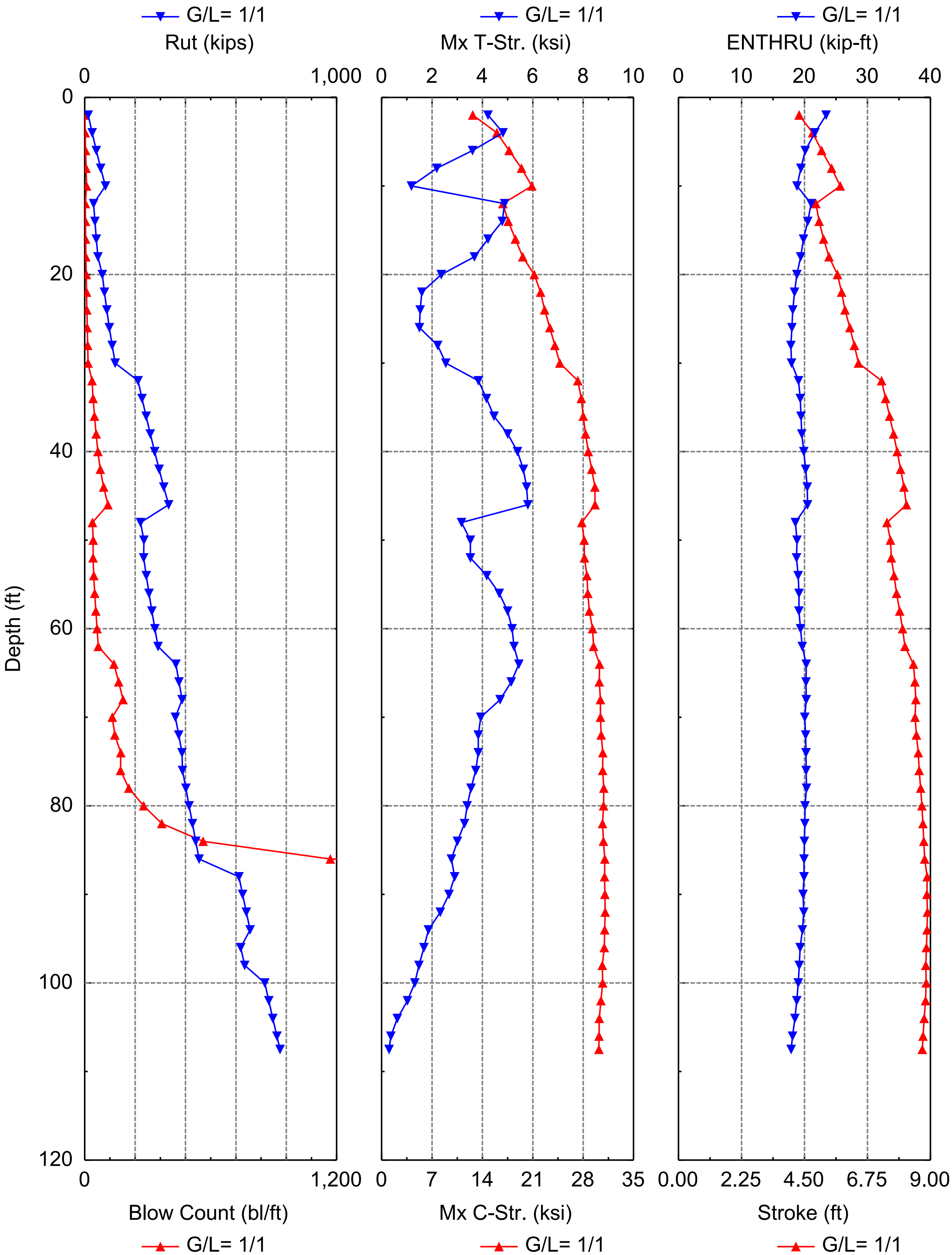
Extrema Results of Gain/Loss at Shaft/Toe = 0.500/1.000 and Depth = 2.00 ft



## Driveability Analysis Summary



Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.500/1.000

| Depth | Rut | Rshaft | Rtoe | Blow Ct | Mx C-Str | Mx T-Str. | Stroke | ENTHRU | Hammer |
|---|---|---|---|---|---|---|---|---|---|
| ft | kips | kips | kips | bl/ft | ksi | ksi | ft | kip-ft | - |
| 2.0 | 13.7 | 0.3 | 13.4 | 1.2 | 12.684 | 4.147 | 4.29 | 22.9 | D 19-42 |
| 4.0 | 28.7 | 1.3 | 27.4 | 2.3 | 16.091 | 4.815 | 4.77 | 21.5 | D 19-42 |
| 6.0 | 44.4 | 3.0 | 41.3 | 4.0 | 17.735 | 3.674 | 5.08 | 20.0 | D 19-42 |
| 8.0 | 60.7 | 5.5 | 55.3 | 6.0 | 19.353 | 2.349 | 5.42 | 19.3 | D 19-42 |
| 10.0 | 77.8 | 8.6 | 69.3 | 8.2 | 20.688 | 1.269 | 5.71 | 18.8 | D 19-42 |
| 12.0 | 28.8 | 11.5 | 17.3 | 2.2 | 15.938 | 4.925 | 4.74 | 21.7 | D 19-42 |
| 14.0 | 31.4 | 14.0 | 17.3 | 2.5 | 16.357 | 4.986 | 4.80 | 21.4 | D 19-42 |
| 16.0 | 34.3 | 16.9 | 17.3 | 2.9 | 16.969 | 4.795 | 4.89 | 20.9 | D 19-42 |
| 18.0 | 37.5 | 20.2 | 17.3 | 3.3 | 17.574 | 4.557 | 5.00 | 20.4 | D 19-42 |
| 20.0 | 50.7 | 24.0 | 26.8 | 4.9 | 19.069 | 3.597 | 5.28 | 19.4 | D 19-42 |
| 22.0 | 55.0 | 28.2 | 26.8 | 5.6 | 19.750 | 3.264 | 5.40 | 19.2 | D 19-42 |
| 24.0 | 59.7 | 32.9 | 26.8 | 6.1 | 20.257 | 3.113 | 5.49 | 19.0 | D 19-42 |
| 26.0 | 64.8 | 38.0 | 26.8 | 7.0 | 20.949 | 2.683 | 5.61 | 18.7 | D 19-42 |
| 28.0 | 70.3 | 43.5 | 26.8 | 7.9 | 21.630 | 2.255 | 5.73 | 18.4 | D 19-42 |
| 30.0 | 76.2 | 49.5 | 26.8 | 8.7 | 22.048 | 1.916 | 5.81 | 18.1 | D 19-42 |
| 32.0 | 162.8 | 55.4 | 107.4 | 23.8 | 25.665 | 2.342 | 6.79 | 18.1 | D 19-42 |
| 34.0 | 175.5 | 61.4 | 114.1 | 26.5 | 26.089 | 2.318 | 6.91 | 18.2 | D 19-42 |
| 36.0 | 188.5 | 67.7 | 120.8 | 29.4 | 26.403 | 2.615 | 7.02 | 18.4 | D 19-42 |
| 38.0 | 201.9 | 74.4 | 127.5 | 33.3 | 26.799 | 2.905 | 7.16 | 18.5 | D 19-42 |
| 40.0 | 215.7 | 81.5 | 134.2 | 37.4 | 27.112 | 3.261 | 7.27 | 18.8 | D 19-42 |
| 42.0 | 229.8 | 88.9 | 140.9 | 42.9 | 27.480 | 3.587 | 7.40 | 19.0 | D 19-42 |
| 44.0 | 244.3 | 96.7 | 147.6 | 49.5 | 27.897 | 3.816 | 7.53 | 19.2 | D 19-42 |
| 46.0 | 259.2 | 104.9 | 154.3 | 57.7 | 27.961 | 3.880 | 7.64 | 19.2 | D 19-42 |
| 48.0 | 141.4 | 111.4 | 29.9 | 20.2 | 25.467 | 1.819 | 6.69 | 17.2 | D 19-42 |
| 50.0 | 147.9 | 118.0 | 29.9 | 21.2 | 25.599 | 1.429 | 6.75 | 17.1 | D 19-42 |
| 52.0 | 141.2 | 123.9 | 17.3 | 20.1 | 25.507 | 1.637 | 6.72 | 17.0 | D 19-42 |
| 54.0 | 146.5 | 129.2 | 17.3 | 21.1 | 25.672 | 1.465 | 6.78 | 16.9 | D 19-42 |
| 56.0 | 152.0 | 134.7 | 17.3 | 22.0 | 25.781 | 1.539 | 6.81 | 16.8 | D 19-42 |
| 58.0 | 157.7 | 140.4 | 17.3 | 23.1 | 25.973 | 1.527 | 6.89 | 16.8 | D 19-42 |
| 60.0 | 163.6 | 146.3 | 17.3 | 24.4 | 26.209 | 1.378 | 6.96 | 16.8 | D 19-42 |
| 62.0 | 169.7 | 152.3 | 17.3 | 25.5 | 26.293 | 1.346 | 7.00 | 16.9 | D 19-42 |
| 64.0 | 235.4 | 159.6 | 75.8 | 45.3 | 27.631 | 2.228 | 7.47 | 17.9 | D 19-42 |
| 66.0 | 245.6 | 169.8 | 75.8 | 49.2 | 27.766 | 2.621 | 7.54 | 18.1 | D 19-42 |
| 68.0 | 256.1 | 180.3 | 75.8 | 52.8 | 27.977 | 3.020 | 7.60 | 18.1 | D 19-42 |
| 70.0 | 226.2 | 189.9 | 36.2 | 40.4 | 27.295 | 2.417 | 7.42 | 17.4 | D 19-42 |
| 72.0 | 232.7 | 196.5 | 36.2 | 41.0 | 27.422 | 2.714 | 7.43 | 17.5 | D 19-42 |
| 74.0 | 239.3 | 203.1 | 36.2 | 44.3 | 27.463 | 2.697 | 7.50 | 17.3 | D 19-42 |
| 76.0 | 234.8 | 209.6 | 25.2 | 41.8 | 27.388 | 2.669 | 7.47 | 17.2 | D 19-42 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 78.0 | 241.4 | 216.2 | 25.2 | 44.5 | 27.556 | 2.560 | 7.52 | 17.3 | D 19-42 |
| 80.0 | 247.9 | 222.7 | 25.2 | 47.2 | 27.789 | 2.421 | 7.58 | 17.3 | D 19-42 |
| 82.0 | 254.5 | 229.3 | 25.2 | 49.3 | 27.875 | 2.308 | 7.62 | 17.4 | D 19-42 |
| 84.0 | 261.1 | 235.9 | 25.2 | 52.5 | 28.049 | 2.024 | 7.68 | 17.4 | D 19-42 |
| 86.0 | 267.6 | 242.4 | 25.2 | 57.6 | 28.338 | 1.650 | 7.75 | 17.6 | D 19-42 |
| 88.0 | 423.5 | 254.4 | 169.1 | 563.5 | 29.340 | 1.699 | 8.19 | 18.6 | D 19-42 |
| 90.0 | 435.7 | 266.5 | 169.1 | 756.1 | 29.297 | 1.604 | 8.19 | 18.5 | D 19-42 |
| 92.0 | 448.0 | 278.9 | 169.1 | 1359.3 | 29.234 | 1.516 | 8.21 | 18.4 | D 19-42 |
| 94.0 | 460.5 | 291.4 | 169.1 | 9999.0 | 29.324 | 1.343 | 8.22 | 18.3 | D 19-42 |
| 96.0 | 420.8 | 304.1 | 116.6 | 401.2 | 29.123 | 0.968 | 8.18 | 18.0 | D 19-42 |
| 98.0 | 433.7 | 317.1 | 116.6 | 496.6 | 28.997 | 1.014 | 8.19 | 17.8 | D 19-42 |
| 100.0 | 511.0 | 330.1 | 180.8 | 9999.0 | 29.474 | 1.061 | 8.38 | 18.2 | D 19-42 |
| 102.0 | 524.1 | 343.3 | 180.8 | 9999.0 | 29.340 | 0.877 | 8.38 | 18.0 | D 19-42 |
| 104.0 | 537.5 | 356.7 | 180.8 | 9999.0 | 29.254 | 0.711 | 8.37 | 17.8 | D 19-42 |
| 106.0 | 551.0 | 370.2 | 180.8 | 9999.0 | 29.228 | 0.514 | 8.36 | 17.6 | D 19-42 |
| 107.5 | 561.3 | 380.5 | 180.8 | 9999.0 | 29.109 | 0.414 | 8.34 | 17.4 | D 19-42 |

Summary_Refusal occurred; no driving time output possible.

Gain/Loss Factor at Shaft/Toe = 1.000/1.000

| Depth | Rut | Rshaft | Rtoe | Blow Ct | Mx C-Str | Mx T-Str. | Stroke | ENTHRU | Hammer |
|---|---|---|---|---|---|---|---|---|---|
| ft | kips | kips | kips | bl/ft | ksi | ksi | ft | kip-ft | - |
| 2.0 | 13.9 | 0.5 | 13.4 | 1.2 | 12.660 | 4.224 | 4.31 | 23.4 | D 19-42 |
| 4.0 | 29.4 | 2.0 | 27.4 | 2.4 | 16.002 | 4.815 | 4.79 | 21.7 | D 19-42 |
| 6.0 | 45.9 | 4.6 | 41.3 | 4.2 | 17.708 | 3.609 | 5.11 | 20.1 | D 19-42 |
| 8.0 | 63.5 | 8.2 | 55.3 | 6.2 | 19.420 | 2.190 | 5.47 | 19.4 | D 19-42 |
| 10.0 | 82.1 | 12.9 | 69.3 | 8.7 | 20.860 | 1.185 | 5.77 | 18.8 | D 19-42 |
| 12.0 | 35.2 | 17.9 | 17.3 | 2.9 | 16.844 | 4.881 | 4.91 | 21.0 | D 19-42 |
| 14.0 | 40.2 | 22.9 | 17.3 | 3.4 | 17.586 | 4.788 | 5.02 | 20.5 | D 19-42 |
| 16.0 | 46.0 | 28.7 | 17.3 | 4.2 | 18.570 | 4.221 | 5.18 | 19.8 | D 19-42 |
| 18.0 | 52.6 | 35.2 | 17.3 | 5.2 | 19.601 | 3.683 | 5.38 | 19.4 | D 19-42 |
| 20.0 | 69.5 | 42.8 | 26.8 | 7.5 | 21.190 | 2.369 | 5.68 | 18.8 | D 19-42 |
| 22.0 | 78.1 | 51.3 | 26.8 | 8.8 | 22.090 | 1.596 | 5.82 | 18.4 | D 19-42 |
| 24.0 | 87.5 | 60.7 | 26.8 | 10.1 | 22.643 | 1.528 | 5.95 | 18.1 | D 19-42 |
| 26.0 | 97.7 | 70.9 | 26.8 | 11.9 | 23.371 | 1.499 | 6.12 | 18.0 | D 19-42 |
| 28.0 | 108.7 | 81.9 | 26.8 | 14.0 | 24.058 | 2.224 | 6.28 | 17.8 | D 19-42 |
| 30.0 | 120.5 | 93.7 | 26.8 | 15.9 | 24.750 | 2.546 | 6.43 | 17.9 | D 19-42 |
| 32.0 | 211.6 | 104.2 | 107.4 | 34.6 | 27.252 | 3.842 | 7.25 | 19.1 | D 19-42 |
| 34.0 | 227.3 | 113.2 | 114.1 | 39.8 | 27.736 | 4.161 | 7.40 | 19.3 | D 19-42 |
| 36.0 | 243.5 | 122.7 | 120.8 | 46.2 | 27.993 | 4.460 | 7.54 | 19.5 | D 19-42 |
| 38.0 | 260.3 | 132.8 | 127.5 | 54.6 | 28.322 | 5.004 | 7.68 | 19.6 | D 19-42 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 40.0 | 277.6 | 143.4 | 134.2 | 62.8 | 28.718 | 5.391 | 7.81 | 19.9 | D 19-42 |
| 42.0 | 295.4 | 154.5 | 140.9 | 74.4 | 29.183 | 5.625 | 7.93 | 20.2 | D 19-42 |
| 44.0 | 313.8 | 166.2 | 147.6 | 90.2 | 29.632 | 5.753 | 8.05 | 20.4 | D 19-42 |
| 46.0 | 332.7 | 178.4 | 154.3 | 110.5 | 29.655 | 5.801 | 8.14 | 20.5 | D 19-42 |
| 48.0 | 221.5 | 191.5 | 29.9 | 36.4 | 27.809 | 3.169 | 7.44 | 18.6 | D 19-42 |
| 50.0 | 234.6 | 204.7 | 29.9 | 40.1 | 28.133 | 3.521 | 7.57 | 18.8 | D 19-42 |
| 52.0 | 233.7 | 216.4 | 17.3 | 39.8 | 28.170 | 3.525 | 7.60 | 18.7 | D 19-42 |
| 54.0 | 244.3 | 227.0 | 17.3 | 43.3 | 28.516 | 4.170 | 7.70 | 19.0 | D 19-42 |
| 56.0 | 255.4 | 238.0 | 17.3 | 47.2 | 28.649 | 4.670 | 7.79 | 19.1 | D 19-42 |
| 58.0 | 266.8 | 249.4 | 17.3 | 52.8 | 28.845 | 5.001 | 7.90 | 19.1 | D 19-42 |
| 60.0 | 278.5 | 261.2 | 17.3 | 58.7 | 29.297 | 5.178 | 8.00 | 19.4 | D 19-42 |
| 62.0 | 290.7 | 273.4 | 17.3 | 64.7 | 29.446 | 5.252 | 8.09 | 19.6 | D 19-42 |
| 64.0 | 361.6 | 285.8 | 75.8 | 138.9 | 30.275 | 5.445 | 8.39 | 20.3 | D 19-42 |
| 66.0 | 373.9 | 298.1 | 75.8 | 161.6 | 30.231 | 5.144 | 8.45 | 20.2 | D 19-42 |
| 68.0 | 386.5 | 310.7 | 75.8 | 182.2 | 30.390 | 4.704 | 8.47 | 20.3 | D 19-42 |
| 70.0 | 359.8 | 323.6 | 36.2 | 131.0 | 30.390 | 3.935 | 8.45 | 20.0 | D 19-42 |
| 72.0 | 372.9 | 336.7 | 36.2 | 143.1 | 30.498 | 3.834 | 8.50 | 20.2 | D 19-42 |
| 74.0 | 386.0 | 349.8 | 36.2 | 171.5 | 30.719 | 3.835 | 8.56 | 20.2 | D 19-42 |
| 76.0 | 388.1 | 362.9 | 25.2 | 170.3 | 30.706 | 3.736 | 8.60 | 20.3 | D 19-42 |
| 78.0 | 401.2 | 376.0 | 25.2 | 209.6 | 30.863 | 3.546 | 8.65 | 20.3 | D 19-42 |
| 80.0 | 414.4 | 389.2 | 25.2 | 280.4 | 30.826 | 3.395 | 8.69 | 20.1 | D 19-42 |
| 82.0 | 427.5 | 402.3 | 25.2 | 366.6 | 30.696 | 3.291 | 8.73 | 20.1 | D 19-42 |
| 84.0 | 440.6 | 415.4 | 25.2 | 563.6 | 30.810 | 3.005 | 8.76 | 20.0 | D 19-42 |
| 86.0 | 453.7 | 428.5 | 25.2 | 1170.2 | 30.996 | 2.769 | 8.79 | 19.9 | D 19-42 |
| 88.0 | 612.0 | 442.9 | 169.1 | 9999.0 | 30.973 | 2.899 | 8.88 | 19.9 | D 19-42 |
| 90.0 | 626.6 | 457.5 | 169.1 | 9999.0 | 31.019 | 2.676 | 8.87 | 19.8 | D 19-42 |
| 92.0 | 641.4 | 472.3 | 169.1 | 9999.0 | 31.052 | 2.330 | 8.89 | 19.9 | D 19-42 |
| 94.0 | 656.4 | 487.3 | 169.1 | 9999.0 | 30.985 | 1.858 | 8.88 | 19.7 | D 19-42 |
| 96.0 | 619.2 | 502.6 | 116.6 | 9999.0 | 30.937 | 1.679 | 8.86 | 19.3 | D 19-42 |
| 98.0 | 634.8 | 518.1 | 116.6 | 9999.0 | 30.652 | 1.478 | 8.83 | 19.2 | D 19-42 |
| 100.0 | 714.6 | 533.8 | 180.8 | 9999.0 | 30.708 | 1.314 | 8.85 | 19.0 | D 19-42 |
| 102.0 | 730.4 | 549.6 | 180.8 | 9999.0 | 30.462 | 1.023 | 8.82 | 18.8 | D 19-42 |
| 104.0 | 746.4 | 565.6 | 180.8 | 9999.0 | 30.231 | 0.622 | 8.77 | 18.5 | D 19-42 |
| 106.0 | 762.7 | 581.9 | 180.8 | 9999.0 | 30.210 | 0.362 | 8.73 | 18.1 | D 19-42 |
| 107.5 | 775.0 | 594.2 | 180.8 | 9999.0 | 30.178 | 0.296 | 8.71 | 17.9 | D 19-42 |

Summary_Refusal occurred; no driving time output possible.

GRLWEAP: Wave Equation Analysis of Pile Foundations

HAM-562-0004 - B-163 - Abut - 16" CIP 6/20/2023
RESOURCE INTERNATIONAL INC GRLWEAP 14.1.15.0

## ABOUT THE WAVE EQUATION ANALYSIS RESULTS

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

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

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

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

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

SOIL PROFILE

| Depth<br>ft | Soil Type<br>- | Spec. Wt<br>lb/ft³ | Su<br>ksf | Phi<br>° | Unit Rs<br>ksf | Unit Rt<br>ksf |
|---|---|---|---|---|---|---|
| 0.0 | Clay | 115.0 | 0.0 | 22.5 | 0.00 | 12.41 |
| 1.0 | Clay | 115.0 | 0.0 | 22.5 | 0.05 | 12.41 |
| 1.0 | Silt | 125.0 | 0.0 | 44.9 | 0.06 | 4.60 |
| 11.0 | Silt | 125.0 | 0.0 | 43.6 | 0.68 | 54.60 |
| 11.0 | Clay | 115.0 | 0.0 | 22.5 | 0.52 | 12.41 |
| 19.0 | Clay | 115.0 | 0.0 | 22.5 | 0.87 | 12.41 |
| 19.0 | Clay | 120.0 | 0.0 | 25.5 | 0.93 | 19.17 |
| 31.0 | Clay | 120.0 | 0.0 | 25.5 | 1.51 | 19.17 |
| 31.0 | Silt | 120.0 | 0.0 | 22.0 | 1.01 | 74.50 |
| 46.0 | Silt | 120.0 | 0.0 | 22.0 | 1.49 | 110.50 |
| 46.0 | Clay | 120.0 | 0.0 | 26.5 | 1.57 | 21.43 |
| 51.0 | Clay | 120.0 | 0.0 | 26.5 | 1.57 | 21.43 |
| 51.0 | Clay | 115.0 | 0.0 | 22.5 | 1.22 | 12.41 |
| 63.5 | Clay | 115.0 | 0.0 | 22.5 | 1.51 | 12.41 |
| 63.5 | Sand | 120.0 | 0.0 | 33.6 | 1.44 | 54.30 |
| 69.5 | Sand | 120.0 | 0.0 | 33.5 | 1.54 | 54.30 |
| 69.5 | Clay | 120.0 | 0.0 | 28.5 | 1.57 | 25.94 |
| 74.5 | Clay | 120.0 | 0.0 | 28.5 | 1.57 | 25.94 |
| 74.5 | Clay | 120.0 | 0.0 | 25.0 | 1.57 | 18.04 |
| 86.0 | Clay | 120.0 | 0.0 | 25.0 | 1.57 | 18.04 |
| 86.0 | Sand | 130.0 | 0.0 | 36.0 | 1.70 | 121.14 |
| 94.0 | Sand | 130.0 | 0.0 | 35.8 | 1.80 | 121.14 |
| 94.0 | Sand | 125.0 | 0.0 | 34.4 | 1.82 | 83.54 |
| 99.0 | Sand | 125.0 | 0.0 | 34.3 | 1.88 | 83.54 |
| 99.0 | Sand | 130.0 | 0.0 | 36.0 | 1.86 | 129.49 |
| 107.5 | Sand | 130.0 | 0.0 | 35.8 | 1.97 | 129.49 |

PILE INPUT

| | | | |
|---|---|---|---|
| Uniform Pile | | Pile Type: | Pipe |
| Pile Length: (ft) | 107.500 | Pile Penetration: (ft) | 107.500 |
| Pile Size: (ft) | 1.33 | Toe Area: (in²) | 201.06 |

Pile Profile

| Lb Top<br>ft | X-Area<br>in² | E-Modulus<br>ksi | Spec. Wt<br>lb/ft³ | Perim.<br>ft | Crit. Index<br>- |
|---|---|---|---|---|---|
| 0.0 | 18.4 | 30,000.0 | 492.0 | 4.2 | 0 |
| 107.5 | 18.4 | 30,000.0 | 492.0 | 4.2 | 0 |

HAMMER INPUT

| | | | |
|---|---|---|---|
| ID | 41 | Made By: | DELMAG |
| Model | D 19-42 | Type: | OED |

Hammer Data

| ID | Ram Wt | Ram L. | Ram Ar. | Rtd. Stk | Effic. | Rtd. Energy |
|---|---|---|---|---|---|---|
| - | kips | in | in² | ft | - | kip-ft |
| 41 | 4.000 | 129.1 | 124.7 | 10.8 | 0.80 | 43.2 |

DRIVE SYSTEM FOR DELMAG D 19-42-OED

| Type | X-Area | E-Modulus | Thickness | COR | Round-out | Stiffness |
|---|---|---|---|---|---|---|
| - | in² | ksi | in | - | in | kips/in |
| Hammer C. | 227.000 | 530.000 | 2.000 | 0.800 | 0.120 | 60155.563 |
| Helmet Wt. | 1.900 | kips | | | | |

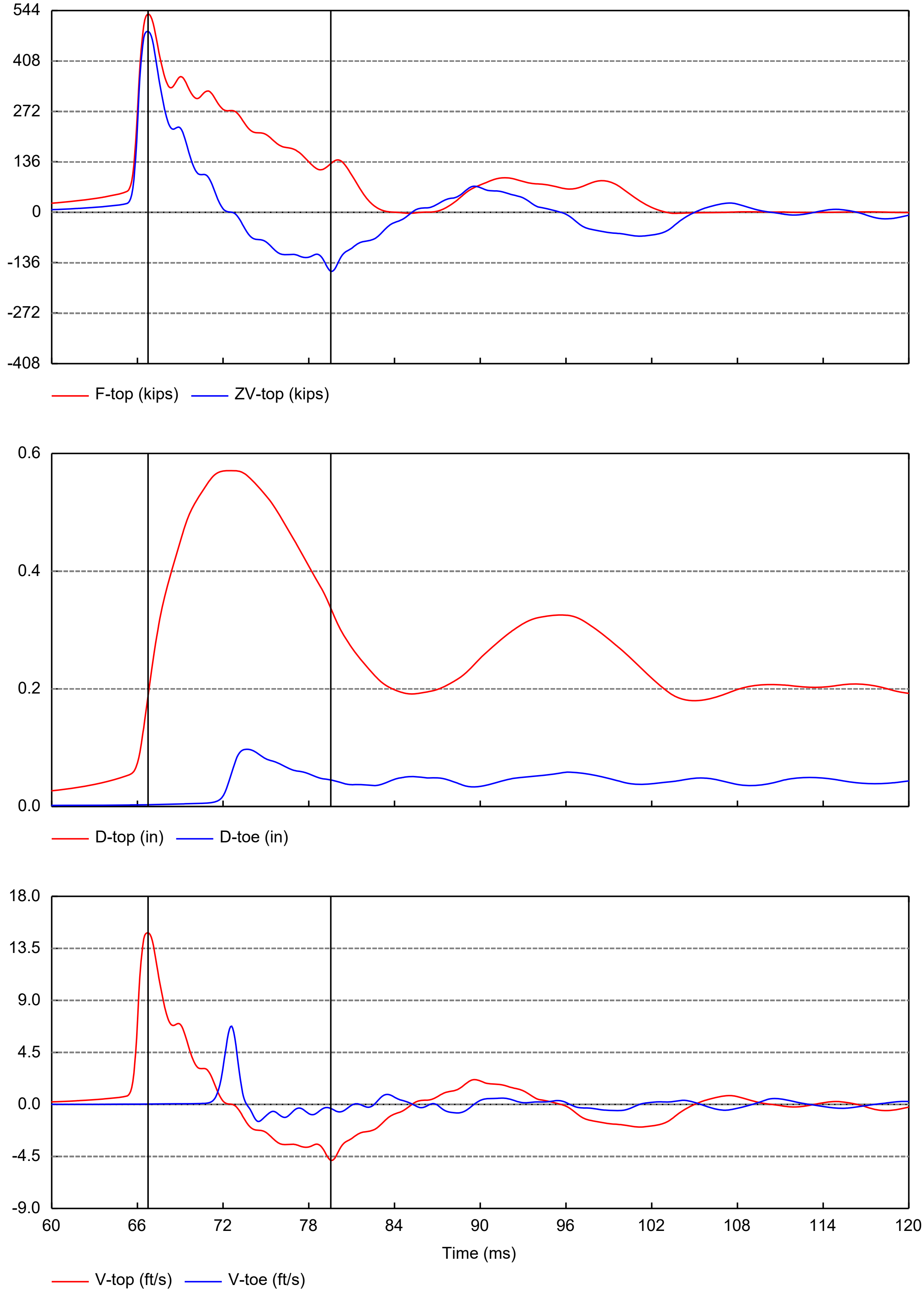
SOIL RESISTANCE DISTRIBUTION

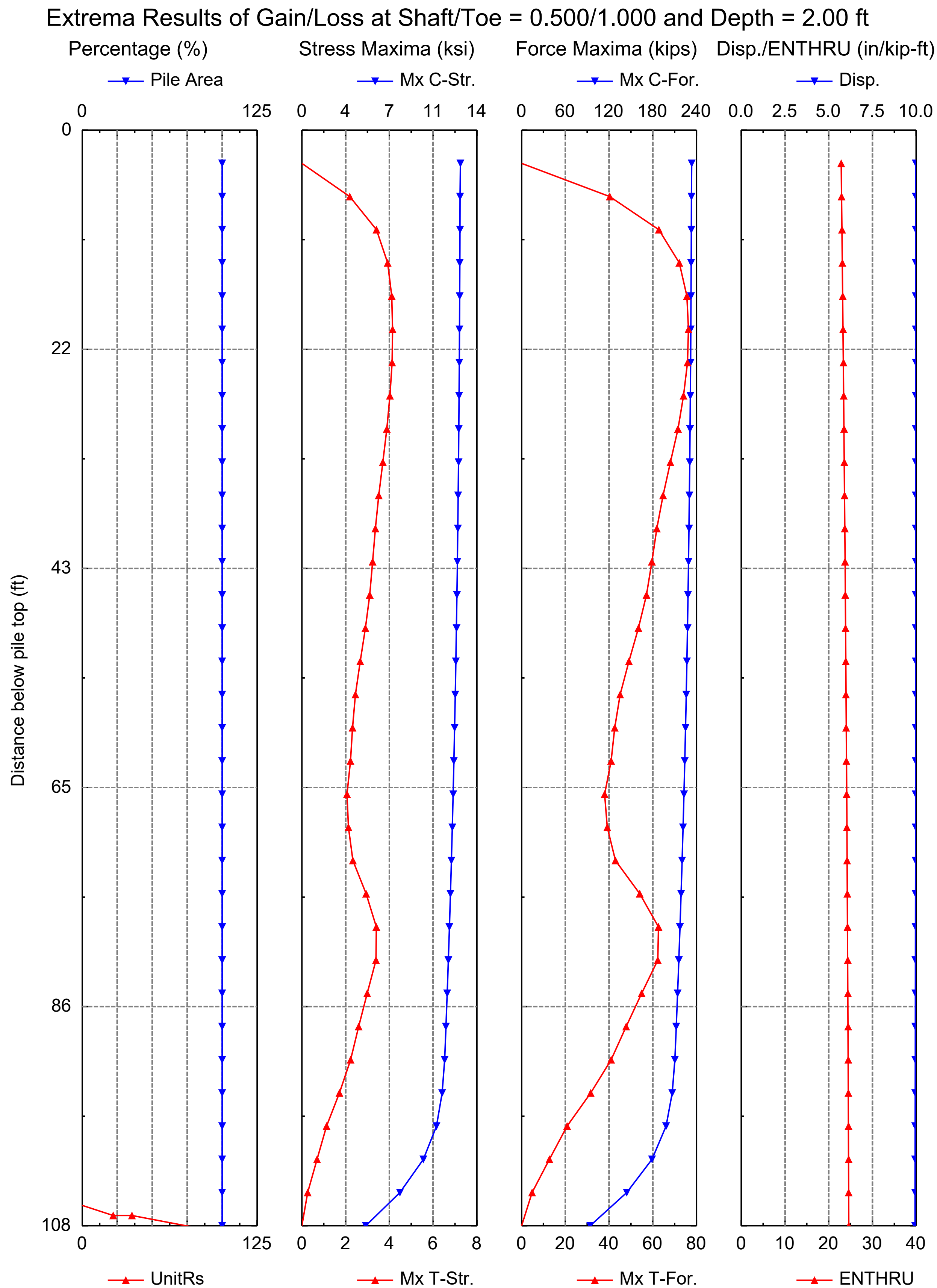
| Depth | Unit Rs | Unit Rt | Qs | Qt | Js | Jt | Set. F. | Limit D. | Set. T. | EB Area |
|---|---|---|---|---|---|---|---|---|---|---|
| ft | ksf | ksf | in | in | s/ft | s/ft | - | ft | Hours | in² |
| 0.0 | 0.0 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 1.0 | 0.0 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 1.0 | 0.1 | 4.6 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 2.7 | 0.2 | 12.9 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 4.3 | 0.3 | 21.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 6.0 | 0.4 | 29.6 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 7.7 | 0.5 | 37.9 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 9.3 | 0.6 | 46.3 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 11.0 | 0.7 | 54.6 | 0.10 | 0.27 | 0.10 | 0.15 | 1.5 | 6.6 | 24.0 | 201.1 |
| 11.0 | 0.5 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 13.0 | 0.6 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 15.0 | 0.7 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 17.0 | 0.8 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 19.0 | 0.9 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 19.0 | 0.9 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 20.7 | 1.0 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 22.4 | 1.1 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 24.1 | 1.2 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 25.9 | 1.3 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 27.6 | 1.3 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 29.3 | 1.4 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 31.0 | 1.5 | 19.2 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 31.0 | 1.0 | 74.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 32.7 | 1.1 | 78.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |
| 34.3 | 1.1 | 82.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |
| 36.0 | 1.2 | 86.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |
| 37.7 | 1.2 | 90.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |
| 39.3 | 1.3 | 94.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |
| 41.0 | 1.3 | 98.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |
| 42.7 | 1.4 | 102.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |
| 44.3 | 1.4 | 106.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |
| 46.0 | 1.5 | 110.5 | 0.10 | 0.27 | 0.20 | 0.15 | 1.5 | 6.6 | 84.0 | 201.1 |
| 46.0 | 1.6 | 21.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 47.7 | 1.6 | 21.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 49.3 | 1.6 | 21.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 51.0 | 1.6 | 21.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 51.0 | 1.2 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 52.8 | 1.3 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 54.6 | 1.3 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 56.4 | 1.3 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 58.1 | 1.4 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 59.9 | 1.4 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 61.7 | 1.5 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 63.5 | 1.5 | 12.4 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 63.5 | 1.4 | 54.3 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 65.5 | 1.5 | 54.3 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 67.5 | 1.5 | 54.3 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 69.5 | 1.5 | 54.3 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 69.5 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 71.2 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 72.8 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 74.5 | 1.6 | 25.9 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 74.5 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 76.1 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 77.8 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 79.4 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 81.1 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 82.7 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 84.4 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 86.0 | 1.6 | 18.0 | 0.10 | 0.27 | 0.20 | 0.15 | 2.0 | 6.6 | 168.0 | 201.1 |
| 86.0 | 1.7 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 88.0 | 1.7 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 90.0 | 1.8 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 92.0 | 1.8 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 94.0 | 1.8 | 121.1 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 94.0 | 1.8 | 83.5 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 95.7 | 1.8 | 83.5 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 97.3 | 1.9 | 83.5 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 99.0 | 1.9 | 83.5 | 0.10 | 0.27 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 99.0 | 1.9 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 100.7 | 1.9 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 102.4 | 1.9 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 104.1 | 1.9 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 105.8 | 1.9 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |
| 107.5 | 2.0 | 129.5 | 0.10 | 0.13 | 0.05 | 0.15 | 1.2 | 6.6 | 1.0 | 201.1 |

Variable Time Hisotry with DELMAG D 19-42; Depth = 107.50ft; Shaft/Toe G/L = 0.500/1.000




Extrema Results of Gain/Loss at Shaft/Toe = 0.500/1.000 and Depth = 2.00 ft
Percentage (%)
Stress Maxima (ksi)
Force Maxima (kips)
Disp./ENTHRU (in/kip-ft)
Pile Area
Mx C-Str.
Mx C-For.
Disp.
0 125
0 4 7 11 14
0 60 120 180 240
0.0 2.5 5.0 7.5 10.0
0
22
43
65
86
108
Distance below pile top (ft)
0 125
0 2 4 6 8
0 20 40 60 80
0 10 20 30 40
UnitRs
Mx T-Str.
Mx T-For.
ENTHRU

# APPENDIX VII

# LATERAL DESIGN PARAMETERS

**HAM-562-0004**
**Lateral Design Parameters**

| Boring No. | Elevation (feet msl) | Soil Class. | Soil Type | Strata | $N_{60}$ | $N1_{60}$ | γ (pcf) | γ' (pcf) | Strength Parameter | k (soil) $k_{rm}$ (rock) | $ε_{50}$ (soil) $E_r$ (rock) | RQD (rock) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B-161-0-07 | 551.1 to 546.1 | A-4a | C | 3 | 9 | 9 | 115 | 115 | Su = 1,000 psf | 500 pci | 0.0070 | - |
| | 546.1 to 543.1 | A-4a | C | 3 | 23 | 23 | 120 | 120 | Su = 3,000 psf | 1,000 pci | 0.0050 | - |
| | 543.1 to 533.1 | A-6a | C | 3 | 29 | 29 | 125 | 125 | Su = 4,000 psf | 2,000 pci | 0.0040 | - |
| | 533.1 to 528.1 | A-1-a | G | 4 | 100 | 93 | 130 | 130 | φ = 35° | 90 pci | - | - |
| | 528.1 to 513.1 | A-4a | G | 4 | 44 | 35 | 130 | 130 | φ = 35° | 90 pci | - | - |
| | 513.1 to 507.6 | A-3a | G | 4 | 6 | 4 | 120 | 120 | φ = 28° | 20 pci | - | - |
| | 507.6 to 502.6 | A-6a | C | 3 | 29 | 29 | 120 | 120 | Su = 3,500 psf | 1,000 pci | 0.0050 | - |
| | 502.6 to 497.6 | A-6a | C | 1 | 5 | 5 | 115 | 115 | Su = 750 psf | 100 pci | 0.0100 | - |
| | 497.6 to 489.1 | A-6a | C | 3 | 18 | 18 | 120 | 120 | Su = 3,000 psf | 1,000 pci | 0.0050 | - |
| | 489.1 to 472.6 | A-6b | C | 3 | 16 | 16 | 120 | 120 | Su = 3,000 psf | 1,000 pci | 0.0050 | - |
| | 472.6 to 461.1 | A-4a | G | 4 | 26 | 12 | 130 | 67.6 | φ = 32° | 60 pci | - | - |
| | 461.1 to 447.6 | A-3a | G | 4 | 34 | 14 | 130 | 67.6 | φ = 35° | 90 pci | - | - |
| | 447.6 to 446.1 | A-3 | G | 4 | 22 | 8 | 130 | 67.6 | φ = 32° | 60 pci | - | - |
| B-162-0-07 | 516.2 to 512.7 | A-3a | G | 4 | 13 | 23 | 125 | 125 | φ = 29° | 30 pci | - | - |
| | 512.7 to 505.2 | A-7-6 | C | 1 | 5 | 5 | 115 | 52.6 | Su = 750 psf | 100 pci | 0.0100 | - |
| | 505.2 to 492.7 | A-7-6 | C | 2 | 9 | 9 | 115 | 52.6 | Su = 1,500 psf | 500 pci | 0.0070 | - |
| | 492.7 to 482.7 | A-4b | C | 2 | 16 | 16 | 125 | 62.6 | Su = 3,000 psf | 1,000 pci | 0.0050 | - |
| | 482.7 to 467.7 | A-6b | C | 2 | 21 | 21 | 125 | 62.6 | Su = 3,000 psf | 1,000 pci | 0.0050 | - |
| | 467.7 to 462.7 | A-4b | C | 2 | 14 | 14 | 125 | 62.6 | Su = 3,000 psf | 1,000 pci | 0.0050 | - |
| | 462.7 to 458.2 | A-6b | C | 2 | 8 | 8 | 115 | 52.6 | Su = 1,250 psf | 500 pci | 0.0070 | - |
| | 458.2 to 452.7 | A-6b | C | 2 | 20 | 20 | 120 | 57.6 | Su = 3,250 psf | 1,000 pci | 0.0050 | - |
| | 452.7 to 448.2 | A-4a | G | 4 | 16 | 12 | 125 | 62.6 | φ = 30° | 30 pci | - | - |
| | 448.2 to 437.7 | A-4a | G | 4 | 28 | 20 | 130 | 67.6 | φ = 33° | 60 pci | - | - |
| | 437.7 to 426.7 | A-6a | C | 2 | 13 | 13 | 120 | 57.6 | Su = 2,000 psf | 750 pci | 0.0060 | - |
| | 426.7 to 421.2 | A-3a | G | 4 | 19 | 12 | 125 | 62.6 | φ = 31° | 30 pci | - | - |
| B-163-0-07 | 555.0 to 552.0 | A-2-4 | G | 4 | 20 | 36 | 125 | 125 | φ = 30° | 30 pci | - | - |
| | 552.0 to 531.5 | A-4a | C | 3 | 10 | 10 | 120 | 120 | Su = 1,500 psf | 500 pci | 0.0070 | - |
| | 531.5 to 523.5 | A-6a | C | 3 | 8 | 8 | 115 | 115 | Su = 1,250 psf | 500 pci | 0.0070 | - |
| | 523.5 to 511.5 | A-6b | C | 3 | 12 | 12 | 120 | 120 | Su = 2,250 psf | 750 pci | 0.0060 | - |
| | 511.5 to 496.5 | A-4b | G | 4 | 7 | 4 | 120 | 120 | φ = 28° | 30 pci | - | - |
| | 496.5 to 491.5 | A-6b | C | 3 | 14 | 14 | 120 | 120 | Su = 2,750 psf | 1,000 pci | 0.0050 | - |
| | 491.5 to 479.0 | A-6b | C | 3 | 8 | 8 | 115 | 115 | Su = 1,500 psf | 500 pci | 0.0070 | - |
| | 479.0 to 473.0 | A-3a | G | 4 | 10 | 5 | 120 | 57.6 | φ = 29° | 30 pci | - | - |
| | 473.0 to 468.0 | A-7-6 | C | 2 | 17 | 17 | 120 | 57.6 | Su = 3,000 psf | 1,000 pci | 0.0050 | - |
| | 468.0 to 456.5 | A-6a | C | 2 | 11 | 11 | 120 | 57.6 | Su = 2,000 psf | 750 pci | 0.0060 | - |
| | 456.5 to 448.5 | A-3a | G | 4 | 21 | 9 | 130 | 67.6 | φ = 32° | 60 pci | - | - |
| | 448.5 to 443.5 | A-3a | G | 4 | 15 | 6 | 125 | 62.6 | φ = 30° | 30 pci | - | - |
| | 443.5 to 435.0 | A-3a | G | 4 | 23 | 10 | 130 | 67.6 | φ = 32° | 60 pci | - | - |

# APPENDIX VIII

# SETTLEMENT CALCULATIONS

B-10-020 HAM-75-7.85 (HAM-562-0004 Bridge Structure)
MSE Wall - Consolidation Settlement

Calculated By: BRT Date: 8/8/2013
Checked By: JPS Date: 8/8/2013

Boring B-161 (HAM-562-0004 Rear Abutment)

15.5' net embankment height considered - Total wall height is 27.5' - Bottom of wall at 532.0, existing grade is at 544.0 and proposed profile grade is at 559.5 for a net embankment height of 15.5'

| | | | |
|---|---|---|---|
| H= | 15.5 | ft | |
| B= | 18.6 | ft | |
| $\gamma_{BF}$ = | 120 | pcf | |
| $D_w$ = | 26.1 | ft | depth below bottom of footing |
| $\gamma_w$ = | 62.4 | pcf | |
| ΔP = | 1860 | psf | at surface |

| | | | | | | | | | | | | | | | Total Settlement at Center of Reinforced Soil Mass | | | | | Total Settlement at Facing of Wall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Layer | Soil Type | Depth | | Thickness | Depth to Midpoint | $\gamma$ | LL | $C_c$ | $C_r$ | $e_o$ | $\sigma_p'$ | $\sigma_{vo}$ Bottom | $\sigma_{vo}$ Midpoint | $\sigma_{vo}'$ Midpoint | $Z_f/B$ | I | $\Delta\sigma_v$ | $\sigma_{vf}'$ Midpoint | $S_c$ (ft) | $S_c$ (in) | I | $\Delta\sigma_v$ | $\sigma_{vf}'$ Midpoint | $S_c$ (ft) | $S_c$ (in) |
| 1 | A-1-b / A-4a / A-3a | 0.0 | 24.0 | 24.0 | 12.0 | 130 | Calculated Separately | | | | | 3120 | 1560 | 1560 | 0.64 | Calculated Separately | | | 0.042 | 0.506 | Calculated Separately | | | 0.020 | 0.238 |
| 2 | A-6a | 24.0 | 27.0 | 3.0 | 25.5 | 120 | 33 | 0.207 | 0.021 | 0.530 | N/A | 3480 | 3300 | 3300 | 1.37 | 0.436 | 810 | 4110 | 0.004 | 0.046 | 0.343 | 638 | 3938 | 0.003 | 0.037 |
| | | 27.0 | 30.0 | 3.0 | 28.5 | 120 | 33 | 0.207 | 0.021 | 0.530 | N/A | 3840 | 3660 | 3510 | 1.53 | 0.395 | 736 | 4246 | 0.003 | 0.040 | 0.326 | 606 | 4116 | 0.003 | 0.034 |
| | | 30.0 | 33.0 | 3.0 | 31.5 | 115 | 33 | 0.207 | 0.021 | 0.530 | N/A | 4185 | 4013 | 3676 | 1.69 | 0.364 | 676 | 4352 | 0.003 | 0.036 | 0.306 | 569 | 4244 | 0.003 | 0.030 |
| | | 33.0 | 36.0 | 3.0 | 34.5 | 120 | 33 | 0.207 | 0.021 | 0.530 | N/A | 4545 | 4365 | 3841 | 1.85 | 0.336 | 626 | 4466 | 0.003 | 0.032 | 0.292 | 543 | 4384 | 0.002 | 0.028 |
| | | 36.0 | 39.0 | 3.0 | 37.5 | 120 | 33 | 0.207 | 0.021 | 0.530 | N/A | 4905 | 4725 | 4014 | 2.01 | 0.305 | 566 | 4580 | 0.002 | 0.028 | 0.278 | 517 | 4531 | 0.002 | 0.026 |
| | | 39.0 | 42.0 | 3.0 | 40.5 | 120 | 33 | 0.207 | 0.021 | 0.530 | N/A | 5265 | 5085 | 4186 | 2.18 | 0.288 | 536 | 4723 | 0.002 | 0.026 | 0.266 | 495 | 4681 | 0.002 | 0.024 |
| 3 | A-6b | 42.0 | 46.0 | 4.0 | 44.0 | 120 | 40 | 0.145 | 0.041 | 0.503 | N/A | 5745 | 5505 | 4388 | 2.36 | 0.270 | 502 | 4890 | 0.005 | 0.062 | 0.250 | 465 | 4853 | 0.005 | 0.057 |
| | | 46.0 | 50.0 | 4.0 | 48.0 | 120 | 40 | 0.145 | 0.041 | 0.503 | N/A | 6225 | 5985 | 4618 | 2.58 | 0.251 | 467 | 5086 | 0.005 | 0.055 | 0.234 | 435 | 5054 | 0.004 | 0.051 |
| | | 50.0 | 54.0 | 4.0 | 52.0 | 115 | 40 | 0.145 | 0.041 | 0.503 | N/A | 6685 | 6455 | 4839 | 2.79 | 0.230 | 428 | 5267 | 0.004 | 0.048 | 0.216 | 402 | 5241 | 0.004 | 0.045 |
| | | 54.0 | 58.0 | 4.0 | 56.0 | 120 | 40 | 0.145 | 0.041 | 0.503 | N/A | 7165 | 6925 | 5059 | 3.01 | 0.212 | 394 | 5453 | 0.004 | 0.043 | 0.200 | 372 | 5431 | 0.003 | 0.040 |
| 4 | A-4a | 58.0 | 62.0 | 4.0 | 60.0 | 120 | 21 | 0.134 | 0.014 | 0.535 | N/A | 7645 | 7405 | 5290 | 3.22 | 0.196 | 365 | 5655 | 0.001 | 0.013 | 0.192 | 357 | 5646 | 0.001 | 0.012 |
| | | 62.0 | 66.0 | 4.0 | 64.0 | 120 | 21 | 0.134 | 0.014 | 0.535 | N/A | 8125 | 7885 | 5520 | 3.44 | 0.189 | 351 | 5871 | 0.001 | 0.012 | 0.185 | 343 | 5863 | 0.001 | 0.011 |
| | | 66.0 | 70.0 | 4.0 | 68.0 | 120 | 21 | 0.134 | 0.014 | 0.535 | N/A | 8605 | 8365 | 5750 | 3.65 | 0.180 | 335 | 6085 | 0.001 | 0.011 | 0.176 | 328 | 6078 | 0.001 | 0.011 |
| | | 70.0 | 75.0 | 5.0 | 72.5 | 125 | 21 | 0.134 | 0.014 | 0.535 | N/A | 9230 | 8918 | 6022 | 3.89 | 0.170 | 317 | 6339 | 0.001 | 0.012 | 0.167 | 311 | 6333 | 0.001 | 0.012 |
| 5 | A-3a / A-3 | 75.0 | 86.0 | 11.0 | 80.5 | 130 | Calculated Separately | | | | | 10660 | 9945 | 6550 | 4.32 | Calculated Separately | | | 0.000 | 0.000 | Calculated Separately | | | 0.000 | 0.000 |

Settlement at Center of Reinforced Soil Mass: 0.968 in

Settlement at Facing of Wall: 0.657 in

B-10-020 HAM-75-7.85 (HAM-562-0004 Bridge Structure)
MSE Wall - Consolidation Settlement

Calculated By: BRT  Date: 8/8/2013
Checked By: JPS  Date: 8/8/2013

Boring B-161 (HAM-562-0004 Rear Abutment)

15.5' net embankment height considered - Total wall height is 27.5' - Bottom of wall at 532.0, existing grade is at 544.0 and proposed profile grade is at 559.5 for a net embankment height of 15.5'

| | | | |
|---|---|---|---|
| H= | 15.5 | ft | |
| B= | 18.62 | ft | |
| $\gamma_{BF}$ = | 120 | pcf | |
| $D_w$ = | 26.1 | ft | depth below bottom of footing |
| $\gamma_w$ = | 62.4 | pcf | |
| $\Delta P$ = | 1860 | psf | at surface |

| | A-7-6 | A-6b | A-6a | | |
|---|---|---|---|---|---|
| $c_v$ = | 150 | 400 | 600 | $ft^2/yr$ | Coefficient of consolitation |
| t = | 0 | 0 | 0 | days | Hold period considered |
| $H_{dr}$ = | NA | 8 | 9 | ft | Length of longest drainage path considered |
| $T_v$ = | NA | 0.000 | 0.000 | | Time factor |
| U = | NA | 0 | 0 | % | Degree of consolidation based on hold period considered |

$(S_c)_t$ = 0.284 in  Settlement complete at the end of the specified hold period

| Layer | Soil Type | Depth | | Thickness | Depth to Midpoint | $\gamma$ | $\sigma_{vo}$ | $\sigma_{vo}'$ | $Z_f$/B | I | $\Delta\sigma_v$ | $\sigma_{vf}'$ | LL | $C_c$ | $C_r$ | $e_o$ | $\sigma_p'$ | $S_c$ (ft) | $S_c$ (in) | Total Settlement at Face of Wall: Layer Settlement (in) | Total Settlement at Face of Wall: Relative Soil Movement (in) | Remaining Settlement at 43% of Primary Consolidation: Layer Settlement (in) | Remaining Settlement at 43% of Primary Consolidation: Relative Soil Movement (in) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | 0.657 | | 0.373 |
| 1 | A-1-b / A-4a / A-3a | 0.0 | 24.0 | 24.0 | 12.0 | 130 | 3120 | 1560 | 0.64 | 0.436 | 811 | 2371 | Calculated Separately | | | | | 0.000 | 0.238 | 0.657 | 0.419 | 0.000 | 0.373 |
| 2 | A-6a | 24.0 | 27.0 | 3.0 | 25.5 | 120 | 3480 | 3300 | 1.37 | 0.343 | 638 | 3938 | 33 | 0.207 | 0.021 | 0.530 | N/A | 0.003 | 0.037 | 0.179 | 0.382 | 0.179 | 0.336 |
| | | 27.0 | 30.0 | 3.0 | 28.5 | 120 | 3840 | 3510 | 1.53 | 0.326 | 606 | 4116 | 33 | 0.207 | 0.021 | 0.530 | N/A | 0.003 | 0.034 | | 0.348 | | 0.302 |
| | | 30.0 | 33.0 | 3.0 | 31.5 | 115 | 4185 | 3676 | 1.69 | 0.306 | 569 | 4244 | 33 | 0.207 | 0.021 | 0.530 | N/A | 0.003 | 0.030 | | 0.318 | | 0.271 |
| | | 33.0 | 36.0 | 3.0 | 34.5 | 120 | 4545 | 3841 | 1.85 | 0.292 | 543 | 4384 | 33 | 0.207 | 0.021 | 0.530 | N/A | 0.002 | 0.028 | | 0.290 | | 0.243 |
| | | 36.0 | 39.0 | 3.0 | 37.5 | 120 | 4905 | 4014 | 2.01 | 0.278 | 517 | 4531 | 33 | 0.207 | 0.021 | 0.530 | N/A | 0.002 | 0.026 | | 0.264 | | 0.218 |
| | | 39.0 | 42.0 | 3.0 | 40.5 | 120 | 5265 | 4186 | 2.18 | 0.266 | 495 | 4681 | 33 | 0.207 | 0.021 | 0.530 | N/A | 0.002 | 0.024 | | 0.241 | | 0.194 |
| 3 | A-6b | 42.0 | 46.0 | 4.0 | 44.0 | 120 | 5745 | 4388 | 2.36 | 0.250 | 465 | 4853 | 40 | 0.145 | 0.041 | 0.503 | N/A | 0.005 | 0.057 | 0.194 | 0.183 | 0.194 | 0.137 |
| | | 46.0 | 50.0 | 4.0 | 48.0 | 120 | 6225 | 4618 | 2.58 | 0.234 | 435 | 5054 | 40 | 0.145 | 0.041 | 0.503 | N/A | 0.004 | 0.051 | | 0.132 | | 0.086 |
| | | 50.0 | 54.0 | 4.0 | 52.0 | 115 | 6685 | 4839 | 2.79 | 0.216 | 402 | 5241 | 40 | 0.145 | 0.041 | 0.503 | N/A | 0.004 | 0.045 | | 0.087 | | 0.040 |
| | | 54.0 | 58.0 | 4.0 | 56.0 | 120 | 7165 | 5059 | 3.01 | 0.200 | 372 | 5431 | 40 | 0.145 | 0.041 | 0.503 | N/A | 0.003 | 0.040 | | 0.046 | | 0.000 |
| 4 | A-4a | 58.0 | 62.0 | 4.0 | 60.0 | 120 | 7645 | 5290 | 3.22 | 0.192 | 357 | 5646 | 21 | 0.134 | 0.014 | 0.535 | N/A | 0.001 | 0.012 | 0.046 | 0.034 | 0.000 | 0.000 |
| | | 62.0 | 66.0 | 4.0 | 64.0 | 120 | 8125 | 5520 | 3.44 | 0.185 | 343 | 5863 | 21 | 0.134 | 0.014 | 0.535 | N/A | 0.001 | 0.011 | | 0.023 | | 0.000 |
| | | 66.0 | 70.0 | 4.0 | 68.0 | 120 | 8605 | 5750 | 3.65 | 0.176 | 328 | 6078 | 21 | 0.134 | 0.014 | 0.535 | N/A | 0.001 | 0.011 | | 0.012 | | 0.000 |
| | | 70.0 | 75.0 | 5.0 | 72.5 | 125 | 9230 | 6022 | 3.89 | 0.167 | 311 | 6333 | 21 | 0.134 | 0.014 | 0.535 | N/A | 0.001 | 0.012 | | 0.000 | | 0.000 |

Note: A-4a, A-4b and all granular soil layers are assumed to be fully drained at the completion of construction of the wall.

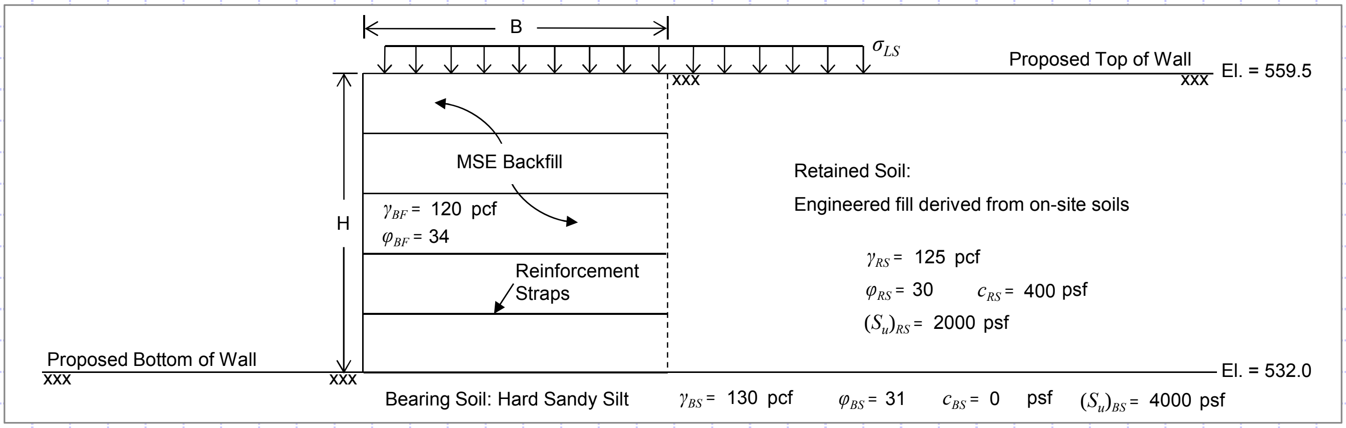
Total Settlement = 0.657

Depth of downdrag: 0 ft. Determined from depth of pile tip at 75.0 ft. and considering 43% primary consolidation. Downdrag occurs along pile length above interface with relative soil movement greater than 0.40 inches.

# APPENDIX IX

# MSE WALL CALCULATIONS

## MSE Wall - Forward Abutment - B-161 - (27.5 ft. Wall Height)




### MSE Wall Dimensions and Retained Soil Parameters

| | | |
|---|---|---|
| MSE Wall Height, $(H)$ = | 27.5 | ft |
| MSE Wall Width (Reinforcement Length), $(B)$ = | 19.3 | ft |
| Live Surcharge Load, $(\sigma_{LS})$ = | 240 | psf |
| Retained Soil Unit Weight, $(\gamma_{RS})$ = | 125 | pcf |
| Retained Soil Friction Angle, $(\varphi_{RS})$ = | 30 | ° |
| Retained Soil Drained Cohesion, $(c_{BS})$ = | 400 | psf |
| Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ = | 2000 | psf |
| Retained Soil Active Earth Pressure Coeff., $(K_a)$ = | 0.333 | |
| MSE Backfill Unit Weight, $(\gamma_{BF})$ = | 120 | pcf |
| MSE Backfill Friction Angle, $(\varphi_{BF})$ = | 34 | ° |

### Bearing Soil Properties:

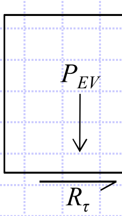
| | | |
|---|---|---|
| Bearing Soil Unit Weight, $(\gamma_{BS})$ = | 130 | pcf |
| Bearing Soil Friction Angle, $(\varphi_{BS})$ = | 31 | ° |
| Bearing Soil Drained Cohesion, $(c_{BS})$ = | 0 | psf |
| Bearing Soil Undrained Shear Strength, $[(S_u)_{BS}]$ = | 4000 | psf |
| Embedment Depth, $(D)$ = | 3.0 | ft |

### LRFD Load Factors

| | EV | EH | LS | |
|---|---|---|---|---|
| Strength Ia | 1.00 | 1.50 | 1.75 | *(AASHTO LRFD BDM Tables 3.4.1-1 and 3.4.1-2 - Active Earth Pressure)* |
| Strength Ib | 1.35 | 1.50 | 1.75 | |
| Service I | 1.00 | 1.00 | 1.00 | |

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

Nominal Sliding Resistance: $R_\tau = P_{EV} \cdot \tan\delta$



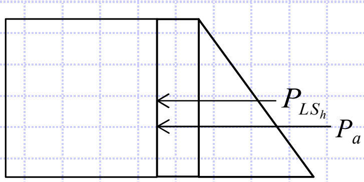

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(27.5 ft)(19.25 ft)(1.00) = 63.53 kip/ft

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

$\tan\delta =$ tan(31) ≤ tan(34) ⟶ 0.6 ≤ 0.67 ⟶ $\tan\delta =$ 0.60

$R_\tau$ = (63.53 kip/ft)(0.6) = 38.12 kip/ft

Sliding Force: $P_H = P_{EH} + P_{LS_h}$




$P_{EH} = \frac{1}{2}\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(125 pcf)(27.5 ft)²(0.333)(1.5) = 23.61 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (240 psf)(27.5 ft)(0.333)(1.75) = 3.85 kip/ft

$P_H$ = 23.61 kip/ft + 3.85 kip/ft = 27.46 kip/ft

### Check Sliding Resistance

$P_H \le R_\tau \cdot \phi_\tau$ ⟶ 27.46 kip/ft ≤ (38.12 kip/ft)(1.0) = 38.12 kip/ft ⟶ 27.46 kip/ft ≤ 38.12 kip/ft **OK**

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

**MSE Wall Dimensions and Retained Soil Parameters**

| | | |
|---|---|---|
| MSE Wall Height, ($H$) = | 27.5 | ft |
| MSE Wall Width (Reinforcement Length), ($B$) = | 19.25 | ft |
| Live Surcharge Load, ($\sigma_{LS}$) = | 240 | psf |
| Retained Soil Unit Weight, ($\gamma_{RS}$) = | 125 | pcf |
| Retained Soil Friction Angle, ($\varphi_{RS}$) = | 30 | ° |
| Retained Soil Drained Cohesion, ($c_{BS}$) = | 400 | psf |
| Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] = | 2000 | psf |
| Retained Soil Active Earth Pressure Coeff., ($K_a$) = | 0.333 | |
| MSE Backfill Unit Weight, ($\gamma_{BF}$) = | 120 | pcf |
| MSE Backfill Friction Angle, ($\varphi_{BF}$) = | 34 | ° |

**Bearing Soil Properties:**

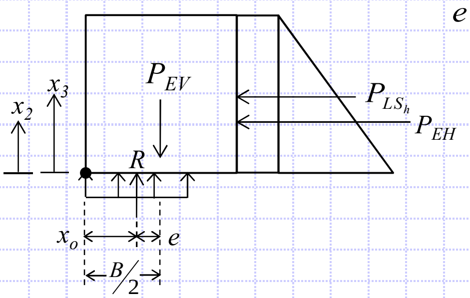
| | | |
|---|---|---|
| Bearing Soil Unit Weight, ($\gamma_{BS}$) = | 130 | pcf |
| Bearing Soil Friction Angle, ($\varphi_{BS}$) = | 31 | ° |
| Bearing Soil Drained Cohesion, ($c_{BS}$) = | 0 | psf |
| Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] = | 4000 | psf |
| Embedment Depth, ($D$) = | 3.0 | ft |

**LRFD Load Factors**

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

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

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



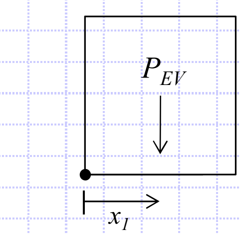

$$e = B/2 - x_o$$

$$x_o = \frac{M_{EV} - M_H}{P_{EV}}$$ = (611.48 kip·ft/ft - 269.44 kip·ft/ft) / (63.53 kip/ft) = 5.38 ft

$M_{EV}$ = 611.48 kip·ft/ft
$M_H$ = 269.44 kip·ft/ft
$P_{EV}$ = 63.53 kip/ft
Defined below

$e =$ (19.25 ft)/2 - 5.38 ft = 4.25 ft

Resisting Moment, $M_{EV}$:



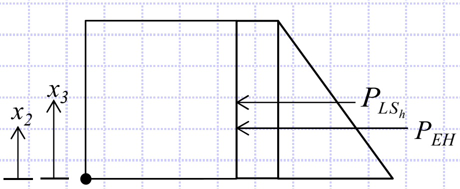

$$M_{EV} = P_{EV}(x_1)$$

$P_{EV} = \gamma_{BF} \cdot H \cdot B \cdot \gamma_{EV}$ = (120 pcf)(27.5 ft)(19.25 ft)(1.00) = 63.53 kip/ft

$x_1 = B/2$ = (19.25 ft) / 2 = 9.63 ft

$M_{EV} =$ (63.53 kip/ft)(9.625 ft) = 611.48 kip·ft/ft

Overturning Moment, $M_H$:




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

$P_{EH} = ½\gamma_{RS} H^2 K_a \gamma_{EH}$ = ½(125 pcf)(27.5 ft)²(0.333)(1.5) = 23.61 kip/ft

$P_{LS_h} = \sigma_{LS} H K_a \gamma_{LS}$ = (240 psf)(27.5 ft)(0.333)(1.75) = 3.85 kip/ft

$x_2 = H/3$ = (27.5 ft) / 3 = 9.17 ft

$x_3 = H/2$ = (27.5 ft) / 2 = 13.75 ft

$M_H =$ (23.61 kip/ft)(9.17 ft) + (3.85 kip/ft)(13.75 ft) = 269.44 kip·ft/ft

Limiting Eccentricity:

$e_{max} = B/4 \longrightarrow e_{max} =$ (19.25 ft) / 4 = 4.81 ft

**Check Eccentricity**

$e < e_{max} \longrightarrow$ 4.25 ft ≤ 4.81 ft **OK**

**MSE Wall Dimensions and Retained Soil Parameters**

| | | |
|---|---|---|
| MSE Wall Height, ($H$) = | 27.5 | ft |
| MSE Wall Width (Reinforcement Length), ($B$) = | 19.25 | ft |
| Live Surcharge Load, ($\sigma_{LS}$) = | 240 | psf |
| Retained Soil Unit Weight, ($\gamma_{RS}$) = | 125 | pcf |
| Retained Soil Friction Angle, ($\varphi_{RS}$) = | 30 | ° |
| Retained Soil Drained Cohesion, ($c_{BS}$) = | 400 | psf |
| Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] = | 2000 | psf |
| Retained Soil Active Earth Pressure Coeff., ($K_a$) = | 0.333 | |
| MSE Backfill Unit Weight, ($\gamma_{BF}$) = | 120 | pcf |
| MSE Backfill Friction Angle, ($\varphi_{BF}$) = | 34 | ° |

**Bearing Soil Properties:**

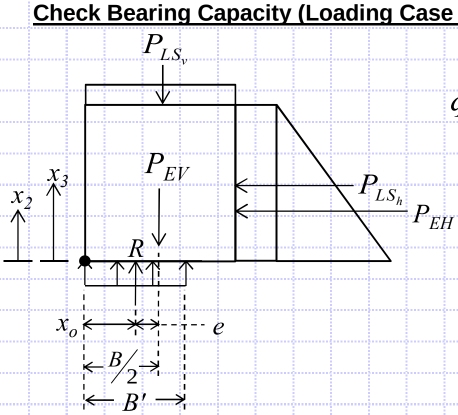
| | | |
|---|---|---|
| Bearing Soil Unit Weight, ($\gamma_{BS}$) = | 130 | pcf |
| Bearing Soil Friction Angle, ($\varphi_{BS}$) = | 31 | ° |
| Bearing Soil Drained Cohesion, ($c_{BS}$) = | 0 | psf |
| Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] = | 4000 | psf |
| Embedment Depth, ($D$) = | 3.0 | ft |

**LRFD Load Factors**

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

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

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




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

$B' = B - 2e$ = 19.3 ft - 2(2.875 ft) = 13.50 ft

$e = B/2 - x_o$ = (19.3 ft) / 2 - 6.75 ft = 2.88 ft

$x_o = \dfrac{M_V - M_H}{P_V}$ = (903.25 kip·ft/ft - 269.38 kip·ft/ft) / 93.84 kip/ft = 6.75 ft

$q_{eq} =$ (93.84 kip/ft) / (13.5 ft) = 6.95 ksf

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

$M_V =$ [(120 pcf)(27.5 ft)(19.25 ft)(1.35)](9.625 ft) + [(240 psf)(19.25 ft)(1.75)](9.625 ft) = 903.25 kip·ft/ft

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

$M_H =$ [½(125 pcf)(27.5 ft)²(0.333)(1.5)](9.17 ft) + [(240 psf)(27.5 ft)(0.333)(1.75)](13.75 ft) = 269.38 kip·ft/ft

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

$P_V =$ (120 pcf)(27.5 ft)(19.25 ft)(1.35) + (240 psf)(19.25 ft)(1.75) = 93.84 kip/ft

Nominal Bearing Resistance:

$q_n = cN_c + \gamma DN_q + \tfrac{1}{2}\gamma BN_\gamma$ = (4000 psf)(5.7) + (130 pcf)(3 ft)(1.0) + ½(130 pcf)(19.25 ft)(0.0) = 23.2 ksf

$N_c$ = 5.7 $N_q$ = 1.0 $N_\gamma$ = 0.0

**Check Bearing Capacity**

$q_{eq} \le q_n \cdot \phi_b \longrightarrow$ 6.95 ksf ≤ (23.2 ksf)(0.65) = 15.08 ksf $\longrightarrow$ 6.95 ksf ≤ 15.08 ksf **OK**

Use $\varphi_b$ = **0.65** *(Per AASHTO LRFD BDM Table 11.5.6-1)*

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

| | | | |
|---|---|---|---|
| JOB | HAM-75-7.85 | NO. | B-10-020 |
| SHEET NO. | 4 | OF | 5 |
| CALCULATED BY | BRT | DATE | 8/8/2013 |
| CHECKED BY | JPS | DATE | 8/8/2013 |

HAM-562-0004 - MSE Wall - Rear Abutment

## MSE Wall Dimensions and Retained Soil Parameters

| | | |
|---|---|---|
| MSE Wall Height, ($H$) = | 27.5 | ft |
| MSE Wall Width (Reinforcement Length), ($B$) = | 19.25 | ft |
| Live Surcharge Load, ($\sigma_{LS}$) = | 240 | psf |
| Retained Soil Unit Weight, ($\gamma_{RS}$) = | 125 | pcf |
| Retained Soil Friction Angle, ($\varphi_{RS}$) = | 30 | ° |
| Retained Soil Drained Cohesion, ($c_{RS}$) = | 400 | psf |
| Retained Soil Undrained Shear Strength, [$(S_u)_{RS}$] = | 2000 | psf |
| Retained Soil Active Earth Pressure Coeff., ($K_a$) = | 0.333 | |
| MSE Backfill Unit Weight, ($\gamma_{BF}$) = | 120 | pcf |
| MSE Backfill Friction Angle, ($\varphi_{BF}$) = | 34 | ° |

## Bearing Soil Properties:

| | | |
|---|---|---|
| Bearing Soil Unit Weight, ($\gamma_{BS}$) = | 130 | pcf |
| Bearing Soil Friction Angle, ($\varphi_{BS}$) = | 31 | ° |
| Bearing Soil Drained Cohesion, ($c_{BS}$) = | 0 | psf |
| Bearing Soil Undrained Shear Strength, [$(s_u)_{BS}$] = | 4000 | psf |
| Embedment Depth, ($D$) = | 3.0 | ft |

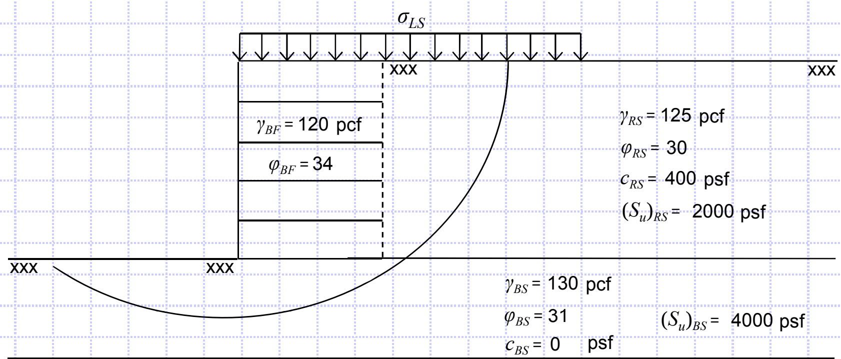
## LRFD Load Factors

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

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

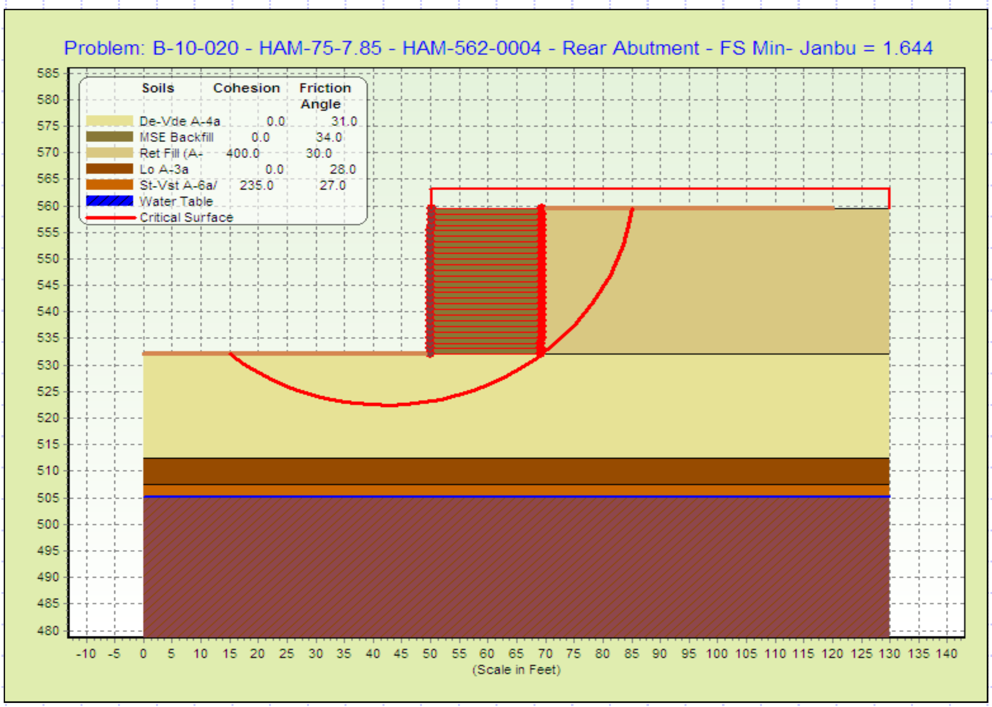
## Check Overall (Global) Stability (Loading Case - Service I) - AASHTO LRFD BDM Sections 11.6.2.3 and 11.10.5.2

Long Term Stability - Drained Conditions




Loading scenario modeled as shown to the left and analyzed for slope stability using STABL for Windows software.

Graphical output shown below and tabular output results are provided as a separate attachment.




## Check Overall (Global) Stability

$1.0 \leq FS \cdot \phi_{GS}$ $\longrightarrow$ 1.00 ≤ (1.644)(0.65) = 1.07 $\longrightarrow$ 1.00 ≤ 1.07 **OK**

$FS$ = **1.644** *(From STABL Slope Stability Analysis)*

Use $\varphi_{GS}$ = **0.65** *(Per AASHTO LRFD BDM Section 11.6.2.3)*

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## MSE Wall Dimensions and Retained Soil Parameters

| | | |
|---|---|---|
| MSE Wall Height, $(H)$ = | 27.5 | ft |
| MSE Wall Width (Reinforcement Length), $(B)$ = | 19.25 | ft |
| Live Surcharge Load, $(\sigma_{LS})$ = | 240 | psf |
| Retained Soil Unit Weight, $(\gamma_{RS})$ = | 125 | pcf |
| Retained Soil Friction Angle, $(\varphi_{RS})$ = | 30 | ° |
| Retained Soil Drained Cohesion, $(c_{BS})$ = | 400 | psf |
| Retained Soil Undrained Shear Strength, $[(S_u)_{RS}]$ = | 2000 | psf |
| Retained Soil Active Earth Pressure Coeff., $(K_a)$ = | 0.333 | |
| MSE Backfill Unit Weight, $(\gamma_{BF})$ = | 120 | pcf |
| MSE Backfill Friction Angle, $(\varphi_{BF})$ = | 34 | ° |

## Bearing Soil Properties:

| | | |
|---|---|---|
| Bearing Soil Unit Weight, $(\gamma_{BS})$ = | 130 | pcf |
| Bearing Soil Friction Angle, $(\varphi_{BS})$ = | 31 | ° |
| Bearing Soil Drained Cohesion, $(c_{BS})$ = | 0 | psf |
| Bearing Soil Undrained Shear Strength, $[(s_u)_{BS}]$ = | 4000 | psf |
| Embedment Depth, $(D)$ = | 3.0 | ft |

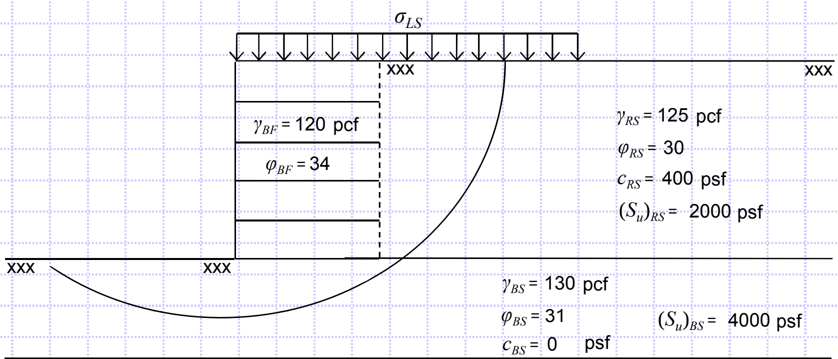
## LRFD Load Factors

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

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

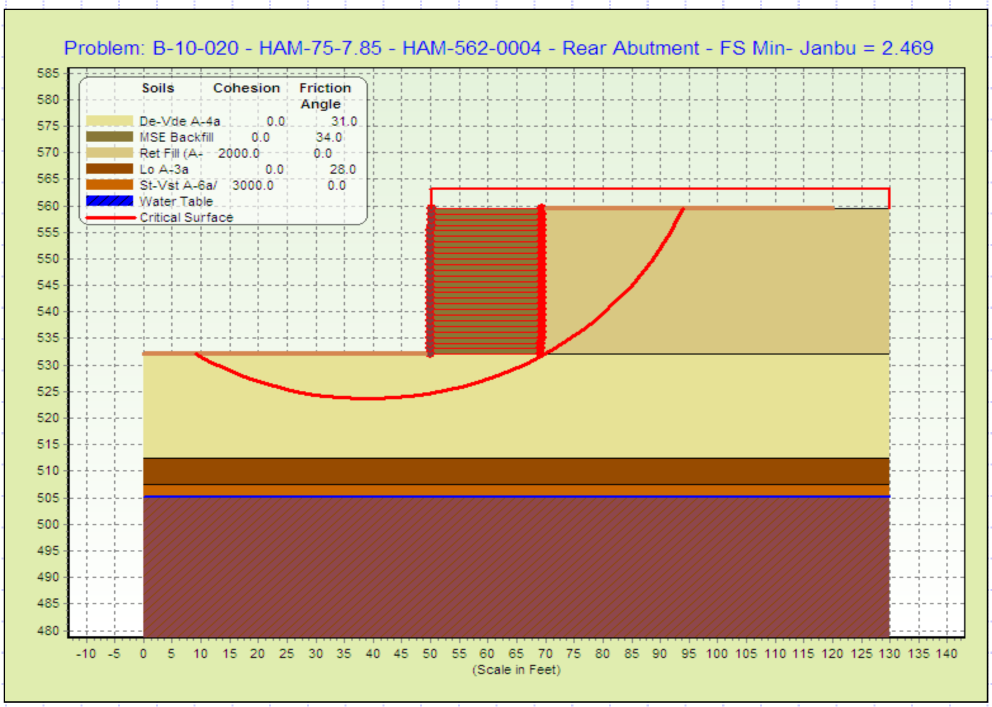
## Check Overall (Global) Stability (Loading Case - Service I) - AASHTO LRFD BDM Sections 11.6.2.3 and 11.10.5.2 *(Cont'd)*

Short Term Stability - Undrained Conditions




Loading scenario modeled as shown to the left and analyzed for slope stability using STABL for Windows software.

Graphical output shown below and tabular output results are provided as a separate attachment.




## Check Overall (Global) Stability

$$1.0 \le FS \cdot \phi_{GS} \quad \longrightarrow \quad 1.00 \le (2.469)(0.65) = 1.60 \quad \longrightarrow \quad 1.00 \le 1.60$$

**OK**

$FS$ = **2.469** *(From STABL Slope Stability Analysis)*

Use $\varphi_{GS}$ = **0.65** *(Per AASHTO LRFD BDM Section 11.6.2.3)*

** STABL for WINDOWS **
by
Geotechnical Software Solutions

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: U.S.C.
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION B-10-020 - HAM-75-7.85 - HAM-562-0004 -
Rear Abutment

BOUNDARY COORDINATES

4 Top Boundaries
9 Total Boundaries

| Boundary No. | X-Left (ft) | Y-Left (ft) | X-Right (ft) | Y-Right (ft) | Soil Type Below Bnd |
|---|---|---|---|---|---|
| 1 | 0.00 | 532.00 | 50.00 | 532.00 | 3 |
| 2 | 50.00 | 532.00 | 50.10 | 559.50 | 1 |
| 3 | 50.10 | 559.50 | 69.40 | 559.50 | 1 |
| 4 | 69.40 | 559.50 | 130.00 | 559.50 | 2 |
| 5 | 50.00 | 532.00 | 69.30 | 532.00 | 3 |
| 6 | 69.30 | 532.00 | 69.40 | 559.50 | 2 |
| 7 | 69.30 | 532.00 | 130.00 | 532.00 | 3 |
| 8 | 0.00 | 512.50 | 130.00 | 512.50 | 4 |
| 9 | 0.00 | 507.50 | 130.00 | 507.50 | 5 |

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

| Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|
| 1 | 125.0 | 130.0 | 0.0 | 34.0 | 0.00 | 0.0 | 1 |
| 2 | 120.0 | 130.0 | 400.0 | 30.0 | 0.00 | 0.0 | 1 |
| 3 | 130.0 | 135.0 | 0.0 | 31.0 | 0.00 | 0.0 | 1 |
| 4 | 120.0 | 125.0 | 0.0 | 28.0 | 0.00 | 0.0 | 1 |
| 5 | 120.0 | 130.0 | 235.0 | 27.0 | 0.00 | 0.0 | 1 |

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 2 Coordinate Points

| Point No. | X-Water (ft) | Y-Water (ft) |
|---|---|---|

| | | |
|---|---|---|
| 1 | 0.00 | 505.10 |
| 2 | 130.00 | 505.10 |

1

BOUNDARY LOAD(S)

1 Load(s) Specified

| Load No. | X-Left (ft) | X-Right (ft) | Intensity (psf) | Deflection (deg) |
|---|---|---|---|---|
| 1 | 50.10 | 130.00 | 240.0 | 1.0 |

NOTE - Intensity Is Specified As A Uniformly Distributed Force Acting On A Horizontally Projected Surface.

GEOSYNTHETIC DATA

1 Geosynthetics(s) group(s) specified

| Ngroup no | Bnr no | Y-top (ft) | Y-bot (ft) | Levels no | Length (ft) | Spacing (ft) | Efficiency | Tallow (lbs/ft) |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 532.0 | 559.5 | 27 | 19.3 | -1.06 | 1.0 | 7500.0 |

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

500 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 50 Points Equally Spaced
Along The Ground Surface Between X = 0.00 ft.
and X = 49.00 ft.

Each Surface Terminates Between X = 70.00 ft.
and X = 120.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y =500.00 ft.

3.00 ft. Line Segments Define Each Trial Failure Surface.

Factor Of Safety Calculation Has Gone Through 30 Iterations, without convergence

The Trial Failure Surface In Question Is Defined By The Following 25 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 17.00 | 532.00 |
| 2 | 19.71 | 530.70 |
| 3 | 22.51 | 529.63 |
| 4 | 25.38 | 528.78 |
| 5 | 28.32 | 528.17 |

| | | |
|---|---|---|
| 6 | 31.30 | 527.79 |
| 7 | 34.29 | 527.65 |
| 8 | 37.29 | 527.76 |
| 9 | 40.27 | 528.10 |
| 10 | 43.21 | 528.69 |
| 11 | 46.10 | 529.50 |
| 12 | 48.91 | 530.55 |
| 13 | 51.63 | 531.82 |
| 14 | 54.24 | 533.30 |
| 15 | 56.72 | 534.99 |
| 16 | 59.06 | 536.87 |
| 17 | 61.24 | 538.93 |
| 18 | 63.24 | 541.16 |
| 19 | 65.06 | 543.55 |
| 20 | 66.69 | 546.07 |
| 21 | 68.10 | 548.71 |
| 22 | 69.30 | 551.46 |
| 23 | 70.28 | 554.30 |
| 24 | 71.02 | 557.21 |
| 25 | 71.42 | 559.50 |

Factor Of Safety For The Preceding Specified Surface = -2.162

Factor Of Safety Calculation Has Gone Through 30 Iterations,
without convergence

The Trial Failure Surface In Question Is Defined
By The Following 21 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 29.00 | 532.00 |
| 2 | 31.86 | 531.11 |
| 3 | 34.80 | 530.48 |
| 4 | 37.78 | 530.13 |
| 5 | 40.78 | 530.06 |
| 6 | 43.77 | 530.27 |
| 7 | 46.73 | 530.75 |
| 8 | 49.63 | 531.51 |
| 9 | 52.46 | 532.53 |
| 10 | 55.17 | 533.81 |
| 11 | 57.75 | 535.33 |
| 12 | 60.18 | 537.09 |
| 13 | 62.44 | 539.06 |
| 14 | 64.51 | 541.24 |
| 15 | 66.36 | 543.60 |
| 16 | 67.99 | 546.12 |
| 17 | 69.38 | 548.78 |
| 18 | 70.51 | 551.55 |
| 19 | 71.39 | 554.42 |
| 20 | 71.99 | 557.36 |
| 21 | 72.23 | 559.50 |

Factor Of Safety For The Preceding Specified Surface =  2.882

Factor Of Safety Calculation Has Gone Through 30 Iterations,
without convergence

The Trial Failure Surface In Question Is Defined
By The Following 19 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 36.00 | 532.00 |
| 2 | 38.91 | 531.25 |
| 3 | 41.87 | 530.81 |
| 4 | 44.87 | 530.69 |
| 5 | 47.86 | 530.89 |
| 6 | 50.82 | 531.41 |
| 7 | 53.70 | 532.24 |
| 8 | 56.48 | 533.36 |
| 9 | 59.13 | 534.78 |
| 10 | 61.61 | 536.47 |
| 11 | 63.89 | 538.41 |
| 12 | 65.96 | 540.59 |
| 13 | 67.78 | 542.97 |
| 14 | 69.35 | 545.53 |
| 15 | 70.63 | 548.24 |
| 16 | 71.61 | 551.08 |
| 17 | 72.29 | 554.00 |
| 18 | 72.66 | 556.98 |
| 19 | 72.70 | 559.50 |

Factor Of Safety For The Preceding Specified Surface = -5.108

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 32 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 15.00 | 532.00 |
| 2 | 17.41 | 530.21 |
| 3 | 19.93 | 528.58 |
| 4 | 22.56 | 527.14 |
| 5 | 25.28 | 525.88 |
| 6 | 28.08 | 524.81 |
| 7 | 30.95 | 523.94 |
| 8 | 33.88 | 523.26 |
| 9 | 36.84 | 522.79 |
| 10 | 39.83 | 522.53 |
| 11 | 42.83 | 522.47 |
| 12 | 45.82 | 522.62 |
| 13 | 48.80 | 522.98 |
| 14 | 51.75 | 523.54 |
| 15 | 54.65 | 524.31 |
| 16 | 57.49 | 525.27 |
| 17 | 60.26 | 526.42 |
| 18 | 62.94 | 527.77 |
| 19 | 65.53 | 529.29 |
| 20 | 68.00 | 530.99 |
| 21 | 70.35 | 532.86 |
| 22 | 72.56 | 534.89 |
| 23 | 74.63 | 537.06 |
| 24 | 76.54 | 539.37 |
| 25 | 78.29 | 541.81 |
| 26 | 79.87 | 544.36 |
| 27 | 81.26 | 547.01 |
| 28 | 82.48 | 549.76 |
| 29 | 83.49 | 552.58 |
| 30 | 84.32 | 555.47 |
| 31 | 84.94 | 558.40 |
| 32 | 85.09 | 559.50 |

*** 1.644 ***

Individual data on the 36 slices

| Slice No. | Width (ft) | Weight (lbs) | Water Force Top (lbs) | Water Force Bot (lbs) | Force Norm (lbs) | Force Tan (lbs) | Earthquake Force Hor (lbs) | Earthquake Force Ver (lbs) | Surcharge Load (lbs) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.4 | 280.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 2.5 | 854.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 2.6 | 1414.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 2.7 | 1943.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 2.8 | 2425.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 2.9 | 2845.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 2.9 | 3192.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 3.0 | 3455.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 3.0 | 3627.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 3.0 | 3703.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 3.0 | 3681.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | 3.0 | 3561.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | 1.2 | 1386.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14 | 0.1 | 286.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | 1.6 | 7518.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 395.9 |
| 16 | 2.9 | 13019.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 696.3 |
| 17 | 2.8 | 12432.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 682.0 |
| 18 | 2.8 | 11731.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 664.4 |
| 19 | 2.7 | 10929.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 643.7 |
| 20 | 2.6 | 10043.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 619.9 |
| 21 | 2.5 | 9091.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 593.1 |
| 22 | 1.3 | 4432.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 303.7 |
| 23 | 0.0 | 129.3 | 0.0 | 0.0 | 108.3 | 136.2 | 0.0 | 0.0 | 9.0 |
| 24 | 0.1 | 335.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 24.0 |
| 25 | 0.9 | 3064.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 226.9 |
| 26 | 2.2 | 6807.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 531.3 |
| 27 | 2.1 | 5840.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 496.4 |
| 28 | 1.9 | 4888.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 459.3 |
| 29 | 1.7 | 3970.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 419.9 |
| 30 | 1.6 | 3107.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 378.5 |
| 31 | 1.4 | 2316.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 335.3 |
| 32 | 1.2 | 1614.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 290.6 |
| 33 | 1.0 | 1018.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 244.4 |
| 34 | 0.8 | 539.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 197.1 |
| 35 | 0.6 | 191.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 148.8 |
| 36 | 0.2 | 10.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 36.9 |

Individual data on the 27 geosynthetics

| Group | Level | Slice | Head Coordinates (ft) | | End Coordinates (ft) | | T (lbs) | Length (ft) | Tallow (lbs) | T/Tall % |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 50.1 | 559.5 | 69.4 | 559.5 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 2 | 0 | 50.1 | 558.4 | 69.4 | 558.4 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 3 | 0 | 50.1 | 557.4 | 69.4 | 557.4 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 4 | 0 | 50.1 | 556.3 | 69.4 | 556.3 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 5 | 0 | 50.1 | 555.3 | 69.4 | 555.3 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 6 | 0 | 50.1 | 554.2 | 69.4 | 554.2 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 7 | 0 | 50.1 | 553.2 | 69.4 | 553.2 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 8 | 0 | 50.1 | 552.1 | 69.4 | 552.1 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 9 | 0 | 50.1 | 551.0 | 69.4 | 551.0 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 10 | 0 | 50.1 | 550.0 | 69.4 | 550.0 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 11 | 0 | 50.1 | 548.9 | 69.4 | 548.9 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 12 | 0 | 50.1 | 547.9 | 69.4 | 547.9 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 13 | 0 | 50.1 | 546.8 | 69.4 | 546.8 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 14 | 0 | 50.0 | 545.8 | 69.3 | 545.8 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 15 | 0 | 50.0 | 544.7 | 69.3 | 544.7 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 16 | 0 | 50.0 | 543.6 | 69.3 | 543.6 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 17 | 0 | 50.0 | 542.6 | 69.3 | 542.6 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 18 | 0 | 50.0 | 541.5 | 69.3 | 541.5 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 19 | 0 | 50.0 | 540.5 | 69.3 | 540.5 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 20 | 0 | 50.0 | 539.4 | 69.3 | 539.4 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 21 | 0 | 50.0 | 538.3 | 69.3 | 538.3 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 22 | 0 | 50.0 | 537.3 | 69.3 | 537.3 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 23 | 0 | 50.0 | 536.2 | 69.3 | 536.2 | 0.0 | 19.3 | 7500.0 | 0.0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24 | 0 | 50.0 | 535.2 | 69.3 | 535.2 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 25 | 0 | 50.0 | 534.1 | 69.3 | 534.1 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 26 | 0 | 50.0 | 533.1 | 69.3 | 533.1 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 27 | 23 | 50.0 | 532.0 | 69.3 | 532.0 | 174.0 | 19.3 | 7500.0 | 2.3 |

Failure Surface Specified By 29 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 22.00 | 532.00 |
| 2 | 24.38 | 530.17 |
| 3 | 26.90 | 528.55 |
| 4 | 29.55 | 527.13 |
| 5 | 32.30 | 525.94 |
| 6 | 35.14 | 524.98 |
| 7 | 38.05 | 524.26 |
| 8 | 41.01 | 523.77 |
| 9 | 44.01 | 523.54 |
| 10 | 47.01 | 523.54 |
| 11 | 49.99 | 523.80 |
| 12 | 52.95 | 524.30 |
| 13 | 55.86 | 525.04 |
| 14 | 58.70 | 526.01 |
| 15 | 61.44 | 527.22 |
| 16 | 64.08 | 528.65 |
| 17 | 66.59 | 530.29 |
| 18 | 68.96 | 532.13 |
| 19 | 71.17 | 534.16 |
| 20 | 73.21 | 536.36 |
| 21 | 75.06 | 538.72 |
| 22 | 76.71 | 541.23 |
| 23 | 78.14 | 543.86 |
| 24 | 79.36 | 546.61 |
| 25 | 80.34 | 549.44 |
| 26 | 81.09 | 552.34 |
| 27 | 81.60 | 555.30 |
| 28 | 81.87 | 558.29 |
| 29 | 81.87 | 559.50 |

*** 1.677 ***

1

Failure Surface Specified By 30 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 24.00 | 532.00 |
| 2 | 26.65 | 530.59 |
| 3 | 29.38 | 529.35 |
| 4 | 32.19 | 528.29 |
| 5 | 35.06 | 527.41 |
| 6 | 37.97 | 526.72 |
| 7 | 40.93 | 526.22 |
| 8 | 43.92 | 525.91 |
| 9 | 46.91 | 525.79 |
| 10 | 49.91 | 525.86 |
| 11 | 52.90 | 526.13 |
| 12 | 55.87 | 526.59 |
| 13 | 58.80 | 527.24 |
| 14 | 61.68 | 528.07 |
| 15 | 64.50 | 529.09 |
| 16 | 67.25 | 530.29 |
| 17 | 69.92 | 531.66 |
| 18 | 72.49 | 533.20 |
| 19 | 74.96 | 534.90 |
| 20 | 77.32 | 536.76 |
| 21 | 79.55 | 538.76 |
| 22 | 81.65 | 540.91 |
| 23 | 83.60 | 543.18 |
| 24 | 85.41 | 545.58 |
| 25 | 87.06 | 548.08 |

| | | |
|---|---|---|
| 26 | 88.54 | 550.69 |
| 27 | 89.85 | 553.39 |
| 28 | 90.99 | 556.17 |
| 29 | 91.95 | 559.01 |
| 30 | 92.08 | 559.50 |

*** 1.684 ***

Failure Surface Specified By 31 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 21.00 | 532.00 |
| 2 | 23.63 | 530.56 |
| 3 | 26.35 | 529.28 |
| 4 | 29.13 | 528.17 |
| 5 | 31.98 | 527.23 |
| 6 | 34.88 | 526.46 |
| 7 | 37.82 | 525.87 |
| 8 | 40.79 | 525.46 |
| 9 | 43.78 | 525.22 |
| 10 | 46.78 | 525.17 |
| 11 | 49.78 | 525.30 |
| 12 | 52.77 | 525.61 |
| 13 | 55.73 | 526.10 |
| 14 | 58.65 | 526.77 |
| 15 | 61.53 | 527.61 |
| 16 | 64.35 | 528.62 |
| 17 | 67.11 | 529.81 |
| 18 | 69.79 | 531.16 |
| 19 | 72.38 | 532.66 |
| 20 | 74.88 | 534.32 |
| 21 | 77.27 | 536.13 |
| 22 | 79.55 | 538.08 |
| 23 | 81.71 | 540.17 |
| 24 | 83.74 | 542.38 |
| 25 | 85.63 | 544.71 |
| 26 | 87.38 | 547.15 |
| 27 | 88.97 | 549.69 |
| 28 | 90.42 | 552.32 |
| 29 | 91.69 | 555.03 |
| 30 | 92.81 | 557.82 |
| 31 | 93.36 | 559.50 |

*** 1.705 ***

1

Failure Surface Specified By 29 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 25.00 | 532.00 |
| 2 | 27.71 | 530.71 |
| 3 | 30.49 | 529.59 |
| 4 | 33.34 | 528.65 |
| 5 | 36.24 | 527.89 |
| 6 | 39.19 | 527.30 |
| 7 | 42.16 | 526.91 |
| 8 | 45.15 | 526.70 |
| 9 | 48.15 | 526.67 |
| 10 | 51.15 | 526.84 |
| 11 | 54.13 | 527.19 |
| 12 | 57.08 | 527.72 |
| 13 | 59.99 | 528.44 |
| 14 | 62.85 | 529.33 |
| 15 | 65.66 | 530.41 |
| 16 | 68.38 | 531.65 |

| | | |
|---|---|---|
| 17 | 71.03 | 533.07 |
| 18 | 73.58 | 534.64 |
| 19 | 76.03 | 536.37 |
| 20 | 78.37 | 538.26 |
| 21 | 80.59 | 540.28 |
| 22 | 82.67 | 542.44 |
| 23 | 84.62 | 544.72 |
| 24 | 86.42 | 547.12 |
| 25 | 88.06 | 549.63 |
| 26 | 89.55 | 552.23 |
| 27 | 90.88 | 554.92 |
| 28 | 92.03 | 557.69 |
| 29 | 92.65 | 559.50 |

*** 1.717 ***

Failure Surface Specified By 35 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 9.00 | 532.00 |
| 2 | 11.62 | 530.53 |
| 3 | 14.30 | 529.20 |
| 4 | 17.06 | 528.00 |
| 5 | 19.86 | 526.95 |
| 6 | 22.72 | 526.03 |
| 7 | 25.62 | 525.26 |
| 8 | 28.56 | 524.64 |
| 9 | 31.52 | 524.17 |
| 10 | 34.50 | 523.85 |
| 11 | 37.50 | 523.68 |
| 12 | 40.50 | 523.66 |
| 13 | 43.49 | 523.79 |
| 14 | 46.48 | 524.07 |
| 15 | 49.45 | 524.51 |
| 16 | 52.39 | 525.09 |
| 17 | 55.30 | 525.82 |
| 18 | 58.17 | 526.69 |
| 19 | 60.99 | 527.71 |
| 20 | 63.76 | 528.87 |
| 21 | 66.46 | 530.17 |
| 22 | 69.10 | 531.61 |
| 23 | 71.66 | 533.17 |
| 24 | 74.14 | 534.86 |
| 25 | 76.53 | 536.68 |
| 26 | 78.82 | 538.61 |
| 27 | 81.01 | 540.65 |
| 28 | 83.10 | 542.81 |
| 29 | 85.08 | 545.06 |
| 30 | 86.94 | 547.42 |
| 31 | 88.68 | 549.86 |
| 32 | 90.29 | 552.39 |
| 33 | 91.78 | 555.00 |
| 34 | 93.13 | 557.68 |
| 35 | 93.94 | 559.50 |

*** 1.735 ***

1

Failure Surface Specified By 31 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 23.00 | 532.00 |
| 2 | 25.41 | 530.21 |
| 3 | 27.94 | 528.60 |
| 4 | 30.58 | 527.18 |

| | | |
|---|---|---|
| 5 | 33.32 | 525.96 |
| 6 | 36.14 | 524.94 |
| 7 | 39.03 | 524.13 |
| 8 | 41.97 | 523.54 |
| 9 | 44.95 | 523.16 |
| 10 | 47.95 | 523.01 |
| 11 | 50.94 | 523.07 |
| 12 | 53.93 | 523.35 |
| 13 | 56.89 | 523.86 |
| 14 | 59.80 | 524.57 |
| 15 | 62.65 | 525.50 |
| 16 | 65.43 | 526.64 |
| 17 | 68.12 | 527.98 |
| 18 | 70.70 | 529.51 |
| 19 | 73.16 | 531.23 |
| 20 | 75.48 | 533.12 |
| 21 | 77.67 | 535.18 |
| 22 | 79.69 | 537.39 |
| 23 | 81.55 | 539.74 |
| 24 | 83.23 | 542.23 |
| 25 | 84.72 | 544.83 |
| 26 | 86.02 | 547.54 |
| 27 | 87.12 | 550.33 |
| 28 | 88.00 | 553.19 |
| 29 | 88.68 | 556.12 |
| 30 | 89.14 | 559.08 |
| 31 | 89.17 | 559.50 |

*** 1.744 ***

Failure Surface Specified By 30 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 25.00 | 532.00 |
| 2 | 27.76 | 530.82 |
| 3 | 30.58 | 529.79 |
| 4 | 33.45 | 528.93 |
| 5 | 36.37 | 528.22 |
| 6 | 39.32 | 527.68 |
| 7 | 42.29 | 527.31 |
| 8 | 45.29 | 527.10 |
| 9 | 48.29 | 527.06 |
| 10 | 51.28 | 527.19 |
| 11 | 54.27 | 527.48 |
| 12 | 57.23 | 527.95 |
| 13 | 60.17 | 528.57 |
| 14 | 63.06 | 529.36 |
| 15 | 65.91 | 530.31 |
| 16 | 68.70 | 531.42 |
| 17 | 71.42 | 532.68 |
| 18 | 74.07 | 534.09 |
| 19 | 76.63 | 535.65 |
| 20 | 79.10 | 537.34 |
| 21 | 81.48 | 539.18 |
| 22 | 83.75 | 541.14 |
| 23 | 85.90 | 543.23 |
| 24 | 87.94 | 545.43 |
| 25 | 89.85 | 547.74 |
| 26 | 91.62 | 550.16 |
| 27 | 93.26 | 552.67 |
| 28 | 94.76 | 555.27 |
| 29 | 96.11 | 557.95 |
| 30 | 96.78 | 559.50 |

*** 1.767 ***

1

Failure Surface Specified By 31 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 20.00 | 532.00 |
| 2 | 22.22 | 529.98 |
| 3 | 24.59 | 528.14 |
| 4 | 27.10 | 526.49 |
| 5 | 29.73 | 525.05 |
| 6 | 32.46 | 523.82 |
| 7 | 35.29 | 522.81 |
| 8 | 38.19 | 522.03 |
| 9 | 41.13 | 521.48 |
| 10 | 44.12 | 521.17 |
| 11 | 47.12 | 521.09 |
| 12 | 50.11 | 521.25 |
| 13 | 53.09 | 521.65 |
| 14 | 56.02 | 522.28 |
| 15 | 58.89 | 523.14 |
| 16 | 61.69 | 524.23 |
| 17 | 64.39 | 525.54 |
| 18 | 66.98 | 527.05 |
| 19 | 69.44 | 528.77 |
| 20 | 71.76 | 530.67 |
| 21 | 73.92 | 532.76 |
| 22 | 75.90 | 535.00 |
| 23 | 77.71 | 537.40 |
| 24 | 79.32 | 539.93 |
| 25 | 80.72 | 542.58 |
| 26 | 81.91 | 545.34 |
| 27 | 82.87 | 548.18 |
| 28 | 83.61 | 551.09 |
| 29 | 84.11 | 554.04 |
| 30 | 84.38 | 557.03 |
| 31 | 84.41 | 559.50 |

*** 1.767 ***

Failure Surface Specified By 29 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 27.00 | 532.00 |
| 2 | 29.41 | 530.21 |
| 3 | 31.95 | 528.61 |
| 4 | 34.61 | 527.23 |
| 5 | 37.37 | 526.06 |
| 6 | 40.22 | 525.12 |
| 7 | 43.14 | 524.41 |
| 8 | 46.10 | 523.94 |
| 9 | 49.09 | 523.71 |
| 10 | 52.09 | 523.71 |
| 11 | 55.08 | 523.96 |
| 12 | 58.04 | 524.45 |
| 13 | 60.95 | 525.17 |
| 14 | 63.80 | 526.12 |
| 15 | 66.55 | 527.30 |
| 16 | 69.21 | 528.70 |
| 17 | 71.74 | 530.30 |
| 18 | 74.14 | 532.11 |
| 19 | 76.39 | 534.10 |
| 20 | 78.47 | 536.26 |
| 21 | 80.36 | 538.58 |
| 22 | 82.07 | 541.05 |
| 23 | 83.57 | 543.65 |
| 24 | 84.86 | 546.36 |
| 25 | 85.93 | 549.16 |
| 26 | 86.77 | 552.04 |
| 27 | 87.37 | 554.98 |
| 28 | 87.74 | 557.96 |
| 29 | 87.80 | 559.50 |

```
        ***     1.768   ***


1
                 Y            A      X      I      S            F      T

                 0.00    130.95    261.89    392.84    523.79    654.73
          X       0.00 +---------+---------+---------+--------*.*--------+
                       -                                      .11
                       -                                      .1G G/1
                       -                                      .1g.g
                       -                                      ..111
                       -                                       ....
                130.95 +                                      * * *1/
                       -
                       -
                       -
                       -
                       -
          A     261.89 +
                       -
                       -
                       -
                       -
                       -
          X     392.84 +
                       -
                       -
                       -
                       -
                       -
          I     523.79 +
                       -
                       -
                       -
                       -
                       -
          S     654.73 +
                       -
                       -
                       -
                       -
                       -
                785.68 +
                       -
                       -
                       -
                       -
                       -
          F     916.63 +
                       -
                       -
                       -
                       -
                       -
          T    1047.58 +
```

** STABL for WINDOWS **
by
Geotechnical Software Solutions

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:
Time of Run:
Run By:
Input Data Filename: run.in
Output Filename: result.out
Unit: U.S.C.
Plotted Output Filename: result.plt

PROBLEM DESCRIPTION B-10-020 - HAM-75-7.85 - HAM-562-0004 - Rear Abutment

BOUNDARY COORDINATES

4 Top Boundaries
9 Total Boundaries

| Boundary No. | X-Left (ft) | Y-Left (ft) | X-Right (ft) | Y-Right (ft) | Soil Type Below Bnd |
|---|---|---|---|---|---|
| 1 | 0.00 | 532.00 | 50.00 | 532.00 | 3 |
| 2 | 50.00 | 532.00 | 50.10 | 559.50 | 1 |
| 3 | 50.10 | 559.50 | 69.40 | 559.50 | 1 |
| 4 | 69.40 | 559.50 | 130.00 | 559.50 | 2 |
| 5 | 50.00 | 532.00 | 69.30 | 532.00 | 3 |
| 6 | 69.30 | 532.00 | 69.40 | 559.50 | 2 |
| 7 | 69.30 | 532.00 | 130.00 | 532.00 | 3 |
| 8 | 0.00 | 512.50 | 130.00 | 512.50 | 4 |
| 9 | 0.00 | 507.50 | 130.00 | 507.50 | 5 |

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

| Soil Type No. | Total Unit Wt. (pcf) | Saturated Unit Wt. (pcf) | Cohesion Intercept (psf) | Friction Angle (deg) | Pore Pressure Param. | Pressure Constant (psf) | Piez. Surface No. |
|---|---|---|---|---|---|---|---|
| 1 | 125.0 | 130.0 | 0.0 | 34.0 | 0.00 | 0.0 | 1 |
| 2 | 120.0 | 130.0 | 2000.0 | 0.0 | 0.00 | 0.0 | 1 |
| 3 | 130.0 | 135.0 | 0.0 | 31.0 | 0.00 | 0.0 | 1 |
| 4 | 120.0 | 125.0 | 0.0 | 28.0 | 0.00 | 0.0 | 1 |
| 5 | 120.0 | 130.0 | 3000.0 | 0.0 | 0.00 | 0.0 | 1 |

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 2 Coordinate Points

| Point No. | X-Water (ft) | Y-Water (ft) |
|---|---|---|

| | | |
|---|---|---|
| 1 | 0.00 | 505.10 |
| 2 | 130.00 | 505.10 |

1

BOUNDARY LOAD(S)

1 Load(s) Specified

| Load No. | X-Left (ft) | X-Right (ft) | Intensity (psf) | Deflection (deg) |
|---|---|---|---|---|
| 1 | 50.10 | 130.00 | 240.0 | 1.0 |

NOTE - Intensity Is Specified As A Uniformly Distributed
Force Acting On A Horizontally Projected Surface.

GEOSYNTHETIC DATA

1 Geosynthetics(s) group(s) specified

| Ngroup no | Bnr no | Y-top (ft) | Y-bot (ft) | Levels no | Length (ft) | Spacing (ft) | Efficiency | Tallow (lbs/ft) |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 532.0 | 559.5 | 27 | 19.3 | -1.06 | 1.0 | 7500.0 |

1

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.

500 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 50 Points Equally Spaced
Along The Ground Surface Between X = 0.00 ft.
and X = 49.00 ft.

Each Surface Terminates Between X = 70.00 ft.
and X = 120.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =500.00 ft.

3.00 ft. Line Segments Define Each Trial Failure Surface.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 35 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 9.00 | 532.00 |
| 2 | 11.62 | 530.53 |
| 3 | 14.30 | 529.20 |
| 4 | 17.06 | 528.00 |

| | | |
|---|---|---|
| 5 | 19.86 | 526.95 |
| 6 | 22.72 | 526.03 |
| 7 | 25.62 | 525.26 |
| 8 | 28.56 | 524.64 |
| 9 | 31.52 | 524.17 |
| 10 | 34.50 | 523.85 |
| 11 | 37.50 | 523.68 |
| 12 | 40.50 | 523.66 |
| 13 | 43.49 | 523.79 |
| 14 | 46.48 | 524.07 |
| 15 | 49.45 | 524.51 |
| 16 | 52.39 | 525.09 |
| 17 | 55.30 | 525.82 |
| 18 | 58.17 | 526.69 |
| 19 | 60.99 | 527.71 |
| 20 | 63.76 | 528.87 |
| 21 | 66.46 | 530.17 |
| 22 | 69.10 | 531.61 |
| 23 | 71.66 | 533.17 |
| 24 | 74.14 | 534.86 |
| 25 | 76.53 | 536.68 |
| 26 | 78.82 | 538.61 |
| 27 | 81.01 | 540.65 |
| 28 | 83.10 | 542.81 |
| 29 | 85.08 | 545.06 |
| 30 | 86.94 | 547.42 |
| 31 | 88.68 | 549.86 |
| 32 | 90.29 | 552.39 |
| 33 | 91.78 | 555.00 |
| 34 | 93.13 | 557.68 |
| 35 | 93.94 | 559.50 |

*** 2.469 ***

Individual data on the 39 slices

| Slice No. | Width (ft) | Weight (lbs) | Water Force Top (lbs) | Water Force Bot (lbs) | Force Norm (lbs) | Force Tan (lbs) | Earthquake Force Hor (lbs) | Earthquake Force Ver (lbs) | Surcharge Load (lbs) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.6 | 249.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 2.7 | 745.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 2.8 | 1215.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 2.8 | 1652.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 2.9 | 2047.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 2.9 | 2394.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 2.9 | 2688.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 3.0 | 2924.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 3.0 | 3097.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 3.0 | 3206.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 3.0 | 3249.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | 3.0 | 3224.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | 3.0 | 3132.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 14 | 3.0 | 2975.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | 0.6 | 533.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 16 | 0.1 | 267.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17 | 2.3 | 10003.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 550.0 |
| 18 | 2.9 | 12479.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 698.4 |
| 19 | 2.9 | 12005.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 688.6 |
| 20 | 2.8 | 11458.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 677.2 |
| 21 | 2.8 | 10842.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 664.0 |
| 22 | 2.7 | 10167.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 649.1 |
| 23 | 2.6 | 9440.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 632.5 |
| 24 | 0.2 | 700.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 48.3 |
| 25 | 0.1 | 340.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 24.0 |
| 26 | 0.3 | 1138.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 82.5 |
| 27 | 1.9 | 6184.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 459.6 |
| 28 | 2.5 | 7577.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 594.6 |
| 29 | 2.4 | 6803.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 573.4 |
| 30 | 2.3 | 6018.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 550.7 |
| 31 | 2.2 | 5231.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 526.6 |
| 32 | 2.1 | 4452.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 501.2 |
| 33 | 2.0 | 3692.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 474.5 |
| 34 | 1.9 | 2960.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 446.5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 35 | 1.7 | 2266.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 417.5 |
| 36 | 1.6 | 1621.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 387.4 |
| 37 | 1.5 | 1034.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 356.3 |
| 38 | 1.4 | 512.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 324.2 |
| 39 | 0.8 | 88.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 193.7 |

Individual data on the 27 geosynthetics

| Group | Level | Slice | Head Coordinates (ft) | | End Coordinates (ft) | | T (lbs) | Length (ft) | Tallow (lbs) | T/Tall % |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 50.1 | 559.5 | 69.4 | 559.5 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 2 | 0 | 50.1 | 558.4 | 69.4 | 558.4 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 3 | 0 | 50.1 | 557.4 | 69.4 | 557.4 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 4 | 0 | 50.1 | 556.3 | 69.4 | 556.3 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 5 | 0 | 50.1 | 555.3 | 69.4 | 555.3 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 6 | 0 | 50.1 | 554.2 | 69.4 | 554.2 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 7 | 0 | 50.1 | 553.2 | 69.4 | 553.2 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 8 | 0 | 50.1 | 552.1 | 69.4 | 552.1 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 9 | 0 | 50.1 | 551.0 | 69.4 | 551.0 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 10 | 0 | 50.1 | 550.0 | 69.4 | 550.0 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 11 | 0 | 50.1 | 548.9 | 69.4 | 548.9 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 12 | 0 | 50.1 | 547.9 | 69.4 | 547.9 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 13 | 0 | 50.1 | 546.8 | 69.4 | 546.8 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 14 | 0 | 50.0 | 545.8 | 69.3 | 545.8 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 15 | 0 | 50.0 | 544.7 | 69.3 | 544.7 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 16 | 0 | 50.0 | 543.6 | 69.3 | 543.6 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 17 | 0 | 50.0 | 542.6 | 69.3 | 542.6 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 18 | 0 | 50.0 | 541.5 | 69.3 | 541.5 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 19 | 0 | 50.0 | 540.5 | 69.3 | 540.5 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 20 | 0 | 50.0 | 539.4 | 69.3 | 539.4 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 21 | 0 | 50.0 | 538.3 | 69.3 | 538.3 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 22 | 0 | 50.0 | 537.3 | 69.3 | 537.3 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 23 | 0 | 50.0 | 536.2 | 69.3 | 536.2 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 24 | 0 | 50.0 | 535.2 | 69.3 | 535.2 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 25 | 0 | 50.0 | 534.1 | 69.3 | 534.1 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 26 | 0 | 50.0 | 533.1 | 69.3 | 533.1 | 0.0 | 19.3 | 7500.0 | 0.0 |
| 1 | 27 | 0 | 50.0 | 532.0 | 69.3 | 532.0 | 0.0 | 19.3 | 7500.0 | 0.0 |

Failure Surface Specified By 35 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 13.00 | 532.00 |
| 2 | 15.58 | 530.47 |
| 3 | 18.24 | 529.09 |
| 4 | 20.97 | 527.84 |
| 5 | 23.77 | 526.75 |
| 6 | 26.61 | 525.80 |
| 7 | 29.50 | 525.00 |
| 8 | 32.43 | 524.36 |
| 9 | 35.39 | 523.87 |
| 10 | 38.38 | 523.54 |
| 11 | 41.37 | 523.37 |
| 12 | 44.37 | 523.35 |
| 13 | 47.37 | 523.50 |
| 14 | 50.35 | 523.80 |
| 15 | 53.32 | 524.26 |
| 16 | 56.25 | 524.88 |
| 17 | 59.15 | 525.65 |
| 18 | 62.01 | 526.57 |
| 19 | 64.81 | 527.65 |
| 20 | 67.55 | 528.87 |
| 21 | 70.22 | 530.23 |
| 22 | 72.82 | 531.73 |
| 23 | 75.33 | 533.37 |
| 24 | 77.76 | 535.14 |
| 25 | 80.08 | 537.03 |
| 26 | 82.31 | 539.05 |
| 27 | 84.42 | 541.17 |
| 28 | 86.42 | 543.41 |
| 29 | 88.30 | 545.75 |
| 30 | 90.05 | 548.19 |
| 31 | 91.67 | 550.71 |
| 32 | 93.15 | 553.32 |

| | | |
|---|---|---|
| 33 | 94.49 | 556.00 |
| 34 | 95.69 | 558.75 |
| 35 | 95.97 | 559.50 |

*** 2.520 ***

1

Failure Surface Specified By 40 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 1.00 | 532.00 |
| 2 | 3.59 | 530.48 |
| 3 | 6.24 | 529.07 |
| 4 | 8.94 | 527.78 |
| 5 | 11.70 | 526.60 |
| 6 | 14.51 | 525.55 |
| 7 | 17.36 | 524.62 |
| 8 | 20.25 | 523.81 |
| 9 | 23.17 | 523.13 |
| 10 | 26.12 | 522.57 |
| 11 | 29.09 | 522.14 |
| 12 | 32.08 | 521.84 |
| 13 | 35.07 | 521.67 |
| 14 | 38.07 | 521.63 |
| 15 | 41.07 | 521.72 |
| 16 | 44.06 | 521.93 |
| 17 | 47.04 | 522.28 |
| 18 | 50.00 | 522.75 |
| 19 | 52.94 | 523.36 |
| 20 | 55.85 | 524.08 |
| 21 | 58.73 | 524.94 |
| 22 | 61.57 | 525.91 |
| 23 | 64.36 | 527.01 |
| 24 | 67.10 | 528.23 |
| 25 | 69.79 | 529.56 |
| 26 | 72.41 | 531.01 |
| 27 | 74.98 | 532.57 |
| 28 | 77.47 | 534.24 |
| 29 | 79.89 | 536.02 |
| 30 | 82.22 | 537.90 |
| 31 | 84.48 | 539.87 |
| 32 | 86.65 | 541.95 |
| 33 | 88.73 | 544.11 |
| 34 | 90.71 | 546.37 |
| 35 | 92.59 | 548.70 |
| 36 | 94.37 | 551.12 |
| 37 | 96.04 | 553.61 |
| 38 | 97.61 | 556.17 |
| 39 | 99.06 | 558.79 |
| 40 | 99.41 | 559.50 |

*** 2.525 ***

Failure Surface Specified By 40 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 0.00 | 532.00 |
| 2 | 2.69 | 530.66 |
| 3 | 5.42 | 529.43 |
| 4 | 8.20 | 528.31 |
| 5 | 11.03 | 527.29 |
| 6 | 13.89 | 526.39 |
| 7 | 16.78 | 525.60 |
| 8 | 19.70 | 524.92 |
| 9 | 22.65 | 524.35 |

| | | |
|---|---|---|
| 10 | 25.61 | 523.90 |
| 11 | 28.59 | 523.56 |
| 12 | 31.59 | 523.34 |
| 13 | 34.58 | 523.23 |
| 14 | 37.58 | 523.24 |
| 15 | 40.58 | 523.37 |
| 16 | 43.57 | 523.61 |
| 17 | 46.55 | 523.97 |
| 18 | 49.51 | 524.45 |
| 19 | 52.45 | 525.03 |
| 20 | 55.37 | 525.74 |
| 21 | 58.26 | 526.55 |
| 22 | 61.11 | 527.48 |
| 23 | 63.93 | 528.51 |
| 24 | 66.70 | 529.65 |
| 25 | 69.43 | 530.90 |
| 26 | 72.11 | 532.26 |
| 27 | 74.73 | 533.72 |
| 28 | 77.29 | 535.28 |
| 29 | 79.79 | 536.93 |
| 30 | 82.23 | 538.68 |
| 31 | 84.59 | 540.53 |
| 32 | 86.89 | 542.47 |
| 33 | 89.10 | 544.49 |
| 34 | 91.24 | 546.59 |
| 35 | 93.29 | 548.78 |
| 36 | 95.25 | 551.05 |
| 37 | 97.13 | 553.39 |
| 38 | 98.92 | 555.80 |
| 39 | 100.61 | 558.28 |
| 40 | 101.37 | 559.50 |

*** 2.527 ***

1

Failure Surface Specified By 36 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 10.00 | 532.00 |
| 2 | 12.52 | 530.37 |
| 3 | 15.12 | 528.88 |
| 4 | 17.80 | 527.53 |
| 5 | 20.55 | 526.32 |
| 6 | 23.35 | 525.25 |
| 7 | 26.21 | 524.34 |
| 8 | 29.11 | 523.57 |
| 9 | 32.05 | 522.96 |
| 10 | 35.01 | 522.50 |
| 11 | 37.99 | 522.20 |
| 12 | 40.99 | 522.05 |
| 13 | 43.99 | 522.06 |
| 14 | 46.99 | 522.23 |
| 15 | 49.97 | 522.56 |
| 16 | 52.93 | 523.04 |
| 17 | 55.86 | 523.67 |
| 18 | 58.76 | 524.46 |
| 19 | 61.61 | 525.40 |
| 20 | 64.40 | 526.49 |
| 21 | 67.14 | 527.72 |
| 22 | 69.80 | 529.09 |
| 23 | 72.40 | 530.60 |
| 24 | 74.91 | 532.25 |
| 25 | 77.32 | 534.02 |
| 26 | 79.65 | 535.92 |
| 27 | 81.87 | 537.94 |
| 28 | 83.98 | 540.07 |
| 29 | 85.98 | 542.31 |
| 30 | 87.85 | 544.65 |
| 31 | 89.61 | 547.08 |
| 32 | 91.23 | 549.61 |
| 33 | 92.72 | 552.21 |
| 34 | 94.06 | 554.89 |

| | | |
|---|---|---|
| 35 | 95.27 | 557.64 |
| 36 | 95.97 | 559.50 |

*** 2.543 ***

Failure Surface Specified By 38 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 9.00 | 532.00 |
| 2 | 11.68 | 530.65 |
| 3 | 14.41 | 529.41 |
| 4 | 17.19 | 528.28 |
| 5 | 20.02 | 527.27 |
| 6 | 22.88 | 526.39 |
| 7 | 25.78 | 525.62 |
| 8 | 28.71 | 524.98 |
| 9 | 31.67 | 524.46 |
| 10 | 34.64 | 524.06 |
| 11 | 37.63 | 523.79 |
| 12 | 40.63 | 523.65 |
| 13 | 43.63 | 523.63 |
| 14 | 46.62 | 523.73 |
| 15 | 49.61 | 523.97 |
| 16 | 52.59 | 524.33 |
| 17 | 55.55 | 524.81 |
| 18 | 58.49 | 525.42 |
| 19 | 61.40 | 526.15 |
| 20 | 64.28 | 527.00 |
| 21 | 67.12 | 527.97 |
| 22 | 69.91 | 529.06 |
| 23 | 72.66 | 530.27 |
| 24 | 75.35 | 531.59 |
| 25 | 77.99 | 533.02 |
| 26 | 80.56 | 534.56 |
| 27 | 83.07 | 536.21 |
| 28 | 85.50 | 537.96 |
| 29 | 87.86 | 539.82 |
| 30 | 90.14 | 541.77 |
| 31 | 92.33 | 543.81 |
| 32 | 94.44 | 545.95 |
| 33 | 96.46 | 548.17 |
| 34 | 98.38 | 550.47 |
| 35 | 100.20 | 552.86 |
| 36 | 101.92 | 555.32 |
| 37 | 103.54 | 557.84 |
| 38 | 104.50 | 559.50 |

*** 2.556 ***

1

Failure Surface Specified By 39 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 3.00 | 532.00 |
| 2 | 5.48 | 530.31 |
| 3 | 8.04 | 528.74 |
| 4 | 10.67 | 527.30 |
| 5 | 13.37 | 525.99 |
| 6 | 16.13 | 524.81 |
| 7 | 18.94 | 523.77 |
| 8 | 21.80 | 522.86 |
| 9 | 24.70 | 522.09 |
| 10 | 27.63 | 521.46 |
| 11 | 30.59 | 520.97 |
| 12 | 33.57 | 520.63 |

| | | |
|---|---|---|
| 13 | 36.56 | 520.43 |
| 14 | 39.56 | 520.38 |
| 15 | 42.56 | 520.47 |
| 16 | 45.55 | 520.71 |
| 17 | 48.53 | 521.09 |
| 18 | 51.48 | 521.62 |
| 19 | 54.41 | 522.28 |
| 20 | 57.30 | 523.09 |
| 21 | 60.14 | 524.04 |
| 22 | 62.94 | 525.12 |
| 23 | 65.68 | 526.34 |
| 24 | 68.36 | 527.68 |
| 25 | 70.98 | 529.16 |
| 26 | 73.51 | 530.76 |
| 27 | 75.97 | 532.48 |
| 28 | 78.34 | 534.32 |
| 29 | 80.62 | 536.27 |
| 30 | 82.80 | 538.33 |
| 31 | 84.89 | 540.49 |
| 32 | 86.86 | 542.75 |
| 33 | 88.72 | 545.10 |
| 34 | 90.47 | 547.54 |
| 35 | 92.10 | 550.06 |
| 36 | 93.60 | 552.65 |
| 37 | 94.97 | 555.32 |
| 38 | 96.22 | 558.05 |
| 39 | 96.80 | 559.50 |

*** 2.558 ***

Failure Surface Specified By 30 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 25.00 | 532.00 |
| 2 | 27.76 | 530.82 |
| 3 | 30.58 | 529.79 |
| 4 | 33.45 | 528.93 |
| 5 | 36.37 | 528.22 |
| 6 | 39.32 | 527.68 |
| 7 | 42.29 | 527.31 |
| 8 | 45.29 | 527.10 |
| 9 | 48.29 | 527.06 |
| 10 | 51.28 | 527.19 |
| 11 | 54.27 | 527.48 |
| 12 | 57.23 | 527.95 |
| 13 | 60.17 | 528.57 |
| 14 | 63.06 | 529.36 |
| 15 | 65.91 | 530.31 |
| 16 | 68.70 | 531.42 |
| 17 | 71.42 | 532.68 |
| 18 | 74.07 | 534.09 |
| 19 | 76.63 | 535.65 |
| 20 | 79.10 | 537.34 |
| 21 | 81.48 | 539.18 |
| 22 | 83.75 | 541.14 |
| 23 | 85.90 | 543.23 |
| 24 | 87.94 | 545.43 |
| 25 | 89.85 | 547.74 |
| 26 | 91.62 | 550.16 |
| 27 | 93.26 | 552.67 |
| 28 | 94.76 | 555.27 |
| 29 | 96.11 | 557.95 |
| 30 | 96.78 | 559.50 |

*** 2.563 ***

1

Failure Surface Specified By 40 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 2.00 | 532.00 |
| 2 | 4.74 | 530.77 |
| 3 | 7.52 | 529.65 |
| 4 | 10.34 | 528.63 |
| 5 | 13.19 | 527.70 |
| 6 | 16.08 | 526.89 |
| 7 | 19.00 | 526.18 |
| 8 | 21.93 | 525.57 |
| 9 | 24.89 | 525.07 |
| 10 | 27.87 | 524.68 |
| 11 | 30.85 | 524.40 |
| 12 | 33.85 | 524.23 |
| 13 | 36.85 | 524.16 |
| 14 | 39.85 | 524.20 |
| 15 | 42.84 | 524.36 |
| 16 | 45.83 | 524.62 |
| 17 | 48.81 | 524.99 |
| 18 | 51.77 | 525.46 |
| 19 | 54.71 | 526.05 |
| 20 | 57.63 | 526.74 |
| 21 | 60.53 | 527.53 |
| 22 | 63.39 | 528.43 |
| 23 | 66.22 | 529.44 |
| 24 | 69.00 | 530.54 |
| 25 | 71.75 | 531.75 |
| 26 | 74.45 | 533.05 |
| 27 | 77.11 | 534.45 |
| 28 | 79.71 | 535.95 |
| 29 | 82.25 | 537.54 |
| 30 | 84.73 | 539.22 |
| 31 | 87.16 | 540.99 |
| 32 | 89.51 | 542.85 |
| 33 | 91.80 | 544.79 |
| 34 | 94.01 | 546.81 |
| 35 | 96.15 | 548.91 |
| 36 | 98.22 | 551.09 |
| 37 | 100.20 | 553.34 |
| 38 | 102.10 | 555.67 |
| 39 | 103.91 | 558.06 |
| 40 | 104.93 | 559.50 |

*** 2.565 ***

Failure Surface Specified By 40 Coordinate Points

| Point No. | X-Surf (ft) | Y-Surf (ft) |
|---|---|---|
| 1 | 3.00 | 532.00 |
| 2 | 5.57 | 530.45 |
| 3 | 8.20 | 529.02 |
| 4 | 10.90 | 527.69 |
| 5 | 13.64 | 526.49 |
| 6 | 16.44 | 525.40 |
| 7 | 19.28 | 524.44 |
| 8 | 22.16 | 523.59 |
| 9 | 25.07 | 522.87 |
| 10 | 28.01 | 522.28 |
| 11 | 30.98 | 521.81 |
| 12 | 33.96 | 521.47 |
| 13 | 36.95 | 521.25 |
| 14 | 39.95 | 521.17 |
| 15 | 42.95 | 521.21 |
| 16 | 45.94 | 521.38 |
| 17 | 48.93 | 521.68 |
| 18 | 51.90 | 522.11 |
| 19 | 54.85 | 522.66 |
| 20 | 57.77 | 523.34 |
| 21 | 60.66 | 524.14 |

```
             22          63.51      525.07
             23          66.32      526.12
             24          69.09      527.29
             25          71.80      528.57
             26          74.45      529.97
             27          77.04      531.48
             28          79.57      533.10
             29          82.02      534.83
             30          84.40      536.66
             31          86.69      538.59
             32          88.91      540.61
             33          91.03      542.73
             34          93.06      544.94
             35          94.99      547.24
             36          96.83      549.61
             37          98.56      552.06
             38         100.18      554.58
             39         101.70      557.17
             40         102.93      559.50

                ***     2.567   ***


1
                     Y            A     X     I     S            F     T


                     0.00    130.95    261.89    392.84    523.79    654.73

          X      0.00 +---------+---------+---------+--------*3*--------+
                      -                                       .11
                      -                                       .1G G/1
                      -                                       .1g.g
                      -                                       ..111
                      -                                        ..43
               130.95 +                                       * * *1/
                      -
                      -
                      -
                      -
                      -
          A    261.89 +
                      -
                      -
                      -
                      -
                      -
          X    392.84 +
                      -
                      -
                      -
                      -
                      -
          I    523.79 +
                      -
                      -
                      -
                      -
                      -
          S    654.73 +
                      -
                      -
                      -
                      -
                      -
               785.68 +
                      -
                      -
                      -
                      -
                      -
          F    916.63 +
                      -
                      -
                      -
                      -
```

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              -
T   1047.58 +
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