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DESIGN MEMORANDUM

Date: April 9, 2025

To: Mr. Vince Amato, Burgess & Niple, Inc.

From: Brendan P. Andrews P.E., NEAS Inc.

RE: **Geotechnical Design Memorandum**
Project HAM-75-1.05, PID 113361/122048
Bridge HAM-75-0104 (Linn St over Gest St & Interstate Route 75) Replacement
City of Cincinnati, Hamilton County, Ohio

INTRODUCTION

Per your request, this memorandum presents preliminary foundation design information for the proposed Bridge HAM-75-0104 replacement as part of the overall Ohio Department of Transportation (ODOT) HAM-75-1.05 (PID 113361) project located in the City of Cincinnati, Hamilton County, Ohio. A summary of: 1) the proposed replacement structure; 2) the existing site conditions; 3) the surficial and subsurface conditions via historical and project borings; and, 4) our preliminary recommendations for bridge foundation design is presented below.

NEAS's preliminary analyses have been performed in accordance with Load and Resistance Factor Design (LRFD) method as set forth in AASHTO's Publication LRFD Bridge Design Specifications, 9th Edition (BDS) (AASHTO, 2020) and ODOT's 2021 LRFD Bridge Design Manual (BDM) (ODOT, 2021).

PROPOSED/EXISTING SITE CONDITIONS

Proposed Construction

The existing Bridge HAM-75-0104 consists of a seven-span, continuous steel beam bridge originally built in 1961. The referenced bridge carries Linn Street (St) over Gest St and Interstate Route 75 (IR-75) and is about 420 ft in length (abutment to abutment) with an approximate roadway width of 70 ft (curb to curb). The structure carries five lanes of traffic on a reinforced concrete bridge deck supported by concrete substructures. As IR-75 and portions of Gest St are planned to be realigned/widened as part of the overall project, Bridge HAM-75-0104 is planned to be replaced with a shortened structure to traverse the new IR-75 and Gest St alignments. Based on the proposed Bridge HAM-75-0104 Stage 2/3 site plan developed by Burgess & Niple, Inc. (B&N) dated January 6, 2025, the new structure will be three spans in total, with a single span rolled beam unit as well as a two span continuous steel plate girder unit. The proposed bridge will have a composite reinforced concrete deck supported by a mechanically stabilized earth (MSE) wall stub abutments at the abutments and cap and column type piers. Each substructure will utilize a deep foundation system consisting of driven cast-in-place (CIP) reinforced concrete pipe piles. The proposed bridge will be approximately 383 ft in length (abutment to abutment) with a roadway width of 70 ft (curb to curb) as well as a sidewalk and bike path, each 5-ft in width.

Historical Records

A historic record search was performed through ODOT's Transportation Information Mapping System (TIMS). The following report/plans were available for review and evaluation for this report:

- Structure Foundation Exploration sheets prepared as part of State of Ohio Department of Highways project HAM-25-0.83 for Bridge No. HAM-25-0105 – Mill Creek Expressway Under Linn St, prepared by Vogt. Ivers. Seaman & Associates, dated November 1959.

Seven (7) historical soil borings that were drilled as part of the above indicated 1959 subsurface investigation for Bridge Structure HAM-25-0105 were reviewed and considered in our evaluation of the proposed bridge foundations. A summary of the utilized historic boring information (location, elevation, etc.) is provided in Table 1 below.

Table 1: Historical Boring Summary

Boring Number	Latitude	Longitude	Elevation (NAVD 88) (ft)	Depth (ft)	Proposed Substructure
B-003-A-59	39.104162	-84.529160	511.1	36.5	Rear Abutment
B-003-B-59	39.104235	-84.529069	510.7	51.5	Rear Abutment
B-003-D-59	39.104516	-84.528998	509.3	51.5	Pier 1
B-003-E-59	39.104751	-84.528841	508.6	40.5	Pier 2
B-003-F-59	39.105093	-84.528759	508.4	76.5	Forward Abutment
B-003-G-59	39.105087	-84.528545	508.9	50.0	Forward Abutment
B-003-H-59	39.105180	-84.528486	508.7	51.5	Forward Abutment

Notes:
1. Based on locations as mapped in ODOT's Transportation Information Mapping System (TIMS).

Site Reconnaissance

A field reconnaissance visit for the HAM-75-0104 bridge was conducted on January 17, 2022, during which site conditions were noted and photographed. During our field reconnaissance, no geohazards were observed within the immediate vicinity of the proposed bridge site. Land use of the area surrounding the proposed project site can be described as a mix of commercial and institutional properties.

The existing bridge carrying Linn St over IR-75 consists of a seven-span, steel multi-beam bridge with stub type abutments and cap and column piers. The existing Linn St bridge abutments are supported on embankments atop cut slopes which IR-75 is situated within. The indicated slopes were observed to be about 3 Horizontal to 1 Vertical (3H:1V). Besides the referenced slopes, the surrounding land in the area of the referenced bridge and IR-75 was relatively flat. The overall bridge structure appeared to be in fair to good condition with some signs of distress observed. The underside of the bridge deck was observed to be in relatively good condition with minor signs of spalling observed (Photograph 1). The abutments appeared to be in fair to poor condition with signs of wear such as spalling, cracking and exposed rebar (Photograph 2). The piers appeared to be in good condition with some signs of patching observed (Photograph 3). The spill-through slopes appeared to be protected with riprap and did not show significant signs of erosion (Photograph 3). No apparent signs of distress due to geotechnical concerns were noted during our field reconnaissance visit.

The bridge deck and concrete wearing course was observed to be in good condition with occasional spalling and pop outs. With respect to drainage, the bridge deck and adjacent pavement appeared to be well drained, with no signs of ponding or drainage issues observed during our field visit. The adjacent IR-75 roadway appeared to drain to concrete drainage channels that that run parallel to the roadway (Photograph 4). The bridge deck drained to scuppers in the shoulder of the bridge deck near each end of the bridge. These drained directly onto the spill-though slope at the northern abutment and to drainage downspouts near the southern abutment. Standing water was not observed during the field reconnaissance.

Photograph 1: Overall Condition of Underside of Deck

Photograph 2: Spalling, Cracking and Exposed Rebar Observed at Each Abutment

Photograph 3: Riprap on Spill-through Slope

Photograph 4: Concrete Drainage Channels

SUBSURFACE EXPLORATION

The exploration for the bridge HAM-75-0104 replacement was conducted by NEAS between November 30, 2021 and January 28, 2022. The exploration for the referenced structure included 5 borings drilled to depths ranging from of 101.5 to 116.5 ft below ground surface (bgs). Boring logs for the borings performed are attached. A summary of the exploration locations including latitude/longitude location information and elevations of the subject structure exploration are shown in Table 2 below. Additional information with respect to the subsurface exploration can be found in the Geotechnical Exploration Report for the overall project, HAM-75-1.05 (PID 113361).

Table 2: Structure Boring Summary

Boring Number	Latitude	Longitude	Elevation (NAVD 88) (ft)	Depth (ft)	Structure
B-005-0-21	39.104313	-84.528656	505.4	101.5	Pier 1
B-007-0-21	39.103968	-84.529004	521.4	116.5	Rear Abutment
B-008-0-21	39.104649	-84.528586	503.0	101.5	Pier 2
B-009-0-21	39.104839	-84.528368	503.7	101.5	Pier 2 / Forward Abutment
B-010-0-21	39.105334	-84.528510	518.0	106.5	Forward Abutment

Notes:
1. *As-drilled boring location and corresponding ground surface elevation was surveyed in the field by NEAS Inc or estimated off topographic data collected along IR-75.*

SUBSURFACE CONDITIONS

At the site of proposed structure, four different materials were encountered below the surficial material. In general, the four different overburden materials consisted of historical or embankment "man-made" fill soils, natural alluvial deposits, followed by natural fine-grained soils then natural sands. These materials and the general profile underlying the site is further described below.

Fill soils were encountered in three of the five borings performed for the proposed structure with the fill primarily being located at or near the existing abutments (B-007-0-21, B-009-0-21, and B-010-0-21). These fill soils were encountered immediately below the topsoil or pavement section and extended to depths ranging from 6.1 to 26.0 ft bgs, approximate elevations 495.4 to 497.6 ft above mean sea level (amsl). Based on laboratory testing results, a visual review of the soil samples obtained, the fill at the site is comprised of fine-grained cohesive material and is classified on the boring logs as Silt and Clay (A-6a), Silty Clay (A-6b), and Clay (A-7-6). The exception being one layer encountered in B-007-0-21 and two different layers encountered in boring B-010-0-21. These non-cohesive granular layers ranged in thickness from 0.7 to 5.6 ft and are classified on the log as Gravel and/or Stone Fragments with Sand and Silt (A-2-4) or Gravel and Stone Fragments with Sand (A-1-b). With respect to the soil strength, the granular fill soils can be described having a relative compactness of medium dense correlating to converted SPT-N values (N_{60}) between 14 and 17 blows per foot (bpf). Natural moisture contents of the granular fill ranged from 6 to 14 percent. With respect to the soil strength of the fine-grained cohesive fill, these soils can be described as having a consistency of very stiff to hard correlating to N_{60} values between 6 and 26 bpf and unconfined compressive strengths (estimated by means of hand penetrometer) between approximately 2.5 and 4.5 tons per square foot (tsf). Natural moisture contents of the cohesive fill ranged from 12 to 21 percent. Based on Atterberg Limits tests performed on representative samples of the cohesive fill material, the liquid and plastic limits ranged from 27 to 41 percent and from 16 to 21 percent, respectively.

The stratum encountered either immediately beneath the fill or below the existing pavement section consisted of natural alluvial soils comprised of an upper fine-grained cohesive strata followed by a layer of granular non-cohesive soils. The alluvial material extends to depths between 12.0 and 48.3 ft bgs (approximate elevations 491.7 and 471.0 ft amsl). Based on laboratory testing results, a visual review of the soil samples obtained within this stratum, the upper soils are comprised of cohesive material classified on the boring logs as Silty Clay (A-6b) and Silt (A-4b). With respect to the soil strength of the fine-grained material encountered within this stratum, these soils can be described as having a consistency of stiff to very stiff correlating to N_{60} values between 7 and 19 bpf and unconfined compressive strengths (estimated by means of hand penetrometer) between 1.25 and 2.5 tsf. Natural moisture contents of the cohesive soils ranged from 18 to 28 percent. Based on Atterberg Limits tests performed on representative samples of the cohesive alluvial material, the liquid and plastic limits ranged from 29 to 36 percent and from 17 to 19 percent, respectively. The granular alluvium in this stratum was classified on the logs as Coarse and Fine Sand (A-3a) and Gravel and/or Stone Fragments with Sand (A-1-b). With respect to the soil strength, the granular alluvium can be described as having a relative compactness of loose to dense correlating to converted N_{60} values between 7 and 31 bpf. Natural moisture contents of the granular alluvium ranged from 2 to 14 percent.

The stratum encountered immediately beneath the alluvium, when present, consisted of natural fine-grained soils comprised of both cohesive and non-cohesive materials. This stratum extended to depths between 28.3 and 68.3 ft bgs (approximate elevations 477.1 and 444.7 ft amsl). The upper 2 to 13 ft of this stratum in borings B-005-0-21, B-008-0-21 and B-009-0-21 was comprised of fine-grained cohesive soil which was classified on the boring logs as Silt and Clay (A-6a) and Silt (A-4b). With respect to the soil strength of the cohesive material encountered within this stratum, these soils can be described as having a consistency of stiff to very stiff correlating to N_{60} values between 9 and 34 bpf and unconfined compressive strengths (estimated by means of hand penetrometer) between 2.25 and 3.5 tsf. Natural moisture contents of the cohesive soils ranged from 20 to 27 percent. Based on Atterberg Limits tests performed on representative samples of the cohesive material, the liquid and plastic limits ranged from 26 to 34 percent and from 18 to 22 percent, respectively. The non-cohesive soils within strata were classified on the logs as Silt (A-4b). With respect to the soil strength, the non-cohesive material can be described as having a relative compactness of loose to dense correlating to converted N_{60} values between 8 and 31 bpf. Natural moisture contents of the non-cohesive material is this stratum ranged from 10 to 29 percent.

The soils encountered directly underlying the natural fine-grained soil stratum consisted of a natural sand layer extending to termination depth of the borings between 101.5 and 116.5 ft bgs (approximate elevations 411.5 and 401.5 ft amsl). Based on laboratory testing results and a visual review of the soil samples obtained within this stratum, these soils are comprised of granular material and are classified on the boring logs as Gravel with Sand (A-1-b), Fine Sand (A-3), Coarse and Fine Sand (A-3a), non-cohesive Sandy Silt (A-4a), and non-cohesive Silt (A-4). With respect to the soil strength, the natural sands can be described as having a relative compactness of medium dense to dense correlating to converted N_{60} values between 15 and 44 bpf. Natural moisture contents of the natural sands ranged from 4 to 31 percent.

Groundwater

Groundwater measurements were taken during the boring drilling procedures at each borehole location. Groundwater was encountered during drilling in the 4 of the 5 project borings performed at the bridge site. Groundwater was encountered at depths ranging from 40 to 68.2 ft bgs (elevations 468.9 to 449.8 ft amsl). It should be noted that groundwater is affected by many hydrologic characteristics in the area and may vary from those measured at the time of the exploration. The specific groundwater readings are included on the attached boring logs.

ANALYSES AND RECOMMENDATIONS

Soil Profile for Bridge Foundation Analysis

For friction pile analyses purposes, each boring drilled for Bridge HAM-75-0104 was reviewed, and a generalized material profile was developed. Utilizing the generalized soil profile, engineering properties for each soil stratum were estimated based on their field (i.e., SPT N_{60} Values, hand penetrometer values, etc.) and laboratory test (i.e., Atterberg Limits, grain size, etc.) results using correlations provided in published engineering manuals, research reports and guidance documents. Engineering soil properties were estimated for each individual classified layer per boring location. The developed soil profiles and estimated engineering soil properties for use in analysis of Bridge HAM-75-0104 (with cited correlation/reference material) are summarized within Tables 3 through 7 below.

Table 3: Soil Profile and Estimated Engineering Properties - At Boring B-005-0-21

Bridge HAM-75-0104: Pier 1, B-005-0-21					
Soil Description	**Unit Weight(1) (pcf)**	**Undrained Shear Strength(2) (psf)**	**Effective Cohesion(3) (psf)**	**Effective Friction Angle(3) (degrees)**	**Setup Factor (f_{su})**
Coarse and Fine Sand Depth (505.4 ft - 501.9 ft)	110	-	-	31	1.0
Silty Clay Depth (501.9 ft - 499.4 ft)	108	900	100	22	1.75
Coarse and Fine Sand Depth (499.4 ft - 490.9 ft)	112	-	-	32	1.0
Gravel with Sand Depth (490.9 ft - 488.4 ft)	118	-	-	39	1.0
Silt Depth (488.4 ft - 485.9 ft)	125	2750	250	26	1.5
Silt Depth (485.9 ft - 477.1 ft)	125	-	-	31	1.5
Sandy Silt Depth (477.1 ft - 467.1 ft)	128	-	-	31	1.2
Coarse and Fine Sand Depth (467.1 ft - 442.1 ft)	128	-	-	33	1.0
Silt Depth (442.1 ft - 437.1 ft)	128	-	-	31	1.5
Coarse and Fine Sand Depth (437.1 ft - 403.9 ft)	128	-	-	33	1.00
Values calculated per ODOT GDM Section 404/1304 and/or ODOT BDM Table 305-2.					

Table 4: Soil Profile and Estimated Engineering Properties - At Boring B-007-0-21

Bridge HAM-75-0104: Rear Abutment, B-007-0-21					
Soil Description	**Unit Weight(1) (pcf)**	**Undrained Shear Strength(2) (psf)**	**Effective Cohesion(3) (psf)**	**Effective Friction Angle(3) (degrees)**	**Setup Factor (f_{su})**
Silt and Clay Depth (521.4 ft - 514.4 ft)	112	1900	200	24	1.5
Silty Clay Depth (514.4 ft - 511.9 ft)	115	2600	250	25	1.75
Silt and Clay Depth (511.9 ft - 506.9 ft)	118	-	-	32	1.5
Gravel with Sand and Silt Depth (506.9 ft - 504.4 ft)	115	-	-	34	1.2
Clay Depth (504.4 ft - 495.4 ft)	110	1700	150	22	2.0
Coarse and Fine Sand Depth (495.4 ft - 473.1 ft)	125	-	-	32	1.0
Sandy Silt Depth (473.1 ft - 458.1 ft)	128	-	-	31	1.2
Coarse and Fine Sand Depth (458.1 ft - 453.1 ft)	128	-	-	33	1.0
Gravel with Sand Depth (453.1 ft - 448.1 ft)	128	-	-	35	1.0
Coarse and Fine Sand Depth (448.1 ft - 443.1 ft)	128	-	-	33	1.0
Gravel with Sand Depth (443.1 ft - 438.1 ft)	125	-	-	34	1.0
Coarse and Fine Sand Depth (438.1 ft - 404.9 ft)	128	-	-	33	1.0
lotes: 1. Values calculated per ODOT GDM Section 404/1304 and/or ODOT BDM Table 305-2.					

Table 5: Soil Profile and Estimated Engineering Properties - At Boring B-008-0-21

Bridge HAM-75-0104: Pier 2, B-008-0-21					
Soil Description	**Unit Weight(1) (pcf)**	**Undrained Shear Strength(2) (psf)**	**Effective Cohesion(3) (psf)**	**Effective Friction Angle(3) (degrees)**	**Setup Factor (f_{su})**
Silt Depth (503 ft - 498.7 ft)	112	2150	200	25	1.5
Coarse and Fine Sand Depth (498.7 ft - 494.5 ft)	115	-	-	34	1.0
Silt and Clay Depth (494.5 ft - 493.5 ft)	112	1750	200	24	1.5
Coarse and Fine Sand Depth (493.5 ft - 487 ft)	115	-	-	33	1.0
Silt Depth (487 ft - 474.7 ft)	125	3050	250	26	1.5
Silt Depth (474.7 ft - 464.7 ft)	125	-	-	31	1.5
Silt Depth (464.7 ft - 449.7 ft)	128	-	-	29	1.5
Silt Depth (449.7 ft - 444.7 ft)	128	-	-	31	1.5
Fine Sand Depth (444.7 ft - 434.7 ft)	128	-	-	33	1.2
Sandy Silt Depth (434.7 ft - 424.7 ft)	128	-	-	31	1.2
Coarse and Fine Sand Depth (424.7 ft - 401.5 ft)	130	-	-	34	1.0
alues calculated per ODOT GDM Section 404/1304 and/or ODOT BDM Table 305-2.					

Table 6: Soil Profile and Estimated Engineering Properties - At Boring B-009-0-21

Bridge HAM-75-0104: Pier 2 / Forward Abutment, B-009-0-21					
Soil Description	**Unit Weight(1) (pcf)**	**Undrained Shear Strength(2) (psf)**	**Effective Cohesion(3) (psf)**	**Effective Friction Angle(3) (degrees)**	**Setup Factor (f_{su})**
Silty Clay Depth (503.7 ft - 497.6 ft)	120	1600	150	23	1.75
Coarse and Fine Sand Depth (497.6 ft - 491.7 ft)	115	-	-	30	1.0
Silt and Clay Depth (491.7 ft - 486.7 ft)	110	1100	100	22	1.5
Silt Depth (486.7 ft - 475.4 ft)	110	-	-	29	1.5
Silt Depth (475.4 ft - 455.4 ft)	120	-	-	30	1.5
Coarse and Fine Sand Depth (455.4 ft - 445.4 ft)	128	-	-	33	1.0
Fine Sand Depth (445.4 ft - 402.2 ft)	128	-	-	32	1.2
s: *1. Values calculated per ODOT GDM Section 404/1304 and/or ODOT BDM Table 305-2.*					

Table 7: Soil Profile and Estimated Engineering Properties – At Boring B-010-0-21

Bridge HAM-75-0104: Forward Abutment, B-010-0-21					
Soil Description	**Unit Weight[(1)] (pcf)**	**Undrained Shear Strength[(2)] (psf)**	**Effective Cohesion[(3)] (psf)**	**Effective Friction Angle[(3)] (degrees)**	**Setup Factor (f_{su})**
Gravel with Sand and Silt Depth (518 ft - 511 ft)	115	-	-	35	1.2
Silt and Clay Depth (511 ft - 501 ft)	112	-	-	29	1.5
Gravel with Sand Depth (501 ft - 499.3 ft)	115	-	-	35	1.0
Silty Clay Depth (499.3 ft - 496 ft)	108	850	100	22	1.75
Coarse and Fine Sand Depth (496 ft - 471 ft)	125	-	-	33	1.0
Silt Depth (471 ft - 449.7 ft)	115	-	-	30	1.5
Sandy Silt Depth (449.7 ft - 439.7 ft)	128	-	-	31	1.2
Coarse and Fine Sand Depth (439.7 ft - 411.5 ft)	128	-	-	32	1.0

1. Values calculated per ODOT GDM Section 404/1304 and/or ODOT BDM Table 305-2.

Pile Foundation Analysis

Based on the determined soil profile and our estimated engineering soil properties, a friction pile analysis utilizing CIP piles was performed using the computer program *GRLWEAP 14* to determine the estimated geotechnical pile length at each substructure location (*GRLWEAP 14* results attached). For the purposes of this report and our analysis, the term 'geotechnical pile length' has been assumed to represent the length of pile from bottom of pile cap (assumed pile cap bearing elevation) to the geotechnical pile tip elevation where the required UBV is obtained. For our analysis it is assumed that the proposed pile cap elevations will match those shown in the Bridge Stage 2/3 plans developed by Burgess & Niple, Inc. (B&N) dated January 6, 2025. Based on the soil profile encountered at the site, it is our opinion that pile resistances obtained during dynamic testing (driving) may be reduced due to the potential for soil disturbance (development of high pore water pressure) near the pile perimeter. This disturbance could cause piles to potentially drive easily or “run” for extended depths and initial driving resistances may not reach the indicated target UBV utilizing the estimated pile lengths. This reduced resistance value obtained at the end of driving the estimated pile length is designated as the End of Initial Driving resistance or EOID. If the EOID is significantly different than the required UBV, it may be necessary to let the piles “set up” (reduction of pore water pressure in the soils adjacent to the pile) for an established time period. To estimate the potential effects of this disturbance during driving, the setup factors presented in Tables 3 through 7 of the previous section of this memo are used to estimate driving strength losses as well as the side resistance expected to gain following the setup period.

The UBV and EOID values are determined in accordance with Section 305.3.2.4 and 305.3.5.9 of the ODOT BDM. The UBV is determined by dividing the total factored load for the highest loaded pile at each substructure by the appropriate driven pile resistance factor while the EOID is determined by subtracting the amount of side resistance expected to gain from soil setup from the UBV value. The amount of side resistance expected to gain from soil setup is taken as the difference between the side resistance obtained in ultimate (post setup) conditions and the side resistance obtained during driving (dynamic) conditions at the determined geotechnical pile length. It is recommended that the piles for the referenced project be installed according to ODOT's Construction and Material Specifications (CMS) 507 and CMS 523, and therefore, a driven pile resistance factor of 0.7 should be used.

The estimated ultimate skin friction (Rs), pile tip bearing values (Rp) for ultimate and during driving conditions are summarized in Table 7 (GRLWEAP 14 results attached). The referenced table also includes 1) required geotechnical pile length for 12-inch and 14-inch diameter CIP piles driven to the respective pile UBV at the proposed abutment and pier locations, respectively; 2) the length of driven pile required in driving conditions for CIP pile driven to the respective UBV per substructure location; and 3) the estimated difference in pile length between a pile in ultimate and driving conditions.

Table 8: Deep Foundation Analysis Summary

Pile Type	Ultimate Conditions		Driving Conditions		Pile Length Difference Ultimate vs. Driving Conditions (ft)	End of Initial Driving Value$^{(3)}$ (kips)	Setup Factor (f_{su})
	Geotechnical Pile Length$^{(1)}$ (ft)	Ultimate Bearing Value$^{(2)}$ (kips)	Driven Pile Length$^{(1)}$ (ft)	Bearing Value During Driving$^{(2)}$ (kips)			
HAM-75-0104 Rear Abutment, B-007-0-21							
12-inch CIP	58.9	251	60.1	251	1.2	230	1.1
HAM-75-0104 Pier 1, B-005-0-21							
14-inch CIP	55.3	383	57.3	383	2.0	359	1.1
HAM-75-0104 Pier 2, B-008-0-21							
14-inch CIP	60.2	377	68.0	377	7.8	298	1.3
HAM-75-0104 Forward Abutment, B-010-0-21							
12-inch CIP	72.1	316	75.3	316	3.2	262	1.2

Notes:
1. *The length of pile from bottom of pile cap (pile cap bearing elevation) to the depth at which the required UBV is obtained.*
2. *Resistance factor for driven piles, dynamic analysis and static load test methods (BDM Table 305-1) for piles installed according to C&MS 507 using dynamic test methods according to C&MS 523 has not been applied to values calculated.*
3. *EOID is based on driving resistance obtained at the indicated geotechnical pile length.*

Pile Drivability

NEAS's pile drivability evaluation estimated a Delmag D19-42 diesel hammer to determine if the pile type or size being considered would be overstressed (i.e., compressive stresses experienced by pile during driving are greater than 90% of the yield strength of the steel) at any time during pile installation. The results of the evaluation indicated that the referenced CIP pile sizes would be overstressed during the pile installation process based on: 1) a minimum wall thickness of 0.25-inches; 2) the use of ASTM A 252 Grade 2 steel piles; 3) a pile hammer with a minimum rated energy of 42,000 ft-lbs; and, 4) our developed model used in the computer program *GRLWEAP* by GRL Engineers, Inc. Based on the results of our drivability analysis, we recommend that ASTM A 252 Grade 3 steel piles be utilized for the foundations of the proposed structure to prevent potential overstressing during pile installation. *GRLWEAP* results for each substructure location are attached.

It should be noted that the driving resistance of CIP piles through soils encountered at the bridge site is expected to be high. Drivability is difficult to assess quantitatively as the field test results (i.e., SPT N_{60} values, pocket penetrometer values, etc.) tend to be very high. Furthermore, pile drivability is highly reliant upon the specific equipment used in construction; therefore, it is recommended that the contractor provide an analysis to demonstrate that the equipment and pile combination planned for use is capable of obtaining the UBV without over-stressing the piles.

Pile Foundation Recommendations

Based on our evaluation of the subsurface conditions and our geotechnical engineering analysis for the proposed Bridge HAM-75-0104, it is our opinion that the bridge foundations can be supported on driven friction CIP piles seated within the medium dense to dense natural sand and gravels encountered at the site.

We recommend that a driven pile foundation be used for support for the proposed bridge foundations. New 12-inch diameter CIP piles (abutments) and 14-inch diameter CIP piles (piers) consisting of ASTM A 252, Grade 3 steel are recommended to be installed in accordance with Sections 507 and 523 of ODOT's CMS. Driven to the UBVs indicated in Table 8 of this report, it is anticipated that the newly driven CIP piles would not “run” for extended depths during driving conditions at any of the proposed substructures (i.e., run lengths greater than 10 ft). Therefore, pile/soil setup will not be utilized during the installation process at these structures, and it is recommended that the proposed piles be driven to the required UBV. It is recommended that all applicable plan notes provided in Section 606.2 be included in the plans.

For piles driven to the assumed UBV (Table 8), a 12-inch diameter CIP piles may be used to support a total factored load (single pile) of 176 kips and 221 kips at the rear and forward abutments, respectively. while a 14-inch diameter CIP pile may be used to support a total factored load (single pile) of 268 kips and 264 kips at Pier 1 and Pier 2, respectively. For piles driven to the indicated UBVs, pile tip elevations are estimated to range from 426 to 453 ft amsl across the bridge site.

Pile lengths based on: 1) our Deep Foundation Analysis (presented in a previous section of this memo); and, 2) the "Estimated Length" and "Order Length" definitions and formulas presented in Section 305.3.5.2 of the ODOT BDM, are presented in Table 9 below.

It should be noted, select piles at the proposed Pier 2 location are planned to be prebored to a depth to 20 ft below bottom of pile cap elevation prior to driving to ensure no conflicts with battered piles of the existing bridge foundations exist at these locations. At these specific pile locations, an additional 5 ft of pile may be required in addition to the “Estimated Length” and “Order Length” values provided in Table 9 in order to obtain the required UBV at these locations.

Table 9: Estimated Pile Lengths

Pile Type	Bottom of Pile Cap Elevation (ft amsl)	Geotechnical Pile Length (ft)	Geotechnical Pile Tip Elevation (ft amsl)	Estimated Pile Length[(1)] (ft)	Order Length[(1)] (ft)
HAM-75-0104 Rear Abutment, B-007-0-21					
12-inch CIP	512.9	60.1	452.9	65	70
HAM-75-0104 Pier 1, B-005-0-21					
14-inch CIP	496.0	57.3	438.7	60	65
HAM-75-0104 Pier 2, B-008-0-21					
14-inch CIP	494.0	68.0	426.0	75	80
HAM-75-0104 Forward Abutment, B-010-0-21					
12-inch CIP	509.1	75.3	433.8	80	85

Notes:
1. *Based on definitions and formulas presented in Section 305.3.5.2 of the 2020 BDM.*

MSE Wall Abutment Analysis and Recommendations

Retaining Wall Design Assumptions

As the proposed retaining wall abutments are planned as MSE type, ODOT's BDM and AASHTO's LRFD BDS dictate analysis parameters and design minimums/constraints to be used in the analysis and design process. The referenced parameters and design minimums/constraints that were significant to our analyses consist of the following:

- Minimum reinforcement strap lengths of proposed MSE walls are to be 70% of the total wall height (as measured from proposed profile grade at the face of the wall to the top of the leveling pad) or 8 ft, whichever is greater, at the section of wall being analyzed, per ODOT's BDM section 307.4-A;
- Minimum MSE wall embedment depths (as measured from top of the leveling pad to the lowest point on the ground surface within 4-ft of the face of the wall) are to conform to Figure 201-5 presented in ODOT's BDM and be the larger of 3 ft or the local frost depth;
- Soils below the bottom of leveling pad will be undercut a minimum of 1 ft and replaced Granular Material Type C according to the requirements of ODOT Construction & Materials Specifications Section 204.07 (CMS 204.07);
- Maximum allowable differential settlement in the longitudinal direction is 1%. (BDM Section 307.1.6); and,
- Reinforced Zone and Retained Fill soils will meet the minimum design soil parameters per Table 840.04-1 of the ODOT Supplemental Specification 840 (SS-840) as shown in Table 10 below.

Table 10: Design Soil Parameters for Fill Materials

Fill Zone	Type of Soil	Soil Unit Weight (pcf)	Friction Angle (°)	Cohesion (psf)
Reinforced Zone	Select Granular Backfill	120	34	0
Retained Soil	On-site soil varying from sandy lean clay to silty sand	120	30	0

Notes:
1. Table reproduced from Section 840.04 - A-1 of ODOT's SS 840.

With respect to design constraints and assumptions specific to the MSE wall abutments, the geometry of the proposed walls (i.e., exposed wall heights, existing ground elevations, proposed final grade behind/at the toe of the wall, etc.) is assumed to be consistent with that shown in the proposed Bridge HAM-75-0104 Stage 2/3 site plan developed by Burgess & Niple, Inc. (B&N) dated January 6, 2025.

Soil Profile for MSE Wall Analysis

For proposed retaining wall external and global stability analyses purposes, the generalized material profile and estimated engineering properties developed for the proposed bridge HAM-75-0104 substructures, presented in the previous *Soil Profile for Bridge Foundation Analysis* section of this memo, were assumed to also be representative of the subsurface conditions at the proposed rear and forward MSE wall locations. Specifically, soil properties estimated for boring B-007-0-21 were utilized for the proposed rear abutment MSE wall while soil properties estimated for boring B-010-0-21 were utilized for the proposed forward abutment MSE wall. Settlement parameters (with sited correlation/reference material) developed for the proposed rear abutment MSE wall are presented below within Table 11.

Table 11: Settlement Parameters for Analysis – Rear Abutment MSE Wall

HAM-75-0105 Rear Abutment: Settlement Analysis B-007-0-21 & B-005-0-21								
Soil Description	Unit Weight (pcf)	Elastic Modulus$^{(1)}$ (psf)	Poissons Ratio$^{(1)}$, v	Void Ratio e_o	Compression Index$^{(2)}$, C_c	Recompression Index$^{(3)}$, C_r	OCR$^{(4)}$	Coeff. of Consol.$^{(5)}$, C_v
Cohesive Soil 1	122	1022000	0.45	0.572	0.21	0.043	9.5	0.50
Granular Soil 1	125	410000	0.30	-	-	-	-	-
Cohesive Soil 2	125	1399000	0.45	0.639	0.13	0.027	4.5	0.75

'alues interpreted from 2017 AASHTO LRFD BDS Table C10.4.6.3-1
'alues calculated from Kulhawy and Mayne, 1990, Equation 6-6.
'alues calculated from Kulhawy and Mayne, 1990, Equation 6-9.
'alues interpreted from Mayne and Kemper, 1988, Figure 7.
'alues interpreted from FHWA GEC No. 5, Boeckmann, et al., 2016, Figure 6-37.
'orings utilized to esimate soil stratificaiton, layer thickness and consolidation charactersistics include: B-007-0-21 and B-005-0-21.

External Stability

Based on our estimated engineering soil properties, the developed generalized profile and the retaining wall design assumptions provided in the previous sections of this memo, external stability analyses of the proposed MSE wall abutments were performed. External stability was evaluated at one (1) cross-section (tallest section) along both the proposed MSE wall alignments. Each cross section was evaluated for resistance to bearing pressure, sliding forces and overturning at the Strength Limit State in accordance with Section 11.10.5 of the AASHTO's LRFD BDS. The capacity to demand ratios (CDRs) calculated for the referenced cross-sections with respect to bearing, sliding and overturning, as well as the calculated factored bearing resistances are presented in Table 12 below. (External Stability and Bearing Resistance Calculation External stability analysis results are attached.

Table 12: External Stability Analysis Summary

Dimensions		
Design Wall Height (feet)	24.1	28.7
Exposed Wall Height (feet)	19.6	23.9
Length of Reinforcement (feet)	19.3	20.1
Length of Reinf. To Height Ratio	0.8	0.7
Approximate Station$^{(1)}$	105+90.2	109+58.9
Capactiy Demand Ratio (CDR)		
Bearing Capacity	1.11	2.91
Overturning / Eccentricity	1.97	1.56
Sliding	1.08	1.55
Factored Bearing Resistance (ksf)$^{(2)}$	6.2	20.8
Maximum Service Bearing Pressure	3.9	5.0
Maximum Factor Bearing Pressure	5.6	7.2

Notes:
1. *Stationing in reference to Linn St alignment.*
2. *Bearing Resistance calculated in accordance to Section 11.10.5.4 of 2014 LRFD BDS and factored using Resistance Factor provided in Table 11.5.7-1 of 2014 LRFD BDS.*

Global Stability Analysis

For purposes of evaluating the stability of the proposed MSE wall abutments, NEAS reviewed cross-sections along the length of the proposed retaining walls to determine the subsurface conditions that posed the greatest potential for slope instability. In general, cross-sections along the proposed wall alignments were reviewed to determine the sections that would represent a combination of existing subsurface conditions and planned site grading that would be most critical to slope stability (i.e., maximum total wall height, maximum embankment height measured from toe of slope to top of wall, proposed/existing grades behind and in front of the wall, weak and/or thick soil layer, etc.). Based on our review of the available information at the referenced location and the associated soil properties, one (1) cross-section for each retaining wall were estimated to be most "critical" and were analyzed for global stability. The cross-sections analyzed for global stability for each of the proposed walls consisted of the maximum wall-height sections at approximate STA. 105+90 (Linn St alignment) at the rear abutment and approximate STA. 109+59 (Linn St alignment).

For the indicated cross-sections, NEAS developed a representative cross-sectional model to use as the basis for global stability analysis. The models were developed from NEAS's interpretation of the available information which included: 1) the proposed Bridge HAM-75-0104 Stage 2/3 site plan developed by Burgess & Niple, Inc. (B&N) dated January 6, 2025; 2) a live load surcharge of 250 pounds per square foot (psf) accounting for traffic induced loads; and, 3) test borings and laboratory data developed as part of this project. With respect to the soil's engineering properties, the provided generalized soil profile and estimated engineering properties presented in the *Soil Profile for Bridge Foundation Analysis* section of this memo were used in our analysis.

The above referenced global stability models were analyzed for long-term (Effective Stress) and short-term (Total Stress) slope stability utilizing the software entitled Slide2 by Rocscience, Inc. Specifically, the Spencer analysis method was used to calculate a factor of safety (FOS) for circular type slope failures. The FOS is the ratio of the resisting forces and the driving forces, with the desired safety factor being more than about 1.5 which equates to an AASHTO resistance factor less than 0.65 (per AASHTO's LRFD BDS, the specified resistance factors are essentially the inverse of the FOS that should be targeted in slope stability programs). For this analysis, a resistance factor of 0.65 or lower was targeted as the MSE wall abutments contain or support a structural element of the proposed bridge. Based on our slope stability analyses for the referenced MSE wall sections, the minimum slope stability factor was estimated to be about 1.52 (0.65 resistance factor). Graphical outputs of the slope stability program (cross-sectional model, calculated safety factor, and critical failure plane) are attached.

Settlement Analysis

In order to estimate the maximum total and differential settlement that could result within the subsurface soils supporting the proposed MSE wall abutment at the rear abutment location, NEAS reviewed: 1) the proposed Bridge HAM-75-0104 Stage 2/3 site plan developed by Burgess & Niple, Inc. (B&N) dated January 6, 2025; 2) Service Limit State loading conditions; and, 3) the generalized subsurface profile and Settlement Parameters for Analysis provided in the *Soil Profile for MSE Wall Analysis* section of this memo. Utilizing this information and the software entitled *Settle3* by Rocscience Inc., a settlement model was developed and analyzed for both elastic (immediate) and consolidation (long term) settlement.

Based on our analysis, the estimated maximum total long-term settlement that could occur along the length of proposed MSE wall abutment as a result of the induced wall and embankment loads is estimated to be about 2.5 inches. The maximum differential settlement along the length of the proposed MSE wall abutment is estimated to be on the order of less than 1 percent. With respect to potential downdrag effects induced by these settlement magnitudes on the proposed pile foundations at the rear abutment location, it is anticipated that approximately 90 percent of the estimated long-term settlement will be complete within the first 35 days following the application of new retaining wall and/or embankment loading. Outputs of the settlement analysis program are attached.

SOIL BORING LOGS

PROJECT: HAM-75-1.05	DRILLING FIRM / OPERATOR: NEAS / ASHBAUGH	DRILL RIG: CME 55T	STATION / OFFSET: 106+63, 76' RT.	EXPLORATION ID B-005-0-21
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: NEAS / ASHBAUGH	HAMMER: CME AUTOMATIC	ALIGNMENT: LINN ST	
PID: 113361 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 12/5/19	ELEVATION: 505.3 (MSL) EOB: 101.5 ft.	PAGE 1 OF 4
START: 1/5/22 END: 1/5/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 68.4	LAT / LONG: 39.104303, -84.528659	

MATERIAL DESCRIPTION AND NOTES	ELEV. 505.3
7.0" CONCRETE AND 10.0" BASE (DRILLERS DESCRIPTION)	503.9
LOOSE, BROWN, **COARSE AND FINE SAND**, LITTLE GRAVEL, TRACE SILT, TRACE CLAY, DAMP	501.8
STIFF TO VERY STIFF, BROWN, **SILTY CLAY**, TRACE SAND, TRACE GRAVEL, MOIST	499.3
LOOSE TO MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, TRACE TO LITTLE SILT, TRACE CLAY, TRACE GRAVEL, DAMP	490.8
DENSE, BROWN, **STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, DAMP	488.3
VERY STIFF, BROWN, **SILT**, SOME CLAY, TRACE SAND, TRACE GRAVEL, MOIST	485.8
MEDIUM DENSE, BROWN, **SILT**, LITTLE SAND, TRACE CLAY, TRACE GRAVEL, CONTAINS INTERBEDDED SAND SEAMS, MOIST	477.0
MEDIUM DENSE, BROWN, **SANDY SILT**, TRACE CLAY, TRACE GRAVEL, (INTERBEDDED A-3A AND A-4B), DAMP	

DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
2.5–4.0	3 3 4	8	72	SS-1A	-	-	-	-	-	-	-	-	-	13	A-3a (V)
				SS-1B	1.25	-	-	-	-	-	-	-	-	28	A-6b (V)
5.0–6.5	3 3 3	7	100	SS-2A	2.00	0	3	7	50	40	35	19	16	24	A-6b (10)
				SS-2B	-	-	-	-	-	-	-	-	-	12	A-3a (V)
7.5–9.0	3 4 3	8	100	SS-3	-	0	7	70	17	6	NP	NP	NP	9	A-3a (0)
10.0–11.5	3 4 6	11	67	SS-4	-	-	-	-	-	-	-	-	-	6	A-3a (V)
12.5–14.0	5 7 9	18	83	SS-5	-	-	-	-	-	-	-	-	-	10	A-3a (V)
15.0–16.5	8 13 14	31	50	SS-6	-	-	-	-	-	-	-	-	-	5	A-1-b (V)
17.5–19.0	7 8 11	22	67	SS-7	2.25	0	0	1	69	30	28	18	10	23	A-4b (8)
20.0–21.5	8 9 11	23	89	SS-8	-	0	0	11	84	5	NP	NP	NP	17	A-4b (8)
22.5–24.0	8 8 11	22	83	SS-9	-	-	-	-	-	-	-	-	-	15	A-4b (V)
25.0–26.5	8 9 11	23	100	SS-10	-	-	-	-	-	-	-	-	-	10	A-4b (V)

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 4/10/25 12:04 - X:\1ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\1ARCHIVE BY YEAR\2024 ARCHIVE\HAM-75-1.05\GINT FILES\HA[

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 106+63, 76' RT.	START: 1/5/22	END: 1/5/22	PG 2 OF 4	B-005-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 475.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE, BROWN, **SANDY SILT**, TRACE CLAY, TRACE GRAVEL, (INTERBEDDED A-3A AND A-4B), DAMP *(continued)*		31	8 10 14	27	72	SS-11	-	0	4	46	45	5	NP	NP	NP	12	A-4a (3)	
		36	9 10 15	29	78	SS-12	-	-	-	-	-	-	-	-	-	8	A-4a (V)	
	467.0	38																
MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, LITTLE TO SOME SILT, TRACE CLAY, TRACE GRAVEL, WET		W 465.3 (40)																
		41	7 9 11	23	89	SS-13	-	-	-	-	-	-	-	-	-	23	A-3a (V)	
		46	8 11 13	27	78	SS-14	-	1	7	57	31	4	NP	NP	NP	24	A-3a (0)	
		51	9 12 13	29	100	SS-15	-	-	-	-	-	-	-	-	-	24	A-3a (V)	
	452.0	53																
MEDIUM DENSE TO DENSE, BROWNISH GRAY, **COARSE AND FINE SAND**, SOME SILT, TRACE CLAY, TRACE GRAVEL, CONTAINS INTERBEDDED SILT SEAMS, WET																		
		56	8 12 13	29	100	SS-16	-	-	-	-	-	-	-	-	-	25	A-3a (V)	
		61	8 11 16	31	100	SS-17	-	-	-	-	-	-	-	-	-	21	A-3a (V)	

MATERIAL DESCRIPTION AND NOTES	ELEV. 443.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
	442.0	63																
MEDIUM DENSE, GRAY, **SILT**, LITTLE SAND, TRACE CLAY, TRACE GRAVEL, WET		64																
		65–66	7 10 12	25	100	SS-18	-	0	0	17	75	8	NP	NP	NP	25	A-4b (8)	
	437.0	67–68																
MEDIUM DENSE TO DENSE, GRAYISH BROWN BECOMING BROWNISH GRAY, **COARSE AND FINE SAND**, TRACE SILT, TRACE CLAY, TRACE GRAVEL, WET		69																
		70–71	6 7 6	15	100	SS-19	-	-	-	-	-	-	-	-	-	19	A-3a (V)	
		72–74																
		75–76	6 8 10	21	100	SS-20	-	-	-	-	-	-	-	-	-	22	A-3a (V)	
		77–79																
		80–81	7 9 13	25	100	SS-21	-	-	-	-	-	-	-	-	-	19	A-3a (V)	
		82–84																
		85–86	8 10 12	25	100	SS-22	-	0	25	62	10	3	NP	NP	NP	18	A-3a (0)	
		87–89																
		90–91	9 12 13	29	100	SS-23	-	-	-	-	-	-	-	-	-	18	A-3a (V)	
		92–94																

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 4/10/25 12:04 - X:\1ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\1ARCHIVE BY YEAR\2024 ARCHIVE\HAM-75-1.05\GINT FILES\HAI

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 106+63, 76' RT.	START: 1/5/22	END: 1/5/22	PG 4 OF 4	B-005-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 411.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE TO DENSE, GRAYISH BROWN BECOMING BROWNISH GRAY, **COARSE AND FINE SAND**, TRACE SILT, TRACE CLAY, TRACE GRAVEL, WET *(continued)*		95																
		96	10 13 14	31	100	SS-24	-	-	-	-	-	-	-	-	-	16	A-3a (V)	
		97																
		98																
		99																
		100																
	403.8	101 EOB	10 13 16	33	100	SS-25	-	-	-	-	-	-	-	-	-	16	A-3a (V)	

NOTES: GROUNDWATER ENCOUNTERED AT 40.0' DURING DRILLING. HOLE DID NOT CAVE. BORING OFFSET 14.0' WEST DUE TO TRAFFIC AND OVERHEAD OBSTRUCTION.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 80 GAL. BENTONITE GROUT; POURED 2 BAGS HOLE PLUG; SHOVELED SOIL CUTTINGS

PROJECT: HAM-75-1.05	DRILLING FIRM / OPERATOR: NEAS / ASHBAUGH	DRILL RIG: CME 55T	STATION / OFFSET: 105+13, 32' RT.	EXPLORATION ID B-007-0-21
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: NEAS / JL	HAMMER: CME AUTOMATIC	ALIGNMENT: LINN ST	
PID: 113361 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 12/5/19	ELEVATION: 521.4 (MSL) EOB: 116.5 ft.	PAGE 1 OF 4
START: 12/6/21 END: 12/8/21	SAMPLING METHOD: SPT	ENERGY RATIO (%): 68.4	LAT / LONG: 39.103968, -84.529004	

MATERIAL DESCRIPTION AND NOTES	ELEV. 521.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
5.0" ASPHALT AND 7.0" CONCRETE AND 5.0" BASE (DRILLERS DESCRIPTION)	520.0																	
HARD, BROWN AND BROWNISH GRAY, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, CONTAINS BRICK AND COAL FRAGMENTS, DAMP **(FILL)**	514.4																	
		3	4 6 7	15	67	SS-1	4.50	9	14	21	35	21	27	16	11	13	A-6a (5)	
		5	4 6 8	16	67	SS-2	4.50	-	-	-	-	-	-	-	-	15	A-6a (V)	
VERY STIFF, BROWN, **SILTY CLAY**, LITTLE SAND, LITTLE GRAVEL AND STONE FRAGMENTS, CONTAINS BRICK AND COAL FRAGMENTS, DAMP **(FILL)**	511.9																	
		8	5 8 10	21	50	SS-3	2.50	16	7	13	33	31	35	18	17	15	A-6b (9)	
VERY STIFF TO HARD, BROWN, **SILT AND CLAY**, SOME GRAVEL AND STONE FRAGMENTS, SOME SAND, CONTAINS BRICK AND COAL FRAGMENTS, DAMP **(FILL)**	506.9																	
		10	9 11 12	26	61	SS-4	4.50	28	11	14	28	19	27	16	11	11	A-6a (3)	
		13	8 10 12	25	72	SS-5	3.25	-	-	-	-	-	-	-	-	12	A-6a (V)	
MEDIUM DENSE, BROWN, **STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, CONTAINS BRICK AND COAL FRAGMENTS, DAMP **(FILL)**	504.4																	
		15	7 8 7	17	61	SS-6	-	-	-	-	-	-	-	-	-	14	A-2-4 (V)	
VERY STIFF TO HARD, BROWN AND ORANGISH BROWN, **CLAY**, "AND" SILT, LITTLE TO SOME SAND, TRACE TO LITTLE GRAVEL AND STONE FRAGMENTS, CONTAINS BRICK AND COAL FRAGMENTS, DAMP **(FILL)**	495.4																	
		18	5 7 6	15	78	SS-7	3.50	6	8	7	46	33	41	21	20	21	A-7-6 (12)	
		20	5 6 7	15	89	SS-8	3.25	-	-	-	-	-	-	-	-	17	A-7-6 (V)	
		23	5 5 7	14	72	SS-9	3.00	-	-	-	-	-	-	-	-	14	A-7-6 (V)	
		25	5 6 4	11	67	SS-10A	4.25	-	-	-	-	-	-	-	-	19	A-7-6 (V)	
LOOSE TO MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, TRACE SILT, TRACE GRAVEL, TRACE CLAY, DAMP						SS-10B	-	-	-	-	-	-	-	-	-	7	A-3a (V)	
		28	4 5 4	10	78	SS-11	-	-	-	-	-	-	-	-	-	3	A-3a (V)	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 4/10/25 12:04 - X:\1ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\1ARCHIVE\ARCHIVE BY YEAR\2024 ARCHIVE\HAM-75-1.05\GINT FILES\HAI

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 105+13, 32' RT.	START: 12/6/21	END: 12/8/21	PG 2 OF 4	B-007-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 491.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
LOOSE TO MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, TRACE SILT, TRACE GRAVEL, TRACE CLAY, DAMP *(continued)*		31	4 5 7	14	39	SS-12	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
		33	5 7 9	18	61	SS-13	-	0	56	38	6	0	NP	NP	NP	2	A-3a (V)	
		36	6 9 9	21	44	SS-14	-	-	-	-	-	-	-	-	-	7	A-3a (V)	
		38	7 8 10	21	56	SS-15	-	-	-	-	-	-	-	-	-	4	A-3a (V)	
		41	8 10 10	23	67	SS-16	-	-	-	-	-	-	-	-	-	4	A-3a (V)	
		46	6 7 11	21	100	SS-17	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
	473.1	48																
MEDIUM DENSE TO DENSE, BROWN, **SANDY SILT**, TRACE CLAY, TRACE GRAVEL, (INTERBEDDED SAND AND SILT), DAMP		51	10 11 12	26	100	SS-18	-	-	-	-	-	-	-	-	-	4	A-4a (V)	
		W 468.9																
SS-19 AND SS-20 BECOME WET		56	8 13 16	33	100	SS-19	-	1	0	59	36	4	NP	NP	NP	17	A-4a (1)	
		61	8 14 15	33	100	SS-20	-	-	-	-	-	-	-	-	-	20	A-4a (V)	

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 105+13, 32' RT.	START: 12/6/21	END: 12/8/21	PG 3 OF 4	B-007-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 459.3	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
	458.1	63																
MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, TRACE SILT, TRACE GRAVEL, TRACE CLAY, DAMP		64 – 67	10 12 14	30	100	SS-21	-	-	-	-	-	-	-	-	-	10	A-3a (V)	
	453.1	68																
DENSE, BROWN, **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST		69 – 72	10 12 15	31	100	SS-22	-	-	-	-	-	-	-	-	-	11	A-1-b (V)	
	448.1	73																
MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, TRACE SILT, TRACE GRAVEL, TRACE CLAY, MOIST		74 – 77	11 11 13	27	100	SS-23	-	-	-	-	-	-	-	-	-	13	A-3a (V)	
	443.1	78																
MEDIUM DENSE, BROWN, **GRAVEL WITH SAND**, TRACE SILT, TRACE CLAY, MOIST		79 – 82	12 10 10	23	100	SS-24	-	-	-	-	-	-	-	-	-	15	A-1-b (V)	
	438.1	83																
MEDIUM DENSE TO DENSE, GRAYISH BROWN, **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE GRAVEL, WET		84 – 87	12 11 12	26	100	SS-25	-	1	14	71	12	2	NP	NP	NP	20	A-3a (0)	
		88 – 92	13 13 14	31	78	SS-26	-	-	-	-	-	-	-	-	-	18	A-3a (V)	
		93 – 94																

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 4/10/25 12:04 - X:\1ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\1ARCHIVE\1ARCHIVE BY YEAR\2024 ARCHIVE\HAM-75-1.05\GINT FILES\HAI

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 105+13, 32' RT.	START: 12/6/21	END: 12/8/21	PG 4 OF 4	B-007-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 427.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE TO DENSE, GRAYISH BROWN, **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE GRAVEL, WET *(continued)*		95–96	13 14 15	33	94	SS-27	-	-	-	-	-	-	-	-	-	24	A-3a (V)	
		100–101	14 14 16	34	83	SS-28	-	-	-	-	-	-	-	-	-	24	A-3a (V)	
		105–106	15 14 16	34	100	SS-29	-	-	-	-	-	-	-	-	-	19	A-3a (V)	
		110–111	15 15 17	36	89	SS-30	-	-	-	-	-	-	-	-	-	20	A-3a (V)	
	404.9	EOB 115–116	16 17 17	39	83	SS-31	-	-	-	-	-	-	-	-	-	19	A-3a (V)	

NOTES: GROUNDWATER ENCOUNTERED AT 52.5' DURING DRILLING. HOLE DID NOT CAVE. DRILLED AS STAKED.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 200 GAL. BENTONITE GROUT

PROJECT: HAM-75-1.05	DRILLING FIRM / OPERATOR: NEAS / ASHBAUGH	DRILL RIG: CME 75T	STATION / OFFSET: 107+87, 47' RT.	EXPLORATION ID B-008-0-21
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: NEAS / ASHBAUGH	HAMMER: CME AUTOMATIC	ALIGNMENT: LINN ST	
PID: 113361 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 5/1/19	ELEVATION: 503.0 (MSL) EOB: 101.5 ft.	PAGE 1 OF 4
START: 1/27/22 END: 1/28/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 89	LAT / LONG: 39.104649, -84.528586	

MATERIAL DESCRIPTION AND NOTES	ELEV. 503.0
5.0" ASPHALT AND 9.5" CONCRETE AND 7.0" BASE (DRILLER DESCRIPTION)	501.2
VERY STIFF, BROWN, **SILT**, "AND" CLAY, TRACE SAND, TRACE GRAVEL, MOIST	498.7
MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, TRACE SILT, TRACE CLAY, TRACE GRAVEL, DAMP	494.5
STIFF, BROWN, **SILT AND CLAY**, LITTLE SAND, TRACE GRAVEL, MOIST	493.5
MEDIUM DENSE, BROWN, **SILT**, LITTLE CLAY, TRACE SAND, TRACE GRAVEL, MOIST	492.7
MEDIUM DENSE, BROWN, **COARSE AND FINE SAND**, TRACE TO LITTLE SILT, TRACE CLAY, TRACE GRAVEL, DAMP	487.0
VERY STIFF, BROWN, **SANDY SILT**, LITTLE CLAY, TRACE GRAVEL, MOIST	486.0
VERY STIFF, BROWN, **SILT**, SOME CLAY, TRACE TO LITTLE SAND, TRACE GRAVEL, WET TO MOIST	474.7
MEDIUM DENSE TO DENSE, BROWN, **SILT**, TRACE TO LITTLE CLAY, TRACE TO LITTLE SAND, TRACE GRAVEL, CONTAINS INTERBEDDED SAND SEAMS, MOIST TO WET	

DEPTHS: 1–29

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
3 5 6	16	67	SS-1	2.50	3	2	2	53	40	29	19	10	21	A-4b (8)
3 5 8	19	56	SS-2A	2.25	-	-	-	-	-	-	-	-	25	A-4b (V)
			SS-2B	-	-	-	-	-	-	-	-	-	6	A-3a (V)
3 5 7	18	61	SS-3	-	-	-	-	-	-	-	-	-	5	A-3a (V)
5 6 5	16	78	SS-4A	-	-	-	-	-	-	-	-	-	5	A-3a (V)
			SS-4B	1.75	-	-	-	-	-	-	-	-	23	A-6a (V)
5 6 9	22	89	SS-5A	-	-	-	-	-	-	-	-	-	23	A-4b (V)
			SS-5B	-	-	-	-	-	-	-	-	-	6	A-3a (V)
5 5 7	18	89	SS-6	-	0	6	81	11	2	NP	NP	NP	5	A-3a (0)
4 5 6	16	83	SS-7A	-	-	-	-	-	-	-	-	-	7	A-3a (V)
			SS-7B	2.75	-	-	-	-	-	-	-	-	22	A-4a (V)
5 6 8	21	94	SS-8	2.50	0	0	1	76	23	28	22	6	27	A-4b (8)
8 7 8	22	100	SS-9	2.50	-	-	-	-	-	-	-	-	20	A-4b (V)
8 9 11	30	89	SS-10	2.75	-	-	-	-	-	-	-	-	25	A-4b (V)
8 11 12	34	100	SS-11	2.75	3	5	7	61	24	26	18	8	18	A-4b (8)

HOLE SEALED

MATERIAL DESCRIPTION AND NOTES	ELEV. 473.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE TO DENSE, BROWN, **SILT**, TRACE TO LITTLE CLAY, TRACE TO LITTLE SAND, TRACE GRAVEL, CONTAINS INTERBEDDED SAND SEAMS, MOIST TO WET *(continued)*		30–31.5	8 10 11	31	100	SS-12	-	-	-	-	-	-	-	-	-	23	A-4b (V)	
		35–36.5	8 7 5	18	100	SS-13	-	-	-	-	-	-	-	-	-	26	A-4b (V)	
		40–41.5	5 4 5	13	100	SS-14	-	-	-	-	-	-	-	-	-	28	A-4b (V)	
		45–46.5	5 5 4	13	89	SS-15	-	0	0	6	81	13	NP	NP	NP	27	A-4b (8)	
		50–51.5	4 4 5	13	100	SS-16	-	-	-	-	-	-	-	-	-	23	A-4b (V)	
@55.0'; BECOMES GRAY		55–56.5	6 9 10	28	94	SS-17	-	0	0	11	82	7	NP	NP	NP	29	A-4b (8)	
	444.7	58.3																
DENSE, GRAY, **FINE SAND**, TRACE SILT, TRACE COARSE SAND, TRACE CLAY, TRACE GRAVEL, WET		60–61.5	11 10 11	31	100	SS-18	-	0	1	92	6	1	NP	NP	NP	24	A-3 (0)	

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 107+87, 47' RT.	START: 1/27/22	END: 1/28/22	PG 3 OF 4	B-008-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 440.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
DENSE, GRAY, **FINE SAND**, TRACE SILT, TRACE COARSE SAND, TRACE CLAY, TRACE GRAVEL, WET *(continued)*		63–65																
		65–66.5	10 12 10	33	100	SS-19	-	-	-	-	-	-	-	-	-	28	A-3 (V)	
	434.7	67–68																
DENSE, GRAY, **SANDY SILT**, TRACE CLAY, TRACE GRAVEL, MOIST TO WET		69–70																
		70–71.5	10 10 12	33	100	SS-20	-	-	-	-	-	-	-	-	-	23	A-4a (V)	
		72–74																
		75–76.5	11 11 12	34	89	SS-21	-	0	0	63	34	3	NP	NP	NP	27	A-4a (0)	
	424.7	77–78																
DENSE, GRAY, **COARSE AND FINE SAND**, TRACE SILT, TRACE GRAVEL, TRACE CLAY, WET TO MOIST		79–80																
		80–81.5	12 12 15	40	100	SS-22	-	-	-	-	-	-	-	-	-	23	A-3a (V)	
		82–84																
		85–86.5	12 14 16	45	100	SS-23	-	-	-	-	-	-	-	-	-	19	A-3a (V)	
		87–89																
		90–91.5	13 12 16	42	100	SS-24	-	-	-	-	-	-	-	-	-	16	A-3a (V)	
		92–94																

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 4/10/25 12:04 - X:\1ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\1ARCHIVE BY YEAR\2024 ARCHIVE\HAM-75-1.05\GINT FILES\HAI

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 107+87, 47' RT.	START: 1/27/22	END: 1/28/22	PG 4 OF 4	B-008-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 408.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
DENSE, GRAY, **COARSE AND FINE SAND**, TRACE SILT, TRACE GRAVEL, TRACE CLAY, WET TO MOIST *(continued)*		95 – 96	12 12 15	40	100	SS-25	-	-	-	-	-	-	-	-	-	15	A-3a (V)	
	401.5	100 – 101 EOB	12 13 16	43	100	SS-26	-	-	-	-	-	-	-	-	-	14	A-3a (V)	

NOTES: GROUNWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE. DRILLED AS STAKED.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; PUMPED 80 GAL. BENTONITE GROUT; POURED 2 BAGS HOLE PLUG; SHOVELED SOIL CUTTINGS

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 4/10/25 12:05 - X:\1ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\1ARCHIVE BY YEAR\2024 ARCHIVE\HAM-75-1.05\GINT FILES\HA

PROJECT: HAM-75-1.05	DRILLING FIRM / OPERATOR: NEAS / ASHBAUGH	DRILL RIG: CME 55T	STATION / OFFSET: 108+77, 77' RT.	EXPLORATION ID B-009-0-21
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: NEAS / ASHBAUGH	HAMMER: CME AUTOMATIC	ALIGNMENT: LINN ST	
PID: 113361 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 12/5/19	ELEVATION: 502.0 (MSL) EOB: 101.5 ft.	PAGE 1 OF 4
START: 1/4/22 END: 1/4/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 68.4	LAT / LONG: 39.104844, -84.528367	

MATERIAL DESCRIPTION AND NOTES	ELEV. 502.0
6.0" TOPSOIL (DRILLERS DESCRIPTION)	501.5
VERY STIFF, BROWN AND DARK BROWN, **SILTY CLAY**, SOME SAND, TRACE GRAVEL, CONTAINS ROOTS AND TRACE BRICK FRAGMENTS, MOIST **(FILL)**	495.9
LOOSE, BROWN, **COARSE AND FINE SAND**, LITTLE SILT, TRACE CLAY, TRACE GRAVEL, WET	490.0
VERY STIFF, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, MOIST	485.0
LOOSE, BROWN, **SILT**, LITTLE CLAY, TRACE SAND, TRACE GRAVEL, WET	480.0
LOOSE TO MEDIUM DENSE, BROWN, **SILT**, LITTLE SAND, LITTLE CLAY, TRACE GRAVEL, CONTAINS INTERBEDDED SAND SEAMS, WET	472.0

SPT/RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)
4-4-5	10	67	SS-1	4.00	-	-	-	-	-	-	-	-	22	A-6b (V)
4-6-7	15	61	SS-2	3.00	4	7	25	32	32	36	17	19	18	A-6b (9)
4-5-7	14	56	SS-3	2.50	1	3	22	44	30	34	18	16	20	A-6b (10)
4-3-4	8	50	SS-4	-	-	-	-	-	-	-	-	-	14	A-3a (V)
3-3-3	7	67	SS-5	-	2	17	58	14	9	NP	NP	NP	14	A-3a (0)
3-4-3	8	72	SS-6	-	-	-	-	-	-	-	-	-	14	A-3a (V)
4-3-5	9	78	SS-7	3.50	2	15	14	37	32	34	19	15	22	A-6a (9)
3-4-4	9	83	SS-8	3.25	-	-	-	-	-	-	-	-	24	A-6a (V)
2-3-4	8	83	SS-9	-	1	1	5	78	15	NP	NP	NP	24	A-4b (8)
3-3-4	8	72	SS-10	-	-	-	-	-	-	-	-	-	21	A-4b (V)
3-4-3	8	83	SS-11	-	0	1	15	73	11	NP	NP	NP	22	A-4b (8)
4-4-6	11	72	SS-12	-	-	-	-	-	-	-	-	-	19	A-4b (V)

MATERIAL DESCRIPTION AND NOTES	ELEV. 472.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE, BROWN BECOMING GRAY, **SILT**, LITTLE CLAY, TRACE SAND, TRACE GRAVEL, WET		30.5–32	5 6 7	15	100	SS-13	-	0	0	2	84	14	NP	NP	NP	29	A-4b (8)	
		35–36.5	5 7 7	16	100	SS-14	-	-	-	-	-	-	-	-	-	25	A-4b (V)	
	463.7	38.3																
MEDIUM DENSE, GRAY, **SILT**, LITTLE SAND, TRACE CLAY, TRACE GRAVEL, WET	W 462.0	40																
		40–41.5	6 7 9	18	100	SS-15	-	0	0	15	80	5	NP	NP	NP	24	A-4b (8)	
		45–46.5	7 8 8	18	100	SS-16	-	-	-	-	-	-	-	-	-	25	A-4b (V)	
	453.7	48.3																
MEDIUM DENSE, GRAY, **COARSE AND FINE SAND**, SOME SILT, TRACE CLAY, TRACE GRAVEL, WET		50–51.5	8 10 13	26	100	SS-17	-	-	-	-	-	-	-	-	-	22	A-3a (V)	
		55–56.5	8 11 14	29	100	SS-18	-	-	-	-	-	-	-	-	-	25	A-3a (V)	
	443.7	58.3																
MEDIUM DENSE TO DENSE, GRAY, **FINE SAND**, "AND" COARSE SAND, TRACE SILT, TRACE GRAVEL, TRACE CLAY, WET		60–61.5	8 10 13	26	100	SS-19	-	-	-	-	-	-	-	-	-	22	A-3 (V)	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 4/10/25 12:05 - X:\1ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\1ARCHIVE\ARCHIVE BY YEAR\2024 ARCHIVE\HAM-75-1.05\GINT FILES\HA

MATERIAL DESCRIPTION AND NOTES	ELEV. 439.9	DEPTHS	SPT/RQD	N60	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE TO DENSE, GRAY, **FINE SAND**, "AND" COARSE SAND, TRACE SILT, TRACE GRAVEL, TRACE CLAY, WET *(continued)* (FS)		63–65																
		65–66.5	9 10 13	26	100	SS-20	-	-	-	-	-	-	-	-	-	24	A-3 (V)	
		70–71.5	10 12 13	29	100	SS-21	-	2	39	52	7	0	NP	NP	NP	19	A-3 (0)	
		75–76.5	12 13 15	32	100	SS-22	-	-	-	-	-	-	-	-	-	16	A-3 (V)	
		80–81.5	12 13 17	34	100	SS-23	-	-	-	-	-	-	-	-	-	25	A-3 (V)	
		85–86.5	13 14 17	35	83	SS-24	-	-	-	-	-	-	-	-	-	22	A-3 (V)	
		90–91.5	13 13 16	33	100	SS-25	-	-	-	-	-	-	-	-	-	19	A-3 (V)	
		92–94																

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 4/10/25 12:05 - X:\1ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\1ARCHIVE BY YEAR\2024 ARCHIVE\HAM-75-1.05\GINT FILES\HAI

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 108+77, 77' RT.	START: 1/4/22	END: 1/4/22	PG 4 OF 4	B-009-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 407.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE TO DENSE, GRAY, **FINE SAND**, "AND" COARSE SAND, TRACE SILT, TRACE GRAVEL, TRACE CLAY, WET *(continued)*		95																
		96	12 12 15	31	100	SS-26	-	-	-	-	-	-	-	-	-	17	A-3 (V)	
		97																
		98																
		99																
		100																
	400.5	101 EOB	12 14 16	34	100	SS-27	-	-	-	-	-	-	-	-	-	21	A-3 (V)	

F S

NOTES: GROUNDWATER ENCOUNTERED AT 40.0' DURING DRILLING. HOLE DID NOT CAVE. BORING OFFSET 16.0' EAST DUE TO OVERHEAD OBSTRUCTION.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 80 GAL. BENTONITE GROUT; POURED 2 BAGS HOLE PLUG; SHOVELED SOIL CUTTINGS

PROJECT: HAM-75-1.05	DRILLING FIRM / OPERATOR: NEAS / ASHBAUGH	DRILL RIG: CME 55T	STATION / OFFSET: 110+26, 28' LT.	EXPLORATION ID B-010-0-21
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: NEAS / ASHBAUGH	HAMMER: CME AUTOMATIC	ALIGNMENT: LINN ST	
PID: 113361 SFN:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 12/5/19	ELEVATION: 518.0 (MSL) EOB: 106.5 ft.	PAGE 1 OF 4
START: 11/29/21 END: 11/30/21	SAMPLING METHOD: SPT	ENERGY RATIO (%): 68.4	LAT / LONG: 39.105334, -84.528510	

MATERIAL DESCRIPTION AND NOTES	ELEV. 518.0
6.0" ASPHALT AND 6.0" CONCRETE AND 5.0" BASE (DRILLERS DESCRIPTION)	516.6
MEDIUM DENSE, BROWN AND GRAY, **GRAVEL AND STONE FRAGMENTS WITH SAND AND SILT**, TRACE CLAY, CONTAINS TRACE BRICK FRAGMENTS, MOIST TO DAMP **(FILL)**	511.0
VERY STIFF TO HARD, BROWN, **SILT AND CLAY**, LITTLE TO SOME GRAVEL AND STONE FRAGMENTS, LITTLE TO SOME SAND, CONTAINS BRICK FRAGMENTS, DAMP **(FILL)**	501.0
MEDIUM DENSE, BROWN, **GRAVEL AND STONE FRAGMENTS WITH SAND**, TRACE SILT, TRACE CLAY, DAMP	499.3
VERY STIFF, BROWN, **SILTY CLAY**, SOME SAND, LITTLE GRAVEL, DAMP TO MOIST	496.0
MEDIUM DENSE TO DENSE, BROWN, **COARSE AND FINE SAND**, TRACE TO LITTLE SILT, TRACE GRAVEL, TRACE CLAY, DAMP TO MOIST @25.0' TO 29.0'; CONTAINS IRON STAINING	

DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
3-4.5	4 5 7	14	11	SS-1	-	-	-	-	-	-	-	-	-	14	A-2-4 (V)	
5.5-7	4 7 8	17	22	SS-2	-	-	-	-	-	-	-	-	-	9	A-2-4 (V)	
8-9.5	5 6 6	14	56	SS-3	4.25	28	12	13	28	19	30	17	13	12	A-6a (3)	
10.5-12	5 4 5	10	39	SS-4	4.50	-	-	-	-	-	-	-	-	14	A-6a (V)	
13-14.5	2 3 2	6	50	SS-5	4.25	-	-	-	-	-	-	-	-	16	A-6a (V)	
15.5-17	3 4 5	10	44	SS-6	2.50	-	-	-	-	-	-	-	-	17	A-6a (V)	
18-19.5	4 6 7	15	61	SS-7A	-	-	-	-	-	-	-	-	-	6	A-1-b (V)	
				SS-7B	2.25	-	-	-	-	-	-	-	-	18	A-6b (V)	
20.5-22	3 3 3	7	72	SS-8	2.25	13	12	9	33	33	36	18	18	21	A-6b (9)	
23-24.5	5 7 8	17	56	SS-9	-	-	-	-	-	-	-	-	-	3	A-3a (V)	
25.5-27	6 7 6	15	67	SS-10	-	5	44	31	18	2	NP	NP	NP	6	A-3a (0)	
28-29.5	8 9 13	25	78	SS-11	-	-	-	-	-	-	-	-	-	6	A-3a (V)	

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 110+26, 28' LT.	START: 11/29/21	END: 11/30/21	PG 2 OF 4	B-010-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 488.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE TO DENSE, BROWN, **COARSE AND FINE SAND**, TRACE TO LITTLE SILT, TRACE GRAVEL, TRACE CLAY, DAMP TO MOIST *(continued)*		31	10 11 16	31	100	SS-12	-	-	-	-	-	-	-	-	-	4	A-3a (V)	
		32–35																
		36	5 4 6	11	100	SS-13	-	-	-	-	-	-	-	-	-	5	A-3a (V)	
		37–40																
@40.0' TO 46.5'; CONTAINS INTERBEDDED SILT SEAMS		41	4 6 7	15	67	SS-14	-	-	-	-	-	-	-	-	-	11	A-3a (V)	
		42–45																
	471.0	46	5 6 7	15	61	SS-15	-	-	-	-	-	-	-	-	-	14	A-3a (V)	
MEDIUM DENSE, BROWN BECOMING BROWN AND GRAY, **SILT**, LITTLE SAND, TRACE TO LITTLE CLAY, TRACE GRAVEL, WET		47–50																
		51	5 7 7	16	72	SS-16	-	0	1	12	78	9	NP	NP	NP	26	A-4b (8)	
		52–55																
		56	5 8 6	16	67	SS-17	-	-	-	-	-	-	-	-	-	27	A-4b (V)	
		57–60																
		61	4 7 8	17	78	SS-18	-	-	-	-	-	-	-	-	-	27	A-4b (V)	

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 110+26, 28' LT.	START: 11/29/21	END: 11/30/21	PG 3 OF 4	B-010-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 455.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GR	CS	FS	SI	CL	LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE, BROWN BECOMING BROWN AND GRAY, **SILT**, LITTLE SAND, TRACE TO LITTLE CLAY, TRACE GRAVEL, WET *(continued)*		63 – 64																
		65 – 66	6 10 11	24	78	SS-19	-	-	-	-	-	-	-	-	-	25	A-4b (V)	
	449.7	67 – 68 (W 449.8)																
MEDIUM DENSE TO DENSE, GRAY, **SANDY SILT**, TRACE CLAY, TRACE GRAVEL, WET		69																
		70 – 71	7 14 13	31	67	SS-20	-	0	1	49	45	5	NP	NP	NP	28	A-4a (3)	
		72 – 74																
		75 – 76	7 12 11	26	72	SS-21	-	-	-	-	-	-	-	-	-	31	A-4a (V)	
	439.7	77 – 78																
MEDIUM DENSE TO DENSE, GRAY, **COARSE AND FINE SAND**, TRACE SILT, TRACE CLAY, TRACE GRAVEL, WET		79																
		80 – 81	7 11 11	25	78	SS-22	-	-	-	-	-	-	-	-	-	20	A-3a (V)	
		82 – 84																
		85 – 86	8 10 12	25	78	SS-23	-	1	3	85	9	2	NP	NP	NP	21	A-3a (0)	
		87 – 89																
		90 – 91	9 10 12	25	78	SS-24	-	-	-	-	-	-	-	-	-	21	A-3a (V)	
		92 – 94																

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 4/10/25 12:05 - X:\1ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\1ARCHIVE\ARCHIVE BY YEAR\2024 ARCHIVE\HAM-75-1.05\GINT FILES\HA

PID: 113361	SFN:	PROJECT: HAM-75-1.05	STATION / OFFSET: 110+26, 28' LT.	START: 11/29/21	END: 11/30/21	PG 4 OF 4	B-010-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 423.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	HOLE SEALED
MEDIUM DENSE TO DENSE, GRAY, **COARSE AND FINE SAND**, TRACE SILT, TRACE CLAY, TRACE GRAVEL, WET *(continued)*		95 – 96	11 11 12	26	72	SS-25	-	-	-	-	-	-	-	-	-	23	A-3a (V)	
		100 – 101	10 13 13	30	83	SS-26	-	-	-	-	-	-	-	-	-	24	A-3a (V)	
	411.5	105 – 106 EOB	12 13 14	31	78	SS-27	-	-	-	-	-	-	-	-	-	21	A-3a (V)	

NOTES: GROUNDWATER ENCOUNTERED AT 68.2' DURING DRILLING. HOLE DID NOT CAVE. DRILLED AS STAKED.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 230 GAL. BENTONITE GROUT

DRIVEN PILE ANALYSIS

REAR ABUTMENT

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	-
5.0	19.1	8.0	11.2	1.6	15.309	1.117	4.20	26.1	D 19-42
10.0	38.4	15.0	23.4	3.3	19.202	0.961	4.70	23.2	D 19-42
15.0	53.1	27.1	26.0	4.5	21.703	1.948	4.99	22.5	D 19-42
20.0	70.2	44.2	26.0	5.8	23.662	2.217	5.23	21.8	D 19-42
25.0	92.4	66.4	26.0	7.7	25.152	2.783	5.54	21.4	D 19-42
30.0	105.2	88.9	16.3	8.9	25.840	3.503	5.70	21.1	D 19-42
35.0	128.4	112.2	16.3	11.2	26.765	3.805	5.97	20.6	D 19-42
40.0	154.4	138.2	16.3	13.9	27.782	3.159	6.32	20.9	D 19-42
45.0	214.4	175.1	39.4	22.1	31.100	6.647	7.31	23.4	D 19-42
50.0	308.7	224.2	84.5	62.6	37.615	9.959	8.82	27.3	D 19-42
55.0	313.2	273.8	39.4	59.1	36.991	8.975	8.69	26.7	D 19-42
60.0	384.3	326.4	57.8	338.3	40.325	9.616	9.38	28.3	D 19-42
65.0	419.8	380.5	39.4	9999.0	42.198	8.902	9.51	28.2	D 19-42
70.0	475.2	435.9	39.4	9999.0	43.494	8.014	9.58	28.0	D 19-42
75.0	533.5	494.2	39.4	9999.0	43.665	7.564	9.60	27.5	D 19-42
80.0	594.7	555.4	39.4	9999.0	43.708	7.511	9.58	27.1	D 19-42
85.0	658.8	619.4	39.4	9999.0	44.141	6.561	9.54	26.5	D 19-42
90.0	725.8	686.4	39.4	9999.0	44.486	4.490	9.50	25.8	D 19-42
94.9	794.2	754.8	39.4	9999.0	44.596	3.491	9.43	24.9	D 19-42

Refusal occurred; no driving time output possible.

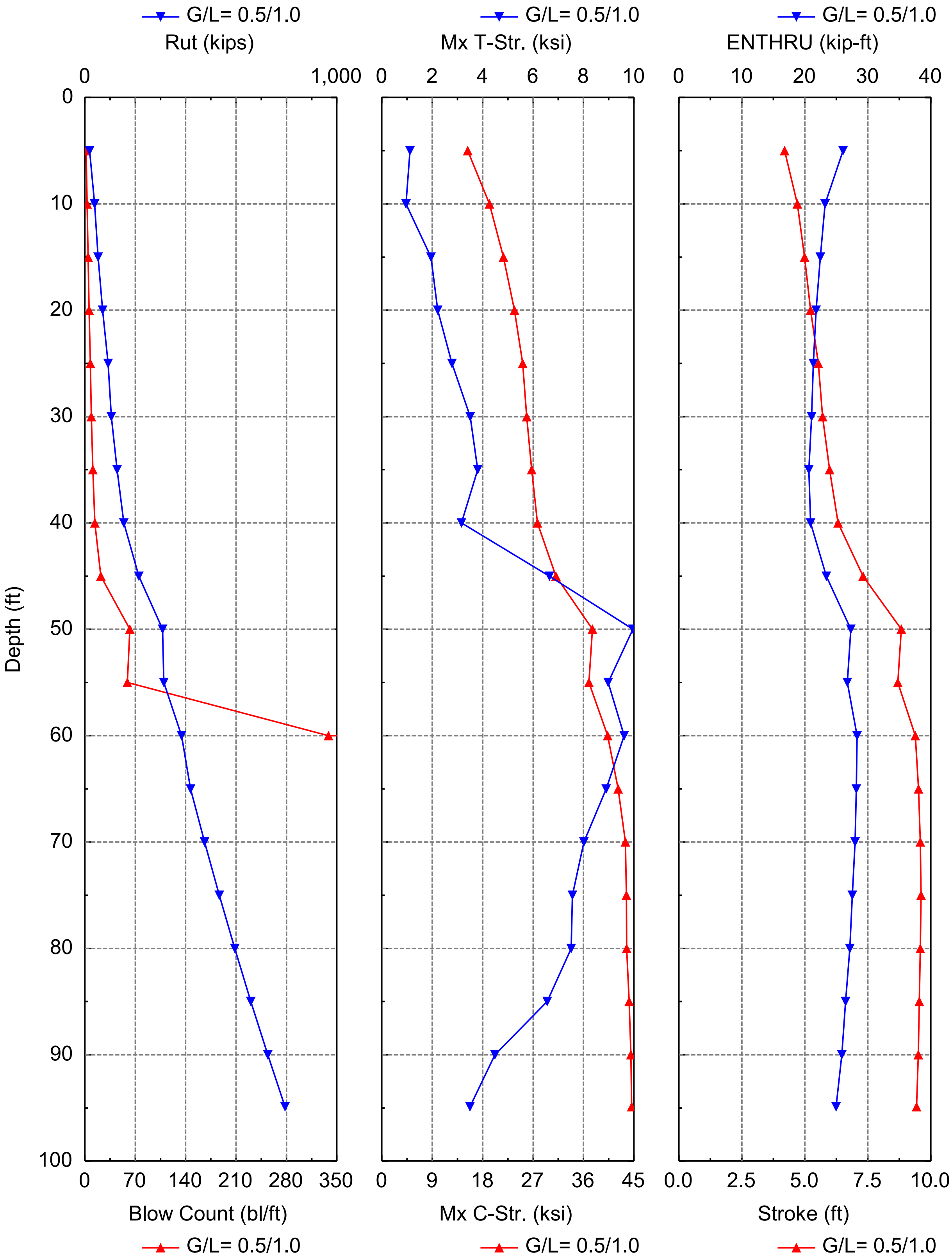
Gain/Loss Factor at Shaft/Toe = 1.000/1.000

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	-
5.0	26.6	15.4	11.2	2.4	17.214	0.335	4.47	24.3	D 19-42
10.0	45.9	22.4	23.4	4.2	20.925	1.243	4.92	22.6	D 19-42
15.0	60.5	34.5	26.0	5.5	23.399	1.959	5.17	21.8	D 19-42
20.0	77.6	51.7	26.0	6.8	24.998	2.315	5.40	21.4	D 19-42
25.0	99.8	73.8	26.0	8.9	26.489	3.525	5.69	21.1	D 19-42
30.0	115.4	99.1	16.3	10.2	26.852	3.928	5.85	20.7	D 19-42
35.0	143.3	127.0	16.3	12.9	28.376	3.274	6.18	20.7	D 19-42
40.0	174.5	158.2	16.3	16.4	29.705	4.493	6.67	21.7	D 19-42
45.0	236.4	197.0	39.4	27.1	33.450	7.477	7.68	24.5	D 19-42
50.0	330.7	246.2	84.5	96.9	39.265	10.293	9.07	27.9	D 19-42
55.0	335.2	295.8	39.4	98.3	39.297	9.514	8.98	27.0	D 19-42
60.0	406.2	348.4	57.8	9999.0	40.845	9.489	9.41	28.1	D 19-42
65.0	441.8	402.4	39.4	9999.0	42.482	8.943	9.48	27.8	D 19-42

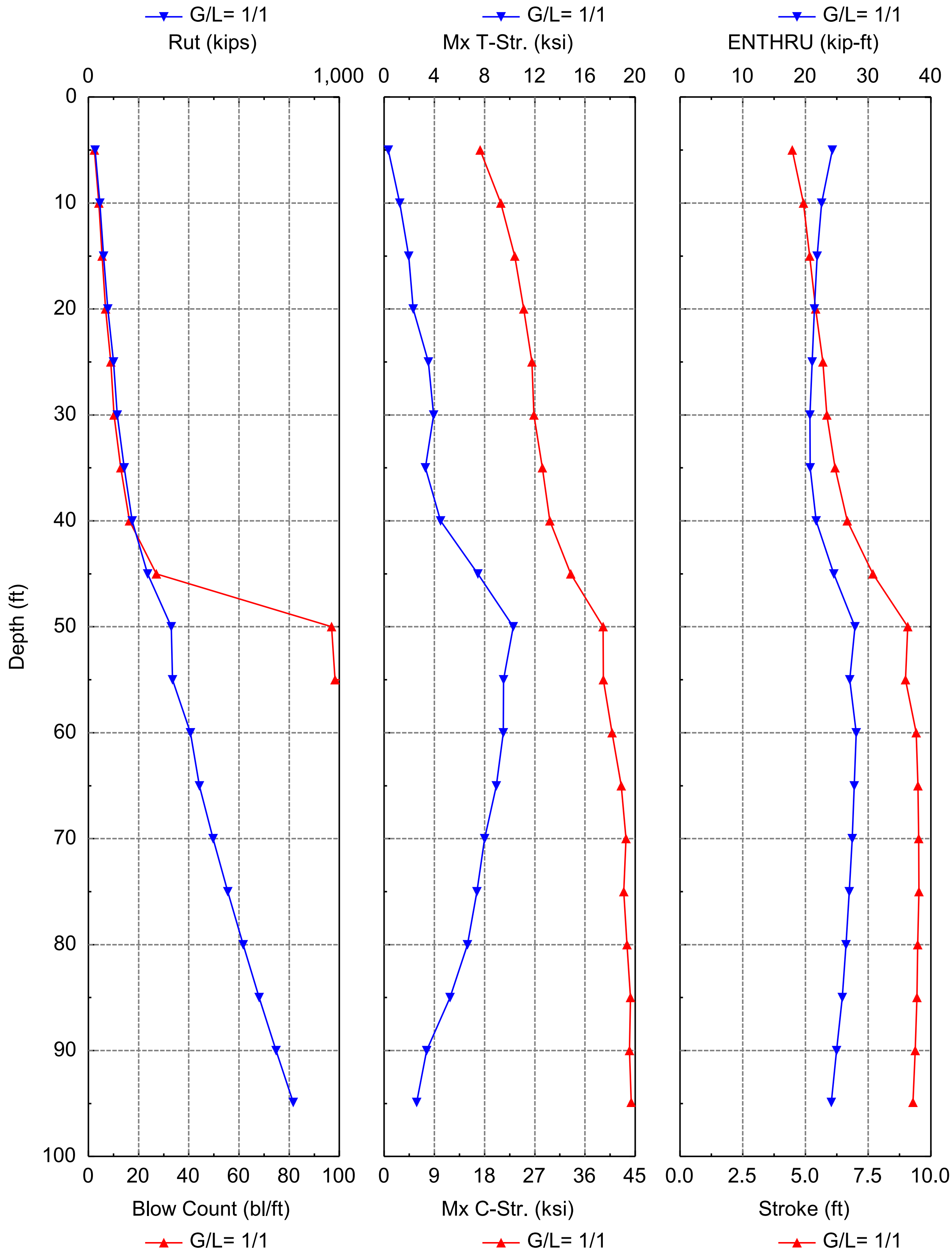
70.0	497.2	457.8	39.4	9999.0	43.332	8.004	9.51	27.5	D 19-42
75.0	555.5	516.1	39.4	9999.0	42.959	7.382	9.52	27.0	D 19-42
80.0	616.7	577.3	39.4	9999.0	43.548	6.625	9.47	26.5	D 19-42
85.0	680.8	641.4	39.4	9999.0	44.171	5.250	9.44	25.9	D 19-42
90.0	747.7	708.4	39.4	9999.0	43.984	3.377	9.37	25.0	D 19-42
94.9	816.1	776.8	39.4	9999.0	44.296	2.582	9.28	24.1	D 19-42

Refusal occurred; no driving time output possible.

Driveability Analysis Summary



Driveability Analysis Summary



GRLWEAP: Wave Equation Analysis of Pile Foundations

Linn St + RA12IN 12/12/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

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	Clay	110.0	1.7	0.0	1.08	15.30
4.4	Clay	110.0	1.7	0.0	1.08	15.30
4.4	Sand	125.0	0.0	32.0	0.25	12.30
26.7	Sand	125.0	0.0	32.0	1.68	33.09
26.7	Sand	128.0	0.0	31.0	1.53	20.71
41.7	Sand	128.0	0.0	31.0	2.16	20.71
41.7	Sand	128.0	0.0	33.0	2.59	50.11
46.7	Sand	128.0	0.0	33.0	2.77	50.11
46.7	Sand	128.0	0.0	35.0	3.26	107.60
51.7	Sand	128.0	0.0	35.0	3.47	107.60
51.7	Sand	128.0	0.0	33.0	2.95	50.11
56.7	Sand	128.0	0.0	33.0	3.14	50.11
56.7	Sand	125.0	0.0	34.0	3.41	73.64
61.7	Sand	125.0	0.0	34.0	3.60	73.64
61.7	Sand	128.0	0.0	33.0	3.31	50.11
94.9	Sand	128.0	0.0	33.0	4.53	50.11

PILE INPUT

Uniform Pile		Pile Type:	Unknown
Pile Length: (ft)	105.000	Pile Penetration: (ft)	94.900
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	9.2	30,000.0	492.0	3.1	0
105.0	9.2	30,000.0	492.0	3.1	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.	415.000	530.000	2.000	0.800	0.120	109976.014
Helmet Wt.	2.500	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	1.1	15.3	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
2.2	1.1	15.3	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
4.4	1.1	15.3	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
4.4	0.2	12.3	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
6.1	0.4	17.8	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
7.8	0.5	23.2	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
9.5	0.6	28.7	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
11.3	0.7	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
13.0	0.8	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
14.7	0.9	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
16.4	1.0	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
18.1	1.1	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
19.8	1.2	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
21.6	1.4	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
23.3	1.5	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
25.0	1.6	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
26.7	1.7	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
26.7	1.5	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
28.4	1.6	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
30.0	1.7	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
31.7	1.7	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
33.4	1.8	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
35.0	1.9	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
36.7	2.0	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
38.4	2.0	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
40.0	2.1	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
41.7	2.2	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
41.7	2.6	50.1	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
43.4	2.6	50.1	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
45.0	2.7	50.1	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
46.7	2.8	50.1	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
46.7	3.3	107.6	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
48.4	3.3	107.6	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1

50.0	3.4	107.6	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
51.7	3.5	107.6	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
51.7	3.0	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
53.4	3.0	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
55.0	3.1	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
56.7	3.1	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
56.7	3.4	73.6	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
58.4	3.5	73.6	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
60.0	3.5	73.6	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
61.7	3.6	73.6	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
61.7	3.3	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
63.4	3.4	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
65.0	3.4	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
66.7	3.5	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
68.3	3.6	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
70.0	3.6	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
71.7	3.7	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
73.3	3.7	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
75.0	3.8	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
76.6	3.9	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
78.3	3.9	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
80.0	4.0	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
81.6	4.0	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
83.3	4.1	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
84.9	4.2	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
86.6	4.2	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
88.3	4.3	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
89.9	4.4	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
91.6	4.4	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
93.2	4.5	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
94.9	4.5	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1

PIER 1

Gain/Loss Factor at Shaft/Toe = 0.570/1.000

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	-
5.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	31.1	1.2	29.9	2.6	17.339	0.596	4.63	23.7	D 19-42
15.0	193.8	15.7	178.1	20.9	38.554	4.173	7.35	23.8	D 19-42
20.0	59.1	37.0	22.1	4.7	21.262	2.084	5.13	22.1	D 19-42
25.0	75.0	52.9	22.1	6.2	23.226	2.282	5.37	21.2	D 19-42
30.0	96.2	74.1	22.1	8.5	25.113	2.937	5.73	20.9	D 19-42
35.0	124.6	102.4	22.1	11.5	26.346	3.656	6.06	20.4	D 19-42
40.0	193.5	140.0	53.6	19.4	29.654	6.205	7.03	22.3	D 19-42
45.0	243.7	190.2	53.6	27.0	31.609	8.316	7.67	24.1	D 19-42
50.0	297.6	244.0	53.6	42.8	33.539	9.980	8.41	25.8	D 19-42
55.0	355.0	301.4	53.6	83.1	35.149	11.418	9.10	27.2	D 19-42
60.0	416.0	362.4	53.6	249.2	36.089	11.884	9.49	27.9	D 19-42
65.0	440.1	418.0	22.1	452.8	37.105	11.325	9.62	27.9	D 19-42
70.0	521.7	468.1	53.6	9999.0	39.183	10.965	9.82	28.1	D 19-42
75.0	593.1	539.5	53.6	9999.0	40.328	10.725	9.94	28.0	D 19-42
80.0	667.8	614.2	53.6	9999.0	41.045	10.229	10.01	27.8	D 19-42
85.0	745.9	692.3	53.6	9999.0	42.062	8.810	10.05	27.6	D 19-42
90.0	827.3	773.8	53.6	9999.0	42.609	7.428	10.05	27.1	D 19-42
95.0	912.2	858.6	53.6	9999.0	42.910	5.988	10.00	26.4	D 19-42
101.5	1027.5	973.9	53.6	9999.0	42.871	5.070	9.89	25.4	D 19-42

Refusal occurred; no driving time output possible.

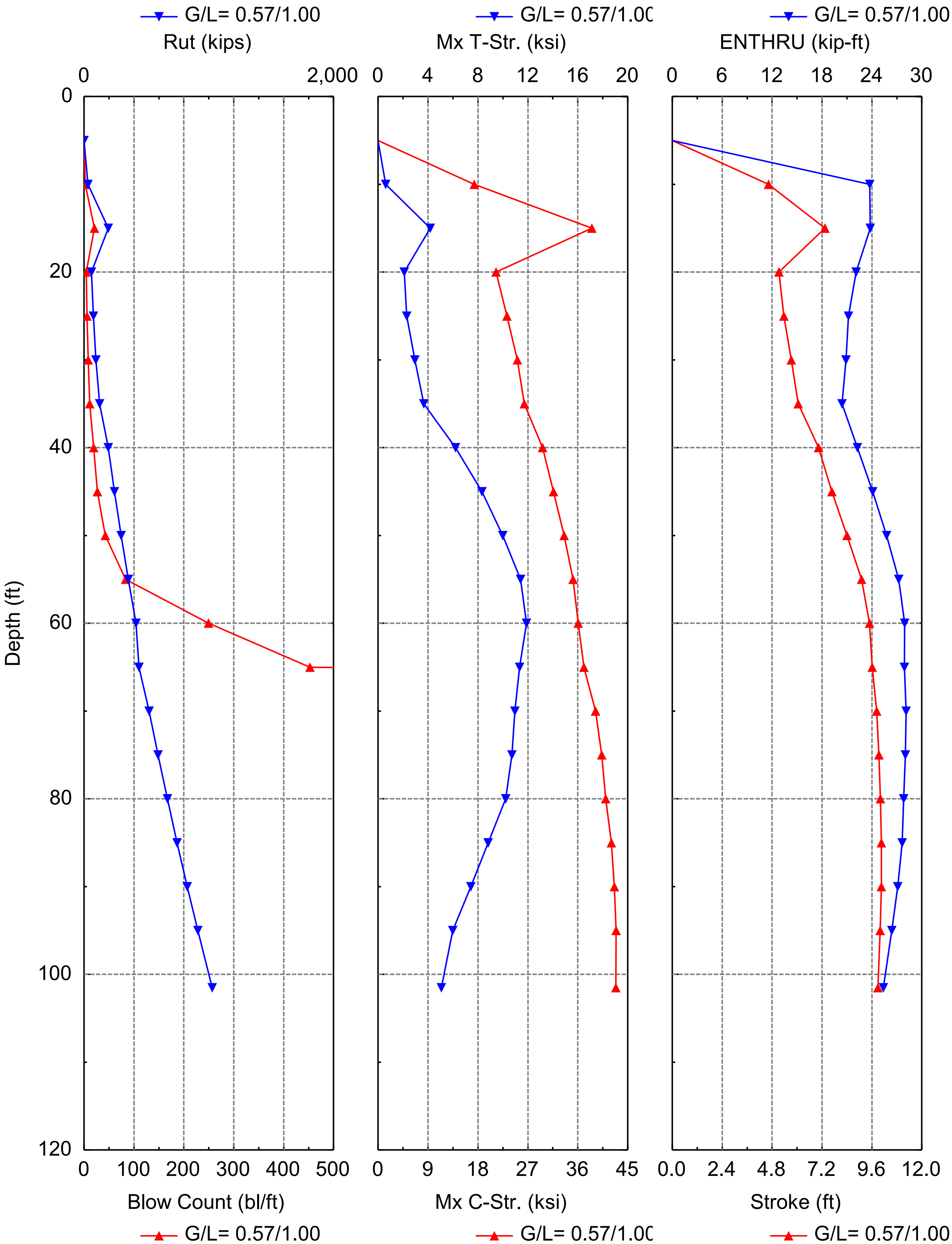
Gain/Loss Factor at Shaft/Toe = 1.000/1.000

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	-
5.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	31.1	1.2	29.9	2.6	17.339	0.596	4.63	23.7	D 19-42
15.0	193.8	15.7	178.1	20.9	38.554	4.173	7.35	23.8	D 19-42
20.0	62.3	40.2	22.1	5.1	21.669	2.076	5.19	21.9	D 19-42
25.0	84.6	62.4	22.1	7.2	24.155	2.068	5.54	21.1	D 19-42
30.0	112.2	90.0	22.1	10.3	25.954	3.973	5.93	20.5	D 19-42
35.0	145.2	123.1	22.1	13.5	27.353	4.015	6.29	20.6	D 19-42
40.0	217.8	164.2	53.6	22.8	31.147	7.664	7.39	23.5	D 19-42
45.0	268.0	214.4	53.6	33.0	32.865	9.550	8.06	25.0	D 19-42
50.0	321.8	268.2	53.6	57.6	34.424	11.214	8.80	26.4	D 19-42
55.0	379.2	325.6	53.6	117.9	36.271	12.279	9.39	28.0	D 19-42
60.0	440.2	386.6	53.6	552.7	37.249	12.114	9.70	28.4	D 19-42

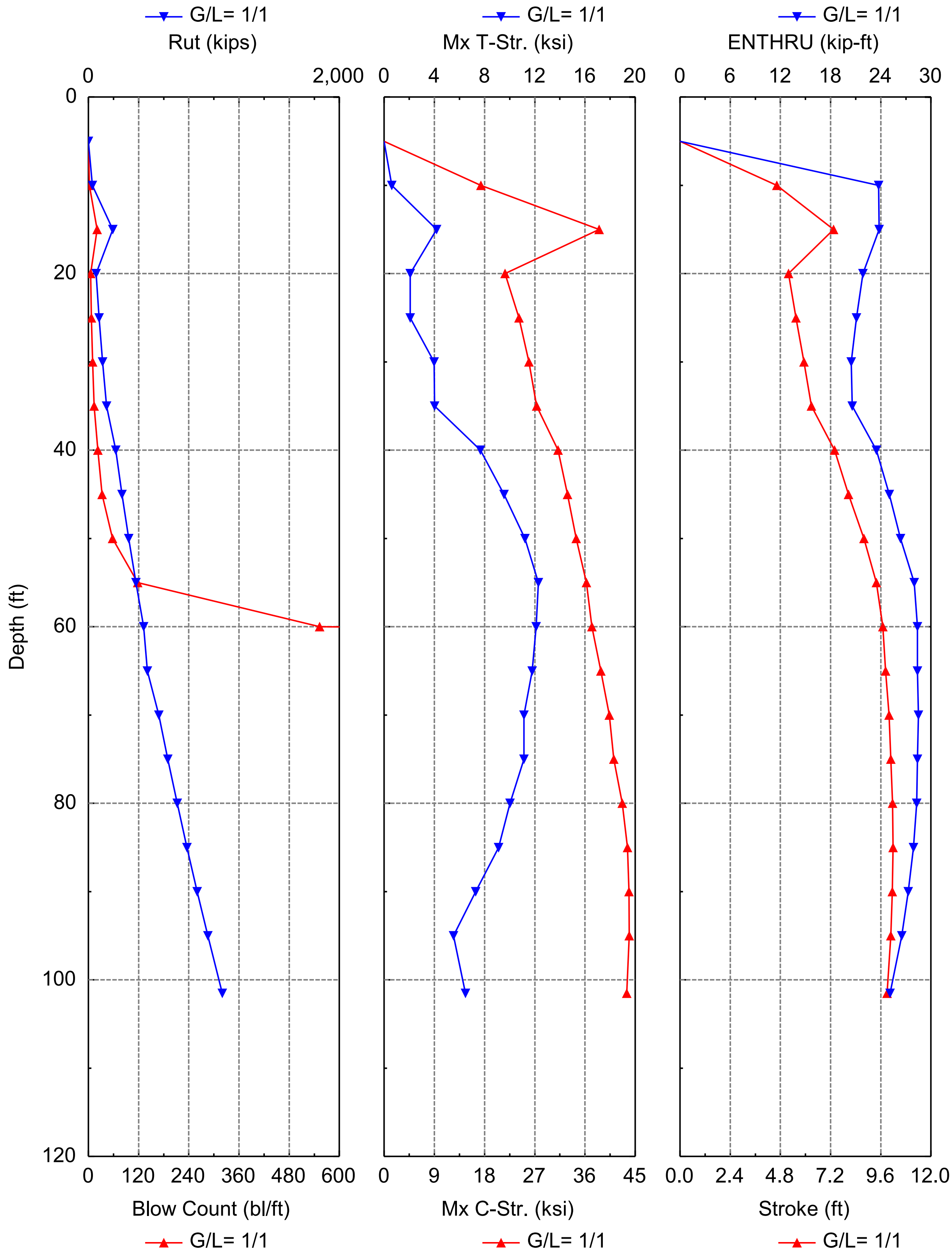
65.0	469.6	447.5	22.1	9999.0	38.846	11.790	9.82	28.4	D 19-42
70.0	561.7	508.2	53.6	9999.0	40.357	11.145	10.00	28.5	D 19-42
75.0	633.1	579.5	53.6	9999.0	41.163	11.130	10.08	28.4	D 19-42
80.0	707.8	654.2	53.6	9999.0	42.666	10.030	10.17	28.3	D 19-42
85.0	785.9	732.3	53.6	9999.0	43.598	9.123	10.18	27.9	D 19-42
90.0	867.4	813.8	53.6	9999.0	43.873	7.289	10.15	27.3	D 19-42
95.0	952.2	898.6	53.6	9999.0	43.940	5.517	10.08	26.5	D 19-42
101.5	1067.5	1013.9	53.6	9999.0	43.480	6.469	9.90	25.1	D 19-42

Refusal occurred; no driving time output possible.

Driveability Analysis Summary



Driveability Analysis Summary



GRLWEAP: Wave Equation Analysis of Pile Foundations

Linn St + RP14IN 12/13/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

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	Sand	110.0	0.0	0.0	0.00	0.00
9.4	Sand	110.0	0.0	0.0	0.00	1.84
9.4	Sand	112.0	0.0	32.0	0.53	26.29
14.5	Sand	112.0	0.0	32.0	0.83	33.09
14.5	Sand	118.0	0.0	39.0	1.61	160.73
17.0	Sand	118.0	0.0	39.0	1.90	190.27
17.0	Clay	125.0	2.7	0.0	1.04	24.75
19.5	Clay	125.0	2.7	0.0	1.04	24.75
19.5	Sand	125.0	0.0	31.0	1.04	20.71
28.3	Sand	125.0	0.0	31.0	1.55	20.71
28.3	Sand	128.0	0.0	31.0	1.55	20.71
38.3	Sand	128.0	0.0	31.0	2.15	20.71
38.3	Sand	128.0	0.0	33.0	2.58	50.11
63.3	Sand	128.0	0.0	33.0	3.56	50.11
63.3	Sand	128.0	0.0	31.0	2.97	20.71
68.3	Sand	128.0	0.0	31.0	3.12	20.71
68.3	Sand	128.0	0.0	33.0	3.74	50.11
101.5	Sand	128.0	0.0	33.0	4.96	50.11

PILE INPUT

Uniform Pile		Pile Type:	Unknown
Pile Length: (ft)	110.000	Pile Penetration: (ft)	101.500
Pile Size: (ft)	1.17	Toe Area: (in²)	153.94

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	10.8	30,000.0	492.0	3.7	0
110.0	10.8	30,000.0	492.0	3.7	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.	415.000	530.000	2.000	0.800	0.120	109976.014
Helmet Wt.	2.500	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	0.13	0.20	0.15	2.0	6.0	168.0	153.9
1.9	0.0	0.4	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
3.8	0.0	0.7	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
5.6	0.0	1.1	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
7.5	0.0	1.5	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
9.4	0.0	1.8	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
9.4	0.5	26.3	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
11.1	0.6	31.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
12.8	0.7	33.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
14.5	0.8	33.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
14.5	1.6	160.7	0.10	0.14	0.05	0.15	1.0	6.0	1.0	153.9
15.8	1.8	175.5	0.10	0.14	0.05	0.15	1.0	6.0	1.0	153.9
17.0	1.9	190.3	0.10	0.14	0.05	0.15	1.0	6.0	1.0	153.9
17.0	1.0	24.7	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
18.3	1.0	24.7	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
19.5	1.0	24.7	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
19.5	1.0	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
21.3	1.1	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
23.0	1.2	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
24.8	1.3	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
26.5	1.4	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
28.3	1.6	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
28.3	1.6	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
30.0	1.7	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
31.6	1.8	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
33.3	1.9	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
35.0	2.0	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
36.6	2.1	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
38.3	2.2	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
38.3	2.6	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
40.0	2.6	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9

41.6	2.7	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
43.3	2.8	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
45.0	2.8	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
46.6	2.9	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
48.3	3.0	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
50.0	3.0	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
51.6	3.1	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
53.3	3.2	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
55.0	3.2	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
56.6	3.3	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
58.3	3.4	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
60.0	3.4	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
61.6	3.5	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
63.3	3.6	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
63.3	3.0	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
65.0	3.0	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
66.6	3.1	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
68.3	3.1	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
68.3	3.7	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
70.0	3.8	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
71.6	3.9	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
73.3	3.9	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
74.9	4.0	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
76.6	4.0	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
78.3	4.1	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
79.9	4.2	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
81.6	4.2	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
83.2	4.3	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
84.9	4.3	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
86.6	4.4	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
88.2	4.5	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
89.9	4.5	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
91.5	4.6	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
93.2	4.7	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
94.9	4.7	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
96.5	4.8	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
98.2	4.8	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
99.8	4.9	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
101.5	5.0	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9

PIER 2

Gain/Loss Factor at Shaft/Toe = 0.570/1.000

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	-
5.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	38.6	2.4	36.2	3.4	19.000	0.560	4.82	22.9	D 19-42
15.0	68.9	16.7	52.2	6.3	22.202	1.565	5.38	21.3	D 19-42
20.0	59.5	30.2	29.3	5.2	21.820	1.732	5.21	21.8	D 19-42
25.0	73.8	44.5	29.3	6.8	23.772	1.866	5.47	21.0	D 19-42
30.0	84.4	62.3	22.1	8.0	24.553	2.069	5.66	20.9	D 19-42
35.0	108.2	86.1	22.1	10.7	25.962	3.565	5.97	20.3	D 19-42
40.0	126.3	112.1	14.2	12.3	26.401	3.269	6.15	20.2	D 19-42
45.0	151.9	137.6	14.2	14.8	27.676	3.380	6.42	20.4	D 19-42
50.0	179.3	165.0	14.2	17.8	28.470	4.562	6.79	21.1	D 19-42
55.0	218.3	196.2	22.1	24.0	30.527	5.950	7.34	22.5	D 19-42
60.0	294.9	241.3	53.6	51.4	32.929	8.761	8.38	25.0	D 19-42
65.0	359.3	305.8	53.6	139.5	34.762	9.400	8.99	26.4	D 19-42
70.0	389.1	367.0	22.1	312.2	35.472	8.633	9.18	26.7	D 19-42
75.0	440.1	417.9	22.1	9999.0	36.976	8.676	9.35	26.7	D 19-42
80.0	559.6	480.9	78.7	9999.0	37.703	7.759	9.44	26.5	D 19-42
85.0	644.4	565.7	78.7	9999.0	38.231	7.067	9.46	26.2	D 19-42
90.0	733.0	654.3	78.7	9999.0	38.335	5.883	9.45	25.8	D 19-42
95.0	825.4	746.6	78.7	9999.0	38.282	4.875	9.43	25.1	D 19-42
101.5	951.1	872.3	78.7	9999.0	38.000	4.850	9.33	24.1	D 19-42

Refusal occurred; no driving time output possible.

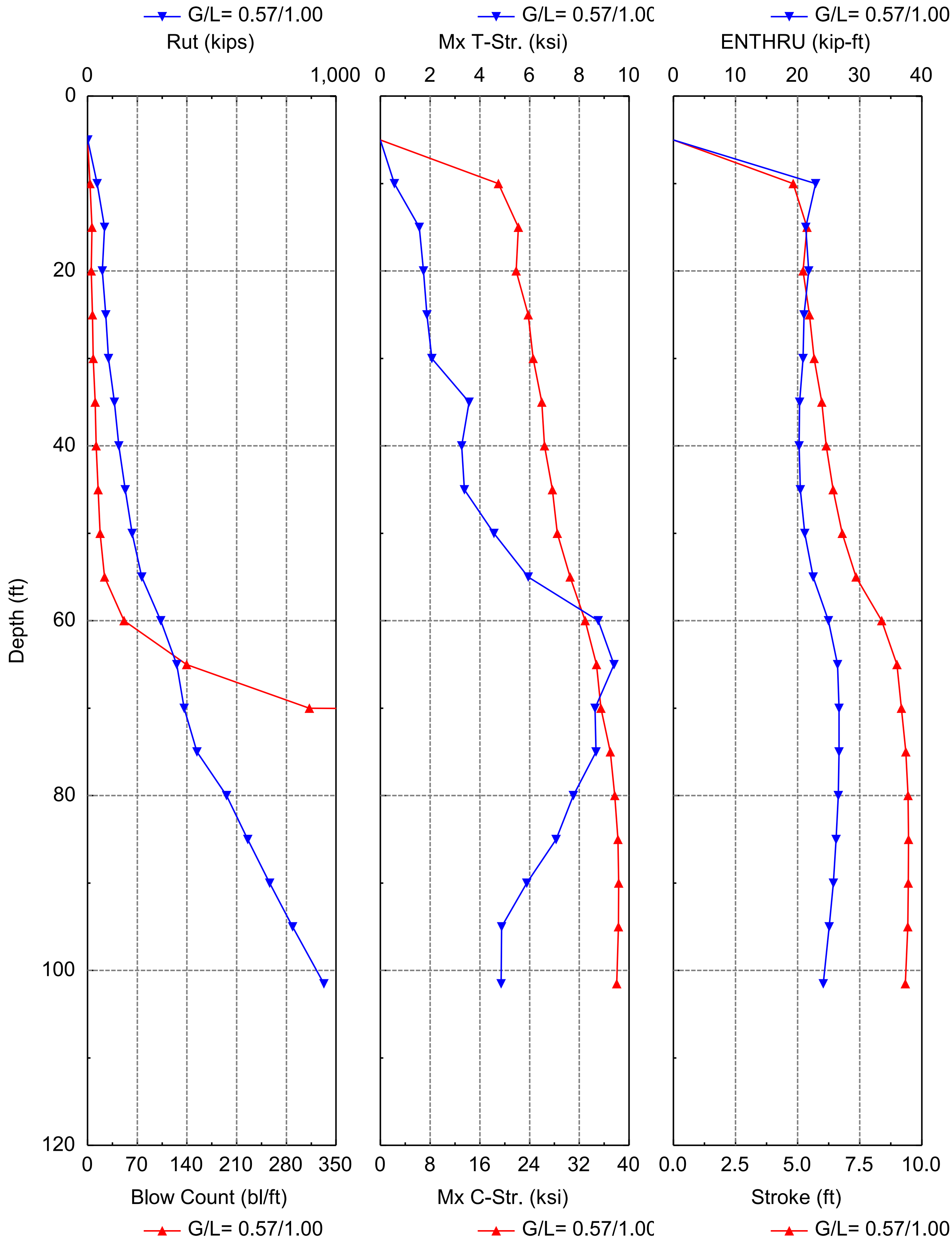
Gain/Loss Factor at Shaft/Toe = 1.000/1.000

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	-
5.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	39.3	3.2	36.2	3.5	19.121	0.549	4.83	22.8	D 19-42
15.0	69.7	17.5	52.2	6.3	22.271	1.614	5.39	21.3	D 19-42
20.0	64.2	34.8	29.3	5.7	22.371	1.633	5.29	21.5	D 19-42
25.0	84.1	54.8	29.3	8.0	24.783	2.245	5.66	20.9	D 19-42
30.0	101.8	79.6	22.1	10.1	25.598	3.080	5.91	20.4	D 19-42
35.0	134.9	112.8	22.1	13.3	27.274	3.410	6.26	20.4	D 19-42
40.0	163.3	149.1	14.2	16.1	28.142	4.678	6.61	21.0	D 19-42
45.0	198.9	184.7	14.2	20.4	30.242	6.316	7.12	22.2	D 19-42
50.0	237.1	222.9	14.2	27.1	31.749	7.572	7.65	23.6	D 19-42
55.0	288.4	266.3	22.1	44.2	33.676	9.579	8.41	25.1	D 19-42
60.0	374.4	320.8	53.6	187.2	35.841	10.971	9.41	27.7	D 19-42

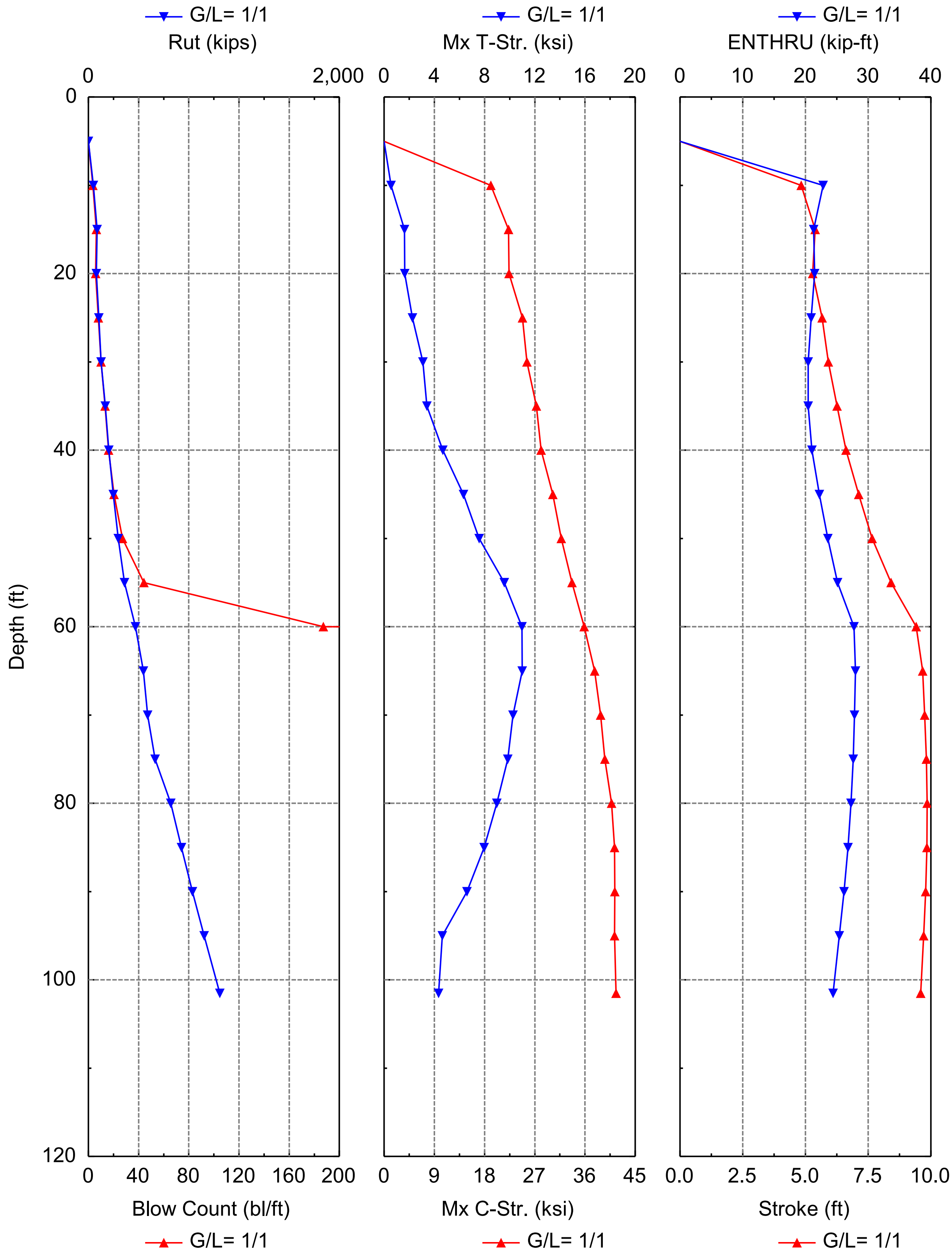
65.0	438.9	385.3	53.6	9999.0	37.715	11.001	9.67	28.0	D 19-42
70.0	471.5	449.3	22.1	9999.0	38.796	10.259	9.75	27.8	D 19-42
75.0	531.0	508.9	22.1	9999.0	39.546	9.838	9.81	27.6	D 19-42
80.0	656.4	577.6	78.7	9999.0	40.752	8.982	9.84	27.2	D 19-42
85.0	741.2	662.5	78.7	9999.0	41.285	7.960	9.83	26.8	D 19-42
90.0	829.8	751.0	78.7	9999.0	41.342	6.594	9.79	26.1	D 19-42
95.0	922.1	843.4	78.7	9999.0	41.292	4.632	9.71	25.4	D 19-42
101.5	1047.8	969.1	78.7	9999.0	41.575	4.336	9.59	24.4	D 19-42

Refusal occurred; no driving time output possible.

Driveability Analysis Summary



Driveability Analysis Summary



GRLWEAP: Wave Equation Analysis of Pile Foundations

Linn St + FP14IN 12/12/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

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	Sand	110.0	0.0	0.0	0.00	0.00
9.0	Sand	110.0	0.0	0.0	0.00	1.76
9.0	Clay	112.0	1.7	0.0	1.13	15.75
9.5	Clay	112.0	1.7	0.0	1.13	15.75
9.5	Sand	115.0	0.0	33.0	0.59	32.08
16.0	Sand	115.0	0.0	33.0	1.01	50.11
16.0	Clay	125.0	3.0	0.0	1.08	27.45
28.3	Clay	125.0	3.0	0.0	1.08	27.45
28.3	Sand	125.0	0.0	31.0	1.56	20.71
38.3	Sand	125.0	0.0	31.0	2.15	20.71
38.3	Sand	128.0	0.0	29.0	1.82	13.32
53.3	Sand	128.0	0.0	29.0	2.25	13.32
53.3	Sand	128.0	0.0	31.0	2.66	20.71
58.3	Sand	128.0	0.0	31.0	2.81	20.71
58.3	Sand	128.0	0.0	33.0	3.36	50.11
68.3	Sand	128.0	0.0	33.0	3.73	50.11
68.3	Sand	128.0	0.0	31.0	3.12	20.71
78.3	Sand	128.0	0.0	31.0	3.43	20.71
78.3	Sand	130.0	0.0	34.0	4.46	73.64
101.5	Sand	130.0	0.0	34.0	5.41	73.64

PILE INPUT

Uniform Pile		Pile Type:	Unknown
Pile Length: (ft)	110.000	Pile Penetration: (ft)	101.500
Pile Size: (ft)	1.17	Toe Area: (in²)	153.94

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	10.8	30,000.0	492.0	3.7	0
110.0	10.8	30,000.0	492.0	3.7	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.	415.000	530.000	2.000	0.800	0.120	109976.014
Helmet Wt.	2.500	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	0.13	0.20	0.15	2.0	6.0	168.0	153.9
1.8	0.0	0.4	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
3.6	0.0	0.7	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
5.4	0.0	1.1	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
7.2	0.0	1.4	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
9.0	0.0	1.8	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
9.0	1.1	15.7	0.10	0.15	0.20	0.15	1.8	6.0	168.0	153.9
9.5	1.1	15.7	0.10	0.15	0.20	0.15	1.8	6.0	168.0	153.9
9.5	0.6	32.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
11.7	0.7	39.7	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
13.8	0.9	47.4	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
16.0	1.0	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
16.0	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
17.8	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
19.5	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
21.3	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
23.0	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
24.8	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
26.5	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
28.3	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
28.3	1.6	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
30.0	1.7	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
31.6	1.8	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
33.3	1.9	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
35.0	2.0	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
36.6	2.0	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
38.3	2.1	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
38.3	1.8	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
40.0	1.9	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9

41.6	1.9	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
43.3	2.0	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
45.0	2.0	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
46.6	2.1	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
48.3	2.1	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
50.0	2.2	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
51.6	2.2	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
53.3	2.3	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
53.3	2.7	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
55.0	2.7	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
56.6	2.8	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
58.3	2.8	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
58.3	3.4	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
60.0	3.4	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
61.6	3.5	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
63.3	3.5	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
65.0	3.6	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
66.6	3.7	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
68.3	3.7	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
68.3	3.1	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
70.0	3.2	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
71.6	3.2	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
73.3	3.3	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
75.0	3.3	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
76.6	3.4	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
78.3	3.4	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
78.3	4.5	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
80.0	4.5	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
81.6	4.6	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
83.3	4.7	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
84.9	4.7	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
86.6	4.8	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
88.2	4.9	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
89.9	4.9	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
91.6	5.0	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
93.2	5.1	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
94.9	5.1	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
96.5	5.2	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
98.2	5.3	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
99.8	5.3	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
101.5	5.4	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9

PIER 2 - PREBORE

SOIL PROFILE

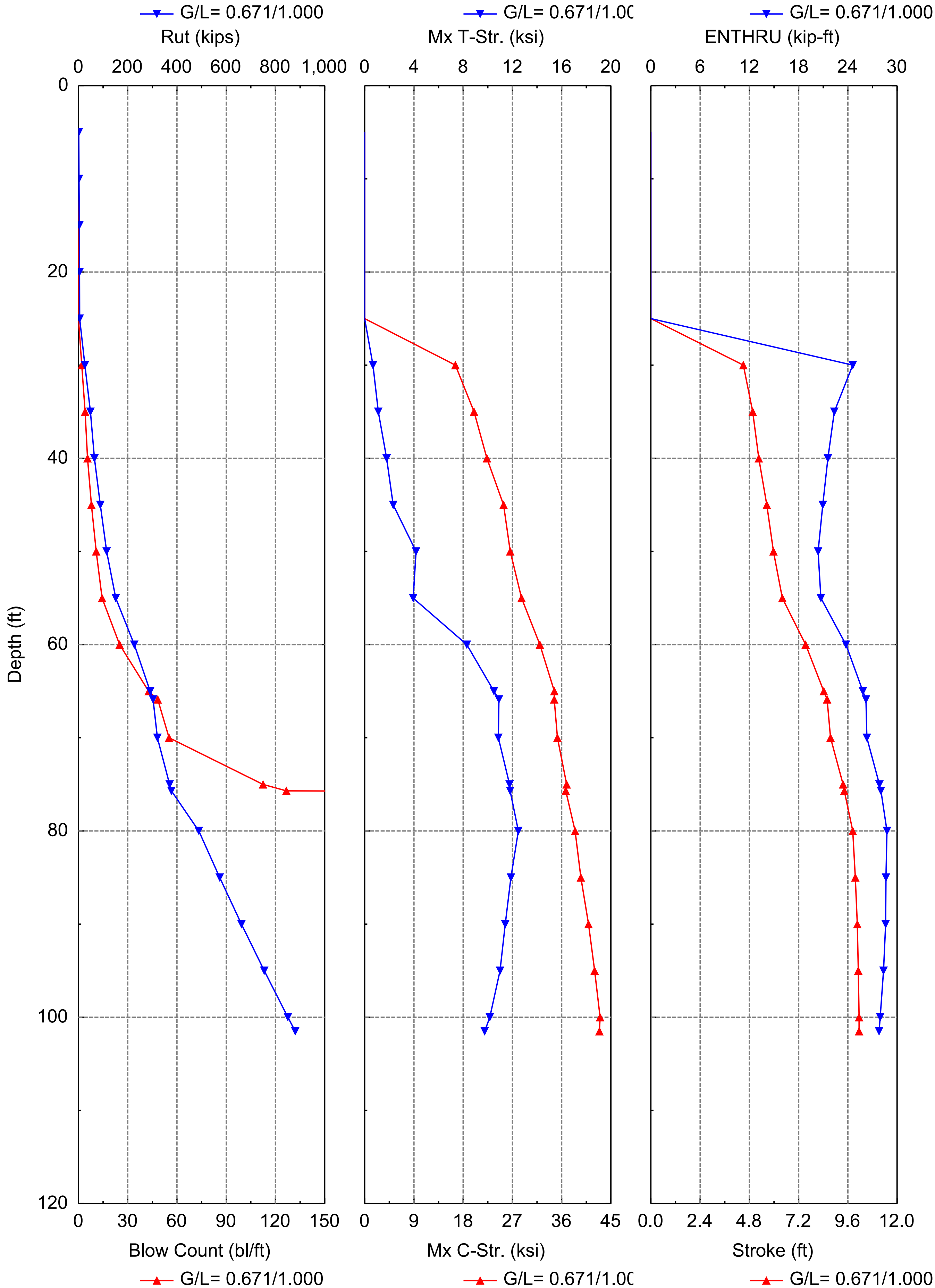
Depth	Soil Type	Spec. Wt	Su	Phi	Unit Rs	Unit Rt
ft	-	lb/ft³	ksf	°	ksf	ksf
0.0	Sand	118.0	0.0	0.0	0.00	0.00
29.0	Sand	118.0	0.0	0.0	0.00	4.23
29.0	Sand	125.0	0.0	31.0	1.60	20.71
38.3	Sand	125.0	0.0	31.0	2.15	20.71
38.3	Sand	128.0	0.0	29.0	1.82	13.32
53.3	Sand	128.0	0.0	29.0	2.26	13.32
53.3	Sand	128.0	0.0	31.0	2.66	20.71
58.3	Sand	128.0	0.0	31.0	2.81	20.71
58.3	Sand	128.0	0.0	33.0	3.37	50.11
68.3	Sand	128.0	0.0	33.0	3.73	50.11
68.3	Sand	128.0	0.0	31.0	3.12	20.71
78.3	Sand	128.0	0.0	31.0	3.43	20.71
78.3	Sand	130.0	0.0	34.0	4.46	73.64
101.5	Sand	130.0	0.0	34.0	5.41	73.64

Driveability Analysis Summary

Gain/Loss Factor at Shaft/Toe = 0.671/1.000

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	-
5.0	1.1	0.0	1.1	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	2.2	0.0	2.2	0.3	0.000	0.000	10.81	0.0	D 19-42
15.0	3.4	0.0	3.4	0.3	0.000	0.000	10.81	0.0	D 19-42
20.0	4.5	0.0	4.5	0.3	0.000	0.000	10.81	0.0	D 19-42
25.0	4.9	0.0	4.9	0.3	0.000	0.000	10.81	0.0	D 19-42
30.0	26.2	4.0	22.1	2.0	16.570	0.674	4.51	24.6	D 19-42
35.0	48.4	26.3	22.1	4.0	19.981	1.109	4.96	22.3	D 19-42
40.0	64.9	50.6	14.2	5.5	22.330	1.785	5.26	21.6	D 19-42
45.0	88.8	74.6	14.2	7.9	25.392	2.317	5.65	20.9	D 19-42
50.0	114.5	100.2	14.2	10.8	26.598	4.177	5.98	20.4	D 19-42
55.0	151.5	129.4	22.1	14.4	28.666	3.941	6.40	20.7	D 19-42
60.0	226.5	173.0	53.6	25.1	32.028	8.296	7.55	23.8	D 19-42
65.0	291.1	237.5	53.6	42.7	34.656	10.495	8.42	25.8	D 19-42
65.9	302.8	249.2	53.6	48.3	34.646	10.907	8.58	26.2	D 19-42
70.0	320.4	298.3	22.1	55.2	35.221	10.861	8.75	26.3	D 19-42
75.0	370.0	347.9	22.1	112.4	36.914	11.769	9.37	27.8	D 19-42
75.7	377.2	355.0	22.1	126.6	36.755	11.814	9.43	28.0	D 19-42
80.0	488.6	409.9	78.7	9999.0	38.465	12.477	9.84	28.8	D 19-42
85.0	573.5	494.8	78.7	9999.0	39.513	11.872	9.96	28.6	D 19-42
90.0	662.1	583.4	78.7	9999.0	40.914	11.413	10.06	28.6	D 19-42
95.0	754.5	675.8	78.7	9999.0	42.031	10.992	10.11	28.3	D 19-42
100.0	850.7	771.9	78.7	9999.0	43.016	10.159	10.14	27.9	D 19-42
101.5	880.3	801.5	78.7	9999.0	42.907	9.746	10.14	27.8	D 19-42

Refusal occurred; no driving time output possible.

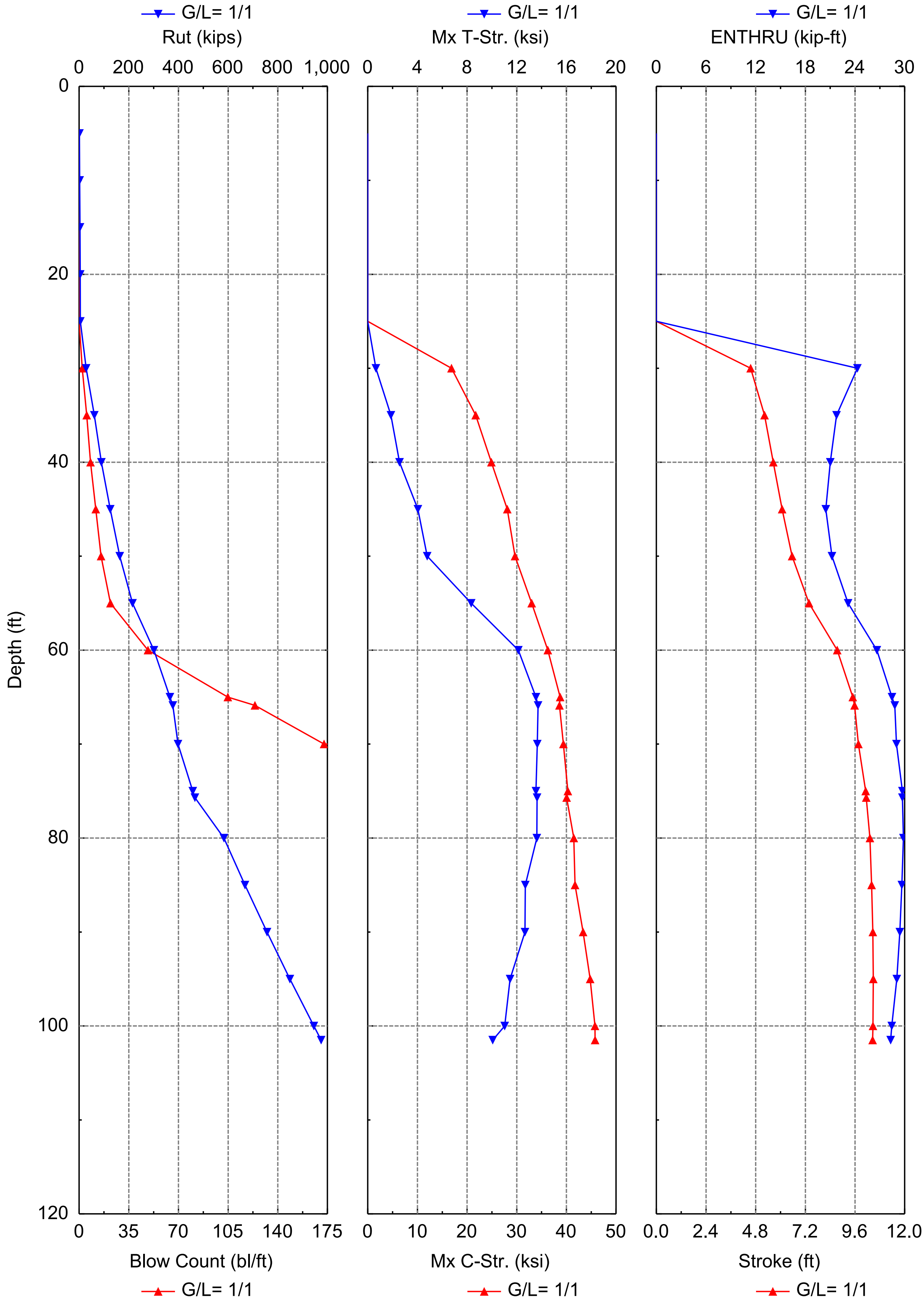


G/L= 0.671/1.000
Rut (kips)
0 200 400 600 800 1,000
G/L= 0.671/1.00
Mx T-Str. (ksi)
0 4 8 12 16 20
G/L= 0.671/1.000
ENTHRU (kip-ft)
0 6 12 18 24 30
Depth (ft)
0 20 40 60 80 100 120
0 30 60 90 120 150
Blow Count (bl/ft)
G/L= 0.671/1.000
0 9 18 27 36 45
Mx C-Str. (ksi)
G/L= 0.671/1.00
0.0 2.4 4.8 7.2 9.6 12.0
Stroke (ft)
G/L= 0.671/1.000

Driveability Analysis Summary
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	-
5.0	1.1	0.0	1.1	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	2.2	0.0	2.2	0.3	0.000	0.000	10.81	0.0	D 19-42
15.0	3.4	0.0	3.4	0.3	0.000	0.000	10.81	0.0	D 19-42
20.0	4.5	0.0	4.5	0.3	0.000	0.000	10.81	0.0	D 19-42
25.0	4.9	0.0	4.9	0.3	0.000	0.000	10.81	0.0	D 19-42
30.0	28.1	6.0	22.1	2.2	16.868	0.651	4.55	24.3	D 19-42
35.0	61.3	39.1	22.1	5.3	21.731	1.863	5.23	21.8	D 19-42
40.0	89.7	75.5	14.2	8.0	24.896	2.558	5.65	21.0	D 19-42
45.0	125.3	111.1	14.2	11.7	28.102	4.042	6.07	20.5	D 19-42
50.0	163.6	149.3	14.2	15.4	29.647	4.787	6.56	21.2	D 19-42
55.0	214.9	192.8	22.1	22.1	33.005	8.328	7.37	23.2	D 19-42
60.0	300.9	247.4	53.6	48.5	36.244	12.130	8.74	26.6	D 19-42
65.0	365.5	311.9	53.6	104.8	38.736	13.542	9.49	28.5	D 19-42
65.9	377.2	323.6	53.6	123.9	38.611	13.720	9.58	28.8	D 19-42
70.0	398.1	375.9	22.1	172.6	39.399	13.653	9.76	29.0	D 19-42
75.0	457.6	435.5	22.1	9999.0	40.285	13.549	10.12	29.7	D 19-42
75.7	466.2	444.0	22.1	9999.0	40.041	13.634	10.14	29.7	D 19-42
80.0	583.0	504.3	78.7	9999.0	41.477	13.617	10.32	29.8	D 19-42
85.0	667.9	589.1	78.7	9999.0	41.727	12.685	10.40	29.7	D 19-42
90.0	756.5	677.8	78.7	9999.0	43.361	12.661	10.46	29.4	D 19-42
95.0	848.9	770.2	78.7	9999.0	44.783	11.461	10.48	29.0	D 19-42
100.0	945.0	866.3	78.7	9999.0	45.751	11.030	10.46	28.4	D 19-42
101.5	974.6	895.9	78.7	9999.0	45.775	10.062	10.45	28.3	D 19-42

Refusal occurred; no driving time output possible.


G/L= 1/1
Rut (kips)
0 200 400 600 800 1,000
G/L= 1/1
Mx T-Str. (ksi)
0 4 8 12 16 20
G/L= 1/1
ENTHRU (kip-ft)
0 6 12 18 24 30
Depth (ft)
0 20 40 60 80 100 120
0 35 70 105 140 175
Blow Count (bl/ft)
G/L= 1/1
0 10 20 30 40 50
Mx C-Str. (ksi)
G/L= 1/1
0.0 2.4 4.8 7.2 9.6 12.0
Stroke (ft)
G/L= 1/1

GRLWEAP: Wave Equation Analysis of Pile Foundations

Linn St + FP14IN 1/2/2025
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

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.

HAMMER DATA

Hammer Model:	D 19-42	Made By:	DELMAG
Hammer ID:	41	Hammer Type:	OED
Hammer Database Type:	PDI		
Hammer Database Name:			PDIHammer.gwh

Hammer and Drive System Segment Data

Segment	Weight	Stiffness	COR	C-Slack	Damping
-	kips	kips/in	-	in	kips/ft/s
1	0.800	140,084.4	1.000	0.000	
2	0.800	140,084.4	1.000	0.000	
3	0.800	140,084.4	1.000	0.000	
4	0.800	140,084.4	1.000	0.000	
5	0.800	70,754.7	0.900	0.120	
Imp Block	0.753	109,976.0	0.800	0.120	
Helmet	2.500				5.3

Ram Weight: (kips)	4.00	Ram Length: (ft)	10.76
Ram Area: (in²)	124.69		
Maximum (Eq) Stroke: (ft)	10.81	Actual (Eq) Stroke: (ft)	10.81
Efficiency:	0.800	Rated Energy: (kip-ft)	43.24
Maximum Pressure: (psi)	1,600.00	Actual Pressure: (psi)	1,600.00
Combustion Delay: (ms)	2.00	Ignition Duration: (ms)	2.00
Expansion Exponent:	1.25		

Hammer Cushion		Pile Cushion	
Cross Sect. Area: (in²)	415.00	Cross Sect. Area: (in²)	0.00
Elastic Modulus: (ksi)	530.0	Elastic Modulus: (ksi)	0.0
Thickness: (in)	2.00	Thickness: (in)	0.00
Coeff. of Restitution:	0.800	Coeff. of Restitution:	0.500
RoundOut: (in)	0.120	RoundOut: (in)	0.120
Stiffness: (kips/in)	109,976.0	Stiffness: (kips/in)	0.0
Helmet Weight: (kips)	2.500		

PILE INPUT

Uniform Pile		Pile Type:	Unknown
Pile Length: (ft)	110.000	Pile Penetration: (ft)	101.500
Pile Size: (ft)	1.17	Toe Area: (in²)	153.94

Table of Depths Analyzed with Driving System Modifiers

Depth	Temp Length	Wait Time	Hammer
ft	ft	Hr	-
5.00	110.0	0.0	DELMAG D 19-42
10.00	110.0	0.0	DELMAG D 19-42
15.00	110.0	0.0	DELMAG D 19-42
20.00	110.0	0.0	DELMAG D 19-42
25.00	110.0	0.0	DELMAG D 19-42
30.00	110.0	0.0	DELMAG D 19-42
35.00	110.0	0.0	DELMAG D 19-42
40.00	110.0	0.0	DELMAG D 19-42
45.00	110.0	0.0	DELMAG D 19-42
50.00	110.0	0.0	DELMAG D 19-42
55.00	110.0	0.0	DELMAG D 19-42
60.00	110.0	0.0	DELMAG D 19-42
65.00	110.0	0.0	DELMAG D 19-42
65.88	110.0	0.0	DELMAG D 19-42
70.00	110.0	0.0	DELMAG D 19-42
75.00	110.0	0.0	DELMAG D 19-42
75.70	110.0	0.0	DELMAG D 19-42
80.00	110.0	0.0	DELMAG D 19-42
85.00	110.0	0.0	DELMAG D 19-42
90.00	110.0	0.0	DELMAG D 19-42
95.00	110.0	0.0	DELMAG D 19-42
100.00	110.0	0.0	DELMAG D 19-42
101.50	110.0	0.0	DELMAG D 19-42

Other Information for DELMAG D 19-42

Depth	Stroke	Diesel Pressure	Efficiency	P.C. Stiff. Fact.	P.C. COR
ft	ft	%	-	-	-
5.00	10.8	100.0	0.80	1.0	0.50
10.00	10.8	100.0	0.80	1.0	0.50
15.00	10.8	100.0	0.80	1.0	0.50
20.00	10.8	100.0	0.80	1.0	0.50
25.00	10.8	100.0	0.80	1.0	0.50
30.00	10.8	100.0	0.80	1.0	0.50
35.00	10.8	100.0	0.80	1.0	0.50
40.00	10.8	100.0	0.80	1.0	0.50
45.00	10.8	100.0	0.80	1.0	0.50
50.00	10.8	100.0	0.80	1.0	0.50
55.00	10.8	100.0	0.80	1.0	0.50
60.00	10.8	100.0	0.80	1.0	0.50

65.00	10.8	100.0	0.80	1.0	0.50
65.88	10.8	100.0	0.80	1.0	0.50
70.00	10.8	100.0	0.80	1.0	0.50
75.00	10.8	100.0	0.80	1.0	0.50
75.70	10.8	100.0	0.80	1.0	0.50
80.00	10.8	100.0	0.80	1.0	0.50
85.00	10.8	100.0	0.80	1.0	0.50
90.00	10.8	100.0	0.80	1.0	0.50
95.00	10.8	100.0	0.80	1.0	0.50
100.00	10.8	100.0	0.80	1.0	0.50
101.50	10.8	100.0	0.80	1.0	0.50

PILE, SOIL, ANALYSIS OPTIONS

Analysis type:	Driveability Analysis	Soil Damping Option:	Smith
Max No Analysis Iterations:	0	Time Increment/Critical:	160
Residual Stress Analysis:	0	Analysis Time-Input(ms):	0
Output Level:	Normal	Gravitational Acceleration (ft/s²):	32.169
Hammer Gravity (ft/s²):	32.169	Pile Gravity (ft/s²):	32.169

DRIVEABILITY ANALYSIS

Analysis Depth (ft)	101.50	Standard Soil Setup	
Hammer Name	DELMAG D 19-42	Hammer ID	41
Diesel Pressure: (psi)	230.40	Stroke (ft)	10.81
Efficiency	0.80		
Shaft Gain/Loss Factor	0.671	Toe Gain/Loss Factor	1.000
Shaft Gain/Loss Factor	1.000	Toe Gain/Loss Factor	1.000

SOIL RESISTANCE PARAMETERS

Depth	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Setup F.	Limit D.	Setup T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.00	0.0	0.0	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
1.71	0.0	0.4	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
3.41	0.0	0.7	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
5.12	0.0	1.1	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
6.82	0.0	1.4	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
8.53	0.0	1.8	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
10.24	0.0	2.1	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
11.94	0.0	2.5	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
13.65	0.0	2.9	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
15.35	0.0	3.2	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
17.06	0.0	3.6	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
18.76	0.0	3.9	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
20.47	0.0	4.3	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
22.18	0.0	4.4	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
23.88	0.0	4.5	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
25.59	0.0	4.6	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
27.29	0.0	4.5	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
29.00	0.0	4.2	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
29.00	1.6	20.7	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
30.86	1.7	20.7	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
32.72	1.8	20.7	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
34.58	1.9	20.7	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
36.44	2.0	20.7	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
38.30	2.1	20.7	0.10	0.162	0.100	0.1	1.5	6.00	24.0	153.94
38.30	1.8	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94
39.97	1.9	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94
41.63	1.9	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94
43.30	2.0	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94
44.97	2.0	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94
46.63	2.1	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94
48.30	2.1	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94

49.97	2.2	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94
51.63	2.2	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94
53.30	2.3	13.3	0.10	0.204	0.100	0.1	1.5	6.00	24.0	153.94
53.30	2.7	20.7	0.10	0.165	0.100	0.1	1.5	6.00	24.0	153.94
54.97	2.7	20.7	0.10	0.165	0.100	0.1	1.5	6.00	24.0	153.94
56.63	2.8	20.7	0.10	0.165	0.100	0.1	1.5	6.00	24.0	153.94
58.30	2.8	20.7	0.10	0.165	0.100	0.1	1.5	6.00	24.0	153.94
58.30	3.4	50.1	0.10	0.160	0.050	0.1	1.0	6.00	1.0	153.94
59.97	3.4	50.1	0.10	0.160	0.050	0.1	1.0	6.00	1.0	153.94
61.63	3.5	50.1	0.10	0.160	0.050	0.1	1.0	6.00	1.0	153.94
63.30	3.6	50.1	0.10	0.160	0.050	0.1	1.0	6.00	1.0	153.94
64.97	3.6	50.1	0.10	0.160	0.050	0.1	1.0	6.00	1.0	153.94
66.63	3.7	50.1	0.10	0.160	0.050	0.1	1.0	6.00	1.0	153.94
68.30	3.7	50.1	0.10	0.160	0.050	0.1	1.0	6.00	1.0	153.94
68.30	3.1	20.7	0.10	0.161	0.100	0.1	1.2	6.00	24.0	153.94
69.97	3.2	20.7	0.10	0.161	0.100	0.1	1.2	6.00	24.0	153.94
71.63	3.2	20.7	0.10	0.161	0.100	0.1	1.2	6.00	24.0	153.94
73.30	3.3	20.7	0.10	0.161	0.100	0.1	1.2	6.00	24.0	153.94
74.97	3.3	20.7	0.10	0.161	0.100	0.1	1.2	6.00	24.0	153.94
76.63	3.4	20.7	0.10	0.161	0.100	0.1	1.2	6.00	24.0	153.94
78.30	3.4	20.7	0.10	0.161	0.100	0.1	1.2	6.00	24.0	153.94
78.30	4.5	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
79.96	4.5	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
81.61	4.6	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
83.27	4.7	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
84.93	4.7	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
86.59	4.8	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
88.24	4.9	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
89.90	4.9	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
91.56	5.0	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
93.21	5.1	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
94.87	5.1	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
96.53	5.2	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
98.19	5.3	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
99.84	5.3	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94
101.50	5.4	73.6	0.10	0.154	0.050	0.1	1.0	6.00	1.0	153.94

PILE PROFILE

Lb Top	X-Area	E-Mod	Spec. Wt	Perim.	C-Index	Wave Sp	Impedance
ft	in²	ksi	lb/ft³	ft	-	ft/s	kips/ft/s
0.00	10.8	30,000	492.00	3.665	0	16,806.4	19.3
110.00	10.8	30,000	492.00	3.665	0	16,806.4	19.3

PILE AND SOIL MODEL Total Capacity Rut (kips): 880.254

Seg.	Weight	Stiffn.	C-Slk	T-Slk	COR	Ru	Js/Jt	Qs/Qt	LbTop	Perim.	X-Area
-	kips	kips/in	in	in	-	kips	s/ft	in	ft	ft	in²
1	0.12	8,345	0.12	0.00	0.85	0.0	0.000	0.10	3.24	3.67	10.8
2	0.12	8,345	0.00	0.00	1.00	0.0	0.000	0.10	6.47	3.67	10.8
11	0.12	8,345	0.00	0.00	1.00	0.0	0.000	0.10	35.59	3.67	10.8
12	0.12	8,345	0.00	0.00	1.00	5.3	0.100	0.10	38.82	3.67	10.8
13	0.12	8,345	0.00	0.00	1.00	14.1	0.100	0.10	42.06	3.67	10.8
14	0.12	8,345	0.00	0.00	1.00	15.6	0.100	0.10	45.29	3.67	10.8
15	0.12	8,345	0.00	0.00	1.00	15.7	0.100	0.10	48.53	3.67	10.8
16	0.12	8,345	0.00	0.00	1.00	15.3	0.100	0.10	51.76	3.67	10.8
17	0.12	8,345	0.00	0.00	1.00	16.0	0.100	0.10	55.00	3.67	10.8
18	0.12	8,345	0.00	0.00	1.00	16.8	0.100	0.10	58.24	3.67	10.8
19	0.12	8,345	0.00	0.00	1.00	17.5	0.100	0.10	61.47	3.67	10.8
20	0.12	8,345	0.00	0.00	1.00	21.2	0.100	0.10	64.71	3.67	10.8
21	0.12	8,345	0.00	0.00	1.00	28.5	0.080	0.10	67.94	3.67	10.8
22	0.12	8,345	0.00	0.00	1.00	41.1	0.050	0.10	71.18	3.67	10.8
23	0.12	8,345	0.00	0.00	1.00	42.5	0.050	0.10	74.41	3.67	10.8
24	0.12	8,345	0.00	0.00	1.00	40.4	0.062	0.10	77.65	3.67	10.8
25	0.12	8,345	0.00	0.00	1.00	31.6	0.100	0.10	80.88	3.67	10.8
26	0.12	8,345	0.00	0.00	1.00	32.6	0.100	0.10	84.12	3.67	10.8
27	0.12	8,345	0.00	0.00	1.00	36.8	0.089	0.10	87.35	3.67	10.8
28	0.12	8,345	0.00	0.00	1.00	53.9	0.050	0.10	90.59	3.67	10.8
29	0.12	8,345	0.00	0.00	1.00	55.5	0.050	0.10	93.82	3.67	10.8
30	0.12	8,345	0.00	0.00	1.00	57.1	0.050	0.10	97.06	3.67	10.8
31	0.12	8,345	0.00	0.00	1.00	58.6	0.050	0.10	100.29	3.67	10.8
32	0.12	8,345	0.00	0.00	1.00	60.2	0.050	0.10	103.53	3.67	10.8
33	0.12	8,345	0.00	0.00	1.00	61.8	0.050	0.10	106.76	3.67	10.8
34	0.12	8,345	0.00	0.00	1.00	63.4	0.050	0.10	110.00	3.67	10.8
Toe						78.7	0.149	0.15	110.00		

4.059 kips total unreduced pile weight (g = 32.169 ft/s²)
4.059 kips total reduced pile weight (g = 32.169 ft/s²)

OTHER OPTIONS

Pile Damping (%):	1	Pile Damping Fact. (kips/ft/s):	0.386

EXTREMA TABLE at 101.5 FT; HAMMER: D 19-42

Shaft/Toe Gain/Loss Factor = 0.671/1.000

Rut = 880.3 kips Rtoe = 78.7 kips Time Inc. = 0.076 ms

Hammer DELMAG D 19-42 Efficiency 0.800

Lb Top ft	Mx.T-For. kips	Mx.C-For kips	Mx.T-Str. ksi	Mx.C-Str. ksi	Mx Vel. ft/s	Mx Dis. in	ENTHRU kip-ft
3.2	0.0	381.6	0.00	35.34	18.43	1.183	27.80
6.5	13.3	387.3	1.23	35.87	18.36	1.137	27.07
9.7	25.3	397.6	2.34	36.82	18.27	1.090	26.30
12.9	35.8	407.0	3.32	37.69	18.17	1.041	25.48
16.2	45.0	415.4	4.17	38.46	18.09	0.992	24.67
19.4	55.4	422.9	5.13	39.16	18.00	0.944	23.87
22.6	64.4	429.4	5.96	39.76	17.93	0.895	23.03
25.9	71.4	434.1	6.61	40.20	17.88	0.844	22.15
29.1	79.8	442.2	7.39	40.95	17.82	0.792	21.22
32.4	89.9	450.2	8.33	41.69	17.68	0.739	20.24
35.6	98.6	457.5	9.13	42.36	17.30	0.685	19.23
38.8	105.2	463.4	9.75	42.91	16.61	0.630	17.92
42.1	102.7	461.4	9.51	42.73	15.81	0.575	16.01
45.3	89.6	448.4	8.30	41.52	14.96	0.522	13.84
48.5	77.3	431.5	7.16	39.96	14.09	0.471	11.85
51.8	64.0	414.5	5.93	38.38	13.21	0.422	10.06
55.0	49.8	403.9	4.61	37.40	12.31	0.374	8.44
58.2	35.3	392.3	3.27	36.33	11.35	0.332	7.08
61.5	23.7	374.7	2.20	34.70	10.36	0.291	5.86
64.7	10.0	354.1	0.92	32.79	9.47	0.250	4.72
67.9	0.0	339.5	0.00	31.43	8.59	0.211	3.64
71.2	0.0	319.4	0.00	29.58	7.76	0.178	2.69
74.4	0.0	281.7	0.00	26.09	7.05	0.148	1.91
77.6	0.0	236.7	0.00	21.92	6.43	0.122	1.33
80.9	0.0	194.1	0.00	17.97	5.90	0.102	0.97
84.1	0.0	170.1	0.00	15.75	5.40	0.086	0.73
87.4	0.0	157.5	0.00	14.59	4.90	0.072	0.55
90.6	0.0	142.1	0.00	13.16	4.40	0.060	0.41
93.8	0.0	115.5	0.00	10.70	3.95	0.051	0.30
97.1	0.0	91.2	0.00	8.45	3.55	0.045	0.23
100.3	0.0	80.6	0.00	7.46	3.23	0.041	0.18
103.5	0.0	68.9	0.00	6.38	3.09	0.039	0.14
106.8	0.0	54.1	0.00	5.01	3.33	0.039	0.10
110.0	0.0	34.0	0.00	3.14	3.52	0.038	0.08

Converged Stroke (ft) 10.14 Fixed Combustion Pressure (psi) 1,600.0

(Eq) Strokes Analyzed and Last Return (ft)

10.81 10.26 10.16 10.14

Shaft/Toe Gain/Loss Factor = 1.000/1.000

Rut = 974.6 kips Rtoe = 78.7 kips Time Inc. = 0.076 ms

Hammer DELMAG D 19-42 Efficiency 0.800

Lb Top	Mx.T-For.	Mx.C-For	Mx.T-Str.	Mx.C-Str.	Mx Vel.	Mx Dis.	ENTHRU
ft	kips	kips	ksi	ksi	ft/s	in	kip-ft
3.2	0.0	405.5	0.00	37.55	18.86	1.152	28.30
6.5	12.8	414.1	1.18	38.35	18.80	1.102	27.46
9.7	24.9	426.4	2.31	39.49	18.72	1.052	26.59
12.9	35.8	438.5	3.31	40.60	18.61	1.001	25.71
16.2	44.9	448.4	4.16	41.52	18.53	0.950	24.81
19.4	55.1	456.6	5.10	42.29	18.43	0.898	23.87
22.6	66.6	464.4	6.17	43.01	18.35	0.844	22.88
25.9	76.8	472.6	7.11	43.77	18.29	0.790	21.84
29.1	86.3	480.5	7.99	44.50	18.20	0.734	20.76
32.4	93.7	487.2	8.67	45.12	18.02	0.677	19.64
35.6	100.2	491.6	9.28	45.52	17.51	0.619	18.50
38.8	108.7	494.3	10.06	45.77	16.55	0.562	17.01
42.1	106.5	487.4	9.86	45.13	15.34	0.505	14.79
45.3	85.2	465.1	7.89	43.06	14.08	0.451	12.31
48.5	59.2	439.2	5.49	40.67	12.83	0.400	10.08
51.8	36.9	414.9	3.42	38.42	11.58	0.351	8.15
55.0	19.4	395.6	1.80	36.63	10.40	0.304	6.46
58.2	0.0	376.4	0.00	34.86	9.48	0.260	5.04
61.5	0.0	350.2	0.00	32.43	8.64	0.224	3.94
64.7	0.0	320.7	0.00	29.69	7.82	0.190	2.99
67.9	0.0	292.6	0.00	27.10	7.11	0.159	2.17
71.2	0.0	262.8	0.00	24.34	6.49	0.132	1.54
74.4	0.0	223.5	0.00	20.70	5.93	0.108	1.06
77.6	0.0	178.4	0.00	16.52	5.40	0.088	0.73
80.9	0.0	144.8	0.00	13.40	4.91	0.073	0.53
84.1	0.0	127.0	0.00	11.76	4.45	0.062	0.41
87.4	0.0	115.0	0.00	10.65	4.02	0.053	0.31
90.6	0.0	105.0	0.00	9.72	3.64	0.045	0.24
93.8	0.0	87.4	0.00	8.10	3.29	0.040	0.19
97.1	0.0	74.8	0.00	6.92	2.97	0.035	0.15
100.3	0.0	66.5	0.00	6.16	2.70	0.032	0.12
103.5	8.3	57.6	0.77	5.33	2.60	0.031	0.09
106.8	12.5	45.3	1.16	4.19	2.81	0.032	0.07
110.0	3.0	28.5	0.28	2.64	3.04	0.032	0.05

Converged Stroke (ft) 10.45 Fixed Combustion Pressure (psi) 1,600.0
(Eq) Strokes Analyzed and Last Return (ft)
10.81 10.51 10.45

SUMMARY TABLE at 101.5 FT; HAMMER: D 19-42

Rut	Bl Ct	Stk Dn	Stk Up	Mx T-Str	LTop	Mx C-Str	LTop	ENTHRU	Bl Rt	ActRes
kips	b/ft	ft	ft	ksi	ft	ksi	ft	kip-ft	b/min	kips
880.3	9,999	10.14	0.00	9.75	38.8	42.91	38.8	27.8	37.1	578.8
974.6	9,999	10.45	0.00	10.06	38.8	45.77	38.8	28.3	36.5	595.1

SUMMARY OVER DEPTHS

G/L at Shaft and Toe: 0.671/1.000

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Bl Ct b/ft	Mx C-Str ksi	Mx T-Str ksi	Stroke ft	ENTHRU kip-ft	Hammer -
5.0	1.1	0.0	1.1	0.0	0.00	0.00	10.81	0.0	D 19-42
10.0	2.2	0.0	2.2	0.0	0.00	0.00	10.81	0.0	D 19-42
15.0	3.4	0.0	3.4	0.0	0.00	0.00	10.81	0.0	D 19-42
20.0	4.5	0.0	4.5	0.0	0.00	0.00	10.81	0.0	D 19-42
25.0	4.9	0.0	4.9	0.0	0.00	0.00	10.81	0.0	D 19-42
30.0	26.2	4.0	22.1	2.0	16.57	0.67	4.51	24.6	D 19-42
35.0	48.4	26.3	22.1	4.0	19.98	1.11	4.96	22.3	D 19-42
40.0	64.9	50.6	14.2	5.5	22.33	1.79	5.26	21.6	D 19-42
45.0	88.8	74.6	14.2	7.9	25.39	2.32	5.65	20.9	D 19-42
50.0	114.5	100.2	14.2	10.8	26.60	4.18	5.98	20.4	D 19-42
55.0	151.5	129.4	22.1	14.4	28.67	3.94	6.40	20.7	D 19-42
60.0	226.5	173.0	53.6	25.1	32.03	8.30	7.55	23.8	D 19-42
65.0	291.1	237.5	53.6	42.7	34.66	10.49	8.42	25.8	D 19-42
65.9	302.8	249.2	53.6	48.3	34.65	10.91	8.58	26.2	D 19-42
70.0	320.4	298.3	22.1	55.2	35.22	10.86	8.75	26.3	D 19-42
75.0	370.0	347.9	22.1	112.4	36.91	11.77	9.37	27.8	D 19-42
75.7	377.2	355.0	22.1	126.6	36.76	11.81	9.43	28.0	D 19-42
80.0	488.6	409.9	78.7	9,999.0	38.47	12.48	9.84	28.8	D 19-42
85.0	573.5	494.8	78.7	9,999.0	39.51	11.87	9.96	28.6	D 19-42
90.0	662.1	583.4	78.7	9,999.0	40.91	11.41	10.06	28.6	D 19-42
95.0	754.5	675.8	78.7	9,999.0	42.03	10.99	10.11	28.3	D 19-42
100.0	850.7	771.9	78.7	9,999.0	43.02	10.16	10.14	27.9	D 19-42
101.5	880.3	801.5	78.7	9,999.0	42.91	9.75	10.14	27.8	D 19-42

G/L at Shaft and Toe: 1.000/1.000

Depth ft	Rut kips	Rshaft kips	Rtoe kips	Bl Ct b/ft	Mx C-Str ksi	Mx T-Str ksi	Stroke ft	ENTHRU kip-ft	Hammer -
5.0	1.1	0.0	1.1	0.0	0.00	0.00	10.81	0.0	D 19-42
10.0	2.2	0.0	2.2	0.0	0.00	0.00	10.81	0.0	D 19-42
15.0	3.4	0.0	3.4	0.0	0.00	0.00	10.81	0.0	D 19-42
20.0	4.5	0.0	4.5	0.0	0.00	0.00	10.81	0.0	D 19-42
25.0	4.9	0.0	4.9	0.0	0.00	0.00	10.81	0.0	D 19-42
30.0	28.1	6.0	22.1	2.2	16.87	0.65	4.55	24.3	D 19-42
35.0	61.3	39.1	22.1	5.3	21.73	1.86	5.23	21.8	D 19-42
40.0	89.7	75.5	14.2	8.0	24.90	2.56	5.65	21.0	D 19-42
45.0	125.3	111.1	14.2	11.7	28.10	4.04	6.07	20.5	D 19-42
50.0	163.6	149.3	14.2	15.4	29.65	4.79	6.56	21.2	D 19-42
55.0	214.9	192.8	22.1	22.1	33.01	8.33	7.37	23.2	D 19-42

60.0	300.9	247.4	53.6	48.5	36.24	12.13	8.74	26.6	D 19-42
65.0	365.5	311.9	53.6	104.8	38.74	13.54	9.49	28.5	D 19-42
65.9	377.2	323.6	53.6	123.9	38.61	13.72	9.58	28.8	D 19-42
70.0	398.1	375.9	22.1	172.6	39.40	13.65	9.76	29.0	D 19-42
75.0	457.6	435.5	22.1	9,999.0	40.29	13.55	10.12	29.7	D 19-42
75.7	466.2	444.0	22.1	9,999.0	40.04	13.63	10.14	29.7	D 19-42
80.0	583.0	504.3	78.7	9,999.0	41.48	13.62	10.32	29.8	D 19-42
85.0	667.9	589.1	78.7	9,999.0	41.73	12.69	10.40	29.7	D 19-42
90.0	756.5	677.8	78.7	9,999.0	43.36	12.66	10.46	29.4	D 19-42
95.0	848.9	770.2	78.7	9,999.0	44.78	11.46	10.48	29.0	D 19-42
100.0	945.0	866.3	78.7	9,999.0	45.75	11.03	10.46	28.4	D 19-42
101.5	974.6	895.9	78.7	9,999.0	45.77	10.06	10.45	28.3	D 19-42

FORWARD ABUTMENT

Gain/Loss Factor at Shaft/Toe = 0.670/1.000

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 -
5.0	17.8	2.8	15.1	1.3	14.251	1.051	3.97	27.0	D 19-42
10.0	41.1	11.0	30.1	3.4	19.237	0.915	4.66	23.3	D 19-42
15.0	64.1	24.8	39.4	5.4	22.318	1.952	5.14	22.0	D 19-42
20.0	83.4	44.1	39.4	6.9	24.028	2.481	5.41	21.4	D 19-42
25.0	75.4	64.9	10.5	5.4	23.235	2.717	5.15	22.0	D 19-42
30.0	90.5	80.1	10.5	6.8	24.375	2.678	5.41	21.3	D 19-42
35.0	108.3	97.8	10.5	8.9	25.640	3.236	5.74	21.0	D 19-42
40.0	128.6	118.2	10.5	11.2	26.968	3.204	6.02	20.5	D 19-42
45.0	157.7	141.4	16.3	14.4	28.216	3.127	6.35	20.4	D 19-42
50.0	191.8	175.5	16.3	18.5	30.261	4.018	6.85	21.2	D 19-42
55.0	238.0	212.1	26.0	26.7	33.750	5.548	7.57	23.0	D 19-42
60.0	288.2	262.2	26.0	41.5	36.984	5.992	8.18	24.2	D 19-42
65.0	341.0	315.0	26.0	83.3	39.431	6.126	8.73	25.1	D 19-42
70.0	396.5	370.5	26.0	403.5	42.139	5.336	9.12	25.9	D 19-42
75.0	454.6	428.6	26.0	9999.0	42.818	4.565	9.23	25.4	D 19-42
80.0	515.4	489.4	26.0	9999.0	42.958	3.533	9.23	24.9	D 19-42
83.0	553.1	527.1	26.0	9999.0	43.198	2.763	9.19	24.4	D 19-42

Refusal occurred; no driving time output possible.

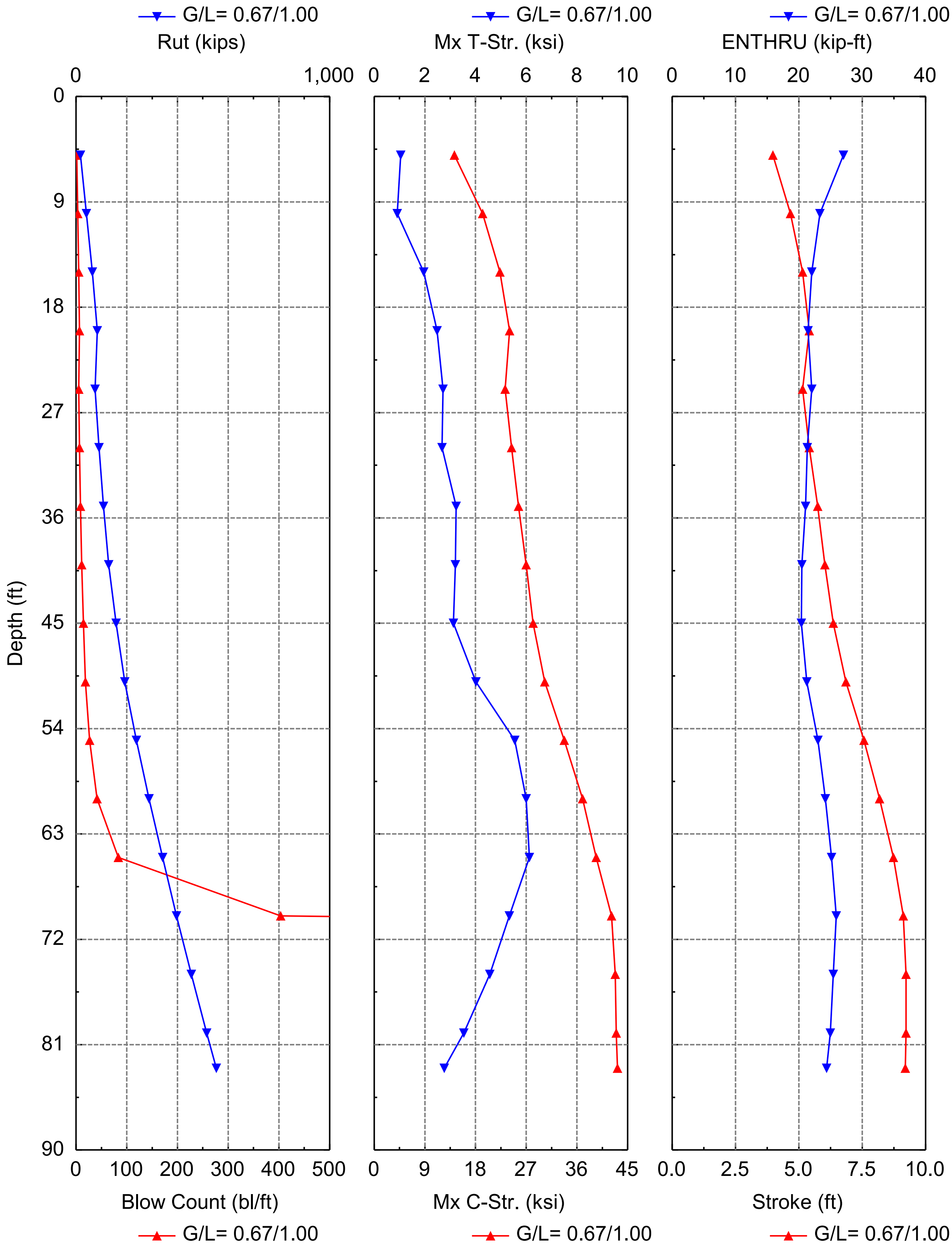
Gain/Loss Factor at Shaft/Toe = 1.000/1.000

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 -
5.0	17.8	2.8	15.1	1.3	14.251	1.051	3.97	27.0	D 19-42
10.0	41.1	11.0	30.1	3.4	19.237	0.915	4.66	23.3	D 19-42
15.0	64.1	24.8	39.4	5.4	22.318	1.952	5.14	22.0	D 19-42
20.0	83.4	44.1	39.4	6.9	24.028	2.481	5.41	21.4	D 19-42
25.0	77.4	66.9	10.5	5.5	23.374	2.738	5.17	21.9	D 19-42
30.0	100.0	89.6	10.5	7.8	25.068	2.580	5.58	21.2	D 19-42
35.0	126.5	116.1	10.5	10.9	26.389	3.450	5.98	20.5	D 19-42
40.0	156.9	146.4	10.5	14.0	28.477	3.316	6.34	20.5	D 19-42
45.0	197.0	180.7	16.3	18.9	30.842	5.571	6.97	21.6	D 19-42
50.0	237.9	221.6	16.3	25.6	33.882	6.235	7.60	23.2	D 19-42
55.0	291.1	265.2	26.0	42.4	38.386	7.360	8.39	24.9	D 19-42
60.0	341.3	315.3	26.0	80.0	41.308	7.515	8.94	25.8	D 19-42
65.0	394.1	368.1	26.0	275.1	43.761	7.384	9.37	26.8	D 19-42
70.0	449.6	423.6	26.0	9999.0	44.681	6.279	9.53	26.6	D 19-42
75.0	507.7	481.7	26.0	9999.0	45.661	5.398	9.54	26.0	D 19-42

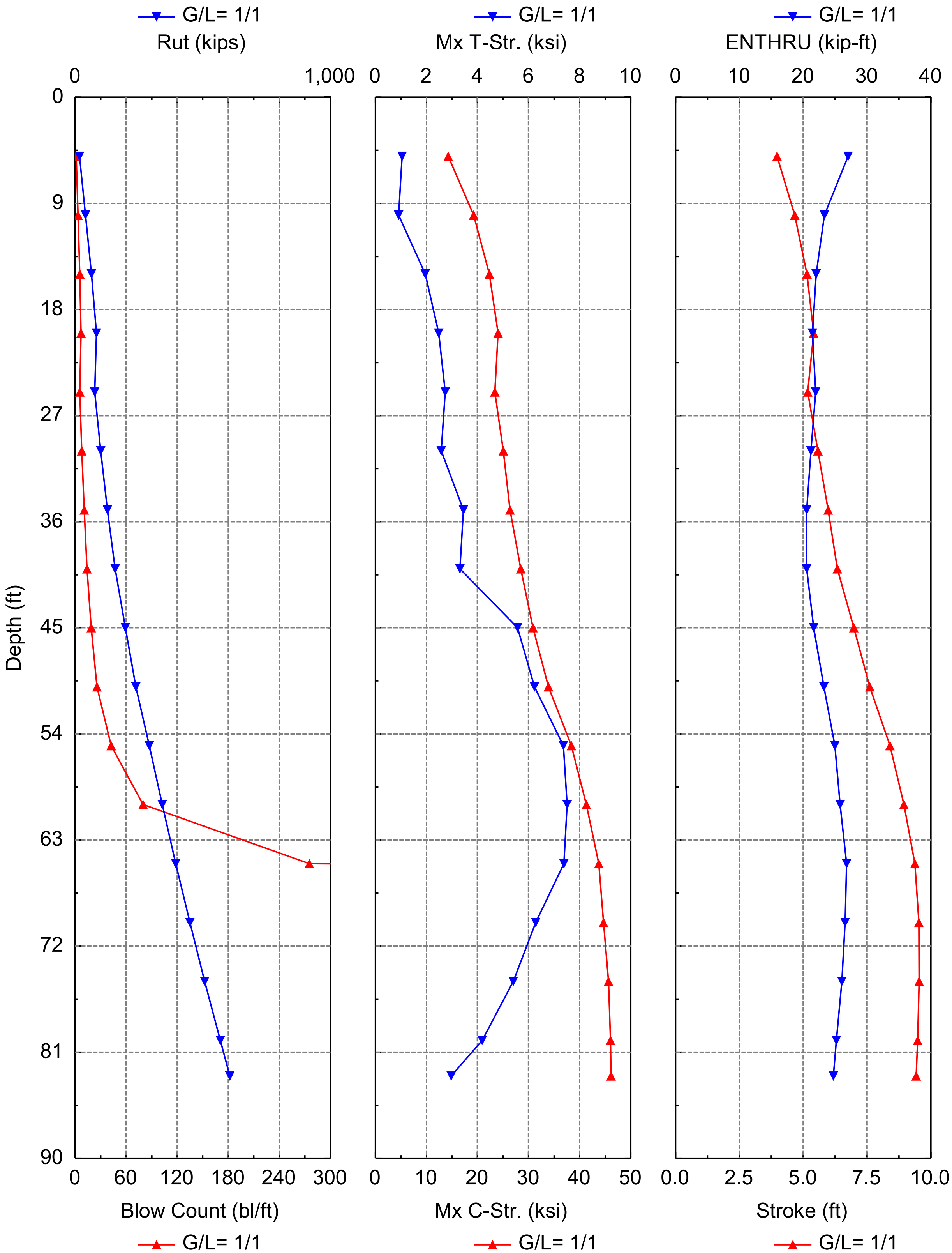
80.0	568.5	542.5	26.0	9999.0	46.042	4.183	9.48	25.2	D 19-42
83.0	606.2	580.2	26.0	9999.0	46.126	2.970	9.42	24.7	D 19-42

Refusal occurred; no driving time output possible.

Driveability Analysis Summary



Driveability Analysis Summary



GRLWEAP: Wave Equation Analysis of Pile Foundations

Linn St + RA12IN 12/12/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

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	Sand	125.0	0.0	33.0	0.00	0.00
23.5	Sand	125.0	0.0	33.0	1.65	50.11
23.5	Sand	115.0	0.0	30.0	1.25	13.32
44.8	Sand	115.0	0.0	30.0	2.29	13.32
44.8	Sand	128.0	0.0	31.0	2.52	20.71
54.8	Sand	128.0	0.0	31.0	2.83	20.71
54.8	Sand	128.0	0.0	32.0	3.10	33.09
83.0	Sand	128.0	0.0	32.0	4.05	33.09

PILE INPUT

Uniform Pile		Pile Type:	Unknown
Pile Length: (ft)	90.000	Pile Penetration: (ft)	83.000
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	9.2	30,000.0	492.0	3.1	0
90.0	9.2	30,000.0	492.0	3.1	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.	415.000	530.000	2.000	0.800	0.120	109976.014
Helmet Wt.	2.500	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

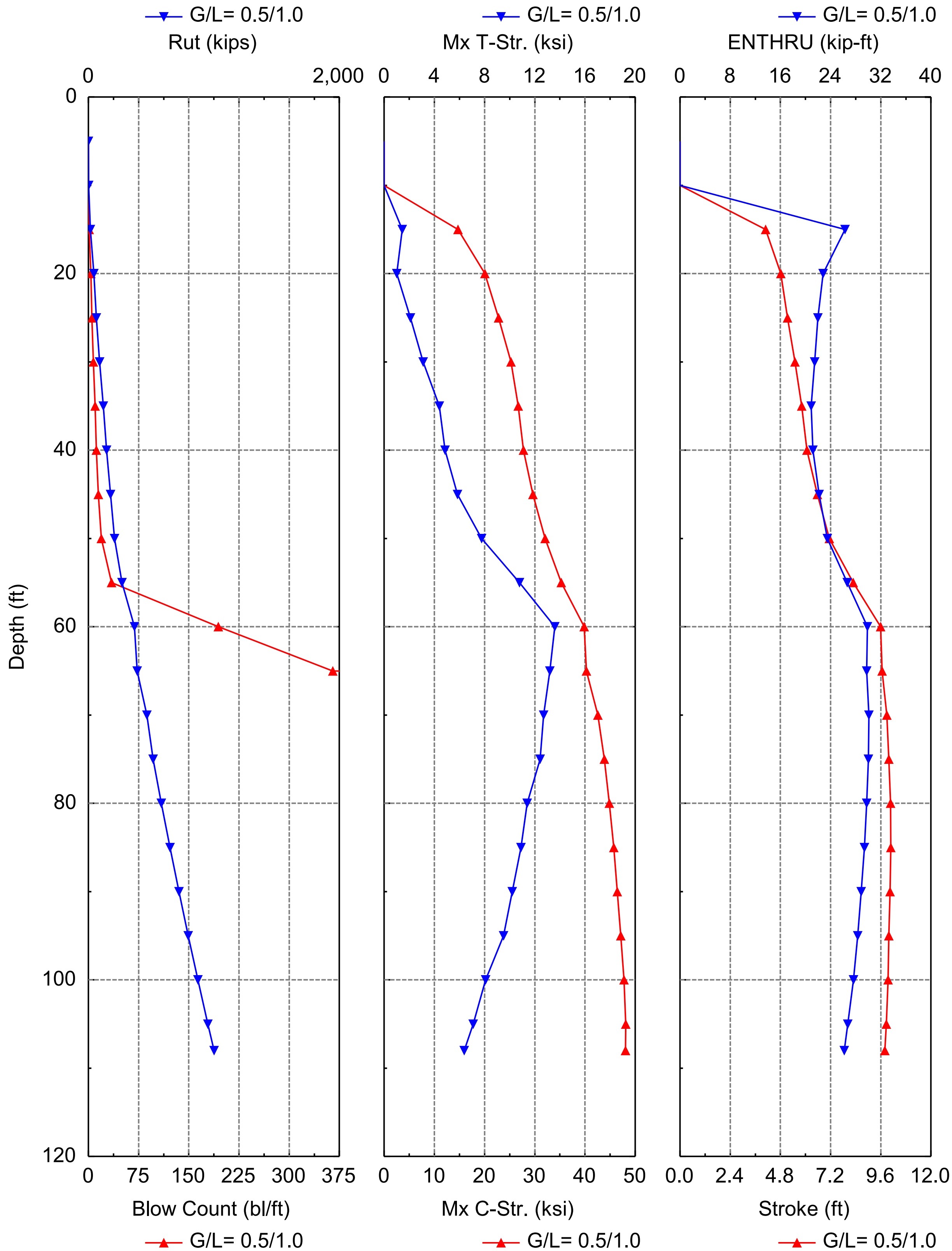
0.0	0.0	0.0	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
1.7	0.1	6.4	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
3.4	0.2	12.9	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
5.0	0.4	19.3	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
6.7	0.5	25.7	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
8.4	0.6	32.2	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
10.1	0.7	38.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
11.8	0.8	45.0	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
13.4	0.9	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
15.1	1.1	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
16.8	1.2	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
18.5	1.3	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
20.1	1.4	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
21.8	1.5	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
23.5	1.6	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
23.5	1.2	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
25.3	1.3	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
27.1	1.4	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
28.8	1.5	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
30.6	1.6	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
32.4	1.7	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
34.2	1.8	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
35.9	1.9	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
37.7	1.9	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
39.5	2.0	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
41.3	2.1	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
43.0	2.2	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
44.8	2.3	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
44.8	2.5	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
46.5	2.6	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
48.1	2.6	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
49.8	2.7	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
51.5	2.7	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
53.1	2.8	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
54.8	2.8	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
54.8	3.1	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
56.5	3.2	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
58.1	3.2	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
59.8	3.3	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
61.4	3.3	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
63.1	3.4	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1

64.8	3.4	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
66.4	3.5	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
68.1	3.5	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
69.7	3.6	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
71.4	3.7	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
73.0	3.7	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
74.7	3.8	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
76.4	3.8	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
78.0	3.9	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
79.7	3.9	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
81.3	4.0	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
83.0	4.1	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1

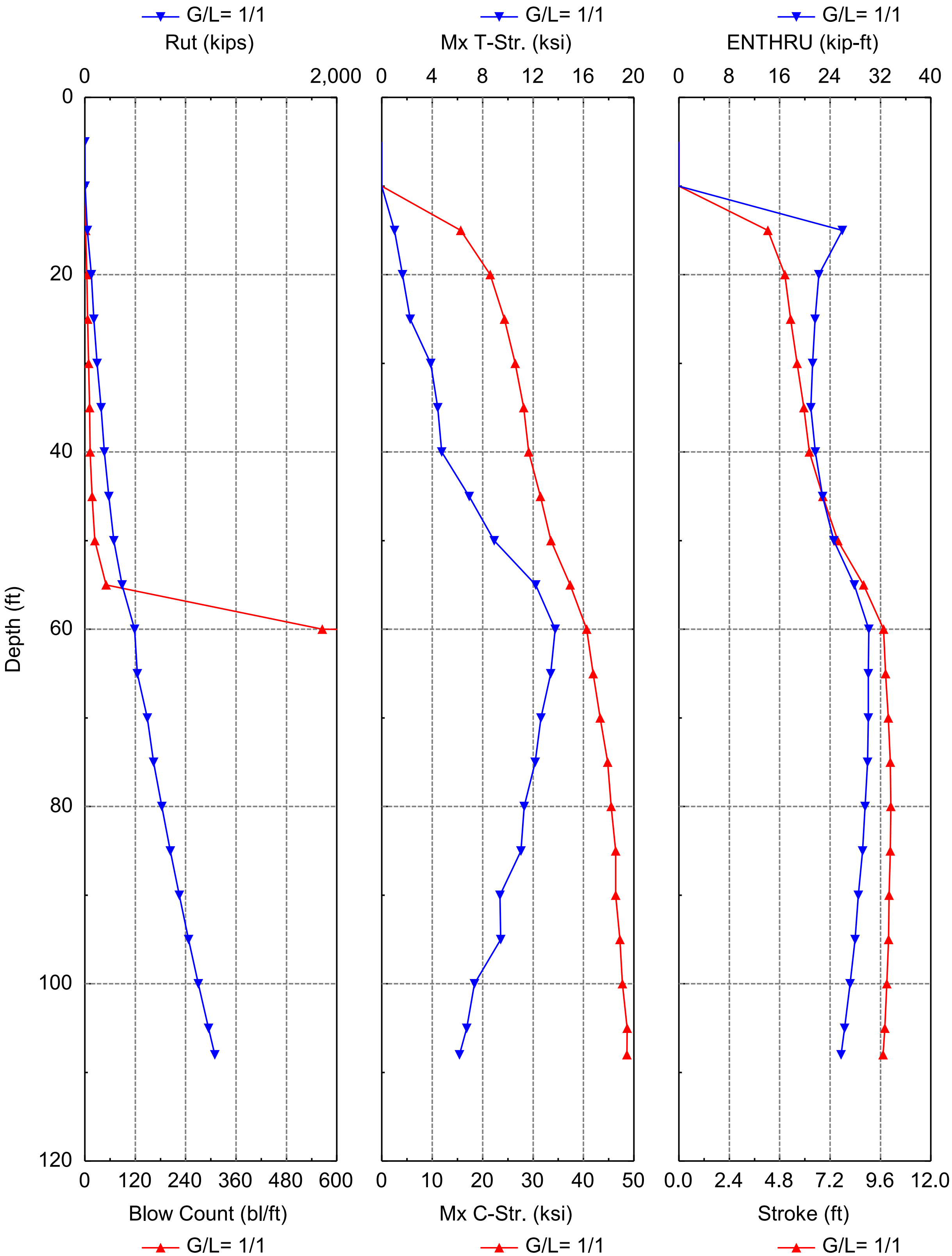
DRIVABILITY ANALYSIS

REAR ABUTMENT

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	-
5.0	0.8	0.0	0.8	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	1.5	0.0	1.5	0.3	0.000	0.000	10.81	0.0	D 19-42
15.0	15.5	3.5	12.0	1.3	14.698	1.444	4.09	26.3	D 19-42
20.0	42.7	16.8	26.0	3.8	20.046	1.005	4.82	22.8	D 19-42
25.0	63.3	37.4	26.0	5.3	22.776	2.095	5.14	22.0	D 19-42
30.0	89.0	63.0	26.0	7.5	25.239	3.103	5.49	21.4	D 19-42
35.0	119.7	93.7	26.0	10.1	26.716	4.389	5.82	20.9	D 19-42
40.0	145.3	129.1	16.3	11.8	27.750	4.847	6.07	21.2	D 19-42
45.0	175.6	159.3	16.3	15.0	29.606	5.835	6.56	22.2	D 19-42
50.0	208.5	192.2	16.3	19.4	32.060	7.774	7.14	23.5	D 19-42
55.0	267.5	228.2	39.4	34.7	35.264	10.778	8.28	26.7	D 19-42
60.0	367.1	282.6	84.5	194.3	39.859	13.602	9.59	29.9	D 19-42
65.0	388.6	349.2	39.4	365.0	40.290	13.207	9.66	29.8	D 19-42
70.0	467.1	409.3	57.8	9999.0	42.552	12.696	9.89	30.1	D 19-42
75.0	516.5	477.1	39.4	9999.0	43.852	12.425	9.98	30.0	D 19-42
80.0	582.0	542.6	39.4	9999.0	44.842	11.387	10.07	29.8	D 19-42
85.0	650.4	611.0	39.4	9999.0	45.722	10.900	10.08	29.4	D 19-42
90.0	721.7	682.3	39.4	9999.0	46.438	10.197	10.04	28.9	D 19-42
95.0	795.8	756.5	39.4	9999.0	47.112	9.509	9.99	28.3	D 19-42
100.0	872.9	833.5	39.4	9999.0	47.781	8.080	9.94	27.7	D 19-42
105.0	952.8	913.4	39.4	9999.0	48.139	7.098	9.86	26.7	D 19-42
108.0	1002.3	963.0	39.4	9999.0	48.072	6.368	9.79	26.2	D 19-42

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	-
5.0	0.8	0.0	0.8	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	1.5	0.0	1.5	0.3	0.000	0.000	10.81	0.0	D 19-42
15.0	19.1	7.1	12.0	1.6	15.658	1.002	4.23	25.9	D 19-42
20.0	51.1	25.1	26.0	4.8	21.485	1.632	5.05	22.2	D 19-42
25.0	71.7	45.7	26.0	6.4	24.323	2.253	5.32	21.6	D 19-42
30.0	97.4	71.4	26.0	8.7	26.439	3.872	5.63	21.2	D 19-42
35.0	128.1	102.1	26.0	11.1	28.114	4.424	5.95	21.0	D 19-42
40.0	153.9	137.7	16.3	12.7	29.135	4.752	6.22	21.6	D 19-42
45.0	190.3	174.0	16.3	17.1	31.453	6.930	6.86	22.8	D 19-42
50.0	229.7	213.4	16.3	23.9	33.533	8.915	7.57	24.6	D 19-42

55.0	295.6	256.2	39.4	50.4	37.367	12.208	8.80	27.8	D 19-42
60.0	395.2	310.7	84.5	565.2	40.611	13.755	9.75	30.2	D 19-42
65.0	416.6	377.2	39.4	9999.0	41.904	13.392	9.84	30.1	D 19-42
70.0	495.1	437.3	57.8	9999.0	43.329	12.615	9.97	30.1	D 19-42
75.0	544.5	505.2	39.4	9999.0	44.799	12.159	10.07	29.9	D 19-42
80.0	610.0	570.7	39.4	9999.0	45.488	11.294	10.09	29.5	D 19-42
85.0	678.4	639.1	39.4	9999.0	46.399	11.045	10.07	29.2	D 19-42
90.0	749.7	710.3	39.4	9999.0	46.387	9.372	10.01	28.5	D 19-42
95.0	823.8	784.5	39.4	9999.0	47.238	9.429	9.98	27.9	D 19-42
100.0	900.9	861.5	39.4	9999.0	47.713	7.342	9.90	27.2	D 19-42
105.0	980.8	941.5	39.4	9999.0	48.688	6.734	9.81	26.3	D 19-42
108.0	1030.3	991.0	39.4	9999.0	48.630	6.168	9.73	25.7	D 19-42

Refusal occurred; no driving time output possible.

GRLWEAP: Wave Equation Analysis of Pile Foundations

Linn St + RA12IN 12/12/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

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	Sand	110.0	0.0	0.0	0.00	0.00
13.1	Sand	110.0	0.0	0.0	0.00	2.56
13.1	Clay	110.0	1.7	0.0	1.21	15.30
17.5	Clay	110.0	1.7	0.0	1.21	15.30
17.5	Sand	125.0	0.0	32.0	0.99	33.09
39.8	Sand	125.0	0.0	32.0	2.42	33.09
39.8	Sand	128.0	0.0	31.0	2.21	20.71
54.8	Sand	128.0	0.0	31.0	2.79	20.71
54.8	Sand	128.0	0.0	33.0	3.34	50.11
59.8	Sand	128.0	0.0	33.0	3.53	50.11
59.8	Sand	128.0	0.0	35.0	4.15	107.60
64.8	Sand	128.0	0.0	35.0	4.36	107.60
64.8	Sand	128.0	0.0	33.0	3.71	50.11
69.8	Sand	128.0	0.0	33.0	3.89	50.11
69.8	Sand	125.0	0.0	34.0	4.23	73.64
74.8	Sand	125.0	0.0	34.0	4.42	73.64
74.8	Sand	128.0	0.0	33.0	4.07	50.11
108.0	Sand	128.0	0.0	33.0	5.29	50.11

PILE INPUT

Uniform Pile		Pile Type:	Unknown
Pile Length: (ft)	115.000	Pile Penetration: (ft)	108.010
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top ft	X-Area in²	E-Modulus ksi	Spec. Wt lb/ft³	Perim. ft	Crit. Index -
0.0	9.2	30,000.0	492.0	3.1	0
115.0	9.2	30,000.0	492.0	3.1	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.	415.000	530.000	2.000	0.800	0.120	109976.014
Helmet Wt.	2.500	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	0.13	0.20	0.15	2.0	6.0	168.0	113.1
1.9	0.0	0.4	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
3.7	0.0	0.7	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
5.6	0.0	1.1	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
7.5	0.0	1.5	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
9.4	0.0	1.8	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
11.2	0.0	2.2	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
13.1	0.0	2.6	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
13.1	1.2	15.3	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
15.3	1.2	15.3	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
17.5	1.2	15.3	0.10	0.13	0.20	0.15	2.0	6.0	168.0	113.1
17.5	1.0	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
19.2	1.1	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
20.9	1.2	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
22.7	1.3	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
24.4	1.4	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
26.1	1.5	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
27.8	1.7	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
29.5	1.8	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
31.2	1.9	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
32.9	2.0	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
34.7	2.1	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
36.4	2.2	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
38.1	2.3	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
39.8	2.4	33.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
39.8	2.2	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
41.5	2.3	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
43.1	2.3	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
44.8	2.4	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
46.5	2.5	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
48.1	2.5	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1

49.8	2.6	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
51.5	2.7	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
53.1	2.7	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
54.8	2.8	20.7	0.10	0.14	0.10	0.15	1.2	6.0	1.0	113.1
54.8	3.3	50.1	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
56.5	3.4	50.1	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
58.1	3.5	50.1	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
59.8	3.5	50.1	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
59.8	4.1	107.6	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
61.5	4.2	107.6	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
63.1	4.3	107.6	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
64.8	4.4	107.6	0.10	0.14	0.05	0.15	1.0	6.0	1.0	113.1
64.8	3.7	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
66.5	3.8	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
68.1	3.8	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
69.8	3.9	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
69.8	4.2	73.6	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
71.5	4.3	73.6	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
73.1	4.4	73.6	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
74.8	4.4	73.6	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
74.8	4.1	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
76.5	4.1	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
78.1	4.2	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
79.8	4.3	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
81.4	4.3	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
83.1	4.4	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
84.8	4.4	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
86.4	4.5	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
88.1	4.6	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
89.7	4.6	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
91.4	4.7	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
93.1	4.7	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
94.7	4.8	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
96.4	4.9	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
98.0	4.9	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
99.7	5.0	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
101.4	5.0	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
103.0	5.1	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
104.7	5.2	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
106.3	5.2	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
108.0	5.3	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1

PIER 1

Gain/Loss Factor at Shaft/Toe = 0.570/1.000

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	-
5.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	31.1	1.2	29.9	2.6	17.339	0.596	4.63	23.7	D 19-42
15.0	193.8	15.7	178.1	20.9	38.554	4.173	7.35	23.8	D 19-42
20.0	59.1	37.0	22.1	4.7	21.262	2.084	5.13	22.1	D 19-42
25.0	75.0	52.9	22.1	6.2	23.226	2.282	5.37	21.2	D 19-42
30.0	96.2	74.1	22.1	8.5	25.113	2.937	5.73	20.9	D 19-42
35.0	124.6	102.4	22.1	11.5	26.346	3.656	6.06	20.4	D 19-42
40.0	193.5	140.0	53.6	19.4	29.654	6.205	7.03	22.3	D 19-42
45.0	243.7	190.2	53.6	27.0	31.609	8.316	7.67	24.1	D 19-42
50.0	297.6	244.0	53.6	42.8	33.539	9.980	8.41	25.8	D 19-42
55.0	355.0	301.4	53.6	83.1	35.149	11.418	9.10	27.2	D 19-42
60.0	416.0	362.4	53.6	249.2	36.089	11.884	9.49	27.9	D 19-42
65.0	440.1	418.0	22.1	452.8	37.105	11.325	9.62	27.9	D 19-42
70.0	521.7	468.1	53.6	9999.0	39.183	10.965	9.82	28.1	D 19-42
75.0	593.1	539.5	53.6	9999.0	40.328	10.725	9.94	28.0	D 19-42
80.0	667.8	614.2	53.6	9999.0	41.045	10.229	10.01	27.8	D 19-42
85.0	745.9	692.3	53.6	9999.0	42.062	8.810	10.05	27.6	D 19-42
90.0	827.3	773.8	53.6	9999.0	42.609	7.428	10.05	27.1	D 19-42
95.0	912.2	858.6	53.6	9999.0	42.910	5.988	10.00	26.4	D 19-42
101.5	1027.5	973.9	53.6	9999.0	42.871	5.070	9.89	25.4	D 19-42

Refusal occurred; no driving time output possible.

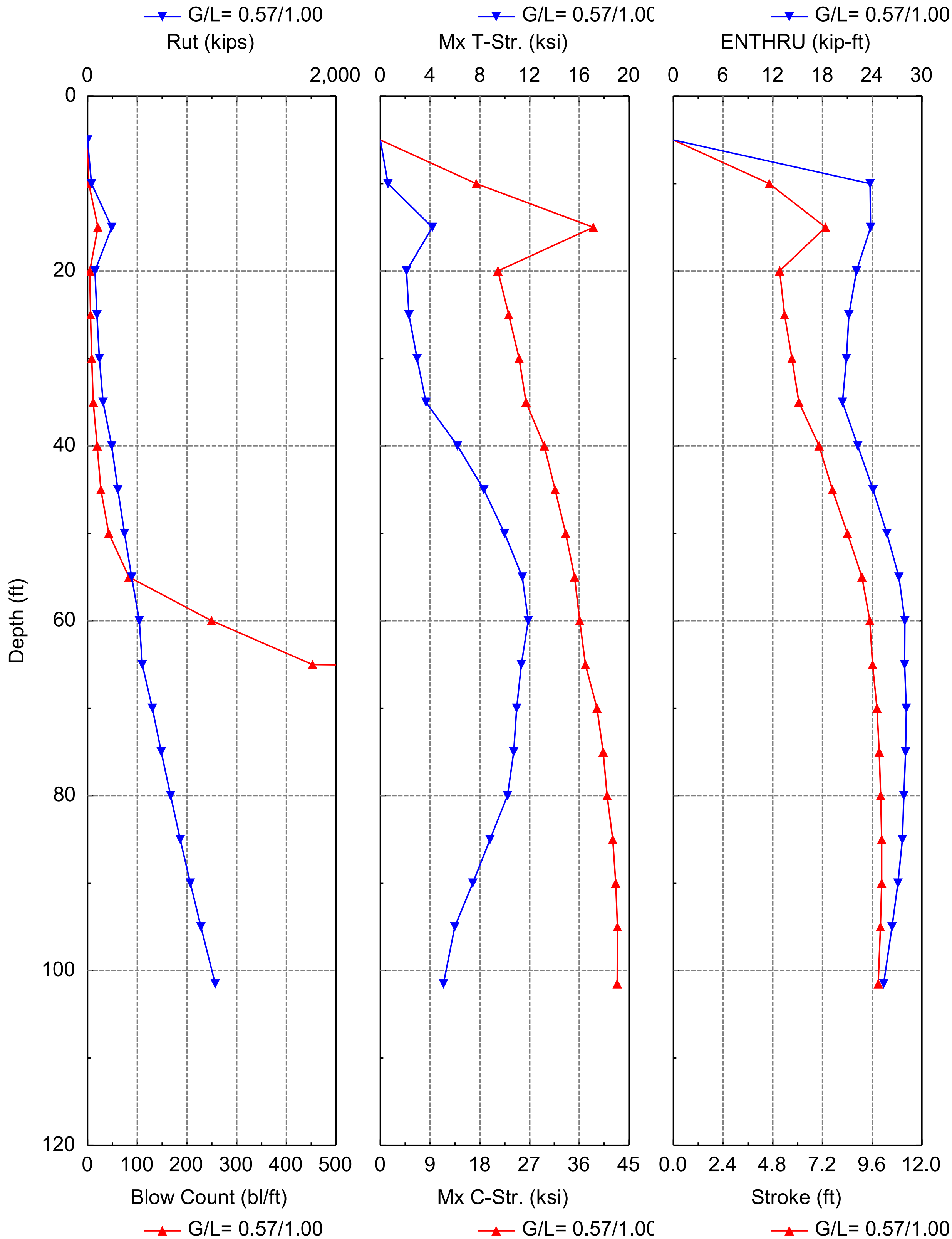
Gain/Loss Factor at Shaft/Toe = 1.000/1.000

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	-
5.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	31.1	1.2	29.9	2.6	17.339	0.596	4.63	23.7	D 19-42
15.0	193.8	15.7	178.1	20.9	38.554	4.173	7.35	23.8	D 19-42
20.0	62.3	40.2	22.1	5.1	21.669	2.076	5.19	21.9	D 19-42
25.0	84.6	62.4	22.1	7.2	24.155	2.068	5.54	21.1	D 19-42
30.0	112.2	90.0	22.1	10.3	25.954	3.973	5.93	20.5	D 19-42
35.0	145.2	123.1	22.1	13.5	27.353	4.015	6.29	20.6	D 19-42
40.0	217.8	164.2	53.6	22.8	31.147	7.664	7.39	23.5	D 19-42
45.0	268.0	214.4	53.6	33.0	32.865	9.550	8.06	25.0	D 19-42
50.0	321.8	268.2	53.6	57.6	34.424	11.214	8.80	26.4	D 19-42
55.0	379.2	325.6	53.6	117.9	36.271	12.279	9.39	28.0	D 19-42
60.0	440.2	386.6	53.6	552.7	37.249	12.114	9.70	28.4	D 19-42

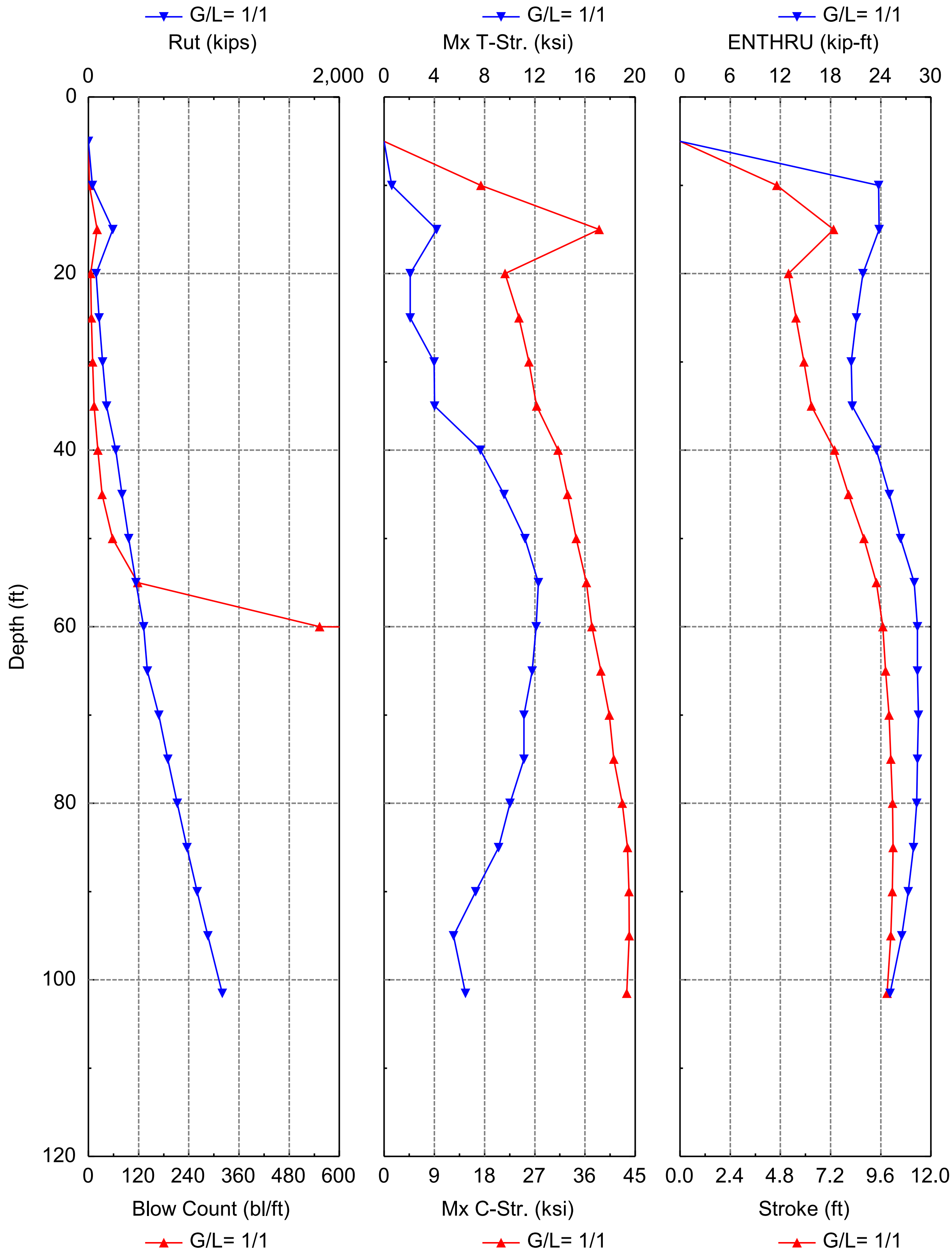
65.0	469.6	447.5	22.1	9999.0	38.846	11.790	9.82	28.4	D 19-42
70.0	561.7	508.2	53.6	9999.0	40.357	11.145	10.00	28.5	D 19-42
75.0	633.1	579.5	53.6	9999.0	41.163	11.130	10.08	28.4	D 19-42
80.0	707.8	654.2	53.6	9999.0	42.666	10.030	10.17	28.3	D 19-42
85.0	785.9	732.3	53.6	9999.0	43.598	9.123	10.18	27.9	D 19-42
90.0	867.4	813.8	53.6	9999.0	43.873	7.289	10.15	27.3	D 19-42
95.0	952.2	898.6	53.6	9999.0	43.940	5.517	10.08	26.5	D 19-42
101.5	1067.5	1013.9	53.6	9999.0	43.480	6.469	9.90	25.1	D 19-42

Refusal occurred; no driving time output possible.

Driveability Analysis Summary



Driveability Analysis Summary



GRLWEAP: Wave Equation Analysis of Pile Foundations

Linn St + RP14IN 12/13/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

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	Sand	110.0	0.0	0.0	0.00	0.00
9.4	Sand	110.0	0.0	0.0	0.00	1.84
9.4	Sand	112.0	0.0	32.0	0.53	26.29
14.5	Sand	112.0	0.0	32.0	0.83	33.09
14.5	Sand	118.0	0.0	39.0	1.61	160.73
17.0	Sand	118.0	0.0	39.0	1.90	190.27
17.0	Clay	125.0	2.7	0.0	1.04	24.75
19.5	Clay	125.0	2.7	0.0	1.04	24.75
19.5	Sand	125.0	0.0	31.0	1.04	20.71
28.3	Sand	125.0	0.0	31.0	1.55	20.71
28.3	Sand	128.0	0.0	31.0	1.55	20.71
38.3	Sand	128.0	0.0	31.0	2.15	20.71
38.3	Sand	128.0	0.0	33.0	2.58	50.11
63.3	Sand	128.0	0.0	33.0	3.56	50.11
63.3	Sand	128.0	0.0	31.0	2.97	20.71
68.3	Sand	128.0	0.0	31.0	3.12	20.71
68.3	Sand	128.0	0.0	33.0	3.74	50.11
101.5	Sand	128.0	0.0	33.0	4.96	50.11

PILE INPUT

Uniform Pile		Pile Type:	Unknown
Pile Length: (ft)	110.000	Pile Penetration: (ft)	101.500
Pile Size: (ft)	1.17	Toe Area: (in²)	153.94

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	10.8	30,000.0	492.0	3.7	0
110.0	10.8	30,000.0	492.0	3.7	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.	415.000	530.000	2.000	0.800	0.120	109976.014
Helmet Wt.	2.500	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	0.13	0.20	0.15	2.0	6.0	168.0	153.9
1.9	0.0	0.4	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
3.8	0.0	0.7	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
5.6	0.0	1.1	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
7.5	0.0	1.5	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
9.4	0.0	1.8	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
9.4	0.5	26.3	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
11.1	0.6	31.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
12.8	0.7	33.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
14.5	0.8	33.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
14.5	1.6	160.7	0.10	0.14	0.05	0.15	1.0	6.0	1.0	153.9
15.8	1.8	175.5	0.10	0.14	0.05	0.15	1.0	6.0	1.0	153.9
17.0	1.9	190.3	0.10	0.14	0.05	0.15	1.0	6.0	1.0	153.9
17.0	1.0	24.7	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
18.3	1.0	24.7	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
19.5	1.0	24.7	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
19.5	1.0	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
21.3	1.1	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
23.0	1.2	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
24.8	1.3	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
26.5	1.4	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
28.3	1.6	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
28.3	1.6	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
30.0	1.7	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
31.6	1.8	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
33.3	1.9	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
35.0	2.0	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
36.6	2.1	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
38.3	2.2	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
38.3	2.6	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
40.0	2.6	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9

41.6	2.7	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
43.3	2.8	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
45.0	2.8	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
46.6	2.9	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
48.3	3.0	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
50.0	3.0	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
51.6	3.1	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
53.3	3.2	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
55.0	3.2	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
56.6	3.3	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
58.3	3.4	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
60.0	3.4	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
61.6	3.5	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
63.3	3.6	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
63.3	3.0	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
65.0	3.0	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
66.6	3.1	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
68.3	3.1	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
68.3	3.7	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
70.0	3.8	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
71.6	3.9	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
73.3	3.9	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
74.9	4.0	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
76.6	4.0	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
78.3	4.1	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
79.9	4.2	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
81.6	4.2	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
83.2	4.3	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
84.9	4.3	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
86.6	4.4	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
88.2	4.5	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
89.9	4.5	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
91.5	4.6	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
93.2	4.7	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
94.9	4.7	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
96.5	4.8	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
98.2	4.8	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
99.8	4.9	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9
101.5	5.0	50.1	0.10	0.18	0.05	0.15	1.0	6.0	1.0	153.9

PIER 2

Gain/Loss Factor at Shaft/Toe = 0.570/1.000

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 -
5.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	38.6	2.4	36.2	3.4	19.000	0.560	4.82	22.9	D 19-42
15.0	68.9	16.7	52.2	6.3	22.202	1.565	5.38	21.3	D 19-42
20.0	59.5	30.2	29.3	5.2	21.820	1.732	5.21	21.8	D 19-42
25.0	73.8	44.5	29.3	6.8	23.772	1.866	5.47	21.0	D 19-42
30.0	84.4	62.3	22.1	8.0	24.553	2.069	5.66	20.9	D 19-42
35.0	108.2	86.1	22.1	10.7	25.962	3.565	5.97	20.3	D 19-42
40.0	126.3	112.1	14.2	12.3	26.401	3.269	6.15	20.2	D 19-42
45.0	151.9	137.6	14.2	14.8	27.676	3.380	6.42	20.4	D 19-42
50.0	179.3	165.0	14.2	17.8	28.470	4.562	6.79	21.1	D 19-42
55.0	218.3	196.2	22.1	24.0	30.527	5.950	7.34	22.5	D 19-42
60.0	294.9	241.3	53.6	51.4	32.929	8.761	8.38	25.0	D 19-42
65.0	359.3	305.8	53.6	139.5	34.762	9.400	8.99	26.4	D 19-42
70.0	389.1	367.0	22.1	312.2	35.472	8.633	9.18	26.7	D 19-42
75.0	440.1	417.9	22.1	9999.0	36.976	8.676	9.35	26.7	D 19-42
80.0	559.6	480.9	78.7	9999.0	37.703	7.759	9.44	26.5	D 19-42
85.0	644.4	565.7	78.7	9999.0	38.231	7.067	9.46	26.2	D 19-42
90.0	733.0	654.3	78.7	9999.0	38.335	5.883	9.45	25.8	D 19-42
95.0	825.4	746.6	78.7	9999.0	38.282	4.875	9.43	25.1	D 19-42
101.5	951.1	872.3	78.7	9999.0	38.000	4.850	9.33	24.1	D 19-42

Refusal occurred; no driving time output possible.

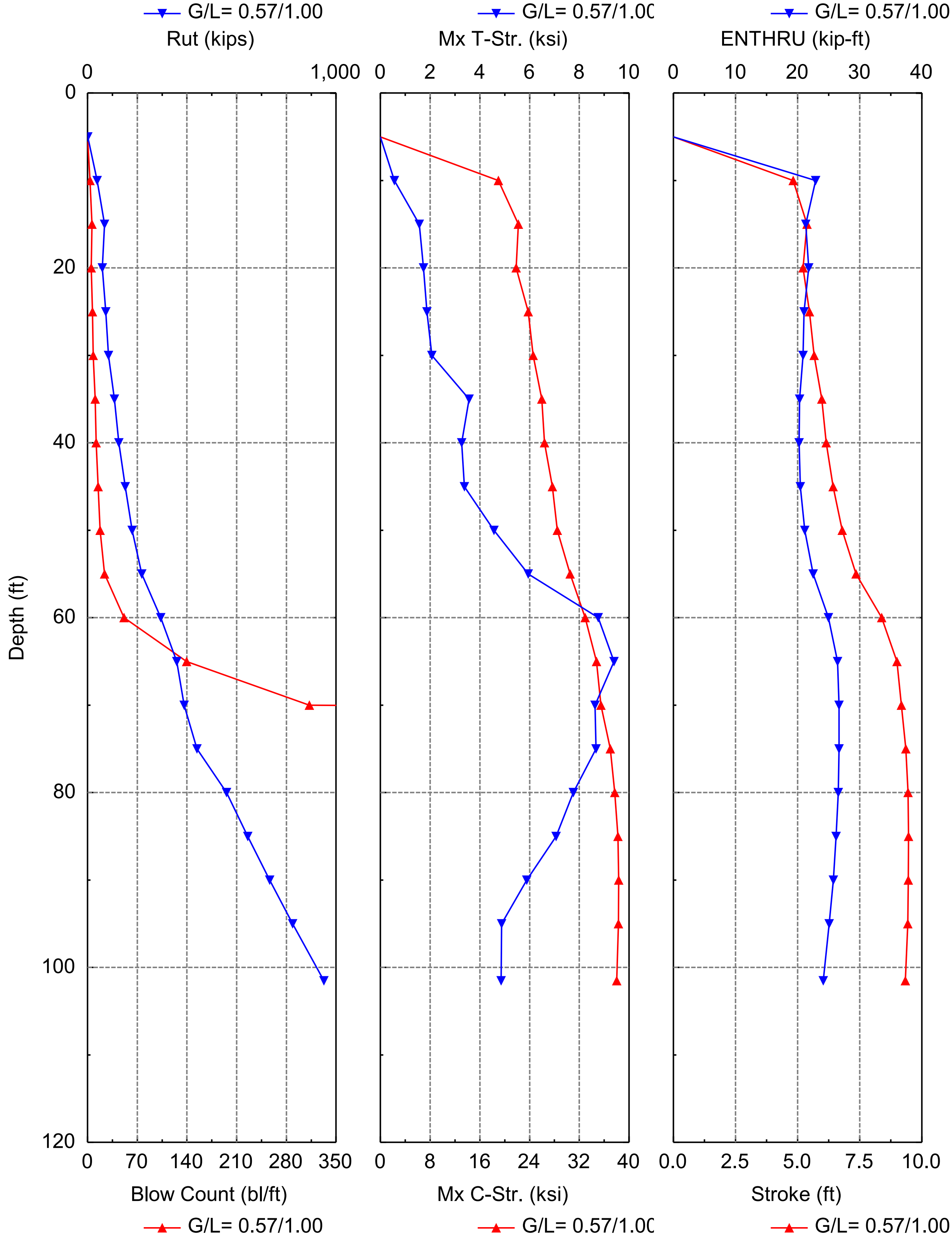
Gain/Loss Factor at Shaft/Toe = 1.000/1.000

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 -
5.0	1.0	0.0	1.0	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	39.3	3.2	36.2	3.5	19.121	0.549	4.83	22.8	D 19-42
15.0	69.7	17.5	52.2	6.3	22.271	1.614	5.39	21.3	D 19-42
20.0	64.2	34.8	29.3	5.7	22.371	1.633	5.29	21.5	D 19-42
25.0	84.1	54.8	29.3	8.0	24.783	2.245	5.66	20.9	D 19-42
30.0	101.8	79.6	22.1	10.1	25.598	3.080	5.91	20.4	D 19-42
35.0	134.9	112.8	22.1	13.3	27.274	3.410	6.26	20.4	D 19-42
40.0	163.3	149.1	14.2	16.1	28.142	4.678	6.61	21.0	D 19-42
45.0	198.9	184.7	14.2	20.4	30.242	6.316	7.12	22.2	D 19-42
50.0	237.1	222.9	14.2	27.1	31.749	7.572	7.65	23.6	D 19-42
55.0	288.4	266.3	22.1	44.2	33.676	9.579	8.41	25.1	D 19-42
60.0	374.4	320.8	53.6	187.2	35.841	10.971	9.41	27.7	D 19-42

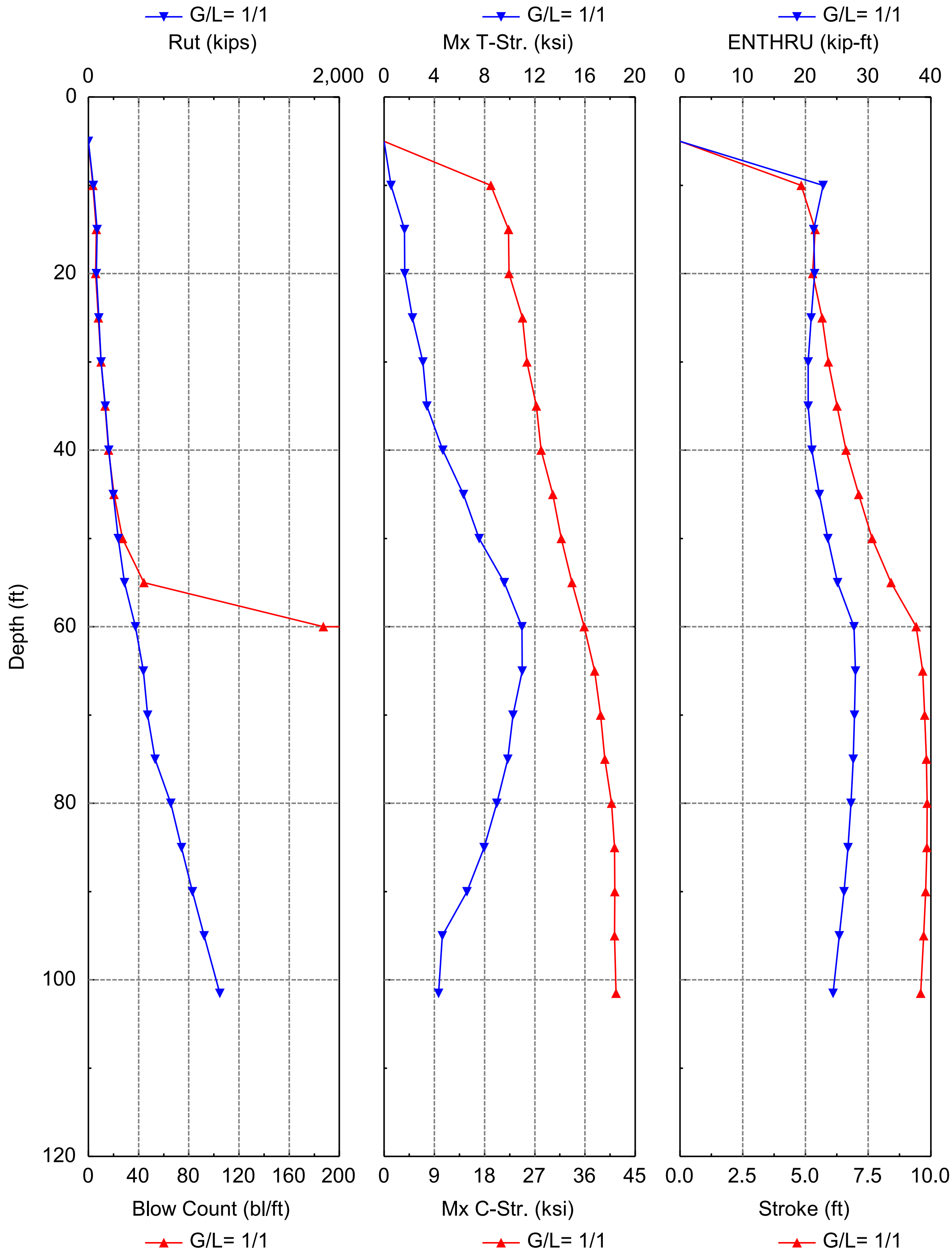
65.0	438.9	385.3	53.6	9999.0	37.715	11.001	9.67	28.0	D 19-42
70.0	471.5	449.3	22.1	9999.0	38.796	10.259	9.75	27.8	D 19-42
75.0	531.0	508.9	22.1	9999.0	39.546	9.838	9.81	27.6	D 19-42
80.0	656.4	577.6	78.7	9999.0	40.752	8.982	9.84	27.2	D 19-42
85.0	741.2	662.5	78.7	9999.0	41.285	7.960	9.83	26.8	D 19-42
90.0	829.8	751.0	78.7	9999.0	41.342	6.594	9.79	26.1	D 19-42
95.0	922.1	843.4	78.7	9999.0	41.292	4.632	9.71	25.4	D 19-42
101.5	1047.8	969.1	78.7	9999.0	41.575	4.336	9.59	24.4	D 19-42

Refusal occurred; no driving time output possible.

Driveability Analysis Summary



Driveability Analysis Summary



GRLWEAP: Wave Equation Analysis of Pile Foundations

Linn St + FP14IN 12/12/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

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	Sand	110.0	0.0	0.0	0.00	0.00
9.0	Sand	110.0	0.0	0.0	0.00	1.76
9.0	Clay	112.0	1.7	0.0	1.13	15.75
9.5	Clay	112.0	1.7	0.0	1.13	15.75
9.5	Sand	115.0	0.0	33.0	0.59	32.08
16.0	Sand	115.0	0.0	33.0	1.01	50.11
16.0	Clay	125.0	3.0	0.0	1.08	27.45
28.3	Clay	125.0	3.0	0.0	1.08	27.45
28.3	Sand	125.0	0.0	31.0	1.56	20.71
38.3	Sand	125.0	0.0	31.0	2.15	20.71
38.3	Sand	128.0	0.0	29.0	1.82	13.32
53.3	Sand	128.0	0.0	29.0	2.25	13.32
53.3	Sand	128.0	0.0	31.0	2.66	20.71
58.3	Sand	128.0	0.0	31.0	2.81	20.71
58.3	Sand	128.0	0.0	33.0	3.36	50.11
68.3	Sand	128.0	0.0	33.0	3.73	50.11
68.3	Sand	128.0	0.0	31.0	3.12	20.71
78.3	Sand	128.0	0.0	31.0	3.43	20.71
78.3	Sand	130.0	0.0	34.0	4.46	73.64
101.5	Sand	130.0	0.0	34.0	5.41	73.64

PILE INPUT

Uniform Pile		Pile Type:	Unknown
Pile Length: (ft)	110.000	Pile Penetration: (ft)	101.500
Pile Size: (ft)	1.17	Toe Area: (in²)	153.94

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	10.8	30,000.0	492.0	3.7	0
110.0	10.8	30,000.0	492.0	3.7	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.	415.000	530.000	2.000	0.800	0.120	109976.014
Helmet Wt.	2.500	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	0.13	0.20	0.15	2.0	6.0	168.0	153.9
1.8	0.0	0.4	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
3.6	0.0	0.7	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
5.4	0.0	1.1	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
7.2	0.0	1.4	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
9.0	0.0	1.8	0.10	0.13	0.20	0.15	2.0	6.0	168.0	153.9
9.0	1.1	15.7	0.10	0.15	0.20	0.15	1.8	6.0	168.0	153.9
9.5	1.1	15.7	0.10	0.15	0.20	0.15	1.8	6.0	168.0	153.9
9.5	0.6	32.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
11.7	0.7	39.7	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
13.8	0.9	47.4	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
16.0	1.0	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
16.0	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
17.8	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
19.5	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
21.3	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
23.0	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
24.8	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
26.5	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
28.3	1.1	27.4	0.10	0.13	0.15	0.15	1.5	6.0	24.0	153.9
28.3	1.6	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
30.0	1.7	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
31.6	1.8	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
33.3	1.9	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
35.0	2.0	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
36.6	2.0	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
38.3	2.1	20.7	0.10	0.16	0.10	0.15	1.5	6.0	24.0	153.9
38.3	1.8	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
40.0	1.9	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9

41.6	1.9	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
43.3	2.0	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
45.0	2.0	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
46.6	2.1	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
48.3	2.1	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
50.0	2.2	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
51.6	2.2	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
53.3	2.3	13.3	0.10	0.20	0.10	0.15	1.5	6.0	24.0	153.9
53.3	2.7	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
55.0	2.7	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
56.6	2.8	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
58.3	2.8	20.7	0.10	0.17	0.10	0.15	1.5	6.0	24.0	153.9
58.3	3.4	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
60.0	3.4	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
61.6	3.5	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
63.3	3.5	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
65.0	3.6	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
66.6	3.7	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
68.3	3.7	50.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	153.9
68.3	3.1	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
70.0	3.2	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
71.6	3.2	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
73.3	3.3	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
75.0	3.3	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
76.6	3.4	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
78.3	3.4	20.7	0.10	0.16	0.10	0.15	1.2	6.0	24.0	153.9
78.3	4.5	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
80.0	4.5	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
81.6	4.6	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
83.3	4.7	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
84.9	4.7	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
86.6	4.8	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
88.2	4.9	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
89.9	4.9	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
91.6	5.0	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
93.2	5.1	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
94.9	5.1	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
96.5	5.2	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
98.2	5.3	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
99.8	5.3	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9
101.5	5.4	73.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	153.9

FORWARD ABUTMENT

Gain/Loss Factor at Shaft/Toe = 0.670/1.000

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 -
5.0	0.9	0.0	0.9	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	1.7	0.0	1.7	0.3	0.000	0.000	10.81	0.0	D 19-42
15.0	40.8	1.4	39.4	3.6	19.707	0.333	4.76	23.0	D 19-42
20.0	60.0	20.7	39.4	5.1	21.813	1.860	5.08	22.2	D 19-42
25.0	84.8	45.5	39.4	7.0	24.025	2.921	5.42	21.6	D 19-42
30.0	115.1	75.8	39.4	9.6	26.383	4.665	5.75	21.3	D 19-42
35.0	150.9	111.6	39.4	12.4	27.994	5.242	6.20	21.5	D 19-42
40.0	155.1	144.6	10.5	12.0	28.265	5.486	6.12	21.4	D 19-42
45.0	177.8	167.3	10.5	14.4	29.843	5.407	6.49	21.8	D 19-42
50.0	202.1	191.7	10.5	17.3	32.391	7.047	6.91	22.7	D 19-42
55.0	228.0	217.6	10.5	21.4	33.634	7.744	7.36	23.6	D 19-42
60.0	262.7	246.4	16.3	28.6	35.803	9.571	7.95	25.2	D 19-42
65.0	302.6	286.3	16.3	45.0	37.415	10.510	8.59	26.4	D 19-42
70.0	355.8	329.8	26.0	124.4	40.871	11.373	9.28	28.1	D 19-42
75.0	413.6	387.6	26.0	9999.0	43.504	11.012	9.63	28.7	D 19-42
80.0	474.0	448.0	26.0	9999.0	44.851	10.530	9.69	28.4	D 19-42
85.0	537.1	511.1	26.0	9999.0	45.193	9.993	9.68	28.0	D 19-42
90.0	602.8	576.8	26.0	9999.0	45.947	8.702	9.63	27.4	D 19-42
95.0	671.1	645.1	26.0	9999.0	46.276	7.508	9.57	26.7	D 19-42
97.6	707.3	681.3	26.0	9999.0	46.080	7.001	9.54	26.3	D 19-42

Refusal occurred; no driving time output possible.

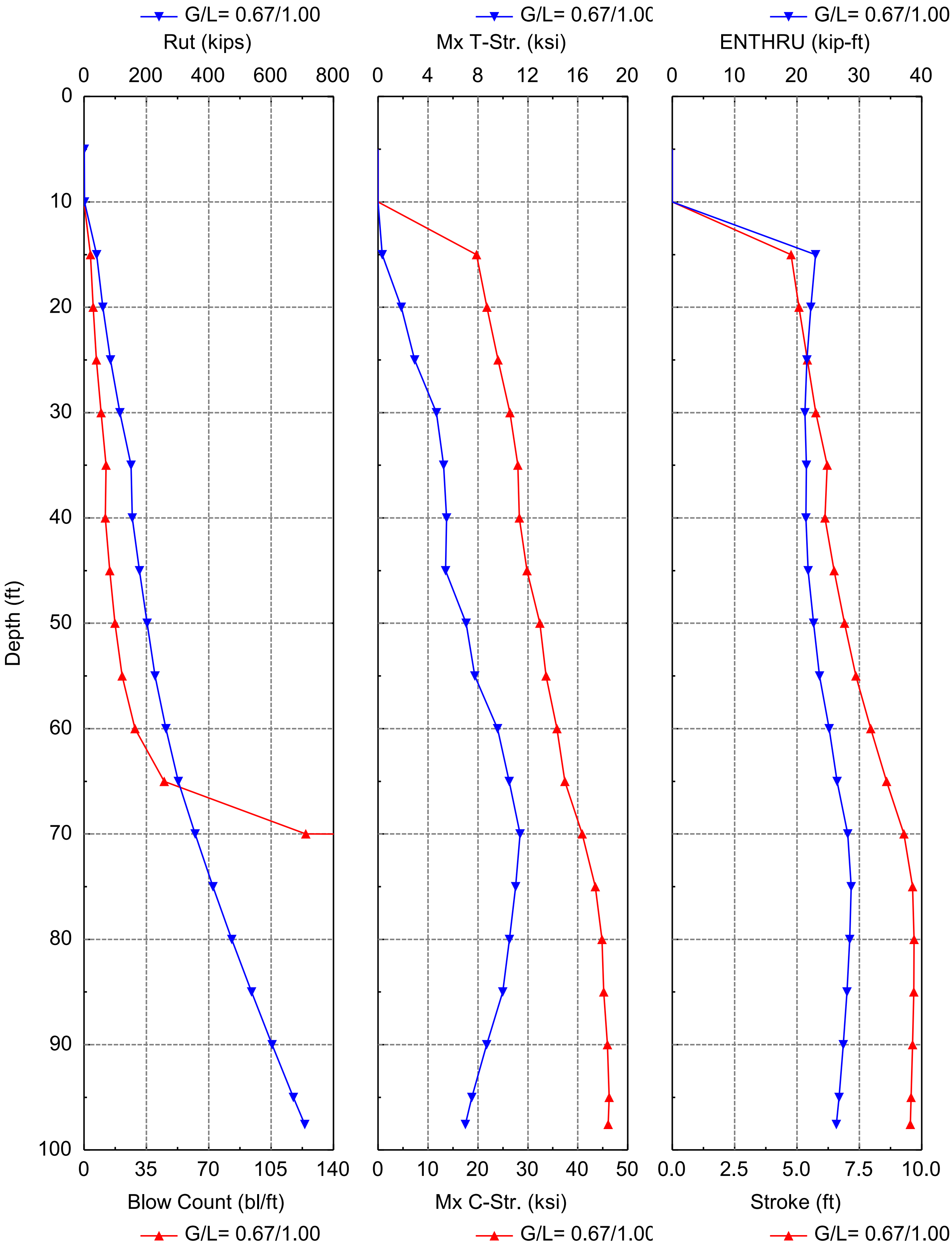
Gain/Loss Factor at Shaft/Toe = 1.000/1.000

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 -
5.0	0.9	0.0	0.9	0.3	0.000	0.000	10.81	0.0	D 19-42
10.0	1.7	0.0	1.7	0.3	0.000	0.000	10.81	0.0	D 19-42
15.0	40.8	1.4	39.4	3.6	19.707	0.333	4.76	23.0	D 19-42
20.0	60.0	20.7	39.4	5.1	21.813	1.860	5.08	22.2	D 19-42
25.0	84.8	45.5	39.4	7.0	24.025	2.921	5.42	21.6	D 19-42
30.0	115.1	75.8	39.4	9.6	26.383	4.665	5.75	21.3	D 19-42
35.0	150.9	111.6	39.4	12.4	27.994	5.242	6.20	21.5	D 19-42
40.0	159.2	148.7	10.5	12.4	28.487	5.723	6.19	21.5	D 19-42
45.0	193.1	182.6	10.5	16.2	30.718	6.748	6.77	22.5	D 19-42
50.0	229.4	218.9	10.5	21.7	34.049	8.699	7.42	24.0	D 19-42
55.0	268.1	257.6	10.5	30.3	36.452	10.139	8.10	25.9	D 19-42
60.0	315.6	299.3	16.3	55.3	38.505	11.852	8.96	27.4	D 19-42

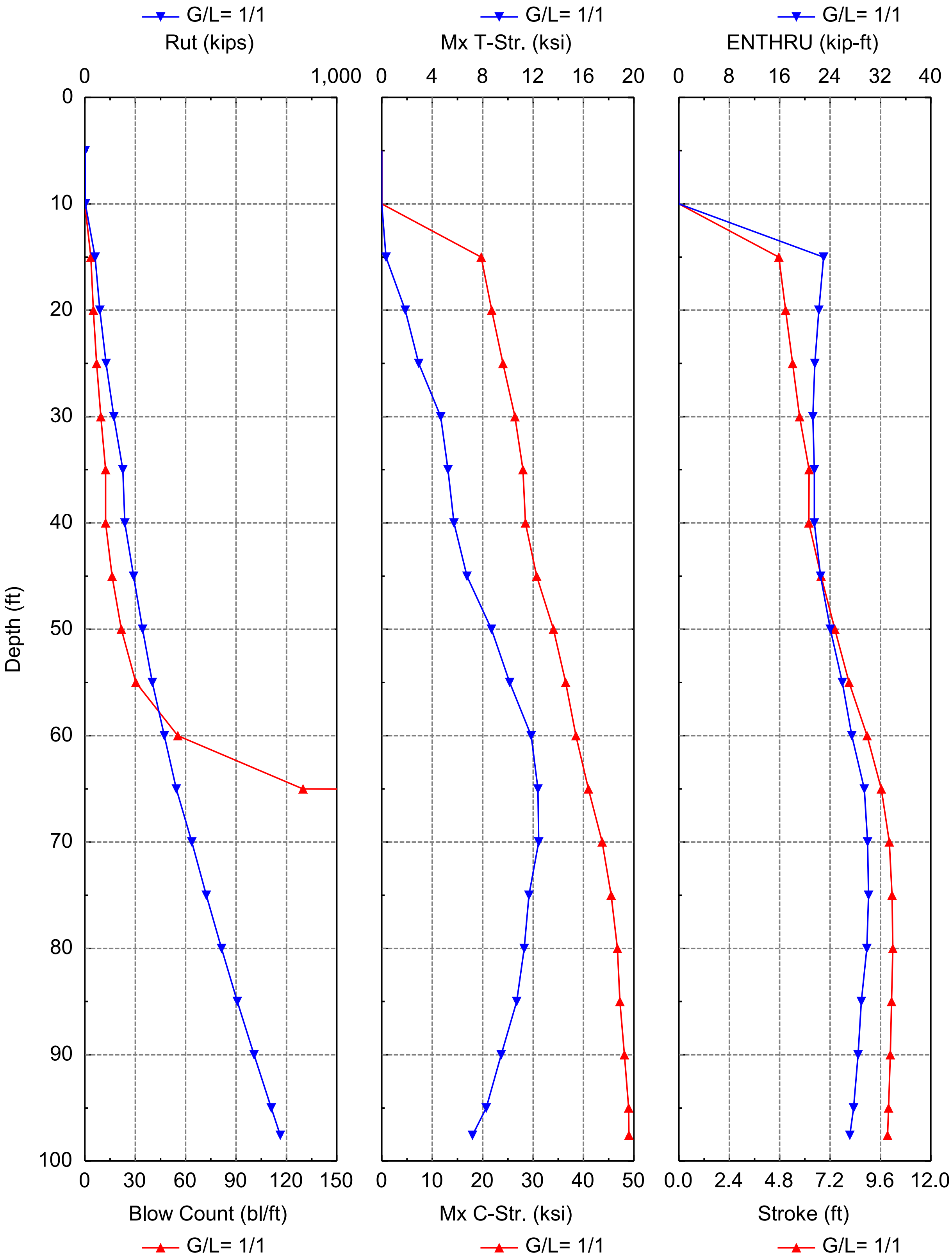
65.0	363.4	347.1	16.3	129.9	40.985	12.383	9.64	29.4	D 19-42
70.0	424.0	398.0	26.0	9999.0	43.707	12.446	10.02	30.0	D 19-42
75.0	481.8	455.8	26.0	9999.0	45.513	11.677	10.15	30.1	D 19-42
80.0	542.2	516.2	26.0	9999.0	46.748	11.289	10.18	29.8	D 19-42
85.0	605.2	579.2	26.0	9999.0	47.226	10.710	10.13	29.0	D 19-42
90.0	670.9	644.9	26.0	9999.0	48.117	9.469	10.07	28.4	D 19-42
95.0	739.3	713.3	26.0	9999.0	48.969	8.271	9.98	27.7	D 19-42
97.6	775.4	749.4	26.0	9999.0	49.004	7.192	9.93	27.1	D 19-42

Refusal occurred; no driving time output possible.

Driveability Analysis Summary



Driveability Analysis Summary



GRLWEAP: Wave Equation Analysis of Pile Foundations

Linn St + RA12IN 12/12/2024
NATIONAL ENGINEERING AND ARCHITECTURAL GRLWEAP 14.1.20.1

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	Sand	125.0	0.0	0.0	0.00	0.00
14.6	Sand	125.0	0.0	0.0	0.00	3.23
14.6	Sand	125.0	0.0	33.0	1.02	50.11
38.1	Sand	125.0	0.0	33.0	2.67	50.11
38.1	Sand	115.0	0.0	30.0	2.02	13.32
59.4	Sand	115.0	0.0	30.0	3.06	13.32
59.4	Sand	128.0	0.0	31.0	3.38	20.71
69.4	Sand	128.0	0.0	31.0	3.68	20.71
69.4	Sand	128.0	0.0	32.0	4.04	33.09
97.6	Sand	128.0	0.0	32.0	4.99	33.09

PILE INPUT

Uniform Pile		Pile Type:	Unknown
Pile Length: (ft)	110.000	Pile Penetration: (ft)	97.570
Pile Size: (ft)	1.00	Toe Area: (in²)	113.10

Pile Profile

Lb Top	X-Area	E-Modulus	Spec. Wt	Perim.	Crit. Index
ft	in²	ksi	lb/ft³	ft	-
0.0	9.2	30,000.0	492.0	3.1	0
110.0	9.2	30,000.0	492.0	3.1	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.	415.000	530.000	2.000	0.800	0.120	109976.014
Helmet Wt.	2.500	kips				

SOIL RESISTANCE DISTRIBUTION

Depth ft	Unit Rs ksf	Unit Rt ksf	Qs in	Qt in	Js s/ft	Jt s/ft	Set. F. -	Limit D. ft	Set. T. Hours	EB Area in²
0.0	0.0	0.0	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
1.8	0.0	0.4	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
3.6	0.0	0.8	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
5.5	0.0	1.2	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
7.3	0.0	1.6	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
9.1	0.0	2.0	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
10.9	0.0	2.4	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
12.7	0.0	2.8	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
14.6	0.0	3.2	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
14.6	1.0	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
16.2	1.1	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
17.9	1.3	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
19.6	1.4	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
21.3	1.5	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
23.0	1.6	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
24.6	1.7	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
26.3	1.8	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
28.0	2.0	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
29.7	2.1	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
31.4	2.2	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
33.0	2.3	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
34.7	2.4	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
36.4	2.6	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
38.1	2.7	50.1	0.10	0.15	0.05	0.15	1.0	6.0	1.0	113.1
38.1	2.0	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
39.8	2.1	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
41.6	2.2	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
43.4	2.3	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
45.2	2.4	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
46.9	2.5	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
48.7	2.5	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
50.5	2.6	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
52.3	2.7	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
54.0	2.8	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
55.8	2.9	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
57.6	3.0	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
59.4	3.1	13.3	0.10	0.17	0.10	0.15	1.5	6.0	24.0	113.1
59.4	3.4	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
61.0	3.4	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1

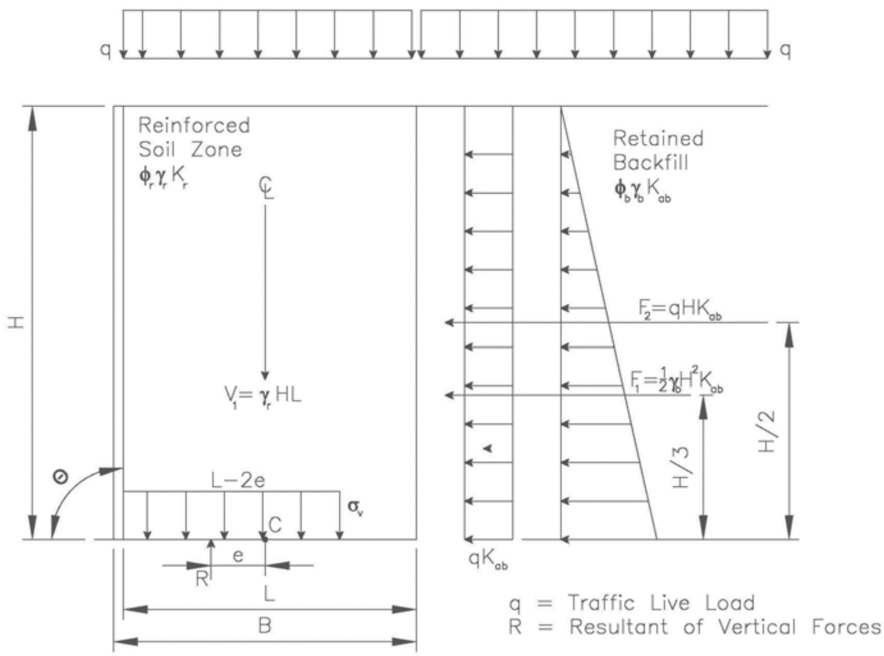
62.7	3.5	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
64.4	3.5	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
66.0	3.6	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
67.7	3.6	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
69.4	3.7	20.7	0.10	0.15	0.10	0.15	1.2	6.0	24.0	113.1
69.4	4.0	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
71.0	4.1	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
72.7	4.2	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
74.3	4.2	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
76.0	4.3	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
77.7	4.3	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
79.3	4.4	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
81.0	4.4	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
82.6	4.5	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
84.3	4.5	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
86.0	4.6	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
87.6	4.7	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
89.3	4.7	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
90.9	4.8	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
92.6	4.8	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
94.3	4.9	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
95.9	4.9	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1
97.6	5.0	33.1	0.10	0.16	0.05	0.15	1.0	6.0	1.0	113.1

EXTERNAL STABILITY ANALYSIS

REAR ABUTMENT

Objective: To evaluate the external stability of MSE wall design with vertical wall face and horizontal backfill.
Method: In accordance with ODOT Bridge Design Manual, 2013 [Sect. 307] LRFD Bridge Design Specifications, 8th Ed., 2018, [Sect. 11.10.5].
Assumptions:

- **Horizontal backfill behind MSE wall on granular (drained) soils.**
- **For battered or vertical walls with a back face of wall angle of θ to horizontal.**
- **Not for sheet type reinforcement. If so, use different assessment for Sliding parameter ϕ_μ.**
- **MSE wall not acting as abutment, if so must meet minimum embedment depth of H/10 if no slope in front of wall**
- **Load combinations and wall configuration are as shown below:**



Givens:

Wall Geometry:

$H_e := 19.6 \cdot ft$ — Exposed wall height

$\theta := 90 \cdot deg$ — Angle of back face of wall to horizontal: 90 deg for vertical or near vertical walls (per Berg et al., 2009; near vertical = 80 deg < θ < 100 deg)

Reinforced Backfill Soil Design Parameters:

$\phi'_r := 34 \cdot deg$ — Effective angle of internal friction (Per BDM [Table 307-1])

$\gamma_r := 120 \cdot \frac{lbf}{ft^3}$ — Unit weight (Per BDM [Table 307-1])

$c'_r := 0 \cdot \frac{lbf}{ft^2}$ — Effective Cohesion

Retained Backfill Soil Design Parameters:

$\phi'_b := 30 \cdot deg$ — Effective angle of internal friction (Per BDM [Table 307-1])

$\gamma_b := 120 \cdot \frac{lbf}{ft^3}$ — Unit weight (Per BDM [Table 307-1])

$c'_b := 0 \cdot \frac{lbf}{ft^2}$ — Effective Cohesion

Foundation Soil Design Parameters:

Drained Conditions (Effective Stress):

$\phi'_f := 22 \cdot deg$ — Effective angle of internal friction

$\gamma_f := 110 \cdot \frac{lbf}{ft^3}$ — Unit weight

$c'_f := 150 \cdot \frac{lbf}{ft^2}$ — Cohesion

$\delta_{fd} := 0.67 \cdot \phi'_f$ $\quad \delta_{fd} = 14.7\ deg$ — Friction angle between embedment soils and MSE wall fill specified in **LRFD BDS C3.11.5.3 (degrees)**

Undrained Conditions (Total Stress):

$\phi_f := 0 \cdot deg$ — Angle of internal friction (Same as Drained Conditions if Sand)

$\gamma_f = 110\ \frac{lbf}{ft^3}$ — Unit weight

$c_f := 1700 \cdot \frac{lbf}{ft^2}$ — Cohesion (Use Su if Angle of internal friction = 0 deg)

Foundation Surcharge Soil Parameters:

$\gamma_q := 115 \cdot \frac{lbf}{ft^3}$ — Unit weight of Soil above bearing depth (Used in Bearing Resistance of Soil Calculation LRFD 10.6.3.1.2a-1)

Depth of Embedment Check:

$d_{frost} := 3\ ft$ $\quad d_{user} := 4.5\ ft$ — Local Frost Depth

$Slope_{fw} := 0\ deg$ — Inclination of ground slope in front of wall :

- Horizontal: **0**
- 3H:1V: **18.435**
- 2H:1V: **26.565**
- 1.5H:1V: **33.690**

$d_{est} := \max(d_{frost}, 3\ ft, d_{user})$ $\quad d_{est} = 4.5\ ft$

$H_{est} := d_{est} + (4\ ft \cdot \tan(Slope_{fw})) + H_e$ $\quad H_{est} = 24.1\ ft$

$$d_{eSlope} := \text{if}\left(Slope_{fw} < 1\ deg, \frac{H_{est}}{20}, \text{if}\left(Slope_{fw} < 26.565\ deg, \frac{H_{est}}{10}, \text{if}\left(Slope_{fw} < 33.69\ deg, \frac{H_{est}}{7}, \frac{H_{est}}{5}\right)\right)\right)$$

$d_{eSlope} = 1.2\ ft$ — Minimum Embedment Depth per Table C11.10.2.2-1 of LRFD BDS

$d_e := \max(d_{est}, d_{eSlope})$ $\quad d_e = 4.5\ ft$ — Minimum Required Embedment Depth used in analysis.

$H := d_e + (4\ ft \cdot \tan(Slope_{fw})) + H_e$ $\quad H = 24.1\ ft$ — Design Wall Height

Estimate Length of Reinforcement:

$L_{user} := 19.28 \cdot ft$ — User inputted value (if changes need to be made to satisfy other requirements)

$L := \max(8 \cdot ft, 0.7 \cdot H, L_{user})$ $\quad L = 19.3\ ft$ — Length of Reinforcement

Live Load Surcharge Parameters:

$SUR := 250 \cdot \frac{lbf}{ft^2}$

Live load surcharge (per **LRFD BDS [3.11.6.4]** & **BDM [307.1.1]**)
Note: If vehicular loading is within 1 ft of the backface of the wall and with a design height, H, less than 20 ft, see **LRFD BDS Section 3.11.6.4 and Table 3.11.6.4-2** for adjusted surcharge load calculation.
Note: When traffic vehicular live loads are not present within 0.5*H from the back of the reinforced zone let SUR equal 100 psf to account for construction loads.

Calculations:

Active Earth Pressure:

$\beta := 0 \qquad \delta := \beta$

Inclination of ground slope behind face of wall and angle of friction between retained backfill and reinforced soil

$$\Gamma := \left(1 + \sqrt{\frac{\left(\sin\left(\phi'_b + \delta\right) \cdot \sin\left(\phi'_b - \beta\right)\right)}{\left(\sin\left(\theta - \delta\right) \cdot \sin\left(\theta + \beta\right)\right)}}\right)^2$$

$$k_{af} := \left(\frac{\left(\sin\left(\theta + \phi'_b\right)\right)^2}{\left(\Gamma \cdot \left(\sin\left(\theta\right)\right)^2 \cdot \sin\left(\theta - \delta\right)\right)}\right) \qquad k_{af} = 0.3333$$

Active Earth Pressure Coefficient

$F_T := \frac{1}{2} \cdot \gamma_b \cdot H^2 \cdot k_{af} \qquad F_T = 11616.2 \ \frac{lbf}{ft}$ — Active Earth Force Resultant (EH)

$F_{SUR} := SUR \cdot H \cdot k_{af} \qquad F_{SUR} = 2008.3 \ \frac{lbf}{ft}$ — Live Load Surcharge (LS)

Vertical Loads:

$V_1 := \gamma_r \cdot H \cdot L \qquad V_1 = 55757.8 \ \frac{lbf}{ft}$ — Soil backfill - reinforced soil (EV)

$V_2 := SUR \cdot L \qquad V_2 = 4820 \ \frac{lbf}{ft}$ — Live Load Surcharge - (LS)

Moment Arm: / Moment:

$d_{v1} := 0 \cdot ft \qquad d_{v1} = 0 \ ft \qquad MV_1 := V_1 \cdot d_{v1} \qquad MV_1 = 0 \ \frac{lbf \cdot ft}{ft}$

$d_{v2} := 0 \ ft \qquad d_{v2} = 0 \ ft \qquad MV_2 := V_2 \cdot d_{v2} \qquad MV_2 = 0 \ \frac{lbf \cdot ft}{ft}$

Horizontal Loads:

$H_1 := F_T = 11616.2 \ \frac{lbf}{ft}$ — Active Earth Force Resultant (horizontal comp. - EH)

$H_2 := F_{SUR} = 2008.3 \ \frac{lbf}{ft}$ — Live Load Surcharge Resultant (horizontal comp. - LS)

Moment Arm: / Moment:

$d_{h1} := \frac{H}{3} \qquad d_{h1} = 8 \ ft \qquad MH_1 := H_1 \cdot d_{h1} \qquad MH_1 = 93316.8 \ \frac{lbf \cdot ft}{ft}$

$d_{h2} := \frac{H}{2} \qquad d_{h2} = 12.1 \ ft \qquad MH_2 := H_2 \cdot d_{h2} \qquad MH_2 = 24200.4 \ \frac{lbf \cdot ft}{ft}$

Unfactored Loads by Load Type

$V_{EV} := V_1$ $\quad V_{EV} = 55757.8\ \frac{lbf}{ft}$

$V_{LS} := V_2$ $\quad V_{LS} = 4820\ \frac{lbf}{ft}$

$H_{EH} := H_1$ $\quad H_{EH} = 11616.2\ \frac{lbf}{ft}$

$H_{LS} := H_2$ $\quad H_{LS} = 2008.3\ \frac{lbf}{ft}$

Unfactored Moments by Load Type

$M_{EV} := MV_1$ $\quad M_{EV} = 0\ \frac{lbf \cdot ft}{ft}$

$M_{LS} := MV_2$ $\quad M_{LS} = 0\ \frac{lbf \cdot ft}{ft}$

$M_{EH2} := MH_1$ $\quad M_{EH2} = 93316.8\ \frac{lbf \cdot ft}{ft}$

$M_{LS2} := MH_2$ $\quad M_{LS2} = 24200.4\ \frac{lbf \cdot ft}{ft}$

Load Combination Limit States:

$\eta := 1$ LRFD Load Modifier

Strength Limit State I: EV(min) = 1.00 EV(max) = 1.35
EH(min) = 0.90 EH(max) = 1.50
LS = 1.75

Strength Limit State Ia: (Sliding and Eccentricity) $\quad Ia_{EV} := 1 \quad Ia_{EH} := 1.5 \quad Ia_{LS} := 1.75$

Strength Limit State Ib: (Bearing Capacity) $\quad Ib_{EV} := 1.35 \quad Ib_{EH} := 1.5 \quad Ib_{LS} := 1.75$

Factored Vertical Loads by Limit State:

$V_{Ia} := \eta \cdot (Ia_{EV} \cdot V_{EV})$ $\quad V_{Ia} = 55757.8\ \frac{lbf}{ft}$

$V_{Ib} := \eta \cdot ((Ib_{EV} \cdot V_{EV}) + (Ib_{LS} \cdot V_{LS}))$ $\quad V_{Ib} = 83708\ \frac{lbf}{ft}$

Factored Horizontal Loads by Limit State:

$H_{Ia} := \eta \cdot ((Ia_{LS} \cdot H_{LS}) + (Ia_{EH} \cdot H_{EH}))$ $\quad H_{Ia} = 20938.9\ \frac{lbf}{ft}$

$H_{Ib} := \eta \cdot ((Ib_{LS} \cdot H_{LS}) + (Ib_{EH} \cdot H_{EH}))$ $\quad H_{Ib} = 20938.9\ \frac{lbf}{ft}$

Factored Moments Produced by Vertical Loads by Limit State:

$MV_{Ia} := \eta \cdot (Ia_{EV} \cdot M_{EV})$ $\quad MV_{Ia} = 0\ \frac{lbf \cdot ft}{ft}$

$MV_{Ib} := \eta \cdot ((Ib_{EV} \cdot M_{EV}) + (Ib_{LS} \cdot M_{LS}))$ $\quad MV_{Ib} = 0\ \frac{lbf \cdot ft}{ft}$

Factored Moments Produced by Horizontal Loads by Limit State:

$MH_{Ia} := \eta \cdot ((Ia_{LS} \cdot M_{LS2}) + (Ia_{EH} \cdot M_{EH2}))$ $\quad MH_{Ia} = 182325.9\ \frac{lbf \cdot ft}{ft}$

$MH_{Ib} := \eta \cdot ((Ib_{LS} \cdot M_{LS2}) + (Ib_{EH} \cdot M_{EH2}))$ $\quad MH_{Ib} = 182325.9\ \frac{lbf \cdot ft}{ft}$

Compute Bearing Resistance:

Compute the Effective Bearing Length (Strength Ib):

$\Sigma M_R := MV_{Ib}$ — $\Sigma M_R = 0\ \frac{lbf \cdot ft}{ft}$ — Sum of Resisting Moments (Strength Ib)

$\Sigma M_O := MH_{Ib}$ — $\Sigma M_O = 182325.9\ \frac{lbf \cdot ft}{ft}$ — Sum of Overturning Moments (Strength Ib)

$\Sigma V := V_{Ib}$ — $\Sigma V = 83708\ \frac{lbf}{ft}$ — Sum of Vertical Loads (Strength Ib)

$e_{wall} := \frac{(\Sigma M_O - \Sigma M_R)}{\Sigma V}$ — $e_{wall} = 2.2\ ft$ — Wall Eccentricity

$B' := \text{if}(e_{wall} > 0, L - 2 \cdot e_{wall}, L)$ — $B' = 14.9\ ft$ — Effective Bearing Width

Foundation Layout:

$L_{Wall} := 93 \cdot ft$ — Assumed Footing Length (Wall Section Length)

$H' := H_{Ib}$ — $H' = 20938.9\ \frac{lbf}{ft}$ — Summation of Horizontal Loads (Strength Ib)

$V' := V_{Ib}$ — $V' = 83708\ \frac{lbf}{ft}$ — Summation of Vertical Loads (Strength Ib)

$D_f := d_e$ — $D_f = 4.5\ ft$ — Footing embedment

$d_w := 0 \cdot ft$ — Depth of Groundwater below Bearing Grade

$\theta' := 90 \cdot deg$ — Direction of H' and V' resultant measured from wall back face **LRFD [Figure C10.6.3.1.2a-1]**

Drained Conditions (Effective Stress):

$N_q := \text{if}\left(\phi'_f > 0, e^{\pi \cdot \tan(\phi'_f)} \cdot \tan\left(45\ deg + \frac{\phi'_f}{2}\right)^2, 1.0\right)$ — $N_q = 7.82$

$N_c := \text{if}\left(\phi'_f > 0, \frac{N_q - 1}{\tan(\phi'_f)}, 5.14\right)$ — $N_c = 16.88$

$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi'_f)$ — $N_\gamma = 7.1$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$s_c := \text{if}\left(\phi'_f > 0, 1 + \left(\frac{B'}{L_{Wall}}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L_{Wall}}\right)\right)$ — $s_c = 1.074$

$s_q := \text{if}\left(\phi'_f > 0, 1 + \left(\frac{B'}{L_{Wall}} \cdot \tan(\phi'_f)\right), 1\right)$ — $s_q = 1.065$

$s_\gamma := \text{if}\left(\phi'_f > 0, 1 - 0.4 \cdot \left(\frac{B'}{L_{Wall}}\right), 1\right)$ — $s_\gamma = 0.936$

Load inclination factors using **LRFD [10.6.3.1.2a-5] thru [10.6.3.1.2a-9]:**

$i_q := 1$ $\quad i_q = 1$

$i_\gamma := 1$ $\quad i_\gamma = 1$

$i_c := 1$ $\quad i_c = 1$

Compute groundwater depth correction factors per **LRFD [Table 10.6.3.1.2a-2]**:

$C_{wq} := \text{if}\left(d_w \geq 0, 1, 0.5\right)$ $\quad C_{wq} = 1$

$C_{w\gamma} := \text{if}\left(d_w > 1.5 \cdot B', 1, 0.5\right)$ $\quad C_{w\gamma} = 0.5$

Depth Correction Factor per **Hanson (1970):**

$$d_q := \text{if}\left(\frac{D_f}{B'} \leq 1, 1 + 2 \cdot \tan\left(\phi'_f\right) \cdot \left(1 - \sin\left(\phi'_f\right)\right)^2 \cdot \frac{D_f}{B'}, 1 + 2 \cdot \tan\left(\phi'_f\right) \cdot \left(1 - \sin\left(\phi'_f\right)\right)^2 \cdot \operatorname{atan}\left(\frac{D_f}{B'}\right)\right)$$

$d_q = 1.1$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $\quad N_{cm} = 18.138$

$N_{qm} := N_q \cdot s_q \cdot i_q$ $\quad N_{qm} = 8.328$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $\quad N_{\gamma m} = 6.67$

Compute nominal bearing resistance, **LRFD [Eq 10.6.3.1.2a-1]:**

$q_{nd} := c'_f \cdot N_{cm} + \gamma_q \cdot D_f \cdot N_{qm} \cdot d_q \cdot C_{wq} + 0.5 \cdot \gamma_f \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma}$ $\quad q_{nd} = 10178.8 \ \frac{lbf}{ft^2}$

Compute factored bearing resistance, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := 0.65$ — Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Rd} := \phi_b \cdot q_{nd}$ $\quad q_{Rd} = 6.6 \ ksf$ — Factored bearing resistance Drained Conditions

Undrained Conditions (Effective Stress):

$N_q := \text{if}\left(\phi_f > 0, e^{\pi \cdot \tan(\phi_f)} \cdot \tan\left(45 \ deg + \frac{\phi_f}{2}\right)^2, 1.0\right)$ $\quad N_q = 1$

$N_c := \text{if}\left(\phi_f > 0, \frac{N_q - 1}{\tan\left(\phi_f\right)}, 5.14\right)$ $\quad N_c = 5.14$

$N_\gamma := 2 \cdot \left(N_q + 1\right) \cdot \tan\left(\phi_f\right)$ $\quad N_\gamma = 0$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$$s_c := \text{if}\left(\phi_f > 0, 1 + \left(\frac{B'}{L_{Wall}}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L_{Wall}}\right)\right)$$ $s_c = 1.032$

$$s_q := \text{if}\left(\phi_f > 0, 1 + \left(\frac{B'}{L_{Wall}} \cdot \tan(\phi_f)\right), 1\right)$$ $s_q = 1$

$$s_\gamma := \text{if}\left(\phi_f > 0, 1 - 0.4 \cdot \left(\frac{B'}{L_{Wall}}\right), 1\right)$$ $s_\gamma = 1$

Load inclination factors using **LRFD [10.6.3.1.2a-5] thru [10.6.3.1.2a-9]:**

$i_q := 1$ $i_q = 1$

$i_\gamma := 1$ $i_\gamma = 1$

$i_c := 1$ $i_c = 1$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $N_{cm} = 5.305$

$N_{qm} := N_q \cdot s_q \cdot i_q$ $N_{qm} = 1$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $N_{\gamma m} = 0$

Compute nominal bearing resistance, **LRFD [Eq 10.6.3.1.2a-1:**

$q_{nu} := c_f \cdot N_{cm} + \gamma_q \cdot D_f \cdot N_{qm} \cdot d_q \cdot C_{wq} + 0.5 \cdot \gamma_f \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma}$ $q_{nu} = 9585.3 \frac{lbf}{ft^2}$

Compute factored bearing resistance, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := 0.65$ Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Ru} := \phi_b \cdot q_{nu}$ $q_{Ru} = 6.2\ ksf$ Factored bearing resistance Undrained Conditions

Factored Bearing Resistance Drained vs. Undrained Conditions:

Drained Conditions: $q_{Rd} = 6.6\ ksf$

Undrained Conditions: $q_{Ru} = 6.2\ ksf$

Factored Bearing Resistance to be used in CDR Calculations:

$q_R := q_{Ru}$

$q_R = 6.2\ ksf$

Evaluate External Stability of Wall:

Bearing Resistance at Base of the Wall:

Compute the resultant location (distance from Point 'O'):

$\Sigma M_R := MV_{Ib}$ | $\Sigma M_R = 0\ \frac{lbf \cdot ft}{ft}$ | Sum of Resisting Moments (Strength Ib)

$\Sigma M_O := MH_{Ib}$ | $\Sigma M_O = 182325.9\ \frac{lbf \cdot ft}{ft}$ | Sum of Overturning Moments (Strength Ib)

$\Sigma V := V_{Ib}$ | $\Sigma V = 83708\ \frac{lbf}{ft}$ | Sum of Vertical Loads (Strength Ib)

$e_{wall} := \frac{(\Sigma M_O - \Sigma M_R)}{\Sigma V}$ | $e_{wall} = 2.2\ ft$ | Wall Eccentricity

$B' := \text{if}\left(e_{wall} > 0, L - 2 \cdot e_{wall}, L\right)$ | $B' = 14.9\ ft$ | Effective Bearing Width

Compute the ultimate bearing stress:

$\sigma_v := \frac{\Sigma V}{B'}$ | $\sigma_v = 5609\ \frac{lbf}{ft^2}$ | Ultimate Bearing Stress

Bearing Capacity:Demand Ratio (CDR)

$CDR_{Bearing} := \frac{q_R}{\sigma_v}$ | Is the CDR > or = to 1.0? | $CDR_{Bearing} = 1.11$

Limiting Eccentricity at Base of MSE Wall (Strength Ia):

$e_{max} := \frac{L}{3}$ | $e_{max} = 6.4\ ft$ | Maximum Eccentricity **LRFD [C11.6.3.3.]**

$\Sigma M_R := MV_{Ia}$ | $\Sigma M_R = 0\ \frac{lbf \cdot ft}{ft}$ | Sum of Resisting Moments (Strength Ia)

$\Sigma M_O := MH_{Ia}$ | $\Sigma M_O = 182325.9\ \frac{lbf \cdot ft}{ft}$ | Sum of Overturning Moments (Strength Ia)

$\Sigma V := V_{Ia}$ | $\Sigma V = 55757.8\ \frac{lbf}{ft}$ | Sum of Vertical Loads (Strength Ia)

$e_{wall} := \frac{(\Sigma M_O - \Sigma M_R)}{\Sigma V}$ | $e_{wall} = 3.3\ ft$

Eccentricity Capacity:Demand Ratio (CDR)

$CDR_{Eccentricity} := \frac{e_{max}}{e_{wall}}$ | Is the CDR > or = to 1.0? | $CDR_{Eccentricity} = 1.97$

Sliding Resistance at Base of Wall LRFD [10.6.3.4]:

Factored Sliding Force (Strength Ia):

$F_\tau := H_{Ia}$ $\qquad F_\tau = 20938.9\ \frac{lbf}{ft}$

Compute sliding resistance between soil and foundation:

Drained Conditions:

$k'_{pd} := 3.6$ — Passive Earth Pressure Coefficient from **LRFD Figure 3.11.5.4-2**

$y_1 := 4.6\ ft$ — Depth to where passive pressure may begin to be utilized in front of wall. (Typically d_{frost})

$y_2 := 4.6\ ft$ — Depth to bottom of passive pressure zone in front of wall.

$r_{ep1} := \left(k'_{pd} \cdot \gamma_f \cdot y_1 + 2 \cdot c'_f \cdot \sqrt{k'_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ — Nominal passive pressure at y1

$r_{ep2} := \left(k'_{pd} \cdot \gamma_f \cdot y_2 + 2 \cdot c'_f \cdot \sqrt{k'_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ — Nominal passive pressure at y2

$R_{ep} := \frac{r_{ep1} + r_{ep2}}{2} \cdot \left(y_2 - y_1\right)$ $\qquad R_{ep} = 0\ \frac{lbf}{ft}$ — Nominal passive resistance Drained Conditions

$\Sigma V := V_{Ia}$ $\qquad \Sigma V = 55757.8\ \frac{lbf}{ft}$ — Sum of Vertical Loads (Strength Ia)

$R_{\tau d} := \Sigma V \cdot \tan\left(\phi'_f\right) + R_{ep}$ $\qquad R_{\tau d} = 22527.6\ \frac{lbf}{ft}$ — Nominal sliding resistance Drained Conditions

Nominal Sliding Resistance Drained Conditions:

Drained Conditions: $R_{\tau d} = 22.528\ \frac{kip}{ft}$

Undrained Conditions:

$\Sigma V := V_{Ia}$ $\qquad \Sigma V = 55757.8\ \frac{lbf}{ft}$ — Sum of Vertical Loads (Strength Ia)

$\sigma'_v := \Sigma V$ $\qquad \sigma'_v = 55757.8\ \frac{lbf}{ft}$

$R_{\tau u} := min\left(\frac{\sigma'_v}{2}, c_f \cdot L\right)$ $\qquad R_{\tau u} = 27878.9\ \frac{lbf}{ft}$ — Nominal sliding resistance Undrained Conditions

Nominal Sliding Resistance Undrained Conditions:

Undrained Conditions: $R_{\tau u} = 27.879\ \frac{kip}{ft}$

Nominal Sliding Resistance to be used in CDR Calculations: $R_\tau := R_{\tau d}$

Compute factored resistance against failure by sliding **LRFD [10.6.3.4]**:

$\phi_\tau := 1.0$ — Resistance factor for sliding resistance specified in **LRFD Table 11.5.7-1.**

$\phi R_n := \phi_\tau \cdot R_\tau$ $\qquad R_R := \phi R_n$

$R_R = 22.5\ \frac{kip}{ft}$

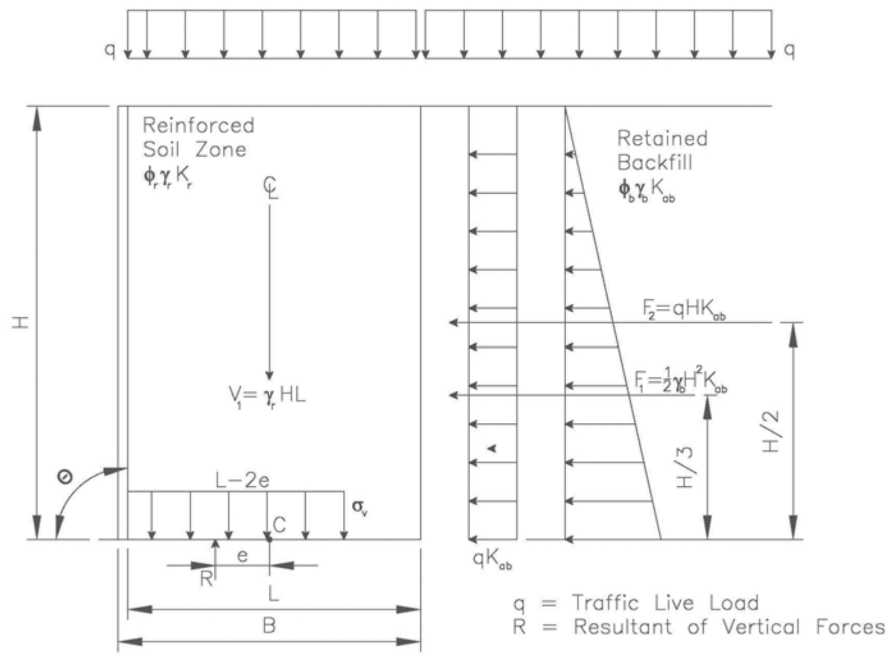
Sliding Capacity:Demand Ratio (CDR)

$CDR_{Sliding} := \frac{R_R}{F_\tau}$ $\qquad$ Is the CDR > or = to 1.0? $\qquad CDR_{Sliding} = 1.08$

FORWARD ABUTMENT

Objective: To evaluate the external stability of MSE wall design with vertical wall face and horizontal backfill.
Method: In accordance with ODOT Bridge Design Manual, 2013 [Sect. 307] LRFD Bridge Design Specifications, 8th Ed., 2018, [Sect. 11.10.5].
Assumptions:

- **Horizontal backfill behind MSE wall on granular (drained) soils.**
- **For battered or vertical walls with a back face of wall angle of θ to horizontal.**
- **Not for sheet type reinforcement. If so, use different assessment for Sliding parameter ϕ_μ.**
- **MSE wall not acting as abutment, if so must meet minimum embedment depth of H/10 if no slope in front of wall**
- **Load combinations and wall configuration are as shown below:**



Givens:

<u>Wall Geometry:</u>

$H_e := 23.9 \cdot ft$ — Exposed wall height

$\theta := 90 \cdot deg$ — Angle of back face of wall to horizontal: 90 deg for vertical or near vertical walls (per Berg et al., 2009; near vertical = 80 deg < θ < 100 deg)

<u>Reinforced Backfill Soil Design Parameters:</u>

$\phi'_r := 34 \cdot deg$ — Effective angle of internal friction (Per BDM [Table 307-1])

$\gamma_r := 120 \cdot \frac{lbf}{ft^3}$ — Unit weight (Per BDM [Table 307-1])

$c'_r := 0 \cdot \frac{lbf}{ft^2}$ — Effective Cohesion

<u>Retained Backfill Soil Design Parameters</u>:

$\phi'_b := 30 \cdot deg$ — Effective angle of internal friction (Per BDM [Table 307-1])

$\gamma_b := 120 \cdot \frac{lbf}{ft^3}$ — Unit weight (Per BDM [Table 307-1])

$c'_b := 0 \cdot \frac{lbf}{ft^2}$ — Effective Cohesion

Foundation Soil Design Parameters:

Drained Conditions (Effective Stress):

$\phi'_f := 33 \cdot deg$ — Effective angle of internal friction

$\gamma_f := 125 \cdot \frac{lbf}{ft^3}$ — Unit weight

$c'_f := 0 \cdot \frac{lbf}{ft^2}$ — Cohesion

$\delta_{fd} := 0.67 \cdot \phi'_f$ $\qquad \delta_{fd} = 22.1\ deg$ — Friction angle between embedment soils and MSE wall fill specified in **LRFD BDS C3.11.5.3 (degrees)**

Undrained Conditions (Total Stress):

$\phi_f := 33 \cdot deg$ — Angle of internal friction (Same as Drained Conditions if Sand)

$\gamma_f = 125\ \frac{lbf}{ft^3}$ — Unit weight

$c_f := 0 \cdot \frac{lbf}{ft^2}$ — Cohesion (Use Su if Angle of internal friction = 0 deg)

Foundation Surcharge Soil Parameters:

$\gamma_q := 115 \cdot \frac{lbf}{ft^3}$ — Unit weight of Soil above bearing depth (Used in Bearing Resistance of Soil Calculation LRFD 10.6.3.1.2a-1)

Depth of Embedment Check:

$d_{frost} := 3\ ft$ $\qquad d_{user} := 4.8\ ft$ — Local Frost Depth

$Slope_{fw} := 0\ deg$

Inclination of ground slope in front of wall :

- Horizontal: **0**
- 3H:1V: **18.435**
- 2H:1V: **26.565**
- 1.5H:1V: **33.690**

$d_{est} := \max(d_{frost}, 3\ ft, d_{user})$ $\qquad d_{est} = 4.8\ ft$

$H_{est} := d_{est} + (4\ ft \cdot \tan(Slope_{fw})) + H_e$ $\qquad H_{est} = 28.7\ ft$

$$d_{eSlope} := \text{if}\left(Slope_{fw} < 1\ deg, \frac{H_{est}}{20}, \text{if}\left(Slope_{fw} < 26.565\ deg, \frac{H_{est}}{10}, \text{if}\left(Slope_{fw} < 33.69\ deg, \frac{H_{est}}{7}, \frac{H_{est}}{5}\right)\right)\right)$$

$d_{eSlope} = 1.4\ ft$ — Minimum Embedment Depth per Table C11.10.2.2-1 of LRFD BDS

$d_e := \max(d_{est}, d_{eSlope})$ $\qquad d_e = 4.8\ ft$ — Minimum Required Embedment Depth used in analysis.

$H := d_e + (4\ ft \cdot \tan(Slope_{fw})) + H_e$ $\qquad H = 28.7\ ft$ — Design Wall Height

Estimate Length of Reinforcement:

$L_{user} := 0 \cdot ft$ — User inputted value (if changes need to be made to satisfy other requirements)

$L := \max(8 \cdot ft, 0.7 \cdot H, L_{user})$ $\qquad L = 20.1\ ft$ — Length of Reinforcement

Live Load Surcharge Parameters:

$SUR := 250 \cdot \frac{lbf}{ft^2}$

Live load surcharge (per **LRFD BDS [3.11.6.4]** & **BDM [307.1.1]**)
Note: If vehicular loading is within 1 ft of the backface of the wall and with a design height, H, less than 20 ft, see **LRFD BDS Section 3.11.6.4 and Table 3.11.6.4-2** for adjusted surcharge load calculation.
Note: When traffic vehicular live loads are not present within 0.5*H from the back of the reinforced zone let SUR equal 100 psf to account for construction loads.

Calculations:

Active Earth Pressure:

$\beta := 0 \qquad \delta := \beta$

Inclination of ground slope behind face of wall and angle of friction between retained backfill and reinforced soil

$$\Gamma := \left(1 + \sqrt{\frac{\left(\sin\left(\phi'_b + \delta\right) \cdot \sin\left(\phi'_b - \beta\right)\right)}{\left(\sin\left(\theta - \delta\right) \cdot \sin\left(\theta + \beta\right)\right)}}\right)^2$$

$$k_{af} := \left(\frac{\left(\sin\left(\theta + \phi'_b\right)\right)^2}{\left(\Gamma \cdot \left(\sin\left(\theta\right)\right)^2 \cdot \sin\left(\theta - \delta\right)\right)}\right) \qquad k_{af} = 0.3333$$

Active Earth Pressure Coefficient

$F_T := \frac{1}{2} \cdot \gamma_b \cdot H^2 \cdot k_{af} \qquad F_T = 16473.8 \frac{lbf}{ft}$ Active Earth Force Resultant (EH)

$F_{SUR} := SUR \cdot H \cdot k_{af} \qquad F_{SUR} = 2391.7 \frac{lbf}{ft}$ Live Load Surcharge (LS)

Vertical Loads:

$V_1 := \gamma_r \cdot H \cdot L \qquad V_1 = 69190 \frac{lbf}{ft}$ Soil backfill - reinforced soil (EV)

$V_2 := SUR \cdot L \qquad V_2 = 5022.5 \frac{lbf}{ft}$ Live Load Surcharge - (LS)

Moment Arm: / Moment:

$d_{v1} := 0 \cdot ft \qquad d_{v1} = 0\ ft \qquad MV_1 := V_1 \cdot d_{v1} \qquad MV_1 = 0 \frac{lbf \cdot ft}{ft}$

$d_{v2} := 0\ ft \qquad d_{v2} = 0\ ft \qquad MV_2 := V_2 \cdot d_{v2} \qquad MV_2 = 0 \frac{lbf \cdot ft}{ft}$

Horizontal Loads:

$H_1 := F_T = 16473.8 \frac{lbf}{ft}$ Active Earth Force Resultant (horizontal comp. - EH)

$H_2 := F_{SUR} = 2391.7 \frac{lbf}{ft}$ Live Load Surcharge Resultant (horizontal comp. - LS)

Moment Arm: / Moment:

$d_{h1} := \frac{H}{3} \qquad d_{h1} = 9.6\ ft \qquad MH_1 := H_1 \cdot d_{h1} \qquad MH_1 = 157599.4 \frac{lbf \cdot ft}{ft}$

$d_{h2} := \frac{H}{2} \qquad d_{h2} = 14.4\ ft \qquad MH_2 := H_2 \cdot d_{h2} \qquad MH_2 = 34320.4 \frac{lbf \cdot ft}{ft}$

Unfactored Loads by Load Type

$V_{EV} := V_1$ $\quad V_{EV} = 69190 \ \frac{lbf}{ft}$

$V_{LS} := V_2$ $\quad V_{LS} = 5022.5 \ \frac{lbf}{ft}$

$H_{EH} := H_1$ $\quad H_{EH} = 16473.8 \ \frac{lbf}{ft}$

$H_{LS} := H_2$ $\quad H_{LS} = 2391.7 \ \frac{lbf}{ft}$

Unfactored Moments by Load Type

$M_{EV} := MV_1$ $\quad M_{EV} = 0 \ \frac{lbf \cdot ft}{ft}$

$M_{LS} := MV_2$ $\quad M_{LS} = 0 \ \frac{lbf \cdot ft}{ft}$

$M_{EH2} := MH_1$ $\quad M_{EH2} = 157599.4 \ \frac{lbf \cdot ft}{ft}$

$M_{LS2} := MH_2$ $\quad M_{LS2} = 34320.4 \ \frac{lbf \cdot ft}{ft}$

Load Combination Limit States:

$\eta := 1$ LRFD Load Modifier

Strength Limit State I: EV(min) = 1.00 EV(max) = 1.35
EH(min) = 0.90 EH(max) = 1.50
LS = 1.75

Strength Limit State Ia: (Sliding and Eccentricity) $\quad Ia_{EV} := 1 \quad Ia_{EH} := 1.5 \quad Ia_{LS} := 1.75$

Strength Limit State Ib: (Bearing Capacity) $\quad Ib_{EV} := 1.35 \quad Ib_{EH} := 1.5 \quad Ib_{LS} := 1.75$

Factored Vertical Loads by Limit State:

$V_{Ia} := \eta \cdot (Ia_{EV} \cdot V_{EV})$ $\quad V_{Ia} = 69190 \ \frac{lbf}{ft}$

$V_{Ib} := \eta \cdot ((Ib_{EV} \cdot V_{EV}) + (Ib_{LS} \cdot V_{LS}))$ $\quad V_{Ib} = 102195.8 \ \frac{lbf}{ft}$

Factored Horizontal Loads by Limit State:

$H_{Ia} := \eta \cdot ((Ia_{LS} \cdot H_{LS}) + (Ia_{EH} \cdot H_{EH}))$ $\quad H_{Ia} = 28896.1 \ \frac{lbf}{ft}$

$H_{Ib} := \eta \cdot ((Ib_{LS} \cdot H_{LS}) + (Ib_{EH} \cdot H_{EH}))$ $\quad H_{Ib} = 28896.1 \ \frac{lbf}{ft}$

Factored Moments Produced by Vertical Loads by Limit State:

$MV_{Ia} := \eta \cdot (Ia_{EV} \cdot M_{EV})$ $\quad MV_{Ia} = 0 \ \frac{lbf \cdot ft}{ft}$

$MV_{Ib} := \eta \cdot ((Ib_{EV} \cdot M_{EV}) + (Ib_{LS} \cdot M_{LS}))$ $\quad MV_{Ib} = 0 \ \frac{lbf \cdot ft}{ft}$

Factored Moments Produced by Horizontal Loads by Limit State:

$MH_{Ia} := \eta \cdot ((Ia_{LS} \cdot M_{LS2}) + (Ia_{EH} \cdot M_{EH2}))$ $\quad MH_{Ia} = 296459.8 \ \frac{lbf \cdot ft}{ft}$

$MH_{Ib} := \eta \cdot ((Ib_{LS} \cdot M_{LS2}) + (Ib_{EH} \cdot M_{EH2}))$ $\quad MH_{Ib} = 296459.8 \ \frac{lbf \cdot ft}{ft}$

Compute Bearing Resistance:

Compute the Effective Bearing Length (Strength Ib):

$\Sigma M_R := MV_{Ib}$ — $\Sigma M_R = 0 \ \frac{lbf \cdot ft}{ft}$ — Sum of Resisting Moments (Strength Ib)

$\Sigma M_O := MH_{Ib}$ — $\Sigma M_O = 296459.8 \ \frac{lbf \cdot ft}{ft}$ — Sum of Overturning Moments (Strength Ib)

$\Sigma V := V_{Ib}$ — $\Sigma V = 102195.8 \ \frac{lbf}{ft}$ — Sum of Vertical Loads (Strength Ib)

$e_{wall} := \frac{(\Sigma M_O - \Sigma M_R)}{\Sigma V}$ — $e_{wall} = 2.9 \ ft$ — Wall Eccentricity

$B' := \text{if}\left(e_{wall} > 0, L - 2 \cdot e_{wall}, L\right)$ — $B' = 14.3 \ ft$ — Effective Bearing Width

Foundation Layout:

$L_{Wall} := 93 \cdot ft$ — Assumed Footing Length (Wall Section Length)

$H' := H_{Ib}$ — $H' = 28896.1 \ \frac{lbf}{ft}$ — Summation of Horizontal Loads (Strength Ib)

$V' := V_{Ib}$ — $V' = 102195.8 \ \frac{lbf}{ft}$ — Summation of Vertical Loads (Strength Ib)

$D_f := d_e$ — $D_f = 4.8 \ ft$ — Footing embedment

$d_w := 0 \cdot ft$ — Depth of Groundwater below Bearing Grade

$\theta' := 90 \cdot deg$ — Direction of H' and V' resultant measured from wall back face **LRFD [Figure C10.6.3.1.2a-1]**

Drained Conditions (Effective Stress):

$N_q := \text{if}\left(\phi'_f > 0, e^{\pi \cdot \tan(\phi'_f)} \cdot \tan\left(45 \ deg + \frac{\phi'_f}{2}\right)^2, 1.0\right)$ — $N_q = 26.09$

$N_c := \text{if}\left(\phi'_f > 0, \frac{N_q - 1}{\tan(\phi'_f)}, 5.14\right)$ — $N_c = 38.64$

$N_\gamma := 2 \cdot (N_q + 1) \cdot \tan(\phi'_f)$ — $N_\gamma = 35.2$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$s_c := \text{if}\left(\phi'_f > 0, 1 + \left(\frac{B'}{L_{Wall}}\right) \cdot \left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5 \cdot L_{Wall}}\right)\right)$ — $s_c = 1.104$

$s_q := \text{if}\left(\phi'_f > 0, 1 + \left(\frac{B'}{L_{Wall}} \cdot \tan(\phi'_f)\right), 1\right)$ — $s_q = 1.1$

$s_\gamma := \text{if}\left(\phi'_f > 0, 1 - 0.4 \cdot \left(\frac{B'}{L_{Wall}}\right), 1\right)$ — $s_\gamma = 0.939$

Load inclination factors using **LRFD [10.6.3.1.2a-5] thru [10.6.3.1.2a-9]:**

$i_q := 1$ $\qquad$ $i_q = 1$

$i_\gamma := 1$ $\qquad$ $i_\gamma = 1$

$i_c := 1$ $\qquad$ $i_c = 1$

Compute groundwater depth correction factors per **LRFD [Table 10.6.3.1.2a-2]**:

$C_{wq} := \text{if}\left(d_w \geq 0, 1, 0.5\right)$ $\qquad$ $C_{wq} = 1$

$C_{w\gamma} := \text{if}\left(d_w > 1.5 \cdot B', 1, 0.5\right)$ $\qquad$ $C_{w\gamma} = 0.5$

Depth Correction Factor per **Hanson (1970):**

$$d_q := \text{if}\left(\frac{D_f}{B'} \leq 1, 1 + 2 \cdot \tan\left(\phi'_f\right) \cdot \left(1 - \sin\left(\phi'_f\right)\right)^2 \cdot \frac{D_f}{B'}, 1 + 2 \cdot \tan\left(\phi'_f\right) \cdot \left(1 - \sin\left(\phi'_f\right)\right)^2 \cdot \operatorname{atan}\left(\frac{D_f}{B'}\right)\right)$$

$d_q = 1.1$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $\qquad$ $N_{cm} = 42.647$

$N_{qm} := N_q \cdot s_q \cdot i_q$ $\qquad$ $N_{qm} = 28.695$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $\qquad$ $N_{\gamma m} = 33.025$

Compute nominal bearing resistance, **LRFD [Eq 10.6.3.1.2a-1]:**

$q_{nd} := c'_f \cdot N_{cm} + \gamma_q \cdot D_f \cdot N_{qm} \cdot d_q \cdot C_{wq} + 0.5 \cdot \gamma_f \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma}$ $\qquad$ $q_{nd} = 32018.8 \ \frac{lbf}{ft^2}$

Compute factored bearing resistance, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := 0.65$ $\qquad$ Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Rd} := \phi_b \cdot q_{nd}$ $\qquad$ $q_{Rd} = 20.8 \ ksf$ $\qquad$ Factored bearing resistance Drained Conditions

Undrained Conditions (Effective Stress):

$N_q := \text{if}\left(\phi_f > 0, e^{\pi \cdot \tan\left(\phi_f\right)} \cdot \tan\left(45\ deg + \frac{\phi_f}{2}\right)^2, 1.0\right)$ $\qquad$ $N_q = 26.09$

$N_c := \text{if}\left(\phi_f > 0, \frac{N_q - 1}{\tan\left(\phi_f\right)}, 5.14\right)$ $\qquad$ $N_c = 38.64$

$N_\gamma := 2 \cdot \left(N_q + 1\right) \cdot \tan\left(\phi_f\right)$ $\qquad$ $N_\gamma = 35.2$

Compute shape correction factors per **LRFD [Table 10.6.3.1.2a-3]**:

$s_c := \text{if}\left(\phi_f > 0, 1 + \left(\frac{B'}{L_{Wall}}\right)\cdot\left(\frac{N_q}{N_c}\right), 1 + \left(\frac{B'}{5\cdot L_{Wall}}\right)\right)$ $s_c = 1.104$

$s_q := \text{if}\left(\phi_f > 0, 1 + \left(\frac{B'}{L_{Wall}}\cdot\tan(\phi_f)\right), 1\right)$ $s_q = 1.1$

$s_\gamma := \text{if}\left(\phi_f > 0, 1 - 0.4\cdot\left(\frac{B'}{L_{Wall}}\right), 1\right)$ $s_\gamma = 0.939$

Load inclination factors using **LRFD [10.6.3.1.2a-5] thru [10.6.3.1.2a-9]:**

$i_q := 1$ $i_q = 1$

$i_\gamma := 1$ $i_\gamma = 1$

$i_c := 1$ $i_c = 1$

Compute modified bearing capacity factors **LRFD [Equation 10.6.3.1.2a-2 to 10.6.3.1.2a-4]:**

$N_{cm} := N_c \cdot s_c \cdot i_c$ $N_{cm} = 42.647$

$N_{qm} := N_q \cdot s_q \cdot i_q$ $N_{qm} = 28.695$

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $N_{\gamma m} = 33.025$

Compute nominal bearing resistance, **LRFD [Eq 10.6.3.1.2a-1:**

$q_{nu} := c_f \cdot N_{cm} + \gamma_q \cdot D_f \cdot N_{qm} \cdot d_q \cdot C_{wq} + 0.5 \cdot \gamma_f \cdot B' \cdot N_{\gamma m} \cdot C_{w\gamma}$ $q_{nu} = 32018.8\ \frac{lbf}{ft^2}$

Compute factored bearing resistance, **LRFD [Eq 10.6.3.1.1]:**

$\phi_b := 0.65$ Bearing resistance factor **LRFD Table 11.5.7-1.**

$q_{Ru} := \phi_b \cdot q_{nu}$ $q_{Ru} = 20.8\ ksf$ Factored bearing resistance Undrained Conditions

Factored Bearing Resistance Drained vs. Undrained Conditions:

Drained Conditions: $q_{Rd} = 20.8\ ksf$

Undrained Conditions: $q_{Ru} = 20.8\ ksf$

Factored Bearing Resistance to be used in CDR Calculations:

$q_R := q_{Ru}$

$q_R = 20.8\ ksf$

Evaluate External Stability of Wall:

Bearing Resistance at Base of the Wall:

Compute the resultant location (distance from Point 'O'):

$\Sigma M_R := MV_{Ib}$ $\Sigma M_R = 0 \ \frac{lbf \cdot ft}{ft}$ Sum of Resisting Moments (Strength Ib)

$\Sigma M_O := MH_{Ib}$ $\Sigma M_O = 296459.8 \ \frac{lbf \cdot ft}{ft}$ Sum of Overturning Moments (Strength Ib)

$\Sigma V := V_{Ib}$ $\Sigma V = 102195.8 \ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ib)

$e_{wall} := \frac{(\Sigma M_O - \Sigma M_R)}{\Sigma V}$ $e_{wall} = 2.9 \ ft$ Wall Eccentricity

$B' := \text{if}(e_{wall} > 0, L - 2 \cdot e_{wall}, L)$ $B' = 14.3 \ ft$ Effective Bearing Width

Compute the ultimate bearing stress:

$\sigma_v := \frac{\Sigma V}{B'}$ $\sigma_v = 7152.5 \ \frac{lbf}{ft^2}$ Ultimate Bearing Stress

Bearing Capacity:Demand Ratio (CDR)

$CDR_{Bearing} := \frac{q_R}{\sigma_v}$ Is the CDR > or = to 1.0? $CDR_{Bearing} = 2.91$

Limiting Eccentricity at Base of MSE Wall (Strength Ia):

$e_{max} := \frac{L}{3}$ $e_{max} = 6.7 \ ft$ Maximum Eccentricity **LRFD [C11.6.3.3.]**

$\Sigma M_R := MV_{Ia}$ $\Sigma M_R = 0 \ \frac{lbf \cdot ft}{ft}$ Sum of Resisting Moments (Strength Ia)

$\Sigma M_O := MH_{Ia}$ $\Sigma M_O = 296459.8 \ \frac{lbf \cdot ft}{ft}$ Sum of Overturning Moments (Strength Ia)

$\Sigma V := V_{Ia}$ $\Sigma V = 69190 \ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$e_{wall} := \frac{(\Sigma M_O - \Sigma M_R)}{\Sigma V}$ $e_{wall} = 4.3 \ ft$

Eccentricity Capacity:Demand Ratio (CDR)

$CDR_{Eccentricity} := \frac{e_{max}}{e_{wall}}$ Is the CDR > or = to 1.0? $CDR_{Eccentricity} = 1.56$

Sliding Resistance at Base of Wall LRFD [10.6.3.4]:

Factored Sliding Force (Strength Ia):

$F_\tau := H_{Ia}$ $\quad F_\tau = 28896.1 \ \frac{lbf}{ft}$

Compute sliding resistance between soil and foundation:

Drained Conditions:

$k'_{pd} := 3.6$ Passive Earth Pressure Coefficient from **LRFD Figure 3.11.5.4-2**

$y_1 := 4.6 \ ft$ Depth to where passive pressure may begin to be utilized in front of wall. (Typically d_{frost})

$y_2 := 4.6 \ ft$ Depth to bottom of passive pressure zone in front of wall.

$r_{ep1} := \left(k'_{pd} \cdot \gamma_f \cdot y_1 + 2 \cdot c'_f \cdot \sqrt{k'_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y1

$r_{ep2} := \left(k'_{pd} \cdot \gamma_f \cdot y_2 + 2 \cdot c'_f \cdot \sqrt{k'_{pd}}\right) \cdot \cos\left(\delta_{fd}\right)$ Nominal passive pressure at y2

$R_{ep} := \frac{r_{ep1} + r_{ep2}}{2} \cdot \left(y_2 - y_1\right)$ $\quad R_{ep} = 0 \ \frac{lbf}{ft}$ Nominal passive resistance Drained Conditions

$\Sigma V := V_{Ia}$ $\quad \Sigma V = 69190 \ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$R_{\tau d} := \Sigma V \cdot \tan\left(\phi'_f\right) + R_{ep}$ $\quad R_{\tau d} = 44932.5 \ \frac{lbf}{ft}$ Nominal sliding resistance Drained Conditions

Nominal Sliding Resistance Drained Conditions:

Drained Conditions: $R_{\tau d} = 44.932 \ \frac{kip}{ft}$

Undrained Conditions:

$\Sigma V := V_{Ia}$ $\quad \Sigma V = 69190 \ \frac{lbf}{ft}$ Sum of Vertical Loads (Strength Ia)

$\sigma'_v := \Sigma V$ $\quad \sigma'_v = 69190 \ \frac{lbf}{ft}$

$R_{\tau u} := min\left(\frac{\sigma'_v}{2}, c_f \cdot L\right)$ $\quad R_{\tau u} = 0 \ \frac{lbf}{ft}$ Nominal sliding resistance Undrained Conditions

Nominal Sliding Resistance Undrained Conditions:

Undrained Conditions: $R_{\tau u} = 0 \ \frac{kip}{ft}$

Nominal Sliding Resistance to be used in CDR Calculations: $R_\tau := R_{\tau d}$

Compute factored resistance against failure by sliding **LRFD [10.6.3.4]**:

$\phi_\tau := 1.0$ Resistance factor for sliding resistance specified in **LRFD Table 11.5.7-1.**

$\phi R_n := \phi_\tau \cdot R_\tau$

$R_R := \phi R_n$

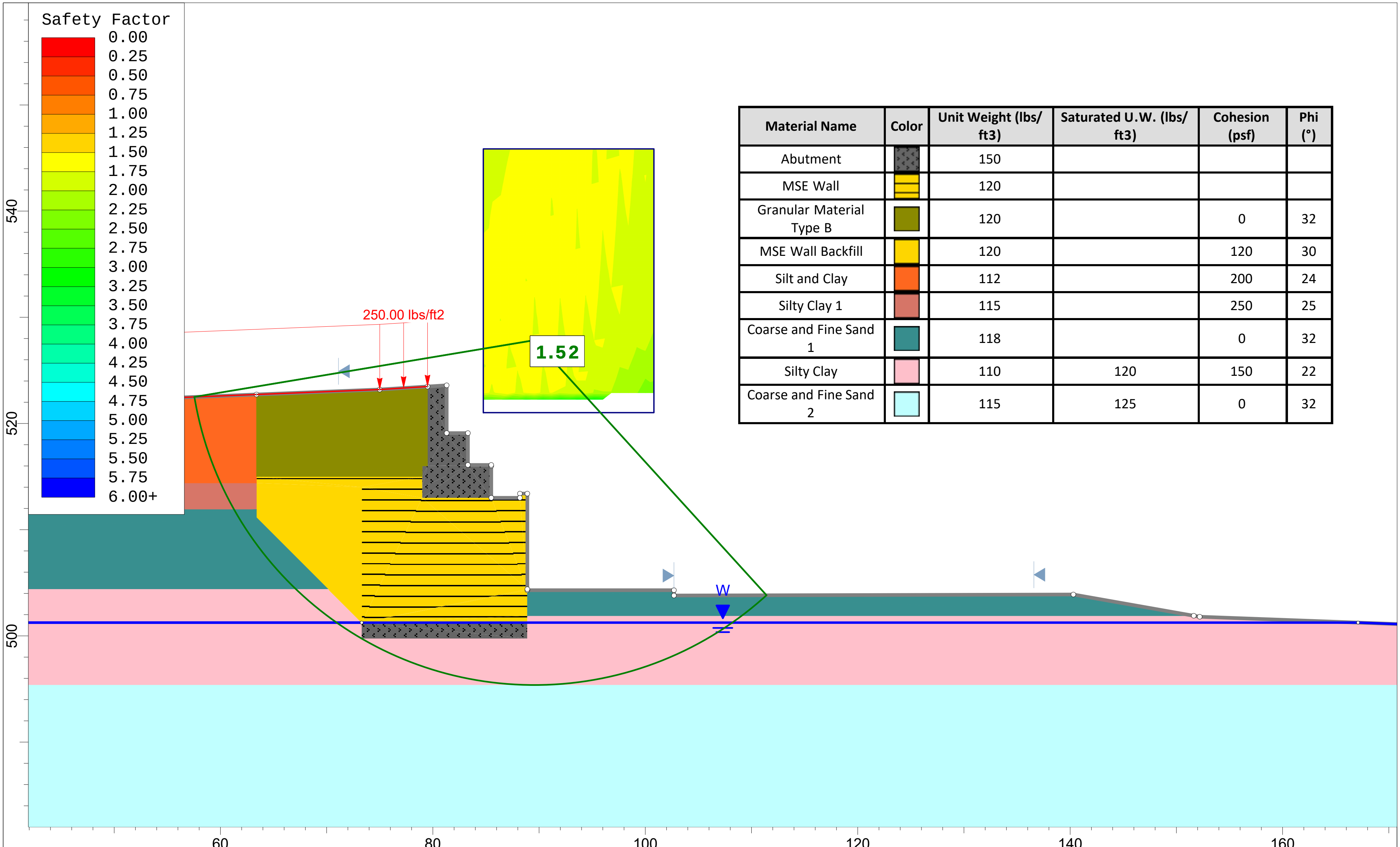
$R_R = 44.9 \ \frac{kip}{ft}$

Sliding Capacity:Demand Ratio (CDR)

$CDR_{Sliding} := \frac{R_R}{F_\tau}$ Is the CDR > or = to 1.0? $CDR_{Sliding} = 1.55$

GLOBAL STABILITY ANALYSIS

REAR ABUTMENT

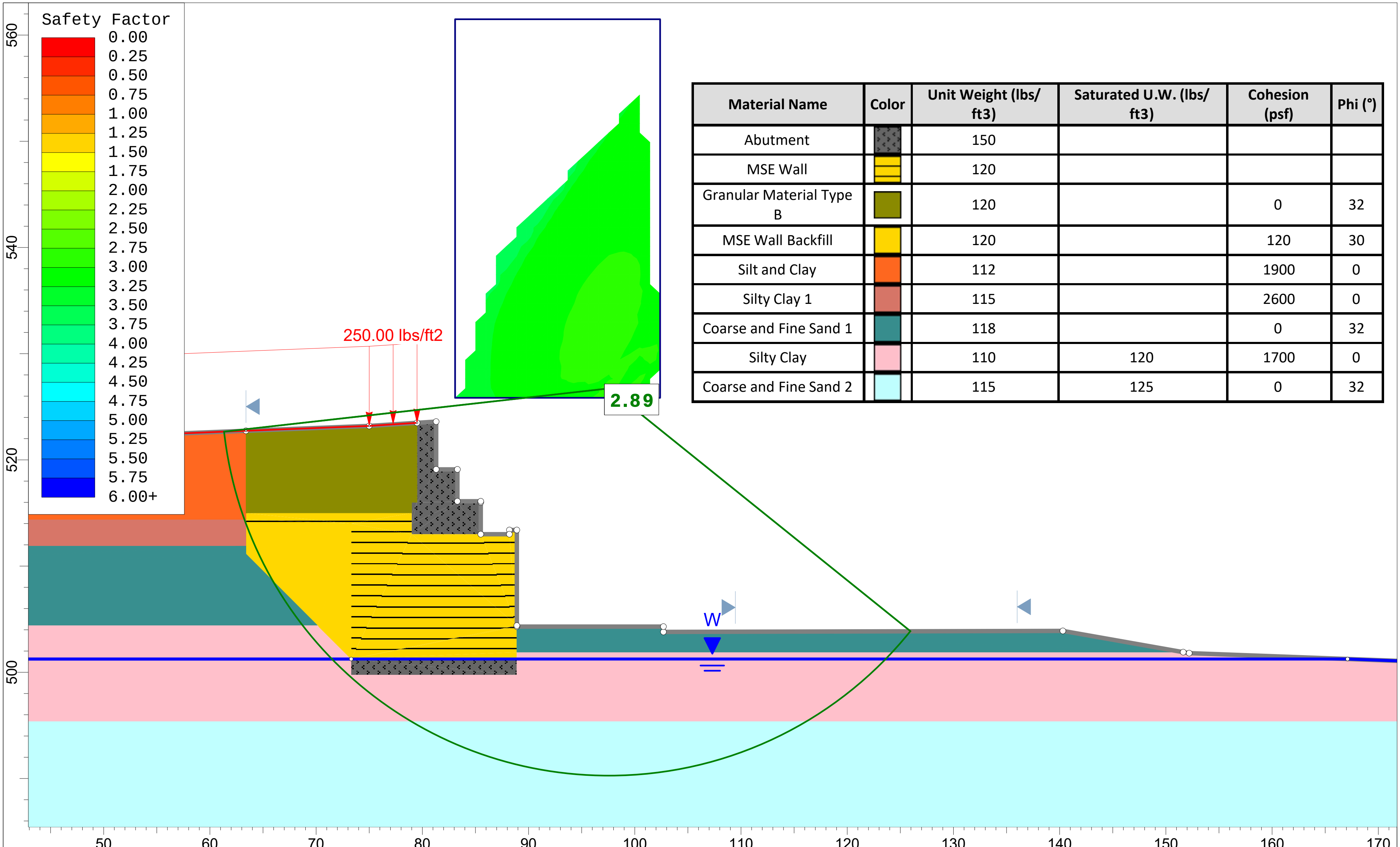


Material Name	Color	Unit Weight (lbs/ ft3)	Saturated U.W. (lbs/ ft3)	Cohesion (psf)	Phi (°)
Abutment		150			
MSE Wall		120			
Granular Material Type B		120		0	32
MSE Wall Backfill		120		120	30
Silt and Clay		112		200	24
Silty Clay 1		115		250	25
Coarse and Fine Sand 1		118		0	32
Silty Clay		110	120	150	22
Coarse and Fine Sand 2		115	125	0	32

rocscience

SLIDEINTERPRET 9.034

Project	HAM-75-1.05, PID 113361		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	KCA	*Company*	NEAS Inc.
Date	8/14/2024, 11:10:35 AM	*File Name*	LinnSt_RA_EffCirc081424.slmd



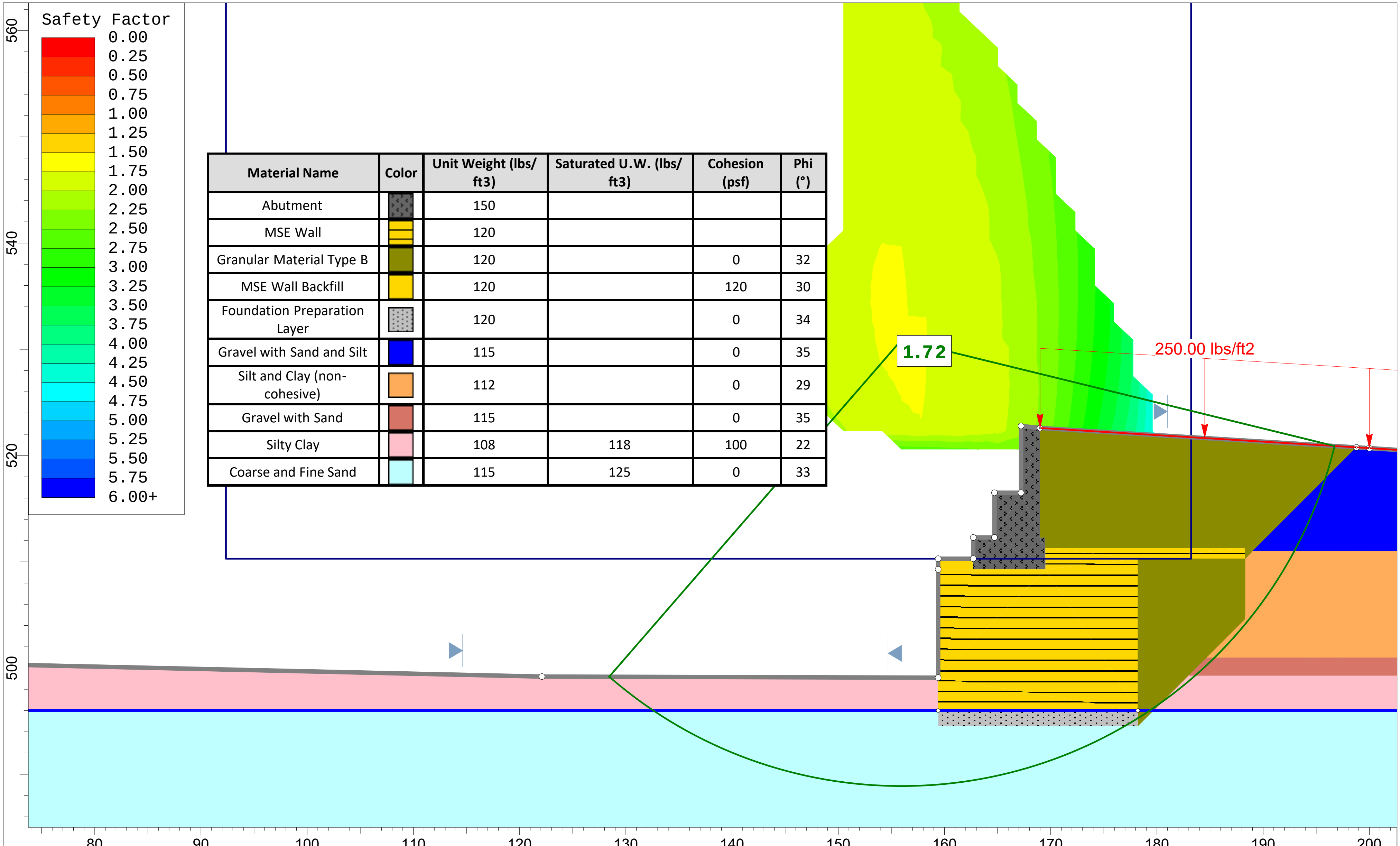
Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Cohesion (psf)	Phi (°)
Abutment		150			
MSE Wall		120			
Granular Material Type B		120		0	32
MSE Wall Backfill		120		120	30
Silt and Clay		112		1900	0
Silty Clay 1		115		2600	0
Coarse and Fine Sand 1		118		0	32
Silty Clay		110	120	1700	0
Coarse and Fine Sand 2		115	125	0	32

rocscience

SLIDEINTERPRET 9.034

Project	HAM-75-1.05, PID 113361		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	KCA	*Company*	NEAS Inc.
Date	8/14/2024, 11:10:35 AM	*File Name*	LinnSt_RA_EffTotal081424.slmd

FORWARD ABUTMENT

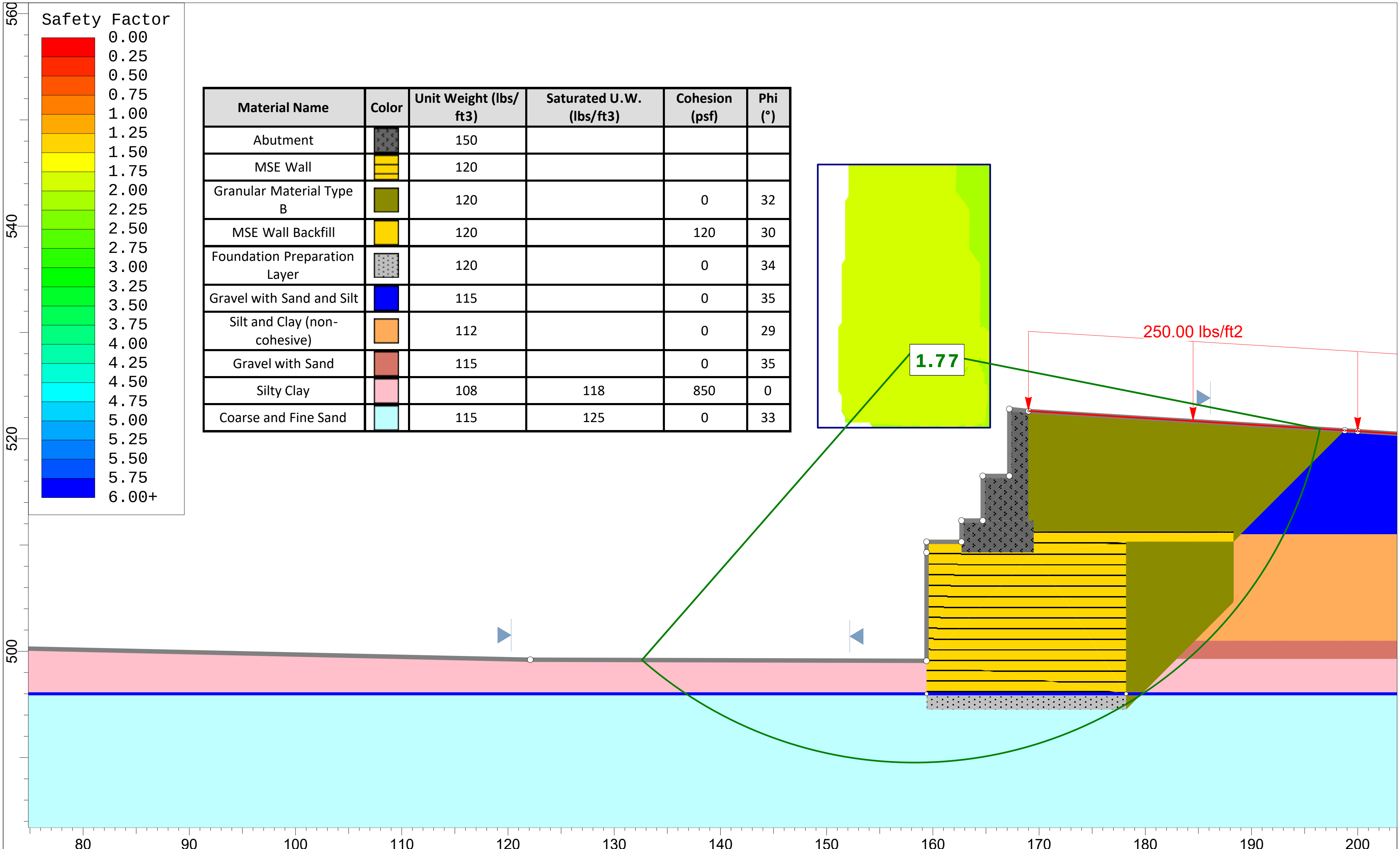


Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Cohesion (psf)	Phi (°)
Abutment		150			
MSE Wall		120			
Granular Material Type B		120		0	32
MSE Wall Backfill		120		120	30
Foundation Preparation Layer		120		0	34
Gravel with Sand and Silt		115		0	35
Silt and Clay (non-cohesive)		112		0	29
Gravel with Sand		115		0	35
Silty Clay		108	118	100	22
Coarse and Fine Sand		115	125	0	33

rocscience

SLIDEINTERPRET 9.034

Project	HAM-75-1.05, PID 113361		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	KCA	*Company*	NEAS Inc.
Date	8/21/2024, 10:07:20 AM	*File Name*	LinnSt_FA_EffCirc010525.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Saturated U.W. (lbs/ft3)	Cohesion (psf)	Phi (°)
Abutment		150			
MSE Wall		120			
Granular Material Type B		120		0	32
MSE Wall Backfill		120		120	30
Foundation Preparation Layer		120		0	34
Gravel with Sand and Silt		115		0	35
Silt and Clay (non-cohesive)		112		0	29
Gravel with Sand		115		0	35
Silty Clay		108	118	850	0
Coarse and Fine Sand		115	125	0	33

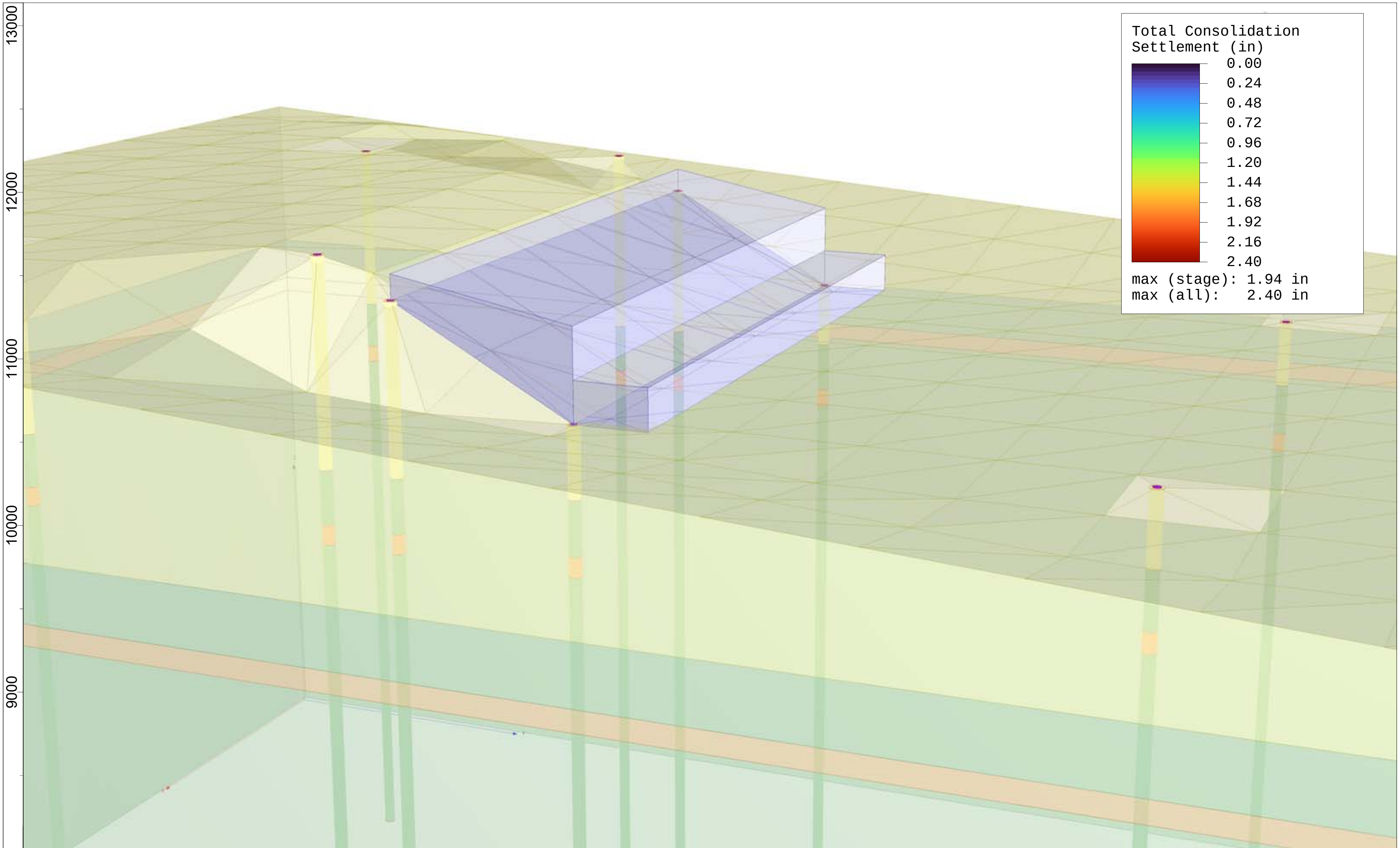
rocscience

Project	HAM-75-1.05, PID 113361		
Group	Group 1	*Scenario*	Master Scenario
Drawn By	KCA	*Company*	NEAS Inc.
Date	8/21/2024, 10:07:20 AM	*File Name*	LinnSt_FA_TotalCirc010525.slmd

SLIDEINTERPRET 9.034

REAR ABUTMENT SETTLEMENT ANALYSIS

HAM-75-01.05 (PID 122048)
NEAS Inc.
Report Creation Date: 2024/12/31, 17:06:39



rocscience	*Project* HAM-75-01.05 (PID 122048)		
	Analysis Description Bridge HAM-75-0105 Rear Abutment		
	Drawn By KCA	*Company* NEAS Inc.	
SETTLE3 5.024	*Date* 12/31/2024, 4:05:52 PM	*File Name* HAM-75-01050_RA.s3z	

Table of Contents

Settle3 Analysis Information

HAM-75-01.05 (PID 122048)

Project Settings

Document Name	HAM-75-01050_RA.s3z
Project Title	HAM-75-01.05 (PID 122048)
Analysis	Bridge HAM-75-0105 Rear Abutment
Author	KCA
Company	NEAS Inc.
Date Created	12/31/2024, 4:05:52 PM
Stress Computation Method	Boussinesq
Stress Units	Imperial, stress as ksf
Settlement Units	inches
Time-dependent Consolidation Analysis	
Time Units	days
Permeability Units	feet/day

Advanced Settings

Start of secondary consolidation (% of primary)	95
Min. stress for secondary consolidation (% of initial)	1
Reset time when load changes for secondary consolidation	No
Minimum settlement ratio for subgrade modulus	0.9
Use average poisson's ratio to calculate layered stresses	
Update Cv in each time step (improves consolidation accuracy)	
Ignore negative effective stresses in settlement calculations	
Add field points to load edges	

Soil Profile

Layer Option	Non-Horizontal Layers
Interpolation Method	TIN Triangulation
Use Non-Horizontal Ground Surface	Yes
Number of Surface Points	200
Vertical Axis	Elevation
Ground Elevation (ft)	504.3

Stage Settings

Stage #	Name	Time [days]
1	Stage 1	0
2	Stage 2	35
3	Stage 3	60
4	Stage 4	10000

Results

Time taken to compute: 0.678717 seconds

Stage: Stage 1 = 0 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	1.50654
Total Consolidation Settlement [in]	0	0
Virgin Consolidation Settlement [in]	0	0
Recompression Consolidation Settlement [in]	0	0
Immediate Settlement [in]	0	1.50654
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	0.127032	1.46036
Loading Stress XX [ksf]	0.10275	0.982699
Loading Stress YY [ksf]	0.571725	1.56732
Effective Stress ZZ [ksf]	0	11.9583
Effective Stress XX [ksf]	0.10275	12.5673
Effective Stress YY [ksf]	0.640032	13.0982
Total Stress ZZ [ksf]	0.530559	12.1312
Total Stress XX [ksf]	0.633308	12.7402
Total Stress YY [ksf]	1.17059	13.2711
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	16.1952
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	16.1952
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	0
Total Strain	0.00031	0.0032929
Pore Water Pressure [ksf]	0.127032	1.46036
Excess Pore Water Pressure [ksf]	0.127032	1.46036
Degree of Consolidation [%]	0	0
Pre-consolidation Stress [ksf]	0.515755	53.7905
Over-consolidation Ratio	4.5	9.5
Void Ratio	0	0.638367
Permeability [ft/d]	0	0.00136695
Coefficient of Consolidation [ft^2/d]	0	0.1
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	0
Undrained Shear Strength	0	0

Stage: Stage 2 = 35 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	3.51639
Total Consolidation Settlement [in]	0	2.00985
Virgin Consolidation Settlement [in]	0	0.512414
Recompression Consolidation Settlement [in]	0	1.49744
Immediate Settlement [in]	0	1.50654
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	0.127032	1.46036
Loading Stress XX [ksf]	0.10275	0.982699
Loading Stress YY [ksf]	0.571725	1.56732
Effective Stress ZZ [ksf]	0.530559	12.1312
Effective Stress XX [ksf]	0.633308	12.7402
Effective Stress YY [ksf]	1.17059	13.2711
Total Stress ZZ [ksf]	0.530559	12.1312
Total Stress XX [ksf]	0.633308	12.7402
Total Stress YY [ksf]	1.17059	13.2711
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	4.35568
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	16.1952
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	6.7475
Total Strain	0.00031	0.075825
Pore Water Pressure [ksf]	0	0.926035
Excess Pore Water Pressure [ksf]	0	0.926035
Degree of Consolidation [%]	0	99.9388
Pre-consolidation Stress [ksf]	0.610234	53.7905
Over-consolidation Ratio	1	6.73316
Void Ratio	0	0.635819
Permeability [ft/d]	0	0.033379
Coefficient of Consolidation [ft^2/d]	0	0.5
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	99.7259
Undrained Shear Strength	0	0.0838424

Stage: Stage 3 = 60 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	3.67421
Total Consolidation Settlement [in]	0	2.16768
Virgin Consolidation Settlement [in]	0	0.512637
Recompression Consolidation Settlement [in]	0	1.65504
Immediate Settlement [in]	0	1.50654
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	0.127032	1.46036
Loading Stress XX [ksf]	0.10275	0.982699
Loading Stress YY [ksf]	0.571725	1.56732
Effective Stress ZZ [ksf]	0.530559	12.1312
Effective Stress XX [ksf]	0.633308	12.7402
Effective Stress YY [ksf]	1.17059	13.2711
Total Stress ZZ [ksf]	0.530559	12.1312
Total Stress XX [ksf]	0.633308	12.7402
Total Stress YY [ksf]	1.17059	13.2711
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	4.14719
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	16.1952
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	6.25996
Total Strain	0.00031	0.0758458
Pore Water Pressure [ksf]	0	0.60444
Excess Pore Water Pressure [ksf]	0	0.60444
Degree of Consolidation [%]	0	99.9989
Pre-consolidation Stress [ksf]	0.610492	53.7905
Over-consolidation Ratio	1	6.03888
Void Ratio	0	0.635817
Permeability [ft/d]	0	0.033379
Coefficient of Consolidation [ft^2/d]	0	0.5
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	99.9951
Undrained Shear Strength	0	0.0838709

Stage: Stage 4 = 10000 d

Data Type	Minimum	Maximum
Total Settlement [in]	0	3.90607
Total Consolidation Settlement [in]	0	2.39953
Virgin Consolidation Settlement [in]	0	0.512957
Recompression Consolidation Settlement [in]	0	1.88658
Immediate Settlement [in]	0	1.50654
Secondary Settlement [in]	0	0
Loading Stress ZZ [ksf]	0.127032	1.46036
Loading Stress XX [ksf]	0.10275	0.982699
Loading Stress YY [ksf]	0.571725	1.56732
Effective Stress ZZ [ksf]	0.530559	12.1312
Effective Stress XX [ksf]	0.633308	12.7402
Effective Stress YY [ksf]	1.17059	13.2711
Total Stress ZZ [ksf]	0.530559	12.1312
Total Stress XX [ksf]	0.633308	12.7402
Total Stress YY [ksf]	1.17059	13.2711
Modulus of Subgrade Reaction (Total) [ksf/ft]	0	3.87097
Modulus of Subgrade Reaction (Immediate) [ksf/ft]	0	16.1952
Modulus of Subgrade Reaction (Consolidation) [ksf/ft]	0	5.65127
Total Strain	0.00031	0.0758758
Pore Water Pressure [ksf]	-1.02347e-28	1.26295e-28
Excess Pore Water Pressure [ksf]	-1.02347e-28	1.26295e-28
Degree of Consolidation [%]	0	100
Pre-consolidation Stress [ksf]	0.610812	53.7905
Over-consolidation Ratio	1	5.53055
Void Ratio	0	0.635817
Permeability [ft/d]	0	0.033379
Coefficient of Consolidation [ft^2/d]	0	0.5
Hydroconsolidation Settlement [in]	0	0
Average Degree of Consolidation [%]	0	100
Undrained Shear Strength	0	0.083912

Loads

1. Polygonal Load: "Polygonal Load 1"

Label	Polygonal Load 1
Load Type	Flexible
Area of Load	873 ft2
Elevation	504.3 ft
Installation Stage	Stage 1 = 0 d

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
0	10580.1	1.08
90	10580.1	1.08
90	10589.8	1.08
0	10589.8	1.08

2. Polygonal Load: "Polygonal Load 2"

Label	Polygonal Load 2
Load Type	Flexible
Area of Load	2196 ft2
Elevation	504.3 ft
Installation Stage	Stage 1 = 0 d

Coordinates and Load

X [ft]	Y [ft]	Load Magnitude [ksf]
0	10555.7	0.66
90	10555.7	0.66
90	10580.1	2.39
0	10580.1	2.39

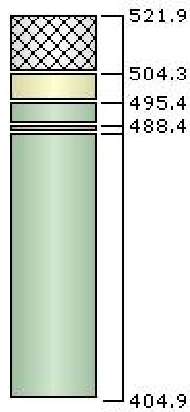
Soil Layers

Ground Surface Drained: Yes

Borehole 1

XY Location: Borehole 1: (0, 10650)

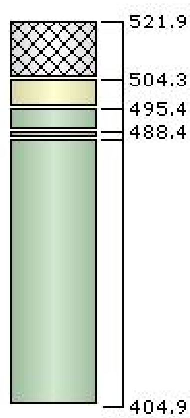
Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Cohesive Soil 1	8.9	504.3	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



Borehole 2

XY Location: Borehole 2: (0, 10580.1)

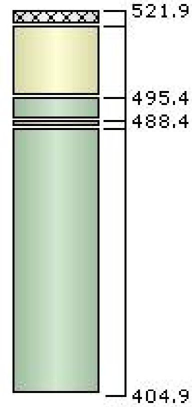
Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Cohesive Soil 1	8.9	504.3	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



Borehole 3

XY Location: Borehole 3: (0, 10555.7)

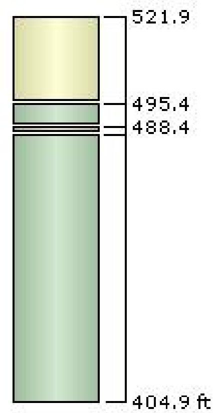
Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Cohesive Soil 1	21.7	517.1	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



Borehole 4

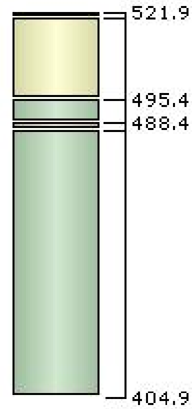
XY Location: Borehole 4: (0, 10545.6)

Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Cohesive Soil 1	26.5	521.9	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



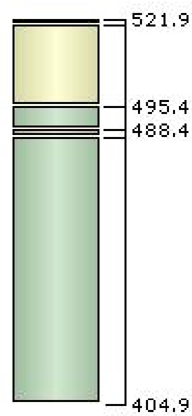
Borehole 5

XY Location:		Borehole 5: (0, 10500)		
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**	**Drained at Bottom**
1	Cohesive Soil 1	24.8	520.2	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



Borehole 6

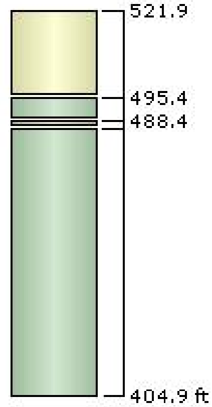
XY Location:		Borehole 6: (90, 10500)		
Layer #	**Type**	**Thickness [ft]**	**Elevation [ft]**	**Drained at Bottom**
1	Cohesive Soil 1	24.8	520.2	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



Borehole 7

XY Location: Borehole 7: (90, 10545.6)

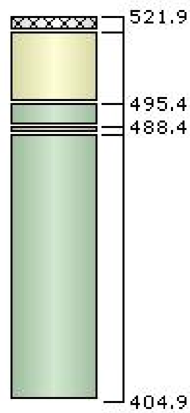
Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Cohesive Soil 1	26.5	521.9	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



Borehole 8

XY Location: Borehole 8: (90, 10555.7)

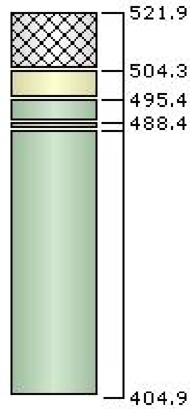
Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Cohesive Soil 1	21.7	517.1	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



Borehole 9

XY Location: Borehole 9: (90, 10580.1)

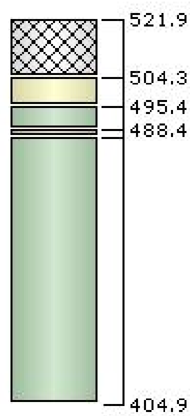
Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Cohesive Soil 1	8.9	504.3	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



Borehole 10

XY Location: Borehole 10: (90, 10650)

Layer #	Type	Thickness [ft]	Elevation [ft]	Drained at Bottom
1	Cohesive Soil 1	8.9	504.3	Yes
2	Granular Soil 1	7	495.4	No
3	Cohesive Soil 2	2.5	488.4	Yes
4	Granular Soil 1	81	485.9	No



Soil Properties

Property	Cohesive Soil 1	Granular Soil 1	Cohesive Soil 2
Color			
Unit Weight [kips/ft3]	0.122	0.12	0.125
Saturated Unit Weight [kips/ft3]	0.122	0.125	0.125
K0	1	1	1
Immediate Settlement	Enabled	Enabled	Enabled
Es [ksf]	1022	410	1399
Esur [ksf]	1022	410	1399
Primary Consolidation	Enabled	Disabled	Enabled
Material Type	Non-Linear		Non-Linear
Cc	0.21	-	0.13
Cr	0.043	-	0.027
e0	0.572	-	0.639
OCR	9.5	-	4.5
Cv [ft2/d]	0.5	-	0.75
Cvr [ft2/d]	0.1	-	0.1
B-bar	1	-	1
Undrained Su A [kips/ft2]	0	0	0
Undrained Su S	0.2	0.2	0.2
Undrained Su m	0.8	0.8	0.8
Piezo Line ID	0	0	0

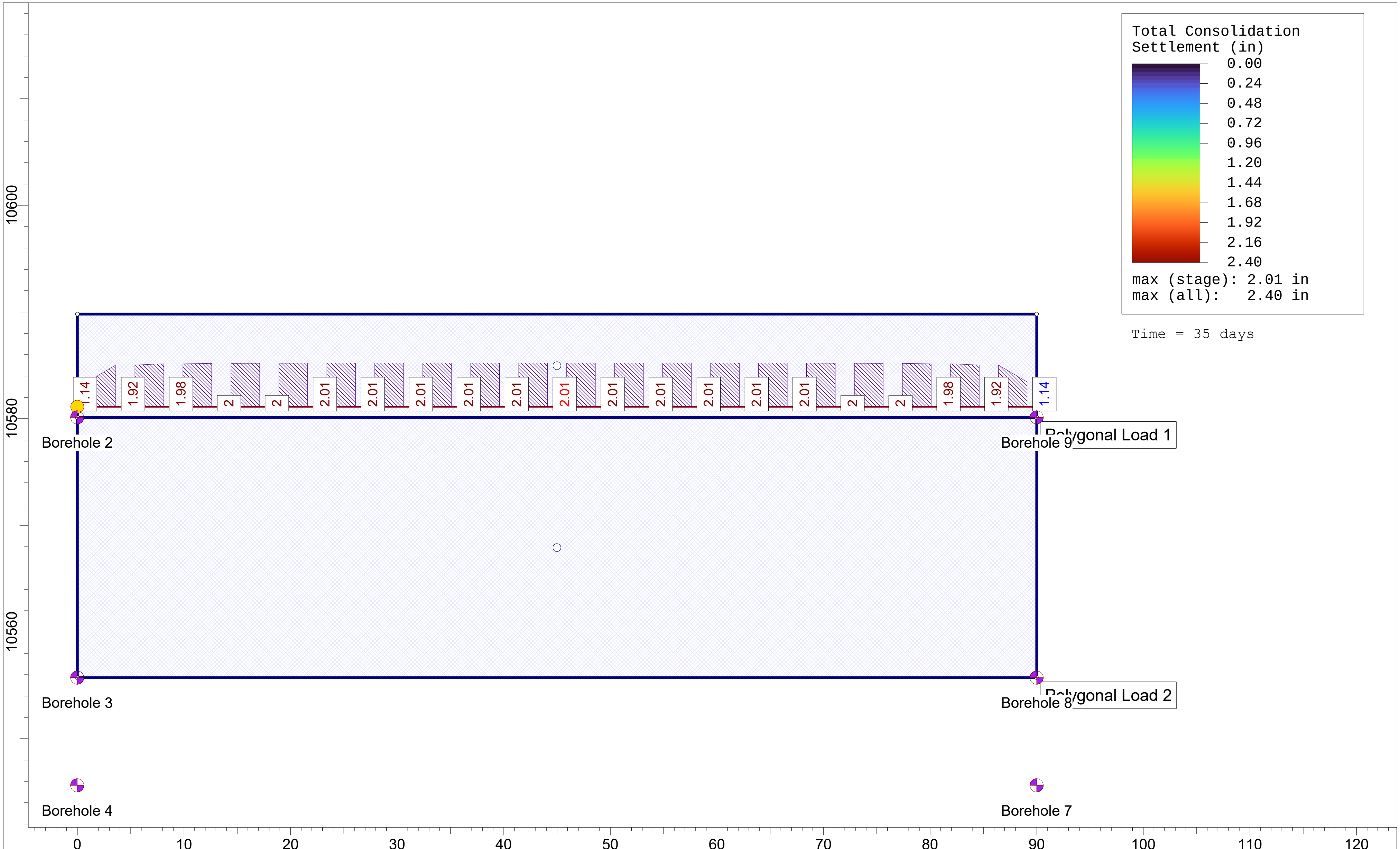
Groundwater

Groundwater method	Piezometric Lines
Water Unit Weight	0.0624 kips/ft3
Generating excess pore pressure above water table	

Query

Query Lines

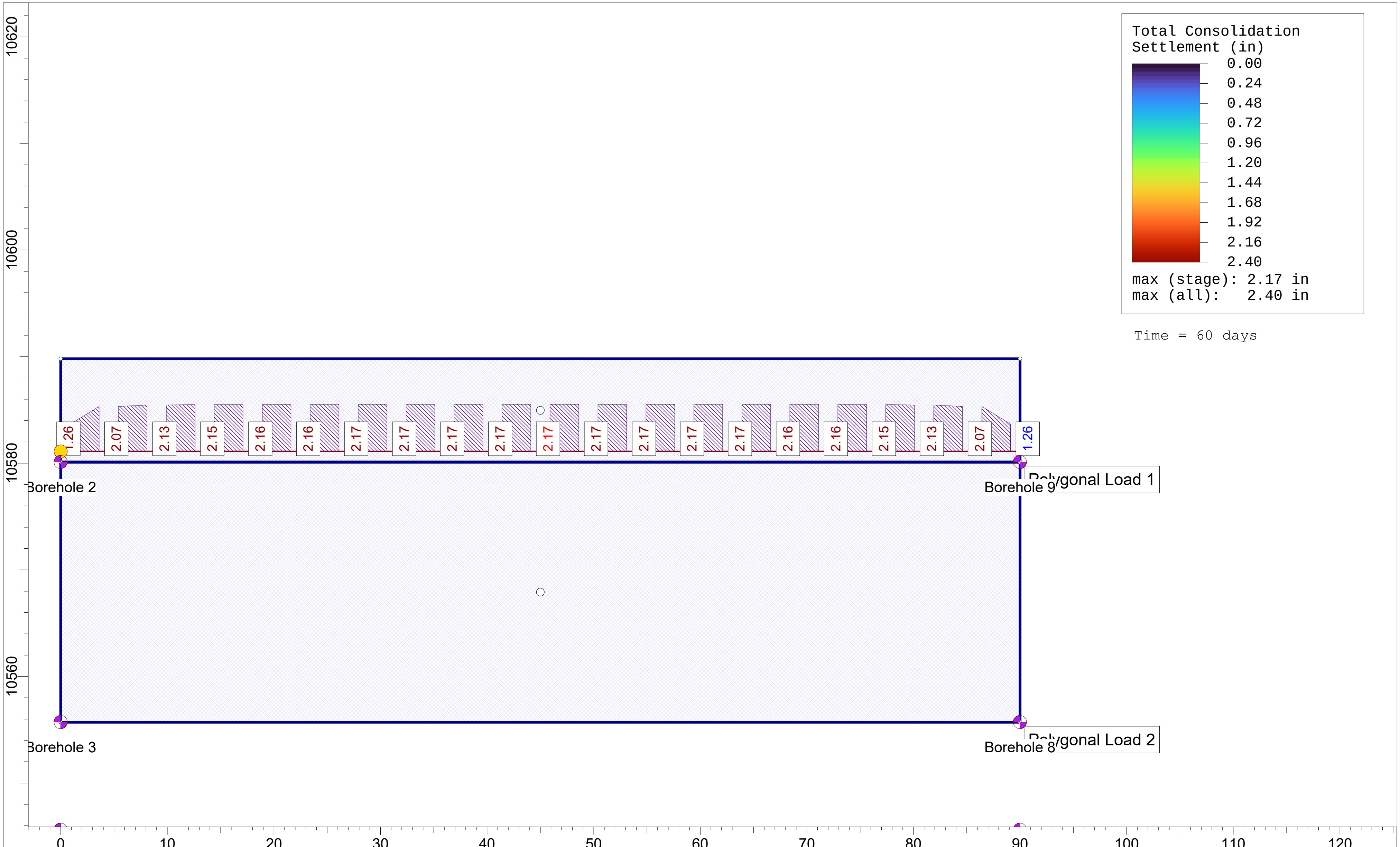
Line #	Query Line Name	Start Location	End Location	Horizontal Divisions	Vertical Divisions
1	Query Line 1	0, 10581.1	90, 10581.1	20	Auto: 49



rocscience

SETTLE3 5.024

Project	HAM-75-01.05 (PID 122048)		
Analysis Description	Bridge HAM-75-0105 Rear Abutment		
Drawn By	KCA	*Company*	NEAS Inc.
Date	12/31/2024, 4:05:52 PM	*File Name*	HAM-75-01050_RA.s3z



rocscience	Project	HAM-75-01.05 (PID 122048)	
	Analysis Description	Bridge HAM-75-0105 Rear Abutment	
	Drawn By: KCA	Company: NEAS Inc.	
SETTLE3 5.024	Date: 12/31/2024, 4:05:52 PM	File Name: HAM-75-01050_RA.s3z	