FINAL REPORT
STRUCTURE FOUNDATION EXPLORATION
BRIDGE RAMP K OVER RAMP O
BRIDGE NO. FRA-00270-25.990A
FRA-71/270-28.27/25.99A
FRANKLIN COUNTY, OHIO
PID#: 105435

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NEAS PROJECT 21-0012

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National Engineering & Architectural Services Inc.

EXECUTIVE SUMMARY

The Ohio Department of Transportation (ODOT) has proposed an interchange improvement project (FRA-71/270-28.27/25.99, PID# 105435) for the Interstate Route (IR) 270 and IR-71 on the north side of Columbus, Franklin County, Ohio. It is our understanding that the overall project objective is to improve capacity to the IR-270 and IR-71 interchange. The interchange and mainline improvements purposed to accomplish this objective include: 1) widening of the IR-71 freeway segment within the project limits; 2) the construction/reconstruction of 5 connecting ramps (Ramp K, M, N, O, P); 3) the replacement of the existing bridge structure FRA-00071-28.265 carrying Ramp K (IR-270 WB to IR-71 SB) over IR-71; 4) the replacement of the existing bridge structure FRA-00071-28.294 carrying Ramp O (IR-71 NB to IR-270 WB) over IR-71; and, 5) the superstructure replacement of the existing bridge structure FRA-00270-25.990A carrying Ramp K (IR-270 WB to IR-71 SB) over Ramp O.

National Engineering and Architectural Services Inc. (NEAS) has been contracted to perform geotechnical engineering services for the project. The purpose of the geotechnical engineering services is to perform geotechnical explorations within the project limits to obtain information concerning the subsurface soil and groundwater conditions relevant to the design and construction of the project. NEAS performed the site reconnaissance for the project between May 3, 2022, and May 7, 2022. The subsequent document presents the results of the structure foundation exploration with respect to the planned superstructure replacement of the existing bridge FRA-00270-25.990A carrying Ramp K over Ramp O. As part of the referenced explorations, NEAS advanced 2 project borings and conducted laboratory testing to characterize the soils for engineering purposes.

The subsurface profile at proposed bridge site generally consists of surficial materials (i.e., pavement) underlain by existing embankment or historical fill soils followed by natural glacial till soils. Where encountered, the embankment fill at the site can generally be described as very stiff to hard cohesive soils. The exception being a layer of non-cohesive material that was encountered within boring B-030-0-21 performed and classified on the logs as Gravel with Sand (A-1-b) between the elevation of 935.7 ft and 933.6 ft amsl. The natural glacial soils can be described as very stiff to hard cohesive fine-grained materials. Bedrock was not encountered within depths of the project borings performed at the bridge site.

A deep foundation system analysis was performed at the referenced bridge abutment site based on developed soil profiles at the boring locations. For the analyses, 12-inch closed-ended cast-in-place (CIP) friction pipe piles were considered at abutments. Based on loading information provided by TranSystems, to obtain the required UBV (pile resistance) at each abutment location, estimated pile lengths are anticipated to be between 60 ft and 65 ft with pile tip elevations ranging from 868.5 ft and 870.0 ft amsl, depending on the location. Based on our analysis, it is recommended that the proposed piles at all substructures be driven to the full estimated length and pile/soil setup be utilized to achieve the required UBV, and the estimated waiting time is 14 days. Based on the pile drivability results, 12-inch CIP piles with a wall thickness of 0.25 inches at the abutments would not be overstressed for ASTM A 252 Grade 3 steel during the pile installation process. The capacity check of the pier spread footings was not performed because it’s not included in our scope and the bridge designer believes that the pier foundations meet the criteria specified in ODOT BDM Section C401.4. To be cautious, NEAS recommends the pier foundations shall be checked for the capacity.

Since only the superstructure of the referenced bridge will be replaced, it is NEAS’s opinion that global stability should not be a concern.

A seismic site class was also determined at the overall bridge site, in which a Seismic Site Class of E is recommended.

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1. INTRODUCTION

1.1. General

National Engineering and Architectural Services Inc. (NEAS) presents our Structure Foundation Exploration Report for the planned superstructure replacement of bridge carrying Ramp K over Ramp O (SFN: 2511460) as part of the FRA-71/270-28.27/25.99A (PID# 105435) project. As part of the Safety and System Preservation project, it is our understanding that the overall project objective is to improve capacity to the IR-270 and IR-71 interchange. The report presents a summary of the encountered surficial and subsurface conditions and our recommendations for bridge foundation design and construction in accordance with Load and Resistance Factor Design (LRFD) method as set forth in AASHTO's Publication Bridge Design Specifications, 9th Edition (BDS) (AASHTO, 2020), ODOT's 2020 Bridge Design Manual (BDM) (ODOT, 2023) and 2023 Geotechnical Design Manual (GDM) (ODOT, 2023)..

The exploration was conducted in general accordance with NEAS, Inc.'s proposal to TranSystems, dated February 25, 2022, and with the provisions of ODOT's *Specifications for Geotechnical Explorations* (SGE) (ODOT, 2022).

The scope of work performed included: 1) a review of published geotechnical information; 2) performing 43 total test borings (2 utilized within this report as part of the referenced structure foundation exploration); 3) laboratory testing of soil samples in accordance with the SGE; 4) performing geotechnical engineering analysis to assess foundation design and construction considerations; and 5) development of this summary report.

1.2. Proposed Construction

The existing FRA-00270-25.990A bridge carrying Ramp K over Ramp O is a three-span continuous steel rolled beam bridge with reinforced concrete deck and substructures supported on spread footings. It is our understanding that ODOT plans to replace the superstructure of the existing bridge (FRA-00270-25.990A) and reuse the existing concrete column and the spread footings at the piers. The existing abutments are planned to be converted to semi-integral abutments supported on Cast-In-Place piles. The new bridge is approximately 183.80 ft in length (abutment to abutment) with an approximate roadway width of 34 ft (toe to toe railing).

2. GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1. Geology and Physiography

The project site is located within the Columbus Lowland Till Plains, a subdivision of the Southern Ohio Loamy Till Plain. This is a moderately low relief (25 ft) lowland surrounded in all directions by relative uplands, having a broad regional slope toward the Scioto Valley, containing many larger streams. Elevations of the region range from 600 to 850 ft above mean sea level (amsl) (950 ft amsl near Powell Moraine). The geology within this region is described as Wisconsinan-age till that is high lime in the west to medium-lime in the east. The geology is also described as containing extensive outwash in Scioto Valley overlying deep Devonian- to Mississippian-age carbonate rocks, shales, and siltstones (ODGS, 1998).

Based on the Quaternary geology map of Ohio, the geology at the project site is mapped as late Wisconsinan-age silty loam till ground moraine that is flat to gently undulating, which is underlain by Devonian-age shale, and mudstone bedrock (Pavey, et al 1999).

Based on the Bedrock Geologic Units Map of Ohio (USGS & ODGS, 2006), bedrock within the project area consists of shale, and mudstone of the Ohio Shale formation. The Ohio Shale formation is comprised of Devonian-age shale, and mudstone. The shale in this formation is described as brownish black to greenish gray and weathers brown in color, carbonaceous to clayey, laminated to thin bedded, fissile partings, and a petroliferous odor. Bedrock is anticipated to generally rise from east to west throughout the project (ODGS, 2003). Based on the ODNR bedrock topography map of Ohio, bedrock elevations at the project site can be expected to be around the elevation of 850 to 800 ft amsl, putting bedrock at depths ranging from about 62 to 112 ft below ground surface (bgs).

The soils at the project site have been mapped (Web Soil Survey) by the Natural Resources Conservation Service (USDA, 2015) as primarily Udorthents-urban land complex throughout the project site. Udorthents are described as material that has been disturbed by cutting and filling operations and as such is not graded. Soils in the portion of the site north of Boswell Dr. and the central portion of exit 26 are mapped as Bennington silt loam. Soils in the Bennington series are characterized as very deep, somewhat poorly drained, soils formed in loamy till of medium lime content. These soils are on ground moraines and end moraines. The Bennington series is comprised of primarily fine-grained soils and classifies as A-4, A-6, and A-7 type soils according to the AASHTO method of soil classification. Soils in the portion of the site south of ramp 26 up to the western end of the bridge carrying exit 26 over IR-71 are mapped as Pewamo silty clay loam. Soils in the Pewamo series are characterized as very deep, very poorly drained, soils formed in till on moraines, near-shore zones (relict), and lake plains. These soils are on ground moraines and end moraines. The Bennington series is comprised of primarily fine-grained soils and classifies as A-6 and A-7 type soils according to the AASHTO method of soil classification.

2.2. Hydrology/Hydrogeology

Groundwater at the project site can be expected at an elevation consistent with that of the nearby tributary to Alum Creek. The water level of the tributary to Alum Creek may be generally representative of the local groundwater table. However, it should be noted that perched groundwater systems may be existent in areas due to the presence of fine-grained soils making it difficult for groundwater to permeate to the phreatic surface.

The project site is not located within a regulatory floodway zone based on available mapping by the Federal Emergency Management Agency's (FEMA) National Flood Hazard mapping program (FEMA, 2019).

2.3. Mining and Oil/Gas Production

No abandoned mines are noted on ODNR’s Abandoned Underground Mine Locator in the vicinity of the project site (ODNR [1], 2020).

No abandoned oil or gas wells are noted on ODNR’s Oil and Gas Well Locator in the vicinity of the project site (ODNR [1], 2020).

2.4. Historical Records and Previous Phases of Project Exploration

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

- Original bridge construction plans for Bridge No. FRA-270-1731N Ramp K over Ramp O, as part of the Ohio Department of Transportation project Job No. 06676 (4), 1964;
- Soil Profile Sheets as part of ODOT project FRA-IR270-16.65N IR-71 Interchange, prepared by DE Leuw, Cather & Brill Consulting Engineers., dated April 13, 1964.

Two historical soil borings (B-001-0-64 and B-008-0-64) that were drilled as part of the 1964 Structure Exploration for ODOT project Job No. 06676 (4), 1964 were reviewed and are utilized in our report and analysis. A summary of the historic boring information (location, elevation, etc.) is provided in Table 1, and their locations are depicted on the Boring Location Plan provided in Appendix A. The historic boring logs of the borings utilized within this report are provided in Appendix B. It should be noted that the elevations in NAVD 88 are typically 0.6 feet to 1.8 feet lower than they are in NGVD 29; herein the elevations in NAVD 88 are 0.55 feet lower than they are in NGVD 29.

Table 1: Historic Boring Summary

Boring Number	Existing Structure	Existing Substructure	Latitude	Longitude	Elevation (NGVD 29) (ft)	Elevation (NAVD 88) (ft)	Depth (ft)
B-001-0-64	Ramp K over Ramp O Bridge	Forward Abutment	40.111199	-82.975243	905.7	905.1	66.0
B-008-0-64		Rear Abutment	40.110768	-82.974656	907.8	907.3	51.0

2.5. Field Reconnaissance

A field reconnaissance visit for the bridge (SFN: 2511460) was conducted on May 3, 2022, at the interchange between IR-71 and IR-270 in Franklin County, Ohio. During our field reconnaissance, site conditions were noted and photographed. Land use at the project site can be described as a combination of woodland, residential and ODOT ROW (Right of Way).

2.5.1. *Bridge Carrying Ramp K over Ramp O (SFN: 2511460)*

The existing bridge carrying Ramp K over Ramp O is a three-span, steel multi-beam bridge with one lane of traffic on a concrete deck with an asphalt wearing course. The bridge sits atop stub-type concrete abutments and cap and column piers. The roadway embankment slopes at the site, generally appeared to be stable with no signs of instability observed during our site visit. The existing roadway embankments appeared to be at about a 2 Horizontal to 1 Vertical (2H:1V) slope and were heavily vegetated. Overall, the bridge appeared to be in fair condition with wear and degradation observed on the bridge superstructure and substructure. Most of the beams were observed to have some surface corrosion along the length of the beam. The beam ends and girders near the abutments were observed to be heavily corroded with through holes in the girders (Photograph 1). Heavy spalling was observed at the bridge deck ends, traffic barriers and signs of patching were observed in the underside of the bridge deck (Photograph 2). Both abutments were observed to have cracking, spalling and efflorescence (Photograph 3). The joints above the abutments were also observed to have failed, with water staining the abutments. The spill-through slopes were observed to be covered with rip-rap. The piers were observed to be in fair condition with spalling and exposed rebar observed (Photograph 4). No apparent signs of structural distress of the bridge due to geotechnical concerns were observed during our field reconnaissance visit.

In general, the existing bridge structure appeared to be well drained with some signs of erosion at the bridge spill-through slopes. The asphalt wearing course was observed to be in poor condition with signs of surface wear. The areas near the edges of the bridge deck were noted as beings especially distressed. Map cracking, and edge cracking was common in the asphalt wearing course as well as potholing and crack sealing deficiencies (Photograph 3). The adjacent ramp pavement was observed to be in better condition with only some edge cracking as well as longitudinal and transverse cracking observed. Water was directed to scuppers on the northern side of the bridge deck. Many of these scuppers were observed to be clogged, and water appeared to run through holes in the curb and traffic barrier. No signs of standing water were observed.

Photograph 1: Corrosion at Beam Ends and Through Holes in Girders

Photograph 2: Signs of Patching in Underside of Bridge Deck

Photograph 3: Western Abutment

Photograph 4: Spalling and Exposed Rebar at Eastern Pier

3. GEOTECHNICAL EXPLORATION

3.1. Field Exploration Program

The project subsurface exploration was conducted by NEAS on August 9, 2022 and included 2 borings drilled to a depth of 40.0 ft below ground surface (bgs). The boring location was selected by NEAS in general accordance with the guidelines contained in the SGE with the intent to evaluate subsurface soil and groundwater conditions. Borings were typically located within the planned project construction areas that were not restricted by underground utilities or dictated by terrain (e.g. steep embankment slopes). Project boring locations were located in the field prior to drilling by NEAS personnel. Each individual project boring log (included within Appendix B) includes the recorded boring latitude and longitude location (based on the surveyed Ohio State Plane South, NAD83, location) and the corresponding ground surface elevation. The boring locations are depicted on the Boring Location Plan provided in Appendix A. Latitude/Longitude, elevations and stationing and offsets (pending) of the borings are shown on Table 2 below.

Table 2: Project Boring Summary

Boring Number	Alignment	Location (Sta/offset)	Latitude	Longitude	Elevation (NAVD 88) (ft)	Depth (ft)	Substructure
B-030-0-21	Ramp K	19+68, 27' RT.	40.110863	-82.974607	937.1	40.0	Rear Abutment/ Rear Pier
B-031-0-21	Ramp K	21+80, 11' LT.	40.111100	-82.975308	940.6	40.0	Forward Abutment/ Forward Pier

Project borings were drilled using a CME 75T truck-mounted drilling rig utilizing 3.25-inch (inner diameter) hollow stem auger. Soil samples were recovered continuously to 9 ft, then at 2.5-ft interval to a depth of 40 ft bgs using an 18-inch split spoon sampler (AASHTO T-206 “Standard Method for Penetration Test and Split Barrel Sampling of Soils.”). The soil samples obtained from the exploration program were visually observed in the field by the NEAS field representative and preserved for review by a Geologist for possible laboratory testing. Standard penetration tests (SPT) were conducted using a CME auto hammer calibrated to be 79% efficient on January 24, 2022, as indicated on the boring logs.

Field /boring logs were prepared by drilling personnel, and included lithological description, SPT results recorded as blows per 6-inch increment of penetration and estimated unconfined shear strength values on specimens exhibiting cohesion (using a hand-penetrometer). Groundwater level observations were recorded both during and after the completion of drilling. These groundwater level observations are included on the individual boring logs. After completing the borings, the boreholes were backfilled with either auger cuttings, bentonite chips, or a combination of these materials, and patched with cold patch asphalt and/or quickset concrete where necessary and appropriate.

3.2. Laboratory Testing Program

The laboratory testing program consisted of classification testing and moisture content determinations. Data from the laboratory testing program was incorporated onto the boring logs (Appendix B). Soil samples are retained at the laboratory through completion and ODOT approval of Stage 2 plans, after which time they will be discarded.

3.2.1. Classification Testing

Representative soil samples were selected for index properties (Atterberg Limits) and gradation testing for classification purposes on approximately 33% of the samples. At each boring location, samples were selected for testing with the intent of identification and classification of all significant soil units. Soils not selected for testing were compared to laboratory tested samples/strata and classified visually. Moisture content testing was conducted on all samples. The laboratory testing was performed in general accordance with applicable AASHTO specifications.

A final classification of the soil strata was made in accordance with AASHTO M-145 “Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes,” as modified by ODOT

"Classification of Soils" once laboratory test results became available. The results of the soil classification are presented on the boring logs provided in Appendix B.

3.2.2. Standard Penetration Test Results

Standard Penetration Tests (SPT) and split-barrel (commonly known as split-spoon) sampling of soils were performed at varying intervals (i.e., continuous, 2.5-ft, or 5.0-ft intervals) in the project borings performed. To account for the high efficiency (automatic) hammers used during SPT sampling, field SPT N-values were converted based on the calibrated efficiency (energy ratio) of the specific drill rig's hammer. Field N-values were converted to an equivalent rod energy of 60% (N_{60}) for use in analysis or for correlation purposes. The resulting N_{60} values are shown on the boring logs provided in Appendix B.

4. GEOTECHNICAL FINDINGS

The subsurface conditions encountered during NEAS's explorations are described in the following subsections and/or on each boring log presented in Appendix B. The boring logs represent NEAS's interpretation of the subsurface conditions encountered at each boring location based on our site observations, field logs, visual review of the soil samples by NEAS's geologist, and laboratory test results. The lines designating the interfaces between various soil strata on the boring logs represent the approximate interface location; the actual transition between strata may be gradual and indistinct. The subsurface soil and groundwater characterizations included herein, including summary test data, are based on the subsurface findings from the geotechnical explorations performed by NEAS as part of the referenced project, and consideration of the geological history of the site.

4.1. Subsurface Conditions

The subsurface profile at proposed bridge site generally consists of surficial materials (i.e., pavement) underlain by existing embankment or historical fill soils followed by natural glacial till soils. Where encountered, the embankment fill at the site can generally be described as stiff to hard cohesive soils with one layer of loose to medium dense granular materials. The natural glacial soils can be described as stiff to hard cohesive materials. Boulder was possibly encountered in boring B-008-0-64 at the elevations of 890.3 ft and 897.8 ft amsl. Bedrock was not encountered within depths of the project boring or two historic borings performed at the bridge site.

4.1.1. Overburden Soil

At the proposed bridge site, two different materials were encountered immediately below the surficial pavement. In general, the two different overburden materials consisted of historical or embankment "man-made" fill soils and natural glacial till soils. These materials and the general profile underlying the site is further described below.

Historical fill soils were encountered in both borings B-030-0-21 and B-031-0-21 performed for the proposed structure. These fill soils were encountered immediately below the pavement section and extended to a depth approximate 30 ft bgs (908 ft at rear abutment and 904 ft at forward abutment). Based on laboratory testing results, a visual review of the soil samples obtained as well as the calculated Soil Behavior Index, the fill at the site is comprised of cohesive materials and one layer of granular soils and is classified on the boring logs as Sandy Silt (A-4a), Silt (A-4b), Silt and Clay (A-6a), Silty Clay (A-6b) and Gravel with Sand (A-6a). With respect to the soil strength of the fine-grained cohesive fill, these soils can be described as having a consistency of stiff to hard correlating to N_{60} values of 3 and 32 bpf and unconfined compressive strengths (estimated by means of hand penetrometer) between 1.25 and 4.5 tons per square foot (tsf). Natural moisture contents of the cohesive fill ranged from 8 percent to 24 percent. Based on a Atterberg Limits test performed on a representative sample of the cohesive fill material, the liquid and plastic limits ranged from 21 to 40 percent and from 14 to 20 percent, respectively. A thin layer of granular fill soils classified as Gravel with Sand (A-1-b) was encountered in the boring B-030-0-21 between the elevation of 933.6 ft and 935.7 ft with a N_{60} value of 12 bpf and water content of 7 percent.

The stratum encountered immediately beneath the fill consisted of natural cohesive glacial till. The natural cohesive glacial till soils in the borings extended to end of boring. The cohesive glacial till soils are classified on the boring logs as Silt and Clay (A-6b). The cohesive soils can be described as having a very stiff to hard consistency based on N_{60} values between 17 bpf and 26 bpf, and unconfined compressive strengths (estimated by means of hand penetrometer) between approximately 4.25 and 4.50 tons per square foot (tsf). Natural moisture contents of the cohesive soils ranged from 14 to 21 percent.

Boulder was possibly encountered in boring B-008-0-64 at the elevations of 890.3 ft and 897.8 ft amsl.

4.1.2. Groundwater

Groundwater measurements were taken during the drilling procedures and/or immediately following the completion of each borehole. Groundwater was not encountered in the project borings during drilling.

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.

4.1.3. Bedrock

Bedrock was not encountered within depths of the borings performed at the bridge site.

5. ANALYSES AND RECOMMENDATIONS

The existing FRA-00270-25.990A bridge carrying Ramp K over Ramp O is a three-span continuous steel rolled beam bridge with reinforced concrete deck and substructures supported on spread footings. Based on the information available at the time of this report, it is our understanding that ODOT plans to replace the superstructure of the existing bridge (FRA-00270-25.990A) and reuse the existing concrete column and the spread footings at the piers. The existing abutments are planned to be converted to semi-integral abutments supported on Cast-In-Place piles. The new bridge is approximately 183.80 ft in length (abutment to abutment) with an approximate roadway width of 34 ft (toe to toe railing).

Based on the above information in addition to: 1) the soil characteristics gathered during the subsurface exploration (i.e., SPT results, laboratory test results, etc.); 2) the developed generalized soil profile and estimated engineering properties and other design assumptions presented in subsequent sections of this report; and, 3) the bridge site plan provided by TranSystems, geotechnical design elements for the new Ramp K over Ramp O bridge will include:

- Deep Foundation Analysis
    - Drivability Analysis
- Global Stability

The geotechnical engineering analyses were performed in accordance with ODOT's BDM (ODOT, 2023) and AASHTO's LRFD BDS (AASHTO, 2020). Design recommendations are provided in the following sections.

5.1. Soil Profile for Analysis

For analysis purposes, each boring log was reviewed including historical borings. A generalized material profile was developed for analysis at each substructure site. Utilizing the generalized soil profile, engineering properties for each soil strata were estimated based on their field (i.e., SPT N_{60} Values, hand penetrometer values, etc.) and laboratory (i.e., Atterberg Limits, grain size, etc.) test results using correlations provided in published engineering manuals, research reports and guidance documents. The developed soil profile and estimated engineering soil and/or rock properties (with cited correlation/reference material) used in our evaluation is summarized per boring within Tables 3 and 4 below.

Table 3: Soil Profile for Rear Abutment Analysis – B-030-0-21 & B-008-0-64

FRA-00270-25.990A Ramp K over Ramp O: Rear Abutment B-030-0-21 & B-008-0-64							
Soil Description	Unit Weight(1) (pcf)	Moist Unit Weight(1) (pcf)	Saturated 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 Depth (937.1 ft - 933.6 ft)	110	110	120	-	-	35	1.00
Silt and Clay Depth (933.6 ft - 927.6 ft)	100	100	110	400	35	19	1.50
Silty Clay Depth (927.6 ft - 917.6 ft)	110	110	120	1300	150	23	1.75
Sandy Silt Depth (917.6 ft - 910.1 ft)	115	115	125	3150	250	27	1.50
Silty Clay Depth (910.1 ft - 905.1 ft)	115	115	125	2850	250	25	1.75
Silty Clay Depth (905.1 ft - 897.1 ft)	112	112	122	1800	200	24	1.75
Sandy Silt Depth (897.1 ft - 888.8 ft)	125	125	135	6000	400	29	1.50
Sandy Silt Depth (888.8 ft - 874.8 ft)	120	120	130	4500	350	28	1.50
Sandy Silt Elevation (874.8 ft - 859.8 ft)	130	130	140	6850	450	30	1.50
Sandy Silt Elevation (859.8 ft - 856.8 ft)	130	130	140	-	-	36	1.20
Notes: *1. Values interpreted from ODOT Geotechnical Design Manual (GDM) Section 405.* *2. Values calculated from Terzaghi and Peck (1967) if N160<52, else Stroud and Butler (1975) was used.* *3. Values interpreted from LRFD BDS Table 10.4.6.2.4-1 and ODOT GDM Table 400-3.*							

Table 4: Soil Profile for Forward Abutment Analysis – B-031-0-21 & B-001-0-64

FRA-00270-25.990A Ramp K over Ramp O: Forward Abutment B-031-0-21 & B-001-0-64							
Soil Description	Unit Weight[(1)] (pcf)	Moist Unit Weight[(1)] (pcf)	Saturated 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 (940.6 ft - 937.6 ft)	108	108	118	850	100	22	1.50
Silty Clay Depth (937.6 ft - 936.1 ft)	108	108	118	1000	100	22	1.75
Silt and Clay Depth (936.1 ft - 933.1 ft)	110	110	120	1250	150	23	1.50
Sandy Silt Depth (933.1 ft - 931.1 ft)	110	110	120	1350	150	24	1.50
Silty Clay Depth (931.1 ft - 928.6 ft)	110	110	120	1500	150	23	1.75
Silt and Clay Depth (928.6 ft - 926.1 ft)	112	112	122	2350	200	25	1.50
Silty Clay Depth (926.1 ft - 921.1 ft)	115	115	125	2500	250	25	1.75
Sandy Silt Depth (921.1 ft - 913.6 ft)	115	115	125	2500	250	26	1.50
Silty Clay Elevation (913.6 ft - 900.6 ft)	115	115	125	3200	250	26	1.75
Sandy Silt Elevation (900.6 ft - 893.7 ft)	115	115	125	2950	250	26	1.50
Sandy Silt Elevation (893.7 ft - 877.7 ft)	125	125	135	5950	400	29	1.50
Sandy Silt Elevation (877.7 ft - 865.7 ft)	130	130	140	7250	450	30	1.50
Sandy Silt Elevation (865.7 ft - 839.7 ft)	130	130	140	8000	450	31	1.50

Notes:
1. *Values interpreted from ODOT Geotechnical Design Manual (GDM) Section 405.*
2. *Values calculated from Terzaghi and Peck (1967) if N160<52, else Stroud and Butler (1975) was used.*
3. *Values interpreted from LRFD BDS Table 10.4.6.2.4-1 and ODOT GDM Table 400-3.*

5.2. Bridge Foundation Analysis and Recommendations

A foundation review was completed for a deep foundation system for the referenced bridge abutments based on the following design information: 1) the Site Plan for Bridge No. FRA-00270-25.990A conducted by TranSystems; 2) historical plans and borings; 3) subsequent conversations with TranSystems, and 4) other design assumptions presented in subsequent sections of this report. A pile foundation will be designed according to ODOT's BDM (ODOT, 2023) and AASHTO's LRFD BDS (AASHTO, 2020). Utilizing the *GRLWeap* computer program, a static pile analysis (FHWA method) was performed to estimate driven pile lengths needed to achieve the Ultimate Bearing Value (UBV) for a single pile. Input information for the *GRLWeap* program was based on the soil characteristics gathered during the geotechnical exploration (i.e., SPT results, laboratory test results, etc.) and our geotechnical experience. The soil strata and their engineering properties presented in Section 5.1. of this report were used in our analyses. Groundwater elevation used in the analysis was assumed to match that of each boring per substructure as encountered during our field investigation and as shown on each individual boring log (Appendix B).

5.2.1. Pile Foundation Analysis

Deep foundations will be used to support the abutments of the FRA-00270-25.990A bridge. Based on the site plan prepared by TranSystems, 12-in Cast-in-place (CIP) piles were proposed to support the abutments of the referenced bridge. Based on the bridge site plan, the bottom footing is approximately at the elevation of 925.71 ft and 928.11 ft for the rear and forward abutment, respectively. The vertical loads were provided by TranSystems through emails on January 2, 2024 with max factored load of 165.2 kips per pile at both abutment locations.

Based on the determined soil profile and our estimated engineering soil properties, a static pile analysis (FHWA method) was performed using the computer program *GRLWeap* to determine the estimated geotechnical pile length at each abutment (*GRLWeap* results included within Appendix C). 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 pier cap bearing elevations) to the depth at which the required Ultimate Bearing Value (UBV) is obtained. The EOID is determined due to the potential for soil disturbance caused during pile driving (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 may not reach the indicated target UBV utilizing the estimated pile lengths. Therefore, it may be necessary to drive the CIP piles to the EOID and then let the piles "set-up" (reduction of pore water pressure in the soils adjacent to the pile) for an established time period based on the material at the substructure and the specific pile size.

The UBV and EOID values are determined in accordance with Section 305.3.2.4 of the ODOT BDM. The UBV is determined by dividing the total factored load for the highest loaded pile at each abutment 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 bearing values (UBV) and required geotechnical pile length following pile setup for 12-in CIP pile per substructure location are given in Table 5 below (*GRLWeap* results included within Appendix C). The referenced table also includes 1) the length of driven pile required in driving conditions for 12-in CIP pile driven to the respective UBV per substructure location; and 2) the estimated difference in pile length between a pile in ultimate and driving conditions.

Table 5: Deep Foundation Analysis Summary

Pile Type	Max Pile Reaction - Strength I (kips)	Required Ultimate Bearing Value(2) (kips)	Geotechnical Pile Length(1) (ft)	End of Initial Driving Value(3) (EOID)(kips)	Predicted Pile Length Accounting for Driving Losses (ft)	Pile Length Difference Ultimate vs. Driving Conditions (ft)	Setup Factor for Waiting Time
FRA-00270-25.990A (Ramp K over O): Rear Abutment, B-008-0-64 & B-030-0-21							
12-inch CIP	165.2	236.0	57.2	161.9	66.2	9.0	1.46
FRA-00270-25.990A (Ramp K over O): Forward Abutment, B-001-0-64 & B-031-0-21							
12-inch CIP	165.2	236.0	58.3	163.1	84.8	26.5	1.45

Notes:
1. *The estimated length of pile from bottom of pile cap to the depth which the required UBV is obtained based on ultimate resistances.*
2. *The referenced resistance factor of 0.7 has been applied to Max Pile Reaction.*
3. *The EOID pile resistances per ODOT BDM Equation C305.3.2.4-4 based on driving resistances at the indicated geotechnical pile length.*

5.2.1.1. Pile Drivability

NEAS's drivability evaluation estimated a Delmag D 19-42 diesel hammer to determine if the 12-inch CIP piles with the minimum wall thickness of 0.25 inches for ASTM A 252 steel, would be overstressed at any time during pile installation. Based on the pile drivability results, 12-inch CIP piles with a wall thickness of 0.25 inches at the abutments would not be overstressed for ASTM A 252 Grade 3 steel during the pile installation process. GRLWEAP Results can be found in Appendix D.

It should be noted that the driving resistance of CIP piles through soils encountered at the bridge site is expected to be high. Driveability 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 driveability 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.

Per the plan notes 606.7-1 of ODOT's 2023 BDM (ODOT, 2023), the maximum rated energy of the hammer used to install the piles shall be (44,000) foot-pounds. Ensure that stresses in the piles during driving do not exceed (45,000) pounds per square inch.

5.2.2. Pile Foundation Recommendations

Based on our evaluation of the subsurface conditions and our geotechnical engineering analysis for the proposed Bridge FRA-00270-25.990A, it is our opinion that the bridge foundations can be supported on driven friction CIP piles seated within the stiff to hard natural glacial till material encountered at the site.

Steel points shall be provided to protect the tips of CIP pipe piles since the boulders were possibly encountered in boring B-008-0-64.

We recommend that a driven pile foundation be used for support for the referenced substructure foundations. New CIP piles are recommended to be installed in accordance with Sections 507 and 523 of ODOT's CMS. During driving conditions and if driven to the UBVs indicated in Table 5 of this report, it is anticipated that the newly driven CIP piles would “run” for extended depths at each substructure location by greater than 10 ft. Therefore, it is recommended that the proposed piles at all substructures be driven to the full estimated length and pile/soil setup be utilized to achieve the required UBV. It is recommended that plan note 606.7-4 of ODOT’s 2020 BDM “Piles Driven To Full Estimated Length With Pile/Soil Setup” be included on the plans for these substructures. At both abutment locations, the first two piles at each abutment should be driven to the full Estimated Length indicated in Table 6 below. After driving and testing the first two piles, drive the remaining piles in the substructure to the same depth as the first two piles. After driving all piles to the estimated length, cease all driving operations at the substructure for a period specified in Table 6. After the specified waiting period, it is recommended that pile driving contractor perform a restrike on both of the first two piles at each substructure. If the restrike test results indicate that both piles achieved the required UBV, all piles in the substructure may be accepted by the Engineer. If the restrike test results indicate that either of the two piles did not achieve the required UBV, immediately notify the Engineer so that the Engineer can notify the District Geotechnical Engineer, the Office of Construction Administration, and the Office of Geotechnical Engineering.

When new piles are installed in accordance with referenced construction specifications, the referenced method as specified in the ODOT BDM, “CIP piles driven to the indicated UBVs”, may be used to support a total factored load (single pile). It should be noted that if preferred, methods B and C specified in Section 305.3.5.9 of ODOT’s 2023 BDM can also be used to establish driving criteria accounting for the anticipated pile/soil setup.

Pile lengths based on: 1) our Deep Foundation Analysis (presented in Section 5.2.1); 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 6 below. The plan note 606.7-4 “Piles Driven To Full Estimated Length With Pile/Soil Setup” shall be provided in the bridge plan set.

Table 6: Estimated Pile Lengths

Pile Type	Bottom of Pile Cap Elevation (ft amsl)	Assumed Pile Cutoff Elevation (ft amsl)	Required UBV per Pile(kips)	Geotechnical Pile Length (ft)	Geotechnical Pile Tip Elevation (ft amsl)	Estimated Pile Length (ft)	Order Length (ft)	Wait Time (day)
FRA-00270-25.990A (Ramp K over O): Rear Abutment, B-008-0-64 & B-030-0-21								
12-inch CIP	925.7	926.7	236.0	57.2	868.5	60	65	14
FRA-00270-25.990A (Ramp K over O): Forward Abutment, B-001-0-64 & B-031-0-21								
12-inch CIP	928.1	929.1	236.0	58.1	870.0	65	70	14

The capacity check of the pier spread footings was not performed because it's not included in our scope and the bridge designer believes that the pier foundations meet the criteria specified in ODOT BDM Section C401.4. To be cautious, NEAS recommends the pier foundations should be checked for the capacity.

5.2.3. Global Stability

Since only the superstructure of the referenced bridge will be replaced, it is NEAS's opinion that global stability should not be a concern.

5.2.4. Parameters for Lateral Load Analysis

Deep foundation elements subjected to horizontal loads and/or moments should be analyzed for maximum bending moments and lateral deflections. Since axially loaded piles will require negligible moment, battered piles can be considered to resist the lateral loads. The required lateral load capacity can be obtained by increasing the diameter or the embedment depth of the foundation element. The generalized soil parameters, including recommended lateral soil modulus, and soil strain to be used to analyze the laterally loaded shaft by the p-y curve method are presented in Tables 7 and 8 below. Furthermore, a resistance factor of 1.0 should be used when estimating the lateral geotechnical resistance of a single pile or pile group in accordance with LRFD BDS Tables 10.5.5.2.3-1 and 10.5.5.2.4-1.

Table 7: Generalized Soil Parameters for Lateral Load Analysis - B-030-0-21 & B-008-0-64

Layer Number (No.)	Top Elev. (ft)	Bottom Elev. (ft)	Layer Depth (ft)	Soil Class	LPILE p-y Model	Soil Strain Parameter ε50	Soil Modulus Parameter p-y k (pci)
FRA-00270-25.990A (Ramp K over O): Rear Abutment B-030-0-21 & B-008-0-64							
1	937.1	933.6	3.5	A-1-b	Sand (Reese)	-	179
2	933.6	927.6	9.5	A-6a	Soft Clay	0.0172	43
3	927.6	917.6	19.5	A-6b	Stiff Clay w/o Water	0.0079	401
4	917.6	910.1	27	A-4a	Stiff Clay w/o Water	0.0050	1056
5	910.1	905.1	32	A-6b	Stiff Clay w/o Water	0.0052	958
6	905.1	897.1	40	A-6b	Stiff Clay w/o Water	0.0065	611
7	897.1	888.8	48.3	A-4a	Stiff Clay w/o Water	0.0039	2010
8	888.8	874.8	62.3	A-4a	Stiff Clay w/o Water	0.0043	1500
9	874.8	859.8	77.3	A-4a	Stiff Clay w/o Water	0.0037	2291
10	859.8	856.8	80.3	A-4a	Sand (Reese)	-	179

Table 8: Generalized Soil Parameters for Lateral Load Analysis - B-031-0-21 & B-001-0-64

Layer Number (No.)	Top Elev. (ft)	Bottom Elev. (ft)	Layer Depth (ft)	Soil Class	LPILE p-y Model	Soil Strain Parameter ε50	Soil Modulus Parameter p-y k (pci)
FRA-00270-25.990A (Ramp K over O): Forward Abutment B-031-0-21 & B-001-0-64							
1	940.6	937.6	3	A-6a	Stiff Clay w/o Water	0.0104	170
2	937.6	936.1	4.5	A-6b	Stiff Clay w/o Water	0.0095	222
3	936.1	933.1	7.5	A-6a	Stiff Clay w/o Water	0.0082	347
4	933.1	931.1	9.5	A-4a	Stiff Clay w/o Water	0.0077	420
5	931.1	928.6	12	A-6b	Stiff Clay w/o Water	0.0073	500
6	928.6	926.1	14.5	A-6a	Stiff Clay w/o Water	0.0057	792
7	926.1	921.1	19.5	A-6b	Stiff Clay w/o Water	0.0056	833
8	921.1	913.6	27	A-4a	Stiff Clay w/o Water	0.0056	833
9	913.6	900.6	40	A-6b	Stiff Clay w/o Water	0.0050	1067
10	900.6	893.7	46.9	A-4a	Stiff Clay w/o Water	0.0051	986
11	893.7	877.7	62.9	A-4a	Stiff Clay w/o Water	0.0039	1986
12	877.7	865.7	74.9	A-4a	Stiff Clay w/o Water	0.0037	2430
13	865.7	839.7	100.9	A-4a	Stiff Clay w/o Water	0.0036	2667

5.3. Seismic Site Class

Based on the results of the subsurface exploration, laboratory test data, and the AASHTO Site Class Definitions indicated in Table 3.10.3.1-1 of the *LRFD Bridge Design Specifications, 9th Edition* (AASHTO LRFD, 2020), the average Standard Penetration Test blow count $\bar{N}$ is 9.4 blows/ft and 16.4 blows/ft for B-030-0-21 and B-031-0-21, respectively. To be conservative, the bridge site is classified as Site Class of E - Soft Soil, with $0<\bar{N}<15$ blows/ft.

6. QUALIFICATIONS

This investigation was performed in accordance with accepted geotechnical engineering practice for the purpose of characterizing the subsurface conditions at the site of the proposed Bridge FRA-00071-25.990A carrying Ramp K over Ramp O for the FRA-71/270-28.27/25.99A (PID# 105435) project. This report has been prepared for TranSystems, ODOT and their design consultants to be used solely in evaluating the soils underlying the indicated structures and presenting geotechnical engineering recommendations specific to this project. The assessment of general site environmental conditions or the presence of pollutants in the soil, rock and groundwater of the site was beyond the scope of this geotechnical exploration. Our recommendations are based on the results of our field explorations, laboratory test results from representative soil samples, and geotechnical engineering analyses. The results of the field explorations and laboratory tests, which form the basis of our recommendations, are presented in the appendices as noted. This report does not reflect any variations that may occur between the borings or elsewhere on the site, or variations whose nature and extent may not become evident until a later stage of construction. In the event that any changes occur in the nature, design or location of the proposed structural work, the conclusions and recommendations contained in this report should not be considered valid until they are reviewed and have been modified or verified in writing by a geotechnical engineer.

It has been a pleasure to be of service to TranSystems in performing this geotechnical exploration for the FRA-71/270-28.27/25.99A (PID# 105435) project. Please call if there are any questions, or if we can be of further service.

Respectfully Submitted,

STATE OF OHIO
CHUNMEI
HE
E-79190
REGISTERED
PROFESSIONAL ENGINEER

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Project Manager

Zhao Mankoci, Ph.D., P.E.
Geotechnical Engineer

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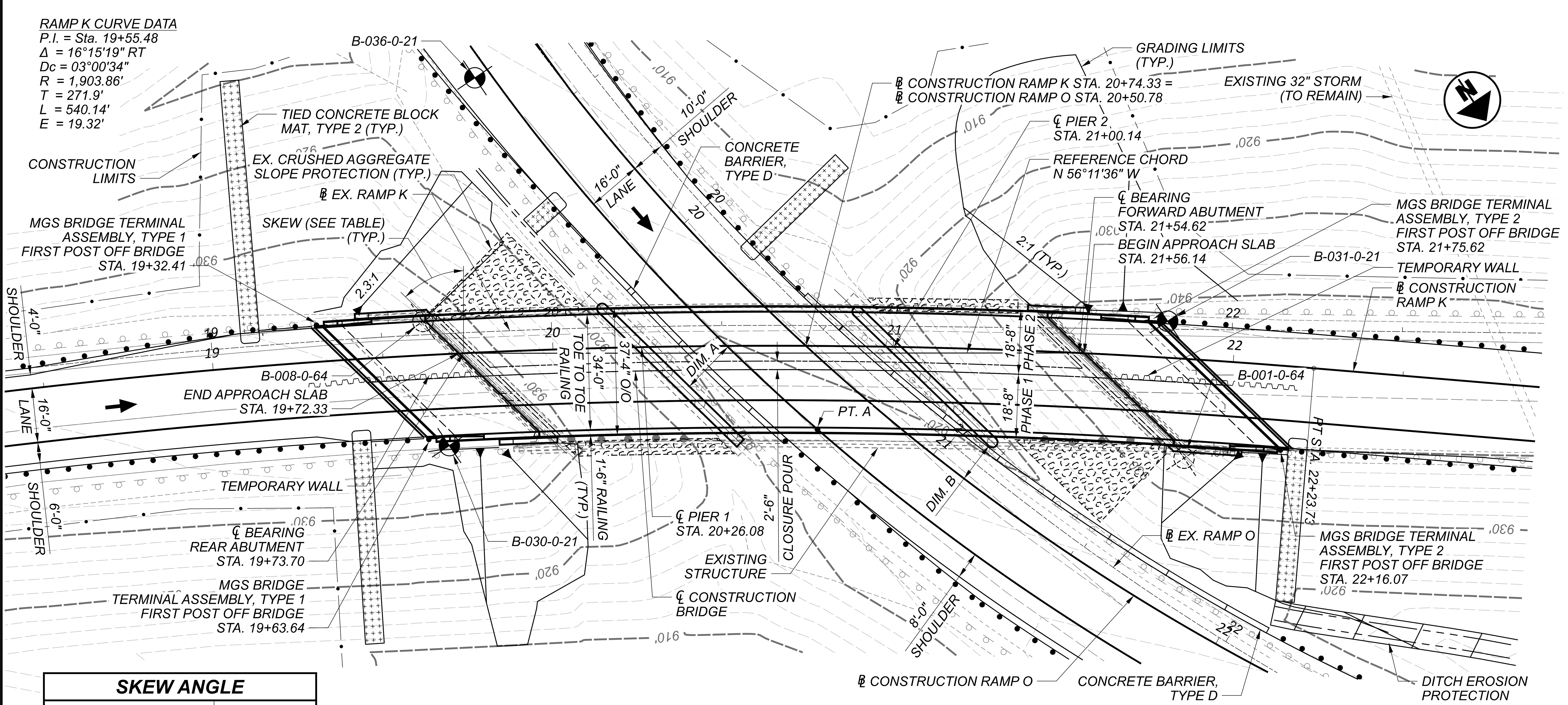
APPENDIX A

SITE PLAN



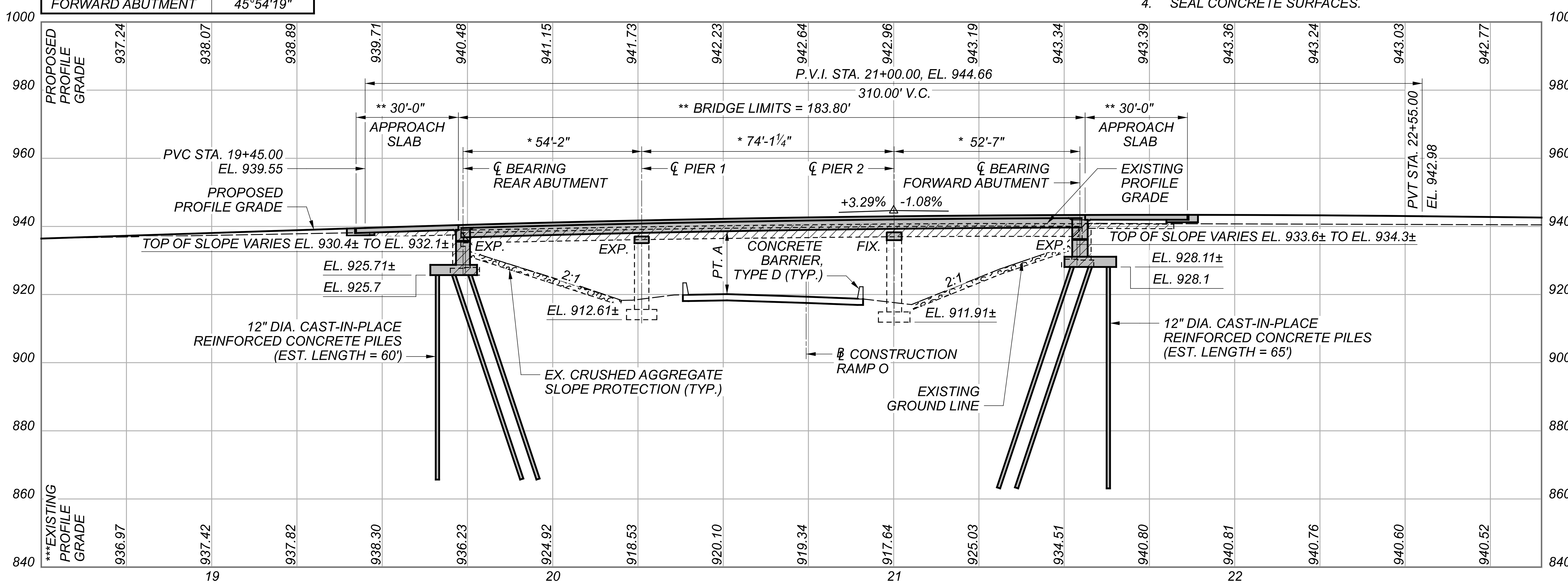
PLAN

SKEW ANGLE

SUBSTRUCTURE UNIT	SKEW ANGLE
REAR ABUTMENT	45°45'11"
PIER 1	45°45'11"
PIER 2	45°54'19"
FORWARD ABUTMENT	45°54'19"

PROPOSED WORK

1. REMOVE AND REPLACE SUPERSTRUCTURE IN PHASES.
2. CONVERT ABUTMENTS TO SEMI-INTEGRAL.
3. MODIFY PIER CAPS.
4. SEAL CONCRETE SURFACES.



PROFILE ALONG ℄ CONSTRUCTION RAMP K

BENCHMARK DATA

BM #1 STA. 155+78.70 (CL EX. IR-71) ELEV. 897.11 , OFFSET 98.04', RT.
BM #2 STA. 133+67.41 (CL EX. IR-71) ELEV. 909.34 , OFFSET 332.20', LT.

FOR ADDITIONAL BENCHMARK INFORMATION, SEE ROADWAY PLAN SHEET P.004.

NOTES:

EARTHWORK LIMITS SHOWN ARE APPROXIMATE. ACTUAL SLOPES SHALL CONFORM TO PLAN CROSS SECTIONS.

ALL EXISTING BRIDGE ELEVATIONS HAVE BEEN ADJUSTED TO THE CURRENT PROJECT SURVEY ELEVATIONS AND ARE APPROXIMATELY 0.99 FEET LOWER THAN THE ELEVATIONS IN THE ORIGINAL PLANS.

DESIGN TRAFFIC:

2023 ADT = 14,720 2023 ADTT = 883
2043 ADT = 16,740 2043 ADTT = 1,004
DIRECTIONAL DISTRIBUTION = N/A

LEGEND:

- PROJECT BORING LOCATION
- HISTORIC BORING LOCATION

* INDICATES MEASURED ALONG REFERENCE CHORD
** INDICATES MEASURED ALONG ℄ CONSTRUCTION RAMP K
*** INDICATES ELEVATION ALONG ℄ CONSTRUCTION RAMP K

LIMITS OF REMOVAL

PROPOSED STRUCTURE

● 16'-6" REQUIRED MINIMUM VERTICAL CLEARANCE

PT. A: 17'-5⅛" ACTUAL MINIMUM VERTICAL CLEARANCE

HORIZONTAL CLEARANCES:
DIM. A: 16'-2½" ACTUAL HORIZONTAL CLEARANCE, 30'-0" REQUIRED
DIM. B: 12'-0½" ACTUAL HORIZONTAL CLEARANCE, 30'-0" REQUIRED

EXISTING STRUCTURE

TYPE: 3 SPAN CONTINUOUS STEEL ROLLED BEAMS WITH REINFORCED CONCRETE DECK AND SUBSTRUCTURE

SPANS: 54.35'±, 75.00'±, 52.50'± C/C BEARINGS MEASURED ALONG REFERENCE TANGENT

ROADWAY: 38'-0"± F/F SAFETY CURB

LOADING: CF=2000(57) ADEQUATE FOR AASHTO ALTERNATE LOADING

SKEW: 46°30'00"± RIGHT FORWARD TO REFERENCE TANGENT

WEARING SURFACE: 1"± MONOLITHIC CONCRETE & 3"± ASPHALT WEARING SURFACE

APPROACH SLABS: 25'-0"± LONG (AS-1-54)

ALIGNMENT: 3°± CURVE RIGHT & TANGENT

SUPERELEVATION: VARIES

STRUCTURE FILE NUMBER: 2511460

DATE BUILT: 1966

DISPOSITION: TO BE REHABILITATED

PROPOSED STRUCTURE

TYPE: NEW 3 SPAN CONTINUOUS CURVED STEEL ROLLED BEAMS (ASTM A709 GRADE 50W) WITH COMPOSITE REINFORCED CONCRETE DECK SUPPORTED ON EXISTING REINFORCED CONCRETE CAP AND COLUMN PIERS ON SPREAD FOOTINGS AND SEMI-INTEGRAL ABUTMENTS ON PILE FOUNDATIONS

SPANS: 54'-2", 74'-1¼" & 52'-7" C/C BEARINGS ALONG REFERENCE CHORD

ROADWAY: 34'-0" TOE/TOE RAILING

LOADING: SEE GENERAL NOTES

SKEW: (SEE TABLE) RIGHT FORWARD TO REFERENCE CHORD

WEARING SURFACE: 1" MONOLITHIC CONCRETE

APPROACH SLABS: 30' LONG, 17" THICK (AS-1-15 & AS-2-15)

ALIGNMENT: 03°00'34" CURVE RIGHT

SUPERELEVATION: 0.040FT/FT

DECK AREA: 6862 SF

COORDINATES: LATITUDE 40°06'39.07" N
LONGITUDE 82°58'28.28" W

SITE PLAN
BRIDGE NO. FRA-00270-25.990A
RAMP K IR-270 WB TO IR-71 SB OVER RAMP O IR-71 NB TO IR-270 WB

SFN	2511460
DESIGN AGENCY	TRANSYSTEMS, 1100 SUPERIOR AVE. E., STE 1000, CLEVELAND, OHIO 44114
DESIGNER	JPD
CHECKER	EA
REVIEWER	NFF 01/24/24
PROJECT ID	105435
SUBSET	1
TOTAL	48
SHEET	P.633
TOTAL	730

FRA-71/270-28.27/25.99A
MODEL: 105435_SFN_2511460_SP001 [Sheet] PAPERSIZE: 34x22 (in.) DATE: 1/31/2024 TIME: 10:21:32 AM USER: btavarello
pw:\\hq-pwint01.a-e.transyscorp.com:transyscorp-pw1\Documents\Projects_2020\CL402\402200080\Agency_Folders\400-Engineering\Structures\SFN_2511460\Sheets\105435_SFN_2511460_SP001.dgn

APPENDIX B

BORING LOGS AND TEST RESULTS

PROJECT: FRA-071/270-28.27/25.99A TYPE: BRIDGE PID: 105435 SFN: 2511460 START: 8/9/22 END: 8/9/22	DRILLING FIRM / OPERATOR: NEAS / J. HODGES SAMPLING FIRM / LOGGER: NEAS / J. HODGES DRILLING METHOD: 3.25" HSA SAMPLING METHOD: SPT	DRILL RIG: CME 75T HAMMER: CME AUTOMATIC CALIBRATION DATE: 1/24/22 ENERGY RATIO (%): 79	STATION / OFFSET: 19+68, 27' RT. ALIGNMENT: RAMP K ELEVATION: 937.1 (MSL) EOB: 40.0 ft. LAT / LONG: 40.110863, -82.974607	EXPLORATION ID B-030-0-21 PAGE 1 OF 2

MATERIAL DESCRIPTION AND NOTES	ELEV. 937.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm
11.0" ASPHALT AND 6.0" BASE (DRILLERS DESCRIPTION)	935.7	1																
LOOSE TO MEDIUM DENSE, BROWN, **GRAVEL WITH SAND**, LITTLE SILT, TRACE CLAY, DAMP		2	6 5 4	12	67	SS-1	-	49	19	12	14	6	NP	NP	NP	7	A-1-b (0)	-
	933.6	3	3 2 2	5	89	SS-2A	-	-	-	-	-	-	-	-	-	7	A-1-b (V)	-
STIFF TO HARD, BROWN, **SILT AND CLAY**, LITTLE TO SOME SAND, TRACE TO LITTLE GRAVEL, SS-2B CONTAINS NO INTACT SOIL FOR HP READINGS, MOIST TO DAMP		4				SS-2B	-	13	10	14	34	29	31	17	14	20	A-6a (7)	-
		5	2 1 1	3	100	SS-3	1.25	-	-	-	-	-	-	-	-	26	A-6a (V)	-
		6–7	1 1 1	3	50	SS-4	4.50	-	-	-	-	-	-	-	-	18	A-6a (V)	-
	927.6	8–9	1 1 1	3	100	SS-5	3.50	-	-	-	-	-	-	-	-	18	A-6a (V)	-
STIFF TO HARD, BROWN MOTTLED WITH GRAY, **SILTY CLAY**, LITTLE TO SOME SAND, TRACE GRAVEL, MOIST		10–11	2 3 5	11	100	SS-6	3.00	4	6	13	40	37	40	18	22	21	A-6b (13)	-
		12–14	1 2 2	5	100	SS-7	1.75	-	-	-	-	-	-	-	-	21	A-6b (V)	-
		15–17	2 4 6	13	100	SS-8	4.25	-	-	-	-	-	-	-	-	24	A-6b (V)	-
	917.6	18–19	2 5 6	14	100	SS-9	4.50	-	-	-	-	-	-	-	-	20	A-6b (V)	-
HARD, BROWN, **SANDY SILT**, SOME STONE FRAGMENTS, TRACE TO LITTLE CLAY, DAMP		20–22	4 10 13	30	100	SS-10	4.50	26	9	11	44	10	21	16	5	8	A-4a (4)	-
SS-11 AND SS-12 BECOME TRACE TO LITTLE GRAVEL		23–24	3 9 10	25	100	SS-11	4.50	-	-	-	-	-	-	-	-	9	A-4a (V)	-
	910.1	25–27	3 7 9	21	100	SS-12	4.50	-	-	-	-	-	-	-	-	12	A-4a (V)	-
HARD, BROWN, **SILTY CLAY**, LITTLE SAND, TRACE GRAVEL, DAMP		28–29	3 7 11	24	72	SS-13	4.50	1	4	13	42	40	40	20	20	19	A-6b (12)	-

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/7/22 14:03 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\FRA-071-270-28.27-25.99 A\GINT FILES\FRA-71-270 REPLACEMENT B

PID: 105435	SFN: 2511460	PROJECT: FRA-071/270-28.27/25.99A	STATION / OFFSET: 19+68, 27' RT.	START: 8/9/22	END: 8/9/22	PG 2 OF 2	B-030-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 907.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
HARD, BROWN, **SILTY CLAY**, LITTLE SAND, TRACE GRAVEL, DAMP *(continued)*		31	3 6 11	22	56	SS-14	4.50	-	-	-	-	-	-	-	-	16	A-6b (V)	-	
		32																	
		33	3 5 8	17	100	SS-15	4.25	-	-	-	-	-	-	-	-	15	A-6b (V)	-	
		34																	
		35																	
		36	5 5 6	14	100	SS-16	4.50	-	-	-	-	-	-	-	-	14	A-6b (V)	-	
		37																	
		38																	
		39	4 5 5	13	100	SS-17	4.50	-	-	-	-	-	-	-	-	15	A-6b (V)	-	
	897.1	EOB 40																	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; PUMPED 50 GAL. BENTONITE GROUT; SHOVELED SOIL CUTTINGS

PROJECT: FRA-071/270-28.27/25.99A	DRILLING FIRM / OPERATOR: NEAS / J. HODGES	DRILL RIG: CME 75T	STATION / OFFSET: 21+80, 11' LT.	EXPLORATION ID B-031-0-21
TYPE: BRIDGE	SAMPLING FIRM / LOGGER: NEAS / J. HODGES	HAMMER: CME AUTOMATIC	ALIGNMENT: RAMP K	
PID: 105435 SFN: 2511460	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 1/24/22	ELEVATION: 940.6 (MSL) EOB: 40.0 ft.	PAGE 1 OF 2
START: 8/9/22 END: 8/9/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 79	LAT / LONG: 40.111100, -82.975308	

MATERIAL DESCRIPTION AND NOTES	ELEV. 940.6
12.0" ASPHALT AND 5.0" BASE (DRILLERS DESCRIPTION)	939.2
HARD, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, MOIST	937.6
VERY STIFF, GRAY AND BROWN, **SILTY CLAY**, SOME SAND, TRACE GRAVEL, MOIST	936.1
STIFF TO VERY STIFF, BROWN, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, DAMP	933.1
HARD, BROWNISH GRAY, **SANDY SILT**, SOME CLAY, LITTLE GRAVEL, DAMP	931.1
HARD, BROWN, **SILTY CLAY**, SOME SAND, LITTLE GRAVEL, DAMP	928.6
HARD, BROWN AND GRAY, **SILT AND CLAY**, SOME SAND, TRACE GRAVEL, DAMP	926.1
HARD, BROWN, **SILTY CLAY**, LITTLE TO SOME SAND, TRACE GRAVEL, DAMP	921.1
HARD, GRAY, **SANDY SILT**, SOME CLAY, TRACE TO LITTLE GRAVEL, DAMP	913.6
VERY STIFF TO HARD, BROWN AND GRAY, **SILTY CLAY**, LITTLE TO SOME SAND, TRACE TO LITTLE GRAVEL, DAMP TO MOIST	

DEPTHS: 1 – 29

SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
3 2 3	7	83	SS-1	4.25	4	8	14	39	35	32	17	15	18	A-6a (10)	-	
3 3 3	8	44	SS-2	4.00	3	10	14	41	32	33	16	17	17	A-6b (10)	-	
2 3 4	9	28	SS-3	1.75	-	-	-	-	-	-	-	-	17	A-6a (V)	-	
3 4 4	11	33	SS-4	2.25	-	-	-	-	-	-	-	-	13	A-6a (V)	-	
2 3 5	11	100	SS-5	4.50	13	13	16	34	24	25	16	9	11	A-4a (5)	-	
3 4 5	12	100	SS-6	4.25	41	6	10	14	29	33	17	16	15	A-6b (3)	-	
4 5 7	16	94	SS-7	4.50	10	14	16	36	24	27	16	11	12	A-6a (5)	-	
4 6 9	20	100	SS-8	4.25	4	7	12	41	36	34	17	17	16	A-6b (11)	-	
6 7 8	20	100	SS-9	4.50	-	-	-	-	-	-	-	-	10	A-6b (V)	-	
6 8 10	24	100	SS-10	4.50	-	-	-	-	-	-	-	-	8	A-4a (V)	-	
5 5 7	16	33	SS-11	4.50	7	12	18	38	25	23	14	9	9	A-4a (6)	-	
3 5 10	20	22	SS-12	4.50	-	-	-	-	-	-	-	-	9	A-4a (V)	-	
5 7 8	20	50	SS-13	4.00	-	-	-	-	-	-	-	-	20	A-6b (V)	-	

STANDARD ODOT LOG W/ SULFATES (8.5 X 11) - OH DOT.GDT - 9/7/22 14:03 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\FRA-071-270-28.27-25.99 A\GINT FILES\FRA-71-270 REPLACEMENT B

PID: 105435	SFN: 2511460	PROJECT: FRA-071/270-28.27/25.99A	STATION / OFFSET: 21+80, 11' LT.	START: 8/9/22	END: 8/9/22	PG 2 OF 2	B-031-0-21

MATERIAL DESCRIPTION AND NOTES	ELEV. 910.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
VERY STIFF TO HARD, BROWN AND GRAY, **SILTY CLAY**, LITTLE TO SOME SAND, TRACE TO LITTLE GRAVEL, DAMP TO MOIST *(continued)*		31	6 8 11	25	78	SS-14	4.50	2	7	15	37	39	37	19	18	17	A-6b (11)	-	
		32																	
		33 / 34	5 10 14	32	44	SS-15	4.50	-	-	-	-	-	-	-	-	16	A-6b (V)	-	
		35 / 36	6 8 12	26	39	SS-16	4.50	-	-	-	-	-	-	-	-	21	A-6b (V)	-	
		37 / 38																	
	900.6	39 / EOB 40	6 9 10	25	44	SS-17	4.50	-	-	-	-	-	-	-	-	21	A-6b (V)	-	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. HOLE DID NOT CAVE.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PLACED 0.5 BAG ASPHALT PATCH; PUMPED 50 GAL. BENTONITE GROUT; SHOVELED SOIL CUTTINGS

Ramp K

A

LOG OF BORING

Date Started 4-8-64
Date Completed 4-10-64
Boring No. B-1
Sampler Type SS Dia. 1 3/8"
Casing: Length 25' Dia. 3 1/2"
Station & Offset 11+85, 34' Rt (FORWARD ABUTMENT)
Water Elev.
Surface Elev. 905.7'

Elev.	Depth	Std. Pen. (N)	Rec. ft.	Loss ft.	Description	Sample No.	% Agg	% C.S.	% F.S.	% Silt	% Clay	L.L.	P.I.	W.C.	SHTL Class.
905.7	0														
	2														
	4														
900.7	6	9/10			Brown Gravelly Sandy Silt	1	18	11	10	29	32	26	8	15	A-4a
898.2	8	11/13			Brown Sandy Silt	2	11	12	15	31	31	26	7	13	A-4a
895.7	10	14/14			Gray Sandy Gravelly Silt	3	28	10	6	32	24	22	7	9	A-4a
893.2	12–14	19/24			Gray Sandy Gravelly Silt	4	V	I	S	U	A	L			V/S
890.7	16	22/27			Gray Sandy Gravelly Silt	5	~~V~~	~~I~~	~~S~~	~~U~~	~~A L~~	~~24~~	~~8~~	~~9~~	V/S
888.2	18	24/24			Gray Clayey Silt	6	0	5	10	36	49	29	10	14	A-4a
885.7	20–22	23/29			Gray Gravelly Clay	7	14	5	3	37	41	45	27	14	A-7-6
883.2	24	20/24			Gray Sandy Silt	8	12	7	9	33	39	26	9	13	A-4a
880.7	26	23/27			Gray Gravelly Sandy Silt	9	17	9	13	27	34	24	7	13	A-4a
	28														
875.7	30–32	29/39			Gray Sandy Gravelly Silt	10	21	11	5	35	28	24	6	11	A-4a
	34														
870.7	36	25/30			Gray Sandy Silt	11	12	9	15	33	31	22	7	12	A-4a
	38														
865.7	40–42	35/41			Gray Sandy Silt	~~12~~	~~11~~	~~11~~	~~15~~	~~35~~	~~28~~	23	8	11	A-4a
	44														
860.7	46	23/26			Gray Sandy Gravelly Silt	13	18	9	6	38	29	22	6	10	A-4a
	48														
855.7	50–52	10/12			Gray Sandy Clay	14	9	10	16	37	28	29	13	14	A-6a
	54														
850.7	56	40/47			Gray Sandy Gravelly Silt	15	24	8	15	29	24	22	8	9	A-4a
	58														
845.7	60–62	39/53			Gray Gravelly Sandy Silt	16	15	7	9	40	29	21	7	8	A-4a
	64														
840.7 / 839.7	66	35/44			Gray Gravelly Sandy Silt	17	17	6	17	32	28	20	5	9	A-4a

BOTTOM OF BORING

LOG OF BORING

Date Started [illegible]
Date Completed [illegible]
Boring No. B-3
Sampler Type SS Dia. 1 3/8"
Casing: Length 25' Dia. 3 1/2"
Station & Offset 9+62, 6' Lt. (REAR ABUTMENT)
Water Elev. ______
Surface Elev. 907.8'

Elev.	Depth	Std. Pen. (N)	Rec. ft.	Loss ft.	Description	Sample No.	% Agg	% C.S.	% F.S.	% Silt	% Clay	L.L.	Pl.	W. C.	SHTL Class.
907.8	0														
	2														
	4														
902.8	6	9/10			Brown and Gray Sandy Gravelly Silt	1	39	8	11	9	33	27	9	15	
900.3	8	11/11			Brown Sandy Silt	2	7	10	7	42	34	24	7	13	
897.8	10	31/43			Gray Sand and Boulders	3	V	I	S	U	A	L			
895.3	12, 14	34/10			Gray Silty Sandy Gravel	4	V	I	S	U	A	L		12	
892.8	16	11/14			Gray Sandy Silt	5	13	10	15	33	29	22	5	13	
890.3	18	37/13			Boulders	6	V	I	S	U	A	L			
887.8	20	16/24			Gray Sandy Clay	7	V	I	S	U	A L	23	11	9	
885.3	22, 24	16/21			Gray Gravelly Silt	8	V	I	S	U	A L	23	7	13	
882.8	26	15/21			Gray Sandy Gravelly Silt	9	24	8	13	31	24	23	9	12	
	28														
877.8	30, 32	14/19			Gray Gravelly Sandy Silt	10	16	12	9	39	24	20	5	11	
	34														
872.8	36	20/31			Gray Gravelly Sandy Silt	11	V	I	S	U	A L	22	6	9	
	38														
867.8	40, 42	23/34			Gray Gravelly Sandy Silt	12	V	I	S	U	A L	22	6	10	
	44														
862.8	46	29/37			Gray Gravelly Sandy Silt	13	V	I	S	U	A L			11	
	48														
857.8	50														
856.8		32/41			Gray Gravelly Sandy Silt	14	16	10	25	38	11	NP	NP	13	

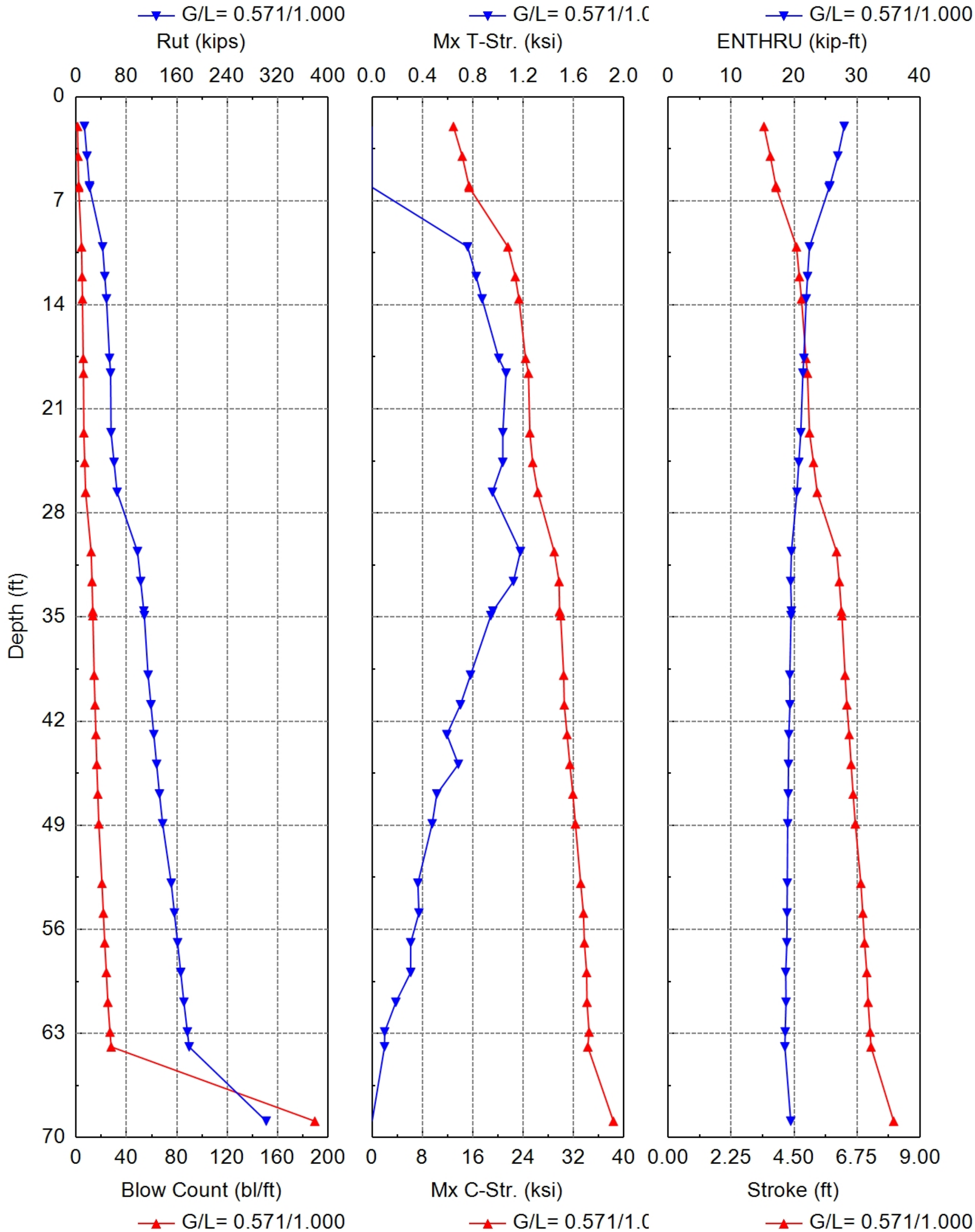
BOTTOM OF BORING

APPENDIX C

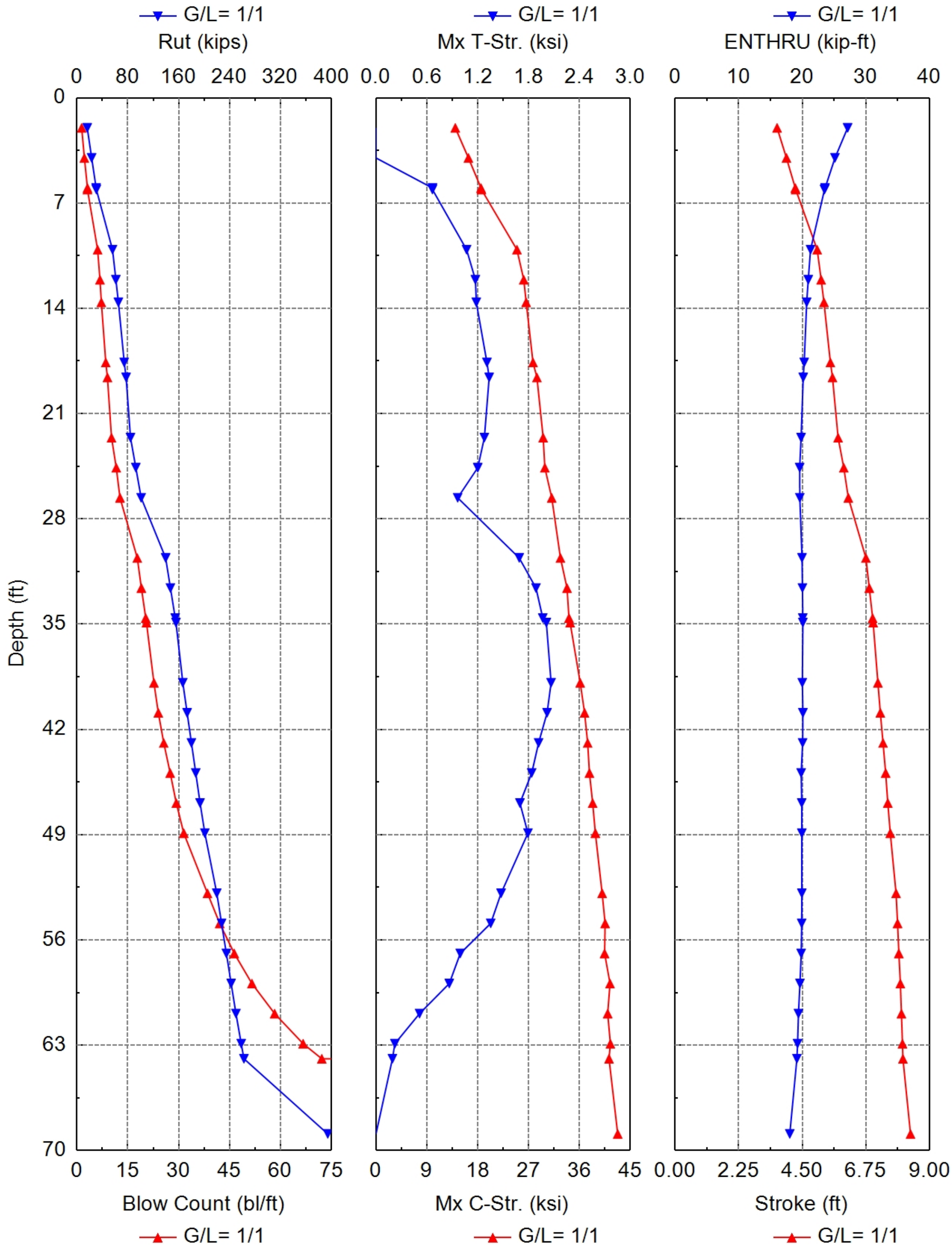
DEEP FOUNDATION ANALYSIS

REAR ABUTMENT

Driveability Analysis Summary



Driveability Analysis Summary



Gain/Loss Factor at Shaft/Toe = 0.571/1.000

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
2.0	13.2	4.0	9.2	1.1	12.908	0.000	3.42	28.0	D 19-32
4.0	17.2	8.0	9.2	1.5	14.315	0.000	3.65	27.0	D 19-32
6.0	21.2	12.0	9.2	2.0	15.384	0.000	3.85	25.7	D 19-32
6.1	21.4	12.2	9.2	2.0	15.432	0.000	3.86	25.6	D 19-32
10.1	42.0	19.7	22.3	4.3	21.565	0.758	4.59	22.5	D 19-32
12.1	45.6	23.3	22.3	4.7	22.741	0.826	4.69	22.1	D 19-32
13.6	48.2	26.0	22.3	5.0	23.320	0.873	4.77	21.9	D 19-32
17.6	53.0	32.9	20.1	5.6	24.373	1.006	4.92	21.6	D 19-32
18.6	54.7	34.6	20.1	5.8	24.835	1.064	4.98	21.4	D 19-32
22.6	55.5	42.8	12.7	6.1	25.053	1.038	5.05	21.1	D 19-32
24.6	60.3	47.5	12.7	6.8	25.503	1.038	5.19	20.7	D 19-32
26.6	65.1	52.3	12.7	7.5	26.320	0.956	5.33	20.5	D 19-32
30.6	97.5	62.1	35.3	11.9	28.926	1.178	6.02	19.6	D 19-32
32.6	102.5	67.2	35.3	12.6	29.691	1.122	6.12	19.5	D 19-32
34.6	107.5	72.2	35.3	13.2	29.782	0.959	6.19	19.6	D 19-32
34.9	108.3	73.0	35.3	13.3	29.944	0.943	6.21	19.5	D 19-32
38.9	114.3	82.5	31.8	14.3	30.432	0.782	6.32	19.3	D 19-32
40.9	118.8	87.0	31.8	15.0	30.525	0.701	6.39	19.3	D 19-32
42.9	123.4	91.6	31.8	15.7	30.967	0.593	6.47	19.2	D 19-32
44.9	127.9	96.1	31.8	16.4	31.411	0.685	6.54	19.1	D 19-32
46.9	132.4	100.6	31.8	17.2	31.893	0.513	6.61	19.1	D 19-32
48.9	137.4	105.6	31.8	18.0	32.294	0.477	6.69	19.0	D 19-32
52.9	151.1	115.8	35.3	20.5	33.131	0.363	6.89	18.9	D 19-32
54.9	156.1	120.8	35.3	21.6	33.567	0.371	6.96	18.9	D 19-32
56.9	161.2	125.8	35.3	22.7	33.719	0.306	7.02	18.9	D 19-32
58.9	166.2	130.8	35.3	24.0	34.077	0.306	7.10	18.7	D 19-32
60.9	171.2	135.9	35.3	25.2	34.136	0.188	7.15	18.7	D 19-32
62.9	176.7	141.4	35.3	26.9	34.462	0.099	7.22	18.6	D 19-32
63.9	179.6	144.2	35.3	27.8	34.266	0.098	7.25	18.5	D 19-32
68.9	302.0	182.8	119.2	189.6	38.324	0.000	8.06	19.5	D 19-32

Total driving time: 29 minutes; Total Number of Blows: 1304 (starting at penetration 2.0 ft)

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

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
2.0	16.2	7.0	9.2	1.4	14.029	0.000	3.61	27.1	D 19-32

4.0	23.2	14.0	9.2	2.2	16.359	0.000	3.94	25.2	D 19-32
6.0	30.2	21.0	9.2	3.1	18.576	0.667	4.25	23.6	D 19-32
6.1	30.5	21.4	9.2	3.1	18.658	0.666	4.27	23.5	D 19-32
10.1	55.9	33.7	22.3	6.1	24.935	1.069	5.03	21.3	D 19-32
12.1	61.3	39.0	22.3	6.8	26.147	1.173	5.17	20.9	D 19-32
13.6	65.2	43.0	22.3	7.2	26.575	1.183	5.27	20.7	D 19-32
17.6	74.4	54.2	20.1	8.5	27.778	1.309	5.50	20.3	D 19-32
18.6	77.3	57.2	20.1	9.0	28.474	1.335	5.57	20.2	D 19-32
22.6	84.2	71.5	12.7	10.2	29.580	1.279	5.77	19.8	D 19-32
24.6	92.6	79.9	12.7	11.6	29.874	1.200	5.97	19.6	D 19-32
26.6	101.0	88.3	12.7	12.7	31.095	0.963	6.13	19.6	D 19-32
30.6	139.5	104.2	35.3	17.8	32.636	1.689	6.75	20.0	D 19-32
32.6	147.1	111.7	35.3	19.0	33.796	1.887	6.87	20.0	D 19-32
34.6	154.6	119.3	35.3	20.3	34.145	1.968	6.99	20.1	D 19-32
34.9	155.7	120.4	35.3	20.5	34.344	2.009	7.01	20.1	D 19-32
38.9	166.5	134.7	31.8	22.7	36.134	2.066	7.18	20.0	D 19-32
40.9	173.3	141.5	31.8	24.0	36.902	2.018	7.26	20.1	D 19-32
42.9	180.1	148.3	31.8	25.6	37.450	1.918	7.36	20.1	D 19-32
44.9	186.9	155.1	31.8	27.5	37.763	1.837	7.45	19.8	D 19-32
46.9	193.7	161.9	31.8	29.3	38.332	1.698	7.53	19.9	D 19-32
48.9	201.1	169.3	31.8	31.5	38.812	1.792	7.62	19.9	D 19-32
52.9	219.9	184.6	35.3	38.5	40.011	1.475	7.82	19.9	D 19-32
54.9	227.5	192.1	35.3	42.1	40.539	1.353	7.87	19.9	D 19-32
56.9	235.0	199.7	35.3	46.4	40.449	0.994	7.92	19.8	D 19-32
58.9	242.6	207.2	35.3	51.6	41.409	0.864	7.97	19.6	D 19-32
60.9	250.1	214.8	35.3	58.3	40.992	0.514	8.01	19.4	D 19-32
62.9	258.4	223.0	35.3	66.7	41.469	0.223	8.05	19.3	D 19-32
63.9	262.6	227.3	35.3	72.2	41.228	0.194	8.06	19.2	D 19-32
68.9	394.5	275.3	119.2	9999.0	42.770	0.000	8.33	18.0	D 19-32

Refusal occurred; no driving time output possible.

GRLWEAP: Wave Equation Analysis of Pile Foundations

Ramp K over O Br + RB B30 1/11/2024
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	1.3	0.0	1.11	11.70
8.1	Clay	110.0	1.3	0.0	1.11	11.70
8.1	Clay	115.0	3.1	0.0	0.85	28.35
15.6	Clay	115.0	3.1	0.0	0.85	28.35
15.6	Clay	115.0	2.8	0.0	0.94	25.65
20.6	Clay	115.0	2.8	0.0	0.94	25.65
20.6	Clay	112.0	1.8	0.0	1.33	16.20
28.6	Clay	112.0	1.8	0.0	1.33	16.20
28.6	Clay	125.0	5.0	0.0	1.20	45.00
36.9	Clay	125.0	5.0	0.0	1.20	45.00
36.9	Clay	120.0	4.5	0.0	1.12	40.50
50.9	Clay	120.0	4.5	0.0	1.12	40.50
50.9	Clay	130.0	5.0	0.0	1.25	45.00
65.9	Clay	130.0	5.0	0.0	1.25	45.00
65.9	Sand	130.0	0.0	36.0	4.07	151.75
68.9	Sand	130.0	0.0	36.0	4.27	151.75

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	68.900	Pile Penetration: (ft)	68.900
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
68.9	9.2	30,000.0	492.0	3.1	0

HAMMER INPUT

ID	40	Made By:	DELMAG
Model	D 19-32	Type:	OED

Hammer Data

ID	Ram Wt	Ram L.	Ram Ar.	Rtd. Stk	Effic.	Rtd. Energy
-	kips	in	in²	ft	-	kip-ft
40	4.000	129.1	124.7	10.6	0.80	42.4

DRIVE SYSTEM FOR DELMAG D 19-32-OED

Type	X-Area	E-Modulus	Thickness	COR	Round-out	Stiffness
-	in²	ksi	in	-	in	kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.550
Helmet Wt.	1.900	kips				

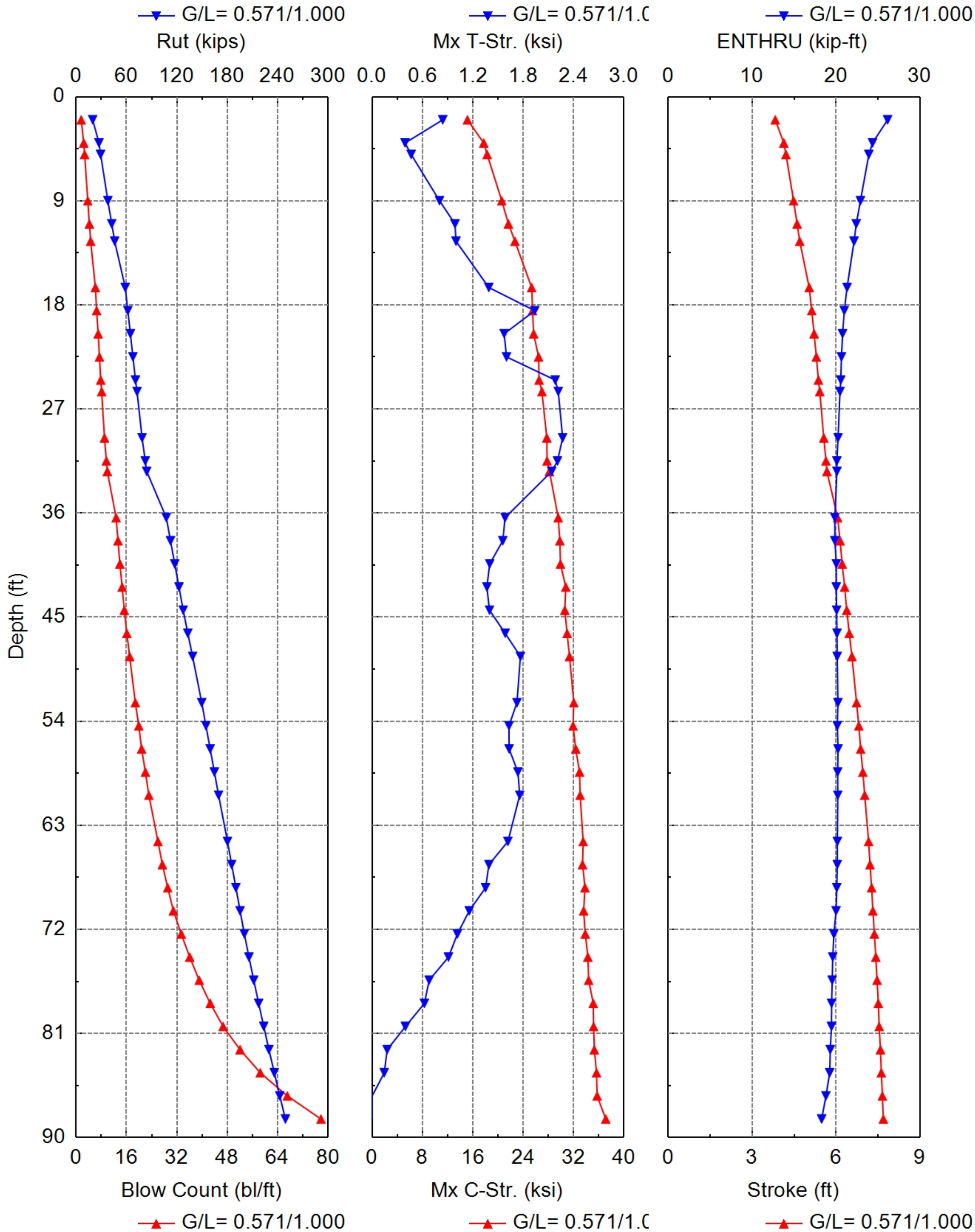
SOIL RESISTANCE DISTRIBUTION

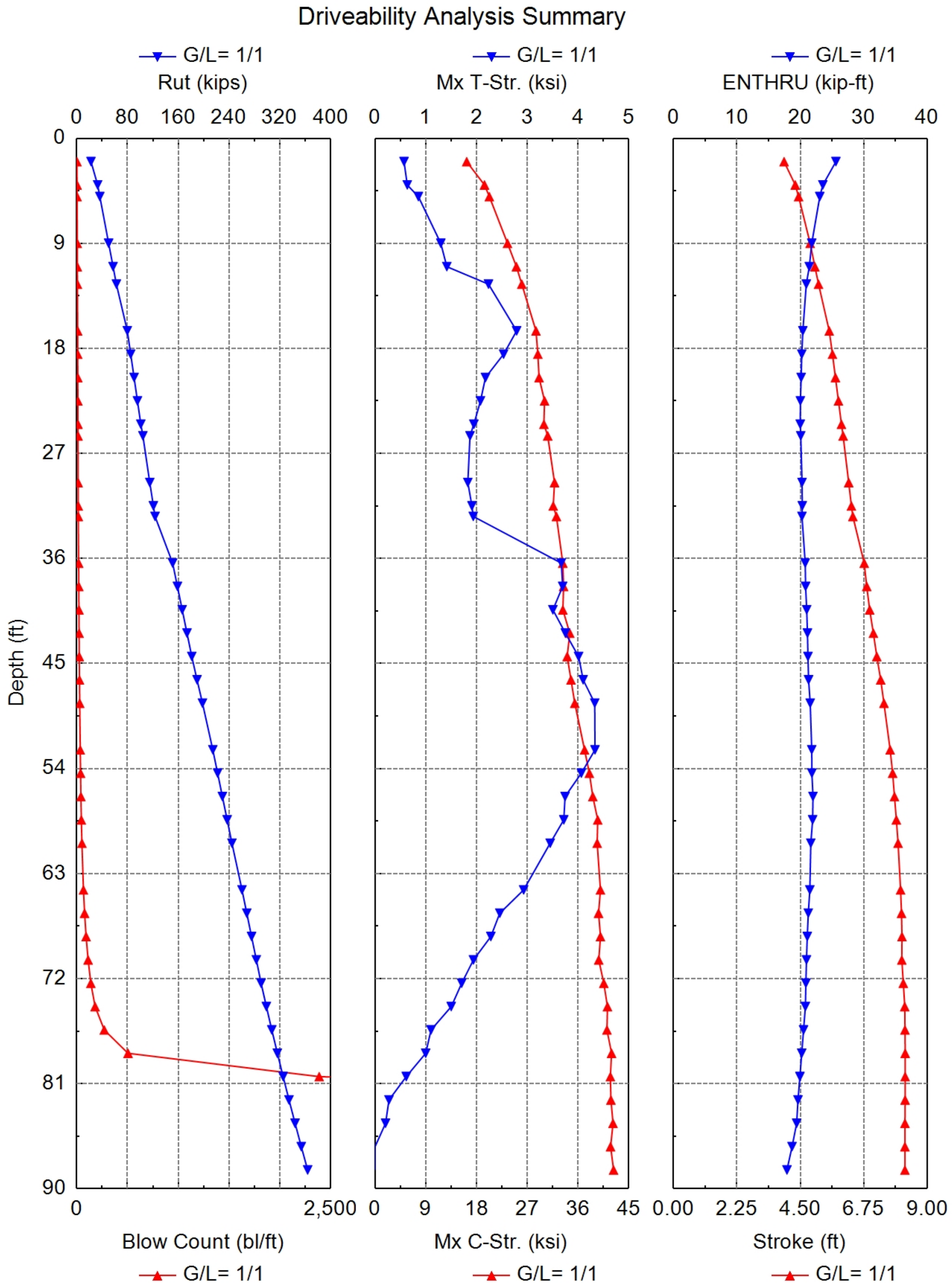
Depth	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	1.1	11.7	0.10	0.13	0.20	0.15	1.8	6.0	168.0	113.1
2.0	1.1	11.7	0.10	0.13	0.20	0.15	1.8	6.0	168.0	113.1
4.1	1.1	11.7	0.10	0.13	0.20	0.15	1.8	6.0	168.0	113.1
6.1	1.1	11.7	0.10	0.13	0.20	0.15	1.8	6.0	168.0	113.1
8.1	1.1	11.7	0.10	0.13	0.20	0.15	1.8	6.0	168.0	113.1
8.1	0.8	28.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
10.0	0.8	28.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
11.9	0.8	28.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
13.7	0.8	28.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
15.6	0.8	28.3	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
15.6	0.9	25.6	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
17.3	0.9	25.6	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
18.9	0.9	25.6	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
20.6	0.9	25.6	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
20.6	1.3	16.2	0.10	0.12	0.20	0.15	1.8	6.0	168.0	113.1
22.6	1.3	16.2	0.10	0.12	0.20	0.15	1.8	6.0	168.0	113.1
24.6	1.3	16.2	0.10	0.12	0.20	0.15	1.8	6.0	168.0	113.1
26.6	1.3	16.2	0.10	0.12	0.20	0.15	1.8	6.0	168.0	113.1
28.6	1.3	16.2	0.10	0.12	0.20	0.15	1.8	6.0	168.0	113.1
28.6	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
30.3	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
31.9	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
33.6	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
35.2	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
36.9	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
36.9	1.1	40.5	0.10	0.10	0.15	0.15	1.5	6.0	168.0	113.1
38.7	1.1	40.5	0.10	0.10	0.15	0.15	1.5	6.0	168.0	113.1
40.4	1.1	40.5	0.10	0.10	0.15	0.15	1.5	6.0	168.0	113.1
42.2	1.1	40.5	0.10	0.10	0.15	0.15	1.5	6.0	168.0	113.1
43.9	1.1	40.5	0.10	0.10	0.15	0.15	1.5	6.0	168.0	113.1
45.7	1.1	40.5	0.10	0.10	0.15	0.15	1.5	6.0	168.0	113.1

47.4	1.1	40.5	0.10	0.10	0.15	0.15	1.5	6.0	168.0	113.1
49.2	1.1	40.5	0.10	0.10	0.15	0.15	1.5	6.0	168.0	113.1
50.9	1.1	40.5	0.10	0.10	0.15	0.15	1.5	6.0	168.0	113.1
50.9	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
52.6	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
54.2	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
55.9	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
57.6	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
59.2	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
60.9	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
62.6	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
64.2	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
65.9	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
65.9	4.1	151.8	0.10	0.11	0.10	0.15	1.2	6.0	24.0	113.1
67.4	4.2	151.8	0.10	0.11	0.10	0.15	1.2	6.0	24.0	113.1
68.9	4.3	151.8	0.10	0.11	0.10	0.15	1.2	6.0	24.0	113.1

FORWARD ABUTMENT

Driveability Analysis Summary




Driveability Analysis Summary
G/L= 1/1
Rut (kips)
0 80 160 240 320 400
G/L= 1/1
Mx T-Str. (ksi)
0 1 2 3 4 5
G/L= 1/1
ENTHRU (kip-ft)
0 10 20 30 40
Depth (ft)
0 9 18 27 36 45 54 63 72 81 90
0 2,500
Blow Count (bl/ft)
G/L= 1/1
0 9 18 27 36 45
Mx C-Str. (ksi)
G/L= 1/1
0.00 2.25 4.50 6.75 9.00
Stroke (ft)
G/L= 1/1

Gain/Loss Factor at Shaft/Toe = 0.571/1.000

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
2.0	19.7	5.5	14.1	1.6	15.134	0.841	3.83	26.1	D 19-32
4.0	27.2	9.5	17.7	2.4	17.724	0.392	4.13	24.3	D 19-32
5.0	29.2	11.5	17.7	2.7	18.270	0.465	4.21	23.9	D 19-32
9.0	37.8	20.1	17.7	3.7	20.592	0.803	4.48	22.9	D 19-32
11.0	42.4	24.7	17.7	4.2	21.654	0.987	4.61	22.4	D 19-32
12.5	45.9	28.2	17.7	4.6	22.683	0.999	4.70	22.1	D 19-32
16.5	58.5	35.9	22.6	6.1	25.340	1.390	5.04	21.3	D 19-32
18.5	61.6	38.9	22.6	6.5	25.478	1.938	5.13	21.0	D 19-32
20.5	64.6	42.0	22.6	7.0	25.657	1.573	5.22	20.8	D 19-32
22.5	67.7	45.0	22.6	7.4	26.442	1.601	5.30	20.6	D 19-32
24.5	70.7	48.1	22.6	7.8	26.521	2.181	5.37	20.6	D 19-32
25.5	72.6	49.9	22.6	8.1	26.972	2.218	5.42	20.5	D 19-32
29.5	78.5	57.7	20.9	9.0	27.745	2.270	5.56	20.2	D 19-32
31.5	82.4	61.5	20.9	9.6	27.782	2.208	5.64	20.1	D 19-32
32.4	84.1	63.2	20.9	9.9	28.170	2.139	5.67	20.1	D 19-32
36.4	107.4	72.1	35.3	12.7	29.564	1.584	6.06	19.9	D 19-32
38.4	112.5	77.1	35.3	13.3	29.819	1.556	6.14	19.9	D 19-32
40.4	117.5	82.1	35.3	13.9	29.913	1.401	6.22	20.0	D 19-32
42.4	122.5	87.2	35.3	14.6	30.764	1.367	6.31	20.0	D 19-32
44.4	127.5	92.2	35.3	15.3	30.602	1.398	6.38	20.1	D 19-32
46.4	133.1	97.7	35.3	16.1	30.980	1.585	6.47	20.1	D 19-32
48.4	138.8	103.4	35.3	17.0	31.353	1.767	6.57	20.1	D 19-32
52.4	149.6	114.3	35.3	18.8	32.034	1.725	6.73	20.2	D 19-32
54.4	154.7	119.3	35.3	19.9	31.919	1.630	6.81	20.1	D 19-32
56.4	159.7	124.4	35.3	20.8	32.339	1.632	6.88	20.2	D 19-32
58.4	164.7	129.4	35.3	22.0	32.953	1.737	6.96	20.2	D 19-32
60.4	169.8	134.4	35.3	23.1	33.039	1.758	7.02	20.2	D 19-32
64.4	180.3	145.0	35.3	26.0	33.524	1.617	7.16	20.2	D 19-32
66.4	185.3	150.0	35.3	27.4	33.427	1.391	7.22	20.1	D 19-32
68.4	190.4	155.0	35.3	29.1	33.816	1.351	7.27	20.1	D 19-32
70.4	195.4	160.0	35.3	30.9	33.596	1.156	7.32	20.0	D 19-32
72.4	200.4	165.1	35.3	33.4	33.864	1.016	7.37	19.7	D 19-32
74.4	205.9	170.6	35.3	36.1	34.273	0.909	7.42	19.6	D 19-32
76.4	211.6	176.3	35.3	39.1	34.401	0.679	7.47	19.5	D 19-32
78.4	217.5	182.2	35.3	42.6	35.124	0.622	7.51	19.5	D 19-32
80.4	223.5	188.2	35.3	46.7	35.184	0.397	7.54	19.5	D 19-32
82.4	229.7	194.4	35.3	52.1	35.297	0.179	7.59	19.3	D 19-32

84.4	236.1	200.8	35.3	58.5	35.647	0.144	7.62	19.2	D 19-32
86.4	242.6	207.3	35.3	67.1	35.742	0.000	7.66	18.8	D 19-32
88.4	249.3	214.0	35.3	77.8	37.112	0.000	7.69	18.3	D 19-32

Total driving time: 40 minutes; Total Number of Blows: 1768 (starting at penetration 2.0 ft)

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

Depth	Rut	Rshaft	Rtoe	Blow Ct	Mx C-Str	Mx T-Str.	Stroke	ENTHRU	Hammer
ft	kips	kips	kips	bl/ft	ksi	ksi	ft	kip-ft	-
2.0	22.5	8.3	14.1	1.9	16.247	0.570	3.93	25.6	D 19-32
4.0	32.9	15.3	17.7	3.1	19.407	0.635	4.32	23.6	D 19-32
5.0	36.4	18.7	17.7	3.5	20.274	0.853	4.44	23.1	D 19-32
9.0	50.3	32.6	17.7	5.2	23.493	1.295	4.85	21.8	D 19-32
11.0	57.3	39.6	17.7	6.0	25.070	1.414	5.02	21.4	D 19-32
12.5	62.5	44.8	17.7	6.6	26.025	2.235	5.15	20.9	D 19-32
16.5	79.7	57.1	22.6	8.9	28.538	2.790	5.53	20.4	D 19-32
18.5	85.0	62.4	22.6	9.7	28.867	2.533	5.64	20.2	D 19-32
20.5	90.4	67.8	22.6	10.4	29.086	2.176	5.75	20.1	D 19-32
22.5	95.7	73.1	22.6	11.2	30.056	2.077	5.85	20.0	D 19-32
24.5	101.0	78.4	22.6	11.9	29.940	1.947	5.96	20.0	D 19-32
25.5	104.3	81.7	22.6	12.3	30.620	1.871	6.02	20.1	D 19-32
29.5	115.1	94.3	20.9	13.7	31.827	1.828	6.22	20.3	D 19-32
31.5	120.9	100.0	20.9	14.5	31.592	1.909	6.31	20.3	D 19-32
32.4	123.4	102.6	20.9	14.9	32.163	1.935	6.37	20.3	D 19-32
36.4	151.2	115.9	35.3	18.8	33.294	3.671	6.77	20.8	D 19-32
38.4	158.7	123.4	35.3	20.1	33.439	3.697	6.86	20.8	D 19-32
40.4	166.3	130.9	35.3	21.5	33.302	3.504	6.96	21.0	D 19-32
42.4	173.8	138.5	35.3	23.1	34.534	3.751	7.09	21.1	D 19-32
44.4	181.4	146.0	35.3	24.8	34.072	4.011	7.22	21.2	D 19-32
46.4	189.7	154.3	35.3	27.0	34.745	4.101	7.35	21.3	D 19-32
48.4	198.2	162.9	35.3	29.2	35.419	4.329	7.47	21.6	D 19-32
52.4	214.5	179.2	35.3	34.6	37.155	4.334	7.69	21.8	D 19-32
54.4	222.1	186.7	35.3	37.7	38.008	4.065	7.78	21.8	D 19-32
56.4	229.6	194.3	35.3	40.9	38.617	3.744	7.84	22.0	D 19-32
58.4	237.2	201.8	35.3	45.1	39.492	3.718	7.91	21.9	D 19-32
60.4	244.7	209.4	35.3	51.0	39.396	3.451	7.97	21.7	D 19-32
64.4	260.5	225.2	35.3	65.9	39.969	2.928	8.06	21.5	D 19-32
66.4	268.1	232.7	35.3	77.4	39.639	2.458	8.09	21.3	D 19-32
68.4	275.6	240.3	35.3	92.2	39.980	2.281	8.11	21.1	D 19-32
70.4	283.1	247.8	35.3	112.2	39.674	1.939	8.10	21.0	D 19-32

72.4	290.7	255.3	35.3	138.7	40.568	1.707	8.16	20.9	D 19-32
74.4	299.0	263.6	35.3	181.2	41.219	1.501	8.21	20.8	D 19-32
76.4	307.5	272.2	35.3	271.5	41.123	1.103	8.21	20.5	D 19-32
78.4	316.3	281.0	35.3	505.3	41.947	0.998	8.22	20.2	D 19-32
80.4	325.4	290.0	35.3	2389.5	41.734	0.614	8.22	19.9	D 19-32
82.4	334.7	299.3	35.3	9999.0	41.827	0.274	8.22	19.6	D 19-32
84.4	344.2	308.9	35.3	9999.0	42.210	0.207	8.21	19.4	D 19-32
86.4	354.0	318.7	35.3	9999.0	41.772	0.000	8.21	18.7	D 19-32
88.4	364.1	328.7	35.3	9999.0	42.306	0.000	8.21	17.9	D 19-32

Refusal occurred; no driving time output possible.

GRLWEAP: Wave Equation Analysis of Pile Foundations

Ramp K over O Br + FB B31 1/12/2024
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	112.0	2.0	0.0	1.32	18.00
2.0	Clay	112.0	2.0	0.0	1.32	18.00
2.0	Clay	115.0	2.5	0.0	1.11	22.50
7.0	Clay	115.0	2.5	0.0	1.11	22.50
7.0	Clay	115.0	2.5	0.0	1.11	22.50
14.5	Clay	115.0	2.5	0.0	1.11	22.50
14.5	Clay	115.0	3.2	0.0	0.90	28.80
27.5	Clay	115.0	3.2	0.0	0.90	28.80
27.5	Clay	115.0	2.9	0.0	0.91	26.55
34.4	Clay	115.0	2.9	0.0	0.91	26.55
34.4	Clay	125.0	5.0	0.0	1.26	45.00
50.4	Clay	125.0	5.0	0.0	1.26	45.00
50.4	Clay	130.0	5.0	0.0	1.22	45.00
62.4	Clay	130.0	5.0	0.0	1.22	45.00
62.4	Clay	130.0	5.0	0.0	1.36	45.00
88.4	Clay	130.0	5.0	0.0	1.36	45.00

PILE INPUT

Uniform Pile		Pile Type:	Closed-End Pipe
Pile Length: (ft)	88.400	Pile Penetration: (ft)	88.400
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
88.4	9.2	30,000.0	492.0	3.1	0

HAMMER INPUT

ID	40	Made By:	DELMAG
Model	D 19-32	Type:	OED

Hammer Data

ID	Ram Wt	Ram L.	Ram Ar.	Rtd. Stk	Effic.	Rtd. Energy
-	kips	in	in²	ft	-	kip-ft
40	4.000	129.1	124.7	10.6	0.80	42.4

DRIVE SYSTEM FOR DELMAG D 19-32-OED

Type	X-Area	E-Modulus	Thickness	COR	Round-out	Stiffness
-	in²	ksi	in	-	in	kips/in
Hammer C.	227.000	530.000	2.000	0.800	0.120	60155.550
Helmet Wt.	1.900	kips				

SOIL RESISTANCE DISTRIBUTION

Depth	Unit Rs	Unit Rt	Qs	Qt	Js	Jt	Set. F.	Limit D.	Set. T.	EB Area
ft	ksf	ksf	in	in	s/ft	s/ft	-	ft	Hours	in²
0.0	1.3	18.0	0.10	0.12	0.15	0.15	1.5	6.0	168.0	113.1
1.0	1.3	18.0	0.10	0.12	0.15	0.15	1.5	6.0	168.0	113.1
2.0	1.3	18.0	0.10	0.12	0.15	0.15	1.5	6.0	168.0	113.1
2.0	1.1	22.5	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
3.7	1.1	22.5	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
5.3	1.1	22.5	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
7.0	1.1	22.5	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
7.0	1.1	22.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
8.9	1.1	22.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
10.8	1.1	22.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
12.6	1.1	22.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
14.5	1.1	22.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
14.5	0.9	28.8	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
16.4	0.9	28.8	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
18.2	0.9	28.8	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
20.1	0.9	28.8	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
21.9	0.9	28.8	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
23.8	0.9	28.8	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
25.6	0.9	28.8	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
27.5	0.9	28.8	0.10	0.11	0.20	0.15	1.8	6.0	168.0	113.1
27.5	0.9	26.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
29.2	0.9	26.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
31.0	0.9	26.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
32.7	0.9	26.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
34.4	0.9	26.5	0.10	0.11	0.15	0.15	1.5	6.0	168.0	113.1
34.4	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
36.2	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
38.0	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
39.7	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
41.5	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
43.3	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1

45.1	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
46.8	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
48.6	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
50.4	1.3	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
50.4	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
52.1	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
53.8	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
55.5	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
57.3	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
59.0	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
60.7	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
62.4	1.2	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
62.4	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
64.1	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
65.9	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
67.6	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
69.3	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
71.1	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
72.8	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
74.5	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
76.3	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
78.0	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
79.7	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
81.5	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
83.2	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
84.9	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
86.7	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1
88.4	1.4	45.0	0.10	0.09	0.15	0.15	1.5	6.0	168.0	113.1