CTL Engineering , Inc.
2860 Fisher Road, P.O. Box 44548, Columbus, Ohio 43204-3538
Phone: 614/276-8123 Fax: 614/276-6377
Email: ctl@ctleng.com

AN EMPLOYEE OWNED COMPANY

Consulting Engineers • Testing • Inspection Services • Analytical Laboratories

Established 1927

June 6, 2023
Revised October 12, 2023

IBI Group
23 Triangle Park Drive
Cincinnati, OH 45246

Attention: Mr. Steven Butler, P.E.
Associate – Manager, Transportation Engineering

Reference: Geohazard Exploration Report – Final
BRO-52-10.25 Slide Repair
PID: 116986
Brown County, Ohio
CTL Project No. 23050011COL

Dear Mr. Butler:

CTL Engineering, Inc. has completed the Geohazard Exploration for the above referenced project. Enclosed is the digital (pdf) copy of the Final report.

Thank you for the opportunity to work with you on this project. If you have any questions or need further information, please feel free to contact our office.

Respectfully Submitted

CTL ENGINEERING, INC.

Sastry Malladi, P.E.
Project Engineer

GEOHAZARD EXPLORATION REPORT - FINAL

BRO-52-10.25 SLIDE REPAIR
PID: 116986
BROWN COUNTY, OHIO
CTL PROJECT NO. 23050011COL

PREPARED FOR:

IBI GROUP
23 TRIANGLE PARK DRIVE
CINCINNATI, OHIO 45246

PREPARED BY:

CTL ENGINEERING, INC.
2860 FISHER ROAD
COLUMBUS, OHIO 43204
Phone 614-276-8123
Fax 614-276-6377

October 12, 2023

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

The project involves exploration of a landslide near mile marker 10.25 of US Highway 52 (US 52) at Union Township in Brown County, Ohio. Within the project limits, the US 52 westbound lanes, shoulder and guardrail were observed to be experiencing instability consisting of rotational/translational movement with a head scarp developed along the roadway pavement, guardrail and into the slope below the roadway.

A total of four (4) test borings were performed by ODOT for this project. Three (3) borings were performed through the pavement of US 52 and one (1) boring was performed within the outside shoulder of the US 52 eastbound lane. All four borings were extended into the underlying bedrock. The top of bedrock was encountered at depths ranging from 28.5 to 35.0 feet below existing grade. These depths correspond to elevations ranging from 485.6 to 478.5 feet.

Slope stability and drilled shaft analyses were performed at the critical section (Station 17+50) along US 52. Based on the results of the analyses, the following drilled shaft retaining wall with plug piles is recommended:

- 3.0-foot diameter reinforced shafts installed at a 5-foot center to center spacing.
- The drilled shafts at begin project to Sta. 17+50 and at Sta. 18+50 to end project will be reinforced with steel section W24x279. A 0.25 inch thick, 15.0 feet long (minimum) steel plate should be welded to the web beginning 5.0 feet from the bottom of the W24x279 section.
- The drilled shafts from Sta. 17+50 to Sta. 18+50 will be reinforced with steel section W24x229.
- 2.5 feet diameter plug (unreinforced) shafts installed between the structural shafts at an offset along the proposed centerline of the reinforced drilled shafts.
- Minimum bedrock embedment length of reinforced shafts of 11.0 feet.
- Constructed at a 22.0-foot offset (right) from the centerline of US 52.

II. INTRODUCTION

This project is located along US Highway 52 (US 52) at Union Township in Brown County, Ohio. The length of the project is approximately 300 feet. The purpose of this report is to provide findings from the subsurface exploration performed by ODOT and to provide recommendations for the repair of the landslide. This is a Final Report.

III. GEOLOGY AND OBSERVATIONS OF THE PROJECT

According to the Ohio Department of Natural Resources, Physiographic Regions of Ohio Map, the site is located within the Outer Bluegrass Region, which is in Blugrass Section of Ohio. According to the Bedrock Geologic Map of Ohio (2006), the underlying bedrock is mapped as Ordovician age interbedded shale and limestone of the Point Pleasant Formation.

According to web based mapping from *United States Department of Agriculture, Natural Resources Conservation Service,* the project area contains soils listed as Pate silty clay (PaE2), 25 to 35 percent slopes, eroded. According to the Soil Survey of Brown County, Ohio, *United States Department of Agriculture,* these soils are well drained with very low to moderately low capacity to transmit water.

According to the Ohio Department of Natural Resources (ODNR) Ohio Karst Areas map, no karst features have been mapped near the project site.

According to mapping from the ODNR Website, No underground mines have been mapped in the project area.

Historic geotechnical records were searched for on the ODOT TIMS website. No historic records were found for this project.

A site visit was performed by ODOT and CTL Engineering personnel on December 1, 2022. The slip is located along U.S. 52, about 2 miles west/northwest of Ripley, Ohio. At the time of the site visit, relatively recent asphalt pavement had been placed on both lanes of the U.S. 52. However, it is understood that both westbound and eastbound lanes within the project area are affected by the slip. The guardrail along the eastbound lanes is bent at a few locations.

IV. EXPLORATION

A. Test Borings

A total of four (4) test borings were performed by ODOT for this project between June 7 and June 15, 2022. Three (3) test borings were performed within the eastbound and westbound lanes of the existing roadway of US 52, designated as B-001-0-22, B-002-1-22, and B-003-0-22. One (1) boring was performed within the outside shoulder of the US 52 eastbound lane, designated as B-002-0-22. The test boring records were provided to CTL to be utilized for this report.

The test borings were performed with a truck mounted drilled rig, utilizing hollow stem augers (HSA). Standard penetration tests were conducted using 140-pound

hammers falling 30 inches to drive 2-inch O.D. split barrel sampler for 18 inches. Rock coring was performed in the borings, using an NQ2-size, double tube core barrel with a diamond bit. The hammer system used was calibrated on April 18, 2022. The hammer system had a drill rod energy ratio of 86.7 percent.

Split spoon soil samples were collected at 2.5-foot intervals until split spoon refusal was encountered. Soil samples obtained from the drilling operation were preserved in glass jars, visually classified in the field and laboratory, and tested for natural moisture content. Representative soil samples were subjected to laboratory testing including grain size distribution, Atterberg limits and Loss on Ignition (LOI) tests.

Rock from the coring operation was visually classified in the field and laboratory. The Rock Quality Designation (RQD) and percent core loss values were determined. Representative samples of the recovered rock were subjected to compressive strength testing.

Latitude and Longitude coordinates and ground surface elevations of the test boring locations were included on the test boring records when provided to CTL.

B. Inclinometer

An inclinometer probe was installed through a casing in the test boring B-002-0-22 by ODOT to monitor lateral movement of soil or rock mass. The results of this testing were provided to CTL. The inclinometer readings are located in Appendix C of this report.

V. FINDINGS

A. Test Borings

Borings B-001-0-22, B-002-1-22, and B-003-0-22 were drilled through the existing roadway of US 52. These borings generally exhibited pavement compositions consisting of 30 inches of asphalt over 8 inches of concrete. The remaining boring, B-002-0-22 was performed within the outside shoulder of the US 52 eastbound lane. This boring encountered 12 inches of asphalt at the surface.

Below the surface cover the borings encountered both cohesive and granular soil to the top of bedrock with depths ranging from 28.5 to 35.0 feet below grade. These depths correspond to elevations ranging from 485.6 to 478.5 feet. These soils were described as stone fragments with sands (A-1-b), stone fragments with sand and silt (A-2-4), stone fragments with sand, silt and clay (A-2-6), sandy silt (A-4a), silt (A-4b), silt and clay (A-6a), silty clay (A-6b), and clay (A-7-6).

A significant portion of the overlying soils in boring B-002-0-22 and B-002-1-22 contained cobbles/boulders. The soils exhibited N_{60} values ranging from 1 blow per foot (bpf) to 50 blows for six inch of penetration. Natural moisture contents ranged from 7 to 34 percent.

Below the native soils, limestone bedrock was encountered in the borings B-001-0-22 at depths ranging from 28.5 to 35.0 feet below grade. These depths correspond to elevations ranging from 485.6 to 478.5 feet. The upper 2.5 feet of bedrock in boring B-001-0-22 was augerable. The augerable bedrock exhibited N_{60} value of 50 blows for 6 inches of penetration.

Below the soil overburden or below the augerable bedrock, the borings exhibited coreable bedrock. The recovered bedrock from the coring operations was described as limestone. The bedrock from the coring operations exhibited Rock Quality Designation (RQD) values ranging from 11 to 52 percent, and core recovery values ranging from 97 to 100 percent.

Groundwater was encountered during drilling and sampling of boring B-003-0-22 at a depth 30.0 feet below grade. This depth correspond to the elevation of 483.5 feet. No groundwater was encountered in the remaining test borings. Accurate water level measurements at the completion of test boring were unable to be obtained due to the introduction of water during rock coring operations.

B. Inclinometer

The inclinometer data from borehole B-002-0-22 indicates that depth of lateral movement approximately at 28.0 feet below the existing grade.

VI. ANALYSES AND RECOMMENDATIONS

A. Global Stability Analyses

Global stability analysis was performed to estimate the shape and depth of the failure surfaces for the existing site conditions. The stability of slope was evaluated using the *Rocscience Slide* computer program, and the analyses were based on the Morgenstern-Price method. The slope on the southern side of US 52 was used in this analysis.

Cross sections within the area of the slip were prepared by IBI Group, and were provided to CTL Engineering. The stability analysis was performed using the most critical cross section (Station 17+50).

The stability of the slope was evaluated from laboratory test results, inclinometer results along with the parameters provided in ODOT's Geotechnical Design Manual (GDM) and engineering judgment. Soil and rock strength parameters used in the analysis are summarized in Table 1.

Table 1 – Soil and Rock Parameters

Material No.	γ_T (pcf)	Effective Stress Parameters		Material Types
		C (psf)	∅ (deg)	
1	145	50	15	Asphalt Pavement
2	122	150	24	A-7-6
3	120	100	22	A-6a
4	112	50	20	A-4a
5	125	0	15	Soft Rock
6	167	2000	40	Coreable Rock

Results of the global stability analyses are appended to this report in Appendix D.

As mentioned above, at the time of CTL's site reconnaissance, relatively recent asphalt pavement had been placed on both lanes of the U.S. 52. Based on the discussions with ODOT personnel, it is understood that both westbound and eastbound lanes within the project area are affected by the slip. Therefore, while performing the slope stability analysis, the shear surface was estimated to intercept the ground surface, left of CL of US 52, into the westbound lane. The failure surface is also assumed to travel above the top of rock and exit near the toe of slope.

B. Slope Repair

Based upon the conditions encountered in our exploration, the existing grades and results of the slope stability analysis, it is CTL's opinion that the slope repair could be performed by installing a retaining wall system on the southern downslope side of US 52. The retaining wall should be extended into the underlying competent (coreable) bedrock. The following retaining wall is being considered for this project:

Drilled Shaft Retaining Wall with Plug Piles– Under this retaining wall type, the roadway can be supported by installing row of structural drilled shafts at an offset location from the edge of roadway. The structural drilled shafts should be reinforced with steel pile sections, and then filled to their full length with structural concrete. The structural shafts should be socketed into competent (coreable) bedrock. The plug piles (non-reinforced shafts), should be installed between the structural, and serve the purpose of lagging between the structural (reinforced) shafts.

C. Drilled Shaft Analysis

Drilled shaft analyses were performed at the critical section of the proposed wall alignment, which was estimated to be at Station 17+50.

The analyses were performed to determine the steel size that will be required for the project. The following assumptions were used in the analyses:

- 3.0-foot diameter reinforced shafts will be installed at 5.0 feet center to center spacing.
- 2.5 feet diameter plug (unreinforced) shafts will be installed between and behind the structural shafts
- The center line of reinforced shafts is assumed to be constructed at 22.0 feet offset from the centerline of the existing roadway.

UA SLOPE Analysis

The shear plane surface obtained from the *SLIDE* analysis was input into the *UA Slope Program Version 2.3* software. The model was initially checked to verify the FS of existing conditions closely resembled the results from the *SLIDE* analysis, which was at 1.0. The output of this initial run is provided in Appendix E.

The analysis then involves modeling drilled shafts at a 22.0-foot offset (right) from the centerline of US 52. The output of the *UA Slope Program* showing the force per shaft value at this assumed drilled shaft location is attached to this report in Appendix E.

L-Pile Analysis

The force per shaft value obtained from the *UA Slope Program* was then entered into the L-pile program to estimate the deflection, shear, and moments within the shafts. Procedures outlined in the ODOT GDM along with AASHTO and LRFD manuals were followed while performing the L-pile analyses.

The steepness of the slope, downhill from the proposed wall location varies within the project limits. Therefore, the following average slope angles were utilized to determine the depths of passive resistance near the downhill side of the wall.

Table 2: Downhill Slope Angle

Location	Average Downhill Slope Angle (degrees)
Begin Project to Sta. 17+50	20
Sta. 17+50 to Sta. 18+50	18
Sta. 18+50 to End Project	20

Design checks per the ODOT GDM were performed for each case**.** Based on the analyses, the steel section that satisfied the necessary design checks is provided in Table 3.

Table 3- Steel Section

Description	Location	CL of Structural Shafts	Force per Shaft (lbs)	Diameter of Structural Shaft* (feet)	C/C spacing between Structural Shafts (feet)	Recommended Steel Section
Plug Pile Retaining Wall	Begin Project to Sta. 17+50	22.0 feet right of the centerline of US 52	151,667	3.0	5.0	W24x279**
	Sta. 17+50 to Sta. 18+50					W24x229
	Sta. 18+50 to End Project					W24x279**

* Due to R/W constraints, drilled shafts larger than 3.0 feet in diameter were not considered while performing the retaining wall design.
** A 0.25-inch-thick, 15.0 feet long (minimum) steel plate should be welded to the web beginning 5.0 feet from the bottom of the W24x279 section

Results of the L-pile analyses are provided in Appendix E. L-pile analyses were initially performed with reinforced shafts extending 10-feet into the underlying competent (coreable) bedrock. The analyses suggested that a heavier steel section (than indicated in the Table 3) with drilled shaft diameter larger than 3.0 feet will be required to resist the shear and moment at the strength limit state, if reinforced shafts are embedded 10 feet. Due to the R/W constraints, drilled shaft diameter larger than 3 feet in diameter are not feasible for this project.

Therefore, additional analyses were performed with reinforced shafts extending 11.0 feet into the underlying coreable bedrock. This rock embedment met the necessary design checks and also addressed the R/W constraints. Therefore, CTL recommends a 11.0 feet rock embedment be utilized for the reinforced shafts.

Based on the analyses, if 11-feet embedment into the bedrock is utilized for the reinforced shafts, then it is CTL's opinion that the steel sections as provided in Table 3 can be used for this project.

The depth to the coreable bedrock at each shaft location should be verified by the on-site engineer during construction. If field conditions indicate deeper bedrock than what was used in our design, then CTL should be notified for further evaluation.

It is recommended that all non-reinforced shafts (plugs) should extend approximately 3-feet below the depth from where passive resistance of the downhill soil mass is effective at the wall location. The lengths provided in the table below can be used as reference for determining the plug pile lengths.

Table 4: Non- reinforced Shafts (plugs) Lengths

Location	Average Downhill Slope Angle (degrees)	Plug Shaft Lengths (ft)
Begin Project to Sta. 17+50	20	15.0
Sta. 17+50 to Sta. 18+50	18	14.0
Sta. 18+50 to End Project	20	15.0

VII. CHANGED CONDITIONS

The evaluations, conclusions, and recommendations in this report are based on our interpretation of the field and laboratory data obtained during the exploration, our understanding of the project and our experience with similar sites and subsurface conditions using generally accepted geotechnical engineering practices. Although individual test borings are representative of the subsurface conditions at the boring locations on the dates drilled, they are not necessarily representative of the subsurface conditions between boring locations or subsurface conditions during other seasons of the year.

In the event that changes in the project are proposed, additional information becomes available, or if it is apparent that subsurface conditions are different from those provided in this report, CTL Engineering should be notified so that our recommendations can modified, if required.

VIII. TESTING AND OBSERVATION

During the design process, it is recommended that CTL Engineering work with the project designers to confirm that the geotechnical recommendations are properly incorporated into the final plans and specifications, and to assist with establishing criteria for the construction observation and testing.

CTL Engineering is not responsible for independent conclusions, opinions and recommendations made by others based on the data and recommendations provided in this report.

IX. CLOSING

This report has been prepared for the exclusive use by the client for use only on this project. Our services have been performed in accordance with generally accepted Geotechnical Engineering principles and practices. No warranty is either expressed or implied.

CTL Engineering's assignment does not include, nor does this geotechnical report address the environmental aspects of this particular site.

Specific design and construction recommendations have been provided in this report. Therefore, the report should be used in its entirety.

Respectfully Submitted,

CTL ENGINEERING, INC.

Shahedur Rahman
Geotechnical Engineer

Sastry Malladi, P.E.
Project Engineer

APPENDIX A
GEOTECHNICAL PLAN AND PROFILE SHEETS

PROJECT DESCRIPTION

THE PROJECT INVOLVES EXPLORATION OF A LANDSLIDE NEAR MILE MARKER 10.30 OF US HIGHWAY 52 (US 52) AT UNION TOWNSHIP IN BROWN COUNTY, OHIO. THE SLOPE INSTABILITY EXTENDS FOR APPROXIMATELY 300 FEET. A NEW RETAINING WALL IS PLANNED TO BE CONSTRUCTED ALONG THE AFFECTED ALIGNMENT.

HISTORIC RECORDS

HISTORIC GEOTECHNICAL RECORDS WERE SEARCHED FOR ON THE ODOT TIMS WEBSITE. NO HISTORIC RECORDS WERE FOUND FOR THIS PROJECT.

GEOLOGY

ACCORDING TO THE OHIO DEPARTMENT OF NATURAL RESOURCES, PHYSIOGRAPHIC REGIONS OF OHIO MAP, THE SITE IS LOCATED WITHIN THE OUTER BLUEGRASS REGION, WHICH IS IN BLUGRASS SECTION OF OHIO. ACCORDING TO THE BEDROCK GEOLOGIC MAP OF OHIO (2006), THE UNDERLYING BEDROCK IS MAPPED AS ORDOVICIAN AGE INTERBEDDED SHALE AND LIMESTONE OF THE POINT PLEASANT FORMATION. ACCORDING TO THE OHIO DEPARTMENT OF NATURAL RESOURCES (ODNR) OHIO KARST AREAS MAP, NO KARST FEATURES HAVE BEEN MAPPED NEAR THE PROJECT SITE. ACCORDING TO MAPPING FROM THE ODNR WEBSITE, NO UNDERGROUND MINES HAVE BEEN MAPPED IN THE PROJECT AREA.

RECONNAISSANCE

A SITE VISIT WAS PERFORMED BY ODOT AND CTL ENGINEERING PERSONNEL ON DECEMBER 1, 2022. THE SLIP IS LOCATED ALONG U.S. 52, ABOUT 2 MILES WEST/NORTHWEST OF RIPLEY, OHIO. AT THE TIME OF THE SITE VISIT, RELATIVELY RECENT ASPHALT PAVEMENT HAD BEEN PLACED ON BOTH LANES OF THE U.S. 52. HOWEVER, IT IS UNDERSTOOD THAT BOTH WESTBOUND AND EASTBOUND LANES WITHIN THE PROJECT AREA ARE AFFECTED BY THE SLIP. THE GUARDRAIL ALONG THE EASTBOUND LANES IS BENT AT A FEW LOCATIONS.

SUBSURFACE EXPLORATION

A TOTAL OF FOUR (4) TEST BORINGS WERE PERFORMED BY ODOT FOR THIS PROJECT. THREE (3) TEST BORINGS DESIGNATED AS B-001-0-22, B-002-1-22, AND B-003-0-22. WERE PERFORMED WITHIN THE EASTBOUND AND WESTBOUND LANES OF THE EXISTING ROADWAY OF US 52. ONE (1) BORING DESIGNATED AS B-002-0-22 WAS PERFORMED WITHIN THE OUTSIDE SHOULDER OF THE US 52 EASTBOUND LAN.

THE TEST BORINGS WERE PERFORMED WITH A TRUCK MOUNTED DRILLED RIG, UTILIZING HOLLOW STEM AUGERS (HSA), BETWEEN JUNE 7 AND JUNE 15, 2022. STANDARD PENETRATION TESTS WERE CONDUCTED USING 140-POUND HAMMERS FALLING 30 INCHES TO DRIVE 2-INCH O.D. SPLIT BARREL SAMPLER FOR 18 INCHES. ROCK CORING WAS PERFORMED IN THE BORINGS, USING AN NQ2-SIZE, DOUBLE TUBE CORE BARREL WITH A DIAMOND BIT. THE HAMMER SYSTEM USED WAS CALIBRATED ON APRIL 18, 2022. THE HAMMER SYSTEM HAD A DRILL ROD ENERGY RATIO OF 86.7 PERCENT.

EXPLORATION FINDINGS

BELOW THE SURFACE COVER THE BORINGS ENCOUNTERED BOTH COHESIVE AND GRANULAR SOIL TO THE TOP OF BEDROCK WITH DEPTHS RANGING FROM 28.5 TO 35.0 FEET BELOW GRADE. THESE SOILS WERE DESCRIBED AS STONE FRAGMENTS WITH SANDS (A-1-b), STONE FRAGMENTS WITH SAND AND SILT (A-2-4), STONE FRAGMENTS WITH SAND, SILT AND CLAY (A-2-6), SANDY SILT (A-4a), SILT (A-4b), SILT AND CLAY (A-6a), SILTY CLAY (A-6b), AND CLAY (A-7-6).

BELOW THE SOIL OVERBURDEN, THE BORINGS ENCOUNTERED BEDROCK. THE RECOVERED BEDROCK FROM THE CORING OPERATIONS WAS DESCRIBED AS LIMESTONE.

GROUNDWATER WAS ENCOUNTERED DURING DRILLING AND SAMPLING OF BORING B-003-0-22 AT A DEPTH 30.0 FEET BELOW GRADE. THIS DEPTH CORRESPOND TO THE ELEVATION OF 483.5 FEET. NO GROUNDWATER WAS ENCOUNTERED IN THE REMAINING TEST BORINGS.

SPECIFICATIONS

THIS GEOTECHNICAL EXPLORATION WAS PERFORMED IN ACCORDANCE WITH THE STATE OF OHIO, DEPARTMENT OF TRANSPORTATION, OFFICE OF GEOTECHNICAL ENGINEERING, SPECIFICATIONS FOR GEOTECHNICAL EXPLORATIONS, DATED JANUARY 2022.

LEGEND

DESCRIPTION	ODOT CLASS	CLASSIFIED MECH./VISUAL	
GRAVEL AND/OR STONE FRAGMENTS WITH SAND	A-1-b (0)	1	0
GRAVEL AND/OR STONE FRAGMENTS W/SAND AND SILT	A-2-4 (0)	1	2
GRAVEL AND/OR STONE FRAGMENTS W/SAND, SILT AND CLAY	A-2-6 (0)	2	0
SANDY SILT	A-4a (5)	2	2
SILT	A-4b (7)	1	1
SILT AND CLAY	A-6a (9)	4	6
SILTY CLAY	A-6b (10)	6	6
CLAY	A-7-6 (13)	7	5
	TOTAL	24	22
BOULDERS	VISUAL		
LIMESTONE	VISUAL		

XXXXX	PAVEMENT OR BASE = X = APPROXIMATE THICKNESS
	INSTRUMENTED BORING LOCATION - PLAN VIEW
	EXPLORATION LOCATION - PLAN VIEW
	DRIVE SAMPLE AND/OR ROCK CORE BORING PLOTTED TO VERTICAL SCALE ONLY. HORIZONTAL BAR INDICATES A CHANGE IN STRATIGRAPHY.
WC	INDICATES WATER CONTENT IN PERCENT.
N_{60}	INDICATES STANDARD PENETRATION RESISTANCE NORMALIZED TO 60% DRILL ROD ENERGY RATIO.
W—	INDICATES FREE WATER ELEVATION.
●	INDICATES A PLASTIC MATERIAL WITH MOISTURE CONTENT EQUAL TO OR GREATER THAN THE LIQUID LIMIT MINUS 3.
SS	INDICATES A SPLIT-SPOON SAMPLE.
TR	INDICATES TOP OF ROCK ELEVATION.
NQ_2	INDICATES AROCK CORE SAMPLE.
QU	INDICATES UNCONFINED COMPRESSION TEST, ASTM D 7012, METHOD C, RESULTS.
LOI	INDICATES LOSS ON IGNITION TEST, ASTM D2974, METHOD A, RESULTS.
r	INDICATES UNIT WEIGHT OF ROCK.

AVAILABLE INFORMATION

THE SOIL, BEDROCK, AND GROUNDWATER INFORMATION COLLECTED FOR THIS SUBSURFACE EXPLORATION THAT CAN BE CONVENIENTLY DISPLAYED ON THE SOIL PROFILE SHEETS HAS BEEN PRESENTED. GEOTECHNICAL REPORTS, IF PREPARED, ARE AVAILABLE FOR REVIEW ON THE OFFICE OF CONTRACT SALES WEBSITE.

BEDROCK TEST SUMMARY

BORING ID	SAMPLE ELEVATION	SAMPLE DEPTH	QU (PSI)	LITHOLOGY
B-001-0-22	476.6' - 476.3'	36.6' - 36.9'	10,445	LIMESTONE
B-002-0-22	472.3' - 471.9'	41.2' - 41.6'	11,790	LIMESTONE
B-002-1-22	480.4' - 480.1'	33.7' - 34.0'	7,889	LIMESTONE
B-003-0-22	482.1' - 481.8'	31.4' - 31.7'	9,085	LIMESTONE

LOCATION MAP

SCALE IN MILES

0 1 2 3 4

N

PARTICLE SIZE DEFINITIONS

12"	3"	2.0 mm	0.42 mm	0.074 mm	0.005 mm
BOULDERS	COBBLES	GRAVEL	COARSE SAND	FINE SAND	SILT	CLAY
		No. 10 SIEVE	No. 40 SIEVE	No. 200 SIEVE		

RECON. - SM 12/01/2022
DRILLING - ODOT 06/07/22 TO 06/15/22
DRAWN - CTL 10/11/23
REVIEWED - SM 10/11/23

GEOTECHNICAL PROFILE - LANDSLIDE

BRO-52-10.25

DESIGN AGENCY

CTL ENGINEERING
2860 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX: (614)276-6377

DESIGNER	N.K.S
REVIEWER	SM 10-11-23
PROJECT ID	116986
SUBSET	1
TOTAL	12
SHEET	P.27
TOTAL	38

BRO-52-10.25

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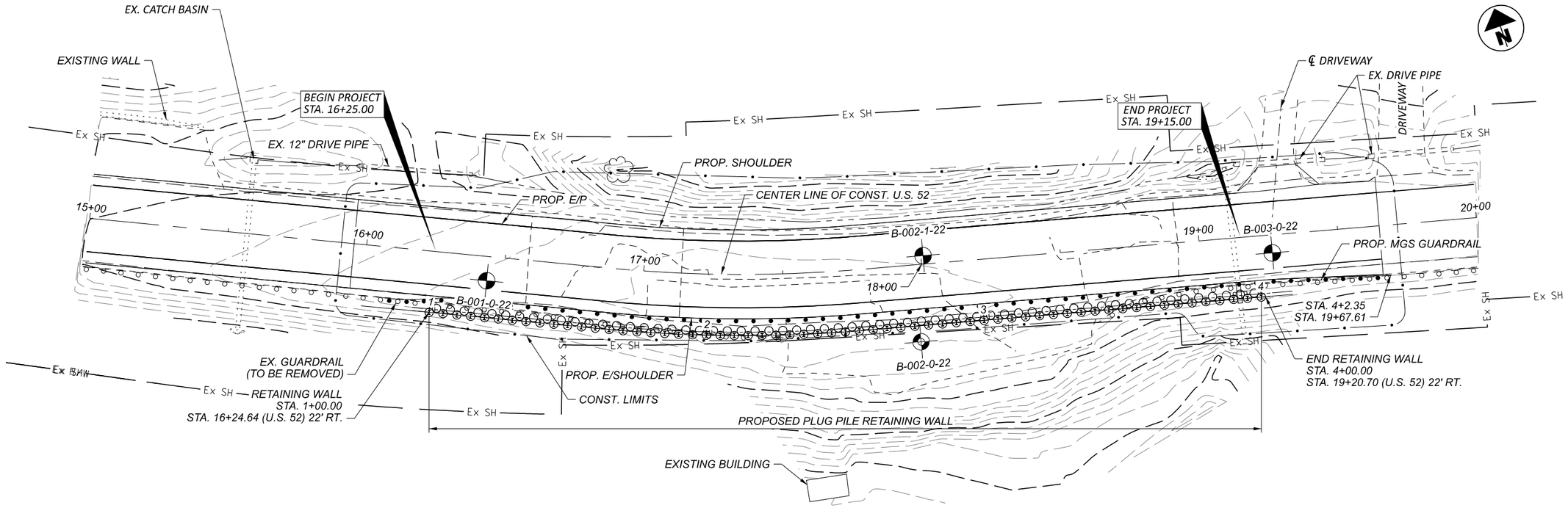

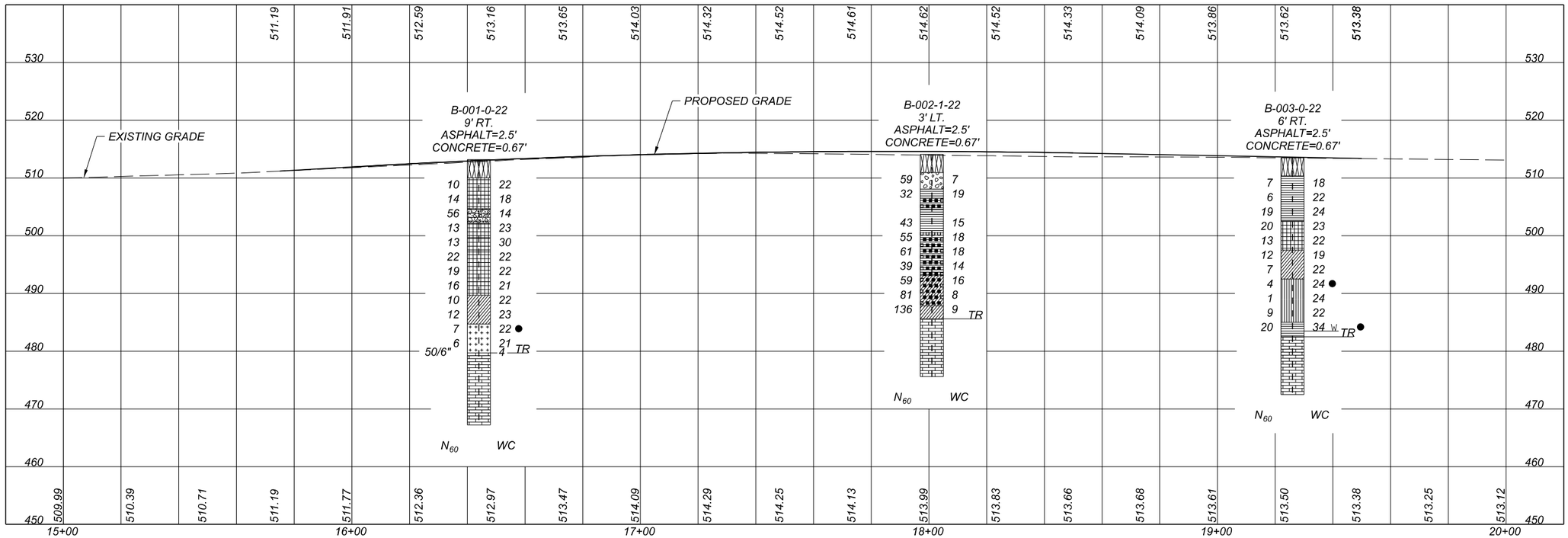

GEOTECHNICAL PROFILE - LANDSLIDE
STA. 15+00.00 TO STA. 20+00.00

DESIGN AGENCY

GTL ENGINEERING
2860 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX: (614)276-6377

DESIGNER	N.K.S
REVIEWER	SM 10-11-23
PROJECT ID	116986
SUBSET / TOTAL	2 / 12
SHEET / TOTAL	P.28 / 38

BRO-52-10.25

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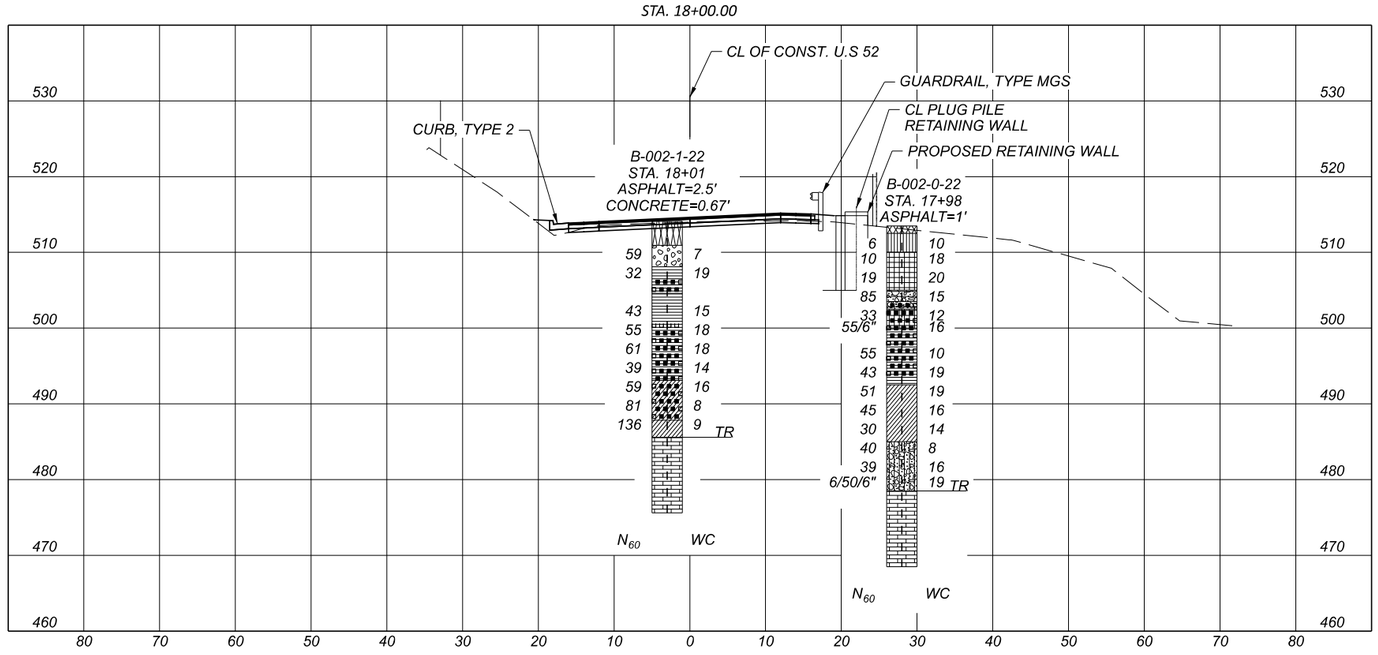

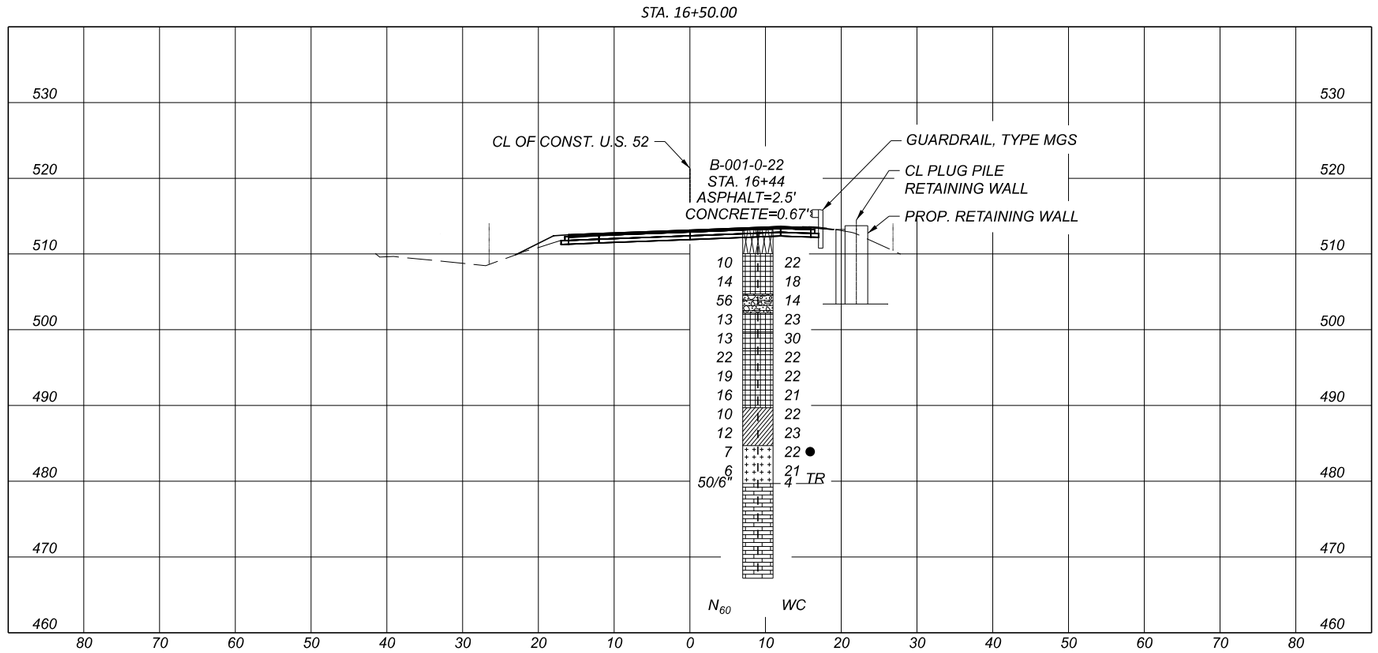

HORIZONTAL SCALE IN FEET
0 5 10 20

GEOTECHNICAL PROFILE - LANDSLIDE
CROSS SECTIONS STA. 16+50.00 AND STA. 18+00.00

DESIGN AGENCY
CTL ENGINEERING
2860 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX: (614)276-6377

DESIGNER	N.K.S
REVIEWER	SM 10-11-23
PROJECT ID	116986
SUBSET / TOTAL	3 / 12
SHEET / TOTAL	P.29 / 38

BRO-52-10.25

MODEL: 16+50.00 PAPERSIZE: 17x11 (in.) DATE: 11-10-2023 TIME: 13:16:59 USER: hp
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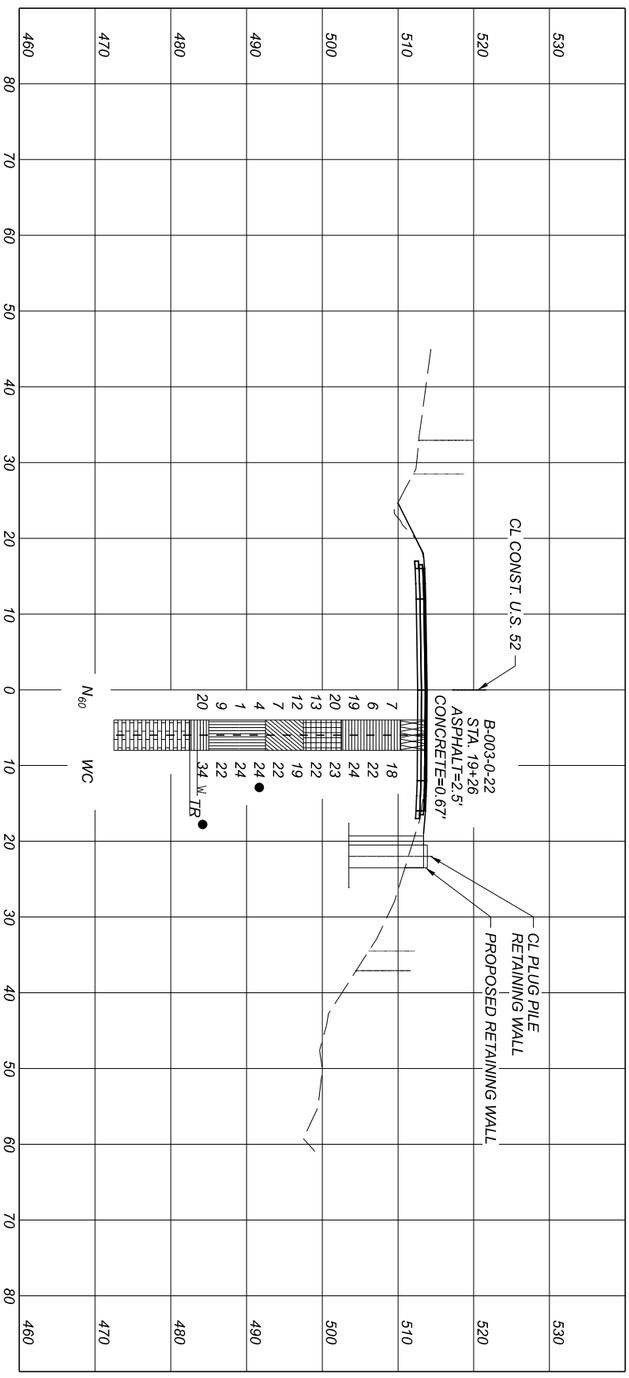

GEOTECHNICAL PROFILE - LANDSLIDE

CROSS SECTION STA. 19+00.00

HORIZONTAL SCALE IN FEET
0 10
5 20

DESIGN AGENCY

CTL ENGINEERING, INC.
COLUMBUS, OHIO 43204
PHONE (614) 276-8123
FAX (614) 276-6377

DESIGNER N.K.S

REVIEWER SM 10-11-23

PROJECT ID 116986

SUBSET 4 TOTAL 12

SHEET P.30 TOTAL 38

BRO-52-10.25

MODEL: Sheet PAPERSIZE: 11x17 (in.) DATE: 11-10-2023 TIME: 13:22:50 USER: hp
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PROJECT: BRO-52-10.25	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 16+44, 9' RT.	EXPLORATION ID B-001-0-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 116986 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4-18-22	ELEVATION: 513.2 (ft) EOB: 46.0 ft.	PAGE 1 OF 1
START: 6-7-22 END: 6-8-22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.7	LAT / LONG: 38.763708, -83.874319	

MATERIAL DESCRIPTION AND NOTES	ELEV. 513.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	SO4 ppm	BACK FILL
ASPHALT (30") & CONCRETE (8")	510.1																		
STIFF, BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE GRAVEL AND STONE FRAGMENTS, MOIST			3 4 3	10	39	SS-1	2.00	6	4	4	36	50	42	19	23	22	A-7-6 (14)	-	
@6.0'; VERY STIFF, DAMP	504.7		3 6 4	14	44	SS-2	2.50	-	-	-	-	-	-	-	-	18	A-7-6 (V)	-	
VERY DENSE, BROWN, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, MOIST	502.2		5 11 28	56	67	SS-3	-	51	10	9	15	15	28	15	13	14	A-2-6 (0)	-	
VERY STIFF, BROWN, **CLAY**, SOME SILT, LITTLE STONE FRAGMENTS, TRACE SAND, MOIST	499.7		3 4 5	13	89	SS-4	3.75	19	3	4	28	46	43	20	23	23	A-7-6 (14)	-	
STIFF, GRAY, **CLAY**, SOME SILT, LITTLE STONE FRAGMENTS, TRACE SAND, MODERATELY ORGANIC (LOI = 6.2%), MOIST	497.2		3 4 5	13	100	SS-5	1.50	15	2	3	33	47	49	23	26	30	A-7-6 (16)	-	
VERY STIFF, BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, MOIST	489.7		5 6 9	22	100	SS-6	4.00	1	0	3	42	54	45	21	24	22	A-7-6 (15)	-	
			3 5 8	19	100	SS-7	4.00	-	-	-	-	-	-	-	-	22	A-7-6 (V)	-	
			4 5 6	16	100	SS-8	4.00	-	-	-	-	-	-	-	-	21	A-7-6 (V)	-	
STIFF, BROWN, **SILT AND CLAY**, SOME SAND, MOIST	484.7		1 3 4	10	100	SS-9	2.00	0	0	22	48	30	30	16	14	22	A-6a (10)	-	
			1 3 5	12	100	SS-10	1.00	-	-	-	-	-	-	-	-	23	A-6a (V)	-	
STIFF, BROWN, **SILT**, SOME SAND, SOME CLAY, WET	479.7		2 2 3	7	100	SS-11	1.50	0	1	27	50	22	25	17	8	22	A-4b (7)	-	
@31.0'; MEDIUM STIFF			22 2 2	6	78	SS-12	1.00	-	-	-	-	-	-	-	-	21	A-4b (V)	-	
LIMESTONE, GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, STYOLITIC, JOINTED, MODERATELY FRACTURED, NARROW, SLIGHTLY ROUGH; BLOCKY, FAIR; RQD 62%, REC 100%.		TR	50	-	100	SS-13	-	-	-	-	-	-	-	-	-	4	Rock (V)	-	
@ 36.6' - 36.9'; γ = 168 pcf; Qu = 10,445 psi @39.1' - 39.2'; SHALE, SEVERELY WEATHERED @39.6' - 39.9'; SHALE, SEVERELY WEATHERED			72		100	NQ2-1											CORE		
@41.6' - 41.8'; SHALE, SEVERELY WEATHERED	467.2	EOB	52		100	NQ2-2											CORE		

NOTES: HOLE DRY BEFORE CORING. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

STANDARD ODOT LOG W/ SULFATES (11 X 17) - OH DOT.GDT - 1-6-23 13:34 - G:\2023\MAY\31\23050011COL\600978.GPJ

DESIGN AGENCY
CTL ENGINEERING
2860 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614) 276-8123
FAX: (614) 276-6377
DESIGNER N.K.S
REVIEWER SM 10-11-23
PROJECT ID 116986
SUBSET 5 TOTAL 12
SHEET P:31 TOTAL 38

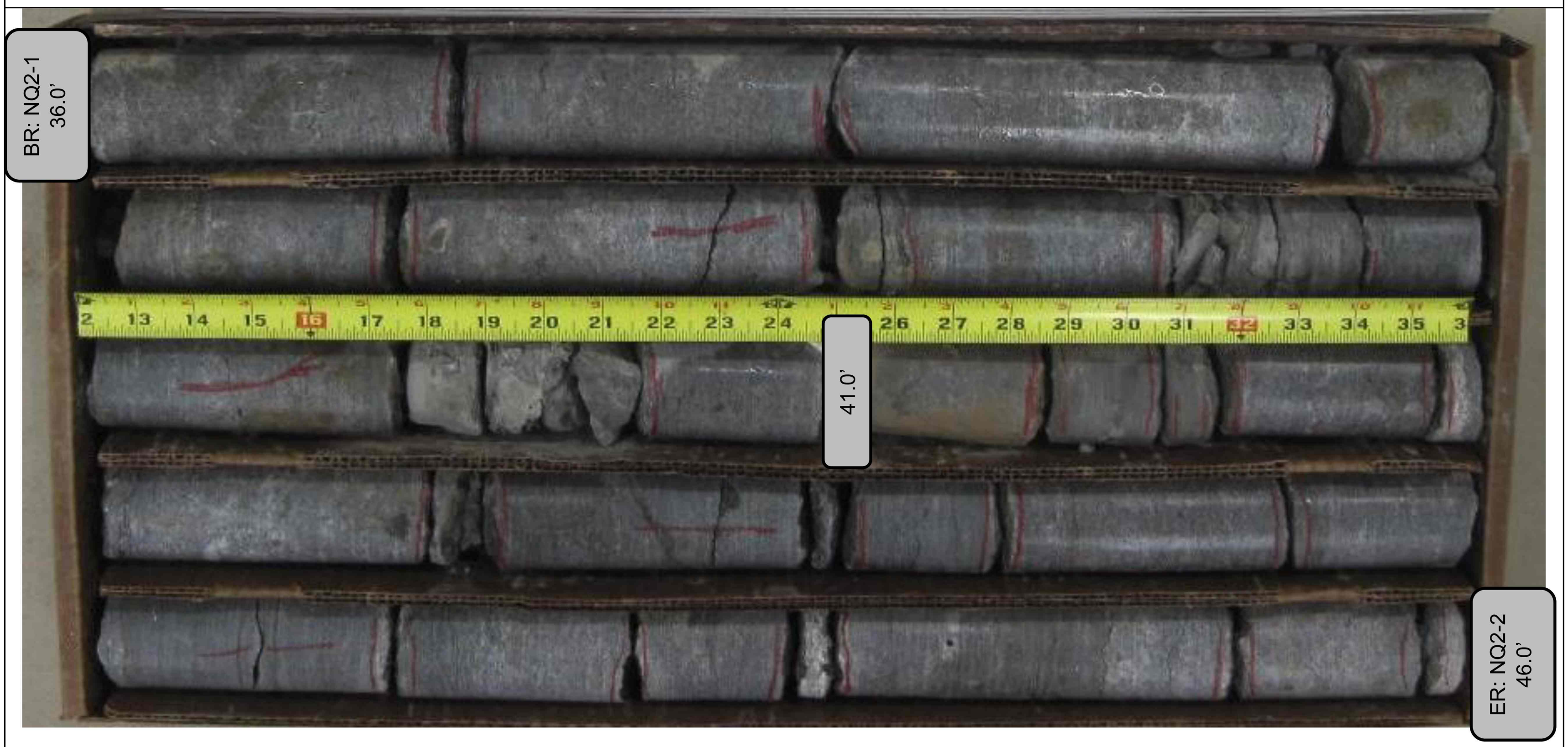
GEOTECHNICAL PROFILE - LANDSLIDE

BORING LOG B-001-0-22

Ohio Department of Transportation
Division of Engineering

Office of Geotechnical Engineering

B-001-0-22



Run #:	Depth		Recovery		RQD	
NQ2-1	36.0’	41.0’	60/60	100%	43/60	72%
NQ2-2	41.0’	46.0’	60/60	100%	31/60	52%
BRO-52-10.25 PID 116986						

GEOTECHNICAL PROFILE - LANDSLIDE

ROCK CORE PHOTO FOR B-001-0-22

BRO-52-10.25

MODEL: Sheet PAPERSIZE: 11x17 (in.) DATE: 11-10-2023 TIME: 13:27:33 USER: hp
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PROJECT: BRO-52-10.25	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 17+98, 28' RT.
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52
PID: 116986 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4-18-22	ELEVATION: 513.5 (ft) EOB: 45.0 ft.
START: 6-9-22 END: 6-15-22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.7	LAT / LONG: 38.763517, -83.873825

EXPLORATION ID: B-002-0-22
PAGE: 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV.	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	INCL.
ASPHALT (12")	513.5																		
LOOSE, BROWN AND GRAY, **SANDY SILT**, "AND" GRAVEL AND STONE FRAGMENTS, LITTLE CLAY, DAMP	512.5	1																	
		2	3 2 2	6	22	SS-1	3.00	37	13	11	20	19	25	16	9	10	A-4a (1)	-	
	510.0	3																	
VERY STIFF, BROWN, **CLAY**, SOME SILT, TRACE SAND, TRACE STONE FRAGMENTS, DAMP		4	5 3 4	10	78	SS-2	2.50	-	-	-	-	-	-	-	-	18	A-7-6 (V)	-	
		5																	
		6																	
		7	3 5 8	19	67	SS-3	3.00	8	4	4	33	51	41	22	19	20	A-7-6 (12)	-	
	505.0	8																	
VERY DENSE, BROWN AND GRAY, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, MOIST		9	16 8 51	85	78	SS-4	1.50	48	17	8	13	14	29	17	12	15	A-2-6 (0)	-	
@10.0' - 20.0'; ENCOUNTERED BOULDERS/COBBLES	502.5	10																	
HARD, BROWN, **CLAY**, "AND" STONE FRAGMENTS, LITTLE SILT, TRACE SAND, DAMP		11																	
		12	9 8 15	33	33	SS-5	4.00	59	2	2	17	20	41	18	23	12	A-7-6 (3)	-	
	500.0	13																	
HARD, BROWN, **SILTY CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP		14	55	-	100	SS-6	-	18	7	4	29	42	40	18	22	16	A-6b (12)	-	
		15																	
@16.0'; POOR RECOVERY		16																	
		17	9 22 16	55	33	SS-7	2.50	-	-	-	-	-	-	-	-	10	A-6b (V)	-	
		18																	
@18.5'; VERY STIFF, GRAYISH BROWN, TRACE SAND, MOIST		19	7 15 15	43	78	SS-8	3.50	14	4	4	31	47	40	18	22	19	A-6b (13)	-	
	492.5	20																	
VERY STIFF, GRAY AND BROWN, **SILT AND CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP		21																	
		22	5 6 29	51	67	SS-9	2.50	18	6	5	31	40	34	20	14	19	A-6a (9)	-	
		23																	
@23.5'; STIFF, SPOON BLOCKED BY STONE FRAGMENTS		24	16 14 17	45	11	SS-10	1.00	-	-	-	-	-	-	-	-	16	A-6a (V)	-	
		25																	
@26.0'; SAMPLE RECOVERED WITH A 3" SPLITSPOON		26																	
		27	11 7 14	30	56	SS-11	1.50	-	-	-	-	-	-	-	-	14	A-6a (V)	-	
	485.0	28																	
DENSE, BROWN, **STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, SAMPLE RECOVERED WITH A 3" SPLITSPOON, MOIST		29	15 16 12	40	67	SS-12	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	-	
		30																	
		31																	
		32	8 10 17	39	78	SS-13	-	57	3	10	19	11	29	19	10	16	A-2-4 (0)	-	
		33																	
		34	6 50	-	100	SS-14	-	-	-	-	-	-	-	-	-	19	A-2-4 (V)	-	
	478.5	35	TR																
LIMESTONE, GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, STYOLITIC, JOINTED, MODERATELY FRACTURED, NARROW, SLIGHTLY ROUGH; BLOCKY, FAIR; RQD 29%, REC 99%.		36																	
@35.1' - 35.2'; CLAY SEAM		37	11		100	NQ2-3											CORE		
@36.1' - 36.2'; CLAY SEAM		38																	
@37.6' - 37.7'; SHALE, SEVERELY WEATHERED		39	25		100	NQ2-4											CORE		
@38.1' - 38.3'; SHALE, SEVERELY WEATHERED		40																	
@38.8' - 39.0'; SHALE, SEVERELY WEATHERED		41																	
@39.7' - 40.0'; SHALE, SEVERELY WEATHERED		42																	
@40.7' - 40.8'; SHALE, SEVERELY WEATHERED		43	42		98	NQ2-5											CORE		
@ 41.2' - 41.6'; γ = 169 pcf; Qu = 11,790 psi		44																	
	468.5	45	EOB																

NOTES: SPLITSPOON SAMPLES SS-5, SS-6, SS-7, SS-8 WERE SAMPLED FROM OFFSET HOLE AFTER ENCOUNTERING COBBLES/BOULDERS FROM 10.0 FEET TO 20.0 FEET.

NOTES: HOLE DRY BEFORE CORING. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 45 GAL. BENTONITE CEMENT GROUT

STANDARD ODOT LOG W/ SULFATES (11 X 17) - OH DOT.GDT - 1-6-23 13:34 - G:\2023\MAY\31\23050011COL\600978.GPJ

DESIGN AGENCY
ENGINEERING
2366 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX: (614)276-8377

DESIGNER N.K.S
REVIEWER SM 10-11-23
PROJECT ID 116986
SUBSET 7 TOTAL 12
SHEET P:33 TOTAL 38

GEOTECHNICAL PROFILE - LANDSLIDE

BORING LOG B-002-0-22

MODEL: Sheet PAPERSIZE: 11x17 (in.) DATE: 11-10-2023 TIME: 13:30:08 USER: hp
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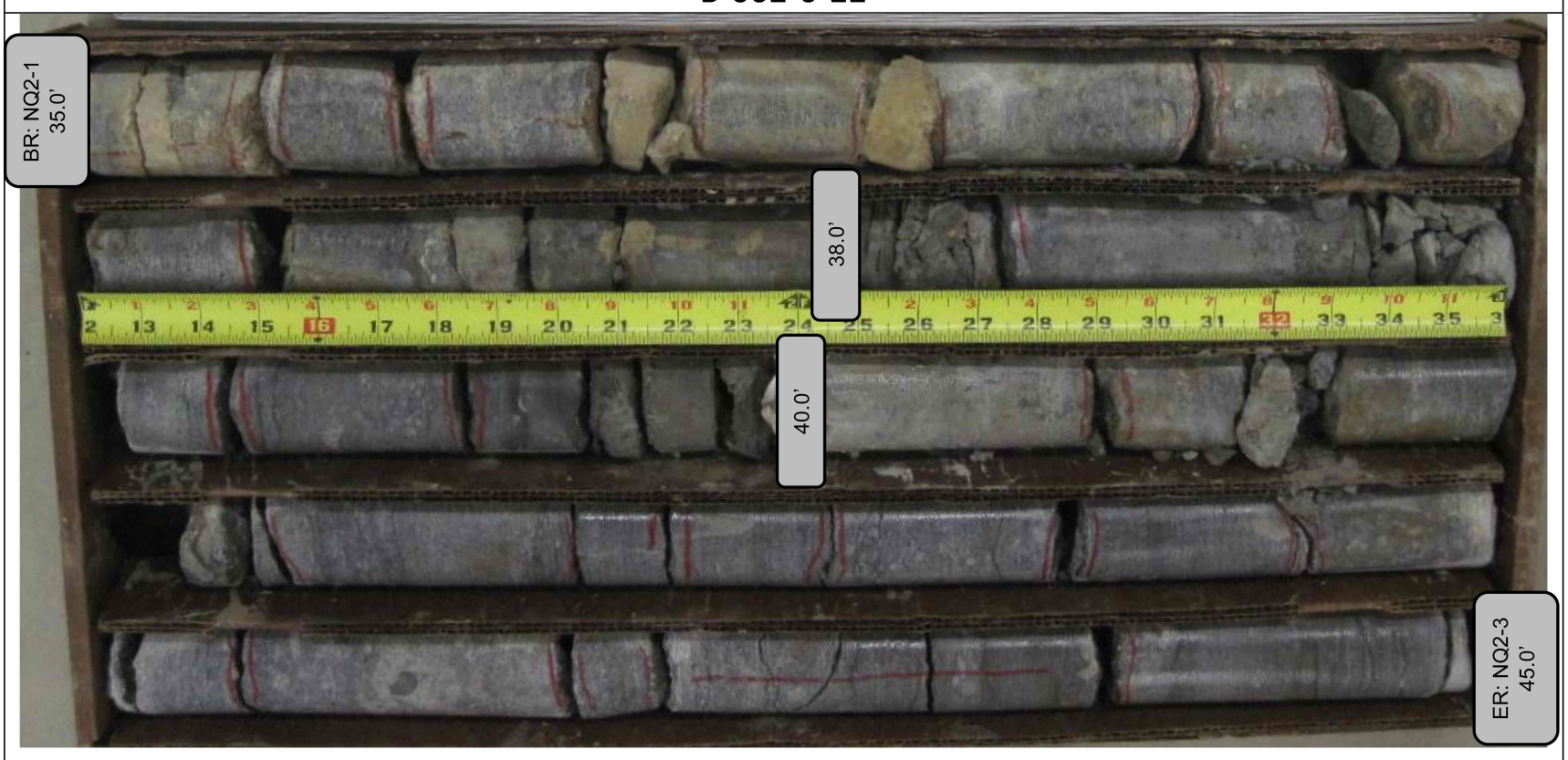
OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-002-0-22



Run #:	Depth		Recovery		RQD	
NQ2-1	35.0’	38.0’	36/36	100%	4/36	11%
NQ2-2	38.0’	40.0’	24/24	100%	6/24	25%
NQ2-3	40.0’	45.0’	59/60	98%	25/60	42%
BRO-52-10.25 PID 116986						

DESIGN AGENCY
ENGINEERING
2740 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX: (614)276-6377

DESIGNER N.K.S
REVIEWER SM 10-11-23
PROJECT ID 116986
SUBSET 8 TOTAL 12
SHEET P:34 TOTAL 38

GEOTECHNICAL PROFILE - LANDSLIDE

ROCK CORE PHOTO FOR B-002-0-22

BRO-52-10.25

MODEL: Sheet PAPERSIZE: 11x17 (in.) DATE: 11-10-2023 TIME: 13:32:29 USER: hp
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PROJECT: BRO-52-10.25	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 18+01, 3' LT.	EXPLORATION ID B-002-1-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 116986 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4-18-22	ELEVATION: 514.1 (ft) EOB: 38.5 ft.	PAGE 1 OF 1
START: 6-15-22 END: 6-15-22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.7	LAT / LONG: 38.763599, -83.873806	

MATERIAL DESCRIPTION AND NOTES	ELEV. 514.1	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
ASPHALT (30") & CONCRETE (8")																			
	511.0																		
VERY DENSE, BROWN AND DARK BROWN, **STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, AUGER SAMPLE TAKEN, DAMP			16 20 21	59	17	SS-1	-	40	17	20	18	5	NP	NP	NP	7	A-1-b (0)	-	
	508.1																		
VERY STIFF, BROWN, **SILTY CLAY**, SOME STONE FRAGMENTS, TRACE SAND, DAMP			10 10 12	32	44	SS-2	3.50	33	5	4	25	33	39	20	19	19	A-6b (8)	-	
@7.5' - 9.5'; ENCOUNTERED BOULDERS/COBBLES																			
@11.0' - 13.5'; HARD, SAMPLE RECOVERED WITH A 3" SPLITSPOON			9 18 12	43	33	SS-3	4.00	-	-	-	-	-	-	-	-	15	A-6b (V)	-	
@13.5'; MOTTLED BROWN AND GRAY @13.5' - 26.25'; ENCOUNTERED BOULDERS/COBBLES			3 10 28	55	56	SS-4	3.50	26	4	3	28	39	40	22	18	18	A-6b (10)	-	
			10 28 14	61	44	SS-5	3.25	-	-	-	-	-	-	-	-	18	A-6b (V)	-	
			4 12 15	39	33	SS-6	3.50	-	-	-	-	-	-	-	-	14	A-6b (V)	-	
	493.1																		
VERY STIFF, BROWN, **SILT AND CLAY**, SOME STONE FRAGMENTS, TRACE SAND, DAMP			12 20 21	59	67	SS-7	3.50	33	4	3	24	36	36	21	15	16	A-6a (7)	-	
@23.5'; HARD, POOR RECOVERY			8 17 39	81	11	SS-8	-	-	-	-	-	-	-	-	-	8	A-6a (V)	-	
			18 46 48	136	17	SS-9	-	-	-	-	-	-	-	-	-	9	A-6a (V)	-	
	485.6	TR																	
LIMESTONE, BLUISH GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, STYOLITIC, JOINTED, MODERATELY FRACTURED TO FRACTURED, NARROW, SLIGHTLY ROUGH; BLOCKY, FAIR; RQD 28%, REC 100%. @28.7' - 29.0'; CLAY SEAM @29.3' - 29.5'; CLAY SEAM			17		100	NQ2-1											CORE		
@ 33.7' - 34.0'; γ = 168 pcf; Qu = 7,889 psi			40		100	NQ2-2											CORE		
	475.6	EOB																	

NOTES: HOLE DRY BEFORE CORING. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

STANDARD ODOT LOG W/ SULFATES (11 X 17) - OH DOT GDT - 1-6-23 13:34 - G:\2023\MAY\31\23050011COL\600978.GPJ

DESIGN AGENCY

ENGINEERING
2200 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX (614)276-6377

DESIGNER N.K.S

REVIEWER SM 10-11-23

PROJECT ID 116986

SUBSET 9 TOTAL 12

SHEET P:35 TOTAL 38

GEOTECHNICAL PROFILE - LANDSLIDE

BORING LOG B-002-1-22

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-002-1-22

Run #:	Depth		Recovery		RQD	
NQ2-1	28.5’	33.5’	60/60	100%	10/60	17%
NQ2-2	33.5’	38.5’	60/60	100%	24/60	40%
BRO-52-10.25 PID 116986						

DESIGN AGENCY
GTL ENGINEERING
2200 FRASER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX: (614)276-6377

DESIGNER N.K.S
REVIEWER SM 10-11-23
PROJECT ID 116986
SUBSET 10 TOTAL 12
SHEET P:36 TOTAL 38

GEOTECHNICAL PROFILE - LANDSLIDE

ROCK CORE PHOTO FOR B-002-1-22

BRO-52-10.25

MODEL: Sheet PAPERSIZE: 11x17 (in.) DATE: 11-10-2023 TIME: 13:45:34 USER: hp
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PROJECT: BRO-52-10.25	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 19+26, 6' RT.	EXPLORATION ID B-003-0-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 116986 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4-18-22	ELEVATION: 513.5 (ft) EOB: 41.0 ft.	PAGE 1 OF 1
START: 6-8-22 END: 6-9-22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.7	LAT / LONG: 38.763494, -83.873370	

MATERIAL DESCRIPTION AND NOTES	ELEV. 513.5	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
ASPHALT (30") & CONCRETE (8")																			
	510.4																		
MEDIUM STIFF, BROWN AND GRAY, **SILTY CLAY**, SOME STONE FRAGMENTS, LITTLE SAND, MOIST @3.5'; NO RECOVERY, AUGER CUTTINGS TAKEN			8 2 3	7	0	SS-1	-	30	9	11	26	24	38	18	20	18	A-6b (7)	-	
@6.0'; STIFF, POOR RECOVERY			3 2 2	6	39	SS-2	2.00	-	-	-	-	-	-	-	-	22	A-6b (V)	-	
@8.5'; VERY STIFF, POOR RECOVERY, ADDITIONAL AUGER CUTTINGS TAKEN			5 6 7	19	11	SS-3	2.25	-	-	-	-	-	-	-	-	24	A-6b (V)	-	
	502.5																		
VERY STIFF, MOTTLED BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, MOIST			4 5 9	20	100	SS-4	4.00	1	1	3	37	58	45	21	24	23	A-7-6 (15)	-	
@13.5'; BROWN MOTTLED WITH GRAY			3 4 5	13	100	SS-5	2.50	-	-	-	-	-	-	-	-	22	A-7-6 (V)	-	
	497.5																		
VERY STIFF, BROWN, **SILT AND CLAY**, SOME SAND, TRACE STONE FRAGMENTS, MOIST			2 4 4	12	100	SS-6	2.50	1	1	20	44	34	31	16	15	19	A-6a (10)	-	
@18.5'; STIFF			2 2 3	7	83	SS-7	2.00	-	-	-	-	-	-	-	-	22	A-6a (V)	-	
	492.5																		
MEDIUM STIFF, BROWN, **SANDY SILT**, SOME CLAY, MOIST			1 1 2	4	100	SS-8	1.00	0	12	13	49	26	27	17	10	24	A-4a (8)	-	
@23.5'; SOFT			0 0 1	1	100	SS-9	0.50	-	-	-	-	-	-	-	-	24	A-4a (V)	-	
@26.0'; MEDIUM STIFF			1 2 4	9	100	SS-10	0.50	-	-	-	-	-	-	-	-	22	A-4a (V)	-	
	485.0																		
STIFF, BROWN, **SILTY CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, WET		W 483.5	2 7 7	20	56	SS-11	1.00	16	3	11	32	38	37	21	16	34	A-6b (9)	-	
	482.5	TR																	
LIMESTONE, BLUISH GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, STYOLITIC, JOINTED, FRACTURED, NARROW, SLIGHTLY ROUGH; BLOCKY, FAIR; RQD 41%, REC 98%. @ 31.4' - 31.7'; γ = 167 pcf; Qu = 9,085 psi				37	97	NQ2-1											CORE		
@34.6' - 34.7'; SHALE, HIGHLY WEATHERED																			
@37.0' - 37.2'; SHALE, HIGHLY WEATHERED				45	100	NQ2-2											CORE		
@38.5' - 38.6'; SHALE, HIGHLY WEATHERED @38.8' - 39.0'; SHALE, HIGHLY WEATHERED @39.6' - 40.0'; SHALE, HIGHLY WEATHERED																			
@40.4' - 40.6'; SHALE, HIGHLY WEATHERED	472.5	EOB																	

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

STANDARD ODOT LOG W/ SULFATES (11 X 17) - OH DOT GDT - 1-6-23 13:34 - G:\2023\MAY\31\23050011COL\600978.GPJ

DESIGN AGENCY
ENGINEERING LTD
2200 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX: (614)276-8377

DESIGNER N.K.S
REVIEWER SM 10-11-23
PROJECT ID 116986
SUBSET 11 TOTAL 12
SHEET P.37 TOTAL 38

GEOTECHNICAL PROFILE - LANDSLIDE

BORING LOG B-003-0-22

MODEL: Sheet PAPERSIZE: 11x17 (in.) DATE: 11-10-2023 TIME: 13:47:55 USER: hp
D:\Drop Box\CTL 2023\October\Dept 05\COL\Shahed\23050011COL_ODOT\Mod_11.10.23\116986ZL008.dgn

OHIO DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING

Office of Geotechnical Engineering

B-003-0-22

Run #:	Depth		Recovery		RQD	
NQ2-1	31.0'	36.0'	58/60	97%	22/60	37%
NQ2-2	36.0'	41.0'	60/60	100%	27/60	45%
BRO-52-10.25 PID 116986						

DESIGN AGENCY
CTL ENGINEERING INC.
2860 FISHER ROAD
COLUMBUS, OHIO 43204
PHONE: (614)276-8123
FAX: (614)276-6377

DESIGNER N.K.S
REVIEWER SM 10-11-23
PROJECT ID 116986
SUBSET 12 TOTAL 12
SHEET P.38 TOTAL 38

GEOTECHNICAL PROFILE - LANDSLIDE

ROCK CORE PHOTO FOR B-003-0-22

APPENDIX B
TEST BORING RECORDS

SOIL DESCRIPTION

Descriptors for soil consistency used in this report are based upon the Standard Penetration Test (SPT), ASTM D 1587, with the penetration (N) values corrected to N_{60} , based upon the efficiency of the SPT Hammer used for the soil sampling.

Descriptors for both non-cohesive and cohesive soils are presented below, with the corresponding range of corrected penetration values.

NON-COHESIVE SOIL DESCRIPTION	CORRECTED PENETRATION VALUES BLOWS PER FOOT (BPF)
Very Loose	0 – 4
Loose	5 – 10
Medium Dense	11- 30
Dense	31 – 50
Very Dense	Over 50

COHESIVE SOIL DESCRIPTION	CORRECTED PENETRATION VALUES BLOWS PER FOOT (BPF)
Very Soft	0 – 1
Soft	2 – 4
Medium Stiff	5 – 8
Stiff	9 – 15
Very Stiff	16 –30
Hard	Over 30

Moisture term descriptors for both non-cohesive and cohesive soils are presented below.

NON-COHESIVE SOIL DESCRIPTION	MOISTURE TERMS	COHESIVE SOIL DESCRIPTION
Powdery	Dry	Powdery
Some Moisture	Damp	Below Plastic Limit
Damp to the Touch	Moist	Above Plastic, Below Liquid Limit
Free Water	Wet	Above Liquid Limit

PROJECT: BRO-52-10.25	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 16+44, 9' RT.	EXPLORATION ID B-001-0-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 116986 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/18/22	ELEVATION: 513.2 (ft) EOB: 46.0 ft.	PAGE 1 OF 2
START: 6/7/22 END: 6/8/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.7	LAT / LONG: 38.763708, -83.874319	

MATERIAL DESCRIPTION AND NOTES	ELEV. 513.2	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (30") & CONCRETE (8")		1 2 3																
STIFF, BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE GRAVEL AND STONE FRAGMENTS, MOIST	510.1	4 5	3 4 3	10	39	SS-1	2.00	6	4	4	36	50	42	19	23	22	A-7-6 (14)	
@6.0'; VERY STIFF, DAMP	504.7	6 7 8	3 6 4	14	44	SS-2	2.50	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
VERY DENSE, BROWN, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, MOIST	502.2	9 10	5 11 28	56	67	SS-3	-	51	10	9	15	15	28	15	13	14	A-2-6 (0)	
VERY STIFF, BROWN, **CLAY**, SOME SILT, LITTLE STONE FRAGMENTS, TRACE SAND, MOIST	499.7	11 12 13	3 4 5	13	89	SS-4	3.75	19	3	4	28	46	43	20	23	23	A-7-6 (14)	
STIFF, GRAY, **CLAY**, SOME SILT, LITTLE STONE FRAGMENTS, TRACE SAND, MODERATELY ORGANIC (LOI = 6.2%), MOIST	497.2	14 15	3 4 5	13	100	SS-5	1.50	15	2	3	33	47	49	23	26	30	A-7-6 (16)	
VERY STIFF, BROWN, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, MOIST	489.7	16 17 18 19 20 21 22 23	5 6 9	22	100	SS-6	4.00	1	0	3	42	54	45	21	24	22	A-7-6 (15)	
			3 5 8	19	100	SS-7	4.00	-	-	-	-	-	-	-	-	22	A-7-6 (V)	
			4 5 6	16	100	SS-8	4.00	-	-	-	-	-	-	-	-	21	A-7-6 (V)	
STIFF, BROWN, **SILT AND CLAY**, SOME SAND, MOIST	484.7	24 25 26 27 28	1 3 4	10	100	SS-9	2.00	0	0	22	48	30	30	16	14	22	A-6a (10)	
			1 3 5	12	100	SS-10	1.00	-	-	-	-	-	-	-	-	23	A-6a (V)	
STIFF, BROWN, **SILT**, SOME SAND, SOME CLAY, WET		29	2 2 3	7	100	SS-11	1.50	0	1	27	50	22	25	17	8	22	A-4b (7)	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 5/30/23 09:58 - O:\PROJECT\2023\COL-05\230500011COL\REPORTS\LOGS\600978.GPJ

PID: 116986	SFN:	PROJECT: BRO-52-10.25	STATION / OFFSET: 16+44, 9' RT.	START: 6/7/22	END: 6/8/22	PG 2 OF 2	B-001-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
STIFF, BROWN, **SILT**, SOME SAND, SOME CLAY, WET *(continued)*	483.2																	
@31.0'; MEDIUM STIFF		31	22 2 2	6	78	SS-12	1.00	-	-	-	-	-	-	-	-	21	A-4b (V)	
	479.7	32																
		TR 33																
LIMESTONE, GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, STYOLITIC, JOINTED, MODERATELY FRACTURED, NARROW, SLIGHTLY ROUGH; BLOCKY, FAIR; RQD 62%, REC 100%.		34	50	-	100	SS-13	-	-	-	-	-	-	-	-	-	4	Rock (V)	
@ 36.6' - 36.9'; γ = 168 pcf; Qu = 10,445 psi		35																
		36																
		37																
		38	72		100	NQ2-1											CORE	
@39.1' - 39.2'; SHALE, SEVERELY WEATHERED		39																
@39.6' - 39.9'; SHALE, SEVERELY WEATHERED		40																
		41																
@41.6' - 41.8'; SHALE, SEVERELY WEATHERED		42																
		43	52		100	NQ2-2											CORE	
		44																
		45																
	467.2	EOB 46																

NOTES: HOLE DRY BEFORE CORING. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

PROJECT: BRO-52-10.25	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 17+98, 28' RT.	EXPLORATION ID B-002-0-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 116986 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/18/22	ELEVATION: 513.5 (ft) EOB: 45.0 ft.	PAGE 1 OF 2
START: 6/9/22 END: 6/15/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.7	LAT / LONG: 38.763517, -83.873825	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	INCL.
ASPHALT (12")	513.5	1																
LOOSE, BROWN AND GRAY, **SANDY SILT**, "AND" GRAVEL AND STONE FRAGMENTS, LITTLE CLAY, DAMP	512.5	2	3 2 2	6	22	SS-1	3.00	37	13	11	20	19	25	16	9	10	A-4a (1)	
VERY STIFF, BROWN, **CLAY**, SOME SILT, TRACE SAND, TRACE STONE FRAGMENTS, DAMP	510.0	3 4 5 6 7 8	5 3 4	10	78	SS-2	2.50	-	-	-	-	-	-	-	-	18	A-7-6 (V)	
			3 5 8	19	67	SS-3	3.00	8	4	4	33	51	41	22	19	20	A-7-6 (12)	
VERY DENSE, BROWN AND GRAY, **STONE FRAGMENTS WITH SAND, SILT, AND CLAY**, MOIST	505.0	9 10	16 8 51	85	78	SS-4	1.50	48	17	8	13	14	29	17	12	15	A-2-6 (0)	
@10.0' - 20.0'; ENCOUNTERED BOULDERS/COBBLES	502.5	11 12 13	9 8 15	33	33	SS-5	4.00	59	2	2	17	20	41	18	23	12	A-7-6 (3)	
HARD, BROWN, **CLAY**, "AND" STONE FRAGMENTS, LITTLE SILT, TRACE SAND, DAMP	500.0	14 15 16 17 18 19 20	55	-	100	SS-6	-	18	7	4	29	42	40	18	22	16	A-6b (12)	
HARD, BROWN, **SILTY CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP																		
@16.0'; POOR RECOVERY			9 22 16	55	33	SS-7	2.50	-	-	-	-	-	-	-	-	10	A-6b (V)	
@18.5'; VERY STIFF, GRAYISH BROWN, TRACE SAND, MOIST	492.5		7 15 15	43	78	SS-8	3.50	14	4	4	31	47	40	18	22	19	A-6b (13)	
VERY STIFF, GRAY AND BROWN, **SILT AND CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, DAMP		21 22 23	5 6 29	51	67	SS-9	2.50	18	6	5	31	40	34	20	14	19	A-6a (9)	
@23.5'; STIFF, SPOON BLOCKED BY STONE FRAGMENTS		24 25	16 14 17	45	11	SS-10	1.00	-	-	-	-	-	-	-	-	16	A-6a (V)	
@26.0'; SAMPLE RECOVERED WITH A 3" SPLITSPOON	485.0	26 27 28	11 7 14	30	56	SS-11	1.50	-	-	-	-	-	-	-	-	14	A-6a (V)	
		29	15 16 12	40	67	SS-12	-	-	-	-	-	-	-	-	-	8	A-2-4 (V)	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 5/30/23 09:58 - O:\PROJECT\2023\COL-05\23050011COL\REPORTS\LOGS\600978.GPJ

PID: 116986	SFN:	PROJECT: BRO-52-10.25	STATION / OFFSET: 17+98, 28' RT.	START: 6/9/22	END: 6/15/22	PG 2 OF 2	B-002-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	INCL.
DENSE, BROWN, **STONE FRAGMENTS WITH SAND AND SILT**, LITTLE CLAY, SAMPLE RECOVERED WITH A 3" SPLITSPOON, MOIST *(continued)*	483.5	31	8 10 17	39	78	SS-13	-	57	3	10	19	11	29	19	10	16	A-2-4 (0)	
		32																
		33																
		34	6 50	-	100	SS-14	-	-	-	-	-	-	-	-	-	19	A-2-4 (V)	
	478.5	TR 35																
LIMESTONE, GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, STYOLITIC, JOINTED, MODERATELY FRACTURED, NARROW, SLIGHTLY ROUGH; BLOCKY, FAIR; RQD 29%, REC 99%. @35.1' - 35.2'; CLAY SEAM @36.1' - 36.2'; CLAY SEAM @37.6' - 37.7'; SHALE, SEVERELY WEATHERED @38.1' - 38.3'; SHALE, SEVERELY WEATHERED @38.8' - 39.0'; SHALE, SEVERELY WEATHERED @39.7' - 40.0'; SHALE, SEVERELY WEATHERED @40.7' - 40.8'; SHALE, SEVERELY WEATHERED @ 41.2' - 41.6'; γ = 169 pcf; Qu = 11,790 psi		36	11		100	NQ2-3											CORE	
		37																
		38																
		39	25		100	NQ2-4											CORE	
		40																
		41																
		42																
		43	42		98	NQ2-5											CORE	
		44																
	468.5	EOB 45																

NOTES: SPLITSPOON SAMPLES SS-5, SS-6, SS-7, SS-8 WERE SAMPLED FROM OFFSET HOLE AFTER ENCOUNTERING COBBLES/BOULDERS FROM 10.0 FEET TO 20.0 FEET.

NOTES: HOLE DRY BEFORE CORING. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: PUMPED 45 GAL. BENTONITE CEMENT GROUT

PROJECT: BRO-52-10.25	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 18+01, 3' LT.	EXPLORATION ID B-002-1-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 116986 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/18/22	ELEVATION: 514.1 (ft) EOB: 38.5 ft.	PAGE 1 OF 2
START: 6/15/22 END: 6/15/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.7	LAT / LONG: 38.763599, -83.873806	

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (30") & CONCRETE (8")	514.1																	
	511.0																	
VERY DENSE, BROWN AND DARK BROWN, **STONE FRAGMENTS WITH SAND**, LITTLE SILT, TRACE CLAY, AUGER SAMPLE TAKEN, DAMP			16 20 21	59	17	SS-1	-	40	17	20	18	5	NP	NP	NP	7	A-1-b (0)	
	508.1																	
VERY STIFF, BROWN, **SILTY CLAY**, SOME STONE FRAGMENTS, TRACE SAND, DAMP			10 10 12	32	44	SS-2	3.50	33	5	4	25	33	39	20	19	19	A-6b (8)	
@7.5' - 9.5'; ENCOUNTERED BOULDERS/COBBLES																		
@11.0' - 13.5'; HARD, SAMPLE RECOVERED WITH A 3" SPLITSPOON			9 18 12	43	33	SS-3	4.00	-	-	-	-	-	-	-	-	15	A-6b (V)	
@13.5'; MOTTLED BROWN AND GRAY @13.5' - 26.25'; ENCOUNTERED BOULDERS/COBBLES			3 10 28	55	56	SS-4	3.50	26	4	3	28	39	40	22	18	18	A-6b (10)	
			10 28 14	61	44	SS-5	3.25	-	-	-	-	-	-	-	-	18	A-6b (V)	
			4 12 15	39	33	SS-6	3.50	-	-	-	-	-	-	-	-	14	A-6b (V)	
	493.1																	
VERY STIFF, BROWN, **SILT AND CLAY**, SOME STONE FRAGMENTS, TRACE SAND, DAMP			12 20 21	59	67	SS-7	3.50	33	4	3	24	36	36	21	15	16	A-6a (7)	
@23.5'; HARD, POOR RECOVERY			8 17 39	81	11	SS-8	-	-	-	-	-	-	-	-	-	8	A-6a (V)	
			18 46 48	136	17	SS-9	-	-	-	-	-	-	-	-	-	9	A-6a (V)	
	485.6	TR																
@28.7' - 29.0'; CLAY SEAM @29.3' - 29.5'; CLAY SEAM																		

PID: 116986	SFN:	PROJECT: BRO-52-10.25	STATION / OFFSET: 18+01, 3' LT.	START: 6/15/22	END: 6/15/22	PG 2 OF 2	B-002-1-22

MATERIAL DESCRIPTION AND NOTES	ELEV.	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
LIMESTONE, BLUISH GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, STYOLITIC, JOINTED, MODERATELY FRACTURED TO FRACTURED, NARROW, SLIGHTLY ROUGH; BLOCKY, FAIR; RQD 28%, REC 100%. *(continued)*	484.1	31 32 33	17		100	NQ2-1											CORE	
@ 33.7' - 34.0'; γ = 168 pcf; Qu = 7,889 psi		34 35 36 37 38	40		100	NQ2-2											CORE	
	475.6	EOB																

NOTES: HOLE DRY BEFORE CORING. LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

PROJECT: BRO-52-10.25	DRILLING FIRM / OPERATOR: ODOT / CAREY	DRILL RIG: CME 55 TRUCK	STATION / OFFSET: 19+26, 6' RT.	EXPLORATION ID B-003-0-22
TYPE: LANDSLIDE	SAMPLING FIRM / LOGGER: ODOT / MCLEISH	HAMMER: CME AUTOMATIC	ALIGNMENT: CL SR 52	
PID: 116986 SFN:	DRILLING METHOD: 3.25" HSA / NQ2	CALIBRATION DATE: 4/18/22	ELEVATION: 513.5 (ft) EOB: 41.0 ft.	PAGE 1 OF 2
START: 6/8/22 END: 6/9/22	SAMPLING METHOD: SPT	ENERGY RATIO (%): 86.7	LAT / LONG: 38.763494, -83.873370	

MATERIAL DESCRIPTION AND NOTES	ELEV. 513.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
ASPHALT (30") & CONCRETE (8")																		
	510.4																	
MEDIUM STIFF, BROWN AND GRAY, **SILTY CLAY**, SOME STONE FRAGMENTS, LITTLE SAND, MOIST @3.5'; NO RECOVERY, AUGER CUTTINGS TAKEN			8 2 3	7	0	SS-1	-	30	9	11	26	24	38	18	20	18	A-6b (7)	
@6.0'; STIFF, POOR RECOVERY			3 2 2	6	39	SS-2	2.00	-	-	-	-	-	-	-	-	22	A-6b (V)	
@8.5'; VERY STIFF, POOR RECOVERY, ADDITIONAL AUGER CUTTINGS TAKEN			5 6 7	19	11	SS-3	2.25	-	-	-	-	-	-	-	-	24	A-6b (V)	
	502.5																	
VERY STIFF, MOTTLED BROWN AND GRAY, **CLAY**, "AND" SILT, TRACE SAND, TRACE STONE FRAGMENTS, MOIST			4 5 9	20	100	SS-4	4.00	1	1	3	37	58	45	21	24	23	A-7-6 (15)	
@13.5'; BROWN MOTTLED WITH GRAY			3 4 5	13	100	SS-5	2.50	-	-	-	-	-	-	-	-	22	A-7-6 (V)	
	497.5																	
VERY STIFF, BROWN, **SILT AND CLAY**, SOME SAND, TRACE STONE FRAGMENTS, MOIST			2 4 4	12	100	SS-6	2.50	1	1	20	44	34	31	16	15	19	A-6a (10)	
@18.5'; STIFF			2 2 3	7	83	SS-7	2.00	-	-	-	-	-	-	-	-	22	A-6a (V)	
	492.5																	
MEDIUM STIFF, BROWN, **SANDY SILT**, SOME CLAY, MOIST			1 1 2	4	100	SS-8	1.00	0	12	13	49	26	27	17	10	24	A-4a (8)	
@23.5'; SOFT			0 0 1	1	100	SS-9	0.50	-	-	-	-	-	-	-	-	24	A-4a (V)	
@26.0'; MEDIUM STIFF			1 2 4	9	100	SS-10	0.50	-	-	-	-	-	-	-	-	22	A-4a (V)	
	485.0																	
STIFF, BROWN, **SILTY CLAY**, LITTLE STONE FRAGMENTS, LITTLE SAND, WET		W 483.5	2 7 7	20	56	SS-11	1.00	16	3	11	32	38	37	21	16	34	A-6b (9)	

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 5/30/23 09:58 - O:\PROJECT\2023\COL-05\23050011COL\REPORTS\LOGS\600978.GPJ

PID: 116986	SFN:	PROJECT: BRO-52-10.25	STATION / OFFSET: 19+26, 6' RT.	START: 6/8/22	END: 6/9/22	PG 2 OF 2	B-003-0-22

MATERIAL DESCRIPTION AND NOTES	ELEV. 483.5	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	ODOT CLASS (GI)	BACK FILL
	482.5	TR 31																
LIMESTONE, BLUISH GRAY, MODERATELY WEATHERED, STRONG, THIN BEDDED, FOSSILIFEROUS, STYOLITIC, JOINTED, FRACTURED, NARROW, SLIGHTLY ROUGH; BLOCKY, FAIR; RQD 41%, REC 98%. @ 31.4' - 31.7'; γ = 167 pcf; Qu = 9,085 psi @34.6' - 34.7'; SHALE, HIGHLY WEATHERED		32 33 34 35 36	37		97	NQ2-1											CORE	
@37.0' - 37.2'; SHALE, HIGHLY WEATHERED @38.5' - 38.6'; SHALE, HIGHLY WEATHERED @38.8' - 39.0'; SHALE, HIGHLY WEATHERED @39.6' - 40.0'; SHALE, HIGHLY WEATHERED @40.4' - 40.6'; SHALE, HIGHLY WEATHERED	472.5	37 38 39 40 EOB 41	45		100	NQ2-2											CORE	

NOTES: LAT/LONG FROM OGE HANDHELD GPS UNIT. ELEV FROM USGS 3DEP MAP SERVICE

ABANDONMENT METHODS, MATERIALS, QUANTITIES: AUGER CUTTINGS MIXED WITH 25 LB. BENTONITE CHIPS

APPENDIX C
INCLINOMETER DATA

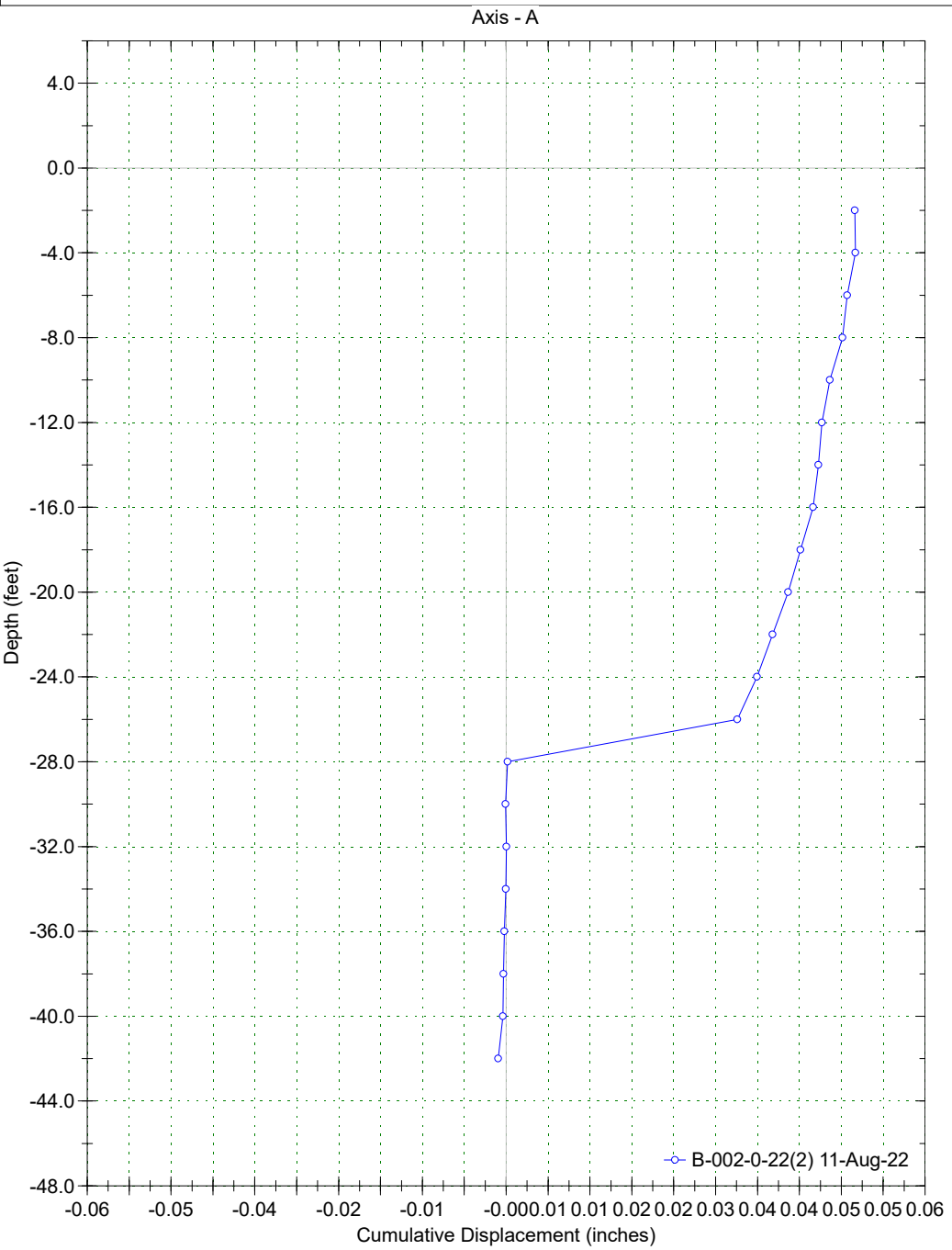
RST Instruments Ltd.

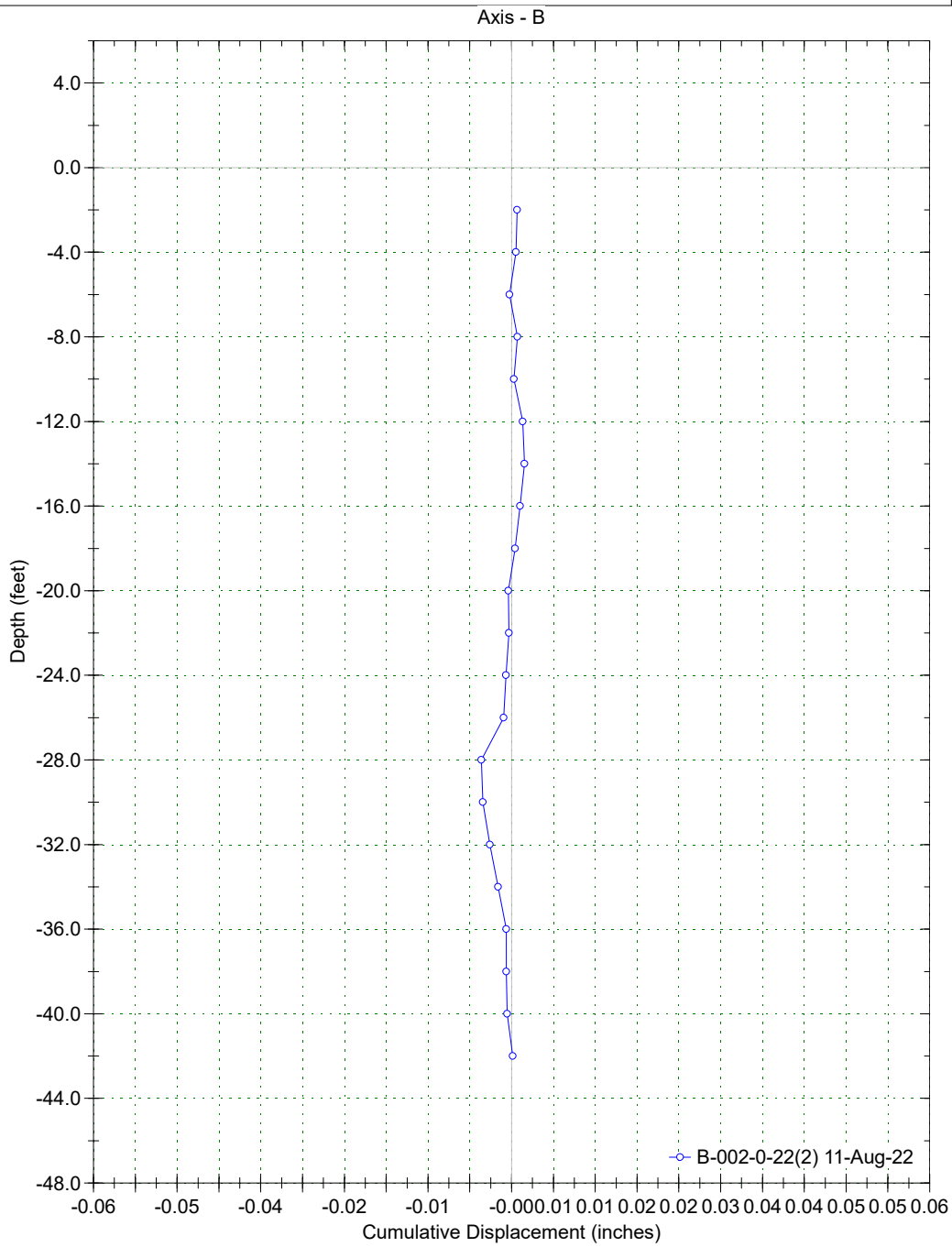
CUMULATIVE DISPLACEMENT

Inclinalysis v. 2.48.7

Borehole : B-002-0-22
Project : BRO-52-10.25
Location :
Northing :
Easting :
Collar :

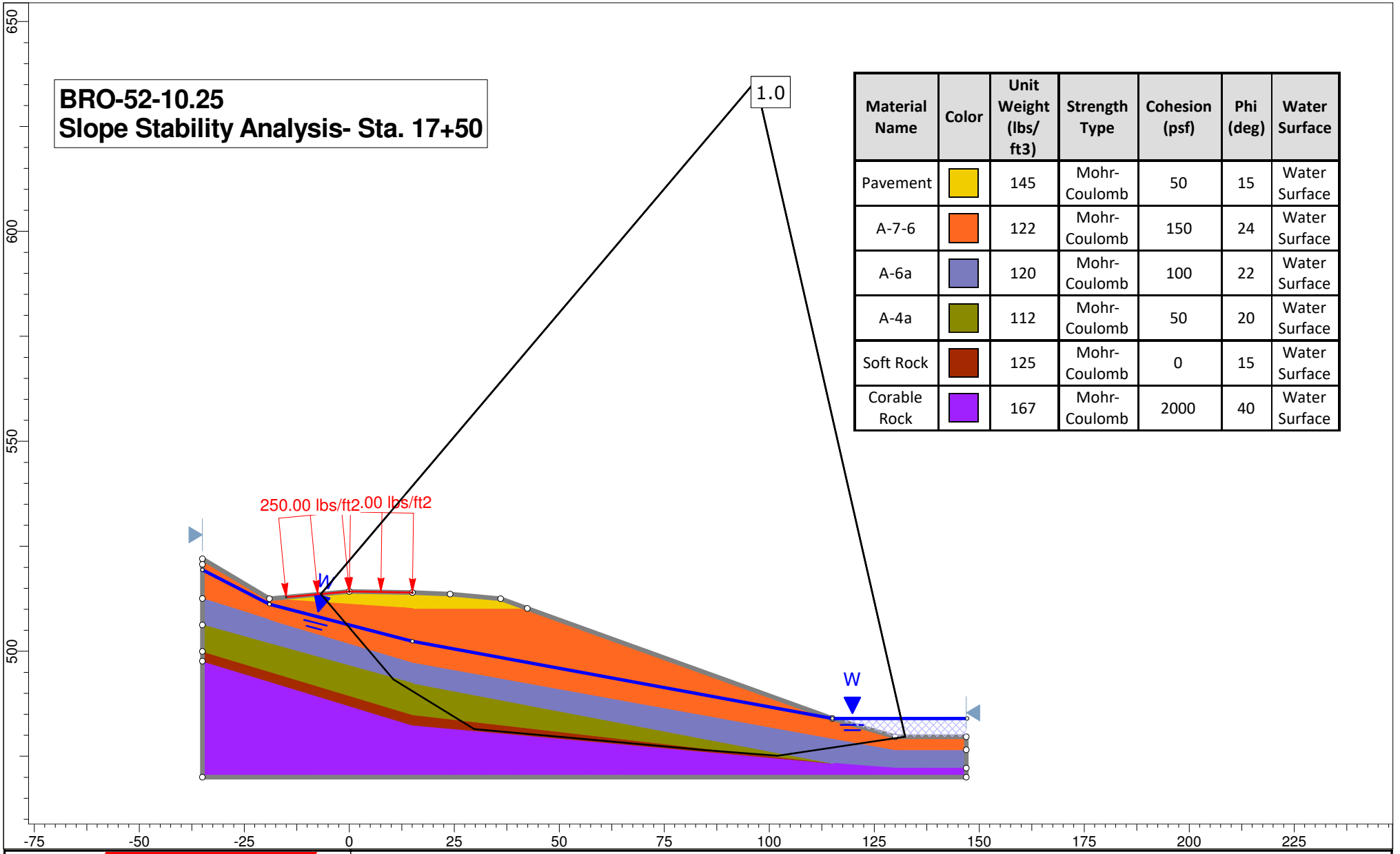
Spiral Correction : N/A
Collar Elevation : 0.00 feet
Reading Depth : 42.0 feet
A+ Groove Azimuth :
Base Reading : 2022 Jul 21 12:37
Applied Azimuth : 0.0 degrees





APPENDIX D
GLOBAL STABILITY ANALYSES

BRO-52-10.25
Slope Stability Analysis- Sta. 17+50



Material Name	Color	Unit Weight (lbs/ ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Pavement		145	Mohr-Coulomb	50	15	Water Surface
A-7-6		122	Mohr-Coulomb	150	24	Water Surface
A-6a		120	Mohr-Coulomb	100	22	Water Surface
A-4a		112	Mohr-Coulomb	50	20	Water Surface
Soft Rock		125	Mohr-Coulomb	0	15	Water Surface
Corable Rock		167	Mohr-Coulomb	2000	40	Water Surface

CTL ENGINEERING INC

Project	BRO-52-10.25		
Group	Group 1	Scenario	Master Scenario
Drawn By	SR	Company	CTL Engineering, Inc.
Date	2/13/2023, 1:18:17 PM	File Name	Sta 17+50 Slope Stability Analysis.slmd

SLIDEINTERPRET 10.0

APPENDIX E
DRILLED SHAFT ANALYSES

UA Slope Program Version 2.3 - O:\PROJECT\2023\COL-05\23050011COL\Design\UA Slope\Without shaft.ua3*

File Run Options Help

Calculated Results

Factor of Safety: 1.04

Force per Shaft: 0.000 lb

Acting Point X: 0.000 ft Y: 0.000 ft

Analysis Unit System

(•) English ( ) Metric

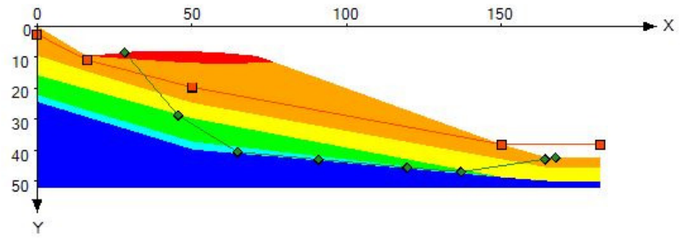
Number of Vertical Sections and Soil Layers

Vertical Section Num: 10 Soil Layer Num: 6

Analysis Method

( ) Total Stress (•) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
▸ Layer1	50.0	15.0	145.0
Layer2	150.0	24.0	122.0
Layer3	100.0	22.0	120.0
Layer4	50.0	20.0	112.0
Layer5	0.0	13.0	125.0
Layer6	2000.0	40.0	167.0

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10
▸ X (ft)	0.00	16.00	35.00	50.00	59.00	71.00	77.35	150.00	165.00	182.00
Y1 (ft)	0.00	9.50	7.75	8.00	8.40	9.50	11.80	38.00	42.35	42.35
Y2 (ft)	0.00	9.50	10.80	11.80	11.90	11.80	11.80	38.00	42.35	42.35
Y3 (ft)	9.40	14.50	20.20	24.60	26.30	28.40	29.60	42.80	45.50	45.46
Y4 (ft)	15.70	20.20	25.40	29.60	31.30	33.60	34.80	48.60	49.80	49.80
Y5 (ft)	22.05	27.00	32.60	37.10	38.20	39.50	40.30	48.60	49.80	49.80
Y6 (ft)	24.30	29.20	35.00	39.60	40.50	41.50	42.00	48.60	49.80	49.80
Y7 (ft)	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00

Coordinates of Crest X: 71.00 ft Y: 9.50 ft Coordinates of Toe X: 165.00 ft Y: 42.35 ft

Drilled Shaft Information

(•) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

( ) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)

Xmin 0.00 Diameter: 0.30 ft

Xmax 0.00 CTC Spacing: 0.00 ft

XDelta 0.00 X Coordinate: 0.00 ft

[ ] Auto Save Data

Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

	Point 1	Point 2	Point 3	Point 4	Point 5
▸ X (ft)	0.00	16.00	50.00	150.00	182.00
Y (ft)	2.60	10.80	19.60	38.00	38.00

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8
▸ X (ft)	28.20	45.50	64.70	90.80	119.50	136.90	164.00	167.40
Y (ft)	8.40	28.70	40.50	42.90	45.50	46.90	42.80	42.30

UA Slope Program Version 2.3 - O:\PROJECT\2023\COL-05\23050011COL\Design\UA Slope\With shaft.ua3

File Run Options Help

Calculated Results

Factor of Safety: 1.81

Force per Shaft: 151667.276 lb

Acting Point X: 57.000 ft Y: 26.274 ft

Analysis Unit System

(•) English ( ) Metric

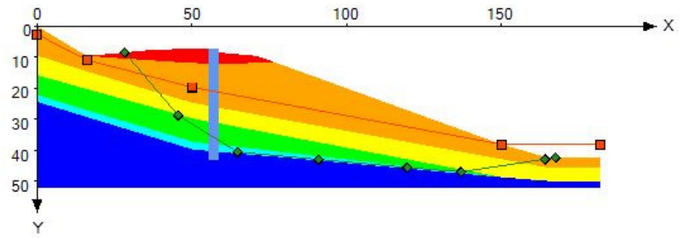
Number of Vertical Sections and Soil Layers

Vertical Section Num: 11 Soil Layer Num: 6

Analysis Method

( ) Total Stress (•) Effective Stress

Chart (Double-Click for More Options)



Soil Properties

	Cohesion (psf)	Friction Angle	Total Unit Weight (pcf)
▸ Layer1	50.0	15.0	145.0
Layer2	150.0	24.0	122.0
Layer3	100.0	22.0	120.0
Layer4	50.0	20.0	112.0
Layer5	0.0	13.0	125.0
Layer6	2000.0	40.0	167.0

Slope Profile Vertical Sections

	Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7	Section 8	Section 9	Section 10	Section 11
▸ X (ft)	0.00	16.00	35.00	50.00	57.00	59.00	71.00	77.35	150.00	165.00	182.00
Y1 (ft)	0.00	9.50	7.75	7.00	7.00	8.40	9.50	11.80	38.00	42.35	42.35
Y2 (ft)	0.00	9.50	10.80	11.80	11.90	11.90	11.80	11.80	38.00	42.35	42.35
Y3 (ft)	9.40	14.50	20.20	24.60	25.80	26.30	28.40	29.60	42.80	45.50	45.46
Y4 (ft)	15.70	20.20	25.40	29.60	31.00	31.30	33.60	34.80	48.60	49.80	49.80
Y5 (ft)	22.05	27.00	32.60	37.10	38.00	38.20	39.50	40.30	48.60	49.80	49.80
Y6 (ft)	24.30	29.20	35.00	39.60	40.30	40.50	41.50	42.00	48.60	49.80	49.80
Y7 (ft)	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00	52.00

Coordinates of Crest X: 71.00 ft Y: 9.50 ft Coordinates of Toe X: 165.00 ft Y: 42.35 ft

Drilled Shaft Information

( ) Calculate without Drilled Shaft

( ) Automatic Load Transfer Factor

(•) Manually Defined Load Transfer Factor

[ ] Anchor (On/Off)

Anchor force: 0.00 lb

Anchor angle: 0.00

Anchor spacing: 0.00 ft

Auto ( ) On (•) Off 0.000 (n)

Xmin 0.00 Diameter: 3.00 ft

Xmax 0.00 CTC Spacing: 5.00 ft

XDelta 0.00 X Coordinate: 57.00 ft

[ ] Auto Save Data

▷ Run

Pore Water Pressure

Pore Pressure Options: ( ) No Pore Pressure ( ) Constant Ratio (•) Specified phreatic surface

	Point 1	Point 2	Point 3	Point 4	Point 5
▸ X (ft)	0.00	16.00	50.00	150.00	182.00
Y (ft)	2.60	10.80	19.60	38.00	38.00

Slip Surface

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8
▸ X (ft)	28.20	45.50	64.70	90.80	119.50	136.90	164.00	167.40
Y (ft)	8.40	28.70	40.50	42.90	45.50	46.90	42.80	42.30

Project: BRO-52-10.25
Project No: 23050011COL
April 5, 2023

L-PILE Soil Parameters

Artificial Lowering of Ground Surface

The passive resistance from the downhill side soil mass should be ignored. In order to include this in the L-pile soil model, the ground level should be artificially lowered.

To do this, first determine the angle of steepness of the slope - downhill of the drilled shafts - from horizontal (β_{dh}), and then determine the depth to the shear surface at the location of the drilled shafts (d_τ). For slopes of steepness from β=0° to 45°, lower the ground surface by an amount equal to $d_\tau TAN(\beta_{dh})$.

For the current project, β_{dh} = 20 degrees (From cross section near Sta. 17+50)

Proposed top of pile elevation = 515.9 (From proposed top of wall elevation)
Existing grade at pile location = 514.4 (From cross section near Sta. 17+50)
Estimated shear surface elevation at pile location = 486.2 feet
d_τ = 514.4 – 486.2 = 28.2 feet

Therefore, $d_\tau TAN(\beta_{dh})$ = 10.3 feet.

The first soil layer should start at elevation 514.4– 10.3 = 504.1

Which is at a depth of 515.9 – 504.1 = 11.8 feet along the shaft

From 11.8'-19.8'

Use soil type – *Stiff Clay with Free Water (Reese)*
Effective Unit Weight (pcf) = 59.6 pcf
N_{60} = 16 bpf (Average blow count, B-003-0-22, SS-4 and SS-5)
Undrained Cohesion (psf) = $N_{60}/8$ = 16/8 = 2,000 psf
Use Strain Factor K_{rm} = 0.005 (From L-pile Technical Manual Table 3-4)
Use Subgrade Modulus K_{static} = 1,000 pci (From L-pile Technical Manual Table 3-3)

From 19.8'-26.8'

Use soil type – *Stiff Clay with Free Water (Reese)*
Effective Unit Weight (pcf) = 57.6 pcf
N_{60} = 8 bpf (Average blow count, B-003-0-22, SS-6, SS-7 and SS-8)
Undrained Cohesion (psf) = $N_{60}/8$ = 8/8 = 1,000 psf
Use Strain Factor K_{rm} = 0.007 (From L-pile Technical Manual Table 3-4)
Use Subgrade Modulus K_{static} = 500 pci (From L-pile Technical Manual Table 3-3)

Project: BRO-52-10.25
Project No: 23050011COL
April 5, 2023

From 26.8'-31.8'

Use soil type – *Soft Clay (Matlock)*
Effective Unit Weight (pcf) = 49.6 pcf
N_{60} = 5 bpf (Average blow count, B-003-0-22, SS-9 and SS-10)
Undrained Cohesion (psf) = $N_{60}/8$ = 5/8 = 625 psf
Use Strain Factor K_{rm} = 0.01 (From L-pile Technical Manual Table 3-4)

From 31.8'-34.1'

Use soil type – *Stiff Clay with Free Water (Reese)*
Effective Unit Weight (pcf) = 62.6 pcf
N_{60} = 20 bpf (B-003-0-22, SS-11)
Undrained Cohesion (psf) = $N_{60}/8$ = 20/8 = 2,500 psf
Use Strain Factor K_{rm} = 0.005 (From L-pile Technical Manual Table 3-4)
Use Subgrade Modulus K_{static} = 1,000 pci (From L-pile Technical Manual Table 3-3)

Below 34.1' (Corable Rock)

Use soil type – *Weak Rock (Reese)*
Effective Unit Weight (pcf) = 167.0 pcf (B-003-0-22, NQ-1 Compressive Strength Test Result)
Compressive strength (q_u) = 9,085 psi (B-003-0-22, NQ-1 Compressive Strength Test Result)
Initial Rock Modulus (E_r) = 680,000 psi (Per ODOT GDM Table 400-6, Strong Rock)
RQD = 41% (Average RQD from B-003-0-22)
Use Strain Factor K_{rm} = 0.00005 (From L-pile Technical Manual)

P-y Modification Factors

If the drilled shafts are at a center-to-center spacing closer than about 3½ diameters, a reduction in the soil resistance p, for the p-y curve behavior of the soil, must be considered.
P- modification factor $\beta_a = 0.64(S/D)^{0.34}$
In which S= Center to Center Spacing between the Piles
D= Diameter of the Shaft

For 36- inch shafts with reinforced shafts placed at 5.0 feet center to center
$\beta a = 0.64(5/3)^{0.34} = 0.76$

No P-Y modification factors are applied to the bedrock layers

BRO-52-10.25

From AASHTO 3.11.5.3, Active Earth Pressure

$$K_a = \mathrm{Sin}^2(\Theta+\emptyset'_f)/\Gamma[\mathrm{Sin}^2(\Theta)*\mathrm{Sin}(\Theta-\delta)]$$

in which $\Gamma = [1+\sqrt{\{(\mathrm{Sin}(\emptyset'f+\delta)*\mathrm{Sin}(\emptyset'f-\beta))/(\mathrm{Sin}(\Theta-\delta)*\mathrm{Sin}(\Theta+\beta))\}}]^2$

Where

Angle of back face of the wall to the horizontal (Degrees), Θ=	90	
Effective angle of internal friction (degrees), Ø'f=	30	(Assumed)
Friction angle between fill and wall (degrees), δ=	20	(2/3 Ø'f)
Angle of fill to the horizontal , β=	0	Assumed)

Calculation

$\mathrm{Sin}(\Theta-\delta)=$	0.94
$\mathrm{Sin}^2(\Theta)=$	1.00
$\mathrm{Sin}(\Theta+\emptyset'_f)=$	0.87
$\mathrm{Sin}^2(\Theta+\emptyset'_f)=$	0.75
$\mathrm{Sin}(\emptyset'_f-\beta)=$	0.50
$\mathrm{Sin}(\Theta+\beta)=$	1.00
$\mathrm{Sin}(\emptyset'_f+\delta)=$	0.77
$\Gamma=$	2.68
$K_a=$	0.30

$\gamma_{LS}=$ 125 pcf (GB7, Section E.7)

Case 1

Diameter of Shaft=	36	inches
C/C Spacing (CC)=	5	feet

Therefore for a 36-inch Shaft placed at 5 feet center to center

Surcharge Load q_{LS}, 31.0 lb/in $\gamma_{LS}*2*K_a*CC/12$

BRO-52-10.25

Conversion of force per Shaft to Distributed Load

The UA Slope 2.3 program calculates the unfactored earth pressure (EH), resultant load per shaft, however, for proper structural analysis of pile reaction, we need to convert this to a realistic load.

The triangular load distribution is a close enough approximation of the actual condition to develop a realistic calculation of distributed shear, moment and displacement in the drilled shaft

Case 1

Diameter of Shaft=	36	inches
C/C Spacing (CC)=	5	feet

For a 36-inch shaft at 5 feet center to center spacing

Load on Shaft (F_{SW})=	151,667	lbs
Depth of Shear plane at Shaft Location(D_S)=	29.7	feet
The Distibuted Load (F_D)=	820.1	lbs/in

a) ***Following cases were evaluated:***

Case1

Diameter of Shaft =	36	inches
Center to Center Spacing =	5	feet

b) ***Unfactored Loads***

Case	Surchage Loads(lbs/in)	Distributed Load(lbs/in)	Total Unfactored Load (lbs/in)
1	31.0	820.1	851.1

c) ***Load Factor per AASHTO Table 3.4.1.1 and 3.4.1.2***

Load Factor for Surcharge Load (LS) = 1.75
Load Factor for Distributed Load (EH) = 1.5

d) ***Factored Distributed loads***

Case	Factored Surcharge Load (lbs/in)	Factored Distributed Loads(lbs/in)	Total Factored Load(lbs/in)
1	54.2	1230.2	1284.4

e) ***Limit State Checks***

1 Use Factored Loads for Strength Limit State and check Moment capacity and Nominal Shear per AASHTO 6.10.8 and 6.10.9
2 Use Unfactored Loads for Service Limit State for deflection

f) ***L-pile Analysis***

Note: It is assumed that 50 Ksi steel will be used.
Section Used= W 24x279 with 0.25 in plate

Case1: 36 inch diameter Shafts with 5 feet center to center spacing

Checks:

Structural Strength Limit State Checks (W 24x279 with 0.25 in plate Section)

Calculated Factored Moment(in-lbs)	Factored Nominal Moment Resistance(in-lbs)	Acceptable Or Unacceptable
16,900,000	35,900,000	Acceptable

Calculated Factored Shear (Kips)	Factored Nominal Shear resistance (Kips)	Acceptable Or Unacceptable
912.6	920.8	Acceptable

See calculation sheets for nominal moment calculations Per AASHTO 6.10.8
and for nominal shear resistance calculation Per AASHTO 6.10.9

Service Limit State Checks (W 24x279 with 0.25 in plate Section)

Drilled Shaft Length above bedrock= 34.1 feet

For the unfactored Service Limit State analysis, the maximum Pilehead deflection must be limited to 1% or less
of the drilled shaft length above bedrock (34.1') or 2 inches in presence of road surcharge within 10 feet of the drilled shaft location, whichever is lesser

Calculated Deflection(in)	Allowable Deflection(in) Per GB7	Acceptable Or Unacceptable
0.6	2.0	Acceptable

BRO-52-10.25

W 24x279 with 0.25 in plate

Thickness of Flange (t_f) =	2.09	in
Depth (d) =	26.70	in
Yield Strength of Steel (F_y) =	50	Ksi
$D = d-2t_f$ =	22.52	in
Thickness of Web (t_w) with Plate=	1.41	in

V_p = $0.58\ F_yDt_w$ =	920.8	Kips
Young's Modulus (E) =	29000	Ksi

Assume Unstiffened Web

Shear Buckling Coefficient (K) =	5.0	
$Sqrt(EK/F_y)$ =	53.9	Equation 1
$1.12*Sqrt(EK/F_y)$ =	60.3	Equation 2
$1.4*Sqrt(EK/F_y)$ =	75.4	Equation 3
D/t_w =	16.0	
Since, $D/t_w \leq$ Equation1, C =	1.0	

Therefore,

Nominal Shear Resistance (V_n) = CV_p	920.8	Kips
ϕ_v =	1.0	
Factored Shear Resistance (V_u) = $\phi_v V_n$	920.8	Kips

BRO-52-10.25

W 24x279 with 0.25 in plate

Per AASHTO, 6.10.8

For Continously Braced Flanges in Tension or Compression

$f_{bu} \leq \phi_f R_h F_{yf}$ Equation 1

Where f_{bu} = Factored Bending Moment Obtained in Strength Limit State
ϕ_f = Flexural Resistance Factor
R_h = Hybrid Factor
F_{yf} = $f_y * S_{x-x}$
f_y = Yield Strength of Steel
S_{x-x} = Section Modulus of Steel Section

ϕ_f =	1.0	Per AASHTO 6.5.4.2
R_h =	1.0	Per AASHTO 6.10.1.10.1
S_{x-x} =	718.0	In^3
f_y =	50.0	ksi
F_{yf} =	35,900,000	lb-in

```
================================================================================

                    LPile for Windows, Version 2022-12.008

                 Analysis of Individual Piles and Drilled Shafts
                Subjected to Lateral Loading Using the p-y Method
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================================================================================

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--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\PROJECT\2023\COL-05\23050011COL\Design\Lpile Analysis\2-27-23 updated analysis\

Name of input data file:
BRO-52-10.25 36 in Shaft with plate.lp12d

Name of output report file:
BRO-52-10.25 36 in Shaft with plate.lp12o

Name of plot output file:
BRO-52-10.25 36 in Shaft with plate.lp12p
```

Name of runtime message file:
BRO-52-10.25 36 in Shaft with plate.lp12r

Date and Time of Analysis

Date: May 15, 2023 Time: 10:07:51

Problem Title

Project Name: BRO-52-10.25

Job Number: 23050011COL

Client: IBI Group

Engineer: SR

Description: Drilled Shaft Analysis

Program Options and Settings

Computational Options:
 - Conventional Analysis
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed = 500
 - Deflection tolerance for convergence = 1.0000E-05 in
 - Maximum allowable deflection = 100.0000 in
 - Number of pile increments = 100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Analysis uses p-y modification factors for p-y curves
 - Analysis uses layering correction (Method of Georgiadis)
 - Analysis includes loading by multiple distributed lateral loads acting on pile
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 45.000 ft
Depth of ground surface below top of pile = 11.8000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	36.0000
2	45.000	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile

Cross-sectional Shape	=	Circular Pile
Length of section	=	45.000000 ft
Width of top of section	=	36.000000 in
Width of bottom of section	=	36.000000 in
Top Area	=	81.900000 sq. in
Bottom Area	=	81.900000 sq. in
Moment of Inertia at Top	=	9600. in^4
Moment of Inertia at Bottom	=	9600. in^4
Elastic Modulus	=	29000000. psi

Soil and Rock Layering Information

The soil profile is modelled using 5 layers

Layer 1 is stiff clay with water-induced erosion

Distance from top of pile to top of layer	=	11.800000 ft
Distance from top of pile to bottom of layer	=	19.800000 ft
Effective unit weight at top of layer	=	59.600000 pcf
Effective unit weight at bottom of layer	=	59.600000 pcf
Undrained cohesion at top of layer	=	2000. psf
Undrained cohesion at bottom of layer	=	2000. psf
Epsilon-50 at top of layer	=	0.005000
Epsilon-50 at bottom of layer	=	0.005000

```
   Subgrade k at top of layer                          =  1000.000000 pci
   Subgrade k at bottom of layer                       =  1000.000000 pci


Layer 2 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    19.800000 ft
   Distance from top of pile to bottom of layer        =    26.800000 ft
   Effective unit weight at top of layer               =    57.600000 pcf
   Effective unit weight at bottom of layer            =    57.600000 pcf
   Undrained cohesion at top of layer                  =  1000.000000 psf
   Undrained cohesion at bottom of layer               =  1000.000000 psf
   Epsilon-50 at top of layer                          =     0.007000
   Epsilon-50 at bottom of layer                       =     0.007000
   Subgrade k at top of layer                          =   500.000000 pci
   Subgrade k at bottom of layer                       =   500.000000 pci


Layer 3 is soft clay, p-y criteria by Matlock, 1970

   Distance from top of pile to top of layer           =    26.800000 ft
   Distance from top of pile to bottom of layer        =    31.800000 ft
   Effective unit weight at top of layer               =    49.600000 pcf
   Effective unit weight at bottom of layer            =    49.600000 pcf
   Undrained cohesion at top of layer                  =   625.000000 psf
   Undrained cohesion at bottom of layer               =   625.000000 psf
   Epsilon-50 at top of layer                          =     0.010000
   Epsilon-50 at bottom of layer                       =     0.010000


Layer 4 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    31.800000 ft
   Distance from top of pile to bottom of layer        =    34.100000 ft
   Effective unit weight at top of layer               =    62.600000 pcf
   Effective unit weight at bottom of layer            =    62.600000 pcf
   Undrained cohesion at top of layer                  =        2500. psf
   Undrained cohesion at bottom of layer               =        2500. psf
   Epsilon-50 at top of layer                          =     0.005000
   Epsilon-50 at bottom of layer                       =     0.005000
   Subgrade k at top of layer                          =  1000.000000 pci
   Subgrade k at bottom of layer                       =  1000.000000 pci
```

Layer 5 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	34.100000 ft
Distance from top of pile to bottom of layer	=	50.000000 ft
Effective unit weight at top of layer	=	167.000000 pcf
Effective unit weight at bottom of layer	=	167.000000 pcf
Uniaxial compressive strength at top of layer	=	9085. psi
Uniaxial compressive strength at bottom of layer	=	9085. psi
Initial modulus of rock at top of layer	=	680000. psi
Initial modulus of rock at bottom of layer	=	680000. psi
RQD of rock at top of layer	=	41.000000 %
RQD of rock at bottom of layer	=	41.000000 %
k rm of rock at top of layer	=	0.0000500
k rm of rock at bottom of layer	=	0.0000500

(Depth of the lowest soil layer extends 5.000 ft below the pile tip)

**** Warning - Possible Input Data Error ****

Values entered for effective unit weight of rock were outside the limits of
50 pcf to 150 pcf.

The maximum input value, in layer 1, for effective unit weight = 167.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	kpy pci	Rock Mass Modulus psi

1	Stiff Clay	11.8000	59.6000	2000.	--	--	0.00500	1000.0000
--	with Free Water	19.8000	59.6000	2000.	--	--	0.00500	1000.0000
--								
2	Stiff Clay	19.8000	57.6000	1000.0000	--	--	0.00700	500.0000
--	with Free Water	26.8000	57.6000	1000.0000	--	--	0.00700	500.0000
--								
3	Soft	26.8000	49.6000	625.0000	--	--	0.01000	--
--	Clay	31.8000	49.6000	625.0000	--	--	0.01000	--
--								
4	Stiff Clay	31.8000	62.6000	2500.	--	--	0.00500	1000.0000
--	with Free Water	34.1000	62.6000	2500.	--	--	0.00500	1000.0000
--								
5	Weak	34.1000	167.0000	--	9085.	41.0000	5.00E-05	--
680000.	Rock	50.0000	167.0000	--	9085.	41.0000	5.00E-05	--
680000.								

Modification Factors for p-y Curves

Distribution of p-y modifiers with depth defined using 3 points

Point No.	Depth X ft	p-mult	y-mult
1	11.800	0.7600	1.0000
2	34.100	0.7600	1.0000
3	34.100	1.0000	1.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading for Individual Load Cases

Distributed lateral load intensity for Load Case 1 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	31.000
2	29.700	851.100

Distributed lateral load intensity for Load Case 2 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	54.200
2	29.700	1284.400

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes
2	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis

S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

---

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	11.8000	0.00	N.A.	No	0.00	22011.
2	19.8000	9.6752	Yes	No	22011.	20276.
3	26.8000	5.9701	No	No	42287.	48905.
4	31.8000	21.5961	No	No	91192.	31128.
5	34.1000	22.3000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals
for Layer n. Layering correction equivalent depths are computed only
for soil types with both shallow-depth and deep-depth expressions for
peak lateral load transfer. These soil types are soft and stiff clays,
non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	0.5984	3.18E-06	0.00	-0.00230	5.96E-09	2.78E+11	0.00	0.00	34.1064
0.4500	0.5860	497.2719	209.3369	-0.00230	0.9324	2.78E+11	0.00	0.00	43.4258
0.9000	0.5736	2261.	477.3856	-0.00230	4.2391	2.78E+11	0.00	0.00	55.8515
1.3500	0.5611	5653.	812.5333	-0.00230	10.5994	2.78E+11	0.00	0.00	68.2773
1.8000	0.5487	11036.	1215.	-0.00230	20.6929	2.78E+11	0.00	0.00	80.7030
2.2500	0.5363	18773.	1684.	-0.00230	35.1987	2.78E+11	0.00	0.00	93.1288
2.7000	0.5239	29225.	2221.	-0.00230	54.7964	2.78E+11	0.00	0.00	105.5545
3.1500	0.5115	42755.	2824.	-0.00230	80.1653	2.78E+11	0.00	0.00	117.9803
3.6000	0.4991	59725.	3495.	-0.00229	111.9848	2.78E+11	0.00	0.00	130.4061
4.0500	0.4868	80498.	4233.	-0.00229	150.9342	2.78E+11	0.00	0.00	142.8318
4.5000	0.4744	105436.	5037.	-0.00229	197.6929	2.78E+11	0.00	0.00	155.2576
4.9500	0.4620	134902.	5909.	-0.00229	252.9403	2.78E+11	0.00	0.00	167.6833
5.4000	0.4497	169256.	6848.	-0.00229	317.3559	2.78E+11	0.00	0.00	180.1091
5.8500	0.4373	208863.	7854.	-0.00228	391.6189	2.78E+11	0.00	0.00	192.5348
6.3000	0.4250	254085.	8928.	-0.00228	476.4087	2.78E+11	0.00	0.00	204.9606
6.7500	0.4127	305283.	10068.	-0.00227	572.4047	2.78E+11	0.00	0.00	217.3864
7.2000	0.4005	362819.	11275.	-0.00227	680.2864	2.78E+11	0.00	0.00	229.8121
7.6500	0.3882	427058.	12550.	-0.00226	800.7330	2.78E+11	0.00	0.00	242.2379
8.1000	0.3761	498359.	13892.	-0.00225	934.4240	2.78E+11	0.00	0.00	254.6636
8.5500	0.3639	577087.	15300.	-0.00224	1082.	2.78E+11	0.00	0.00	267.0894
9.0000	0.3519	663604.	16776.	-0.00223	1244.	2.78E+11	0.00	0.00	279.5152
9.4500	0.3399	758270.	18319.	-0.00221	1422.	2.78E+11	0.00	0.00	291.9409
9.9000	0.3280	861450.	19929.	-0.00220	1615.	2.78E+11	0.00	0.00	304.3667
10.3500	0.3162	973505.	21606.	-0.00218	1825.	2.78E+11	0.00	0.00	316.7924

10.8000	0.3044	1094798.	23351.	-0.00216	2053.	2.78E+11	0.00	0.00	329.2182
11.2500	0.2928	1225691.	25162.	-0.00214	2298.	2.78E+11	0.00	0.00	341.6439
11.7000	0.2814	1366546.	27040.	-0.00211	2562.	2.78E+11	0.00	0.00	354.0697
12.1500	0.2700	1517726.	28405.	-0.00208	2846.	2.78E+11	-215.287	4305.	366.4955
12.6000	0.2589	1673315.	28923.	-0.00205	3137.	2.78E+11	-338.109	7053.	378.9212
13.0500	0.2479	1830094.	28869.	-0.00202	3431.	2.78E+11	-452.213	9852.	391.3470
13.5000	0.2370	1985099.	28286.	-0.00198	3722.	2.78E+11	-558.825	12730.	403.7727
13.9500	0.2264	2135582.	27212.	-0.00194	4004.	2.78E+11	-658.705	15708.	416.1985
14.4000	0.2161	2278993.	25684.	-0.00190	4273.	2.78E+11	-752.360	18803.	428.6242
14.8500	0.2059	2412965.	23732.	-0.00185	4524.	2.78E+11	-840.145	22030.	441.0500
15.3000	0.1960	2535298.	21388.	-0.00181	4754.	2.78E+11	-922.330	25405.	453.4758
15.7500	0.1864	2643960.	18683.	-0.00176	4957.	2.78E+11	-999.124	28940.	465.9015
16.2000	0.1771	2737074.	15644.	-0.00170	5132.	2.78E+11	-1071.	32649.	478.3273
16.6500	0.1680	2812913.	12299.	-0.00165	5274.	2.78E+11	-1137.	36546.	490.7530
17.1000	0.1593	2869902.	8675.	-0.00159	5381.	2.78E+11	-1199.	40643.	503.1788
17.5500	0.1508	2906608.	4800.	-0.00154	5450.	2.78E+11	-1255.	44954.	515.6045
18.0000	0.1427	2921738.	697.4241	-0.00148	5478.	2.78E+11	-1307.	49492.	528.0303
18.4500	0.1348	2914140.	-3606.	-0.00143	5464.	2.78E+11	-1355.	54268.	540.4561
18.9000	0.1273	2882796.	-8085.	-0.00137	5405.	2.78E+11	-1397.	59294.	552.8818
19.3500	0.1200	2826826.	-12714.	-0.00131	5300.	2.78E+11	-1435.	64576.	565.3076
19.8000	0.1131	2745489.	-16565.	-0.00126	5148.	2.78E+11	-1134.	54162.	577.7333
20.2500	0.1064	2647926.	-18307.	-0.00121	4965.	2.78E+11	-679.083	34460.	590.1591
20.7000	0.1000	2547770.	-18698.	-0.00116	4777.	2.78E+11	-658.407	35542.	602.5848
21.1500	0.09392	2445987.	-18911.	-0.00111	4586.	2.78E+11	-637.967	36680.	615.0106
21.6000	0.08806	2343534.	-18947.	-0.00106	4394.	2.78E+11	-617.750	37881.	627.4364
22.0500	0.08245	2241364.	-18807.	-0.00102	4203.	2.78E+11	-597.739	39149.	639.8621
22.5000	0.07707	2140422.	-18492.	-9.75E-04	4013.	2.78E+11	-577.915	40492.	652.2879
22.9500	0.07192	2041648.	-18004.	-9.35E-04	3828.	2.78E+11	-558.257	41918.	664.7136
23.4000	0.06698	1945979.	-17343.	-8.96E-04	3649.	2.78E+11	-538.742	43436.	677.1394
23.8500	0.06224	1854346.	-16510.	-8.59E-04	3477.	2.78E+11	-519.344	45059.	689.5652
24.3000	0.05770	1767676.	-15505.	-8.24E-04	3314.	2.78E+11	-500.035	46799.	701.9909
24.7500	0.05334	1686895.	-14329.	-7.90E-04	3163.	2.78E+11	-480.786	48672.	714.4167
25.2000	0.04916	1612927.	-12982.	-7.58E-04	3024.	2.78E+11	-461.562	50699.	726.8424
25.6500	0.04515	1546695.	-11464.	-7.28E-04	2900.	2.78E+11	-442.331	52904.	739.2682
26.1000	0.04130	1489121.	-9774.	-6.98E-04	2792.	2.78E+11	-423.056	55314.	751.6939
26.5500	0.03761	1441130.	-7914.	-6.70E-04	2702.	2.78E+11	-403.697	57966.	764.1197
27.0000	0.03406	1403650.	-5092.	-6.42E-04	2632.	2.78E+11	-91.830	14557.	776.5455
27.4500	0.03067	1386135.	-1359.	-6.15E-04	2599.	2.78E+11	-90.875	16000.	788.9712
27.9000	0.02742	1388977.	2448.	-5.88E-04	2604.	2.78E+11	-89.662	17658.	801.3970
28.3500	0.02431	1412573.	6329.	-5.61E-04	2649.	2.78E+11	-88.173	19582.	813.8227
28.8000	0.02136	1457330.	10286.	-5.33E-04	2732.	2.78E+11	-86.386	21841.	826.2485
29.2500	0.01855	1523660.	14320.	-5.04E-04	2857.	2.78E+11	-84.278	24528.	838.6742
29.7000	0.01591	1611989.	17281.	-4.74E-04	3022.	2.78E+11	-81.824	27772.	423.9968

30.1500	0.01343	1710295.	17992.	-4.42E-04	3207.	2.78E+11	-78.996	31753.	0.00
30.6000	0.01114	1806298.	17574.	-4.08E-04	3387.	2.78E+11	-75.766	36735.	0.00
31.0500	0.00903	1900092.	17175.	-3.72E-04	3563.	2.78E+11	-72.099	43114.	0.00
31.5000	0.00712	1991783.	16796.	-3.34E-04	3735.	2.78E+11	-67.952	51521.	0.00
31.9500	0.00542	2081493.	15389.	-2.95E-04	3903.	2.78E+11	-453.442	451563.	0.00
32.4000	0.00394	2157980.	13121.	-2.53E-04	4046.	2.78E+11	-386.561	529691.	0.00
32.8500	0.00269	2223195.	11215.	-2.11E-04	4168.	2.78E+11	-319.092	641689.	0.00
33.3000	0.00166	2279106.	9676.	-1.67E-04	4273.	2.78E+11	-251.077	815518.	0.00
33.7500	8.79E-04	2327695.	8523.	-1.23E-04	4364.	2.78E+11	-175.863	1080994.	0.00
34.2000	3.38E-04	2371156.	-56824.	-7.70E-05	4446.	2.78E+11	-24027.	3.84E+08	0.00
34.6500	4.64E-05	1714001.	-132308.	-3.74E-05	3214.	2.78E+11	-3931.	4.57E+08	0.00
35.1000	-6.59E-05	942232.	-125450.	-1.17E-05	1767.	2.78E+11	6470.	5.30E+08	0.00
35.5500	-7.95E-05	359140.	-83975.	9.59E-07	673.3882	2.78E+11	8891.	6.04E+08	0.00
36.0000	-5.55E-05	35301.	-41168.	4.78E-06	66.1893	2.78E+11	6964.	6.77E+08	0.00
36.4500	-2.78E-05	-85475.	-11916.	4.30E-06	160.2657	2.78E+11	3870.	7.51E+08	0.00
36.9000	-9.11E-06	-93389.	2289.	2.56E-06	175.1050	2.78E+11	1391.	8.24E+08	0.00
37.3500	-1.63E-07	-60756.	6117.	1.07E-06	113.9171	2.78E+11	27.1316	8.98E+08	0.00
37.8000	2.42E-06	-27331.	5014.	2.13E-07	51.2458	2.78E+11	-435.319	9.71E+08	0.00
38.2500	2.14E-06	-6600.	2720.	-1.16E-07	12.3756	2.78E+11	-414.347	1.04E+09	0.00
38.7000	1.17E-06	2048.	946.3346	-1.60E-07	3.8402	2.78E+11	-242.676	1.12E+09	0.00
39.1500	4.17E-07	3620.	42.8424	-1.05E-07	6.7877	2.78E+11	-91.950	1.19E+09	0.00
39.6000	4.05E-08	2511.	-231.041	-4.53E-08	4.7078	2.78E+11	-9.488	1.26E+09	0.00
40.0500	-7.28E-08	1125.	-207.960	-1.01E-08	2.1091	2.78E+11	18.0360	1.34E+09	0.00
40.5000	-6.82E-08	264.8395	-111.094	3.41E-09	0.4966	2.78E+11	17.8404	1.41E+09	0.00
40.9500	-3.60E-08	-74.956	-36.216	5.25E-09	0.1405	2.78E+11	9.8924	1.49E+09	0.00
41.4000	-1.15E-08	-126.290	-0.508	3.30E-09	0.2368	2.78E+11	3.3326	1.56E+09	0.00
41.8500	-3.51E-10	-80.445	8.7764	1.29E-09	0.1508	2.78E+11	0.1062	1.63E+09	0.00
42.3000	2.42E-09	-31.505	7.0011	2.07E-10	0.05907	2.78E+11	-0.764	1.71E+09	0.00
42.7500	1.89E-09	-4.833	3.2603	-1.45E-10	0.00906	2.78E+11	-0.622	1.78E+09	0.00
43.2000	8.51E-10	3.7063	0.8004	-1.56E-10	0.00695	2.78E+11	-0.289	1.84E+09	0.00
43.6500	2.02E-10	3.8106	-0.166	-8.31E-11	0.00714	2.78E+11	-0.06877	1.84E+09	0.00
44.1000	-4.72E-11	1.9097	-0.309	-2.77E-11	0.00358	2.78E+11	0.01603	1.84E+09	0.00
44.5500	-9.66E-11	0.4762	-0.177	-4.53E-12	8.93E-04	2.78E+11	0.03283	1.84E+09	0.00
45.0000	-9.61E-11	0.00	0.00	0.00	0.00	2.78E+11	0.03266	9.18E+08	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

Pile-head deflection = 0.59836520 inches
Computed slope at pile head = -0.0022974 radians
Maximum bending moment = 2921738. inch-lbs

```
Maximum shear force              =       -132308. lbs
Depth of maximum bending moment  =    18.00000000 feet below pile head
Depth of maximum shear force     =    34.65000000 feet below pile head
Number of iterations             =             25
Number of zero deflection points =              5
Pile deflection at ground        =     0.27884258 inches
```

Pile-head Deflection vs. Pile Length for Load Case 1

Boundary Condition Type 1, Shear and Moment

```
Shear      =              0. lbs
Moment     =              0. in-lbs
Axial Load =              0. lbs
```

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
45.00000	0.59836520	2921738.	-132308.
42.75000	0.59141938	2902842.	-130352.
40.50000	0.60971209	2920534.	-133196.
38.25000	0.59835478	2890177.	-134672.
36.00000	0.59247405	2895306.	-147611.
33.75000	0.67266816	2908410.	29298.
31.50000	0.71651786	2905789.	29325.
29.25000	0.79529496	2925285.	-29655.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 2

Pile-head conditions are Shear and Moment (Loading Type 1)

```
Shear force at pile head                          =          0.0 lbs
Applied moment at pile head                       =          0.0 in-lbs
```

Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	3.0917	-1.95E-04	0.00	-0.00997	3.66E-07	2.78E+11	0.00	0.00	58.8598
0.4500	3.0379	858.1764	355.5880	-0.00997	1.6091	2.78E+11	0.00	0.00	72.8394
0.9000	2.9840	3840.	799.2470	-0.00997	7.2007	2.78E+11	0.00	0.00	91.4788
1.3500	2.9302	9490.	1344.	-0.00997	17.7938	2.78E+11	0.00	0.00	110.1182
1.8000	2.8764	18351.	1989.	-0.00997	34.4077	2.78E+11	0.00	0.00	128.7576
2.2500	2.8226	30966.	2734.	-0.00997	58.0614	2.78E+11	0.00	0.00	147.3970
2.7000	2.7688	47880.	3580.	-0.00996	89.7741	2.78E+11	0.00	0.00	166.0364
3.1500	2.7150	69635.	4527.	-0.00996	130.5647	2.78E+11	0.00	0.00	184.6758
3.6000	2.6612	96775.	5575.	-0.00996	181.4526	2.78E+11	0.00	0.00	203.3152
4.0500	2.6074	129844.	6723.	-0.00996	243.4567	2.78E+11	0.00	0.00	221.9545
4.5000	2.5536	169385.	7972.	-0.00996	317.5961	2.78E+11	0.00	0.00	240.5939
4.9500	2.4999	215941.	9322.	-0.00995	404.8900	2.78E+11	0.00	0.00	259.2333
5.4000	2.4461	270057.	10772.	-0.00995	506.3575	2.78E+11	0.00	0.00	277.8727
5.8500	2.3924	332276.	12323.	-0.00994	623.0177	2.78E+11	0.00	0.00	296.5121
6.3000	2.3388	403141.	13974.	-0.00994	755.8897	2.78E+11	0.00	0.00	315.1515
6.7500	2.2851	483196.	15726.	-0.00993	905.9926	2.78E+11	0.00	0.00	333.7909
7.2000	2.2315	572984.	17579.	-0.00992	1074.	2.78E+11	0.00	0.00	352.4303
7.6500	2.1780	673049.	19532.	-0.00990	1262.	2.78E+11	0.00	0.00	371.0697
8.1000	2.1246	783935.	21587.	-0.00989	1470.	2.78E+11	0.00	0.00	389.7091
8.5500	2.0712	906184.	23741.	-0.00987	1699.	2.78E+11	0.00	0.00	408.3485
9.0000	2.0179	1040341.	25997.	-0.00985	1951.	2.78E+11	0.00	0.00	426.9879
9.4500	1.9648	1186949.	28353.	-0.00983	2226.	2.78E+11	0.00	0.00	445.6273
9.9000	1.9117	1346551.	30810.	-0.00981	2525.	2.78E+11	0.00	0.00	464.2667
10.3500	1.8588	1519692.	33367.	-0.00978	2849.	2.78E+11	0.00	0.00	482.9061
10.8000	1.8061	1706913.	36025.	-0.00975	3200.	2.78E+11	0.00	0.00	501.5455
11.2500	1.7536	1908760.	38784.	-0.00971	3579.	2.78E+11	0.00	0.00	520.1848
11.7000	1.7012	2125776.	41643.	-0.00968	3986.	2.78E+11	0.00	0.00	538.8242
12.1500	1.6491	2358503.	44550.	-0.00963	4422.	2.78E+11	-19.583	64.1264	557.4636
12.6000	1.5972	2606916.	47450.	-0.00958	4888.	2.78E+11	-39.789	134.5275	576.1030
13.0500	1.5456	2870967.	50341.	-0.00953	5383.	2.78E+11	-60.523	211.4594	594.7424
13.5000	1.4942	3150596.	53220.	-0.00947	5907.	2.78E+11	-81.288	293.7659	613.3818
13.9500	1.4433	3445741.	56088.	-0.00941	6461.	2.78E+11	-101.782	380.8217	632.0212
14.4000	1.3926	3756347.	58913.	-0.00934	7043.	2.78E+11	-134.513	521.5820	650.6606
14.8500	1.3424	4082005.	61463.	-0.00926	7654.	2.78E+11	-241.122	969.9479	669.3000
15.3000	1.2926	4420148.	63515.	-0.00918	8288.	2.78E+11	-356.002	1487.	687.9394
15.7500	1.2433	4767970.	65029.	-0.00909	8940.	2.78E+11	-477.952	2076.	706.5788
16.2000	1.1944	5122459.	65968.	-0.00899	9605.	2.78E+11	-605.888	2739.	725.2182

16.6500	1.1461	5480428.	66304.	-0.00889	10276.	2.78E+11	-738.840	3481.	743.8576
17.1000	1.0984	5838543.	66011.	-0.00878	10947.	2.78E+11	-875.936	4306.	762.4970
17.5500	1.0513	6193351.	65070.	-0.00867	11613.	2.78E+11	-1016.	5221.	781.1364
18.0000	1.0048	6541297.	63463.	-0.00854	12265.	2.78E+11	-1160.	6232.	799.7758
18.4500	0.9590	6878752.	61178.	-0.00841	12898.	2.78E+11	-1305.	7347.	818.4152
18.9000	0.9139	7202022.	58205.	-0.00828	13504.	2.78E+11	-1452.	8578.	837.0545
19.3500	0.8696	7507367.	54536.	-0.00813	14076.	2.78E+11	-1600.	9935.	855.6939
19.8000	0.8261	7791010.	50455.	-0.00798	14608.	2.78E+11	-1642.	10731.	874.3333
20.2500	0.7834	8052279.	47675.	-0.00783	15098.	2.78E+11	-1155.	7963.	892.9727
20.7000	0.7415	8305900.	46292.	-0.00767	15574.	2.78E+11	-1162.	8460.	911.6121
21.1500	0.7005	8552228.	44980.	-0.00751	16035.	2.78E+11	-1166.	8986.	930.2515
21.6000	0.6604	8791689.	43755.	-0.00734	16484.	2.78E+11	-1167.	9544.	948.8909
22.0500	0.6213	9024783.	42629.	-0.00717	16921.	2.78E+11	-1166.	10137.	967.5303
22.5000	0.5830	9252081.	41616.	-0.00699	17348.	2.78E+11	-1163.	10769.	986.1697
22.9500	0.5458	9474230.	40729.	-0.00681	17764.	2.78E+11	-1157.	11444.	1005.
23.4000	0.5095	9691953.	39983.	-0.00662	18172.	2.78E+11	-1148.	12166.	1023.
23.8500	0.4742	9906046.	39392.	-0.00643	18574.	2.78E+11	-1137.	12942.	1042.
24.3000	0.4400	1.01E+07	38969.	-0.00624	18970.	2.78E+11	-1123.	13778.	1061.
24.7500	0.4069	1.03E+07	38729.	-0.00604	19363.	2.78E+11	-1106.	14681.	1079.
25.2000	0.3748	1.05E+07	38686.	-0.00584	19754.	2.78E+11	-1087.	15661.	1098.
25.6500	0.3438	1.07E+07	38856.	-0.00563	20146.	2.78E+11	-1065.	16728.	1117.
26.1000	0.3140	1.10E+07	39251.	-0.00542	20541.	2.78E+11	-1040.	17894.	1135.
26.5500	0.2853	1.12E+07	39888.	-0.00521	20941.	2.78E+11	-1013.	19174.	1154.
27.0000	0.2577	1.14E+07	42948.	-0.00499	21349.	2.78E+11	-180.277	3777.	1173.
27.4500	0.2314	1.16E+07	48362.	-0.00476	21811.	2.78E+11	-178.234	4159.	1191.
27.9000	0.2063	1.19E+07	53889.	-0.00454	22328.	2.78E+11	-175.687	4599.	1210.
28.3500	0.1824	1.22E+07	59532.	-0.00430	22902.	2.78E+11	-172.607	5110.	1228.
28.8000	0.1598	1.26E+07	65294.	-0.00406	23534.	2.78E+11	-168.964	5709.	1247.
29.2500	0.1385	1.29E+07	71178.	-0.00382	24224.	2.78E+11	-164.723	6421.	1266.
29.7000	0.1186	1.33E+07	75447.	-0.00356	24975.	2.78E+11	-159.845	7277.	639.8701
30.1500	0.1001	1.37E+07	76326.	-0.00330	25752.	2.78E+11	-154.284	8324.	0.00
30.6000	0.08299	1.41E+07	75510.	-0.00303	26521.	2.78E+11	-147.986	9629.	0.00
31.0500	0.06738	1.45E+07	74730.	-0.00275	27281.	2.78E+11	-140.889	11291.	0.00
31.5000	0.05330	1.50E+07	73991.	-0.00246	28034.	2.78E+11	-132.911	13467.	0.00
31.9500	0.04078	1.53E+07	70275.	-0.00217	28780.	2.78E+11	-1243.	164668.	0.00
32.4000	0.02986	1.57E+07	64044.	-0.00187	29457.	2.78E+11	-1064.	192415.	0.00
32.8500	0.02060	1.60E+07	58785.	-0.00156	30076.	2.78E+11	-883.752	231689.	0.00
33.3000	0.01301	1.63E+07	54503.	-0.00125	30647.	2.78E+11	-702.393	291512.	0.00
33.7500	0.00714	1.66E+07	51202.	-9.27E-04	31180.	2.78E+11	-520.202	393608.	0.00
34.2000	0.00300	1.69E+07	-331899.	-6.01E-04	31684.	2.78E+11	-141369.	2.54E+08	0.00
34.6500	6.41E-04	1.30E+07	-860146.	-3.11E-04	24459.	2.78E+11	-54278.	4.57E+08	0.00
35.1000	-3.55E-04	7608720.	-912565.	-1.11E-04	14266.	2.78E+11	34864.	5.30E+08	0.00
35.5500	-5.54E-04	3189182.	-651060.	-6.00E-06	5980.	2.78E+11	61990.	6.04E+08	0.00

36.0000	-4.20E-04	577268.	-341548.	3.05E-05	1082.	2.78E+11	52644.	6.77E+08	0.00
36.4500	-2.25E-04	-499541.	-115086.	3.13E-05	936.6393	2.78E+11	31231.	7.51E+08	0.00
36.9000	-8.19E-05	-665659.	2978.	2.00E-05	1248.	2.78E+11	12497.	8.24E+08	0.00
37.3500	-8.84E-06	-467374.	40685.	8.99E-06	876.3255	2.78E+11	1469.	8.98E+08	0.00
37.8000	1.53E-05	-226263.	37243.	2.27E-06	424.2439	2.78E+11	-2743.	9.71E+08	0.00
38.2500	1.56E-05	-65149.	21664.	-5.59E-07	122.1553	2.78E+11	-3027.	1.04E+09	0.00
38.7000	9.22E-06	7707.	8340.	-1.12E-06	14.4500	2.78E+11	-1908.	1.12E+09	0.00
39.1500	3.59E-06	24927.	1049.	-8.00E-07	46.7373	2.78E+11	-792.400	1.19E+09	0.00
39.6000	5.78E-07	19040.	-1456.	-3.73E-07	35.7002	2.78E+11	-135.365	1.26E+09	0.00
40.0500	-4.42E-07	9206.	-1526.	-9.95E-08	17.2621	2.78E+11	109.4145	1.34E+09	0.00
40.5000	-4.97E-07	2563.	-879.663	1.46E-08	4.8061	2.78E+11	129.8344	1.41E+09	0.00
40.9500	-2.83E-07	-293.932	-318.736	3.67E-08	0.5511	2.78E+11	77.9163	1.49E+09	0.00
41.4000	-1.01E-07	-879.089	-29.843	2.53E-08	1.6483	2.78E+11	29.0812	1.56E+09	0.00
41.8500	-1.03E-08	-616.239	57.0686	1.08E-08	1.1554	2.78E+11	3.1084	1.63E+09	0.00
42.3000	1.56E-08	-262.749	52.1224	2.25E-09	0.4927	2.78E+11	-4.940	1.71E+09	0.00
42.7500	1.40E-08	-53.318	26.2871	-8.12E-10	0.09997	2.78E+11	-4.628	1.78E+09	0.00
43.2000	6.87E-09	21.1521	7.4818	-1.12E-09	0.03966	2.78E+11	-2.337	1.84E+09	0.00
43.6500	1.91E-09	27.4865	-0.581	-6.52E-10	0.05154	2.78E+11	-0.650	1.84E+09	0.00
44.1000	-1.73E-10	14.8804	-2.176	-2.41E-10	0.02790	2.78E+11	0.05867	1.84E+09	0.00
44.5500	-6.97E-10	3.9852	-1.378	-5.85E-11	0.00747	2.78E+11	0.2370	1.84E+09	0.00
45.0000	-8.04E-10	0.00	0.00	-1.98E-11	0.00	2.78E+11	0.2733	9.18E+08	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 2:

```
Pile-head deflection             =     3.09167964 inches
Computed slope at pile head      =     -0.0099662 radians
Maximum bending moment           =      16898301. inch-lbs
Maximum shear force              =       -912565. lbs
Depth of maximum bending moment  =    34.20000000 feet below pile head
Depth of maximum shear force     =    35.10000000 feet below pile head
Number of iterations             =             86
Number of zero deflection points =              5
Pile deflection at ground        =     1.68960908 inches
```

Pile-head Deflection vs. Pile Length for Load Case 2

Boundary Condition Type 1, Shear and Moment

Shear = 0. lbs
Moment = 0. in-lbs
Axial Load = 0. lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
45.00000	3.09167964	16898301.	-912565.
42.75000	3.16155762	17416440.	-964955.
40.50000	3.45517070	18933208.	-1080826.
38.25000	3.44094134	18851653.	-1093018.
36.00000	3.19555635	17429595.	-1122729.

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	0.5984	-0.00230	-132308.	2921738.
2	V, lb	0.00	M, in-lb	0.00	0.00	3.0917	-0.00997	-912565.	1.69E+07

Maximum pile-head deflection = 3.0916796435 inches
Maximum pile-head rotation = -0.0099661540 radians = -0.571019 deg.

Summary of Warning Messages

The following warning was reported 8615 times

**** Warning ****

An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.

Project: BRO-52-10.25
Project No: 23050011COL
April 5, 2023

L-PILE Soil Parameters

Artificial Lowering of Ground Surface

The passive resistance from the downhill side soil mass should be ignored. In order to include this in the L-pile soil model, the ground level should be artificially lowered.

To do this, first determine the angle of steepness of the slope - downhill of the drilled shafts - from horizontal (β_{dh}), and then determine the depth to the shear surface at the location of the drilled shafts (d_τ). For slopes of steepness from β=0° to 45°, lower the ground surface by an amount equal to $d_\tau TAN(\beta_{dh})$.

For the current project, β_{dh} = 18 degrees (From average slope rates)

Proposed top of pile elevation = 515.9 (From proposed top of wall elevation)
Existing grade at pile location = 514.4 (From cross section near Sta. 17+50)
Estimated shear surface elevation at pile location = 486.2 feet
d_τ = 514.4 – 486.2 = 28.2 feet

Therefore, $d_\tau TAN(\beta_{dh})$ = 9.2 feet.

The first soil layer should start at elevation 514.4– 9.2 = 505.2

Which is at a depth of 515.9 – 505.2 = 10.7 feet along the shaft

From 10.7'-19.8'

Use soil type – *Stiff Clay with Free Water (Reese)*
Effective Unit Weight (pcf) = 59.6 pcf
N_{60} = 16 bpf (Average blow count, B-003-0-22, SS-4 and SS-5)
Undrained Cohesion (psf) = $N_{60}/8$ = 16/8 = 2,000 psf
Use Strain Factor K_{rm} = 0.005 (From L-pile Technical Manual Table 3-4)
Use Subgrade Modulus K_{static} = 1,000 pci (From L-pile Technical Manual Table 3-3)

From 19.8'-26.8'

Use soil type – *Stiff Clay with Free Water (Reese)*
Effective Unit Weight (pcf) = 57.6 pcf
N_{60} = 8 bpf (Average blow count, B-003-0-22, SS-6, SS-7 and SS-8)
Undrained Cohesion (psf) = $N_{60}/8$ = 8/8 = 1,000 psf
Use Strain Factor K_{rm} = 0.007 (From L-pile Technical Manual Table 3-4)
Use Subgrade Modulus K_{static} = 500 pci (From L-pile Technical Manual Table 3-3)

Project: BRO-52-10.25
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From 26.8'-31.8'

Use soil type – *Soft Clay (Matlock)*
Effective Unit Weight (pcf) = 49.6 pcf
N_{60} = 5 bpf (Average blow count, B-003-0-22, SS-9 and SS-10)
Undrained Cohesion (psf) = $N_{60}/8$ = 5/8 = 625 psf
Use Strain Factor K_{rm} = 0.01 (From L-pile Technical Manual Table 3-4)

From 31.8'-34.1'

Use soil type – *Stiff Clay with Free Water (Reese)*
Effective Unit Weight (pcf) = 62.6 pcf
N_{60} = 20 bpf (B-003-0-22, SS-11)
Undrained Cohesion (psf) = $N_{60}/8$ = 20/8 = 2,500 psf
Use Strain Factor K_{rm} = 0.005 (From L-pile Technical Manual Table 3-4)
Use Subgrade Modulus K_{static} = 1,000 pci (From L-pile Technical Manual Table 3-3)

Below 34.1' (Corable Rock)

Use soil type – *Weak Rock (Reese)*
Effective Unit Weight (pcf) = 167.0 pcf (B-003-0-22, NQ-1 Compressive Strength Test Result)
Compressive strength (q_u) = 9,085 psi (B-003-0-22, NQ-1 Compressive Strength Test Result)
Initial Rock Modulus (E_r) = 680,000 psi (Per ODOT GDM Table 400-6, Strong Rock)
RQD = 41% (Average RQD from B-003-0-22)
Use Strain Factor K_{rm} = 0.00005 (From L-pile Technical Manual)

P-y Modification Factors

If the drilled shafts are at a center-to-center spacing closer than about 3½ diameters, a reduction in the soil resistance p, for the p-y curve behavior of the soil, must be considered.
P- modification factor $\beta_a = 0.64(S/D)^{0.34}$
In which S= Center to Center Spacing between the Piles
D= Diameter of the Shaft

For 36- inch shafts with reinforced shafts placed at 5.0 feet center to center
$\beta a = 0.64(5/3)^{0.34} = 0.76$

No P-Y modification factors are applied to the bedrock layers

BRO-52-10.25

From AASHTO 3.11.5.3, Active Earth Pressure

$$K_a = \mathrm{Sin}^2(\Theta+\emptyset'_f)/\Gamma[\mathrm{Sin}^2(\Theta)*\mathrm{Sin}(\Theta-\delta)]$$

in which $\Gamma = [1+\sqrt{\{(\mathrm{Sin}(\emptyset'f+\delta)*\mathrm{Sin}(\emptyset'f-\beta))/(\mathrm{Sin}(\Theta-\delta)*\mathrm{Sin}(\Theta+\beta))\}}]^2$

Where

Angle of back face of the wall to the horizontal (Degrees), Θ=	90	
Effective angle of internal friction (degrees), Ø'f=	30	(Assumed)
Friction angle between fill and wall (degrees), δ=	20	(2/3 Ø'f)
Angle of fill to the horizontal , β=	0	Assumed)

Calculation

$\mathrm{Sin}(\Theta-\delta)=$	0.94
$\mathrm{Sin}^2(\Theta)=$	1.00
$\mathrm{Sin}(\Theta+\emptyset'_f)=$	0.87
$\mathrm{Sin}^2(\Theta+\emptyset'_f)=$	0.75
$\mathrm{Sin}(\emptyset'_f-\beta)=$	0.50
$\mathrm{Sin}(\Theta+\beta)=$	1.00
$\mathrm{Sin}(\emptyset'_f+\delta)=$	0.77
$\Gamma=$	2.68
$K_a=$	0.30

$\gamma_{LS}=$ 125 pcf (GB7, Section E.7)

Case 1

Diameter of Shaft=	36	inches
C/C Spacing (CC)=	5	feet

Therefore for a 36-inch Shaft placed at 5 feet center to center

Surcharge Load q_{LS}, 31.0 lb/in $\gamma_{LS}*2*K_a*CC/12$

BRO-52-10.25

Conversion of force per Shaft to Distributed Load

The UA Slope 2.3 program calculates the unfactored earth pressure (EH), resultant load per shaft, however, for proper structural analysis of pile reaction, we need to convert this to a realistic load.

The triangular load distribution is a close enough approximation of the actual condition to develop a realistic calculation of distributed shear, moment and displacement in the drilled shaft

Case 1

Diameter of Shaft=	36	inches
C/C Spacing (CC)=	5	feet

For a 36-inch shaft at 5 feet center to center spacing

Load on Shaft (F_{SW})=	151,667	lbs
Depth of Shear plane at Shaft Location(D_S)=	29.7	feet
The Distibuted Load (F_D)=	820.1	lbs/in

a) ***Following cases were evaluated:***

Case1

Diameter of Shaft =	36	inches
Center to Center Spacing =	5	feet

b) ***Unfactored Loads***

Case	Surchage Loads(lbs/in)	Distributed Load(lbs/in)	Total Unfactored Load (lbs/in)
1	31.0	820.1	851.1

c) ***Load Factor per AASHTO Table 3.4.1.1 and 3.4.1.2***

Load Factor for Surcharge Load (LS) = 1.75
Load Factor for Distributed Load (EH) = 1.5

d) ***Factored Distributed loads***

Case	Factored Surcharge Load (lbs/in)	Factored Distributed Loads(lbs/in)	Total Factored Load(lbs/in)
1	54.2	1230.2	1284.4

e) ***Limit State Checks***

1 Use Factored Loads for Strength Limit State and check Moment capacity and Nominal Shear per AASHTO 6.10.8 and 6.10.9
2 Use Unfactored Loads for Service Limit State for deflection

f) ***L-pile Analysis***

Note: It is assumed that 50 Ksi steel will be used.
Section Used= W 24x229

Case1: 36 inch diameter Shafts with 5 feet center to center spacing

Checks:

Structural Strength Limit State Checks (W 24x229 Section)

Calculated Factored Moment(in-lbs)	Factored Nominal Moment Resistance(in-lbs)	Acceptable Or Unacceptable
6,022,894	29,400,000	Acceptable

Calculated Factored Shear (Kips)	Factored Nominal Shear resistance (Kips)	Acceptable Or Unacceptable
358.9	627.5	Acceptable

See calculation sheets for nominal moment calculations Per AASHTO 6.10.8
and for nominal shear resistance calculation Per AASHTO 6.10.9

Service Limit State Checks (W 24x229 Section)

Drilled Shaft Length above bedrock= 34.1 feet
For the unfactored Service Limit State analysis, the maximum Pilehead deflection must be limited to 1% or less
of the drilled shaft length above bedrock (34.1') or 2 inches in presence of road surcharge within 10 feet of the drilled shaft location, whichever is lesser

Calculated Deflection(in)	Allowable Deflection(in) Per GB7	Acceptable Or Unacceptable
0.4	2.0	Acceptable

BRO-52-10.25

W 24x229

Thickness of Flange (t_f) =	1.73	in
Depth (d) =	26.00	in
Yield Strength of Steel (F_y) =	50	Ksi
$D = d-2t_f$ =	22.54	in
Thickness of Web (t_w) =	0.96	in

V_p =	$0.58 F_y D t_w$ =	627.5	Kips
	Young's Modulus (E) =	29000	Ksi

Assume Unstiffened Web

Shear Buckling Coefficient (K) =	5.0	
$Sqrt(EK/F_y)$ =	53.9	Equation 1
$1.12*Sqrt(EK/F_y)$ =	60.3	Equation 2
$1.4*Sqrt(EK/F_y)$ =	75.4	Equation 3
D/t_w =	23.5	
Since, $D/t_w \leq$ Equation1, C =	1.0	

Therefore,

Nominal Shear Resistance (V_n) = CV_p	627.5	Kips
ϕ_v =	1.0	
Factored Shear Resistance (V_u) = $\phi_v V_n$	627.5	Kips

BRO-52-10.25

W 24x229

Per AASHTO, 6.10.8

For Continously Braced Flanges in Tension or Compression

$f_{bu} \leq \phi_f R_h F_{yf}$ Equation 1

Where f_{bu} = Factored Bending Moment Obtained in Strength Limit State
ϕ_f = Flexural Resistance Factor
R_h = Hybrid Factor
F_{yf} = $f_y * S_{x-x}$
f_y = Yield Strength of Steel
S_{x-x} = Section Modulus of Steel Section

ϕ_f =	1.0	Per AASHTO 6.5.4.2
R_h =	1.0	Per AASHTO 6.10.1.10.1
S_{x-x} =	588.0	In^3
f_y =	50.0	ksi
F_{yf} =	29,400,000	lb-in

```
================================================================================

                    LPile for Windows, Version 2022-12.008

                 Analysis of Individual Piles and Drilled Shafts
                Subjected to Lateral Loading Using the p-y Method
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--------------------------------------------------------------------------------
                             Files Used for Analysis
--------------------------------------------------------------------------------

Path to file locations:
\PROJECT\2023\COL-05\23050011COL\Design\Lpile Analysis\2-27-23 updated analysis\

Name of input data file:
BRO-52-10.25 36 in Shaft without plate.lp12d

Name of output report file:
BRO-52-10.25 36 in Shaft without plate.lp12o

Name of plot output file:
BRO-52-10.25 36 in Shaft without plate.lp12p
```

Name of runtime message file:
BRO-52-10.25 36 in Shaft without plate.lp12r

Date and Time of Analysis

Date: May 12, 2023 Time: 16:29:50

Problem Title

Project Name: BRO-52-10.25

Job Number: 23050011COL

Client: IBI Group

Engineer: SR

Description: Drilled Shaft Analysis

Program Options and Settings

Computational Options:
 - Conventional Analysis
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

Analysis Control Options:
 - Maximum number of iterations allowed = 500
 - Deflection tolerance for convergence = 1.0000E-05 in
 - Maximum allowable deflection = 100.0000 in
 - Number of pile increments = 100

Loading Type and Number of Cycles of Loading:
 - Static loading specified

 - Analysis uses p-y modification factors for p-y curves
 - Analysis uses layering correction (Method of Georgiadis)
 - Analysis includes loading by multiple distributed lateral loads acting on pile
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Input of moment resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

Output Options:
 - Output files use decimal points to denote decimal symbols.
 - Values of pile-head deflection, bending moment, shear force, and
   soil reaction are printed for full length of pile.
 - Printing Increment (nodal spacing of output points) = 1
 - No p-y curves to be computed and reported for user-specified depths
 - Print using wide report formats

Pile Structural Properties and Geometry

Number of pile sections defined = 1
Total length of pile = 45.000 ft
Depth of ground surface below top of pile = 10.7000 ft

Pile diameters used for p-y curve computations are defined using 2 points.

p-y curves are computed using pile diameter values interpolated with depth over
the length of the pile. A summary of values of pile diameter vs. depth follows.

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	36.0000
2	45.000	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile

Cross-sectional Shape	=	Circular Pile
Length of section	=	45.000000 ft
Width of top of section	=	36.000000 in
Width of bottom of section	=	36.000000 in
Top Area	=	67.200000 sq. in
Bottom Area	=	67.200000 sq. in
Moment of Inertia at Top	=	7650. in^4
Moment of Inertia at Bottom	=	7650. in^4
Elastic Modulus	=	29000000. psi

Soil and Rock Layering Information

The soil profile is modelled using 5 layers

Layer 1 is stiff clay with water-induced erosion

Distance from top of pile to top of layer	=	10.700000 ft
Distance from top of pile to bottom of layer	=	19.800000 ft
Effective unit weight at top of layer	=	59.600000 pcf
Effective unit weight at bottom of layer	=	59.600000 pcf
Undrained cohesion at top of layer	=	2000. psf
Undrained cohesion at bottom of layer	=	2000. psf
Epsilon-50 at top of layer	=	0.005000
Epsilon-50 at bottom of layer	=	0.005000

```
   Subgrade k at top of layer                          =  1000.000000 pci
   Subgrade k at bottom of layer                       =  1000.000000 pci


Layer 2 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    19.800000 ft
   Distance from top of pile to bottom of layer        =    26.800000 ft
   Effective unit weight at top of layer               =    57.600000 pcf
   Effective unit weight at bottom of layer            =    57.600000 pcf
   Undrained cohesion at top of layer                  =  1000.000000 psf
   Undrained cohesion at bottom of layer               =  1000.000000 psf
   Epsilon-50 at top of layer                          =     0.007000
   Epsilon-50 at bottom of layer                       =     0.007000
   Subgrade k at top of layer                          =   500.000000 pci
   Subgrade k at bottom of layer                       =   500.000000 pci


Layer 3 is soft clay, p-y criteria by Matlock, 1970

   Distance from top of pile to top of layer           =    26.800000 ft
   Distance from top of pile to bottom of layer        =    31.800000 ft
   Effective unit weight at top of layer               =    49.600000 pcf
   Effective unit weight at bottom of layer            =    49.600000 pcf
   Undrained cohesion at top of layer                  =   625.000000 psf
   Undrained cohesion at bottom of layer               =   625.000000 psf
   Epsilon-50 at top of layer                          =     0.010000
   Epsilon-50 at bottom of layer                       =     0.010000


Layer 4 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    31.800000 ft
   Distance from top of pile to bottom of layer        =    34.100000 ft
   Effective unit weight at top of layer               =    62.600000 pcf
   Effective unit weight at bottom of layer            =    62.600000 pcf
   Undrained cohesion at top of layer                  =        2500. psf
   Undrained cohesion at bottom of layer               =        2500. psf
   Epsilon-50 at top of layer                          =     0.005000
   Epsilon-50 at bottom of layer                       =     0.005000
   Subgrade k at top of layer                          =  1000.000000 pci
   Subgrade k at bottom of layer                       =  1000.000000 pci
```

Layer 5 is weak rock, p-y criteria by Reese, 1997

Distance from top of pile to top of layer	=	34.100000 ft
Distance from top of pile to bottom of layer	=	50.000000 ft
Effective unit weight at top of layer	=	167.000000 pcf
Effective unit weight at bottom of layer	=	167.000000 pcf
Uniaxial compressive strength at top of layer	=	9085. psi
Uniaxial compressive strength at bottom of layer	=	9085. psi
Initial modulus of rock at top of layer	=	680000. psi
Initial modulus of rock at bottom of layer	=	680000. psi
RQD of rock at top of layer	=	41.000000 %
RQD of rock at bottom of layer	=	41.000000 %
k rm of rock at top of layer	=	0.0000500
k rm of rock at bottom of layer	=	0.0000500

(Depth of the lowest soil layer extends 5.000 ft below the pile tip)

**** Warning - Possible Input Data Error ****

Values entered for effective unit weight of rock were outside the limits of
50 pcf to 150 pcf.

The maximum input value, in layer 1, for effective unit weight = 167.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Cohesion psf	Uniaxial qu psi	RQD %	E50 or krm	kpy pci	Rock Mass Modulus psi

1	Stiff Clay	10.7000	59.6000	2000.	--	--	0.00500	1000.0000
--	with Free Water	19.8000	59.6000	2000.	--	--	0.00500	1000.0000
--								
2	Stiff Clay	19.8000	57.6000	1000.0000	--	--	0.00700	500.0000
--	with Free Water	26.8000	57.6000	1000.0000	--	--	0.00700	500.0000
--								
3	Soft	26.8000	49.6000	625.0000	--	--	0.01000	--
--	Clay	31.8000	49.6000	625.0000	--	--	0.01000	--
--								
4	Stiff Clay	31.8000	62.6000	2500.	--	--	0.00500	1000.0000
--	with Free Water	34.1000	62.6000	2500.	--	--	0.00500	1000.0000
--								
5	Weak	34.1000	167.0000	--	9085.	41.0000	5.00E-05	--
680000.	Rock	50.0000	167.0000	--	9085.	41.0000	5.00E-05	--
680000.								

Modification Factors for p-y Curves

Distribution of p-y modifiers with depth defined using 3 points

Point No.	Depth X ft	p-mult	y-mult
1	10.700	0.7600	1.0000
2	34.100	0.7600	1.0000
3	34.100	1.0000	1.0000

Static Loading Type

Static loading criteria were used when computing p-y curves for all analyses.

Distributed Lateral Loading for Individual Load Cases

Distributed lateral load intensity for Load Case 1 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	31.000
2	29.700	851.100

Distributed lateral load intensity for Load Case 2 defined using 2 points

Point No.	Depth X ft	Dist. Load lb/in
1	0.000	54.200
2	29.700	1284.400

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length	Run Analysis
1	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes
2	1	V = 0.0000 lbs	M = 0.0000 in-lbs	0.0000000	Yes	Yes

V = shear force applied normal to pile axis
M = bending moment applied to pile head
y = lateral deflection normal to pile axis

S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with
specified shear loading (Load Types 1, 2, and 3).
Thrust force is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

---

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	10.7000	0.00	N.A.	No	0.00	27971.
2	19.8000	11.7348	Yes	No	27971.	20276.
3	26.8000	6.6539	No	No	48247.	50587.
4	31.8000	22.3834	No	No	98834.	31128.
5	34.1000	23.4000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals
for Layer n. Layering correction equivalent depths are computed only
for soil types with both shallow-depth and deep-depth expressions for
peak lateral load transfer. These soil types are soft and stiff clays,
non-liquefied sands, and cemented c-phi soil.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 1

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	0.4295	-4.65E-06	3.91E-08	-0.00182	1.09E-08	2.22E+11	0.00	0.00	34.1064
0.4500	0.4197	497.2719	209.3369	-0.00182	1.1701	2.22E+11	0.00	0.00	43.4258
0.9000	0.4099	2261.	477.3856	-0.00182	5.3196	2.22E+11	0.00	0.00	55.8515
1.3500	0.4001	5653.	812.5333	-0.00182	13.3013	2.22E+11	0.00	0.00	68.2773
1.8000	0.3903	11036.	1215.	-0.00182	25.9675	2.22E+11	0.00	0.00	80.7030
2.2500	0.3805	18773.	1684.	-0.00182	44.1710	2.22E+11	0.00	0.00	93.1288
2.7000	0.3707	29225.	2221.	-0.00182	68.7641	2.22E+11	0.00	0.00	105.5545
3.1500	0.3609	42755.	2824.	-0.00181	100.5996	2.22E+11	0.00	0.00	117.9803
3.6000	0.3511	59725.	3495.	-0.00181	140.5299	2.22E+11	0.00	0.00	130.4061
4.0500	0.3413	80498.	4233.	-0.00181	189.4076	2.22E+11	0.00	0.00	142.8318
4.5000	0.3315	105436.	5037.	-0.00181	248.0852	2.22E+11	0.00	0.00	155.2576
4.9500	0.3217	134902.	5909.	-0.00181	317.4153	2.22E+11	0.00	0.00	167.6833
5.4000	0.3120	169256.	6848.	-0.00180	398.2505	2.22E+11	0.00	0.00	180.1091
5.8500	0.3023	208863.	7854.	-0.00180	491.4433	2.22E+11	0.00	0.00	192.5348
6.3000	0.2926	254085.	8928.	-0.00179	597.8462	2.22E+11	0.00	0.00	204.9606
6.7500	0.2829	305283.	10068.	-0.00179	718.3118	2.22E+11	0.00	0.00	217.3864
7.2000	0.2733	362819.	11275.	-0.00178	853.6927	2.22E+11	0.00	0.00	229.8121
7.6500	0.2637	427058.	12550.	-0.00177	1005.	2.22E+11	0.00	0.00	242.2379
8.1000	0.2542	498359.	13892.	-0.00176	1173.	2.22E+11	0.00	0.00	254.6636
8.5500	0.2447	577087.	15300.	-0.00174	1358.	2.22E+11	0.00	0.00	267.0894
9.0000	0.2354	663604.	16776.	-0.00173	1561.	2.22E+11	0.00	0.00	279.5152
9.4500	0.2261	758270.	18319.	-0.00171	1784.	2.22E+11	0.00	0.00	291.9409
9.9000	0.2169	861450.	19929.	-0.00169	2027.	2.22E+11	0.00	0.00	304.3667
10.3500	0.2078	973505.	21606.	-0.00167	2291.	2.22E+11	0.00	0.00	316.7924

10.8000	0.1989	1094798.	22861.	-0.00164	2576.	2.22E+11	-181.357	4925.	329.2182
11.2500	0.1901	1220403.	23339.	-0.00162	2872.	2.22E+11	-312.439	8877.	341.6439
11.7000	0.1814	1346859.	23268.	-0.00158	3169.	2.22E+11	-409.617	12193.	354.0697
12.1500	0.1729	1471695.	22757.	-0.00155	3463.	2.22E+11	-499.991	15612.	366.4955
12.6000	0.1647	1592639.	21843.	-0.00151	3747.	2.22E+11	-584.246	19159.	378.9212
13.0500	0.1566	1707595.	20555.	-0.00147	4018.	2.22E+11	-662.824	22856.	391.3470
13.5000	0.1488	1814635.	18925.	-0.00143	4270.	2.22E+11	-736.036	26718.	403.7727
13.9500	0.1412	1911986.	16981.	-0.00138	4499.	2.22E+11	-804.110	30761.	416.1985
14.4000	0.1338	1998026.	14749.	-0.00134	4701.	2.22E+11	-867.225	34997.	428.6242
14.8500	0.1267	2071276.	12257.	-0.00129	4874.	2.22E+11	-925.517	39439.	441.0500
15.3000	0.1199	2130399.	9530.	-0.00124	5013.	2.22E+11	-979.080	44092.	453.4758
15.7500	0.1134	2174196.	6593.	-0.00118	5116.	2.22E+11	-1028.	48961.	465.9015
16.2000	0.1071	2201603.	3473.	-0.00113	5180.	2.22E+11	-1072.	54036.	478.3273
16.6500	0.1012	2211700.	198.9009	-0.00108	5204.	2.22E+11	-1110.	59231.	490.7530
17.1000	0.09549	2203751.	-3188.	-0.00102	5185.	2.22E+11	-1139.	64391.	503.1788
17.5500	0.09011	2177270.	-6657.	-9.70E-04	5123.	2.22E+11	-1165.	69813.	515.6045
18.0000	0.08502	2131852.	-10195.	-9.17E-04	5016.	2.22E+11	-1189.	75506.	528.0303
18.4500	0.08021	2067166.	-13787.	-8.66E-04	4864.	2.22E+11	-1210.	81478.	540.4561
18.9000	0.07567	1982949.	-17422.	-8.17E-04	4666.	2.22E+11	-1229.	87737.	552.8818
19.3500	0.07138	1879006.	-21088.	-7.70E-04	4421.	2.22E+11	-1247.	94294.	565.3076
19.8000	0.06735	1755199.	-23731.	-7.26E-04	4130.	2.22E+11	-875.302	70179.	577.7333
20.2500	0.06355	1622715.	-24358.	-6.85E-04	3818.	2.22E+11	-524.772	44593.	590.1591
20.7000	0.05996	1492137.	-23930.	-6.47E-04	3511.	2.22E+11	-509.734	45909.	602.5848
21.1500	0.05656	1364267.	-23356.	-6.12E-04	3210.	2.22E+11	-495.097	47266.	615.0106
21.6000	0.05335	1239894.	-22636.	-5.80E-04	2917.	2.22E+11	-480.823	48669.	627.4364
22.0500	0.05030	1119796.	-21773.	-5.51E-04	2635.	2.22E+11	-466.869	50124.	639.8621
22.5000	0.04739	1004743.	-20769.	-5.26E-04	2364.	2.22E+11	-453.188	51637.	652.2879
22.9500	0.04462	895495.	-19624.	-5.02E-04	2107.	2.22E+11	-439.734	53217.	664.7136
23.4000	0.04197	792807.	-18339.	-4.82E-04	1865.	2.22E+11	-426.452	54874.	677.1394
23.8500	0.03942	697430.	-16917.	-4.64E-04	1641.	2.22E+11	-413.291	56621.	689.5652
24.3000	0.03696	610109.	-15356.	-4.48E-04	1436.	2.22E+11	-400.192	58475.	701.9909
24.7500	0.03458	531588.	-13657.	-4.34E-04	1251.	2.22E+11	-387.100	60452.	714.4167
25.2000	0.03227	462612.	-11821.	-4.22E-04	1088.	2.22E+11	-373.954	62578.	726.8424
25.6500	0.03002	403926.	-9846.	-4.11E-04	950.4141	2.22E+11	-360.694	64878.	739.2682
26.1000	0.02783	356279.	-7731.	-4.02E-04	838.3042	2.22E+11	-347.259	67388.	751.6939
26.5500	0.02568	320426.	-5477.	-3.94E-04	753.9434	2.22E+11	-333.587	70150.	764.1197
27.0000	0.02357	297127.	-2446.	-3.86E-04	699.1221	2.22E+11	-84.378	19329.	776.5455
27.4500	0.02151	294011.	1327.	-3.79E-04	691.7917	2.22E+11	-83.792	21039.	788.9712
27.9000	0.01948	311459.	5171.	-3.72E-04	732.8448	2.22E+11	-82.960	22999.	801.3970
28.3500	0.01749	349856.	9087.	-3.64E-04	823.1912	2.22E+11	-81.857	25272.	813.8227
28.8000	0.01555	409598.	13077.	-3.55E-04	963.7590	2.22E+11	-80.457	27941.	826.2485
29.2500	0.01366	491086.	17142.	-3.44E-04	1155.	2.22E+11	-78.731	31119.	838.6742
29.7000	0.01184	594735.	20132.	-3.30E-04	1399.	2.22E+11	-76.653	34962.	423.9968

30.1500	0.01009	708512.	20870.	-3.14E-04	1667.	2.22E+11	-74.193	39688.	0.00
30.6000	0.00844	820125.	20477.	-2.96E-04	1930.	2.22E+11	-71.323	45616.	0.00
31.0500	0.00690	929659.	20100.	-2.75E-04	2187.	2.22E+11	-68.005	53226.	0.00
31.5000	0.00548	1037210.	19743.	-2.51E-04	2440.	2.22E+11	-64.197	63284.	0.00
31.9500	0.00419	1142889.	18494.	-2.24E-04	2689.	2.22E+11	-398.722	513536.	0.00
32.4000	0.00306	1236941.	16498.	-1.95E-04	2910.	2.22E+11	-340.503	601341.	0.00
32.8500	0.00209	1321064.	14819.	-1.64E-04	3108.	2.22E+11	-281.194	728175.	0.00
33.3000	0.00129	1396987.	13464.	-1.31E-04	3287.	2.22E+11	-220.866	927070.	0.00
33.7500	6.71E-04	1466470.	12486.	-9.61E-05	3451.	2.22E+11	-141.127	1135166.	0.00
34.2000	2.49E-04	1531838.	-35632.	-5.96E-05	3604.	2.22E+11	-17680.	3.84E+08	0.00
34.6500	2.79E-05	1081646.	-89740.	-2.78E-05	2545.	2.22E+11	-2360.	4.57E+08	0.00
35.1000	-5.10E-05	562646.	-82585.	-7.76E-06	1324.	2.22E+11	5009.	5.30E+08	0.00
35.5500	-5.59E-05	189722.	-52173.	1.40E-06	446.4051	2.22E+11	6254.	6.04E+08	0.00
36.0000	-3.59E-05	-820.837	-23120.	3.69E-06	1.9314	2.22E+11	4506.	6.77E+08	0.00
36.4500	-1.60E-05	-59969.	-4937.	2.95E-06	141.1038	2.22E+11	2228.	7.51E+08	0.00
36.9000	-4.01E-06	-54139.	2733.	1.57E-06	127.3861	2.22E+11	612.4761	8.24E+08	0.00
37.3500	8.87E-07	-30449.	3989.	5.37E-07	71.6454	2.22E+11	-147.362	8.98E+08	0.00
37.8000	1.78E-06	-11057.	2725.	3.16E-08	26.0155	2.22E+11	-320.772	9.71E+08	0.00
38.2500	1.23E-06	-1018.	1218.	-1.15E-07	2.3943	2.22E+11	-237.492	1.04E+09	0.00
38.7000	5.38E-07	2096.	275.8379	-1.02E-07	4.9322	2.22E+11	-111.400	1.12E+09	0.00
39.1500	1.24E-07	1961.	-98.744	-5.28E-08	4.6152	2.22E+11	-27.334	1.19E+09	0.00
39.6000	-3.25E-08	1030.	-151.991	-1.64E-08	2.4229	2.22E+11	7.6128	1.26E+09	0.00
40.0500	-5.36E-08	319.9746	-95.605	-3.61E-12	0.7529	2.22E+11	13.2710	1.34E+09	0.00
40.5000	-3.25E-08	-2.802	-36.804	3.86E-09	0.00659	2.22E+11	8.5070	1.41E+09	0.00
40.9500	-1.19E-08	-77.513	-4.999	2.88E-09	0.1824	2.22E+11	3.2728	1.49E+09	0.00
41.4000	-1.45E-09	-56.789	4.9659	1.24E-09	0.1336	2.22E+11	0.4178	1.56E+09	0.00
41.8500	1.54E-09	-23.881	4.8368	2.63E-10	0.05619	2.22E+11	-0.466	1.63E+09	0.00
42.3000	1.39E-09	-4.552	2.3941	-8.33E-11	0.01071	2.22E+11	-0.439	1.71E+09	0.00
42.7500	6.41E-10	1.9753	0.6383	-1.15E-10	0.00465	2.22E+11	-0.211	1.78E+09	0.00
43.2000	1.52E-10	2.3419	-0.07172	-6.21E-11	0.00551	2.22E+11	-0.05171	1.84E+09	0.00
43.6500	-2.93E-11	1.2007	-0.184	-1.90E-11	0.00283	2.22E+11	0.00997	1.84E+09	0.00
44.1000	-5.29E-11	0.3501	-0.109	0.00	8.24E-04	2.22E+11	0.01799	1.84E+09	0.00
44.5500	-3.05E-11	0.02407	-0.03242	4.45E-12	5.66E-05	2.22E+11	0.01036	1.84E+09	0.00
45.0000	-4.86E-12	0.00	0.00	4.74E-12	0.00	2.22E+11	0.00165	9.18E+08	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 1:

Pile-head deflection = 0.42949875 inches
Computed slope at pile head = -0.0018166 radians
Maximum bending moment = 2211700. inch-lbs

```
Maximum shear force              =        -89740. lbs
Depth of maximum bending moment  =    16.65000000 feet below pile head
Depth of maximum shear force     =    34.65000000 feet below pile head
Number of iterations             =             20
Number of zero deflection points =              6
Pile deflection at ground        =     0.20084519 inches
```

Pile-head Deflection vs. Pile Length for Load Case 1

Boundary Condition Type 1, Shear and Moment

```
Shear      =              0. lbs
Moment     =              0. in-lbs
Axial Load =              0. lbs
```

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
45.00000	0.42949875	2211700.	-89740.
42.75000	0.43558807	2252602.	-88783.
40.50000	0.43464151	2219983.	-89348.
38.25000	0.43784731	2241735.	-89929.
36.00000	0.43006925	2214550.	-97334.
33.75000	0.42225006	2202202.	-28001.
31.50000	0.28659916	2327426.	23790.
29.25000	0.26168163	2347444.	23645.
27.00000	0.49198924	2191336.	-28287.
24.75000	0.76237148	2204062.	-34763.

Computed Values of Pile Loading and Deflection
for Lateral Loading for Load Case Number 2

Pile-head conditions are Shear and Moment (Loading Type 1)

Shear force at pile head = 0.0 lbs
Applied moment at pile head = 0.0 in-lbs
Axial thrust load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/inch	Soil Spr. Es*H lb/inch	Distrib. Lat. Load lb/inch
0.00	1.6857	8.62E-05	-1.56E-07	-0.00605	2.03E-07	2.22E+11	0.00	0.00	58.8598
0.4500	1.6531	858.1766	355.5880	-0.00605	2.0192	2.22E+11	0.00	0.00	72.8394
0.9000	1.6204	3840.	799.2470	-0.00605	9.0361	2.22E+11	0.00	0.00	91.4788
1.3500	1.5877	9490.	1344.	-0.00605	22.3295	2.22E+11	0.00	0.00	110.1182
1.8000	1.5551	18351.	1989.	-0.00605	43.1783	2.22E+11	0.00	0.00	128.7576
2.2500	1.5224	30966.	2734.	-0.00605	72.8614	2.22E+11	0.00	0.00	147.3970
2.7000	1.4898	47880.	3580.	-0.00605	112.6577	2.22E+11	0.00	0.00	166.0364
3.1500	1.4571	69635.	4527.	-0.00604	163.8460	2.22E+11	0.00	0.00	184.6758
3.6000	1.4245	96775.	5575.	-0.00604	227.7052	2.22E+11	0.00	0.00	203.3152
4.0500	1.3919	129844.	6723.	-0.00604	305.5142	2.22E+11	0.00	0.00	221.9545
4.5000	1.3593	169385.	7972.	-0.00604	398.5520	2.22E+11	0.00	0.00	240.5939
4.9500	1.3267	215941.	9322.	-0.00603	508.0973	2.22E+11	0.00	0.00	259.2333
5.4000	1.2941	270057.	10772.	-0.00603	635.4290	2.22E+11	0.00	0.00	277.8727
5.8500	1.2616	332276.	12323.	-0.00602	781.8261	2.22E+11	0.00	0.00	296.5121
6.3000	1.2291	403141.	13974.	-0.00601	948.5675	2.22E+11	0.00	0.00	315.1515
6.7500	1.1967	483196.	15726.	-0.00600	1137.	2.22E+11	0.00	0.00	333.7909
7.2000	1.1644	572984.	17579.	-0.00599	1348.	2.22E+11	0.00	0.00	352.4303
7.6500	1.1321	673049.	19532.	-0.00597	1584.	2.22E+11	0.00	0.00	371.0697
8.1000	1.0999	783935.	21587.	-0.00595	1845.	2.22E+11	0.00	0.00	389.7091
8.5500	1.0678	906184.	23741.	-0.00593	2132.	2.22E+11	0.00	0.00	408.3485
9.0000	1.0358	1040341.	25997.	-0.00591	2448.	2.22E+11	0.00	0.00	426.9879
9.4500	1.0040	1186949.	28353.	-0.00588	2793.	2.22E+11	0.00	0.00	445.6273
9.9000	0.9723	1346551.	30810.	-0.00585	3168.	2.22E+11	0.00	0.00	464.2667
10.3500	0.9408	1519692.	33367.	-0.00582	3576.	2.22E+11	0.00	0.00	482.9061
10.8000	0.9095	1706913.	36001.	-0.00578	4016.	2.22E+11	-8.858	52.5923	501.5455
11.2500	0.8784	1908502.	38615.	-0.00573	4491.	2.22E+11	-44.748	275.0847	520.1848
11.7000	0.8476	2123954.	41005.	-0.00568	4998.	2.22E+11	-129.110	822.5663	538.8242
12.1500	0.8170	2351354.	43004.	-0.00563	5533.	2.22E+11	-226.898	1500.	557.4636
12.6000	0.7868	2588393.	44544.	-0.00557	6090.	2.22E+11	-336.065	2307.	576.1030
13.0500	0.7569	2832431.	45570.	-0.00550	6665.	2.22E+11	-454.820	3245.	594.7424
13.5000	0.7274	3080550.	46034.	-0.00543	7248.	2.22E+11	-581.574	4318.	613.3818
13.9500	0.6982	3329596.	45896.	-0.00535	7834.	2.22E+11	-714.910	5529.	632.0212
14.4000	0.6696	3576225.	45124.	-0.00527	8415.	2.22E+11	-853.554	6884.	650.6606
14.8500	0.6413	3816938.	43693.	-0.00518	8981.	2.22E+11	-996.362	8389.	669.3000
15.3000	0.6136	4048113.	41583.	-0.00508	9525.	2.22E+11	-1142.	10052.	687.9394

15.7500	0.5865	4266039.	38780.	-0.00498	10038.	2.22E+11	-1290.	11883.	706.5788
16.2000	0.5598	4466939.	35306.	-0.00488	10510.	2.22E+11	-1428.	13774.	725.2182
16.6500	0.5338	4647347.	31210.	-0.00476	10935.	2.22E+11	-1558.	15763.	743.8576
17.1000	0.5084	4804007.	26531.	-0.00465	11304.	2.22E+11	-1681.	17856.	762.4970
17.5500	0.4836	4933883.	21310.	-0.00453	11609.	2.22E+11	-1797.	20061.	781.1364
18.0000	0.4594	5034150.	15584.	-0.00441	11845.	2.22E+11	-1905.	22391.	799.7758
18.4500	0.4360	5102188.	9391.	-0.00429	12005.	2.22E+11	-2007.	24856.	818.4152
18.9000	0.4132	5135576.	2768.	-0.00416	12084.	2.22E+11	-2102.	27470.	837.0545
19.3500	0.3910	5132086.	-4249.	-0.00404	12075.	2.22E+11	-2190.	30247.	855.6939
19.8000	0.3696	5089683.	-10022.	-0.00391	11976.	2.22E+11	-1678.	24518.	874.3333
20.2500	0.3488	5023847.	-12667.	-0.00379	11821.	2.22E+11	-1069.	16548.	892.9727
20.7000	0.3286	4952884.	-13523.	-0.00367	11654.	2.22E+11	-1053.	17302.	911.6121
21.1500	0.3092	4877799.	-14190.	-0.00355	11477.	2.22E+11	-1036.	18097.	930.2515
21.6000	0.2903	4799629.	-14663.	-0.00343	11293.	2.22E+11	-1018.	18936.	948.8909
22.0500	0.2721	4719442.	-14934.	-0.00331	11105.	2.22E+11	-998.972	19825.	967.5303
22.5000	0.2545	4638338.	-14999.	-0.00320	10914.	2.22E+11	-978.798	20767.	986.1697
22.9500	0.2375	4557449.	-14852.	-0.00309	10723.	2.22E+11	-957.520	21767.	1005.
23.4000	0.2212	4477939.	-14486.	-0.00298	10536.	2.22E+11	-935.110	22832.	1023.
23.8500	0.2054	4401005.	-13894.	-0.00287	10355.	2.22E+11	-911.519	23967.	1042.
24.3000	0.1902	4327879.	-13072.	-0.00276	10183.	2.22E+11	-886.668	25179.	1061.
24.7500	0.1755	4259828.	-12011.	-0.00266	10023.	2.22E+11	-860.411	26472.	1079.
25.2000	0.1614	4198162.	-10703.	-0.00256	9878.	2.22E+11	-832.429	27845.	1098.
25.6500	0.1479	4144240.	-9132.	-0.00246	9751.	2.22E+11	-800.574	29230.	1117.
26.1000	0.1349	4099534.	-7278.	-0.00236	9646.	2.22E+11	-764.618	30604.	1135.
26.5500	0.1225	4065638.	-5129.	-0.00226	9566.	2.22E+11	-728.490	32122.	1154.
27.0000	0.1106	4044146.	-1195.	-0.00216	9516.	2.22E+11	-141.235	6899.	1173.
27.4500	0.09917	4052729.	4429.	-0.00206	9536.	2.22E+11	-139.467	7594.	1191.
27.9000	0.08832	4091980.	10165.	-0.00196	9628.	2.22E+11	-137.310	8395.	1210.
28.3500	0.07801	4162506.	16013.	-0.00186	9794.	2.22E+11	-134.740	9327.	1228.
28.8000	0.06824	4264926.	21978.	-0.00176	10035.	2.22E+11	-131.726	10423.	1247.
29.2500	0.05904	4399870.	28061.	-0.00165	10353.	2.22E+11	-128.239	11729.	1266.
29.7000	0.05041	4567985.	32525.	-0.00154	10748.	2.22E+11	-124.242	13308.	639.8701
30.1500	0.04239	4751136.	33594.	-0.00143	11179.	2.22E+11	-119.697	15248.	0.00
30.6000	0.03499	4930796.	32961.	-0.00131	11602.	2.22E+11	-114.560	17681.	0.00
31.0500	0.02824	5107115.	32358.	-0.00119	12017.	2.22E+11	-108.778	20803.	0.00
31.5000	0.02216	5280263.	31788.	-0.00106	12424.	2.22E+11	-102.283	24930.	0.00
31.9500	0.01677	5450428.	29359.	-9.31E-04	12825.	2.22E+11	-797.380	256786.	0.00
32.4000	0.01210	5597341.	25378.	-7.97E-04	13170.	2.22E+11	-677.281	302321.	0.00
32.8500	0.00816	5724505.	22047.	-6.59E-04	13469.	2.22E+11	-556.328	368049.	0.00
33.3000	0.00498	5835446.	19371.	-5.18E-04	13730.	2.22E+11	-434.538	471204.	0.00
33.7500	0.00256	5933716.	17356.	-3.75E-04	13962.	2.22E+11	-311.816	656658.	0.00
34.2000	9.29E-04	6022894.	-161540.	-2.30E-04	14172.	2.22E+11	-65946.	3.84E+08	0.00
34.6500	8.45E-05	4189079.	-358903.	-1.05E-04	9857.	2.22E+11	-7151.	4.57E+08	0.00

35.1000	-2.09E-04	2146741.	-322809.	-2.82E-05	5051.	2.22E+11	20519.	5.30E+08	0.00
35.5500	-2.20E-04	702741.	-200940.	6.47E-06	1654.	2.22E+11	24618.	6.04E+08	0.00
36.0000	-1.39E-04	-23411.	-87394.	1.47E-05	55.0850	2.22E+11	17437.	6.77E+08	0.00
36.4500	-6.10E-05	-241111.	-17427.	1.15E-05	567.3209	2.22E+11	8477.	7.51E+08	0.00
36.9000	-1.46E-05	-211625.	11485.	6.01E-06	497.9405	2.22E+11	2231.	8.24E+08	0.00
37.3500	3.92E-06	-117078.	15749.	2.01E-06	275.4766	2.22E+11	-651.865	8.98E+08	0.00
37.8000	7.07E-06	-41539.	10554.	7.81E-08	97.7383	2.22E+11	-1272.	9.71E+08	0.00
38.2500	4.77E-06	-3090.	4631.	-4.65E-07	7.2713	2.22E+11	-921.720	1.04E+09	0.00
38.7000	2.05E-06	8481.	996.3454	-3.99E-07	19.9549	2.22E+11	-424.613	1.12E+09	0.00
39.1500	4.51E-07	7670.	-419.051	-2.03E-07	18.0476	2.22E+11	-99.608	1.19E+09	0.00
39.6000	-1.40E-07	3955.	-599.526	-6.14E-08	9.3060	2.22E+11	32.7661	1.26E+09	0.00
40.0500	-2.11E-07	1195.	-369.592	1.30E-09	2.8126	2.22E+11	52.3946	1.34E+09	0.00
40.5000	-1.26E-07	-36.526	-139.311	1.54E-08	0.08594	2.22E+11	32.8946	1.41E+09	0.00
40.9500	-4.50E-08	-309.204	-17.052	1.12E-08	0.7275	2.22E+11	12.3868	1.49E+09	0.00
41.4000	-4.89E-09	-220.684	20.2044	4.75E-09	0.5193	2.22E+11	1.4117	1.56E+09	0.00
41.8500	6.25E-09	-90.997	18.9159	9.56E-10	0.2141	2.22E+11	-1.889	1.63E+09	0.00
42.3000	5.43E-09	-16.392	9.1849	-3.51E-10	0.03857	2.22E+11	-1.715	1.71E+09	0.00
42.7500	2.46E-09	8.1993	2.3686	-4.51E-10	0.01929	2.22E+11	-0.809	1.78E+09	0.00
43.2000	5.61E-10	9.1893	-0.331	-2.39E-10	0.02162	2.22E+11	-0.191	1.84E+09	0.00
43.6500	-1.28E-10	4.6194	-0.729	-7.12E-11	0.01087	2.22E+11	0.04335	1.84E+09	0.00
44.1000	-2.09E-10	1.3138	-0.421	0.00	0.00309	2.22E+11	0.07093	1.84E+09	0.00
44.5500	-1.17E-10	0.07655	-0.122	1.79E-11	1.80E-04	2.22E+11	0.03980	1.84E+09	0.00
45.0000	-1.54E-11	0.00	0.00	1.88E-11	0.00	2.22E+11	0.00525	9.18E+08	0.00

* The above values of total stress are combined axial and bending stresses.

Output Summary for Load Case No. 2:

```
Pile-head deflection             =     1.68571774 inches
Computed slope at pile head      =     -0.0060479 radians
Maximum bending moment           =       6022894. inch-lbs
Maximum shear force              =       -358903. lbs
Depth of maximum bending moment  =    34.20000000 feet below pile head
Depth of maximum shear force     =    34.65000000 feet below pile head
Number of iterations             =            103
Number of zero deflection points =              6
Pile deflection at ground        =     0.91644962 inches
```

Pile-head Deflection vs. Pile Length for Load Case 2

Boundary Condition Type 1, Shear and Moment

Shear   =   0. lbs
Moment   =   0. in-lbs
Axial Load =   0. lbs

Pile Length feet	Pile Head Deflection inches	Maximum Moment ln-lbs	Maximum Shear lbs
45.00000	1.68571774	6022894.	-358903.
42.75000	1.63718473	5832374.	-345125.
40.50000	5.03707773	22995811.	-1374410.
38.25000	1.92764577	6886487.	-410551.
36.00000	1.69779150	6052270.	-384169.

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, V, lbs, and Load 2 = Moment, M, in-lbs
Load Type 2: Load 1 = Shear, V, lbs, and Load 2 = Slope, S, radians
Load Type 3: Load 1 = Shear, V, lbs, and Load 2 = Rot. Stiffness, R, in-lbs/rad.
Load Type 4: Load 1 = Top Deflection, y, inches, and Load 2 = Moment, M, in-lbs
Load Type 5: Load 1 = Top Deflection, y, inches, and Load 2 = Slope, S, radians

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	0.00	M, in-lb	0.00	0.00	0.4295	-0.00182	-89740.	2211700.
2	V, lb	0.00	M, in-lb	0.00	0.00	1.6857	-0.00605	-358903.	6022894.

Maximum pile-head deflection = 1.6857177407 inches
Maximum pile-head rotation   = -0.0060479256 radians = -0.346521 deg.

Summary of Warning Messages

The following warning was reported 10000 times

**** Warning ****

An unreasonable input value for unconfined compressive strength has been specified for a soil defined using the weak rock criteria. The input value is greater than 500 psi. Please check your input data for correctness.

The analysis ended normally.

APPENDIX F
RESPONSE TO STAGE 2 COMMENTS

CTL Engineering , Inc.
2860 Fisher Road, P.O. Box 44548, Columbus, Ohio 43204-3538
Phone: 614/276-8123 Fax: 614/276-6377
Email: ctl@ctleng.com

October 12, 2023

IBI Group
23 Triangle Park Drive
Cincinnati, Ohio 45246

Attention: Mr. Steven Butler, P.E.
Associate – Manager, Transportation Engineering

Reference: Response to Stage 2 Comments
BRO-52-10.25 Slide Repair
PID No. 116986
Brown County, Ohio
CTL Project No. 23050011COL

Dear Mr. Butler:

This letter provides our responses to the comments prepared by ODOT OGE on the Stage 2 Submittals. These comments were provided to CTL via email by IBI Group personnel on May 11, 2023

CTL Responses to Comments received from OGE on Stage 2 Submittal

Geotech Report/Geotechnical profile

1) Update elevations on boring logs to match surveyed information.

Response: The elevation on the boring logs were updated to match the surveyed information.

2) Provide justification in report for 11-foot rock socket.

Response: L-pile analyses were initially performed with reinforced shafts extending 10-feet into the underlying competent (coreable) bedrock. The analyses suggested that a heavier steel section with drilled shaft diameter larger than 3.0 feet will be required to resist the shear and moment at the strength limit state, if reinforced shafts are embedded 10 feet. Due to the R/W constraints, drilled shaft diameter larger than 3 feet in diameter are not feasible for this project. Therefore, additional analyses were performed with reinforced shafts extending 11.0 feet into the underlying coreable bedrock. This rock embedment met the necessary design checks and also addressed the R/W constraints. Therefore, CTL recommends a 11.0 feet rock embedment be utilized for the reinforced shafts.

3) In Lpile analysis - Compute top y vs pile length should be check yes to determine/check socket length

Response: The Lpile analyses were updated to compute y vs pile length

4) Verify that the plans meet or exceed the design in the report.

Response: CTL will review the Final plans and provide a plan certification letter.

Closing

We appreciate the opportunity to be of service to you on this project. If you have any questions or need further information, please do not hesitate to contact us.

Respectfully submitted,

CTL ENGINEERING, INC.

Shahedur Rahman
Geotechnical Engineer

Sastry Malladi, P.E.
Project Engineer

APPENDIX G
GEOTECHNICAL CERTIFICATE OF REVIEW- FINAL PLANS

CTL Engineering, Inc.
2860 Fisher Road, P.O. Box 44548, Columbus, Ohio 43204-3538
Phone: 614/276-8123; Fax: 614/276-6377
Email: ctl@ctleng.com

AN EMPLOYEE OWNED COMPANY

Consulting Engineers • Testing • Inspection Services • Analytical Laboratories

Established 1927

October 12, 2023

IBI Group
23 Triangle Park Drive
Cincinnati, OH 45246

Attention: Mr. Steven Butler, P.E.
Associate – Manager, Transportation Engineering

Reference: Certification Letter- Final Plans
BRO-52-10.25 Slide Repair
PID: 116986
Brown County, Ohio
CTL Project No. 23050011COL

Dear Mr. Butler:

As the Geotechnical Engineer of Record for the subject project, I certify that I have reviewed the Final plans for the subject project.

Respectfully Submitted

CTL ENGINEERING, INC.

Sastry Malladi, P.E.
Project Engineer