



Proactive by Design



GEOTECHNICAL DESIGN REPORT BARRELL BRIDGE NO. 3500 OVER DOLLY GORDON BROOK MAINE DOT WIN 18957.00 YORK, MAINE

Prepared for:
Maine Department of Transportation
Augusta, ME

December 2017
09.0025948.00

Prepared by:
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Via Email

December 11, 2017
File No. 09.0025948.00

Ms. Laura Krusinski
Maine Department of Transportation
16 State House Station
Augusta, Maine 04333-0016

Re: Geotechnical Design Report
Barrell Bridge No. 3500 Over Dolly Gordon Brook
MaineDOT WIN 18957.00
York, Maine

Dear Laura:

We are pleased to provide this Geotechnical Design Report for MaineDOT Barrell Bridge No. 3500 over Dolly Gordon Brook in York, Maine. Our services were provided in accordance with Assignment Letter No. 10 (dated July 19, 2017) associated with the Bridge Program Multi-PIN Project Contract Number 2015060800000000793 between MaineDOT and GZA dated July 22, 2015, which incorporates GZA's Proposal No. 09.P000036.18, dated July 13, 2017. This report is subject to the *Limitations* included in **Appendix A**.

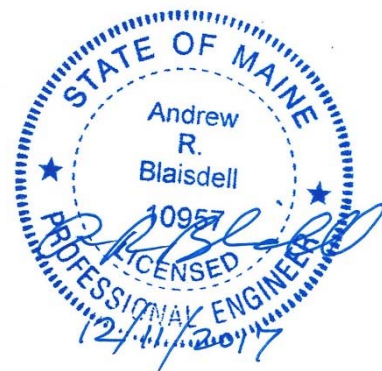
It has been a pleasure serving the Maine Department of Transportation team on this project. If you have any questions regarding the report, or if we can provide further assistance, please do not hesitate to contact the undersigned.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.


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1.0 INTRODUCTION

This report presents the results of the geotechnical evaluation completed by GZA GeoEnvironmental, Inc. (GZA) for the proposed replacement of Maine Department of Transportation (MaineDOT) Barrell Bridge No. 3500 which carries Beech Ridge Road over Dolly Gordon Brook in York, Maine. Our services were provided in accordance with Assignment Letter No. 10 (dated July 19, 2017) associated with the Bridge Program Multi-PIN Project Contract Number 2015060800000000793 between MaineDOT and GZA dated July 22, 2015, which incorporates GZA's Proposal No. 09.P000036.18, dated July 13, 2017. This report is subject to the *Limitations* included in **Appendix A**.

1.1 BACKGROUND

The existing Barrell Bridge No. 3500 carries Beech Ridge Road over Dolly Gordon Brook in York, at the location shown on **Figure 1, Locus Plan**. Our understanding of the existing bridge is based on our review of the Preliminary Design Report¹ (PDR). The existing bridge was constructed in 1937 and consists of an approximately 46-foot-long, 25-foot-wide, single-span bridge with a steel beam superstructure and a cast-in-place deck. The bridge is supported on spill-through abutments consisting of concrete backwalls and wingwalls supported by timber piles bearing on bedrock.

Based on our review of the progress plan set dated November 28, 2017 provided by MaineDOT, we understand the replacement bridge will consist of a 75-foot-long, 31.5-foot-wide, single-span bridge, the location of which is shown on **Figure 2, Boring Location Plan**. The replacement bridge will consist of four NEXT (36F) precast concrete beams on integral abutments. The abutment height will be approximately 10 feet, with a bottom of pile cap elevation of El. 2 at both abutments. Elevations in this report are in feet and reference the North American Vertical Datum of 1988 (NAVD 88).

Each abutment will be supported on six micropiles. Based on information provided by MaineDOT, the bridge designer, we understand the maximum factored axial pile load is 359 kips for a 6-pile configuration. MaineDOT estimated that thermal deformation of the bridge superstructure could result in 0.41 inches of lateral deflection at each abutment, as well as a live load-induced pile head rotation of 0.00210 inches/inch in the direction opposite of the imposed lateral load.

The horizontal alignment of the roadway and bridge in the project area will not be significantly modified as part of the project. The approach roadway will be 1 foot or less above existing grades, and the roadway will be widened at the bridge approaches to match the increased bridge width. Approach embankment modifications will include placing additional fill and riprap along the sides of the approach embankments up to about 4 feet thick to facilitate the widened roadway and provide a slope inclination of 2H:1V in the vicinity of the bridge. The bridge opening at water level will be increased significantly, which will result in removal of the abutments and excavation of soil on the water side of the new abutments to proposed grades. Riprap will be placed in front of each abutment and along the embankment slopes up to El. 6.

¹ MaineDOT's "Preliminary Design Report, Barrell Bridge #3500 over Dolly Gordon Brook, WIN 018957.00," approval date September 22, 2017.



The project plans call for the bridge to be constructed in 2018 using Accelerated Bridge Construction (ABC) inside of a 40-day road closure, during which traffic will be detoured.

1.2 OBJECTIVES AND SCOPE OF SERVICES

The objectives of our work were to evaluate subsurface conditions and to provide final geotechnical engineering recommendations for the proposed Barrell Bridge No. 3500 replacement. To meet these objectives, GZA completed the following Scope of Services:

- Conducted site visits to observe surficial conditions and reviewed mapped surficial and bedrock geology of the site;
- Reviewed existing test boring data from two borings and two probes conducted by MaineDOT;
- Coordinated and observed a subsurface exploration program, consisting of two test borings, to provide supplemental data to evaluate subsurface conditions;
- Conducted an independent review of the MaineDOT boring rock cores for one boring;
- Conducted a laboratory testing program to evaluate engineering properties and index properties of the site soils and bedrock;
- Conducted geotechnical engineering analyses to evaluate axial and lateral foundation design for the replacement bridge, embankment design considerations, and seismic design considerations;
- Developed geotechnical engineering recommendations including foundation design recommendations for micropiles, lateral earth pressures and seismic design parameters;
- Prepared a preliminary memorandum summarizing our findings and preliminary design recommendations; and
- Prepared this final report summarizing our findings and design recommendations.

2.0 SUBSURFACE EXPLORATIONS

Prior to GZA's engagement in the project, an exploration program was completed by MaineDOT in 2016. GZA completed a supplemental subsurface exploration program in 2017. Details of these programs are described below.

2.1 PREVIOUS TEST BORINGS

On December 13 through December 19, 2016, New England Test Boring of Derry, New Hampshire drilled two test borings, designated as BB-YCGB-101 and -104, and two probes, designated as BB-YCGB-102 and -103. The borings were drilled to depths ranging from approximately 19 to 37 feet below ground surface (bgs). The borings were drilled using 4- and 3-inch driven casing and drive-and-wash drilling techniques. Standard penetration testing (SPT) and split-spoon sampling were performed at 5-foot typical intervals in the overburden using a 24-inch-long, 1-3/8-inch inside-diameter sampler, driven with an automatic hammer with a rated hammer efficiency factor of 0.572. Cores were obtained using NQ2 (approximately 2-inch diameter) wire-line coring equipment. Bedrock was encountered and cored in BB-YCGB-101 and



-104 at depths of 17 and 19 feet bgs, respectively. BB-YCGB-102 and -103 were terminated upon practical refusal of a 4.5-inch solid stem auger. Soil sampling was not conducted in probes BB-YCGB-102 or -103.

MaineDOT developed draft logs of the borings and provided them to GZA. GZA reviewed and edited the boring logs to reflect engineering review of draft logs, laboratory test results, interpretation of subsurface strata, and bedrock classifications. Boring logs for the 100-series borings and probes are presented in **Appendix B**.

2.2 SUPPLEMENTAL TEST BORINGS

GZA completed two supplemental test borings (BB YCGB-201 and -202) during final design. BB-YCGB-201 and -202 were drilled behind the existing abutments near the locations of previous probes BB-YCGB-102 and BB-YCGB-103, respectively. The 200-series borings were drilled to depths of approximately 37 to 57 feet bgs, including coring approximately 9 and 32 feet into bedrock. New England Boring Contractors of Hermon, Maine provided drilling services and coordinated utility clearance. The drilling was completed on August 2 and 3, 2017. GZA personnel monitored the drilling work and prepared logs of the borings that are included in **Appendix B**.

The borings were drilled using 4-inch driven casing and drive-and-wash drilling techniques with a truck-mounted drill rig. SPT and split-spoon sampling were performed at 5-foot typical intervals in the overburden using a 24-inch-long, 1-3/8-inch inside-diameter sampler, driven with an automatic hammer with a rated hammer efficiency factor of 0.677. Bedrock cores were obtained using NQ2 coring equipment. Wet and dry photographs of the rock core specimens are presented in **Appendix C**.

The borings were backfilled with cuttings, crushed stone, and asphalt cold patch. The approximate as-drilled boring locations were determined by GZA using taped ties to existing bridge structure components and nearby sign structures, and later surveyed by MaineDOT surveyors. See **Figure 2** for the as-drilled boring location plan.

2.3 REVIEW OF ROCK CORE

GZA requested access to the rock core samples to make an independent assessment of the rock. After receiving approval of the MaineDOT Geotechnical Group, a GZA engineer visited MaineDOT's laboratory in Bangor, reviewed the available rock core specimens, and prepared an independent description of core samples from boring BB-YCGB-101. Samples for boring BB-YCGB-104 were not available during GZA's visit. The GZA observations were used to develop the rock descriptions included on the log for BB-YCGB-101 in **Appendix B**. GZA took wet and dry photographs of the rock core specimens for BB-YCGB-101 and MaineDOT provided wet and dry photograph logs for the rock core specimens from BB-YCGB-104, both of which are presented in **Appendix C**.

3.0 LABORATORY TESTING

MaineDOT completed a laboratory testing program consisting of water content and gradation analysis/AASHTO Classification/Frost Classification assessments on four soil samples from the 100-series borings.



GZA retained GeoTesting Express of Acton, Massachusetts to complete a laboratory testing program to assess the gradation and index properties of the soil and bedrock testing to evaluate the strength of the bedrock. The program included the following tests on samples from the 200-series borings: five (5) gradation analysis / AASHTO Classifications, five (5) moisture content tests on soils, and two (2) unconfined compressive strength / secant modulus tests on bedrock core samples.

Results of the laboratory testing are included in **Appendix D**.

4.0 SUBSURFACE CONDITIONS

4.1 SURFICIAL AND BEDROCK GEOLOGY

Based on available surficial geology mapping², the surficial unit along the river at the bridge alignment consists of Marine nearshore deposits, described as thin, discontinuous till, water-laid sediments and/or wetland deposits overlying bedrock. The Presumpscot Formation is mapped adjacent to the Marine nearshore deposit in the vicinity of the bridge alignment, which is described as massive to laminated, gray-blue silt and clay.

Bedrock in the vicinity of the site is mapped³ as the Kittery formation, part of the Merrimack group. The Kittery formation is characterized as variably thin to thick bedded, buff weathering, feldspathic and calcareous METAWACKE.

4.2 SUBSURFACE PROFILE

Four soil units were encountered and interpreted in the test borings overlying bedrock: Fill, mixed Timber Crib Fill/Glaciomarine Deposit, Glaciomarine Deposit, and Gravel. Approximately 4 to 5 inches of asphalt pavement was encountered in the borings. The thicknesses and generalized descriptions of the soil units are presented in the following table, in descending order from existing ground surface. Detailed descriptions of the materials encountered at specific locations are provided in the boring logs in **Appendix B**. The subsurface conditions are also shown in relation to the bridge alignment on **Figure 2**, and in relation to the abutment cross-sections on **Figure 3**.

² Clinch, J. Michael, O'Toole, Patrick B., Cameron, & Cornelia C. 1999. Surficial geology of the York Harbor quadrangle, Maine: Maine Geological Survey, Open-File Map 99-107, map, scale 1:24,000. *Maine Geological Survey Maps*. 998. http://digitalmaine.com/mgs_maps/998

³ Hussey, Arthur M., II, & Brooks, John A. 2014. Bedrock geology of the York Harbor quadrangle, Maine: Maine Geological Survey, Progress Map 14-1, color map, scale 1:24,000. *Maine Geological Survey Maps*. 72. http://digitalmaine.com/mgs_maps/72



GENERALIZED SUBSURFACE CONDITIONS		
Soil Unit	Approximate Encountered Thickness (ft)	Generalized Description
Fill	5	Brown, dry to moist, medium dense to dense, fine to coarse SAND, some to little Gravel, little to trace Silt (USCS: SM, SP-SM) • MaineDOT Frost Classification = II - III • Encountered in all borings
Timber Crib Fill/Glaciomarine Deposit	5 to 10	Brown to grey, moist, very soft to stiff, SILT, some Sand to Sandy, trace to little Gravel, with timber fragments, organics, and asphalt (USCS: ML). Interpreted mixture of fill and naturally deposited soil within zone of cribbing. Wood from apparent cribbing was encountered in each borehole. • MaineDOT Frost Classification = III • Encountered in all borings
Glaciomarine Deposit	7 to 8	Grey, light Brown, and tan, moist to wet, very stiff to hard, SILT, some Gravel, some Sand to Sandy (USCS: ML) • MaineDOT Frost Classification = III - IV • Encountered in borings BB-YCGB-104, and -202
Gravel	0 to 6	Grey, wet, very dense, GRAVEL, some Sand to Sandy, trace to some Silt (USCS: GW-GM, GM). • Encountered in all borings
Top of Bedrock Elevation	<u>Abutment 1 Encountered Top of Rock:</u> Approximate El. -6.3 (BB-YCGB-101) to El. -4.6 (BB-YCGB-201) <u>Abutment 2 Encountered Top of Rock:</u> Approximate El. -12.2 (BB-YCGB-202) to El. -8.7 (BB-YCGB-104)	

GZA did not observe the soil samples from the 100-series borings. We relied on classifications made by MainedOT combined with laboratory test results for our description of the soil.

4.2.1 Bedrock

Bedrock was cored in the four test borings and was described as moderately hard to hard, fresh to slightly weathered, fine- to coarse-grained, grey to dark grey, METAWACKE. Joints are described as extremely close (resulting in angular gravel recovery) to moderately spaced, low to high angle, planar to stepped, smooth to rough, discolored, and tight to open. The Rock Quality Designation (RQD) in the core runs ranged from 0 to 81 percent. Borings BB-YCGB-101, -104 and -201 encountered 5 feet or less of rock with an RQD of 0 percent in the upper cored rock. Boring BB-YCGB-202 encountered approximately 24 feet of rock with an RQD of 0 percent in the upper cored rock (25 to 49 feet bgs; El. -13 to El. -37). The high angle jointing in the rock likely resulted in fracturing of the upper rock during coring and contributed to the low RQDs.

Unconfined compressive strength (UCS) testing was conducted on two bedrock samples, the results of which are summarized in the following table.



SUMMARY OF BEDROCK STRENGTH TEST RESULTS							
Boring	Approximate Depth Below Existing Ground (ft bgs)	Approximate Depth below Top of Rock (ft bgs)	Approximate Elevation @ Top of Sample (ft NAVD 88)	Unconfined Compressive Strength (psi)	Secant Modulus @ 50 Percent of Failure Stress (ksi)	Unit Weight (pcf)	Rock Type
BB-YCGB-201	28.5	12.0	-16.6	17,136	8,240	174	METAWACKE
BB-YCGB-202	51.6	27.5	-39.7	21,720	8,650	183	METAWACKE

4.2.2 Groundwater

Groundwater levels were measured from approximately 6 to 10 feet bgs, corresponding to approximately El. 6 to El. 2. Considering the presence of the brook adjacent to the approaches, groundwater levels in the approaches near the abutments are anticipated to be at or above the brook level. Fluctuations in groundwater levels occur due to variations in season, precipitation, tides, brook level and other factors. Consequently, water levels during and after construction are likely to vary from those encountered in the borings at the time the observations were made.

5.0 ENGINEERING EVALUATIONS

5.1 GENERAL

GZA has conducted geotechnical engineering evaluations in accordance with 2014 AASHTO LRFD Bridge Design Specifications, 7th Edition, with Interims (herein known as AASHTO) and the MaineDOT Bridge Design Guide, 2014 Edition (MaineDOT BDG). The sections that follow describe the evaluations and the geotechnical basis for each element. Supporting calculations developed by GZA for the project are attached in **Appendix E** of this report.

5.2 APPROACH EMBANKMENTS

The approach embankments will be raised by 1 foot or less above existing pavement grade and will be widened by 6 to 8 feet in the vicinity of the bridge, resulting in placement of up to 4 feet new fill above existing embankment grades. Proposed side slope angles at both approaches will be flattened to approximately 2H:1V.

Considering the total fill thickness of 4 feet and the limited plan area of the fill, the stress increase in natural silt strata below the existing fill will be minimal. Total estimated settlement within the roadway is less than ½ inch, and downdrag loading is not anticipated on the piles. Settlement will likely be on the order of ½ to 1 inch or less beneath new slope fills and is expected to occur rapidly during embankment construction.

Considering that the approach elevation is not changing significantly and the proposed embankment slopes will be flatter than the existing slopes, it is our opinion that the potential for global instability of the embankments is low.



These settlement and stability considerations assume that weak organic deposits are not present beneath the widened embankment. If these materials are encountered, they should be removed as recommended later herein.

5.3 SEISMIC DESIGN CONSIDERATIONS

Seismic site class was evaluated in accordance with the 2014 AASHTO LRFD, along with consideration of the 2011 AASHTO Guide Specifications for LRFD Bridge Design (Seismic Guide Specification).

The subsurface profile for seismic design includes the approach fills (including backfill behind abutments) and underlying Glaciomarine silt and Gravel overlying bedrock. Seismic site class was determined in general accordance with LRFD Table C3.10.3.1, considering the average SPT N-value of granular soils encountered in the borings. The SPT N-value used to determine the site class was evaluated by including only the soil profile, resulting in an effective profile thickness ranging from 6 to 14 feet.

The average SPT N-value for encountered granular soils is between 15 and 50 blows per foot. Therefore, the bridge is assigned to Site Class D.

The available subsurface data indicates that the natural materials encountered at the site are sufficiently stiff or dense that the potential for liquefaction is low.

5.4 EVALUATION OF FOUNDATIONS

5.4.1 Foundation Type Assessment

Considering that rock will be within about six feet of the bottom of the integral abutment at Abutment 1, GZA considered three foundation types during preliminary design: rock-socketed H-piles, spun piles, or micropiles. Socketed H-piles were considered less favorable than the other socketed foundations due to the large required socket diameter, and engineering evaluations were conducted to assess performance of potential spun pile and micropile configurations.

Preliminary lateral pile evaluations were conducted for spun piles and micropiles constructed with N80 9.625-inch and 10.75-inch outside-diameter (OD) pipe sections, including wall thicknesses of 0.545 and 0.595 inches. The spun piles and micropiles were both evaluated for a pile length of 6 feet between bottom of abutment and top of rock. The results indicated the maximum stress for the selected pile sections with only 6 feet of pile above rock would be approaching or at yield (80 ksi) under combined bending.

The micropiles were also analyzed for a pile length of 9 feet above rock, that could be developed using an oversized socket that would extend 3 feet into rock, and allow additional lateral movement in that segment. The results showed that a 9.625-inch OD by 0.545-inch micropile would have a steel stress of approximately 70 ksi under combined bending. GZA shared the results of the preliminary analyses with MaineDOT in a Preliminary Geotechnical Design Basis memorandum dated November 15, 2017. Based on these results, MaineDOT selected a system of six, 9.625-inch OD micropiles to support each integral abutment.



5.4.2 Pile Design Considerations

Evaluations were conducted for axial compressive geotechnical resistance of micropiles. The geotechnical static resistance of micropiles was calculated using drilled shaft side resistance in rock methodology in accordance with AASHTO LRFD 10.8.3.5.4. End bearing resistance was ignored. Axial tensile geotechnical (uplift) resistance was not evaluated because the structural loadings provided by MainedOT do not include uplift loading on the piles.

By utilizing piles supported in bedrock, total and differential settlement will be limited to elastic compression of the piles and is anticipated to be less than ½ inch.

The piles will be installed partially through Fill material that may contain saline groundwater which could be corrosive. Therefore, we recommend that the piles consist of galvanized pipe, and as a result, no allowance for corrosive section loss is considered in the design.

Pile design recommendations are presented in **Section 6.4** of this report.

5.4.3 Load and Resistance Factors

Structural resistance of the micropiles at the strength limit state should be based on a resistance factor of $\phi_{cc}=0.75$ for axial compression resistance per AASHTO LRFD Table 10.5.5.2.5-2. Since the piles will be subject to lateral loading, the piles should also be checked for resistance to combined axial compression and flexure per AASHTO LRFD Articles 6.9.2.2 and 6.15.2. Per LRFD Article 6.5.4.2, the axial resistance factor $\phi_{cc}=0.75$ and the flexural resistance factor $\phi_r=1.0$ should be applied to the combined axial and flexural resistance of the pile in the interaction equation (AASHTO LRFD Eq. 6.9.2.2-1 or -2).

The piles should be designed at the strength limit state considering geotechnical resistance of the piles using a resistance factor of 0.55 for micropile side resistance in rock, per AASHTO Table 10.5.5.2.5-1. This resistance factor is based on the use of empirical predictive methodologies and does not require verification by pile load testing.

AASHTO LRFD load factors should be applied to horizontal earth pressure (EH), vertical earth pressure (EV), earth surcharge (ES), and live load surcharge (LS) loads using the load factors for permanent loads (γ_p) provided in AASHTO Table 3.4.1-2 for strength and extreme limit state design. Load factors are not provided for passive earth pressure because this is considered a resistance in AASHTO LRFD. A load factor of 1.5 may be applied to the passive pressure used to design the integral backwall (end diaphragm) to account for deformation of the backwall into the soil as a result of thermal expansion of the integral bridge deck, consistent with the load factor provided for active earth pressure in AASHTO Table 3.4.1-2.

5.4.4 Pile Type and Loading Data

The abutments will be supported on micropiles consisting of:

- Casing: 9.625-inch OD, 0.545-inch thick American Petroleum Institute (API) 5CT N80, galvanized, steel pipe with a minimum yield strength (f_y) of 80 kips per square inch (ksi);
- Central Reinforcing Steel: #20 Grade 75 All-Thread Rebar, ASTM A615; and



- Grout with an unconfined compressive strength of 5,000 psi.

Each abutment will include a single row of six piles. The maximum factored axial load for the strength condition provided by MaineDOT is 359 kips per pile. Therefore, the required geotechnical, nominal, axial pile resistance value is 653 kips based on a geotechnical resistance factor of 0.55.

5.4.5 Axial Pile Resistance

The primary input parameters used in our evaluation of pile resistance in rock, in accordance with 2014 AASHTO LRFD, included the Geologic Strength Index (GSI), unconfined compressive strength (q_u) and the rock group constant (m_i). The bedrock input parameters selected for our evaluation are based on the range in rock quality interpreted from cored bedrock and laboratory test data for the Metawacke encountered at the site. The Best Estimate properties consider the lower unconfined compressive strength and more fractured rock mass and are therefore appropriate for evaluation of axial compressive resistance, where a lower quality rock mass controls foundation design considerations. The Upper Bound properties consider stronger rock and less fracturing and are therefore appropriate for evaluation of lateral pile behavior, in which case stiffer rock creates a higher bending stress considering the short pile length. The selected values are presented in the table below.

PRELIMINARY BEDROCK ENGINEERING PROPERTIES				
Parameter Description	Parameter Symbol (units)	Best Estimate Values	Upper Bound Values	Reference
Unconfined Compressive Strength, Intact Rock	q_u (psi)	17,000	21,720	Laboratory test data
Geologic Strength Index	GSI	45	60	AASHTO Figure 10.4.6.4-1
Rock Group Constant	m_i	19	19	AASHTO Table 10.4.6.4-1

GZA calculated nominal and factored side resistance for micropile rock sockets using the drilled shaft side resistance methodology, in accordance with AASHTO 10.8.3.5.2. The results are presented in the table below.

PRELIMINARY MICROPILE GEOTECHNICAL UNIT SIDE RESISTANCE				
Rock Type	Nominal Unit Side Resistance (ksf)	Factored Unit Side Resistance, Compression (ksf)	Factored Side Resistance per Foot of Socket, 8-inch-diameter Socket (kips/foot)	Minimum Required Micropile Socket Length (feet, rounded up to nearest foot)
Metawacke	32.4	17.8	37.3	10

5.4.6 Lateral Pile Analysis

The Abutment 1 profile was chosen for the lateral pile analyses to model the shortest length of pile between the bottom of the pile cap and top of rock, estimated to be approximately 6 feet. The shallowest rock controls the pile design because combined stresses are higher when pile tip fixity occurs



at a shorter distance below the pile head. The soil strata anticipated between the top of rock and base of the abutment consist primarily of Silt and a thin layer of Sandy Gravel at Abutment 1.

GZA conducted lateral pile analyses using L-PILE 2015®. GZA calculated p-y curves for the rock using the hyperbolic function developed by Gabr et al. (2002) as presented in the National Cooperative Highway Research Program (NCHRP) Synthesis 360, "Rock-Socketed Shafts for Highway Structure Foundations." Gabr's correlation uses GSI, uniaxial compressive strength, Poisson's ratio, and effective unit weight of the intact rock, as well as rock mass modulus as input parameters. See **Appendix E** for the calculations of the Gabr p-y curves.

We modeled a micropile consisting of 12 feet of 9.625-inch OD by 0.545-inch wall casing below the base of the pile cap, above a 10-foot long by 8-inch diameter uncased rock socket, with a central Grade 75 #20 (2.5-inch-diameter) reinforcing bar, and 5,000 psi grout. Our evaluation used an 11-inch diameter rock socket drilled to 12 feet below the bottom of the pile cap before casing installation, with the lower 3 feet of the socket filled with grout to provide fixity for the casing. The portion of the casing embedded in grout was modeled using Upper Bound p-y curves, and the portion above the grout was modeled using Best Estimate p-y curves. Based on the annular space between the pile and socket, the pile will be able to move laterally at least ½ inch before it contacts rock. We then used the Best Estimate rock p-y curves to provide an upper bound estimate of pile stress.

GZA conducted lateral pile analyses using a maximum thermal deflection of 0.41 inches, a pile head slope of 0.00210 inch/inch, applied in the direction opposite of imposed lateral deflection, and a maximum factored axial load of 359 kips.

Our results are presented in the table below and in **Appendix D**.

SUMMARY OF L-PILE ANALYSES				
Pile Type and Size	Factored Axial Load (kips)	Calculated Shear Force to induce Lateral Deflection of 0.41 in. (kips)	Moment at Pile Head (in-kips)	Total Stress at Pile Head (ksi)
9.625" x .545" Micropile with oversized socket	359	47.8	2198	70.2

The results of the L-Pile analyses were shared with MaineDOT in our November 15, 2017 memorandum. Based on their review of that data, we understand the calculated stresses in the micropile are considered acceptable by MaineDOT.

Abutment 2 rock depths are anticipated to be greater than 9 feet below the bottom of pile cap elevation. Micropile casing will be installed 3 feet into bedrock to provide fixity and transfer moment into the rock. Therefore, by observation, pile stresses will be lower at Abutment 2.



5.4.7 Lateral Earth Pressure

Thermal expansion of the bridge will push the backwalls and wingwalls of the integral abutment toward the backfill, which will result in earth pressures ranging from at-rest to passive earth pressure. The material properties will be controlled by the backfill material, which is proposed to consist of Granular Borrow for Underwater Backfill, BDG Type 4 soil.

Based on the estimated thermal bridge expansion of 0.41 inches and the abutment height of approximately 10.5 feet, the calculated abutment rotation is 0.0033 feet/foot. In accordance with the requirements of the BDG Section 5.4.2.11, integral abutment reinforcement is to be designed for full Coloumb passive pressure if the wall rotation is greater than 0.005 feet/foot. Considering that the anticipated rotation is less than half of the value that triggers full Coloumb pressure in the BDG, we conclude that Rankine passive earth pressure may be used for design.

We recommend using a Rankine Coefficient of Passive Earth Pressure, $K_p = 3.25$ for design of backwalls and wingwalls. Design lateral earth pressure recommendations are provided in **Section 6.3** of this report.

5.4.8 Frost Penetration

Fill soils are anticipated to be present at the abutments, either as existing fill or imported backfill. Based on the MaineDOT BDG, Section 5.2.1, the Freezing Index for the site is 1,100, and with low to moderate moisture content (± 10 percent) soils, the estimated depth of frost penetration is 5.8 feet.

6.0 RECOMMENDATIONS

6.1 SEISMIC DESIGN

The United States Geological Survey online Design Maps Tool was used to develop parameters for bridge design. Based on the site coordinates, the software provided the recommended AASHTO Response Spectra (Site Class D) for a 7 percent probability of exceedance in 75 years. These results are summarized for the site as follows:

SITE CLASS D SEISMIC DESIGN PARAMETERS	
Parameter	Design Value
Fpga	1.6
Fa	1.6
Fv	2.4
As (Period = 0.0 sec)	0.157 g
SDs (Period = 0.2 sec)	0.301 g
SD1 (Period = 1.0 sec)	0.106 g

Per AASHTO Article 4.7.4.2, single span bridges need not be analyzed for seismic loads, but the minimum requirements for superstructure connections and support lengths apply as specified in AASHTO Articles 4.7.4.4 and 3.10.9.



6.2 EMBANKMENT DESIGN

Widened embankments should be constructed in accordance with MaineDOT Standard Details, including the following:

- Fill slopes that are not riprap covered should be constructed with an inclination no steeper than 2H:1V.
- Fill slopes with inclinations ranging from 1.75H:1V to 2H:1V should be covered by a minimum of 3 feet of plain riprap, which should be underlain by a minimum 12-inch-thick protective aggregate cushion consisting of MaineDOT 703.19, Granular Borrow for Underwater Backfill, underlain by a loosely placed, non-woven erosion control geotextile meeting the requirements of Standard Specification 722.03.

If the mudline outside of the existing embankment is found to be underlain by weak organic soil, this material should be assumed to consist of “Muck” and should be fully removed in accordance with the MaineDOT Standard Specifications, Section 203.05 to expose suitable, inorganic soil as confirmed by the Resident and/or Engineer. We recommend that a pay item be included for Muck removal in the bid documents. Additional construction considerations are presented in **Section 7.3**.

6.3 ABUTMENT AND WINGWALL DESIGN

- Backfill between new abutments and a 1.5H:1V plane extending up from the bottom of the abutment to the pavement subgrade should consist of MaineDOT 703.19 Granular Borrow for Underwater Backfill, BDG Type 4 soil. Recommended soil properties for Type 4 soils to be used as backfill are as follows:
 - Internal Friction Angle of Soil = 32°
 - Soil Total Unit Weight = 125 pcf
 - Rankine Coefficient of Passive Earth Pressure, $K_p = 3.25$ (use for design of backwalls and wingwalls)
- Live load surcharge should be applied as a uniform lateral surcharge pressure using the equivalent fill height (Heq) values developed in accordance with AASHTO Article 3.11.6.4 based on the abutment/wingwall height and distance from the wall backface to the edge of traffic.
- Foundation drainage should be provided in accordance with Section 5.4.1.9 of the BDG.
 - We recommend the use of French drains and/or geocomposite drainage boards on the uphill side of abutments and wing walls to prevent buildup of differential hydrostatic pressure. Foundation drains should be sloped to drain by gravity and should daylight through weep holes in the abutments.

6.4 MICROPILE DESIGN

- The proposed abutments may be supported on micropiles including the following components to provide a geotechnical factored resistance of 359 kips and to meet the lateral loading requirements:



- Steel pipe for the micropiles should be 9.625-inch OD by 0.545-inch wall thickness and should consist of API 5CT N80 or ASTM A252 Grade 3 Modified galvanized steel with a minimum yield strength (F_y) of 80 ksi, and shall be straight-seamed.
- Micropiles should have a minimum 10-foot-long, 8-inch-diameter rock socket below the bottom of the casing, not including a minimum clear distance of 6 inches between the bottom of the bar and bottom of the socket.
- A No. 20 (2.5-inch-diameter), Grade 75 hot-dipped galvanized steel All-Thread bar conforming to ASTM A615 should be placed in each micropile extending through the entire casing and 10 feet into the socket.
- Grout should consist of a water-cement mixture with a maximum water-cement ratio of 0.45 and a minimum 28-day compressive strength of 5,000 psi.
- At Abutment 1, a minimum 11-inch-diameter rock socket should be drilled to a minimum depth of 12 feet below the bottom of pile cap before micropile installation, corresponding to El. -10. The 9.625-inch casing should then be placed at the bottom of the 11-inch socket, and a 3-foot grout plug should be placed around the tip of the casing in the oversized socket, up to El. -7.
- At Abutment 2, the 9.625-inch casing should be installed a minimum of 3 feet into bedrock prior to drilling the socket.
- Steel centralizers should be welded on the outside of the casing at Abutment 1 to center the tip in the oversized socket. A minimum of two centralizer levels should be provided on the lower 3 feet of the casing.
- Prior to removal of the temporary casing used to drill the 11-inch socket, the annular space between the temporary and permanent casings should be filled with MaineDOT 703.05 Aggregate for Sand Leveling.
- The casing tip elevations used in the drawings should be determined as follows:
 - Abutment 1: Each micropile will be installed in an oversized socket drilled to a minimum depth of 12 feet below the bottom of abutment, corresponding to a casing tip at El. -10. The central bar tip elevation will be El. -20.
 - Abutment 2: Encountered top of rock ranged from El. -12.2 (BB-YCGB-202) to El. -8.7 (BB-YCGB-104) where explored. We recommend using a casing tip elevation approximately 5 feet deeper than the encountered top of rock, corresponding to a casing tip at El. -18 for the deepest encountered rock, and a central bar tip at El. -28. The intent of this recommendation is to allow for 3 feet of casing penetration into rock and to account for potential variability in the top of rock surface.
- The structural engineer should complete structural evaluation of the piles using the bending stress results from the LPile analyses summarized in **Section 5.4.5** (output provided in **Appendix E**) in accordance with the design steps listed in BDG Section 5.4.2.4.C.



7.0 CONSTRUCTION CONSIDERATIONS

This section provides guidance regarding quality control during pile installation, excavation, dewatering, and foundation subgrade preparation and protection. These items are discussed in the paragraphs that follow.

7.1 EMBANKMENT CONSTRUCTION

The subgrade material beneath the widened embankments is anticipated to consist of riprap over portions of the existing embankment, or Glaciomarine silt. However, explorations were not conducted in the inter-tidal zone beneath the widened embankment footprint, so the potential for weak organic deposits has not been explored. We recommend that the material outside of the current embankment footprint be assumed to consist of Muck. For planning purposes, we recommend that 1 foot of Muck removal be assumed.

In the absence of weak organic soil, conventional embankment construction procedures should be suitable, provided the work is completed in-the-dry. The widened approach embankments will be constructed partially in the inter-tidal zone. Therefore, fill placement could be completed in-the-dry working with the tides. If necessary, an initial layer of separation geotextile beneath coarse aggregate or choked riprap may be appropriate to provide a stable subgrade for subsequent filling conducted partially in-the-wet. Embankment construction in the wet should address permitting considerations for work in the river, which we anticipate would include the use of a silt curtain at a minimum.

7.2 PILE INSTALLATION AND GROUT INFILL

Micropiles should be installed in accordance with the requirements of Special Provision Section 501, Foundation Piles (Micropiles).

The anticipated sequence for micropile installation at Abutment 1 will generally include:

1. Install temporary casing and core and clean-out an 11-inch socket through the casing to El. -10 or deeper;
2. Place a 9.625-inch casing to the bottom of the socket, with steel centralizers between El. -7 and El. -10;
3. Place a 3-foot grout plug to fix the lower portion of the casing in the socket, taking care to ensure that the grout remains below El. -7;
4. After grout plug setup, drill the micropile rock socket through the grout plug and to the required depth into rock;
5. Place the central bar and grout via tremie methods using a tube attached to the central bar; and
6. Remove the temporary casing, placing sand backfill outside of the permanent casing as the temporary casing is extracted.

Preparation of an oversized socket is not anticipated to be required at Abutment 2 because the encountered rock elevation was below El. -7.



After completion of drilling each step, including completion of the oversized socket and the micropile socket, the depth and soundness of the hole should be assessed using a weighted tape prior to grouting. The grout level should also be carefully monitored during placement in the oversized socket to ensure that it is not placed above El. -7.

The drill holes should be tremie grouted from the bottom up. A plug should be placed in the tremie pipe prior to insertion into the pile to prevent water entry into the pipe. The tremie pipe should remain at least 5 feet below the top of grout level throughout the grout placement, if it is pulled during grouting.

Because load testing is not planned, the presence of a Geotechnical Engineer is strongly recommended during drilling and pile installation to ensure that the intent of the design and special provisions are met. The Geotechnical Engineer should provide full-time observation during pile installation and assess the following portions of the work: depth to top of rock, depth of oversized socket, grout level in oversized socket, bottom cleanliness, depth of hole, length of casing installed, and grout volumes.

7.3 PILE OBSTRUCTIONS

Wood, cobbles, boulders, riprap and/or rock fill may be encountered in the overburden. We recommend that the contractor be required to provide micropile pile installation equipment and methods capable of advancing through possible obstructions.

7.4 EXCAVATION, TEMPORARY LATERAL SUPPORT AND DEWATERING

Excavations for abutment foundations are anticipated to be on the order of 11 feet below existing pavement grades and at least 2 feet below high tide level in the creek. It is our understanding that Beech Ridge Road will be out of service during construction of the new bridge. In areas where sufficient space is available and water conditions permit, the excavation adjacent to the approaches may be constructed with sloped, open cuts. In all cases, temporary excavations should comply with Occupational Safety and Health Administration (OSHA) excavation safety requirements.

Considering the proximity of the required abutment excavations to the river water level, management of water will be related to brook/tidal water levels at the time of construction. Considering the deepest excavation level at approximately El. 2 and Mean Higher High Water is at El. 4.4, water levels will rise above the bottom of excavation level tidally. A technically feasible alternative to provide a dry working area for pile installation and abutment construction is to install a cofferdam. Other alternatives, such as construction of a temporary work platform, may be feasible if construction phasing allows foundation installation and abutment construction to be completed while working with the tides.

We anticipate that the inflow of groundwater or surface water to excavations can be handled by open pumping from sumps installed at the bottom of excavations if cofferdams are installed. The contractor should be responsible for controlling groundwater, surface runoff, tidal inflow, infiltration and water from all other sources by methods which preserve the undisturbed condition of the subgrade and permit foundation construction in-the-dry. Discharge of pumped groundwater and river water should comply with all local, State, and federal regulations.



7.5 REUSE OF ON-SITE MATERIALS

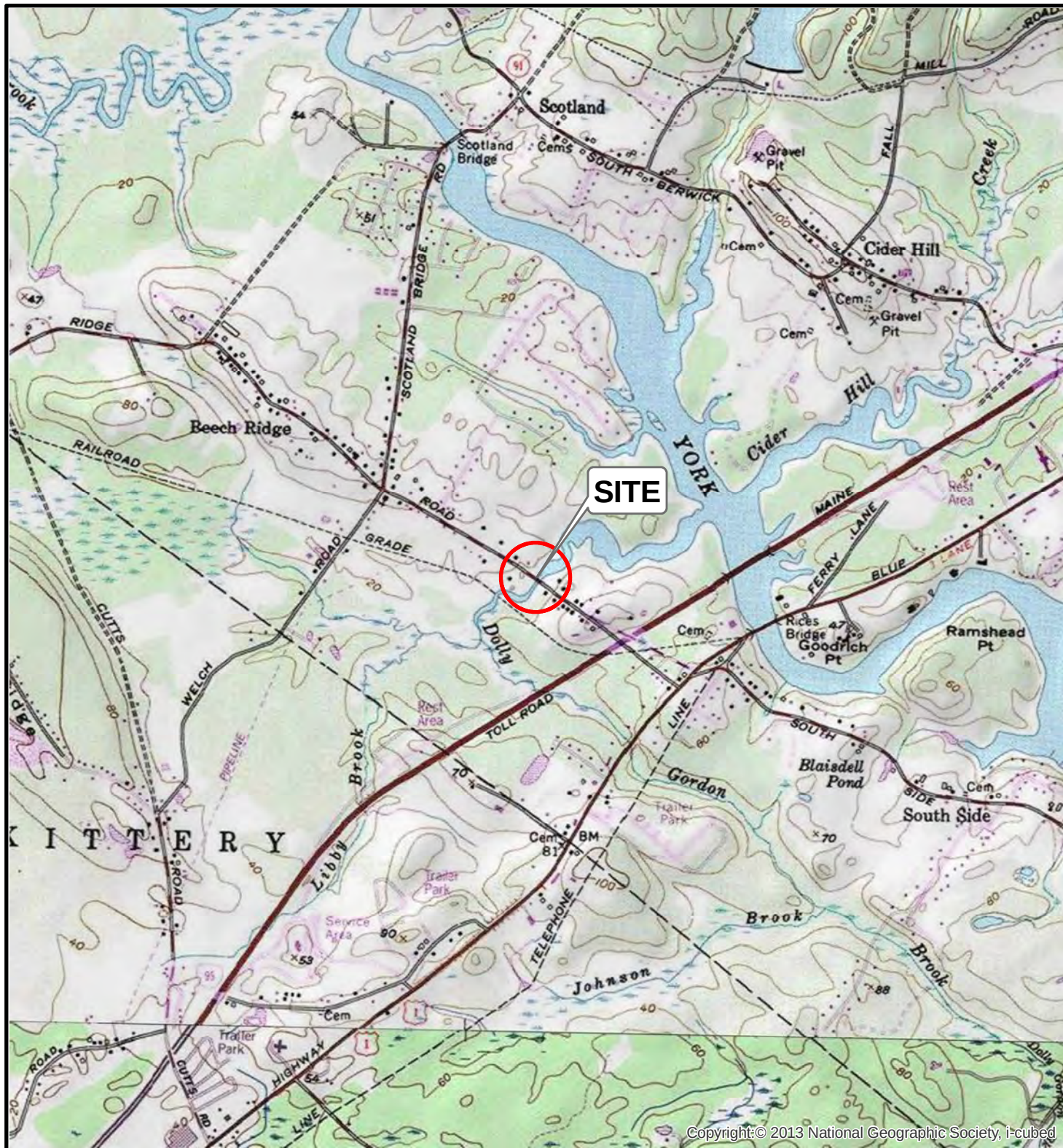
Based on the test boring results, the one fill sample tested had 15 percent passing the No. 200 sieve. Therefore, some of the excavated fill may meet MaineDOT specifications for Granular Borrow, but it is unlikely to meet the specifications for Granular Borrow for Underwater Backfill. Any remaining material exceeding 20 percent passing the No. 200 sieve is considered suitable for use as Common Borrow.

If the contractor wishes to reuse excavated material as embankment fill or in other areas, we recommend that the proposed material be stockpiled and tested for grain size distribution. Stockpiled materials meeting the appropriate MaineDOT specifications may be reused on the project.

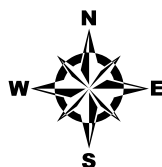


December 11, 2017
MAINEDOT BARRELL BRIDGE NO. 3500 OVER DOLLY GORDON BROOK
09.0025948.00

FIGURES



Copyright © 2013 National Geographic Society, i-cubed



USGS
QUADRANGLE
LOCATION

SOURCE : THIS MAP CONTAINS THE ESRI ARCGIS ONLINE USA TOPOGRAPHIC MAP SERVICE, PUBLISHED DECEMBER 12, 2009 BY ESRI ARCGIS SERVICES AND UPDATED AS NEEDED. THIS SERVICE USES UNIFORM NATIONALLY RECOGNIZED DATUM AND CARTOGRAPHY STANDARDS AND A VARIETY OF AVAILABLE SOURCES FROM SEVERAL DATA PROVIDERS. THIS MAP ALSO CONTAINS THE ESRI ARCGIS ONLINE USA COUNTIES WHICH PROVIDES DETAILED BOUNDARIES THAT ARE CONSISTENT WITH THE TRACT, BLOCK GROUP, AND STATE DATA SETS AND ARE EFFECTIVE AT REGIONAL AND STATE LEVELS.

Data Supplied by :



0 1,000 2,000 4,000 6,000

SCALE IN FEET



PROJ. MGR.: BMC
DESIGNED BY: BMC
REVIEWED BY: ARB
OPERATOR: ADM

DATE: 10-27-2017

LOCUS PLAN

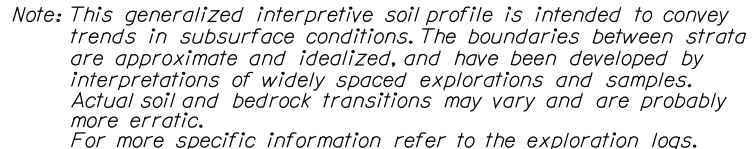
BARRELL BRIDGE NO.3500, MAINEDOT WIN 18957.00
YORK, MAINE

JOB NO.

09.0025948.00

FIGURE NO.

1



Date:12/15/2017

Username: Terry.White

Division: GEOTECH

Filename: ...\\00\\geotech\\msta\\007_ISCSI1.dgn

BARRELL BRIDGE NO. 3500 OVER DOLLY GORDON BROOK
MAINEDOT WIN 018957.00
YORK, ME

INTERPRETIVE SUBSURFACE CROSS SECTIONS
ABUTMENTS 1 & 2

PREPARED BY:
 **GZA GeoEnvironmental, Inc.**
Engineers and Scientists
www.gza.com

PREPARED FOR:
MAINE DEPARTMENT OF
TRANSPORTATION

PROJ MGR: BMC
DESIGNED BY: BMC
DATE: 12/11/17

REVIEWED BY: ARB
DRAWN BY: TW
PROJECT NO: 09.0025948.00

CHECKED BY: CLS
SCALE: AS SHOWN
REVISION NO: 0

FIGURE
3

SHEET NO. 1 OF 1

LEGEND

Weathered Bedrock, if applicable

Boring No. Station

Pavement Thickness, if applicable

Approximate Top of Bedrock

Rock Quality Designation of Bedrock Core Sample

BOE = Bottom of Exploration

BB = Bridge Boring

NR = No Refusal

R = Refusal

CROSS SECTION

HORIZ 5 0 5 10

VERT 5 0 5 10

SCALE

Note: This generalized interpretive soil cross section is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and have been developed by interpretations of widely spaced explorations and samples. Actual soil and bedrock transitions may vary and are probably more erratic. For more specific information refer to the exploration logs.

STATE OF MAINE DEPARTMENT OF TRANSPORTATION	018957.00	
	WIN	18957.00
	BRIDGE NO. 3500	BRIDGE PLANS

PROJ. MANAGER	DESIGN-DETAILED	CHECKED-REVIEWED	DESIGN-DETAILED	SIGNATURE
BY	DATE	P.E. NUMBER	DATE	
D. DAVEN	DEC 2017			
T. WHITE				
B. CARROLL				



APPENDIX A - LIMITATIONS



GEOTECHNICAL LIMITATIONS

Use of Report

1. GZA GeoEnvironmental, Inc. (GZA) prepared this report on behalf of, and for the exclusive use of our Client for the stated purpose(s) and location(s) identified in the Proposal for Services and/or Report. Use of this report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions; and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not expressly identified in the contract documents, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

Standard of Care

2. GZA's findings and conclusions are based on the work conducted as part of the Scope of Services set forth in Proposal for Services and/or Report, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. If conditions other than those described in this report are found at the subject location(s), or the design has been altered in any way, GZA shall be so notified and afforded the opportunity to revise the report, as appropriate, to reflect the unanticipated changed conditions .
3. GZA's services were performed using the degree of skill and care ordinarily exercised by qualified professionals performing the same type of services, at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made.
4. In conducting our work, GZA relied upon certain information made available by public agencies, Client and/or others. GZA did not attempt to independently verify the accuracy or completeness of that information. Inconsistencies in this information which we have noted, if any, are discussed in the Report.

Subsurface Conditions

5. The generalized soil profile(s) provided in our Report are based on widely-spaced subsurface explorations and are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location refer to the exploration logs. The nature and extent of variations between these explorations may not become evident until further exploration or construction. If variations or other latent conditions then become evident, it will be necessary to reevaluate the conclusions and recommendations of this report.
6. In preparing this report, GZA relied on certain information provided by the Client, state and local officials, and other parties referenced therein which were made available to GZA at the time of our



evaluation. GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this evaluation.

7. Water level readings have been made in test holes (as described in this Report) and monitoring wells at the specified times and under the stated conditions. These data have been reviewed and interpretations have been made in this Report. Fluctuations in the level of the groundwater however occur due to temporal or spatial variations in areal recharge rates, soil heterogeneities, the presence of subsurface utilities, and/or natural or artificially induced perturbations. The water table encountered in the course of the work may differ from that indicated in the Report.
8. GZA's services did not include an assessment of the presence of oil or hazardous materials at the property. Consequently, we did not consider the potential impacts (if any) that contaminants in soil or groundwater may have on construction activities, or the use of structures on the property.
9. Recommendations for foundation drainage, waterproofing, and moisture control address the conventional geotechnical engineering aspects of seepage control. These recommendations may not preclude an environment that allows the infestation of mold or other biological pollutants.

Compliance with Codes and Regulations

10. We used reasonable care in identifying and interpreting applicable codes and regulations. These codes and regulations are subject to various, and possibly contradictory, interpretations. Compliance with codes and regulations by other parties is beyond our control.

Cost Estimates

11. Unless otherwise stated, our cost estimates are only for comparative and general planning purposes. These estimates may involve approximate quantity evaluations. Note that these quantity estimates are not intended to be sufficiently accurate to develop construction bids, or to predict the actual cost of work addressed in this Report. Further, since we have no control over either when the work will take place or the labor and material costs required to plan and execute the anticipated work, our cost estimates were made by relying on our experience, the experience of others, and other sources of readily available information. Actual costs may vary over time and could be significantly more, or less, than stated in the Report.

Additional Services

12. GZA recommends that we be retained to provide services during any future: site observations, design, implementation activities, construction and/or property development/redevelopment. This will allow us the opportunity to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.



APPENDIX B - TEST BORING LOGS

UNIFIED SOIL CLASSIFICATION SYSTEM					MODIFIED BURMISTER SYSTEM			
MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES				
COARSE-GRAINED SOILS (more than half of material is larger than No. 200 sieve size)	GRAVELS (more than half of coarse fraction is larger than No. 4 sieve size)	CLEAN GRAVELS	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Descriptive Term		Portion of Total (%)	
		(little or no fines)	GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.	trace	0 - 10		
					little	11 - 20		
					some	21 - 35		
					adjective (e.g. sandy, clayey)	36 - 50		
	SANDS (more than half of coarse fraction is smaller than No. 4 sieve size)	GRAVEL WITH FINES (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	TERMS DESCRIBING DENSITY/CONSISTENCY			
		GC	Clayey gravels, gravel-sand-clay mixtures.					
		CLEAN SANDS	SW	Well-graded sands, gravelly sands, little or no fines	Coarse-grained soils (more than half of material is larger than No. 200 sieve); Includes (1) clean gravels; (2) silty or clayey gravels; and (3) silty, clayey or gravelly sands. Density is rated according to standard penetration resistance (N-value).			
		(little or no fines)	SP	Poorly-graded sands, gravelly sand, little or no fines.				
		SANDS WITH FINES (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures	Density of Cohesionless Soils			
SC	Clayey sands, sand-clay mixtures.							
FINE-GRAINED SOILS (more than half of material is smaller than No. 200 sieve size)	SILTS AND CLAYS (liquid limit less than 50)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity.	Standard Penetration Resistance		N-Value (blows per foot)		
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Very loose	0 - 4			
				Loose	5 - 10			
				Medium Dense	11 - 30			
				Dense	31 - 50			
	SILTS AND CLAYS (liquid limit greater than 50)	OL	Organic silts and organic silty clays of low plasticity.	Very Dense	> 50			
		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Fine-grained soils (more than half of material is smaller than No. 200 sieve); Includes (1) inorganic and organic silts and clays; (2) gravelly, sandy or silty clays; and (3) clayey silts. Consistency is rated according to undrained shear strength as indicated.				
		CH	Inorganic clays of high plasticity, fat clays.					
		OH	Organic clays of medium to high plasticity, organic silts.	Approximate Undrained Shear Strength (psf)				
HIGHLY ORGANIC SOILS	Pt	Peat and other highly organic soils.	Consistency of Cohesive soils		SPT N-Value (blows per foot)			
Desired Soil Observations (in this order, if applicable): Color (Munsell color chart) Moisture (dry, damp, moist, wet) Density/Consistency (from above right hand side) Texture (fine, medium, coarse, etc.) Name (sand, silty sand, clay, etc., including portions - trace, little, etc.) Gradation (well-graded, poorly-graded, uniform, etc.) Plasticity (non-plastic, slightly plastic, moderately plastic, highly plastic) Structure (layering, fractures, cracks, etc.) Bonding (well, moderately, loosely, etc.,) Cementation (weak, moderate, or strong) Geologic Origin (till, marine clay, alluvium, etc.) Groundwater level					Rock Quality Designation (RQD): RQD (%) = $\frac{\text{sum of the lengths of intact pieces of core} > 4 \text{ inches}}{\text{length of core advance}}$ *Minimum NQ rock core (1.88 in. OD of core)			
					Correlation of RQD to Rock Mass Quality			
					Rock Mass Quality		RQD (%)	
					Very Poor		≤25	
					Poor		26 - 50	
					Fair		51 - 75	
					Good		76 - 90	
					Excellent		91 - 100	
					Desired Rock Observations (in this order, if applicable): Color (Munsell color chart) Texture (aphanitic, fine-grained, etc.) Rock Type (granite, schist, sandstone, etc.) Hardness (very hard, hard, mod. hard, etc.) Weathering (fresh, very slight, slight, moderate, mod. severe, severe, etc.) Geologic discontinuities/jointing: -dip (horiz - 0-5 deg., low angle - 5-35 deg., mod. dipping - 35-55 deg., steep - 55-85 deg., vertical - 85-90 deg.) -spacing (very close - <2 inch, close - 2-12 inch, mod. close - 1-3 feet, wide - 3-10 feet, very wide >10 feet) -tightness (tight, open, or healed) -infilling (grain size, color, etc.) Formation (Waterville, Ellsworth, Cape Elizabeth, etc.) RQD and correlation to rock mass quality (very poor, poor, etc.) ref: ASTM D6032 and AASHTO Standard Specification for Highway Bridges, 17th Ed. Table 4.4.8.1.2A Recovery (inch/inch and percentage) Rock Core Rate (X.X ft - Y.Y ft (min:sec))			
					Sample Container Labeling Requirements: WIN Blow Counts Bridge Name / Town Sample Recovery Boring Number Date Sample Number Personnel Initials Sample Depth			
Maine Department of Transportation Geotechnical Section Key to Soil and Rock Descriptions and Terms Field Identification Information								

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Barrell Bridge #3500 Over Dolly Gordon Brook Location: York, Maine		Boring No.: BB-YCGB-101 PIN: 18957.00																																																																																																																																																																																																																																																																																																					
Driller: New England Boring Contractors			Elevation (ft.) 11.6		Auger ID/OD: 4.5 inch																																																																																																																																																																																																																																																																																																						
Operator: C. Cooley/J. Dupuis			Datum: NAVD 88		Sampler: Standard Split																																																																																																																																																																																																																																																																																																						
Logged By: B. Schonewald			Rig Type: Mobile B-53 Truck Mounted		Hammer Wt./Fall: 140 pounds/30																																																																																																																																																																																																																																																																																																						
Date Start/Finish: 12/19/2016; 10:55-14:45			Drilling Method: Cased Wash Boring		Core Barrel: NQ2																																																																																																																																																																																																																																																																																																						
Boring Location: Sta 102+88.9, 6.2 feet Lt.			Casing ID/OD: 3/3.5 inch		Water Level*: Not Observed																																																																																																																																																																																																																																																																																																						
Hammer Efficiency Factor: 0.572			Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐																																																																																																																																																																																																																																																																																																								
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample attempt V = Insitu Vane Shear Test MV = Unsuccessful Insitu Vane Shear Test attempt			R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = weight of 140lb. hammer WOR = weight of rods WO1P = Weight of one person		S _u = Insitu Field Vane Shear Strength (psf) T _v = Pocket Torvane Shear Strength (psf) q _p = Unconfined Compressive Strength (ksf) N _{uncorrected} = Raw field SPT N-value Hammer Efficiency Factor = Annual Calibration Value N ₆₀ = SPT N-uncorrected corrected for hammer efficiency N ₆₀ = (Hammer Efficiency Factor/60%)*N _{uncorrected}																																																																																																																																																																																																																																																																																																						
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Soil/Rock Exploration Log
US CUSTOMARY UNITS

Boring No.: BB-YCGB-102

PIN: 18957.00

Driller:	New England Boring Contractors	Elevation (ft.)	11.8	Auger ID/OD:	4.5 inch
Operator:	C. Cooley/J. Dupuis	Datum:	NAVD 88	Sampler:	Standard Split
Logged By:	B. Schonewald	Rig Type:	Mobile B-53 Truck Mounted	Hammer Wt./Fall:	140 pounds/30
Date Start/Finish:	12/15/2016; 11:45-12:55	Drilling Method:	Solid Stem Auger	Core Barrel:	N/A
Boring Location:	Sta 102+89.7, 5.2 feet Rt.	Casing ID/OD:	N/A	Water Level*:	Not Observed
Hammer Efficiency Factor: 0.572		Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐			

Definitions:	R = Rock Core Sample	S _U = Insitu Field Vane Shear Strength (psf)	S _{U(lab)} = Lab Vane Shear Strength (psf)
D = Split Spoon Sample	SSA = Solid Stem Auger	T _v = Pocket Torvane Shear Strength (psf)	WC = water content, percent
MD = Unsuccessful Split Spoon Sample attempt	HSA = Hollow Stem Auger	q _p = Unconfined Compressive Strength (ksf)	LL = Liquid Limit
U = Thin Wall Tube Sample	RC = Roller Cone	N-uncorrected = Raw field SPT N-value	PL = Plastic Limit
MU = Unsuccessful Thin Wall Tube Sample attempt	WOH = weight of 140lb. hammer	Hammer Efficiency Factor = Annual Calibration Value	PI = Plasticity Index
V = Insitu Vane Shear Test	WOR = weight of rods	N ₆₀ = SPT N-uncorrected corrected for hammer efficiency	G = Grain Size Analysis
MV = Unsuccessful Insitu Vane Shear Test attempt	WO1P = Weight of one person	N ₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected	C = Consolidation Test

[illegible]

- bgs = below existing ground surface
- Hammer ID No. MTB-AH2
- Soil and bedrock samples/descriptions were not reviewed by GZA.

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Boring No.: BB-YCGB-103

PIN: 18957.00

Auger ID/OD:	4.5 inch
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Sampler:	N/A
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Hammer Wt./Fall:	140 pounds/30
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Core Barrel:	N/A
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Water Level*:	6.2 feet bgs
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Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐

$$S_{u(lab)} = \text{Lab Vane Shear Strength (psf)}$$

WC = water content, percent

LL = Liquid Limit

PL = Plastic Limit

Value PI = Plasticity Index

efficiency G = Grain Size Analysis

Corrected C = Consolidation Test

Remarks: -bgs = below existing ground surface -Hammer ID No. MTB-AH2 -Soil and bedrock samples/descriptions were not reviewed by GZA.

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Barrell Bridge #3500 Over Dolly Gordon Brook Location: York, Maine		Boring No.: BB-YCGB-104 PIN: 18957.00																																																																																																																																																																																																																																																										
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Date Start/Finish: 12/13/2016 to 12/15/16		Drilling Method: Cased Wash Boring		Core Barrel: NQ2																																																																																																																																																																																																																																																												
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RC to 15 feet bgs.</td><td></td></tr><tr><td>15</td><td>4D</td><td>24/18</td><td>15.0 - 17.0</td><td>17/19/22/28</td><td>41</td><td>39</td><td>74</td><td></td><td></td><td>Grey, wet, hard, SILT, some gravel, some sand, (GLACIOMARINE DEPOSIT).</td><td>G#304331 A-4, ML WC=13.4%</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>20</td><td>5D</td><td>4.8/3</td><td>20.0 - 20.4</td><td>75(4.8")</td><td>---</td><td></td><td>RC</td><td>-8.3</td><td></td><td>Grey, wet, very dense, GRAVEL, some sand, trace to little silt, trace bedrock fragments. Apparent top of bedrock at 20.4 feet bgs. RC to 25 feet bgs, and set up to core.</td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>-8.7</td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>25</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></tbody></table>										Depth (ft.)	Sample Information							Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	0							SSA			1.2-foot-thick layer of pavement.			1D	24/15	1.0 - 3.0	46/19/13/12	32	31		10.5		Black decomposed asphalt.										9.1														Brown, moist, dense, SAND, some gravel, little silt, (FILL).		5	2D	24/10	5.0 - 7.0	2/2/4/2	6	6		6.7		Light brown, moist, medium stiff, sandy SILT, trace gravel, with trace weathered asphalt and wood, (TIMBER CRIB FILL / GLACIOMARINE DEPOSIT).	G#304330 A-4, ML WC=23.5%									4.4		Encountered wood from 7.3 to 10 feet bgs.										1.7				10	3D	24/14	10.0 - 12.0	12/4/3/3	7	7	RC	1.2		Light brown, wet, medium stiff, sandy SILT, with traces of wood (TIMBER CRIB FILL / GLACIOMARINE DEPOSIT).										-0.3		Dark grey, wet, medium stiff, SILT, some sand, trace shell fragments, (TIMBER CRIB FILL / GLACIOMARINE DEPOSIT). RC to 15 feet bgs.		15	4D	24/18	15.0 - 17.0	17/19/22/28	41	39	74			Grey, wet, hard, SILT, some gravel, some sand, (GLACIOMARINE DEPOSIT).	G#304331 A-4, ML WC=13.4%																																																	20	5D	4.8/3	20.0 - 20.4	75(4.8")	---		RC	-8.3		Grey, wet, very dense, GRAVEL, some sand, trace to little silt, trace bedrock fragments. Apparent top of bedrock at 20.4 feet bgs. RC to 25 feet bgs, and set up to core.										-8.7																												25											
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Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Barrell Bridge #3500 Over Dolly Gordon Brook Location: York, Maine		Boring No.: BB-YCGB-201 PIN: 18957.00																																																																																																																																																																																																																							
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Roller cone ahead to 16.5'; set up to core at 16.5'.</td><td rowspan="3"></td></tr><tr><td></td><td>4D</td><td>5/3</td><td>15.0 - 15.4</td><td>124/4"</td><td>--</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td>R1</td><td>30/29</td><td>16.5 - 19.0</td><td>RQD = 0%</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>20</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>-4.6</td><td>R1: Hard, slightly weathered, fine grained, grey, METAWACKE. Joints are extremely close, highly fractured resulting in angular gravel. Kittery Formation Rock Mass Quality = Very Poor Recovery = 97% Rock Core Times (min:sec): 16.5-17.5 (2:40), 17.5-18.5 (2:33), 18.5-19.0 (0:58) R2: Hard, slightly weathered, fine grained, grey, METAWACKE. Joints are close to extremely close (highly fractured at bottom), low to high angle, planar, smooth and rough, discolored to decomposed, open. Rock Mass Quality = Very Poor Recovery = 77% Rock Core Times (min:sec): 19.0-19.5 (0:36), 19.5-20.5 (3:48), 20.5-20.8 (2:57) R3: Hard, slightly weathered to fresh, fine to medium</td><td rowspan="3"></td></tr><tr><td></td><td>R2</td><td>22/19</td><td>19.0 - 20.8</td><td>RQD = 0%</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td>R3</td><td>43/43</td><td>20.8 - 24.4</td><td>RQD = 21%</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>25</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td>R4</td><td>44/44</td><td>24.4 - 28.1</td><td>RQD = 66%</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></tbody></table>										Depth (ft.)	Sample Information							Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) 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Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Barrell Bridge #3500 Over Dolly Gordon Brook Location: York, Maine		Boring No.: BB-YCGB-202 PIN: 18957.00																																																																																																										
Driller: New England Boring Contractors			Elevation (ft.): 11.9'			Auger ID/OD: 2.5" SSA																																																																																																										
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<table><thead><tr><th rowspan="2">Depth (ft.)</th><th colspan="7">Sample Information</th><th rowspan="2">Elevation (ft.)</th><th rowspan="2">Graphic Log</th><th rowspan="2">Visual Description and Remarks</th><th rowspan="2">Laboratory Testing Results/ AASHTO and Unified Class.</th></tr><tr><th>Sample No.</th><th>Pen./Rec. (in.)</th><th>Sample Depth (ft.)</th><th>Blows (6 in.) Shear Strength (psf) or RQD (%)</th><th>N-uncorrected</th><th>N₆₀</th><th>Casing Blows</th></tr></thead><tbody><tr><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>-ASPHALT-</td><td></td></tr><tr><td></td><td>1D</td><td>24/16</td><td>1.0 - 3.0</td><td>15-12-15-11</td><td>27</td><td>30</td><td></td><td></td><td>10.9</td><td>Brown, dry, medium dense, fine to coarse SAND, some Gravel, little Silt. -FILL- (SM)</td><td>G#3 A-1-b, SM WC=5.7</td></tr><tr><td>5</td><td>2D</td><td>24/7</td><td>5.0 - 7.0</td><td>2-1-2-3</td><td>3</td><td>3</td><td></td><td></td><td>6.9</td><td>Brown, moist, soft, sandy SILT, little Gravel. -TIMBER CRIB FILL / GLACIOMARINE DEPOSIT- (ML)</td><td>G#4 A-4, ML WC=16.5</td></tr><tr><td>10</td><td>3D</td><td>24/12</td><td>10.0 - 12.0</td><td>2-6-2-2</td><td>8</td><td>9</td><td>52</td><td></td><td>-0.1</td><td>Grey, moist, medium stiff, sandy SILT, little Gravel. Wood fragments present. -TIMBER CRIB FILL / GLACIOMARINE DEPOSIT- (ML)</td><td>G#5 A-4, ML WC=45.5</td></tr><tr><td>15</td><td>4D</td><td>24/10</td><td>15.0 - 17.0</td><td>8-10-14-15</td><td>24</td><td>27</td><td>63</td><td></td><td>-6.6</td><td>Light brown to tan, wet, very stiff, sandy SILT. -GLACIOMARINE DEPOSIT- (ML)</td><td></td></tr><tr><td>20</td><td>5D</td><td>14/12</td><td>20.0 - 21.2</td><td>70-158-47/2"</td><td>--</td><td></td><td>RC</td><td></td><td>-12.2</td><td>Gravel-sized rock fragments. Possible gravel or fractured rock. Roller cone ahead through gravel/fractured rock with low resistance.</td><td></td></tr><tr><td>25</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Increased resistance at 24.1', continue to 25.0' and start to</td><td></td></tr></tbody></table>										Depth (ft.)	Sample Information							Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	0										-ASPHALT-			1D	24/16	1.0 - 3.0	15-12-15-11	27	30			10.9	Brown, dry, medium dense, fine to coarse SAND, some Gravel, little Silt. -FILL- (SM)	G#3 A-1-b, SM WC=5.7	5	2D	24/7	5.0 - 7.0	2-1-2-3	3	3			6.9	Brown, moist, soft, sandy SILT, little Gravel. -TIMBER CRIB FILL / GLACIOMARINE DEPOSIT- (ML)	G#4 A-4, ML WC=16.5	10	3D	24/12	10.0 - 12.0	2-6-2-2	8	9	52		-0.1	Grey, moist, medium stiff, sandy SILT, little Gravel. Wood fragments present. -TIMBER CRIB FILL / GLACIOMARINE DEPOSIT- (ML)	G#5 A-4, ML WC=45.5	15	4D	24/10	15.0 - 17.0	8-10-14-15	24	27	63		-6.6	Light brown to tan, wet, very stiff, sandy SILT. -GLACIOMARINE DEPOSIT- (ML)		20	5D	14/12	20.0 - 21.2	70-158-47/2"	--		RC		-12.2	Gravel-sized rock fragments. Possible gravel or fractured rock. Roller cone ahead through gravel/fractured rock with low resistance.		25										Increased resistance at 24.1', continue to 25.0' and start to	
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Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS										Project: Barrell Bridge #3500 Over Dolly Gordon Brook Location: York, Maine										Boring No.: BB-YCGB-202 PIN: 18957.00																																																																																																													
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25										R1										16/15										25.0 - 26.3										RQD = 0%																														NQ2																														core.																													
										R2										24/20										26.3 - 28.3										RQD = 0%																																																												R1: Hard, slightly weathered, fine to medium grained, grey, METAWACKE. Joints are extremely close to close, low to high angle, planar, rough and smooth, discolored, open. Trace grey silt infilling.																													
																																																																																																				Kittery Formation																													
										R3										23/14										28.3 - 30.2										RQD = 0%																																																												Rock Mass Quality = Very Poor																													
																																																																																																				Recovery = 94%																													
																																																																																																				Rock Core Times (min:sec): 25.0-26.0 (2:43), 25.0-26.3 (2:51)																													
30																																																																																																														R2: Hard, fresh to slightly weathered, fine to medium grained, grey, METAWACKE. Joints are very close to close, low to high angle, stepped and planar, rough and smooth, discolored, tight to open.																			
										R4										16/16										31.0 - 32.3										RQD = 0%																																																												Rock Mass Quality = Very Poor																													
										R5										20.4/11										32.3 - 34.0										RQD = 0%																																																												Recovery = 83%																													
																																																																																																				Rock Core Times (min:sec): 25.3-27.0 (0:53), 27.0-28.0 (2:28), 28.0-28.3 (0:32)																													
																																																																																																				R3: Hard, slightly weathered, fine to medium grained, grey, METAWACKE. Joints are extremely close, stepped and planar, smooth and rough, discolored, open.																													
35										R6										28/11										34.0 - 36.3										RQD = 0%																																																												Rock Mass Quality = Very Poor																													
																																																																																																				Recovery = 42%																													
										R7										14.4/6										36.3 - 37.5										RQD = 0%																																																												Rock Core Times (min:sec): 28.3-29.0 (4:46), 29.0-30.0 (2:53), 30.0-31.0 (2:51)																													
										R8										29/29										37.5 - 39.9										RQD = 0%																																																												R4: Hard, slightly weathered, fine to medium grained, grey, METAWACKE. Joints are extremely close to close, low to high angle, stepped and planar, rough and undulating, discolored, open.																													
																																																																																																				Rock Mass Quality = Very Poor																													
										R9										24/18										39.9 - 41.9										RQD = 0%																																																												Recovery = 100%																													
40																																																																																																				Rock Core Times (min:sec): 31.0-32.0 (2:55), 32.0-32.3 (1:53)																													
										R10										19/15										41.9 - 43.5										RQD = 0%																																																												R5: Hard, slightly weathered, fine to medium grained, grey, METAWACKE. Joints are extremely close to close, low to high angle, planar, rough to smooth, discolored, open.																													
																																																																																																				Rock Mass Quality = Very Poor																													
										R11										24/24										43.5 - 45.5										RQD = 0%																																																												Recovery = 52%																													
																																																																																																				Rock Core Times (min:sec): 32.3-33.0 (2:15), 33.0-34.0 (4:44)																													
45																																																																																																				R6: Similar to R5.																													
																																																																																																				Rock Mass Quality = Very Poor																													
																																																																																																				Recovery = 39%																													
																																																																																																				Rock Core Times (min:sec): 34.0-35.0 (2:15), 35.0-36.0 (4:35), 36.0-36.3 (1:51)																													
										R12										14.4/14.4										47.9 - 49.1										RQD = 0%																																																												R7: Hard, slightly weathered, fine to medium grained, grey, METAWACKE. Joints are extremely close, low to high angle, planar, rough to smooth, discolored, open.																													
																																																																																																				Rock Mass Quality = Very Poor																													
																																																																																																				Recovery = 40%																													
										R13										46/46										49.1 - 52.9										RQD = 76%																																																												Rock Core Times (min:sec): 36.3-37.0 (3:11), 37.0-37.5 (2:09)																													
50																																																																																																				R8: Hard, fresh to slightly weathered, fine grained, grey										q _p =21.7 ksi																			
Remarks: -Advance 3" casing to 37.5' after R7. -Hammer NEBC #1, energy transfer rate = .677.																																																																																																																																	
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Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS						Project: Barrell Bridge #3500 Over Dolly Gordon Brook Location: York, Maine				Boring No.: BB-YCGB-202 PIN: 18957.00			
Driller: New England Boring Contractors				Elevation (ft.): 11.9'				Auger ID/OD: 2.5" SSA					
Operator: Brad Enos				Datum: NAVD 88				Sampler: Split Spoon					
Logged By: B. Woodman				Rig Type: Mobile B-53 ATV				Hammer Wt./Fall: 140 lb./30 in.					
Date Start/Finish: 8/2/17-8/3/17				Drilling Method: SSA/Drive & Wash				Core Barrel: NQ2					
Boring Location: Sta. 103 + 61.8 5.8' Lt.				Casing ID/OD: 4"/4.5"				Water Level*: 10.0'					
Hammer Efficiency Factor: 0.677				Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐									
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample attempt V = Insitu Vane Shear Test MV = Unsuccessful Insitu Vane Shear Test attempt R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = weight of 140lb. hammer WOR = weight of rods WO1P = Weight of one person S_u = Insitu Field Vane Shear Strength (psf) T_v = Pocket Torvane Shear Strength (psf) q_p = Unconfined Compressive Strength (ksf) N-uncorrected = Raw field SPT N-value Hammer Efficiency Factor = Annual Calibration Value N₆₀ = SPT N-uncorrected corrected for hammer efficiency N₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected S_{u(lab)} = Lab Vane Shear Strength (psf) WC = water content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test													
Sample Information													
Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows /6 in. Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/AASHTO and Unified Class.		
50										with occasional white banding, METAWACKE. Joints are very close to close, horizontal to high angle, planar, smooth and rough, discolored, open to tight. Occasional healed fracture (quartz fill). Kittery Formation Rock Mass Quality = Very Poor Recovery = 100% Rock Core Times (min:sec): 37.5-38.5 (1:59), 38.5-39.5 (2:15), 39.5-39.9 (2:17) R9: Hard, slightly weathered, fine to medium grained, grey, METAWACKE. Joints are extremely close to close, low to high angle, planar and stepped, smooth and rough, discolored, open. Rock Mass Quality = Very Poor Recovery = 75% Rock Core Times (min:sec): 39.9-40.5 (1:26), 40.5-41.5 (1:49), 41.5-41.9 (0:47) R10: Similar to R9. Rock Mass Quality = Very Poor Recovery = 79% Rock Core Times (min:sec): 41.9-42.5 (0:34), 42.5-43.5 (2:51) R11: Similar to R9, with dark grey banding. Rock Mass Quality = Very Poor Recovery = 100% Rock Core Times (min:sec): 43.5-44.5 (2: 57), 44.5-45.5 (3:46) R12: Similar to R11. Rock Mass Quality = Very Poor Recovery = 100% Rock Core Times (min:sec): 47.9-48.0 (1: 22), 48.0-49.0 (1:32), 49.0-49.1 (0:50) R13: Hard, slightly weathered, fine to coarse grained (feldspar porphyroblasts), grey, METAWACKE. Joints are close to moderately spaced, low to high angle, planar and stepped, rough, discolored, open. Quartz infilling, vugs. Rock Mass Quality = Fair Recovery = 100% Rock Core Times (min:sec): 49.1-50.0 (1:41), 50.0-51.0 (1:18), 51.0-52.0 (1:19), 52.0-53.3 (1:33) R14: Hard, fresh, fine to coarse grained (feldspar infilling), grey, METAWACKE. Joints are cloe to moderately spaced, low to high angle, planar, stepped, rough, discolored, partially open to open. Rock Mass Quality = Fair Recovery = 100% Rock Core Times (min:sec): 52.9-53.0 (1:43), 53.0-54.0 (1:12), 54.0-55.0 (1:38), 55.0-56.0 (1:45), 56.0-56.7 (0:37)			
	R14	46/46	52.9 - 56.7	RQD = 76%				-44.8					
55													
60													
65													
70													
75													
Remarks: -Advance 3" casing to 37.5' after R7. -Hammer NEBC #1, energy transfer rate = .677.													
Stratification lines represent approximate boundaries between soil types; transitions may be gradual. * Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.										Page 3 of 3 Boring No.: BB-YCGB-202			



APPENDIX C - ROCK CORE PHOTOGRAPHS



MaineDOT Barrell
Bridge #3500 Carries Beech Ridge Road over Dolly Gordon Brook
York, ME
Rock Core Photographs

Boring No.	Run	Depth (ft)	Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB-YCGB-101	R1	17.2 - 22.2	56	93%	25	42%	METAWACKE	1
BB-YCGB-101	R2	22.2 - 27.7	56	93%	33	55%	METAWACK	2



- Notes:
1. Box row corresponds to the core box section in which the rock core sample is contained; Row 1=Top, Row 4=Bottom.
 2. Top photo is dry, bottom photo is wet.
 3. Transition between core runs within a row are marked by wood separators.



MaineDOT Barrell
Bridge #3500 Carries Beech Ridge Road over Dolly Gordon Brook
York, ME
Rock Core Photographs

Boring No.	Run	Depth (ft)		Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB-YCGB -201	R1	16.5	- 19.0	29	97%	0	0%	METAWACKE	1
BB-YCGB -201	R2	19.0	- 20.8	19	86%	0	0%	METAWACKE	1
BB-YCGB -201	R3	20.8	- 24.4	43	100%	5	21%	METAWACKE	1, 2
BB-YCGB -201	R4	24.4	- 28.1	44	100%	29	66%	METWACKE	2, 3
BB-YCGB -201	R5	28.1	- 32	40	85%	29	62%	METAWACKE	3, 4
BB-YCGB -201	R6	32	- 35	36	100%	9	25%	METAWACKE	4
BB-YCGB -201	R7	35	- 37	24	100%	8	33%	METAWACKE	4*



- Notes:**
1. Box row corresponds to the core box section in which the rock core sample is contained; Row 1=Top, Row 4=Bottom.
 2. Top photo is dry, bottom photo is wet.
 3. Transition between core runs within a row are marked by wood or paper separators.
- * Bottom of R7 is shown in Row 1 on the following page.



MaineDOT Barrell
Bridge #3500 Carries Beech Ridge Road over Dolly Gordon Brook
York, ME
Rock Core Photographs

Boring No.	Run	Depth (ft)	Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB-YCGB -202	R1	25 - 26.3	15	94%	0	0%	METAWACKE	2
BB-YCGB -202	R2	26.3 - 28.3	19	86%	0	0%	METAWACKE	2
BB-YCGB -202	R3	28.3 - 30.2	14	61%	0	0%	METAWACKE	2
BB-YCGB -202	R4	31 - 32.3	16	100%	0	0%	METAWACKE	2,3
BB-YCGB -202	R5	32.3 - 34.0	11	54%	0	0%	METAWACKE	3
BB-YCGB -202	R6	34.0 - 36.3	11	39%	0	0%	METAWACKE	3
BB-YCGB -202	R7	36.3 - 37.5	6	42%	0	0%	METAWACKE	3
BB-YCGB -202	R8	37.5 - 39.9	29	100%	0	0%	METAWACKE	3, 4
BB-YCGB -202	R9	39.9 - 41.9	18	75%	0	0%	METAWACKE	4
BB-YCGB -202	R10	41.9 - 43.5	15	79%	0	0%	METAWACKE	4



- Notes:**
1. Box row corresponds to the core box section in which the rock core sample is contained; Row 1=Top, Row 4=Bottom.
 2. Top photo is dry, bottom photo is wet.
 3. Transition between core runs within a row are marked by wood or paper separators.



MaineDOT Barrell
Bridge #3500 Carries Beech Ridge Road over Dolly Gordon Brook
York, ME
Rock Core Photographs

Boring No.	Run	Depth (ft)	Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB-YCGB -202	R11	43.5 - 45.5	24	100%	0	0%	METAWACKE	1
BB-YCGB -202	R12	47.9 - 49.1	14.4	100%	0	0%	METAWACKE	1
BB-YCGB -202	R13	49.1 - 52.9	46	100%	35	76%	METWACKE	1, 2
BB-YCGB -202	R14	52.9 - 56.7	46	100%	35	76%	METAWACKE	2, 3



- Notes:
1. Box row corresponds to the core box section in which the rock core sample is contained; Row 1=Top, Row 4=Bottom.
 2. Top photo is dry, bottom photo is wet.
 3. Transition between core runs within a row are marked by wood separators.



Photo 1: Core box containing wetted rock core from test boring BB-YCGB-104; left side of core box (top portion of cores).

Slots from top to bottom 1) BB-YCGB-104, R1 / R2; 2) BB-YCGB-104, R2 / R3; 3) BB-YCGB-104, R3.

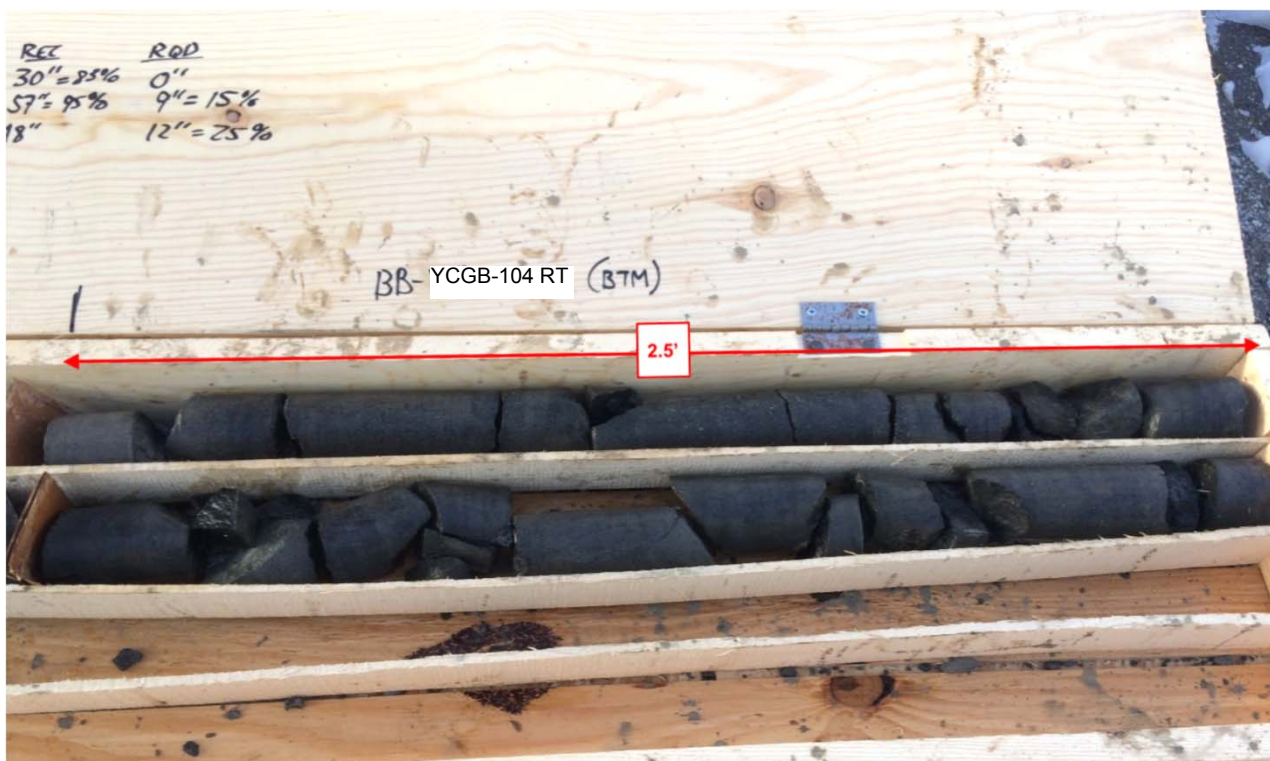


Photo 2 Core box containing wetted rock core from test boring BB-YCGB-104; right side of core box (bottom portion of cores).

Slots from top to bottom 1) BB-YCGB-104, R2; 2) BB-YCGB-104, R3; 3) empty.

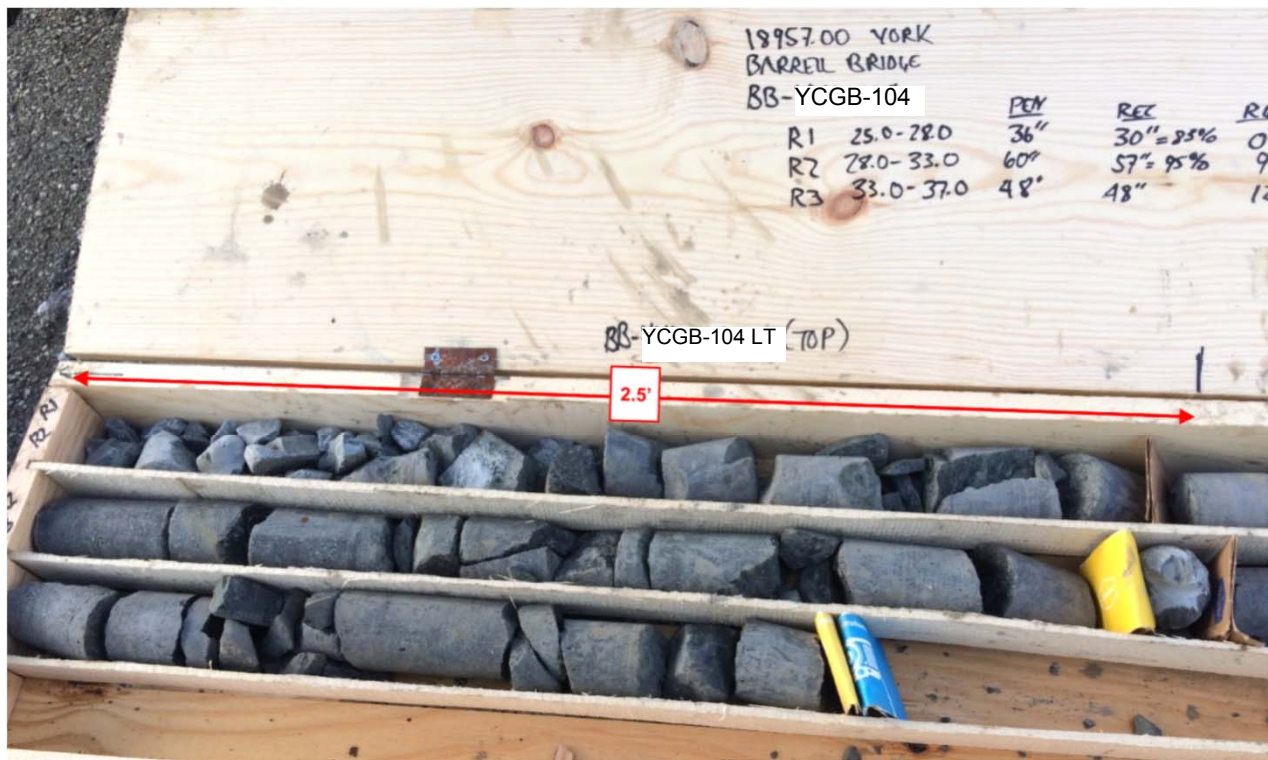


Photo 1: Core box containing **dried** rock core from test boring **BB-YCGB-104**; left side of core box (top portion of cores).

Slots from top to bottom 1) BB-YCGB-104, R1 / R2; 2) BB-YCGB-104, R2 / R3; 3) BB-YCGB-104, R3.

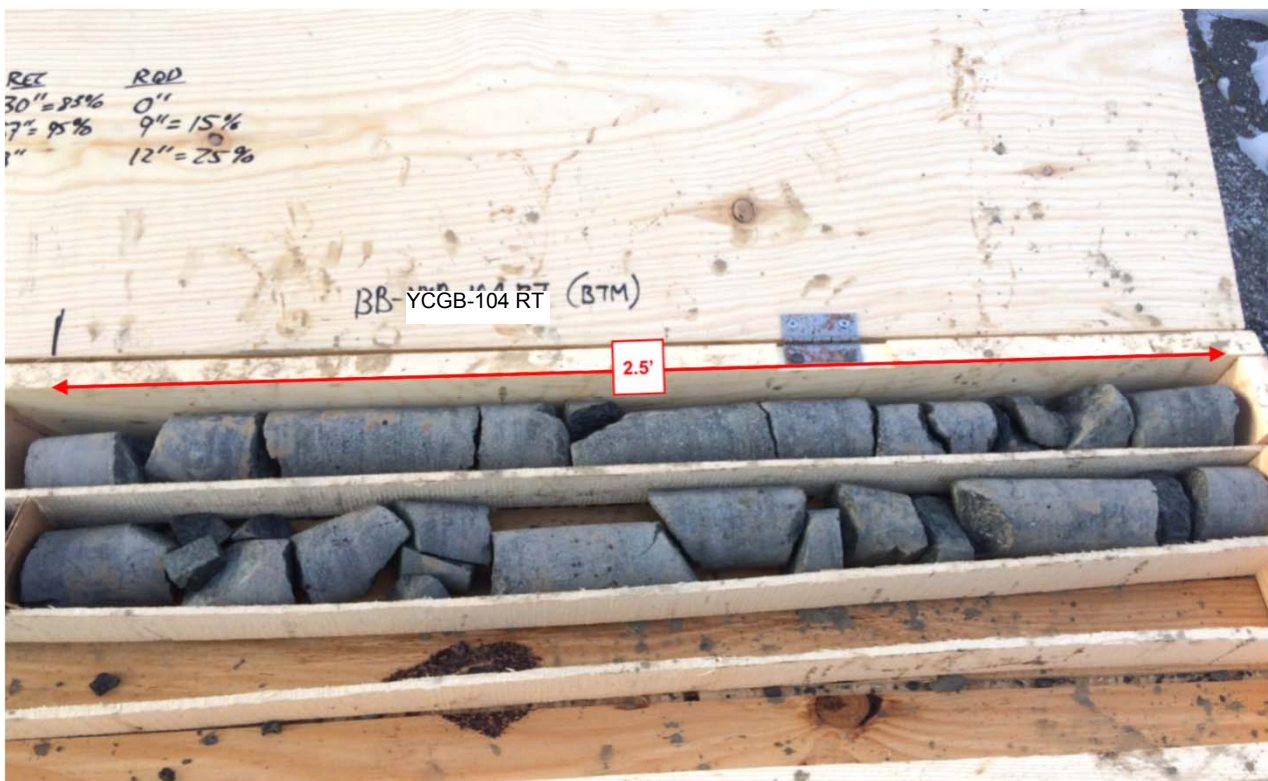


Photo 2 Core box containing **dried** rock core from test boring **BB-YCGB-104**; right side of core box (bottom portion of cores).

Slots from top to bottom 1) BB-YCGB-104, R2; 2) BB-YCGB-104, R3; 3) empty.



APPENDIX D - LABORATORY TESTING RESULTS

Work Number: 18957.00



GEOTECHNICAL TEST REPORT

Central Laboratory

SAMPLE INFORMATION

Reference No. **304328** Boring No./Sample No. **BB-YCGB-101/2D** Sample Description **GEOTECHNICAL (DISTURBED)** Sampled **12/19/2016** Received **12/28/2016**

Sample Type: **GEOTECHNICAL** Location: Station: **102+88.9** Offset, ft: **6.2** LT Dbfg, ft: **5.0-7.0**

WIN/Town **018957.00 - YORK** Sampler: **BE SCHONEWALD**

TEST RESULTS

Sieve Analysis (T 88)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	100.0
¾ in. [19.0 mm]	96.6
½ in. [12.5 mm]	96.6
⅜ in. [9.5 mm]	96.1
¼ in. [6.3 mm]	94.4
No. 4 [4.75 mm]	93.6
No. 10 [2.00 mm]	90.0
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	81.2
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	48.8
[0.0320 mm]	44.6
[0.0212 mm]	33.5
[0.0125 mm]	27.9
[0.0090 mm]	22.3
[0.0065 mm]	16.7
[0.0032 mm]	11.2
[0.0014 mm]	8.4

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	2.63
Loss on Ignition, % (T 267)	
Water Content (T 265), %	16.7

Consolidation (T 216)

Trimming, Water Content, %					
	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear tons/ft²	Remold tons/ft²	U. Shear tons/ft²	Remold tons/ft²		

Comments:

AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE**

Date Reported: **1/6/2017**

Paper Copy: Lab File; Project File; Geotech File



GEOTECHNICAL TEST REPORT

Central Laboratory

SAMPLE INFORMATION

Reference No. **304330** Boring No./Sample No. **BB-YCGB-104/2D** Sample Description **GEOTECHNICAL (DISTURBED)** Sampled **12/13/2016** Received **12/28/2016**

Sample Type: **GEOTECHNICAL** Location: Station: **103+55.3** Offset, ft: **5.4** RT Dbfg, ft: **5.0-7.0**

WIN/Town **018957.00 - YORK** Sampler: **BE SCHONEWALD**

TEST RESULTS

Sieve Analysis (T 88)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	100.0
½ in. [12.5 mm]	98.4
⅜ in. [9.5 mm]	95.3
¼ in. [6.3 mm]	92.5
No. 4 [4.75 mm]	91.1
No. 10 [2.00 mm]	86.4
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	73.6
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	46.9
[0.0322 mm]	31.3
[0.0209 mm]	26.8
[0.0126 mm]	17.9
[0.0090 mm]	15.6
[0.0067 mm]	13.4
[0.0033 mm]	8.9
[0.0014 mm]	4.5

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	2.69
Loss on Ignition, % (T 267)	
Water Content (T 265), %	23.5

Consolidation (T 216)

Trimmings, Water Content, %					
	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear tons/ft²	Remold tons/ft²	U. Shear tons/ft²	Remold tons/ft²		

Comments:

AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE**

Date Reported: **1/6/2017**

Paper Copy: Lab File; Project File; Geotech File



GEOTECHNICAL TEST REPORT

Central Laboratory

SAMPLE INFORMATION

Reference No. **304331** Boring No./Sample No. **BB-YCGB-104/4D** Sample Description **GEOTECHNICAL (DISTURBED)** Sampled **12/14/2016** Received **12/28/2016**

Sample Type: **GEOTECHNICAL** Location: Station: **103+55.3** Offset, ft: **5.4** RT Dbfg, ft: **15.0-17.0**

WIN/Town **018957.00 - YORK** Sampler: **BE SCHONEWALD**

TEST RESULTS

Sieve Analysis (T 88)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	100.0
¾ in. [19.0 mm]	96.1
½ in. [12.5 mm]	88.8
⅜ in. [9.5 mm]	80.8
¼ in. [6.3 mm]	76.1
No. 4 [4.75 mm]	73.0
No. 10 [2.00 mm]	66.8
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	59.6
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	48.0
[0.0310 mm]	36.5
[0.0203 mm]	31.1
[0.0121 mm]	25.6
[0.0090 mm]	18.2
[0.0065 mm]	14.6
[0.0033 mm]	7.3
[0.0014 mm]	3.7

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	2.60
Loss on Ignition, % (T 267)	
Water Content (T 265), %	13.4

Consolidation (T 216)

Trimming, Water Content, %					
	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear	Remold	U. Shear	Remold		
	tons/ft²	tons/ft²	tons/ft²	tons/ft²		

Comments:

AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE**

Date Reported: **1/6/2017**

Paper Copy: Lab File; Project File; Geotech File



GEOTECHNICAL TEST REPORT

Central Laboratory

SAMPLE INFORMATION

Reference No. **304329** Boring No./Sample No. **BP-YCGB-102/1D** Sample Description **GEOTECHNICAL (DISTURBED)** Sampled **12/15/2016** Received **12/28/2016**

Sample Type: **GEOTECHNICAL** Location: Station: **102+89.7** Offset, ft: **5.2** RT Dbfg, ft: **15.4-15.9**

WIN/Town **018957.00 - YORK** Sampler: **BE SCHONEWALD**

TEST RESULTS

Sieve Analysis (T 88)

Wash Method

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	100.0
¾ in. [19.0 mm]	91.3
½ in. [12.5 mm]	89.5
⅜ in. [9.5 mm]	82.8
¼ in. [6.3 mm]	79.0
No. 4 [4.75 mm]	76.6
No. 10 [2.00 mm]	71.1
No. 20 [0.850 mm]	
No. 40 [0.425 mm]	58.3
No. 60 [0.250 mm]	
No. 100 [0.150 mm]	
No. 200 [0.075 mm]	48.4
[0.0296 mm]	34.3
[0.0192 mm]	30.9
[0.0116 mm]	24.0
[0.0084 mm]	20.5
[0.0061 mm]	17.1
[0.0030 mm]	12.0
[0.0013 mm]	6.8

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	2.73
Loss on Ignition, % (T 267)	
Water Content (T 265), %	15.6

Consolidation (T 216)

Trimming, Water Content, %					
	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear	Remold	U. Shear	Remold		
	tons/ft²	tons/ft²	tons/ft²	tons/ft²		

Comments:

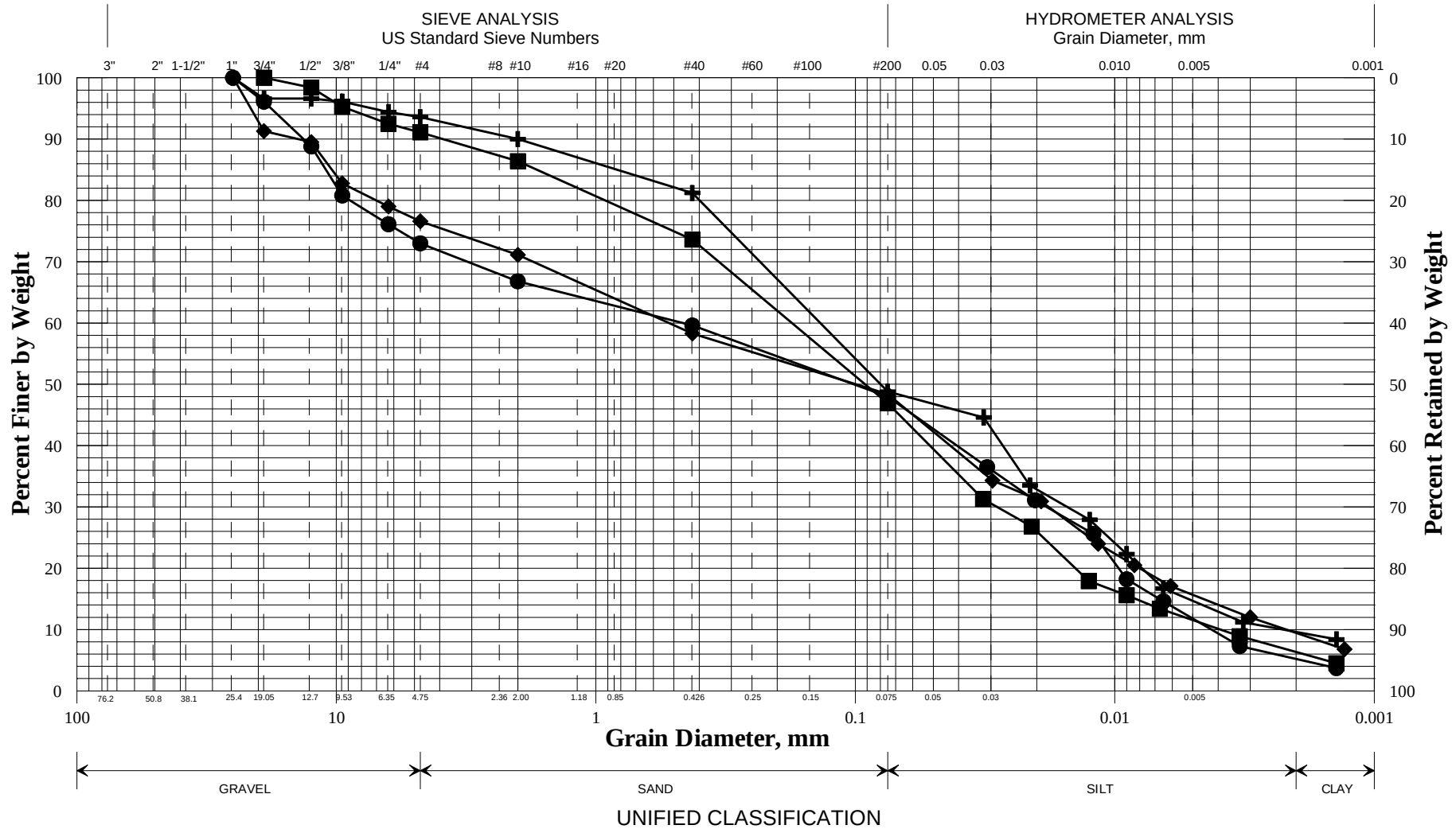
AUTHORIZATION AND DISTRIBUTION

Reported by: **GREGORY LIDSTONE**

Date Reported: **1/6/2017**

Paper Copy: Lab File; Project File; Geotech File

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE



	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
+	BB-YCGB-101/2D	102+88.9	6.2 LT	5.0-7.0	Silty SAND, trace clay, trace gravel.	16.7			
◆	BP-YCGB-102/1D	102+89.7	5.2 RT	15.4-15.9	SILT, some sand, some gravel, trace clay.	15.6			
■	BB-YCGB-104/2D	103+55.3	5.4 RT	5.0-7.0	Silty SAND, trace gravel, trace clay.	23.5			
●	BB-YCGB-104/4D	103+55.3	5.4 RT	15.0-17.0	SILT, some gravel, some sand, trace clay.	13.4			
▲									
×									

WIN	
018957.00	
Town	
York	
Reported by/Date	
WHITE, TERRY A	1/17/2017



Client: GZA GeoEnvironmental, Inc.
Project Name: Barrell Bridge Replacement
Project Location: York, ME
GTX #: 306980
Date: 09/18/17

Soil Classification - AASHTO M 145

Boring ID	Sample ID	Depth, ft	Group Name	Group Symbol	Gravel, %	Sand, %	Fines, %
BB-YCGB-201	2D	5-7	Silty Soils	A-4 (0)	7	27	66
BB-YCGB-201	3D	10-12	Silty Soils	A-4 (0)	2	36	62
BB-YCGB-202	1D	1-3	Stone Fragments, Gravel and Sand	(A-1-b (0))	35	50	15
BB-YCGB-202	2D	5-7	Silty Soils	A-4 (0)	22	32	46
BB-YCGB-202	3D	10-12	Silty Soils	A-4 (0)	25	9	66

Remarks: Grain Size Analysis performed by ASTM D422, results enclosed
Atterberg Limits performed by ASTM D4318, results enclosed



Client:	GZA GeoEnvironmental, Inc.		
Project:	Barrell Bridge Replacement		
Location:	York, ME	Project No:	GTX-306980
Boring ID:	---	Sample Type:	---
Sample ID:	---	Test Date:	09/15/17
Depth :	---	Test Id:	423903
		Tested By:	GA
		Checked By:	emm

Moisture Content of Soil and Rock - ASTM D2216

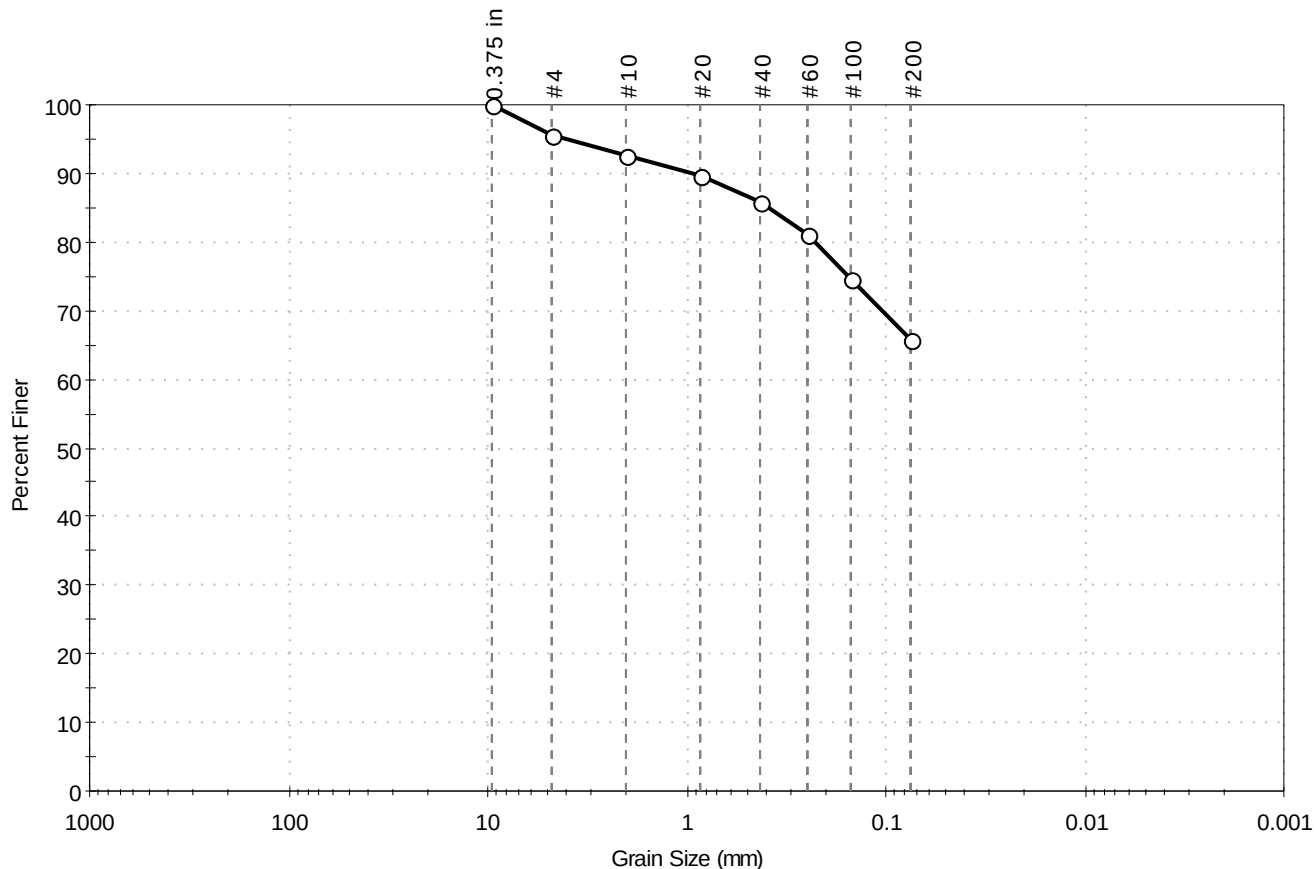
Boring ID	Sample ID	Depth	Description	Moisture Content, %
BB-YCGB-201	2D	5-7 ft	Moist, olive silt,some sand, trace gravel	16.9
BB-YCGB-201	3D	10-12 ft	Moist, very dark gray sandy clay, trace gravel	62.9
BB-YCGB-202	1D	1-3 ft	Moist, olive gray sand, some gravel, little clay	5.7
BB-YCGB-202	2D	5-7 ft	Moist, olive sandy clay, little gravel	16.5
BB-YCGB-202	3D	10-12 ft	Moist, very dark grayish brown clay, some gravel, little sand	45.5

Notes: Temperature of Drying : 110° Celsius



Client:	GZA GeoEnvironmental, Inc.		
Project:	Barrell Bridge Replacement		
Location:	York, ME	Project No:	GTX-306980
Boring ID:	BB-YCGB-201	Sample Type:	bag
Sample ID:	2D	Test Date:	09/15/17
Depth :	5-7 ft	Test Id:	423894
Test Comment:	---		
Visual Description:	Moist, olive silt,some sand, trace gravel		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	4.5	29.8	65.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	96		
#10	2.00	93		
#20	0.85	90		
#40	0.42	86		
#60	0.25	81		
#100	0.15	75		
#200	0.075	66		

Coefficients

D ₈₅ = 0.3881 mm	D ₃₀ = N/A
D ₆₀ = N/A	D ₁₅ = N/A
D ₅₀ = N/A	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

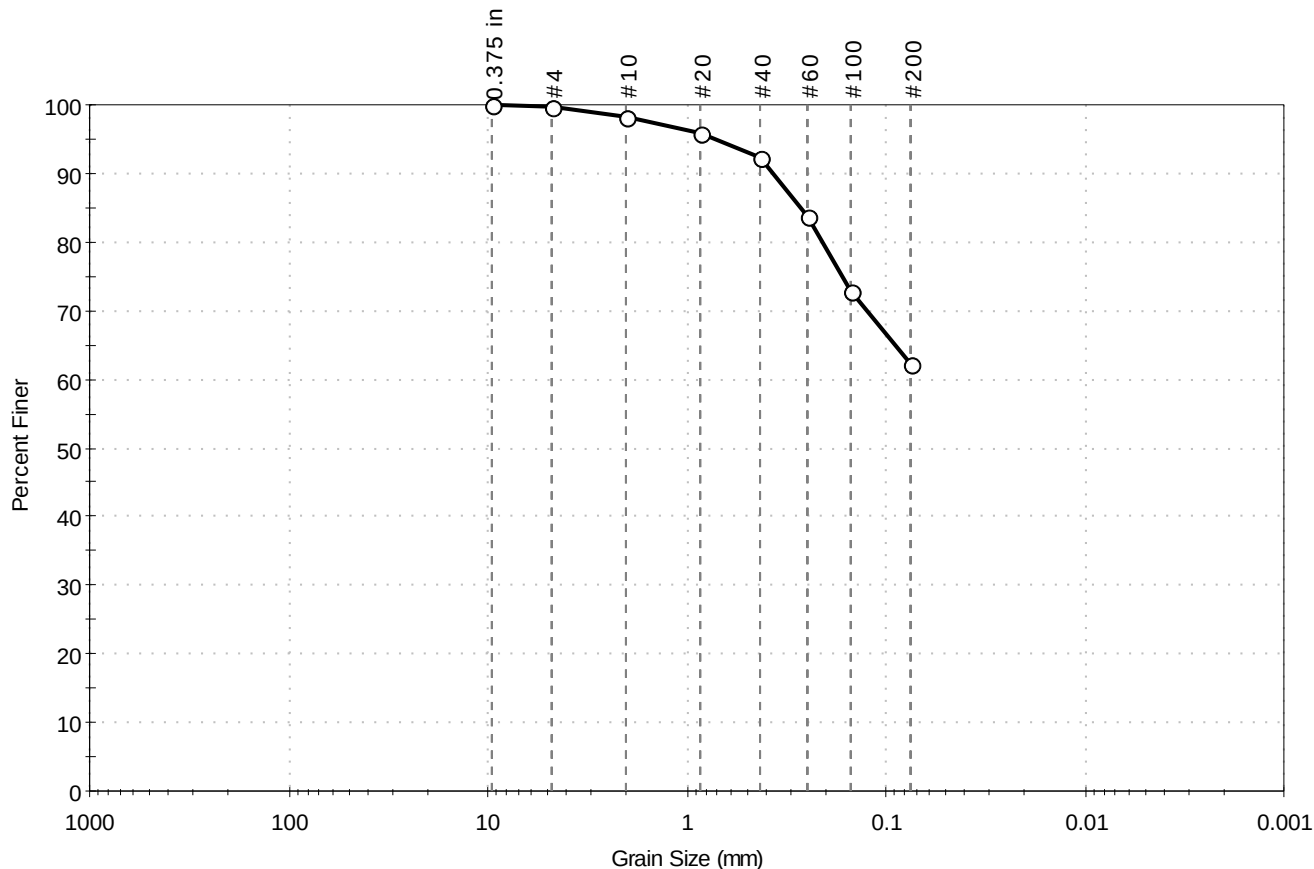
Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD



Client:	GZA GeoEnvironmental, Inc.		
Project:	Barrell Bridge Replacement		
Location:	York, ME	Project No:	GTX-306980
Boring ID:	BB-YCGB-201	Sample Type:	bag
Sample ID:	3D	Test Date:	09/15/17
Depth :	10-12 ft	Test Id:	423895
Test Comment:	---		
Visual Description:	Moist, very dark gray sandy clay, trace gravel		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.4	37.5	62.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	100		
#10	2.00	98		
#20	0.85	96		
#40	0.42	92		
#60	0.25	84		
#100	0.15	73		
#200	0.075	62		

Coefficients

D ₈₅ = 0.2716 mm	D ₃₀ = N/A
D ₆₀ = N/A	D ₁₅ = N/A
D ₅₀ = N/A	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

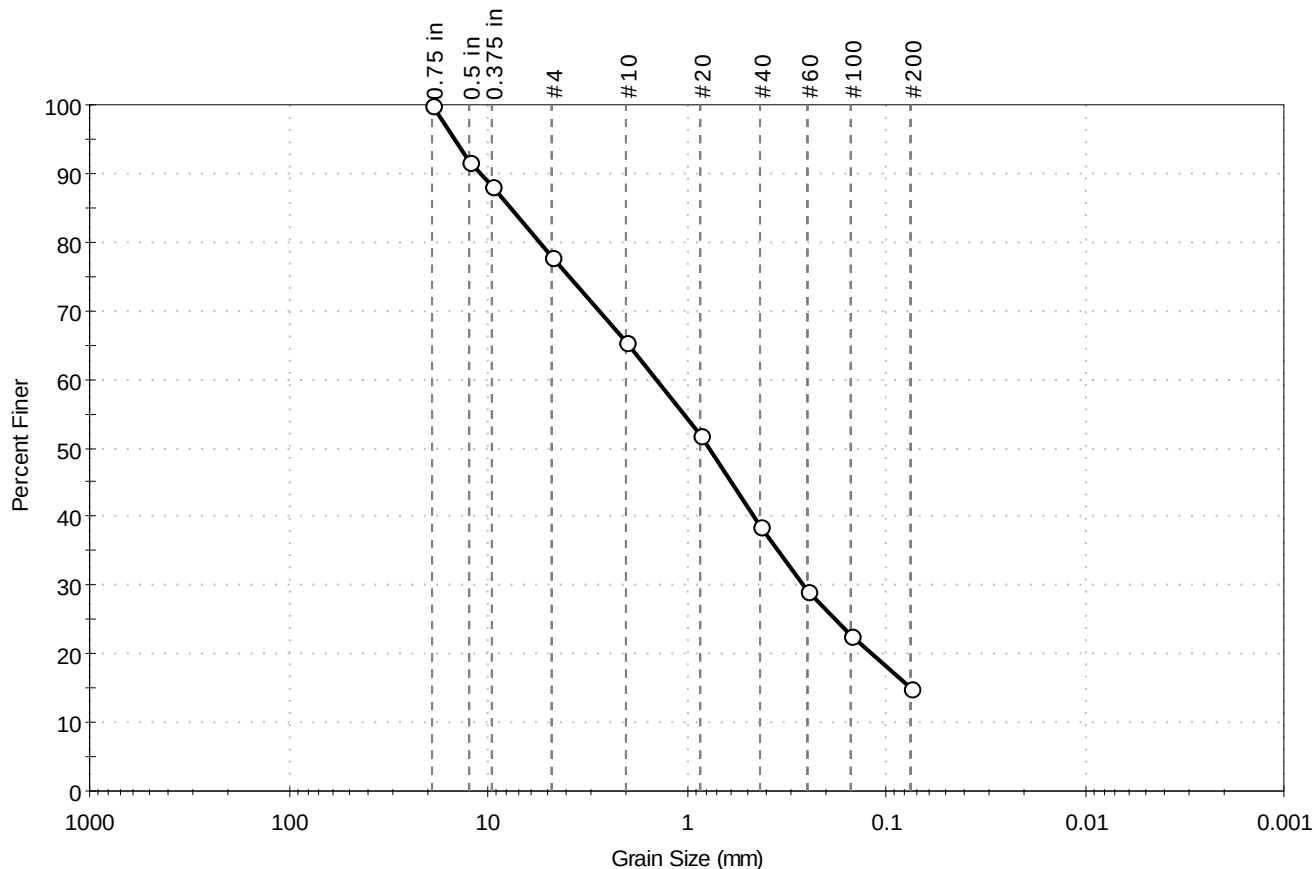
Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD



Client:	GZA GeoEnvironmental, Inc.		
Project:	Barrell Bridge Replacement		
Location:	York, ME	Project No:	GTX-306980
Boring ID:	BB-YCGB-202	Sample Type:	bag
Sample ID:	1D	Test Date:	09/15/17
Depth :	1-3 ft	Test Id:	423896
Test Comment:	---		
Visual Description:	Moist, olive gray sand, some gravel, little clay		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	22.1	62.8	15.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	92		
0.375 in	9.50	88		
#4	4.75	78		
#10	2.00	65		
#20	0.85	52		
#40	0.42	39		
#60	0.25	29		
#100	0.15	23		
#200	0.075	15		

Coefficients

D ₈₅ = 7.6339 mm	D ₃₀ = 0.2606 mm
D ₆₀ = 1.4155 mm	D ₁₅ = N/A
D ₅₀ = 0.7696 mm	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

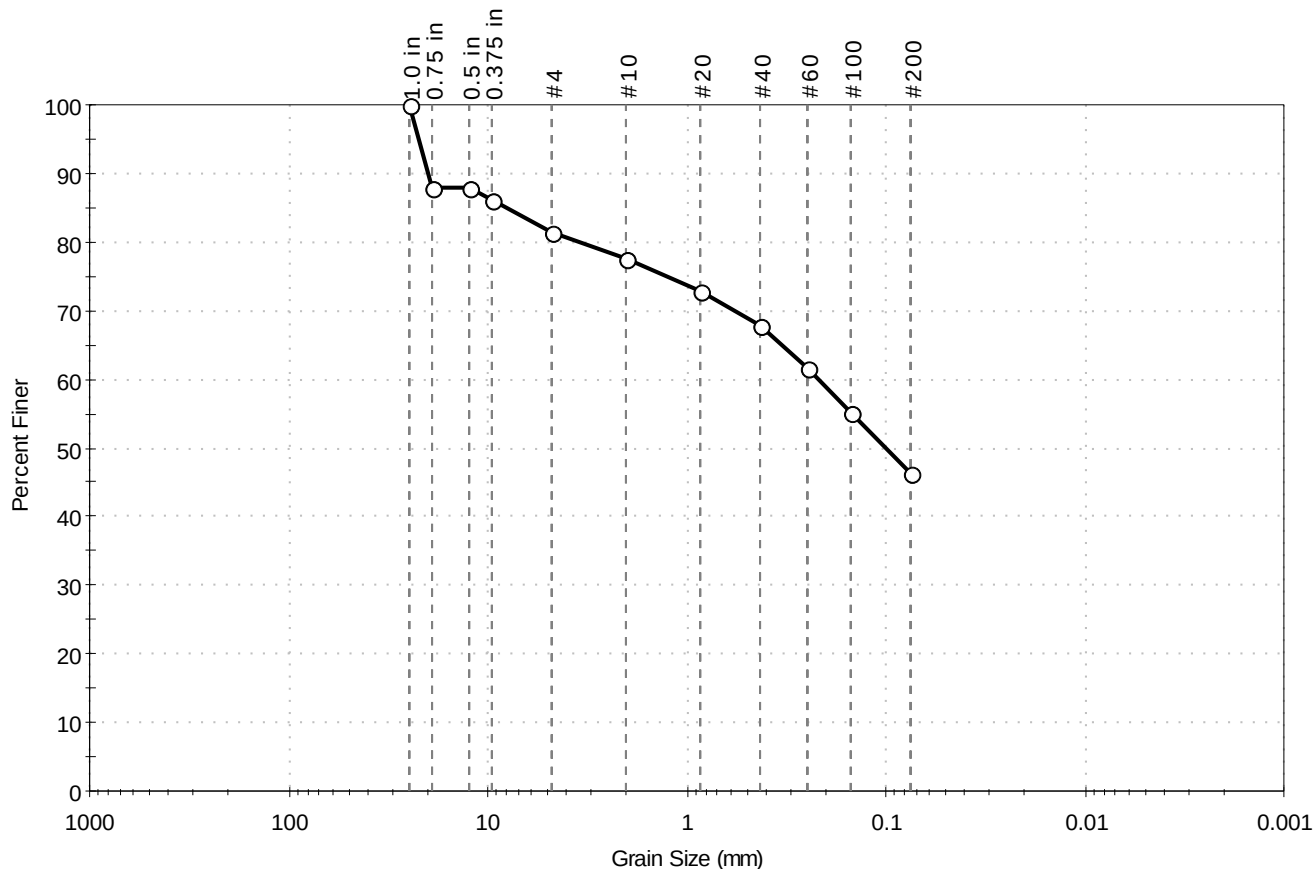
AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD

Client:	GZA GeoEnvironmental, Inc.		
Project:	Barrell Bridge Replacement		
Location:	York, ME	Project No:	GTX-306980
Boring ID:	BB-YCGB-202	Sample Type:	bag
Sample ID:	2D	Test Date:	09/15/17
Depth :	5-7 ft	Test Id:	423897
Test Comment:	---		
Visual Description:	Moist, olive sandy clay, little gravel		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	18.5	35.1	46.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.0 in	25.00	100		
0.75 in	19.00	88		
0.5 in	12.50	88		
0.375 in	9.50	86		
#4	4.75	81		
#10	2.00	78		
#20	0.85	73		
#40	0.42	68		
#60	0.25	62		
#100	0.15	55		
#200	0.075	46		

Coefficients

D ₈₅ = 8.0761 mm	D ₃₀ = N/A
D ₆₀ = 0.2193 mm	D ₁₅ = N/A
D ₅₀ = 0.0999 mm	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

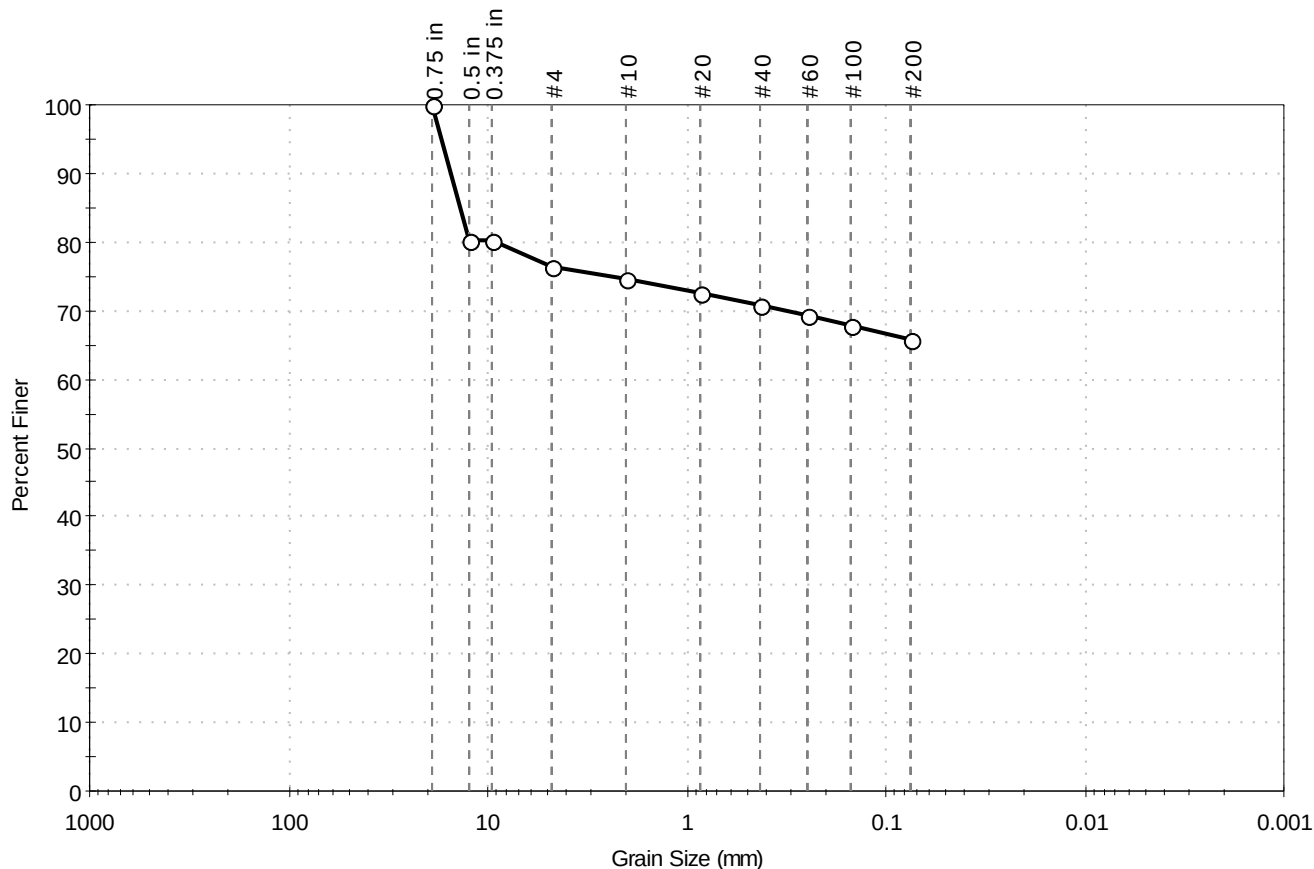
Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD



Client:	GZA GeoEnvironmental, Inc.		
Project:	Barrell Bridge Replacement		
Location:	York, ME	Project No:	GTX-306980
Boring ID:	BB-YCGB-202	Sample Type:	bag
Sample ID:	3D	Test Date:	09/15/17
Depth :	10-12 ft	Test Id:	423898
Test Comment:	---		
Visual Description:	Moist, very dark grayish brown clay, some gravel, little sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	23.5	10.9	65.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	80		
0.375 in	9.50	80		
#4	4.75	77		
#10	2.00	75		
#20	0.85	73		
#40	0.42	71		
#60	0.25	69		
#100	0.15	68		
#200	0.075	66		

Coefficients

D ₈₅ = 13.8460 mm	D ₃₀ = N/A
D ₆₀ = N/A	D ₁₅ = N/A
D ₅₀ = N/A	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

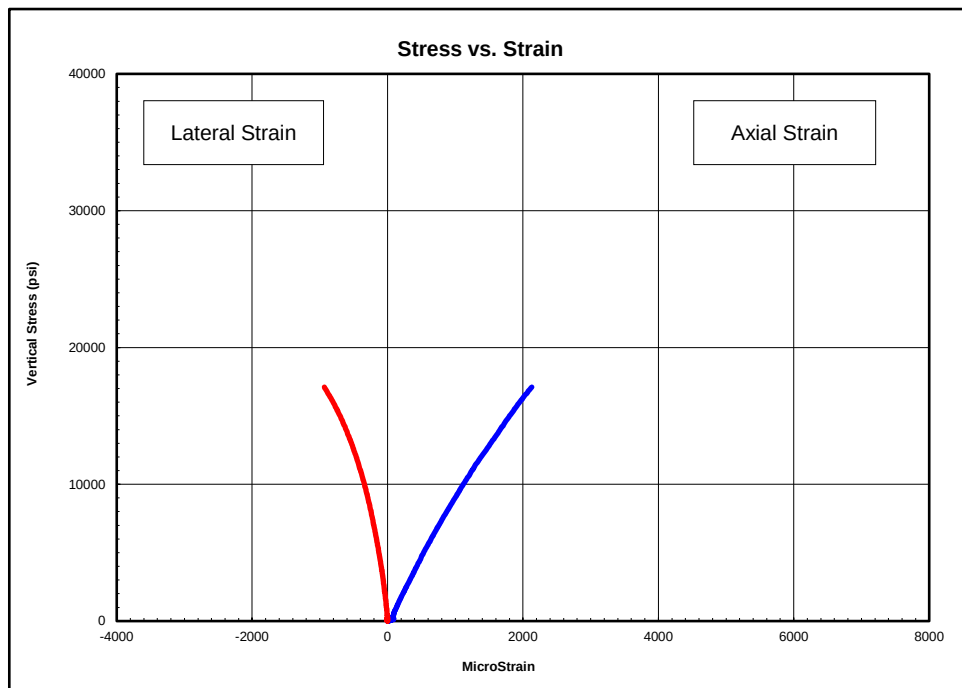
Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD



Client:	GZA GeoEnvironmental, Inc.
Project Name:	Barrell Bridge #3500,018957.00
Project Location:	York, ME
GTX #:	306902
Test Date:	8/24/2017
Tested By:	rlc
Checked By:	jsc
Boring ID:	BB-YCGB-201
Sample ID:	R5
Depth, ft:	28.50-28.88
Sample Type:	rock core
Sample Description:	See photographs Intact material failure

Compressive Strength and Elastic Moduli of Rock by ASTM D7012 - Method D



Peak Compressive Stress: 17,136 psi

Stress Range, psi	Young's Modulus, psi	Poisson's Ratio
1700-6300	9,660,000	0.30
6300-10800	8,240,000	0.39
10800-15400	7,150,000	---

Notes: Test specimen tested at the approximate as-received moisture content and at standard laboratory temperature.
The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.
Young's Modulus and Poisson's Ratio calculated using the tangent to the line in the stress range listed.
Calculations assume samples are isotropic, which is not necessarily the case.

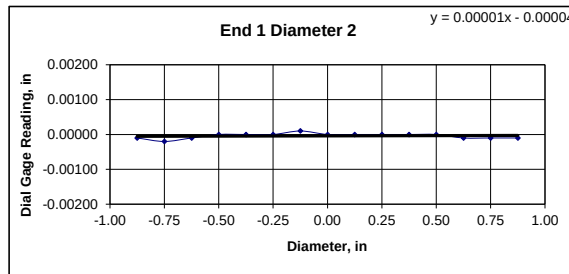
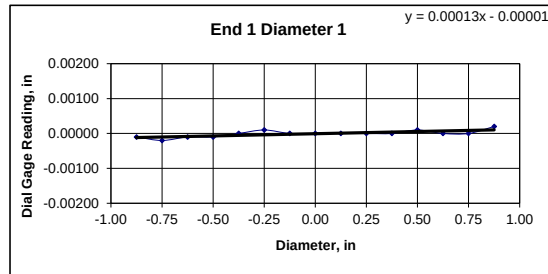


Client:	GZA GeoEnvironmental, Inc.	Test Date:	8/24/2017
Project Name:	Barrell Bridge #3500,018957.00	Tested By:	rlc
Project Location:	York, ME	Checked By:	jsc
GTX #:	306902		
Boring ID:	BB-YCGB-201		
Sample ID:	R5		
Depth:	28.50-28.88 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY				DEVIATION FROM STRAIGHTNESS (Procedure S1)	
	1	2	Average	Maximum gap between side of core and reference surface plate: Is the maximum gap $\leq$ 0.02 in.? YES	
Specimen Length, in:	4.51	4.51	4.51	Maximum difference must be $<$ 0.020 in.	
Specimen Diameter, in:	1.98	1.98	1.98	Straightness Tolerance Met? YES	
Specimen Mass, g:	634.72				
Bulk Density, lb/ft ³ :	174				
Length to Diameter Ratio:	2.3				
		Minimum Diameter Tolerance Met?	YES		
		Length to Diameter Ratio Tolerance Met?	YES		

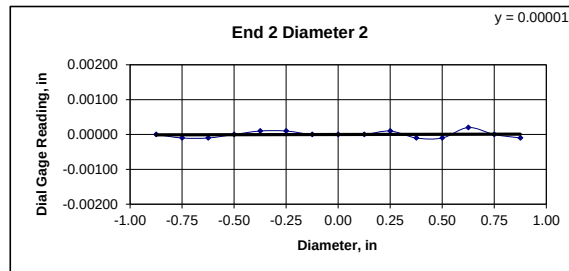
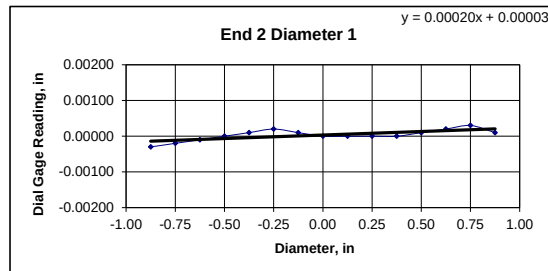
END FLATNESS AND PARALLELISM (Procedure FP1)														
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750
Diameter 1, in	-0.00010	-0.00020	-0.00010	-0.00010	0.00000	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010	0.00000	0.00020
Diameter 2, in (rotated 90°)	-0.00010	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00010
Difference between max and min readings, in:														
0° = 0.00040 90° = 0.00030														
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750
Diameter 1, in	-0.00030	-0.00020	-0.00010	0.00000	0.00010	0.00020	0.00010	0.00000	0.00000	0.00000	0.00000	0.00010	0.00020	0.00030
Diameter 2, in (rotated 90°)	0.00000	-0.00010	-0.00010	0.00000	0.00010	0.00010	0.00000	0.00000	0.00000	0.00010	-0.00010	-0.00010	0.00000	-0.00010
Difference between max and min readings, in:														
0° = 0.0006 90° = 0.0003														
Maximum difference must be $<$ 0.0020 in. Difference = $\pm$ 0.00030														
Flatness Tolerance Met? YES														



DIAMETER 1

End 1:		
Slope of Best Fit Line	0.00013	
Angle of Best Fit Line:	0.00745	
End 2:		
Slope of Best Fit Line	0.00020	
Angle of Best Fit Line:	0.01146	
Maximum Angular Difference:	0.00401	

Parallelism Tolerance Met? YES
Spherically Seated



DIAMETER 2

End 1:		
Slope of Best Fit Line	0.00001	
Angle of Best Fit Line:	0.00057	
End 2:		
Slope of Best Fit Line	0.00001	
Angle of Best Fit Line:	0.00057	
Maximum Angular Difference:	0.00000	

Parallelism Tolerance Met? YES
Spherically Seated

PERPENDICULARITY (Procedure P1)						Maximum angle of departure must be $\leq$ 0.25°	
END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?		
Diameter 1, in	0.00040	1.980	0.00020	0.012	YES		
Diameter 2, in (rotated 90°)	0.00030	1.980	0.00015	0.009	YES		
END 2							
Diameter 1, in	0.00060	1.980	0.00030	0.017	YES		
Diameter 2, in (rotated 90°)	0.00030	1.980	0.00015	0.009	YES		
						Perpendicularity Tolerance Met?	YES



Client:	GZA GeoEnvironmental, Inc.
Project Name:	Barrell Bridge #3500,018957.00
Project Location:	York, ME
GTX #:	306902
Test Date:	8/24/2017
Tested By:	rlc
Checked By:	jsc
Boring ID:	BB-YCGB-201
Sample ID:	R5
Depth, ft:	28.50-28.88



After cutting and grinding

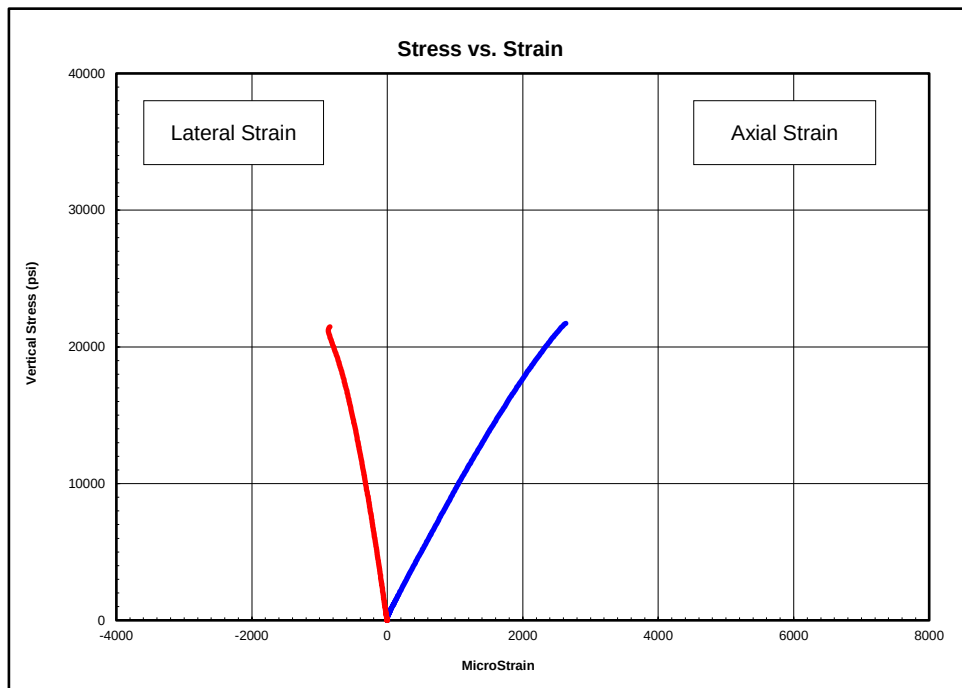


After break



Client:	GZA GeoEnvironmental, Inc.
Project Name:	Barrell Bridge #3500,018957.00
Project Location:	York, ME
GTX #:	306902
Test Date:	8/24/2017
Tested By:	rlc
Checked By:	jsc
Boring ID:	BB-YCGB-202
Sample ID:	R13
Depth, ft:	51.55-51.92
Sample Type:	rock core
Sample Description:	See photographs Intact material failure

Compressive Strength and Elastic Moduli of Rock by ASTM D7012 - Method D



Peak Compressive Stress: 21,720 psi

Stress Range, psi	Young's Modulus, psi	Poisson's Ratio
2200-8000	9,170,000	0.29
8000-13800	8,650,000	0.32
13800-19500	7,540,000	0.38

Notes: Test specimen tested at the approximate as-received moisture content and at standard laboratory temperature.
The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.
Young's Modulus and Poisson's Ratio calculated using the tangent to the line in the stress range listed.
Calculations assume samples are isotropic, which is not necessarily the case.

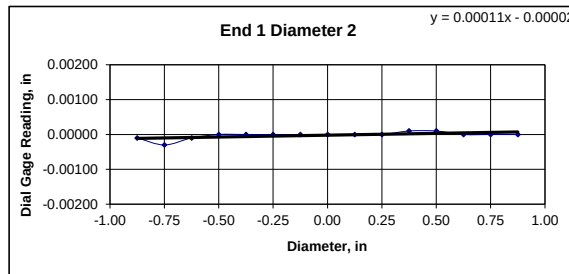
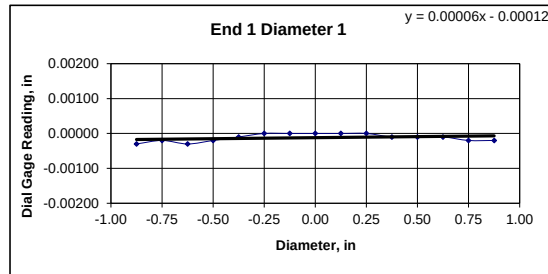


Client:	GZA GeoEnvironmental, Inc.	Test Date:	8/24/2017
Project Name:	Barrell Bridge #3500,018957.00	Tested By:	rlc
Project Location:	York, ME	Checked By:	jsc
GTX #:	306902		
Boring ID:	BB-YCGB-202		
Sample ID:	R13		
Depth:	51.55-51.92 ft		
Visual Description:	See photographs		

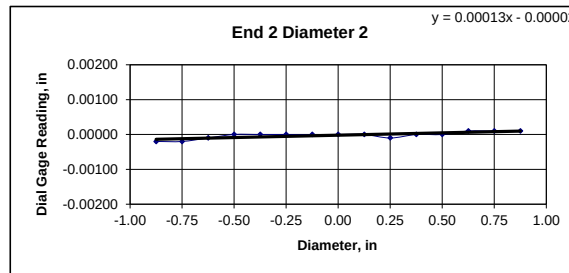
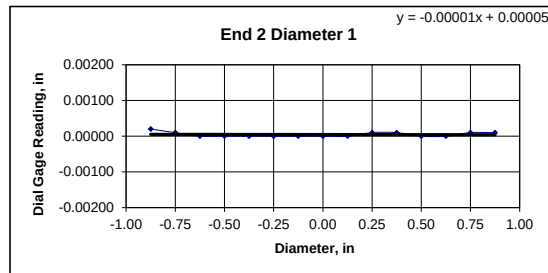
UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY				DEVIATION FROM STRAIGHTNESS (Procedure S1)	
	1	2	Average	Maximum gap between side of core and reference surface plate: Is the maximum gap $\leq$ 0.02 in.? YES	
Specimen Length, in:	4.34	4.34	4.34	Maximum difference must be $<$ 0.020 in. Straightness Tolerance Met? YES	
Specimen Diameter, in:	1.98	1.98	1.98		
Specimen Mass, g:	643.47				
Bulk Density, lb/ft ³ :	183	Minimum Diameter Tolerance Met? YES			
Length to Diameter Ratio:	2.2	Length to Diameter Ratio Tolerance Met? YES			

END FLATNESS AND PARALLELISM (Procedure FP1)															
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00030	-0.00020	-0.00030	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00010	-0.00010	-0.00020	-0.00020
Diameter 2, in (rotated 90°)	-0.00010	-0.00030	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010	0.00010	0.00000	0.00000	0.00000
Difference between max and min readings, in: 0° = 0.00030 90° = 0.00040															
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	0.00020	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00010	0.00010	0.00000	0.00000	0.00010	0.00010
Diameter 2, in (rotated 90°)	-0.00020	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	0.00000	0.00000	0.00010	0.00010	0.00010
Difference between max and min readings, in: 0° = 0.0002 90° = 0.0003 Maximum difference must be < 0.0020 in. Difference = ± 0.00020															
Flatness Tolerance Met? YES															



DIAMETER 1	
End 1:	
Slope of Best Fit Line	0.00006
Angle of Best Fit Line:	0.00344
End 2:	
Slope of Best Fit Line	0.00001
Angle of Best Fit Line:	0.00057
Maximum Angular Difference:	0.00286
Parallelism Tolerance Met? Spherically Seated	YES



DIAMETER 2	
End 1:	
Slope of Best Fit Line	0.00011
Angle of Best Fit Line:	0.00630
End 2:	
Slope of Best Fit Line	0.00013
Angle of Best Fit Line:	0.00745
Maximum Angular Difference:	0.00115
Parallelism Tolerance Met? Spherically Seated	YES

PERPENDICULARITY (Procedure P1)						Maximum angle of departure must be $\leq$ 0.25°	
END 1	(Calculated from End Flatness and Parallelism measurements above)						
	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?		
Diameter 1, in	0.00030	1.980	0.00015	0.009	YES		
Diameter 2, in (rotated 90°)	0.00040	1.980	0.00020	0.012	YES	Perpendicularity Tolerance Met?	YES
END 2							
Diameter 1, in	0.00020	1.980	0.00010	0.006	YES		
Diameter 2, in (rotated 90°)	0.00030	1.980	0.00015	0.009	YES		

Client:	GZA GeoEnvironmental, Inc.
Project Name:	Barrell Bridge #3500,018957.00
Project Location:	York, ME
GTX #:	306902
Test Date:	8/24/2017
Tested By:	rlc
Checked By:	jsc
Boring ID:	BB-YCGB-202
Sample ID:	R13
Depth, ft:	51.55-51.92



After cutting and grinding



After break



APPENDIX E - GEOTECHNICAL ENGINEERING CALCULATIONS

Seismic Evaluation



Design Maps Detailed Report

2009 AASHTO Guide Specifications for LRFD Seismic Bridge Design (43.14274°N, 70.70433°W)

Site Class D – “Stiff Soil”

Article 3.4.1 — Design Spectra Based on General Procedure

Note: Maps in the 2009 AASHTO Specifications are provided by AASHTO for Site Class B.
Adjustments for other Site Classes are made, as needed, in Article 3.4.2.3.

From Figure 3.4.1-2 ^[1]	PGA = 0.098 g
From Figure 3.4.1-3 ^[2]	S _s = 0.188 g
From Figure 3.4.1-4 ^[3]	S ₁ = 0.044 g

Article 3.4.2.1 — Site Class Definitions

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class D, based on the site soil properties in accordance with Article 3.4.2.

Table 3.4.2.1-1 Site Class Definitions

SITE CLASS	SOIL PROFILE NAME	Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5,000$	N/A	N/A
B	Rock	$2,500 < \bar{v}_s \leq 5,000$	N/A	N/A
C	Very dense soil and soft rock	$1,200 < \bar{v}_s \leq 2,500$	$\bar{N} > 50$	$> 2,000$ psf
D	Stiff soil profile	$600 \leq \bar{v}_s < 1,200$	$15 \leq \bar{N} \leq 50$	1,000 to 2,000 psf
E	Stiff soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$< 1,000$ psf
E	—	Any profile with more than 10 ft of soil having the characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet)		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Article 3.4.2.3 — Site Coefficients

Table 3.4.2.3-1 (for F_{pga})—Values of F_{pga} as a Function of Site Class and Mapped Peak Ground Acceleration Coefficient

Site Class	Mapped Peak Ground Acceleration				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See AASHTO Article 3.4.3				

Note: Use straight-line interpolation for intermediate values of PGA

For Site Class = D and PGA = 0.098 g, $F_{PGA} = 1.600$

Table 3.4.2.3-1 (for F_a)—Values of F_a as a Function of Site Class and Mapped Short-Period Spectral Acceleration Coefficient

Site Class	Spectral Response Acceleration Parameter at Short Periods				
	$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See AASHTO Article 3.4.3				

Note: Use straight-line interpolation for intermediate values of S_s

For Site Class = D and $S_s = 0.188$ g, $F_a = 1.600$

Table 3.4.2.3-2—Values of F_v as a Function of Site Class and Mapped 1-sec Period Spectral Acceleration Coefficient

Site Class	Mapped Spectral Response Acceleration Coefficient at 1-sec Periods				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See AASHTO Article 3.4.3				

Note: Use straight-line interpolation for intermediate values of S_1

For Site Class = D and $S_1 = 0.044$ g, $F_v = 2.400$

Equation (3.4.1-1):

$$A_S = F_{PGA} \text{ PGA} = 1.600 \times 0.098 = 0.157 \text{ g}$$

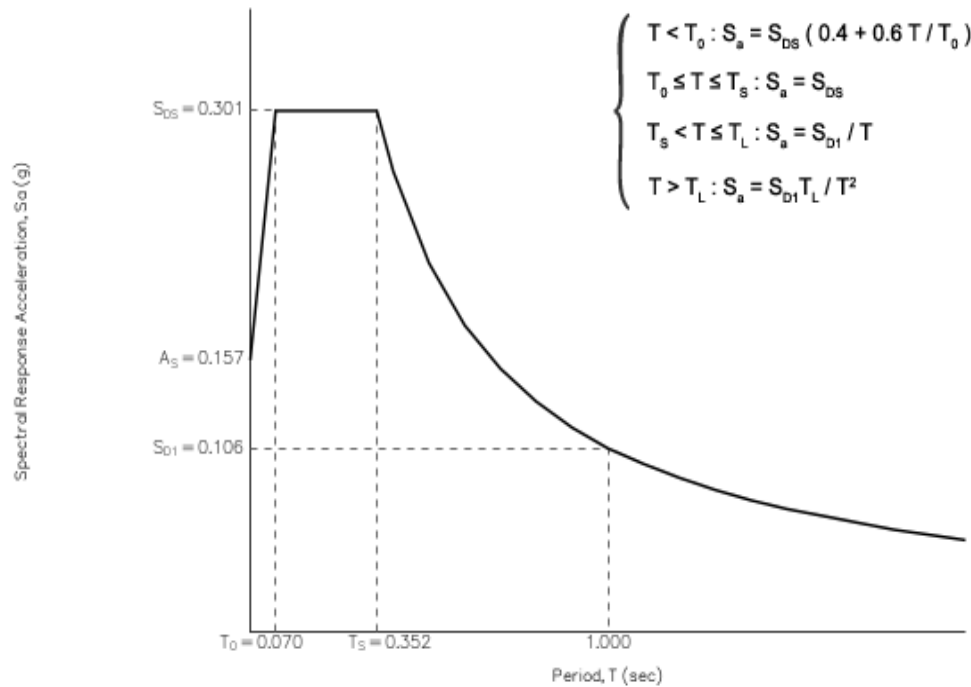
Equation (3.4.1-2):

$$S_{DS} = F_a S_S = 1.600 \times 0.188 = 0.301 \text{ g}$$

Equation (3.4.1-3):

$$S_{D1} = F_v S_1 = 2.400 \times 0.044 = 0.106 \text{ g}$$

Figure 3.4.1-1: Design Response Spectrum



Article 3.5 - Selection of Seismic Design Category (SDC)

Table 3.5-1—Partitions for Seismic Design Categories A, B, C, and D

VALUE OF S_{D1}	SDC
$S_{D1} < 0.15g$	A
$0.15g \leq S_{D1} < 0.30g$	B
$0.30g \leq S_{D1} < 0.50g$	C
$0.50g \leq S_{D1}$	D

For $S_{D1} = 0.106\text{ g}$, Seismic Design Category = A

Seismic Design Category $\equiv$ “the design category in accordance with Table 3.5-1” = A

References

1. *Figure 3.4.1-2*: <https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/AASHTO-2009-Figure-3.4.1-2.pdf>
2. *Figure 3.4.1-3*: <https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/AASHTO-2009-Figure-3.4.1-3.pdf>
3. *Figure 3.4.1-4*: <https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/AASHTO-2009-Figure-3.4.1-4.pdf>

Micropile Evaluation



Foundation Design Parameters in Bedrock

Project:	Barrell Bridge	Project No.:	09.0025948.00
Location:	York, ME		
Calculated By:	B.Cardali	Date:	12/2/2017
Checked By:	A.Blaissdell	Date:	12/2/2017

Objective: Develop foundation design parameters for micropiles in bedrock, including axial support and p-y curves for lateral evaluation using AASHTO methodology and NCHRP Synthesis 360.

Subsurface Information: Rock core data from test borings BB-YCGB-101, 104, 201 and 202, including rock type and RQD, and laboratory test data, including unconfined compressive strength, secant modulus of elasticity and Poisson's ratio for two specimens.

Approach:

- 1) Evaluate Geologic Strength Index (GSI) in accordance with AASHTO methodology for two rock conditions: Best Estimate (BE), corresponding to average rock conditions, and Upper Bound (UB), corresponding to highest quality anticipated rock condition. See pages 2-4.
- 2) Evaluate side resistance of micropile socket in rock using BE rock properties to assess required micropile length. Use resistance factors for untested micropile. See pages 3 and 5.
- 3) Develop p-y curves for bedrock using Gabr et al (2002) method as presented in the National Cooperative Highway Research Program (NCHRP) Synthesis 360, "Rock Socketed Shafts for Highway Structure Foundations." Develop curves for 8" socket and 9-5/8" casing, for both BE and UB conditions. BE are assumed for the portion of the casing in an ungrouted overdrilled 11" socket, and UB are assumed for the portion of the casing grouted in the overdrilled 11" socket and in the 8" socket. UB controls for lateral pile analyses for foundation in direct contact with rock because stresses in the pile are highest for the stiffer p-y curves. See calculations and plotted curves on pages 6-9. Plotted p-y curves are used as user-entered p-y curves in LPile.

Calculation: GSI-Based Rock Parameters

References: 1) AASHTO LRFD Bridge Design Specifications, 7th Ed. (2014, with 2015 and 2016 Interims)

Parameter Description	Parameter Symbol	BE Values	UB Values	Reference
Rock Type		Metawacke		Rock ID per boring logs/geologic mapping
Comparable Rock Texture		Metasandstone		AASHTO Table 10.4.6.4-1
Unconfined compressive strength of intact rock	q_u (psi)	17,000	21,720	Lower/upper value from two lab UCS tests
Elastic Secant Modulus of Intact Rock	E_i (ksi)	8,445	8,650	Average/upper value from two lab UCS tests, 50% strain
Poisson's Ratio of Intact Rock	ν	0.36	0.32	Average/upper value from two lab UCS tests, 50% strain
Rock Total Unit Weight	γ' (psf)	178	183	Average/upper value from two lab UCS tests
Rock Effective Unit Weight	γ' (psf)	115.6	120.6	
Geological Strength Index	GSI	45	60	AASHTO FIG 10.4.6.4-1
Hoek - Brown 2002	D	0	0	Hoek - Brown 2002
Rock Quality Designation	RQD (%)	0	40	Based on quality of upper rock
Empirically determined rock mass parameter	s	0.002	0.012	AASHTO Eq. 10.4.6.4-2
Empirically determined rock mass parameter	a	0.51	0.50	AASHTO Eq. 10.4.6.4-3
Rock group constant	m_i	19	19	AASHTO Table 10.4.6.4-1
Empirically determined rock mass parameter	m_b	2.7	4.6	AASHTO Eq. 10.4.6.4-4
Equivalent Rock Mass Modulus, Hoek & Brown	E_{m1} (ksi)	1,088	2,579	AASHTO Table 10.4.6.5-1
Equivalent Rock Mass Modulus, Yang	E_{m2} (ksi)	672	1,374	AASHTO Table 10.4.6.5-2
Average Equivalent Rock Modulus	E_m (ksi)	880	1,976	

Notes:

1. Yellow cell is user input, white is calculated.
2. BE corresponds to Best Estimate; recommended design parameters. UB used to check high-end lateral stiffness of rock.

Table 10.5.5.2.5-1—Resistance Factors for Geotechnical Resistance of Axially Loaded Micropiles

Limit State	Method/ Ground Condition	Resistance Factor
Compression Resistance of Single Micropile, ϕ_{star}	Side Resistance (Bond Resistance): Presumptive Values	0.55 ⁽¹⁾
	Tip Resistance on Rock O'Neill and Reese (1999)	0.50
	Side Resistance and Tip Resistance Load Test	Values in Table 10.5.5.2.3-1, but no greater than 0.70
Block Failure, ϕ_{bl}	Clay	0.60
Uplift Resistance of Single Micropile, ϕ_{up}	Presumptive Values	0.55 ⁽¹⁾
	Tension Load Test	Values in Table 10.5.5.2.3-1, but no greater than 0.70
Group Uplift Resistance, ϕ_{ug}	Sand & Clay	0.5

⁽¹⁾ Apply to presumptive grout-to-ground bond values for preliminary design only in Article C10.9.3.5.2.

Table 10.5.5.2.5-2—Resistance Factors for Structural Resistance of Axially Loaded Micropiles

Section / Loading Condition	Resistance Factor
Pile Cased Length	Tension, ϕ_{TC}
	Compression, ϕ_{CC}
Pile Uncased Length	Tension, ϕ_{TU}
	Compression, ϕ_{CU}

Table 10.4.6.4-1—Values of the Constant m , by Rock Group (after Marinos and Hoek 2000; with updated values from Rocscience, Inc., 2007)

Rock type	Class	Group	Texture			
			Coarse	Medium	Fine	Very fine
SEDIMENTARY	Clastic		Conglomerate (21 ± 3)	Sandstone 17 ± 4	Siltstone 7 ± 2	Claystone 4 ± 2
			Breccia (19 ± 5)		Greywacke (18 ± 3)	Shale (6 ± 2)
						Marl (7 ± 2)
	Non-Clastic	Carbonates	Crystalline Limestone (12 ± 3)	Sparitic Limestone (10 ± 5)	Micritic Limestone (8 ± 3)	Dolomite (9 ± 3)
		Evaporites		Gypsum 10 ± 2	Anhydrite 12 ± 2	
		Organic				Chalk 7 ± 2
METAMORPHIC	Non Foliated		Marble 9 ± 3	Hornfels (19 ± 4)	Quartzite 20 ± 3	
				Metasandstone (19 ± 3)		
	Slightly foliated		Migmatite (29 ± 3)	Amphibolite 26 ± 6	Gneiss 28 ± 5	
	Foliated*			Schist (10 ± 3)	Phyllite (7 ± 3)	Slate 7 ± 4
IGNEOUS	Plutonic	Light	Granite 32 ± 3	Diorite 25 ± 5		
				Granodiorite (29 ± 3)		
		Dark	Gabbro 27 ± 3	Dolerite (16 ± 5)		
	Volcanic			Norite 20 ± 5		
		Hypabyssal		Porphyries (20 ± 5)	Diabase (15 ± 5)	Peridotite (25 ± 5)
		Lava		Rhyolite (25 ± 5)	Dacite (25 ± 3)	
				Andesite 25 ± 5	Basalt (25 ± 5)	
			Agglomerate (19 ± 3)	Volcanic breccia (19 ± 5)	Tuff (13 ± 5)	

Resistance Factors for Friction/ End Bearing on Rock, with and without testing

Metawacke, use mean value

SECTION 10: FOUNDATIONS

10-23

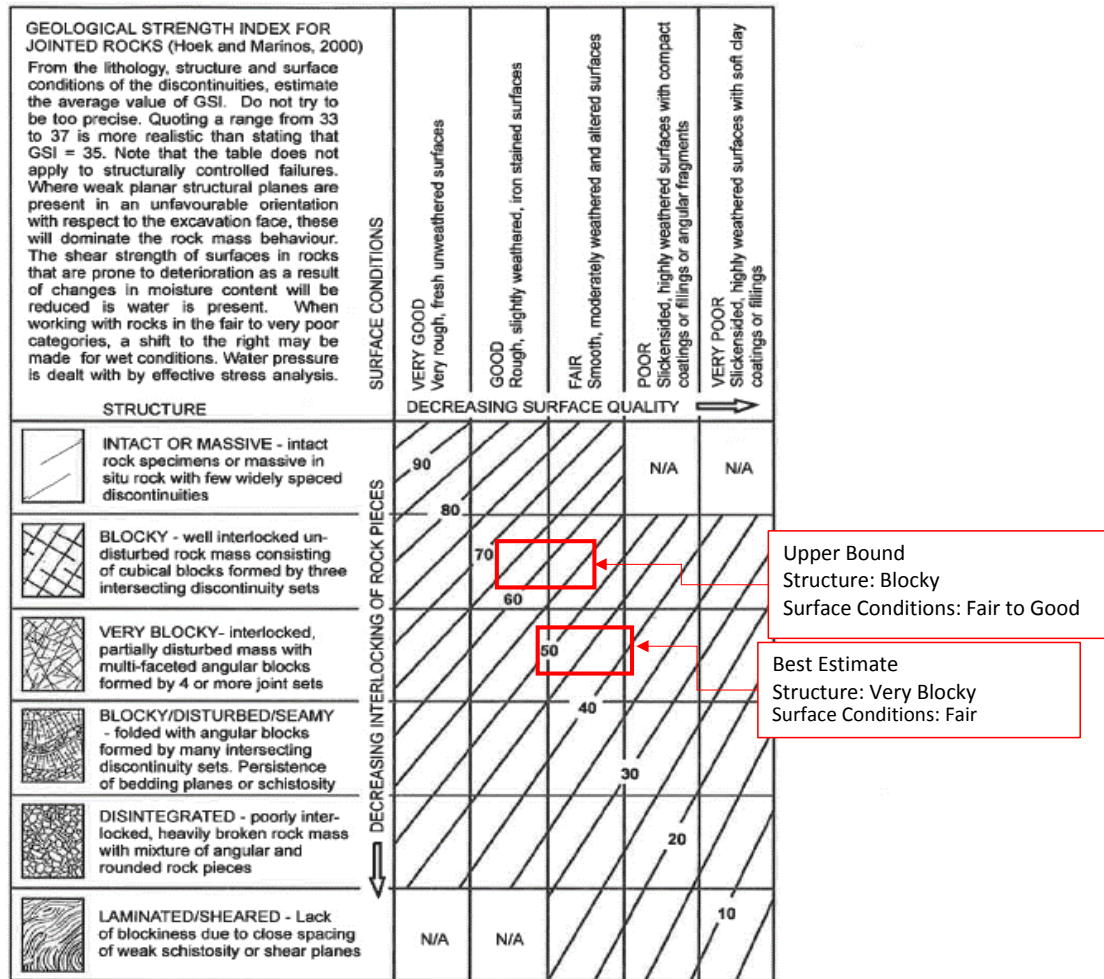


Figure 10.4.6.4-1—Determination of *GSI* for Jointed Rock Mass (Hoek and Marinos, 2000)

Calculation: Drilled Shaft (Micropile) Side Resistance in Rock

References: 1) AASHTO LRFD Bridge Design Specifications, 7th Ed. (2014, with 2015 and 2016 Interims)

Parameter Description	Parameter Symbol	Values	Reference
Socket Diameter	B (in)	8	
Method 1: Kulhawy et al 2005			
Concrete Unconfined Compressive Strength	fc' (psi)	5,000	
Design Unconfined Compressive Strength	qur-c (psi)	5,000	Minimum of Rock or Concrete
Regression Coefficient	C	1	AASHTO 10.8.3.5.4b
Nominal Unit Side Resistance (Method 1)	qs1 (ksf)	39.1	AASHTO Eq. 10.8.3.5.4b-1
Method 2: O'Neill and Reese 1999, Brown et al 2010			
Joint Modification Factor	a _E	0.45	AASHTO 10.8.3.5.4b
Nominal Unit Side Resistance (Method 2)	qs2 (ksf)	32.4	AASHTO Eq. 10.8.3.5.4b-2
Side Resistance Design Parameters			
Nominal Side Resistance	qs (ksf)	32.4	Minimum of Methods 1 and 2
Nominal Side Resistance	qs (psi)	225	
Load Testing Planned?	Y / N	N	
Resistance Factor, Compression, Strength	φ _{stat}	0.55	AASHTO Table 10.5.5.2.4-1, Kulhawy 2005
Resistance Factor, Tension, Strength	φ _{up}	0.40	AASHTO Table 10.5.5.2.4-1, Kulhawy 2006
Resistance Factor, Compression, Load Test	φ _{load}	0.70	AASHTO Table 10.5.5.2.4-1, Static Load Test
Resistance Factor, Tension, Load Test	φ _{upload}	0.60	AASHTO Table 10.5.5.2.4-1, Static Load Test
Factored Side Resistance, Compression	qs,f (ksf)	17.8	
Factored Side Resistance, Tension	qs,t (ksf)	13.0	
Factored Side Resistance/Foot Socket	Rs/ft (kip/ft)	37.3	Compression
Required Factored Compression Resistance	Rs (kips)	359	
Minimum Required Bond Length	Lbond (ft)	10.0	Bond length rounded up to nearest foot

Notes:

1. Typical side resistance values for micropile in rock from AASHTO Table C10.9.3.5.2-1 are 10.8 to 36.0 ksf; calculated value within range.

Calculation: NCHRP Synthesis 360 p-y curves

References: 1) NCHRP Synthesis 360 - Rock-Socketed Shafts for Highway Structure Foundations.

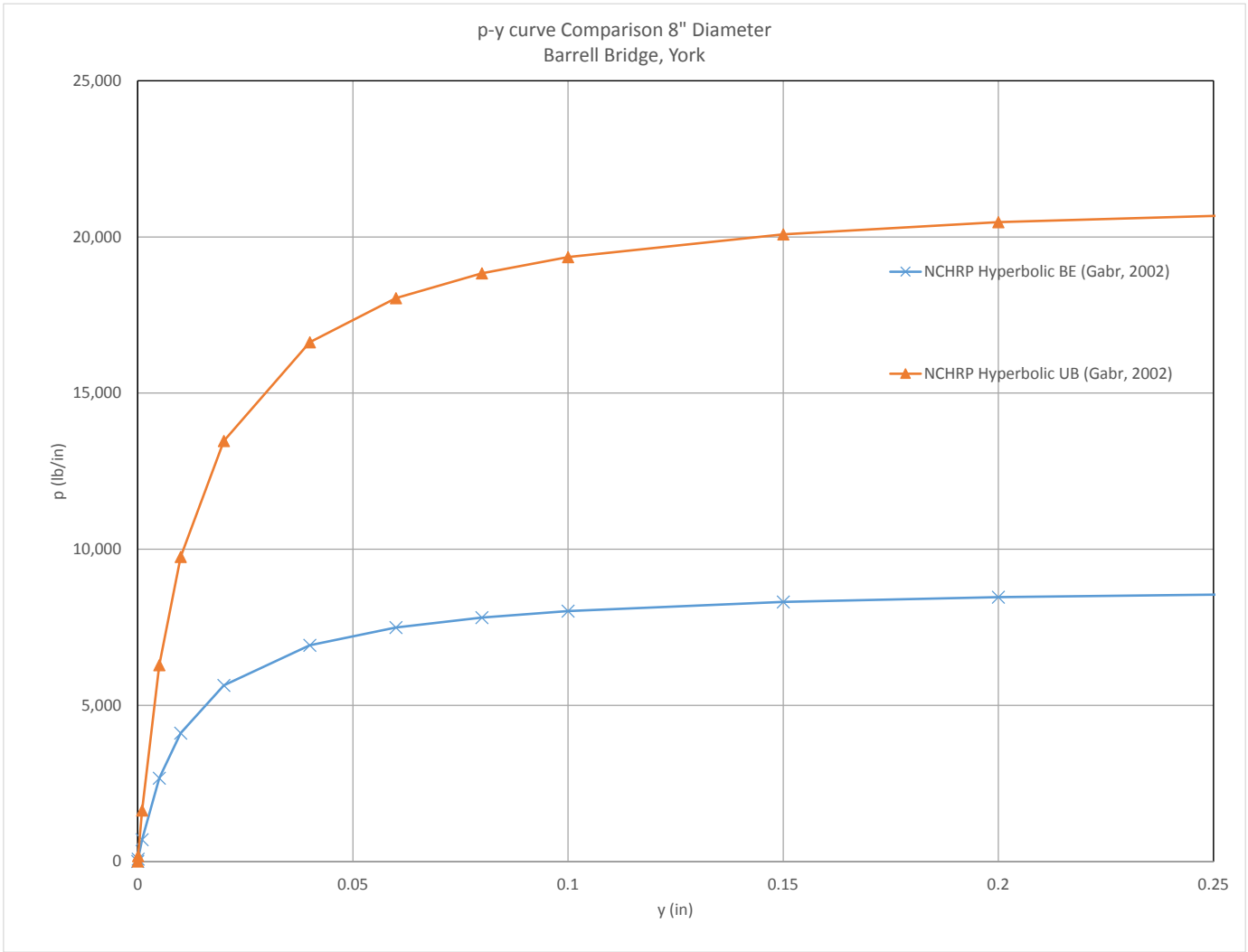
Parameter Description	Parameter Symbol	BE Values	UB Values	Reference
Pile Socket Diameter	B (in)	8	8	
Effective Composite Socket Stiffness	Esls (kips-in ²)	633,000	633,000	
Coefficient of Lateral Subgrade Reaction	k _h (lb/in ³)	94,924	221,226	NCHRP Eq. 109
Lateral Subgrade Modulus	K _h (psi)	759,391	1,769,812	NCHRP Eq. 110
Depth of Limit Normal Stress	z (ft)	2	2	
Effective Overburden at Limit Stress Depth	γ'z (psi)	1.6	1.7	
Limit Normal Stress	p _L (psi)	807	2,361	NCHRP Eq. 113
Maximum Side Resistance	τ _{max} (psi)	314	355	NCHRP Eq. 112
Ultimate Lateral Resistance	p _{ult} (lb/in)	8,966	21,729	NCHRP Eq. 111

Notes:

1. Yellow cell is user input, white is calculated.

Hyperbolic p-y curves			
BE Values		UB Values	
γ (in)	p (lb/in)	p (lb/in)	γ (in)
0	0	0	0
0.0001	75	176	0.0001
0.001	700	1,637	0.001
0.005	2,667	6,288	0.005
0.01	4,111	9,754	0.01
0.02	5,638	13,464	0.02
0.04	6,922	16,626	0.04
0.06	7,491	18,038	0.06
0.08	7,813	18,838	0.08
0.1	8,019	19,353	0.1
0.15	8,311	20,085	0.15
0.2	8,466	20,472	0.2
0.3	8,626	20,874	0.3
0.4	8,709	21,082	0.4
0.6	8,793	21,293	0.6
0.8	8,835	21,400	0.8

Calculation: p-y curves 8" diameter
Plotted p-y curves



Calculation: NCHRP Synthesis 360 p-y curves for 9.625" OD pile

References: 1) NCHRP Synthesis 360 - Rock-Socketed Shafts for Highway Structure Foundations.

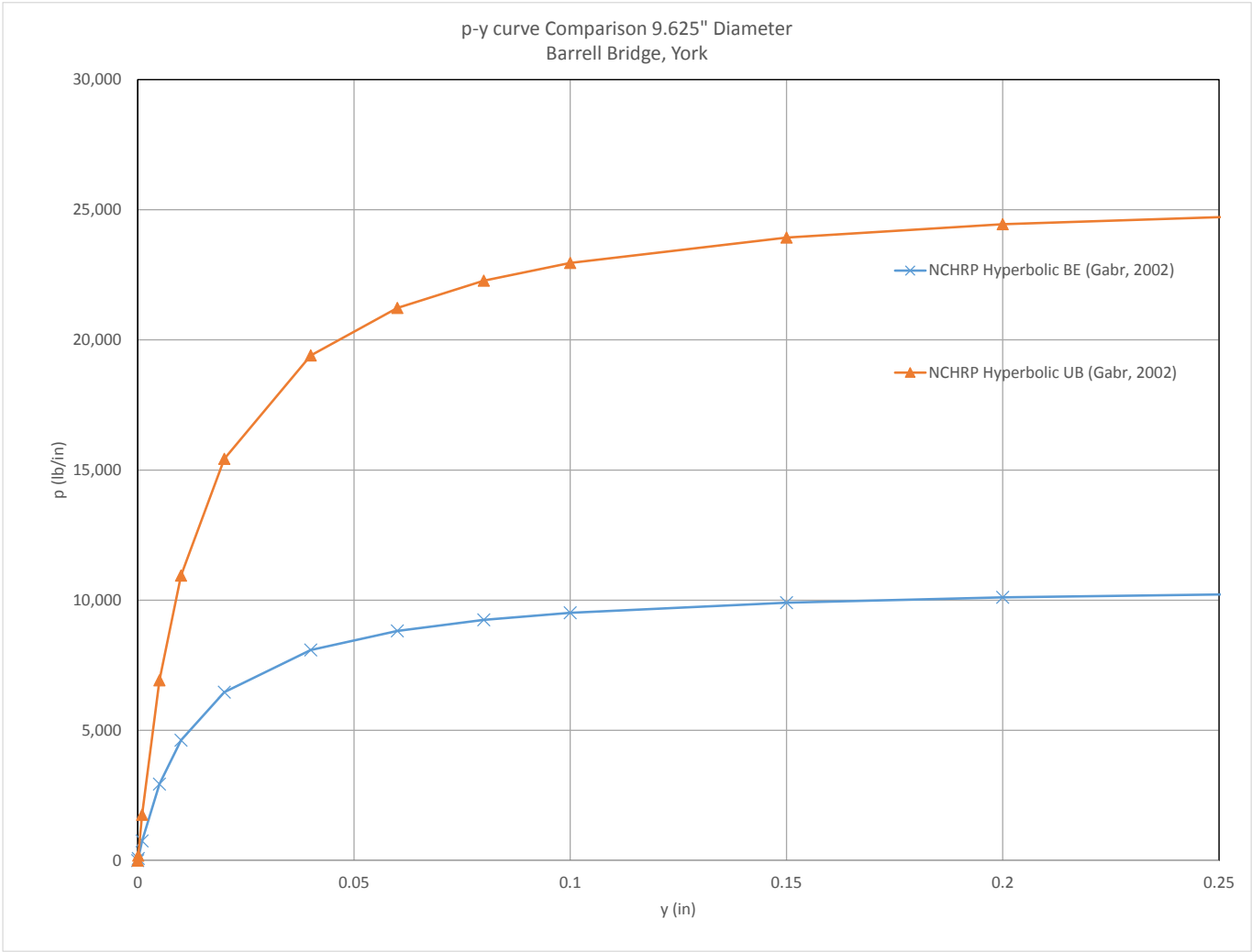
Parameter Description	Parameter Symbol	BE Values	UB Values	Reference
Pile Socket Diameter	B (in)	9.625	9.625	
Effective Composite Socket Stiffness	Esls (kips-in ²)	633,000	633,000	
Coefficient of Lateral Subgrade Reaction	k _h (lb/in ³)	83,914	195,567	NCHRP Eq. 109
Lateral Subgrade Modulus	K _h (psi)	807,673	1,882,337	NCHRP Eq. 110
Depth of Limit Normal Stress	z (ft)	2	2	
Effective Overburden at Limit Stress Depth	γ'z (psi)	1.6	1.7	
Limit Normal Stress	p _L (psi)	807	2,361	NCHRP Eq. 113
Maximum Side Resistance	τ _{max} (psi)	314	355	NCHRP Eq. 112
Ultimate Lateral Resistance	p _{ult} (lb/in)	10,787	26,142	NCHRP Eq. 111

Notes:

1. Yellow cell is user input, white is calculated.
2. UCS = 5ksi used for Reese Weak Rock comparison because it is the highest strength in the field conducted for the method.

Hyperbolic p-y curves			
BE Values		UB Values	
γ (in)	p (lb/in)	p (lb/in)	γ (in)
0	0	0	0
0.0001	80	187	0.0001
0.001	751	1,756	0.001
0.005	2,938	6,920	0.005
0.01	4,619	10,944	0.01
0.02	6,468	15,429	0.02
0.04	8,087	19,405	0.04
0.06	8,823	21,229	0.06
0.08	9,244	22,275	0.08
0.1	9,516	22,954	0.1
0.15	9,905	23,927	0.15
0.2	10,111	24,445	0.2
0.3	10,327	24,986	0.3
0.4	10,438	25,265	0.4
0.6	10,552	25,551	0.6
0.8	10,610	25,696	0.8

Calculation: *p-y curves*
Plotted p-y curves



Lateral Pile Evaluation

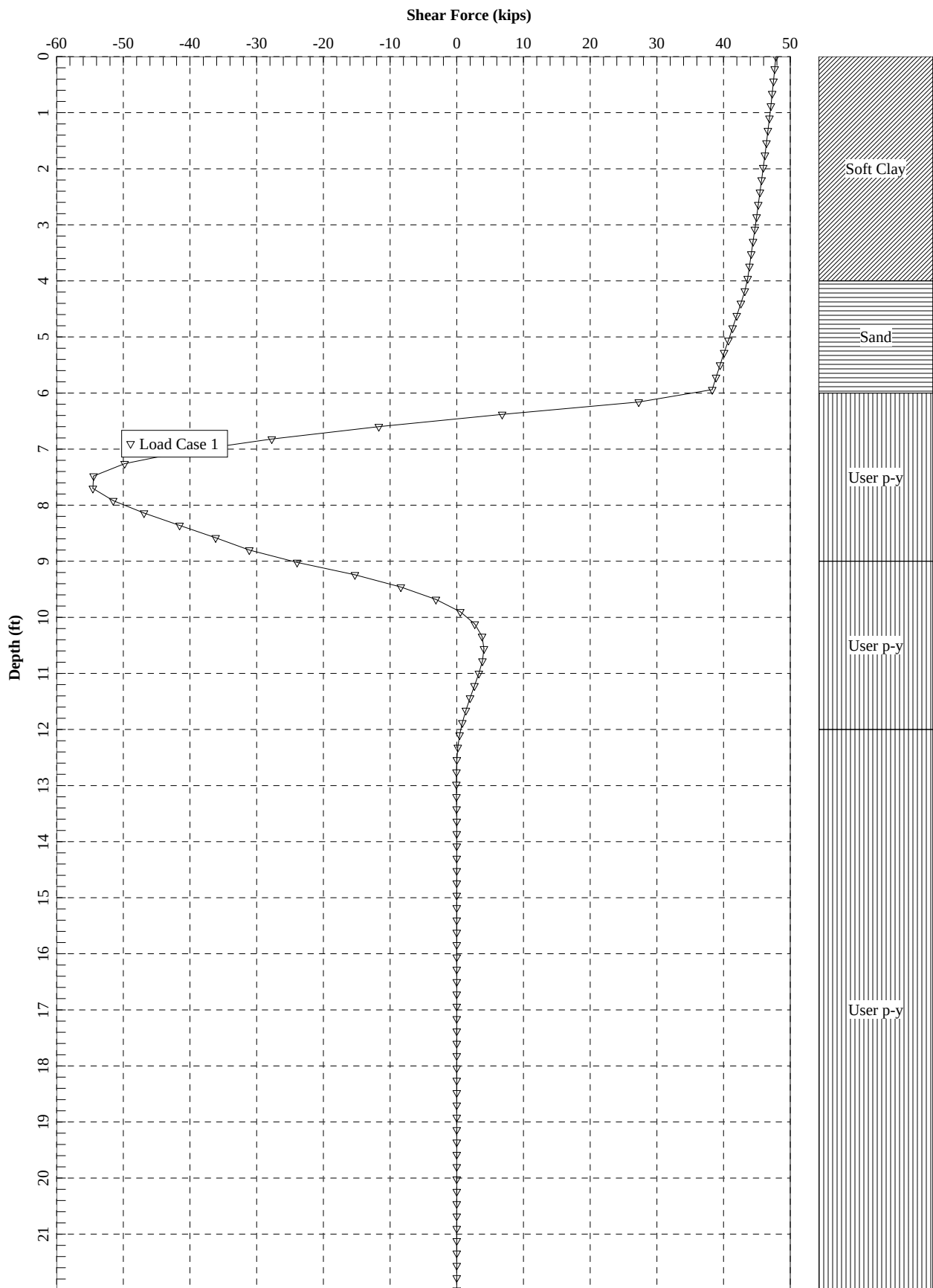
Table 2 - Updated LPILE Result Summary
Barrell Bridge #3500 Over Dolly Gordon Brook, York, ME
 GZA GeoEnvironmental, Inc.

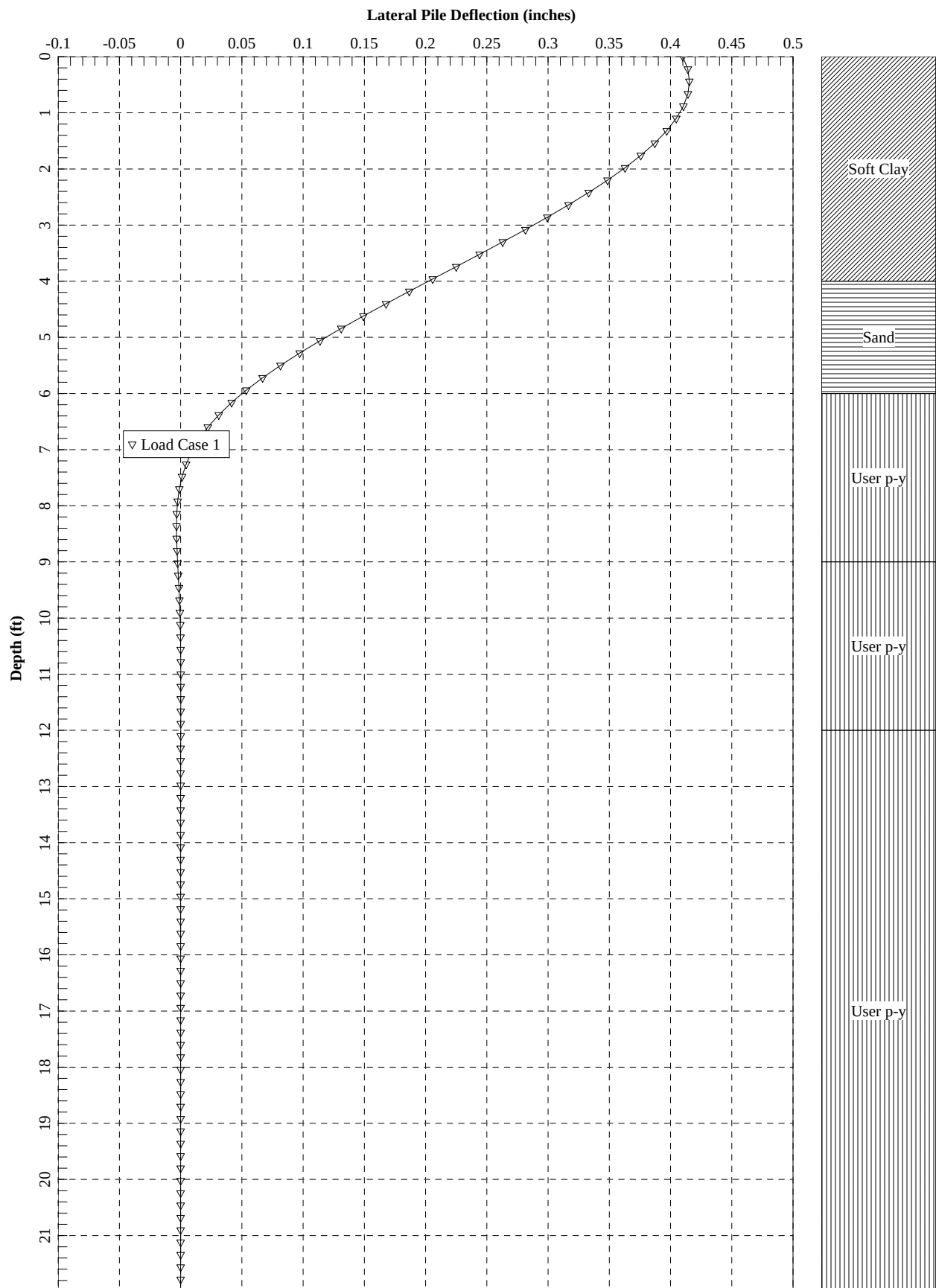
GZA FILE NO.	09.0025948.00
CALCULATED BY	B.Cardali
CHECKED BY	A. Blaisdell
DATE	12/2/2017

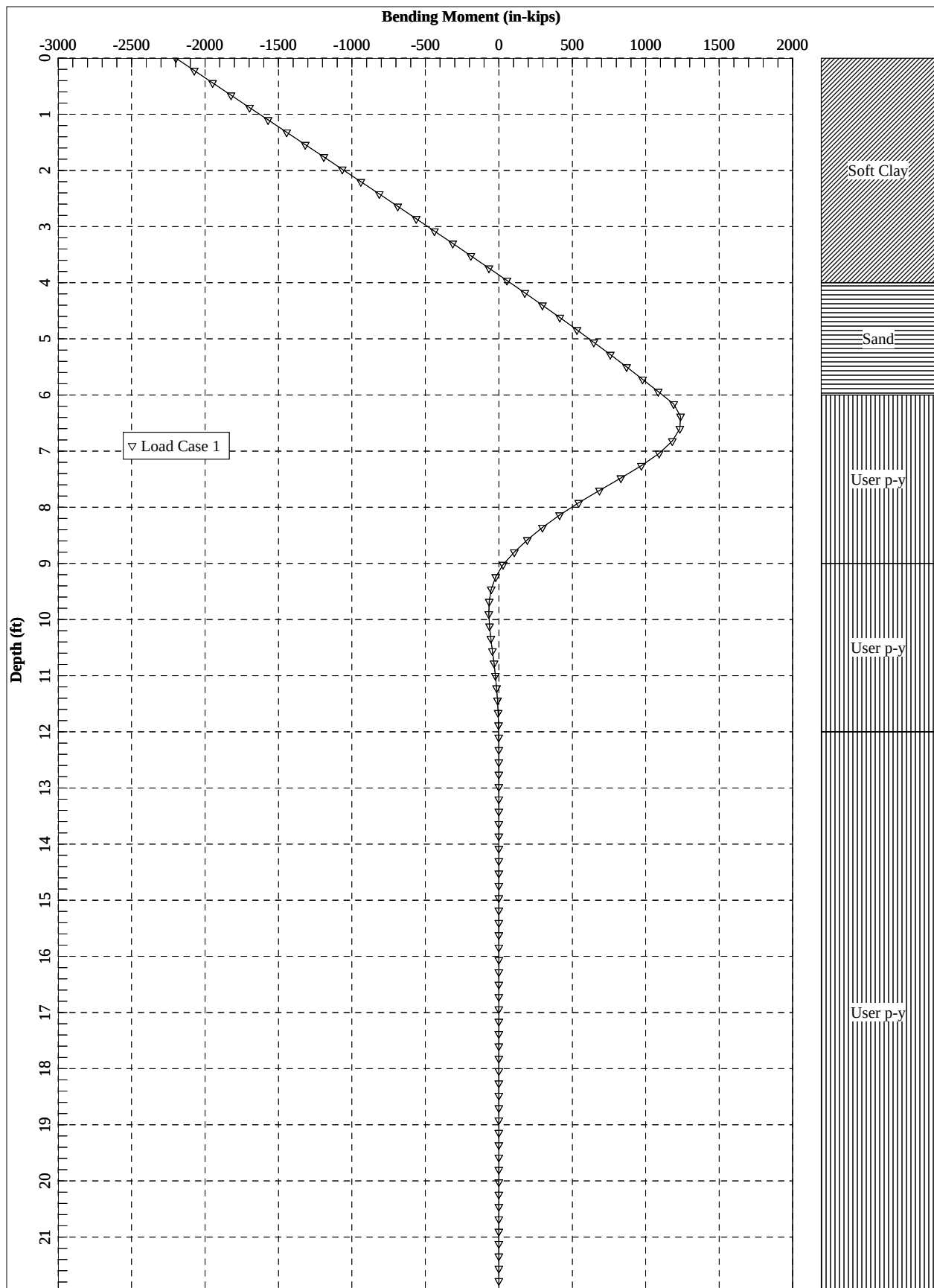
Lpile Summary Table						
Location	Pile Type and Size	Rock p-y input method	Axial Load (kips)	Shear Force for Lateral deflection of 0.41 in. (kips)	Moment at Pile Head (in-kips)	Total Stress in Steel at Pile Head (ksi)
Abutment 1	9.625" x .545" Micropile with predrill to 9' below pile cap	Upper Bound Hyperbolic	359	47.8	2198	70.2

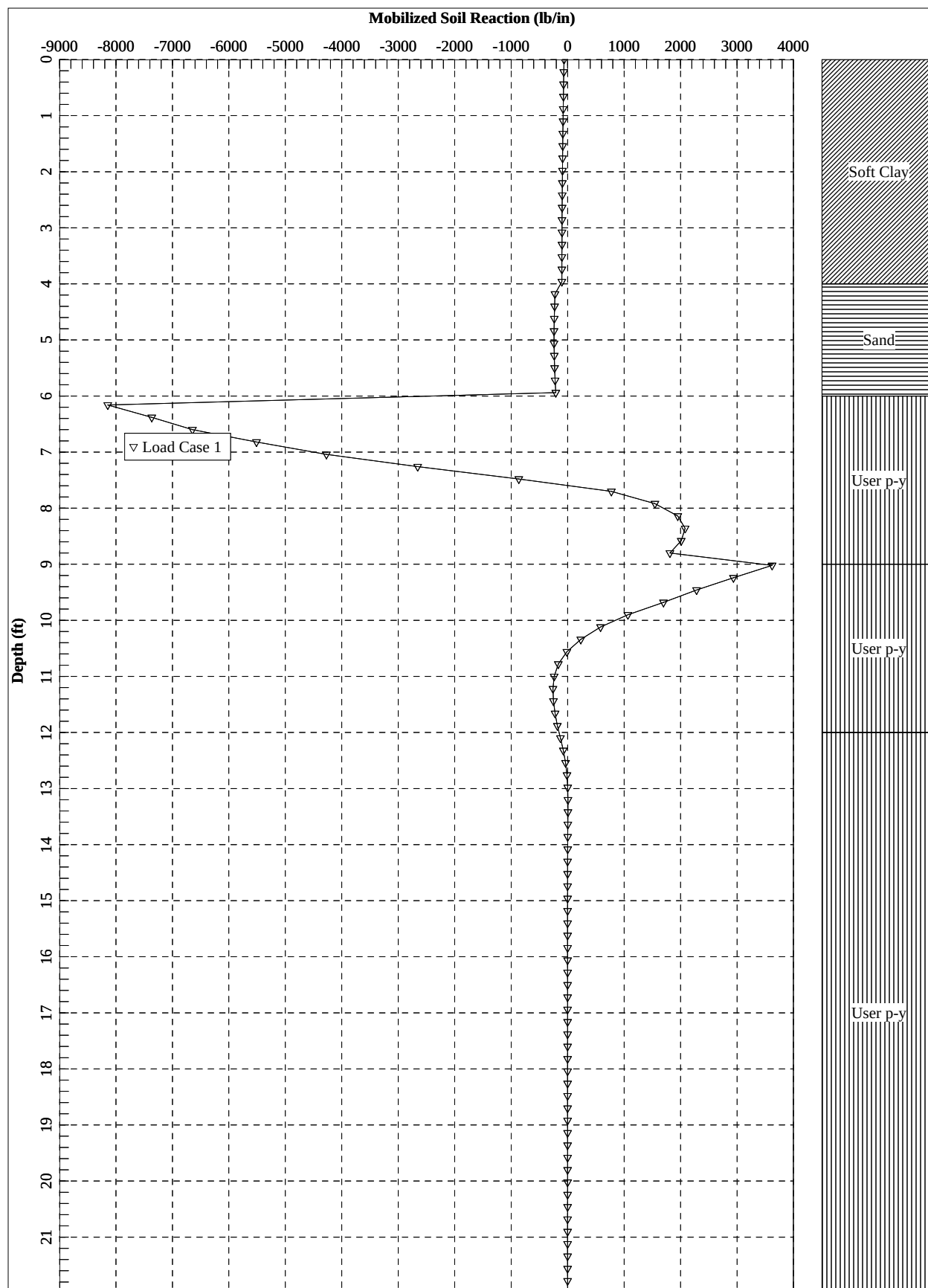
Notes:

1. Slope of 0.0021 in/in was applied at pile head in direction opposite of imposed lateral deflection.
2. The axial load is the maximum Factored Axial Load provided by Devon Eaton (MaineDOT) via email on 11/21/17. 359 kip axial load for the 6-pile configuration.
3. The predrill is based on the upper rock being cored to a depth of approximately 6 feet below top of rock, including the upper 9 feet of the casing being either in soil or an ungrouted socket, and an additional 3 feet of casing being grouted into rock. The portion of the pile in the ungrouted 11-inch core is modeled using the NCHRP BE hyperbolic p-y curve and the rest is modeled using the UB curve.









LPILE for Windows, Version 2015-08.003

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:

\09 Jobs\0025900s\09.0025948.00 - MDOT Barrell Bridge York\Work\Calcs\Lpile\

Name of input data file:

Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8d

Name of output report file:

Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o

Name of plot output file:

Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8p

Name of runtime message file:

Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8r

Date and Time of Analysis

Date: November 28, 2017 Time: 10:07:19

Problem Title

Project Name: Barrell Bridge #3500 Dolly Gordon Brook, York, ME

Job Number: 09.0025948.00

Page 1

Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o

Client: MaineDOT

Engineer:

Description:

Program Options and Settings

Computational Options:

- Use unfactored loads in computations (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
- Use of p-y modification factors for p-y curves not selected
- No distributed lateral loads are entered
- Loading by lateral soil movements acting on pile not selected
- Input of shear 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

Total number of pile sections = 2
Total length of pile = 22.00 ft
Depth of ground surface below top of pile = 0.00 ft

Pile diameters used for p-y curve computations are defined using 4 points.

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

Page 2

Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o

Point	Depth X ft	Pile Diameter in
1	0.00000	9.62500000
2	12.0000000	9.62500000
3	12.0000000	8.00000000
4	22.0000000	8.00000000

Input Structural Properties:

Pile Section No. 1:

Section Type = Drilled Shaft with Casing
 Section Length = 12.000000 ft
 Section Diameter = 9.625000 in
 Shear Capacity of Section = 0.0000 lbs

Pile Section No. 2:

Section Type = Drilled Shaft (Bored Pile)
 Section Length = 10.000000 ft
 Section Diameter = 8.000000 in
 Shear Capacity of Section = 0.0000 lbs

Ground Slope and Pile Batter Angles

Ground Slope Angle = 0.000 degrees
 = 0.000 radians
 Pile Batter Angle = 0.000 degrees
 = 0.000 radians

Soil and Rock Layering Information

The soil profile is modelled using 5 layers

Layer 1 is soft clay, p-y criteria by Matlock, 1970

Distance from top of pile to top of layer = 0.0000 ft
 Distance from top of pile to bottom of layer = 4.000000 ft
 Effective unit weight at top of layer = 54.000000 pcf
 Effective unit weight at bottom of layer = 54.000000 pcf
 Undrained cohesion at top of layer = 500.000000 psf
 Undrained cohesion at bottom of layer = 500.000000 psf
 Epsilon-50 at top of layer = 0.000000
 Epsilon-50 at bottom of layer = 0.000000

Layer 2 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 4.000000 ft

Page 3

Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o

Distance from top of pile to bottom of layer	=	6.000000 ft
Effective unit weight at top of layer	=	67.000000 pcf
Effective unit weight at bottom of layer	=	67.000000 pcf
Friction angle at top of layer	=	38.000000 deg.
Friction angle at bottom of layer	=	38.000000 deg.
Subgrade k at top of layer	=	80.000000 pci
Subgrade k at bottom of layer	=	80.000000 pci

Layer 3 is modelled using user-specified p-y curves

Distance from top of pile to top of layer = 6.000000 ft
 Distance from top of pile to bottom of layer = 9.000000 ft
 Effective unit weight at top of layer = 115.600000 pcf
 Effective unit weight at bottom of layer = 115.600000 pcf

User-input p-y curve at top of layer 3, Depth = 6.000 ft

Point No.	y in	p lbs/in
1	0.0000	0.0000
2	0.0001000	80.167075
3	0.0010000	751.410151
4	0.005000	2938.
5	0.010000	4619.
6	0.020000	6468.
7	0.040000	8087.
8	0.060000	8823.
9	0.080000	9244.
10	0.100000	9516.
11	0.150000	9905.
12	0.200000	10111.
13	0.300000	10327.
14	0.400000	10438.
15	0.600000	10552.
16	0.800000	10610.

User-input p-y curve at bottom of layer 3, Depth = 9.000 ft

Point No.	y in	p lbs/in
1	0.0000	0.0000
2	0.0001000	80.167075
3	0.0010000	751.410150
4	0.005000	2938.
5	0.010000	4619.
6	0.020000	6468.
7	0.040000	8087.
8	0.060000	8823.
9	0.080000	9244.
10	0.100000	9516.
11	0.150000	9905.
12	0.200000	10111.
13	0.300000	10327.
14	0.400000	10438.
15	0.600000	10552.
16	0.800000	10610.

Layer 4 is modelled using user-specified p-y curves

Distance from top of pile to top of layer = 9.000000 ft
 Distance from top of pile to bottom of layer = 12.000000 ft
 Effective unit weight at top of layer = 115.600000 pcf
 Effective unit weight at bottom of layer = 115.600000 pcf

User-input p-y curve at top of layer 4, Depth = 9.000 ft

Point No.	y in	p lbs/in
1	0.0000	0.0000
2	0.0001000	186.888033
3	0.0010000	1756.
4	0.005000	6920.
5	0.010000	10944.
6	0.020000	15429.
7	0.040000	19405.
8	0.060000	21229.
9	0.080000	22275.
10	0.100000	22954.
11	0.150000	23927.
12	0.200000	24445.
13	0.300000	24986.
14	0.400000	25265.
15	0.600000	25551.
16	0.800000	25696.

User-input p-y curve at bottom of layer 4, Depth = 12.000 ft

Point No.	y in	p lbs/in
1	0.0000	0.0000
2	0.0001000	186.888030
3	0.0010000	1756.
4	0.005000	6920.
5	0.010000	10944.
6	0.020000	15429.
7	0.040000	19405.
8	0.060000	21229.
9	0.080000	22275.
10	0.100000	22954.
11	0.150000	23927.
12	0.200000	24445.
13	0.300000	24986.
14	0.400000	25265.
15	0.600000	25551.
16	0.800000	25696.

Layer 5 is modelled using user-specified p-y curves

Distance from top of pile to top of layer = 12.000000 ft
 Distance from top of pile to bottom of layer = 22.000000 ft
 Effective unit weight at top of layer = 115.600000 pcf
 Effective unit weight at bottom of layer = 115.600000 pcf

User-input p-y curve at top of layer 5, Depth = 12.000 ft

Point No.	y in	p lbs/in
1	0.0000	0.0000
2	0.0001000	176.000000
3	0.0010000	1637.
4	0.005000	6288.
5	0.010000	9754.
6	0.020000	13464.
7	0.040000	16626.
8	0.060000	18038.
9	0.080000	18838.
10	0.100000	19353.
11	0.150000	20085.
12	0.200000	20472.
13	0.300000	20874.
14	0.400000	21082.
15	0.600000	21293.
16	0.800000	21400.

User-input p-y curve at bottom of layer 5, Depth = 22.000 ft

Point No.	y in	p lbs/in
1	0.0000	0.0000
2	0.0001000	176.000000
3	0.0010000	1637.
4	0.005000	6288.
5	0.010000	9754.
6	0.020000	13464.
7	0.040000	16626.
8	0.060000	18038.
9	0.080000	18838.
10	0.100000	19353.
11	0.150000	20085.
12	0.200000	20472.
13	0.300000	20874.
14	0.400000	21082.
15	0.600000	21293.
16	0.800000	21400.

(Depth of lowest soil layer extends 0.00 ft below pile tip)

Summary of Input Soil Properties

Layer Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Angle of Friction deg.	E50 or krm	kpy pci
1	Soft Clay	0.00	54.0000	500.0000	--	0.00800	--
2	Sand	4.0000	54.0000	500.0000	--	0.00800	--
		4.0000	67.0000	--	38.0000	--	80.0000

Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp80
 (Reese, et al.) 6.0000 67.0000 -- 38.0000 -- 80.0000
 3 User Input 6.0000 115.6000 -- -- --
 p-y Curves 9.0000 115.6000 -- -- --
 4 User Input 9.0000 115.6000 -- -- --
 p-y Curves 12.0000 115.6000 -- -- --
 5 User Input 12.0000 115.6000 -- -- --
 p-y Curves 22.0000 115.6000 -- -- --

Static Loading Type

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

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	5	y = 0.410000 in	S = 0.002100 in/in	359000.	N.A.

V = perpendicular shear force applied to pile head
 M = bending moment applied to pile head
 y = lateral deflection relative 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.
 Axial thrust 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 = 2

Pile Section No. 1:

Dimensions and Properties of Drilled Shaft (Bored Pile) with Permanent Casing:

Length of Section = 12.000000 ft
 Outer Diameter of Casing = 9.625000 in
 Concrete Cover Thickness Inside Casing = 3.000000 in
 Casing Wall Thickness = 0.545000 in
 Moment of Inertia of Steel Casing = 160.796181 in⁴
 Yield Stress of Casing = 80000. psi
 Elastic Modulus of Casing = 29000000. psi
 Number of Reinforcing Bars = 1 bar
 Area of Single Reinforcing Bar = 4.908739 sq. in.
 Edge-to-Edge Bar Spacing = 2.500000 in

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Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp80
 Maximum Concrete Aggregate Size = 0.750000 in
 Ratio of Bar Spacing to Aggregate Size = -3.33
 Offset of Center of Rebar Cage from Center of Pile = 0.0000 in
 Yield Stress of Reinforcing Bars = 75000. psi
 Modulus of Elasticity of Reinforcing Bars = 29000000. psi
 Gross Area of Pile = 72.759777 sq. in.
 Area of Concrete = 52.304553 sq. in.
 Cross-sectional Area of Steel Casing = 15.546485 sq. in.
 Area of All Steel (Casing and Bars) = 20.455224 sq. in.
 Area Ratio of All Steel to Gross Area of Pile = 28.11 percent

Axial Structural Capacities:

Nom. Axial Structural Capacity = 0.85 F_c A_c + F_y A_s = 1834.169 kips
 Tensile Load for Cracking of Concrete = -92.443 kips
 Nominal Axial Tensile Capacity = -1611.874 kips

Reinforcing Bar Dimensions and Positions Used in Computations:

Bar Number	Bar Diam. inches	Bar Area sq. in.	X inches	Y inches
1	2.500000	4.908739	0.00000	0.00000

NOTE: The positions of the above rebars were computed by LPILE

Concrete Properties:

Compressive Strength of Concrete = 5000. psi
 Modulus of Elasticity of Concrete = 4030509. psi
 Modulus of Rupture of Concrete = -530.330074 psi
 Compression Strain at Peak Stress = 0.002109
 Tensile Strain at Fracture of Concrete = -0.0001150
 Maximum Coarse Aggregate Size = 0.0000 in

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	359.000

Definitions of Run Messages and Notes:

C = concrete in section has cracked in tension.
 Y = stress in reinforcing steel has reached yield stress.
 T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318, Section 10.3.4.
 Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
 Position of neutral axis is measured from edge of compression side of pile.

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Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 359.000 kips

Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in ²	Depth to N Axis in	Max Comp Strain in/in	Max Tens Strain in/in	Max Conc Stress ksi	Max Steel Stress ksi	Run Msg	Run Msg
0.00000125	7.1115187	5689215.	357.0644461	0.0004463	0.0004343	1.8922169	12.9418416	12.9418416	
0.00000250	14.2230348	5689214.	180.9391636	0.0004523	0.0004283	1.9144471	13.1146093	13.1146093	
0.00000375	21.3345459	5689212.	122.2310430	0.0004584	0.0004223	1.9366018	13.2873923	13.2873923	
0.00000500	28.4460495	5689210.	92.8772128	0.0004644	0.0004163	1.9586810	13.4602178	13.4602178	
0.00000625	35.5575431	5689207.	75.2550909	0.0004704	0.0004103	1.9806845	13.6330755	13.6330755	
0.00000750	42.6690241	5689203.	62.5238431	0.0004764	0.0004042	2.0026124	13.8059687	13.8059687	
0.00000875	49.7800490	5689199.	55.1373633	0.0004825	0.0003982	2.0244646	13.9788942	13.9788942	
0.00001000	56.8919384	5689194.	48.8476185	0.0004885	0.0003922	2.0462410	14.1518532	14.1518532	
0.00001125	64.0033667	5689188.	43.9556971	0.0004945	0.0003862	2.0679417	14.3248454	14.3248454	
0.00001250	71.1147725	5689182.	40.0422521	0.0005005	0.0003802	2.0895665	14.4978711	14.4978711	
0.00001375	78.2261531	5689175.	36.8404262	0.0005066	0.0003742	2.1111153	14.6709302	14.6709302	
0.00001500	85.3375061	5689167.	34.1723147	0.0005126	0.0003682	2.1325883	14.8440226	14.8440226	
0.00001625	92.4482890	5689159.	31.9147527	0.0005186	0.0003622	2.1539853	15.0171484	15.0171484	
0.00001750	99.5601193	5689150.	29.9797654	0.0005246	0.0003562	2.1753062	15.1903075	15.1903075	
0.00001875	106.6713745	5689140.	28.3028377	0.0005307	0.0003502	2.1965511	15.3635001	15.3635001	
0.00002000	113.7825920	5689130.	26.8355836	0.0005367	0.0003442	2.2177198	15.5367260	15.5367260	
0.00002125	120.8937693	5689119.	25.5410017	0.0005427	0.0003382	2.2388124	15.7099853	15.7099853	
0.00002250	128.0049040	5689107.	24.3903134	0.0005488	0.0003322	2.2598287	15.8832780	15.8832780	
0.00002375	135.1159393	5689094.	23.3607987	0.0005548	0.0003262	2.2807688	16.0566041	16.0566041	
0.00002500	142.2270354	5689081.	22.4342815	0.0005609	0.0003202	2.3016326	16.2299634	16.2299634	
0.00002625	149.3380271	5689068.	21.5960478	0.0005669	0.0003142	2.3224200	16.4033562	16.4033562	
0.00002750	156.4489660	5689053.	20.8340571	0.0005729	0.0003082	2.3431310	16.5767824	16.5767824	
0.00002875	163.5598497	5689038.	20.1337303	0.0005790	0.0003022	2.3637656	16.7502420	16.7502420	
0.00003000	170.6706758	5689023.	19.5006939	0.0005850	0.0002963	2.3843237	16.9237350	16.9237350	
0.00003125	177.7814415	5689006.	18.9140685	0.0005911	0.0002903	2.4048052	17.0972613	17.0972613	
0.00003250	184.8921446	5688989.	18.3726035	0.0005971	0.0002843	2.4252102	17.2708210	17.2708210	
0.00003375	192.0027823	5688971.	17.8712812	0.0006032	0.0002783	2.4455385	17.4444141	17.4444141	
0.00003500	199.1133523	5688953.	17.4058005	0.0006092	0.0002723	2.4657902	17.6180406	17.6180406	
0.00003625	206.2238521	5688934.	16.9724536	0.0006153	0.0002663	2.4859651	17.7917095	17.7917095	
0.00003750	213.3342790	5688914.	16.5680272	0.0006213	0.0002604	2.5060632	17.9653937	17.9653937	
0.00003875	220.4446307	5688894.	16.1897226	0.0006274	0.0002544	2.5260845	18.1391203	18.1391203	
0.00004000	227.5549046	5688873.	15.8350908	0.0006334	0.0002484	2.5460290	18.3128804	18.3128804	
0.00004125	234.6650981	5688851.	15.5019797	0.0006395	0.0002424	2.5658965	18.4866738	18.4866738	
0.00004250	241.7752088	5688828.	15.1884905	0.0006455	0.0002364	2.5856871	18.6605005	18.6605005	
0.00004375	248.8852342	5688805.	14.8929413	0.0006516	0.0002305	2.6054007	18.8343607	18.8343607	
0.00004500	255.9951717	5688782.	14.6138370	0.0006576	0.0002245	2.6250372	19.0082543	19.0082543	
0.00004625	263.1050189	5688757.	14.3498444	0.0006637	0.0002185	2.6445967	19.1821812	19.1821812	
0.00004750	270.2147732	5688732.	14.0997703	0.0006697	0.0002126	2.6640790	19.3561415	19.3561415	
0.00004875	277.3244321	5688706.	13.8625442	0.0006758	0.0002066	2.6834841	19.5301353	19.5301353	
0.00005000	284.4340338	5688683.	13.6248754	0.0006819	0.0002006	2.7028625	19.7041291	19.7041291	
0.00005125	291.5435458	5688653.	13.3924917	0.0006879	0.0001946	2.7220625	19.8782229	19.8782229	
0.00005250	305.6530638	5688629.	13.1649081	0.0006939	0.0001887	2.7410316	20.0523448	20.0523448	
0.00005375	319.7624240	5688605.	12.9421917	0.0006999	0.0001827	2.7603316	20.2264448	20.2264448	
0.00005500	333.8719684	5688581.	12.7245081	0.0007059	0.0001768	2.7798210	20.4005448	20.4005448	
0.00005625	347.9815128	5688557.	12.5118245	0.0007119	0.0001708	2.7992910	20.5746448	20.5746448	
0.00005750	362.0910572	5688533.	12.3041409	0.0007179	0.0001649	2.8188410	20.7487448	20.7487448	
0.00005875	376.2006016	5688509.	12.1014573	0.0007239	0.0001589	2.8383910	20.9228448	20.9228448	
0.00006000	390.3101460	5688485.	11.9037737	0.0007299	0.0001529	2.8579410	21.0969448	21.0969448	
0.00006125	404.4196904	5688461.	11.7110901	0.0007359	0.0001469	2.8774910	21.2710448	21.2710448	
0.00006250	418.5292348	5688437.	11.5234065	0.0007419	0.0001409	2.8970410	21.4451448	21.4451448	
0.00006375	432.6387792	5688413.	11.3407229	0.0007479	0.0001349	2.9165910	21.6192448	21.6192448	
0.00006500	446.7483236	5688389.	11.1630393	0.0007539	0.0001289	2.9361410	21.7933448	21.7933448	
0.00006625	460.8578680	5688365.	10.9903557	0.0007599	0.0001229	2.9556910	21.9674448	21.9674448	
0.00006750	474.9674124	5688341.	10.8226721	0.0007659	0.0001169	2.9752410	22.1415448	22.1415448	
0.00006875	489.0769568	5688317.	10.6600885	0.0007719	0.0001109	2.9947910	22.3156448	22.3156448	
0.00007000	503.1865012	5688293.	10.5024049	0.0007779	0.0001049	3.0143410	22.4897448	22.4897448	
0.00007125	517.2960456	5688269.	10.3497213	0.0007839	0.0000989	3.0338910	22.6638448	22.6638448	
0.00007250	531.4055900	5688245.	10.2020377	0.0007899	0.0000929	3.0534410	22.8379448	22.8379448	
0.00007375	545.5151344	5688221.	10.0593541	0.0007959	0.0000869	3.0729910	23.0120448	23.0120448	
0.00007500	559.6246788	5688197.	9.9216705	0.0008019	0.0000809	3.0925410	23.1861448	23.1861448	
0.00007625	573.7342232	5688173.	9.7890869	0.0008079	0.0000749	3.1120910	23.3602448	23.3602448	
0.00007750	587.8437676	5688149.	9.6614033	0.0008139	0.0000689	3.1316410	23.5343448	23.5343448	
0.00007875	601.9533120	5688125.	9.5387197	0.0008199	0.0000629	3.1511910	23.7084448	23.7084448	
0.00008000	616.0628564	5688101.	9.4210361	0.0008259	0.0000569	3.1707410	23.8825448	23.8825448	

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Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o

0.00008375	476.3459598	5687713.	10.1008343	0.0008459	0.00003985	3.1952980	24.4155179	24.4155179	
0.00008625	490.5573894	5687622.	9.9493647	0.0008581	0.00002798	3.2295120	24.7654760	24.7654760	
0.00008875	504.7681258	5687528.	9.8064805	0.0008703	0.00001611	3.2634114	25.1155677	25.1155677	
0.00009125	518.9781491	5687432.	9.6714761	0.0008825	0.00000424	3.2969959	25.4657931	25.4657931	
0.00009375	533.1874390	5687333.	9.5437211	0.0008947	-0.00000762	3.3302651	25.8161521	25.8161521	
0.00009625	547.3959755	5687231.	9.4226506	0.0009069	-0.00001948	3.3632187	26.1666449	26.1666449	
0.00009875	561.6037384	5687126.	9.3077570	0.0009191	-0.00003133	3.3958561	26.5174714	26.5174714	
0.0001013	575.8107076	5687019.	9.1985827	0.0009314	-0.00004317	3.4281772	26.8680316	26.8680316	
0.0001038	590.0168630	5686910.	9.0947142	0.0009436	-0.00005502	3.4601815	27.2189255	27.2189255	
0.0001063	604.2221599	5686797.	8.9957770	0.0009558	-0.00006685	3.4918685	27.5699530	27.5699530	
0.0001088	618.4263917	5686679.	8.9014304	0.0009680	-0.00007869	3.5232379	27.9211123	27.9211123	
0.0001113	632.6291789	5686554.	8.8113640	0.0009803	-0.00009052	3.5542889	28.2724002	28.2724002	
0.0001138	646.8309009	5686418.	8.7252944	0.0009925	-0.0001023	3.5850208	28.6238129	28.6238129	
0.0001163	661.0286366	5686268.	8.6429624	0.010047	-0.0001142	3.6154329	28.9753460	28.9753460	
0.0001188	674.5620673	5686023.	8.5623450	0.010168	-0.0001262	3.6450011	29.3208455	29.3208455	C
0.0001213	688.4781563	5678170.	8.4860813	0.010289	-0.0001381	3.6745548	29.6699641	29.6699641	
0.0001238	702.3468772	5675530.	8.4128035	0.010411	-0.0001500	3.7037542	30.0187404	30.0187404	C
0.0001263	716.1557387	5672521.	8.3422958	0.010532	-0.0001619	3.7325886	30.3670333	30.3670333	C
0.0001288	729.9117182	5669217.	8.2744122	0.010653	-0.0001739	3.7610640	30.7149002	30.7149002	C
0.0001313	743.6280179	5665737.	8.2090381	0.010774	-0.0001858	3.7891924	31.0624758	31.0624758	C
0.0001338	757.2958598	5662025.	8.1460064	0.010895	-0.0001978	3.8169665	31.4096577	31.4096577	C
0.0001363	770.9083592	5658043.	8.0851643	0.011016	-0.0002098	3.8443801	31.7563519	31.7563519	C
0.0001388	784.4923283	5653999.	8.0264683	0.011137	-0.0002218	3.8714579	32.1068616	32.1068616	C
0.0001413	798.6193938	5649972.	7.9697125	0.011258	-0.0002338	3.8981741	32.4448111	32.4448111	C
0.0001438	811.5128962	5645307.	7.9148859	0.011378	-0.0002458	3.9254504	32.7945601	32.7945601	C
0.0001463	824.9692175	5640815.	7.8618524	0.011498	-0.0002579	3.9505842	33.1399716	33.1399716	C
0.0001488	838.3805059	5636171.	7.8105492	0.011618	-0.0002699	3.9762680	33.4849639	33.4849639	C
0.0001588	891.675596	5616993.	7.6206808	0.012098	-0.0003182	4.0756258	34.8621542	34.8621542	C
0.0001688	944.5303763	5597217.	7.4524967	0.012576	-0.0003666	4.1696329	36.2351445	36.2351445	C
0.0001788	996.9188286	5577168.	7.3023527	0.013053	-0.0004152	4.2583464	37.6041033	37.6041033	C
0.0001888	1049.	5557446.	7.1676097	0.013529	-0.0004638	4.3418844	38.9702800	38.9702800	C
0.0001988	1101.	5537974.	7.0458830	0.014004	-0.0005126	4.4202583	40.3333284	40.3333284	C
0.0002088	1152.	5519077.	6.9354695	0.014478	-0.0005614	4.4935551	41.6942626	41.6942626	C
0.0002188	1203.	5500790.	6.8348582	0.014951	-0.0006103	4.5618101	43.0533395	43.0533395	C
0.0002288	1254.	5483135.	6.7428066	0.015424	-0.0006593	4.6250566	44.4108450	44.4108450	C
0.0002388	1305.	5466131.	6.6582485	0.015897	-0.0007083	4.6833245	45.7670927	45.7670927	C
0.0002488	1356.	5449786.	6.5804399	0.016369	-0.0007573	4.7366401	47.1224223	47.1224223	C
0.0002588	1406.	5434028.	6.5084627	0.016841	-0.0008064	4.7850111	48.4767597	48.4767597	C
0.0002688	1456.	5418823.	6.4417311	0.017312	-0.0008555	4.8284051	49.8301683	49.8301683	C
0.0002788	1506.	5403625.	6.3797784	0.017784	-0.0009046	4.8698993	51.1849793	51.1849793	C
0.0002888	1556.	5390280.	6.3220635	0.018255	-0.0009537	4.9066229	52.5363392	52.5363392	C
0.0002988	1606.	5376640.	6.2681641	0.018726	-0.0010029	4.9235442	53.8886848	53.8886848	C
0.0003088	1656.	5363619.	6.2178037	0.019197	-0.0010520	4.9352022	55.2417612	55.2417612	C
0.0003188	1706.	5350976.	6.1705339	0.019669	-0.0011011	4.9721487	56.5940183	56.5940183	C
0.0003288	1755.	5338825.	6.1262165	0.020140	-0.0011502	4.9862127	57.9470059	57.9470059	C
0.0003388	1805.	5327029.	6.0844900	0.020611	-0.0011993	4.9953813	59.2997413	59.2997413	C
0.0003488	1854.	5315624.	6.0452008	0.021083	-0.0012485	4.9996583	60.6529262	60.6529262	C
0.0003588	1903.	5304612.	6.0081789	0.021554	-0.0012975	4.9999687	62.0069116	62.0069116	C
0.0003688	1952.	5293866.	5.9731349	0.022026	-0.0013466	4.9989512	63.3605758	63.3605758	C
0.0003788	2001.	5283488.	5.9400497	0.022498	-0.0013957	4.9993960	64.7154290	64.7154290	C
0.0003888	2050.	5273407.	5.9087218	0.022970	-0.0014447	4.9996488	66.0709042	66.0709042	C
0.0003988	2099.	5263561.	5.8789754	0.023442	-0.0014937	4.9997752	67.4264977	67.4264977	C
0.0004088	2148.	5253991.	5.8507921	0.023915	-0.0015427	4.9989852	68.7833662	68.7833662	C
0.0004188	2196.	5244064.	5.8240644	0.024388	-0.0015916	4.9989193	70.1415652	70.1415652	C
0.0004288	2245.	5235483.	5.7985769	0.024861	-0.0016406	4.9995833	71.4996821	71.4996821	C
0.0004388	2293.	5226520.	5.7743591	0.025335	-0.0016895	4.9996014	72.8590579	72.8590579	C
0.0004488	2342.	5217711.	5.7513915	0.025809	-0.0017384	4.9992509	74.2273028	74.2273028	C
0.0004588	2390.	5209233.	5.7293511	0.026283	-0.0017871	4.9988119	75.5816125	75.5816125	CY
0.0004688	2438.	5200841.	5.7083404	0.026758	-0.0018359	4.9987117	75.0000000	76.9435540	CY
0.0004788	2486.	5192637.	5.6882835	0.027233	-0.0018847	4.9993929	75.0000000	76.935524	CY
0.0004888	2534.	5184626.	5.6691728	0.027708	-0.0019334	4.9995394	75.0000000	79.0766983	CY
0.0004988	2581.	5175601.	5.6512035	0.028185	-0.0019819	4.9986658	75.0000000	80.0000000	CY

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0.0005088	2627.	5164378.	5.6348524	0.0028667	-0.0020300	4.9999984	75.0000000	80.0000000	CY
0.0005188	2672.	5150342.	5.6201952	0.0029155	-0.0020775	4.9996644	75.0000000	80.0000000	CY
0.0005288	2714.	5133267.	5.6073256	0.0029649	-0.0021243	4.9986499	75.0000000	80.0000000	CY
0.0005388	2755.	5113034.	5.5962906	0.0030150	-0.0021705	4.9999979	75.0000000	80.0000000	CY
0.0005488	2793.	5089659.	5.5870736	0.0030659	-0.0022158	4.9995446	75.0000000	80.0000000	CY
0.0006088	2991.	4912989.	5.5582943	0.0033836	-0.0024756	4.9978602	75.0000000	80.0000000	CY
0.0006688	3155.	4718113.	5.5556614	0.0037153	-0.0027214	4.9986283	75.0000000	80.0000000	CY
0.0007288	3293.	4518847.	5.5633737	0.0040543	-0.0029599	4.9967631	75.0000000	80.0000000	CY

Summary of Results for Nominal (Unfactored) Moment Capacity for Section 1

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

Load No.	Axial Thrust kips	Nominal Mom. Cap. in-kip	Max. Comp. Strain
1	359.000	2742.547	0.00300000

Note that the values of moment capacity in the table above are not factored by a strength reduction factor (ϕ -factor).

In ACI 318, the value of the strength reduction factor depends on whether the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.70).

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to ACI 318, Section 9.3.2.2 or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding bending stiffnesses computed for common resistance factor values used for reinforced concrete sections.

Axial Load No.	Resist. Factor for Moment	Nominal Moment Cap in-kips	Ult. (Fac) Ax. Thrust kips	Ult. (Fac) Moment Cap in-kips	Bend. Stiff. at Ult Mom kip-in^2
1	0.65	2743.	233.349991	1783.	5332253.
1	0.70	2743.	251.299996	1920.	5300944.
1	0.75	2743.	269.250000	2057.	5272020.

Pile Section No. 2:

Dimensions and Properties of Drilled Shaft (Bored Pile):

Length of Section	=	10.000000 ft
Shaft Diameter	=	8.000000 in
Concrete Cover Thickness	=	2.187500 in
Number of Reinforcing Bars	=	1 bar
Yield Stress of Reinforcing Bars	=	75000. psi
Modulus of Elasticity of Reinforcing Bars	=	29000000. psi
Gross Area of Shaft	=	50.265482 sq. in.
Total Area of Reinforcing Steel	=	4.908739 sq. in.
Area Ratio of Steel Reinforcement	=	9.77 percent

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Edge-to-Edge Bar Spacing	=	-2.500000 in
Maximum Concrete Aggregate Size	=	0.750000 in
Ratio of Bar Spacing to Aggregate Size	=	-3.33
Offset of Center of Rebar Cage from Center of Pile	=	0.00000 in

Axial Structural Capacities:

Nom. Axial Structural Capacity = $0.85 F_c A_c + F_y A_s$	=	560.922 kips
Tensile Load for Cracking of Concrete	=	-37.386 kips
Nominal Axial Tensile Capacity	=	-368.155 kips

Reinforcing Bar Dimensions and Positions Used in Computations:

Bar Number	Bar Diam. inches	Bar Area sq. in.	X inches	Y inches
1	2.500000	4.908739	0.00000	0.00000

NOTE: The positions of the above rebars were computed by LPile

Concrete Properties:

Compressive Strength of Concrete	=	5000. psi
Modulus of Elasticity of Concrete	=	4039509. psi
Modulus of Rupture of Concrete	=	-530.330074 psi
Compression Strain at Peak Stress	=	0.002100
Tensile Strain at Fracture of Concrete	=	-0.0001150
Maximum Coarse Aggregate Size	=	0.750000 in

Number of Axial Thrust Force Values Determined from Pile-head Loadings = 1

Number	Axial Thrust Force kips
1	359.000

Definitions of Run Messages and Notes:

C = concrete in section has cracked in tension.
Y = stress in reinforcing steel has reached yield stress.
T = ACI 318 criteria for tension-controlled section met, tensile strain in reinforcement exceeds 0.005 while simultaneously compressive strain in concrete more than 0.003. See ACI 318, Section 10.3.4.
Z = depth of tensile zone in concrete section is less than 10 percent of section depth.

Bending Stiffness (EI) = Computed Bending Moment / Curvature.
Position of neutral axis is measured from edge of compression side of pile.
Compressive stresses and strains are positive in sign.
Tensile stresses and strains are negative in sign.

Axial Thrust Force = 359.000 kips

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Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o										
Bending Curvature rad/in.	Bending Moment in-kip	Bending Stiffness kip-in2	Depth to N Axis in	Max Comp Strain in/in	Max Tens Strain in/in	Max Conc Stress ksi	Max Steel Stress ksi	Run Msg		
0.00000125	0.5699942	455995.	976.0114467	0.0012200	0.0012100	4.1116027	35.3789649			
0.00000250	1.1399833	455993.	490.0075212	0.0012250	0.0012050	4.1214780	35.5226453			
0.00000375	1.7099624	455990.	328.0070118	0.0012300	0.0012000	4.1313039	35.6664125			
0.00000500	2.2799264	455985.	247.0073563	0.0012350	0.0011950	4.1410805	35.8102667			
0.00000625	2.8498703	455979.	198.4080425	0.0012401	0.0011901	4.1508076	35.9542077			
0.00000750	3.4197890	455972.	166.0088995	0.0012451	0.0011851	4.1604852	36.0982357			
0.00000875	3.9896775	455963.	142.8669969	0.0012501	0.0011801	4.1701130	36.2423595			
0.00001000	4.5595308	455953.	125.5108697	0.0012551	0.0011751	4.1796911	36.3865522			
0.00001125	5.1293439	455942.	112.0119260	0.0012601	0.0011701	4.1892194	36.5308409			
0.00001250	5.6991116	455929.	101.2130108	0.0012652	0.0011652	4.1986976	36.6752165			
0.00001375	6.2682900	455915.	92.3777527	0.0012702	0.0011602	4.2081258	36.8196789			
0.00001500	6.8384911	455899.	85.0152374	0.0012752	0.0011552	4.2175038	36.9642283			
0.00001625	7.4080927	455883.	78.7856012	0.0012803	0.0011503	4.2268315	37.1088646			
0.00001750	7.9776290	455865.	73.4460844	0.0012853	0.0011453	4.2361089	37.2535879			
0.00001875	8.5470948	455845.	68.8186630	0.0012903	0.0011403	4.2453358	37.3983980			
0.00002000	9.1164851	455824.	64.7698191	0.0012954	0.0011354	4.2545121	37.5432951			
0.00002125	9.6857948	455802.	61.1974509	0.0013004	0.0011304	4.2636377	37.6882792			
0.00002250	10.2550190	455779.	58.0221457	0.0013055	0.0011255	4.2727126	37.8333502			
0.00002375	10.8241526	455754.	55.1812095	0.0013106	0.0011206	4.2817366	37.9785081			
0.00002500	11.3931905	455728.	52.6244868	0.0013156	0.0011156	4.2907096	38.1237530			
0.00002625	11.9621278	455700.	50.3113757	0.0013207	0.0011107	4.2996315	38.2690848			
0.00002750	12.5309593	455671.	48.2086565	0.0013257	0.0011057	4.3085023	38.4145037			
0.00002875	13.0996801	455641.	46.2888868	0.0013308	0.0011008	4.3173217	38.5600095			
0.00003000	13.6682851	455610.	44.5291979	0.0013359	0.0010959	4.3260898	38.7056023			
0.00003125	14.2367692	455577.	42.9103801	0.0013409	0.0010909	4.3348064	38.8512820			
0.00003250	14.8051274	455542.	41.4161790	0.0013460	0.0010860	4.3434714	38.9970488			
0.00003375	15.3733548	455507.	40.0327484	0.0013511	0.0010811	4.3520948	39.1429026			
0.00003500	15.9414461	455470.	38.7482200	0.0013562	0.0010762	4.3606463	39.2888434			
0.00003625	16.5093965	455432.	37.5523626	0.0013613	0.0010713	4.3691559	39.4348713			
0.00003750	17.0772008	455392.	36.4363900	0.0013664	0.0010664	4.3776136	39.5809062			
0.00003875	17.6448540	455351.	35.3923364	0.0013715	0.0010615	4.3860192	39.7271881			
0.00004000	18.2123510	455309.	34.4136871	0.0013765	0.0010565	4.3943726	39.8734771			
0.00004125	18.7796868	455265.	33.4944226	0.0013816	0.0010516	4.4026736	40.0198532			
0.00004250	19.3468564	455220.	32.6293032	0.0013867	0.0010467	4.4109223	40.1663163			
0.00004375	19.9138547	455174.	31.8136878	0.0013918	0.0010418	4.4191185	40.3128666			
0.00004500	20.4806767	455126.	31.0434512	0.0013970	0.0010370	4.4272621	40.4595039			
0.00004625	21.0473172	455077.	30.3149139	0.0014021	0.0010321	4.4353530	40.6062284			
0.00004750	21.6137713	455027.	29.6247839	0.0014072	0.0010272	4.4433911	40.7530400			
0.00004875	22.1800338	454975.	28.9701069	0.0014123	0.0010223	4.4513763	40.8999387			
0.00005125	23.3119642	454868.	27.7567351	0.0014225	0.0010125	4.4671875	41.1939977			
0.00005375	24.4430678	454755.	26.6564588	0.0014328	0.0010028	4.4827859	41.4884054			
0.00005625	25.5733943	454637.	25.6541988	0.0014430	0.0009930	4.4981707	41.7831619			
0.00005875	26.7026329	454513.	24.7374423	0.0014533	0.0009833	4.5133410	42.0782674			
0.00006125	27.8310133	454384.	23.8957195	0.0014636	0.0009736	4.5282959	42.3737220			
0.00006375	28.9584049	454249.	23.1202032	0.0014739	0.0009639	4.5430348	42.6695258			
0.00006625	30.0847670	454110.	22.4033982	0.0014842	0.0009542	4.5575567	42.9658790			
0.00006875	31.2100591	453964.	21.7389908	0.0014945	0.0009445	4.5719608	43.2621817			
0.00007125	32.3342405	453814.	21.1212021	0.0015049	0.0009349	4.5859464	43.5590341			
0.00007375	33.4572706	453658.	20.5455458	0.0015152	0.0009252	4.5998125	43.8562363			
0.00007625	34.5791086	453497.	20.0077957	0.0015256	0.0009156	4.6134584	44.1537884			
0.00007875	35.6997138	453330.	19.5043418	0.0015360	0.0009060	4.6268833	44.4516907			
0.00008125	36.8190455	453157.	19.0320183	0.0015464	0.0008964	4.6400862	44.7499433			
0.00008375	37.9370629	452980.	18.5880375	0.0015567	0.0008867	4.6530664	45.0485464			
0.00008625	39.0537251	452797.	18.1699350	0.0015672	0.0008772	4.6658231	45.3475001			
0.00008875	40.1689912	452608.	17.7755238	0.0015776	0.0008676	4.6783553	45.6468047			
0.00009125	41.2828204	452414.	17.4028569	0.0015880	0.0008580	4.6906624	45.9464604			
0.00009375	42.3951716	452215.	17.0501948	0.0015985	0.0008485	4.7027433	46.2464673			
0.00009625	43.5060040	452010.	16.7159786	0.0016089	0.0008389	4.7145974	46.5468256			

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Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o										
0.00009875	44.6152764	451800.	16.3988076	0.0016194	0.0008294	4.7262237	46.8475357			
0.0001013	45.7229479	451585.	16.0974193	0.0016299	0.0008199	4.7376215	47.1485976			
0.0001038	46.8289773	451364.	15.8106726	0.0016404	0.0008104	4.7487898	47.4500116			
0.0001063	47.9333234	451137.	15.5375343	0.0016509	0.0008009	4.7597279	47.7517780			
0.0001088	49.0359451	450905.	15.2770659	0.0016614	0.0007914	4.7704349	48.0538969			
0.0001113	50.1368011	450668.	15.0284133	0.0016719	0.0007819	4.7809099	48.3563686			
0.0001138	51.2358501	450425.	14.7907975	0.0016825	0.0007725	4.7911521	48.6591935			
0.0001163	52.3330508	450177.	14.5635065	0.0016930	0.0007630	4.8011606	48.9623716			
0.0001188	53.4283618	449923.	14.3458883	0.0017036	0.0007536	4.8109347	49.2659032			
0.0001213	54.5217416	449664.	14.1373447	0.0017142	0.0007442	4.8204734	49.5697888			
0.0001238	55.6131487	449399.	13.9373258	0.0017247	0.0007347	4.8297759	49.8740284			
0.0001263	56.7025417	449129.	13.7453252	0.0017353	0.0007253	4.8388413	50.1786224			
0.0001288	57.7898788	448853.	13.5608760	0.0017460	0.0007160	4.8476888	50.4835710			
0.0001313	58.8751185	448572.	13.3835466	0.0017566	0.0007066	4.8562576	50.7888746			
0.0001338	59.9582190	448286.	13.2129380	0.0017672	0.0006972	4.8646067	51.0945335			
0.0001363	61.0391386	447994.	13.0486802	0.0017779	0.0006879	4.8727152	51.4005479			
0.0001388	62.1178353	447696.	12.8904300	0.0017885	0.0006785	4.8805825	51.7069181			
0.0001413	63.1942674	447393.	12.7378686	0.0017992	0.0006692	4.8882074	52.0136445			
0.0001438	64.2683928	447084.	12.5906991	0.0018099	0.0006599	4.8955893	52.3207274			
0.0001463	65.3401696	446770.	12.4486453	0.0018206	0.0006506	4.9027272	52.6281671			
0.0001488	66.4095557	446451.	12.3114491	0.0018313	0.0006413	4.9096202	52.9359639			
0.0001513	67.4762346	446137.	12.1792511	0.0018420	0.0006320	4.9163640	53.2442000			
0.0001538	68.5405577	445818.	12.0519511	0.0018527	0.0006227	4.9230668	53.5494456			
0.0001563	69.6007989	445500.	11.9292511	0.0018634	0.0006134	4.9297696	53.8546912			
0.0001588	70.6623486	445177.	11.8066331	0.0018743	0.0006043	4.9364726	54.1707295			
0.0001613	71.7175377	444853.	11.6848359	0.0018851	0.0005951	4.9431754	54.4818674			
0.0001638	72.7727291	444530.	11.5630387	0.0018959	0.0005859	4.9498782	54.7929053			
0.0001663	73.8279205	444206.	11.4412415	0.0019067	0.0005767	4.9565810	55.1039432			
0.0001688	74.8831119	443883.	11.3194443	0.0019175	0.0005675	4.9632838	55.4149811			
0.0001713	75.9383033	443559.	11.1976471	0.0019283	0.0005583	4.9699866	55.7260190			
0.0001738	76.9934947	443236.	11.0758499	0.0019391	0.0005491	4.9766894	56.0370569			
0.0001763	78.0486861	442912.	10.9540527	0.0019499	0.0005399	4.9833922	56.3480948			
0.0001788	79.1038775	442589.	10.8322555	0.0019607	0.0005307	4.9900950	56.6591327			
0.0001813	80.1590689	442265.	10.7104583	0.0019715	0.0005215	4.9967978	56.9701706			
0.0001838	81.2142603	441942.	10.5886611	0.0019823	0.0005123	4.9935006	57.2812085			
0.0001863	82.2694517	441618.	10.4668639	0.0019931	0.0005031	4.9902034	57.5922464			
0.0001888	83.3246431	441295.	10.3450667	0.0020039	0.0004939	4.9869062	57.9032843			
0.0001913	84.3798345	440971.	10.2232695	0.0020147	0.0004847	4.9836090	58.2143222			
0.0001938	85.4350259	440648.	10.1014723	0.0020255	0.0004755	4.9803118	58.5253601			
0.0001963	86.4902173	440324.	9.9796751	0.0020363	0.0004663	4.9770146	58.8363980			
0.0001988	87.5454087	440001.	9.8578779	0.0020471	0.0004571	4.9737174	59.1474359			
0.0002013	88.6006001	439677.	9.7360807	0.0020579	0.0004479	4.9704202	59.4584738			
0.0002038	89.6557915	439354.	9.6142835	0.0020687	0.0004387	4.9671230	59.7695117			
0.0002063	90.7109829	439030.	9.4924863	0.0020795	0.0004295	4.9638258	60.0805496			
0.0002088	91.7661743	438707.	9.3706891	0.0020903	0.0004203	4.9605286	60.3915875			
0.0002113	92.8213657	438383.	9.2488919	0.0021011	0.0004111	4.9572314	60.7026254			
0.0002138	93.8765571	438060.	9.1270947	0.0021119	0.0004019	4.9539342	61.0136633			
0.0002163	94.9317485	437736.	9.0052975	0.0021227	0.0003927	4.9506370	61.3247012			
0.0002188	95.9869399	437413.	8.8835003	0.0021335	0.0003835	4.9473398	61.6357391			
0.0002213	97.0421313	437089.	8.7617031	0.0021443	0.0003743	4.9440426	61.9467770			
0.0002238	98.0973227	436766.	8.6399059	0.0021551	0.0003651	4.9407454	62.2578149			
0.0002263	99.1525141	436442.	8.5181087	0.0021659	0.0003559	4.9374482	62.5688528			
0.0002288	100.2077055	436119.	8.3963115	0.0021767	0.0003467	4.9341510	62.8798907			
0.0002313	101.2628969	435795.	8.2745143	0.0021875	0.0003375	4.9308538	63.1909286			
0.0002338	102.3180883	435472.	8.1527171	0.0021983	0.0003283	4.9275566	63.5019665			
0.0002363	103.3732797	435148.	8.0309199	0.0022091	0.0003191	4.9242594	63.8130044			
0.0002388	104.4284711	434825.	7.9091227	0.0022199	0.0003099	4.9209622	64.1240423			
0.0002413	105.4836625	434501.	7.7873255	0.0022307	0.0003007	4.9176650	64.4350802			
0.0002438	106.5388539	434178.	7.6655283	0.0022415	0.0002915	4.9143678	64.7461181			
0.0002463	107.5940453	433854.	7.5437311	0.0022523	0.0002823	4.9110706	65.0571560			
0.0002488	108.6492367	433531.	7.4219339	0.0022631	0.0002731	4.9077734	65.3681939			
0.0002513	109.7044281	433207.	7.3001367	0.0022739	0.0002639	4.9044762	65.6792318			
0.0002538	110.7596195	432884.	7.1783395	0.0022847	0.0002547	4.9011790	65.9902697			
0.0002563	111.8148109	432560.	7.0565423	0.0022955	0.0002455	4.8978818	66.3013076			
0.0002588	112.8700023	432237.	6.9347451	0.0023063	0.0002363	4.8945846	66.6123455			
0.0002613	113.9251937	431913.	6.8129479	0.0023171	0.0002271	4.8912874	66.9233834			
0.0002638	114.9803851	431590.	6.6911507	0.0023279	0.0002179	4.8879902	67.2344213			
0.0002663	116.0355765	431266.	6.5693535	0.0023387	0.0002087	4.8846930	67.5454592			
0.0002688	117.0907679	430943.	6.4475563	0.0023495	0.0001995	4.8813958	67.8564971			
0.0002713	118.1459593	430619.	6.3257591	0.0023603	0.0001903	4.8780986	68.1675350			
0.0002738	119.2011507	430296.	6.2039619	0.0023711	0.0001811	4.8748014	68.4785729			
0.0002763	120.2563421	429972.	6.0821647	0.0023819	0.0001719	4.8715042	68.7896108			
0.0002788	121.3115335	429649.	5.9603675	0.0023927	0.0001627	4.8682070	69.1006487			
0.0002813	122.3667249	429325.	5.8385703	0.0024035	0.0001535	4.8649098	69.4116866			
0.0002838	123.4219163	429002.	5.7167731	0.0024143	0.0001443	4.8616126	69.7227245			
0.0002863	124.4771077	428678.	5.5949759	0.0024251	0.0001351	4.8583154	70.0337624			
0.0002888	125.5322991	428355.	5.4731787	0.0024359	0.0001259	4.8550182	70.3448003			
0.0002913	126.5874905	428031.	5.3513815	0.0024467	0.0001167	4.8517210	70.6558382			
0.0002938	127.6426819	427708.	5.2295843	0.0024575	0.0001075	4.8484238	70.9668761			
0.0002963	128.6978733	427384.	5.1077871	0.0024683	0.0000983	4.8451266	71.2779140			
0.0002988	129.7530647	427061.	4.9859899	0.0024791	0.0000891	4.8418294	71.5889519			
0.0003013	130.8082561	426737.	4.8641927	0.0024899	0.0000799	4.8385322	71.8999898			
0.0003038	131.8634475	426414.	4.7423955	0.0025007	0.0000707	4.8352350	72.2110277			
0.0003063	132.9186389	426090.	4.6205983	0.0025115	0.0000615	4.8319378	72.5220656			
0.0003088	133.9738303	425767.	4.4988011	0.0025223	0.0000523	4.8286406	72.8331035			
0.0003113	135.0290217	425443.	4.3770039	0.0025331	0.0000431	4.8253434	73.1441414			
0.0003138	136.0842131	425120.	4.2552067	0.0025439	0.0000339	4.8220462	73.4551793			
0.0003163	137.1394045	424796.	4.1334095	0.0025547	0.0000247	4.8187490	73.7662172			
0.0003188	138.1945959	424473.	4.0116123	0.0025655	0.0000155	4.8154518	74.0772551			
0.0003213	139.2497873	424149.	3.8898151	0.0025763	0.0000063	4.8121546	74.3882930			
0.0003238	140.3049787	423826.	3.7680179	0.0025871	0.0000000	4.8088574	74.6993309			
0.0003263	141.3601701	423502.	3.6462207	0.0025979	0.0000000	4.8055602	75.0103688			
0.0003288	142.4153615	423179.	3.5244235	0.0026087	0.0000000	4.8022630	75.3214067			
0.0003313	143.4705529	422855.	3.4026263	0.0026195	0.0000000	4.7989658	75.6324446			
0.0003338	144.5257443	422532.	3.2808291	0.0026303	0.0000000	4.7956686	75.9434825			
0.0003363	145.5809357	422208.	3.1590319	0.0026411	0.0000000	4.7923714	76.2545204			
0.0003388	146.6361271	421885.	3.03723							

Summary of Results for Nominal (Unfactored) Moment Capacity for Section 2

Moment values interpolated at maximum compressive strain = 0.003
or maximum developed moment if pile fails at smaller strains.

Load No.	Axial Thrust kips	Nominal Mom. Cap. in-kip	Max. Comp. Strain
1	359.000	155.536	0.00300000

Note that the values of moment capacity in the table above are not factored by a strength reduction factor (ϕ -factor).

In ACI 318, the value of the strength reduction factor depends on whether the transverse reinforcing steel bars are tied hoops (0.65) or spirals (0.70).

The above values should be multiplied by the appropriate strength reduction factor to compute ultimate moment capacity according to ACI 318, Section 9.3.2.2 or the value required by the design standard being followed.

The following table presents factored moment capacities and corresponding bending stiffnesses computed for common resistance factor values used for reinforced concrete sections.

Axial Load No.	Resist. Factor for Moment	Nominal Moment Cap in-kips	Ult. (Fac) Ax. Thrust kips	Ult. (Fac) Moment Cap in-kips	Bend. Stiff. at Ult Mom kip-in ²
1	0.65	155.536436	233.349991	101.098679	431903.
1	0.70	155.536436	251.299996	108.875503	426681.
1	0.75	155.536436	269.250000	116.652327	420738.

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

Pile-head conditions are Displacement and Pile-head Rotation (Loading Type 5)
Displacement of pile head = 0.410000 inches
Rotation of pile head = 2.100E-03 radians
Axial load on pile head = 359000.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb ²	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.4100	-2198137.	47846.	0.00210	0.00	5.24E+09	-64.4986	207.6542	0.00
0.2200	0.4141	-2073528.	47666.	0.00102	0.00	5.24E+09	-68.1828	434.7016	0.00
0.4400	0.4154	-1948405.	47481.	1.71E-05	0.00	5.29E+09	-71.7301	455.8559	0.00
0.6600	0.4142	-1822861.	47287.	-9.21E-04	0.00	5.32E+09	-75.1299	478.8882	0.00
0.8800	0.4105	-1696985.	47084.	-0.00179	0.00	5.35E+09	-78.3711	503.9573	0.00
1.1000	0.4047	-1570861.	46873.	-0.00259	0.00	5.39E+09	-81.4426	531.2568	0.00
1.3200	0.3969	-1444575.	46655.	-0.00333	0.00	5.42E+09	-84.3335	561.0184	0.00

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Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o

1.5400	0.3871	-1318210.	46428.	-0.00400	0.00	5.46E+09	-87.0329	593.5171	0.00
1.7600	0.3757	-1191848.	46195.	-0.00461	0.00	5.50E+09	-89.5298	629.0782	0.00
1.9800	0.3628	-1065568.	45956.	-0.00515	0.00	5.55E+09	-91.8134	668.0862	0.00
2.2000	0.3486	-939448.	45711.	-0.00562	0.00	5.60E+09	-93.8722	710.9975	0.00
2.4200	0.3331	-813562.	45461.	-0.00603	0.00	5.64E+09	-95.6950	758.3559	0.00
2.6400	0.3167	-687982.	45206.	-0.00638	0.00	5.68E+09	-97.2699	810.8147	0.00
2.8600	0.2994	-562778.	44947.	-0.00667	0.00	5.69E+09	-98.5841	869.1660	0.00
3.0800	0.2815	-438012.	44686.	-0.00690	0.00	5.69E+09	-99.6243	934.3795	0.00
3.3000	0.2630	-313749.	44422.	-0.00708	0.00	5.69E+09	-100.3760	1008.	0.00
3.5200	0.2441	-190847.	44156.	-0.00720	0.00	5.69E+09	-100.8243	1090.	0.00
3.7400	0.2250	-66964.	43890.	-0.00726	0.00	5.69E+09	-100.9532	1185.	0.00
3.9600	0.2058	55445.	43624.	-0.00726	0.00	5.69E+09	-100.7458	1292.	0.00
4.1800	0.1867	177127.	43196.	-0.00720	0.00	5.69E+09	-223.1424	3156.	0.00
4.4000	0.1678	297176.	42597.	-0.00709	0.00	5.69E+09	-230.8158	3632.	0.00
4.6200	0.1492	415486.	41980.	-0.00693	0.00	5.69E+09	-236.5804	4186.	0.00
4.8400	0.1312	531964.	41351.	-0.00671	0.00	5.69E+09	-239.7299	4825.	0.00
5.0600	0.1138	646537.	40718.	-0.00644	0.00	5.69E+09	-239.9609	5568.	0.00
5.2800	0.09719	759153.	40088.	-0.00611	0.00	5.66E+09	-237.0513	6439.	0.00
5.5000	0.08153	869782.	39471.	-0.00573	0.00	5.62E+09	-230.8216	7474.	0.00
5.7200	0.06695	978415.	38874.	-0.00529	0.00	5.58E+09	-221.1531	8721.	0.00
5.9400	0.05359	1085068.	38308.	-0.00480	0.00	5.54E+09	-208.0145	10248.	0.00
6.1600	0.04159	1189781.	27280.	-0.00426	0.00	5.51E+09	-8146.	517075.	0.00
6.3800	0.03110	1237179.	6802.	-0.00368	0.00	5.49E+09	-7367.	625349.	0.00
6.6000	0.02218	1232666.	-11694.	-0.00308	0.00	5.49E+09	-6646.	790879.	0.00
6.8200	0.01483	1181274.	-27743.	-0.00250	0.00	5.51E+09	-5512.	981346.	0.00
7.0400	0.00897	1090927.	-40659.	-0.00196	0.00	5.54E+09	-4273.	1257582.	0.00
7.2600	0.00448	970308.	-49805.	-0.00147	0.00	5.59E+09	-2656.	1563980.	0.00
7.4800	0.00121	830745.	-54451.	-0.00105	0.00	5.64E+09	-864.3596	1892380.	0.00
7.7000	-0.00104	684790.	-54509.	-6.93E-04	0.00	5.68E+09	775.1878	1959923.	0.00
7.9200	-0.00245	543935.	-51505.	-4.08E-04	0.00	5.69E+09	1546.	1663447.	0.00
8.1400	-0.00320	413617.	-46887.	-1.85E-04	0.00	5.69E+09	1952.	1612336.	0.00
8.3600	-0.00343	296724.	-41562.	-2.06E-05	0.00	5.69E+09	2081.	1600729.	0.00
8.5800	-0.00331	194208.	-36159.	9.33E-05	0.00	5.69E+09	2012.	1606804.	0.00
8.8000	-0.00294	105628.	-31111.	1.63E-04	0.00	5.69E+09	1812.	1627119.	0.00
9.0200	-0.00245	29632.	-23938.	1.94E-04	0.00	5.69E+09	3622.	3910223.	0.00
9.2400	-0.00191	-21131.	-15280.	1.96E-04	0.00	5.69E+09	2937.	4049399.	0.00
9.4600	-0.00141	-51417.	-8388.	1.79E-04	0.00	5.69E+09	2285.	4279110.	0.00
9.6800	-9.67E-04	-65757.	-3129.	1.52E-04	0.00	5.69E+09	1699.	4636712.	0.00
9.9000	-6.06E-04	-68227.	524.3869	1.21E-04	0.00	5.69E+09	1069.	4657161.	0.00
10.1200	-3.28E-04	-63218.	2706.	9.06E-05	0.00	5.69E+09	584.1463	4703557.	0.00
10.3400	-1.27E-04	-54110.	3787.	6.34E-05	0.00	5.69E+09	234.5662	4862864.	0.00
10.5600	6.89E-06	-43344.	4080.	4.08E-05	0.00	5.69E+09	-12.8813	4933844.	0.00
10.7800	8.80E-05	-32648.	3845.	2.32E-05	0.00	5.69E+09	-164.5181	4933844.	0.00
11.0000	1.29E-04	-23084.	3314.	1.02E-05	0.00	5.69E+09	-237.7423	4858916.	0.00
11.2200	1.42E-04	-15167.	2657.	1.35E-06	0.00	5.69E+09	-260.1692	4835718.	0.00
11.4400	1.36E-04	-9857.	1983.	-4.27E-06	0.00	5.69E+09	-250.2029	4845520.	0.00
11.6600	1.20E-04	-4686.	1362.	-7.46E-06	0.00	5.69E+09	-220.8936	4879733.	0.00
11.8800	9.70E-05	-1854.	830.8420	-8.97E-06	0.00	5.69E+09	-181.1928	4933844.	0.00
12.1000	7.21E-05	-282.6332	424.9992	-1.02E-05	0.00	4.56E+08	-126.9457	4646400.	0.00
12.3200	4.30E-05	405.0712	156.6706	-9.87E-06	0.00	4.56E+08	-75.6518	4646400.	0.00
12.5400	2.00E-05	563.2905	10.2744	-7.06E-06	0.00	4.56E+08	-35.2544	4646400.	0.00
12.7600	5.69E-06	472.7096	-49.4746	-4.06E-06	0.00	4.56E+08	-10.0099	4646400.	0.00
12.9800	-1.43E-06	309.7697	-59.3633	-1.80E-06	0.00	4.56E+08	2.5185	4646400.	0.00
13.2000	-3.81E-06	162.6828	-47.1765	-4.32E-07	0.00	4.56E+08	6.7139	4646400.	0.00
13.4200	-3.71E-06	61.4965	-29.6905	2.17E-07	0.00	4.56E+08	6.5331	4646400.	0.00
13.6400	-2.67E-06	5.5060	-14.8653	4.11E-07	0.00	4.56E+08	4.6980	4646400.	0.00
13.8600	-1.54E-06	-17.7714	-5.0804	3.75E-07	0.00	4.56E+08	2.7148	4646400.	0.00
14.0800	-6.87E-07	-22.0299	0.1000	2.60E-07	0.00	4.56E+08	1.2097	4646400.	0.00
14.3000	-1.69E-07	-17.7365	2.0891	1.45E-07	0.00	4.56E+08	0.2972	4646400.	0.00
14.5200	7.85E-08	-11.2747	2.2989	6.11E-08	0.00	4.56E+08	-0.1382	4646400.	0.00
14.7400	1.54E-07	-5.7144	1.7595	1.19E-08	0.00	4.56E+08	-0.2703	4646400.	0.00
14.9600	1.41E-07	-2.0069	1.0744	-1.05E-08	0.00	4.56E+08	-0.2487	4646400.	0.00

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Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o
15.1800 9.84E-08 -0.02192 0.5175 -1.63E-08 0.00 4.56E+08 -0.1731 4646400. 0.00
15.4000 5.51E-08 0.7565 0.1610 -1.42E-08 0.00 4.56E+08 -0.09695 4646400. 0.00
15.6200 2.34E-08 0.8551 -0.02123 -9.54E-09 0.00 4.56E+08 -0.04111 4646400. 0.00
15.8400 4.70E-09 0.6625 -0.08642 -5.15E-09 0.00 4.56E+08 -0.00827 4646400. 0.00
16.0600 -3.83E-09 0.4086 -0.08844 -2.05E-09 0.00 4.56E+08 0.00674 4646400. 0.00
16.2800 -6.11E-09 0.1994 -0.06534 -2.88E-10 0.00 4.56E+08 0.01076 4646400. 0.00
16.5000 -5.35E-09 0.06413 -0.03870 4.74E-10 0.00 4.56E+08 0.00942 4646400. 0.00
16.7200 -3.61E-09 -0.00584 -0.01788 6.43E-10 0.00 4.56E+08 0.00635 4646400. 0.00
16.9400 -1.96E-09 -0.03149 -0.00495 5.35E-10 0.00 4.56E+08 0.00344 4646400. 0.00
17.1600 -7.85E-10 -0.03297 0.00142 3.48E-10 0.00 4.56E+08 0.00138 4646400. 0.00
17.3800 -1.17E-10 -0.02464 0.00352 1.82E-10 0.00 4.56E+08 2.05E-04 4646400. 0.00
17.6000 1.75E-10 -0.01474 0.00338 6.78E-11 0.00 4.56E+08 -3.08E-04 4646400. 0.00
17.8200 2.41E-10 -0.00691 0.00242 5.09E-12 0.00 4.56E+08 -4.24E-04 4646400. 0.00
18.0400 2.02E-10 -0.00199 0.00139 -2.07E-11 0.00 4.56E+08 -3.55E-04 4646400. 0.00
18.2600 1.32E-10 4.58E-04 6.12E-04 -2.51E-11 0.00 4.56E+08 -2.32E-04 4646400. 0.00
18.4800 6.91E-11 0.00129 1.45E-04 -2.01E-11 0.00 4.56E+08 -1.22E-04 4646400. 0.00
18.7000 2.60E-11 0.00126 -7.57E-05 -1.27E-11 0.00 4.56E+08 -4.58E-05 4646400. 0.00
18.9200 2.21E-12 9.12E-04 -1.41E-04 -6.38E-12 0.00 4.56E+08 -3.89E-06 4646400. 0.00
19.1400 -7.65E-12 5.29E-04 -1.29E-04 -2.20E-12 0.00 4.56E+08 1.35E-05 4646400. 0.00
19.3600 -9.42E-12 2.37E-04 -8.90E-05 0.00 0.00 4.56E+08 1.66E-05 4646400. 0.00
19.5800 -7.57E-12 5.95E-05 -4.95E-05 0.00 0.00 4.56E+08 1.33E-05 4646400. 0.00
19.8000 -4.80E-12 -2.57E-05 -2.08E-05 0.00 0.00 4.56E+08 8.45E-06 4646400. 0.00
20.0200 -2.43E-12 -5.19E-05 -3.97E-06 0.00 0.00 4.56E+08 4.27E-06 4646400. 0.00
20.2400 0.00 -4.81E-05 3.64E-06 0.00 0.00 4.56E+08 1.49E-06 4646400. 0.00
20.4600 0.00 -3.36E-05 5.61E-06 0.00 0.00 4.56E+08 2.40E-09 4646400. 0.00
20.6800 0.00 -1.89E-05 4.84E-06 0.00 0.00 4.56E+08 -5.82E-07 4646400. 0.00
20.9000 0.00 -8.16E-06 3.20E-06 0.00 0.00 4.56E+08 -6.58E-07 4646400. 0.00
21.1200 0.00 -1.97E-06 1.66E-06 0.00 0.00 4.56E+08 -5.14E-07 4646400. 0.00
21.3400 0.00 6.55E-07 5.59E-07 0.00 0.00 4.56E+08 -3.18E-07 4646400. 0.00
21.5600 0.00 1.06E-06 -4.39E-08 0.00 0.00 4.56E+08 -1.39E-07 4646400. 0.00
21.7800 0.00 4.91E-07 -2.12E-07 0.00 0.00 4.56E+08 1.16E-08 4646400. 0.00
22.0000 0.00 0.00 0.00 0.00 0.00 4.56E+08 1.49E-07 2323200. 0.00

```

* This analysis computed pile response using nonlinear moment-curvature relationships. Values of total stress due to combined axial and bending stresses are computed only for elastic sections only and do not equal the actual stresses in concrete and steel. Stresses in concrete and steel may be interpolated from the output for nonlinear bending properties relative to the magnitude of bending moment developed in the pile.

Output Summary for Load Case No. 1:

```

Pile-head deflection      = 0.41000000 inches
Computed slope at pile head = 0.00206864 radians
Maximum bending moment    = -2198137. inch-lbs
Maximum shear force       = -54569. lbs
Depth of maximum bending moment = 0.000000 feet below pile head
Depth of maximum shear force = 7.70000000 feet below pile head
Number of iterations      = 11
Number of zero deflection points = 9

```

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.

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Barrel Bridge Abutment 1 9.625 in diam x .545 Over drilled micro piles NCHRP p-y UB Hyperbolic 6 pile loading.lp8o
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	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	y, in	0.4100	S, rad	0.00210	359000.	0.4100	0.00207	-54569.	-2198137.

```

Maximum pile-head deflection = 0.41000000 inches
Maximum pile-head rotation   = 0.002068636 radians

```

The analysis ended normally.

Lateral Earth Pressure Evaluation



GZA
GeoEnvironmental, Inc
 477 Congress Street
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 Portland, Maine 04101
 207-879-9190
 Fax 207-879-0099

Engineers and
 Scientists

JOB: 09.0025948.00 York Barrell Bridge
 SUBJECT: Lateral Earth Pressures
 SHEET: 1 OF 1
 CALCULATED BY B. Cardali 12/3/17
 CHECKED BY A. Blaisdell 12/4/17

Subject: Evaluate lateral earth pressure coefficients

References:

1. MaineDOT Bridge Design Guide, Chapter 3
2. AASHTO LRFD Bridge Design Specifications, 7th Edition (2014, with 2015 and 2016 Interims)

Input Parameters:

$\beta := 0\text{deg}$ Angle of backfill to the horizontal

$\theta := 90\text{deg}$ Angle of backface of wall to the horizontal

$\phi := 32\text{deg}$ Effective angle of internal friction (*Granular borrow, Soil Type 4, BDG Table 3-3*)

$\delta_f := 19.5\text{deg}$ Average value, precast concrete against clean sand/silty sand-gravel mixture (*AASHTO LRFD Table 3.11.5.3-1*)

Passive Earth Pressure on Integral Backwall:

Per BDG Section 5.4.2.11, developing full passive pressure requires that ratio of lateral abutment movement (y) to abutment height (H_b) exceeds 0.005. If the calculated rotation is significantly less, Rankine earth pressure may be considered.

$y := 0.41\text{in}$

$H_b := 10.5\text{ft}$

$\frac{y}{H_b} = 0.0033$ Ratio of lateral movement to abutment height is less than 0.05, use Rankine Pressure

Rankine Passive Earth Pressure Coefficient

$$K_{pr} := \frac{1 + \sin(\phi)}{1 - \sin(\phi)}$$

$$K_{pr} = 3.25$$