



## GEOTECHNICAL REPORT

20-1403

October 31, 2025

Sabattus River Bridge #5393 Replacement  
Route 126 (Sabattus Road) over Sabattus  
River  
Sabattus, Maine  
WIN 026184.00

**PREPARED FOR:**

Maine Department of Transportation  
Attention: Laura Krusinski, P.E.  
State House Station 16  
Augusta, ME 04333-0016

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Explorations and Geotechnical Engineering Services  
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Dear Laura:

In accordance with our Proposal, dated February 16, 2024, and project specific Assignment Letter #14, dated February 23, 2024, we have reviewed the provided information and completed geotechnical services for the subject project. The purpose of our services was to review historic subsurface information and obtain subsurface information in order to provide geotechnical recommendations for foundations and earthwork associated with the proposed construction. Our scope of services included subsurface explorations, soils laboratory testing, geotechnical analyses of the subsurface findings, and preparation of this report.

The services provided by S. W. Cole Engineering, Inc. (S.W.COLE) were conducted in accordance with our Multi-PIN Agreement with the Maine Department of Transportation (MaineDOT), No. 20200623000000000765, dated June 22, 2020. The contents of this report are subject to the limitations in Appendix A.

## **1.0 INTRODUCTION**

### **1.1 Site Conditions**

The site is Sabattus River Bridge (MaineDOT Bridge #5393) carrying Route 126 (Sabattus Road) over the Sabattus River in Sabattus, Maine. The site location is shown on the "Site Location Map" attached in Appendix B. Based on the provided information, we understand the existing structure was constructed in 1951 and consist of a ±65-foot-long, single-span, steel multi-girder bridge with cast-in-place concrete deck with concrete abutments. Historic Plans (c.1950) indicate the abutments are supported on steel H-piles.

### **1.2 Proposed Construction**

Based on the provided information, we understand the existing bridge will be replaced with a new 72-foot-long, single-span, integral abutment bridge (IAB) supported on steel H-piles that are

driven to end-bearing on bedrock. We understand the replacement structure will be constructed on the existing horizontal alignment. We understand the vertical profile will be raised 3 feet to provide more freeboard. Additionally, the structure will be widened to accommodate increased shoulder width requiring tapered embankment fills. Approach embankments will be constructed at 2H:1V or flatter. We understand 1.75H:1V riprap slopes will wrap around and in front of the abutments matching into the approach side slopes.

We understand conceptual planning includes a temporary detour structure on the northerly side of the existing crossing. For conceptual planning, we anticipate the detour structure will have a span of 66 feet. We anticipate detour approach embankments will require tapered fills of up to 8.5 feet at the easterly detour approach and 10.5 feet along the westerly detour approach.

## **2.0 EXPLORATIONS AND TESTING**

### **2.1 Explorations**

Two test borings (BB-SSR-101 and -102) were made at the site for the proposed replacement structure on April 10, 11, and 15, 2024, by Seaboard Drilling, LLC (Seaboard) using a track-mounted Diedrich D-50 drill rig. The exploration locations were selected in coordination with MaineDOT and established in the field by S.W. COLE using taped measurements from existing site features. The “as-drilled” exploration locations are shown on the “Boring Location Plan” provided in Appendix B. Logs of the test borings and a Key to Soil and Rock Descriptions and Terms used on the logs are provided in Appendix C.

### **2.2 Testing**

The test borings were drilled using a combination of solid-stem auger, cased wash boring, and NQ2 rock core drilling techniques. The soils were sampled at approximate 5-foot intervals using a split-spoon sampler and Standard Penetration Test (SPT) methods using a calibrated automatic hammer. Undisturbed Shelby tube sampling and Vane Shear Testing (VST), using a Geonor vane kit, were performed where softer cohesive soils were encountered. Upon encountering refusal, the borings BB-SSR-101 and BB-SSR-102 were advanced  $\pm 10$  feet into bedrock using NQ2 rock coring.

The Seaboard drill rig was equipped with an automatic hammer to drive the split-spoon sampler. The automatic hammer was calibrated per ASTM D4633-10 “Standard Test Method for Energy Measurement for Dynamic Penetrometers.” Corrected N-values discussed in this report were computed by applying the corresponding average energy transfer factor of 1.087 to the raw field N-values. The hammer efficiency factor (1.087), uncorrected SPT blow counts, uncorrected and corrected SPT N-values, VST results, rock core intervals, and Rock Quality Designation (RQD) are shown on the boring logs provided in Appendix C.

Laboratory testing was performed on disturbed SPT, and undisturbed Shelby tube samples obtained during the explorations. Laboratory testing was performed following applicable American Association of State Highway and Transportation Officials (AASHTO) testing procedures. Laboratory testing included nine natural water content tests, five grain size analyses (two with

hydrometer and three without hydrometer), three Atterberg limits tests, and one consolidation test. A summary and results of the laboratory testing are provided in Appendix D.

### **3.0 SUBSURFACE CONDITIONS**

#### **3.1 Surficial and Bedrock Geology**

According to the Maine Geological Survey's (MGS's) mapping of the Lisbon Falls North Quadrangle, Maine (Open-File Map 03-14)<sup>1</sup>, surficial geologic units within the site vicinity consist of Marine Deposits (Presumpscot Formation - silt, clay, and sand) and freshwater wetlands (muck, peat, silt, and sand). Based on historic subsurface information presented in Soils Reports prepared by MaineDOT in March and April 1950 and October 1955, the site is underlain by silt, sand, and organic matter over silt and clay with thin sand layers over sand and gravel. The subsurface geologic units encountered were generally consistent with the mapped geology and historic subsurface information at the site.

Bedrock in the site vicinity is mapped as Sangerville Formation, Patch Mountain Member (Open-File Map 22-15)<sup>2</sup>. This material is generally composed of biotite granite. The bedrock cored in the 2024 borings consisted of granofels. There are no mapped faults within the site vicinity.

#### **3.2 Soil and Bedrock**

Subsurface conditions at the project site were explored by drilling two test borings. Borings BB-SSR-101 and BB-SSR-102 were drilled for the proposed west and east abutments, respectively. Test boring BB-SSR-101 encountered a soils profile generally consisting of fill overlying marine clay overlying glacial till overlying bedrock. Test boring BB-SSR-102 encountered a soil profile generally consisting of fill overlying wetland alluvium overlying marine clay overlying glacial till overlying bedrock. The principal strata encountered in the explorations are summarized below. An Interpretive Subsurface Profile is attached in Appendix B. Refer to the boring logs in Appendix C for more detailed descriptions of the subsurface findings at the exploration locations.

Surficial: Test borings BB-SSR-101 and BB-SSR-102 were made within the roadway and encountered a 10-and-11-inch-thick layer of pavement, respectively.

Fill: Below the pavement, fill was extending in each boring to depths of 13.0 to 14.0 feet below ground surface (bgs), corresponding to Elevation (El.) 193.1 to 191.3 feet. Where sampled, the fill generally consisted of:

- Brown, SAND, some to little gravel, little to trace silt.
- Brown, GRAVEL, some sand, little silt.

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<sup>1</sup> Weddle, Thomas K., Normand, Amanda E., and Bernotavicz, Alexa A., 2003, Surficial geology of the Lisbon Falls North quadrangle, Maine: Maine Geological Survey, Open-File Map 03-14, map, scale 1:24,000.

<sup>2</sup> Whittaker, Amber T. H., West, David P., Jr., and Hussey, Arthur M., II, 2022, Bedrock geology of the Lisbon Falls North quadrangle, Maine: Maine Geological Survey, Geologic Map 22-15, scale 1:24,000.

The fill was generally medium dense to very dense with SPT  $N_{60}$  values ranging from 14 to 94 blows per foot (bpf).

Alluvium: Below the fill, boring BB-SSR-102 encountered a wetland alluvium to a depth of 20 feet (El. 186.1 feet). The alluvial deposit generally consisted of:

- Brown, SAND, some silt, trace gravel, with organics.

The wetland alluvium was very loose with an SPT  $N_{60}$  value of 2 bpf, where sampled.

Marine Clay: Below the fill in boring BB-SSR-101 and wetland alluvium in boring BB-SSR-102, marine clay was observed to depths of 35 to 36.3 feet bgs (El. 171.1 to 169.0 feet). The marine clay generally consisted of:

- Grey, Silty CLAY, trace fine sand.
- Grey, Silty CLAY, trace fine sand, with fine sandy silt seams.

The thickness of the marine clay deposit appears to decrease from west to east across the alignment from about 22.3 feet at the west abutment to about 15 feet at the east abutment. The sandy silt layers within the marine clay appear to increase in frequency within the lower 10 feet of the deposit.

Vane shear tests completed in the marine clay measured undisturbed undrained shear strengths ranging from about 723 to 804 pounds per square foot (psf), indicating a medium stiff consistency. The remolded shear strengths ranged from about 112 to 268 psf. Based on the ratio of peak (undisturbed) to remolded shear strength, the glaciomarine clay has a sensitivity ranging from about 3 to 7 and classified as low to medium sensitive<sup>3</sup>.

Atterberg Limits tests were conducted on three samples of the glaciomarine silt and clay. Results of the Atterberg Limits testing are summarized in the following table:

Boring No.	Sample No.	USCS Classification	Water Content (%)	Atterberg Limits			Liquidity Index (LI)
				LL	PL	PI	
BB-SSR-101	1U	CL	30.0	38	22	16	0.5
BB-SSR-101	2U	CL	35.9	36	21	15	1.0
BB-SSR-102	5D	CL	28.3	31	15	16	0.8

LL = Liquid Limit

PL = Plastic Limit

PI = Plasticity Index

The plasticity indices (PI) of these samples ranged from 15 to 16 indicating the soils generally have a low to medium plasticity<sup>3</sup>. The natural water contents for these samples ranged from about 28.3 to 35.9 percent and liquid limits (LL) ranged from 31 to 38. The liquidity indices (LI) ranged from 0.5 to 1.0. Interpretation of these results indicate the soils with a LI of 1 or less are normally or over-consolidated while those with LI in excess of 1 are on the verge of being a viscous liquid as the natural water content exceeds the LL. Soils with LI in excess of 1 have a high liquefaction

<sup>3</sup> Holtz, Robert D. and Kovacs, William D., 1981, An Introduction to Geotechnical Engineering, Prentice-Hall, Inc.

potential and loss of strength and structure when disturbed. LI values greater than or equal to 1 are also indicative of soils that are unconsolidated and are commonly referred to as “quick.”

One, one-dimensional consolidation test was conducted on an undisturbed Shelby Tube sample. Results of the test are included in Appendix D and summarized in the following table:

Boring & Sample No.	Sample Depth (ft)	Sample Elevation (ft)	Stress History			Compressibility	
			Existing Vertical Effective Stress (psf)	Maximum Previous Stress (psf)	OCR	C <sub>c</sub>	C <sub>r</sub>
BB-SSR-101, 1U	20	185.3	1,800	3,800	2.1	0.45	0.02

OCR = Over-consolidation Ratio

C<sub>c</sub> = Compression Index

C<sub>r</sub> = Recompression Index

Based on the consolidation test results, the maximum previous stress (e.g., pre-consolidation stress) within the glaciomarine deposit is greater than the existing vertical effective stress (Over-Consolidation Ratio, OCR = 2.1) indicating the glaciomarine deposit is over-consolidated.

Glacial Till: Underlying the marine clay, the borings encountered glacial till which generally consisted of:

- Grey, Sandy GRAVEL, little silt.

The glacial till was generally dense to very dense with SPT N<sub>60</sub> values ranging from 42 bpf to 50 blows for 4 inches (sampler refusal). The thickness of the glacial till was observed to be 2.9 feet at boring BB-SSR-101 and 8.4 feet at boring BB-SSR-102.

Bedrock: Bedrock was encountered and sampled in borings BB-SSR-101 and BB-SSR-102. The top of bedrock varied from about 39.2 to 43.4 feet bgs (El. 166.1 to 162.7 feet). The bedrock generally consisted of grey, medium-grained, hard, biotite-quartz granofels of the Patch Mountain Member of the Sangerville Formation. Joints were generally low angle to moderately dipping, close to moderately close, tight. The following table summarizes the approximate depths to bedrock, corresponding top of bedrock elevations and Rock Quality Designation (RQD) where encountered.

Boring Number (Substructure)	Approximate Depth to Bedrock (feet)	Approximate Bedrock Elevation (feet)	RQD (RMQ)
BB-SSR-101 (West Abutment)	39.2	166.1	R1: 50% (Poor) R2: 72% (Fair)
BB-SSR-102 (East Abutment)	43.4	162.7	R2: 70% (Fair) R3: 70% (Fair)

RQD values for the bedrock generally ranged from 50 to 72 percent corresponding to a Rock Quality of poor to fair. Detailed descriptions of the rock core and RQD values for each core run are shown on the exploration logs in Appendix C. A rock core photograph is attached in Appendix C.

### **3.3 Groundwater**

The soils encountered at the test borings were generally moist to wet from the ground surface. Water levels measured in the test borings, after drilling, ranged from a depth of 5 to 10 feet bgs. It should be noted that water was introduced during drilling; therefore, water levels indicated may not represent stabilized ground water conditions. Long term groundwater information is not available. It should be anticipated that groundwater levels will fluctuate seasonally, particularly in response to periods of snowmelt and precipitation, changes in site use and the water level of Sabattus River.

## **4.0 GEOTECHNICAL EVALUATIONS**

S.W.COLE conducted geotechnical engineering evaluations in accordance with 2020 AASHTO LRFD Bridge Design Specifications, 9<sup>th</sup> Edition (LRFD) and the MaineDOT Bridge Design Guide, 2003 Edition with revisions through June 2018 (MaineDOT BDG). Geotechnical engineering calculations and reference documents used to support the recommendations within this report are provided in Appendix E.

### **4.1 Foundation Options and Discussion**

We understand a pile-supported integral abutment bridge (IAB) is the preferred replacement structure, and driven piles are the preferred foundation option. The following sections provide geotechnical design considerations and recommendations for H-pile supported IAB.

### **4.2 Seismic Considerations**

#### **4.2.1 Seismic Design**

Seismic site class was evaluated in accordance with LRFD Article 3.10.3.1 Method B (average N-value method). AASHTO allows for an N-value of 100 to be used for bedrock in the upper 100 feet of the soil profile. Based on the subsurface information and an N-value of 100 for the bedrock, the average N-value fell below 15 bpf corresponding to an AASHTO Site Class E as defined in LRFD Table 3.10.3.1-1.

The United States Geological Survey (USGS) Seismic Design Parameters program (Version 2.1) was used to obtain the seismic design parameters for the site. Based on the assigned site class (AASHTO Site Class E) and site coordinates, the software provides the recommended AASHTO Response Spectrum for a 7 percent probability of exceedance in 75 years (1,000-year return period). The results for the project site are summarized below. Program output is provided in Appendix E.

RECOMMENDED SEISMIC DESIGN PARAMETERS	
Site Class	E
PGA	0.085 g
$S_s$	0.172 g
$S_1$	0.046 g
$F_{pga}$	2.5
$F_a$	2.5
$F_v$	3.5
$A_s$	0.21 g
$S_{DS}$	0.43 g
$S_{D1}$	0.16 g
Seismic Zone (based on $S_{D1}$ )	Zone 2

NOTE: Site Coordinates: N44.113165, W70.107872

#### 4.2.2 Liquefaction

Based on LRFD Section 10.5.4.2, the potential for liquefaction should be considered for bridges in Seismic Zone 2 underlain by loose to very loose, saturated sands and non-plastic silts. We evaluated the potential for liquefaction of the site following the liquefaction triggering method following the empirical SPT-based method by Idriss and Boulanger (2008)<sup>4</sup>.

Based on our evaluation, the lowest calculated factor of safety against liquefaction triggering is about 1.3 during a design earthquake event. Therefore, the risk of liquefaction is low and not anticipated to affect bridge design. Liquefaction triggering evaluation is provided in Appendix E.

#### 4.3 Settlement

We understand the proposed replacement structure will be generally constructed on the existing horizontal alignment; however, the vertical profile will be raised about 3 feet from existing grades. As described above, the glaciomarine soils encountered at the site are generally medium stiff in consistency with an OCR of 2.1 within the existing roadway embankment.

We estimated the magnitude of stress increase within the glaciomarine deposit as a result of the anticipated fill placement and widening using normal-weight fills with a unit weight of 125 pounds per cubic foot (pcf). Since the combination of the existing vertical effective stress and estimated stress increase from the placement of about 3 feet of fill for the approach widening will be less than the maximum previous stress, the magnitude of consolidation settlement generally will be a function of the glaciomarine clays recompression index ( $C_r = 0.02$ ).

We performed settlement evaluations at approximately Sta. 6+25 and 7+00 using RocScience Settle3 software to estimate the amount of immediate settlement resulting from the 3-foot raise in grade using normal-weight fills proposed at the east and west approaches. The settlement evaluation indicates the estimated magnitude of total ground surface settlement due to embankment grade raise will result in a total settlement of approximately 0.3 to 0.35 inches at the east and west approaches. The estimated settlement will occur immediately and as recompression since the combination of existing vertical stress and estimated stress increase

<sup>4</sup> Idriss I.M. & Boulanger, R.W., 2008, Soil Liquefaction During Earthquakes, Earthquake Engineering Research Institute.

within the glaciomarine deposit is less than the maximum past pressure. Model run output is provided in Appendix E.

**4.4 Global Stability**

We performed global stability evaluations for the north approach embankment at approximately Sta. 7+00 considering the embankment widening and 3-foot raise in roadway grade. Our slope stability analyses were made using RocScience Slide2 software.

We evaluated global stability considering the resistance factors outlined in AASHTO LRFD, Section 11.6.3.7 and guidance in Section C11.6.3.7 as follows:

Global Stability for Static Conditions

FS ≥ 1.3 ( $\phi = 0.75$ ) for slopes or walls supporting a structural element

Global Stability for Seismic Conditions

FS ≥ 1.0 ( $\phi = 1$ )

In accordance with LRFD Article 11.6.5.2.2, the seismic condition includes a seismic load by incorporating a horizontal seismic coefficient,  $k_h$  of 0.105 g, equal to one-half of the calculated acceleration coefficient ( $A_s$ ) of 0.21 g. Results of our global stability model runs are summarized in the following table and included in Appendix E.

Model	Safety Factor	
	Static	Seismic
Sta 7+00 Right; Embankment widening and 3-foot raise in road grade	1.34	1.05
Sta 7+00 Left; Embankment widening and 3-foot raise in road grade	1.31	1.03

Results of our global stability model runs indicated safety factors against global stability failure during static conditions and seismic conditions are above the referenced safety factors per LRFD Section 11.6.2.3.

**4.5 Integral Abutment H-Piles**

We understand the abutments will be integral abutments founded on a single row of steel HP 14x89 or HP 14x117 H-piles. Piles shall be end-bearing and driven to the required nominal resistance on or within bedrock. H-piles shall be 50 ksi, Grade A572 steel with pile tips conforming to 2020 MaineDOT Standard Specification 711.10 to help reduce damage to the piles during driving and improve penetration.

Based on the depth to bedrock encountered at the borings we estimate the following pile lengths:

Location	Approx. Bottom of Proposed Abutment	Approx. Top of Competent Bedrock	Estimated Pile Length <sup>1</sup> (feet)
	Elevation (feet)		
Abutment No. 1 BB-SSR-101	196.7	166.1	35
Abutment No. 2 BB-SSR-102	197.4	162.7	40

**Notes:** 1. Pile lengths are rounded up to the nearest 5-foot increment, and include additional 2-foot pile length needed for embedment in to pile cap.

The estimated pile lengths presented do not account for variations in the bedrock surface elevation, pile damage, additional footage (5 feet typical) of pile required for dynamic testing instrumentation (per ASTM D4945), or additional pile length needed to accommodate leads and driving equipment.

#### 4.5.1 Strength Limit State Design

Design of pile foundations bearing on or within bedrock at the strength limit state shall consider:

- Compressive axial geotechnical resistance of individual piles bearing on bedrock.
- Drivability resistance of individual piles driven to bedrock.
- Structural resistance of individual piles in axial compression.
- Structural resistance of individual piles in combined axial loading and flexure.

Pile groups should be designed to resist all lateral earth loads, vehicular loads, dead and live loads, and lateral forces transferred through the abutments. The pile group resistance after scour due to the design flood shall provide adequate foundation resistance using the resistance factors given in this section.

Per LRFD Article 6.5.4.2, at the strength limit state, the axial resistance factor  $\phi_c = 0.50$ , for severe driving conditions shall be applied to the structural compressive resistance of the pile. The H-piles will be subjected to lateral loading; therefore, the piles shall be evaluated for resistance against combined axial compression and flexure in accordance with LRFD Articles 6.9.2.2 and 6.15.2. Per LRFD Article 6.5.4.2, at the strength limit state, the axial resistance factor  $\phi_c = 0.70$  and the flexural resistance factor  $\phi_f = 1.0$  shall be applied to the combined axial and flexural resistance of the pile in the interaction equation (LRFD Eq. 6.9.2.2-1 or -2).

Abutment H-piles should be analyzed for determination of unbraced lengths and fixity using LPILE® 2022 (LPile) software. The calculated unbraced lengths should be used to analyze the piles in combined axial compression and flexure resistance provided in LRFD Articles 6.9.2.2 and 6.15.2.

**Structural Resistance.** The nominal axial compressive structural resistance ( $P_n$ ) for piles loaded in compression shall be as specified in LRFD Article 6.9.4.1. The nominal axial structural compressive resistance ( $P_n$ ) subject to the combined axial compression and flexure shall be evaluated based on unbraced lengths ( $l$ ) and effective length factors ( $K$ ) as determined from LPile once structural loads are available. The nominal axial structural resistance should be evaluated based on combined axial compression and flexure.

Preliminary estimates of the structural axial resistance for selected H-pile sections were calculated using a resistance factor,  $\phi_c = 0.50$ , for severe driving conditions. The unbraced pile lengths (l) and effective length factors (K) in these evaluations have been assumed. It is the responsibility of the structural engineer to calculate the nominal axial structural compressive resistance ( $P_n$ ) based on unbraced lengths (l) and effective length factors (K) determined from L-Pile.

Geotechnical Resistance. The nominal axial geotechnical resistance in the strength limit state were calculated using the guidance in LRFD Article 10.7.3.2.3 which states the nominal bearing resistance of piles driven to point bearing on hard rock shall not exceed the structural pile resistances obtained from LRFD Article 6.9.4.1 with a resistance factor  $\phi_c = 0.50$  for severe driving conditions.

Drivability Analyses. Preliminary drivability analyses were performed to determine the pile resistance that might be achieved considering available diesel hammers. The maximum driving stresses in the pile, assuming the use of 50 ksi steel, shall be less than 45 ksi. The drivability resistances were calculated using the resistance factor,  $\phi_{dyn}$ , of 0.65, for a single pile in axial compression when a dynamic test is performed as specified in LRFD Table 10.5.5.2.3-1.

A summary of the calculated factored axial compressive structural, geotechnical, and drivability resistances of selected H-piles for the strength limit states are provided in the following table.

<b>Factored Axial Pile Resistances at Strength Limit States</b>				
<b>Pile Section</b>	<b>Factored Axial Pile Resistance (kips)</b>			
	<b>Structural Resistance <math>\phi_c = 0.5</math></b>	<b>Controlling Geotechnical Resistance <math>\phi = 0.5</math></b>	<b>Drivability Resistance<sup>1</sup> <math>\phi_{dyn} = 0.65</math></b>	<b>Controlling Axial Pile Resistance</b>
HP 14x89	652	652	393	393
HP 14x117	860	860	429	429

**Notes:** 1. Drivability resistances based on Delmag D19-42.

LRFD Article 10.7.3.2.3 states the nominal axial compressive resistance of piles driven to hard rock is typically controlled by the structural resistance with a resistance factor for severe driving conditions applied. However, the estimated factored axial pile resistance from the drivability analyses for the H-pile sections are less than the controlling factored axial structural resistance per LRFD Article 10.7.3.2.3 therefore, drivability controls. The maximum applied factored axial pile load for the strength limit states should not exceed the controlling factored pile resistance shown in above table.

#### 4.5.2 Service and Extreme Limit State Design

The design of H-piles at the service limit state shall consider tolerable transverse and longitudinal movement of piles and pile group movement considering changes in soil conditions due to scour based on the design flood ( $Q_{100}$ ). For the service limit state, resistance factors of  $\phi = 1.0$  should be used in accordance with LRFD Article 10.5.5.1. The exception is the overall global stability of

the foundation which should be investigated at the Service I load combination and a resistance factor,  $\phi$ , of 0.65.

Extreme limit state design shall include pile axial compressive resistance, overall global stability of the pile group, pile failure by uplift in tension, and structural failure. The extreme event load combinations are those related to seismic forces, ice loads, debris loads, and hydraulic events. Extreme limit state design shall also check that the nominal pile foundation resistance remaining after scour due to the check flood ( $Q_{500}$ ) can support the extreme limit state loads. Resistance factors for extreme limit states, per LRFD Article 10.5.5.3, shall be taken as  $\phi = 1.0$  with the exception of uplift of piles, for which the resistance factor,  $\phi_{up}$ , shall be 0.80 or less per LRFD Article 10.5.5.3.2.

The nominal axial geotechnical pile resistance at the service and extreme limit state was calculated using the guidance in LRFD Article 10.7.3.2.3. A summary of the calculated factored axial structural, geotechnical, and drivability resistances of selected H-piles for the extreme and service limit states are provided in the following table.

<b>Factored Axial Pile Resistances at Service and Extreme Limit States</b>				
<b>Pile Section</b>	<b>Factored Axial Pile Resistance (kips)</b>			
	<b>Structural Resistance <math>\phi_c = 1.0</math></b>	<b>Controlling Geotechnical Resistance <math>\phi = 1.0</math></b>	<b>Drivability Resistance <math>\phi_{dyn} = 1.0</math></b>	<b>Controlling Axial Pile Resistance</b>
HP 14x89	1305	1305	605	605
HP 14x117	1720	1720	660	660

LRFD Article 10.7.3.2.3 states that the nominal axial compressive resistance of piles driven to hard rock is typically controlled by the structural resistance with a resistance factor for severe driving conditions applied. However, the estimated factored axial pile resistances from the drivability analyses for the H-pile sections are less than the controlling factored axial structural resistance per LRFD Article 10.7.3.2.3 and the nominal structural resistances. The maximum applied factored axial pile load for the extreme and service limit states should not exceed the controlling factored pile resistance shown in above table.

#### **4.5.3 Downdrag**

As previously discussed, we estimate about 0.3 to 0.35 inches of settlement resulting from the proposed 3-foot raise in roadway grade. We anticipate settlement will occur as recompression during construction with negligible long-term settlement. Therefore, downdrag is not considered to be an issue.

#### **4.5.4 Lateral Pile Resistance**

In accordance with LRFD Article 6.15.1, the structural analysis of piles subjected to lateral loads shall include consideration of soil-structure interaction effects as specified in LRFD Article 10.7.3.9. We anticipate expansion of the bridge deck with pile head buried below an approach slab will control lateral design. Assumptions regarding a fixed or pinned condition at the pile tip should be also confirmed with soil-structure interaction analyses.

A series of lateral pile resistance analyses were performed to evaluate pile behavior using LPILE® software using thermal deflection and axial load per pile as provided by the structural engineer. Preliminary evaluations at each abutment for an HP 14x89 and 14x117 piles are included in Appendix E. The analyses confirm the pile lengths are adequate to achieve full fixity and prevent translation of the pile tip. The designer should utilize the results of the LPILE analyses to recalculate axial compressive structural pile resistances based on unbraced pile segments and K-factors and verify pile bending stresses do not exceed allowable stresses.

Geotechnical parameters for generation of soil-resistance (p-y) curves in lateral pile analyses using LPILE® software are shown in the following Table. In general, the model developed emulates the soil at the site by using the soil layers, appropriate pile material properties, section parameters, and pile-head boundary conditions for the pile section being analyzed.

Recommended LPILE® Soil Parameters							
Elevation Range <sup>1,2</sup> (Depth Range)		Soil Layer <sup>2</sup> (Soil Model)	K <sub>static</sub> (pci)	Soil Parameters			
Top	Bottom			Effective Unit Wt. $\gamma'$ , (pcf)	Cohesion c, (psf)	e <sub>50</sub>	Friction Angle $\phi'$ , (deg)
<b>Abutment 1 (Boring BB-SSR-101)</b>							
196.7 (0)	191.3 (5.4)	med dense to v. dense Sand Fill (Sand-Reese)	90	62.6	-	-	30
191.3 (5.4)	169.0 (27.7)	med stiff Marine Clay (Soft Clay-Matlock)	-	47.6	750	0.010	-
169.0 (27.7)	166.1 (30.6)	med dense Glacial Till (Sand-Reese)	125	67.6	-	-	32
<b>Abutment 2 (Boring BB-SSR-102)</b>							
197.4 (0)	193.1 (4.3)	med dense to dense Sand Fill (Sand-Reese)	90	62.6	-	-	30
193.1 (4.3)	186.1 (11.3)	soft Silt Alluvium (Sand-Reese)	20	47.6	-	-	28
186.1 (11.3)	171.1 (26.3)	med stiff Marine Clay (Soft Clay-Matlock)	-	47.6	700	0.010	-
171.1 (26.3)	162.7 (35)	dense to v. dense Glacial Till (Sand-Reese)	125	67.6	-	-	32

Notes: 1. Bottom of Abutment 1 pile cap at El 196.7 feet, Abutment 2 at El 197.4.  
2. Groundwater at El. 204.36 feet corresponding to Q<sub>50</sub>.

#### 4.5.5 Driven Pile Resistance and Pile Quality Control

The contract documents shall require the contractor to perform a wave equation analysis for the proposed pile-hammer system and conduct dynamic pile load tests with signal matching. The first pile driven at each abutment should be dynamically tested to confirm nominal pile resistance and verify the stopping criteria developed by the contractor in the wave equation analysis. Minimum 24-hour restrrike tests will be required and should be noted on the plans. Additional dynamic tests may be required as part of the pile field quality control program if:

- Pile behavior vary radically between adjacent piles.
- Pile behavior indicates pile refusal on a boulder or in a cobble layer above bedrock.
- Pile tip is not firmly embedded in bedrock.

- Pile tip “walks” out of position and is out of tolerance.

Piles should be driven to an acceptable penetration resistance based on the results of a wave equation analysis provided by the contractor and as approved by the design team. Pile load testing should be completed by PDA testing with signal matching including one pile at each abutment. Driving stresses in the pile determined in the drivability analysis and confirmed by PDA testing shall be less than 45 ksi, in accordance with LRFD Article 10.7.8. The pile hammer should be selected such that the required pile resistance when the penetration resistance for the final 3 to 6 inches is between 3 to 15 blows per inch (bpi). If an abrupt increase in driving resistance is encountered, the driving may be terminated when the penetration is less than 0.5-inch in 10 consecutive blows. Termination criteria shall be confirmed and evaluated for the selected pile hammer.

#### **4.6 Integral Abutment Design**

Integral abutment sections shall be designed for all relevant strength, service, and extreme limit states and load combinations specified in LRFD Articles 3.4.1 and 11.5.5. Stub abutments shall be designed to resist all lateral earth loads, vehicular loads, dead and live loads, and lateral forces transferred through the integral superstructure. The design of the integral abutment at the strength limit state shall consider reinforced-concrete structural design. Strength limit state design shall also consider changes in foundation conditions and foundation resistance after scour due to the design ( $Q_{100}$ ) flood.

A resistance factor ( $\phi$ ) of 1.0 shall be used to assess abutment design at the service limit state, including: settlement, excessive horizontal movement, and movement resulting after scour due to the design ( $Q_{100}$ ) flood. The overall stability of the foundation should be investigated at the Service I Load Combination and a resistance factor,  $\phi$ , of 0.65.

Extreme limit state design of integral abutment supported on H-piles shall include pile structural resistance, pile geotechnical resistance, pile resistance in combined axial and flexure, and overall stability. Resistance factors for extreme limit state shall be taken as 1.0. Extreme limit state design shall also check that the nominal foundation resistance remaining after scour due to the check ( $Q_{500}$ ) flood can support the extreme limit state loads with a resistance factor of 1.0.

The designer may assume Soil Type 4 (MaineDOT Bridge Design Guide (BDG) Section 3.6.1) for abutment backfill material soil properties. The backfill properties are as follows:

- Angle of internal friction ( $\phi$ ) of 32 degrees.
- Total unit weight ( $\gamma$ ) of 125 pcf.
- Soil-concrete interface friction angle ( $\delta$ ) of 20 degrees.

Integral abutment sections shall be designed to withstand a lateral earth load equal to the passive pressure state. AASHTO LRFD Article C3.11.5.4 suggests full passive pressure is mobilized when the ratio of lateral abutment movement to abutment height ( $y/H$ ) is less than or equal to 0.05 in dense backfills. Additionally, Federal Highway Authority (FHWA) NHI-06-089 Figure 10-4, indicates mobilization of full passive pressure in dense backfill occurs at a  $y/H$  ratio of 0.02.

Considering the above information, the structural designer should estimate the abutment rotation (thermal expansion) and then select a passive pressure coefficient,  $K_p$ , in accordance with Figure 3.10.8-1 of the Massachusetts Department of Transportation (MassDOT) Bridge Design Manual. However, the recommended design passive earth pressure shall not be less than the passive earth pressure coefficient of 3.25 based on Rankine Theory.

Additional lateral earth pressure due to live load surcharge is required per Section 3.6.8 of the MaineDOT BDG for abutments if an approach slab is not specified. When a structural approach slab is specified, reduction, not elimination, of the surcharge load is permitted per LRFD Article 3.11.6.5. The live load surcharge may be estimated as a uniform horizontal earth pressure due to an equivalent height of soil ( $h_{eq}$ ) based on LRFD Table 3.11.6.4-1.

The abutment design shall include a drainage system behind the abutment to mitigate excessive hydrostatic pressures. Drainage behind the structure shall be in accordance with MaineDOT BDG Section 5.4.2.13. MaineDOT Geotechnical groups preferred drainage system is a French drain.

Backfill within 10 feet of the abutments and side slope fill shall conform to MaineDOT Specification 703.19 "Granular Borrow for Underwater Backfill."

Slopes in front of the pile supported integral abutments should be constructed with riprap and erosion control geotextile. The riprap slopes in front of the abutments should not exceed 1.75:1(H:V) in accordance with MaineDOT Standard Detail 610(03). The riprap slopes for approaches should not exceed 2:1(H:V) in accordance with MaineDOT Standard Detail 610(02). The 1.75:1 and 2:1 riprap slopes shall "toe-in" at least 3 feet.

#### **4.7 Frost Considerations**

According to MaineDOT BDG Section 5.2.1 and BDG Figure 5-2, pile supported integral abutments shall be embedded a minimum of 4.0 feet for frost protection. Foundations bearing on soil should be designed with an appropriate embedment for frost protection. Based on BDG Figure 5-1, Design Freezing Index Map, the design freezing index for the Sabattus, Maine area is approximately 1,500 freezing degree-days. Based on Section 5.2.1 of the MaineDOT BDG and subsurface soils encountered the maximum seasonal frost penetration is estimated to be on the order of about 6.8 feet. Considering this, we recommend soil-supported foundations should have at least 6.8 feet of soil cover to provide frost protection.

Riprap is not to be considered as contributing to the overall thickness of soils required for frost protection.

#### **4.8 Recommendations for Scour Evaluation**

Laboratory grain size analyses were performed on soil samples taken near the approximate streambed elevation to generate parameters to be used in scour analyses. Results of the grain size analyses tests are included in Appendix D and summarized in the following table:

Boring No.	Sample No.	Depth (ft)	Elevation (ft)	Estimated D <sub>95</sub> (mm)	Estimated D <sub>50</sub> (mm)	Classification of D50 Particle Size
BB-SSR-101	4D	15	190.3	0.08	0.01	Silt
BB-SSR-102	4D	15	191.1	3.1	0.06	Silt

Design at the strength limit state should consider loss of lateral and vertical support due to scour. Design at the extreme limit state should check that the nominal foundation resistance due to the check flood (Q<sub>500</sub>) event is no less than the extreme limit state loads. At the service limit state, the design shall limit movements and ensure overall stability considering scour at the design load.

For scour protection of the pile-supported abutments, the bridge and abutment slopes will be armored with riprap. It is our understanding the existing abutments will remain at or below the streambed to provide additional protection to the new abutments. In accordance with MaineDOT BDG Section 2.3.11.3, the top of the riprap shall be located at the Q<sub>50</sub> elevation. It is our understanding that new riprap slopes in front of the new abutments will be keyed-in behind the existing abutments that remain at or below the streambed. The toe of the new riprap slopes outside of the existing abutments that remain should be keyed into the existing soils at least 3 feet.

Riprap shall conform to MaineDOT Standard Specification 703.26 “Plain and Hand Laid Riprap” and should be placed at a maximum slope of 1.75H:1V on the abutment fore slope and a maximum of 2H:1V on approach side slopes. The riprap section shall be underlain by a 1-foot layer of MaineDOT Standard Specification 703.19 “Granular Borrow Material for Underwater Backfill” and a Class 1 non-woven erosion control geotextile per MaineDOT Standard Specification 722.03.

#### **4.9 Construction Considerations**

Construction of the abutments will require pile driving. Cofferdams and temporary lateral earth support systems may be needed for construction of the detour structure and partial removal of the existing abutments. The new integral abutments will be constructed behind the existing abutments avoiding disturbance to the sensitive soils in the streambed and avoiding placement of fills in the river.

Although cobbles were not noted within the glacial till deposit. There is potential for obstructions to impede the driving of H-piles to bedrock for abutment foundations. Obstructions may be cleared by conventional excavation methods, pre-augering, predrilling or spudding. Alternative methods to clear obstructions may be used as approved by the Resident. Care should be taken to drive H-piles within allowable tolerances without damaging the H-piles.

Excavations for the proposed abutments may expose pockets of soft or unsuitable material. Soft or unsuitable material shall be removed and replaced with compacted granular borrow or crushed stone. Sloughing and instability of the soils due to runoff, traffic vibrations, and construction activity is likely. The contractor should monitor the stability of slopes, excavation, soils at the roadway grade and the temporary earth retaining systems during construction. The contractor should control groundwater, surface water infiltration and soil erosion. Water should be controlled by pumping from sumps.

#### **4.10 Temporary Detour**

As previously discussed, a temporary detour alignment and structure located on the northerly side of the existing crossing will be used to maintain traffic during construction. Based on conceptual planning, we anticipate the detour structure will have a span of about 66 feet and the detour alignment will require tapered fills of up to 10.5 feet to achieve temporary roadway grades. As previously described, the glaciomarine soils encountered at the site are over-consolidated with a conservatively estimated OCR of about 2.1. The glaciomarine deposit encountered along the proposed temporary detour are characterized as sensitive and having low shear strength in their natural state and will undergo strength loss when disturbed. The glaciomarine soils pose constructability and stability concerns for the temporary detour and temporary bridge.

##### **4.10.1 Settlement**

We performed preliminary settlement evaluations using RocScience Settle3 software to assess feasibility of the detour embankment construction. We evaluated the magnitude of settlement as a result of placing an 8.5 and 10.5-foot approach embankment using normal-weight fills with a unit weight of 125 pcf.

Settlement evaluations were estimated for the short-term (0.1 year), 1 year, and 2 years after constructing the detour embankments. Our preliminary evaluation indicates the estimated magnitude of total ground surface settlement due to placement of the detour embankment will result in a total settlement of approximately 1 inch at the east and west approaches. The contractor should anticipate having to shim the temporary detour as needed to maintain ride-ability. Model run outputs are provided in Appendix E.

<b>Model</b>	<b>Total Settlement</b>
Detour Sta 56+25; proposed 8.5-foot embankment	1.01
Detour Sta 57+50; proposed 10-foot embankment	0.97
Detour Sta 58+00; proposed 10.5-foot embankment	1.01

##### **4.10.2 Global Stability**

We performed preliminary global stability evaluations for an anticipated 8.5 and 10.5-foot-high temporary detour embankment at approximately Detour Sta. 56+25, 57+50, and 58+00 in the transverse direction, using RocScience Slide2 software. Results of our global stability model runs are summarized in the following table and included in Appendix E.

<b>Model</b>	<b>Safety Factor (Static)</b>
Detour Sta 56+25; proposed 8.5-foot embankment	1.27
Detour Sta 57+50; proposed 10-foot embankment	1.29
Detour Sta 58+00; proposed 10.5-foot embankment	1.46

The results of the static global stability analyses for the anticipated conditions in the longitudinal direction at the east approach does not generally meet the minimum LRFD requirements of a factor of safety of 1.3 in the transverse direction.

Based on the evaluation, we anticipate embankment construction measures to improve stability will be required as part of the contractor's temporary detour design at both the east and west approaches. Increasing the factor of safety could be accomplished by reducing the driving forces (e.g., using lightweight fills, reducing the volume of conventional fill), or increasing the resisting forces (e.g., excavating weak materials, constructing toe berms, installing slope reinforcement elements such as geotextile, sheeting or piles).

The contractor shall be required in the contract documents (Special Provision 510) to demonstrate that the east and west temporary detour embankments (in both the transverse and longitudinal directions) and abutments have acceptable factors of safety for slope stability. Minimum factors of safety shall be 1.3 for embankment slopes and 1.5 for slopes that contain or support an abutment.

## 5.0 CLOSURE

We trust this information meets your present needs. Please contact us if you have any questions or need further assistance.

Sincerely,

**S. W. Cole Engineering, Inc.**

Michael A. St. Pierre, P.E.  
Principal Geotechnical Engineer



*Robert E. Chaput, Jr.*

Robert E. Chaput, Jr., P.E.  
Principal Geotechnical Engineer

MAS/als-rec



## **APPENDIX A**

### **Limitations**

This report has been prepared for the exclusive use of the Maine Department of Transportation for specific application to the Proposed Sabattus River Bridge (#5393) Replacement carrying Route 126 (Sabattus Road) over Sabattus River (MaineDOT WIN 026184.00) in Sabattus, Maine. S. W. Cole Engineering, Inc. (S.W.COLE) has endeavored to conduct our services in accordance with generally accepted soil and foundation engineering practices. No warranty, expressed or implied, is made.

The soil profiles described in the report are intended to convey general trends in subsurface conditions. The boundaries between strata are approximate and are based upon interpretation of exploration data and samples.

The analyses performed during this investigation and recommendations presented in this report are based in part upon the data obtained from subsurface explorations made at the site. Variations in subsurface conditions may occur between explorations and may not become evident until construction. If variations in subsurface conditions become evident after submission of this report, it will be necessary to evaluate their nature and to review the recommendations of this report.

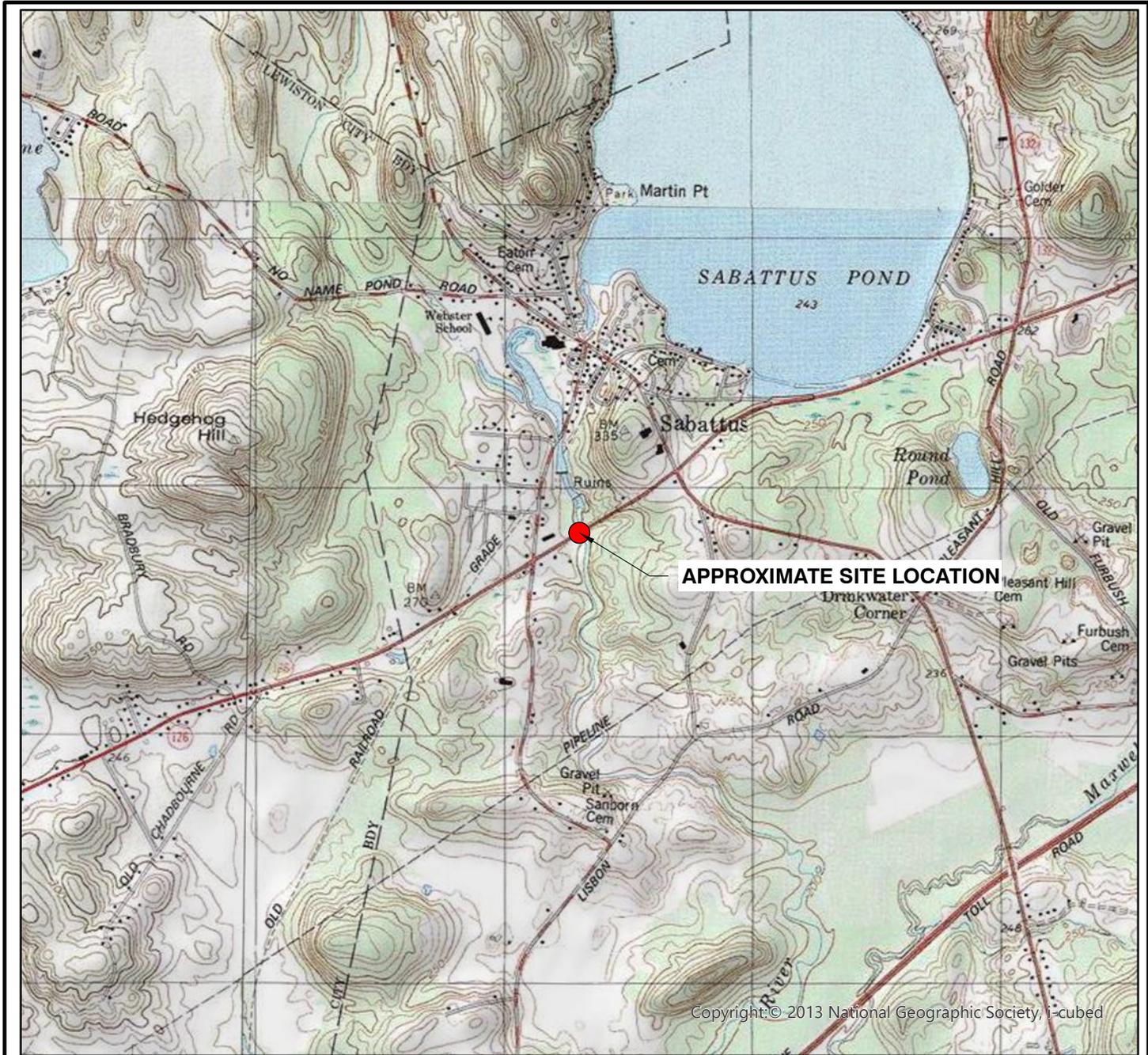
Observations have been made during exploration work to assess site groundwater levels. Fluctuations in water levels will occur due to variations in rainfall, temperature, and other factors.

Recommendations contained in this report are based substantially upon information provided by others regarding the proposed project. In the event that any changes are made in the design, nature, or location of the proposed project, S.W.COLE should review such changes as they relate to analyses associated with this report. Recommendations contained in this report shall not be considered valid unless the changes are reviewed by S.W.COLE.



## **APPENDIX B**

### **Figures**



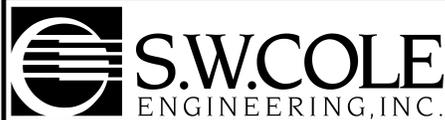
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2,000 0 2,000 4,000



Scale in Feet



MAINE DEPARTMENT OF TRANSPORTATION

**SITE LOCATION MAP**

SABATTUS RIVER BRIDGE #5393 REPLACEMENT  
 ROUTE 126 (SABATTUS ROAD) OVER SABATTUS RIVER  
 SABATTUS, MAINE  
 WIN 026184.00

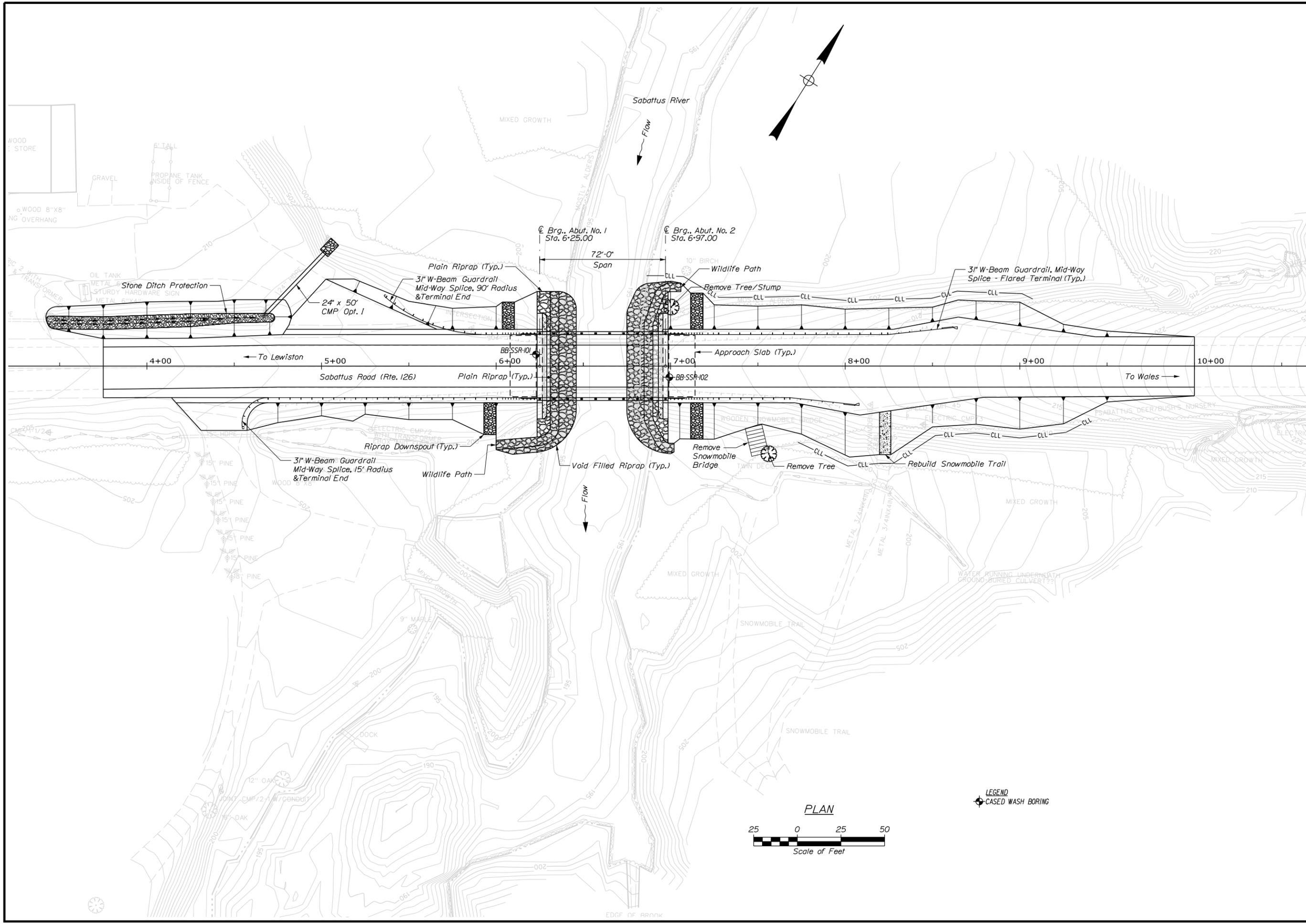
**NOTE:**  
 SITE LOCATION MAP PREPARED FROM  
 ESRI ArcGIS ONLINE AND DATA PARTNERS  
 INCLUDING USGS AND © 2007 NATIONAL  
 GEOGRAPHIC SOCIETY.

Job No.	20-1403-026184	Scale	1" = 2000'
Date:	05/07/2024	Sheet	1

Date: 1/15/2026

Username: Terry.White

Filename: ... \00\GEOTECH\MSTAN005\_BLP1.dgn Division: GEOTECH



STATE OF MAINE DEPARTMENT OF TRANSPORTATION		2618400	
BRIDGE NO. 6393		WIN 26184.00	
BRIDGE PLANS			
SABATTUS RIVER BRIDGE SABATTUS RIVER ANDROSCOGGIN COUNTY		BORING LOCATION PLAN	
APPENDIX B FIGURE		2	
OF 3			

PROJ. MANAGER	JOB TASK	BY	DATE
DESIGNED	DESIGNED	E. BREWER	JAN 2023
CHECKED	REVIEWED	M.P.	
DESIGNED	DETAILED	M.S.T. PIERRE	JUL 2025
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

DESIGN-DETAILED	CHECKED-REVIEWED	DESIGNED-DETAILED	DESIGNED-DETAILED	REVISIONS 1	REVISIONS 2	REVISIONS 3	REVISIONS 4	FIELD CHANGES

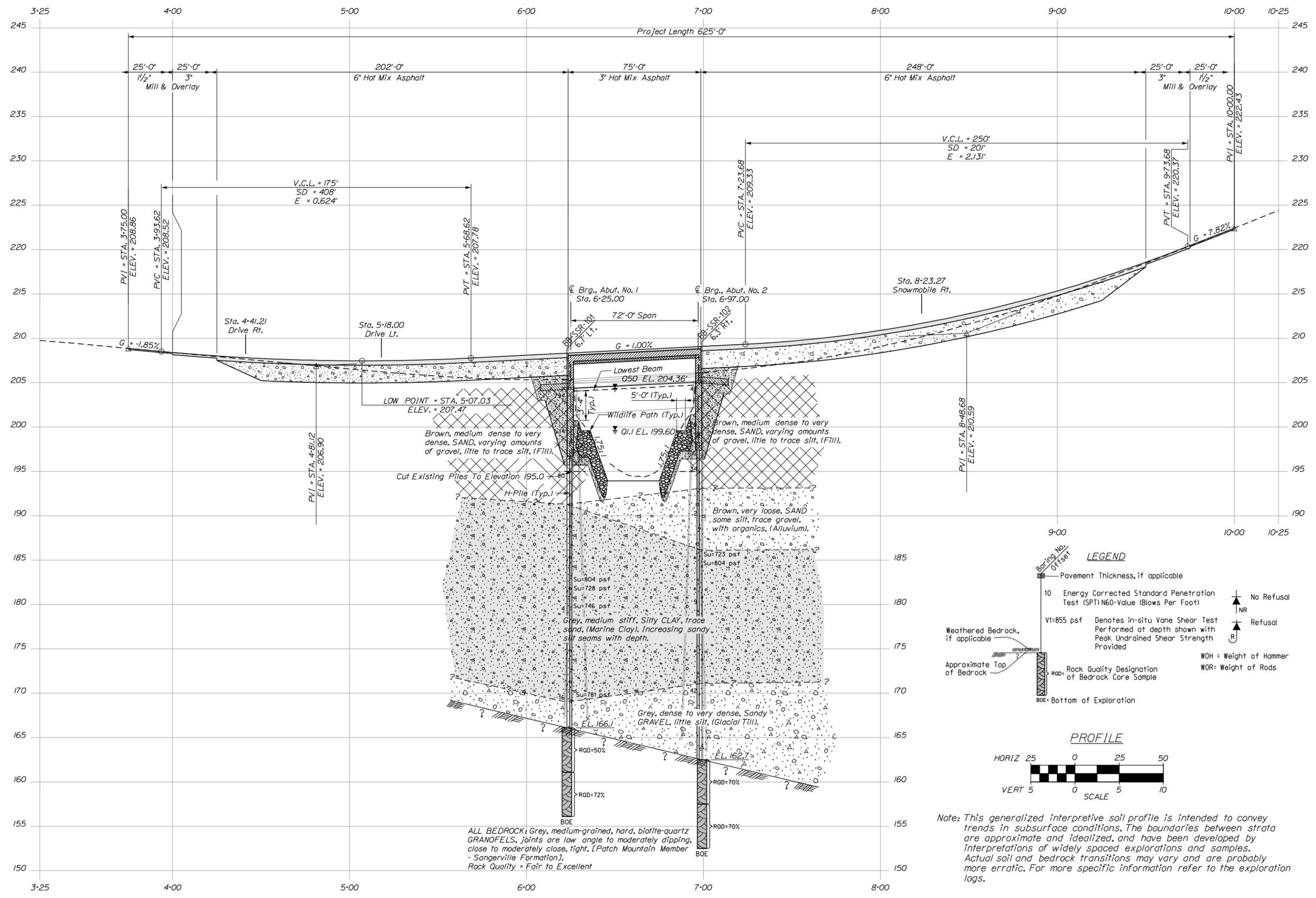
SIGNATURE	P.E. NUMBER	DATE

Date: 10/31/2025

Username: Terry.White

Division: GEOTECH

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**LEGEND**

- Pavement Thickness, if applicable
- 10 Energy Corrected Standard Penetration Test (SPT) N60-Value (Blows Per Foot)
- VI-855 psf Denotes in-situ Vane Shear Test Performed at depth shown with Peak Undrained Shear Strength Provided
- No Refusal (NR)
- Refusal (R)
- ROD = Rock Quality Designation of Bedrock Core Sample
- Weathered Bedrock, if applicable
- Approximate Top of Bedrock
- BOE = Bottom of Exploration
- WOH = Weight of Hammer
- WOR = Weight of Rods



Note: This generalized interpretive soil profile 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		BRIDGE PLANS	
		2618400		WIN	
		BRIDGE NO. 6393		26184.00	
PROJ. MANAGER	D. EATON	BY	E. BREWER	DATE	JAN 2023
CHECKED/REVIEWED	M.P.	DESIGNED/DETAILS	M.S.T. PIERRE	SIGNATURE	JUL 2025
DESIGNED/DETAILS	T. WHITE	REVISIONS 1		P.E. NUMBER	
REVISIONS 2		REVISIONS 3		DATE	
REVISIONS 4		FIELD CHANGES			
SABATTUS RIVER BRIDGE			SABATTUS RIVER		
SABATTUS			ANDROSCOGGIN COUNTY		
<b>INTERPRETIVE SUBSURFACE PROFILE</b>					
APPENDIX B FIGURE					
<b>3</b>					
OF 3					



## **APPENDIX C**

### **Key to Soil and Rock Descriptions and Terms Boring Logs & Rock Core Photo**

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.	
		(little or no fines)	GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.	
	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.	
			GC	Clayey gravels, gravel-sand-clay mixtures.	
		CLEAN SANDS  (little or no fines)	SW	Well-graded sands, Gravelly sands, little or no fines	
			SP	Poorly-graded sands, Gravelly sand, little or no fines.	
FINE-GRAINED SOILS  (more than half of material is smaller than No. 200 sieve size)	SILTS AND CLAYS  (liquid limit less than 50)	SM	Silty sands, sand-silt mixtures		
		SC	Clayey sands, sand-clay mixtures.		
		ML	Inorganic silts and very fine sands, rock flour, Silty or Clayey fine sands, or Clayey silts with slight plasticity.		
	SILTS AND CLAYS  (liquid limit greater than 50)	CL	Inorganic clays of low to medium plasticity, Gravelly clays, Sandy clays, Silty clays, lean clays.		
OL		Organic silts and organic Silty clays of low plasticity.			
MH		Inorganic silts, micaceous or diatomaceous fine Sandy or Silty soils, elastic silts.			
CH		Inorganic clays of high plasticity, fat clays.			
HIGHLY ORGANIC SOILS	Pt	Peat and other highly organic soils.			

Descriptive Term		Portion of Total (%)	
trace		0 - 10	
little		11 - 20	
some		21 - 35	
adjective (e.g. Sandy, Clayey)		36 - 50	

TERMS DESCRIBING DENSITY/CONSISTENCY			
<b>Coarse-grained soils</b> (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).			
<u>Density of Cohesionless Soils</u>		<u>Standard Penetration Resistance N<sub>60</sub>-Value (blows per foot)</u>	
Very loose		0 - 4	
Loose		5 - 10	
Medium Dense		11 - 30	
Dense		31 - 50	
Very Dense		> 50	
<b>Fine-grained soils</b> (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.			
		<u>Approximate Undrained Shear</u>	<u>Field</u>
<u>Consistency of Cohesive soils</u>	<u>SPT N<sub>60</sub>-Value (blows per foot)</u>	<u>Strength (psf)</u>	<u>Guidelines</u>
Very Soft	WOH, WOR, WOP, <2	0 - 250	Fist easily penetrates
Soft	2 - 4	250 - 500	Thumb easily penetrates
Medium Stiff	5 - 8	500 - 1000	Thumb penetrates with moderate effort
Stiff	9 - 15	1000 - 2000	Indented by thumb with great effort
Very Stiff	16 - 30	2000 - 4000	Indented by thumbnail
Hard	>30	over 4000	Indented by thumbnail with difficulty

<u>Rock Quality Designation (RQD):</u>			
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)			
<u>Rock Quality Based on RQD</u>			
<u>Rock Quality</u>	<u>RQD (%)</u>		
Very Poor	≤25		
Poor	26 - 50		
Fair	51 - 75		
Good	76 - 90		
Excellent	91 - 100		

<u>Desired Rock Observations (in this order, if applicable):</u>	
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 quality (very poor, poor, etc.)	
ref: ASTM D6032 and FHWA NHI-16-072 GEC 5 - Geotechnical Site Characterization, Table 4-12	
Recovery (inch/inch and percentage)	
Rock Core Rate (X.X ft - Y.Y ft (min:sec))	

<u>Sample Container Labeling Requirements:</u>	
WIN	Blow Counts
Bridge Name / Town	Sample Recovery
Boring Number	Date
Sample Number	Personnel Initials
Sample Depth	

<b>Maine Department of Transportation Geotechnical Section</b>	
<b>Key to Soil and Rock Descriptions and Terms</b>	
Field Identification Information	

<b>Driller:</b> Seaboard Drilling, LLC	<b>Elevation (ft.):</b> 205.3	<b>Auger ID/OD:</b> SSA 2.5"/4.5"
<b>Operator:</b> R. Hackett	<b>Datum:</b> NAVD88	<b>Sampler:</b> Standard Split Spoon
<b>Logged By:</b> S. Hlywa	<b>Rig Type:</b> Track-mounted Diedrich D-50	<b>Hammer Wt./Fall:</b> 140 lb / 30"
<b>Date Start/Finish:</b> 4-15-2024	<b>Drilling Method:</b> Cased Wash	<b>Core Barrel:</b> NQ2 (2")
<b>Boring Location:</b> Sta. 6+22.8, 6.7 ft Lt.	<b>Casing ID/OD:</b> HW 4"/4.5"	<b>Water Level*:</b> 5' (after drilling)

**Hammer Efficiency Factor:** 1.087      **Hammer Type:** Automatic     Hydraulic     Rope & Cathead

Definitions:      R = Rock Core Sample       $S_u$  = Peak/Remolded Field Vane Undrained Shear Strength (psf)       $T_v$  = Pocket Torvane Shear Strength (psf)  
 D = Split Spoon Sample      SSA = Solid Stem Auger       $S_{u(lab)}$  = Lab Vane Undrained 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 = Rig Specific Annual Calibration Value      PI = Plasticity Index  
 V = Field Vane Shear Test,    PP = Pocket Penetrometer      WOR/C = Weight of Rods or Casing       $N_{60}$  = SPT N-uncorrected Corrected for Hammer Efficiency      G = Grain Size Analysis  
 MV = Unsuccessful Field Vane Shear Test Attempt      WO1P = Weight of One Person       $N_{60}$  = (Hammer Efficiency Factor/60%)\*N-uncorrected      C = Consolidation Test

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 <sub>60</sub>	Casing Blows					
0									204.5	10" of Pavement.		
	1D	24/2	1.00 - 3.00	40-28-24-20	52	94				Brown, damp, very dense, SAND, some gravel, little silt, (Fill).		
5	2D	24/8	5.00 - 7.00	5-4-4-6	8	14	28			Brown, wet, medium dense, SAND, some gravel, trace silt, (Fill).	15474A A-1-b, SW-SM WC=9.3%	
							53					
							63					
							80					
							53					
10	3D	24/4	10.00 - 12.00	21-26-18-15	44	80	62		191.3	Brown, wet, very dense, GRAVEL, some sand, little silt, (Fill).		
							73					
							75					
							59					
							10					
15	4D	24/9	15.00 - 17.00	WOH/12"-1/12"	--		10			Grey, wet, soft, Silty CLAY, trace fine sand, (Marine Clay).	15475A A-6, CL WC=32.1%	
							9					
							10					
							14					
							13					
20	1U	24/24	20.00 - 22.00	PUSH	--		14			Grey, wet, medium stiff, Silty CLAY, trace fine sand, (Marine Clay).	23755S AASHTO, USCS WC=30.0% LL=36 PL=21 PI=15	
							7					
	1V		22.64 - 23.00	$S_u=804/134$ psf			10			55x110 mm vane raw torque readings. 1V: 18.0/3.0 ft-lbs		
	2V		23.64 - 24.00	$S_u=728/134$ psf			17			2V: 16.3/3.0 ft-lbs		
							17					
25												

**Remarks:**  
 Autohammer SN 362; Calibrated 11/03/2023.  
 bgs = below ground surface

<b>Maine Department of Transportation</b> Soil/Rock Exploration Log US CUSTOMARY UNITS	Project: Sabattus River Bridge #5393 carries Route 126 (Sabattus Road) over Sabattus River Location: Sabattus, ME	Boring No.: <u>BB-SSR-101</u> WIN: <u>26184.00</u>
--	--	---

Driller: Seaboard Drilling, LLC	Elevation (ft.): 205.3	Auger ID/OD: SSA 2.5"/4.5"
Operator: R. Hackett	Datum: NAVD88	Sampler: Standard Split Spoon
Logged By: S. Hlywa	Rig Type: Track-mounted Diedrich D-50	Hammer Wt./Fall: 140 lb / 30"
Date Start/Finish: 4-15-2024	Drilling Method: Cased Wash	Core Barrel: NQ2 (2")
Boring Location: Sta. 6+22.8, 6.7 ft Lt.	Casing ID/OD: HW 4"/4.5"	Water Level*: 5' (after drilling)

Hammer Efficiency Factor: 1.087	Hammer Type: Automatic <input checked="" type="checkbox"/> Hydraulic <input type="checkbox"/> Rope & Cathead <input type="checkbox"/>	
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt	R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140 lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person	S <sub>u</sub> = Peak/Remolded Field Vane Undrained Shear Strength (psf) S <sub>u(lab)</sub> = Lab Vane Undrained Shear Strength (psf) q <sub>p</sub> = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N <sub>60</sub> = SPT N-uncorrected Corrected for Hammer Efficiency N <sub>60</sub> = (Hammer Efficiency Factor/60%)N-uncorrected
		T <sub>v</sub> = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test

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 <sub>60</sub>	Casing Blows				
25	5D	24/4	25.00 - 27.00	WOH-1-1-1 Su=746/187 psf	2	4	19		Grey, wet, medium stiff, Silty CLAY, with fine sandy silt seams, (Marine Clay). 55x110 mm vane raw torque readings 3V: 16.7/4.2 ft-lbs MV: Failed vanes attempt. Could not push.		
	3V		25.64 - 26.00				19				
	MV						24				
30							16				
	2U	24/10	30.00 - 32.00	PUSH	--		14		Grey, wet, medium stiff, Silty CLAY, with frequent fine sandy silt seams, (Marine Clay).	23756S A-6, CL WC=35.9% LL=36 PL=21 PI=15	
							21		Failed 55x110 mm vane attempt. Could not push.		
MV						26					
35							24				
	6D	24/24	35.00 - 37.00	WOH/12"-9-6 Su=781/112 psf	9	16	27		Similar to above. 55x110 mm vane raw torque readings 4V: 17.5/2.5 ft-lbs MV: Failed vane attempt. Could not push.		
	4V		35.64 - 36.00				96				
MV			54								
40							98				
	R1	60/60	39.20 - 44.20	RQD = 50%			NQ2		Gray, wet, medium dense, Sandy GRAVEL, little silt, (Glacial Till).		
								166.1	Top of Bedrock at Elev. 166.1 ft.		
45											
	R2	60/54	44.20 - 49.20	RQD = 72%					R1: Grey, medium-grained, biotite-quartz GRANOFELS, hard, fresh, joints are low angle to moderately dipping, close to moderately close, tight, [Patch Mountain Member - Sangerville Formation]. Rock Quality = Poor. R1:Core Times (min:sec) 39.2-40.2 ft (2:30) 40.2-41.2 ft (2:16) 41.2-42.4 ft (2:27) 42.2-43.2 ft (1:45) 43.2-44.2 ft (2:15) 100% Recovery. R2: Similar to R1. Rock Quality = Fair. R2:Core Times (min:sec) 44.2-45.2 ft (1:48) 45.2-46.2 ft (2:08) 46.2-47.2 ft (2:30) 47.2-48.2 ft (1:48) 48.2-49.2 ft (1:58) 90% Recovery.		
50							156.1		Bottom of Exploration at 49.2 feet below ground surface.		

**Remarks:**  
 Autohammer SN 362; Calibrated 11/03/2023.  
 bgs = below ground surface

<b>Driller:</b> Seaboard Drilling, LLC	<b>Elevation (ft.):</b> 206.1	<b>Auger ID/OD:</b> SSA 2.5"/4.5"
<b>Operator:</b> R. Hackett	<b>Datum:</b> NAVD88	<b>Sampler:</b> Standard Split Spoon
<b>Logged By:</b> S. Hlywa	<b>Rig Type:</b> Track-mounted Diedrich D-50	<b>Hammer Wt./Fall:</b> 140 lb / 30"
<b>Date Start/Finish:</b> 4-10-2024 / 4-11-2024	<b>Drilling Method:</b> Cased Wash	<b>Core Barrel:</b> NQ2 (2")
<b>Boring Location:</b> Sta. 6+99.2, 6.3 ft Rt.	<b>Casing ID/OD:</b> HW 4"/4.5"	<b>Water Level*:</b> 10' (after drilling)

**Hammer Efficiency Factor:** 1.087      **Hammer Type:** Automatic     Hydraulic     Rope & Cathead

Definitions: R = Rock Core Sample      S<sub>u</sub> = Peak/Remolded Field Vane Undrained Shear Strength (psf)      T<sub>v</sub> = Pocket Torvane Shear Strength (psf)  
 D = Split Spoon Sample      SSA = Solid Stem Auger      S<sub>u(lab)</sub> = Lab Vane Undrained Shear Strength (psf)      WC = Water Content, percent  
 MD = Unsuccessful Split Spoon Sample Attempt      HSA = Hollow Stem Auger      q<sub>p</sub> = 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 = Rig Specific Annual Calibration Value      PI = Plasticity Index  
 V = Field Vane Shear Test, PP = Pocket Penetrometer      WOR/C = Weight of Rods or Casing      N<sub>60</sub> = SPT N-uncorrected Corrected for Hammer Efficiency      G = Grain Size Analysis  
 MV = Unsuccessful Field Vane Shear Test Attempt      WO1P = Weight of One Person      N<sub>60</sub> = (Hammer Efficiency Factor/60%)\*N-uncorrected      C = Consolidation Test

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 <sub>60</sub>	Casing Blows					
0									205.2	11" of Pavement.		
	1D	24/13	1.00 - 3.00	17-13-13-17	26	47				Brown, damp, dense, SAND, some gravel, trace silt, (Fill).	0.9	
5												
	2D	24/12	5.00 - 7.00	7-6-5-6	11	20	44			Brown, moist, medium dense, SAND, some gravel, trace silt, (Fill).	15476A A-1-b, SW WC=9.4%	
							62					
							82					
							117					
10							103					
	3D	24/3	10.00 - 12.00	7-11-8-6	19	34	32		193.1	Brown, wet, medium dense, SAND, little silt, little gravel, (Fill).		
							41					
							27					
							15					
15												
	4D	24/2	15.00 - 17.00	1-1/12"-1	1	2	20			Brown, wet, very loose, SAND, some silt, trace clay, trace fine gravel, with organics, (Alluvium).	15477A A-2-4, SM WC=64.4% OC=8.3%	
							17					
							23					
							26			Wood fiber in wash water observed.		
							36					
20									186.1			
	5D	24/24	20.00 - 22.00	WOH/24"	-	-	33			Gray, wet, medium stiff, Silty CLAY, trace fine sand, (Marine Clay).	15478A A-6, CL WC=28.3% LL=31 PL=15 PI=16	
	1V		20.64 - 21.00	723/268 psf			32			55x110 mm vane raw torque readings		
	2V		21.64 - 22.00	804/170 psf			33			1V: 16.2/6.0 ft-lbs		
							32			2V: 18.0/3.8 ft-lbs		
							34					
							39					
25												

**Remarks:**  
 Autohammer SN 362; Calibrated 11/03/2023.  
 bgs = below ground surface

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Sabattus River Bridge #5393 carries Route 126 (Sabattus Road) over Sabattus River Location: Sabattus, ME				Boring No.: BB-SSR-102 WIN: 26184.00							
Driller: Seaboard Drilling, LLC				Elevation (ft.): 206.1				Auger ID/OD: SSA 2.5"/4.5"							
Operator: R. Hackett				Datum: NAVD88				Sampler: Standard Split Spoon							
Logged By: S. Hlywa				Rig Type: Track-mounted Diedrich D-50				Hammer Wt./Fall: 140 lb / 30"							
Date Start/Finish: 4-10-2024 / 4-11-2024				Drilling Method: Cased Wash				Core Barrel: NQ2 (2")							
Boring Location: Sta. 6+99.2, 6.3 ft Rt.				Casing ID/OD: HW 4"/4.5"				Water Level*: 10' (after drilling)							
Hammer Efficiency Factor: 1.087				Hammer Type: Automatic <input checked="" type="checkbox"/> Hydraulic <input type="checkbox"/> Rope & Cathead <input type="checkbox"/>											
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt				R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140 lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person				S <sub>u</sub> = Peak/Remolded Field Vane Undrained Shear Strength (psf) S <sub>u(lab)</sub> = Lab Vane Undrained Shear Strength (psf) q <sub>p</sub> = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N <sub>60</sub> = SPT N-uncorrected Corrected for Hammer Efficiency N <sub>60</sub> = (Hammer Efficiency Factor/60%)*N-uncorrected				T <sub>v</sub> = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test			
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 <sub>60</sub>	Casing Blows								
25	MV/6D	24/2	25.00 - 27.00	1-1-4-1	5	9	26	171.1	Grey, wet, stiff, Silty CLAY, frequent fine sand seams, (Marine Clay). Failed 55x110 mm vane attempt. Could not push.	15479A A-6, CL WC=28.6%					
							31								
							44								
							51								
							40								
30	MV/7D	24/2	30.00 - 32.00	1/24"	--		65				Similar to above. Failed 55x110 mm vane attempt. Could not push.	15480A A-1-b, GM WC=9.8%			
							50								
							45								
							47								
							40								
							40								
35	8D	24/12	35.00 - 37.00	18-17-6-11	23	42	75		171.1		Grey, wet, dense, Sandy GRAVEL, little silt, (Glacial Till).	15480A A-1-b, GM WC=9.8%			
							55								
							69								
							96								
							93								
							40								
40	9D	4/4	40.00 - 40.33	50/4"	--		182		Similar to above.	15480A A-1-b, GM WC=9.8%					
							OPEN								
45	R1	60/48	43.60 - 48.60	RQD = 70%			NQ2	162.7	Top of Bedrock at Elev. 162.7 ft. R1: Grey, medium-grained, biotite-quartz GRANOFELS, hard, fresh, joints are low angle to moderately dipping, close to moderately close, tight, [Patch Mountain Member - Sangerville Formation]. Rock Quality = Fair. R1:Core Times (min:sec) 43.6-44.6 ft (2:37) 44.6-45.6 ft (2:00) 45.6-46.6 ft (2:39) 46.6-47.6 ft (2:28) 47.6-48.6 ft (2:07) 80% Recovery.	15480A A-1-b, GM WC=9.8%					
50	R2	60/59	48.60 - 53.60	RQD = 70%				162.7	R2: Similar to R1. Rock Quality = Fair.	15480A A-1-b, GM WC=9.8%					
<b>Remarks:</b> Autohammer SN 362; Calibrated 11/03/2023. bgs = below ground surface															
Stratification lines represent approximate boundaries between soil types; transitions may be gradual.										Page 2 of 3					
* 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.										Boring No.: BB-SSR-102					

<b>Maine Department of Transportation</b> Soil/Rock Exploration Log US CUSTOMARY UNITS	<b>Project:</b> Sabattus River Bridge #5393 carries Route 126 (Sabattus Road) over Sabattus River <b>Location:</b> Sabattus, ME	<b>Boring No.:</b> BB-SSR-102 <b>WIN:</b> 26184.00
--	--	---

<b>Driller:</b> Seaboard Drilling, LLC	<b>Elevation (ft.):</b> 206.1	<b>Auger ID/OD:</b> SSA 2.5"/4.5"
<b>Operator:</b> R. Hackett	<b>Datum:</b> NAVD88	<b>Sampler:</b> Standard Split Spoon
<b>Logged By:</b> S. Hlywa	<b>Rig Type:</b> Track-mounted Diedrich D-50	<b>Hammer Wt./Fall:</b> 140 lb / 30"
<b>Date Start/Finish:</b> 4-10-2024 / 4-11-2024	<b>Drilling Method:</b> Cased Wash	<b>Core Barrel:</b> NQ2 (2")
<b>Boring Location:</b> Sta. 6+99.2, 6.3 ft Rt.	<b>Casing ID/OD:</b> HW 4"/4.5"	<b>Water Level*:</b> 10' (after drilling)

<b>Hammer Efficiency Factor:</b> 1.087	<b>Hammer Type:</b> Automatic <input checked="" type="checkbox"/> Hydraulic <input type="checkbox"/> Rope & Cathead <input type="checkbox"/>	
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt	R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140 lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person	S <sub>u</sub> = Peak/Remolded Field Vane Undrained Shear Strength (psf) S <sub>u</sub> (lab) = Lab Vane Undrained Shear Strength (psf) q <sub>p</sub> = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N <sub>60</sub> = SPT N-uncorrected Corrected for Hammer Efficiency N <sub>60</sub> = (Hammer Efficiency Factor/60%)*N-uncorrected
T <sub>v</sub> = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test		

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 <sub>60</sub>	Casing Blows					
50											R2:Core Times (min:sec) 48.6-49.6 ft (0:07) 49.6-50.6 ft (2:22) 50.6-51.6 ft (2:25) 51.6-52.6 ft (2:29) 52.6-53.6 fr (2:00) 98% Recovery.	
											53.6	
											<b>Bottom of Exploration at 53.6 feet below ground surface.</b>	
55												
60												
65												
70												
75												

**Remarks:**  
 Autohammer SN 362; Calibrated 11/03/2023.  
 bgs = below ground surface

**MaineDOT**  
**Sabattus River Bridge #5393 carries Route 126 (Sabattus Road) over Sabattus River**  
**Sabattus, Maine**  
*Rock Core Photograph*

Boring No.	Run	Depth (ft)	Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Box Row
BB-SSR-102	R1	43.6 – 48.6	60	100%	42	70%	GRANOFELS	1
BB-SSR-102	R2	48.6 – 53.6	54	90%	42	70%	GRANOFELS	2
BB-SSR-101	R1	39.2 – 44.2	48	80%	30	50%	GRANOFELS	3
BB-SSR-101	R2	44.2 – 49.2	59	98%	43	72%	GRANOFELS	4

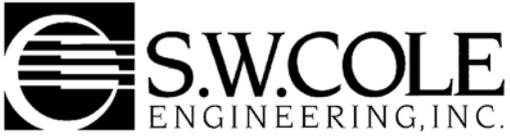


- Notes:**
1. "Box row" indicates the section of the box where the core run is contained: 1 = top, 4 = bottom.
  2. Transition between core runs within box row is marked by wood separators.



## **APPENDIX D**

### **Laboratory Test Results**



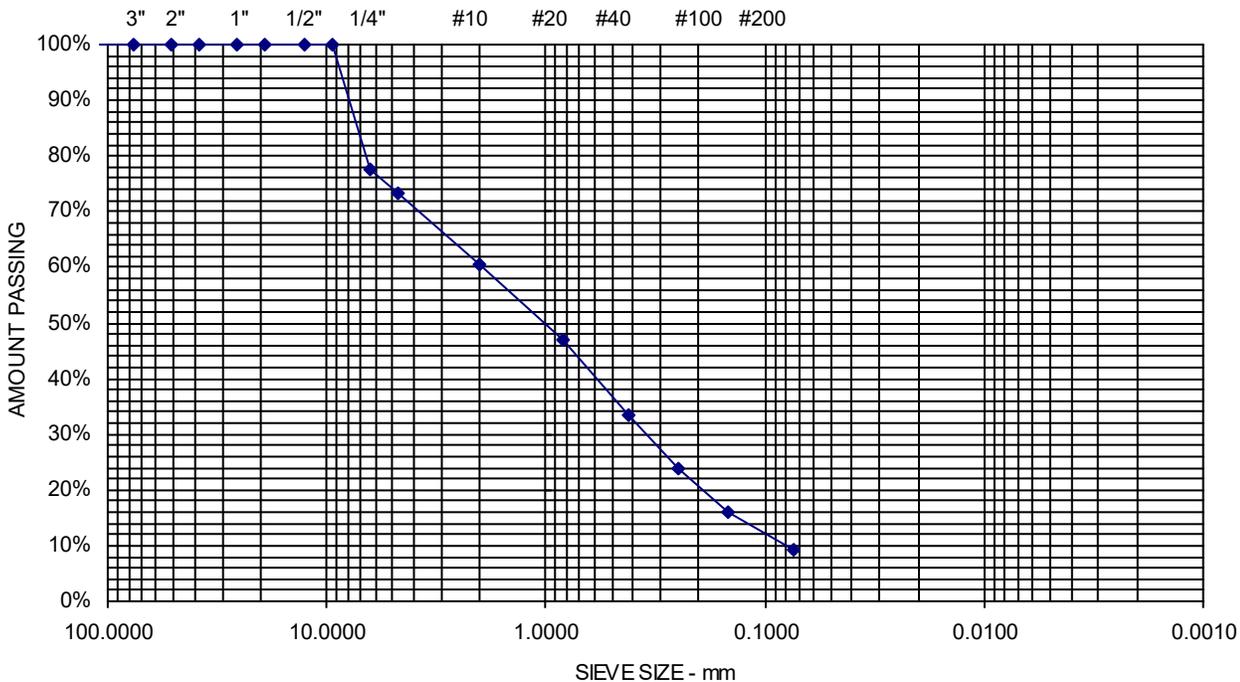
# Report of Gradation

ASTM C-117 & C-136

Project Name VARIOUS ME - STATEWIDE BRIDGE PROJECTS  
 (2020062300000000765) - GEOTECHNICAL INVESTIGATIONS AND  
 Client STATE OF MAINE DEPARTMENT OF TRANSPORTATION  
 Exploration **BB-SSR-101**  
 Material Source **2D, 5FT**

Project Number 20-1403  
 Lab ID 15474A  
 Date Received 4/22/2024  
 Date Completed 5/8/2024  
 Tested By NEIL DAVIS

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
150 mm	6"	100	
125 mm	5"	100	
100 mm	4"	100	
75 mm	3"	100	
50 mm	2"	100	
38.1 mm	1-1/2"	100	
25.0 mm	1"	100	
19.0 mm	3/4"	100	
12.5 mm	1/2"	100	
9.5 mm	3/8"	100	
6.3 mm	1/4"	77	
4.75 mm	No. 4	73	26.7% Gravel
2.00 mm	No. 10	60	
850 μm	No. 20	47	
425 μm	No. 40	34	64.2% Sand
250 μm	No. 60	24	
150 μm	No. 100	16	
75 μm	No. 200	9.1	9.1% Fines

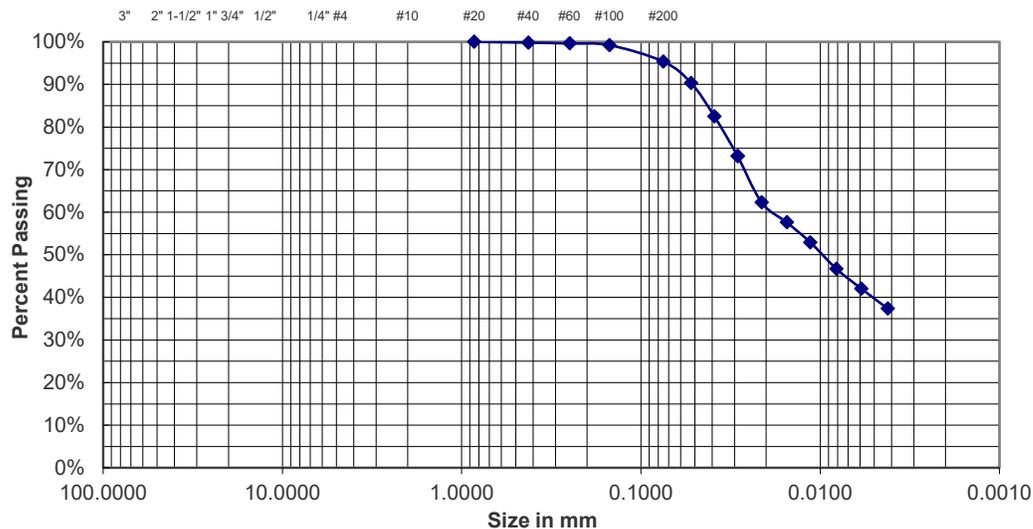


Comments: Moisture Content = 9.3%

**Project Name:** Statewide Bridge Projects  
**Project Location:** Various, ME  
**Client:** State of Maine Department of Transportation  
**Material Description:** Exploration  
**Material Source:** BB-SSR-101, 4D, 15'

**Project Number:** 20-1403  
**Lab ID:** 15475A  
**Date Received:** 4/22/2024  
**Date Completed:** 5/3/2024  
**Tested By:** N. Davis

Sieve Analysis			Hydrometer Analysis		
Sieve Size	Standard Designation (mm)	Amount Passing (%)	Specification	Particle Size (mm)	Amount Passing (%)
3"	76	100		0.05245	90.3
2"	50	100		0.03894	82.5
1½"	38.1	100		0.02879	73.2
1"	25	100		0.02879	73.2
¾"	19	100		0.02121	62.3
½"	12.5	100		0.01536	57.6
¼"	6.3	100		0.01137	52.9
No. 4	4.75	100		0.00812	46.7
No. 10	2	100		0.00589	42.0
No. 20	0.85	100		0.00420	37.4
No. 40	0.425	100		0.00301	34.3
No. 60	0.25	100		0.00213	31.1
No. 100	0.15	99		0.00125	29.6
No. 200	0.075	95.4			



**Particle Distribution:** Gravel (3" - No. 4) **0.0%** Fines (0.074 - 0.005) **56.3%**  
 Sand (No. 4 - No. 200) **4.6%** Clay (<0.005) **39.1%**

Comments:

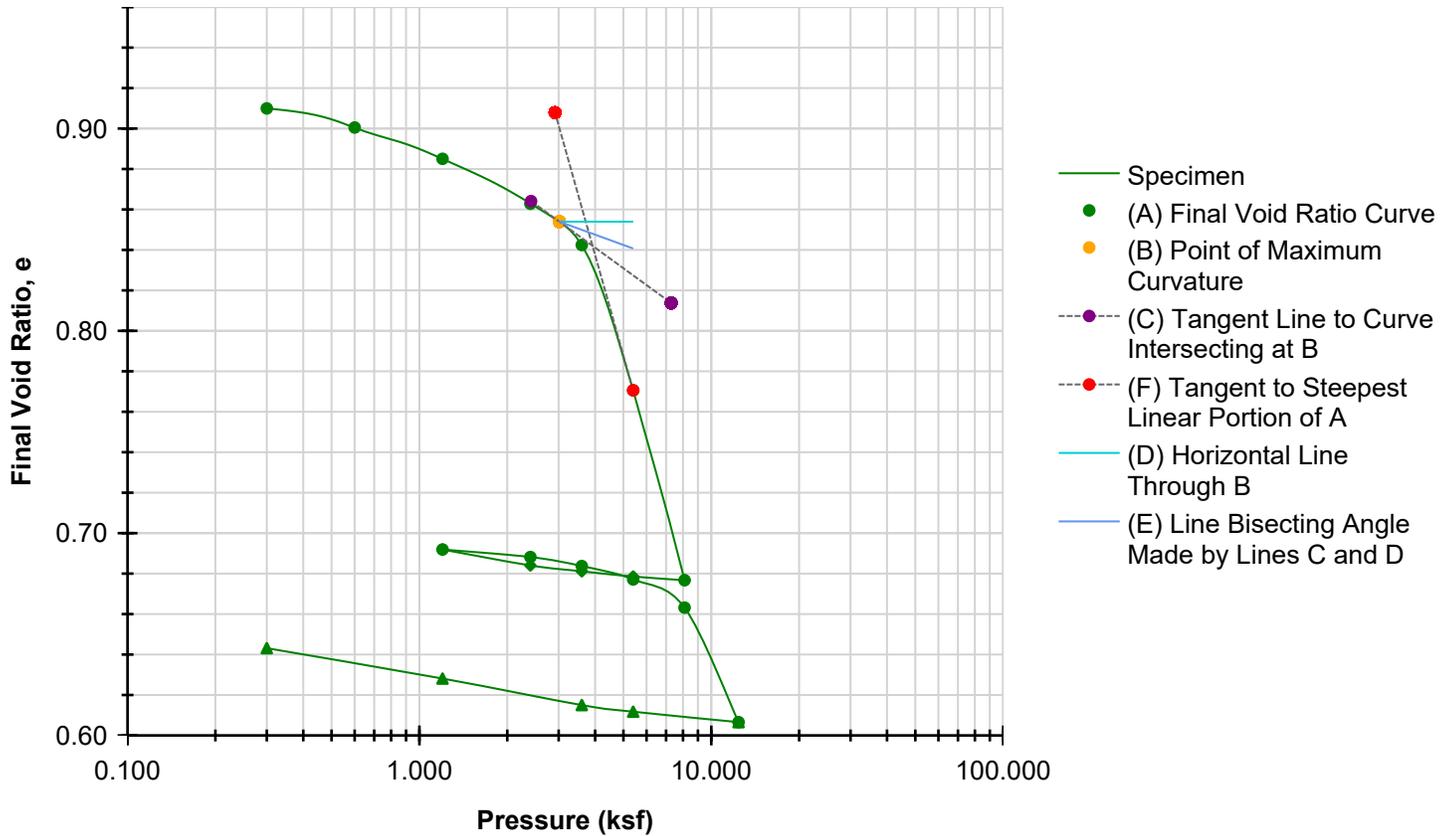
Reviewed By

26 Coles Crossing Drive, Sidney, ME 04330 • P: (207) 626.0600 • F: (207) 626.0700 • E: [infosidney@swcole.com](mailto:infosidney@swcole.com)



# Final Voids [Log]

ASTM D2435



Preconsolidation Stress (ksf)	3.80	Cc	0.453	Cr	0.023
-------------------------------	------	----	-------	----	-------

	BEFORE	AFTER	Liquid Limits	38	Test Date	4/22/2024
Moisture (%)	30.0	31.3	Plastic Limits	22		
Dry Density (pcf)	88.4	95.3				
Saturation (%)	88.5	108.8				
Void Ratio	0.92	0.78	Specific Gravity	2.72	ASSUMED	

Sample Description			
Project Number	20-1403	Depth (ft)	20-22
Sample Number	1U	Boring Number	BB-SSR-101
Project	WIN 026184 - Sabattus River Bridge #5393 Replacement		
Client	Maine Department of Transportation		
Location	Route 126 over Sabattus River		
Remarks			

Project Name: WIN 026184 - Sabattus River Bridge #5393 Replacement Project Number: 20-1403

Technician: TSD

Test Date: 4/22/2024

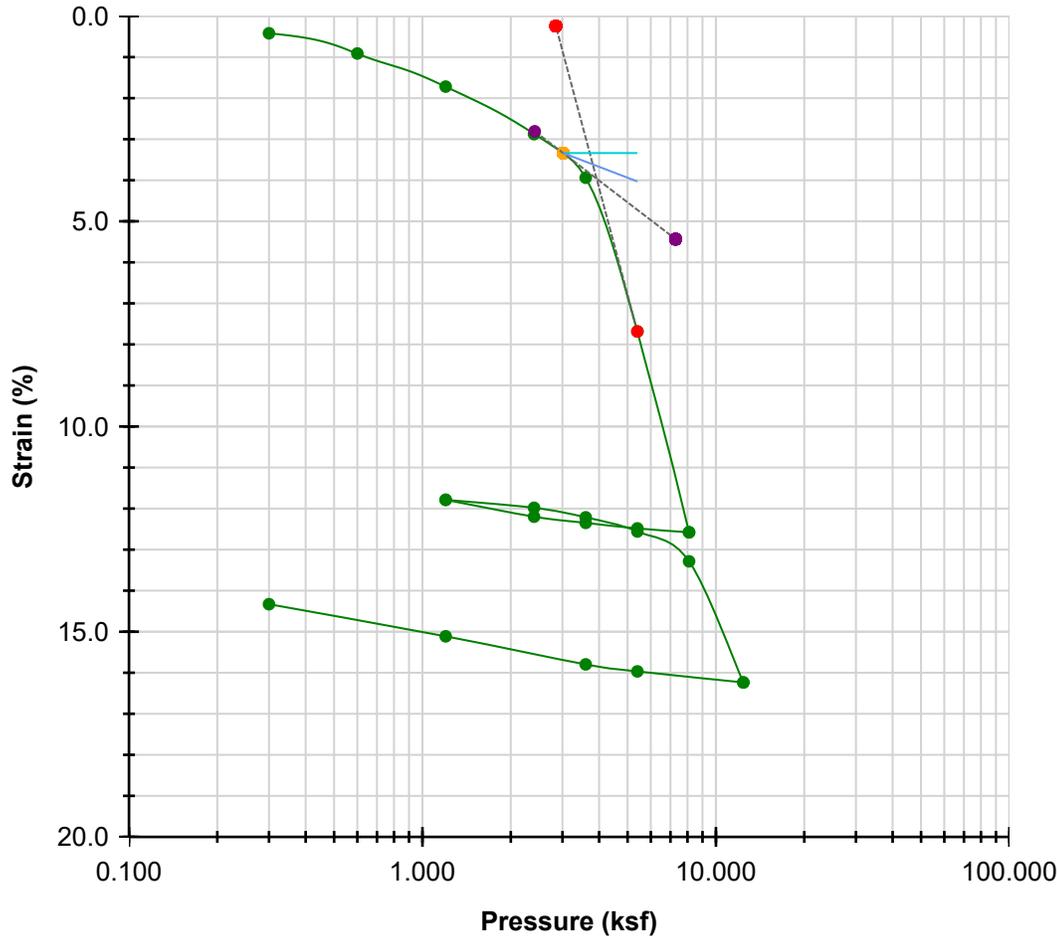
Checked By: \_\_\_\_\_

Date: \_\_\_\_\_



# Percent Strain [Log]

ASTM D2435



- (A) Stress Strain Curve
- (B) Point of Maximum Curvature
- (C) Tangent Line to Curve Intersecting at B
- (F) Tangent to Steepest Linear Portion of A
- (D) Horizontal Line Through B
- (E) Line Bisecting Angle Made by Lines C and D

Preconsolidation Stress (ksf)	3.80	Cc	0.453	Cr	0.023
-------------------------------	------	----	-------	----	-------

	BEFORE	AFTER	Liquid Limits	38	Test Date	4/22/2024
Moisture (%)	30.0	31.3	Plastic Limits	22		
Dry Density (pcf)	88.4	95.3				
Saturation (%)	88.5	108.8				
Void Ratio	0.92	0.78	Specific Gravity	2.72		ASSUMED

Sample Description			
Project Number	20-1403	Depth (ft)	20-22
Sample Number	1U	Boring Number	BB-SSR-101
Project	WIN 026184 - Sabattus River Bridge #5393 Replacement		
Client	Maine Department of Transportation		
Location	Route 126 over Sabattus River		
Remarks			

Project Name: WIN 026184 - Sabattus River Bridge #5393 Replacement Project Number: 20-1403

Technician: TSD

Test Date: 4/22/2024

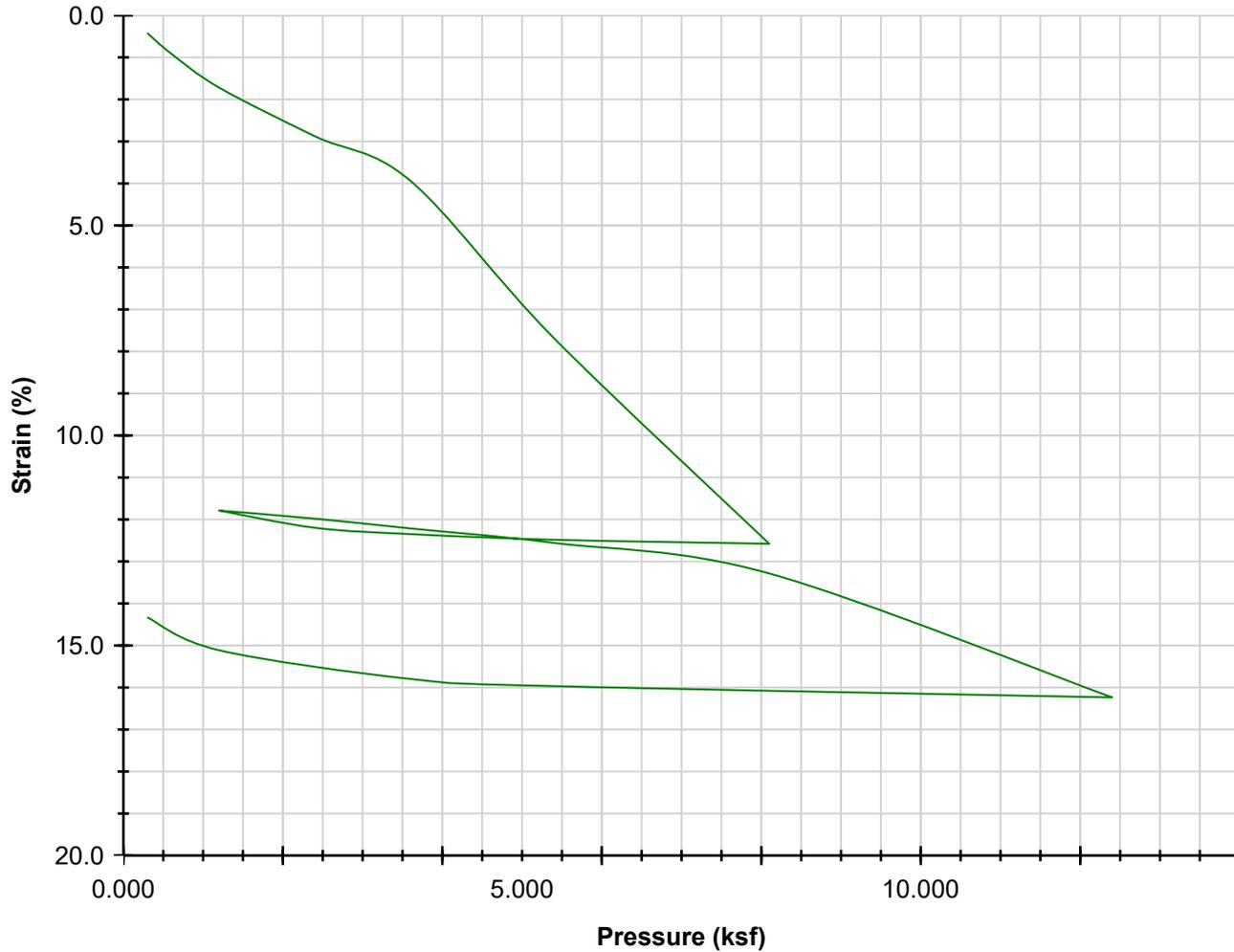
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Date: \_\_\_\_\_



# Percent Strain

ASTM D2435



	<b>BEFORE</b>	<b>AFTER</b>	<b>Liquid Limits</b>	38	<b>Test Date</b> 4/22/2024
<b>Moisture (%)</b>	30.0	31.3	<b>Plastic Limits</b>	22	
<b>Dry Density (pcf)</b>	88.4	95.3			
<b>Saturation (%)</b>	88.5	108.8			
<b>Void Ratio</b>	0.92	0.78	<b>Specific Gravity</b>	2.72	ASSUMED

<b>Sample Description</b>					
<b>Project Number</b>	20-1403	<b>Depth (ft)</b>	20-22	<b>Remarks</b>	
<b>Sample Number</b>	1U	<b>Boring Number</b>	BB-SSR-101		
<b>Project</b>	WIN 026184 - Sabattus River Bridge #5393 Replacement				
<b>Client</b>	Maine Department of Transportation				
<b>Location</b>	Route 126 over Sabattus River				

Project Name: WIN 026184 - Sabattus River Bridge #5393 Replacement Project Number: 20-1403

Technician: TSD

Test Date: 4/22/2024

Checked By: \_\_\_\_\_

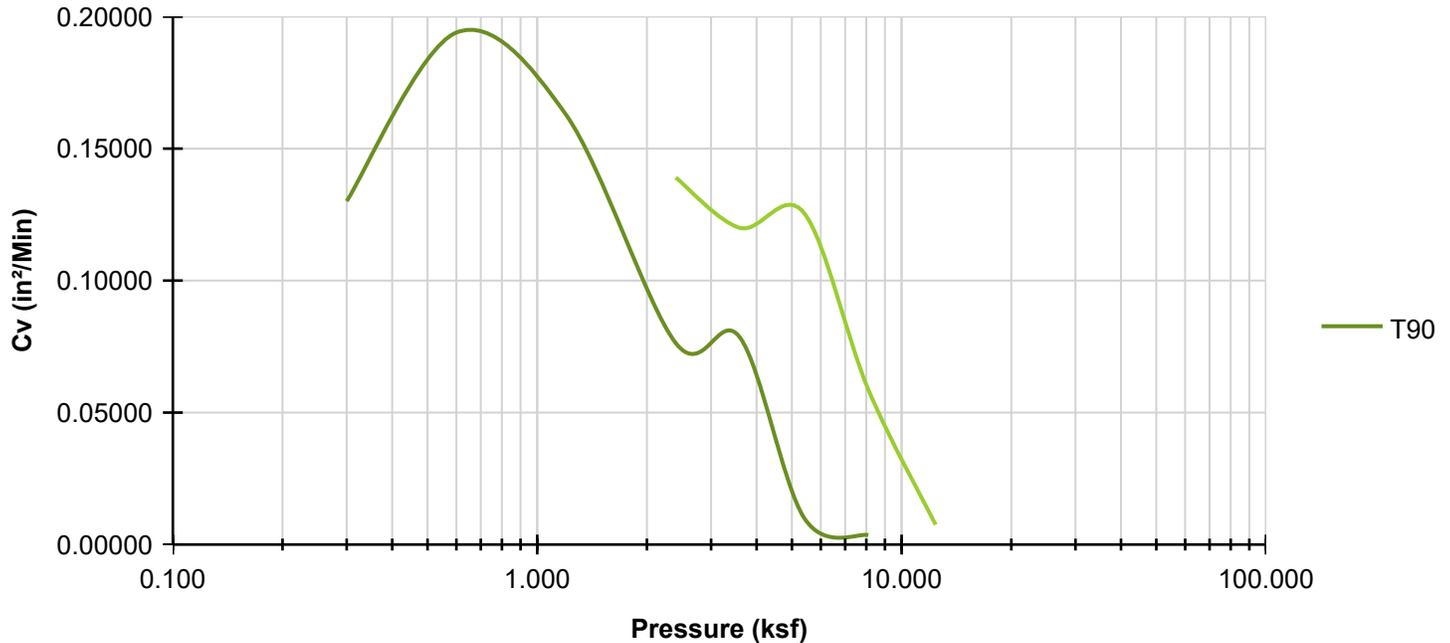
Date: \_\_\_\_\_



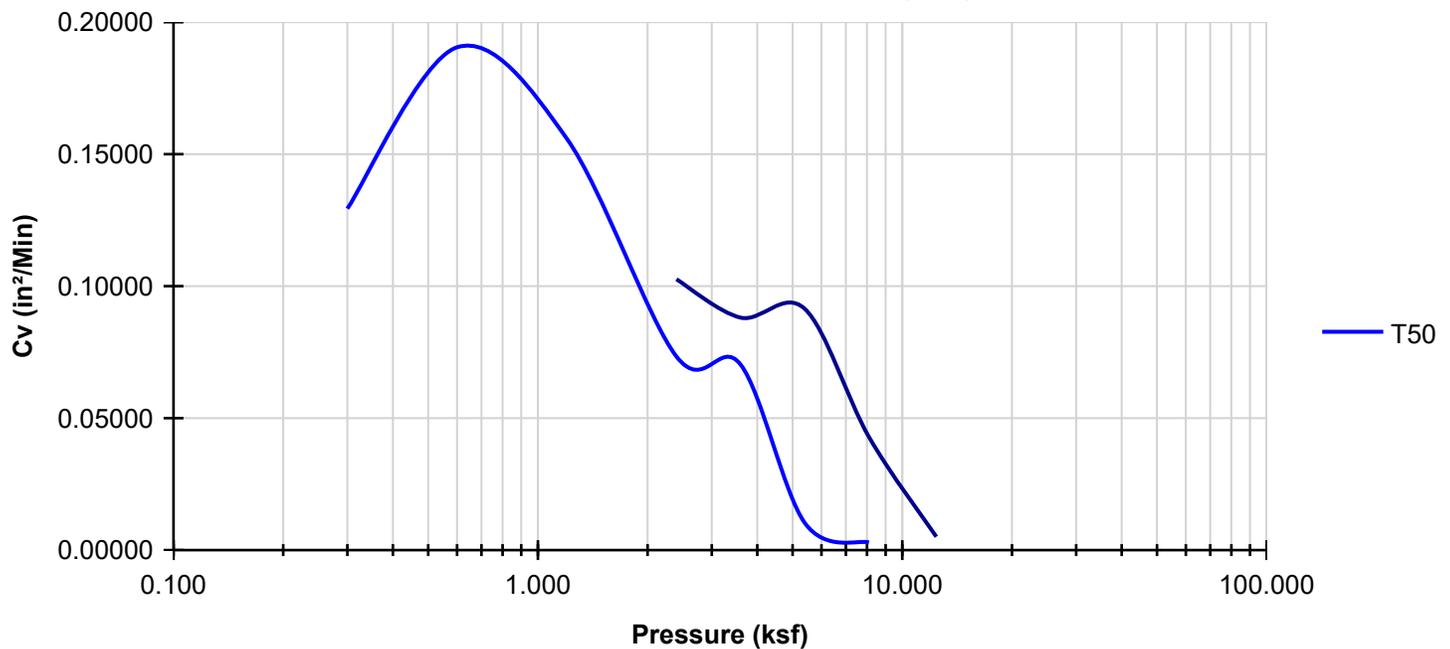
# Coefficients of Consolidation

ASTM D2435

### Coefficients of Consolidation (T90)



### Coefficients of Consolidation (T50)



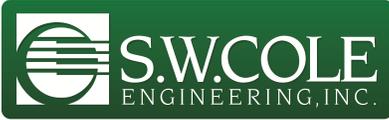
Project Name: WIN 026184 - Sabattus River Bridge #5393 Replacement Project Number: 20-1403

Technician: TSD

Test Date: 4/22/2024

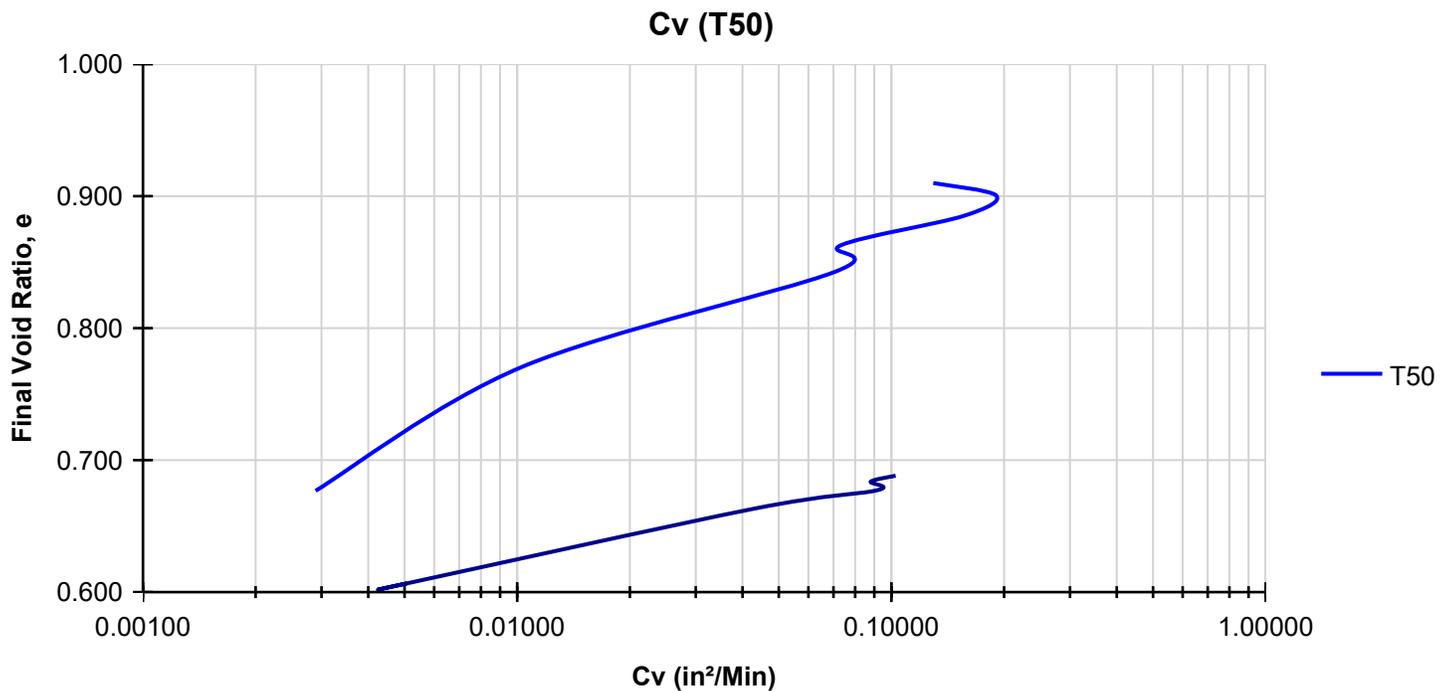
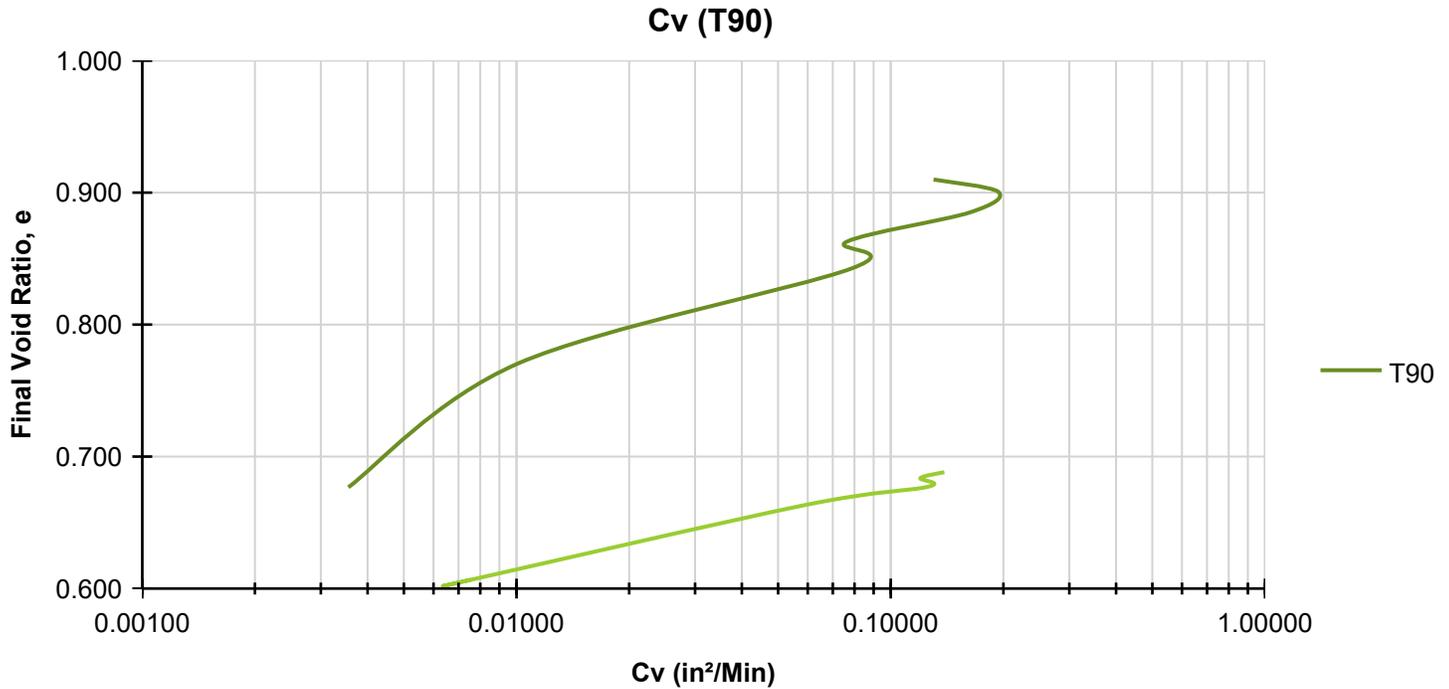
Checked By: \_\_\_\_\_

Date: \_\_\_\_\_



# Cv - Void Ratio

ASTM D2435



Project Name: WIN 026184 - Sabattus River Bridge #5393 Replacement Project Number: 20-1403

Technician: TSD

Test Date: 4/22/2024

Checked By: \_\_\_\_\_

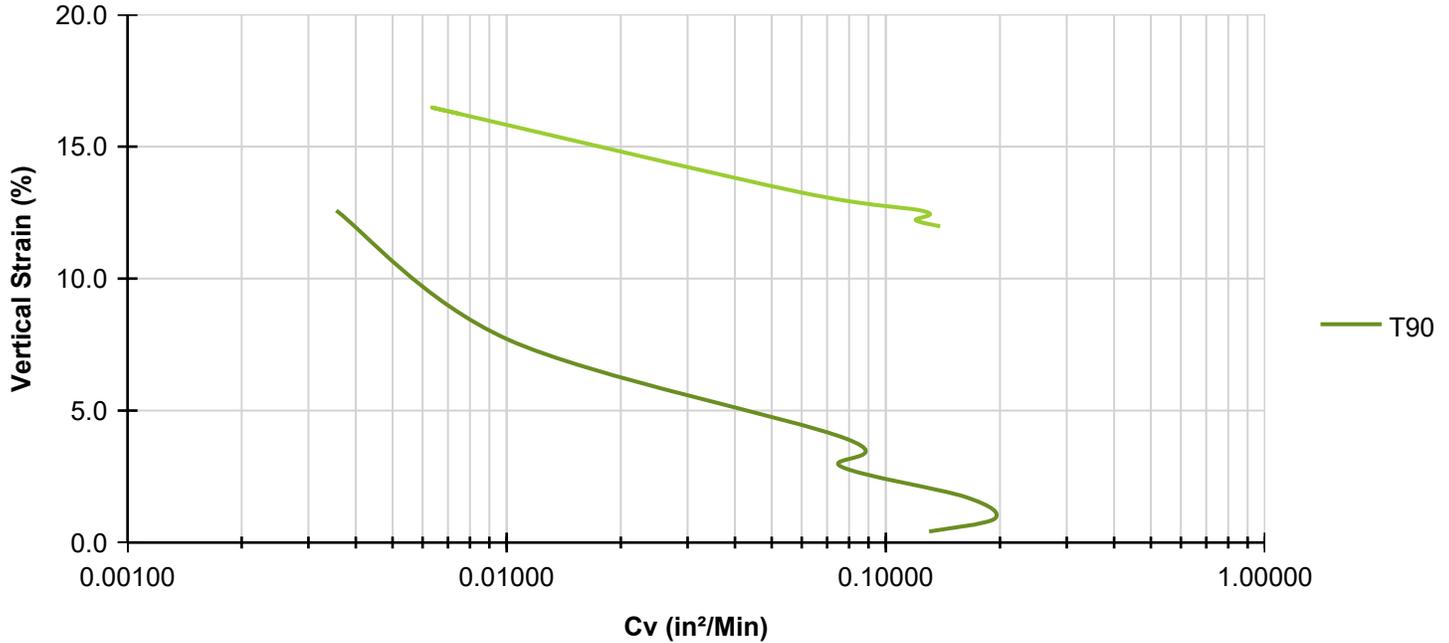
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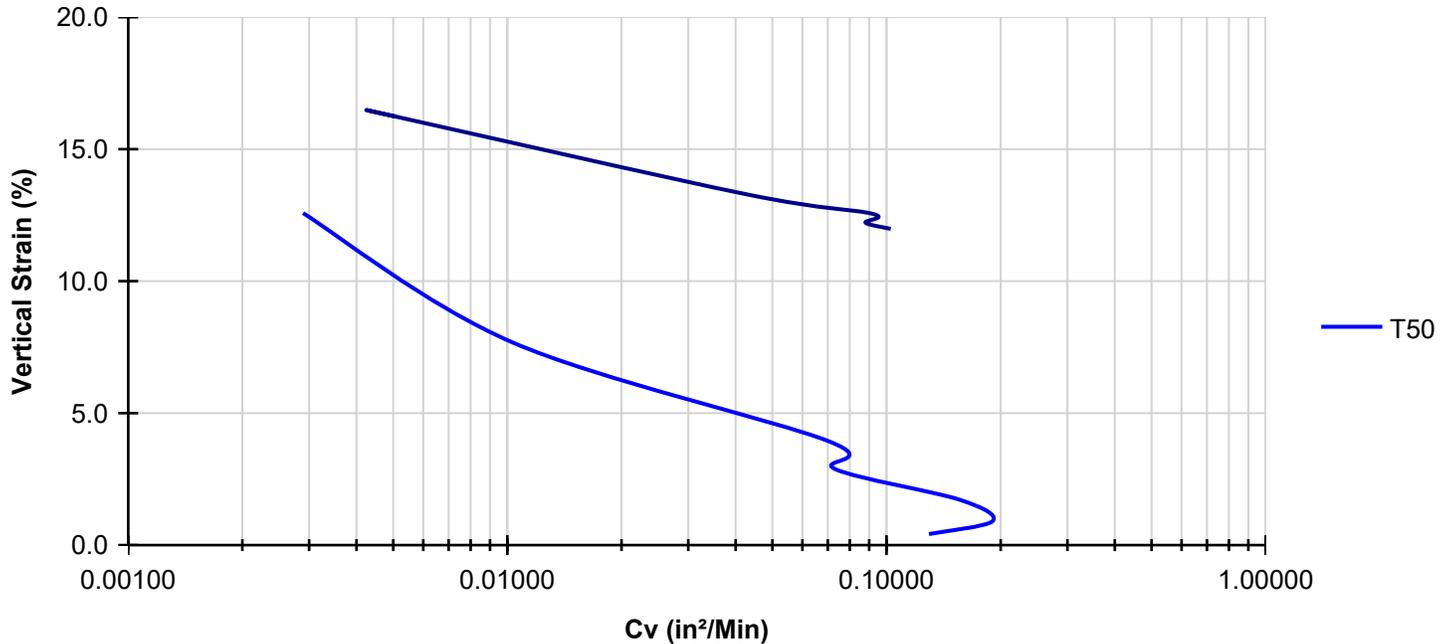
# Cv - Vertical Strain

ASTM D2435

### Cv (T90)



### Cv (T50)



Project Name: WIN 026184 - Sabbattus River Bridge #5393 Replacement Project Number: 20-1403

Technician: TSD

Test Date: 4/22/2024

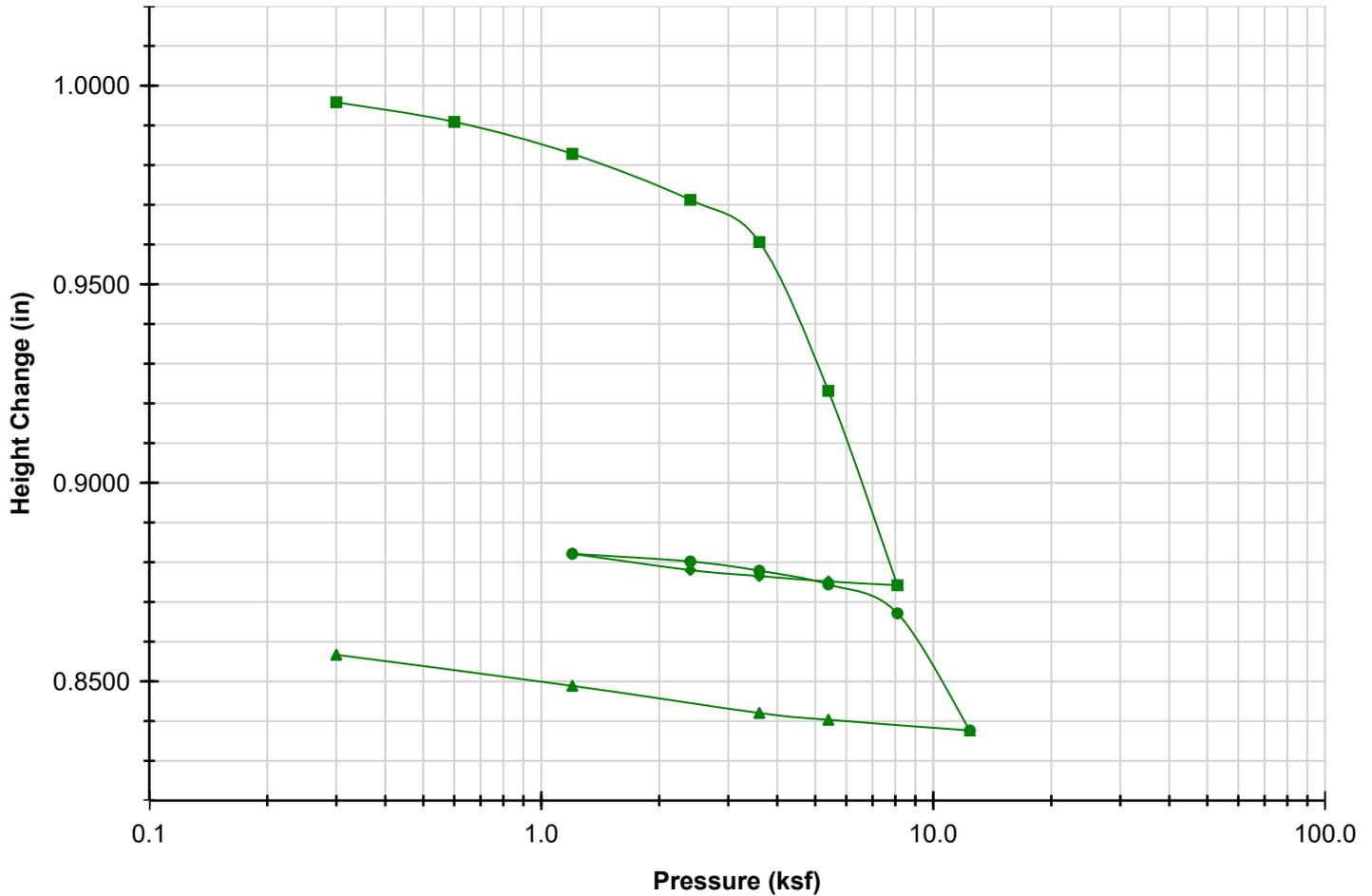
Checked By: \_\_\_\_\_

Date: \_\_\_\_\_



# Height Change [Log]

ASTM D2435



	<b>BEFORE</b>	<b>AFTER</b>	Liquid Limits	38	Test Date 4/22/2024
Moisture (%)	30.0	31.3	Plastic Limits	22	
Dry Density (pcf)	88.4	95.3			
Saturation (%)	88.5	108.8			
Void Ratio	0.92	0.78	Specific Gravity	2.72	ASSUMED

<b>Sample Description</b>				
Project Number	20-1403	Depth (ft)	20-22	Remarks
Sample Number	1U	Boring Number	BB-SSR-101	
Project	WIN 026184 - Sabattus River Bridge #5393 Replacement			
Client	Maine Department of Transportation			
Location	Route 126 over Sabattus River			

Project Name: WIN 026184 - Sabattus River Bridge #5393 Replacement Project Number: 20-1403

Technician: TSD

Test Date: 4/22/2024

Checked By: \_\_\_\_\_

Date: \_\_\_\_\_

# Summary

ASTM D2435

Sample Description			
<b>Project Number</b>	20-1403	<b>Depth (ft)</b>	20-22
<b>Sample Number</b>	1U	<b>Boring Number</b>	BB-SSR-101
<b>Project</b>	WIN 026184 - Sabattus River Bridge #5393 Replacement		
<b>Client</b>	Maine Department of Transportation		
<b>Location</b>	Route 126 over Sabattus River		

Index	Loading Sequence (ksf)	Cummulative Change in Height (in)	Specimen Height (in)	Height of Voids (in)	Vertical Strain (%)	Void Ratio	T90 Fitting Time (Hr)	T50 Fitting Time (Hr)	T90 Cv (in <sup>2</sup> /Min)	T50 Cv (in <sup>2</sup> /Min)	Sequence Status
0	0.000	0.0000	1.0000	0.0000	0.0	0.921	0.000	0.000	0.00000	0.00000	ENABLED
1	0.300	0.0042	0.9958	0.4744	0.4	0.910	0.027	0.006	0.13008	0.12936	ENABLED
2	0.600	0.0091	0.9909	0.4695	0.9	0.901	0.018	0.004	0.19398	0.19049	ENABLED
3	1.200	0.0172	0.9828	0.4614	1.7	0.885	0.021	0.005	0.16280	0.15591	ENABLED
4	2.400	0.0288	0.9712	0.4499	2.9	0.863	0.044	0.010	0.07632	0.07334	ENABLED
5	3.600	0.0394	0.9606	0.4392	3.9	0.842	0.042	0.010	0.07844	0.07027	ENABLED
6	5.400	0.0768	0.9232	0.4018	7.7	0.771	0.298	0.061	0.01010	0.01029	ENABLED
7	8.100	0.1258	0.8742	0.3528	12.6	0.677	0.760	0.172	0.00355	0.00289	ENABLED
8	5.400	0.1248	0.8752	0.3538	12.5	0.679	0.000	0.000	0.00000	0.00000	ENABLED
9	3.600	0.1235	0.8765	0.3551	12.3	0.681	0.000	0.000	0.00000	0.00000	ENABLED
10	2.400	0.1220	0.8780	0.3566	12.2	0.684	0.000	0.000	0.00000	0.00000	ENABLED
11	1.200	0.1179	0.8821	0.3607	11.8	0.692	0.000	0.000	0.00000	0.00000	ENABLED
12	2.400	0.1198	0.8802	0.3588	12.0	0.688	0.020	0.005	0.13906	0.10261	ENABLED
13	3.600	0.1221	0.8779	0.3565	12.2	0.684	0.023	0.005	0.11996	0.08807	ENABLED
14	5.400	0.1256	0.8744	0.3530	12.6	0.677	0.022	0.005	0.12558	0.09139	ENABLED
15	8.100	0.1329	0.8671	0.3458	13.3	0.663	0.045	0.010	0.05876	0.04287	ENABLED
16	12.400	0.1624	0.8376	0.3163	16.2	0.607	0.329	0.078	0.00754	0.00507	ENABLED

Project Name: WIN 026184 - Sabattus River Bridge #5393 Replacement Project Number: 20-1403

Technician: TSD

Test Date: 4/22/2024

Checked By: \_\_\_\_\_ Date: \_\_\_\_\_

Report Created: 5/2/2024

# Summary

ASTM D2435

Index	Loading Sequence (ksf)	Cummulative Change in Height (in)	Specimen Height (in)	Height of Voids (in)	Vertical Strain (%)	Void Ratio	T90 Fitting Time (Hr)	T50 Fitting Time (Hr)	T90 Cv (in <sup>2</sup> /Min)	T50 Cv (in <sup>2</sup> /Min)	Sequence Status
17	5.400	0.1597	0.8403	0.3190	16.0	0.612	0.000	0.000	0.00000	0.00000	ENABLED
18	3.600	0.1580	0.8420	0.3207	15.8	0.615	0.000	0.000	0.00000	0.00000	ENABLED
19	1.200	0.1511	0.8489	0.3275	15.1	0.628	0.000	0.000	0.00000	0.00000	ENABLED
20	0.300	0.1433	0.8567	0.3353	14.3	0.643	0.000	0.000	0.00000	0.00000	ENABLED

Project Name: WIN 026184 - Sabattus River Bridge #5393 Replacement Project Number: 20-1403

Technician: TSD

Test Date: 4/22/2024

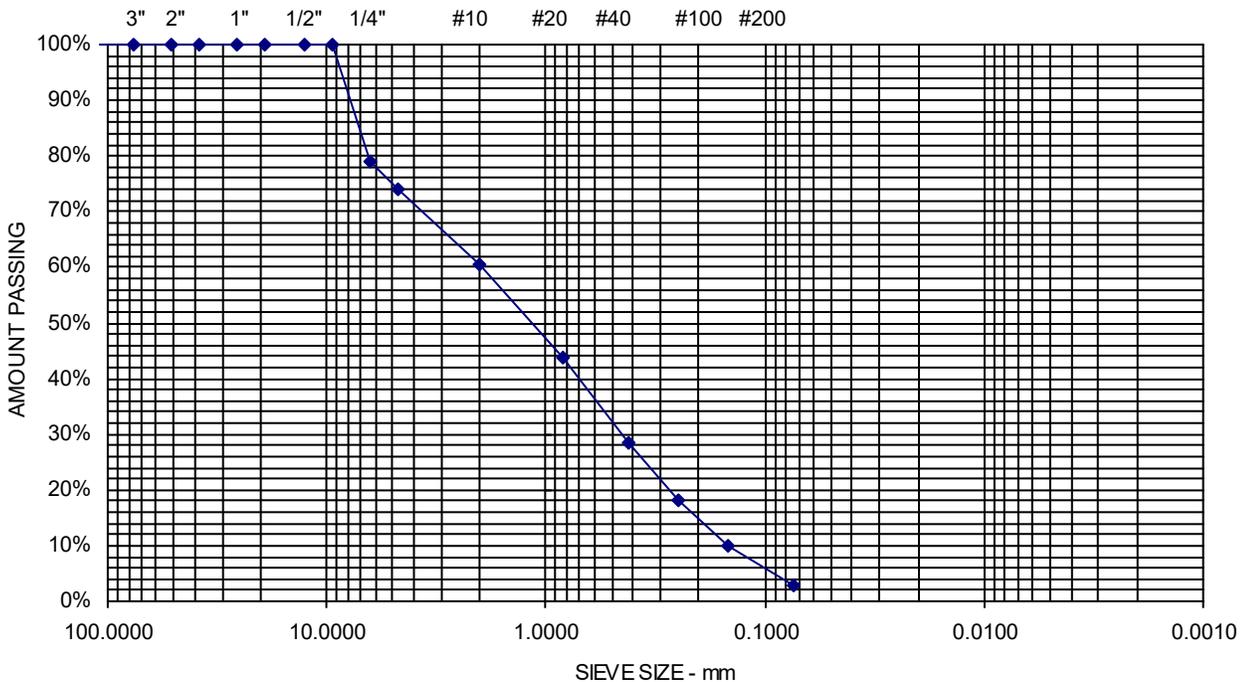
Checked By: \_\_\_\_\_ Date: \_\_\_\_\_

Report Created: 5/2/2024

Project Name VARIOUS ME - STATEWIDE BRIDGE PROJECTS  
(2020062300000000765) - GEOTECHNICAL INVESTIGATIONS AND  
Client STATE OF MAINE DEPARTMENT OF TRANSPORTATION  
Exploration **BB-SSR-102**  
Material Source **2D, 5FT**

Project Number 20-1403  
Lab ID 15476A  
Date Received 4/22/2024  
Date Completed 5/8/2024  
Tested By NEIL DAVIS

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
150 mm	6"	100	
125 mm	5"	100	
100 mm	4"	100	
75 mm	3"	100	
50 mm	2"	100	
38.1 mm	1-1/2"	100	
25.0 mm	1"	100	
19.0 mm	3/4"	100	
12.5 mm	1/2"	100	
9.5 mm	3/8"	100	
6.3 mm	1/4"	79	
4.75 mm	No. 4	74	26.1% Gravel
2.00 mm	No. 10	60	
850 μm	No. 20	44	
425 μm	No. 40	28	71.1% Sand
250 μm	No. 60	18	
150 μm	No. 100	10	
75 μm	No. 200	2.8	2.8% Fines

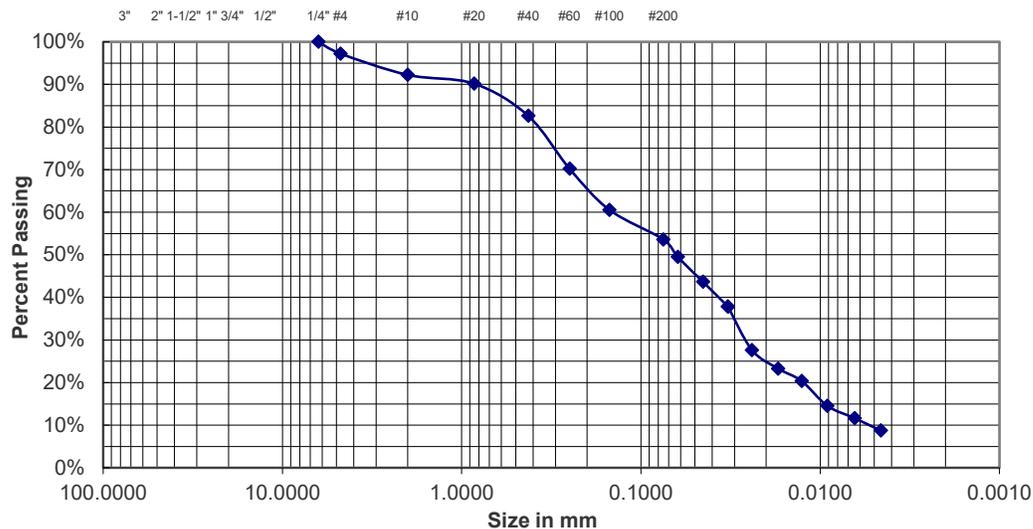


Comments: Moisture Content = 9.4%

**Project Name:** Statewide Bridge Projects  
**Project Location:** Various, ME  
**Client:** State of Maine Department of Transportation  
**Material Description:** Exploration  
**Material Source:** BB-SSR-102, 4D, 15'

**Project Number:** 20-1403  
**Lab ID:** 15477A  
**Date Received:** 4/22/2024  
**Date Completed:** 5/3/2024  
**Tested By:** N. Davis

Sieve Analysis			Hydrometer Analysis		
Sieve Size	Standard Designation (mm)	Amount Passing (%)	Specification (name)	Particle Size (mm)	Amount Passing (%)
3"	76	100		0.06229	49.5
2"	50	100		0.04503	43.6
1½"	38.1	100		0.03266	37.8
1"	25	100		0.03266	37.8
¾"	19	100		0.02403	27.6
½"	12.5	100		0.01719	23.3
¼"	6.3	100		0.01269	20.4
No. 4	4.75	97		0.00914	14.5
No. 10	2	92		0.00643	11.6
No. 20	0.85	90		0.00459	8.7
No. 40	0.425	83		0.00328	7.3
No. 60	0.25	70		0.00231	2.9
No. 100	0.15	61		0.00135	4.4
No. 200	0.075	53.6			



**Particle Distribution:** Gravel (3" - No. 4) **2.8%** Fines (0.074 - 0.005) **44.1%**  
 Sand (No. 4 - No. 200) **43.6%** Clay (<0.005) **9.5%**

Comments:

Reviewed By

26 Coles Crossing Drive, Sidney, ME 04330 • P: (207) 626.0600 • F: (207) 626.0700 • E: infosidney@swcole.com



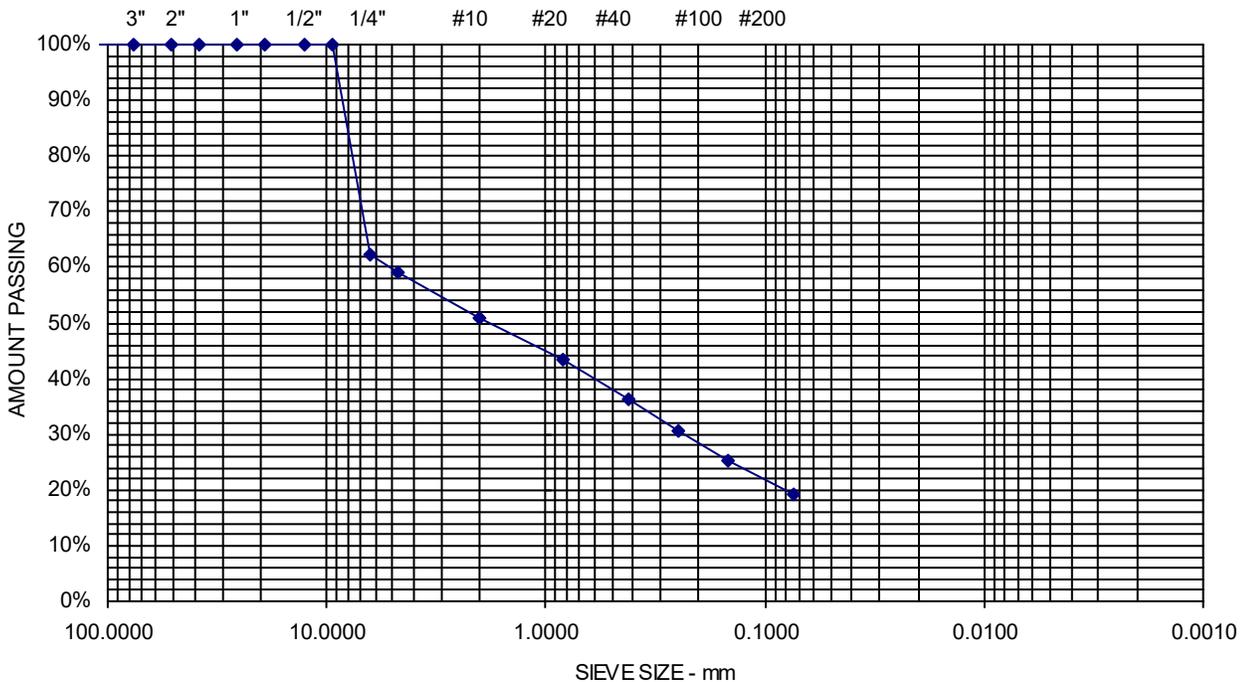
# Report of Gradation

ASTM C-117 & C-136

Project Name VARIOUS ME - STATEWIDE BRIDGE PROJECTS  
 (2020062300000000765) - GEOTECHNICAL INVESTIGATIONS AND  
 Client STATE OF MAINE DEPARTMENT OF TRANSPORTATION  
 Exploration **BB-SSR-102**  
 Material Source **8D, 35FT**

Project Number 20-1403  
 Lab ID 15480A  
 Date Received 4/22/2024  
 Date Completed 5/8/2024  
 Tested By NEIL DAVIS

<u>STANDARD DESIGNATION (mm/μm)</u>	<u>SIEVE SIZE</u>	<u>AMOUNT PASSING (%)</u>	
150 mm	6"	100	
125 mm	5"	100	
100 mm	4"	100	
75 mm	3"	100	
50 mm	2"	100	
38.1 mm	1-1/2"	100	
25.0 mm	1"	100	
19.0 mm	3/4"	100	
12.5 mm	1/2"	100	
9.5 mm	3/8"	100	
6.3 mm	1/4"	62	
4.75 mm	No. 4	59	40.8% Gravel
2.00 mm	No. 10	51	
850 μm	No. 20	43	
425 μm	No. 40	36	40.1% Sand
250 μm	No. 60	31	
150 μm	No. 100	25	
75 μm	No. 200	19.1	19.1% Fines



Comments: Moisture Content = 9.8



## **APPENDIX E**

### **Calculations**



## **Seismic Site Classification**

Determine Seismic Site Classification per AASHTO LRFD Table C3.10.3.1-1 - Method B

Data From BB-SSR-101

Layer No.	Layer Description	Depth Range (ft)		N <sub>60</sub> values recorded within layer								Average N <sub>60</sub> value	Layer Thickness	d <sub>i</sub> /N <sub>i</sub>	
		Top	End									N <sub>i</sub>	d <sub>i</sub>		
1	Fill	0	14	94	14	80							62.7	14	0.22
2	Marine Clay	14	36.3	1	4								2.5	22.3	8.92
3	Glacial Till	36.3	39.2	16									16.0	2.9	0.18
4	Bedrock	39.2	100	100									100.0	60.8	0.61
<b>Σ =</b>											<b>100</b>	<b>9.93</b>			

$N_{bar} = d_i/d_i/N_i = \frac{10.07}{E}$

Data From BB-SSR-102

Layer No.	Layer Description	Depth Range (ft)		N <sub>60</sub> values recorded within layer								Average N <sub>60</sub> value	Layer Thickness	d <sub>i</sub> /N <sub>i</sub>	
		Top	End									N <sub>i</sub>	d <sub>i</sub>		
1	Fill	0	13	47	20	34							33.7	13	0.39
2	Alluvium	13	20	2									2.0	7	3.50
3	Marine Clay	20	35	9									9.0	15	1.67
4	Glacial Till	35	43.4	42	100								71.0	8.4	0.12
5	Bedrock	43.4	100	100									100.0	56.6	0.57
<b>Σ =</b>											<b>100</b>	<b>6.24</b>			

$N_{bar} = d_i/d_i/N_i = \frac{16.03}{D}$

- NOTES:**
1. Weight of Rod (WOR) and Weight of Hammer (WOH) values taken as N=1
  2. N<sub>60</sub> values > 100 taken as N=100
  3. N<sub>60</sub> value for bedrock taken as N=100

Sabattus River Bridge #5393

Conterminous 48 States  
 2007 AASHTO Bridge Design Guidelines  
 AASHTO Spectrum for 7% PE in 75 years

Latitude = 44.113165

Longitude = -070.107872

Site Class B

Data are based on a 0.05 deg grid spacing.

Period (sec)	Sa (g)	
0.0	0.085	PGA - Site Class B
0.2	0.172	Ss - Site Class B
1.0	0.046	S1 - Site Class B

Conterminous 48 States  
 2007 AASHTO Bridge Design Guidelines  
 Spectral Response Accelerations SDs and SD1

Latitude = 44.113165

Longitude = -070.107872

As = FpgaPGA, SDs = FaSs, and SD1 = FvS1

Site Class E - Fpga = 2.50, Fa = 2.50, Fv = 3.50

Data are based on a 0.05 deg grid spacing.

Period (sec)	Sa (g)	
0.0	0.213	As - Site Class E
0.2	0.430	SDs - Site Class E
1.0	0.161	SD1 - Site Class E

Conterminous 48 States  
 2007 AASHTO Bridge Design Guidelines  
 Design Response Spectra for Site Class E

Latitude = 44.113165

Longitude = -070.107872

As = FpgaPGA, SDs = FaSs, SD1 = FvS1

Site Class E - Fpga = 2.50, Fa = 2.50, Fv = 3.50

Data are based on a 0.05 deg grid spacing.

Period (sec)	Sa (g)	Sd in.	
0.000	0.213	0.000	T = 0.0, Sa = As
0.075	0.430	0.024	
0.200	0.430	0.168	T = 0.2, Sa = SDs
0.375	0.430	0.591	T = Ts, Sa = SDs
0.400	0.403	0.630	
0.600	0.269	0.946	
0.800	0.202	1.261	
1.000	0.161	1.576	T = 1.0, Sa = SD1
1.200	0.134	1.891	
1.400	0.115	2.206	
1.600	0.101	2.521	
1.800	0.090	2.837	
2.000	0.081	3.152	
2.200	0.073	3.467	
2.400	0.067	3.782	
2.600	0.062	4.097	
2.800	0.058	4.412	
3.000	0.054	4.728	

3.200	0.050	5.043
3.400	0.047	5.358
3.600	0.045	5.673
3.800	0.042	5.988
4.000	0.040	6.304

## **Liquefaction Potential**



**SPT-BASED LIQUEFACTION POTENTIAL EVALUATION OF SANDS AND NON-PLASTIC SILTS**

Project Name: Sabattus River Bridge #5393 Replacement  
 Project No.: 20-1403-026184  
 Evaluated By/Date: MAS / May 2024  
 Reviewed By: ALS

Exploration: BB-SSR-102

**Site Data (Time of Exploration)**

Ground Surface Elevation (ft) =	100
Groundwater Depth (ft) =	10
Groundwater Elevation (ft) =	90

**Drilling Data**

Typ Rod Stick-Up (ft) =	3
Typ Rod Stick-Up (m) =	0.91
Borehole Diameter (in) =	4
Borehole Diameter (mm) =	101.6
Hammer Energy Ratio (%) =	108.7

**Seismic Parameters/Assumptions**

PGA on Rock (g) =	0.085
AASHTO Site Class =	E
Peak Ground Acceleration (g) =	0.213
Mean Earthquake Magnitude =	5.55 (from USGS 975-yr event)
Magnitude Scaling Factor =	1.66 (Youd and Idriss, 1997)

**Design Site Data**

Design Ground Surface =	103
Design Groundwater Elev =	10
Design Groundwater Depth (ft) =	93
Thickness of New Fill (ft) =	3
Thickness of New Fill (m) =	0.91
Assumed Unit Weight of New Fill (pcf) =	125

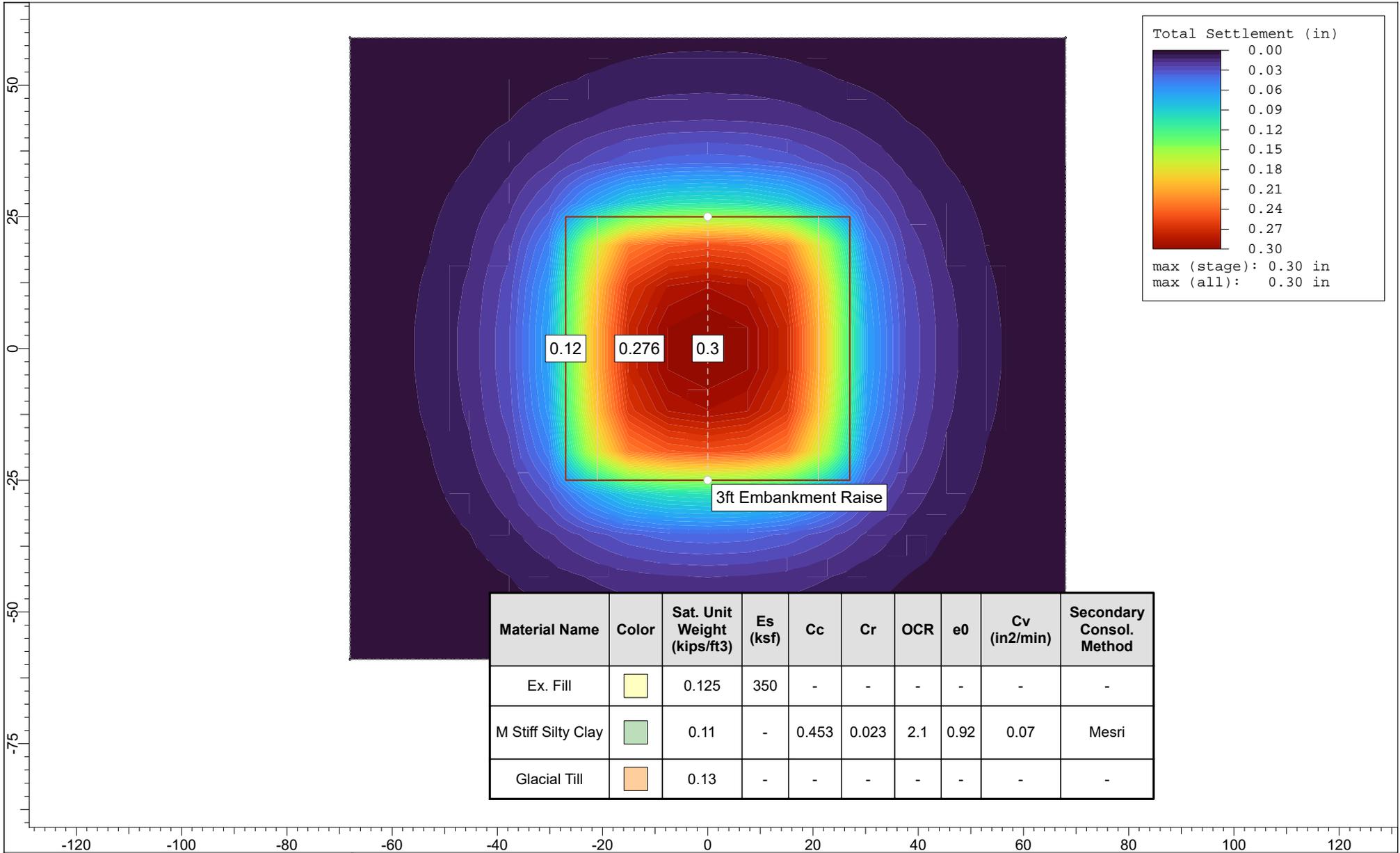
Soil Layer	Stratum	Sample No.	Mid Sample Depth		Elev. (ft)	Field N-Value	Fines Content (%)	Total Stress (psf)	Effective Stress (psf)	Flags unsaturated PI>5	Correction Factors				Parameter Calculations				Capacity Demand Ration Calculations							Lateral Displacement Calculation				Settlement					
			(ft)	(m)							N <sub>m</sub>	C <sub>E</sub>	C <sub>B</sub>	C <sub>R</sub>	C <sub>S</sub>	N <sub>60</sub> blows/ft	Overburden Stress C <sub>N</sub>	(N <sub>1</sub> ) <sub>60</sub> blows/ft	Δ(N <sub>1</sub> ) <sub>60</sub> blows/ft	(N <sub>1</sub> ) <sub>60cs</sub> blows/ft	CRR <sub>M=7.5, σ=1atm</sub>	C <sub>r</sub>	K <sub>r</sub>	CRR	Design Total Stress	Design Effective Stress	Stress Reduction Coeff. r <sub>d</sub>	CSR	FS	F <sub>α</sub>	γ <sub>sm</sub>	γ <sub>max</sub>	Layer Thickness (ft)	Lateral Displacement Index LDI	Vertical Re-consol Strain (ft)
1	Fill	1D	2.0	0.61	98.0	26	5	250	250	unsaturated	1.81	1.0	0.75	1.0	35	1.56	56	0	56	4.13	0.30	1.10	7.57	625	625	0.98	0.14	N/L	-2.10	0.000	0.000	4.0	0.01	0.000	0.09
1	Fill	2D	6.0	1.83	94.0	11	10	750	750	unsaturated	1.81	1.0	0.75	1.0	15	1.51	25	1	27	0.33	0.17	1.10	0.61	1125	1125	0.96	0.13	N/L	0.14	0.073	0.000	4.5	0.01	0.000	0.09
1	Fill	3D	11.0	3.35	89.0	19	10	1375	1375		1.81	1.0	0.85	1.0	29	1.15	35	1	37	1.57	0.27	1.10	2.87	1750	1750	0.92	0.13	5.00	-0.55	0.017	0.000	5.0	0.01	0.000	0.09
2	Alluvium	1D	16.0	4.88	84.0	1	60	1951	1951		1.81	1.0	0.85	1.0	2	1.05	2	6	7	0.10	0.06	1.01	0.17	2326	2326	0.89	0.12	1.38	0.95	0.633	0.003	5.0	0.01	0.001	0.09
3	Marine Clay	2D	21.0	6.40	79.0	1	95	2501	2501	PI>5	1.81	1.0	0.95	1.0	2	0.89	2	6	7	0.10	0.06	0.99	0.16	2876	2876	0.85	0.12	N/L	0.95	0.642	0.000	5.0	0.00	0.000	0.00
3	Marine Clay	3D	26.0	7.92	74.0	5	95	3051	3051	PI>5	1.81	1.0	0.95	1.0	9	0.81	8	6	14	0.15	0.09	0.97	0.24	3426	3426	0.80	0.11	N/L	0.80	0.312	0.000	5.0	0.00	0.000	0.00
3	Marine Clay	4D	31.0	9.45	69.0	1	95	3601	3601	PI>5	1.81	1.0	1.00	1.0	2	0.69	2	6	7	0.10	0.06	0.97	0.16	3976	3976	0.76	0.11	N/L	0.95	0.655	0.000	5.0	0.00	0.000	0.00
4	Glacial Till	5D	36.0	10.97	64.0	23	15	4176	4176		1.81	1.0	1.00	1.0	42	0.79	34	3	37	1.75	0.24	0.83	2.43	4551	4551	0.72	0.10	5.00	-0.58	0.016	0.000	4.5	0.00	0.000	0.00
4	Glacial Till	6D	40.0	12.19	60.0	100	15	4696	4696		1.81	1.0	1.00	1.0	181	1.09	136	3	139	4.13	0.30	0.76	5.26	5071	5071	0.69	0.10	5.00	-9.92	0.000	0.000	2.0	0.00	0.000	0.00

Reference: Idriss and Boulanger (2008), Soil Liquefaction During Earthquakes, Earthquake Engineering Research Institute.

Notes:  
 N/L = Not Liquefiable  
 Factor of safety (FS) for unsaturated soils and cohesive soils with PI >5 not calculated.  
 Factor of safety calculations limited to a maximum value of 5. Actual FS value may be greater than shown.  
 Design ground surface elevation was estimate based on bridge profile drawing.  
 Fines content shown were estimated base on boring log soil descriptions where laboratory test results are not available.  
 Field N-values limited to a minimum value of 1 bpf.

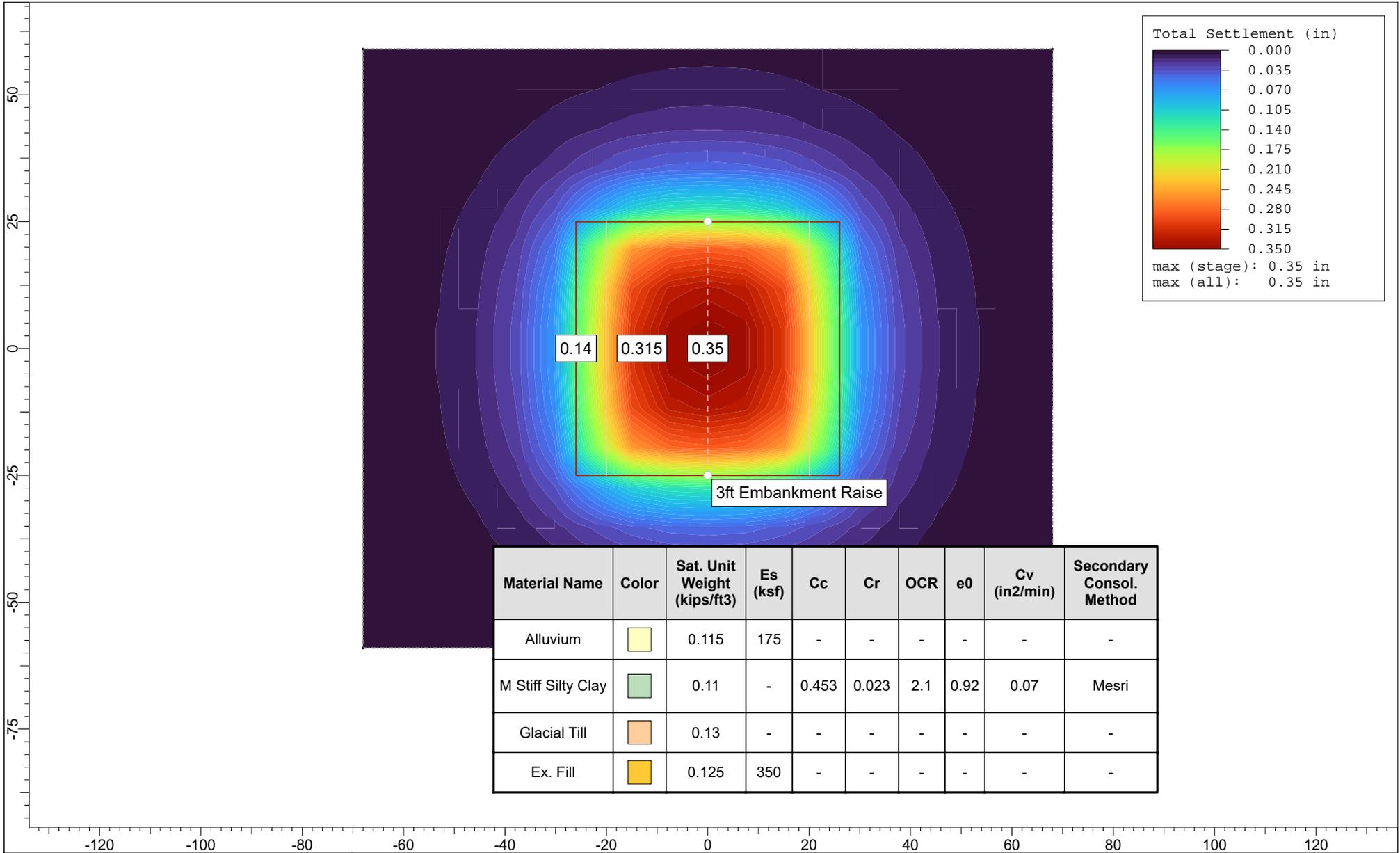


## Settlement



Material Name	Color	Sat. Unit Weight (kips/ft3)	Es (ksf)	Cc	Cr	OCR	e0	Cv (in2/min)	Secondary Consol. Method
Ex. Fill		0.125	350	-	-	-	-	-	-
M Stiff Silty Clay		0.11	-	0.453	0.023	2.1	0.92	0.07	Mesri
Glacial Till		0.13	-	-	-	-	-	-	-

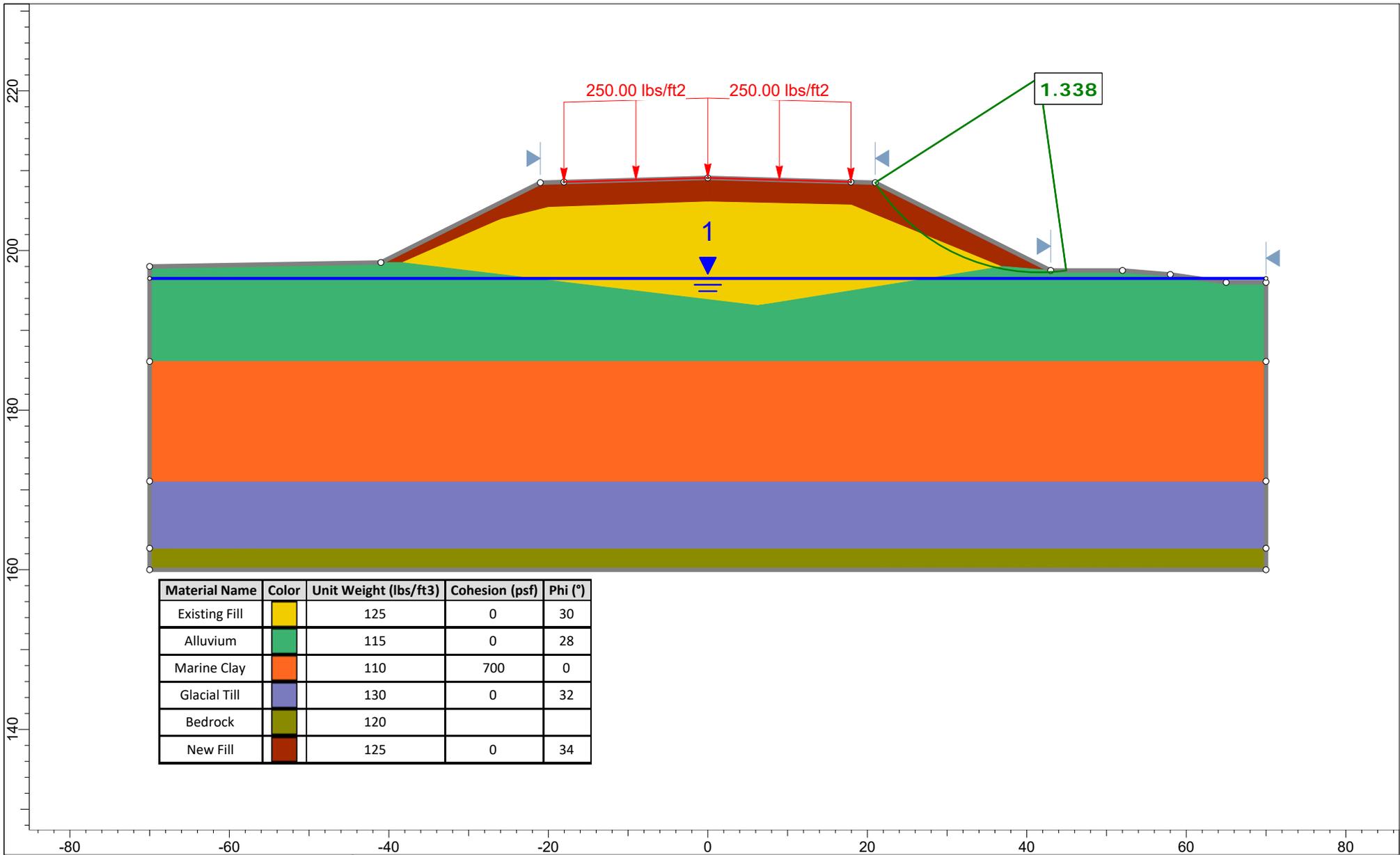
	Project			WIN 26184 Sabattus River Bridge		
	Analysis Description			Sta. 6+25 - 3 ft Grade Raise Fill		
	Drawn By	MAS	Reviewed By	ALS	Date	May 2025
	Company	S. W. Cole Engineering, Inc.		File Name	6+25.s3z	



	Project			WIN 26184 Sabattus River Bridge		
	Analysis Description			Sta. 7+00 - 3 ft Grade Raise Fill		
	Drawn By	MAS	Reviewed By	ALS	Date	May 2025
	Company	S. W. Cole Engineering, Inc.		File Name	7+00.s3z	

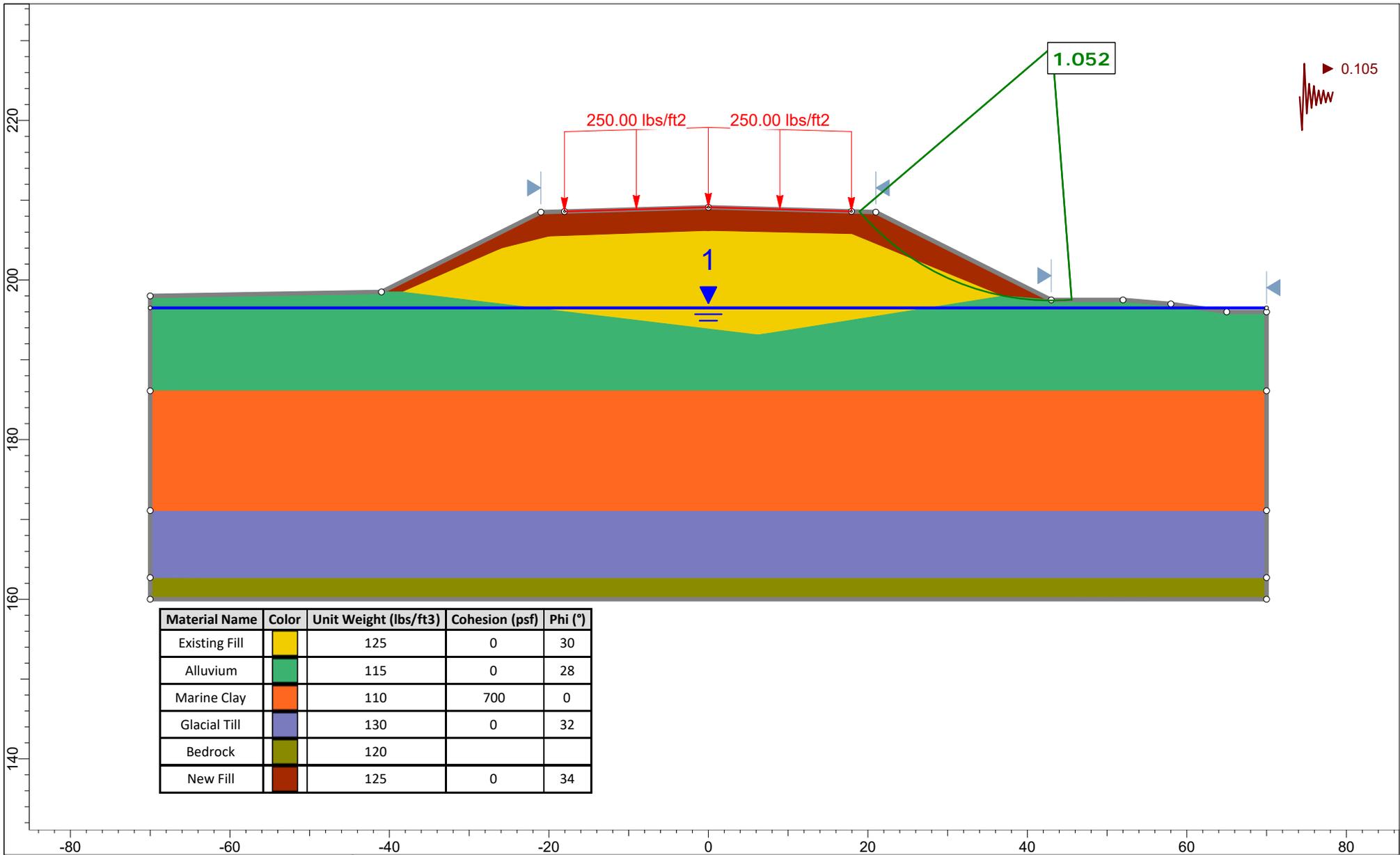


**Global Stability**

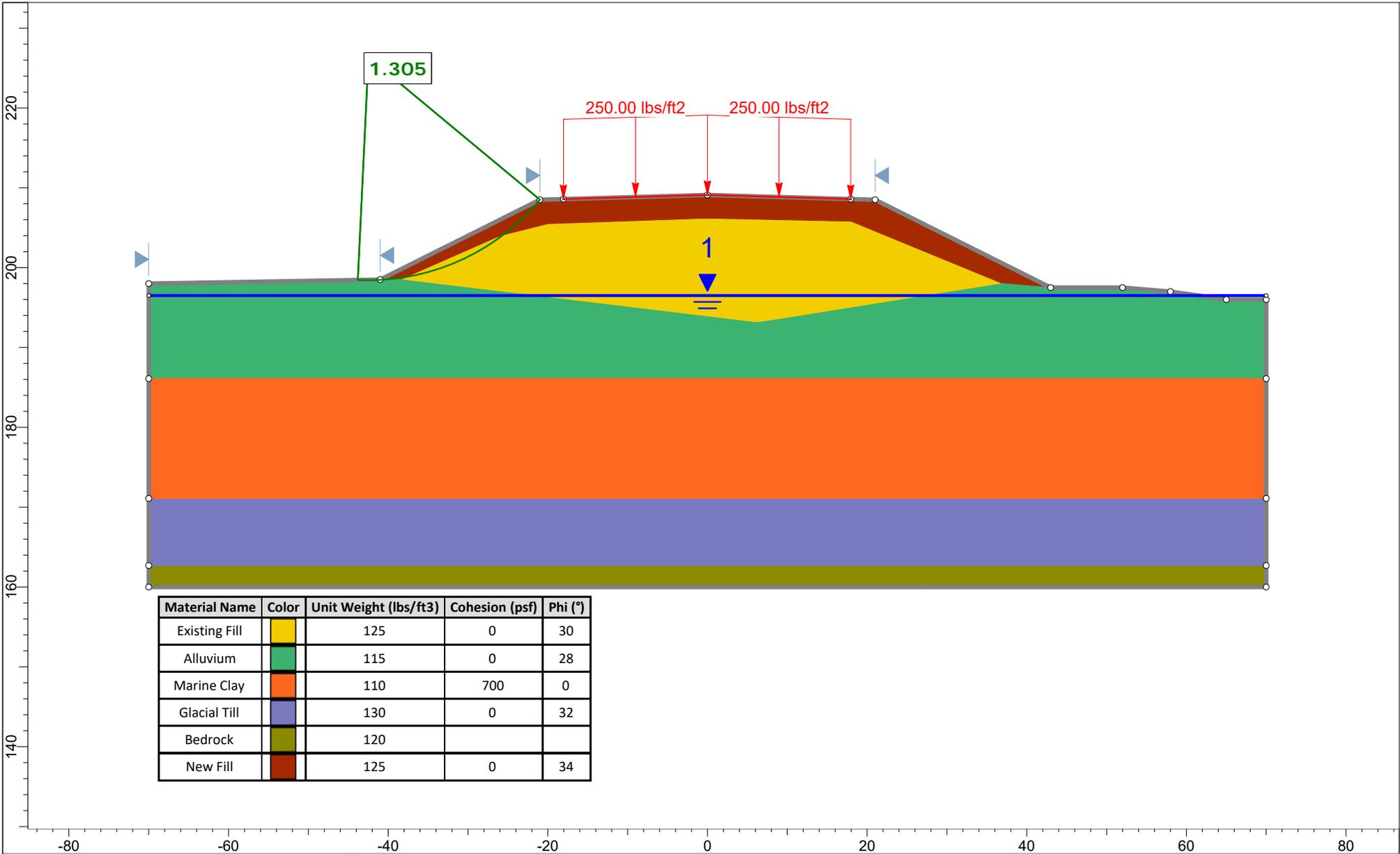


Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (psf)	Phi (°)
Existing Fill	Yellow	125	0	30
Alluvium	Green	115	0	28
Marine Clay	Orange	110	700	0
Glacial Till	Purple	130	0	32
Bedrock	Brown	120		
New Fill	Red	125	0	34

	Project				WIN 26184 Sabattus River Bridge			
	Analysis Description				Sta. 7+00 - Static			
	Scale	1:200	Drawn By	MAS	Reviewed By	ALS	Date	May 2025
	Company				S. W. Cole Engineering, Inc.			
				File Name				7+00.slmd



	Project				WIN 26184 Sabattus River Bridge			
	Analysis Description				Sta. 7+00 - Seismic			
	Scale	1:200	Drawn By	MAS	Reviewed By	ALS	Date	May 2025
	Company	S. W. Cole Engineering, Inc.			File Name	7+00.slmd		

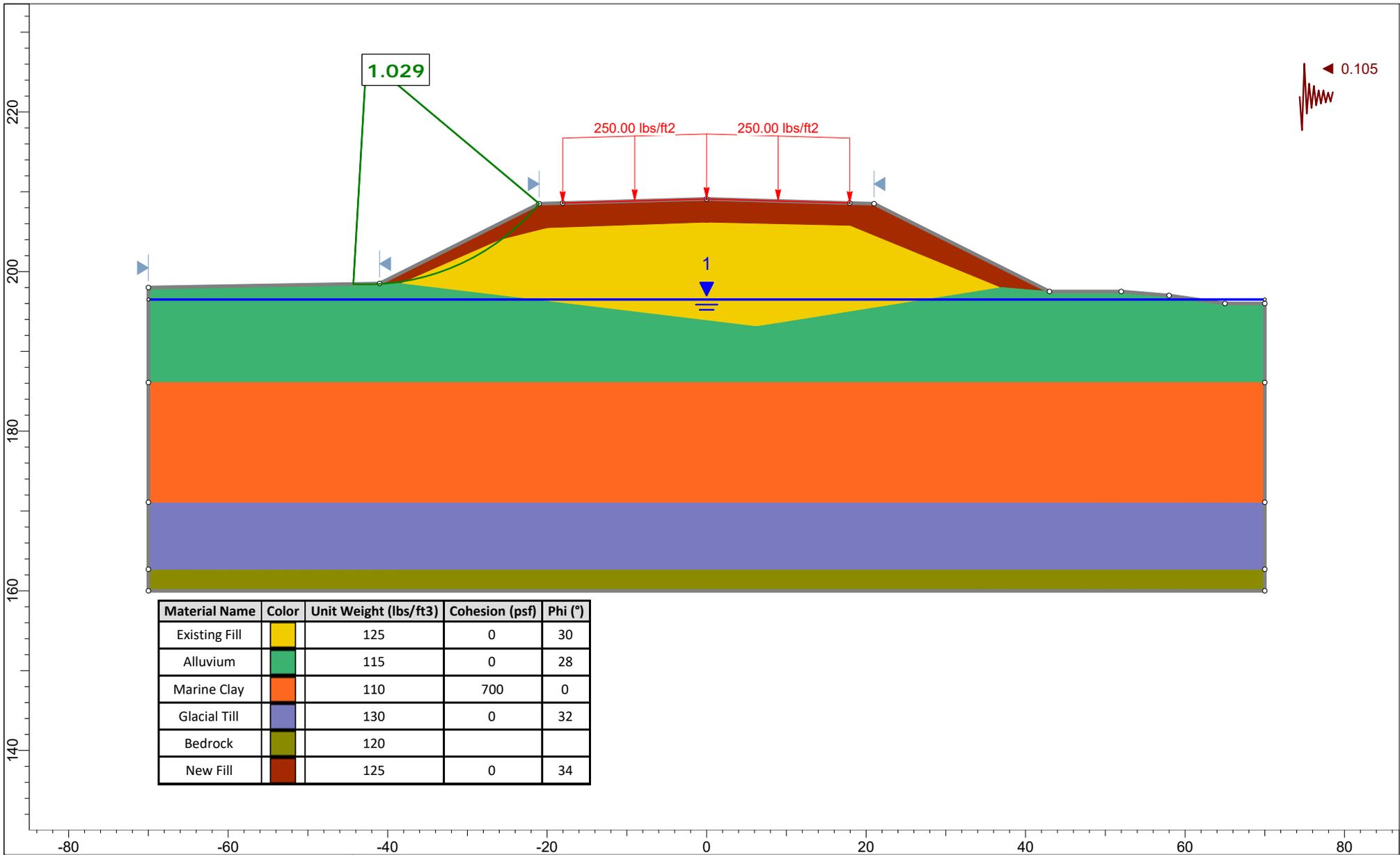


Material Name	Color	Unit Weight (lbs/ft <sup>3</sup> )	Cohesion (psf)	Phi (°)
Existing Fill	Yellow	125	0	30
Alluvium	Green	115	0	28
Marine Clay	Orange	110	700	0
Glacial Till	Purple	130	0	32
Bedrock	Olive	120		
New Fill	Brown	125	0	34



SLIDEINTERPRET 9.031

Project		WIN 26184 Sabattus River Bridge			
Analysis Description		Sta. 7+00 - Static			
Scale	1:200	Drawn By	MAS	Reviewed By	ALS
Company		S. W. Cole Engineering, Inc.		Date	May 2025
				File Name	7+00.slmd



	Project				WIN 26184 Sabattus River Bridge			
	Analysis Description				Sta. 7+00 - Seismic			
	Scale	1:200	Drawn By	MAS	Reviewed By	ALS	Date	May 2025
	Company	S. W. Cole Engineering, Inc.			File Name	7+00.slmd		



## **H-Piles**

## Design of Bearing H-Piles

### References:

1. AASHTO LRFD Bridge Design Specifications, 9th Edition, 2020. (LRFD)
2. AASHTO Standard Specifications for Highway Bridges 17th Edition, 2002. (AASHTO)

### Bedrock Properties

RQD: BB-SSR-101 R1, R2 = 50, 72% Range: 0-78%  
 BB-SSR-102 R1, R2 = 70, 70% Weighted Average: 65%

Rock Type: GRANOFELS, hard, fresh, joints generally close to moderately close, and tight

Pile Properties: HP14x89  
 HP14x117

**All matrices in document  
 in following order:  
 HP14x89  
 HP14x117**

$$f_y := 50 \text{ ksi}$$

$$A_s := \begin{bmatrix} 26.1 \\ 34.4 \end{bmatrix} \cdot \text{in}^2$$

$$d := \begin{bmatrix} 13.8 \\ 14.2 \end{bmatrix} \cdot \text{in}$$

$$b := \begin{bmatrix} 14.7 \\ 14.9 \end{bmatrix} \cdot \text{in}$$

$$A_p := \overrightarrow{(d \cdot b)} = \begin{bmatrix} 202.86 \\ 211.58 \end{bmatrix} \text{ in}^2 \quad \text{Area of Plugged Pile}$$

$$P_p := \overrightarrow{(2 \cdot d + 2 \cdot b)} = \begin{bmatrix} 57 \\ 58.2 \end{bmatrix} \text{ in} \quad \text{Perimeter of Pile}$$

## **Nominal and Factored Structural Compressive Resistance**

Determine Nominal Axial Structural Resistance

$$P_o := f_y \cdot A_s = \begin{bmatrix} 1305 \\ 1720 \end{bmatrix} \text{ kip}$$

Structural Resistance of unbraced segment

Assume 4 foot unbraced section due to scour  
 Determine elastic critical buckling resistance,  $P_e$

$$E_s := 29000 \text{ ksi}$$

$$K_{eff} := 1.0 \quad \text{effective length factor / LRFD Table C4.6.2.5-1}$$

$$l_{unbraced} := 4 \text{ ft} \quad \text{unbraced length top of pile assumed}$$

$$r_y := \begin{bmatrix} 3.53 \\ 3.59 \end{bmatrix} \cdot \text{in} \quad \text{radius of gyration, weak axis / LRFD Article C6.9.4.1.2}$$

LRFD Eqn 6.9.4.1.2-1

$$P_{e1} := \left( \frac{\pi^2 \cdot E_s}{\left( \frac{K_{eff} \cdot l_{unbraced}}{r_y} \right)^2} \cdot A_s \right) = \begin{bmatrix} 40402 \\ 55076 \end{bmatrix} \text{ kip}$$

LRFD Article 6.9.4.1.1

$$\frac{P_{e1}}{P_o} = \begin{bmatrix} 30.96 \\ 32.021 \end{bmatrix} \quad P_{n1} := \begin{cases} \text{if } \left\| \frac{P_{e1}}{P_o} \geq 0.44 \right\| \\ \frac{0.658 \left( \frac{P_o}{P_{e1}} \right) \cdot P_o}{\text{if } \left\| \frac{P_{e1}}{P_o} < 0.44 \right\|} \\ 0.877 \cdot P_{e1} \end{cases} = \begin{bmatrix} 1287 \\ 1698 \end{bmatrix} \text{ kip}$$

Determine Factored Axial Structural Resistance at Strength Limit State

$\phi_{cu} := 0.7$  For combined axial and flexural resistance of H piles  
 LRFD Article 6.5.4.2

$$P_{r1} := \phi_{cu} \cdot P_{n1} = \begin{bmatrix} 901 \\ 1188 \end{bmatrix} \text{ kip} \quad \text{LRFD Eqn 6.9.2.1-1}$$

Determine Factored Axial Structural Resistance at Strength Limit State

Structural Resistance of braced length

$$l_{braced} := 0.1 \text{ ft}$$

LRFD Eqn 6.9.4.1.2-1

$$P_{e2} := \left( \frac{\pi^2 \cdot E_s}{\left( \frac{K_{eff} \cdot l_{braced}}{r_y} \right)^2} \cdot A_s \right) = \begin{bmatrix} 64643546 \\ 88121644 \end{bmatrix} \text{ kip}$$

LRFD Article 6.9.4.1.1

Check if  $P_e/P_o \geq 0.44$

$$\frac{P_{e2}}{P_o} = \begin{bmatrix} 49535 \\ 51234 \end{bmatrix} \quad P_{n2} := \begin{cases} \text{if } \left\| \frac{P_{e2}}{P_o} \geq 0.44 \right\| \\ \quad \frac{0.658 \left( \frac{P_o}{P_{e2}} \right) \cdot P_o}{\text{if } \left\| \frac{P_{e2}}{P_o} < 0.44 \right\|} \\ \quad 0.877 \cdot P_{e2} \end{cases} = \begin{bmatrix} 1305 \\ 1720 \end{bmatrix} \text{ kip}$$

Determine Factored Axial Structural Resistance at Strength Limit State

$$\phi_c := 0.5$$

LRFD Article 6.5.4.2 for Severe Driving

$$P_{r2} := \phi_c \cdot P_{n2} = \begin{bmatrix} 652 \\ 860 \end{bmatrix} \text{ kip}$$

LRFD Eqn 6.9.2.1-1

Determine Factored Axial Structural Resistance at Service and Extreme Limit State

$$\phi_{s\_ex} := 1.0$$

$$P_{r\_e} := \phi_{s\_ex} \cdot P_{n2} = \begin{bmatrix} 1305 \\ 1720 \end{bmatrix} \text{ kip}$$

LRFD Eqn 6.9.2.1-1

### Nominal and Factored Geotechnical Resistance

LRFD Article 10.7.3.2.3 states "the nominal resistance of piles driven to point bearing on hard rock where pile penetration into the rock formation is minimal is controlled by the structural limit state. The nominal bearing resistance shall not exceed the values obtained from Article 6.9.4.1 with the resistance factor specified in Article 6.5.4.2 and Article 6.15 for severe driving conditions. A pile-driving acceptance criteria shall be developed that will prevent pile damage."

#### Nominal Structural Resistance

$$P_o = \begin{bmatrix} 1305 \\ 1720 \end{bmatrix} \text{ kip}$$

#### Determine Factored Geotechnical Resistance for Abutment 2 at Strength Limit States

$$\phi_c = 0.5 \quad \text{LRFD 6.9.2.1-1 for Strength Limit State}$$

$$P_{rg} := \phi_c \cdot P_{n2} = \begin{bmatrix} 652 \\ 860 \end{bmatrix} \text{ kip}$$

#### Determine Factored Geotechnical Resistance for Abutment 1 at Service and Extreme Limit State

$$\phi_{s\_ex} = 1 \quad \text{LRFD 6.9.2.1-1 for the Services and Extreme Limit States}$$

$$P_{rg\_e} := \phi_{s\_ex} \cdot P_{n2} = \begin{bmatrix} 1305 \\ 1720 \end{bmatrix} \text{ kip}$$

### Drivability Analysis

From LRFD Article 10.7.8

For steel piles in compression or tension, limit driving stresses to 90% fy

$$\phi_{da} := 1.0 \quad \text{LRFD Table 10.5.5.2.3-1, Drivability Analysis, Steel Piles (See LRFD 6.5.4.2)}$$

$$\sigma_{da} := 0.9 \cdot f_y \cdot \phi_{da} = 45 \text{ ksi} \quad \text{LRFD Eqn 10.7.8.1}$$

Per LRFD, limit driving stresses to 45 ksi or less or

Per BDG Section 501, limit blow counts to 5-15 blows to inch (bpi) with 6-10 bpi optimal

ASSUME 10 bpi

Determine maximum resistance from drivability analysis:

$$\phi_{dyn} := 0.65 \quad \text{LRFD Table 10.5.5.2.3-1 Strength Limit State (min. 1 PDA test per abutment)}$$

$$\phi_s := 1 \quad \text{Service and Extreme Limit States}$$

### GRLWeap Soil and Pile Model Assumptions

Assume contractor drives **50 ft piles** to account for additional pile length for testing (5 ft), rock embedment (< 1 ft), pile cap embedment (3 ft) and cut off.

Delmag D19-42 hammer chosen as typical pile hammer capable of producing energy of about 42,000 ft-lbs. The following pile hammer and cushion parameters were used in the analysis:

Delmag D 19-42

Hammer parameters			
Efficiency	0.8		
Pressure	1600	psi	Fixed 100 %
Stroke	10.81	ft	Fixed

From GRLWeap output:

$$R_{n1dr} := \begin{bmatrix} 605 \\ 660 \end{bmatrix} \text{ kip}$$

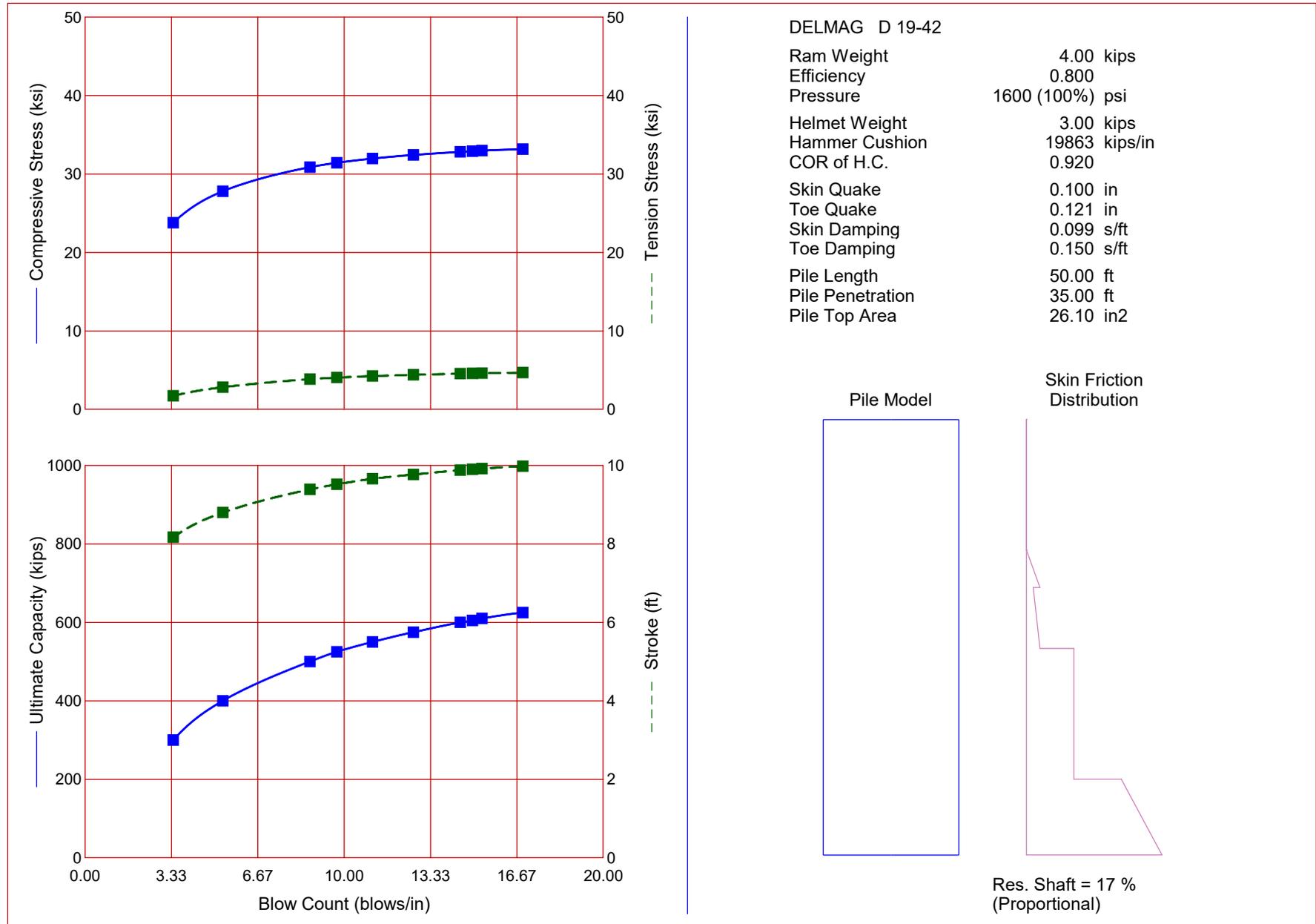
Cushion Information			
	Hammer	Pile	
Area	227.	0.	in <sup>2</sup>
Elastic Modulus	530.	0.	ksi
Thickness	2.	0.	in
C.O.R.	0.8	0.	
Stiffness	0	0	kips/in
Helmet Weight	1.9		kips

Strength Limit State

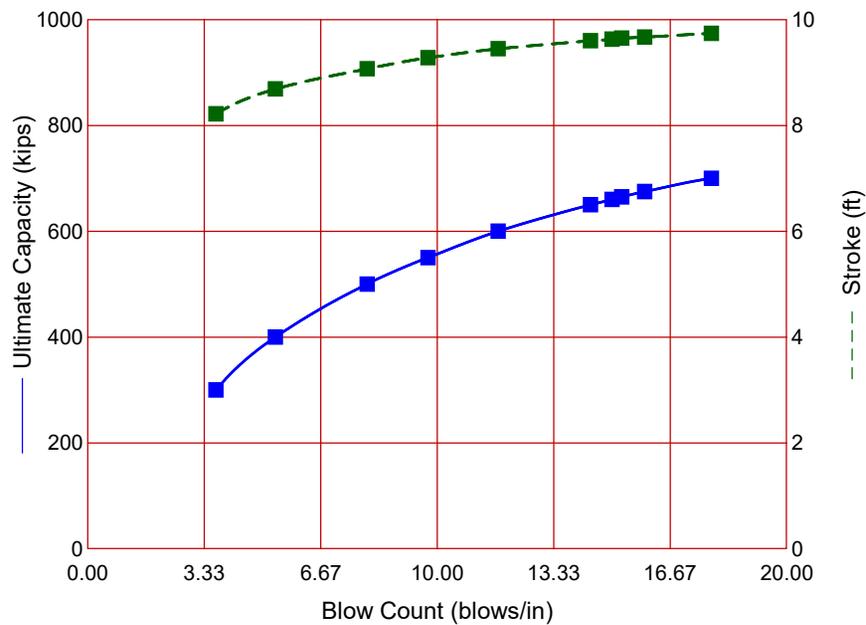
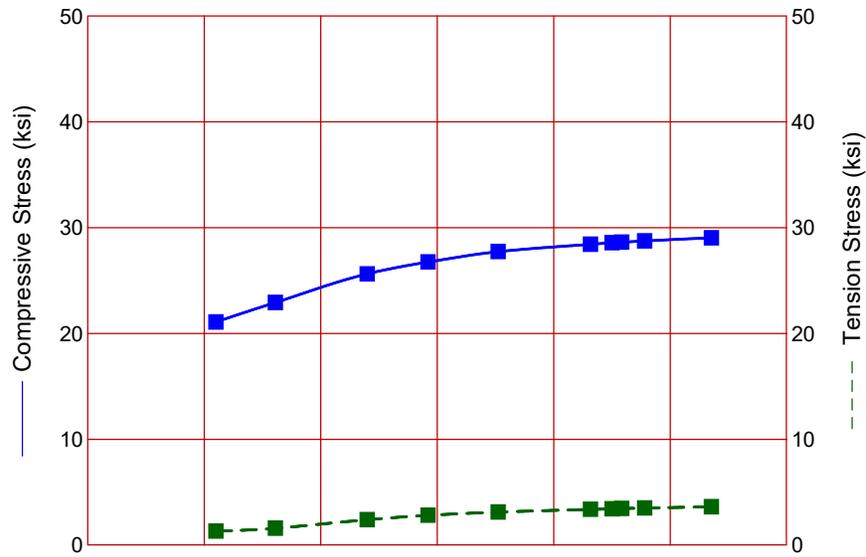
$$R_{f1dr} := \overrightarrow{R_{n1dr}} \cdot \phi_{dyn} = \begin{bmatrix} 393 \\ 429 \end{bmatrix} \text{ kip}$$

Service and Extreme Limit States

$$R_{1dr} := \overrightarrow{R_{n1dr}} \cdot \phi_s = \begin{bmatrix} 605 \\ 660 \end{bmatrix} \text{ kip}$$



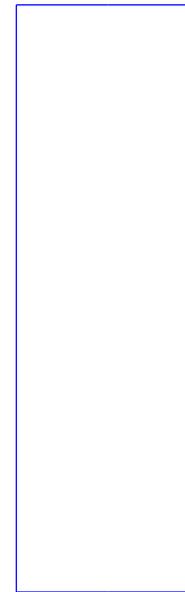
Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
300.0	23.79	1.73	3.4	8.17	18.53
400.0	27.80	2.83	5.3	8.80	19.39
500.0	30.87	3.86	8.7	9.39	20.69
525.0	31.43	4.06	9.7	9.52	21.08
550.0	31.96	4.26	11.1	9.66	21.34
575.0	32.43	4.42	12.7	9.77	21.63
600.0	32.82	4.56	14.5	9.88	21.93
605.0	32.90	4.59	15.0	9.90	21.95
610.0	32.98	4.62	15.3	9.92	22.04
625.0	33.16	4.69	16.9	9.98	22.10



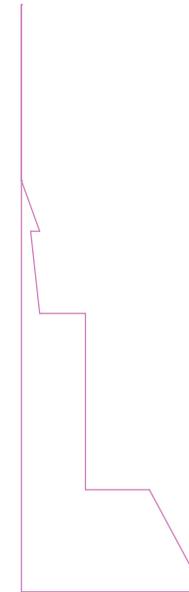
DELMAG D 19-42

Ram Weight	4.00 kips
Efficiency	0.800
Pressure	1600 (100%) psi
Helmet Weight	3.00 kips
Hammer Cushion	19863 kips/in
COR of H.C.	0.920
Skin Quake	0.100 in
Toe Quake	0.121 in
Skin Damping	0.099 s/ft
Toe Damping	0.150 s/ft
Pile Length	50.00 ft
Pile Penetration	35.00 ft
Pile Top Area	34.40 in <sup>2</sup>

Pile Model



Skin Friction Distribution



Res. Shaft = 17 %  
 (Proportional)

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/in	Stroke ft	Energy kips-ft
300.0	21.08	1.32	3.7	8.22	17.94
400.0	22.92	1.60	5.4	8.69	18.41
500.0	25.62	2.40	8.0	9.07	19.23
550.0	26.75	2.82	9.7	9.28	19.68
600.0	27.73	3.12	11.8	9.45	20.13
650.0	28.43	3.38	14.4	9.60	20.46
660.0	28.57	3.43	15.0	9.63	20.52
665.0	28.62	3.46	15.3	9.65	20.58
675.0	28.75	3.51	15.9	9.67	20.64
700.0	29.03	3.63	17.8	9.74	20.77

**Integral Abutment Pile Design - Abutment 1 (West Abutment) HP 14x89**

**Maximum Vertical Load From Structural Engineer**  
 (provided by email on 05/27/2025 and 06/13/2025)

$P_u := 390 \text{ kip}$  Vertical Load per Pile

$\delta_{per\_abut} := 0.27 \text{ in}$  Thermal Deflection per Abutment

**AASHTO Reduction Factors (From AASHTO 6.5.4.2)**

$\phi_{cl} := 0.5$  For severe driving conditions where pile tip necessary - Lower Zone

$\phi_{cu} := 0.7$  For combined axial and flexural resistance undamaged pile / axial - Upper Zone

$\phi_f := 1$  For combined axial and flexural resistance undamaged pile / flexural - Lower Zone

$\phi_v := 1$  Shear

**Required Axial Resistance**

$R_{n,upper} := \frac{P_u}{\phi_{cu}} = 557.143 \text{ kip}$

$R_{n,lower} := \frac{P_u}{\phi_{cl}} = 780 \text{ kip}$

$R_n := \max(R_{n,upper}, R_{n,lower}) = 780 \text{ kip}$

**Required Area of Steel**

$f_y := 50 \text{ ksi}$

$E := 29000 \text{ ksi}$

$A_{s,required} := \frac{R_n}{0.8 \cdot f_y} = 19.5 \text{ in}^2$

**Select Pile Section Properties (from AISC Manual) HP 14x89**

$d := 13.8 \text{ in}$      $b_f := 14.7 \text{ in}$      $t_w := 0.615 \text{ in}$      $t_f := 0.615 \text{ in}$      $h_w := d - 2 \cdot t_f = 12.57 \text{ in}$

Allow 1/16 inch section loss on all surfaces for corrosion     $t_{cor} := 0.0625 \text{ in}$

$d_c := d - 2 \cdot t_{cor} = 13.675 \text{ in}$      $t_{w_c} := t_w - 2 \cdot t_{cor} = 0.49 \text{ in}$

$b_{f_c} := b_f - 2 \cdot t_{cor} = 14.575 \text{ in}$      $t_{f_c} := t_f - 2 \cdot t_{cor} = 0.49 \text{ in}$

### Calculate Corroded Section Properties

$$A_{s_c} := 2 \cdot (b_{f_c} \cdot t_{f_c}) + h_w \cdot t_{w_c} = 20.44 \text{ in}^2$$

$Check1 := \text{if } \frac{A_{s_c}}{A_{s_{required}}} > 1 = \text{"OK!"}$
$\quad \quad \quad \parallel \text{"OK!"}$
$\quad \quad \quad \text{else}$
$\quad \quad \quad \parallel \text{"NG!"}$

$$S_{y_c} := \frac{b_{f_c}^2 \cdot (2 t_{f_c})}{6} + \frac{((b_{f_c}) - (b_{f_c} - t_{w_c}))^3 \cdot (d_c - 2 \cdot t_{f_c})}{6 \cdot b_f} = 34.7 \text{ in}^3$$

$$Z_{y_c} := \frac{(b_{f_c}^2 \cdot t_{f_c})}{2} + .25 \cdot t_{w_c}^2 \cdot (d_c - 2 t_{f_c}) = 52.8 \text{ in}^3$$

$$I_{y_c} := \frac{2 \cdot t_{f_c} \cdot b_{f_c}^3 + h_w \cdot t_{w_c}^3}{12} = 252.98 \text{ in}^4$$

from L-pile calculation

$$I_{LPILE} := 252.98 \text{ in}^4$$

$$r_{y_c} := \sqrt{\frac{I_{y_c}}{A_{s_c}}} = 3.52 \text{ in}$$

### Check Local Buckling From AASHTO eqn 6.10.8.2.2-3

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 11.951 \quad \text{for flange}$$

$$\lambda_w := \frac{h_w}{t_w} = 20.439 \quad \text{for web}$$

### Check Slenderness From AASHTO Table 6.9.4.2.1-1, find k

$$k_f := 0.56 \quad \lambda_{rf} := k_f \cdot \sqrt{\frac{E}{f_y}} = 13.487$$

$Check2_f := \text{if } \lambda_f \leq \lambda_{rf} = \text{"OK!"}$
$\quad \quad \quad \parallel \text{"OK!"}$
$\quad \quad \quad \text{else}$
$\quad \quad \quad \parallel \text{"NG!"}$

$$k_w := 1.49 \quad \lambda_{rw} := k_w \cdot \sqrt{\frac{E}{f_y}} = 35.884$$

$Check2_w := \text{if } \lambda_w \leq \lambda_{rw} = \text{"OK!"}$
$\quad \quad \quad \parallel \text{"OK!"}$
$\quad \quad \quad \text{else}$
$\quad \quad \quad \parallel \text{"NG!"}$

**Thermal deflection per abutment (provided by structural designer)**

$$\delta_{per\_abut} = 0.27 \text{ in}$$

$$\theta := 0 \quad \text{Assume no rotation} \quad P_u = 390 \text{ kip} \quad \text{From Structural Engineer}$$

**From L-pile model run output for bending of pile in the Weak Axis**

$$M_{u,top} := 679.025 \text{ in} \cdot \text{kip}$$

$$M_{u,2nd} := 230.168 \text{ kip} \cdot \text{in}$$

$$V_u := 12.409 \text{ kip}$$

**Obtain unbraced Lengths from L-pile (locations where moment = 0)**

$$l_{b,top} := 5.1 \cdot \text{ft} = 61 \text{ in}$$

$$l_{b,2nd} := 17.5 \cdot \text{ft} = 210 \text{ in}$$

**Calculate Slenderness Factor,  $\lambda$**

$$k_{top} := 1.2 \quad \text{Fixed- pinned}$$

$$k_{2nd} := 1.0 \quad \text{Pinned- pinned}$$

$$\lambda_{top} := \left( \frac{k_{top} \cdot l_{b,top}}{r_{y\_c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.076$$

$$\lambda_{2nd} := \left( \frac{k_{2nd} \cdot l_{b,2nd}}{r_{y\_c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.623$$

**Check Nominal Compressive Resistance**

For  $\lambda \leq 2.25$

$$P_{n,top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s\_c} = 990.3 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r,top} := \phi_{cu} \cdot P_{n,top} = 693.2 \text{ kip}$$

$$P_{n,2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s\_c} = 789.2 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r,2nd} := \phi_{cu} \cdot P_{n,2nd} = 552.4 \text{ kip}$$

$$P_{n,bot} := 0.66^0 \cdot f_y \cdot A_{s\_c} = (1 \cdot 10^3) \text{ kip} \quad \text{Full Braced } \lambda = 0$$

$$P_{r,bot} := \phi_{cl} \cdot P_{n,bot} = 511.1 \text{ kip}$$

**Check Ratio of Applied Load to Structural Resistance** Should NOT be Less than 0.2

$$\frac{P_u}{P_{r.top}} = 0.563$$

$$\frac{P_u}{P_{r.2nd}} = 0.706$$

$$\frac{P_u}{P_{r.bot}} = 0.763$$

**Compute Nominal Flexural Resistance**

$$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{f_y}} = 9.152 \quad \text{AASHTO Eq. 6.12.2.2.1-4}$$

$$\lambda_{rf} := 0.83 \cdot \sqrt{\frac{E}{f_y}} = 19.989 \quad \text{AASHTO Eq. 6.12.2.2.1-5}$$

$$\lambda_f = 11.951$$

**Calculate Nominal Flexural Resistance (AASHTO Eq. 6.12.2.2.1-1)**

$$M_{ny} := \begin{cases} \text{if } \lambda_f \leq \lambda_{pf} \\ \quad \parallel f_y \cdot Z_{y.c} \\ \text{if } \lambda_{pf} < \lambda_f \leq \lambda_{rf} \\ \quad \parallel \left( 1 - \left( 1 - \frac{S_{y.c}}{Z_{y.c}} \right) \cdot \left( \frac{\lambda_f - \lambda_{pf}}{.45 \cdot \sqrt{\frac{E}{f_y}}} \right) \right) \cdot f_y \cdot Z_{y.c} \\ \text{if } \lambda_f > \lambda_{rf} \\ \quad \parallel \text{"Pick New Pile Section"} \end{cases} = 2406.7 \text{ kip} \cdot \text{in}$$

$$M_{ry} := \phi_f \cdot M_{ny} = 2406.7 \text{ kip} \cdot \text{in} \quad \text{AASHTO Eq. 6.12.1.2.1-1}$$

**Check Pile Size**

$$PileSizeCheck := \begin{cases} \text{if } \frac{P_u}{P_{r.top}} \geq 0.2 \\ \quad \parallel \text{"Pile Size OK"} \\ \text{if } \frac{P_u}{P_{r.top}} < 0.2 \\ \quad \parallel \text{"Pile Size Too Big"} \end{cases} = \text{"Pile Size OK"}$$

### Find Moment Causing Plastic Hinge

Solving AASHTO Eq. 6.9.2.2-2 for  $M_u$

$$M_{uy} := \frac{9}{8} \cdot \left( 1 - \frac{P_u}{P_{r.top}} \right) M_{ry} = 38103016.4 \frac{ft}{s^2} \cdot lb \cdot in \text{ Moment for Load Case 2}$$

$$M_p := M_{uy} = 1184.3 \text{ kip} \cdot in$$

Check If Pile is in Plastic Range

if $M_{u.top} > M_p'$ "Plastic Hinge Formed/Iterate in L-Pile" if $M_{u.top} \leq M_p'$ "Pile Not in Plastic Range/Continue"	= "Pile Not in Plastic Range/Continue"
---	--

### From L-pile model run output for bending of pile in the Weak Axis with plastic hinge

$$M_{u.top} := 1184.3 \text{ in} \cdot \text{kip}$$

$$M_{u.2nd} := 264.293 \text{ kip} \cdot in$$

$$V_u := 17.618 \text{ kip}$$

### Obtain unbraced Lengths from L-pile (locations where moment = 0)

$$l_{b.top} := 6.8 \cdot ft = 82 \text{ in}$$

$$l_{b.2nd} := 19.3 \cdot ft = 232 \text{ in}$$

### Calculate Slenderness Factor $\lambda$

$$k_{top} := 2.1 \quad \text{Plastic Hinge}$$

$$k_{2nd} := 1.0 \quad \text{Pinned-Pinned}$$

$$\lambda_{top} := \left( \frac{k_{top} \cdot l_{b.top}}{r_{y.c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.415$$

$$\lambda_{2nd} := \left( \frac{k_{2nd} \cdot l_{b.2nd}}{r_{y.c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.757$$

Check Nominal Compressive Resistance

For  $\lambda \leq 2.25$

$$P_{n.top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s.c} = 860.41 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r.top} := \phi_{cu} \cdot P_{n.top} = 602.29 \text{ kip}$$

$$P_{n.2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = 746.23 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r.2nd} := \phi_{cu} \cdot P_{n.2nd} = 522.358 \text{ kip}$$

$$P_{n.bot} := 0.66^0 \cdot f_y \cdot A_{s_c} = 1022.14 \text{ kip} \quad \text{Full Braced } \lambda = 0$$

$$P_{r.bot} := \phi_{cl} \cdot P_{n.bot} = 511.07 \text{ kip}$$

**Check Ratio of Applied Load to Structural Resistance** Should NOT be Less than 0.2

$$\frac{P_u}{P_{r.top}} = 0.648$$

$$\frac{P_u}{P_{r.2nd}} = 0.747$$

$$\frac{P_u}{P_{r.bot}} = 0.763$$

Check Pile Size

$PileSizeCheck :=$	if $\frac{P_u}{P_{r.top}} \geq 0.2$	= "Pile Size OK"
	"Pile Size OK"	
	if $\frac{P_u}{P_{r.top}} < 0.2$	
	"Pile Size Too Big"	

**Check Second Segment of Pile for Combined Stress**

$$\frac{P_u}{2 P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}} = 0.483$$

$$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}} = 0.844$$

AASHTO 6.9.2.2-1 and 6.9.2.2-2

$Check3 :=$	if $\frac{P_u}{P_{r.2nd}} < 0.2$	= 0.844
	$\frac{P_u}{2 P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}}$	
	if $\frac{P_u}{P_{r.2nd}} \geq 0.2$	
	$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}}$	

if $Check3 < 1$	= "OK"
"OK"	
if $Check3 \geq 1$	
"Pile Undersized"	

Check Bottom Segment of Pile

$$Check4 := \frac{P_u}{P_{r.bot}} = 0.763$$

if $Check4 < 1$	= "OK"
"OK"	
if $Check4 \geq 1$	
"Pile Undersized"	

**Check Shear**

AASHTO does not address weak axis shear - Use AISC Steel Manual

$$K_v := 1.2$$

$$C_v := 1$$

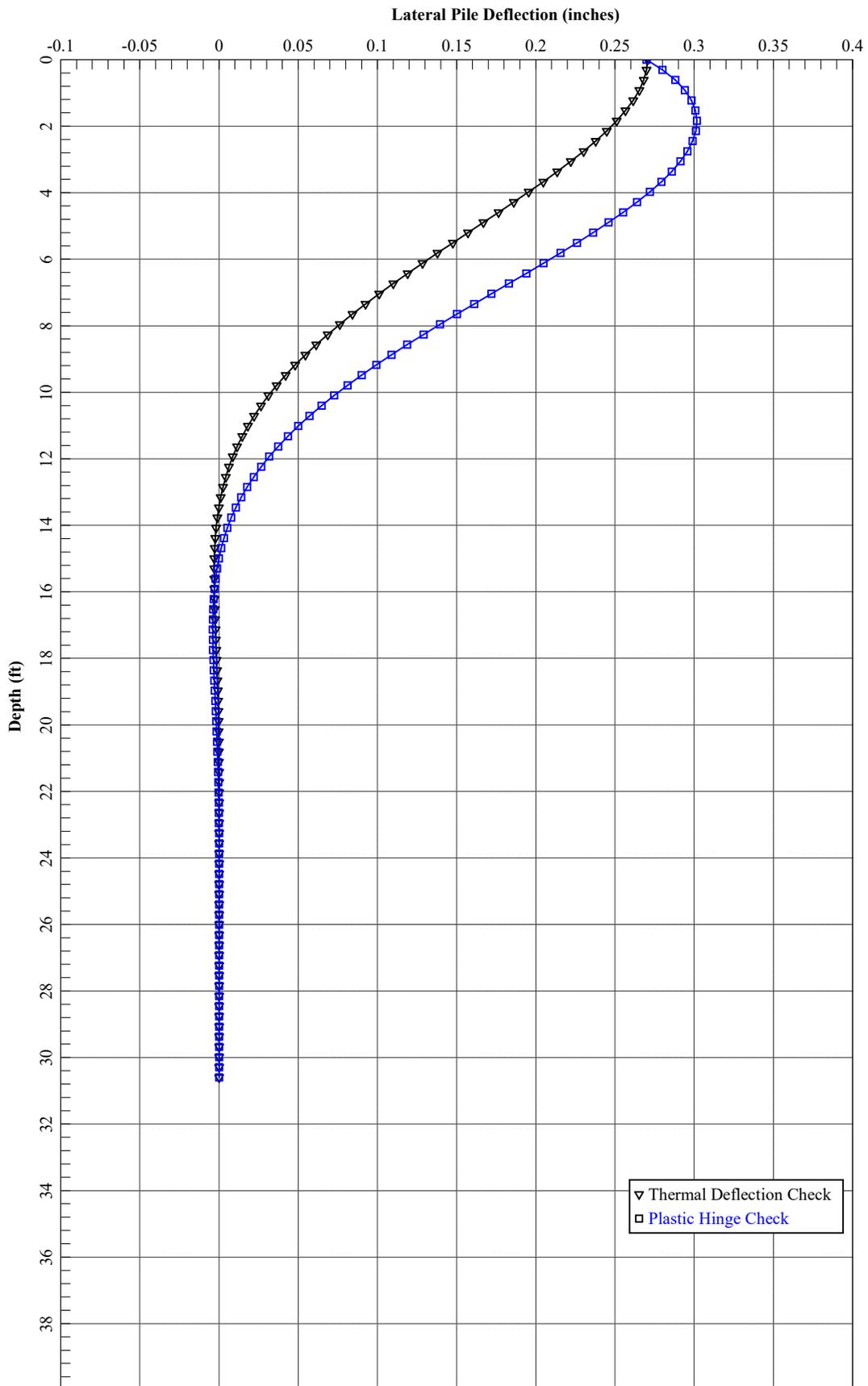
$$A_w := 2 b_{f.c} \cdot t_{f.c} = 14.284 \text{ in}^2$$

$$V_n := 0.6 f_y \cdot A_w \cdot C_v = 428.505 \text{ kip}$$

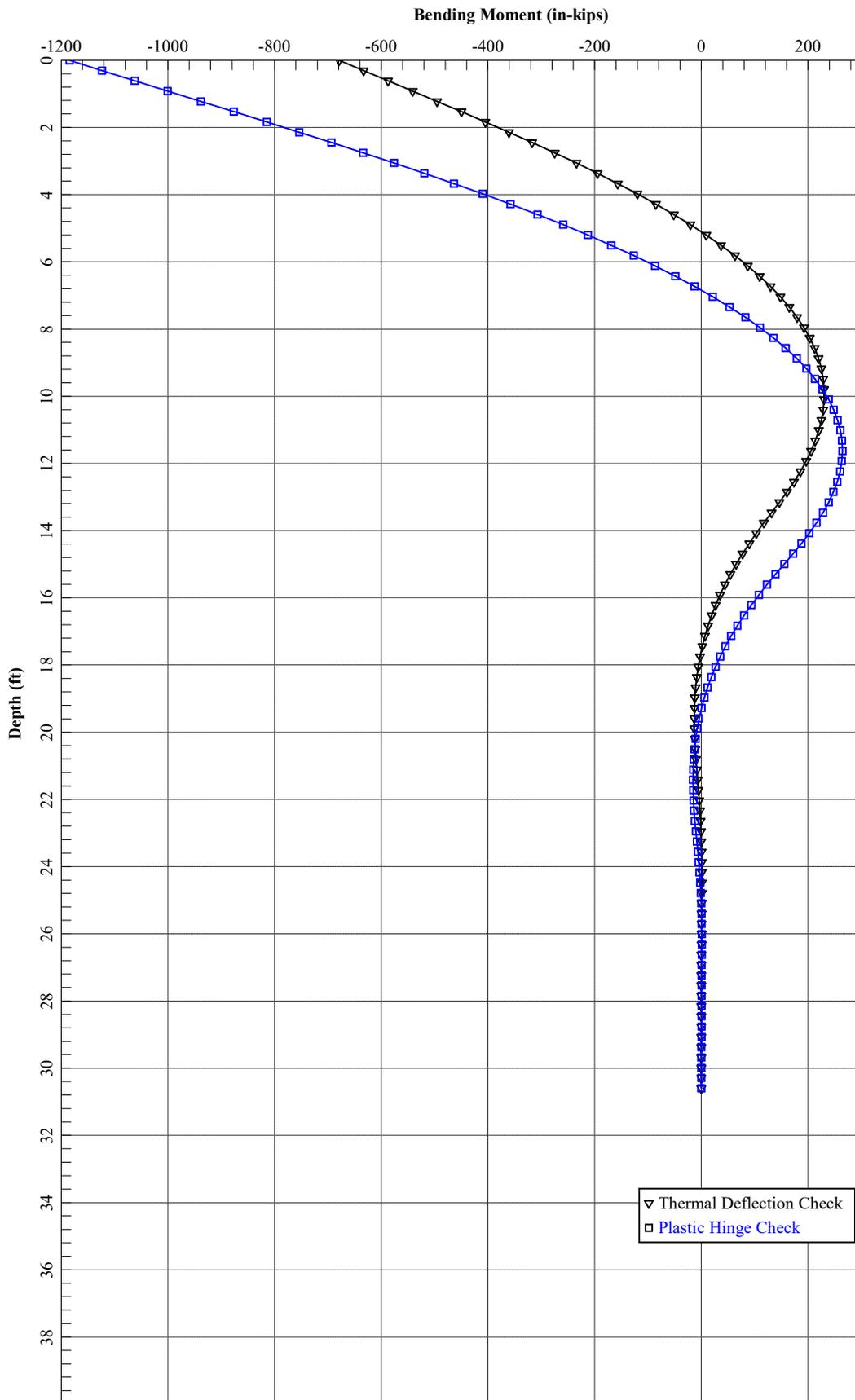
$$V_r := \phi_v \cdot V_n = 428.5 \text{ kip}$$

$$Check5 := \frac{V_u}{V_r} = 0.041$$

if $Check5 < 1$	= "OK"
"OK"	
if $Check5 \geq 1$	
"Pile Undersized"	



▽ Thermal Deflection Check  
□ Plastic Hinge Check



=====  
LPile for Windows, Version 2016-09.010

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:

\Users\mst.pierre\OneDrive - SW Cole Engineering\Desktop\LPile Output Files\20-1403-026184 Sabattus\

Name of input data file:

Abutment 1 HP14x89.lp9d

Name of output report file:

Abutment 1 HP14x89.lp9o

Name of plot output file:

Abutment 1 HP14x89.lp9p

Name of runtime message file:

Abutment 1 HP14x89.lp9r

-----  
Date and Time of Analysis  
-----

Date: June 26, 2025

Time: 14:30:00

-----  
Problem Title  
-----

Sabattus River Bridge #5393 Replacement

WIN 026184

MaineDOT

S. W. Cole Engineering, Inc.

Abutment No. 1 - HP14x89

-----  
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  
-----

Number of pile sections defined = 1  
 Total length of pile = 30.600 ft  
 Depth of ground surface below top of pile = 0.0000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	13.6750
2	30.600	13.6750

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile  
 Cross-sectional Shape = Weak H-Pile  
 Length of section = 30.600000 ft  
 Flange Width = 14.575000 in  
 Section Depth = 13.675000 in  
 Flange Thickness = 0.490000 in  
 Web Thickness = 0.490000 in  
 Section Area = 20.504050 sq. in  
 Moment of Inertia = 252.978866 in<sup>4</sup>  
 Elastic Modulus = 29000000. psi

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 3 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer	=	0.0000 ft
Distance from top of pile to bottom of layer	=	5.400000 ft
Effective unit weight at top of layer	=	62.600000 pcf
Effective unit weight at bottom of layer	=	62.600000 pcf
Friction angle at top of layer	=	30.000000 deg.
Friction angle at bottom of layer	=	30.000000 deg.
Subgrade k at top of layer	=	90.000000 pci
Subgrade k at bottom of layer	=	90.000000 pci

Layer 2 is soft clay, p-y criteria by Matlock, 1970

Distance from top of pile to top of layer	=	5.400000 ft
Distance from top of pile to bottom of layer	=	27.700000 ft
Effective unit weight at top of layer	=	47.600000 pcf
Effective unit weight at bottom of layer	=	47.600000 pcf
Undrained cohesion at top of layer	=	750.000000 psf
Undrained cohesion at bottom of layer	=	750.000000 psf
Epsilon-50 at top of layer	=	0.010000
Epsilon-50 at bottom of layer	=	0.010000

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 27.700000 ft  
 Distance from top of pile to bottom of layer = 30.600000 ft  
 Effective unit weight at top of layer = 67.600000 pcf  
 Effective unit weight at bottom of layer = 67.600000 pcf  
 Friction angle at top of layer = 32.000000 deg.  
 Friction angle at bottom of layer = 32.000000 deg.  
 Subgrade k at top of layer = 125.000000 pci  
 Subgrade k at bottom of layer = 125.000000 pci

(Depth of the lowest soil layer extends 0.000 ft below the 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	Sand (Reese, et al.)	0.00 5.4000	62.6000 62.6000	-- --	30.0000 30.0000	-- --	90.0000 90.0000
2	Soft Clay	5.4000 27.7000	47.6000 47.6000	750.0000 750.0000	-- --	0.01000 0.01000	-- --
3	Sand (Reese, et al.)	27.7000 30.6000	67.6000 67.6000	-- --	32.0000 32.0000	-- --	125.0000 125.0000

-----  
 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 = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	5	y = 0.270000 in	S = 0.0000 in/in	390000.	N.A.
2	4	y = 0.270000 in	M = -1184300. in-lbs	390000.	N.A.

V = shear force applied normal to pile axis

M = bending moment applied to pile head

y = lateral deflection normal to pile axis

S = pile slope relative to original pile batter angle

R = rotational stiffness applied to pile head

Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).

Thrust force is assumed to be acting axially for all pile batter angles.

-----  
Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness  
-----

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:  
-----

Moment-curvature properties were derived from elastic section properties

-----  
Layering Correction Equivalent Depths of Soil & Rock Layers  
-----

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	9612.
2	5.4000	2.9773	No	No	9612.	156216.
3	27.7000	27.7000	No	No	165829.	N.A.

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

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

Pile-head conditions are Displacement and Pile-head Rotation (Loading Type 5)  
 Displacement of pile head = 0.270000 inches  
 Rotation of pile head = 0.000E+00 radians  
 Axial load on pile head = 390000.0 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	0.2706	-679025.	12409.	0.00	37373.	7.34E+09	0.00	0.00	0.00
0.3060	0.2700	-633314.	12360.	-3.28E-04	36138.	7.34E+09	-11.9876	163.0317	0.00
0.6120	0.2682	-587311.	12291.	-6.34E-04	34894.	7.34E+09	-25.5255	349.4606	0.00
0.9180	0.2653	-541230.	12172.	-9.16E-04	33649.	7.34E+09	-39.7561	550.1684	0.00

1.2240	0.2615	-495298.	12000.	-0.00118	32408.	7.34E+09	-53.7757	755.1724	0.00
1.5300	0.2567	-449736.	11778.	-0.00141	31176.	7.34E+09	-66.9765	958.0363	0.00
1.8360	0.2511	-404755.	11510.	-0.00163	29960.	7.34E+09	-79.0257	1156.	0.00
2.1420	0.2448	-360549.	11200.	-0.00182	28766.	7.34E+09	-90.0164	1350.	0.00
2.4480	0.2378	-317298.	10852.	-0.00199	27597.	7.34E+09	-99.3551	1534.	0.00
2.7540	0.2302	-275160.	10474.	-0.00214	26458.	7.34E+09	-106.7325	1703.	0.00
3.0600	0.2221	-234263.	10070.	-0.00226	25352.	7.34E+09	-113.0802	1870.	0.00
3.3660	0.2136	-194723.	9647.	-0.00237	24284.	7.34E+09	-117.4105	2019.	0.00
3.6720	0.2047	-156627.	9205.	-0.00246	23254.	7.34E+09	-123.3503	2213.	0.00
3.9780	0.1955	-120082.	8744.	-0.00253	22266.	7.34E+09	-127.8959	2402.	0.00
4.2840	0.1861	-85175.	8271.	-0.00258	21323.	7.34E+09	-129.7575	2560.	0.00
4.5900	0.1766	-51957.	7794.	-0.00261	20425.	7.34E+09	-129.7520	2698.	0.00
4.8960	0.1669	-20451.	7302.	-0.00263	19573.	7.34E+09	-138.0663	3037.	0.00
5.2020	0.1572	9208.	6782.	-0.00263	19270.	7.34E+09	-145.4424	3397.	0.00
5.5080	0.1476	36899.	6277.	-0.00262	20018.	7.34E+09	-129.4919	3222.	0.00
5.8140	0.1380	62818.	5799.	-0.00260	20718.	7.34E+09	-130.6667	3477.	0.00
6.1200	0.1285	86930.	5318.	-0.00256	21370.	7.34E+09	-131.5526	3759.	0.00
6.4260	0.1192	109206.	4834.	-0.00251	21972.	7.34E+09	-132.1436	4072.	0.00
6.7320	0.1101	129622.	4348.	-0.00245	22524.	7.34E+09	-132.4342	4419.	0.00
7.0380	0.1012	148159.	3862.	-0.00238	23025.	7.34E+09	-132.4187	4806.	0.00
7.3440	0.09256	164804.	3376.	-0.00230	23475.	7.34E+09	-132.0917	5240.	0.00
7.6500	0.08426	179551.	2892.	-0.00222	23874.	7.34E+09	-131.4478	5729.	0.00
7.9560	0.07628	192396.	2411.	-0.00212	24221.	7.34E+09	-130.4815	6281.	0.00
8.2620	0.06865	203344.	1935.	-0.00203	24517.	7.34E+09	-129.1871	6910.	0.00
8.5680	0.06141	212404.	1463.	-0.00192	24761.	7.34E+09	-127.5588	7628.	0.00
8.8740	0.05455	219592.	998.4527	-0.00181	24956.	7.34E+09	-125.5901	8455.	0.00
9.1800	0.04809	224930.	541.5386	-0.00170	25100.	7.34E+09	-123.2738	9413.	0.00
9.4860	0.04205	228444.	93.7833	-0.00159	25195.	7.34E+09	-120.6016	10532.	0.00
9.7920	0.03643	230168.	-343.4881	-0.00147	25242.	7.34E+09	-117.5636	11851.	0.00
10.0980	0.03123	230142.	-768.9098	-0.00136	25241.	7.34E+09	-114.1475	13423.	0.00
10.4040	0.02645	228411.	-1181.	-0.00124	25194.	7.34E+09	-110.3373	15318.	0.00
10.7100	0.02209	225030.	-1578.	-0.00113	25103.	7.34E+09	-106.1120	17636.	0.00
11.0160	0.01815	220056.	-1960.	-0.00102	24968.	7.34E+09	-101.4422	20523.	0.00
11.3220	0.01461	213557.	-2323.	-9.10E-04	24793.	7.34E+09	-96.2862	24197.	0.00
11.6280	0.01147	205606.	-2666.	-8.05E-04	24578.	7.34E+09	-90.5810	29010.	0.00
11.9340	0.00870	196287.	-3005.	-7.05E-04	24326.	7.34E+09	-94.3016	39813.	0.00
12.2400	0.00629	185555.	-3334.	-6.09E-04	24036.	7.34E+09	-84.6567	49421.	0.00
12.5460	0.00422	173549.	-3625.	-5.19E-04	23711.	7.34E+09	-74.1480	64464.	0.00
12.8520	0.00248	160419.	-3875.	-4.36E-04	23356.	7.34E+09	-62.0857	92068.	0.00

13.1580	0.00102	146337.	-4074.	-3.59E-04	22976.	7.34E+09	-46.3175	166157.	0.00
13.4640	-1.60E-04	131525.	-4114.	-2.89E-04	22575.	7.34E+09	24.5089	562309.	0.00
13.7700	-0.00110	116949.	-3983.	-2.27E-04	22182.	7.34E+09	47.2495	157446.	0.00
14.0760	-0.00183	102927.	-3793.	-1.72E-04	21803.	7.34E+09	55.9954	112423.	0.00
14.3820	-0.00237	89586.	-3578.	-1.24E-04	21442.	7.34E+09	61.0416	94706.	0.00
14.6880	-0.00274	77004.	-3348.	-8.24E-05	21102.	7.34E+09	64.1074	85916.	0.00
14.9940	-0.00297	65230.	-3110.	-4.68E-05	20784.	7.34E+09	65.8743	81402.	0.00
15.3000	-0.00308	54299.	-2866.	-1.68E-05	20488.	7.34E+09	66.6972	79432.	0.00
15.6060	-0.00310	44228.	-2621.	7.81E-06	20216.	7.34E+09	66.7895	79235.	0.00
15.9120	-0.00303	35025.	-2377.	2.76E-05	19967.	7.34E+09	66.2930	80448.	0.00
16.2180	-0.00289	26692.	-2135.	4.31E-05	19742.	7.34E+09	65.3077	82917.	0.00
16.5240	-0.00271	19220.	-1898.	5.46E-05	19540.	7.34E+09	63.9083	86613.	0.00
16.8300	-0.00249	12596.	-1667.	6.25E-05	19361.	7.34E+09	62.1520	91607.	0.00
17.1360	-0.00225	6801.	-1442.	6.74E-05	19204.	7.34E+09	60.0849	98055.	0.00
17.4420	-0.00200	1811.	-1226.	6.96E-05	19070.	7.34E+09	57.7441	106213.	0.00
17.7480	-0.00174	-2402.	-1019.	6.94E-05	19086.	7.34E+09	55.1605	116457.	0.00
18.0540	-0.00149	-5869.	-821.2277	6.73E-05	19179.	7.34E+09	52.3600	129332.	0.00
18.3600	-0.00124	-8626.	-634.4621	6.37E-05	19254.	7.34E+09	49.3642	145625.	0.00
18.6660	-0.00102	-10711.	-459.0227	5.89E-05	19310.	7.34E+09	46.1910	166496.	0.00
18.9720	-8.12E-04	-12166.	-295.5352	5.31E-05	19349.	7.34E+09	42.8544	193701.	0.00
19.2780	-6.28E-04	-13034.	-144.5821	4.68E-05	19373.	7.34E+09	39.3640	230011.	0.00
19.5840	-4.68E-04	-13362.	-6.7223	4.02E-05	19382.	7.34E+09	35.7230	280043.	0.00
19.8900	-3.33E-04	-13198.	117.4779	3.36E-05	19377.	7.34E+09	31.9242	352080.	0.00
20.1960	-2.22E-04	-12595.	227.3895	2.71E-05	19361.	7.34E+09	27.9405	462672.	0.00
20.5020	-1.34E-04	-11606.	322.2019	2.11E-05	19334.	7.34E+09	23.7002	650928.	0.00
20.8080	-6.70E-05	-10289.	400.6083	1.56E-05	19299.	7.34E+09	19.0048	1041975.	0.00
21.1140	-1.92E-05	-8709.	459.6106	1.08E-05	19256.	7.34E+09	13.1315	2516338.	0.00
21.4200	1.26E-05	-6945.	465.6537	6.92E-06	19208.	7.34E+09	-9.8400	2857601.	0.00
21.7260	3.17E-05	-5309.	421.7275	3.86E-06	19164.	7.34E+09	-14.0849	1632199.	0.00
22.0320	4.10E-05	-3859.	367.4091	1.56E-06	19125.	7.34E+09	-15.5003	1389118.	0.00
22.3380	4.32E-05	-2615.	309.8696	-5.68E-08	19091.	7.34E+09	-15.8393	1347344.	0.00
22.6440	4.06E-05	-1583.	252.2398	-1.11E-06	19063.	7.34E+09	-15.5495	1407864.	0.00
22.9500	3.50E-05	-759.2247	196.4602	-1.69E-06	19041.	7.34E+09	-14.8315	1554443.	0.00
23.2560	2.81E-05	-135.1169	143.8957	-1.92E-06	19024.	7.34E+09	-13.7984	1801828.	0.00
23.5620	2.10E-05	303.0362	95.5722	-1.88E-06	19029.	7.34E+09	-12.5216	2194089.	0.00
23.8680	1.43E-05	572.1361	52.3001	-1.66E-06	19036.	7.34E+09	-11.0471	2827053.	0.00
24.1740	8.79E-06	691.8719	14.7674	-1.34E-06	19039.	7.34E+09	-9.3956	3923599.	0.00
24.4800	4.51E-06	684.4251	-16.3252	-9.95E-07	19039.	7.34E+09	-7.5393	6139695.	0.00
24.7860	1.48E-06	574.8308	-32.0004	-6.80E-07	19036.	7.34E+09	-0.9984	2472214.	0.00

25.0920	-4.87E-07	451.3628	-33.2317	-4.23E-07	19033.	7.34E+09	0.3277	2472214.	0.00
25.3980	-1.63E-06	331.9899	-30.6190	-2.27E-07	19030.	7.34E+09	1.0953	2472214.	0.00
25.7040	-2.16E-06	227.1478	-25.9420	-8.75E-08	19027.	7.34E+09	1.4521	2472214.	0.00
26.0100	-2.27E-06	141.7223	-20.4709	4.84E-09	19024.	7.34E+09	1.5278	2472214.	0.00
26.3160	-2.12E-06	76.7957	-15.0437	5.95E-08	19023.	7.34E+09	1.4282	2472214.	0.00
26.6220	-1.83E-06	31.0709	-10.1569	8.65E-08	19021.	7.34E+09	1.2335	2472214.	0.00
26.9280	-1.49E-06	1.9559	-6.0555	9.48E-08	19021.	7.34E+09	1.0004	2472214.	0.00
27.2340	-1.14E-06	-13.6718	-2.8145	9.19E-08	19021.	7.34E+09	0.7648	2472214.	0.00
27.5400	-8.11E-07	-18.9769	-0.4074	8.37E-08	19021.	7.34E+09	0.5462	2472214.	0.00
27.8460	-5.21E-07	-16.9034	0.6355	7.47E-08	19021.	7.34E+09	0.02178	153376.	0.00
28.1520	-2.63E-07	-14.5241	0.6958	6.68E-08	19021.	7.34E+09	0.01109	155061.	0.00
28.4580	-3.06E-08	-11.9848	0.7186	6.02E-08	19021.	7.34E+09	0.00131	156747.	0.00
28.7640	1.79E-07	-9.4193	0.7068	5.48E-08	19021.	7.34E+09	-0.00774	158432.	0.00
29.0700	3.72E-07	-6.9514	0.6627	5.08E-08	19021.	7.34E+09	-0.01623	160118.	0.00
29.3760	5.52E-07	-4.6974	0.5883	4.78E-08	19021.	7.34E+09	-0.02433	161803.	0.00
29.6820	7.23E-07	-2.7681	0.4845	4.60E-08	19021.	7.34E+09	-0.03221	163488.	0.00
29.9880	8.90E-07	-1.2711	0.3518	4.50E-08	19021.	7.34E+09	-0.04002	165174.	0.00
30.2940	1.05E-06	-0.3129	0.1905	4.46E-08	19021.	7.34E+09	-0.04788	166859.	0.00
30.6000	1.22E-06	0.00	0.00	4.45E-08	19021.	7.34E+09	-0.05586	84272.	0.00

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

Output Summary for Load Case No. 1:

Pile-head deflection = 0.27062399 inches  
 Computed slope at pile head = 0.000000 radians  
 Maximum bending moment = -679025. inch-lbs  
 Maximum shear force = 12409. lbs  
 Depth of maximum bending moment = 0.000000 feet below pile head  
 Depth of maximum shear force = 0.000000 feet below pile head  
 Number of iterations = 15  
 Number of zero deflection points = 4

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

Pile-head conditions are Displacement and Moment (Loading Type 4)

Displacement of pile head = 0.270000 inches

Moment at pile head = -1184300.0 in-lbs

Axial load at pile head = 390000.0 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	0.2700	-1184300.	17618.	0.00304	51030.	7.34E+09	0.00	0.00	0.00
0.3060	0.2801	-1123531.	17596.	0.00246	49387.	7.34E+09	-12.1242	158.9647	0.00
0.6120	0.2881	-1062121.	17526.	0.00191	47728.	7.34E+09	-26.1285	333.0669	0.00
0.9180	0.2941	-1000301.	17402.	0.00140	46057.	7.34E+09	-41.1494	513.7584	0.00
1.2240	0.2983	-938319.	17223.	9.11E-04	44381.	7.34E+09	-56.2542	692.4383	0.00
1.5300	0.3008	-876424.	16990.	4.57E-04	42709.	7.34E+09	-70.7717	863.9435	0.00
1.8360	0.3017	-814854.	16705.	3.37E-05	41044.	7.34E+09	-84.3320	1027.	0.00
2.1420	0.3010	-753837.	16372.	-3.59E-04	39395.	7.34E+09	-97.0153	1183.	0.00
2.4480	0.2990	-693588.	15996.	-7.21E-04	37767.	7.34E+09	-108.0946	1327.	0.00
2.7540	0.2958	-634299.	15582.	-0.00105	36164.	7.34E+09	-117.1675	1455.	0.00
3.0600	0.2913	-576136.	15136.	-0.00136	34592.	7.34E+09	-125.5897	1583.	0.00
3.3660	0.2858	-519253.	14663.	-0.00163	33055.	7.34E+09	-132.3103	1700.	0.00
3.6720	0.2793	-463782.	14160.	-0.00188	31556.	7.34E+09	-141.4199	1859.	0.00
3.9780	0.2720	-409885.	13626.	-0.00210	30099.	7.34E+09	-149.6121	2020.	0.00
4.2840	0.2639	-357712.	13066.	-0.00229	28689.	7.34E+09	-155.4599	2163.	0.00
4.5900	0.2552	-307378.	12487.	-0.00245	27328.	7.34E+09	-159.7220	2298.	0.00
4.8960	0.2459	-258978.	11877.	-0.00260	26020.	7.34E+09	-172.4848	2575.	0.00
5.2020	0.2362	-212718.	11222.	-0.00271	24770.	7.34E+09	-184.5953	2870.	0.00
5.5080	0.2260	-168794.	10609.	-0.00281	23583.	7.34E+09	-149.2582	2425.	0.00
5.8140	0.2155	-126762.	10056.	-0.00288	22447.	7.34E+09	-151.6098	2583.	0.00
6.1200	0.2048	-86684.	9496.	-0.00294	21364.	7.34E+09	-153.6715	2755.	0.00
6.4260	0.1940	-48615.	8928.	-0.00297	20335.	7.34E+09	-155.4366	2943.	0.00
6.7320	0.1830	-12607.	8355.	-0.00299	19361.	7.34E+09	-156.8985	3148.	0.00
7.0380	0.1720	21294.	7777.	-0.00298	19596.	7.34E+09	-158.0509	3374.	0.00
7.3440	0.1611	53049.	7195.	-0.00296	20454.	7.34E+09	-158.8878	3622.	0.00
7.6500	0.1503	82623.	6610.	-0.00293	21254.	7.34E+09	-159.4033	3895.	0.00
7.9560	0.1396	109989.	6025.	-0.00288	21993.	7.34E+09	-159.5919	4199.	0.00
8.2620	0.1291	135124.	5439.	-0.00282	22673.	7.34E+09	-159.4481	4536.	0.00

8.5680	0.1189	158013.	4854.	-0.00275	23291.	7.34E+09	-158.9663	4911.	0.00
8.8740	0.1089	178645.	4272.	-0.00266	23849.	7.34E+09	-158.1414	5332.	0.00
9.1800	0.09929	197016.	3694.	-0.00257	24346.	7.34E+09	-156.9680	5805.	0.00
9.4860	0.09004	213130.	3120.	-0.00247	24781.	7.34E+09	-155.4405	6339.	0.00
9.7920	0.08118	226995.	2553.	-0.00236	25156.	7.34E+09	-153.5533	6946.	0.00
10.0980	0.07273	238626.	1993.	-0.00224	25470.	7.34E+09	-151.3002	7639.	0.00
10.4040	0.06472	248047.	1442.	-0.00212	25725.	7.34E+09	-148.6746	8435.	0.00
10.7100	0.05717	255285.	901.7544	-0.00199	25920.	7.34E+09	-145.6689	9356.	0.00
11.0160	0.05009	260376.	373.0906	-0.00186	26058.	7.34E+09	-142.2743	10430.	0.00
11.3220	0.04349	263363.	-142.3742	-0.00173	26139.	7.34E+09	-138.4800	11693.	0.00
11.6280	0.03737	264293.	-643.1480	-0.00160	26164.	7.34E+09	-134.2726	13195.	0.00
11.9340	0.03173	263223.	-1156.	-0.00147	26135.	7.34E+09	-145.1398	16795.	0.00
12.2400	0.02658	260008.	-1674.	-0.00134	26048.	7.34E+09	-136.8243	18900.	0.00
12.5460	0.02191	254761.	-2161.	-0.00121	25906.	7.34E+09	-128.2915	21499.	0.00
12.8520	0.01771	247602.	-2616.	-0.00108	25713.	7.34E+09	-119.5035	24781.	0.00
13.1580	0.01396	238654.	-3038.	-9.61E-04	25471.	7.34E+09	-110.4005	29041.	0.00
13.4640	0.01065	228046.	-3426.	-8.44E-04	25184.	7.34E+09	-100.8848	34787.	0.00
13.7700	0.00776	215915.	-3777.	-7.33E-04	24856.	7.34E+09	-90.7885	42971.	0.00
14.0760	0.00526	202405.	-4091.	-6.29E-04	24491.	7.34E+09	-79.7959	55662.	0.00
14.3820	0.00314	187673.	-4361.	-5.31E-04	24093.	7.34E+09	-67.2158	78554.	0.00
14.6880	0.00136	171901.	-4578.	-4.41E-04	23667.	7.34E+09	-50.9784	137158.	0.00
14.9940	-9.65E-05	155319.	-4634.	-3.59E-04	23219.	7.34E+09	20.3059	773030.	0.00
15.3000	-0.00127	138898.	-4506.	-2.85E-04	22775.	7.34E+09	49.5411	142988.	0.00
15.6060	-0.00219	123046.	-4306.	-2.20E-04	22346.	7.34E+09	59.4665	99583.	0.00
15.9120	-0.00289	107908.	-4077.	-1.62E-04	21937.	7.34E+09	65.2036	82930.	0.00
16.2180	-0.00338	93572.	-3831.	-1.12E-04	21550.	7.34E+09	68.7562	74627.	0.00
16.5240	-0.00371	80096.	-3574.	-6.82E-05	21185.	7.34E+09	70.8936	70221.	0.00
16.8300	-0.00388	67518.	-3312.	-3.13E-05	20846.	7.34E+09	72.0093	68078.	0.00
17.1360	-0.00394	55863.	-3047.	-3.87E-07	20530.	7.34E+09	72.3380	67473.	0.00
17.4420	-0.00389	45143.	-2782.	2.49E-05	20241.	7.34E+09	72.0342	68052.	0.00
17.7480	-0.00375	35362.	-2519.	4.50E-05	19976.	7.34E+09	71.2063	69651.	0.00
18.0540	-0.00356	26515.	-2260.	6.05E-05	19737.	7.34E+09	69.9346	72214.	0.00
18.3600	-0.00331	18593.	-2006.	7.18E-05	19523.	7.34E+09	68.2809	75760.	0.00
18.6660	-0.00303	11578.	-1759.	7.94E-05	19334.	7.34E+09	66.2941	80374.	0.00
18.9720	-0.00273	5449.	-1520.	8.36E-05	19168.	7.34E+09	64.0142	86208.	0.00
19.2780	-0.00241	178.4349	-1289.	8.50E-05	19025.	7.34E+09	61.4740	93487.	0.00
19.5840	-0.00210	-4263.	-1069.	8.40E-05	19136.	7.34E+09	58.7012	102536.	0.00
19.8900	-0.00180	-7910.	-858.4965	8.10E-05	19234.	7.34E+09	55.7191	113817.	0.00
20.1960	-0.00151	-10800.	-659.7190	7.63E-05	19313.	7.34E+09	52.5475	127987.	0.00

20.5020	-0.00124	-12973.	-472.9059	7.03E-05	19371.	7.34E+09	49.2025	146006.	0.00
20.8080	-9.91E-04	-14474.	-298.6705	6.35E-05	19412.	7.34E+09	45.6969	169307.	0.00
21.1140	-7.71E-04	-15348.	-137.5880	5.60E-05	19435.	7.34E+09	42.0387	200122.	0.00
21.4200	-5.80E-04	-15645.	9.7854	4.82E-05	19443.	7.34E+09	38.2300	242104.	0.00
21.7260	-4.17E-04	-15415.	142.8815	4.05E-05	19437.	7.34E+09	34.2624	301659.	0.00
22.0320	-2.83E-04	-14712.	261.0652	3.29E-05	19418.	7.34E+09	30.1078	391173.	0.00
22.3380	-1.75E-04	-13592.	363.5175	2.58E-05	19388.	7.34E+09	25.6941	538444.	0.00
22.6440	-9.28E-05	-12116.	448.9328	1.94E-05	19348.	7.34E+09	20.8284	824119.	0.00
22.9500	-3.27E-05	-10350.	514.3709	1.38E-05	19300.	7.34E+09	14.8133	1665905.	0.00
23.2560	8.48E-06	-8378.	525.1105	9.10E-06	19247.	7.34E+09	-8.9639	3882444.	0.00
23.5620	3.42E-05	-6520.	481.6184	5.38E-06	19197.	7.34E+09	-14.7246	1580497.	0.00
23.8680	4.80E-05	-4856.	424.2280	2.53E-06	19152.	7.34E+09	-16.5338	1265927.	0.00
24.1740	5.28E-05	-3412.	362.4968	4.60E-07	19113.	7.34E+09	-17.0888	1188860.	0.00
24.4800	5.13E-05	-2195.	300.0239	-9.44E-07	19080.	7.34E+09	-16.9378	1211573.	0.00
24.7860	4.59E-05	-1206.	238.9757	-1.79E-06	19053.	7.34E+09	-16.3128	1306383.	0.00
25.0920	3.82E-05	-435.1985	180.8599	-2.21E-06	19032.	7.34E+09	-15.3407	1476405.	0.00
25.3980	2.97E-05	128.8095	126.8080	-2.28E-06	19024.	7.34E+09	-14.0994	1745777.	0.00
25.7040	2.14E-05	502.6153	77.7194	-2.12E-06	19034.	7.34E+09	-12.6373	2168960.	0.00
26.0100	1.41E-05	705.6643	34.3665	-1.82E-06	19040.	7.34E+09	-10.9753	2866977.	0.00
26.3160	8.02E-06	760.2205	-2.4655	-1.45E-06	19041.	7.34E+09	-9.0857	4161744.	0.00
26.6220	3.37E-06	691.7244	-31.5920	-1.09E-06	19039.	7.34E+09	-6.7785	7379215.	0.00
26.9280	9.51E-10	531.3346	-44.0385	-7.85E-07	19035.	7.34E+09	-6.40E-04	2472214.	0.00
27.2340	-2.39E-06	370.5553	-41.0797	-5.60E-07	19031.	7.34E+09	1.6122	2472214.	0.00
27.5400	-4.11E-06	231.2485	-24.6940	-4.09E-07	19027.	7.34E+09	7.3124	6534532.	0.00
27.8460	-5.40E-06	190.3738	-10.8544	-3.04E-07	19026.	7.34E+09	0.2255	153376.	0.00
28.1520	-6.34E-06	152.4031	-9.9490	-2.18E-07	19025.	7.34E+09	0.2677	155061.	0.00
28.4580	-7.00E-06	117.9321	-8.9091	-1.50E-07	19024.	7.34E+09	0.2987	156747.	0.00
28.7640	-7.44E-06	87.4043	-7.7713	-9.87E-08	19023.	7.34E+09	0.3210	158432.	0.00
29.0700	-7.72E-06	61.1425	-6.5636	-6.15E-08	19022.	7.34E+09	0.3367	160118.	0.00
29.3760	-7.89E-06	39.3773	-5.3068	-3.64E-08	19022.	7.34E+09	0.3478	161803.	0.00
29.6820	-7.99E-06	22.2732	-4.0152	-2.09E-08	19021.	7.34E+09	0.3557	163488.	0.00
29.9880	-8.05E-06	9.9496	-2.6976	-1.29E-08	19021.	7.34E+09	0.3619	165174.	0.00
30.2940	-8.08E-06	2.4990	-1.3586	-9.77E-09	19021.	7.34E+09	0.3674	166859.	0.00
30.6000	-8.12E-06	0.00	0.00	-9.14E-09	19021.	7.34E+09	0.3726	84272.	0.00

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

Output Summary for Load Case No. 2:

Pile-head deflection = 0.27000000 inches  
 Computed slope at pile head = 0.00303696 radians  
 Maximum bending moment = -1184300. inch-lbs  
 Maximum shear force = 17618. lbs  
 Depth of maximum bending moment = 0.000000 feet below pile head  
 Depth of maximum shear force = 0.000000 feet below pile head  
 Number of iterations = 19  
 Number of zero deflection points = 3

-----  
 Summary of Pile-head Responses for Conventional Analyses  
 -----

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	y, in	0.2700	S, rad	0.00	390000.	0.2706	0.00	12409.	-679025.
2	y, in	0.2700	M, in-lb	-1184300.	390000.	0.2700	0.00304	17618.	-1184300.

Maximum pile-head deflection = 0.2706239919 inches  
 Maximum pile-head rotation = 0.0030369553 radians = 0.174005 deg.

The analysis ended normally.

**Integral Abutment Pile Design - Abutment 2 (East Abutment) HP 14x89**

**Maximum Vertical Load From Structural Engineer**  
 (provided by email on 05/27/2025 and 06/13/2025)

$P_u := 390 \text{ kip}$  Vertical Load per Pile

$\delta_{per\_abut} := 0.27 \text{ in}$  Thermal Deflection per Abutment

**AASHTO Reduction Factors (From AASHTO 6.5.4.2)**

$\phi_{cl} := 0.5$  For severe driving conditions where pile tip necessary - Lower Zone

$\phi_{cu} := 0.7$  For combined axial and flexural resistance undamaged pile / axial - Upper Zone

$\phi_f := 1$  For combined axial and flexural resistance undamaged pile / flexural - Lower Zone

$\phi_v := 1$  Shear

**Required Axial Resistance**

$R_{n,upper} := \frac{P_u}{\phi_{cu}} = 557.143 \text{ kip}$

$R_{n,lower} := \frac{P_u}{\phi_{cl}} = 780 \text{ kip}$

$R_n := \max(R_{n,upper}, R_{n,lower}) = 780 \text{ kip}$

**Required Area of Steel**

$f_y := 50 \text{ ksi}$

$E := 29000 \text{ ksi}$

$A_{s,required} := \frac{R_n}{0.8 \cdot f_y} = 19.5 \text{ in}^2$

**Select Pile Section Properties (from AISC Manual) HP 14x89**

$d := 13.8 \text{ in}$      $b_f := 14.7 \text{ in}$      $t_w := 0.615 \text{ in}$      $t_f := 0.615 \text{ in}$      $h_w := d - 2 \cdot t_f = 12.57 \text{ in}$

Allow 1/16 inch section loss on all surfaces for corrosion     $t_{cor} := 0.0625 \text{ in}$

$d_c := d - 2 \cdot t_{cor} = 13.675 \text{ in}$      $t_{w_c} := t_w - 2 \cdot t_{cor} = 0.49 \text{ in}$

$b_{f_c} := b_f - 2 \cdot t_{cor} = 14.575 \text{ in}$      $t_{f_c} := t_f - 2 \cdot t_{cor} = 0.49 \text{ in}$

### Calculate Corroded Section Properties

$$A_{s_c} := 2 \cdot (b_{f_c} \cdot t_{f_c}) + h_w \cdot t_{w_c} = 20.44 \text{ in}^2$$

$Check1 := \text{if } \frac{A_{s_c}}{A_{s_{required}}} > 1 = \text{"OK!"}$
$\quad \quad \quad \parallel \text{"OK!"}$
$\quad \quad \quad \text{else}$
$\quad \quad \quad \parallel \text{"NG!"}$

$$S_{y_c} := \frac{b_{f_c}^2 \cdot (2 t_{f_c})}{6} + \frac{((b_{f_c}) - (b_{f_c} - t_{w_c}))^3 \cdot (d_c - 2 \cdot t_{f_c})}{6 \cdot b_f} = 34.7 \text{ in}^3$$

$$Z_{y_c} := \frac{(b_{f_c}^2 \cdot t_{f_c})}{2} + .25 \cdot t_{w_c}^2 \cdot (d_c - 2 t_{f_c}) = 52.8 \text{ in}^3$$

$$I_{y_c} := \frac{2 \cdot t_{f_c} \cdot b_{f_c}^3 + h_w \cdot t_{w_c}^3}{12} = 252.98 \text{ in}^4$$

from L-pile calculation

$$I_{LPILE} := 252.98 \text{ in}^4$$

$$r_{y_c} := \sqrt{\frac{I_{y_c}}{A_{s_c}}} = 3.52 \text{ in}$$

### Check Local Buckling From AASHTO eqn 6.10.8.2.2-3

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 11.951 \quad \text{for flange}$$

$$\lambda_w := \frac{h_w}{t_w} = 20.439 \quad \text{for web}$$

### Check Slenderness From AASHTO Table 6.9.4.2.1-1, find k

$$k_f := 0.56 \quad \lambda_{rf} := k_f \cdot \sqrt{\frac{E}{f_y}} = 13.487$$

$Check2_f := \text{if } \lambda_f \leq \lambda_{rf} = \text{"OK!"}$
$\quad \quad \quad \parallel \text{"OK!"}$
$\quad \quad \quad \text{else}$
$\quad \quad \quad \parallel \text{"NG!"}$

$$k_w := 1.49 \quad \lambda_{rw} := k_w \cdot \sqrt{\frac{E}{f_y}} = 35.884$$

$Check2_w := \text{if } \lambda_w \leq \lambda_{rw} = \text{"OK!"}$
$\quad \quad \quad \parallel \text{"OK!"}$
$\quad \quad \quad \text{else}$
$\quad \quad \quad \parallel \text{"NG!"}$

**Thermal deflection per abutment (provided by structural designer)**

$$\delta_{per\_abut} = 0.27 \text{ in}$$

$$\theta := 0 \quad \text{Assume no rotation} \quad P_u = 390 \text{ kip} \quad \text{From Structural Engineer}$$

**From L-pile model run output for bending of pile in the Weak Axis**

$$M_{u,top} := 666.243 \text{ in} \cdot \text{kip}$$

$$M_{u,2nd} := 218.086 \text{ kip} \cdot \text{in}$$

$$V_u := 12.143 \text{ kip}$$

**Obtain unbraced Lengths from L-pile (locations where moment = 0)**

$$l_{b,top} := 5.2 \cdot \text{ft} = 62 \text{ in}$$

$$l_{b,2nd} := 17.9 \cdot \text{ft} = 215 \text{ in}$$

**Calculate Slenderness Factor,  $\lambda$** 

$$k_{top} := 1.2 \quad \text{Fixed- pinned}$$

$$k_{2nd} := 1.0 \quad \text{Pinned- pinned}$$

$$\lambda_{top} := \left( \frac{k_{top} \cdot l_{b,top}}{r_{y_c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.079$$

$$\lambda_{2nd} := \left( \frac{k_{2nd} \cdot l_{b,2nd}}{r_{y_c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.651$$

**Check Nominal Compressive Resistance**

 For  $\lambda \leq 2.25$ 

$$P_{n,top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s_c} = 989.1 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r,top} := \phi_{cu} \cdot P_{n,top} = 692.3 \text{ kip}$$

$$P_{n,2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = 779.8 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r,2nd} := \phi_{cu} \cdot P_{n,2nd} = 545.8 \text{ kip}$$

$$P_{n,bot} := 0.66^0 \cdot f_y \cdot A_{s_c} = (1 \cdot 10^3) \text{ kip} \quad \text{Full Braced } \lambda = 0$$

$$P_{r,bot} := \phi_{cl} \cdot P_{n,bot} = 511.1 \text{ kip}$$

**Check Ratio of Applied Load to Structural Resistance** Should NOT be Less than 0.2

$$\frac{P_u}{P_{r.top}} = 0.563$$

$$\frac{P_u}{P_{r.2nd}} = 0.714$$

$$\frac{P_u}{P_{r.bot}} = 0.763$$

**Compute Nominal Flexural Resistance**

$$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{f_y}} = 9.152 \quad \text{AASHTO Eq. 6.12.2.2.1-4}$$

$$\lambda_{rf} := 0.83 \cdot \sqrt{\frac{E}{f_y}} = 19.989 \quad \text{AASHTO Eq. 6.12.2.2.1-5}$$

$$\lambda_f = 11.951$$

**Calculate Nominal Flexural Resistance (AASHTO Eq. 6.12.2.2.1-1)**

$$M_{ny} := \begin{cases} \text{if } \lambda_f \leq \lambda_{pf} & f_y \cdot Z_{y.c} \\ \text{if } \lambda_{pf} < \lambda_f \leq \lambda_{rf} & \left( 1 - \left( 1 - \frac{S_{y.c}}{Z_{y.c}} \right) \cdot \left( \frac{\lambda_f - \lambda_{pf}}{.45 \cdot \sqrt{\frac{E}{f_y}}} \right) \right) \cdot f_y \cdot Z_{y.c} \\ \text{if } \lambda_f > \lambda_{rf} & \text{"Pick New Pile Section"} \end{cases} = 2406.7 \text{ kip} \cdot \text{in}$$

$$M_{ry} := \phi_f \cdot M_{ny} = 2406.7 \text{ kip} \cdot \text{in} \quad \text{AASHTO Eq. 6.12.1.2.1-1}$$

**Check Pile Size**

$$PileSizeCheck := \begin{cases} \text{if } \frac{P_u}{P_{r.top}} \geq 0.2 & \text{"Pile Size OK"} \\ \text{if } \frac{P_u}{P_{r.top}} < 0.2 & \text{"Pile Size Too Big"} \end{cases}$$

### Find Moment Causing Plastic Hinge

Solving AASHTO Eq. 6.9.2.2-2 for  $M_u$

$$M_{uy} := \frac{9}{8} \cdot \left( 1 - \frac{P_u}{P_{r.top}} \right) M_{ry} = 38041580.4 \frac{ft}{s^2} \cdot lb \cdot in \text{ Moment for Load Case 2}$$

$$M_{p'} := M_{uy} = 1182.4 \text{ kip} \cdot in$$

Check If Pile is in Plastic Range

if $M_{u.top} > M_{p'}$    "Plastic Hinge Formed/Iterate in L-Pile" if $M_{u.top} \leq M_{p'}$    "Pile Not in Plastic Range/Continue"	= "Pile Not in Plastic Range/Continue"
---	--

### From L-pile model run output for bending of pile in the Weak Axis with plastic hinge

$$\overline{M}_{u.top} := 1182.4 \text{ in} \cdot \text{kip}$$

$$\overline{M}_{u.2nd} := 263.411 \text{ kip} \cdot in$$

$$\overline{V}_y := 17.814 \text{ kip}$$

### Obtain unbraced Lengths from L-pile (locations where moment = 0)

$$\overline{l}_{b.top} := 6.6 \cdot ft = 79 \text{ in}$$

$$\overline{l}_{b.2nd} := 19.1 \cdot ft = 229 \text{ in}$$

### Calculate Slenderness Factor $\lambda$

$$\overline{k}_{top} := 2.1 \quad \text{Plastic Hinge}$$

$$\overline{k}_{2nd} := 1.0 \quad \text{Pinned-Pinned}$$

$$\overline{\lambda}_{top} := \left( \frac{\overline{k}_{top} \cdot \overline{l}_{b.top}}{r_{y.c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.39$$

$$\overline{\lambda}_{2nd} := \left( \frac{\overline{k}_{2nd} \cdot \overline{l}_{b.2nd}}{r_{y.c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.742$$

Check Nominal Compressive Resistance

For  $\lambda \leq 2.25$

$$\overline{P}_{n.top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s.c} = 869.05 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$\overline{P}_{r.top} := \phi_{cu} \cdot \overline{P}_{n.top} = 608.33 \text{ kip}$$

$$P_{n.2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = 751.08 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r.2nd} := \phi_{cu} \cdot P_{n.2nd} = 525.757 \text{ kip}$$

$$P_{n.bot} := 0.66^0 \cdot f_y \cdot A_{s_c} = 1022.14 \text{ kip} \quad \text{Full Braced } \lambda = 0$$

$$P_{r.bot} := \phi_{cl} \cdot P_{n.bot} = 511.07 \text{ kip}$$

**Check Ratio of Applied Load to Structural Resistance** Should NOT be Less than 0.2

$$\frac{P_u}{P_{r.top}} = 0.641$$

$$\frac{P_u}{P_{r.2nd}} = 0.742$$

$$\frac{P_u}{P_{r.bot}} = 0.763$$

Check Pile Size

$PileSizeCheck :=$	if $\frac{P_u}{P_{r.top}} \geq 0.2$	= "Pile Size OK"
	"Pile Size OK"	
	if $\frac{P_u}{P_{r.top}} < 0.2$	
	"Pile Size Too Big"	

**Check Second Segment of Pile for Combined Stress**

$$\frac{P_u}{2 P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}} = 0.48$$

$$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}} = 0.839$$

AASHTO 6.9.2.2-1 and 6.9.2.2-2

$Check3 :=$	if $\frac{P_u}{P_{r.2nd}} < 0.2$	= 0.839
	$\frac{P_u}{2 P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}}$	
	if $\frac{P_u}{P_{r.2nd}} \geq 0.2$	
	$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}}$	

if $Check3 < 1$	= "OK"
"OK"	
if $Check3 \geq 1$	
"Pile Undersized"	

Check Bottom Segment of Pile

$$Check4 := \frac{P_u}{P_{r.bot}} = 0.763$$

if $Check4 < 1$	= "OK"
"OK"	
if $Check4 \geq 1$	
"Pile Undersized"	

**Check Shear**

AASHTO does not address weak axis shear - Use AISC Steel Manual

$$K_v := 1.2$$

$$C_v := 1$$

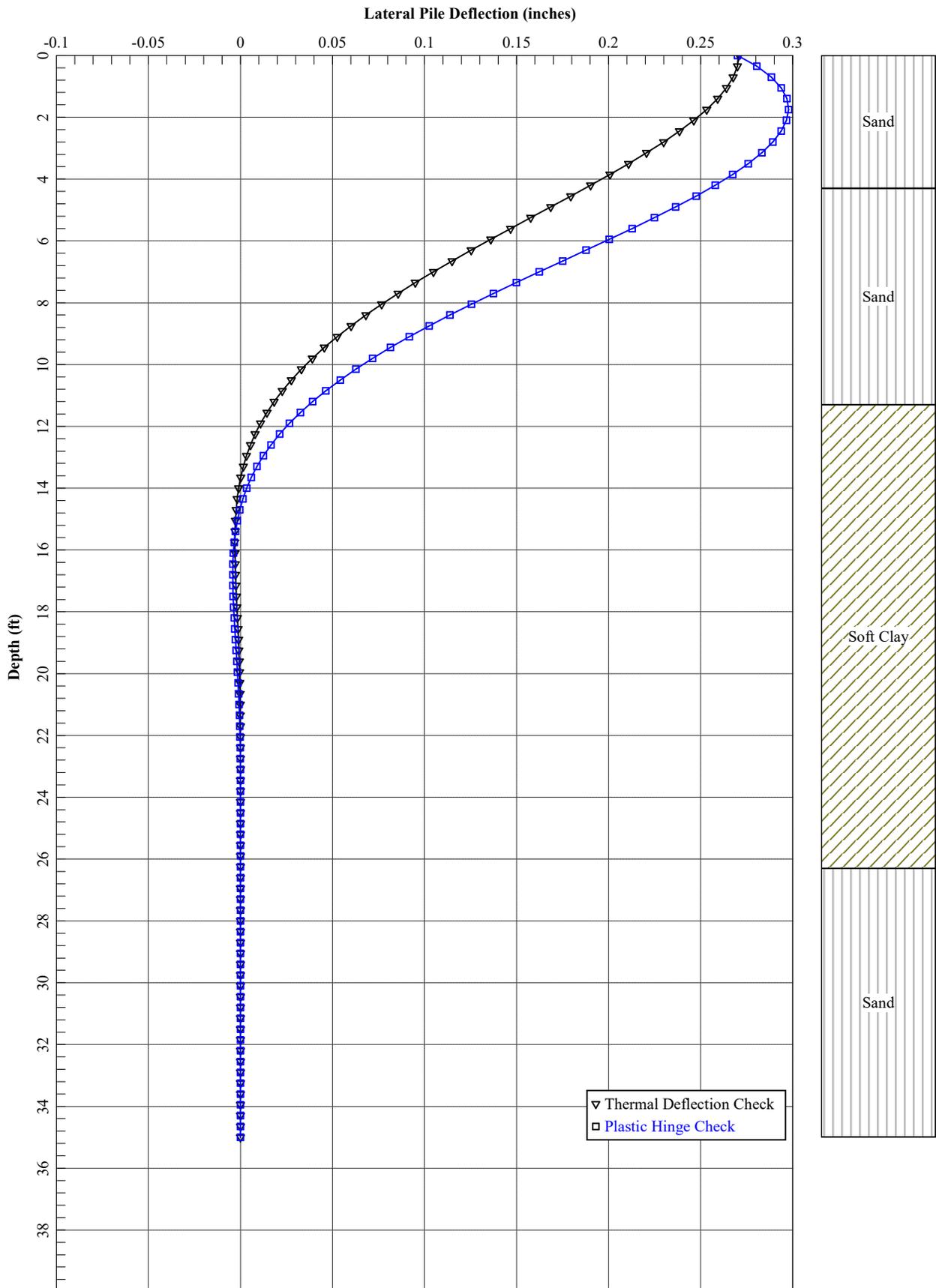
$$A_w := 2 b_{f.c} \cdot t_{f.c} = 14.284 \text{ in}^2$$

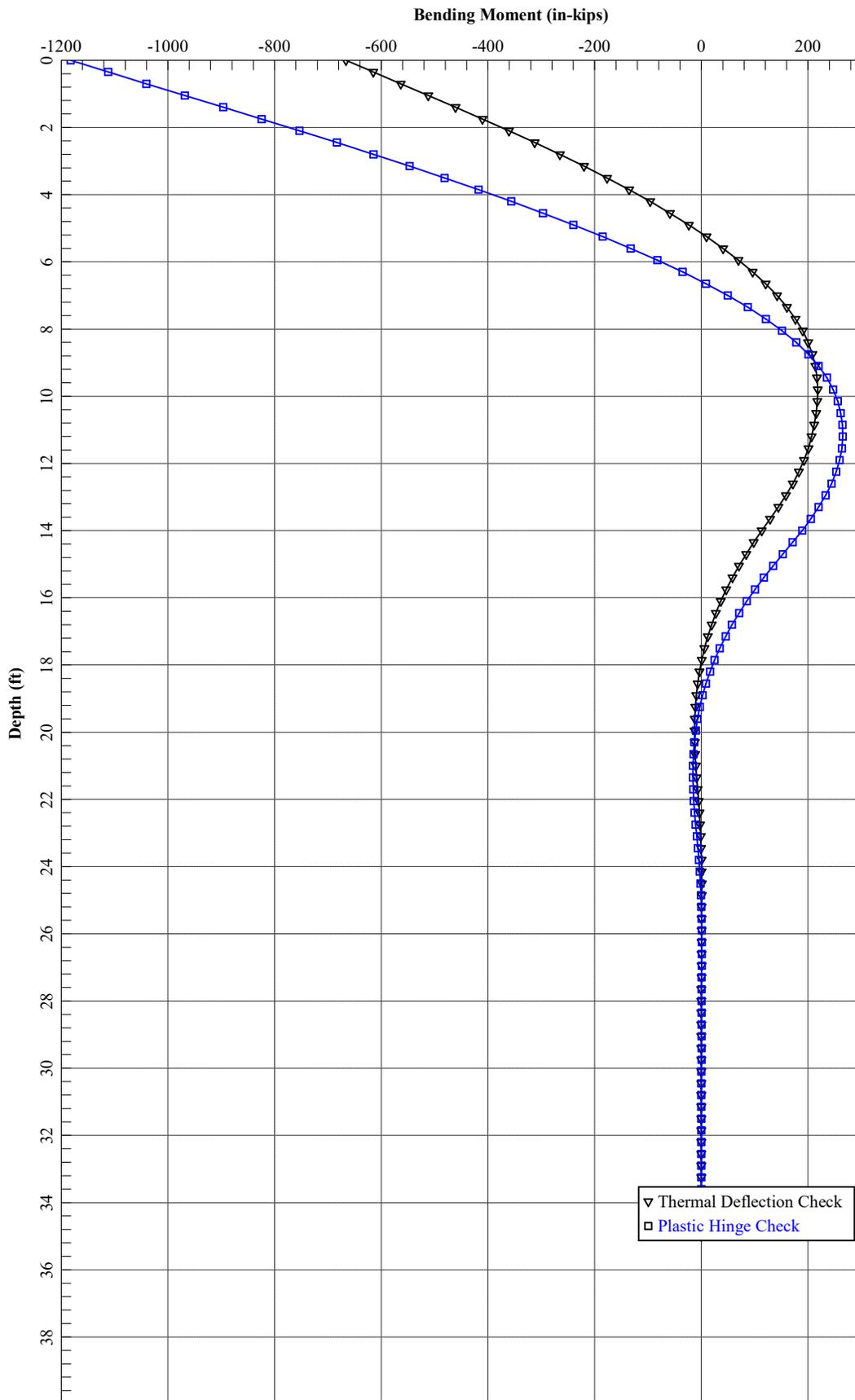
$$V_n := 0.6 f_y \cdot A_w \cdot C_v = 428.505 \text{ kip}$$

$$V_r := \phi_v \cdot V_n = 428.5 \text{ kip}$$

$$Check5 := \frac{V_u}{V_r} = 0.042$$

if $Check5 < 1$	= "OK"
"OK"	
if $Check5 \geq 1$	
"Pile Undersized"	





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LFile for Windows, Version 2016-09.010

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:

\Users\mst.pierre\OneDrive - SW Cole Engineering\Desktop\LFile Output Files\20-1403-026184 Sabattus\

Name of input data file:

Abutment 2 HP14x89.lp9d

Name of output report file:

Abutment 2 HP14x89.lp9o

Name of plot output file:

Abutment 2 HP14x89.lp9p

Name of runtime message file:  
Abutment 2 HP14x89.lp9r

-----  
Date and Time of Analysis  
-----

Date: June 26, 2025

Time: 15:12:01

-----  
Problem Title  
-----

Sabattus River Bridge #5393 Replacement

WIN 026184

MaineDOT

S. W. Cole Engineering, Inc.

Abutment No. 2 - HP14x89

-----  
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  
-----

- Number of pile sections defined = 1
- Total length of pile = 35.000 ft
- Depth of ground surface below top of pile = 0.0000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	13.6750
2	35.000	13.6750

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile  
 Cross-sectional Shape = Weak H-Pile Corroded Pile Properties  
 Length of section = 35.000000 ft  
 Flange Width = 14.575000 in  
 Section Depth = 13.675000 in  
 Flange Thickness = 0.490000 in  
 Web Thickness = 0.490000 in  
 Section Area = 20.504050 sq. in  
 Moment of Inertia = 252.978866 in<sup>4</sup>  
 Elastic Modulus = 29000000. psi

-----  
 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

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The soil profile is modelled using 4 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer	=	0.0000	ft
Distance from top of pile to bottom of layer	=	4.300000	ft
Effective unit weight at top of layer	=	62.600000	pcf
Effective unit weight at bottom of layer	=	62.600000	pcf
Friction angle at top of layer	=	30.000000	deg.
Friction angle at bottom of layer	=	30.000000	deg.
Subgrade k at top of layer	=	90.000000	pci
Subgrade k at bottom of layer	=	90.000000	pci

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

Distance from top of pile to top of layer	=	4.300000	ft
Distance from top of pile to bottom of layer	=	11.300000	ft
Effective unit weight at top of layer	=	47.600000	pcf
Effective unit weight at bottom of layer	=	47.600000	pcf
Friction angle at top of layer	=	28.000000	deg.
Friction angle at bottom of layer	=	28.000000	deg.
Subgrade k at top of layer	=	20.000000	pci
Subgrade k at bottom of layer	=	20.000000	pci

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

Distance from top of pile to top of layer	=	11.300000	ft
Distance from top of pile to bottom of layer	=	26.300000	ft
Effective unit weight at top of layer	=	47.600000	pcf
Effective unit weight at bottom of layer	=	47.600000	pcf
Undrained cohesion at top of layer	=	700.000000	psf
Undrained cohesion at bottom of layer	=	700.000000	psf
Epsilon-50 at top of layer	=	0.010000	
Epsilon-50 at bottom of layer	=	0.010000	

Layer 4 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 26.300000 ft  
 Distance from top of pile to bottom of layer = 35.000000 ft  
 Effective unit weight at top of layer = 67.600000 pcf  
 Effective unit weight at bottom of layer = 67.600000 pcf  
 Friction angle at top of layer = 32.000000 deg.  
 Friction angle at bottom of layer = 32.000000 deg.  
 Subgrade k at top of layer = 125.000000 pci  
 Subgrade k at bottom of layer = 125.000000 pci

(Depth of the lowest soil layer extends 0.000 ft below the 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	Sand (Reese, et al.)	0.00 4.3000	62.6000 62.6000	-- --	30.0000 30.0000	-- --	90.0000 90.0000
2	Sand (Reese, et al.)	4.3000 11.3000	47.6000 47.6000	-- --	28.0000 28.0000	-- --	20.0000 20.0000
3	Soft Clay	11.3000 26.3000	47.6000 47.6000	700.0000 700.0000	-- --	0.01000 0.01000	-- --
4	Sand (Reese, et al.)	26.3000 35.0000	67.6000 67.6000	-- --	32.0000 32.0000	-- --	125.0000 125.0000

-----  
 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 = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	5	y = 0.270000 in	S = 0.0000 in/in	390000.	N.A.
2	4	y = 0.270000 in	M = -1182400. in-lbs	390000.	N.A.

V = shear force applied normal to pile axis

M = bending moment applied to pile head

y = lateral deflection normal to pile axis

S = pile slope relative to original pile batter angle

R = rotational stiffness applied to pile head

Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).

Thrust force is assumed to be acting axially for all pile batter angles.

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Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness  
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Axial thrust force values were determined from pile-head loading conditions

Number of Pile Sections Analyzed = 1

Pile Section No. 1:  
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Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers  
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Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	5993.
2	4.3000	4.3000	Yes	No	5993.	42770.
3	11.3000	10.6473	No	No	48763.	107518.
4	26.3000	26.3000	No	No	156281.	N.A.

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

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

Pile-head conditions are Displacement and Pile-head Rotation (Loading Type 5)  
 Displacement of pile head = 0.270000 inches  
 Rotation of pile head = 0.000E+00 radians  
 Axial load on pile head = 390000.0 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	0.2708	-666243.	12143.	0.00	37028.	7.34E+09	0.00	0.00	0.00
0.3500	0.2700	-615078.	12079.	-3.67E-04	35645.	7.34E+09	-13.8644	215.6690	0.00
0.7000	0.2677	-563580.	11987.	-7.04E-04	34253.	7.34E+09	-29.6015	464.3894	0.00
1.0500	0.2641	-512077.	11829.	-0.00101	32861.	7.34E+09	-45.8708	729.5278	0.00
1.4000	0.2592	-460902.	11603.	-0.00129	31478.	7.34E+09	-61.5761	997.6879	0.00

1.7500	0.2532	-410381.	11315.	-0.00154	30112.	7.34E+09	-75.6232	1254.	0.00
2.1000	0.2463	-360810.	10970.	-0.00176	28773.	7.34E+09	-88.7156	1513.	0.00
2.4500	0.2385	-312465.	10575.	-0.00195	27466.	7.34E+09	-99.5174	1753.	0.00
2.8000	0.2299	-265582.	10140.	-0.00212	26199.	7.34E+09	-107.7308	1968.	0.00
3.1500	0.2207	-220351.	9672.	-0.00226	24976.	7.34E+09	-114.8685	2186.	0.00
3.5000	0.2109	-176940.	9179.	-0.00237	23803.	7.34E+09	-120.0383	2390.	0.00
3.8500	0.2007	-135480.	8661.	-0.00246	22682.	7.34E+09	-126.6829	2651.	0.00
4.2000	0.1902	-96128.	8122.	-0.00253	21619.	7.34E+09	-130.0535	2871.	0.00
4.5500	0.1795	-58979.	7619.	-0.00257	20615.	7.34E+09	-109.2016	2555.	0.00
4.9000	0.1686	-23702.	7148.	-0.00260	19661.	7.34E+09	-115.1183	2867.	0.00
5.2500	0.1577	9567.	6654.	-0.00260	19279.	7.34E+09	-120.3214	3204.	0.00
5.6000	0.1468	40704.	6140.	-0.00259	20121.	7.34E+09	-124.4160	3560.	0.00
5.9500	0.1360	69609.	5606.	-0.00255	20902.	7.34E+09	-129.7800	4008.	0.00
6.3000	0.1253	96159.	5049.	-0.00251	21620.	7.34E+09	-135.3331	4535.	0.00
6.6500	0.1149	120231.	4471.	-0.00244	22270.	7.34E+09	-140.1150	5120.	0.00
7.0000	0.1048	141719.	3874.	-0.00237	22851.	7.34E+09	-144.0548	5773.	0.00
7.3500	0.09503	160533.	3262.	-0.00228	23360.	7.34E+09	-147.0895	6501.	0.00
7.7000	0.08564	176602.	2640.	-0.00219	23794.	7.34E+09	-149.1647	7316.	0.00
8.0500	0.07667	189874.	2016.	-0.00208	24153.	7.34E+09	-148.1227	8114.	0.00
8.4000	0.06815	200355.	1416.	-0.00197	24436.	7.34E+09	-137.4002	8467.	0.00
8.7500	0.06012	208225.	862.7582	-0.00185	24649.	7.34E+09	-126.2593	8820.	0.00
9.1000	0.05259	213672.	356.4024	-0.00173	24796.	7.34E+09	-114.8625	9173.	0.00
9.4500	0.04558	216892.	-101.8770	-0.00161	24883.	7.34E+09	-103.3658	9526.	0.00
9.8000	0.03908	218086.	-511.9705	-0.00148	24915.	7.34E+09	-91.9168	9878.	0.00
10.1500	0.03311	217453.	-874.3691	-0.00136	24898.	7.34E+09	-80.6540	10231.	0.00
10.5000	0.02766	215194.	-1190.	-0.00124	24837.	7.34E+09	-69.7056	10584.	0.00
10.8500	0.02273	211504.	-1461.	-0.00111	24737.	7.34E+09	-59.1892	10937.	0.00
11.2000	0.01831	206571.	-1688.	-9.94E-04	24604.	7.34E+09	-49.2115	11290.	0.00
11.5500	0.01438	200577.	-2002.	-8.77E-04	24442.	7.34E+09	-100.0726	29224.	0.00
11.9000	0.01094	192629.	-2411.	-7.65E-04	24227.	7.34E+09	-94.9389	36452.	0.00
12.2500	0.00796	182826.	-2790.	-6.57E-04	23962.	7.34E+09	-85.3771	45055.	0.00
12.6000	0.00542	171345.	-3127.	-5.56E-04	23652.	7.34E+09	-75.0885	58205.	0.00
12.9500	0.00329	158379.	-3418.	-4.61E-04	23301.	7.34E+09	-63.5512	81135.	0.00
13.3000	0.00154	144143.	-3655.	-3.75E-04	22917.	7.34E+09	-49.2951	134262.	0.00
13.6500	1.41E-04	128903.	-3804.	-2.97E-04	22505.	7.34E+09	-21.6170	644294.	0.00
14.0000	-9.50E-04	113161.	-3761.	-2.27E-04	22079.	7.34E+09	42.2548	186755.	0.00
14.3500	-0.00177	98057.	-3563.	-1.67E-04	21671.	7.34E+09	51.8758	123137.	0.00
14.7000	-0.00235	83777.	-3334.	-1.15E-04	21285.	7.34E+09	57.0108	101774.	0.00
15.0500	-0.00273	70424.	-3089.	-7.08E-05	20924.	7.34E+09	59.9275	92040.	0.00
15.4000	-0.00295	58062.	-2834.	-3.40E-05	20590.	7.34E+09	61.4351	87550.	0.00
15.7500	-0.00302	46730.	-2575.	-3.99E-06	20284.	7.34E+09	61.9359	86132.	0.00

16.1000	-0.00298	36446.	-2315.	1.98E-05	20006.	7.34E+09	61.6666	86891.	0.00
16.4500	-0.00285	27216.	-2058.	3.80E-05	19756.	7.34E+09	60.7814	89456.	0.00
16.8000	-0.00266	19032.	-1806.	5.13E-05	19535.	7.34E+09	59.3886	93728.	0.00
17.1500	-0.00242	11878.	-1560.	6.01E-05	19342.	7.34E+09	57.5684	99788.	0.00
17.5000	-0.00216	5729.	-1323.	6.52E-05	19175.	7.34E+09	55.3824	107878.	0.00
17.8500	-0.00188	550.6384	-1096.	6.70E-05	19036.	7.34E+09	52.8797	118410.	0.00
18.2000	-0.00159	-3695.	-879.4801	6.61E-05	19121.	7.34E+09	50.0999	132029.	0.00
18.5500	-0.00132	-7053.	-675.4114	6.30E-05	19211.	7.34E+09	47.0756	149703.	0.00
18.9000	-0.00106	-9575.	-484.5020	5.82E-05	19279.	7.34E+09	43.8336	172916.	0.00
19.2500	-8.32E-04	-11314.	-307.6221	5.22E-05	19326.	7.34E+09	40.3949	204001.	0.00
19.6000	-6.26E-04	-12330.	-145.5662	4.55E-05	19354.	7.34E+09	36.7746	246796.	0.00
19.9500	-4.50E-04	-12686.	0.9164	3.83E-05	19364.	7.34E+09	32.9791	308040.	0.00
20.3000	-3.04E-04	-12448.	131.0734	3.11E-05	19357.	7.34E+09	29.0005	400688.	0.00
20.6500	-1.88E-04	-11687.	244.0566	2.42E-05	19336.	7.34E+09	24.8010	553364.	0.00
21.0000	-1.01E-04	-10477.	338.6953	1.79E-05	19304.	7.34E+09	20.2650	846105.	0.00
21.3500	-3.81E-05	-8900.	412.7547	1.23E-05	19261.	7.34E+09	15.0014	1651896.	0.00
21.7000	2.91E-06	-7050.	434.9991	7.76E-06	19211.	7.34E+09	-4.4088	6360792.	0.00
22.0500	2.70E-05	-5272.	399.7173	4.23E-06	19163.	7.34E+09	-12.3921	1926820.	0.00
22.4000	3.84E-05	-3706.	343.9630	1.66E-06	19121.	7.34E+09	-14.1576	1546991.	0.00
22.7500	4.10E-05	-2388.	283.6996	-8.51E-08	19085.	7.34E+09	-14.5392	1491189.	0.00
23.1000	3.77E-05	-1323.	223.3760	-1.15E-06	19056.	7.34E+09	-14.1863	1579487.	0.00
23.4500	3.13E-05	-507.5797	165.5351	-1.67E-06	19034.	7.34E+09	-13.3570	1791549.	0.00
23.8000	2.37E-05	72.8344	111.8820	-1.80E-06	19023.	7.34E+09	-12.1921	2162103.	0.00
24.1500	1.62E-05	438.1123	63.6328	-1.65E-06	19032.	7.34E+09	-10.7838	2790764.	0.00
24.5000	9.83E-06	612.7536	21.6574	-1.35E-06	19037.	7.34E+09	-9.2045	3933519.	0.00
24.8500	4.90E-06	624.4529	-13.5019	-9.95E-07	19038.	7.34E+09	-7.5381	6460815.	0.00
25.2000	1.47E-06	502.5954	-31.2769	-6.72E-07	19034.	7.34E+09	-0.9262	2639182.	0.00
25.5500	-7.44E-07	363.9282	-32.2403	-4.24E-07	19030.	7.34E+09	0.4674	2639182.	0.00
25.9000	-2.09E-06	233.1653	-28.5052	-2.53E-07	19027.	7.34E+09	1.3112	2639182.	0.00
26.2500	-2.87E-06	125.3135	-15.7539	-1.50E-07	19024.	7.34E+09	4.7608	6969892.	0.00
26.6000	-3.35E-06	101.3253	-5.4755	-8.55E-08	19023.	7.34E+09	0.1337	167580.	0.00
26.9500	-3.59E-06	79.5997	-4.8903	-3.37E-08	19023.	7.34E+09	0.1450	169785.	0.00
27.3000	-3.63E-06	60.3573	-4.2734	6.37E-09	19022.	7.34E+09	0.1488	171990.	0.00
27.6500	-3.53E-06	43.6824	-3.6532	3.61E-08	19022.	7.34E+09	0.1465	174195.	0.00
28.0000	-3.33E-06	29.5517	-3.0519	5.71E-08	19021.	7.34E+09	0.1398	176400.	0.00
28.3500	-3.05E-06	17.8597	-2.4855	7.07E-08	19021.	7.34E+09	0.1299	178605.	0.00
28.7000	-2.74E-06	8.4417	-1.9655	7.82E-08	19021.	7.34E+09	0.1178	180810.	0.00
29.0500	-2.40E-06	1.0931	-1.4989	8.09E-08	19021.	7.34E+09	0.1044	183015.	0.00
29.4000	-2.06E-06	-4.4143	-1.0892	8.00E-08	19021.	7.34E+09	0.09065	185220.	0.00
29.7500	-1.72E-06	-8.3185	-0.7372	7.63E-08	19021.	7.34E+09	0.07697	187425.	0.00
30.1000	-1.41E-06	-10.8571	-0.4415	7.09E-08	19021.	7.34E+09	0.06385	189630.	0.00

30.4500	-1.13E-06	-12.2592	-0.1991	6.42E-08	19021.	7.34E+09	0.05160	191835.	0.00
30.8000	-8.75E-07	-12.7395	-0.00584	5.71E-08	19021.	7.34E+09	0.04041	194040.	0.00
31.1500	-6.50E-07	-12.4952	0.1428	4.99E-08	19021.	7.34E+09	0.03038	196245.	0.00
31.5000	-4.56E-07	-11.7032	0.2518	4.29E-08	19021.	7.34E+09	0.02154	198450.	0.00
31.8500	-2.90E-07	-10.5203	0.3261	3.66E-08	19021.	7.34E+09	0.01383	200655.	0.00
32.2000	-1.49E-07	-9.0835	0.3703	3.10E-08	19021.	7.34E+09	0.00718	202860.	0.00
32.5500	-2.95E-08	-7.5116	0.3884	2.62E-08	19021.	7.34E+09	0.00144	205065.	0.00
32.9000	7.15E-08	-5.9072	0.3840	2.24E-08	19021.	7.34E+09	-0.00353	207270.	0.00
33.2500	1.58E-07	-4.3595	0.3600	1.94E-08	19021.	7.34E+09	-0.00790	209475.	0.00
33.6000	2.35E-07	-2.9471	0.3185	1.73E-08	19021.	7.34E+09	-0.01183	211680.	0.00
33.9500	3.04E-07	-1.7406	0.2612	1.60E-08	19021.	7.34E+09	-0.01548	213885.	0.00
34.3000	3.69E-07	-0.8056	0.1888	1.53E-08	19021.	7.34E+09	-0.01899	216090.	0.00
34.6500	4.32E-07	-0.2047	0.1017	1.50E-08	19021.	7.34E+09	-0.02247	218295.	0.00
35.0000	4.95E-07	0.00	0.00	1.49E-08	19021.	7.34E+09	-0.02598	110250.	0.00

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

#### Output Summary for Load Case No. 1:

Pile-head deflection = 0.27080097 inches  
 Computed slope at pile head = 0.000000 radians  
 Maximum bending moment = -666243. inch-lbs  
 Maximum shear force = 12143. lbs  
 Depth of maximum bending moment = 0.000000 feet below pile head  
 Depth of maximum shear force = 0.000000 feet below pile head  
 Number of iterations = 14  
 Number of zero deflection points = 4

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 Computed Values of Pile Loading and Deflection  
 for Lateral Loading for Load Case Number 2  
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Pile-head conditions are Displacement and Moment (Loading Type 4)

Displacement of pile head = 0.270000 inches  
 Moment at pile head = -1182400.0 in-lbs  
 Axial load at pile head = 390000.0 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	0.2700	-1182400.	17814.	0.00285	50978.	7.34E+09	0.00	0.00	0.00
0.3500	0.2806	-1111699.	17784.	0.00219	49068.	7.34E+09	-14.0313	210.0541	0.00
0.7000	0.2884	-1040203.	17691.	0.00158	47135.	7.34E+09	-30.3357	441.7275	0.00
1.0500	0.2938	-968266.	17527.	0.00100	45191.	7.34E+09	-47.5513	679.7288	0.00
1.4000	0.2969	-896260.	17292.	4.70E-04	43245.	7.34E+09	-64.5186	912.7886	0.00
1.7500	0.2978	-824552.	16989.	-2.24E-05	41307.	7.34E+09	-80.0473	1129.	0.00
2.1000	0.2967	-753483.	16621.	-4.74E-04	39386.	7.34E+09	-94.8512	1343.	0.00
2.4500	0.2938	-683380.	16197.	-8.85E-04	37491.	7.34E+09	-107.4151	1536.	0.00
2.8000	0.2892	-614532.	15725.	-0.00126	35630.	7.34E+09	-117.3135	1703.	0.00
3.1500	0.2832	-547176.	15212.	-0.00159	33810.	7.34E+09	-126.6360	1878.	0.00
3.5000	0.2759	-481541.	14664.	-0.00188	32036.	7.34E+09	-134.3653	2045.	0.00
3.8500	0.2674	-417825.	14079.	-0.00214	30314.	7.34E+09	-144.4098	2268.	0.00
4.2000	0.2579	-356265.	13457.	-0.00236	28650.	7.34E+09	-151.5347	2468.	0.00
4.5500	0.2476	-297043.	12865.	-0.00255	27049.	7.34E+09	-130.7171	2218.	0.00
4.9000	0.2365	-239849.	12297.	-0.00270	25503.	7.34E+09	-139.7441	2482.	0.00
5.2500	0.2248	-184895.	11692.	-0.00283	24018.	7.34E+09	-148.2166	2769.	0.00
5.6000	0.2128	-132382.	11054.	-0.00292	22599.	7.34E+09	-155.6481	3073.	0.00
5.9500	0.2003	-82491.	10382.	-0.00298	21250.	7.34E+09	-164.2588	3443.	0.00
6.3000	0.1877	-35419.	9674.	-0.00301	19978.	7.34E+09	-173.0149	3871.	0.00
6.6500	0.1751	8633.	8930.	-0.00302	19254.	7.34E+09	-180.9586	4342.	0.00
7.0000	0.1624	49485.	8156.	-0.00300	20358.	7.34E+09	-187.9860	4862.	0.00
7.3500	0.1498	86975.	7353.	-0.00296	21371.	7.34E+09	-194.0018	5438.	0.00
7.7000	0.1375	120961.	6528.	-0.00290	22290.	7.34E+09	-198.9200	6077.	0.00
8.0500	0.1254	151325.	5685.	-0.00283	23111.	7.34E+09	-202.6647	6786.	0.00
8.4000	0.1138	177972.	4828.	-0.00273	23831.	7.34E+09	-205.1708	7575.	0.00
8.7500	0.1025	200832.	3964.	-0.00262	24449.	7.34E+09	-206.3841	8457.	0.00
9.1000	0.09172	219864.	3110.	-0.00250	24963.	7.34E+09	-200.3148	9173.	0.00
9.4500	0.08147	235156.	2301.	-0.00237	25376.	7.34E+09	-184.7790	9526.	0.00
9.8000	0.07179	246968.	1559.	-0.00223	25696.	7.34E+09	-168.8517	9878.	0.00
10.1500	0.06270	255570.	883.4330	-0.00209	25928.	7.34E+09	-152.7444	10231.	0.00
10.5000	0.05423	261238.	275.6859	-0.00194	26081.	7.34E+09	-136.6589	10584.	0.00
10.8500	0.04638	264250.	-264.9476	-0.00179	26163.	7.34E+09	-120.7856	10937.	0.00
11.2000	0.03917	264883.	-739.7321	-0.00164	26180.	7.34E+09	-105.3022	11290.	0.00
11.5500	0.03260	263411.	-1237.	-0.00149	26140.	7.34E+09	-131.4811	16938.	0.00
11.9000	0.02666	259373.	-1781.	-0.00134	26031.	7.34E+09	-127.7983	20131.	0.00
12.2500	0.02135	252836.	-2299.	-0.00119	25854.	7.34E+09	-118.6654	23347.	0.00
12.6000	0.01664	243970.	-2778.	-0.00105	25615.	7.34E+09	-109.2039	27565.	0.00

12.9500	0.01252	232948.	-3215.	-9.15E-04	25317.	7.34E+09	-99.3142	33322.	0.00
13.3000	0.00896	219956.	-3611.	-7.85E-04	24966.	7.34E+09	-88.8192	41650.	0.00
13.6500	0.00592	205191.	-3960.	-6.63E-04	24567.	7.34E+09	-77.3732	54853.	0.00
14.0000	0.00339	188869.	-4257.	-5.50E-04	24125.	7.34E+09	-64.1796	79622.	0.00
14.3500	0.00130	171237.	-4489.	-4.47E-04	23649.	7.34E+09	-46.5808	150416.	0.00
14.7000	-3.72E-04	152624.	-4522.	-3.55E-04	23146.	7.34E+09	31.0736	350470.	0.00
15.0500	-0.00168	134415.	-4350.	-2.72E-04	22654.	7.34E+09	50.9558	127508.	0.00
15.4000	-0.00266	116979.	-4118.	-2.01E-04	22182.	7.34E+09	59.3744	93703.	0.00
15.7500	-0.00336	100481.	-3859.	-1.38E-04	21736.	7.34E+09	64.1747	80149.	0.00
16.1000	-0.00382	85020.	-3583.	-8.52E-05	21319.	7.34E+09	66.9701	73576.	0.00
16.4500	-0.00408	70661.	-3299.	-4.06E-05	20930.	7.34E+09	68.4285	70467.	0.00
16.8000	-0.00416	57443.	-3010.	-3.95E-06	20573.	7.34E+09	68.9053	69499.	0.00
17.1500	-0.00411	45387.	-2722.	2.55E-05	20247.	7.34E+09	68.6181	70092.	0.00
17.5000	-0.00395	34498.	-2435.	4.83E-05	19953.	7.34E+09	67.7124	71996.	0.00
17.8500	-0.00371	24772.	-2154.	6.53E-05	19690.	7.34E+09	66.2923	75138.	0.00
18.2000	-0.00340	16191.	-1879.	7.70E-05	19458.	7.34E+09	64.4358	79563.	0.00
18.5500	-0.00306	8733.	-1613.	8.42E-05	19257.	7.34E+09	62.2034	85421.	0.00
18.9000	-0.00269	2363.	-1358.	8.73E-05	19084.	7.34E+09	59.6438	92971.	0.00
19.2500	-0.00232	-2957.	-1113.	8.72E-05	19101.	7.34E+09	56.7965	102612.	0.00
19.6000	-0.00196	-7272.	-880.9990	8.43E-05	19217.	7.34E+09	53.6944	114934.	0.00
19.9500	-0.00162	-10633.	-662.4753	7.91E-05	19308.	7.34E+09	50.3645	130815.	0.00
20.3000	-0.00130	-13096.	-458.3684	7.23E-05	19375.	7.34E+09	46.8292	151588.	0.00
20.6500	-0.00101	-14721.	-269.5054	6.44E-05	19419.	7.34E+09	43.1055	179352.	0.00
21.0000	-7.57E-04	-15571.	-96.6557	5.57E-05	19441.	7.34E+09	39.2039	217577.	0.00
21.3500	-5.42E-04	-15715.	59.4368	4.67E-05	19445.	7.34E+09	35.1258	272415.	0.00
21.7000	-3.64E-04	-15225.	197.9969	3.79E-05	19432.	7.34E+09	30.8552	355896.	0.00
22.0500	-2.23E-04	-14176.	318.1062	2.95E-05	19404.	7.34E+09	26.3397	495405.	0.00
22.4000	-1.17E-04	-12649.	418.4243	2.18E-05	19363.	7.34E+09	21.4308	772159.	0.00
22.7500	-4.02E-05	-10733.	496.2808	1.51E-05	19311.	7.34E+09	15.6437	1632546.	0.00
23.1000	1.03E-05	-8530.	512.7850	9.59E-06	19251.	7.34E+09	-7.7846	3183563.	0.00
23.4500	4.03E-05	-6457.	466.8834	5.30E-06	19195.	7.34E+09	-14.0733	1467557.	0.00
23.8000	5.48E-05	-4626.	404.0286	2.12E-06	19146.	7.34E+09	-15.8576	1216300.	0.00
24.1500	5.81E-05	-3070.	336.5212	-7.88E-08	19104.	7.34E+09	-16.2888	1177151.	0.00
24.5000	5.41E-05	-1798.	268.7744	-1.47E-06	19069.	7.34E+09	-15.9716	1240037.	0.00
24.8500	4.57E-05	-807.2536	203.4062	-2.22E-06	19042.	7.34E+09	-15.1561	1391379.	0.00
25.2000	3.55E-05	-82.6122	142.2332	-2.47E-06	19023.	7.34E+09	-13.9739	1654979.	0.00
25.5500	2.50E-05	395.6066	86.6435	-2.38E-06	19031.	7.34E+09	-12.4973	2101448.	0.00
25.9000	1.54E-05	653.0014	37.8307	-2.08E-06	19038.	7.34E+09	-10.7469	2922785.	0.00
26.2500	7.48E-06	720.2090	-2.9048	-1.69E-06	19040.	7.34E+09	-8.6510	4858244.	0.00
26.6000	1.25E-06	634.1378	-21.1763	-1.30E-06	19038.	7.34E+09	-0.04973	167580.	0.00
26.9500	-3.46E-06	546.5947	-20.9869	-9.64E-07	19035.	7.34E+09	0.1399	169785.	0.00

27.3000	-6.85E-06	461.0073	-20.1036	-6.76E-07	19033.	7.34E+09	0.2807	171990.	0.00
27.6500	-9.14E-06	379.9394	-18.7180	-4.35E-07	19031.	7.34E+09	0.3791	174195.	0.00
28.0000	-1.05E-05	305.2021	-16.9948	-2.39E-07	19029.	7.34E+09	0.4415	176400.	0.00
28.3500	-1.11E-05	237.9664	-15.0721	-8.37E-08	19027.	7.34E+09	0.4741	178605.	0.00
28.7000	-1.12E-05	178.8709	-13.0626	3.56E-08	19025.	7.34E+09	0.4828	180810.	0.00
29.0500	-1.08E-05	128.1241	-11.0559	1.23E-07	19024.	7.34E+09	0.4728	183015.	0.00
29.4000	-1.02E-05	85.5970	-9.1205	1.85E-07	19023.	7.34E+09	0.4488	185220.	0.00
29.7500	-9.30E-06	50.9068	-7.3066	2.24E-07	19022.	7.34E+09	0.4150	187425.	0.00
30.1000	-8.30E-06	23.4888	-5.6484	2.45E-07	19021.	7.34E+09	0.3746	189630.	0.00
30.4500	-7.24E-06	2.6574	-4.1672	2.53E-07	19021.	7.34E+09	0.3307	191835.	0.00
30.8000	-6.18E-06	-12.3427	-2.8734	2.50E-07	19021.	7.34E+09	0.2854	194040.	0.00
31.1500	-5.14E-06	-22.2974	-1.7695	2.40E-07	19021.	7.34E+09	0.2403	196245.	0.00
31.5000	-4.16E-06	-27.9926	-0.8520	2.25E-07	19021.	7.34E+09	0.1967	198450.	0.00
31.8500	-3.25E-06	-30.1924	-0.1130	2.09E-07	19021.	7.34E+09	0.1552	200655.	0.00
32.2000	-2.41E-06	-29.6259	0.4572	1.92E-07	19021.	7.34E+09	0.1163	202860.	0.00
32.5500	-1.64E-06	-26.9796	0.8696	1.75E-07	19021.	7.34E+09	0.08002	205065.	0.00
32.9000	-9.35E-07	-22.8964	1.1345	1.61E-07	19021.	7.34E+09	0.04612	207270.	0.00
33.2500	-2.85E-07	-17.9782	1.2612	1.49E-07	19021.	7.34E+09	0.01422	209475.	0.00
33.6000	3.21E-07	-12.7923	1.2570	1.41E-07	19021.	7.34E+09	-0.01618	211680.	0.00
33.9500	8.97E-07	-7.8799	1.1272	1.35E-07	19021.	7.34E+09	-0.04565	213885.	0.00
34.3000	1.45E-06	-3.7654	0.8743	1.31E-07	19021.	7.34E+09	-0.07476	216090.	0.00
34.6500	2.00E-06	-0.9661	0.4990	1.30E-07	19021.	7.34E+09	-0.1040	218295.	0.00
35.0000	2.55E-06	0.00	0.00	1.30E-07	19021.	7.34E+09	-0.1336	110250.	0.00

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

#### Output Summary for Load Case No. 2:

Pile-head deflection = 0.27000000 inches  
 Computed slope at pile head = 0.00285142 radians  
 Maximum bending moment = -1182400. inch-lbs  
 Maximum shear force = 17814. lbs  
 Depth of maximum bending moment = 0.000000 feet below pile head  
 Depth of maximum shear force = 0.000000 feet below pile head  
 Number of iterations = 14  
 Number of zero deflection points = 4

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 Summary of Pile-head Responses for Conventional Analyses

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 Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	y, in	0.2700	S, rad	0.00	390000.	0.2708	0.00	12143.	-666243.
2	y, in	0.2700	M, in-lb	-1182400.	390000.	0.2700	0.00285	17814.	-1182400.

Maximum pile-head deflection = 0.2708009748 inches  
 Maximum pile-head rotation = 0.0028514233 radians = 0.163375 deg.

The analysis ended normally.

**Integral Abutment Pile Design - Abutment 1 (West Abutment)**

**Maximum Vertical Load From Structural Engineer**  
 (provided by email on 05/27/2025 and 06/13/2025)

$P_u := 390 \text{ kip}$  Vertical Load per Pile

$\delta_{per\_abut} := 0.27 \text{ in}$  Thermal Deflection per Abutment

**AASHTO Reduction Factors (From AASHTO 6.5.4.2)**

$\phi_{cl} := 0.5$  For severe driving conditions where pile tip necessary - Lower Zone

$\phi_{cu} := 0.7$  For combined axial and flexural resistance undamaged pile / axial - Upper Zone

$\phi_f := 1$  For combined axial and flexural resistance undamaged pile / flexural - Lower Zone

$\phi_v := 1$  Shear

**Required Axial Resistance**

$R_{n,upper} := \frac{P_u}{\phi_{cu}} = 557.143 \text{ kip}$

$R_{n,lower} := \frac{P_u}{\phi_{cl}} = 780 \text{ kip}$

$R_n := \max(R_{n,upper}, R_{n,lower}) = 780 \text{ kip}$

**Required Area of Steel**

$f_y := 50 \text{ ksi}$

$E := 29000 \text{ ksi}$

$A_{s,required} := \frac{R_n}{0.8 \cdot f_y} = 19.5 \text{ in}^2$

**Select Pile Section Properties (from AISC Manual) HP 14x117**

$d := 14.2 \text{ in}$      $b_f := 14.9 \text{ in}$      $t_w := 0.805 \text{ in}$      $t_f := 0.805 \text{ in}$      $h_w := d - 2 t_f = 12.59 \text{ in}$

Allow 1/16 inch section loss on all surfaces for corrosion     $t_{cor} := 0.0625 \text{ in}$

$d_c := d - 2 \cdot t_{cor} = 14.075 \text{ in}$      $t_{w_c} := t_w - 2 \cdot t_{cor} = 0.68 \text{ in}$

$b_{f_c} := b_f - 2 \cdot t_{cor} = 14.775 \text{ in}$      $t_{f_c} := t_f - 2 \cdot t_{cor} = 0.68 \text{ in}$

### Calculate Corroded Section Properties

$$A_{s_c} := 2 \cdot (b_{f_c} \cdot t_{f_c}) + h_w \cdot t_{w_c} = 28.66 \text{ in}^2$$

$Check1 := \text{if } \frac{A_{s_c}}{A_{s\_required}} > 1 = \text{"OK!"}$
$\quad \quad \quad \parallel \text{"OK!"}$
$\quad \quad \quad \text{else}$
$\quad \quad \quad \parallel \text{"NG!"}$

$$S_{y_c} := \frac{b_{f_c}^2 \cdot (2 t_{f_c})}{6} + \frac{((b_{f_c}) - (b_{f_c} - t_{w_c}))^3 \cdot (d_c - 2 \cdot t_{f_c})}{6 \cdot b_f} = 49.5 \text{ in}^3$$

$$Z_{y_c} := \frac{(b_{f_c}^2 \cdot t_{f_c})}{2} + .25 \cdot t_{w_c}^2 \cdot (d_c - 2 t_{f_c}) = 75.7 \text{ in}^3$$

$$I_{y_c} := \frac{2 \cdot t_{f_c} \cdot b_{f_c}^3 + h_w \cdot t_{w_c}^3}{12} = 365.87 \text{ in}^4$$

from L-pile calculation  
 $I_{LPILE} := 365.88 \text{ in}^4$

$$r_{y_c} := \sqrt{\frac{I_{y_c}}{A_{s_c}}} = 3.57 \text{ in}$$

### Check Local Buckling From AASHTO eqn 6.10.8.2.2-3

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 9.255 \quad \text{for flange}$$

$$\lambda_w := \frac{h_w}{t_w} = 15.64 \quad \text{for web}$$

### Check Slenderness From AASHTO Table 6.9.4.2.1-1, find k

$$k_f := 0.56 \quad \lambda_{rf} := k_f \cdot \sqrt{\frac{E}{f_y}} = 13.487$$

$Check2_f := \text{if } \lambda_f \leq \lambda_{rf} = \text{"OK!"}$
$\quad \quad \quad \parallel \text{"OK!"}$
$\quad \quad \quad \text{else}$
$\quad \quad \quad \parallel \text{"NG!"}$

$$k_w := 1.49 \quad \lambda_{rw} := k_w \cdot \sqrt{\frac{E}{f_y}} = 35.884$$

$Check2_w := \text{if } \lambda_w \leq \lambda_{rw} = \text{"OK!"}$
$\quad \quad \quad \parallel \text{"OK!"}$
$\quad \quad \quad \text{else}$
$\quad \quad \quad \parallel \text{"NG!"}$

**Thermal deflection per abutment (provided by structural designer)**

$$\delta_{per\_abut} = 0.27 \text{ in}$$

$$\theta := 0 \quad \text{Assume no rotation} \quad P_u = 390 \text{ kip} \quad \text{From Structural Engineer}$$

**From L-pile model run output for bending of pile in the Weak Axis**

$$M_{u,top} := 842.86 \text{ in} \cdot \text{kip}$$

$$M_{u,2nd} := 283.68 \text{ kip} \cdot \text{in}$$

$$V_u := 14.462 \text{ kip}$$

**Obtain unbraced Lengths from L-pile (locations where moment = 0)**

$$l_{b,top} := 5.5 \cdot \text{ft} = 66 \text{ in}$$

$$l_{b,2nd} := 19.1 \cdot \text{ft} = 229 \text{ in}$$

**Calculate Slenderness Factor,  $\lambda$**

$$k_{top} := 1.2 \quad \text{Fixed- pinned}$$

$$k_{2nd} := 1.0 \quad \text{Pinned- pinned}$$

$$\lambda_{top} := \left( \frac{k_{top} \cdot l_{b,top}}{r_{y\_c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.086$$

$$\lambda_{2nd} := \left( \frac{k_{2nd} \cdot l_{b,2nd}}{r_{y\_c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.719$$

**Check Nominal Compressive Resistance**

For  $\lambda \leq 2.25$

$$P_{n,top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s\_c} = (1.4 \cdot 10^3) \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r,top} := \phi_{cu} \cdot P_{n,top} = 967.8 \text{ kip}$$

$$P_{n,2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s\_c} = (1.1 \cdot 10^3) \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r,2nd} := \phi_{cu} \cdot P_{n,2nd} = 744 \text{ kip}$$

$$P_{n,bot} := 0.66^0 \cdot f_y \cdot A_{s\_c} = (1.4 \cdot 10^3) \text{ kip} \quad \text{Full Braced } \lambda=0$$

$$P_{r,bot} := \phi_{cl} \cdot P_{n,bot} = 716.4 \text{ kip}$$

**Check Ratio of Applied Load to Structural Resistance** Should NOT be Less than 0.2

$$\frac{P_u}{P_{r.top}} = 0.403$$

$$\frac{P_u}{P_{r.2nd}} = 0.524$$

$$\frac{P_u}{P_{r.bot}} = 0.544$$

**Compute Nominal Flexural Resistance**

$$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{f_y}} = 9.152 \quad \text{AASHTO Eq. 6.12.2.2.1-4}$$

$$\lambda_{rf} := 0.83 \cdot \sqrt{\frac{E}{f_y}} = 19.989 \quad \text{AASHTO Eq. 6.12.2.2.1-5}$$

$$\lambda_f = 9.255$$

**Calculate Nominal Flexural Resistance (AASHTO Eq. 6.12.2.2.1-1)**

$$M_{ny} := \begin{cases} \text{if } \lambda_f \leq \lambda_{pf} \\ \quad \parallel f_y \cdot Z_{y.c} \\ \text{if } \lambda_{pf} < \lambda_f \leq \lambda_{rf} \\ \quad \parallel \left( 1 - \left( 1 - \frac{S_{y.c}}{Z_{y.c}} \right) \cdot \left( \frac{\lambda_f - \lambda_{pf}}{.45 \cdot \sqrt{\frac{E}{f_y}}} \right) \right) \cdot f_y \cdot Z_{y.c} \\ \text{if } \lambda_f > \lambda_{rf} \\ \quad \parallel \text{"Pick New Pile Section"} \end{cases} = 3772.2 \text{ kip} \cdot \text{in}$$

$$M_{ry} := \phi_f \cdot M_{ny} = 3772.2 \text{ kip} \cdot \text{in} \quad \text{AASHTO Eq. 6.12.1.2.1-1}$$

**Check Pile Size**

$$PileSizeCheck := \begin{cases} \text{if } \frac{P_u}{P_{r.top}} \geq 0.2 \\ \quad \parallel \text{"Pile Size OK"} \\ \text{if } \frac{P_u}{P_{r.top}} < 0.2 \\ \quad \parallel \text{"Pile Size Too Big"} \end{cases} = \text{"Pile Size OK"}$$

### Find Moment Causing Plastic Hinge

Solving AASHTO Eq. 6.9.2.2-2 for  $M_u$

$$M_{uy} := \frac{9}{8} \cdot \left( 1 - \frac{P_u}{P_{r.top}} \right) M_{ry} = 81515453.4 \frac{ft}{s^2} \cdot lb \cdot in \text{ Moment for Load Case 2}$$

$$M_p := M_{uy} = 2533.6 \text{ kip} \cdot in$$

Check If Pile is in Plastic Range

if $M_{u.top} > M_p'$    "Plastic Hinge Formed/Iterate in L-Pile" if $M_{u.top} \leq M_p'$    "Pile Not in Plastic Range/Continue"	= "Pile Not in Plastic Range/Continue"
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From L-pile model run output for bending of pile in the Weak Axis with plastic hinge

$$\overline{M_{u.top}} := 2533.58 \text{ in} \cdot \text{kip}$$

$$\overline{M_{u.2nd}} := 427.56 \text{ kip} \cdot in$$

$$\overline{V_u} := 30.04 \text{ kip}$$

Obtain unbraced Lengths from L-pile (locations where moment = 0)

$$\overline{l_{b.top}} := 8.2 \cdot ft = 98 \text{ in}$$

$$\overline{l_{b.2nd}} := 22.0 \cdot ft = 264 \text{ in}$$

Calculate Slenderness Factor  $\lambda$

$$\overline{k_{top}} := 2.1 \quad \text{Plastic Hinge}$$

$$\overline{k_{2nd}} := 1.0 \quad \text{Pinned-Pinned}$$

$$\overline{\lambda_{top}} := \left( \frac{\overline{k_{top}} \cdot \overline{l_{b.top}}}{r_{y.c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.584$$

$$\overline{\lambda_{2nd}} := \left( \frac{\overline{k_{2nd}} \cdot \overline{l_{b.2nd}}}{r_{y.c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.954$$

Check Nominal Compressive Resistance

For  $\lambda \leq 2.25$

$$\overline{P_{n.top}} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s.c} = 1123.95 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$\overline{P_{r.top}} := \phi_{cu} \cdot \overline{P_{n.top}} = 786.77 \text{ kip}$$

$$P_{n.2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = 964.04 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r.2nd} := \phi_{cu} \cdot P_{n.2nd} = 674.83 \text{ kip}$$

$$P_{n.bot} := 0.66^0 \cdot f_y \cdot A_{s_c} = 1432.76 \text{ kip} \quad \text{Full Braced } \lambda = 0$$

$$P_{r.bot} := \phi_{cl} \cdot P_{n.bot} = 716.38 \text{ kip}$$

**Check Ratio of Applied Load to Structural Resistance** Should NOT be Less than 0.2

$$\frac{P_u}{P_{r.top}} = 0.496$$

$$\frac{P_u}{P_{r.2nd}} = 0.578$$

$$\frac{P_u}{P_{r.bot}} = 0.544$$

Check Pile Size

$PileSizeCheck :=$	if $\frac{P_u}{P_{r.top}} \geq 0.2$	= "Pile Size OK"
	"Pile Size OK"	
	if $\frac{P_u}{P_{r.top}} < 0.2$	
	"Pile Size Too Big"	

**Check Second Segment of Pile for Combined Stress**

$$\frac{P_u}{2 P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}} = 0.402$$

$$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}} = 0.679$$

AASHTO 6.9.2.2-1 and 6.9.2.2-2

$Check3 :=$	if $\frac{P_u}{P_{r.2nd}} < 0.2$	= 0.679
	$\frac{P_u}{2 P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}}$	
	if $\frac{P_u}{P_{r.2nd}} \geq 0.2$	
	$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}}$	

if $Check3 < 1$	= "OK"
"OK"	
if $Check3 \geq 1$	
"Pile Undersized"	

Check Bottom Segment of Pile

$$Check4 := \frac{P_u}{P_{r.bot}} = 0.544$$

if $Check4 < 1$	= "OK"
"OK"	
if $Check4 \geq 1$	
"Pile Undersized"	

**Check Shear**

AASHTO does not address weak axis shear - Use AISC Steel Manual

$$K_v := 1.2$$

$$C_v := 1$$

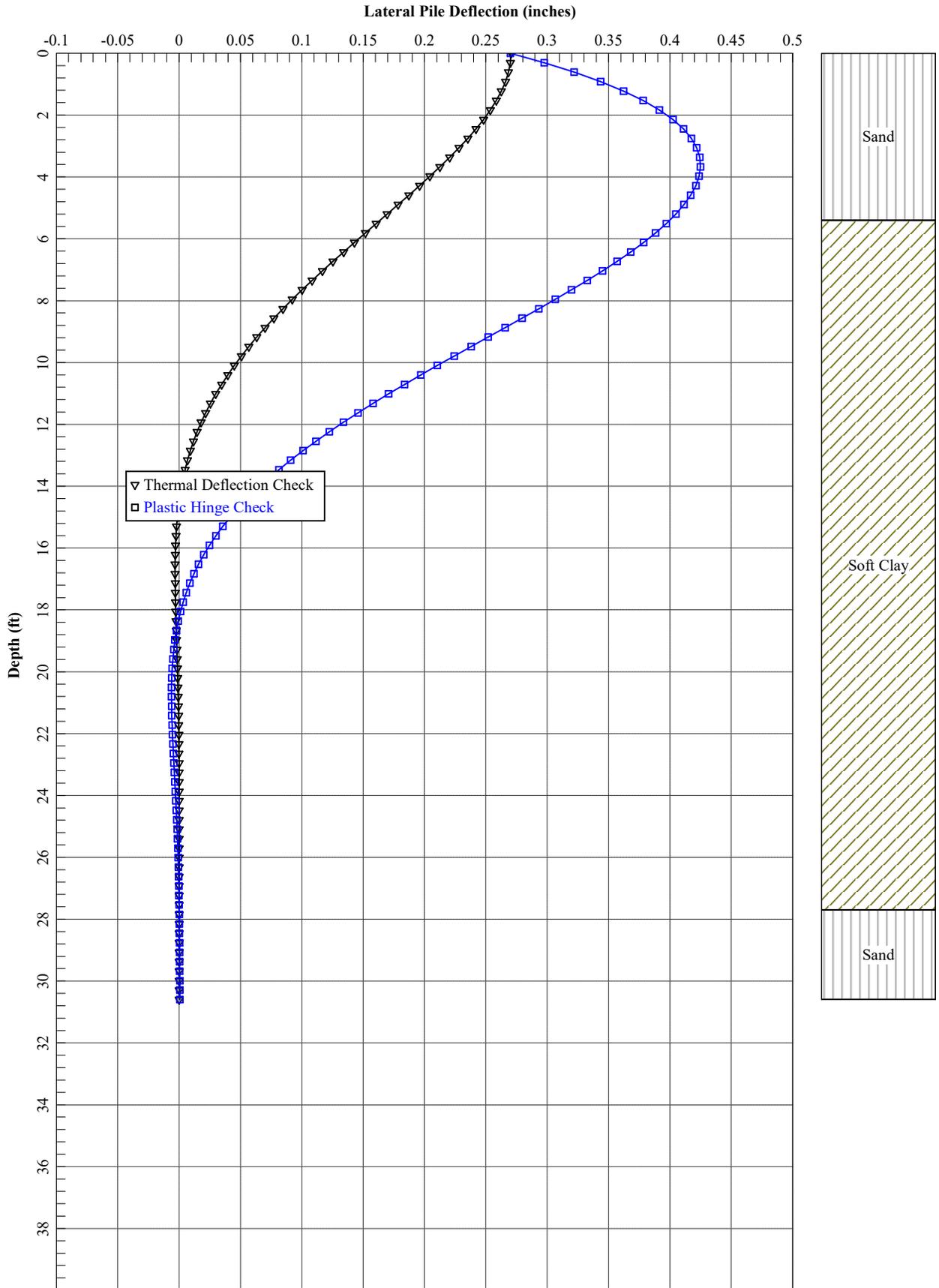
$$A_w := 2 b_{f.c} \cdot t_{f.c} = 20.094 \text{ in}^2$$

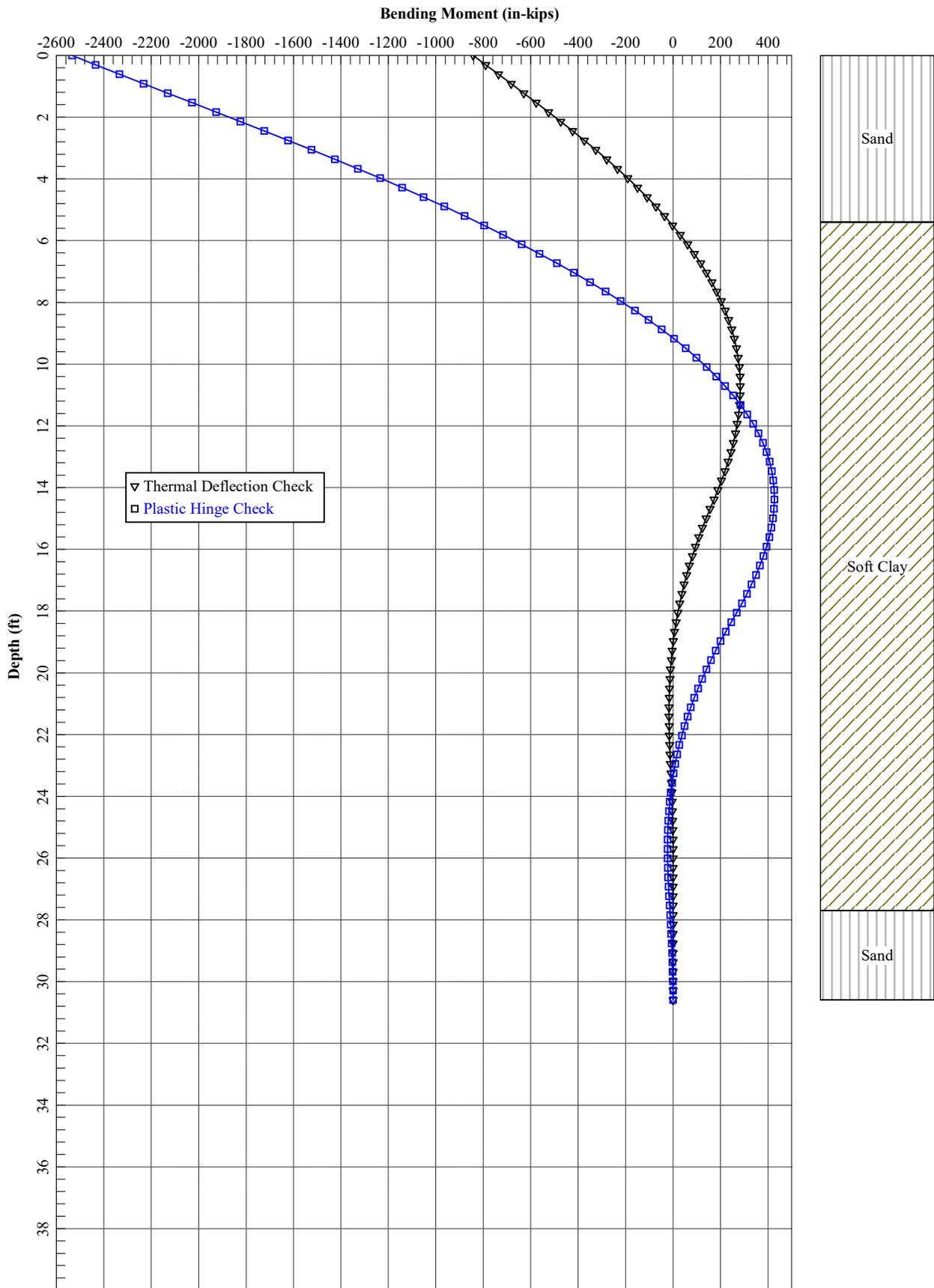
$$V_n := 0.6 f_y \cdot A_w \cdot C_v = 602.82 \text{ kip}$$

$$V_r := \phi_v \cdot V_n = 602.8 \text{ kip}$$

$$Check5 := \frac{V_u}{V_r} = 0.05$$

if $Check5 < 1$	= "OK"
"OK"	
if $Check5 \geq 1$	
"Pile Undersized"	





=====  
LPile for Windows, Version 2016-09.010

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:

\Users\mst.pierre\OneDrive - SW Cole Engineering\Desktop\LPile Output Files\20-1403-026184 Sabattus\

Name of input data file:

Abutment 1 HP14x117 r1.lp9d

Name of output report file:

Abutment 1 HP14x117 r1.lp9o

Name of plot output file:

Abutment 1 HP14x117 r1.lp9p

Name of runtime message file:  
Abutment 1 HP14x117 r1.lp9r

-----  
Date and Time of Analysis  
-----

Date: June 16, 2025

Time: 16:55:40

-----  
Problem Title  
-----

Sabattus River Bridge #5393 Replacement

WIN 026184

MaineDOT

S. W. Cole Engineering, Inc.

Abutment No. 1 - HP14x117

-----  
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  
-----

Number of pile sections defined = 1

Total length of pile = 30.600 ft  
 Depth of ground surface below top of pile = 0.0000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	14.0750
2	30.600	14.0750

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile  
 Cross-sectional Shape = Weak H-Pile Corroded Pile Properties  
 Length of section = 30.600000 ft  
 Flange Width = 14.775000 in  
 Section Depth = 14.075000 in  
 Flange Thickness = 0.680000 in  
 Web Thickness = 0.680000 in  
 Section Area = 28.740200 sq. in  
 Moment of Inertia = 365.877563 in^4  
 Elastic Modulus = 29000000. psi

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 3 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 0.0000 ft  
Distance from top of pile to bottom of layer = 5.400000 ft  
Effective unit weight at top of layer = 62.600000 pcf  
Effective unit weight at bottom of layer = 62.600000 pcf  
Friction angle at top of layer = 30.000000 deg.  
Friction angle at bottom of layer = 30.000000 deg.  
Subgrade k at top of layer = 90.000000 pci  
Subgrade k at bottom of layer = 90.000000 pci

Layer 2 is soft clay, p-y criteria by Matlock, 1970

Distance from top of pile to top of layer = 5.400000 ft  
Distance from top of pile to bottom of layer = 27.700000 ft  
Effective unit weight at top of layer = 47.600000 pcf  
Effective unit weight at bottom of layer = 47.600000 pcf  
Undrained cohesion at top of layer = 750.000000 psf  
Undrained cohesion at bottom of layer = 750.000000 psf  
Epsilon-50 at top of layer = 0.010000  
Epsilon-50 at bottom of layer = 0.010000

Layer 3 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 27.700000 ft  
 Distance from top of pile to bottom of layer = 30.600000 ft  
 Effective unit weight at top of layer = 67.600000 pcf  
 Effective unit weight at bottom of layer = 67.600000 pcf  
 Friction angle at top of layer = 32.000000 deg.  
 Friction angle at bottom of layer = 32.000000 deg.  
 Subgrade k at top of layer = 125.000000 pci  
 Subgrade k at bottom of layer = 125.000000 pci

(Depth of the lowest soil layer extends 0.000 ft below the 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	Sand (Reese, et al.)	0.00 5.4000	62.6000 62.6000	-- --	30.0000 30.0000	-- --	90.0000 90.0000
2	Soft Clay	5.4000 27.7000	47.6000 47.6000	750.0000 750.0000	-- --	0.01000 0.01000	-- --
3	Sand (Reese, et al.)	27.7000 30.6000	67.6000 67.6000	-- --	32.0000 32.0000	-- --	125.0000 125.0000

-----  
 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 = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	5	y = 0.270000 in	S = 0.0000 in/in	390000.	N.A.
2	4	y = 0.270000 in	M = -2533580. in-lbs	390000.	N.A.

V = shear force applied normal to pile axis

M = bending moment applied to pile head

y = lateral deflection normal to pile axis

S = pile slope relative to original pile batter angle

R = rotational stiffness applied to pile head

Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).

Thrust force is assumed to be acting axially for all pile batter angles.

-----  
Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness  
-----

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:  
-----

Moment-curvature properties were derived from elastic section properties

-----  
Layering Correction Equivalent Depths of Soil & Rock Layers  
-----

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	9832.
2	5.4000	2.9742	No	No	9832.	160092.
3	27.7000	27.7000	No	No	169924.	N.A.

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

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

Pile-head conditions are Displacement and Pile-head Rotation (Loading Type 5)  
 Displacement of pile head = 0.270000 inches  
 Rotation of pile head = 0.000E+00 radians  
 Axial load on pile head = 390000.0 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	0.2705	-842860.	14462.	0.00	29782.	1.06E+10	0.00	0.00	0.00
0.3060	0.2700	-789643.	14413.	-2.82E-04	28758.	1.06E+10	-12.2034	165.9667	0.00
0.6120	0.2685	-736200.	14343.	-5.47E-04	27730.	1.06E+10	-25.9609	355.0929	0.00
0.9180	0.2660	-682742.	14221.	-7.92E-04	26702.	1.06E+10	-40.4716	558.7193	0.00
1.2240	0.2626	-629491.	14046.	-0.00102	25678.	1.06E+10	-54.8251	766.5036	0.00

1.5300	0.2585	-576668.	13820.	-0.00123	24662.	1.06E+10	-68.5089	973.1633	0.00
1.8360	0.2536	-524482.	13545.	-0.00142	23658.	1.06E+10	-80.9027	1171.	0.00
2.1420	0.2481	-473128.	13227.	-0.00159	22670.	1.06E+10	-92.5888	1370.	0.00
2.4480	0.2419	-422787.	12869.	-0.00175	21702.	1.06E+10	-102.4418	1555.	0.00
2.7540	0.2353	-373618.	12477.	-0.00188	20756.	1.06E+10	-110.7673	1729.	0.00
3.0600	0.2281	-325758.	12058.	-0.00200	19836.	1.06E+10	-117.3977	1890.	0.00
3.3660	0.2205	-279319.	11617.	-0.00211	18942.	1.06E+10	-122.8669	2046.	0.00
3.6720	0.2126	-234398.	11156.	-0.00220	18078.	1.06E+10	-128.1567	2213.	0.00
3.9780	0.2044	-191089.	10675.	-0.00227	17245.	1.06E+10	-133.9175	2406.	0.00
4.2840	0.1959	-149491.	10178.	-0.00233	16445.	1.06E+10	-137.2154	2572.	0.00
4.5900	0.1873	-109669.	9673.	-0.00238	15679.	1.06E+10	-137.6906	2700.	0.00
4.8960	0.1785	-71649.	9157.	-0.00241	14948.	1.06E+10	-143.3555	2949.	0.00
5.2020	0.1696	-35527.	8615.	-0.00243	14253.	1.06E+10	-151.9692	3290.	0.00
5.5080	0.1607	-1436.	8088.	-0.00243	13597.	1.06E+10	-134.6754	3078.	0.00
5.8140	0.1517	30839.	7591.	-0.00243	14163.	1.06E+10	-136.2824	3298.	0.00
6.1200	0.1428	61262.	7088.	-0.00241	14748.	1.06E+10	-137.6340	3538.	0.00
6.4260	0.1340	89799.	6580.	-0.00238	15297.	1.06E+10	-138.7248	3801.	0.00
6.7320	0.1253	116420.	6070.	-0.00235	15809.	1.06E+10	-139.5498	4089.	0.00
7.0380	0.1168	141102.	5556.	-0.00230	16284.	1.06E+10	-140.1039	4406.	0.00
7.3440	0.1084	163826.	5041.	-0.00225	16721.	1.06E+10	-140.3823	4755.	0.00
7.6500	0.1002	184575.	4526.	-0.00219	17120.	1.06E+10	-140.3802	5143.	0.00
7.9560	0.09231	203340.	4011.	-0.00212	17481.	1.06E+10	-140.0929	5573.	0.00
8.2620	0.08463	220115.	3497.	-0.00205	17804.	1.06E+10	-139.5157	6053.	0.00
8.5680	0.07724	234900.	2987.	-0.00197	18088.	1.06E+10	-138.6438	6591.	0.00
8.8740	0.07015	247699.	2480.	-0.00189	18334.	1.06E+10	-137.4723	7196.	0.00
9.1800	0.06337	258521.	1978.	-0.00180	18542.	1.06E+10	-135.9960	7881.	0.00
9.4860	0.05692	267382.	1482.	-0.00171	18713.	1.06E+10	-134.2095	8658.	0.00
9.7920	0.05081	274301.	992.5838	-0.00162	18846.	1.06E+10	-132.1067	9548.	0.00
10.0980	0.04504	279302.	511.9420	-0.00152	18942.	1.06E+10	-129.6807	10572.	0.00
10.4040	0.03964	282416.	40.8165	-0.00142	19002.	1.06E+10	-126.9236	11758.	0.00
10.7100	0.03459	283680.	-419.5591	-0.00133	19026.	1.06E+10	-123.8257	13146.	0.00
11.0160	0.02990	283132.	-867.9118	-0.00123	19016.	1.06E+10	-120.3752	14783.	0.00
11.3220	0.02557	280822.	-1303.	-0.00113	18971.	1.06E+10	-116.5569	16737.	0.00
11.6280	0.02160	276801.	-1723.	-0.00103	18894.	1.06E+10	-112.3511	19099.	0.00
11.9340	0.01798	271127.	-2127.	-9.39E-04	18785.	1.06E+10	-107.7309	22000.	0.00
12.2400	0.01471	263867.	-2535.	-8.46E-04	18645.	1.06E+10	-114.5105	28592.	0.00
12.5460	0.01177	254932.	-2941.	-7.56E-04	18473.	1.06E+10	-106.3129	33176.	0.00
12.8520	0.00915	244437.	-3315.	-6.70E-04	18271.	1.06E+10	-97.7742	39233.	0.00
13.1580	0.00685	232502.	-3658.	-5.88E-04	18042.	1.06E+10	-88.7688	47613.	0.00

13.4640	0.00484	219256.	-3966.	-5.09E-04	17787.	1.06E+10	-79.0735	60037.	0.00
13.7700	0.00311	204834.	-4237.	-4.36E-04	17510.	1.06E+10	-68.2393	80692.	0.00
14.0760	0.00163	189391.	-4463.	-3.68E-04	17213.	1.06E+10	-55.1414	123872.	0.00
14.3820	4.05E-04	173111.	-4628.	-3.05E-04	16900.	1.06E+10	-34.7922	315815.	0.00
14.6880	-6.06E-04	156275.	-4620.	-2.48E-04	16576.	1.06E+10	39.3693	238738.	0.00
14.9940	-0.00142	139893.	-4451.	-1.97E-04	16261.	1.06E+10	52.3998	135787.	0.00
15.3000	-0.00205	124148.	-4246.	-1.51E-04	15958.	1.06E+10	59.3070	106195.	0.00
15.6060	-0.00253	109142.	-4021.	-1.11E-04	15669.	1.06E+10	63.5981	92428.	0.00
15.9120	-0.00286	94939.	-3782.	-7.54E-05	15396.	1.06E+10	66.3219	85036.	0.00
16.2180	-0.00308	81583.	-3535.	-4.49E-05	15139.	1.06E+10	67.9618	81012.	0.00
16.5240	-0.00319	69103.	-3284.	-1.88E-05	14899.	1.06E+10	68.7890	79099.	0.00
16.8300	-0.00322	57516.	-3031.	3.12E-06	14676.	1.06E+10	68.9748	78694.	0.00
17.1360	-0.00317	46830.	-2779.	2.12E-05	14471.	1.06E+10	68.6358	79492.	0.00
17.4420	-0.00306	37047.	-2528.	3.57E-05	14282.	1.06E+10	67.8566	81348.	0.00
17.7480	-0.00291	28161.	-2281.	4.70E-05	14112.	1.06E+10	66.7009	84213.	0.00
18.0540	-0.00272	20160.	-2039.	5.53E-05	13958.	1.06E+10	65.2186	88108.	0.00
18.3600	-0.00250	13028.	-1803.	6.11E-05	13820.	1.06E+10	63.4496	93117.	0.00
18.6660	-0.00227	6746.	-1573.	6.45E-05	13700.	1.06E+10	61.4268	99386.	0.00
18.9720	-0.00203	1288.	-1352.	6.59E-05	13595.	1.06E+10	59.1775	107127.	0.00
19.2780	-0.00179	-3372.	-1139.	6.55E-05	13635.	1.06E+10	56.7248	116647.	0.00
19.5840	-0.00155	-7266.	-935.7800	6.37E-05	13710.	1.06E+10	54.0885	128368.	0.00
19.8900	-0.00132	-10427.	-742.3134	6.06E-05	13770.	1.06E+10	51.2854	142885.	0.00
20.1960	-0.00110	-12891.	-559.4202	5.66E-05	13818.	1.06E+10	48.3296	161040.	0.00
20.5020	-9.02E-04	-14697.	-387.6404	5.18E-05	13853.	1.06E+10	45.2324	184057.	0.00
20.8080	-7.21E-04	-15886.	-227.4775	4.65E-05	13875.	1.06E+10	42.0023	213772.	0.00
21.1140	-5.61E-04	-16501.	-79.4116	4.09E-05	13887.	1.06E+10	38.6436	253053.	0.00
21.4200	-4.21E-04	-16587.	56.0823	3.52E-05	13889.	1.06E+10	35.1548	306634.	0.00
21.7260	-3.02E-04	-16190.	178.5053	2.95E-05	13881.	1.06E+10	31.5243	382921.	0.00
22.0320	-2.04E-04	-15360.	287.2798	2.41E-05	13865.	1.06E+10	27.7210	498513.	0.00
22.3380	-1.26E-04	-14149.	381.6344	1.90E-05	13842.	1.06E+10	23.6704	692022.	0.00
22.6440	-6.50E-05	-12612.	460.3053	1.43E-05	13812.	1.06E+10	19.1787	1083628.	0.00
22.9500	-2.04E-05	-10810.	520.4489	1.03E-05	13778.	1.06E+10	13.5792	2443523.	0.00
23.2560	1.04E-05	-8819.	528.3254	6.87E-06	13739.	1.06E+10	-9.2892	3267273.	0.00
23.5620	3.01E-05	-6950.	485.3765	4.15E-06	13704.	1.06E+10	-14.1034	1721746.	0.00
23.8680	4.09E-05	-5267.	430.4768	2.03E-06	13671.	1.06E+10	-15.7983	1418858.	0.00
24.1740	4.50E-05	-3794.	371.3832	4.64E-07	13643.	1.06E+10	-16.3877	1337211.	0.00
24.4800	4.43E-05	-2540.	311.2896	-6.32E-07	13619.	1.06E+10	-16.3430	1354831.	0.00
24.7860	4.04E-05	-1506.	252.1508	-1.33E-06	13599.	1.06E+10	-15.8677	1443668.	0.00
25.0920	3.45E-05	-684.7923	195.3469	-1.71E-06	13583.	1.06E+10	-15.0713	1603585.	0.00

25.3980	2.78E-05	-66.4653	141.9404	-1.84E-06	13571.	1.06E+10	-14.0173	1851991.	0.00
25.7040	2.10E-05	362.8917	92.8195	-1.79E-06	13577.	1.06E+10	-12.7371	2228308.	0.00
26.0100	1.46E-05	620.3275	48.8229	-1.62E-06	13582.	1.06E+10	-11.2262	2814368.	0.00
26.3160	9.09E-06	726.0864	10.9291	-1.39E-06	13584.	1.06E+10	-9.4131	3801073.	0.00
26.6220	4.46E-06	704.5632	-19.2526	-1.14E-06	13583.	1.06E+10	-7.0258	5781315.	0.00
26.9280	7.27E-07	587.9584	-33.0502	-9.16E-07	13581.	1.06E+10	-0.4893	2472214.	0.00
27.2340	-2.26E-06	464.4652	-31.1526	-7.34E-07	13579.	1.06E+10	1.5228	2472214.	0.00
27.5400	-4.66E-06	361.2747	-22.5963	-5.91E-07	13577.	1.06E+10	3.1375	2472214.	0.00
27.8460	-6.60E-06	300.2097	-16.3298	-4.76E-07	13576.	1.06E+10	0.2756	153376.	0.00
28.1520	-8.16E-06	242.7126	-15.1913	-3.82E-07	13575.	1.06E+10	0.3445	155061.	0.00
28.4580	-9.41E-06	189.7397	-13.8217	-3.07E-07	13573.	1.06E+10	0.4015	156747.	0.00
28.7640	-1.04E-05	142.0867	-12.2595	-2.50E-07	13573.	1.06E+10	0.4493	158432.	0.00
29.0700	-1.12E-05	100.4221	-10.5345	-2.08E-07	13572.	1.06E+10	0.4902	160118.	0.00
29.3760	-1.19E-05	65.3175	-8.6683	-1.79E-07	13571.	1.06E+10	0.5262	161803.	0.00
29.6820	-1.26E-05	37.2757	-6.6756	-1.62E-07	13571.	1.06E+10	0.5592	163488.	0.00
29.9880	-1.31E-05	16.7549	-4.5647	-1.52E-07	13570.	1.06E+10	0.5905	165174.	0.00
30.2940	-1.37E-05	4.1885	-2.3394	-1.49E-07	13570.	1.06E+10	0.6215	166859.	0.00
30.6000	-1.42E-05	0.00	0.00	-1.48E-07	13570.	1.06E+10	0.6527	84272.	0.00

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

Output Summary for Load Case No. 1:

Pile-head deflection = 0.27053555 inches  
 Computed slope at pile head = 0.000000 radians  
 Maximum bending moment = -842860. inch-lbs  
 Maximum shear force = 14462. lbs  
 Depth of maximum bending moment = 0.000000 feet below pile head  
 Depth of maximum shear force = 0.000000 feet below pile head  
 Number of iterations = 15  
 Number of zero deflection points = 3

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

Pile-head conditions are Displacement and Moment (Loading Type 4)

Displacement of pile head = 0.270000 inches

Moment at pile head = -2533580.0 in-lbs

Axial load at pile head = 390000.0 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	0.2700	-2533580.	30041.	0.00794	62302.	1.06E+10	0.00	0.00	0.00
0.3060	0.2976	-2434016.	30017.	0.00708	60387.	1.06E+10	-12.5761	155.1974	0.00
0.6120	0.3220	-2333416.	29944.	0.00626	58452.	1.06E+10	-27.5810	314.5154	0.00
0.9180	0.3435	-2232031.	29812.	0.00547	56502.	1.06E+10	-44.2101	472.5978	0.00
1.2240	0.3622	-2130136.	29618.	0.00471	54542.	1.06E+10	-61.4964	623.5196	0.00
1.5300	0.3781	-2028014.	29360.	0.00399	52578.	1.06E+10	-78.7814	765.0794	0.00
1.8360	0.3915	-1925950.	29041.	0.00331	50615.	1.06E+10	-95.3140	894.0145	0.00
2.1420	0.4024	-1824216.	28661.	0.00266	48658.	1.06E+10	-111.7392	1020.	0.00
2.4480	0.4110	-1723085.	28223.	0.00205	46713.	1.06E+10	-126.5619	1131.	0.00
2.7540	0.4174	-1622806.	27734.	0.00147	44784.	1.06E+10	-139.8499	1230.	0.00
3.0600	0.4218	-1523609.	27198.	9.22E-04	42876.	1.06E+10	-152.0196	1323.	0.00
3.3660	0.4242	-1425707.	26617.	4.12E-04	40993.	1.06E+10	-164.3492	1423.	0.00
3.6720	0.4248	-1329313.	25989.	-6.46E-05	39139.	1.06E+10	-177.9077	1538.	0.00
3.9780	0.4237	-1234660.	25306.	-5.08E-04	37318.	1.06E+10	-193.8449	1680.	0.00
4.2840	0.4211	-1142009.	24568.	-9.19E-04	35536.	1.06E+10	-208.2781	1816.	0.00
4.5900	0.4170	-1051600.	23780.	-0.00130	33797.	1.06E+10	-220.7835	1944.	0.00
4.8960	0.4115	-963647.	22936.	-0.00165	32105.	1.06E+10	-238.9244	2132.	0.00
5.2020	0.4049	-878438.	22019.	-0.00197	30466.	1.06E+10	-260.5138	2363.	0.00
5.5080	0.3971	-796306.	21207.	-0.00226	28886.	1.06E+10	-182.0867	1684.	0.00
5.8140	0.3883	-716234.	20530.	-0.00252	27346.	1.06E+10	-186.4097	1763.	0.00
6.1200	0.3786	-638321.	19838.	-0.00275	25848.	1.06E+10	-190.4732	1847.	0.00
6.4260	0.3681	-562660.	19132.	-0.00296	24392.	1.06E+10	-194.2702	1938.	0.00
6.7320	0.3569	-489340.	18412.	-0.00314	22982.	1.06E+10	-197.7937	2035.	0.00
7.0380	0.3450	-418444.	17680.	-0.00330	21618.	1.06E+10	-201.0373	2140.	0.00
7.3440	0.3326	-350051.	16936.	-0.00343	20303.	1.06E+10	-203.9946	2252.	0.00
7.6500	0.3198	-284236.	16182.	-0.00354	19037.	1.06E+10	-206.6594	2373.	0.00
7.9560	0.3066	-221066.	15419.	-0.00363	17822.	1.06E+10	-209.0261	2503.	0.00
8.2620	0.2932	-160605.	14647.	-0.00370	16659.	1.06E+10	-211.0888	2644.	0.00
8.5680	0.2795	-102910.	13869.	-0.00374	15549.	1.06E+10	-212.8424	2796.	0.00

8.8740	0.2657	-48035.	13085.	-0.00377	14494.	1.06E+10	-214.2815	2962.	0.00
9.1800	0.2518	3975.	12296.	-0.00377	13646.	1.06E+10	-215.4013	3141.	0.00
9.4860	0.2380	53079.	11504.	-0.00377	14591.	1.06E+10	-216.1969	3336.	0.00
9.7920	0.2242	99241.	10709.	-0.00374	15479.	1.06E+10	-216.6638	3549.	0.00
10.0980	0.2105	142433.	9913.	-0.00370	16309.	1.06E+10	-216.7976	3782.	0.00
10.4040	0.1970	182631.	9117.	-0.00364	17083.	1.06E+10	-216.5939	4037.	0.00
10.7100	0.1838	219818.	8323.	-0.00357	17798.	1.06E+10	-216.0486	4317.	0.00
11.0160	0.1708	253982.	7531.	-0.00349	18455.	1.06E+10	-215.1577	4626.	0.00
11.3220	0.1581	285120.	6743.	-0.00340	19054.	1.06E+10	-213.9171	4967.	0.00
11.6280	0.1459	313233.	5961.	-0.00329	19595.	1.06E+10	-212.3231	5345.	0.00
11.9340	0.1340	338327.	5185.	-0.00318	20077.	1.06E+10	-210.3715	5766.	0.00
12.2400	0.1225	360417.	4373.	-0.00306	20502.	1.06E+10	-232.0786	6956.	0.00
12.5460	0.1115	379198.	3533.	-0.00293	20864.	1.06E+10	-224.9131	7407.	0.00
12.8520	0.1010	394760.	2721.	-0.00280	21163.	1.06E+10	-217.6059	7913.	0.00
13.1580	0.09097	407192.	1936.	-0.00266	21402.	1.06E+10	-210.1590	8483.	0.00
13.4640	0.08146	416588.	1178.	-0.00252	21583.	1.06E+10	-202.5729	9131.	0.00
13.7700	0.07249	423046.	448.1988	-0.00237	21707.	1.06E+10	-194.8470	9870.	0.00
14.0760	0.06406	426667.	-252.8334	-0.00222	21777.	1.06E+10	-186.9788	10718.	0.00
14.3820	0.05617	427556.	-924.7034	-0.00208	21794.	1.06E+10	-178.9635	11700.	0.00
14.6880	0.04882	425820.	-1567.	-0.00193	21760.	1.06E+10	-170.7934	12846.	0.00
14.9940	0.04201	421570.	-2179.	-0.00178	21679.	1.06E+10	-162.4568	14199.	0.00
15.3000	0.03574	414920.	-2760.	-0.00164	21551.	1.06E+10	-153.9362	15816.	0.00
15.6060	0.03000	405990.	-3309.	-0.00149	21379.	1.06E+10	-145.2063	17775.	0.00
15.9120	0.02477	394900.	-3826.	-0.00136	21166.	1.06E+10	-136.2295	20197.	0.00
16.2180	0.02004	381777.	-4309.	-0.00122	20913.	1.06E+10	-126.9500	23260.	0.00
16.5240	0.01580	366754.	-4757.	-0.00109	20624.	1.06E+10	-117.2817	27257.	0.00
16.8300	0.01202	349967.	-5169.	-9.68E-04	20301.	1.06E+10	-107.0860	32701.	0.00
17.1360	0.00869	331563.	-5542.	-8.50E-04	19947.	1.06E+10	-96.1238	40597.	0.00
17.4420	0.00579	311699.	-5873.	-7.38E-04	19565.	1.06E+10	-83.9340	53276.	0.00
17.7480	0.00327	290548.	-6154.	-6.34E-04	19158.	1.06E+10	-69.4420	77931.	0.00
18.0540	0.00113	268317.	-6371.	-5.37E-04	18731.	1.06E+10	-48.7821	158779.	0.00
18.3600	-6.75E-04	245296.	-6386.	-4.49E-04	18288.	1.06E+10	40.8014	222047.	0.00
18.6660	-0.00217	222703.	-6200.	-3.68E-04	17853.	1.06E+10	60.3784	102363.	0.00
18.9720	-0.00337	200813.	-5961.	-2.94E-04	17432.	1.06E+10	70.0296	76213.	0.00
19.2780	-0.00433	179769.	-5693.	-2.28E-04	17028.	1.06E+10	76.1007	64580.	0.00
19.5840	-0.00505	159661.	-5406.	-1.70E-04	16641.	1.06E+10	80.1408	58255.	0.00
19.8900	-0.00557	140555.	-5107.	-1.18E-04	16273.	1.06E+10	82.8159	54565.	0.00
20.1960	-0.00592	122496.	-4799.	-7.22E-05	15926.	1.06E+10	84.4861	52438.	0.00
20.5020	-0.00610	105515.	-4488.	-3.28E-05	15599.	1.06E+10	85.3724	51361.	0.00

20.8080	-0.00616	89634.	-4174.	1.00E-06	15294.	1.06E+10	85.6232	51067.	0.00
21.1140	-0.00610	74862.	-3860.	2.95E-05	15010.	1.06E+10	85.3439	51406.	0.00
21.4200	-0.00594	61204.	-3548.	5.30E-05	14747.	1.06E+10	84.6132	52303.	0.00
21.7260	-0.00571	48656.	-3239.	7.20E-05	14506.	1.06E+10	83.4919	53722.	0.00
22.0320	-0.00541	37210.	-2935.	8.69E-05	14286.	1.06E+10	82.0282	55661.	0.00
22.3380	-0.00507	26852.	-2637.	9.80E-05	14086.	1.06E+10	80.2613	58144.	0.00
22.6440	-0.00469	17563.	-2346.	1.06E-04	13908.	1.06E+10	78.2237	61218.	0.00
22.9500	-0.00429	9319.	-2063.	1.10E-04	13749.	1.06E+10	75.9424	64958.	0.00
23.2560	-0.00388	2095.	-1789.	1.12E-04	13610.	1.06E+10	73.4404	69468.	0.00
23.5620	-0.00347	-4140.	-1524.	1.12E-04	13649.	1.06E+10	70.7368	74890.	0.00
23.8680	-0.00306	-9418.	-1270.	1.10E-04	13751.	1.06E+10	67.8476	81417.	0.00
24.1740	-0.00266	-13778.	-1026.	1.06E-04	13835.	1.06E+10	64.7857	89312.	0.00
24.4800	-0.00228	-17257.	-794.1986	1.00E-04	13902.	1.06E+10	61.5605	98939.	0.00
24.7860	-0.00193	-19898.	-574.3604	9.38E-05	13953.	1.06E+10	58.1771	110814.	0.00
25.0920	-0.00160	-21744.	-367.2364	8.66E-05	13988.	1.06E+10	54.6355	125692.	0.00
25.3980	-0.00129	-22842.	-173.4222	7.88E-05	14009.	1.06E+10	50.9278	144730.	0.00
25.7040	-0.00102	-23243.	6.4344	7.09E-05	14017.	1.06E+10	47.0333	169801.	0.00
26.0100	-7.72E-04	-22998.	171.5699	6.29E-05	14012.	1.06E+10	42.9098	204194.	0.00
26.3160	-5.55E-04	-22163.	320.9895	5.51E-05	13996.	1.06E+10	38.4734	254364.	0.00
26.6220	-3.67E-04	-20798.	453.2215	4.76E-05	13970.	1.06E+10	33.5483	335365.	0.00
26.9280	-2.06E-04	-18971.	565.6787	4.07E-05	13935.	1.06E+10	27.7029	494566.	0.00
27.2340	-6.81E-05	-16761.	652.0293	3.46E-05	13892.	1.06E+10	19.3291	1041480.	0.00
27.5400	4.81E-05	-14282.	656.8298	2.92E-05	13845.	1.06E+10	-16.7145	1276347.	0.00
27.8460	1.46E-04	-12021.	614.9322	2.46E-05	13801.	1.06E+10	-6.1056	153376.	0.00
28.1520	2.29E-04	-9836.	585.9689	2.09E-05	13759.	1.06E+10	-9.6696	155061.	0.00
28.4580	2.99E-04	-7777.	544.7584	1.78E-05	13719.	1.06E+10	-12.7762	156747.	0.00
28.7640	3.60E-04	-5886.	492.8051	1.54E-05	13683.	1.06E+10	-15.5208	158432.	0.00
29.0700	4.13E-04	-4202.	431.2704	1.37E-05	13651.	1.06E+10	-17.9948	160118.	0.00
29.3760	4.60E-04	-2758.	360.9940	1.25E-05	13623.	1.06E+10	-20.2821	161803.	0.00
29.6820	5.04E-04	-1587.	282.5250	1.17E-05	13600.	1.06E+10	-22.4570	163488.	0.00
29.9880	5.46E-04	-717.0733	196.1619	1.13E-05	13584.	1.06E+10	-24.5817	165174.	0.00
30.2940	5.88E-04	-178.5504	102.0020	1.12E-05	13573.	1.06E+10	-26.7037	166859.	0.00
30.6000	6.29E-04	0.00	0.00	1.12E-05	13570.	1.06E+10	-28.8530	84272.	0.00

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

Output Summary for Load Case No. 2:

Pile-head deflection = 0.27000000 inches  
 Computed slope at pile head = 0.00794165 radians  
 Maximum bending moment = -2533580. inch-lbs  
 Maximum shear force = 30041. lbs  
 Depth of maximum bending moment = 0.000000 feet below pile head  
 Depth of maximum shear force = 0.000000 feet below pile head  
 Number of iterations = 20  
 Number of zero deflection points = 2

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 Summary of Pile-head Responses for Conventional Analyses  
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Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	y, in	0.2700	S, rad	0.00	390000.	0.2705	0.00	14462.	-842860.
2	y, in	0.2700	M, in-lb	-2533580.	390000.	0.2700	0.00794	30041.	-2533580.

Maximum pile-head deflection = 0.2705355462 inches  
 Maximum pile-head rotation = 0.0079416503 radians = 0.455023 deg.

The analysis ended normally.

**Integral Abutment Pile Design - Abutment 2 (East Abutment)**

**Maximum Vertical Load From Structural Engineer**

(provided by email on 05/27/2025)

$P_u := 390 \text{ kip}$  Vertical Load per Pile

$\delta_{per\_abut} := 0.27 \text{ in}$  Thermal Deflection per Abutment

**AASHTO Reduction Factors (From AASHTO 6.5.4.2)**

$\phi_{cl} := 0.5$  For severe driving conditions where pile tip necessary - Lower Zone

$\phi_{cu} := 0.7$  For combined axial and flexural resistance undamaged pile / axial - Upper Zone

$\phi_f := 1$  For combined axial and flexural resistance undamaged pile / flexural - Lower Zone

$\phi_v := 1$  Shear

**Required Axial Resistance**

$R_{n,upper} := \frac{P_u}{\phi_{cu}} = 557.143 \text{ kip}$

$R_{n,lower} := \frac{P_u}{\phi_{cl}} = 780 \text{ kip}$

$R_n := \max(R_{n,upper}, R_{n,lower}) = 780 \text{ kip}$

**Required Area of Steel**

$f_y := 50 \text{ ksi}$

$E := 29000 \text{ ksi}$

$A_{s,required} := \frac{R_n}{0.8 \cdot f_y} = 19.5 \text{ in}^2$

**Select Pile Section Properties (from AISC Manual) HP 14x117**

$d := 14.2 \text{ in}$      $b_f := 14.9 \text{ in}$      $t_w := 0.805 \text{ in}$      $t_f := 0.805 \text{ in}$      $h_w := d - 2 t_f = 12.59 \text{ in}$

Allow 1/16 inch section loss on all surfaces for corrosion  $t_{cor} := 0.0625 \text{ in}$

$d_c := d - 2 \cdot t_{cor} = 14.075 \text{ in}$      $t_{w_c} := t_w - 2 \cdot t_{cor} = 0.68 \text{ in}$

$b_{f_c} := b_f - 2 \cdot t_{cor} = 14.775 \text{ in}$      $t_{f_c} := t_f - 2 \cdot t_{cor} = 0.68 \text{ in}$

### Calculate Corroded Section Properties

$$A_{s_c} := 2 \cdot (b_{f_c} \cdot t_{f_c}) + h_w \cdot t_{w_c} = 28.66 \text{ in}^2$$

$Check1 := \text{if } \frac{A_{s_c}}{A_{s_{required}}} > 1 = \text{"OK!"}$
$\parallel \text{"OK!"}$
$\text{else}$
$\parallel \text{"NG!"}$

$$S_{y_c} := \frac{b_{f_c}^2 \cdot (2 t_{f_c})}{6} + \frac{((b_{f_c}) - (b_{f_c} - t_{w_c}))^3 \cdot (d_c - 2 \cdot t_{f_c})}{6 \cdot b_f} = 49.5 \text{ in}^3$$

$$Z_{y_c} := \frac{(b_{f_c}^2 \cdot t_{f_c})}{2} + .25 \cdot t_{w_c}^2 \cdot (d_c - 2 t_{f_c}) = 75.7 \text{ in}^3$$

$$I_{y_c} := \frac{2 \cdot t_{f_c} \cdot b_{f_c}^3 + h_w \cdot t_{w_c}^3}{12} = 365.87 \text{ in}^4$$

from L-pile calculation  
 $I_{LPILE} := 365.88 \text{ in}^4$

$$r_{y_c} := \sqrt{\frac{I_{y_c}}{A_{s_c}}} = 3.57 \text{ in}$$

### Check Local Buckling From AASHTO eqn 6.10.8.2.2-3

$$\lambda_f := \frac{b_f}{2 \cdot t_f} = 9.255 \quad \text{for flange}$$

$$\lambda_w := \frac{h_w}{t_w} = 15.64 \quad \text{for web}$$

### Check Slenderness From AASHTO Table 6.9.4.2.1-1, find k

$$k_f := 0.56 \quad \lambda_{rf} := k_f \cdot \sqrt{\frac{E}{f_y}} = 13.487$$

$Check2_f := \text{if } \lambda_f \leq \lambda_{rf} = \text{"OK!"}$
$\parallel \text{"OK!"}$
$\text{else}$
$\parallel \text{"NG!"}$

$$k_w := 1.49 \quad \lambda_{rw} := k_w \cdot \sqrt{\frac{E}{f_y}} = 35.884$$

$Check2_w := \text{if } \lambda_w \leq \lambda_{rw} = \text{"OK!"}$
$\parallel \text{"OK!"}$
$\text{else}$
$\parallel \text{"NG!"}$

**Thermal deflection per abutment (provided by structural designer)**

$$\delta_{per\_abut} = 0.27 \text{ in}$$

$$\theta := 0 \quad \text{Assume no rotation} \quad P_u = 390 \text{ kip} \quad \text{From Structural Engineer}$$

**From L-pile model run output for bending of pile in the Weak Axis**

$$M_{u,top} := 838.15 \text{ in} \cdot \text{kip}$$

$$M_{u,2nd} := 276.05 \text{ kip} \cdot \text{in}$$

$$V_u := 14.35 \text{ kip}$$

**Obtain unbraced Lengths from L-pile (locations where moment = 0)**

$$l_{b,top} := 5.57 \cdot \text{ft} = 67 \text{ in}$$

$$l_{b,2nd} := 19.22 \cdot \text{ft} = 231 \text{ in}$$

**Calculate Slenderness Factor,  $\lambda$**

$$k_{top} := 1.2 \quad \text{Fixed- pinned}$$

$$k_{2nd} := 1.0 \quad \text{Pinned- pinned}$$

$$\lambda_{top} := \left( \frac{k_{top} \cdot l_{b,top}}{r_{y_c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.088$$

$$\lambda_{2nd} := \left( \frac{k_{2nd} \cdot l_{b,2nd}}{r_{y_c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.728$$

**Check Nominal Compressive Resistance**

For  $\lambda \leq 2.25$

$$P_{n,top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s_c} = (1.4 \cdot 10^3) \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r,top} := \phi_{cu} \cdot P_{n,top} = 966.9 \text{ kip}$$

$$P_{n,2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = (1.1 \cdot 10^3) \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r,2nd} := \phi_{cu} \cdot P_{n,2nd} = 741.2 \text{ kip}$$

$$P_{n,bot} := 0.66^0 \cdot f_y \cdot A_{s_c} = (1.4 \cdot 10^3) \text{ kip} \quad \text{Full Braced } \lambda=0$$

$$P_{r,bot} := \phi_{cl} \cdot P_{n,bot} = 716.4 \text{ kip}$$

**Check Ratio of Applied Load to Structural Resistance** Should NOT be Less than 0.2

$$\frac{P_u}{P_{r.top}} = 0.403$$

$$\frac{P_u}{P_{r.2nd}} = 0.526$$

$$\frac{P_u}{P_{r.bot}} = 0.544$$

**Compute Nominal Flexural Resistance**

$$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{f_y}} = 9.152 \quad \text{AASHTO Eq. 6.12.2.2.1-4}$$

$$\lambda_{rf} := 0.83 \cdot \sqrt{\frac{E}{f_y}} = 19.989 \quad \text{AASHTO Eq. 6.12.2.2.1-5}$$

$$\lambda_f = 9.255$$

**Calculate Nominal Flexural Resistance (AASHTO Eq. 6.12.2.2.1-1)**

$$M_{ny} := \begin{cases} \text{if } \lambda_f \leq \lambda_{pf} \\ \quad \left\| f_y \cdot Z_{y.c} \right. \\ \text{if } \lambda_{pf} < \lambda_f \leq \lambda_{rf} \\ \quad \left\| \left( 1 - \left( 1 - \frac{S_{y.c}}{Z_{y.c}} \right) \cdot \left( \frac{\lambda_f - \lambda_{pf}}{.45 \cdot \sqrt{\frac{E}{f_y}}} \right) \right) \cdot f_y \cdot Z_{y.c} \right. \\ \text{if } \lambda_f > \lambda_{rf} \\ \quad \left\| \text{"Pick New Pile Section"} \right. \end{cases} = 3772.2 \text{ kip} \cdot \text{in}$$

$$M_{ry} := \phi_f \cdot M_{ny} = 3772.2 \text{ kip} \cdot \text{in} \quad \text{AASHTO Eq. 6.12.1.2.1-1}$$

**Check Pile Size**

$$PileSizeCheck := \begin{cases} \text{if } \frac{P_u}{P_{r.top}} \geq 0.2 \\ \quad \left\| \text{"Pile Size OK"} \right. \\ \text{if } \frac{P_u}{P_{r.top}} < 0.2 \\ \quad \left\| \text{"Pile Size Too Big"} \right. \end{cases} = \text{"Pile Size OK"}$$

### Find Moment Causing Plastic Hinge

Solving AASHTO Eq. 6.9.2.2-2 for  $M_u$

$$M_{uy} := \frac{9}{8} \cdot \left( 1 - \frac{P_u}{P_{r.top}} \right) M_{ry} = 2532015 \text{ } \mathbf{lb \cdot in} \quad \text{Moment for Load Case 2}$$

$$M_{p'} := M_{uy} = 2532 \text{ } \mathbf{kip \cdot in}$$

Check If Pile is in Plastic Range

$\begin{aligned} &\text{if } M_{u.top} > M_{p'} \\ &\quad \text{"Plastic Hinge Formed/Iterate in L-Pile"} \\ &\text{if } M_{u.top} \leq M_{p'} \\ &\quad \text{"Pile Not in Plastic Range/Continue"} \end{aligned}$	= "Pile Not in Plastic Range/Continue"
---	--

### From L-pile model run output for bending of pile in the Weak Axis with plastic hinge

$$M_{u.top} := 2532 \text{ } \mathbf{in \cdot kip}$$

$$M_{u.2nd} := 424.85 \text{ } \mathbf{kip \cdot in}$$

$$V_u := 31.4 \text{ } \mathbf{kip}$$

### Obtain unbraced Lengths from L-pile

$$l_{b.top} := 8.1 \cdot \mathbf{ft} = 97 \text{ } \mathbf{in}$$

$$l_{b.2nd} := 22.1 \cdot \mathbf{ft} = 265 \text{ } \mathbf{in}$$

### Calculate Slenderness Factor $\lambda$

$$k_{top} := 2.1 \quad \text{Plastic Hinge}$$

$$k_{2nd} := 1.0 \quad \text{Pinned-Pinned}$$

$$\lambda_{top} := \left( \frac{k_{top} \cdot l_{b.top}}{r_{y.c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.57$$

$$\lambda_{2nd} := \left( \frac{k_{2nd} \cdot l_{b.2nd}}{r_{y.c} \cdot \pi} \right)^2 \cdot \frac{f_y}{E} = 0.962$$

Check Nominal Compressive Resistance

For  $\lambda \leq 2.25$

$$P_{n.top} := 0.66^{\lambda_{top}} \cdot f_y \cdot A_{s.c} = 1130.59 \text{ } \mathbf{kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r.top} := \phi_{cu} \cdot P_{n.top} = 791.41 \text{ } \mathbf{kip}$$

$$P_{n.2nd} := 0.66^{\lambda_{2nd}} \cdot f_y \cdot A_{s_c} = 960.57 \text{ kip} \quad \text{AASHTO 6.9.5.1-1}$$

$$P_{r.2nd} := \phi_{cu} \cdot P_{n.2nd} = 672.398 \text{ kip}$$

$$P_{n.bot} := 0.66^0 \cdot f_y \cdot A_{s_c} = 1432.76 \text{ kip} \quad \text{Full Braced } \lambda = 0$$

$$P_{r.bot} := \phi_{cl} \cdot P_{n.bot} = 716.38 \text{ kip}$$

**Check Ratio of Applied Load to Structural Resistance** Should NOT be Less than 0.2

$$\frac{P_u}{P_{r.top}} = 0.493$$

$$\frac{P_u}{P_{r.2nd}} = 0.58$$

$$\frac{P_u}{P_{r.bot}} = 0.544$$

Check Pile Size

$PileSizeCheck :=$	if $\frac{P_u}{P_{r.top}} \geq 0.2$	= "Pile Size OK"
	"Pile Size OK"	
	if $\frac{P_u}{P_{r.top}} < 0.2$	
	"Pile Size Too Big"	

**Check Second Segment of Pile for Combined Stress**

$$\frac{P_u}{2 P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}} = 0.403$$

$$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}} = 0.68$$

AASHTO 6.9.2.2-1 and 6.9.2.2-2

$Check3 :=$	if $\frac{P_u}{P_{r.2nd}} < 0.2$	= 0.68
	$\frac{P_u}{2 P_{r.2nd}} + \frac{M_{u.2nd}}{M_{ry}}$	
	if $\frac{P_u}{P_{r.2nd}} \geq 0.2$	
	$\frac{P_u}{P_{r.2nd}} + \frac{8}{9} \cdot \frac{M_{u.2nd}}{M_{ry}}$	

if $Check3 < 1$	= "OK"
"OK"	
if $Check3 \geq 1$	
"Pile Undersized"	

Check Bottom Segment of Pile

$$Check4 := \frac{P_u}{P_{r.bot}} = 0.544$$

if $Check4 < 1$	= "OK"
"OK"	
if $Check4 \geq 1$	
"Pile Undersized"	

**Check Shear**

AASHTO does not address weak axis shear - Use AISC Steel Manual

$$K_v := 1.2$$

$$C_v := 1$$

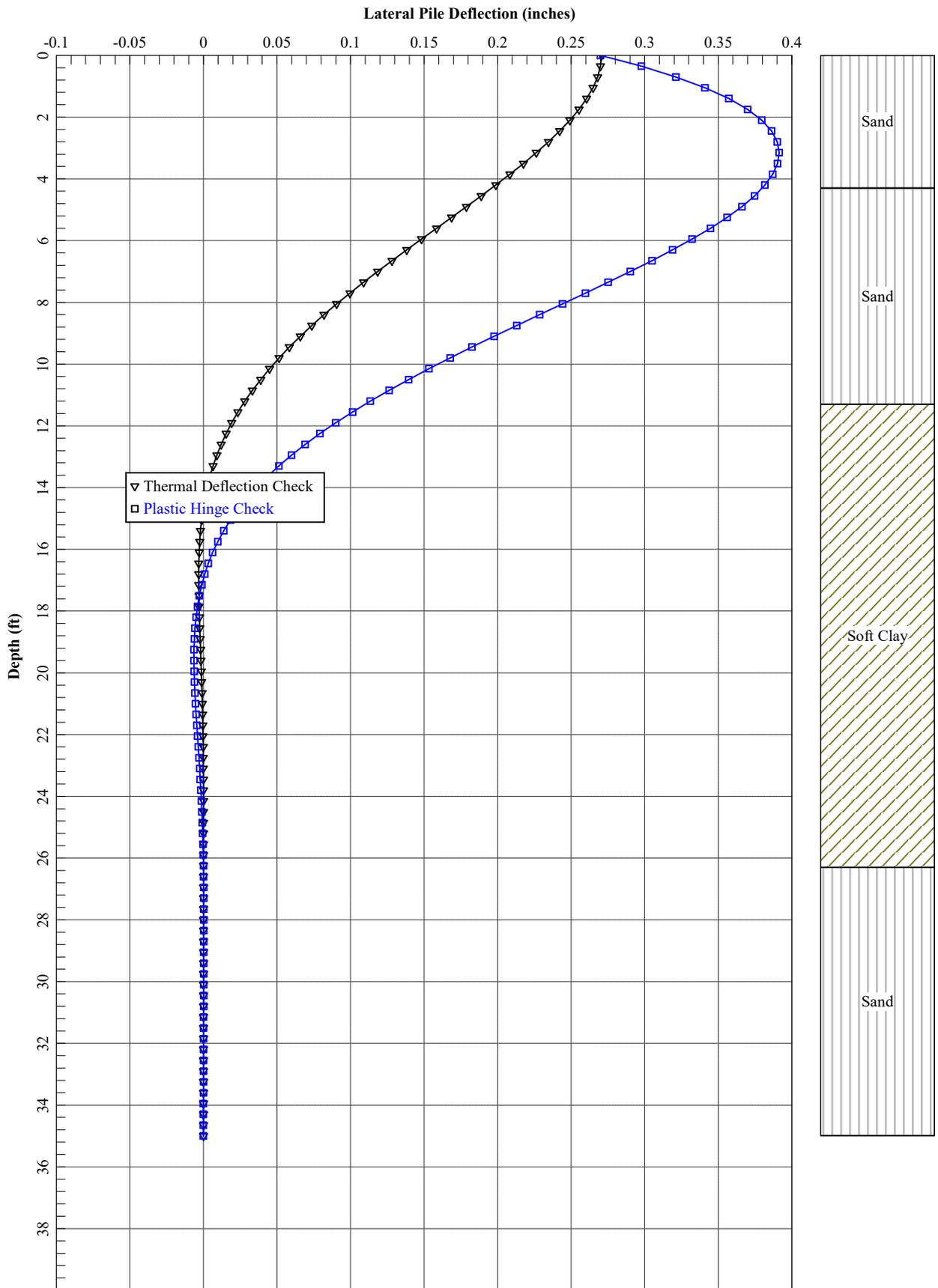
$$A_w := 2 b_{f.c} \cdot t_{f.c} = 20.094 \text{ in}^2$$

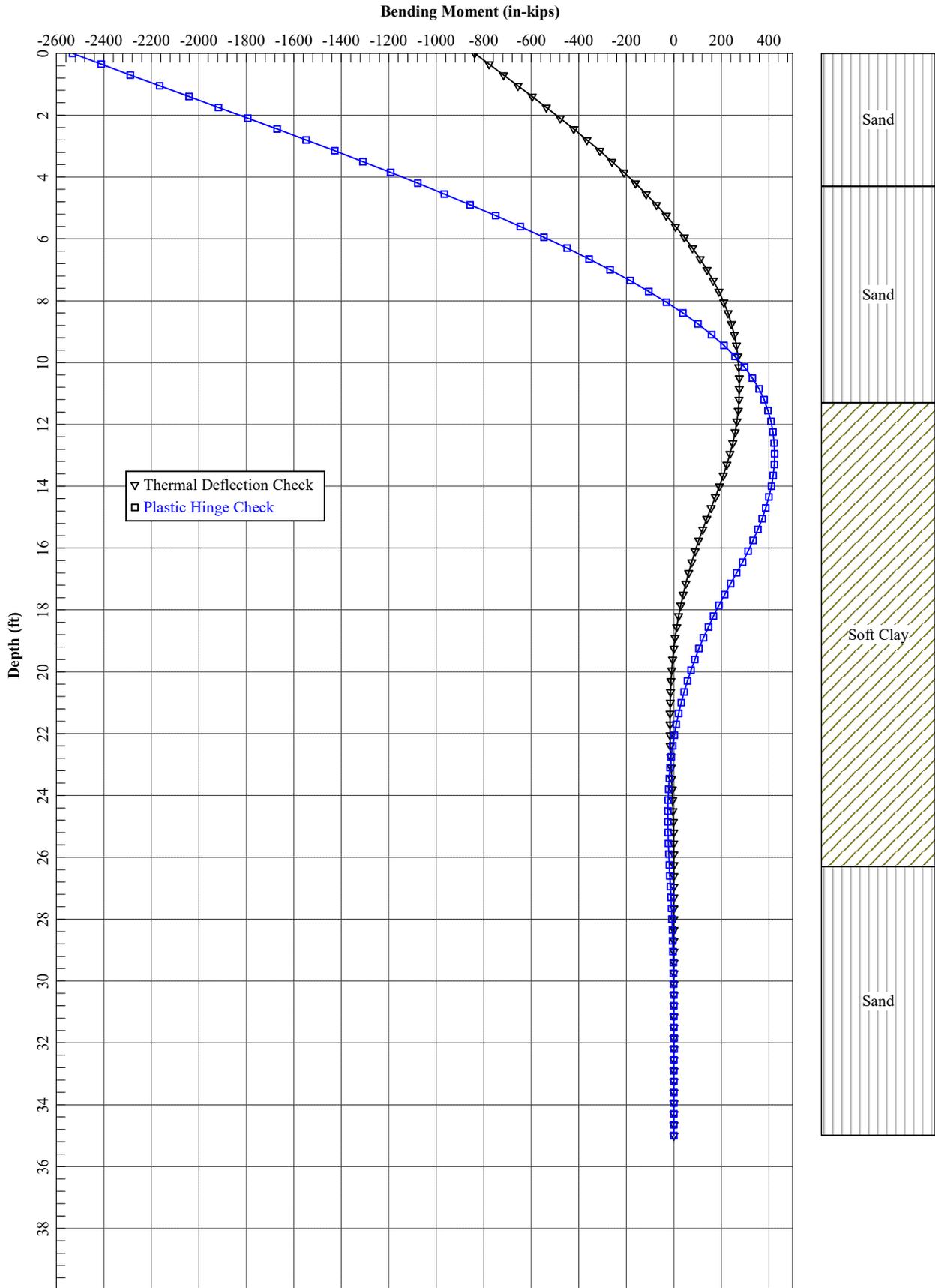
$$V_n := 0.6 f_y \cdot A_w \cdot C_v = 602.82 \text{ kip}$$

$$V_r := \phi_v \cdot V_n = 602.8 \text{ kip}$$

$$Check5 := \frac{V_u}{V_r} = 0.052$$

if $Check5 < 1$	= "OK"
"OK"	
if $Check5 \geq 1$	
"Pile Undersized"	





=====  
LPile for Windows, Version 2016-09.010

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:

\Users\mst.pierre\OneDrive - SW Cole Engineering\Desktop\LPile Output Files\20-1403-026184 Sabattus\

Name of input data file:

Abutment 2 HP14x117 r1.lp9d

Name of output report file:

Abutment 2 HP14x117 r1.lp9o

Name of plot output file:

Abutment 2 HP14x117 r1.lp9p

Name of runtime message file:  
Abutment 2 HP14x117 r1.lp9r

-----  
Date and Time of Analysis  
-----

Date: June 16, 2025

Time: 17:20:39

-----  
Problem Title  
-----

Sabattus River Bridge #5393 Replacement

WIN 026184

MaineDOT

S. W. Cole Engineering, Inc.

Abutment No. 2 - HP14x117

-----  
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  
-----

Number of pile sections defined = 1

Total length of pile = 35.000 ft  
 Depth of ground surface below top of pile = 0.0000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	14.0750
2	35.000	14.0750

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile  
 Cross-sectional Shape = Weak H-Pile Corroded Pile Properties  
 Length of section = 35.000000 ft  
 Flange Width = 14.775000 in  
 Section Depth = 14.075000 in  
 Flange Thickness = 0.680000 in  
 Web Thickness = 0.680000 in  
 Section Area = 28.740200 sq. in  
 Moment of Inertia = 365.877563 in^4  
 Elastic Modulus = 29000000. psi

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 4 layers

Layer 1 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 0.0000 ft  
Distance from top of pile to bottom of layer = 4.300000 ft  
Effective unit weight at top of layer = 62.600000 pcf  
Effective unit weight at bottom of layer = 62.600000 pcf  
Friction angle at top of layer = 30.000000 deg.  
Friction angle at bottom of layer = 30.000000 deg.  
Subgrade k at top of layer = 90.000000 pci  
Subgrade k at bottom of layer = 90.000000 pci

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

Distance from top of pile to top of layer = 4.300000 ft  
Distance from top of pile to bottom of layer = 11.300000 ft  
Effective unit weight at top of layer = 47.600000 pcf  
Effective unit weight at bottom of layer = 47.600000 pcf  
Friction angle at top of layer = 28.000000 deg.  
Friction angle at bottom of layer = 28.000000 deg.  
Subgrade k at top of layer = 20.000000 pci  
Subgrade k at bottom of layer = 20.000000 pci

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

Distance from top of pile to top of layer = 11.300000 ft  
 Distance from top of pile to bottom of layer = 26.300000 ft  
 Effective unit weight at top of layer = 47.600000 pcf  
 Effective unit weight at bottom of layer = 47.600000 pcf  
 Undrained cohesion at top of layer = 700.000000 psf  
 Undrained cohesion at bottom of layer = 700.000000 psf  
 Epsilon-50 at top of layer = 0.010000  
 Epsilon-50 at bottom of layer = 0.010000

Layer 4 is sand, p-y criteria by Reese et al., 1974

Distance from top of pile to top of layer = 26.300000 ft  
 Distance from top of pile to bottom of layer = 35.000000 ft  
 Effective unit weight at top of layer = 67.600000 pcf  
 Effective unit weight at bottom of layer = 67.600000 pcf  
 Friction angle at top of layer = 32.000000 deg.  
 Friction angle at bottom of layer = 32.000000 deg.  
 Subgrade k at top of layer = 125.000000 pci  
 Subgrade k at bottom of layer = 125.000000 pci

(Depth of the lowest soil layer extends 0.000 ft below the 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	Sand (Reese, et al.)	0.00 4.3000	62.6000 62.6000	-- --	30.0000 30.0000	-- --	90.0000 90.0000
2	Sand (Reese, et al.)	4.3000 11.3000	47.6000 47.6000	-- --	28.0000 28.0000	-- --	20.0000 20.0000
3	Soft	11.3000	47.6000	700.0000	--	0.01000	--

	Clay	26.3000	47.6000	700.0000	--	0.01000	--
4	Sand	26.3000	67.6000	--	32.0000	--	125.0000
	(Reese, et al.)	35.0000	67.6000	--	32.0000	--	125.0000

-----  
 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 = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
-----	-----	-----	-----	-----	-----
1	5	y = 0.270000 in	S = 0.0000 in/in	390000.	N.A.
2	4	y = 0.270000 in	M = -2532015. in-lbs	390000.	N.A.

V = shear force applied normal to pile axis

M = bending moment applied to pile head

y = lateral deflection normal to pile axis

S = pile slope relative to original pile batter angle

R = rotational stiffness applied to pile head

Values of top y vs. pile lengths can be computed only for load types with specified shear loading (Load Types 1, 2, and 3).

Thrust force is assumed to be acting axially for all pile batter angles.

-----  
 Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness  
 -----

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

-----  
Moment-curvature properties were derived from elastic section properties

-----  
Layering Correction Equivalent Depths of Soil & Rock Layers  
-----

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	0.00	0.00	N.A.	No	0.00	6180.
2	4.3000	4.3000	Yes	No	6180.	42992.
3	11.3000	10.5834	No	No	49171.	110513.
4	26.3000	26.3000	No	No	159684.	N.A.

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

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

Pile-head conditions are Displacement and Pile-head Rotation (Loading Type 5)  
 Displacement of pile head = 0.270000 inches  
 Rotation of pile head = 0.000E+00 radians  
 Axial load on pile head = 390000.0 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	0.2707	-838149.	14350.	0.00	29691.	1.06E+10	0.00	0.00	0.00
0.3500	0.2700	-777753.	14286.	-3.20E-04	28530.	1.06E+10	-14.1107	219.4991	0.00
0.7000	0.2680	-717102.	14193.	-6.16E-04	27363.	1.06E+10	-30.1080	471.8244	0.00
1.0500	0.2648	-656516.	14031.	-8.88E-04	26198.	1.06E+10	-46.7280	741.0753	0.00
1.4000	0.2606	-596330.	13801.	-0.00114	25040.	1.06E+10	-62.8722	1013.	0.00
1.7500	0.2553	-536865.	13507.	-0.00136	23896.	1.06E+10	-77.3565	1273.	0.00
2.1000	0.2491	-478417.	13153.	-0.00156	22772.	1.06E+10	-91.1395	1536.	0.00
2.4500	0.2422	-421267.	12746.	-0.00174	21673.	1.06E+10	-102.5440	1778.	0.00
2.8000	0.2345	-365652.	12296.	-0.00189	20603.	1.06E+10	-111.8303	2003.	0.00
3.1500	0.2263	-311773.	11811.	-0.00203	19567.	1.06E+10	-119.3660	2216.	0.00
3.5000	0.2175	-259798.	11299.	-0.00214	18567.	1.06E+10	-124.3945	2402.	0.00
3.8500	0.2083	-209848.	10760.	-0.00223	17606.	1.06E+10	-131.8972	2660.	0.00
4.2000	0.1987	-162089.	10196.	-0.00231	16688.	1.06E+10	-136.7203	2890.	0.00
4.5500	0.1889	-116636.	9665.	-0.00236	15813.	1.06E+10	-116.3258	2587.	0.00
4.9000	0.1789	-73160.	9171.	-0.00240	14977.	1.06E+10	-119.0267	2795.	0.00
5.2500	0.1687	-31737.	8658.	-0.00242	14180.	1.06E+10	-125.1964	3117.	0.00
5.6000	0.1585	7499.	8121.	-0.00243	13714.	1.06E+10	-130.3951	3455.	0.00
5.9500	0.1483	44430.	7563.	-0.00242	14424.	1.06E+10	-135.3259	3832.	0.00
6.3000	0.1382	78945.	6981.	-0.00239	15088.	1.06E+10	-142.0129	4315.	0.00
6.6500	0.1282	110904.	6372.	-0.00235	15703.	1.06E+10	-148.0475	4849.	0.00
7.0000	0.1184	140179.	5739.	-0.00230	16266.	1.06E+10	-153.3552	5438.	0.00
7.3500	0.1089	166659.	5085.	-0.00224	16775.	1.06E+10	-157.8680	6090.	0.00
7.7000	0.09960	190245.	4414.	-0.00217	17229.	1.06E+10	-161.5240	6811.	0.00
8.0500	0.09063	210859.	3730.	-0.00209	17626.	1.06E+10	-164.2685	7613.	0.00
8.4000	0.08201	228438.	3038.	-0.00201	17964.	1.06E+10	-165.3301	8467.	0.00
8.7500	0.07377	242953.	2365.	-0.00191	18243.	1.06E+10	-154.9166	8820.	0.00
9.1000	0.06593	254577.	1738.	-0.00182	18467.	1.06E+10	-144.0010	9173.	0.00
9.4500	0.05852	263496.	1157.	-0.00171	18638.	1.06E+10	-132.7291	9526.	0.00
9.8000	0.05155	269903.	623.2976	-0.00161	18761.	1.06E+10	-121.2422	9878.	0.00

10.1500	0.04502	273997.	138.3677	-0.00150	18840.	1.06E+10	-109.6768	10231.	0.00
10.5000	0.03895	275978.	-298.0959	-0.00139	18878.	1.06E+10	-98.1630	10584.	0.00
10.8500	0.03334	276048.	-686.5694	-0.00128	18880.	1.06E+10	-86.8243	10937.	0.00
11.2000	0.02819	274408.	-1028.	-0.00117	18848.	1.06E+10	-75.7766	11290.	0.00
11.5500	0.02349	271253.	-1435.	-0.00106	18787.	1.06E+10	-117.8921	21075.	0.00
11.9000	0.01925	265843.	-1919.	-9.58E-04	18683.	1.06E+10	-112.5576	24558.	0.00
12.2500	0.01545	258275.	-2383.	-8.54E-04	18538.	1.06E+10	-108.5873	29524.	0.00
12.6000	0.01207	248624.	-2821.	-7.54E-04	18352.	1.06E+10	-100.0170	34792.	0.00
12.9500	0.00911	237047.	-3222.	-6.58E-04	18129.	1.06E+10	-91.0549	41962.	0.00
13.3000	0.00655	223711.	-3585.	-5.67E-04	17873.	1.06E+10	-81.5355	52300.	0.00
13.6500	0.00435	208791.	-3905.	-4.81E-04	17586.	1.06E+10	-71.1390	68629.	0.00
14.0000	0.00251	192481.	-4179.	-4.02E-04	17272.	1.06E+10	-59.1340	99082.	0.00
14.3500	9.80E-04	175003.	-4394.	-3.29E-04	16936.	1.06E+10	-43.1064	184803.	0.00
14.7000	-2.56E-04	156651.	-4425.	-2.63E-04	16583.	1.06E+10	28.2402	462671.	0.00
15.0500	-0.00123	138696.	-4267.	-2.05E-04	16238.	1.06E+10	46.9403	160030.	0.00
15.4000	-0.00198	121479.	-4053.	-1.53E-04	15906.	1.06E+10	54.8748	116580.	0.00
15.7500	-0.00252	105151.	-3813.	-1.08E-04	15592.	1.06E+10	59.4675	99112.	0.00
16.1000	-0.00289	89804.	-3558.	-6.99E-05	15297.	1.06E+10	62.2183	90476.	0.00
16.4500	-0.00311	75496.	-3293.	-3.72E-05	15022.	1.06E+10	63.7448	86164.	0.00
16.8000	-0.00320	62264.	-3024.	-9.92E-06	14767.	1.06E+10	64.3743	84475.	0.00
17.1500	-0.00319	50126.	-2754.	1.23E-05	14534.	1.06E+10	64.3064	84653.	0.00
17.5000	-0.00310	39091.	-2485.	3.00E-05	14322.	1.06E+10	63.6747	86349.	0.00
17.8500	-0.00294	29154.	-2220.	4.35E-05	14131.	1.06E+10	62.5741	89431.	0.00
18.2000	-0.00273	20301.	-1960.	5.33E-05	13960.	1.06E+10	61.0757	93900.	0.00
18.5500	-0.00249	12513.	-1708.	5.98E-05	13811.	1.06E+10	59.2346	99866.	0.00
18.9000	-0.00223	5762.	-1463.	6.34E-05	13681.	1.06E+10	57.0948	107545.	0.00
19.2500	-0.00196	13.6917	-1229.	6.45E-05	13570.	1.06E+10	54.6923	117274.	0.00
19.6000	-0.00169	-4770.	-1004.	6.36E-05	13662.	1.06E+10	52.0569	129549.	0.00
19.9500	-0.00142	-8631.	-791.7206	6.09E-05	13736.	1.06E+10	49.2136	145093.	0.00
20.3000	-0.00118	-11620.	-591.3873	5.69E-05	13793.	1.06E+10	46.1832	164965.	0.00
20.6500	-9.46E-04	-13786.	-404.1392	5.19E-05	13835.	1.06E+10	42.9825	190755.	0.00
21.0000	-7.40E-04	-15184.	-230.6649	4.62E-05	13862.	1.06E+10	39.6243	224938.	0.00
21.3500	-5.59E-04	-15874.	-71.6113	4.00E-05	13875.	1.06E+10	36.1155	271555.	0.00
21.7000	-4.04E-04	-15917.	72.3870	3.37E-05	13876.	1.06E+10	32.4551	337660.	0.00
22.0500	-2.75E-04	-15377.	200.6576	2.75E-05	13866.	1.06E+10	28.6262	436773.	0.00
22.4000	-1.72E-04	-14322.	312.3899	2.17E-05	13845.	1.06E+10	24.5796	598777.	0.00
22.7500	-9.34E-05	-12824.	406.3875	1.63E-05	13817.	1.06E+10	20.1811	907902.	0.00
23.1000	-3.56E-05	-10961.	480.2560	1.16E-05	13781.	1.06E+10	14.9943	1767567.	0.00
23.4500	3.88E-06	-8828.	500.6085	7.66E-06	13740.	1.06E+10	-5.3027	5743136.	0.00

23.8000	2.87E-05	-6781.	462.3076	4.57E-06	13700.	1.06E+10	-12.9358	1892482.	0.00
24.1500	4.23E-05	-4959.	403.7464	2.25E-06	13665.	1.06E+10	-14.9505	1485673.	0.00
24.5000	4.76E-05	-3397.	339.4804	5.92E-07	13635.	1.06E+10	-15.6523	1381760.	0.00
24.8500	4.72E-05	-2109.	273.6847	-4.98E-07	13610.	1.06E+10	-15.6790	1393966.	0.00
25.2000	4.34E-05	-1097.	208.6428	-1.13E-06	13591.	1.06E+10	-15.2933	1480092.	0.00
25.5500	3.77E-05	-353.1373	145.7709	-1.42E-06	13577.	1.06E+10	-14.6457	1630287.	0.00
25.9000	3.15E-05	132.3645	85.9531	-1.46E-06	13572.	1.06E+10	-13.8390	1846550.	0.00
26.2500	2.54E-05	373.6608	29.6996	-1.36E-06	13577.	1.06E+10	-12.9484	2137436.	0.00
26.6000	2.00E-05	386.3049	0.8295	-1.21E-06	13577.	1.06E+10	-0.7992	167580.	0.00
26.9500	1.53E-05	384.6002	-2.1443	-1.06E-06	13577.	1.06E+10	-0.6169	169785.	0.00
27.3000	1.11E-05	371.7639	-4.3969	-9.10E-07	13577.	1.06E+10	-0.4558	171990.	0.00
27.6500	7.62E-06	350.6469	-6.0175	-7.67E-07	13577.	1.06E+10	-0.3159	174195.	0.00
28.0000	4.69E-06	323.7299	-7.0943	-6.34E-07	13576.	1.06E+10	-0.1969	176400.	0.00
28.3500	2.30E-06	293.1304	-7.7127	-5.11E-07	13575.	1.06E+10	-0.09762	178605.	0.00
28.7000	3.91E-07	260.6188	-7.9530	-4.02E-07	13575.	1.06E+10	-0.01684	180810.	0.00
29.0500	-1.08E-06	227.6412	-7.8896	-3.05E-07	13574.	1.06E+10	0.04705	183015.	0.00
29.4000	-2.17E-06	195.3459	-7.5896	-2.21E-07	13574.	1.06E+10	0.09580	185220.	0.00
29.7500	-2.94E-06	164.6139	-7.1129	-1.50E-07	13573.	1.06E+10	0.1312	187425.	0.00
30.1000	-3.43E-06	136.0895	-6.5118	-9.07E-08	13572.	1.06E+10	0.1551	189630.	0.00
30.4500	-3.70E-06	110.2119	-5.8311	-4.20E-08	13572.	1.06E+10	0.1691	191835.	0.00
30.8000	-3.79E-06	87.2457	-5.1086	-2.88E-09	13572.	1.06E+10	0.1749	194040.	0.00
31.1500	-3.73E-06	67.3088	-4.3756	2.77E-08	13571.	1.06E+10	0.1741	196245.	0.00
31.5000	-3.55E-06	50.3996	-3.6574	5.10E-08	13571.	1.06E+10	0.1679	198450.	0.00
31.8500	-3.30E-06	36.4198	-2.9739	6.82E-08	13571.	1.06E+10	0.1576	200655.	0.00
32.2000	-2.98E-06	25.1956	-2.3407	8.04E-08	13570.	1.06E+10	0.1440	202860.	0.00
32.5500	-2.62E-06	16.4950	-1.7694	8.86E-08	13570.	1.06E+10	0.1280	205065.	0.00
32.9000	-2.24E-06	10.0424	-1.2687	9.39E-08	13570.	1.06E+10	0.1104	207270.	0.00
33.2500	-1.83E-06	5.5302	-0.8448	9.70E-08	13570.	1.06E+10	0.09146	209475.	0.00
33.6000	-1.42E-06	2.6280	-0.5023	9.86E-08	13570.	1.06E+10	0.07167	211680.	0.00
33.9500	-1.01E-06	0.9883	-0.2442	9.93E-08	13570.	1.06E+10	0.05122	213885.	0.00
34.3000	-5.88E-07	0.2514	-0.07312	9.95E-08	13570.	1.06E+10	0.03025	216090.	0.00
34.6500	-1.70E-07	0.04797	0.00892	9.96E-08	13570.	1.06E+10	0.00882	218295.	0.00
35.0000	2.49E-07	0.00	0.00	9.96E-08	13570.	1.06E+10	-0.01306	110250.	0.00

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

Output Summary for Load Case No. 1:

Pile-head deflection = 0.27069672 inches  
 Computed slope at pile head = 0.000000 radians  
 Maximum bending moment = -838149. inch-lbs  
 Maximum shear force = 14350. lbs  
 Depth of maximum bending moment = 0.000000 feet below pile head  
 Depth of maximum shear force = 0.000000 feet below pile head  
 Number of iterations = 14  
 Number of zero deflection points = 4

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 Computed Values of Pile Loading and Deflection  
 for Lateral Loading for Load Case Number 2  
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Pile-head conditions are Displacement and Moment (Loading Type 4)

Displacement of pile head = 0.270000 inches  
 Moment at pile head = -2532015.0 in-lbs  
 Axial load at pile head = 390000.0 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	0.2700	-2532015.	31423.	0.00707	62272.	1.06E+10	0.00	0.00	0.00
0.3500	0.2976	-2410803.	31393.	0.00610	59941.	1.06E+10	-14.5454	205.2753	0.00
0.7000	0.3212	-2288285.	31295.	0.00517	57584.	1.06E+10	-31.9851	418.2376	0.00
1.0500	0.3410	-2164847.	31121.	0.00428	55210.	1.06E+10	-51.0148	628.3549	0.00
1.4000	0.3572	-2040906.	30866.	0.00345	52826.	1.06E+10	-70.4018	827.8364	0.00
1.7500	0.3700	-1916883.	30531.	0.00267	50440.	1.06E+10	-88.7122	1007.	0.00
2.1000	0.3796	-1793182.	30120.	0.00193	48061.	1.06E+10	-106.9844	1184.	0.00
2.4500	0.3862	-1670205.	29637.	0.00125	45696.	1.06E+10	-123.1104	1339.	0.00
2.8000	0.3901	-1548318.	29091.	6.11E-04	43351.	1.06E+10	-137.0335	1475.	0.00
3.1500	0.3914	-1427843.	28488.	2.22E-05	41034.	1.06E+10	-150.0765	1611.	0.00
3.5000	0.3903	-1309091.	27834.	-5.20E-04	38750.	1.06E+10	-161.5187	1738.	0.00
3.8500	0.3870	-1192338.	27121.	-0.00101	36504.	1.06E+10	-177.7845	1929.	0.00
4.2000	0.3817	-1077949.	26344.	-0.00146	34304.	1.06E+10	-192.3649	2116.	0.00
4.5500	0.3747	-966254.	25578.	-0.00187	32155.	1.06E+10	-172.1309	1929.	0.00

4.9000	0.3660	-856969.	24833.	-0.00223	30053.	1.06E+10	-182.9033	2099.	0.00
5.2500	0.3560	-750355.	24034.	-0.00255	28003.	1.06E+10	-197.2526	2327.	0.00
5.6000	0.3446	-646734.	23178.	-0.00282	26009.	1.06E+10	-210.8161	2569.	0.00
5.9500	0.3322	-546412.	22264.	-0.00306	24080.	1.06E+10	-224.0821	2833.	0.00
6.3000	0.3189	-449689.	21292.	-0.00326	22219.	1.06E+10	-238.7135	3144.	0.00
6.6500	0.3049	-356885.	20260.	-0.00342	20434.	1.06E+10	-252.6739	3481.	0.00
7.0000	0.2902	-268307.	19172.	-0.00354	18731.	1.06E+10	-265.8675	3847.	0.00
7.3500	0.2751	-184245.	18029.	-0.00363	17114.	1.06E+10	-278.2161	4247.	0.00
7.7000	0.2597	-104971.	16836.	-0.00369	15589.	1.06E+10	-289.6596	4684.	0.00
8.0500	0.2442	-30739.	15598.	-0.00371	14161.	1.06E+10	-300.1570	5163.	0.00
8.4000	0.2285	38219.	14317.	-0.00371	14305.	1.06E+10	-309.6611	5691.	0.00
8.7500	0.2130	101689.	12999.	-0.00369	15526.	1.06E+10	-317.8884	6269.	0.00
9.1000	0.1976	159486.	11650.	-0.00363	16637.	1.06E+10	-324.6927	6902.	0.00
9.4500	0.1825	211452.	10275.	-0.00356	17637.	1.06E+10	-329.9965	7596.	0.00
9.8000	0.1677	257459.	8881.	-0.00347	18522.	1.06E+10	-333.7335	8359.	0.00
10.1500	0.1533	297413.	7475.	-0.00336	19290.	1.06E+10	-335.8493	9199.	0.00
10.5000	0.1395	331249.	6064.	-0.00323	19941.	1.06E+10	-336.3006	10127.	0.00
10.8500	0.1262	358939.	4667.	-0.00310	20474.	1.06E+10	-328.5671	10937.	0.00
11.2000	0.1135	380599.	3337.	-0.00295	20891.	1.06E+10	-305.0108	11290.	0.00
11.5500	0.1014	396633.	2293.	-0.00280	21199.	1.06E+10	-191.9807	7952.	0.00
11.9000	0.08998	409022.	1495.	-0.00264	21437.	1.06E+10	-188.2463	8786.	0.00
12.2500	0.07925	417826.	705.9809	-0.00247	21607.	1.06E+10	-187.3397	9929.	0.00
12.6000	0.06921	423055.	-63.4801	-0.00231	21707.	1.06E+10	-179.0703	10867.	0.00
12.9500	0.05987	424850.	-797.8456	-0.00214	21742.	1.06E+10	-170.6276	11969.	0.00
13.3000	0.05124	423360.	-1496.	-0.00197	21713.	1.06E+10	-162.0023	13278.	0.00
13.6500	0.04332	418737.	-2158.	-0.00180	21624.	1.06E+10	-153.1792	14852.	0.00
14.0000	0.03609	411141.	-2783.	-0.00164	21478.	1.06E+10	-144.1349	16776.	0.00
14.3500	0.02954	400736.	-3368.	-0.00148	21278.	1.06E+10	-134.8333	19171.	0.00
14.7000	0.02366	387693.	-3915.	-0.00132	21027.	1.06E+10	-125.2192	22229.	0.00
15.0500	0.01842	372189.	-4419.	-0.00117	20729.	1.06E+10	-115.2048	26264.	0.00
15.4000	0.01381	354412.	-4881.	-0.00103	20387.	1.06E+10	-104.6452	31834.	0.00
15.7500	0.00978	334559.	-5297.	-8.93E-04	20005.	1.06E+10	-93.2824	40066.	0.00
16.1000	0.00631	312844.	-5662.	-7.65E-04	19587.	1.06E+10	-80.6003	53676.	0.00
16.4500	0.00336	289504.	-5968.	-6.45E-04	19138.	1.06E+10	-65.3163	81760.	0.00
16.8000	8.85E-04	264824.	-6194.	-5.36E-04	18664.	1.06E+10	-41.9095	198871.	0.00
17.1500	-0.00114	239234.	-6186.	-4.36E-04	18171.	1.06E+10	45.6162	167350.	0.00
17.5000	-0.00278	214292.	-5961.	-3.46E-04	17692.	1.06E+10	61.3103	92726.	0.00
17.8500	-0.00405	190294.	-5686.	-2.66E-04	17230.	1.06E+10	69.5520	72075.	0.00
18.2000	-0.00501	167399.	-5384.	-1.95E-04	16790.	1.06E+10	74.6627	62560.	0.00

18.5500	-0.00569	145712.	-5063.	-1.33E-04	16373.	1.06E+10	77.9079	57468.	0.00
18.9000	-0.00613	125305.	-4732.	-7.97E-05	15980.	1.06E+10	79.8664	54696.	0.00
19.2500	-0.00636	106226.	-4394.	-3.39E-05	15613.	1.06E+10	80.8614	53369.	0.00
19.6000	-0.00642	88504.	-4054.	4.64E-06	15272.	1.06E+10	81.0963	53073.	0.00
19.9500	-0.00632	72156.	-3714.	3.64E-05	14958.	1.06E+10	80.7095	53597.	0.00
20.3000	-0.00611	57184.	-3377.	6.20E-05	14670.	1.06E+10	79.8007	54840.	0.00
20.6500	-0.00580	43583.	-3045.	8.20E-05	14408.	1.06E+10	78.4451	56770.	0.00
21.0000	-0.00542	31337.	-2719.	9.68E-05	14173.	1.06E+10	76.7008	59403.	0.00
21.3500	-0.00499	20425.	-2401.	1.07E-04	13963.	1.06E+10	74.6144	62797.	0.00
21.7000	-0.00452	10815.	-2093.	1.13E-04	13778.	1.06E+10	72.2233	67054.	0.00
22.0500	-0.00404	2472.	-1795.	1.16E-04	13617.	1.06E+10	69.5584	72327.	0.00
22.4000	-0.00355	-4645.	-1509.	1.15E-04	13659.	1.06E+10	66.6446	78834.	0.00
22.7500	-0.00307	-10584.	-1236.	1.12E-04	13773.	1.06E+10	63.5019	86886.	0.00
23.1000	-0.00261	-15396.	-976.3316	1.07E-04	13866.	1.06E+10	60.1456	96924.	0.00
23.4500	-0.00217	-19137.	-731.1964	1.00E-04	13938.	1.06E+10	56.5854	109595.	0.00
23.8000	-0.00176	-21867.	-501.4357	9.23E-05	13990.	1.06E+10	52.8245	125874.	0.00
24.1500	-0.00139	-23651.	-287.9056	8.33E-05	14025.	1.06E+10	48.8565	147307.	0.00
24.5000	-0.00106	-24559.	-91.5197	7.38E-05	14042.	1.06E+10	44.6605	176502.	0.00
24.8500	-7.73E-04	-24662.	86.6637	6.40E-05	14044.	1.06E+10	40.1887	218276.	0.00
25.2000	-5.25E-04	-24040.	245.2720	5.44E-05	14032.	1.06E+10	35.3391	282786.	0.00
25.5500	-3.16E-04	-22780.	382.2250	4.51E-05	14008.	1.06E+10	29.8767	396596.	0.00
25.9000	-1.46E-04	-20977.	493.5077	3.65E-05	13973.	1.06E+10	23.1150	665855.	0.00
26.2500	-1.01E-05	-18754.	562.6871	2.86E-05	13931.	1.06E+10	9.8276	4093865.	0.00
26.6000	9.45E-05	-16345.	575.4103	2.17E-05	13884.	1.06E+10	-3.7689	167580.	0.00
26.9500	1.72E-04	-13991.	552.9087	1.57E-05	13839.	1.06E+10	-6.9461	169785.	0.00
27.3000	2.26E-04	-11751.	518.8925	1.06E-05	13796.	1.06E+10	-9.2520	171990.	0.00
27.6500	2.61E-04	-9667.	476.7738	6.32E-06	13756.	1.06E+10	-10.8045	174195.	0.00
28.0000	2.79E-04	-7767.	429.4761	2.87E-06	13719.	1.06E+10	-11.7182	176400.	0.00
28.3500	2.85E-04	-6069.	379.4532	1.29E-07	13687.	1.06E+10	-12.1022	178605.	0.00
28.7000	2.80E-04	-4580.	328.7173	-1.98E-06	13658.	1.06E+10	-12.0577	180810.	0.00
29.0500	2.68E-04	-3301.	278.8749	-3.54E-06	13633.	1.06E+10	-11.6767	183015.	0.00
29.4000	2.50E-04	-2226.	231.1678	-4.63E-06	13613.	1.06E+10	-11.0409	185220.	0.00
29.7500	2.29E-04	-1344.	186.5166	-5.34E-06	13596.	1.06E+10	-10.2215	187425.	0.00
30.1000	2.06E-04	-641.8746	145.5659	-5.73E-06	13582.	1.06E+10	-9.2788	189630.	0.00
30.4500	1.81E-04	-102.7394	108.7288	-5.88E-06	13572.	1.06E+10	-8.2627	191835.	0.00
30.8000	1.56E-04	290.7092	76.2304	-5.84E-06	13575.	1.06E+10	-7.2128	194040.	0.00
31.1500	1.32E-04	556.7361	48.1487	-5.67E-06	13581.	1.06E+10	-6.1594	196245.	0.00
31.5000	1.08E-04	713.7495	24.4528	-5.42E-06	13584.	1.06E+10	-5.1243	198450.	0.00
31.8500	8.63E-05	779.9072	5.0369	-5.13E-06	13585.	1.06E+10	-4.1214	200655.	0.00

32.2000	6.54E-05	772.8582	-10.2492	-4.82E-06	13585.	1.06E+10	-3.1577	202860.	0.00
32.5500	4.58E-05	709.6056	-21.5738	-4.53E-06	13583.	1.06E+10	-2.2349	205065.	0.00
32.9000	2.74E-05	606.4690	-29.1015	-4.27E-06	13582.	1.06E+10	-1.3497	207270.	0.00
33.2500	9.93E-06	479.1301	-32.9765	-4.05E-06	13579.	1.06E+10	-0.4955	209475.	0.00
33.6000	-6.68E-06	342.7403	-33.3094	-3.89E-06	13576.	1.06E+10	0.3369	211680.	0.00
33.9500	-2.27E-05	212.0715	-30.1707	-3.78E-06	13574.	1.06E+10	1.1577	213885.	0.00
34.3000	-3.84E-05	101.6875	-23.5872	-3.72E-06	13572.	1.06E+10	1.9773	216090.	0.00
34.6500	-5.40E-05	26.1166	-13.5455	-3.69E-06	13570.	1.06E+10	2.8045	218295.	0.00
35.0000	-6.94E-05	0.00	0.00	-3.69E-06	13570.	1.06E+10	3.6457	110250.	0.00

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

#### Output Summary for Load Case No. 2:

Pile-head deflection = 0.27000000 inches  
 Computed slope at pile head = 0.00707332 radians  
 Maximum bending moment = -2532015. inch-lbs  
 Maximum shear force = 31423. lbs  
 Depth of maximum bending moment = 0.000000 feet below pile head  
 Depth of maximum shear force = 0.000000 feet below pile head  
 Number of iterations = 14  
 Number of zero deflection points = 3

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#### Summary of Pile-head Responses for Conventional Analyses

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#### Definitions of Pile-head Loading Conditions:

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

Load	Load	Load	Axial	Pile-head	Pile-head	Max Shear	Max Moment
------	------	------	-------	-----------	-----------	-----------	------------

Case No.	Type	Pile-head Load 1	Type	Pile-head Load 2	Loading lbs	Deflection inches	Rotation radians	in Pile lbs	in Pile in-lbs
1	y, in	0.2700	S, rad	0.00	390000.	0.2707	0.00	14350.	-838149.
2	y, in	0.2700	M, in-lb	-2532015.	390000.	0.2700	0.00707	31423.	-2532015.

Maximum pile-head deflection = 0.2706967167 inches

Maximum pile-head rotation = 0.0070733249 radians = 0.405272 deg.

The analysis ended normally.

## **Lateral Earth Pressure**



**From Structural Designer**

 Thermal Displacement (per Abutment)  $\delta_T := 0.15 \text{ in}$ 
**From Plan Set (received/dated 6/2/2025)**

 Abutment Height  $h := 7.5 \text{ ft}$ 
**Relative Wall Displacement**

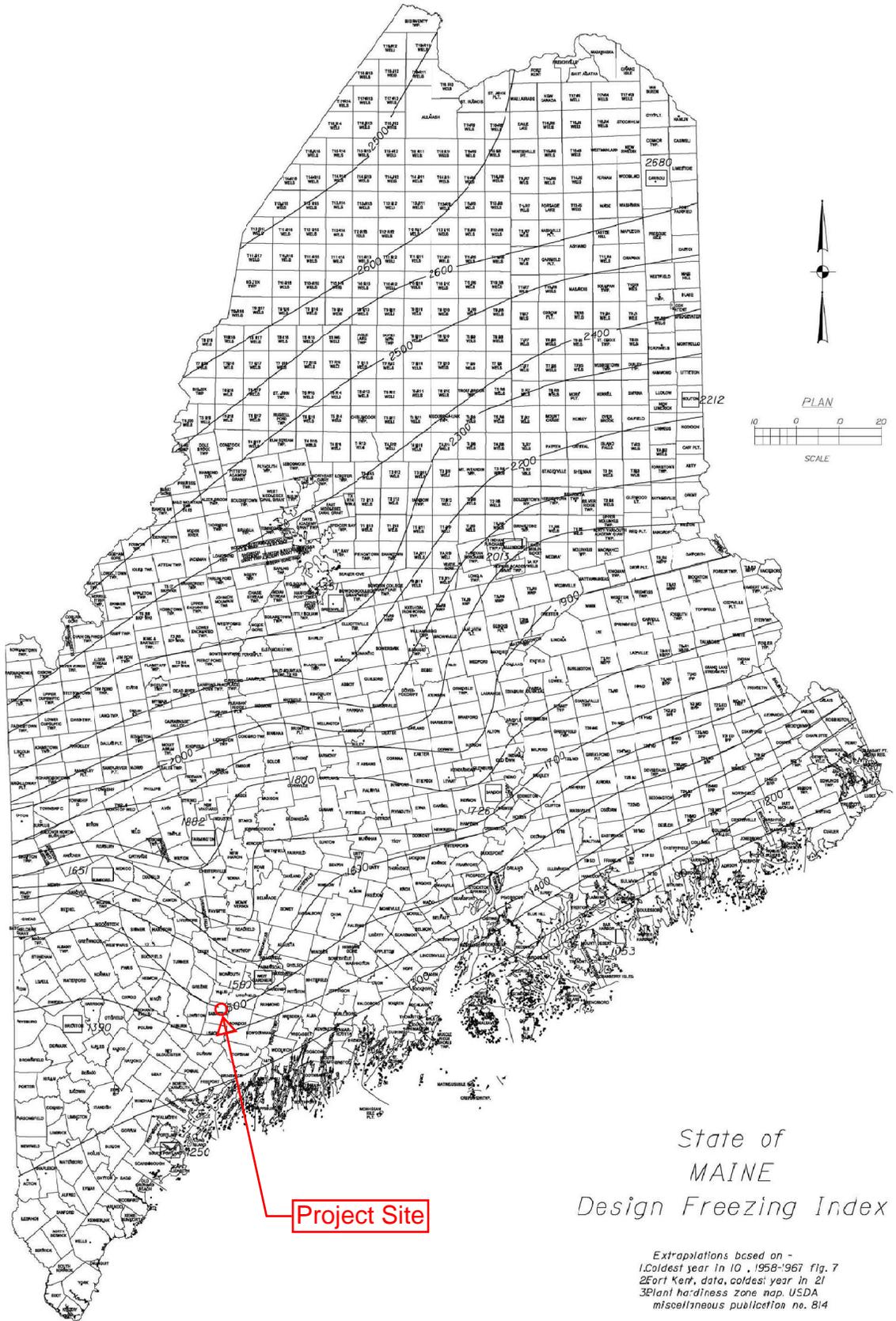
$$\frac{\delta_T}{h} = 0.002$$

$$K_P := \begin{cases} \text{if } \left\| \left\| 0.43 + 5.7 \left( 1 - e^{-190 \cdot \left( \frac{\delta_T}{h} \right)} \right) \geq 3.25 \right\| \right\| = 3.25 \\ \left\| \frac{0.43 + 5.7 \left( 1 - e^{-190 \cdot \left( \frac{\delta_T}{h} \right)} \right)}{0.43 + 5.7 \left( 1 - e^{-190 \cdot \left( \frac{\delta_T}{h} \right)} \right)} \right\| \\ \text{if } \left\| \left\| 0.43 + 5.7 \left( 1 - e^{-190 \cdot \left( \frac{\delta_T}{h} \right)} \right) > 6 \right\| \right\| \\ 6 \\ \text{if } \left\| \left\| 0.43 + 5.7 \left( 1 - e^{-190 \cdot \left( \frac{\delta_T}{h} \right)} \right) < 3.25 \right\| \right\| \\ 3.25 \end{cases}$$



## Frost Depth

Figure 5-1 Maine Design Freezing Index Map



Project Site

State of  
MAINE  
Design Freezing Index

Extrapolations based on -  
1) Coldest year in 10, 1958-1967 fig. 7  
2) Fort Kent, data, coldest year in 21  
3) Plant hardiness zone map, USDA  
miscellaneous publication no. 814

## 5.2 General

### 5.2.1 Frost

Any foundation placed on seasonally frozen soils must be embedded below the depth of frost penetration to provide adequate frost protection and to minimize the potential for freeze/thaw movements. Fine-grained soils with low cohesion tend to be most frost susceptible. Soils containing a high percentage of particles smaller than the No. 200 sieve also tend to promote frost penetration.

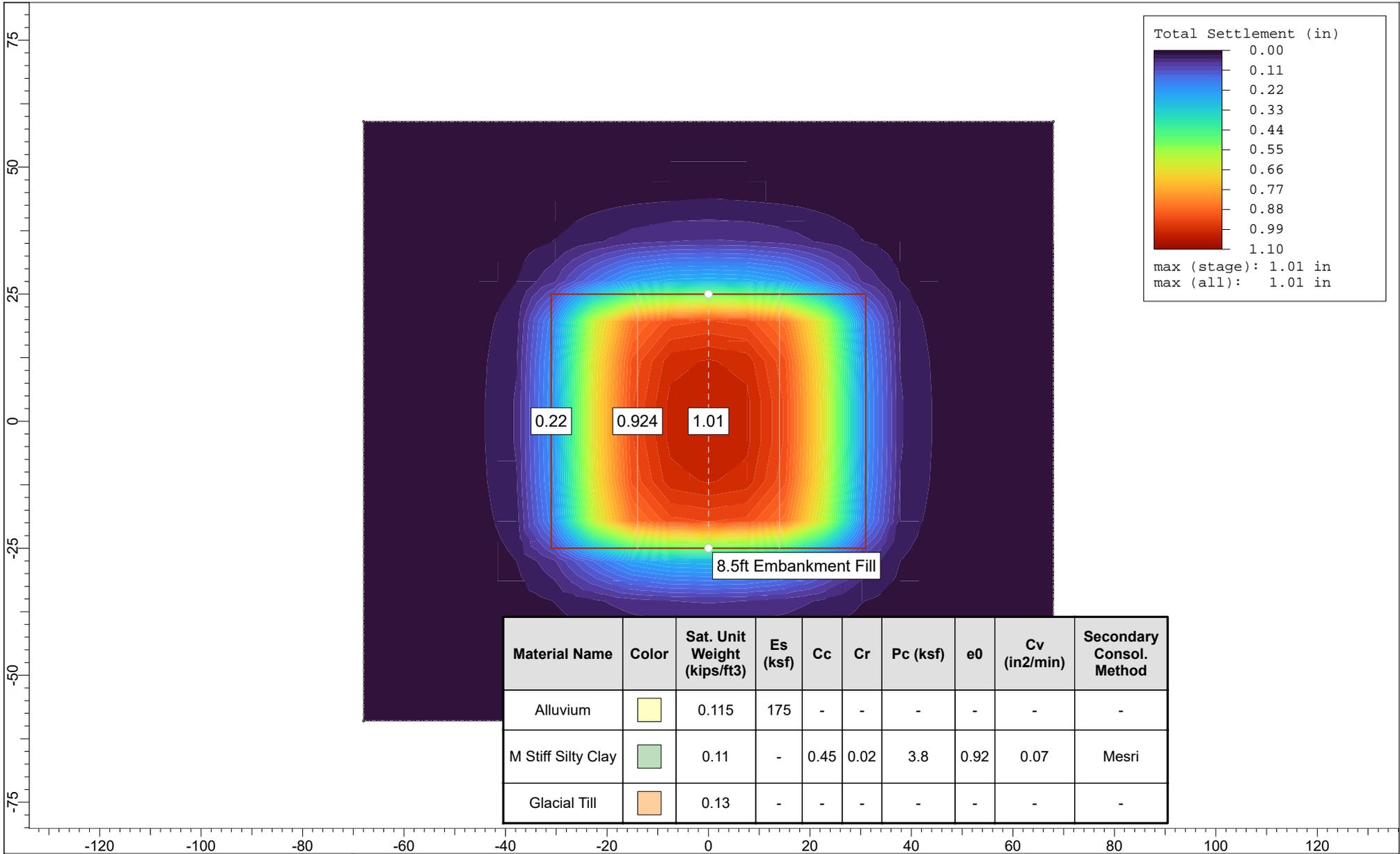
In order to estimate the depth of frost penetration at a site, Table 5-1 has been developed using the Modified Berggren equation and Figure 5-1 Maine Design Freezing Index Map. The use of Table 5-1 assumes site specific, uniform soil conditions where the Geotechnical Designer has evaluated subsurface conditions. Coarse-grained soils are defined as soils with sand as the major constituent. Fine-grained soils are those having silt and/or clay as the major constituent. If the make-up of the soil is not easily discerned, consult the Geotechnical Designer for assistance. In the event that specific site soil conditions vary, the depth of frost penetration should be calculated by the Geotechnical Designer.

**Table 5-1 Depth of Frost Penetration**

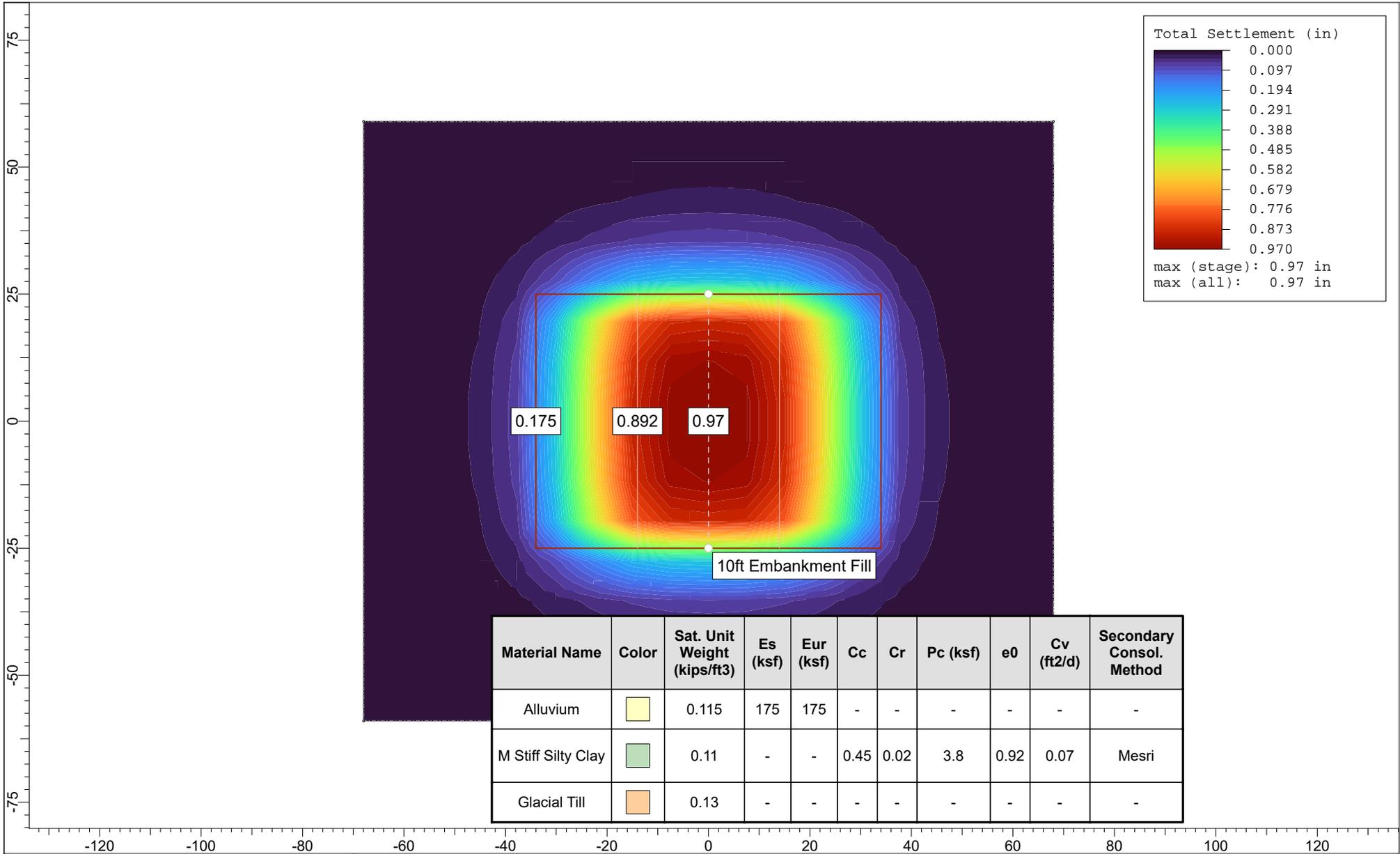
Design Freezing Index	Frost Penetration (in)					
	Coarse Grained			Fine Grained		
	w=10%	w=20%	w=30%	w=10%	w=20%	w=30%
1000	66.3	55.0	47.5	47.1	40.7	36.9
1100	69.8	57.8	49.8	49.6	42.7	38.7
1200	73.1	60.4	52.0	51.9	44.7	40.5
1300	76.3	63.0	54.3	54.2	46.6	42.2
1400	79.2	65.5	56.4	56.3	48.5	43.9
1500	82.1	67.9	58.4	58.3	50.2	45.4
1600	84.8	70.2	60.3	60.2	51.9	46.9
1700	87.5	72.4	62.2	62.2	53.5	48.4
1800	90.1	74.5	64.0	64.0	55.1	49.8
1900	92.6	76.6	65.7	65.8	56.7	51.1
2000	95.1	78.7	67.5	67.6	58.2	52.5
2100	97.6	80.7	69.2	69.3	59.7	53.8
2200	100.0	82.6	70.8	71.0	61.1	55.1
2300	102.3	84.5	72.4	72.7	62.5	56.4
2400	104.6	86.4	74.0	74.3	63.9	57.6
2500	106.9	88.2	75.6	75.9	65.2	58.8
2600	109.1	89.9	77.1	77.5	66.5	60.0



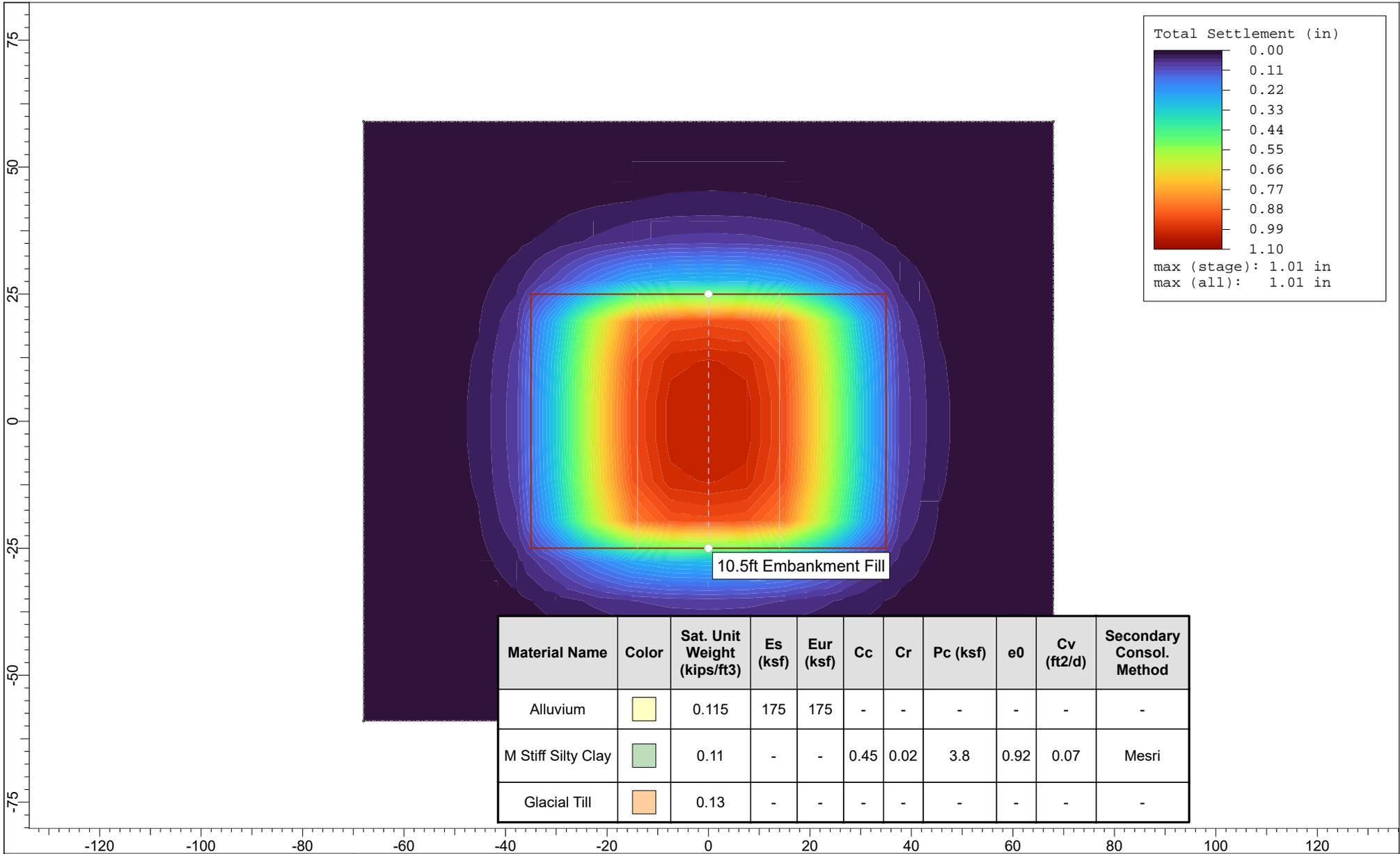
## **Detour Structure Settlement & Global Stability**



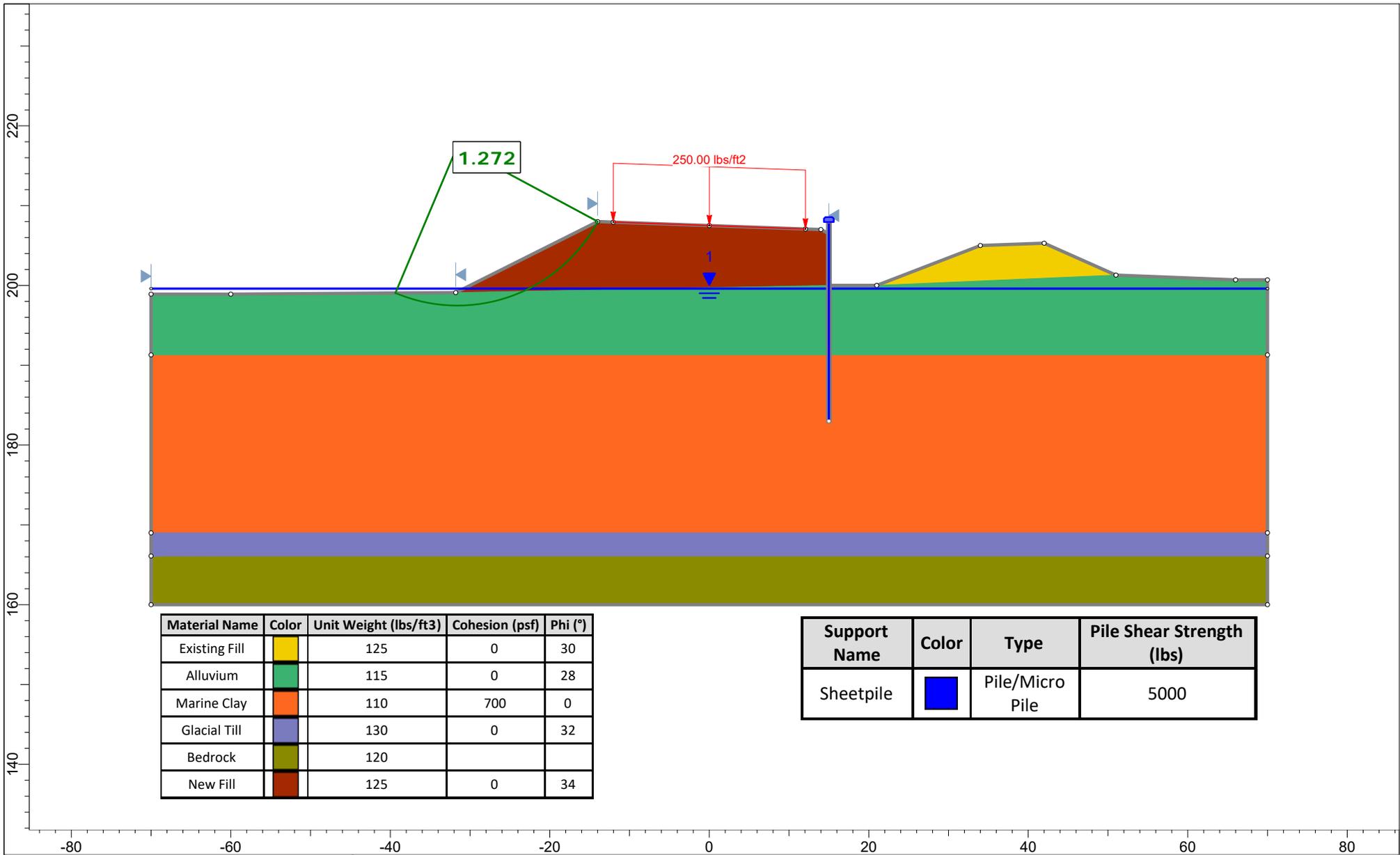
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	Analysis Description			Temp Detour Sta. 56+25 - 8.5 ft Embankment Fill		
	Drawn By	MAS	Reviewed By	ALS	Date	May 2025
	Company	S. W. Cole Engineering, Inc.		File Name	Detour 56+25.s3z	



	Project			WIN 26184 Sabattus River Bridge		
	Analysis Description			Temp Detour Sta. 57+50 - 10 ft Embankment Fill		
	Drawn By	MAS	Reviewed By	ALS	Date	May 2025
	Company	S. W. Cole Engineering, Inc.		File Name	Detour 57+50.s3z	



	<i>Project</i>		
	WIN 26184 Sabattus River Bridge		
	<i>Analysis Description</i>		
	Temp Detour Sta. 58+00 - 10.5 ft Embankment Fill		
<i>Drawn By</i>	MAS	<i>Reviewed By</i>	ALS
		<i>Date</i>	May 2025
<i>Company</i>	S. W. Cole Engineering, Inc.		<i>File Name</i>
			Detour 58+00.s3z

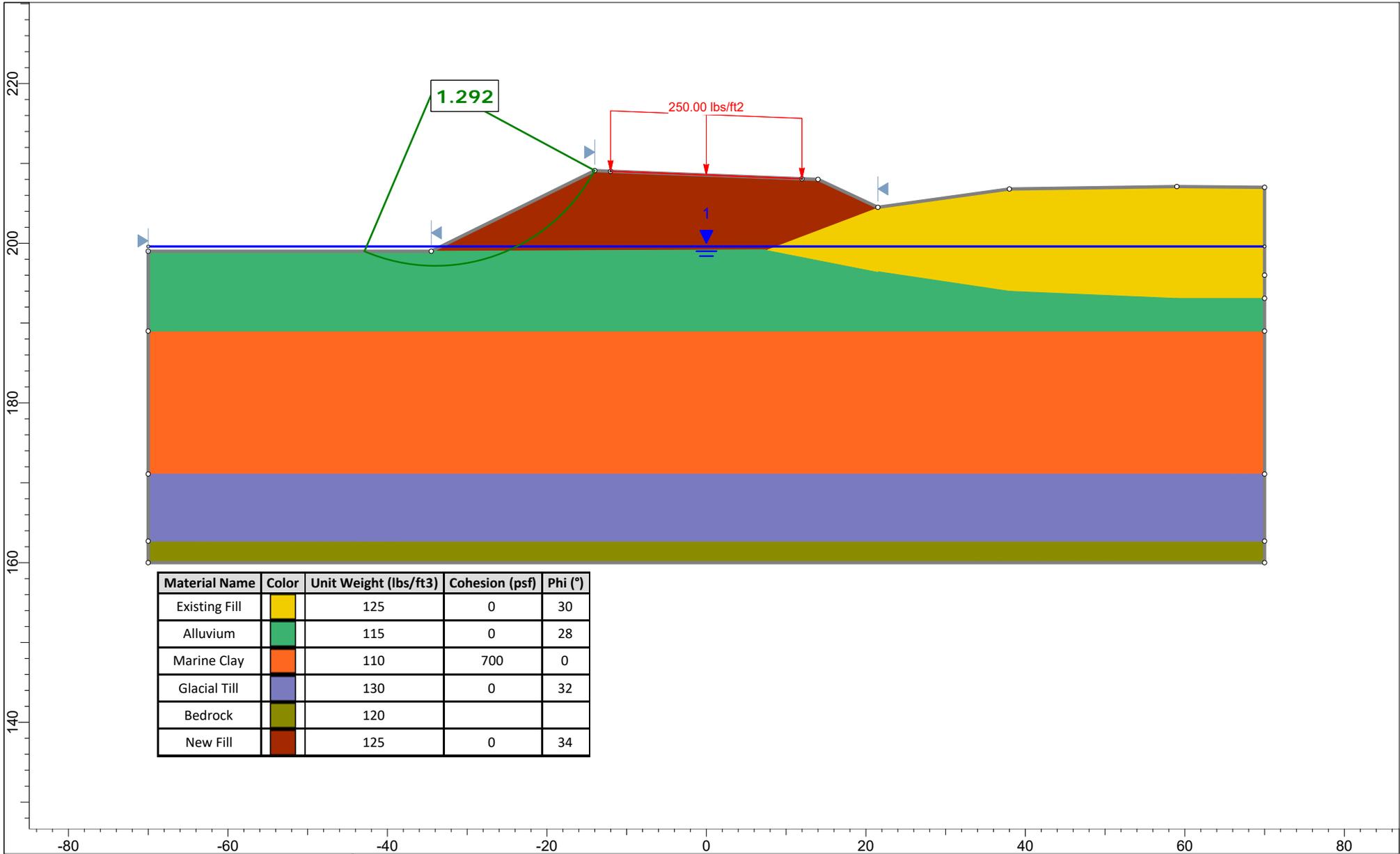


Material Name	Color	Unit Weight (lbs/ft <sup>3</sup> )	Cohesion (psf)	Phi (°)
Existing Fill	Yellow	125	0	30
Alluvium	Green	115	0	28
Marine Clay	Orange	110	700	0
Glacial Till	Purple	130	0	32
Bedrock	Olive	120		
New Fill	Brown	125	0	34

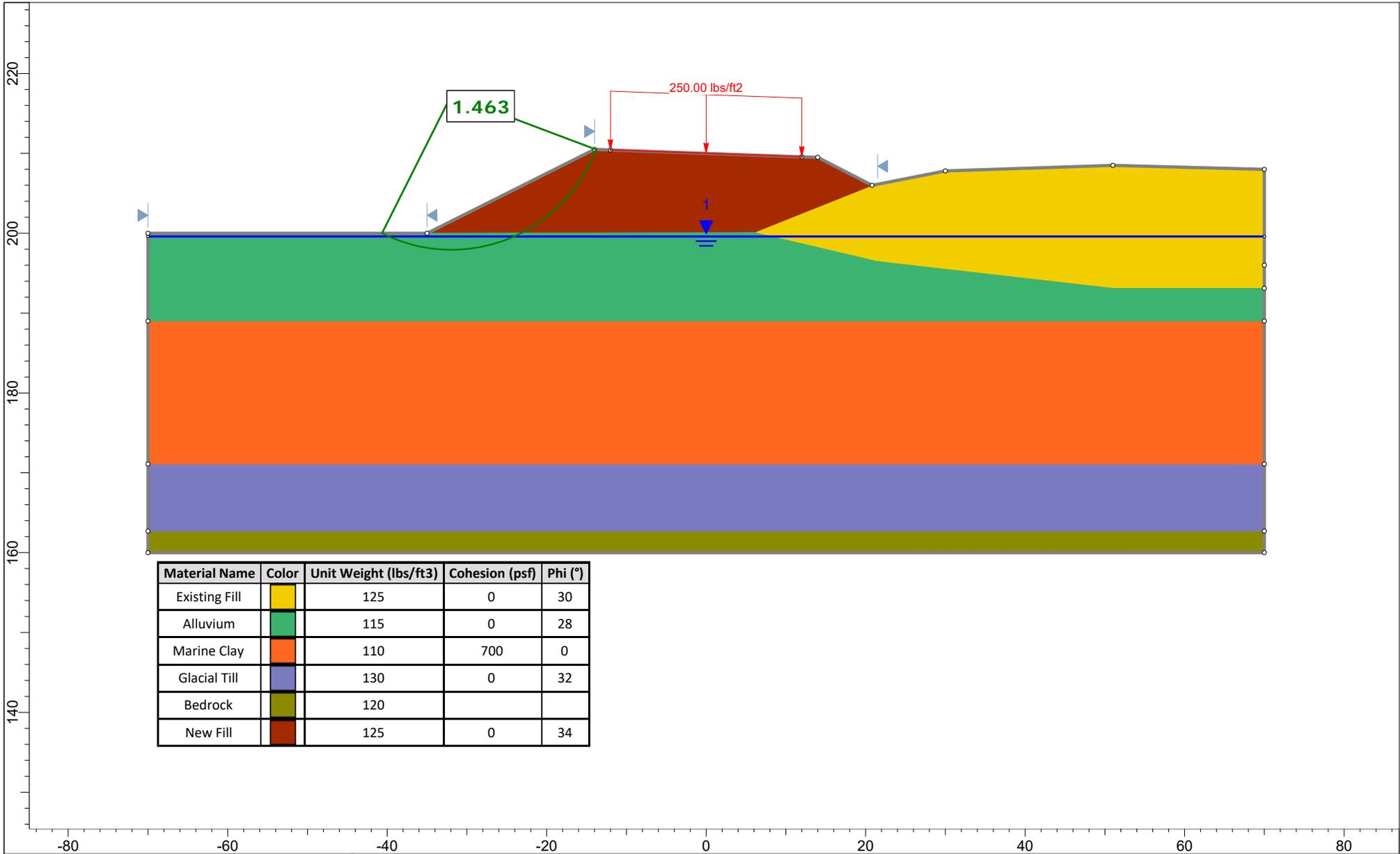
Support Name	Color	Type	Pile Shear Strength (lbs)
Sheetpile	Blue	Pile/Micro Pile	5000



Project		WIN 26184 Sabattus River Bridge	
Analysis Description		Temp Detour Sta. 56+25 - Static	
Scale	1:200	Drawn By	MAS
		Reviewed By	ALS
		Date	May 2025
Company		S. W. Cole Engineering, Inc.	
		File Name	
		Detour 56+25.slmd	



	Project				WIN 26184 Sabattus River Bridge																		
	Analysis Description				Temp Detour Sta. 57+50 - Static																		
	Scale		1:200		Drawn By		MAS		Reviewed By		ALS		Date		May 2025								
	Company						S. W. Cole Engineering, Inc.						File Name						Detour 57+50.slmd				



	Project				WIN 26184 Sabattus River Bridge			
	Analysis Description				Temp Detour Sta. 58+00 - Static			
	Scale	1:200	Drawn By	MAS	Reviewed By	ALS	Date	May 2025
	Company				S. W. Cole Engineering, Inc.			
				File Name				Detour 58+00.slmd