GEOTECHNICAL REPORT

BROOK ROAD

OVER

BEAVER DAM BROOK

IN

PLYMOUTH, MASSACHUSETTS

BRIDGE NO. P-13-011

DATE : MARCH 2020

PREPARED BY:

4/15/2020

COMMONWEALTH OF MASSACHUSETTS
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1.0 INTRODUCTION

This Report presents the results of subsurface explorations, our evaluation or existing subsurface conditions and our geotechnical recommendations for the proposed replacement of Bridge No. P-13-011(9KM). Our recommendations conform to AASHTO 2017 LRFD Bridge Design Specifications 8th Edition, AASHTO 2011 Guide Specifications for LRFD Seismic Bridge Design 2nd Edition with interim revisions through 2016, and MassDOT 2013 LRFD Bridge Manual.

The bridge is located on Brook Road over Beaver Dam Brook in Plymouth Massachusetts as shown on the Location Map contained in Appendix A. The date of the original bridge construction is unknown, but based on similar construction methods it is estimated that the date of construction is circa 1925.

The existing structure consists of an approximately 12 foot clear span reinforced concrete deck with eight concrete encased steel I-beams embedded within the deck, all supported by fieldstone masonry abutments with a concrete cap. There are fieldstone u-wingwalls, approximately 10 feet long at each of the four corners. The existing roadway over the bridge is a single lane approximately 16.5 wide.

The proposed structure will be a 21.5 span, and the roadway over the bridge will be widened to approximately 30.5 feet. The hydraulic opening will be widened to mitigate overtopping of roadway during flood. The proposed design flood (25 year) elevation is EL.12.85 NAVD. The proposed grades across and adjacent to the bridge will be the same as existing grades. The existing height of abutments measured from the stream bed to the top of roadway is 8.2 feet at the east and 8.2 feet at the west and approximately 8.9 feet deep along centerline of channel.

Hydraulic analysis yielded a Design Scour Elevation of -6.2 feet and a Check Scour Elevation of -7.7 feet. Theses elevations are 7.8 feet & 9.3 feet respectively below the proposed bottom of pile cap.

There is no previously existing site-specific subsurface information for the bridge or vicinity.

2.0 SUBSURFACE CONDITIONS

The USGS Surficial Geology Map for the area per the Scientific Investigations Map 3402 indicates that it falls within the 169 Manomet Quadrangle. Information per the map in the immediate vicinity of the bridge indicates a combination of coarse deposits and swamp deposits with the swamp deposits indicated close to the brook. According to the USGS publication, the coarse deposits consist of gravel deposits, sand and gravel deposits and sand deposits, which are not differentiated in the USGS report. The boring log indicates that the coarse deposits fall within the category of sand deposits. Sand deposits are composed mainly of very coarse to fine sand, commonly in well-sorted layers. Coarser layers may contain up to 25 percent gravel particles, generally granules and pebbles; finer layers may contain some very fine sand, silt, and clay.

Per the USGS description of the map units the swamp deposits consist of organic muck and peat that contain minor amounts of sand, silt and clay, are stratified and poorly sorted, and occur in swamps and freshwater marshes, in kettle depressions (depression left in an outwash plain by a retreating glacier), or in poorly drained areas. This unit is shown only where deposits are estimated to be at last 3 ft. thick; most deposits are less than 10 ft. thick. Swamp deposits overlie glacial deposits or bedrock. They locally overlie glacial till even where they occur within thin glacial meltwater deposits. As the soils investigation was limited to a single boring, it is not certain if any organic swamp deposits would be encountered.

The USGS-GIS-Bedrock Lithology Data set guide indicates the bedrock underlying the site is Avalon Granite which is described as granitoid plutonic rocks, including quartz monzonite, granodiorite, tonalite, trondhjemite, and equivalent gneiss.

In September 2019, Miller Engineering & Testing, Inc. (Miller) of Manchester, NH drilled a single boring, took split spoon samples and prepared the boring log. The boring was located at approximately 41 feet from the face of east abutment. This location was determined due to conflicts with the overhead wires. The top of road elevation at the boring location was approximately at EL. 14.0 feet.

2.0 SUBSURFACE CONDITIONS (Continued)

According to the boring logs, Miller advanced the boring to a depth of 67 feet using a Field Joint Coated Casing (FJC) and obtained samples via spilt spoon at different intervals during advancement of the boring. The groundwater was observed at a depth of 5 feet below the surface. No soil samples were provided for testing. The desired 10 foot rock core could not be obtained due to the strata material and depth of the final samples.

Based on our review, our interpretation of the strata at the project site is described below in order of increasing depth. Subsurface conditions at other locations near the bridge may be different than those indicated below.

Asphalt: Three and a half inches (3.5") of asphalt was encountered below the Brook Road roadway surface in both borings.

Fine to Medium Sand: Below the asphalt layer the borings indicated a fill layer approximately 9 feet in depth (approx. EL. 4.7 to 13.7). This layer consisted of wet fine to medium brown sand. No fill was encountered. During advancement through this layer the drill encountered a boulder at 7.5 to 8 feet. The auger was pulled out and moved 2 feet to continue the boring. N values ranged from 11 to 14 blows per foot (bpf), indicating medium dense soil.

Light Grey Fine Sand: A 6 foot layer (approx. EL -1.2 to EL -4.8) of light grey fine sand has N values of 27 blows per foot, indicating medium dense soil.

Fine Sand: An approximately 20-foot-thick layer (EL. -21.2 to EL -1.2) of brown fine to medium sand. N values of 11 to 15 blows per foot (bpf) indicate medium dense soil.

Fine to Medium Sand: An approximately 5-foot-thick layer (El. -26 to -21) of wet loose fine to medium sand was encountered below the layer above. N values at the depth between 35 and 37 feet below the top of road indicated loose sand with average blow count of approximately 7 blows per foot.

2.0 SUBSURFACE CONDITIONS (Continued)

Clayey Silt: An approximately 10-foot-thick layer (El. -36 to -26) of hard clayey silt was encountered below the above layer above. N values indicate medium to dense layer with the average blow count of approximately 25 blows per foot.

Fine to Medium Sand: An approximately 5-foot-thick layer (El. -36 to -41) of wet fine to medium sand, medium dense was encountered below the layer above. N values indicate medium dense to dense layer with the average blow count of approximately 27 blows per foot.

Fine Sand: An approximately 10-foot-thick layer (El. -41 to -51) of wet loose fine sand was encountered below the layer above. N values indicate a loose layer with the average blow counts of approximately 5 blows per foot.

Fine Sand: An approximately 2-foot-thick layer (El. -51 to -53.2) of fine sand, medium dense was encountered below the fill layer above. N values indicate medium dense layer with the average blow count of approximately 12 blows per foot. The boring was terminated at approximate El.53.2, which was 67 feet below the surface.

Piles will be driven to ledge and bear on rock. Dynamic analysis will be conducted at each abutment. Seismic Refracting Testing has been performed to determine the depth of the ledge. See the appendix.

3.0 DESIGN RECOMMENDATIONS

Recommendations for design of the new bridge are presented below. Calculations supporting these recommendations are provided in Appendix B. Recommended soil properties for design were selected based on published correlations to SPT N-values, our review of the soil descriptions, and our engineering judgment.

Based on a computed 25-year flood scour depth of 11.8 feet, a cantilevered abutment is typically uneconomical. Additionally, there is multiple strata within the groundwater table that are classified as loose and granular. It was advised that piles be used and driven to ledge to avoid potential liquefaction conditions. Therefore, it is expected that the proposed replacement bridge substructure will consist of integral abutments supported on steel H-piles. The pile design should consider the following requirements provided in Chapter 3 Subsection 3.10.10 of the Bridge Manual:

- The integral bridge abutments should be supported on a single row of vertical H-piles. Section 3.10.11 of the Bridge Manual indicates that HP10x57 and HP12x84 piles should be used exclusively for integral bridge abutment design.
- The minimum and maximum distances between the edge of the pile and the end of the abutment, should be 18 and 36 inches, respectively.
- The piles should be embedded 2 feet into the pile cap.
- The minimum and maximum pile spacing should be 40 inches and 10 feet, respectively. A minimum of one pile per beam line at each abutment should be used.
- A zone of crushed stone should be provided around the tops of the piles, to reduce the stresses in the piles due to lateral displacements of the abutments. The Bridge Manual calls for a trench with a depth of 3 feet and a minimum width of 30 inches to be constructed directly below the pile cap, and filled with crushed stone.

The plans shall identify a minimum pile penetration based on the pile length requirements described in Paragraph 3.10.11.2 of the MassDOT LRFD Bridge Manual. The piles will be driven to bedrock which is at a depth which is far greater than minimum required embedment. When considering the potential scour depth is below the bottom of the pile cap, the Simplified Method does not apply. For the check scour condition, it is recommended that the equivalent lengths of 15.3 and 16.3 feet be used in the Finite Element Design model for the HP10x57 and HP12x84 pile sections, respectively. The depths to fixity, defined as the depth to the second point of zero deflection, of 24.8 feet and 26.8 feet for the HP10x57 and HP12x84 pile sections respectively.

The piles will be driven to bedrock so the available structural resistance will be used for the axial resistance and not the geotechnical capacity. The structural resistance of the proposed piles will be calculated using a resistance factor of 0.60. A pile corrosion loss of 22% (1/16") was anticipated. The pile should be driven to bedrock without exceeding the permissible driving stresses of 13 ksi (for 50 ksi steel piles).

Dynamic pile testing with restrike testing and signal matching is required on at least two piles (one per abutment) prior to installation of remaining piles. A recommended resistance factor of 0.65 should be used when verifying the Factored Strength Limit state vs. the required ultimate geotechnical resistance determined through testing.

Having the piles driven to bedrock limits the settlement to the elastic compression of the pile to 1/4" or less.

Based on our review of the borings and our seismic design calculations, which are provided in Appendix B, the foundation conditions for the proposed structure are representative of Site Class D. Site coefficients for peak ground acceleration ([FPGA], short-period range [FA], and long-period range [Fv]) are 2.5, 2.5, and 3.5, respectively.

3.0 DESIGN RECOMMENDATIONS (Continued)

Based on the maps in the AASHTO "Guide Specifications for LRFD Seismic Bridge Design," we recommend the following parameters for seismic design based on a 7 percent probability of exceedance in 75 years (approximately 1,000-year return period):

- Horizontal Peak Ground Coefficient (PGA) = 0.080
- Horizontal Response Spectral Coefficient (period = 0.2 sec) (Ss) = 0.135
- Horizontal Response Spectral Coefficient (period = 1.0 sec) (S1) = 0.05

Application of the above site coefficients results in the following recommended coefficients for development of design response spectra:

- Response Spectral Acceleration, As = 0.128
- Design Spectral Acceleration Coefficient at 0.2 second period, SDS = 0.216
- Design Spectral Acceleration Coefficient at 1.0 second period, SD1 = 0.120

We did not perform a formal liquefaction evaluation, because the Guide Specifications (Article 6.8) state that liquefaction need not be evaluated for SDC A structures. The pile-supported bridge should not be affected, since the piles are driven to bedrock.

The retaining walls will butt up with the integral abutment wingwalls and are beyond the extent of the potential scour. It is expected that premanufactured engineered concrete modular wall systems will be utilized. The Meyerhof method was used to determine the Factored Bearing Resistance. The Factored Bearing Resistance was calculated for effective footing widths of 4.0', 6.0' and 8.0' producing pressures of 3.5 ksf, 4.0 ksf, and 4.6 ksf respectively.

4.0 CONSTRUCTION RECOMMENDATIONS

All excavations should be made in accordance with OSHA standards. All excavation supports should be designed and sealed by a Massachusetts professional engineer that is engaged by the contractor. It is anticipated that the construction of abutment and wingwalls will take place within a temporary sheet pile structure to facilitate dewatering.

Piles shall be installed in accordance with the appropriate MassDOT standard specifications. It is recommended that a wave equation (WEAP) analysis be performed to check that the necessary capacity can be achieved without overstressing the piles and to establish hammer size and driving criteria. The construction specifications will require the contractor to perform Dynamic Load Tests (DLT) with signal matching analyses (such as CAPWAP) to confirm that the pile driving system has adequately driven the pile to the required capacity. The dynamic testing and signal matching will be performed on a restrike of the test piles, after waiting overnight or longer. The required ultimate capacity should be calculated using the most critical factored load case and a Resistance Factor of 0.65 for the CAPWAP-generated capacity. The maximum allowable driving stress is 90% of the yield stress of the pile. The final driving criteria should be selected based on the results of the DLTs and CAPWAP analyses and the calculated ultimate capacity of the piles.

Prior to wall construction, the wall subgrades should be compacted with at least four passes of a smooth-drum vibratory compactor weighing at least 10,000 lbs. In confined areas, proof compact with a vibratory plate compacting that weighs at least 200 lbs. and imparts an impact load of at least 2.5 tons. Where exposed footing subgrades are at or near the groundwater level, static proof compaction methods may be recommended by the Geotechnical Engineer in lieu of vibratory methods. At wall foundation locations, unsuitable soils and soils that do not become firm under proof compaction should be removed and replaced with compacted Gravel Borrow for Bridge Foundations or Crushed Stone for Bridge Foundations to create a competent bearing surface. Where footings would otherwise bear on the native silt, we recommend over excavation of 12 inches of the silt and replacement with compacted Gravel Borrow.

4.0 CONSTRUCTION RECOMMENDATIONS (Continued)

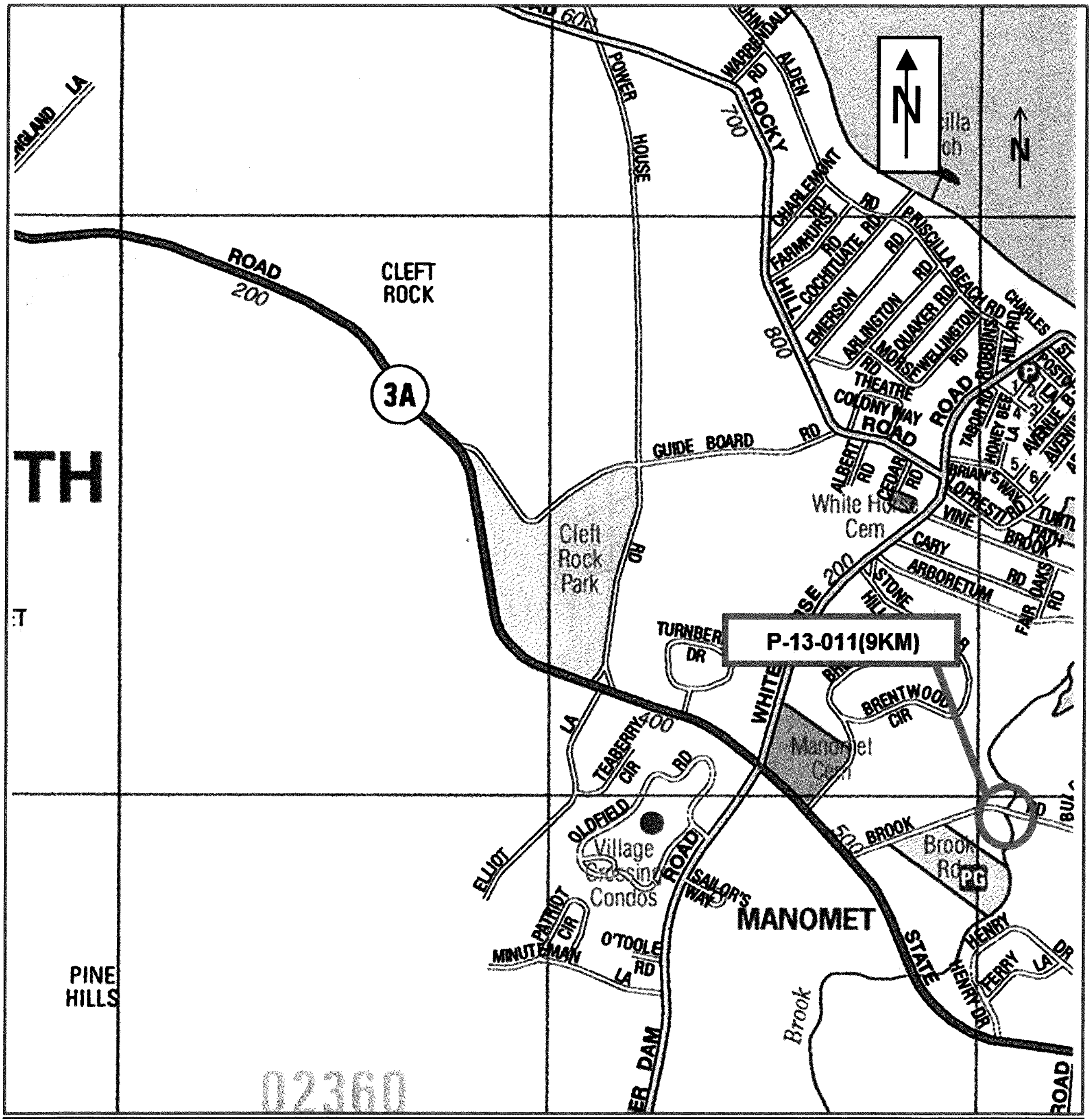
We recommend using Gravel Borrow for Bridge Foundations (MassDOT Standard Specification No. M1.03 Type a) where fill is to be placed (such as for replacement of unsuitable soils) below the proposed walls.

Backfill for excavations for removal of existing foundations or utilities should consist of Ordinary Borrow (MassDOT Standard Specification No. M1.01.0) or Gravel Borrow (MassDOT Standard Specification No. M1.03 Type b).

Backfill within prefabricated engineered wall systems should be granular soil that meets the strength, drainage and chemical requirements of the retaining wall manufacturer.

Crushed stone (or Crushed Stone for Bridge Foundations) may be used as backfill as needed; however, the crushed stone should be wrapped in nonwoven geotextile (with a minimum overlap of two feet) to prevent fines from migrating into the stone. The nonwoven geotextile should be an approved product for subsurface drainage on the MassDOT qualified materials list for geotextile fabrics (M9.50.0). Crushed stone should be placed in maximum 12 inch thick loose lifts and compacted to an unyielding surface in accordance with the requirements of MassDOT Standard Specification 150.67.

APPENDIX A - LOCATION MAP



APPENDIX B - BORING LOG

TEST BORING LOG

MILLER ENGINEERING & TESTING, INC.
100 Sheffield Road - Manchester, NH 03103
Ph. (603) 668-6016 - Fax: (603) 668-8641

Project:	Brook Rd. Bridge Plymouth, MA	Sheet	1 of 3
Project No:	19.162.NH	Boring No:	B-1
Date Start:	09-10-19	Location:	By Client
Date End:	09-12-19	Approx. Surface Elev:	

	CASING	SAMPLER	GROUNDWATER OBSERVATIONS Date	Depth	Casing At	Stabilization Period
Type	FJC	SS	09-12-19	5'	20'	
Size	4"					
Hammer	300/140	140 lbs.				
Fall	24/30	30"				

Depth/ Elev.	Cas bl/ft	SAMPLE Sample No.	Depth Range	Pen.	Rec.	BLOWS 0-6"	6-12"	12-18"	18-24"	Strata Change	Sample Description	Notes
0		-	0.0-0.3	3.5							: 3.5" Asphalt	
		S-1	0.5-2.0	18	18		8	6	5		S-1: Medium dense, brownish orange, fine to medium sand, little silt	
4		S-2	4.0-6.0	24	15	4	5	6	8		S-2: Wet, brown, fine to medium sand, medium dense	
8		S-3	7.5-8.0	6	6	125					S-3: Wet, very dense, brown, fine to coarse sand, fractured rock pieces in spoon tip	(1)
		S-4	9.0-11.0	24	16	14	14	13	12		S-4: Wet, light gray fine sand	
12												
		S-5	15.0-17.0	24	14	10	7	7	8		S-5: Wet, medium dense, brown, fine sand	
16												
20		S-6	20.0-22.0	24	10	12	5	6	6		S-6: Wet, medium dense, brown, fine to coarse sand, some gravel	
24												

Driller: R. Marcoux
Helper: J. Donahue
Inspector:

COHESIVE CONSISTENCY (Blows/Foot)	COHESIONLESS (Blows/Foot)	PROPORTIONS USED
0-2 VERY SOFT	0-4 VERY LOOSE	TRACE: 0-10%
2-4 SOFT	4-10 LOOSE	LITTLE: 10-20%
4-8 MEDIUM STIFF	10-30 MEDIUM DENSE	SOME: 20-35%
8-15 STIFF	30-50 DENSE	AND: 35-50%
15-30 HARD	50+ VERY DENSE	

NOTES: (1) Augers kicked off boulder at 7.5-8', pulled out. Moved over 2', started with 4" casing

REMARKS: THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES. TRANSITION MAY BE GRADUAL. WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

APPENDIX B - BORING LOG (Continued)

TEST BORING LOG

MILLER ENGINEERING & TESTING, INC.
100 Sheffield Road - Manchester, NH 03103
Ph. (603) 668-6016 - Fax: (603) 668-8641

Project:	Brook Rd. Bridge, Plymouth, MA
Project No.:	19.162.NH
Date Start:	09-10-19
Date End:	09-12-19
Sheet	2 of 3
Boring No:	B-1
Location:	By Client
Approx. Surface Elev:	

	CASING	SAMPLER	GROUNDWATER OBSERVATIONS Date	Depth	Casing At	Stabilization Period
Type	FJC	SS	09-12-19	5'	20'	
Size	4"					
Hammer	300/140	140 lbs.				
Fall	24/30	30"				

Depth/ Elev.	Cas bl/ft	Sample No.	Depth Range	Pen.	Rec.	Blows 0-6"	Blows 6-12"	Blows 12-18"	Blows 18-24"	Strata Change	Sample Description	Notes
		S-7	25.0-27.0	24	12	10	7	8	8		S-7: Wet, medium dense, brownish orange, fine to coarse sand and gravel	
28												
		S-8	30.0-32.0	24	16	7	7	6	6		S-8: Wet, medium dense, brown, fine sand, trace of silt	
32												
	49	S-9	35.0-37.0	24	18	1	2	3	7		S-9: Wet, loose, brownish orange, fine to medium sand	
36												
40		S-10	40.0-42.0	24	18	10	15	13	12		S-10: Wet, hard, gray, clayey silt	
44												
		S-11	45.0-47.0	24	22	13	19	11	11		S-11: Wet, hard, gray, clayey silt	
48												

Driller: R. Marcoux
Helper: J. Donahue
Inspector:

COHESIVE CONSISTENCY (Blows/Foot)
0-2 VERY SOFT
2-4 SOFT
4-8 MEDIUM STIFF
8-15 STIFF
15-30 HARD

COHESIONLESS (Blows/Foot)
0-4 VERY LOOSE
4-10 LOOSE
10-30 MEDIUM DENSE
30-50 DENSE
50+ VERY DENSE

PROPORTIONS USED
TRACE: 0-10%
LITTLE: 10-20%
SOME: 20-35%
AND: 35-50%

NOTES: (1) Augers kicked off boulder at 7.5-8', pulled out. Moved over 2', started with 4" casing

REMARKS: THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES. TRANSITION MAY BE GRADUAL. WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

APPENDIX B - BORING LOG (Continued)

TEST BORING LOG

MILLER ENGINEERING & TESTING, INC.

100 Sheffield Road - Manchester, NH 03103
Ph. (603) 668-6016 - Fax: (603) 668-8641

Project:	Brook Rd. Bridge	Sheet	3 of 3
	Plymouth, MA	Boring No:	B-1
Project No.:	19.162.NH	Location:	By Client
Date Start:	09-10-19		
Date End:	09-12-19	Approx. Surface Elev:	

	CASING	SAMPLER	GROUNDWATER OBSERVATIONS			
			Date	Depth	Casing At	Stabilization Period
Type	FJC	SS	09-12-19	5'	20'	
Size	4"					
Hammer	300/140	140 lbs.				
Fall	24/30	30"				

Depth/ Elev.	Cas bl/ft	SAMPLE: Sample No.	SAMPLE: Depth Range	SAMPLE: Pen.	SAMPLE: Rec.	BLOWS: 0-6"	BLOWS: 6-12"	BLOWS: 12-18"	BLOWS: 18-24"	Strata Change	Sample Description	Notes
		S-12	50.0-52.0	24	18	14	13	13	15		S-12: Wet, medium dense, brown, fine to medium sand	
52												
56		S-13	55.0-57.0	24	12	1	1	2	3		S-13: Wet, loose, brown, fine sand	
60		S-14	60.0-62.0	24	14	2	2	5	7		S-14: Wet, loose, brown, fine sand	
64		S-15	65.0-67.0	24	18	3	5	8	8		S-15: Wet, medium dense, brown, fine sand	
											BORING TERMINATED AT 67 ft	
68												
72												

Driller: R. Marcoux
Helper: J. Donahue
Inspector:

COHESIVE CONSISTENCY (Blows/Foot)	COHESIONLESS (Blows/Foot)	PROPORTIONS USED
0-2 VERY SOFT	0-4 VERY LOOSE	TRACE: 0-10%
2-4 SOFT	4-10 LOOSE	LITTLE: 10-20%
4-8 MEDIUM STIFF	10-30 MEDIUM DENSE	SOME: 20-35%
8-15 STIFF	30-50 DENSE	AND: 35-50%
15-30 HARD	50+ VERY DENSE	

NOTES: (1) Augers kicked off boulder at 7.5-8', pulled out. Moved over 2', started with 4" casing

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APPENDIX C - CALCULATIONS

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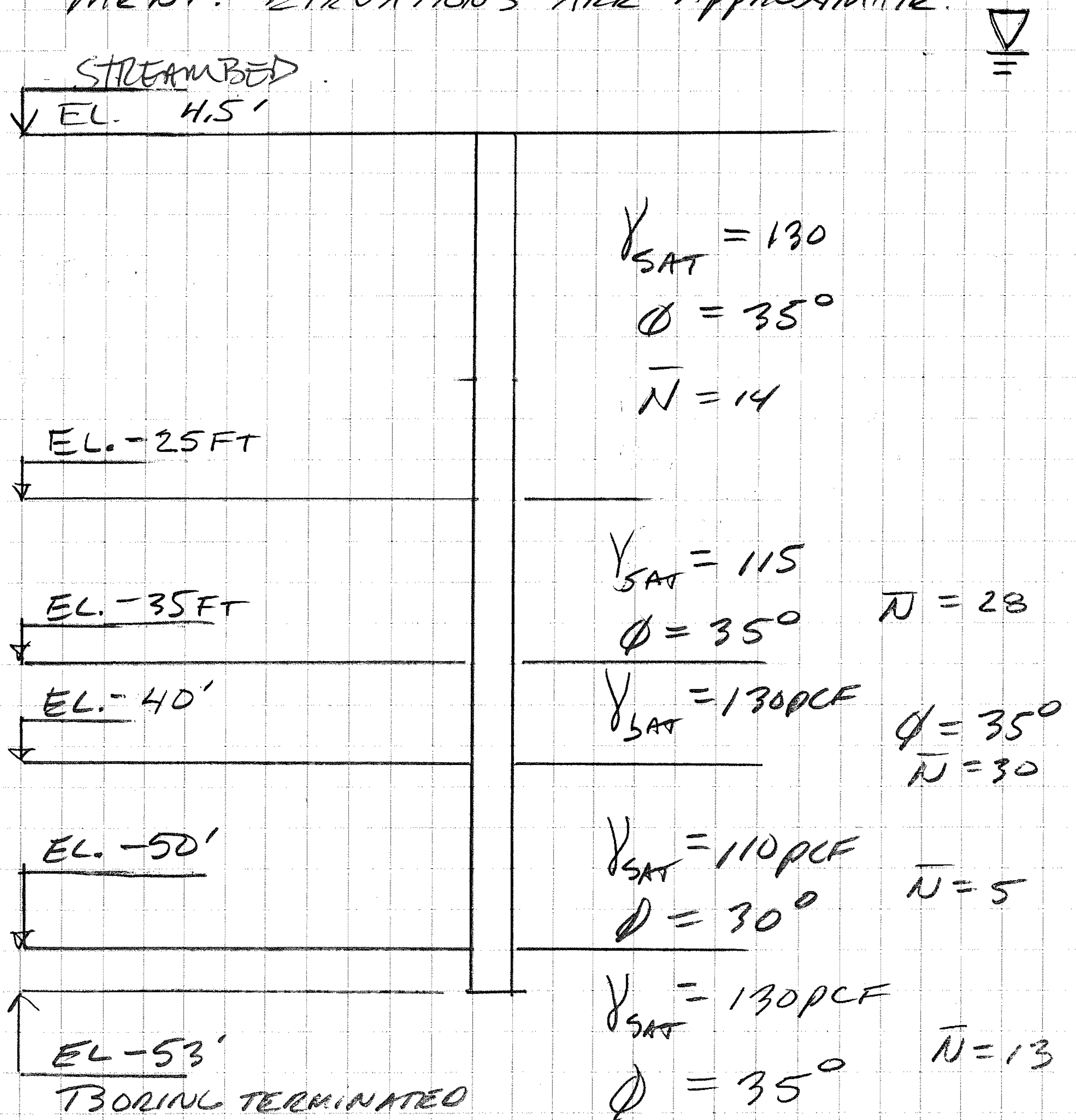
www.baysideengineering.com

JOB P-13-011
SHEET NO ______ OF ______
CALCULATED BY / DATE ______
CHECKED BY ______ DATE ______
SCALE ______

SOIL PROPERTIES

PROPERTIES SELECTED BASED ON PUBLISHED CORRELATIONS TO SPT N-VALUES, OUR REVIEW OF SOIL DESCRIPTIONS AND ENGINEERING JUDGEMENT. ELEVATIONS ARE APPROXIMATE.



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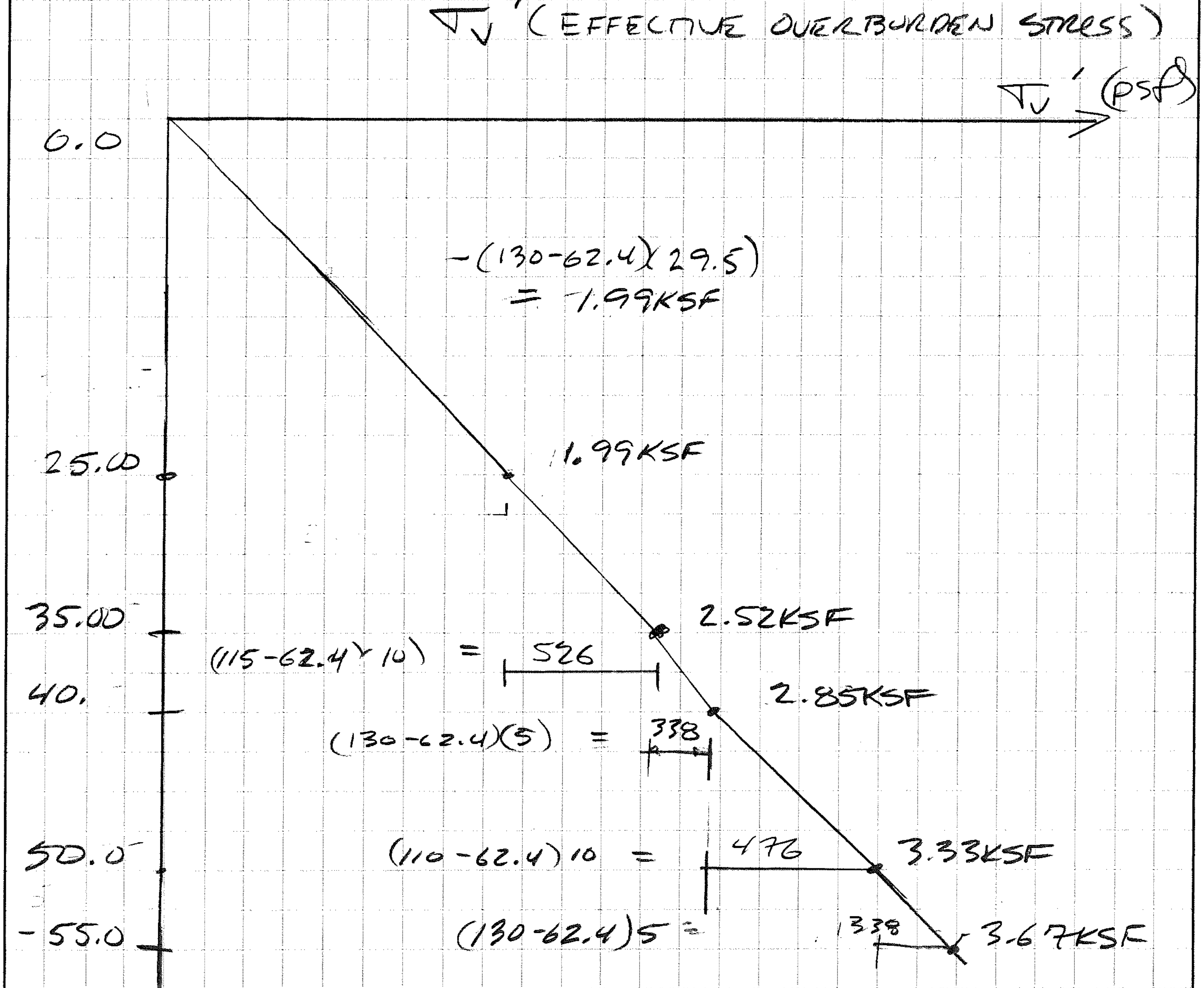
JOB P-13-011
SHEET NO ______ OF ______
CALCULATED BY 2 DATE ______
CHECKED BY ______ DATE ______
SCALE ______



$\sigma_v' = (130-62.4)(29.5)$
$(115-62.4)(10) + (130-62.4)(5)$
$(110-62.4)(10) + (130-62.4)(5)$

DEPTH (FT)

$\sigma_v' = 3.67\,KSF$

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JOB Plymouth
SHEET NO 3 OF
CALCULATED BY JK DATE 3/2020
CHECKED BY BAB DATE 3/2020
SCALE

PILE DESIGN

FLEXURAL RESISTANCE, M_n

EXTREME EVENT II –

HYDRODYNAMIC LOADS – WITH SCOUR.

UNBRACED LENGTH = $L_b = 11.8\,FT$ (HYDRAULIC REPORT)
– 4FT From Top of STREAMBED to Bottom of Abutment Cap $\Rightarrow L_b = 7.8\,FT$

CHECK FOR LATERAL TORSIONAL BUCKLING

L_p = LIMITING UNBRACED LENGTH for (F_{YC})

$$L_p = 1.0\, r_T \sqrt{\frac{E}{F_{YC}}} \quad (6.10.8.2.3-4)$$

$$L_p = \frac{(1.0)(2.74'')}{12\,IN/FT}\left(\frac{29{,}000}{50.0}\right)^{1/2} = 5.5\ FEET.$$

L_r = LIMITING UNBRACED LENGTH

$$L_r = (\pi)(r_T)\sqrt{\frac{E}{F_{yr}}}$$

$$L_r = \frac{(\pi)\,2.74''}{12\,IN/FT}\left(\frac{29{,}000}{(.7)(50)}\right)^{1/2} = 20.6\,FT$$

PILE DESIGN

FLEXURAL RESISTANCE

IF $L_p \le L_b < L_r$

$5.5 \le 7.8 < 20.6$ then (6.10.8.2.3-2)

$$F_{nc} = C_b \left[1 - \left(1 - \frac{F_{yr}}{F_{yc}}\right)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] F_{yc} \le F_{yc}$$

$$F_{nc} = (1.0)\left[1 - \left(1 - \frac{(.7)(50)}{50}\right)\left(\frac{7.8 - 5.5}{20.6 - 5.5}\right)\right]$$

$$F_{nc} = 0.95\, F_{yc}$$

$$M_{nc_x} = 0.95 F_{yc}(S_x)$$

$$M_{nc_x} = \left(\frac{(0.95)(50\,ksi)(58.8\,in^3)}{12\,in/ft}\right) = 233\ FT\text{-}KIP$$

NOTE: HYDRAULIC LOADS ACT TRANSVERSE TO BRIDGE RESULTING IN STRONG AXIS BENDING

$$M_{nc_y} = \frac{(.95)(50\,ksi)(19.7\,in^3)}{12} = 78.0\ FT.K$$

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FOUNDATION SUMMARY: **PILE DESIGN**

Pile Capacity:

	HP 10x57	HP 12x84
Fy (ksi)	50	50
Area, A (in^2)	16.8	24.6
Depth, d (in)	9.99	12.28
Thickness of web, tw (in)	0.565	0.685
Width of flange, b_f (in)	10.225	12.295
Thickness of flange, tf (In)	0.565	0.685
Moment of Inertia (Axis X-X), Ixx (in)	294	650
Moment of Inertia (Axis Y-Y), Iyy (in^4)	101	213
Section Modulus (Axis Y-Y), *Syy* (in^3)	19.7	34.6
Perimeter, P = 2d + $2b_f$ + $2(b_f$ - tw) (in)	59.75	72.37
Assumed corrosion loss (In)	0.0625	0.0625
Area of corrosion, Ac (in^2)	3.73	4.52
Area of steel after corrosion, As = A - Ac (in^2)	13.07	20.08
Nominal Compressive Structural Pile Resistance, Pn (kips) Pn = Fy* *As*	653.28	1003.84
Resistance Factor, RF	0.6	0.6
AASHTO Reference for RF	6.5.4.2, for axial resistance of piles in compression under good driving conditions where pile tip not needed	
Factored Structural Resistance, Pr (kips) Pr = Pn	392.0	602.3

•per Section 3.10.10 of MassDOT LRFD Bridge Manual, a minimum of one pile per beam is required.

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FOUNDATION SUMMARY:

PILE DESIGN

Pile Capacity:

max deflection: 0.50 in.
Pile type: H10x57
Axial Capacity: 392.0 k

Foundation Model Results: (See Strength I and Extreme Event STAAD Model Output)

max deflection: 0.11 in. (using factored loads)
max Axial Load: 97.0 k (using factored loads)

Capacity Check:

Pile type: H10x57
max deflection: OK
Axial Capacity: OK

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PILE FOUNDATION SUMMARY: **PILE DESIGN**

Pile Capacity:

Per LRFD Bridge Manual Sect. 3.10.11.3:

max allowable deflection: 0.50 in. (at Pile Cap)
Pile type: H10x57 (All Pile Properties from AISC Table 1-4)
Compact Shape: Yes

Pr = 392.0 k (Previous Page)
Fy = 50.0 ksi (50 ksi, MassDOT reccommedation)
Mr = Z * Fy
Z ≤ 1.5 * S
Zx = 66.5 in^3
Sx = 58.8 in^3
1.5 * Sx = 88.2 in^3
Use Zx = 66.5 in^3
Mrx = 277 k-ft (Strong Axis)
Zy = 30.3 in^3
Sy = 19.7 in^3
1.5 * Sy = 29.55 in^3
Use Zy = 29.55 in^3
Mry = 123 k-ft (Weak Axis)

Pile Loads: Pile Self Weight wt= 57.0 plf length = 88.00 ft.

Strength I: (From STAAD Output)				At Top Extreme Event II	At Base Extreme Event II	
			l_b=7.8' Mrx =	213	277	k-ft
Pu =	96.97	k	Pu =	70.05	70.05	k
Muz =	19.54	k-ft	Muz =	0.09	0.06	k-ft
Mux =	0.08	k-ft	Mux =	0.10	0.06	k-ft
dx =	0.108	in. (max deflectic	dx =	0.001	0	in. (max deflection)
dy =	0.018	in. (max deflectic	dy =	0.026	0	in. (max deflection)

Design Check: *(Per LRFD Bridge Manual Sect. 3.10.11.3)*

Condition 1:
(Pu/Pr) + (8/9) * [(Muz/(1.75*Mry)) + (Mux/Mrx))] ≤ 1.0

Condition 2:
dmax ≤ dallow

Strength I:				
Condition 1:	0.3410	≤	1.0	OK
Condition 2:	0.108	≤	0.5	OK
Extreme Event II:At Top				
Condition 1:	0.1923	≤	1.0	OK
Condition 2:	0.001	≤	0.5	OK
Extreme Event II: At Base				
Condition 1:	0.1919	≤	1.0	OK
Condition 2:	0.000	≤	0.5	OK

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JOB P-13-011
SHEET NO 8 OF
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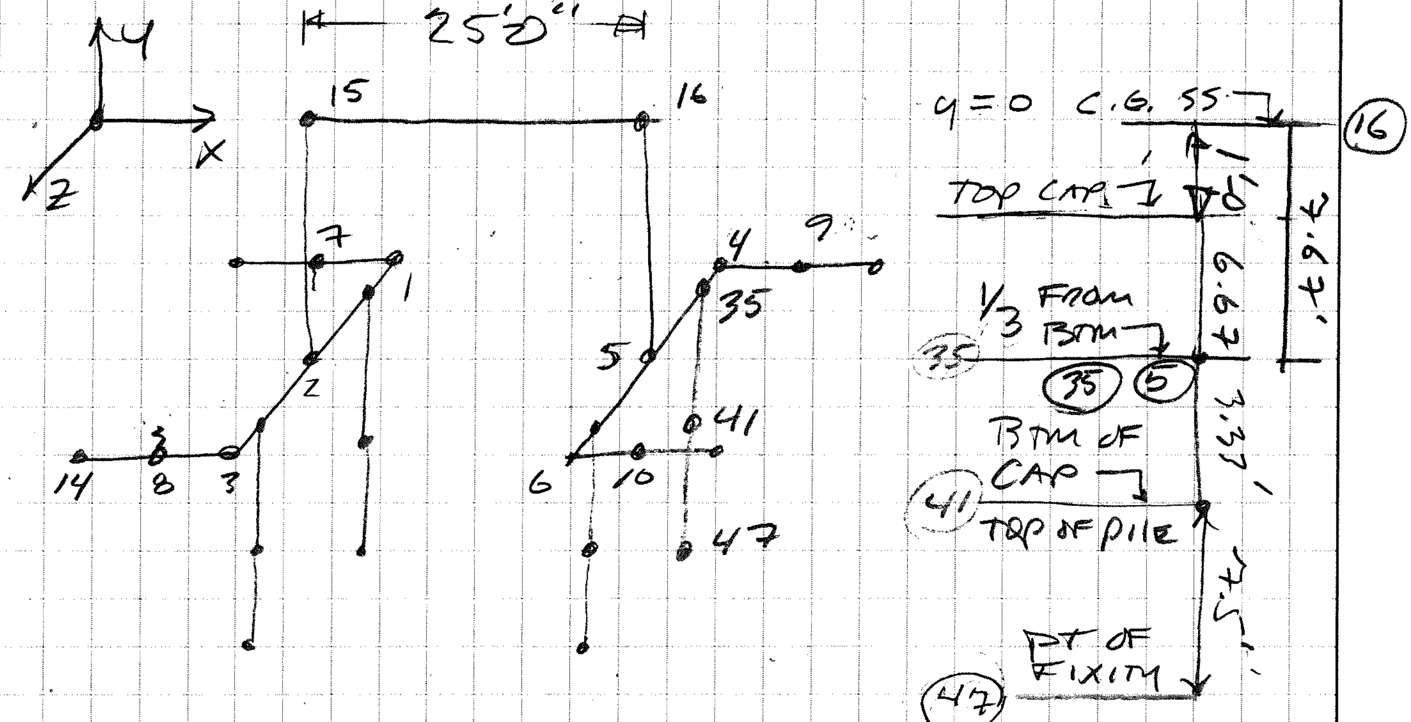
STAAD Model

REF BR.M SECT 3.10.11



ORIGIN AT NODE 1 = (0, -7.67, 0)

SOIL TYPE = WET DENSE SAND

L_E = 7.5 FT STGH I comb (TABLE 3.10-11-4)
L_E = 7.5' + 7.8' (SCOUR PER HYD. REPORT)
L_E = 15.3 FT EXTREME II Combo

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SHEET NO.	9	OF	
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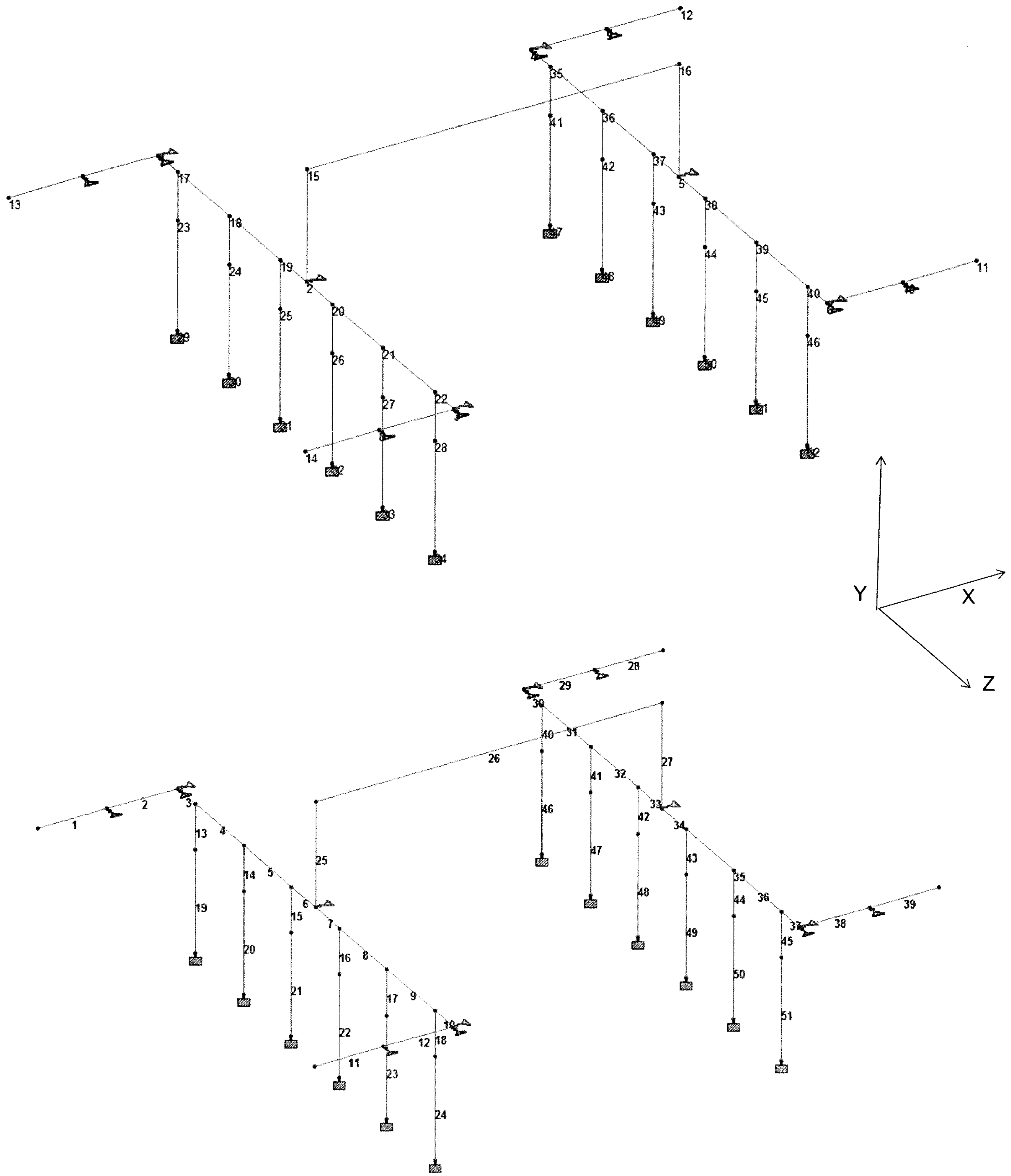
STAAD STICK MODEL

NODE & MEMBER DESIGNATIONS



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JOB	P-13-011
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CALCULATED BY	JK DATE
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STICK MODEL GEOMETRY:

STRENGTH I

Nodes: STRENGTH I

	Location (ft.)			
No.	X	Y	Z	Support
1	0.00	-7.67	0.00	Spring
2	0.00	-7.67	15.25	Spring
3	0.00	-7.67	30.50	Spring
4	25.00	-7.67	0.00	Spring
5	25.00	-7.67	15.25	Spring
6	25.00	-7.67	30.50	Spring
7	-5.00	-7.67	0.00	Spring
8	-5.00	-7.67	30.50	Spring
9	30.00	-7.67	0.00	Spring
10	30.00	-7.67	30.50	Spring
11	35.00	-7.67	30.50	-
12	35.00	-7.67	0.00	-
13	-10.00	-7.67	0.00	-
14	-10.00	-7.67	30.50	-
15	0.00	0.00	15.25	Superstructure
16	25.00	0.00	15.25	Superstructure
17	0.00	-7.67	2.75	-
18	0.00	-7.67	7.75	-
19	0.00	-7.67	12.75	-
20	0.00	-7.67	17.75	-
21	0.00	-7.67	22.75	-
22	0.00	-7.67	27.75	-
23	0.00	-11.00	2.75	BTM of Cap
24	0.00	-11.00	7.75	BTM of Cap
25	0.00	-11.00	12.75	BTM of Cap
26	0.00	-11.00	17.75	BTM of Cap
27	0.00	-11.00	22.75	BTM of Cap
28	0.00	-11.00	27.75	BTM of Cap
29	0.00	-18.50	2.75	Fixed
30	0.00	-18.50	7.75	Fixed
31	0.00	-18.50	12.75	Fixed
32	0.00	-18.50	17.75	Fixed
33	0.00	-18.50	22.75	Fixed
34	0.00	-18.50	27.75	Fixed
35	25.00	-7.67	2.75	-
36	25.00	-7.67	7.75	-
37	25.00	-7.67	12.75	-
38	25.00	-7.67	17.75	-
39	25.00	-7.67	22.75	-
40	25.00	-7.67	27.75	-
41	25.00	-11.00	2.75	BTM of Cap
42	25.00	-11.00	7.75	BTM of Cap
43	25.00	-11.00	12.75	BTM of Cap
44	25.00	-11.00	17.75	BTM of Cap
45	25.00	-11.00	22.75	BTM of Cap
46	25.00	-11.00	27.75	BTM of Cap
47	25.00	-18.50	2.75	Fixed
48	25.00	-18.50	7.75	Fixed
49	25.00	-18.50	12.75	Fixed
50	25.00	-18.50	17.75	Fixed
51	25.00	-18.50	22.75	Fixed
52	25.00	-18.50	27.75	Fixed

Members:

	Node		Properties (in, in^4)	
No.	Start	End	A	I
1	13	7	Infinite Stiffness	
2	7	1	Infinite Stiffness	
3	1	17	Infinite Stiffness	
4	17	18	Infinite Stiffness	
5	18	19	Infinite Stiffness	
6	19	2	Infinite Stiffness	
7	2	20	Infinite Stiffness	
8	20	21	Infinite Stiffness	
9	21	22	Infinite Stiffness	
10	22	3	Infinite Stiffness	
11	14	8	Infinite Stiffness	
12	8	3	Infinite Stiffness	
13	17	23	Infinite Stiffness	
14	18	24	Infinite Stiffness	
15	19	25	Infinite Stiffness	
16	20	26	Infinite Stiffness	
17	21	27	Infinite Stiffness	
18	22	28	Infinite Stiffness	
19	23	29	HP10x57 or HP12x86	
20	24	30	HP10x57 or HP12x86	
21	25	31	HP10x57 or HP12x87	
22	26	32	HP10x57 or HP12x88	
23	27	33	HP10x57 or HP12x89	
24	28	34	HP10x57 or HP12x90	
25	2	15	Infinite Stiffness	
26	15	16	468	12874
27	16	5	Infinite Stiffness	
28	9	12	Infinite Stiffness	
29	4	9	Infinite Stiffness	
30	4	35	Infinite Stiffness	
31	35	36	Infinite Stiffness	
32	36	37	Infinite Stiffness	
33	37	5	Infinite Stiffness	
34	5	38	Infinite Stiffness	
35	38	39	Infinite Stiffness	
36	39	40	Infinite Stiffness	
37	40	6	Infinite Stiffness	
38	6	10	Infinite Stiffness	
39	10	11	Infinite Stiffness	
40	35	41	Infinite Stiffness	
41	36	42	Infinite Stiffness	
42	37	43	Infinite Stiffness	
43	38	44	Infinite Stiffness	
44	39	45	Infinite Stiffness	
45	40	46	Infinite Stiffness	
46	41	47	HP10x57 or HP12x84	
47	42	48	HP10x57 or HP12x85	
48	43	49	HP10x57 or HP12x86	
49	44	50	HP10x57 or HP12x87	
50	45	51	HP10x57 or HP12x88	
51	46	52	HP10x57 or HP12x89	

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STICK MODEL GEOMETRY:

Extreme II Combo

Nodes: Extreme II Combo

	Location (ft.)			
No.	X	Y	Z	Support
1	0.00	-7.67	0.00	Spring
2	0.00	-7.67	15.25	Spring
3	0.00	-7.67	30.50	Spring
4	25.00	-7.67	0.00	Spring
5	25.00	-7.67	15.25	Spring
6	25.00	-7.67	30.50	Spring
7	-5.00	-7.67	0.00	Spring
8	-5.00	-7.67	30.50	Spring
9	30.00	-7.67	0.00	Spring
10	30.00	-7.67	30.50	Spring
11	35.00	-7.67	30.50	-
12	35.00	-7.67	0.00	-
13	-10.00	-7.67	0.00	-
14	-10.00	-7.67	30.50	-
15	0.00	0.00	15.25	Superstructure
16	25.00	0.00	15.25	Superstructure
17	0.00	-7.67	2.75	-
18	0.00	-7.67	7.75	-
19	0.00	-7.67	12.75	-
20	0.00	-7.67	17.75	-
21	0.00	-7.67	22.75	-
22	0.00	-7.67	27.75	-
23	0.00	-11.00	2.75	BTM of Cap
24	0.00	-11.00	7.75	BTM of Cap
25	0.00	-11.00	12.75	BTM of Cap
26	0.00	-11.00	17.75	BTM of Cap
27	0.00	-11.00	22.75	BTM of Cap
28	0.00	-11.00	27.75	BTM of Cap
29	0.00	-26.30	2.75	Fixed
30	0.00	-26.30	7.75	Fixed
31	0.00	-26.30	12.75	Fixed
32	0.00	-26.30	17.75	Fixed
33	0.00	-26.30	22.75	Fixed
34	0.00	-26.30	27.75	Fixed
35	25.00	-7.67	2.75	-
36	25.00	-7.67	7.75	-
37	25.00	-7.67	12.75	-
38	25.00	-7.67	17.75	-
39	25.00	-7.67	22.75	-
40	25.00	-7.67	27.75	-
41	25.00	-11.00	2.75	BTM of Cap
42	25.00	-11.00	7.75	BTM of Cap
43	25.00	-11.00	12.75	BTM of Cap
44	25.00	-11.00	17.75	BTM of Cap
45	25.00	-11.00	22.75	BTM of Cap
46	25.00	-11.00	27.75	BTM of Cap
47	25.00	-26.30	2.75	Fixed
48	25.00	-26.30	7.75	Fixed
49	25.00	-26.30	12.75	Fixed
50	25.00	-26.30	17.75	Fixed
51	25.00	-26.30	22.75	Fixed
52	25.00	-26.30	27.75	Fixed

Members:

	Node		Properties (in, in^4)	
No.	Start	End	A	I
1	13	7	Infinite Stiffness	
2	7	1	Infinite Stiffness	
3	1	17	Infinite Stiffness	
4	17	18	Infinite Stiffness	
5	18	19	Infinite Stiffness	
6	19	2	Infinite Stiffness	
7	2	20	Infinite Stiffness	
8	20	21	Infinite Stiffness	
9	21	22	Infinite Stiffness	
10	22	3	Infinite Stiffness	
11	14	8	Infinite Stiffness	
12	8	3	Infinite Stiffness	
13	17	23	Infinite Stiffness	
14	18	24	Infinite Stiffness	
15	19	25	Infinite Stiffness	
16	20	26	Infinite Stiffness	
17	21	27	Infinite Stiffness	
18	22	28	Infinite Stiffness	
19	23	29	HP10x57 or HP12x86	
20	24	30	HP10x57 or HP12x86	
21	25	31	HP10x57 or HP12x87	
22	26	32	HP10x57 or HP12x88	
23	27	33	HP10x57 or HP12x89	
24	28	34	HP10x57 or HP12x90	
25	2	15	Infinite Stiffness	
26	15	16	468	12874
27	16	5	Infinite Stiffness	
28	9	12	Infinite Stiffness	
29	4	9	Infinite Stiffness	
30	4	35	Infinite Stiffness	
31	35	36	Infinite Stiffness	
32	36	37	Infinite Stiffness	
33	37	5	Infinite Stiffness	
34	5	38	Infinite Stiffness	
35	38	39	Infinite Stiffness	
36	39	40	Infinite Stiffness	
37	40	6	Infinite Stiffness	
38	6	10	Infinite Stiffness	
39	10	11	Infinite Stiffness	
40	35	41	Infinite Stiffness	
41	36	42	Infinite Stiffness	
42	37	43	Infinite Stiffness	
43	38	44	Infinite Stiffness	
44	39	45	Infinite Stiffness	
45	40	46	Infinite Stiffness	
46	41	47	HP10x57 or HP12x84	
47	42	48	HP10x57 or HP12x85	
48	43	49	HP10x57 or HP12x86	
49	44	50	HP10x57 or HP12x87	
50	45	51	HP10x57 or HP12x88	
51	46	52	HP10x57 or HP12x89	

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SHEET NO.	12	OF	
CALCULATED BY	JK	DATE	Jan-20
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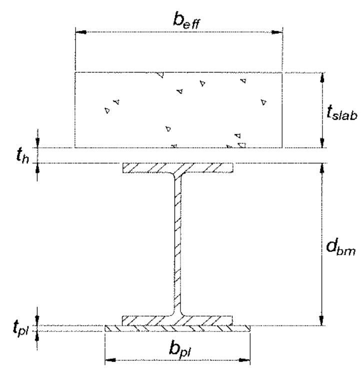
CALCULATE THEORETICAL COMPOSITE SECTION PROPERTIES -W12X58

EXTERIOR BEAM



INPUT DATA

(All units in inches)

BEAM	A =	17.00	d_{bm} =	12.12	I_o =	475.00
BOT. PLATE	b_{pl} =	0.00	t_{pl} =	0.00		
THEO. SLAB	b_{eff} =	63.00	exterior bm	8.00		
HAUNCH			t_h =	0.00	negative haunch	
MODULAR RATIO, n =		8.00				

OUTPUT

NON-COMPOSITE, n = 0

Component	Area	y	Ay	d	Ad^2	I_o
Bottom Plate	0.00	0.00	0.00	-6.06	0.00	0.00
Beam	17.00	6.06	103.02	0.00	0.00	475.00
	17.00		103.02		0.00	475.00

Y = 6.06 I_{tot} = 475.00 ***S_{bos} = 78.38*** ***S_{tos} = 78.38***

SDL COMPOSITE, 3n = 24

Component	Area	y	Ay	d	Ad^2	I_o
Bottom Plate	0.00	0.00	0.00	-11.62	0.00	0.00
Beam	17.00	6.06	103.02	-5.56	525.43	475.00
Theo. Slab	21.00	16.12	338.52	4.50	425.35	112.00
	38.00		441.54		950.78	587.00

Y = 11.62 I_{tot} = 1537.78 ***S_{bos} = 132.35*** ***S_{tos} = 3072.33*** ***S_{toc} = 180.90***

COMPOSITE, n = 8

Component	Area	y	Ay	d	Ad^2	I_o
Bottom Plate	0.00	0.00	0.00	-13.98	0.00	0.00
Beam	17.00	6.06	103.02	-7.92	1066.95	475.00
Theo. Slab	63.00	16.12	1015.56	2.14	287.91	336.00
	80.00		1118.58		1354.86	811.00

Y = 13.98 I_{tot} = 2165.86 ***S_{bos} = 154.90*** ***S_{tos} = -1163.04*** ***S_{toc} = 352.88***

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CALCULATED BY	JK	DATE	Jan-20
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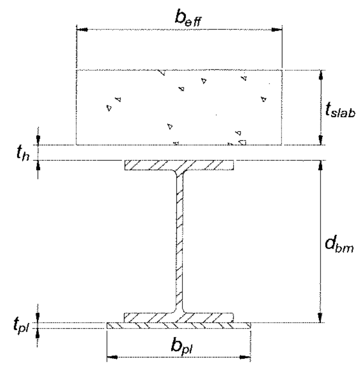
CALCULATE THEORETICAL COMPOSITE SECTION PROPERTIES -W12X58

INTERIOR



INPUT DATA

(All units in inches)

BEAM	A =	17.00	d_{bm} =	12.12	I_o =	475.00
BOT. PLATE	b_{pl} =	0.00	t_{pl} =	0.00	t_f =	0.00
THEO. SLAB	b_{eff} =	60.00	t_{slab} =	8.00		
HAUNCH			t_h =	0.00		
MODULAR RATIO, n =		8.00				

OUTPUT

NON-COMPOSITE, n = 0

Component	Area	y	Ay	d	Ad^2	I_o
Bottom Plate	0.00	0.00	0.00	-6.06	0.00	0.00
Beam	17.00	6.06	103.02	0.00	0.00	475.00
	17.00		103.02		0.00	475.00

Y = 6.06 I_{tot} = 475.00 ***S_{bos} = 78.38*** ***S_{tos} = 78.38***

SDL COMPOSITE, 3n = 24

Component	Area	y	Ay	d	Ad^2	I_o
Bottom Plate	0.00	0.00	0.00	-11.50	0.00	0.00
Beam	17.00	6.06	103.02	-5.44	502.69	475.00
Theo. Slab	20.00	16.12	322.40	4.62	427.29	106.67
	37.00		425.42		929.98	581.67

Y = 11.50 I_{tot} = 1511.65 ***S_{bos} = 131.47*** ***S_{tos} = 2429.67*** ***S_{toc} = 175.32***

COMPOSITE, n = 8

Component	Area	y	Ay	d	Ad^2	I_o
Bottom Plate	0.00	0.00	0.00	-13.90	0.00	0.00
Beam	17.00	6.06	103.02	-7.84	1044.64	475.00
Theo. Slab	60.00	16.12	967.20	2.22	295.98	320.00
	77.00		1070.22		1340.62	795.00

Y = 13.90 I_{tot} = 2135.62 ***S_{bos} = 153.65*** ***S_{tos} = -1200.49*** ***S_{toc} = 343.29***

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NON-COMPOSITE DEAD LOAD (DC1) (Unfactored)

Bridge Foundation Model Loads
STRENGTH I

Bridge Foundation Model Loads

BEAMS:

Beam 1-6:

Type: W12x58
n = 6 (quantity)

w = 0.058 klf, (each)
BM_{DC1} = n * w = **0.3 klf**

ABUTMENT APPLIED LOADS:

ABUTMENTS: (each)

H = 9.40 ft. EL. 11.0' =-EL 1.6' = 9.4'
W = 3.50 ft.
L = 30.50 ft.
w_c = 0.145 kcf
$Abut_{DC1}$ = H * W * L * w_c = **145.5 k**

BEAM END ENCASEMENT:

H = 2.67 ft.
W = 4.00 ft.
L = 30.50 ft.
w_c = 0.145 kcf
$Encase_{DC1}$ = H * L * W * w_c = **47.2 k**

INTEGRAL WINGWALL:

H = 12.50 ft.
W = 1.50 ft.
L = 10.00 ft.
w_c = 0.145 kcf
n = 1 (per abutment)
WW_{DC1} = H * W * L* n* w_c = APPLIED TO WW NODES, 7 - 10 **27.2 k**

APPROACH SLAB: (per LRFD Bridge Manual Sect. 3.10.2)

L = 1.00 ft.
W = 22.00 ft.
t = 0.833 ft.
w_c = 0.145 kcf
APP_{DC1} = L * W * t * w_c = **2.7 k**

DECK

W = 30.5 ft, (each)
t = 8 (thickness)
L = 18.0 ft (clear span length, beam ends included in encasement calc)
d.f. = 0.5 (distribution factor per abutment)
W_{DC1} = W * t/12* L * df*150PCF = **27.5 k**

P_{DC1} = 223 k

TOTALS:

L = 30.50 ft. (pile cap length)
W_{DC1} = P_{DC1}/L = **7.31 klf**

SAY: 7.40 klf

NON-COMPOSITE DEAD LOAD (DC1) (Unfactored)

Bridge Foundation Model Loads
EXTREME II COMBO

Bridge Foundation Model Loads

BEAMS:

Beam 1-6:

Type: W12x58
n = 6 (quantity)

w = 0.058 klf, (each)
$BM_{DC1} = n * w =$ **0.3 klf**

ABUTMENT APPLIED LOADS:

ABUTMENTS: (each)

H = 9.40 ft. EL. 11.0' =-EL 1.6' = 9.4'
W = 3.50 ft.
L = 30.50 ft.
w_c = 0.145 kcf
$Abut_{DC1} = H * W * L * w_c =$ **145.5 k**

BEAM END ENCASEMENT:

H = 2.67 ft.
W = 4.00 ft.
L = 30.50 ft.
w_c = 0.145 kcf
$Encase_{DC1} = H * L * W * w_c =$ **47.2 k**

INTEGRAL WINGWALL:

H = 12.50 ft.
W = 1.50 ft.
L = 10.00 ft.
w_c = 0.145 kcf
n = 2 (per abutment)
$WW_{DC1} = H * W * L * n * w_c =$ APPLIED TO WW NODES, 7 - 10 **54.4 k**

APPROACH SLAB: (per LRFD Bridge Manual Sect. 3.10.2)

L = 1.00 ft.
W = 22.00 ft.
t = 0.833 ft.
w_c = 0.145 kcf
$APP_{DC1} = L * W * t * w_c =$ **2.7 k**

DECK

W = 30.5 ft, (each)
t = 8 (thickness)
L = 18.0 ft (clear span length, beam ends included in encasement calc)
d.f. = 0.5 (distribution factor per abutment)
$W_{DC1} = W * t/12 * L * df * 150PCF =$ **27.5 k**

P_{DC1} = 223 k

TOTALS:

L = 30.50 ft. (pile cap length)
$W_{DC1} = P_{DC1}/L =$ **7.31 klf**

SAY: 7.40 klf

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SUPERIMPOSED DEAD LOAD (DC2) (Unfactored) **Bridge Foundation Model Loads**

BEAM APPLIED LOADS:

SIDEWALKS: (See Beam Design Load Calcs)

w =	1.03	klf, (north sidewalk)	
n =	1	(quantity)	**1.03 klf**
w =	0.229	klf (south safety curb)	**0.229 klf**
n =	1		
$SDWK_{DC2}$ = w * n =			**1.3 klf**

BRIDGERAIL: (See Beam Design Load Calcs)

w =	0.09	plf, (each)	
n =	2	(quantity)	
$RAIL_{DC2}$ = w * n =			**0.18 klf**

W_{DC2} = 1.44 klf

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WEARING SURFACE DEAD LOAD (DW) (Unfactored) **Bridge Foundation Model Loads**

BEAM APPLIED LOADS:

WEARING SURFACE:

$A =$ 5.50 ft^2

$w_{HMA} =$ 0.150 kcf

$WS_{DW} = A * w_{HMA} =$ **0.83 klf**

UTILITY: (See Beam Design Load Calcs)

$w =$ 0.250 klf

$n =$ 1 (quantity)

$U_{DW} = w * n =$ **0.250 klf**

$W_{DW} =$ 1.08 klf

VERTICAL EARTH LOADS (EV) & HORIZONTAL EARTH LOADS (EH) (Unfactored) **Bridge Foundation Model Loads**

Vertical Earth Pressure EV

The structure is not burried, there is not any vertical earth loads.

ABUTMENT APPLIED LOADS:
Horizontal Earth Pressure EH

Per the LRFD Bridge Manual 3.3.4.4:

Max Earth Pressure is 50% of vertical pressure, therefore the maximum equivalent fluid pressure = 0.5 * 0.120 kcf = 0.06 kcf
EH_{max} = (Depth Abutment) * 0.06 kcf

Min. Earth Pressure is 25% of vertical pressure, therefore the maximum equivalent fluid pressure = 0.25 * 0.120 kcf = 0.03 kcf
EH_{min} = (Depth Abutment) * 0.03 kcf

D = 10.00 ft.

EH_{max} = 0.600 ksf

EH_{min} = 0.300 ksf

Note: Approach slabs are used, therefore there is not any surcharge.

y = D/3 = 3.33 ft. (Location of Force)
P_{max} = 0.5 * EH_{max} * D = 3.000 k
P_{min} = 0.5 * EH_{min} * D = 1.500 k

S = 5.00 ft, Pile Spacing

$W_{max} = P_{max} * S =$ **15.00 k**
$W_{min} = P_{min} * S =$ **7.50 k**

S = 7.50 ft, Wingwall Trib Length, Nodes 7,8,9,10

$W_{max} = P_{max} * S =$ **22.50 k**
$W_{min} = P_{min} * S =$ **11.25 k**

LRFD

9-1 HL-93 Loading (LRFD)

Table of Maximum Moments, Shears, and Reactions Simple Spans, One Lane **Without** Dynamic Load Allowance

Span(ft)	Moment (k-ft)		End Shear and End Reaction (k)	
1	8.1	a	32.3	a
2	16.3	a	32.6	a
3	24.7	a	33.0	a
4	33.3	a	33.3	a
5	42.0	a	33.6	a
6	50.9	a	35.3	b
7	59.9	a	38.0	b
8	69.1	a	40.1	b
9	78.5	a	41.8	b
10	88.0	a	43.2	b
11	97.7	b	44.4	b
12	111.5	b	45.5	b
13	126.0	b	46.5	b
14	140.7	b	47.3	b
15	155.5	b	48.1	b
16	170.5	b	48.9	b
17	185.6	b	49.6	b
18	200.9	b	50.2	b
19	216.4	b	50.8	b
20	232.0	b	51.4	b
21	247.8	b	52.0	b
22	263.7	b	52.5	b
23	279.8	b	53.0	b
24	296.1	b	53.5	b
25	312.5	b	54.1	a
26	329.1	b	55.1	a
27	345.8	b	56.0	a
28	362.7	b	57.0	a
29	379.8	b	58.1	a
30	397.0	b	59.2	a
31	414.4	b	60.2	a
32	431.9	b	61.2	a
33	449.6	b	62.2	a
34	467.5	b	63.1	a
35	485.5	b	64.0	a
36	503.7	b	64.9	a
37	522.0	b	65.7	a
38	540.5	b	66.5	a
39	559.2	b	67.2	a
40	578.0	b	68.0	a

a controlled by Design Truck + Lane Loading
b controlled by Design Tandem + Lane Loading

Table of Maximum Moments, Shears, and Reactions Simple Spans, One Lane **Without** Dynamic Load Allowance (cont.)

Span(ft)	Moment (k-ft)		End Shear and End Reaction (k)	
42	617.1	a	69.4	a
44	666.9	a	70.8	a
46	717.3	a	72.1	a
48	768.3	a	73.4	a
50	820.0	a	74.6	a
52	872.3	a	75.7	a
54	925.3	a	76.8	a
56	978.9	a	77.9	a
58	1033.1	a	79.0	a
60	1088.0	a	80.0	a
62	1143.5	a	81.0	a
64	1199.7	a	82.0	a
66	1256.5	a	82.9	a
68	1313.9	a	83.9	a
70	1372.0	a	84.8	a
75	1520.0	a	87.0	a
80	1672.0	a	89.2	a
85	1828.0	a	91.3	a
90	1988.0	a	93.3	a
95	2152.0	a	95.3	a

Span(ft)	Moment (k-ft)		End Shear and End Reaction (k)	
100	2320.0	a	97.3	a
110	2668.0	a	101.1	a
120	3032.0	a	104.8	a
130	3412.0	a	108.4	a
140	3808.0	a	112.0	a
150	4220.0	a	115.5	a
160	4648.0	a	119.0	a
170	5092.0	a	122.4	a
180	5552.0	a	125.9	a
190	6028.0	a	129.3	a
200	6520.0	a	132.6	a
220	7552.0	a	139.3	a
240	8648.0	a	146.0	a
260	9808.0	a	152.6	a
280	11032.0	a	159.2	a
300	12320.0	a	165.8	a

a controlled by Design Truck + Lane Loading
b controlled by Design Tandem + Lane Loading

Table of Maximum Moments, Shears, and Reactions Simple Spans, One Lane **With** Dynamic Load Allowance (cont.)

Span(ft)	Moment (k-ft)		End Shear and End Reaction (k)		Span(ft)	Moment (k-ft)		End Shear and End Reaction (k)	
1	10.7	a	42.9	a	21	317.9	b	66.9	b
2	21.6	a	43.2	a	22	338.0	b	67.5	b
3	32.6	a	43.5	a	23	358.2	b	68.1	b
4	43.8	a	43.8	a	24	378.6	b	68.6	b
5	55.2	a	44.2	a	25	399.1	b	69.3	a
6	66.7	a	46.3	b	26	419.8	b	70.5	a
7	78.4	a	49.7	b	27	440.7	b	71.7	a
8	90.2	a	52.4	b	28	461.7	b	72.8	a
9	102.2	a	54.6	b	29	482.9	b	74.2	a
10	114.4	a	56.4	b	30	504.3	b	75.6	a
11	126.7	b	57.9	b	31	525.8	b	76.8	a
12	144.5	b	59.3	b	32	547.4	b	78.1	a
13	163.1	b	60.4	b	33	569.2	b	79.2	a
14	181.9	b	61.5	b	34	591.2	b	80.4	a
15	200.9	b	62.4	b	35	613.4	b	81.4	a
16	220.0	b	63.3	b	36	635.7	b	82.5	a
17	239.3	b	64.1	b	37	658.1	b	83.4	a
18	258.7	b	64.9	b	38	680.8	b	84.4	a
19	278.3	b	65.6	b	39	703.6	b	85.3	a
20	298.0	b	66.3	b	40	726.5	b	86.2	a

a controlled by Design Truck + Lane Loading
b controlled by Design Tandem + Lane Loading

Table of Maximum Moments, Shears, and Reactions Simple Spans, One Lane **With** Dynamic Load Allowance (cont.)

Span(ft)		Moment (k-ft)		End Shear and End Reaction (k)	
42	————	774.2	a	87.9	a
44	————	835.8	a	89.5	a
46	————	898.1	a	91.1	a
48	————	961.0	a	92.5	a
50	————	1024.6	a	93.9	a
52	————	1088.8	a	95.2	a
54	————	1153.6	a	96.5	a
56	————	1219.1	a	97.7	a
58	————	1285.2	a	98.9	a
60	————	1352.0	a	100.1	a
62	————	1419.4	a	101.2	a
64	————	1487.4	a	102.3	a
66	————	1556.1	a	103.3	a
68	————	1625.4	a	104.4	a
70	————	1695.4	a	105.4	a
75	————	1873.1	a	107.8	a
80	————	2054.8	a	110.2	a
85	————	2240.5	a	112.4	a
90	————	2430.2	a	114.6	a
95	————	2623.9	a	116.8	a

Span(ft)		Moment (k-ft)		End Shear and End Reaction (k)	
100	————	2821.6	a	118.8	a
110	————	3229.0	a	122.8	a
120	————	3652.4	a	126.7	a
130	————	4091.8	a	130.5	a
140	————	4547.2	a	134.2	a
150	————	5018.6	a	137.8	a
160	————	5506.0	a	141.4	a
170	————	6009.4	a	144.9	a
180	————	6528.8	a	148.4	a
190	————	7064.2	a	151.9	a
200	————	7615.6	a	155.3	a
220	————	8766.4	a	162.1	a
240	————	9981.2	a	168.8	a
260	————	11260.0	a	175.5	a
280	————	12602.8	a	182.2	a
300	————	14009.6	a	188.8	a

a controlled by Design Truck + Lane Loading

b controlled by Design Tandem + Lane Loading

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LIVE LOAD (LL) (Unfactored) **Bridge Foundation Model Loads**

Note: Live load results are from Caltrans Bridge Design Aids, Reaction at beam end.

R_{LLmax} = 52.5 k, (From LL Shear at Beam End) **STRENGTH I**

2 lanes loaded: $R_{LLmax} * 2 =$ 105 k

3 lanes loaded: $R_{LLmax} * 3 * 0.9 =$ **N/A** (Point Load Appliend at Beam Ends)

Non-essential bridge under Etreme II Load Combo

R_{LLmax} = 0 k, (From LL Shear at Beam End) **EXTREME II**

CENTRIFUGAL FORCE (CE) & PEDESTRIAN LIVE LOAD (PL) (Unfactored) **Bridge Foundation Model Loads**

LRFD Bridge Manual Sect. 3.10.2.2

Centrifugal Force (CE):

Centrifugal force shall be considered in the design of integral abutments of a curved bridge.

The structure is neither curved nor on a curved section of roadway. Therefore centrifugal forces do not need to be considered.

Pedestrian Live Load (PL):

For bridges with sidewalks, the following two cases are to be investigated and the most conservative shall be used.

1. *Pedestrian load is ignored. The number of traffic lanes is calculated based on the total out-to-out width of the bridge, including the width of sidewalk(s) as if it was/were a part of the travelled way.*
2. *The number of traffic lanes is calculated based on the actual curb-to-curb width. Pedestrian load is applied to the abutment.*

The structure has a mountable sidewalk and therefore the pedestrian live load does not need to be considered per AASHTO LRFD 3.6.1.6

BRAKING FORCE (BR) (Unfactored) **Bridge Foundation Model Loads**

Breaking Force (BR):

LRFD Bridge Manual Sect. 3.10.2.2

Braking forces shall not be considered in the design of integral abutments due to the fact that they are resisted by the soil forces acting on the rear face of the abutments.

AASHTO LRFD Sect. 3.6.4

Breaking force shall be taken as the greater of:

1. 25% of the axle weights of the design truck or design tandem.
2. 5% of the design truck plus lane load or 5% of the design tandem plus lane load.

Case I: *(Include multiple presence factors, m = 1.00, See Beam Live Load Calcs)*

25% Truck = 0.25(8 + 32 + 32) * m = 18.0 k

25% Tandem = 0.25(25 + 25) * m = 12.5 k

Case II: *(Include multiple presence factors, m = 1.00, See Beam Live Load Calcs)*

$W =$ 10.0 ft. (Lane Load Width)
$w_{LL} =$ 0.640 klf
$P_{LL} = W * w_{LL} =$ 6.40 k

5% (Truck + Lane Load) = $0.05((8 + 32 + 32) * m + P_{LL}) =$ 3.9 k

5% (Tandem + Lane Load) = $0.05((25 + 25) * m + P_{LL}) =$ 2.8 k

BR = ~~18.0 k~~ applied at 6.0' above the roadway surface

This structure has integral abutments, therefore braking forces do not need to be considered.

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Bridge Foundation Model Loads

LIVE LOAD SURCHARGE LS (Unfactored)

AASHTO LRFD 3.11.6

The factored soil stress increases behind or within the wall caused by concentrated surcharge loads or stresses...

There are approach slabs at both approaches, therefore no live load surcharge exists.

UNIFORM SURCHARGE ES (Unfactored)

No uniform surcharge

DOWNDRAG DD (Unfactored)

AASHTO LRFD 3.11.8

Possible development of downdrag on piles or shafts shall be evaluated where:

1. *Sites are underlain by compressible material such as clays, silts, or organic soils.*
2. *Fill will be or has recently been placed adjacent to the piles or shafts, such as is frequently the case for bridge approach fills.*
3. *The groundwater is substantially lowered.*
4. *Liquefaction of loose sandy soil can occur.*

The downdrag forces will not be calculated based on Geotechnical Report.

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UNIFORM TEMPERATURE LOADS (TU) (Unfactored) **Bridge Foundation Model Loads**

Note: See Beam Design Loads for Thermal Calcs.

ΔT_{Rise} = 70 deg. F (ambient of 50 deg. F) (LRFD Bridge Manual 3.1.8)
ΔT_{Fall} = 100 deg. F (ambient of 70 deg. F) (LRFD Bridge Manual 3.1.8)

$\delta_T = L\alpha\Delta T$ (AASHTO LRFD Eq. 3.12.2.3-1)

δ_{TRise} = 0.068 in. (Beam Expansion)
δ_{TFall} = 0.098 in. (Beam Contraction)

UNIFORM TEMPERATURE LOADS (TU) (Unfactored) **Beam Design Loads**

Structure Type: Steel
Fixed Locations: Midspan (Zero Movement)
Location of movement: Ends (Per LRFD Bridge Manual Sect. 3.10.2.4)

L= 12.50 ft. (distance from movement location to zero movement)

α = 0.0000065 (LRFD Bridge Manual 3.1.8)

ΔT_{Rise} = 70 deg. F (ambient of 50 deg. F) (LRFD Bridge Manual 3.1.8)
ΔT_{Fall} = 100 deg. F (ambient of 70 deg. F) (LRFD Bridge Manual 3.1.8)

$\delta_T = L\alpha\Delta T$ (AASHTO LRFD Eq. 3.12.2.3-1)

δ_{TRise} = 0.068250 in. (Beam Expansion)
δ_{TFall} = 0.097500 in. (Beam Contraction)

Design for cold climate per AASHTO's procedure A (LRFD Bridge Manual 3.1.8.1)

AASHTOware BrD calculates beam expansion and contraction due thermal loads.

TEMPERATURE Gradient (TG) (Unfactored)

LRFD Bridge Manual Sect. 3.1.8.2

The effects of a thermal gradient need not be considered for typical steel or concrete girder bridges with concrete or timber decks, for timber bridges, or for solid slab and deck beam bridges.

This bridge is a typical steel girder bridge and therefore temperature gradient does not need to be considered

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Hydrodynamic Forces (WA):

Note: Hydrodynamic Coefficients are metric

Flood EL:

10 yr:	12.85
50 yr:	14.17
100 yr:	14.61
500 yr:	15.44

Streambed EL:	4.6	(upstream)
Streambed EL:	4.6	(down stream)
Low Chord EL:	11.46	(down stream)

S =	2.5	ft.	*0.762*	*m*	(Superstructure Height)
L =	18.0	ft.	*5.486*	*m*	(Span Length)
W =	30.5	ft.	*9.296*	*m*	(Superstructure Width)

hu = Flood EL - Upstream Streambed EL

hu_{10} =	8.25	ft.	*2.515*	*m*
hu_{50} =	9.57	ft.	*2.917*	*m*
hu_{100} =	10.01	ft.	*3.051*	*m*
hu_{500} =	10.84	ft.	*3.304*	*m*

hb = Low Chord EL - Down Stream Streambed EL = 6.86 ft

h* = (hu - hb)/S

h^*_{10} =	0.556	*0.556*
h^*_{50} =	1.084	*1.084*
h^*_{100} =	1.260	*1.260*
h^*_{500} =	1.592	*1.592*

g =	32.2	ft/s^2	*9.81*	*m/s^2*
p =	62.4	pcf	*997*	*kg/m^3*

v = Upstream Flood Flow Velocity from Hydraulic Report

v_{10} =	6.8	ft/s	*2.073*	*m/s*
v_{50} =	9.0	ft/s	*2.743*	*m/s*
v_{100} =	9.0	ft/s	*2.743*	*m/s*
v_{500} =	8.4	ft/s	*2.560*	*m/s*

Fr = $v/(hu*g)^{0.5}$

Fr_{10} =	0.417	*0.417*
Fr_{50} =	0.513	*0.513*
Fr_{100} =	0.501	*0.501*
Fr_{500} =	0.450	*0.450*

e = 2.718 (Eulers Number)

Notes:

1. All coefficient values are from Hydrodynamic Forces on Inundated Bridge Decks May 2009 Table 1
2. Use 6 girder values

Upper Values:		Lower Values:	
A =	2.7	A =	2.7
B =	2.7	B =	2.7
a =	2.15	a =	1.75
b =	2	b =	3
c =	0.65	c =	0.62
d =	1	d =	0.08
f =	1.4	f =	1.6
g =	0.03	g =	-0.07
α =	2	α =	2

Hydrodynamic Forces (WA) Cont.:

Drag Coefficient:

$C_D = A*e^{-2*(h*)^2} - B*e^{-0.75*(h*)^2} + a$ (3 and 6 Girder Bridges Only)

$C_{D10, Low} =$ 1.064
$C_{D10, Up} =$ 1.464

$C_{D50, Low} =$ 0.889
$C_{D50, Up} =$ 1.289

$C_{D100, Low} =$ 1.042
$C_{D100, Up} =$ 1.442

$C_{D500, Low} =$ 1.363
$C_{D500, Up} =$ 1.763

Lift Coefficient:

$C_L = b[(e^{-3.5*(h*)^2})-(e^{-c*(h*)^{1.7}})]$ (3 and 6 Girder Bridges Only)

$C_{L50, Low} =$ -1.370

$C_{L50, Up} =$ -0.896

$C_{L50, Low} =$ -1.424
$C_{L50, Up} =$ -0.916

$C_{L100, Low} =$ -1.186
$C_{L100, Up} =$ -0.756

$C_{L500, Low} =$ -0.764
$C_{L500, Up} =$ -0.477

Moment Coefficient:

$C_M = d*(h*)^{\alpha} * e^{-f*(h*)^2} + g$ (All Bridge Types)

$C_{M10, Low} =$ -0.055

$C_{M10, Up} =$ 0.231

$C_{M50, Low} =$ -0.056
$C_{M50, Up} =$ 0.257

$C_{M100, Low} =$ -0.060
$C_{M100, Up} =$ 0.202

$C_{M500, Low} =$ -0.066
$C_{M500, Up} =$ 0.103

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Hydrodynamic Forces (WA) Cont.:

Drag Force:

F_D = $pC_Dv^2S/2$ for h* > 1 **OR** $pC_Dv^2Sh^*/2$ for h* < 1

$F_{D10, Low}$ =	1266.5	N/m	=	0.087	k/ft of span length
$F_{D10, Up}$ =	1742.8	N/m	=	0.119	k/ft of span length
$F_{D50, Low}$ =	2541.2	N/m	=	0.174	k/ft of span length
$F_{D50, Up}$ =	3684.6	N/m	=	0.252	k/ft of span length
$F_{D100, Low}$ =	2978.5	N/m	=	0.204	k/ft of span length
$F_{D100, Up}$ =	4121.9	N/m	=	0.282	k/ft of span length
$F_{D500, Low}$ =	3395.2	N/m	=	0.233	k/ft of span length
$F_{D500, Up}$ =	4391.2	N/m	=	0.301	k/ft of span length

Lift Force:

$F_L = p^*C_Lv^2W/2$

$F_{L10, Low}$ =	-27278.7	N/m	=	-1.869	k/ft of span length
$F_{L10, Up}$ =	-17837.3	N/m	=	-1.222	k/ft of span length
$F_{L50, Low}$ =	-49666.6	N/m	=	-3.403	k/ft of span length
$F_{L50, Up}$ =	-31952.5	N/m	=	-2.189	k/ft of span length
$F_{L100, Low}$ =	-41356.8	N/m	=	-2.834	k/ft of span length
$F_{L100, Up}$ =	-26361.1	N/m	=	-1.806	k/ft of span length
$F_{L500, Low}$ =	-23220.4	N/m	=	-1.591	k/ft of span length
$F_{L500, Up}$ =	-14489.1	N/m	=	-0.993	k/ft of span length

Moment:

$M = p^*C_M{}^*v^2W^2/2$

$M_{10, Low}$ =	-10164.0	N-m/m	=	-0.696	k-ft/ft of span length
$M_{10, Up}$ =	42665.8	N-m/m	=	2.923	k-ft/ft of span length
$M_{50, Low}$ =	-18043.9	N-m/m	=	-1.236	k-ft/ft of span length
$M_{50, Up}$ =	83248.3	N-m/m	=	5.704	k-ft/ft of span length
$M_{100, Low}$ =	-19447.0	N-m/m	=	-1.333	k-ft/ft of span length
$M_{100, Up}$ =	65479.2	N-m/m	=	4.487	k-ft/ft of span length
$M_{500, Low}$ =	-18776.3	N-m/m	=	-1.287	k-ft/ft of span length
$M_{500, Up}$ =	29068.4	N-m/m	=	1.992	k-ft/ft of span length

Extreme Event Loads:

F_D =	**0.30**	**k/ft of span length**	**$F_Z = F_D$ * 18ft /2 =**	**2.71 k**
F_L =	**3.40**	**k/ft of span length**	**$F_Y = F_L$ * 18ft /2 =**	**30.6 k**
M_{CG} =	**5.70**	**k-ft/ft of span length**	**$M_X = M_{CG}$ * 18ft /2 =**	**51.3 k-ft**

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Hydrodynamic Forces (WA) Cont.:

From Publication No. FHWA-HFT-09-028
Hydrodynamic Forces on Inundated Bridge Decks May 2009

Table 1. Fitting equation coefficient values for six-girder (6-g) and three-girder (3-g) bridges.

Equation	A	B	a	b	c	d	f	g	α
6-g upper	2.7	2.7	2.15	2	0.65	1	1.4	0.03	2
6-g lower	2.7	2.7	1.75	3	0.62	0.8	1.6	-0.07	2
3-g upper	1.8	2	1.95	2	0.6	1	1.5	0	2
3-g lower	1.8	2	1.62	3	0.5	0.8	1.5	-0.11	2

Table 2. Fitting equation coefficient values for the streamlined bridge.

Equation	m	n	j	d	f	g	α
Streamlined upper	1.2	0.25	1.4	0.25	0.8	0.05	3
Streamlined lower	1.7	0.11	1.0	0.25	0.8	0	3

Table 3. Critical coefficient values by bridge type.

Bridge type	C_D	h^*_{crit}	C_L	h^*_{crit}	C_M	h^*_{crit}
6-g	2.15	0, > 3	-1.644	0.8025	0.2927 hi -0.07 lo	0.8452 0, > 2.5
3-g	1.95	0, > 3	-1.815	0.8312	0.2453 hi -0.11 lo	0.8165 0, > 2.5
Streamlined	~ 1.1	~ 4	-1.219	1.367	0.1932	1.369

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WATER LOAD (WA) (Unfactored) **Bridge Foundation Model Loads**

AASHTO LRFD 3.7.2 Bouyancy

Bouyancy shall be considered to be an uplift force, taken as the sum of the vertical components of static pressures acting on all components below design water level.

Bouyancy shall be considered as part of uplift analysis

AASHTO LRFD 3.7.3 Stream Pressure

The pressure of flowing water in the longitudinal direction.

Stream pressure shall be considered as part of uplift analysis

AASHTO LRFD 3.7.3 Wave Load

Water load shall be considered as part of uplift

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WIND LOAD ON STRUCTURE (WS) (Unfactored) **Bridge Foundation Model Loads**

Design Wind Speed:

$V_{DZ} = 2.5 * V_0(V_{30}/V_B)\ln(Z/Z_0)$ (AASHTO LRFD EQ. 3.8.1.1-1)

Surface Condition: Open Country (AASHTO LRFD C.3.8.1.1)
$V_0 =$ 8.20 mph (AASHTO LRFD Table 3.8.1.1-1)
$Z_0 =$ 0.23 ft. (AASHTO LRFD Table 3.8.1.1-1)
V30 = VB = 100 mph
Top of Slab: EL 13.9 (avg)
Design Water: EL 4.6
Barrier Height: 3.82 ft.
Z = Top of Slab EL + Barrier Height -Design Water EL
Z = 13.12 (height of structure above design water level) < 30'

Use: $V_{DZ} =$ 100.0 mph

Wind Pressure on Structure:

$P_D = P_B(V_{DZ}^2/10{,}000)$ (AASHTO LRFD EQ. 3.8.1.2.1-1)

Superstructure Component: Beams (Conservatively assumed to be an arch)
$P_B =$ 0.050 ksf Windward (AASHTO LRFD Table 3.8.1.2.1-1)
$P_B =$ NA Leeward (AASHTO LRFD Table 3.8.1.2.1-1)

$P_B =$ 0.050 ksf (AASHTO LRFD C3.8.1.2.2)

$P_D =$ 0.050 ksf

A = 150.3 ft^2

Vw = P_D * A = 7.5 k

Rw = Vw / 2 = **3.8 k** (Reaction at each abutment)

WIND ON LIVE LOAD (WL) (Factored)

Skew: 0 deg.
$F_{Normal} =$ 0.100 klf (AASHTO LRFD Table 3.8.1.3-1)
$F_{Parallel} =$ 0.000 klf (AASHTO LRFD Table 3.8.1.3-1)
Width = 10.0 ft. (Same as Design Lane Load)
applied at 6.0' above roadway

Note: AASHTOware BrD applies the wind load on the live load. See output

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ICE LOAD (IC) (Unfactored) **Bridge Foundation Model Loads**

AASHTO LRFD 3.9.1

Ice forces on piers shall be determined with reguard to site condition and expected modes of ice action.

The structure is a single span and does not utilize any piers. Therefore the ice loads do not need to be considered.

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EARTHQUAKE LOAD (EQ) (Unfactored) **Bridge Foundation Model Loads**

LRFD Bridge Manual Sect. 3.4.1.2:

All seismic analysis and design of bridges shall be performed in accordance with the AASHTO Guide Specifications for LRFD Seismic Bridge Design.

The following is per AASHTO Guide Specifications for LRFD Seismic Bridge Design:

PGA = 0.08 **Figure 3.4.1-2b** (Use charts from MassDOT LRFD Bridge Manual)
S_S = 0.135 **Figure 3.4.1-3b** (Use charts from MassDOT LRFD Bridge Manual)
S_1 = 0.05 **Figure 3.4.1-4b** (Use charts from MassDOT LRFD Bridge Manual)

Site Class: D **Table 3.4.2.1-1** Soil to EL. -40.0' **15< N<50**

$F_a = F_{pga}$ = 1.6 **Table 3.4.2.3-1**
F_v = 2.4 **Table 3.4.2.3-2**

$A_s = F_{pga} * PGA$ **Equation 3.4.1-1**
A_s = 0.128

$S_{DS} = F_a * S_s$ **Equation 3.4.1-2**
S_{DS} = 0.216

$S_{D1} = F_v * S_1$ **Equation 3.4.1-3**
S_{D1} = 0.120

SDC = A **Table 3.5-1**

$T_s = S_{D1}/S_{DS}$ **Equation 3.4.1-6**
T_s = 0.556

$T_o = 0.2 * T_s$ **Equation 3.4.1-5**
T_o = 0.111

$S_a = S_{DS}$ **Equation 3.4.1-7**
S_a = 0.216

$T = S_{D1}/S_a$ **Equation 3.4.1-8**
T = 0.556

$S_a = (S_{DS} - A_S) * (T/T_o) + A_s$ **Equation 3.4.1-4**
S_a = 0.568

Design Category A Requirements: **Sect. 4.6**

As > 0.05, therefore the horizontal design connection force in the restrained directions shall not be <0.25 times the vertical reaction due to the tributary permanent load and the tributary live loads.

Horizontal Design Connection Force:

RXN	DL (k)	LL (k)	% Vert. Reaction	Total (k)
1	303.0	105	25	**102.0**

DL = ((DC1 + DC2 +DW) * Span length)/2 + (Encasement + Wingwalls)
See AASHTOware BrD output for LL
Total = (DL + LL) % Vert. Reaction

SDC A: **Sect. 3.5**

1 No identification of ERS according to section 3.3
2 No Demand analysis
3 No implicit capacity check needed
4 No capacity design required
5 Minimum detailing requirements for support length, superstructure/substructure connection design force, and column transvers steel
6 No liquefaction evaluation required

```
**************************************************
*                                                *
*          STAAD.Pro V8i SELECTseries6           *
*          Version  20.07.11.45                  *
*          Proprietary Program of                *
*          Bentley Systems, Inc.                 *
*          Date=    MAR 18, 2020                 *
*          Time=    13:17:51                     *
*                                                *
*     USER ID: bayside                           *
**************************************************
```

STRENGTH I

```
     1. STAAD SPACE
INPUT FILE: Q:\Projects\19 PROJECTS\2192599 - TOWN OF PLYMOUTH Bridge Replacement\Calculations\Pile De.. .STD
     2. START JOB INFORMATION
     3. ENGINEER DATE 12-JAN-20
     4. ENGINEER NAME JK
     5. END JOB INFORMATION
     6. * FILE: STRENGTH I
     7. * BRIDGE: P-13-001, PLYMOUTH
     8. * PILE: HP 10X57
     9. * STRENGTH I
    10. *
    11. UNIT FEET POUND
    12. JOINT COORDINATES
    13. 1 0 -7.67 0; 2 0 -7.67 15.25; 3 0 -7.67 30.5; 4 25 -7.67 0
    14. 5 25 -7.67 15.25; 6 25 -7.67 30.5; 7 -5 -7.67 0; 8 -5 -7.67 30.5
    15. 9 30 -7.67 0; 10 30 -7.67 30.5; 11 35 -7.67 30.5; 12 35 -7.67 0
    16. 13 -10 -7.67 0; 14 -10 -7.67 30.5; 15 0 0 15.25; 16 25 0 15.25
    17. 17 0 -7.67 2.75; 18 0 -7.67 7.75; 19 0 -7.67 12.75; 20 0 -7.67 17.75
    18. 21 0 -7.67 22.75; 22 0 -7.67 27.75; 23 0 -11 2.75; 24 0 -11 7.75
    19. 25 0 -11 12.75; 26 0 -11 17.75; 27 0 -11 22.75; 28 0 -11 27.75
    20. 29 0 -18.5 2.75; 30 0 -18.5 7.75; 31 0 -18.5 12.75; 32 0 -18.5 17.75
    21. 33 0 -18.5 22.75; 34 0 -18.5 27.75; 35 25 -7.67 2.75; 36 25 -7.67 7.75
    22. 37 25 -7.67 12.75; 38 25 -7.67 17.75; 39 25 -7.67 22.75
    23. 40 25 -7.67 27.75; 41 25 -11 2.75; 42 25 -11 7.75; 43 25 -11 12.75
    24. 44 25 -11 17.75; 45 25 -11 22.75; 46 25 -11 27.75; 47 25 -18.5 2.75
    25. 48 25 -18.5 7.75; 49 25 -18.5 12.75; 50 25 -18.5 17.75
    26. 51 25 -18.5 22.75; 52 25 -18.5 27.75
    27. MEMBER INCIDENCES
    28. 1 13 7; 2 7 1; 3 1 17; 4 17 18; 5 18 19; 6 19 2; 7 2 20; 8 20 21
    29. 9 21 22; 10 22 3; 11 14 8; 12 8 3; 13 17 23; 14 18 24; 15 19 25
    30. 16 20 26; 17 21 27; 18 22 28; 19 23 29; 20 24 30; 21 25 31; 22 26 32
    31. 23 27 33; 24 28 34; 25 2 15; 26 15 16; 27 16 5; 28 9 12; 29 4 9
    32. 30 4 35; 31 35 36; 32 36 37; 33 37 5; 34 5 38; 35 38 39; 36 39 40
    33. 37 40 6; 38 6 10; 39 10 11; 40 35 41; 41 36 42; 42 37 43; 43 38 44
    34. 44 39 45; 45 40 46; 46 41 47; 47 42 48; 48 43 49; 49 44 50; 50 45 51
    35. 51 46 52
    36. UNIT INCHES POUND
    37. MEMBER PROPERTY AMERICAN
    38. 19 TO 24 PRIS AX 16.8 AZ 16.8 IX 294 IY 1E+006 IZ 101
```

```
39. 46 TO 51 PRIS AX 16.8 AZ 16.8 IX 294 IY 1E+006 IZ 101
40. UNIT FEET KIP
41. MEMBER PROPERTY AMERICAN
42. 26 PRIS AX 468 IX 12874 IY 1E+006 IZ 1E+006
43. 25 27 PRIS AX 1000 AY 1000 AZ 1000 IX 1E+006 IY 1E+006 IZ 1E+006
44. 1 TO 18 PRIS AX 1000 AY 1000 AZ 1000 IX 1E+006 IY 1E+006 IZ 1E+006
45. 28 TO 45 PRIS AX 1000 AY 1000 AZ 1000 IX 1E+006 IY 1E+006 IZ 1E+006
46. DEFINE MATERIAL START
47. ISOTROPIC MATERIAL1
48. E 580393
49. POISSON 0.2
50. DENSITY 0.15
51. ISOTROPIC STEEL
52. E 4.176E+006
53. POISSON 0.3
54. DENSITY 0.489024
55. ALPHA 6E-006
56. DAMP 0.03
57. TYPE STEEL
58. STRENGTH FY 5184 FU 8352 RY 1.5 RT 1.2
59. ISOTROPIC CONCRETE
60. E 453600
61. POISSON 0.17
62. DENSITY 0.150336
63. ALPHA 5E-006
64. DAMP 0.05
65. TYPE CONCRETE
66. STRENGTH FCU 576
67. END DEFINE MATERIAL
68. UNIT INCHES KIP
69. CONSTANTS
70. MATERIAL STEEL MEMB 19 TO 24 26 46 TO 51
71. MATERIAL CONCRETE MEMB 1 TO 18 25 27 TO 45
72. UNIT FEET KIP
73. SUPPORTS
74. 29 TO 34 47 TO 52 FIXED
75. 7 9 FIXED BUT FX FY MX MY MZ KFZ 108
76. 8 10 FIXED BUT FX FY MX MY MZ KFZ 108
77. 2 FIXED BUT FY FZ MX MY MZ KFX 170.2
78. 5 FIXED BUT FY FZ MX MY MZ KFX 170.2
79. 1  3 FIXED BUT FY FZ MX MY MZ KFX 85.1
80. 4  6 FIXED BUT FY FZ MX MY MZ KFX 85.1
81. SPRING COMPRESSION
82. 7 9 KFZ
83. SPRING TENSION
84. 8 10 KFZ
85. SPRING COMPRESSION
86. 1 TO 3 KFX
87. SPRING TENSION
88. 4 TO 6 KFX
89. *NON-COMPOSITE DEAD LOAD
90. LOAD 1 (DC 1)
91. MEMBER LOAD
92. 26 UNI GY -0.3
93. 3 TO 10 UNI GY -7.4
94. 30 TO 37 UNI GY -7.4
```

```
 95. JOINT LOAD
 96. 7 TO 10 FY -27.2
 97. *SUPERIMPOSED DEAD LOAD
 98. LOAD 2 (DC 2)
 99. MEMBER LOAD
100. 26 UNI GY -1.44
101. *WEARING SURFACE
102. LOAD 3 (DW)
103. MEMBER LOAD
104. 26 UNI GY -1.08
105. *VERTICAL EARTH PRESSURE
106. LOAD 4 (EV)
107. *HORIZONTAL EARTH PRESSURE (MAX)
108. LOAD 5 (EH MAX)
109. JOINT LOAD
110. 17 TO 22 FX 15
111. 35 TO 40 FX -15
112. 8 10 FZ 22.5
113. 7 9 FZ -22.5
114. *HORIZONTAL EARTH PRESSURE (MIN)
115. LOAD 6 (EH MIN)
116. JOINT LOAD
117. 17 TO 22 FX 7.5
118. 35 TO 40 FX -7.5
119. 8 10 FZ 11.25
120. 7 9 FZ -11.25
121. *LIVE LOAD
122. LOAD 7 (LL)
123. JOINT LOAD
124. 15 FY -105
125. 16 FY -105
126. *THERMAL LOADS
127. *SHRINK
128. LOAD 8 LOADTYPE TEMPERATURE  TITLE TU (SHRINK)
129. TEMPERATURE LOAD
130. 26 TEMP -100
131. *EXPAND
132. LOAD 9 LOADTYPE TEMPERATURE  TITLE TU (EXPAND)
133. TEMPERATURE LOAD
134. 26 TEMP 70
135. *LOAD COMBINATIONS
136. *STRENGTH I LOAD COMBINATIONS
137. *SHRINK
138. LOAD COMB 10 STRENGTH I COMBINATION 1
139. 1 1.25 2 1.25 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 0.5 9 0.0
140. LOAD COMB 11 STRENGTH I COMBINATION 2
141. 1 1.25 2 1.25 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 1.2 9 0.0
142. LOAD COMB 12 STRENGTH I COMBINATION 3
143. 1 1.25 2 1.25 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 0.5 9 0.0
144. *DEAD LOAD ONLY
145. LOAD COMB 13 STRENGTH I COMBINATION 4
146. 1 1.25 2 1.25 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 1.2 9 0.0
147. LOAD COMB 14 STRENGTH I COMBINATION 13
148. 1 0.9 2 0.9 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 0.5 9 0.0
149. LOAD COMB 15 STRENGTH I COMBINATION 14
150. 1 0.9 2 0.9 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 1.2 9 0.0
```

```
151. LOAD COMB 16 STRENGTH I COMBINATION 15
152. 1 0.9 2 0.9 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 0.5 9 0.0
153. LOAD COMB 17 STRENGTH I COMBINATION 16
154. 1 0.9 2 0.9 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 1.2 9 0.0
155. *EXPAND
156. LOAD COMB 18 STRENGTH I COMBINATION 17
157. 1 1.25 2 1.25 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 0.5
158. LOAD COMB 19 STRENGTH I COMBINATION 18
159. 1 1.25 2 1.25 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 1.2
160. LOAD COMB 20 STRENGTH I COMBINATION 19
161. 1 1.25 2 1.25 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 0.5
162. LOAD COMB 21 STRENGTH I COMBINATION 20
163. 1 1.25 2 1.25 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 1.2
164. LOAD COMB 22 STRENGTH I COMBINATION 29
165. 1 0.9 2 0.9 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 0.5
166. LOAD COMB 23 STRENGTH I COMBINATION 30
167. 1 0.9 2 0.9 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 1.2
168. LOAD COMB 24 STRENGTH I COMBINATION 31
169. 1 0.9 2 0.9 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 0.5
170. LOAD COMB 25 STRENGTH I COMBINATION 32
171. 1 0.9 2 0.9 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 1.2
172. *END OF COMBINATIONS
173. PERFORM ANALYSIS
```

P R O B L E M   S T A T I S T I C S

NUMBER OF JOINTS	**52**	**NUMBER OF MEMBERS**	**51**
NUMBER OF PLATES	**0**	**NUMBER OF SOLIDS**	**0**
NUMBER OF SURFACES	**0**	**NUMBER OF SUPPORTS**	**22**

SOLVER USED IS THE OUT-OF-CORE BASIC SOLVER

```
  ORIGINAL/FINAL BAND-WIDTH=    34/     7/     42 DOF
TOTAL      PRIMARY LOAD CASES =     9, TOTAL DEGREES OF FREEDOM =      240
TOTAL LOAD COMBINATION  CASES =    16  SO FAR.
  SIZE OF STIFFNESS MATRIX =        11 DOUBLE  KILO-WORDS
  REQRD/AVAIL. DISK SPACE  =      12.2/ 933061.8 MB
```

**NOTE-Tension/Compression converged after 1 iterations, Case= 1

**NOTE-Tension/Compression converged after 1 iterations, Case= 2

```
 **NOTE-Tension/Compression converged after  1 iterations, Case=    3


 **NOTE-Tension/Compression converged after  1 iterations, Case=    4

*** LOAD CASE     5 -- START ITERATION NO.  2

 **NOTE-Tension/Compression converged after  2 iterations, Case=    5

*** LOAD CASE     6 -- START ITERATION NO.  2

 **NOTE-Tension/Compression converged after  2 iterations, Case=    6


 **NOTE-Tension/Compression converged after  1 iterations, Case=    7

*** LOAD CASE     8 -- START ITERATION NO.  2

 **NOTE-Tension/Compression converged after  2 iterations, Case=    8


 **NOTE-Tension/Compression converged after  1 iterations, Case=    9

  174. *LOAD LIST 13
  175. LOAD LIST 10 TO 25
  176. PRINT MEMBER FORCES LIST 19 TO 24
```

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET (LOCAL)

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
19	10	23	96.83	2.17	-0.02	0.00	0.17	8.15
		29	-96.83	-2.17	0.02	-0.00	0.01	8.15
	11	23	96.83	5.21	-0.02	0.00	0.17	19.54
		29	-96.83	-5.21	0.02	-0.00	0.01	19.54
	12	23	96.83	2.17	-0.01	0.00	0.11	8.14
		29	-96.83	-2.17	0.01	-0.00	-0.05	8.14
	13	23	96.83	5.21	-0.01	0.00	0.11	19.53
		29	-96.83	-5.21	0.01	-0.00	-0.05	19.53
	14	23	77.31	2.17	-0.02	0.00	0.19	8.15
		29	-77.31	-2.17	0.02	-0.00	-0.02	8.15
	15	23	77.31	5.21	-0.02	0.00	0.19	19.54
		29	-77.31	-5.21	0.02	-0.00	-0.02	19.54
	16	23	77.31	2.17	-0.01	0.00	0.13	8.14
		29	-77.31	-2.17	0.01	-0.00	-0.08	8.14
	17	23	77.31	5.21	-0.01	0.00	0.13	19.53
		29	-77.31	-5.21	0.01	-0.00	-0.08	19.53
	18	23	96.83	-1.51	-0.02	0.00	0.17	-5.67
		29	-96.83	1.51	0.02	-0.00	0.01	-5.67
	19	23	96.83	-3.64	-0.02	0.00	0.17	-13.64
		29	-96.83	3.64	0.02	-0.00	0.01	-13.65
	20	23	96.83	-1.52	-0.01	0.00	0.11	-5.69
		29	-96.83	1.52	0.01	-0.00	-0.05	-5.69
	21	23	96.83	-3.64	-0.01	0.00	0.11	-13.66
		29	-96.83	3.64	0.01	-0.00	-0.05	-13.66
	22	23	77.31	-1.51	-0.02	0.00	0.19	-5.67
		29	-77.31	1.51	0.02	-0.00	-0.02	-5.67
	23	23	77.31	-3.64	-0.02	0.00	0.19	-13.65
		29	-77.31	3.64	0.02	-0.00	-0.02	-13.65
	24	23	77.31	-1.52	-0.01	0.00	0.13	-5.69
		29	-77.31	1.52	0.01	-0.00	-0.08	-5.69
	25	23	77.31	-3.64	-0.01	0.00	0.13	-13.66
		29	-77.31	3.64	0.01	-0.00	-0.08	-13.66
20	10	24	96.86	2.17	-0.01	0.00	0.15	8.15
		30	-96.86	-2.17	0.01	-0.00	-0.05	8.15
	11	24	96.86	5.21	-0.01	0.00	0.15	19.54
		30	-96.86	-5.21	0.01	-0.00	-0.05	19.54
	12	24	96.86	2.17	-0.00	0.00	0.12	8.14
		30	-96.86	-2.17	0.00	-0.00	-0.08	8.14
	13	24	96.86	5.21	-0.00	0.00	0.12	19.53
		30	-96.86	-5.21	0.00	-0.00	-0.08	19.53
	14	24	77.34	2.17	-0.01	0.00	0.17	8.15
		30	-77.34	-2.17	0.01	-0.00	-0.06	8.15

MEMBER END FORCES   STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET   (LOCAL)

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	15	24	77.34	5.21	-0.01	0.00	0.17	19.54
		30	-77.34	-5.21	0.01	-0.00	-0.06	19.54
	16	24	77.34	2.17	-0.00	0.00	0.13	8.14
		30	-77.34	-2.17	0.00	-0.00	-0.10	8.14
	17	24	77.34	5.21	-0.00	0.00	0.13	19.53
		30	-77.34	-5.21	0.00	-0.00	-0.10	19.53
	18	24	96.86	-1.51	-0.01	0.00	0.15	-5.68
		30	-96.86	1.51	0.01	-0.00	-0.05	-5.68
	19	24	96.86	-3.64	-0.01	0.00	0.15	-13.65
		30	-96.86	3.64	0.01	-0.00	-0.05	-13.65
	20	24	96.86	-1.52	-0.00	0.00	0.12	-5.69
		30	-96.86	1.52	0.00	-0.00	-0.08	-5.69
	21	24	96.86	-3.64	-0.00	0.00	0.12	-13.66
		30	-96.86	3.64	0.00	-0.00	-0.08	-13.66
	22	24	77.34	-1.51	-0.01	0.00	0.17	-5.68
		30	-77.34	1.51	0.01	-0.00	-0.06	-5.68
	23	24	77.34	-3.64	-0.01	0.00	0.17	-13.65
		30	-77.34	3.64	0.01	-0.00	-0.06	-13.65
	24	24	77.34	-1.52	-0.00	0.00	0.13	-5.69
		30	-77.34	1.52	0.00	-0.00	-0.10	-5.69
	25	24	77.34	-3.64	-0.00	0.00	0.13	-13.66
		30	-77.34	3.64	0.00	-0.00	-0.10	-13.66
21	10	25	96.97	2.17	-0.01	0.00	0.08	8.15
		31	-96.97	-2.17	0.01	-0.00	-0.04	8.15
	11	25	96.97	5.21	-0.01	0.00	0.08	19.54
		31	-96.97	-5.21	0.01	-0.00	-0.04	19.54
	12	25	96.97	2.17	-0.00	0.00	0.07	8.14
		31	-96.97	-2.17	0.00	-0.00	-0.06	8.14
	13	25	96.97	5.21	-0.00	0.00	0.07	19.53
		31	-96.97	-5.21	0.00	-0.00	-0.06	19.53
	14	25	77.45	2.17	-0.01	0.00	0.09	8.15
		31	-77.45	-2.17	0.01	-0.00	-0.05	8.15
	15	25	77.45	5.21	-0.01	0.00	0.09	19.54
		31	-77.45	-5.21	0.01	-0.00	-0.05	19.54
	16	25	77.45	2.17	-0.00	0.00	0.07	8.14
		31	-77.45	-2.17	0.00	-0.00	-0.06	8.14
	17	25	77.45	5.21	-0.00	0.00	0.07	19.53
		31	-77.45	-5.21	0.00	-0.00	-0.06	19.53
	18	25	96.97	-1.51	-0.01	0.00	0.08	-5.68
		31	-96.97	1.51	0.01	-0.00	-0.04	-5.68
	19	25	96.97	-3.64	-0.01	0.00	0.08	-13.65
		31	-96.97	3.64	0.01	-0.00	-0.04	-13.65
	20	25	96.97	-1.52	-0.00	0.00	0.07	-5.69
		31	-96.97	1.52	0.00	-0.00	-0.06	-5.69

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET (LOCAL)

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	21	25	96.97	-3.64	-0.00	0.00	0.07	-13.66
		31	-96.97	3.64	0.00	-0.00	-0.06	-13.66
	22	25	77.45	-1.51	-0.01	0.00	0.09	-5.68
		31	-77.45	1.51	0.01	-0.00	-0.05	-5.68
	23	25	77.45	-3.64	-0.01	0.00	0.09	-13.65
		31	-77.45	3.64	0.01	-0.00	-0.05	-13.65
	24	25	77.45	-1.52	-0.00	0.00	0.07	-5.69
		31	-77.45	1.52	0.00	-0.00	-0.06	-5.69
	25	25	77.45	-3.64	-0.00	0.00	0.07	-13.66
		31	-77.45	3.64	0.00	-0.00	-0.06	-13.66
22	10	26	96.97	2.17	0.01	-0.00	-0.08	8.15
		32	-96.97	-2.17	-0.01	0.00	0.04	8.15
	11	26	96.97	5.21	0.01	-0.00	-0.08	19.54
		32	-96.97	-5.21	-0.01	0.00	0.04	19.54
	12	26	96.97	2.17	0.00	-0.00	-0.07	8.14
		32	-96.97	-2.17	-0.00	0.00	0.06	8.14
	13	26	96.97	5.21	0.00	-0.00	-0.07	19.53
		32	-96.97	-5.21	-0.00	0.00	0.06	19.53
	14	26	77.45	2.17	0.01	-0.00	-0.09	8.15
		32	-77.45	-2.17	-0.01	0.00	0.05	8.15
	15	26	77.45	5.21	0.01	-0.00	-0.09	19.54
		32	-77.45	-5.21	-0.01	0.00	0.05	19.54
	16	26	77.45	2.17	0.00	-0.00	-0.07	8.14
		32	-77.45	-2.17	-0.00	0.00	0.06	8.14
	17	26	77.45	5.21	0.00	-0.00	-0.07	19.53
		32	-77.45	-5.21	-0.00	0.00	0.06	19.53
	18	26	96.97	-1.51	0.01	-0.00	-0.08	-5.68
		32	-96.97	1.51	-0.01	0.00	0.04	-5.68
	19	26	96.97	-3.64	0.01	-0.00	-0.08	-13.65
		32	-96.97	3.64	-0.01	0.00	0.04	-13.65
	20	26	96.97	-1.52	0.00	-0.00	-0.07	-5.69
		32	-96.97	1.52	-0.00	0.00	0.06	-5.69
	21	26	96.97	-3.64	0.00	-0.00	-0.07	-13.66
		32	-96.97	3.64	-0.00	0.00	0.06	-13.66
	22	26	77.45	-1.51	0.01	-0.00	-0.09	-5.68
		32	-77.45	1.51	-0.01	0.00	0.05	-5.68
	23	26	77.45	-3.64	0.01	-0.00	-0.09	-13.65
		32	-77.45	3.64	-0.01	0.00	0.05	-13.65
	24	26	77.45	-1.52	0.00	-0.00	-0.07	-5.69
		32	-77.45	1.52	-0.00	0.00	0.06	-5.69
	25	26	77.45	-3.64	0.00	-0.00	-0.07	-13.66
		32	-77.45	3.64	-0.00	0.00	0.06	-13.66
23	10	27	96.86	2.17	0.01	-0.00	-0.15	8.15
		33	-96.86	-2.17	-0.01	0.00	0.05	8.15

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET (LOCAL)

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	11	27	96.86	5.21	0.01	-0.00	-0.15	19.54
		33	-96.86	-5.21	-0.01	0.00	0.05	19.54
	12	27	96.86	2.17	0.00	-0.00	-0.12	8.14
		33	-96.86	-2.17	-0.00	0.00	0.08	8.14
	13	27	96.86	5.21	0.00	-0.00	-0.12	19.53
		33	-96.86	-5.21	-0.00	0.00	0.08	19.53
	14	27	77.34	2.17	0.01	-0.00	-0.17	8.15
		33	-77.34	-2.17	-0.01	0.00	0.06	8.15
	15	27	77.34	5.21	0.01	-0.00	-0.17	19.54
		33	-77.34	-5.21	-0.01	0.00	0.06	19.54
	16	27	77.34	2.17	0.00	-0.00	-0.13	8.14
		33	-77.34	-2.17	-0.00	0.00	0.10	8.14
	17	27	77.34	5.21	0.00	-0.00	-0.13	19.53
		33	-77.34	-5.21	-0.00	0.00	0.10	19.53
	18	27	96.86	-1.51	0.01	-0.00	-0.15	-5.68
		33	-96.86	1.51	-0.01	0.00	0.05	-5.68
	19	27	96.86	-3.64	0.01	-0.00	-0.15	-13.65
		33	-96.86	3.64	-0.01	0.00	0.05	-13.65
	20	27	96.86	-1.52	0.00	-0.00	-0.12	-5.69
		33	-96.86	1.52	-0.00	0.00	0.08	-5.69
	21	27	96.86	-3.64	0.00	-0.00	-0.12	-13.66
		33	-96.86	3.64	-0.00	0.00	0.08	-13.66
	22	27	77.34	-1.51	0.01	-0.00	-0.17	-5.68
		33	-77.34	1.51	-0.01	0.00	0.06	-5.68
	23	27	77.34	-3.64	0.01	-0.00	-0.17	-13.65
		33	-77.34	3.64	-0.01	0.00	0.06	-13.65
	24	27	77.34	-1.52	0.00	-0.00	-0.13	-5.69
		33	-77.34	1.52	-0.00	0.00	0.10	-5.69
	25	27	77.34	-3.64	0.00	-0.00	-0.13	-13.66
		33	-77.34	3.64	-0.00	0.00	0.10	-13.66
24	10	28	96.83	2.17	0.02	-0.00	-0.17	8.15
		34	-96.83	-2.17	-0.02	0.00	-0.01	8.15
	11	28	96.83	5.21	0.02	-0.00	-0.17	19.54
		34	-96.83	-5.21	-0.02	0.00	-0.01	19.54
	12	28	96.83	2.17	0.01	-0.00	-0.11	8.14
		34	-96.83	-2.17	-0.01	0.00	0.05	8.14
	13	28	96.83	5.21	0.01	-0.00	-0.11	19.53
		34	-96.83	-5.21	-0.01	0.00	0.05	19.53
	14	28	77.31	2.17	0.02	-0.00	-0.19	8.15
		34	-77.31	-2.17	-0.02	0.00	0.02	8.15
	15	28	77.31	5.21	0.02	-0.00	-0.19	19.54
		34	-77.31	-5.21	-0.02	0.00	0.02	19.54
	16	28	77.31	2.17	0.01	-0.00	-0.13	8.14
		34	-77.31	-2.17	-0.01	0.00	0.08	8.14

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET (LOCAL)

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	17	28	77.31	5.21	0.01	-0.00	-0.13	19.53
		34	-77.31	-5.21	-0.01	0.00	0.08	19.53
	18	28	96.83	-1.51	0.02	-0.00	-0.17	-5.67
		34	-96.83	1.51	-0.02	0.00	-0.01	-5.67
	19	28	96.83	-3.64	0.02	-0.00	-0.17	-13.64
		34	-96.83	3.64	-0.02	0.00	-0.01	-13.65
	20	28	96.83	-1.52	0.01	-0.00	-0.11	-5.69
		34	-96.83	1.52	-0.01	0.00	0.05	-5.69
	21	28	96.83	-3.64	0.01	-0.00	-0.11	-13.66
		34	-96.83	3.64	-0.01	0.00	0.05	-13.66
	22	28	77.31	-1.51	0.02	-0.00	-0.19	-5.67
		34	-77.31	1.51	-0.02	0.00	0.02	-5.67
	23	28	77.31	-3.64	0.02	-0.00	-0.19	-13.65
		34	-77.31	3.64	-0.02	0.00	0.02	-13.65
	24	28	77.31	-1.52	0.01	-0.00	-0.13	-5.69
		34	-77.31	1.52	-0.01	0.00	0.08	-5.69
	25	28	77.31	-3.64	0.01	-0.00	-0.13	-13.66
		34	-77.31	3.64	-0.01	0.00	0.08	-13.66

************** END OF LATEST ANALYSIS RESULT **************

177. PRINT MAXFORCE ENVELOPE LIST 19 TO 24

MEMBER FORCE ENVELOPE

ALL UNITS ARE KIP FEET

MAX AND MIN FORCE VALUES AMONGST ALL SECTION LOCATIONS

MEMB		FY/ FZ	DIST	LD	MZ/ MY	DIST	LD	FX	DIST	LD
19	MAX	5.21	0.00	11	19.54	0.00	11			
		-0.01	0.00	21	0.19	0.00	14	96.83 C	0.00	10
	MIN	-3.64	7.50	25	-19.54	7.50	11			
		-0.02	7.50	23	-0.01	7.50	11	77.31 C	7.50	25
20	MAX	5.21	0.00	11	19.54	0.00	11			
		-0.00	0.00	12	0.17	0.00	14	96.86 C	0.00	10
	MIN	-3.64	7.50	25	-19.54	7.50	11			
		-0.01	7.50	23	0.05	7.50	19	77.34 C	7.50	25
21	MAX	5.21	0.00	11	19.54	0.00	11			
		-0.00	0.00	21	0.09	0.00	14	96.97 C	0.00	10
	MIN	-3.64	7.50	25	-19.54	7.50	11			
		-0.01	7.50	23	0.04	7.50	19	77.45 C	7.50	25
22	MAX	5.21	0.00	11	19.54	0.00	11			
		0.01	0.00	14	-0.04	7.50	10	96.97 C	0.00	10
	MIN	-3.64	7.50	25	-19.54	7.50	11			
		0.00	7.50	21	-0.09	0.00	23	77.45 C	7.50	25
23	MAX	5.21	0.00	11	19.54	0.00	11			
		0.01	0.00	14	-0.05	7.50	10	96.86 C	0.00	10
	MIN	-3.64	7.50	25	-19.54	7.50	11			
		0.00	7.50	21	-0.17	0.00	23	77.34 C	7.50	25
24	MAX	5.21	0.00	11	19.54	0.00	11			
		0.02	0.00	14	0.01	7.50	11	96.83 C	0.00	10
	MIN	-3.64	7.50	25	-19.54	7.50	11			
		0.01	7.50	21	-0.19	0.00	23	77.31 C	7.50	25

********** END OF FORCE ENVELOPE FROM INTERNAL STORAGE **********

178. *PRINT SUPPORT REACTION
179. PRINT JOINT DISPLACEMENTS LIST 19 TO 24

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
19	10	0.04508	-0.01792	-0.00000	0.00000	-0.00000	0.00000
	11	0.10807	-0.01792	-0.00000	0.00000	-0.00000	0.00000
	12	0.04502	-0.01792	-0.00000	0.00000	-0.00000	0.00000
	13	0.10801	-0.01792	-0.00000	0.00000	-0.00000	0.00000
	14	0.04508	-0.01431	-0.00000	0.00000	-0.00000	0.00000
	15	0.10807	-0.01431	-0.00000	0.00000	-0.00000	0.00000
	16	0.04502	-0.01431	-0.00000	0.00000	-0.00000	0.00000
	17	0.10801	-0.01431	-0.00000	0.00000	-0.00000	0.00000
	18	-0.03141	-0.01792	-0.00000	0.00000	-0.00000	0.00000
	19	-0.07550	-0.01792	-0.00000	0.00000	-0.00000	0.00000
	20	-0.03147	-0.01792	-0.00000	0.00000	-0.00000	0.00000
	21	-0.07556	-0.01792	-0.00000	0.00000	-0.00000	0.00000
	22	-0.03141	-0.01431	-0.00000	0.00000	-0.00000	0.00000
	23	-0.07550	-0.01431	-0.00000	0.00000	-0.00000	0.00000
	24	-0.03147	-0.01431	-0.00000	0.00000	-0.00000	0.00000
	25	-0.07556	-0.01431	-0.00000	0.00000	-0.00000	0.00000
20	10	0.04508	-0.01792	0.00000	-0.00000	0.00000	0.00000
	11	0.10807	-0.01792	0.00000	-0.00000	0.00000	0.00000
	12	0.04502	-0.01792	0.00000	-0.00000	0.00000	0.00000
	13	0.10801	-0.01792	0.00000	-0.00000	0.00000	0.00000
	14	0.04508	-0.01431	0.00000	-0.00000	0.00000	0.00000
	15	0.10807	-0.01431	0.00000	-0.00000	0.00000	0.00000
	16	0.04502	-0.01431	0.00000	-0.00000	0.00000	0.00000
	17	0.10801	-0.01431	0.00000	-0.00000	0.00000	0.00000
	18	-0.03141	-0.01792	0.00000	-0.00000	0.00000	0.00000
	19	-0.07550	-0.01792	0.00000	-0.00000	0.00000	0.00000
	20	-0.03147	-0.01792	0.00000	-0.00000	0.00000	0.00000
	21	-0.07556	-0.01792	0.00000	-0.00000	0.00000	0.00000
	22	-0.03141	-0.01431	0.00000	-0.00000	0.00000	0.00000
	23	-0.07550	-0.01431	0.00000	-0.00000	0.00000	0.00000
	24	-0.03147	-0.01431	0.00000	-0.00000	0.00000	0.00000
	25	-0.07556	-0.01431	0.00000	-0.00000	0.00000	0.00000
21	10	0.04509	-0.01790	0.00001	-0.00000	0.00000	0.00000
	11	0.10808	-0.01790	0.00001	-0.00000	0.00000	0.00000
	12	0.04502	-0.01790	0.00000	-0.00000	0.00000	0.00000
	13	0.10801	-0.01790	0.00000	-0.00000	0.00000	0.00000
	14	0.04509	-0.01429	0.00001	-0.00000	0.00000	0.00000
	15	0.10808	-0.01429	0.00001	-0.00000	0.00000	0.00000
	16	0.04502	-0.01429	0.00000	-0.00000	0.00000	0.00000
	17	0.10801	-0.01429	0.00000	-0.00000	0.00000	0.00000
	18	-0.03139	-0.01790	0.00001	-0.00000	0.00000	0.00000
	19	-0.07548	-0.01790	0.00001	-0.00000	0.00000	0.00000
	20	-0.03146	-0.01790	0.00000	-0.00000	0.00000	0.00000
	21	-0.07555	-0.01790	0.00000	-0.00000	0.00000	0.00000
	22	-0.03139	-0.01429	0.00001	-0.00000	0.00000	0.00000
	23	-0.07548	-0.01429	0.00001	-0.00000	0.00000	0.00000

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
	24	-0.03146	-0.01429	0.00000	-0.00000	0.00000	0.00000
	25	-0.07555	-0.01429	0.00000	-0.00000	0.00000	0.00000
22	10	0.04510	-0.01790	0.00001	-0.00000	0.00000	0.00000
	11	0.10808	-0.01790	0.00001	-0.00000	0.00000	0.00000
	12	0.04502	-0.01790	0.00000	-0.00000	0.00000	0.00000
	13	0.10801	-0.01790	0.00000	-0.00000	0.00000	0.00000
	14	0.04510	-0.01429	0.00001	-0.00000	0.00000	0.00000
	15	0.10808	-0.01429	0.00001	-0.00000	0.00000	0.00000
	16	0.04502	-0.01429	0.00000	-0.00000	0.00000	0.00000
	17	0.10801	-0.01429	0.00000	-0.00000	0.00000	0.00000
	18	-0.03138	-0.01790	0.00001	-0.00000	0.00000	0.00000
	19	-0.07547	-0.01790	0.00001	-0.00000	0.00000	0.00000
	20	-0.03146	-0.01790	0.00000	-0.00000	0.00000	0.00000
	21	-0.07555	-0.01790	0.00000	-0.00000	0.00000	0.00000
	22	-0.03138	-0.01429	0.00001	-0.00000	0.00000	0.00000
	23	-0.07547	-0.01429	0.00001	-0.00000	0.00000	0.00000
	24	-0.03146	-0.01429	0.00000	-0.00000	0.00000	0.00000
	25	-0.07555	-0.01429	0.00000	-0.00000	0.00000	0.00000
23	10	0.04510	-0.01789	-0.00001	0.00000	-0.00000	0.00000
	11	0.10808	-0.01789	-0.00001	0.00000	-0.00000	0.00000
	12	0.04502	-0.01789	-0.00000	0.00000	-0.00000	0.00000
	13	0.10801	-0.01789	-0.00000	0.00000	-0.00000	0.00000
	14	0.04510	-0.01428	-0.00001	0.00000	-0.00000	0.00000
	15	0.10808	-0.01428	-0.00001	0.00000	-0.00000	0.00000
	16	0.04502	-0.01428	-0.00000	0.00000	-0.00000	0.00000
	17	0.10801	-0.01428	-0.00000	0.00000	-0.00000	0.00000
	18	-0.03138	-0.01789	-0.00001	0.00000	-0.00000	0.00000
	19	-0.07547	-0.01789	-0.00001	0.00000	-0.00000	0.00000
	20	-0.03146	-0.01789	-0.00000	0.00000	-0.00000	0.00000
	21	-0.07555	-0.01789	-0.00000	0.00000	-0.00000	0.00000
	22	-0.03138	-0.01428	-0.00001	0.00000	-0.00000	0.00000
	23	-0.07547	-0.01428	-0.00001	0.00000	-0.00000	0.00000
	24	-0.03146	-0.01428	-0.00000	0.00000	-0.00000	0.00000
	25	-0.07555	-0.01428	-0.00000	0.00000	-0.00000	0.00000
24	10	0.04509	-0.01789	-0.00001	0.00000	-0.00000	0.00000
	11	0.10808	-0.01789	-0.00001	0.00000	-0.00000	0.00000
	12	0.04502	-0.01789	-0.00000	0.00000	-0.00000	0.00000
	13	0.10801	-0.01789	-0.00000	0.00000	-0.00000	0.00000
	14	0.04509	-0.01429	-0.00001	0.00000	-0.00000	0.00000
	15	0.10808	-0.01429	-0.00001	0.00000	-0.00000	0.00000
	16	0.04502	-0.01429	-0.00000	0.00000	-0.00000	0.00000
	17	0.10801	-0.01429	-0.00000	0.00000	-0.00000	0.00000
	18	-0.03139	-0.01789	-0.00001	0.00000	-0.00000	0.00000
	19	-0.07548	-0.01789	-0.00001	0.00000	-0.00000	0.00000
	20	-0.03146	-0.01789	-0.00000	0.00000	-0.00000	0.00000
	21	-0.07555	-0.01789	-0.00000	0.00000	-0.00000	0.00000

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
	22	-0.03139	-0.01429	-0.00001	0.00000	-0.00000	0.00000
	23	-0.07548	-0.01429	-0.00001	0.00000	-0.00000	0.00000
	24	-0.03146	-0.01429	-0.00000	0.00000	-0.00000	0.00000
	25	-0.07555	-0.01429	-0.00000	0.00000	-0.00000	0.00000

************** END OF LATEST ANALYSIS RESULT **************

180. FINISH

*********** END OF THE STAAD.Pro RUN ***********

**** DATE= MAR 18,2020 TIME= 13:17:53 ****

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**********************************************************
*   For technical assistance on STAAD.Pro, please visit   *
*   http://selectservices.bentley.com/en-US/              *
*                                                         *
*   Details about additional assistance from              *
*   Bentley and Partners can be found at program menu     *
*   Help->Technical Support                               *
*                                                         *
*      Copyright (c) 1997-2015 Bentley Systems, Inc.
*               http://www.bentley.com                    *
**********************************************************
```

```
**************************************************
*                                                *
*           STAAD.Pro V8i SELECTseries6          *
*           Version  20.07.11.45                 *
*           Proprietary Program of               *
*           Bentley Systems, Inc.                *
*           Date=    MAR 18, 2020                *
*           Time=    13:18:56                    *
*                                                *
*      USER ID: bayside                          *
**************************************************
```

EXTREME I

```
     1. STAAD SPACE
INPUT FILE: Q:\Projects\19 PROJECTS\2192599 - TOWN OF PLYMOUTH Bridge Replacement\Calculations\Pile De.. .STD
     2. START JOB INFORMATION
     3. ENGINEER DATE 12-JAN-20
     4. ENGINEER NAME JK
     5. END JOB INFORMATION
     6. * FILE: EXTREME I
     7. * BRIDGE: P-13-001, PLYMOUTH
     8. * PILE: HP 10X57
     9. * EXTREME I
    10. *
    11. UNIT FEET POUND
    12. JOINT COORDINATES
    13. 1 0 -7.67 0; 2 0 -7.67 17.25; 3 0 -7.67 34.5; 4 25 -7.67 0
    14. 5 25 -7.67 17.25; 6 25 -7.67 34.5; 7 -5 -7.67 0; 8 -5 -7.67 34.5
    15. 9 30 -7.67 0; 10 30 -7.67 34.5; 11 35 -7.67 34.5; 12 35 -7.67 0
    16. 13 -10 -7.67 0; 14 -10 -7.67 34.5; 15 0 0 17.25; 16 25 0 17.25
    17. 17 0 -7.67 2.25; 18 0 -7.67 8.25; 19 0 -7.67 14.25; 20 0 -7.67 20.25
    18. 21 0 -7.67 26.25; 22 0 -7.67 32.25; 23 0 -11 2.25; 24 0 -11 8.25
    19. 25 0 -11 14.25; 26 0 -11 20.25; 27 0 -11 26.25; 28 0 -11 32.25
    20. 29 0 -18.5 2.25; 30 0 -18.5 8.25; 31 0 -18.5 14.25; 32 0 -18.5 20.25
    21. 33 0 -18.5 26.25; 34 0 -18.5 32.25; 35 25 -7.67 2.25; 36 25 -7.67 8.25
    22. 37 25 -7.67 14.25; 38 25 -7.67 20.25; 39 25 -7.67 26.25
    23. 40 25 -7.67 32.25; 41 25 -11 2.25; 42 25 -11 8.25; 43 25 -11 14.25
    24. 44 25 -11 20.25; 45 25 -11 26.25; 46 25 -11 32.25; 47 25 -18.5 2.25
    25. 48 25 -18.5 8.25; 49 25 -18.5 14.25; 50 25 -18.5 20.25
    26. 51 25 -18.5 26.25; 52 25 -18.5 32.25
    27. MEMBER INCIDENCES
    28. 1 13 7; 2 7 1; 3 1 17; 4 17 18; 5 18 19; 6 19 2; 7 2 20; 8 20 21
    29. 9 21 22; 10 22 3; 11 14 8; 12 8 3; 13 17 23; 14 18 24; 15 19 25
    30. 16 20 26; 17 21 27; 18 22 28; 19 23 29; 20 24 30; 21 25 31; 22 26 32
    31. 23 27 33; 24 28 34; 25 2 15; 26 15 16; 27 5 16; 28 9 12; 29 4 9
    32. 30 4 35; 31 35 36; 32 36 37; 33 37 5; 34 5 38; 35 38 40; 36 39 40
    33. 37 40 6; 38 6 10; 39 10 11; 40 35 41; 41 36 42; 42 37 43; 43 38 44
    34. 44 39 45; 45 40 46; 46 41 47; 47 42 48; 48 43 49; 49 44 50; 50 45 51
    35. 51 46 52
    36. UNIT INCHES POUND
    37. MEMBER PROPERTY AMERICAN
    38. 19 TO 24 PRIS AX 16.8 AZ 16.8 IX 294 IY 1E+006 IZ 101
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39. 46 TO 51 PRIS AX 16.8 AZ 16.8 IX 294 IY 1E+006 IZ 101
40. UNIT FEET KIP
41. MEMBER PROPERTY AMERICAN
42. 26 PRIS AX 3.008 IX 0.704745 IY 1E+006 IZ 1E+006
43. 25 27 PRIS AX 1000 AY 1000 AZ 1000 IX 1E+006 IY 1E+006 IZ 1E+006
44. 1 TO 18 PRIS AX 1000 AY 1000 AZ 1000 IX 1E+006 IY 1E+006 IZ 1E+006
45. 28 TO 45 PRIS AX 1000 AY 1000 AZ 1000 IX 1E+006 IY 1E+006 IZ 1E+006
46. DEFINE MATERIAL START
47. ISOTROPIC MATERIAL1
48. E 580393
49. POISSON 0.2
50. DENSITY 0.15
51. ISOTROPIC STEEL
52. E 4.176E+006
53. POISSON 0.3
54. DENSITY 0.489024
55. ALPHA 6E-006
56. DAMP 0.03
57. TYPE STEEL
58. STRENGTH FY 5184 FU 8352 RY 1.5 RT 1.2
59. ISOTROPIC CONCRETE
60. E 453600
61. POISSON 0.17
62. DENSITY 0.150336
63. ALPHA 5E-006
64. DAMP 0.05
65. TYPE CONCRETE
66. STRENGTH FCU 576
67. END DEFINE MATERIAL
68. UNIT INCHES KIP
69. CONSTANTS
70. MATERIAL STEEL MEMB 19 TO 24 26 46 TO 51
71. MATERIAL CONCRETE MEMB 1 TO 18 25 27 TO 45
72. UNIT FEET KIP
73. SUPPORTS
74. 29 TO 34 47 TO 52 FIXED
75. *7 9 FIXED BUT FX FY MX MY MZ KFZ 108
76. *8 10 FIXED BUT FX FY MX MY MZ KFZ 108
77. *1 TO 3 FIXED BUT FY FZ MX MY MZ KFX 170.2
78. *4 TO 6 FIXED BUT FY FZ MX MY MZ KFX 170.2
79. *SPRING COMPRESSION
80. *7 9 KFZ
81. *SPRING TENSION
82. *8 10 KFZ
83. *SPRING COMPRESSION
84. *1 TO 3 KFX
85. *SPRING TENSION
86. *4 TO 6 KFX
87. *NON-COMPOSITE DEAD LOAD
88. LOAD 1 (DC 1)
89. MEMBER LOAD
90. 26 UNI PY -.3
91. 3 TO 10 UNI PY -7.4
92. 30 TO 37 UNI PY -7.4
93. JOINT LOAD
94. 7 TO 10 FY -27.2
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 95. *SUPERIMPOSED DEAD LOAD
 96. LOAD 2 (DC 2)
 97. MEMBER LOAD
 98. 26 UNI PY -1.44
 99. *WEARING SURFACE
100. LOAD 3 (DW)
101. MEMBER LOAD
102. 26 UNI PY -1.08
103. *VERTICAL EARTH PRESSURE
104. LOAD 4 (EV)
105. *HORIZONTAL EARTH PRESSURE (MAX)
106. LOAD 5 (EH MAX)
107. JOINT LOAD
108. 17 TO 22 FX 15
109. 35 TO 40 FX -15
110. 8 10 FZ 22.5
111. 7 9 FZ -22.5
112. *HORIZONTAL EARTH PRESSURE (MIN)
113. LOAD 6 (EH MIN)
114. JOINT LOAD
115. 17 TO 22 FX 7.5
116. 35 TO 40 FX -7.5
117. 8 10 FZ 11.25
118. 7 9 FZ -11.25
119. *LIVE LOAD
120. LOAD 7 (LL)
121. JOINT LOAD
122. 15 FY -105
123. 16 FY -105
124. *THERMAL LOADS
125. *SHRINK
126. LOAD 8 LOADTYPE TEMPERATURE  TITLE TU (SHRINK)
127. TEMPERATURE LOAD
128. 26 TEMP -100
129. *EXPAND
130. LOAD 9 LOADTYPE TEMPERATURE  TITLE TU (EXPAND)
131. TEMPERATURE LOAD
132. 26 TEMP 70
133. LOAD 42 EQ
134. JOINT LOAD
135. 15 FX 102
136. 16 FX 102
137. *STRENGTH I LOAD COMBINATIONS
138. *SHRINK
139. *LOAD COMBINATIONS
140. LOAD COMB 10 STRENGTH I COMBINATION 1
141. 1 1.25 2 1.25 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 0.5 9 0.0
142. LOAD COMB 11 STRENGTH I COMBINATION 2
143. 1 1.25 2 1.25 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 1.2 9 0.0
144. LOAD COMB 12 STRENGTH I COMBINATION 3
145. 1 1.25 2 1.25 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 0.5 9 0.0
146. LOAD COMB 13 STRENGTH I COMBINATION 4
147. 1 1.25 2 1.25 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 1.2 9 0.0
148. LOAD COMB 14 STRENGTH I COMBINATION 5
149. 1 1.25 2 1.25 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 0.5 9 0.0
150. LOAD COMB 15 STRENGTH I COMBINATION 6
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151. 1 1.25 2 1.25 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 1.2 9 0.0
152. LOAD COMB 16 STRENGTH I COMBINATION 7
153. 1 1.25 2 1.25 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 0.5 9 0.0
154. LOAD COMB 17 STRENGTH I COMBINATION 8
155. 1 1.25 2 1.25 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 1.2 9 0.0
156. LOAD COMB 18 STRENGTH I COMBINATION 9
157. 1 0.9 2 0.9 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 0.5 9 0.0
158. LOAD COMB 19 STRENGTH I COMBINATION 10
159. 1 0.9 2 0.9 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 1.2 9 0.0
160. LOAD COMB 20 STRENGTH I COMBINATION 11
161. 1 0.9 2 0.9 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 0.5 9 0.0
162. LOAD COMB 21 STRENGTH I COMBINATION 12
163. 1 0.9 2 0.9 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 1.2 9 0.0
164. LOAD COMB 22 STRENGTH I COMBINATION 13
165. 1 0.9 2 0.9 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 0.5 9 0.0
166. LOAD COMB 23 STRENGTH I COMBINATION 14
167. 1 0.9 2 0.9 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 1.2 9 0.0
168. LOAD COMB 24 STRENGTH I COMBINATION 15
169. 1 0.9 2 0.9 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 0.5 9 0.0
170. LOAD COMB 25 STRENGTH I COMBINATION 16
171. 1 0.9 2 0.9 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 1.2 9 0.0
172. *EXPAND
173. LOAD COMB 26 STRENGTH I COMBINATION 17
174. 1 1.25 2 1.25 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 0.5
175. LOAD COMB 27 STRENGTH I COMBINATION 18
176. 1 1.25 2 1.25 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 1.2
177. LOAD COMB 28 STRENGTH I COMBINATION 19
178. 1 1.25 2 1.25 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 0.5
179. LOAD COMB 29 STRENGTH I COMBINATION 20
180. 1 1.25 2 1.25 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 1.2
181. LOAD COMB 30 STRENGTH I COMBINATION 21
182. 1 1.25 2 1.25 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 0.5
183. LOAD COMB 31 STRENGTH I COMBINATION 22
184. 1 1.25 2 1.25 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 1.2
185. LOAD COMB 32 STRENGTH I COMBINATION 23
186. 1 1.25 2 1.25 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 0.5
187. LOAD COMB 33 STRENGTH I COMBINATION 24
188. 1 1.25 2 1.25 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 1.2
189. LOAD COMB 34 STRENGTH I COMBINATION 25
190. 1 0.9 2 0.9 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 0.5
191. LOAD COMB 35 STRENGTH I COMBINATION 26
192. 1 0.9 2 0.9 3 1.5 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 1.2
193. LOAD COMB 36 STRENGTH I COMBINATION 27
194. 1 0.9 2 0.9 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 0.5
195. LOAD COMB 37 STRENGTH I COMBINATION 28
196. 1 0.9 2 0.9 3 1.5 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 1.2
197. LOAD COMB 38 STRENGTH I COMBINATION 29
198. 1 0.9 2 0.9 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 0.5
199. LOAD COMB 39 STRENGTH I COMBINATION 30
200. 1 0.9 2 0.9 3 0.65 4 0.0 5 1.5 6 0.0 7 1.75 8 0.0 9 1.2
201. LOAD COMB 40 STRENGTH I COMBINATION 31
202. 1 0.9 2 0.9 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 0.5
203. LOAD COMB 41 STRENGTH I COMBINATION 32
204. 1 0.9 2 0.9 3 0.65 4 0.0 5 0.0 6 0.9 7 1.75 8 0.0 9 1.2
205. * EXTREME I EQ LOAD COMBO
206. LOAD COMB 43 EXTREME I (EQ+LL)
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207. 1 1.0 2 1.0 3 1.0 7 0.5 42 1.0
208. LOAD COMB 44 EXTREME I (EQ ONLY)
209. 1 1.0 2 1.0 3 1.0 7 0.0 42 1.0
210. *END OF COMBINATIONS
211. PERFORM ANALYSIS


        P R O B L E M   S T A T I S T I C S
        -----------------------------------

  NUMBER OF JOINTS            52  NUMBER OF MEMBERS        51
  NUMBER OF PLATES             0  NUMBER OF SOLIDS          0
  NUMBER OF SURFACES           0  NUMBER OF SUPPORTS       12

       SOLVER USED IS THE OUT-OF-CORE BASIC SOLVER

  ORIGINAL/FINAL BAND-WIDTH=    34/      8/      48 DOF
TOTAL      PRIMARY LOAD CASES =     10, TOTAL DEGREES OF FREEDOM =      240
TOTAL LOAD COMBINATION  CASES =     34  SO FAR.
  SIZE OF STIFFNESS MATRIX =        12 DOUBLE  KILO-WORDS
  REQRD/AVAIL. DISK SPACE  =      12.2/ 933062.2 MB


212. LOAD LIST 43 44
213. PRINT MEMBER FORCES LIST 19 TO 24
```

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET (LOCAL)

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
19	43	23	46.22	17.01	0.01	0.00	-0.10	63.72
		29	-46.22	-17.01	-0.01	-0.00	0.04	63.88
	44	23	37.50	17.01	0.01	0.00	-0.19	63.72
		29	-37.50	-17.01	-0.01	-0.00	0.11	63.88
20	43	24	46.18	17.01	0.01	0.00	-0.06	63.70
		30	-46.18	-17.01	-0.01	-0.00	-0.01	63.86
	44	24	37.44	17.01	0.01	0.00	-0.13	63.70
		30	-37.44	-17.01	-0.01	-0.00	0.07	63.86
21	43	25	46.15	17.00	0.01	0.00	0.02	63.68
		31	-46.15	-17.00	-0.01	-0.00	-0.09	63.84
	44	25	37.37	17.00	0.01	0.00	-0.01	63.68
		31	-37.37	-17.00	-0.01	-0.00	-0.05	63.84
22	43	26	46.15	17.00	0.01	0.00	0.14	63.66
		32	-46.15	-17.00	-0.01	-0.00	-0.19	63.82
	44	26	37.37	17.00	0.01	0.00	0.17	63.66
		32	-37.37	-17.00	-0.01	-0.00	-0.23	63.82
23	43	27	46.19	16.99	0.01	0.00	0.22	63.64
		33	-46.19	-16.99	-0.01	-0.00	-0.27	63.80
	44	27	37.44	16.99	0.01	0.00	0.29	63.64
		33	-37.44	-16.99	-0.01	-0.00	-0.34	63.80
24	43	28	46.23	16.99	0.01	0.00	0.26	63.62
		34	-46.23	-16.99	-0.01	-0.00	-0.31	63.78
	44	28	37.51	16.99	0.01	0.00	0.35	63.62
		34	-37.51	-16.99	-0.01	-0.00	-0.39	63.78

************** END OF LATEST ANALYSIS RESULT **************

214. PRINT MAXFORCE ENVELOPE LIST 19 TO 24

MEMBER FORCE ENVELOPE

ALL UNITS ARE KIP FEET

MAX AND MIN FORCE VALUES AMONGST ALL SECTION LOCATIONS

MEMB		FY/ FZ	DIST	LD	MZ/ MY	DIST	LD	FX	DIST	LD
19	MAX	17.01	0.00	43	63.72	0.00	43			
		0.01	0.00	44	-0.04	7.50	43	46.22 C	0.00	43
	MIN	17.01	7.50	44	-63.88	7.50	43			
		0.01	7.50	43	-0.19	0.00	44	37.50 C	7.50	44
20	MAX	17.01	0.00	43	63.70	0.00	43			
		0.01	0.00	44	0.01	7.50	43	46.18 C	0.00	43
	MIN	17.01	7.50	44	-63.86	7.50	43			
		0.01	7.50	43	-0.13	0.00	44	37.44 C	7.50	44
21	MAX	17.00	0.00	43	63.68	0.00	44			
		0.01	0.00	44	0.09	7.50	43	46.15 C	0.00	43
	MIN	17.00	7.50	44	-63.84	7.50	43			
		0.01	7.50	43	-0.01	0.00	44	37.37 C	7.50	44
22	MAX	17.00	0.00	44	63.66	0.00	44			
		0.01	0.00	43	0.23	7.50	44	46.15 C	0.00	43
	MIN	17.00	7.50	43	-63.82	7.50	43			
		0.01	7.50	44	0.14	0.00	43	37.37 C	7.50	44
23	MAX	16.99	0.00	44	63.64	0.00	44			
		0.01	0.00	43	0.34	7.50	44	46.19 C	0.00	43
	MIN	16.99	7.50	43	-63.80	7.50	44			
		0.01	7.50	44	0.22	0.00	43	37.44 C	7.50	44
24	MAX	16.99	0.00	44	63.62	0.00	44			
		0.01	0.00	43	0.39	7.50	44	46.23 C	0.00	43
	MIN	16.99	7.50	43	-63.78	7.50	44			
		0.01	7.50	44	0.26	0.00	43	37.51 C	7.50	44

********** END OF FORCE ENVELOPE FROM INTERNAL STORAGE **********

215. *PRINT SUPPORT REACTION
216. PRINT JOINT DISPLACEMENTS LIST 23 TO 28

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
23	43	0.35420	-0.00854	0.00000	-0.00000	-0.00000	-0.00003
	44	0.35420	-0.00693	0.00000	-0.00000	-0.00000	-0.00003
24	43	0.35410	-0.00853	0.00000	-0.00000	-0.00000	-0.00003
	44	0.35410	-0.00692	0.00000	-0.00000	-0.00000	-0.00003
25	43	0.35400	-0.00852	0.00000	0.00000	-0.00000	-0.00003
	44	0.35400	-0.00690	0.00000	0.00000	-0.00000	-0.00003
26	43	0.35389	-0.00853	0.00000	0.00000	-0.00000	-0.00003
	44	0.35389	-0.00690	0.00000	0.00000	-0.00000	-0.00003
27	43	0.35377	-0.00853	0.00000	0.00000	-0.00000	-0.00003
	44	0.35376	-0.00692	0.00000	0.00000	-0.00000	-0.00003
28	43	0.35365	-0.00854	0.00000	0.00000	-0.00000	-0.00003
	44	0.35365	-0.00693	0.00000	0.00000	-0.00000	-0.00003

************** END OF LATEST ANALYSIS RESULT **************

217. FINISH

*********** END OF THE STAAD.Pro RUN ***********

**** DATE= MAR 18,2020 TIME= 13:18:57 ****

```
**********************************************************
*  For technical assistance on STAAD.Pro, please visit   *
*  http://selectservices.bentley.com/en-US/              *
*                                                        *
*  Details about additional assistance from              *
*  Bentley and Partners can be found at program menu     *
*  Help->Technical Support                               *
*                                                        *
*     Copyright (c) 1997-2015 Bentley Systems, Inc.
*               http://www.bentley.com                   *
**********************************************************
```

```
 **************************************************
 *                                                *
 *           STAAD.Pro V8i SELECTseries6          *
 *           Version  20.07.11.45                 *
 *           Proprietary Program of               *
 *           Bentley Systems, Inc.                *
 *           Date=    MAR 18, 2020                *
 *           Time=    13:19:24                    *
 *                                                *
 *      USER ID: bayside                          *
 **************************************************
```

EXTREME II

```
     1. STAAD SPACE
INPUT FILE: Q:\Projects\19 PROJECTS\2192599 - TOWN OF PLYMOUTH Bridge Replacement\Calculations\Pile De.. .STD
     2. START JOB INFORMATION
     3. ENGINEER DATE 12-JAN-20
     4. ENGINEER NAME DP
     5. END JOB INFORMATION
     6. * FILE: EXTREME II
     7. * BRIDGE: P-13-001, PLYMOUTH
     8. * PILE: HP 10X57
     9. * EXTREME II
    10. *
    11. UNIT FEET POUND
    12. JOINT COORDINATES
    13. 1 0 -7.67 0; 2 0 -7.67 15.25; 3 0 -7.67 30.5; 4 25 -7.67 0
    14. 5 25 -7.67 15.25; 6 25 -7.67 30.5; 7 -5 -7.67 0; 8 -5 -7.67 30.5
    15. 9 30 -7.67 0; 10 30 -7.67 30.5; 11 35 -7.67 30.5; 12 35 -7.67 0
    16. 13 -10 -7.67 0; 14 -10 -7.67 30.5; 15 0 0 15.25; 16 25 0 15.25
    17. 17 0 -7.67 2.75; 18 0 -7.67 7.75; 19 0 -7.67 12.75; 20 0 -7.67 17.75
    18. 21 0 -7.67 22.75; 22 0 -7.67 27.75; 23 0 -11 2.75; 24 0 -11 7.75
    19. 25 0 -11 12.75; 26 0 -11 17.75; 27 0 -11 22.75; 28 0 -11 27.75
    20. 29 0 -26.3 2.75; 30 0 -26.3 7.75; 31 0 -26.3 12.75; 32 0 -26.3 17.75
    21. 33 0 -26.3 22.75; 34 0 -26.3 27.75; 35 25 -7.67 2.75
    22. 36 25 -7.67 7.75; 37 25 -7.67 12.75; 38 25 -7.67 17.75
    23. 39 25 -7.67 22.75; 40 25 -7.67 27.75; 41 25 -11 2.75
    24. 42 25 -11 7.75; 43 25 -11 12.75; 44 25 -11 17.75
    25. 45 25 -11 22.75; 46 25 -11 27.75; 47 25 -26.3 2.75
    26. 48 25 -26.3 7.75; 49 25 -26.3 12.75; 50 25 -26.3 17.75
    27. 51 25 -26.3 22.75; 52 25 -26.3 27.75
    28. MEMBER INCIDENCES
    29. 1 13 7; 2 7 1; 3 1 17; 4 17 18; 5 18 19; 6 19 2; 7 2 20; 8 20 21
    30. 9 21 22; 10 22 3; 11 14 8; 12 8 3; 13 17 23; 14 18 24; 15 19 25
    31. 16 20 26; 17 21 27; 18 22 28; 19 23 29; 20 24 30; 21 25 31; 22 26 32
    32. 23 27 33; 24 28 34; 25 2 15; 26 15 16; 27 16 5; 28 9 12; 29 4 9
    33. 30 4 35; 31 35 36; 32 36 37; 33 37 5; 34 5 38; 35 38 39; 36 39 40
    34. 37 40 6; 38 6 10; 39 10 11; 40 35 41; 41 36 42; 42 37 43; 43 38 44
    35. 44 39 45; 45 40 46; 46 41 47; 47 42 48; 48 43 49; 49 44 50; 50 45 51
    36. 51 46 52
    37. UNIT INCHES POUND
    38. MEMBER PROPERTY AMERICAN
```

```
39. 19 TO 24 PRIS AX 16.8 IX 294 IY 1000000 IZ 101
40. 46 TO 51 PRIS AX 16.8 IX 294 IY 1000000 IZ 101
41. MEMBER PROPERTY AMERICAN
42. 26 PRIS AX 468 IX 12874 IY 1000000 IZ 1000000
43. UNIT FEET KIP
44. MEMBER PROPERTY AMERICAN
45. 25 27 PRIS AX 1000 AY 1000 AZ 1000 IX 1E+006 IY 1E+006 IZ 1E+006
46. 1 TO 18 PRIS AX 1000 AY 1000 AZ 1000 IX 1E+006 IY 1E+006 IZ 1E+006
47. 28 TO 45 PRIS AX 1000 AY 1000 AZ 1000 IX 1E+006 IY 1E+006 IZ 1E+006
48. DEFINE MATERIAL START
49. ISOTROPIC MATERIAL1
50. E 580393
51. POISSON 0.2
52. DENSITY 0.15
53. ISOTROPIC STEEL
54. E 4.176E+006
55. POISSON 0.3
56. DENSITY 0.489024
57. ALPHA 6E-006
58. DAMP 0.03
59. TYPE STEEL
60. STRENGTH FY 5184 FU 8352 RY 1.5 RT 1.2
61. ISOTROPIC CONCRETE
62. E 453600
63. POISSON 0.17
64. DENSITY 0.150336
65. ALPHA 5E-006
66. DAMP 0.05
67. TYPE CONCRETE
68. STRENGTH FCU 576
69. END DEFINE MATERIAL
70. UNIT INCHES KIP
71. CONSTANTS
72. MATERIAL STEEL MEMB 26
73. MATERIAL STEEL MEMB 19 TO 24 46 TO 51
74. MATERIAL CONCRETE MEMB 1 TO 18 27 TO 45
75. MATERIAL CONCRETE MEMB 25
76. UNIT FEET KIP
77. SUPPORTS
78. 29 TO 34 47 TO 52 FIXED
79. *7 9 FIXED BUT FX FY MX MY MZ KFZ 108
80. *8 10 FIXED BUT FX FY MX MY MZ KFZ 108
81. *2 FIXED BUT FY FZ MX MY MZ KFX 170.2
82. *5 FIXED BUT FY FZ MX MY MZ KFX 170.2
83. *1  3 FIXED BUT FY FZ MX MY MZ KFX 85.1
84. *4  6 FIXED BUT FY FZ MX MY MZ KFX 85.1
85. *SPRING COMPRESSION
86. *7 9 KFZ
87. *SPRING TENSION
88. *8 10 KFZ
89. *SPRING COMPRESSION
90. *1 TO 3 KFX
91. *SPRING TENSION
92. *4 TO 6 KFX
93. *NON-COMPOSITE DEAD LOAD
94. LOAD 1 (DC 1)
```

```
 95. MEMBER LOAD
 96. 26 UNI PY -.3
 97. 3 TO 10 UNI PY -7.4
 98. 30 TO 37 UNI PY -7.4
 99. JOINT LOAD
100. 7 TO 10 FY -27.2
101. *SUPERIMPOSED DEAD LOAD
102. LOAD 2 (DC 2)
103. MEMBER LOAD
104. 26 UNI PY -1.44
105. *WEARING SURFACE
106. LOAD 3 (DW)
107. MEMBER LOAD
108. 26 UNI PY -1.08
109. *THERMAL LOADS
110. *SHRINK
111. LOAD 4 WA HYDRO LOADS
112. JOINT LOAD
113. 15 16 FY 30.6 FZ -2.7 MX 51.3
114. LOAD 5 LIVE LOAD
115. JOINT LOAD
116. 15 16 FY -105.0
117. LOAD COMB 6 EXTREME II (WA + SCOUR) COMBINATION 25
118. 1 1.0 2 1.0 3 1.0 4 1.0 5 0.0
119. LOAD COMB 7 EXTREME II (WA + LL) COMBINATION 26
120. 1 1.0 2 1.0 3 1.0 4 1.0 5 0.5
121. LOAD COMB 8 EXTREME II (SCOUR + LL) COMBINATION 27
122. 1 1.0 2 1.0 3 1.0 4 0.0 5 1.0
123. *END OF COMBINATIONS
124. PERFORM ANALYSIS
```

P R O B L E M   S T A T I S T I C S

NUMBER OF JOINTS	**52**	**NUMBER OF MEMBERS**	**51**
NUMBER OF PLATES	**0**	**NUMBER OF SOLIDS**	**0**
NUMBER OF SURFACES	**0**	**NUMBER OF SUPPORTS**	**12**

SOLVER USED IS THE OUT-OF-CORE BASIC SOLVER

```
  ORIGINAL/FINAL BAND-WIDTH=    34/      7/     42 DOF
TOTAL      PRIMARY LOAD CASES =      5, TOTAL DEGREES OF FREEDOM =      240
TOTAL LOAD COMBINATION  CASES =      3  SO FAR.
  SIZE OF STIFFNESS MATRIX =        11 DOUBLE  KILO-WORDS
  REQRD/AVAIL. DISK SPACE  =      12.2/ 933061.3 MB
```

```
125. LOAD LIST 6 TO 8
126. PRINT MEMBER FORCES  LIS 19 TO 24
```

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET (LOCAL)

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
19	6	23	47.47	0.01	-0.41	-0.00	3.21	0.09
		29	-47.47	-0.01	0.41	0.00	3.07	0.06
	7	23	56.21	0.01	-0.43	-0.00	3.35	0.09
		29	-56.21	-0.01	0.43	0.00	3.16	0.06
	8	23	70.05	0.01	-0.00	-0.00	0.04	0.09
		29	-70.05	-0.01	0.00	0.00	0.02	0.06
20	6	24	47.45	0.01	-0.42	-0.00	3.34	0.09
		30	-47.45	-0.01	0.42	0.00	3.16	0.06
	7	24	56.20	0.01	-0.44	-0.00	3.46	0.09
		30	-56.20	-0.01	0.44	0.00	3.24	0.06
	8	24	70.05	0.01	-0.01	-0.00	0.10	0.09
		30	-70.05	-0.01	0.01	0.00	0.06	0.06
21	6	25	47.45	0.01	-0.45	-0.00	3.54	0.09
		31	-47.45	-0.01	0.45	0.00	3.31	0.06
	7	25	56.21	0.01	-0.45	-0.00	3.61	0.09
		31	-56.21	-0.01	0.45	0.00	3.34	0.06
	8	25	70.08	0.01	-0.01	-0.00	0.08	0.09
		31	-70.08	-0.01	0.01	0.00	0.05	0.06
22	6	26	47.45	0.01	-0.46	0.00	3.71	0.09
		32	-47.45	-0.01	0.46	-0.00	3.40	0.06
	7	26	56.21	0.01	-0.46	0.00	3.64	0.09
		32	-56.21	-0.01	0.46	-0.00	3.37	0.06
	8	26	70.08	0.01	0.01	0.00	-0.08	0.09
		32	-70.08	-0.01	-0.01	-0.00	-0.05	0.06
23	6	27	47.46	0.01	-0.47	0.00	3.80	0.09
		33	-47.46	-0.01	0.47	-0.00	3.44	0.06
	7	27	56.21	0.01	-0.46	0.00	3.67	0.09
		33	-56.21	-0.01	0.46	-0.00	3.36	0.06
	8	27	70.05	0.01	0.01	0.00	-0.10	0.09
		33	-70.05	-0.01	-0.01	-0.00	-0.06	0.06
24	6	28	47.48	0.01	-0.48	0.00	3.87	0.09
		34	-47.48	-0.01	0.48	-0.00	3.47	0.06
	7	28	56.22	0.01	-0.46	0.00	3.73	0.09
		34	-56.22	-0.01	0.46	-0.00	3.39	0.06
	8	28	70.05	0.01	0.00	0.00	-0.04	0.09
		34	-70.05	-0.01	-0.00	-0.00	-0.02	0.06

************** END OF LATEST ANALYSIS RESULT **************

127. PRINT MAXFORCE ENVELOPE LIS 19 TO 24

MEMBER FORCE ENVELOPE

ALL UNITS ARE KIP FEET

MAX AND MIN FORCE VALUES AMONGST ALL SECTION LOCATIONS

MEMB		FY/ FZ	DIST	LD	MZ/ MY	DIST	LD	FX	DIST	LD
19	MAX	0.01	0.00	6	0.09	0.00	6			
		-0.00	0.00	8	3.35	0.00	7	70.05 C	0.00	8
	MIN	0.01	15.30	8	-0.06	15.30	8			
		-0.43	15.30	7	-3.16	15.30	7	47.47 C	15.30	6
20	MAX	0.01	0.00	6	0.09	0.00	6			
		-0.01	0.00	8	3.46	0.00	7	70.05 C	0.00	8
	MIN	0.01	15.30	8	-0.06	15.30	8			
		-0.44	15.30	7	-3.24	15.30	7	47.45 C	15.30	6
21	MAX	0.01	0.00	6	0.09	0.00	6			
		-0.01	0.00	8	3.61	0.00	7	70.08 C	0.00	8
	MIN	0.01	15.30	8	-0.06	15.30	8			
		-0.45	15.30	7	-3.34	15.30	7	47.45 C	15.30	6
22	MAX	0.01	0.00	6	0.09	0.00	6			
		0.01	0.00	8	3.71	0.00	6	70.08 C	0.00	8
	MIN	0.01	15.30	8	-0.06	15.30	8			
		-0.46	15.30	6	-3.40	15.30	6	47.45 C	15.30	6
23	MAX	0.01	0.00	6	0.09	0.00	6			
		0.01	0.00	8	3.80	0.00	6	70.05 C	0.00	8
	MIN	0.01	15.30	8	-0.06	15.30	8			
		-0.47	15.30	6	-3.44	15.30	6	47.46 C	15.30	6
24	MAX	0.01	0.00	6	0.09	0.00	6			
		0.00	0.00	8	3.87	0.00	6	70.05 C	0.00	8
	MIN	0.01	15.30	8	-0.06	15.30	8			
		-0.48	15.30	6	-3.47	15.30	6	47.48 C	15.30	6

********** END OF FORCE ENVELOPE FROM INTERNAL STORAGE **********

128. *PRINT SUPPORT REACTION
129. PRINT JOINT DISPLACEMENTS LIST 23 TO 28

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
23	6	0.00102	-0.01789	-0.00001	0.00000	0.00000	0.00001
	7	0.00102	-0.02118	-0.00001	0.00000	0.00000	0.00001
	8	0.00102	-0.02640	-0.00000	0.00000	0.00000	0.00001
24	6	0.00102	-0.01788	-0.00001	0.00000	0.00000	0.00001
	7	0.00102	-0.02118	-0.00001	0.00000	0.00000	0.00001
	8	0.00102	-0.02640	-0.00000	0.00000	0.00000	0.00001
25	6	0.00102	-0.01788	-0.00001	0.00000	0.00000	0.00001
	7	0.00102	-0.02118	-0.00001	0.00000	0.00000	0.00001
	8	0.00102	-0.02641	-0.00000	0.00000	0.00000	0.00001
26	6	0.00102	-0.01788	-0.00001	0.00000	0.00000	0.00001
	7	0.00102	-0.02118	-0.00001	0.00000	0.00000	0.00001
	8	0.00102	-0.02641	0.00000	-0.00000	0.00000	0.00001
27	6	0.00102	-0.01788	-0.00001	0.00000	0.00000	0.00001
	7	0.00102	-0.02118	-0.00001	0.00000	0.00000	0.00001
	8	0.00102	-0.02640	0.00000	-0.00000	0.00000	0.00001
28	6	0.00102	-0.01789	-0.00001	0.00000	0.00000	0.00001
	7	0.00102	-0.02118	-0.00001	0.00000	0.00000	0.00001
	8	0.00102	-0.02640	0.00000	-0.00000	0.00000	0.00001

************** END OF LATEST ANALYSIS RESULT **************

130. FINISH

*********** END OF THE STAAD.Pro RUN ***********

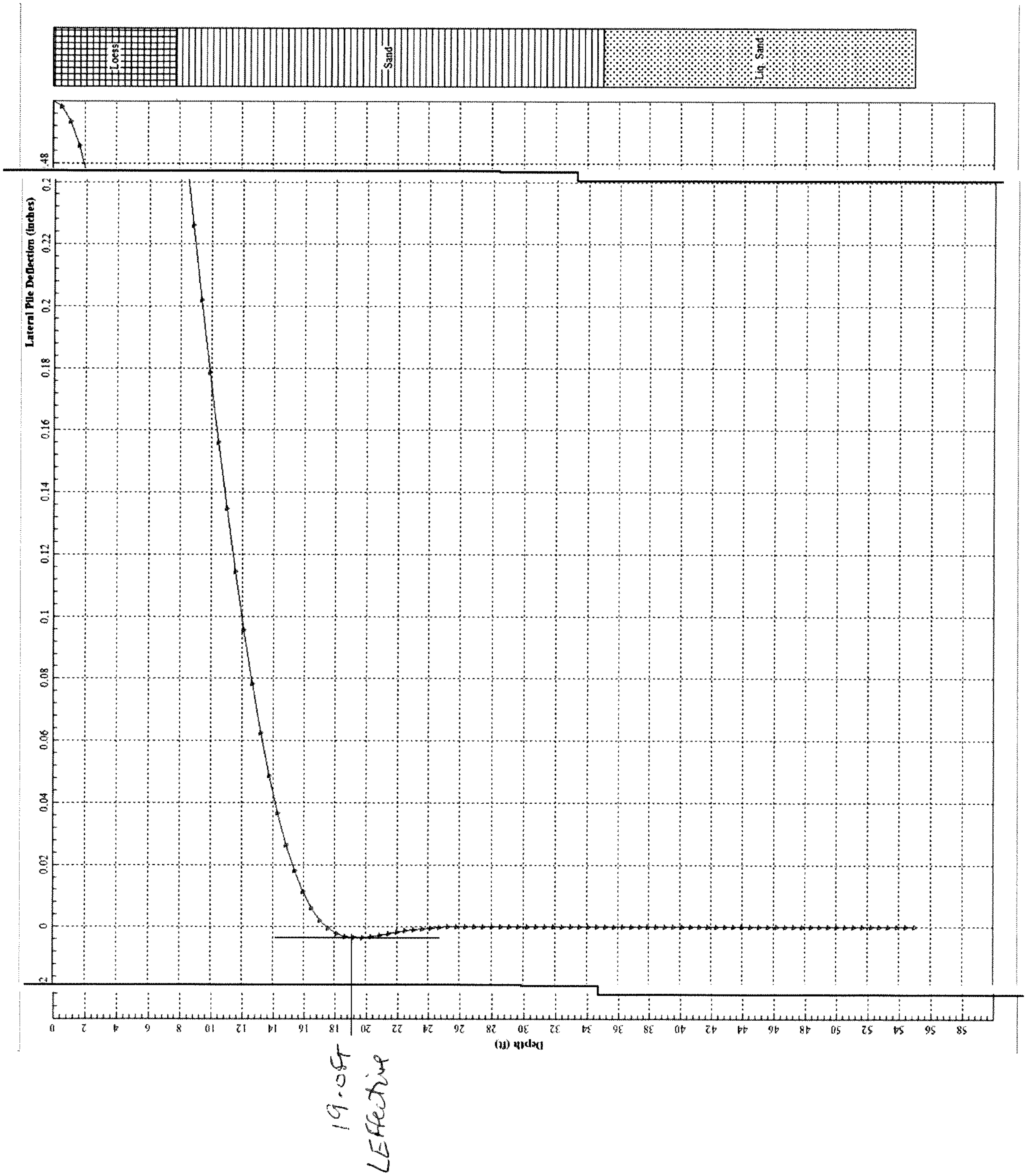
**** DATE= MAR 18,2020 TIME= 13:19:25 ****

BAYSIDE ENGINEERING
600 Unicorn Park Drive Woburn, MA 01801
Phone: 781.932.3201 Fax: 781.932.3413
www.baysideengineering.com

L-PILE RESULTS

Extreme II

0.5" deflection at top



since actual lateral deflection is far less than 1/2", use Lepp for BM (7.5Ft) plus the scour hole depth (7.9Ft) for Le = 15.3Ft instead of 19.0Ft from Lpile graph.

===

LPile for Windows, Version 2015-08.003

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

===

This copy of LPile is being used by:

john kelleher
bayside engineering

Serial Number of Security Device: 164289849

This copy of LPile is licensed for exclusive use by:

Bayside Engineering, Inc., Wobur

Files Used for Analysis

Path to file locations:
\Projects\19 PROJECTS\2192599 - TOWN OF PLYMOUTH Bridge Replacement\Calculations\Pile Design\L-PILE\

Name of input data file:
P-13-011_ EXTREMEI.lp8d

Name of output report file:
P-13-011_ EXTREMEI.lp8o

Name of plot output file:
P-13-011_ EXTREMEI.lp8p

Name of runtime message file:
P-13-011_ EXTREMEI.lp8r

Date and Time of Analysis

Date: March 19, 2020   Time: 14:08:58

Problem Title

Project Name: p-13-001

Job Number: p-13-001

Client: plymouth

Engineer: jk

Description: pile anal

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              =          100
 - Deflection tolerance for convergence              =   1.0000E-05 in
 - Maximum allowable deflection                      =     100.0000 in
 - Number of pile increments                         =          100

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

 - Analysis uses p-y modification factors for p-y curves
 - Analysis includes loading by one distributed lateral load acting on pile
 - Analysis includes loading by one lateral soil movement profile acting on pile
 - Input of shear resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

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

Pile Structural Properties and Geometry

```
Total number of pile sections                        =          1
```

Total length of pile = 55.00 ft

Depth of ground surface below top of pile = 0.00 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.

Point	Depth X ft	Pile Diameter in
1	0.00000	9.99000000
2	55.0000000	9.99000000

Input Structural Properties:

Pile Section No. 1:

Section Type	=	Elastic Pile
Cross-sectional Shape	=	Weak H-Pile
Section Length	=	55.000000 ft
Flange Width	=	10.225000 in
Section Depth	=	9.990000 in
Flange Thickness	=	0.565000 in
Web Thickness	=	0.565000 in
Section Area	=	16.800000 sq. in
Moment of Inertia	=	101.000000 in^4
Elastic Modulus	=	29000000. lbs/in^2

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 loess silt

Distance from top of pile to top of layer	=	0.0000 ft
Distance from top of pile to bottom of layer	=	7.800000 ft
Effective unit weight at top of layer	=	0.0000 pcf
Effective unit weight at bottom of layer	=	0.0000 pcf
Cone tip resistance at top of layer	=	0.0000 psi
Cone tip resistance at bottom of layer	=	0.0000 psi

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

Distance from top of pile to top of layer	=	7.800000 ft
Distance from top of pile to bottom of layer	=	35.000000 ft
Effective unit weight at top of layer	=	64.000000 pcf
Effective unit weight at bottom of layer	=	64.000000 pcf
Friction angle at top of layer	=	35.000000 deg.
Friction angle at bottom of layer	=	35.000000 deg.
Subgrade k at top of layer	=	90.000000 pci
Subgrade k at bottom of layer	=	90.000000 pci

Layer 3 is liquefiable sand, by Rollins et al., 2004

Distance from top of pile to top of layer	=	35.000000 ft
Distance from top of pile to bottom of layer	=	55.000000 ft
Effective unit weight at top of layer	=	65.000000 pcf
Effective unit weight at bottom of layer	=	65.000000 pcf

Warning : The depth of this layer is deeper than the recommended depth limit for using the p-y criteria for liquefied sand.

Please consult the LPile Technical Manual for additional background information regarding limitations on the use of the liquefied sand criteria.

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

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

Values entered for effective unit weights of soil were outside the limits of 0.011574 pci (20 pcf) or 0.0810019 pci (140 pcf)
This data may be erroneous. Please check your data.

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Angle of Friction deg.	kpy pci	In-situ Test Type	In-situ Test Property
1	Loess	0.00	0.00	--	--	CPT	0.00
		7.8000	0.00	--	--	CPT	0.00
2	Sand	7.8000	64.0000	35.0000	90.0000	--	--
	(Reese, et al.)	35.0000	64.0000	35.0000	90.0000	--	--
3	Liquefied	35.0000	65.0000	--	--	--	--
	Sand	55.0000	65.0000	--	--	--	--

---

p-y Modification Factors for Group Action

Distribution of p-y modifiers with depth defined using 2 points

Point No.	Depth X ft	p-mult	y-mult
1	0.000	1.0000	1.0000
2	0.000	1.0000	1.0000

Lateral Soil Movements Applied to All Load Cases

Profile of soil movement with depth defined using 2 points

Point No.	Depth X ft	Soil Movement in
1	0.00000	0.00000
2	0.00000	0.00000

Static Loading Type

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

Distributed Lateral Loading Used For All Load Cases

Distributed lateral load intensity defined using 2 points

Point No.	Depth X in	Dist. Load lbs/in
1	0.000	0.000
2	0.000	0.000

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 1

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length

----
1 5 y = 0.500000 in S = 0.0000 in/in 0.0000000 N.A.

V = perpendicular shear force applied to pile head
M = bending moment applied to pile head
y = lateral deflection relative to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applied to pile head
Values of top y vs. pile lengths can be computed only for load types with specified shear loading.
Axial thrust is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

---

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 = 0.500000 inches
Rotation of pile head = 0.000E+00 radians
Axial load on pile head = 0.0 lbs

Depth X feet	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness in-lb^2	Soil Res. p lb/inch	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.5000	-227958.	2396.	0.00	11274.	2.93E+09	0.00	0.00	0.00
0.5500	0.4983	-212144.	2396.	-4.96E-04	10492.	2.93E+09	0.00	0.00	0.00
1.1000	0.4935	-196329.	2396.	-9.56E-04	9710.	2.93E+09	0.00	0.00	0.00
1.6500	0.4857	-180514.	2396.	-0.00138	8927.	2.93E+09	0.00	0.00	0.00
2.2000	0.4752	-164699.	2396.	-0.00177	8145.	2.93E+09	0.00	0.00	0.00
2.7500	0.4623	-148885.	2396.	-0.00212	7363.	2.93E+09	0.00	0.00	0.00
3.3000	0.4472	-133070.	2396.	-0.00244	6581.	2.93E+09	0.00	0.00	0.00
3.8500	0.4301	-117255.	2396.	-0.00272	5799.	2.93E+09			

```
0.00         0.00         0.00
     4.4000       0.4113   -101440.       2396.   -0.00297      5017.   2.93E+09
0.00         0.00         0.00
     4.9500       0.3909    -85626.       2396.   -0.00318      4235.   2.93E+09
0.00         0.00         0.00
     5.5000       0.3693    -69811.       2396.   -0.00335      3453.   2.93E+09
0.00         0.00         0.00
     6.0500       0.3466    -53996.       2396.   -0.00349      2670.   2.93E+09
0.00         0.00         0.00
     6.6000       0.3232    -38182.       2396.   -0.00360      1888.   2.93E+09
0.00         0.00         0.00
     7.1500       0.2991    -22367.       2396.   -0.00367      1106.   2.93E+09
0.00         0.00         0.00
     7.7000       0.2748     -6552.       2396.   -0.00370   324.0354   2.93E+09
0.00         0.00         0.00
     8.2500       0.2503      9263.       2392.   -0.00370   458.0895   2.93E+09
-1.1312      29.8257        0.00
     8.8000       0.2260     25028.       2370.   -0.00366      1238.   2.93E+09
-5.5881     163.1994        0.00
     9.3500       0.2020     40550.       2312.   -0.00358      2005.   2.93E+09
-12.1203     395.9363       0.00
     9.9000       0.1787     55544.       2210.   -0.00348      2747.   2.93E+09
-18.8817     697.4129       0.00
    10.4500       0.1562     69716.       2064.   -0.00333      3448.   2.93E+09
-25.3206        1070.       0.00
    11.0000       0.1347     82785.       1879.   -0.00316      4094.   2.93E+09
-30.6140        1500.       0.00
    11.5500       0.1144     94520.       1654.   -0.00296      4675.   2.93E+09
-37.5778        2168.       0.00
    12.1000      0.09557    104618.       1380.   -0.00274      5174.   2.93E+09
-45.4168        3136.       0.00
    12.6500      0.07828    112738.       1052.   -0.00249      5575.   2.93E+09
-54.0702        4559.       0.00
    13.2000      0.06266    118502.   670.7265    -0.00223      5861.   2.93E+09
-61.4209        6469.       0.00
    13.7500      0.04881    121591.   247.5401    -0.00196      6013.   2.93E+09
-66.8174        9035.       0.00
    14.3000      0.03676    121770.  -202.8866    -0.00169      6022.   2.93E+09
-69.6756       12509.       0.00
    14.8500      0.02653    118913.  -662.1661    -0.00142      5881.   2.93E+09
-69.5000       17291.       0.00
    15.4000      0.01806    113029.      -1109.   -0.00116      5590.   2.93E+09
-65.8839       24076.       0.00
    15.9500      0.01127    104275.      -1519.  -9.11E-04      5157.   2.93E+09
-58.4622       34222.       0.00
    16.5000      0.00604     92975.      -1866.  -6.88E-04      4598.   2.93E+09
-46.7235       51056.       0.00
    17.0500      0.00219     79639.      -2093.  -4.94E-04      3939.   2.93E+09
-21.8540       65934.       0.00
    17.6000    -4.80E-04     65351.      -2148.  -3.31E-04      3232.   2.93E+09
5.0842       69854.       0.00
    18.1500     -0.00218     51285.      -2051.  -1.99E-04      2536.   2.93E+09
24.3279       73775.       0.00
    18.7000     -0.00311     38278.      -1850.  -9.83E-05      1893.   2.93E+09
36.6081       77695.       0.00
    19.2500     -0.00347     26866.      -1587.  -2.49E-05      1329.   2.93E+09
42.9574       81616.       0.00
    19.8000     -0.00344     17326.      -1299.   2.49E-05   856.8462   2.93E+09
44.5609       85536.       0.00
    20.3500     -0.00315      9726.      -1011.   5.54E-05   481.0033   2.93E+09
42.6300       89456.       0.00
    20.9000     -0.00271      3983.  -743.6965    7.08E-05   196.9972   2.93E+09
38.3043       93377.       0.00
```

21.4500	-0.00221	-90.8018	-509.7611	7.52E-05	4.4906	2.93E+09	32.5852	97297.	0.00
22.0000	-0.00171	-2746.	-315.4519	7.20E-05	135.7809	2.93E+09	26.2964	101218.	0.00
22.5500	-0.00126	-4255.	-162.4460	6.41E-05	210.4214	2.93E+09	20.0691	105138.	0.00
23.1000	-8.68E-04	-4890.	-48.8730	5.38E-05	241.8276	2.93E+09	14.3470	109058.	0.00
23.6500	-5.49E-04	-4900.	29.5073	4.28E-05	242.3263	2.93E+09	9.4046	112979.	0.00
24.2000	-3.03E-04	-4500.	78.2768	3.22E-05	222.5649	2.93E+09	5.3741	116899.	0.00
24.7500	-1.24E-04	-3867.	103.5237	2.28E-05	191.2262	2.93E+09	2.2765	120820.	0.00
25.3000	-2.81E-06	-3134.	111.2112	1.49E-05	154.9834	2.93E+09	0.05305	124740.	0.00
25.8500	7.21E-05	-2399.	106.7456	8.65E-06	118.6262	2.93E+09	-1.4063	128660.	0.00
26.4000	1.11E-04	-1725.	94.7195	4.01E-06	85.2985	2.93E+09	-2.2380	132581.	0.00
26.9500	1.25E-04	-1148.	78.8004	7.70E-07	56.7922	2.93E+09	-2.5859	136501.	0.00
27.5000	1.22E-04	-684.5895	61.7309	-1.29E-06	33.8567	2.93E+09	-2.5867	140422.	0.00
28.0500	1.08E-04	-333.5036	45.4047	-2.44E-06	16.4936	2.93E+09	-2.3606	144342.	0.00
28.6000	8.93E-05	-85.2471	30.9916	-2.91E-06	4.2159	2.93E+09	-2.0070	148262.	0.00
29.1500	6.95E-05	75.5849	19.0818	-2.92E-06	3.7381	2.93E+09	-1.6020	152183.	0.00
29.7000	5.07E-05	166.6332	9.8351	-2.65E-06	8.2409	2.93E+09	-1.2000	156103.	0.00
30.2500	3.45E-05	205.4084	3.1167	-2.23E-06	10.1586	2.93E+09	-0.8359	160024.	0.00
30.8000	2.13E-05	207.7737	-1.3849	-1.77E-06	10.2755	2.93E+09	-0.5283	163944.	0.00
31.3500	1.11E-05	187.1283	-4.0638	-1.32E-06	9.2545	2.93E+09	-0.2835	167864.	0.00
31.9000	3.81E-06	154.1316	-5.3270	-9.38E-07	7.6226	2.93E+09	-0.09926	171785.	0.00
32.4500	-1.23E-06	116.8113	-5.5466	-6.32E-07	5.7770	2.93E+09	0.03272	175705.	0.00
33.0000	-4.53E-06	80.9164	-5.0314	-4.10E-07	4.0018	2.93E+09	0.1234	179626.	0.00
33.5500	-6.64E-06	50.3974	-4.0150	-2.62E-07	2.4924	2.93E+09	0.1846	183546.	0.00
34.1000	-7.99E-06	27.9180	-2.6571	-1.73E-07	1.3807	2.93E+09	0.2269	187466.	0.00
34.6500	-8.93E-06	15.3234	-1.0541	-1.25E-07	0.7578	2.93E+09	0.2589	191387.	0.00
35.2000	-9.64E-06	14.0044	-0.1986	-9.17E-08	0.6926	2.93E+09	3.72E-04	254.8029	0.00
35.7500	-1.01E-05	12.7016	-0.1959	-6.16E-08	0.6282	2.93E+09	4.67E-04	304.1493	0.00
36.3000	-1.04E-05	11.4191	-0.1924	-3.44E-08	0.5647	2.93E+09	5.71E-04	360.6034	0.00
36.8500	-1.06E-05	10.1615	-0.1883	-1.01E-08	0.5025	2.93E+09	6.82E-04	425.0992	0.00
37.4000	-1.06E-05	8.9336	-0.1834	1.14E-08	0.4418	2.93E+09	8.00E-04	498.6682	0.00
37.9500	-1.04E-05	7.7405	-0.1777	3.02E-08	0.3828	2.93E+09	9.21E-04	582.4563	0.00
38.5000	-1.02E-05	6.5876	-0.1712	4.63E-08	0.3258	2.93E+09			

0.00105	677.7404	0.00				
39.0500	-9.83E-06	5.4803	-0.1639	5.99E-08	0.2710	2.93E+09
0.00117	785.9483	0.00				
39.6000	-9.39E-06	4.4239	-0.1558	7.11E-08	0.2188	2.93E+09
0.00129	908.6801	0.00				
40.1500	-8.89E-06	3.4239	-0.1469	7.99E-08	0.1693	2.93E+09
0.00141	1048.	0.00				
40.7000	-8.34E-06	2.4853	-0.1372	8.66E-08	0.1229	2.93E+09
0.00152	1205.	0.00				
41.2500	-7.75E-06	1.6131	-0.1268	9.12E-08	0.07978	2.93E+09
0.00162	1383.	0.00				
41.8000	-7.14E-06	0.8117	-0.1158	9.39E-08	0.04014	2.93E+09
0.00171	1584.	0.00				
42.3500	-6.51E-06	0.08481	-0.1042	9.49E-08	0.00419	2.93E+09
0.00179	1812.	0.00				
42.9000	-5.88E-06	-0.5642	-0.09225	9.44E-08	0.02790	2.93E+09
0.00184	2069.	0.00				
43.4500	-5.26E-06	-1.1328	-0.07995	9.25E-08	0.05603	2.93E+09
0.00188	2359.	0.00				
44.0000	-4.66E-06	-1.6196	-0.06748	8.94E-08	0.08010	2.93E+09
0.00190	2687.	0.00				
44.5500	-4.08E-06	-2.0236	-0.05497	8.53E-08	0.1001	2.93E+09
0.00189	3058.	0.00				
45.1000	-3.54E-06	-2.3452	-0.04258	8.03E-08	0.1160	2.93E+09
0.00186	3477.	0.00				
45.6500	-3.02E-06	-2.5856	-0.03045	7.48E-08	0.1279	2.93E+09
0.00181	3952.	0.00				
46.2000	-2.55E-06	-2.7472	-0.01875	6.88E-08	0.1359	2.93E+09
0.00173	4491.	0.00				
46.7500	-2.12E-06	-2.8332	-0.00763	6.25E-08	0.1401	2.93E+09
0.00164	5102.	0.00				
47.3000	-1.72E-06	-2.8479	0.00277	5.61E-08	0.1408	2.93E+09
0.00152	5799.	0.00				
47.8500	-1.38E-06	-2.7966	0.01230	4.97E-08	0.1383	2.93E+09
0.00137	6594.	0.00				
48.4000	-1.07E-06	-2.6855	0.02085	4.36E-08	0.1328	2.93E+09
0.00121	7506.	0.00				
48.9500	-8.01E-07	-2.5214	0.02829	3.77E-08	0.1247	2.93E+09
0.00104	8558.	0.00				
49.5000	-5.71E-07	-2.3121	0.03450	3.22E-08	0.1143	2.93E+09
8.46E-04	9782.	0.00				
50.0500	-3.75E-07	-2.0660	0.03940	2.73E-08	0.1022	2.93E+09
6.38E-04	11230.	0.00				
50.6000	-2.10E-07	-1.7920	0.04288	2.30E-08	0.08862	2.93E+09
4.14E-04	13003.	0.00				
51.1500	-7.21E-08	-1.5000	0.04480	1.93E-08	0.07418	2.93E+09
1.69E-04	15443.	0.00				
51.7000	4.38E-08	-1.2006	0.04497	1.62E-08	0.05938	2.93E+09
-1.19E-04	17984.	0.00				
52.2500	1.42E-07	-0.9064	0.04321	1.38E-08	0.04483	2.93E+09
-4.13E-04	19207.	0.00				
52.8000	2.26E-07	-0.6302	0.03946	1.21E-08	0.03117	2.93E+09
-7.24E-04	21110.	0.00				
53.3500	3.02E-07	-0.3856	0.03355	1.10E-08	0.01907	2.93E+09
-0.00107	23328.	0.00				
53.9000	3.71E-07	-0.1874	0.02524	1.03E-08	0.00927	2.93E+09
-0.00145	25811.	0.00				
54.4500	4.38E-07	-0.05245	0.01420	1.00E-08	0.00259	2.93E+09
-0.00189	28550.	0.00				
55.0000	5.04E-07	0.00	0.00	9.99E-09	0.00	2.93E+09
-0.00241	15775.	0.00				

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

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

Pile-head deflection              =     0.50000000 inches
Computed slope at pile head       =    -0.00001782 radians
Maximum bending moment            =       -227958. inch-lbs
Maximum shear force               =          2396. lbs
Depth of maximum bending moment   =       0.000000 feet below pile head
Depth of maximum shear force      =     1.10000000 feet below pile head
Number of iterations              =              9
Number of zero deflection points =               4


--------------------------------------------------------------------------------
            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 Load                Load                  Axial    Pile-head  Pile-head  Max
Shear Max Moment
Case Type   Pile-head    Type     Pile-head   Loading  Deflection  Rotation    in
Pile    in Pile
 No.  1      Load 1       2        Load 2       lbs      inches     radians      lbs
     in-lbs
---- ----- ---------- ---------- ---------- ---------- ---------- ----------
---------- ----------
  1  y, in     0.5000   S, rad         0.00       0.00     0.5000  -1.78E-05
2396.   -227958.


Maximum pile-head deflection =     0.500000000 inches
Maximum pile-head rotation   =    -0.000017818 radians

No error or warning messages were generated by this analysis.

The analysis ended normally.
```

RETAINING WALL FACTORED BEARING RESISTANCE

NOMINAL BEARING PRESSURE

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5\gamma \ BN_{\gamma m} C_{w\gamma} \quad (10.6.3.1.2a\text{-}1)$$

in which:

$$N_{cm} = N_c s_c i_c \quad (10.6.3.1.2a\text{-}2)$$

$$N_{qm} = N_q s_q d_q i_q \quad (10.6.3.1.2a\text{-}3)$$

$$N_\gamma m = N_\gamma s_\gamma i_\gamma \quad (10.6.3.1.2a\text{-}4)$$

where:

c = cohesion, taken as undrained shear strength (ksf)

N_c = cohesion term (undrained loading) bearing capacity factor as specified in Table 10.6.3.1.2a-1 (dim)

N_q = surcharge (embedment) term (drained or undrained loading) bearing capacity factor as specified in Table 10.6.3.1.2a-1 (dim)

N_γ = unit weight (footing width) term (drained loading) bearing capacity factor as specified in Table 10.6.3.1.2a-1 (dim)

γ = total (moist) unit weight of soil above or below the bearing depth of the footing (kcf)

D_f = footing embedment depth (ft)

B = footing width (ft)

$C_{wq}, C_{w\gamma}$ = correction factors to account for the location of the groundwater table as specified in Table 10.6.3.1.2a-2 (dim)

s_c, s_γ, s_q = footing shape correction factors as specified in Table 10.6.3.1.2a-3 (dim)

d_q = correction factor to account for the shearing resistance along the failure surface passing through cohesionless material above the bearing elevation as specified in Table 10.6.3.1.2a-4 (dim)

i_c, i_γ, i_q = load inclination factors determined from Eqs. 10.6.3.1.2a-5 or 10.6.3.1.2a-6, and 10.6.3.1.2a-7 and 10.6.3.1.2a-8 (dim)

Additional formulas for correction factors are provided at the back of this calculation packet.
We assumed all load inclination factors to be 1.0, rather than use the provided equations.

SOIL PROPERTIES

Kulhawy and Mayne presented the following N value relationships based on Peck, Hanson, and Thornburn and Meyerhof.

N Value (blows/ft or 305 mm)	Relative Density	Approximate $\bar{\phi}_{tc}$ (degrees) (a)	(b)
0 to 4	very loose	< 28	< 30
4 to 10	loose	28 to 30	30 to 35
10 to 30	medium	30 to 36	35 to 40
30 to 50	dense	36 to 41	40 to 45
> 50	very dense	> 41	> 45

a - Source: Peck, Hanson, and Thornburn (12), p. 310.
b - Source: Meyerhof (13), p. 17.

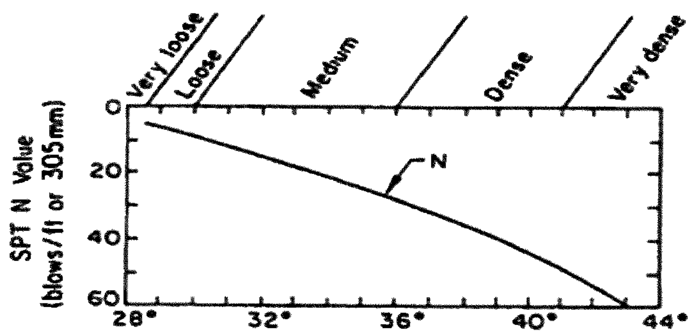


Figure 4-12. N versus $\bar{\phi}_{tc}$

Source: Peck, Hanson, and Thornburn (12), p. 310.

USE FRICTION ANGLE = 30 DEGREES (Meduim Dense Sand); 10 < N < 30

SOIL PROPERTIES

Typical Soil Characteristics (from Lindeburg, *Civil Engineering Reference Manual for the PE Exam, 8th ed.*)

Soil Type	γ (lb/ft^3)	γ_{sat} (lb/ft^3)
Sand, loose and uniform	90	118
Sand, dense and uniform	109	130
sand, loose and well graded	99	124
Sand, dense and well graded	116	135
glacial clay, soft	76	110
glacial clay, stiff	106	125

USE DENSITY =109PCF; Medium Dence Sand

BAYSIDE ENGINEERING
600 Unicorn Park Drive Woburn, MA 01801
Phone: 781.932.3201 Fax: 781.932.3413
www.baysideengineering.com

NOMINAL BEARING PRESSURE

B' = 4.00

Nominal Bearing Pressure - Variables

c = 0.00 ksf

Depth of Fill, Df = 15.00 ft. ft max. (to bottom of footing, back of wall)

Dfl = 5.00 ft. ft min. (to bottom of footing, face of wall)

B' = 4.00 ft (B = B' for bearing resistance calcs) (bf - 2*ebf)

L' = 30.00 ft (L = L' for bearing resistance calcs)

g = 0.109 kcf

ϕf = 30

C_{wq} = 0.5 (AASHTO LRFD Table 10.6.3.1.2a-2)

C_{wg} = 0.5 (AASHTO LRFD Table 10.6.3.1.2a-2)

N_c = 30.1 (AASHTO LRFD Table 10.6.3.1.2a-1)

N_q = 18.4 (AASHTO LRFD Table 10.6.3.1.2a-1)

N_g = 22.4 (AASHTO LRFD Table 10.6.3.1.2a-1)

sc = 1 + (B'/L') * (Nq/Nc) (AASHTO LRFD Table 10.6.3.1.2a-3)

sc = 1.08

sg = 1 - 0.4 * (B'/L') (AASHTO LRFD Table 10.6.3.1.2a-3)

sg = 0.947

sq = 1 + (B'/L' * tanϕf) (AASHTO LRFD Table 10.6.3.1.2a-3)

sq = 1.08

$N_{cm} = N_c * sc =$ 32.6 (AASHTO LRFD 10.6.3.1.2a-2)

Dfl/B' = 1.25

dq = 1.00 (Conservative) (AASHTO LRFD Table 10.6.3.1.2a-4)

N_{qm} = Nq * sq * dq = 19.8 (AASHTO LRFD 10.6.3.1.2a-3)

N_{gm} = Ng * sg = 21.2 (AASHTO LRFD 10.6.3.1.2a-4)

$q_n = c * N_{cm} + g * D_{fl} * N_{qm} * C_{wq} + 0.5 * g * B * N_{gm} * C_{wg}$ (AASHTO LRFD 10.6.3.1.2a-1)

q_n = 7.7 ksf

Factored resistance

q_R = qn * Resistance factor (AASHTO LRFD 10.6.3.1.1-1)

Resistance Factor = 0.45 (AASHTO LRFD 10.5.5.2.2)

q_R = 3.5 ksf

Soil Properties:

gs = 0.109 kcf saturated soil weight

ϕ = 30.0 deg. (Bearing Material)

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NOMINAL BEARING PRESSURE

B' = 6.00

Nominal Bearing Pressure - Variables

Soil Properties:

gs = 0.109 kcf saturated soil weight

ϕ = 30.0 deg. (Bearing Material)

c = 0.00 ksf
Depth of Fill, Df = 15.00 ft. ft max. (to bottom of footing, back of wall)
Df1 = 5.00 ft. ft min. (to bottom of footing, face of wall)
B' = 6.00 ft (B = B' for bearing resistance calcs) (bf - 2*ebf)
L' = 30.00 ft (L = L' for bearing resistance calcs)
g = 0.109 kcf
ϕf = 30
C_{wq} = 0.5 (AASHTO LRFD Table 10.6.3.1.2a-2)
C_{wg} = 0.5 (AASHTO LRFD Table 10.6.3.1.2a-2)
N_c = 30.1 (AASHTO LRFD Table 10.6.3.1.2a-1)
N_q = 18.4 (AASHTO LRFD Table 10.6.3.1.2a-1)
N_g = 22.4 (AASHTO LRFD Table 10.6.3.1.2a-1)
sc = 1 + (B'/L') * (Nq/Nc) (AASHTO LRFD Table 10.6.3.1.2a-3)
sc = 1.12
sg = 1 - 0.4 * (B'/L') (AASHTO LRFD Table 10.6.3.1.2a-3)
sg = 0.920
sq = 1 + (B'/L' * tanϕf) (AASHTO LRFD Table 10.6.3.1.2a-3)
sq = 1.12
$N_{cm} = N_c$ * sc = 33.8 (AASHTO LRFD 10.6.3.1.2a-2)
Df1/B' = 0.83
dq = 1.00 (Conservative) (AASHTO LRFD Table 10.6.3.1.2a-4)
N_{qm} = Nq * sq * dq = 20.5 (AASHTO LRFD 10.6.3.1.2a-3)
N_{gm} = Ng * sg = 20.6 (AASHTO LRFD 10.6.3.1.2a-4)

$q_n = c * N_{cm} + g * D_{f1} * N_{qm} * C_{wq} + 0.5 * g * B * N_{gm} * C_{wg}$ (AASHTO LRFD 10.6.3.1.2a-1)

q_n = 9.0 ksf

Factored resistance

q_R = qn * Resistance factor (AASHTO LRFD 10.6.3.1.1-1)

Resistance Factor = 0.45 (AASHTO LRFD 10.5.5.2.2)

q_R = 4.0 ksf

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NOMINAL BEARING PRESSURE

B' = 8.00

Nominal Bearing Pressure - Variables

Soil Properties:

gs = 0.109 kcf saturated soil weight

ϕ = 30.0 deg. (Bearing Material)

c = 0.00 ksf
Depth of Fill, Df = 15.00 ft. ft max. (to bottom of footing, back of wall)
Dfl = 5.00 ft. ft min. (to bottom of footing, face of wall)
B' = 8.00 ft (B = B' for bearing resistance calcs) (bf - 2*ebf)
L' = 30.00 ft (L = L' for bearing resistance calcs)
g = 0.109 kcf
ϕf = 30
C_{wq} = 0.5 (AASHTO LRFD Table 10.6.3.1.2a-2)
C_{wg} = 0.5 (AASHTO LRFD Table 10.6.3.1.2a-2)
N_c = 30.1 (AASHTO LRFD Table 10.6.3.1.2a-1)
N_q = 18.4 (AASHTO LRFD Table 10.6.3.1.2a-1)
N_g = 22.4 (AASHTO LRFD Table 10.6.3.1.2a-1)
sc = 1 + (B'/L') * (Nq/Nc) (AASHTO LRFD Table 10.6.3.1.2a-3)
sc = 1.16
sg = 1 - 0.4 * (B'/L') (AASHTO LRFD Table 10.6.3.1.2a-3)
sg = 0.893
sq = 1 + (B'/L' * tanϕf) (AASHTO LRFD Table 10.6.3.1.2a-3)
sq = 1.15
$N_{cm} = N_c$ * sc = 35.0 (AASHTO LRFD 10.6.3.1.2a-2)
Dfl/B' = 0.63
dq = 1.00 (Conservative) (AASHTO LRFD Table 10.6.3.1.2a-4)
N_{qm} = Nq * sq * dq = 21.2 (AASHTO LRFD 10.6.3.1.2a-3)
N_{gm} = Ng * sg = 20.0 (AASHTO LRFD 10.6.3.1.2a-4)

$q_n = c * N_{cm} + g * D_{fl} * N_{qm} * C_{wq} + 0.5 * g * B * N_{gm} * C_{wg}$ (AASHTO LRFD 10.6.3.1.2a-1)

q_n = 10.1 ksf

Factored resistance

q_R = qn * Resistance factor (AASHTO LRFD 10.6.3.1.1-1)

Resistance Factor = 0.45 (AASHTO LRFD 10.5.5.2.2)

q_R = 4.6 ksf

APPENDIX D – GEOPHYSICAL SEISMIC REFRACTION TOP OF ROCK SURVEY BY NDT

GEOPHYSICAL SEISMIC REFRACTION
TOP OF ROCK SURVEY

BRIDGE # P-13-011(9KM)
BROOK ROAD OVER BEAVER DAM BROOK

PLYMOUTH, MASSACHUSETTS

Prepared for

BAYSIDE ENGINEERING, INC

MARCH, 2020

NDT CORPORATION
Concrete & Geophysical Testing

NDT CORPORATION
153 Clinton Road, Sterling, MA 01564
Main: 978-563-1327 | Fax: 978-563-1340
eMail: Info@NDTCorporation.com

March 13, 2020

Brian Boucher, P.E.
Bridge Engineer
Bayside Engineering, Inc.
600 Unicorn Park Drive
Woburn, MA 01801

Subject: Geophysical Seismic Refraction top of bedrock profiling for the replacement of Bridge # P-13-011(9KM) – Brook Road over Beaver Dam Brook in Plymouth, Massachusetts.

Dear Mr. Boucher:

In accordance with your authorization to proceed, NDT Corporation conducted a geophysical seismic refraction survey at Bridge # P-13-011(9KM) – Brook Road over Beaver Dam Brook in Plymouth, Massachusetts. The fieldwork was completed on March 10th, 2020. The objective of this survey was to determine the depth to rock at this bridge location to assist Bayside Engineering with preliminary foundation design effort to replace the bridge.

We thank you for the opportunity to perform this work and look forward to being of service to you in the future. If you have any questions or require additional information, call the undersigned at 978-573-1327.

NDT Corporation

William Horne

William Horne

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	4.1 SEISMIC REFRACTION	Page 1
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	APPENDIX 1 SEISMIC REFRACTION	

1.0 SUMMARY OF RESULTS

Seismic refraction data collected at this bridge location indicated 95+/- feet of water-saturated overburden with a velocity of 5,000+/- ft/sec overlying a competent bedrock with a seismic velocity of 12,000 to 14,000 ft/sec.

2.0 INTRODUCTION AND PURPOSE

NDT Corporation conducted two (2) – 400-foot lines of seismic refraction coverage at Bridge # P-13-011(9KM) – Brook Road over Beaver Dam Brook in Plymouth, Massachusetts. Field work was conducted on March 10th, 2020. The purpose of this survey was to obtain top of bedrock information which will be used to assist Bayside Engineering in the preliminary foundation design effort to replace the bridge crossing the brook.

3.0 LOCATION AND SURVEY CONTROL

The general location Bridge # P-13-011(9KM) in Plymouth, Massachusetts is shown on Figure 1. The locations of the 2 – 400-foot seismic refraction lines of coverage are also shown on Figure 1. The top of the road surface at the bridge was used as depth elevation 0.

Seismic Line 1 was located south and parallel to Brook Road from station 0+00 to the west and station 4+00 to the east with an approximate offset of 5-10 feet south from south EOR. The brook/bridge spanned from station 2+70 to 3+00.

Seismic Line 2 was located in Beaver Dam Brook with station 0+00 to the south and station 4+00 to the north. The line passed under the bridge between stations 0+70 to 0+90.

Due to the length of the lines and access to private property a Plymouth DPW representative was on site during the survey.

4.0 METHODS OF INVESTIGATION

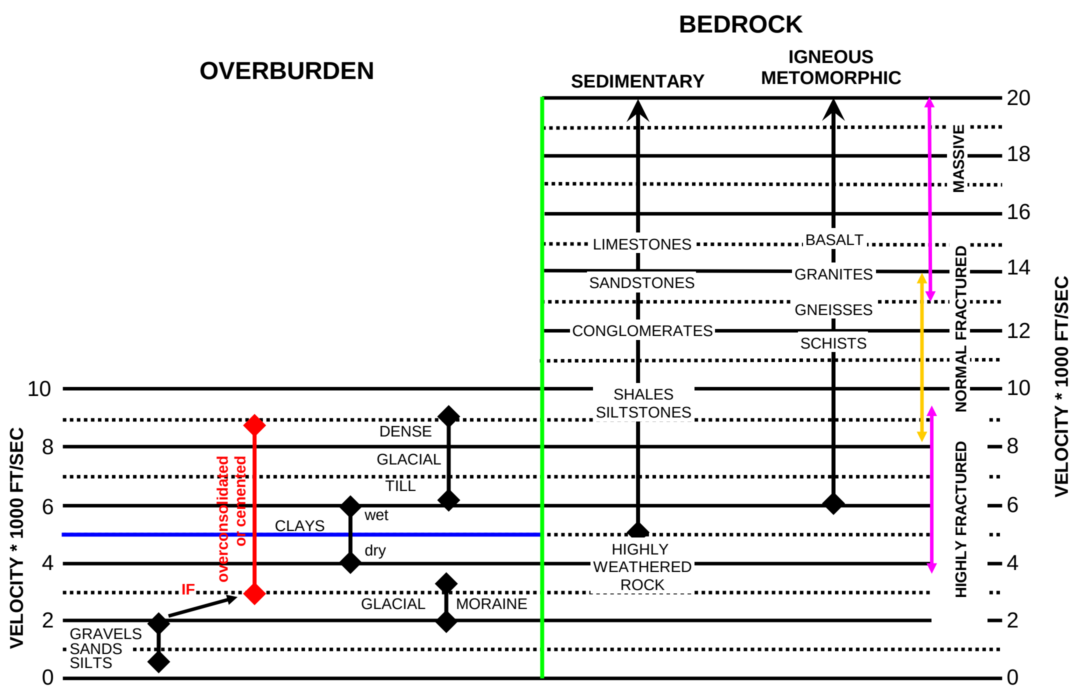
4.1 SEISMIC REFRACTION:

Seismic refraction data was acquired with a 24-channel system with 10 and 20 foot geophone/hydrophone spacing and seismic energy generated approximately every 100 feet with a Betsy Seisgun (non-projectile) energy source. Seismic Refraction utilizes the natural energy transmitting properties of the soils and rocks and is based on the principle that the velocity at which seismic waves travel through the earth is a function of the physical properties (elastic moduli and Poisson's ratio) of the materials. Refracted compressional wave data are used to evaluate material types and thickness, profile top of bedrock, and to determine the approximate depth to layer interfaces. The seismic refraction data were interpreted using the critical distance method. Variations of 5 to 10 feet are not accurately profiled, particularly in deep bedrock areas. A more complete discussion of the seismic refraction survey method is included in Appendix 1.

Overburden with a 1,000-1,500+/- ft/sec velocity is consistent with normally consolidated soils/sands/fill material typical of natural soils, fluvial deposits, and/or construction fill. Till with a 2,600+/- ft/sec velocity value is consistent with unstratified glacial drift or ground moraine. These tills typically deposited by receding glaciers consisting of an admixture of clays, sands and gravels with occasional and sometimes frequent boulders associated with an ablation till. All of these materials when saturated with water have a seismic velocity of 5,000+/- ft/sec.

Bedrock velocities of less than 10,000 ft/sec are indicative of highly weathered and/or fractured rock typical of sedimentary and low-grade metamorphic rocks such as shales, silt stones and schists. Bedrock with a velocity of 10,000 to 15,000 ft/sec is indicative of competent bedrock that will require drilling and blasting for removal. This velocity range is typical of competent sedimentary and metamorphic rocks such as sandstones, limestones, schists, and gneisses. Bedrock velocities greater than 15,000 ft/sec are indicative of massive bedrock typical in metamorphic and igneous rocks such as gneisses, granites and basalts.

Bedrock velocity ranges are determined by rock type and the degree of fracturing, bedding, joints, and weathering.



5.0 RESULTS

Seismic data indicated a thin layer of dry fill/soil materials with a velocity of 1+000+/- ft/sec overlying a thick layer of water saturated overburden layer with a velocity of 5,000+/- feet; data indicates that the overburden ranged from 90 to 100 feet across the profile area; overlying a competent bedrock with a seismic velocity of 12,000 +/- ft/sec.

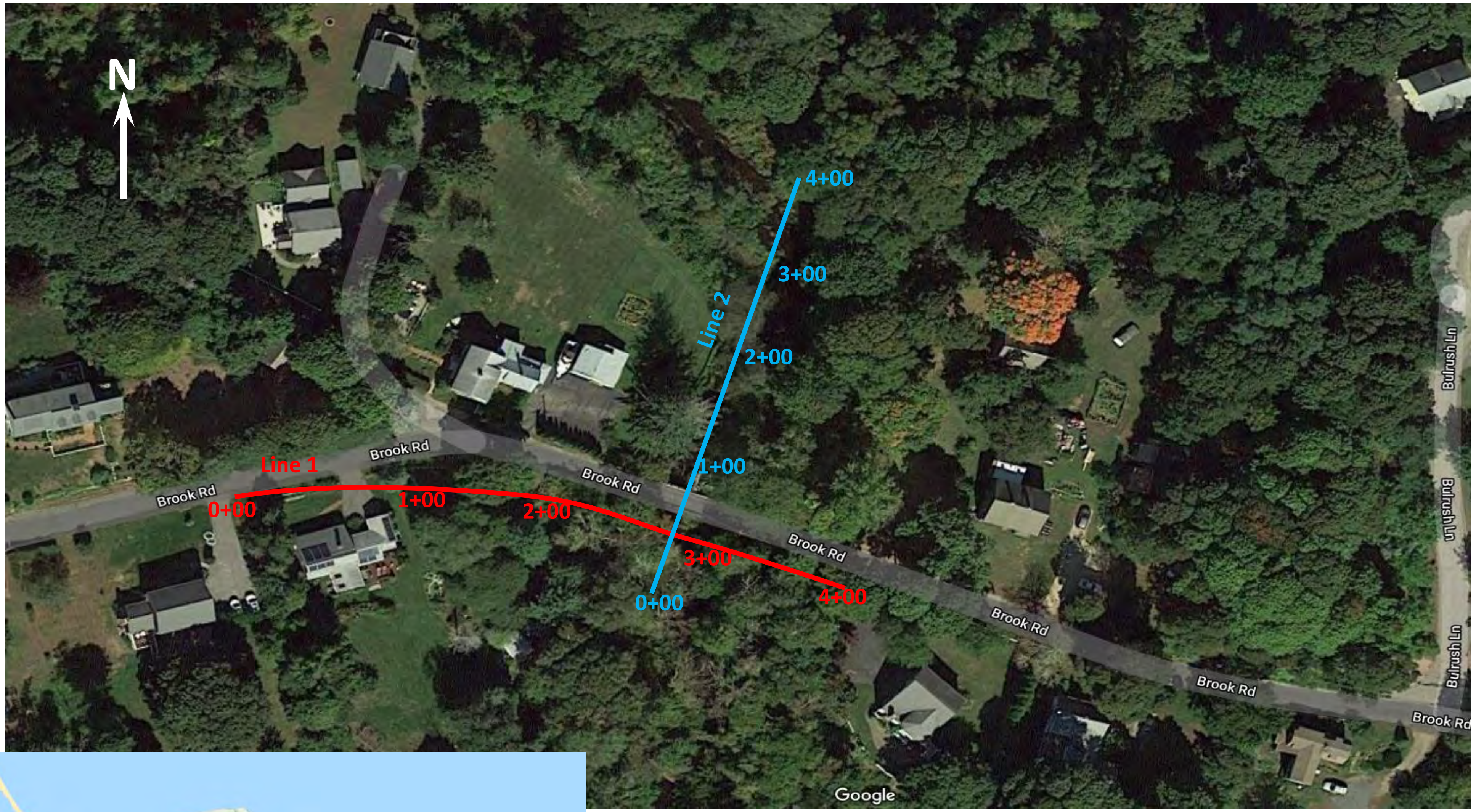
The seismic lines of coverage are shown in Figure 1. Figure 2 shows the top of rock profile Seismic Line 1 which crosses the brook from west to east and Figure 3 shows the top of rock profile along Seismic Line 2 which runs south to north in the streambed under the bridge.

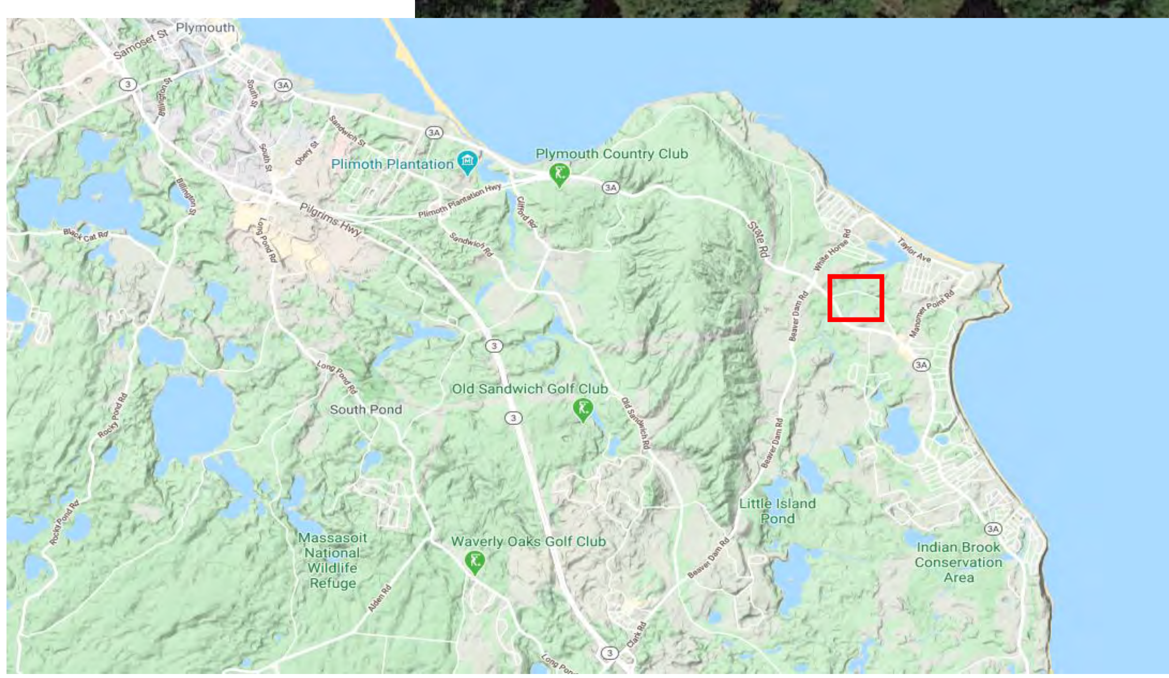
Both seismic lines indicate that the top of rock at the location of the bridge is approximately 95+/- feet below the top of pavement at the bridge. Localized high and low areas exist. Definition of high and low areas is a function of the seismic spread length, number of "shots" taken, geophone spacing, velocity contrast, and the irregularity of the rock surface. Due to the depth of bedrock at this location only the end shots (0+00 and 4+00) showed a definitive rock velocity. Without additional data points each profile shows an interpolated top of rock line between these two points variations of 5 - 10 feet could exist and not defined by the limitations of this survey.

FIGURES

Seismic Refraction Survey- Bridge # P-13-011(9KM)

Brook Road over Beaver Dam Brook Plymouth, MA





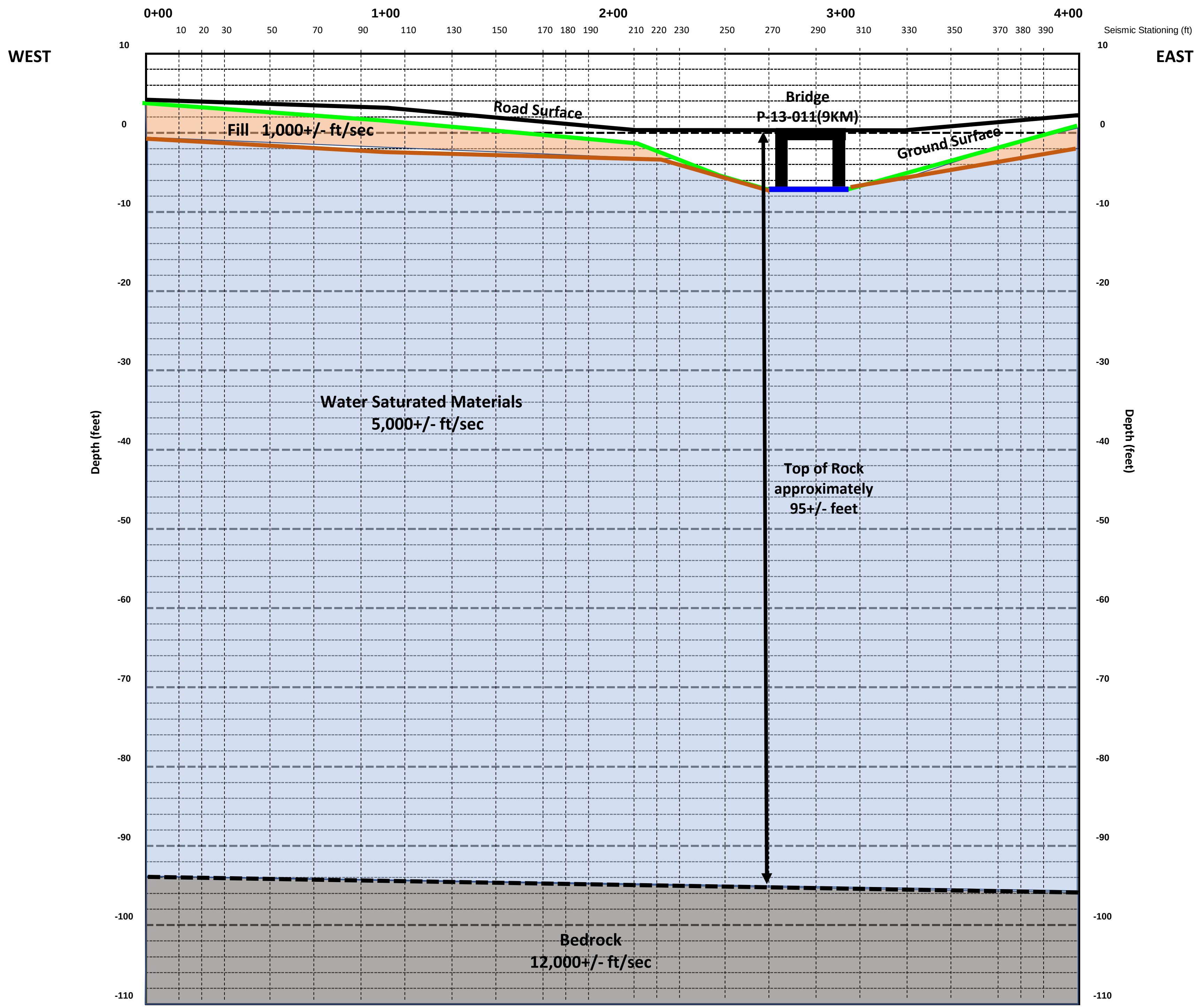
Seismic Refraction Top of Rock Survey Bridge # P-13-011 (9KM) Brook Road over Beaver Dam Brook Plymouth, Massachusetts prepared for Bayside Engineering, Inc by NDT Corporation	Area of Investigation and Lines of Coverage	
	March, 2020	Figure 1

3/10/2020

Seismic Line 1 - Bridge # P-13-011(9KM)

Brook Road over Beaver Dam Brook Plymouth, MA

Seismic Line 1 is offset approximately 5-10 feet South of the Bridge/Road



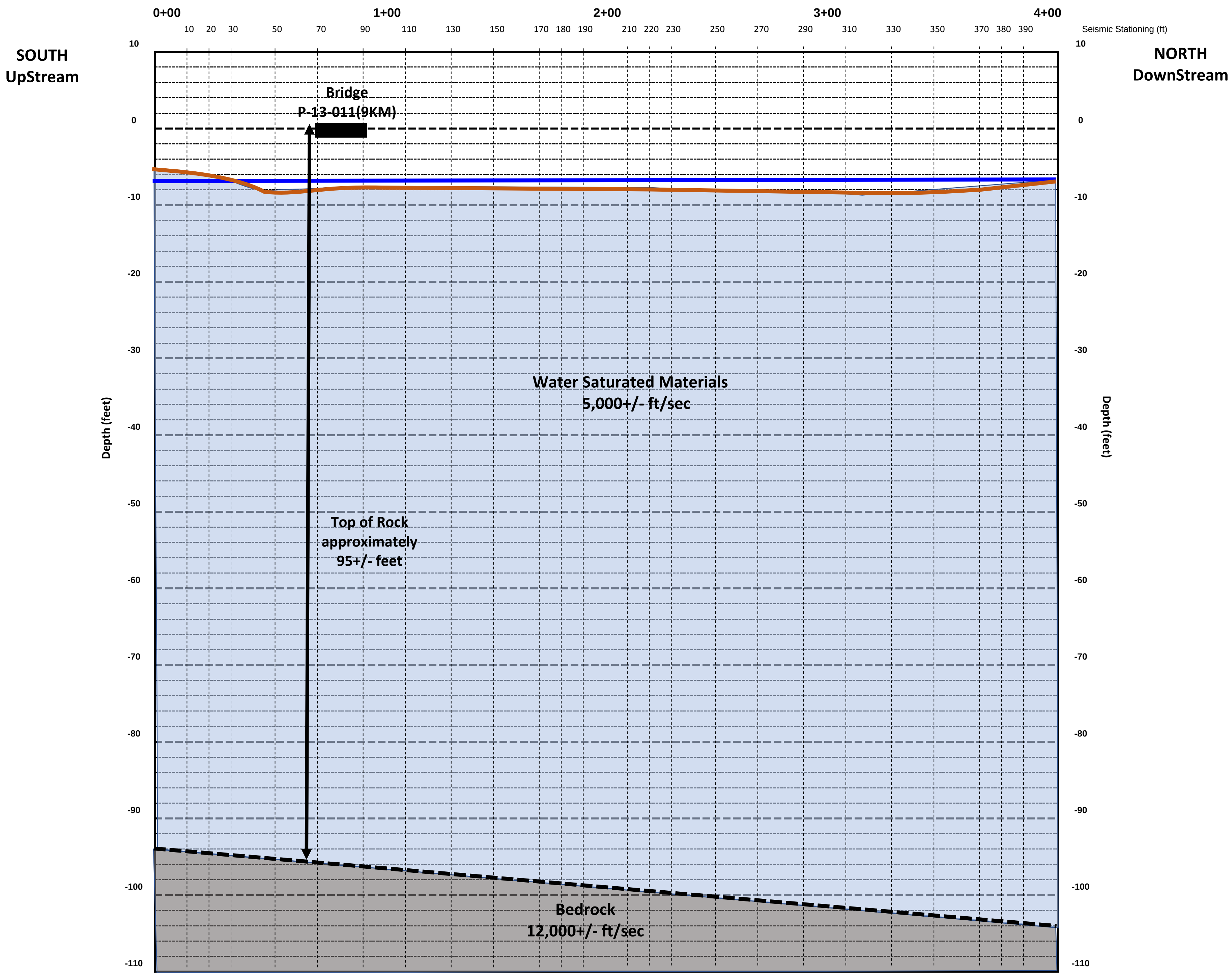
Seismic Refraction Top of Rock Survey Bridge # P-13-011 (9KM) Brook Road over Beaver Dam Brook Plymouth, Massachusetts prepared for Bayside Engineering, Inc by NDT Corporation	Seismic Line 1 Results	
	March, 2020	Figure 2

3/10/2020

Seismic Line 2 - Bridge # P-13-011(9KM)

Brook Road over Beaver Dam Brook Plymouth, MA

Seismic Line 2 centered in stream bed (Bridge located between station 0+70 and 0+90)



Seismic Refraction Top of Rock Survey Bridge # P-13-011 (9KM) Brook Road over Beaver Dam Brook Plymouth, Massachusetts prepared for Bayside Engineering, Inc by NDT Corporation	Seismic Line 2 Results	
	March, 2020	Figure 3

APPENDIX 1

SEISMIC REFRACTION

APPENDIX: SEISMIC REFRACTION

OVERVIEW

Seismic exploration methods utilize the natural energy transmitting properties of the soils and rocks and are based on the principle that the velocity at which seismic waves travel through the earth is a function of the physical properties (elastic moduli and Poisson's ratio) of the materials. Energy is generated at the ends and at the center of the seismic spread. The geophone/hydrophone is in direct contact with the earth/water and converts the earth's motion resulting from the energy generation into electric signals with a voltage proportional to the particle velocity of the ground motion. The field operator can amplify and filter the seismic signals to minimize background noise. Data are recorded on magnetic disk and can be printed in the field. Interpretations are based on the time required for a seismic wave to travel form a source to a series of geophones/hydrophones located at specific intervals along the ground surface. The resultant seismic velocities are used for:

* Material identification.
* Stratigraphic correlation.
* Depth determinations.
* Calculation of elastic moduli values and Poison's ratio.

A variety of seismic wave types, differing in resultant particle motion, are generated by a near surface seismic energy source. The two types of seismic waves for seismic exploration are the compressional (P) wave and the shear (S) wave. Particle motion resulting from a (P-wave) is an oscillation, consisting of alternating compression and dilatation, orientated parallel to the direction of propagation. An S-wave causes particle motion transverse to the direction of propagation. The P-wave travels with a higher velocity of the two waves and is of greater importance for seismic surveying. The following discussions are concerned principally with P-waves.

Possible seismic wave paths include a direct wave path, a reflected wave path or a refracted wave path. These wave paths are illustrated in FIGURE A1. The different paths result in different travel times, so that the recorded seismic waveform will theoretically show three distinct wave arrivals. The direct and refracted wave paths are important to seismic refraction exploration while the reflected wave path is important for seismic reflection studies.

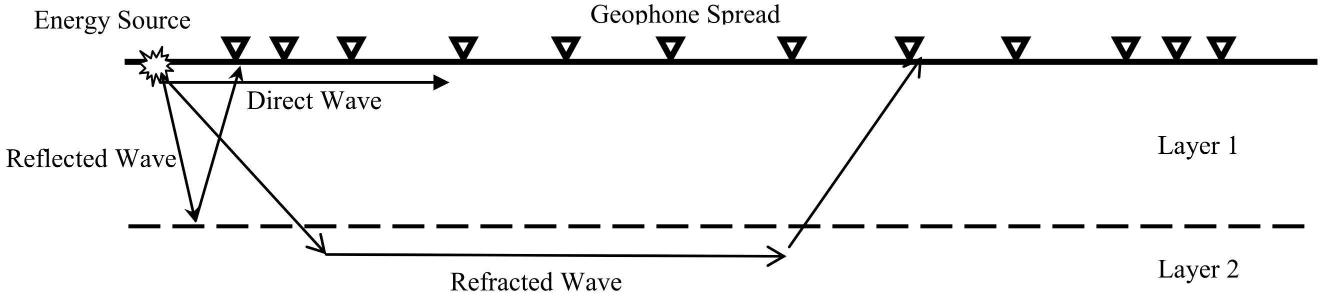


FIGURE A1:
SEISMIC WAVE PATHS FOR DIRECT WAVE, REFLECTED WAVE AND REFRACTED WAVE ILLUSTRATING EFFECTS OF A BOUNDARY BETWEEN MATERIALS WITH DIFFERENT ELASTIC PROPERTIES

Seismic waves incident on the interface between materials of different elastic properties at what is termed the critical angle are refracted and travel along the top of the lower layer. The critical angle is a function of the seismic velocities of the two materials. These same waves are then refracted back to the surface at the same angle. The recorded arrival times of these refracted waves, because they depend on the properties and geometry of the subsurface, can be analyzed to produce a vertical profile of the subsurface. Information such as the number, thickness and depths of stratigraphic layers, as well as clues to the composition of these units can be ascertained.

The first arrivals at the geophones/hydrophones located near the energy source are direct waves that travel through the near surface. At greater distances, the first arrival is a refracted wave. Lower layers typically are higher velocity materials, therefore the refracted wave will overtake both the direct wave and the reflected wave, because of the time gained travelling through the higher velocity material compensates for the longer wave path. Depth computations are based on the ratio of the layer velocities and the distance from the energy source to the point where refracted wave arrivals over take direct arrivals.

Although not the usual case, a constraint on refraction theory is that material velocities ideally should increase with depth. If a velocity inversion exists, i.e. where a higher velocity layer overlies a low velocity layer, depths and seismic velocities can be calculated but the uncertainty in calculations is increased unless borehole data are available.

APPLICATIONS

Seismic refraction technique is an accurate and effective method for determining the thickness of subsurface geologic layers. Applications for engineering design, assessment, and remediation as well as ground water and hydrogeologic studies include:

* Continuous profiling of subsurface layers including the bedrock surface
* Water-table depth determinations
* Mapping and general identification of significant stratigraphic layers
* Detection of sinkholes and cavities
* Detection of bedrock fracture zones
* Detection of filled-in areas
* Elastic moduli and Poisson’s ratio values for subsurface layers

Seismic refraction investigations are particularly useful because seismic velocities can be used for material identification. FIGURE A2 presents a guide to material identification based on P-wave seismic velocities. In rocks and compacted overburden material, the seismic waves travel from grain to grain so that the measured seismic velocity value is a direct function of the solid material. In porous or fractured rock and most overburden materials the seismic waves travel partly or wholly though the fluid between the grains.

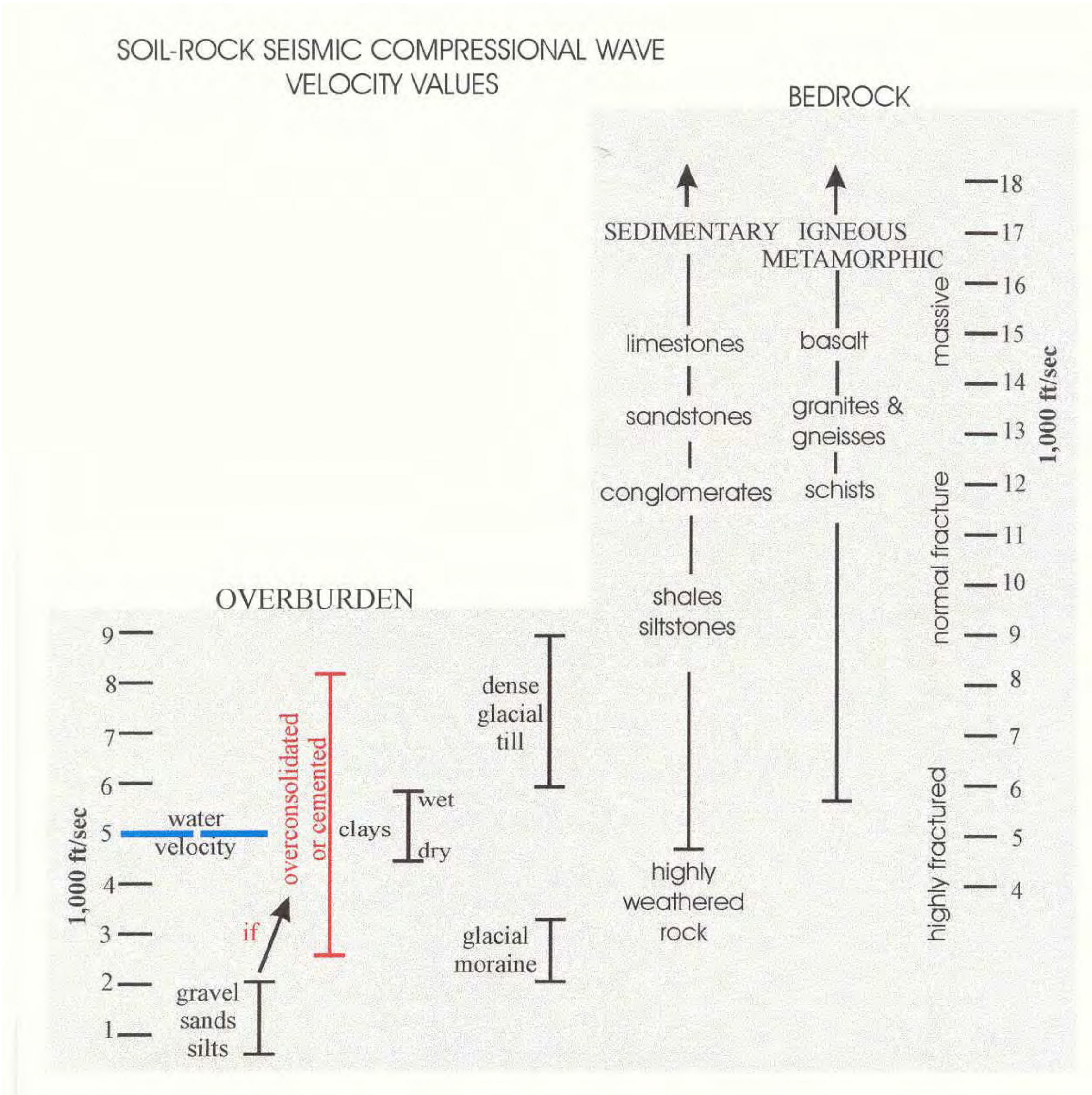


FIGURE A2:
GUIDE TO MATERIAL IDENTIFICATION BY P-WAVE VELOCITY

Seismic compressional wave velocities in unconsolidated deposits are significantly affected by water saturation. The seismic velocity values of unsaturated overburden materials such gravels, sands and silts generally fall in the range of 1,000 to 2,000 ft/sec. When these materials are water saturated, that is when the space between individual grains are 100% filled with water, the seismic velocities range from 4,800 to 5,100 ft/sec, equivalent to the compressional P-wave velocity of sound in water. This is because the seismic wave assumes the velocity of the faster medium, that of water. Even a small decrease in the saturation level will substantially lower the measured P-wave velocity of the material. Because of this velocity contrast between saturated and unsaturated materials, the water table acts as a strong refractor.

Seismic investigations over unconsolidated deposits are used to map stratigraphic discontinuities and to unravel the gross stratigraphy of the subsurface. These can be vertically as in the case of a dense till layer beneath a layer of saturated material or horizontally as in the case of the boundaries of a fill material. Often these boundaries represent significant hydrologic boundaries, such as those between aquifers and aquicludes.

A common use of seismic refraction is the determination of the thickness of a saturated layer in unconsolidated sediments and the depth to relatively impermeable bedrock or dense glacial till. Continuous subsurface profiles and even contour maps of the top of a particular horizon or layer of interest can be developed from a suite of seismic refraction data.

Bedrock velocities FIGURE A2 vary over a broad range depending on variables, which include:

* Rock type
* Density
* Degree of jointing/fracturing
* Degree of weathering

Fracturing and weathering generally reduce seismic velocity values in bedrock. Low velocity zones in seismic data must be evaluated carefully to determine if they are due to overburden conditions or fractured/weathered or perhaps even faulted bedrock.

<u>EQUIPMENT:</u>

The basic equipment necessary to conduct a seismic refraction investigation consists of:

* Energy source
* Seismometers (Geophones/Hydrophones)
* Seismic cables
* Seismograph

Energy sources used for seismic surveys are categorized as either non-explosive or explosive. The energy for a non-explosive seismic signal can be provided by one of the following:

* Sledge Hammer (very shallow penetration)
* Weight Drop
* Seisgun
* Airgun
* Sparker
* Vibrators (for reflection surveys)

Explosive sources can be categorized as:

* Dynamite
* Primers
* Blasting Agents

Choice of energy source is dependent on site conditions, depth of investigation, and seismic technique chosen as well as local restrictions. Explosive sources may be prohibited in urban areas where non-explosive sources can be routinely used. Deeper investigations usually require a larger energy source: therefore, explosives may be required for sufficient penetration.

Geophones/Hydrophones are sensitive vibration detectors, which convert ground motion to an electric voltage for recording the seismic wave arrivals. Seismic cables, which link the geophones/hydrophones and seismograph are generally fabricated with pre-measured locations for the geophones/hydrophones and shot point definitions.

The seismograph can be single channel or multi-channel, although, multi-channel seismographs (12 to 24 channels) are preferred and necessary for all but the simplest of very shallow surveys. The seismograph, amplifies (increases the voltage output of the geophones), conditions/filters the data, and produces analog and digital archives of the data. The analog archive is in the form of a thermal print of the data, which can be printed directly after acquisition in the field. The digital archive is stored on magnetic disk and can be used for subsequent computer processing and enable more extensive and detailed interpretation of seismic data.

ACQUISITION CONSIDERATIONS:

Several concerns arise before data collection, which must be addressed before of any seismic survey:

* Geophone spacing and Spread length
* Energy Source (discussed above)
* On-site utilities and cultural features (buildings, high tension lines, buried utilities, etc.)
* Vibration generating activities
* Geology
* Topography

To acquire seismic refraction data, a specific number of geophones are spaced at regular intervals along a straight line on the ground surface; this line is commonly referred to as a seismic spread. The length of spread determines the depth of penetration; a longer spread is required for a greater depth of penetration. Spread length should be approximately three to five times the required depth of penetration. Required resolution will control the number of geophones in each spread and the distance between each geophone. Closer spacings and more geophones usually result in more detail and greater resolution.

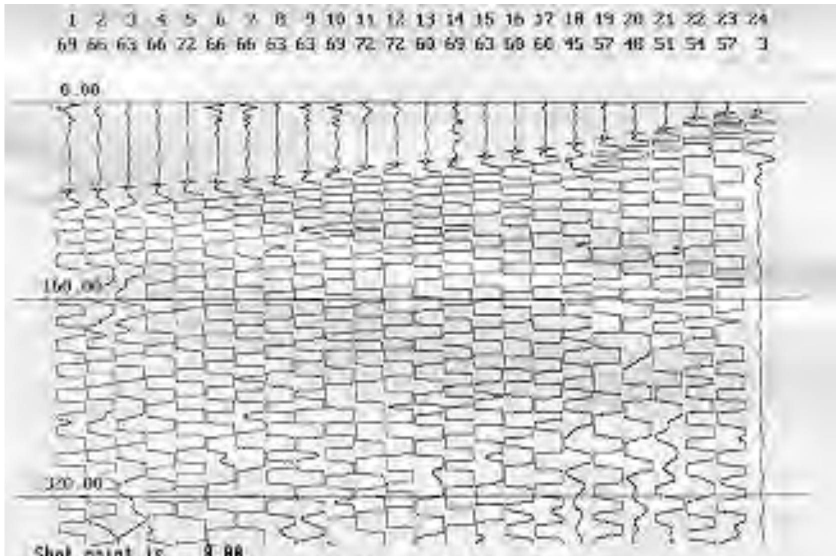
Cultural effects such as vibration generating activities, on-site utilities, and building affect where data can be acquired, and where lines/spreads are located. High volume traffic areas may require nighttime acquisition. If the survey is to be conducted near a building where vibration-sensitive manufacturing is conducted, data acquisition may be constrained to particular time intervals and appropriate energy sources must be used. Over head and buried utilities must be located an avoided, for both safety and induced electrical noise concerns. Since the seismic method measures ground vibration, it is inherently sensitive to noise from a variety of sources such as traffic, wind, rain etc. Signal Enhancement, such as record stacking, accomplished by adding a number of seismic signals from a repeated source, causes the seismic signal to “grow” out of the noise level, permitting operation in noisier environments and at greater source to phone spacings.

Knowledge of site geology can be used to determine the energy source. Some geologic materials, such as loose, unsaturated alluvium, do not transmit seismic energy as well and a powerful energy source may be required. Geologic conditions also dictate whether or not drilled shotholes are required. Site geology can also dictate the positioning of seismic lines/spreads. Where a bedrock depression of a feature is suspected, seismic lines should be orientated perpendicular to the suspected trend of the feature. Seismic cross profiles may be necessary to confirm depths to a particular refracting horizon.

The topography of a site dictates whether or not surveyed elevations are required. If possible, refraction profile lines should be positioned along level topography. For highly variable topography, a continuous elevation profile may be required to ensure sufficiently accurate cross-sections and to permit the use of time corrections in the interpretation of the refraction data.

DATA PRESENTATION AND INTERPETATION:

Interpretation of seismic refraction data involves solving a number of mathematical equations with the refraction data as it is presented on a travel-time versus distance chart. Seismic refraction data FIGURE A3 can be processed by plotting the “First Arrival” travel times at each geophone location. The preferred format of data presentation is a graph (Travel Time Plot) illustrated in FIGURE A4, in which travel time in milliseconds is plotted against source-receiver distance. From such a chart, the velocities of each layer can be obtained directly from the increase slope of each straight-line segment. Using the velocities the critical angle of refraction for each boundary can be calculated using Snell’s Law. Then, utilizing these velocities, and angles and the recorded distances to crossover points (where line segments cross); the depths and thickness of each layer can be calculated using simple geometric relationships.



Shot point is 0.00

Channel	1	Phone location	195.00	Arrival time	71.3	msec
Channel	2	Phone location	190.00	Arrival time	70.3	msec
Channel	3	Phone location	185.00	Arrival time	68.5	msec
Channel	4	Phone location	175.00	Arrival time	66.3	msec
Channel	5	Phone location	165.00	Arrival time	63.3	msec
Channel	6	Phone location	155.00	Arrival time	63.0	msec
Channel	7	Phone location	145.00	Arrival time	62.0	msec
Channel	8	Phone location	135.00	Arrival time	59.0	msec
Channel	9	Phone location	125.00	Arrival time	56.0	msec
Channel	10	Phone location	115.00	Arrival time	54.0	msec
Channel	11	Phone location	110.00	Arrival time	51.5	msec
Channel	12	Phone location	105.00	Arrival time	49.3	msec
Channel	13	Phone location	95.00	Arrival time	47.3	msec
Channel	14	Phone location	90.00	Arrival time	45.0	msec
Channel	15	Phone location	85.00	Arrival time	43.0	msec
Channel	16	Phone location	75.00	Arrival time	39.0	msec
Channel	17	Phone location	65.00	Arrival time	37.0	msec
Channel	18	Phone location	55.00	Arrival time	33.0	msec
Channel	19	Phone location	45.00	Arrival time	28.0	msec
Channel	20	Phone location	35.00	Arrival time	25.0	msec
Channel	21	Phone location	25.00	Arrival time	20.0	msec
Channel	22	Phone location	15.00	Arrival time	12.0	msec
Channel	23	Phone location	10.00	Arrival time	8.0	msec
Channel	24	Phone location	5.00	Arrival time	7.0	msec

FIGURE A3:
TYPICAL 24 CHANNEL ANALOG SEISMIC REFRACTION RECORD, WITH FIRST ARRIVAL TIMES

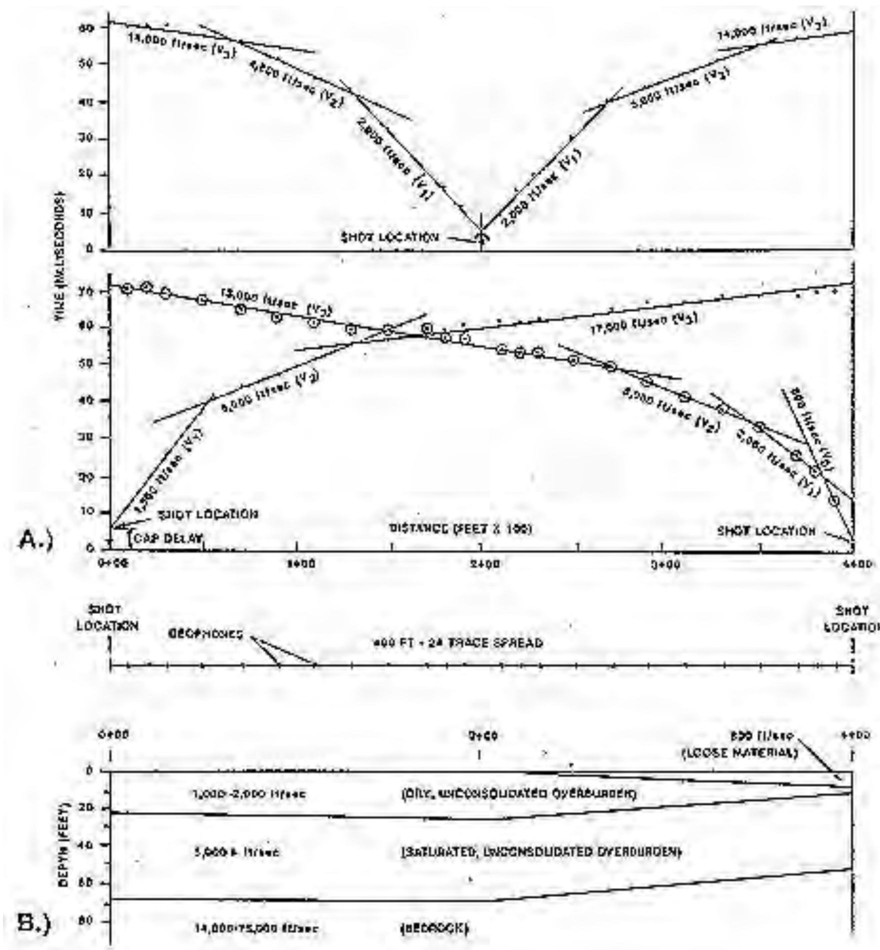


FIGURE A4:
A: TRAVEL-TIME PLOTS; UPPER PLOT IS A CENTER SHOT, LOWER PLOT IS TWO END SHOTS
B: RESULTING PROFILE OF SUBSURFACE MATERIALS SHOWING INTERFACE BETWEEN DIFFERENT SEISMIC VELOCITY LAYERS

The results of any seismic survey, refraction or reflection are usually presented in profile form showing elevations of seismic horizons/layers. Data acquired on a grid basis can be contoured and used to construct isopach maps. Seismic velocities and therefore, generalized material identifications should be presented on refraction profiles along with any test borings used for correlation to establish confidence in the overall subsurface data, both seismic and borings.

Where profiles indicate dipping boundaries, calculation of dips, true depths and true velocities involve more complicated equations. Further more, corrections for differing elevations and varying thicknesses of weathered zones must often be made. Fracturing and weathering generally reduce seismic velocity values in bedrock. Consequently, travel-time plots with late arrivals must be evaluated carefully to determine if the late arrival times (slower velocities) are due to overburden conditions or fractured/weathered bedrock.

Very thin layers or low velocity zones often complicate the travel-time chart as well. Although not the usual case, one constraint on refraction theory is that material velocities ideally should increase with depth. If a velocity inversion exists, i.e. where a higher velocity layer overlies a low velocity layer, depths and seismic velocities can be calculated but the uncertainty in calculations is increased unless borehole velocity data are available.

ADVANTAGES AND LIMITATIONS:

The seismic refraction technique, when properly employed, is the most accurate of the geophysical methods for determining subsurface layering and materials. It is extremely effective in that as much as 2,000 linear feet or more of profiling can be acquired in a field day. The resulting profiles can be used to minimize drilling and place drilling at locations where borehole information will be maximized resulting in cost-effective exploration. A standard drilling program runs the risk of missing key locations due to drillhole spacing. This risk is substantially reduced when refraction is used.

In summary, the advantages and limitations of the seismic techniques are:

Advantages:

* Material identification
* Subsurface data over broader areas at less cost than drilling
* Relatively accurate depth determination
* Correlation between drillholes
* Preliminary results available almost immediately
* Rapid data processing

Limitations:

* As depth of interest and geophone spacing increases, resolution decreases
* Thin layers may be undetected
* Velocity inversions may add uncertainty to calculations
* Susceptible to noise interference in urban areas, which require use of grounded cables and equipment, signal enhancement and alternative energy sources.

APPENDIX E – TABULATED SOIL DESIGN PARAMETERS

Typical Soil Characteristics (from Lindeburg, *Civil Engineering Reference Manual for the PE Exam, 8th ed.*)

Soil Type	γ (lb/ft^3)	γ_{sat} (lb/ft^3)
Sand, loose and uniform	90	118
Sand, dense and uniform	109	130
sand, loose and well graded	99	124
Sand, dense and well graded	116	135
glacial clay, soft	76	110
glacial clay, stiff	106	125

Typical Values of Soil Index Properties (from *NAVFAC 7.01*)

Soil Type	γ (lb/ft^3)	γ_{sub} (lb/ft^3)
Sand; clean, uniform, fine or medium	84 - 136	52 - 73
Silt; uniform, inorganic	81 - 136	51 - 73
Silty Sand	88 - 142	54 - 79
Sand; Well-graded	86 - 148	53 - 86
Silty Sand and Gravel	90 - 155	56 - 92
Sandy or Silty Clay	100 - 147	38 - 85
Silty Clay with Gravel; uniform	115 - 151	53 - 89
Well-graded Gravel, Sand, Silt and Clay	125 - 156	62 - 94
Clay	94 - 133	31 - 71
Colloidal Clay	71 - 128	8 - 66
Organic Silt	87 - 131	25 - 69
Organic Clay	81 - 125	18 - 62

SoilMechanicsinEngineeringPractice

In *Soil Mechanics in Engineering Practice,* Karl Terzaghi and Ralph Peck compiled various parameters of soils into the table below:

Table 6.3

Porosity, Void Ratio, and Unit Weight of Typical Soils in Natural State

Description	Porosity, n (%)	Void ratio, e	Water content, w (%)	Unit weight grams/cm³ γ_d	Unit weight grams/cm³ γ	Unit weight lb/ft³ γ_d	Unit weight lb/ft³ γ
1. Uniform sand, loose	46	0.85	32	1.43	1.89	90	118
2. Uniform sand, dense	34	0.51	19	1.75	2.09	109	130
3. Mixed-grained sand, loose	40	0.67	25	1.59	1.99	99	124
4. Mixed-grained sand, dense	30	0.43	16	1.86	2.16	116	135
5. Glacial till, very mixed-grained	20	0.25	9	2.12	2.32	132	145
6. Soft glacial clay	55	1.2	45	–	1.77	–	110
7. Stiff glacial clay	37	0.6	22	–	2.07	–	129
8. Soft slightly organic clay	66	1.9	70	–	1.58	–	98
9. Soft very organic clay	75	3.0	110	–	1.43	–	89
10. Soft bentonite	84	5.2	194	–	1.27	–	80

w = water content when saturated, in per cent of dry weight.

γ^d = unit weight in dry state.

γ = unit weight in saturated state.

Relationship between ϕ, and standard penetration number for sands, (from Peck 1974, *Foundation Engineering Handbook*).

SPT Penetration, N-Value (blows/ foot)	Density of Sand	ϕ (degrees)
<4	Very loose	<29
4 - 10	Loose	29 - 30
10 - 30	Medium	30 - 36
30 - 50	Dense	36 - 41
>50	Very dense	>41

Relationship between ϕ, and standard penetration number for sands, (from Meyerhof 1956, *Foundation Engineering Handbook*).

SPT Penetration, N-Value (blows/ foot)	Density of Sand	ϕ (degrees)
<4	Very loose	<30
4 - 10	Loose	30 - 35
10 - 30	Medium	35 - 40
30 - 50	Dense	40 - 45
>50	Very dense	>45

Additionally, Terzaghi and Peck offer the following table, listing representative values for φ for various materials under effective pressures less than about 5 kg/cm^2.

Table 17.1
Representative Values of ϕ for Sands and Silts

Material	Degrees *Loose*	Degrees *Dense*
Sand, round grains, uniform	27.5	34
Sand, angular grains, well graded	33	45
Sandy gravels	35	50
Silty sand	27–33	30–34
Inorganic silt	27–30	30–35

Kulhawy and Mayne presented the following N value relationships based on Peck, Hanson, and Thornburn and Meyerhof.

N Value (blows/ft or 305 mm)	Relative Density	Approximate $\bar{\phi}_{tc}$ (degrees) (a)	(b)
0 to 4	very loose	< 28	< 30
4 to 10	loose	28 to 30	30 to 35
10 to 30	medium	30 to 36	35 to 40
30 to 50	dense	36 to 41	40 to 45
> 50	very dense	> 41	> 45

a - Source: Peck, Hanson, and Thornburn (12), p. 310.
b - Source: Meyerhof (13), p. 17.

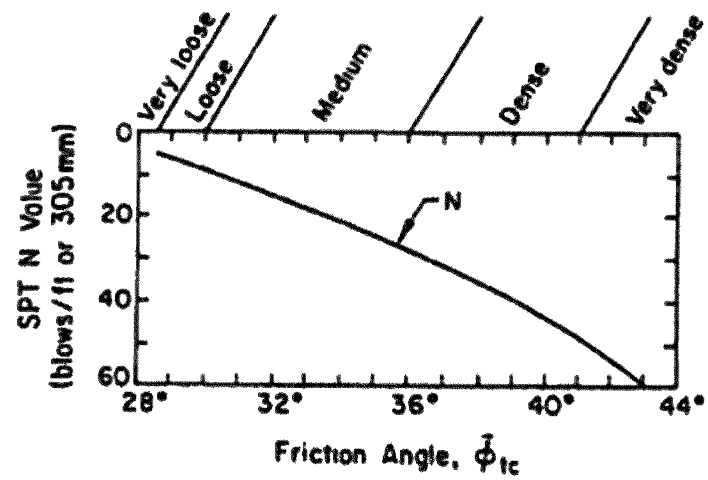


Figure 4-12. N versus $\bar{\phi}_{tc}$

Source: Peck, Hanson, and Thornburn (12), p. 310.