FROEHLING & ROBERTSON, INC.


Report of Subsurface Investigation and Bridge Foundation Design Recommendations

Bridge No. 56 on NC 27 over Upper Little River
WBS No. 67082.1.1 TIP No. BR-0082
Harnett County, North Carolina
F&R PROJECT NO. 66X-0152

Prepared for:

Mr. Greg S. Purvis, P.E.
Project Manager
Wetherill Engineering, Inc.
1223 Jones Franklin Road
Raleigh, North Carolina 27606

May 12, 2020

310 Hubert Street Raleigh, North Carolina 27603 919.828.3441

FROEHLING & ROBERTSON, INC.

Engineering Stability Since 1881

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May 12, 2020

Mr. Greg S. Purvis, P.E.
Project Manager
Wetherill Engineering, Inc.
1223 Jones Franklin Road
Raleigh, North Carolina 27606

Re:	**Report of Subsurface Investigation & Bridge Foundation Design Recommendations**
WBS Element No.:	67082.1.1
TIP No.:	BR-0082
County:	Harnett
Site Description:	Bridge 56 on NC 27 over Upper Little River
F&R Project No.:	66X-0152

Dear Mr. Purvis,

Froehling & Robertson, Inc. (F&R) has completed the subsurface investigation and bridge foundation design recommendations for the proposed bridge No. 56 on NC 27 over Upper Little River. The work was performed in general accordance with F&R's Proposal No. 1966-00759 dated June 24, 2019. This report contains the bridge foundation recommendation, Structure Subsurface Investigation report, and supporting calculations.

Please do not hesitate to contact us if you have any questions regarding this report or if you need additional services.

FROEHLING & ROBERTSON, INC.

Cheng Wang
May 12 2020 1:50 PM
DocuSign

Cheng Wang, Ph.D., P.E.
Geotechnical Engineer

NORTH CAROLINA PROFESSIONAL SEAL 048123 ENGINEER Cheng Wang

Patrick Alton
May 12 2020 12:49 PM
DocuSign

W. Patrick Alton, P.E.
Transportation Services Manager

APPENDIX A

FOUNDATION RECOMMENDATIONS

FOUNDATION RECOMMENDATIONS

WBS # 67082.1.1

DESCRIPTION Bridge No. 56 on NC 27 over Upper Little River

T.I.P. NO. BR-0082

COUNTY Harnett

STATION 18+15.00 -L-

	INITIALS	DATE
DESIGN	CW	5/12/20
CHECK	WPA	5/12/20
APPROVED		

SEAL

NORTH CAROLINA PROFESSIONAL SEAL 048123 ENGINEER CHENG WANG

Cheng Wang
May 12 2020 1:50 PM

SIGNATURE

Document Not Considered Final Unless All Signatures Are Completed

	STATION (-L-)	FOUNDATION TYPE	FACTORED RESISTANCE	MISCELLANEOUS DETAILS
END BENT 1	17+02.50	Cap on HP 12X53 Steel Piles	90 Tons/Pile	BOC Elev = 178.72 ft Avg. Pile Length = 15 ft (Lt), 10 ft (Rt) 4 vertical piles & 3 battered piles @ 9'-0" spacing
BENT 1	17+78.38	30-inch Column on 36-inch Diameter Drilled Pier	350 Tons/Pier	BOC Elev = 178.59 ft Top of Pier Elevation = 170.59 ft Point of Fixity Elev = 153.0 ft (Lt), 148.0 ft (Ctr & Rt) Tip No Higher Elev = 148.0 ft (Lt), 143.0 ft (Ctr & Rt)
BENT 2	18+51.63	30-inch Column on 36-inch Diameter Drilled Pier	345 Tons/Pier	BOC Elev = 178.55 ft Top of Pier Elevation = 170.55 ft Point of Fixity Elev = 155.0 ft (Lt), 154.0 ft (Ctr & Rt) Tip No Higher Elev = 151.0 ft (Lt), 150.0 ft (Ctr & Rt)
END BENT 2	19+27.50	Cap on HP 12X53 Steel Piles	90 Tons/Pile	BOC Elev = 178.61 ft Avg. Pile Length = 20 ft (Lt), 15 ft (Rt) 4 vertical piles & 3 battered piles @ 9'-0" spacing

NOTES ON PLANS & COMMENTS

(See following page)

TIP # BR-0082 **County** Harnett

FOUNDATION RECOMMENDATION NOTES ON PLANS

1) For Piles, see geotechnical special provisions and Section 450 of the Standard Specifications.

2) Piles at End Bent No. 1 and End Bent No. 2 are designed for a factored resistance of 90 tons per pile.

3) Drive piles at End Bent No. 1 and End Bent No. 2 to a required driving resistance of 150 tons per pile.

4) Steel H-pile points are required for steel H-piles at End Bent No. 1 and End Bent No. 2. For steel pile points, see Section 450 of the Standard Specifications.

5) Testing piles with the PDA during driving, restriking or redriving may be required at the End Bents. The Engineer will determine the need for PDA testing. For PDA testing, see Section 450 of the Standard Specifications.

6) It has been estimated that a hammer with an equivalent rated energy in the range of 13,000 to 34,000 ft-lbs per blow will be required to drive piles at End Bent No.1 and End Bent No. 2. This estimated energy range does not release the contractor from providing driving equipment in accordance with subarticle 450-3(D)(2) of the Standard Specifications.

7) For drilled piers, see geotechnical special provisions and Section 411 of the Standard Specifications.

8) Drilled piers at Bent No. 1 are designed for a factored resistance of 350 tons per pier. Check field conditions for the required tip resistance of 5 tsf.

9) Drilled piers at Bent No. 2 are designed for a factored resistance of 345 tons per pier. Check field conditions for the required tip resistance of 5 tsf.

10) Permanent steel casings are required for drilled piers at Bent No. 1. Do not extend permanent casings below elevation 160.0 ft without prior approval from the engineer.

11) Install permanent casings at Bent No. 1 by vibrating, screwing or driving permanent casings before excavating or disturbing any material below elevation 160.0 ft.

12) Permanent steel casings are required for drilled piers at Bent No. 2, left. Do not extend permanent casings below elevation 158.0 ft without prior approval from the engineer.

13) Install permanent casings at Bent No. 2, left by vibrating, screwing or driving permanent casings before excavating or disturbing any material below elevation 158.0 ft.

14) Permanent steel casings are required for drilled piers at Bent No. 2, center and right. Do not extend permanent casings below elevation 159.0 ft without prior approval from the engineer.

15) Install permanent casings at Bent No. 2, center and right by vibrating, screwing or driving permanent casings before excavating or disturbing any material below elevation 159.0 ft.

16) Install drilled piers at Bent No. 1, left , to a tip elevation no higher than 148.0 ft, with the required tip resistance and a penetration of at least 5 ft into rock as defined by Article 411-1 of the Standard Specifications.

17) Install drilled piers at Bent No. 1, center and right, to a tip elevation no higher than 143.0 ft, with the required tip resistance and a penetration of at least 5 ft into rock as defined by Article 411-1 of the Standard Specifications.

18) Install drilled piers at Bent No. 2, left, to a tip elevation no higher than 151.0 ft, with the required tip resistance and a penetration of at least 5 ft into rock as defined by Article 411-1 of the Standard Specifications.

19) Install drilled piers at Bent No. 2, center and right, to a tip elevation no higher than 150.0 ft, with the required tip resistance and a penetration of at least 5 ft into rock as defined by Article 411-1 of the Standard Specifications.

20) SID Inspections may be required for drilled piers. The engineer will determine the need for SID inspections. For SID inspections, see Section 411 of the Standard Specifications.

21) CSL tubes are required and CSL testing may be required for drilled piers. The Engineer will determine the need for CSL testing. For CSL testing, see Section 411 of the Standard Specifications.

22) SPT may be required for drilled piers. The engineer will determine the need for SPT. For SPT testing, see Section 411 of the Standard Specifications.

23) The scour critical elevation for Bent No. 1 is elevation 157 feet.
The scour critical elevation for Bent No. 2 is elevation 158 feet.
Scour critical elevations are used to monitor possible scour problems during the life of the structure.

TIP # BR-0082 **County** Harnett

FOUNDATION RECOMMENDATION COMMENTS

1) A Delmag D12-32 pile hammer was utilized as a common hammer type to determine potential pile driving stresses. This hammer should provide sufficient energy to drive the piles to the required driving resistances at the end bents, although a reduced stroke or smaller hammer may be necessary. However, the actual hammer to be utilized will need to be submitted by the contractor prior to construction.

2) 1.5:1 (H:V) slopes at the End Bents are OK with slope protection.

3) Type I approach fill detail should be used at both end bents.

4) The design scour elevation at Bent No. 1 is elevation 158.0 ft.
   The design scour elevation at Bent No. 2 is elevation 159.0 ft.

5) No waiting period is required at either end bent.

PILE PAY ITEMS

(Revised 8/11/15)

WBS ELEMENT 67082.1.1 DATE 5/12/2020

TIP NO. BR-0082 DESIGNED BY CW

COUNTY Harnett CHECKED BY WPA

STATION 18+15.00 -L-

DESCRIPTION Bridge No. 56 on NC 27 over Upper Little River

NUMBER OF BENTS WITH PILES

NUMBER OF PILES PER BENT

NUMBER OF END BENTS WITH PILES

NUMBER OF PILES PER END BENT

Only required for "Predrilling for Piles" & "Pile

Bent # or End Bent #	PILE PAY ITEM QUANTITIES						
	Steel Pile Points (yes/no)	Pipe Pile Plates (yes/no/maybe)	Predrilling For Piles (per linear ft)	Pile Redrives (per each)	Pile Excavation (per linear ft)		PDA Testing (per each)
					In Soil	Not In Soil	
End Bent 1	Yes	No	0	0	0	0	
End Bent 2	Yes	No	0	0	0	0	
TOTALS			0	0	0	0	1

Notes:

Blanks or "no" represent quantity of zero.

If steel pile points are required, calculate quantity of "Steel Pile Points" as equal to the number of steel piles.

If pipe pile plates are or may be required, calculate the quantity of "Pipe Pile Plates" as equal to the number of pipe piles.

Show quantity of "PDA Testing" on the plans as total only.

DRILLED PIER PAY ITEMS

(For LRFD Projects - Revised 8/15/12)

WBS ELEMENT 67082.1.1 DATE 5/12/20

TIP NO. BR-0082 DESIGNED BY CW

COUNTY Harnett CHECKED BY WPA

STATION 18+15.00 -L-

DESCRIPTION Bridge No. 56 on NC 27 over Upper Little River

NUMBER OF BENTS WITH DRILLED PIERS 2

NUMBER OF DRILLED PIERS PER BENT 3

NUMBER OF END BENTS WITH DRILLED PIERS 0

NUMBER OF DRILLED PIERS PER END BENT 0

	DRILLED PIER PAY ITEM QUANTITIES				
Bent # or End Bent #	**36 in. Dia. Drilled Piers Not In Soil (per linear ft/m)**	**Permanent Steel Casing For 36 in. Dia. Drilled Pier (yes/no/maybe)**	**SID Inspections (per each)**	**SPT Testing (per each)**	**CSL Testing (per each)**
Bent 1	29	yes	1	1	1
Bent 2	26	yes	1	1	1
TOTALS	55		2	2	2

Notes:

Blanks or "no" represent quantity of zero.

If drilled piers not in soil are required, calculate quantity of "____ Dia. Drilled Piers in Soil" as the difference between the total drilled pier length and the "____ Dia. Drilled Piers Not in Soil" from the table above. If there is none or zero quantity for drilled piers not in soil in the table above, calculate quantity of "____ Dia. Drilled Piers" as the total drilled pier length and do not use the "____ Dia. Drilled Piers in Soil" pay item.

If permanent steel casing is or may be required, calculate quantity of "Permanent Steel Casing for ____ Dia. Drilled Pier" as the difference between the ground line or top of drilled pier elevation, whichever is higher, and the elevation the permanent casing can not extend below from the foundation recommendations.

If "SID Inspections", "SPT Testing" or "CSL Testing" may be required, show quantities of these pay items on the plans as totals only. If "SID Inspections", "SPT Testing" or "CSL Testing" is required, show quantities of these pay items on the plans for each bent or end bent.

The number of CSL tubes required per drilled pier is equal to one tube per foot of design pier diameter with at least four tubes per pier. Calculate the length of each CSL tube as the total drilled pier length plus 1.5 ft.

APPENDIX B

STRUCTURE SUBSURFACE INVESTIGATION REPORT

STATE	STATE PROJECT REFERENCE NO.	SHEET NO.	TOTAL SHEETS
N.C.	BR-0082	1	19

REFERENCE: BR-0082

PROJECT: 67082

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
GEOTECHNICAL ENGINEERING UNIT

STRUCTURE SUBSURFACE INVESTIGATION

COUNTY *Harnett*

SITE DESCRIPTION *Bridge No. 56 on -L- (NC 27) over Upper Little River*

CONTENTS

APPENDIX

CAUTION NOTICE

THE SUBSURFACE INFORMATION AND THE SUBSURFACE INVESTIGATION ON WHICH IT IS BASED WERE MADE FOR THE PURPOSE OF STUDY, PLANNING AND DESIGN, AND NOT FOR CONSTRUCTION OR PAY PURPOSES. THE VARIOUS FIELD BORING LOGS, ROCK CORES AND SOIL TEST DATA AVAILABLE MAY BE REVIEWED OR INSPECTED IN RALEIGH BY CONTACTING THE N. C. DEPARTMENT OF TRANSPORTATION, GEOTECHNICAL ENGINEERING UNIT AT (919) 707-6850. THE SUBSURFACE PLANS AND REPORTS, FIELD BORING LOGS, ROCK CORES AND SOIL TEST DATA ARE NOT PART OF THE CONTRACT.

GENERAL SOIL AND ROCK STRATA DESCRIPTIONS AND INDICATED BOUNDARIES ARE BASED ON A GEOTECHNICAL INTERPRETATION OF ALL AVAILABLE SUBSURFACE DATA AND MAY NOT NECESSARILY REFLECT THE ACTUAL SUBSURFACE CONDITIONS BETWEEN BORINGS OR BETWEEN SAMPLED STRATA WITHIN THE BOREHOLE. THE LABORATORY SAMPLE DATA AND THE IN SITU (IN-PLACE) TEST DATA CAN BE RELIED ON ONLY TO THE DEGREE OF RELIABILITY INHERENT IN THE STANDARD TEST METHOD. THE OBSERVED WATER LEVELS OR SOIL MOISTURE CONDITIONS INDICATED IN THE SUBSURFACE INVESTIGATIONS ARE AS RECORDED AT THE TIME OF THE INVESTIGATION. THESE WATER LEVELS OR SOIL MOISTURE CONDITIONS MAY VARY CONSIDERABLY WITH TIME ACCORDING TO CLIMATIC CONDITIONS INCLUDING TEMPERATURES, PRECIPITATION AND WIND, AS WELL AS OTHER NON-CLIMATIC FACTORS.

THE BIDDER OR CONTRACTOR IS CAUTIONED THAT DETAILS SHOWN ON THE SUBSURFACE PLANS ARE PRELIMINARY ONLY AND IN MANY CASES THE FINAL DESIGN DETAILS ARE DIFFERENT. FOR BIDDING AND CONSTRUCTION PURPOSES, REFER TO THE CONSTRUCTION PLANS AND DOCUMENTS FOR FINAL DESIGN INFORMATION ON THIS PROJECT. THE DEPARTMENT DOES NOT WARRANT OR GUARANTEE THE SUFFICIENCY OR ACCURACY OF THE INVESTIGATION MADE, NOR THE INTERPRETATIONS MADE, OR OPINION OF THE DEPARTMENT AS TO THE TYPE OF MATERIALS AND CONDITIONS TO BE ENCOUNTERED. THE BIDDER OR CONTRACTOR IS CAUTIONED TO MAKE SUCH INDEPENDENT SUBSURFACE INVESTIGATIONS AS HE DEEMS NECESSARY TO SATISFY HIMSELF AS TO CONDITIONS TO BE ENCOUNTERED ON THE PROJECT. THE CONTRACTOR SHALL HAVE NO CLAIM FOR ADDITIONAL COMPENSATION OR FOR AN EXTENSION OF TIME FOR ANY REASON RESULTING FROM THE ACTUAL CONDITIONS ENCOUNTERED AT THE SITE DIFFERING FROM THOSE INDICATED IN THE SUBSURFACE INFORMATION.

NOTES:
1. THE INFORMATION CONTAINED HEREIN IS NOT IMPLIED OR GUARANTEED BY THE N. C. DEPARTMENT OF TRANSPORTATION AS ACCURATE NOR IS IT CONSIDERED PART OF THE PLANS, SPECIFICATIONS OR CONTRACT FOR THE PROJECT.
2. BY HAVING REQUESTED THIS INFORMATION, THE CONTRACTOR SPECIFICALLY WAIVES ANY CLAIMS FOR INCREASED COMPENSATION OR EXTENSION OF TIME BASED ON DIFFERENCES BETWEEN THE CONDITIONS INDICATED HEREIN AND THE ACTUAL CONDITIONS AT THE PROJECT SITE.

PERSONNEL

W. Pesl

S. Davis

T. Beard

INVESTIGATED BY *F&R, Inc.*

DRAWN BY *T.T. Walker, F&R Inc.*

CHECKED BY *P. Alton, P.E.*

SUBMITTED BY *C. Weng, P.E.*

DATE *May 2020*

SINCE 1881

Prepared in the Office of:

FROEHLING & ROBERTSON, INC.

Engineering Stability Since 1881

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Cheng Wang
May 12 2020 1:50 PM

SIGNATURE DATE

DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

PROJECT REFERENCE NO.	SHEET NO.
BR-0082	2

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
GEOTECHNICAL ENGINEERING UNIT

SUBSURFACE INVESTIGATION

SOIL AND ROCK LEGEND, TERMS, SYMBOLS, AND ABBREVIATIONS

SOIL DESCRIPTION

SOIL IS CONSIDERED UNCONSOLIDATED, SEMI-CONSOLIDATED, OR WEATHERED EARTH MATERIALS THAT CAN BE PENETRATED WITH A CONTINUOUS FLIGHT POWER AUGER AND YIELD LESS THAN 100 BLOWS PER FOOT ACCORDING TO THE STANDARD PENETRATION TEST (AASHTO T 206, ASTM D1586). SOIL CLASSIFICATION IS BASED ON THE AASHTO SYSTEM. BASIC DESCRIPTIONS GENERALLY INCLUDE THE FOLLOWING: CONSISTENCY, COLOR, TEXTURE, MOISTURE, AASHTO CLASSIFICATION, AND OTHER PERTINENT FACTORS SUCH AS MINERALOGICAL COMPOSITION, ANGULARITY, STRUCTURE, PLASTICITY, ETC. FOR EXAMPLE,
VERY STIFF, GRAY, SILTY CLAY, MOIST WITH INTERBEDDED FINE SAND LAYERS, HIGHLY PLASTIC, A-7-6

SOIL LEGEND AND AASHTO CLASSIFICATION

GENERAL CLASS.	GRANULAR MATERIALS (≤ 35% PASSING #200)							SILT-CLAY MATERIALS (> 35% PASSING #200)				ORGANIC MATERIALS		
GROUP CLASS.	A-1		A-3	A-2				A-4	A-5	A-6	A-7	A-1, A-2 A-3	A-4, A-5 A-6, A-7	
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5, A-7-6			
SYMBOL														
% PASSING #10 #40 #200	50 MX 30 MX 15 MX		50 MX 25 MX	51 MN 10 MX	35 MX	35 MX	35 MX	35 MX	36 MN	36 MN	36 MN	36 MN	GRANULAR SOILS	SILT-CLAY SOILS	MUCK, PEAT
MATERIAL PASSING #40 LL PI	– 6 MX		– NP		40 MX 10 MX	41 MN 10 MX	40 MX 11 MN	41 MN 11 MN	40 MX 10 MX	41 MN 10 MX	40 MX 11 MN	41 MN 11 MN	SOILS WITH LITTLE OR MODERATE AMOUNTS OF ORGANIC MATTER		HIGHLY ORGANIC SOILS
GROUP INDEX	0		0	0		4 MX		8 MX	12 MX	16 MX	NO MX			
USUAL TYPES OF MAJOR MATERIALS	STONE FRAGS. GRAVEL, AND SAND		FINE SAND	SILTY OR CLAYEY GRAVEL AND SAND				SILTY SOILS		CLAYEY SOILS				
GEN. RATING AS SUBGRADE	EXCELLENT TO GOOD							FAIR TO POOR				FAIR TO POOR	POOR	UNSUITABLE

PI OF A-7-5 SUBGROUP IS ≤ LL - 30 ; PI OF A-7-6 SUBGROUP IS > LL - 30

CONSISTENCY OR DENSENESS

PRIMARY SOIL TYPE	COMPACTNESS OR CONSISTENCY	RANGE OF STANDARD PENETRATION RESISTENCE (N-VALUE)	RANGE OF UNCONFINED COMPRESSIVE STRENGTH ($TONS/FT^2$)
GENERALLY GRANULAR MATERIAL (NON-COHESIVE)	VERY LOOSE	< 4	
	LOOSE	4 TO 10	
	MEDIUM DENSE	10 TO 30	N/A
	DENSE	30 TO 50	
	VERY DENSE	> 50	
GENERALLY SILT-CLAY MATERIAL (COHESIVE)	VERY SOFT	< 2	< 0.25
	SOFT	2 TO 4	0.25 TO 0.5
	MEDIUM STIFF	4 TO 8	0.5 TO 1.0
	STIFF	8 TO 15	1 TO 2
	VERY STIFF	15 TO 30	2 TO 4
	HARD	> 30	> 4

TEXTURE OR GRAIN SIZE

U.S. STD. SIEVE SIZE	4	10	40	60	200	270
OPENING (MM)	4.76	2.00	0.42	0.25	0.075	0.053

BOULDER (BLDR.)	COBBLE (COB.)	GRAVEL (GR.)	COARSE SAND (CSE. SD.)	FINE SAND (F SD.)	SILT (SL.)	CLAY (CL.)

GRAIN SIZE	MM	305	75	2.0	0.25	0.05	0.005
	IN.	12	3				

SOIL MOISTURE - CORRELATION OF TERMS

SOIL MOISTURE SCALE (ATTERBERG LIMITS)	FIELD MOISTURE DESCRIPTION	GUIDE FOR FIELD MOISTURE DESCRIPTION
	- SATURATED - (SAT.)	USUALLY LIQUID; VERY WET, USUALLY FROM BELOW THE GROUND WATER TABLE
LL — LIQUID LIMIT		
PLASTIC RANGE (PI)	- WET - (W)	SEMISOLID; REQUIRES DRYING TO ATTAIN OPTIMUM MOISTURE
PL — PLASTIC LIMIT		
OM — OPTIMUM MOISTURE SL — SHRINKAGE LIMIT	- MOIST - (M)	SOLID; AT OR NEAR OPTIMUM MOISTURE
	- DRY - (D)	REQUIRES ADDITIONAL WATER TO ATTAIN OPTIMUM MOISTURE

PLASTICITY

	PLASTICITY INDEX (PI)	DRY STRENGTH
NON PLASTIC	0-5	VERY LOW
SLIGHTLY PLASTIC	6-15	SLIGHT
MODERATELY PLASTIC	16-25	MEDIUM
HIGHLY PLASTIC	26 OR MORE	HIGH

COLOR

DESCRIPTIONS MAY INCLUDE COLOR OR COLOR COMBINATIONS (TAN, RED, YELLOW-BROWN, BLUE-GRAY). MODIFIERS SUCH AS LIGHT, DARK, STREAKED, ETC. ARE USED TO DESCRIBE APPEARANCE.

GRADATION

WELL GRADED - INDICATES A GOOD REPRESENTATION OF PARTICLE SIZES FROM FINE TO COARSE.
UNIFORMLY GRADED - INDICATES THAT SOIL PARTICLES ARE ALL APPROXIMATELY THE SAME SIZE.
GAP-GRADED - INDICATES A MIXTURE OF UNIFORM PARTICLE SIZES OF TWO OR MORE SIZES.

ANGULARITY OF GRAINS

THE ANGULARITY OR ROUNDNESS OF SOIL GRAINS IS DESIGNATED BY THE TERMS: ANGULAR, SUBANGULAR, SUBROUNDED, OR ROUNDED.

MINERALOGICAL COMPOSITION

MINERAL NAMES SUCH AS QUARTZ, FELDSPAR, MICA, TALC, KAOLIN, ETC. ARE USED IN DESCRIPTIONS WHEN THEY ARE CONSIDERED OF SIGNIFICANCE.

COMPRESSIBILITY

SLIGHTLY COMPRESSIBLE	LL < 31
MODERATELY COMPRESSIBLE	LL = 31 - 50
HIGHLY COMPRESSIBLE	LL > 50

PERCENTAGE OF MATERIAL

ORGANIC MATERIAL	GRANULAR SOILS	SILT - CLAY SOILS	OTHER MATERIAL	
TRACE OF ORGANIC MATTER	2 - 3%	3 - 5%	TRACE	1 - 10%
LITTLE ORGANIC MATTER	3 - 5%	5 - 12%	LITTLE	10 - 20%
MODERATELY ORGANIC	5 - 10%	12 - 20%	SOME	20 - 35%
HIGHLY ORGANIC	> 10%	> 20%	HIGHLY	35% AND ABOVE

GROUND WATER

- WATER LEVEL IN BORE HOLE IMMEDIATELY AFTER DRILLING
- STATIC WATER LEVEL AFTER 24 HOURS
- PW — PERCHED WATER, SATURATED ZONE, OR WATER BEARING STRATA
- SPRING OR SEEP

MISCELLANEOUS SYMBOLS

- ROADWAY EMBANKMENT (RE) WITH SOIL DESCRIPTION
- SOIL SYMBOL
- ARTIFICIAL FILL (AF) OTHER THAN ROADWAY EMBANKMENT
- INFERRED SOIL BOUNDARY
- INFERRED ROCK LINE
- ALLUVIAL SOIL BOUNDARY
- 25/025 — DIP & DIP DIRECTION OF ROCK STRUCTURES
- SPT, DPT, DMT, VST, PMT — TEST BORING
- AUGER BORING
- CORE BORING
- MW — MONITORING WELL
- PIEZOMETER INSTALLATION
- SLOPE INDICATOR INSTALLATION
- CONE PENETROMETER TEST
- SOUNDING ROD
- TEST BORING WITH CORE
- SPT N-VALUE

RECOMMENDATION SYMBOLS

- UNDERCUT
- SHALLOW UNDERCUT
- UNCLASSIFIED EXCAVATION - UNSUITABLE WASTE
- UNCLASSIFIED EXCAVATION - ACCEPTABLE DEGRADABLE ROCK
- UNCLASSIFIED EXCAVATION - ACCEPTABLE, BUT NOT TO BE USED IN THE TOP 3 FEET OF EMBANKMENT OR BACKFILL

ABBREVIATIONS

AR - AUGER REFUSAL
BT - BORING TERMINATED
CL. - CLAY
CPT - CONE PENETRATION TEST
CSE. - COARSE
DMT - DILATOMETER TEST
DPT - DYNAMIC PENETRATION TEST
e - VOID RATIO
F - FINE
FOSS. - FOSSILIFEROUS
FRAC. - FRACTURED, FRACTURES
FRAGS. - FRAGMENTS
HI. - HIGHLY
MED. - MEDIUM
MICA. - MICACEOUS
MOD. - MODERATELY
NP - NON PLASTIC
ORG. - ORGANIC
PMT - PRESSUREMETER TEST
SAP. - SAPROLITIC
SD. - SAND, SANDY
SL. - SILT, SILTY
SLI. - SLIGHTLY
TCR - TRICONE REFUSAL
w - MOISTURE CONTENT
V - VERY
VST - VANE SHEAR TEST
WEA. - WEATHERED
γ - UNIT WEIGHT
γ_d - DRY UNIT WEIGHT

SAMPLE ABBREVIATIONS

S - BULK
SS - SPLIT SPOON
ST - SHELBY TUBE
RS - ROCK
RT - RECOMPACTED TRIAXIAL
CBR - CALIFORNIA BEARING RATIO

EQUIPMENT USED ON SUBJECT PROJECT

DRILL UNITS:
- [ ] CME-45C
- [X] CME-55
- [ ] CME-550
- [ ] VANE SHEAR TEST
- [ ] PORTABLE HOIST
- [ ] _____
- [ ] _____

ADVANCING TOOLS:
- [ ] CLAY BITS
- [ ] 6" CONTINUOUS FLIGHT AUGER
- [X] 8" HOLLOW AUGERS
- [ ] HARD FACED FINGER BITS
- [ ] TUNG.-CARBIDE INSERTS
- [X] CASING [X] W/ ADVANCER
- [ ] TRICONE _____" STEEL TEETH
- [ ] TRICONE _____" TUNG.-CARB.
- [X] CORE BIT
- [ ] _____

HAMMER TYPE:
- [X] AUTOMATIC [ ] MANUAL

CORE SIZE:
- [ ] -B _____ [ ] -H _____
- [X] -N 03

HAND TOOLS:
- [ ] POST HOLE DIGGER
- [ ] HAND AUGER
- [ ] SOUNDING ROD
- [ ] VANE SHEAR TEST
- [ ] _____

ROCK DESCRIPTION

HARD ROCK IS NON-COASTAL PLAIN MATERIAL THAT WOULD YIELD SPT REFUSAL IF TESTED. AN INFERRED ROCK LINE INDICATES THE LEVEL AT WHICH NON-COASTAL PLAIN MATERIAL WOULD YIELD SPT REFUSAL. SPT REFUSAL IS PENETRATION BY A SPLIT SPOON SAMPLER EQUAL TO OR LESS THAN 0.1 FOOT PER 60 BLOWS IN NON-COASTAL PLAIN MATERIAL, THE TRANSITION BETWEEN SOIL AND ROCK IS OFTEN REPRESENTED BY A ZONE OF WEATHERED ROCK.
ROCK MATERIALS ARE TYPICALLY DIVIDED AS FOLLOWS:

WEATHERED ROCK (WR)	NON-COASTAL PLAIN MATERIAL THAT WOULD YIELD SPT N VALUES > 100 BLOWS PER FOOT IF TESTED.
CRYSTALLINE ROCK (CR)	FINE TO COARSE GRAIN IGNEOUS AND METAMORPHIC ROCK THAT WOULD YIELD SPT REFUSAL IF TESTED. ROCK TYPE INCLUDES GRANITE, GNEISS, GABBRO, SCHIST, ETC.
NON-CRYSTALLINE ROCK (NCR)	FINE TO COARSE GRAIN METAMORPHIC AND NON-COASTAL PLAIN SEDIMENTARY ROCK THAT WOULD YEILD SPT REFUSAL IF TESTED. ROCK TYPE INCLUDES PHYLLITE, SLATE, SANDSTONE, ETC.
COASTAL PLAIN SEDIMENTARY ROCK (CP)	COASTAL PLAIN SEDIMENTS CEMENTED INTO ROCK, BUT MAY NOT YIELD SPT REFUSAL. ROCK TYPE INCLUDES LIMESTONE, SANDSTONE, CEMENTED SHELL BEDS, ETC.

WEATHERING

FRESH	ROCK FRESH, CRYSTALS BRIGHT, FEW JOINTS MAY SHOW SLIGHT STAINING. ROCK RINGS UNDER HAMMER IF CRYSTALLINE.
VERY SLIGHT (V SLI.)	ROCK GENERALLY FRESH, JOINTS STAINED, SOME JOINTS MAY SHOW THIN CLAY COATINGS IF OPEN, CRYSTALS ON A BROKEN SPECIMEN FACE SHINE BRIGHTLY. ROCK RINGS UNDER HAMMER BLOWS IF OF A CRYSTALLINE NATURE.
SLIGHT (SLI.)	ROCK GENERALLY FRESH, JOINTS STAINED AND DISCOLORATION EXTENDS INTO ROCK UP TO 1 INCH. OPEN JOINTS MAY CONTAIN CLAY. IN GRANITOID ROCKS SOME OCCASIONAL FELDSPAR CRYSTALS ARE DULL AND DISCOLORED. CRYSTALLINE ROCKS RING UNDER HAMMER BLOWS.
MODERATE (MOD.)	SIGNIFICANT PORTIONS OF ROCK SHOW DISCOLORATION AND WEATHERING EFFECTS. IN GRANITOID ROCKS, MOST FELDSPARS ARE DULL AND DISCOLORED, SOME SHOW CLAY. ROCK HAS DULL SOUND UNDER HAMMER BLOWS AND SHOWS SIGNIFICANT LOSS OF STRENGTH AS COMPARED WITH FRESH ROCK.
MODERATELY SEVERE (MOD. SEV.)	ALL ROCK EXCEPT QUARTZ DISCOLORED OR STAINED. IN GRANITOID ROCKS, ALL FELDSPARS DULL AND DISCOLORED AND A MAJORITY SHOW KAOLINIZATION. ROCK SHOWS SEVERE LOSS OF STRENGTH AND CAN BE EXCAVATED WITH A GEOLOGIST'S PICK. ROCK GIVES "CLUNK" SOUND WHEN STRUCK. *IF TESTED, WOULD YIELD SPT REFUSAL*
SEVERE (SEV.)	ALL ROCK EXCEPT QUARTZ DISCOLORED OR STAINED. ROCK FABRIC CLEAR AND EVIDENT BUT REDUCED IN STRENGTH TO STRONG SOIL. IN GRANITOID ROCKS ALL FELDSPARS ARE KAOLINIZED TO SOME EXTENT. SOME FRAGMENTS OF STRONG ROCK USUALLY REMAIN. *IF TESTED, WOULD YIELD SPT N VALUES > 100 BPF*
VERY SEVERE (V SEV.)	ALL ROCK EXCEPT QUARTZ DISCOLORED OR STAINED. ROCK FABRIC ELEMENTS ARE DISCERNIBLE BUT MASS IS EFFECTIVELY REDUCED TO SOIL STATUS, WITH ONLY FRAGMENTS OF STRONG ROCK REMAINING. SAPROLITE IS AN EXAMPLE OF ROCK WEATHERED TO A DEGREE THAT ONLY MINOR VESTIGES OF ORIGINAL ROCK FABRIC REMAIN. *IF TESTED, WOULD YIELD SPT N VALUES < 100 BPF*
COMPLETE	ROCK REDUCED TO SOIL. ROCK FABRIC NOT DISCERNIBLE, OR DISCERNIBLE ONLY IN SMALL AND SCATTERED CONCENTRATIONS. QUARTZ MAY BE PRESENT AS DIKES OR STRINGERS. SAPROLITE IS ALSO AN EXAMPLE.

ROCK HARDNESS

VERY HARD	CANNOT BE SCRATCHED BY KNIFE OR SHARP PICK. BREAKING OF HAND SPECIMENS REQUIRES SEVERAL HARD BLOWS OF THE GEOLOGIST'S PICK.
HARD	CAN BE SCRATCHED BY KNIFE OR PICK ONLY WITH DIFFICULTY. HARD HAMMER BLOWS REQUIRED TO DETACH HAND SPECIMEN.
MODERATELY HARD	CAN BE SCRATCHED BY KNIFE OR PICK. GOUGES OR GROOVES TO 0.25 INCHES DEEP CAN BE EXCAVATED BY HARD BLOW OF A GEOLOGIST'S PICK. HAND SPECIMENS CAN BE DETACHED BY MODERATE BLOWS.
MEDIUM HARD	CAN BE GROOVED OR GOUGED 0.05 INCHES DEEP BY FIRM PRESSURE OF KNIFE OR PICK POINT. CAN BE EXCAVATED IN SMALL CHIPS TO PEICES 1 INCH MAXIMUM SIZE BY HARD BLOWS OF THE POINT OF A GEOLOGIST'S PICK.
SOFT	CAN BE GROVED OR GOUGED READILY BY KNIFE OR PICK. CAN BE EXCAVATED IN FRAGMENTS FROM CHIPS TO SEVERAL INCHES IN SIZE BY MODERATE BLOWS OF A PICK POINT. SMALL, THIN PIECES CAN BE BROKEN BY FINGER PRESSURE.
VERY SOFT	CAN BE CARVED WITH KNIFE. CAN BE EXCAVATED READILY WITH POINT OF PICK. PIECES 1 INCH OR MORE IN THICKNESS CAN BE BROKEN BY FINGER PRESSURE. CAN BE SCRATCHED READILY BY FINGERNAIL.

FRACTURE SPACING

TERM	SPACING
VERY WIDE	MORE THAN 10 FEET
WIDE	3 TO 10 FEET
MODERATELY CLOSE	1 TO 3 FEET
CLOSE	0.16 TO 1 FOOT
VERY CLOSE	LESS THAN 0.16 FEET

BEDDING

TERM	THICKNESS
VERY THICKLY BEDDED	4 FEET
THICKLY BEDDED	1.5 - 4 FEET
THINLY BEDDED	0.16 - 1.5 FEET
VERY THINLY BEDDED	0.03 - 0.16 FEET
THICKLY LAMINATED	0.008 - 0.03 FEET
THINLY LAMINATED	< 0.008 FEET

INDURATION

FOR SEDIMENTARY ROCKS, INDURATION IS THE HARDENING OF MATERIAL BY CEMENTING, HEAT, PRESSURE, ETC.

FRIABLE	RUBBING WITH FINGER FREES NUMEROUS GRAINS; GENTLE BLOW BY HAMMER DISINTEGRATES SAMPLE.
MODERATELY INDURATED	GRAINS CAN BE SEPARATED FROM SAMPLE WITH STEEL PROBE; BREAKS EASILY WHEN HIT WITH HAMMER.
INDURATED	GRAINS ARE DIFFICULT TO SEPARATE WITH STEEL PROBE; DIFFICULT TO BREAK WITH HAMMER.
EXTREMELY INDURATED	SHARP HAMMER BLOWS REQUIRED TO BREAK SAMPLE; SAMPLE BREAKS ACROSS GRAINS.

TERMS AND DEFINITIONS

ALLUVIUM (ALLUV.) - SOILS THAT HAVE BEEN TRANSPORTED BY WATER.

AQUIFER - A WATER BEARING FORMATION OR STRATA.

ARENACEOUS - APPLIED TO ROCKS THAT HAVE BEEN DERIVED FROM SAND OR THAT CONTAIN SAND.

ARGILLACEOUS - APPLIED TO ALL ROCKS OR SUBSTANCES COMPOSED OF CLAY MINERALS, OR HAVING A NOTABLE PROPORTION OF CLAY IN THEIR COMPOSITION, SUCH AS SHALE, SLATE, ETC.

ARTESIAN - GROUND WATER THAT IS UNDER SUFFICIENT PRESSURE TO RISE ABOVE THE LEVEL AT WHICH IT IS ENCOUNTERED, BUT WHICH DOES NOT NECESSARILY RISE TO OR ABOVE THE GROUND SURFACE.

CALCAREOUS (CALC.) - SOILS THAT CONTAIN APPRECIABLE AMOUNTS OF CALCIUM CARBONATE.

COLLUVIUM - ROCK FRAGMENTS MIXED WITH SOIL DEPOSITED BY GRAVITY ON SLOPE OR AT BOTTOM OF SLOPE.

CORE RECOVERY (REC.) - TOTAL LENGTH OF ALL MATERIAL RECOVERED IN THE CORE BARREL DIVIDED BY TOTAL LENGTH OF CORE RUN AND EXPRESSED AS A PERCENTAGE.

DIKE - A TABULAR BODY OF IGNEOUS ROCK THAT CUTS ACROSS THE STRUCTURE OF ADJACENT ROCKS OR CUTS MASSIVE ROCK.

DIP - THE ANGLE AT WHICH A STRATUM OR ANY PLANAR FEATURE IS INCLINED FROM THE HORIZONTAL.

DIP DIRECTION (DIP AZIMUTH) - THE DIRECTION OR BEARING OF THE HORIZONTAL TRACE OF THE LINE OF DIP, MEASURED CLOCKWISE FROM NORTH.

FAULT - A FRACTURE OR FRACTURE ZONE ALONG WHICH THERE HAS BEEN DISPLACEMENT OF THE SIDES RELATIVE TO ONE ANOTHER PARALLEL TO THE FRACTURE.

FISSILE - A PROPERTY OF SPLITTING ALONG CLOSELY SPACED PARALLEL PLANES.

FLOAT - ROCK FRAGMENTS ON SURFACE NEAR THEIR ORIGINAL POSITION AND DISLODGED FROM PARENT MATERIAL.

FLOOD PLAIN (FP) - LAND BORDERING A STREAM, BUILT OF SEDIMENTS DEPOSITED BY THE STREAM.

FORMATION (FM.) - A MAPPABLE GEOLOGIC UNIT THAT CAN BE RECOGNIZED AND TRACED IN THE FIELD.

JOINT - FRACTURE IN ROCK ALONG WHICH NO APPRECIABLE MOVEMENT HAS OCCURRED.

LEDGE - A SHELF-LIKE RIDGE OR PROJECTION OF ROCK WHOSE THICKNESS IS SMALL COMPARED TO ITS LATERAL EXTENT.

LENS - A BODY OF SOIL OR ROCK THAT THINS OUT IN ONE OR MORE DIRECTIONS.

MOTTLED (MOT.) - IRREGULARLY MARKED WITH SPOTS OF DIFFERENT COLORS. MOTTLING IN SOILS USUALLY INDICATES POOR AERATION AND LACK OF GOOD DRAINAGE.

PERCHED WATER - WATER MAINTAINED ABOVE THE NORMAL GROUND WATER LEVEL BY THE PRESENCE OF AN INTERVENING IMPERVIOUS STRATUM.

RESIDUAL (RES.) SOIL - SOIL FORMED IN PLACE BY THE WEATHERING OF ROCK.

ROCK QUALITY DESIGNATION (RQD) - A MEASURE OF ROCK QUALITY DESCRIBED BY TOTAL LENGTH OF ROCK SEGMENTS EQUAL TO OR GREATER THAN 4 INCHES DIVIDED BY THE TOTAL LENGTH OF CORE RUN AND EXPRESSED AS A PERCENTAGE.

SAPROLITE (SAP.) - RESIDUAL SOIL THAT RETAINS THE RELIC STRUCTURE OR FABRIC OF THE PARENT ROCK.

SILL - AN INTRUSIVE BODY OF IGNEOUS ROCK OF APPROXIMATELY UNIFORM THICKNESS AND RELATIVELY THIN COMPARED WITH ITS LATERAL EXTENT, THAT HAS BEEN EMPLACED PARALLEL TO THE BEDDING OR SCHISTOSITY OF THE INTRUDED ROCKS.

SLICKENSIDE - POLISHED AND STRIATED SURFACE THAT RESULTS FROM FRICTION ALONG A FAULT OR SLIP PLANE.

STANDARD PENETRATION TEST (PENETRATION RESISTANCE) (SPT) - NUMBER OF BLOWS (N OR BPF) OF A 140 LB. HAMMER FALLING 30 INCHES REQUIRED TO PRODUCE A PENETRATION OF 1 FOOT INTO SOIL WITH A 2 INCH OUTSIDE DIAMETER SPLIT SPOON SAMPLER. SPT REFUSAL IS PENETRATION EQUAL TO OR LESS THAN 0.1 FOOT PER 60 BLOWS.

STRATA CORE RECOVERY (SREC.) - TOTAL LENGTH OF STRATA MATERIAL RECOVERED DIVIDED BY TOTAL LENGTH OF STRATUM AND EXPRESSED AS A PERCENTAGE.

STRATA ROCK QUALITY DESIGNATION (SRQD) - A MEASURE OF ROCK QUALITY DESCRIBED BY TOTAL LENGTH OF ROCK SEGMENTS WITHIN A STRATUM EQUAL TO OR GREATER THAN 4 INCHES DIVIDED BY THE TOTAL LENGTH OF STRATA AND EXPRESSED AS A PERCENTAGE.

TOPSOIL (TS.) - SURFACE SOILS USUALLY CONTAINING ORGANIC MATTER.

BENCH MARK: BL-101: -BL- STA. 10+23.11, N: 578747.4590, E: 2014348.63

ELEVATION: 185.91 FEET

NOTES:

FIAD= FILLED IMMEDIATELY AFTER DRILLING

DATE: 8-15-14

PROJECT REFERENCE NO.	SHEET NO.
BR-0082	2A

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
GEOTECHNICAL ENGINEERING UNIT

SUBSURFACE INVESTIGATION

SUPPLEMENTAL LEGEND, GEOLOGICAL STRENGTH INDEX (GSI) TABLES FROM AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS

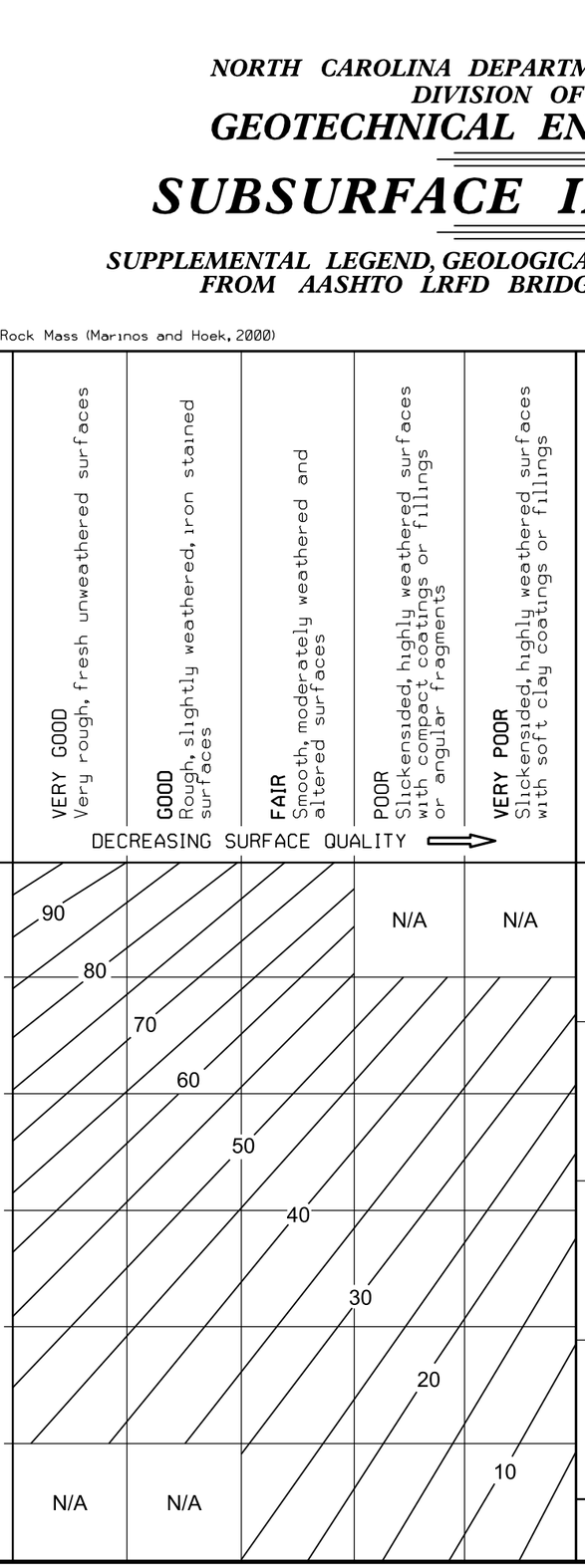
AASHTO LRFD Figure 10.4.6.4-1 — Determination of GSI for Jointed Rock Mass (Marinos and Hoek, 2000)

GEOLOGICAL STRENGTH INDEX (GSI) FOR JOINTED ROCKS (Hoek and Marinos, 2000)

From the lithology, structure and surface conditions of the discontinuities, estimate the average value of GSI. Do not try to be too precise. Quoting a range from 33 to 37 is more realistic than stating that GSI = 35. Note that the table does not apply to structurally controlled failures. Where weak planar structural planes are present in an unfavorable orientation with respect to the excavation face, these will dominate the rock mass behaviour. The shear strength of surfaces in rocks that are prone to deterioration as a result of changes in moisture content will be reduced if water is present. When working with rocks in the fair to very poor categories, a shift to the right may be made for wet conditions. Water pressure is dealt with by effective stress analysis.

STRUCTURE

- INTACT OR MASSIVE - intact rock specimens or massive in situ rock with few widely spaced discontinuities
- BLOCKY - well interlocked undisturbed rock mass consisting of cubical blocks formed by three intersecting discontinuity sets
- VERY BLOCKY - interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets
- BLOCKY/DISTURBED/SEAMY - folded with angular blocks formed by many intersecting discontinuity sets. Persistence of bedding planes or schistosity
- DISINTEGRATED - poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces
- LAMINATED/SHEARED - Lack of blockiness due to close spacing of weak schistosity or shear planes

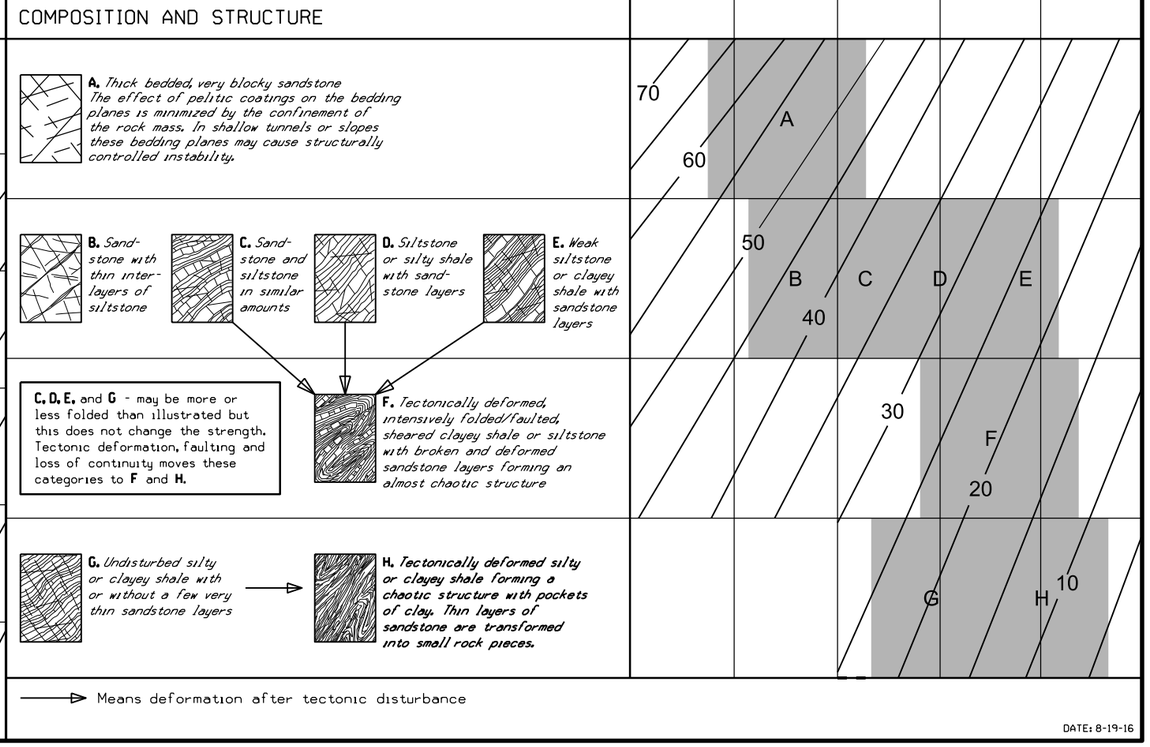


AASHTO LRFD Figure 10.4.6.4-2 — Determination of GSI for Tectonically Deformed Heterogeneous Rock Masses (Marinos and Hoek, 2000)

GSI FOR HETEROGENEOUS ROCK MASSES SUCH AS FLYSCH (Marinos. P and Hoek E., 2000)

From a description of the lithology, structure and surface conditions (particularly of the bedding planes), choose a box in the chart. Locate the position in the box that corresponds to the condition of the discontinuities and estimate the average value of GSI from the contours. Do not attempt to be too precise. Quoting a range from 33 to 37 is more realistic than giving GSI = 35. Note that the Hoek-Brown criterion does not apply to structurally controlled failures. Where unfavourably oriented continuous weak planar discontinuities are present, these will dominate the behaviour of the rock mass. The strength of some rock masses is reduced by the presence of groundwater and this can be allowed for by a slight shift to the right in the columns for fair, poor and very poor conditions. Water pressure does not change the value of GSI and it is dealt with by using effective stress analysis.

COMPOSITION AND STRUCTURE



A. *Thick bedded, very blocky sandstone The effect of pelitic coatings on the bedding planes is minimized by the confinement of the rock mass. In shallow tunnels or slopes these bedding planes may cause structurally controlled instability.*

B. *Sandstone with thin interlayers of siltstone*

C. *Sandstone and siltstone in similar amounts*

D. *Siltstone or silty shale with sandstone layers*

E. *Weak siltstone or clayey shale with sandstone layers*

C, D, E, and **G** - may be more or less folded than illustrated but this does not change the strength. Tectonic deformation, faulting and loss of continuity moves these categories to **F** and **H.**

F. *Tectonically deformed, intensively folded/faulted, sheared clayey shale or siltstone with broken and deformed sandstone layers forming an almost chaotic structure*

G. *Undisturbed silty or clayey shale with or without a few very thin sandstone layers*

H. ***Tectonically deformed silty or clayey shale forming a chaotic structure with pockets of clay. Thin layers of sandstone are transformed into small rock pieces.***

→ Means deformation after tectonic disturbance

DATE: 8-19-16

PROJECT REFERENCE NO.	SHEET NO.
BR-0082	3

SITE PLAN

0 60 120

FEET

SKEW = 45°

JENNIE P. STANCIL

NC GRID
NAD 83 NA 2011

END BRIDGE
-L- POT STA. 19+27.50

BEGIN BRIDGE
-L- POT STA. 17+02.50

UPPER LITTLE RIVER

15

20

WOODS

WOODS

WOODS

WOODS

WOODS

WOODS

SOIL

CONC HW

30" RCP

EB1-A

B1-A

B2-A

CONC

EB2-A

Bridge No. 56

EB1-B

B1-B

B2-B

EB2-B

CONC

8:1

8:1

8:1

8:1

-L-

NC 27

To Pineview

To Lillington

BL-101

BL-102

GUY

FSS

T FO

MELINDA K. SPENCE

LEROY D. SMALLS
PRISCILLA E. ROBINSON-SMALLS

BM 1

UPPER LITTLE RIVER

LEROY D. SMALLS
PRISCILLA E. ROBINSON-SMALLS

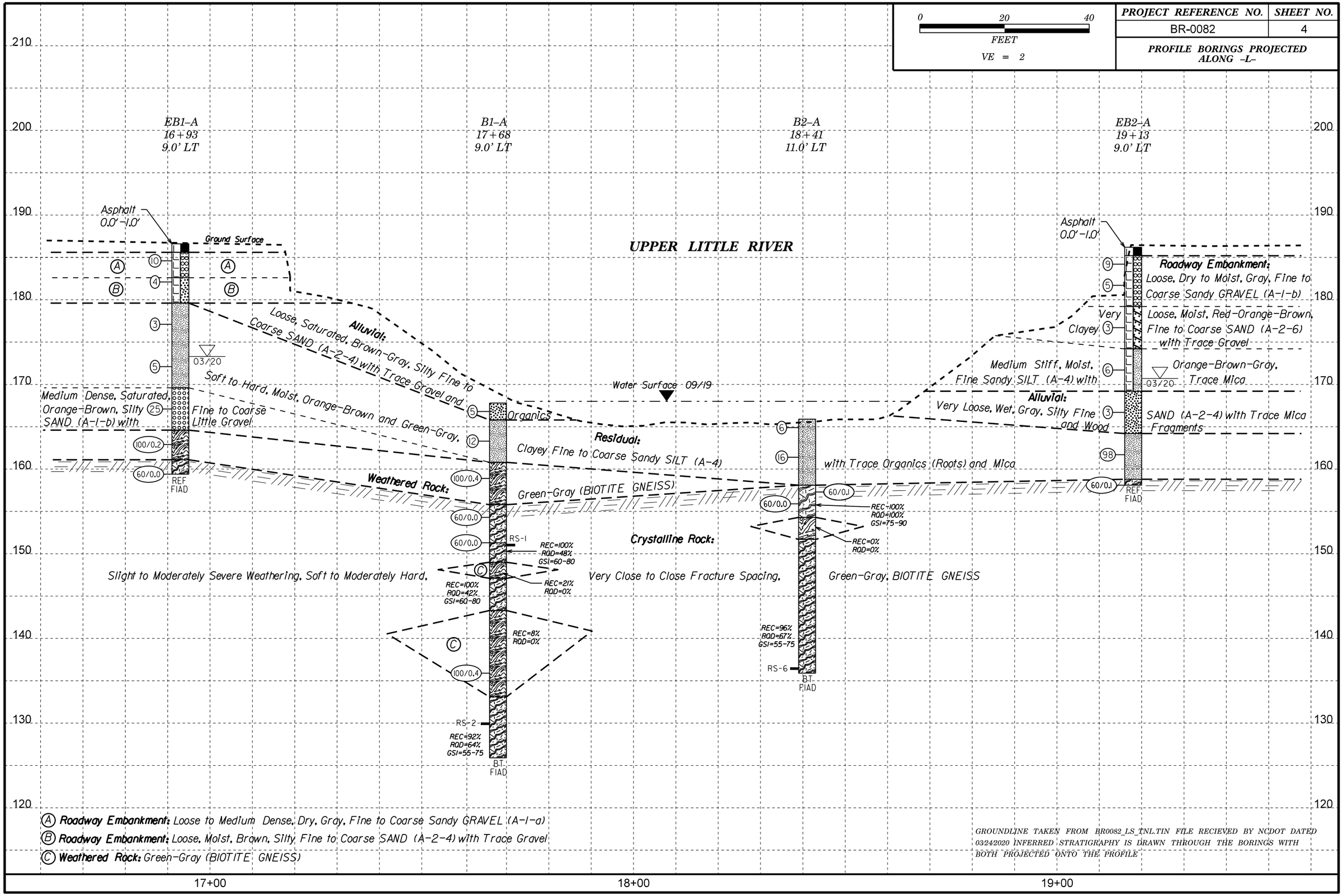
0	20	40

FEET

VE = 2

PROJECT REFERENCE NO.	SHEET NO.
BR-0082	4

PROFILE BORINGS PROJECTED ALONG -L-



(A) **Roadway Embankment:** Loose to Medium Dense, Dry, Gray, Fine to Coarse Sandy GRAVEL (A-1-a)

(B) **Roadway Embankment:** Loose, Moist, Brown, Silty Fine to Coarse SAND (A-2-4) with Trace Gravel

(C) **Weathered Rock:** Green-Gray (BIOTITE GNEISS)

GROUNDLINE TAKEN FROM BR0082_LS_TNL.TIN FILE RECIEVED BY NCDOT DATED 03242020 INFERRED STRATIGRAPHY IS DRAWN THROUGH THE BORINGS WITH BOTH PROJECTED ONTO THE PROFILE

PROJECT REFERENCE NO.	SHEET NO.
BR-0082	5

CROSS SECTION THROUGH END BENT 1
AT -L- STATION 17+02.50
SKEW=45°

0 10 20
FEET
VE = 1

EB1-A
16+93
9.0' LT

℄

EB1-B
17+03
9.0' RT

Asphalt
0.0'-1.0'

Asphalt
0.0'-0.8'

Ground Surface

Ⓐ 10 4 — Roadway Embankment: Loose to Medium Dense, Moist, Brown, Silty Fine to Coarse SAND

25 7 — Embankment: (A-2-4) with Trace Gravel

3 3 — Residual: Soft to Medium Stiff, Moist to Wet, Orange-Brown, Clayey Fine Sandy SILT (A-4) with Trace Mica

▽ 03/20

5 4 — Medium Dense, Saturated, Orange-Brown, Silty Fine to Coarse SAND (A-1-b) with Little Gravel

25 — 60/0.1 — 60/0.0 — REF — 0 HR DRY — FIAD

Weathered Rock: Green-Gray (BIOTITE GNEISS)

100/0.2 — 60/0.0 — REF — FIAD

Crystalline Rock: Green-Gray (BIOTITE GNEISS)

Note:
Caved at 13.9' at Probable Groundwater Level

Ⓐ Roadway Embankment: Loose to Medium Dense, Dry, Gray, Fine to Coarse Sandy GRAVEL (A-1-a)

GROUNDLINE TAKEN FROM BR0082_LS_TNL.TIN FILE RECIEVED BY NCDOT DATED 03242020 INFERRED STRATIGRAPHY IS DRAWN THROUGH THE BORINGS WITH BOTH PROJECTED ONTO THE CROSS SECTION

210 200 190 180 170 160 150 140 130 120

60 50 40 30 20 10 0 10 20 30 40 50 60

PROJECT REFERENCE NO.	SHEET NO.
BR-0082	6

CROSS SECTION THROUGH BENT 1
AT -L- STATION 17+77.50
SKEW=45°

0 10 20
FEET
VE = 1

B1-A
17+68
9.0' LT

℄

B1-B
17+88
10.0' RT

Water Surface 03/20

Ground Surface

Alluvial: Loose, Saturated, Brown-Gray, Silty (5) Fine to Coarse SAND (4) (A-2-4) with Trace Gravel and Organics

Residual: Stiff to Very Stiff, Moist, Dark Brown-Orange and (12) Green-Brown-Gray, (21) Fine to Coarse Sandy SILT (A-4) with Trace Mica

Weathered Rock:

100/0.4 Green-Gray 100/0.8 (BIOTITE GNEISS)

60/0.0

Residual:

(72) Hard, Moist, Gray-White, Fine to Coarse Sandy SILT (A-4) with Trace Mica

Crystalline Rock:

Slight to Moderately Severe Weathering, Soft to Moderately Hard, Close Fracture Spacing, Green-Gray BIOTITE GNEISS

60/0.0 RS-1 REC=100% RQD=48% GSI=60-80

60/0.0

Ⓐ REC=100% RQD=42% GSI=60-80

REC=21% RQD=0%

RS-3 REC=95% RQD=68% GSI=65-85

REC=8% RQD=0%

Weathered Rock:

Green-Gray (BIOTITE GNEISS)

100/0.4

BT FIAD

Crystalline Rock:

RS-2 REC=92% RQD=64% GSI=55-75

Slightly to Moderately Severe Weathering, Soft to Hard, Very Close to Close Fracture Spacing, Green-Gray BIOTITE GNEISS

BT FIAD

Ⓐ **Weathered Rock:** Green-Gray (BIOTITE GNEISS)

180 170 160 150 140 130 120 110 100

60 50 40 30 20 10 0 10 20 30 40 50 60

GROUNDLINE TAKEN FROM BR0082_LS_TNL.TIN FILE RECIEVED BY NCDOT DATED 03242020 INFERRED STRATIGRAPHY IS DRAWN THROUGH THE BORINGS WITH BOTH PROJECTED ONTO THE CROSS SECTION

PROJECT REFERENCE NO.	SHEET NO.
BR-0082	7

CROSS SECTION THROUGH BENT 2
AT -L- STATION 18+52.50
SKEW=45°

0 10 20
FEET
VE = 1

B2-A
18+41
11.0' LT

℄

B2-B
18+60
7.0' RT

Water Surface 03/20

Ground Surface

Residual: Medium Stiff to Hard, Moist, Green-Brown-Gray, Fine to Coarse Sandy SILT (A-4) with Trace Roots, Organics, and Mica

Weathered Rock: Green-Gray (BIOTITE GNEISS)

Weathered Rock: Green-Gray (BIOTITE GNEISS)

Crystalline Rock: Slight to Moderately Severe Weathering, Soft to Moderately Hard, Very Close to Close Fracture Spacing, Green-Gray, BIOTITE GNEISS

Crystalline Rock: Hard, Very Close to Close Fracture Spacing, Green-Gray, BIOTITE GNEISS

B2-A: 6, 16, 60/0.0, 60/0.1, REC=100% RQD=100% GSI=75-90, REC=0% RQD=0%, REC=96% RQD=67% GSI=55-75, RS-6, BT FIAD

B2-B: 75, 100/0.4, 60/0.1, 60/0.0, REC=100% RQD=35% GSI=55-75, RS-4, REC=0% RQD=0%, RS-5, REC=100% RQD=84% GSI=60-80, BT FIAD

190 180 170 160 150 140 130 120

60 50 40 30 20 10 0 10 20 30 40 50 60

Ⓐ **Crystalline Rock:** Slight to Moderately Severe Weathering, Soft to Moderately Hard, Very Close to Close Fracture Spacing, Green-Gray, BIOTITE GNEISS

GROUNDLINE TAKEN FROM BR0082_LS_TNL.TIN FILE RECIEVED BY NCDOT DATED 03/24/2020 INFERRED STRATIGRAPHY IS DRAWN THROUGH THE BORINGS WITH BOTH PROJECTED ONTO THE CROSS SECTION

PROJECT REFERENCE NO.	SHEET NO.
BR-0082	8

CROSS SECTION THROUGH END BENT 2
AT -L- STATION 19+27.50
SKEW=45°

0 10 20
FEET
VE = 1

EB2-A
19+13
9.0' LT

℄

EB2-B
19+41
9.0' RT

Asphalt
0.0'-1.0'

Asphalt
0.0'-0.9'

Ground Surface

Roadway Embankment: Loose to Medium Dense, Dry to Moist, Very Loose, Moist, Brown-Gray and Silty Clayey Fine to Medium Stiff, Moist, (A-4)

Gray, Fine to Red-Orange-Brown, Coarse SAND (A-2-6) Orange-Brown-Gray, with Trace Mica

Coarse Sandy GRAVEL (A-1-a) Silty Fine to Coarse SAND (A-2-4) and with Trace Gravel Fine Sandy Clayey SILT (A-2-4) with Trace Organics, Woods Fragments, and Mica

9 5 3 6 — 03/20

10 4 2 6 — 03/20

Alluvial: Very Loose to Loose, Moist to Wet, Black-Gray, Silty Fine SAND

3 — 4

Residual: Very Dense, Moist, Green-Gray, Fine Sandy SILT (A-4) with Trace Mica

98 — 60/0.1 REF FIAD

60/0.0 REF FIAD

Crystalline Rock: Green-Gray (BIOTITE GNEISS)

200 190 180 170 160 150 140 130 120

60 50 40 30 20 10 0 10 20 30 40 50 60

GROUNDLINE TAKEN FROM BR0082_LS_TNL.TIN FILE RECIEVED BY NCDOT DATED 03242020 INFERRED STRATIGRAPHY IS DRAWN THROUGH THE BORINGS WITH BOTH PROJECTED ONTO THE CROSS SECTION

GEOTECHNICAL BORING REPORT
BORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. EB1-A	**STATION** 16+93	**OFFSET** 9 ft LT	**ALIGNMENT** -L-	**0 HR.** 13.3
COLLAR ELEV. 186.6 ft	**TOTAL DEPTH** 27.2 ft	**NORTHING** 578,769	**EASTING** 2,014,323	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 02/28/20	**COMP. DATE** 02/28/20	**SURFACE WATER DEPTH** N/A	

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION ELEV. (ft) — DEPTH (ft)
190										
										186.6 GROUND SURFACE 0.0
185	185.6	1.0	6	5	5	10		D		185.6 **ASPHALT** 1.0
	183.1	3.5	4	2	2	4		M		**ROADWAY EMBANKMENT** Gray, Fine to Coarse Sandy GRAVEL (A-1-a)
180										182.6 4.0 Brown, Silty Fine to Coarse SAND (A-2-4) with Trace Gravel
	178.1	8.5	2	2	1	3		M		179.6 7.0 **RESIDUAL** Orange-Brown, Clayey Fine Sandy SILT (A-4) with Trace Mica
175										
	173.1	13.5	2	2	3	5		M		
170										169.6 17.0 Orange-Brown, Silty Fine to Coarse SAND (A-1-b) with Little Gravel
	168.1	18.5	15	13	12	25		Sat.		
165										164.6 22.0 **WEATHERED ROCK** Green-Gray (BIOTITE GNEISS)
	163.1	23.5	100/0.2			100/0.2				161.1 25.5 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)
160	159.4	27.2	60/0.0			60/0.0				159.4 27.2 Boring Terminated with Standard Penetration Test Refusal at Elevation 159.4 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. Driller indicated harder drilling at 25.5'
2. Auger refusal at 27.2'

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. EB1-B	**STATION** 17+03	**OFFSET** 9 ft RT	**ALIGNMENT** -L-	**0 HR.** Caved
COLLAR ELEV. 186.4 ft	**TOTAL DEPTH** 21.2 ft	**NORTHING** 578,754	**EASTING** 2,014,337	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 03/02/20	**COMP. DATE** 03/02/20	**SURFACE WATER DEPTH** N/A	

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
190										
										186.4 GROUND SURFACE 0.0
185	185.6	0.8	8	13	12	25		M		185.6 **ASPHALT** 0.8
	182.9	3.5	3	3	4	7		M		**ROADWAY EMBANKMENT** Brown-Gray, Silty Fine to Coarse SAND (A-2-4)
180										179.4 7.0
	177.9	8.5	2	1	2	3		M		**RESIDUAL** Orange-Brown, Clayey Fine Sandy SILT (A-4) with Trace Mica
175										
	172.9	13.5	2	2	2	4		W		
170										169.4 17.0
	167.9	18.5	60/0.1			60/0.1				**CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)
165	165.2	21.2	60/0.0			60/0.0				165.2 21.2 Boring Terminated with Standard Penetration Test Refusal at Elevation 165.2 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. Driller indicated harder drilling at 17.0'
2. Auger refusal at 21.2'
3. Caved at 13.9' at probable groundwater level

GEOTECHNICAL BORING REPORT
BORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. B1-A	**STATION** 17+68	**OFFSET** 9 ft LT	**ALIGNMENT** -L-	**0 HR.** N/A
COLLAR ELEV. 167.8 ft	**TOTAL DEPTH** 41.5 ft	**NORTHING** 578,787	**EASTING** 2,014,396	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** NW Casing w/ Advancer	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 03/04/20	**COMP. DATE** 03/06/20	**SURFACE WATER DEPTH** 4.2ft	

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION ELEV. (ft)	DEPTH (ft)
										WATER SURFACE (03/04/20)	
170											
	167.8	0.0	1	3	2	5		Sat.		167.8 GROUND SURFACE	0.0
165										165.8 **ALLUVIAL** Brown-Gray, Silty Fine to Coarse SAND (A-2-4) with Trace Gravel and Organics	2.0
	164.3	3.5	2	4	8	12		M		**RESIDUAL** Dark Brown-Orange, Clayey Fine to Coarse Sandy SILT (A-4) with Trace Mica	
160										160.8 **WEATHERED ROCK** Green-Gray (BIOTITE GNEISS)	7.0
	159.3	8.5	100/0.4			100/0.4					
155										155.8 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)	12.0
	154.3	13.5	60/0.0			60/0.0					
	151.3	16.5	60/0.0			60/0.0	RS-1			151.3	16.5
150										149.0 **WEATHERED ROCK** Green-Gray (BIOTITE GNEISS)	18.8
										147.1 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)	20.7
145										143.3 **WEATHERED ROCK** Green-Gray (BIOTITE GNEISS)	24.5
140											
	136.3	31.5	100/0.4			100/0.4				133.5 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)	34.3
135											
							RS-2			126.3	41.5
130										Boring Terminated at Elevation 126.3 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)	

Notes:
1. 0 HR water level not measured due to water being introduced for coring
2. Driller indicated harder drilling at 12.0'
3. Casing Advancer refusal and start rock coring at 16.5'

NCDOT BORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/23/20

GEOTECHNICAL BORING REPORT
CORE LOG

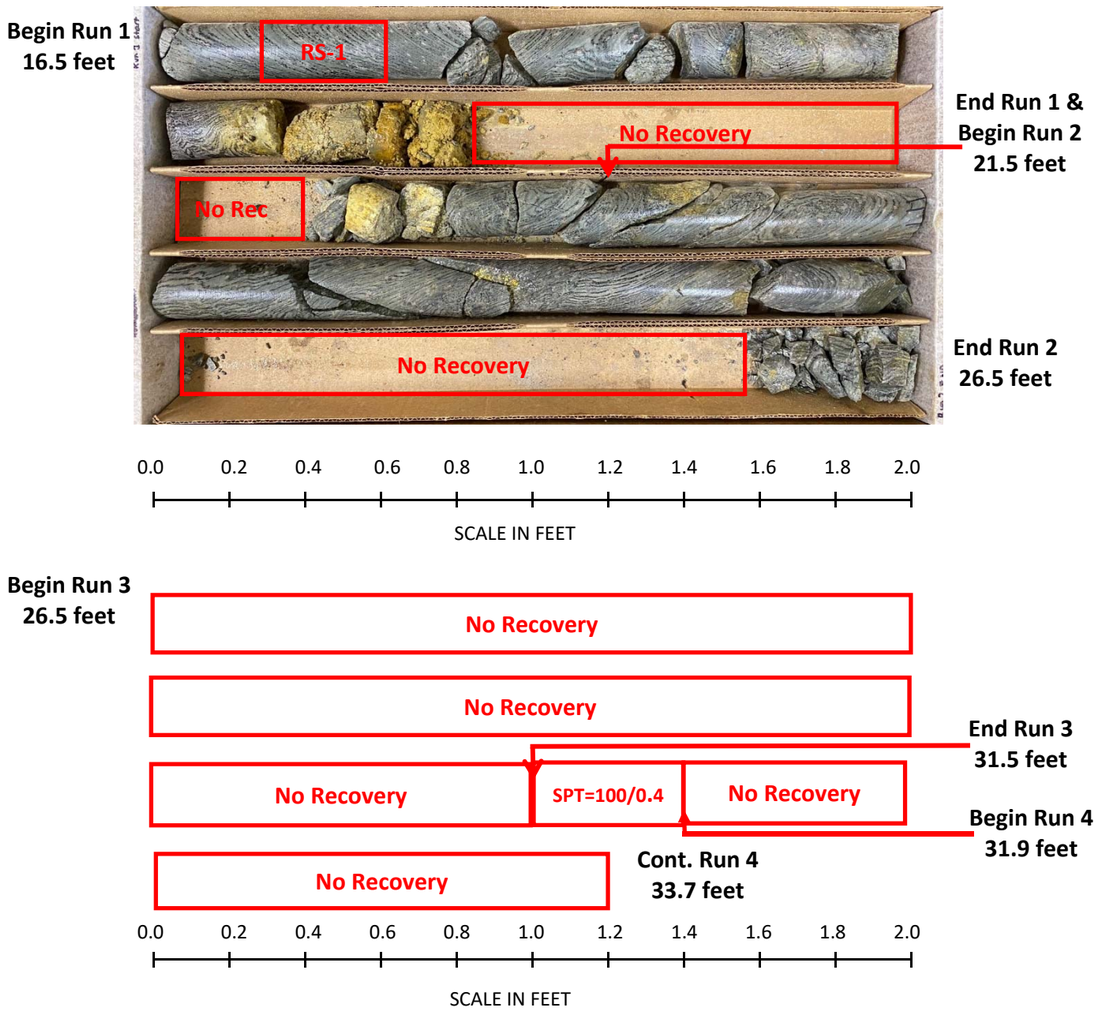
WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. B1-A	**STATION** 17+68	**OFFSET** 9 ft LT	**ALIGNMENT** -L-	**0 HR.** N/A
COLLAR ELEV. 167.8 ft	**TOTAL DEPTH** 41.5 ft	**NORTHING** 578,787	**EASTING** 2,014,396	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** NW Casing w/ Advancer	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 03/04/20	**COMP. DATE** 03/06/20	**SURFACE WATER DEPTH** 4.2ft	
CORE SIZE N	**TOTAL RUN** 24.6 ft			

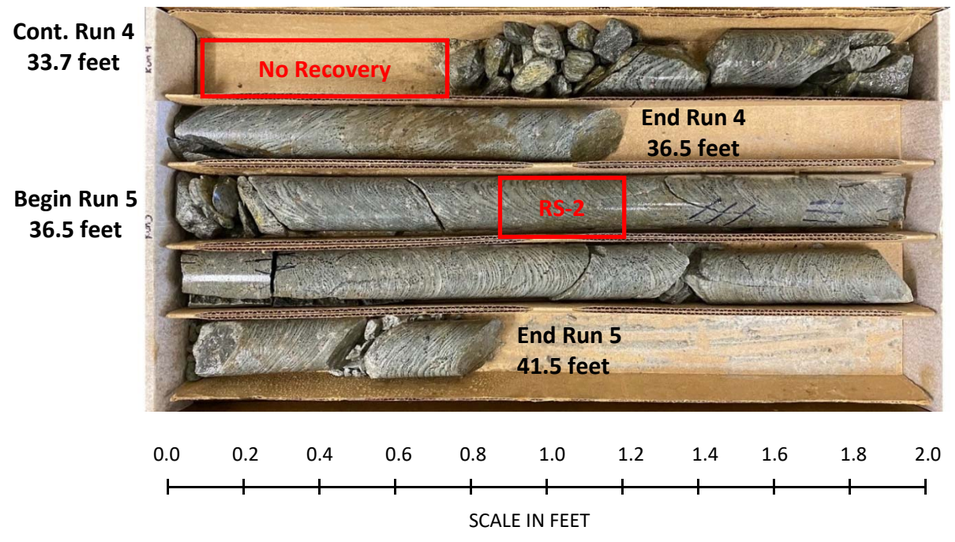
ELEV (ft)	RUN ELEV (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS ELEV. (ft)	DEPTH (ft)
151.3											Begin Coring @ 16.5 ft	
150	151.3	16.5	5.0	1:40/1.0 1:33/1.0 1:36/1.0 1:50/1.0 1:51/1.0	(3.5) 70%	(1.1) 22%	RS-1	(2.3) 100%	(1.1) 48%		151.3 **CRYSTALLINE ROCK**	16.5
	146.3	21.5						(0.4) 21%	(0.0) 0%		149.0 Slight to Moderately Severe Weathering, Soft to Moderately Hard, Close Fracture Spacing, Green-Gray BIOTITE GNEISS RS-1: 16.6'-16.9', qu=3,088 psi, GSI=60-80	18.8
145			5.0	1:23/1.0 1:30/1.0 1:50/1.0 2:15/1.0 2:02/1.0	(3.3) 66%	(1.6) 32%		(3.8) 100%	(1.6) 42%		147.1 **WEATHERED ROCK** Green-Gray BIOTITE GNEISS	20.7
	141.3	26.5									143.3 **CRYSTALLINE ROCK**	24.5
140			5.0	1:08/1.0 1:02/1.0 1:03/1.0 1:20/1.0 1:31/1.0	(0.0) 0%	(0.0) 0%		(0.8) 8%	(0.0) 0%		Slight to Moderately Severe Weathering, Soft to Moderately Hard, Close Fracture Spacing, Green-Gray BIOTITE GNEISS GSI=60-80	
	136.3	31.5									**WEATHERED ROCK** Green-Gray BIOTITE GNEISS	
135	135.8	31.0	4.6	N=100/0.4 1:11/0.6 1:33/1.0 1:30/1.0 1:44/1.0 1:29/1.0	(2.4) 52%	(1.2) 26%					133.5 **CRYSTALLINE ROCK**	34.3
	131.3	36.5						(6.6) 92%	(4.6) 64%		Slightly to Moderately Severe Weathering, Soft to Moderately Hard, Very Close to Close Fracture Spacing, Green-Gray BIOTITE GNEISS RS-2: 37.7'-40.0', qu=5,682 psi, GSI=55-75	
130			5.0	1:07/1.0 1:27/1.0 1:22/1.0 1:36/1.0 1:44/1.0	(4.7) 94%	(3.4) 68%	RS-2				126.3	41.5
	126.3	41.5									Boring Terminated at Elevation 126.3 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)	

Notes:
1. 0 HR water level not measured due to water being introduced for coring
2. Driller indicated harder drilling at 12.0'
3. Casing Advancer refusal and start rock coring at 16.5'

NCDOT CORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/23/20

CORE PHOTOGRAPHS:
BR-0082 I 67082.1.1
B1-A: -L- Station 17+68, 9’ LT





GEOTECHNICAL BORING REPORT
BORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. B1-B	**STATION** 17+88	**OFFSET** 10 ft RT	**ALIGNMENT** -L-	**0 HR.** N/A
COLLAR ELEV. 167.2 ft	**TOTAL DEPTH** 32.5 ft	**NORTHING** 578,774	**EASTING** 2,014,420	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** NW Casing w/ Advancer	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 03/02/20	**COMP. DATE** 03/04/20	**SURFACE WATER DEPTH** 4.5ft	

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION ELEV. (ft)	DEPTH (ft)
										WATER SURFACE (03/02/20)	
170											
	167.2	0.0	1	1	3	4		Sat.		167.2 GROUND SURFACE	0.0
165										165.2 **ALLUVIAL** Brown-Gray, Silty Fine to Coarse SAND (A-2-4) with Trace Organics	2.0
	163.7	3.5	4	8	13	21		M		**RESIDUAL** Green-Brown-Gray, Fine to Coarse Sandy SILT (A-4) with Trace Mica	
160										160.7	6.5
	158.7	8.5	44	56/0.3		100/0.8				**WEATHERED ROCK** Green-Gray (BIOTITE GNEISS)	
155										155.2	12.0
	153.7	13.5	18	33	39	72		M		**RESIDUAL** Gray-White, Fine to Coarse Sandy SILT (A-4) with Trace Mica	
150										149.7	17.5
	148.7	18.5	60/0.0			60/0.0				148.7 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)	18.5
145											
							RS-3				
140											
135										134.7	32.5

Boring Terminated at Elevation 134.7 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. 0 HR water level not measured due to being water introduced for coring
2. Driller indicated harder drilling at 6.5' and 17.5'
3. Start rock coring at 18.5'

NCDOT BORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/22/20

GEOTECHNICAL BORING REPORT
CORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. B1-B	**STATION** 17+88	**OFFSET** 10 ft RT	**ALIGNMENT** -L-	**0 HR.** N/A
COLLAR ELEV. 167.2 ft	**TOTAL DEPTH** 32.5 ft	**NORTHING** 578,774	**EASTING** 2,014,420	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** NW Casing w/ Advancer	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 03/02/20	**COMP. DATE** 03/04/20	**SURFACE WATER DEPTH** 4.5ft	
CORE SIZE N	**TOTAL RUN** 14.0 ft			

ELEV (ft)	RUN ELEV (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS ELEV. (ft)	DEPTH (ft)
148.7											Begin Coring @ 18.5 ft	
	148.7	18.5	4.0	1:27/1.0 1:28/1.0 1:36/1.0 1:55/1.0	(3.6) 90%	(2.0) 50%		(13.3) 95%	(9.5) 68%		148.7 **CRYSTALLINE ROCK** Slight to Moderately Severe Weathering, Medium Hard to Hard, Very Close to Close Fracture Spacing, Green-Gray BIOTITE GNEISS RS-3: 23.2'-23.5', qu=2,664 psi, GSI=65-85	18.5
145	144.7	22.5	5.0	1:35/1.0 1:30/1.0 1:39/1.0 2:42/1.0 2:35/1.0	(4.7) 94%	(3.3) 66%	RS-3					
140	139.7	27.5	5.0	1:35/1.0 1:29/1.0 1:36/1.0 1:29/1.0 1:31/1.0	(5.0) 100%	(4.2) 84%						
135	134.7	32.5									134.7	32.5

Boring Terminated at Elevation 134.7 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. 0 HR water level not measured due to being water introduced for coring
2. Driller indicated harder drilling at 6.5' and 17.5'
3. Start rock coring at 18.5'

NCDOT CORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/22/20

CORE PHOTOGRAPHS:
BR-0082 I 67082.1.1
B1-B: -L- Station 17+88, 10’ RT

Begin Run 1
18.5 feet

End Run 1
22.5 feet

Begin Run 2
22.5 feet

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

SCALE IN FEET

Begin Run 3
27.5 feet

End Run 3
32.5 feet

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

SCALE IN FEET

s

GEOTECHNICAL BORING REPORT
BORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. B2-A	**STATION** 18+41	**OFFSET** 11 ft LT	**ALIGNMENT** -L-	**0 HR.** N/A
COLLAR ELEV. 165.9 ft	**TOTAL DEPTH** 30.0 ft	**NORTHING** 578,807	**EASTING** 2,014,466	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** NW Casing w/ Advancer	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 03/09/20	**COMP. DATE** 03/09/20	**SURFACE WATER DEPTH** 5.5ft	

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION ELEV. (ft)	DEPTH (ft)
										WATER SURFACE (03/09/20)	
170											
	165.9	0.0								GROUND SURFACE	0.0
165			1	2	4	6		M		**RESIDUAL** Green-Brown-Gray, Fine to Coarse Sandy SILT (A-4) with Trace Organics and Mica	
	162.4	3.5	3	6	10	16		M			
160											
	157.4	8.5				1					158.1 7.8
155	155.9	10.0	60/0.1			60/0.1				**CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)	155.9 10.0
			60/0.0			60/0.0					154.3 11.6
										WEATHERED ROCK Green-Gray (BIOTITE GNEISS)	151.7 14.2
150										**CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)	
145											
140											
							RS-6				135.9 30.0

Boring Terminated at Elevation 135.9 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. 0 HR water level not measured due to water being introduced for coring
2. Driller indicated harder drilling at 7.8'
3. Casing Advancer refusal and start rock coring at 10.0'

NCDOT BORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/23/20

GEOTECHNICAL BORING REPORT
CORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. B2-A	**STATION** 18+41	**OFFSET** 11 ft LT	**ALIGNMENT** -L-	**0 HR.** N/A
COLLAR ELEV. 165.9 ft	**TOTAL DEPTH** 30.0 ft	**NORTHING** 578,807	**EASTING** 2,014,466	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** NW Casing w/ Advancer	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 03/09/20	**COMP. DATE** 03/09/20	**SURFACE WATER DEPTH** 5.5ft	
CORE SIZE N	**TOTAL RUN** 20.0 ft			

ELEV (ft)	RUN ELEV (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS ELEV. (ft)	DEPTH (ft)
155.9											Begin Coring @ 10.0 ft	
155	155.9	10.0	5.0	1:00/1.0 1:16/1.0 2:34/1.0 2:56/1.0 3:01/1.0	(2.3) 46%	(1.6) 32%		(1.6) 100%	(1.6) 100%		155.9 **CRYSTALLINE ROCK**	10.0
								(0.0) 0%	(0.0) 0%		154.3 Slight to Moderately Severe Weathering, Medium Soft to Moderately Hard, Very Close Fracture Spacing, Green-Gray BIOTITE GNEISS GSI=75-90	11.6
	150.9	15.0									151.7 **WEATHERED ROCK** Green-Gray BIOTITE GNEISS	14.2
150			5.0	1:55/1.0 1:50/1.0 2:04/1.0 2:04/1.0 1:44/1.0	(5.0) 100%	(4.3) 86%		(15.3) 97%	(10.6) 67%		**CRYSTALLINE ROCK** Slight to Moderately Severe Weathering, Soft to Moderately Hard, Very Close to Close Fracture Spacing, Green-Gray BIOTITE GNEISS RS-6: 29.3'-29.6', qu=3,351 psi, GSI=55-75	
	145.9	20.0										
145			5.0	1:54/1.0 1:54/1.0 1:42/1.0 1:52/1.0 1:52/1.0	(4.7) 94%	(3.0) 60%						
140	140.9	25.0										
			5.0	2:09/1.0 2:09/1.0 1:53/1.0 1:32/1.0 1:32/1.0	(4.9) 98%	(3.3) 66%						
	135.9	30.0					RS-6				135.9	30.0

Boring Terminated at Elevation 135.9 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. 0 HR water level not measured due to water being introduced for coring
2. Driller indicated harder drilling at 7.8'
3. Casing Advancer refusal and start rock coring at 10.0'

NCDOT CORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/23/20

CORE PHOTOGRAPHS:
BR-0082 I 67082.1.1
B2-A: -L- Station 18+41, 11’ LT

Begin Run 1
10.0 feet

End Run 1 &
Begin Run 2
15.0 feet

End Run 2
20.0 feet

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

SCALE IN FEET

Begin Run 3
20.0 feet

End Run 3 &
Begin Run 4
25.0 feet

End Run 4
25.0 feet

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

SCALE IN FEET

GEOTECHNICAL BORING REPORT
BORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. B2-B	**STATION** 18+60	**OFFSET** 7 ft RT	**ALIGNMENT** -L-	**0 HR.** N/A
COLLAR ELEV. 165.2 ft	**TOTAL DEPTH** 29.5 ft	**NORTHING** 578,795	**EASTING** 2,014,489	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** NW Casing w/ Advancer		**HAMMER TYPE** Automatic
DRILLER S. Davis	**START DATE** 03/10/20	**COMP. DATE** 03/10/20	**SURFACE WATER DEPTH** 6.1ft	

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION ELEV. (ft)	DEPTH (ft)
										WATER SURFACE (03/10/20)	
170											
165	165.2	0.0	25	46	29	75		M		165.2 GROUND SURFACE	0.0
	161.7	3.5	100/0.4			100/0.4				163.3 **RESIDUAL** Green-Tan, Fine to Coarse Sandy SILT (A-4) with Trace Mica	1.9
160										**WEATHERED ROCK** Green-Gray (BIOTITE GNEISS)	
	156.7	8.5	60/0.1			60/0.1				157.7 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)	7.5
155	154.7	10.5	60/0.0			60/0.0	RS-4			154.7	10.5
										152.7 **WEATHERED ROCK** Green-Gray (BIOTITE GNEISS)	12.5
150										151.1 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)	14.1
145											
140							RS-5			135.7	29.5

Boring Terminated at Elevation 135.7 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. 0 HR water level not measured due to water being introduced for coring
2. Driller indicated harder drilling at 1.9' and 7.5'
3. Casing Advancer refusal and start rock coring at 10.5'

NCDOT BORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/23/20

GEOTECHNICAL BORING REPORT
CORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. B2-B	**STATION** 18+60	**OFFSET** 7 ft RT	**ALIGNMENT** -L-	**0 HR.** N/A
COLLAR ELEV. 165.2 ft	**TOTAL DEPTH** 29.5 ft	**NORTHING** 578,795	**EASTING** 2,014,489	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** NW Casing w/ Advancer		**HAMMER TYPE** Automatic
DRILLER S. Davis	**START DATE** 03/10/20	**COMP. DATE** 03/10/20	**SURFACE WATER DEPTH** 6.1ft	
CORE SIZE N	**TOTAL RUN** 19.0 ft			

ELEV (ft)	RUN ELEV (ft)	DEPTH (ft)	RUN (ft)	DRILL RATE (Min/ft)	RUN REC. (ft) %	RUN RQD (ft) %	SAMP. NO.	STRATA REC. (ft) %	STRATA RQD (ft) %	LOG	DESCRIPTION AND REMARKS ELEV. (ft)	DEPTH (ft)
154.7											Begin Coring @ 10.5 ft	
	154.7	10.5	4.0	1:27/1.0 1:09/1.0 1:10/1.0 1:19/1.0	(2.4) 60%	(0.7) 18%	RS-4	(2.0) 100%	(0.7) 35%		154.7 **CRYSTALLINE ROCK** Slight to Moderately Severe Weathering, Soft to Moderately Hard, Very Close to Close Fracture Spacing, Green-Gray BIOTITE GNEISS RS-4: 10.7'-11.0', qu=1,520 psi, GSI=55-75	10.5
150	150.7	14.5						(0.0) 0%	(0.0) 0%		152.7	12.5
			5.0	1:18/1.0 1:21/1.0 1:33/1.0 1:41/1.0 1:49/1.0	(5.0) 100%	(4.2) 84%		(15.4) 100%	(13.0) 84%		151.1 **WEATHERED ROCK** Green-Gray BIOTITE GNEISS	14.1
145	145.7	19.5									**CRYSTALLINE ROCK** Slight to Moderately Severe Weathering, Soft to Moderately Hard, Very Close to Close Fracture Spacing, Green-Gray BIOTITE GNEISS RS-5: 24.6'-24.9', qu=3,948 psi, GSI=60-80	
			5.0	1:20/1.0 1:20/1.0 1:24/1.0 1:24/1.0 1:23/1.0	(5.0) 100%	(4.8) 96%						
140	140.7	24.5										
			5.0	1:21/1.0 1:24/1.0 1:37/1.0 2:18/1.0 2:17/1.0	(5.0) 100%	(4.0) 80%	RS-5					
	135.7	29.5									135.7	29.5

Boring Terminated at Elevation 135.7 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. 0 HR water level not measured due to water being introduced for coring
2. Driller indicated harder drilling at 1.9' and 7.5'
3. Casing Advancer refusal and start rock coring at 10.5'

NCDOT CORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/23/20

CORE PHOTOGRAPHS:
BR-0082 I 67082.1.1
B2-B: -L- Station 18+60, 7’ RT

Begin Run 1
10.5 feet

End Run 1
14.5 feet

Begin Run 2
14.5 feet

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

SCALE IN FEET

Begin Run 3
19.5 feet

End Run 3 &
Begin Run 4
24.5 feet

End Run 4
29.5 feet

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

SCALE IN FEET

GEOTECHNICAL BORING REPORT
BORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. EB2-A	**STATION** 19+18	**OFFSET** 9 ft LT	**ALIGNMENT** -L-	**0 HR.** 15.5
COLLAR ELEV. 186.2 ft	**TOTAL DEPTH** 28.1 ft	**NORTHING** 578,824	**EASTING** 2,014,541	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 02/28/20	**COMP. DATE** 02/28/20	**SURFACE WATER DEPTH** N/A	

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION ELEV. (ft) — DEPTH (ft)
190										
	186.2	0.0								GROUND SURFACE
185	185.2	1.0	6	4	5	9		D		**ASPHALT** 185.2 — 1.0 **ROADWAY EMBANKMENT** Gray, Fine to Coarse Sandy GRAVEL (A-1-a)
	182.7	3.5	2	2	3	5		M		
180										179.2 — 7.0 Red-Orange-Brown, Clayey Fine to Coarse SAND (A-2-6) with Trace Gravel
	177.7	8.5	2	2	1	3		M		
175										174.2 — 12.0 Orange-Brown-Gray, Clayey Fine Sandy SILT (A-4) with Trace Mica
	172.7	13.5	3	2	4	6		M		
170										169.2 — 17.0 **ALLUVIAL** Black-Gray, Silty Fine SAND (A-2-4) with Trace Mica and Wood Fragments
	167.7	18.5	1	2	1	3		W		
165										164.2 — 22.0 **RESIDUAL** Green-Gray, Fine Sandy SILT (A-4) with Trace Mica
	162.7	23.5	18	38	60	98		M		
160										158.8 — 27.4 158.1 — 28.1 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS) Boring Terminated with Standard Penetration Test Refusal at Elevation 158.1 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)
	158.2	28.0	60/0.1			60/0.1				Notes: 1. Driller indicated harder drilling at 27.4' 2. Auger refusal at 28.0'

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl	
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River				**GROUND WTR (ft)**
BORING NO. EB2-B	**STATION** 19+37	**OFFSET** 9 ft RT	**ALIGNMENT** -L-	**0 HR.** 16.0
COLLAR ELEV. 186.2 ft	**TOTAL DEPTH** 23.2 ft	**NORTHING** 578,812	**EASTING** 2,014,564	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic	
DRILLER S. Davis	**START DATE** 03/02/20	**COMP. DATE** 03/02/20	**SURFACE WATER DEPTH** N/A	

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
190										
	186.2	0.0								GROUND SURFACE
185	185.3	0.9	6	6	4	10		M		185.3 — 0.9 **ASPHALT** **ROADWAY EMBANKMENT** Gray, Fine to Coarse Sandy GRAVEL (A-1-a)
	182.7	3.5	2	2	2	4		M		
180										179.2 — 7.0 Brown-Gray, Silty Fine to Coarse SAND (A-2-4)
	177.7	8.5	2	1	1	2		M		
175										174.2 — 12.0 Orange-Brown-Gray, Clayey Fine Sandy SILT (A-4) with Trace Mica
	172.7	13.5	1	2	4	6		M		
170										169.2 — 17.0 **ALLUVIAL** Black-Gray, Silty Fine SAND (A-2-4) with Trace Organics
	167.7	18.5	1	2	2	4		W		
165										164.2 — 22.0 163.0 — 23.2 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS) Boring Terminated with Standard Penetration Test Refusal at Elevation 163.0 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)
	163.0	23.2	60/0.0			60/0.0				Notes: 1. Driller indicated harder drilling at 22.0' 2. Auger refusal at 23.2'

LABORATORY SUMMARY SHEET FOR ROCK CORE SAMPLES

PROJECT NO.: 67082.1.1
TIP NO.: BR-0082
COUNTY: Harnett
DESCRIPTION: Bridge 56 on NC 27 over Upper Little River

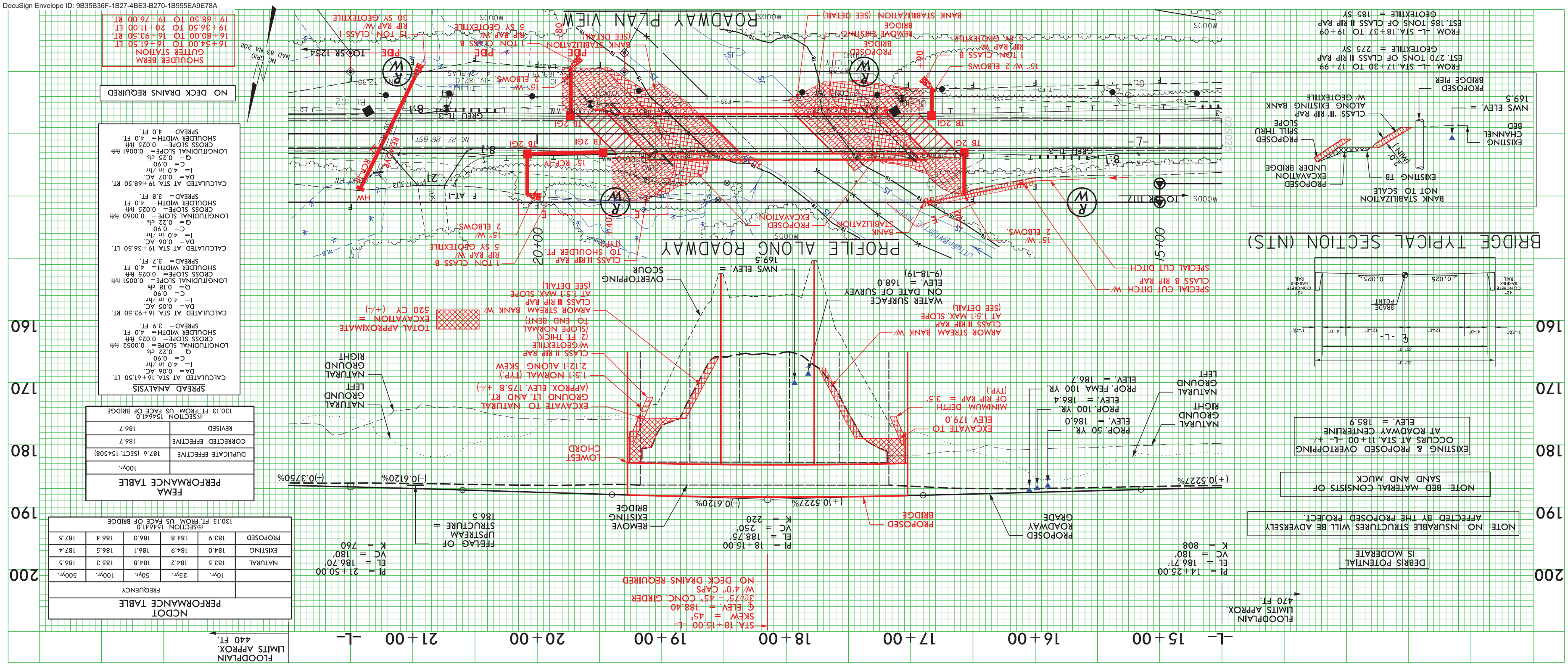
Sample #	Boring #	Alignment	Station	Offset	Depth (ft)	Rock Type	Geologic Map Unit	Run RQD	Length (in)	Diameter (in)	Unit Weight (pcf)	Unconfined Compressive Strength (psi)	Young's Modulus, E (ksf)	GSI
RS-1	B1-A	-L-	17+68	9' Lt.	16.6 - 16.9	Biotite Gneiss	CZbg	48%	4.24	1.76	169.0	3,088	71,536	60-80
RS-2	B1-A	-L-	17+68	9' Lt.	37.7 - 40.0	Biotite Gneiss	CZbg	65%	4.35	1.77	170.2	5,682	146,016	55-75
RS-3	B1-B	-L-	17+88	10' Rt.	23.2 - 23.5	Biotite Gneiss	CZbg	68%	4.13	1.77	172.5	2,664	42,480	65-85
RS-4	B2-B	-L-	18+60	7' Rt.	10.7 - 11.0	Biotite Gneiss	CZbg	35%	4.31	1.77	163.9	1,520	35,657	55-75
RS-5	B2-B	-L-	18+60	7' Rt.	24.6 - 24.9	Biotite Gneiss	CZbg	84%	4.27	1.77	170.3	3,948	96,581	60-80
RS-6	B2-A	-L-	18+41	11' Lt.	29.3 - 29.6	Biotite Gneiss	CZbg	67%	4.31	1.77	170.9	3,351	73,267	55-75

TIP: BR-0082

WBS No.: 67082.1.1

Bridge No. 56 on NC 27 over Upper Little River

FOUNDATION RECOMMENDATIONS: SUPPORTIVE DOCUMENTS



INFORMATION TO BE SHOWN ON PLANS

WS EL. Taken @ River Station 154641.0

	Discharge	Frequency	Elev.
Design:	9000 c.f.s.	50 yr.	186.0 ft.
Base Flood:	10400 c.f.s.	100 yr.	186.4 ft.
*Overtopping:	8900 c.f.s.	50+/– yr.	185.9 ft.

*OVERTOPPING OCCURS AT –L– STA. 11+00 +/– AT ROADWAY CENTERLINE

ADDITIONAL INFORMATION AND COMPUTATIONS

HYDROLOGY

DA = 145.0 mi^2

FROM USGS RURAL REGRESSION EQUATIONS FOR REGION 1 (PIEDMONT) AND REGION 4 (COASTAL PLAIN) PER USGS SIR 2009–5158 (50% REGION 1 & 50% REGION 4)

$Q_{10} = 10^{[(0.0260)(50)+(0.0224)(50)]} DA^{0.617} = 5670$ CFS SAY 5700 CFS

$Q_{25} = 10^{[(0.0273)(50)+(0.0239)(50)]} DA^{0.606} = 7410$ CFS SAY 7400 CFS

$Q_{50} = 10^{[(0.0282)(50)+(0.0249)(50)]} DA^{0.600} = 8950$ CFS SAY 9000 CFS

$Q_{100} = 10^{[(0.0289)(50)+(0.0258)(50)]} DA^{0.594} = 10444$ CFS SAY 10400 CFS

$Q_{500} = 10^{[(0.0303)(50)+(0.0274)(50)]} DA^{0.583} = 13966$ CFS SAY 14000 CFS

FEMA DISCHARGES (USED FOR COMPLIANCE):	USGS DISCHARGES (USED FOR DESIGN):
Q_{10} = N/A	Q_{10} = 5700 cfs
Q_{25} = N/A	Q_{25} = 7400 cfs
Q_{50} = N/A	Q_{50} = 9000 cfs
Q_{100} = 11511 cfs	Q_{100} = 10400 cfs
Q_{500} = N/A	Q_{500} = 14000 cfs

SCOUR ANALYSIS (USING SECTION 154641 AS APPROACH)

SCOUR ANALYSIS BASED OFF OF HEC–18, FIFTH EDITION, APRIL 2012

OVERTOPPING LIVE–BED CONTRACTION SCOUR PREDICTION

$Ys_{FREQUENCY} = [(Y_1)(Q_2/Q_1)^{6/7}(W_1/W_2)^{0.69}] - H_B$

$Ys_{OVERTOPPING} = [18.0(8268/4585)^{6/7}(72.5/83.8)^{0.69}] - 17.7 = 9.3$ FT.

OVERTOPPING LOCAL SCOUR PREDICTION

$Ys_{PIER\ \#} = a\,[(2.0)(K_1)(K_2)(K_3)(Y_1/a)^{0.35}(Fr)^{0.43}]$

$Ys_{OVERTOPPING}^{PIER\ \#1} = 3.5\,[(2.0)(1.0)(1.0)(1.1)(18.0/3.5)^{0.35}(0.24)^{0.43}] = 7.4$ FT.

$Ys_{OVERTOPPING}^{PIER\ \#2} = 3.5\,[(2.0)(1.0)(1.0)(1.1)(18.5/3.5)^{0.35}(0.06)^{0.43}] = 4.1$ FT.

OVERTOPPING ABUTMENT SCOUR (NCHRP 24–20 EQUATION)

$Y_{MAX} = \alpha(Y_C) = \alpha[Y_1(q_{2C}/q_1)^{6/7}]$ $\quad Y_S = Y_{MAX} - Y_O$

$Y_{MAX} = 1.2\,[(18.0)(56.9/63.2)^{6/7}] = 19.7$ FT.

$Y_S = 19.7 - 17.7 = 2.0$ FT.

SITE DATA

Drainage Area 145.0 SQ. MI. Source USGS STREAMSTATS

River Basin CAPE FEAR Character RURAL RESIDENTIAL

Stream Classification (Such as Trout, High Quality Water, etc.) CLASS C

Data on Existing Structure 5 @ 40' (EFFECTIVE OPENING 197.2')– R.C. FLOOR ON I–BEAMS W/ R.C. CAPS AND PILES Total Waterway Opening 1428 s.f.

Waterway Opening Below 100yr. WS EL. 1428 s.f.

Debris Potential: Low ...... Moderate X High ......

Data on Structures Up and Down Stream 6.2 MI. DOWNSTREAM: BRIDGE #420055 ON SR 1130: 4@48.17' PPC CORED SLAB W/ R.C. CAPS AND CONCRETE DRILLED SHAFT PILES

NO COMPARABLE UPSTREAM STRUCTURE

Design Control Elev. 186.7 ft. (EXIST FEMA 100 YR WSEL SINCE HOMES ARE IN UPSTREAM FLOODPLAIN – SECTION 154641.0 USED)

Gage Station No. NONE Period of Records N/A yrs.

Max. Discharge N/A c.f.s. Date N/A Frequency N/A

Historical Flood Information:

Date SEPT. 2018 Elev. 189.5 ft. Est. Freq. 500+ YR. yr. Source JONATHAN MOORE NCDOT HYDRAULICS UNIT Period of Knowledge N/A yrs.

Date SEPT. 2019 Elev. 180.5 ft. Est. Freq. 10+/– YR. yr. Source RECENT DRIFT (JUST BELOW LOW STEEL) Period of Knowledge N/A yrs.

Date .... Elev. .... ft. Est. Freq. .... yr. Source .... Period of Knowledge .... yrs.

Historical Scour Info. : General NONE ft. Contraction ~2 FT. (HURR. MATTHEW) ft. Local ~2 FT. (HURR. MATTHEW) ft.

Channel Slope 0.0090 ft/ft Source USGS QUAD MAP Normal Water Surface Elev. 169.5 ft.

Manning's n: Left O.B. 0.12 Channel 0.4 Right O.B. 0.12 Source FEMA MODEL

Flood Study /Status FEMA SPECIAL FLOOD HAZARD ZONE AE / LIMITED STUDY (FIS DATED 10–3–06 / REV. 7–17–07) Non–Encroachment Established? YES

Flood Study 100yr. Discharge 11511 c.f.s. WS Elev.: With Non–Encroachment 188.3 ft. Without Non–Encroachment 187.6 ft. @ River Station 154508.0

DESIGN DATA

Hydrological Method USGS RURAL REGRESSION EQUATIONS – 50% REGION 1 / 50% REGION 4 (USGS SIR 2009–2158 & FEMA 100–YR Q)

Hydraulic Design Method HEC RAS VERSION 4.1.0 (PROJECT NAME: UpperLittleRiverA.prj)

Floods Evaluated: @ River Station 154641.0	Freq. (yr.)	Q (c.f.s)	Elev. (ft.)	Backwater (ft.)	Bridge Opening Velocity (f.p.s.)
	10	5700	183.9	0.4	3.6
	25	7400	184.8	0.6	4.7
(DESIGN)	50	9000	186.0	1.2	5.7
	100	10400	186.4	1.1	6.4
	500	14000	187.5	1.0	6.9
(FEMA)	100	11511	186.7	1.0	6.8

Waterway Opening Provided Below:Design W.S. Elev. 1578 s.f., 100yr W.S. Elev. 1578 s.f., Total 1578 s.f.,

Average Channel Velocity (Design) 5.8 f.p.s. Average Overbank Velocity (Design) 1.0 f.p.s.

Computed Scour : General – – – ft. Contraction 9.3 (OT) ft. Local PIER #1=7.4 (OT) PIER #2=4.1 (OT) ft.

Is a Floodway Revision Required? YES – MOA TYPE 1

Stream UPPER LITTLE RIVER Struc. Inv. No.420056 I.D. No. BR–0082 Project No. 67082.1.1 PDF File 420056 2020 BR–0082 UPPER LITTLE RIVER NC27.PDF

BRIDGE SURVEY & HYDRAULIC DESIGN REPORT

N. C. DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HYDRAULICS UNIT
RALEIGH, N. C.

I.D. No. BR–0082 Project No. 67082.1.1 Proj. Station 18+15.00 –L–

County HARNETT Bridge Over UPPER LITTLE RIVER Bridge Inv. No. 420056

On Highway NC 27 Between SR 1117 (NURSERY RD.) and SR 1234 (LEAFLET CHURCH RD.)

Recommended Structure 3 @ 75' – 45" CONC. GIRDER W/ 4'0" CAPS

Recommended Width of Roadway 32' CLEAR ROADWAY 35.25' OUT TO OUT Skew 45°

Recommended Location is (~~Up~~, At, ~~Down) Stream from~~ Existing Crossing.

Latitude 35.34032 Longitude –78.95156

Statewide Tier ☐ Regional Tier ■ Sub–Regional Tier ☐

Bench Mark is BM–1; BENCHLITE NAIL SET IN 24" HARDWOOD; –L– STA. 17+80.32; 172.54' RT.

Northing 578615 Easting 2014452 Elev. 182.48 ft. Datum: NAVD 88

Temporary Crossing NONE REQUIRED – OFFSITE DETOUR

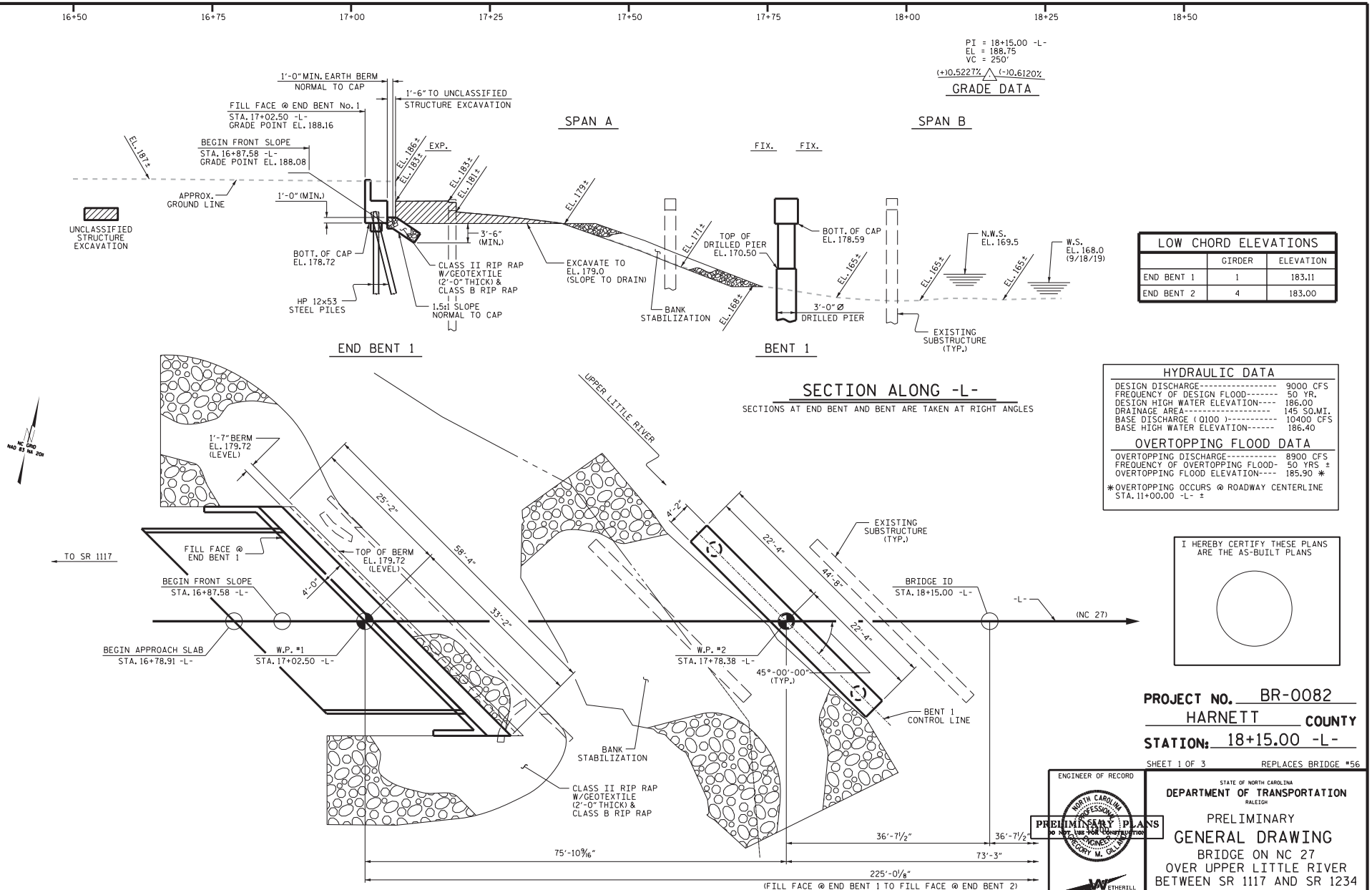
Designed by: WETHERILL ENGINEERING

Assisted by: MATTHEW HARVEY

Project Engineer : KEVIN B. ALFORD, P.E. Date 1/3/2020

Reviewed by: 1/7/2020

NORTH CAROLINA PROFESSIONAL SEAL 31977 ENGINEER KEVIN B. ALFORD



LOW CHORD ELEVATIONS		
	GIRDER	ELEVATION
END BENT 1	1	183.11
END BENT 2	4	183.00

SECTION ALONG -L-

SECTIONS AT END BENT AND BENT ARE TAKEN AT RIGHT ANGLES

HYDRAULIC DATA	
DESIGN DISCHARGE	9000 CFS
FREQUENCY OF DESIGN FLOOD	50 YR.
DESIGN HIGH WATER ELEVATION	186.00
DRAINAGE AREA	145 SQ.MI.
BASE DISCHARGE (Q100)	10400 CFS
BASE HIGH WATER ELEVATION	186.40

OVERTOPPING FLOOD DATA	
OVERTOPPING DISCHARGE	8900 CFS
FREQUENCY OF OVERTOPPING FLOOD	50 YRS ±
OVERTOPPING FLOOD ELEVATION	185.90 *

*OVERTOPPING OCCURS @ ROADWAY CENTERLINE STA. 11+00.00 -L- ±

PLAN

(PILES AND DRILLED PIERS NOT SHOWN FOR CLARITY)

I HEREBY CERTIFY THESE PLANS ARE THE AS-BUILT PLANS

PROJECT NO. BR-0082

HARNETT **COUNTY**

STATION: 18+15.00 -L-

SHEET 1 OF 3 REPLACES BRIDGE #56

ENGINEER OF RECORD

PRELIMINARY PLANS DO NOT USE FOR CONSTRUCTION

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
RALEIGH

PRELIMINARY

GENERAL DRAWING

BRIDGE ON NC 27
OVER UPPER LITTLE RIVER
BETWEEN SR 1117 AND SR 1234

ETHERELL ENGINEERING
1223 Jones Franklin Rd.
Raleigh, N.C. 27606
Bus: 919 851 8077
Fax: 919 851 8107
LICENSE NO. F-0377

REVISIONS						SHEET NO.
NO.	BY:	DATE:	NO.	BY:	DATE:	
1			3			TOTAL SHEETS
2			4			

DRAWN BY : D. HODGE DATE : 11/19
CHECKED BY : G. GILLAND DATE : 12/19

DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

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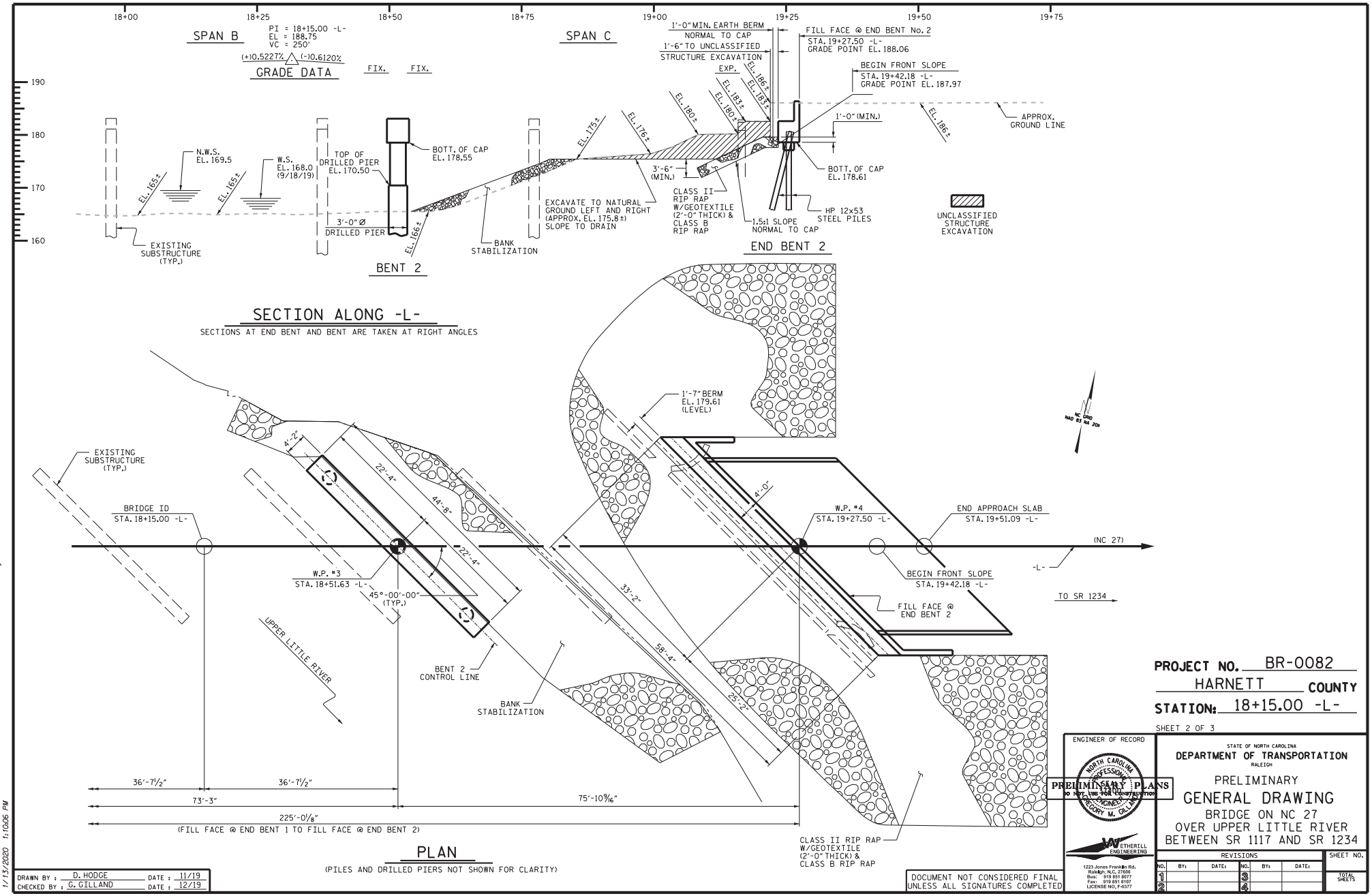

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DRAWN BY : D. HODGE DATE : 11/19
CHECKED BY : G. GILLAND DATE : 12/19

DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

ENGINEER OF RECORD

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL GREGORY M. GILLAND

PRELIMINARY PLANS
DO NOT USE FOR CONSTRUCTION

ETHERILL ENGINEERING
1223 Jones Franklin Rd.
Raleigh, N.C. 27606
Bus: 919 851 8077
Fax: 919 851 8107
LICENSE NO. F-0377

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
RALEIGH

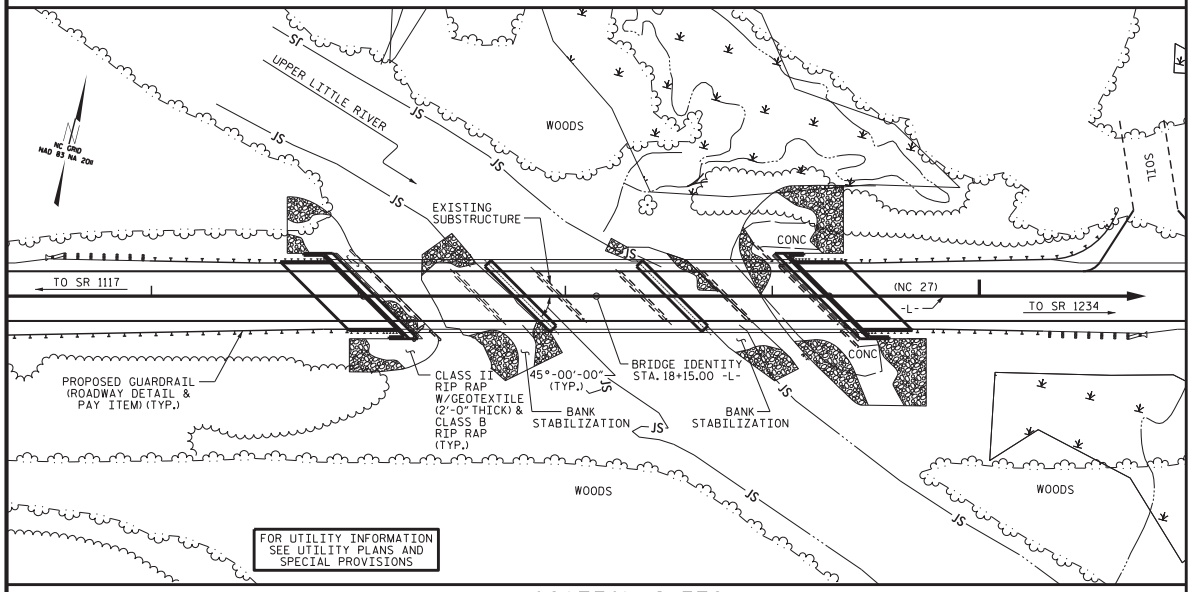
PRELIMINARY
GENERAL DRAWING
BRIDGE ON NC 27
OVER UPPER LITTLE RIVER
BETWEEN SR 1117 AND SR 1234

PROJECT NO. BR-0082
HARNETT COUNTY
STATION: 18+15.00 -L-

SHEET 2 OF 3

REVISIONS						SHEET NO.
NO.	BY:	DATE:	NO.	BY:	DATE:	
1			3			TOTAL SHEETS
2			4			

BM #1: BENCHLITE NAIL SET IN 24"Ø HARDWOOD 172.54' RIGHT OF STA. 17+80.32 -L-, ELEV. 182.48; N 578615, E 2014452



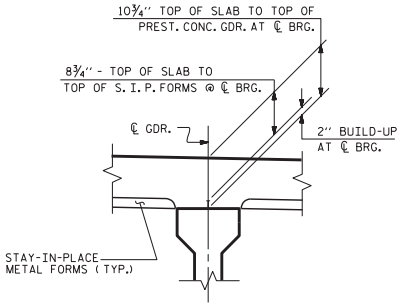
LOCATION SKETCH

NOTES:

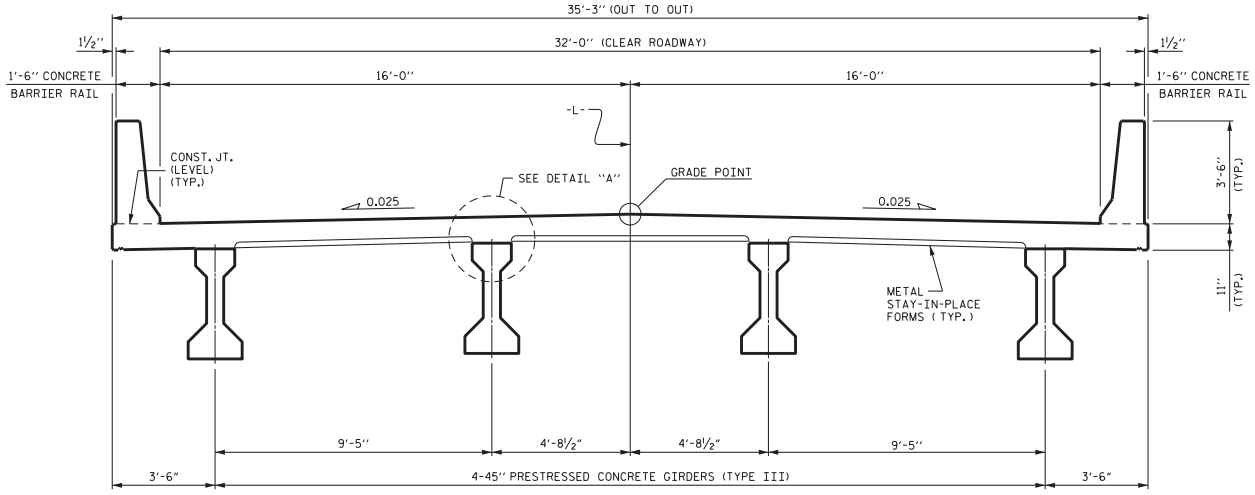
ASSUMED LIVE LOAD = HL-93 OR ALTERNATE LOADING.

THIS BRIDGE HAS BEEN DESIGNED IN ACCORDANCE WITH THE AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS.

THIS BRIDGE IS LOCATED IN SEISMIC ZONE 1.



DETAIL "A"



TYPICAL SECTION

3 SPAN CONTINUOUS FOR LIVE LOAD WITH COMPOSITE DECK ON 45" PRESTRESSED CONCRETE GIRDERS

PROJECT NO. BR-0082

HARNETT COUNTY

STATION: 18+15.00 -L-

SHEET 3 OF 3

ENGINEER OF RECORD

NORTH CAROLINA PROFESSIONAL ENGINEER GREGORY M. GILLAND

PRELIMINARY PLANS DO NOT USE FOR CONSTRUCTION

ETHERILL ENGINEERING
1223 Jones Franklin Rd.
Raleigh, N.C. 27606
Bus: 919 851 8077
Fax: 919 851 8107
LICENSE NO. F-0377

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
RALEIGH

PRELIMINARY

GENERAL DRAWING

BRIDGE ON NC 27
OVER UPPER LITTLE RIVER
BETWEEN SR 1117 AND SR 1234

REVISIONS						SHEET NO.
NO.	BY:	DATE:	NO.	BY:	DATE:	
1			3			TOTAL SHEETS
2			4			

DRAWN BY : D. HODGE DATE : 11/19
CHECKED BY : G. GILLAND DATE : 12/19

DOCUMENT NOT CONSIDERED FINAL UNLESS ALL SIGNATURES COMPLETED

P:\2019\19155.01_BR-0082_HARNETT_56\Structures\DGN\401_001_BR0082_SMU_PGD_001.dgn
1/13/2020 1:10:47 PM

WETHERILL ENGINEERING

1223 JONES FRANKLIN RD.
RALEIGH NC 27606

SUBJECT FACTORED LOADS PROJECT BR-0082

HARNETT COUNTY

PREPARED BY GMG DATE 11-26-19 STATION 18+15.00 -L-

CHECKED BY BCH DATE 1-13-20 STR NO ____ SHEET 1 OF 1

END BENT #1

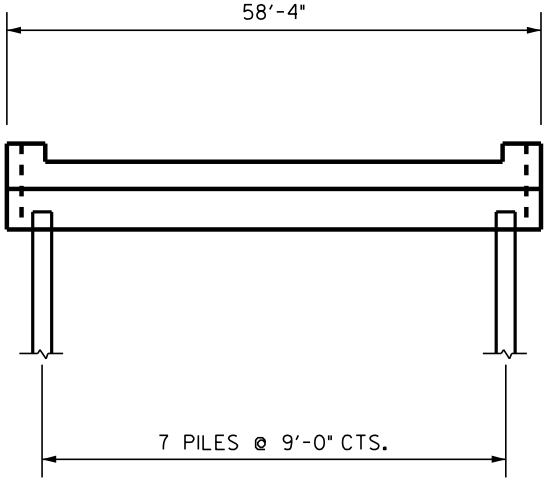
SINGLE ROW OF PILES

THREE (3) BATTERED PILES

PILE TYPE : HP 12 X 53

BOC ELEV = 178.72 FT±

FACTORED AXIAL PILE LOAD = 172 KIPS (86 TONS)



END BENT #1 SKETCH

NO SCALE

END BENT #2

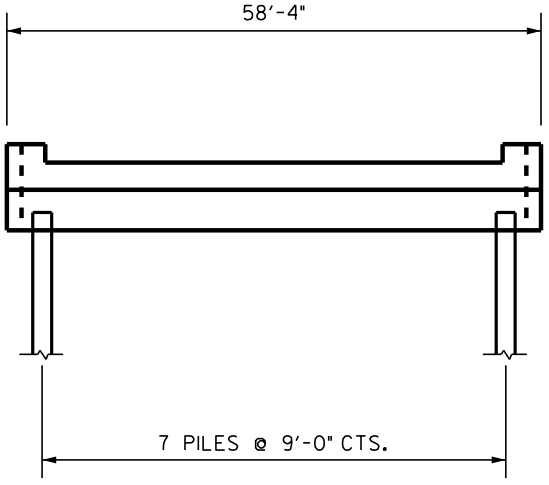
SINGLE ROW OF PILES

THREE (3) BATTERED PILES

PILE TYPE : HP 12 X 53

BOC ELEV = 178.61 FT±

FACTORED AXIAL PILE LOAD = 172 KIPS (86 TONS)

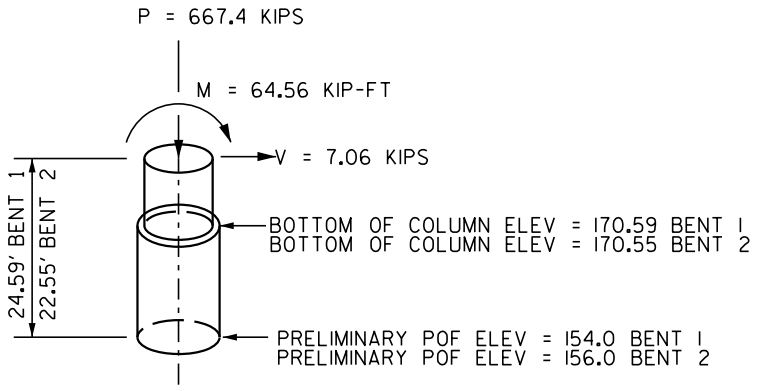


END BENT #2 SKETCH

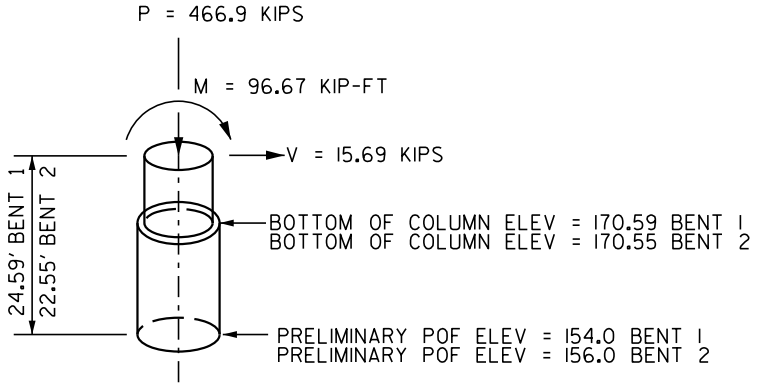
NO SCALE

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HIGHWAY BUILDING
P. O. BOX 25201
RALEIGH, NORTH CAROLINA 27611

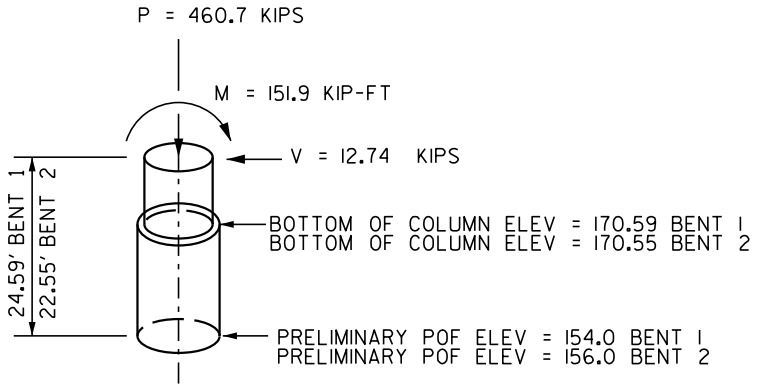
SUBJECT: CONTROLLING COLUMN FACTORED LOADS
PROJECT: BR-0082
COUNTY: HARNETT
PREPARED BY: BCH DATE: 5-5-20 STATION: 18+15.00 -L-
CHECKED BY: GMG DATE: 5-5-20 STR NO ____ SHEET ___ OF ___



MAXIMUM AXIAL LOAD WITH LONGITUDINAL SHEAR & MOMENT



MAXIMUM LONGITUDINAL SHEAR WITH AXIAL LOAD & LONGITUDINAL MOMENT

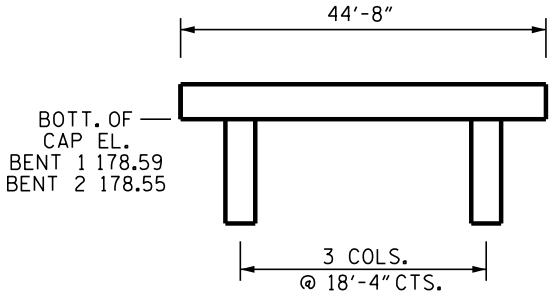


MAXIMUM TRANSVERSE SHEAR WITH AXIAL LOAD & TRANSVERSE MOMENT

BENT Nos. 1 and 2

COLUMN Ø = 2'-6"

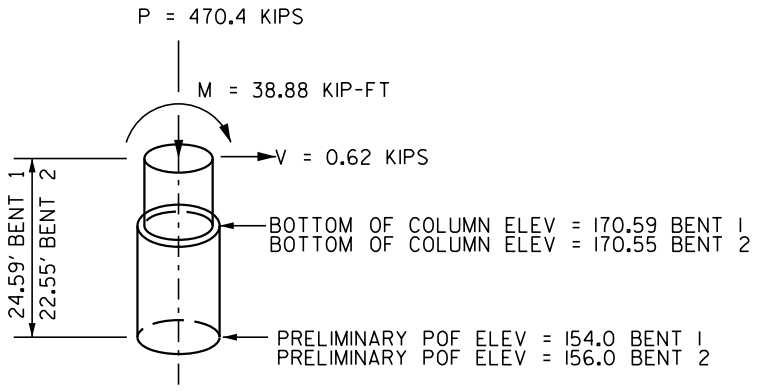
DRILLED SHAFT Ø = 3'-0"



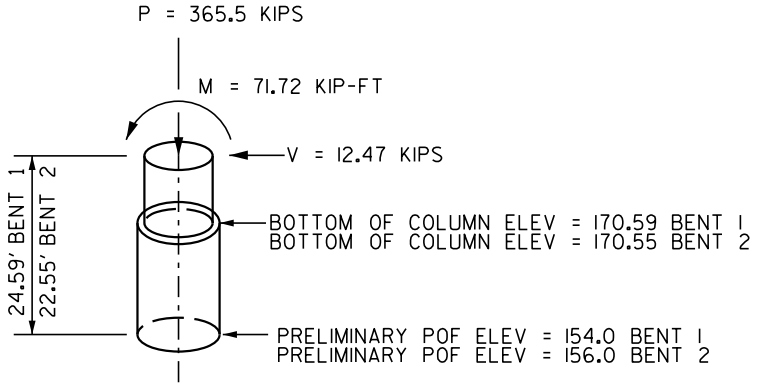
NO SCALE

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
HIGHWAY BUILDING
P. O. BOX 25201
RALEIGH, NORTH CAROLINA 27611

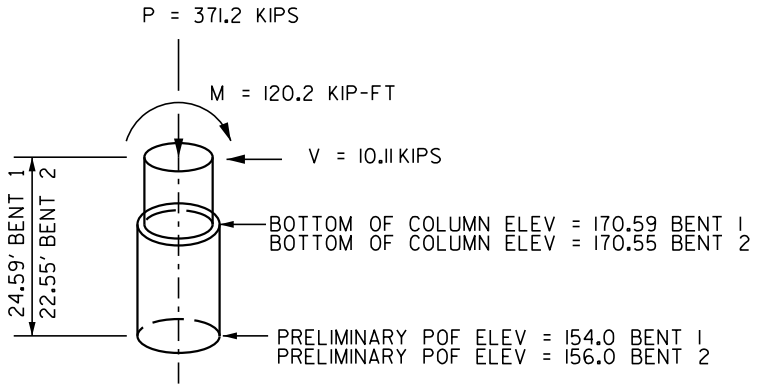
SUBJECT: CONTROLLING COLUMN SERVICE LOADS
PROJECT: BR-0082
COUNTY: HARNETT
PREPARED BY: BCH DATE: 5-5-20 STATION: 18+15.00 -L-
CHECKED BY: GMG DATE: 5-5-20 STR NO ____ SHEET ___ OF ___



MAXIMUM AXIAL LOAD WITH LONGITUDINAL SHEAR & MOMENT



MAXIMUM LONGITUDINAL SHEAR WITH AXIAL LOAD & LONGITUDINAL MOMENT

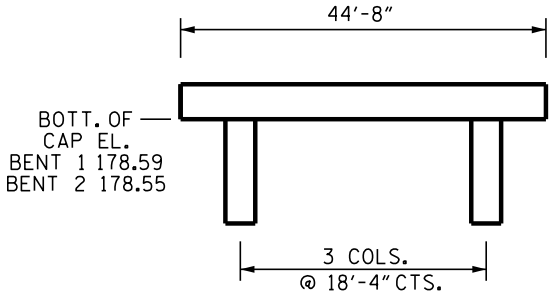


MAXIMUM TRANSVERSE SHEAR WITH AXIAL LOAD & TRANSVERSE MOMENT

BENT Nos. 1 and 2

COLUMN Ø = 2'-6"

DRILLED SHAFT Ø = 3'-0"



NO SCALE

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS HIGHWAY BUILDING 1589 MAIL SERVICE CENTER RALEIGH, NORTH CAROLINA 27699-1589	SUBJECT: Bridge No. 56 on NC 27 over Upper Little River		
	PREPARED BY:	CW	WBS No.:
	DATE:	5/20	67082.1.1
	CHECKED BY:	WPA	COUNTY:
	DATE:	5/20	Harnett

END BENTS SUMMARY

END BENT 1

Pile Type:	HP 12X53 Steel Piles	
Bottom of Cap Elevation:	178.72 ft	Obtained from PGD provided by WEI
Anticipated Pile Length:	15 ft ±, Lt.	By inspection of boring EB1-A
	10 ft ±, Rt.	By inspection of boring EB1-B
Average Pile Length:	15 ft ± , Lt.	Anticipated Pile Lengths Rounded Up to Nearest 5 ft
	10 ft ± , Rt.	Anticipated Pile Lengths Rounded Up to Nearest 5 ft
Max Factored Load:	90 Tons/Pile	Max Strength loads rounded up to nearest 5 tons
Required Ultimate Resistance:	200 Tons/Pile	AASHTO Resistance Factor = 0.45
Required Driving Resistance:	150 Tons/Pile	NCDOT Driving Resistance Factor = 0.6 for WEAP Analysis with limited or no PDAs

END BENT 2

Pile Type:	HP 12X53 Steel Piles	
Bottom of Cap Elevation:	178.61 ft	Obtained from PGD provided by WEI
Anticipated Pile Length:	20 ft ±, Lt.	By inspection of boring EB2-A
	15 ft ±, Rt.	By inspection of boring EB2-B
Average Pile Length:	20 ft ±, Lt.	Anticipated Pile Lengths Rounded Up to Nearest 5 ft
	15 ft ±, Rt.	Anticipated Pile Lengths Rounded Up to Nearest 5 ft
Max Factored Load:	90 Tons/Pile	Max Strength loads rounded up to nearest 5 tons
Required Ultimate Resistance:	200 Tons/Pile	AASHTO Resistance Factor = 0.45
Required Driving Resistance:	150 Tons/Pile	NCDOT Driving Resistance Factor = 0.6 for WEAP Analysis with limited or no PDAs

NOTES

See Notes on Sheet 2 of the Foundation Recommendations.

COMMENTS

See Comments on Sheet 3 of the Foundation Recommendations.

GEOTECHNICAL BORING REPORT
BORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River			**GROUND WT**
BORING NO. EB1-A	**STATION** 16+93	**OFFSET** 9 ft LT	**ALIGNMENT** -L-
COLLAR ELEV. 186.6 ft	**TOTAL DEPTH** 27.2 ft	**NORTHING** 578,769	**EASTING** 2,014,323
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Auton
DRILLER S. Davis	**START DATE** 02/28/20	**COMP. DATE** 02/28/20	**SURFACE WATER DEPTH** N/A

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
190										
										186.6 GROUND SURFACE
185	185.6	1.0	6	5	5	10		D		185.6 **ASPHALT**
	183.1	3.5	4	2	2	4		M		**ROADWAY EMBANKMENT** Gray, Fine to Coarse Sandy GRAVEL (A-1-a) 182.6
180										Brown, Silty Fine to Coarse SAND (A-2-4) with Trace Gravel 179.6
	178.1	8.5	2	2	1	3		M		BOC=178.7 ft Orange-Brown, Clayey Fine Sandy SILT (A-4) with Trace Mica
175										
	173.1	13.5	2	2	3	5		M		
170										169.6
	168.1	18.5	15	13	12	25		Sat.		Orange-Brown, Silty Fine to Coarse SAND (A-1-b) with Little Gravel
165										164.6
	163.1	23.5	100/0.2			100/0.2				**WEATHERED ROCK** Green-Gray (BIOTITE GNEISS) 161.1
160	159.4	27.2	60/0.0			60/0.0				**CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS) 159.4

Boring Terminated with Standard Penetration Test Refusal at Elevation 159.4 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. Driller indicated harder drilling at 25.5'
2. Auger refusal at 27.2'

Piles like to refuse on top of WR
Pile length=BOC-TIP=178.7-164.6=14.1ft
round up to 15ft

NCDOT BORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/23/20

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River			**GROUND WTR (ft)**
BORING NO. EB1-B	**STATION** 17+03	**OFFSET** 9 ft RT	**ALIGNMENT** -L-	**0 HR.** Caved
COLLAR ELEV. 186.4 ft	**TOTAL DEPTH** 21.2 ft	**NORTHING** 578,754	**EASTING** 2,014,337	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic
DRILLER S. Davis	**START DATE** 03/02/20	**COMP. DATE** 03/02/20	**SURFACE WATER DEPTH** N/A

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
190										
	186.4	0.0								GROUND SURFACE
185	185.6	0.8	8	13	12	25		M		**ASPHALT** 0.8
	182.9	3.5	3	3	4	7		M		**ROADWAY EMBANKMENT** Brown-Gray, Silty Fine to Coarse SAND (A-2-4)
180										BOC=178.7 ft
	179.4	7.0								**RESIDUAL**
	177.9	8.5	2	1	2	3		M		Orange-Brown, Clayey Fine Sandy SILT (A-4) with Trace Mica
175										
	172.9	13.5	2	2	2	4		W		
170										
	169.4	17.0								**CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS)
	167.9	18.5	60/0.1			60/0.1				
	165.2	21.2	60/0.0			60/0.0				Boring Terminated with Standard Penetration Test Refusal at Elevation 165.2 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. Driller indicated harder drilling at 17.0'
2. Auger refusal at 21.2'
3. Caved at 13.9' at probable groundwater level

Piles like to refuse on top of CR
Pile length=BOC-TIP=178.7-169.4=9.3ft
round up to 10ft

WEAP Parameter Calculation

Bent #: **Bridge 56 EB1B**

Toe quake 0.04 per GRLWEAP manual

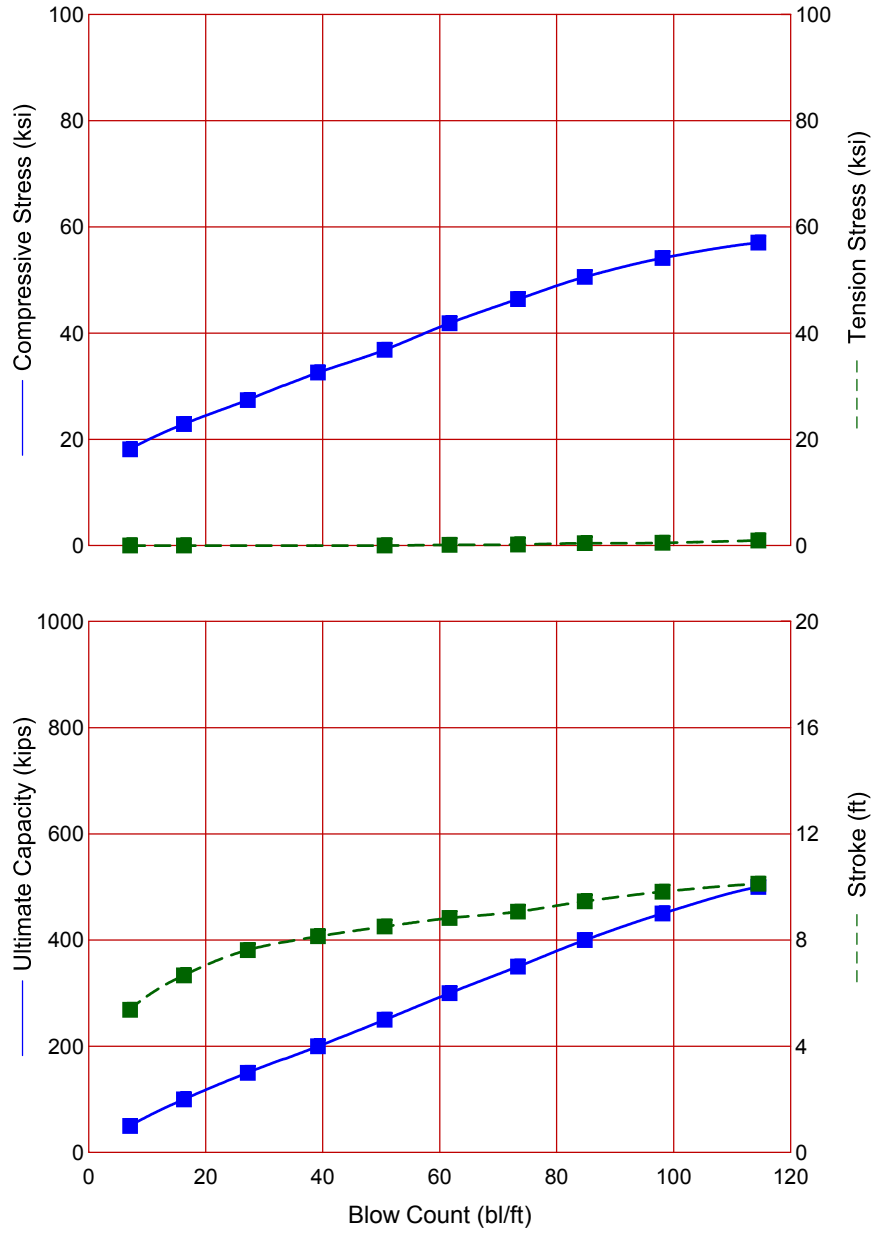
		Toe Quake	Shaft Quake
Pile Type:	HP 12X53	~~**0.10**~~ 0.04	**0.10**

Subsurface Conditions: Loose/Soft or Submerged

Layer #	Top	Bottom	Navg	Soil Type	Shaft Damping	
1	178.7	169.4	4	Sand	0.20	
2						
3						
4						
5						
6						
7						
8						**Toe Damping**
					0.20	**0.15**

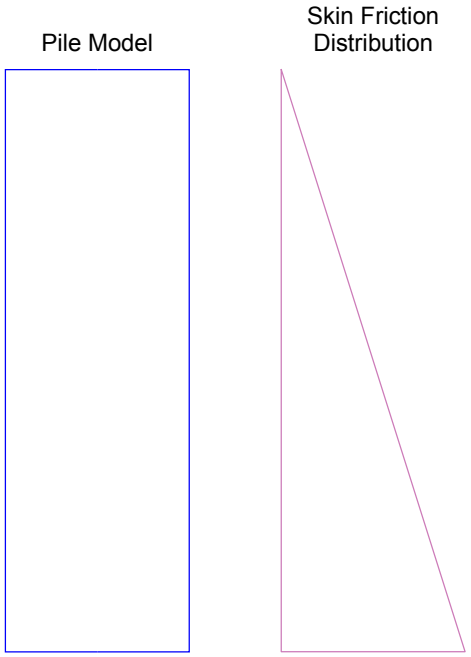
Froehling & Robertson, Inc.
Bridge 56 Harnett County End Bent 1

02-May-2020
GRLWEAP Version 2010



DELMAG D 12-32

Ram Weight	2.82	kips
Efficiency	0.800	
Pressure	1640 (100%)	psi
Helmet Weight	1.90	kips
Hammer Cushion	60155	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.040	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	10.00	ft
Pile Penetration	10.00	ft
Pile Top Area	15.50	in2



Res. Shaft = 5 %
(Proportional)

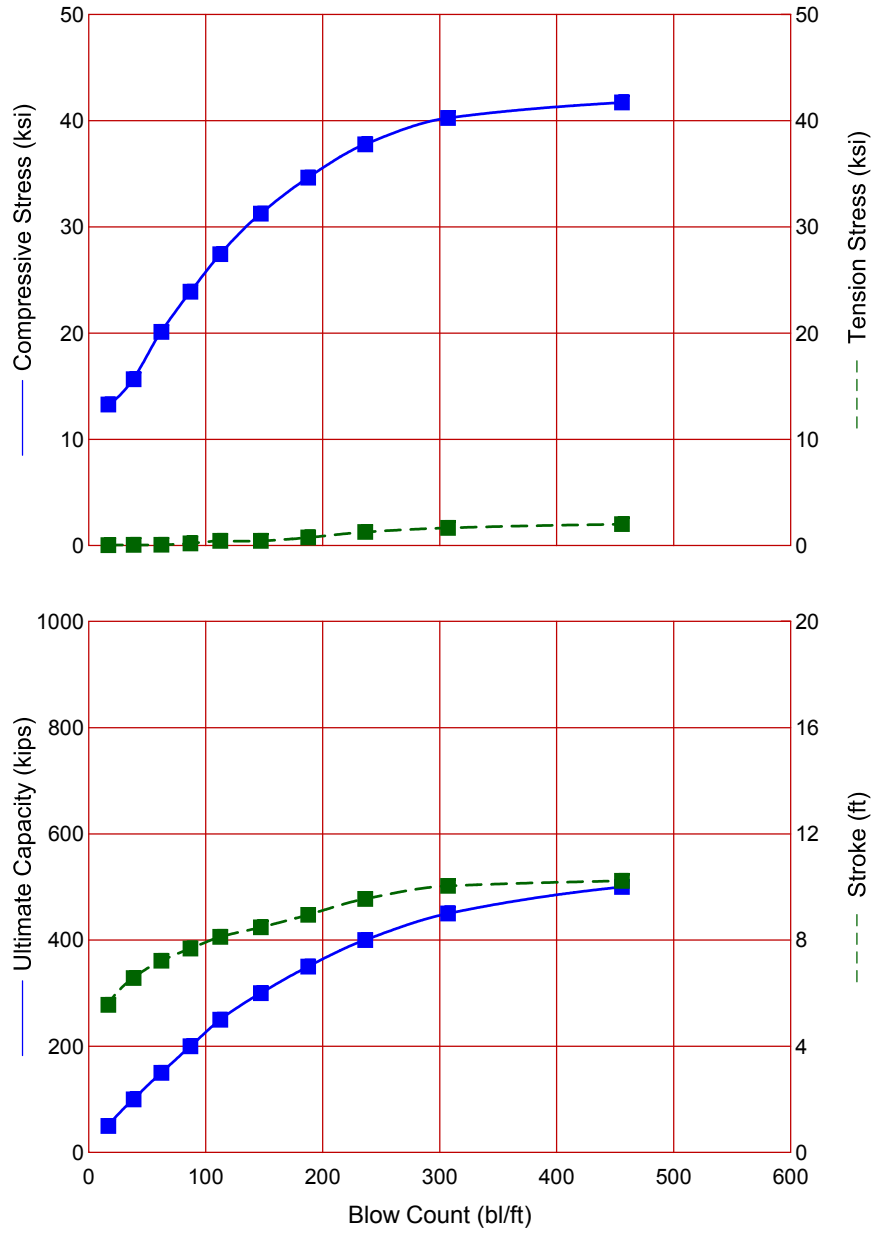
Froehling & Robertson, Inc. 02-May-2020
Bridge 56 Harnett County End Bent 1 GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi		Maximum Tension Stress ksi		Blow Count bl/ft		Stroke ft	Energy kips-ft
50.0	18.13		0.01		7.1		5.37	14.89
100.0	22.87		0.01		16.3		6.67	12.70
150.0	27.39		0.00		27.2		7.62	11.89
200.0	32.58		0.00		39.2		8.14	11.23
250.0	36.85		0.01		50.6		8.51	10.95
300.0	41.86	<45	0.14	<30	61.7	<180	8.83	10.90
350.0	46.39		0.20		73.4		9.07	10.81
400.0	50.58		0.45		84.8		9.46	10.94
450.0	54.13		0.51		98.1		9.82	11.00
500.0	57.02		0.95		114.5		10.12	11.00

Model piles at End Bent 1,right since 10ft pile might have the highest stress.
D12 should be able to drive the piles, but lower energy setting or smaller hammers should be used.

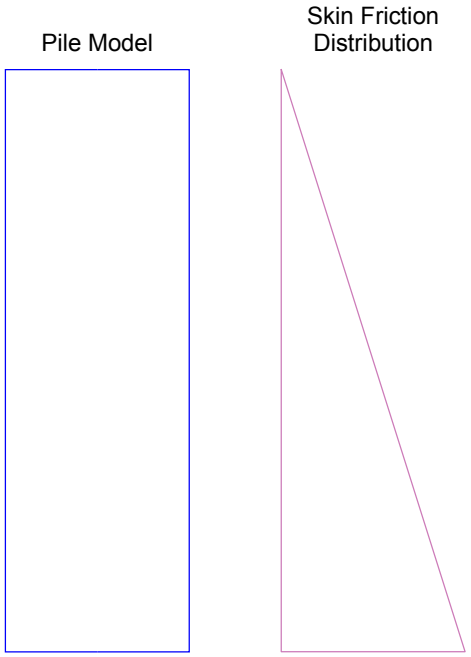
Froehling & Robertson, Inc.
Bridge 56 Harnett County End Bent 1

11-May-2020
GRLWEAP Version 2010



DELMAG D 6-32

Ram Weight	1.32	kips
Efficiency	0.800	
Pressure	1850 (100%)	psi
Helmet Weight	1.90	kips
Hammer Cushion	60155	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.040	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	10.00	ft
Pile Penetration	10.00	ft
Pile Top Area	15.50	in2



Res. Shaft = 5 %
(Proportional)

Froehling & Robertson, Inc.
Bridge 56 Harnett County End Bent 1

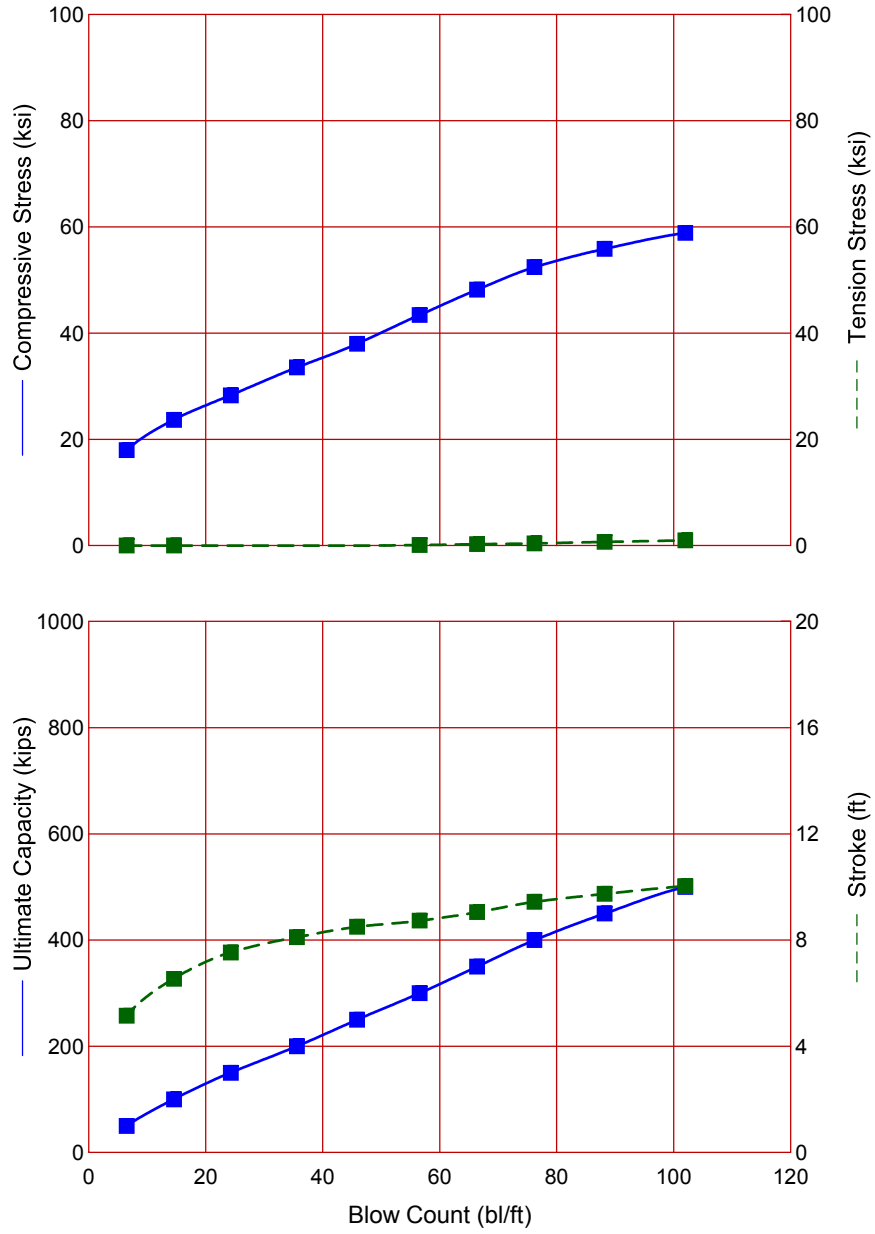
11-May-2020
GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi		Maximum Tension Stress ksi		Blow Count bl/ft		Stroke ft	Energy kips-ft
50.0	13.28		0.04		16.8		5.56	5.52
100.0	15.66		0.07		38.5		6.57	4.93
150.0	20.12		0.08		62.2		7.22	4.72
200.0	23.90		0.21		87.0		7.68	4.60
250.0	27.42		0.44		112.5		8.12	4.61
300.0	31.25	<45	0.45	30<	147.2	<180	8.48	4.52
350.0	34.63		0.76		187.7		8.95	4.60
400.0	37.77		1.28		236.4		9.55	4.77
450.0	40.26		1.67		307.2		10.04	4.92
500.0	41.71		2.01		455.9		10.23	4.87

D6-32 (13.5 kip-ft) hammer seems OK and should be the lower limit of energy range.

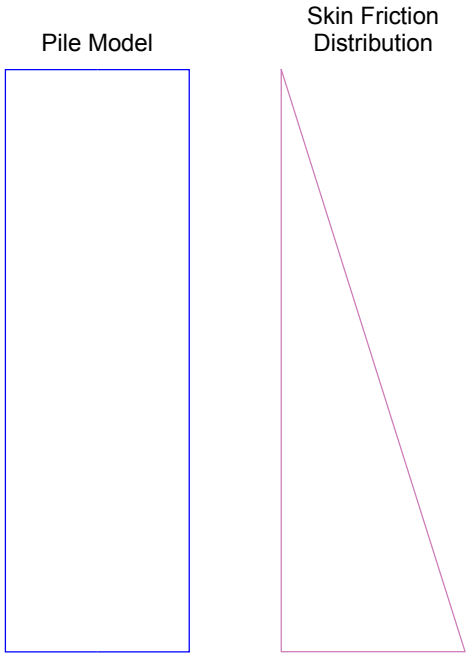
Froehling & Robertson, Inc.
Bridge 56 Harnett County End Bent 1

11-May-2020
GRLWEAP Version 2010



DELMAG D 14-42

Ram Weight	3.09	kips
Efficiency	0.800	
Pressure	1780 (100%)	psi
Helmet Weight	1.90	kips
Hammer Cushion	60155	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.040	in
Skin Damping	0.200	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	10.00	ft
Pile Penetration	10.00	ft
Pile Top Area	15.50	in2



Res. Shaft = 5 %
(Proportional)

Froehling & Robertson, Inc.
Bridge 56 Harnett County End Bent 1

11-May-2020
GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
50.0	17.97	0.01	6.5	5.15	16.68
100.0	23.65	0.01	14.6	6.54	14.40
150.0	28.27	0.00	24.3	7.53	13.43
200.0	33.53	0.00	35.6	8.11	12.59
250.0	37.98	0.00	45.9	8.50	12.27
300.0	43.41	0.11	56.6	8.73	12.08
350.0	48.18	0.28	66.4	9.05	12.11
400.0	52.42	0.42	76.2	9.44	12.26
450.0	55.86	0.70	88.2	9.74	12.23
500.0	58.86	0.97	102.0	10.03	12.19

<45 but close to 45

30<

<180

D14-32 (34.5 kip-ft) seems OK and should be the upper limit of energy range

GEOTECHNICAL BORING REPORT
BORE LOG

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River			**GROUND WT**
BORING NO. EB2-A	**STATION** 19+18	**OFFSET** 9 ft LT	**ALIGNMENT** -L-
COLLAR ELEV. 186.2 ft	**TOTAL DEPTH** 28.1 ft	**NORTHING** 578,824	**EASTING** 2,014,541
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Auton
DRILLER S. Davis	**START DATE** 02/28/20	**COMP. DATE** 02/28/20	**SURFACE WATER DEPTH** N/A

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	BLOWS PER FOOT 0 25 50 75 100	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
										ELEV. (ft) DE
190										
185	185.2	1.0	6	4	5	9		D		186.2 GROUND SURFACE 185.2 **ASPHALT**
	182.7	3.5	2	2	3	5		M		**ROADWAY EMBANKMENT** Gray, Fine to Coarse Sandy GRAVEL (A-1-a)
180										BOC=178.6 ft 179.2
	177.7	8.5	2	2	1	3		M		Red-Orange-Brown, Clayey Fine to Coarse SAND (A-2-6) with Trace Gravel
175										174.2
	172.7	13.5	3	2	4	6		M		Orange-Brown-Gray, Clayey Fine Sandy SILT (A-4) with Trace Mica
170										169.2
	167.7	18.5	1	2	1	3		W		**ALLUVIAL** Black-Gray, Silty Fine SAND (A-2-4) with Trace Mica and Wood Fragments
165										164.2
	162.7	23.5	18	38	60	98		M		**RESIDUAL** Green-Gray, Fine Sandy SILT (A-4) with Trace Mica
160										158.8
	158.2	28.0	60/0.1			60/0.1				158.1 **CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS) Boring Terminated with Standard Penetration Test Refusal at Elevation 158.1 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

Notes:
1. Driller indicated harder drilling at 27.4'
2. Auger refusal at 28.0'

Piles like to refuse on top of CR
Pile length=BOC-TIP=178.6-158.8=19.8 ft
round up to 20 ft

NCDOT BORE DOUBLE 66X-0152 BORING LOGS.GPJ NC_DOT.GDT 4/22/20

WBS 67082.1.1	**TIP** BR-0082	**COUNTY** HARNETT	**GEOLOGIST** W. Pesl
SITE DESCRIPTION Bridge 56 on NC 27 over Upper Little River			**GROUND WTR (ft)**
BORING NO. EB2-B	**STATION** 19+37	**OFFSET** 9 ft RT	**ALIGNMENT** -L-	**0 HR.** 16.0
COLLAR ELEV. 186.2 ft	**TOTAL DEPTH** 23.2 ft	**NORTHING** 578,812	**EASTING** 2,014,564	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE F&R2175 CME-55 92% 02/07/2020		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic
DRILLER S. Davis	**START DATE** 03/02/20	**COMP. DATE** 03/02/20	**SURFACE WATER DEPTH** N/A

ELEV (ft)	DRIVE ELEV (ft)	DEPTH (ft)	BLOW COUNT 0.5ft	0.5ft	0.5ft	SAMP. NO.	MOI	LOG	SOIL AND ROCK DESCRIPTION
									186.2 GROUND SURFACE 0.0
	185.3	0.9					M		185.3 **ASPHALT** 0.9
			6	6	4				**ROADWAY EMBANKMENT** Gray, Fine to Coarse Sandy GRAVEL (A-1-a)
	182.7	3.5	2	2	2		M		
									BOC=178.6 ft
	179.2	7.0							Brown-Gray, Silty Fine to Coarse SAND (A-2-4)
	177.7	8.5	2	1	1		M		
	174.2	12.0							Orange-Brown-Gray, Clayey Fine Sandy SILT (A-4) with Trace Mica
	172.7	13.5	1	2	4		M		
	169.2	17.0							**ALLUVIAL** Black-Gray, Silty Fine SAND (A-2-4) with Trace Organics
	167.7	18.5	1	2	2		W		
	164.2	22.0							
	163.0	23.2	60/0.0						**CRYSTALLINE ROCK** Green-Gray (BIOTITE GNEISS) 23.2
									Boring Terminated with Standard Penetration Test Refusal at Elevation 163.0 ft in CRYSTALLINE ROCK (BIOTITE GNEISS)

BLOWS PER FOOT: 0 25 50 75 100; 10, 4, 2, 6, 4, 60/0.0

Notes:
1. Driller indicated harder drilling at 22.0'
2. Auger refusal at 23.2'

Piles like to refuse on top of CR
Pile length=BOC-TIP=178.6-164.2=14.4 ft
round up to 15 ft

BR0082 Bridge 56 End Slope Stability

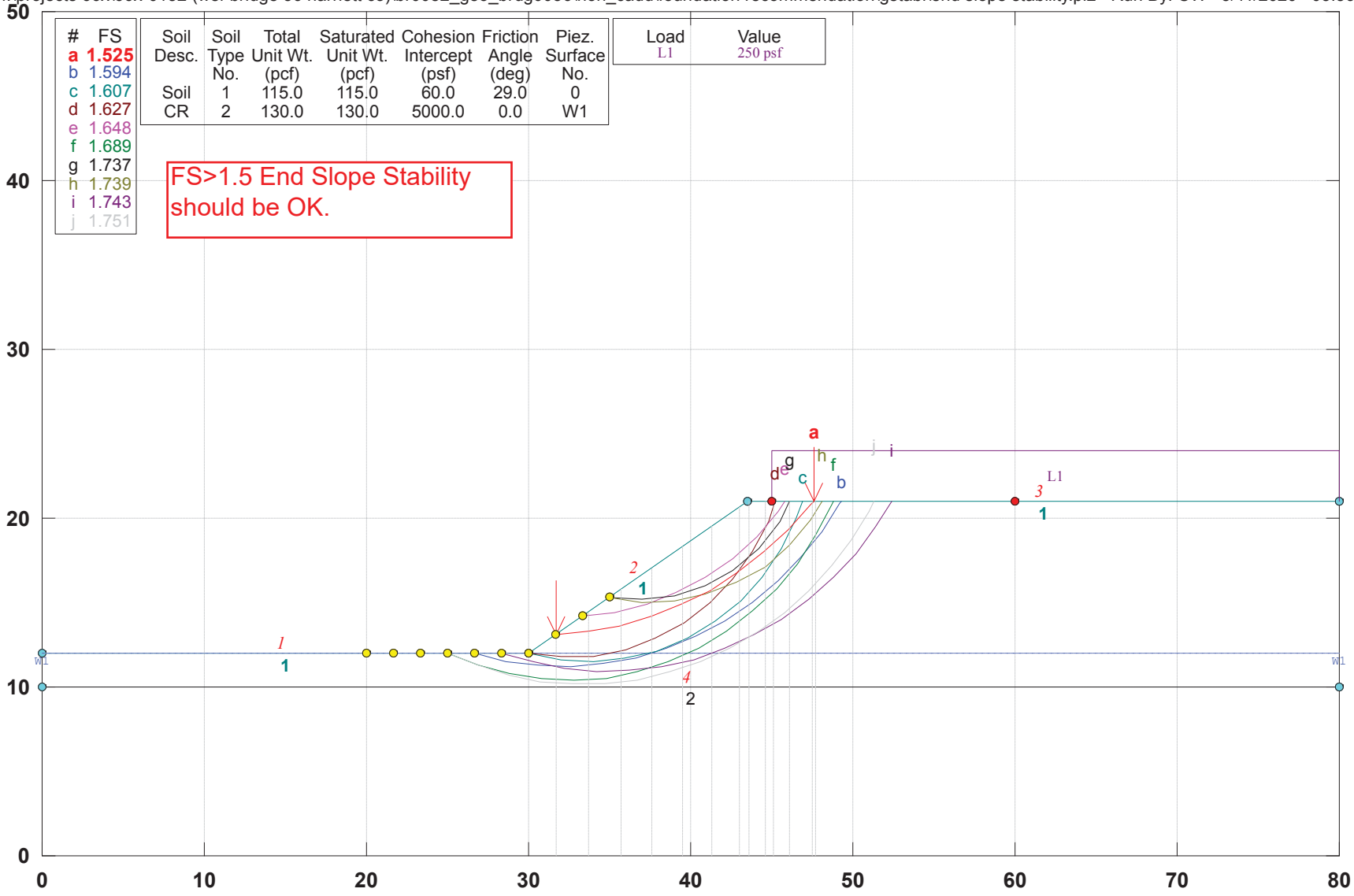
f:\projects 66x\66x-0152 (wei-bridge 56 harnett co)\br0082_geo_brdg0056\non_cadd\foundation recommendation\gstabl\end slope stability.pl2 Run By: CW 5/11/2020 03:56PM

#	FS
a	1.525
b	1.594
c	1.607
d	1.627
e	1.648
f	1.689
g	1.737
h	1.739
i	1.743
j	1.751

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Soil	1	115.0	115.0	60.0	29.0	0
CR	2	130.0	130.0	5000.0	0.0	W1

Load	Value
L1	250 psf

FS>1.5 End Slope Stability should be OK.



GSTABL7 v.2 FSmin=1.525

Safety Factors Are Calculated By The Modified Bishop Method

GSTABL7

SINCE 1881

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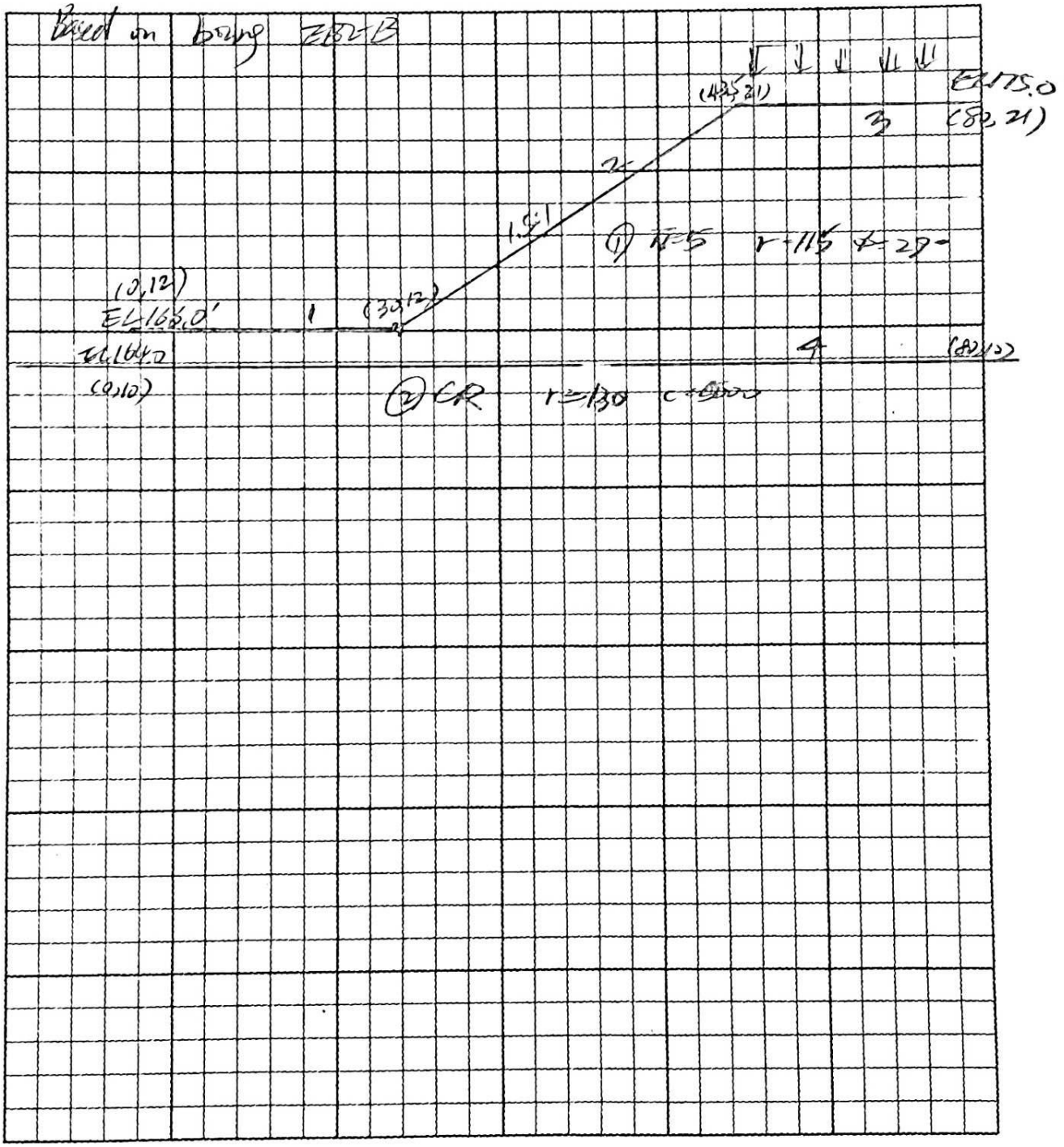
SHEET NO. 1 OF 1

JOB BR-0082 Bridge 56 DATE 5/3/2020

COMPUTATIONS FOR End slope stability BY CW CHKD



Form No. 502
Revised 05/2008

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS HIGHWAY BUILDING 1589 MAIL SERVICE CENTER RALEIGH, NORTH CAROLINA 27699-1589	SUBJECT: Bridge No. 56 on NC 27 over Upper Little River		
	PREPARED BY:	CW	WBS No.:
	DATE:	5/20	67082.1.1
	CHECKED BY:	WPA	COUNTY:
	DATE:	5/20	Harnett

INTERIOR BENT SUMMARY

BENT 1

Foundation Type:	36-inch drilled piers	
Bottom of Cap Elevation:	178.59 ft	Obtained from PGD provided by WEI
Top of Pier Elevation:	170.59 ft	Provided by WEI
Max Factored Load:	335 Tons/Pier	Max Strength loads rounded up to nearest 5 tons
Factored Resistance:	350 Tons/Pier	Axial Capacity Calculations
Required Tip Resistance:	5 tons/ft^2	For quality control purposes
Point of Fixity (POF) Elevation:	153.0 ft, Lt.	"LPILE" program calculations
	148.0 ft, Ctr. & Rt.	"LPILE" program calculations
Tip No Higher Than Elevation:	148.0 ft, Lt.	Mintip per lateral anlysis
	143.0 ft, Ctr. & Rt.	Mintip per lateral anlysis

BENT 2

Foundation Type:	36-inch drilled piers	
Bottom of Cap Elevation:	178.55 ft	Obtained from PGD provided by WEI
Top of Pier Elevation:	170.55 ft	Provided by WEI
Max Factored Load:	335 Tons/Pier	Max Strength loads rounded up to nearest 5 tons
Factored Resistance:	345 Tons/Pier	Axial Capacity Calculations
Required Tip Resistance:	5 tons/ft^2	For quality control purposes
Point of Fixity (POF) Elevation:	155.0 ft, Lt.	"LPILE" program calculations
	154.0 ft, Ctr. & Rt.	"LPILE" program calculations
Tip No Higher Than Elevation:	151.0 ft, Lt.	Axial Capacity Calculations
	150.0 ft, Ctr. & Rt..	Axial Capacity Calculations

NOTES

See Notes on Sheet 2 of the Foundation Recommendations

COMMENTS

See Comments on Sheet 3 of the Foundation Recommendations

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS HIGHWAY BUILDING 1589 MAIL SERVICE CENTER RALEIGH, NORTH CAROLINA 27699-1589	SUBJECT: Bridge No. 56 on NC 27 over Upper Little River		
	PREPARED BY:	CW	WBS No.:
	DATE:	5/20	67082.1.1
	CHECKED BY:	WPA	COUNTY:
	DATE:	5/20	Harnett

SCOUR DETERMINATION

HYDRAULICS SCOUR ELEVATIONS

(100-year scour elevations estimated from Bridge Survey & Hydraulic Design Report dated 1/3/20)

BENT #1	**150.5**	ft
BENT #2	**152.5**	ft

DESIGN SCOUR ELEVATIONS

(Scour memo dated 4/28/2020)

BENT #1	**158.0**	ft
BENT #2	**159.0**	ft

SCOUR CRITICAL ELEVATIONS

(Used 1 to 2 feet below design scour elevations, below top of WR or CR)

BENT #1	**157.0**	ft
BENT #2	**158.0**	ft

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS HIGHWAY BUILDING PO BOX 25201 RALEIGH, NORTH CAROLINA 27611	SUBJECT: Bridge No. 56 on NC 27 over Upper Little River		
	PREPARED BY:	CW	WBS No.:
	DATE:	5/20	67082.1.1
	CHECKED BY:	WPA	COUNTY:
	DATE:	5/20	Harnett

QUANTITY OF DRILLED PIER IN SOIL & NOT IN SOIL CALCULATION SHEET

INTERIOR BENTS (Elevs. In feet)

	B1-A	B1-B	B2-A	B2-B
APPROX. EXISTING GROUND ELEV. =	167.8	167.2	165.9	165.2
TOP OF WEATHERED ROCK (WR) ELEV. =	160.8	160.7	154.3	163.3
INTERMEDIATE LAYER OF CRYSTALLINE ROCK (FT)	6.8		3.8	5.0
INTERMEDIATE LAYER OF SOIL (FT)		5.5		
TOP OF CRYSTALLINE ROCK (CR) ELEV. =	147.1	149.7	151.7	151.1
TIP NO HIGHER THAN ELEV. =	148.0	143.0	151.0	150.0
NUMBER OF SHAFTS PER BORING:	**1.0**	**2.0**	**1.0**	**2.0**
QUANTITY OF PIERS BELOW TOP OF SHAFT:	19.8	48.4	14.9	30.4
QUANTITY OF PIERS IN WR - Total:	6.0	11.0	2.6	14.4
QUANTITY OF PIERS IN WR - Soil (1/2 of total):	3.0	5.5	1.3	7.2
QUANTITY OF PIERS IN WR - Not in Soil (1/2 of total):	3.0	5.5	1.3	7.2
QUANTITY OF PIERS IN CR - Not in Soil:	6.8	13.4	4.5	12.2
TOTAL QUANTITY OF PIERS NOT IN SOIL:	9.8	18.9	5.8	19.4
ROUND UP TO NEAREST WHOLE NUMBER:	10	19	6	20
TOTAL QTY OF PIERS NOT IN SOIL (lf)	**29**		**26**	
TOTAL QUANTITY OF PIERS IN SOIL:	10.0	29.5	9.1	11.0
ROUND UP TO NEAREST WHOLE NUMBER:	10	30	10	11
TOTAL QTY OF PIERS IN SOIL (lf)	**40**		**21**	

Lateral Analysis

FROEHLING & ROBERTSON, INC.
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SINCE 1881

JOB: BR-0082 Bridge 58 | SHEET NO. 1 OF 1
COMPUTATIONS FOR: Bent 1 Left lateral | DATE 4/28/2020
BY CIV | CHKD

5-5-2020

Based on box lot BHA and loads provided by WEI on

Depth (ft)		Elev. (ft)
0	Boc = EL 178.6	178.6
	ϕ column = 30 inch.	
8	Top of pier = EL 170.6	170.6
	ϕ pier = 36 inch	
	DSE = EL 158.0'	
20.6		158.0
	Model as clay w/ free water	
	① WR r=100pcf, c=5000psf, ε=0.004, k=2000	
22.8		155.8
	② CR r=169pcf, q_u = 3088psi Per RS-1 results	
29.6		149.0
	③ WR r=100pcf, c=5000psf, ε=0.004, k=2000	
31.5		147.1

① Model max. longitudinal shear as free head

V = 15,690 lbs, M = 1,160,040 lbs-in, Axial = 466,900 lbs

Based on LPILE results:

⇒ y = 0.69" 1st neg = 24.6' (EL 154.0'), max neg = 26.6' (EL 152.0')

② Model max transverse shear as fixed head

V = 12,740 lbs, slope = 0, Axial = 460,700 lbs

⇒ y = 0.14", 1st neg = 24.6' (EL 154.0'), max neg = 27.2' (EL 151.4')

∴ POF = EL 153.0'

MinTip: 1.5B below 1st negative = EL 149.5'
1.0B below max negative = EL 148.4'
∴ MinTip per lateral analysis = EL 148.0'

Per Axial Calcs MinTip = EL150.0

∴ MinTip @ Bent 1 Left is EL148.0

Form No. 502
Revised 05/2008

LPile for Windows, Version 2018-10.003

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

This copy of LPile is being used by:

fnr
fnr

Serial Number of Security Device: 293783516

This copy of LPile is licensed for exclusive use by:

Froehling & Robertson, Inc., Ric

Use of this program by any entity other than Froehling & Robertson, Inc., Ric
is a violation of the software license agreement.

Files Used for Analysis

Path to file locations:
\Projects 66X\66X-0152 (WEI-Bridge 56 Harnett Co)\BR0082_GEO_BRDG0056\NON_CADD\Foundation Recommendation\Lateral Analysis\

Name of input data file:
Bent 1 Left.lp10

Name of output report file:
Bent 1 Left.lp10

Name of plot output file:
Bent 1 Left.lp10

Name of runtime message file:
Bent 1 Left.lp10

Date and Time of Analysis

Date: May 11, 2020 Time: 7:27:44

Problem Title

Project Name: Bridge 56 Harnett County

Job Number: 66X-0152

Client: WEI

Engineer: CW

Description: Bent 1 Left

Program Options and Settings

Computational Options:
 - Use unfactored loads in computations (conventional analysis)
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

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

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

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - No distributed lateral loads are entered
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

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

Pile Structural Properties and Geometry

Number of pile sections defined = 2
Total length of pile = 28.000 ft
Depth of ground surface below top of pile = 20.6000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	30.0000
2	8.000	30.0000

3	8.000	36.0000
4	28.000	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	8.000000 ft
Width of top of section	=	30.000000 in
Width of bottom of section	=	30.000000 in
Top Area	=	706.858347 sq. in
Bottom Area	=	706.858347 sq. in
Moment of Inertia at Top	=	39761. in^4
Moment of Inertia at Bottom	=	39761. in^4
Elastic Modulus	=	3122019. psi

Pile Section No. 2:

Section 2 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	20.000000 ft
Width of top of section	=	36.000000 in
Width of bottom of section	=	36.000000 in
Top Area	=	1018. sq. in
Bottom Area	=	1018. sq. in
Moment of Inertia at Top	=	82448. in^4
Moment of Inertia at Bottom	=	82448. in^4
Elastic Modulus	=	3823676. psi

Ground Slope and Pile Batter Angles

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

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay with water-induced erosion

Distance from top of pile to top of layer	=	20.600000 ft
Distance from top of pile to bottom of layer	=	22.800000 ft
Effective unit weight at top of layer	=	100.000000 pcf
Effective unit weight at bottom of layer	=	100.000000 pcf
Undrained cohesion at top of layer	=	5000. psf
Undrained cohesion at bottom of layer	=	5000. psf
Epsilon-50 at top of layer	=	0.004000
Epsilon-50 at bottom of layer	=	0.004000
Subgrade k at top of layer	=	2000. pci
Subgrade k at bottom of layer	=	2000. pci

Layer 2 is strong rock (vuggy limestone)

Distance from top of pile to top of layer	=	22.800000 ft
Distance from top of pile to bottom of layer	=	29.600000 ft
Effective unit weight at top of layer	=	130.000000 pcf
Effective unit weight at bottom of layer	=	130.000000 pcf
Uniaxial compressive strength at top of layer	=	3088. psi
Uniaxial compressive strength at bottom of layer	=	3088. psi

Layer 3 is stiff clay with water-induced erosion

Distance from top of pile to top of layer	=	29.600000 ft
Distance from top of pile to bottom of layer	=	31.500000 ft
Effective unit weight at top of layer	=	100.000000 pcf
Effective unit weight at bottom of layer	=	100.000000 pcf
Undrained cohesion at top of layer	=	5000. psf
Undrained cohesion at bottom of layer	=	5000. psf
Epsilon-50 at top of layer	=	0.004000
Epsilon-50 at bottom of layer	=	0.004000
Subgrade k at top of layer	=	2000. pci
Subgrade k at bottom of layer	=	2000. pci

(Depth of the lowest soil layer extends 3.500 ft below the pile tip)

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	E50 or krm	kpy pci
1	Stiff Clay	20.6000	100.0000	5000.	--	0.00400	2000.
	with Free Water	22.8000	100.0000	5000.	--	0.00400	2000.
2	Strong Rock	22.8000	130.0000	--	3088.	--	--
	(Vuggy Limestone)	29.6000	130.0000	--	3088.	--	--
3	Stiff Clay	29.6000	100.0000	5000.	--	0.00400	2000.
	with Free Water	31.5000	100.0000	5000.	--	0.00400	2000.

Static Loading Type

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

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1		Condition 2		Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V =	15690. lbs	M =	1160040. in-lbs	466900.	No
2	2	V =	12740. lbs	S =	0.0000 in/in	460700.	No

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

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

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

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

Number of Pile Sections Analyzed = 2

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

Pile Section No. 2:

Moment-curvature properties were derived from elastic section properties

---

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	20.6000	0.00	N.A.	No	0.00	5972.
2	22.8000	2.2000	No	Yes	N.A.	N.A.
3	29.6000	9.0000	No	Yes	N.A.	N.A.

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

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

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

Shear force at pile head = 15690.0 lbs
Applied moment at pile head = 1160040.0 in-lbs
Axial thrust load on pile head = 466900.0 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	0.6949	1160040.	15690.	-0.00446	1098.	1.24E+11	0.00	0.00	0.00
0.2800	0.6800	1219723.	15690.	-0.00442	1121.	1.24E+11	0.00	0.00	0.00

0.5600	0.6651	1279354.	15690.	-0.00439	1143.	1.24E+11	0.00	0.00	0.00
0.8400	0.6505	1338931.	15690.	-0.00435	1166.	1.24E+11	0.00	0.00	0.00
1.1200	0.6359	1398450.	15690.	-0.00432	1188.	1.24E+11	0.00	0.00	0.00
1.4000	0.6215	1457911.	15690.	-0.00428	1211.	1.24E+11	0.00	0.00	0.00
1.6800	0.6071	1517309.	15690.	-0.00424	1233.	1.24E+11	0.00	0.00	0.00
1.9600	0.5930	1576643.	15690.	-0.00420	1255.	1.24E+11	0.00	0.00	0.00
2.2400	0.5789	1635911.	15690.	-0.00415	1278.	1.24E+11	0.00	0.00	0.00
2.5200	0.5651	1695108.	15690.	-0.00411	1300.	1.24E+11	0.00	0.00	0.00
2.8000	0.5513	1754234.	15690.	-0.00406	1322.	1.24E+11	0.00	0.00	0.00
3.0800	0.5378	1813285.	15690.	-0.00401	1345.	1.24E+11	0.00	0.00	0.00
3.3600	0.5244	1872260.	15690.	-0.00396	1367.	1.24E+11	0.00	0.00	0.00
3.6400	0.5112	1931154.	15690.	-0.00391	1389.	1.24E+11	0.00	0.00	0.00
3.9200	0.4981	1989967.	15690.	-0.00386	1411.	1.24E+11	0.00	0.00	0.00
4.2000	0.4852	2048695.	15690.	-0.00380	1433.	1.24E+11	0.00	0.00	0.00
4.4800	0.4725	2107336.	15690.	-0.00375	1456.	1.24E+11	0.00	0.00	0.00
4.7600	0.4601	2165888.	15690.	-0.00369	1478.	1.24E+11	0.00	0.00	0.00
5.0400	0.4478	2224348.	15690.	-0.00363	1500.	1.24E+11	0.00	0.00	0.00
5.3200	0.4357	2282713.	15690.	-0.00357	1522.	1.24E+11	0.00	0.00	0.00
5.6000	0.4238	2340982.	15690.	-0.00351	1544.	1.24E+11	0.00	0.00	0.00
5.8800	0.4121	2399151.	15690.	-0.00344	1566.	1.24E+11	0.00	0.00	0.00
6.1600	0.4006	2457218.	15690.	-0.00338	1588.	1.24E+11	0.00	0.00	0.00
6.4400	0.3894	2515181.	15690.	-0.00331	1609.	1.24E+11	0.00	0.00	0.00
6.7200	0.3784	2573037.	15690.	-0.00324	1631.	1.24E+11	0.00	0.00	0.00
7.0000	0.3676	2630783.	15690.	-0.00317	1653.	1.24E+11	0.00	0.00	0.00
7.2800	0.3571	2688418.	15690.	-0.00310	1675.	1.24E+11	0.00	0.00	0.00
7.5600	0.3468	2745939.	15690.	-0.00302	1696.	1.24E+11	0.00	0.00	0.00
7.8400	0.3368	2803343.	15690.	-0.00295	1718.	1.24E+11	0.00	0.00	0.00
8.1200	0.3270	2860629.	15690.	-0.00290	1083.	3.15E+11	0.00	0.00	0.00
8.4000	0.3173	2917866.	15690.	-0.00287	1096.	3.15E+11	0.00	0.00	0.00
8.6800	0.3078	2975055.	15690.	-0.00283	1108.	3.15E+11	0.00	0.00	0.00
8.9600	0.2983	3032193.	15690.	-0.00280	1121.	3.15E+11	0.00	0.00	0.00
9.2400	0.2889	3089282.	15690.	-0.00277	1133.	3.15E+11	0.00	0.00	0.00
9.5200	0.2797	3146318.	15690.	-0.00274	1146.	3.15E+11	0.00	0.00	0.00
9.8000	0.2705	3203302.	15690.	-0.00270	1158.	3.15E+11	0.00	0.00	0.00
10.0800	0.2615	3260232.	15690.	-0.00267	1170.	3.15E+11	0.00	0.00	0.00
10.3600	0.2526	3317108.	15690.	-0.00263	1183.	3.15E+11	0.00	0.00	0.00
10.6400	0.2438	3373928.	15690.	-0.00260	1195.	3.15E+11	0.00	0.00	0.00
10.9200	0.2352	3430692.	15690.	-0.00256	1208.	3.15E+11	0.00	0.00	0.00
11.2000	0.2266	3487399.	15690.	-0.00252	1220.	3.15E+11	0.00	0.00	0.00
11.4800	0.2182	3544047.	15690.	-0.00249	1232.	3.15E+11	0.00	0.00	0.00
11.7600	0.2099	3600636.	15690.	-0.00245	1245.	3.15E+11	0.00	0.00	0.00
12.0400	0.2018	3657165.	15690.	-0.00241	1257.	3.15E+11	0.00	0.00	0.00
12.3200	0.1937	3713633.	15690.	-0.00237	1269.	3.15E+11	0.00	0.00	0.00
12.6000	0.1858	3770038.	15690.	-0.00233	1282.	3.15E+11	0.00	0.00	0.00
12.8800	0.1781	3826381.	15690.	-0.00229	1294.	3.15E+11	0.00	0.00	0.00
13.1600	0.1704	3882659.	15690.	-0.00225	1306.	3.15E+11	0.00	0.00	0.00
13.4400	0.1630	3938873.	15690.	-0.00221	1319.	3.15E+11	0.00	0.00	0.00
13.7200	0.1556	3995021.	15690.	-0.00216	1331.	3.15E+11	0.00	0.00	0.00
14.0000	0.1484	4051102.	15690.	-0.00212	1343.	3.15E+11	0.00	0.00	0.00
14.2800	0.1414	4107115.	15690.	-0.00208	1355.	3.15E+11	0.00	0.00	0.00
14.5600	0.1344	4163059.	15690.	-0.00203	1368.	3.15E+11	0.00	0.00	0.00
14.8400	0.1277	4218934.	15690.	-0.00199	1380.	3.15E+11	0.00	0.00	0.00
15.1200	0.1211	4274739.	15690.	-0.00194	1392.	3.15E+11	0.00	0.00	0.00
15.4000	0.1146	4330472.	15690.	-0.00190	1404.	3.15E+11	0.00	0.00	0.00
15.6800	0.1083	4386132.	15690.	-0.00185	1416.	3.15E+11	0.00	0.00	0.00
15.9600	0.1022	4441719.	15690.	-0.00181	1428.	3.15E+11	0.00	0.00	0.00
16.2400	0.09619	4497232.	15690.	-0.00176	1441.	3.15E+11	0.00	0.00	0.00
16.5200	0.09036	4552670.	15690.	-0.00171	1453.	3.15E+11	0.00	0.00	0.00
16.8000	0.08470	4608032.	15690.	-0.00166	1465.	3.15E+11	0.00	0.00	0.00
17.0800	0.07920	4663316.	15690.	-0.00161	1477.	3.15E+11	0.00	0.00	0.00
17.3600	0.07388	4718523.	15690.	-0.00156	1489.	3.15E+11	0.00	0.00	0.00
17.6400	0.06872	4773651.	15690.	-0.00151	1501.	3.15E+11	0.00	0.00	0.00
17.9200	0.06373	4828699.	15690.	-0.00146	1513.	3.15E+11	0.00	0.00	0.00
18.2000	0.05891	4883666.	15690.	-0.00141	1525.	3.15E+11	0.00	0.00	0.00
18.4800	0.05427	4938551.	15690.	-0.00136	1537.	3.15E+11	0.00	0.00	0.00
18.7600	0.04980	4993354.	15690.	-0.00130	1549.	3.15E+11	0.00	0.00	0.00
19.0400	0.04552	5048074.	15690.	-0.00125	1561.	3.15E+11	0.00	0.00	0.00

19.3200	0.04141	5102709.	15690.	-0.00119	1573.	3.15E+11	0.00	0.00	0.00
19.6000	0.03749	5157258.	15690.	-0.00114	1585.	3.15E+11	0.00	0.00	0.00
19.8800	0.03375	5211722.	15690.	-0.00108	1597.	3.15E+11	0.00	0.00	0.00
20.1600	0.03020	5266098.	15690.	-0.00103	1608.	3.15E+11	0.00	0.00	0.00
20.4400	0.02684	5320386.	15690.	-9.72E-04	1620.	3.15E+11	0.00	0.00	0.00
20.7200	0.02367	5374586.	15575.	-9.15E-04	1632.	3.15E+11	-68.1636	9677.	0.00
21.0000	0.02069	5427926.	15127.	-8.58E-04	1644.	3.15E+11	-198.6100	32256.	0.00
21.2800	0.01790	5478933.	14303.	-8.00E-04	1655.	3.15E+11	-292.1860	54835.	0.00
21.5600	0.01531	5526549.	13219.	-7.41E-04	1665.	3.15E+11	-352.8525	77414.	0.00
21.8400	0.01292	5570090.	11980.	-6.82E-04	1675.	3.15E+11	-384.6157	99994.	0.00
22.1200	0.01073	5609195.	10676.	-6.22E-04	1683.	3.15E+11	-391.5224	122573.	0.00
22.4000	0.00874	5643787.	9384.	-5.62E-04	1691.	3.15E+11	-377.6543	145152.	0.00
22.6800	0.00695	5674020.	8166.	-5.02E-04	1697.	3.15E+11	-347.1230	167731.	0.00
22.9600	0.00537	5700240.	-20267.	-4.41E-04	1703.	3.15E+11	-16578.	1.04E+07	0.00
23.2400	0.00399	5539211.	-68803.	-3.82E-04	1668.	3.15E+11	-12313.	1.04E+07	0.00
23.5200	0.00280	5239084.	-104038.	-3.24E-04	1602.	3.15E+11	-8660.	1.04E+07	0.00
23.8000	0.00181	4841096.	-127974.	-2.70E-04	1516.	3.15E+11	-5588.	1.04E+07	0.00
24.0800	9.88E-04	4379945.	-142485.	-2.21E-04	1415.	3.15E+11	-3050.	1.04E+07	0.00
24.3600	3.23E-04	3884287.	-149284.	-1.77E-04	1307.	3.15E+11	-996.8731	1.04E+07	0.00
24.6400	-2.03E-04	3377310.	-149906.	-1.38E-04	1196.	3.15E+11	626.7632	1.04E+07	0.00
24.9200	-6.08E-04	2877353.	-145700.	-1.05E-04	1087.	3.15E+11	1877.	1.04E+07	0.00
25.2000	-9.10E-04	2398537.	-137828.	-7.70E-05	982.3477	3.15E+11	2809.	1.04E+07	0.00
25.4800	-0.00113	1951392.	-127270.	-5.39E-05	884.7272	3.15E+11	3476.	1.04E+07	0.00
25.7600	-0.00127	1543453.	-114834.	-3.52E-05	795.6661	3.15E+11	3927.	1.04E+07	0.00
26.0400	-0.00136	1179817.	-101170.	-2.07E-05	716.2773	3.15E+11	4207.	1.04E+07	0.00
26.3200	-0.00141	863654.	-86784.	-9.83E-06	647.2528	3.15E+11	4357.	1.04E+07	0.00
26.6000	-0.00143	596661.	-72054.	-2.05E-06	588.9630	3.15E+11	4411.	1.04E+07	0.00
26.8800	-0.00142	379454.	-57254.	3.15E-06	541.5426	3.15E+11	4399.	1.04E+07	0.00
27.1600	-0.00141	211906.	-42563.	6.30E-06	504.9635	3.15E+11	4345.	1.04E+07	0.00
27.4400	-0.00138	93413.	-28092.	7.93E-06	479.0941	3.15E+11	4268.	1.04E+07	0.00
27.7200	-0.00135	23106.	-13897.	8.55E-06	463.7448	3.15E+11	4181.	1.04E+07	0.00
28.0000	-0.00132	0.00	0.00	8.67E-06	458.7003	3.15E+11	4091.	5187840.	0.00

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

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.69486964 inches
Computed slope at pile head      =    -0.00445507 radians
Maximum bending moment           =       5700240. inch-lbs
Maximum shear force              =       -149906. lbs
Depth of maximum bending moment  =    22.96000000 feet below pile head
Depth of maximum shear force     =    24.64000000 feet below pile head
Number of iterations             =              6
Number of zero deflection points =              1
```

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

Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

```
Shear force at pile head                          =      12740.0 lbs
Rotation of pile head                             =    0.000E+00 radians
Axial load at pile head                           =     460700.0 lbs
```

(Zero slope for this load indicates fixed-head conditions)

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	0.1382	-1499904.	12740.	0.00	1218.	1.24E+11	0.00	0.00	0.00

0.2800	0.1381	-1457066.	12740.	-4.00E-05	1201.	1.24E+11	0.00	0.00	0.00
0.5600	0.1379	-1414167.	12740.	-7.89E-05	1185.	1.24E+11	0.00	0.00	0.00
0.8400	0.1376	-1371209.	12740.	-1.17E-04	1169.	1.24E+11	0.00	0.00	0.00
1.1200	0.1371	-1328193.	12740.	-1.53E-04	1153.	1.24E+11	0.00	0.00	0.00
1.4000	0.1366	-1285122.	12740.	-1.88E-04	1137.	1.24E+11	0.00	0.00	0.00
1.6800	0.1359	-1241997.	12740.	-2.23E-04	1120.	1.24E+11	0.00	0.00	0.00
1.9600	0.1351	-1198820.	12740.	-2.56E-04	1104.	1.24E+11	0.00	0.00	0.00
2.2400	0.1342	-1155593.	12740.	-2.88E-04	1088.	1.24E+11	0.00	0.00	0.00
2.5200	0.1331	-1112317.	12740.	-3.18E-04	1071.	1.24E+11	0.00	0.00	0.00
2.8000	0.1320	-1068994.	12740.	-3.48E-04	1055.	1.24E+11	0.00	0.00	0.00
3.0800	0.1308	-1025627.	12740.	-3.76E-04	1039.	1.24E+11	0.00	0.00	0.00
3.3600	0.1295	-982217.	12740.	-4.03E-04	1022.	1.24E+11	0.00	0.00	0.00
3.6400	0.1281	-938766.	12740.	-4.29E-04	1006.	1.24E+11	0.00	0.00	0.00
3.9200	0.1266	-895275.	12740.	-4.54E-04	989.5053	1.24E+11	0.00	0.00	0.00
4.2000	0.1250	-851747.	12740.	-4.78E-04	973.0840	1.24E+11	0.00	0.00	0.00
4.4800	0.1234	-808183.	12740.	-5.00E-04	956.6493	1.24E+11	0.00	0.00	0.00
4.7600	0.1217	-764586.	12740.	-5.22E-04	940.2018	1.24E+11	0.00	0.00	0.00
5.0400	0.1199	-720956.	12740.	-5.42E-04	923.7422	1.24E+11	0.00	0.00	0.00
5.3200	0.1180	-677296.	12740.	-5.61E-04	907.2713	1.24E+11	0.00	0.00	0.00
5.6000	0.1161	-633608.	12740.	-5.78E-04	890.7896	1.24E+11	0.00	0.00	0.00
5.8800	0.1142	-589893.	12740.	-5.95E-04	874.2979	1.24E+11	0.00	0.00	0.00
6.1600	0.1121	-546153.	12740.	-6.10E-04	857.7969	1.24E+11	0.00	0.00	0.00
6.4400	0.1101	-502391.	12740.	-6.24E-04	841.2872	1.24E+11	0.00	0.00	0.00
6.7200	0.1079	-458607.	12740.	-6.37E-04	824.7696	1.24E+11	0.00	0.00	0.00
7.0000	0.1058	-414805.	12740.	-6.49E-04	808.2448	1.24E+11	0.00	0.00	0.00
7.2800	0.1036	-370985.	12740.	-6.60E-04	791.7134	1.24E+11	0.00	0.00	0.00
7.5600	0.1013	-327149.	12740.	-6.69E-04	775.1761	1.24E+11	0.00	0.00	0.00
7.8400	0.09908	-283300.	12740.	-6.78E-04	758.6337	1.24E+11	0.00	0.00	0.00
8.1200	0.09679	-239438.	12740.	-6.83E-04	504.8832	3.15E+11	0.00	0.00	0.00
8.4000	0.09449	-195573.	12740.	-6.85E-04	495.3066	3.15E+11	0.00	0.00	0.00
8.6800	0.09218	-151705.	12740.	-6.87E-04	485.7293	3.15E+11	0.00	0.00	0.00
8.9600	0.08987	-107834.	12740.	-6.88E-04	476.1514	3.15E+11	0.00	0.00	0.00
9.2400	0.08756	-63961.	12740.	-6.89E-04	466.5731	3.15E+11	0.00	0.00	0.00
9.5200	0.08524	-20087.	12740.	-6.90E-04	456.9946	3.15E+11	0.00	0.00	0.00
9.8000	0.08292	23787.	12740.	-6.90E-04	457.8022	3.15E+11	0.00	0.00	0.00
10.0800	0.08061	67660.	12740.	-6.89E-04	467.3807	3.15E+11	0.00	0.00	0.00
10.3600	0.07829	111533.	12740.	-6.88E-04	476.9589	3.15E+11	0.00	0.00	0.00
10.6400	0.07598	155403.	12740.	-6.87E-04	486.5368	3.15E+11	0.00	0.00	0.00
10.9200	0.07368	199272.	12740.	-6.85E-04	496.1140	3.15E+11	0.00	0.00	0.00
11.2000	0.07138	243136.	12740.	-6.82E-04	505.6906	3.15E+11	0.00	0.00	0.00
11.4800	0.06909	286997.	12740.	-6.80E-04	515.2663	3.15E+11	0.00	0.00	0.00
11.7600	0.06681	330853.	12740.	-6.76E-04	524.8409	3.15E+11	0.00	0.00	0.00
12.0400	0.06455	374704.	12740.	-6.73E-04	534.4144	3.15E+11	0.00	0.00	0.00
12.3200	0.06229	418549.	12740.	-6.68E-04	543.9865	3.15E+11	0.00	0.00	0.00
12.6000	0.06005	462386.	12740.	-6.64E-04	553.5571	3.15E+11	0.00	0.00	0.00
12.8800	0.05783	506216.	12740.	-6.59E-04	563.1260	3.15E+11	0.00	0.00	0.00
13.1600	0.05563	550038.	12740.	-6.53E-04	572.6931	3.15E+11	0.00	0.00	0.00
13.4400	0.05345	593850.	12740.	-6.47E-04	582.2582	3.15E+11	0.00	0.00	0.00
13.7200	0.05128	637653.	12740.	-6.40E-04	591.8212	3.15E+11	0.00	0.00	0.00
14.0000	0.04914	681445.	12740.	-6.33E-04	601.3819	3.15E+11	0.00	0.00	0.00
14.2800	0.04703	725226.	12740.	-6.26E-04	610.9402	3.15E+11	0.00	0.00	0.00
14.5600	0.04494	768995.	12740.	-6.18E-04	620.4958	3.15E+11	0.00	0.00	0.00
14.8400	0.04288	812751.	12740.	-6.09E-04	630.0486	3.15E+11	0.00	0.00	0.00
15.1200	0.04084	856494.	12740.	-6.00E-04	639.5986	3.15E+11	0.00	0.00	0.00
15.4000	0.03884	900223.	12740.	-5.91E-04	649.1454	3.15E+11	0.00	0.00	0.00
15.6800	0.03687	943937.	12740.	-5.81E-04	658.6890	3.15E+11	0.00	0.00	0.00
15.9600	0.03494	987635.	12740.	-5.71E-04	668.2292	3.15E+11	0.00	0.00	0.00
16.2400	0.03303	1031317.	12740.	-5.60E-04	677.7659	3.15E+11	0.00	0.00	0.00
16.5200	0.03117	1074982.	12740.	-5.49E-04	687.2988	3.15E+11	0.00	0.00	0.00
16.8000	0.02935	1118630.	12740.	-5.37E-04	696.8278	3.15E+11	0.00	0.00	0.00
17.0800	0.02756	1162258.	12740.	-5.25E-04	706.3529	3.15E+11	0.00	0.00	0.00
17.3600	0.02582	1205868.	12740.	-5.12E-04	715.8737	3.15E+11	0.00	0.00	0.00
17.6400	0.02412	1249458.	12740.	-4.99E-04	725.3902	3.15E+11	0.00	0.00	0.00
17.9200	0.02246	1293027.	12740.	-4.86E-04	734.9022	3.15E+11	0.00	0.00	0.00
18.2000	0.02085	1336575.	12740.	-4.72E-04	744.4095	3.15E+11	0.00	0.00	0.00
18.4800	0.01929	1380101.	12740.	-4.57E-04	753.9121	3.15E+11	0.00	0.00	0.00
18.7600	0.01778	1423604.	12740.	-4.42E-04	763.4096	3.15E+11	0.00	0.00	0.00

19.0400	0.01632	1467083.	12740.	-4.27E-04	772.9020	3.15E+11	0.00	0.00	0.00
19.3200	0.01491	1510538.	12740.	-4.11E-04	782.3892	3.15E+11	0.00	0.00	0.00
19.6000	0.01355	1553969.	12740.	-3.95E-04	791.8709	3.15E+11	0.00	0.00	0.00
19.8800	0.01226	1597374.	12740.	-3.78E-04	801.3470	3.15E+11	0.00	0.00	0.00
20.1600	0.01101	1640752.	12740.	-3.61E-04	810.8173	3.15E+11	0.00	0.00	0.00
20.4400	0.00983	1684103.	12740.	-3.43E-04	820.2818	3.15E+11	0.00	0.00	0.00
20.7200	0.00871	1727427.	12698.	-3.25E-04	829.7402	3.15E+11	-25.0808	9677.	0.00
21.0000	0.00765	1770439.	12532.	-3.06E-04	839.1305	3.15E+11	-73.4204	32256.	0.00
21.2800	0.00665	1812592.	12227.	-2.87E-04	848.3335	3.15E+11	-108.5396	54835.	0.00
21.5600	0.00572	1853491.	11823.	-2.68E-04	857.2624	3.15E+11	-131.7513	77414.	0.00
21.8400	0.00485	1892872.	11359.	-2.48E-04	865.8600	3.15E+11	-144.4077	99994.	0.00
22.1200	0.00405	1930590.	10868.	-2.27E-04	874.0948	3.15E+11	-147.8984	122573.	0.00
22.4000	0.00333	1966608.	10378.	-2.06E-04	881.9581	3.15E+11	-143.6483	145152.	0.00
22.6800	0.00267	2000971.	9913.	-1.85E-04	889.4602	3.15E+11	-133.1157	167731.	0.00
22.9600	0.00208	2033799.	-1099.	-1.64E-04	896.6271	3.15E+11	-6422.	1.04E+07	0.00
23.2400	0.00157	1994092.	-20009.	-1.42E-04	887.9584	3.15E+11	-4834.	1.04E+07	0.00
23.5200	0.00112	1899776.	-33956.	-1.22E-04	867.3673	3.15E+11	-3467.	1.04E+07	0.00
23.8000	7.48E-04	1766285.	-43662.	-1.02E-04	838.2237	3.15E+11	-2310.	1.04E+07	0.00
24.0800	4.37E-04	1606685.	-49808.	-8.41E-05	803.3798	3.15E+11	-1348.	1.04E+07	0.00
24.3600	1.83E-04	1431834.	-53022.	-6.79E-05	765.2065	3.15E+11	-564.4484	1.04E+07	0.00
24.6400	-1.98E-05	1250588.	-53867.	-5.36E-05	725.6369	3.15E+11	61.2266	1.04E+07	0.00
24.9200	-1.78E-04	1070012.	-52843.	-4.13E-05	686.2136	3.15E+11	548.6058	1.04E+07	0.00
25.2000	-2.97E-04	895612.	-50379.	-3.08E-05	648.1387	3.15E+11	917.6582	1.04E+07	0.00
25.4800	-3.85E-04	731557.	-46843.	-2.21E-05	612.3223	3.15E+11	1188.	1.04E+07	0.00
25.7600	-4.46E-04	580898.	-42534.	-1.51E-05	579.4306	3.15E+11	1377.	1.04E+07	0.00
26.0400	-4.86E-04	445773.	-37698.	-9.66E-06	549.9302	3.15E+11	1502.	1.04E+07	0.00
26.3200	-5.11E-04	327594.	-32526.	-5.54E-06	524.1294	3.15E+11	1577.	1.04E+07	0.00
26.6000	-5.24E-04	227216.	-27160.	-2.58E-06	502.2149	3.15E+11	1617.	1.04E+07	0.00
26.8800	-5.28E-04	145085.	-21705.	-5.98E-07	484.2840	3.15E+11	1631.	1.04E+07	0.00
27.1600	-5.28E-04	81362.	-16228.	6.09E-07	470.3721	3.15E+11	1629.	1.04E+07	0.00
27.4400	-5.24E-04	36029.	-10773.	1.23E-06	460.4750	3.15E+11	1618.	1.04E+07	0.00
27.7200	-5.19E-04	8964.	-5361.	1.47E-06	454.5662	3.15E+11	1603.	1.04E+07	0.00
28.0000	-5.14E-04	0.00	0.00	1.52E-06	452.6091	3.15E+11	1588.	5187840.	0.00

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

Output Summary for Load Case No. 2:

Pile-head deflection = 0.13820041 inches
Computed slope at pile head = 0.000000 radians
Maximum bending moment = 2033799. inch-lbs
Maximum shear force = -53867. lbs
Depth of maximum bending moment = 22.96000000 feet below pile head
Depth of maximum shear force = 24.64000000 feet below pile head
Number of iterations = 6
Number of zero deflection points = 1

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	15690.	M, in-lb	1160040.	466900.	0.6949	-0.00446	-149906.	5700240.

2	V, lb	12740.	S, rad	0.00	460700.	0.1382	0.00	-53867.	2033799.

Maximum pile-head deflection = 0.6948696410 inches
Maximum pile-head rotation = -0.0044550682 radians = -0.255257 deg.

The analysis ended normally.

SINCE 1881

FROEHLING & ROBERTSON, INC.

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SHEET NO. 1 OF 1

JOB BR-0082 Bridge #6 DATE 4/28/2020

COMPUTATIONS FOR Bent 1 Right Lateral BY CW CHKD

Based on boring B18 and loads by WSP on 5-5-2020

Depth (ft)		Elev. (ft)
0	BOC = EL 178.6	178.6
	ϕ column = 3 ft Top of DGR = EL 170.0	170.6
	ϕ DGR = 36 inch	
20.6	DSE = EL 158.0'	158.0'
24	DWR γ = 140 pcf, c = 500 psf, ε = 0.01 (k = 2000)	154.2'
28.9	① SM γ = 72 k = 63 ϕ = 41° k = 125	149.7
43.9	② CR γ = 173 pcf, q_u = 2,604 psf per US-3 results (BR-7)	

① Model max. longitudinal shear as free head

V = 15,690 lbs. M = 1,160,040 lbs-in. Axial = 466,900 lbs

Based on LPILE results:

⇒ y = 0.98" 1st neg = 30.3' (EL 148.3'), max neg = 32.0' (EL 146.6')

② Model max. transverse shear as fixed head

V = 12,740 lbs, slope = 0, Axial = 400,700 lbs

⇒ y = 0.19", 1st neg = 30.3' (EL 148.3'), max neg = 32.3' (EL 146.3')

∴ PDT = EL 148.0'

MinTip: 1.5B below 1st negative = EL 143.8'

10B below max negative = EL 143.3'

∴ MinTip per lateral analysis = EL 143.0' MinTip per Axial at EL 144.0

∴ MinTip @ Bent 1 right is EL 143.0'

Form No. 502
Revised 05/2008

LPile for Windows, Version 2018-10.003

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

This copy of LPile is being used by:

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Files Used for Analysis

Path to file locations:
\Projects 66X\66X-0152 (WEI-Bridge 56 Harnett Co)\BR0082_GEO_BRDG0056\NON_CADD\Foundation Recommendation\Lateral Analysis\

Name of input data file:
Bent 1 Right.lp10

Name of output report file:
Bent 1 Right.lp10

Name of plot output file:
Bent 1 Right.lp10

Name of runtime message file:
Bent 1 Right.lp10

Date and Time of Analysis

Date: May 6, 2020 Time: 9:50:21

Problem Title

Project Name: Bridge 56 Harnett County

Job Number: 66X-0152

Client: WEI

Engineer: CW

Description: Bent 1 Right

Program Options and Settings

Computational Options:
 - Use unfactored loads in computations (conventional analysis)
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

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

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

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - No distributed lateral loads are entered
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

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

Pile Structural Properties and Geometry

Number of pile sections defined = 2
Total length of pile = 34.000 ft
Depth of ground surface below top of pile = 20.6000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	30.0000
2	8.000	30.0000

3	8.000	36.0000
4	34.000	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	8.000000 ft
Width of top of section	=	30.000000 in
Width of bottom of section	=	30.000000 in
Top Area	=	706.858347 sq. in
Bottom Area	=	706.858347 sq. in
Moment of Inertia at Top	=	39761. in^4
Moment of Inertia at Bottom	=	39761. in^4
Elastic Modulus	=	3122019. psi

Pile Section No. 2:

Section 2 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	26.000000 ft
Width of top of section	=	36.000000 in
Width of bottom of section	=	36.000000 in
Top Area	=	1018. sq. in
Bottom Area	=	1018. sq. in
Moment of Inertia at Top	=	82448. in^4
Moment of Inertia at Bottom	=	82448. in^4
Elastic Modulus	=	3823676. psi

Ground Slope and Pile Batter Angles

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

Soil and Rock Layering Information

The soil profile is modelled using 3 layers

Layer 1 is stiff clay with water-induced erosion

Distance from top of pile to top of layer	=	20.600000 ft
Distance from top of pile to bottom of layer	=	23.400000 ft
Effective unit weight at top of layer	=	100.000000 pcf
Effective unit weight at bottom of layer	=	100.000000 pcf
Undrained cohesion at top of layer	=	5000. psf
Undrained cohesion at bottom of layer	=	5000. psf
Epsilon-50 at top of layer	=	0.004000
Epsilon-50 at bottom of layer	=	0.004000
Subgrade k at top of layer	=	2000. pci
Subgrade k at bottom of layer	=	2000. pci

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

Distance from top of pile to top of layer	=	23.400000 ft
Distance from top of pile to bottom of layer	=	28.900000 ft
Effective unit weight at top of layer	=	63.000000 pcf
Effective unit weight at bottom of layer	=	63.000000 pcf
Friction angle at top of layer	=	41.000000 deg.
Friction angle at bottom of layer	=	41.000000 deg.
Subgrade k at top of layer	=	125.000000 pci
Subgrade k at bottom of layer	=	125.000000 pci

Layer 3 is strong rock (vuggy limestone)

Distance from top of pile to top of layer	=	28.900000 ft
Distance from top of pile to bottom of layer	=	43.900000 ft
Effective unit weight at top of layer	=	173.000000 pcf
Effective unit weight at bottom of layer	=	173.000000 pcf
Uniaxial compressive strength at top of layer	=	2664. psi
Uniaxial compressive strength at bottom of layer	=	2664. psi

(Depth of the lowest soil layer extends 9.900 ft below the pile tip)

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

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

The maximum input value, in layer 1, for effective unit weight = 173.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Angle of Friction deg.	Uniaxial qu psi	E50 or krm	kpy pci
1	Stiff Clay	20.6000	100.0000	5000.	--	--	0.00400	2000.
	with Free Water	23.4000	100.0000	5000.	--	--	0.00400	2000.
2	Sand	23.4000	63.0000	--	41.0000	--	--	125.0000
	(Reese, et al.)	28.9000	63.0000	--	41.0000	--	--	125.0000
3	Strong Rock	28.9000	173.0000	--	--	2664.	--	--
	(Vuggy Limestone)	43.9000	173.0000	--	--	2664.	--	--

Static Loading Type

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

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V = 15690. lbs	M = 1160040. in-lbs	466900.	No
2	2	V = 12740. lbs	S = 0.0000 in/in	460700.	No

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

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

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

Number of Pile Sections Analyzed = 2

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

Pile Section No. 2:

Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	20.6000	0.00	N.A.	No	0.00	7419.
2	23.4000	1.7272	No	No	7419.	125740.
3	28.9000	8.3000	No	Yes	N.A.	N.A.

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

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

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

Shear force at pile head = 15690.0 lbs
Applied moment at pile head = 1160040.0 in-lbs
Axial thrust load on pile head = 466900.0 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	0.9754	1160040.	15690.	-0.00532	1098.	1.24E+11	0.00	0.00	0.00
0.3400	0.9538	1234163.	15690.	-0.00529	1126.	1.24E+11	0.00	0.00	0.00
0.6800	0.9323	1308208.	15690.	-0.00524	1154.	1.24E+11	0.00	0.00	0.00
1.0200	0.9110	1382171.	15690.	-0.00520	1182.	1.24E+11	0.00	0.00	0.00
1.3600	0.8899	1456048.	15690.	-0.00515	1210.	1.24E+11	0.00	0.00	0.00
1.7000	0.8689	1529834.	15690.	-0.00510	1238.	1.24E+11	0.00	0.00	0.00
2.0400	0.8482	1603523.	15690.	-0.00505	1265.	1.24E+11	0.00	0.00	0.00
2.3800	0.8277	1677113.	15690.	-0.00500	1293.	1.24E+11	0.00	0.00	0.00
2.7200	0.8074	1750597.	15690.	-0.00494	1321.	1.24E+11	0.00	0.00	0.00
3.0600	0.7874	1823972.	15690.	-0.00488	1349.	1.24E+11	0.00	0.00	0.00
3.4000	0.7676	1897233.	15690.	-0.00482	1376.	1.24E+11	0.00	0.00	0.00
3.7400	0.7480	1970375.	15690.	-0.00476	1404.	1.24E+11	0.00	0.00	0.00
4.0800	0.7287	2043393.	15690.	-0.00469	1431.	1.24E+11	0.00	0.00	0.00
4.4200	0.7097	2116284.	15690.	-0.00462	1459.	1.24E+11	0.00	0.00	0.00
4.7600	0.6910	2189042.	15690.	-0.00455	1486.	1.24E+11	0.00	0.00	0.00
5.1000	0.6726	2261663.	15690.	-0.00448	1514.	1.24E+11	0.00	0.00	0.00
5.4400	0.6544	2334142.	15690.	-0.00440	1541.	1.24E+11	0.00	0.00	0.00
5.7800	0.6366	2406475.	15690.	-0.00433	1568.	1.24E+11	0.00	0.00	0.00
6.1200	0.6191	2478658.	15690.	-0.00425	1596.	1.24E+11	0.00	0.00	0.00
6.4600	0.6020	2550685.	15690.	-0.00416	1623.	1.24E+11	0.00	0.00	0.00
6.8000	0.5852	2622553.	15690.	-0.00408	1650.	1.24E+11	0.00	0.00	0.00
7.1400	0.5687	2694257.	15690.	-0.00399	1677.	1.24E+11	0.00	0.00	0.00
7.4800	0.5526	2765791.	15690.	-0.00390	1704.	1.24E+11	0.00	0.00	0.00
7.8200	0.5369	2837153.	15690.	-0.00381	1731.	1.24E+11	0.00	0.00	0.00
8.1600	0.5215	2908337.	15690.	-0.00374	1094.	3.15E+11	0.00	0.00	0.00
8.5000	0.5063	2979449.	15690.	-0.00371	1109.	3.15E+11	0.00	0.00	0.00
8.8400	0.4913	3050488.	15690.	-0.00367	1125.	3.15E+11	0.00	0.00	0.00
9.1800	0.4764	3121452.	15690.	-0.00363	1140.	3.15E+11	0.00	0.00	0.00
9.5200	0.4617	3192338.	15690.	-0.00359	1156.	3.15E+11	0.00	0.00	0.00
9.8600	0.4471	3263146.	15690.	-0.00354	1171.	3.15E+11	0.00	0.00	0.00
10.2000	0.4327	3333874.	15690.	-0.00350	1187.	3.15E+11	0.00	0.00	0.00
10.5400	0.4185	3404519.	15690.	-0.00346	1202.	3.15E+11	0.00	0.00	0.00
10.8800	0.4045	3475080.	15690.	-0.00341	1217.	3.15E+11	0.00	0.00	0.00
11.2200	0.3907	3545556.	15690.	-0.00337	1233.	3.15E+11	0.00	0.00	0.00
11.5600	0.3770	3615944.	15690.	-0.00332	1248.	3.15E+11	0.00	0.00	0.00
11.9000	0.3636	3686243.	15690.	-0.00327	1263.	3.15E+11	0.00	0.00	0.00
12.2400	0.3503	3756452.	15690.	-0.00323	1279.	3.15E+11	0.00	0.00	0.00
12.5800	0.3372	3826567.	15690.	-0.00318	1294.	3.15E+11	0.00	0.00	0.00
12.9200	0.3244	3896589.	15690.	-0.00313	1309.	3.15E+11	0.00	0.00	0.00
13.2600	0.3117	3966514.	15690.	-0.00308	1325.	3.15E+11	0.00	0.00	0.00
13.6000	0.2993	4036341.	15690.	-0.00303	1340.	3.15E+11	0.00	0.00	0.00
13.9400	0.2870	4106069.	15690.	-0.00297	1355.	3.15E+11	0.00	0.00	0.00
14.2800	0.2750	4175696.	15690.	-0.00292	1370.	3.15E+11	0.00	0.00	0.00
14.6200	0.2632	4245220.	15690.	-0.00286	1386.	3.15E+11	0.00	0.00	0.00
14.9600	0.2516	4314639.	15690.	-0.00281	1401.	3.15E+11	0.00	0.00	0.00
15.3000	0.2403	4383952.	15690.	-0.00275	1416.	3.15E+11	0.00	0.00	0.00
15.6400	0.2292	4453156.	15690.	-0.00270	1431.	3.15E+11	0.00	0.00	0.00
15.9800	0.2183	4522251.	15690.	-0.00264	1446.	3.15E+11	0.00	0.00	0.00
16.3200	0.2077	4591235.	15690.	-0.00258	1461.	3.15E+11	0.00	0.00	0.00
16.6600	0.1973	4660105.	15690.	-0.00252	1476.	3.15E+11	0.00	0.00	0.00
17.0000	0.1871	4728860.	15690.	-0.00246	1491.	3.15E+11	0.00	0.00	0.00

17.3400	0.1772	4797499.	15690.	-0.00240	1506.	3.15E+11	0.00	0.00	0.00
17.6800	0.1676	4866019.	15690.	-0.00233	1521.	3.15E+11	0.00	0.00	0.00
18.0200	0.1582	4934420.	15690.	-0.00227	1536.	3.15E+11	0.00	0.00	0.00
18.3600	0.1490	5002699.	15690.	-0.00221	1551.	3.15E+11	0.00	0.00	0.00
18.7000	0.1402	5070854.	15690.	-0.00214	1566.	3.15E+11	0.00	0.00	0.00
19.0400	0.1316	5138884.	15690.	-0.00207	1581.	3.15E+11	0.00	0.00	0.00
19.3800	0.1232	5206788.	15690.	-0.00201	1595.	3.15E+11	0.00	0.00	0.00
19.7200	0.1152	5274564.	15690.	-0.00194	1610.	3.15E+11	0.00	0.00	0.00
20.0600	0.1074	5342209.	15690.	-0.00187	1625.	3.15E+11	0.00	0.00	0.00
20.4000	0.09991	5409723.	15690.	-0.00180	1640.	3.15E+11	0.00	0.00	0.00
20.7400	0.09271	5477103.	15055.	-0.00173	1654.	3.15E+11	-311.4927	13709.	0.00
21.0800	0.08579	5539163.	12403.	-0.00166	1668.	3.15E+11	-988.2783	47002.	0.00
21.4200	0.07916	5584635.	8034.	-0.00159	1678.	3.15E+11	-1153.	59441.	0.00
21.7600	0.07283	5610771.	3038.	-0.00152	1684.	3.15E+11	-1296.	72599.	0.00
22.1000	0.06680	5615196.	-2501.	-0.00144	1685.	3.15E+11	-1419.	86684.	0.00
22.4400	0.06106	5595858.	-8501.	-0.00137	1680.	3.15E+11	-1522.	101706.	0.00
22.7800	0.05562	5551045.	-14855.	-0.00130	1671.	3.15E+11	-1593.	116829.	0.00
23.1200	0.05047	5479585.	-21446.	-0.00123	1655.	3.15E+11	-1638.	132442.	0.00
23.4600	0.04561	5380719.	-25187.	-0.00116	1633.	3.15E+11	-195.6555	17503.	0.00
23.8000	0.04103	5278463.	-25988.	-0.00109	1611.	3.15E+11	-196.9508	19584.	0.00
24.1400	0.03673	5172798.	-26788.	-0.00102	1588.	3.15E+11	-195.0587	21665.	0.00
24.4800	0.03271	5063759.	-27574.	-9.54E-04	1564.	3.15E+11	-190.3731	23746.	0.00
24.8200	0.02895	4951427.	-28336.	-8.89E-04	1540.	3.15E+11	-183.2755	25826.	0.00
25.1600	0.02546	4835921.	-29065.	-8.25E-04	1514.	3.15E+11	-174.1344	27907.	0.00
25.5000	0.02222	4717397.	-29754.	-7.64E-04	1489.	3.15E+11	-163.3050	29988.	0.00
25.8400	0.01923	4596038.	-30395.	-7.03E-04	1462.	3.15E+11	-151.1288	32069.	0.00
26.1800	0.01648	4472051.	-30985.	-6.45E-04	1435.	3.15E+11	-137.9332	34150.	0.00
26.5200	0.01397	4345657.	-31519.	-5.88E-04	1407.	3.15E+11	-124.0315	36230.	0.00
26.8600	0.01169	4217091.	-31996.	-5.32E-04	1379.	3.15E+11	-109.7223	38311.	0.00
27.2000	0.00963	4086595.	-32414.	-4.78E-04	1351.	3.15E+11	-95.2894	40392.	0.00
27.5400	0.00778	3954412.	-32774.	-4.26E-04	1322.	3.15E+11	-81.0018	42473.	0.00
27.8800	0.00615	3820783.	-33076.	-3.76E-04	1293.	3.15E+11	-67.1135	44554.	0.00
28.2200	0.00471	3685942.	-33323.	-3.27E-04	1263.	3.15E+11	-53.8632	46634.	0.00
28.5600	0.00347	3550115.	-33518.	-2.81E-04	1234.	3.15E+11	-41.4746	48715.	0.00
28.9000	0.00242	3413509.	-46766.	-2.36E-04	1204.	3.15E+11	-6453.	1.09E+07	0.00
29.2400	0.00155	3169404.	-68358.	-1.93E-04	1151.	3.15E+11	-4132.	1.09E+07	0.00
29.5800	8.47E-04	2856440.	-81392.	-1.54E-04	1082.	3.15E+11	-2257.	1.09E+07	0.00
29.9200	2.94E-04	2505833.	-87595.	-1.19E-04	1006.	3.15E+11	-783.9185	1.09E+07	0.00
30.2600	-1.26E-04	2142116.	-88508.	-8.92E-05	926.3659	3.15E+11	336.7056	1.09E+07	0.00
30.6000	-4.34E-04	1783950.	-85463.	-6.38E-05	848.1714	3.15E+11	1156.	1.09E+07	0.00
30.9400	-6.47E-04	1444984.	-79587.	-4.29E-05	774.1685	3.15E+11	1724.	1.09E+07	0.00
31.2800	-7.84E-04	1134686.	-71807.	-2.62E-05	706.4244	3.15E+11	2089.	1.09E+07	0.00
31.6200	-8.61E-04	859143.	-62862.	-1.33E-05	646.2679	3.15E+11	2295.	1.09E+07	0.00
31.9600	-8.93E-04	621780.	-53326.	-3.76E-06	594.4470	3.15E+11	2380.	1.09E+07	0.00
32.3000	-8.92E-04	424013.	-43624.	3.00E-06	551.2707	3.15E+11	2377.	1.09E+07	0.00
32.6400	-8.69E-04	265800.	-34054.	7.47E-06	516.7296	3.15E+11	2314.	1.09E+07	0.00
32.9800	-8.31E-04	146103.	-24816.	1.01E-05	490.5975	3.15E+11	2214.	1.09E+07	0.00
33.3200	-7.86E-04	63265.	-16027.	1.15E-05	472.5122	3.15E+11	2094.	1.09E+07	0.00
33.6600	-7.37E-04	15281.	-7747.	1.20E-05	462.0363	3.15E+11	1965.	1.09E+07	0.00
34.0000	-6.88E-04	0.00	0.00	1.21E-05	458.7003	3.15E+11	1833.	5434560.	0.00

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

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.97541292 inches
Computed slope at pile head      =    -0.00532488 radians
Maximum bending moment           =       5615196. inch-lbs
Maximum shear force              =        -88508. lbs
Depth of maximum bending moment  =    22.10000000 feet below pile head
Depth of maximum shear force     =    30.26000000 feet below pile head
Number of iterations             =              8
Number of zero deflection points =              1
```

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

Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

Shear force at pile head = 12740.0 lbs
Rotation of pile head = 0.000E+00 radians
Axial load at pile head = 460700.0 lbs

(Zero slope for this load indicates fixed-head conditions)

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	0.1929	-1678067.	12740.	0.00	1285.	1.24E+11	0.00	0.00	0.00
0.3400	0.1928	-1626036.	12740.	-5.43E-05	1265.	1.24E+11	0.00	0.00	0.00
0.6800	0.1925	-1573905.	12740.	-1.07E-04	1246.	1.24E+11	0.00	0.00	0.00
1.0200	0.1919	-1521676.	12740.	-1.58E-04	1226.	1.24E+11	0.00	0.00	0.00
1.3600	0.1912	-1469353.	12740.	-2.07E-04	1206.	1.24E+11	0.00	0.00	0.00
1.7000	0.1902	-1416940.	12740.	-2.54E-04	1186.	1.24E+11	0.00	0.00	0.00
2.0400	0.1891	-1364439.	12740.	-3.00E-04	1167.	1.24E+11	0.00	0.00	0.00
2.3800	0.1878	-1311853.	12740.	-3.44E-04	1147.	1.24E+11	0.00	0.00	0.00
2.7200	0.1863	-1259187.	12740.	-3.86E-04	1127.	1.24E+11	0.00	0.00	0.00
3.0600	0.1846	-1206443.	12740.	-4.27E-04	1107.	1.24E+11	0.00	0.00	0.00
3.4000	0.1828	-1153624.	12740.	-4.66E-04	1087.	1.24E+11	0.00	0.00	0.00
3.7400	0.1808	-1100734.	12740.	-5.03E-04	1067.	1.24E+11	0.00	0.00	0.00
4.0800	0.1787	-1047776.	12740.	-5.38E-04	1047.	1.24E+11	0.00	0.00	0.00
4.4200	0.1764	-994753.	12740.	-5.72E-04	1027.	1.24E+11	0.00	0.00	0.00
4.7600	0.1740	-941669.	12740.	-6.03E-04	1007.	1.24E+11	0.00	0.00	0.00
5.1000	0.1715	-888527.	12740.	-6.33E-04	986.9594	1.24E+11	0.00	0.00	0.00
5.4400	0.1689	-835330.	12740.	-6.62E-04	966.8904	1.24E+11	0.00	0.00	0.00
5.7800	0.1661	-782081.	12740.	-6.88E-04	946.8019	1.24E+11	0.00	0.00	0.00
6.1200	0.1633	-728784.	12740.	-7.13E-04	926.6953	1.24E+11	0.00	0.00	0.00
6.4600	0.1603	-675441.	12740.	-7.36E-04	906.5716	1.24E+11	0.00	0.00	0.00
6.8000	0.1573	-622057.	12740.	-7.58E-04	886.4322	1.24E+11	0.00	0.00	0.00
7.1400	0.1541	-568635.	12740.	-7.77E-04	866.2783	1.24E+11	0.00	0.00	0.00
7.4800	0.1509	-515178.	12740.	-7.95E-04	846.1111	1.24E+11	0.00	0.00	0.00
7.8200	0.1476	-461688.	12740.	-8.11E-04	825.9319	1.24E+11	0.00	0.00	0.00
8.1600	0.1443	-408170.	12740.	-8.21E-04	541.7207	3.15E+11	0.00	0.00	0.00
8.5000	0.1409	-354643.	12740.	-8.26E-04	530.0346	3.15E+11	0.00	0.00	0.00
8.8400	0.1376	-301106.	12740.	-8.30E-04	518.3465	3.15E+11	0.00	0.00	0.00
9.1800	0.1342	-247563.	12740.	-8.34E-04	506.6569	3.15E+11	0.00	0.00	0.00
9.5200	0.1307	-194013.	12740.	-8.37E-04	494.9659	3.15E+11	0.00	0.00	0.00
9.8600	0.1273	-140458.	12740.	-8.39E-04	483.2739	3.15E+11	0.00	0.00	0.00
10.2000	0.1239	-86900.	12740.	-8.40E-04	471.5812	3.15E+11	0.00	0.00	0.00
10.5400	0.1205	-33340.	12740.	-8.41E-04	459.8880	3.15E+11	0.00	0.00	0.00
10.8800	0.1170	20220.	12740.	-8.41E-04	457.0237	3.15E+11	0.00	0.00	0.00
11.2200	0.1136	73781.	12740.	-8.41E-04	468.7169	3.15E+11	0.00	0.00	0.00
11.5600	0.1102	127339.	12740.	-8.39E-04	480.4098	3.15E+11	0.00	0.00	0.00
11.9000	0.1068	180895.	12740.	-8.37E-04	492.1020	3.15E+11	0.00	0.00	0.00
12.2400	0.1033	234446.	12740.	-8.35E-04	503.7932	3.15E+11	0.00	0.00	0.00
12.5800	0.09994	287991.	12740.	-8.31E-04	515.4832	3.15E+11	0.00	0.00	0.00
12.9200	0.09656	341529.	12740.	-8.27E-04	527.1717	3.15E+11	0.00	0.00	0.00
13.2600	0.09319	395059.	12740.	-8.22E-04	538.8583	3.15E+11	0.00	0.00	0.00
13.6000	0.08985	448580.	12740.	-8.17E-04	550.5429	3.15E+11	0.00	0.00	0.00
13.9400	0.08653	502089.	12740.	-8.11E-04	562.2250	3.15E+11	0.00	0.00	0.00
14.2800	0.08323	555586.	12740.	-8.04E-04	573.9045	3.15E+11	0.00	0.00	0.00
14.6200	0.07997	609070.	12740.	-7.96E-04	585.5811	3.15E+11	0.00	0.00	0.00
14.9600	0.07673	662539.	12740.	-7.88E-04	597.2544	3.15E+11	0.00	0.00	0.00
15.3000	0.07353	715992.	12740.	-7.79E-04	608.9242	3.15E+11	0.00	0.00	0.00
15.6400	0.07037	769427.	12740.	-7.70E-04	620.5902	3.15E+11	0.00	0.00	0.00
15.9800	0.06725	822844.	12740.	-7.59E-04	632.2521	3.15E+11	0.00	0.00	0.00
16.3200	0.06418	876241.	12740.	-7.48E-04	643.9096	3.15E+11	0.00	0.00	0.00
16.6600	0.06115	929616.	12740.	-7.37E-04	655.5625	3.15E+11	0.00	0.00	0.00

17.0000	0.05816	982969.	12740.	-7.24E-04	667.2104	3.15E+11	0.00	0.00	0.00
17.3400	0.05524	1036298.	12740.	-7.11E-04	678.8532	3.15E+11	0.00	0.00	0.00
17.6800	0.05236	1089601.	12740.	-6.98E-04	690.4904	3.15E+11	0.00	0.00	0.00
18.0200	0.04954	1142878.	12740.	-6.83E-04	702.1218	3.15E+11	0.00	0.00	0.00
18.3600	0.04679	1196128.	12740.	-6.68E-04	713.7472	3.15E+11	0.00	0.00	0.00
18.7000	0.04409	1249348.	12740.	-6.52E-04	725.3662	3.15E+11	0.00	0.00	0.00
19.0400	0.04146	1302538.	12740.	-6.36E-04	736.9786	3.15E+11	0.00	0.00	0.00
19.3800	0.03891	1355696.	12740.	-6.18E-04	748.5840	3.15E+11	0.00	0.00	0.00
19.7200	0.03642	1408821.	12740.	-6.01E-04	760.1823	3.15E+11	0.00	0.00	0.00
20.0600	0.03401	1461912.	12740.	-5.82E-04	771.7731	3.15E+11	0.00	0.00	0.00
20.4000	0.03167	1514967.	12740.	-5.63E-04	783.3561	3.15E+11	0.00	0.00	0.00
20.7400	0.02941	1567986.	12538.	-5.43E-04	794.9310	3.15E+11	-98.8296	13709.	0.00
21.0800	0.02724	1619321.	11697.	-5.22E-04	806.1385	3.15E+11	-313.8110	47002.	0.00
21.4200	0.02515	1665393.	10047.	-5.01E-04	816.1969	3.15E+11	-495.0111	80294.	0.00
21.7600	0.02315	1703184.	7722.	-4.79E-04	824.4475	3.15E+11	-644.5907	113587.	0.00
22.1000	0.02124	1730204.	4847.	-4.57E-04	830.3464	3.15E+11	-764.7746	146880.	0.00
22.4400	0.01943	1744451.	1537.	-4.34E-04	833.4568	3.15E+11	-857.8272	180173.	0.00
22.7800	0.01770	1744375.	-2046.	-4.12E-04	833.4404	3.15E+11	-898.3945	207096.	0.00
23.1200	0.01607	1729303.	-5764.	-3.89E-04	830.1497	3.15E+11	-924.2932	234739.	0.00
23.4600	0.01452	1698802.	-7777.	-3.67E-04	823.4907	3.15E+11	-62.3010	17503.	0.00
23.8000	0.01307	1667222.	-8032.	-3.45E-04	816.5963	3.15E+11	-62.7327	19584.	0.00
24.1400	0.01170	1634558.	-8287.	-3.24E-04	809.4651	3.15E+11	-62.1497	21665.	0.00
24.4800	0.01043	1600820.	-8537.	-3.03E-04	802.0993	3.15E+11	-60.6768	23746.	0.00
24.8200	0.00923	1566032.	-8780.	-2.83E-04	794.5045	3.15E+11	-58.4345	25826.	0.00
25.1600	0.00812	1530234.	-9013.	-2.63E-04	786.6891	3.15E+11	-55.5398	27907.	0.00
25.5000	0.00709	1493474.	-9233.	-2.43E-04	778.6636	3.15E+11	-52.1053	29988.	0.00
25.8400	0.00614	1455810.	-9437.	-2.24E-04	770.4409	3.15E+11	-48.2392	32069.	0.00
26.1800	0.00526	1417307.	-9625.	-2.05E-04	762.0351	3.15E+11	-44.0458	34150.	0.00
26.5200	0.00446	1378038.	-9796.	-1.87E-04	753.4617	3.15E+11	-39.6243	36230.	0.00
26.8600	0.00373	1338075.	-9949.	-1.70E-04	744.7370	3.15E+11	-35.0701	38311.	0.00
27.2000	0.00308	1297495.	-10082.	-1.53E-04	735.8777	3.15E+11	-30.4733	40392.	0.00
27.5400	0.00249	1256377.	-10197.	-1.36E-04	726.9008	3.15E+11	-25.9200	42473.	0.00
27.8800	0.00197	1214797.	-10294.	-1.20E-04	717.8230	3.15E+11	-21.4911	44554.	0.00
28.2200	0.00151	1172829.	-10373.	-1.05E-04	708.6607	3.15E+11	-17.2631	46634.	0.00
28.5600	0.00111	1130546.	-10435.	-8.97E-05	699.4294	3.15E+11	-13.3076	48715.	0.00
28.9000	7.78E-04	1088013.	-14693.	-7.53E-05	690.1437	3.15E+11	-2074.	1.09E+07	0.00
29.2400	5.00E-04	1010933.	-21640.	-6.18E-05	673.3156	3.15E+11	-1331.	1.09E+07	0.00
29.5800	2.75E-04	911664.	-25848.	-4.93E-05	651.6433	3.15E+11	-731.3814	1.09E+07	0.00
29.9200	9.74E-05	800198.	-27870.	-3.82E-05	627.3081	3.15E+11	-259.5245	1.09E+07	0.00
30.2600	-3.75E-05	684393.	-28195.	-2.86E-05	602.0255	3.15E+11	99.7705	1.09E+07	0.00
30.6000	-1.36E-04	570231.	-27252.	-2.05E-05	577.1018	3.15E+11	362.7938	1.09E+07	0.00
30.9400	-2.05E-04	462095.	-25399.	-1.38E-05	553.4936	3.15E+11	545.6041	1.09E+07	0.00
31.2800	-2.49E-04	363030.	-22932.	-8.49E-06	531.8658	3.15E+11	663.4126	1.09E+07	0.00
31.6200	-2.74E-04	275000.	-20089.	-4.36E-06	512.6470	3.15E+11	730.1546	1.09E+07	0.00
31.9600	-2.85E-04	199117.	-17053.	-1.29E-06	496.0804	3.15E+11	758.2130	1.09E+07	0.00
32.3000	-2.85E-04	135851.	-13960.	8.75E-07	482.2682	3.15E+11	758.2621	1.09E+07	0.00
32.6400	-2.77E-04	85205.	-10905.	2.31E-06	471.2110	3.15E+11	739.2014	1.09E+07	0.00
32.9800	-2.66E-04	46861.	-7952.	3.16E-06	462.8397	3.15E+11	708.1551	1.09E+07	0.00
33.3200	-2.52E-04	20304.	-5140.	3.59E-06	457.0419	3.15E+11	670.5171	1.09E+07	0.00
33.6600	-2.36E-04	4908.	-2486.	3.76E-06	453.6807	3.15E+11	630.0230	1.09E+07	0.00
34.0000	-2.21E-04	0.00	0.00	3.79E-06	452.6091	3.15E+11	588.8384	5434560.	0.00

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

Output Summary for Load Case No. 2:

```
Pile-head deflection             =     0.19290753 inches
Computed slope at pile head      =       0.000000 radians
Maximum bending moment           =       1744451. inch-lbs
Maximum shear force              =        -28195. lbs
Depth of maximum bending moment  =    22.44000000 feet below pile head
Depth of maximum shear force     =    30.26000000 feet below pile head
Number of iterations             =              6
Number of zero deflection points =              1
```

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	15690.	M, in-lb	1160040.	466900.	0.9754	-0.00532	-88508.	5615196.
2	V, lb	12740.	S, rad	0.00	460700.	0.1929	0.00	-28195.	1744451.

Maximum pile-head deflection = 0.9754129244 inches
Maximum pile-head rotation = -0.0053248847 radians = -0.305093 deg.

The analysis ended normally.

SINCE 1881

FROEHLING & ROBERTSON, INC.

Engineering • Environmental • Geotechnical

SHEET NO. 1 OF 1

JOB BR-0082 Bridge 56 DATE 4/29/2020

COMPUTATIONS FOR Bent 2, Left BY CW CHKD

Based on bridge log B2-A & loads provided by WE2 on 5-5-2020

Depth (ft)		EL (ft)
0	Bot: EL 178.6	178.6
	ϕ column = 3 inch.	
8	Top of Pile1 = EL 170.6	170.6
19.6	DSE: EL 159.0'	159.0
20.5	① SAT γ=58 ϕ=32° k=60	158.1
24.3	② CR PI 25% passing γ=121 q_u=3325 PSI	154.3
26.9	③ MR γ=100 c=5000 ε=0.004 k=2000	151.7
42.7	④ CR γ=121 q_u=3,325 PSI	135.9

① Model max. longitudinal shear as free head

V = 15,690 lbs. M = 4,160,040 lbs-in, Axial = 466,900 lbs

Per LPILE analysis

⇒ y = 0.55", 1st neg = 22.4' (EL 156.2'), max neg = 24.6 (EL 154.0')

② Model max transverse shear as fixed head

V = 12,740 lbs. slope = 0, Axial = 460,700 lbs

⇒ y = 0.41", 1st neg = 22.4' (EL 156.2'), max neg = 24.6 (EL 154.0')

∴ PST: EL 155.0'

Mintip: 1.5B below 1st negative: EL 151.7'

1.0B below max negative = EL 151.0'

∴ Mintip per Lateral analysis = EL 151.0'

Mintip per Axial ② EL 151.0'

Form No. 502
Revised 05/2008

∴ Mintip @ Bent 2, Rt is EL 151.0'

LPile for Windows, Version 2018-10.003

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

This copy of LPile is being used by:

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Files Used for Analysis

Path to file locations:
\Projects 66X\66X-0152 (WEI-Bridge 56 Harnett Co)\BR0082_GEO_BRDG0056\NON_CADD\Foundation Recommendation\Lateral Analysis\

Name of input data file:
Bent 2 Left.lp10

Name of output report file:
Bent 2 Left.lp10

Name of plot output file:
Bent 2 Left.lp10

Name of runtime message file:
Bent 2 Left.lp10

Date and Time of Analysis

Date: May 6, 2020 Time: 10:33:39

Problem Title

Project Name: Bridge 56 Harnett County

Job Number: 66X-0152

Client: WEI

Engineer: CW

Description: Bent 2 Left

Program Options and Settings

Computational Options:
 - Use unfactored loads in computations (conventional analysis)
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

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

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

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - No distributed lateral loads are entered
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

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

Pile Structural Properties and Geometry

Number of pile sections defined = 2
Total length of pile = 28.000 ft
Depth of ground surface below top of pile = 19.6000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	30.0000
2	8.000	30.0000

3	8.000	36.0000
4	28.000	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	8.000000 ft
Width of top of section	=	30.000000 in
Width of bottom of section	=	30.000000 in
Top Area	=	706.858347 sq. in
Bottom Area	=	706.858347 sq. in
Moment of Inertia at Top	=	39761. in^4
Moment of Inertia at Bottom	=	39761. in^4
Elastic Modulus	=	3122019. psi

Pile Section No. 2:

Section 2 is an elastic pile		
Cross-sectional Shape	=	Circular Pile
Length of section	=	20.000000 ft
Width of top of section	=	36.000000 in
Width of bottom of section	=	36.000000 in
Top Area	=	1018. sq. in
Bottom Area	=	1018. sq. in
Moment of Inertia at Top	=	82448. in^4
Moment of Inertia at Bottom	=	82448. in^4
Elastic Modulus	=	3823676. psi

Ground Slope and Pile Batter Angles

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

Soil and Rock Layering Information

The soil profile is modelled using 4 layers

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

Distance from top of pile to top of layer	=	19.600000 ft
Distance from top of pile to bottom of layer	=	20.500000 ft
Effective unit weight at top of layer	=	58.000000 pcf
Effective unit weight at bottom of layer	=	58.000000 pcf
Friction angle at top of layer	=	32.000000 deg.
Friction angle at bottom of layer	=	32.000000 deg.
Subgrade k at top of layer	=	60.000000 pci
Subgrade k at bottom of layer	=	60.000000 pci

Layer 2 is strong rock (vuggy limestone)

```
   Distance from top of pile to top of layer           =    20.500000 ft
   Distance from top of pile to bottom of layer        =    24.300000 ft
   Effective unit weight at top of layer               =   171.000000 pcf
   Effective unit weight at bottom of layer            =   171.000000 pcf
   Uniaxial compressive strength at top of layer       =        3351. psi
   Uniaxial compressive strength at bottom of layer    =        3351. psi


Layer 3 is stiff clay with water-induced erosion

   Distance from top of pile to top of layer           =    24.300000 ft
   Distance from top of pile to bottom of layer        =    26.900000 ft
   Effective unit weight at top of layer               =   100.000000 pcf
   Effective unit weight at bottom of layer            =   100.000000 pcf
   Undrained cohesion at top of layer                  =        5000. psf
   Undrained cohesion at bottom of layer               =        5000. psf
   Epsilon-50 at top of layer                          =     0.004000
   Epsilon-50 at bottom of layer                       =     0.004000
   Subgrade k at top of layer                          =        2000. pci
   Subgrade k at bottom of layer                       =        2000. pci


Layer 4 is strong rock (vuggy limestone)

   Distance from top of pile to top of layer           =    26.900000 ft
   Distance from top of pile to bottom of layer        =    42.700000 ft
   Effective unit weight at top of layer               =   171.000000 pcf
   Effective unit weight at bottom of layer            =   171.000000 pcf
   Uniaxial compressive strength at top of layer       =        3351. psi
   Uniaxial compressive strength at bottom of layer    =        3351. psi


 (Depth of the lowest soil layer extends 14.700 ft below the pile tip)


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

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

The maximum input value, in layer   3, for effective unit weight = 171.00 pcf

This data may be erroneous. Please check your data.
```

Summary of Input Soil Properties

Layer Num.	Soil Type (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Angle of Friction deg.	Uniaxial qu psi	E50 or krm	kpy pci
1	Sand (Reese, et al.)	19.6000 20.5000	58.0000 58.0000	-- --	32.0000 32.0000	-- --	-- --	60.0000 60.0000
2	Strong Rock (Vuggy Limestone)	20.5000 24.3000	171.0000 171.0000	-- --	-- --	3351. 3351.	-- --	--
3	Stiff Clay	24.3000	100.0000	5000.	--	--	0.00400	

2000.								
	with Free Water	26.9000	100.0000	5000.	--	--	0.00400	
2000.								
4	Strong Rock	26.9000	171.0000	--	--	3351.	--	--
	(Vuggy Limestone)	42.7000	171.0000	--	--	3351.	--	--

Static Loading Type

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

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1		Condition 2		Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V =	15690. lbs	M =	1160040. in-lbs	466900.	No
2	2	V =	12740. lbs	S =	0.0000 in/in	460700.	No

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

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

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

Number of Pile Sections Analyzed = 2

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

Pile Section No. 2:

Moment-curvature properties were derived from elastic section properties

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Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head	Equivalent Top Depth Below Grnd Surf	Same Layer Type As Layer	Layer is Rock or is Below	F0 Integral for Layer	F1 Integral for Layer

	ft	ft	Above	Rock Layer	lbs	lbs
1	19.6000	0.00	N.A.	No	0.00	645.3567
2	20.5000	0.9000	No	Yes	N.A.	N.A.
3	24.3000	4.7000	No	Yes	N.A.	N.A.
4	26.9000	7.3000	No	Yes	N.A.	N.A.

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

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

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

Shear force at pile head = 15690.0 lbs
Applied moment at pile head = 1160040.0 in-lbs
Axial thrust load on pile head = 466900.0 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	0.5511	1160040.	15690.	-0.00394	1098.	1.24E+11	0.00	0.00	0.00
0.2800	0.5379	1218914.	15690.	-0.00391	1120.	1.24E+11	0.00	0.00	0.00
0.5600	0.5248	1277737.	15690.	-0.00387	1143.	1.24E+11	0.00	0.00	0.00
0.8400	0.5119	1336505.	15690.	-0.00384	1165.	1.24E+11	0.00	0.00	0.00
1.1200	0.4990	1395217.	15690.	-0.00380	1187.	1.24E+11	0.00	0.00	0.00
1.4000	0.4863	1453870.	15690.	-0.00376	1209.	1.24E+11	0.00	0.00	0.00
1.6800	0.4737	1512460.	15690.	-0.00372	1231.	1.24E+11	0.00	0.00	0.00
1.9600	0.4613	1570987.	15690.	-0.00368	1253.	1.24E+11	0.00	0.00	0.00
2.2400	0.4490	1629446.	15690.	-0.00364	1275.	1.24E+11	0.00	0.00	0.00
2.5200	0.4369	1687837.	15690.	-0.00359	1297.	1.24E+11	0.00	0.00	0.00
2.8000	0.4249	1746156.	15690.	-0.00355	1319.	1.24E+11	0.00	0.00	0.00
3.0800	0.4130	1804400.	15690.	-0.00350	1341.	1.24E+11	0.00	0.00	0.00
3.3600	0.4014	1862569.	15690.	-0.00345	1363.	1.24E+11	0.00	0.00	0.00
3.6400	0.3898	1920658.	15690.	-0.00340	1385.	1.24E+11	0.00	0.00	0.00
3.9200	0.3785	1978665.	15690.	-0.00334	1407.	1.24E+11	0.00	0.00	0.00
4.2000	0.3674	2036588.	15690.	-0.00329	1429.	1.24E+11	0.00	0.00	0.00
4.4800	0.3564	2094425.	15690.	-0.00323	1451.	1.24E+11	0.00	0.00	0.00
4.7600	0.3456	2152173.	15690.	-0.00318	1472.	1.24E+11	0.00	0.00	0.00
5.0400	0.3351	2209830.	15690.	-0.00312	1494.	1.24E+11	0.00	0.00	0.00
5.3200	0.3247	2267393.	15690.	-0.00306	1516.	1.24E+11	0.00	0.00	0.00
5.6000	0.3145	2324859.	15690.	-0.00300	1538.	1.24E+11	0.00	0.00	0.00
5.8800	0.3046	2382227.	15690.	-0.00293	1559.	1.24E+11	0.00	0.00	0.00
6.1600	0.2948	2439494.	15690.	-0.00287	1581.	1.24E+11	0.00	0.00	0.00
6.4400	0.2853	2496657.	15690.	-0.00280	1602.	1.24E+11	0.00	0.00	0.00
6.7200	0.2760	2553714.	15690.	-0.00273	1624.	1.24E+11	0.00	0.00	0.00
7.0000	0.2669	2610663.	15690.	-0.00266	1645.	1.24E+11	0.00	0.00	0.00
7.2800	0.2581	2667500.	15690.	-0.00259	1667.	1.24E+11	0.00	0.00	0.00
7.5600	0.2495	2724225.	15690.	-0.00252	1688.	1.24E+11	0.00	0.00	0.00
7.8400	0.2412	2780833.	15690.	-0.00244	1710.	1.24E+11	0.00	0.00	0.00
8.1200	0.2331	2837324.	15690.	-0.00239	1078.	3.15E+11	0.00	0.00	0.00
8.4000	0.2252	2893767.	15690.	-0.00236	1090.	3.15E+11	0.00	0.00	0.00
8.6800	0.2173	2950162.	15690.	-0.00233	1103.	3.15E+11	0.00	0.00	0.00
8.9600	0.2095	3006508.	15690.	-0.00230	1115.	3.15E+11	0.00	0.00	0.00
9.2400	0.2018	3062803.	15690.	-0.00226	1127.	3.15E+11	0.00	0.00	0.00
9.5200	0.1943	3119047.	15690.	-0.00223	1140.	3.15E+11	0.00	0.00	0.00
9.8000	0.1869	3175239.	15690.	-0.00220	1152.	3.15E+11	0.00	0.00	0.00

10.0800	0.1795	3231378.	15690.	-0.00216	1164.	3.15E+11	0.00	0.00	0.00
10.3600	0.1723	3287463.	15690.	-0.00213	1176.	3.15E+11	0.00	0.00	0.00
10.6400	0.1652	3343493.	15690.	-0.00209	1189.	3.15E+11	0.00	0.00	0.00
10.9200	0.1583	3399467.	15690.	-0.00206	1201.	3.15E+11	0.00	0.00	0.00
11.2000	0.1514	3455384.	15690.	-0.00202	1213.	3.15E+11	0.00	0.00	0.00
11.4800	0.1447	3511243.	15690.	-0.00198	1225.	3.15E+11	0.00	0.00	0.00
11.7600	0.1381	3567044.	15690.	-0.00195	1237.	3.15E+11	0.00	0.00	0.00
12.0400	0.1316	3622785.	15690.	-0.00191	1250.	3.15E+11	0.00	0.00	0.00
12.3200	0.1253	3678465.	15690.	-0.00187	1262.	3.15E+11	0.00	0.00	0.00
12.6000	0.1190	3734084.	15690.	-0.00183	1274.	3.15E+11	0.00	0.00	0.00
12.8800	0.1130	3789640.	15690.	-0.00179	1286.	3.15E+11	0.00	0.00	0.00
13.1600	0.1070	3845133.	15690.	-0.00175	1298.	3.15E+11	0.00	0.00	0.00
13.4400	0.1012	3900562.	15690.	-0.00171	1310.	3.15E+11	0.00	0.00	0.00
13.7200	0.09555	3955926.	15690.	-0.00167	1322.	3.15E+11	0.00	0.00	0.00
14.0000	0.09003	4011223.	15690.	-0.00162	1334.	3.15E+11	0.00	0.00	0.00
14.2800	0.08465	4066454.	15690.	-0.00158	1346.	3.15E+11	0.00	0.00	0.00
14.5600	0.07942	4121616.	15690.	-0.00154	1359.	3.15E+11	0.00	0.00	0.00
14.8400	0.07433	4176709.	15690.	-0.00149	1371.	3.15E+11	0.00	0.00	0.00
15.1200	0.06939	4231733.	15690.	-0.00145	1383.	3.15E+11	0.00	0.00	0.00
15.4000	0.06461	4286686.	15690.	-0.00140	1395.	3.15E+11	0.00	0.00	0.00
15.6800	0.05997	4341567.	15690.	-0.00136	1407.	3.15E+11	0.00	0.00	0.00
15.9600	0.05550	4396376.	15690.	-0.00131	1419.	3.15E+11	0.00	0.00	0.00
16.2400	0.05118	4451111.	15690.	-0.00126	1430.	3.15E+11	0.00	0.00	0.00
16.5200	0.04702	4505771.	15690.	-0.00121	1442.	3.15E+11	0.00	0.00	0.00
16.8000	0.04302	4560357.	15690.	-0.00117	1454.	3.15E+11	0.00	0.00	0.00
17.0800	0.03918	4614866.	15690.	-0.00112	1466.	3.15E+11	0.00	0.00	0.00
17.3600	0.03551	4669298.	15690.	-0.00107	1478.	3.15E+11	0.00	0.00	0.00
17.6400	0.03201	4723652.	15690.	-0.00102	1490.	3.15E+11	0.00	0.00	0.00
17.9200	0.02868	4777926.	15690.	-9.67E-04	1502.	3.15E+11	0.00	0.00	0.00
18.2000	0.02552	4832121.	15690.	-9.15E-04	1514.	3.15E+11	0.00	0.00	0.00
18.4800	0.02253	4886236.	15690.	-8.64E-04	1525.	3.15E+11	0.00	0.00	0.00
18.7600	0.01971	4940268.	15690.	-8.11E-04	1537.	3.15E+11	0.00	0.00	0.00
19.0400	0.01707	4994218.	15690.	-7.58E-04	1549.	3.15E+11	0.00	0.00	0.00
19.3200	0.01462	5048084.	15690.	-7.05E-04	1561.	3.15E+11	0.00	0.00	0.00
19.6000	0.01234	5101866.	15690.	-6.51E-04	1573.	3.15E+11	0.00	0.00	0.00
19.8800	0.01024	5155563.	15687.	-5.96E-04	1584.	3.15E+11	-2.0648	677.3760	0.00
20.1600	0.00833	5209150.	15677.	-5.41E-04	1596.	3.15E+11	-3.3592	1355.	0.00
20.4400	0.00661	5262612.	15665.	-4.85E-04	1608.	3.15E+11	-3.9960	2032.	0.00
20.7200	0.00507	5315941.	-12893.	-4.29E-04	1619.	3.15E+11	-16995.	1.13E+07	0.00
21.0000	0.00373	5177317.	-62422.	-3.73E-04	1589.	3.15E+11	-12487.	1.13E+07	0.00
21.2800	0.00257	4897635.	-97848.	-3.19E-04	1528.	3.15E+11	-8600.	1.13E+07	0.00
21.5600	0.00158	4520778.	-121203.	-2.69E-04	1446.	3.15E+11	-5301.	1.13E+07	0.00
21.8400	7.59E-04	4083997.	-134384.	-2.23E-04	1350.	3.15E+11	-2545.	1.13E+07	0.00
22.1200	8.31E-05	3618416.	-139127.	-1.82E-04	1249.	3.15E+11	-278.5392	1.13E+07	0.00
22.4000	-4.64E-04	3149631.	-136985.	-1.46E-04	1146.	3.15E+11	1554.	1.13E+07	0.00
22.6800	-8.98E-04	2698332.	-129323.	-1.15E-04	1048.	3.15E+11	3008.	1.13E+07	0.00
22.9600	-0.00123	2280944.	-117318.	-8.82E-05	956.6748	3.15E+11	4138.	1.13E+07	0.00
23.2400	-0.00149	1910234.	-101975.	-6.59E-05	875.7416	3.15E+11	4995.	1.13E+07	0.00
23.5200	-0.00168	1595879.	-84139.	-4.72E-05	807.1119	3.15E+11	5622.	1.13E+07	0.00
23.8000	-0.00181	1344968.	-64517.	-3.15E-05	752.3331	3.15E+11	6058.	1.13E+07	0.00
24.0800	-0.00189	1162425.	-43701.	-1.82E-05	712.4804	3.15E+11	6332.	1.13E+07	0.00
24.3600	-0.00193	1051353.	-32693.	-6.38E-06	688.2311	3.15E+11	220.4786	383846.	0.00
24.6400	-0.00193	942751.	-31929.	4.24E-06	664.5213	3.15E+11	233.7657	406426.	0.00
24.9200	-0.00190	836774.	-31129.	1.37E-05	641.3843	3.15E+11	242.7774	429005.	0.00
25.2000	-0.00184	733523.	-30305.	2.21E-05	618.8426	3.15E+11	247.3434	451584.	0.00
25.4800	-0.00175	633052.	-29474.	2.94E-05	596.9078	3.15E+11	247.3811	474163.	0.00
25.7600	-0.00164	535363.	-28651.	3.56E-05	575.5805	3.15E+11	242.8931	496742.	0.00
26.0400	-0.00151	440408.	-27850.	4.08E-05	554.8499	3.15E+11	233.9630	519322.	0.00
26.3200	-0.00137	348086.	-27086.	4.50E-05	534.6943	3.15E+11	220.7526	541901.	0.00
26.6000	-0.00121	258251.	-26373.	4.82E-05	515.0816	3.15E+11	203.4995	564480.	0.00
26.8800	-0.00104	170710.	-25724.	5.05E-05	495.9695	3.15E+11	182.5145	587059.	0.00
27.1600	-8.72E-04	85225.	-20510.	5.19E-05	477.3066	3.15E+11	2921.	1.13E+07	0.00
27.4400	-6.96E-04	32721.	-11684.	5.25E-05	465.8440	3.15E+11	2332.	1.13E+07	0.00
27.7200	-5.19E-04	6545.	-4845.	5.27E-05	460.1292	3.15E+11	1739.	1.13E+07	0.00
28.0000	-3.42E-04	0.00	0.00	5.28E-05	458.7003	3.15E+11	1145.	5629680.	0.00

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

Output Summary for Load Case No. 1:

```
Pile-head deflection             =     0.55107865 inches
Computed slope at pile head      =    -0.00393977 radians
Maximum bending moment           =       5315941. inch-lbs
Maximum shear force              =       -139127. lbs
Depth of maximum bending moment  =    20.72000000 feet below pile head
Depth of maximum shear force     =    22.12000000 feet below pile head
Number of iterations             =              6
Number of zero deflection points =              1
```

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

Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

```
Shear force at pile head                          =      12740.0 lbs
Rotation of pile head                             =    0.000E+00 radians
Axial load at pile head                           =     460700.0 lbs
```

(Zero slope for this load indicates fixed-head conditions)

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	0.1053	-1362302.	12740.	0.00	1166.	1.24E+11	0.00	0.00	0.00
0.2800	0.1052	-1319467.	12740.	-3.63E-05	1150.	1.24E+11	0.00	0.00	0.00
0.5600	0.1051	-1276577.	12740.	-7.14E-05	1133.	1.24E+11	0.00	0.00	0.00
0.8400	0.1048	-1233633.	12740.	-1.05E-04	1117.	1.24E+11	0.00	0.00	0.00
1.1200	0.1044	-1190637.	12740.	-1.38E-04	1101.	1.24E+11	0.00	0.00	0.00
1.4000	0.1038	-1147592.	12740.	-1.70E-04	1085.	1.24E+11	0.00	0.00	0.00
1.6800	0.1032	-1104499.	12740.	-2.00E-04	1068.	1.24E+11	0.00	0.00	0.00
1.9600	0.1025	-1061359.	12740.	-2.30E-04	1052.	1.24E+11	0.00	0.00	0.00
2.2400	0.1017	-1018175.	12740.	-2.58E-04	1036.	1.24E+11	0.00	0.00	0.00
2.5200	0.1008	-974948.	12740.	-2.85E-04	1020.	1.24E+11	0.00	0.00	0.00
2.8000	0.09975	-931681.	12740.	-3.11E-04	1003.	1.24E+11	0.00	0.00	0.00
3.0800	0.09867	-888374.	12740.	-3.35E-04	986.9017	1.24E+11	0.00	0.00	0.00
3.3600	0.09750	-845030.	12740.	-3.59E-04	970.5500	1.24E+11	0.00	0.00	0.00
3.6400	0.09626	-801651.	12740.	-3.81E-04	954.1849	1.24E+11	0.00	0.00	0.00
3.9200	0.09494	-758238.	12740.	-4.02E-04	937.8071	1.24E+11	0.00	0.00	0.00
4.2000	0.09355	-714793.	12740.	-4.22E-04	921.4173	1.24E+11	0.00	0.00	0.00
4.4800	0.09210	-671319.	12740.	-4.41E-04	905.0163	1.24E+11	0.00	0.00	0.00
4.7600	0.09059	-627816.	12740.	-4.58E-04	888.6046	1.24E+11	0.00	0.00	0.00
5.0400	0.08902	-584287.	12740.	-4.75E-04	872.1830	1.24E+11	0.00	0.00	0.00
5.3200	0.08740	-540733.	12740.	-4.90E-04	855.7521	1.24E+11	0.00	0.00	0.00
5.6000	0.08573	-497157.	12740.	-5.04E-04	839.3128	1.24E+11	0.00	0.00	0.00
5.8800	0.08402	-453560.	12740.	-5.17E-04	822.8655	1.24E+11	0.00	0.00	0.00
6.1600	0.08226	-409944.	12740.	-5.29E-04	806.4111	1.24E+11	0.00	0.00	0.00
6.4400	0.08046	-366311.	12740.	-5.39E-04	789.9502	1.24E+11	0.00	0.00	0.00
6.7200	0.07864	-322662.	12740.	-5.48E-04	773.4836	1.24E+11	0.00	0.00	0.00
7.0000	0.07678	-279000.	12740.	-5.57E-04	757.0118	1.24E+11	0.00	0.00	0.00
7.2800	0.07490	-235327.	12740.	-5.63E-04	740.5356	1.24E+11	0.00	0.00	0.00
7.5600	0.07299	-191643.	12740.	-5.69E-04	724.0557	1.24E+11	0.00	0.00	0.00
7.8400	0.07107	-147951.	12740.	-5.74E-04	707.5728	1.24E+11	0.00	0.00	0.00
8.1200	0.06914	-104254.	12740.	-5.76E-04	475.3697	3.15E+11	0.00	0.00	0.00
8.4000	0.06720	-60554.	12740.	-5.77E-04	465.8293	3.15E+11	0.00	0.00	0.00
8.6800	0.06526	-16853.	12740.	-5.78E-04	456.2886	3.15E+11	0.00	0.00	0.00
8.9600	0.06331	26847.	12740.	-5.78E-04	458.4705	3.15E+11	0.00	0.00	0.00
9.2400	0.06137	70548.	12740.	-5.77E-04	468.0111	3.15E+11	0.00	0.00	0.00
9.5200	0.05944	114247.	12740.	-5.76E-04	477.5515	3.15E+11	0.00	0.00	0.00

9.8000	0.05750	157944.	12740.	-5.75E-04	487.0915	3.15E+11	0.00	0.00	0.00
10.0800	0.05557	201639.	12740.	-5.73E-04	496.6309	3.15E+11	0.00	0.00	0.00
10.3600	0.05365	245330.	12740.	-5.70E-04	506.1696	3.15E+11	0.00	0.00	0.00
10.6400	0.05174	289018.	12740.	-5.68E-04	515.7074	3.15E+11	0.00	0.00	0.00
10.9200	0.04984	332700.	12740.	-5.64E-04	525.2441	3.15E+11	0.00	0.00	0.00
11.2000	0.04795	376377.	12740.	-5.60E-04	534.7797	3.15E+11	0.00	0.00	0.00
11.4800	0.04607	420048.	12740.	-5.56E-04	544.3139	3.15E+11	0.00	0.00	0.00
11.7600	0.04421	463712.	12740.	-5.52E-04	553.8466	3.15E+11	0.00	0.00	0.00
12.0400	0.04237	507369.	12740.	-5.46E-04	563.3776	3.15E+11	0.00	0.00	0.00
12.3200	0.04054	551017.	12740.	-5.41E-04	572.9068	3.15E+11	0.00	0.00	0.00
12.6000	0.03873	594655.	12740.	-5.35E-04	582.4340	3.15E+11	0.00	0.00	0.00
12.8800	0.03695	638284.	12740.	-5.28E-04	591.9591	3.15E+11	0.00	0.00	0.00
13.1600	0.03518	681903.	12740.	-5.21E-04	601.4819	3.15E+11	0.00	0.00	0.00
13.4400	0.03345	725510.	12740.	-5.13E-04	611.0022	3.15E+11	0.00	0.00	0.00
13.7200	0.03173	769105.	12740.	-5.06E-04	620.5199	3.15E+11	0.00	0.00	0.00
14.0000	0.03005	812688.	12740.	-4.97E-04	630.0348	3.15E+11	0.00	0.00	0.00
14.2800	0.02839	856257.	12740.	-4.88E-04	639.5468	3.15E+11	0.00	0.00	0.00
14.5600	0.02677	899812.	12740.	-4.79E-04	649.0558	3.15E+11	0.00	0.00	0.00
14.8400	0.02518	943353.	12740.	-4.69E-04	658.5614	3.15E+11	0.00	0.00	0.00
15.1200	0.02362	986877.	12740.	-4.59E-04	668.0637	3.15E+11	0.00	0.00	0.00
15.4000	0.02209	1030386.	12740.	-4.48E-04	677.5624	3.15E+11	0.00	0.00	0.00
15.6800	0.02061	1073877.	12740.	-4.37E-04	687.0575	3.15E+11	0.00	0.00	0.00
15.9600	0.01916	1117351.	12740.	-4.25E-04	696.5486	3.15E+11	0.00	0.00	0.00
16.2400	0.01775	1160806.	12740.	-4.13E-04	706.0357	3.15E+11	0.00	0.00	0.00
16.5200	0.01638	1204242.	12740.	-4.00E-04	715.5187	3.15E+11	0.00	0.00	0.00
16.8000	0.01506	1247658.	12740.	-3.87E-04	724.9973	3.15E+11	0.00	0.00	0.00
17.0800	0.01378	1291054.	12740.	-3.74E-04	734.4714	3.15E+11	0.00	0.00	0.00
17.3600	0.01255	1334428.	12740.	-3.60E-04	743.9408	3.15E+11	0.00	0.00	0.00
17.6400	0.01136	1377780.	12740.	-3.45E-04	753.4055	3.15E+11	0.00	0.00	0.00
17.9200	0.01023	1421110.	12740.	-3.30E-04	762.8652	3.15E+11	0.00	0.00	0.00
18.2000	0.00914	1464416.	12740.	-3.15E-04	772.3198	3.15E+11	0.00	0.00	0.00
18.4800	0.00811	1507698.	12740.	-2.99E-04	781.7691	3.15E+11	0.00	0.00	0.00
18.7600	0.00713	1550955.	12740.	-2.83E-04	791.2129	3.15E+11	0.00	0.00	0.00
19.0400	0.00621	1594187.	12740.	-2.66E-04	800.6512	3.15E+11	0.00	0.00	0.00
19.3200	0.00534	1637392.	12740.	-2.49E-04	810.0838	3.15E+11	0.00	0.00	0.00
19.6000	0.00454	1680570.	12740.	-2.31E-04	819.5104	3.15E+11	0.00	0.00	0.00
19.8800	0.00379	1723720.	12739.	-2.13E-04	828.9310	3.15E+11	-0.7638	677.3760	0.00
20.1600	0.00310	1766834.	12735.	-1.94E-04	838.3435	3.15E+11	-1.2514	1355.	0.00
20.4400	0.00248	1809904.	12731.	-1.75E-04	847.7465	3.15E+11	-1.5010	2032.	0.00
20.7200	0.00192	1852927.	1892.	-1.56E-04	857.1394	3.15E+11	-6450.	1.13E+07	0.00
21.0000	0.00143	1823102.	-17018.	-1.36E-04	850.6280	3.15E+11	-4806.	1.13E+07	0.00
21.2800	0.00101	1738991.	-30770.	-1.17E-04	832.2650	3.15E+11	-3380.	1.13E+07	0.00
21.5600	6.46E-04	1616688.	-40085.	-9.94E-05	805.5638	3.15E+11	-2164.	1.13E+07	0.00
21.8400	3.40E-04	1469931.	-45636.	-8.30E-05	773.5239	3.15E+11	-1141.	1.13E+07	0.00
22.1200	8.79E-05	1310268.	-48049.	-6.82E-05	738.6663	3.15E+11	-294.7104	1.13E+07	0.00
22.4000	-1.18E-04	1147256.	-47881.	-5.51E-05	703.0776	3.15E+11	394.3573	1.13E+07	0.00
22.6800	-2.82E-04	988678.	-45630.	-4.37E-05	668.4568	3.15E+11	945.7508	1.13E+07	0.00
22.9600	-4.11E-04	840760.	-41725.	-3.40E-05	636.1635	3.15E+11	1379.	1.13E+07	0.00
23.2400	-5.10E-04	708391.	-36536.	-2.57E-05	607.2648	3.15E+11	1710.	1.13E+07	0.00
23.5200	-5.84E-04	595320.	-30374.	-1.88E-05	582.5791	3.15E+11	1957.	1.13E+07	0.00
23.8000	-6.36E-04	504335.	-23503.	-1.29E-05	562.7152	3.15E+11	2133.	1.13E+07	0.00
24.0800	-6.71E-04	437417.	-16145.	-7.87E-06	548.1059	3.15E+11	2247.	1.13E+07	0.00
24.3600	-6.89E-04	395866.	-12237.	-3.43E-06	539.0345	3.15E+11	78.7471	383846.	0.00
24.6400	-6.94E-04	355198.	-11963.	5.71E-07	530.1557	3.15E+11	83.9167	406426.	0.00
24.9200	-6.85E-04	315471.	-11675.	4.14E-06	521.4825	3.15E+11	87.5219	429005.	0.00
25.2000	-6.66E-04	276726.	-11378.	7.30E-06	513.0239	3.15E+11	89.4975	451584.	0.00
25.4800	-6.36E-04	238988.	-11077.	1.00E-05	504.7849	3.15E+11	89.8116	474163.	0.00
25.7600	-5.98E-04	202260.	-10777.	1.24E-05	496.7664	3.15E+11	88.4641	496742.	0.00
26.0400	-5.53E-04	166527.	-10485.	1.44E-05	488.9651	3.15E+11	85.4858	519322.	0.00
26.3200	-5.02E-04	131756.	-10205.	1.60E-05	481.3740	3.15E+11	80.9370	541901.	0.00
26.6000	-4.46E-04	97897.	-9944.	1.72E-05	473.9819	3.15E+11	74.9069	564480.	0.00
26.8800	-3.86E-04	64882.	-9704.	1.80E-05	466.7741	3.15E+11	67.5119	587059.	0.00
27.1600	-3.25E-04	32628.	-7763.	1.86E-05	459.7325	3.15E+11	1088.	1.13E+07	0.00
27.4400	-2.62E-04	12654.	-4463.	1.88E-05	455.3717	3.15E+11	876.7500	1.13E+07	0.00
27.7200	-1.98E-04	2577.	-1874.	1.89E-05	453.1718	3.15E+11	664.2344	1.13E+07	0.00
28.0000	-1.35E-04	0.00	0.00	1.89E-05	452.6091	3.15E+11	451.4096	5629680.	0.00

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

Output Summary for Load Case No. 2:

```
Pile-head deflection             =     0.10530305 inches
Computed slope at pile head      =       0.000000 radians
Maximum bending moment           =       1852927. inch-lbs
Maximum shear force              =        -48049. lbs
Depth of maximum bending moment  =    20.72000000 feet below pile head
Depth of maximum shear force     =    22.12000000 feet below pile head
Number of iterations             =              6
Number of zero deflection points =              1
```

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	15690.	M, in-lb	1160040.	466900.	0.5511	-0.00394	-139127.	5315941.
2	V, lb	12740.	S, rad	0.00	460700.	0.1053	0.00	-48049.	1852927.

Maximum pile-head deflection = 0.5510786487 inches
Maximum pile-head rotation   = -0.0039397672 radians = -0.225732 deg.

The analysis ended normally.

SINCE 1881

FROEHLING & ROBERTSON, INC.

Engineering • Environmental • Geotechnical

SHEET NO. 1 OF 1

JOB BR-0082 Bridge 56 DATE 4/29/2020

COMPUTATIONS FOR Bent 2, right Lateral BY CW CHKD

Based on Boring 139 B-B & loads provided by NCDOT on 5-5-2020

Depth (ft)		EL (ft)
0	BK = EL 178.6	178.6
	4' column = 30"	
8'	Top of pier = EL 170.6	170.6
19.6	DSE = EL 159.0'	159.0'
20.9	① WR r=100 c=5000 ε=0.004 k=2000	157.7'
25.9	② CR per RS-4 rankins r=164 q_u = 1,520 psi	152.7'
27.5	③ WR r=100 c=5,000 ε=0.004 k=2,000	151.1'
42.9	④ CR per RS-5 rankins r=170 q_u = 3,948 psi	137.7'

① Model max. longitudinal shear as free head

V = 15,690 lbs, M = 1,160,040 lbs-in, Axial = 466,900 lbs per LPILE analysis

⇒ y = 0.59", 1st neg = 23.0' (EL 153.6'), max neg = 25.2' (EL 151.4')

② Model max. transverse shear as fixed head

V = 12,740 lbs, slope = 0, Axial = 460,700 lbs

⇒ y = 0.11", 1st neg = 23.2' (EL 155.4'), max neg = 25.5' (EL 153.1')

∴ POT = EL 154.0'

MinTip: 1.5B below 1st negative = EL 150.9'

1.0B below max negative = EL 150.1'

∴ MinTip per lateral analysis = EL 150.0' MinTip per Axial ④ EL 150.0'

∴ MinTip @ Bent 2 right EL 150.0'

Form No. 502
Revised 05/2008

LPile for Windows, Version 2018-10.003

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

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Files Used for Analysis

Path to file locations:
\Projects 66X\66X-0152 (WEI-Bridge 56 Harnett Co)\BR0082_GEO_BRDG0056\NON_CADD\Foundation Recommendation\Lateral Analysis\

Name of input data file:
Bent 2 Right.lp10

Name of output report file:
Bent 2 Right.lp10

Name of plot output file:
Bent 2 Right.lp10

Name of runtime message file:
Bent 2 Right.lp10

Date and Time of Analysis

Date: May 6, 2020 Time: 10:41:15

Problem Title

Project Name: Bridge 56 Harnett County

Job Number: 66X-0152

Client: WEI

Engineer: CW

Description: Bent 2 Right

Program Options and Settings

Computational Options:
 - Use unfactored loads in computations (conventional analysis)
Engineering Units Used for Data Input and Computations:
 - US Customary System Units (pounds, feet, inches)

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

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

 - Use of p-y modification factors for p-y curves not selected
 - Analysis uses layering correction (Method of Georgiadis)
 - No distributed lateral loads are entered
 - Loading by lateral soil movements acting on pile not selected
 - Input of shear resistance at the pile tip not selected
 - Computation of pile-head foundation stiffness matrix not selected
 - Push-over analysis of pile not selected
 - Buckling analysis of pile not selected

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

Pile Structural Properties and Geometry

Number of pile sections defined = 2
Total length of pile = 28.000 ft
Depth of ground surface below top of pile = 19.6000 ft

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

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

Point No.	Depth Below Pile Head feet	Pile Diameter inches
1	0.000	30.0000
2	8.000	30.0000

3	8.000	36.0000
4	28.000	36.0000

Input Structural Properties for Pile Sections:

Pile Section No. 1:

Section 1 is an elastic pile

Cross-sectional Shape	=	Circular Pile
Length of section	=	8.000000 ft
Width of top of section	=	30.000000 in
Width of bottom of section	=	30.000000 in
Top Area	=	706.858347 sq. in
Bottom Area	=	706.858347 sq. in
Moment of Inertia at Top	=	39761. in^4
Moment of Inertia at Bottom	=	39761. in^4
Elastic Modulus	=	3122019. psi

Pile Section No. 2:

Section 2 is an elastic pile

Cross-sectional Shape	=	Circular Pile
Length of section	=	20.000000 ft
Width of top of section	=	36.000000 in
Width of bottom of section	=	36.000000 in
Top Area	=	1018. sq. in
Bottom Area	=	1018. sq. in
Moment of Inertia at Top	=	82448. in^4
Moment of Inertia at Bottom	=	82448. in^4
Elastic Modulus	=	3823676. psi

Ground Slope and Pile Batter Angles

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

Soil and Rock Layering Information

The soil profile is modelled using 4 layers

Layer 1 is stiff clay with water-induced erosion

Distance from top of pile to top of layer	=	19.600000 ft
Distance from top of pile to bottom of layer	=	20.900000 ft
Effective unit weight at top of layer	=	100.000000 pcf
Effective unit weight at bottom of layer	=	100.000000 pcf
Undrained cohesion at top of layer	=	5000. psf
Undrained cohesion at bottom of layer	=	5000. psf
Epsilon-50 at top of layer	=	0.004000
Epsilon-50 at bottom of layer	=	0.004000
Subgrade k at top of layer	=	2000. pci
Subgrade k at bottom of layer	=	2000. pci

Layer 2 is strong rock (vuggy limestone)

Distance from top of pile to top of layer	=	20.900000 ft
Distance from top of pile to bottom of layer	=	25.900000 ft
Effective unit weight at top of layer	=	164.000000 pcf
Effective unit weight at bottom of layer	=	164.000000 pcf
Uniaxial compressive strength at top of layer	=	1520. psi
Uniaxial compressive strength at bottom of layer	=	1520. psi

Layer 3 is stiff clay with water-induced erosion

Distance from top of pile to top of layer	=	25.900000 ft
Distance from top of pile to bottom of layer	=	27.500000 ft
Effective unit weight at top of layer	=	100.000000 pcf
Effective unit weight at bottom of layer	=	100.000000 pcf
Undrained cohesion at top of layer	=	5000. psf
Undrained cohesion at bottom of layer	=	5000. psf
Epsilon-50 at top of layer	=	0.004000
Epsilon-50 at bottom of layer	=	0.004000
Subgrade k at top of layer	=	2000. pci
Subgrade k at bottom of layer	=	2000. pci

Layer 4 is strong rock (vuggy limestone)

Distance from top of pile to top of layer	=	27.500000 ft
Distance from top of pile to bottom of layer	=	42.900000 ft
Effective unit weight at top of layer	=	170.000000 pcf
Effective unit weight at bottom of layer	=	170.000000 pcf
Uniaxial compressive strength at top of layer	=	3948. psi
Uniaxial compressive strength at bottom of layer	=	3948. psi

(Depth of the lowest soil layer extends 14.900 ft below the pile tip)

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

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

The maximum input value, in layer 3, for effective unit weight = 170.00 pcf

This data may be erroneous. Please check your data.

Summary of Input Soil Properties

Layer Num.	Soil Type Name (p-y Curve Type)	Layer Depth ft	Effective Unit Wt. pcf	Undrained Cohesion psf	Uniaxial qu psi	E50 or krm	kpy pci
1	Stiff Clay	19.6000	100.0000	5000.	--	0.00400	2000.
	with Free Water	20.9000	100.0000	5000.	--	0.00400	2000.
2	Strong Rock	20.9000	164.0000	--	1520.	--	--
	(Vuggy Limestone)	25.9000	164.0000	--	1520.	--	--
3	Stiff Clay	25.9000	100.0000	5000.	--	0.00400	2000.
	with Free Water	27.5000	100.0000	5000.	--	0.00400	2000.
4	Strong Rock	27.5000	170.0000	--	3948.	--	--
	(Vuggy Limestone)	42.9000	170.0000	--	3948.	--	--

Static Loading Type

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

Pile-head Loading and Pile-head Fixity Conditions

Number of loads specified = 2

Load No.	Load Type	Condition 1	Condition 2	Axial Thrust Force, lbs	Compute Top y vs. Pile Length
1	1	V = 15690. lbs	M = 1160040. in-lbs	466900.	No
2	2	V = 12740. lbs	S = 0.0000 in/in	460700.	No

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

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

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

Number of Pile Sections Analyzed = 2

Pile Section No. 1:

Moment-curvature properties were derived from elastic section properties

Pile Section No. 2:

Moment-curvature properties were derived from elastic section properties

Layering Correction Equivalent Depths of Soil & Rock Layers

Layer No.	Top of Layer Below Pile Head ft	Equivalent Top Depth Below Grnd Surf ft	Same Layer Type As Layer Above	Layer is Rock or is Below Rock Layer	F0 Integral for Layer lbs	F1 Integral for Layer lbs
1	19.6000	0.00	N.A.	No	0.00	1933.
2	20.9000	1.3000	No	Yes	N.A.	N.A.
3	25.9000	6.3000	No	Yes	N.A.	N.A.
4	27.5000	7.9000	No	Yes	N.A.	N.A.

Notes: The F0 integral of Layer n+1 equals the sum of the F0 and F1 integrals
for Layer n. Layering correction equivalent depths are computed only
for soil types with both shallow-depth and deep-depth expressions for

peak lateral load transfer. These soil types are soft and stiff clays, non-liquefied sands, and cemented c-phi soil.

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

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

Shear force at pile head = 15690.0 lbs
Applied moment at pile head = 1160040.0 in-lbs
Axial thrust load on pile head = 466900.0 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	0.5920	1160040.	15690.	-0.00409	1098.	1.24E+11	0.00	0.00	0.00
0.2800	0.5783	1219151.	15690.	-0.00406	1120.	1.24E+11	0.00	0.00	0.00
0.5600	0.5648	1278210.	15690.	-0.00402	1143.	1.24E+11	0.00	0.00	0.00
0.8400	0.5513	1337215.	15690.	-0.00399	1165.	1.24E+11	0.00	0.00	0.00
1.1200	0.5379	1396163.	15690.	-0.00395	1187.	1.24E+11	0.00	0.00	0.00
1.4000	0.5247	1455051.	15690.	-0.00391	1209.	1.24E+11	0.00	0.00	0.00
1.6800	0.5116	1513878.	15690.	-0.00387	1232.	1.24E+11	0.00	0.00	0.00
1.9600	0.4987	1572641.	15690.	-0.00383	1254.	1.24E+11	0.00	0.00	0.00
2.2400	0.4859	1631337.	15690.	-0.00379	1276.	1.24E+11	0.00	0.00	0.00
2.5200	0.4732	1689963.	15690.	-0.00374	1298.	1.24E+11	0.00	0.00	0.00
2.8000	0.4607	1748518.	15690.	-0.00370	1320.	1.24E+11	0.00	0.00	0.00
3.0800	0.4484	1806998.	15690.	-0.00365	1342.	1.24E+11	0.00	0.00	0.00
3.3600	0.4362	1865402.	15690.	-0.00360	1364.	1.24E+11	0.00	0.00	0.00
3.6400	0.4242	1923727.	15690.	-0.00355	1386.	1.24E+11	0.00	0.00	0.00
3.9200	0.4124	1981970.	15690.	-0.00349	1408.	1.24E+11	0.00	0.00	0.00
4.2000	0.4007	2040129.	15690.	-0.00344	1430.	1.24E+11	0.00	0.00	0.00
4.4800	0.3893	2098201.	15690.	-0.00338	1452.	1.24E+11	0.00	0.00	0.00
4.7600	0.3780	2156184.	15690.	-0.00333	1474.	1.24E+11	0.00	0.00	0.00
5.0400	0.3669	2214075.	15690.	-0.00327	1496.	1.24E+11	0.00	0.00	0.00
5.3200	0.3560	2271873.	15690.	-0.00321	1518.	1.24E+11	0.00	0.00	0.00
5.6000	0.3454	2329574.	15690.	-0.00314	1539.	1.24E+11	0.00	0.00	0.00
5.8800	0.3349	2387176.	15690.	-0.00308	1561.	1.24E+11	0.00	0.00	0.00
6.1600	0.3247	2444676.	15690.	-0.00302	1583.	1.24E+11	0.00	0.00	0.00
6.4400	0.3146	2502073.	15690.	-0.00295	1604.	1.24E+11	0.00	0.00	0.00
6.7200	0.3048	2559364.	15690.	-0.00288	1626.	1.24E+11	0.00	0.00	0.00
7.0000	0.2953	2616546.	15690.	-0.00281	1648.	1.24E+11	0.00	0.00	0.00
7.2800	0.2860	2673617.	15690.	-0.00274	1669.	1.24E+11	0.00	0.00	0.00
7.5600	0.2769	2730574.	15690.	-0.00267	1691.	1.24E+11	0.00	0.00	0.00
7.8400	0.2681	2787415.	15690.	-0.00259	1712.	1.24E+11	0.00	0.00	0.00
8.1200	0.2595	2844138.	15690.	-0.00254	1080.	3.15E+11	0.00	0.00	0.00
8.4000	0.2510	2900814.	15690.	-0.00251	1092.	3.15E+11	0.00	0.00	0.00
8.6800	0.2426	2957441.	15690.	-0.00248	1104.	3.15E+11	0.00	0.00	0.00
8.9600	0.2344	3014018.	15690.	-0.00244	1117.	3.15E+11	0.00	0.00	0.00
9.2400	0.2262	3070546.	15690.	-0.00241	1129.	3.15E+11	0.00	0.00	0.00
9.5200	0.2182	3127021.	15690.	-0.00238	1141.	3.15E+11	0.00	0.00	0.00
9.8000	0.2102	3183445.	15690.	-0.00234	1154.	3.15E+11	0.00	0.00	0.00
10.0800	0.2024	3239815.	15690.	-0.00231	1166.	3.15E+11	0.00	0.00	0.00
10.3600	0.1947	3296131.	15690.	-0.00228	1178.	3.15E+11	0.00	0.00	0.00
10.6400	0.1871	3352392.	15690.	-0.00224	1191.	3.15E+11	0.00	0.00	0.00
10.9200	0.1796	3408597.	15690.	-0.00220	1203.	3.15E+11	0.00	0.00	0.00
11.2000	0.1723	3464745.	15690.	-0.00217	1215.	3.15E+11	0.00	0.00	0.00
11.4800	0.1651	3520835.	15690.	-0.00213	1227.	3.15E+11	0.00	0.00	0.00
11.7600	0.1580	3576866.	15690.	-0.00209	1240.	3.15E+11	0.00	0.00	0.00
12.0400	0.1510	3632838.	15690.	-0.00205	1252.	3.15E+11	0.00	0.00	0.00
12.3200	0.1442	3688748.	15690.	-0.00202	1264.	3.15E+11	0.00	0.00	0.00
12.6000	0.1375	3744597.	15690.	-0.00198	1276.	3.15E+11	0.00	0.00	0.00

12.8800	0.1309	3800383.	15690.	-0.00194	1288.	3.15E+11	0.00	0.00	0.00
13.1600	0.1245	3856106.	15690.	-0.00189	1301.	3.15E+11	0.00	0.00	0.00
13.4400	0.1182	3911764.	15690.	-0.00185	1313.	3.15E+11	0.00	0.00	0.00
13.7200	0.1120	3967357.	15690.	-0.00181	1325.	3.15E+11	0.00	0.00	0.00
14.0000	0.1060	4022884.	15690.	-0.00177	1337.	3.15E+11	0.00	0.00	0.00
14.2800	0.1001	4078343.	15690.	-0.00173	1349.	3.15E+11	0.00	0.00	0.00
14.5600	0.09441	4133734.	15690.	-0.00168	1361.	3.15E+11	0.00	0.00	0.00
14.8400	0.08883	4189056.	15690.	-0.00164	1373.	3.15E+11	0.00	0.00	0.00
15.1200	0.08340	4244308.	15690.	-0.00159	1385.	3.15E+11	0.00	0.00	0.00
15.4000	0.07813	4299489.	15690.	-0.00155	1397.	3.15E+11	0.00	0.00	0.00
15.6800	0.07301	4354598.	15690.	-0.00150	1409.	3.15E+11	0.00	0.00	0.00
15.9600	0.06804	4409634.	15690.	-0.00145	1421.	3.15E+11	0.00	0.00	0.00
16.2400	0.06324	4464597.	15690.	-0.00141	1433.	3.15E+11	0.00	0.00	0.00
16.5200	0.05859	4519485.	15690.	-0.00136	1445.	3.15E+11	0.00	0.00	0.00
16.8000	0.05411	4574297.	15690.	-0.00131	1457.	3.15E+11	0.00	0.00	0.00
17.0800	0.04979	4629033.	15690.	-0.00126	1469.	3.15E+11	0.00	0.00	0.00
17.3600	0.04563	4683691.	15690.	-0.00121	1481.	3.15E+11	0.00	0.00	0.00
17.6400	0.04164	4738272.	15690.	-0.00116	1493.	3.15E+11	0.00	0.00	0.00
17.9200	0.03783	4792772.	15690.	-0.00111	1505.	3.15E+11	0.00	0.00	0.00
18.2000	0.03418	4847193.	15690.	-0.00106	1517.	3.15E+11	0.00	0.00	0.00
18.4800	0.03071	4901533.	15690.	-0.00101	1529.	3.15E+11	0.00	0.00	0.00
18.7600	0.02741	4955791.	15690.	-9.55E-04	1541.	3.15E+11	0.00	0.00	0.00
19.0400	0.02429	5009966.	15690.	-9.02E-04	1552.	3.15E+11	0.00	0.00	0.00
19.3200	0.02135	5064057.	15690.	-8.48E-04	1564.	3.15E+11	0.00	0.00	0.00
19.6000	0.01859	5118063.	15690.	-7.94E-04	1576.	3.15E+11	0.00	0.00	0.00
19.8800	0.01602	5171984.	15509.	-7.39E-04	1588.	3.15E+11	-107.6257	22579.	0.00
20.1600	0.01363	5224603.	15021.	-6.84E-04	1599.	3.15E+11	-183.1263	45158.	0.00
20.4400	0.01142	5275068.	14326.	-6.28E-04	1610.	3.15E+11	-230.2736	67738.	0.00
20.7200	0.00941	5322845.	13515.	-5.71E-04	1621.	3.15E+11	-252.8882	90317.	0.00
21.0000	0.00758	5367677.	-6278.	-5.14E-04	1631.	3.15E+11	-11528.	5107200.	0.00
21.2800	0.00595	5282271.	-40847.	-4.57E-04	1612.	3.15E+11	-9049.	5107200.	0.00
21.5600	0.00451	5094621.	-67567.	-4.02E-04	1571.	3.15E+11	-6856.	5107200.	0.00
21.8400	0.00325	4829482.	-87387.	-3.49E-04	1513.	3.15E+11	-4941.	5107200.	0.00
22.1200	0.00216	4508475.	-101215.	-2.99E-04	1443.	3.15E+11	-3289.	5107200.	0.00
22.4000	0.00124	4150258.	-109904.	-2.53E-04	1365.	3.15E+11	-1883.	5107200.	0.00
22.6800	4.62E-04	3770716.	-114246.	-2.11E-04	1282.	3.15E+11	-702.0160	5107200.	0.00
22.9600	-1.80E-04	3383186.	-114966.	-1.73E-04	1197.	3.15E+11	273.4456	5107200.	0.00
23.2400	-7.00E-04	2998686.	-112718.	-1.39E-04	1113.	3.15E+11	1065.	5107200.	0.00
23.5200	-0.00111	2626156.	-108085.	-1.09E-04	1032.	3.15E+11	1693.	5107200.	0.00
23.8000	-0.00143	2272694.	-101582.	-8.29E-05	954.8739	3.15E+11	2178.	5107200.	0.00
24.0800	-0.00167	1943783.	-93657.	-6.04E-05	883.0660	3.15E+11	2539.	5107200.	0.00
24.3600	-0.00184	1643507.	-84696.	-4.13E-05	817.5100	3.15E+11	2795.	5107200.	0.00
24.6400	-0.00195	1374758.	-75025.	-2.52E-05	758.8368	3.15E+11	2961.	5107200.	0.00
24.9200	-0.00201	1139417.	-64922.	-1.18E-05	707.4571	3.15E+11	3052.	5107200.	0.00
25.2000	-0.00203	938517.	-54617.	-7.36E-07	663.5968	3.15E+11	3082.	5107200.	0.00
25.4800	-0.00201	772394.	-44299.	8.38E-06	627.3289	3.15E+11	3060.	5107200.	0.00
25.7600	-0.00197	640803.	-34124.	1.59E-05	598.6001	3.15E+11	2996.	5107200.	0.00
26.0400	-0.00191	543027.	-28596.	2.22E-05	577.2537	3.15E+11	294.6236	519322.	0.00
26.3200	-0.00182	448569.	-27607.	2.75E-05	556.6316	3.15E+11	293.8233	541901.	0.00
26.6000	-0.00172	357420.	-26628.	3.18E-05	536.7320	3.15E+11	289.1901	564480.	0.00
26.8800	-0.00161	269530.	-25670.	3.51E-05	517.5438	3.15E+11	280.9704	587059.	0.00
27.1600	-0.00149	184807.	-24745.	3.76E-05	499.0472	3.15E+11	269.4774	609638.	0.00
27.4400	-0.00136	103123.	-23864.	3.91E-05	481.2141	3.15E+11	255.0873	632218.	0.00
27.7200	-0.00122	24318.	-15327.	3.98E-05	464.0094	3.15E+11	4826.	1.33E+07	0.00
28.0000	-0.00109	0.00	0.00	3.99E-05	458.7003	3.15E+11	4297.	6632640.	0.00

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

Output Summary for Load Case No. 1:

```
Pile-head deflection              =     0.59202282 inches
Computed slope at pile head       =    -0.00409044 radians
Maximum bending moment            =       5367677. inch-lbs
Maximum shear force               =       -114966. lbs
Depth of maximum bending moment   =    21.00000000 feet below pile head
Depth of maximum shear force      =    22.96000000 feet below pile head
```

Number of iterations = 6
Number of zero deflection points = 1

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

Pile-head conditions are Shear and Pile-head Rotation (Loading Type 2)

Shear force at pile head = 12740.0 lbs
Rotation of pile head = 0.000E+00 radians
Axial load at pile head = 460700.0 lbs

(Zero slope for this load indicates fixed-head conditions)

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	0.1147	-1403391.	12740.	0.00	1181.	1.24E+11	0.00	0.00	0.00
0.2800	0.1147	-1360556.	12740.	-3.74E-05	1165.	1.24E+11	0.00	0.00	0.00
0.5600	0.1145	-1317663.	12740.	-7.37E-05	1149.	1.24E+11	0.00	0.00	0.00
0.8400	0.1142	-1274715.	12740.	-1.09E-04	1133.	1.24E+11	0.00	0.00	0.00
1.1200	0.1138	-1231713.	12740.	-1.43E-04	1116.	1.24E+11	0.00	0.00	0.00
1.4000	0.1132	-1188660.	12740.	-1.75E-04	1100.	1.24E+11	0.00	0.00	0.00
1.6800	0.1126	-1145557.	12740.	-2.07E-04	1084.	1.24E+11	0.00	0.00	0.00
1.9600	0.1118	-1102407.	12740.	-2.37E-04	1068.	1.24E+11	0.00	0.00	0.00
2.2400	0.1110	-1059210.	12740.	-2.67E-04	1051.	1.24E+11	0.00	0.00	0.00
2.5200	0.1100	-1015968.	12740.	-2.95E-04	1035.	1.24E+11	0.00	0.00	0.00
2.8000	0.1090	-972684.	12740.	-3.22E-04	1019.	1.24E+11	0.00	0.00	0.00
3.0800	0.1079	-929359.	12740.	-3.47E-04	1002.	1.24E+11	0.00	0.00	0.00
3.3600	0.1067	-885996.	12740.	-3.72E-04	986.0046	1.24E+11	0.00	0.00	0.00
3.6400	0.1054	-842595.	12740.	-3.95E-04	969.6313	1.24E+11	0.00	0.00	0.00
3.9200	0.1040	-799159.	12740.	-4.18E-04	953.2448	1.24E+11	0.00	0.00	0.00
4.2000	0.1026	-755689.	12740.	-4.39E-04	936.8456	1.24E+11	0.00	0.00	0.00
4.4800	0.1011	-712188.	12740.	-4.59E-04	920.4345	1.24E+11	0.00	0.00	0.00
4.7600	0.09949	-668657.	12740.	-4.77E-04	904.0122	1.24E+11	0.00	0.00	0.00
5.0400	0.09786	-625098.	12740.	-4.95E-04	887.5792	1.24E+11	0.00	0.00	0.00
5.3200	0.09617	-581513.	12740.	-5.11E-04	871.1364	1.24E+11	0.00	0.00	0.00
5.6000	0.09442	-537903.	12740.	-5.26E-04	854.6844	1.24E+11	0.00	0.00	0.00
5.8800	0.09263	-494271.	12740.	-5.40E-04	838.2239	1.24E+11	0.00	0.00	0.00
6.1600	0.09079	-450618.	12740.	-5.53E-04	821.7556	1.24E+11	0.00	0.00	0.00
6.4400	0.08892	-406946.	12740.	-5.65E-04	805.2801	1.24E+11	0.00	0.00	0.00
6.7200	0.08700	-363257.	12740.	-5.75E-04	788.7982	1.24E+11	0.00	0.00	0.00
7.0000	0.08505	-319553.	12740.	-5.84E-04	772.3106	1.24E+11	0.00	0.00	0.00
7.2800	0.08307	-275836.	12740.	-5.92E-04	755.8179	1.24E+11	0.00	0.00	0.00
7.5600	0.08107	-232107.	12740.	-5.99E-04	739.3209	1.24E+11	0.00	0.00	0.00
7.8400	0.07905	-188368.	12740.	-6.05E-04	722.8202	1.24E+11	0.00	0.00	0.00
8.1200	0.07701	-144621.	12740.	-6.08E-04	484.1828	3.15E+11	0.00	0.00	0.00
8.4000	0.07496	-100872.	12740.	-6.09E-04	474.6316	3.15E+11	0.00	0.00	0.00
8.6800	0.07291	-57122.	12740.	-6.10E-04	465.0799	3.15E+11	0.00	0.00	0.00
8.9600	0.07086	-13370.	12740.	-6.11E-04	455.5281	3.15E+11	0.00	0.00	0.00
9.2400	0.06881	30382.	12740.	-6.11E-04	459.2421	3.15E+11	0.00	0.00	0.00
9.5200	0.06676	74133.	12740.	-6.10E-04	468.7938	3.15E+11	0.00	0.00	0.00
9.8000	0.06471	117883.	12740.	-6.09E-04	478.3453	3.15E+11	0.00	0.00	0.00
10.0800	0.06266	161631.	12740.	-6.08E-04	487.8964	3.15E+11	0.00	0.00	0.00
10.3600	0.06063	205377.	12740.	-6.06E-04	497.4469	3.15E+11	0.00	0.00	0.00
10.6400	0.05859	249119.	12740.	-6.03E-04	506.9967	3.15E+11	0.00	0.00	0.00
10.9200	0.05657	292857.	12740.	-6.00E-04	516.5455	3.15E+11	0.00	0.00	0.00
11.2000	0.05456	336590.	12740.	-5.97E-04	526.0933	3.15E+11	0.00	0.00	0.00
11.4800	0.05256	380318.	12740.	-5.93E-04	535.6399	3.15E+11	0.00	0.00	0.00
11.7600	0.05058	424039.	12740.	-5.89E-04	545.1851	3.15E+11	0.00	0.00	0.00
12.0400	0.04860	467753.	12740.	-5.84E-04	554.7288	3.15E+11	0.00	0.00	0.00
12.3200	0.04665	511460.	12740.	-5.79E-04	564.2708	3.15E+11	0.00	0.00	0.00

12.6000	0.04471	555158.	12740.	-5.73E-04	573.8110	3.15E+11	0.00	0.00	0.00
12.8800	0.04280	598847.	12740.	-5.67E-04	583.3492	3.15E+11	0.00	0.00	0.00
13.1600	0.04090	642526.	12740.	-5.60E-04	592.8852	3.15E+11	0.00	0.00	0.00
13.4400	0.03903	686195.	12740.	-5.53E-04	602.4189	3.15E+11	0.00	0.00	0.00
13.7200	0.03719	729852.	12740.	-5.46E-04	611.9501	3.15E+11	0.00	0.00	0.00
14.0000	0.03537	773497.	12740.	-5.38E-04	621.4787	3.15E+11	0.00	0.00	0.00
14.2800	0.03357	817130.	12740.	-5.29E-04	631.0045	3.15E+11	0.00	0.00	0.00
14.5600	0.03181	860749.	12740.	-5.20E-04	640.5274	3.15E+11	0.00	0.00	0.00
14.8400	0.03008	904353.	12740.	-5.11E-04	650.0472	3.15E+11	0.00	0.00	0.00
15.1200	0.02838	947943.	12740.	-5.01E-04	659.5637	3.15E+11	0.00	0.00	0.00
15.4000	0.02671	991517.	12740.	-4.91E-04	669.0768	3.15E+11	0.00	0.00	0.00
15.6800	0.02508	1035075.	12740.	-4.80E-04	678.5863	3.15E+11	0.00	0.00	0.00
15.9600	0.02348	1078616.	12740.	-4.69E-04	688.0921	3.15E+11	0.00	0.00	0.00
16.2400	0.02193	1122139.	12740.	-4.57E-04	697.5940	3.15E+11	0.00	0.00	0.00
16.5200	0.02041	1165643.	12740.	-4.45E-04	707.0919	3.15E+11	0.00	0.00	0.00
16.8000	0.01894	1209129.	12740.	-4.32E-04	716.5855	3.15E+11	0.00	0.00	0.00
17.0800	0.01751	1252594.	12740.	-4.19E-04	726.0748	3.15E+11	0.00	0.00	0.00
17.3600	0.01612	1296038.	12740.	-4.05E-04	735.5596	3.15E+11	0.00	0.00	0.00
17.6400	0.01479	1339462.	12740.	-3.91E-04	745.0398	3.15E+11	0.00	0.00	0.00
17.9200	0.01350	1382863.	12740.	-3.77E-04	754.5151	3.15E+11	0.00	0.00	0.00
18.2000	0.01225	1426241.	12740.	-3.62E-04	763.9854	3.15E+11	0.00	0.00	0.00
18.4800	0.01106	1469596.	12740.	-3.46E-04	773.4506	3.15E+11	0.00	0.00	0.00
18.7600	0.00993	1512926.	12740.	-3.31E-04	782.9105	3.15E+11	0.00	0.00	0.00
19.0400	0.00884	1556232.	12740.	-3.14E-04	792.3650	3.15E+11	0.00	0.00	0.00
19.3200	0.00781	1599512.	12740.	-2.97E-04	801.8138	3.15E+11	0.00	0.00	0.00
19.6000	0.00684	1642765.	12740.	-2.80E-04	811.2569	3.15E+11	0.00	0.00	0.00
19.8800	0.00593	1685992.	12673.	-2.62E-04	820.6941	3.15E+11	-39.8653	22579.	0.00
20.1600	0.00508	1728740.	12491.	-2.44E-04	830.0269	3.15E+11	-68.2897	45158.	0.00
20.4400	0.00429	1770689.	12231.	-2.25E-04	839.1852	3.15E+11	-86.5210	67738.	0.00
20.7200	0.00357	1811632.	11925.	-2.06E-04	848.1239	3.15E+11	-95.8479	90317.	0.00
21.0000	0.00290	1851463.	4346.	-1.87E-04	856.8197	3.15E+11	-4415.	5107200.	0.00
21.2800	0.00231	1841419.	-8970.	-1.67E-04	854.6268	3.15E+11	-3511.	5107200.	0.00
21.5600	0.00178	1791705.	-19417.	-1.48E-04	843.7733	3.15E+11	-2707.	5107200.	0.00
21.8400	0.00132	1711397.	-27326.	-1.29E-04	826.2405	3.15E+11	-2001.	5107200.	0.00
22.1200	9.13E-04	1608471.	-33020.	-1.11E-04	803.7697	3.15E+11	-1388.	5107200.	0.00
22.4000	5.67E-04	1489849.	-36800.	-9.50E-05	777.8724	3.15E+11	-862.2895	5107200.	0.00
22.6800	2.75E-04	1361469.	-38951.	-7.98E-05	749.8443	3.15E+11	-417.8099	5107200.	0.00
22.9600	3.12E-05	1228348.	-39732.	-6.60E-05	720.7816	3.15E+11	-47.4388	5107200.	0.00
23.2400	-1.68E-04	1094672.	-39382.	-5.36E-05	691.5975	3.15E+11	256.0697	5107200.	0.00
23.5200	-3.29E-04	963869.	-38112.	-4.26E-05	663.0406	3.15E+11	499.9921	5107200.	0.00
23.8000	-4.55E-04	838695.	-36110.	-3.30E-05	635.7126	3.15E+11	691.4483	5107200.	0.00
24.0800	-5.51E-04	721313.	-33542.	-2.47E-05	610.0859	3.15E+11	837.2519	5107200.	0.00
24.3600	-6.21E-04	613371.	-30550.	-1.76E-05	586.5201	3.15E+11	943.7925	5107200.	0.00
24.6400	-6.69E-04	516075.	-27255.	-1.16E-05	565.2783	3.15E+11	1017.	5107200.	0.00
24.9200	-6.99E-04	430250.	-23763.	-6.53E-06	546.5412	3.15E+11	1062.	5107200.	0.00
25.2000	-7.13E-04	356408.	-20158.	-2.34E-06	530.4201	3.15E+11	1084.	5107200.	0.00
25.4800	-7.14E-04	294795.	-16513.	1.13E-06	516.9686	3.15E+11	1086.	5107200.	0.00
25.7600	-7.05E-04	245435.	-12888.	4.01E-06	506.1925	3.15E+11	1072.	5107200.	0.00
26.0400	-6.87E-04	208175.	-10908.	6.43E-06	498.0579	3.15E+11	106.2519	519322.	0.00
26.3200	-6.62E-04	172112.	-10550.	8.45E-06	490.1845	3.15E+11	106.7869	541901.	0.00
26.6000	-6.31E-04	137250.	-10193.	1.01E-05	482.5736	3.15E+11	105.9460	564480.	0.00
26.8800	-5.94E-04	103583.	-9841.	1.14E-05	475.2234	3.15E+11	103.8232	587059.	0.00
27.1600	-5.54E-04	71086.	-9497.	1.23E-05	468.1287	3.15E+11	100.5380	609638.	0.00
27.4400	-5.11E-04	39723.	-9167.	1.29E-05	461.2815	3.15E+11	96.2346	632218.	0.00
27.7200	-4.67E-04	9446.	-5905.	1.32E-05	454.6714	3.15E+11	1845.	1.33E+07	0.00
28.0000	-4.23E-04	0.00	0.00	1.32E-05	452.6091	3.15E+11	1670.	6632640.	0.00

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

Output Summary for Load Case No. 2:

Pile-head deflection = 0.11474195 inches
Computed slope at pile head = 0.000000 radians
Maximum bending moment = 1851463. inch-lbs
Maximum shear force = -39732. lbs
Depth of maximum bending moment = 21.00000000 feet below pile head

Depth of maximum shear force = 22.96000000 feet below pile head
Number of iterations = 6
Number of zero deflection points = 1

Summary of Pile-head Responses for Conventional Analyses

Definitions of Pile-head Loading Conditions:

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

Load Case No.	Load Type 1	Pile-head Load 1	Load Type 2	Pile-head Load 2	Axial Loading lbs	Pile-head Deflection inches	Pile-head Rotation radians	Max Shear in Pile lbs	Max Moment in Pile in-lbs
1	V, lb	15690.	M, in-lb	1160040.	466900.	0.5920	-0.00409	-114966.	5367677.
2	V, lb	12740.	S, rad	0.00	460700.	0.1147	0.00	-39732.	1851463.

Maximum pile-head deflection = 0.5920228221 inches
Maximum pile-head rotation = -0.0040904434 radians = -0.234365 deg.

The analysis ended normally.

Axial Analysis

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING UNIT
Drilled Pier Axial Resistance Worksheet

PROJECT: BR-0082 COUNTY: Harnett
DESCRIPTION: Bridge 56 on NC 27 over Upper Little River, bent 1 Lt
DESIGNED BY: CW DATE: 05/11/20 STATION: 16+93
CHECKED BY: DATE: STR. NO.: PAGE: 1 OF 6

Elevations

Bottom of Cap (BOC) Elevation =	178.59	ft
Top of Pier/Bottom of Column Elevation =	170.59	ft
Natural Ground / Finished Grade Elevation =	167.80	ft
Groundwater Table (GWT) Elevation =	171.40	ft
Design Scour (DSE) Elevation =	158.00	ft
Amount of Contraction Scour (from BSR) =	9.30	ft
Is Permanent Casing Required? ◉ Yes / Maybe ○ No		
Bottom of Permanent Casing Elevation =	160.00	ft
Drilled Pier Tip Elevation =	150.00	ft

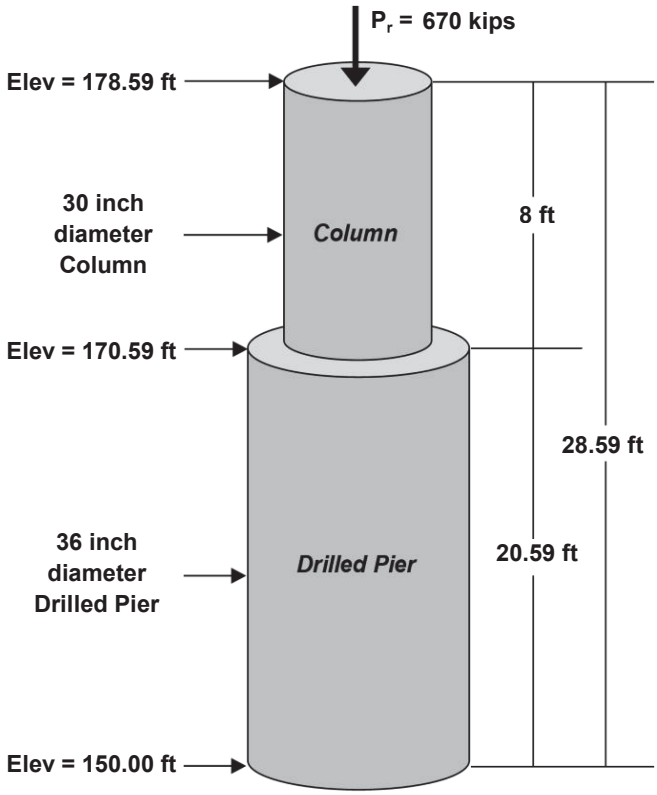


Figure shows typical drilled pier

Drilled Pier Information

Maximum Factored Axial Load (P_r) =	670.0	kips
Number of Drilled Piers per Bent =	3	
Diameter of Column (d_{Column}) =	30	in
Diameter of Drilled Pier (d_{DP}) =	36	in
Unit Weight of Concrete (γ_c) =	0.150	kcf
Compressive Strength of Concrete (f'_c) =	4.500	ksi

Subsurface Information and Soil/Rock Layer Properties

internally calculate $N1_{60}$ values at midpoint of each layer : ☑

Subsurface Boring Name / ID No. =	B1A	
SPT Hammer Energy Efficiency Rating (ER) =	92	%
Top of Boring (Collar) Elevation =	167.80	ft
Depth to Groundwater Table (for actual boring) =	0.00	ft

Calculate GSI using RQD values : ☐
(Use if GSI is not shown on boring)

Layer No.	Material Description	Layer Elevations Top[1] (ft)	Layer Elevations Bottom (ft)	Total γ (kcf)	N (bpf)	N_{60} (bpf)	$N1_{60}$ (bpf)	RQD (%)	[2] GSI	q_u (ksf)	E_i (ksi)	v
1	Weathered Rock	158.00	155.80	0.130	100	153	211					
2	Hard Rock	155.80	150.00	0.169			N/A	48	60	445		
3												
4												
5												
6												
7												
8												
TIP [3]	Weathered Rock	150.00	144.00	0.130	100	153	167	48	60	445		

Notes

1. Resistance from subsurface layers above the Bottom of Column Elevation, Drilled Pier Design Scour Elevation, and Permanent Casing Elevation will be ignored.
2. Hard rock layers with poor or very poor quality rock mass (GSI < 30) will be modeled as weathered rock.
3. Input the subsurface information for the soil / rock at the base of the drilled pier to a distance of 2 pier diameters below the base of the drilled pier.

Correcting SPT Values for Hammer Efficiency and Overburden Pressure

SPT-N Value Corrected for Hammer Efficiency, (N_{60})

$N_{60} = (ER/60\%)(N)$ *AASHTO Eqn. 10.4.6.2.4-2*

N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)

ER = hammer efficiency expressed as percent of theoretical free fall energy delivered by the hammer system actually used. If ER is not known, use 80% for automatic hammers and 60% for drop hammers.

N = uncorrected SPT blow count (blows/ft)

SPT-N Value Corrected for Overburden Pressure, (N1)

$N1 = (C_N)(N)$ *AASHTO Eqn. 10.4.6.2.4-1*

N1 = SPT blow count corrected for overburden pressure (blows/ft)

C_N = correction factor = $[0.77\log_{10}(40/\sigma'_v) < 2.0$

$\sigma'_v = \sigma_v - \mu$ = effective vertical stress at the depth of the SPT-N value (ksf)

σ_v = total vertical stress at the depth of the SPT-N value (ksf)

μ = total pore water pressure at the depth of the SPT-N value (ksf)

N = uncorrected SPT blow count (blows/ft)

SPT-N Value Corrected for both Overburden Pressure and Hammer Efficiency, ($N1_{60}$)

$N1_{60} = (C_N)(N)$ *AASHTO Eqn. 10.4.6.2.4-3*

Summary of Corrected N Values for Boring

Top of Boring (Collar) Elevation = 167.8 ft Depth to Groundwater Table = 0.0 ft

Hammer Efficiency (ER) = 92 % Unit Weight of Water = 0.0624 kcf

Layer No.	Layer Elevations		σ_v at top (ksf)	Δz (ft)	Total γ (kcf)	σ_v at bottom (ksf)	σ_v at midpoint (ksf)	z_{water} (ft)	μ at midpoint (ksf)	σ'_{vo} at midpoint (ksf)	N (bpf)	N_{60} (bpf)	C_N	$N1_{60}$ (bpf)
	Top (ft)	Bottom (ft)												
1	158.00	155.80	1.176	2.20	0.130	1.462	1.319	10.90	0.680	0.639	100	153	1.38	211
2	155.80	150.00	1.462	5.80	0.169	2.442	1.952	14.90	0.930	1.022	N/A			N/A
3														
4														
5														
6														
7														
8														
TIP	150.00	144.00	2.442	6.00	0.130	3.222	2.832	20.80	1.298	1.534	100	153	1.09	167

Side Resistance in Weathered and Hard Rock

$R_s = (A_s)(q_s)$ *AASHTO Eqn. 10.8.3.5-3*

q_s = unit side resistance for weathered or hard rock layer (ksf)

For weathered rock layers or hard rock layers with a GSI < 30

= 8 ksf *NCDOT Policy*

For drilled piers socketed into hard rock

$$= \left(C \sqrt{\frac{q_u}{p_a}} \right) p_a$$ *AASHTO Eqn. 10.8.3.5.4b-1*

C = regression coefficent taken as 1.0 for normal rock sockets (see AASHTO C10.8.3.5.4b-1 for details)

For fractured rock that caves and cannot be drilled without artificial support

$$= \left(0.65 \alpha_E \sqrt{\frac{q_u}{p_a}} \right) p_a$$ *AASHTO Eqn. 10.8.3.5.4b-2*

a_E = reduction factor to account for jointing in rock (from AASHTO Table 10.8.3.5.4b-1)

RQD (%)	Joint Modificaiton Factor, α_E	
	Closed Joints	Open or Gouge-Filled Joints
100	1.00	0.85
70	0.85	0.55
50	0.60	0.55
30	0.50	0.50
20	0.45	0.45

q_u = Uniaxial Compressive Strength of Intact Rock (ksf) $\leq f'_c$

f'_c = 28 day Compressive Strength of Concrete (4.5 ksi = 648 ksf)

p_a = atmospheric pressure (2.12 ksf)

A_s = area of drilled pier side resistance (ft^2)

= $(\pi)(B)(\Delta z)$

B = diameter of drilled pier (subtract 2 inches to account for possible reduction of drilled pier in rock)
= (36 inches - 2 inches) / 12 inches per ft = 2.83 ft

Δz = effective thickness of the soil layer (ft)

Layer No.	Rock Type	Layer Elevations		AASHTO Equation and Rock Joint Condition to use	RQD (%)	α_E	q_u (ksf)	q_s (ksf)	Δz (ft)	A_s (ft^2)	R_s (kips)
		Top (ft)	Bottom (ft)								
1	Weathered Rock	158.00	155.80	N/A	N/A	N/A	N/A	8.000	2.20	19.58	157
2	Hard Rock	155.80	150.00	10.8.3.5.4b-1 (all joints)	48	N/A	445	30.715	5.80	51.63	1586

Total Side Resistance in Weathered and Hard Rock = 1,743

Note: *Hard Rock Layers with a poor surface quality (GSI < 30) will be modeled as weathered rock with an N_{60} = 600 blows/ft.*

Tip Resistance in Weathered Rock

$R_p = (q_p)(A_p)$ *AASHTO Eqn. 10.8.3.5-2*

q_p = unit tip resistance (ksf)

$= (N_C)(S_U)$ *AASHTO Eqn. 10.8.3.5.1c-1*

N_C = cohesion bearing capacity factor *N_c = 9 for Weathered Rock per NCDOT Policy*

S_U = undrained shear strength of material below drilled pier tip (ksf)

$= 0.23(OCR)^{0.8}(\sigma'_{vo})$ *Mayne and Harris, 1993 (after Jamiolkowski, et al., 1985)*

$OCR = (\sigma'_p)/(\sigma'_{vo})$

$\sigma'_p = 0.47(N_{60})^{0.8}(\rho_a)$ *AASHTO Eqn. 10.8.3.5.2b-4*

N_{60} = SPT-N value corrected for hammer efficiency *N_{60} limited to 600 blows/ft*

ρ_a = atmospheric pressure (2.12 ksf)

σ'_{vo} = effective vertical stress at drilled pier tip as defined in FHWA GEC 010 pages 13-46

A_p = area of drilled pier tip resistance (ft^2)

$= (\pi)(B^2)/4$

B = diameter of drilled pier (subtract 2 inches to account for possible reduction of drilled pier in rock)
(36 inches - 2 inches) / 12 inches per ft = 2.83 ft

Tip Elevation (ft)	N_C	N_{60}	σ'_p (ksf)	σ'_{vo} (ksf)	OCR	S_U (ksf)	q_p (ksf)	A_p (ft^2)	R_p (kips)
150.00	9	153	56	0.796	70.046	5.481	49.329	6.31	311

Summary of Nominal and Factored Side Resistance

Material Type	Nominal Side Resistance (kips)	Resistance Factor from AASHTO Table 10.5.5.2.4-1	Factored Side Resistance (kips)	Percentage of Side Resistance produced by Material Type
Cohesive Soil	0	0.45	0	0.0%
Cohesionless Soil	0	0.55	0	0.0%
Cohesive IGM	0	0.60	0	0.0%
Weathered Rock	157	0.60	94	9.0%
Hard Rock	1,586	0.55	872	91.0%
Total	**1,743**		**966**	**100%**

Summary of Total Nominal and Factored Tip Resistance

Total Nominal Tip Resistance = 311 kips

Tip Resistance Factor = 0.55

Total Factored Tip Resistance = 171 kips

the drilled pier is bearing on Weathered Rock
for Weathered Rock (use IGM), see AASHTO Table 10.5.5.2.4-1.

Required Factored Resistance

$R_{req} = P_r + \gamma_{DC}(W_{Column} + W_{Pier}) - \gamma_{WA}W_{Water} - \gamma_{DC}W_{Soil/Rock} \geq P_r$ *Required Factored Resistance*

P_r = 670 kips *Maximum Factored Axial Load Reported by Structure Design*
γ_{DC} = 1.25 *Factor for Permanent Dead Loads, from AASHTO Table 3.4.1-2*
γ_{WA} = 1.00 *Factor for Water Loads, from AASHTO Table 3.4.1-1*

$W_{Column} = (A_{Column})(L_{Column})(\gamma_c)$ *Unfactored Weight of Column*

A_{Column} = 4.91 ft^2 *Area of Column*
L_{Column} = 8 ft *Length of Column*
γ_c = 0.150 kcf *Unit Weight of Concrete*
= 6 kips

$W_{Pier} = (A_{Pier})(L_{Pier})(\gamma_c)$ *Unfactored Weight of Drilled Pier*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
L_{Pier} = 20.59 ft *Length of Drilled Pier*
γ_c = 0.150 kcf *Unit Weight of Concrete*
= 22 kips

$W_{Water} = (A_{Pier})(z_w)(\gamma_w)$ *Unfactored Weight of Water Displaced by Drilled Pier*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
z_w = 21 ft *Depth from water surface to the drilled pier tip*
γ_w = 0.0624 kcf *Unit Weight of Water*
= 9 kips

$W_{Soil/Rock} = (A_{Pier})(\sigma'_{vo})$ *Unfactored Effective Weight of Soil / Rock that will be displaced*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
σ'_{vo} = 0.796 ksf *effective vertical stress at drilled pier tip as defined in FHWA GEC 010 pages 13-46*

$W_{Soil/Rock}$ = 6 kips

R_{req} = 670 kips + 1.25(6 kips + 22 kips) -1.00(9 kips) -1.25(6 kips) = 689 kips

=344.5T round up to 345T, say 350T which is equal to the factored resistance at B1-B.

Load Transfer of Side and Tip Resistance

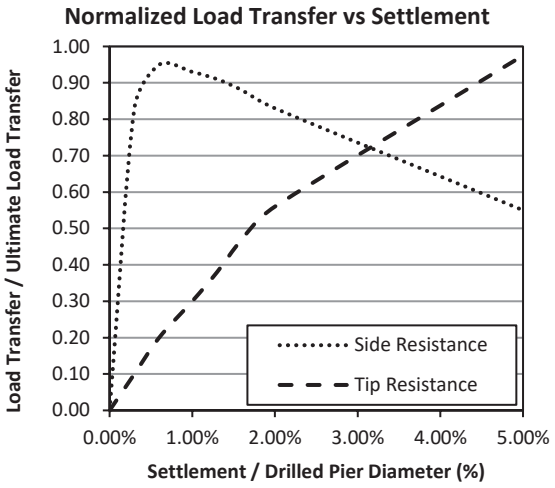
The majority of the side resistance is produced by Hard Rock , which is treated as a cohesive material for Load transfer. Use AASHTO Figure 10.8.2.2.2.1 to predict the normalized load transfer for side resistance.

The drilled pier tip is bearing on Weathered Rock, which is treated as a cohesive material for load transfer. Use AASHTO Figure 10.8.2.2.2.2 to predict the normalized load transfer for tip resistance.

Load Transfer of Side and Tip Resistance (continued)

$\Delta z / D$ (%)	Normalized Side Transfer R_{sd} / R_s AASHTO Figure 10.8.2.2.2.1	Normalized Tip Transfer R_{pd} / R_p AASHTO Figure 10.8.2.2.2.2
0.0	0.00	0.00
0.3	0.83	0.10
0.6	0.95	0.20
1.0	0.93	0.30
1.3	0.91	0.38
1.6	0.88	0.47
2.0	0.83	0.56
5.0	0.55	0.98

$\Delta z / D$ = total settlement / drilled pier diameter
R_{sd} / R_s = developed side resistance / total nominal side resistance
R_{pd} / R_p = developed tip resistance / total nominal tip resistance



Developed Factored Resistance, (R_{rd})

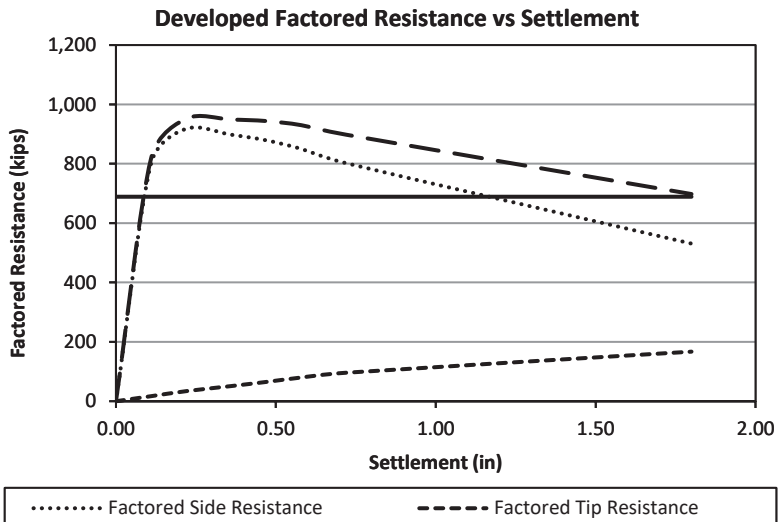
Use the normalized load transfer values along with the total factored side and tip resistance values to calculate the developed side and tip resistance at different vertical displacements. The developed factored resistance must be greater than or equal to the required axial resistance, ($R_{rd} \geq R_{req}$).

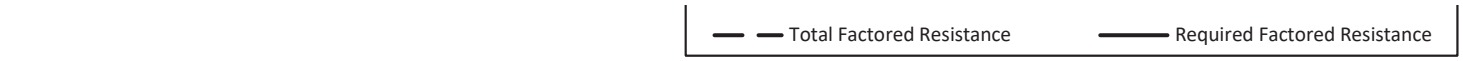
$\frac{\Delta z}{D}$	D (in)	Δz (in)	$\varphi_{qs}R_s$ (kips)	$\frac{R_{sd}}{R_s}$	$\varphi_{qs}R_{sd}$ (kips)	$\varphi_{qp}R_p$ (kips)	$\frac{R_{pd}}{R_p}$	$\varphi_{qp}R_{pd}$ (kips)	R_{rd} (kips)	R_{req} (kips)	Axial Resistance Requirement Satisfied
0.3%	**36**	**0.11**	**966**	**0.83**	**802**	**171**	**0.10**	**17**	**819**	**689**	**YES**
0.6%	36	0.22	966	0.95	918	171	0.20	34	952	689	YES
1.0%	36	0.36	966	0.93	898	171	0.30	51	949	689	YES
1.3%	36	0.47	966	0.91	879	171	0.38	65	944	689	YES
1.6%	36	0.58	966	0.88	850	171	0.47	80	930	689	YES
2.0%	36	0.72	966	0.83	802	171	0.56	96	898	689	YES
5.0%	36	1.80	966	0.55	531	171	0.98	167	698	689	YES

$\varphi_{qs}R_s$ = total factored side resistance
$\varphi_{qp}R_p$ = total factored tip resistance
$\varphi_{qs}R_{sd}$ = developed factored side resistance
= $(R_{sd}/R_s)(\varphi_{qs}R_s)$
$\varphi_{qp}R_{pd}$ = developed factored tip resistance
= $(R_{pd}/R_p)(\varphi_{qp}R_p)$

The axial resistance requirement is satisfied at an estimated vertical displacement of 0.11 inches.

Developed Factored Side Resistance = 802 kips
Developed Factored Tip Resistance = 17 kips
Developed Factored Total Resistance = 819 kips





Required Tip Resistance

q_{req} = required tip resistance (rounded up to the nearest 10 ksf or 5 tsf)

$$= \frac{\frac{R_{req} - \varphi_{qs} R_{sd}}{A_T}}{\varphi_{qp}} \leq q_p$$

NCDOT policy

R_r = required factored geotechnical resistance (kips)
$\varphi_{qs}R_{sd}$ = factored developed side resistance (kips)
A_T = area of drilled pier tip (ft^2)
φ_{qp} = tip resistance factor
q_p = unit tip resistance (ksf)

R_{req} (kips)	$\varphi_{qs}R_{sd}$ (kips)	A_{Tip} (ft^2)	φ_{qp}	q_p (ksf)	q_{req} (ksf)
689	802	6.31	0.55	49	0

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING UNIT
Drilled Pier Axial Resistance Worksheet

PROJECT: BR-0082 COUNTY: Harnett
DESCRIPTION: Bridge 56 on NC 27 over Upper Little River Bent 1, Rt
DESIGNED BY: CW DATE: 05/11/20 STATION: 17+88
CHECKED BY: DATE: STR. NO.: PAGE: 1 OF 7

Elevations

Bottom of Cap (BOC) Elevation =	178.59	ft
Top of Pier/Bottom of Column Elevation =	170.59	ft
Natural Ground / Finished Grade Elevation =	167.20	ft
Groundwater Table (GWT) Elevation =	171.70	ft
Design Scour (DSE) Elevation =	158.00	ft
Amount of Contraction Scour (from BSR) =	9.30	ft
Is Permanent Casing Required? ◉ Yes / Maybe ○ No		
Bottom of Permanent Casing Elevation =	160.00	ft
Drilled Pier Tip Elevation =	144.00	ft

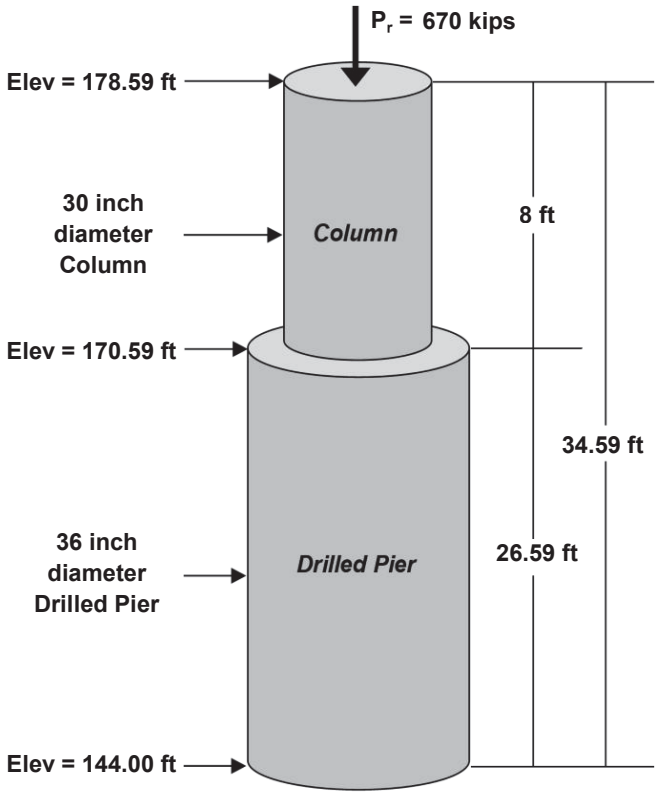


Figure shows typical drilled pier

Drilled Pier Information

Maximum Factored Axial Load (P_r) =	670.0	kips
Number of Drilled Piers per Bent =	3	
Diameter of Column (d_{Column}) =	30	in
Diameter of Drilled Pier (d_{DP}) =	36	in
Unit Weight of Concrete (γ_c) =	0.150	kcf
Compressive Strength of Concrete (f'_c) =	4.500	ksi

Subsurface Information and Soil/Rock Layer Properties

internally calculate $N1_{60}$ values at midpoint of each layer : ☑

Subsurface Boring Name / ID No. =	B1B	
SPT Hammer Energy Efficiency Rating (ER) =	92	%
Top of Boring (Collar) Elevation =	167.20	ft
Depth to Groundwater Table (for actual boring) =	0.00	ft

Calculate GSI using RQD values : ☐
(Use if GSI is not shown on boring)

Layer No.	Material Description	Layer Elevations Top[1] (ft)	Layer Elevations Bottom (ft)	Total γ (kcf)	N (bpf)	N_{60} (bpf)	$N1_{60}$ (bpf)	RQD (%)	[2] GSI	q_u (ksf)	E_i (ksi)	v
1	Weathered Rock	158.00	155.20	0.130	100	153	213					
2	Cohesionless Soil (Silty Sand)	155.20	149.70	0.125	72	110	140					
3	Hard Rock	149.70	144.00	0.130	100		N/A	50	65	384		
4												
5												
6												
7												
8												
TIP [3]	Hard Rock	144.00	138.00	0.130	100		N/A	66	70	384	297	0.200

Notes

1. Resistance from subsurface layers above the Bottom of Column Elevation, Drilled Pier Design Scour Elevation, and Permanent Casing Elevation will be ignored.
2. Hard rock layers with poor or very poor quality rock mass (GSI < 30) will be modeled as weathered rock.
3. Input the subsurface information for the soil / rock at the base of the drilled pier to a distance of 2 pier diameters below the base of the drilled pier.

Correcting SPT Values for Hammer Efficiency and Overburden Pressure

SPT-N Value Corrected for Hammer Efficiency, (N_{60})

$N_{60} = (ER/60\%)(N)$ *AASHTO Eqn. 10.4.6.2.4-2*

N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)

ER = hammer efficiency expressed as percent of theoretical free fall energy delivered by the hammer system actually used. If ER is not known, use 80% for automatic hammers and 60% for drop hammers.

N = uncorrected SPT blow count (blows/ft)

SPT-N Value Corrected for Overburden Pressure, (N1)

$N1 = (C_N)(N)$ *AASHTO Eqn. 10.4.6.2.4-1*

N1 = SPT blow count corrected for overburden pressure (blows/ft)

C_N = correction factor = $[0.77\log_{10}(40/\sigma'_v) < 2.0$

$\sigma'_v = \sigma_v - \mu$ = effective vertical stress at the depth of the SPT-N value (ksf)

σ_v = total vertical stress at the depth of the SPT-N value (ksf)

μ = total pore water pressure at the depth of the SPT-N value (ksf)

N = uncorrected SPT blow count (blows/ft)

SPT-N Value Corrected for both Overburden Pressure and Hammer Efficiency, ($N1_{60}$)

$N1_{60} = (C_N)(N)$ *AASHTO Eqn. 10.4.6.2.4-3*

Summary of Corrected N Values for Boring

Top of Boring (Collar) Elevation = 167.2 ft Depth to Groundwater Table = 0.0 ft

Hammer Efficiency (ER) = 92 % Unit Weight of Water = 0.0624 kcf

Layer No.	Layer Elevations		σ_v at top (ksf)	Δz (ft)	Total γ (kcf)	σ_v at bottom (ksf)	σ_v at midpoint (ksf)	z_{water} (ft)	μ at midpoint (ksf)	σ'_{vo} at midpoint (ksf)	N (bpf)	N_{60} (bpf)	C_N	$N1_{60}$ (bpf)
	Top (ft)	Bottom (ft)												
1	158.00	155.20	1.104	2.80	0.130	1.468	1.286	10.60	0.661	0.625	100	153	1.39	213
2	155.20	149.70	1.468	5.50	0.125	2.156	1.812	14.75	0.920	0.891	72	110	1.27	140
3	149.70	144.00	2.156	5.70	0.130	2.897	2.526	20.35	1.270	1.256	N/A		2	N/A
4														
5														
6														
7														
8														
TIP	144.00	138.00	2.897	6.00	0.130	3.677	3.287	26.20	1.635	1.652	N/A		2	N/A

Selecting Design Properties for Hard Rock

1. q_u values for rock should be based on AASHTO Table 10.4.6.4-1 (which uses Point Load Index Testing) or actual values from Uniaxial Compressive Strength Testing. If neither of these options is available, the NCDOT Rock Core Database may be used to estimate compressive strength.

2. E_i and v values for rock should be based on AASHTO Tables C10.4.6.5-1, and 2 if lab test data is not available

Unconfined Compressive Strength from Point Load Strength Index for Hard Rock — AASHTO Table C10.4.6.4-1

Parameter			Ranges of Values						
1	Strength of intact rock material	Point load strength index	>175 ksf	85–175 ksf	45–85 ksf	20–45 ksf	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength	>4320 ksf	2160–4320 ksf	1080–2160 ksf	520–1080 ksf	215–520 ksf	70–215 ksf	20–70 ksf
	Relative Rating		15	12	7	4	2	1	0

Summary of Elastic Moduli for Intact Rock, E_i (modified by Kulhawy, 1978) — AASHTO Table C10.4.6.5-1

Rock Type	No. of Values	No. of Rock Types	Elastic Modulus, E_i (ksi $\times 10^3$)			Standard Deviation (ksi $\times 10^3$)
			Maximum	Minimum	Mean	
Granite	26	26	14.5	0.93	7.64	3.55
Diorite	3	3	16.2	2.48	7.45	6.19
Gabbro	3	3	12.2	9.8	11.0	0.97
Diabase	7	7	15.1	10.0	12.8	1.78
Basalt	12	12	12.2	4.20	8.14	2.60
Quartzite	7	7	12.8	5.29	9.59	2.32
Marble	14	13	10.7	0.58	6.18	2.49
Gneiss	13	13	11.9	4.13	8.86	2.31
Slate	11	2	3.79	0.35	1.39	0.96
Schist	13	12	10.0	0.86	4.97	3.18
Phyllite	3	3	2.51	1.25	1.71	0.57
Sandstone	27	19	5.68	0.09	2.13	1.19
Siltstone	5	5	4.76	0.38	2.39	1.65
Shale	30	14	5.60	0.001	1.42	1.45
Limestone	30	30	13.0	0.65	5.7	3.73
Dolostone	17	16	11.4	0.83	4.22	3.44

Summary of Poisson's Ratio for Intact Rock, v (modified by Kulhawy, 1978) — AASHTO Table C10.4.6.5-2

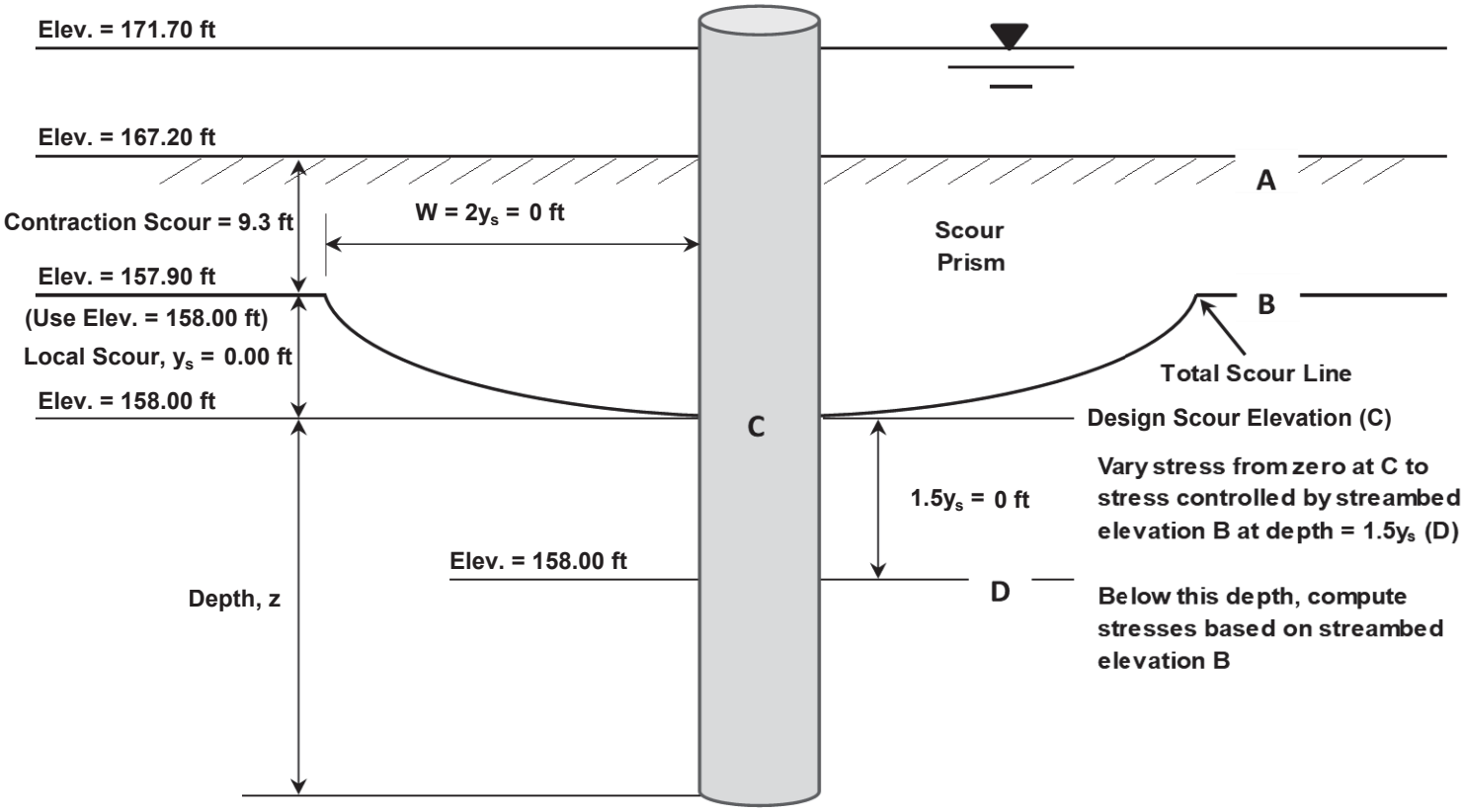
Rock Type	No. of Values	No. of Rock Types	Poisson's Ratio, v			Standard Deviation
			Maximum	Minimum	Mean	
Granite	22	22	0.39	0.09	0.20	0.08
Gabbro	3	3	0.20	0.16	0.18	0.02
Diabase	6	6	0.38	0.20	0.29	0.06
Basalt	11	11	0.32	0.16	0.23	0.05
Quartzite	6	6	0.22	0.08	0.14	0.05
Marble	5	5	0.40	0.17	0.28	0.08
Gneiss	11	11	0.40	0.09	0.22	0.09
Schist	12	11	0.31	0.02	0.12	0.08
Sandstone	12	9	0.46	0.08	0.20	0.11
Siltstone	3	3	0.23	0.09	0.18	0.06
Shale	3	3	0.18	0.03	0.09	0.06
Limestone	19	19	0.33	0.12	0.23	0.06
Dolostone	5	5	0.35	0.14	0.29	0.08

Calculating Design Stresses for Drilled Piers based on Scour Prism used in FHWA GEC 010

For analysis purposes, lower ground line to the contraction scour elevation (CSE) to account for contraction scour reported in the bridge survey report.

- If the CSE is lower than or equal to the design scour elevation (DSE), consider all scour as contraction scour and lower the ground line to the design scour elevation (DSE).
- If the CSE is higher than the DSE, consider the difference between the CSE and the DSE as local scour.

Groundwater Elevation =	171.70	ft	
Original Pre-Scour Streambed Elevation (Point A) =	167.20	ft	*= Natural Ground / Finished Grade Elevation*
Amount of Contraction Scour =	9.30	ft	
Streambed Elevation after General Scour (Point B) =	158.00	ft	*= Point A - Contraction Scour ≥ Design Scour Elevation*
Amount of Local Scour (y_s) =	0.00	ft	
Top of the embedded length of the drilled pier (Point C) =	158.00	ft	*= Design Scour Elevation*
$1.5(y_s)$ =	0.00	ft	
Elevation corresponding to a depth of $1.5(y_s)$, (Point D) =	158.00	ft	*= Point C - $1.5y_s$*



Adapted from FHWA GEC 010 Figure 13.18: Illustration of Scour Prism and Effects on Drilled Pier

Per FHWA GEC 010 page 13-46, vertical stress along any depth of the drilled pier can be estimated as follows;

1) At the top of the embedded drilled pier (Point C) the vertical stress is equal to zero.
2) At a depth of 1.5ys (Point D) or greater, assume the vertical stress is controlled by the streambed elevation (Point B).
3) Assume a linear variation in vertical stress from 0 at Point C to the vertical stress value controlled by the streambed at Point D.

Soil Layer Profile and Effective Vertical Stress controlled by the streambed elevation (Point B)

- Assume the streambed elevation is equal to the contraction scour elevation (Elevation 158.00 ft).

Layer No.	Top (ft)	Midpoint (ft)	Bottom (ft)	σ_{v_top} (ksf)	$\mu_{\_top}$ (ksf)	σ'_{v_top} (ksf)	Δz (ft)	γ (kcf)	σ_{v_bottom} (ksf)	$\mu_{\_bottom}$ (ksf)	σ'_{v_bottom} (ksf)
0	158.00	158.00	158.00	0.000	0.000	0.000	0.00	0.120	0.000	0.000	0.000
1	158.00	156.60	155.20	0.000	0.000	0.000	2.80	0.130	0.364	0.175	0.189
2	155.20	152.45	149.70	0.364	0.175	0.189	5.50	0.125	1.052	0.518	0.534
3	149.70	146.85	144.00	1.052	0.518	0.534	5.70	0.130	1.793	0.874	0.919
4											
5											
6											
7											
8											

Variation in Vertical Stress from Point C to Point D

- Assume the top of the embedded drilled pier is equal to the design scour elevation.
- Vertical stress at elevation 158 ft (Point C) = 0 ksf
- Assume a linear variation in vertical stress from 0 ksf at elevation 158.00 ft (Point C) to a stress value controlled by the elevation 158.00 ft (Point B) at the depth Point D, elevation 158.00 ft.
- PointD lies within Soil Layer No.0

Point D Elevation (ft)	Top of Layer 0 (ft)	σ_v at 158.00 ft	Depth below Layer 0 (ft)	γ for Layer 2	μ at Point D (ksf)	σ'_v at Point D (ksf)
158.00	158.00	0.000	0.00	0.120	0.000	0.000

Point	Elevation (ft)	z (ft)	σ'_v (ksf)	Equation for linear variation over a depth of $1.5y_s$
C	158.00	0.00	0.000	σ'_v (for z = 0 to 0 ft) = (0.0000)z
D	158.00	0.00	0.000	

- All stress calculations below elevation 158.00 ft (Point D) will be based on elevation 158.00 ft (Point B).

Summary of Design Stress at the Midpoint of each Soil Layer and at Tip of Drilled Pier

Layer	Top (ft)	Bottom (ft)	Midpoint (ft)	z (ft)	Is z < $1.5y_s$?	$\sigma_{v\_midpoint}$ (ksf)	μ (ksf)	$\sigma'_{v\_midpoint}$ (ksf)
1	158.00	155.20	156.60	1.40	no	0.182	0.087	0.095
2	155.20	149.70	152.45	5.55	no	0.708	0.346	0.361
3	149.70	144.00	146.85	11.15	no	1.422	0.696	0.726

Tip Elev. (ft)	z (ft)	σ_{v_bottom} (ksf)	μ (ksf)	σ'_{v_bottom} (ksf)
144.00	14.00	1.793	0.874	0.919

Side Resistance in Cohesionless Soil (Sand / Gravel with $N1_{60} \leq 100$)

$R_s = (q_s)(A_s)$ *AASHTO Eqn. 10.8.3.5-3*

q_s = unit side resistance for soil layer (ksf)

$= (\beta)(\sigma'_v)$ *AASHTO Eqn. 10.8.3.5.2b-1*

β = load transfer coefficient

$$= \left(1 - \sin \phi'_f\right)\left(\frac{\sigma'_p}{\sigma'_v}\right)^{\sin \phi'_f} \tan \phi'_f$$ *AASHTO Eqn. 10.8.3.5.2b-2*

ϕ'_f = effective friction angle

$= 27.5 + 9.2 \log(N1_{60}), \quad N1_{60} \leq 100$ *AASHTO Eqn. 10.8.3.5.2b-3*

$N1_{60}$ = SPT - N value corrected for hammer efficiency and overburden (limited to 100 bpf)

σ'_p = effective vertical preconsolidation stress

For Sands: $\frac{\sigma'_p}{\rho_a} \approx 0.47(N_{60})^m$ *AASHTO Eqn. 10.8.3.5.2b-4*

For Gravels: $\frac{\sigma'_p}{\rho_a} = 0.15(N_{60})$ *AASHTO Eqn. 10.8.3.5.2b-5*

m = 0.6 for clean sands; 0.8 for silty sands and sandy silts

N_{60} = SPT - N value corrected for hammer efficiency (limited to 100 bpf)

ρ_a = atmospheric pressure (2.12 ksf)

σ'_v = effective vertical stress at soil layer mid-depth as defined in FHWA GEC 010 pages 13-46

A_s = area of drilled pier side resistance (ft^2)

$= (\pi)(B)(\Delta z)$

B = diameter of drilled pier (3 ft)

Δz = effective thickness of the soil layer (ft)

Layer No.	Layer Elevations		Material Type	$N1_{60}$	ϕ' (deg)	m	N_{60}	σ'_p/ρ_a	σ'_v (ksf)	β	q_s (ksf)	Δz (ft)	A_s (ft^2)	R_s (kips)
	Top (ft)	Bottom (ft)												
2	155.20	149.70	Sand	140	47	0.8	110	20.190	0.364	6.911	2.516	5.50	51.84	130

Total Side Resistance in Cohesionless Soil = 130

Side Resistance in Weathered and Hard Rock

$R_s = (A_s)(q_s)$ *AASHTO Eqn. 10.8.3.5-3*

q_s = unit side resistance for weathered or hard rock layer (ksf)

For weathered rock layers or hard rock layers with a GSI < 30

= 8 ksf *NCDOT Policy*

For drilled piers socketed into hard rock

$$= \left(C \sqrt{\frac{q_u}{p_a}} \right) p_a$$ *AASHTO Eqn. 10.8.3.5.4b-1*

C = regression coefficent taken as 1.0 for normal rock sockets (see AASHTO C10.8.3.5.4b-1 for details)

For fractured rock that caves and cannot be drilled without artificial support

$$= \left(0.65 \alpha_E \sqrt{\frac{q_u}{p_a}} \right) p_a$$ *AASHTO Eqn. 10.8.3.5.4b-2*

a_E = reduction factor to account for jointing in rock (from AASHTO Table 10.8.3.5.4b-1)

RQD (%)	Joint Modificaiton Factor, α_E	
	Closed Joints	Open or Gouge-Filled Joints
100	1.00	0.85
70	0.85	0.55
50	0.60	0.55
30	0.50	0.50
20	0.45	0.45

q_u = Uniaxial Compressive Strength of Intact Rock (ksf) $\leq f'_c$

f'_c = 28 day Compressive Strength of Concrete (4.5 ksi = 648 ksf)

p_a = atmospheric pressure (2.12 ksf)

A_s = area of drilled pier side resistance (ft^2)

= $(\pi)(B)(\Delta z)$

B = diameter of drilled pier (subtract 2 inches to account for possible reduction of drilled pier in rock)
= (36 inches - 2 inches) / 12 inches per ft = 2.83 ft

Δz = effective thickness of the soil layer (ft)

Layer No.	Rock Type	Layer Elevations Top (ft)	Layer Elevations Bottom (ft)	AASHTO Equation and Rock Joint Condition to use	RQD (%)	α_E	q_u (ksf)	q_s (ksf)	Δz (ft)	A_s (ft^2)	R_s (kips)
1	Weathered Rock	158.00	155.20	N/A	N/A	N/A	N/A	8.000	2.80	24.92	199
3	Hard Rock	149.70	144.00	10.8.3.5.4b-1 (all joints)	50	N/A	384	28.532	5.70	50.74	1448

Total Side Resistance in Weathered and Hard Rock = 1,647

Tip Resistance in Hard Rock

$R_p = (q_p)(A_p)$ *AASHTO Eqn. 10.8.3.5-2*

q_p = unit tip resistance (ksf)

If rock to a depth of 2B below drilled pier tip is intact or tightly jointed and the depth of socket > 1.5 D

$= 2.5q_u$ *AASHTO Eqn. 10.8.3.5.4c-1*

If the rock to a depth of 2D below the drilled pier tip is jointed with random orientation

$$= A + q_u\left[m_b\left(\frac{A}{q_u}\right) + s\right]^a$$ *AASHTO Eqn. 10.8.3.5.4c-2*

q_u = Uniaxial Compressive Strength of Intact Rock (ksf)

σ'_{vb} = vertical effective stress at the socket bearing elevation

$$A = \sigma'_{vb} + q_u\left[m_b\left(\frac{\sigma'_{vb}}{q_u}\right) + s\right]^a$$ *AASHTO Eqn. 10.8.3.5.4c-3*

$$s = exp\left(\frac{GSI - 100}{9}\right)$$ *AASHTO Eqn. 10.4.6.4-2*

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{\frac{-GSI}{15}} - e^{\frac{-20}{3}}\right)$$ *AASHTO Eqn. 10.4.6.4-3*

$$m_b = exp\left(\frac{GSI - 100}{28}\right) m_i$$ *AASHTO Eqn. 10.4.6.4-4*

m_i = constant for intact rock *AASHTO Table 10.4.6.4-1*

GSI = Global Strength Index

***Hard Rock Layers with an GSI less than 30 will be modeled as weathered rock.**

A_p = area of drilled pier tip resistance (ft^2)

$= (\pi)(B^2)/4$

B = diameter of drilled pier - 2 inches to account for possible reduction for drilled pier in rock (B = 2.83 ft)

Tip Elevation (ft)	AASHTO Equation used to calculate q_u	q_u (ksf)	GSI	m	m_b	s	a	A	q_p (ksf)	A_p (ft^2)	R_p (kips)
144.00	10.8.3.5.4c-1	384	70	13	N/A	N/A	N/A	N/A	960	6.31	6,058

Tip Resistance in Hard Rock (continued)

Table 10.4.6.4-1—Values of the Constant mi by Rock Group

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

Summary of Nominal and Factored Side Resistance

Cohesionless IGM	Nominal Side Resistance (kips)	Resistance Factor from AASHTO Table 10.5.5.2.4-1	Factored Side Resistance (kips)	Percentage of Side Resistance produced by Material Type
Cohesive Soil	0	0.45	0	0.0%
Cohesionless Soil	130	0.55	72	7.3%
Cohesive IGM	0	0.60	0	0.0%
Weathered Rock	199	0.60	119	11.2%
Hard Rock	1,448	0.55	796	81.5%
Total	**1,777**		**987**	**100%**

Note: *When drilled piers are socketed in hard rock, the side resistance above the hard rock will be ignored. For the purpose of this spreadsheet, a drilled pier will be considered socketed in hard rock if either of these conditions are met;*

1. *The pier is embedded the greater of 3 feet or 1 pier diameter into hard rock.*

2. At least 50% of the total nominal side resistance is produced by the hard rock layer(s).

Summary of Nominal and Factored Side Resistance (continued)

Total Nominal Side Resistance =	1,448	kips
Side Resistance Factor =	0.55	
Total Factored Side Resistance =	796	kips

for Hard Rock, see AASHTO Table 10.5.5.2.4-1.

Summary of Total Nominal and Factored Tip Resistance

Total Nominal Tip Resistance =	6,058	kips
Tip Resistance Factor =	0.50	
Total Factored Tip Resistance =	3,029	kips

the drilled pier is bearing on Hard Rock
for Hard Rock, see AASHTO Table 10.5.5.2.4-1.

Required Factored Resistance

$R_{req} = P_r + \gamma_{DC}(W_{Column} + W_{Pier}) - \gamma_{WA}W_{Water} - \gamma_{DC}W_{Soil/Rock} \geq P_r$ *Required Factored Resistance*

P_r = 670 kips *Maximum Factored Axial Load Reported by Structure Design*
γ_{DC} = 1.25 *Factor for Permanent Dead Loads, from AASHTO Table 3.4.1-2*
γ_{WA} = 1.00 *Factor for Water Loads, from AASHTO Table 3.4.1-1*

$W_{Column} = (A_{Column})(L_{Column})(\gamma_c)$ *Unfactored Weight of Column*

A_{Column} = 4.91 ft^2 *Area of Column*
L_{Column} = 8 ft *Length of Column*
γ_c = 0.150 kcf *Unit Weight of Concrete*
= 6 kips

$W_{Pier} = (A_{Pier})(L_{Pier})(\gamma_c)$ *Unfactored Weight of Drilled Pier*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
L_{Pier} = 26.59 ft *Length of Drilled Pier*
γ_c = 0.150 kcf *Unit Weight of Concrete*
= 28 kips

$W_{Water} = (A_{Pier})(z_w)(\gamma_w)$ *Unfactored Weight of Water Displaced by Drilled Pier*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
z_w = 28 ft *Depth from water surface to the drilled pier tip*
γ_w = 0.0624 kcf *Unit Weight of Water*
= 12 kips

$W_{Soil/Rock} = (A_{Pier})(\sigma'_{vo})$ *Unfactored Effective Weight of Soil / Rock that will be displaced*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
σ'_{vo} = 0.919 ksf *effective vertical stress at drilled pier tip as defined in FHWA GEC 010 pages 13-46*

$W_{Soil/Rock}$ = 6 kips

R_{req} = 670 kips + 1.25(6 kips + 28 kips) -1.00(12 kips) -1.25(6 kips) = 693 kips

=346.5T round up to 350T factored resistance

Load Transfer of Side and Tip Resistance for Drilled Piers in Hard Rock with no Rock Socket

Per AASHTO Section 10.8.3.5.4a, The Factored Geotechnical Resistance for Drilled Piers socketed in hard rock will be based on side resistance, tip resistance, or a combination of both. Using a combination of both side and tip resistance requires a displacement based analysis and falls outside the limitations of this spreadsheet. For details on displacement based analysis, see *FHWA GEC 010 Appendix D.3.1* .

Developed Factored Resistance, (R_{rd})

Select which value to use for the Factored Developed Resistance

◉ Use the Factored Side Resistance of the rock socket.

○ Use the Factored Tip Resistance of the rock socket.

796 kips ≥ 693 kips

The axial resistance requirement is satisfied.

Required Tip Resistance

q_{req} = required tip resistance (rounded up to the nearest 10 ksf or 5 tsf)

$$= \frac{\frac{R_{req} - \varphi_{qs} R_{sd}}{A_T}}{\varphi_{qp}} \leq q_p$$

NCDOT policy

R_r = required factored geotechnical resistance (kips)

$\varphi_{qs}R_{sd}$ = factored developed side resistance (kips)

A_T = area of drilled pier tip (ft^2)

φ_{qp} = tip resistance factor

q_p = unit tip resistance (ksf)

R_{req} (kips)	$\varphi_{qs}R_{sd}$ (kips)	A_{Tip} (ft^2)	φ_{qp}	q_p (ksf)	q_{req} (ksf)
693	796	6.31	0.50	960	0

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING UNIT
Drilled Pier Axial Resistance Worksheet

PROJECT: BR0082 COUNTY: Harnett
DESCRIPTION: Bent 2 Left
DESIGNED BY: CW DATE: 05/11/20 STATION: 18+41
CHECKED BY: DATE: STR. NO.: 1 PAGE: 1 OF 7

Elevations

Bottom of Cap (BOC) Elevation =	178.55	ft
Top of Pier/Bottom of Column Elevation =	170.55	ft
Natural Ground / Finished Grade Elevation =	165.90	ft
Groundwater Table (GWT) Elevation =	171.40	ft
Design Scour (DSE) Elevation =	159.00	ft
Amount of Contraction Scour (from BSR) =	9.40	ft
Is Permanent Casing Required? ◉ Yes / Maybe ○ No		
Bottom of Permanent Casing Elevation =	158.00	ft
Drilled Pier Tip Elevation =	151.00	ft

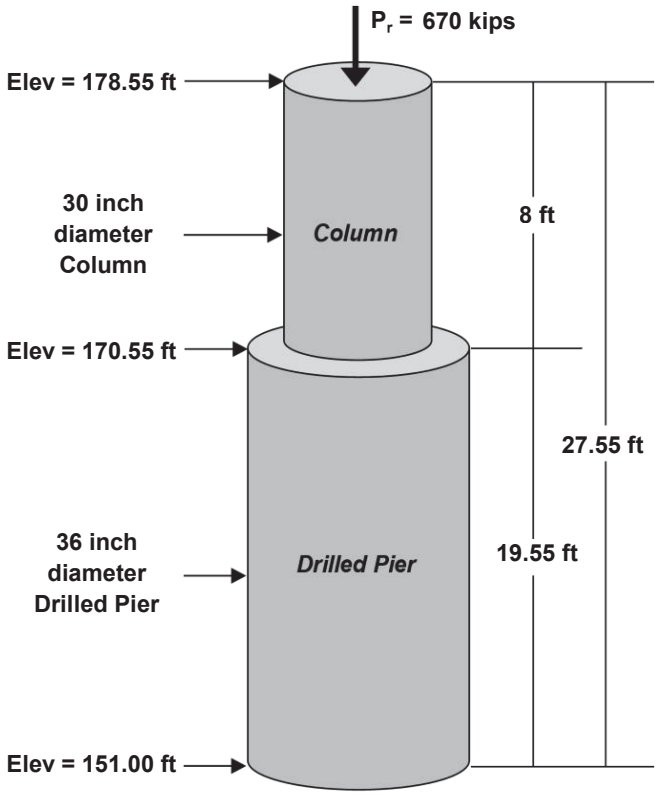


Figure shows typical drilled pier

Drilled Pier Information

Maximum Factored Axial Load (P_r) =	670.0	kips
Number of Drilled Piers per Bent =	3	
Diameter of Column (d_{Column}) =	30	in
Diameter of Drilled Pier (d_{DP}) =	36	in
Unit Weight of Concrete (γ_c) =	0.150	kcf
Compressive Strength of Concrete (f'_c) =	4.500	ksi

Subsurface Information and Soil/Rock Layer Properties

internally calculate $N1_{60}$ values at midpoint of each layer : ☑

Subsurface Boring Name / ID No. =	B2A	
SPT Hammer Energy Efficiency Rating (ER) =	92	%
Top of Boring (Collar) Elevation =	165.90	ft
Depth to Groundwater Table (for actual boring) =	0.00	ft

Calculate GSI using RQD values : ☐
(Use if GSI is not shown on boring)

Layer No.	Material Description	Layer Elevations Top[1] (ft)	Layer Elevations Bottom (ft)	Total γ (kcf)	N (bpf)	N_{60} (bpf)	$N1_{60}$ (bpf)	RQD (%)	[2] GSI	q_u (ksf)	E_i (ksi)	v
1	Cohesionless Soil (Silty Sand)	158.00	158.10	0.120	16	25	38					
2	Hard Rock	158.10	154.30	0.171			N/A	100	75	483		
3	Weathered Rock	154.30	151.70	0.130	100	153	191					
4	Hard Rock	151.70	151.00	0.171			N/A	67	55	483		
5												
6												
7												
8												
TIP [3]	Hard Rock	151.00	145.00	0.171			N/A	67	55	483	513	0.200

Notes

1. Resistance from subsurface layers above the Bottom of Column Elevation, Drilled Pier Design Scour Elevation, and Permanent Casing Elevation will be ignored.
2. Hard rock layers with poor or very poor quality rock mass (GSI < 30) will be modeled as weathered rock.
3. Input the subsurface information for the soil / rock at the base of the drilled pier to a distance of 2 pier diameters below the base of the drilled pier.

Correcting SPT Values for Hammer Efficiency and Overburden Pressure

SPT-N Value Corrected for Hammer Efficiency, (N_{60})

$N_{60} = (ER/60\%)(N)$ *AASHTO Eqn. 10.4.6.2.4-2*

N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)

ER = hammer efficiency expressed as percent of theoretical free fall energy delivered by the hammer system actually used. If ER is not known, use 80% for automatic hammers and 60% for drop hammers.

N = uncorrected SPT blow count (blows/ft)

SPT-N Value Corrected for Overburden Pressure, (N1)

$N1 = (C_N)(N)$ *AASHTO Eqn. 10.4.6.2.4-1*

N1 = SPT blow count corrected for overburden pressure (blows/ft)

C_N = correction factor = $[0.77\log_{10}(40/\sigma'_v) < 2.0$

$\sigma'_v = \sigma_v - \mu$ = effective vertical stress at the depth of the SPT-N value (ksf)

σ_v = total vertical stress at the depth of the SPT-N value (ksf)

μ = total pore water pressure at the depth of the SPT-N value (ksf)

N = uncorrected SPT blow count (blows/ft)

SPT-N Value Corrected for both Overburden Pressure and Hammer Efficiency, ($N1_{60}$)

$N1_{60} = (C_N)(N)$ *AASHTO Eqn. 10.4.6.2.4-3*

Summary of Corrected N Values for Boring

Top of Boring (Collar) Elevation = 165.9 ft Depth to Groundwater Table = 0.0 ft

Hammer Efficiency (ER) = 92 % Unit Weight of Water = 0.0624 kcf

Layer No.	Layer Elevations		σ_v at top (ksf)	Δz (ft)	Total γ (kcf)	σ_v at bottom (ksf)	σ_v at midpoint (ksf)	z_{water} (ft)	μ at midpoint (ksf)	σ'_{vo} at midpoint (ksf)	N (bpf)	N_{60} (bpf)	C_N	$N1_{60}$ (bpf)
	Top (ft)	Bottom (ft)												
1	158.00	158.10	0.948		0.120	0.936	0.942	7.85	0.490	0.452	16	25	1.5	38
2	158.10	154.30	0.936	3.80	0.171	1.586	1.261	9.70	0.605	0.656	N/A			N/A
3	154.30	151.70	1.586	2.60	0.130	1.924	1.755	12.90	0.805	0.95	100	153	1.25	191
4	151.70	151.00	1.924	0.70	0.171	2.044	1.984	14.55	0.908	1.076	N/A			N/A
5														
6														
7														
8														
TIP	151.00	145.00	2.044	6.00	0.171	3.070	2.557	17.90	1.117	1.44	N/A			N/A

Selecting Design Properties for Hard Rock

1. q_u values for rock should be based on AASHTO Table 10.4.6.4-1 (which uses Point Load Index Testing) or actual values from Uniaxial Compressive Strength Testing. If neither of these options is available, the NCDOT Rock Core Database may be used to estimate compressive strength.

2. E_i and v values for rock should be based on AASHTO Tables C10.4.6.5-1, and 2 if lab test data is not available

Unconfined Compressive Strength from Point Load Strength Index for Hard Rock — AASHTO Table C10.4.6.4-1

Parameter			Ranges of Values						
1	Strength of intact rock material	Point load strength index	>175 ksf	85–175 ksf	45–85 ksf	20–45 ksf	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength	>4320 ksf	2160–4320 ksf	1080–2160 ksf	520–1080 ksf	215–520 ksf	70–215 ksf	20–70 ksf
	Relative Rating		15	12	7	4	2	1	0

Summary of Elastic Moduli for Intact Rock, E_i (modified by Kulhawy, 1978) — AASHTO Table C10.4.6.5-1

Rock Type	No. of Values	No. of Rock Types	Elastic Modulus, E_i (ksi $\times 10^3$)			Standard Deviation (ksi $\times 10^3$)
			Maximum	Minimum	Mean	
Granite	26	26	14.5	0.93	7.64	3.55
Diorite	3	3	16.2	2.48	7.45	6.19
Gabbro	3	3	12.2	9.8	11.0	0.97
Diabase	7	7	15.1	10.0	12.8	1.78
Basalt	12	12	12.2	4.20	8.14	2.60
Quartzite	7	7	12.8	5.29	9.59	2.32
Marble	14	13	10.7	0.58	6.18	2.49
Gneiss	13	13	11.9	4.13	8.86	2.31
Slate	11	2	3.79	0.35	1.39	0.96
Schist	13	12	10.0	0.86	4.97	3.18
Phyllite	3	3	2.51	1.25	1.71	0.57
Sandstone	27	19	5.68	0.09	2.13	1.19
Siltstone	5	5	4.76	0.38	2.39	1.65
Shale	30	14	5.60	0.001	1.42	1.45
Limestone	30	30	13.0	0.65	5.7	3.73
Dolostone	17	16	11.4	0.83	4.22	3.44

Summary of Poisson's Ratio for Intact Rock, v (modified by Kulhawy, 1978) — AASHTO Table C10.4.6.5-2

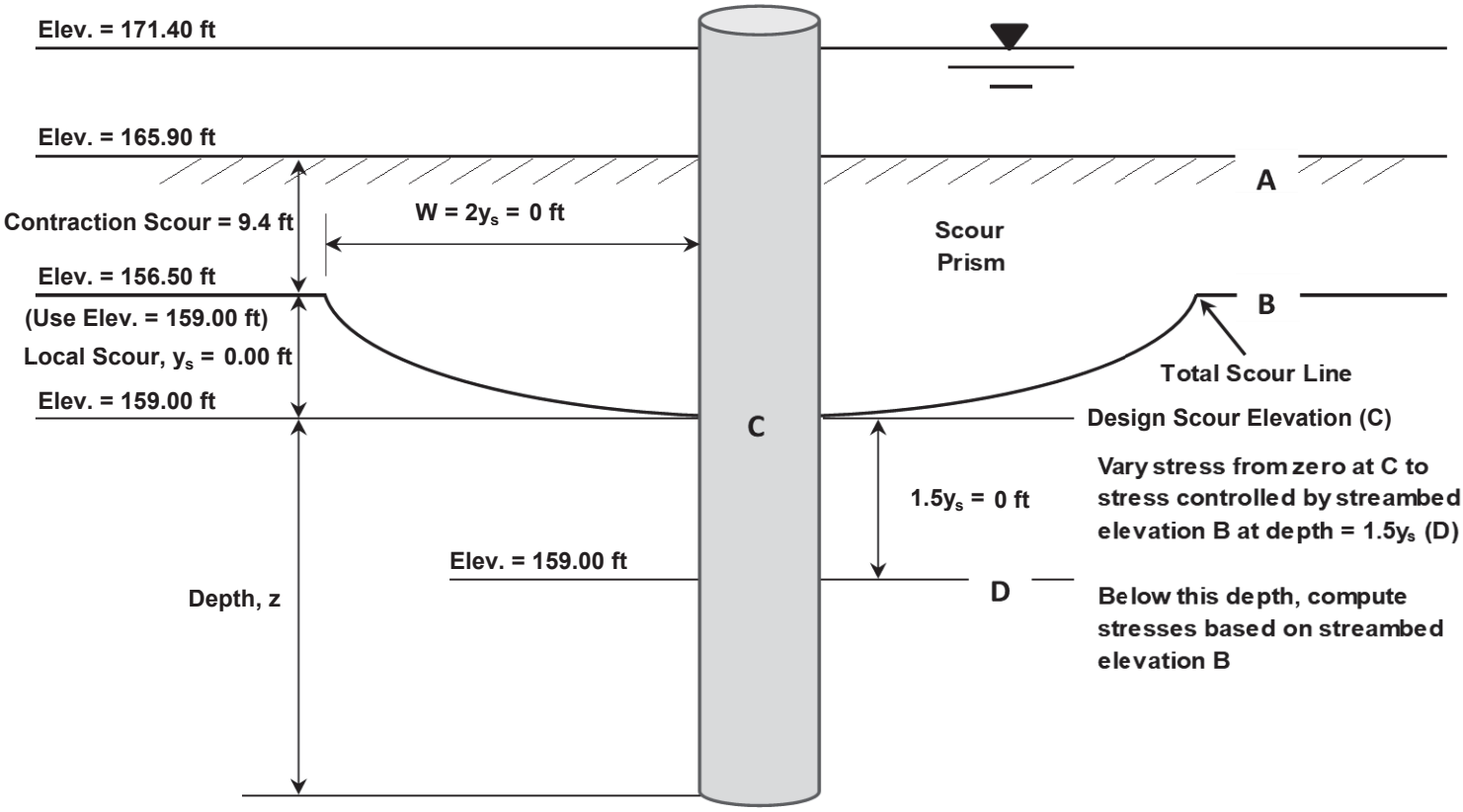
Rock Type	No. of Values	No. of Rock Types	Poisson's Ratio, v			Standard Deviation
			Maximum	Minimum	Mean	
Granite	22	22	0.39	0.09	0.20	0.08
Gabbro	3	3	0.20	0.16	0.18	0.02
Diabase	6	6	0.38	0.20	0.29	0.06
Basalt	11	11	0.32	0.16	0.23	0.05
Quartzite	6	6	0.22	0.08	0.14	0.05
Marble	5	5	0.40	0.17	0.28	0.08
Gneiss	11	11	0.40	0.09	0.22	0.09
Schist	12	11	0.31	0.02	0.12	0.08
Sandstone	12	9	0.46	0.08	0.20	0.11
Siltstone	3	3	0.23	0.09	0.18	0.06
Shale	3	3	0.18	0.03	0.09	0.06
Limestone	19	19	0.33	0.12	0.23	0.06
Dolostone	5	5	0.35	0.14	0.29	0.08

Calculating Design Stresses for Drilled Piers based on Scour Prism used in FHWA GEC 010

For analysis purposes, lower ground line to the contraction scour elevation (CSE) to account for contraction scour reported in the bridge survey report.

- If the CSE is lower than or equal to the design scour elevation (DSE), consider all scour as contraction scour and lower the ground line to the design scour elevation (DSE).
- If the CSE is higher than the DSE, consider the difference between the CSE and the DSE as local scour.

Groundwater Elevation =	171.40	ft	
Original Pre-Scour Streambed Elevation (Point A) =	165.90	ft	*= Natural Ground / Finished Grade Elevation*
Amount of Contraction Scour =	9.40	ft	
Streambed Elevation after General Scour (Point B) =	159.00	ft	*= Point A - Contraction Scour ≥ Design Scour Elevation*
Amount of Local Scour (y_s) =	0.00	ft	
Top of the embedded length of the drilled pier (Point C) =	159.00	ft	*= Design Scour Elevation*
$1.5(y_s)$ =	0.00	ft	
Elevation corresponding to a depth of $1.5(y_s)$, (Point D) =	159.00	ft	*= Point C - $1.5y_s$*



Adapted from FHWA GEC 010 Figure 13.18: Illustration of Scour Prism and Effects on Drilled Pier

Per FHWA GEC 010 page 13-46, vertical stress along any depth of the drilled pier can be estimated as follows;

1) At the top of the embedded drilled pier (Point C) the vertical stress is equal to zero.
2) At a depth of 1.5ys (Point D) or greater, assume the vertical stress is controlled by the streambed elevation (Point B).
3) Assume a linear variation in vertical stress from 0 at Point C to the vertical stress value controlled by the streambed at Point D.

Soil Layer Profile and Effective Vertical Stress controlled by the streambed elevation (Point B)

- Assume the streambed elevation is equal to the contraction scour elevation (Elevation 159.00 ft).

Layer No.	Top (ft)	Midpoint (ft)	Bottom (ft)	σ_{v_top} (ksf)	$\mu_{\_top}$ (ksf)	σ'_{v_top} (ksf)	Δz (ft)	γ (kcf)	σ_{v_bottom} (ksf)	$\mu_{\_bottom}$ (ksf)	σ'_{v_bottom} (ksf)
0	159.00	159.00	159.00	0.000	0.000	0.000	0.00	0.120	0.000	0.000	0.000
1	159.00	158.55	158.10	0.000	0.000	0.000	0.90	0.120	0.108	0.056	0.052
2	158.10	156.20	154.30	0.108	0.056	0.052	3.80	0.171	0.758	0.293	0.465
3	154.30	153.00	151.70	0.758	0.293	0.465	2.60	0.130	1.096	0.456	0.640
4	151.70	151.35	151.00	1.096	0.456	0.640	0.70	0.171	1.216	0.499	0.716
5											
6											
7											
8											

Variation in Vertical Stress from Point C to Point D

- Assume the top of the embedded drilled pier is equal to the design scour elevation.
- Vertical stress at elevation 159 ft (Point C) = 0 ksf
- Assume a linear variation in vertical stress from 0 ksf at elevation 159.00 ft (Point C) to a stress value controlled by the elevation 159.00 ft (Point B) at the depth Point D, elevation 159.00 ft.
- PointD lies within Soil Layer No.0

Point D Elevation (ft)	Top of Layer 0 (ft)	σ_v at 159.00 ft	Depth below Layer 0 (ft)	γ for Layer 2	μ at Point D (ksf)	σ'_v at Point D (ksf)
159.00	159.00	0.000	0.00	0.120	0.000	0.000

Point	Elevation (ft)	z (ft)	σ'_v (ksf)	Equation for linear variation over a depth of $1.5y_s$
C	159.00	0.00	0.000	σ'_v (for z = 0 to 0 ft) = (0.0000)z
D	159.00	0.00	0.000	

- All stress calculations below elevation 159.00 ft (Point D) will be based on elevation 159.00 ft (Point B).

Summary of Design Stress at the Midpoint of each Soil Layer and at Tip of Drilled Pier

Layer	Top (ft)	Bottom (ft)	Midpoint (ft)	z (ft)	Is z < $1.5y_s$?	$\sigma_{v\_midpoint}$ (ksf)	μ (ksf)	$\sigma'_{v\_midpoint}$ (ksf)
1	158.00	158.10	158.05	0.95	no	0.054	0.028	0.057
2	158.10	154.30	156.20	2.80	no	0.433	0.175	0.258
3	154.30	151.70	153.00	6.00	no	0.927	0.374	0.552
4	151.70	151.00	151.35	7.65	no	1.156	0.477	0.678

Tip Elev. (ft)	z (ft)	σ_{v_bottom} (ksf)	μ (ksf)	σ'_{v_bottom} (ksf)
151.00	8.00	1.216	0.499	0.716

Side Resistance in Cohesionless Soil (Sand / Gravel with $N1_{60} \leq 100$)

$R_s = (q_s)(A_s)$ *AASHTO Eqn. 10.8.3.5-3*

q_s = unit side resistance for soil layer (ksf)

$= (\beta)(\sigma'_v)$ *AASHTO Eqn. 10.8.3.5.2b-1*

β = load transfer coefficient

$$= \left(1 - \sin \phi'_f\right)\left(\frac{\sigma'_p}{\sigma'_v}\right)^{\sin \phi'_f} \tan \phi'_f$$ *AASHTO Eqn. 10.8.3.5.2b-2*

ϕ'_f = effective friction angle

$= 27.5 + 9.2 \log(N1_{60}), \quad N1_{60} \leq 100$ *AASHTO Eqn. 10.8.3.5.2b-3*

$N1_{60}$ = SPT - N value corrected for hammer efficiency and overburden (limited to 100 bpf)

σ'_p = effective vertical preconsolidation stress

For Sands: $\frac{\sigma'_p}{\rho_a} \approx 0.47(N_{60})^m$ *AASHTO Eqn. 10.8.3.5.2b-4*

For Gravels: $\frac{\sigma'_p}{\rho_a} = 0.15(N_{60})$ *AASHTO Eqn. 10.8.3.5.2b-5*

m = 0.6 for clean sands; 0.8 for silty sands and sandy silts

N_{60} = SPT - N value corrected for hammer efficiency (limited to 100 bpf)

ρ_a = atmospheric pressure (2.12 ksf)

σ'_v = effective vertical stress at soil layer mid-depth as defined in FHWA GEC 010 pages 13-46

A_s = area of drilled pier side resistance (ft^2)

$= (\pi)(B)(\Delta z)$

B = diameter of drilled pier (3 ft)

Δz = effective thickness of the soil layer (ft)

Layer No.	Layer Elevations		Material Type	$N1_{60}$	ϕ' (deg)	m	N_{60}	σ'_p/ρ_a	σ'_v (ksf)	β	q_s (ksf)	Δz (ft)	A_s (ft^2)	R_s (kips)
	Top (ft)	Bottom (ft)												
1	158.00	158.10	Sand	38	42	0.8	25	6.170	0.108	4.543	0.491	-0.10	-0.94	0

Total Side Resistance in Cohesionless Soil = 0

Side Resistance in Weathered and Hard Rock

$R_s = (A_s)(q_s)$ *AASHTO Eqn. 10.8.3.5-3*

q_s = unit side resistance for weathered or hard rock layer (ksf)

For weathered rock layers or hard rock layers with a GSI < 30

= 8 ksf *NCDOT Policy*

For drilled piers socketed into hard rock

$$= \left(C \sqrt{\frac{q_u}{p_a}} \right) p_a$$ *AASHTO Eqn. 10.8.3.5.4b-1*

C = regression coefficent taken as 1.0 for normal rock sockets (see AASHTO C10.8.3.5.4b-1 for details)

For fractured rock that caves and cannot be drilled without artificial support

$$= \left(0.65 \alpha_E \sqrt{\frac{q_u}{p_a}} \right) p_a$$ *AASHTO Eqn. 10.8.3.5.4b-2*

a_E = reduction factor to account for jointing in rock (from AASHTO Table 10.8.3.5.4b-1)

RQD (%)	Joint Modificaiton Factor, α_E	
	Closed Joints	Open or Gouge-Filled Joints
100	1.00	0.85
70	0.85	0.55
50	0.60	0.55
30	0.50	0.50
20	0.45	0.45

q_u = Uniaxial Compressive Strength of Intact Rock (ksf) $\leq f'_c$

f'_c = 28 day Compressive Strength of Concrete (4.5 ksi = 648 ksf)

p_a = atmospheric pressure (2.12 ksf)

A_s = area of drilled pier side resistance (ft^2)

= $(\pi)(B)(\Delta z)$

B = diameter of drilled pier (subtract 2 inches to account for possible reduction of drilled pier in rock)

= (36 inches - 2 inches) / 12 inches per ft = 2.83 ft

Δz = effective thickness of the soil layer (ft)

Layer No.	Rock Type	Layer Elevations		AASHTO Equation and Rock Joint Condition to use	RQD (%)	α_E	q_u (ksf)	q_s (ksf)	Δz (ft)	A_s (ft^2)	R_s (kips)
		Top (ft)	Bottom (ft)								
2	Hard Rock	158.10	154.30	10.8.3.5.4b-1 (all joints)	100	N/A	483	31.999	3.80	33.82	1082
3	Weathered Rock	154.30	151.70	N/A	N/A	N/A	N/A	8.000	2.60	23.14	185
4	Hard Rock	151.70	151.00	10.8.3.5.4b-1 (all joints)	67	N/A	483	31.999	0.70	6.23	199

Total Side Resistance in Weathered and Hard Rock = 1,466

Tip Resistance in Hard Rock

$R_p = (q_p)(A_p)$ *AASHTO Eqn. 10.8.3.5-2*

q_p = unit tip resistance (ksf)

If rock to a depth of 2B below drilled pier tip is intact or tightly jointed and the depth of socket > 1.5 D

$= 2.5q_u$ *AASHTO Eqn. 10.8.3.5.4c-1*

If the rock to a depth of 2D below the drilled pier tip is jointed with random orientation

$$= A + q_u\left[m_b\left(\frac{A}{q_u}\right) + s\right]^a$$ *AASHTO Eqn. 10.8.3.5.4c-2*

q_u = Uniaxial Compressive Strength of Intact Rock (ksf)

σ'_{vb} = vertical effective stress at the socket bearing elevation

$$A = \sigma'_{vb} + q_u\left[m_b\left(\frac{\sigma'_{vb}}{q_u}\right) + s\right]^a$$ *AASHTO Eqn. 10.8.3.5.4c-3*

$$s = exp\left(\frac{GSI - 100}{9}\right)$$ *AASHTO Eqn. 10.4.6.4-2*

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{\frac{-GSI}{15}} - e^{\frac{-20}{3}}\right)$$ *AASHTO Eqn. 10.4.6.4-3*

$$m_b = exp\left(\frac{GSI - 100}{28}\right) m_i$$ *AASHTO Eqn. 10.4.6.4-4*

m_i = constant for intact rock *AASHTO Table 10.4.6.4-1*

GSI = Global Strength Index

***Hard Rock Layers with an GSI less than 30 will be modeled as weathered rock.**

A_p = area of drilled pier tip resistance (ft^2)

$= (\pi)(B^2)/4$

B = diameter of drilled pier - 2 inches to account for possible reduction for drilled pier in rock (B = 2.83 ft)

Tip Elevation (ft)	AASHTO Equation used to calculate q_u	q_u (ksf)	GSI	m	m_b	s	a	A	q_p (ksf)	A_p (ft^2)	R_p (kips)
151.00	10.8.3.5.4c-1	483	55	13	N/A	N/A	N/A	N/A	1,208	6.31	7,622

Tip Resistance in Hard Rock (continued)

Table 10.4.6.4-1—Values of the Constant mi by Rock Group

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

Summary of Nominal and Factored Side Resistance

Cohesionless IGM	Nominal Side Resistance (kips)	Resistance Factor from AASHTO Table 10.5.5.2.4-1	Factored Side Resistance (kips)	Percentage of Side Resistance produced by Material Type
Cohesive Soil	0	0.45	0	0.0%
Cohesionless Soil	0	0.55	0	0.0%
Cohesive IGM	0	0.60	0	0.0%
Weathered Rock	185	0.60	111	12.6%
Hard Rock	1,281	0.55	705	87.4%
Total	**1,466**		**816**	**100%**

Note: *When drilled piers are socketed in hard rock, the side resistance above the hard rock will be ignored. For the purpose of this spreadsheet, a drilled pier will be considered socketed in hard rock if either of these conditions are met;*

1. *The pier is embedded the greater of 3 feet or 1 pier diameter into hard rock.*

2. At least 50% of the total nominal side resistance is produced by the hard rock layer(s).

Summary of Nominal and Factored Side Resistance (continued)

Total Nominal Side Resistance =	1,281	kips
Side Resistance Factor =	0.55	
Total Factored Side Resistance =	705	kips

for Hard Rock, see AASHTO Table 10.5.5.2.4-1.

Summary of Total Nominal and Factored Tip Resistance

Total Nominal Tip Resistance =	7,622	kips
Tip Resistance Factor =	0.50	
Total Factored Tip Resistance =	3,811	kips

the drilled pier is bearing on Hard Rock
for Hard Rock, see AASHTO Table 10.5.5.2.4-1.

Required Factored Resistance

$R_{req} = P_r + \gamma_{DC}(W_{Column} + W_{Pier}) - \gamma_{WA}W_{Water} - \gamma_{DC}W_{Soil/Rock} \geq P_r$ *Required Factored Resistance*

P_r = 670 kips *Maximum Factored Axial Load Reported by Structure Design*
γ_{DC} = 1.25 *Factor for Permanent Dead Loads, from AASHTO Table 3.4.1-2*
γ_{WA} = 1.00 *Factor for Water Loads, from AASHTO Table 3.4.1-1*

$W_{Column} = (A_{Column})(L_{Column})(\gamma_c)$ *Unfactored Weight of Column*

A_{Column} = 4.91 ft^2 *Area of Column*
L_{Column} = 8 ft *Length of Column*
γ_c = 0.150 kcf *Unit Weight of Concrete*
= 6 kips

$W_{Pier} = (A_{Pier})(L_{Pier})(\gamma_c)$ *Unfactored Weight of Drilled Pier*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
L_{Pier} = 19.55 ft *Length of Drilled Pier*
γ_c = 0.150 kcf *Unit Weight of Concrete*
= 21 kips

$W_{Water} = (A_{Pier})(z_w)(\gamma_w)$ *Unfactored Weight of Water Displaced by Drilled Pier*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
z_w = 20 ft *Depth from water surface to the drilled pier tip*
γ_w = 0.0624 kcf *Unit Weight of Water*
= 9 kips

$W_{Soil/Rock} = (A_{Pier})(\sigma'_{vo})$ *Unfactored Effective Weight of Soil / Rock that will be displaced*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
σ'_{vo} = 0.716 ksf *effective vertical stress at drilled pier tip as defined in FHWA GEC 010 pages 13-46*

$W_{Soil/Rock}$ = 5 kips

R_{req} = 670 kips + 1.25(6 kips + 21 kips) -1.00(9 kips) -1.25(5 kips) = 689 kips

=344.5T, round up to 345T

Load Transfer of Side and Tip Resistance for Drilled Piers in Hard Rock with no Rock Socket

Per AASHTO Section 10.8.3.5.4a, The Factored Geotechnical Resistance for Drilled Piers socketed in hard rock will be based on side resistance, tip resistance, or a combination of both. Using a combination of both side and tip resistance requires a displacement based analysis and falls outside the limitations of this spreadsheet. For details on displacement based analysis, see *FHWA GEC 010 Appendix D.3.1* .

Developed Factored Resistance, (R_{rd})

Select which value to use for the Factored Developed Resistance

◉ Use the Factored Side Resistance of the rock socket.

○ Use the Factored Tip Resistance of the rock socket.

705 kips ≥ 689 kips

The axial resistance requirement is satisfied.

Required Tip Resistance

q_{req} = required tip resistance (rounded up to the nearest 10 ksf or 5 tsf)

$$= \frac{\frac{R_{req} - \varphi_{qs} R_{sd}}{A_T}}{\varphi_{qp}} \leq q_p$$

NCDOT policy

R_r = required factored geotechnical resistance (kips)
$\varphi_{qs}R_{sd}$ = factored developed side resistance (kips)
A_T = area of drilled pier tip (ft^2)
φ_{qp} = tip resistance factor
q_p = unit tip resistance (ksf)

R_{req} (kips)	$\varphi_{qs}R_{sd}$ (kips)	A_{Tip} (ft^2)	φ_{qp}	q_p (ksf)	q_{req} (ksf)
689	705	6.31	0.50	1208	0

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING UNIT
Drilled Pier Axial Resistance Worksheet

PROJECT:	BR-0082			COUNTY	Harnett
DESCRIPTION:	Bridge 56 on NC 27 over Upper Little River Bent 2 Right				
DESIGNED BY:	CW	DATE:	05/11/20	STATION:	16+93
CHECKED BY:		DATE:		STR. NO.:	PAGE: 1 OF 6

Elevations

Bottom of Cap (BOC) Elevation =	178.55	ft
Top of Pier/Bottom of Column Elevation =	170.55	ft
Natural Ground / Finished Grade Elevation =	165.20	ft
Groundwater Table (GWT) Elevation =	171.30	ft
Design Scour (DSE) Elevation =	159.00	ft
Amount of Contraction Scour (from BSR) =	9.30	ft
Is Permanent Casing Required?	◉ Yes / Maybe ○ No	
Bottom of Permanent Casing Elevation =	159.00	ft
Drilled Pier Tip Elevation =	150.00	ft

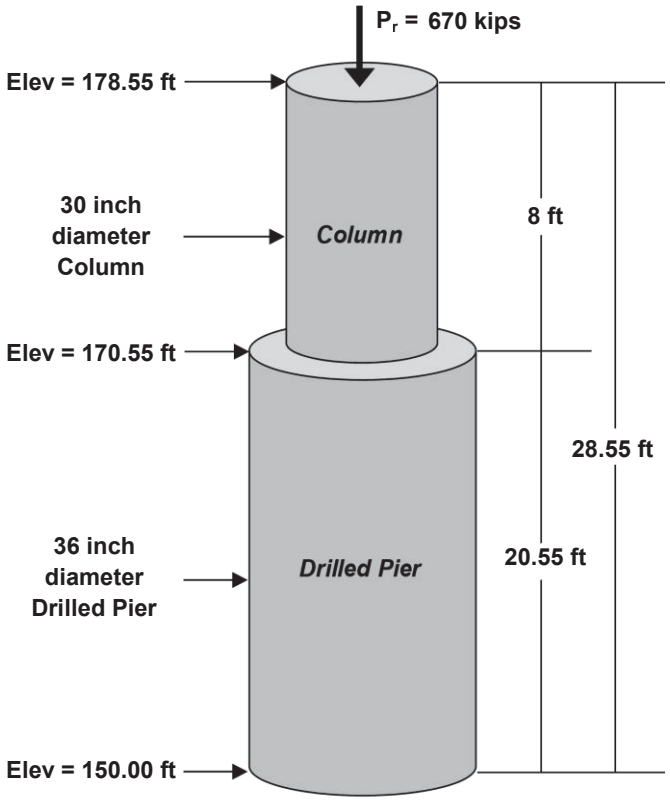


Figure shows typical drilled pier

Drilled Pier Information

Maximum Factored Axial Load (P_r) =	670.0	kips
Number of Drilled Piers per Bent =	3	
Diameter of Column (d_{Column}) =	30	in
Diameter of Drilled Pier (d_{DP}) =	36	in
Unit Weight of Concrete (γ_c) =	0.150	kcf
Compressive Strength of Concrete (f'_c) =	4.500	ksi

Subsurface Information and Soil/Rock Layer Properties

internally calculate $N1_{60}$ values at midpoint of each layer : ☑

Subsurface Boring Name / ID No. =	B2B	
SPT Hammer Energy Efficiency Rating (ER) =	92	%
Top of Boring (Collar) Elevation =	165.20	ft
Depth to Groundwater Table (for actual boring) =	0.00	ft

Calculate GSI using RQD values : ☐
(Use if GSI is not shown on boring)

Layer No.	Material Description	Layer Elevations Top[1] (ft)	Layer Elevations Bottom (ft)	Total γ (kcf)	N (bpf)	N_{60} (bpf)	$N1_{60}$ (bpf)	RQD (%)	[2] GSI	q_u (ksf)	E_i (ksi)	v
1	Weathered Rock	159.00	157.70	0.130	100	153	236					
2	Hard Rock	157.70	152.70	0.169			N/A	18	55	219		
3	Weathered Rock	152.70	151.10	0.130	100	153	187					
4	Hard Rock	151.10	150.00	0.169			N/A	84	60	569		
5												
6												
7												
8												
TIP [3]	Hard Rock	150.00	144.00	0.130	100		N/A	18	60	569	676	0.200

Notes

1. Resistance from subsurface layers above the Bottom of Column Elevation, Drilled Pier Design Scour Elevation, and Permanent Casing Elevation will be ignored.
2. Hard rock layers with poor or very poor quality rock mass (GSI < 30) will be modeled as weathered rock.
3. Input the subsurface information for the soil / rock at the base of the drilled pier to a distance of 2 pier diameters below the base of the drilled pier.

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING UNIT
Drilled Pier Axial Resistance Worksheet

PROJECT: BR-0082 COUNTY Harnett
DESCRIPTION: Bridge 56 on NC 27 over Upper Little River Bent 2 Right
DESIGNED BY: CW DATE: 05/11/20 STATION: 16+93
CHECKED BY: DATE: STR. NO.: PAGE: 1A OF 6

Correcting SPT Values for Hammer Efficiency and Overburden Pressure

SPT-N Value Corrected for Hammer Efficiency, (N_{60})

$N_{60} = (ER/60\%)(N)$ *AASHTO Eqn. 10.4.6.2.4-2*

N_{60} = SPT blow count corrected for hammer efficiency (blows/ft)
ER = hammer efficiency expressed as percent of theoretical free fall energy delivered by the hammer system actually used. If ER is not known, use 80% for automatic hammers and 60% for drop hammers.
N = uncorrected SPT blow count (blows/ft)

SPT-N Value Corrected for Overburden Pressure, (N1)

$N1 = (C_N)(N)$ *AASHTO Eqn. 10.4.6.2.4-1*

N1 = SPT blow count corrected for overburden pressure (blows/ft)
C_N = correction factor = $[0.77\log_{10}(40/\sigma'_v) < 2.0$

$\sigma'_v = \sigma_v - \mu$ = effective vertical stress at the depth of the SPT-N value (ksf)

σ_v = total vertical stress at the depth of the SPT-N value (ksf)
μ = total pore water pressure at the depth of the SPT-N value (ksf)

N = uncorrected SPT blow count (blows/ft)

SPT-N Value Corrected for both Overburden Pressure and Hammer Efficiency, ($N1_{60}$)

$N1_{60} = (C_N)(N)$ *AASHTO Eqn. 10.4.6.2.4-3*

Summary of Corrected N Values for Boring

Top of Boring (Collar) Elevation = 165.2 ft
Depth to Groundwater Table = 0.0 ft
Hammer Efficiency (ER) = 92 %
Unit Weight of Water = 0.0624 kcf

Layer No.	Layer Elevations		σ_v at top (ksf)	Δz (ft)	Total γ (kcf)	σ_v at bottom (ksf)	σ_v at midpoint (ksf)	z_{water} (ft)	μ at midpoint (ksf)	σ'_{vo} at midpoint (ksf)	N (bpf)	N_{60} (bpf)	C_N	$N1_{60}$ (bpf)
	Top (ft)	Bottom (ft)												
1	159.00	157.70	0.744	1.30	0.130	0.913	0.828	6.85	0.427	0.401	100	153	1.54	236
2	157.70	152.70	0.913	5.00	0.169	1.758	1.336	10.00	0.624	0.712	N/A			N/A
3	152.70	151.10	1.758	1.60	0.130	1.966	1.862	13.30	0.830	1.032	100	153	1.22	187
4	151.10	150.00	1.966	1.10	0.169	2.152	2.059	14.65	0.914	1.145	N/A			N/A
5														
6														
7														
8														
TIP	150.00	144.00	2.152	6.00	0.130	2.932	2.542	18.20	1.136	1.406	N/A		2	N/A

Selecting Design Properties for Hard Rock

1. q_u values for rock should be based on AASHTO Table 10.4.6.4-1 (which uses Point Load Index Testing) or actual values from Uniaxial Compressive Strength Testing. If neither of these options is available, the NCDOT Rock Core Database may be used to estimate compressive strength.

2. E_i and v values for rock should be based on AASHTO Tables C10.4.6.5-1, and 2 if lab test data is not available

Unconfined Compressive Strength from Point Load Strength Index for Hard Rock — AASHTO Table C10.4.6.4-1

Parameter			Ranges of Values						
1	Strength of intact rock material	Point load strength index	>175 ksf	85–175 ksf	45–85 ksf	20–45 ksf	For this low range, uniaxial compressive test is preferred		
		Uniaxial compressive strength	>4320 ksf	2160–4320 ksf	1080–2160 ksf	520–1080 ksf	215–520 ksf	70–215 ksf	20–70 ksf
	Relative Rating		15	12	7	4	2	1	0

Summary of Elastic Moduli for Intact Rock, E_i (modified by Kulhawy, 1978) — AASHTO Table C10.4.6.5-1

Rock Type	No. of Values	No. of Rock Types	Elastic Modulus, E_i (ksi $\times 10^3$)			Standard Deviation (ksi $\times 10^3$)
			Maximum	Minimum	Mean	
Granite	26	26	14.5	0.93	7.64	3.55
Diorite	3	3	16.2	2.48	7.45	6.19
Gabbro	3	3	12.2	9.8	11.0	0.97
Diabase	7	7	15.1	10.0	12.8	1.78
Basalt	12	12	12.2	4.20	8.14	2.60
Quartzite	7	7	12.8	5.29	9.59	2.32
Marble	14	13	10.7	0.58	6.18	2.49
Gneiss	13	13	11.9	4.13	8.86	2.31
Slate	11	2	3.79	0.35	1.39	0.96
Schist	13	12	10.0	0.86	4.97	3.18
Phyllite	3	3	2.51	1.25	1.71	0.57
Sandstone	27	19	5.68	0.09	2.13	1.19
Siltstone	5	5	4.76	0.38	2.39	1.65
Shale	30	14	5.60	0.001	1.42	1.45
Limestone	30	30	13.0	0.65	5.7	3.73
Dolostone	17	16	11.4	0.83	4.22	3.44

Summary of Poisson's Ratio for Intact Rock, v (modified by Kulhawy, 1978) — AASHTO Table C10.4.6.5-2

Rock Type	No. of Values	No. of Rock Types	Poisson's Ratio, v			Standard Deviation
			Maximum	Minimum	Mean	
Granite	22	22	0.39	0.09	0.20	0.08
Gabbro	3	3	0.20	0.16	0.18	0.02
Diabase	6	6	0.38	0.20	0.29	0.06
Basalt	11	11	0.32	0.16	0.23	0.05
Quartzite	6	6	0.22	0.08	0.14	0.05
Marble	5	5	0.40	0.17	0.28	0.08
Gneiss	11	11	0.40	0.09	0.22	0.09
Schist	12	11	0.31	0.02	0.12	0.08
Sandstone	12	9	0.46	0.08	0.20	0.11
Siltstone	3	3	0.23	0.09	0.18	0.06
Shale	3	3	0.18	0.03	0.09	0.06
Limestone	19	19	0.33	0.12	0.23	0.06
Dolostone	5	5	0.35	0.14	0.29	0.08

Side Resistance in Weathered and Hard Rock

$R_s = (A_s)(q_s)$ *AASHTO Eqn. 10.8.3.5-3*

q_s = unit side resistance for weathered or hard rock layer (ksf)

For weathered rock layers or hard rock layers with a GSI < 30

= 8 ksf *NCDOT Policy*

For drilled piers socketed into hard rock

$$= \left(C \sqrt{\frac{q_u}{p_a}} \right) p_a$$ *AASHTO Eqn. 10.8.3.5.4b-1*

C = regression coefficent taken as 1.0 for normal rock sockets (see AASHTO C10.8.3.5.4b-1 for details)

For fractured rock that caves and cannot be drilled without artificial support

$$= \left(0.65 \alpha_E \sqrt{\frac{q_u}{p_a}} \right) p_a$$ *AASHTO Eqn. 10.8.3.5.4b-2*

a_E = reduction factor to account for jointing in rock (from AASHTO Table 10.8.3.5.4b-1)

RQD (%)	Joint Modificaiton Factor, α_E	
	Closed Joints	Open or Gouge-Filled Joints
100	1.00	0.85
70	0.85	0.55
50	0.60	0.55
30	0.50	0.50
20	0.45	0.45

q_u = Uniaxial Compressive Strength of Intact Rock (ksf) $\leq f'_c$

f'_c = 28 day Compressive Strength of Concrete (4.5 ksi = 648 ksf)

p_a = atmospheric pressure (2.12 ksf)

A_s = area of drilled pier side resistance (ft^2)

= $(\pi)(B)(\Delta z)$

B = diameter of drilled pier (subtract 2 inches to account for possible reduction of drilled pier in rock)
= (36 inches - 2 inches) / 12 inches per ft = 2.83 ft

Δz = effective thickness of the soil layer (ft)

Layer No.	Rock Type	Layer Elevations		AASHTO Equation and Rock Joint Condition to use	RQD (%)	α_E	q_u (ksf)	q_s (ksf)	Δz (ft)	A_s (ft^2)	R_s (kips)
		Top (ft)	Bottom (ft)								
1	Weathered Rock	159.00	157.70	N/A	N/A	N/A	N/A	8.000	1.30	11.57	93
2	Hard Rock	157.70	152.70	10.8.3.5.4b-1 (all joints)	18	N/A	219	21.547	5.00	44.51	959
3	Weathered Rock	152.70	151.10	N/A	N/A	N/A	N/A	8.000	1.60	14.24	114
4	Hard Rock	151.10	150.00	10.8.3.5.4b-1 (all joints)	84	N/A	569	34.732	1.10	9.79	340

Total Side Resistance in Weathered and Hard Rock = 1,506

Note: *Hard Rock Layers with a poor surface quality (GSI < 30) will be modeled as weathered rock with an N_{60} = 600 blows/ft.*

Tip Resistance in Weathered Rock

$R_p = (q_p)(A_p)$ *AASHTO Eqn. 10.8.3.5-2*

q_p = unit tip resistance (ksf)

$= (N_C)(S_U)$ *AASHTO Eqn. 10.8.3.5.1c-1*

N_C = cohesion bearing capacity factor — *N_c = 9 for Weathered Rock per NCDOT Policy*

S_U = undrained shear strength of material below drilled pier tip (ksf)

$= 0.23(OCR)^{0.8}(\sigma'_{vo})$ *Mayne and Harris, 1993 (after Jamiolkowski, et al., 1985)*

$OCR = (\sigma'_p)/(\sigma'_{vo})$

$\sigma'_p = 0.47(N_{60})^{0.8}(\rho_a)$ *AASHTO Eqn. 10.8.3.5.2b-4*

N_{60} = SPT-N value corrected for hammer efficiency — *N_{60} limited to 600 blows/ft*

ρ_a = atmospheric pressure (2.12 ksf)

σ'_{vo} = effective vertical stress at drilled pier tip as defined in FHWA GEC 010 pages 13-46

A_p = area of drilled pier tip resistance (ft^2)

$= (\pi)(B^2)/4$

B = diameter of drilled pier (subtract 2 inches to account for possible reduction of drilled pier in rock)
(36 inches - 2 inches) / 12 inches per ft = 2.83 ft

Tip Elevation (ft)	N_C	N_{60}	σ'_p (ksf)	σ'_{vo} (ksf)	OCR	S_U (ksf)	q_p (ksf)	A_p (ft^2)	R_p (kips)
150.00	9	600	166	0.846	196.531	13.304	119.736	6.31	756

Summary of Nominal and Factored Side Resistance

Material Type	Nominal Side Resistance (kips)	Resistance Factor from AASHTO Table 10.5.5.2.4-1	Factored Side Resistance (kips)	Percentage of Side Resistance produced by Material Type
Cohesive Soil	0	0.45	0	0.0%
Cohesionless Soil	0	0.55	0	0.0%
Cohesive IGM	0	0.60	0	0.0%
Weathered Rock	207	0.60	124	13.7%
Hard Rock	1,299	0.55	714	86.3%
Total	**1,506**		**838**	**100%**

Summary of Total Nominal and Factored Tip Resistance

Total Nominal Tip Resistance = 756 kips
Tip Resistance Factor = 0.55
Total Factored Tip Resistance = 416 kips

the drilled pier is bearing on Weathered Rock
for Weathered Rock (use IGM), see AASHTO Table 10.5.5.2.4-1.

Required Factored Resistance

$R_{req} = P_r + \gamma_{DC}(W_{Column} + W_{Pier}) - \gamma_{WA}W_{Water} - \gamma_{DC}W_{Soil/Rock} \geq P_r$ *Required Factored Resistance*

P_r = 670 kips *Maximum Factored Axial Load Reported by Structure Design*
γ_{DC} = 1.25 *Factor for Permanent Dead Loads, from AASHTO Table 3.4.1-2*
γ_{WA} = 1.00 *Factor for Water Loads, from AASHTO Table 3.4.1-1*

$W_{Column} = (A_{Column})(L_{Column})(\gamma_c)$ *Unfactored Weight of Column*

A_{Column} = 4.91 ft^2 *Area of Column*
L_{Column} = 8 ft *Length of Column*
γ_c = 0.150 kcf *Unit Weight of Concrete*
= 6 kips

$W_{Pier} = (A_{Pier})(L_{Pier})(\gamma_c)$ *Unfactored Weight of Drilled Pier*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
L_{Pier} = 20.55 ft *Length of Drilled Pier*
γ_c = 0.150 kcf *Unit Weight of Concrete*
= 22 kips

$W_{Water} = (A_{Pier})(z_w)(\gamma_w)$ *Unfactored Weight of Water Displaced by Drilled Pier*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
z_w = 21 ft *Depth from water surface to the drilled pier tip*
γ_w = 0.0624 kcf *Unit Weight of Water*
= 9 kips

$W_{Soil/Rock} = (A_{Pier})(\sigma'_{vo})$ *Unfactored Effective Weight of Soil / Rock that will be displaced*

A_{Pier} = 7.07 ft^2 *Area of Drilled Pier*
σ'_{vo} = 0.846 ksf *effective vertical stress at drilled pier tip as defined in FHWA GEC 010 pages 13-46*

$W_{Soil/Rock}$ = 6 kips

R_{req} = 670 kips + 1.25(6 kips + 22 kips) -1.00(9 kips) -1.25(6 kips) = 689 kips

=344.5T, round up to 345T

Load Transfer of Side and Tip Resistance

The majority of the side resistance is produced by Hard Rock , which is treated as a cohesive material for Load transfer. Use AASHTO Figure 10.8.2.2.2.1 to predict the normalized load transfer for side resistance.

The drilled pier tip is bearing on Weathered Rock, which is treated as a cohesive material for load transfer. Use AASHTO Figure 10.8.2.2.2.2 to predict the normalized load transfer for tip resistance.

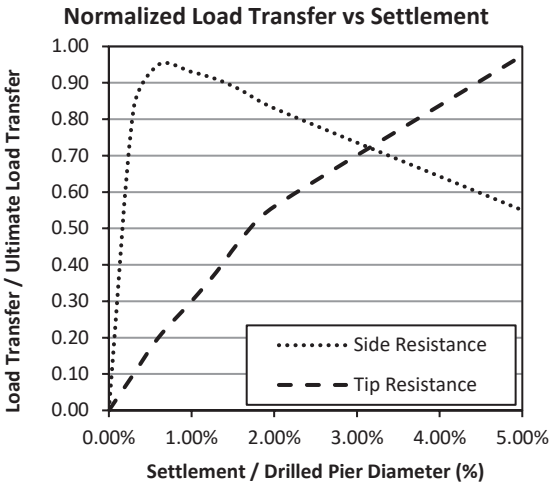
Load Transfer of Side and Tip Resistance (continued)

Δz / D (%)	Normalized Side Transfer R_{sd} / R_s AASHTO Figure 10.8.2.2.2.1	Normalized Tip Transfer R_{pd} / R_p AASHTO Figure 10.8.2.2.2.2
0.0	0.00	0.00
0.3	0.83	0.10
0.6	0.95	0.20
1.0	0.93	0.30
1.3	0.91	0.38
1.6	0.88	0.47
2.0	0.83	0.56
5.0	0.55	0.98

$\Delta z / D$ = total settlement / drilled pier diameter

R_{sd} / R_s = developed side resistance / total nominal side resistance

R_{pd} / R_p = developed tip resistance / total nominal tip resistance



Developed Factored Resistance, (R_{rd})

Use the normalized load transfer values along with the total factored side and tip resistance values to calculate the developed side and tip resistance at different vertical displacements. The developed factored resistance must be greater than or equal to the required axial resistance, ($R_{rd} \geq R_{req}$).

$\frac{\Delta z}{D}$	D (in)	Δz (in)	$\varphi_{qs}R_s$ (kips)	$\frac{R_{sd}}{R_s}$	$\varphi_{qs}R_{sd}$ (kips)	$\varphi_{qp}R_p$ (kips)	$\frac{R_{pd}}{R_p}$	$\varphi_{qp}R_{pd}$ (kips)	R_{rd} (kips)	R_{req} (kips)	Axial Resistance Requirement Satisfied
0.3%	**36**	**0.11**	**838**	**0.83**	**696**	**416**	**0.10**	**42**	**738**	**689**	**YES**
0.6%	36	0.22	838	0.95	796	416	0.20	83	879	689	YES
1.0%	36	0.36	838	0.93	779	416	0.30	125	904	689	YES
1.3%	36	0.47	838	0.91	763	416	0.38	158	921	689	YES
1.6%	36	0.58	838	0.88	737	416	0.47	195	932	689	YES
2.0%	36	0.72	838	0.83	696	416	0.56	233	929	689	YES
5.0%	36	1.80	838	0.55	461	416	0.98	405	866	689	YES

$\varphi_{qs}R_s$ = total factored side resistance

$\varphi_{qp}R_p$ = total factored tip resistance

$\varphi_{qs}R_{sd}$ = developed factored side resistance

= $(R_{sd}/R_s)(\varphi_{qs}R_s)$

$\varphi_{qp}R_{pd}$ = developed factored tip resistance

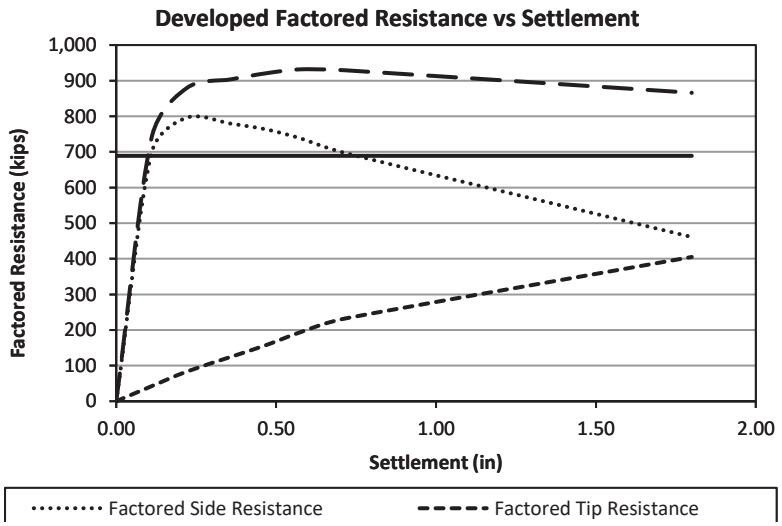
= $(R_{pd}/R_p)(\varphi_{qp}R_p)$

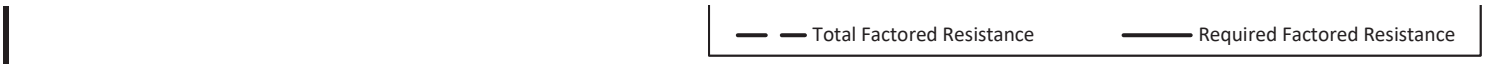
The axial resistance requirement is satisfied at an estimated vertical displacement of 0.11 inches.

Developed Factored Side Resistance = 696 kips

Developed Factored Tip Resistance = 42 kips

Developed Factored Total Resistance = 738 kips





Required Tip Resistance

q_{req} = required tip resistance (rounded up to the nearest 10 ksf or 5 tsf)

$$= \frac{\frac{R_{req} - \varphi_{qs} R_{sd}}{A_T}}{\varphi_{qp}} \leq q_p$$

NCDOT policy

R_r = required factored geotechnical resistance (kips)
$\varphi_{qs}R_{sd}$ = factored developed side resistance (kips)
A_T = area of drilled pier tip (ft^2)
φ_{qp} = tip resistance factor
q_p = unit tip resistance (ksf)

R_{req} (kips)	$\varphi_{qs}R_{sd}$ (kips)	A_{Tip} (ft^2)	φ_{qp}	q_p (ksf)	q_{req} (ksf)
689	696	6.31	0.55	120	0

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