FOUNDATION RECOMMENDATIONS

PROJECT 17BP.7.R.28 DESCRIPTION

T.I.P. NO. 17BP.7.R.28 Bridge #330 on Strawberry Road (SR 2321)

COUNTY Guilford over Mears Fork Creek

STATION ~12+08.50 -L-

	INITIALS	DATE
DESIGN	JPM	2/18/2013
CHECKED	SAS	2/19/2013
FINAL	JPM	3/4/2013

SEAL

NORTH CAROLINA PROFESSIONAL SEAL 034441 ENGINEER JONATHAN P. MANKE

3-4-13

SIGNATURE

	STATION	FOUNDATION TYPE	FACTORED RESISTANCE	MISCELLANEOUS DETAILS
END BENT NO. 1	11+59.81 -L-	Cap on HP 12 x 53 steel piles	50 tons/pile	Bottom of Cap Elevation = 773 feet +/- Estimated Average Pile Length = 35 feet +/- Number of Piles/Cap = 7
BENT NO. 1	11+86.00 -L-	36-inch Drilled Pier	395 tons/pier	Bottom of Cap Elevation = 773.5 feet +/- Point of Fixity Elevation* = 744.5 feet +/-, **left**, 739.5 feet +/-,**right and center** Tip No Higher Than Elevation = 738.5 feet +/-, **left**, 728.5 feet +/-, **right and center** Number of Piers/Cap = 3
END BENT NO. 2	12+57.19 -L-	Cap on HP 12 x 53 steel piles	90 tons/pile	Bottom of Cap Elevation = 772.5 feet +/- Estimated Average Pile Length = 35 feet +/- Number of Piles/Cap = 7

*The estimated point of fixity was determined using the L-Pile program. A 36-inch diameter unyielding shaft was used in our analysis. The structural integrity of the shaft was not verified in our analysis and should be verified by the structural engineer.

COMMENTS & NOTES (See Following Page)

FOUNDATION RECOMMENDATION NOTE ON PLANS AND COMMENTS

W.B.S. No.: 17BP.7.R.28 BRIDGE NO: 400330 COUNTY: Guilford
STATION: 12+08.50 -L-
DESCRIPTION: Bridge #330 on Strawberry Road (SR 2321) over Mears Fork Creek

Note on Plans:

1. FOR PILES, SEE SECTION 450 OF THE STANDARD SPECIFICATION.

2. PILES AT END BENT NO. 1 ARE DESIGNED FOR A FACTORED RESISTANCE OF 50 TONS PER PILE.

3. PILES AT END BENT NO. 2 ARE DESIGNED FOR A FACTORED RESISTANCE OF 90 TONS PER PILE.

4. DRIVE PILES AT END BENT NO. 1 TO A REQUIRED DRIVING RESISTANCE OF 85 TONS PER PILE.

5. DRIVE PILES AT END BENT NO. 2 TO A REQUIRED DRIVING RESISTANCE OF 150 TONS PER PILE.

6. STEEL H-PILE POINTS ARE REQUIRED FOR STEEL H-PILES. FOR STEEL PILE POINTS, SEE SECTION 450 OF THE STANDARD SPECIFICATIONS.

7. FOR DRILLED PIERS, SEE SECTION 411 OF THE STANDARD SPECIFICATIONS.

8. DRILLED PIERS AT BENT NO. 1 ARE DESIGNED FOR A FACTORED RESISTANCE OF 395 TONS PER PIER. CHECK FIELD CONDITIONS FOR THE REQUIRED TIP RESISTANCE OF 130 TSF.

9. INSTALL DRILLED PIERS AT BENT NO. 1 TO A TIP ELEVATION NO HIGHER THAN 738.5 FT, LEFT AND 728.5 FEET, RIGHT AND CENTER, WITH THE REQUIRED TIP RESISTANCE AND PENETRATION OF AT LEAST 1 FOOT INTO ROCK AS DEFINED BY ARTICLE 411-1 OF THE STANDARD SPECIFICATIONS.

10. 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.

11. THE SCOUR CRITICAL ELEVATION FOR BENT NO. 1 IS ELEVATION 750 FT, LEFT AND 757 FT, RIGHT. SCOUR CRITICAL ELEVATIONS ARE USED TO MONITOR POSSIBLE SCOUR PROBLEMS DURING THE LIFE OF THE STRUCTURE.

Special Note on Plans:

1. TEST HOLES ARE REQUIRED FOR DRILLED PIERS AT BENT NO. 1. FOR TEST HOLES, DRILL A 1.5” DIAMETER TEST HOLE AT LEAST 15 FEET BELOW THE BOTTOM OF THE PIER TIP ELEVATION FOR THE ENGINEER TO DETERMINE THE CONTINUITY OF ROCK.

FOUNDATION RECOMMENDATION NOTE ON PLANS AND COMMENTS

W.B.S. No.: 17BP.7.R.28 BRIDGE NO: 400330 COUNTY: Guilford
STATION: 12+08.50 -L-
DESCRIPTION: Bridge #330 on Strawberry Road (SR 2321) over Mears Fork Creek

Comments:

1. USE 1.5 : 1 (H:V) END BENT SLOPES WITH CLASS II RIP-RAP SLOPE PROTECTION.

2. PLEASE ADVISE OUR OFFICE IF THE FACTORED RESISTANCE IS LESS THAN THE MAXIMUM FACTORED AXIAL LOAD.

3. THE AVERAGE FACTORED AXIAL LOAD AT END BENT 1 IS 50 TONS PER PILE.

4. THE AVERAGE FACTORED AXIAL LOAD AT END BENT 2 IS 88 TONS PER PILE.

5. THE MAXIMUM FACTORED AXIAL LOAD AT BENT 1 IS 395 TONS PER PIER.

6. THE DESIGN SCOUR ELEVATION AT BENT NO. 1 IS 753 FT, LEFT AND 760 FT, RIGHT.

7. USE SUB-REGIONAL BRIDGE APPROACH FILLS AT BOTH END BENTS.

8. THE TEST HOLES ARE REQUIRED TO VERIFY THAT A VERY POOR ZONE OF ROCK IDENTIFIED IN THE BORINGS IS NOT PRESENT BELOW THE PIER TIP ELEVATION.

DRILLED PIER PAY ITEMS

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

WBS ELEMENT 17BP.7.R.28 DATE 2/19/2013

TIP NO. 17BP.7.R.28 DESIGNED BY J. Manke

COUNTY GUILFORD CHECKED BY S. Saunders

STATION ~12+08.50 -L-

DESCRIPTION Bridge No. 330 on SR 2321 (Strawberry Road) over Mears Fork Creek

NUMBER OF BENTS WITH DRILLED PIERS 1

NUMBER OF DRILLED PIERS PER BENT 3

NUMBER OF END BENTS WITH DRILLED PIERS

NUMBER OF DRILLED PIERS PER END BENT

	DRILLED PIER PAY ITEM QUANTITIES				
Bent # or End Bent #	**Permanent Steel Casing For 36-inch Dia. Drilled Pier (yes/no/maybe)**	**36-inch Dia. Drilled Piers Not In Soil (per linear ft)**	**SID Inspections (per each)**	**SPT Testing (per each)**	**CSL Testing (per each)**
Bent No. 1	no	35			1
TOTALS		35	0	0	1

Notes:

Blanks or "no" represent quantity of zero.

If drilled piers not in soil are required, calculate quantity of "36-inch Dia. Drilled Piers in Soil" as the difference between the total drilled pier length and the "36-inch 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 "36-inch Dia. Drilled Piers" as the total drilled pier length and do not use the "36-inch Dia. Drilled Piers in Soil" pay item.

If permanent steel casing is or may be required, calculate quantity of "Permanent Steel Casing for 36-inch 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 4 tubes per pier. Calculate the length of each CSL tube as the total drilled pier length plus 1.5 ft.

PILE PAY ITEMS
(Revised 8/15/12)

WBS ELEMENT 17BP.7.R.28 DATE 2/19/2013

TIP NO. 17BP.7.R.28 DESIGNED BY J. Manke

COUNTY Guilford CHECKED BY S. Saunders

STATION ~12+08.50 -L-

DESCRIPTION Bridge No. 330 on SR 2321 Strawberry Road) over Mears Fork Creek

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 Excavation" pay items

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 2	yes	no	no	no	no	no	
End Bent 1	yes	no	no	no	no	no	
TOTALS			0	0	0	0	

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.

If quantity of "PDA Testing" is 3 or less, reference "Pile Driving Criteria" provision in PDA notes on plans and include "Pile Driving Criteria" provision in the contract.

CALCULATIONS

BRIDGE 400330 – GUILFORD COUNTY

DESIGN CALCULATIONS AND DISCUSSION

APPENDIX A – END BENT ANALYSES
APPENDIX A-1 –END BENT 1
APPENDIX A-2 –END BENT 2

APPENDIX B – INTERIOR BENT ANALYSES
APPENDIX B-1 – BENT 1, BORING B1-A
APPENDIX B-2 – BENT 1, BORING B1-B
APPENDIX B-3 – PIER PAY ITEMS

BRIDGE 400330 DESIGN COMMENTS AND CALCULATIONS

The following table summarizes the loads provided for the interior bent with 3, 3-foot piers at Bent 1:

Table 1. Provided Controlling Column Factored Loads for 3 Piers

	Case 1	Case 2	Case 3*
Axial	-790 k	-480 k	-490 k
Shear	6 k	-11 k	13 k
Moment	80 kft	-60 kft	445 kft

*****Moment and Shear acting in opposite directions for Case 3 only.

L-PILE CALCULATIONS:

The provided loads are based on being applied at the ”bottom of the cap” elevation. The bottom of cap elevation appears to be the same as the top of pier elevation (no columns) on the drawings provided by KHA at approximately 773.5 feet. The 100 year hydraulic scour elevation was indicated on the BSR as 767 feet. As such, any soil above this elevation is not considered to provide lateral resistance. In some instances, very soft and loose soil was present below the design scour elevation and was also ignored for providing lateral resistance.

We understand that NCDOT prefers to review only two loading cases, the maximum shear case (Case 2) with free head condition and the maximum transverse shear case (Case 3) with fixed head condition.

In order to run the fixed-head case, the moment needs to be converted to a shear at the top of the pier and then summed with the applied shear. The moment must be divided by the unsupported length of the pier/column (the unsupported length is from the bottom of the cap to the point of fixity). The following table summarizes the elevations utilized in determining the unsupported length to be used in converting the moment to a shear for the fixed-head condition. The table also provides the “Column Length” which is used in the L-pile analysis as the top section of the shaft.

Table 2. Calculations for the Unsupported Length and Column Length

Boring	(A) Bottom of Cap Elevation	(B) Top of Shaft Elevation	(C) Column Length = (A) –(B)	(D) Est. Point of Fixity	(E) Unsupported Length (A)-(D)
B1-A	773.5	773.5	0	744.5	29
B1-B	773.5	773.5	0	739.5	34

Table 3. Calculations for Shear for Case 3 with fixed-head.

Boring	Shear (k)	Moment (k-ft)	Unsupported Length (ft)	Calculated Shear from Moment (k)	Net Shear (k)
B1-A	13	-445	29	-15.5	-2.5
B1-B	13	-445	34	-13	0

Based on the aforementioned discussion and calculations, the following 2 cases with the units adjusted for L-Pile input were analyzed for each boring location.

Table 4. Load Cases for L-Pile – Free Head Condition

	Case 2	Case 3
Axial	480,000 lb	490,000 lb
Shear	11,000 lb	See Table 3.
Moment / Slope	720,000 lb-in	0 radians

A summary of deflection, maximum moment, and maximum shear is on the last page of each L-Pile output.

Table 5. Point of Fixity from L-Pile Analyses for Case 2 only.

Boring	Depth to Bottom of Shaft (in-ft)	Depth to Point of Fixity (in)*	(a) Depth to Point of Fixity (ft)	(b) Top of Pier Elevation	(c) Point of Fixity Elevation (ft)
B1-A	372 – 31	346	~29	773.5	744.5
B1-B	432 - 36	406	~34	773.5	739.5

*Point of Fixity is taken as the point of maximum negative deflection.

AXIAL CALCULATIONS:
The maximum factored axial load provided is 790 kips.

<u>Bent 1</u>
Based on our understanding of NCDOT design practices for drilled piers in weathered rock, the 790 kip load can be achieved in the weathered rock zone if there is a minimum of 12.5 feet of weathered rock. The calculations for this are as follows:

Factored Load = 790 kips
Resistance factor for side resistance in IGM based on O'Neill and Reese (ϕs) = 0.6
Resistance factor for tip resistance in clay based on the Total Stress method (ϕt) = 0.4
Per NCDOT, the nominal side resistance in weathered rock is 8 ksf.
Per NCDOT, the nominal tip resistance in weathered rock can be based on the maximum value of AASHTO Equation 10.8.3.5.1c-1 of 80 ksf.
The shaft diameter is 3 feet, radius is 1.5 feet.

Therefore,

790 kips = $\phi s * (8\ ksf) * (\pi * D) * z + \phi t * \pi * r * r * (80\ ksf)$, where z is the depth into weathered rock.

$= 0.6 * 8 * 3.14 * 3 * z + 0.4 * 3.14 * 1.5 * 1.5 * 80$

$790 = 45.216z + 226$ => z = 12.5 feet into weathered rock.

For both borings, there is not enough weathered rock to terminate the borings above crystalline rock. However, the upper 9.2 feet of the rock core was very poor crystalline rock and we have assumed this material has a capacity closer to weathered rock than crystalline rock. As such, we consider weathered rock at Boring B1-A to extend from an elevation of 749 to 738.6 feet for a total of 10.4 feet of PWR and at Boring B1-B from an elevation of 743 to 729.3 feet for a total of 13.7 feet of PWR. Boring B1-A does not have the required 12.5 feet of PWR, so it needs to be advanced into rock. Boring B1-B has 1.5 feet more PWR than required, however, the PWR at this elevation was sampled with a recovery of 66% and RQD of 0% and the core sample crumbles with some hand pressure. We do not recommend the drilled pier tip bear on this material and recommend the tip be advanced the additional 1.5 feet to the more competent crystalline rock encountered in the core.

For design purposes we consider the upper 9.2 feet of material to be weathered rock at best; however, for excavation purposes we consider this material to be “not in soil”.

- Borings B1A and B1B

Based on the aforementioned reasons, the piers at Bent 1 need to be advanced into the rock for axial capacity. The rock cores indicate the rock type is Granite. Based on the NCDOT Rock Database, the typical unconfined compressive strength for these rock types in Guilford County range from 10,000 to 20,000 psi; however, the lowest unconfined test results was observed to be around 3,000 psi. Based on our experience, an unconfined compressive strength of 576 ksf (4,000 psi) is a reasonable value and was used as part of the design. The attached spreadsheets indicate that a total tip resistance of 4,086 kips can be expected for a 3-foot diameter pier (with a 2.83 foot rock socket) advanced 1 foot into rock. Using a reduction factor of 0.5 for tip resistance in rock the factored tip resistance is 2,043 kips, which is much greater than the required 790 kips. As such, no skin resistance is needed for axial capacity and only the tip resistance was used for this analysis.

Critical Scour Elevations

The 100-year hydraulic scour elevation was provided to be approximately 767 feet. The 100-year hydraulic scour elevation is the design scour elevation. The critical scour elevation is considered 2 to 3 feet below the 100-year design scour elevation.

Table 6. Scour Critical Elevation

Boring	100-Year Hydraulic Scour Elevation (HSE)	100-Year Design Scour Elevation (DSE)	Scour Critical Elevation (SCE)*
B1-A	767	753	750
B1-B	767	760	757

*SCE is taken as approximately 2 to 3 feet below the 100-yr design scour elevation

REVISED PER NCDOT COMMENTS

APPENDIX A – END BENT ANALYSES

APPENDIX A-1 –END BENT 1

BORINGS EB1-A AND EB1-B WITH RELEVANT ELEVATIONS
WEAP ANALYSES FOR EB1-A AND EB1-B

NCDOT GEOTECHNICAL ENGINEERING UNIT
BORELOG REPORT

WBS 17BP.7.R.28	**TIP** 17BP.7.R.28	**COUNTY** GUILFORD	**GEOLOGIST** Huelsman, CJ
SITE DESCRIPTION Bridge Number 330 over Mears Fork Creek on SR 2321 (Strawberry Road)			**GROUND WTR (ft)**
BORING NO. EB1-A	**STATION** 11+61	**OFFSET** 15 ft LT	**ALIGNMENT** L — **0 HR.** 5.1
COLLAR ELEV. 777.3 ft	**TOTAL DEPTH** 48.7 ft	**NORTHING** N/A	**EASTING** N/A — **24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE HPC0279 DIEDRICH D-50 90% 02/17/2012		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic
DRILLER Cain, J.	**START DATE** 02/05/13	**COMP. DATE** 02/05/13	**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)
780											
775	776.3	1.0	2	2	3	5		W		777.3 GROUND SURFACE	0.0
	773.8	3.5	2	2	2	4		W		776.8 Topsoil	0.5
770	771.3	6.0	WOH	2	1	3		W		ROADWAY EMBANKMENT — Red Slightly Micaceous Sandy Silty CLAY	
	768.8	8.5	WOH	WOH	WOH	WOH 0		W		770.8 ALLUVIAL — Gray Slightly Micaceous Sandy CLAY	6.5
765	763.8	13.5	1	2	1	3		W			
760	758.8	18.5	3	4	4	8		W		760.3 RESIDUAL — Tan and Orange Micaceous Sandy SILT	17.0
755	753.8	23.5	6	7	9	16		W			
750	748.8	28.5	9	10	11	21		W			
745	743.8	33.5	14	26	47	73		W		745.3 RESIDUAL — Tan and Orange Micaceous Sandy SILT	32.0
740	738.8	38.5	80	20/0.1		100/0.6				738.8 WEATHERED ROCK (Gray to Tan Granitic Rock)	38.5
735	733.8	43.5	60/0.2			60/0.2					
730	728.8	48.5	60/0.2			60/0.2				728.6 Boring Terminated at Elevation 728.6 ft In Weathered Rock	48.7

B.O.C. ~773

0

13

28

TIP ~735

34

44

773-735=38'

SAY 40' pile

REVISED PER NCDOT COMMENTS TO 35' PILES.

GRLWEAP 2005-2-Terracon Consultants Inc - [BRIDGE~1.GWW]

File Edit View Options Tools Window Help

English | Simple Resistance Distr | Uniform Pile | Bearing Graph - prop. shaft resistance

Bridge 330- EB1A

Hammer Information

Select from following list [8/28/2009-2003]: ID: 38

ID	Name	Type	Ram Wt	Energy/Power
36	DELMAG D 6-32	OED	1.3220	13.524
37	DELMAG D 12-32	OED	2.8200	31.330
38	DELMAG D 12-42	OED	2.8200	33.304

Hammer parameters

Efficiency	0.8			
Pressure	1640.0	psi	Fixed	100 %
Stroke	11.81	ft	Variable	of Max

Pile material

Concrete Steel Timber

Cushion Information

	Hammer	Pile	
Area	227.	0.	in^2
Elastic Modulus	530.	0.	ksi
Thickness	2.	0.	in
C.O.R.	0.8	0.	
Stiffness	0.	0.	kips/in
Helmet Weight	1.9		kips

Pile Information

Length	40.	ft	Auto	Segments
Penetration	38.	ft	Auto.	S-Length
Section Area	15.5	in^2	Auto.	S-St. Wt
Elast Modulus	30000.	ksi		
Spec Weight	492.0	lb/ft^3		
Toe Area	144.	in^2	0	Splices
Perimeter	4.	ft	Pile Type:	
Pile Size	12.	in	H Pile	

Ultimate Capacities (up to 10)

kips

1	110.0	6	210.0
2	130.0	7	230.0
3	150.0	8	250.0
4	170.0	9	270.0
5	190.0	10	290.0

Incr. 0 Action >>

Soil Parameters

Quake

Shaft	0.1	in	Const
Toe	0.1	in	

Damping

Shaft	0.125	s/ft	Const
Toe	0.15	s/ft	Smith

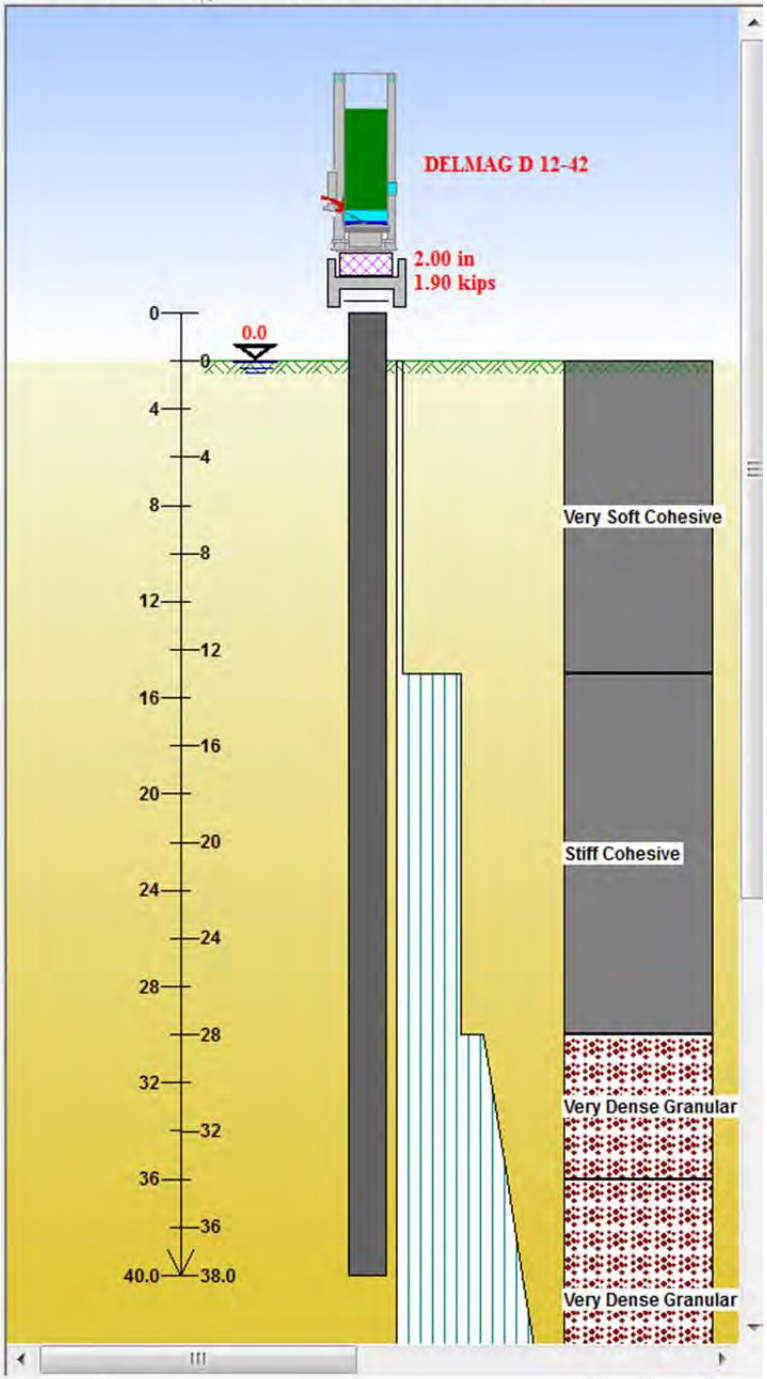
Shaft Resistance

Percentage 23 %

100%

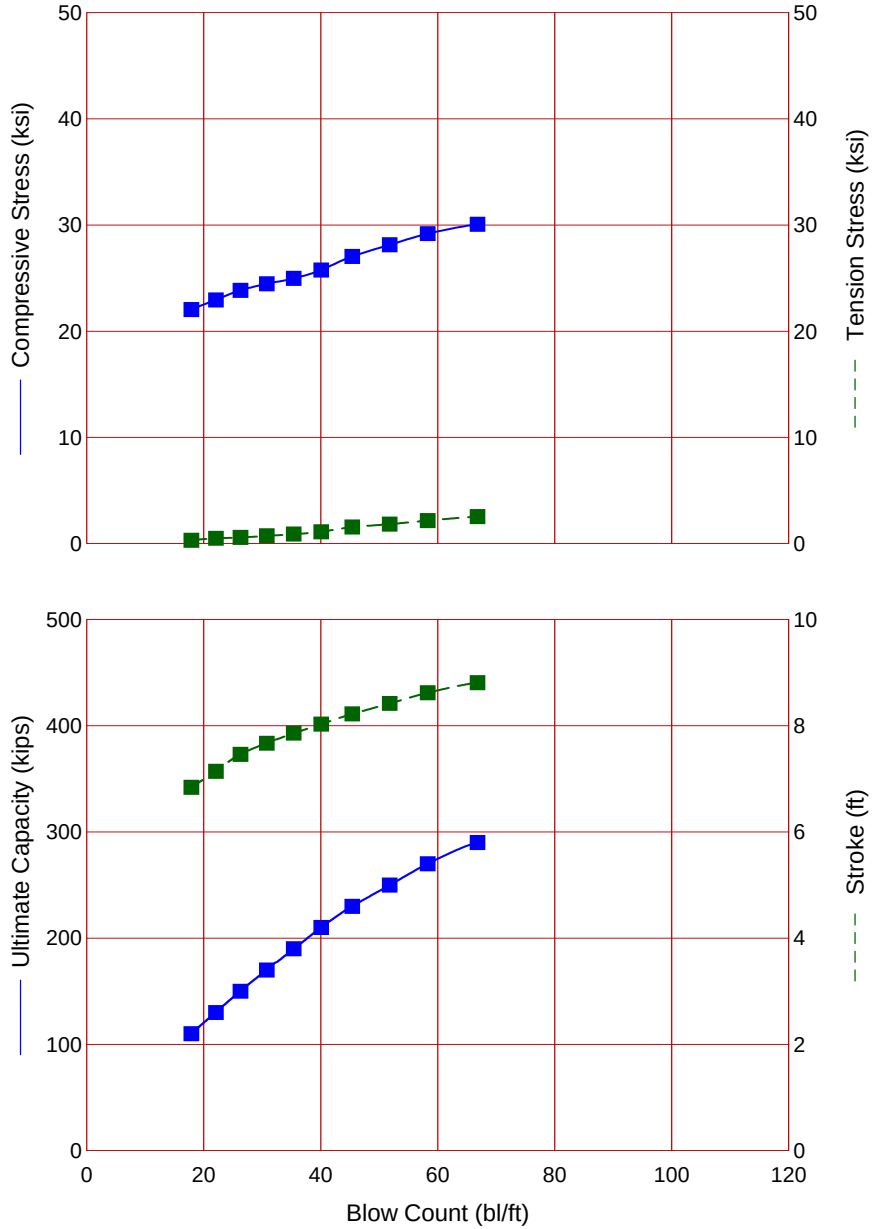
Dist. Shape Numb 0.0

Residual Stress Analysis: No



Terracon Consultants Inc
Bridge 330- EB1A

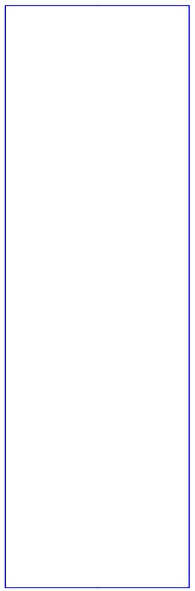
18-Feb-2013
GRLWEAP (TM) Version 2005



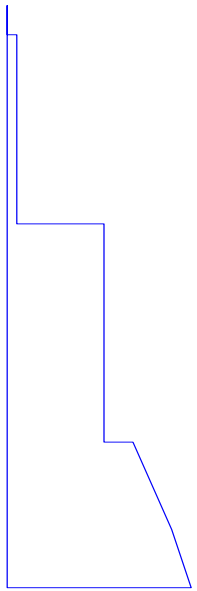
DELMAG D 12-42

Efficiency	0.800	
Helmet	1.90	kips
Hammer Cushion	60155	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.125	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	40.00	ft
Pile Penetration	38.00	ft
Pile Top Area	15.50	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 23 %
(Proportional)

Terracon Consultants Inc 18-Feb-2013
Bridge 330- EB1A GRLWEAP (TM) Version 2005

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
110.0	22.04	0.32	17.9	6.84	12.83
130.0	22.95	0.50	22.1	7.14	12.61
150.0	23.84	0.59	26.3	7.46	12.61
170.0	24.47	0.73	30.8	7.67	12.54
190.0	24.98	0.90	35.4	7.86	12.53
210.0	25.76	1.12	40.1	8.03	12.66
230.0	27.04	1.57	45.4	8.22	12.81
250.0	28.14	1.84	51.8	8.42	12.90
270.0	29.18	2.17	58.3	8.62	13.14
290.0	30.06	2.55	66.8	8.81	13.27

NCDOT GEOTECHNICAL ENGINEERING UNIT
BORELOG REPORT

WBS 17BP.7.R.28	**TIP** 17BP.7.R.28	**COUNTY** GUILFORD	**GEOLOGIST** Huelsman, CJ
SITE DESCRIPTION Bridge Number 330 over Mears Fork Creek on SR 2321 (Strawberry Road)			**GROUND WTR (ft)**
BORING NO. EB1-B	**STATION** 11+58	**OFFSET** 16 ft RT	**ALIGNMENT** L — **0 HR.** 6.7
COLLAR ELEV. 777.8 ft	**TOTAL DEPTH** 44.0 ft	**NORTHING** N/A	**EASTING** N/A — **24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE HPC0279 DIEDRICH D-50 90% 02/17/2012		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic
DRILLER Cain, J.	**START DATE** 02/04/13	**COMP. DATE** 02/04/13	**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)
780											
										777.8 GROUND SURFACE	0.0
										Topsoil	
	776.8	1.0								ROADWAY EMBANKMENT	
775			2	1	2	3		M		Red Slightly Micaceous Sandy CLAY	
	774.3	3.5	WOH	2	1	3		W			
	771.8	6.0	WOH	1	2	3		W		771.3	6.5
770	769.3	8.5								ALLUVIAL	
			1	1	1	2		W		Gray Slightly Micaceous Sandy CLAY	
765	764.3	13.5	2	1	2	3		W			
760	759.3	18.5	4	5	7	12		W		760.8 — 12 — RESIDUAL	17.0
										Tan to Light Brown Micaceous Sandy CLAY	
755	754.3	23.5	4	5	7	12		W			
750	749.3	28.5	15	24	28	52		W		750.8 — 22 — RESIDUAL	27.0
										Tan to Light Brown Micaceous Sandy SILT	
745	744.3	33.5	46	90	10/0.1	100/0.6				743.8 — 29	34.0
										WEATHERED ROCK (Gray Granitic Rock)	
740	739.3	38.5	65	35/0.2		100/0.7					
735	734.3	43.5	100							733.8 — 39	44.0
										Boring Terminated at Elevation 733.8 ft In Weathered Rock	

Bot 773

Top N 738

773-738=35'

w/ EB3B A sum up for both

REVISED PER NCDOT COMMENTS TO 35' PILES.

GRLWEAP 2005-2-Terracon Consultants Inc - [Bridge 330- EB1b.gww]

File Edit View Options Tools Window Help

English | Simple Resistance Distr | Uniform Pile | Bearing Graph - prop. shaft resistance

Bridge 330- EB1B

Hammer Information

Select from following list [8/28/2009-2003]: ID: 38

ID	Name	Type	Ram Wt	Energy/Power
36	DELMAG D 6-32	OED	1.3220	13.524
37	DELMAG D 12-32	OED	2.8200	31.330
38	DELMAG D 12-42	OED	2.8200	33.304

Hammer parameters

Efficiency	0.8			
Pressure	1640.0	psi	Fixed	100 %
Stroke	11.81	ft	Variable	of Max

Pile material

Concrete Steel Timber

Cushion Information

	Hammer	Pile	
Area	227.	0.	in^2
Elastic Modulus	530.	0.	ksi
Thickness	2.	0.	in
C.O.R.	0.8	0.	
Stiffness	0.	0.	kips/in
Helmet Weight	1.9		kips

Pile Information

Length	40.	ft	Auto	Segments
Penetration	35.	ft	Auto.	S-Length
Section Area	15.5	in^2	Auto.	S-St. Wt
Elast Modulus	30000.	ksi		
Spec Weight	492.0	lb/ft^3		
Toe Area	144.	in^2	0	Splices
Perimeter	4.	ft	Pile Type:	
Pile Size	12.	in	H Pile	

Ultimate Capacities (up to 10)

kips

1	110.0	6	210.0
2	130.0	7	230.0
3	150.0	8	250.0
4	170.0	9	270.0
5	190.0	10	290.0

Incr. 0 Action >>

Soil Parameters

Quake

Shaft	0.1	in	Const
Toe	0.1	in	

Damping

Shaft	0.102	s/ft	Const
Toe	0.15	s/ft	Smith

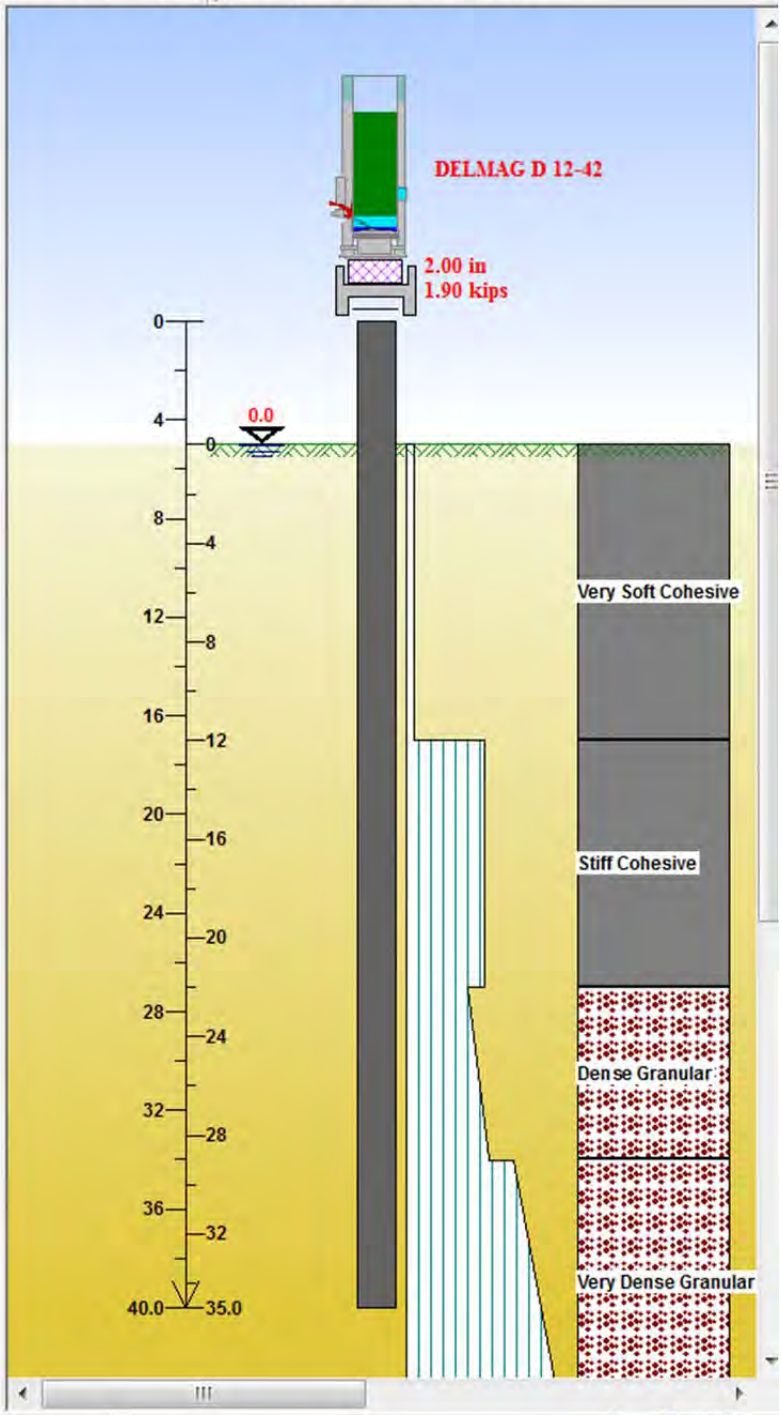
Shaft Resistance

Percentage 22 %

100%

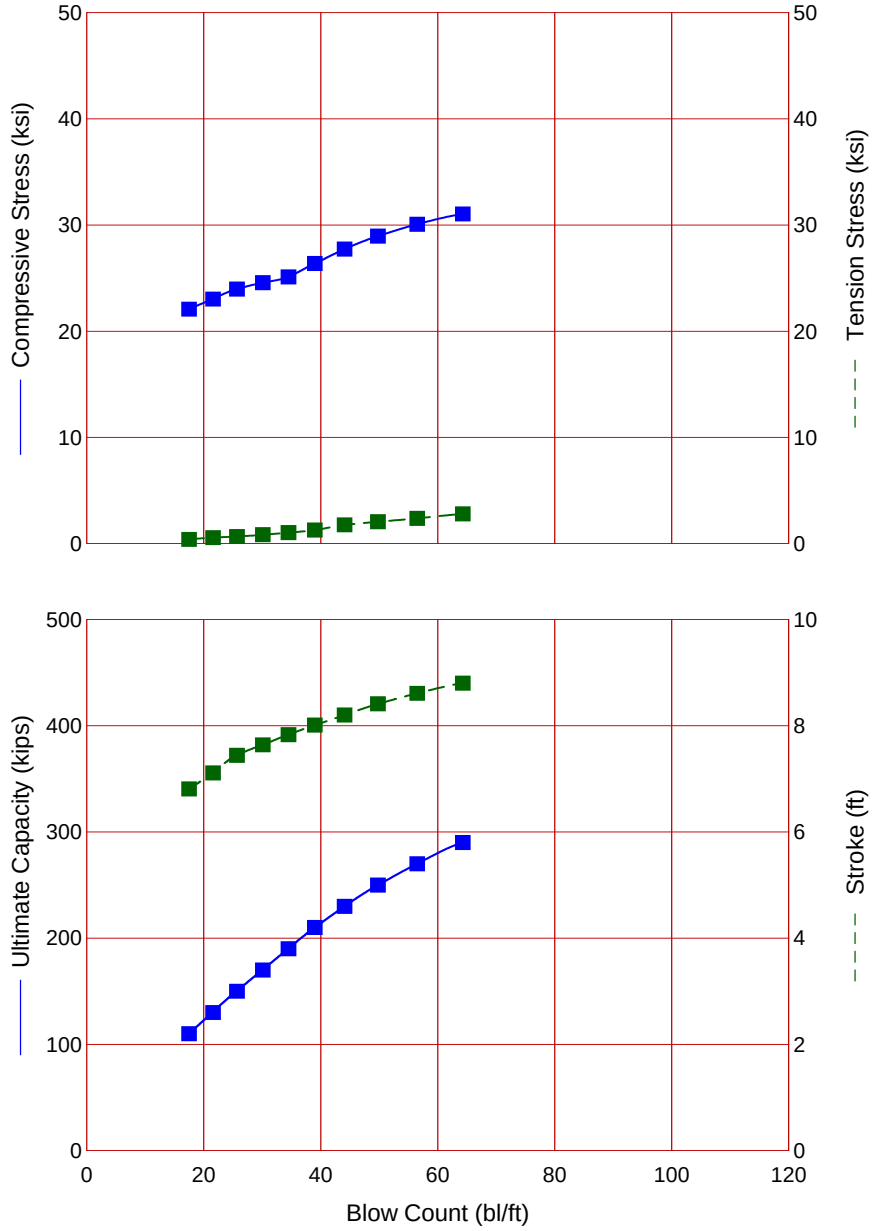
Dist. Shape Numb 0.0

Residual Stress Analysis: No



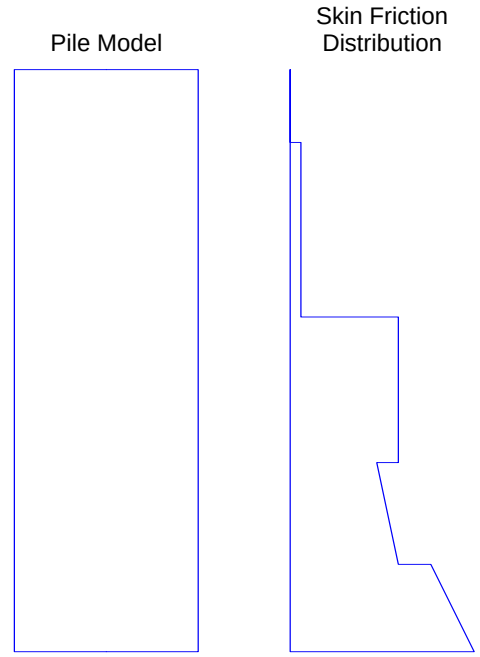
Terracon Consultants Inc
Bridge 330- EB1B

18-Feb-2013
GRLWEAP (TM) Version 2005



DELMAG D 12-42

Efficiency	0.800	
Helmet	1.90	kips
Hammer Cushion	60155	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.102	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	40.00	ft
Pile Penetration	35.00	ft
Pile Top Area	15.50	in2



Res. Shaft = 22 %
(Proportional)

Terracon Consultants Inc 18-Feb-2013
Bridge 330- EB1B GRLWEAP (TM) Version 2005

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
110.0	22.07	0.40	17.5	6.81	12.88
130.0	23.02	0.57	21.6	7.11	12.71
150.0	23.96	0.68	25.7	7.44	12.69
170.0	24.57	0.84	30.1	7.64	12.63
190.0	25.11	1.04	34.5	7.83	12.60
210.0	26.38	1.28	39.0	8.01	12.72
230.0	27.73	1.77	44.1	8.20	12.86
250.0	28.96	2.06	49.8	8.41	13.03
270.0	30.07	2.38	56.5	8.61	13.17
290.0	31.03	2.79	64.3	8.80	13.34

APPENDIX A-2 –END BENT 2

BORINGS EB2-A AND EB2-B WITH RELEVANT ELEVATIONS
WEAP ANALYSES FOR EB2-A AND EB2-B

NCDOT GEOTECHNICAL ENGINEERING UNIT
BORELOG REPORT

WBS 17BP.7.R.28	**TIP** 17BP.7.R.28	**COUNTY** GUILFORD	**GEOLOGIST** Huelsman, CJ
SITE DESCRIPTION Bridge Number 330 over Mears Fork Creek on SR 2321 (Strawberry Road)			**GROUND WTR (ft)**
BORING NO. EB2-A	**STATION** 12+46	**OFFSET** 21 ft LT	**ALIGNMENT** L	**0 HR.** 7.8
COLLAR ELEV. 778.2 ft	**TOTAL DEPTH** 41.6 ft	**NORTHING** N/A	**EASTING** N/A	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE HPC0279 DIEDRICH D-50 90% 02/17/2012		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic
DRILLER Cain, J.	**START DATE** 02/01/13	**COMP. DATE** 02/01/13	**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))
780										
	777.2	1.0	1	3	2	5		M		778.2 / 0.0 GROUND SURFACE; 0.4 Topsoil
775	774.7	3.5	2	2	2	4		W		775.2 / 3.0 ROADWAY EMBANKMENT Brown Sandy CLAY w/ Asphalt Fragments; ROADWAY EMBANKMENT Red Sandy CLAY
	772.2	6.0	2	2	2	4		W7		
770	769.7	8.5	2	1	1	2		W		770.2 / 8.0 ALLUVIAL Gray Slightly Micaceous Sandy CLAY
765	764.7	13.5	2	2	3	5		W		
760	759.7	18.5	WOH	WOH	WOH	0		W		
755	754.7	23.5	4	2	5	7		W		
750	749.7	28.5	7	9	8	17		W		751.2 / 27.0 RESIDUAL Tan Silty SAND
745	744.7	33.5	27	24	47	71		W		
740	739.7	38.5	60	40/0.2		100/0.7				739.7 / 38.5 WEATHERED ROCK (Gray Granitic Rock)
	736.6	41.6	60/0.1			60/0.1				736.6 / 41.6 Boring Terminated at Elevation 736.6 ft On Crystalline Rock

Bot ~772.5

Tip ~736.5

21

32.5

35.5

772.5 − 736.5 = 36'

REVISED PER NCDOT COMMENTS TO 35' PILES.

GRLWEAP 2005-2-Terracon Consultants Inc - [BRIDGE~3.GWW]

File Edit View Options Tools Window Help

English | Simple Resistance Distr | Uniform Pile | Bearing Graph - prop. shaft resistance

Bridge 330- EB2a

Hammer Information

Select from following list [8/28/2009-2003]: ID: 41

ID	Name	Type	Ram Wt	Energy/Power
39	DELMAG D 14-42	OED	3.086	34.501
40	DELMAG D 19-32	OED	4.000	42.440
41	DELMAG D 19-42	OED	4.000	43.240

Hammer parameters

Efficiency	0.8			
Pressure	1520.0	psi	Fixed	100 %
Stroke	10.81	ft	Variable	of Max

Pile material

Concrete ○ Steel ● Timber

Cushion Information

	Hammer	Pile	
Area	227.	0.	in^2
Elastic Modulus	530.	0.	ksi
Thickness	2.	0.	in
C.O.R.	0.8	0.	
Stiffness	0.	0.	kips/in
Helmet Weight	1.9		kips

Pile Information

Length	40.	ft	Auto	Segments
Penetration	35.	ft	Auto.	S-Length
Section Area	15.5	in^2	Auto.	S-St. Wt
Elast Modulus	30000.	ksi		
Spec Weight	492.0	lb/ft^3		
Toe Area	144.	in^2	0	Splices
Perimeter	4.	ft	Pile Type:	
Pile Size	12.	in	H Pile	

Ultimate Capacities (up to 10)

kips

1	200.0	6	325.0
2	225.0	7	350.0
3	250.0	8	375.0
4	275.0	9	400.0
5	300.0	10	425.0

Incr. 0 Action >>

Soil Parameters

Quake

Shaft	0.1	in	Const
Toe	0.1	in	

Damping

Shaft	0.092	s/ft	Const
Toe	0.15	s/ft	Smith

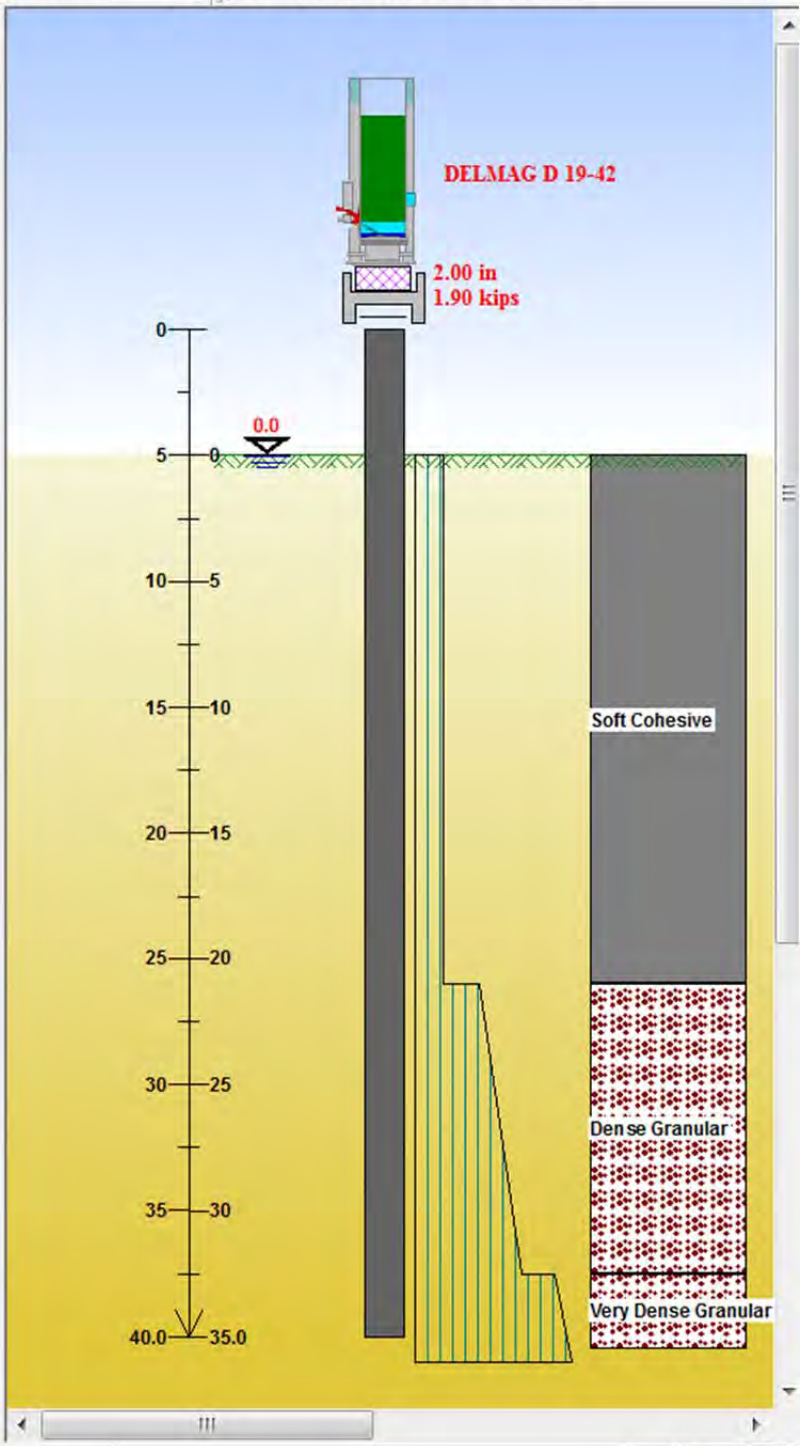
Shaft Resistance

Percentage 18 %

100%

Dist. Shape Numb 0.0

Residual Stress Analysis: No

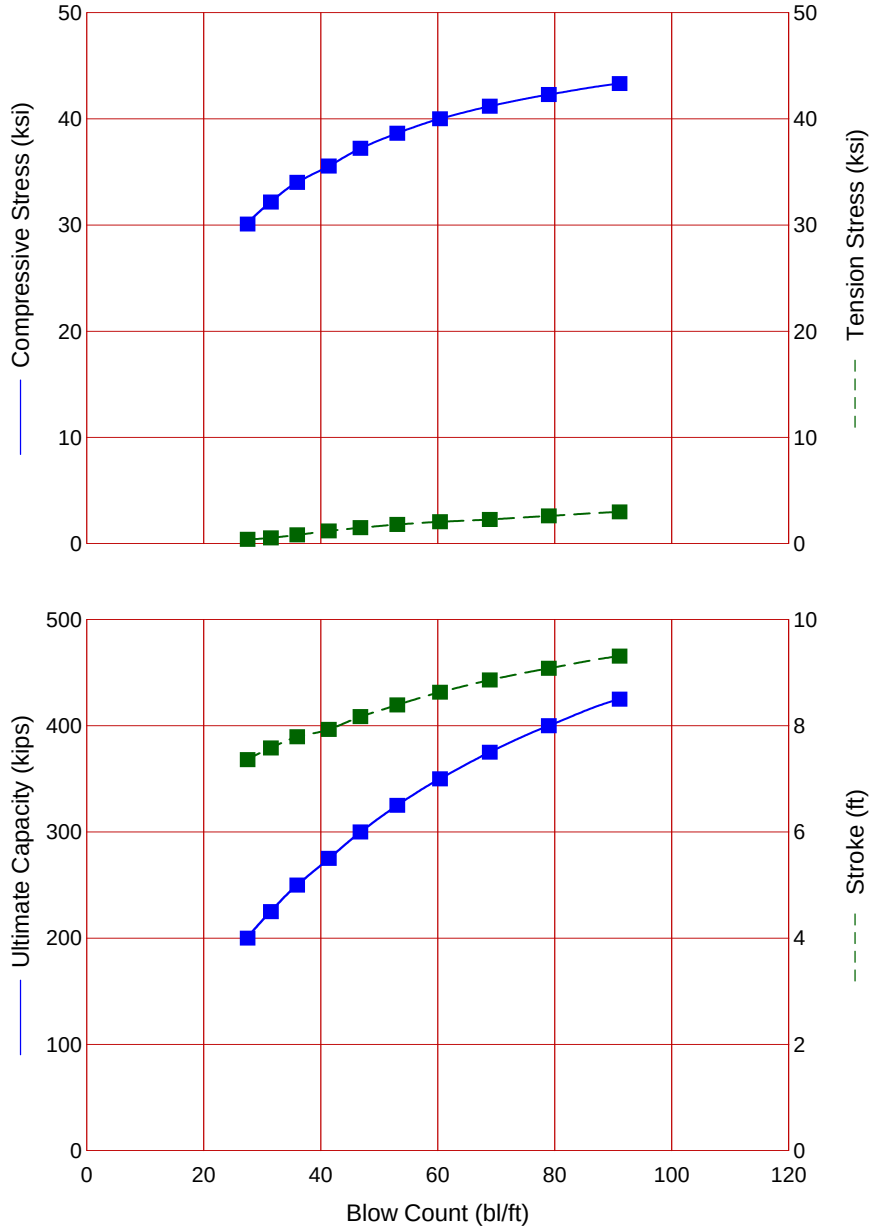


Press F1 for General Help Topics or F3 for Specific Help on Current Parameters

NUM

Terracon Consultants Inc
Bridge 330- EB2a

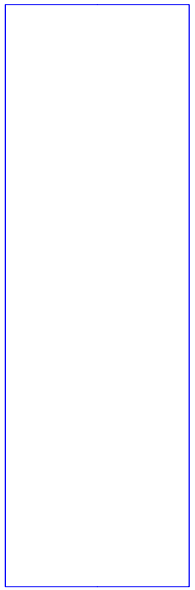
18-Feb-2013
GRLWEAP (TM) Version 2005



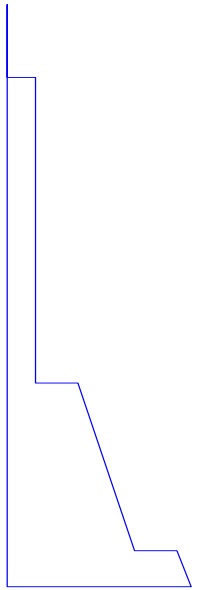
DELMAG D 19-42

Efficiency	0.800	
Helmet	1.90	kips
Hammer Cushion	60155	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.092	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	40.00	ft
Pile Penetration	35.00	ft
Pile Top Area	15.50	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 18 %
(Proportional)

Terracon Consultants Inc 18-Feb-2013
Bridge 330- EB2a GRLWEAP (TM) Version 2005

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
200.0	30.09	0.41	27.5	7.36	16.84
225.0	32.15	0.55	31.5	7.58	17.00
250.0	34.02	0.83	36.0	7.79	17.19
275.0	35.55	1.20	41.4	7.93	17.27
300.0	37.21	1.50	46.8	8.17	17.63
325.0	38.63	1.80	53.1	8.39	17.99
350.0	39.99	2.06	60.4	8.63	18.37
375.0	41.18	2.28	68.9	8.86	18.79
400.0	42.28	2.62	79.0	9.08	19.19
425.0	43.31	3.00	91.1	9.31	19.60

NCDOT GEOTECHNICAL ENGINEERING UNIT
BORELOG REPORT

WBS 17BP.7.R.28	**TIP** 17BP.7.R.28	**COUNTY** GUILFORD	**GEOLOGIST** Huelsman, CJ
SITE DESCRIPTION Bridge Number 330 over Mears Fork Creek on SR 2321 (Strawberry Road)			**GROUND WTR (ft)**
BORING NO. EB2-B	**STATION** 12+63	**OFFSET** 16 ft RT	**ALIGNMENT** L	**0 HR.** 7.7
COLLAR ELEV. 778.2 ft	**TOTAL DEPTH** 38.5 ft	**NORTHING** N/A	**EASTING** N/A	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE HPC0279 DIEDRICH D-50 90% 02/17/2012		**DRILL METHOD** H.S. Augers	**HAMMER TYPE** Automatic
DRILLER Cain, J.	**START DATE** 02/01/13	**COMP. DATE** 02/01/13	**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)
780											
	777.2	1.0								778.2 GROUND SURFACE	0.0
			3	2	3	5		M		Topsoil	0.1
775	774.7	3.5								**ROADWAY EMBANKMENT** Orange Brown Sandy CLAY	
			WOH	1	2	3		W		773.7	4.5
	772.2	6.0								**ALLUVIAL** Gray Slightly Micaceous Sandy CLAY	
			2	2	2	4		W			
770	769.7	8.5									
			2	2	2	4		W			
765	764.7	13.5									
			1	2	3	5		W			
760	759.7	18.5									
			1	1	2	3		W			
755	754.7	23.5									
			4	5	6	11		W			
750	749.7	28.5									
			2	1	4	5		W			
745	744.7	33.5								744.7 **WEATHERED ROCK** (Tan Granitic Rock)	33.5
			70	30/0.2		100/0.7					
740	739.7	38.5								739.7	38.5
			60/0.0			60/0.0				Boring Terminated with Standard Penetration Test Refusal at Elevation 739.7 ft On Crystalline Rock	

B.o.c. 772.5

27.5

32.5

772.5-740=32.5
w/ EB2A-1 says 40' pile

REVISED PER NCDOT COMMENTS TO 35' PILES.

GRLWEAP 2005-2-Terracon Consultants Inc - [Bridge 330- EB2b.gww]

File Edit View Options Tools Window Help

English | Simple Resistance Distr | Uniform Pile | Bearing Graph - prop. shaft resistance

Bridge 330- EB2b

Hammer Information

Select from following list [8/28/2009-2003]: ID: 41

ID	Name	Type	Ram Wt	Energy/Power
39	DELMAG D 14-42	OED	3.086	34.501
40	DELMAG D 19-32	OED	4.000	42.440
41	DELMAG D 19-42	OED	4.000	43.240

Hammer parameters

Efficiency	0.8			
Pressure	1520.0	psi	Fixed	100 %
Stroke	10.81	ft	Variable	of Max

Pile material

Concrete Steel Timber

Cushion Information

	Hammer	Pile	
Area	227.	0.	in^2
Elastic Modulus	530.	0.	ksi
Thickness	2.	0.	in
C.O.R.	0.8	0.	
Stiffness	0.	0.	kips/in
Helmet Weight	1.9		kips

Pile Information

Length	40.	ft	Auto	Segments
Penetration	32.	ft	Auto.	S-Length
Section Area	15.5	in^2	Auto.	S-St. Wt
Elast Modulus	30000.	ksi		
Spec Weight	492.0	lb/ft^3		
Toe Area	144.	in^2	0	Splices
Perimeter	4.	ft	Pile Type:	
Pile Size	12.	in	H Pile	

Ultimate Capacities (up to 10)

kips

1	200.0	6	325.0
2	225.0	7	350.0
3	250.0	8	375.0
4	275.0	9	400.0
5	300.0	10	425.0

Incr. 0 Action >>

Soil Parameters

Quake

Shaft	0.1	in	Const
Toe	0.1	in	

Damping

Shaft	0.138	s/ft	Const
Toe	0.15	s/ft	Smith

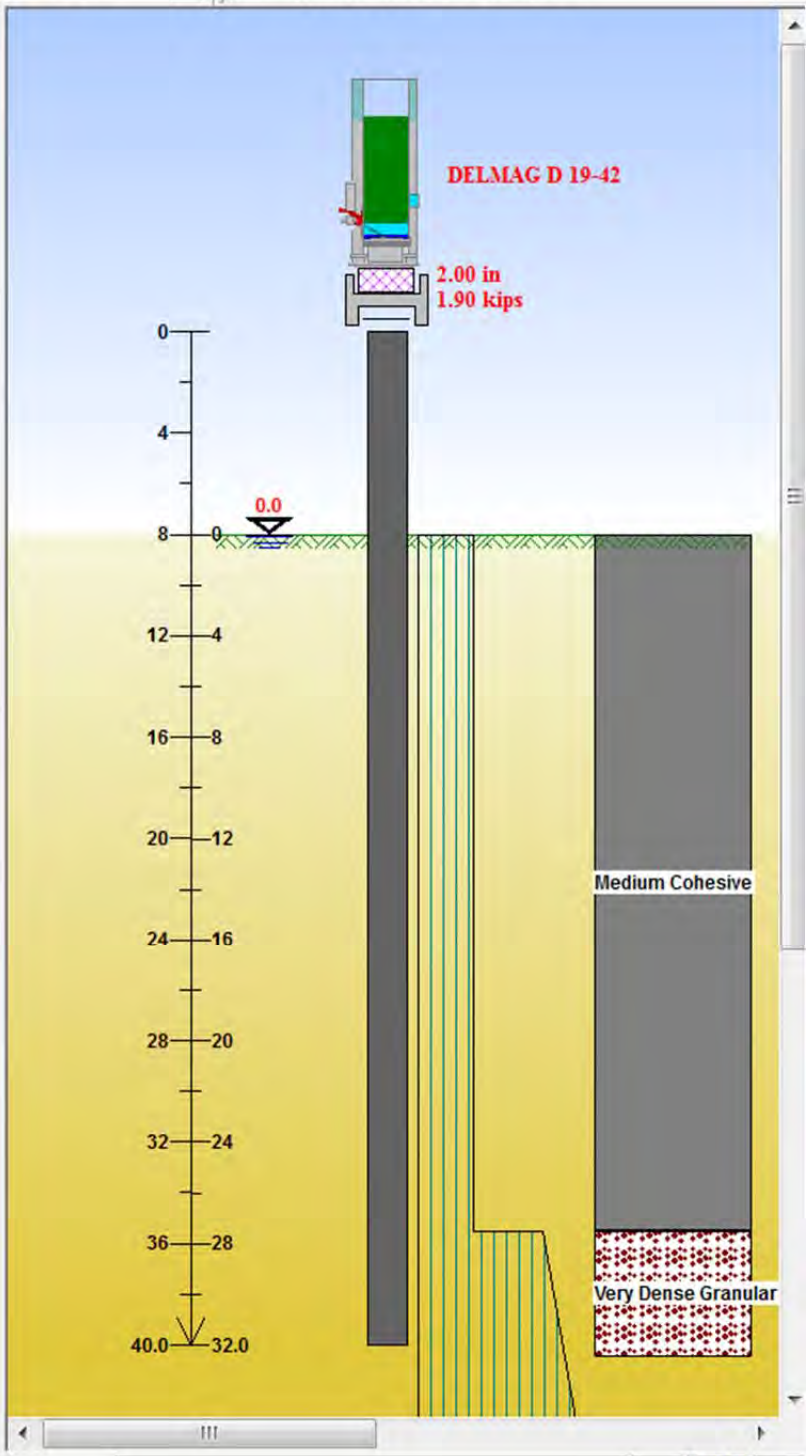
Shaft Resistance

Percentage 22 %

100%

Dist. Shape Numb 0.0

Residual Stress Analysis: No

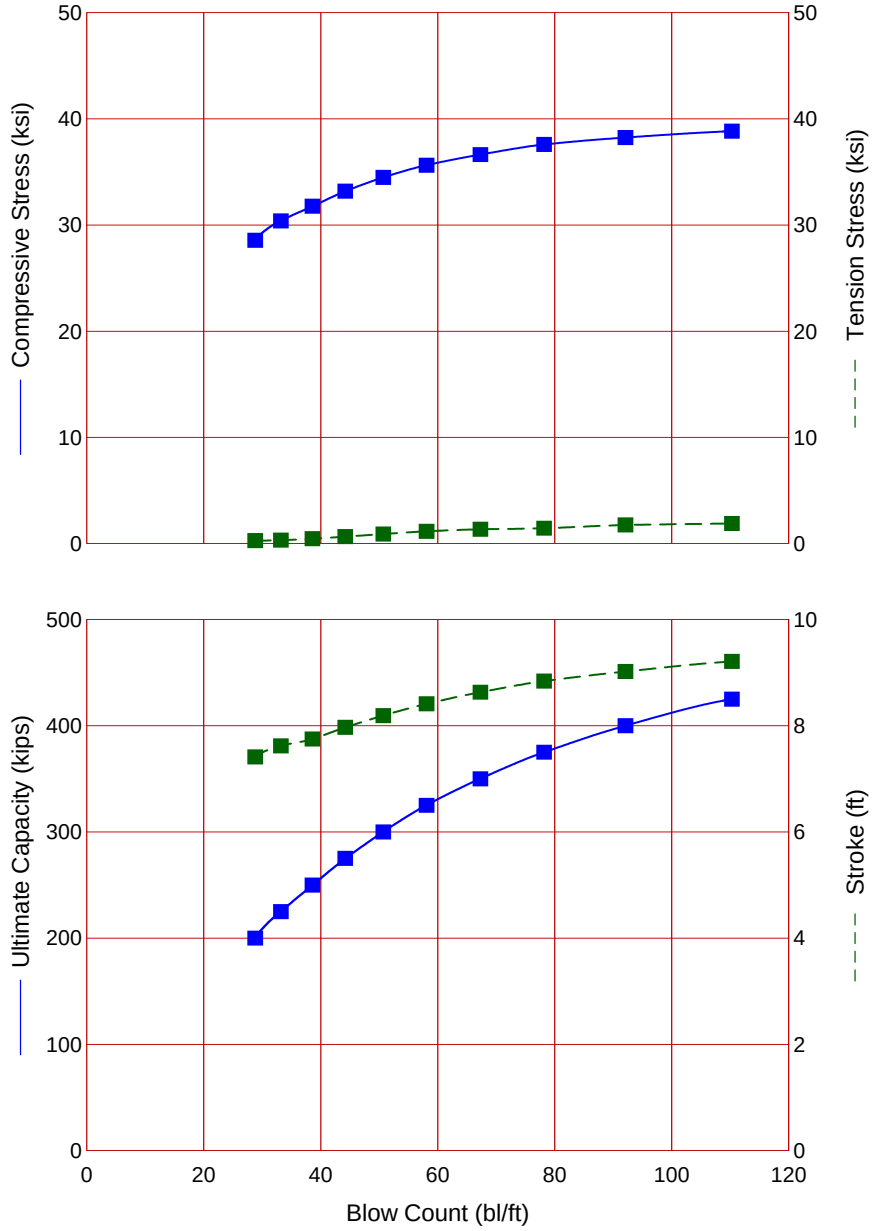


Press F1 for General Help Topics or F3 for Specific Help on Current Parameters

NUM

Terracon Consultants Inc
Bridge 330- EB2b

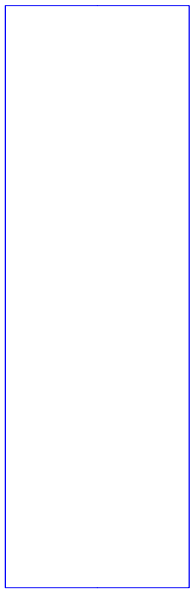
18-Feb-2013
GRLWEAP (TM) Version 2005



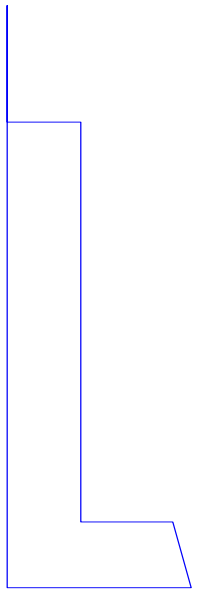
DELMAG D 19-42

Efficiency	0.800	
Helmet	1.90	kips
Hammer Cushion	60155	kips/in
Skin Quake	0.100	in
Toe Quake	0.100	in
Skin Damping	0.138	sec/ft
Toe Damping	0.150	sec/ft
Pile Length	40.00	ft
Pile Penetration	32.00	ft
Pile Top Area	15.50	in2

Pile Model



Skin Friction Distribution



Res. Shaft = 22 %
(Proportional)

Terracon Consultants Inc 18-Feb-2013
Bridge 330- EB2b GRLWEAP (TM) Version 2005

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
200.0	28.55	0.29	28.8	7.41	16.68
225.0	30.39	0.33	33.2	7.62	16.85
250.0	31.77	0.47	38.6	7.75	16.83
275.0	33.18	0.67	44.2	7.97	17.10
300.0	34.48	0.91	50.7	8.19	17.38
325.0	35.62	1.17	58.1	8.41	17.77
350.0	36.62	1.36	67.3	8.63	18.09
375.0	37.58	1.46	78.2	8.84	18.44
400.0	38.23	1.76	92.1	9.02	18.75
425.0	38.83	1.90	110.3	9.21	19.02

APPENDIX B – INTERIOR BENT ANALYSES

APPENDIX B-1 – BENT 1, BORING B1-A

BORING B1-A WITH RELEVANT ELEVATIONS
AXIAL CALCULATIONS
L-PILE ANALYSES
REQUIRED TIP RESISTANCE CALCULATIONS

NCDOT GEOTECHNICAL ENGINEERING UNIT
BORELOG REPORT

WBS 17BP.7.R.28	TIP 17BP.7.R.28	COUNTY GUILFORD	GEOLOGIST Huelsman, CJ
SITE DESCRIPTION Bridge Number 330 over Mears Fork Creek on SR 2321 (Strawberry Road)			GROUND WTR (ft)
BORING NO. B1-A	STATION 11+86	OFFSET 16 ft LT	ALIGNMENT L — 0 HR. 1.9
COLLAR ELEV. 775.0 ft	TOTAL DEPTH 27.2 ft	NORTHING N/A	EASTING N/A — 24 HR. FIAD
DRILL RIG/HAMMER EFF./DATE HPC0279 DIEDRICH D-50 90% 02/17/2012		DRILL METHOD H.S. Augers	HAMMER TYPE Automatic
DRILLER Cain, J.	START DATE 02/05/13	COMP. DATE 02/05/13	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))
780										
775										775.0 / 0.0 GROUND SURFACE
	774.0	1.0	2	2	2	4		W		Topsoil
	771.5	3.5	1	2	1	3		W		ROADWAY EMBANKMENT Red Slightly Micaceous Sandy Silty CLAY
770	769.0	6.0	WOH	WOH	1	1		W		
	766.5	8.5	WOH	WOH	WOH	WOH 0		W		767.0 / 8.0 ALLUVIAL Gray Slightly Micaceous Sandy CLAY
765	761.5	13.5	WOH	WOH	2	2		W		
760	756.5	18.5	2	3	1	4		W		
755	751.5	23.5	18	32	60	92		W		753.0 / 22.0 RESIDUAL Tan Sandy SILT
750	747.8	27.2	60/0.0			60/0.0				749.0 / 26.0; 747.8 / 27.2 WEATHERED ROCK (Tan Granitic Rock) Boring Terminated with Standard Penetration Test Refusal at Elevation 747.8 ft On Crystalline Rock

Backs ~773.5

Approx scour

20.5

D.S.E ~767

25.7

WR 35

Rock 45

Terracon

Analysis Performed By:	*JPM*
Date of Analysis:	*2/15/2013*
Analysis Reviewed By:	

ANALYSIS OF DRILLED SHAFT TIP RESISTANCE IN SOIL, IGM OR ROCK

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Left*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1A*	
Boring Elevation:	*773.50*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	*ft*
Shaft Length:	*36*	*ft (below grade)*	**Tip Elevation:**	*737.50*	*ft MSL*	**Cross-section Area:**	*7.1*	*ft^2*
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*	**Water Table Depth:**	*0.0*	*ft*

Type of Material at the Tip:	**Rock**	f_c': concrete compressive strength =	**4.50**	ksi

For Soil Section 10.8.3.5.2c, *2010 AASHTO LRFD Bridge Design Specifications*

Cohesionless Soils: $N_{60} \leq 50$, $q_p = 1.2*N_{60}$ Equation 10.8.3.5.2c-1, *2010 AASHTO LRFD Bridge Design Specifications*

Cohesive Soils: $N_c = 6(1+0.2(Z/D)) \leq 9$ $q_p = N_c * S_u \leq 80$ where Z= penetration of shaft in bearing layer

S_u = ksf

Z = ft

N_c =

Cohesionless Soils: **Unit Tip Resistance in Soil, q_p =** (q_p is limited to a maximum of 60 ksf)

Cohesive Soils: **Unit Tip Resistance in Soil, q_p =** (q_p is limited to a maximum of 80 ksf)

For IGM (IGM: Cohesionless soils with blow counts greater than 50 blows/ft, i.e., Very Dense/Hard Soils and PWR)
Section 10.8.3.5.2c, *2010 AASHTO LRFD Bridge Design Specifications*

$$q_p = 0.59 \left[N_{60} \left\{ \frac{p_a}{\sigma'_v} \right\} \right]^{0.8} \sigma'_v$$

Equation 10.8.3.5.2c-2, *2010 AASHTO LRFD Bridge Design Specifications*

Material unit weight at tip =	0.14	kcf		Depth of the tip:	36	ft	Water Level (ft):	0	ft
N: Uncorrected SPT Blow Count at the Tip =	1000	blows/ft		N_{60}* = (ER/60%)N =	100	blows/ft	Type of Hammer:	auto	
p_a: atmospheric pressure =	2.12	ksf		σ'_v : vertical effective stress at tip =	2.03	ksf	ER: Hammer Efficiency:	80%	

*N_{60} is limited to a maximum of 100 bpf

Unit Tip Resistance in IGM, q_p =

For Rock

$$q_p = A + q_u [m_b (A/q_u) + s]^a$$ where $A = \sigma'_v + q_u [m_b (\sigma'_v/q_u) + s]^a$

Reference: Turner (2006). *NCHRP Synthesis 360 Rock-Socketed Shafts for Highways Structure Foundations*. Transportation Research Board of National Academies. 136 pp.

q_u: unconfined compressive strength of intact rock	s, a : constant for the Rock Mass	GSI: Geological Strength Index	$GSI^* \approx 18.7e^{(0.0152RQD)}$
m_b: Reduced Value of m_i	$s = \exp^{((GSI-100)/9)}$	$m_b = m_i (\exp^{((GSI-100)/28)})$	$a = 1/2 + 1/6(e^{-GSI/15} - e^{-20/3})$ RQD: Rock Quality Designation

q_u =	576	ksf	m_i =	29		RQD =	88	%	A =	162.35	ksf
GSI =	71	s =	4.12E-02	a =	0.50	m_b =	10.41				

* Correlation defined by Truzman et. al. (2011) "Determination of Unit Tip Resistance for Drilled Shafts in Fractured Rocks using the Global Rock Mass Strength", 2011 Pan-Am CGS Geotechnical Conference

Unit Tip Resistance in Rock, q_p = **1,157** **ksf in Rock** **Not <** **fc' =** **648** **ksf** **Use qp =** **648** **ksf**

NOTE: Please input the required data where indicated in Blue. When calculating Tip Resistance in Cohesive Soil, please input an Undrained Shear Strength value, Su, into the "Side in Soils (using a-method)" sheet for the bearing layer to generate a tip resistance in cohesive soils output on this sheet. When calculating Tip Resistance in IGM, no data needs to be input onto this sheet other than indicating IGM or Rock as the material at the tip, and the Project Information at the top of the sheet. Please input all soil strata data and shaft information into the "Side in Soils (using B-method)" sheet to generate a tip resistance in IGM output on this sheet. You should always check the input and output values on this sheet to ensure accuracy and correctness.

Terracon

Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

DRILLED SHAFT SIDE RESISTANCE CALCULATION USING β-METHOD

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Left*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1A*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*36*	*ft (below grade)*	**Tip Elevation:**	*737.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*			

UNIT SIDE RESISTANCE (q_s) (*Section 10.8.3.5.2b, 2010 AASHTO LRFD Bridge Design Specifications*)

$q_s = \beta\sigma_v'$ **≤ 4.0 ksf** **for 0.25 ≤ β ≤ 1.2** (Eq. 10.8.3.5.2b-1)

For N_{60} ≤ 15	$\beta = (1.5 - 0.135\,(z)^{0.5})\,N_{60}/15$		
For N_{60} ≥ 15	$\beta = 1.5 - 0.135\,(z)^{0.5}$ (sandy soils)	or	$\beta = 2.0 - 0.06\,(z)^{0.75}$ (gravelly sands and gravels)
N_{60} = (ER/60%)N	N_{60}: SPT blow count corrected for hammer efficiency (blows/ft)		N: uncorrected SPT blow count
σ'_v = vertical effective stress	Hammer efficiency = 80%	Type of Hammer: **auto**	Water Level (ft): 0 ft

# of Layers:	4	Layer the Tip is located in:	4											
Layer	USCS	Soil Type	Top of layer (ft)	Bottom of layer (ft)	Unit weight (kcf)	Mid-layer Depth (ft)	σ'_v mid-layer (ksf)	N-value (blows/ft)	N_{60} (blows/ft)	β	Check if 0.25<β<1.2	q_s (ksf)	Check if q_s ≤ 4.0 ksf	Q_{si} (kips)
1	**CL**	**Clay**	0	**20.5**	**0.110**	10.3	0.488	**0**	0					
2	**ML**	**Silt**	20.5	**25.7**	**0.130**	23.1	1.152	**92**	123	0.85	0.85	IGM Mat'l		
3	**PWR**	**IGM**	25.7	**35**	**0.130**	30.4	1.642	**100**	133	0.76	0.76	IGM Mat'l		
4	**Rock**	**Rock**	35	**45**	**0.140**	35.5	1.995	**1000**				Rock		

Total Skin Friction in Soils, $\Sigma(Q_{s,soils})_i$ = 0

Terracon

Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

DRILLED SHAFT SIDE RESISTANCE CALCULATION USING α-METHOD

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Left*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1A*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*36*	*ft (below grade)*	**Tip Elevation:**	*737.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*			

UNIT SIDE RESISTANCE (q_s) (*Section 10.8.3.5.1b, 2010 AASHTO LRFD Bridge Design Specifications*)

$q_s = \alpha S_u$ (Eq. 10.8.3.5.1b-1)

For $S_u/p_a \leq 1.5$	$\alpha = 0.55$			
For $1.5 \leq S_u/p_a \leq 2.5$	$\alpha = 0.55 - 0.1(S_u/p_a - 1.5)$	Su = undrained shear strength (ksf)	α = adhesion factor	p_a = atm. pressure = 2.12 ksf
N_{60} = (ER/60%)N	N_{60}: SPT blow count corrected for hammer efficiency (blows/ft)		N: uncorrected SPT blow count	
σ'_v = vertical effective stress	Hammer efficiency = 80%	Type of Hammer: auto	Water Level (ft): 0 ft	

# of Layers: 4	Layer the Tip is located in: 4

Layer	USCS	Soil Type	Top of layer (ft)	Bottom of layer (ft)	Unit weight (kcf)	Mid-layer Depth (ft)	σ'_v mid-layer (ksf)	N-value (blows/ft)	N_{60} (blows/ft)	S_u (ksf)	S_u/p_a	α	q_s (ksf)	Q_{si} (kips)
1	CL	Clay	0	20.5	0.110	10.3	0.488	0	0	0.00	0.00	0.55	0.00	0
2	ML	Silt	20.5	25.7	0.130	23.1	1.152	92	123	0.00	0.00	IGM Mat'l		
3	PWR	IGM	25.7	35	0.130	30.4	1.642	100	133			IGM Mat'l		
4	Rock	Rock	35	45	0.140	35.5	1.995	1000				Rock		

Total Skin Friction in Soils, $\Sigma(Q_{s,soils})_i$ = 0

Terracon

Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

ANALYSIS OF DRILLED SHAFT RESISTANCE IN IGM OR WEAK ROCK

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Left*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1A*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*36*	*ft (below grade)*	**Tip Elevation:**	*737.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*	**Water Table Depth:**	*0.0*	ft

UNIT SIDE RESISTANCE (q_s) for COHESIONLESS IGM SOILS (*Section 10.8.3.5.5, 2010 AASHTO LRFD Bridge Design Specifications*)

$$q_s = \sigma'_v K_o \tan \Phi'$$

Equation referenced from Chapter 11, *Drilled Shafts: Construction Procedures and Design Methods*, FHWA Publication No. FHWA-IF-99-025, O'Neill and Reese, August, 1999.

IGM: Very Hard/Very Dense Cohesionless Soils and PWR with SPT N_{60} > 50 blows-per-foot		N_{60} = (ER/60%)N = SPT N-value corrected for Hammer Efficiency
$\Phi' = \tan^{-1}((N_{60}/(12.3+20.3(\sigma'_v/p_a)))^{0.34}$	Φ' = effective stress friction angle of IGM	N: Uncorrected SPT N-Value along the shaft
$K_o = (1-\sin\Phi')OCR^{\sin\Phi'}$	K_o = in-situ coefficient of lateral earth pressure	Hammer Efficiency, ER = 80%
$OCR = \sigma'_p/\sigma'_v$	σ'_v = vertical effective stress	Type of hammer = auto
$\sigma'_p = 0.2N_{60}p_a$	σ'_p = vertical effective stress	Atmospheric Pressure, p_a = 2.12 ksf

# of Layers: 4

Layer	Material	Top of layer (ft)	Bottom of layer (ft)	Unit weight (kcf)	Mid-layer Depth (ft)	σ'_v mid-layer (ksf)	N-value (blows/ft)	N_{60} (blows/ft)	ϕ' (degrees)	σ'_p (ksf)	OCR	K_o	q_s ** (ksf)	Q_s (kips)
1	CL	0	20.5	0.110	10.3	0.488	0	0				Not IGM		
2	ML	20.5	25.7	0.130	23.1	1.152	92	123	58.6	42.400	36.82	3.18	3.0	147
3	PWR	25.7	35	0.130	30.4	1.642	100	133	57.0	42.400	25.83	2.46	3.1	273
4	Rock	35	45	0.140	35.5	1.995	1000					Not IGM		

*****Unit Side Resistance, qs, has been reduced by 50% of its calculated value based on past local experience in IGM Materials.***

Total Skin Friction in IGM, $\Sigma(Q_{s,IGM})_i$ = 420

NOTE: No data needs to be input on this sheet to calculate skin resistance in IGM. Please input all soil strata information into the "Side in Soils" sheet to generate a skin resistance in IGM output on this sheet. You should always check the input and output information on this sheet to ensure accuracy and correctness.

Terracon

Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

ANALYSIS OF DRILLED SHAFT RESISTANCE IN IGM OR ROCK

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Left*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1A*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*36*	*ft (below grade)*	**Tip Elevation:**	*737.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*	**Water Table Depth:**	*0.0*	ft

UNIT SIDE RESISTANCE (q_s) for DRILLED SHAFTS in ROCK (*Section 10.8.3.5.4b, 2010 AASHTO LRFD Bridge Design Specifications*)

$$q_s = 0.65\ \alpha_E\ p_a\ (q_u/p_a)^{0.5} < 7.8\ p_a\ (f_c'/p_a)^{0.5}$$ (Equation 10.8.3.5.4b-1)

For Rock Layer 1

p_a: atmospheric pressure =		2.12	ksf	f_c': concrete compressive strength =		4.50	ksi
q_u: unconfined compressive strength of rock =	576	ksf		E_m/E_i: reduction factor (determined from Table 10.4.6.5-1) =		0.40	
RQD = 88 %	GSI =	71		α_E = reduction factor to account for jointing in rock =		0.75	

q_s = 17.04 ksf ≤ 24.09 ksf

calculation of qs is OK **use qs = 17.04 ksf for Rock Layer 1**

For Rock Layer 2

p_a: atmospheric pressure =		2.12	ksf	f_c': concrete compressive strength =		4.50	ksi
q_u: unconfined compressive strength of rock =			ksf	E_m/E_i: reduction factor (determined from Table 10.4.6.5-1) =		0.05	
RQD = %	GSI =			α_E = reduction factor to account for jointing in rock =		0.45	

q_s = 0.00 ksf ≤ 24.09 ksf

calculation of qs is OK **use qs = 0.00 ksf for Rock Layer 2**

AREA OF SHAFT SIDE SURFACE (As) in ROCK

Length in Layer 1 =	1	ft
Length in Layer 2 =		ft
Socket Diameter =	2.8333	ft
Socket perimeter =	8.90	ft

A_s = 8.90 ft^2

Total Skin Friction in Rock, $Q_{s,rock}$ = 152 kips

NOTE: When calculating side resistance in Rock on this sheet, please input the required input data where indicated in Blue. Please input all rock/soil data and shaft information correctly into the "Tip" sheet to generate a Skin Resistance in Rock output on this sheet. You should always check the input and output values on this sheet to ensure accuracy and correctness.

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Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

ANALYSIS OF DRILLED SHAFT RESISTANCE IN IGM OR ROCK

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Left*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1A*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*36*	*ft (below grade)*	**Tip Elevation:**	*737.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*	**Water Table Depth:**	0.0	ft

Table 10.5.5.2.4-1 Resistance Factors for Geotechnical resistance of Drilled Shafts (2010 AASHTO LRFD Bridge Design Specifications)

Method/Soil/Condition			Resistance Factor
Nominal Axial Compressive Resistance of Single-Drilled Shafts, φ_{stat}	Side resistance in clay	α-method (O'Neill and Reese, 1999)	0.45
	Tip resistance in clay	Total Stress (O'Neill and Reese, 1999)	0.40
	Side resistance in sand	β-method (O'Neill and Reese, 1999)	0.55
	Tip resistance in sand	O'Neill and Reese (1999)	0.50
	Side resistance in IGMs	O'Neill and Reese (1999)	0.60
	Tip resistance in IGMs	O'Neill and Reese (1999)	0.55
	Side resistance in rock	Horvath and Kenney (1979)	0.5
	Tip resistance in rock	O'Neill and Reese (1999)	0.50
Static Load Test (compression), φ_{load}	All Materials		Values in Table 10.5.5.2.3-2, but no greater than 0.70

Nominal Shaft Tip Resistance (R_p)

$R_p = q_p \times A_p$ (Equation 10.8.3.5-2)

$q_p =$ 648 ksf $A_p =$ 6.30 ft^2 **$R_p =$ 4,086 kips** ***(Concrete Limits)***

Nominal Shaft Side Resistance (R_s)

$R_s = q_s \times A_s$ (Equation 10.8.3.5-3)

$R_{s,clay} =$ 0 kips **$R_{s,sand} =$ 0 kips** **$R_{s,IGM} =$ 420 kips** **$R_{s,rock} =$ 152 kips**

Total Nominal Resistance ($R_p + R_s$) = 4,657 kips equivalent to **20,717 kN**

REDUCTION DUE TO GROUP EFFECTS

$0.65 \le \eta \le 1.00$ for 2.5*dia. ≤ Distance Between Shafts ≤ 6*dia. (Section 10.8.3.6.3)

Distance Between Shafts = 18 **feet** **$\eta =$ 1.00**

FACTORED RESISTANCE OF SINGLE DRILLED SHAFT

$R_R = \varphi R_n = \varphi_{qp} R_p + \varphi_{qs} R_s$ (Equation 10.8.3.5-1)

φ_{qp} = resistance factor for tip resistance specified in Table 10.5.5.2.4-1

φ_{qs} = resistance factor for shaft side resistance specified in Table 10.5.5.2.4-1

$\varphi_{qp} =$	0.50	**Concrete**									
$\varphi_{qs} =$	0.45	**Clay**	$\varphi_{qs} =$	0.55	**Sand**	$\varphi_{qs} =$	0.60	**IGM**	$\varphi_{qs} =$	0.55	**Rock**

Total Factored Resistance, $R_R =$ 2,378 kips

==========

LPile Plus for Windows, Version 6 (6.0.28)

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

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Serial Number of Security Device: 156316250
Company Name Stored in Security Device: WPC, Inc.

Files Used for Analysis

Path to file locations: N:\Projects\2011\71115060\Working Files\Bridge 330\Calculations-Analyses\
Name of input data file: Bridge 330 - B1a.lp6d
Name of output report file: Bridge 330 - B1a.lp6o
Name of plot output file: Bridge 330 - B1a.lp6p
Name of runtime messeage file: Bridge 330 - B1a.lp6r

Date and Time of Analysis

Date: February 15, 2013 Time: 8:55:28

Problem Title

Low Impact Bridge - Guilford County No. 330

71115060

KHA

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Boring B1A - Bent 1

Program Options

Engineering units are US Customary Units: pounds, inches, feet

Basic Program Options:

This analysis computes pile response to lateral loading and will compute nonlinear moment-curvature and nominal moment capacity for selected section types.

Computation Options:
- Only internally-generated p-y curves used in analysis
- Analysis does not use p-y multipliers (individual pile or shaft action only)
- Analysis assumes no shear resistance at pile tip
- Analysis for fixed-length pile or shaft only
- No computation of foundation stiffness matrix elements
- Output pile response for full length of pile
- Analysis assumes no soil movements acting on pile
- No p-y curves to be computed and output for user-specified depths

Solution Control Parameters:

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

Pile Response Output Options:
- 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

Pile Structural Properties and Geometry

Total Number of Sections = 1

Total Pile Length = 31.00 ft

Depth of ground surface below top of pile = 20.50 ft

Pile dimensions used for p-y curve computations defined using 2 points.
p-y curves are computed using values of pile diameter interpolated over the length of the pile.

Point	Depth X ft	Pile Diameter in
1	0.00000	36.0000000
2	31.000000	36.0000000

Input Structural Properties:

Pile Section No. 1:

```
   Section Type                                    =    Elastic Pile
   Cross-sectional Shape                           =        Circular
   Section Length                                  =          31.000 ft
   Top Width                                       =          36.000 in
   Bottom Width                                    =          36.000 in
   Top Area                                        =     1017.876020 sq. in
   Bottom Area                                     =     1017.876020 sq. in
   Moment of Inertia at Top                        =       82447.958 in^4
   Moment of Inertia at Bottom                     =       82447.958 in^4
   Elastic Modulus                                 =        3283676. lbs/in^2
```

Ground Slope and Pile Batter Angles

```
Ground Slope Angle                                 =        0.000 degrees
                                                   =        0.000 radians

Pile Batter Angle                                  =        0.000 degrees
                                                   =        0.000 radians
```

Soil and Rock Layering Information

The soil profile is modelled using 2 layers

Layer 1 is stiff clay without free water

```
Distance from top of pile to top of layer          =       20.500 ft
Distance from top of pile to bottom of layer       =       35.000 ft
```

Layer 2 is strong rock (vuggy limestone)

```
Distance from top of pile to top of layer          =       35.000 ft
Distance from top of pile to bottom of layer       =       45.000 ft
```

(Depth of lowest layer extends 14.00 ft below pile tip)

Effective Unit Weight of Soil vs. Depth

Effective unit weight of soil with depth defined using 4 points

Point No.	Depth X ft	Eff. Unit Weight pcf

1	20.50	70.00000
2	35.00	70.00000
3	35.00	80.00000
4	45.00	80.00000

Summary of Soil Properties

Layer Num.	Soil Type (p-y Curve Criteria)	Depth ft	Eff. Unit Wt., pcf	Cohesion psf	Friction Ang., deg.	qu psi	RQD percent	Epsilon 50	J	kpy pci	Rock Emass psi	krm	Test Type	Test Prop.	Elas. Subgr. pci
1	Stiff Clay w/o Free Water	20.500	70.000	4000.000	--	--	--	5.00E-04	--	--	--	--	--	--	--
		35.000	70.000	4000.000	--	--	--	5.00E-04	--	--	--	--	--	--	--
2	Vuggy Limestone	35.000	80.000	--	--	5000.000	--	--	--	--	--	--	--	--	--
		45.000	80.000	--	--	5000.000	--	--	--	--	--	--	--	--	--

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
1	1	V = 11000. lbs	M = 720000. in-lbs	480000.
2	2	V = 2500.00000 lbs	S = 0.0000 in/in	490000.

V = perpendicular shear force applied to pile head
M = bending moment applied to pile head
y = lateral deflection relative to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applie to pile head
Axial thrust is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-Curvature properties derived from elastic section properties

---

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)

Horizontal shear force at pile head = 11000.000 lbs
Applied moment at pile head = 720000.000 in-lbs
Axial thrust load on pile head = 480000.000 lbs

Depth X inches	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/in	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.5579	720000.	11000.	-0.002924	628.7603	2.707E+11	0.000	0.000	0.000
3.720	0.5470	766131.	11000.	-0.002913	638.8317	2.707E+11	0.000	0.000	0.000
7.440	0.5362	812244.	11000.	-0.002902	648.8989	2.707E+11	0.000	0.000	0.000
11.160	0.5255	858337.	11000.	-0.002891	658.9619	2.707E+11	0.000	0.000	0.000
14.880	0.5147	904408.	11000.	-0.002879	669.0202	2.707E+11	0.000	0.000	0.000
18.600	0.5040	950458.	11000.	-0.002866	679.0737	2.707E+11	0.000	0.000	0.000
22.320	0.4934	996484.	11000.	-0.002853	689.1221	2.707E+11	0.000	0.000	0.000
26.040	0.4828	1042486.	11000.	-0.002839	699.1652	2.707E+11	0.000	0.000	0.000
29.760	0.4723	1088462.	11000.	-0.002824	709.2026	2.707E+11	0.000	0.000	0.000
33.480	0.4618	1134411.	11000.	-0.002809	719.2343	2.707E+11	0.000	0.000	0.000
37.200	0.4514	1180333.	11000.	-0.002793	729.2599	2.707E+11	0.000	0.000	0.000
40.920	0.4410	1226225.	11000.	-0.002776	739.2791	2.707E+11	0.000	0.000	0.000
44.640	0.4307	1272088.	11000.	-0.002759	749.2918	2.707E+11	0.000	0.000	0.000
48.360	0.4205	1317919.	11000.	-0.002741	759.2977	2.707E+11	0.000	0.000	0.000
52.080	0.4103	1363718.	11000.	-0.002723	769.2965	2.707E+11	0.000	0.000	0.000
55.800	0.4002	1409483.	11000.	-0.002704	779.2880	2.707E+11	0.000	0.000	0.000
59.520	0.3902	1455214.	11000.	-0.002684	789.2719	2.707E+11	0.000	0.000	0.000
63.240	0.3803	1500910.	11000.	-0.002664	799.2481	2.707E+11	0.000	0.000	0.000
66.960	0.3704	1546568.	11000.	-0.002643	809.2162	2.707E+11	0.000	0.000	0.000
70.680	0.3606	1592188.	11000.	-0.002621	819.1760	2.707E+11	0.000	0.000	0.000
74.400	0.3509	1637770.	11000.	-0.002599	829.1273	2.707E+11	0.000	0.000	0.000
78.120	0.3413	1683311.	11000.	-0.002576	839.0699	2.707E+11	0.000	0.000	0.000
81.840	0.3317	1728811.	11000.	-0.002553	849.0034	2.707E+11	0.000	0.000	0.000
85.560	0.3223	1774268.	11000.	-0.002529	858.9276	2.707E+11	0.000	0.000	0.000
89.280	0.3129	1819682.	11000.	-0.002504	868.8424	2.707E+11	0.000	0.000	0.000
93.000	0.3036	1865052.	11000.	-0.002479	878.7474	2.707E+11	0.000	0.000	0.000
96.720	0.2945	1910375.	11000.	-0.002453	888.6424	2.707E+11	0.000	0.000	0.000
100.440	0.2854	1955652.	11000.	-0.002426	898.5272	2.707E+11	0.000	0.000	0.000
104.160	0.2764	2000881.	11000.	-0.002399	908.4015	2.707E+11	0.000	0.000	0.000
107.880	0.2675	2046060.	11000.	-0.002371	918.2651	2.707E+11	0.000	0.000	0.000
111.600	0.2588	2091190.	11000.	-0.002343	928.1177	2.707E+11	0.000	0.000	0.000

115.320	0.2501	2136268.	11000.	-0.002314	937.9592	2.707E+11	0.000	0.000	0.000
119.040	0.2415	2181293.	11000.	-0.002284	947.7891	2.707E+11	0.000	0.000	0.000
122.760	0.2331	2226265.	11000.	-0.002254	957.6074	2.707E+11	0.000	0.000	0.000
126.480	0.2248	2271183.	11000.	-0.002223	967.4138	2.707E+11	0.000	0.000	0.000
130.200	0.2166	2316045.	11000.	-0.002192	977.2080	2.707E+11	0.000	0.000	0.000
133.920	0.2085	2360850.	11000.	-0.002160	986.9898	2.707E+11	0.000	0.000	0.000
137.640	0.2005	2405597.	11000.	-0.002127	996.7590	2.707E+11	0.000	0.000	0.000
141.360	0.1926	2450285.	11000.	-0.002093	1006.5153	2.707E+11	0.000	0.000	0.000
145.080	0.1849	2494913.	11000.	-0.002059	1016.2584	2.707E+11	0.000	0.000	0.000
148.800	0.1773	2539480.	11000.	-0.002025	1025.9882	2.707E+11	0.000	0.000	0.000
152.520	0.1699	2583984.	11000.	-0.001990	1035.7044	2.707E+11	0.000	0.000	0.000
156.240	0.1625	2628425.	11000.	-0.001954	1045.4067	2.707E+11	0.000	0.000	0.000
159.960	0.1553	2672801.	11000.	-0.001917	1055.0950	2.707E+11	0.000	0.000	0.000
163.680	0.1483	2717112.	11000.	-0.001880	1064.7689	2.707E+11	0.000	0.000	0.000
167.400	0.1413	2761357.	11000.	-0.001843	1074.4283	2.707E+11	0.000	0.000	0.000
171.120	0.1345	2805533.	11000.	-0.001804	1084.0729	2.707E+11	0.000	0.000	0.000
174.840	0.1279	2849641.	11000.	-0.001766	1093.7025	2.707E+11	0.000	0.000	0.000
178.560	0.1214	2893679.	11000.	-0.001726	1103.3168	2.707E+11	0.000	0.000	0.000
182.280	0.1151	2937645.	11000.	-0.001686	1112.9156	2.707E+11	0.000	0.000	0.000
186.000	0.1089	2981540.	11000.	-0.001645	1122.4987	2.707E+11	0.000	0.000	0.000
189.720	0.1028	3025362.	11000.	-0.001604	1132.0658	2.707E+11	0.000	0.000	0.000
193.440	0.0969	3069109.	11000.	-0.001562	1141.6167	2.707E+11	0.000	0.000	0.000
197.160	0.0912	3112781.	11000.	-0.001520	1151.1511	2.707E+11	0.000	0.000	0.000
200.880	0.0856	3156377.	11000.	-0.001477	1160.6689	2.707E+11	0.000	0.000	0.000
204.600	0.0802	3199895.	11000.	-0.001433	1170.1698	2.707E+11	0.000	0.000	0.000
208.320	0.0750	3243335.	11000.	-0.001389	1179.6535	2.707E+11	0.000	0.000	0.000
212.040	0.0699	3286695.	11000.	-0.001344	1189.1199	2.707E+11	0.000	0.000	0.000
215.760	0.0650	3329974.	11000.	-0.001299	1198.5687	2.707E+11	0.000	0.000	0.000
219.480	0.0602	3373172.	11000.	-0.001252	1207.9996	2.707E+11	0.000	0.000	0.000
223.200	0.0556	3416287.	11000.	-0.001206	1217.4124	2.707E+11	0.000	0.000	0.000
226.920	0.0512	3459318.	11000.	-0.001159	1226.8070	2.707E+11	0.000	0.000	0.000
230.640	0.0470	3502265.	11000.	-0.001111	1236.1830	2.707E+11	0.000	0.000	0.000
234.360	0.0430	3545125.	11000.	-0.001062	1245.5403	2.707E+11	0.000	0.000	0.000
238.080	0.0391	3587899.	11000.	-0.001013	1254.8785	2.707E+11	0.000	0.000	0.000
241.800	0.0354	3630584.	11000.	-0.000964	1264.1976	2.707E+11	0.000	0.000	0.000
245.520	0.0319	3673180.	11000.	-0.000914	1273.4972	2.707E+11	0.000	0.000	0.000
249.240	0.0286	3715686.	8466.7450	-0.000863	1282.7771	2.707E+11	-1361.9650	176883.	0.000
252.960	0.0255	3739254.	3426.0298	-0.000812	1287.9224	2.707E+11	-1348.0969	196443.	0.000
256.680	0.0226	3744074.	-1558.4875	-0.000760	1288.9748	2.707E+11	-1331.7511	219159.	0.000
260.400	0.0199	3730374.	-6477.3758	-0.000709	1285.9836	2.707E+11	-1312.8125	245745.	0.000
264.120	0.0173	3698414.	-11321.	-0.000658	1279.0063	2.707E+11	-1291.1452	277130.	0.000
267.840	0.0150	3648496.	-16078.	-0.000607	1268.1083	2.707E+11	-1266.5851	314553.	0.000
271.560	0.0128	3580962.	-20738.	-0.000558	1253.3641	2.707E+11	-1238.9297	359696.	0.000
275.280	0.0108	3496194.	-25290.	-0.000509	1234.8577	2.707E+11	-1207.9215	414902.	0.000
279.000	0.009026	3394626.	-29718.	-0.000462	1212.6833	2.707E+11	-1173.2235	483535.	0.000
282.720	0.007395	3276738.	-34011.	-0.000416	1186.9461	2.707E+11	-1134.3786	570615.	0.000
286.440	0.005932	3143072.	-38149.	-0.000372	1157.7642	2.707E+11	-1090.7405	683994.	0.000
290.160	0.004630	2994235.	-42115.	-0.000330	1125.2701	2.707E+11	-1041.3487	836747.	0.000
293.880	0.003480	2830913.	-45883.	-0.000290	1089.6139	2.707E+11	-984.6798	1052546.	0.000
297.600	0.002475	2653896.	-49423.	-0.000252	1050.9676	2.707E+11	-918.0978	1379727.	0.000
301.320	0.001606	2464109.	-52686.	-0.000217	1009.5333	2.707E+11	-836.4010	1937079.	0.000
305.040	0.000863	2262687.	-55593.	-0.000184	965.5589	2.707E+11	-726.6988	3132224.	0.000
308.760	0.000236	2051152.	-57374.	-0.000155	919.3769	2.707E+11	-230.5679	3641292.	0.000
312.480	-0.000287	1836377.	-57272.	-0.000128	872.4873	2.707E+11	285.0933	3693747.	0.000
316.200	-0.000716	1625503.	-55401.	-0.000104	826.4492	2.707E+11	720.9676	3746201.	0.000
319.920	-0.001062	1424565.	-52553.	-8.315E-05	782.5805	2.707E+11	810.0805	2838523.	0.000
323.640	-0.001335	1234802.	-49429.	-6.488E-05	741.1517	2.707E+11	869.5858	2423940.	0.000
327.360	-0.001544	1057043.	-46111.	-4.913E-05	702.3434	2.707E+11	914.1760	2202076.	0.000

331.080	-0.001700	891909.	-42646.	-3.574E-05	666.2913	2.707E+11	948.9635	2076449.	0.000
334.800	-0.001810	739885.	-39064.	-2.453E-05	633.1015	2.707E+11	976.7345	2007152.	0.000
338.520	-0.001883	601359.	-35389.	-1.532E-05	602.8586	2.707E+11	999.2313	1974473.	0.000
342.240	-0.001924	476646.	-31637.	-7.910E-06	575.6314	2.707E+11	1017.6557	1967397.	0.000
345.960	-0.001941	366005.	-27823.	-2.121E-06	551.4762	2.707E+11	1032.9022	1979135.	0.000
349.680	-0.001940	269648.	-23957.	2.246E-06	530.4395	2.707E+11	1045.6755	2005121.	0.000
353.400	-0.001925	187754.	-20047.	5.388E-06	512.5607	2.707E+11	1056.5536	2042029.	0.000
357.120	-0.001900	120478.	-16099.	7.506E-06	497.8729	2.707E+11	1066.0207	2087267.	0.000
360.840	-0.001869	67950.	-12118.	8.801E-06	486.4050	2.707E+11	1074.4814	2138732.	0.000
364.560	-0.001834	30290.	-8106.2536	9.476E-06	478.1831	2.707E+11	1082.2648	2194710.	0.000
368.280	-0.001798	7605.7580	-4066.5507	9.736E-06	473.2307	2.707E+11	1089.6185	2253883.	0.000
372.000	-0.001762	0.000	0.000	9.788E-06	471.5702	2.707E+11	1096.6991	1157704.	0.000

* This analysis makes computations of pile response using nonlinear moment-curvature relationships.
  The above values of total stress are computed for combined axial stress and do not equal the
  actual stresses in concrete and steel in the range of nonlinear bending.

Output Verification: Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =      0.5579067 inches
Computed slope at pile head      =     -0.0029235 radians
Maximum bending moment           =       3744074. inch-lbs
Maximum shear force              =        -57374. lbs
Depth of maximum bending moment  =    256.6800000 inches below pile head
Depth of maximum shear force     =    308.7600000 inches below pile head
Number of iterations             =             27
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                                =        2500.000 lbs
Rotation of pile head                                   =       0.000E+00 radians
Axial load at pile head                                 =      490000.000 lbs
```

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

Depth X inches	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/in	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.0175	-356367.	2500.0000	0.000	559.1964	2.707E+11	0.000	0.000	0.000
3.720	0.0175	-347062.	2500.0000	-4.833E-06	557.1650	2.707E+11	0.000	0.000	0.000
7.440	0.0175	-337749.	2500.0000	-9.538E-06	555.1318	2.707E+11	0.000	0.000	0.000
11.160	0.0174	-328427.	2500.0000	-1.411E-05	553.0967	2.707E+11	0.000	0.000	0.000
14.880	0.0174	-319098.	2500.0000	-1.856E-05	551.0598	2.707E+11	0.000	0.000	0.000
18.600	0.0173	-309760.	2500.0000	-2.288E-05	549.0212	2.707E+11	0.000	0.000	0.000
22.320	0.0172	-300414.	2500.0000	-2.708E-05	546.9809	2.707E+11	0.000	0.000	0.000

26.040	0.0171	-291061.	2500.0000	-3.114E-05	544.9389	2.707E+11	0.000	0.000	0.000
29.760	0.0170	-281701.	2500.0000	-3.507E-05	542.8953	2.707E+11	0.000	0.000	0.000
33.480	0.0168	-272333.	2500.0000	-3.888E-05	540.8502	2.707E+11	0.000	0.000	0.000
37.200	0.0167	-262959.	2500.0000	-4.256E-05	538.8036	2.707E+11	0.000	0.000	0.000
40.920	0.0165	-253578.	2500.0000	-4.611E-05	536.7556	2.707E+11	0.000	0.000	0.000
44.640	0.0163	-244191.	2500.0000	-4.953E-05	534.7062	2.707E+11	0.000	0.000	0.000
48.360	0.0162	-234797.	2500.0000	-5.282E-05	532.6555	2.707E+11	0.000	0.000	0.000
52.080	0.0160	-225398.	2500.0000	-5.598E-05	530.6034	2.707E+11	0.000	0.000	0.000
55.800	0.0157	-215993.	2500.0000	-5.901E-05	528.5502	2.707E+11	0.000	0.000	0.000
59.520	0.0155	-206583.	2500.0000	-6.191E-05	526.4957	2.707E+11	0.000	0.000	0.000
63.240	0.0153	-197168.	2500.0000	-6.469E-05	524.4401	2.707E+11	0.000	0.000	0.000
66.960	0.0150	-187747.	2500.0000	-6.733E-05	522.3835	2.707E+11	0.000	0.000	0.000
70.680	0.0148	-178322.	2500.0000	-6.985E-05	520.3258	2.707E+11	0.000	0.000	0.000
74.400	0.0145	-168893.	2500.0000	-7.223E-05	518.2671	2.707E+11	0.000	0.000	0.000
78.120	0.0142	-159459.	2500.0000	-7.449E-05	516.2076	2.707E+11	0.000	0.000	0.000
81.840	0.0140	-150021.	2500.0000	-7.662E-05	514.1471	2.707E+11	0.000	0.000	0.000
85.560	0.0137	-140580.	2500.0000	-7.861E-05	512.0858	2.707E+11	0.000	0.000	0.000
89.280	0.0134	-131135.	2500.0000	-8.048E-05	510.0238	2.707E+11	0.000	0.000	0.000
93.000	0.0131	-121686.	2500.0000	-8.222E-05	507.9611	2.707E+11	0.000	0.000	0.000
96.720	0.0128	-112235.	2500.0000	-8.382E-05	505.8976	2.707E+11	0.000	0.000	0.000
100.440	0.0124	-102781.	2500.0000	-8.530E-05	503.8336	2.707E+11	0.000	0.000	0.000
104.160	0.0121	-93324.	2500.0000	-8.665E-05	501.7690	2.707E+11	0.000	0.000	0.000
107.880	0.0118	-83865.	2500.0000	-8.786E-05	499.7039	2.707E+11	0.000	0.000	0.000
111.600	0.0115	-74404.	2500.0000	-8.895E-05	497.6383	2.707E+11	0.000	0.000	0.000
115.320	0.0111	-64940.	2500.0000	-8.991E-05	495.5723	2.707E+11	0.000	0.000	0.000
119.040	0.0108	-55476.	2500.0000	-9.074E-05	493.5060	2.707E+11	0.000	0.000	0.000
122.760	0.0105	-46010.	2500.0000	-9.143E-05	491.4394	2.707E+11	0.000	0.000	0.000
126.480	0.0101	-36542.	2500.0000	-9.200E-05	489.3725	2.707E+11	0.000	0.000	0.000
130.200	0.009780	-27074.	2500.0000	-9.244E-05	487.3054	2.707E+11	0.000	0.000	0.000
133.920	0.009435	-17605.	2500.0000	-9.274E-05	485.2382	2.707E+11	0.000	0.000	0.000
137.640	0.009090	-8136.1302	2500.0000	-9.292E-05	483.1709	2.707E+11	0.000	0.000	0.000
141.360	0.008744	1333.3496	2500.0000	-9.297E-05	481.6857	2.707E+11	0.000	0.000	0.000
145.080	0.008398	10803.	2500.0000	-9.289E-05	483.7530	2.707E+11	0.000	0.000	0.000
148.800	0.008053	20272.	2500.0000	-9.267E-05	485.8203	2.707E+11	0.000	0.000	0.000
152.520	0.007709	29741.	2500.0000	-9.233E-05	487.8875	2.707E+11	0.000	0.000	0.000
156.240	0.007366	39209.	2500.0000	-9.185E-05	489.9546	2.707E+11	0.000	0.000	0.000
159.960	0.007025	48676.	2500.0000	-9.125E-05	492.0214	2.707E+11	0.000	0.000	0.000
163.680	0.006687	58141.	2500.0000	-9.052E-05	494.0879	2.707E+11	0.000	0.000	0.000
167.400	0.006352	67605.	2500.0000	-8.965E-05	496.1542	2.707E+11	0.000	0.000	0.000
171.120	0.006020	77068.	2500.0000	-8.866E-05	498.2200	2.707E+11	0.000	0.000	0.000
174.840	0.005692	86529.	2500.0000	-8.753E-05	500.2855	2.707E+11	0.000	0.000	0.000
178.560	0.005369	95987.	2500.0000	-8.628E-05	502.3505	2.707E+11	0.000	0.000	0.000
182.280	0.005050	105443.	2500.0000	-8.490E-05	504.4149	2.707E+11	0.000	0.000	0.000
186.000	0.004737	114897.	2500.0000	-8.338E-05	506.4788	2.707E+11	0.000	0.000	0.000
189.720	0.004430	124347.	2500.0000	-8.174E-05	508.5420	2.707E+11	0.000	0.000	0.000
193.440	0.004129	133795.	2500.0000	-7.997E-05	510.6046	2.707E+11	0.000	0.000	0.000
197.160	0.003835	143239.	2500.0000	-7.806E-05	512.6664	2.707E+11	0.000	0.000	0.000
200.880	0.003548	152679.	2500.0000	-7.603E-05	514.7274	2.707E+11	0.000	0.000	0.000
204.600	0.003269	162116.	2500.0000	-7.387E-05	516.7877	2.707E+11	0.000	0.000	0.000
208.320	0.002999	171549.	2500.0000	-7.157E-05	518.8470	2.707E+11	0.000	0.000	0.000
212.040	0.002737	180977.	2500.0000	-6.915E-05	520.9054	2.707E+11	0.000	0.000	0.000
215.760	0.002484	190401.	2500.0000	-6.660E-05	522.9628	2.707E+11	0.000	0.000	0.000
219.480	0.002241	199820.	2500.0000	-6.392E-05	525.0191	2.707E+11	0.000	0.000	0.000
223.200	0.002009	209234.	2500.0000	-6.111E-05	527.0744	2.707E+11	0.000	0.000	0.000
226.920	0.001787	218642.	2500.0000	-5.817E-05	529.1285	2.707E+11	0.000	0.000	0.000
230.640	0.001576	228046.	2500.0000	-5.510E-05	531.1814	2.707E+11	0.000	0.000	0.000
234.360	0.001377	237443.	2500.0000	-5.190E-05	533.2331	2.707E+11	0.000	0.000	0.000
238.080	0.001190	246835.	2500.0000	-4.858E-05	535.2835	2.707E+11	0.000	0.000	0.000

241.800	0.001015	256220.	2500.0000	-4.512E-05	537.3325	2.707E+11	0.000	0.000	0.000
245.520	0.000854	265599.	2500.0000	-4.154E-05	539.3801	2.707E+11	0.000	0.000	0.000
249.240	0.000706	274972.	1510.5185	-3.782E-05	541.4263	2.707E+11	-531.9793	2802019.	0.000
252.960	0.000573	276976.	-296.1910	-3.403E-05	541.8638	2.707E+11	-439.3699	2854474.	0.000
256.680	0.000453	272892.	-1771.9596	-3.025E-05	540.9723	2.707E+11	-354.0540	2906928.	0.000
260.400	0.000348	263903.	-2944.7241	-2.656E-05	539.0097	2.707E+11	-276.4645	2959383.	0.000
264.120	0.000255	251080.	-3843.6322	-2.303E-05	536.2103	2.707E+11	-206.8194	3011838.	0.000
267.840	0.000176	235390.	-4498.2941	-1.968E-05	532.7848	2.707E+11	-145.1494	3064292.	0.000
271.560	0.000109	217685.	-4938.1373	-1.657E-05	528.9194	2.707E+11	-91.3255	3116747.	0.000
275.280	5.292E-05	198710.	-5191.8619	-1.371E-05	524.7770	2.707E+11	-45.0856	3169201.	0.000
279.000	6.998E-06	179107.	-5286.9938	-1.111E-05	520.4972	2.707E+11	-6.0606	3221656.	0.000
282.720	-2.977E-05	159416.	-5249.5309	-8.789E-06	516.1982	2.707E+11	26.2019	3274110.	0.000
286.440	-5.839E-05	140083.	-5103.6760	-6.731E-06	511.9774	2.707E+11	52.2146	3326565.	0.000
290.160	-7.985E-05	121469.	-4871.6500	-4.934E-06	507.9136	2.707E+11	72.5305	3379019.	0.000
293.880	-9.510E-05	103856.	-4573.5761	-3.386E-06	504.0683	2.707E+11	87.7243	3431474.	0.000
297.600	-0.000105	87454.	-4227.4287	-2.072E-06	500.4875	2.707E+11	98.3765	3483928.	0.000
301.320	-0.000111	72411.	-3849.0377	-9.735E-07	497.2034	2.707E+11	105.0595	3536383.	0.000
305.040	-0.000112	58821.	-3452.1405	-7.188E-08	494.2363	2.707E+11	108.3261	3588838.	0.000
308.760	-0.000111	46728.	-3048.4727	6.533E-07	491.5961	2.707E+11	108.6996	3641292.	0.000
312.480	-0.000107	36138.	-2647.8914	1.223E-06	489.2841	2.707E+11	106.6667	3693747.	0.000
316.200	-0.000102	27023.	-2258.5226	1.656E-06	487.2942	2.707E+11	102.6714	3746201.	0.000
319.920	-9.510E-05	19328.	-1886.9268	1.975E-06	485.6143	2.707E+11	97.1113	3798656.	0.000
323.640	-8.726E-05	12977.	-1538.2765	2.197E-06	484.2277	2.707E+11	90.3352	3851110.	0.000
327.360	-7.876E-05	7875.3657	-1216.5392	2.340E-06	483.1139	2.707E+11	82.6419	3903565.	0.000
331.080	-6.985E-05	3917.2914	-924.6632	2.421E-06	482.2498	2.707E+11	74.2807	3956019.	0.000
334.800	-6.074E-05	987.0447	-664.7594	2.455E-06	481.6101	2.707E+11	65.4525	4008474.	0.000
338.520	-5.158E-05	-1037.4681	-438.2764	2.455E-06	481.6211	2.707E+11	56.3125	4060929.	0.000
342.240	-4.248E-05	-2282.6799	-246.1656	2.432E-06	481.8929	2.707E+11	46.9729	4113383.	0.000
345.960	-3.349E-05	-2877.8051	-89.0328	2.396E-06	482.0229	2.707E+11	37.5071	4165838.	0.000
349.680	-2.465E-05	-2953.8195	32.7263	2.356E-06	482.0395	2.707E+11	27.9547	4218292.	0.000
353.400	-1.596E-05	-2642.9111	118.8092	2.318E-06	481.9716	2.707E+11	18.3264	4270747.	0.000
357.120	-7.409E-06	-2078.3289	168.9107	2.285E-06	481.8483	2.707E+11	8.6099	4323201.	0.000
360.840	1.040E-06	-1394.5469	182.6508	2.261E-06	481.6990	2.707E+11	-1.2228	4375656.	0.000
364.560	9.416E-06	-727.6515	159.5278	2.247E-06	481.5534	2.707E+11	-11.2089	4428110.	0.000
368.280	1.776E-05	-215.8511	98.9004	2.240E-06	481.4417	2.707E+11	-21.3865	4480565.	0.000
372.000	2.608E-05	0.000	0.000	2.239E-06	481.3946	2.707E+11	-31.7858	2266510.	0.000

* This analysis makes computations of pile response using nonlinear moment-curvature relationships.
The above values of total stress are computed for combined axial stress and do not equal the actual stresses in concrete and steel in the range of nonlinear bending.

Output Verification: Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 2:

```
Pile-head deflection             =      0.0175195 inches
Computed slope at pile head      =       0.000000 radians
Maximum bending moment           =       -356367. inch-lbs
Maximum shear force              =  -5286.9938114 lbs
Depth of maximum bending moment  =       0.000000 inches below pile head
Depth of maximum shear force     =    279.0000000 inches below pile head
Number of iterations             =              6
Number of zero deflection points =              2
```

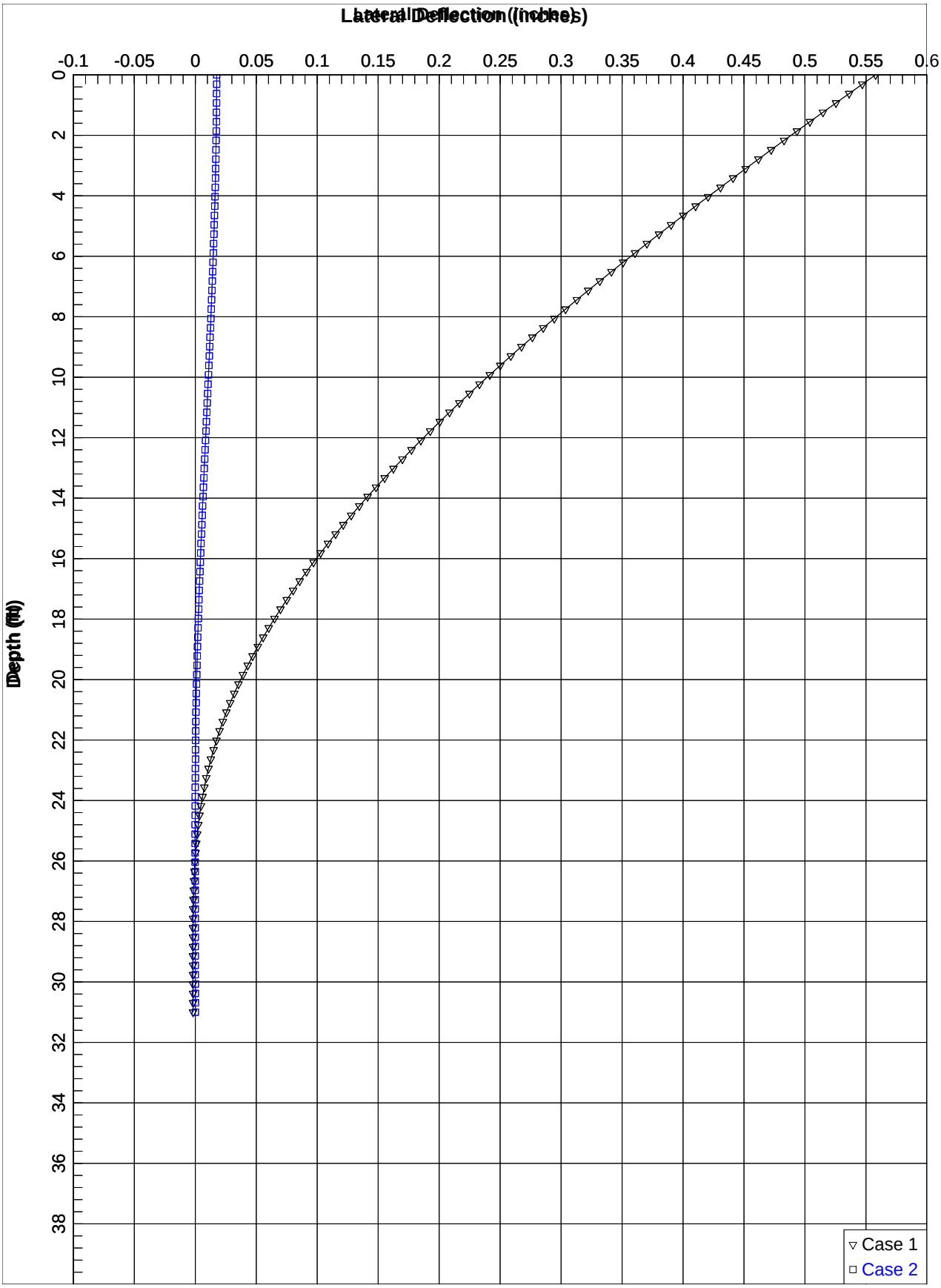
Summary of Pile Response(s)

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, lbs, and Load 2 = Moment, in-lbs
Load Type 2: Load 1 = Shear, lbs, and Load 2 = Slope, radians
Load Type 3: Load 1 = Shear, lbs, and Load 2 = Rotational Stiffness, in-lbs/radian
Load Type 4: Load 1 = Top Deflection, inches, and Load 2 = Moment, in-lbs
Load Type 5: Load 1 = Top Deflection, inches, and Load 2 = Slope, radians

Load Case No.	Load Type No.	Pile-head Condition 1 V(lbs) or y(inches)	Pile-head Condition 2 in-lb, rad., or in-lb/rad.	Axial Loading lbs	Pile-head Deflection inches	Maximum Moment in-lbs	Maximum Shear lbs	Pile-head Rotation radians
1	1	V = 11000.	M = 720000.	480000.	0.55790665	3744074.	-57374.	-0.00292352
2	2	V = 2500.0000	S = 0.000	490000.	0.01751954	-356367.	-5286.9938	0.00000000

The analysis ended normally.


Lateral Deflection (inches)
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Case 1
Case 2

Bridge 330 - Bent 1 - Boring B1-A

Required tip resistance

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

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

R_{req}	791	kips	Required factored geotechnical resistance
$\varphi_{qs,\ rock}$	0.55		side resistance factor, in Rock
$R_{sd,\ rock}$	0	kips	nominal side resistance, in Rock
$\varphi_{qs,\ IGM}$	0.6		side resistance factor, in IGM
$R_{sd,\ IGM}$	0	kips	nominal side resistance, in IGM
$\varphi_{qs} R_{sd}$	0	kips	factored developed side resistance
A_T	6.30	ft^2	Area of drilled pier tip (smaller than shaft diameter if rock sock
φ_{tip}	0.5		tip resistance factor
q_{req}	251	ksf	required tip resistance
=	260	ksf	required tip resistance rounded to the nearest 10 ksf
=	130	tsf	required tip resistance rounded in tsf
q_p	324	tsf	estimated nominal tip resistance

Required Resistance

R_{req} = required resistance

$= P_r + y_{DL}(W_T - W_{Soil/Rock}) - y_{WA} W_{Water}$

P_r	790	kips		Maximum factored axial load
y_{DL}	1.25			Factor for Permanent Dead loads from AASHTO Table 3.4.1-2
W_T	38	kips		Unfactored Weight of Drilled Pier and Column
Pier Diameter	3	ft		
Pier Length	35	ft		
Column Diameter	2.5	ft		
Column Length	0	ft		
Weight of Concrete	0.155	$kips/ft^3$		
$W_{Soil/Rock}$	25	kips		Unfactored Weight of Soil/Rock that will be displaced below the Design Scour Elevation
Pier Diameter	3	ft		
Pier Length - Soil	18	ft		Pier Length in Soil Below the Design Scour Elevation
				DSE: 767 Bottom of Soil: 749
Unit Weight - Soil	0.12	$kips/ft^3$		
Pier Length - IGM	9.5	ft		Pier Length in IGM Below the Design Scour Elevation
				Top of IGM: 749 Bottom of IGM: 739.5
Unit Weight - IGM	0.13	$kips/ft^3$		
Pier Length - Rock	1	ft		Pier Length in Rock Below the Design Scour Elevation
				Top of Rock: 739.5 Bottom of Rock: 738.5
Unit Weight - Rock	0.15	$kips/ft^3$		
y_{WA}	1			Factor for Water Loads from AASHTO Table 3.4.1-1
W_{water}	15	kips		Unfactored Weight of Water Displaced
Unit Weight - Water	0.0624	$kips/ft^3$		

APPENDIX B-2 – BENT 1, BORING B1-B

BORING B1-B WITH RELEVANT ELEVATIONS
AXIAL CALCULATIONS
L-PILE ANALYSES
REQUIRED TIP RESISTANCE CALCULATIONS

NCDOT GEOTECHNICAL ENGINEERING UNIT
BORELOG REPORT

WBS 17BP.7.R.28	**TIP** 17BP.7.R.28	**COUNTY** GUILFORD	**GEOLOGIST** Huelsman, CJ
SITE DESCRIPTION Bridge Number 330 over Mears Fork Creek on SR 2321 (Strawberry Road)			**GROUND WTR (ft)**
BORING NO. B1-B	**STATION** 11+80	**OFFSET** 20 ft RT	**ALIGNMENT** L	**0 HR.** 6.3
COLLAR ELEV. 777.0 ft	**TOTAL DEPTH** 57.7 ft	**NORTHING** N/A	**EASTING** N/A	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE HPC0279 DIEDRICH D-50 90% 02/17/2012		**DRILL METHOD** NW Casing w/ Core	**HAMMER TYPE** Automatic
DRILLER Cain, J.	**START DATE** 02/04/13	**COMP. DATE** 02/04/13	**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))
780										
										777.0 / 0.0 GROUND SURFACE
	776.0	1.0								Topsoil
775			2	2	2	4		M		**ROADWAY EMBANKMENT** Red Slightly Micaceous Sandy Silty CLAY
	773.5	3.5								
			2	1	1	2		M		
	771.0	6.0								770.5 / 6.5
770			WOH	1	2	3		W		**ALLUVIAL** Gray Slightly Micaceous Sandy CLAY
	768.5	8.5								
			1	1	2	3		W		
765										
	763.5	13.5								
			3	3	2	5		W		
760										760.0 / 17.0 **RESIDUAL** Tan to Light Brown Clayey SAND
	758.5	18.5								
			3	4	6	10		W		
755										
	753.5	23.5								
			6	9	15	24		W		
750										
	748.5	28.5								
			17	21	22	43		W		
745										
	743.5	33.5								743.0 / 34.0
			17	80	20/0.2					**WEATHERED ROCK** (Light Brown Granitic Rock)
740						100/0.7				
	738.5	38.5								738.5 / 38.5
			60/0.0			60/0.0				**CRYSTALLINE ROCK** Light brown and gray Granitic Rock
735										
730										729.3 / 47.7
										CRYSTALLINE ROCK Light gray, white, and brown-orange Granitic Rock
725										
720										719.3 / 57.7
										Boring Terminated at Elevation 719.3 ft In Crystalline Rock

3.0 c. / 4.0 s. ~ 773.5

A/L

DSE=767

Pressure Scale

13.5

18.5

23.5

30.5

WR

44

CR

54

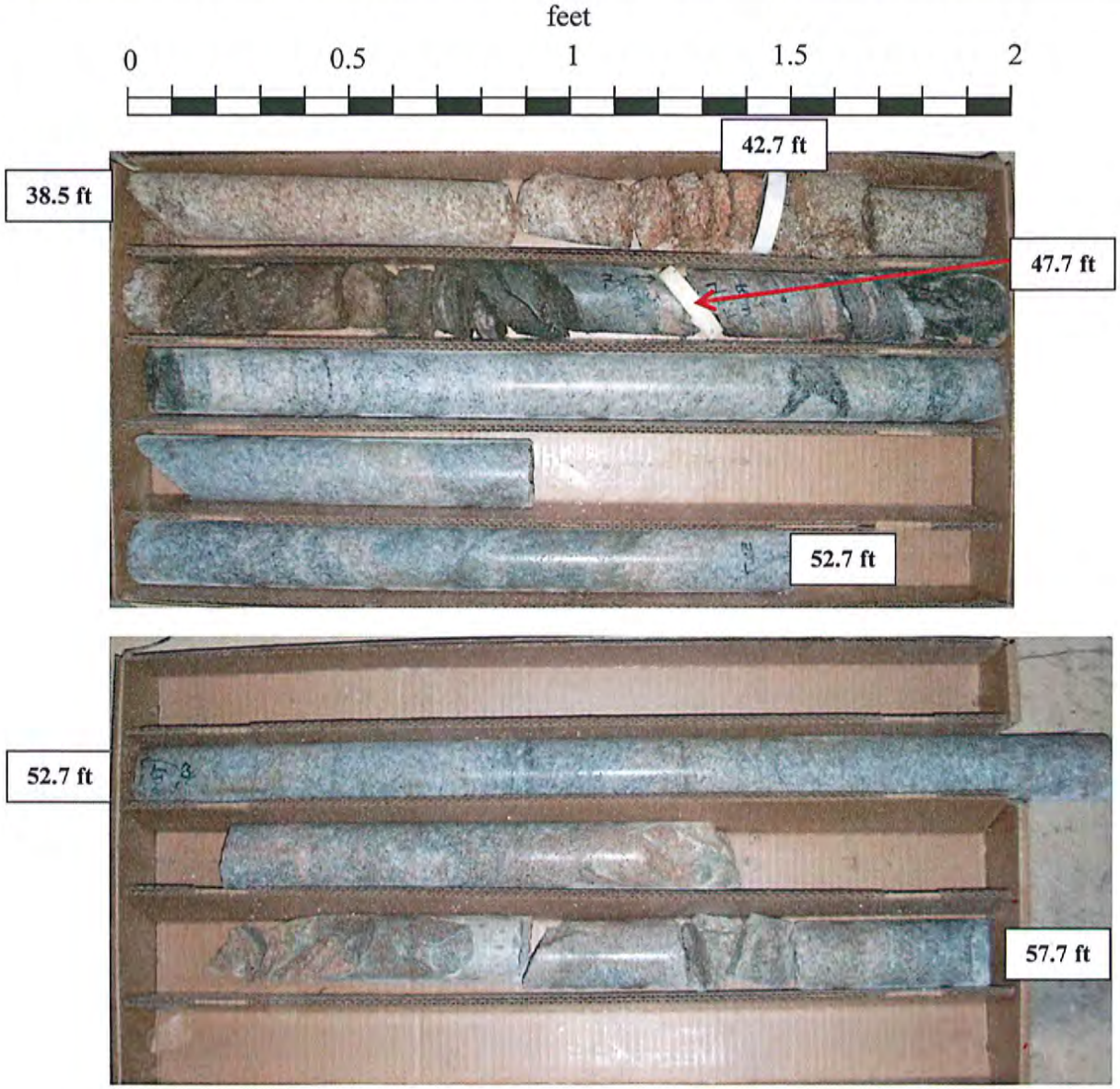
NCDOT GEOTECHNICAL ENGINEERING UNIT
CORE BORING REPORT

WBS 17BP.7.R.28	**TIP** 17BP.7.R.28	**COUNTY** GUILFORD	**GEOLOGIST** Huelsman, CJ
SITE DESCRIPTION Bridge Number 330 over Mears Fork Creek on SR 2321 (Strawberry Road)			**GROUND WTR (ft)**
BORING NO. B1-B	**STATION** 11+80	**OFFSET** 20 ft RT	**ALIGNMENT** L	**0 HR.** 6.3
COLLAR ELEV. 777.0 ft	**TOTAL DEPTH** 57.7 ft	**NORTHING** N/A	**EASTING** N/A	**24 HR.** FIAD
DRILL RIG/HAMMER EFF./DATE HPC0279 DIEDRICH D-50 90% 02/17/2012		**DRILL METHOD** NW Casing w/ Core	**HAMMER TYPE** Automatic
DRILLER Cain, J.	**START DATE** 02/04/13	**COMP. DATE** 02/04/13	**SURFACE WATER DEPTH** N/A
CORE SIZE NQ2	**TOTAL RUN** 19.2 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))
738.48											Begin Coring @ 38.5 ft
	738.5	38.5	4.2	1:31/1.0 0:49/1.0 1:35/1.0 1:00/1.0	(1.5) 36%	(0.9) 21%		(4.8) 52%	(0.9) 10%		738.5 / 38.5 **CRYSTALLINE ROCK** Brown, Severe to Moderate Weathering, Medium Hard, Wide Fracture Spacing Medium Grain GRANITIC ROCK
735	734.3	42.7	5.0	0:15/0.2 1:03/1.0 1:10/1.0 1:08/1.0 2:30/1.0 1:48/1.0	(3.3) 66%	(0.0) 0%					
730	729.3	47.7	5.0	2:17/1.0 3:31/1.0 3:22/1.0 3:19/1.0 4:27/1.0	(5.0) 100%	(4.4) 88%		(10.0) 100%	(9.2) 92%		729.3 / 47.7 **CRYSTALLINE ROCK** Gray to Dark Gray, Very Slight Weathering, Hard, Wide Fracture Spacing Medium Grain GRANITIC ROCK
725	724.3	52.7	5.0	3:48/1.0 4:03/1.0 4:27/1.0 3:31/1.0 2:58/1.0	(5.0) 100%	(4.8) 95%					
720	719.3	57.7									719.3 / 57.7 Boring Terminated at Elevation 719.3 ft In Crystalline Rock

North Carolina Department of Transportation
Geotechnical Unit
Rock Core Photo

T.I.P. No.: 17BP.7.R.28	*Bridge No.*: 400330	*County*: Guilford	*Boring Location:* **B1-B**
Site Description: Bridge Number 330 on State Route 2321 (Strawberry Road) over the Mears Fork Creek			
Driller: J. Cain (HPC Land Services)	*Core Size*: NQ2	*Drill Machine:* CME 550X	
Geologist / Engineer: C. Huelsman	*Total Run Length:* 19.2 feet	*Date:* 2/4/2013	



Notes:
1) Used NQ2 core barrel with wire line

Terracon

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www.terracon.com

Terracon

Analysis Performed By:	*JPM*
Date of Analysis:	*2/15/2013*
Analysis Reviewed By:	

ANALYSIS OF DRILLED SHAFT TIP RESISTANCE IN SOIL, IGM OR ROCK

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Right*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1B*	
Boring Elevation:	*773.50*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	*ft*
Shaft Length:	*45*	*ft (below grade)*	**Tip Elevation:**	*728.50*	*ft MSL*	**Cross-section Area:**	*7.1*	*ft^2*
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*	**Water Table Depth:**	*0.0*	*ft*

Type of Material at the Tip:	**Rock**	f_c': concrete compressive strength =	**4.50**	ksi

For Soil Section 10.8.3.5.2c, *2010 AASHTO LRFD Bridge Design Specifications*

Cohesionless Soils: $N_{60} \leq 50$, $q_p = 1.2*N_{60}$ Equation 10.8.3.5.2c-1, *2010 AASHTO LRFD Bridge Design Specifications*

Cohesive Soils: $N_c = 6(1+0.2(Z/D)) \leq 9$ $q_p = N_c * S_u \leq 80$ where Z= penetration of shaft in bearing layer

S_u = ksf

Z = ft

N_c =

Cohesionless Soils: **Unit Tip Resistance in Soil, q_p =** (q_p is limited to a maximum of 60 ksf)

Cohesive Soils: **Unit Tip Resistance in Soil, q_p =** (q_p is limited to a maximum of 80 ksf)

For IGM (IGM: Cohesionless soils with blow counts greater than 50 blows/ft, i.e., Very Dense/Hard Soils and PWR)
Section 10.8.3.5.2c, *2010 AASHTO LRFD Bridge Design Specifications*

$$q_p = 0.59 \left[N_{60} \left\{ \frac{p_a}{\sigma'_v} \right\} \right]^{0.8} \sigma'_v$$

Equation 10.8.3.5.2c-2, *2010 AASHTO LRFD Bridge Design Specifications*

Material unit weight at tip =	0.14	kcf		Depth of the tip:	45	ft	Water Level (ft):	0	ft
N: Uncorrected SPT Blow Count at the Tip =	1000	blows/ft		N_{60}* = (ER/60%)N =	100	blows/ft	Type of Hammer:	auto	
p_a: atmospheric pressure =	2.12	ksf		σ'_v : vertical effective stress at tip =	2.61	ksf	ER: Hammer Efficiency:	80%	

*N_{60} is limited to a maximum of 100 bpf

Unit Tip Resistance in IGM, q_p =

For Rock

$$q_p = A + q_u [m_b (A/q_u) + s]^a \quad \text{where} \quad A = \sigma'_v + q_u [m_b (\sigma'_v/q_u) + s]^a$$

Reference: Turner (2006). *NCHRP Synthesis 360 Rock-Socketed Shafts for Highways Structure Foundations*. Transportation Research Board of National Academies. 136 pp.

q_u: unconfined compressive strength of intact rock	s, a : constant for the Rock Mass	GSI: Geological Strength Index	$GSI^* \approx 18.7e^{(0.0152RQD)}$
m_b: Reduced Value of m_i	$s = \exp^{((GSI-100)/9)}$	$m_b = m_i (\exp^{((GSI-100)/28)})$	$a = 1/2 + 1/6(e^{-GSI/15} - e^{-20/3})$ RQD: Rock Quality Designation

q_u =	576	ksf	m_i =	29		RQD =	88	%	A =	173.36	ksf
GSI =	71	s =	4.12E-02	a =	0.50	m_b =	10.41				

* Correlation defined by Truzman et. al. (2011) "Determination of Unit Tip Resistance for Drilled Shafts in Fractured Rocks using the Global Rock Mass Strength", 2011 Pan-Am CGS Geotechnical Conference

Unit Tip Resistance in Rock, q_p = **1,201** **ksf in Rock** **Not <** **fc' =** **648** **ksf** **Use qp =** **648** **ksf**

NOTE: Please input the required data where indicated in Blue. When calculating Tip Resistance in Cohesive Soil, please input an Undrained Shear Strength value, Su, into the "Side in Soils (using a-method)" sheet for the bearing layer to generate a tip resistance in cohesive soils output on this sheet. When calculating Tip Resistance in IGM, no data needs to be input onto this sheet other than indicating IGM or Rock as the material at the tip, and the Project Information at the top of the sheet. Please input all soil strata data and shaft information into the "Side in Soils (using B-method)" sheet to generate a tip resistance in IGM output on this sheet. You should always check the input and output values on this sheet to ensure accuracy and correctness.

Terracon

Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

DRILLED SHAFT SIDE RESISTANCE CALCULATION USING β-METHOD

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Right*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1B*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*45*	*ft (below grade)*	**Tip Elevation:**	*728.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*			

UNIT SIDE RESISTANCE (q_s) (*Section 10.8.3.5.2b, 2010 AASHTO LRFD Bridge Design Specifications*)

$q_s = \beta\sigma_v'$ **≤ 4.0 ksf** **for 0.25 ≤ β ≤ 1.2** (Eq. 10.8.3.5.2b-1)

For N_{60} ≤ 15	$\beta = (1.5 - 0.135\,(z)^{0.5})\,N_{60}/15$		
For N_{60} ≥ 15	$\beta = 1.5 - 0.135\,(z)^{0.5}$ (sandy soils)	or	$\beta = 2.0 - 0.06\,(z)^{0.75}$ (gravelly sands and gravels)
N_{60} = (ER/60%)N	N_{60}: SPT blow count corrected for hammer efficiency (blows/ft)		N: uncorrected SPT blow count
σ'_v = vertical effective stress	Hammer efficiency = 80%	Type of Hammer: **auto**	Water Level (ft): 0 ft

# of Layers:	6	Layer the Tip is located in:	6												
Layer	USCS	Soil Type	Top of layer (ft)	Bottom of layer (ft)	Unit weight (kcf)	Mid-layer Depth (ft)	σ'_v mid-layer (ksf)	N-value (blows/ft)	N_{60} (blows/ft)	β	Check if 0.25<β<1.2	q_s (ksf)	Check if q_s ≤ 4.0 ksf	Q_{si} (kips)
1	**CL**	**Clay**	0	**13.5**	**0.110**	6.8	0.321	**0**	0					
2	**SM**	**Sand**	13.5	**18.5**	**0.120**	16.0	0.787	**10**	13	0.85	0.85	0.67	0.67	32
3	**SM**	**Sand**	18.5	**23.5**	**0.120**	21.0	1.075	**24**	32	0.88	0.88	0.95	0.95	45
4	**SM**	**Sand**	23.5	**30.5**	**0.120**	27.0	1.420	**43**	57	0.80	0.80	IGM Mat'l		
5	**PWR**	**IGM**	30.5	**44**	**0.130**	37.3	2.078	**100**	133	0.68	0.68	IGM Mat'l		
6	**Rock**	**Rock**	44	**54**	**0.140**	44.5	2.573	**1000**				Rock		

Total Skin Friction in Soils, $\Sigma(Q_{s,soils})_i$ = 76

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Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

DRILLED SHAFT SIDE RESISTANCE CALCULATION USING α-METHOD

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Right*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1B*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*45*	*ft (below grade)*	**Tip Elevation:**	*728.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*			

UNIT SIDE RESISTANCE (q_s) (*Section 10.8.3.5.1b, 2010 AASHTO LRFD Bridge Design Specifications*)

$q_s = \alpha S_u$ (Eq. 10.8.3.5.1b-1)

For $S_u/p_a \leq 1.5$	$\alpha = 0.55$			
For $1.5 \leq S_u/p_a \leq 2.5$	$\alpha = 0.55 - 0.1(S_u/p_a - 1.5)$	Su = undrained shear strength (ksf)	α = adhesion factor	p_a = atm. pressure = 2.12 ksf
N_{60} = (ER/60%)N	N_{60}: SPT blow count corrected for hammer efficiency (blows/ft)		N: uncorrected SPT blow count	
σ'_v = vertical effective stress	Hammer efficiency = 80%	Type of Hammer: auto	Water Level (ft): 0 ft	

# of Layers: 6	Layer the Tip is located in: 6

Layer	USCS	Soil Type	Top of layer (ft)	Bottom of layer (ft)	Unit weight (kcf)	Mid-layer Depth (ft)	σ'_v mid-layer (ksf)	N-value (blows/ft)	N_{60} (blows/ft)	S_u (ksf)	S_u/p_a	α	q_s (ksf)	Q_{si} (kips)
1	CL	Clay	0	13.5	0.110	6.8	0.321	0	0	0.00	0.00	0.55	0.00	0
2	SM	Sand	13.5	18.5	0.120	16.0	0.787	10	13	0.00	0.00	0.55	0.00	0
3	SM	Sand	18.5	23.5	0.120	21.0	1.075	24	32					
4	SM	Sand	23.5	30.5	0.120	27.0	1.420	43	57			IGM Mat'l		
5	PWR	IGM	30.5	44	0.130	37.3	2.078	100	133			IGM Mat'l		
6	Rock	Rock	44	54	0.140	44.5	2.573	1000				Rock		

Total Skin Friction in Soils, $\Sigma(Q_{s,soils})_i$ = 0

Terracon

Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

ANALYSIS OF DRILLED SHAFT RESISTANCE IN IGM OR WEAK ROCK

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Right*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1B*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*45*	*ft (below grade)*	**Tip Elevation:**	*728.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*	**Water Table Depth:**	*0.0*	ft

UNIT SIDE RESISTANCE (q_s) for COHESIONLESS IGM SOILS (*Section 10.8.3.5.5, 2010 AASHTO LRFD Bridge Design Specifications*)

$$q_s = \sigma'_v K_o \tan \Phi'$$

Equation referenced from Chapter 11, *Drilled Shafts: Construction Procedures and Design Methods*, FHWA Publication No. FHWA-IF-99-025, O'Neill and Reese, August, 1999.

IGM: Very Hard/Very Dense Cohesionless Soils and PWR with SPT N_{60} > 50 blows-per-foot		N_{60} = (ER/60%)N = SPT N-value corrected for Hammer Efficiency
$\Phi' = \tan^{-1}((N_{60}/(12.3+20.3(\sigma'_v/p_a)))^{0.34}$	Φ' = effective stress friction angle of IGM	N: Uncorrected SPT N-Value along the shaft
$K_o = (1-\sin\Phi')OCR^{\sin\Phi'}$	K_o = in-situ coefficient of lateral earth pressure	Hammer Efficiency, ER = 80%
$OCR = \sigma'_p/\sigma'_v$	σ'_v = vertical effective stress	Type of hammer = auto
$\sigma'_p = 0.2N_{60}p_a$	σ'_p = vertical effective stress	Atmospheric Pressure, p_a = 2.12 ksf

# of Layers: 6

Layer	Material	Top of layer (ft)	Bottom of layer (ft)	Unit weight (kcf)	Mid-layer Depth (ft)	σ'_v mid-layer (ksf)	N-value (blows/ft)	N_{60} (blows/ft)	ϕ' (degrees)	σ'_p (ksf)	OCR	K_o	q_s ** (ksf)	Q_s (kips)
1	CL	0	13.5	0.110	6.8	0.321	0	0				Not IGM		
2	SM	13.5	18.5	0.120	16.0	0.787	10	13				Not IGM		
3	SM	18.5	23.5	0.120	21.0	1.075	24	32				Not IGM		
4	SM	23.5	30.5	0.120	27.0	1.420	43	57	52.6	24.309	17.12	1.96	1.8	120
5	PWR	30.5	44	0.130	37.3	2.078	100	133	55.8	42.400	20.40	2.10	3.2	407
6	Rock	44	54	0.140	44.5	2.573	1000					Not IGM		

*****Unit Side Resistance, qs, has been reduced by 50% of its calculated value based on past local experience in IGM Materials.***

Total Skin Friction in IGM, $\Sigma(Q_{s,IGM})_i$ = 528

NOTE: No data needs to be input on this sheet to calculate skin resistance in IGM. Please input all soil strata information into the "Side in Soils" sheet to generate a skin resistance in IGM output on this sheet. You should always check the input and output information on this sheet to ensure accuracy and correctness.

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Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

ANALYSIS OF DRILLED SHAFT RESISTANCE IN IGM OR ROCK

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Right*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1B*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*45*	*ft (below grade)*	**Tip Elevation:**	*728.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*	**Water Table Depth:**	*0.0*	ft

UNIT SIDE RESISTANCE (q_s) for DRILLED SHAFTS in ROCK (*Section 10.8.3.5.4b, 2010 AASHTO LRFD Bridge Design Specifications*)

$$q_s = 0.65\ \alpha_E\ p_a\ (q_u/p_a)^{0.5} < 7.8\ p_a\ (f_c'/p_a)^{0.5}$$ (Equation 10.8.3.5.4b-1)

For Rock Layer 1

p_a: atmospheric pressure =		2.12	ksf	f_c': concrete compressive strength =		4.50	ksi
q_u: unconfined compressive strength of rock =	576	ksf		E_m/E_i: reduction factor (determined from Table 10.4.6.5-1) =		0.40	
RQD = 88 %	GSI =	71		α_E = reduction factor to account for jointing in rock =		0.75	

q_s = 17.04 ksf ≤ 24.09 ksf

calculation of qs is OK **use qs = 17.04 ksf for Rock Layer 1**

For Rock Layer 2

p_a: atmospheric pressure =		2.12	ksf	f_c': concrete compressive strength =		4.50	ksi
q_u: unconfined compressive strength of rock =			ksf	E_m/E_i: reduction factor (determined from Table 10.4.6.5-1) =		0.05	
RQD = %	GSI =			α_E = reduction factor to account for jointing in rock =		0.45	

q_s = 0.00 ksf ≤ 24.09 ksf

calculation of qs is OK **use qs = 0.00 ksf for Rock Layer 2**

AREA OF SHAFT SIDE SURFACE (As) in ROCK

Length in Layer 1 =	1	ft
Length in Layer 2 =		ft
Socket Diameter =	2.8333	ft
Socket perimeter =	8.90	ft

A_s = 8.90 ft^2

Total Skin Friction in Rock, $Q_{s,rock}$ = 152 kips

NOTE: When calculating side resistance in Rock on this sheet, please input the required input data where indicated in Blue. Please input all rock/soil data and shaft information correctly into the "Tip" sheet to generate a Skin Resistance in Rock output on this sheet. You should always check the input and output values on this sheet to ensure accuracy and correctness.

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Analysis Performed By:	***JPM***
Date of Analysis:	***2/15/2013***
Analysis Reviewed By:	

ANALYSIS OF DRILLED SHAFT RESISTANCE IN IGM OR ROCK

Project Name:	*Bridge 330, Low Impact*		**Project Number:**	*71115060*		**Project Location:**	*Guilford Cnty*	
Shaft Location:	*Interior Bent 1, Right*		**Diameter of Shaft:**	*3*	*ft*	**Boring:**	*B1B*	
Boring Elevation:	*773.5*	*ft MSL*	**Boring Depth:**	*43*	*ft*	**Shaft Perimeter:**	*9.4*	ft
Shaft Length:	*45*	*ft (below grade)*	**Tip Elevation:**	*728.5*	*ft MSL*	**Cross-section Area:**	*7.1*	ft^2
Proposed Fill Depth:	*0*	*ft (for End Bents)*	**Tip Diameter:**	*2.8333*	*ft*	**Water Table Depth:**	0.0	ft

Table 10.5.5.2.4-1 Resistance Factors for Geotechnical resistance of Drilled Shafts (2010 AASHTO LRFD Bridge Design Specifications)

Method/Soil/Condition			Resistance Factor
Nominal Axial Compressive Resistance of Single-Drilled Shafts, φ_{stat}	Side resistance in clay	α-method (O'Neill and Reese, 1999)	0.45
	Tip resistance in clay	Total Stress (O'Neill and Reese, 1999)	0.40
	Side resistance in sand	β-method (O'Neill and Reese, 1999)	0.55
	Tip resistance in sand	O'Neill and Reese (1999)	0.50
	Side resistance in IGMs	O'Neill and Reese (1999)	0.60
	Tip resistance in IGMs	O'Neill and Reese (1999)	0.55
	Side resistance in rock	Horvath and Kenney (1979)	0.5
	Tip resistance in rock	O'Neill and Reese (1999)	0.50
Static Load Test (compression), φ_{load}	All Materials		Values in Table 10.5.5.2.3-2, but no greater than 0.70

Nominal Shaft Tip Resistance (R_p)

$R_p = q_p \times A_p$ (Equation 10.8.3.5-2)

$q_p =$ 648 ksf $A_p =$ 6.30 ft^2 **$R_p =$ 4,086 kips** ***(Concrete Limits)***

Nominal Shaft Side Resistance (R_s)

$R_s = q_s \times A_s$ (Equation 10.8.3.5-3)

$R_{s,clay} =$ 0 kips **$R_{s,sand} =$ 76 kips** **$R_{s,IGM} =$ 528 kips** **$R_{s,rock} =$ 152 kips**

Total Nominal Resistance ($R_p + R_s$) = 4,841 kips equivalent to **21,534 kN**

REDUCTION DUE TO GROUP EFFECTS

$0.65 \le \eta \le 1.00$ for 2.5*dia. ≤ Distance Between Shafts ≤ 6*dia. (Section 10.8.3.6.3)

Distance Between Shafts = 18 **feet** **$\eta =$ 1.00**

FACTORED RESISTANCE OF SINGLE DRILLED SHAFT

$R_R = \varphi R_n = \varphi_{qp} R_p + \varphi_{qs} R_s$ (Equation 10.8.3.5-1)

φ_{qp} = resistance factor for tip resistance specified in Table 10.5.5.2.4-1

φ_{qs} = resistance factor for shaft side resistance specified in Table 10.5.5.2.4-1

$\varphi_{qp} =$	0.50	**Concrete**									
$\varphi_{qs} =$	0.45	**Clay**	$\varphi_{qs} =$	0.55	**Sand**	$\varphi_{qs} =$	0.60	**IGM**	$\varphi_{qs} =$	0.55	**Rock**

Total Factored Resistance, $R_R =$ 2,485 kips

==========

LPile Plus for Windows, Version 6 (6.0.28)

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

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Serial Number of Security Device: 156316250
Company Name Stored in Security Device: WPC, Inc.

Files Used for Analysis

Path to file locations: N:\Projects\2011\71115060\Working Files\Bridge 330\Calculations-Analyses\
Name of input data file: Bridge 330 - B1b.lp6d
Name of output report file: Bridge 330 - B1b.lp6o
Name of plot output file: Bridge 330 - B1b.lp6p
Name of runtime messeage file: Bridge 330 - B1b.lp6r

Date and Time of Analysis

Date: February 15, 2013 Time: 9:23:40

Problem Title

Low Impact Bridge - Guilford County No. 330

71115060

KHA

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Boring B1B - Bent 1

Program Options

Engineering units are US Customary Units: pounds, inches, feet

Basic Program Options:

This analysis computes pile response to lateral loading and will compute nonlinear moment-curvature and nominal moment capacity for selected section types.

Computation Options:
- Only internally-generated p-y curves used in analysis
- Analysis does not use p-y multipliers (individual pile or shaft action only)
- Analysis assumes no shear resistance at pile tip
- Analysis for fixed-length pile or shaft only
- No computation of foundation stiffness matrix elements
- Output pile response for full length of pile
- Analysis assumes no soil movements acting on pile
- No p-y curves to be computed and output for user-specified depths

Solution Control Parameters:

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

Pile Response Output Options:
- 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

Pile Structural Properties and Geometry

Total Number of Sections	=	1
Total Pile Length	=	36.00 ft
Depth of ground surface below top of pile	=	13.50 ft

Pile dimensions used for p-y curve computations defined using 2 points.
p-y curves are computed using values of pile diameter interpolated over the length of the pile.

Point	Depth X ft	Pile Diameter in
1	0.00000	36.0000000
2	36.000000	36.0000000

Input Structural Properties:

Pile Section No. 1:

Section Type	=	Elastic Pile
Cross-sectional Shape	=	Circular
Section Length	=	36.000 ft
Top Width	=	36.000 in
Bottom Width	=	36.000 in
Top Area	=	1017.876020 sq. in
Bottom Area	=	1017.876020 sq. in
Moment of Inertia at Top	=	82447.958 in^4
Moment of Inertia at Bottom	=	82447.958 in^4
Elastic Modulus	=	3283676. lbs/in^2

Ground Slope and Pile Batter Angles

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

Soil and Rock Layering Information

The soil profile is modelled using 5 layers

Layer 1 is cemented silt with cohesion and friction

Distance from top of pile to top of layer	=	13.500 ft
Distance from top of pile to bottom of layer	=	18.500 ft
p-y subgrade modulus k for top of soil layer	=	20.000 lbs/in**3
p-y subgrade modulus k for bottom of soil layer	=	20.000 lbs/in**3

Layer 2 is cemented silt with cohesion and friction

Distance from top of pile to top of layer	=	18.500 ft
Distance from top of pile to bottom of layer	=	23.500 ft
p-y subgrade modulus k for top of soil layer	=	60.000 lbs/in**3
p-y subgrade modulus k for bottom of soil layer	=	60.000 lbs/in**3

Layer 3 is cemented silt with cohesion and friction

Distance from top of pile to top of layer	=	23.500 ft

```
Distance from top of pile to bottom of layer          =       30.500 ft
p-y subgrade modulus k for top of soil layer          =      125.000 lbs/in**3
p-y subgrade modulus k for bottom of soil layer       =      125.000 lbs/in**3

Layer 4 is stiff clay without free water

Distance from top of pile to top of layer             =       30.500 ft
Distance from top of pile to bottom of layer          =       44.000 ft

Layer 5 is strong rock (vuggy limestone)

Distance from top of pile to top of layer             =       44.000 ft
Distance from top of pile to bottom of layer          =       54.000 ft


(Depth of lowest layer extends   18.00 ft below pile tip)


--------------------------------------------------------------------------------
                    Effective Unit Weight of Soil vs. Depth
--------------------------------------------------------------------------------

Effective unit weight of soil with depth defined using 10 points

Point        Depth X    Eff. Unit Weight
 No.           ft              pcf
-----      ----------   ----------------
  1            13.50       55.00000
  2            18.50       55.00000
  3            18.50       55.00000
  4            23.50       55.00000
  5            23.50       60.00000
  6            30.50       60.00000
  7            30.50       70.00000
  8            44.00       70.00000
  9            44.00       80.00000
 10            54.00       80.00000


--------------------------------------------------------------------------------
                           Summary of Soil Properties
--------------------------------------------------------------------------------

Layer               Soil Type                   Depth     Eff. Unit     Cohesion     Friction        qu           RQD
Epsilon 50        J          kpy       Rock Emass      krm       Test Type    Test Prop.   Elas. Subgr.
 Num.         (p-y Curve Criteria)               ft       Wt., pcf         psf      Ang., deg.       psi        percent
                        pci          psi                                                  pci
-----   ----------------------------------   ----------   ----------   ----------   ----------   ----------   ----------
----------   ----------   ----------   ----------   ----------   ----------   ----------   ------------
  1     Cemented Silt                            13.500       55.000     1000.000       26.000       --           --
  0.00       --           20.000       --           --           --           --           --
                                                 18.500       55.000     1000.000       26.000       --           --
  0.00       --           20.000       --           --           --           --           --
  2     Cemented Silt                            18.500       55.000     2000.000       28.000       --           --
  0.00       --           60.000       --           --           --           --           --
                                                 23.500       55.000     2000.000       28.000       --           --
```

```
  0.00       --           60.000       --           --           --           --
  3     Cemented Silt                              23.500       60.000     3000.000       34.000       --           --
  0.00       --          125.000       --           --           --           --           --
                                                   30.500       60.000     3000.000       34.000       --           --
  0.00       --          125.000       --           --           --           --           --
  4     Stiff Clay w/o Free Water                  30.500       70.000     4000.000       --           --           --
5.00E-04       --           --           --           --           --           --           --
                                                   44.000       70.000     4000.000       --           --           --
5.00E-04       --           --           --           --           --           --           --
  5     Vuggy Limestone                            44.000       80.000       --           --         5000.000       --
--           --           --           --           --           --           --           --
                                                   54.000       80.000       --           --         5000.000       --
--           --           --           --           --           --           --           --
```

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
1	1	V = 11000. lbs	M = 720000. in-lbs	480000.
2	2	V = 0.0000 lbs	S = 0.0000 in/in	490000.

V = perpendicular shear force applied to pile head
M = bending moment applied to pile head
y = lateral deflection relative to pile axis
S = pile slope relative to original pile batter angle
R = rotational stiffness applie to pile head
Axial thrust is assumed to be acting axially for all pile batter angles.

Computations of Nominal Moment Capacity and Nonlinear Bending Stiffness

---

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

Number of Pile Sections Analyzed = 1

Pile Section No. 1:

Moment-Curvature properties derived from elastic section properties

---

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)

Horizontal shear force at pile head = 11000.000 lbs
Applied moment at pile head = 720000.000 in-lbs
Axial thrust load on pile head = 480000.000 lbs

Depth X inches	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/in	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.7072	720000.	11000.	-0.003340	628.7603	2.707E+11	0.000	0.000	0.000
4.320	0.6928	774434.	11000.	-0.003328	640.6444	2.707E+11	0.000	0.000	0.000
8.640	0.6784	828843.	11000.	-0.003316	652.5229	2.707E+11	0.000	0.000	0.000
12.960	0.6641	883225.	11000.	-0.003302	664.3954	2.707E+11	0.000	0.000	0.000
17.280	0.6499	937577.	11000.	-0.003287	676.2615	2.707E+11	0.000	0.000	0.000
21.600	0.6357	991898.	11000.	-0.003272	688.1209	2.707E+11	0.000	0.000	0.000
25.920	0.6216	1046186.	11000.	-0.003256	699.9731	2.707E+11	0.000	0.000	0.000
30.240	0.6076	1100440.	11000.	-0.003239	711.8177	2.707E+11	0.000	0.000	0.000
34.560	0.5936	1154657.	11000.	-0.003221	723.6544	2.707E+11	0.000	0.000	0.000
38.880	0.5798	1208836.	11000.	-0.003202	735.4828	2.707E+11	0.000	0.000	0.000
43.200	0.5660	1262975.	11000.	-0.003182	747.3024	2.707E+11	0.000	0.000	0.000
47.520	0.5523	1317073.	11000.	-0.003161	759.1129	2.707E+11	0.000	0.000	0.000
51.840	0.5387	1371126.	11000.	-0.003140	770.9138	2.707E+11	0.000	0.000	0.000
56.160	0.5251	1425135.	11000.	-0.003118	782.7049	2.707E+11	0.000	0.000	0.000
60.480	0.5117	1479096.	11000.	-0.003094	794.4857	2.707E+11	0.000	0.000	0.000
64.800	0.4984	1533008.	11000.	-0.003070	806.2558	2.707E+11	0.000	0.000	0.000
69.120	0.4852	1586870.	11000.	-0.003046	818.0148	2.707E+11	0.000	0.000	0.000
73.440	0.4721	1640679.	11000.	-0.003020	829.7624	2.707E+11	0.000	0.000	0.000
77.760	0.4591	1694433.	11000.	-0.002993	841.4981	2.707E+11	0.000	0.000	0.000
82.080	0.4462	1748132.	11000.	-0.002966	853.2216	2.707E+11	0.000	0.000	0.000
86.400	0.4335	1801773.	11000.	-0.002937	864.9324	2.707E+11	0.000	0.000	0.000
90.720	0.4209	1855354.	11000.	-0.002908	876.6302	2.707E+11	0.000	0.000	0.000
95.040	0.4084	1908874.	11000.	-0.002878	888.3146	2.707E+11	0.000	0.000	0.000
99.360	0.3960	1962330.	11000.	-0.002847	899.9853	2.707E+11	0.000	0.000	0.000
103.680	0.3838	2015722.	11000.	-0.002816	911.6417	2.707E+11	0.000	0.000	0.000
108.000	0.3717	2069047.	11000.	-0.002783	923.2836	2.707E+11	0.000	0.000	0.000
112.320	0.3597	2122304.	11000.	-0.002750	934.9106	2.707E+11	0.000	0.000	0.000
116.640	0.3479	2175490.	11000.	-0.002715	946.5222	2.707E+11	0.000	0.000	0.000
120.960	0.3363	2228604.	11000.	-0.002680	958.1181	2.707E+11	0.000	0.000	0.000
125.280	0.3248	2281645.	11000.	-0.002644	969.6979	2.707E+11	0.000	0.000	0.000
129.600	0.3134	2334610.	11000.	-0.002607	981.2612	2.707E+11	0.000	0.000	0.000
133.920	0.3022	2387498.	11000.	-0.002570	992.8077	2.707E+11	0.000	0.000	0.000
138.240	0.2912	2440307.	11000.	-0.002531	1004.3369	2.707E+11	0.000	0.000	0.000
142.560	0.2804	2493035.	11000.	-0.002492	1015.8485	2.707E+11	0.000	0.000	0.000
146.880	0.2697	2545681.	11000.	-0.002452	1027.3420	2.707E+11	0.000	0.000	0.000
151.200	0.2592	2598242.	11000.	-0.002411	1038.8172	2.707E+11	0.000	0.000	0.000
155.520	0.2489	2650718.	11000.	-0.002369	1050.2736	2.707E+11	0.000	0.000	0.000
159.840	0.2387	2703105.	11000.	-0.002326	1061.7109	2.707E+11	0.000	0.000	0.000

164.160	0.2288	2755404.	10979.	-0.002282	1073.1286	2.707E+11	-9.8822	186.6240	0.000
168.480	0.2190	2807426.	10896.	-0.002238	1084.4862	2.707E+11	-28.3811	559.8720	0.000
172.800	0.2094	2858826.	10737.	-0.002193	1095.7079	2.707E+11	-45.2344	933.1200	0.000
177.120	0.2000	2909288.	10509.	-0.002147	1106.7246	2.707E+11	-60.4933	1306.3680	0.000
181.440	0.1909	2958524.	10218.	-0.002100	1117.4738	2.707E+11	-74.2104	1679.6160	0.000
185.760	0.1819	3006277.	9870.6618	-0.002052	1127.8993	2.707E+11	-86.4391	2052.8640	0.000
190.080	0.1731	3052318.	9473.9271	-0.002004	1137.9509	2.707E+11	-97.2343	2426.1120	0.000
194.400	0.1646	3096443.	9033.5335	-0.001955	1147.5842	2.707E+11	-106.6516	2799.3600	0.000
198.720	0.1562	3138475.	8555.3104	-0.001905	1156.7607	2.707E+11	-114.7479	3172.6080	0.000
203.040	0.1481	3178262.	8044.8402	-0.001855	1165.4470	2.707E+11	-121.5809	3545.8560	0.000
207.360	0.1402	3215675.	7507.4541	-0.001804	1173.6149	2.707E+11	-127.2090	3919.1040	0.000
211.680	0.1325	3250607.	6948.2285	-0.001752	1181.2413	2.707E+11	-131.6917	4292.3520	0.000
216.000	0.1251	3282975.	6371.9820	-0.001700	1188.3077	2.707E+11	-135.0891	4665.6000	0.000
220.320	0.1179	3312712.	5783.2724	-0.001647	1194.7999	2.707E+11	-137.4617	5038.8480	0.000
224.640	0.1108	3339774.	4923.6037	-0.001594	1200.7082	2.707E+11	-260.5331	10154.	0.000
228.960	0.1041	3361864.	3774.2147	-0.001541	1205.5308	2.707E+11	-271.5914	11273.	0.000
233.280	0.0975	3378774.	2583.2013	-0.001487	1209.2226	2.707E+11	-279.8036	12393.	0.000
237.600	0.0912	3390350.	1362.4618	-0.001433	1211.7499	2.707E+11	-285.3536	13513.	0.000
241.920	0.0852	3396489.	123.1000	-0.001379	1213.0902	2.707E+11	-288.4250	14633.	0.000
246.240	0.0793	3397133.	-1124.5730	-0.001325	1213.2307	2.707E+11	-289.2013	15752.	0.000
250.560	0.0737	3392267.	-2371.0356	-0.001271	1212.1684	2.707E+11	-287.8647	16872.	0.000
254.880	0.0683	3381917.	-3607.5502	-0.001217	1209.9087	2.707E+11	-284.5958	17992.	0.000
259.200	0.0632	3366143.	-4826.1553	-0.001163	1206.4650	2.707E+11	-279.5733	19111.	0.000
263.520	0.0583	3345041.	-6019.6561	-0.001109	1201.8580	2.707E+11	-272.9734	20231.	0.000
267.840	0.0536	3318733.	-7181.6125	-0.001056	1196.1145	2.707E+11	-264.9694	21351.	0.000
272.160	0.0492	3287371.	-8306.3255	-0.001003	1189.2676	2.707E+11	-255.7311	22471.	0.000
276.480	0.0449	3251128.	-9388.8217	-0.000951	1181.3549	2.707E+11	-245.4246	23590.	0.000
280.800	0.0409	3210196.	-10425.	-0.000900	1172.4188	2.707E+11	-234.2118	24710.	0.000
285.120	0.0372	3164788.	-11661.	-0.000849	1162.5052	2.707E+11	-338.0466	39288.	0.000
289.440	0.0336	3112966.	-13091.	-0.000799	1151.1915	2.707E+11	-323.8449	41621.	0.000
293.760	0.0303	3054997.	-14455.	-0.000749	1138.5358	2.707E+11	-307.9845	43953.	0.000
298.080	0.0271	2991180.	-15749.	-0.000701	1124.6032	2.707E+11	-290.7701	46286.	0.000
302.400	0.0242	2921837.	-16965.	-0.000654	1109.4643	2.707E+11	-272.4934	48619.	0.000
306.720	0.0215	2847312.	-18101.	-0.000608	1093.1940	2.707E+11	-253.4321	50952.	0.000
311.040	0.0190	2767963.	-19154.	-0.000563	1075.8706	2.707E+11	-233.8490	53285.	0.000
315.360	0.0166	2684158.	-20121.	-0.000520	1057.5744	2.707E+11	-213.9918	55617.	0.000
319.680	0.0145	2596271.	-21003.	-0.000478	1038.3870	2.707E+11	-194.0920	57950.	0.000
324.000	0.0125	2504676.	-21798.	-0.000437	1018.3899	2.707E+11	-174.3648	60283.	0.000
328.320	0.0107	2409744.	-22510.	-0.000398	997.6644	2.707E+11	-155.0086	62616.	0.000
332.640	0.009060	2311839.	-23139.	-0.000360	976.2899	2.707E+11	-136.2048	64949.	0.000
336.960	0.007584	2211316.	-23688.	-0.000324	954.3438	2.707E+11	-118.1174	67281.	0.000
341.280	0.006261	2108516.	-24161.	-0.000289	931.9004	2.707E+11	-100.8928	69614.	0.000
345.600	0.005083	2003763.	-24562.	-0.000257	909.0307	2.707E+11	-84.6600	71947.	0.000
349.920	0.004044	1897363.	-24895.	-0.000226	885.8016	2.707E+11	-69.5303	74280.	0.000
354.240	0.003135	1789603.	-25165.	-0.000196	862.2755	2.707E+11	-55.5973	76613.	0.000
358.560	0.002350	1680746.	-25378.	-0.000168	838.5100	2.707E+11	-42.9373	78945.	0.000
362.880	0.001680	1571033.	-25539.	-0.000142	814.5573	2.707E+11	-31.6088	81278.	0.000
367.200	0.001119	1460677.	-27901.	-0.000118	790.4646	2.707E+11	-1061.8485	4100189.	0.000
371.520	0.000658	1330457.	-32096.	-9.600E-05	762.0349	2.707E+11	-880.3022	5777691.	0.000
375.840	0.000289	1183764.	-34844.	-7.594E-05	730.0090	2.707E+11	-391.7021	5848151.	0.000
380.160	2.092E-06	1029721.	-35696.	-5.828E-05	696.3785	2.707E+11	-2.8662	5918623.	0.000
384.480	-0.000214	875592.	-35061.	-4.308E-05	662.7289	2.707E+11	296.9354	5989105.	0.000
388.800	-0.000370	726974.	-33298.	-3.029E-05	630.2829	2.707E+11	519.1332	6059596.	0.000
393.120	-0.000476	588021.	-30718.	-1.980E-05	599.9467	2.707E+11	675.3105	6130097.	0.000
397.440	-0.000541	461652.	-27582.	-1.143E-05	572.3577	2.707E+11	776.7628	6200607.	0.000
401.760	-0.000575	349763.	-24102.	-4.952E-06	547.9303	2.707E+11	834.1511	6271125.	0.000

406.080	-0.000584	253430.	-20449.	-1.395E-07	526.8989	2.707E+11	857.2393	6341651.	0.000
410.400	-0.000576	173087.	-16751.	3.263E-06	509.3584	2.707E+11	854.7031	6412184.	0.000
414.720	-0.000556	108689.	-13103.	5.512E-06	495.2990	2.707E+11	833.9976	6482724.	0.000
419.040	-0.000528	59851.	-9571.1270	6.856E-06	484.6369	2.707E+11	801.2724	6553271.	0.000
423.360	-0.000497	25966.	-6195.9234	7.541E-06	477.2390	2.707E+11	761.3219	6623825.	0.000
427.680	-0.000463	6287.1566	-3001.5306	7.798E-06	472.9428	2.707E+11	717.5636	6694384.	0.000
432.000	-0.000429	0.000	0.000	7.848E-06	471.5702	2.707E+11	672.0339	3382475.	0.000

* This analysis makes computations of pile response using nonlinear moment-curvature relationships.
  The above values of total stress are computed for combined axial stress and do not equal the
  actual stresses in concrete and steel in the range of nonlinear bending.

Output Verification: Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 1:

```
Pile-head deflection             =      0.7071787 inches
Computed slope at pile head      =     -0.0033402 radians
Maximum bending moment           =       3397133. inch-lbs
Maximum shear force              =        -35696. lbs
Depth of maximum bending moment  =    246.2400000 inches below pile head
Depth of maximum shear force     =    380.1600000 inches 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                              =          0.000 lbs
Rotation of pile head                                 =      0.000E+00 radians
Axial load at pile head                               =     490000.000 lbs
```

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

Depth X inches	Deflect. y inches	Bending Moment in-lbs	Shear Force lbs	Slope S radians	Total Stress psi*	Bending Stiffness lb-in^2	Soil Res. p lb/in	Soil Spr. Es*h lb/inch	Distrib. Lat. Load lb/inch
0.00	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
4.320	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
8.640	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
12.960	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
17.280	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
21.600	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
25.920	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
30.240	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
34.560	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
38.880	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000

43.200	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
47.520	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
51.840	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
56.160	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
60.480	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
64.800	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
69.120	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
73.440	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
77.760	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
82.080	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
86.400	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
90.720	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
95.040	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
99.360	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
103.680	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
108.000	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
112.320	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
116.640	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
120.960	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
125.280	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
129.600	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
133.920	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
138.240	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
142.560	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
146.880	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
151.200	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
155.520	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
159.840	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	0.000	0.000
164.160	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	186.6240	0.000
168.480	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	559.8720	0.000
172.800	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	933.1200	0.000
177.120	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	1306.3680	0.000
181.440	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	1679.6160	0.000
185.760	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	2052.8640	0.000
190.080	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	2426.1120	0.000
194.400	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	2799.3600	0.000
198.720	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	3172.6080	0.000
203.040	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	3545.8560	0.000
207.360	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	3919.1040	0.000
211.680	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	4292.3520	0.000
216.000	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	4665.6000	0.000
220.320	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	5038.8480	0.000
224.640	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	10154.	0.000
228.960	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	11273.	0.000
233.280	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	12393.	0.000
237.600	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	13513.	0.000
241.920	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	14633.	0.000
246.240	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	15752.	0.000
250.560	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	16872.	0.000
254.880	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	17992.	0.000
259.200	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	19111.	0.000
263.520	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	20231.	0.000
267.840	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	21351.	0.000
272.160	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	22471.	0.000
276.480	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	23590.	0.000
280.800	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	24710.	0.000

285.120	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	39288.	0.000
289.440	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	41621.	0.000
293.760	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	43953.	0.000
298.080	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	46286.	0.000
302.400	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	48619.	0.000
306.720	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	50952.	0.000
311.040	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	53285.	0.000
315.360	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	55617.	0.000
319.680	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	57950.	0.000
324.000	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	60283.	0.000
328.320	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	62616.	0.000
332.640	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	64949.	0.000
336.960	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	67281.	0.000
341.280	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	69614.	0.000
345.600	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	71947.	0.000
349.920	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	74280.	0.000
354.240	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	76613.	0.000
358.560	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	78945.	0.000
362.880	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	81278.	0.000
367.200	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	5707242.	0.000
371.520	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	5777691.	0.000
375.840	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	5848151.	0.000
380.160	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	5918623.	0.000
384.480	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	5989105.	0.000
388.800	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6059596.	0.000
393.120	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6130097.	0.000
397.440	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6200607.	0.000
401.760	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6271125.	0.000
406.080	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6341651.	0.000
410.400	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6412184.	0.000
414.720	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6482724.	0.000
419.040	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6553271.	0.000
423.360	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6623825.	0.000
427.680	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	6694384.	0.000
432.000	0.000	0.000	0.000	0.000	481.3946	2.707E+11	0.000	3382475.	0.000

* This analysis makes computations of pile response using nonlinear moment-curvature relationships.
  The above values of total stress are computed for combined axial stress and do not equal the
  actual stresses in concrete and steel in the range of nonlinear bending.

Output Verification: Computed forces and moments are within specified convergence limits.

Output Summary for Load Case No. 2:

```
Pile-head deflection             =       0.000000 inches
Computed slope at pile head      =       0.000000 radians
Maximum bending moment           =       0.000000 inch-lbs
Maximum shear force              =       0.000000 lbs
Depth of maximum bending moment  =    246.2400000 inches below pile head
Depth of maximum shear force     =    380.1600000 inches below pile head
Number of iterations             =              6
Number of zero deflection points =              0
```

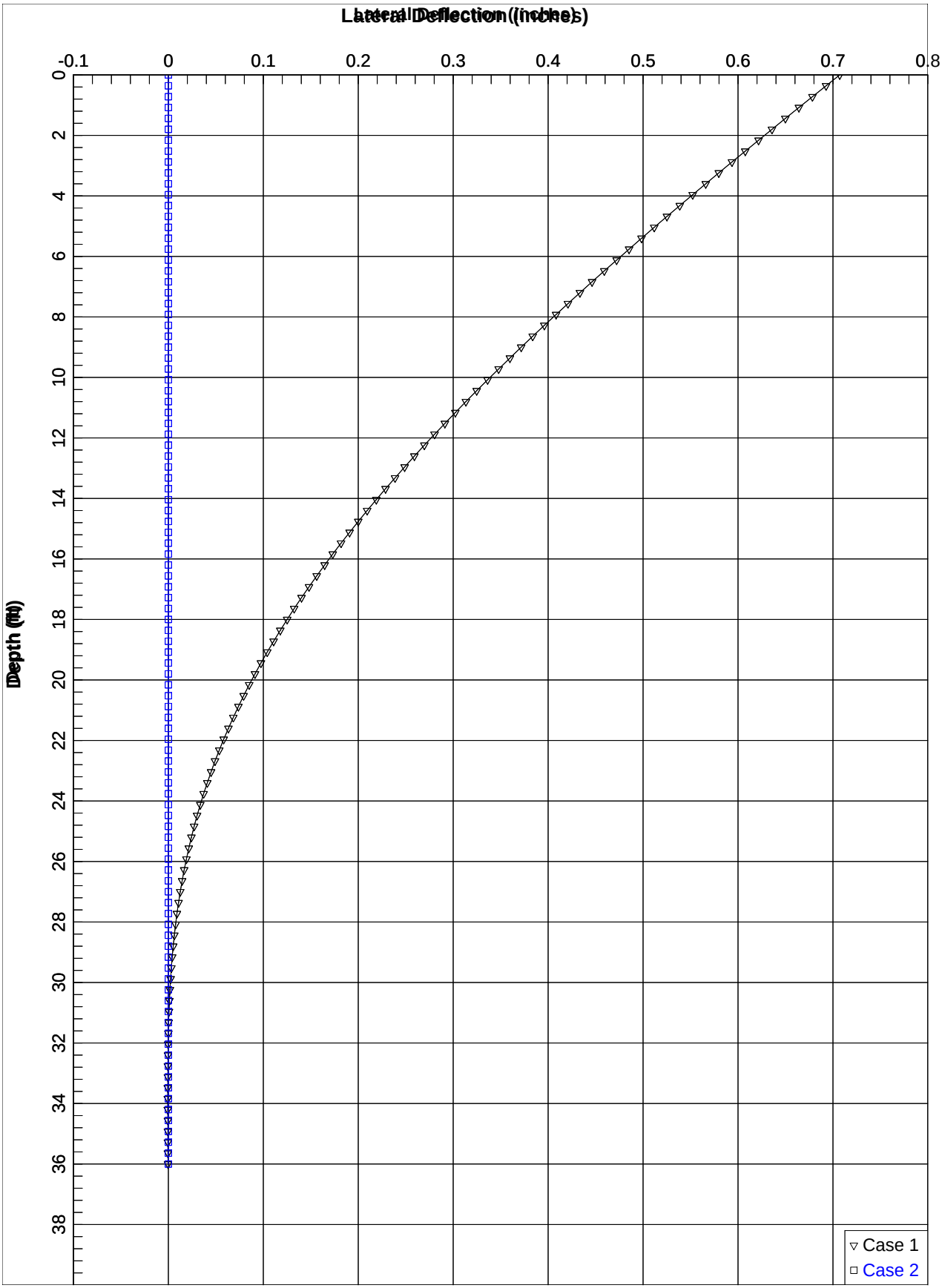
Summary of Pile Response(s)

Definitions of Pile-head Loading Conditions:

Load Type 1: Load 1 = Shear, lbs, and Load 2 = Moment, in-lbs
Load Type 2: Load 1 = Shear, lbs, and Load 2 = Slope, radians
Load Type 3: Load 1 = Shear, lbs, and Load 2 = Rotational Stiffness, in-lbs/radian
Load Type 4: Load 1 = Top Deflection, inches, and Load 2 = Moment, in-lbs
Load Type 5: Load 1 = Top Deflection, inches, and Load 2 = Slope, radians

Load Case No.	Load Type No.	Pile-head Condition 1 V(lbs) or y(inches)	Pile-head Condition 2 in-lb, rad., or in-lb/rad.	Axial Loading lbs	Pile-head Deflection inches	Maximum Moment in-lbs	Maximum Shear lbs	Pile-head Rotation radians
1	1	V = 11000.	M = 720000.	480000.	0.70717868	3397133.	-35696.	-0.00334024
2	2	V = 0.000	S = 0.000	490000.	0.0000000	0.0000000	0.000	0.00000000

The analysis ended normally.


Lateral Deflection (inches)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
Case 1
Case 2

Bridge 330 - Bent 1 - Boring B1-B

Required tip resistance

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

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

R_{req}	790	kips	Required factored geotechnical resistance
$\varphi_{qs,\ rock}$	0.55		side resistance factor, in Rock
$R_{sd,\ rock}$	0	kips	nominal side resistance, in Rock
$\varphi_{qs,\ IGM}$	0.6		side resistance factor, in IGM
$R_{sd,\ IGM}$	0	kips	nominal side resistance, in IGM
$\varphi_{qs} R_{sd}$	0	kips	factored developed side resistance
A_T	6.30	ft^2	Area of drilled pier tip (smaller than shaft diameter if rock sock
φ_{tip}	0.5		tip resistance factor
q_{req}	251	ksf	required tip resistance
=	260	ksf	required tip resistance rounded to the nearest 10 ksf
=	130	tsf	required tip resistance rounded in tsf
q_p	324	tsf	estimated nominal tip resistance

Required Resistance

R_{req} = required resistance

$= P_r + y_{DL}(W_T - W_{Soil/Rock}) - y_{WA} W_{Water}$

P_r	790	kips		Maximum factored axial load
y_{DL}	1.25			Factor for Permanent Dead loads from AASHTO Table 3.4.1-2
W_T	49	kips		Unfactored Weight of Drilled Pier and Column
	Pier Diameter	3	ft	
	Pier Length	45	ft	
	Column Diameter	2.5	ft	
	Column Length	0	ft	
	Weight of Concrete	0.155	$kips/ft^3$	
$W_{Soil/Rock}$	34	kips		Unfactored Weight of Soil/Rock that will be displaced below the Design Scour Elevation
	Pier Diameter	3	ft	
	Pier Length - Soil	24	ft	Pier Length in Soil Below the Design Scour Elevation
				DSE: 767 Bottom of Soil: 743
	Unit Weight - Soil	0.12	$kips/ft^3$	
	Pier Length - IGM	13.5	ft	Pier Length in IGM Below the Design Scour Elevation
				Top of IGM: 743 Bottom of IGM: 729.5
	Unit Weight - IGM	0.13	$kips/ft^3$	
	Pier Length - Rock	1	ft	Pier Length in Rock Below the Design Scour Elevation
				Top of Rock: 729.5 Bottom of Rock: 728.5
	Unit Weight - Rock	0.15	$kips/ft^3$	
y_{WA}	1			Factor for Water Loads from AASHTO Table 3.4.1-1
W_{water}	20	kips		Unfactored Weight of Water Displaced
	Unit Weight - Water	0.0624	$kips/ft^3$	

APPENDIX B-5 – PIER PAY ITEMS CALCULATIONS

Bent No. 1

Weathered Rock

Boring	Pier	Top Elevation	Bottom Elevation	Length	Comment
B1-A	Left	749	747.8	1.2	
B1-B	Center	743	738.5	4.5	
B1-B	Right	743	738.5	4.5	
				0	
				0	
				0	
			Total Weathered Rock:	10.2	

Rock

Boring	Pier	Top Elevation	Bottom Elevation	Length	Comment
B1-A	Left	747.8	737.8	10	
B1-B	Center	738.5	728.5	10	
B1-B	Right	738.5	728.5	10	
				0	
				0	
				0	
			Total Rock:	30	

Total Driled Shaft not in Soil for Bent No. 1: 35.1