ADSC Southeastern Chapter Drilled Shaft Research Project

LOAD TESTING OF DRILLED SHAFT FOUNDATIONS IN
PIEDMONT ROCK
LAWRENCEVILLE, GA

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Georgia Section ASCE Geotechnical Group
November 15, 2011

Site Characterization

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Site Characterization

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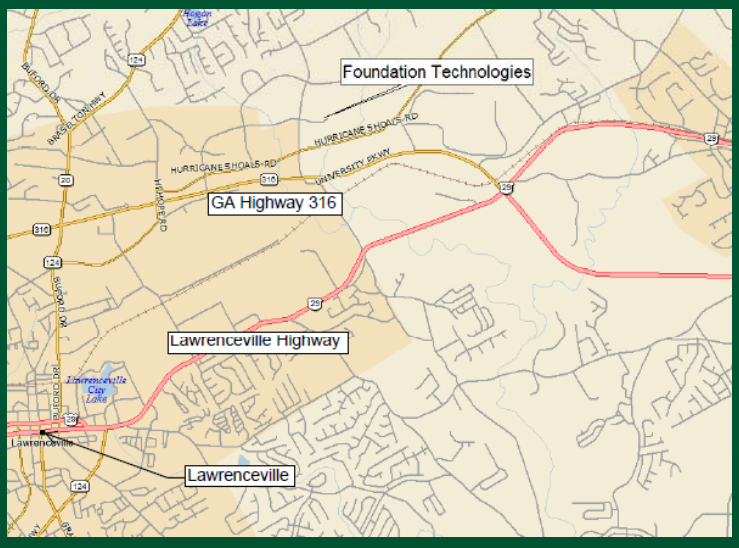
Site Location Plan



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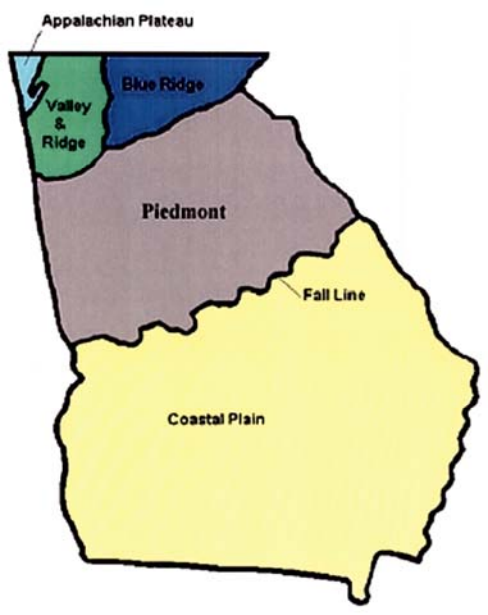
Site Geology



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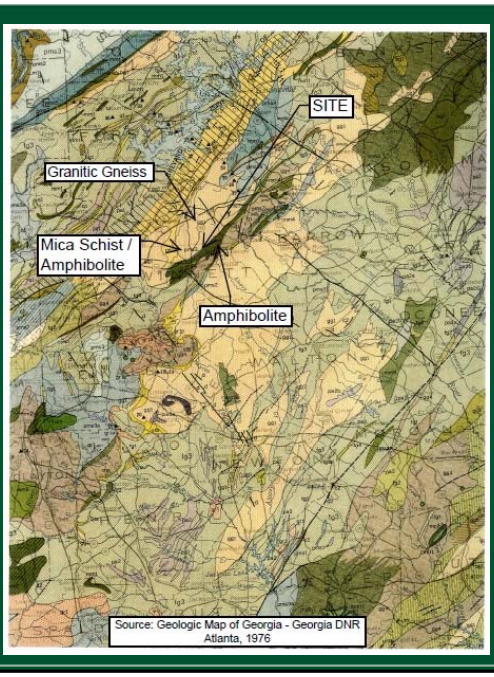

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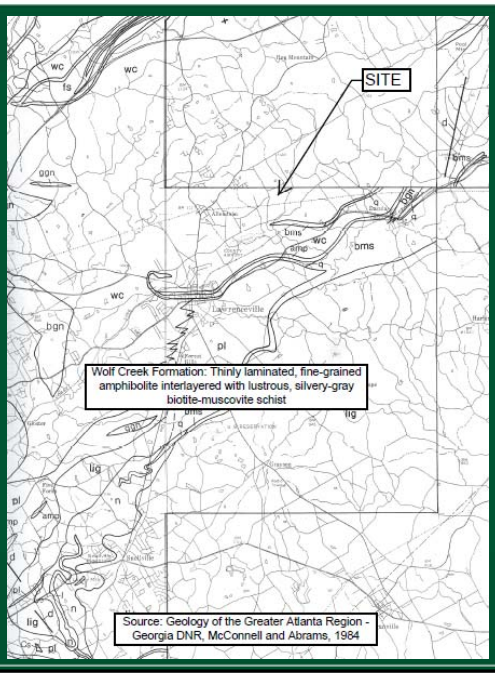

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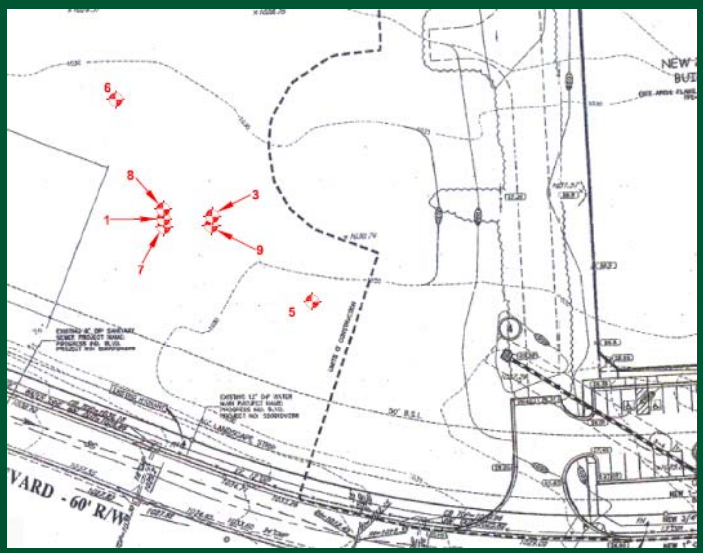
Geotechnical Exploration



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B-1 Test Boring Record

Project: Foundation Technologies Site		Project No:
Location: 1400 Progress Industrial Blvd., Lawrenceville, Georgia 30043		Date: 6/23/09
Method: HSA- ASTM D1586	GWT at Drilling: 16 feet	G.S. Elev: 1030
Drill: CME 550 AUTO HAMMER	GWT at 24 hrs: 13.5 feet	Logged By: TB

Elev. (ft)	Depth (ft)	GWT	Description	N-Value	Blows/ft	Standard Penetration Test (Blows/Foot)
1025	5		RESIDUAL SOIL - classified as silty sand (SM) and sandy silt (ML) with varying mica content	8	8	
				9	9	
1020	10			10	10	
1015	15			20	20	
1010	20			66	66	
1005	25			36	36	
1000	30		PARTIALLY WEATHERED ROCK - sampled as slightly micaceous silty fine sand (SM)	50/5"	50/5"	
995	35			50/1"	50/1"	
990	40		Auger Refusal at 36 1/2 feet REC - 60%, RQD - 13% REC - 98%, RQD - 23%			
985	45		REC - 100%, RQD - 7%			
980	50		REC - 100%, RQD - 0%			
975	55		Coring terminated at 51 1/2 feet			
970	60					

Remarks: Rock consists of moderately hard to hard hornblende gneiss, thinly laminated

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Rock Core B-1, 36.5 to 44 feet

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Rock Core B-1, 44 to 51.5 feet

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B-3 Test Boring Record

Project: Foundation Technologies Site			Project No:
Location: 1400 Progress Industrial Blvd., Lawrenceville, Georgia 30043			Date: 6/24/09
Method: HSA- ASTM D1586	GWT at Drilling: 22 feet		G.S. Elev: 1030
Drill: CME 550 AUTO HAMMER	GWT at 24 hrs: 13.5 feet		Logged By: TB

Elev. (ft)	Depth (ft)	GWT	Symbol	Description	N-Value	Blows/6"	Standard Penetration Test (Blows/Foot)
1025	5			RESIDUAL SOIL - classified as silty sand (SM)	8	8	
					6	6	
1020	10				23	23	
1015	15				9	9	
1010	20			PARTIALLY WEATHERED ROCK - sampled as silty fine sand (SM) with varying mica content	50/5"	50/5"	
1005	25				50/1"	50/1"	
1000	30			Auger Refusal at 30 feet			
				REC - 31%, RQD - 12%			
995	35			REC - 70%, RQD - 0%			
990	40			REC - 71%, RQD - 19%			
985	45			Coring terminated at 43 feet			
980	50						
975	55						
970	60						

Remarks: Rock consists of moderately hard to hard hornblende gneiss, thinly laminated

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Rock Core B-3, 30 to 43 feet

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Laboratory Testing

- Unconfined Compressive Strength (ASTM D7102)
  - Peak Compressive strengths of about 7,000 to 11,300 psi
  - Young's Modulii ranged from about 500 to 6,700 ksi depending on stress range.
  - Poisson's Ratio ranged from about 0.14 to 0.86 depending on stress range.
- Point Load Strength Index (ASTM D5731)
  - Strengths of about 3,100 to 16,000 psi in the axial direction and 1,400 to 9,100 psi in the diametral direction.
  - Diametral strength possibly affected by weathering and weakness along foliation that could not be observed.

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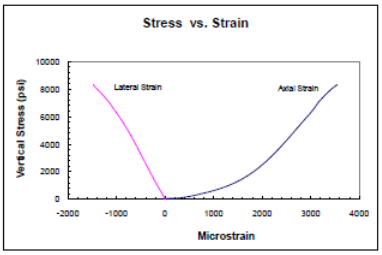
Compressive Strength Data Sheet

Drilled Shaft Load Testing Program	
Foundation Technologies Site	
1400 Progress Industrial Boulevard	
Sample #	Boring B-8, 43.5 to 44 feet
Sample Type	NQ Rock Core

Unconfined Compressive Strength and Elastic Modulus of Rock
ASTM D 7012 - Method D



Peak Compressive Strength 8,332 psi

Stress Range (psi)	Young's Modulus (psi)	Poisson's Ratio
1,000-3,000	2,505,000	0.34
3,000-5,000	3,905,000	0.58
5,000-7,000	4,210,000	0.81

Notes: Young's modulus and Poisson's ratio calculated using the tangent method in stress range indicated.
Calculations assume rock sample is isotropic.

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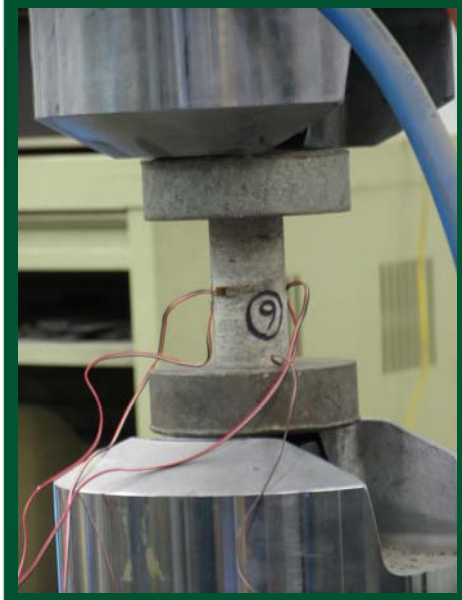

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General Site Characterization

- Site can be considered "typical" Piedmont site that does not have an extremely deep, weathered profile (found acceptable site on first try).
- 20 to 30 feet of moderate to high consistency residual soil overburden.
- 8 to 10 feet or partially weathered rock before auger refusal with a CME 550.
- Variability in auger refusal of 3 to 4 feet for closely-spaced borings (4 to 5 feet separating borings).
- Rock coring used conventional techniques, double core barrel, which would be used on most projects.

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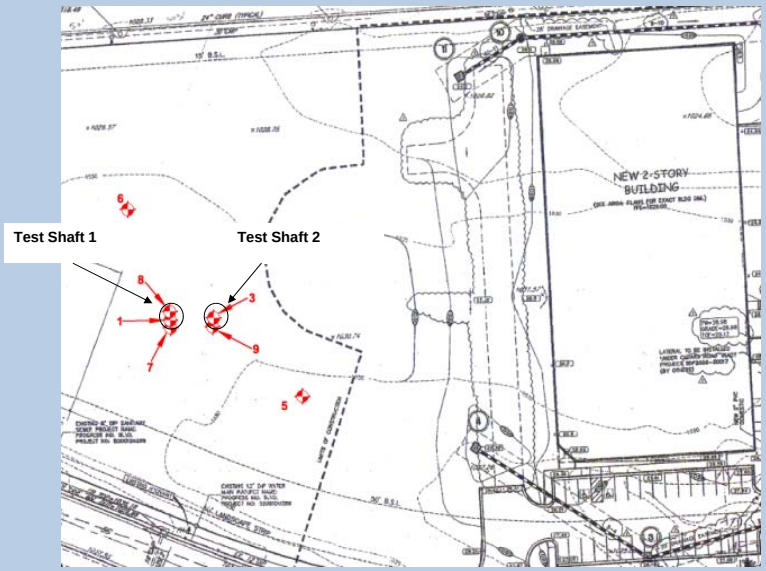
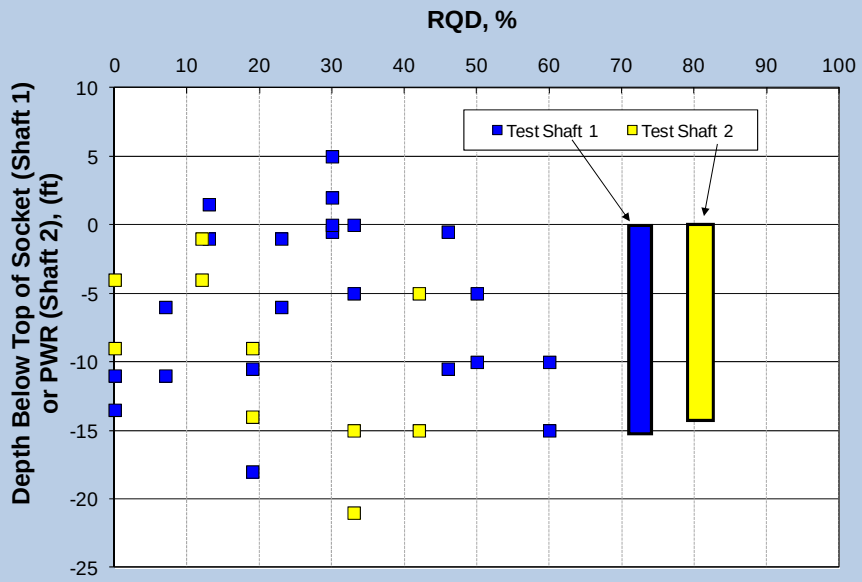
Site Characterization (continued)

- Cored rock generally of poor to moderate quality. Recoveries not bad but RQD typically low- 0 to 60% with most below 50%.
- Cored rock consisted of horneblende gneiss. Mapping indicated amphibolite/schist/gneiss? Do your homework but understand limitations of available information. If underlying geology is critical, sample it.
- Difficult to correlate compressive strength testing and point load index testing.

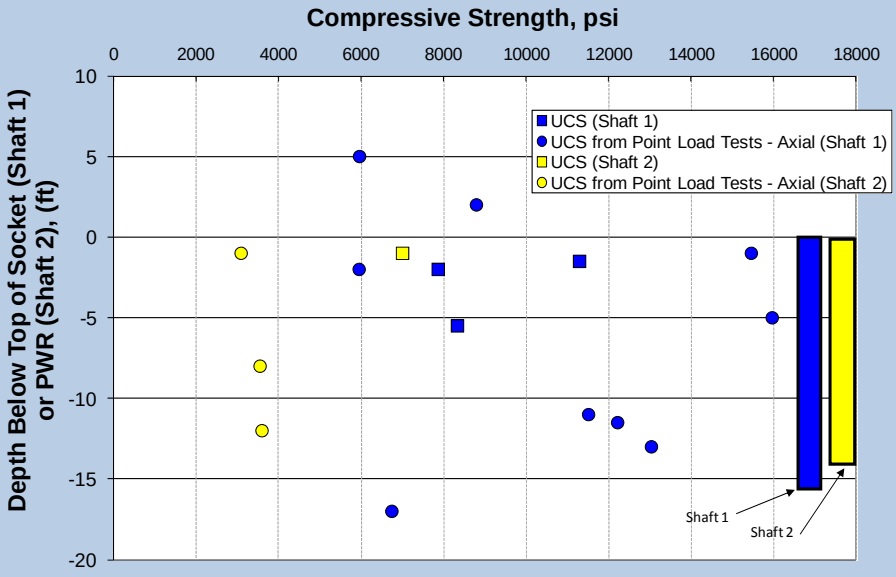
Planned Test Shafts



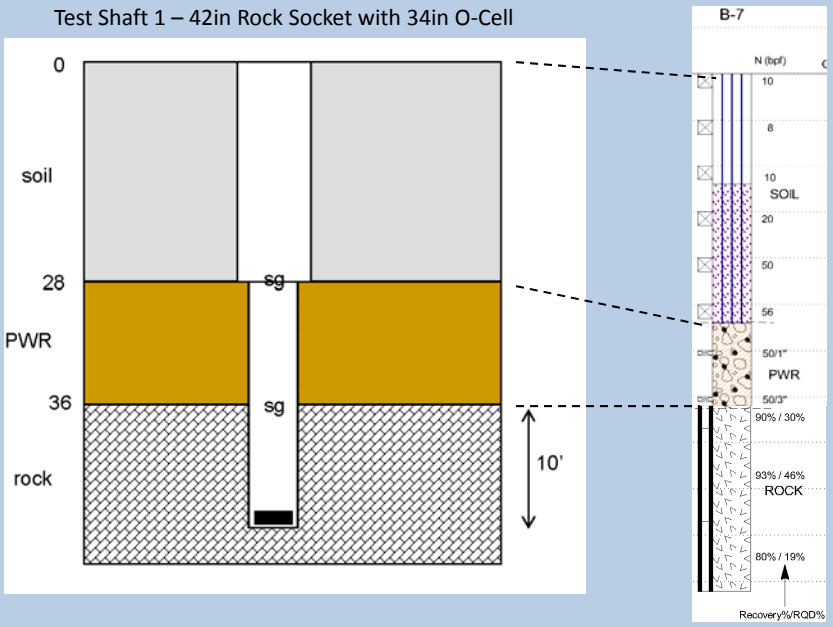
RQD from Rock Cores



Compressive Strength of Rock

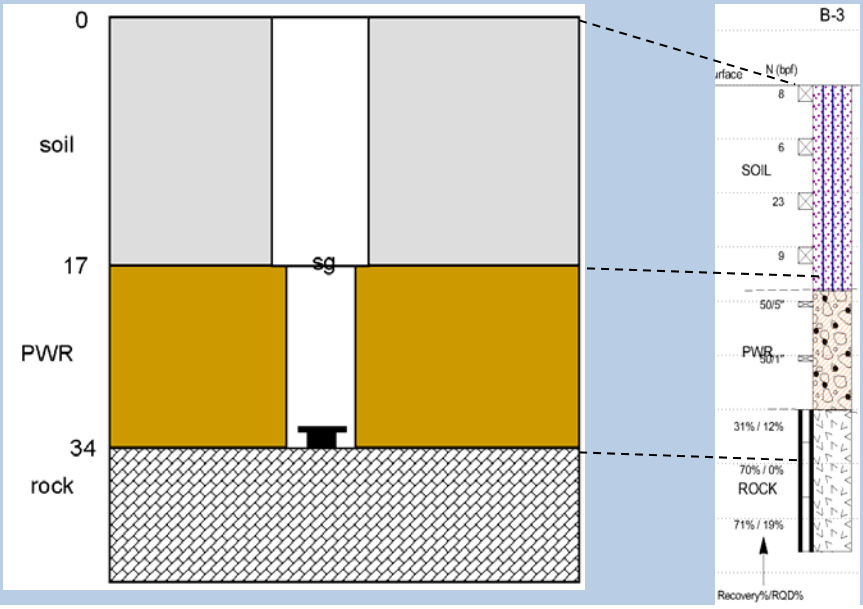


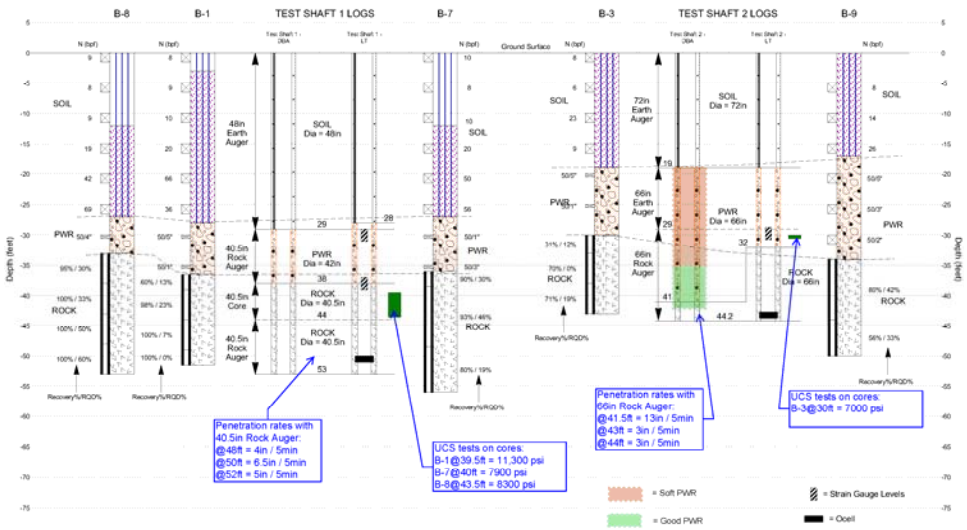
Planned Test Shafts



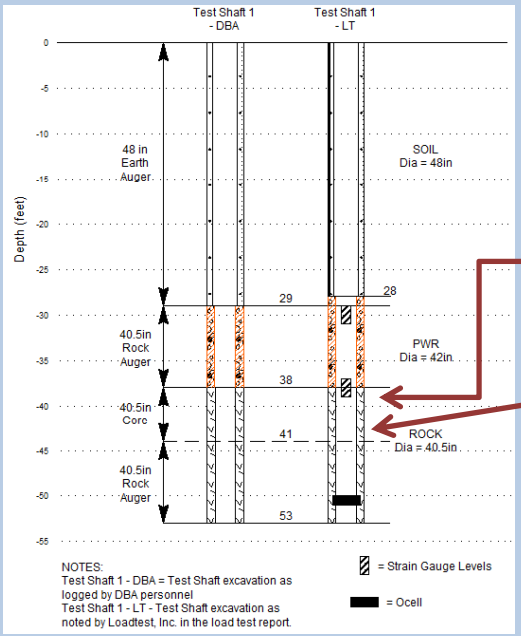
Planned Test Shafts

Test Shaft 2 – 66in Shaft to Rock Auger Refusal with 16in O-Cell on 20in Bearing Plate

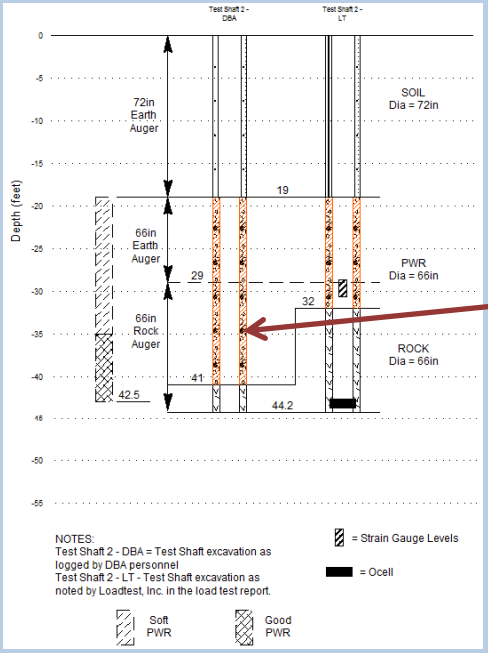




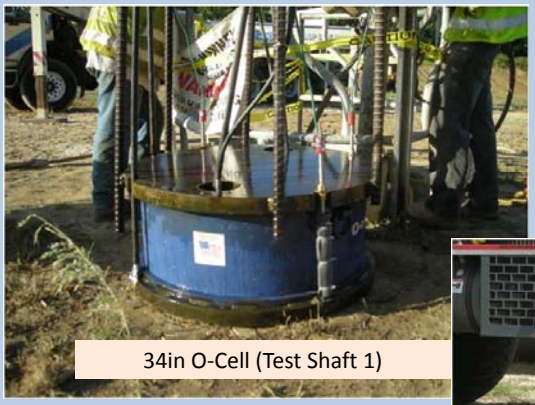
Actual Test Shaft 1



Actual Test Shaft 2



O-Cells



34in O-Cell (Test Shaft 1)

16in O-cell with 20in base plate (Test Shaft 2)

Test Day

Test Results – Unit Side Resistance

- Limit of the O-cell was reached
  - TS 1 = 8900 kips (34in cell)
  - TS 2 = 1850 kips (16in cell)
- USR vs displacement curves indicate tests were close to maximum.
- Significant resistance was mobilized in the gneiss at small displacement (0.2in or less).

Test Results – Unit Side Resistance

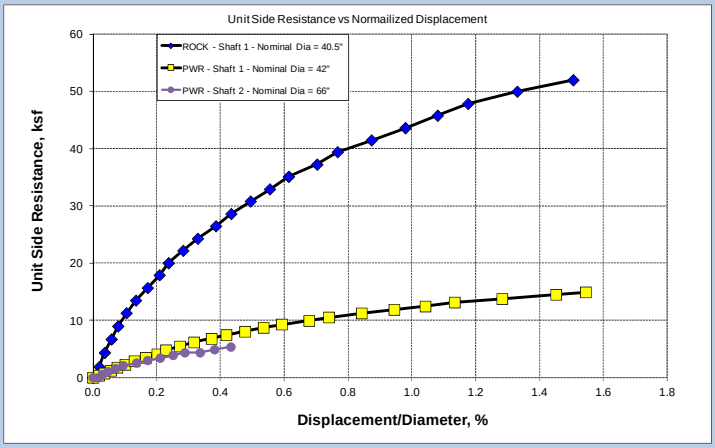


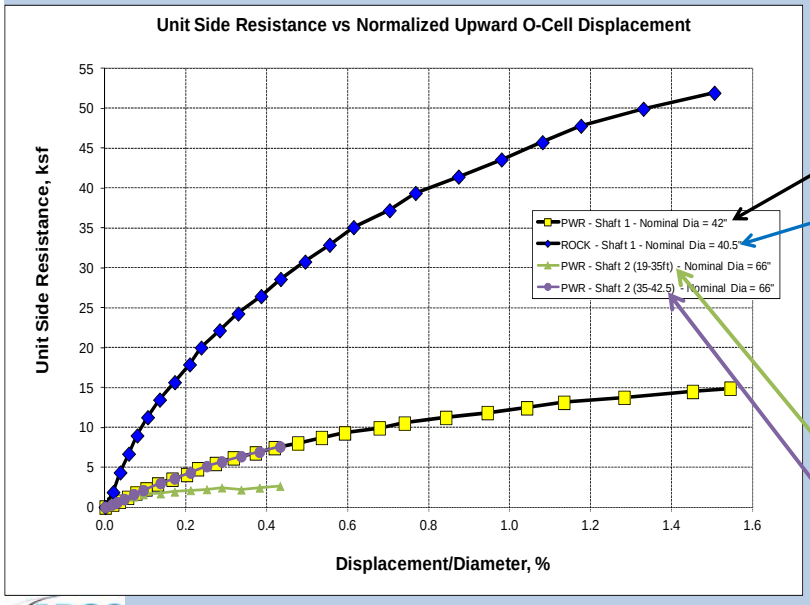
Table 3 – Maximum Average Unit Side Resistance

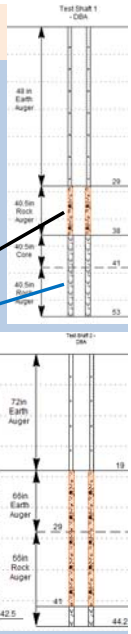
Shaft	*Material*	*Maximum Unit Side Shear (ksf)*	*Normalized Displacement (% Diameter)*
1	Gneiss Rock	52	1.5
1	PWR	15	1.5
2	Soft PWR (Upper PWR)	2.5	0.5

≈ 0.6in

≈ 0.3in

Test Results – Unit Side Resistance





Test Results – Unit Base Resistance

- Limit of the O-cell was reached
- UBR vs displacement curves indicate TS 1 had more to give, TS 2 close to maximum.
- TS 1 factor out side resistance of 2ft plug below cell
- TS 2 projected area through seating layer bearing on rock

Test Results – Unit Base Resistance

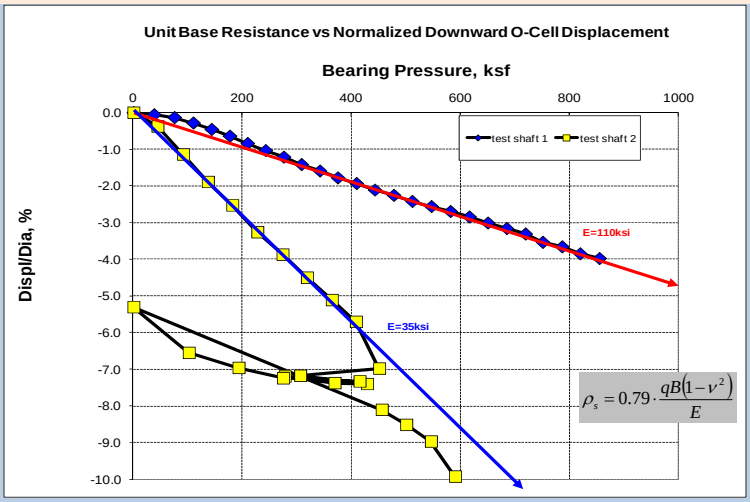


Table 4 – Maximum Unit Base Resistance

Shaft	*Material*	*Maximum Unit Base Resistance (ksf)*	*Normalized Displacement (% Diameter)*
1	Gneiss Rock	850	4
2	Gneiss Rock	600	10

≈ 1.6in

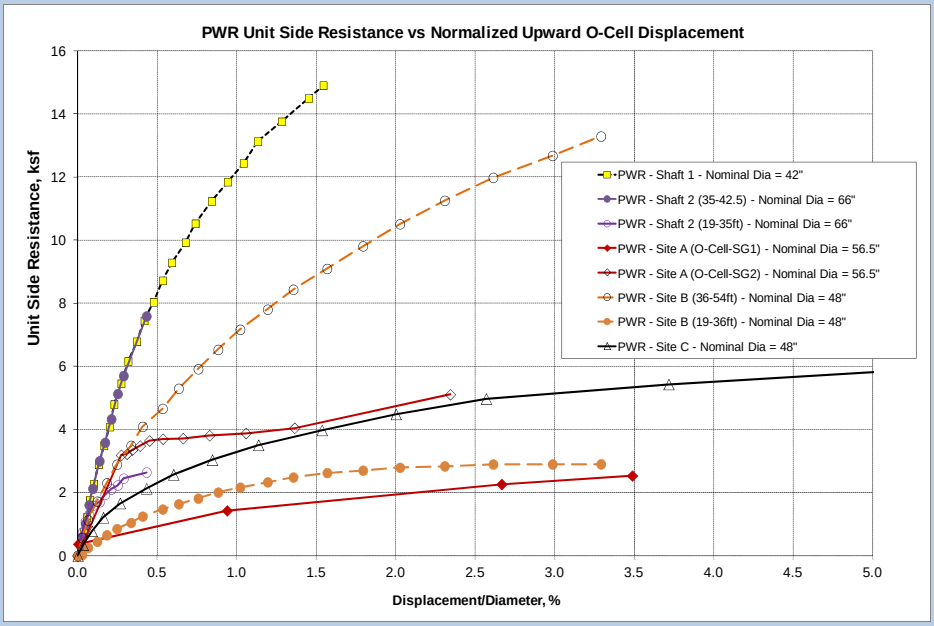
≈ 2in

Other Atlanta Area Tests

Table 5 – Load Tests in Atlanta Area in Similar Geology

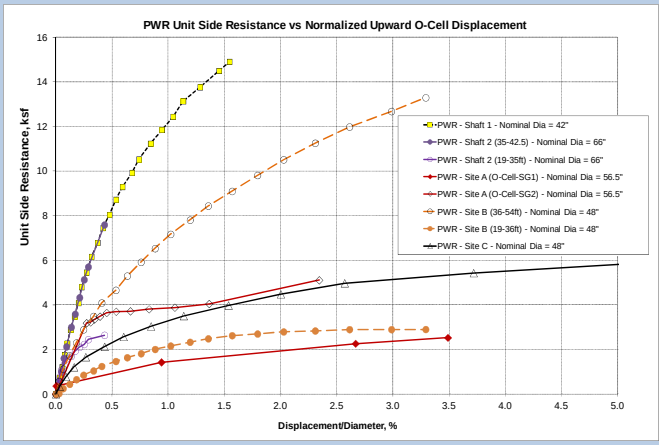
Site	*Shaft Dia. (in)*	*Material*	*Unit Side Resistance (ksf)*	*Normalized Displacement (%D)*	*Unit Base Resistance (ksf)*	*Normalized Displacement (%D)*
A	56.5	PWR (sampled as sand with silt and rock fragments)	2	1.8	70	6.7
B	48	PWR (sampled as micaceous silty sand	2.8	1.9		
		Weathered gneiss (RQD = 50%)	12.2	2.1	233	1.5
C	48	PWR (weathered gneiss (RQD = 24% and sandy silt)	6.8	5.8		
			5.5	2.1		
	36	Weathered gneiss (RQD = 49%)			449	2.5

Other Atlanta Area Tests – Unit Side Resistance

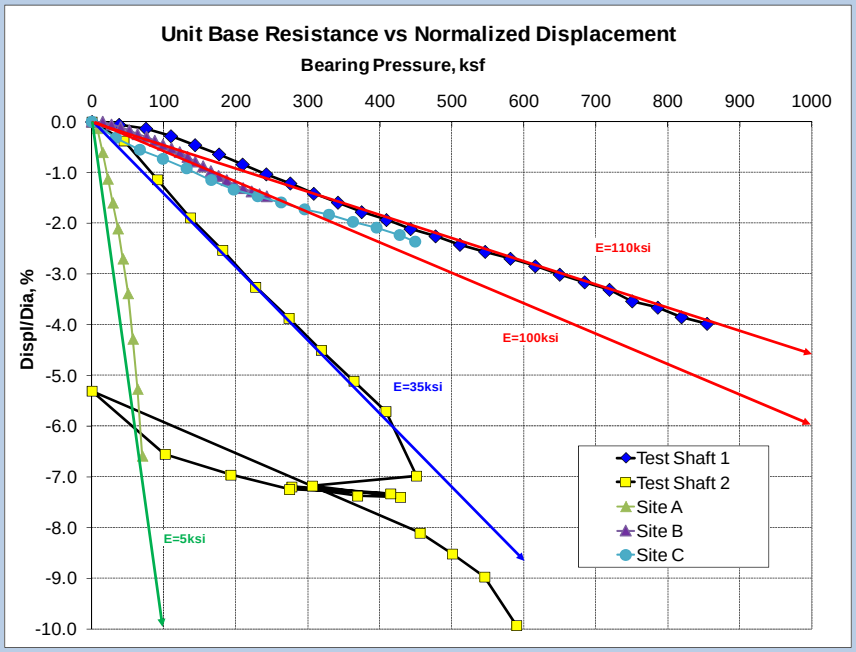


Other ATL Tests Observations – Unit Side Resistance

- 2 to 12.2 ksf at 1.8 to 2.1% normalized displacement.
- Site A likely influenced by installation technique
- TS 1 higher
- TS 2 in the range

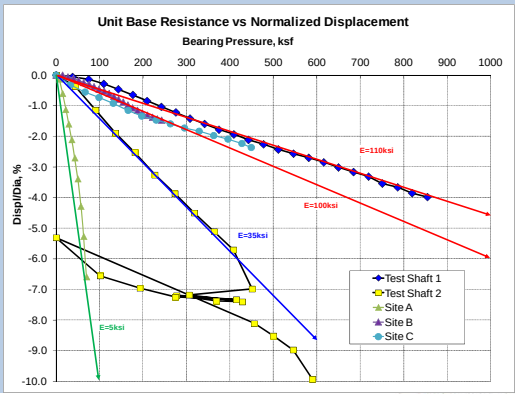


Other Atlanta Area Tests – Unit Base Resistance



Other ATL Tests Observations – Unit Base Resistance

- Curves and calculated elastic modulus for Sites B and C compare favorably to Test Shaft 1 (UBR from test Shaft 1 = reasonable value for this material).
- Site A had a much softer base response than any of the other tests.
- Tests B and C terminated at lower nominal displacements than TS 1, but could have probably achieved similar magnitudes of UBR.



Summary of Results and Design Implications

- The test data suggest that the current rock auger refusal criteria of 2in/5min may be too restrictive.
  - Both test shafts were terminated in material that did not meet the current criteria for rock auger refusal (TS 1 = 4 to 6 in/5min; TS 2 = 3in/5min)
  - Significantly higher UBR and USR were achieved than are commonly used for design at these conditions
  - A less restrictive criterion of 5in/5min appears appropriate

Summary of Results and Design Implications

- The ultimate or strength limit state base resistance exceeds the structural capacity of typical reinforced concrete shaft.
- UBR = 60 to 150ksf was observed at a small displacement of only 0.5% D. Range is current maximum allowable values for more stringent rock criteria

Summary of Results and Design Implications

- Significant USR (over 50ksf) is available in rock that would not meet current “rock” criteria for maximum bearing.
- Significant USR (2.5 to 15ksf) is available in the PWR.

Current Practice

- Typical Factor of Safety = 2.
- Allowable base resistance ranges from 30ksf for soft PWR to 150ksf for hard rock.
- Settlement limited to ¼in, not including the elastic compression of the shaft.
- Typically design for base resistance only bearing on rock, typically defined by “rock auger refusal” as defined below. Side resistance is very rarely used.
- Allowable side resistance in PWR typically 1 to 2 ksf, in rare cases where it is used (possibly 3ksf in very hard PWR).
- Criteria for “rock auger refusal” is related to refusal using an LLDH rig at a penetration rate of 2in/5min.
- Quality of PWR/rock below rock auger refusal assessed by downhole inspection w/probe holes. The depth and thickness of seams is determined and a judgment made if the shaft needs to go deeper to get below the seams noted.

Open Discussion – Your Contribution!

Can we get consensus on 3 points?

- An allowable unit base resistance for rock equal to or better than the rock tested at this site (perhaps coin a term such as “Lawrenceville grade rock”).
- A lower-bound unit base resistance for rock with soil/PWR seams.
- Use of an allowable unit side resistance in PWR and/or rock to use the socket length plus the lower bound unit base resistance base to satisfy demand.