

ADSC Southeastern Chapter Drilled Shaft Research Project

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

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Dan Brown and Associates, PC

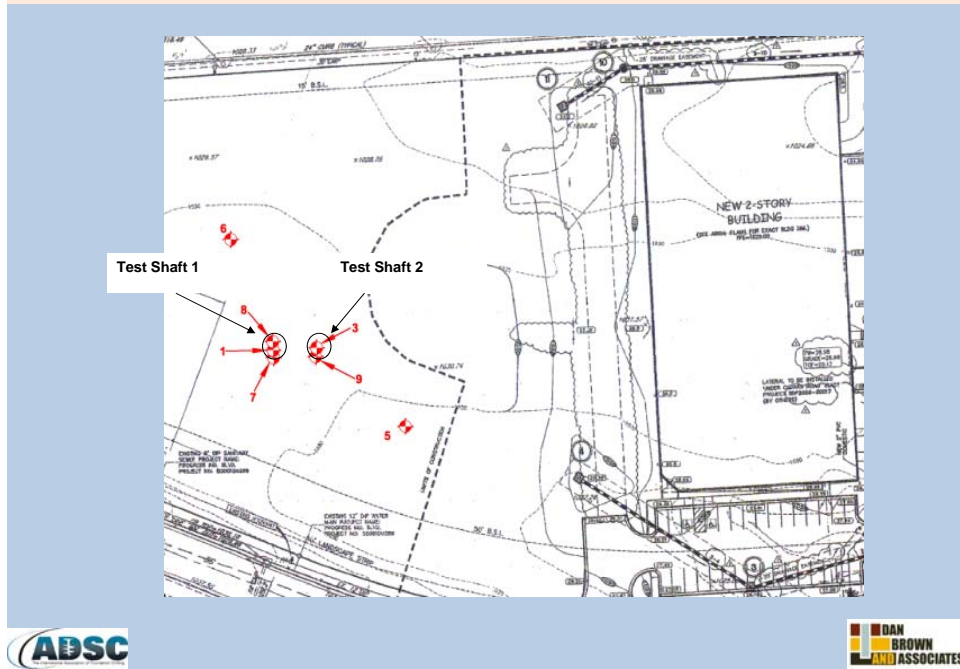
Georgia Section ASCE Geotechnical Group
November 15, 2011



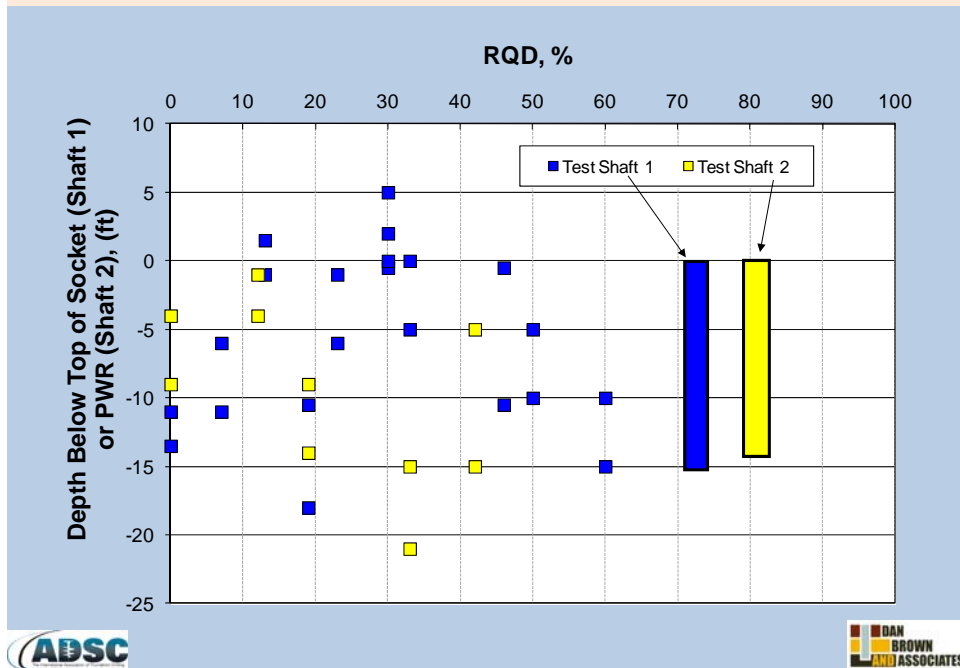
Site Characterization

TODD BARBER, P.E.
GEO-HYDRO ENGINEERS, Inc.

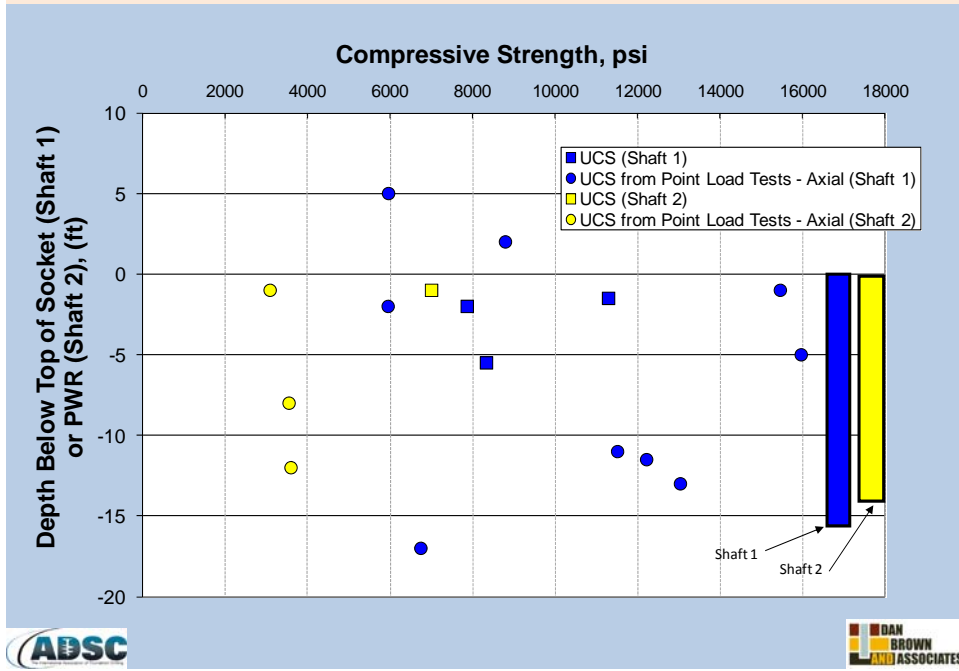
Planned Test Shafts



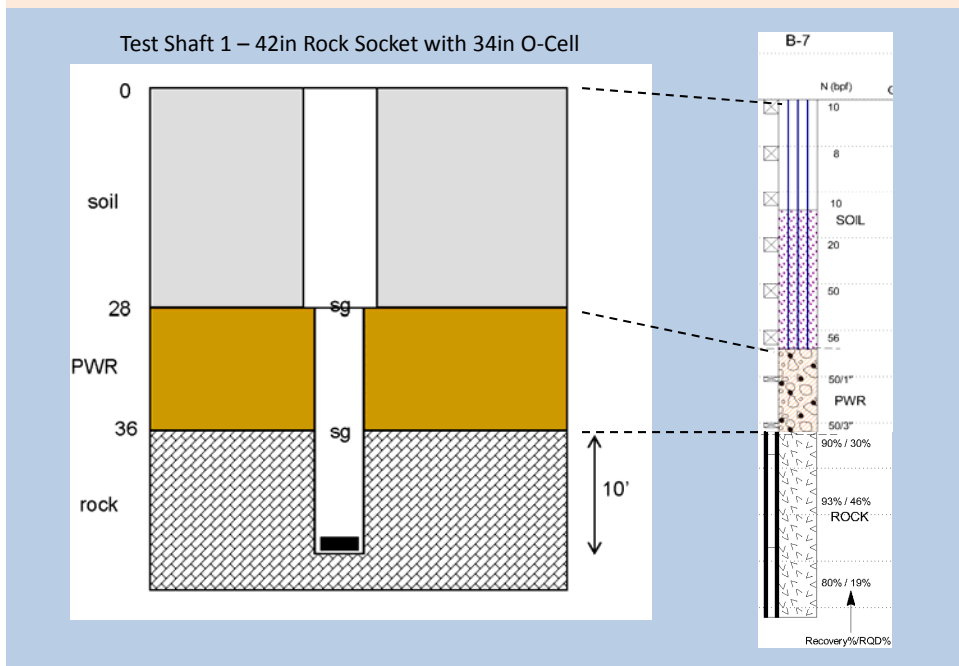
RQD from Rock Cores



Compressive Strength of Rock

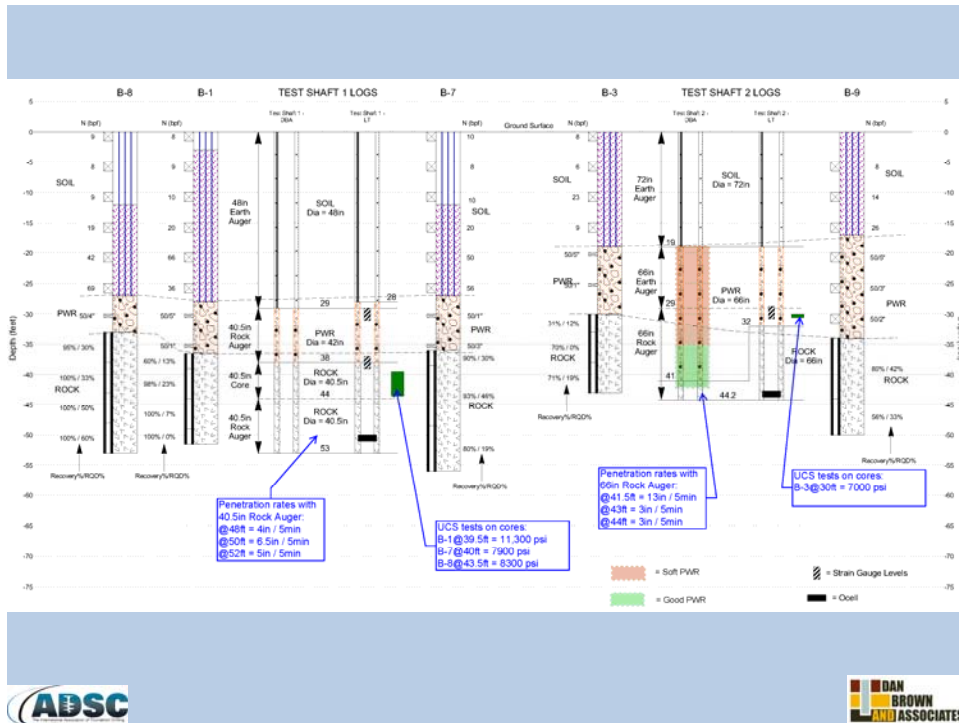
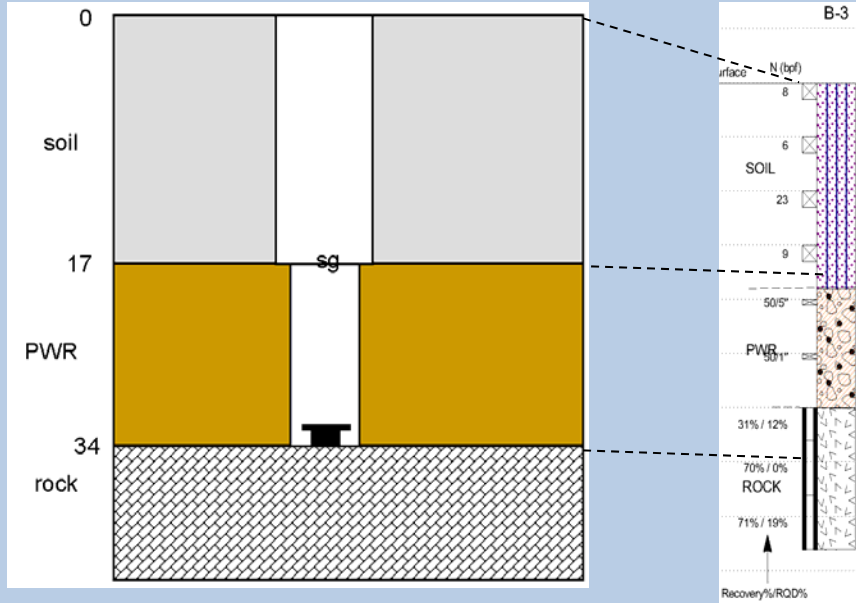


Planned Test Shafts

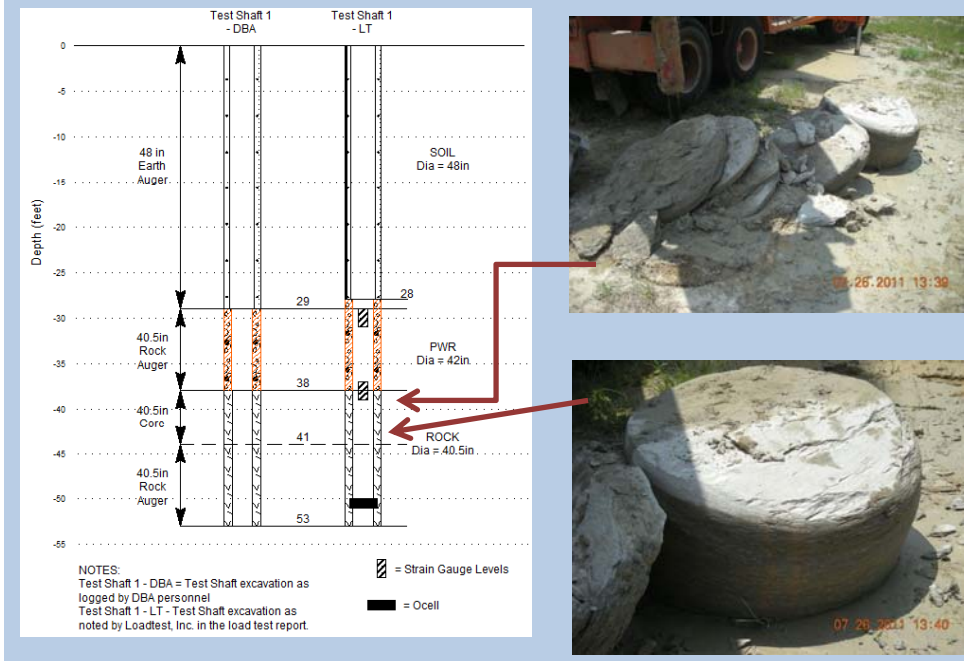


Planned Test Shafts

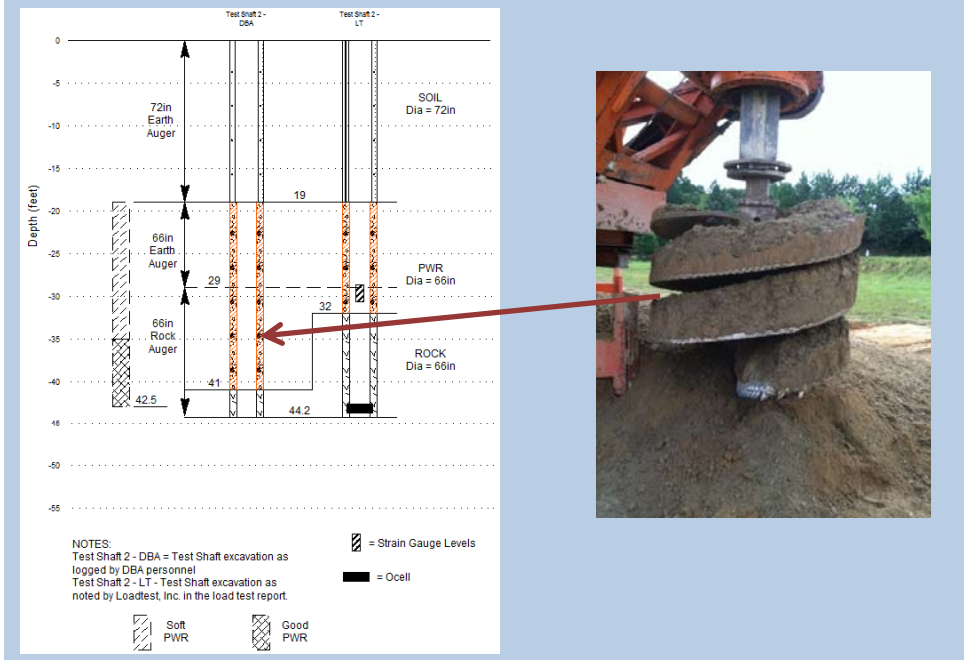
Test Shaft 2 – 66in Shaft to Rock Auger Refusal with 16in O-Cell on 20in Bearing Plate



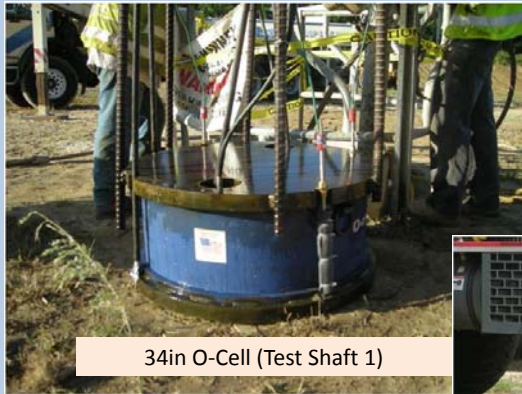
Actual Test Shaft 1



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

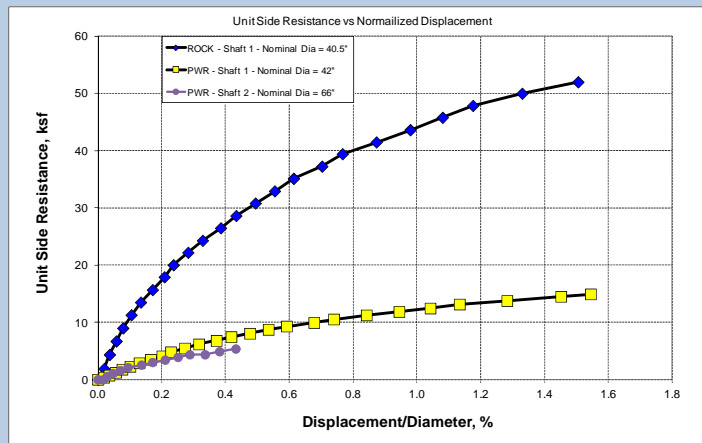


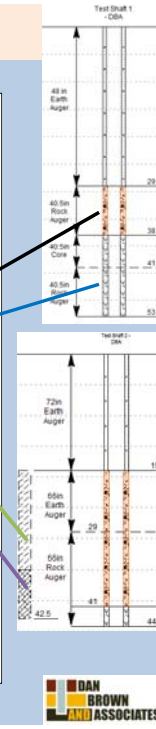
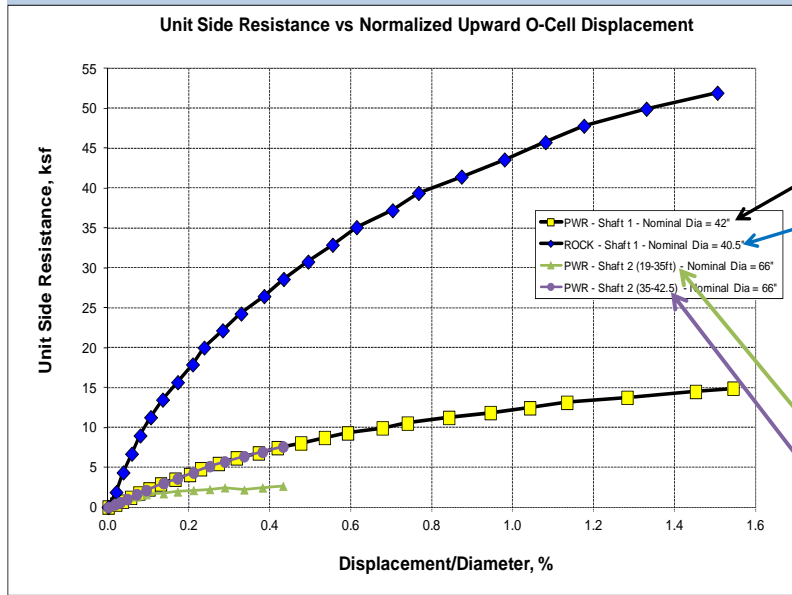
Table 3 – Maximum Average Unit Side Resistance

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

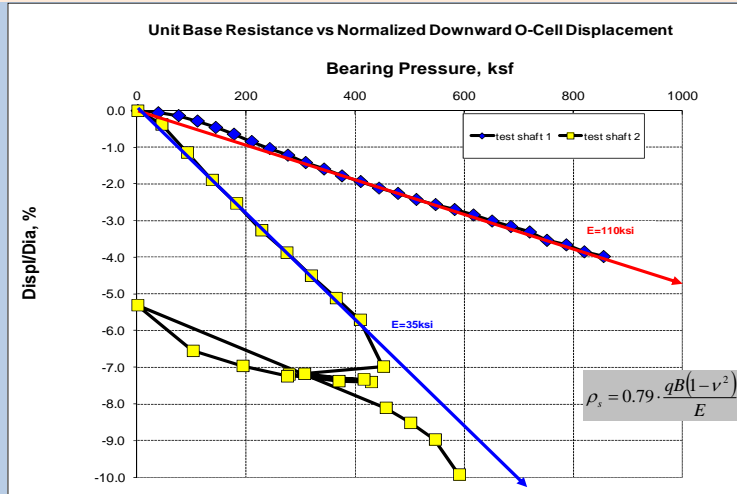


Table 4 – Maximum Unit Base Resistance

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

≈ 1.6in

≈ 2in

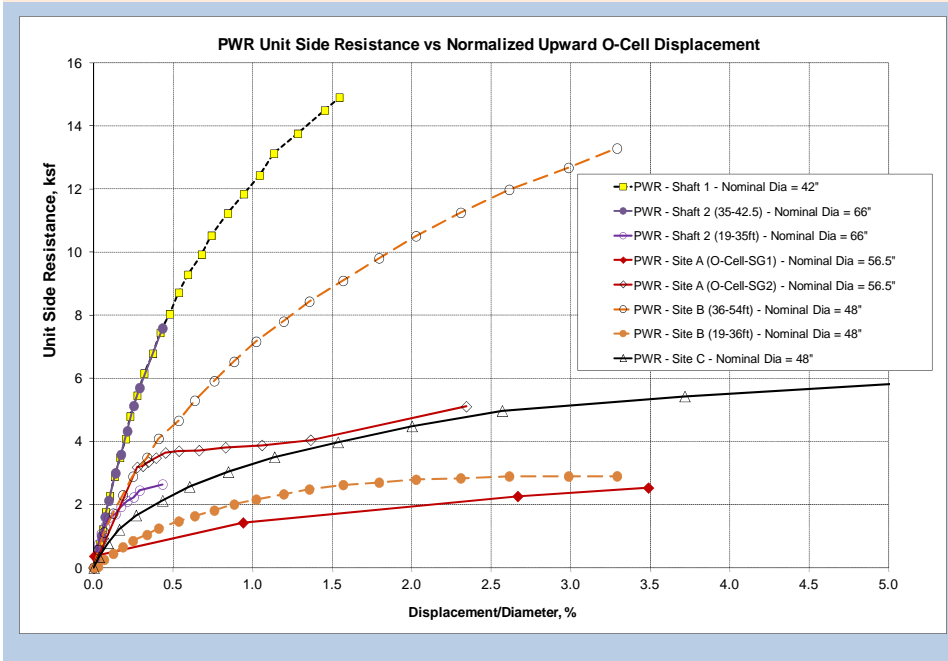
Other Atlanta Area Tests

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

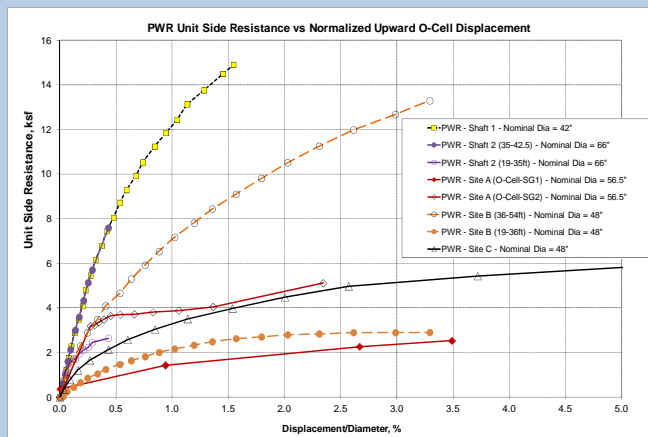


Other Atlanta Area Tests – Unit Side Resistance

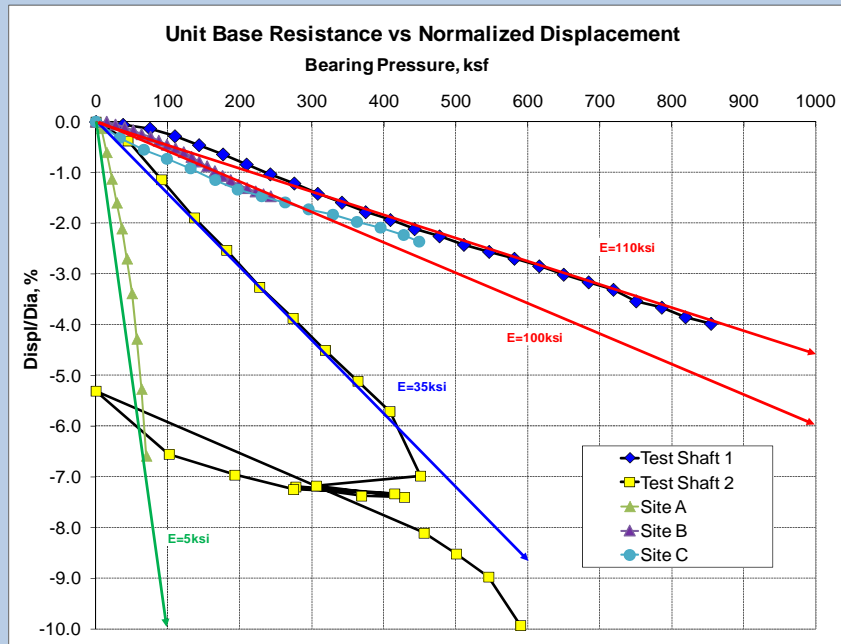


Other ATL Tests Observations – Unit Side Resistance

- 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

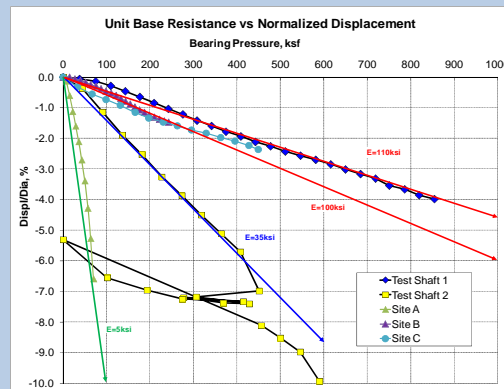


Other Atlanta Area Tests – Unit Base Resistance



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).
- Tests B and C terminated at lower nominal displacements than TS 1, but could have probably achieved similar magnitudes of UBR.
- Site A had a much softer base response than any of the other tests.



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.