# 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
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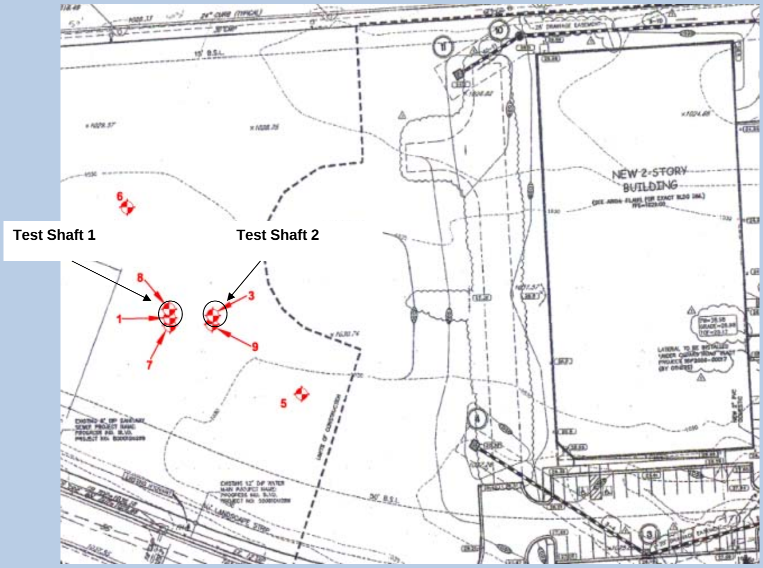
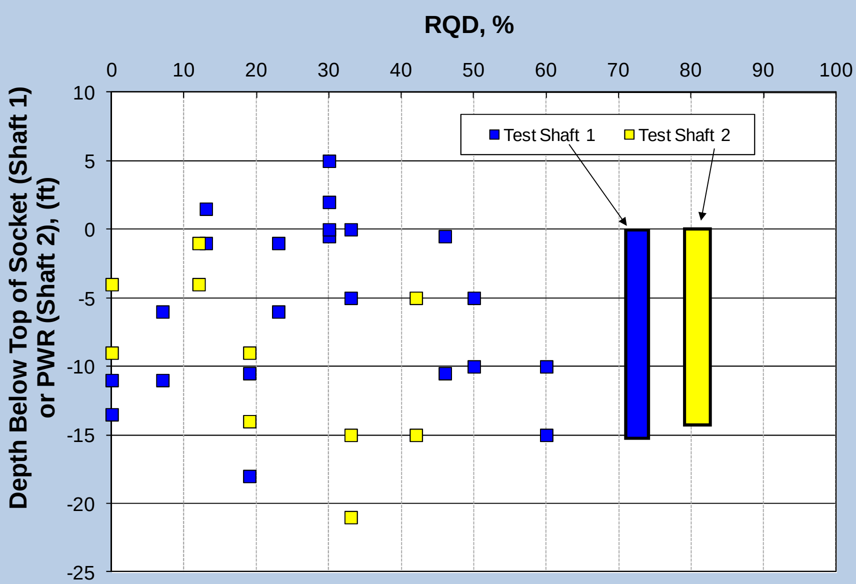
## Site Characterization

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

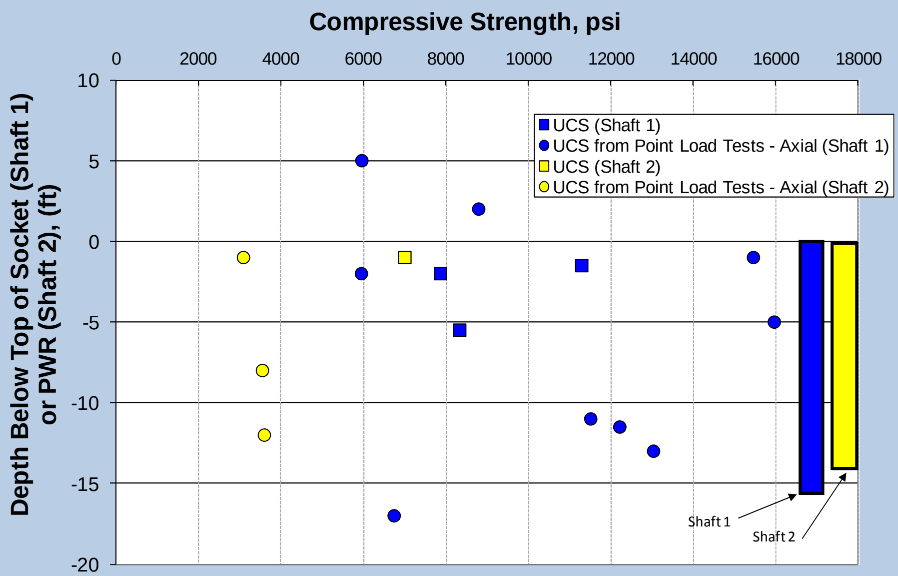
## Planned Test Shafts




## RQD from Rock Cores

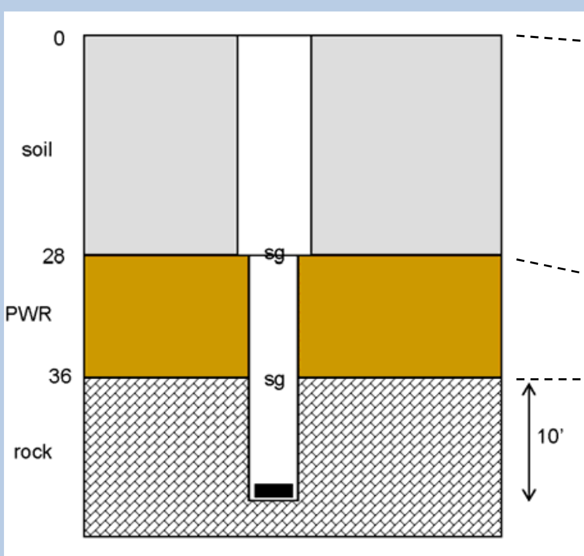


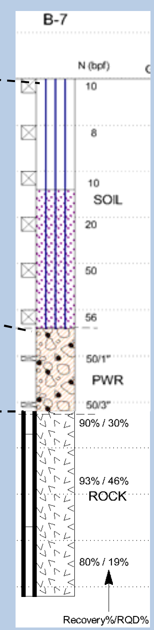
## Compressive Strength of Rock




## Planned Test Shafts

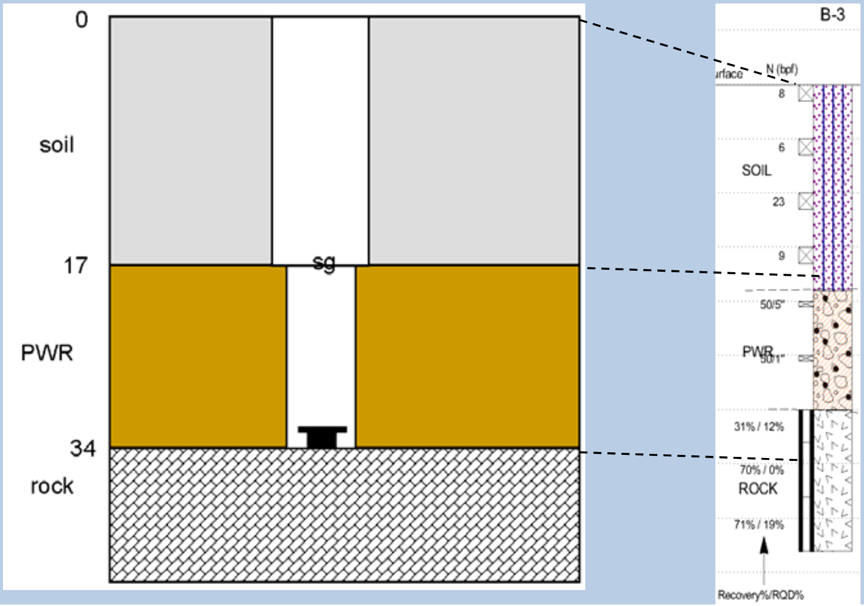
Test Shaft 1 – 42in Rock Socket with 34in O-Cell

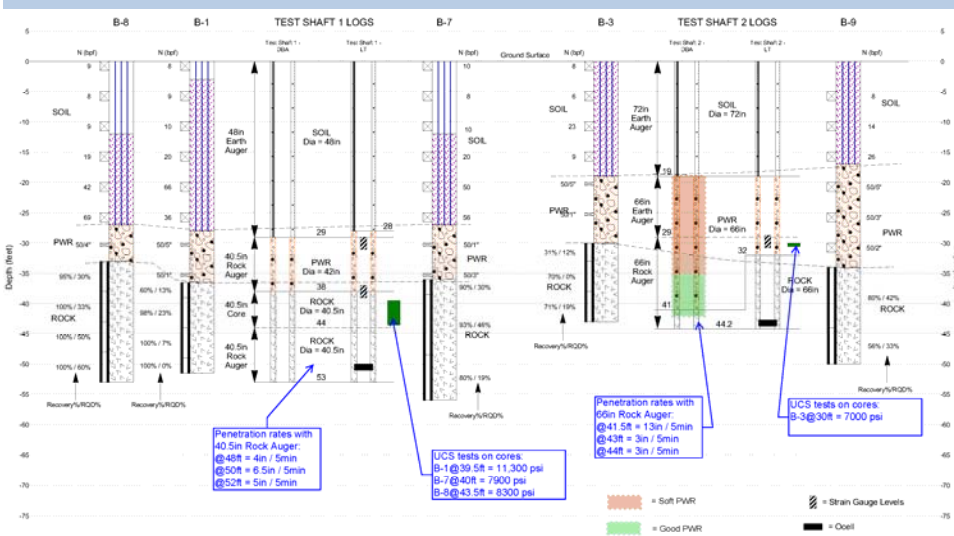


## Planned Test Shafts

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

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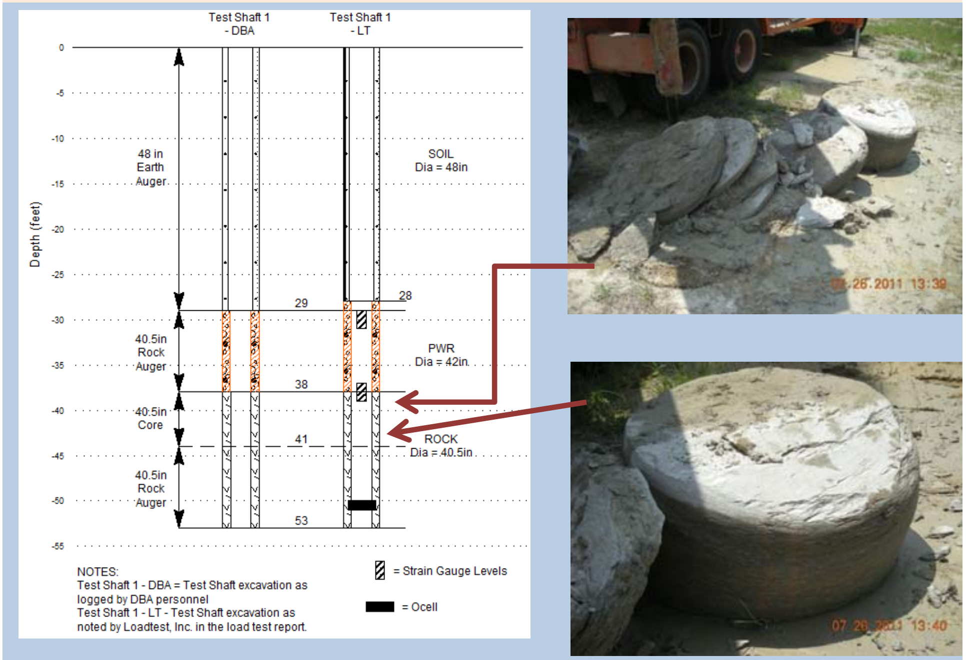
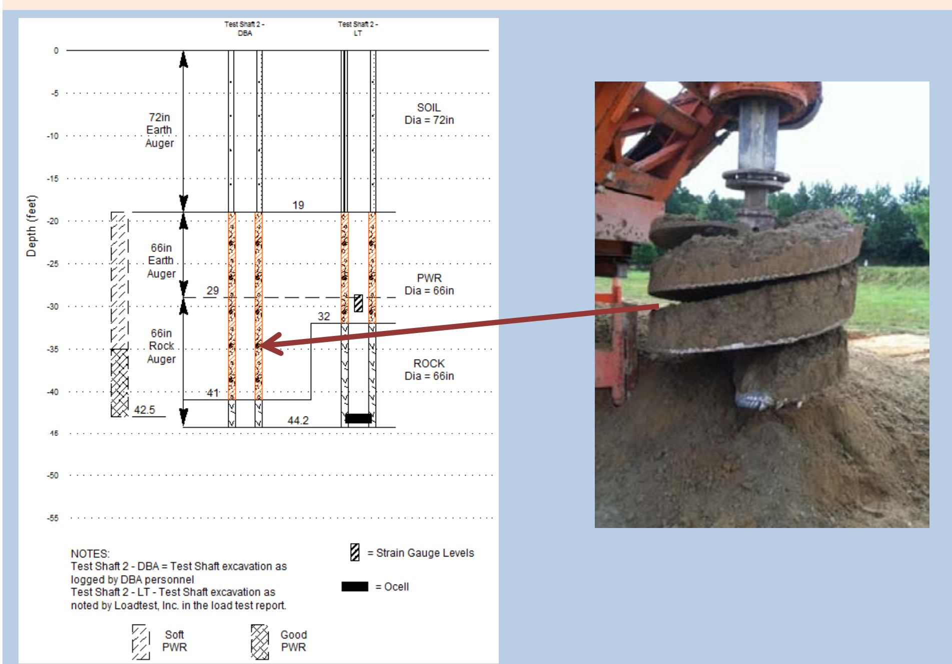
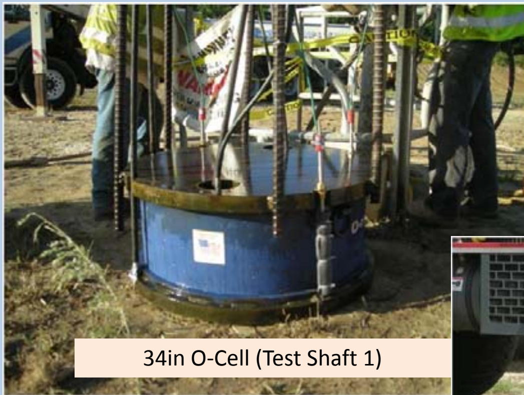
## Actual Test Shaft 1




## Actual Test Shaft 2



## O-Cells


34in O-Cell (Test Shaft 1)


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

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## Test Day

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## 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

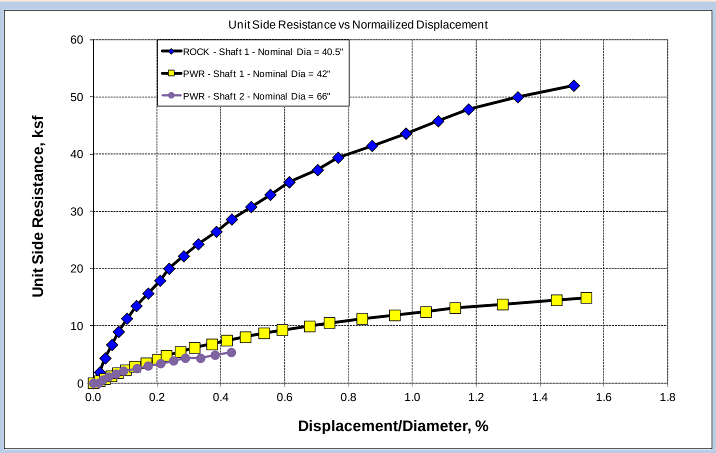


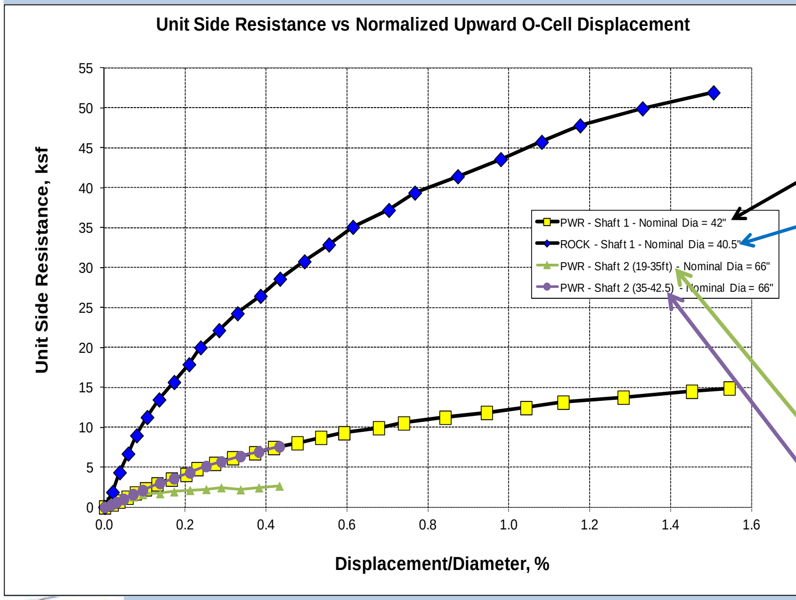

**Table 3 – Maximum Average Unit Side Resistance**

| *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

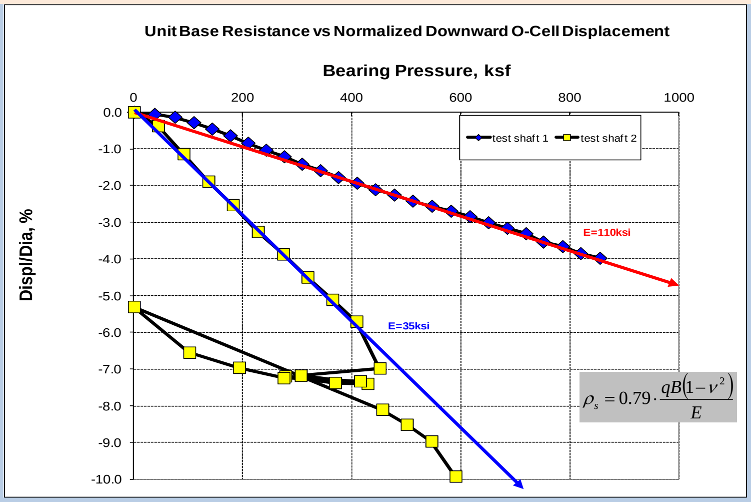



**Table 4 – Maximum Unit Base Resistance**

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

≈ 1.6in

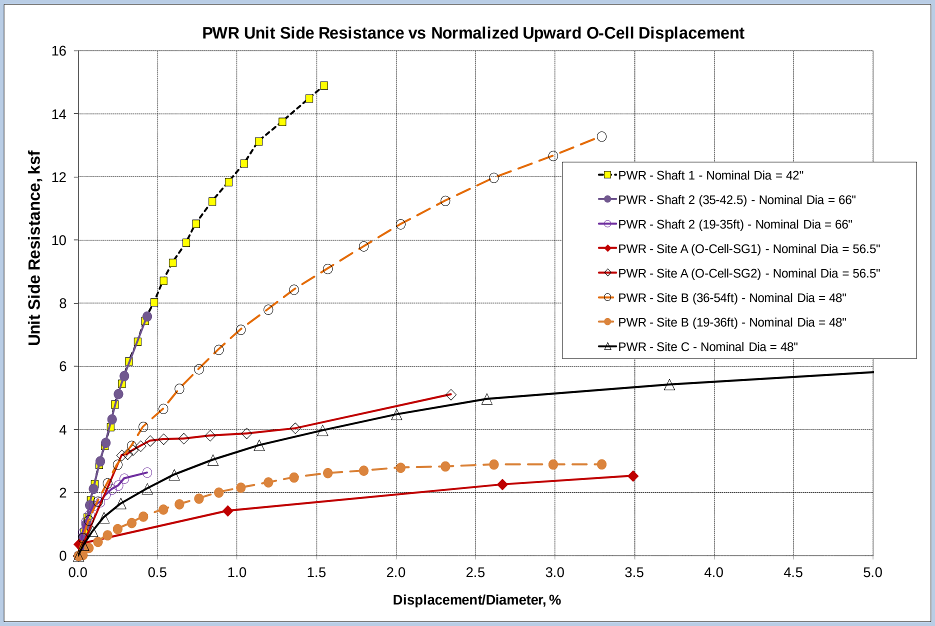
≈ 2in

## Other Atlanta Area Tests

**Table 5 – Load Tests in Atlanta Area in Similar Geology**

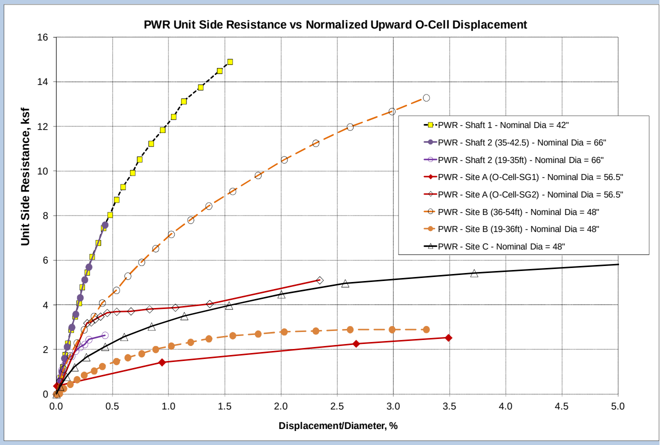
| *Site* | *Shaft Dia. (in)* | *Material* | *Unit Side Resistance (ksf)* | *Normalized Displacement (%D)* | *Unit Base Resistance (ksf)* | *Normalized Displacement (%D)* |
|---|---|---|---|---|---|---|
| A | 56.5 | PWR (sampled as sand with silt and rock fragments) | 2 | 1.8 | 70 | 6.7 |
| B | 48 | PWR (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

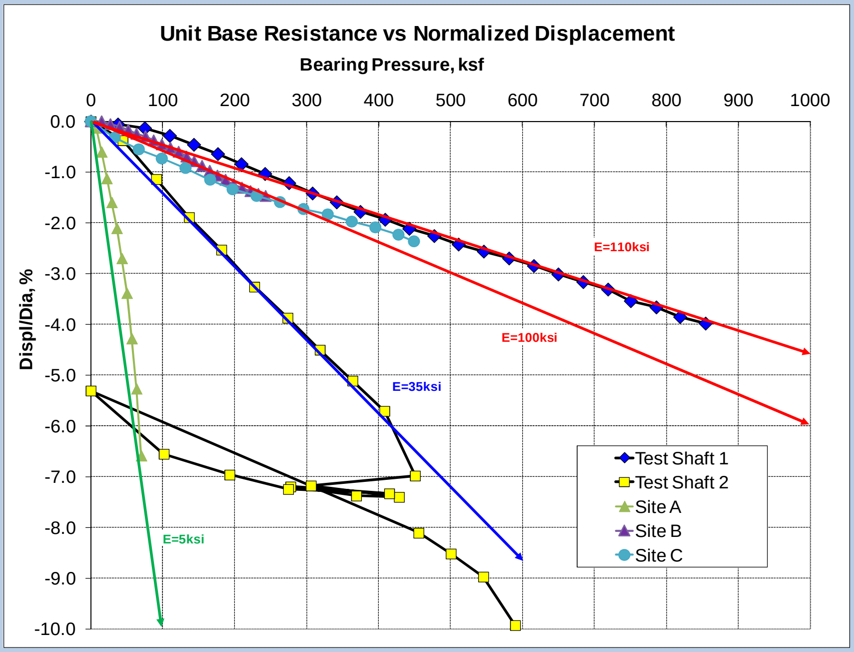



## Other ATL Tests Observations – Unit Side Resistance

- 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

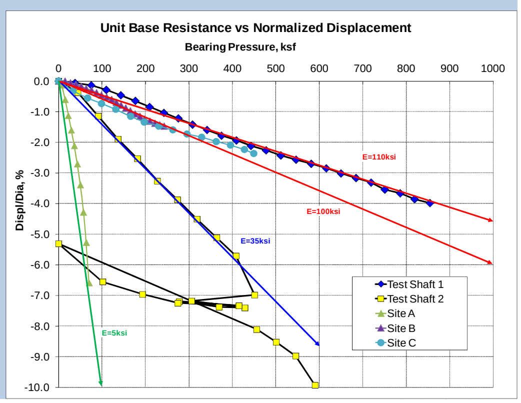


## Other Atlanta Area Tests – Unit Base Resistance




## 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.