Drilled Shaft Performance in Cemented Calcareous Formations in the Southeast US

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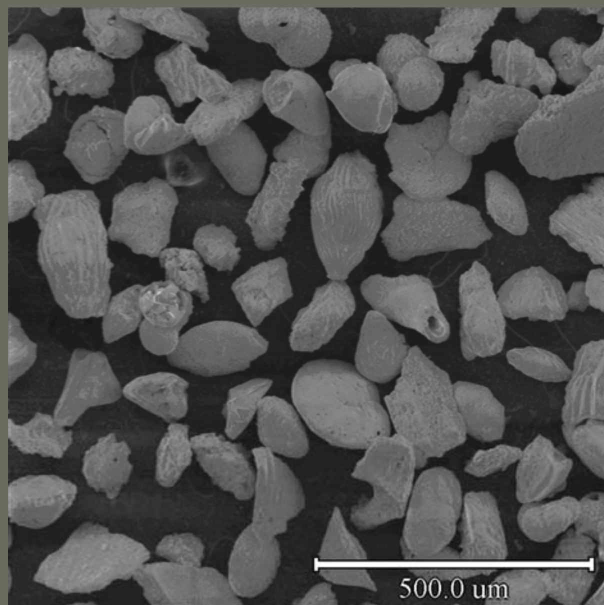
Background

This paper grew from:

- Research project funded by Alabama DOT to evaluate a specific load test for application in similar geology
- Research funded by ADSC Industry Advancement Fund
- Work on the revised FHWA Drilled Shaft Manual

Cemented Calcareous Formations?

- Called Chalk or Marl (by locality)
- Difficult Sampling
  - SPT
  - Core Barrel
  - Pitcher-barrel or Piston Sampler
- Soft Rock or Hard Clay?



Cemented Calcareous Formations?

- Typically classified as “Intermediate Geomaterials” or IGM for design
- Typically massive, ancient seabed deposits, abundant microfossils
- Sometimes sand present

Analysis

- Goal of ALDOT study:
  - WAS NOT to develop new relationships based on q_u for design
  - WAS to compare the data from the subject load tests with other data and with existing q_u relationships

Analysis

- Load test data from a group of southeastern US
- 14 sites, 26 tests: 22 O-cell, 3 conventional, 1 Statnamic
- Most used unconfined compressive strength, q_u, to characterize IGM
- Some only SPT, such as in Cooper Marl in SC

Table 1. Summary of Load Test Data (Brown and Thompson, 2008) (bpf = b/0.3m; 1 ksf = 47.88 kPa)

State	*Project*	*Test No.*	*Reference*	*Test Type*	*Material*	*Shaft Dia. (in)*	*SPT N values (bpf)*	*q_u (ksf)*	*Unit Side Shear (ksf)*	*Unit End Bearing (ksf)*
AL	US 80 over Mill Creek	AFT-106058	1	Statnamic	Demopolis/Mooreville Chalk (hard gray, clayey silt)	84	N > 100	---	5.8 – 10.7	41.6
AL	SR 10 Blue Springs	LT-8571	2	O-Cell	Claystone	54	N > 100	---	0.9 - 1.7	27.4
AL	Hyundai Motor Manufacturing	LT-8904	2	O-Cell	Demopolis Chalk	42	42 - 62	18.4	3.4 – 9.4	90.9
AL	Andalusia, AL	WRT-1-1	3	Conventional	Claystone	28	---	17 - 127	7.0 - 9.6	---
MS	US 45 over Town Creek	LT-8194	2	O-cell	Mooreville Chalk (Hard grey, clayey, silt)	48	---	22.9	5.1	36.9
MS	SR 25 over Talking Warrior Creek	LT-8373	2	O-cell	Basal Formation (Hard Clayey Silt and Silty Clay)	42	---	6.1 - 27.9	2.2 - 5.9	67.8
MS	US 82 Oktibbeha County	LT-8461-1	2	O-cell	Demopolis Formation (Hard, Argillaceous Chalk)	48	---	10.9 - 38.6	3.1 - 7.3	214.0
MS	US 82 Oktibbeha County	LT-8461-2	2	O-cell	Prairie Bluff Formation (Hard, Silty, Clay) and Ripley Formation (Hard, Sandy, Silt)	48	---	27.1 - 28.8	2.1 - 3.9	108.0
MS	SR 42 over Thompson Creek	LT-8487	2	O-cell	Very stiff to hard, clayey silt and silty sand	54	---	11.1	1.9 - 5.0	24.8
MS	I-55 at Old Agency Rd.	LT-8788	2	O-cell	Yazoo Formation (Hard, tan, silty clay)	24	---	9.0 - 11.1	0.3 - 1.5	52.3
MS	SR 9 over SR 6	LT-8912-1	2	O-cell	Clayton Formation (Hard, clayey silt and silty clay)	48	N > 100	18.0	7.7 - 8.4	202.8
MS	SR 9 over SR 6	LT-8912-2	2	O-cell	Ripley Formation (Hard, very fossiliferous, sandy silt)	48	N > 100	18.0	8.8 - 12.9	221
MS	Leake County, MS	WRT-4	3	O-cell	Chalk	66		12.1	3.2	46.2
SC	Mt. Pleasant, SC	WRT-5-1	3	Conventional	Cooper Marl	24	9 - 100+	2.9	3.6	28.6
SC	Mt. Pleasant, SC	WRT-5-2	3	Conventional	Cooper Marl	24	9 - 100+	2.9	3.6	---
SC	Cooper River Bridge Charleston/Mt. Pleasant	LT-8650	2,4	O-cell (10 tests)	Cooper Marl (Clayey sand, sandy clay, sandy silt)	72 and 96	15 - 100+	---	2.0 - 6.5	43.5 - 80
SC	Breach inlet Bridge	LT-8661	2	O-cell	Cooper Marl (Clayey sand, sandy clay, sandy silt)	48	15 - 28	4.2 - 5.9	0.2 - 2.8	49.4

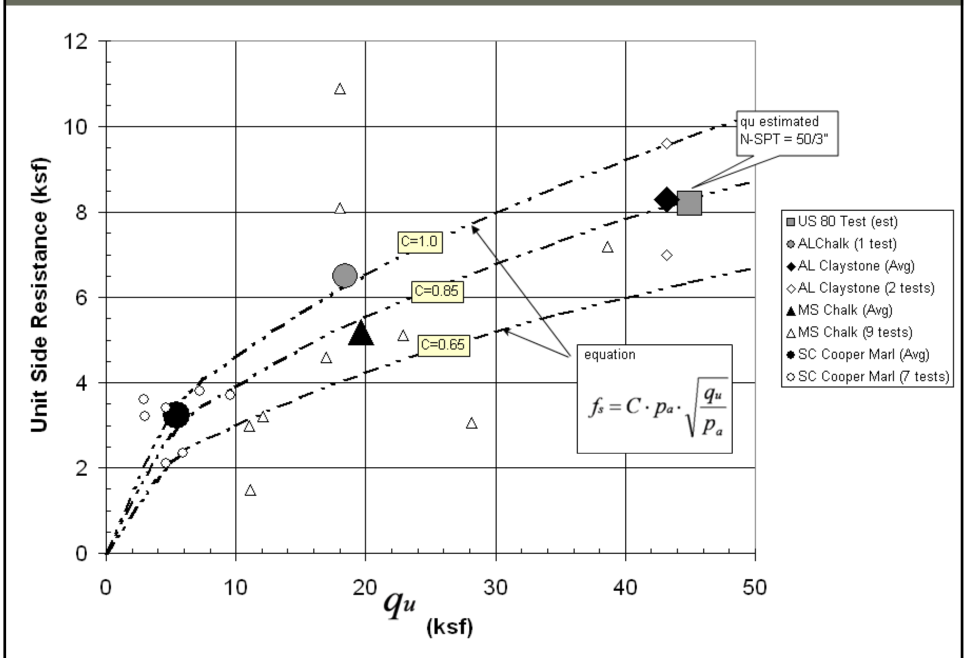
Reference:
1. AFT-XXXXXX: Statnamic test report from AFT, Inc. with permission of owning state DOT
2. LT-XXXX: O-Cell test report from Loadtest, Inc. with permission of owning state DOT;;
3. WRT-X: Test data from Thompson, W.R. III (1994) *Axial Capacity of Drilled Shafts Socketed into Soft Rock*, M.S. Thesis, Auburn University, AL
4. Values shown are the ranges from the 10 tests. Seven shafts were 96 inches in diameter, three were 72 inches. Shaft LT-8650-1 is used as representative for Figure 4a.

Analysis – Unit Side Shear

$$f_s = C \cdot p_a \cdot \sqrt{\frac{q_u}{p_a}}$$

(NCHRP Synthesis 360: Rock Socketed Shafts, Turner, 2006)

- Horvath and Kenney (1979): C = 0.65
- C = 1 (lower bound) up to C = 3 (upper bound for roughened sockets)
- Kulhaway et al (2005) evaluation suggests C = 1 represents the mean estimate of design ultimate side shear values



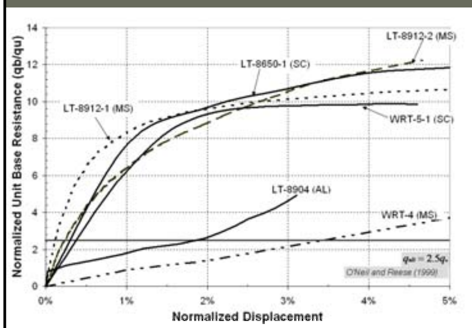
Analysis – Unit End Bearing

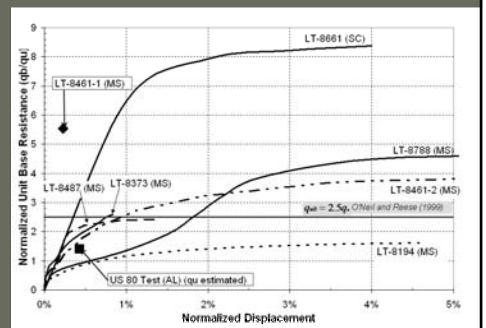
$$q_{ult} = 2.5 q_u$$

(FHWA Drilled Shaft Manual, 2006)

- Deflection to mobilize base resistance >> mobilize side resistance
- Evaluated as a function of displacement in terms of the shaft diameter

Unit Base Resistance Data





The shaft displacements are expressed as a percent of the shaft diameter.

The mobilized unit base resistance was normalized by *qu*.

Conclusions

- Utilize unconfined compressive strength
- Design for side shear using C=0.65
- Design for base resistance using $q_{ult} = 2.5q_u$
- More to come in revised Drilled Shaft Manual !!