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/W; lksf = 47.88 kPa)

<table>
<thead>
<tr>
<th>State</th>
<th>Project</th>
<th>Test No.</th>
<th>Reference</th>
<th>Test Type</th>
<th>Material</th>
<th>Shaft Dia. (in)</th>
<th>EPT 'S' value (bpf)</th>
<th>q (kips)</th>
<th>Uad Side Shear (lksf)</th>
<th>Curt End Bearing (lksf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>US 80 near Mill Creek</td>
<td>I 10508</td>
<td>1</td>
<td>Statmic</td>
<td>Danbury/Minnetonka chalk (hard gray, clayey silt)</td>
<td>84</td>
<td>N &gt; 100</td>
<td>—</td>
<td>5.8 - 10.7</td>
<td>41.6</td>
</tr>
<tr>
<td>AL</td>
<td>SR 13 Blue Springs</td>
<td>I 4571</td>
<td>2</td>
<td>O-Cell</td>
<td>Chryse</td>
<td>54</td>
<td>N &gt; 100</td>
<td>—</td>
<td>0.9 - 1.7</td>
<td>27.4</td>
</tr>
<tr>
<td>AL</td>
<td>Alabama River</td>
<td>I 4004</td>
<td>2</td>
<td>O-Cell</td>
<td>Danbury Chalk</td>
<td>42</td>
<td>42 - 42</td>
<td>18.4</td>
<td>3.4 - 9.4</td>
<td>90.0</td>
</tr>
<tr>
<td>AL</td>
<td>Andalusia, AL</td>
<td>W 51-1</td>
<td>3</td>
<td>Conventional</td>
<td>Chryse</td>
<td>28</td>
<td>37 - 127</td>
<td>17 - 30</td>
<td>7.1 - 13.6</td>
<td>—</td>
</tr>
<tr>
<td>MS</td>
<td>US 45 near Tobacco Creek</td>
<td>I 4194</td>
<td>2</td>
<td>O-Cell</td>
<td>Danbury Chalk</td>
<td>48</td>
<td></td>
<td>22.9</td>
<td>5.1</td>
<td>30.9</td>
</tr>
<tr>
<td>MS</td>
<td>NE 25 near Talking</td>
<td>I 4373</td>
<td>2</td>
<td>O-Cell</td>
<td>Denovo Formation (Hard, Clean, Silty and Silt, Clay)</td>
<td>42</td>
<td></td>
<td>6.1 - 27.9</td>
<td>2.2 - 5.9</td>
<td>67.8</td>
</tr>
<tr>
<td>MS</td>
<td>US 82 Oldfield County</td>
<td>I 4601</td>
<td>1</td>
<td>O-Cell</td>
<td>Denovo Formation (Hard, Argillaceous Chalk)</td>
<td>48</td>
<td></td>
<td>10.9 - 38.6</td>
<td>3.1 - 7.3</td>
<td>214.0</td>
</tr>
<tr>
<td>MS</td>
<td>US 82 Oldfield County</td>
<td>I 4601</td>
<td>2</td>
<td>O-Cell</td>
<td>Denovo Formation (Hard, Silty, Clay, and Silt, Clay)</td>
<td>48</td>
<td></td>
<td>27.1 - 28.8</td>
<td>2.1 - 3.9</td>
<td>108.0</td>
</tr>
<tr>
<td>MS</td>
<td>NE 42 over Thompson Creek</td>
<td>I 4487</td>
<td>2</td>
<td>O-Cell</td>
<td>Very stiff clay, very silty sand</td>
<td>54</td>
<td></td>
<td>11.1</td>
<td>1.9 - 5.0</td>
<td>24.8</td>
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<tr>
<td>MS</td>
<td>US 2 over CR 58</td>
<td>I 4798</td>
<td>2</td>
<td>O-Cell</td>
<td>Yuenso Formation (Hard, Very Silty, Silty Clay)</td>
<td>24</td>
<td></td>
<td>8.6 - 11.4</td>
<td>5.3 - 13.5</td>
<td>53.2</td>
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<tr>
<td>MS</td>
<td>NE 9 over SR 6</td>
<td>I 4932</td>
<td>2</td>
<td>O-Cell</td>
<td>Claytryn Formation (Hard, Clean, Silty and Silt, Clay)</td>
<td>48</td>
<td></td>
<td>8.0 - 8.4</td>
<td>7.7 - 7.4</td>
<td>202.8</td>
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<tr>
<td>MS</td>
<td>NE 9 over SR 6</td>
<td>I 4932</td>
<td>2</td>
<td>O-Cell</td>
<td>Riptide Formation (Silty, Very Silty, Silty Clay)</td>
<td>48</td>
<td></td>
<td>8.0 - 8.0</td>
<td>8.8 - 13.9</td>
<td>221</td>
</tr>
<tr>
<td>MS</td>
<td>Lake County, MS</td>
<td>W 5 1</td>
<td>3</td>
<td>O-Cell</td>
<td>Chalk</td>
<td>65</td>
<td></td>
<td>22.1</td>
<td>5.4</td>
<td>40.4</td>
</tr>
<tr>
<td>SC</td>
<td>Mt. Pleasant, SC</td>
<td>W 51-5</td>
<td>3</td>
<td>Conventional</td>
<td>Cooper Marl</td>
<td>24</td>
<td>9 - 100</td>
<td>2.9</td>
<td>3.6</td>
<td>28.6</td>
</tr>
<tr>
<td>SC</td>
<td>Mt. Pleasant, SC</td>
<td>W 51-5</td>
<td>3</td>
<td>Conventional</td>
<td>Cooper Marl</td>
<td>24</td>
<td>9 - 100</td>
<td>2.9</td>
<td>3.6</td>
<td>—</td>
</tr>
<tr>
<td>SC</td>
<td>Cooper River Bridge</td>
<td>N 57/50</td>
<td>2.4</td>
<td>O-Cell (10 tests)</td>
<td>(Clayey sand, sandy clay, silty clay)</td>
<td>72 and 96</td>
<td>15 - 100</td>
<td>2.9 - 7.0</td>
<td>43.5 - 90.7</td>
<td>39.3</td>
</tr>
<tr>
<td>NC</td>
<td>Morrisville Bridge</td>
<td>W 501-1</td>
<td>2</td>
<td>O-Cell (tests)</td>
<td>Cooper Marl (Clayey sand, sandy clay, silty clay)</td>
<td>48</td>
<td></td>
<td>13.2 - 25</td>
<td>4.3 - 5.9</td>
<td>49.4</td>
</tr>
</tbody>
</table>

Reference:
1. AST XXXX: Statmic test report from ALT Inc. with permission of owning state DOT.
2. ALT XXXX: O-Cell test report from Loudest Inc. with permission of owning state DOT.
3. ALT: Test data from Thompson, W.R. (1944), Axial Capacity of Drilled Shafts, Sociedad de Ingenieros, 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 E T-80001 is used as representative for Figure 4a.

Analysis – Unit Side Shear

\[ f_s = C \cdot p_u \cdot \frac{q_u}{P_a} \]

(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

\[ q_{ult} = 2.5q_u \]

(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 $q_u$.

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 !!