Identification of High Pile Rebound Soils:

The Mysterious Case of the Bouncing Piles

Phase II

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Defining the Problem

- Excessive Pile Rebound and/or Bouncing
  - High Displacement Piles
  - Typically Driven by Diesel Hammers
  - Very Dense Saturated Silty Sands to Sandy Silts

- **FDOT Section 455-5.10.3 Practical Refusal**
- Design Capacities & Depths Not Achieved
Project Overview

- Florida Pile Driving Sites experience > 0.25 inch rebound
  - Manual Data

- Engineers & Contractors need to anticipate this problem
Approach

- Soil Property Evaluations
- Cyclic Loading Evaluations
- Field Testing Evaluations
Phase I

Retested Soils at 3 sites

- I-4/SR 408 Anderson Street Overpass
- I-4/John Young Parkway
- Ramsey Branch Bridge SR 83 US 331 over Choctawhatchee Bay: District 3

SPT, CPT, PMT, DMT

Shelby Tubes
# Fines Content and N-Value Summary

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Fines Content Rebound Soil (%)</th>
<th>N Rebound Soil (blows/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson Street</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>John Young</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>Ramsey Branch</td>
<td>20</td>
<td>7</td>
</tr>
</tbody>
</table>
Interim FIT research

- FDOT SMO worked with us
- Jarushi (2012) tested additional sites
- Correlations
  - Fines content
  - SPT N-values
  - CPTu pore pressure
- Plotted data on Soil Behavior Charts
Rebound & CPT Pore Water Pressure

Soils: Typically Fine Sand with Silts or Clays

Rebound = 0.025U₂ + 0.03
Fines Content and N vs Rebound

- Second Order Polynomial
  \[ R^2 = 0.50 \]

- Linear Regression
  \[ R^2 = 0.18 \]

- Still under evaluation
- SPT will penetrate hard/dense layers
- CPT would not
- Weak correlations
Soil Behavior Type [SBT] Charts

- **Schmertmann (1978)**
  - CPT $q_c - f_s$

- **Eslami & Fellenius (2004)**
  - CPTu $q_E - f_s$

- **Robertson (1990)**
  - $Q_{tn} - R_f$ CPT chart

- **Robertson (1990)**
  - $Q_{tn} - F_r$ CPT
  - $Q_{tn} - B_q$ CPTu

- **Schneider et al. (2008)**
  - $q_{cnet}/\sigma_{vo} = [\Delta u_2/\sigma_{vo}]$ CPTu

- Cone Point = $q_c$
- Effective Cone Point = $q_E$
- Friction = $f_s$
- Friction Ratio = $R_f$
- Normalized $q_t = Q_{tn}$
- $q_t = q_c - u_2(1-a)$
  - $a$ = net pore pressure area ratio
- Normalized $f_s = F_r$
- Pore Pressure Ratio = $B_q$
- Normalized $q_{cnet} = q_t - \sigma_{vo}$
Schneider SBT

Rebound Soils

Non-rebound Soils

Net Cone Tip Resistance/Effective Stress

Change in Pore Pressure/Effective Stress

Net Cone Tip Resistance/Effective Stress

Change in Pore Pressure/Effective Stress
Interim Conclusions

- Rebound is a function of:
  - Fines Content?
  - N values?
  - CPTu pore pressure

- Schneider et al SBT charts show clear differences
Phase II Research Objective

Prove these correlations and SBT charts are reliable
Phase II Tasks

- Task 1 - Literature Search
- Task 2 - Develop Locations of New Testing Sites
- Task 3 - Test Program for New Testing Sites
- Task 4 - Field Data Reduction
- Task 5 - Laboratory Testing & Reduction of Disturbed Samples
- Task 6 - Laboratory Testing, Reduction & Analysis of Shelby Tube Samples
- Task 7 - Analyze Reduced Laboratory Data from Testing
- Task 8 - Analyze Reduced Field Data
- Task 9 - Technology Transfer for Reporting and Presentations
Literature Findings

- High Displacement Piles
- Florida -- Eastern Canada -- Washington State
- Rebound & High Toe Quake occur
- Rebound Soils Dense or Hard
### Critical Cyclic Parameters

<table>
<thead>
<tr>
<th>Reference</th>
<th>CSL</th>
<th>LFC</th>
<th>Load Duration (s)</th>
<th>Soil Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Putri at al. (2012)</td>
<td>0.3-0.38</td>
<td>N/A</td>
<td>N/A</td>
<td>Clay with sand</td>
</tr>
<tr>
<td>Awad (1975)</td>
<td>0.37-0.5</td>
<td>N/A</td>
<td>45</td>
<td>Silty clay</td>
</tr>
<tr>
<td>Moses and Rao (2003)</td>
<td>0.25-0.7</td>
<td>N/A</td>
<td>6, 12, 20</td>
<td>Marine clay</td>
</tr>
<tr>
<td>Puppala et al. (2004)</td>
<td>0.2, 0.4, 0.6</td>
<td>N/A</td>
<td>1</td>
<td>Sandy clay soils</td>
</tr>
<tr>
<td>Shahin et al. (2011)</td>
<td>0.36, 0.71</td>
<td>N/A</td>
<td>1</td>
<td>Soft Clay</td>
</tr>
<tr>
<td>Okur et al. (2008)</td>
<td>0.35</td>
<td>N/A</td>
<td>10</td>
<td>Fine grain soils</td>
</tr>
<tr>
<td>Dash and Sitharam (2009)</td>
<td>0.128-0.154</td>
<td>21%</td>
<td>1</td>
<td>Silty sand</td>
</tr>
</tbody>
</table>

- **CSL** = Critical Stress Level 0.25 to 0.60 typical
- **LFC** = Limiting Fines Content Generally not reported
- **Load Durations** slow
<table>
<thead>
<tr>
<th>Sites No.</th>
<th>Description</th>
<th>County</th>
<th>Soil Data Retrieved</th>
<th>PDA Data Retrieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anderson St. Overpass at I-4/SR-408</td>
<td>Orange</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>I-4/SR-408 Ramp B</td>
<td>Orange</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>I-4/US-192</td>
<td>Osceola</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>I-4 Osceola Parkway</td>
<td>Osceola</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>I-4/SR-423 John Young Parkway</td>
<td>Orange</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>6</td>
<td>I-4/SR-482 Sand Lake Rd.</td>
<td>Orange</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>7</td>
<td>SR-50 and SR-436</td>
<td>Orange</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>8</td>
<td>SR -417 and International Drive</td>
<td>Osceola</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>SR-528 and US 441</td>
<td>Orange</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>10</td>
<td>SR-83 Ramsey Branch</td>
<td>Walton</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>11</td>
<td>SR-528 over Indian River</td>
<td>Brevard</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>12</td>
<td>I-10 at Chaffee Road</td>
<td>Jacksonville</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>13</td>
<td>Heritage Parkway Palm Bay</td>
<td>Brevard</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>14</td>
<td>I-4 Widening Daytona</td>
<td>Volusia</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>15</td>
<td>SR-83 Ramsey Branch Revisited</td>
<td>Walton</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
I-4/US-192 ...... Osceola County

Testing Locations

- **Soil Profile**
  - Depth (ft): 0 to 180
  - **Brown Fine Sand with Silt (SP-SM)**
  - **Light Brown Fine Sand (SP)**
  - **Gray Fine Sand with Silt (SP-SM)**
  - **Brown Silty Fine Sand (SM)**
  - **Light Gray Silty Fine Sand**
  - **Tan Weathered Limestone with Trace**

- **G.S.E = 109.6**
- **G.W.T**
I-4/US-192 ... PDA Data

Pier 6 Pile 16

Pier 7 Pile 10

Pier 8 Pile 4
High Pore Pressure (over 400 psi) at rebound depth (70 ft)

CPTu Data

CPTu-4

CPTu-3

CPTu-2

Pore Pressure (psi)

Depth (ft)

Rebound
Estimated Soil Properties Based on CPTu Data

- Coefficient of Permeability (cm/sec)
- Fines Content (%)
- Depth (ft)
- CPTu 4 Pore Pressure (psi)
- Rebound

Predicted FC
Measured FC
Questions?