Benefits of Pile Setup on Deep Foundation Design

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Introduction and Objectives

- No bedrock in Louisiana, so we often utilize clayey soils to grab piles. Driven precast concrete piles support ~90% of LA DOTD bridges.
- Piles driven in clayey soils usually experience significant gain in capacity with time after installation, referred to as pile "setup".
- Current LA DOTD pile design ignores setup after 14 days.
- Incorporating setup into pile design can result in significant cost and time savings.

Objectives:
- Evaluate the increase in pile capacity due to setup for LA DOTD Piles.
- Develop empirical model(s) to estimate pile setup using typical soil properties (i.e., $S_u$, PI, $C_v$).
- Incorporate setup into LRFD design methodology of driven pile in Louisiana (calibrate setup resistance factor, $f_{setup}$).

LRFD = Load & Resistance Factored Design
Results of Bayou Laccassine Static Load Tests

Pile Casting Yard

Pressure cell
Piezometer

TP-1 and Load Frame

Instrumented Test Pile, TP-1

Axial Force (kN)
Depth (m)

Axial Force (kips)

Casing

Axial Force, Qa (kN)

Load (kips)

1st SLT (13 days)
2nd SLT (53 days)
3rd SLT (127 days)
4th SLT (148 days)
5th SLT (208 days)

Time, t (Days)

Static Load Test
Dynamic Load Test

Qa = 105.9ln (t) + 2003.5
R² = 0.86

TP-1

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Pressure cell
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Static Load Test
Dynamic Load Test

Qa = 105.9ln (t) + 2003.5
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TP-1
The models will predict future setup at a specific time, t. The amount of setup depends upon the parameter A. And A depends on typical soil properties:

- Undrained Shear Strength
- Plasticity Index
- Overconsolidated Ratio

Incorporating setup can reduce pile lengths (with same capacity). Setup may also reduce the total pile count (their time & costs).
Calibration of Setup Resistance Factors ($\phi$) for LRFD Pile Design (For Implementation)

- **Strength Limit State in LRFD Design:**
  \[ \gamma_D Q_D + \gamma_L Q_L \leq \phi_{14} R_{14} \]

<table>
<thead>
<tr>
<th>Setup Time Frame (days)</th>
<th>For $\beta_T = 2.33$</th>
<th>Recommended $\phi$</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>FOSM</td>
<td>FORM</td>
</tr>
<tr>
<td>14-30 Days</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>14-45 Days</td>
<td>0.32</td>
<td>0.33</td>
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<tr>
<td>14-60 Days</td>
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<td>0.35</td>
</tr>
<tr>
<td>14-90 Days</td>
<td>0.34</td>
<td>0.36</td>
</tr>
<tr>
<td>Ng et al. (2013)</td>
<td>0.36</td>
<td>-</td>
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<tr>
<td>Yang &amp; Liang (2006)</td>
<td>-</td>
<td>0.30</td>
</tr>
</tbody>
</table>

- **Overall:** $\phi_{\text{setup}} = 0.35$ (This means: increase of pile capacity by $\phi_{\text{setup}} \times R_{\text{setup}}$)

Measured vs Predicted Resistance-Model-1-30 day

Probability distribution for 14-30 days
Summary and Conclusions

- Significant amount of setup was exhibited, mainly the side resistance. The tip resistance was almost constant,

- The setup parameter “A” was correlated with typical soil properties ($S_u, \text{PI}, C_v, S_t$), and three empirical models were developed,

- Resistance factors ($\phi_{\text{setup}}$) were calibrated for implementing setup into LRFD design of pile foundations,

- Incorporating pile setup into deep foundation design will result in significant cost and time savings in terms of:
  - Shorter pile lengths and/or using smaller pile sizes,
  - Fewer pile quantities and hence fewer piles to drive (time wise),
  - Smaller pile driving hammer equipment.
Thank You
Question?