Evaluation of Pile Setup using Dynamic Restrike Analysis in Alabama Soils

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Elisa Prado (LRFD Design)
Marcus Shekouh (Lab Correlations)
Pile Setup (Freeze)

Time Dependent Capacity Increase from Various Studies (Titi et al., 1999)
• Utilizing setup is often not considered during design
• Most states load test or perform dynamic analysis on only a few test piles (if at all)
  – Pile load tests are used to verify bearing capacity
  – 1 to 7 days after EOD only
  – Typically no time to wait for long-term testing

_Time is money! Start building!_
Significance of Pile Setup in Design

• Increased pile capacity can reduce:
  – The size of pile
  – The embedment depth of pile
  – The size of the driving equipment
  – The time of project construction

= \downarrow \$
I-15 Reconstruction Project, Salt Lake City 1997 – 2001
I-15 Reconstruction Project, Salt Lake City 1997 – 2001

• Preparation for Salt Lake 2002 Olympic Games
  – 17 miles of interstate with transit system
  – 140 bridges with 18,000 driven steel pipe piles
  – 9 indicator piles were installed in the beginning stages of construction
  – Restrikes were conducted out to 93 days after EOD
  – Results of long-term setup was used to correlate with short-term restrikes or production piles as a form of QC/QA for the project.
RECONNECTED

Hurricane Katrina knocked parts of the bridge carrying U.S. Route 90 over Biloxi Bay, in Mississippi right off their piers and into the rapidly moving water below. When the storm retreated, engineers were left to design and construct a replacement crossing that had to have one lane in each direction operational in just 18 months and three lanes in each direction operational in less than two years. The design/build project delivery method made it possible.

By Patrick Cassity, P.E.

The alignment of the 72-span bridge was curved at both ends to avoid the shoals of the original crossing, some parts of which will remain in the bay for use as reefs. The loss of the bridge created a significant hardship for the surrounding communities, adding roughly 30 minutes to what had been a 2-minute trip.
U.S. 90 - Biloxi Bay Bridge

- 22 indicator piles installed and tested during the geotechnical investigation program
  - Installed using PDA
  - 5 types of load tests (axial and lateral tests)
  - Restrikes at 1 day, then up to 85 days after EOD
  - Results showed setup in clays 3x, sands 1.5x from day 1 capacity
- Test results provided driving criteria and assurance of axial resistances based upon setup
- 18 month project completed 2 weeks early
- How much $$ saved???
“The writer (Dr. Osterberg) is disappointed that in many cases the design engineer was only interested in proving that the ultimate capacity exceeded the design load by a required factor of safety and was not interested in using the test results to design a more economical pile.”

- 1999, 10 years after inventing the O-cell for load testing piles
Let’s Predict Setup to use in Design

- **Goal:** Develop a mechanistic method to predict long-term axial resistance of piles.
  1. Acquire data from load tested piles over time
  2. Acquire soil from borings to test in the lab
     - Long-term frictional behavior
     - Stress history
  3. Use a deterministic prediction model to calculate long-term bearing capacity for the site
  4. Calculate resistance factors based on load tests and predictions at some time (7, 14, 30, 90 days?)
AL DoT Project Objectives

• Develop a statewide database for Pile data
• Analyze and Evaluate pile setup in Alabama
• Develop resistance factors for design of piles in setup prone soils
• Provide recommendations to utilize setup in design of future pile projects throughout the state
  – Provide information regarding LRFD resistance factors
  – Implement preliminary soil testing regime for design
Test Data Analysis

• Collected all pile load tests from 2009 – present
  – PDA Data (27)
  – Static Load Tests (7) – Tested to 3x Design, not failure

• Analyze PDA data
  – Determine if the test data has appropriate waves
  – Determine valid parameters for iCAP software
  – Determine the best wave for each dataset
  – Organize information and input into GIS
What is iCAP Software?

- Produced by Pile Dynamics, Inc.
- Automatic Signal Matching software
- Quicker than CAPWAP, with good correlation to SLT
- Alabama DOT is using SLT, PDA, and iCAP
- Time and budget constraints
- Correlation opportunity (to be continued...)

![Graph showing Total Resistance (kips) for Pile IDs 26, 27, and 28.]

- Pile ID 26: ε = 4.7%
- Pile ID 27: ε = 5.7%
- Pile ID 28: ε = 9.9%
Pile Driving Test Data GIS Map

- 19 Clayey Sand
  - All produced setup effects

- 8 Silt or silty sand
  - 7 slightly relaxed
Pile Setup in AL

Graph showing the relationship between time after EOID (Days) and the ratio $Q/Q_o$. The graph plots data points for PSC and Steel HP piles.
### Pile Relaxation

<table>
<thead>
<tr>
<th>ALDOT Test Pile</th>
<th>Pile Type</th>
<th>Pile Penetration (m)</th>
<th>Blow Type</th>
<th>iCAP Total Resistance (kN)</th>
<th>Elapsed Time from EOID (days)</th>
<th>Time Effect ($R_t/R_o$)</th>
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<tr>
<td>SS1</td>
<td>HP 10x42</td>
<td>14.3</td>
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<td>667</td>
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<td>EOID</td>
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<td></td>
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<td>674</td>
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Setup Results – Mobile River Site

HP 12 x 53

<table>
<thead>
<tr>
<th>Time after EOD (days)</th>
<th>Resistance (kips)</th>
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<tr>
<td>1.6</td>
<td>152.6</td>
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<td>6.7</td>
<td>29.6</td>
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<td>29.6</td>
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45% increase

HP 14 x 117

<table>
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<th>Time after EOD (days)</th>
<th>Resistance (kips)</th>
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<td>0.1</td>
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<tr>
<td>1.6</td>
<td>29.6</td>
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280% increase

PSC 24" x 24"

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<td>2.8</td>
<td>30.8</td>
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<tr>
<td>6.8</td>
<td>6.7</td>
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68% increase

PSC 36" x 36"

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<td>155.1</td>
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<tr>
<td>3.0</td>
<td>31.9</td>
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<td>7.0</td>
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38% increase
LRFD Resistance Factor

- Developing Bias factor using various design methods
  - AL DoT Method (WBUZPILE)
  - DRIVEN
- Very small dataset
  - Ideally need 50
  - Looking at side resistance layers for each pile?
    - Setup is typically along shaft
- Either validate current method or recommend adjustments based on resistance calibration
Soil Setup Laboratory Testing

- Require soil samples
  - Undisturbed or bulk samples from pile tested sites
  - Same depth and location of clay and silty sand sites of test piles
- Interface shear testing to investigate correlation between lab and field
  - Previous history with testing in LA
- Requires additional laboratory equipment
• Questions
• Comments
• Suggestions

Thank you
Alabama
Department of Transportation

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