DRIVEN CONCRETE PILE FOUNDATION MONITORING WITH EMBEDDED DATA COLLECTOR SYSTEM

RODRIGO HERRERA, P.E.
LAWRENCE E. JONES, P.E.
PETER LAI, P.E.

INTERNATIONAL FOUNDATION CONGRESS & EQUIPMENT EXPO
MARCH 15-19, 2009
ORLANDO, FLORIDA
Introduction

- Majority of Florida bridges are supported on deep foundations;
- Most common deep foundation: Precast Prestressed Concrete piles
- All test piles are monitored with the PDA
CURRENT FDOT PRACTICE

- Test Pile Program
  - Pre-field WEAP
  - PDA
  - CAPWAP
  - Final WEAP
- Install Production Piles
Alternate method was investigated through FDOT sponsored research

University of Florida’s Final report issued on August 2002

- Theory
- First generation hardware and software
- Construction Project BB349

Smart Structures, Inc. holds the license to develop the UF/FDOT patented technology.
WHAT IS EMBEDDED DATA COLLECTOR?

- **FDOT Design Standard Index 20602**
- Instruments cast into solid concrete piles;
- Two instrumentation levels, pile head and tip
WHAT IS EMBEDDED DATA COLLECTOR?

- Wireless data transfer
- Antenna connects to laptop PC
- Monitoring concrete piles during driving;
- Estimates soil damping for every blow during driving;
- Real-time estimates of static resistances, i.e., side, tip and total.
CALCULATION METHODS

• Fixed Case Method
  • constant damping (input by operator)

• Dynamic Case Method
  • dynamic damping (calculated for every hammer blow)

• Paikowsky Method
  • energy-displacement approach

• UF Method
  • dynamic damping (calculated for every hammer blow)
PURPOSE OF EVALUATION

- To compare the EDC to the results from the “gold standard” PDA & CAPWAP;
- To generate a database of projects using EDC for resistance factor calibration
EDC EVALUATION

Phase 1: Compare EDC to PDA and CAPWAP

- EDC data is collected and reported by different engineers than those collecting the PDA data.

- Neither engineer gets to see the other’s data until test pile program is complete and both reports turned in.

- All project related decisions made based on PDA data and analyses.
EDC EVALUATION

CR 392 Cypress Creek Pier 4 Pile 4

MAXIMUM COMPRESSION STRESS

EDC/PDA

Avg = 0.98
StdDev = 0.02
COV = 0.02

Stress (kN)

EDC PDA

Blow Number
CR 392 Cypress Creek Pier 4 Pile 4
MAXIMUM COMPRRESSIVE STRESS AT PILE TIP

EDC/PDA (CSB)
Avg = 0.87
Stdev = 0.16
COV = 0.18

Stress (ksi)

Blow Number

EDC  PDA
EDC EVALUATION

CR 392 Cypress Creek Pier 4 Pile 4

ENERGY

EDC/PDA
(EMX)
Avg = 0.93
Stddev = 0.04
COV = 0.05

Energy (kip-ft)

Blow Number

EDC  PDA
EDC EVALUATION

CR 392 Cypress Creek Pier 4 Pile 4

PILE INTEGRITY

EDC/PDA (BTA)
Avg = 0.98
Stddev = 0.01
COV = 0.01
## DATABASE

<table>
<thead>
<tr>
<th>Database Files</th>
<th>Paper</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge Sites</td>
<td>42</td>
<td>46</td>
</tr>
<tr>
<td>PDA (.WO1)</td>
<td>122</td>
<td>150</td>
</tr>
<tr>
<td>EDC (.ssn)</td>
<td>122</td>
<td>150</td>
</tr>
<tr>
<td>CAPWAP</td>
<td>60</td>
<td>74</td>
</tr>
</tbody>
</table>
EDC EVALUATION

- PDA estimate > 50 tons
- Data within three standard deviations from the mean used in the development of statistical parameters
Population “n” = 116,048 blows from 68 piles
Population “n” = 135,569 blows from 76 piles

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fixed Method/PDA</th>
<th>UF Method/PDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of n</td>
<td>98.7</td>
<td>97.4</td>
</tr>
<tr>
<td>Mean</td>
<td>0.97</td>
<td>1.08</td>
</tr>
<tr>
<td>Median</td>
<td>0.96</td>
<td>1.06</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.14</td>
<td>0.17</td>
</tr>
<tr>
<td>Coefficient of Variation</td>
<td>0.14</td>
<td>0.15</td>
</tr>
</tbody>
</table>
Population “n” = 78,826 blows from 49 piles

<table>
<thead>
<tr>
<th>STRESS, ENERGY, INTEGRITY AND BLOW COUNT</th>
<th>EDC/PDA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CSX</td>
</tr>
<tr>
<td>Mean</td>
<td>0.92</td>
</tr>
<tr>
<td>Median</td>
<td>0.92</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>0.09</td>
</tr>
<tr>
<td>Coefficient of Variation</td>
<td>0.10</td>
</tr>
</tbody>
</table>
EDC EVALUATION

TOTAL STATIC CAPACITY

\[ y = 1.0034x \]
\[ R^2 = 0.9485 \]

- Paper
- New Points

Linear (All)
EDC EVALUATION

**SKIN FRICTION STATIC CAPACITY**

\[ y = 0.6451x \]
\[ R^2 = 0.9295 \]

**END BEARING STATIC CAPACITY**

\[ y = 1.0979x \]
\[ R^2 = 0.8723 \]
Summary

- Comparisons of total static capacity indicate that both UF and Fixed methods compare well with PDA with averages within 8 percent and coefficients of variation under 0.20.
- The discrepancies noted in predicted stress levels, particularly in maximum tension stress (TSX) and compressive stress at the bottom of the pile (CSB), are being investigated.
- Comparisons made with CAPWAP predictions of total static capacity produced mean values within 10 percent with COV under 0.25 for both methods.
Questions??

- Larry.Jones@DOT.STATE.FL.US

- Presentation available March 23 - April 30
  - http://www.dot.state.fl.us/geotechnical/

- In Memory of Millard Fuller 1935-2009:
  Oyée