Geotechnical Consultant Workshop
PILE LOAD TEST CASE HISTORIES

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Office of Structural Engineering

Geotechnical Consultant Workshop
May 8, 2012
Projects

CUY-90 WB
High strain dynamic test of H-piles
Define refusal on bedrock

FRA-71/670
Static load test of an H-pile
Determine pile set-up
I-90 Project

Walsh Construction
HNTB
Shannon & Wilson
Main Viaduct

- Bridge Length: 4347 ft
- Piers 2 through 11: 3092 ft
- Span Lengths: 303 to 380 ft
- Deck Heights: 100 to 142 ft
Soil Profile

Alluvial Deposits
Very-Loose to Medium-Dense Sands & Silts
Very-Soft to Medium-Stiff Silty Clay & Clay

Lacustrine Deposits
Medium-Stiff to Very-Stiff Silty Clays

Glacial Till
Dense to Very-Dense Sandy Silt
Very-Stiff to Hard Clayey Silt

Ohio Devonian Shale Bedrock

20-55’
Thick

55-100’
Thick

25-65’
Thick

160-185’
Deep
Pile Types Investigated

• Friction Pipe Piles
  – Closed Ended 16 to 24-in
  – Open Ended 30 to 72-in

• End Bearing Piles
  – Standard Sizes HP 14x89, HP 14x117
  – Jumbo Sizes HP 16x141, HP 18x204

• Economy & Schedule Considerations

• Selected Pile: HP 18x204, 60 ksi Steel, Refusal on Bedrock
## Pile Properties

<table>
<thead>
<tr>
<th>Pile Style</th>
<th>Area (in²)</th>
<th>$I_{xx}$ (in⁴)</th>
<th>$I_{yy}$ (in⁴)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP10x42, t = 0.42”</td>
<td>12.4</td>
<td>210</td>
<td>71.1</td>
</tr>
<tr>
<td>HP14x117, t = 0.81”</td>
<td>34.4</td>
<td>1220</td>
<td>443</td>
</tr>
<tr>
<td>HP18x204, t = 1.13”</td>
<td>60.0</td>
<td>3450</td>
<td>1119</td>
</tr>
</tbody>
</table>

Increase over HP14x117:
- Area: 1.74X
- $I_{xx}$: 2.83X
- $I_{yy}$: 2.53X
Pile Footing Layouts

Footing Sizes - 30 x 38’ to 41 x 44’

Pier 7 – 24 piles/ftg

Pier 9 – 14 piles/ftg
Pile Foundations

- Piles per Column Footing: 12 to 24
- Factored Axial Loads: 1183 to 1917 kilonewtons
- Pile Lengths: 150 to 215 feet
- Total No. of Viaduct Piles: 284
- Equivalent number of HP14x117 with 50 ksi steel: 25 to 32
Pile Driving

- Initial driving with vibratory hammer to its refusal
- Final driving with open ended diesel hammer: D80-23
  - Rated at 198 kip-ft
  - 18.0 kip ram weight
  - Max. stroke 13 ft
Defining Refusal

[606.1-1] PILES TO BEDROCK: Drive piles to refusal on bedrock. The Department will consider refusal to be obtained by penetrating weak bedrock for several inches to a minimum resistance of 20 blows per inch or by contacting strong bedrock and the pile receiving at least 20 blows. Select the hammer size to achieve the required depth to bedrock and refusal. Instead of driving to refusal, the Contractor may perform dynamic load testing according to C&MS 523 to establish a driving criteria for each pile type and capacity. Establish the driving criteria to achieve an Ultimate Bearing Value (UBV) that is 1.5 times the total factored load given below for the piles. Payment for dynamic load testing performed at the Contractor’s option is included in the unit price pay item for piles driven.
Refusal Plan Note

• Refusal Considerations
  – 20 Blows / inch
  – Drive Logs
  – Depth to Bedrock
  – PDA/CAPWAP Analyses

• Required Pile Capacity Not Achieved
  – High Strain Dynamic Testing
  – Mobilize & Redrive with Larger Hammer
High Strain Dynamic Testing

• Max. UBV = 2876\(^K\)

• GRL APPLE IV
  – 80-kip ram
  – 9-ft max. drop

• Test device, not a pile driving hammer
Pier 9 – Initial Testing

- Factored Axial Load = 1747 kips
- UBV = 2620 kips
- Top of Rock @ 143.7’
- Top of Coring @ 150.0’
## Pier 9 LT Results

<table>
<thead>
<tr>
<th>Pile No.</th>
<th>Test Type</th>
<th>Tip Depth</th>
<th>Drop Ht / Stroke</th>
<th>Set / Blow Count</th>
<th>Trans’d Energy</th>
<th>Case Mobil’d Capacity</th>
<th>CAPWAP Mobilized Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>164</td>
<td>ID</td>
<td>144.0</td>
<td>9.9</td>
<td>43/12”</td>
<td>-</td>
<td>-</td>
<td>1249</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>781</td>
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<td></td>
<td></td>
<td>468</td>
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<tr>
<td>164</td>
<td>EOID</td>
<td>146.6</td>
<td>11.5</td>
<td>25/1”</td>
<td>68%</td>
<td>1918</td>
<td>1911</td>
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<td></td>
<td>451</td>
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<tr>
<td>166</td>
<td>APPLE</td>
<td>153.8</td>
<td>6.0</td>
<td>0.25”</td>
<td>98%</td>
<td>2998</td>
<td>2899</td>
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<td></td>
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<td></td>
<td>770</td>
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</tbody>
</table>

**Note:** Required UBV = 2160 kips  
1.5 * UBV = 2620 kips
# Pier 9 RT Results

<table>
<thead>
<tr>
<th>Pile No.</th>
<th>Test Type</th>
<th>Tip Depth</th>
<th>Drop Ht / Stroke</th>
<th>Set / Blow Count</th>
<th>Trans’d Energy</th>
<th>Case Mobil’d Capacity</th>
<th>CAPWAP Mobilized Capacity</th>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>178</td>
<td>ID</td>
<td>153.0</td>
<td>12.3</td>
<td>8/1”</td>
<td>-</td>
<td>-</td>
<td>1770</td>
</tr>
<tr>
<td>178</td>
<td>EOID</td>
<td>154.0</td>
<td>12.3</td>
<td>20+/1”</td>
<td>70%</td>
<td>2071</td>
<td>2050 1536 514</td>
</tr>
<tr>
<td>176</td>
<td>EOID</td>
<td>154.7</td>
<td>12.2</td>
<td>23/1”</td>
<td>63%</td>
<td>1927</td>
<td>1907 1127 780</td>
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<tr>
<td>176</td>
<td>APPLE</td>
<td>154.7</td>
<td>6.0</td>
<td>0.25”</td>
<td>97.4%</td>
<td>2757</td>
<td>2850 1749 1101</td>
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</tbody>
</table>

Note: Required UBV = 2160 kips  
1.5 * UBV = 2620 kips
D80-23 Driving Criteria

- Greater Than 40 Blows per 2 inches
- Minimum Average Stroke of 11.5 feet
I-71/670 Interchange Design Build Project
Columbus, Ohio

Kokosing Construction Co.

CH2M HILL

E.L. Robinson Engineering of Ohio
Soil Profile

- Shallow, Dense to Very Dense, Sands & Gravels, N<sub>60</sub> > 50 bpf

Bottom of Footing @ 787.0
Pile Foundations

- HP 14x73 at Piers
- UBV = 440 kips
- Short Lengths, 25 to 35 ft
- Uplift = 32 to 47 kips
  - Minimum Tip Elevations
Pile Driving Problems

• Piles Running – Driven 45 to 60 ft Without Achieving UBV & Required Splicing

• Contractor Proposed Static Load Test (SLT)
  – Determine Pile Set-up
  – Increase $\phi_{\text{DYN}}$ to 0.80 (AASHTO) from 0.70 (BDM)
    ▪ Applied Only to B-11 & B-12 Pier Piles
    ▪ Dynamic Load Tests Before & After SLT to Recalibrate Driving Criteria (EOID & BOR)

• Revised UBV to 385 kips = \( \frac{440 \times 0.70}{0.80} \)
Test Location – B-11, Pier 3

- Soils at Both Bridge Sites Are Geologically Similar
- Pier 3 Selected as Being Most Representative

HP14x73 Piles
Soil Profile

Bottom of Footing

Desired Tip Elevation

Test Pile Tip
Pier 3 Footing

- Test Pile #92
- Driven on 1/25/12
- Pileco D19-42
  - 4.2^K Ram, 150” Stroke
- Est. Pile Length= 35 ft
- Driven Length= 44.3 ft
- Blow Count= 45/12”

- PDA/CAPWAP Analyses
  - EOID Capacity= 355^K
  - BOR Capacity= 560^K
Static Load Test Frame
SLT Results

• Quick Test Method, 5% load steps at 5-minute intervals 30-minute final hold (ASTM D1143, Procedure A)

• Davisson Failure Criteria to Define Ultimate Failure Load

• Test on February 1, 2012
  – Max. Load = 770 kips
  – Max. Settlement = 0.64”

• Post SLT BOR = 560 kips
Testing Interpretation

• Failure Did Not Occur, Davisson criteria not met

• Ultimate Failure Load estimated $\approx 780$ kips

• Test Pile Length Longer Than Desired Length
PDA/CAPWAP Results

- CAPWAP Analyses of PDA Data at Select Driving Depths & at BOR
- Average Unit Side Resistance Versus Depth for Driving & BOR
- Curves Used to Adjust Soil Properties In Static Analysis (DRIVEN)
Static Analysis Recalibration

- Avg. Side Resistance During Driving Curve & PDA Total Capacity Used to Obtain End Bearing Resistance
- BOR Side Resistance & End Resistance are Used to Adjust Internal Friction Angles in DRIVEN to Obtain a Total Capacity of 780 kips
Driving Criteria

1. Minimum Length For Uplift where the Total Capacity from the Static Analysis = 385 kips

2. Minimum Blow Count > 25 / Foot with Minimum 8.0-foot Stroke

3. Two Pile Restrikes Tests at Each Pier with BOR Resistances > 308 kips
   - Calibration of BOR to SLT (780/560):
     1.25 * 308 kips = 385 kips

4. Static Analysis Recalibrated for Each Pier
• Office of Construction
• District 6 & 12
• Field Construction Personnel