Non-Destructive Testing of Drilled Shafts

Current Practices and New Methods

Brent Robinson, Pile Dynamics, Inc.
Why Test Integrity?
Survey of State DOT Practice:
Use of NDE for Drilled Shafts

- 94% use CSL
- 3% use G-G
- 3% use PIT

Ref: Khamis Haramy, FHWA Denver 2008
Anomaly Location (anomaly is not always a defect)

**Percentage of Shafts with Anomalies**

<table>
<thead>
<tr>
<th>Bottom 1/3</th>
<th>Mid 1/3</th>
<th>Top 1/3</th>
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<tbody>
<tr>
<td>45%</td>
<td>11%</td>
<td>44%</td>
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<table>
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<tr>
<th>Bottom 2 Diam.</th>
<th>Middle</th>
<th>Top 2 Diam.</th>
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<td>46%</td>
<td>13%</td>
<td>41%</td>
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Billy Camp, S&ME Inc. Southeast USA


Jones & Wu, Geotechnology, Inc. Missouri and Kansas

CSL
Cross-hole Sonic Logging

Top view of pile with 4 access tubes –
test all paths

Stress Waves, emitted in one tube are received in another one if concrete quality is satisfactory

Fill Tubes with water

Pull Probes From Bottom To Top

Transmit Receive
Cross-hole Sonic Logging

**Advantages**

- Checks concrete quality inside cage
  - by depth and by quadrant
- Tomography available for complicated cases

**Limitations / Disadvantages**

- Needs access tubes (steel tubes preferred)
- Wait min 3 days prior to test (7 days preferred)
- Cannot evaluate concrete cover
Indiana Drilled Shaft—Soft Toe

- Length: 92 feet
- Geometry:
  - 7 ft diameter, upper 16 ft, temporary casing
  - 6 ft diameter, 16 to 92 ft (top of rock), temporary casing
  - 5.5 ft diameter, 72 to 92 ft (20 ft rock socket)
- CSL Results:
  - Arrival delays of 50 to 100% on all profiles
    - Over bottom 1-2 ft of shaft
Core Results

- “Tools dropped from 88 to 91 ft”
- Recovered 7” concrete, 38.75” void, 21.25” sandstone
Indiana Drilled Shaft—Top

- Same project, different shaft
- Similar geometry, slightly longer
- Anomaly identified near the top
  - CSL identified 20-100% reductions within 2-5 ft of top
Core results

- Core samples compression tested
  - Compressive strength
    - 6000 to 7000 psi
- Cage was wet slabbed
  - Concrete poured
  - Cage installed
Low Strain Integrity Testing:
- Looks for major defects

Small hammer impact device

Accelerometer measures response

(defect)
Advantages

• Cost Effective
• Apply to any or even all concrete pile/shaft minimal pile preparation
• Finds MAJOR defects
• Sometimes test piles in structure

Limitations / Disadvantages

• Best use: CFA/ACIP or drilled shafts
  • Solid section of concrete needed
• Limited to 30 to 50 L/D
• Difficult interpretation for highly non-uniform
• Cannot locate defect quadrant
Indiana Shafts—PIT results
Gamma-Gamma Logging

**Advantages**

- Gives data on concrete cover perhaps to 3 inch range rad.energy halved every 2”
- Compliments CSL testing

**Disadvantages**

- Needs many PVC access tubes (3 inch range) (steel access tubes generally preferred for CSL)
- Uses radioactive materials (Cesium 137) Probe must be retrieved (note: long probe vs. bent PVC tubes)
Thermal Integrity Profiling

- Temperature from concrete curing is directly related to concrete quality

- Heat from concrete curing evaluates concrete both inside and outside cage (100% testing – entire section)

- Obtain temperature vs. depth vs. quadrant
  - Infra-red probe via CSL tubes
  - Thermal wires on cage cast in shaft
Shaft Heat Signature

Temperature ↑
Data Interpretation
Cage alignment

Degrees F

Depth (ft.)

A1
A2
AVG
Data Interpretation
Local Defect near C2

Degrees F

Depth (ft.)

C1
C2
Average
Thermal Testing Timeframe
4000-P Mix Design

Optimal Testing Window
Acceptable Testing Window
Test Procedure using probes

- Transfer water from first tube into container
- Warm temperature probe

- Lower probe into tube – data collected from top to bottom – 1’/sec. rate

- Remove probe
- Transfer water from second tube into first
- Repeat scan in second tube

- Continue for all remaining tubes
Thermal Integrity Profiler (TIP) - probe testing
Thermal Wire Data Collection

Future: Wireless transmission from TAP to computer, and offsite
Thermal wires eliminate need for access tubes
Interpretation: Direct Observation (Field)

- Verify shaft length - Identify top and bottom
- Confirm cage alignment
- Locate changes in shaft diameter
- **Locate immediate areas of concern**
Field Observations: Scatter Creek, Florida

- No cage eccentricity (all tubes ~same temp)
- Clean top and toe signature (approximate 1 diameter temperature roll-off top and bottom)
- Good Shaft
Interpretation: Added Field Records

- Confirm direct observations and preliminary information
- Find relationship between concrete volume and measured temperature
- Predict as-built shaft radius, shape, and cover
- Correlate soil strata to thermal conductivity and observe influence on less prominent temperature fluctuations
Average temp. is determined for a given truck yield (diam.)

Shape of avg. profile mimics diameter from concrete yield
How to determine cover?

- **Correlate** temp. with concrete volume
- **Measure** the temperature “gradient”
  - **Thermal Wire option**
    - Short parallel separate wire of known offset
    - Attach to cross brace
    - Simplifies the interpretation
- **Model** the mix to get the “gradient”
Shaft Details

- Halstead Medows Bridge
- Tubes (3) and T-wires (4 +2 Grad)
- 38 inch diameter casing (0-20’)
- 36 inch diameter (20-49’)
- 30 inch rebar diameter
- 49 ft long
- ~18% more concrete required
- CSL and Thermal Testing
- Poured 9/19/2011
Abutment 2

Pier 2

- SW-SM
- SM
- SM
Basic Temperature Display
Abutment 2 Pile C
Corrected Shaft Radius Display
Abutment 2 Pile C
Abutment 2 Pile C
GRL Engineers, Inc.
HALSTEAD MEDOWS BRIDGE

Pile Dynamics, Inc.
Cross-Hole Analyzer
Abutment 2

Pier 2
Corrected Shaft Radius Display
Pier 2 Pile C
3D Representation
Pier 2 Pile C
Abutment 2 and Pier 2
Summary

- Significant improvements in NDT technology over the last 20 years.
- CSL, PIT and Gamma continue to provide useful information.
- Thermal Integrity Profiling promising for determining:
  - Integrity of 100% of shaft
  - Cage location and alignment
  - Concrete cover
  - Overall profile of the shaft
Drilled shaft application – IN DOT