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

33%

Bottom 2 Diam. 41%
Middle 13%
Top 2 Diam. 46%

38%

Bottom 1/3 45%
Mid 1/3 11%
Top 1/3 44%

Billy Camp, S&ME Inc.
Southeast USA

“Crosshole Sonic Logging of South Carolina Drilled Shafts: A Five Year Summary”
Proceedings of GeoDenver, ASCE, Feb 2007

Jones & Wu, Geotechnology, Inc.
Missouri and Kansas

“Experiences with Cross-hole Sonic Logging and Concrete Coring for Verification of Drilled Shaft Integrity”,
ADSC GEO³ Construction Quality Assurance/Quality Control Technical Conference, Dallas Nov 2005
Cross-hole Sonic Logging (CSL) uses stress waves, emitted in one tube, to be received in another if concrete quality is satisfactory. To conduct the test:

1. Fill Tubes with water.
2. Transmit from the bottom to the top.
3. Pull Probes From Bottom To Top.
4. Test all paths.

The top view of the pile shows 4 access tubes, indicating the paths to be tested.

Stress Waves, emitted in one tube, are received in another if concrete quality is satisfactory.
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)
Low Strain Integrity Testing

**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
Data Interpretation
Cage alignment

Degrees F

Depth (ft.)

A1
A2
AVG

Data Interpretation
Cage Alignment
Data Interpretation
Local Defect near C2

Degrees F

0 5 10 15 20 25 30 35 40 45 50

90 110 130 150

Depth (ft.)

C1
C2
Average

Data Interpretation
Local Defect

C2
C1
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
No Correction for Over-pour Concrete

- Average
- Grnd Surf
- TOS
- WT
- BOC
- TOLime
- TOR
- BOS
- Effective Diam.
- Theoretical Diam.

The shape of the average profile mimics the diameter from concrete yield.

- Average temp. is determined for a given truck yield (diam.).
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
Basic Temperature Display
Abutment 2 Pile C

![Graph showing temperature vs depth with various curves for different depths and temperatures.]

- Depth (ft)
- Temperature (F)

Curves for different depths:
- 000
- 001
- 003
- 004
- Average

Graph indicates temperature trends with depth for Abutment 2 Pile C.
3D Representation
Abutment 2 Pile C
GRL Engineers, Inc.
HALSTEAD MEDOWS BRIDGE

A2C-2
L=54.00 feet
Spacing=24.0 in
Gain=625 (x10)
09/20/2011 10:46

A2C-2
L=54.00 feet
Spacing=25.0 in
Gain=625 (x10)
09/20/2011 10:49

A2C-2
L=54.00 feet
Spacing=26.0 in
Gain=625 (x10)
09/20/2011 10:51

A2C-3
L=54.00 feet
Spacing=24.0 in
Gain=625 (x10)
09/20/2011 10:46

A2C-3
L=54.00 feet
Spacing=25.0 in
Gain=625 (x10)
09/20/2011 10:49

A2C-3
L=54.00 feet
Spacing=26.0 in
Gain=625 (x10)
09/20/2011 10:51

Pile Dynamics, Inc.
Cross-Hole Analyzer

Energy (log)
2 / 5

Pile Dynamics, Inc.
Cross-Hole Analyzer

Energy (log)
2 / 5
Abutment 2

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

- Significant improvements in NDT technology over the last 20 years.
- CSL, PIT and Gamma 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