New Drilled Shaft Inspection and Testing Technologies

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Why should we test?
Major defects can lead to foundation failures
Outline

• What Nondestructive Tests (NDT) are available?
  – Crosshole Sonic Logging (CSL)
  – Pile Integrity Testing (PIT)

• Thermal Integrity Profiling

• Shaft Quantitative Inspection

• Case Histories
Typical Drilled Shaft QA / QC

Dry Cast
  • Frequently visual inspection only

Wet Cast
  • Visual inspection is impossible, some NDT is needed.

1. PIT (pulse echo)
2. Crosshole Sonic Logging (CSL)
3. Gamma Gamma Logging
4. Thermal Integrity Profiling (TIP)
Cross Hole Sonic Logging (CSL)
Cross Hole Sonic Logging

D6760-02 - Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing

Sonic Waves, emitted in one tube are received in another one if concrete quality is satisfactory.
Cross Hole Sonic Logging

Advantages

• Evaluates concrete quality inside cage
• Provide results by depth and by quadrant
• Tomography available for complex cases

Limitations

• Wait a minimum of 3-4 days prior to testing
• Requires access tubes
  – Post grouting
• Cannot evaluate concrete cover
• Debonding and bleed water may lead to unnecessary coring
Energy is the integration of signal amplitude.

“Energy” is integration of signal amplitude.
Low Strain Integrity Testing
Low Strain Integrity Testing

**Advantages**
- Fast and economical
- Can test any/all piles on site with no special installation requirements
  - No access tubes
  - No pile build up

**Limitations**
- Limited L/D ratio
  - Difficult to get toe reflection when L/D > 30 or in very dense soils
- Non-uniform piles create many reflections making data interpretation difficult
- Reinforcing cage extending above pile top can cause interference
- Site vibrations can cause interference
Low Strain Pile Integrity Test

**Good Pile**

**Potentially Bad Pile**
Pile Integrity Test

Good Pile

-0.15
0.00
0.15
0.30
40 FT GOOD - 5: # 1 cm/s

Vel

F/Z

MA: 1.00
MD: 2.44
LE: 12.19
WS: 3962
LO: 0.61
HI: 30.5
PV: 0
T1: 32

0 2 4 6 8 10 12 m

T1 Toe
Pile Integrity Test
Defective Pile
Thermal Integrity Profiling
Thermal Integrity Profiling

- Heat generated by curing cement used to assess the quality
- Provides evaluation of shaft integrity between 12 and 48 hours after placement
- Evaluates rebar cage alignment and concrete cover of rebar
- Generates 3-D model of shaft profile
- Evaluates the entire shaft, inside and outside rebar cage
Advantages

- Ability to analyze the full cross section of shaft – Including estimation of concrete cover outside reinforcing cage
- Assess reinforcing cage alignment
- Insensitive to debonding
- Insensitive to bleed water
- Access tubes eliminated – wire method
- Less post construction requirements – wire method
- Accelerated Schedules
  - TIP Results – 24-48 hours
  - CSL Results – 4-7 days
Limitations

• Thermal Wire® cables require preplanning
  – Lengths and quantities of cables needs to be calculated
• Early testing window
  – Data is collected for analysis near the time of peak temperature which is early in the curing process
  – After peak temperature of concrete is reached temperatures normalize and anomalies are less evident
• Requires drilled shaft installation records, concrete volume logs, and soil borings to perform high level analysis when drastic boundary conditions are present
Proposed Rating Criteria

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<th>Satisfactory (S)</th>
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<td>0 to 6% Effective Average Radius reduction and Effective Local Radius meets cover criteria</td>
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<th>Probable Defect (PD)</th>
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<td>Greater than 6% Effective Average Radius Reduction or Effective Local Radius does not meet cover criteria.</td>
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TIP Analysis Terms:
- Effective Local Radius – computed radius from individual wire or tube data at a given depth (cover criteria)
- Average Shaft Radius – radius based on user input volume of concrete and length of shaft – not based on temperature data
- Effective Average Radius – computed average radius at a given depth – based on the recorded temperature at that depth (strength of geotechnical criteria)
TIP Improvements

• TIP Wires with **improved** strain relief
  – **Doubles** wire strength

• TAG
  – TAP like device with built in Cellular modem to send data to cloud and built in WiFi to communicate with WiFi TAP units
  – Reduce mobilizations
  – View results remotely in real time
What methods are available to inspect excavated shafts prior to concrete placement?
Inspection Device Examples

- Time consuming
- Deployment is difficult
- Potentially dangerous near open hole
- Still lots of uncertainty
“Joe the Construction Worker”

- OSHA CERTIFICATE FOR CONFINED SPACES
- COSTLY
- DANGEROUS
- UNECESSARY
Shaft QUantitative Inspection Device
What Does the SQUID Do?

The **SQUID** Measures:

- Thickness of debris layer or non-competent material
- Quantitative evaluation of the bearing layer’s strength
- Three cone penetrometers with independent displacement measurements
- Uses Standard 60° - 10 cm² cones
• Quickly attaches to stub drive of Kelly Bar with a 4”, 6” or 8” adapter

• Quick deployment accelerates inspection and minimizes debris settling from slurry.

• Less than 5 minutes to run a complete test

• Real time results allow for quick data assessment

• Bluetooth communication allows user to remain a safe distance from the excavation

• Output is cone tip resistance as a function of penetration
Case Study: Defect Detected Using TIP
Location: Tacoma, Washington
Shaft Details:
• 9.84 ft. diameter
• 127.5 ft. length
Typical Temperature vs. Elevation Profile from drilled shafts on this project
Any difference in this temperature profile?
Core near Wires 7 and 8
Case Study 2: Caliper vs. TIP

Location: Arizona
Shaft Details:
• 6 ft. diameter
• 100 ft. length
Test Type: Each shaft tested with TIP and Mechanical Caliper
Data Comparison: TIP vs. Caliper Data TS-1
Data Comparison: TIP vs. Caliper Data TS-2
Case Study 3: TIP & SQUID

Location: Pennsylvania
Shaft Details:
• 8 shafts total
• 36 in. diameter
• 15-16 ft. length
• Wet construction
• Placed via tremie
• Permanently cased to rock

Test Type: Each shaft tested with TIP and inspected with SQUID
TIP Results

Temperature vs. Depth Plot

3D Cage View
SQUID DATA – Before and After Clean out

Failed to meet spec on first 7 tests

Passed on first test after clean out
QUESTIONS?

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THANK YOU