THERMAL INTEGRITY PROFILING AS A DRILLED SHAFT QUALITY ASSURANCE TOOL

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PRESENTATION OVERVIEW

• WSDOT's drilled shaft construction program
• Traditional shaft quality assurance at WSDOT
• Thermal Integrity Profiling Basics
• Implementation on Construction Contracts
• What we learned
• The way forward
WSDOT’S DRILLED SHAFT CONSTRUCTION PROGRAM

• WSDOT’s started drilled shaft construction in late 70’s.
• For past 10 years, average exceeds 100 shafts per year.
• Range from 4-12 feet in diameter and 40-200 feet in length.
• Vast majority (95%) constructed as “wet” shafts.
TRADITIONAL SHAFT QUALITY ASSURANCE AT WSDOT

• Primary QA has been cross-hole sonic log (CSL) testing
• 100% of the “wet” shafts are CSL tested
• Backed up by:
  • Inspector observations
  • Monitoring of concrete and slurry levels
  • Concrete yield plots
TRADITIONAL SHAFT QUALITY ASSURANCE AT WSDOT
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TRADITIONAL SHAFT QUALITY ASSURANCE AT WSDOT

- Limitations on CSL Testing:
  - Can be a “sensitive” test.
  - “False anomalies” aren’t uncommon.
  - Only validates core of shaft.

WSDOT has used Thermal Integrity Profiling on two recent projects.
THERMAL INTEGRITY PROFILING BASICS

• Uses heat generated by hydrating concrete to determine quality.
• Measurements taken near shaft perimeter and uniformly around and along shaft.
• Adjustments for shaft geometry, concrete properties, water table, type of soils, presence of casing, etc.

ASTM D7949 – Standard Test Methods for Thermal Integrity Profiling of Concrete Deep Foundations
THERMAL INTEGRITY PROFILING BASICS
THERMAL WIRE METHOD

- One wire per foot diameter of shaft
- Sensors located every foot
THERMAL INTEGRITY PROFILING BASICS
THERMAL PROBE METHOD

• One access duct per foot diameter of shaft
• Reusable thermal probe to get temperatures
THERMAL INTEGRITY PROFILING BASICS

• Basic output is temps at each node
• Data is further post-processed (discussed later)
IMPLEMENTATION AT WSDOT

• Participated in research testing in 2010
  • Used the thermal probe method
• WSDOT purchased testing equipment and used for QA testing and shaft acceptance on two contracts
  • Selected the thermal wire method
IMPLEMENTATION AT WSDOT
INSTALLING THE THERMAL WIRES
IMPLEMENTATION AT WSDOT
PROTECTING THE TAPS
IMPLEMETATION AT WSDOT
OBTAINING DATA READINGS

Thermal Testing Timeframe
4000-P Mix Design

- Optimal Testing Window
- Acceptable Testing Window
IMPLEMENTATION AT WSDOT
COLLECTING THE TAPS

• TAP’s obtained:
  • Once slurry pumped down, and
  • Once sufficient time has elapsed
• If needed, TAP’s can be reconnected.
IMPLEMENTATION AT WSDOT
DOWNLOADING THE THERMAL DATA
IMPLEMENTATION AT WSDOT
DATA SUPPLIED BY THE FIELD

SHAFT CONCRETE POUR LOG

<table>
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<th>Task</th>
<th>Time (h)</th>
<th>Details</th>
<th>Comment</th>
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</tbody>
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Personnel & Equipment
- Crew: Data Consultants
- WSDOT: S. A. Luerso
- Dept. of Energy: John M. McCarron
- Dept. of Civil Engineering: Eugene N. Moore

Thermal Integrity Wires
- Wire: 1
- Wire: 2
- Wire: 3
- Wire: 4
- Wire: 5
- Wire: 6
- Wire: 7
- Wire: 8
- Wire: 9
- Wire: 10
- Wire: 11
- Wire: 12
- Wire: 13
- Wire: 14
- Wire: 15
- Wire: 16
- Wire: 17
- Wire: 18
IMPLEMENTATION AT WSDOT
POST-PROCESSING AND RESULTS

LEVEL 1 – Performed in the field using TIP Main Unit
• Verify shaft length – Identify top and bottom
• Locate immediate areas of concern

LEVEL 2 – Added Element – Field Records
• Find relationship between concrete volume and measured temperature
• Predict as-built shaft radius, shape, and cover

Information and graphics courtesy of Pile Dynamics Inc.
LEVEL 3 – Thermal Modeling using TIP Reporter
- Completed with desktop software
- Top & Bottom Roll Off Corrections
- Analyze Radius vs. Depth
WHAT WE LEARNED

SOME EXAMPLES FROM WSDOT PROJECTS
• After placing cage, 40 CY of material sluffed into shaft
• Cage was extracted and soils removed
• Used TIP to evaluate actual shaft geometry
WHAT WE LEARNED
MANETTE BRIDGE SOIL CAVING

• Results showed as-built geometry
  • Limits of voiding
  • Effective radius at all shaft locations
• Good correlation with concrete yield plot}

Actual vs. Modeled Temps.  Predicted Shaft Radius
WHAT WE LEARNED
I-5 M-STREET TO PORTLAND “BULGE”

• “Bulge” of concrete identified.
• Potential for affecting seismic design.
• Allowed Engineer to review for structural acceptance.
WHAT WE LEARNED
I-5 M-STREET TO PORTLAND CAGE RACKING

• Detailed for 6” cover
• Testing identified cage racking near shaft tip
• Min. cover approx. 3.5”
• Due to low corrosion potential at shaft tip, shaft was accepted.

Estimated concrete cover

Section near shaft tip
THE WAY FORWARD
PROS AND CONS OF THERMAL INTEGRITY PROFILING

Pros
• Indicates quality of shaft core and cover
• Testing as early as 24 hours after placement
• Builds a 3D model of shaft geometry

Cons
• A bit of a “black box”
• Thermal wires prone to damage/failure
• Thermal wires are a proprietary product
THE WAY FORWARD

OTHER OBSERVATIONS

• Cost-wise, comparable to CSL testing.
  • CSL tubes and thermal wires have similar costs
  • Equivalent labor for each method

• TIP methods/materials are improving!
  • New wire just released to reduce failures

• TIP data often leads to more acceptance evaluation
  • This is a good thing.
THE WAY FORWARD
FUTURE USE AT WSDOT

• WSDOT is generally pleased with the TIP methods
• Provides deeper review than CSL testing
• Currently reviewing/ updating specifications
• Likely expand use to additional projects
  • Still want to keep CSL testing
  • May reserve TIP for larger, deeper shafts
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Comments/Thoughts?

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