THERMAL INTEGRITY PROFILING (TIP)
Drilled Shafts in South Carolina
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Drilled Shafts in South Carolina

- Non-Destructive Test (NDT) Methods
  - Crosshole Sonic Logging (CSL) and TIP

- Carolina Bays Parkway Phase III
  - TIP; Probe, Embedded Wires, Suspended Wires

- US-15 O-Cell Test Shaft
  - Manufactured Anomalies

- Project YEEO (for Your Eyes and Ears Only)
  - Aggressive Schedule

David Schoen, EIT
S&ME, Inc.
Charleston, SC
dschoen@smeinc.com
843-884-0005
Receive

Transmit

Pull Probes From Bottom To Top

Non-Destructive Tests Background

Graphics courtesy of PDI
TIP TESTING
Non-Destructive Tests Background

- **Heat Generation**
  - Cement content, mix design, shaft volume
  - Necks and Bulges

- **Temperature Distribution**
  - Cage Eccentricity/Cover
  - Top and Bottom Roll-Off

- **Time Dependent**
  - Concrete Placement
  - Pre-Peak
  - Peak
  - Shaft Cooling
PROJECT OVERVIEW
Carolina Bays Parkway

- CSL Testing – Scope
  - 116 drilled shafts
    - 92 @ 7-ft diameter
    - 12 @ 8½-ft diameter

- TIP Testing – To Date
  - Probe (22 Shafts)
  - Embedded Wires (3 Shafts)
  - Suspended Wire (1 Tube)

- Exploratory Coring
  - 5 shafts to date
“No Signal” in CSL data
- Long permanent casing
- Two cages in upper portion of shaft
- Common in coastal plain drilled shafts
- CSL on column cage

“Anomalies” attributed to bleedwater
- Observed “welling” of water on top of shaft
- Coring indicated bleedwater path cavities and small air bubbles

Are defects being masked?
TIP PROBE
Carolina Bays Parkway

- Must dewater CSL tubes
- Lower potential for failure of equipment
- Reusable investment
- Allows for subsequent CSL readings
**TIP PROBE**

**Carolina Bays Parkway**

- **Difficulty in scheduling**
  - Not typically performed at Peak-Temp (When is Peak?)

- **Curing and environmental effects during readings**

- **Snapshot temperature**
Minimally used on project

- Budget constraints
- Wires donated by PDI
- 7 embedded (1 damaged)
- 1 suspended in water filled CSL tube
TIP WIRES – EMBEDDED AND SUSPENDED

Carolina Bays Parkway

- Embedded Wires
  - Labor intensive to install
  - Potential for damage to wire

- Suspended Wires
  - Somewhat reusable
  - Good correlation with other TIP methods?
  - Still allows for subsequent CSL if needed
Wave of concrete as being placed
Concrete not always level
Only recording every 15 min., but could reduce increment
PROJECT OVERVIEW
US-15 O-Cell Test Shaft

- Two-levels of O-Cells
- Manufactured defects
  - Gravel filled canvas bags
  - Sand filled bags not used
  - Two discreet levels (>3D apart)
  - Roll-off area (upper 1D)
  - 2D above strain gage
  - 15% of cross-sectional area
EMBEDDED WIRES – ISSUES ENCOUNTERED
US-15 O-Cell Test Shaft

- Installation of Thermal Wires
- Damage to Wire
  - Wire Install
  - Cage Modification
  - Cage Installation
  - Concrete Placement
- Security and data retrieval
Defects not apparent after concrete placement

Concrete and slurry at similar temps?
Embedded Wires
- Top defect – 9 to 11% temp reduction
- Lower defect – 10 to 13% temp reduction

Wires in CSL tubes
- Top defect – 3 to 5% temp reduction
- Lower defect – 4 to 7% temp reduction

What is too big of a reduction?
- Tube 4 at depth of 15 ft?
Embedded wires
- Still show some indication of defects

Wires in CSL tubes
- Barely indicate defects

What if this was when the probe was performed?
- Wires allow for multiple time points to be analyzed
CSL ANALYSIS
US-15 O-Cell Test Shaft

- CSL verified TIP results
  - Found extra anomalies?
  - Shaft “bled” a lot, but did not lose much signal in CSL readings
  - Upper anomaly difficult to see in CSL data
SUSPENDED TIP WIRES – GRADIENT

Back to Carolina Bays Parkway

- **7-ft Diam. Shaft**
  - 6-ft Diam. Drilled Shaft Cage
  - 5-ft Diam. Column Cage

- **Analysis at “Peak-Temp”**
  - not used for anomaly detection

- **Gradient of approx. ¾-ft**
  - About 15°F
  - Similar for both wire methods

(Bold – Drilled Shaft Cage)
(Faded – Column Cage)
SUSPENDED TIP WIRES – GRADIENT

8.5-ft Diam. Shaft w/ two full length cages
- 94-in Diam. with 9 CSL tubes
- 80-in Diam. with “Centralized” CSL tube offset 1½-ft from center

Analysis at “Peak-Temp” of “Centralized” Location
- About 8 hrs after “Peak-Temp” at perimeter location

Gradient of approx. 2¼-ft
- Embedded wires about 40 to 42°F
- Suspended wires about 37 to 39°F

Purple Lines – “Centralized” Location
Bold Lines – Embedded Wires
Faded Lines – Suspended Wires
PROJECT OVERVIEW
YEEO (for Your Eyes and Ears Only)

- Private Sector Job
  - 303 total drilled shafts
    - 4-ft, 6-ft, 8-ft diameters
    - Shaft tops up to 13 ft below ground
  - 6 total rigs, 5 working at a time
  - Install all shafts in 6 weeks

- Embedded TIP Wires
  - Installed on every shaft
  - Specs: up to 35% evaluated by TIP
  - 93 shafts (31%) evaluated by TIP

- Exploratory Coring
  - 4 shafts (1 @ 8ft, 3 @ 4-ft)
1,680 Total TIP Wires Installed (≈70,000 LF)
- At top of cage, wires tied to single sister bar
- Cages moved multiple times
- Concrete placed by freefall
- Uncased excavation backfilled

93 shafts (516 wires) evaluated by TIP
- 45 wires (8.7%) did not work at all
- 67 wires (13.0%) did not work entire time/depth

86 shafts (464 wires) checked to determine if wires working
- 156 wires (33.8%) giving error light
- Temp. casing pulled after concreting
- Numerous bulges in “cased section”
- Some minor necking (or insufficient quality concrete)
- Very little information on concrete placement
- Damaged wires

Middle truck not heating 9 hours after concreting

“Peak-Temp” 21 hours after concreting
TIP ANALYSIS – THE BAD

YEEO

“Concrete Placement”
2 hours after concreting

“Pre-Peak”
15 hours after concreting

“Peak-Temp”
1 day, 3 hours after concreting

- Core near Wire #6 – “poor” concrete from 4½ to 6 ft
- Core in center of shaft – 2 in. of concrete w/o coarse aggregate
“Concrete Placement”  
1 hour after concreting

“Pre-Peak”  
11 hours after concreting

“Peak-Temp”  
20 hours after concreting

- Cores near Wires #2 and #4 – “poor” concrete from 5 to 6½ ft
- Anomalies consisted of segregated concrete and “no-recovery”
**EXPLORATORY CORING AND REMEDIATION**

**YEEO**

- Cored one 8-ft shaft and three 4-ft shafts, in two locations each

**Pressure Grouting**

- Packers or plugs
- Flush with water (connect holes)
- Pump with grout
ANY QUESTIONS?
Did I Leave Enough Time?

Where can I get some dam beer?