PT Grout Segregation

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Florida Department of Transportation

SCOBS, AASHTO Technical Committee
T-18 Bridge Inspection, Repair and Rehabilitation
Grout Issues

- 2 issues currently being faced by DOTs
  - High Chlorides (slow moving ~ 1 MPH)
  - Segregation (fast moving ~ 100 MPH)

Both coming right at you

Which one do you worry about first?
Ringling Bridge, Sarasota Florida

• January 28, 2011 tendon found on the floor while doing electrical inspection.

• July 11, 2011 second failed tendon found.

• Service life of ~8 years.
Ringling Bridge, Sarasota Florida

- Both cases failure due to corrosion
- Segregation of the grout
- Unreacted (putty) paste
Grout Environment Condition

- High pH
- No chlorides
- High moisture content in grout layers
- High sulfate content
RINGLING CAUSEWAY BRIDGE

EXTERNAL TENDON INVESTIGATION SUMMARY

| EXTERNAL TENDONS | 132 | 2 Tendons replaced |
| TENDONS INVESTIGATED | 132 | 100.0% |
| TENDONS REJECTED | 15 | 11.3% of Total Tendons Investigated |

COUPLER INVESTIGATION/REPAIRS COMPLETED FEBRUARY 7, 2012

| TOTAL COUPLERS | 1416 |
| COUPLERS INVESTIGATED | 1416 | 100.0% of Total Couplers |

<p>| TOTAL VOIDS | 655 | 46.3% of All Couplers |
| Minor Voids ≤ 1/16” deep | 201 | 30.7% of Total Voids |
| Voids &gt; 1/16” deep – no exposed strand | 346 | 52.8% of Total Voids |
| Voids &gt; 1/16” deep - exposed strand | 72 | 11.0% of Total Voids |
| Voids w/ Corroded strand | 36 | 5.5% of Total Voids |
| Voids w/ Soft-Wet Grout | 94 | 14.4% of Total Voids |
| Strand corrosion found in voids with Soft-Wet Grout | 20 | 55.6% of Voids w/ Corrosion |
| Voids w/ Dry-Chalky Grout | 171 | 26.1% of Total Voids |
| Strand corrosion found in Voids with Dry-Chalky Grout | 11 | 30.6% of Voids w/ Corrosion |
| Voids w/ Hard Grout | 189 | 28.9% of Total Voids |
| Strand corrosion found in Voids with Hard Grout | 5 | 13.8% of Voids w/ Corrosion |</p>
<table>
<thead>
<tr>
<th>Cross Section at Deficiency Location</th>
<th>Image</th>
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<td><img src="image.png" alt="Diagram" /></td>
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- No significant corrosion (Class II or better)
- Significant corrosion (Class III or worse), little wire cross-sectional loss
- Significant corrosion (Class III or worse), significant wire cross-sectional loss
- Broken wire
- Unobservable

*Parsons Brinckerhoff*
• Segregated grout and severe corrosion was also seen at lower elevation anchor cap!

*Image*Tendon 404-9 West Anchor Cap
No significant corrosion (Class II or better)

Significant corrosion (Class III or worse), little wire cross-sectional loss

Significant corrosion (Class III or worse), significant wire cross-sectional loss

Broken wire

Unobservable
I4 – Leroy Selmon Expressway Connector, Tampa, Florida

- Under Construction
- 1 Mile long
- 29 concrete segmental bridges
- 2,765 segments
- 3149 longitudinal PT Tendons
  - 2549 grouted so far (81%)
- 252 transverse short tendons
  - 122 grouted so far (48%)
I4 – Leroy Selmon Expressway Connector

9/20/2011
I4 – Leroy Selmon Expressway Connector

- No segregation on short transverse tendons
- Out of the first 100 longitudinal tendons, 63 used SIKA grout
- 10/63 ~ 16% had soft “putty” grout
- No segregation since switching grouts
Investigation Tasks

- Task 1 - Identify cause of corrosion – Corrosion cell – Dr. Kingsley Lau, FIU

- Task 2 – Reproduce Segregation – Dr. Trey Hamilton, UF

- Task 3 – New, not commercially available, NDT – Mario Paredes, FDOT
Task 1 - SEGREGATED GROUT DESCRIPTION

- Grout segregation characterized as:
  - A. Wet plastic
  - B. Sedimented Silica
  - C. White chalky

- Corrosion attributed to wet plastic grout but not necessarily to void presence.
- Grout segregation created environment with dissimilar pore water chemistry and physical properties.
Current theory: Sulfates prevent passivation
Task 2 Inclined Grouting Test

Objective: generate soft grout using Inclined Tube Test
Task 2 Constricted Duct

Moisture content

- PT4-2
- PT1
- PT2
- PT3
- PT4-2

Soft grout

No soft grout
Task 2 Water in Duct

Moisture content

PT2 | PT3 | PT1 | PT4-1 | PT4-2
0%  | 20% | 40% | 60%   | 80%
Task 2 15% Excess Water in Mix

Moisture content

PT3 PT2 PT3 PT2 PT3 PT2 PT1 PT1 PT1 PT4-2 PT4-2 PT4-2

Soft grout

No soft grout
Task 2 Other Conditions

Moisture content

- Duct full of strand (PT4-1)
- Pressurized injection (55 psi) (PT4-1)
- Strand at top of duct (PT4-1)
- Pressurized set (60 psi) (PT4-2)
- High temp injection (PT4-2)
- 2 gal water in hose (PT4-1)
- 50% extra mix water (PT4-1)

Soft grout

No soft grout
Out of shelf life grouts

- All grouts produced soft grout
- Regardless of conditions
- Need definition of “Shelf Life”
- Storage conditions extremely important
Task 2 Findings-Prepackaged Grout

• Consistently produced soft grout in PT4 with 15% excess water

• Single instance of constricted duct produced soft grout in PT4

• PT1, PT2, and PT3 did not produce soft grout under any condition tested

• Out of shelf life produces segregation

• PT4 new bags just received produced soft grout
Materials Recommendations to Design

- Use grout 4? months prior to end of shelf life not to exceed 6 months after manufacturing

- Sealed air tight plastic containers for powder grouts

- No fillers until their role understood

- Low chlorides to max 0.04% (1.2 Lbs/cyd) by mass

- Drastic increase of QC/QA of grout powders
Task 3 USF Strand Position Mapping Method
Alberto Sagues, USF
US Patent and Trademark Office
Application No. 61/761,960

Determines strand position in tendon cross section for subsequent precise application of grout condition by electromagnetic, acoustic, thermal or other methods.

• Non destructive
• No holes needed
• Fast
• Can be done while grout is still fluid (to allow for instant QC).
• Produces image of cross section
Task 3

Imaging output (left) compared with actual strand distribution (right)
Task 3  Florida Department of Transportation
State Materials Office, Corrosion Research Lab
5007 NE 39th Ave.
Gainesville, Fl. 32609

Steven Schein System (SS System)

Reference Scan

Scale

\[ D_{\text{total}} = \frac{1}{2} \text{ in.} \]
\[ D_{\text{strand}} = 0.1660 \text{ in.} \]
Task 3  Florida Department of Transportation
State Materials Office, Corrosion Research Lab
5007 NE 39th Ave.
Gainesville, Fl. 32609

Cut Defect
Break Defect
Task 3  Florida Department of Transportation
State Materials Office, Corrosion Research Lab
5007 NE 39th Ave.
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Drill Defect

Buried Damage
Last But Not Least
Corrosion
Task 3 Chihuahua Project
QUESTIONS?