Corrosion of PT Tendons in Presence of Deficient Grout

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2014 PTI Convention Norfolk, VA
Introduction- Corrosion of PT Tendons

• Several Bridges in Florida are documented to corrosion of Post tension tendons in 1990’s.

• In early 2000 Corrosion attributed to void formation due to bleed water and chloride was found.

• Subsequent specifications in FL include low bleed grout requirements.

• However, corrosion problems persists.

• Investigation of recent PT corrosion and repair issues are on-going. This presentation overviews the findings from field and laboratory explorations of deficient grout in tendons.
Grout Segregation

- 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.
Corrosion at Low Elevation Anchor Caps

![Graph showing concentration and moisture content](image)

- **Concentration (ppm):**
  - SO\(_4^{2-}\)
  - K\(^+\)
  - Na\(^+\)
  - Ca\(^{2+}\)
  - Cl\(^-\)
  - NO\(_3^-\)

- **Moisture Content %**

![Image of corrosion](image)

- **Corrosion at Low Elevation Anchor Caps**
- **Anchor Caps**

![Graph showing chloride content and pH](image)

- **Total Chloride Content / mg Cl\(^-\)/g dry substance**
- **pH**

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• At least five other bridges contained grout with some form of deficiency.
• Extent of grout deficiencies vary greatly by bridge.
• Grout leachate remains alkaline.
- High chlorides found in some bridges (but thought to be unrelated to segregation).
- Deficient grout shows higher moisture and free sulfate concentrations.
• Compilation of data from research in aqueous environments show more negative potentials and increases $i_{\text{corr}}$ for $[\text{SO}_4^{2-}]/[\text{OH}^-] > 0.1$.

Lau et al. 2013 NACE Corrosion2013 : paper 2602
Sulfate Content in Field-Extracted Grout

- Corrosion observed in bridges when [SO₄²⁻]/[OH⁻] exceeds 0.1.
- But in presence of deficient grout.
- Important role of moisture/grout condition.
- Comparable limits suggested in the literature for corrosion in aqueous environments.
Mockup Tendons with Sulfates Additions in Mix Water

• 15 ft tendon mockup cast with varying sulfates and chlorides addition to the mix water.
  • 0 %, ~0.09%, ~0.9%, ~5.5% sulfates by cement weight.
  • 0.08%, 0.2 % chlorides by cement weight.
  • (Grout was past expiration and mix had excess water).
• Crevice and Non crevice steel probes were embedded in the grout.
• The tendons were inclined at 30°.
• Top portion of tendon appear to have greater degree of grout deficiency. Pore water chemistry to be tested after sample autopsy.
• Corrosion potentials were measured by voltmeter at regular intervals.
• Corrosion current of embedded steel probes measured by LPR.
• Grout solution resistance measured along tendon elevation.

- Grout deficiency appears more severe at high elevation (TOP).
  • Generally, deficient grout at high elevations have lower solution resistance.
  • (Moisture content and sulfate content in pore water to be determined.)
• Potentials indicative of possible active corrosion in top portion of tendon with both enhanced sulfates and chlorides.
• Active corrosion also apparent for steel with crevice including control condition.

Results shown in the graphs are averages of several sensor readings.
• Potentials indicative of passive corrosion condition for steel in lower portion of tendon for enhanced sulfate cases. Possibility of active corrosion condition for 0.2% chloride case.
• Similar behavior for steel with crevice.
• Higher corrosion current density in top portion of tendon with suspected deficient grout than in bottom portion with hardened grout.
• Some indication of greater current density for steel in grout with enhanced chloride and sulfate concentrations.

✓ Results indicate importance of grout condition in corrosion activity.
• Expected severe corrosion condition in of steel with crevices and enhanced chloride and sulfate concentrations not strongly manifested in results to date. Testing continues.
Conclusions

• At least five Florida bridges have been identified to contain deficient grout analogous to grout associated with severe corrosion.
• Amount and level of severity of deficient grout vary significantly from bridge to bridge.
• Deficient grout contain high moisture content, >20%.
• Leachate from deficient grout contain enhanced sulfate ion concentrations.
• Sulfate to hydroxyl ratio exceeded 0.1 where corrosion has been observed.
• Initial lab testing of large scale tendon mockups with enhanced chloride and sulfate concentrations in mix water show some indication of corrosion activity.
• Initial testing results indicate importance of grout condition in corrosion activity.
Acknowledgements

• The staff at the FDOT State Materials Office and contractors involved in this work are acknowledged here. The opinions and findings are those of the authors and not necessarily those of the supporting agencies.
• The assistance by Samanbar Permeh and Roberto Rodriguez is much appreciated.
• Acknowledgment is made to Dr. H.R. Hamilton and his students at UF for assistance in casting of the mockup tendons.

Questions?