Corrosion Evaluation of Post-Tensioned Tendons on Mid-Bay Bridge

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Location of the Bridge – Florida SR 293

Mid-Bay Bridge, Destin, Florida

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Corrosion Guys – What Do they Do?

• Identify areas of corrosion
• Measure rate of corrosion
• Define factors that cause corrosion
• Quantify section losses for use in remaining strength analysis
• Design corrosion protection system to prevent additional section losses
• Extend the life cost effectively

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**Corrosion Evaluation of Post-Tensioned Bridges**

- Rust classification
- Moisture content of the grout (ASTM C566)
- Chloride content of the grout (AASHTO T260)
- Alkalinity (pH) of the grout.
- Corrosion potentials (ASTM C876)
- Corrosion rate (ASTM G59)
- Petrographic Evaluation of the grout

**When does corrosion initiate on strands**

- When there is sufficient chlorides
- When the grout is carbonated
- When the combination of chlorides and partially carbonated grout results in condition conducive for corrosion
- When the air voids and/or carbonated grout are in contact with the strands

**The Mid Bay Bridge**

- Segmental precast concrete box girders - eight to nine segments held together by six post-tensioning tendons.
Typical View of the Anchorage

- Each tendon = 19 strands, each strand = 7 spirally wound 5/8 inch diameter wires.

The Schematics

The Magnitude of the Problem

- As many as 13 tendons were replaced in about 8 years of operation.
- Can we determine the extent of the problem?
- Is there a systematic way to identify problem spans?
Infrastructure Corrosion – Case Studies

Problems – Duct Crack

Problems – Broken Wires

Problems – Voids in the Grout
Problems – Voids in the Anchorage

Problems – Air Void Clusters

Are voids problematic?

• Voids are a problem. The common industry thinking is: no voids – no problems.
• If there is carbonated grout in contact with the tendon, it will lead to corrosion.
• Remember, it is not just the voids that are of concern on post-tensioned structures.
Problems – Corrosion on Strands

TYPICAL CORROSION

Problems – Corrosion at the Anchors

Corrosion at Anchorage

Significance of Corrosion

• Reduced cross section resulting in increased stress on individual wires
• Increased stress can lead to wire breaks, which in turn can lead further increase in stress
• Subsequent wire breaks occurs more frequently until the strand/tendon is completely lost
**Time to 50% Section Loss of a 0.5-inch Rebar**

At 1 mil per year, time-to 50% section loss of 0.5-inch rebar is >100 years.

**Time to 50% Section Loss of a 0.5-inch Strand**

At 1 mil per year, time-to 50% section loss of outer wires is about 25 years.

**Questions**

- Were the strands free of corrosion prior to grouting?
- Were the ducts dry prior to grouting?
- What was the quality of the grout?
- What is the alkalinity of the grout?
- What was the W/CM ratio of the grout, as installed?
- Any pumping aids used?
Field Investigations

- Grout composition and quality
- Variation in grout quality along the tendon
- Electrochemical tests
- Chloride content of the grout material

Anomalies

- Corrosion potential data indicated no active corrosion.
- Chloride content of the grout material was well below the standard threshold level.

Variation in Grout pH

\[
\begin{align*}
\text{pH} & \leq 6 \\
\text{pH} & \geq 12
\end{align*}
\]
Distribution of Grout pH

- pH is in the range of 12 in the bulk of the grout.
- At depth less than 1/4" from the top of the duct.

Distribution of W/C Ratio based on Petrographic Analysis

- W/C = 1.0 (Top 1/8")
- W/C = 0.6 to 0.7 (1/8" to 3/8")
- W/C = 0.4 to 0.5 (Bottom of the Duct)

Recommendations

- Identify and replace problem/failed tendons.
- Seal all the duct cracks and anchorage assemblies to eliminate direct access to moisture, oxygen, and chlorides.
**Void at High Point**

- Void in the top half of the tendon

**Void in the Coupler**

- Void – top 3 to 4 inches
- White chalky grout

**Broken Wire at High Point**

- Broken Wire (possibly during stressing)
**Typical Condition near Anchorage**

Severe corrosion of strands (with several wire breaks)

**Tendon in Ramp D – Bottom Slab**

Air void in contact with tendon trace
Low pH grout in contact with tendon

White chalky grout in contact with tendon

Tendon trace

Reflective grout smear