PT Evaluation and Repair

T-9 Committee AASHTO SCOBS, May 16, Norfolk, VA

Siva Venugopalan, SCS, Inc.
www.SivaCorrosion.com
Dangers of PT Tendon Corrosion

• Reduced cross section – increased stress on individual wires
• Increased stress – leads to wire breaks, which in turn can lead to further increase in stress
• Subsequent wire breaks – more frequent 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
Types of Investigation

• Visual inspection - cracks, efflorescence, rust stains, misalignment, etc.
• Visual inspection alone can be misleading
• Non-destructive testing - **must quantify** - not just identify - the problem
Case Study 1 – Mid Bay Bridge, FL

- 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 = 5/8 inch diameter
Problems - Duct Crack

Cracked Duct
Problems - Broken Wires

- Corroded & Broken Wire
- Heavily Corroded Wire
Variation in Grout pH

- pH = 6
- pH = 8
- pH > 12
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
When Does Corrosion Initiate?

• When there are sufficient chlorides
• When the grout is carbonated
• When the combination of chlorides and partially carbonated grout results in conditions conducive for corrosion
What Does it Mean?

- Visual evaluation – though necessary - not sufficient for PT structures
- Measure section losses and the rate of corrosion at critical points
- Document the quality of the grout
- Calculate time-to-criticality
Case Study II – Structure B

- Cast-in-place concrete box girders – three to four post-tensioned tendons in the web walls
Problems

• Visual inspection of this bridge revealed:
  1) Cracks on the riding deck
  2) Active cracks on webs and diaphragms
  3) Corrosion related distress on the underside of the riding surface
  4) Voids along the tendons
Typical Condition of the Top Deck
Void Channel

Void Channel with exposed strand
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
Typical Condition near Anchorage
Measure Corrosion Rate

Measure corrosion rate of tendons
Air Void in Contact with Tendon Trace
Low pH Grout in Contact with Tendon

White chalky (low pH) grout in contact with tendon

Tendon

Trace

7X

GROUT 4

1 mm
How Do I Use This Information?

- Visual evaluation – though necessary - not sufficient for PT structures
- Measure section losses and the rate of corrosion at critical points
- Document the quality of grout
- Perform structural analysis and calculate time-to-criticality/remaining strength
PT Conclusions

• It is not just the voids in tendons that are problems
• Varying grout quality or carbonated grout is a problem
• Quantifying instead of just identifying corrosion is necessary to determine the time-to-criticality/remaining strength
• SCS has experience in providing solutions to PT box girder bridge problems
Suspected Stray Current problem from nearby railroad tracks

1/3 section loss of underwater steel piles
Life Extension for Beam Ends

Cathodic Protection System
Carbon Fiber

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Corrosion of Steel Piles

- Performed tests at site and in laboratory
- Quantified the extent/root causes of corrosion
- Designed a Cathodic Protection System to extend service lives of piles
- Ruled out unnecessary mitigation measures (Owner saved costs)
Problems:
- Significant cracking, spalls and delaminations
- Visible strand corrosion - more not yet visible?
- Are there tools that can accurately quantify the condition?
- Is preservation possible in this case?
### Strand Section Losses

<table>
<thead>
<tr>
<th>No.</th>
<th>Test Location</th>
<th>Strand Size (inch)</th>
<th>Measurement (inch)</th>
<th>Difference in Diameter</th>
<th>Section Loss (%)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Location 1 (Strand 1)</td>
<td>0.50</td>
<td>0.45</td>
<td>0.05</td>
<td>19</td>
<td>Spall</td>
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<tr>
<td>2</td>
<td>Location 1 (Strand 2)</td>
<td>0.50</td>
<td>0.43</td>
<td>0.07</td>
<td>26</td>
<td>Spall</td>
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<tr>
<td>3</td>
<td>Location 2 (Strand 13)</td>
<td>0.50</td>
<td>0.48</td>
<td>0.02</td>
<td>8</td>
<td>Chipout</td>
</tr>
<tr>
<td>4</td>
<td>Location 2 (Strand 14)</td>
<td>0.50</td>
<td>0.48</td>
<td>0.02</td>
<td>8</td>
<td>Chipout</td>
</tr>
<tr>
<td>5</td>
<td>Location 3 (Strand 7)</td>
<td>0.50</td>
<td>0.48</td>
<td>0.02</td>
<td>8</td>
<td>Spall</td>
</tr>
<tr>
<td>6</td>
<td>Location 3 (Strand 8)</td>
<td>0.50</td>
<td>0.42</td>
<td>0.08</td>
<td>29</td>
<td>Spall</td>
</tr>
<tr>
<td>7</td>
<td>Location 4 (Strand 1)</td>
<td>0.50</td>
<td>0.00</td>
<td>0.50</td>
<td>100</td>
<td>Spall</td>
</tr>
<tr>
<td>8</td>
<td>Location 4 (Strand 1)</td>
<td>0.50</td>
<td>0.00</td>
<td>0.50</td>
<td>100</td>
<td>Spall</td>
</tr>
<tr>
<td>9</td>
<td>Rebar (Near Strand 1)</td>
<td>0.50</td>
<td>0.33</td>
<td>0.17</td>
<td>56</td>
<td>Spall</td>
</tr>
</tbody>
</table>
Visual/Delam/Potential Data

% Damage

- Visual
- Visual + Delam
- Corrosion Potential

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The owner better understood proper combinations of NDT tools needed to:

– Quantify existing deterioration
– Predict the future deterioration of beams
A Production Plant
External PT on P/S Beams
Corrosion of Strands
Broken Strand
**Service Life Extension:**
- Typically only 10-25% of replacement cost
- Solutions for simple/complex steel & concrete structures
- **Our Goal:** Life Extension at the lowest overall cost

**About SCS**

**Closing:**

In-Depth Evaluation

Life Extension Design

Installation Inspection
Siva Corrosion Services, Inc.

Specialize in identifying and quantifying corrosion

NDT firm

Independent consulting firm – we do not sell materials or products

Help government and private entities to solve problems
Siva Corrosion Services, Inc.

Post-tensioned structures

Reinforced concrete structures

*Including:*
Box girder bridges
Wastewater tanks
PCCP
Parking garages
Condominiums
Thank Questions?