Use of NDT Tools in Preserving and Extending Life of Concrete Structures

by

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FHWA Preservation Guide

• Bridge preservation is defined as actions or strategies that prevent, delay or reduce deterioration of bridges or bridge elements, restore the function of existing bridges, keep bridges in good condition and extend their life. Preservation actions may be preventive or condition-driven. Source: FHWA Bridge Preservation Expert Task Group, May 2011.
Bridge Preservation

• When a bridge experiences corrosion, we want to answer the questions:
  – What is the primary factor contributing to deterioration?
  – What is the current and future rate of deterioration?
  – Are there options to extend the service life by another 25 to 50 years?

• Develop a strategic inspection/evaluation plan to identify/quantify problems

Average preservation cost: 75-80% compared to replacement
Agenda

• Corrosion Deterioration & Cost
• Bridge Preservation using NDT
• Case Studies
  ➢ Cable Stay Bridge
  ➢ Deck Overlay Deterioration
• Conclusions
Corrosion Deterioration & Cost

- **Condition of Structure**
  - **Good:** Preserve
  - **Fair:** Extend Life
  - **Poor:** Replace

- **First Visible Damage**
- **Internal Damage**
- **Damage Accelerates**
- **Potential Failure**
  - **Critical Point**

- **Use NDT**

- **Reinforced concrete:** address here
- **PS/PT:** address here
Non-Destructive Testing (NDT)

- Use NDT to identify hidden problems
- Minimize inspection time and damage to the structure
- Primary NDT tools:
  - Ground Penetrating Radar (GPR)
  - Infrared Thermography
  - Impact-Echo
  - Ultrasonic Tomography
  - Stat Test (Electrical Impedance Test for PT Strands and Rods)
  - Sensors
  - Service Life Estimates
Ground Penetrating Radar (GPR)
Delamination Survey
GPR Evaluation

Horizontal Rebars in good concrete
GPR Evaluation

Horizontal Rebars in delaminated concrete
GPR at Traffic Speed
Application of GPR

- Inspect a deck/pavement without traffic control
- Examine for delamination/corrosion hot spots/pavement thickness
- Flag problem areas for further evaluation
- Inspect decks with overlays and membranes
Infrared Thermography (IRT)
Infrared Thermography (IRT)
IRT Results
IRT Results
IRT Results

Delaminations
Impact Echo

• Find flaws not detectable by GPR and provide more information about those flaws
• Well suited for structures with access constraints and multiple layers of materials (e.g., overlays)
IE Results

Transient Response

Thickess Frequency

Frequency Response
Ultrasonic Tomography
UT Application in Concrete Structures

• Delaminations in concrete
• Thickness measurement of concrete
• Bonding of overlay
• Crack evaluation
• Flaws, holes, and honeycombs
• Foreign inclusions
• Voids in PT duct
STAT Test

To identify:

• Severely corroded or broken strand in PT structures
• Severely corroded or broken PT rods
• Combination of STAT test results and statistical analysis to identify corroded strands/rods
Measure voltage between rod ends

STAT Test

Potentiostat

Data Logger
Service Life Estimate

• Applicable to new and existing infrastructure
• Calculate future concrete damage based on current existing condition
• Impact of protection solutions on the service life:
  ➢ Sealers
  ➢ Membranes
  ➢ Thin and Rigid overlays
  ➢ Coatings
  ➢ High Performance Concrete
  ➢ Corrosion Mitigation (GCP, ICCP, ECE)
Service Life Estimate

• Corrosion thresholds for different types of rebar
• Concrete mixtures properties
• Exposure conditions
• Comparisons of what-if scenarios
• Ion transport characteristics
• Effects of temperature
Service Life – For Mitigation Options

Projected Damage of Repair Options
- Pier Caps

- 25% Damage Eligible for Replacement
- Total Damage - No Repairs
- Visual Damage - No Repairs

Year

Concrete Damage, % Area


0 5 10 15 20 25 30 35

- Patch Only - Total Damage
- No Repairs - Total Damage
- LCC Option - ECE - Total Damage
- No Repairs - Visual Damage
Case Study 1: Cable Stay Bridge
Problem/Concern

- During past inspections, cracks and voids were observed in the HDPE stay pipes.
- Water had been observed inside the Tendon Anchorages and Neoprene Boots.
- Water or voids within grouted stay cables could lead to corrosion of the strands.
GPR & IR – Cable Stay Bridge
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Elastomeric Cable Wrap System on PE Cables (not damaged by NDT)
Cable Stay Bridge – Deficiency Location

West Tower - South
Elevation View Looking North

1. Item # in Table of Cable Deficiencies - Marked by SCS Phase I
2. Item # in Table of Cable Deficiencies - Marked by SCS Phase II
### A2: CABLE DEFICIENCIES

**SCS Project #: 10048-02 YEAR: 2012**

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>CABLE</th>
<th>LOCATION</th>
<th>IMAGE</th>
<th>DEFICIENCY</th>
<th>PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E1N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>19” void</td>
<td>I</td>
</tr>
<tr>
<td>2</td>
<td>E1N</td>
<td>20’ above deck</td>
<td>2647</td>
<td>40” void; cracked pipe**</td>
<td>I</td>
</tr>
<tr>
<td>73</td>
<td>E1N</td>
<td>20’ above deck</td>
<td>1204240004</td>
<td>½” void at top of cable; dry top half of one strand was visible; grout around void was cracked; no visible corrosion (Image 1)</td>
<td>II</td>
</tr>
<tr>
<td>74</td>
<td>E1N</td>
<td>87’ above deck</td>
<td>100_3667</td>
<td>19” void (Image 2)</td>
<td>II</td>
</tr>
<tr>
<td>3</td>
<td>E3N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>16” void</td>
<td>I</td>
</tr>
<tr>
<td>75</td>
<td>E3N</td>
<td>69’ above deck</td>
<td>100_3662</td>
<td>20” void (Image 3, 4)</td>
<td>II</td>
</tr>
<tr>
<td>4</td>
<td>E4N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>11” void</td>
<td>I</td>
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<tr>
<td>5</td>
<td>E5N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>12” void</td>
<td>I</td>
</tr>
<tr>
<td>6</td>
<td>E6N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>13” void</td>
<td>I</td>
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<tr>
<td>76</td>
<td>E7N</td>
<td>Lower Boot</td>
<td>100_3650</td>
<td>Cut at bottom of boot; wet to the touch</td>
<td>II</td>
</tr>
<tr>
<td>7</td>
<td>E7N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>13” void</td>
<td>I</td>
</tr>
<tr>
<td>8</td>
<td>E7N</td>
<td>~40-50’ above deck</td>
<td>SS 1</td>
<td>Butt weld</td>
<td>I</td>
</tr>
<tr>
<td>9</td>
<td>E8N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>16” void</td>
<td>I</td>
</tr>
<tr>
<td>77</td>
<td>E8N</td>
<td>8’ above deck</td>
<td>1205180030</td>
<td>3/8” gap between pipes; grout observed lower down in pipe sleeve (Image 5)</td>
<td>II</td>
</tr>
<tr>
<td>10</td>
<td>E9N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>32” void</td>
<td>I</td>
</tr>
<tr>
<td>11</td>
<td>E10N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>19” void</td>
<td>I</td>
</tr>
<tr>
<td>78</td>
<td>E10N</td>
<td>8’ above deck</td>
<td>1205180024</td>
<td>5/16” gap between pipes; grout observed lower down in pipe sleeve</td>
<td>II</td>
</tr>
<tr>
<td>79</td>
<td>E10N</td>
<td>15’ above acoustic sensor along the top of the cable*</td>
<td>100_2920</td>
<td>Small cuts/bubbles in wrapping; water present in one cut (shortly after precipitation)</td>
<td>II</td>
</tr>
<tr>
<td>12</td>
<td>E11N</td>
<td>Top of lower PE pipe sleeve</td>
<td>N/A</td>
<td>23” void</td>
<td>I</td>
</tr>
</tbody>
</table>
In-Depth Inspection
In-Depth Inspection
Recommendation

- Corrosion rate of strand due to rain water was low
- Grout is of good quality
- No observable water inside the cable or anchorage
- Future deterioration is expected to be low
Case Study 2: Overlay Deterioration

Reinforced Concrete Deck with LMC Overlay
Problem

- A significant amount of the overlay had delaminated and spalled off.
- The areas of spalls were growing over time.
- Large portions of the overlay exhibited visible cracking.
- Repairing spalls became very costly.
- The cause of delamination was unknown.
Problem

Delaminations and Previous Repairs
GPR at Highway Speed

Towable RoadCart GPR System at 45mph

GPR Antennas
GPR at Highway Speed

Southbound

No Debonding

Debonding Area

Pier 11
Impact Echo (IE)

Frequency Response of Debonded Overlay in Span 5

Extracted core confirming debonding
Recommendation

- Overlay will continue to debond
- SCS recommended removing and replacing the overlay
Conclusions

• Preservation program applied consistently over time is necessary to realize the benefits of preservation

• Using **right tools** at the **right time** for the **right structure** is essential for cost effective preservation program

• Quantifying instead of just identifying deterioration is necessary to schedule repairs or preservation activities

• If deterioration is left unaddressed, the repair can be very expensive
Conclusions

• Deterioration is like cancer – typically hidden
• An appropriate combination of NDT/statistical/service life tools help us diagnose the problem correctly
• Correct diagnosis help design effective preservation/remediation
• Preservation is beneficial to environment and future generations
Questions?

Let us talk!