Use of NDT Tools in Preserving Pre-stressed and Reinforced Concrete Substructures

by

Siva Venugopalan
Principal Engineer
Siva Corrosion Services, Inc.
Siva@SivaCorrosion.com
In This Presentation

• Impact Echo (IE) – New Jersey Pier Apron
• IR – Indiana I-65 Bridge Substructure
• GPR & IR – Illinois Cable-Stay Bridge
• GPR – New Jersey Deck Survey
• STAT Test – Wisconsin Post-Tensioned Box Girder Bridge
• PT Tendon & PT Bars – Virginia Varina-Enon Bridge
• Service Life Estimate – Virginia King Street Bridge
Corrosion Cost Progression

Condition of Structure

Cost of Maintenance

- Good: Preserve
- Fair: Extend Life
- Poor: Replace

First Visible Damage
Internal Damage
Damage Accelerates
Potential Failure
Critical Point
Reinforced concrete: address here
PS/PT: address here
Impact-Echo (IE): NJ Pier Apron
Impact-Echo (IE): NJ Pier Apron

Challenge:

• Concrete apron was cast-in-place around pier to protect against scour

• During pouring, the form was breached and cementitious material leaked out

• Owner was concerned that excessive voids may lead to lack of scour protection
Impact-Echo (IE): NJ Pier Apron

Solution:

• Utilized Impact-Echo (IE) acoustic technique to identify large voids within the apron
  – Ultrasonic waves are introduced into the concrete via impacts with steel ball bearings
  – Sound waves reflect off of discontinuities (i.e. voids, cracks, honeycombing), thus locating voids

• Tests were performed in a 2’x 13’ grid along the apron
Impact-Echo (IE): NJ Pier Apron
InfraRed Survey: IN I-65 Bridge
IR: IN I-65 Bridge

Challenge:

• Highway I-65 in Indianapolis, Indiana passes over seven city streets and was constructed in 1972 of reinforced concrete.

• The substructure of its 45 spans showed significant corrosion-related damage.

• SCS evaluated the deck and substructure components to determine whether corrosion mitigation methods may be used to extend the structure’s life.

• IR quickly and effectively identifies areas of delamination.
IR: IN I-65 Bridge
IR: IN I-65 Bridge
IR: IN I-65 Bridge

Solution:
• IR quickly and effectively identified areas of delamination
• Delamination was used in conjunction with other data (cover, chloride profiles, etc.) to estimate remaining service life & life cycle cost of various repair options
• Recommended installation of an ICCP system at expansion joint piers to extend the life of the substructure
Challenge:

• During past inspections, cracks and voids were observed in the HDPE stay pipes
• Water was observed inside the tendon anchorages and neoprene boots
• Water or voids within grouted stay cables could lead to corrosion of the strands
Solution:

- As part of the overall inspection, one of the goals was to **non-destructively identify voids within the stay cables**.
- After brief field trials, SCS identified infrared thermography (IR) and ground penetrating radar (GPR) to be the most effective tools.
- Impact Echo was used as well, but cable wrapping significantly dampened the acoustic waves.
GPR & IR: IL Cable Stay Bridge
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GPR & IR: IL Cable Stay Bridge

- Identified over 100 voided locations using IR/GPR
- All voids were confirmed with IR, GPR, or Sounding
- Invasive testing (borescoping) was performed to determine if voids are problematic
- Additional cable openings at voids locations is planned to quantify the extent of damage
GPR: NJ Deck Survey

Reinforced Concrete Deck with LMC Overlay
GPR: NJ Deck Survey

Challenge:
- The NJTA deck was over 100,000 sq. ft.
- The overlay placed in 1994 had current significant delamination and spall, cracks, and growth of spall.
- Requested to determine the cause of delamination and quantify the extent of damage on the riding surface.
- Use Ground Penetrating Radar (GPR) to identify deck delamination and confirm results via sounding and coring at select locations.
- Perform petrographic analysis and chloride content testing on cores.
GPR: NJ Deck Survey

Towable RoadCart System at 45mph

GPR Antennas
GPR: NJ Deck Survey

Southbound

No Debonding

Debonding Area

Pier 11
GPR: NJ Deck Survey

Core from Debonded Area

LMC Overlay

Base Concrete

Debond Plane
Solution:

• Extent of delamination quantified

• Petrographic analysis revealed:
  – Cause of delamination was improper finishing of the base concrete leading to a weakened layer at the overlay-base interface
  – High chlorides at the rebar due to escalating delamination

• Replacement of overlay recommended
STAT Test: WI PT Box Girder Bridge
Challenge:

- Post-tensioned (PT) rods may be broken or deteriorated.
- Remaining strength depends on the number of PT rods still in good condition.
- Unlike regular reinforced concrete structures, any significant reduction in PT rod section can result in increased stress which then lead to sudden failure.
- Test Wisconsin bridge PT rods in a unit that also had visible corrosion on the exterior of the boxes.
STAT Test: WI PT Box Girder Bridge
Post-tensioned (PT) rods: reinforce concrete boxes of some bridges along the East – West Freeway.
Measure voltage between rod ends

Potentiostat

Computer/Data Logger
Problem Rods – Interior End
Exterior

Test Sequence – Interior End

Potentiostat

Interior
Test Sequence – Exterior End
Solution:

• Remove and replace all rods identified as significantly corroded or already broken

• By identifying and replacing severely corroded PT rods, the Department can mitigate risks and extend the service life
PT Tendon & Bars Evaluation: VA Varina-Enon Bridge
PT Tendon & Bars Evaluation:
VA Varina-Enon Bridge

Challenge:

• During previous inspections, voids were identified in the tendons and PT bar ducts

• Some tendons had experienced significant corrosion (broken wires)
PT Tendon & Bars Evaluation: VA Varina-Enon Bridge

Solution:

• Inspect 18 vertical PT bar’s condition
  – 9 Northbound / 9 Southbound
  – Using the borescope check for presence of
    • Voids
    • Grout segregation
    • Water
    • Tendon corrosion
  – Seal and mark drilled holes
  – Document process with pictures and video

• Future monitoring can be performed in the same locations to compare condition over time
PT Tendon & Bars Evaluation:
VA Varina-Enon Bridge
Borescope: VA Varina-Enon Bridge
Service Life Estimate: VA Bridges

Bridge #100-1821 King St over I-395 & Ramp C&G

Bridge #000-5000, 34th St over I-395 & Ramp D&F
Service Life Estimate: VA Bridges

Challenge:

• Heavy traffic area bridges (over 180,000 VPD) along the I-395 and King Street Interchange in Alexandria, VA - exhibit evidence of: ongoing corrosion - concrete damage - reinforcement section losses

• VDOT desired an additional 50 year life and required rehabilitation alternatives to facilitate that goal

• Evaluated the deck and substructure of two bridges to determine whether corrosion mitigation methods can be used to extend service life
Service Life Estimate: VA Bridges

Rebar Cover Meter & Data Logger
Service Life Estimate: VA Bridges

- Deck

UNIT 1 DECK PLAN
- DELAMINATION
- SPALLING
- PATCH

UNIT 2 DECK PLAN
- DELAMINATION
- SPALLING
- PATCH

UNIT 3 DECK PLAN
- DELAMINATION
- SPALLING
- PATCH

BLUE FILLED CIRCLE AREA REPRESENTS CHLORIDE TEST LOCATIONS

SCALE: 1” = 20’
King St. Surface Chlorides

- Chloride (lb/CY)
- Core No.
- Surface CL, lb/CY
- Threshold (2 lb/CY)
Petrographic Testing Results -

- Water/cement ratio was normal for age of deck
- Total air void content was more than the minimum required for freeze thaw resistance; however, the structure did not exhibit freeze thaw damage yet
- The unit weight is 149 lb/ft$^3$
- Carbonation was less than 1mm and not a corrosion concern
- Small, observed amount of Alkali-Silica Reaction (ASR) produced no cracks
Service Life Estimate: VA Bridges

• Using NCHRP 558 service life modeling, the deck is projected to experience 39% of concrete damage in about 50 years if nothing is done.
• The deck has a total compromised area of 28% (5.28% delam + 23% chloride above threshold).
• The SR for this structure is 56.1.
• The deck would not last another 50 years if nothing other than patching is done.
# Service Life Estimate: VA Bridges

<table>
<thead>
<tr>
<th>Deck Repair Option</th>
<th>Life Cycle Cost</th>
<th>MOT Cost</th>
<th>Total LCC</th>
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<tbody>
<tr>
<td>A Patch + LPC</td>
<td>$1,581,643</td>
<td>$126,431</td>
<td>$1,708,074</td>
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<td>B Patch+LMC+ICCP</td>
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<td>C Patch+ECE</td>
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<td>D Replace</td>
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Conclusions

• Deterioration is like cancer – typically hidden
• Necessary to quantify deterioration to determine remaining strength and time-to-failure
• If left unaddressed, deterioration is costly
• An appropriate combination of corrosion rate analysis and NDT testing helps to identify and quantify hidden corrosion problems
• Infrastructure preservation benefits the environment and future generations
Questions?

Thank you!