Corrosion Strategies to Extend the Service Life of Concrete Structures

Presented to Virginia Concrete Conference by Siva Venugopalan, Principal Engineer, SCS, Inc. Siva@SivaCorrosion.com
Current Status

• Most bridges were built in the 60’s and 70’s.
• Majority of them require repair/replacement.
• More capacity is required in many routes.
• Investment for new and existing structure.
• All happening at the same time.
• Funding is scarce.
• Staggering replacement is necessary.
• Preservation is a requisite tool.
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.

When a bridge experiences corrosion, we want to answer the questions:

– How bad is bad?
– What is the rate of deterioration?
– How do we cost effectively extend the life?

SCS develops a strategic inspection/evaluation plan to quickly identify/quantify problems.

Average preservation cost savings for owners: **75-80%** compared to replacement.
In This Presentation

• Brief Introduction to Corrosion
• Bridge Preservation using NDT
• Case Studies
  – Pre-stressed Concrete Structures
  – Post-tensioned Concrete Structures
  – Reinforced Concrete Structures
• Corrosion Mitigation and Life Extension
Corrosion Cost Progression

**Condition of Structure**

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

**Cost of Maintenance**

- First Visible Damage
- Internal Damage
- Damage Accelerates
- Potential Failure

**Critical Point**

- Reinforced concrete: address here
- PS/PT: address here
Why Test?

- Material Performance
- Quantifying Damage
- Corrosion Evaluation
- Lab Testing
- NDT

Where are you in the deterioration cycle? Early or Late?
Assessment of Concrete Structures

1. Non-Destructive Evaluation (earlier identification)
   • Identify and quantify deterioration of concrete and steel

2. Electrochemical Testing
   • Quantify time-to-failure, corrosion rates, future section losses

3. Laboratory Testing
   • Additional material and corrosion analysis

4. Estimate Service Life
   • Recommend cost effective solution
Non-Destructive Testing (NDT)

• Use NDT to see hidden problems
• Minimize inspection time and damage to the structure
• Primary NDT tools:
  – Bore Scope (small video camera)
  – Ground Penetrating Radar (GPR)
  – Infrared Thermography
  – Impact-Echo
  – Ultrasonic Tomography
  – Stat Test (Electrical Impedance Test for PT Strands and Rods)
Ground Penetrating Radar (GPR)

Probe

Reinforcing Steel or Tendon
Ground Penetrating Radar (GPR)
Ground Penetrating Radar (GPR)

Probe
Identify Steel Location

- **Rebar**
- **PT Cable**
Identify Delamination/Void
Identify Delamination/Void

Line Scan 29

Line Scan 28
Identify Delamination/Void

Horizontal Rebars in good concrete
Horizontal Rebars in delaminated concrete

Identify Delamination/Void
GPR at 45 mph
GPR at 45 mph

- Inspect a deck without traffic control
- Examine for delamination/corrosion hot spots
- Flag problem areas for further inspection
- Inspect decks with an asphalt overlay
Infrared Thermography (IRT)
Infrared Thermography (IRT)
Infrared Camera
Impact Echo

- Can find flaws not detectable by GPR and provide more information about those flaws
- Well suited for flaw determination on structures with difficult access or multiple layers of materials (e.g. overlays)
Impact Echo

Transient Response

Thicknenss Frequency

Frequency Response
Impact Echo
Ultrasonic Tomography

Concrete Slab
Ultrasonic Tomography

First Row of Transducers

Concrete Slab
Ultrasonic Tomography

Concrete Slab
Ultrasonic Tomography Scanning Process

Handheld Device

UT Probes

All Probes Send, All Probes Receive
Ultrasonic Tomography
Determine Internal Flaws

- Partially Voided Duct
- Back of Stem Wall
Application - Concrete Structures

- Delaminations in Concrete
- Thickness Measurement of Concrete
- Bonding of Overlay
- Crack Evaluation
- Flaws, Holes, and Honeycombs
- Foreign Inclusions
- Voids in PT Duct
Electrochemical Testing: Corrosion Rate
Application In Concrete Structures

- Identify Areas Experiencing Corrosion
- Determine the Rate of Corrosion
- Estimate Time to Concrete Damage
- Predict Future Corrosion Activity
NJ Turnpike (I-95)

Reinforced Concrete Deck with LMC Overlay
Problem

• A new LMC overlay was placed in 1994
• 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
• SCS was retained to determine the cause of delamination and quantify the extent of damage on the riding surface
• SCS performed GPR at highway speeds to identify all delamination present on the deck
• SCS confirmed GPR results via sounding and coring at select locations within delaminated and sound areas
• SCS performed petrographic analysis and chloride content testing on cores
GPR at High way Speed

Towable RoadCart GPR System at 45mph

GPR Antennas
GPR at Highway Speed

Core from Debonded Area

LMC Overlay

Base Concrete

Debond Plane
Solution

• The extent of debonding was quantified
• Petrographic analysis revealed the cause of debonding
  – Improper finishing of the base concrete lead to a weakened layer at the overlay-base interface
• High chlorides were found at the rebar
• Due to increasing debonding and high chlorides, SCS recommended replacing the entire overlay
Benefit

• The Authority was able to make an informed decision to repair or replace the overlay.

• Since the cost of MPT is significant and additional spalls were expected to develop, repair costs over time would exceed replacement of the entire overlay.
Ribault River Bridge (SR-115)
Little Cedar Creek Bridge (I-95)
Cedar Creek Bridge (I-95)
Trout River Bridge (US-17)
Moncrief Creek Bridge (SR-111)
Trout River Bridge (SR-115)
Broward River Bridge (US-17)
San Pablo River Bridge (SR-10)
Cresent Beach Bridge
- Over 8,000 miles of tidal coast line
- Entire coastal area is considered extremely corrosive.
- The most common type of deterioration on Florida marine bridges is corrosion induced damage to substructure components.

Typical Corrosion Deterioration of Florida Bridges

Courtesy of FDOT
Patches Accelerate Corrosion

Good Encapsulation – New Corrosion

Courtesy of FDOT
Patch Corrosion Continues

Conventional encapsulation allows continued corrosion

Courtesy of FDOT
- Conventional repairs are not adequate for the rehabilitation of chloride contaminated structures.
- The approach to preserve corrosion affected bridges is based on controlling corrosion by using cathodic protection and concrete rehabilitation.

Goal: Provide an extension of service life of the structure as needed.
Impressed Current Cathodic Protection

Titanium Anode Mesh

CP Wires are routed to the rectifier in conduit.

Courtesy of FDOT
Encapsulation of a Titanium Anode within a Standard Pile Jacket

1) A fiberglass form is placed around the pile leaving an annular space between pile and form.
2) Form is filled with mortar/concrete.
3) Several piles are combined into one C.P. Circuit.
4) Combines spall repairs and C.P. into one operation.
Impressed Current
Cathodic Protection

Titanium Anode Mesh Jacket

Courtesy of FDOT
Sacrificial Cathodic Protection

Arc-sprayed Zinc Anode

Courtesy of FDOT
Benefits of Corrosion Protection

- FDOT cathodic protection program has been **successful in extending the service life** of bridges in marine environments.
- The cathodic protection program has **proven to be a cost effective** means for the long term preservation of corrosion affected structures.

Courtesy of FDOT
Post-tensioned Box Girders

- Fully grouted tendons
- Half Cell Potential: 90% probability of no corrosion
- Chloride Content of Grout: Well below corrosion threshold
Grout Void
Void at Couplers
Void and Corrosion

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Corrosion Damage
Grout Problems in Vertical Tendons

- Bleed water at high points and anchors
- Tendons completely corroded
- Leaky duct connections
PT Anchorage Encapsulation

• Incomplete pourbacks
• Spalled pourbacks
• Possible entry of contaminants into the P-T system
Duct Connections

- Metal duct connections are not air tight or water tight.
- Adhesive tape has fabric backing
- Fiber cloth retains moisture; promotes corrosion
Leaking Drain Pipe

- Clogged from ice or road debris
- Corroded pipe
- Leaking joints
Grout with High Chlorides

- Several PT tendons are filled with grout with varying levels of chlorides
- Can significantly impact the future performance of these bridges
- Important to document the levels of chlorides at critical areas
- Measure the effects of chlorides on tendons over time
About SCS

• Expertise in Materials, Corrosion and NDT
  – Specialized in NDT & Corrosion of Concrete Infrastructure
  – Identify & Quantify problems

• Independent Consulting Firm
  – Do Not Sell Materials or Install Products
  – NDT and Corrosion Inspections
  – Laboratory Analysis
  – Statistical Analysis
  – Recommendation
  – Corrosion Control Design
Questions?

Thank you!