Designing Bridges for a 100-year Service Life

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By

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In This Presentation

• Brief Introduction Bridge Condition
• Deterioration Mechanisms
• Designing for 100 years and beyond
• Corrosion Mitigation and Life Extension
FHWA All US Bridges
2015 NBIS Data

- SD Bridges
- SD Deck Area

Legend:
- All-US
- All-Missouri
NHS Bridges Only
2015 NBIS Data

SD Bridges
SD Deck Area

NHS-US
NHS-Missouri
Bridges on Salt
Bridge Deterioration due to Salt
Poor Concrete Quality
Bridge Deterioration due to Salt
Typical Corrosion Deterioration Of Marine Structures
Conventional Repairs On Chloride Contaminated Concrete

- Even when a good encapsulation is achieved, new corrosion cells are developed and corrosion continues.

- Corrosion develops around repair patches due to the characteristics change of the repaired rebar.

* NCHRP D10-37C
- Removal of standard jackets showed that conventional encapsulations allow continued corrosion.

- Good patches promote accelerated corrosion in the concrete surrounding the patch and new spalls develop within a few years.
Corrosion Cost Progression

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

**Condition of Structure**

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

**Critical Point**

- Reinforced concrete: address here
- PS/PT: address here
Designing for 100 Yeas – New Bridges

• Would we design bridges where we do not specify compressive strength?
• Would we build bridges where we do not test concrete for compressive strength, slump, air, and water/cement ratio?
• Why are we not designing structures with diffusion parameters?
• Why are we not making sure that diffusion parameters are achieved in the field?
Designing for 100 Yeas – New Bridges

• Define Life Requirements

• Develop a Corrosion Protection plan (CPP)

• Elements of CPP include:
  - Replaceable and non-replaceable elements
  - Define pile thickness or corrosion protection to compensate for corrosion related loss due to corrosive soil.
  - Define paint deterioration based on environment and location of member
Design durable concrete to account for salt usage or marine environment

- Non-reactive aggregates/Freeze thaw resistance (if required)
- Required minimum chloride diffusion coefficient

- NT Build 492 - chloride migration coefficient from non-steady-state migration experiments

\[ C(x, t) = C_o + (C_z - C_o) \cdot \left(1 - \text{erf} \left( \frac{x}{2 \cdot \sqrt{D_{\text{app},C} \cdot t}} \right) \right) \]
Chloride Diffusion Test Setup (NT Build 492)
# Chloride Diffusion Report

## NT Build 492

### Siva Corrosion Services, Inc.

1313 Wilmington Pike  
Suite 2B  
West Chester, PA 19382  
(610) 692-6551  
www.SivaCorrosion.com  

- **Date Core Arrived at SCS:** 12/2/2015  
- **Concrete Type:** Class 3300 Structural  
- **Test Date:** 12/15/2015  
- **Age at Test Date (days):** 28  
- **Test Method:** NT Build 492

<table>
<thead>
<tr>
<th>Core Number</th>
<th>Core #1</th>
<th>Core #2</th>
<th>Core #3</th>
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<tbody>
<tr>
<td>Core Length, mm</td>
<td>202</td>
<td>202</td>
<td>202</td>
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<tr>
<td>Core Diameter, mm</td>
<td>102</td>
<td>102</td>
<td>102</td>
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<tr>
<td>Test Sample Thickness, mm</td>
<td>49.65</td>
<td>50.76</td>
<td>50.73</td>
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<tr>
<td>Test Sample Diameter, mm</td>
<td>102</td>
<td>102</td>
<td>102</td>
</tr>
</tbody>
</table>

### Test Result

- **Applied Voltage, Volts:** 20, 20, 20  
- **Test Duration, Hours:** 24, 24, 24  
- **Initial Current, mA:** 70.2, 58.5, 73.7  
- **Final Current, mA:** 75.2, 57.4, 82  
- **Initial Temperature, °C:** 24, 24, 24  
- **Final Temperature, °C:** 21, 21, 21  
- **Average Temperature, °C:** 22.5, 22.5, 22.5  
- **Average Chloride Penetration Depth, mm:** (see table below for calculation) 22.67, 17.18, 22.91  
- **Non-stady State Migration Coefficient, \(10^{-12} \text{ m}^2/\text{s}\):** 15.77504, 11.89445, 16.27677

### Average Non-stady State Migration Coefficient, \(10^{-12} \text{ m}^2/\text{s}\)

- **Average:** 14.64875
Kosciuszko Bridge
Designing for 100 Yeas – Existing Bridges

• Perform service life analysis using:
  
  ➢ Chloride diffusion coefficient
    
    ➢ ASTM C1556, "Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion"
    
    ➢ Alternatively, Nordtest NT Build 443, "Accelerated Chloride Penetration" (also known as the Bulk Diffusion Test).
• Project future concrete deterioration

• If future deterioration is excessive – change the trajectory of future deterioration by reducing future corrosion
Typical Corrosion Mitigation Systems

1. Sealers/Membranes
2. Thin & Rigid Overlays
3. Paint Systems
4. Surface applied or encapsulated galvanic cathodic protection
5. Encapsulated active cathodic protection systems
6. Submerged bulk galvanic anode systems (Zn, Al or Mg)
Epoxy Coated Bridge Deck

Projected Concrete Damage of Deck - 28731

- **Auto Threshold Damage**
- **1800ppm Threshold Damage**

- **5.4% Actual Damage in 2015**
- **10% Damage by 2045**


Concrete Damage, % Area: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100
## Preservation Options for a 100 Year Life

<table>
<thead>
<tr>
<th>Deck Repair Options</th>
<th>Repair Life, years</th>
<th>Initial Cost</th>
<th>Life Repair, Present Value</th>
<th>Life Repair MOT, Present Value</th>
<th>Life Cycle Cost of Repair Options</th>
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</thead>
<tbody>
<tr>
<td>1 LSHD Overlay</td>
<td>20</td>
<td>$83,360</td>
<td>$201,642</td>
<td>$35,897</td>
<td>$237,539</td>
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<td>2 Overlay + GCP</td>
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<td>$294,034</td>
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<td>$24,500</td>
<td>$332,563</td>
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</table>
Iowa 9 over Crank Creek
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!