Re-alkalization and Galvanic Protection of Reinforced Concrete Structures

David Whitmore, P.Eng., FCSCE
Vector Corrosion Technologies
Washington National Airport Dedication; September 18, 1940
Test Program

• Photographic Conditions Survey
• Crack Mapping – extensive pattern cracking
• Sounding – revealed correlation between rebar depth and spalling concrete
• Coring – revealed carbonation \( \frac{3}{4}'' \) to \( 1 \frac{1}{2}'' \) - chlorides in one section
• Pachometer – revealed variable rebar depth
• Half-cell Potential - inconclusive
Rebar Issues

Corrosion Due to Carbonation and Low Concrete Cover over Rebar.
Corrosion Mitigation Options

- Galvanic Protection
- Impressed Current Cathodic Protection
- Corrosion Passivation using Electrochemical Treatments
  - Chloride Extraction
  - Re-alkalization
Washington National Airport Façade Repair Program

- Install site protection
- Remove loose concrete
- Chemically strip paint
- Abrasive cleaning and surface preparation
- Replace corroded rebar and patch concrete
- Realkalisation of all exposed concrete
- Apply coating
- Perform all other work (roofing, railings, etc)
Realkalization

- Draws highly alkaline electrolyte sodium carbonate (Na$_2$CO$_3$) to the reinforcing steel
- Restores lost alkalinity to carbonated concrete
- Alkalinity around reinforcing steel is maintained over time, will not re-carbonate
- Lower cost, less disruptive than mechanical removal and replacement of carbonated concrete
Realkalization

Diagram showing a cross-sectional view of a concrete reinforcing bar with anode and electrolyte layers. The diagram labels include:

- **Anode**
- **Electrolyte**
- **Concrete**
- **Reinforcement**
- Positive (+ve) and Negative (-ve) charges
Realkalization
Realkalization

Anode

Electrolyte

Reinforcement

Concrete

OH⁻
Realkalization

Anode

Electrolyte

Na$_2$CO$_3$ & NaHCO$_3$

Concrete

Reinforcement
Access & Protection

- Protection of windows in occupied areas.
- Access to work areas for all project elements.
Norcure® Chloride Extraction and Re-alkalization of Concrete Facade.

Reagan National Airport
Washington, DC
Verification of Results

- Phenolphthalein Testing on Cores
  
  Before
  
  After Realkalization
Realkalization - Results

- Highly alkaline zone around steel
- Strong passivation occurs
- Cover zone impregnated with potassium carbonate, high final pH
- Low alkalinity problem is rectified
- Entire surface treated
- No further corrosion
Ohio DOT
I-75 Substructure Restoration
- Ohio DOT
- I-75 Substructure Restoration
Ohio DOT
I-75 Substructure Restoration
Completed repair
Kirkwood Road – Protective Current
## Kirkwood Road Performance

<table>
<thead>
<tr>
<th>Date</th>
<th>Temp</th>
<th>mA/m2</th>
<th>Polarization</th>
<th>Instant Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/6/05</td>
<td>37.7</td>
<td></td>
<td>654*</td>
<td></td>
</tr>
<tr>
<td>7/20/05</td>
<td>13.9</td>
<td>346</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>8/16/05</td>
<td>31</td>
<td>12.9</td>
<td>333</td>
<td>987</td>
</tr>
<tr>
<td>10/26/05</td>
<td>12</td>
<td>5.4</td>
<td>394</td>
<td>1048</td>
</tr>
<tr>
<td>12/7/05</td>
<td>11</td>
<td>3.2</td>
<td>339</td>
<td>993</td>
</tr>
<tr>
<td>5/1/06</td>
<td>14</td>
<td>7.5</td>
<td>335</td>
<td>989</td>
</tr>
<tr>
<td>12/20/06</td>
<td>4</td>
<td>4.3</td>
<td>500</td>
<td>1154</td>
</tr>
<tr>
<td>5/30/07</td>
<td>26</td>
<td>7.5</td>
<td>446</td>
<td>1100</td>
</tr>
<tr>
<td>9/20/07</td>
<td>24</td>
<td>9.7</td>
<td>484</td>
<td>1138</td>
</tr>
<tr>
<td>12/09/08</td>
<td>4</td>
<td>3.3</td>
<td>470</td>
<td>1124</td>
</tr>
<tr>
<td>7/9/09</td>
<td>23</td>
<td>3.3</td>
<td>475</td>
<td>1129</td>
</tr>
</tbody>
</table>
Presentation Summary:

• Corrosion of Steel in Concrete
• Types of Corrosion Protection Systems
• Electrochemical Treatments
  – Re-alkalization
• Galvanic Protection
• Project Examples
Thank You

Vector Corrosion Technologies

www.vector-corrosion.com
Questions
Compliments of Computer History Museum
Sustainability and the Environment
Concrete in Society

- Concrete is the most widely used man-made product in the world
- 6 Billion tons per year (~4 Billion m$^3$)
- Huge consumer of raw materials and energy
  - Cement
  - Aggregate
  - Concrete production and transport
  - Steel production is also energy intensive
Concrete in Society

- Overall Total CO$_2$ produced
  - Cement: 1 Billion tons CO$_2$ per year
  - Aggregate: $\sim$ 50 Million tons CO$_2$ per year
  - Ready Mix: $150^+$ Million tons CO$_2$ per year
  - Rebar: 200 Million tons per year

- Total CO$_2$ produced: $\sim 1.5$ Billion tons / yr
Concrete in Society

• Other Emissions
  – Carbon Monoxide: 10 Million tons per year
  – Nitrogen Oxides: 30 Million tons per year
  – Sulfur Dioxide: 29 Million tons per year
  – Volatile Organic Compounds: (VOC’s) 2 Million tons per year

• Thermal pollution is also significant.
Concrete in Society

• Thermal pollution from concrete production is ~ 8 Billion GJ / yr.
• 1 GJ = A lot of Heat
• This is enough heat energy to raise the temperature of 1 million square kilometers of water (1 meter deep) by 1°C / year. (3 feet deep by 2°F / year)
50 Year Life Extension to a 75 Year Old Structure

ICRI Project of the Year
Norcure® Electrochemical Chloride Extraction

Historic Rainbow Bridge
Cascade, ID
Rainbow Bridge Rehabilitation

• 50 year service life extension.
• 1,809 yd$^3$ of concrete were maintained in service.
• Reduced CO$_2$ emissions by ~ 450 tons.
• Prevented the release of 4,800 GJ of heat. (enough heat to boil 3 Olympic Pools)
• Equivalent to annual emissions of 90 people
ICRI Award of Excellence for Concrete Rehabilitation Longevity.

Seven Sister’s Generating Station 1981
Manitoba, Canada
Seven Sisters Rehabilitation

• 40 - 50 year service life extension.
• 38,000 yd$^3$ of concrete were maintained in service.
• Reduced CO$_2$ emissions by 9,500 tons.
• Equivalent to annual emissions of 1,900 people.
Call to Action

• This is Important
• Think about the Reality,
• Accept Responsibility, and
• Take Action
Thank You

Vector Corrosion Technologies

www.vector-corrosion.com
Questions