Galvanic Cathodic Protection of Concrete Structures

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Vector Corrosion Technologies
Concrete Repair Process

Cause & Effect
- Defect, damage or deterioration
  - Leakage
  - Settlement
  - Deflection
  - Wear
  - Spall
  - Disintegration
  - Crack

Repair required?
- Safety
- Structural catastrophe
- Use dysfunction
- Leakage
- Effects on environment
- Aesthetics
- Preventive maintenance

Condition Survey
- Evaluate
- Quantify
- Document

Repair Analysis
- Owner Criteria
  - Urgency
  - Cost
  - Expectations
  - Service life
  - Aesthetics
- Engineering Criteria
  - Structural req.
  - Effect
  - Constructability
  - Environment
  - Safety

Repair Strategy
- Methods
  - Surface repair
  - Stabilization
  - Strengthening
  - Waterproofing
  - Protection
- Materials
- Techniques

Repair
Corrosion Ravaged Bridge Columns
Halo Effect / Patch Accelerated Corrosion
# Levels of Corrosion Protection

<table>
<thead>
<tr>
<th>Cathodic Protection</th>
<th>Highest level of protection intended to stop on-going corrosion activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrosion Control</td>
<td>Significantly reducing or stopping on-going corrosion activity</td>
</tr>
<tr>
<td>Corrosion Prevention (Cathodic Prevention)</td>
<td>Preventing new corrosion activity from initiating</td>
</tr>
</tbody>
</table>
Cathodic Protection

- Address active corrosion
- Reduce corrosion rate to approximately zero
- Typical applied current: 5 to 20 mA/m²
- 100 mV+ potential shift
Corrosion Control

- Address Active Corrosion
- Significantly reduce corrosion rate
- Typical applied current: 1 to 7 mA/m$^2$
- Research has shown that as little as 1 mA/m$^2$ achieved 96% reduction in delamination growth
Corrosion (Cathodic) Prevention

- Mitigate the initiation of corrosion
- Current density required is lower than amount necessary to stop on-going corrosion activity
  - Research has shown that 0.25 to 2 mA/m² is sufficient to prevent corrosion initiation

- New Construction
- Repair
Corrosion Protection

- Current Provided to the Reinforcing Steel
  - Impressed Current Systems
  - Galvanic Systems
- Both Types of Systems can Provide Corrosion Protection to Steel in Concrete
Abutment Repair Detail With Galvanic Protection

Replace Joint Seal

Approach Slab

Existing Bridge Deck

± 6-in SCC Facing

Galvanic Strip Anodes

#5 @ 18” OC EW ECR

#5 ECR Dowels
I-75 Ohio DOT
Forms installed
Completed repair
Kirkwood Road – Monitoring
Protective Current and Temperature
## Kirkwood Road Monitoring

<table>
<thead>
<tr>
<th>Date</th>
<th>Temp</th>
<th>mA/m2</th>
<th>Polarization</th>
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</thead>
<tbody>
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<td>(C)</td>
<td>37.7</td>
<td>(mA)</td>
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<tr>
<td>7/20/05</td>
<td></td>
<td>13.9</td>
<td>346</td>
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<tr>
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</tbody>
</table>
Galvanode® Galvanic Protection System for Concrete Piles in Marine Environment

Robert Moses Causeway
Long Island, NY
Pier 4 - Anode Current Output over Time

- Anode Current (mA)
- Average Temperature (°F)
- Poly. (Pier 4 Current (mA))
Cathodic Protection: Robert Moses Causeway

- Contract Specified Monitoring for 1 Year
- Temperature has varied from -10°C to 25°C.
- Current has varied from 17 to 55 mA.
- Current Density: 4.0 to 12 mA/m².
- Polarization: 128 to 297 mV.
- System meets all CP Criteria.
Pile Cap Repair

- 2,000 meters of pile cap repair
- Remove bottom 20 cm
- Install distributed strip anodes
  - 4 cm x 4 cm x 2.5 m
- Form and Pour Repair
Distributed Anode Strips for Pile Caps
Parking Garage
Bridge Widening
Leister Bridge Cross Beam

- Completed in 1999
- Monitored for 10 years
10 Year Monitoring - Current

![Graph showing current monitoring over 10 years with various curves representing different days and mean values.](image)

- X-axis: Time (days)
- Y-axis: Current (μA)
- Legend: Mean and individual days (1 to 12)
Current Density

• Cathodic Prevention
  – European Standard EN 12696
  – Current Density 0.2-2mA/m$^2$

• Leister Bridge
  – Ranged 0.6 mA/m$^2$ and 3.0 mA/m$^2$
  – Overall mean of around 1.4 mA/m$^2$
Zinc Consumption

- Calculated based on current output and 85% utilization
Forensic Analysis after 10 yrs

(a) Extent of pores containing white corrosion products
(b) Encasing Mortar
Coherent interface
Zinc corrosion product
Bright Zinc substrate (top darker layer scraped off)
Zinc substrate
Uncorroded tie wires
Repair mortar

Anode Connection to Reinforcing Steel
Preventative Galvanic Protection with FRP Strengthening
Galvanic Anodes in New Construction

- General Protection
- Targeted protection
  - High chloride exposure
  - Critical structural elements
  - Construction joints
Catano Ferry Terminal

• First Green Building in Puerto Rico as certified by as LEED
• 2nd ferry terminal in the USA certified by LEED
• Construction Complete 2012

• $22.5 million ferry terminal in Catano
• Replace the existing 35 year old terminal
• 4,600 passengers daily
Catano Ferry Terminal

- Galvanic Anodes used for Cathodic Prevention
- Piles
- Beams
- Columns
Summary

• Large Range of Corrosion Mitigation Options Available

• Mitigation Strategies can be
  – Global, Targeted, or Localized

• System Selection
  – Existing Condition, Exposure Conditions, Service Life Required, Budget, and Maintenance Considerations