Bridge Preservation: Evaluation, Repair and Protection

Webinar Wednesday Series

We Save Structures™
The Concrete Preservation Alliance is a growing coalition of organizations committed to advancing best practices in the field of concrete preservation and infrastructure renewal.

Working together to promote education and awareness of concrete repair industry standards, new and innovative corrosion prevention technologies and sustainable construction practices.

WeSaveStructures.info
OUR MEMBERS

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Concrete & Geophysical Testing
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The construction industry is the largest user of resources and raw materials.

Approx. 40% of solid waste comes from construction and demolition.

Making new structures last longer and the rehabilitation and reuse of existing structures saves money compared to the cost of premature failure, demolition and rebuilding.

In addition to economic benefits, repairing and extending the service life of structures reduces the consumption of natural resources, pollution and construction waste.

https://www.wesavestructures.info/environmental-impact-calculator
Chris Ball

Chris Ball is Senior Vice President of Sales and Marketing for Vector Corrosion Technologies, a leading provider of solutions to preserve and extend the service life of concrete structures.

Chris has over 20 years of construction industry experience with a specialty in concrete rehabilitation and corrosion protection systems. He is a member of NACE, ICRI, and ACI where he is currently Chairman of ACI E706, Concrete Repair Education.
Repair & Protection of Severely Corroded Bridge Substructures with Galvanic Encasements

- Substructure preservation and accelerated bridge construction
- Abutments, beam and column protection with galvanic encasements
Corrosion Cell in Concrete

\[ \text{Fe} \rightarrow \text{Fe}^{2+} + 2e^- \]

\[ \text{Fe}^{2+} + 2\text{Cl}^- \rightarrow \text{FeCl}_2 \]

\[ \text{Fe}^{2+} + 2\text{Cl}^- \rightarrow \text{FeCl}_2 \]

\[ 2\text{Fe(OH)}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{Fe}_2\text{O}_3 + 2\text{H}_2\text{O} \]

\[ \frac{1}{2}\text{O}_2 + \text{H}_2\text{O} + 2e^- \rightarrow 2\text{OH}^- \]

\[ 2\text{OH}^- \rightarrow \text{FeCl}_2 + 2\text{OH}^- \]

Anode

Cathode
Corrosion of Steel in Concrete
Interface of New/Old Concrete

Chloride Contaminated Concrete

1. $\text{Fe} \rightarrow \text{Fe}^{2+} + 2e^-$
2. $\text{Fe}^{2+} + 2\text{Cl}^- \rightarrow \text{FeCl}_2$
3. $\text{FeCl}_2 + 2\text{OH}^- \rightarrow \text{Fe(OH)}_2 + 2\text{Cl}^-$
4. $2\text{Fe(OH)}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{Fe}_2\text{O}_3 + 2\text{H}_2\text{O}$

Chloride-Free Patch

1. $\frac{1}{2}\text{O}_2 + \text{H}_2\text{O} + 2e^- \rightarrow 2\text{OH}^-$

Anode $\rightarrow 2e^- \rightarrow$ Cathode
Corrosion Protection Options

- Electrochemical Chloride Extraction
- Impressed Current Cathodic Protection
- Localized Protection
  - Type 1 anodes around repairs
  - Distributed anodes in joint repairs or joint eliminations
- Targeted Protection
  - Areas of corrosion risk
  - Type 2 anodes or Fusion Technology
- Galvanic Cathodic Protection
  - Galvanic Encasements and Overlays
  - Arc Spray Zinc Metalizing

Rainbow Bridge, Idaho
Electrochemical Chloride Extraction
ICRI 2007 Project of the Year
Galvanic Series

Electrochemical Cell
## Galvanic Protection in Concrete

### Partial Galvanic Series

<table>
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<th>Metal</th>
<th>Voltage</th>
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<tr>
<td>Zinc</td>
<td>-1100 mV</td>
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<td>Steel in concrete</td>
<td>-200 mV to -500 mV</td>
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*Typical potentials measured with respect to copper-copper sulfate electrode

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![Diagram showing galvanic protection in concrete](image)
Zinc Activation Technology

**Alkali Activated**

- Bare zinc anodes in concrete will be extremely passive.
- Create high pH environment around the zinc anodes.
- High pH is corrosive to zinc but not to steel like chloride or bromide.
- Allows zinc anodes to remain active and provide protection to reinforced concrete over time.
The Original Embedded Galvanic Anode
Circa 1999
Embedded Galvanic Anode

Chloride Contaminated Concrete
-350 mV

Chloride-Free Patch
-200 mV

-1100 mV

Anode Galvanically Protects Surrounding Rebar
Type 1 Anodes – Extend the Life of Repairs
Other Applications for Type 1 Anodes

Bridge Widening

New Construction
Corrosion Control Anodes in Sound Concrete
Circa 2001

Precast Box Beam Protection
Galvanic Cathodic Protection

- Distributed Anode Systems
- Global or Large Area Protection
- Higher Current Density
- Long Life 20-40+ years

Galvanic Encasement with Distributed Anodes
Distributed Galvanic Anodes
Circa 2003

Bridge Deck Overlay
Global Protection

Plaza Deck Overlay
High Potential Areas Only
MTO Galvanic Bridge Deck Overlay (2003)
MTO Bridge Deck Overlay

- Most recent data collected was in July 2020.
- Steel is cathodically protected.
- Current density is still greater than 1 mA/m² after almost 17 years.

<table>
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<tr>
<th>Date</th>
<th>Temp C / F</th>
<th>Current (mA)</th>
<th>Current/m² (mA/m²)</th>
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</table>
Pile Cap Repair
Circa 2005

Form and Pour Repairs with Distributed Anodes

Beam Condition in 2017
Slab Bridges in Ohio
Options and Previous Repair Practices

- Do Nothing
  - Not a feasible alternative for deficient bridges on the interstate system
- Repair bridge
  - With appropriate repair, most of these bridges have remaining service life
- Replace bridge
  - Not cost-effective to remove a good slab

- Repair Practices
  - Slab would be temporarily supported
  - Abutments would be replaced
  - Requires closure or part-width construction
Early Repair with Discrete Anodes
Galvanic Encasement of ODOT Abutment
Circa 2005

- Replace Joint Seal
- Approach Slab
- Existing Bridge Deck
- ± 6-in SCC Facing
- Distributed Galvanic Anodes
- #5 @ 18" OC EW ECR
- #5 ECR Dowels
Spall removal
Dowels and anodes installed
Anodes wired together and to reinforcing
Anodes wired for monitoring
Monitoring station
Forms installed
SCC Pumping Port
Forms removed
Completed Repair

2005

2020
Galvanic Anode Monitoring

- Data logger installed in junction box
  - Measurements taken every 4 hours
    - Anode Current Output
    - Internal and Ambient Temperatures
- Corrosion potentials and depolarization data collected on periodic site visits
  - Surface readings with copper-copper sulfate reference electrode
- Information used to determine level of protection and estimate anode service life
Current & Temperature Monitoring

Note:
Gaps in data record are a result of battery or data recorder failure.
# 15 Year Performance Summary

<table>
<thead>
<tr>
<th>Date</th>
<th>Temperature, degree C</th>
<th>Instant Off $E_{\text{OFF}}$, mV</th>
<th>Anode Current $I_{cp}$, mA/m²</th>
<th>Polarization, $E_{\text{pol}}$, mV</th>
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</table>

- Current demand varies with temperature and is generally decreasing over time
- Instant off $< -850$ mV
- Greater than $100$ mV off potential vs native
- $> 35$ year estimated anode service life
- Structure is Cathodically Protected
Accelerated Bridge Construction Island Park Bridge
Island Park Bridge Abutment Encasement
After the Abutments were Repaired, the Superstructure was Removed and Replaced Overnight
Highway 417 Kirkwood Ave Overpass DAS Monitoring

Reading interval: one hour
2m Long Anodes: 8 pieces
Area: 8m²

Total Readings: 55872
Average Readings: 2.37mV = 2.37mA
George N. Wade Memorial Bridge

- Carries I-81 and the Capital Beltway across the Susquehanna River in Harrisburg, Pennsylvania
- 5,188 feet (1,581 m) long
- Construction completed in early 1970’s
- $42 million Repair Project from 2009-2012
Concrete Deterioration

- Pier caps were repaired, protected and strengthened using galvanic encasements.

- Columns and abutments were protected using arc spray zinc metalizing with humectant
Distributed Anodes and Additional Steel Installed Around Pier Cap
Galvanic Encasement and Concrete Forms
Surface Preparation and Installation of Activated Arc Spray Zinc
Frederick G. Gardiner Expressway

- Built in late 1950s in Toronto, Ontario
- 6-lane, 6.8 kilometers (4.2 mi), elevated expressway
- The elevated section is supported by reinforced concrete columns. The concrete deck was constructed on steel girders or concrete girders.
- De-icing salt caused severe corrosion of the reinforcing steel within the concrete piers (vertical columns and horizontal pier caps), which expanded, weakening the steel and causing pieces of concrete to dislodge.
Severe Corrosion Damage

Toronto

Falling concrete on the Gardiner is often from trucks, not the aging highway

City numbers show only 25% of 86 cases of falling concrete were from the Gardiner

Nicole Martin - CBC News - Posted: Jun 06, 2017 12:11 PM ET | Last Updated: June 6, 2017

Chunk of concrete that fell from the Gardiner Expressway (City of Toronto)
Gardiner Expressway Strategic Rehabilitation

- The City’s first project as part of the Gardiner Expressway Strategic Rehabilitation Plan will:
  - Rehabilitate the westbound off-ramp leading to Yonge, Bay and York Streets,
  - Replace the entire concrete deck and steel girders of the Expressway between Jarvis Street and Cherry Street, and
  - Replace the westbound off-ramp at Sherbourne Street and the eastbound on-ramp at Jarvis Street.

- This rehabilitation plan will:
  - Rehabilitate and protect the substructures from Jarvis to Cherry St. to support the brand-new superstructure.
  - Replace the concrete deck and steel girders superstructure using Accelerated Bridge Construction techniques
Gardiner Pier Rehabilitation Plan

• To implement city’s strategic rehabilitation plan successfully, the piers are repaired, strengthened and protected with galvanic encasement.
• The pier repairs were to match the service life of the new bridge deck.
• A galvanic encasement was used to repair and provide corrosion protection to the deteriorated substructure components (columns and pier caps).
• Specifications required the galvanic cathodic protection supplier to design and install a system based on long-term field performance data for galvanic anodes in a similar environment.
• Anode size and spacing was designed to protect all reinforcing steel in each pier for the specified service life requirements.
Galvanic Encasement Plan

NEW REFACING

GALVANIC CORROSION PROTECTION SYSTEM UNITS (33mm DIA. DISTRIBUTED ANODE SYSTEM), SPACING TO BE DETERMINED BY DESIGNER (TYP.)

LIMITS OF CONCRETE REMOVAL

1370 ±
Gardiner Expressway

Galvanic Encasement of Piers to Extend Life of Substructure
Gardiner Expressway Pier Rehabilitation

- 25+ year service life extension.
- 53,865 m³ of concrete was maintained in service.
- Reduced potential CO₂ emissions by 35,000 metric tons, the annual equivalent 8,726 people.
- Prevented the generation of 130,000 metric tons of solid waste.
- Saved 1.8 million gallons of potable water, the daily usage of 17,000 people.

Approximate values estimated by the WeSaveStructures.Info Environmental Impact Calculator at https://www.wesavestructures.info/environmental-impact-calculator
Florida DOT
Galvanic Encasement (Above High Tide)
Florida DOT
Galvanic Encasement (Above Tide)
FRP or PVC
Stay-in-place Forming Systems

Preformed FRP Jackets

Modular PVC Forms
## Florida Keys Column Encasement

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<th>mA</th>
<th>On (mV)</th>
<th>Off (mV)</th>
<th>Pol. (mV)</th>
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<td>-679</td>
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Conclusions

Galvanic encasements are an option to save severely damaged bridge substructures.

The galvanic encasement is a one-step repair and protection option that can also incorporate additional reinforcement.

The protection is provided by alkali-activated discrete anodes.

Alkali-activated discrete anodes installed in early 2000’s are providing cathodic protection to with an estimated service life of 20-40+ years.
IN ADDITION TO SHORTENING CONSTRUCTION TIME AND REDUCED DISRUPTION TO THE PUBLIC, WE USE LESS CONCRETE AND OTHER CONSTRUCTION MATERIALS BY EXTENDING THE SERVICE LIFE OF EXISTING STRUCTURES.

THIS IS A CHALLENGE, BUT IT IS POSSIBLE IF WE MAKE IT A PRIORITY.
QUESTIONS?
Contact Chris

Chris Ball
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Frankfort, KY

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chrisb@vector-corrosion.com
Nov 11, 2020 | Pile Protection for Coastal Bridges  
Jason Chadachek  
Vector Corrosion Technologies  
Description: Marine environments are among the most corrosive exposure conditions for reinforced concrete or steel structures. Tidal action and salt water splashing on piles creates ideal conditions for corrosion and the effects can wreak havoc on marine structures of all kinds. While the marine environment presents significant challenges for service life, there are proven methods of extending the life of both concrete and steel piles in fresh, brackish and even salt water. This webinar will compare the various marine pile protection options available today and explore methods of evaluating and protecting steel sheet piles.  
Click Here to Register - 7:00 AM EST / 1:00 PM CEST  
Click Here to Register - 2:00 PM EST / 11:00 AM PDT

Dec 9, 2020 | Targeted Proactive Corrosion Protection for Bridges with Embedded Galvanic Anodes  
David Simpson, ICCor Level IV Senior Cathodic Protection Engineer  
Vector Corrosion Technologies  
Description: Corrosion potential surveys have long been an effective non-destructive method of quantifying corrosion risk and locating “hot spots” in concrete structures before repairs are required. High corrosion risk areas can be proactively targeted using embedded galvanic anodes to halt corrosion before the active corrosion causes concrete failure and a need for repair. This webinar will discuss this proactive approach in detail and introduce an innovative “two-phase” anode technology combining the benefits of both impressed current and galvanic protection in a single unit.  
Click Here to Register - 7:00 AM EST / 1:00 PM CEST  
Click Here to Register - 2:00 PM EST / 11:00 AM PDT
WESAVESTRUCTURES.INFO