Impressed Current Cathodic Protection

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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.

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Matt Miltenberger, P.E.
Cathodic Protection Specialist

Matt Miltenberger is the Vice President of VCS, is a licensed professional engineer in 12 states and is a NACE certified cathodic protection specialist. He has over 35 years experience in concrete the concrete industry. His areas of expertise include concrete evaluation, concrete materials, service life modeling and corrosion mitigation.

Matt started his career in commercial construction in the 1980's, worked as a materials specialist trainee for the FHWA, as a research engineer for Master Builders Technologies, as a concrete durability consultant for TCG, and now conducts concrete rehabilitation and corrosion mitigation design as a CP specialist for VCS.

Today Matt will be talking about the use of impressed current cathodic protection to extend the life of concrete infrastructure.

VCS VECTOR CORROSION SERVICES

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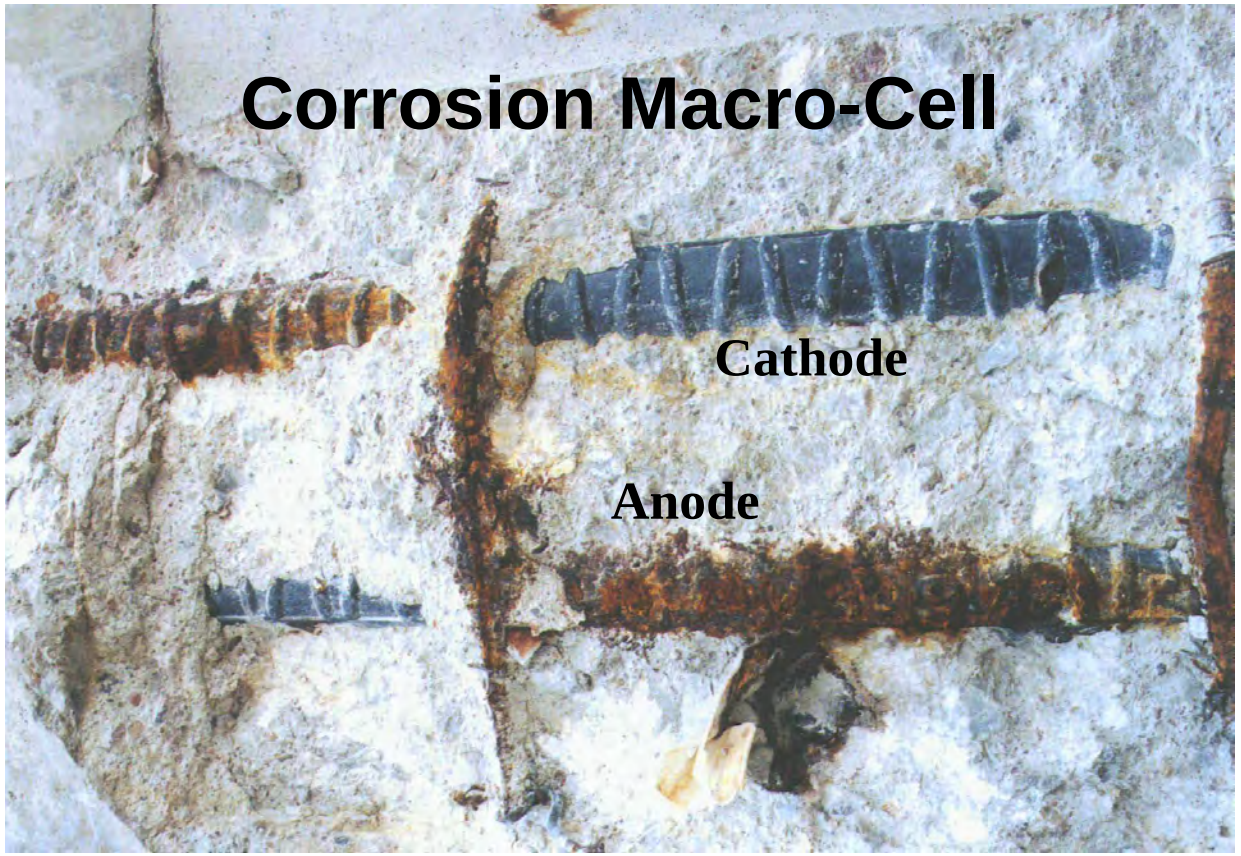
Learning Objectives

- Brief history of Cathodic Protection on Concrete Bridges
- Corrosion Basics
- Understand the differences between impressed current and galvanic cathodic protection systems
- Identify modern ICCP system types and applications



Corrosion Protection Systems

Galvanic Corrosion Protection	Uses sacrificial metal anodes to provide galvanic current to the steel Minimal maintenance (low-voltage battery)
Impressed Current Cathodic Protection	Use an external power supply and inert anodes to distribute DC current to the steel Annual maintenance / monitoring required (adjustable power)
Electrochemical Treatments	Change the chemistry of the concrete around the steel to facilitate passivation Long-term low-maintenance solution Protect against recontamination

Corrosion Basics

A – anode

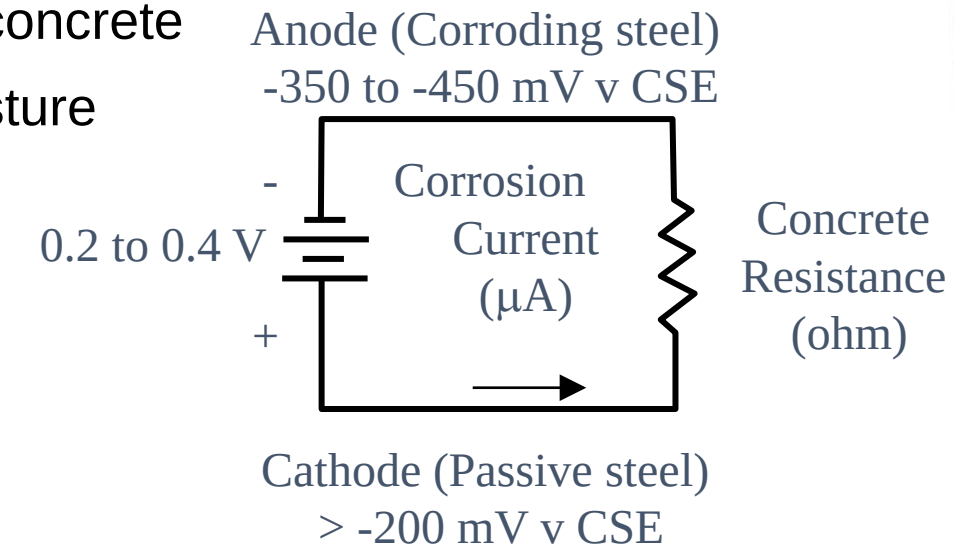
C – cathode

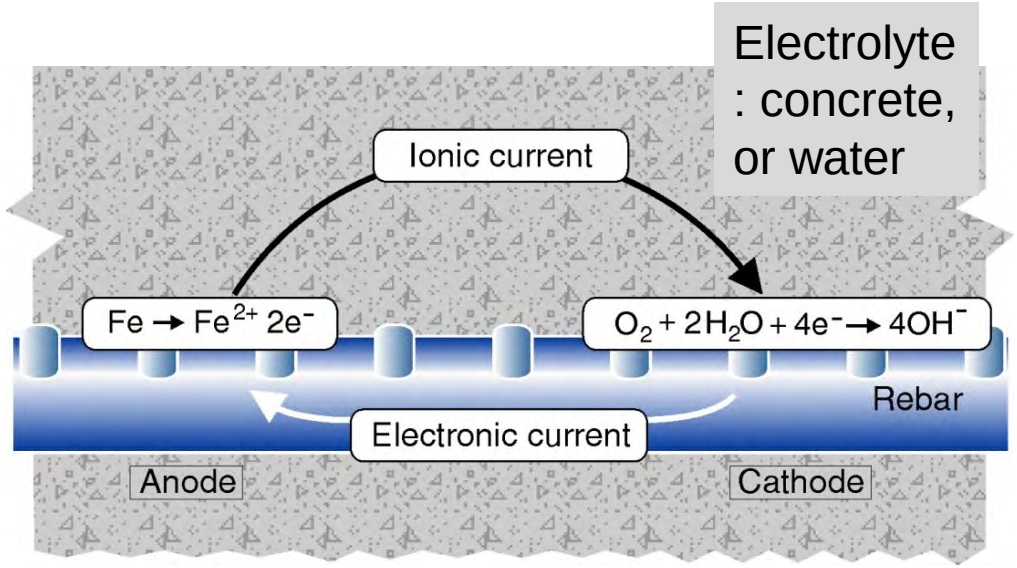
M – metallic path

E – electrolytic path

Corrosion Circuit

- **A**node – Location where rust is formed
- **C**athode – Location with no section loss
- **M**etallic path – steel
- **E**lectrolyte – concrete
- Requires Moisture



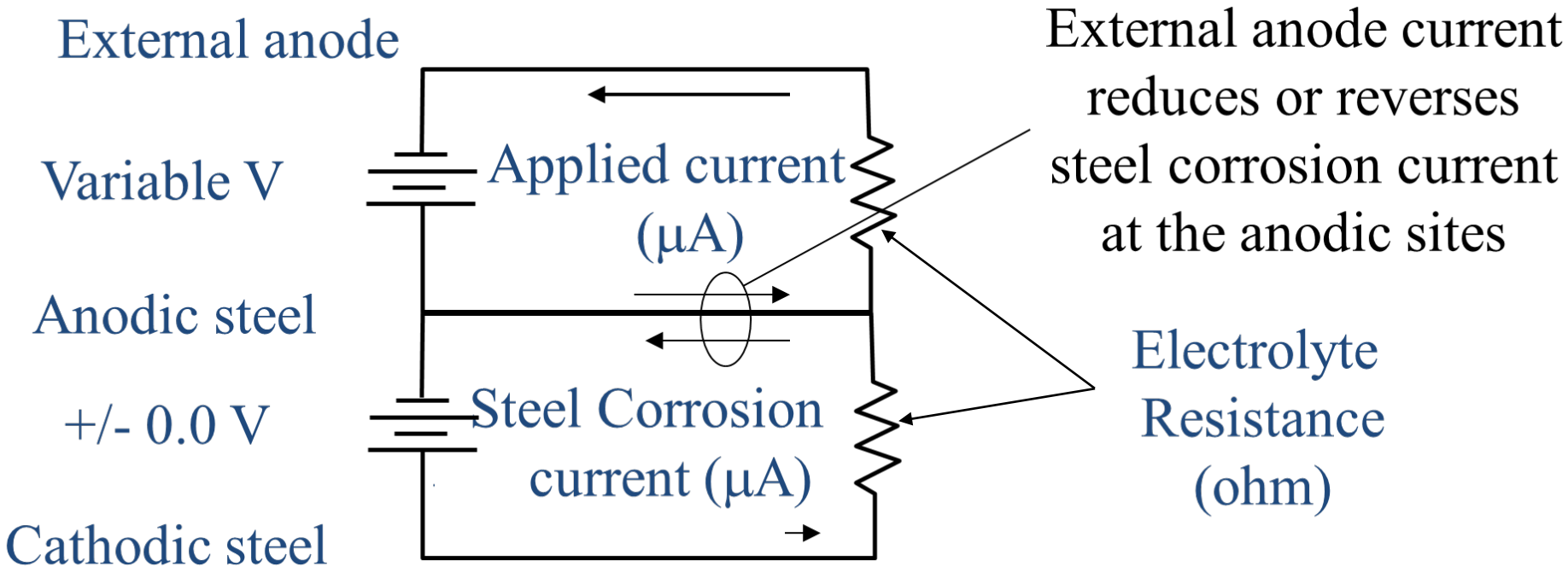


V = IR
Driving voltage is ~constant, so
Lower resistance, R, = Higher current, I

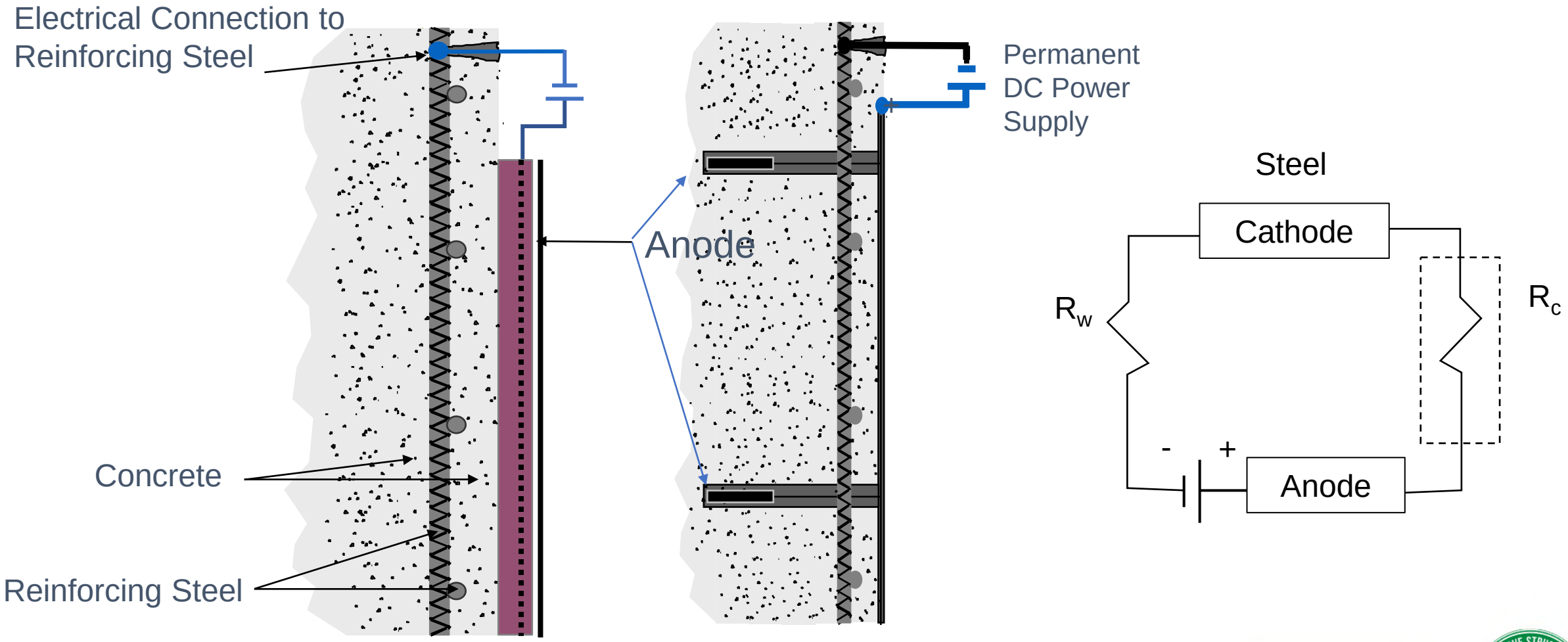
What is Cathodic Protection?

- Cathodic protection (CP)
  - is corrosion control through the application of direct current **onto** a metal, forcing it to become a cathode
  - The **anode** delivers current into the electrolyte (metal loss, rust occurs at the anode)
  - The **cathode** receives current from the electrolyte (The cathode is protected from section loss)
- Two main types of CP
  - Galvanic
  - Impressed current

Cathodic Protection Circuit



Cathodic Protection Circuit



ICCP Early Years

- FHWA Experimentation
- Conductive Paint
- Conductive Overlay
- Slot Systems
  - Conductive Polymer
  - Ribbon MMO in grout

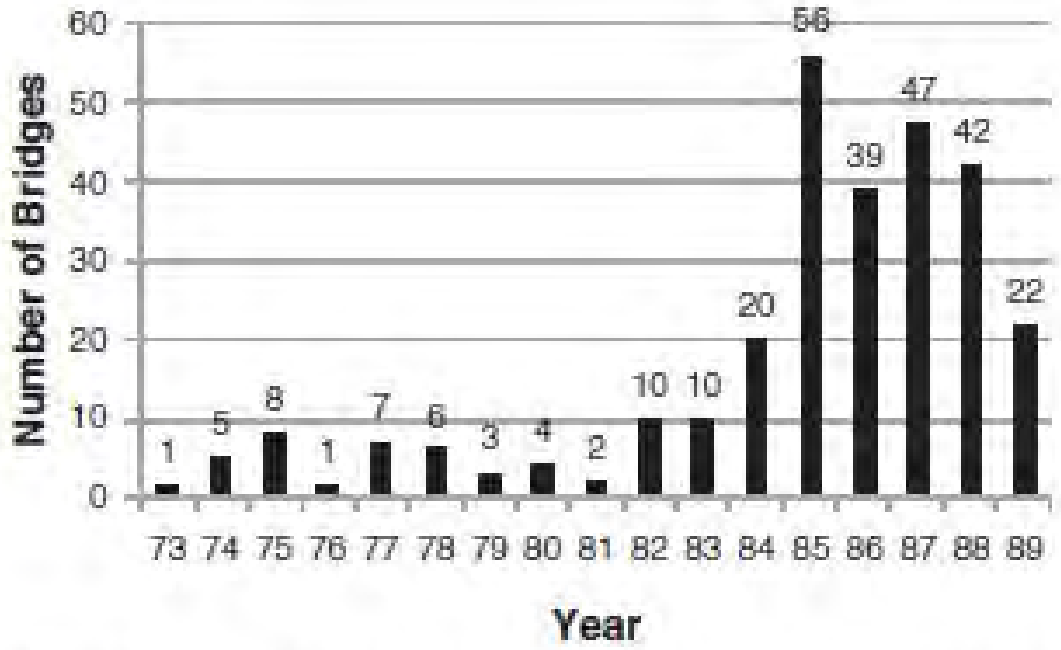
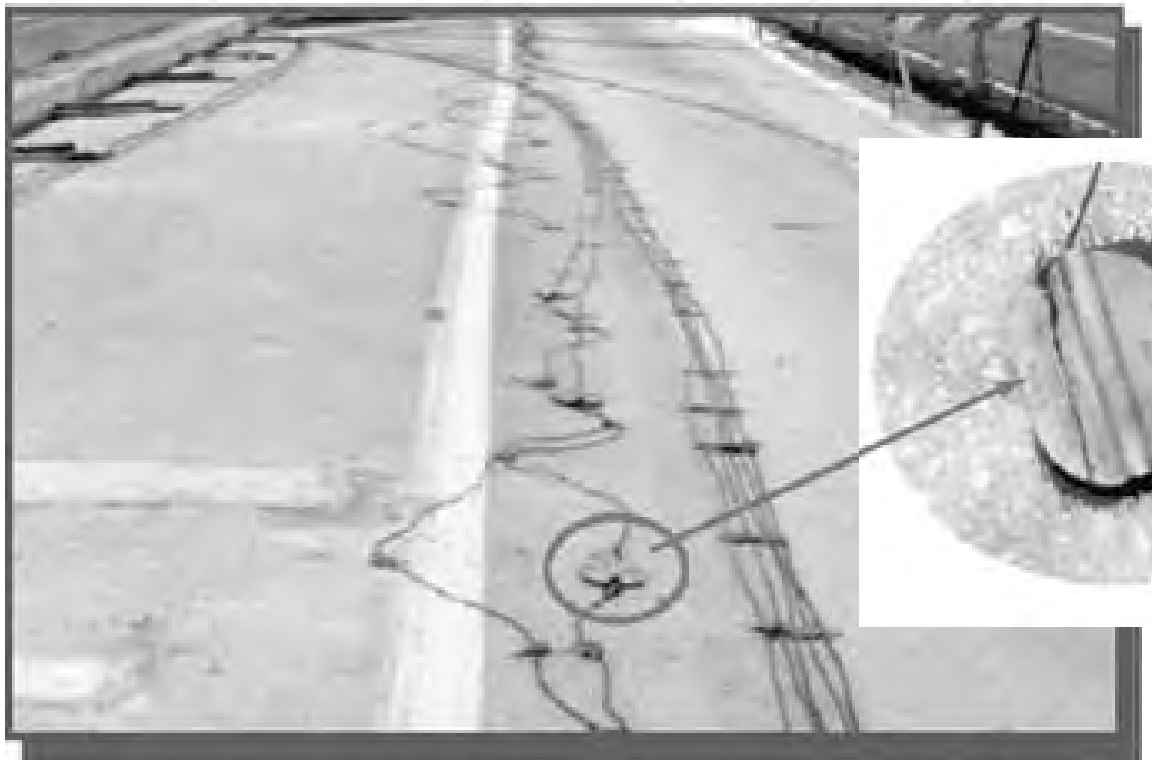


FIGURE 20 Number of cathodic protection system installations per year (1973–1989).

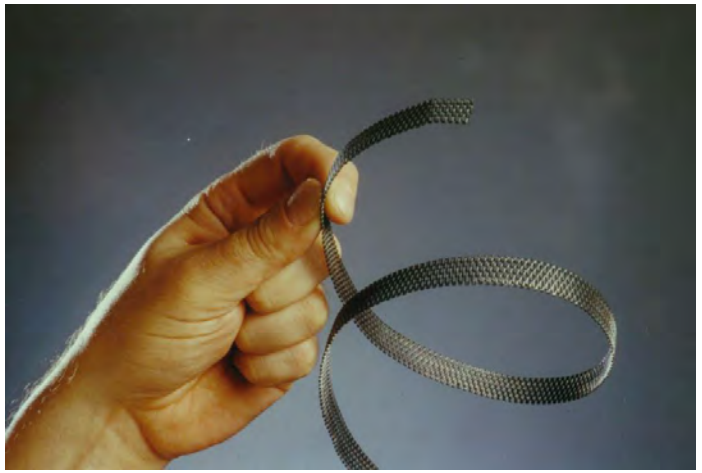
NCHRP Synthesis 389 – Cathodic Protection for Life Extension of Existing Reinforced Concrete Bridge Elements, 2009

Pancake Anode with Conductive Asphalt



Lessons Learned

Slot Systems



Slot Systems

- Initially, systems used titanium wire anodes in conductive polymer grout.
- Systems were effective but failed due to installation defects.
- Improper design, anode placement, and grouting techniques caused localized acidification.
- Wiring connection failures
- Small zones increase driving voltage

Lessons Learned

- Proper design, installation and maintenance is required for long-term effectiveness
  - Lightning strikes
  - Vandalism
- Inert anode materials required
  - Longer life
  - Acidification of grout/concrete
  - MMO coated titanium
  - Ceramic
- Wiring connections are weak link
- Anode current density limited by acid generation
- Concrete corrosion protection can be achieved at lower current density than pipelines
- ICCP can repassivate reinforcing steel
- Potential hydrogen embrittlement for PT steels if not controlled properly

Criteria / Standards

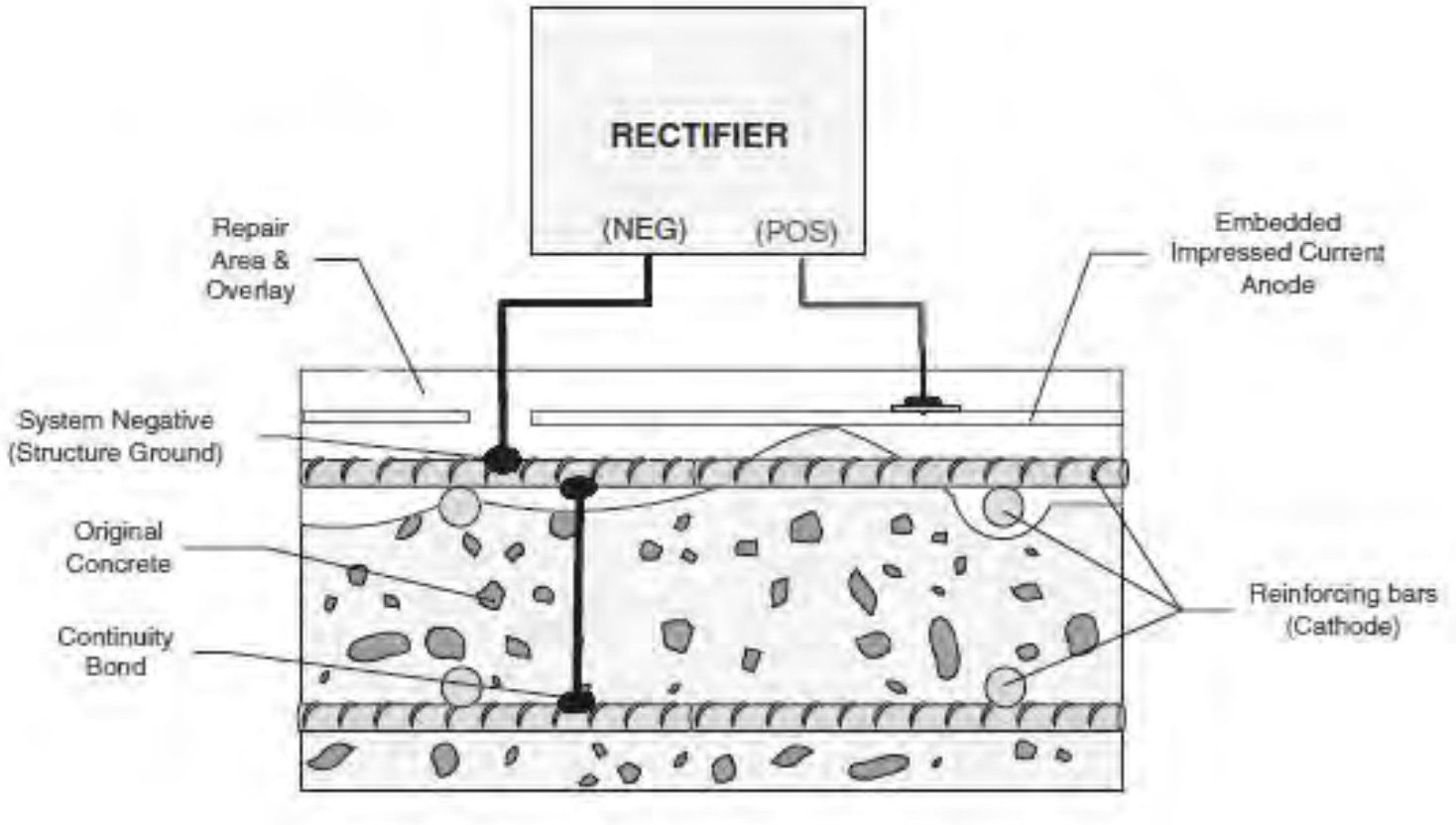
- NACE SP0290 “Impressed Current Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures”
- NACE SP0408 “Cathodic Protection of Reinforcing Steel in Buried or Submerged Concrete Structures”
- DNVGL-RP-B401 “Cathodic Protection Design” (Marine Structures)
- BS EN ISO 12696 “ Cathodic protection of steel in concrete”
- BS EN ISO 13174 “ Cathodic protection of harbour installations”

Criteria / Standards

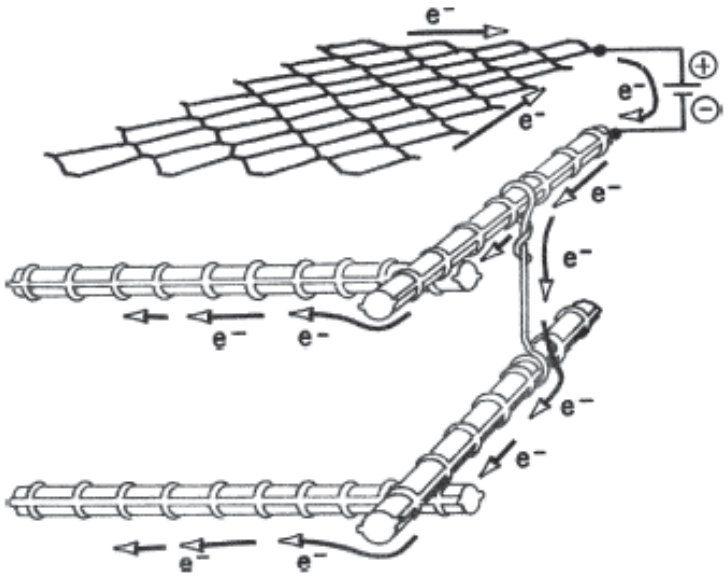
- > -200 mV CSE (passive steel)
- < -850 mV CSE (full cathodic polarization)
  - After reconsideration of IR drop between structure and reference
  - Or interrupted current (instant off potential)
- 100 mV Polarization
  - Difference between native and polarized potential

Modern Bridge Deck Systems

- Normally used in accessible, high volume, high corrosion risk areas.
- Candidate decks are sound with deep chloride penetration
- Overlay, slot, and soffit systems
- Wiring can be susceptible to vandalism
- Global solution
- Current distribution
  - Top mat 70% to 75% of current
- 1-2 mA/SF (10 to 20 mA/m^2) cathode current density
- 110 mA/SF (1.2A/m^2) anode current density



MMO Overlay System



MMO Overlay System

- Hydro-demolition surface preparation
- Patch delaminations
- Verify rebar continuity
- Install reference electrodes and structure connections
- Locate wiring ports to conduit below deck

Overlay System Wiring

- Reference electrodes:
  - Required for system monitoring
  - 2 to 4 per zone
  - Install at anodic area or pre-defined location

Overlay System Wiring

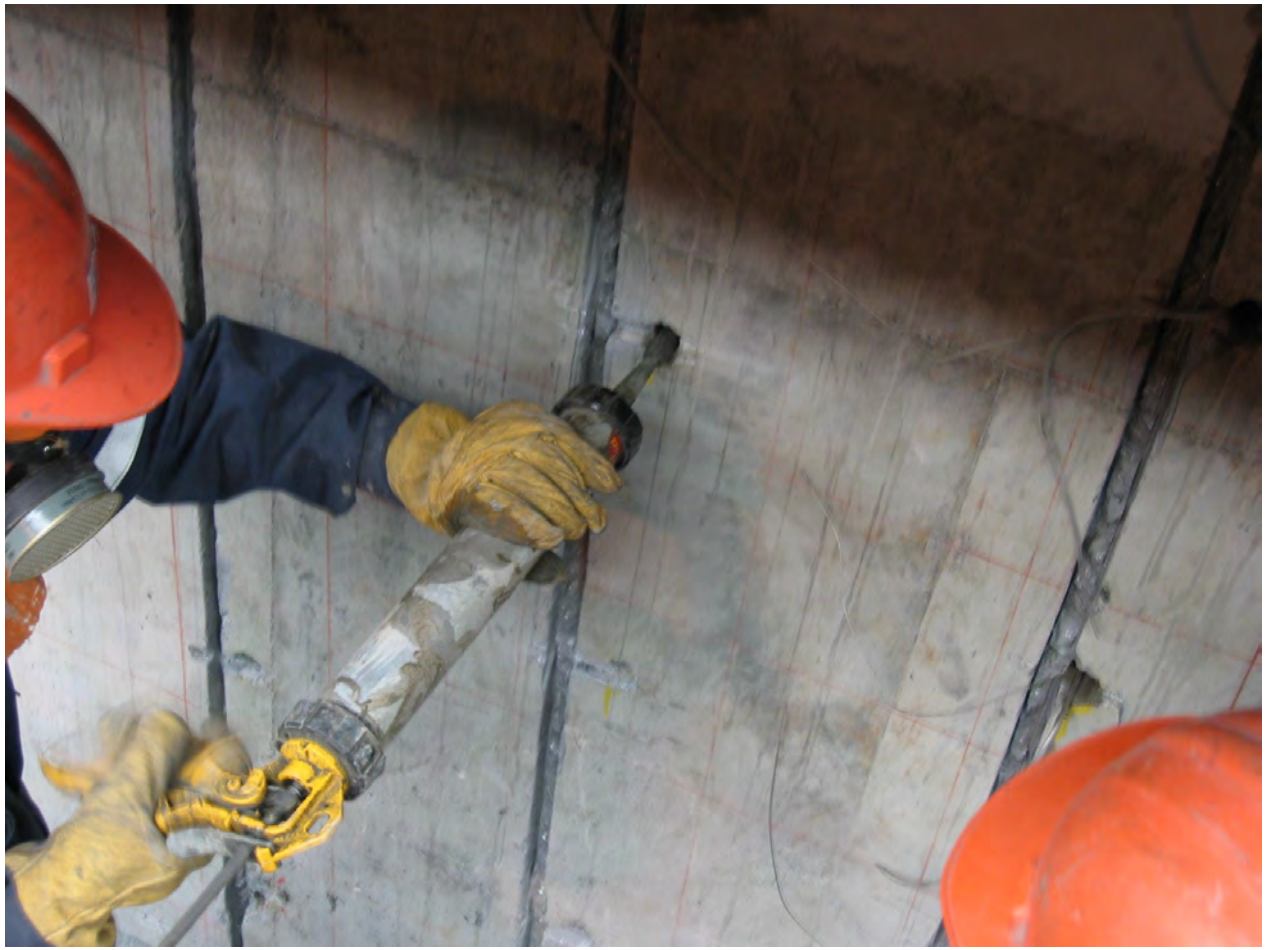
- Structure connections for:
  - Rectifier connection
  - Reference electrode
- Wiring runs in conduit mounted below slab to rectifier(s)

Overlay System Wiring

MMO Overlay System

- High pressure (10,000 PSI) surface clean prior to installation
- Anode rolls installed longitudinally on the bridge
- 6” gap between mesh rows, and any permanent metal items
- Plastic anchors 1 to 2 ft OC
- Low pressure surface clean post-mesh install (3000 psi)
- Transverse conductor bars distribute current to rolls.

Substructure Applications



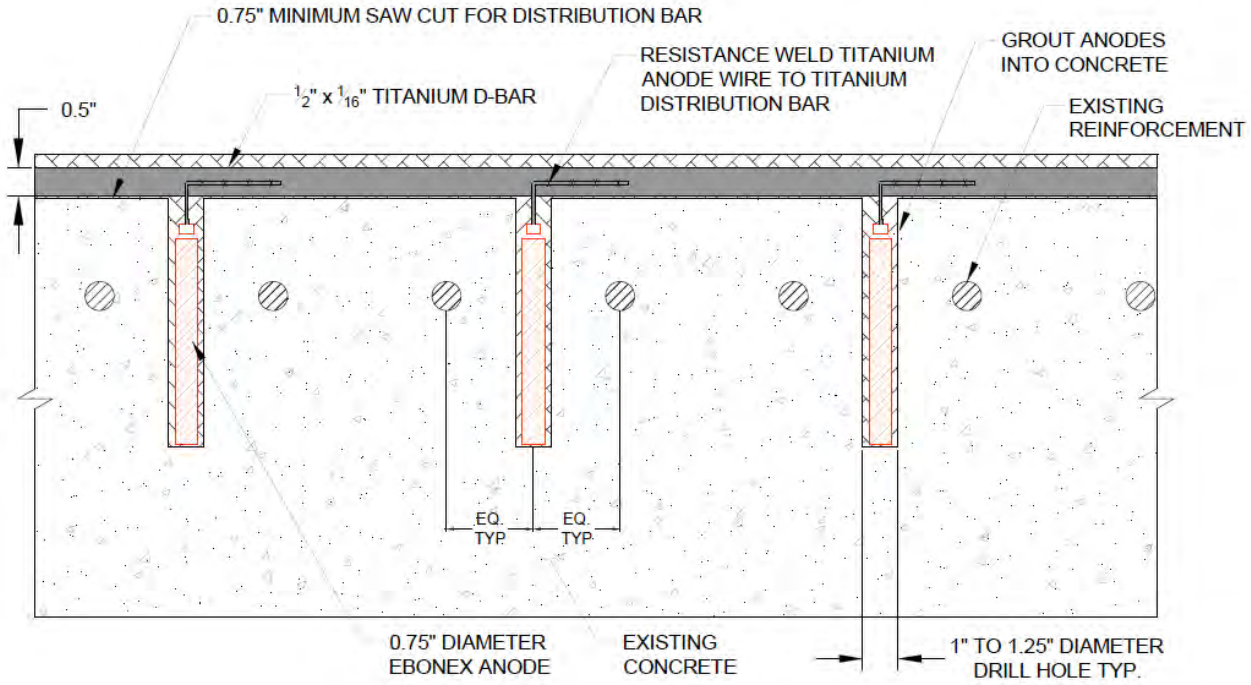
MMO Mesh Anode

MMO Mesh Anode

Discrete Ceramic Anode System

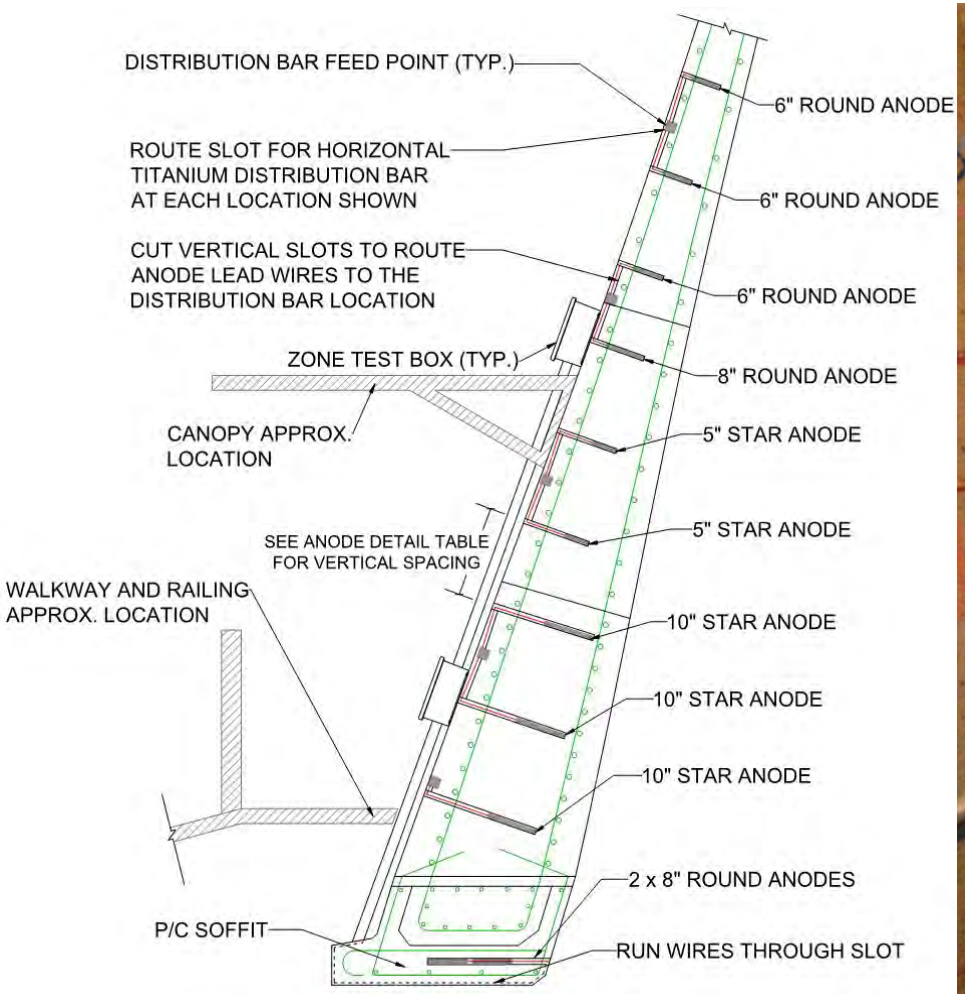
- Drill and grout system for columns and beams.
- Embedded anode distributes current evenly to all reinforcement layers
- Titanium current distribution bars embedded in grout or epoxy are very durable.
- Elements can be coated afterward if required aesthetically (vent tube)

Discrete Anode Installation



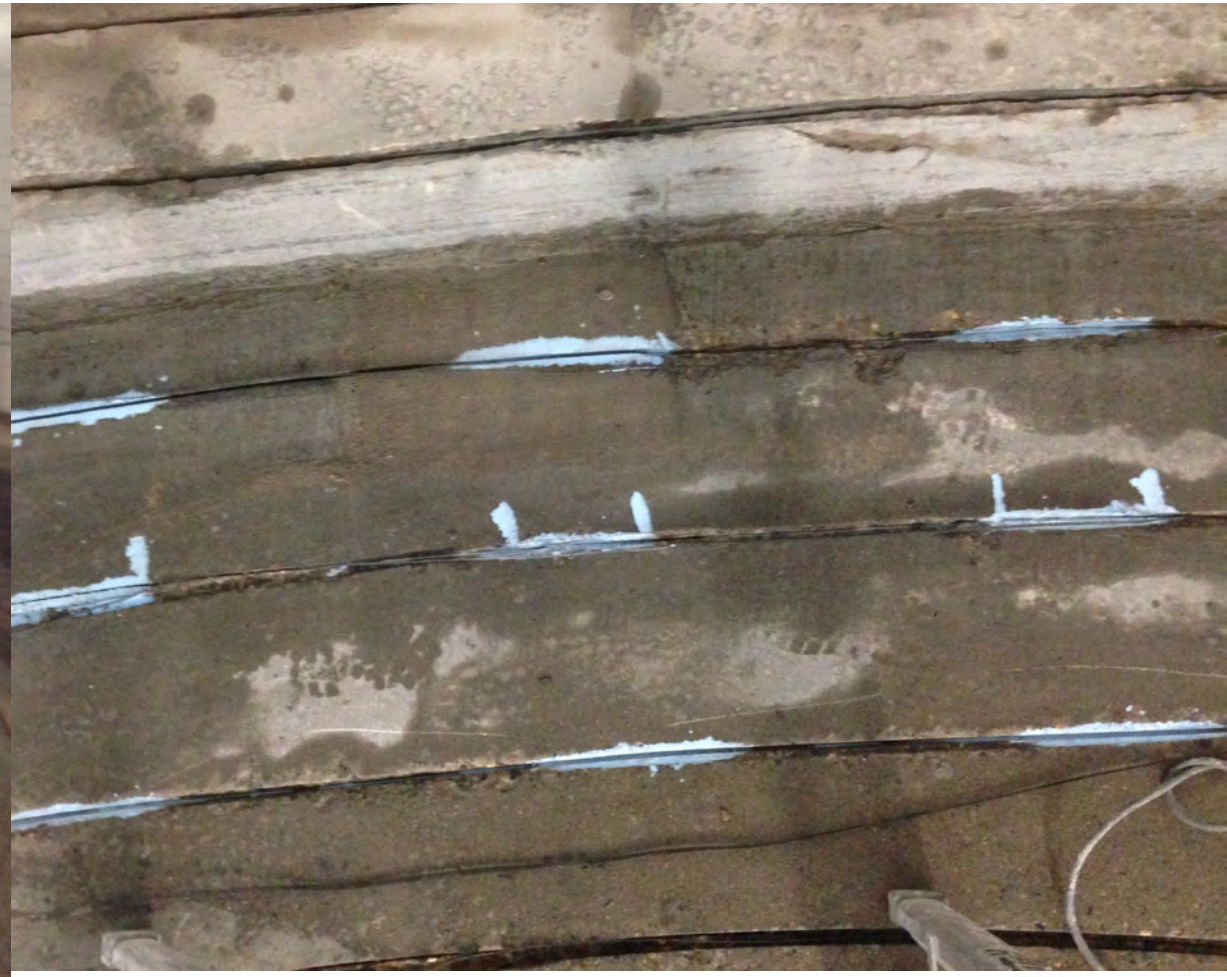
SECTION OF ANODE INSTALLATION

Discrete Anode Installation



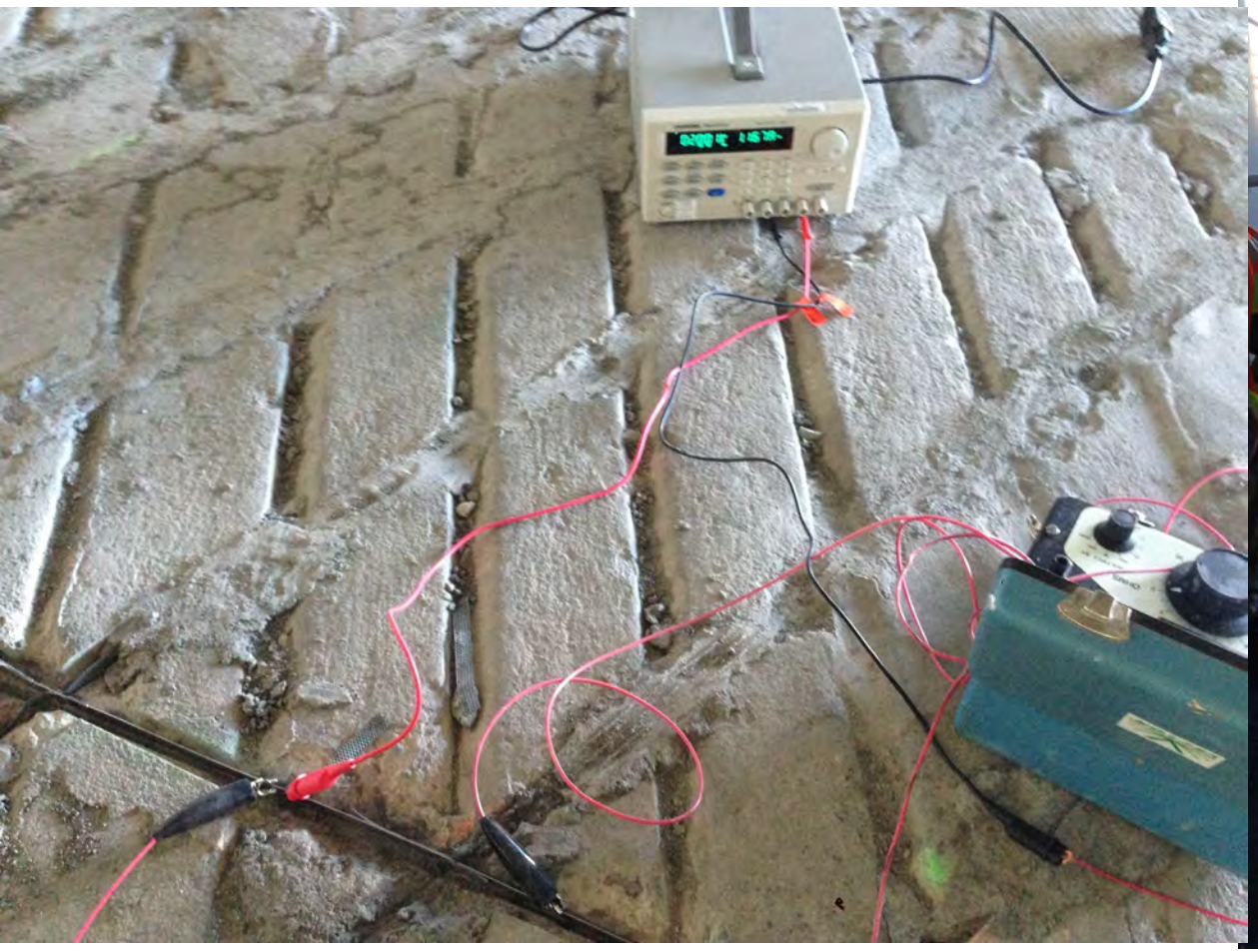
Discrete Anode Installation

MMO Ribbon Anode Slot System



MMO Ribbon Anode Slot System

MMO Ribbon Anode Slot System



MMO Ribbon Anode Application

- Ribbon anode was used to prevent corrosion of large plate transfer girders cast in flowable fill over the Big Dig tunnels in Boston.
- An apartment building was built over the tunnel on top of the girders.
- Corrosion prevention application 75+ yr system.

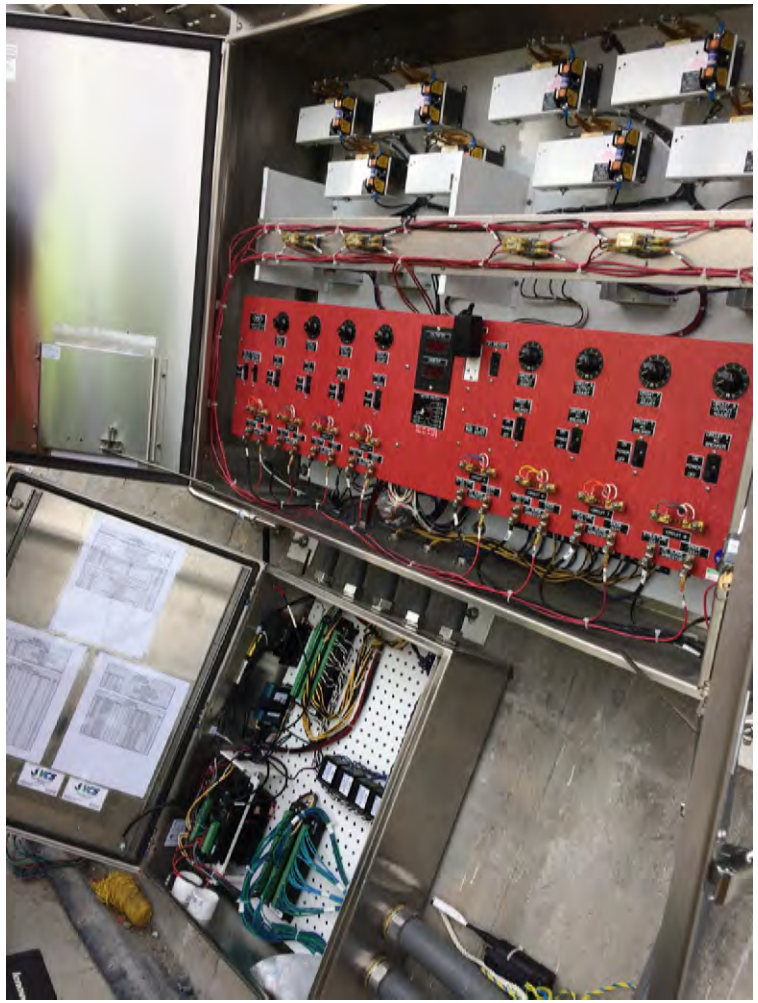
MMO Ribbon Anode Application

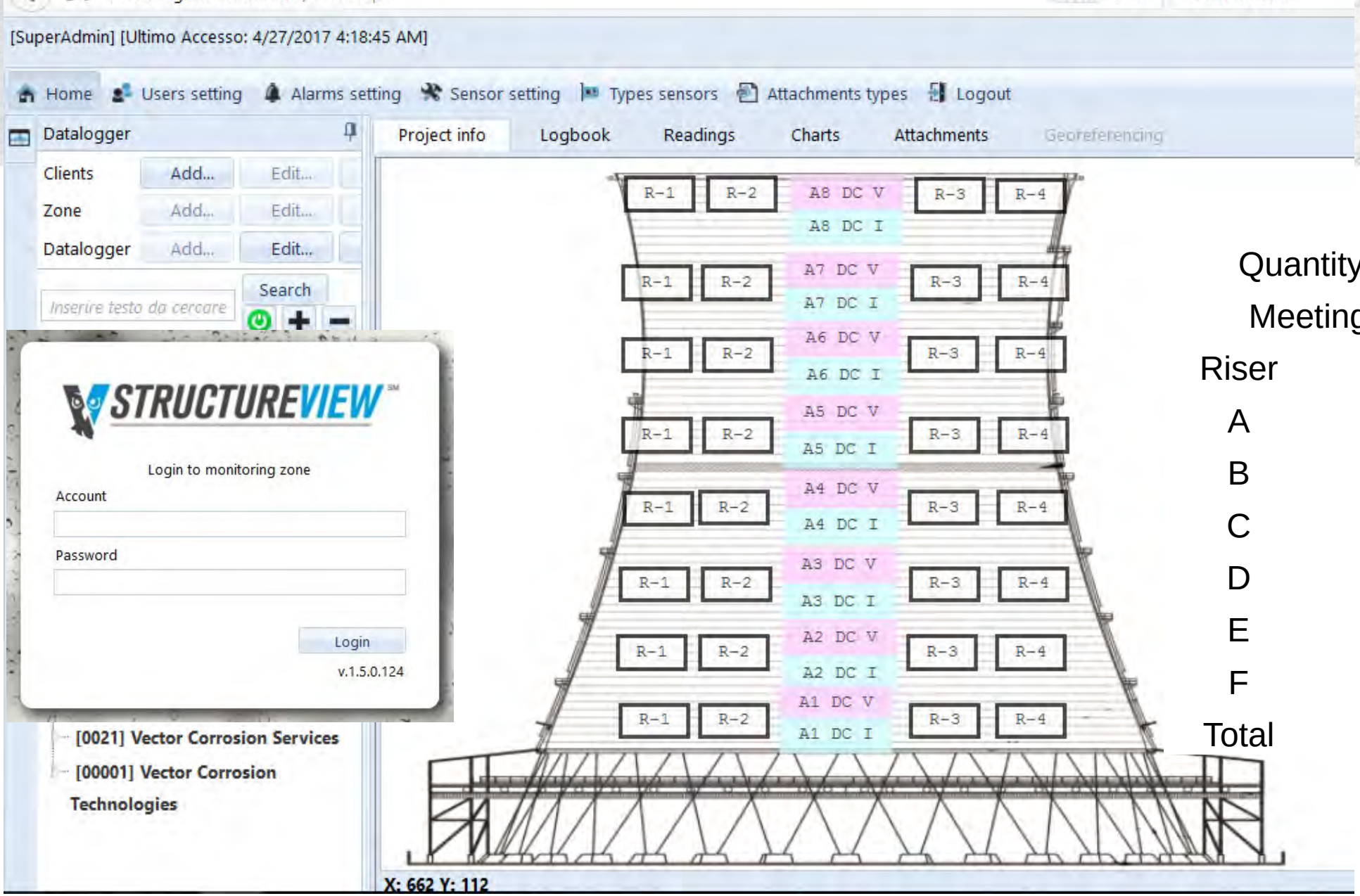
MMO Ribbon Anode in New Construction

- Ribbon anode can be used in new construction for aggressive applications
- Care must be taken to avoid shorts from tie wire and form ties.
- Corrosion prevention for rebuilt areas of existing structures

Remote Monitoring

- Wireless technology advances allow web-based CP system health monitoring
- Cellular & Satellite communication available
- System alerts sent in text message format
- Automated data collection
- Remote depolarization/ System interrogation





Quantity of Reference Locations Meeting NACE SP0290 Criteria

Riser	Qty	Total RE	Percent
A	31	32	96.9%
B	29	31	93.5%
C	30	32	93.8%
D	32	32	100.0%
E	31	32	96.9%
F	31	32	96.9%
Total	184	191	96.3%

QUESTIONS?

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May 12, 2021 | Electrochemical Treatments to Extend the life of Corroding Substructures

David Whitmore, P.Eng.

Vector Corrosion Technologies

Description: Electrochemical Chloride Extraction and Re-Alkalization are two temporary treatments to address the underlying cause of corrosion in reinforce concrete bridge structures. Both of these techniques were pioneered in Norway in the late 1980s. This webinar will discuss the history and development of both electrochemical treatments and how they can be effectively employed to halt corrosion and reset the clock on actively corroding structures.

Click Here to Register - 12:00 PM GMT | 7:00 AM EST (United States)

Click Here to Register - 7:00 PM GMT | 2:00 PM EST (United States)

Jun 9, 2021 | Surface Applied Cathodic Protection of Substructures

Travis Marman, NACE CP2

Vector Construction

Description: The galvanizing of atmospherically exposed steel has been an effective option in the field of corrosion mitigation for decades, but this surface applied approach is also applicable to reinforced concrete structures as well. This webinar will discuss how metalizing and other surface applied systems can be used to extend the service life of existing concrete bridge substructures in corrosive environments.

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