New Corrosion Protection System Extends the Life of Concrete Structures

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Vector Corrosion Technologies

Outline

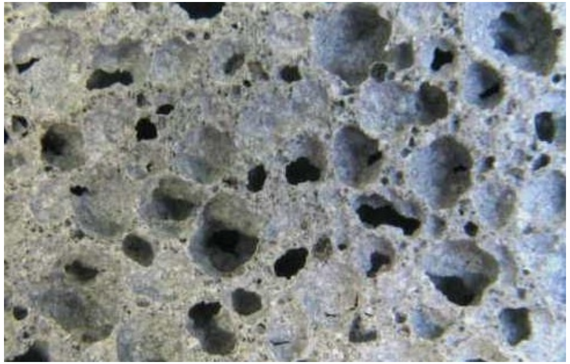
- Corrosion and Cathodic Protection Basics
- 1800 - 1943 – Origins & Early Years
- 1959 - Impressed Current Cathodic Protection
- 1987 - Electro-chemical Treatments
- 1999 - Galvanic Anode Systems
- 2018 – The Future and New Corrosion Protection Systems
- Summary

The Nature of Corrosion

- Corrosion is a natural electro-chemical process involving the passage of current

Steel, Concrete and Corrosion

The highly alkaline environment of concrete passivates and protects embedded steel



But remember concrete is like a sponge…

Keeping water and contaminants out is key!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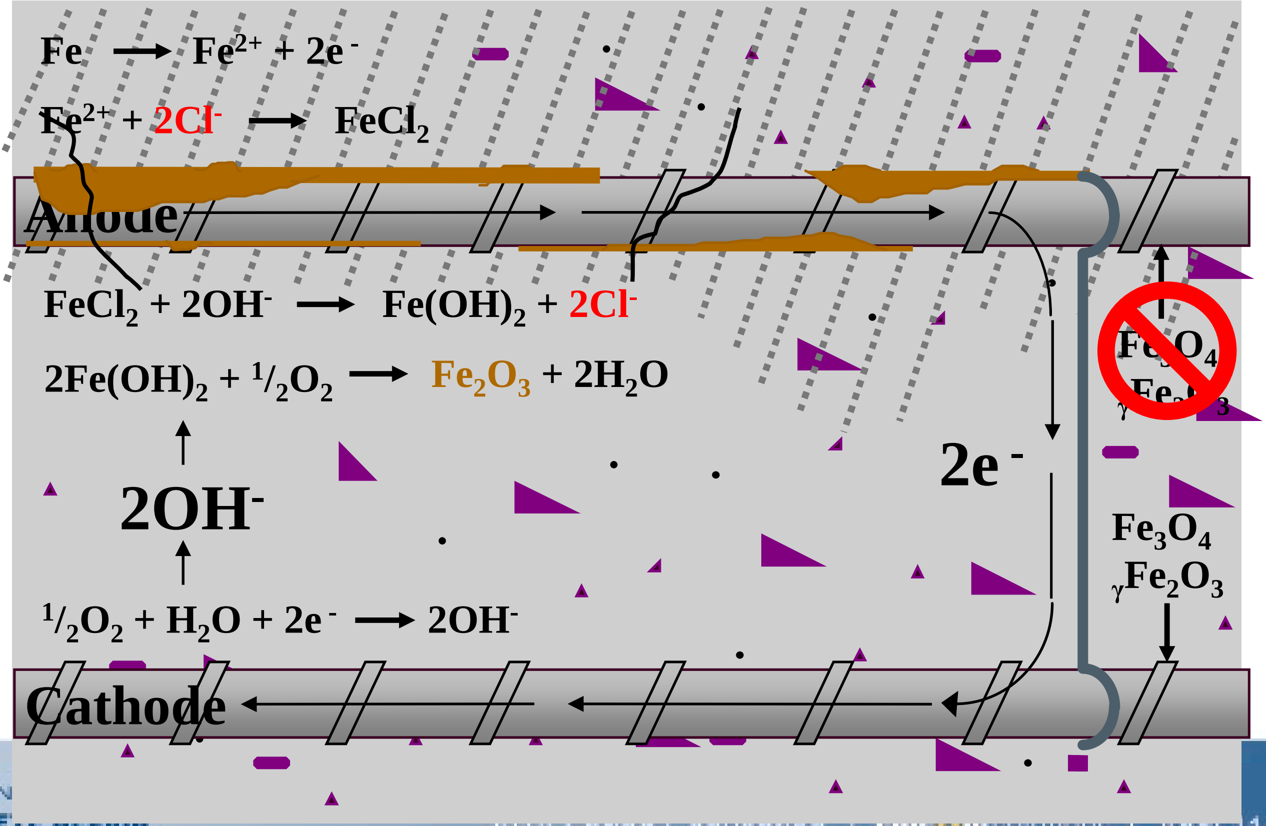
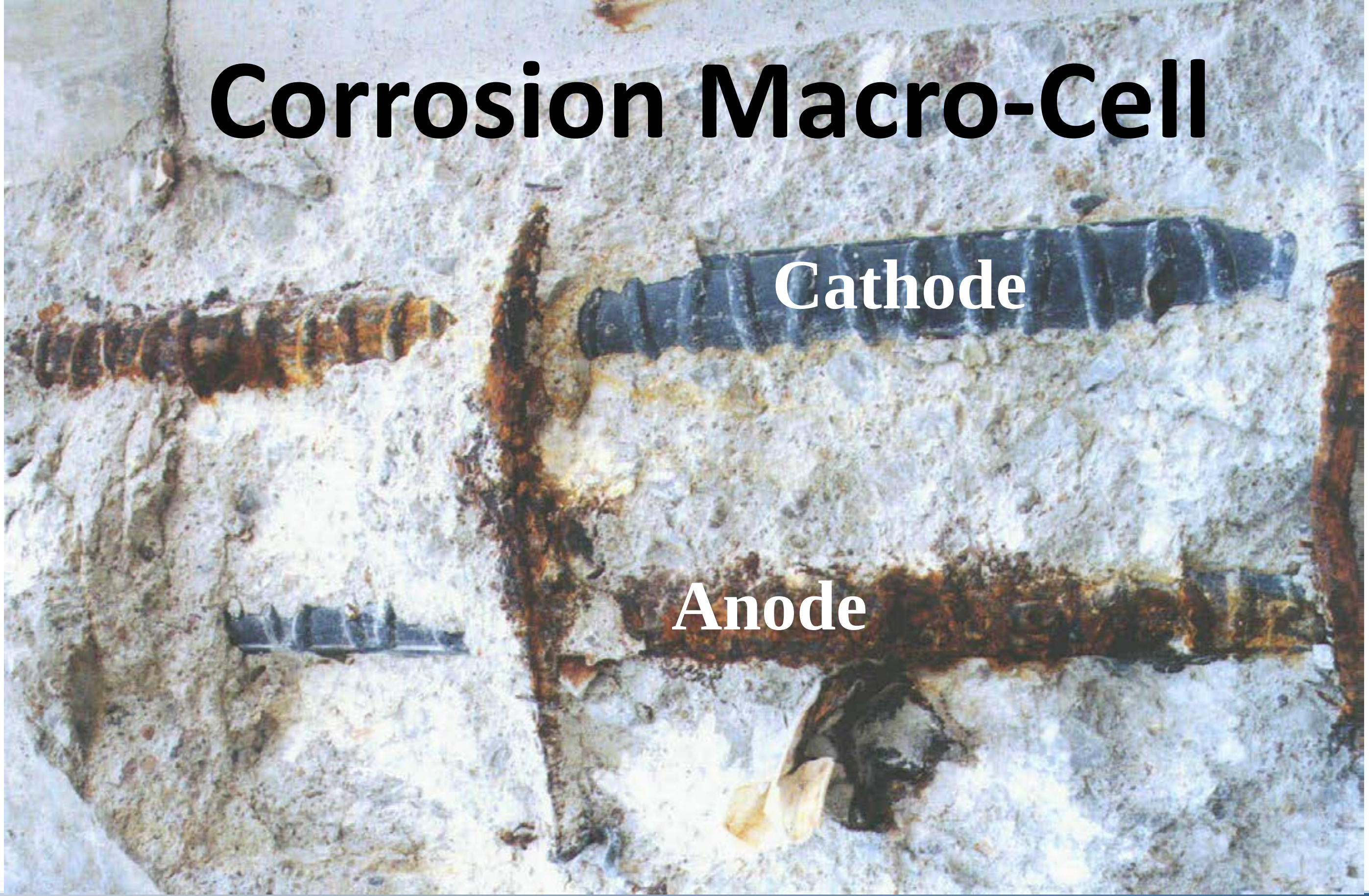
Corrosion Cell in Concrete



Corrosion Macro-Cell



Types of Electro-Chemical Corrosion Protection Systems

- They work by applying current to reinforcing steel in order to overcome the corrosion process or change the environment around the steel
- Impressed Current Systems: D.C. power makes electrons flow from anode to reinforcement (cathode)
- Electrochemical Treatments: Temporarily apply current to change the environment and chemistry around the steel
- Galvanic Systems: Sacrificial metal corrodes to provide continuous source of electrons

System Requirements

- Electrical connection to the steel
- Electrical continuity of the steel you wish to protect
- Steel must be embedded
- Steel can not be isolated inside non-conductive ducts or by non-conductive layers. Ionic current needs to be able to get to the steel to be protected.

1800 – Origins of Cathodic Protection

Luigi Galvani

Alessandro Volta

1824 – Sir Humphry Davy

- **Cornish chemist, inventor and pioneer of Cathodic Protection**
- **First Application of CP financed by the British Navy**
- **Succeeded in protecting copper sheathing using iron and zinc**

1834 – Michael Faraday

- Student of Sir Humphry Davy
- Discovered the relationship between corrosion metal weight loss and electric current transfer


Zinc Anode

1943 – National Association of Corrosion Engineers (NACE)

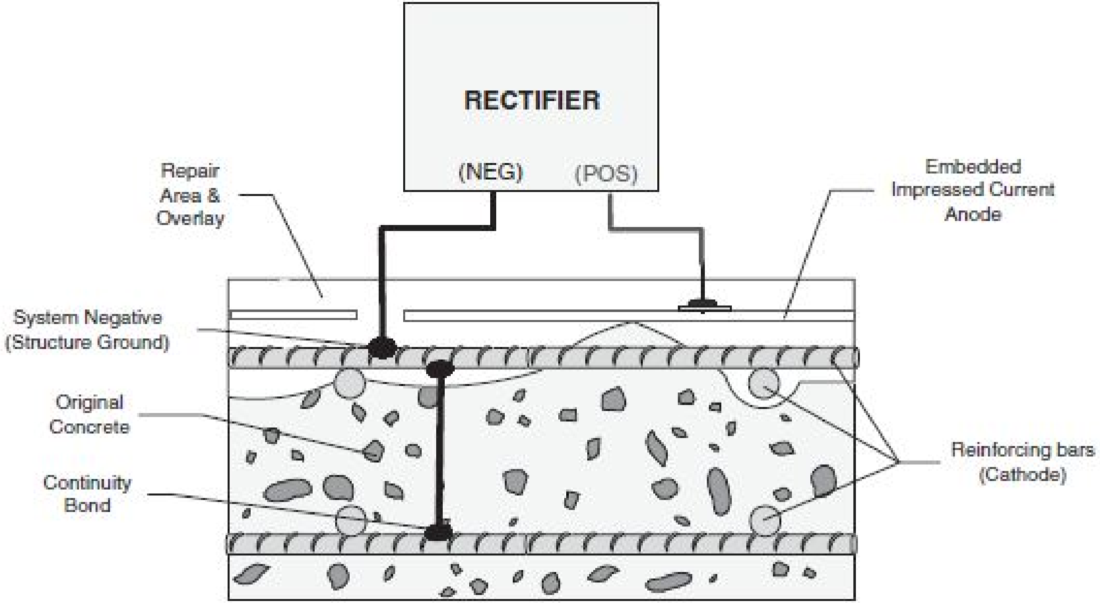
- Founded by 11 corrosion engineers from the pipeline industry
- Established and maintained standards for Cathodic Protection
- Nearly 36000 members today in 130 countries

NACE® INTERNATIONAL
75th Anniversary 1943 - 2018

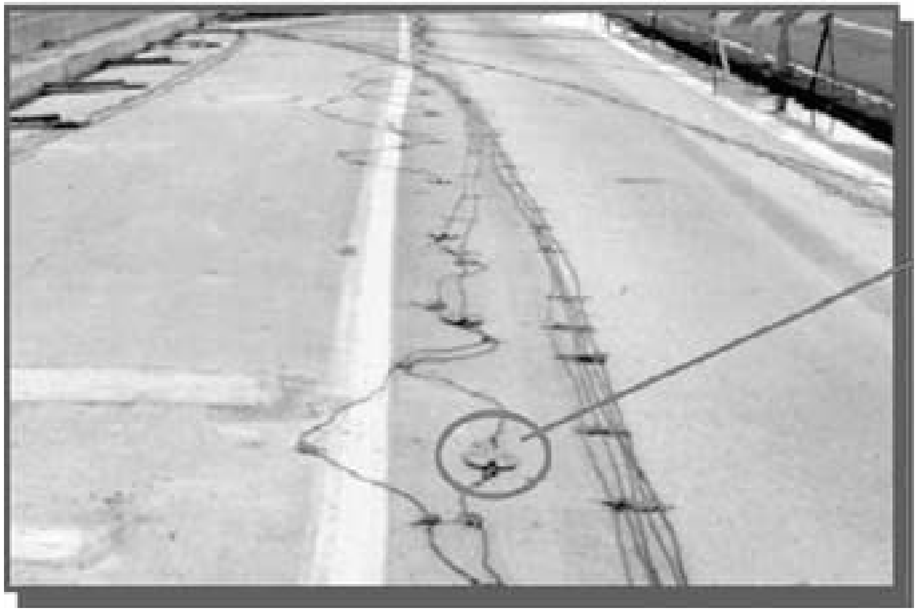
1959 – Cathodic Protection, Concrete and Dick Stratfull

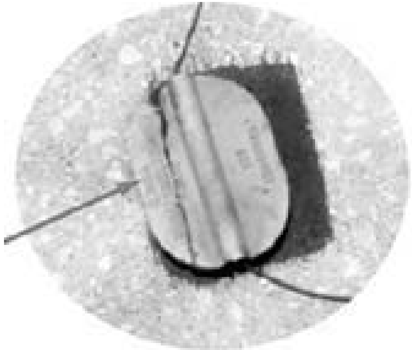
- Pioneered Cathodic Protection in concrete structures as a materials engineer with Caltrans
- First small scale experiment on bridge beam in 1959
- First large scale field trial on the Sly Park bridge deck in 1972
- Trials borrowed Impressed Current Cathodic Protection techniques from the pipeline sector

1972 - Impressed Current Cathodic Protection Systems



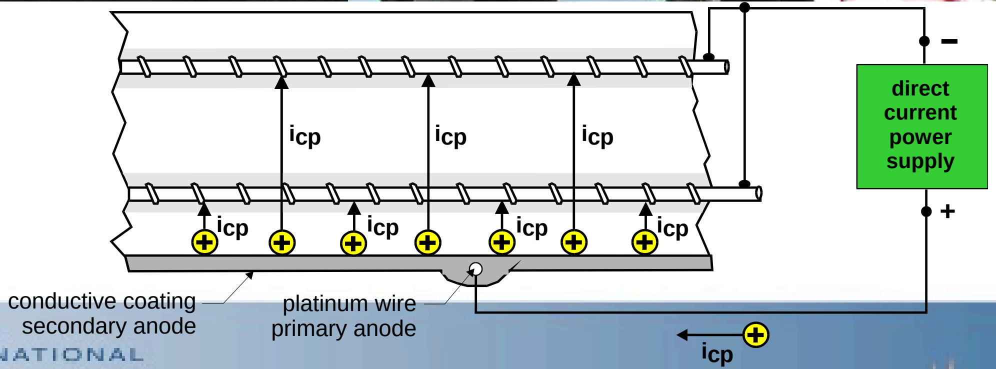
Early Years - Conductive Overlays

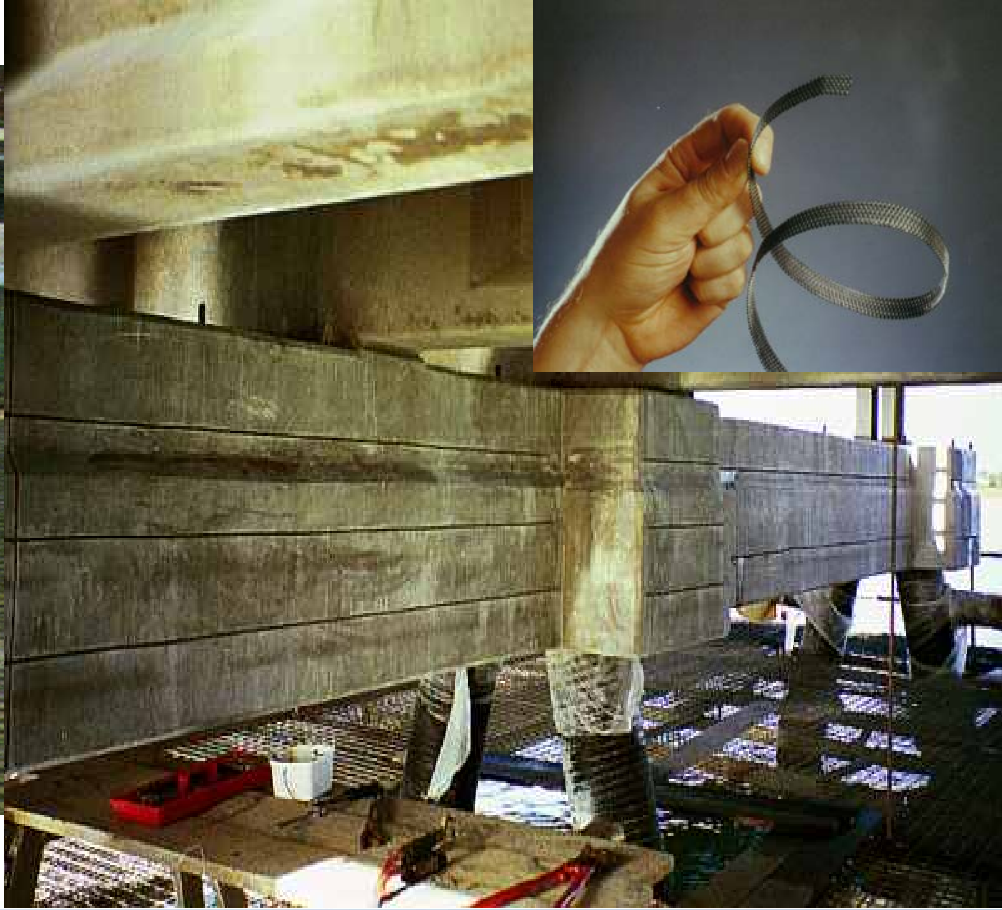




Early Years – Conductive Polymer Slotted Systems

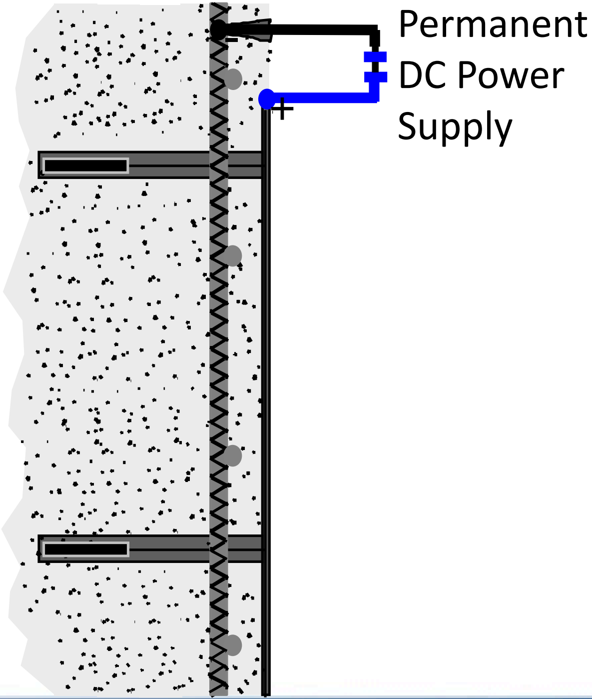
Early Years – Conductive Coating Systems





Modern Discrete Anode Impressed Current Cathodic Protection System

- Outside power source required
- High level of control
- System monitoring and maintenance required



Impressed Current Cathodic Protection

Advantages of ICCP

- Long term solution (+50 years)
- Adjustable level of protection
- Able to re-passivate steel

Impressed Current
Cathodic Protection

Lessons Learned

- Requires detailed design and careful installation
- Requires specialized materials and equipment
- Continued ongoing monitoring & maintenance for life of system

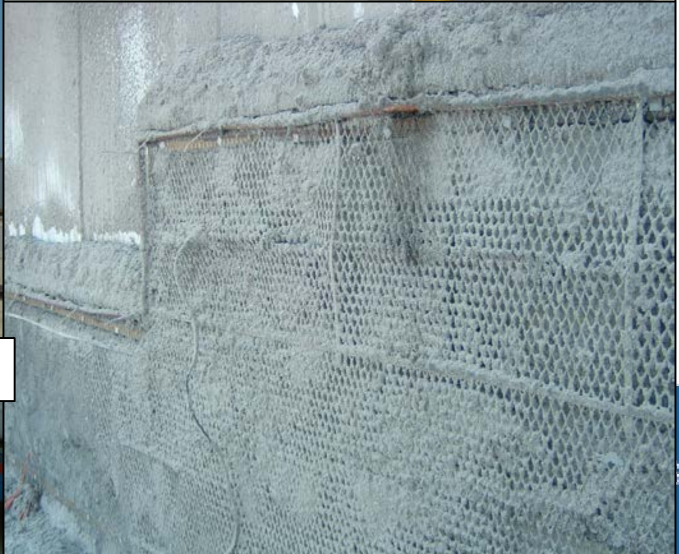
1987 – Electro-Chemical Treatments

- Pioneered in Norway
- 1st Re-alkalization commercial trial in 1987
- 1st Electro-Chemical Chloride Extraction commercial trial in 1988
- 1st North American ECE Project in 1989 for the MTO.

Re-Alkalization

- Draws highly alkaline electrolyte (sodium or potassium carbonate) 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
- Treatment time of between 3-7 days



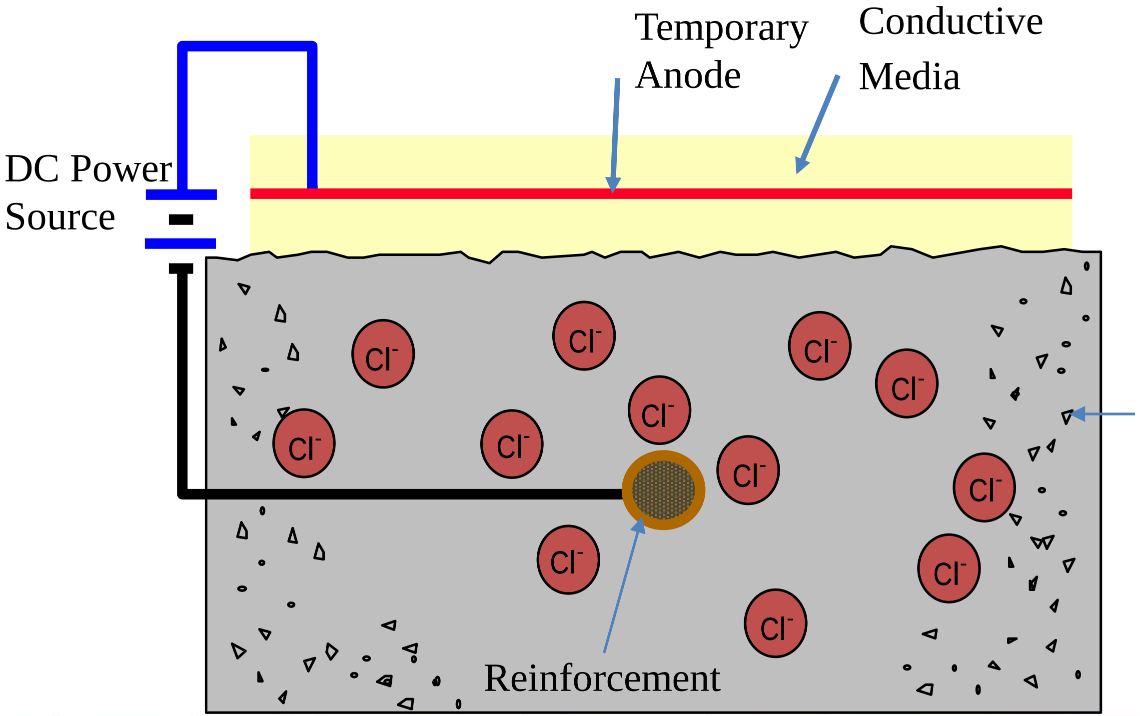



Re-alkalization of Historic Building Façade

Electrochemical Chloride Extraction (ECE)

- Addresses the cause of corrosion
- Chloride levels are significantly reduced
- Alkalinity is increased at the level of the steel
- Reinforcing steel is returned to a passive, non-corroding state
- Treatment time of between 4-8 weeks

Electrochemical Chloride Extraction (ECE) From Chloride Contaminated Concrete



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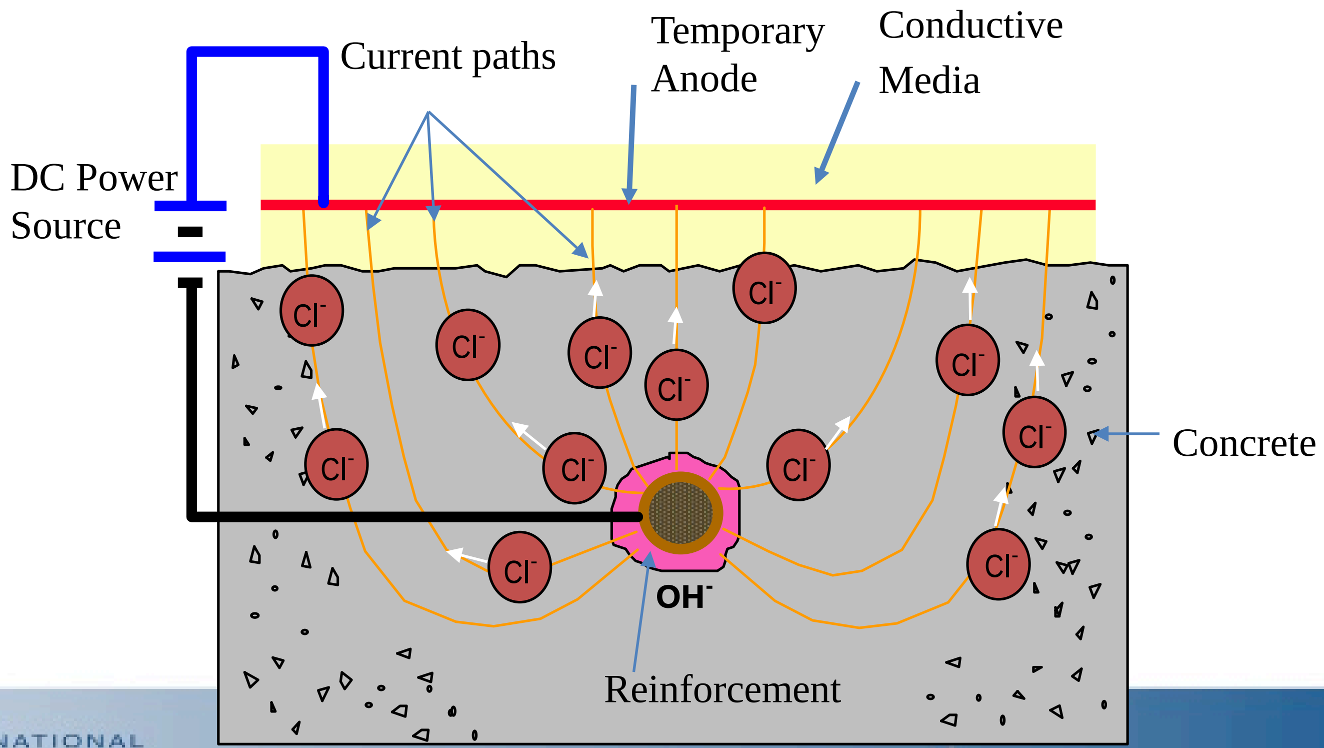

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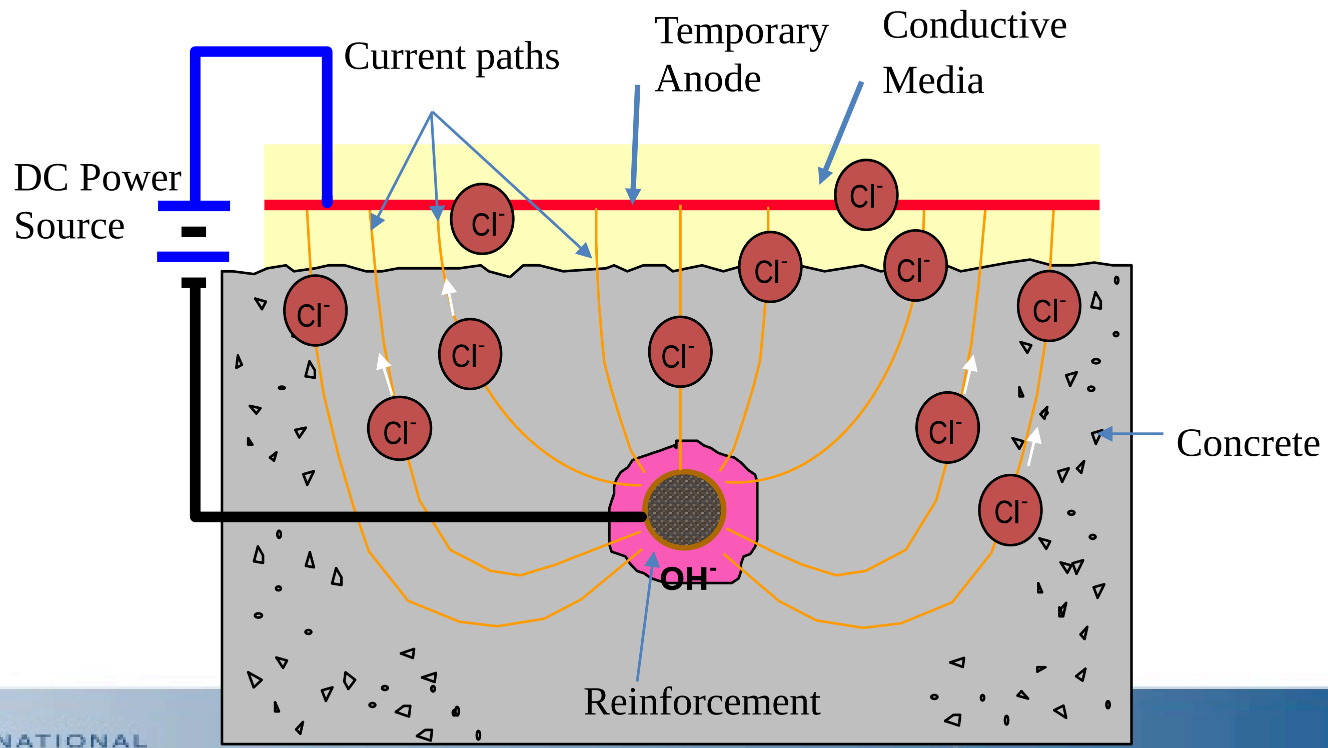

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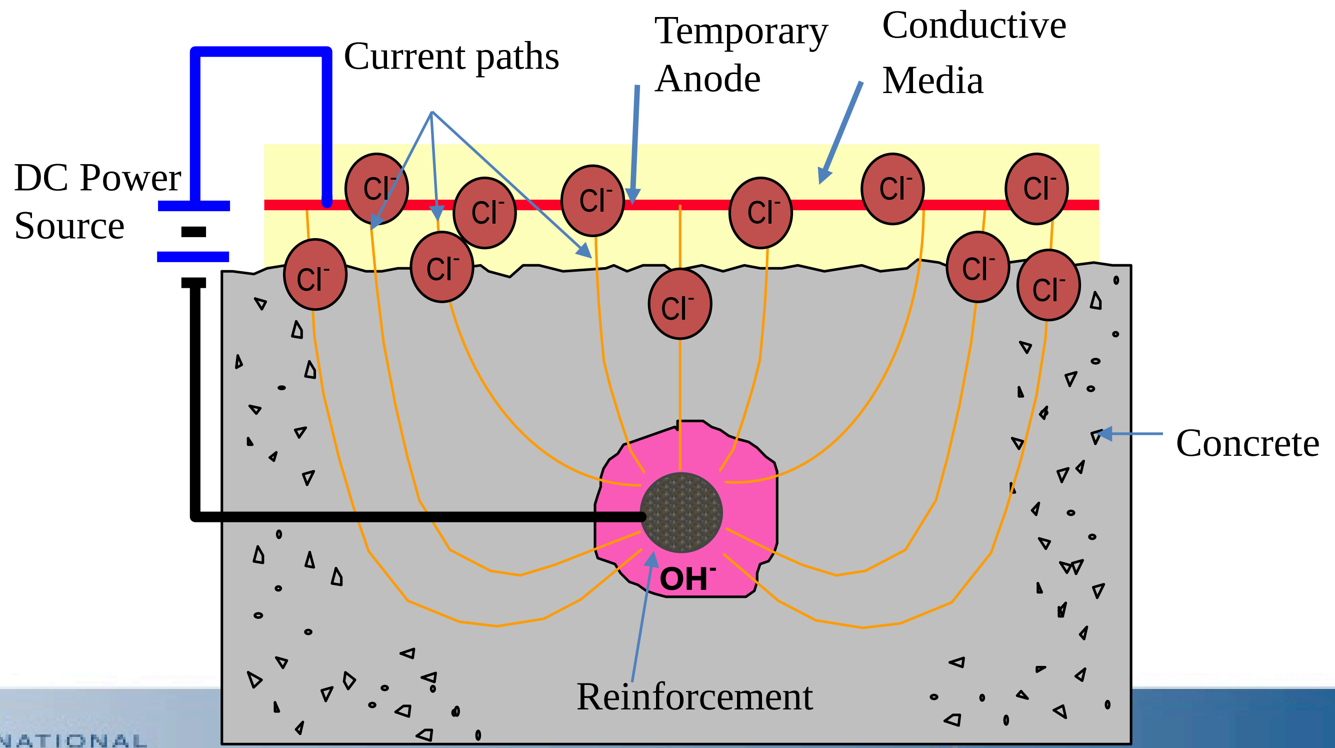
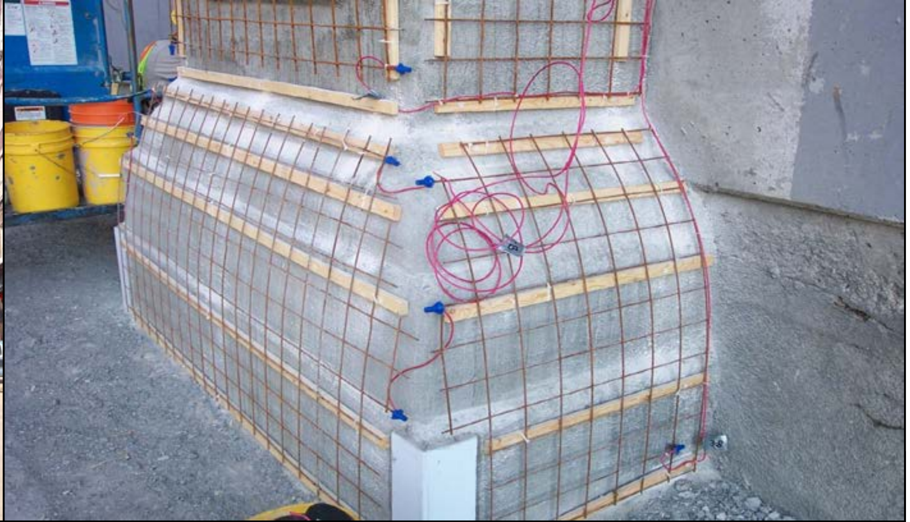




Electrochemical Chloride Extraction

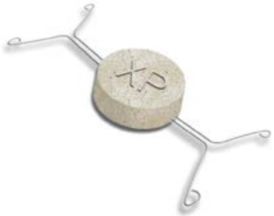
Lessons Learned - ECE

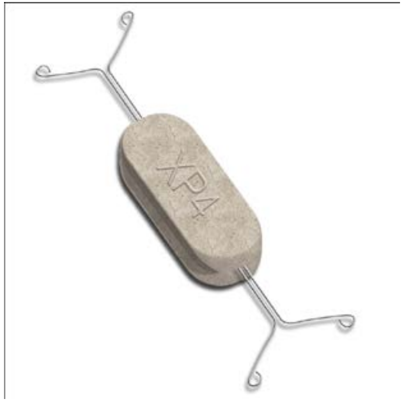
- Highly effective method of extending service life without altering aesthetics
- Employed on structural elements that can be taken out of service for the length of treatment
- Can be very cost effective, depending on the application.

1999 - Galvanic Systems

- Discrete Galvanic Anodes (Type 1&2)
- Distributed Anode Systems (DAS)

1999 – Type 1 Discrete Galvanic Anodes used in Repairs





Halo Effect

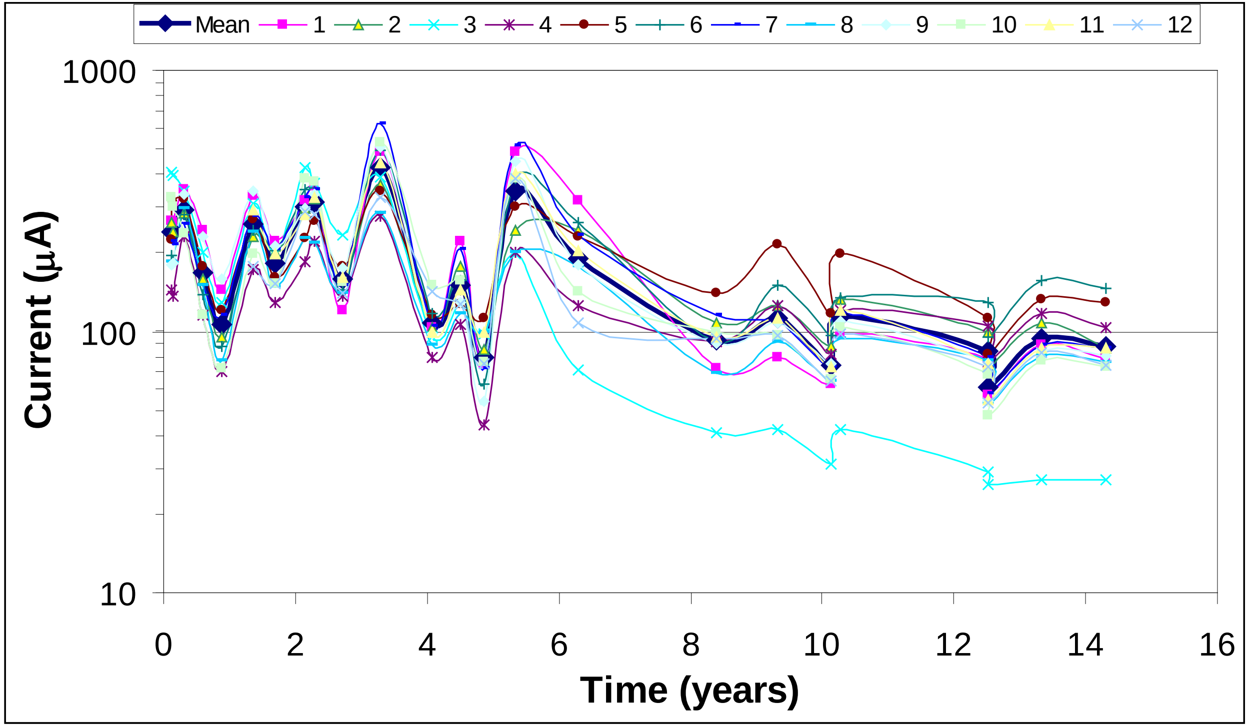
Underside of Parking Deck
Washington, DC

Leicester Bridge, 1999

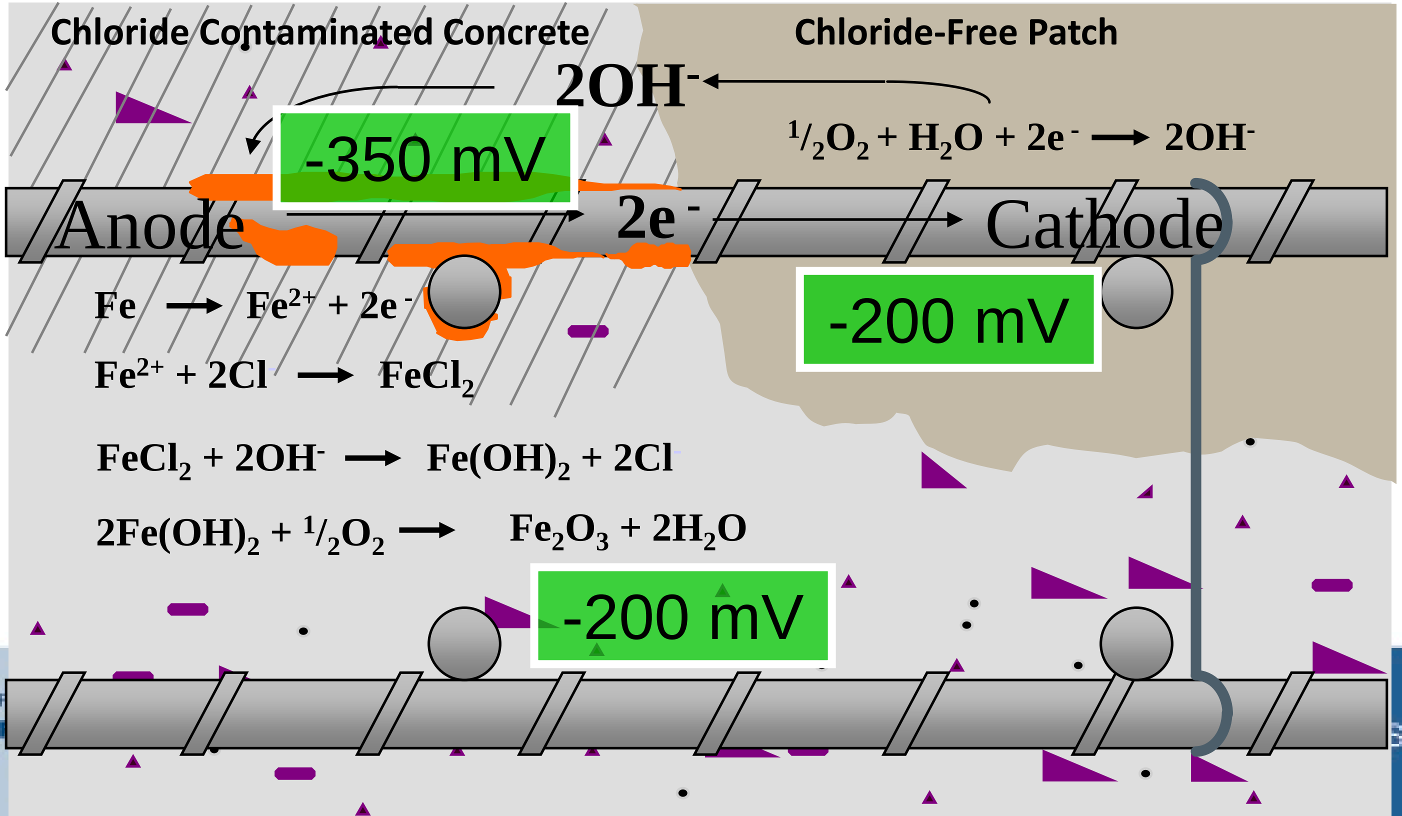
Leicester Bridge Beam Repair

– Completed in 1999
– Monitored for 18 years (Each Anode)

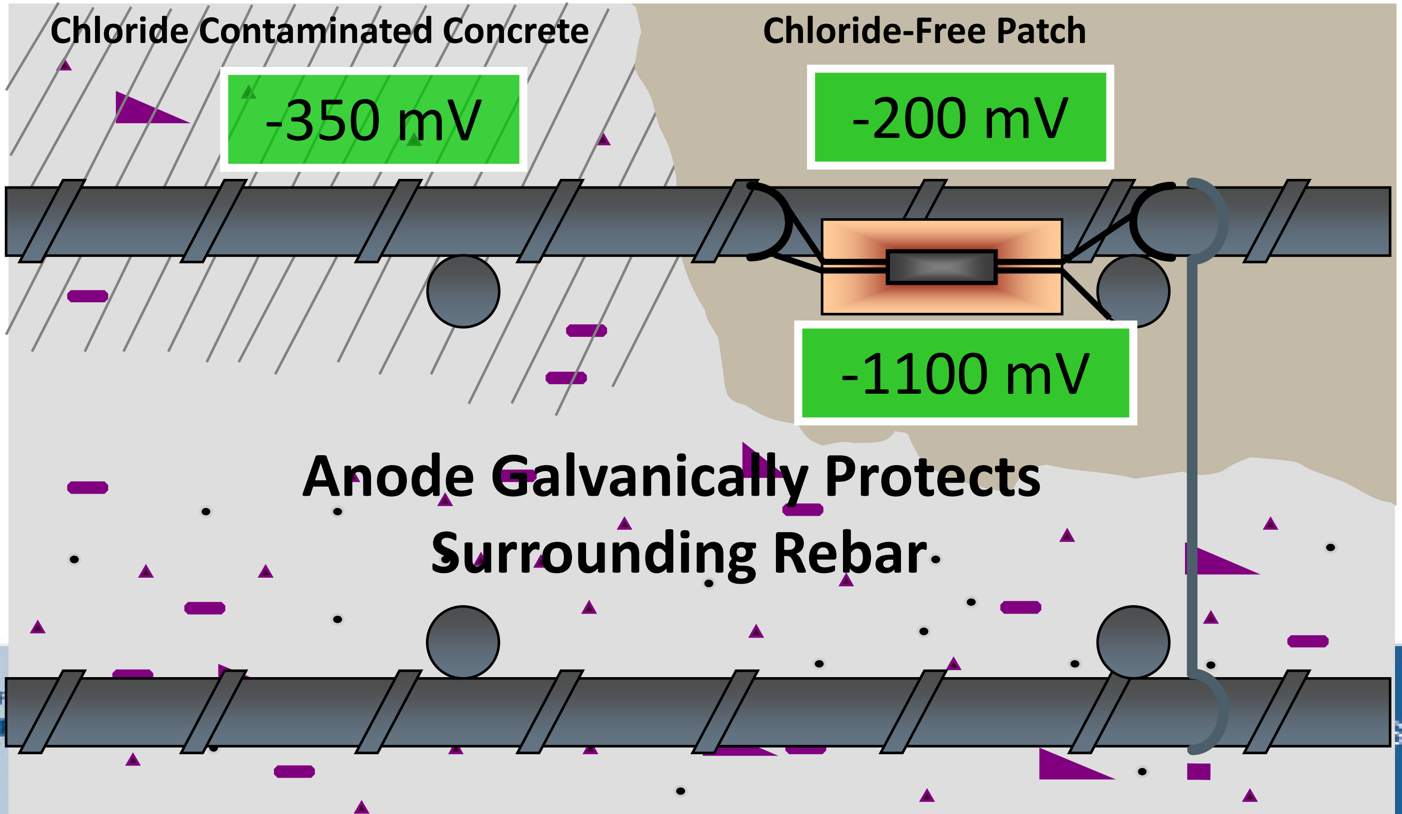
Galvanic Current vs Time, 1999 to 2014



Patch Accelerated Corrosion

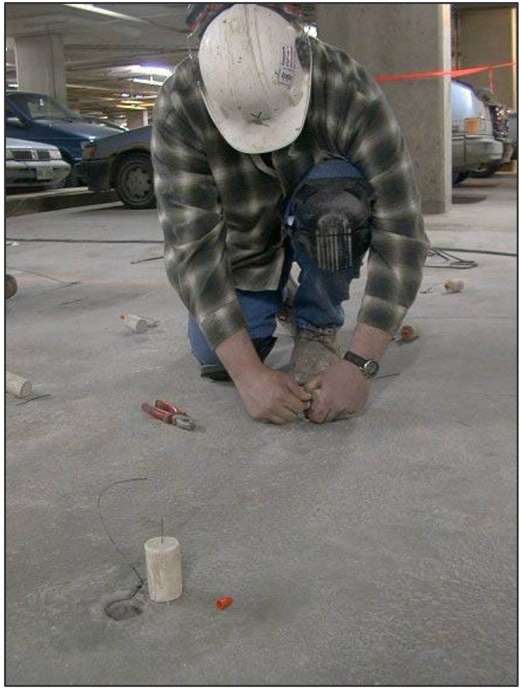


Type 1 Discrete Anode Installation

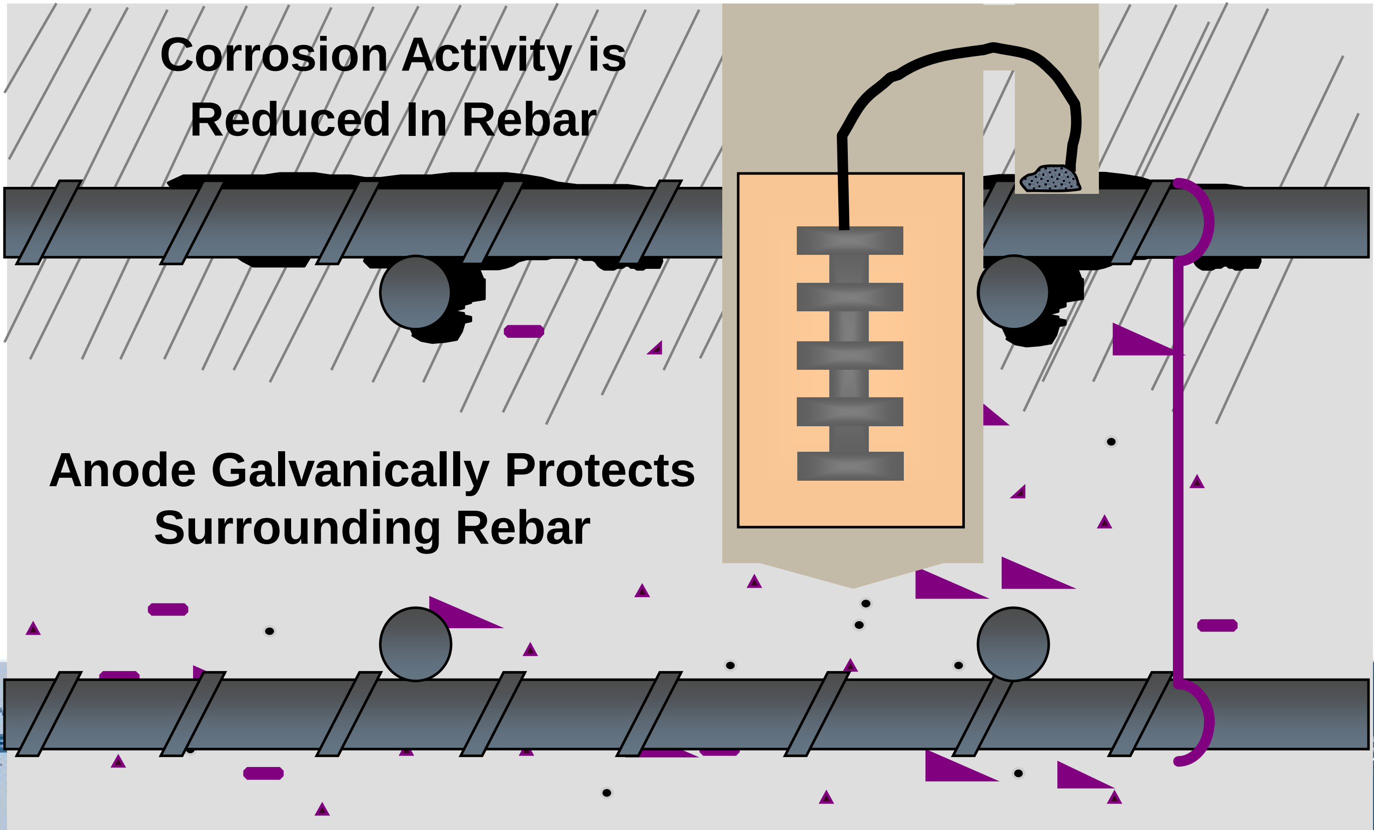


2001 – Type 2 Discrete Galvanic Anodes in Sound Concrete

- Embedded anode for corrosion control
- Installed into drilled holes
- Protect sound but contaminated areas
- Corrosion "hot spots"



Type 2 Discrete Anode Installation



Different Sizes

Type 2 Discrete Anodes in Structural Slab Repair

2003 - Distributed Anode Systems (DAS) in Galvanic Encasements

- **Large custom galvanic anodes distributed throughout large repair areas to provide a high level of protection and long service life.**

Bridge Column Jacket

Parking Garage Column Overbuild

Lessons Learned with Galvanic Cathodic Protection

- Proper design is required
- Local and Distributed systems
- Self regulating current flow
- Low maintenance
- Relatively simple installation

Technical Standards for Electro-Chemical Corrosion Protection Systems

- ICRI Guideline No. 510.1-2013 (Guide for Electrochemical Techniques to Mitigate the Corrosion of steel for reinforced Concrete Structures)
- ACI RAP Bulletin 8 (Installation of Embedded Galvanic Anodes)
- FHWA Bridge Preservation Guide
- NACE SP0216-2016 (Sacrificial Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures)
- NACE SP0290-2007 (Impressed Current Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures)

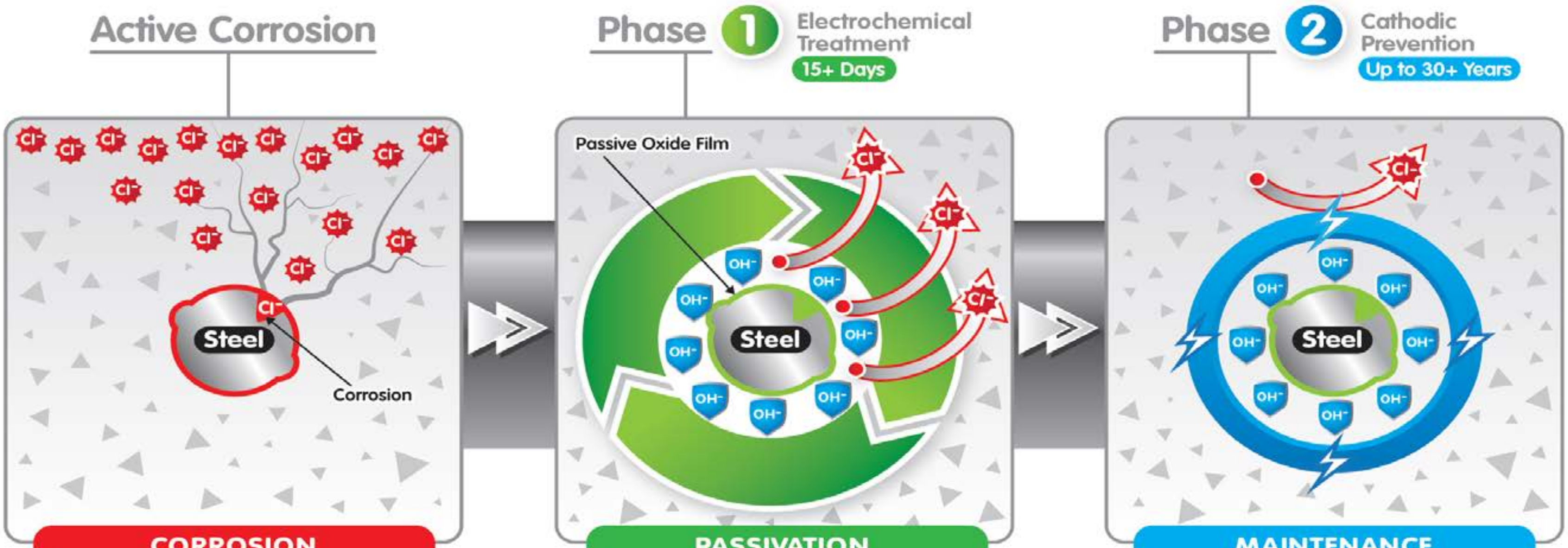
2018 – "Two Stage" Anode System

- Type 2 Embedded Galvanic Anodes
  - Embedment into Sound Concrete

- Two-stage Protection

  - The *power of Corrosion Passivation* from ICCP / ECE (**Stage 1**)

  - The *simplicity of Corrosion Prevention* from a maintenance free galvanic system (**Stage 2**)



CORROSION

- Chloride ions enter the concrete
- Chlorides break down passive film
- Corrosion initiates
- Acidic corrosion pits form on the steel
- Rust forms and occupies 7-12 times the volume
- Stress builds within the concrete
- Cracking & rust staining is visible

PASSIVATION

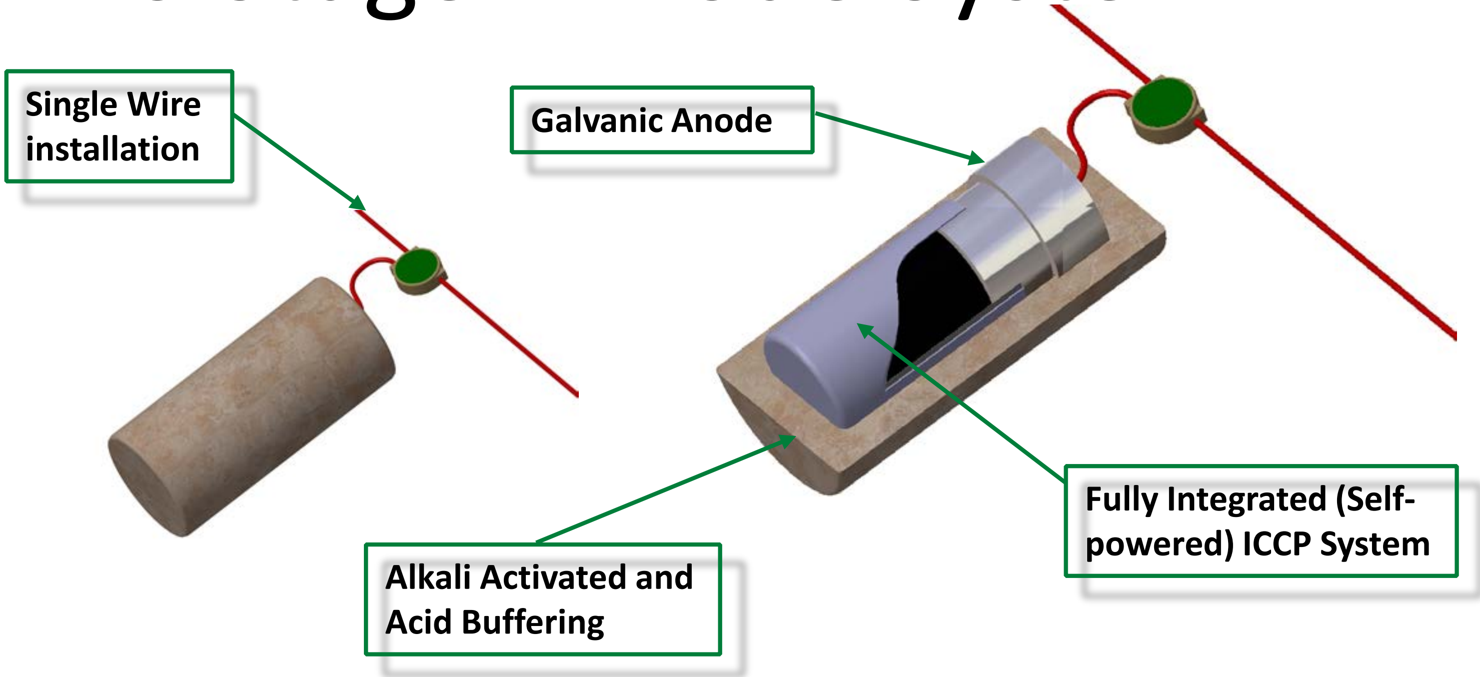
- Concrete repairs carried out as required
- High charge density delivered
- Alkalinity restored around steel
- Chlorides pushed away from steel surface
- Corrosion mitigated in pits
- Steel passivity is restored
- Phase 1 can be repeated

MAINTENANCE

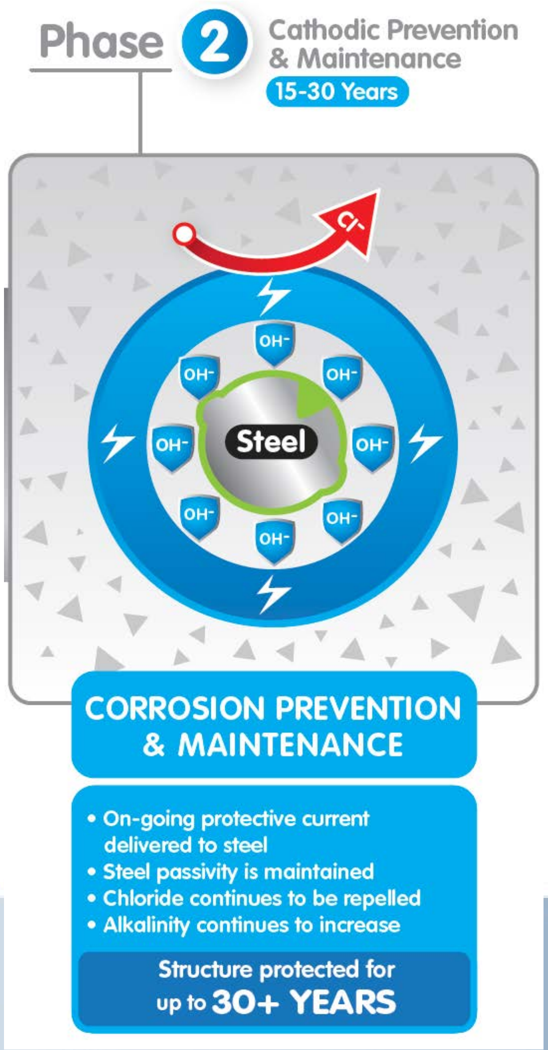
- On-going protective current delivered to steel
- Steel passivity is maintained
- Chloride continues to be repelled
- Alkalinity continues to increase

Structure protected for up to **30+ YEARS**

"Two Stage" Anode System



- **The ICCP anode delivers a period of high current density sufficient to passivate active corrosion**
  - **No external power needed**
    - **Internal power supply**
  - **Temporary treatment**
    - **Charge is passed over a period of 45 to 90 days depending upon the environment**
  - **Passivates corrosion**
    - **Removes chloride**
    - **Builds alkalinity at the steel surface**
  - **Economical/Cost-Effective**



- **The galvanic anode produces a lower charge density sufficient to mitigate the initiation of corrosion**

  - **Galvanic Technology**
    - 20 years of performance history
  - **Cathodic Prevention Current**
    - Current density of between 0.2-2.0mA/m^2
  - **Long Lasting**
    - unit produces a smaller current for up to 30+ years

Summary

- Understanding corrosion allows you to address it effectively and extend service life
- Primary Corrosion Mitigation Options:
  – Good concrete cover, Keep Water and Salt Out of Concrete
  – Electro-chemical Methods (Galvanic, ICCP, ECE)
- The field of cathodic protection has and will continue to evolve and innovate.

Thank You