Corrosion Mitigation Systems for Existing Concrete Structures

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Corrosion Ravaged Columns
Chicago, Illinois

Corrosion Mitigation Solutions

- Galvanic Protection Systems
- Electrochemical Treatments
- Cable Impregnation

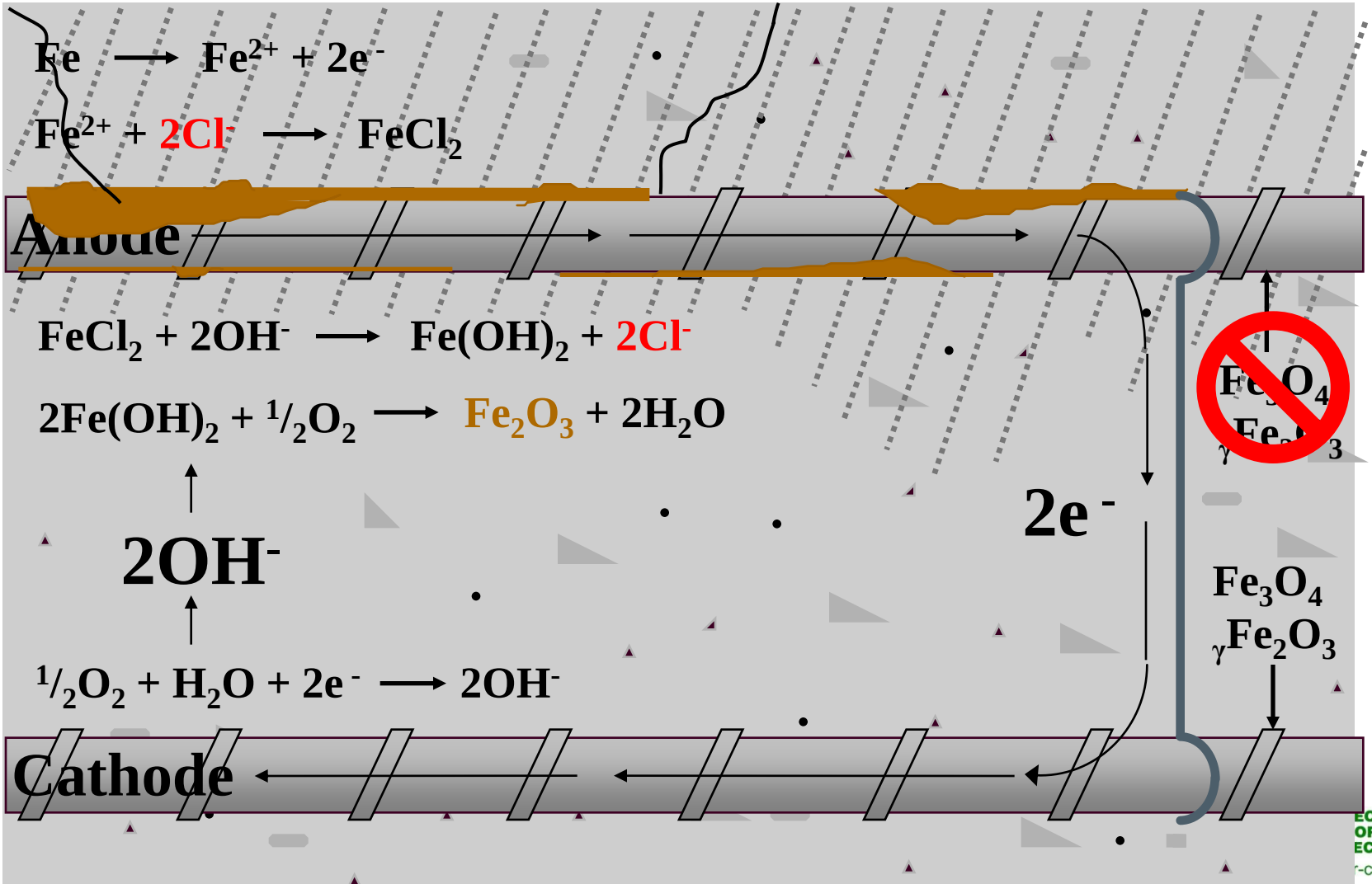
Corrosion Basics

Causes of Corrosion

- Chlorides
- Carbonation
- Dissimilar Metals

Results in the Destruction of the Steel's Passive Oxide Layer

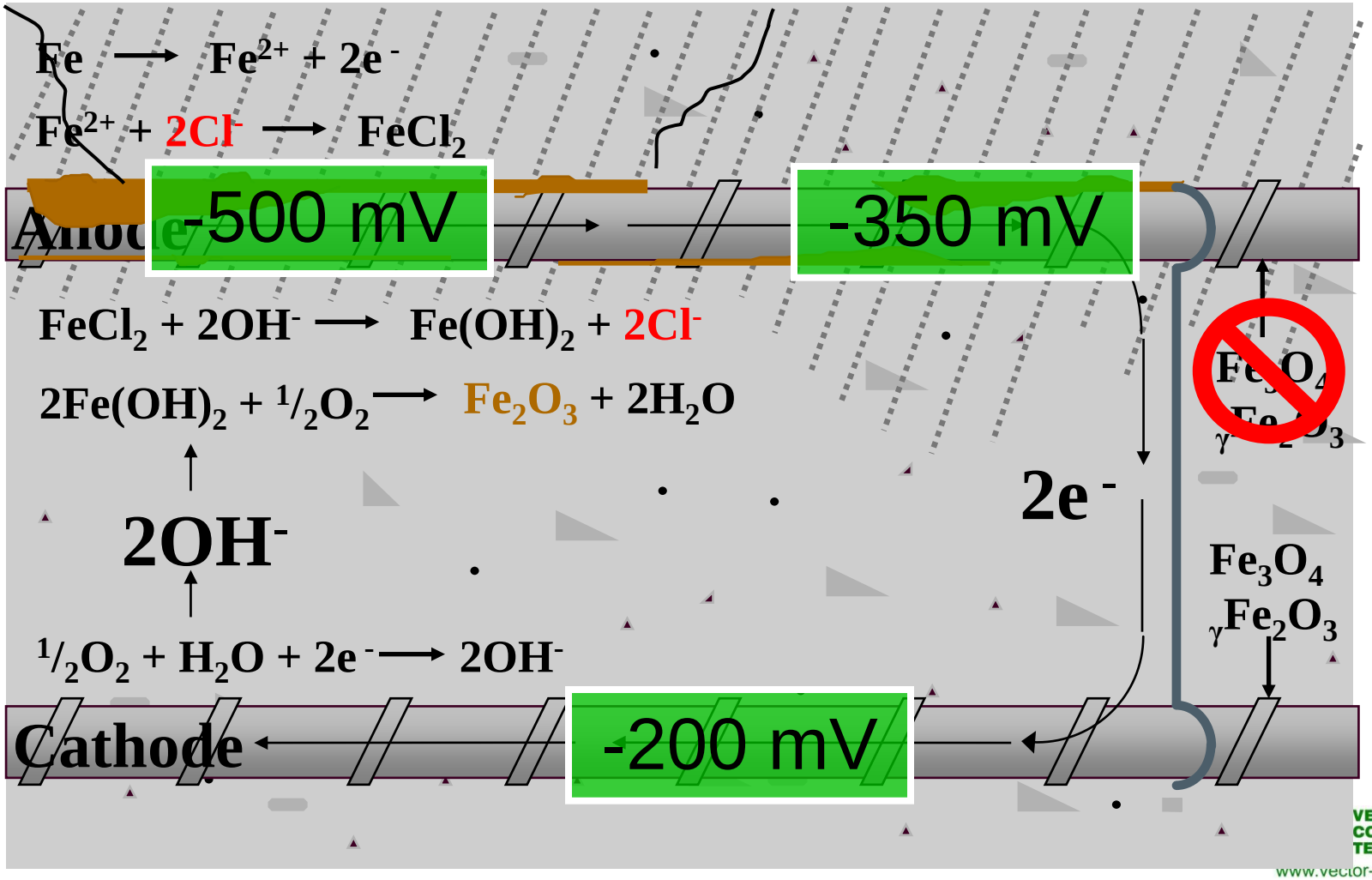
Corrosion Cell in Concrete



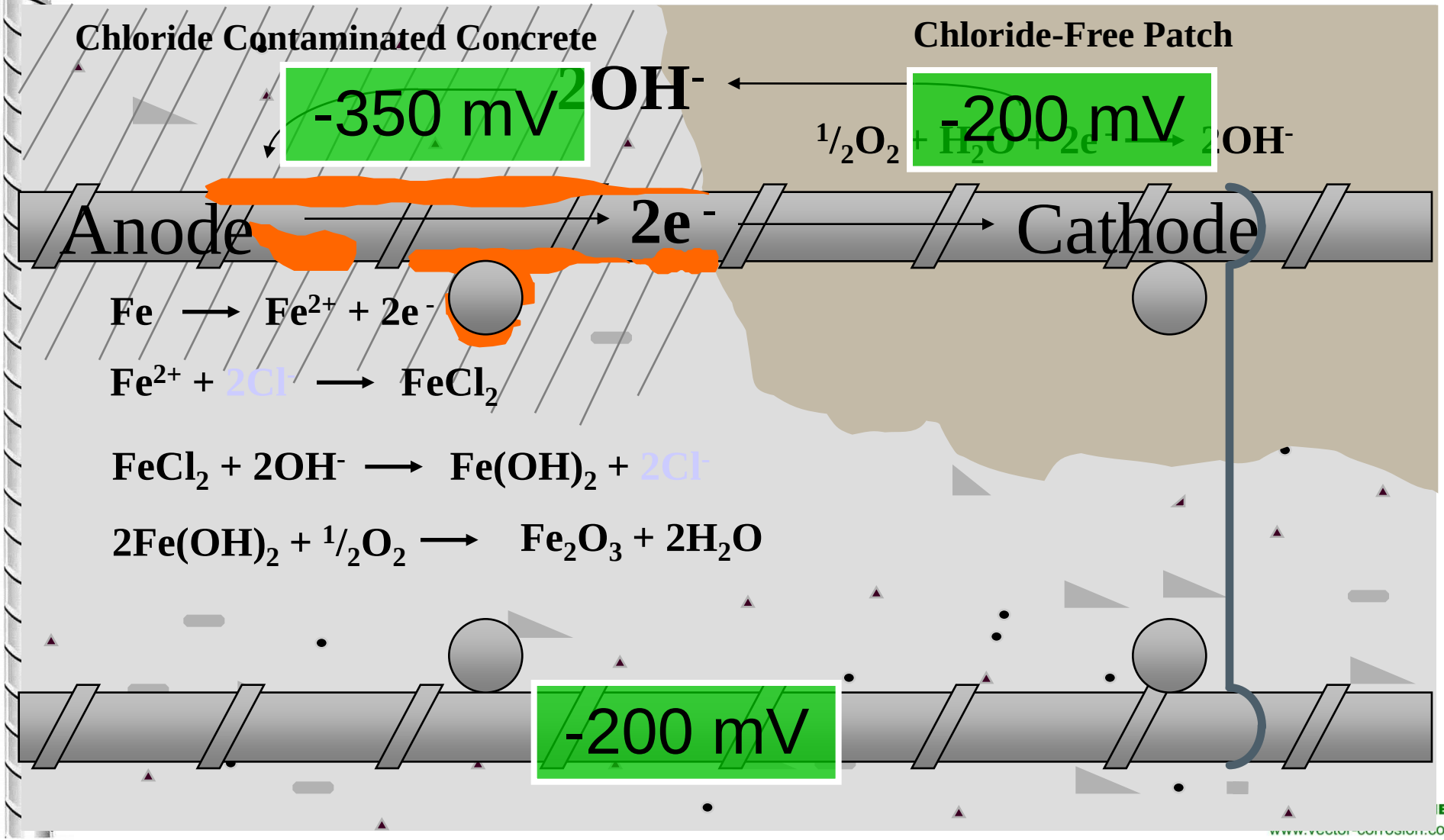
Why Does This Occur?

Corrosion Potential for Steel in Concrete	
Metal	Voltage
Steel in Chloride-Free Concrete	0 to -200 mV
Steel in Chloride-Contaminated Concrete	-350 to -500 mV
*Typical potentials measured with respect to copper-copper sulfate electrode	

Corrosion Cell in Concrete



Patch Accelerated Corrosion



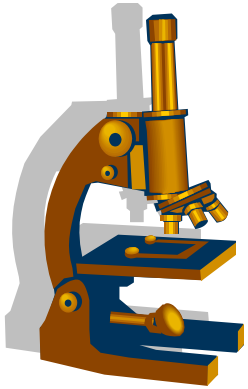
Halo Effect

Galvanic Corrosion Protection Systems

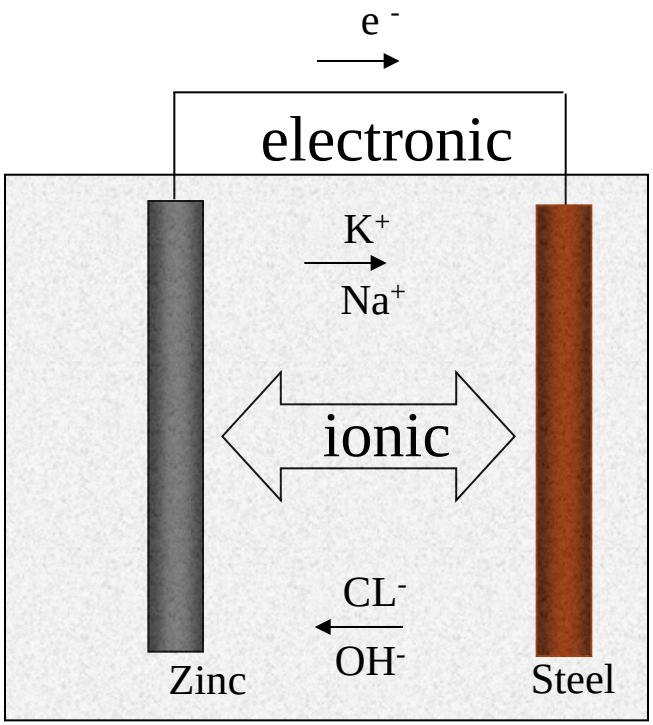
Galvanic Protection Systems

- Two different metals are connected in same electrolyte (concrete)
- More “active” metal = anode
- More “noble” metal = cathode
- Anode corrodes to protect cathode
- Natural reaction
  - no external power required
- Safe for prestressed concrete

Potentials and Current Flow

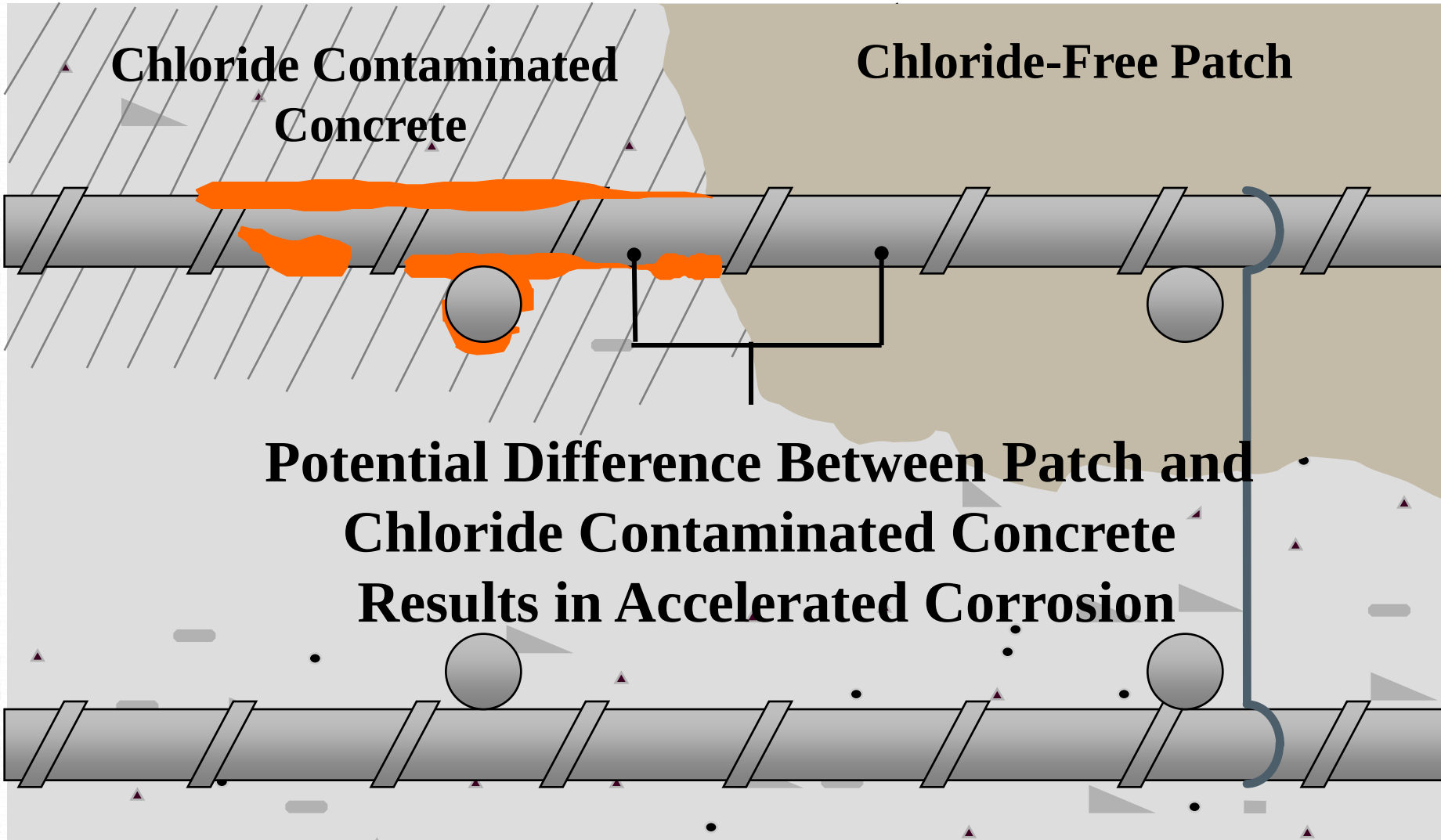


Partial Galvanic Series	
Metal	Voltage
Zinc	-1100 mV
Steel in concrete	-200 mV to -500 mV
*Typical potentials measured with respect to copper-copper sulfate electrode	

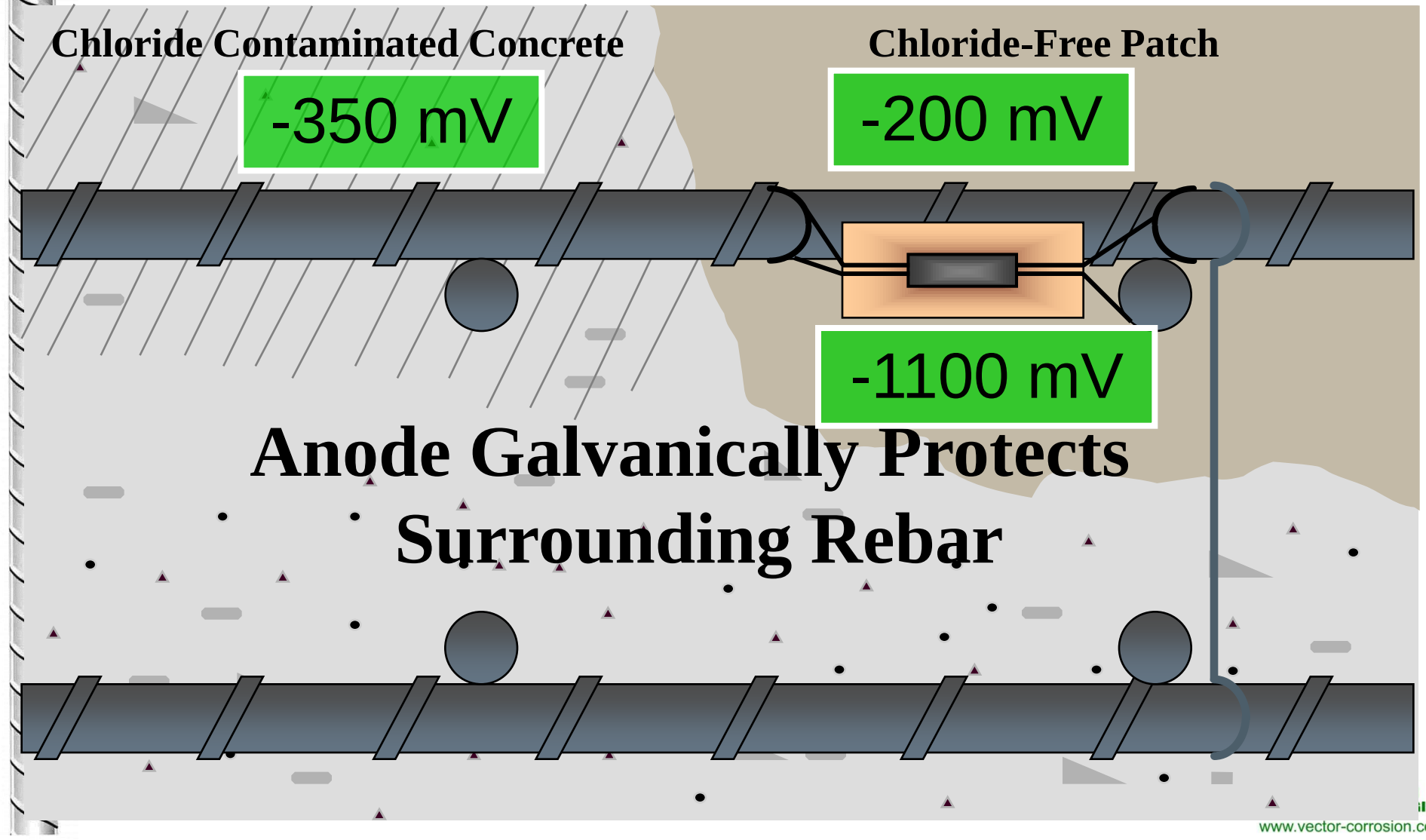


Embedded Galvanic Anodes for Corrosion Prevention

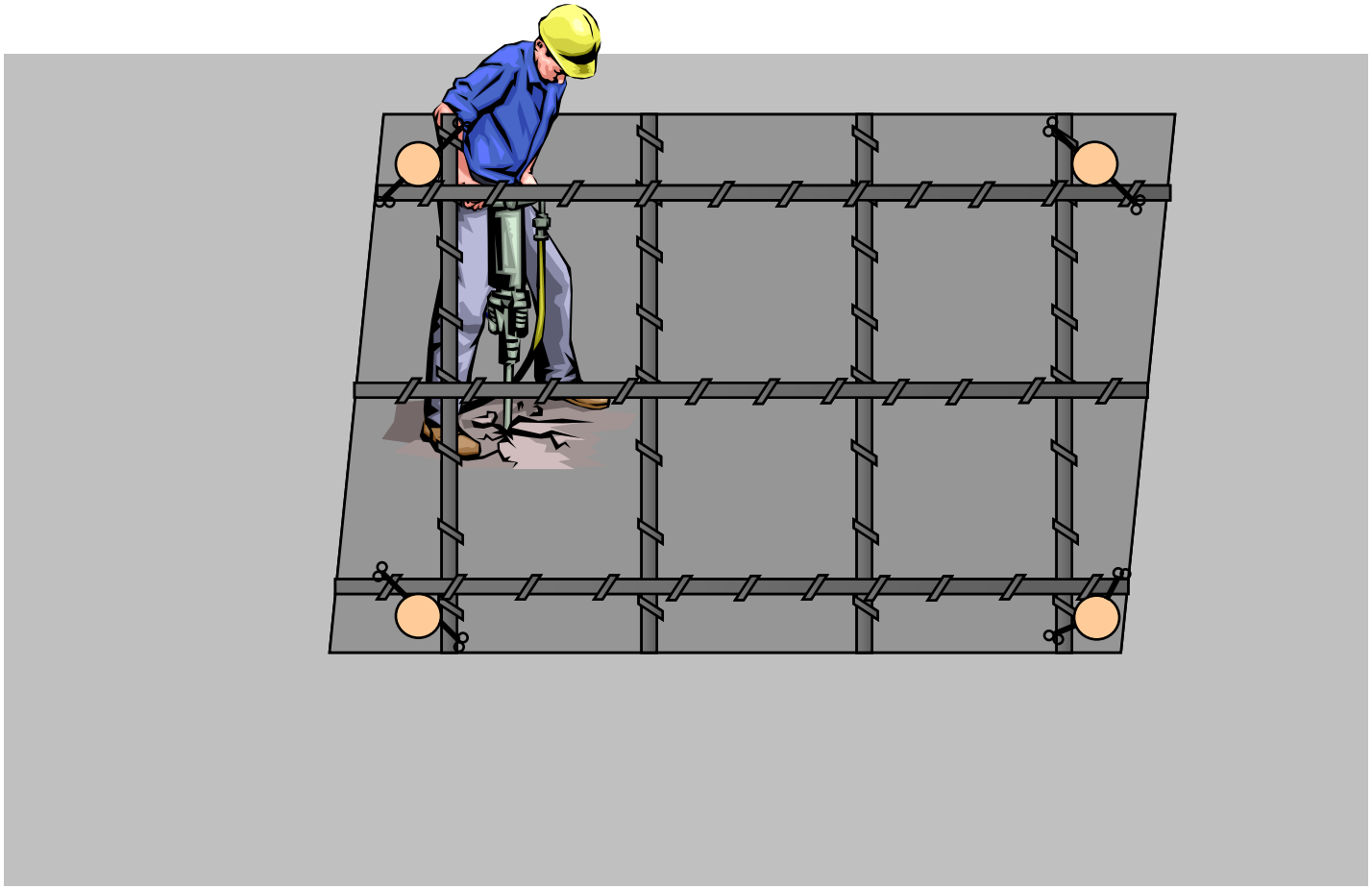
Patch Accelerated Corrosion



Installed Galvanic Anode



Installation of Galvanic Anodes



Anode Installation

Saw cut and cleaned repair area.

Anode Installation

Installing anodes around the perimeter of the repair.


Quick and Easy Installation

Anode Installation

Testing anode connection to reinforcing steel.

Anode Installation

Embedding anodes with repair material.

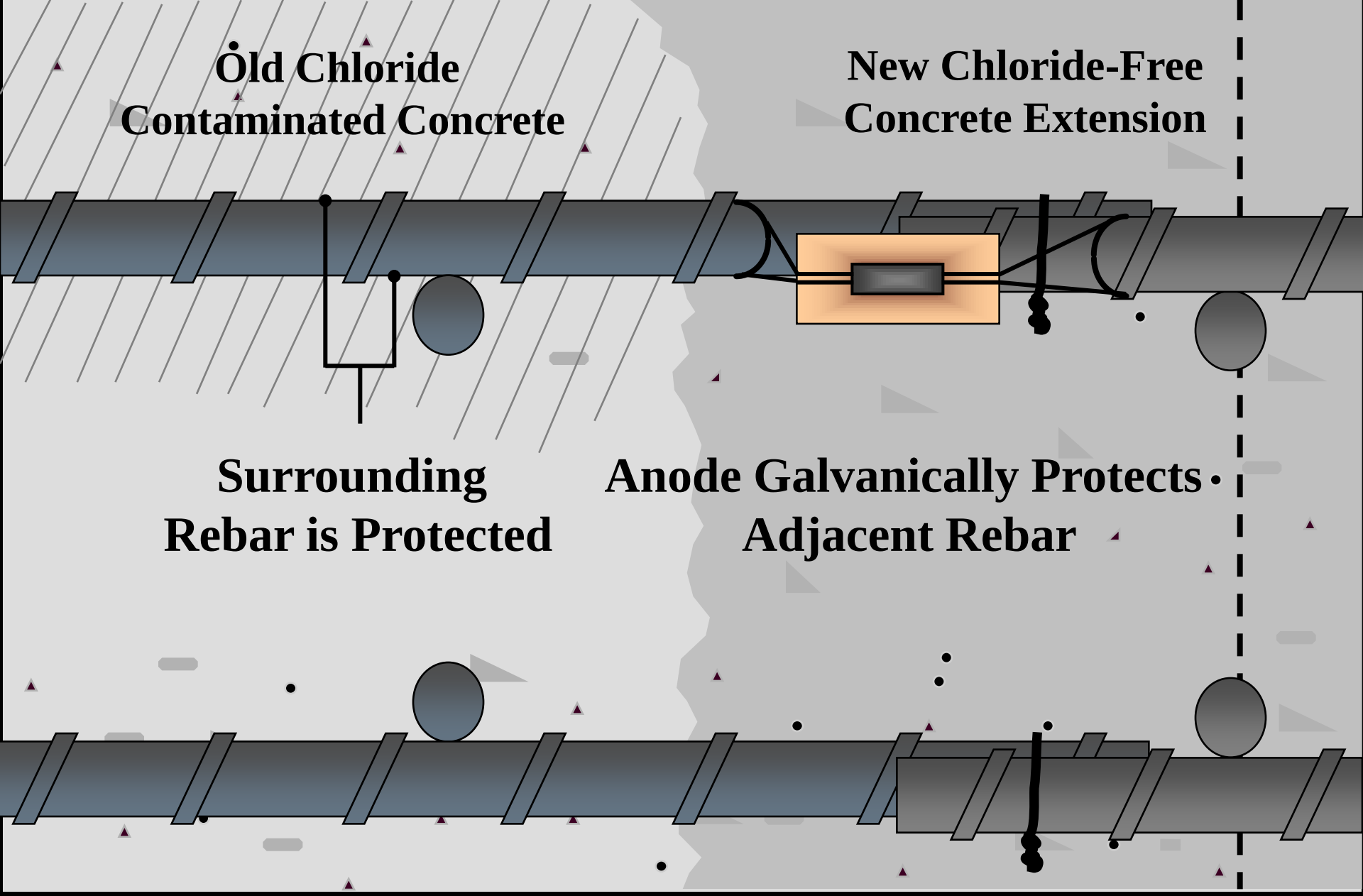
Joints and Interfaces

Corroded Joint
Pittsburgh, Pennsylvania

New Concrete Extension

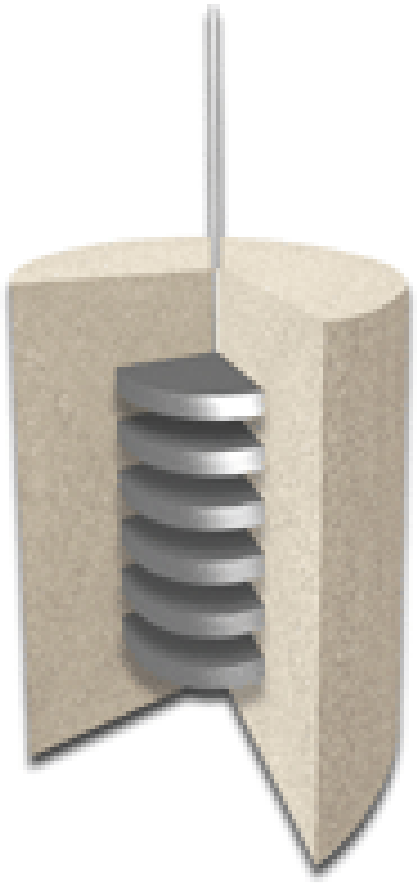
Old Retaining Wall

Failed Concrete Next to Joint Due to Corrosion

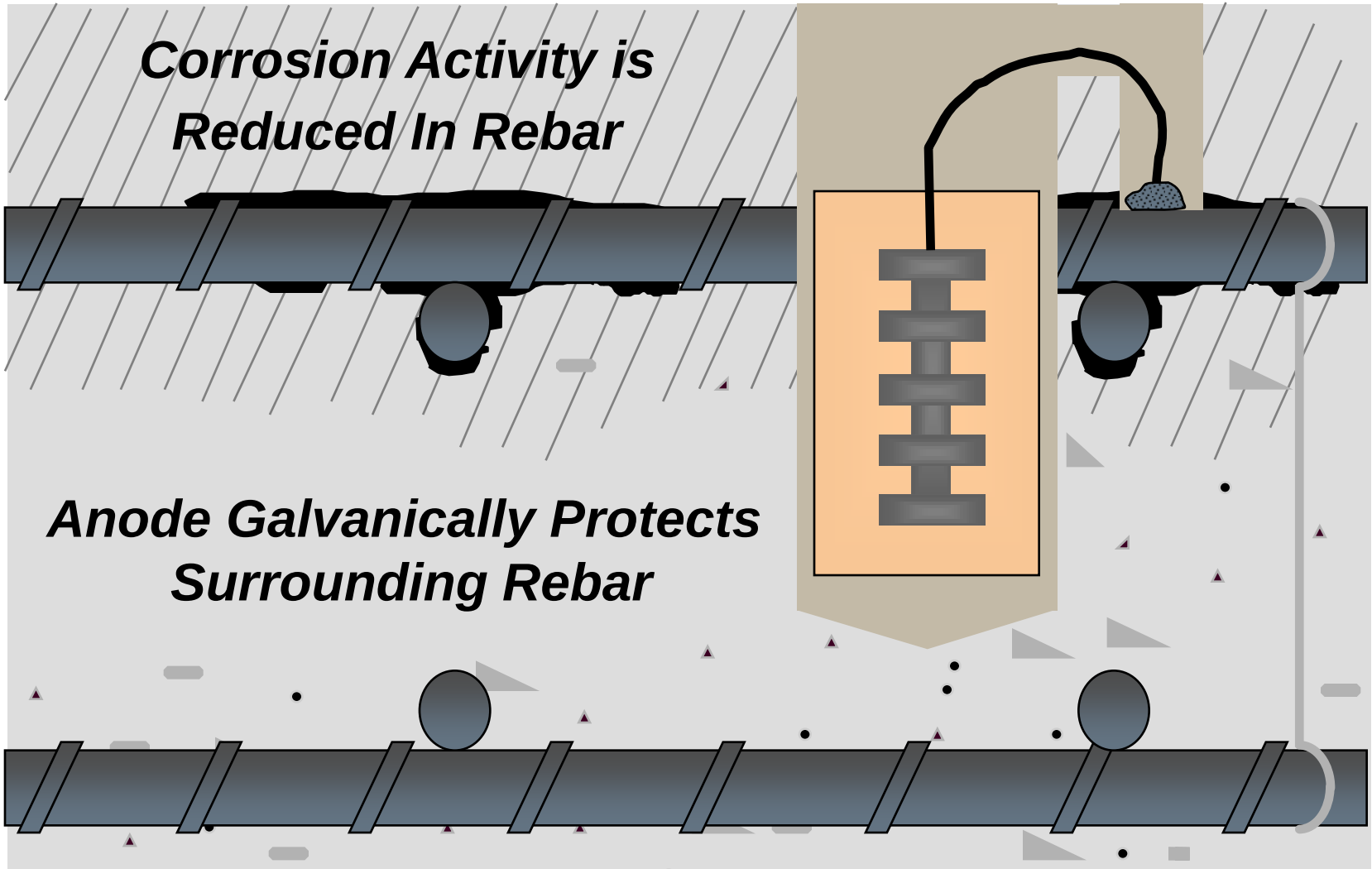

Old Chloride
Contaminated Concrete
New Chloride-Free
Concrete Extension
Surrounding
Rebar is Protected
Anode Galvanically Protects
Adjacent Rebar

Bridge Widening
Port Mann Bridge, Vancouver, British Columbia

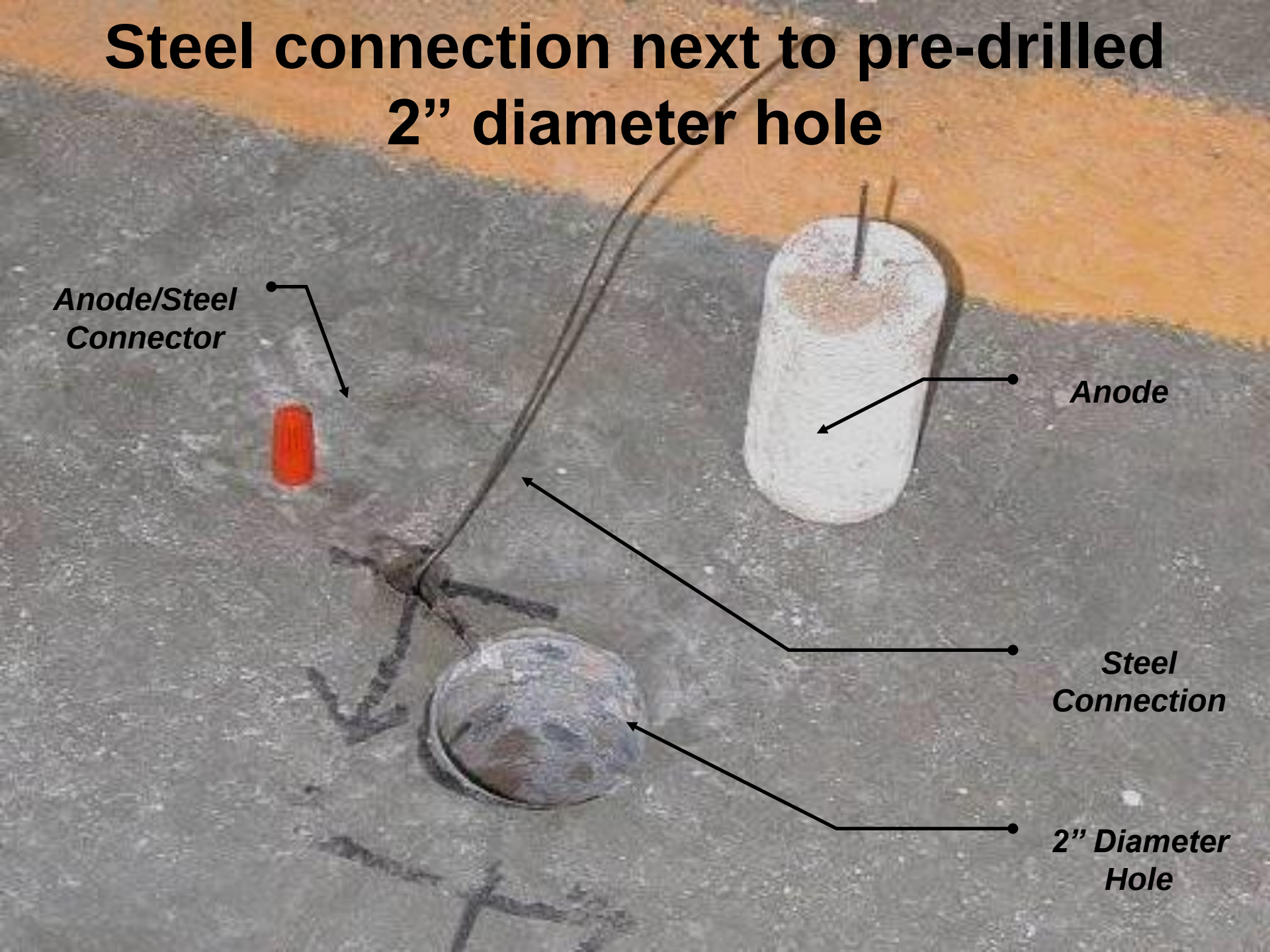
Embedded Galvanic Anodes for Corrosion Control



Corrosion Control Anode Installation



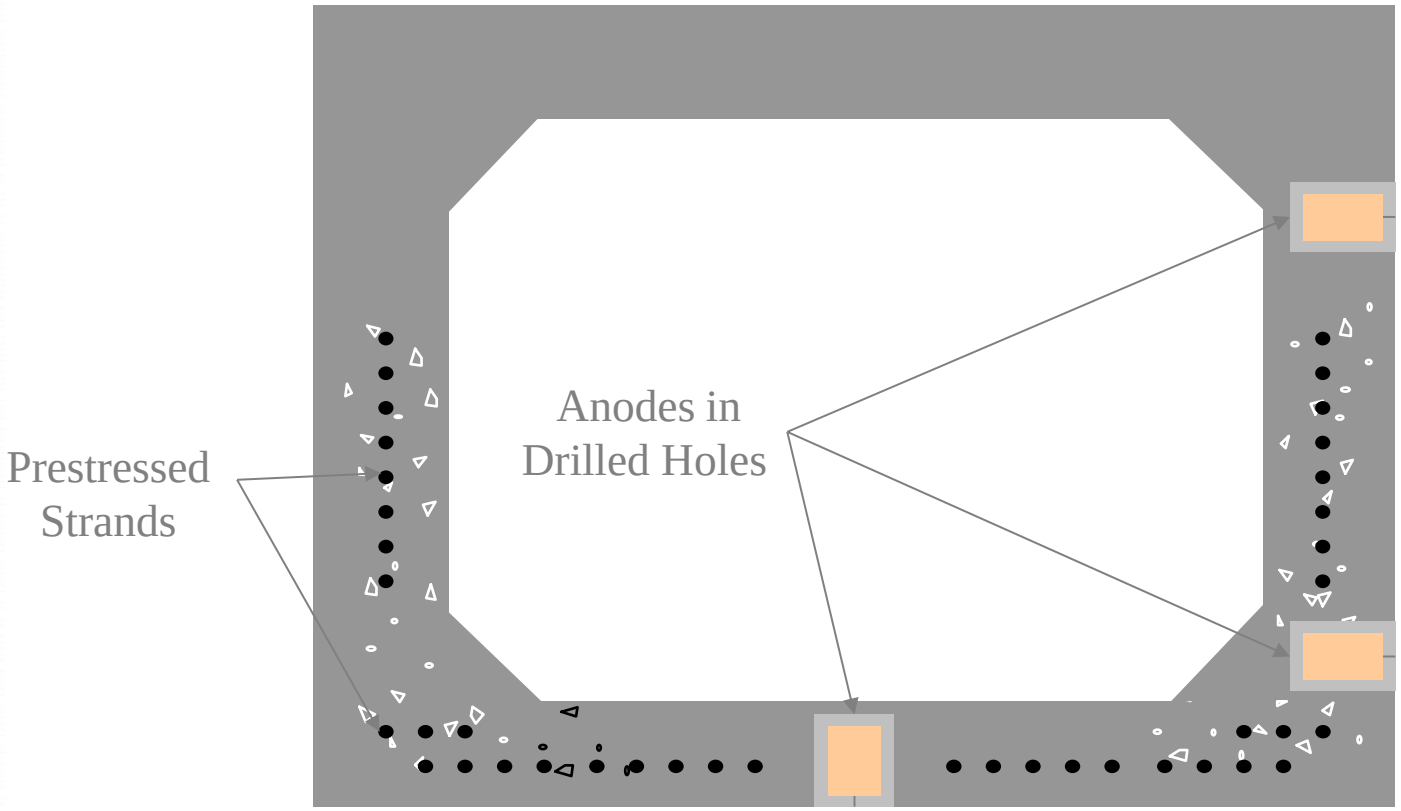
Steel connection next to pre-drilled 2” diameter hole



Anode Connection to Reinforcing Steel

Predrilled Holes for CC Installation
Parking Garage Deck

Galvanic Anodes in Prestressed Box Girder



Galvanic Anodes in Prestressed Box Girder

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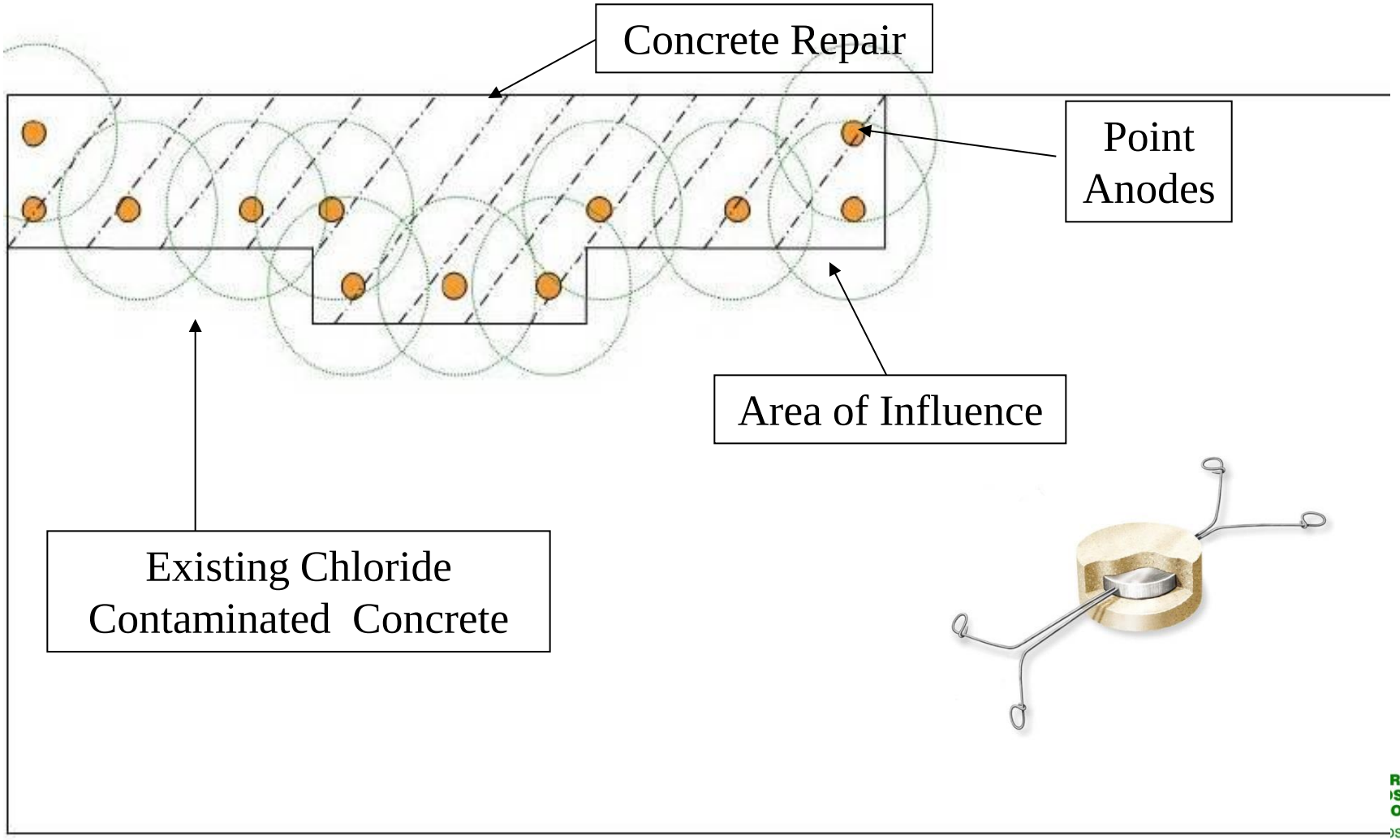
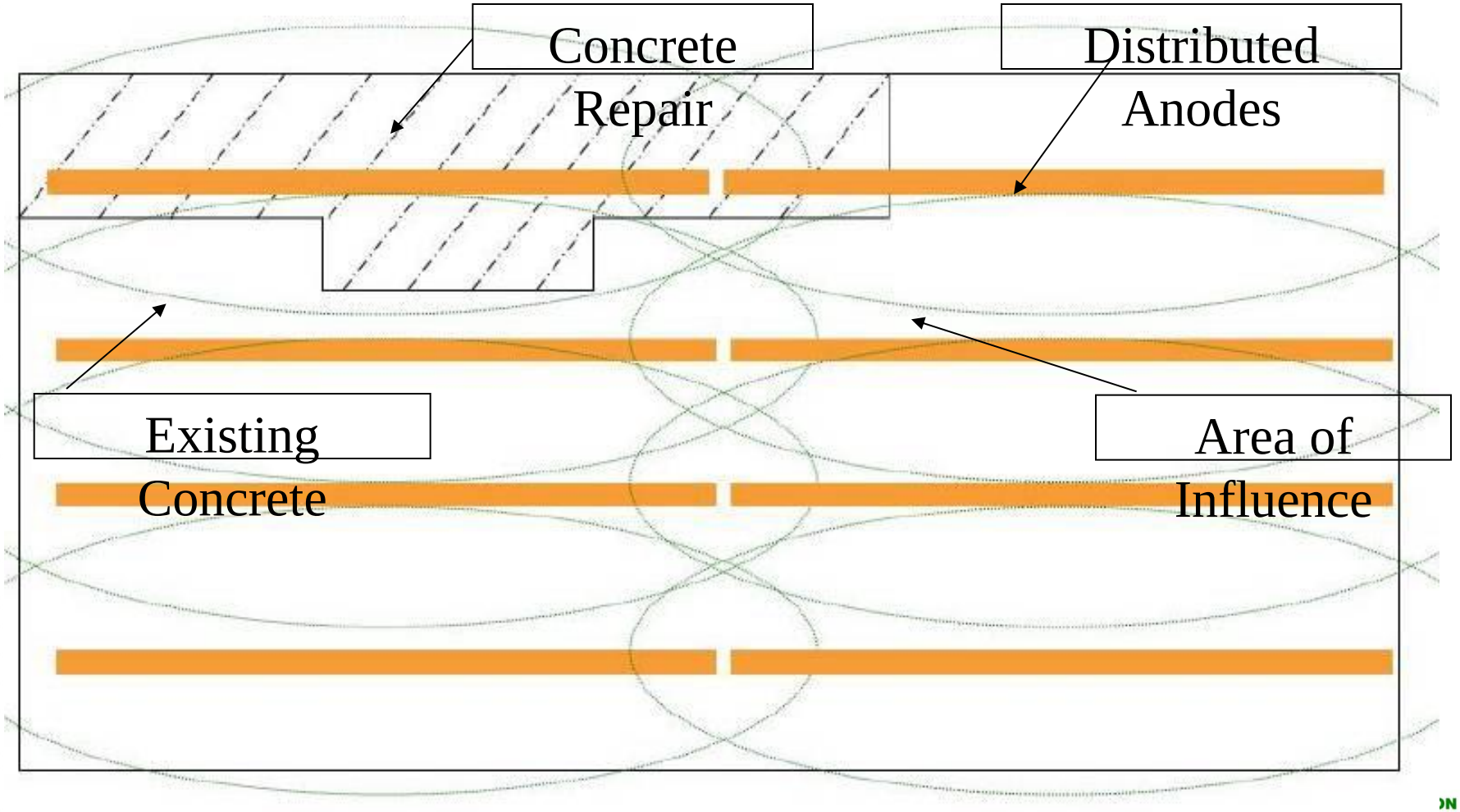
Galvanic Anodes in Prestressed Box Girder

Point Anodes
vs.
Distributed Anodes

Point Anodes Protection



Distributed Anodes Protection



Distributed Galvanic Anodes

- Distributed anode units are pre-manufactured
  - Zinc around a steel core
  - Integral connections
- Anode size and spacing: based on steel-to-concrete surface area ratio and service life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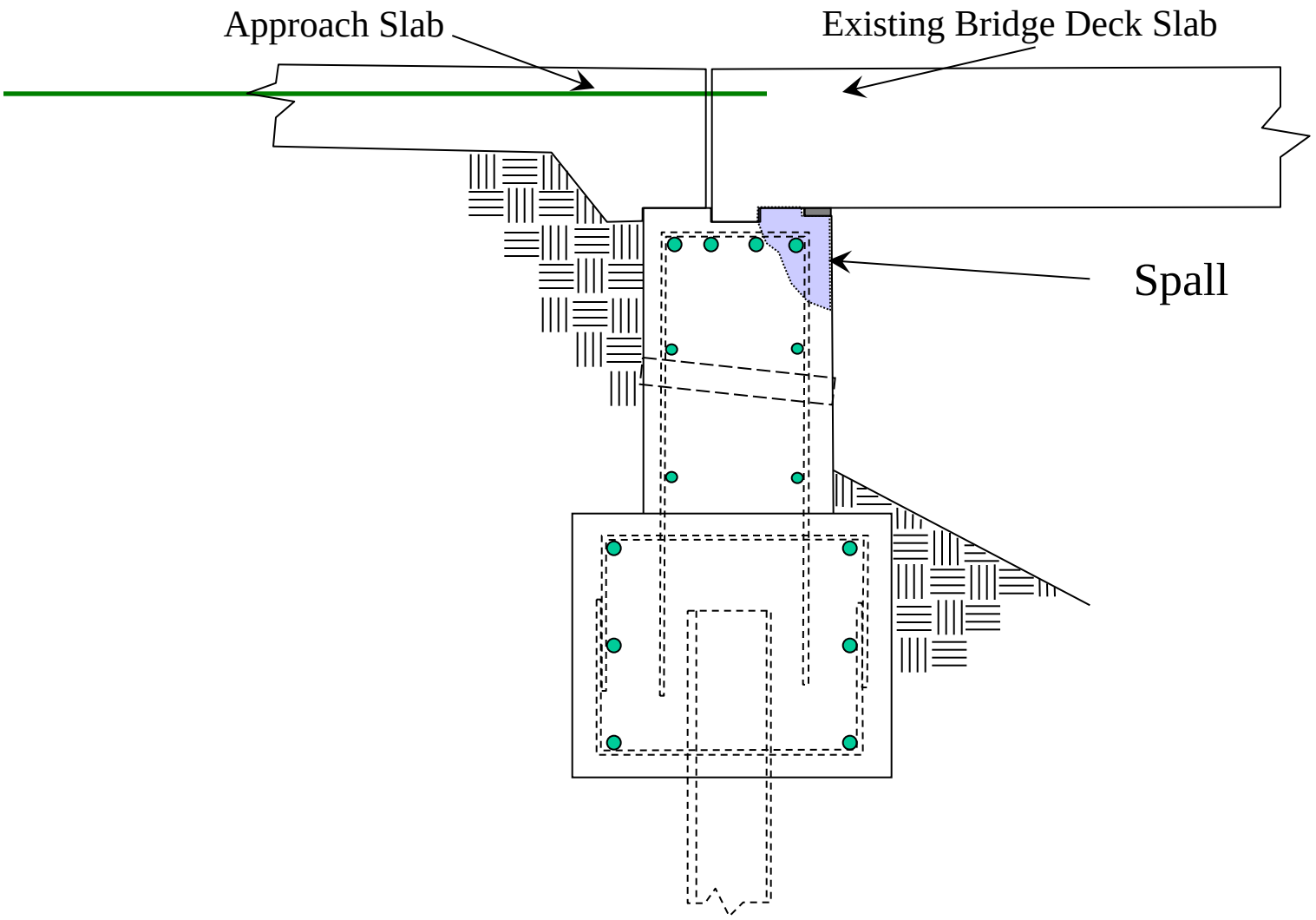
Applications

- Deck Overlays
- Abutment Encasements
- Column & Beam Encasements
- Interface Protection
- And more!

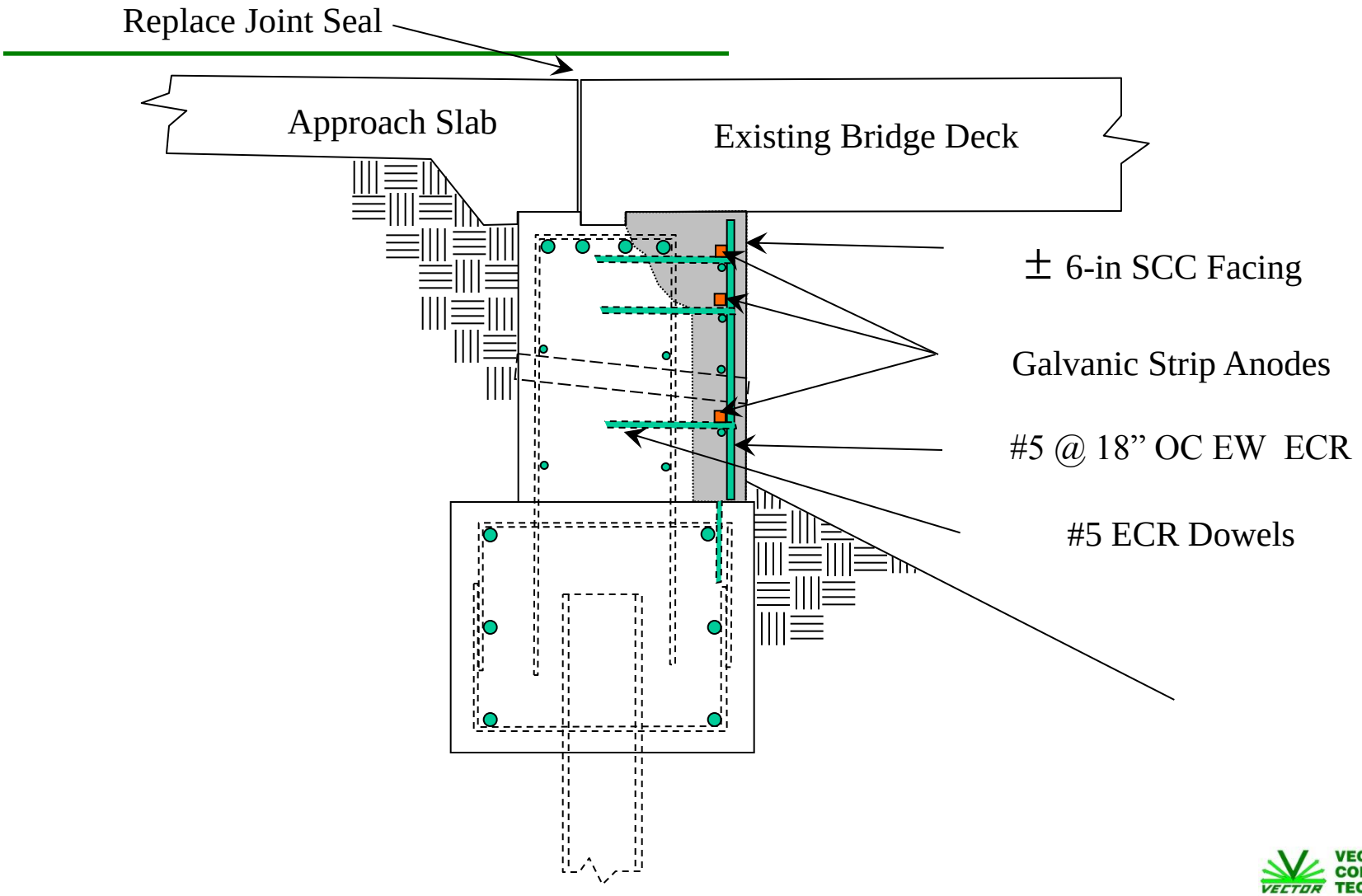
On Many Slab Bridges…

- Slabs are in good condition
- Deterioration at abutment around the key way

Typical Slab Bridge Abutment



Abutment Repair Detail With Galvanic Protection

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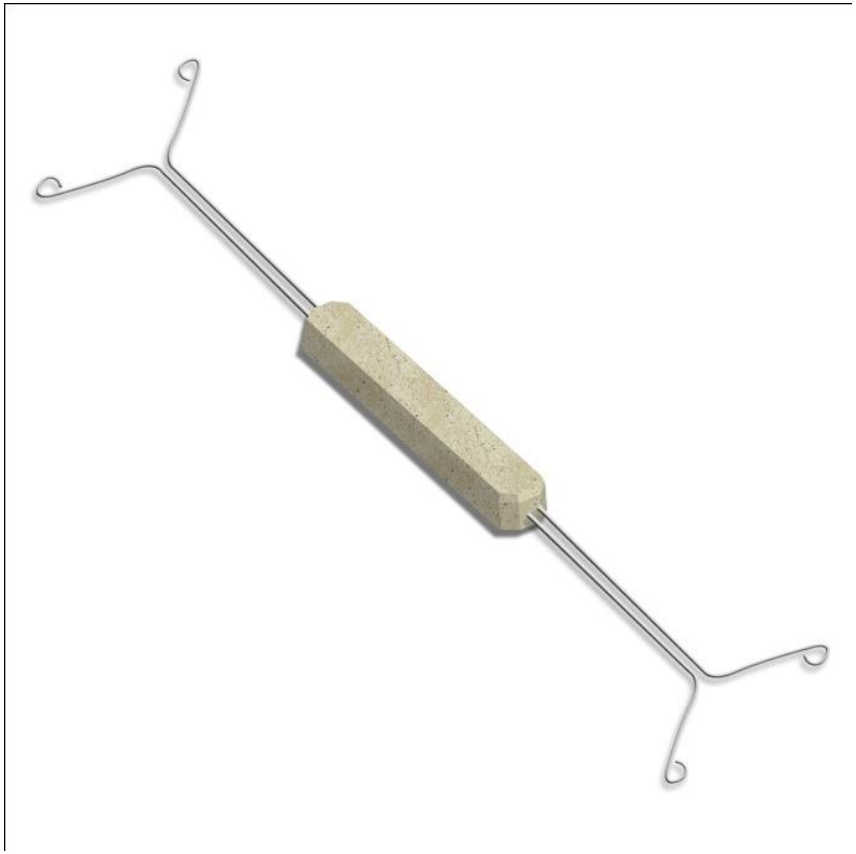
Other Distributed Anode System Applications

Galvanic Strips In 8 Bridge Deck Overlays Lake County, OH

Bridge Column Repair with Reinforced Concrete Jacket

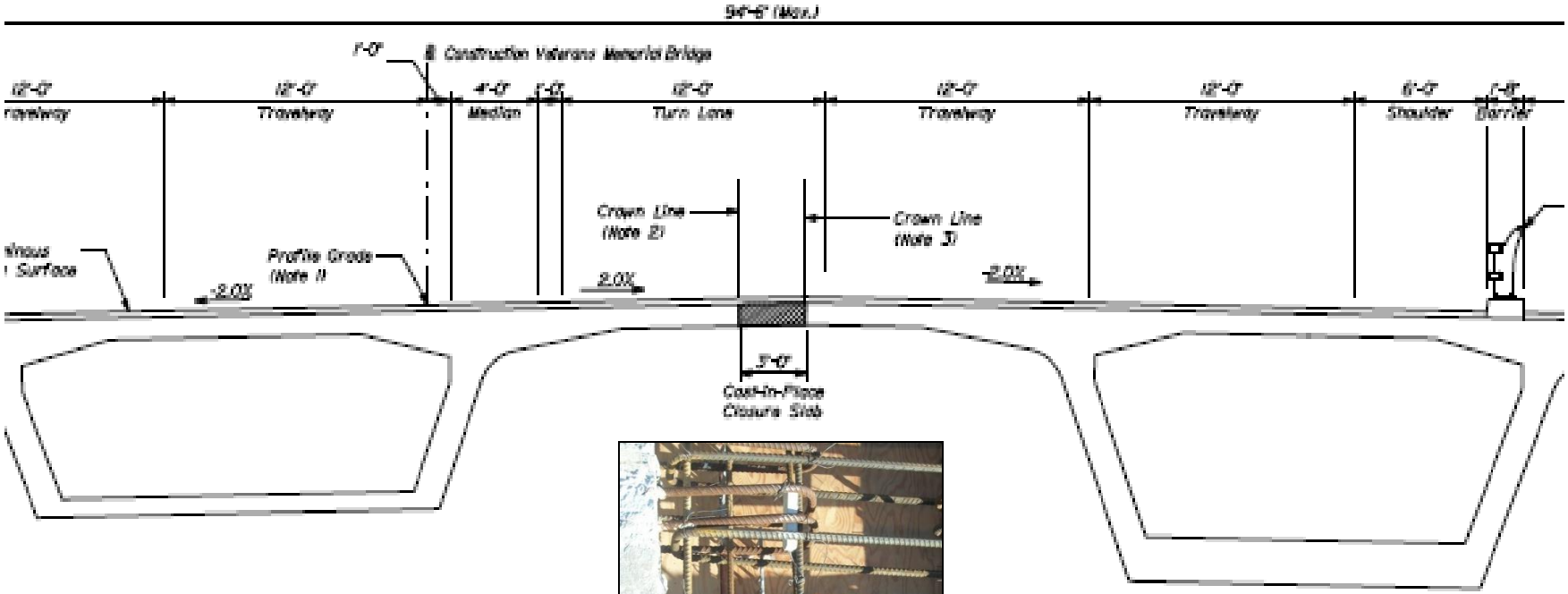
Bridge Pier Cap Repair with Galvanic Anode Strips

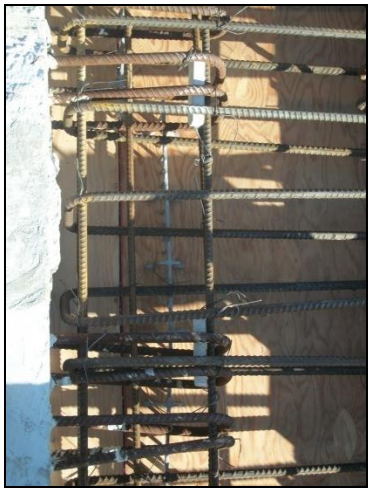
Galvanic Anodes for Corrosion Prevention In New Construction



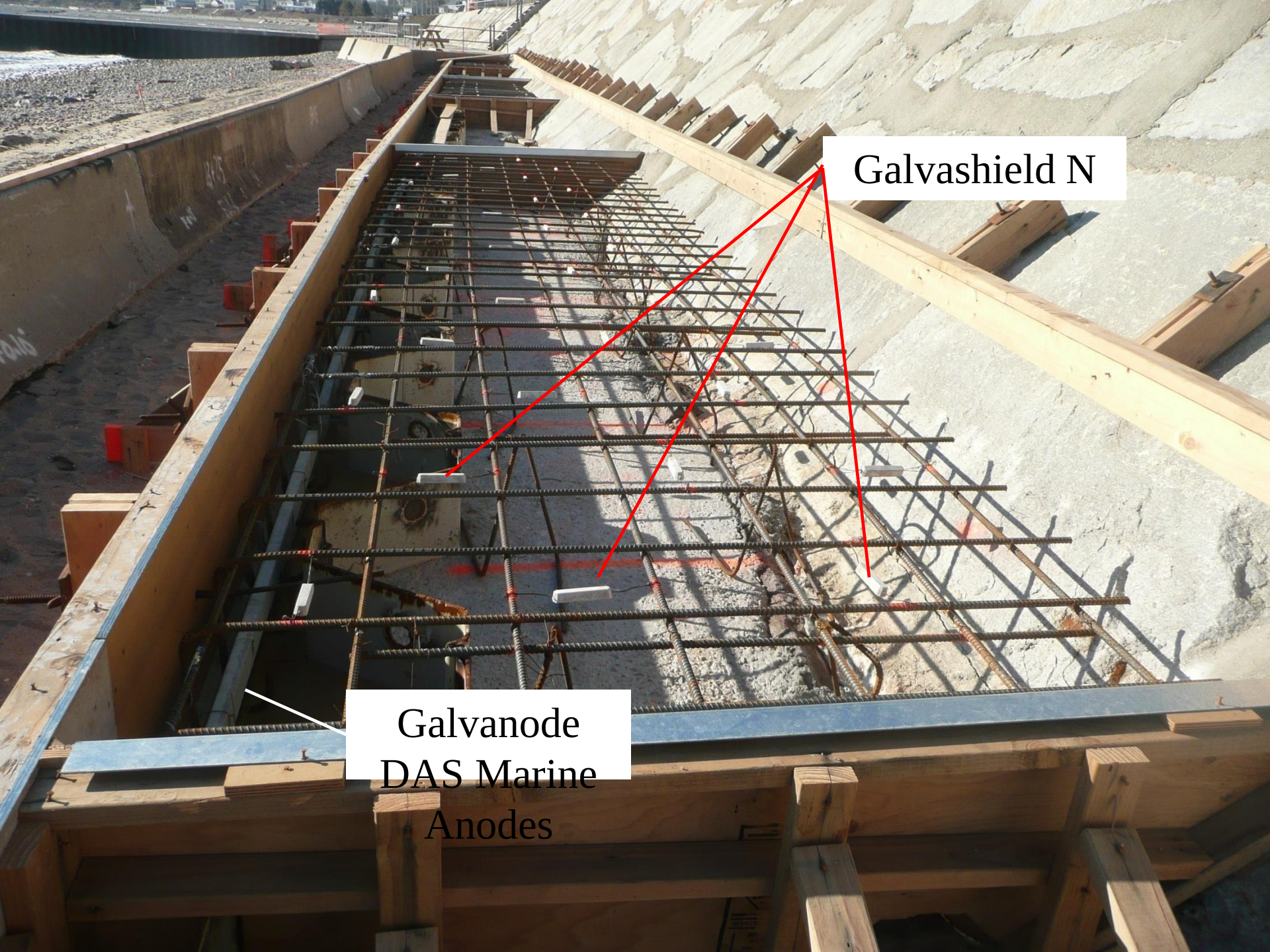
Galvashield N

Precast Closure Strip



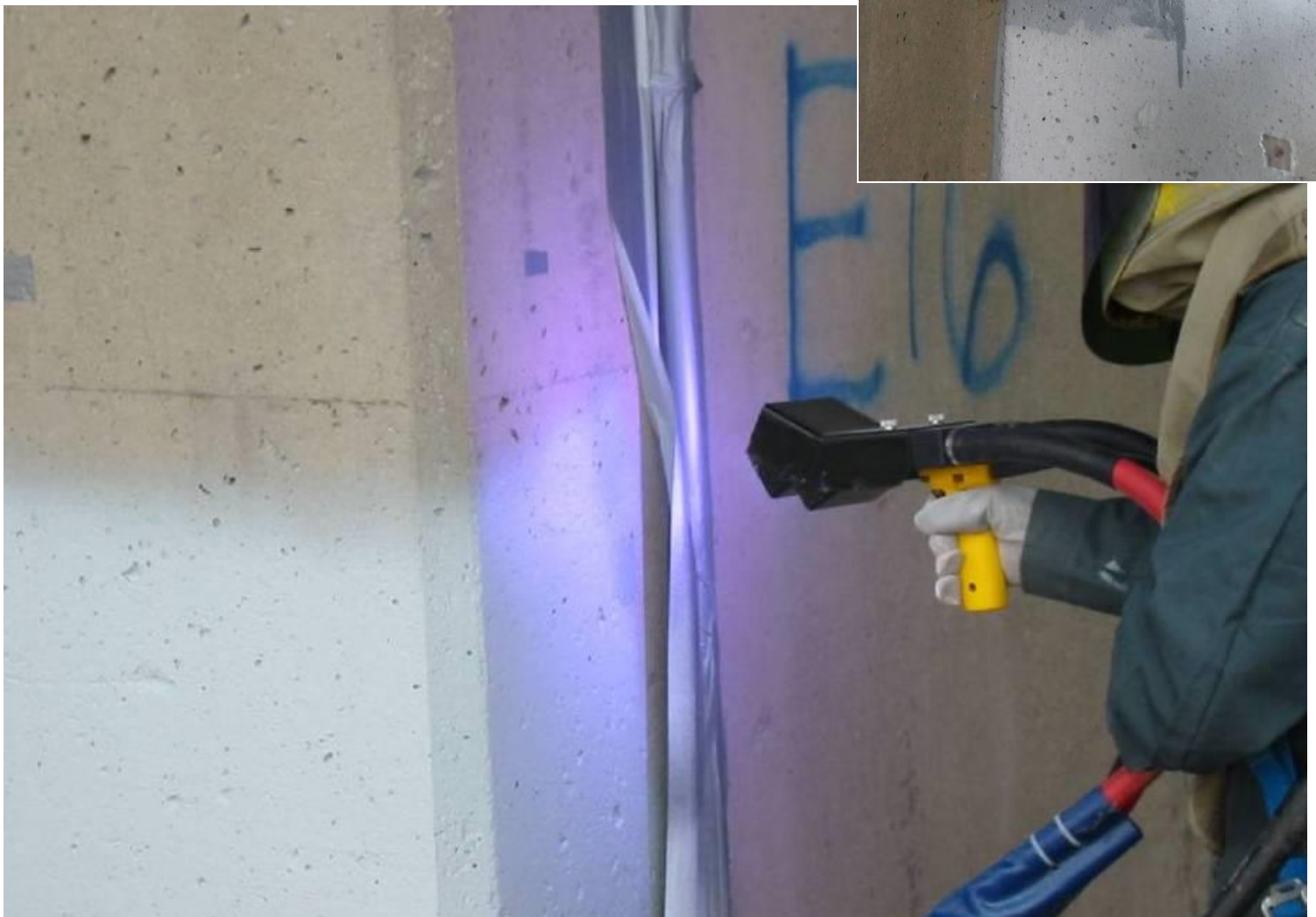


Seawall Reconstruction


Galvashield N
Galvanode
DAS Marine
Anodes

DECK PROTECTION

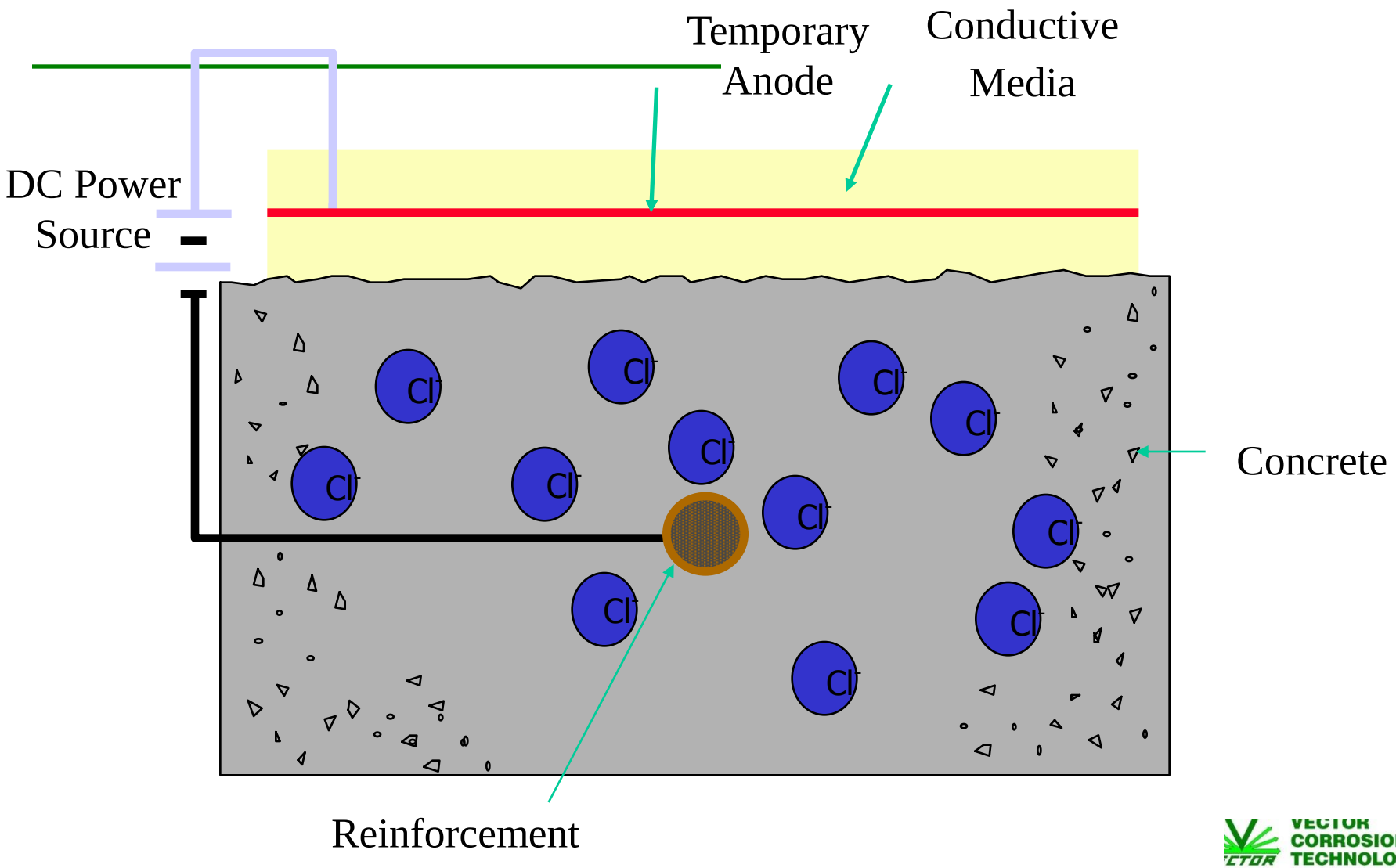
“Distributed” Protection with Activated Arc Sprayed Thermal Zinc



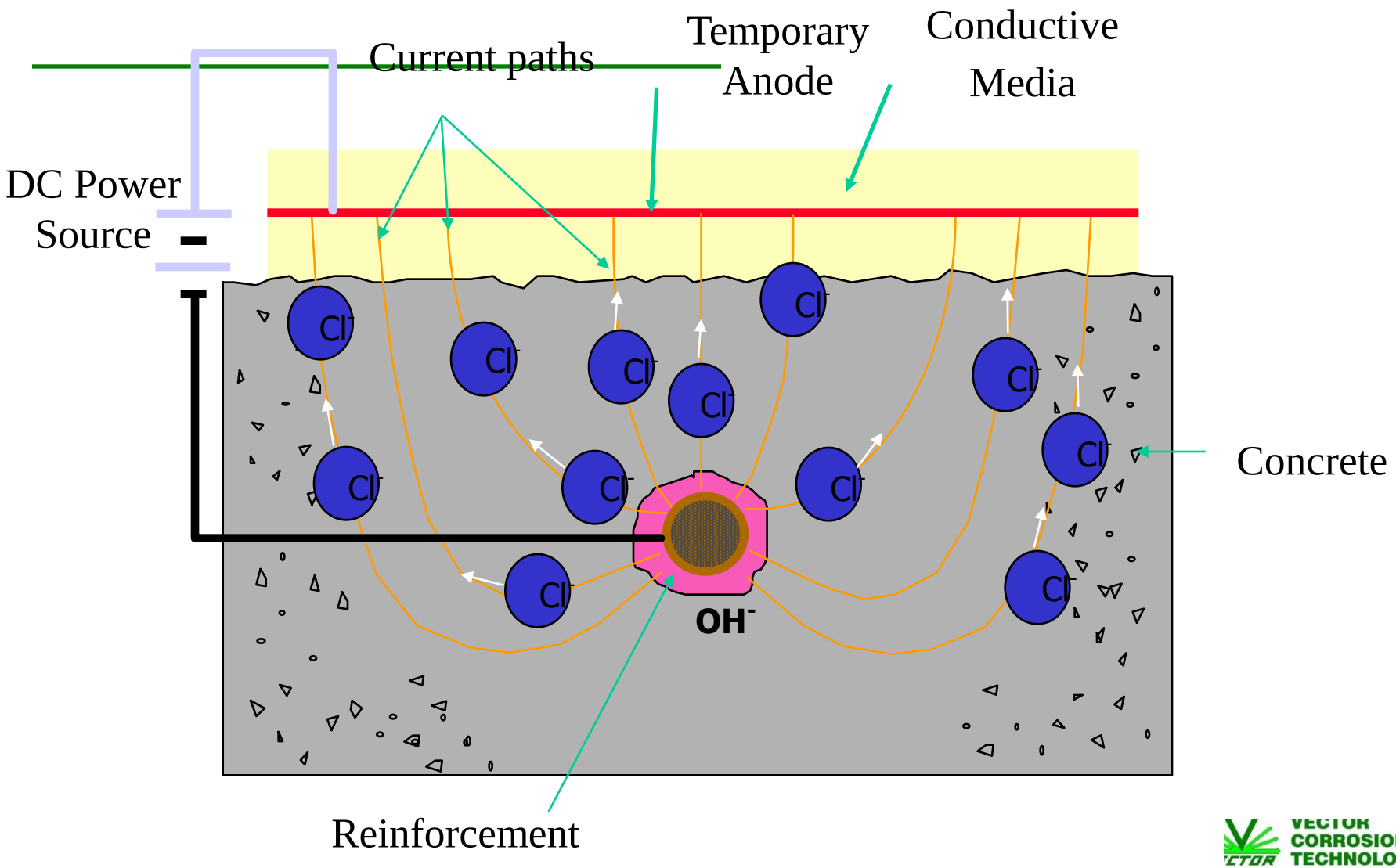
Electrochemical Treatments

- **Chloride Extraction (ECE)**
- Re-alkalization
- Lithium Impregnation (ASR Treatment)

Electrochemical Chloride Extraction (ECE) From Salt Contaminated Concrete



Electrochemical Chloride Extraction (ECE) From Salt Contaminated Concrete



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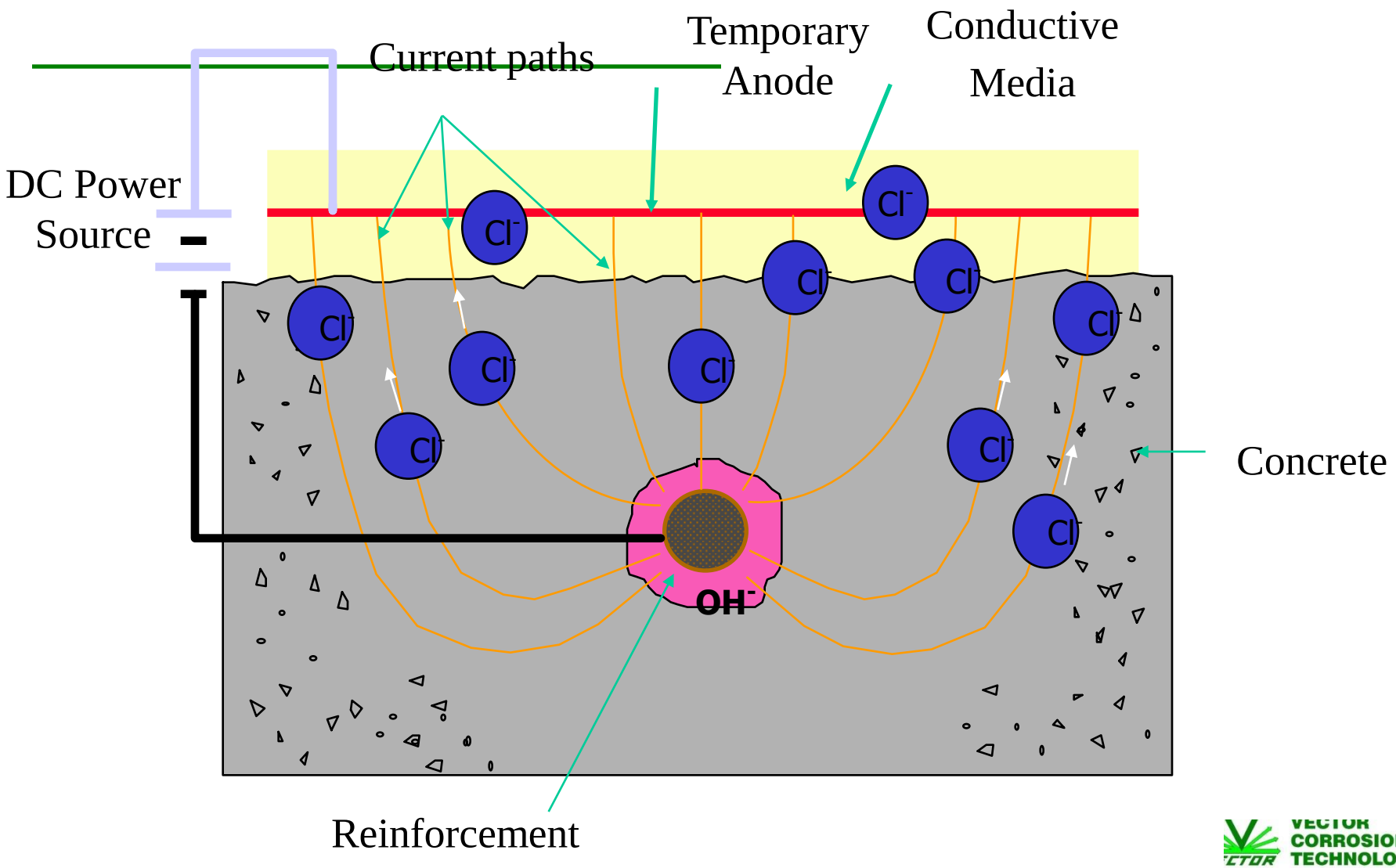
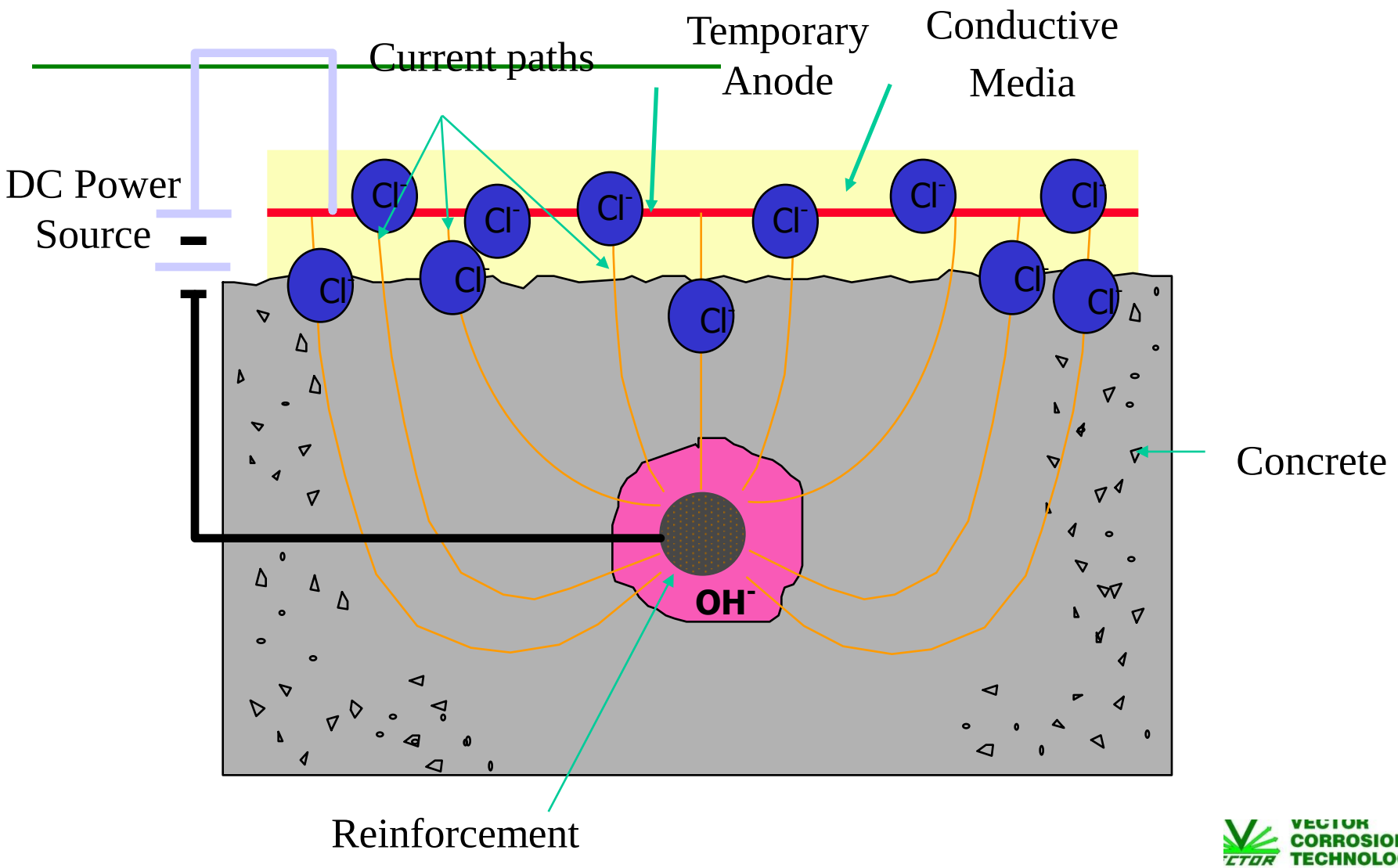


Electrochemical Chloride Extraction (ECE) From Salt Contaminated Concrete



ECE Treatment Process

ECE Treatment Process

Cellulose Fiber Serves as Electrolyte

Installation Complete
Ready to Start Treatment

Several Piers Wrapped and Undergoing ECE Treatment
Omaha, Nebraska

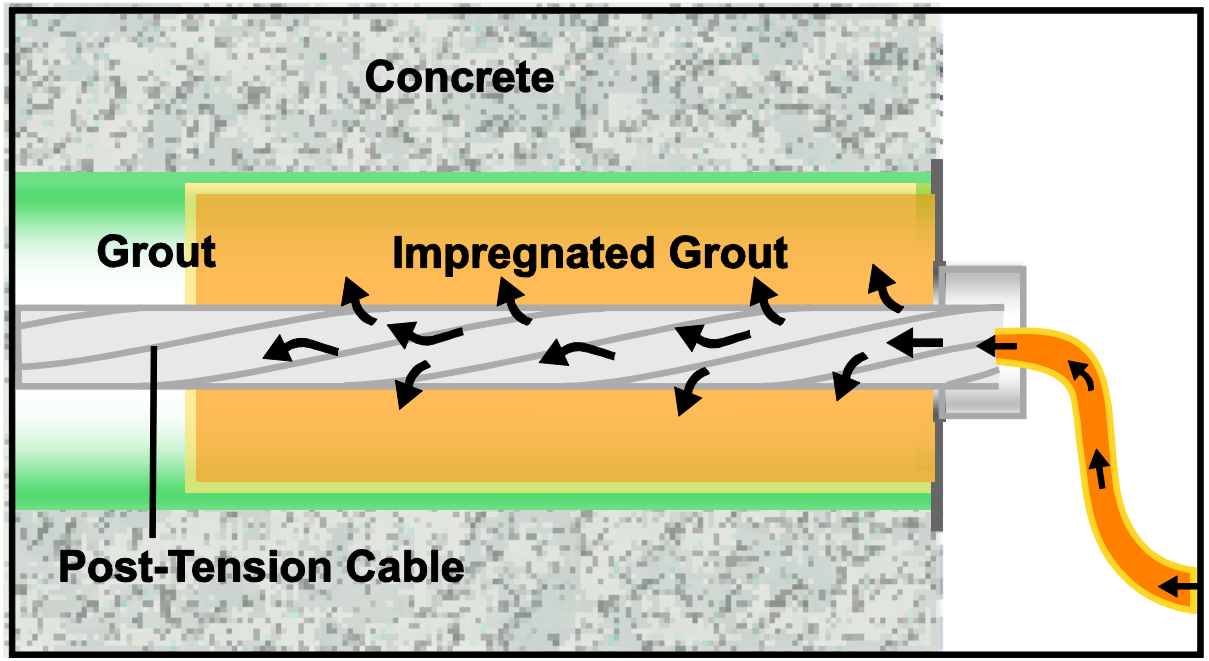
Piers after ECE Treatment
Cleaned and Sealed

Rainbow Bridge- Idaho

Problem: Corrosion or Grout related issues
Example: Bleed water issues within duct

Cable Impregnation

Cable Impregnation



Cable Impregnation

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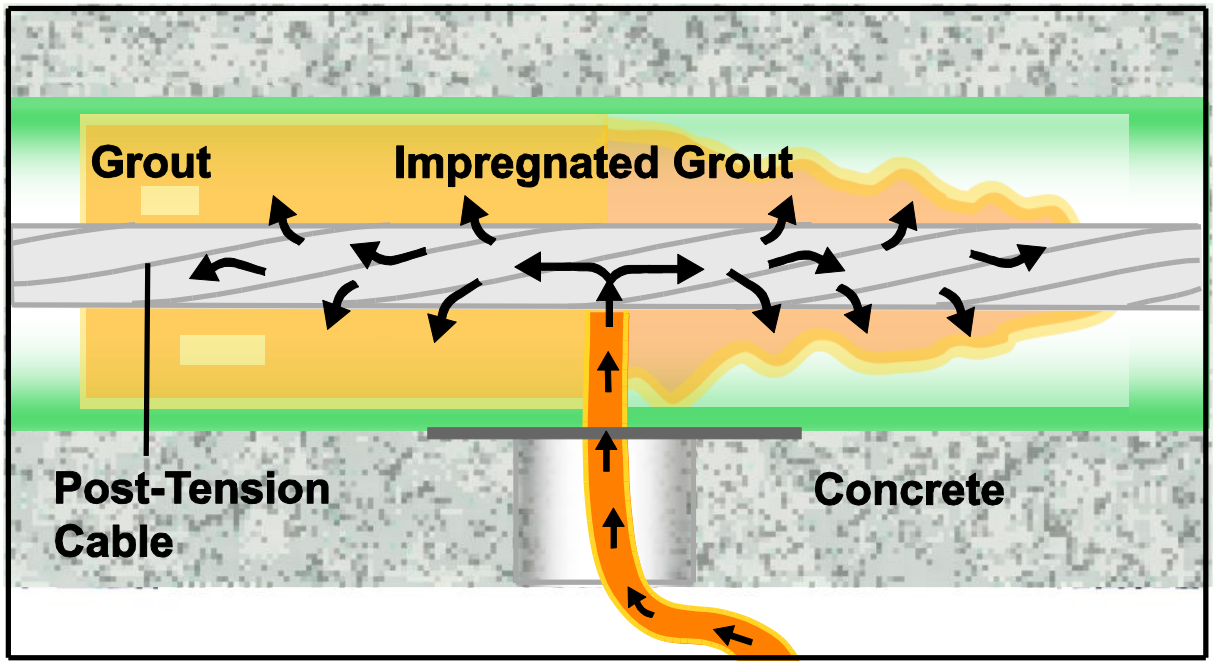
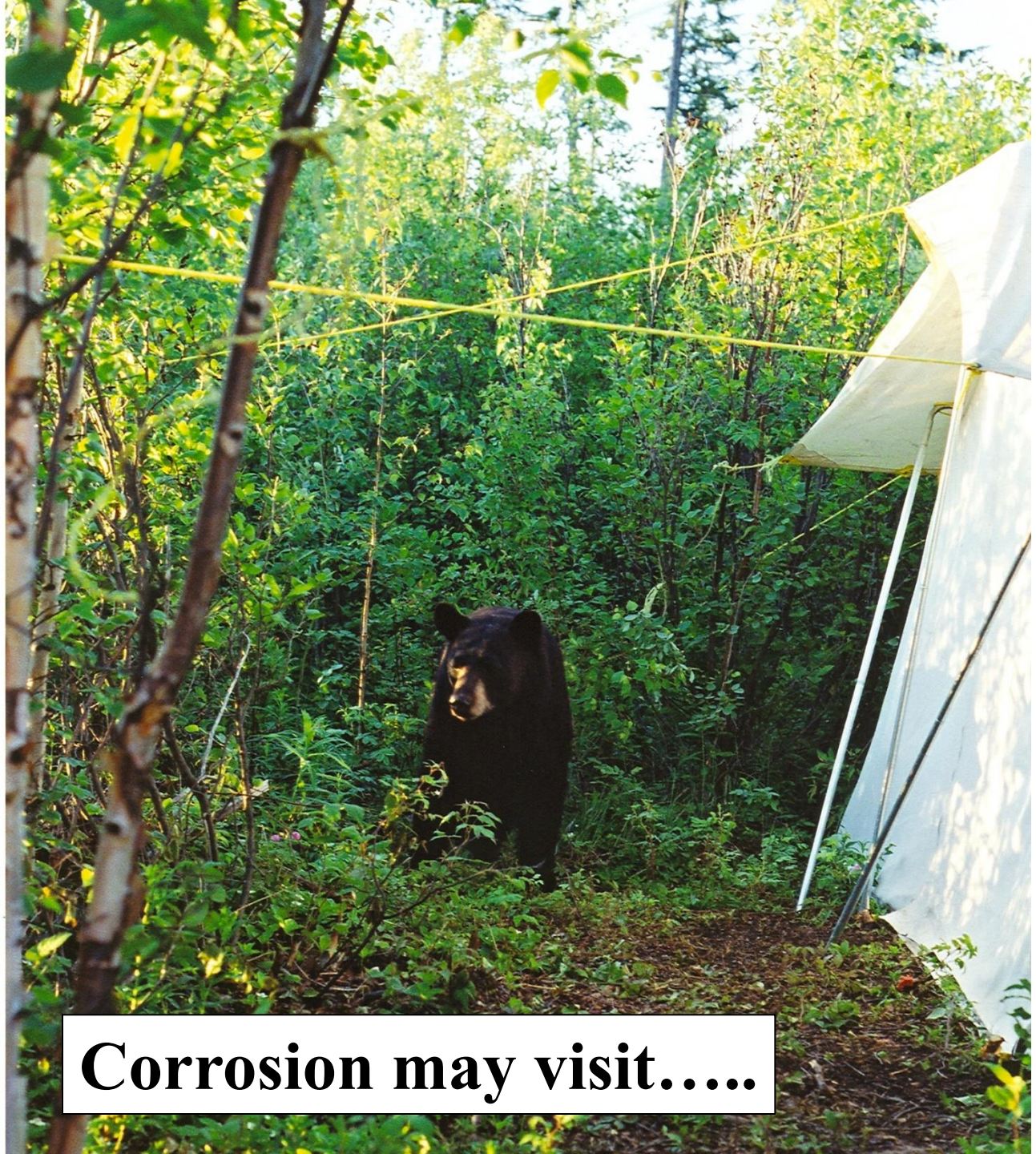


Cable Impregnation

Impregnation Pattern

Corrosion Testing of Impregnation Material on Exposed Steel



Corrosion may visit…..

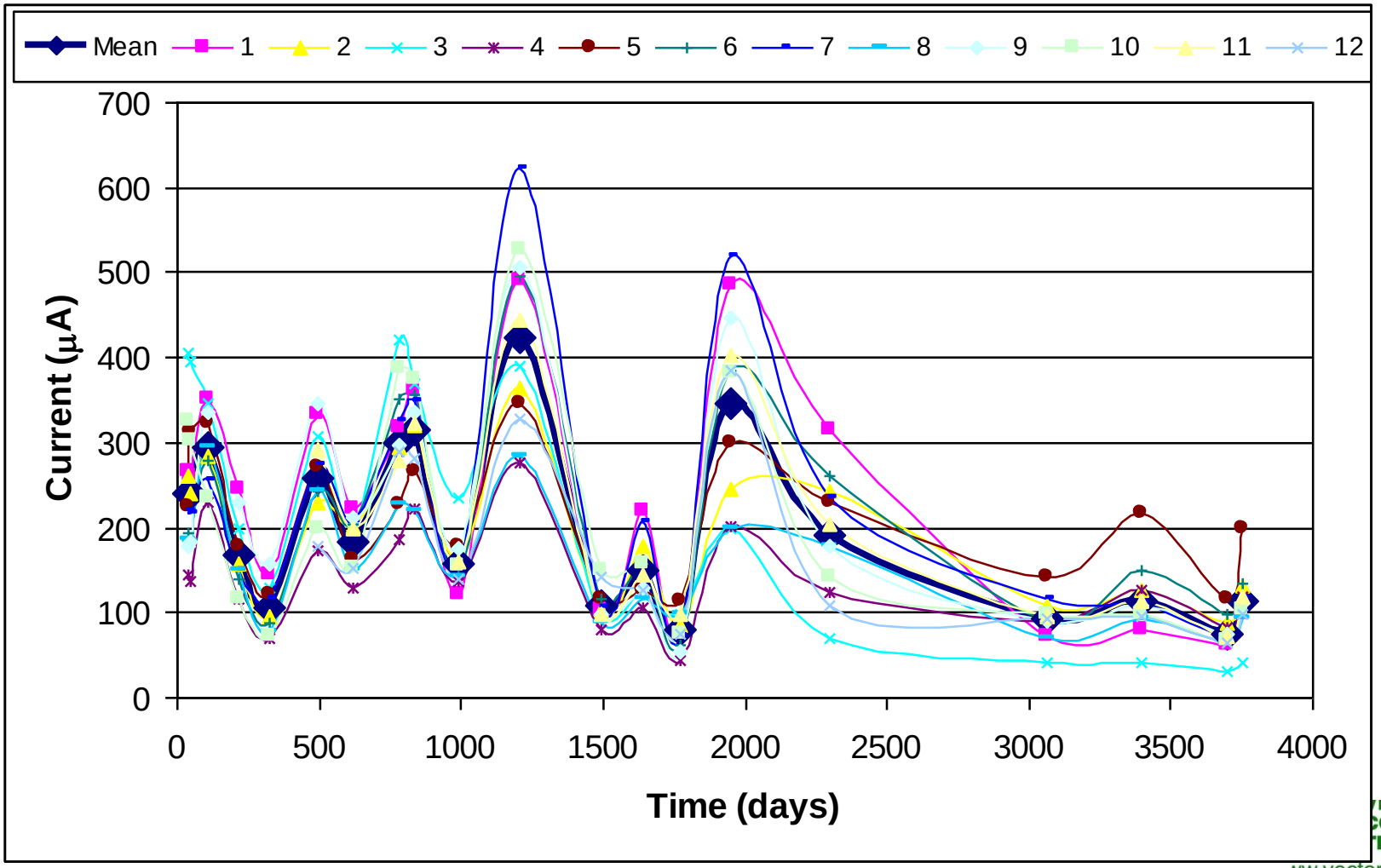
Questions

Do we have a few more minutes?

Leister Bridge Cross Beam

- Completed in 1999
- Monitored for 10 years

10 Year Monitoring - Current

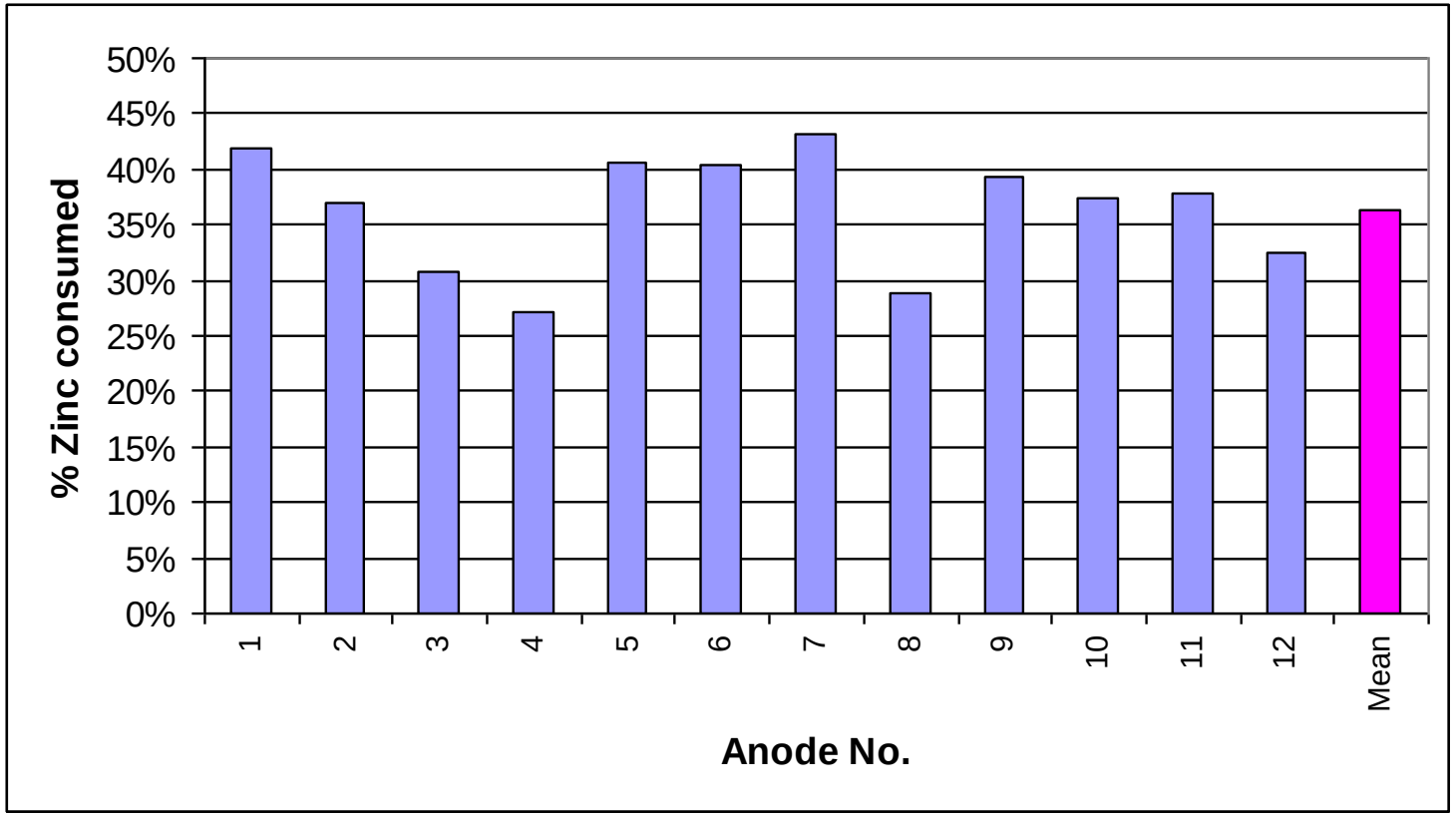


Current Density

- Cathodic Prevention
  - European Standard EN 12696
  - Current Density 0.2-2mA/m^2
  - No polarization criteria

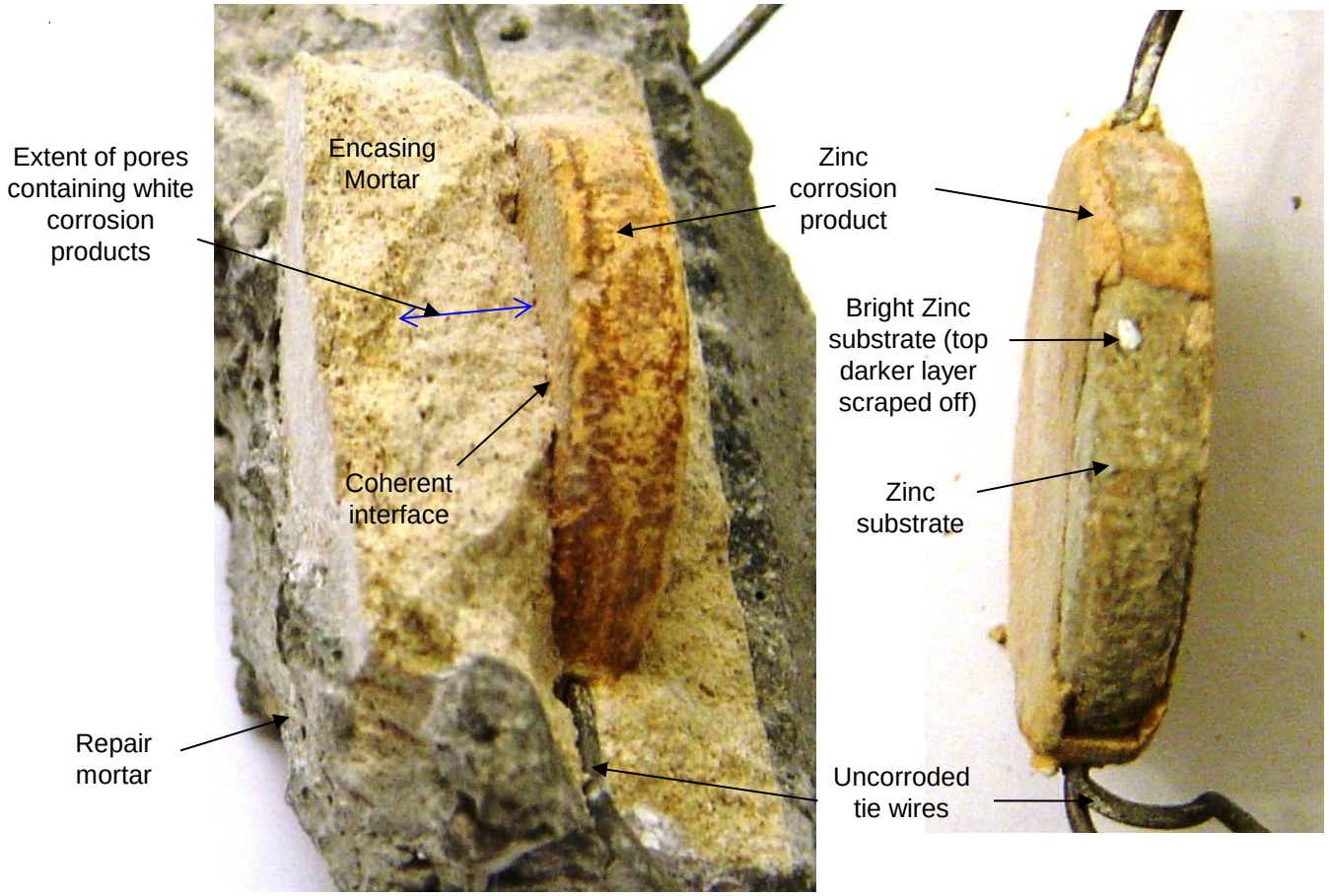
- Leister Bridge
  - Ranged 0.6 mA/m^2 and 3.0 mA/m^2
  - Overall mean of around 1.4 mA/m^2

Approximate Zinc Consumption



- Calculated based on current output and 85% utilization

Forensic Analysis after 10 yrs



(a) (b)