Electrochemical Treatments to Significantly Extend the Service Life of Reinforced Concrete Structures

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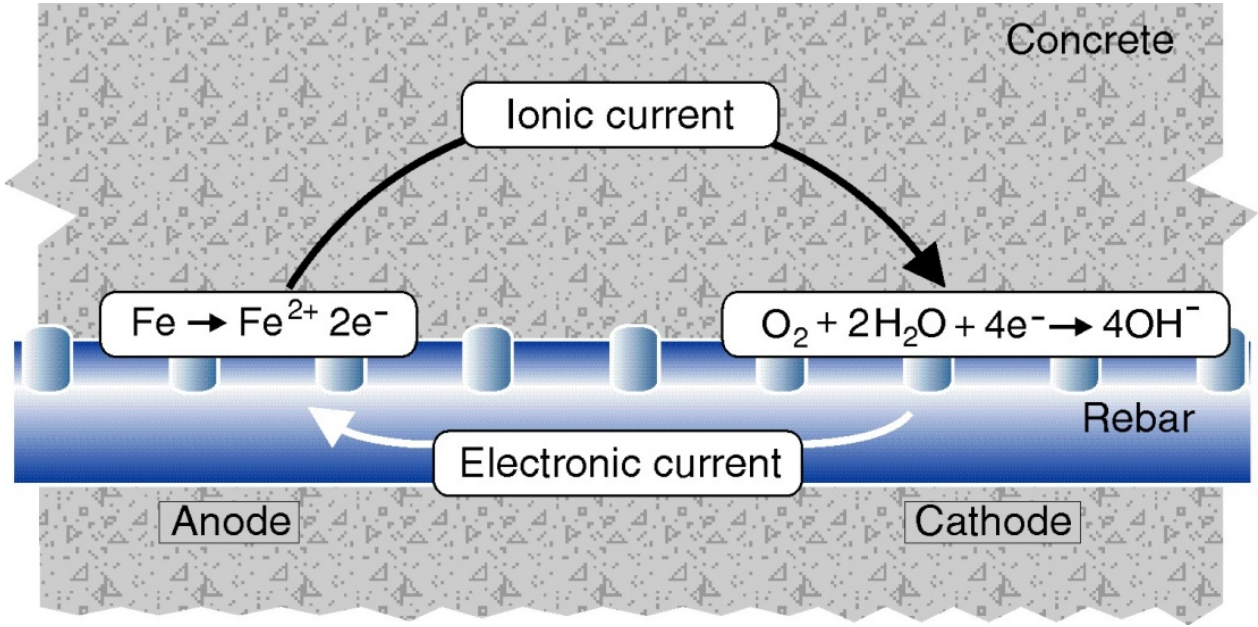
Vector Corrosion Services

Outline

- Corrosion basics
- What are electrochemical treatments and how do they work?
- Project case histories
  - I-480 – Omaha, Nebraska – Electrochemical chloride extraction
  - University of Chicago – Re-alkalization

Corrosion

- Electrochemical reaction
- Requires
  - Moisture
  - Electrolyte – concrete
  - Metallic path – steel
- Anode
  - Where rust is formed
- Cathode
  - No section loss



Corrosion of Reinforced Concrete

- Concrete is naturally alkaline
  - pH of about 13
- Steel is naturally passive at this alkalinity
  - Formation of passive layer
- Passive layer can be destroyed by;
  - Chlorides
  - Carbonation

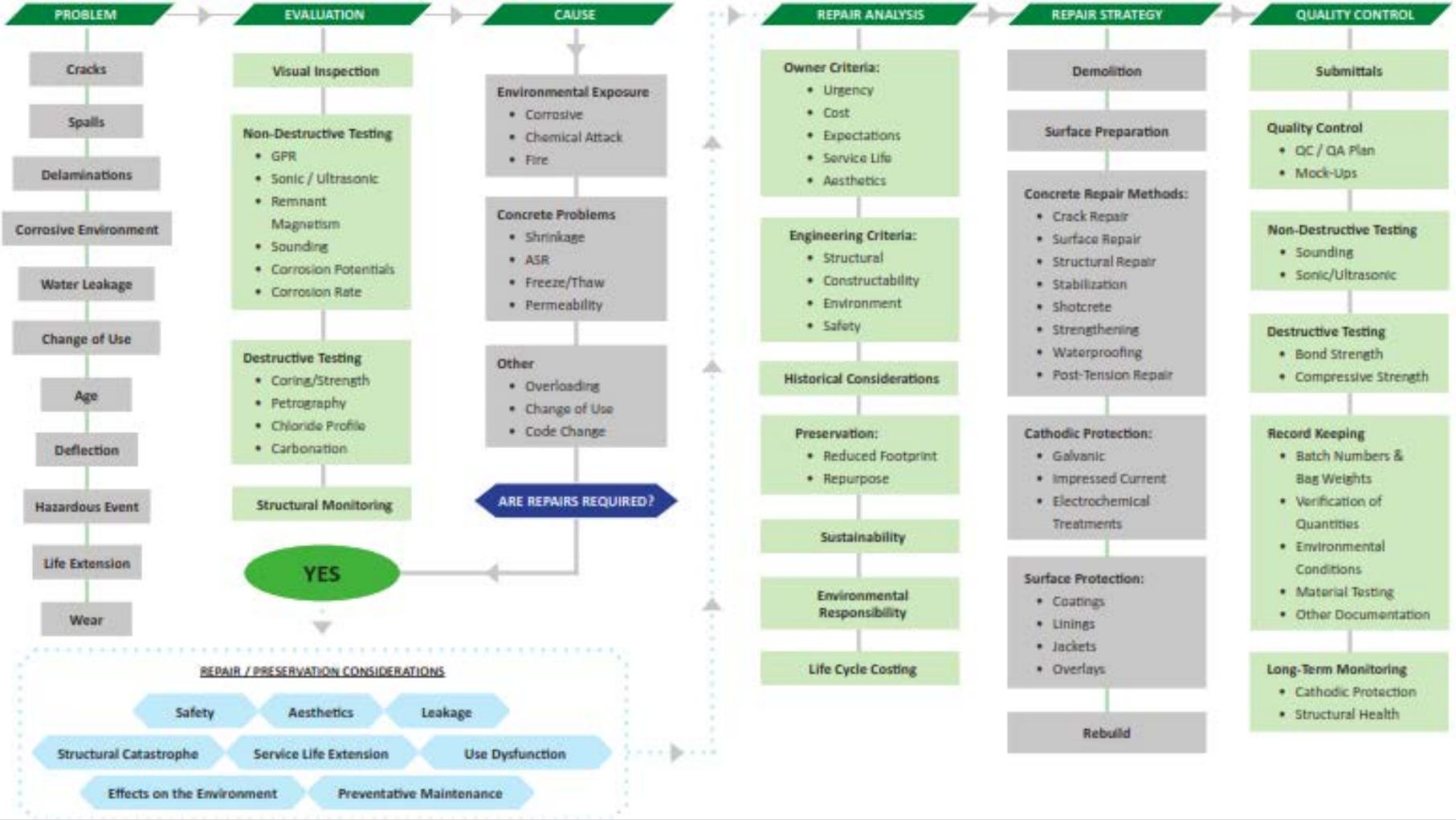
Chloride Induced

- Chloride ions diffuse into concrete and destroy steel's passive layer
- Source of chlorides
  - Marine environments
  - De-icing salts
  - Chemical/processing plants
  - Cast into concrete
- Chlorides are not consumed in corrosion reaction, therefore, once threshold concentration reached, corrosion can occur unabated

Carbonation

- Carbon dioxide permeates into concrete
- Reduces pH of concrete
  - CO_2 reacts with free lime, $Ca(OH)_2$, resulting in $CaCO_3$ and H_2O
- Reduced pH de-passivates steel
- Often seen when
  - Concrete permeability is high
  - Industrial sites
  - Very old structures – carbonation is a result of time and exposure

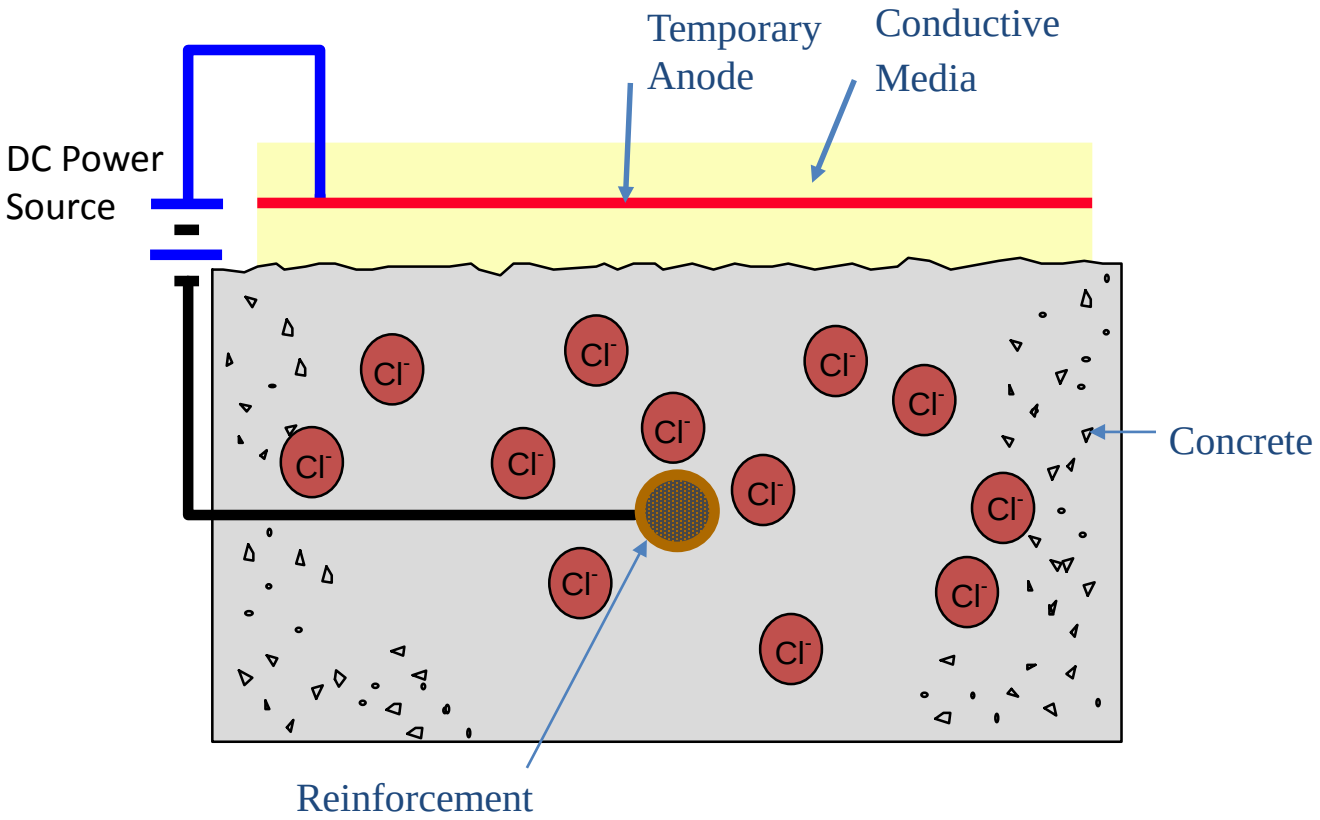
CONCRETE PRESERVATION PROCESS

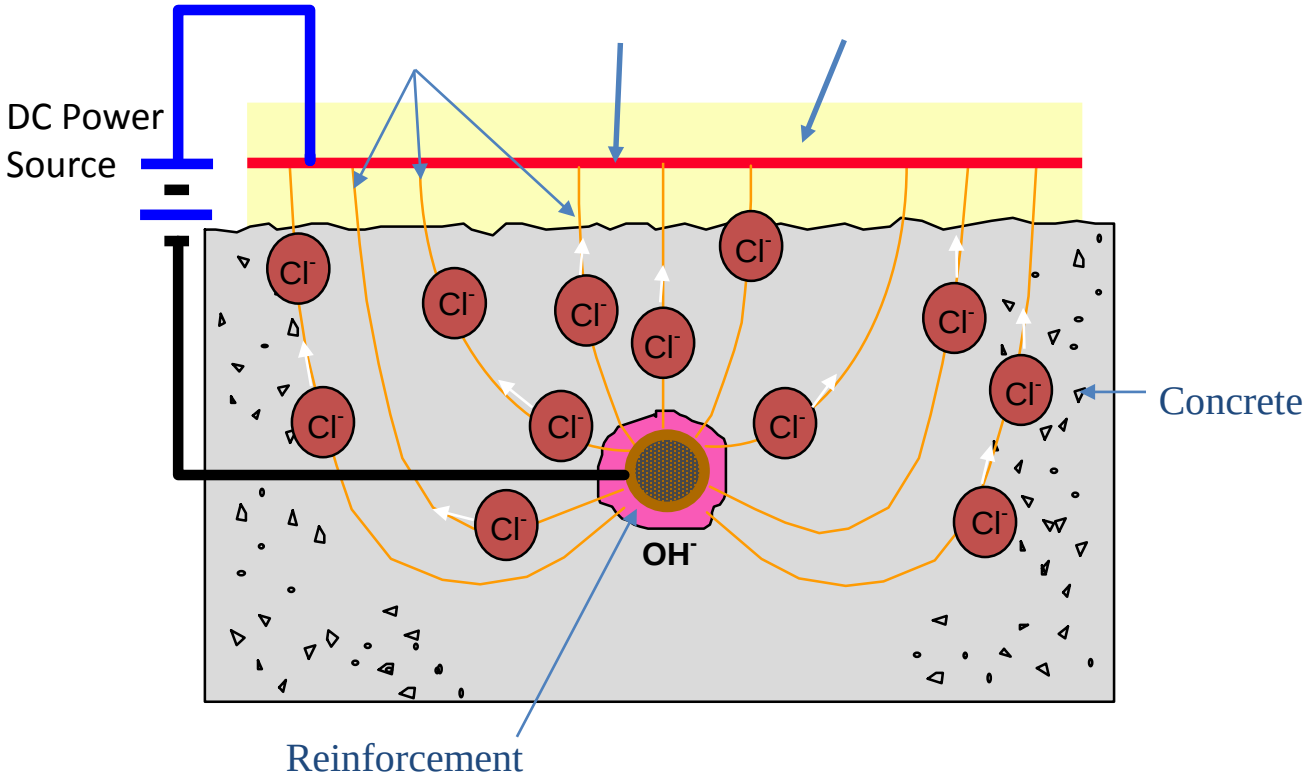


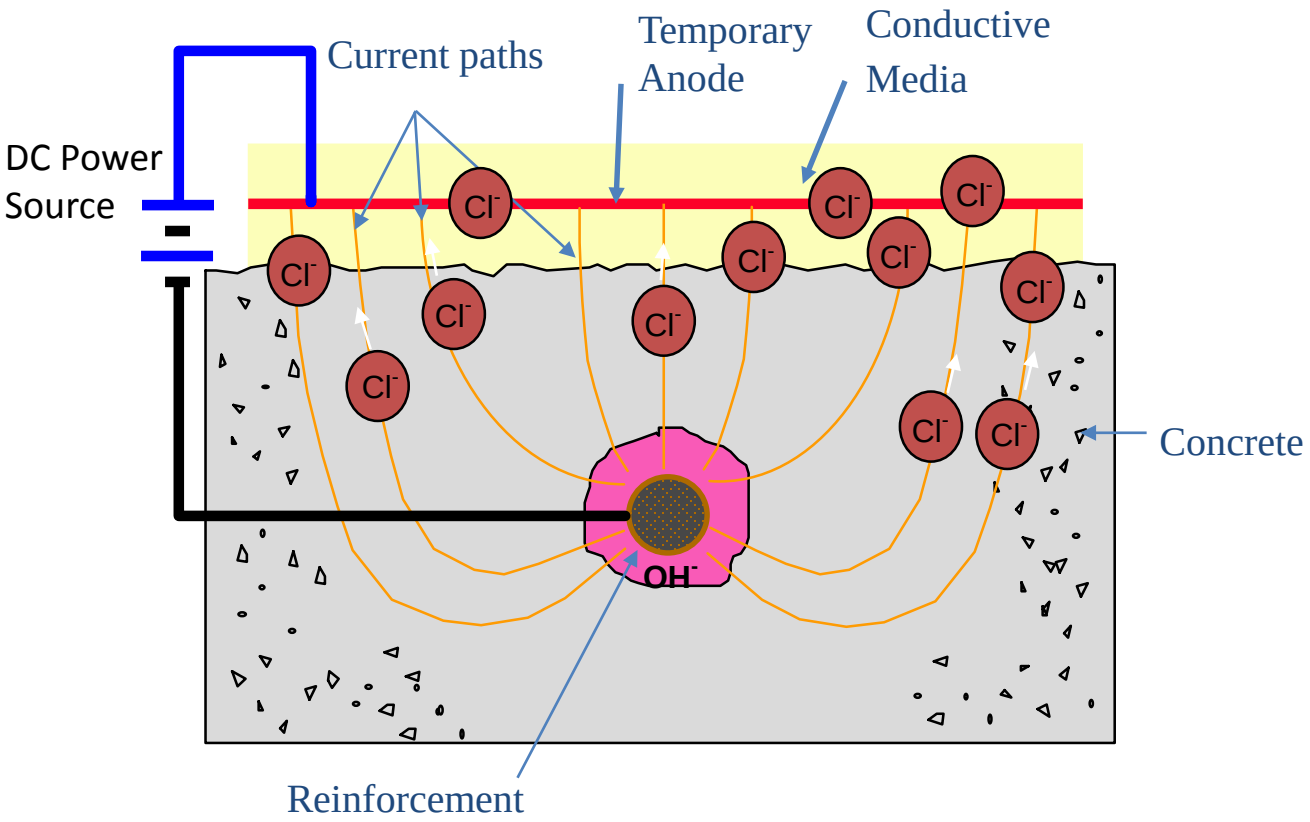
Electrochemical Chloride Extraction

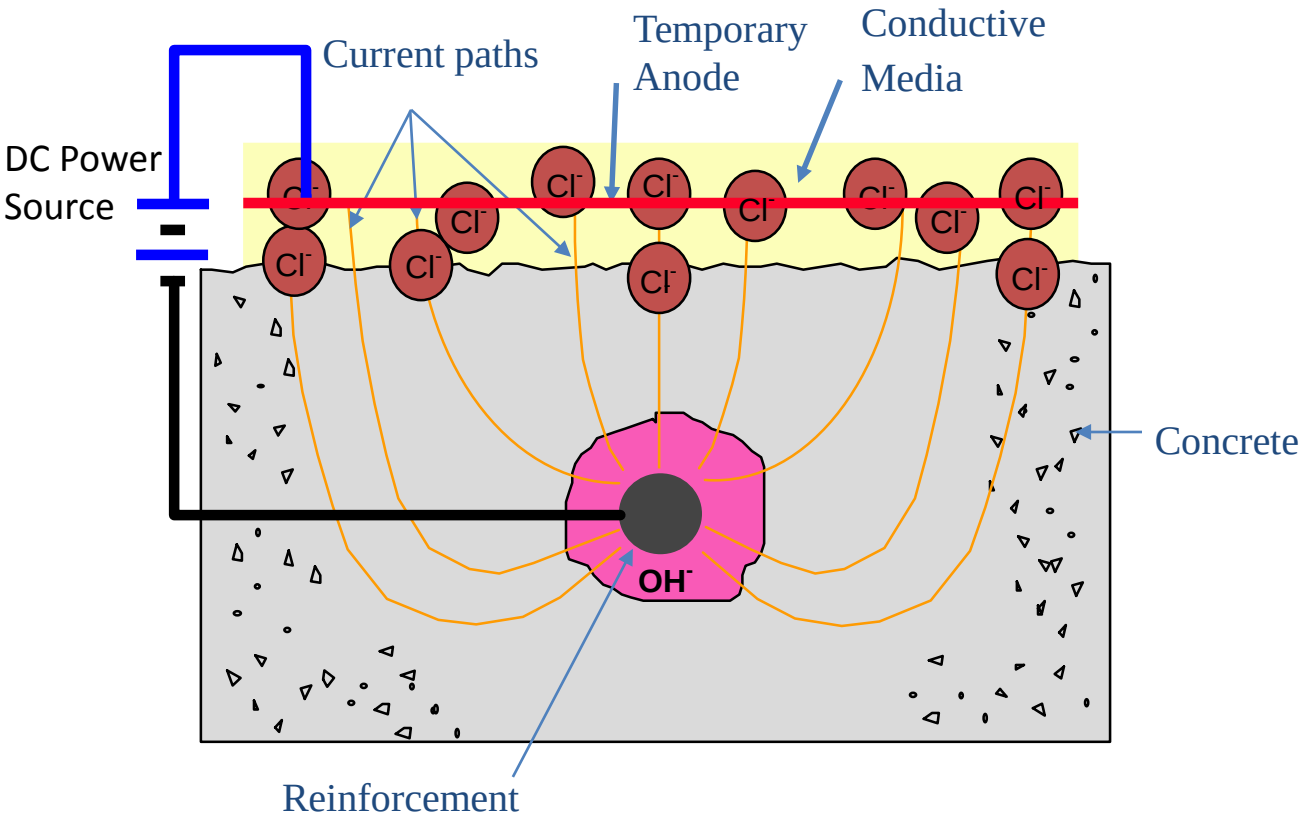
Electrochemical Chloride Extraction

- Application of temporary impressed current to draw chlorides out of concrete and repassivate the steel.
- Addresses the root cause of chloride induced corrosion
- Chloride levels in concrete are significantly reduced by ECE
- Alkalinity is increased at the level of the steel
  - Increases the chloride concentration required to reinitiate corrosion
- Reinforcing steel is returned to a passive, non-corroding state
  - For as long as chlorides can be kept from the steel


Temporary Anode
Conductive Media
DC Power Source
Concrete
Reinforcement
Cl-


DC Power Source
Cl-
OH-
Concrete
Reinforcement


Current paths
Temporary Anode
Conductive Media
DC Power Source
Cl-
OH-
Concrete
Reinforcement

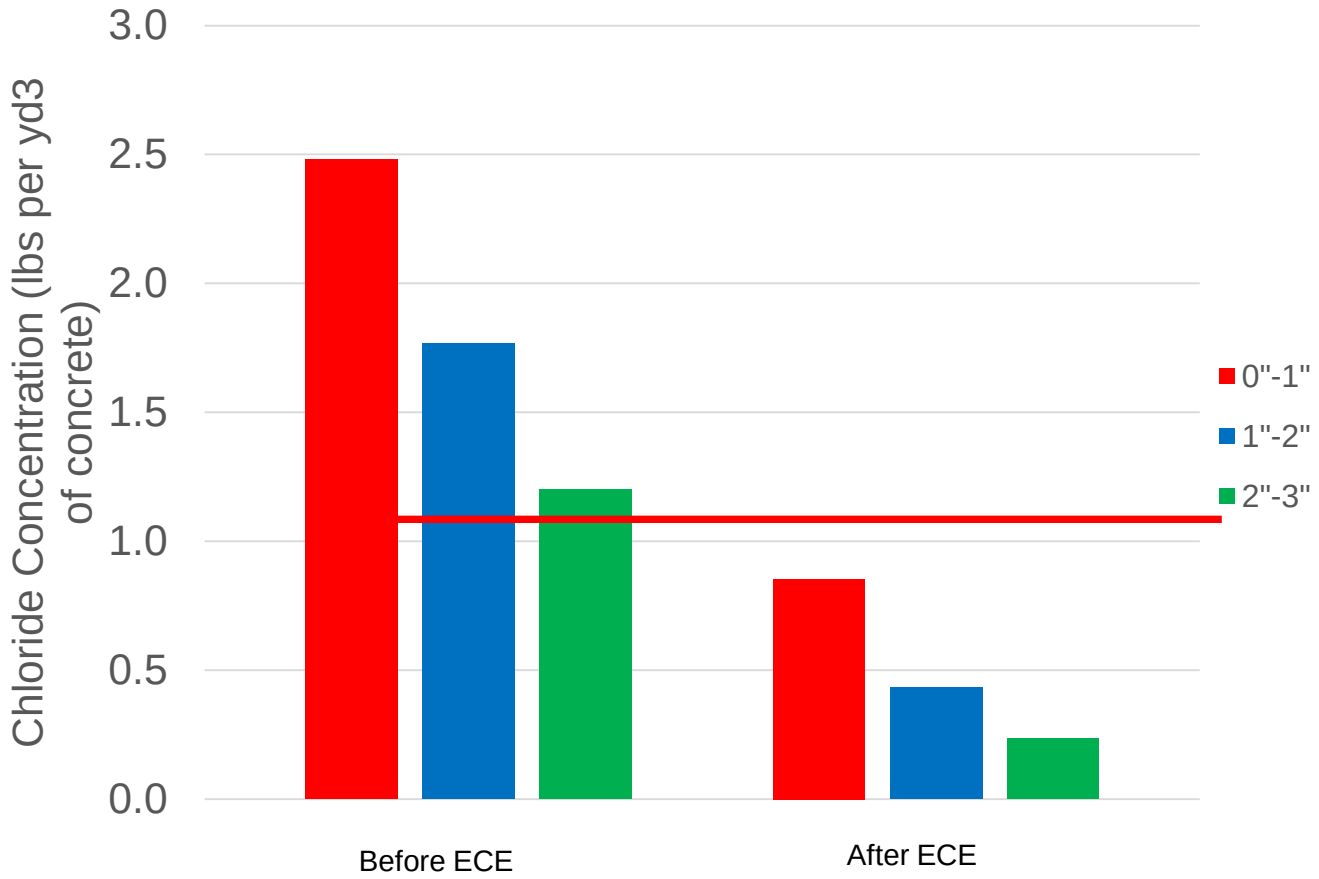

Current paths
Temporary Anode
Conductive Media
DC Power Source
Cl-
OH-
Concrete
Reinforcement

I-480 Omaha

- Rehabilitation to I—480 included deck replacement and substructure rehabilitation
- ECE completed on hammer head piers in 2002

I-480 Omaha

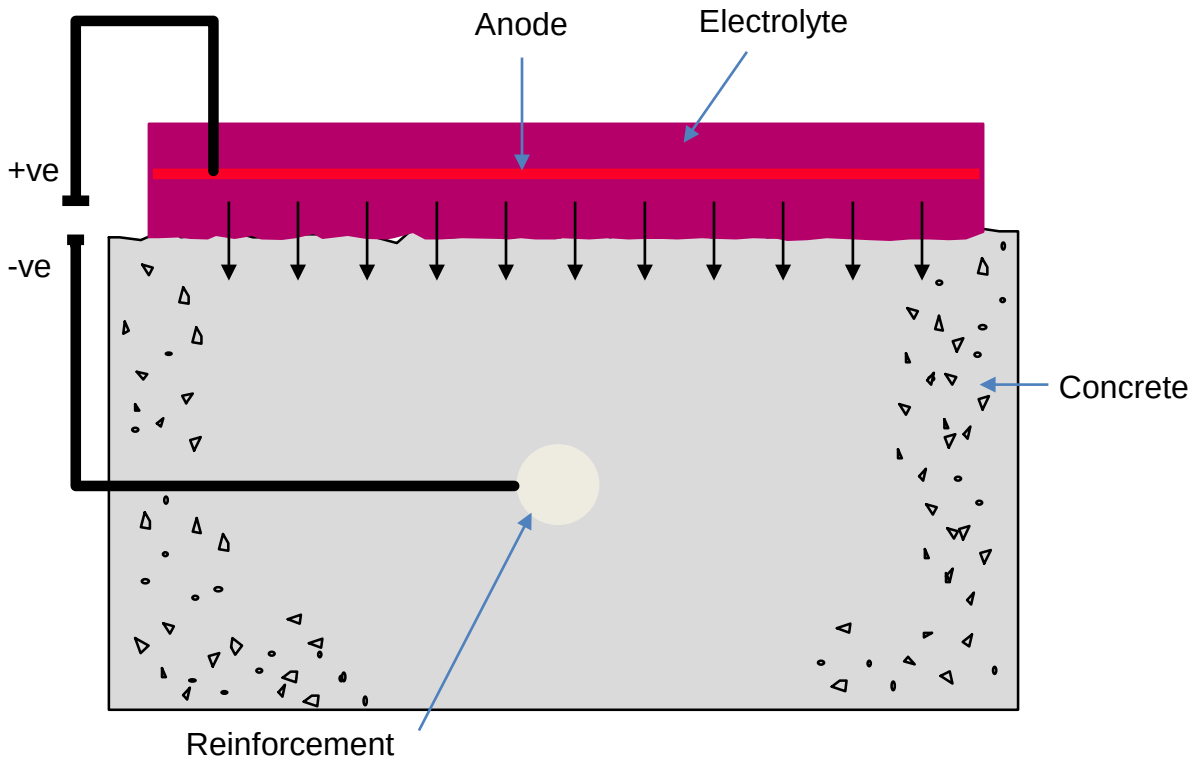

8995

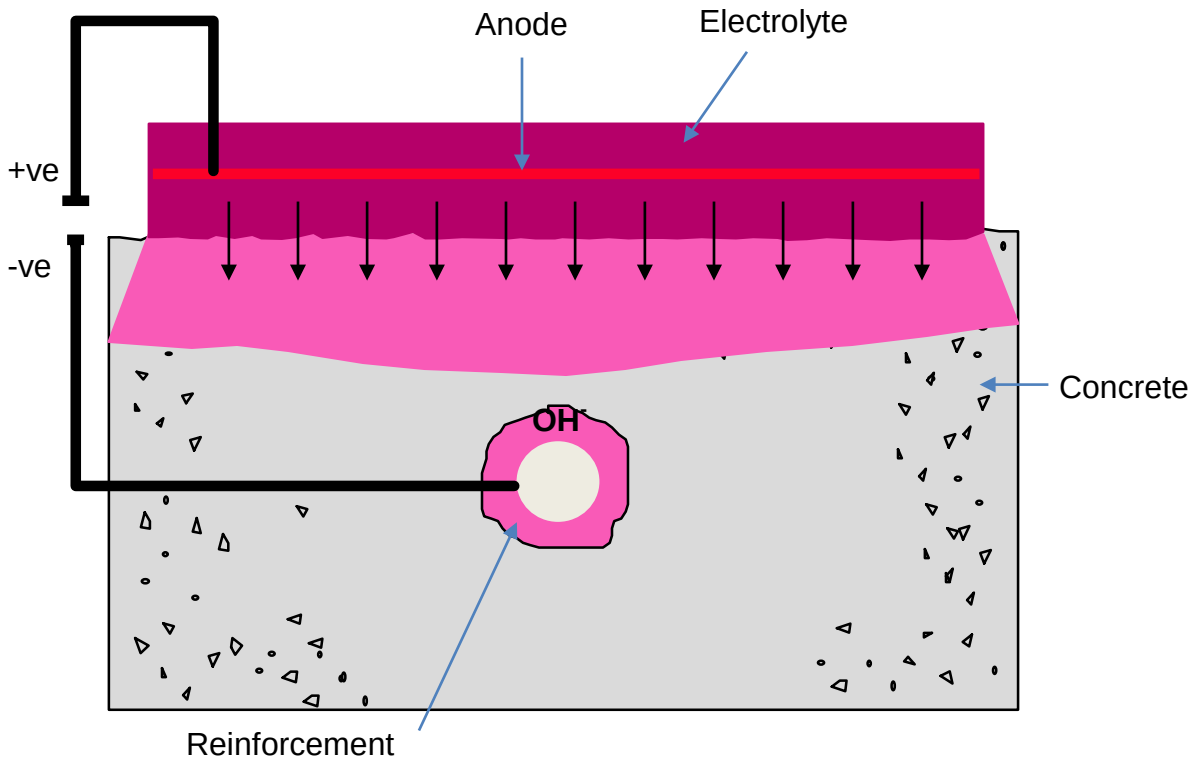


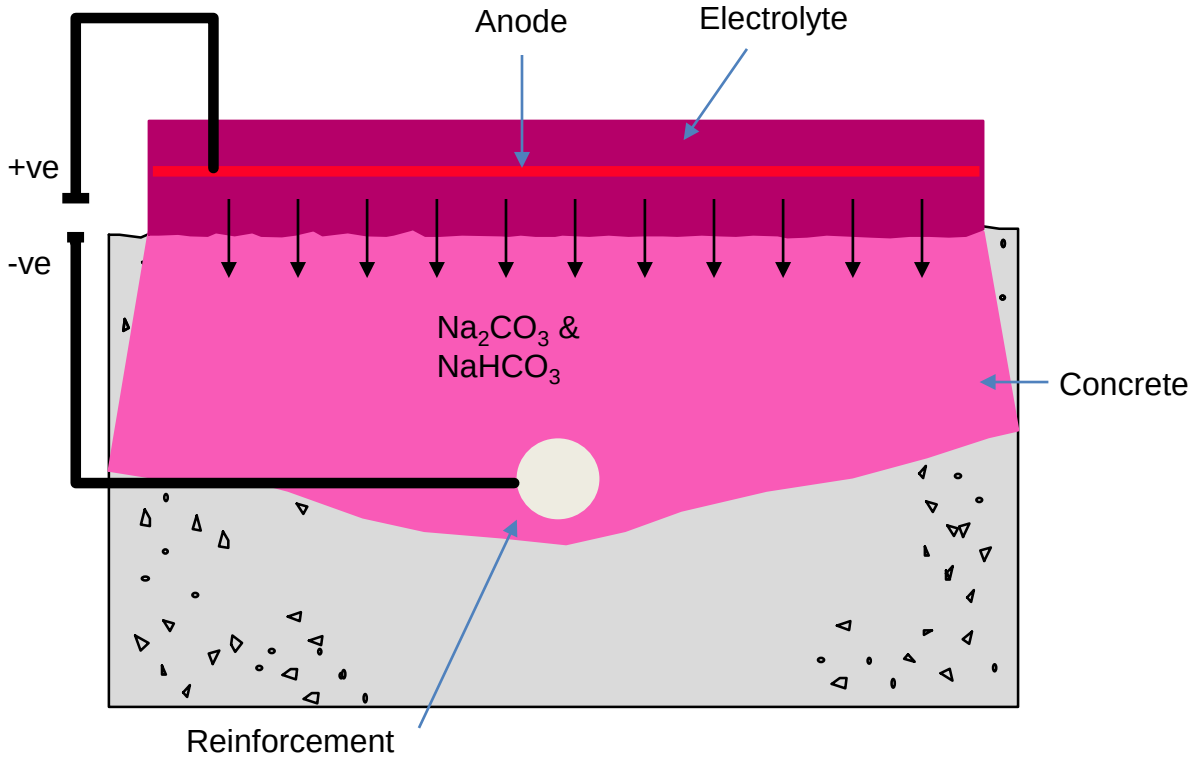
Sample Depth (in)	Percent Reduction
0"-1"	66%
1"-2"	76%
2"-3"	80%

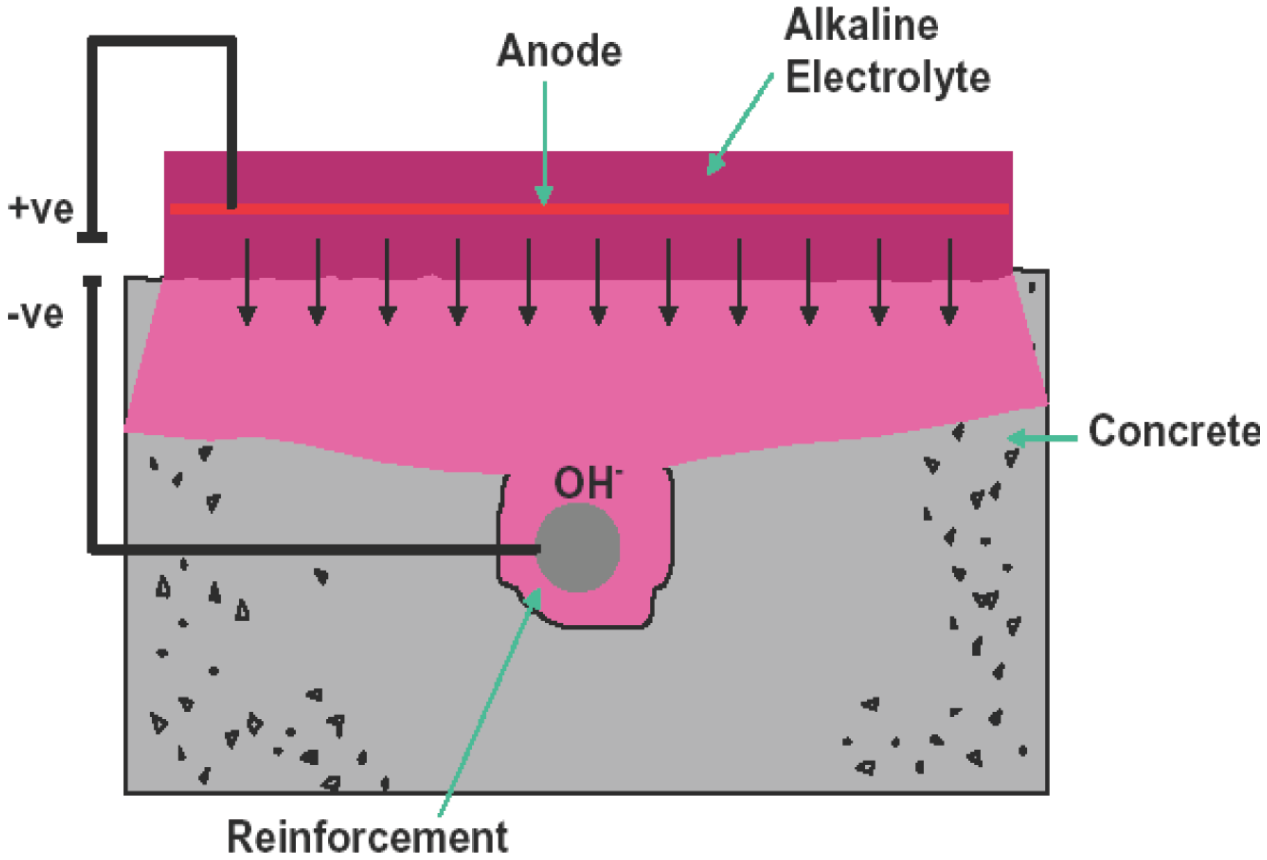

HERE

Re-Alkalization


Anode
Electrolyte
+ve
-ve
Concrete
Reinforcement


Anode
Electrolyte
+ve
-ve
Concrete
OH
Reinforcement

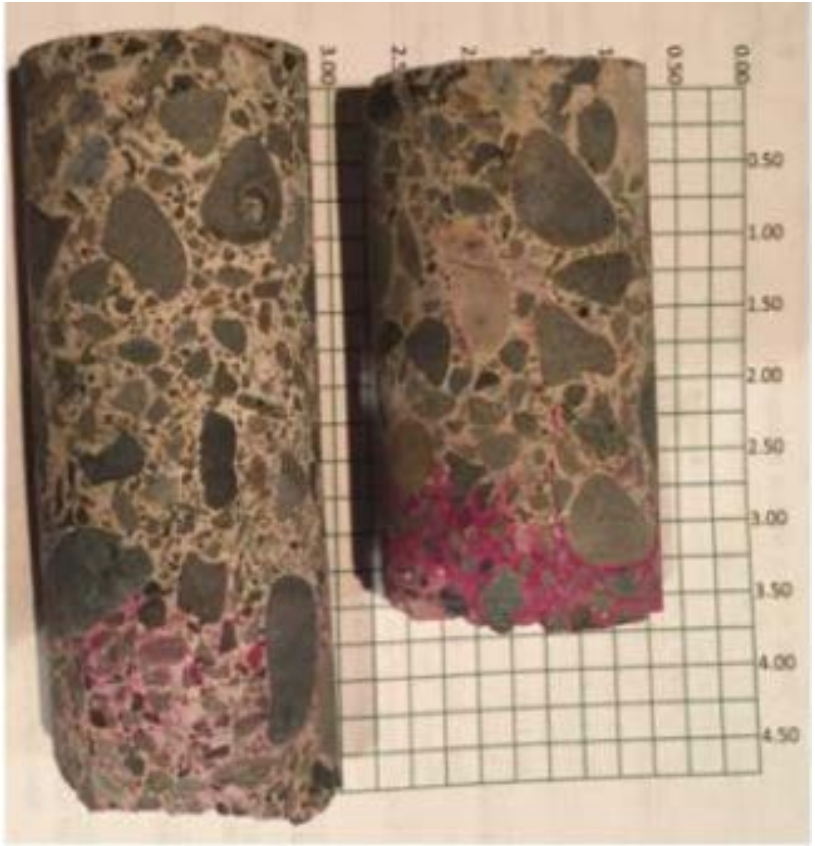

Anode
Electrolyte
+ve
-ve
Na_2CO_3 &
$NaHCO_3$
Concrete
Reinforcement


Anode
Alkaline
Electrolyte
+ve
-ve
Concrete
OH-
Reinforcement

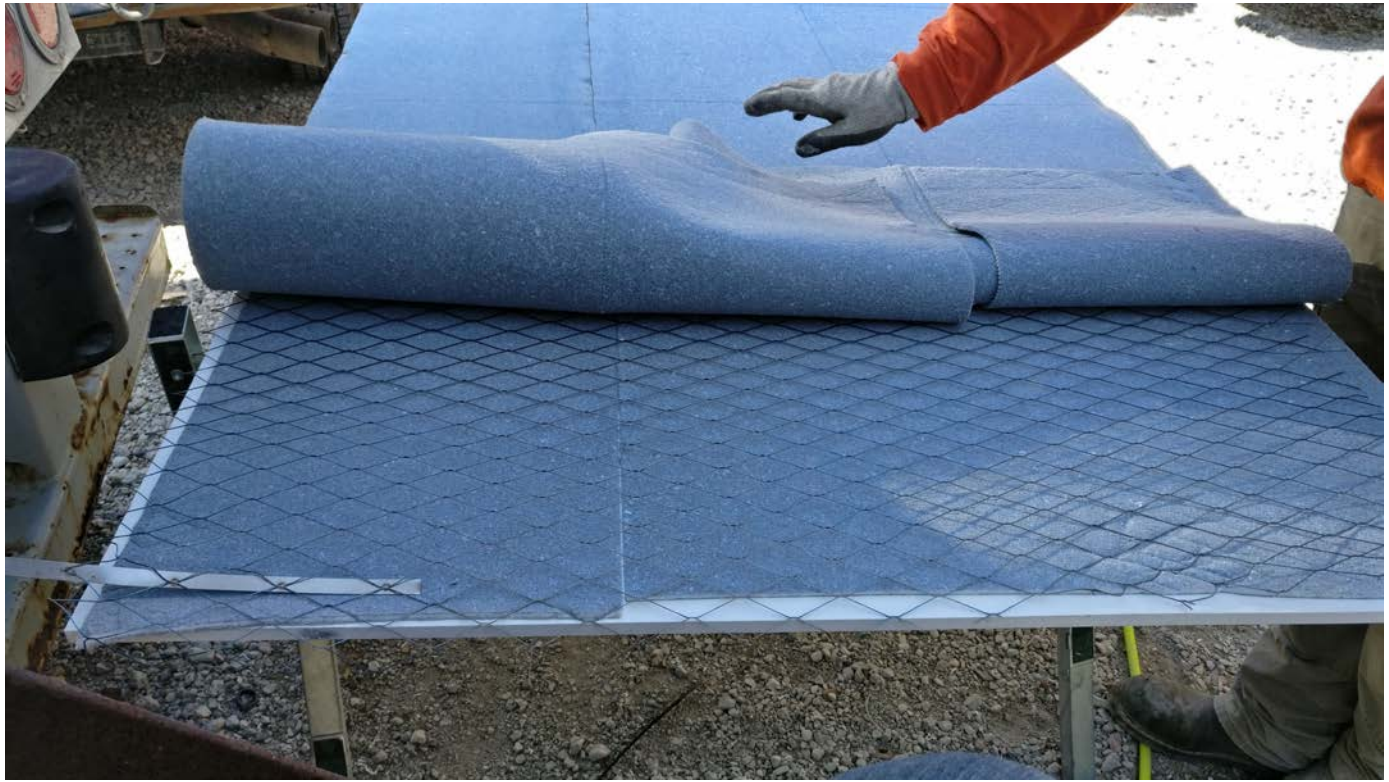
University of Chicago University Hall Façade Repair

- Corrosion deterioration occurring due to carbonation of the concrete
- Re-alkalization conducted to façade
  - 72,300 ft^2 of concrete surface area
  - Completed spring of 2018

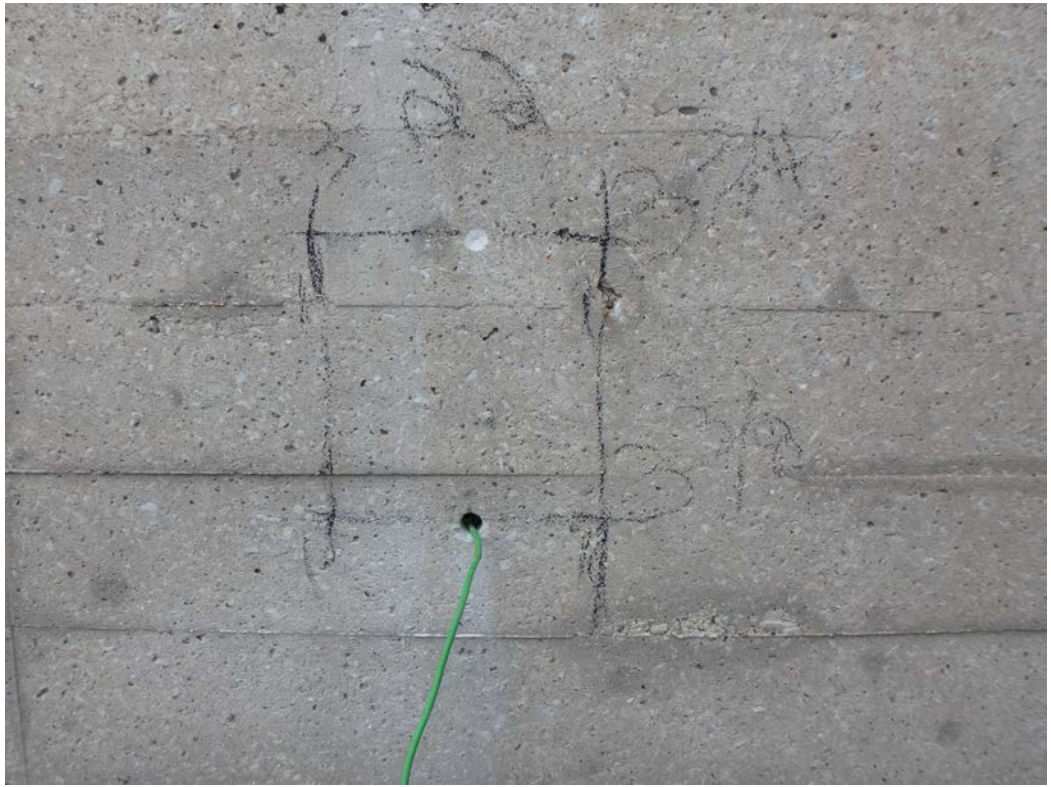
Prior to Treatment

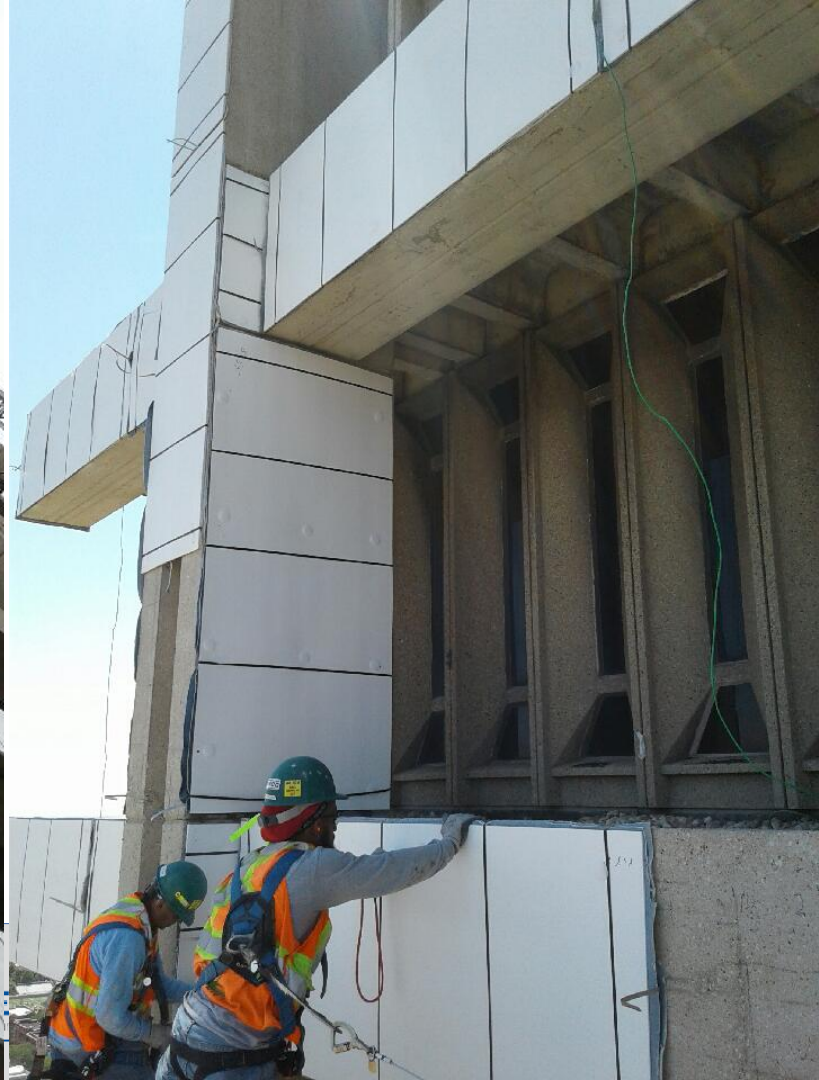


Temporary Anode

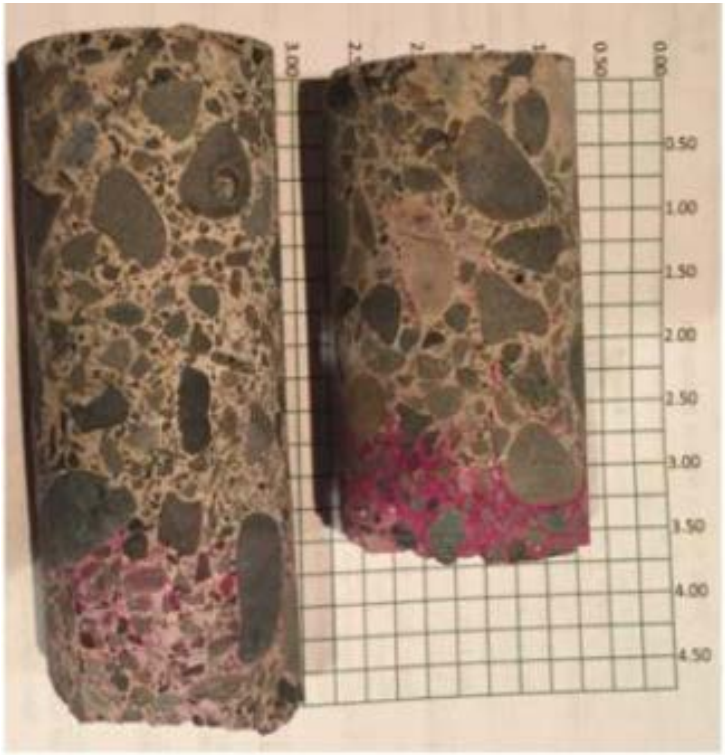


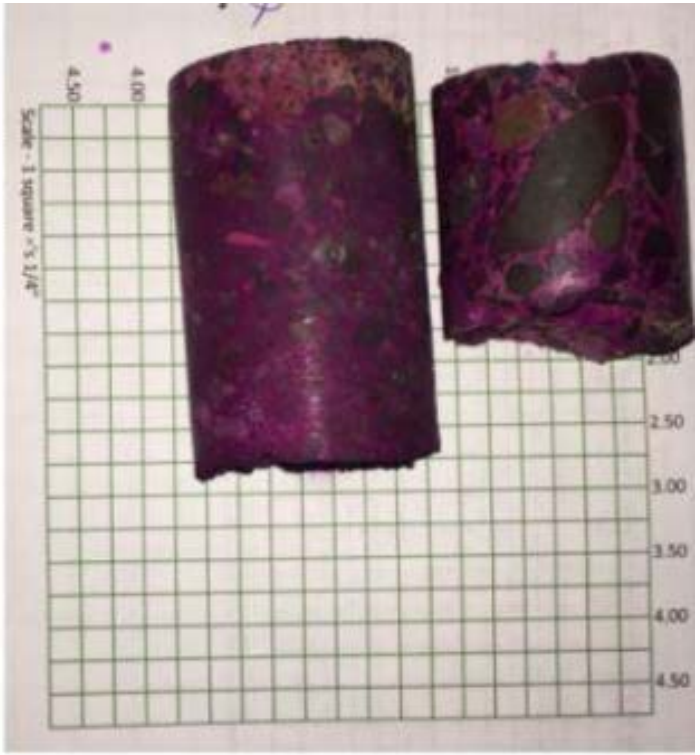
Connection to Reinforcement





Post Treatment





Post Treatment

Sustainability I-480

- 6,700 yd^3 of concrete preserved prevents
  - 6,530 pounds of nitrous oxides
  - 3,663 tons of carbon dioxide
    - Equivalent to annual emissions of about 833 people.
  - 13,191 tons of natural resources
  - Potable water to fulfill the daily needs of 1,695 people,
  - Waste generation 15,975 tons
  - Heat to boil 20 Olympic-sized swimming pools.

Sustainability University of Chicago

- 1,300 yd^3 of concrete preserved prevents
  - 1,267 pounds of nitrous oxides
  - 711 tons of carbon dioxide
    - Equivalent to annual emissions of about 162 people.
  - 2,559 tons of natural resources
  - Potable water to fulfill the daily needs of 329 people,
  - Waste generation 2,633 tons
  - Heat to boil 4 Olympic-sized swimming pools.

- ICRI
  - 510.1-2013 – Electrochemical Techniques to Mitigate the Corrosion of Steel
- NACE
  - SP 0390 – Maintenance and Rehabilitation Considerations for Corrosion Control of Atmospherically Exposed Existing Steel-Reinforced Concrete Structures
  - SP 0107 – Electrochemical Realkalization and Chloride Extraction for Reinforced Concrete
- FHWA
  - Bridge Preservation Guide
  - Long-Term Effects of Electrochemical Chloride Extraction on Laboratory Specimens and Concrete Bridge Components FHWA-HRT-10-069
  - Several other SHRP studies on ECE and Realkalization
- ACI
  - 222.3R-03 - Design and Construction Practices to Mitigate Corrosion of Reinforcement in Concrete Structures

Thank you.
Questions?