We Save Structures™

Corrosion Background & Galvanic Anode Installation Considerations

Highway Maintenance Conference 2023

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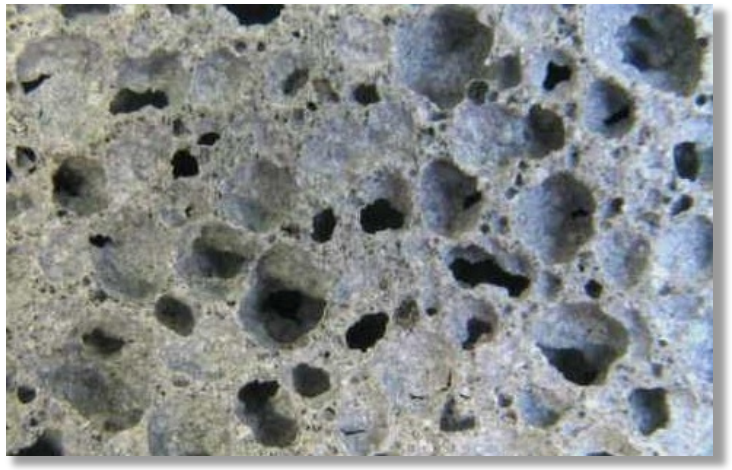
Outline

- Corrosion Background
- Corrosion Basics
- Corrosion Solutions
  - Galvanic Anodes
- Spacing
- Type 1A Installation
- Type 2A Installation
- Installation Considerations

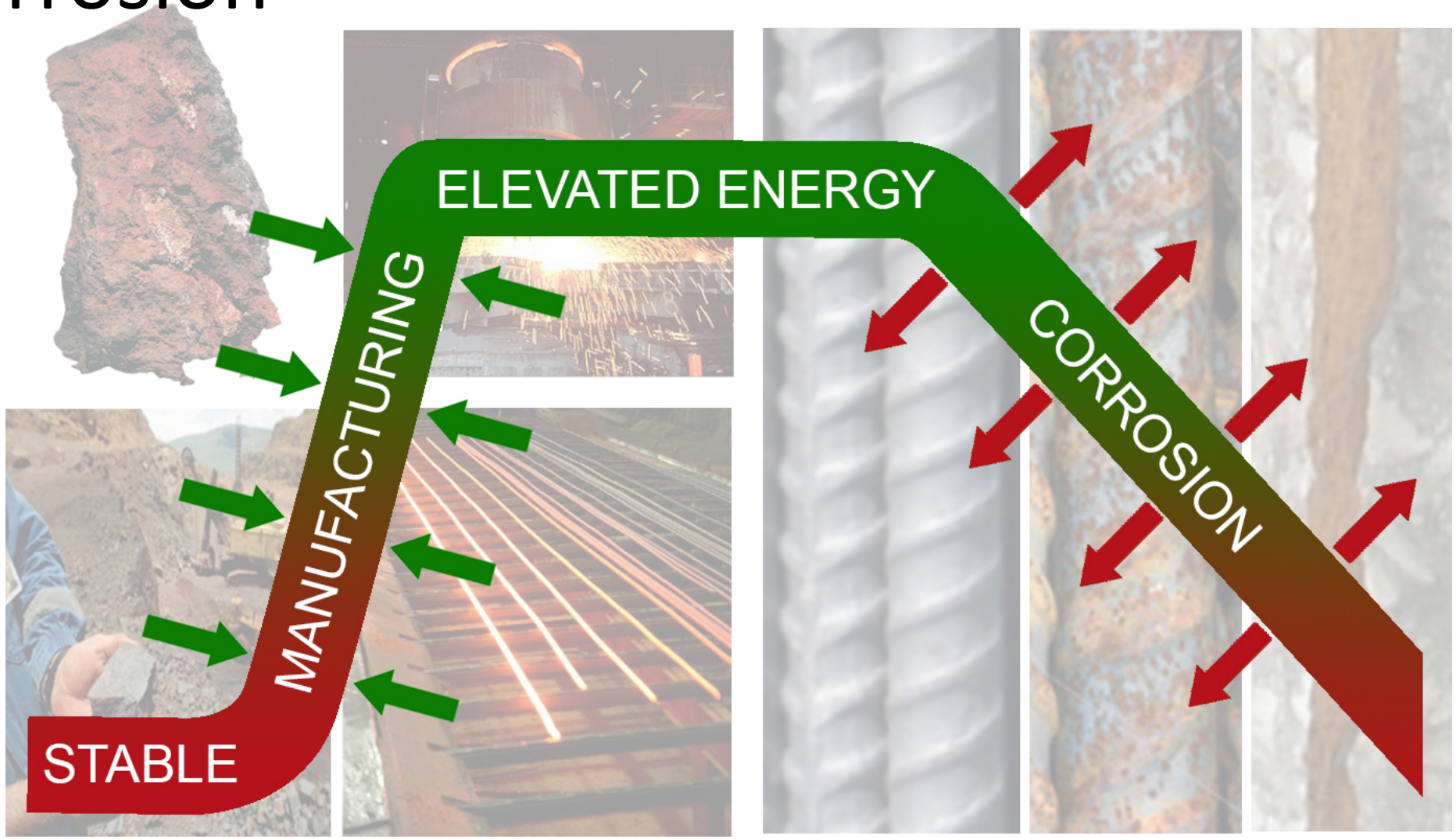
Why Are Anodes Used in Concrete?

Background: Nature of Steel, Concrete and Corrosion

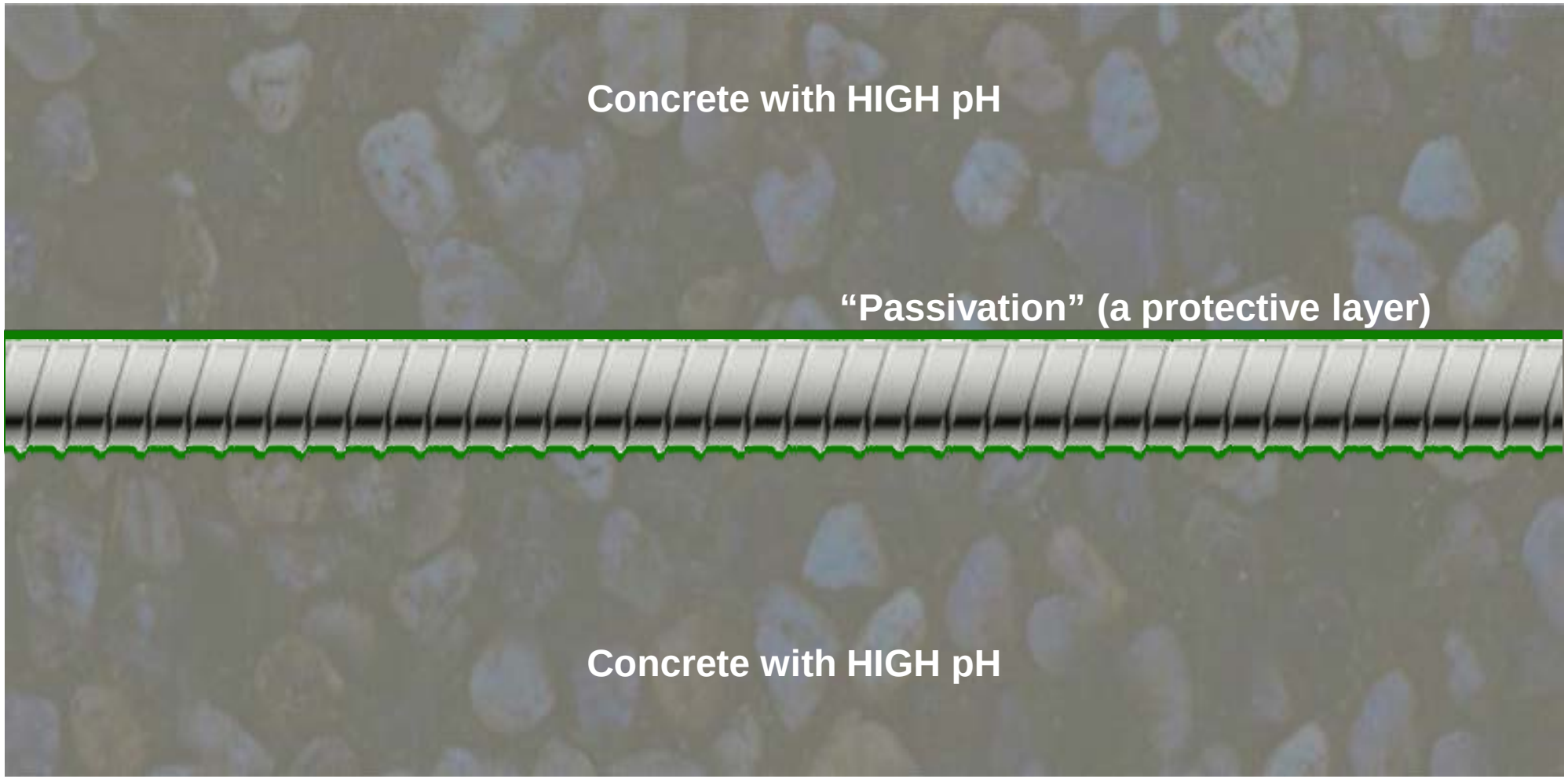


- Hard Sponge (very porous)
- Great in Compression
- Poor in Tension
- Requires Reinforcement
- Highly Alkaline

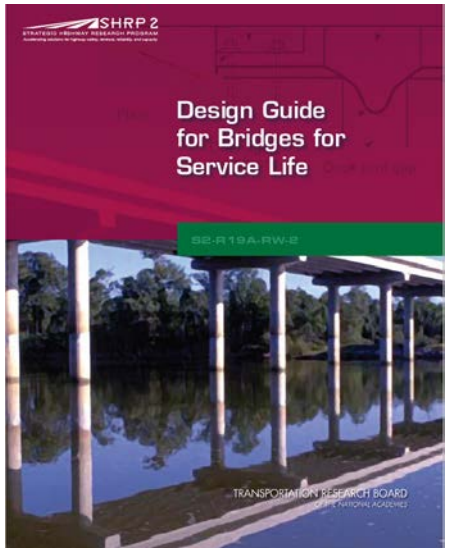
Background: Nature of Steel, Concrete and Corrosion



Background: Nature of Steel, Concrete and Corrosion



Causes of Corrosion of Steel in Concrete – The Driving Force



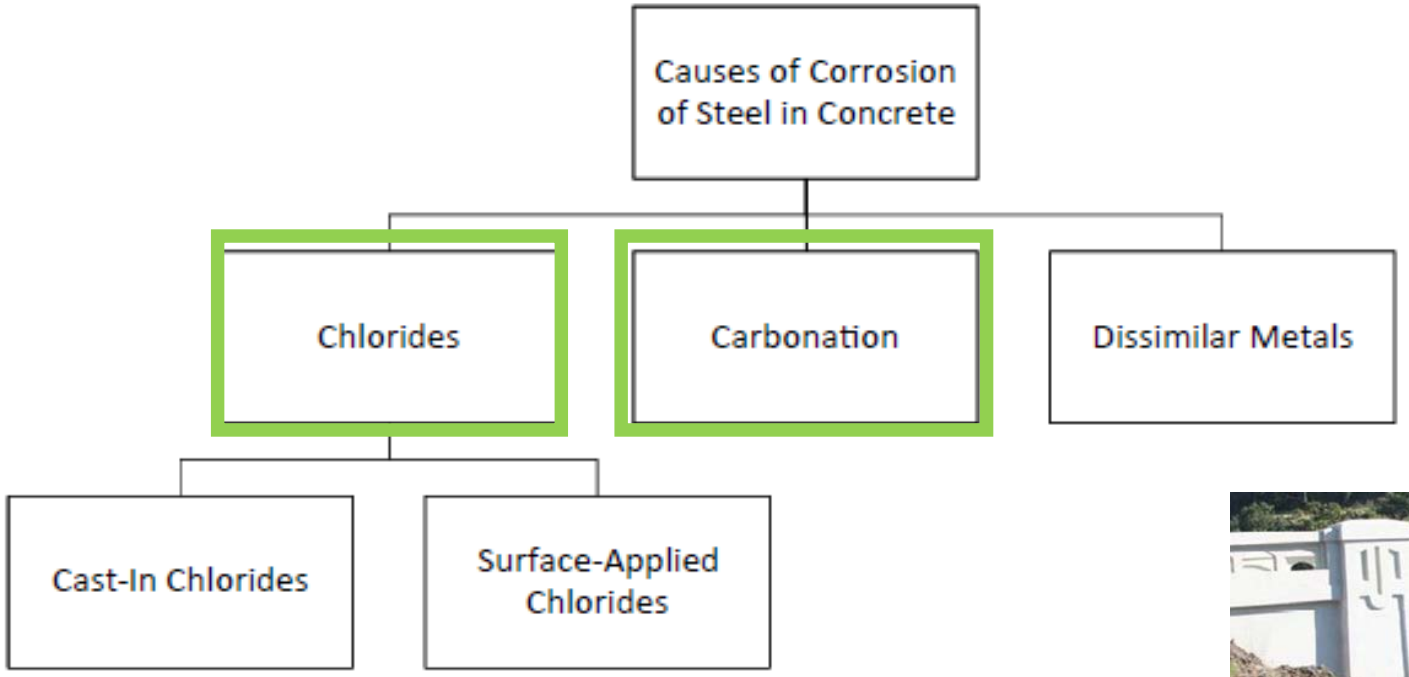
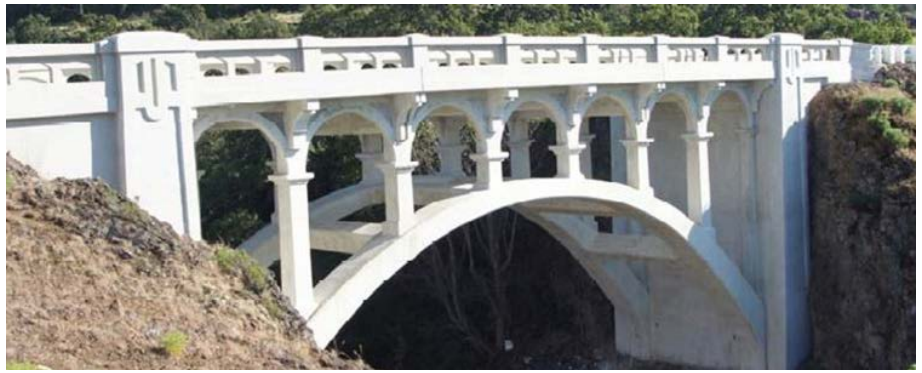


Figure 5.6. *Causes of corrosion of steel in concrete.*

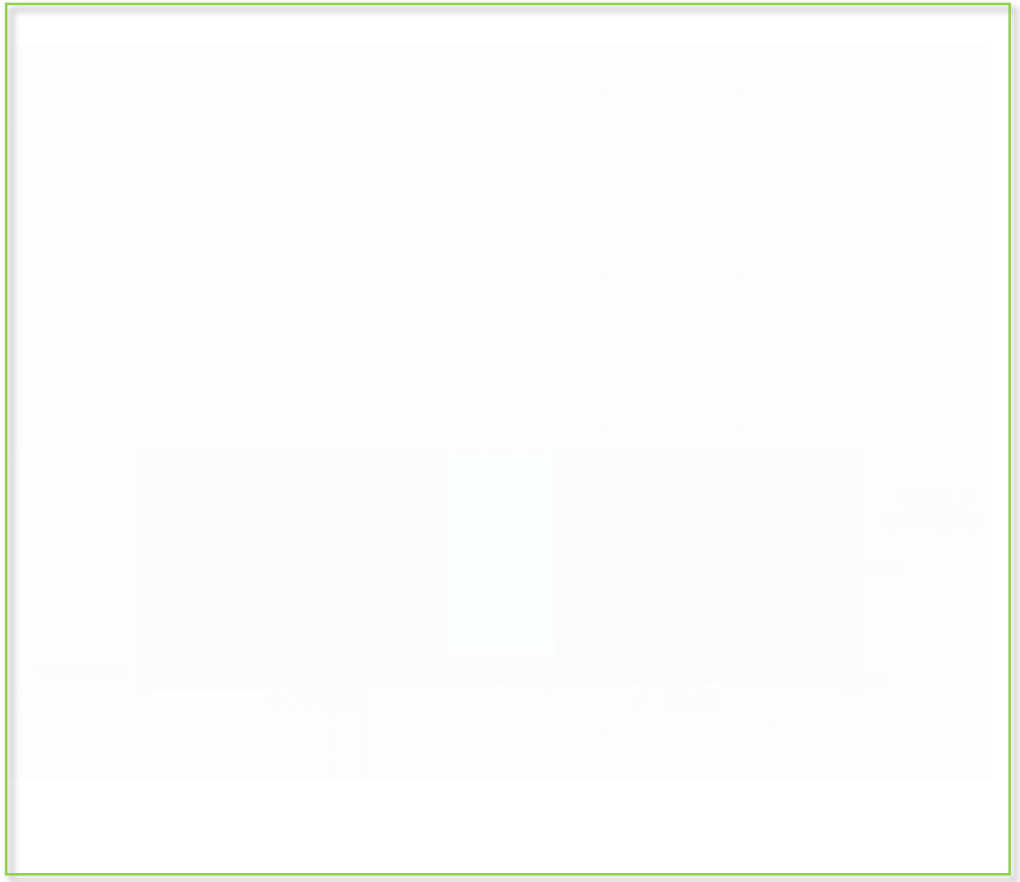
- 100 Years of Service Life



Chloride-induced Corrosion

- Caused by chlorides breaking up passive oxide layer
- Sources of chlorides:
  - Marine Environments
  - De-icing Salts (NaCl, CaCl2)
  - Chemical Plant Environment
  - Cast-in Chlorides
- Vicious Circle: Chlorides are a catalyst and not consumed

Corrosion Animation



Carbonation induced Corrosion

- Typically found in older structures
- Structures with low concrete cover
- Reduction of pH in cover concrete which causes loss of passive oxide layer
- Low pH caused by reaction of free lime ($Ca(OH)_2$) in concrete with atmospheric carbon dioxide (CO_2)

$$Ca(OH)_2 + CO_2 \Rightarrow CaCO_3 + H_2O$$

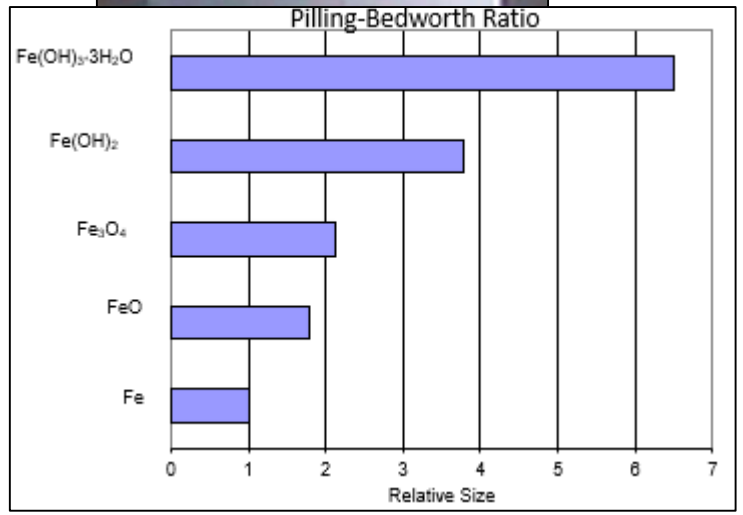
lime (soluble) ⇒ (insoluble)

pH 12-13 ⇒ pH < 9

Carbonation Testing of Core Taken from Precast Double T Stem

Corrosion Induced Damage

- Conventional mild reinforcing bar
  - In most cases loss of steel section not primary concern
  - Typically damage to concrete becomes significant and observable prior to severe section loss
- High Strength Tendons
  - Minor section loss of steel can have significant effect on strength
  - Steel can have significant section loss without significant concrete damage



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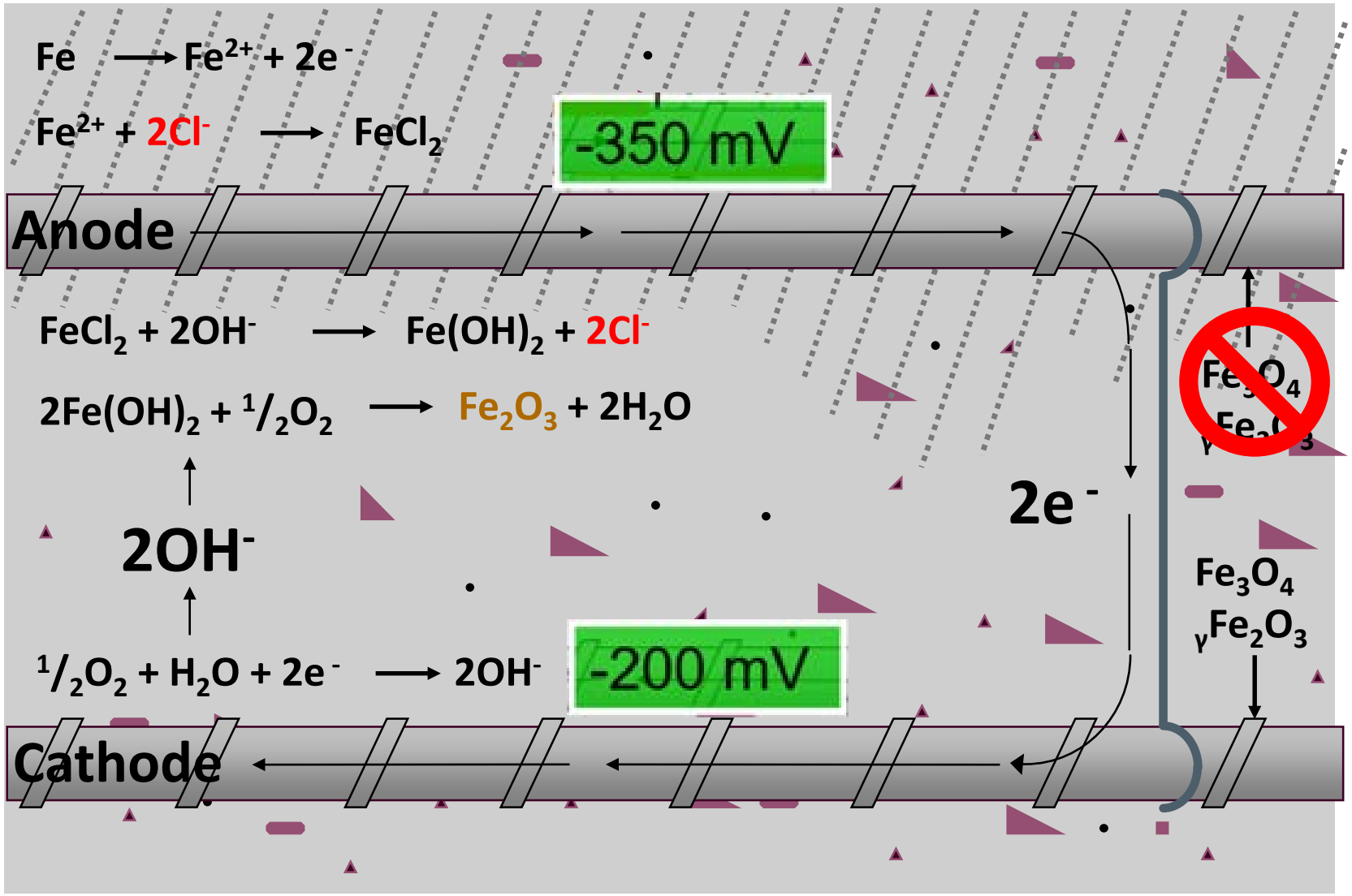
Review - Corrosion Cell in Concrete



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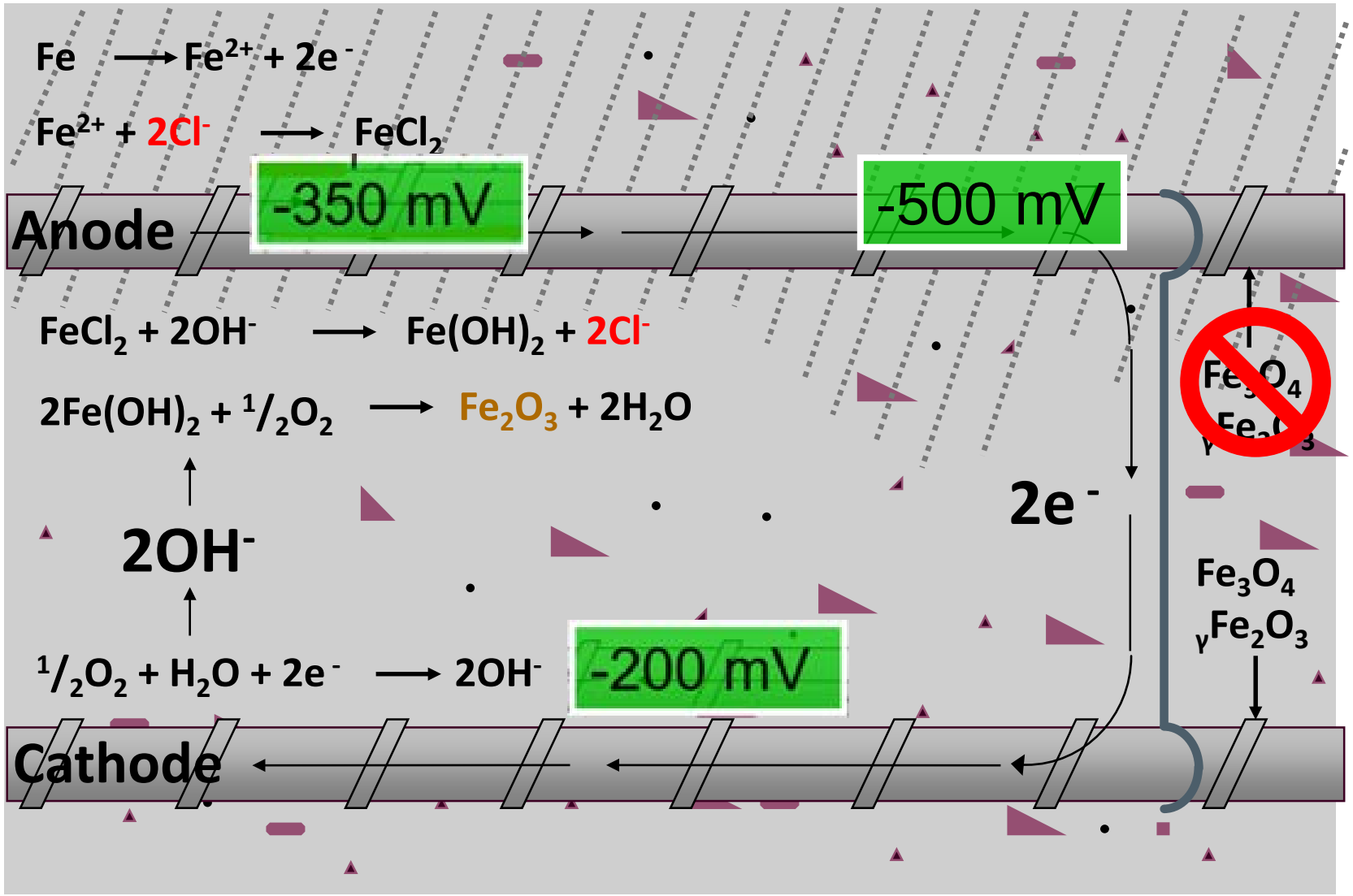

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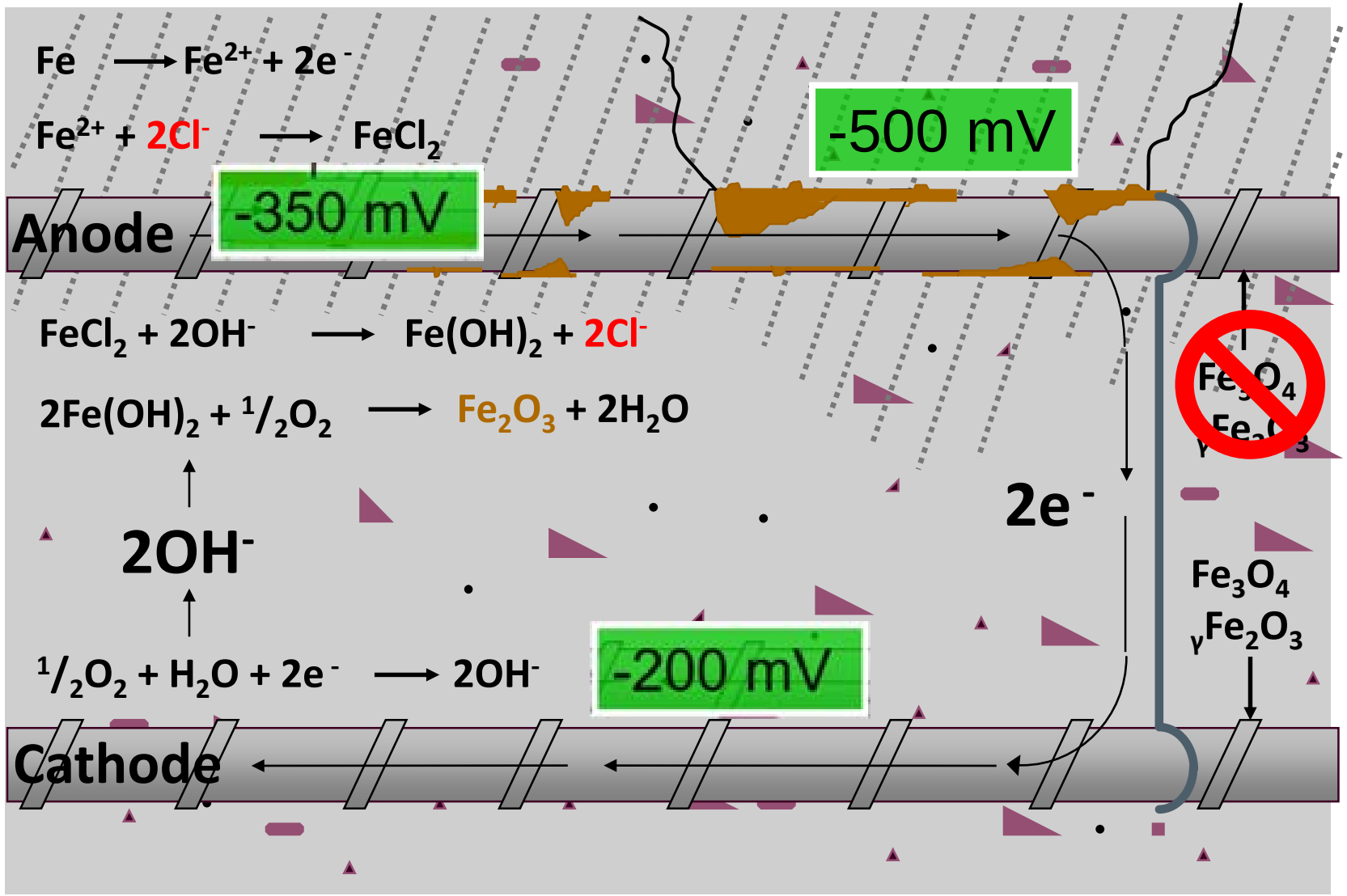
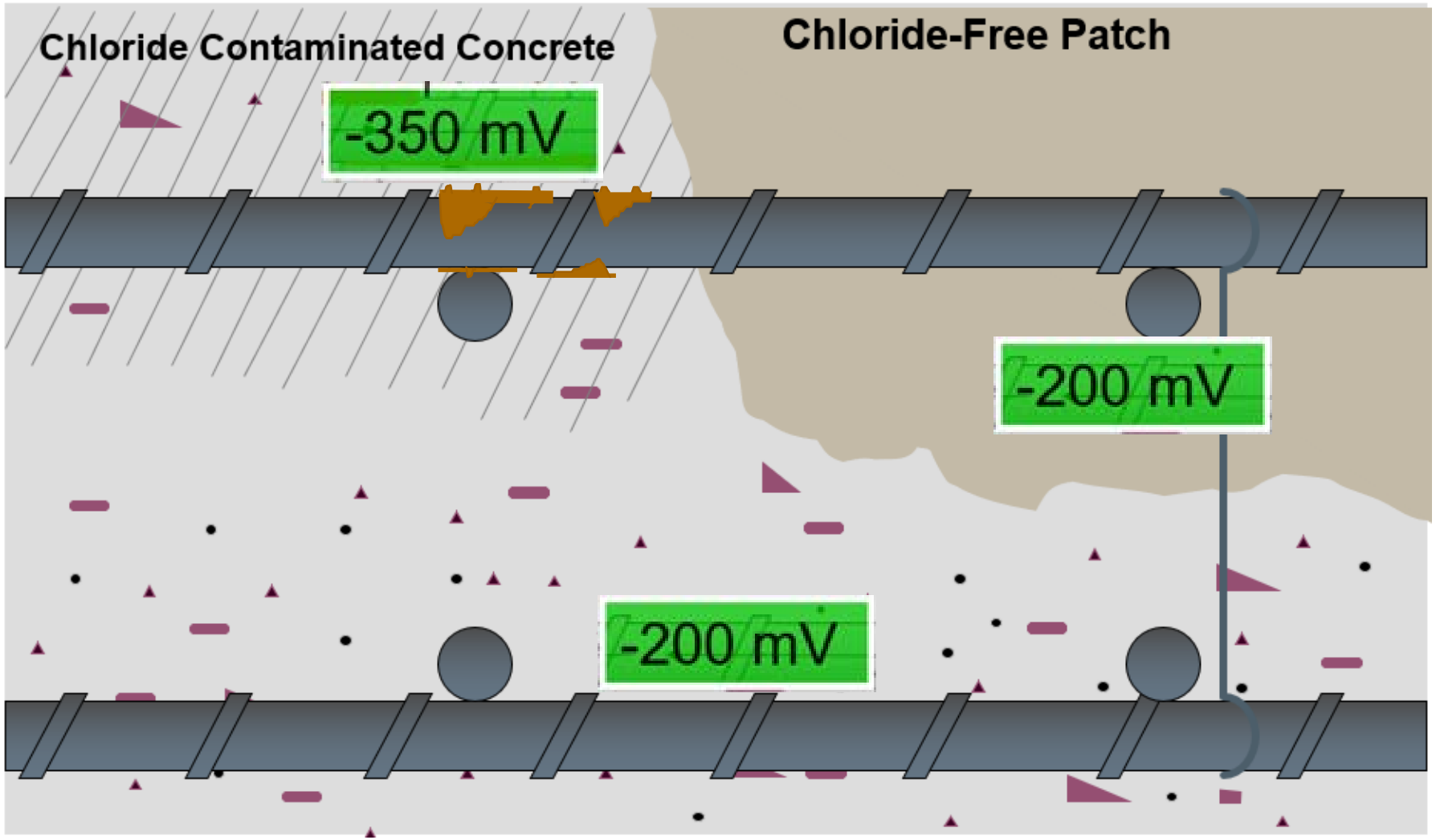
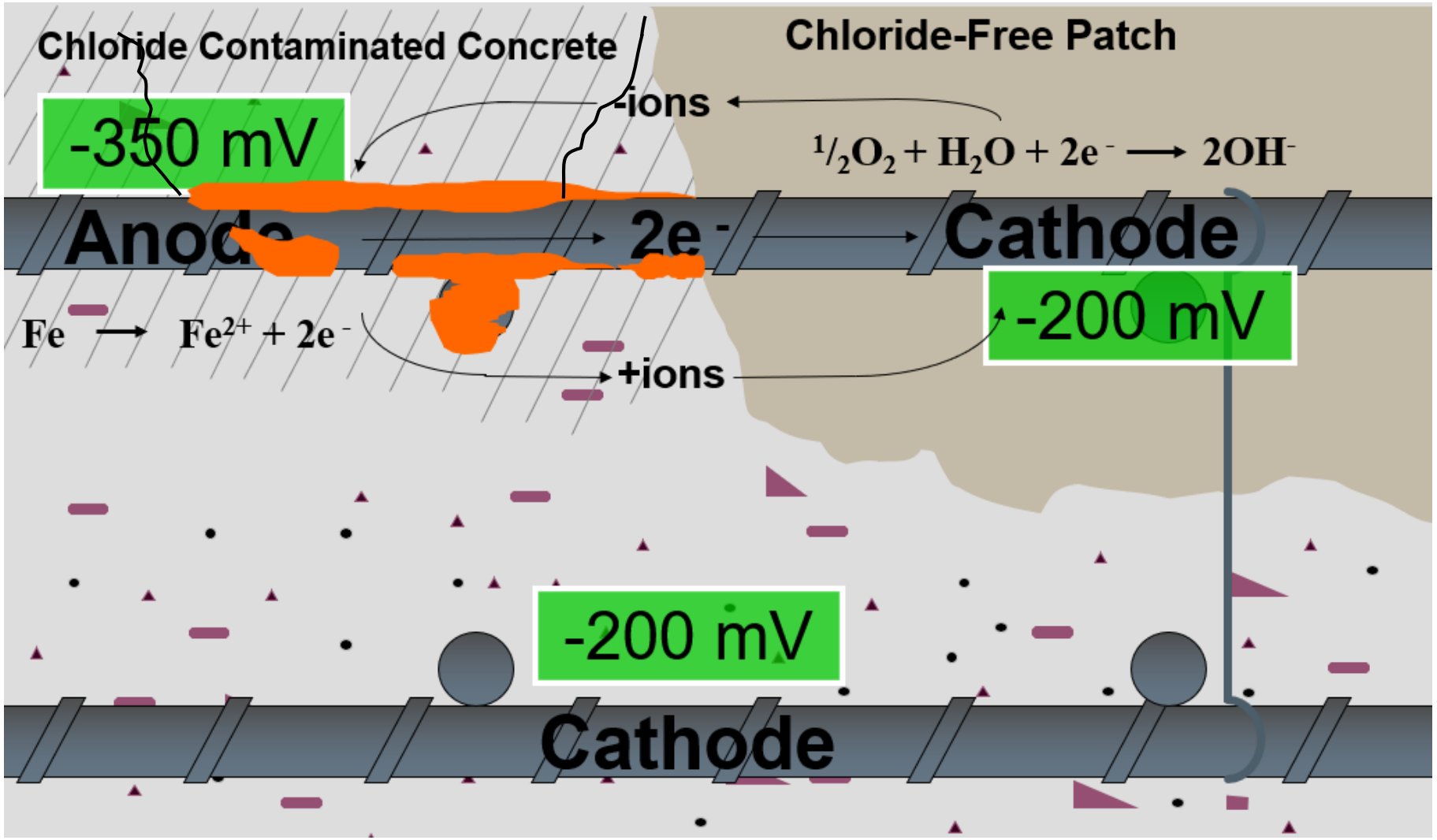


Historically Patched Section

Set up to Fail



Patch Accelerated Corrosion – Halo Effect



Patch Accelerated Corrosion – Halo Effect

Bridge Pier

Bridge Deck

Patch Accelerated Corrosion on Larger Scale

Corroded Joint
Pittsburgh, Pennsylvania

New Concrete Extension

Old Retaining Wall

Failed Concrete Next to Joint Due to Corrosion

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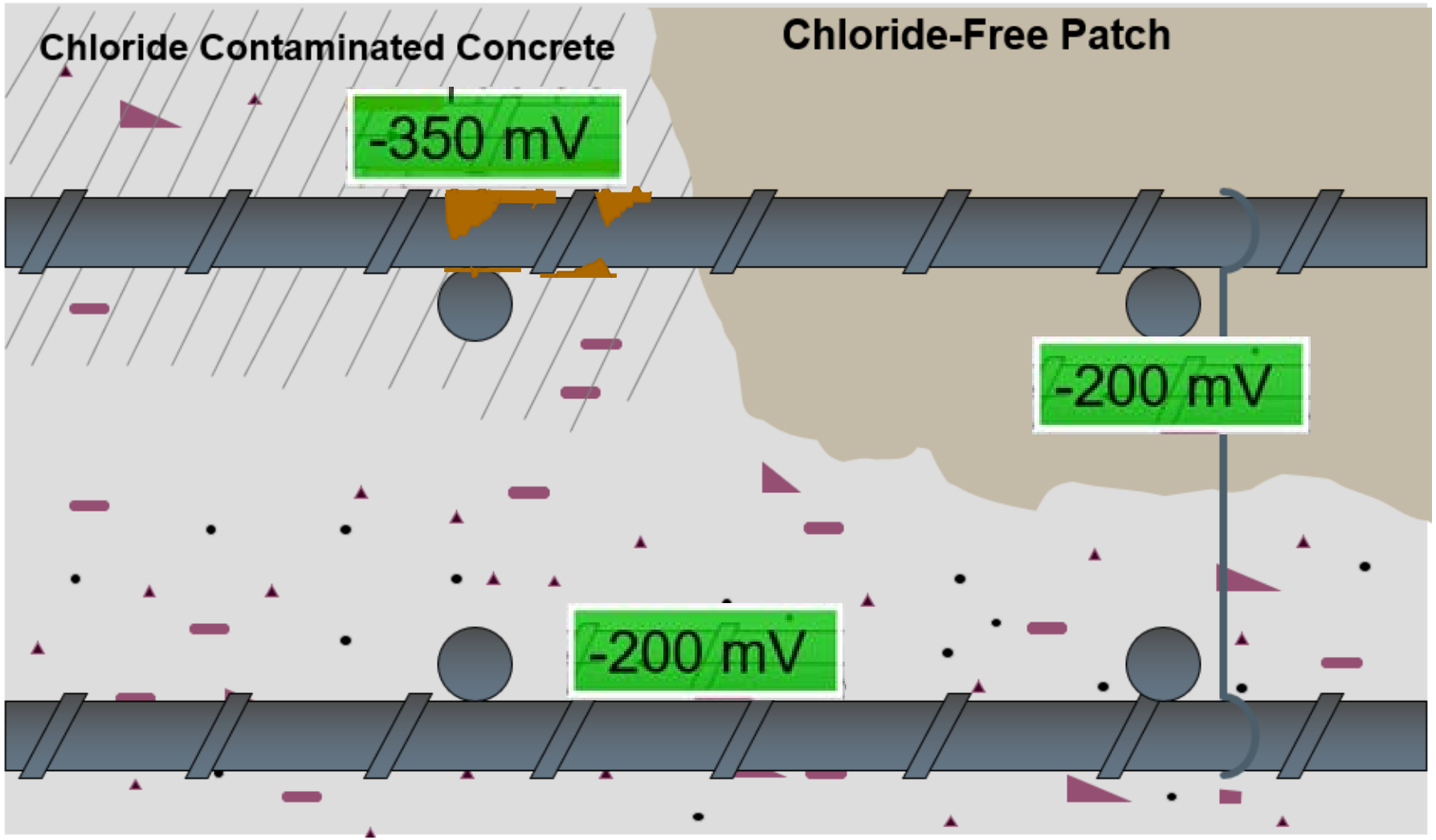
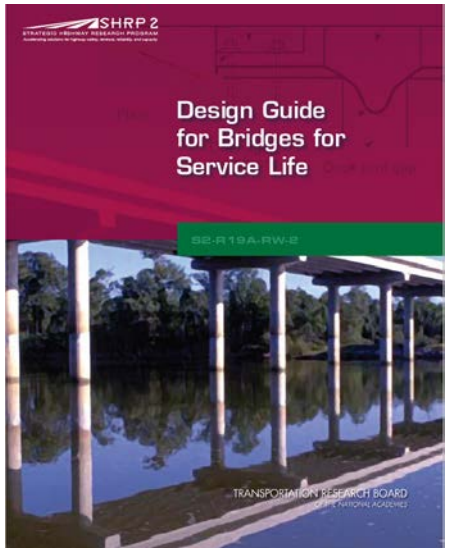
Other Options for Patched Section?



Strategic Highway Research Program 2: Project R19A



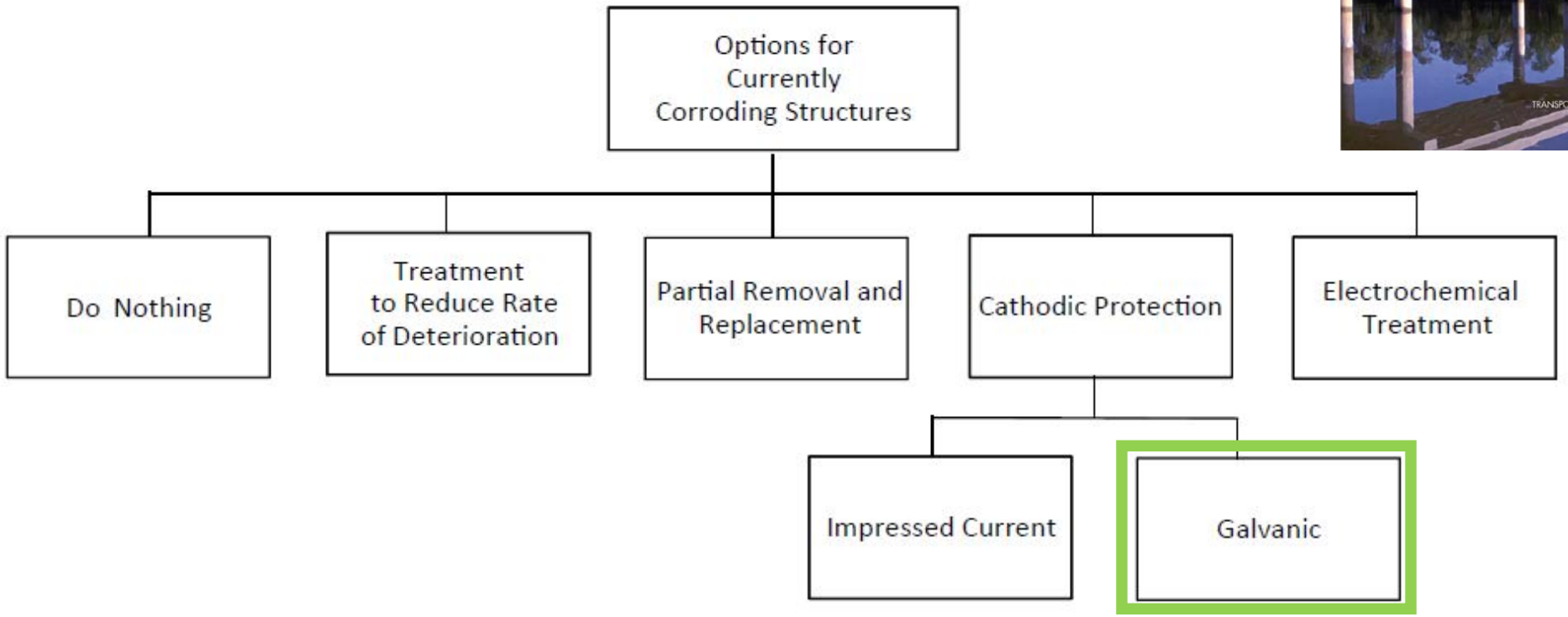
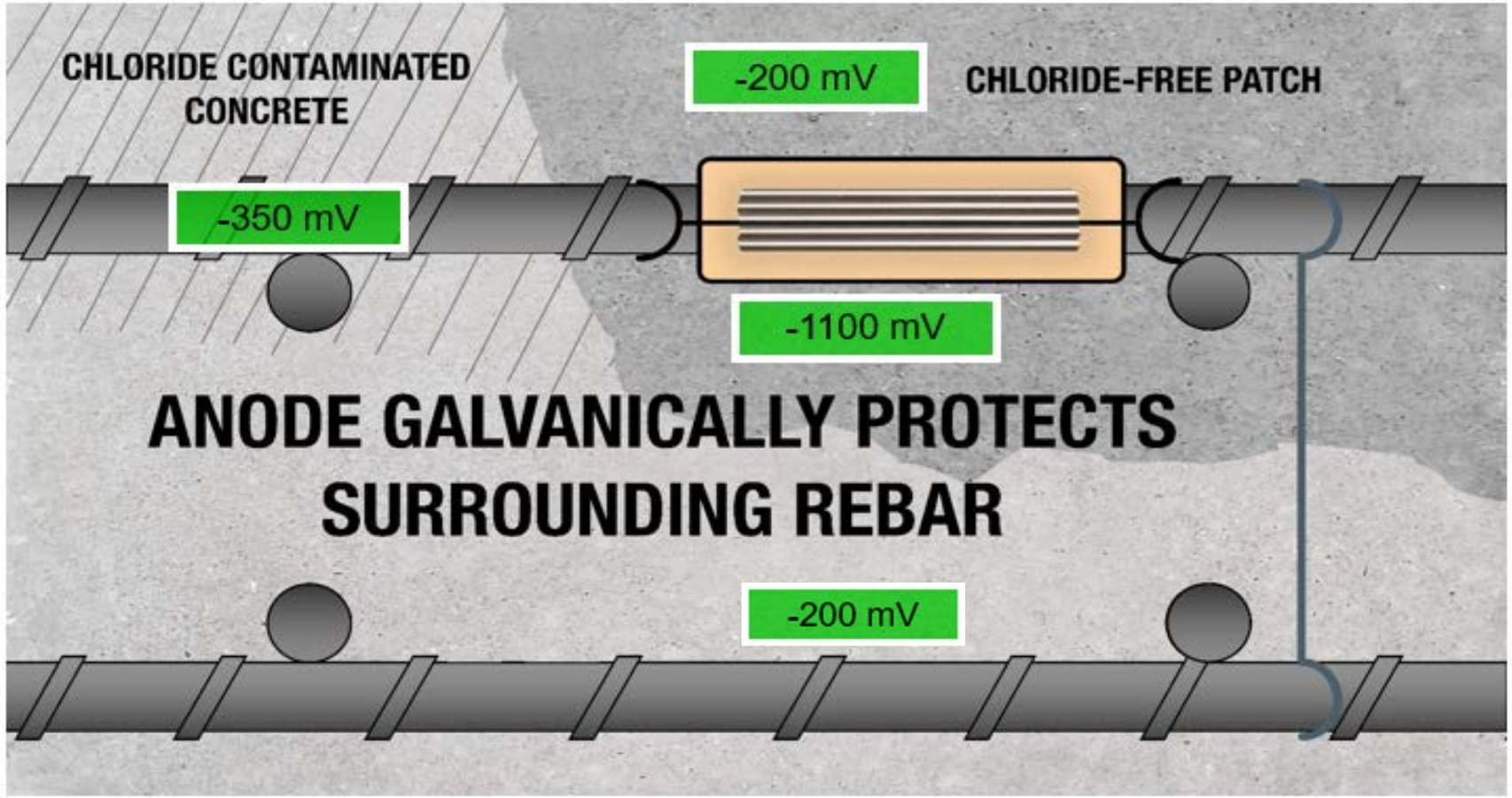
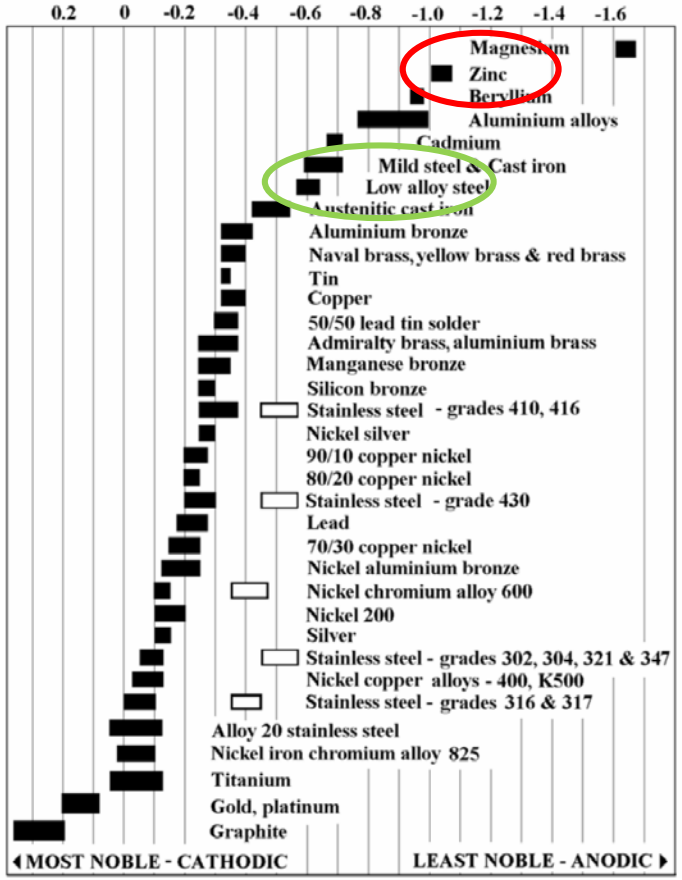


Figure 5.13. *Options for corroding structures.*

Galvanic Cathodic Protection Option

Make the Steel Cathode - Install Sacrificial Anode





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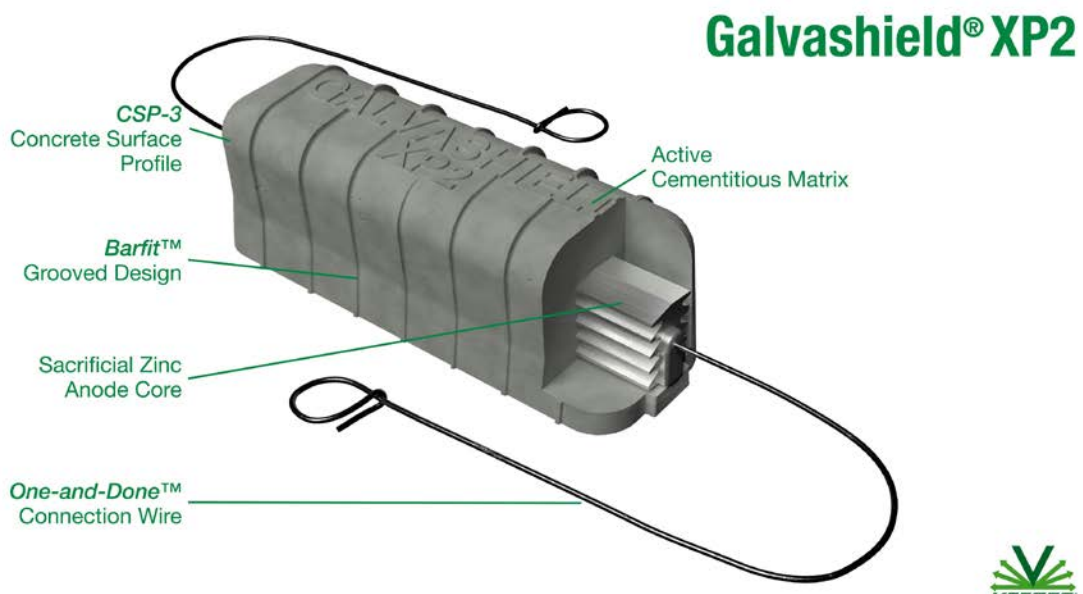
Type 1A vs Type 2A



Concrete Repair, Alkali Activated VS Sound Concrete, Alkali Activated

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Standard Units

What are the Considerations for choosing?

What is the service life objective?

For Design

- Corrosion Risk
- Steel Density
- Temperature

Anode Name	Anode Type	Nominal Dimensions	Zinc Mass (g)
XP Compact	1A	25 x 31 x 64 mm (1 x 1.25 x 2.5 in.)	40
XPT	1A	24 x 28 x 100 mm (1 x 1.13 x 4 in.)	60
XP2	1A	32 x 34 x 100 mm (1.25 x 1.34 x 4 in.)	100
XP4	1A	33 x 35 x 130 mm (1.3 x 1.38 x 5.12 in.)	160
XPX	1A	33 x 35 x 170 mm (1.3 x 1.38 x 6.7 in.)	330

How do you Determine Appropriate Spacing?

Low to Moderate Corrosion Risk (Chloride Content* <0.8% or Carbonated Concrete)						
Steel Density	XPT/XPC**		XP2		XP4/XPX***	
	inch	mm	inch	mm	inch	mm
<0.3	27	675	28	700	28	700
0.31-0.6	18	450	28	700	28	700
0.61-0.9	14	350	23	575	28	700
0.91-1.2	12	300	19	475	25	625
1.21-1.5	11	275	17	425	22	550
1.51-1.8	10	250	15	375	20	500
1.81-2.1	9	225	14	350	19	475

High Corrosion Risk (Chloride Content* 0.8% to 1.5%)						
Steel Density	XPT/XPC**		XP2		XP4/XPX***	
	inch	mm	inch	mm	inch	mm
<0.3	18	450	28	700	28	700
0.31-0.6	12	300	19	475	25	625
0.61-0.9	10	250	15	375	20	500
0.91-1.2	8	200	13	325	17	425
1.21-1.5	7	175	11	275	15	375
1.51-1.8	6	150	10	250	14	350
1.81-2.1	5	125	9	225	13	325

Extremely High Corrosion Risk (Chloride Content* >1.5%)						
Steel Density	XPT/XPC**		XP2		XP4/XPX***	
	inch	mm	inch	mm	inch	mm
<0.3	12	300	19	475	25	625
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0.61-0.9	7	175	10	250	14	350
0.91-1.2	6	150	9	225	11	275
1.21-1.5	5	125	7	175	10	250
1.51-1.8	4	100	6	150	9	225
1.81-2.1	N/A	N/A	5	125	8	200

Assumptions

- 20-year design life for the anodes
- Average annual temperature of 50 to 60°F
- Anode aging of 12.5 years (half life)

Considerations

Steel Density

$$\frac{\text{Surface area of steel}}{\text{Surface area of concrete}} = \text{steel density ratio}$$

or

$$\frac{\pi \times D \times L \times n}{1\ ft^2\ (144\ in^2)} = \text{steel density ratio}$$

where:

$\pi = 3.14$

D = bar diameter

L = length of bars in calculated area

n = number of bars in calculated area

Steel Density Calculation

Example

Heavily Reinforced Slab (Bridge Deck)
 # 5 Bars @ 8” on center each way (2 mats)

Top mat longitudinal bars (per ft^2)

$$\pi \times D \times L \times n = \pi \times {}^{5}/_{8}\text{”} \times 12\text{”} \times {}^{12}/_{8}\text{”} = 35\ in.^2 \rightarrow \frac{35\ in.^2}{144\ in.^2} = .245$$

Top mat transverse bars (per ft^2)

$$\pi \times D \times L \times n = \pi \times {}^{5}/_{8}\text{”} \times 12\text{”} \times {}^{12}/_{8}\text{”} = 35\ in.^2 \rightarrow \frac{35\ in.^2}{144\ in.^2} = .245$$

Bottom mat longitudinal bars (per ft^2)	.245
Bottom mat transverse bars (per ft^2)	.245
Total steel density	0.98 ≈ 1.0

Considerations
Corrosion Risk

- Minimum current density as detailed below (depth of rebar)

Corrosion Risk Category	Chloride Level*	Minimum Current Density at 20 Years
Low to Moderate	<0.8%	0.4mA/m^2 (0.04mA/ft^2)
High	0.8%-1.5%	0.8mA/m^2 (0.07mA/ft^2)
Extremely High	1.5%	1.6mA/m^2 (0.15mA/ft^2)

* Chloride content is based on percent by weight of cement.

Custom designs can be provided using different assumptions such as anode life or current density.

Back to the Spacing Charts

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Appropriate spacing versus steel density were produced for each risk level and type of anode.

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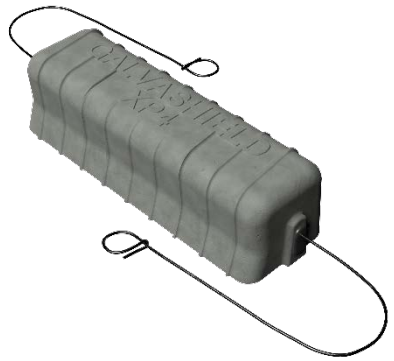
XP (Type 1A) Installation



Prepare the Area Before Installing

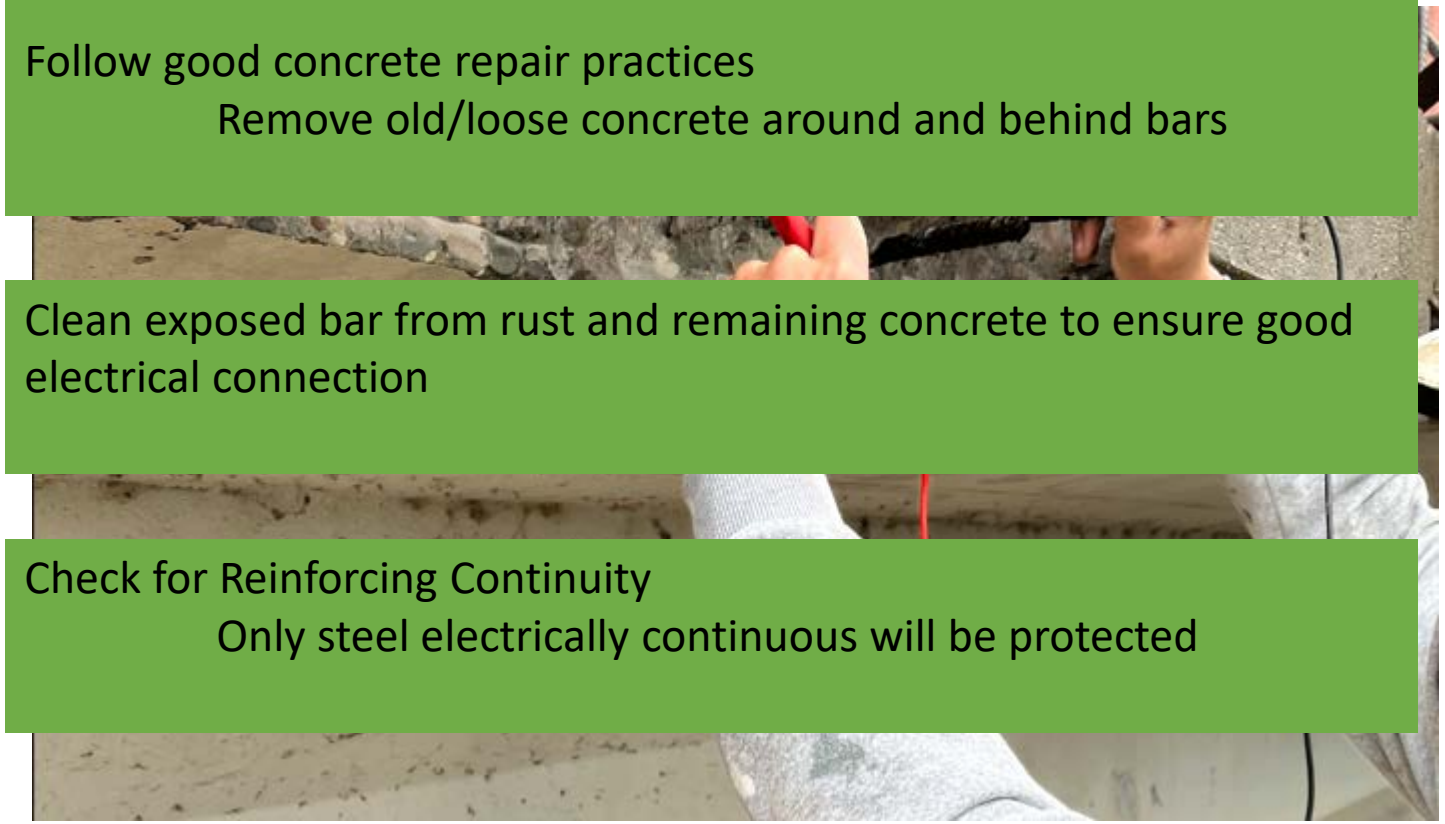
Follow good concrete repair practices

Remove old/loose concrete around and behind bars

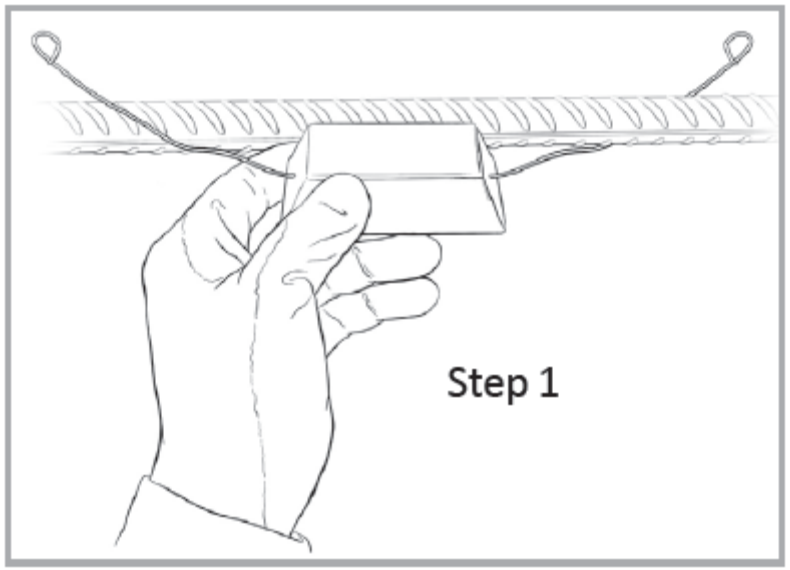
Clean exposed bar from rust and remaining concrete to ensure good electrical connection

Check for Reinforcing Continuity

Only steel electrically continuous will be protected



Follow the install steps…



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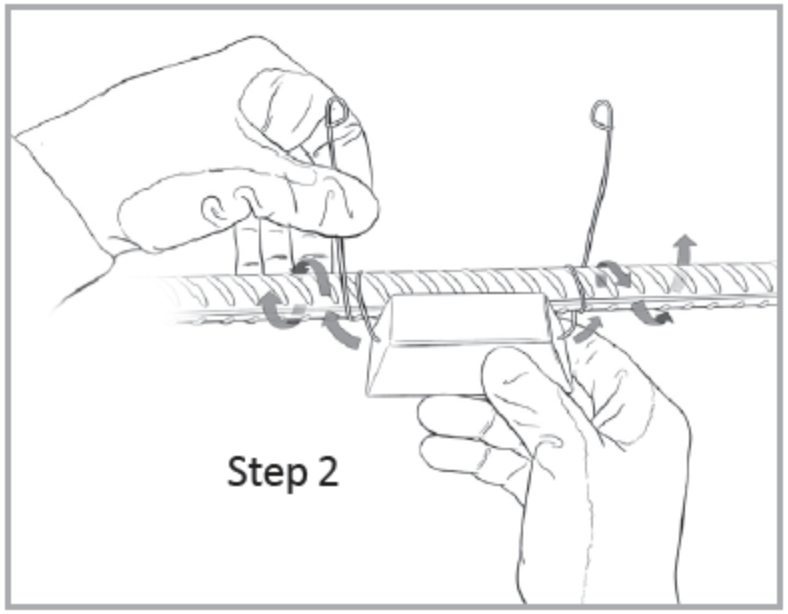

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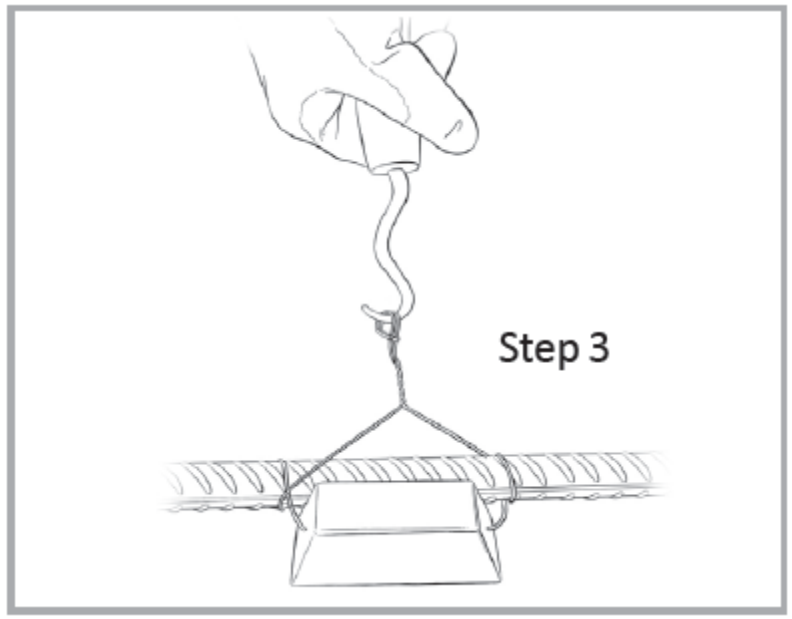

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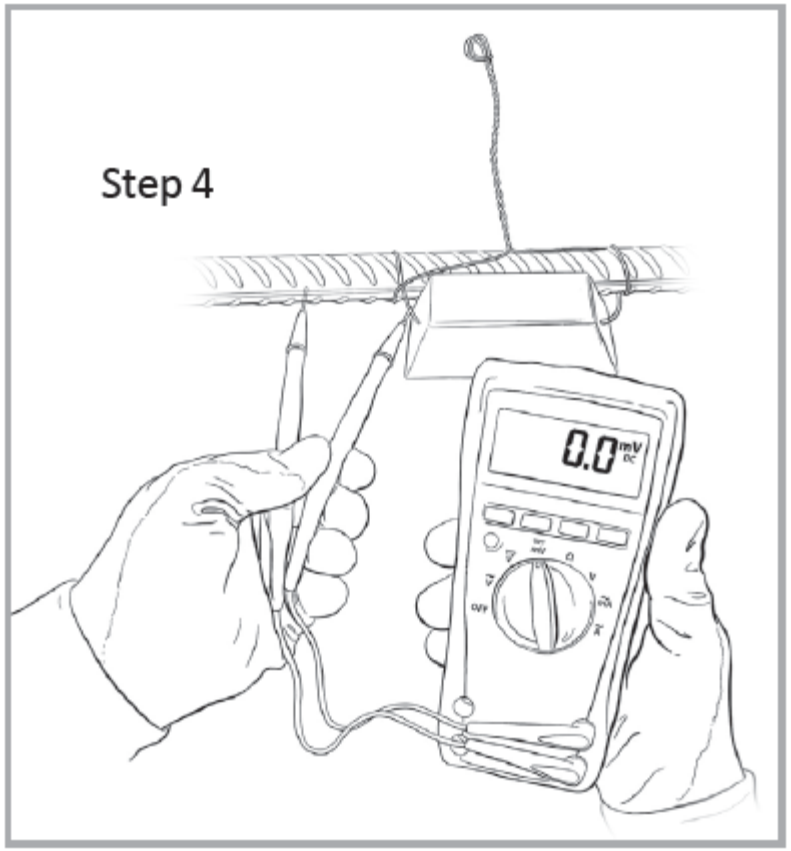
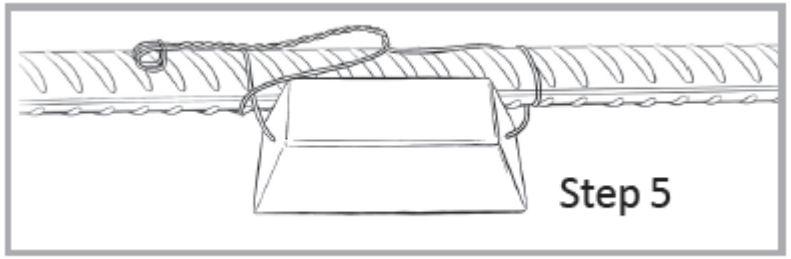


Continue with the rest of the repair!



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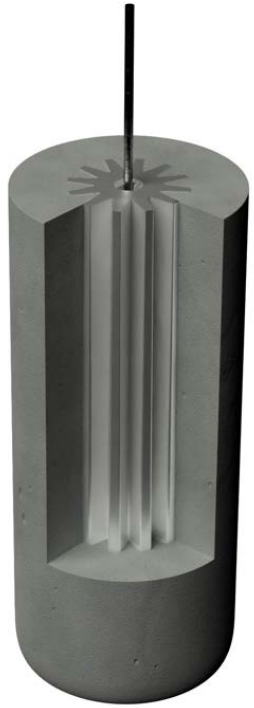
CC (Type 2A) Installation

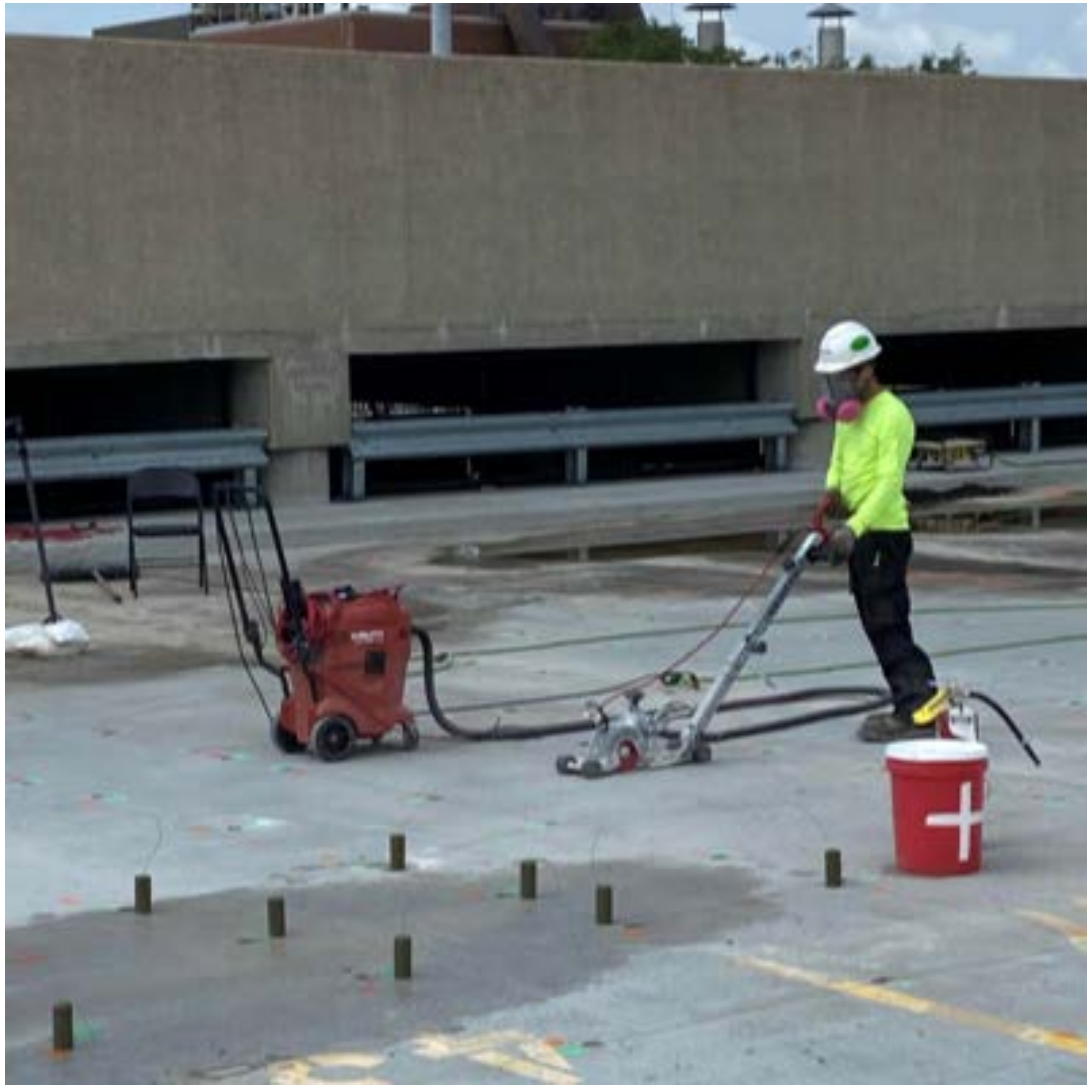


Find Reinforcing Layout and Mark Out Anode Areas

Drill out anode holes

Drill out steel connections

Saw-cut Header Wire Channel



Clean drilled out holes and saw-cuts

Make steel connections and test for continuity

Grout the anodes

Connect the chase wire

Top off grouting and finish

VECTOR CORROSION TECHNOLOGIES

Galvashield CC
Installation Instructions

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Clean Steel


Remove Epoxy Coating


Use Ties for Continuity

We Save Structures™

Thank You!

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