Existing Structures

Engineering, Inc.

Presents

Concrete Corrosion and Control: A Crash Course

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Objectives

- Concrete
- Reinforced Concrete
- Corrosion
- Corrosion Control
- Stay Awake and Happy

Concrete

- Most abundant construction material
- 1 cubic yard each (each year)
- Serbia, 5600 BC
- Cement, aggregate, water

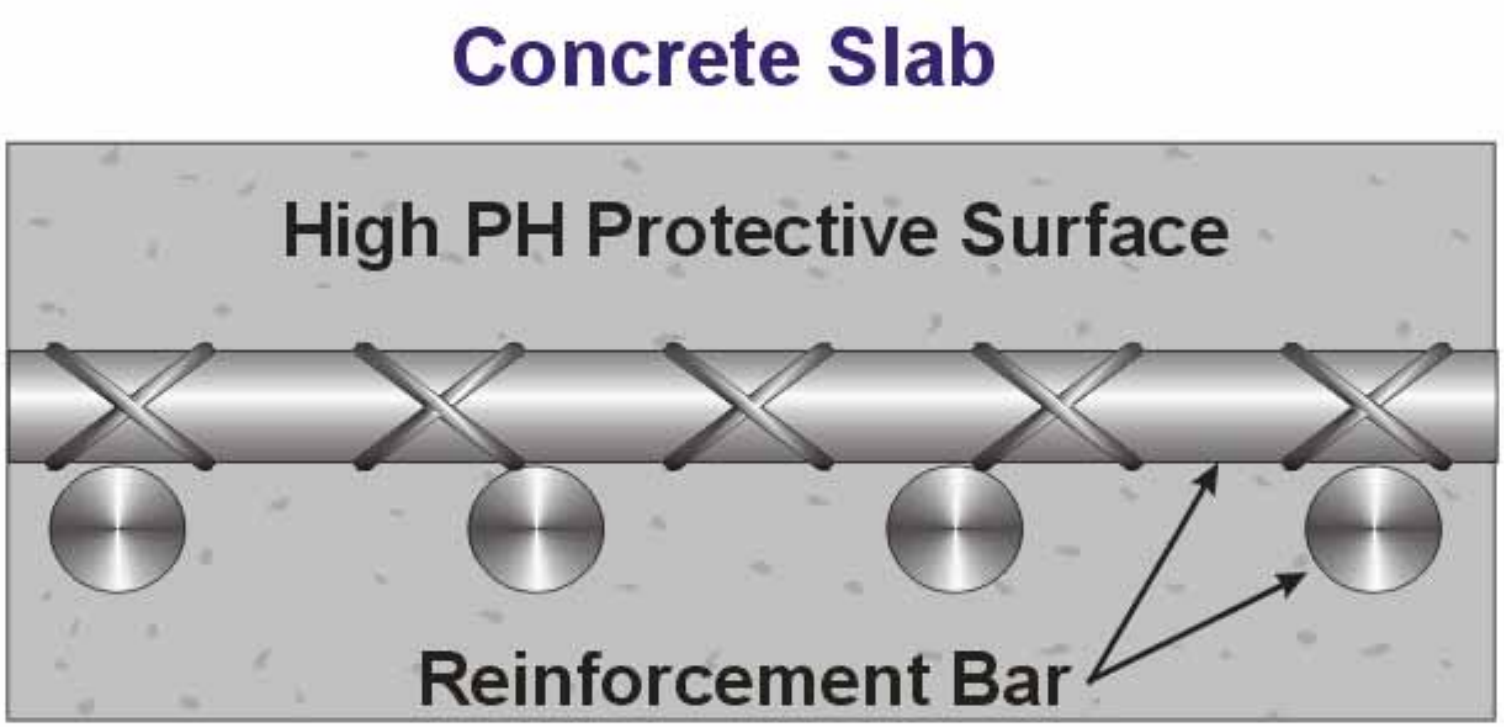
Concrete ingredients

- Cement
  - Portland Cement
  - Oxides of Ca, Si and Al
- Water
  - The good, the bad
  - 0.25 needed, 0.40-0.5 common
- Aggregate
  - Fines
  - Course
- Admixtures
  - Plasticizers
  - Inhibitors
  - Retarders

Reinforced Concrete

- Adds tension capacity
- Accounts for nearly all concrete
- 1848, French gardener
- F’c=4000psi
- Fy=60,000psi

Reinforced Concrete



Non-Amphoteric

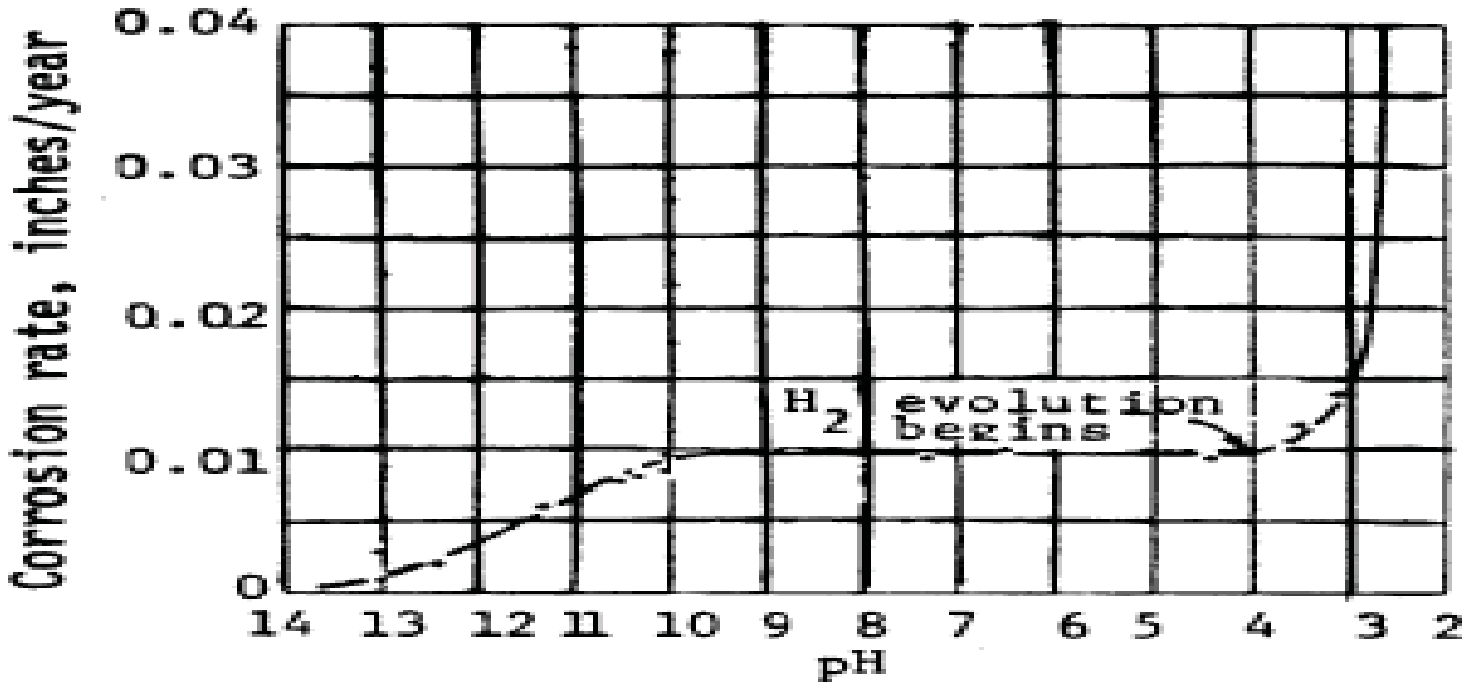


Fig. 2.3—Effect of pH on corrosion of iron in aerated soft water at room temperature[2.1]

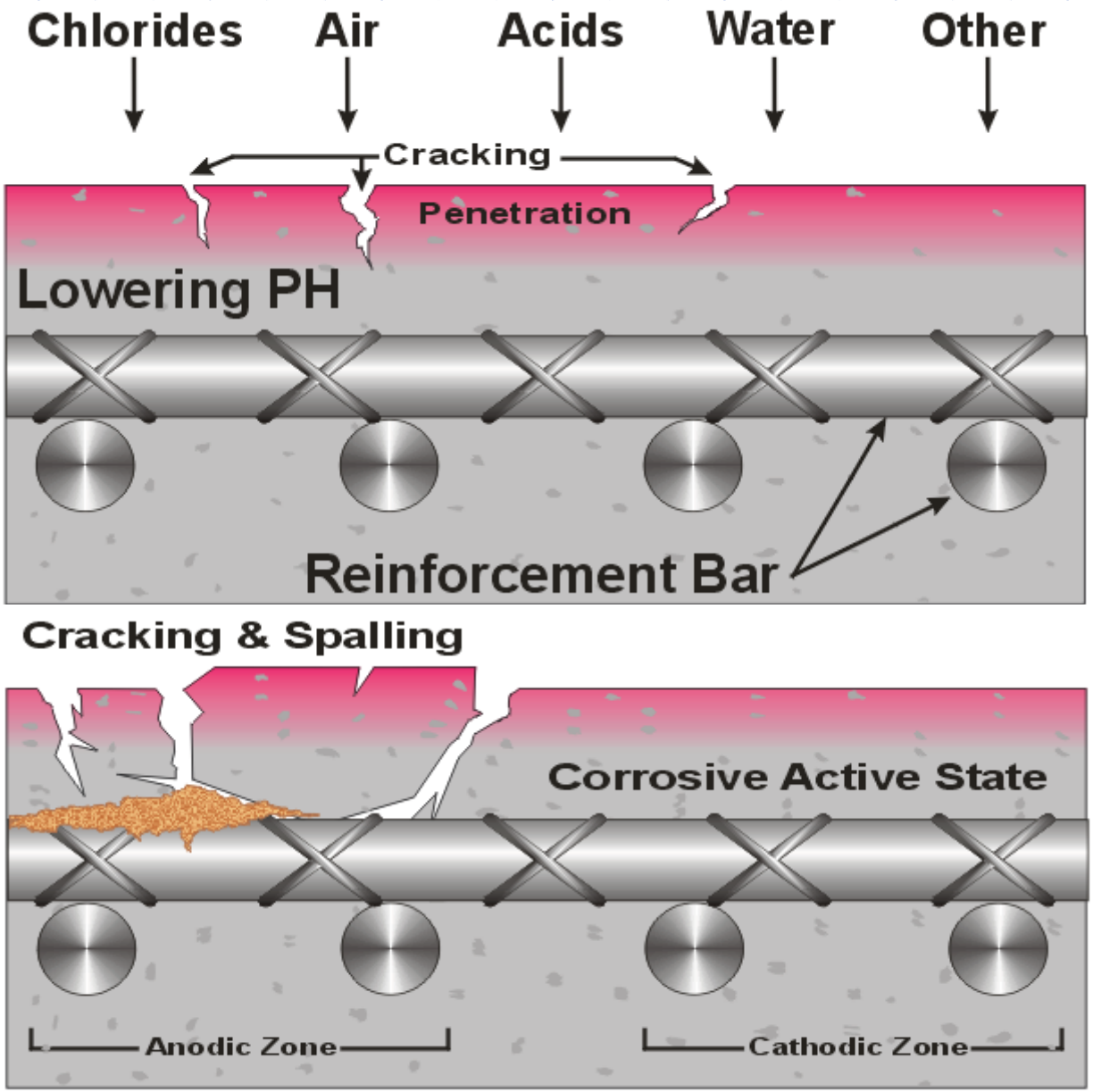
Corrosion:

- The deterioration of a material, usually a metal, that results from a reaction with its environment.

Corrosion is a $276 Billion problem!

Concrete Corro$ion

- Chloride Attack
- Carbonation
- Sulfate Attack
- ASR


Chlorides
Air
Acids
Water
Other
Cracking
Penetration
Lowering PH
Reinforcement Bar
Cracking & Spalling
Corrosive Active State
Anodic Zone
Cathodic Zone

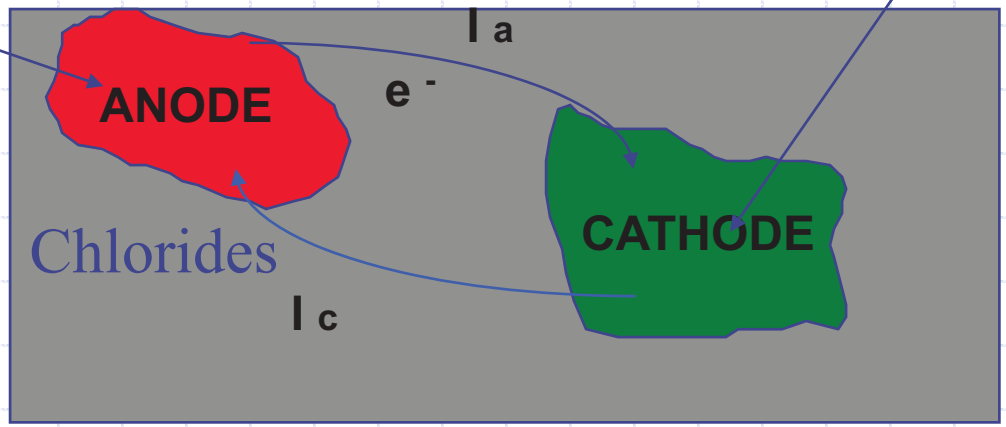
- CATHODE (protected area)
- ANODE (corrosion occurs)
- ELECTROLYTE (concrete)
- METALLIC PATH

REDUCTION

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

OXIDATION

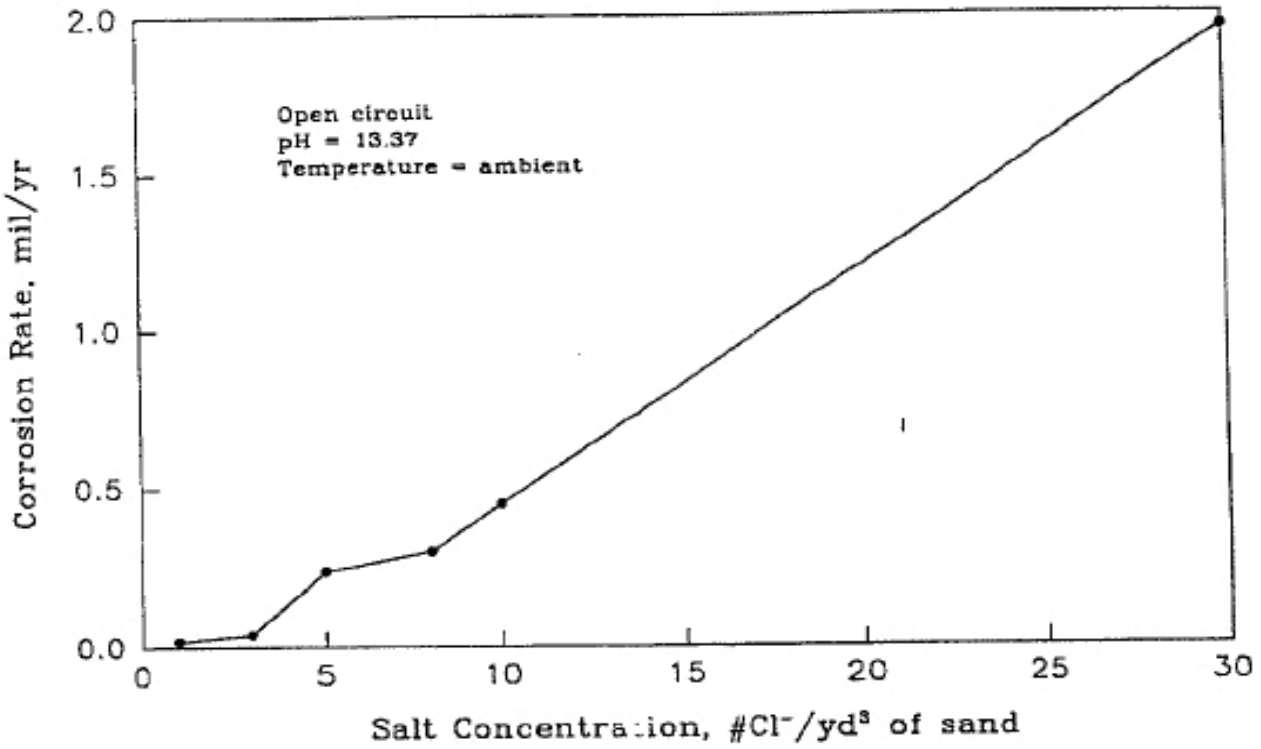
$Fe \rightarrow Fe^{++} + 2e^-$



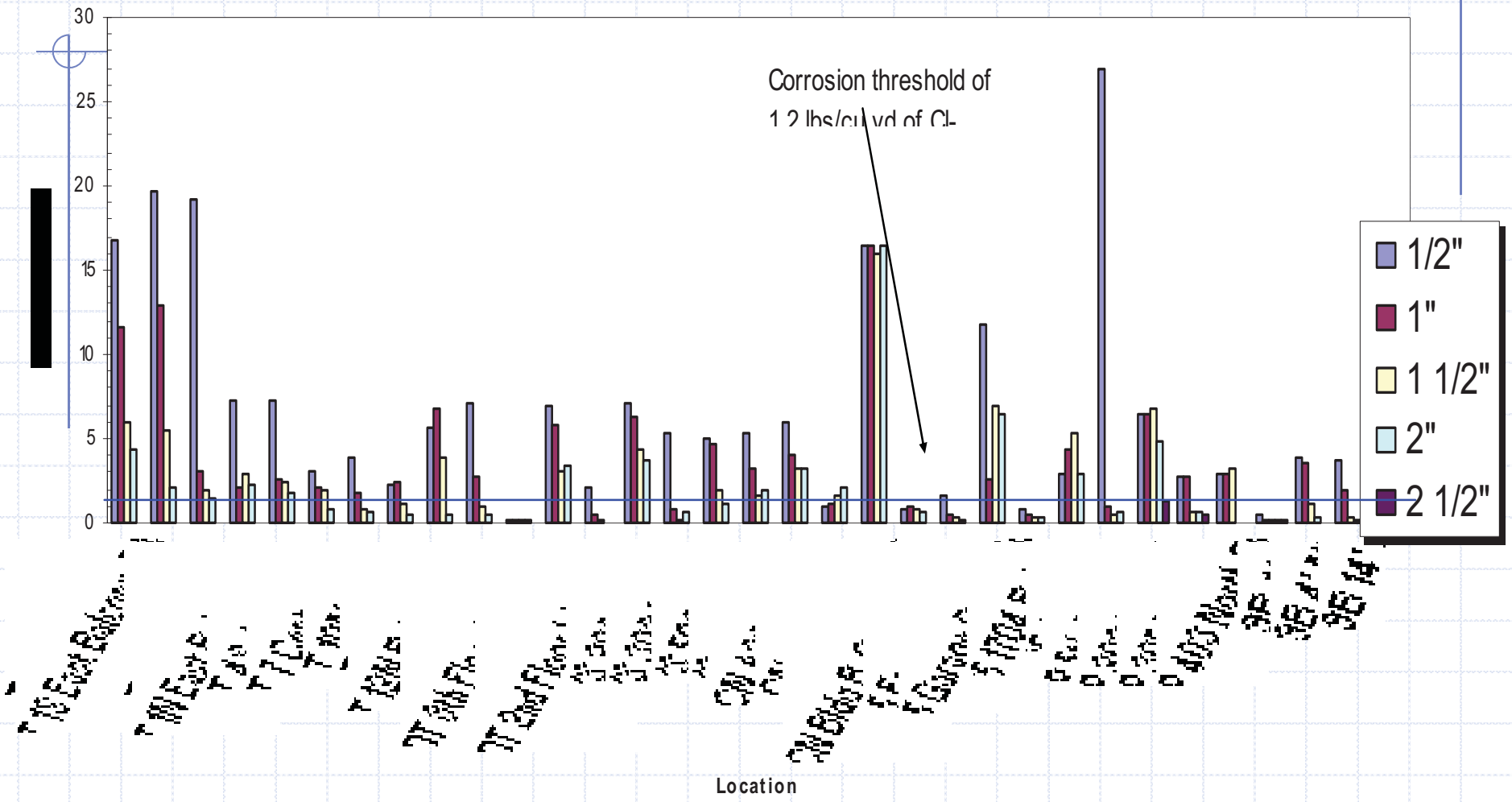
CHUNK-O-METAL
(reinforcing steel)

Effect of Cl on Corrosion Rate

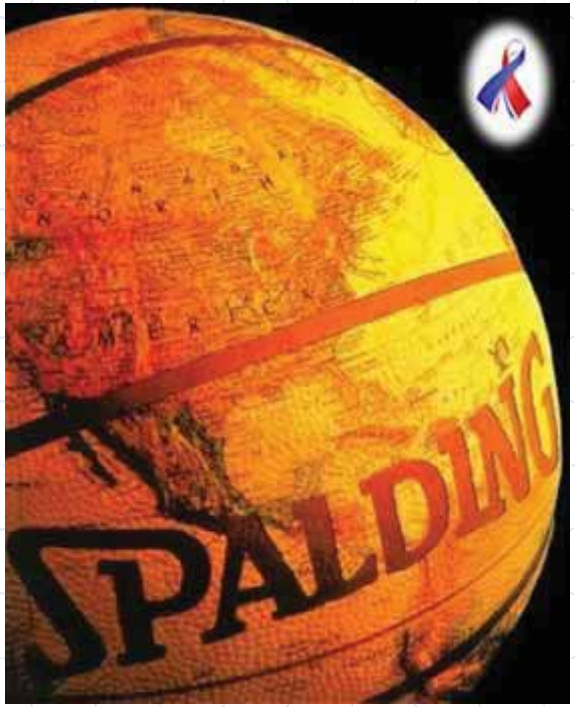
Figure 3-4. Effect of Chloride Concentration on Corrosion Rate



Cl- ions vs. depth



Spalling



This is Spalling

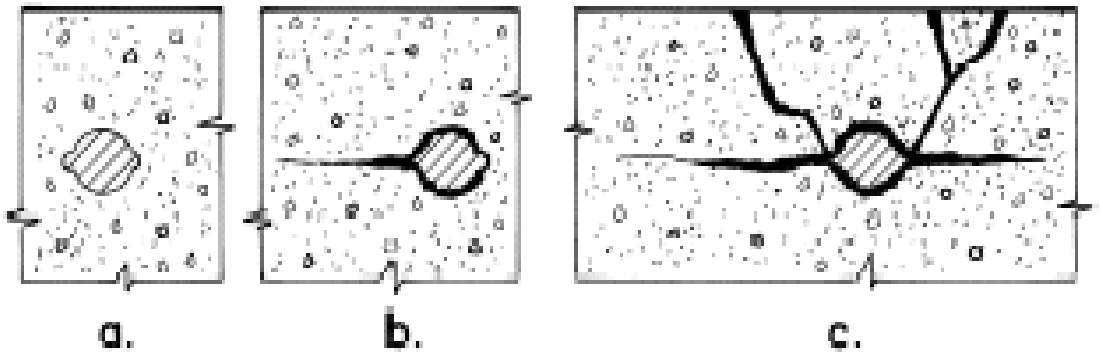
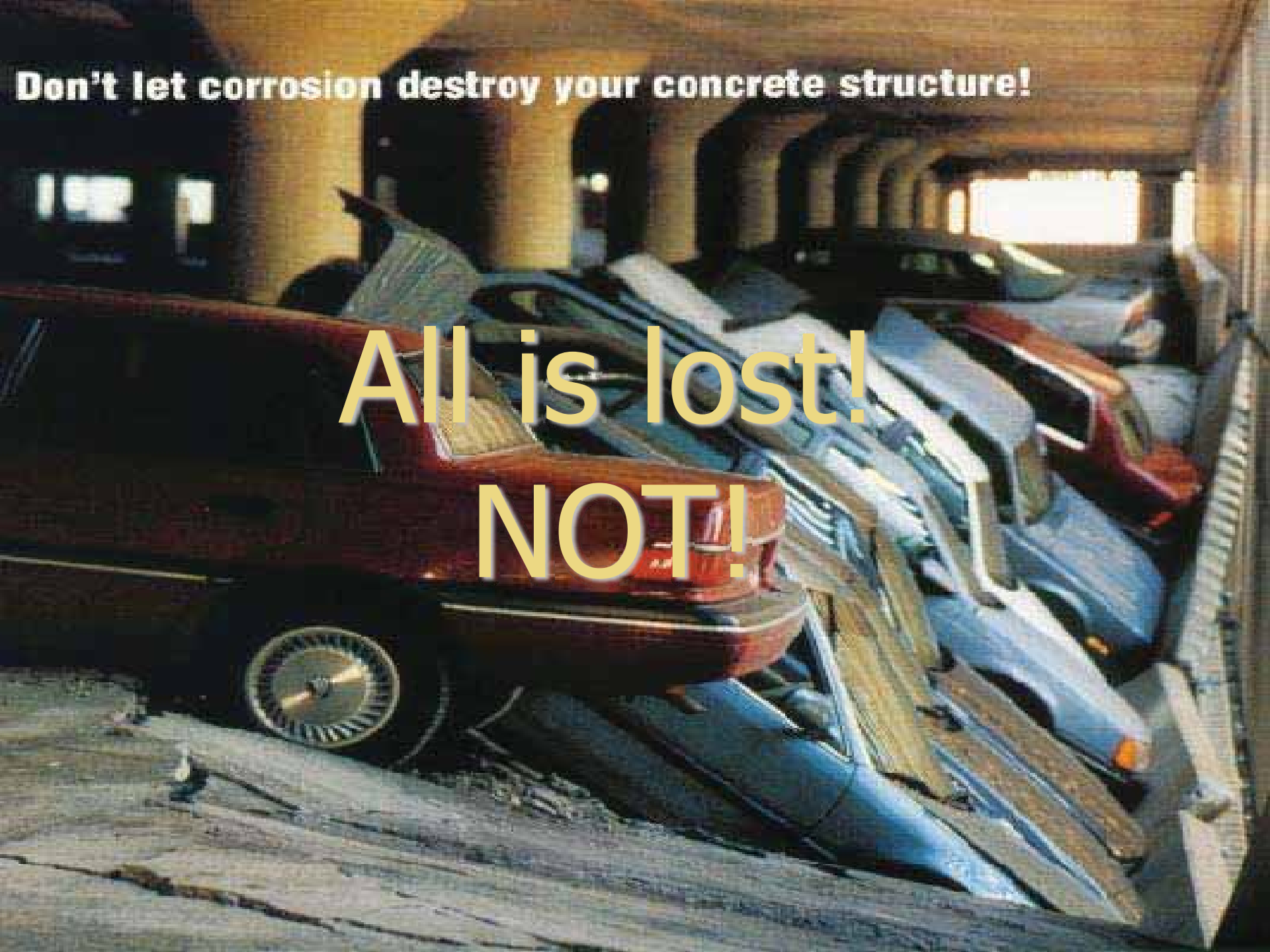
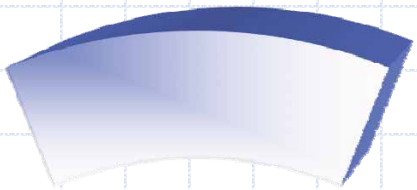


Figure 3. Corrosion-induced cracking of the concrete.


Don’t let corrosion destroy your concrete structure!
All is lost!
NOT!

Tools on the belt

- Design and Material Selection
- Corrosion Inhibitors
- Cathodic Protection
- Protective Coatings



Inhibitors

Materials & Design

Final Product

Coating

Cathodic Protection

Design and Material Selection

- Most cost effective
- Easiest to implement
- Design with end use in mind
- Design: details, maintenance
- Not easily retrofitted

Durable Concrete Design

- Reduce Water/Cement Ratio
- Increase rebar coverage
- Introduce pozzalans/inhibitors
- Rebar material
- CP, Apply coatings

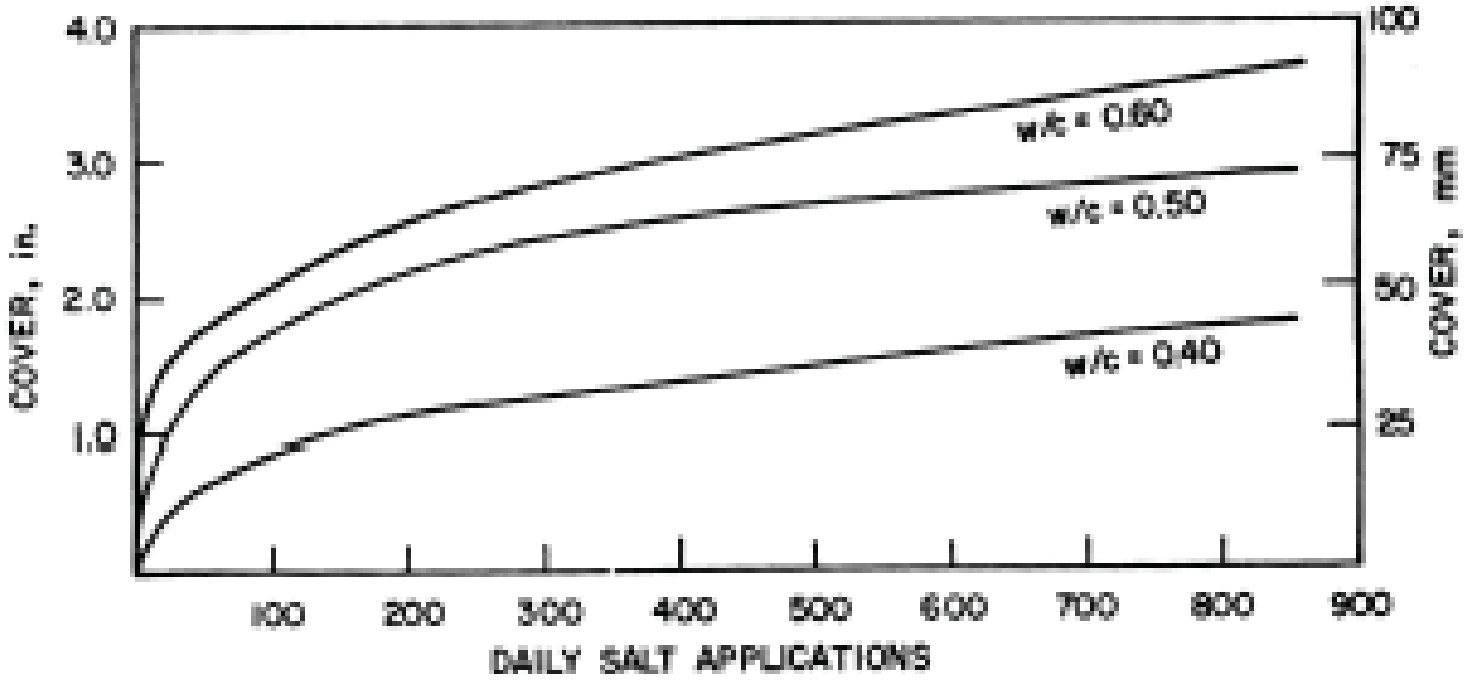


Fig. 3.3—Effect of water-cement ratio and depth of cover on relative time to corrosion[3.5]

Microcomposite Rebar

- High in Cr, groovy microstructure
- Corrosion resistance is not altered during placement
- High mechanical strength, ASTM A615, Gr 75 (vs 60)
- Increases Cl- corrosion threshold to 5-6x
- Cost competitive
  - $0.80/lb vs. $0.50/lb installed
- Really hard to bend/cut in the field

Corrosion Inhibitors

- Chemical compounds that when in the environment reduce or stop corrosion
- Resistance to acids, alkalis, salt & moisture
- New or retrofitted
- Proven track record
- Admixed or topically applied

Gut Check

- Do I have 15 minutes left?

Inhibitor Types

- Anodic
  - Nitrites
  - Chromates
- Cathodic
  - Arsenates
- Mixed
  - Amines

Calcium Nitrites

Table 1			
Dosage Rates vs Chloride Protection			
DCI		Chloride	
L/m³	(gal/yd³)	kg/m³	(lbs/yd³)
10.0	2	3.6	6.0
12.5	2.5	4.8	8.0
15.0	3	5.9	9.9
17.5	3.5	6.8	11.5
20.0	4	7.7	13.0
22.5	4.5	8.4	14.1
25.0	5	8.9	15.0
27.5	5.5	9.3	15.6
30.0	6	9.5	16.0

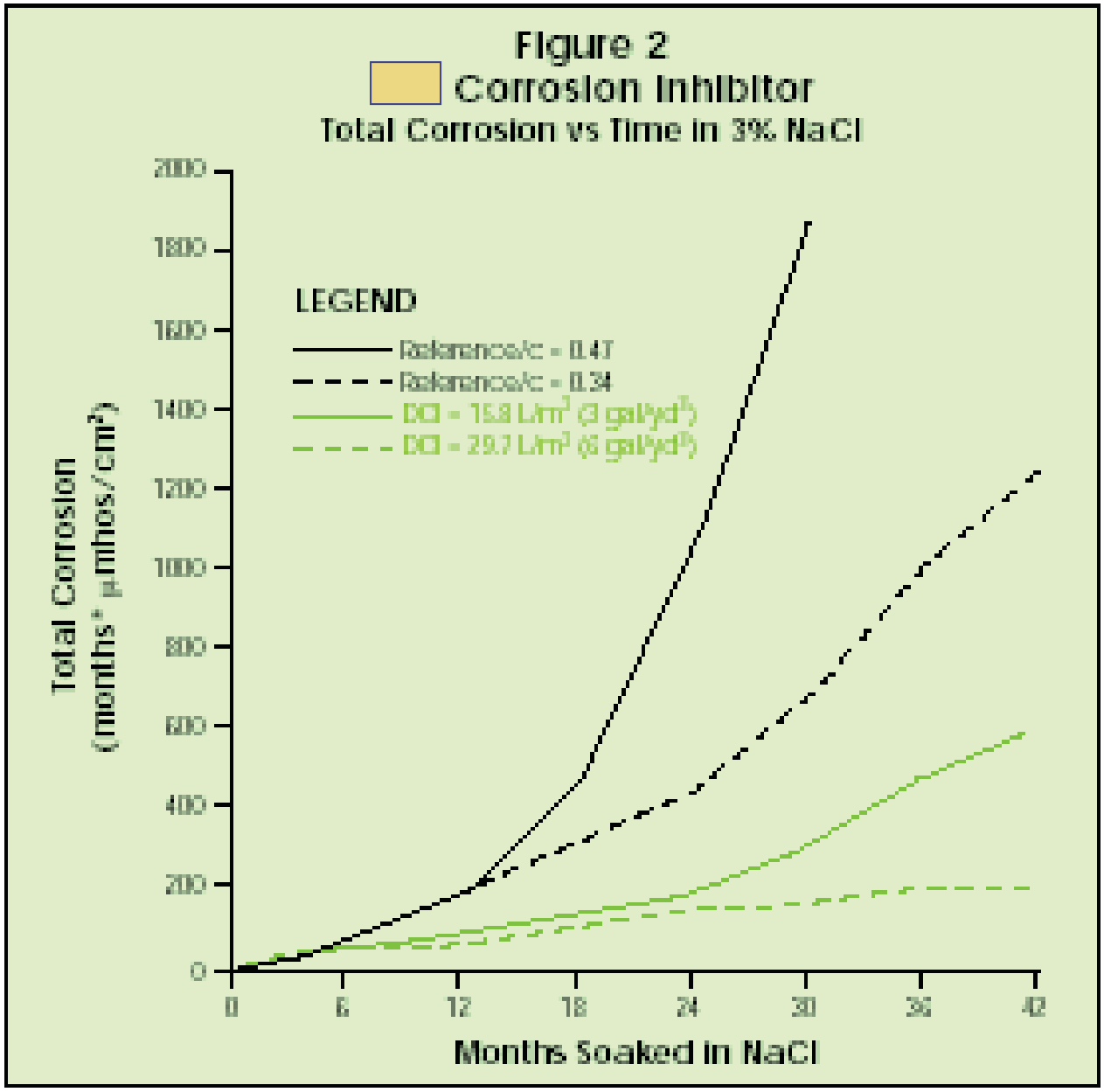
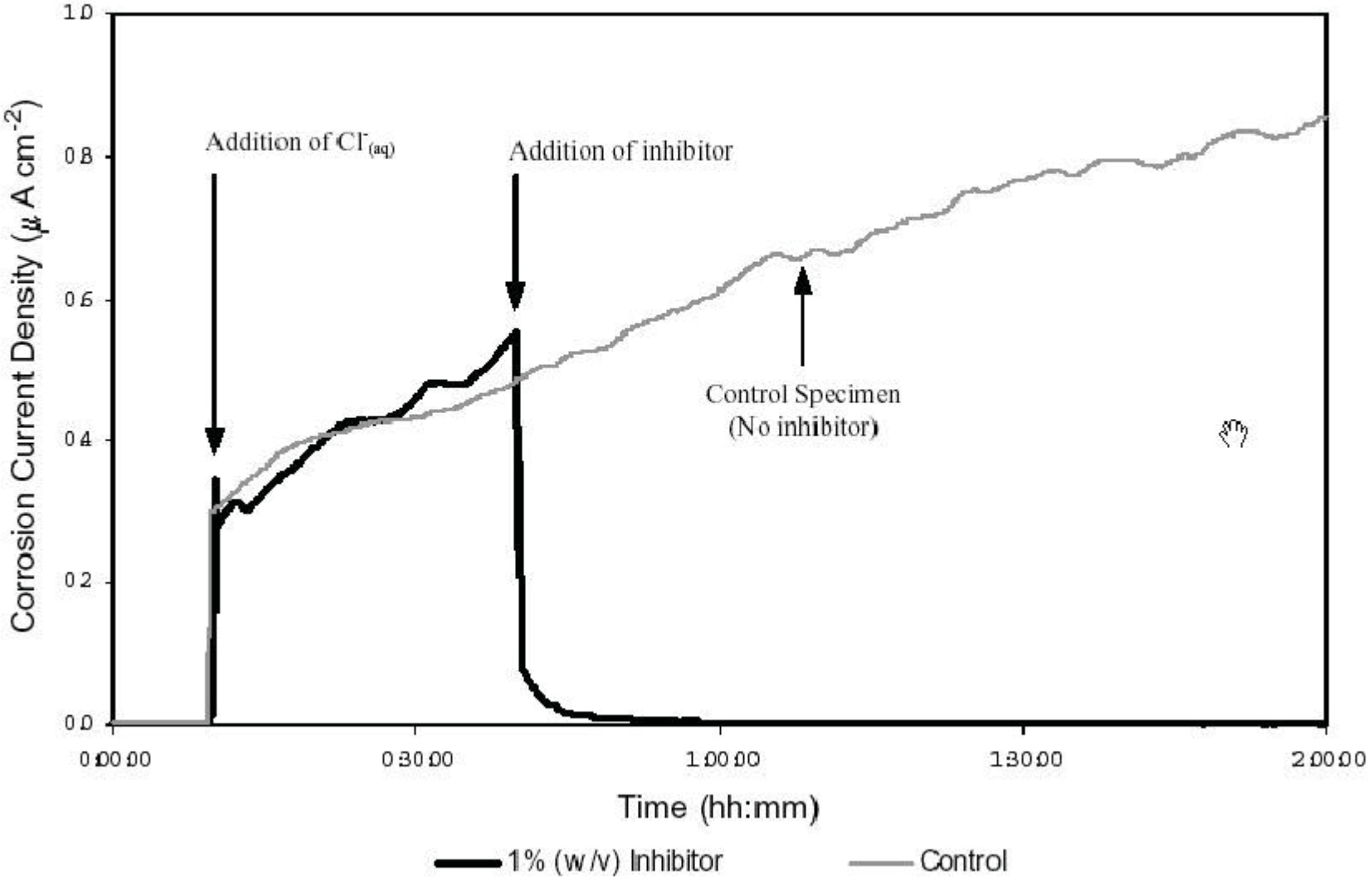


Figure 2
Corrosion Inhibitor
Total Corrosion vs Time in 3% NaCl
LEGEND
Rakarence/c = 0.47
Rakarence/c = 0.34
DCI = 15.8 L/m³ (3 gal/yd³)
DCI = 29.7 L/m³ (6 gal/yd³)
Total Corrosion
(months* µmhos/cm²)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
6
12
18
24
30
36
42
Months Soaked in NaCl

Figure 2 Galvanic current measurement of steel immersed in 0.0125 M KOH solution containing 0.2% $Cl_{(aq)}$ with and without the addition of 1% amino-alcohol inhibitor.



Project Title:	ICRI examples	Date:	2003/2/18 - 3:42 pm
Performed by:	ESE		
Structure:	1D slab/wall structure	Exposure:	Within 800 m of Ocean
Location:	JACKSONVILLE , Florida		0.60 %wt conc @ 15 years
Clear cover:	0.75 in		
Design Life:	75 years	Discount Rate:	3.0 %

Scenario Name	Initial Cost ($/ft^2)	Repair Cost ($/ft^2)	Repair Area (%)	Repair Interval (years)	Time to Initiation (years)	Time to 1st Repair (years)	Total Life Cycle Cost ($/ft^2)
MMFX rebar	6.35	175.00	10	10	34.6	40.6	18.45
Durable w/ CN	5.40	175.00	10	10	15.2	21.1	33.65
Free Durable	5.03	175.00	10	10	5.0	11.0	46.09
Base Case	5.03	175.00	10	10	3.1	9.1	50.72
Coated	9.53	175.00	10	10	9.7	15.7	55.32
*User - Amine Carbox	5.40	175.00	10	10	8.1	38.1	20.79

Cathodic Protection

- Uses electrical current to reduce corrosion by making the component metal a cathode of the electrochemical cell.
- Applies to metals: steel, aluminum, concrete
- Electrolytes: concrete, soil, water, closed or open systems
- Passive or driven
- New or retrofitted
- Invisible and harmless to guests (maybe not animals)

Cathodic Protection

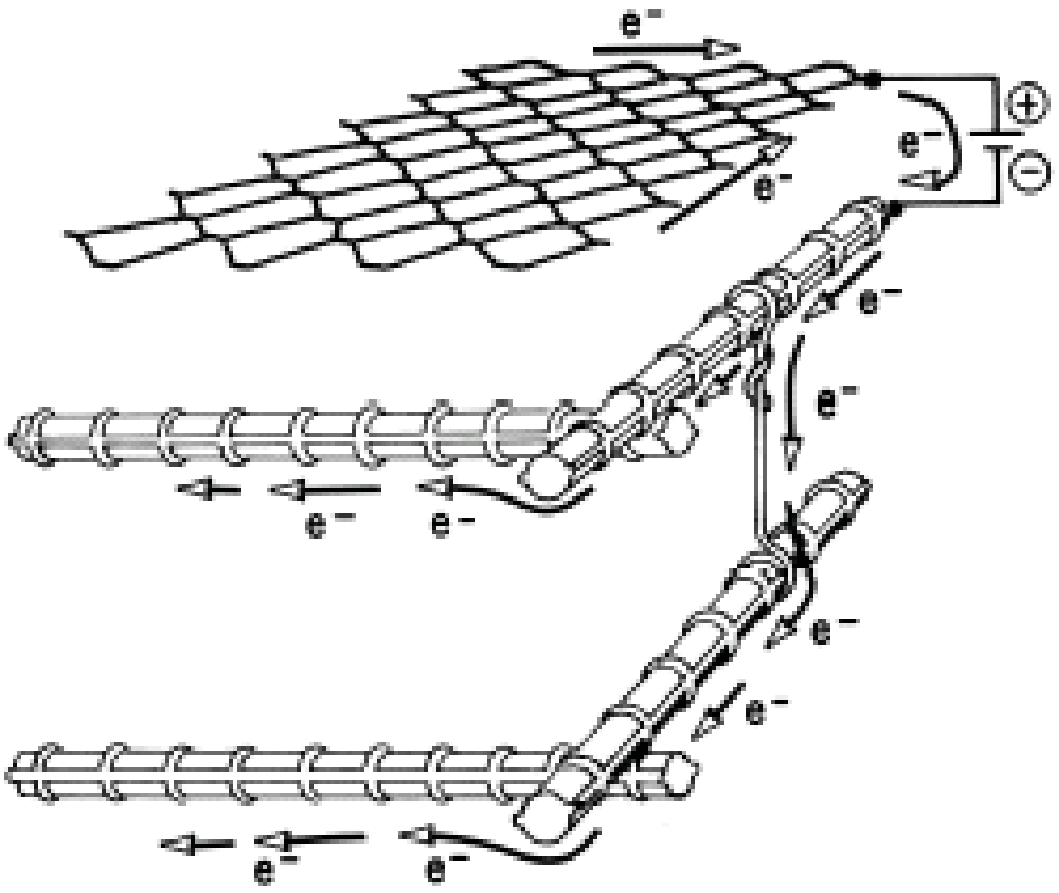
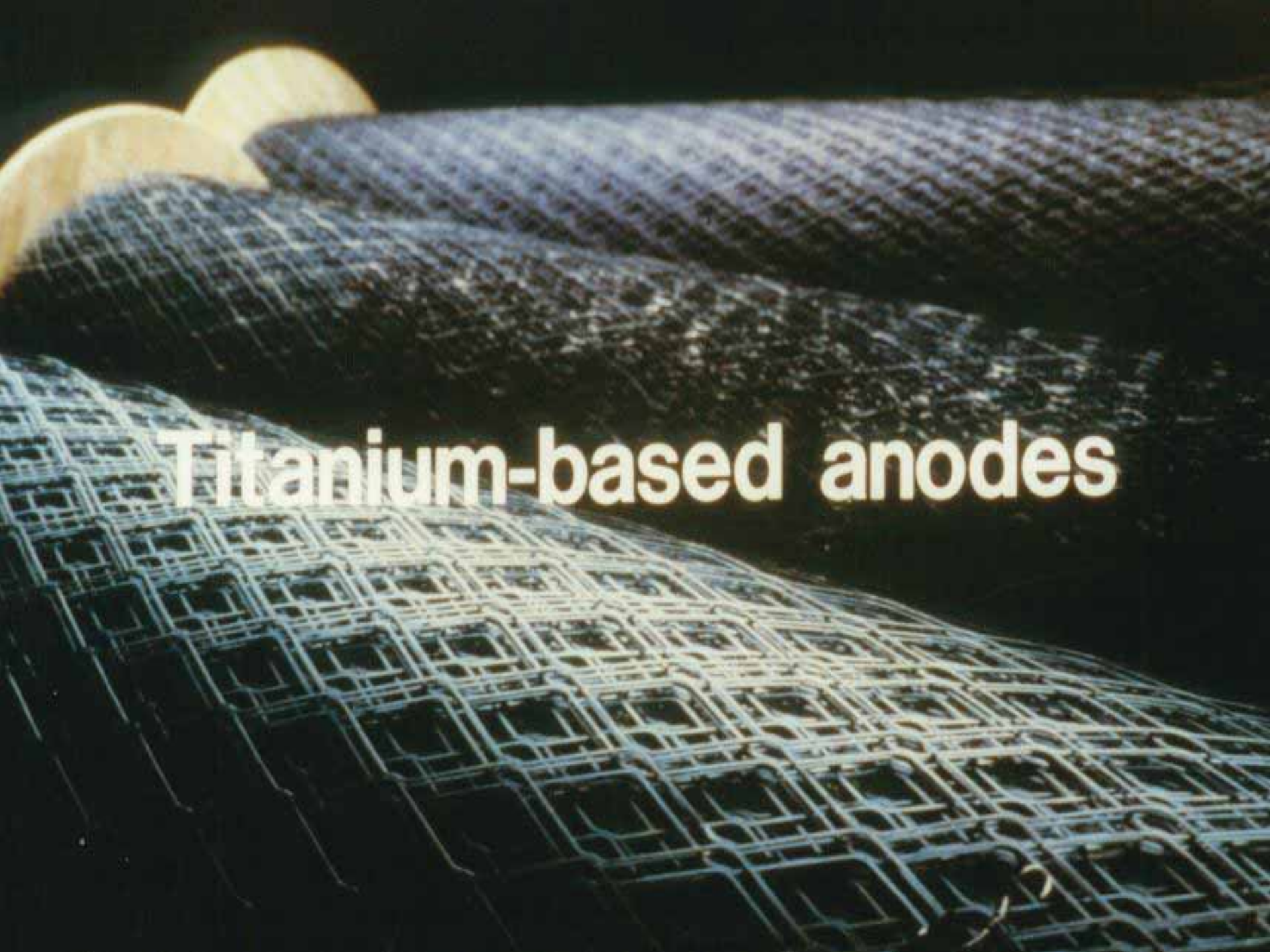
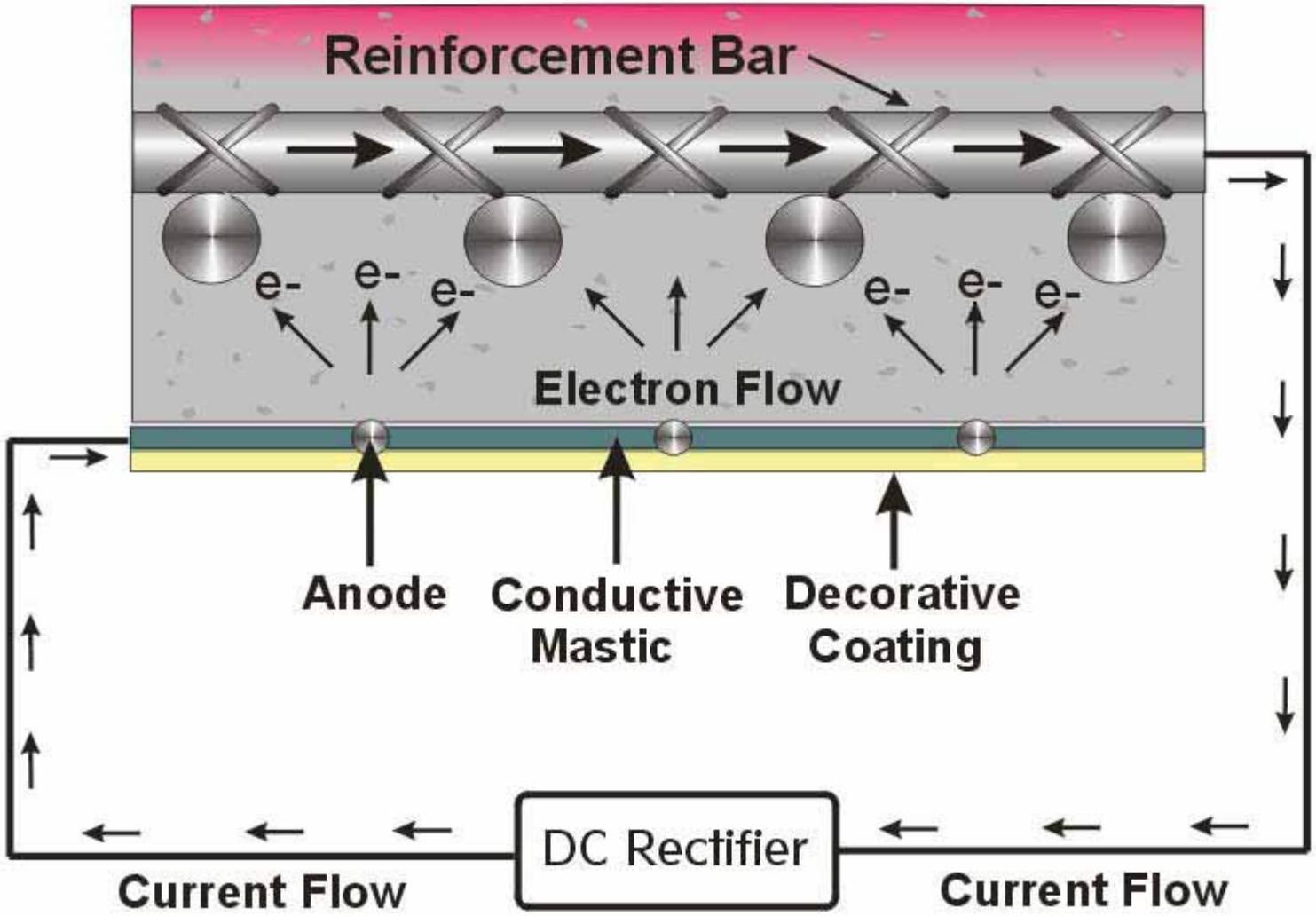


Figure 4. Schematic of impressed current CP system.


Titanium-based anodes


12 6'99


Reinforcement Bar
e-
e-
e-
e-
e-
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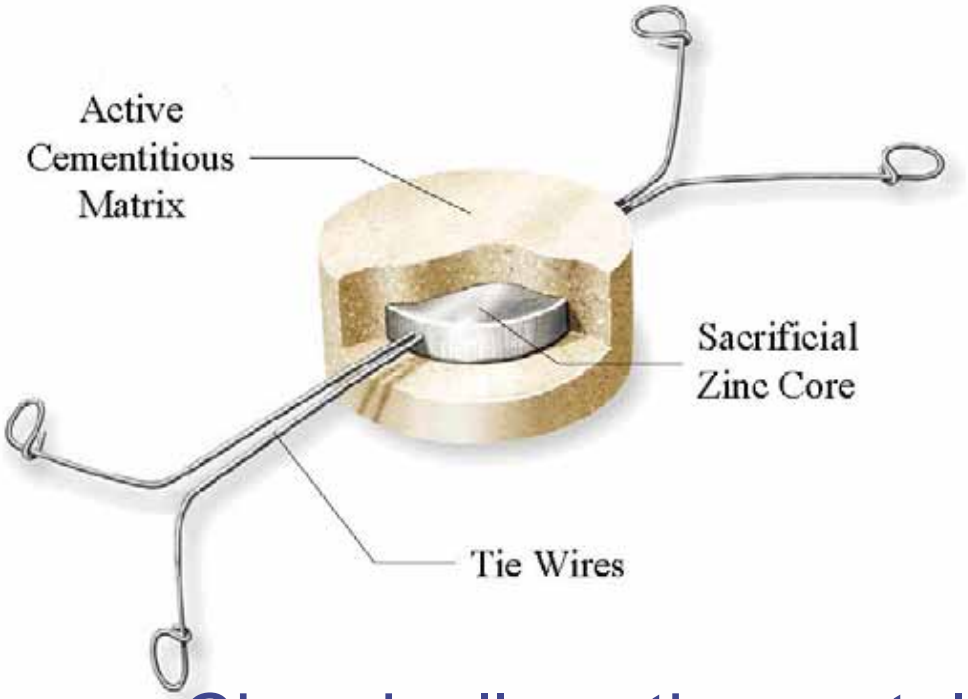
Electron Flow
Anode
Conductive Mastic
Decorative Coating
DC Rectifier
Current Flow
Current Flow

ELGARD™ 100 Titanium Ribbon Mesh

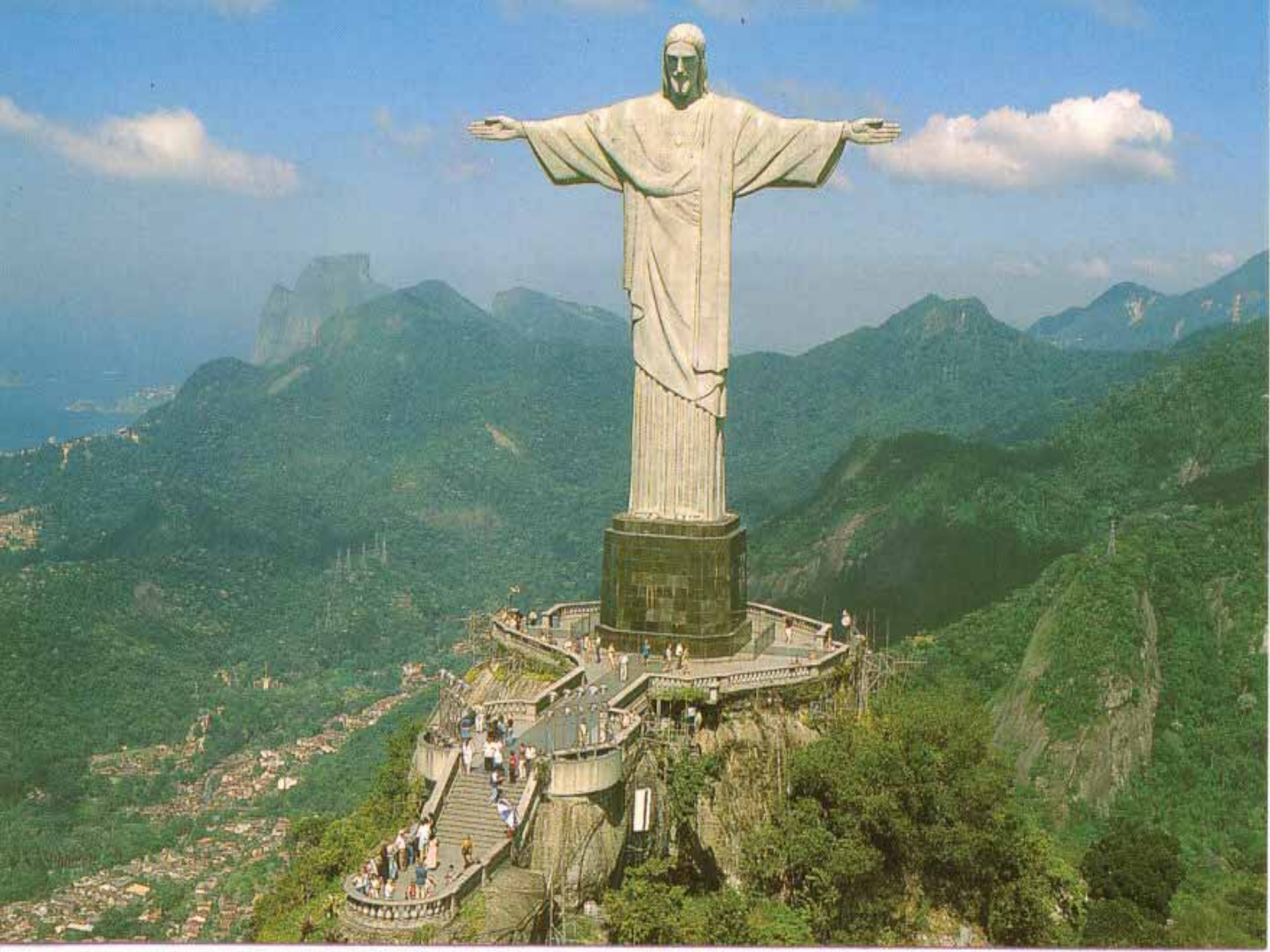

HITACHI



Sacrificial Anode

Chemically active metals which when electrically connected to reinforcing steel, will provide the energy needed to cathodically protect the steel. The sacrificial anode deteriorates at a rate proportional to the energy needed to protect the steel plus whatever may deteriorate by local action corrosion.

installed in balcony repair edge



Protective Coatings

- A coating applied to the surface to protect the substrate from corrosion.
- Complex chemical compounds, often assembled on site.
- Paint: Sometimes it sticks, sometimes it don't. (EK)
- Most often used, least effective means of corrosion control (maybe).

Concrete Coatings

- Epoxy
- Urethanes
- Acrylics

Epoxies

- Normally two component, water or solvent based, high performance system
- Excellent adhesion.
- Very low permeability.
- Chalks, needs topcoats.
- Moisture can be an issue.

Polyurethanes

- Normally two component.
- Excellent UV resistance.
- Abrasion and chemical resistance.
- Low permeability.
- Sensitive to moisture and temperature.
- Expensive but low service life cost.

Acrylics

- Normally single component, water based.
- Inexpensive (and cheap).
- *May* be a moisture barrier.
- Most permeable.
- Most common architectural coating.
- Usually not suitable for immersion

Permeability

- Polyurethane Deck Coating

Water Resistance	ASTM D471	<3%	<3%
MVT @ 20 mils	ASTM E96	2.6 English	2 English
Taber Abrasion (cs17)	ASTM D4060	30 mg/1,000 rev	25 mg/1,000 rev

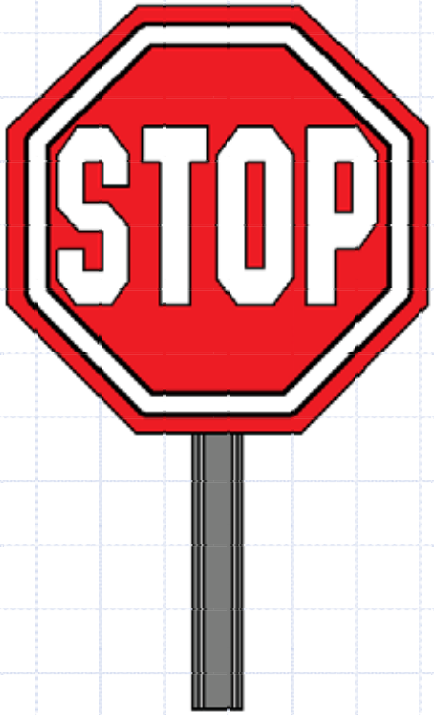
- High Build Acrylic Deck Coating

ASTM E96		
Water Vapor Trans	20 mils film	12-14 perms

- High Perm Acrylic Coating

Permeability ASTM D1653 61.02 Perms

The audience is often done before the speaker!



Questions?

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