Bridge Preservation

Corrosion Mitigation Option in Concrete Repair Systems

September 29, 2010

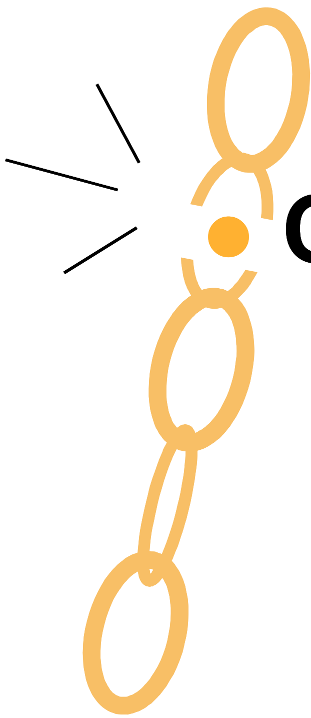
Northeast Bridge Preservation Partnership Meeting

TSP-2

TODAY WE WILL DISCUSS

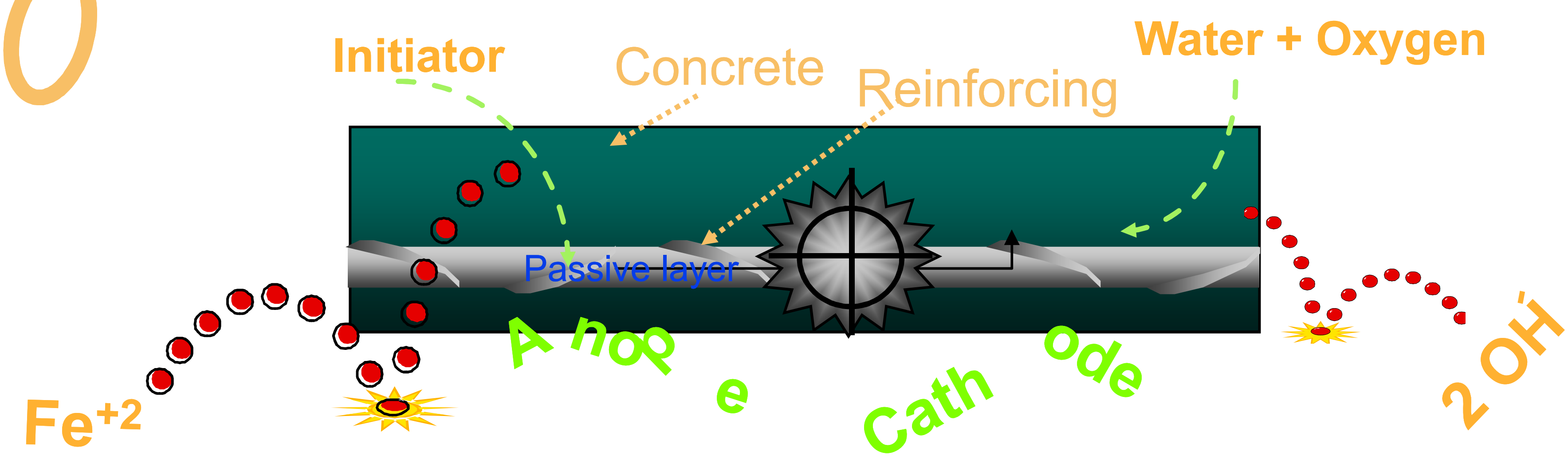
- Corrosion of Bridge Decks
- Surface Applied Corrosion Inhibitors
- Advances in Surface Applied Corrosion Inhibitors
- Extension of Service Life of Bridge Decks using Advanced Corrosion Mitigation Technology

CORROSION PROCESS



Corrosion is like a chain.

The entire process can be interfered with if a link is broken.



Electrochemical Corrosion Reactions

Reactants $\longrightarrow$ **Products**

- $Fe^{+2} + 2Cl^{-} \longrightarrow FeCl_2$
- $FeCl_2 + H_2O + OH^{-} \longrightarrow Fe(OH)_2 + H^{+} + 2Cl^{-}$
- $2Fe(OH)_2 + \frac{1}{2}O^{-} \longrightarrow Fe_2O_3 + 2H_2O$ **anode (rust)**
- $\frac{1}{2}O + H_2O + 2e^{-} \longrightarrow 2\,OH^{-}$ **cathode**

Electrolyte

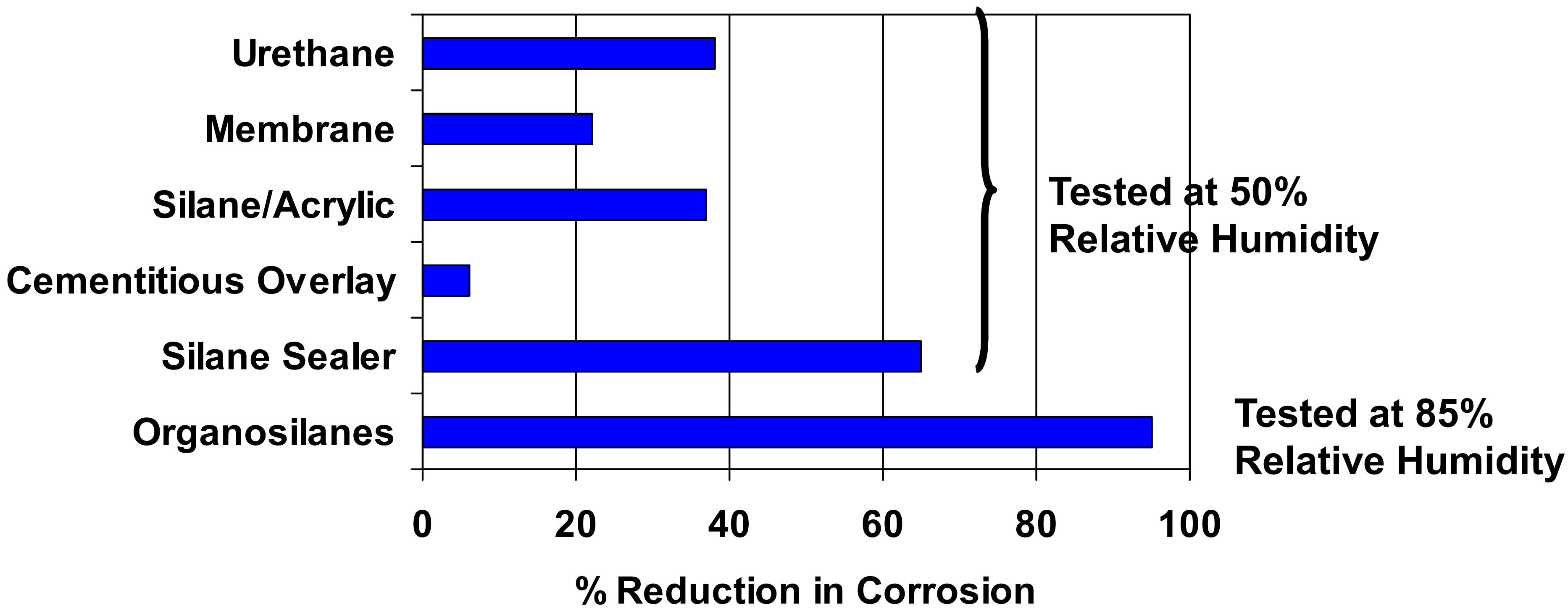
Important Takeaways:

- Chlorides are not consumed in the process
- Reinforcing steel acts as both the “Anode” and “Cathode”
- [H+] produced drops pH and further deteriorates the passivation layer
- The electrolyte is the ion-rich pore solution in the concrete
- Anode-Cathode reactions occur at the same rate
- Need both oxygen and water to complete the reaction

WHAT IS A SURFACE APPLIED CORROSION INHIBITOR?

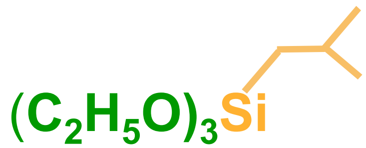
- Clear Penetrating Liquid
  - Low Viscosity
  - Low Surface Tension
  - Reactive (Concrete / steel)
- Application
  - Bridge Decks
  - Piles
  - Girders
  - Jersey Barriers
- Spray or Roller Applied

VARIOUS TECHNOLOGIES

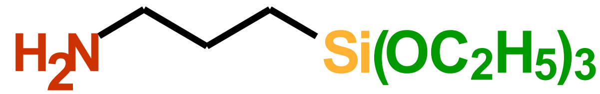


Conventional protection methods may prevent corrosion, but they are not as effective on active corrosion

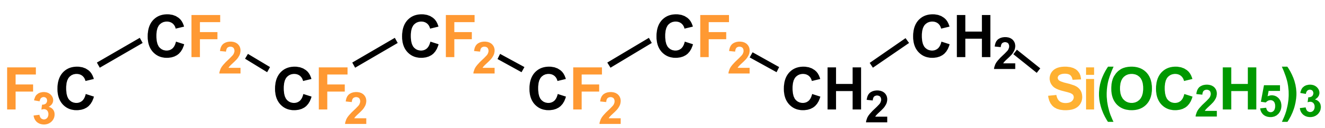
Silanes:
Made with Different Functionality



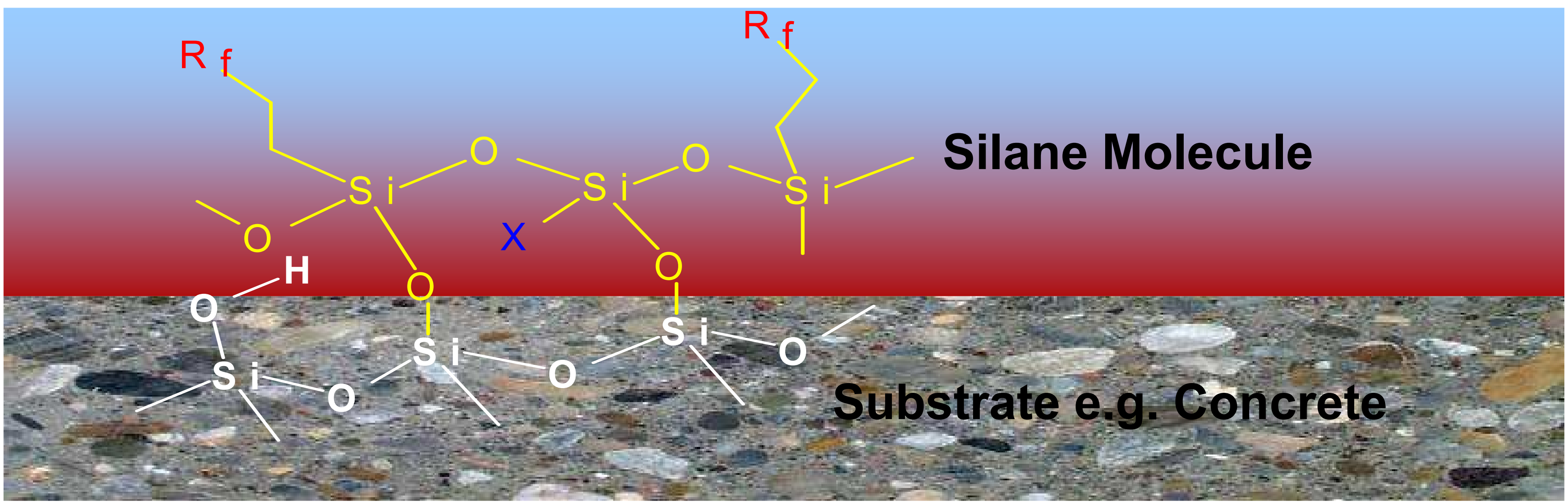
Alkyltrialkoxysilane
Hydrophobic Effect



Aminoalkyltrialkoxysilane
Corrosion inhibitor

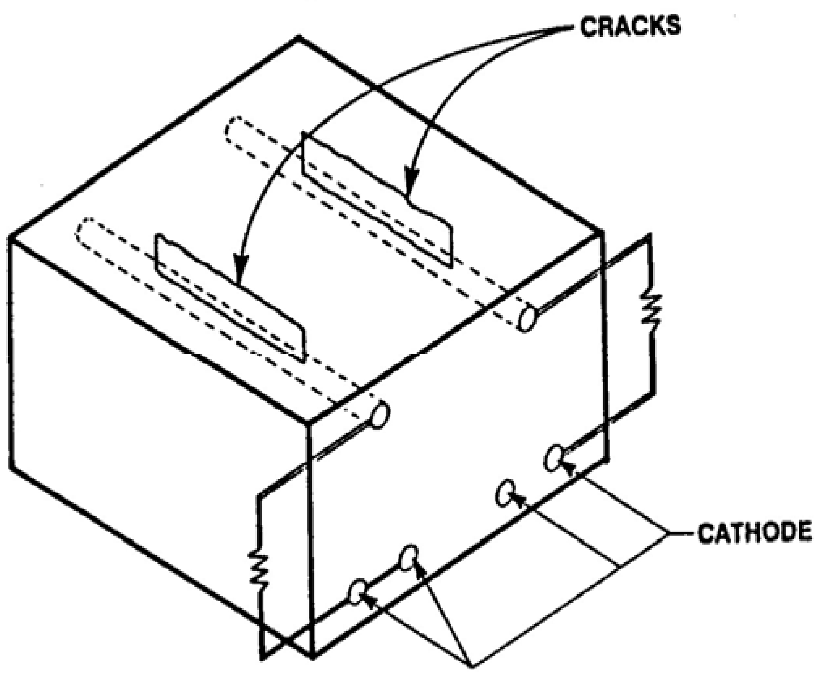


FluoroAlkyltrialkoxysilane
Anti-Graffiti, Easy to Clean



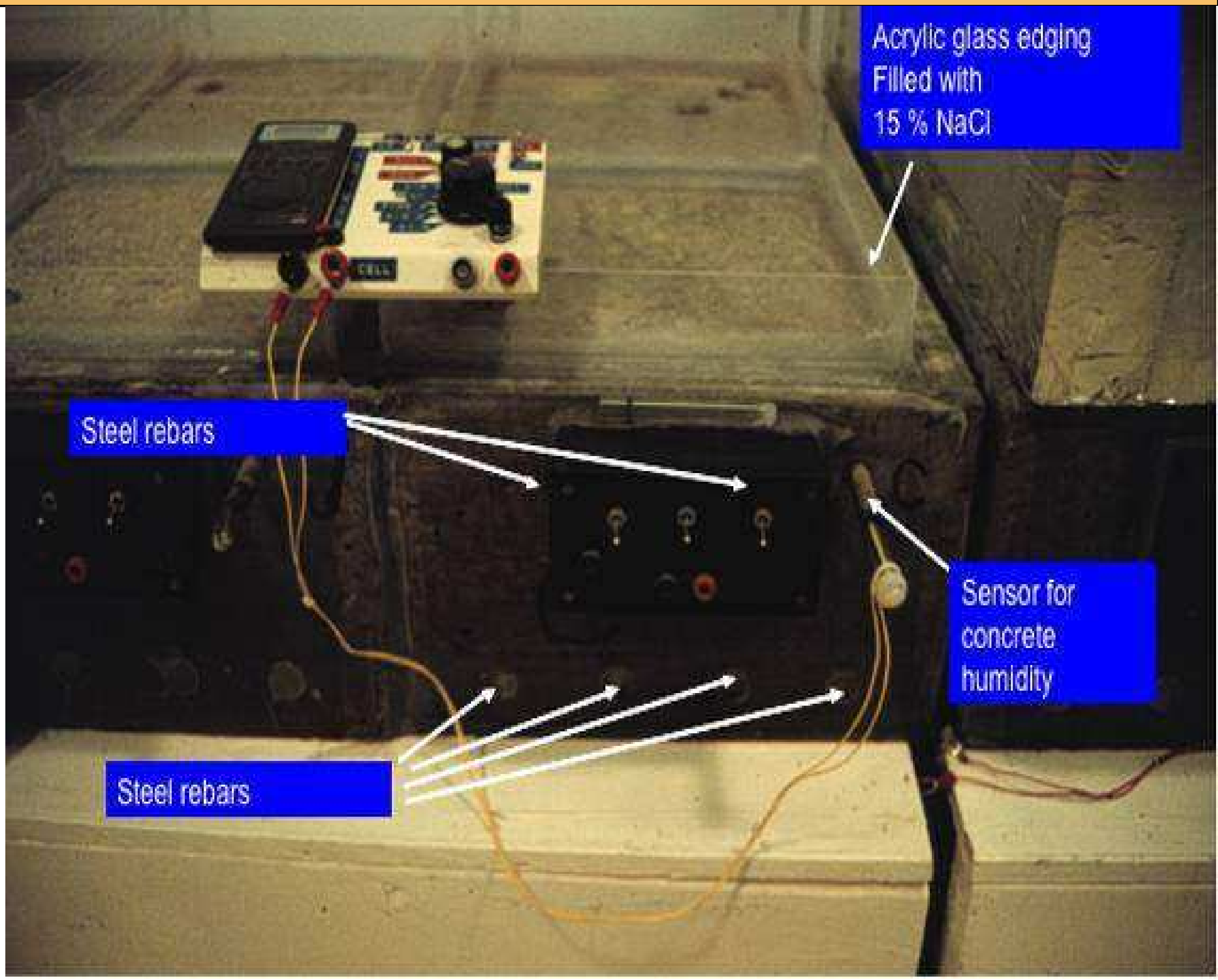
FHWA RD 98-153
Crack Beam Corrosion Study

- Based on FHWA Sponsored Research
- 0.47 w/c Concrete Slabs 12” x 12” x 7”
- 5/8 inch Diameter Black Bars
- One Inch Clear Cover
- Two 12 mil Cracks, One Inch Deep
- Cracks Run Along Top Bars



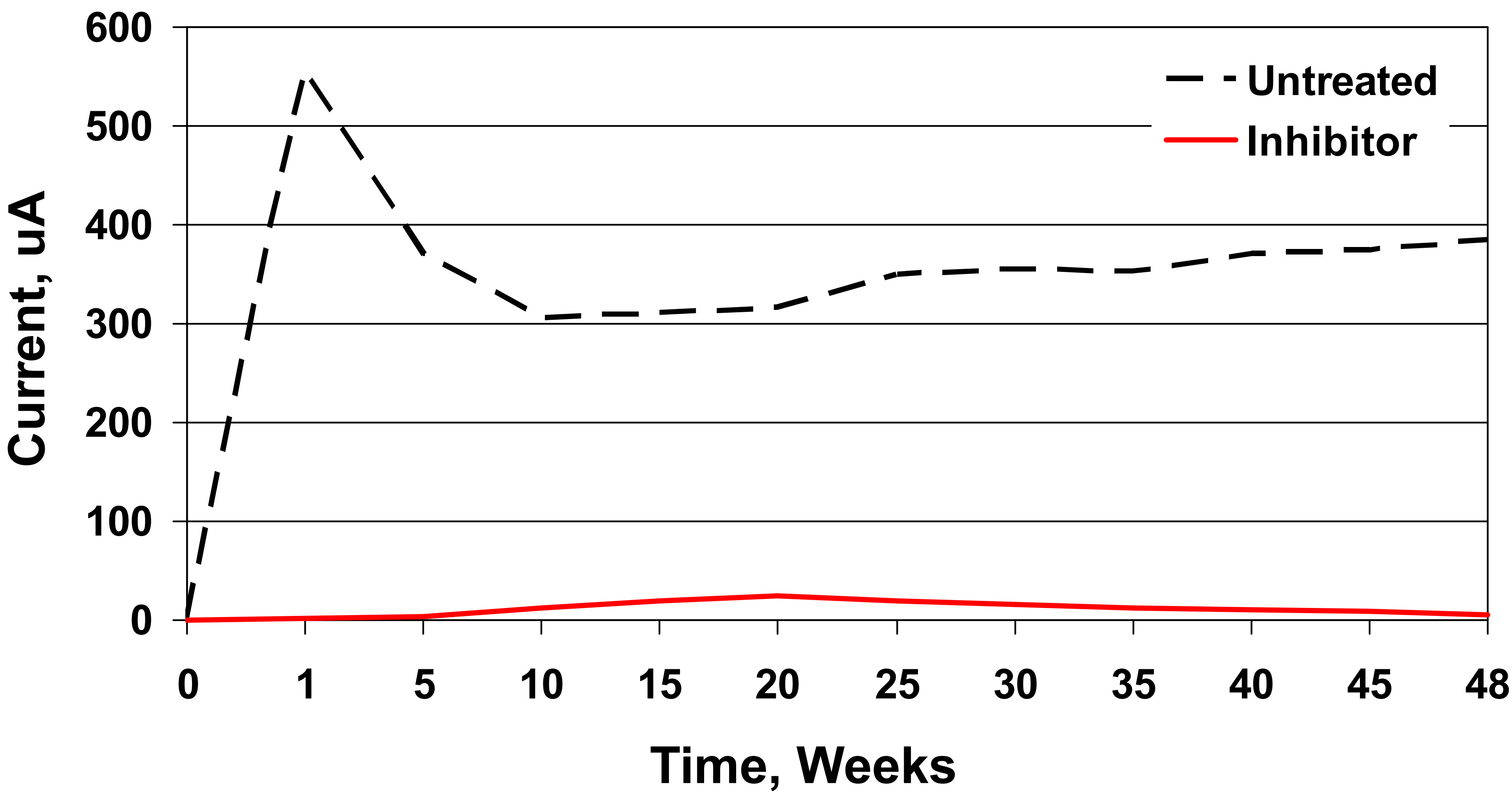
TEST CONDITIONS

- 48 Weeks Cyclic Salt Water Ponding
- 15% NaCl Solution
- Four Days Ponding with Salt Water @ RT
- Three Days Drying at 100ºF
- Humidity Maintained at 60% to 80%

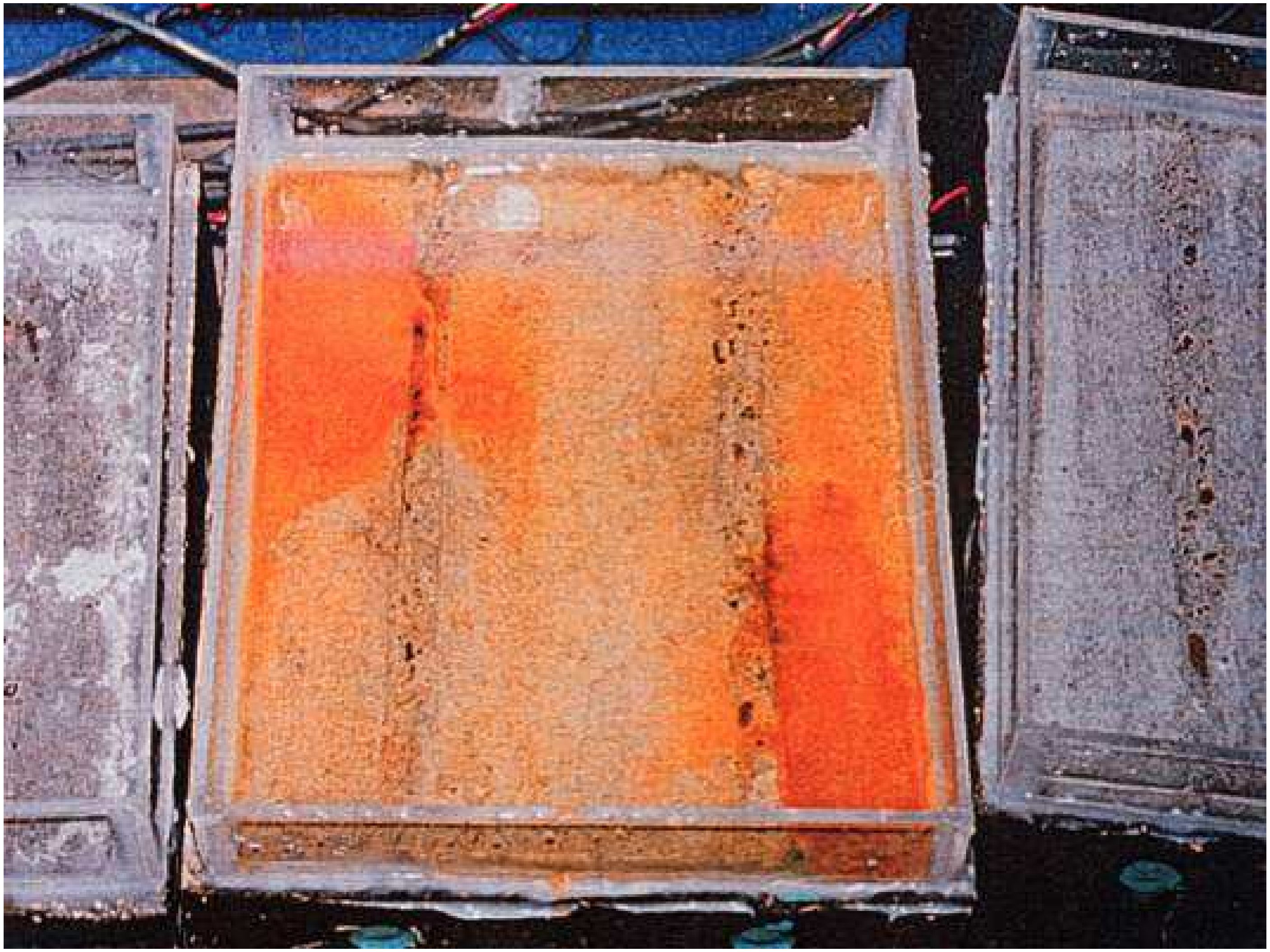


Scenario 1:
PRESERVATION “New Concrete”

RESULTS
PRESERVATION "New Concrete"

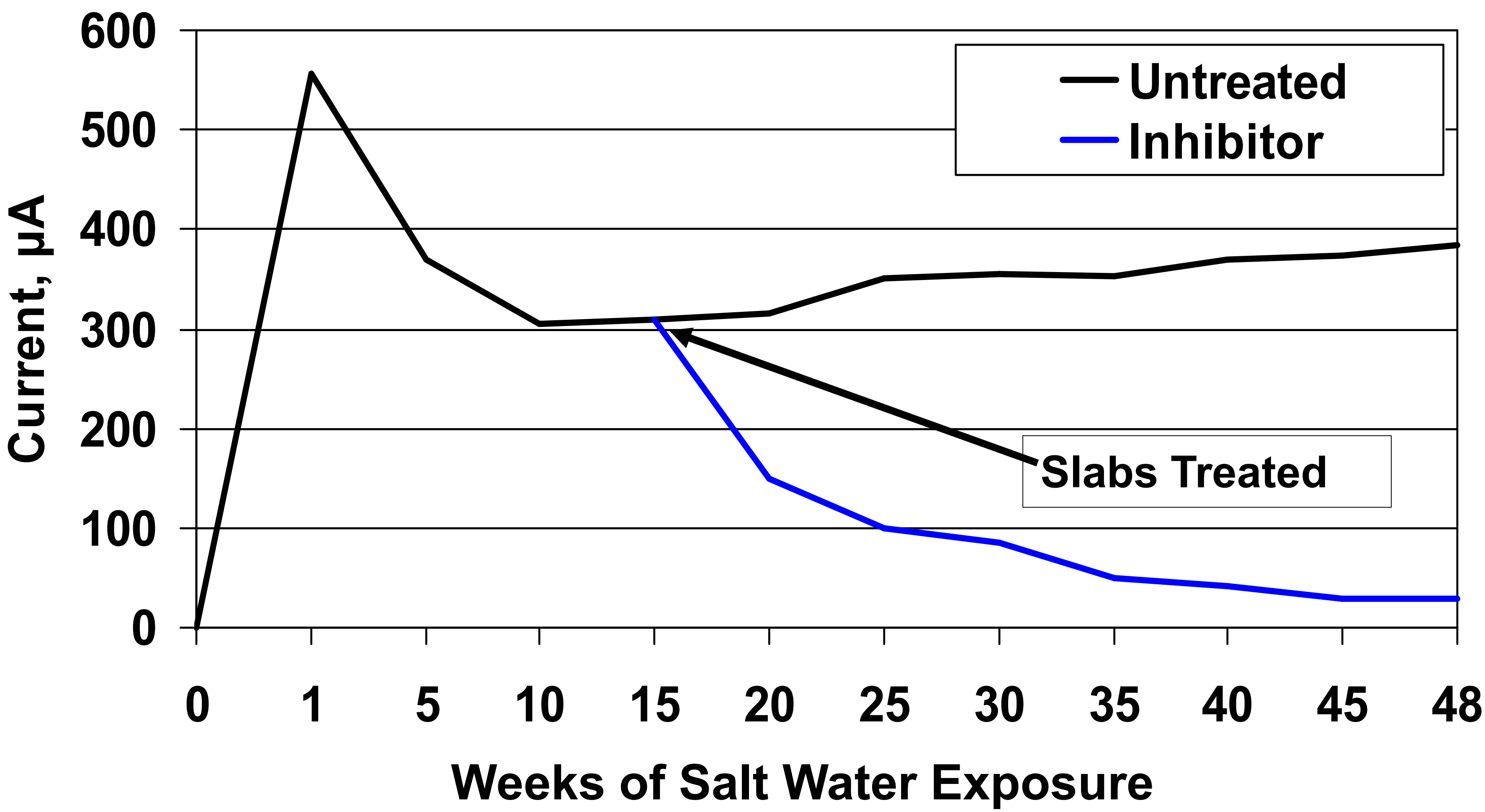


Scenario 2:
RESTORATION Existing Corrosion in Concrete



RESULTS

RESTORATION Existing Corrosion in Concrete



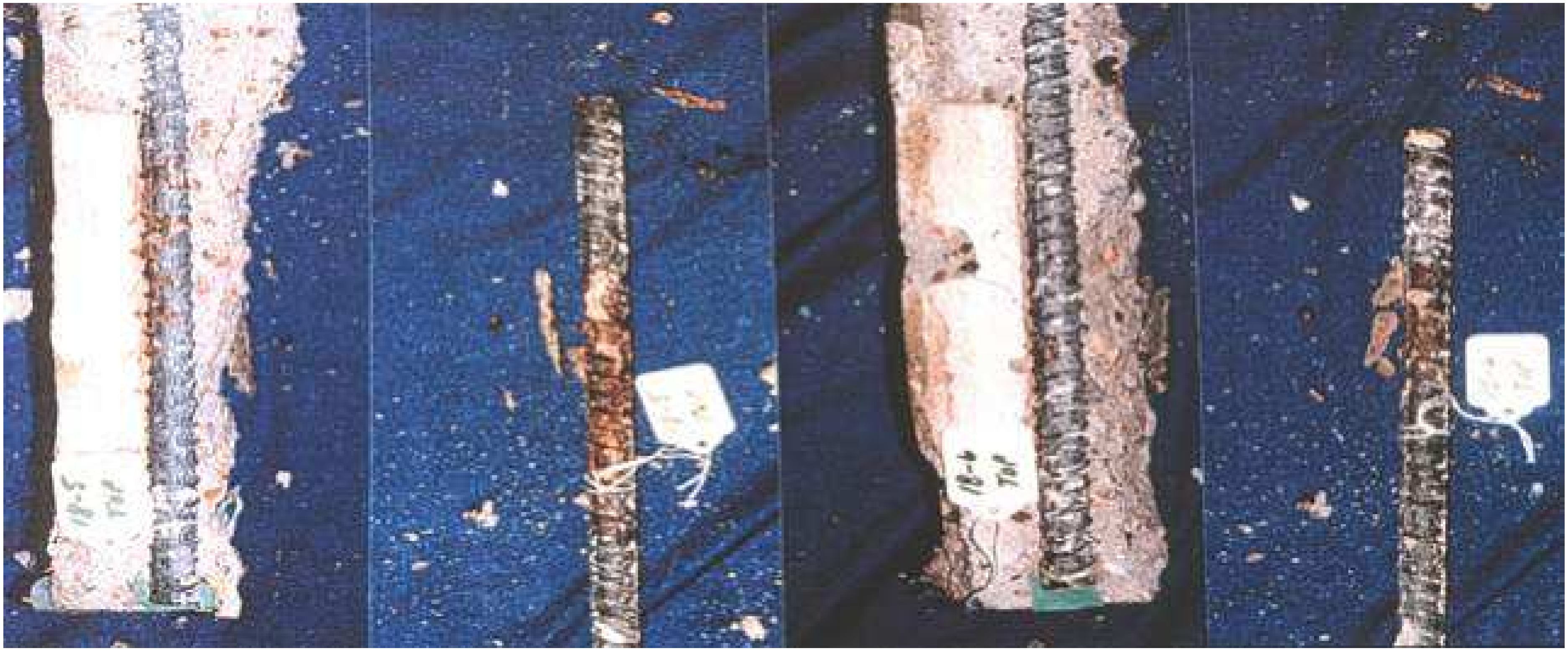
FHWA RD 98-153
“Autopsy”

FHWA SUMMARY
Performance on Cracked Concrete

99% Effective in Preventing Corrosion in New Construction

92% Effective in Reducing Active Corrosion

93% More Effective Than Epoxy Coated Steel



FHWA Protocol Summary

	Reduction in Corrosion	Increase in Resistance	Reduction in ½ Cell Potential
New Construction	99%	1090%	71%
Existing Corrosion	92%	386%	40%

COMPARATIVE DATA
Cracked Specimens

Corrosion Rate on Cracked Specimens for Different Systems Using FHWA-RD-98-153 Protocol

- Black Bars -- 4053 mV
- Epoxy, 0.004% damage -- 325 mV
- Epoxy, 0.5% damage -- 971 mV
- Copper-clad -- 111 mV
- 316 SS -- 5 mV
- ORGANOSILANE CORROSION INHIBITORS -- 58 mV

FIELD EVALUATIONS
Imbedded Reference Anodes
Continuous Monitoring

Chemical Treatment

CASE HISTORY

Measurement of a Corrosion Inhibitor Through Online Monitoring

M. BÜCHLER, *SGK, Swiss Society for Corrosion Protection, Zürich, Switzerland*
Y. SCHIEGG, *Corrsensys AG, Cham, Switzerland*
S. GIESSLER, *Degussa AG, Rheinfelden, Germany*

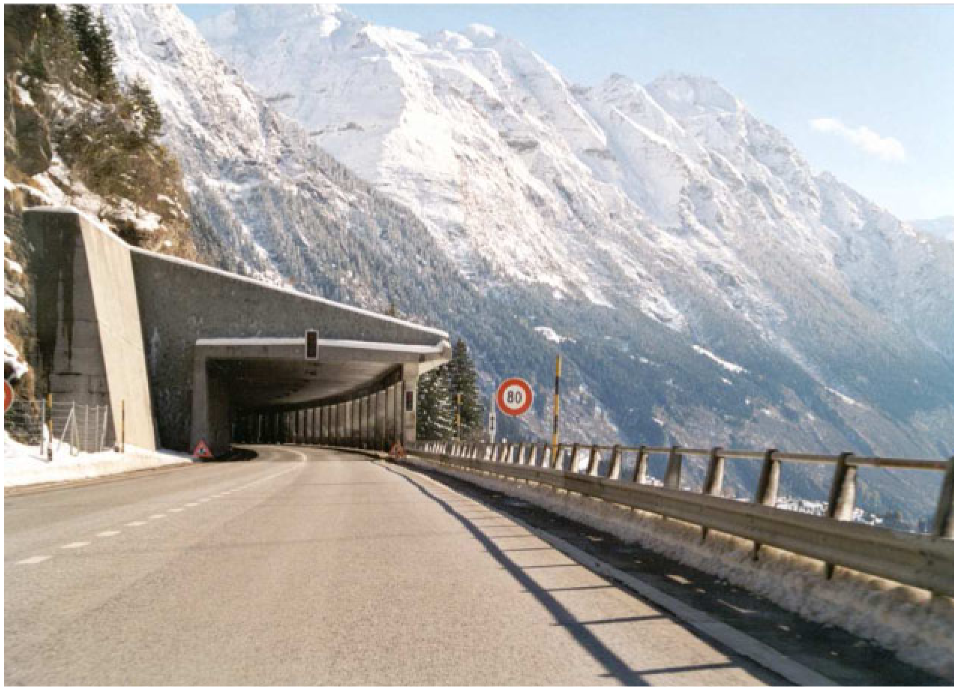
Typical repair of reinforced concrete structures showing corrosion damage involves removal of carbonated or chloride-contaminated concrete and subsequent retrofilling with new concrete. Corrosion inhibitors that can be applied by spraying onto the

Protecting Steel in Concrete

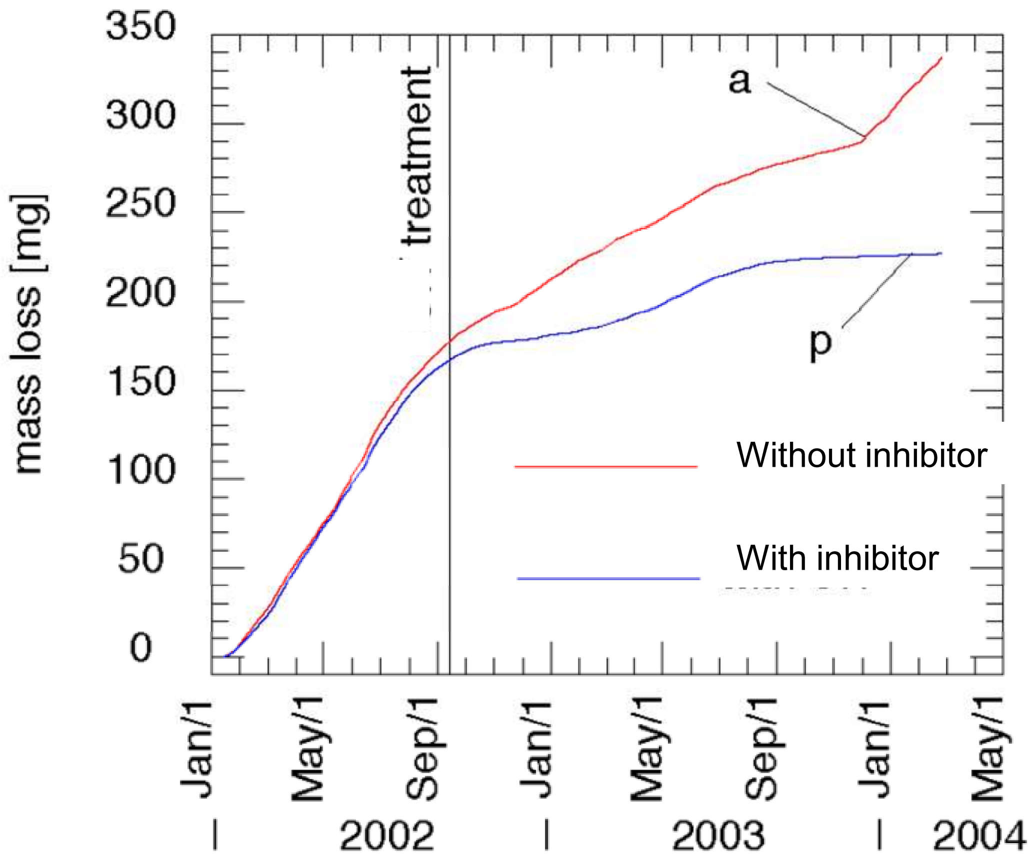
The combination of steel and concrete provides ideal corrosion protection for steel, since the alkalinity of the concrete in combination with water and oxygen causes the formation of a thin protective oxide film on the steel surface (Figure 1[a]). This passive film decreases the corrosion rate of steel to virtually zero and increases the durability of steel-reinforced concrete structures to more than 100 years. It is well known that such natural corrosion protection of steel can be compromised by chloride ions and other substances that penetrate into the concrete and diffuse to the steel surface (Figure 1[b]). In this case, significant corrosion may occur, causing decreased load capacity in the structure. Under certain conditions, corrosion rates of up to 0.7 mm/y may occur.[1]

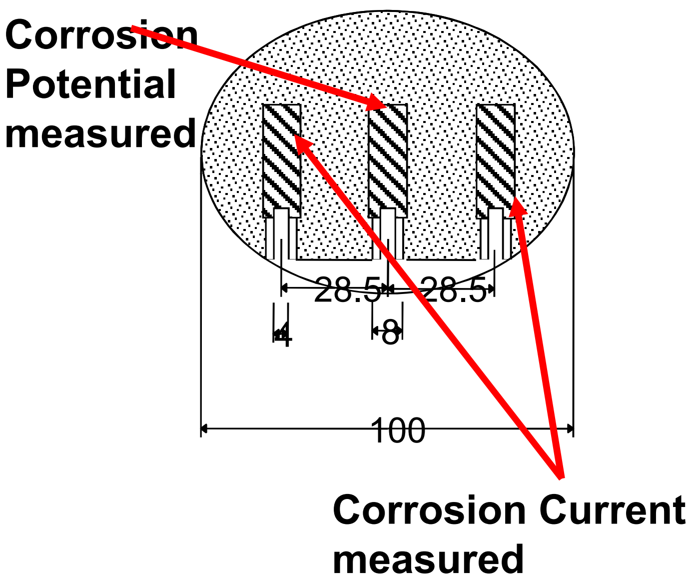
Chlorides, often originating from deicing salts, have caused significant corrosion damage on reinforced concrete structures. Also, carbonation—the reaction of carbon dioxide (CO_2) with concrete—may decrease the alkalinity of the concrete and activate corrosion.

Typically, repair for such corrosion involves the removal of the carbonated or chloride-contaminated concrete, followed



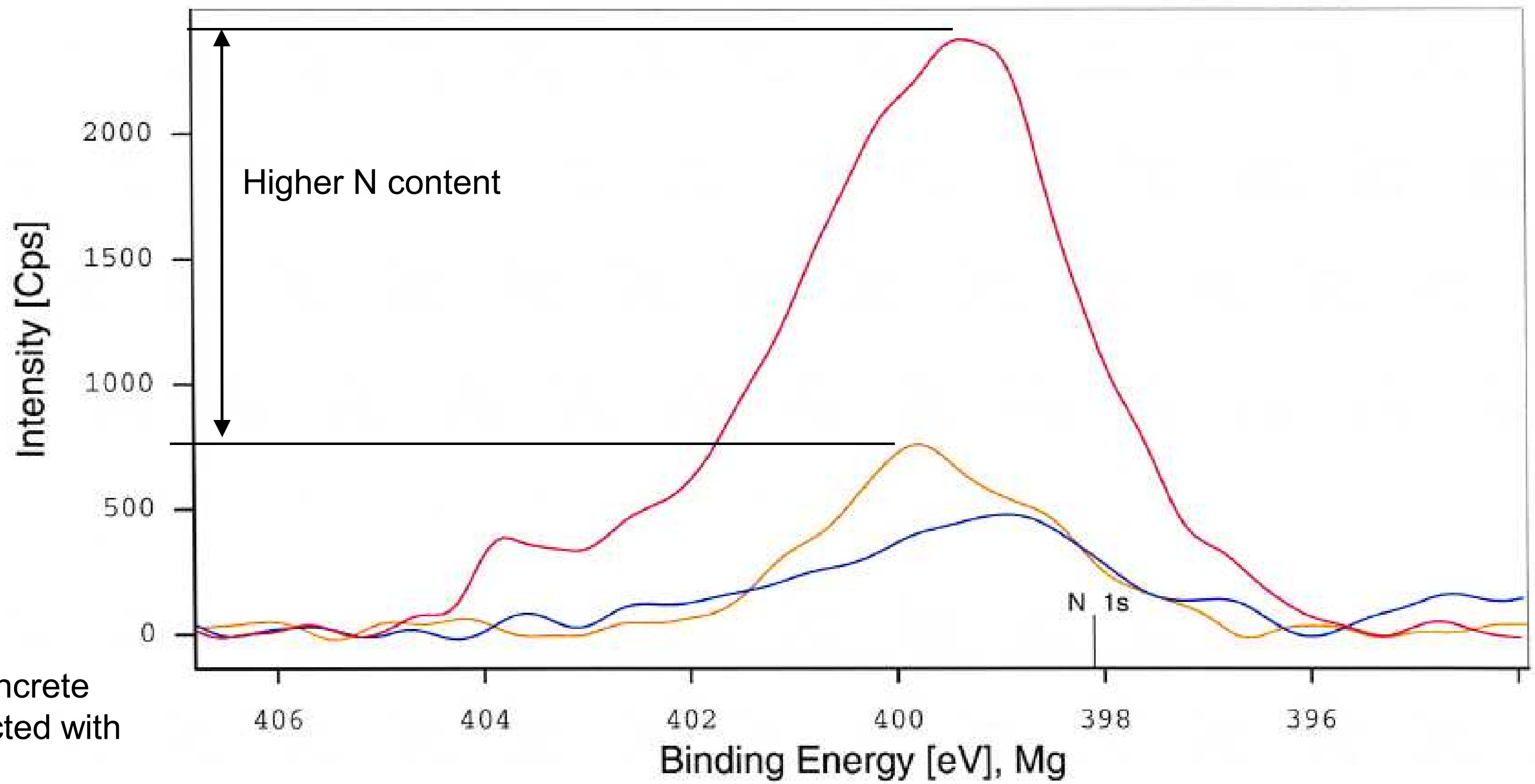
PERFORMANCE
Field Evaluation Silane Based Inhibitor





REPASSIVATION OF STEEL
Reaction with passivation layer

This is the nitrogen area of the curve. The admixture contains no amines, while the surface applied Corrosion Inhibitor has aminosilanes. This accounts for the higher intensity of the surface applied inhibitor.



- Rebar from unprotected concrete
- Rebar from concrete protected with **Admixture**
- Rebar from concrete protected with **Amino Silane**

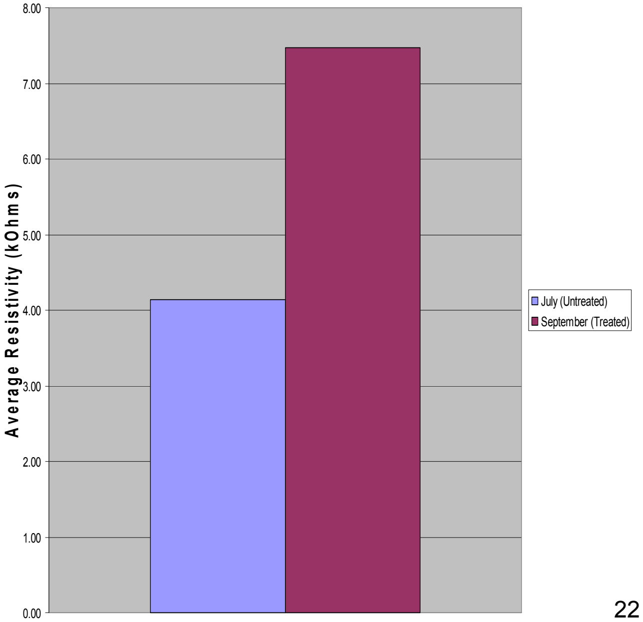
FIELD PERFORMANCE

TEST IT!!!

It is always better to protect than to repair!

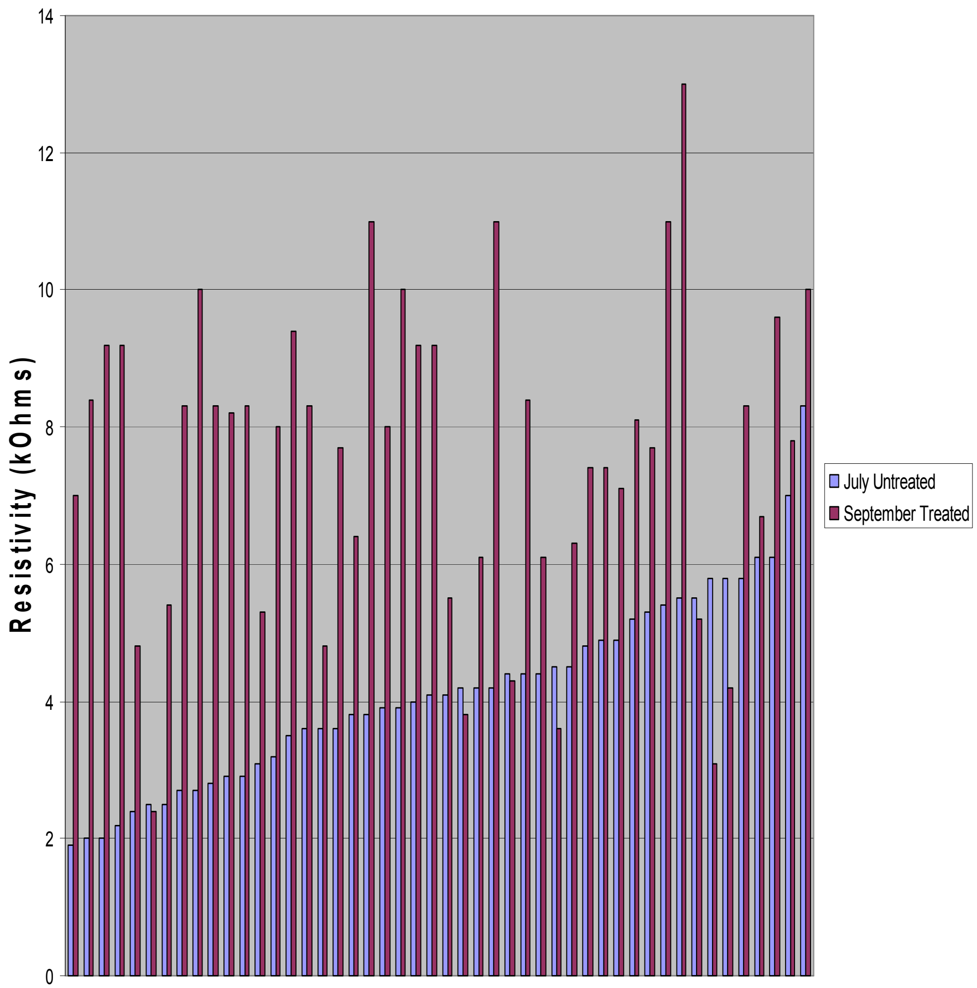
FIELD EVALUATION
Dillon Road – Chatham, ON

- July 2009 untreated testing performed by the University of Waterloo, Toronto
  - Corrosion rates were low although evidence of corrosion was apparent
  - A section was then treated with silane based SACI
- September 2009 measurements were taken on both treated and untreated areas
- Where SACI was applied, the resistivity of the concrete deck **increased by 180% on average.**



FIELD EVALUATION
Dillon Road – Chatham, ON

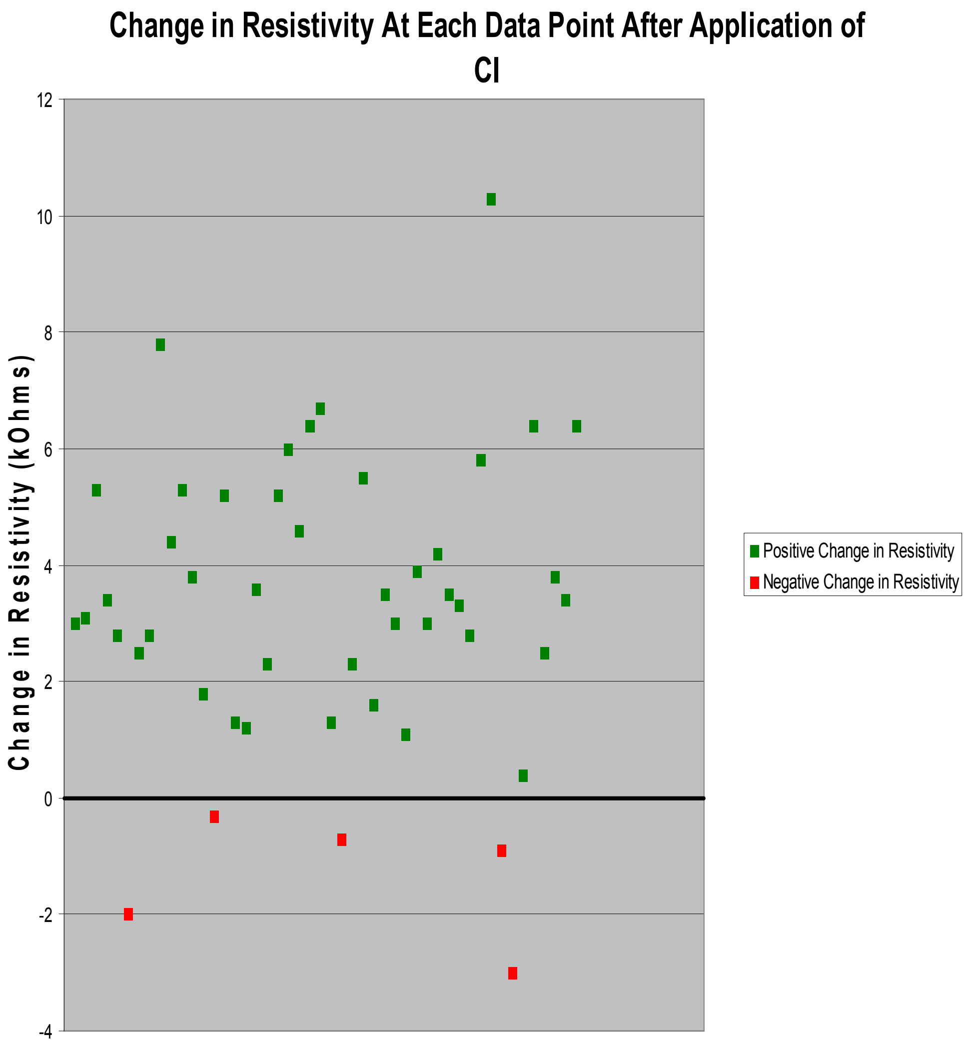
Change in Resistivity from Untreated to Treated Surface



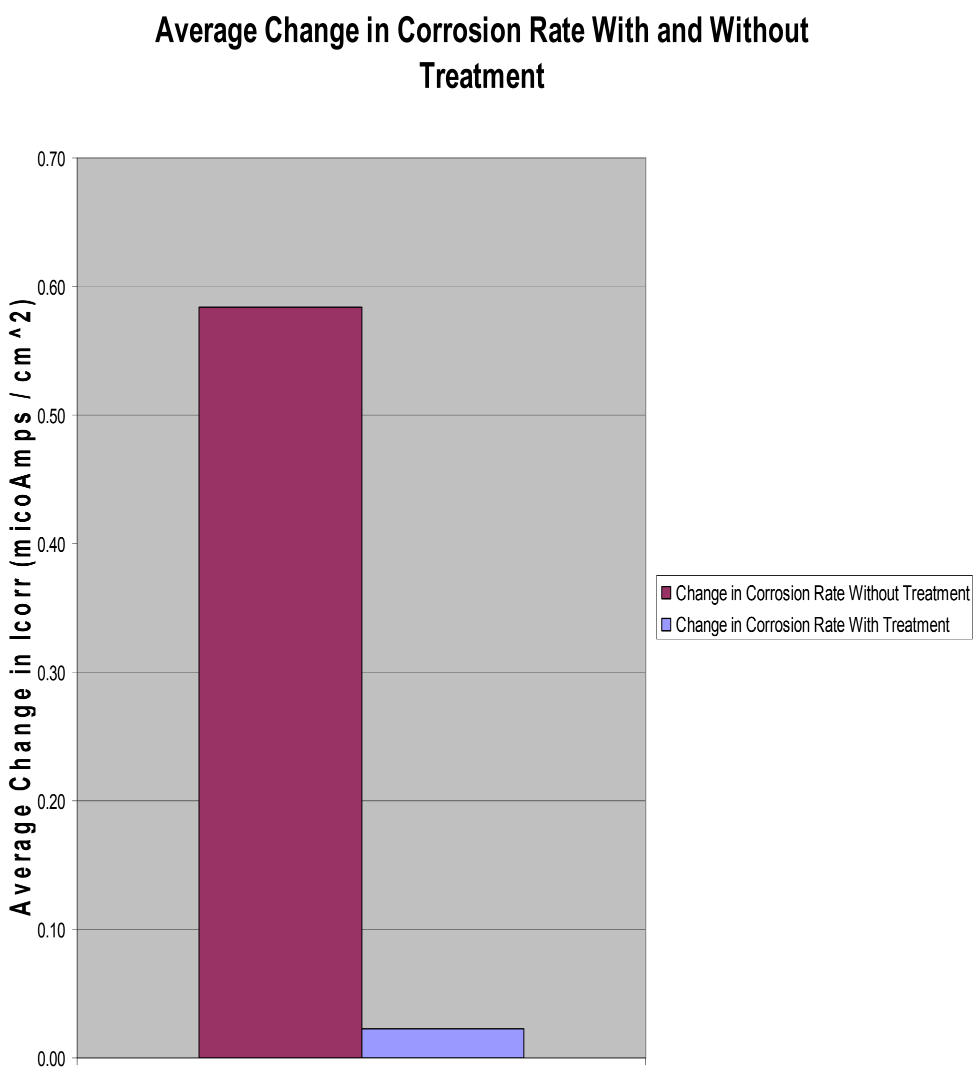
- The resistivity at each location within the treated surface exceeded the low-to-high values of the untreated surface measurements in nearly all cases.

FIELD EVALUATION
Dillon Road – Chatham, ON

- The vast majority of the locations show an increase in the resistivity of the concrete deck.
- The inverse relationship between resistivity and corrosion rate provides excellent insight into the effectiveness of silane based SACI.



FIELD EVALUATION
Dillon Road – Chatham, ON

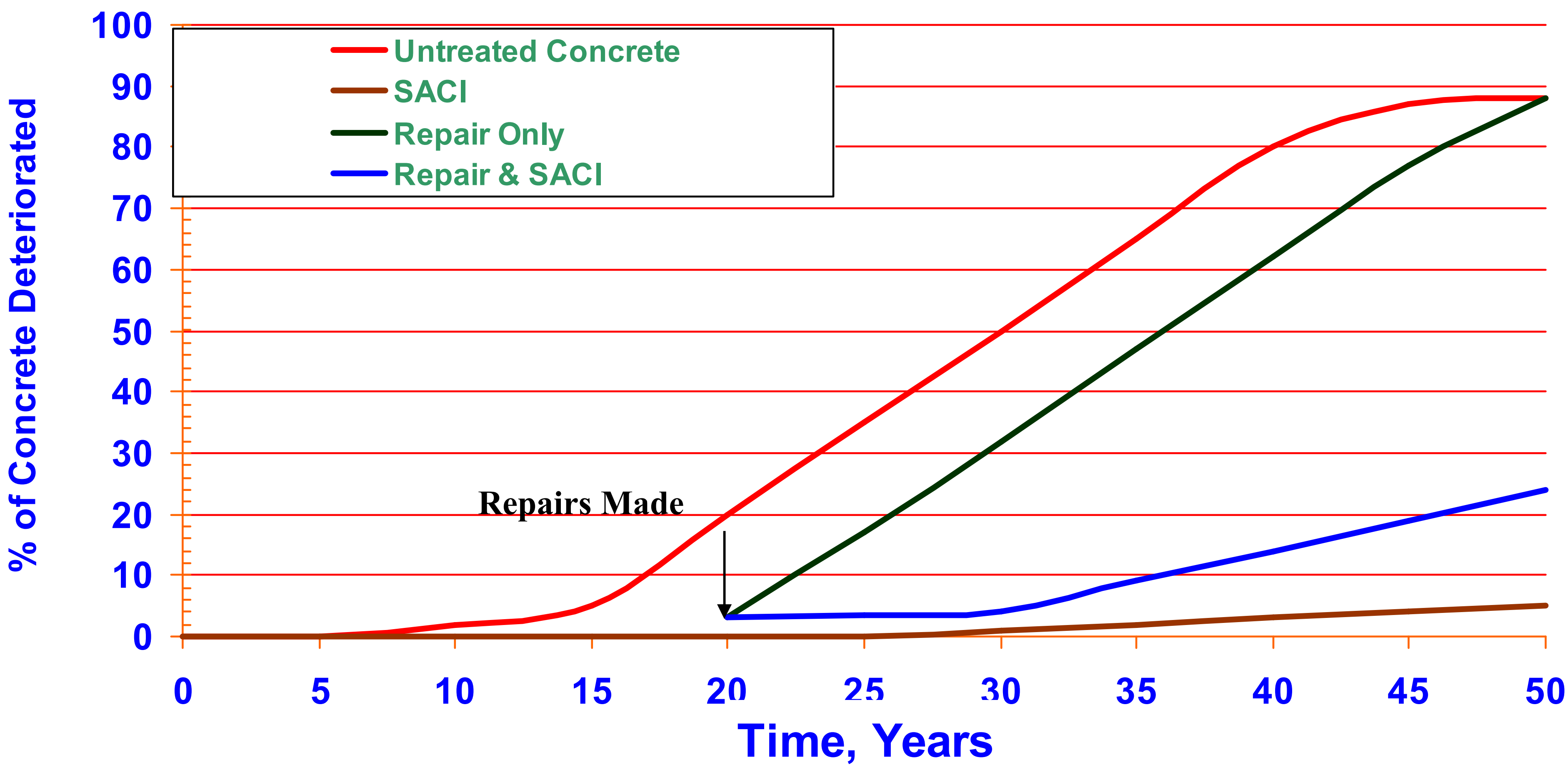


- Untreated areas **increased** by 0.58 µA/cm^{2}.
- The treated areas demonstrated **virtually no change** at all
- The corrosion inhibiting properties of silane based SACI had a significant impact on the corrosion rate in a relatively short period of time.

WHAT TO LOOK FOR…

- Proven Performance History
  - Lab
  - Field
- Compatibility
  - Overlays
  - Concrete Repair
- Ask: What does this do for me……

Extension of Service Life Due to SACI Treatment



Based on concrete cover of 1” average and diffusion data from concrete

Estimated Retreat Times for SACI