

Corrosion Risk Assessment, and Corrosion Mitigation for Balconies Concrete Slab

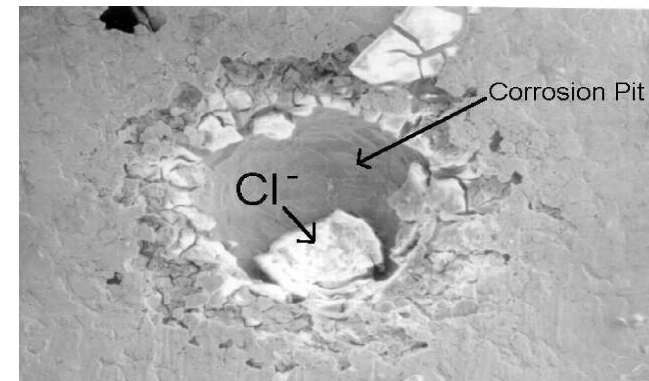
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NACE Certified Specialist in Corrosion, Cathodic Protection, Coating, Material Selection/Design
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Outline of Presentation

- Introduction to Matergenics
- Understanding the Corrosion of Steel Reinforcement in Concrete in C5 Environment
- Corrosion Risk Assessment
- Corrosion Mitigation
- Final Words
- Q & A



Certifications

- National Association of Corrosion Engineers (NACE)
- NACE Certified Materials Selection/Design Specialist
- NACE Certified Coating Specialist
- NACE Certified Cathodic Protection Specialist
- NACE Certified Corrosion Specialist



Awards:

- Nominated for NACE 2018 Award Corrosion 2018 Phoenix Arizona National Conference
- Colonel Cox Award, 2010
- Elected Fellow, NACE International, National Association of Corrosion Engineers, 2008
- Elected Fellow, ASM International, American Society for Metals, 2007
- Entrepreneur of the Year Award (2004), ASM
- Outstanding Service Award (1996), NACE

Achievements:

- 55 Patents on materials, coatings, Concrete Corrosion Sensors and Cathodic Protection
- 80+ Publications in Technical Journals
- Instructor for t annual short courses at AUCSC on Failure Analysis, Coatings and Materials Selection
- Instructor for NACE CP1, CP2, CP3, Condition Assessment, Design/Materials Selection
- Lecturer for Technical Societies: ASM, NACE International, AFS, SAE, ...
- Consulting Engineer in Wildfire West Coast for SCE and Miami Condo Collapse Failure Analysis

Publications





TRAINING COURSE MAKES A DIFFERENCE

Concrete Degradation

- Corrosion of rebar steel due to salt
- Carbonation
 - Reaction with atmospheric CO₂
- Freeze-thaw damage
- By acids, leaching by soft waters
- Vibration-induced cracking
- Improper cleaning by Bleach and acidic chlorides

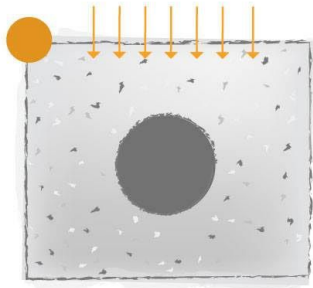


Improper paint repair resulted in hiding and further corrosion

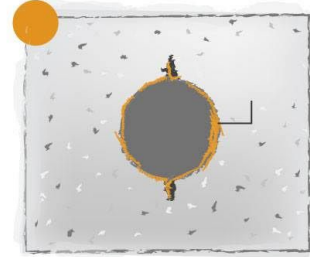
Steps in Rebar Corrosion

It is all about chlorides(salt) in Concrete

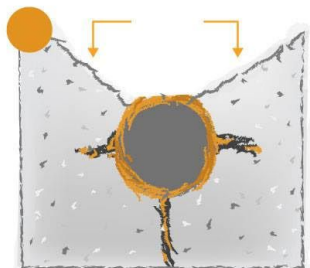
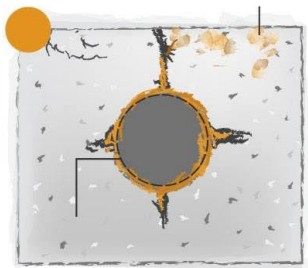
Salt & Moisture



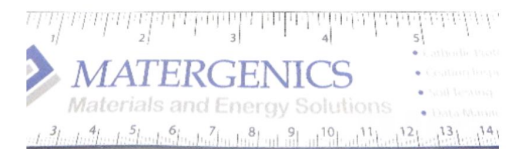
Corrosion Activity Begins



Loss in rebar thickness and spalling



- Ingress of chlorides
- Corrosion, Loss in Thickness
- Generation of voluminous rebar corrosion products
- Spalling of concrete



Wall Street Journal : Steps in rebar corrosion, Sketch provided by Dr. Zee

Corrosion Risk For Aging Structures in C5 Environments

There are more than 1.5 million condominium units in Florida of these , more than 912,000 and are older than 30 years the home of 2,000,000 residents. The tragic event in Surfside building (Condo Collapse) brought the topic of safety of aging structures to the surface. More likely than not proper inspection and corrosion risk assessment in 2018 would have prevented this tragic event.

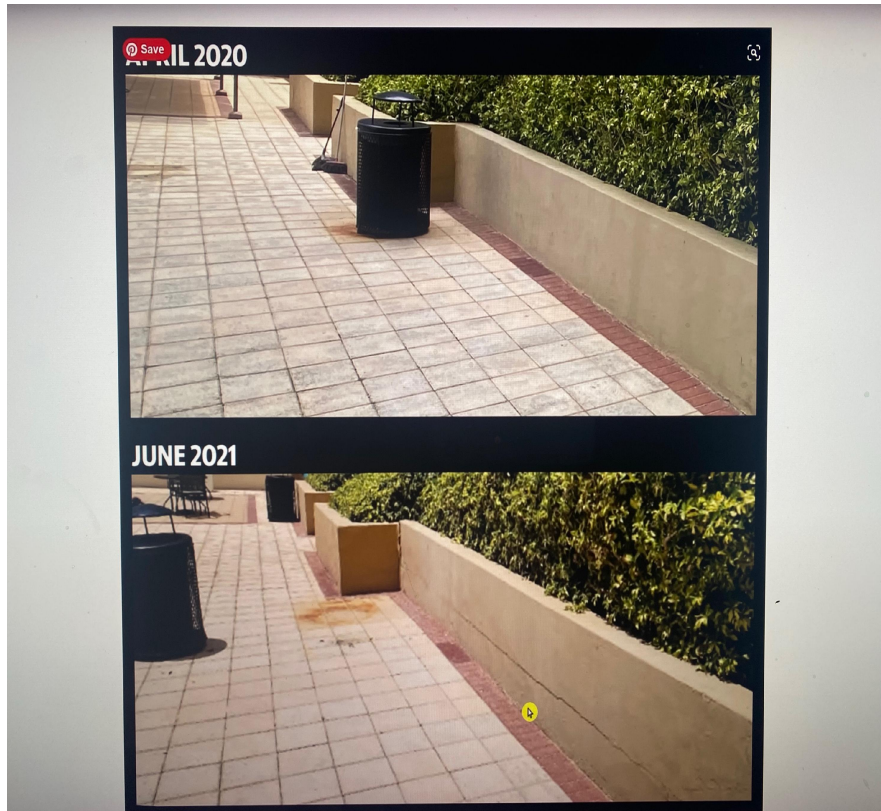
Corrosion of steel reinforcement in concrete also led to the partial collapse of the federal office building housing the United States Drug Enforcement Administration (DEA) Miami Field Division (Pistorino, 2021). That building collapsed on the morning of August 5, 1974, crushing to death 7 DEA employees and injuring 15 others. The rooftop parking lot caved in causing the partial collapse (Miami Dade Grand Jury, 2021).



Corrosivity of concrete is primary cause of accelerated corrosion and should be quantified in condition assessment

The challenge is the cost of corrosion assessment and corrosion mitigation!

Crack Nucleation and Growth Monitoring



Rapid growth of surfside building crack one week prior to tragic collapse that resulted in loss of hundred souls indicated unacceptable risk is present. The inspection company did not pay attention and neglected the formation and propagation of the crack.

Corrosion and Murphy's law

Definition - What does *Corrosion* mean?

Corrosion is the deterioration and loss of a material and its critical properties due to chemical, electrochemical and other reactions of the exposed material surface with the surrounding environment

Important Note

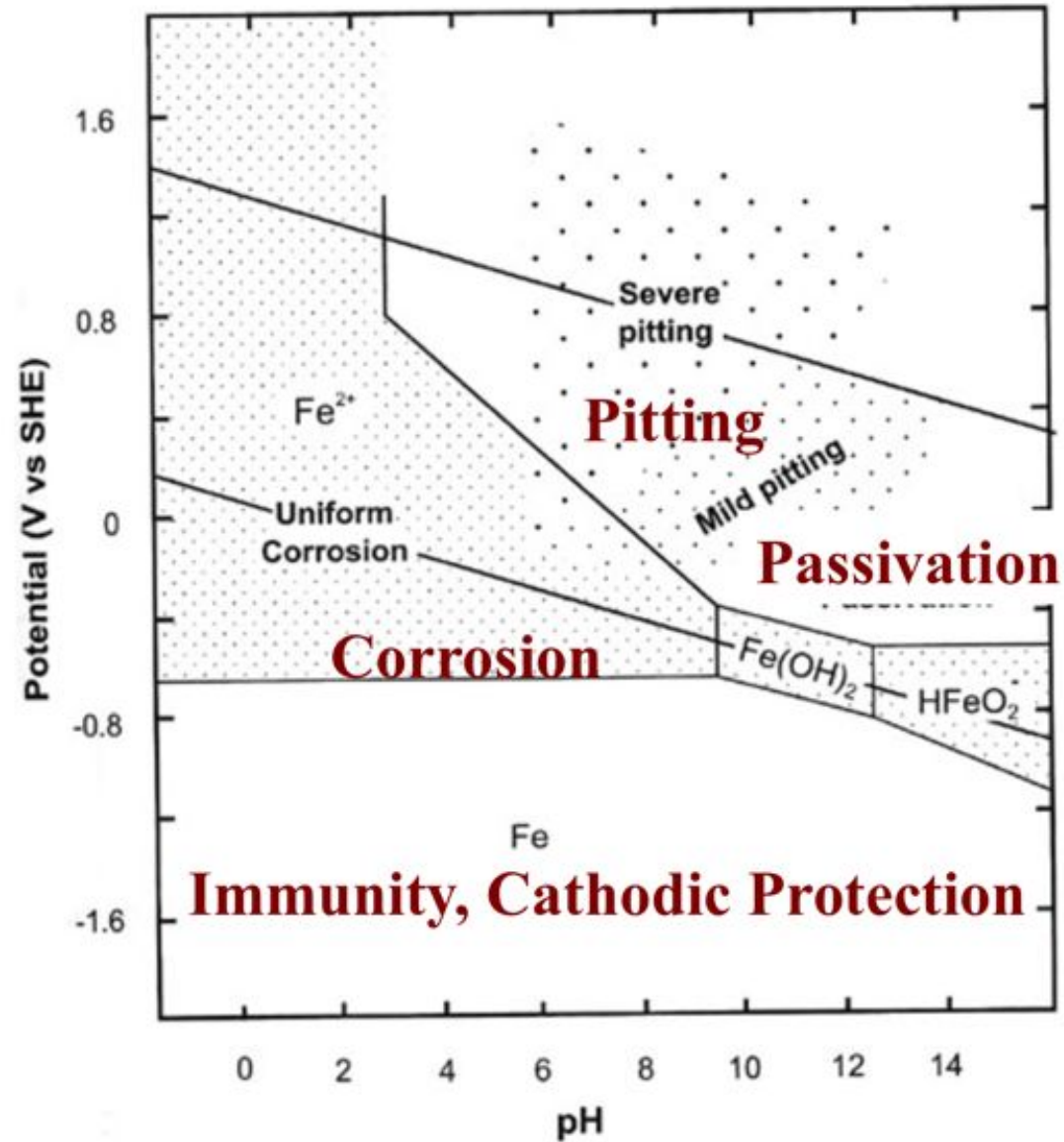
MURPHY'S FAMOUS LAW STATES THAT "LEFT TO THEMSELVES , THINGS WILL ALWAYS GO FROM BAD TO WORSE.

IT IS LIKE LIKE THE 2ND LAW OF THERMODYNAMICS : ENTROPY (DISORDER) INCREASES AND TO OFFSET THE EFFECTS OF ENTROPY, ENERGY MUST BE INJECTED , OTHERWISE THE SYSTEM BECOMES INCREASINGLY DISORDERED

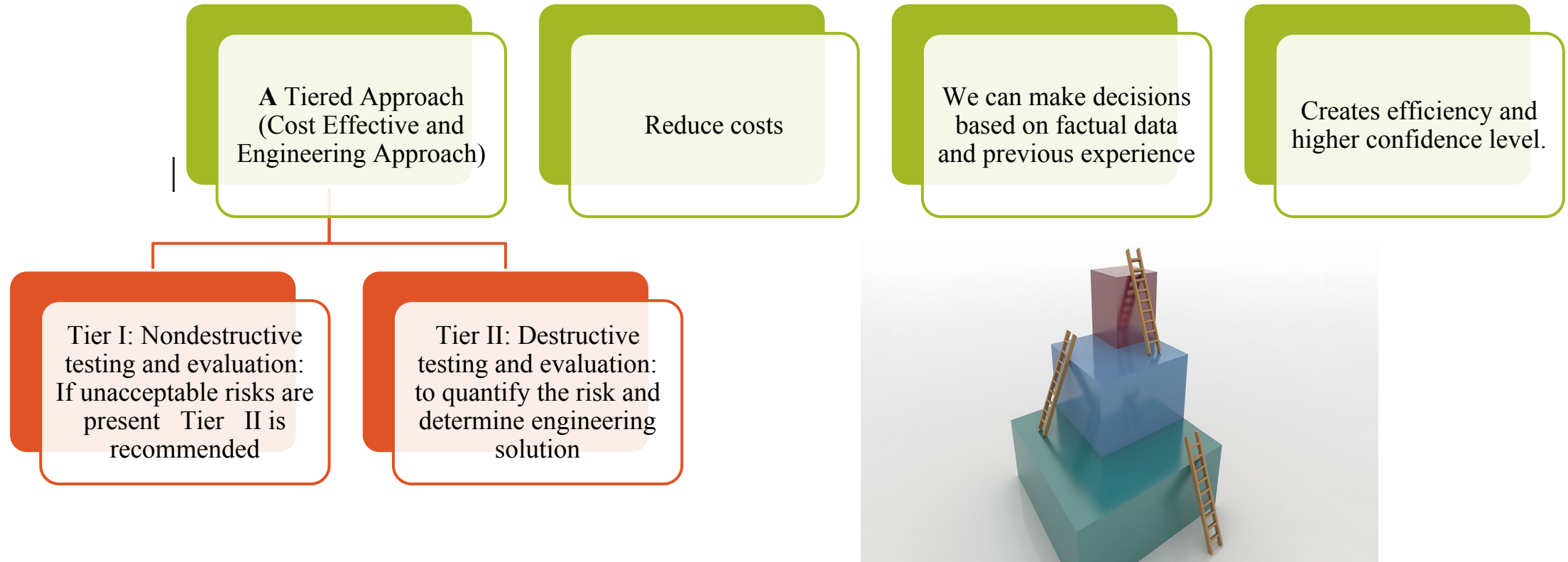
Stability Diagram

Applications:

- Rebar in Concrete
- Concrete Foundations
- Atmospheric Corrosion
- Cathodic Protection
- Passivity



Team Matergenics Approach: Tiered Approach Corrosion Risk Assessment Protocol



Test Protocols for Tier I and Tier II

Tier I Testing

- Visual, ground penetrating rebar and Thermal Imaging
- Thermal Imaging & Sound test to detect lamination
- | ● Schmidt Hammer Test (Compressive Strength)
- Resistivity - To determine concrete corrosivity
- Electrochemical potential: to determine corrosion activity
- Phenolphthalein - to determine pH and carbonation
- Stray current Survey - To determine stray current corrosion risks

Thermal Imaging and Ground Penetrating Rebar

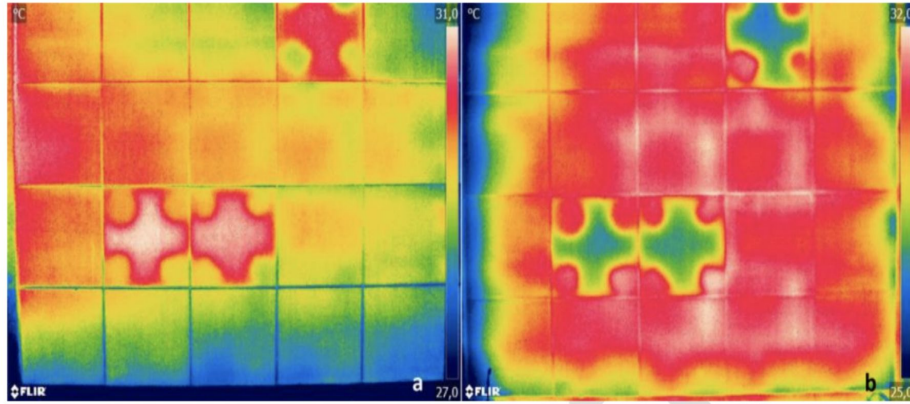


Figure 1: Thermograms from the tiles during day (left) and night (right)

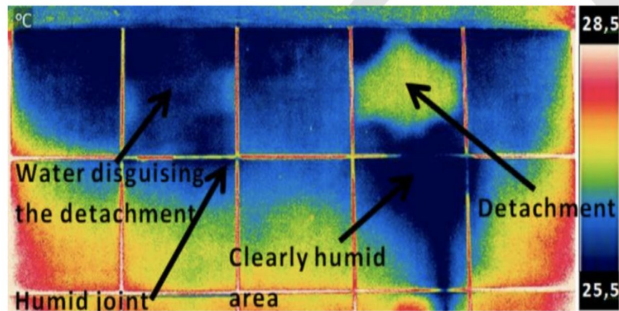
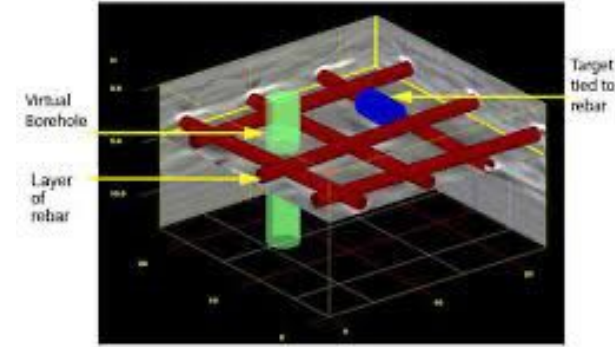


Figure 1: A thermogram and classification of anomalous tiles is shown



Corrosion Activity Per ASTM C876

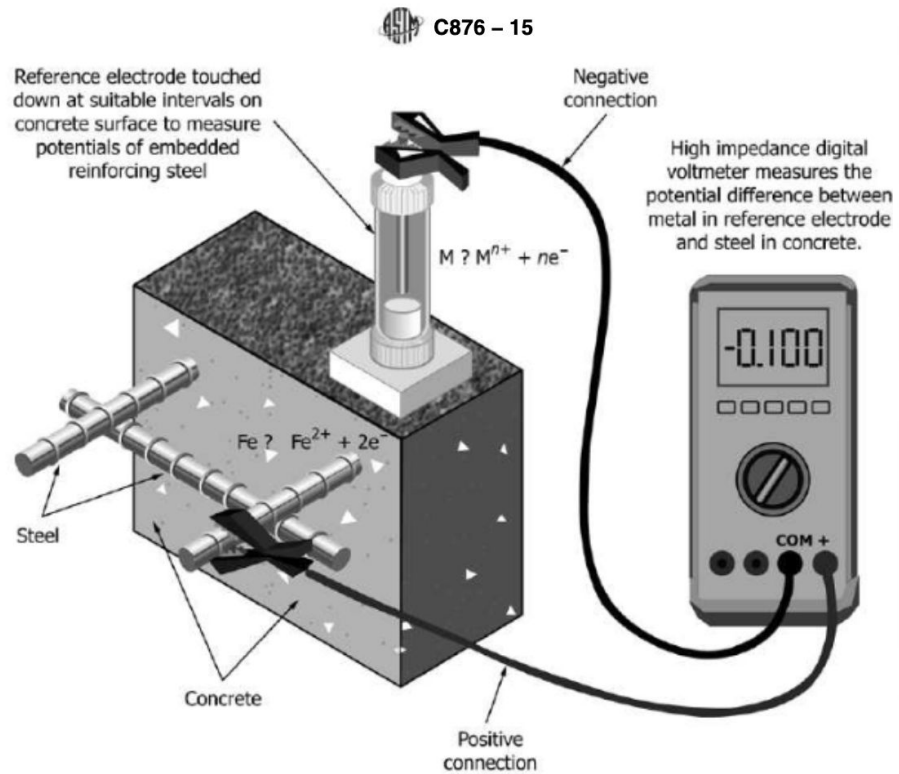


FIG. 1 Reference Electrode Circuitry



Tier II Inspection

The approach requires a small hole in concrete and provides an estimate of corrosion rate. You need to expose the DW for several hours .

- ASTM G102 & ASTM G59 (Polarization Resistance measurements) (= General Corrosion Rate)
- In lab analysis of concrete samples to determine chloride profile analysis.
- Concrete Resistivity on the bottom side of Balcony Slab
- Current Requirement Testing if feasible

*Other Contractors selected by client will be responsible for repair and restoration of areas.

*Access to balconies below are required upon Tier II Inspections

Recommendations of minor/major structural repairs, coating or even cathodic protection installation.

Case Study (Tier I)



Area selected for corrosion risk assessment exhibiting mortar and water proofing coating

Chloride and PH are Corrosion Performance Parameters



Corrosion Risk Assessment



No evidence of corrosion risk at this location

Figure on the left shows phenolphthalein (Pink) , colorless in acidic environments and pink in basic solutions.

Figure on the right is a closeup on the point in which rebar is underneath and measurements were taken as close as possible and also see the formation of rust if present .

Corrosion Activity per ASTM C876



Potential Measurement on Rebar Location marked with a x.

Concrete Resistivity Measurement



Concrete electrical resistivity measurement



Electrochemical potential measurement

Quantification of Corrosion Risk

Concrete Condition	Rebar Corrosion	Corrosive Ions	Risk of Corrosion	Comments Recommendations
<ul style="list-style-type: none"> No cracking No red discoloration 	Passive	Low	Negligible	<ul style="list-style-type: none"> No action
<ul style="list-style-type: none"> Small surface cracking No red discoloration 	Passive	Low-Medium	Low	<ul style="list-style-type: none"> No action, Establish Inspection frequency based on Tier I data
<ul style="list-style-type: none"> Cracking Visible red discoloration 	Moderate Activity	Medium to High	High	<ul style="list-style-type: none"> Perform Tier II Testing and Evaluation
<ul style="list-style-type: none"> Cracks, minor spalling Detachment Red discoloration and "bleeding" 	Moderate to high activity	High	Very High	<ul style="list-style-type: none"> Perform Tier II Testing and Evaluation
<ul style="list-style-type: none"> Aging structure Major cracks Spalling Detachment Extensive discoloration C5 Environment 	High corrosion with substantial loss of section.	Very High Severe	Very High /Severe	<ul style="list-style-type: none"> Perform Tier II and Repair and Corrosion Mitigation

Final Words

- Thermography, sound, and visual will be used in Tier I Inspections to determine which tiles would be acceptable for removal.
- Ground penetrating radar identifies the exact locations of rebars. Moisture content, concrete resistivity and corrosion potentials will indicate if there is likelihood of unacceptable corrosion risks and rebar thinning
- Using these techniques, we can determine which spots have accelerated corrosion, cracks, high moisture areas, water entrapment locations, and even mortar file delamination's and cracking
- Testing should be completed during early mornings, cloudy days, or in the evenings to ensure accuracy or using artificial heat to monitor transient temperature change
- The results will then be cross checked with one another (multiple tests) to ensure if there is accelerated corrosion. No speculations, all based on corrosion performance parameters and corrosion engineering practice. If there is unacceptable risk, we will identify and quantify the risk.

Questions?

Thank you for your attention!

