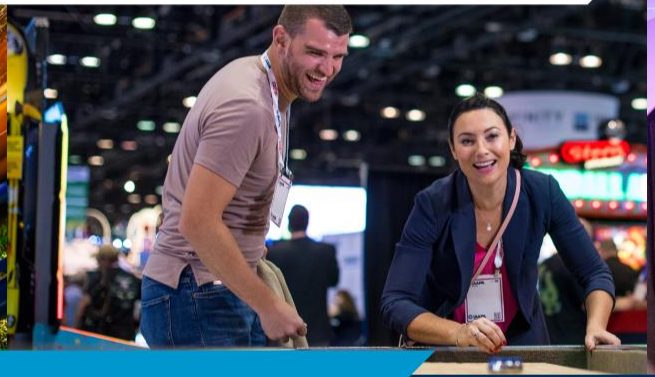
IAAPA® EXPO



CONFERENCE: Nov. 16–19, 2020
TRADE SHOW: Nov. 17–20, 2020

IAAPA.org/IAAPAExpo

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Eliminate Corrosion:
Improve Guest Safety, Add Years to the Lifespan of Attractions and Save Money

November 17, 2021

Bob Chalker – AMPP
Terry Greenfield – Consulex
Ryan Tinnea – Tinnea and Associates
Chris Ball – Vector
Matt Mills – Consulex

Corrosion: The Silent Menace

- Corrosion is real threat
- Although it is a threat, it can be prevented or mitigated
- The expertise exists, but not always recognized

Having an IMPACT

Preventing and mitigating corrosion requires not only the right technology but good management practices

- **Solid decision making**
- **Investment in both the design and maintenance of assets**
- **A total Corrosion Management System**
- **Justification based on business impact**

Today's Panel

Terry Greenfield

Matt Mills

Ryan Tinnea

Chris Ball

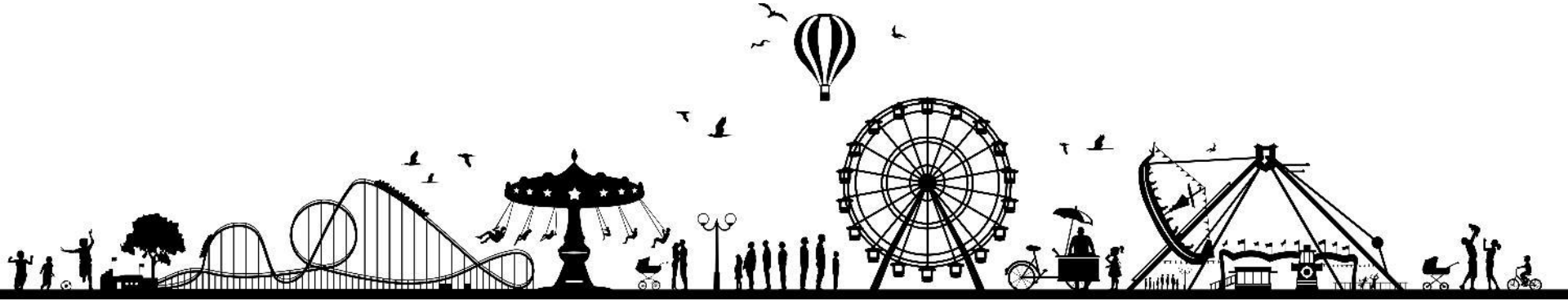
CORROSION MANAGEMENT

Presented by: Terry Greenfield

Corrosion Management

For all Physical Assets including Amusement Park Structures and Assets,

We Know It's Possible to effectively Control Corrosion and that effort will result in unmatched Safety, Reliability, and Sustainability of those Assets…



Total Corrosion Management

- Safe Operations
- Asset Integrity & Reliability
- Sustainability
- Regulatory Compliance
- Economics

2016 NACE International IMPACT Study

“by using available corrosion control practices, it is estimated that savings of between 15 and 35% of the cost of corrosion could be realized (between US$375 and US$875 billion annually on a global basis)…”

The Platinum Rules of Corrosion Control Success

- A focus towards meeting the minimum requirements is NOT the path to Success
- Utilizing Skilled and Experiences Service Providers is required; cost is managed but secondary
- Long term vison is a must
- Trained and Qualified Personnel
- Accurate Assessment (Diagnosis)
- Knowledge-Based Standards
- Requirements-Based Specifications
- Qualified Materials
- Quality Control
- Quality Assurance
- Continuous System Improvement (Lessons Learned)

What is Total Program Corrosion Management?

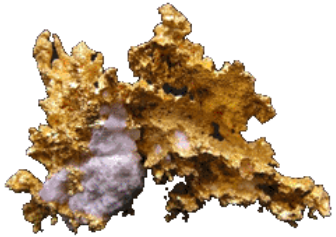
- A Corporate commitment to combat corrosion
- Integration of corporate “silos” to align with the fight
- Corporate recognition of the benefits of corrosion control
- Synchronizing corrosion control technologies in use to be the most effective
- Ensuring the best solutions are in place
- The value of Corrosion Management is recognized across all corporate operations
- Sustainability

CORROSION FUNDAMENTALS

Presented by: Ryan Tinnea

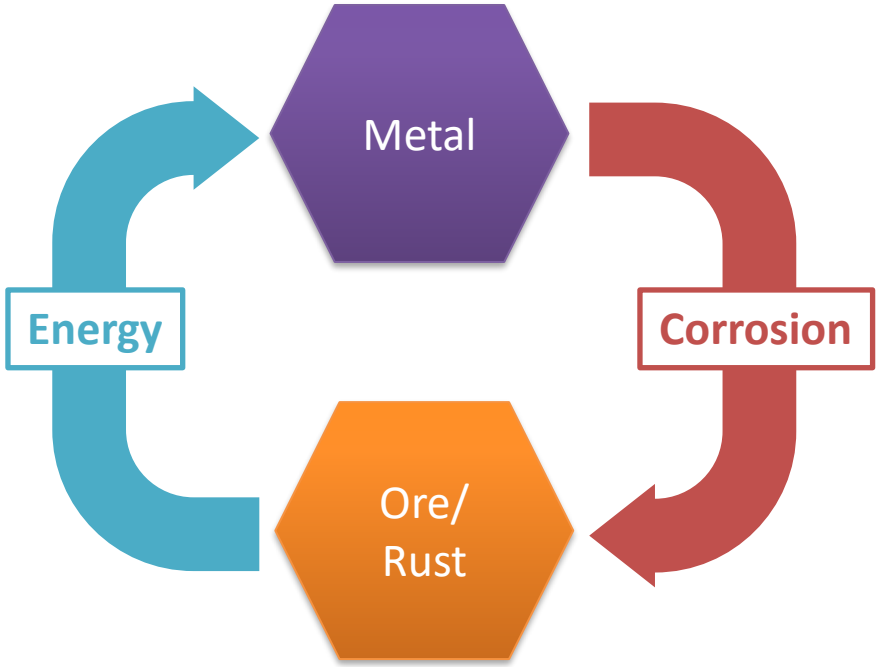
Corrosion Basics

- Some metals are mined as metals:
  - Gold
  - Silver
  - Copper
  - Mercury



Corrosion Basics

- Most metals are mined as ore
- Energy is added
- The ore converts from an oxide to a metal



Corrosion Basics

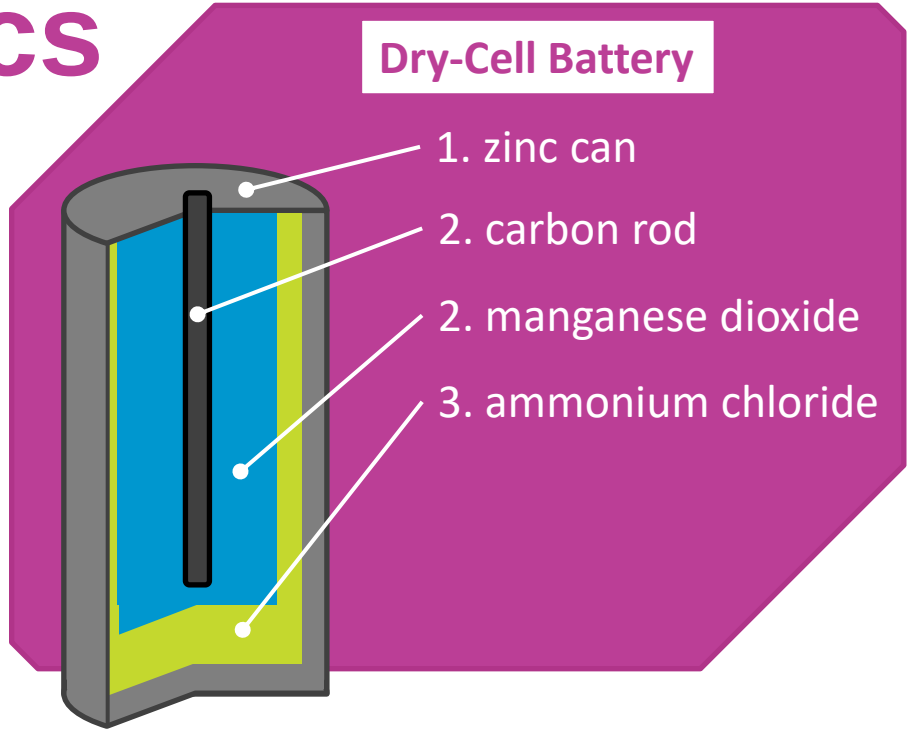
=

ore

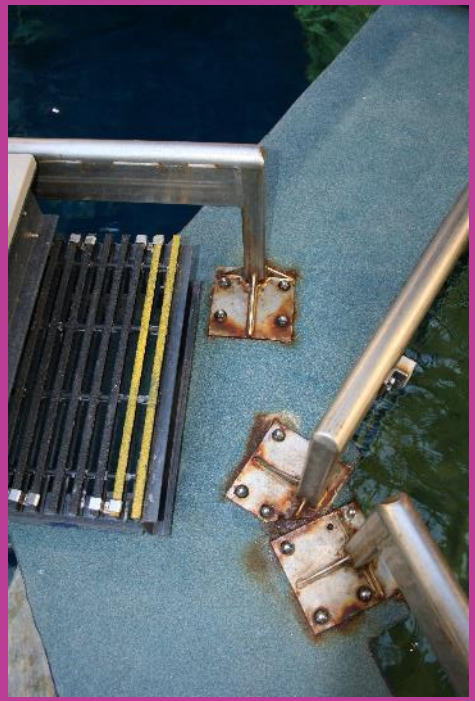
rust

Corrosion Basics

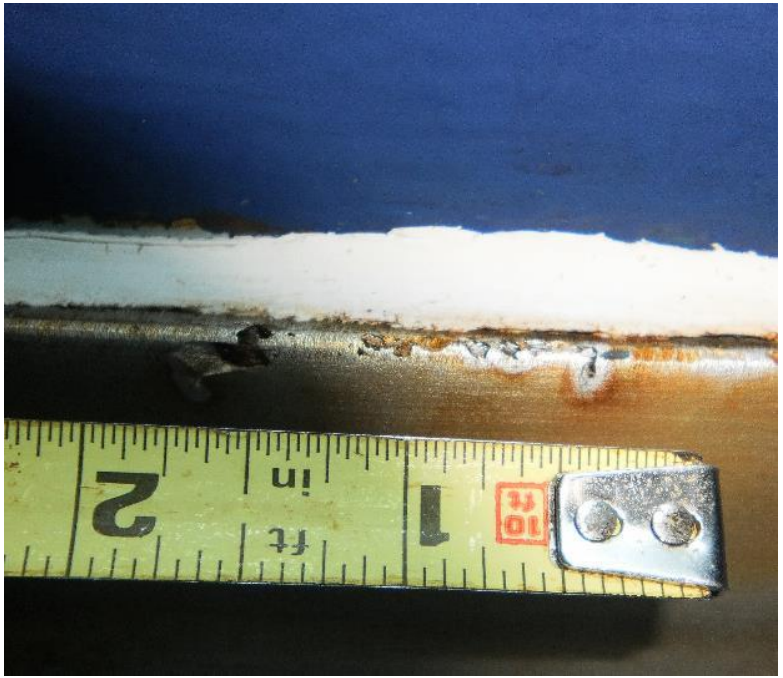
- Four Elements of a Corrosion Cell
  1. Anode
  2. Cathode
  3. Electrolyte
  4. Metallic Path



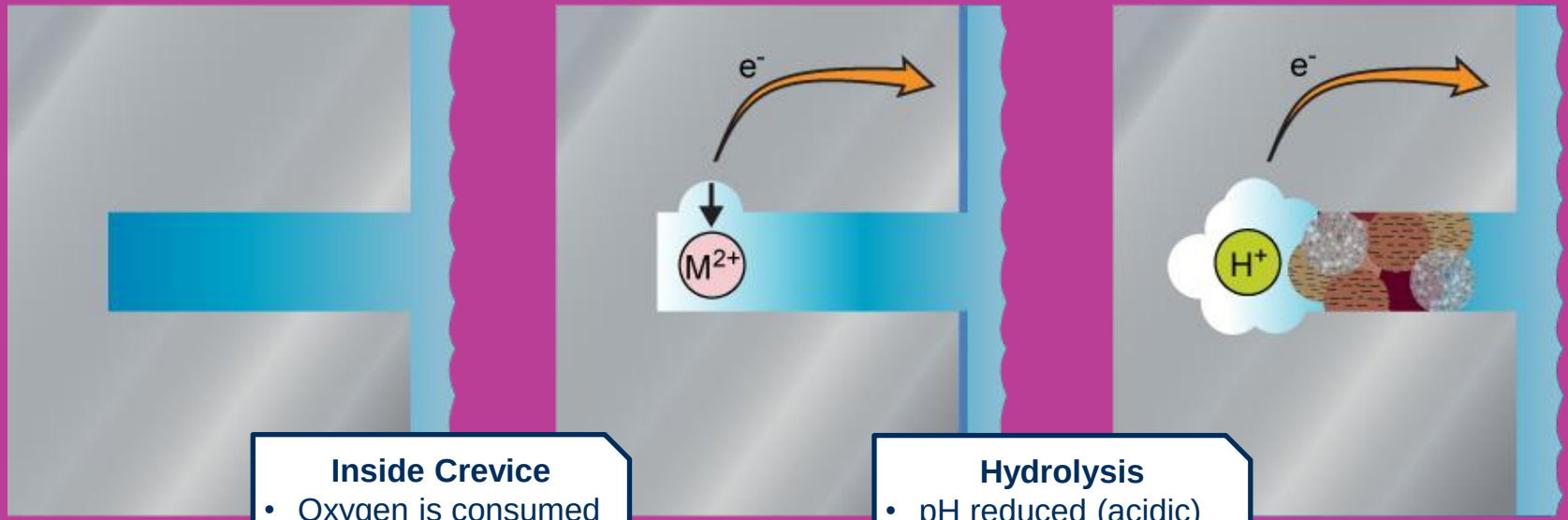
Case Study – Stainless Steel



Case Study – Stainless Steel



Case Study – Stainless Steel



Inside Crevice
- Oxygen is consumed
- Anode forms at depth

Hydrolysis
- pH reduced (acidic)
- Corrosion Accelerated

Case Study – Stainless Steel

Less Aggressive to 300 Series SS

- Fresh water
- Soils
- Concrete
- Atmospheric exposure (low chloride environments)
- Fast moving salt water
- Cold salt water near surface

More Aggressive to 300 Series SS

- Crevices
- Machined/stressed areas
- Anaerobic environments (deep water)
- Splash zones & alternating wetting/drying areas
- Slow moving/stagnate salt water

Case Study – Stainless Steel

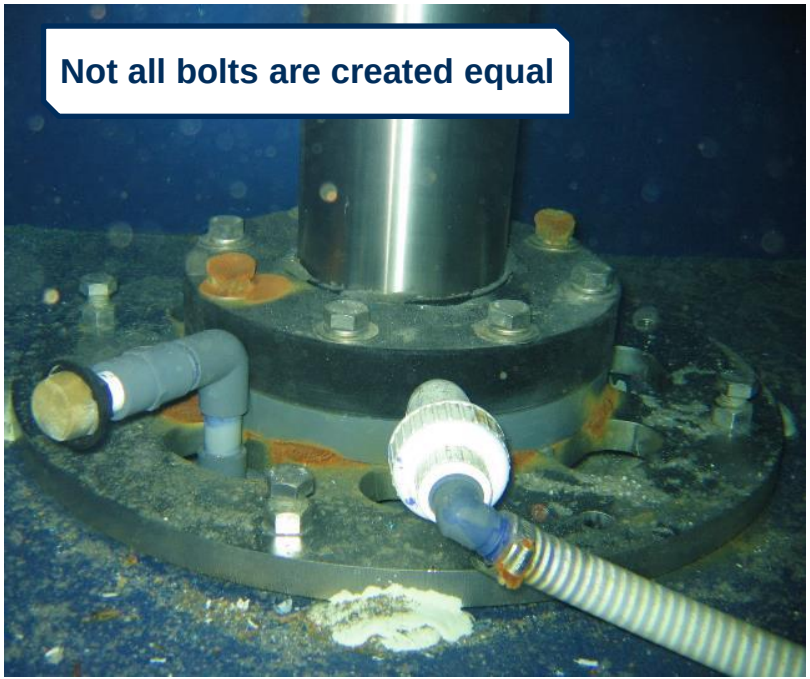
Corrosion Conditions

- Heat affected zone (welding)
- Crevices (threads, washers, nuts)
- Alternate wetting & drying
- Splash Zones

Case Study – Stainless Steel

Corrosion Conditions

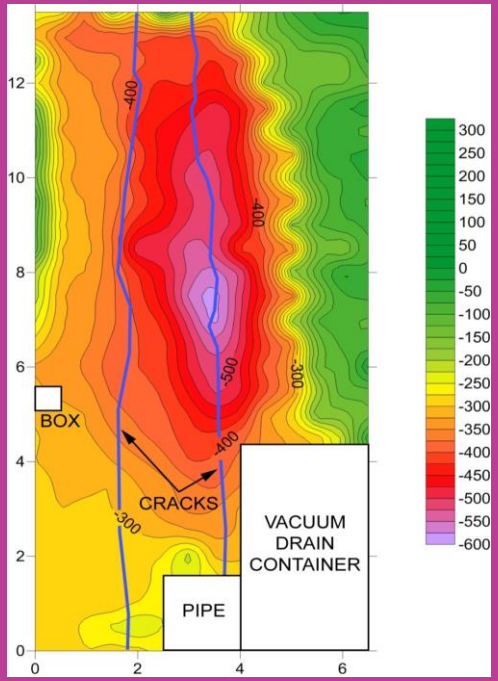
- Slow moving salt water
- Crevices (threads, washers, nuts)
- Machined surfaces



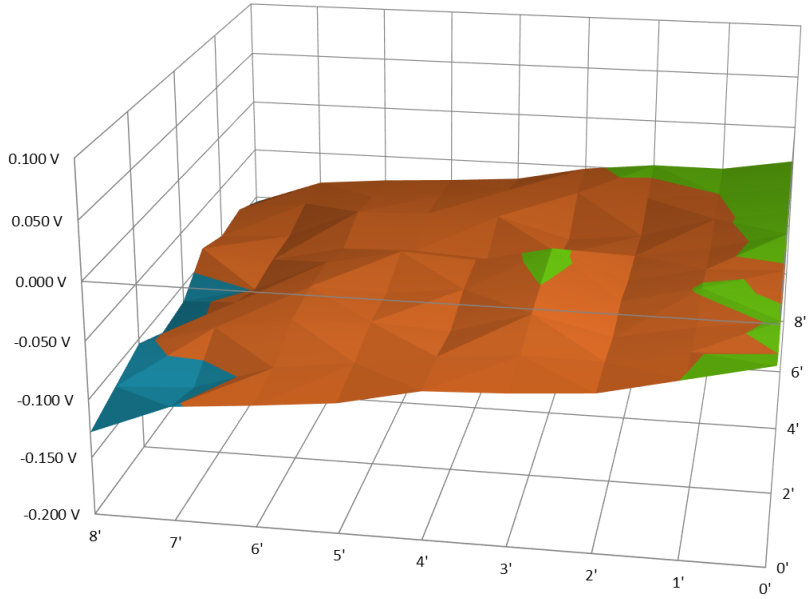
Case Study - Concrete Tanks

Potential Mapping

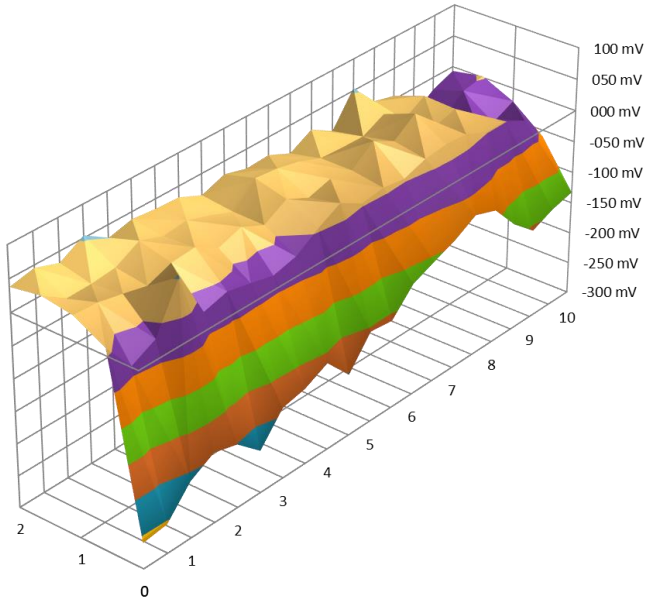
- ASTM C876
- Measures active corrosion of embedded steel (rebar)
- Slope can be key



Case Study – Concrete Tanks



Flat topography – corrosion unlikely



Large “valley” – corrosion likely

Case Study – Concrete Tanks

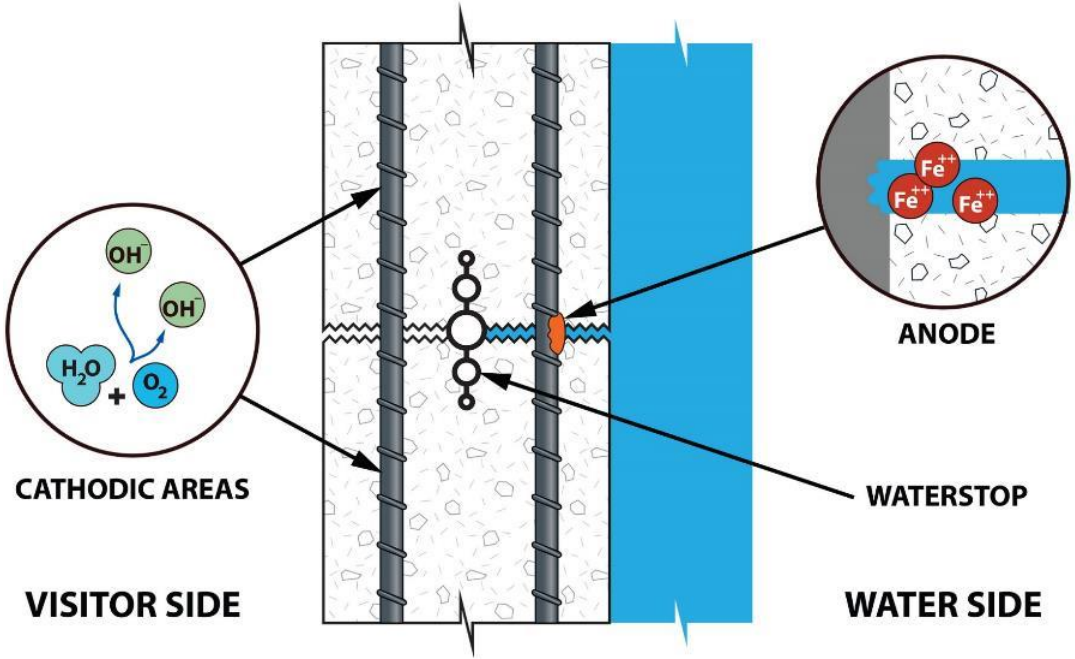
Non-Delaminated Cold Joint

What was Embedded

Case Study – Concrete Tanks

Case Study – Concrete Tanks

Case Study – Concrete Tanks



Case Study – Concrete Tanks

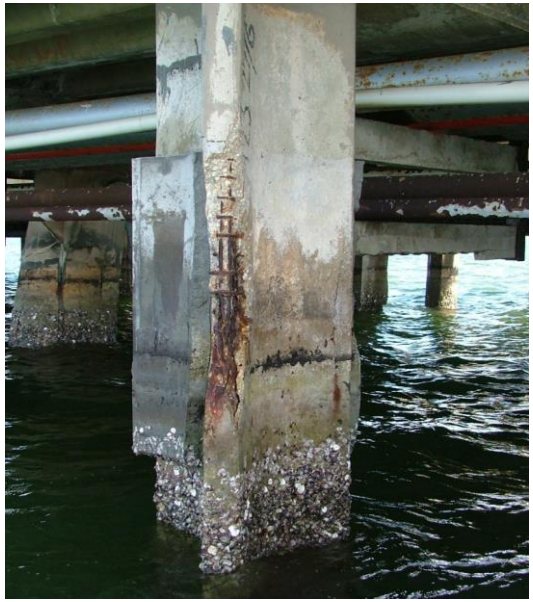
CORROSION MITIGATION IN CONCRETE

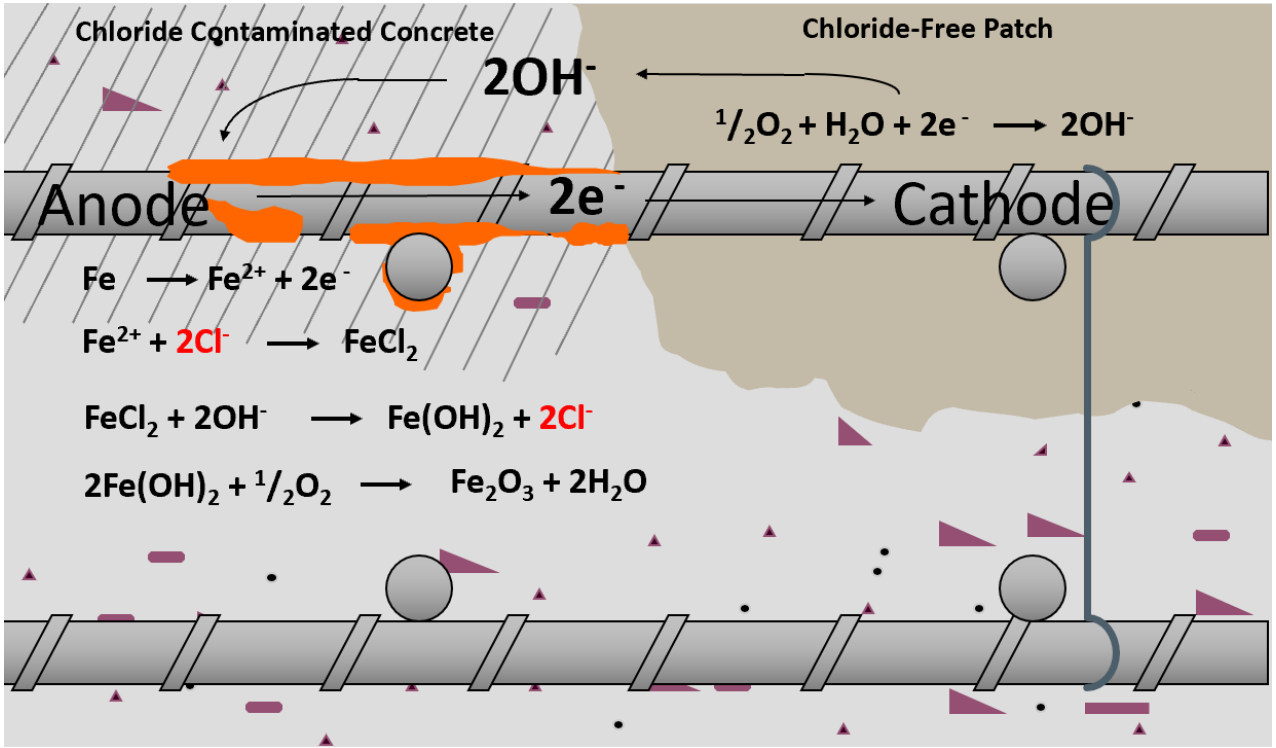
Presented by: Chris Ball

Sustainability

- The construction industry is the single largest consumer of resources and raw materials, almost 50% of the total.
- It is estimated that up to 40% of solid waste derives from construction and demolition.
- Maintenance and repair is a sustainable activity and reduces the generation of solid waste, pollution and the consumption of natural resources including potable water.

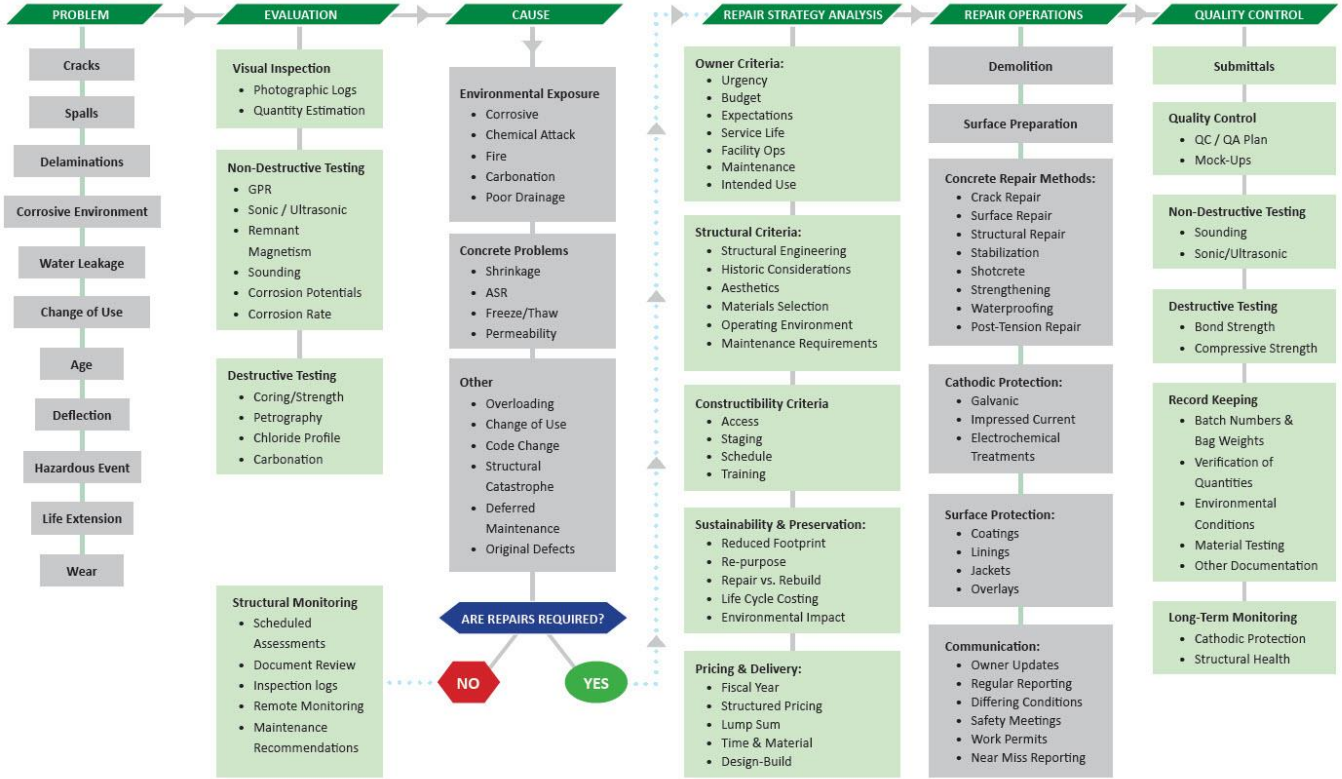
Failed Concrete Repairs Due to On-Going Corrosion




Chloride Contaminated Concrete
Chloride-Free Patch
$2OH^-$
$^1/_2O_2 + H_2O + 2e^- \rightarrow 2OH^-$
Anode
$2e^-$
Cathode
$Fe \rightarrow Fe^{2+} + 2e^-$
$Fe^{2+} + 2Cl^- \rightarrow FeCl_2$
$FeCl_2 + 2OH^- \rightarrow Fe(OH)_2 + 2Cl^-$
$2Fe(OH)_2 + {}^1/_2O_2 \rightarrow Fe_2O_3 + 2H_2O$

CONCRETE PRESERVATION PROCESS

Form A Rev 01 November 01, 2018



We Save Structures™

Electrochemical Corrosion Protection
Types of Systems

- Galvanic Protection
- Impressed Current Cathodic Protection
- Electrochemical Treatments
  - Chloride Extraction
  - Re-alkalization
- Fusion Technology
  - Powered Galvanic Anodes
  - ICCP / Electrochemical Treatment and Galvanic Protection

Embedded Galvanic Anodes in Parking Structure

- Anodes installed at interface between new and old concrete
- Localized protection
- Extend the life of concrete repairs

Impressed Current CP - Balconies

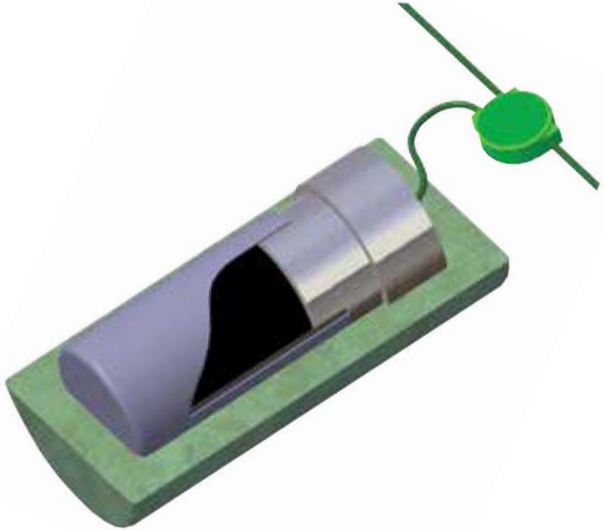
- Outside power source required
- High level of control
- System monitoring and maintenance required

Re-alkalization of Carbonated Concrete

- Carbonation is a natural process that leads to corrosion over time
- Temporary treatment to address the cause of the problem
- No system left in place to monitor

Fusion Two-Stage Technology

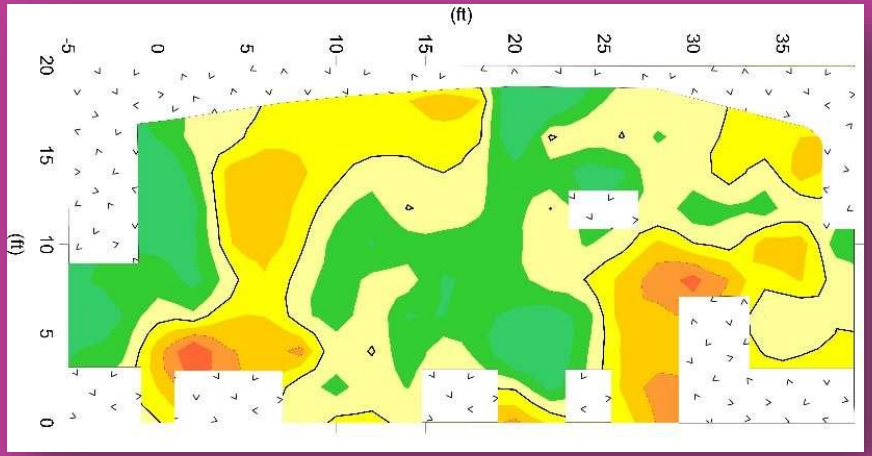
- Embedded into drilled holes in sound concrete
- Commonly used to proactively target active corrosion
- Two-stage Protection
  - **Stage 1 -** Power of ICCP
  - **Stage 2 -** Maintenance free galvanic protection



Corrosion in Swimming Pool Equipment Building at Amusement Facility

Scope of Work

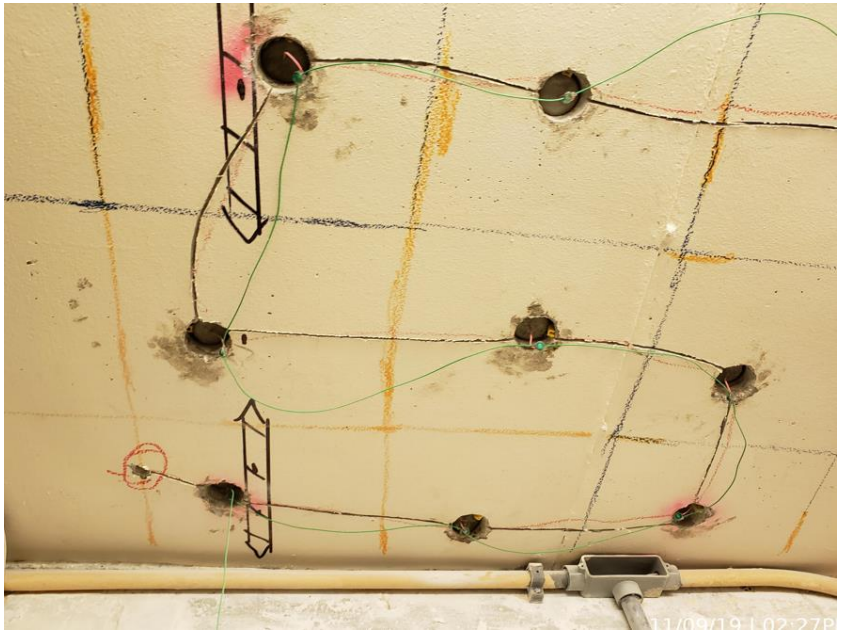
- Concrete repairs
- CFRP Strengthening
- Targeted protection of “Hot Spots” using Fusion Anodes
- Waterproofing



Corrosion Potential Survey to Identify Active Corrosion

Anode Holes Drilled Into Slab

Steel Reinforcement Connection



Anodes Installed and Interconnected through Header Wire

Anodes and Wiring Grouted in Place

Completed Repairs

Considerations When Selecting Protective Coating Systems

Presented by: Matt Mills

Corrosion Control with Protective Coatings

- Corrosion Protection
- Appearance Matters
- Balance of the Two
- Cost Basis

Coatings Selection

- Diverse Service Environments
- Life-Cycle (cost bias)
- Corrosion Protection
- Color Performance

Best Opportunities

- Design & Construction
- Standards (Lessons Learned)
- Inspection during Installation

Atmospheric Protection

- Materials Selection
- Coatings Selection
  - Primer & Intermediate Coats
  - Topcoat & Color Finishes

Wet Environments

- Water Rides
  - Exposures
  - Human Contact
- Aquaria
  - Coatings/Linings
  - Cathodic Protection

Common Problems & Solutions

- Design & New Construction
  - Materials
  - Cathodic Protection
  - Coatings
- Maintenance

Example #1

- Product selection to improve life-cycle of coating systems

Example #2

- Use of protective coatings to solve existing problems

Example #3

- Assemble a qualified and experienced team

Questions

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