

# Rehabilitation of Reinforced Concrete Port Infrastructure that Implements Corrosion Mitigation to Improve a Structure's Service Life

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Principal Engineer

Vector Corrosion Services

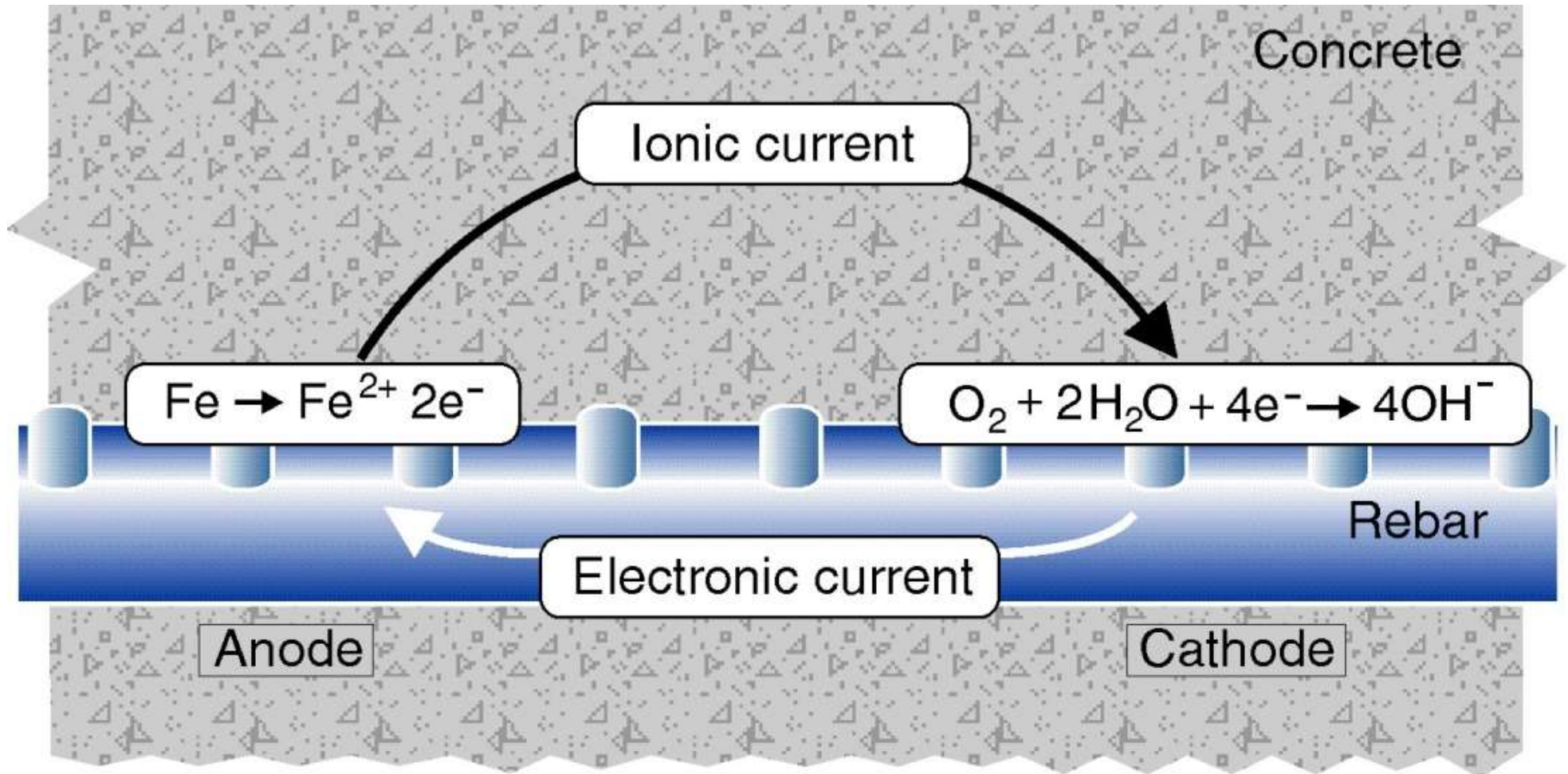


# Outline

- Corrosion Basics
- Corrosion Mitigation
  - Port Canaveral – Zinc Metalizing
  - Port of Corpus Christi – Embedded Anodes
  - Port of Houston – CP Jackets

# Corrosion Basics

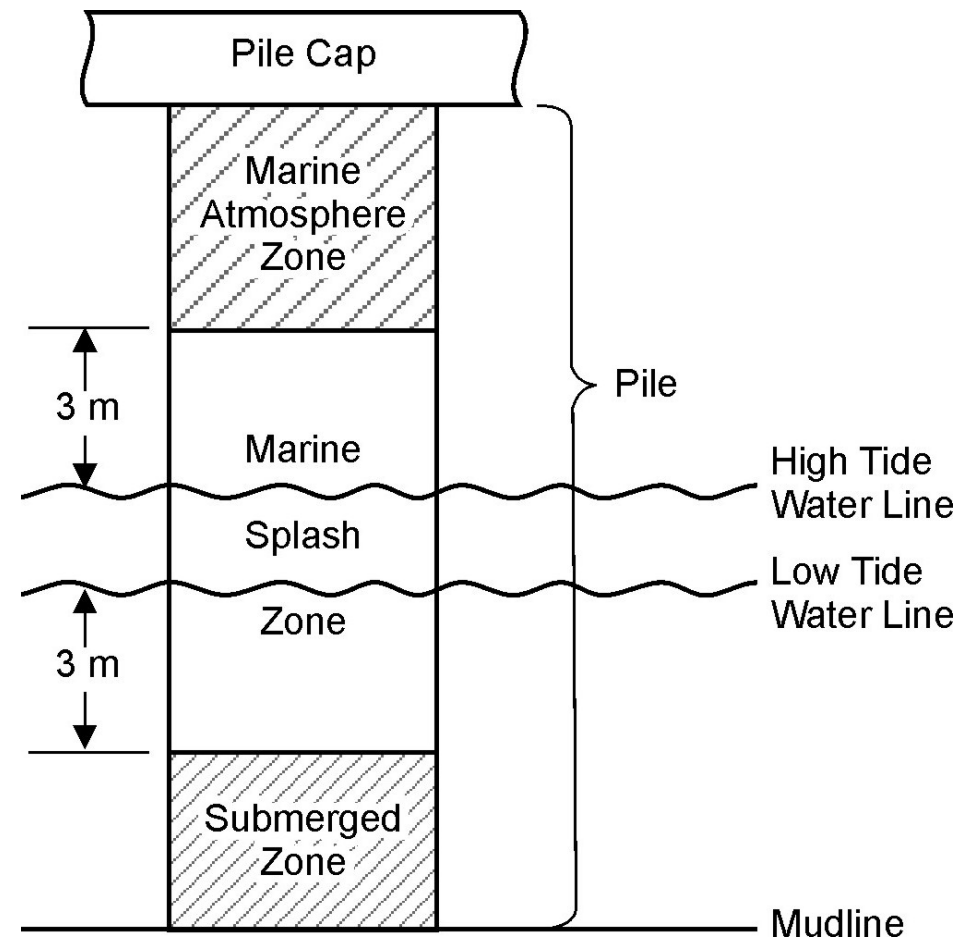
# Corrosion Reaction





# Environment

- Most severe marine environment?
  - Tidal splash zone
    - Repeated wet/drying cycles
    - High oxygen availability
    - Exposure to chlorides in saltwater and brackish water ways



# Steel Structures

- Directly exposed to environment
- Primary factors affecting corrosion
  - pH
  - Temperature
  - Moisture
    - Wetting drying cycles
  - Ion content
    - Chlorides, sulfates, etc.
  - Oxygen Content
  - Water Velocity
  - Coating quality



# Reinforced Concrete Structures

Concrete is naturally alkaline  
pH of about 13

Steel is naturally passive at this  
alkalinity

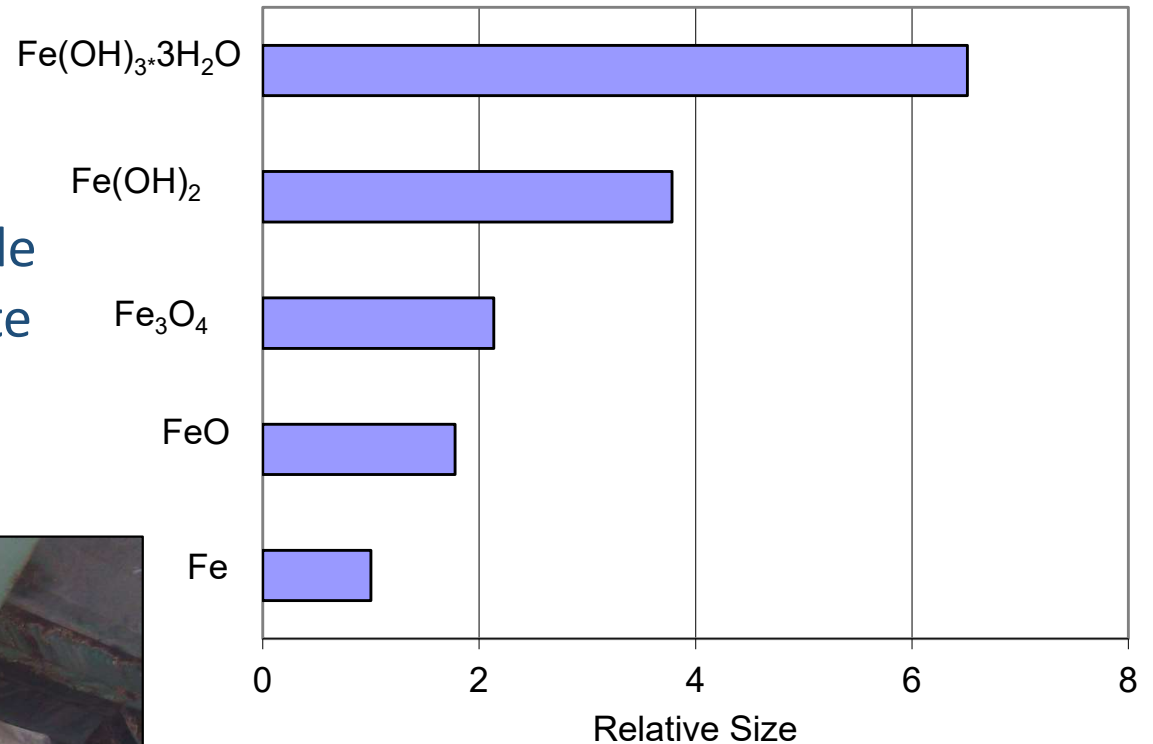
Formation of passive layer

Passive layer can be destroyed by;  
Chlorides  
Carbonation



# Corrosion Induced Damage

- Damage resulting from
- Metal section loss and
- Formation of iron oxide (rust)
- Expansive properties of iron oxide create tensile stresses in concrete
- Leads to cracking, delamination, and eventual spalling





# Corrosion 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



# Corrosion Mitigation

# How do we protect steel from corrosion?

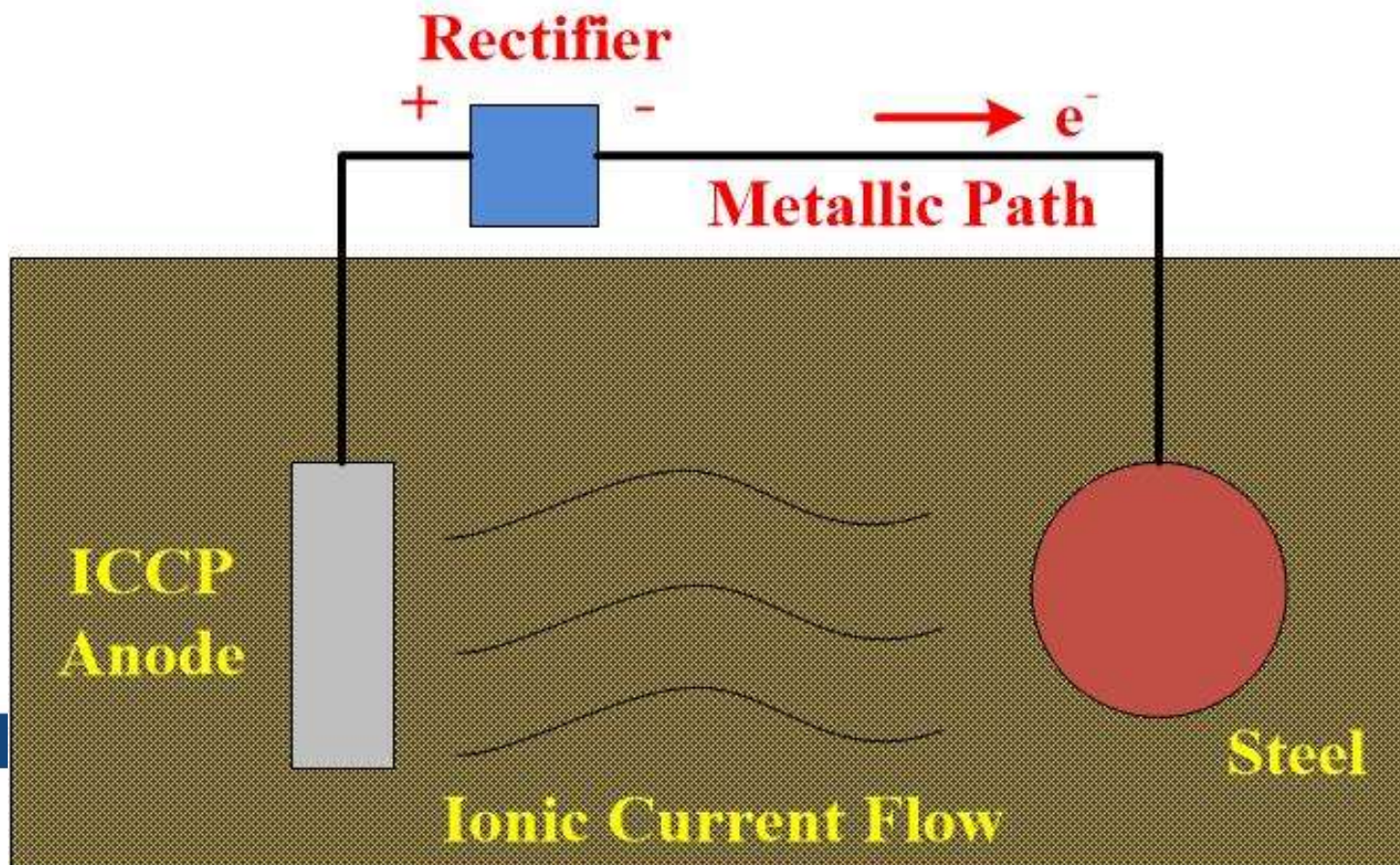
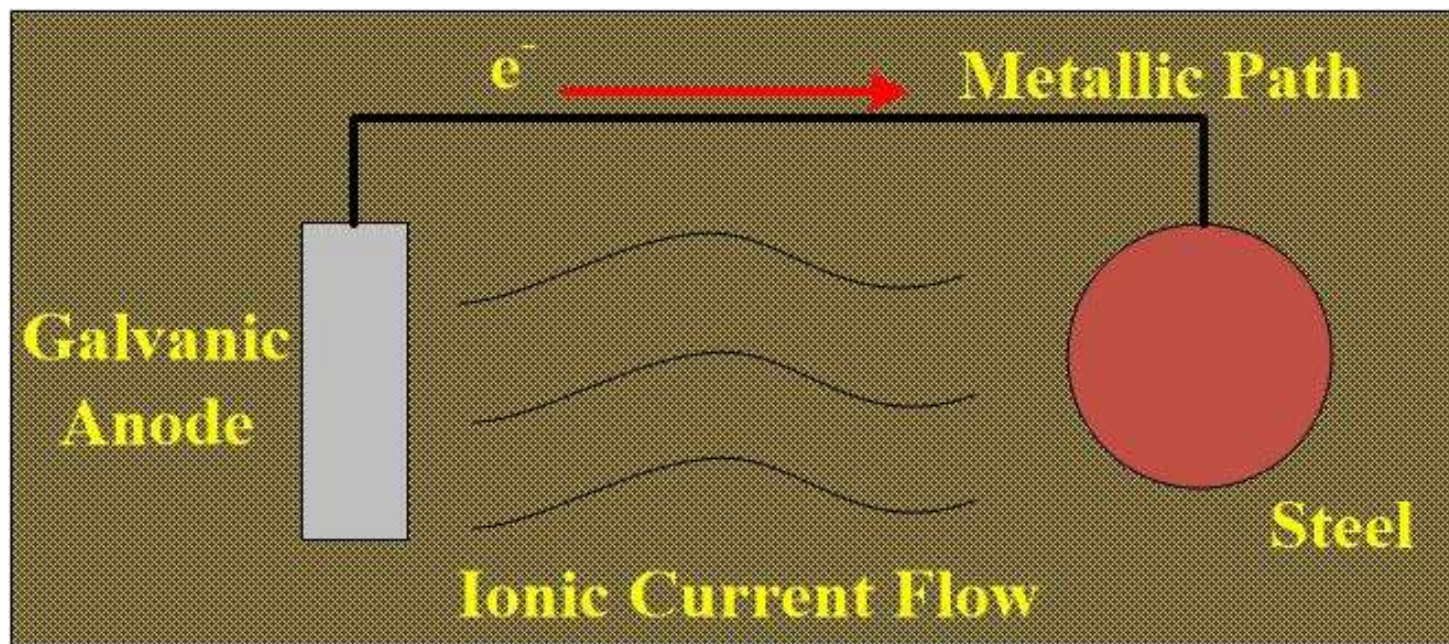
- Barriers
  - Coatings
  - Concrete
- Cathodic protection
  - Galvanic and impressed current
- Corrosion resistant construction materials
  - Improved steel grades or composite materials



# Cathodic Protection

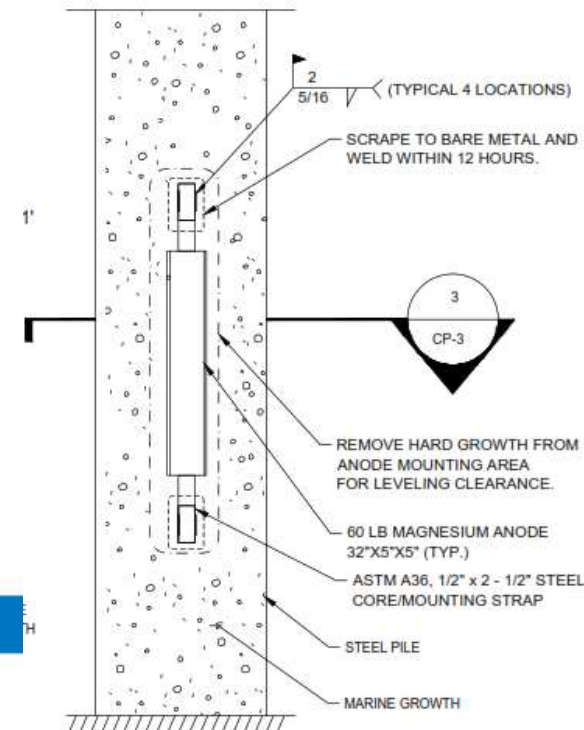
- Cathodic protection (CP) is a method of corrosion control through the application of direct current to a metal under protection, forcing it to become a cathode
  - Anode is where rust occur and the cathode is protected from section loss
- Two main types of CP
  - Galvanic
  - Impressed current





# Design Parameters

- Service life – Galvanic run between 20-30 years, ICCP can be longer
  - After 30 years size of galvanic anodes becomes cost prohibitive
- Environment
  - Salt content drives anode selection
- Coating degradation rate
  - Between 1.0-2.5% degradation per year
- Microbiological induced corrosion
  - Requires anodes to drive potential lower to mitigate





# Port of Canaveral North Cargo Pier Repairs



## LONGEVITY CATEGORY

# Port of Canaveral: North Cargo Piers Cathodic Protection 10 Years Later

CAPE CANAVERAL, FL

SUBMITTED BY VECTOR CORROSION TECHNOLOGIES

The North Cargo Piers at the Port of Canaveral consist of four wharves that handle bulk cargo such as cement, slag, salt, automobiles, and lumber. Each wharf consists of square prestressed concrete piles, cast-in-place concrete pile caps and beams, and prestressed hollow-core deck units with a cast-in-place topping slab.

After years of exposure to the corrosive saltwater environment, a major rehabilitation was conducted

concrete deck units were protected using activated arc sprayed zinc applied to the deck soffit.

Completing this project on an operating port facility on the ocean created many unique challenges to overcome, including having the piers remain operational at all times; dealing with tides; and at times, moving work areas or delaying work to avoid impacting marine life such as manatees, pelicans and sea turtles in the Port.



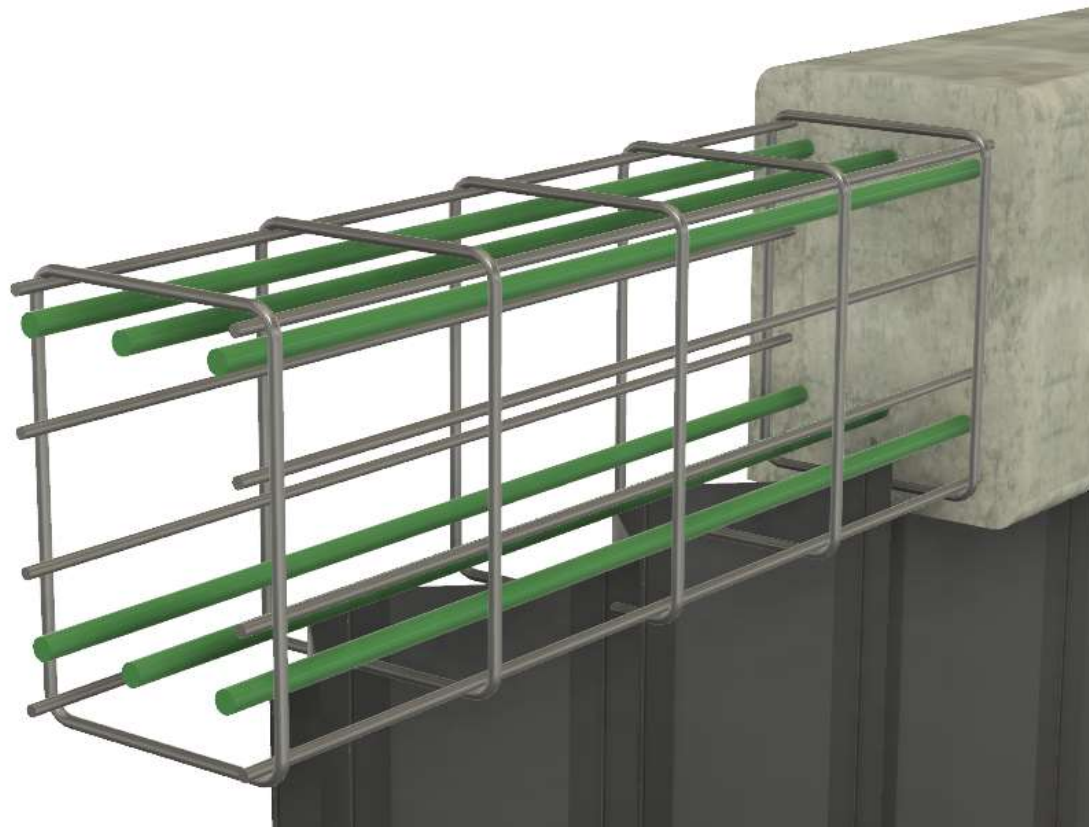
Over the last 10+ years, the North Cargo Piers have continued to be subjected to the corrosive marine environment and the portions of the structure that were repaired and received the galvanic cathodic protection are showing no signs of corrosion-related deterioration. Other areas which were not repaired and protected have continued to deteriorate and are now in need of repair. Accordingly, the repairs and cathodic protection systems are meeting the owner's goals of providing a long-term, operator-free, maintenance-free protection to the piers in the Port.



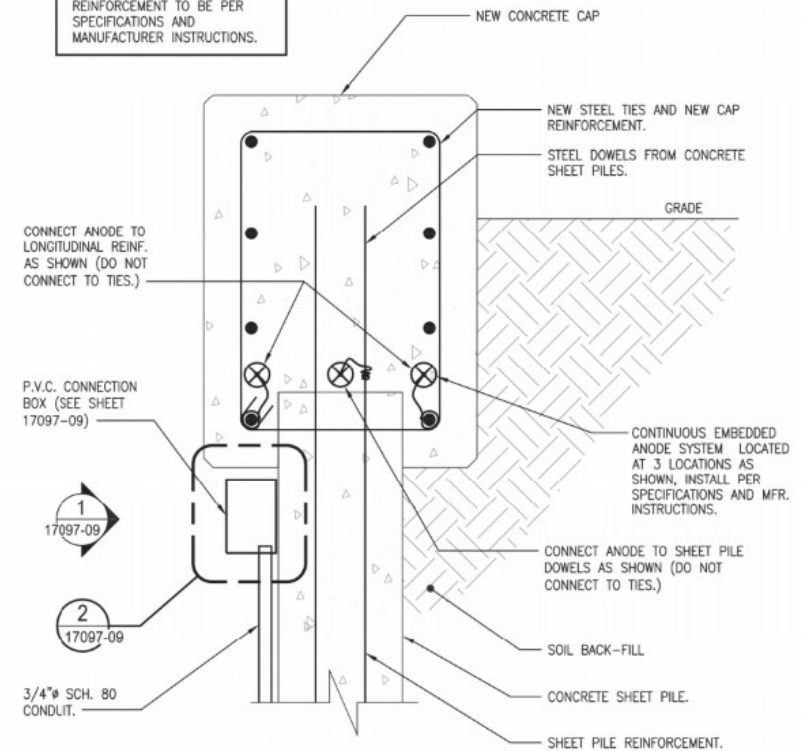
# Pile Cap Deterioration



# Design Example



ALL ANODE CONNECTION TO REINFORCEMENT TO BE PER SPECIFICATIONS AND MANUFACTURER INSTRUCTIONS.



1 SECTION  
17097-08



2 SECTION DETAIL  
17097-08

ITEM	BY	REMARKS	DESIGNED BY:	NAME	DATE	REVISIONS	BY	DATE	Prepared By:	ENGINEERING & CAPITAL IMPROVEMENTS DEPARTMENT CITY OF ST. PETERSBURG	2 <sup>ND</sup> AVENUE NE SEAWALL INSPECTION AND REPAIRS PROJECT NO. 17097-110	DATE: 4/16/2018 SCALE: SEE BAR SCALE DRAWING No. 17097-08
			BP	KB	3/18				BRIAN PAILES, P.E. LIC. NO: 81340	GTJ PROJECT MANAGER: ZIBA MOHAMMADI, P.E., PTOE		



# Distributed Anodes





# Distributed Anodes





# Pre-Cast Deck Panels



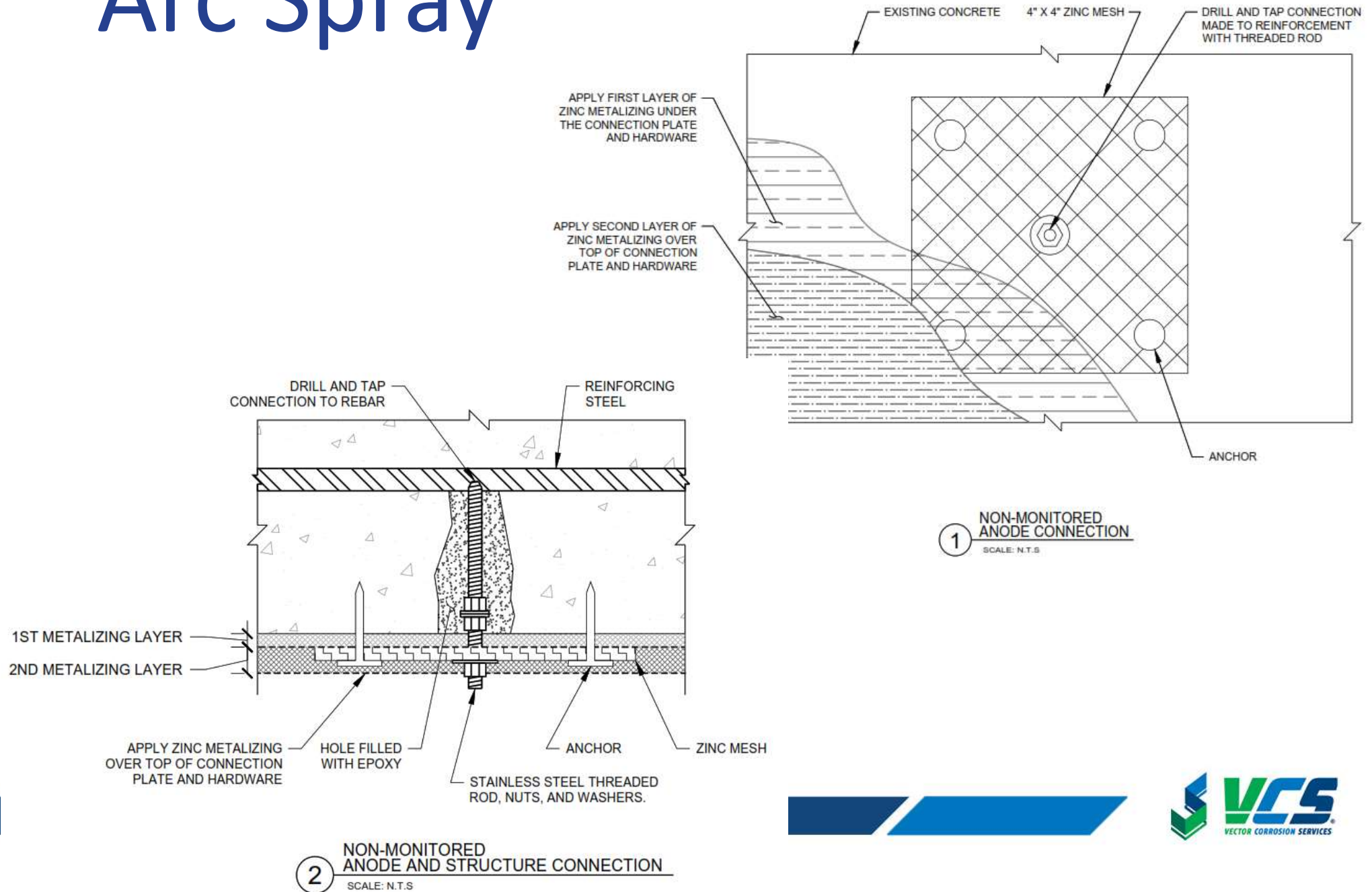


# Arc Spray Surface Applied Galvanic Anode

- Molten Zinc
- Surface Applied
- Multiple passes to reach desired thickness

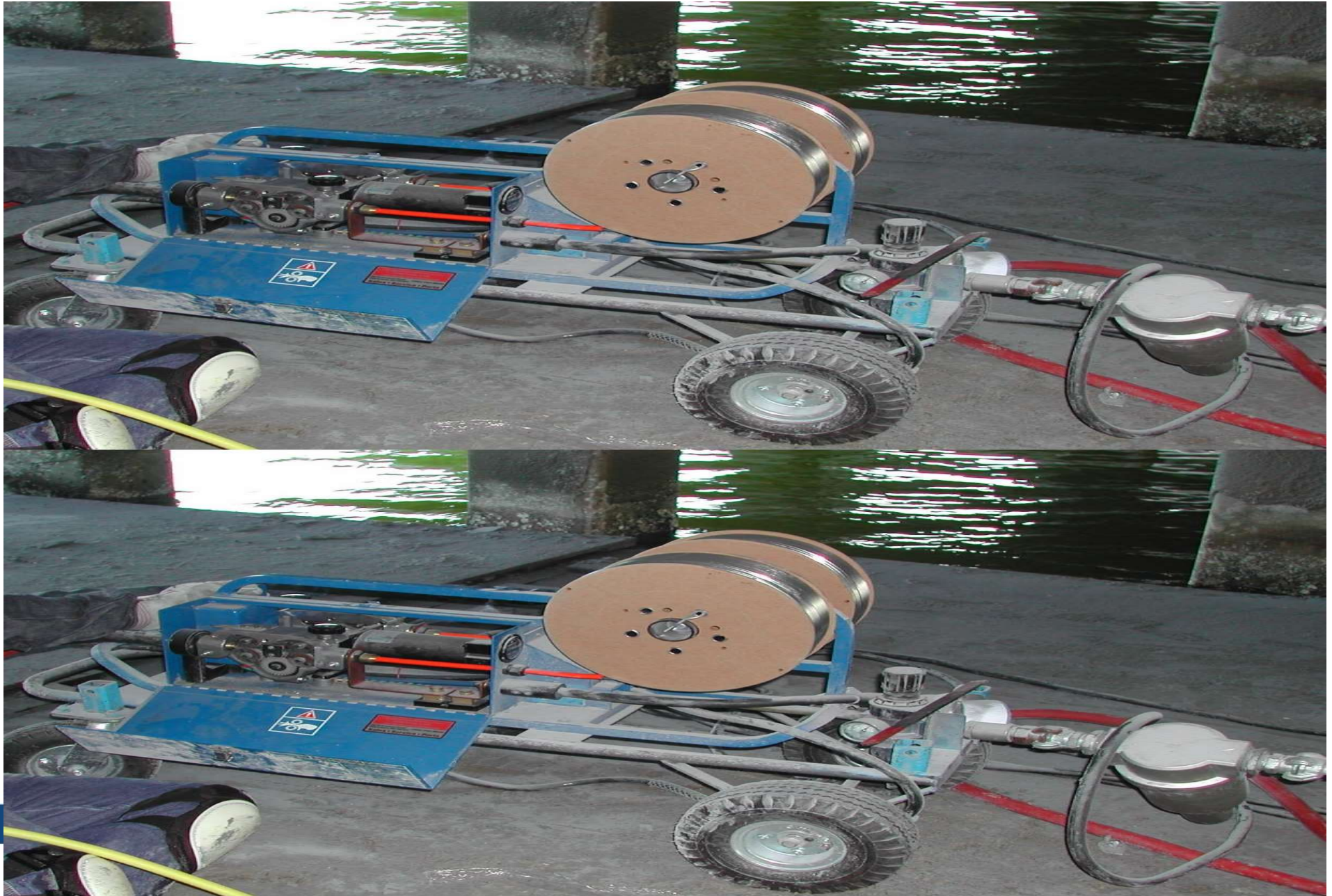


# Arc Spray





# Arc Spray





# Arc Spray



# Arc Spray





# Arc Spray



# Arc Spray





**AWARD OF EXCELLENCE**  
WATER STRUCTURES CATEGORY



# Extending the Service Life of Oil Docks at Port of Corpus Christi

CORPUS CHRISTI, TEXAS

SUBMITTED BY VCS, INC.



Fig 1: Aerial view of a) Oil Dock 7 and b) Oil Dock 4



# Oil Docks 4 & 7





# Original repairs

- Original plans requested zinc metalizing as the cathodic protection system
- Zinc metalizing requires sand blasting the concrete surface then arc melting and spraying of zinc onto concrete surface.



# Schedule Constraints

- Initial bids for repairs came in way higher than POCC expected
- Primary reason for this was limitations of schedule

During a typical month, various docks in no particular order or consistency will be available for construction a total of 14 days per month, distributed over several single- or multiple-day work segments. There is no guaranteed pattern, but generally the historical ship and barge call records indicate possible work period durations as shown below:

	Workdays/Month
3 – One-day windows/month <u>at any dock</u>	= 3
4 – Two-day continuous work windows/month <u>at any dock</u>	= 8
1 – Three-day continuous work window/month <u>at any dock</u>	= 3
Average Total days	=14

# Why So Expensive?

- Zinc metalizing is almost all hot work
  - Sandblasting of concrete surface
  - Arc spraying zinc
  - Drilling into concrete to make connection
- Prep work can be lost due to an outage
  - Must metalize area same day it is sandblasted
  - If delayed light brush blasting is required before metalizing
- Environmental controls





# Drilled in Galvanic Anodes

- To reduce the project budget how can we better utilize days where hot-work was not allowed?
- Drilled in galvanic anodes
  - Still require hot-work, drilling and cutting concrete
  - But grouting of anodes can be done during outages



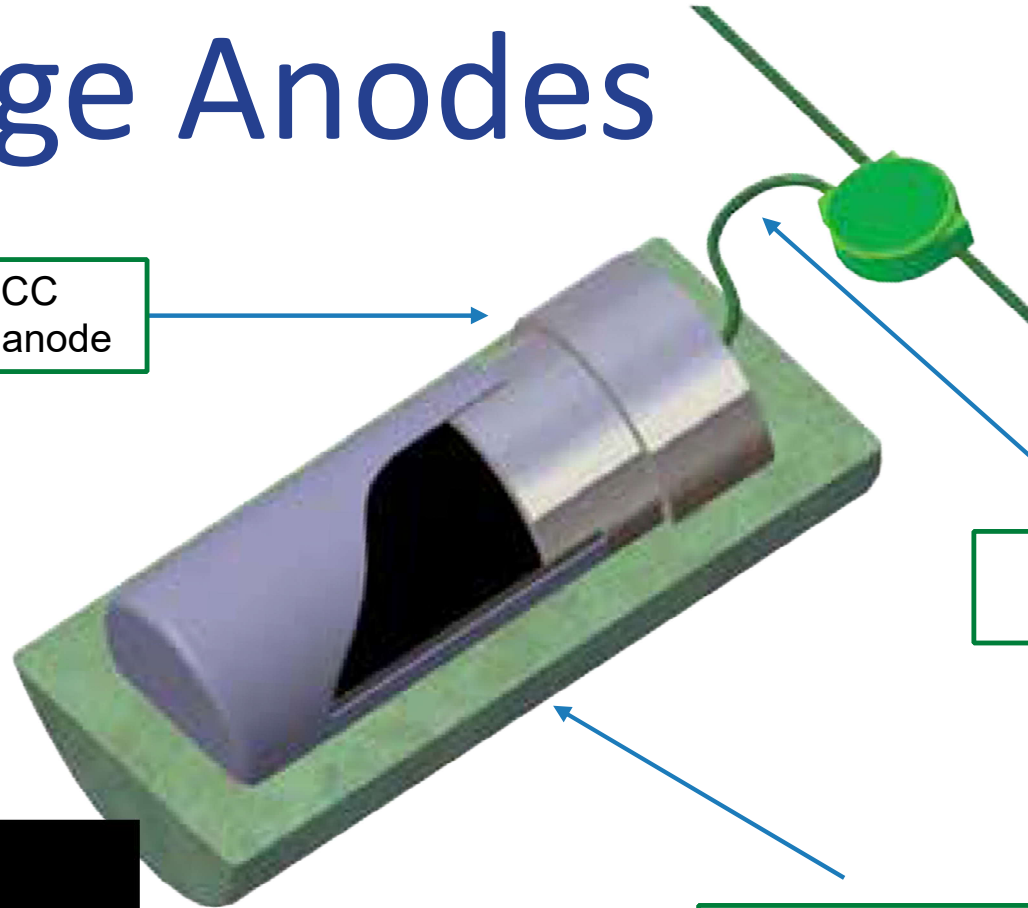
# Galvashield® Fusion™ T2 Two Stage Anodes



Galvashield CC  
alkali-activated anode

Single wire  
installation

Self-powered  
ICCP System



2018  
**MIP**

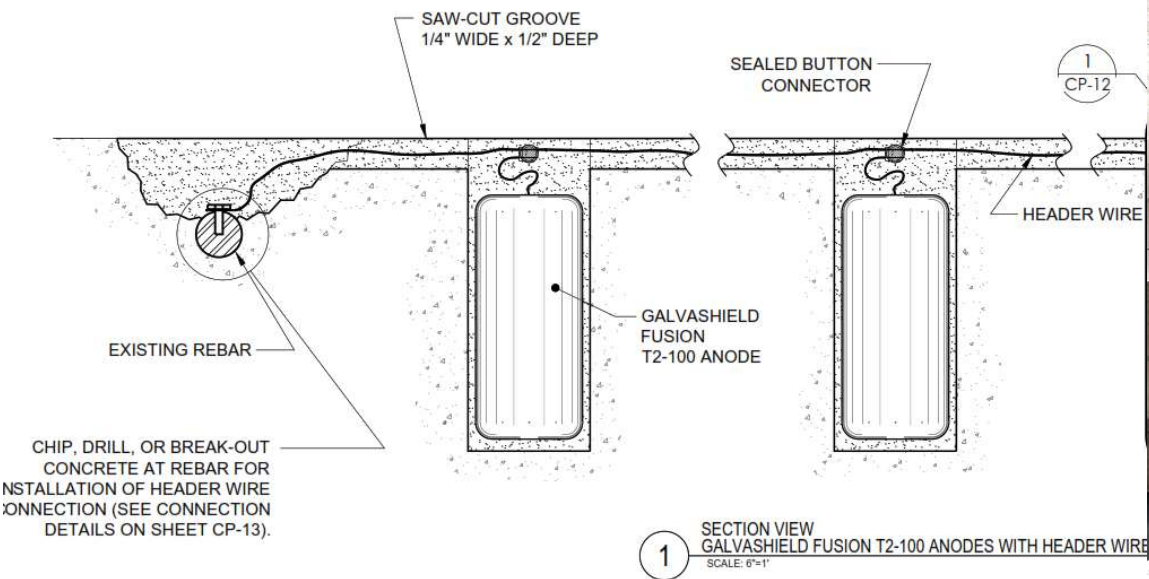
most **innovative** products

AT WORLD OF CONCRETE



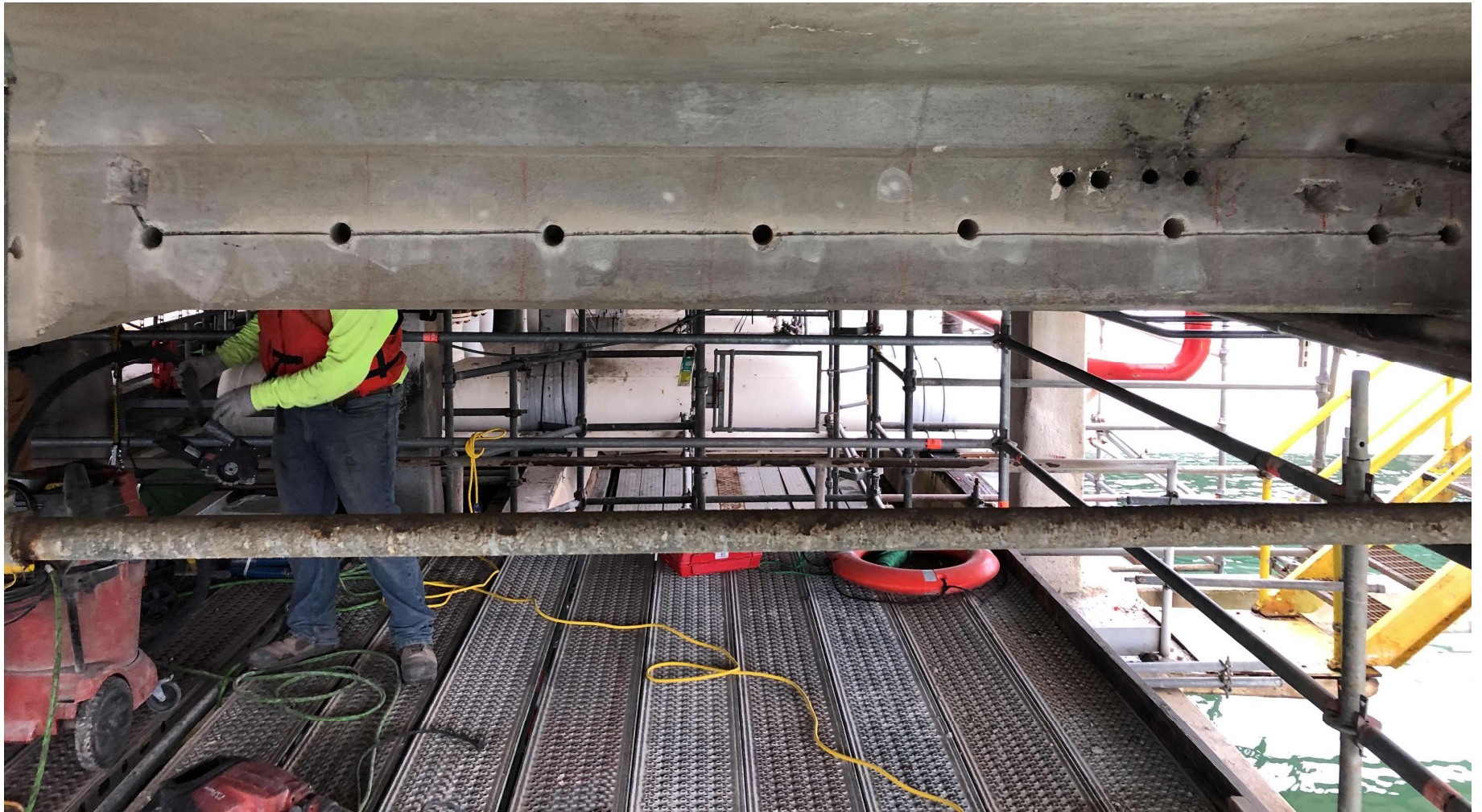


# Installation



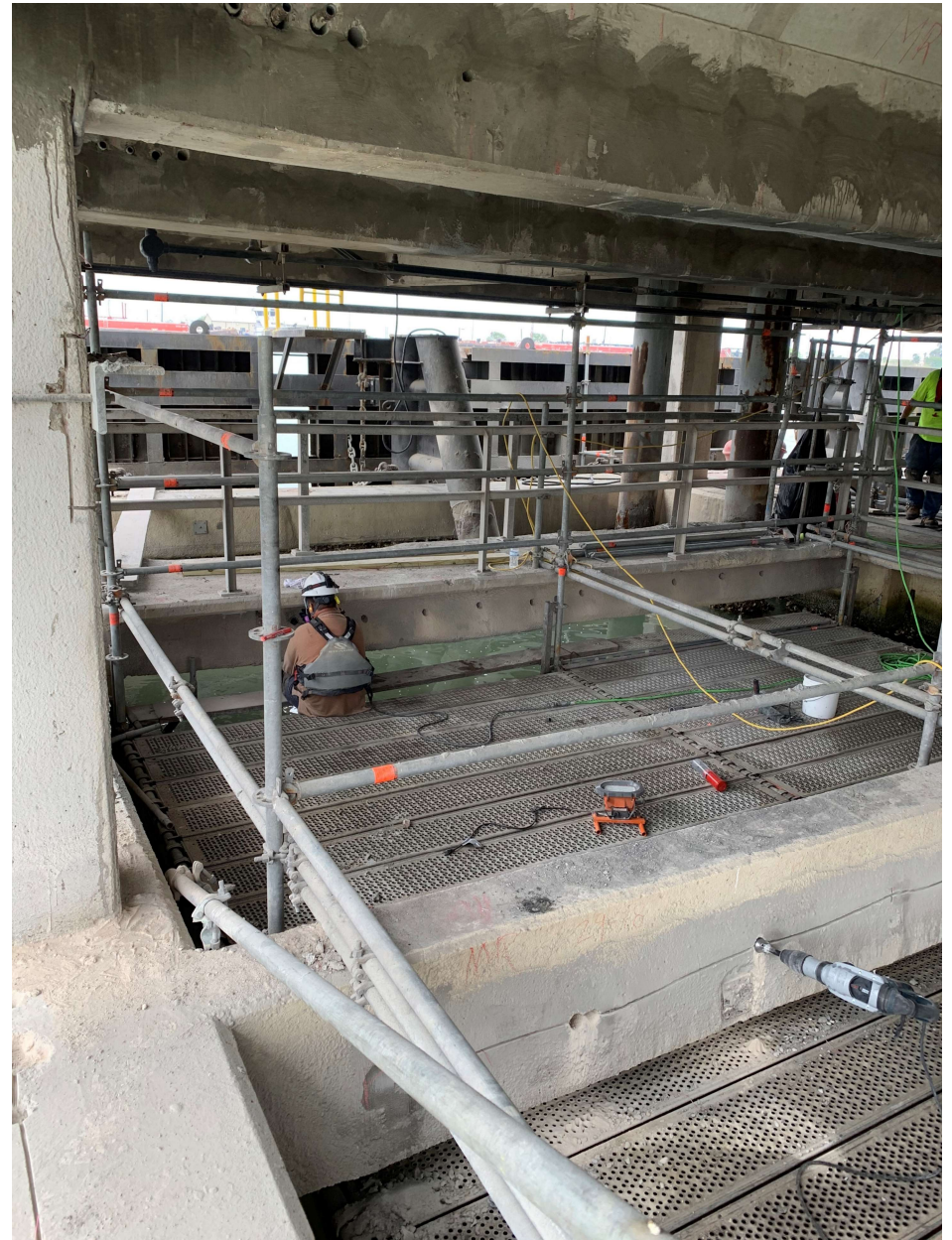


# Installation





# Installation

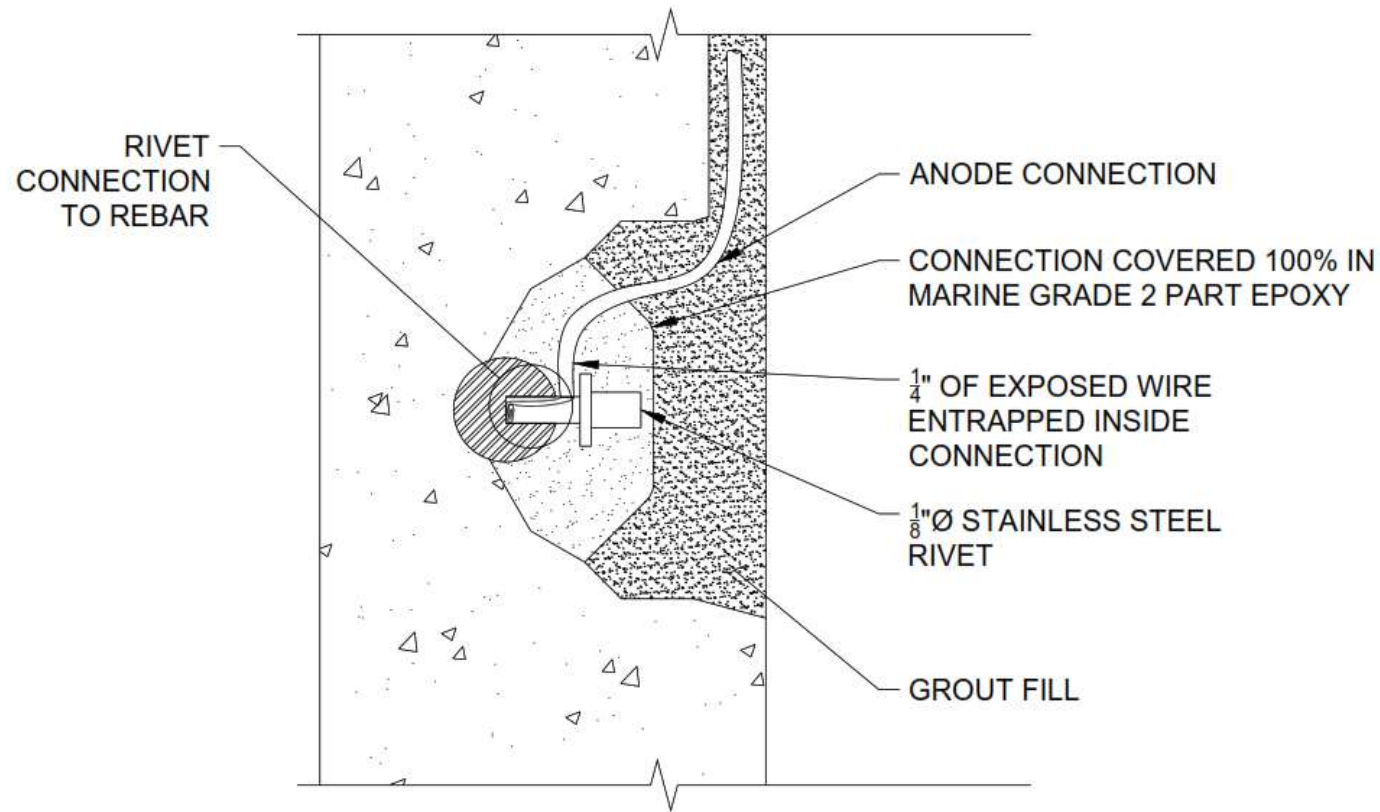




# Anode Connections



# Connections to Steel



1  
OPTION 1 - RIVET  
STEEL CONNECTION DETAIL  
SCALE: N.T.S



# Grouting Anode

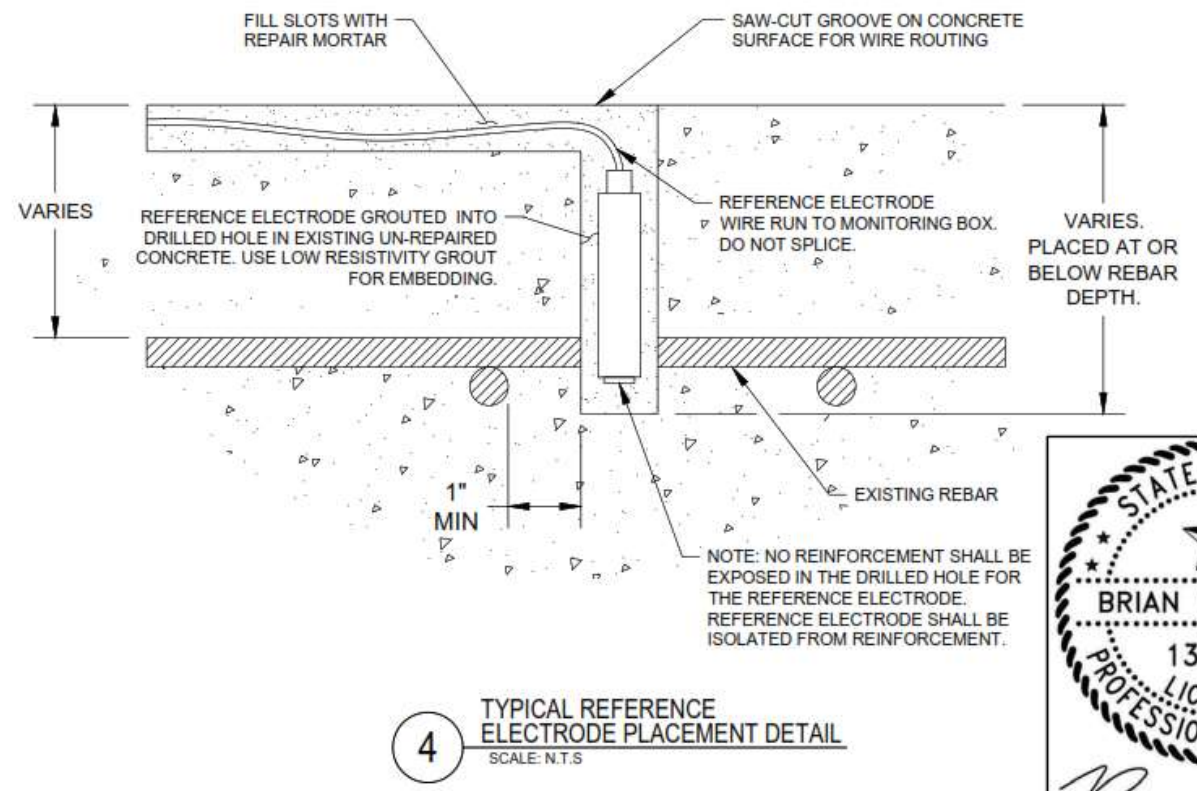








# Reference Electrodes





# Completed





# Completed





# Completed





# Performance

- Per the original plans test stations were required to monitor the performing of the zinc metalizing system
- Measured
  - Current from anode
  - Polarization with embedded reference electrode
- Embedded system utilized same test stations for monitoring performance





# Jackets





# Piles



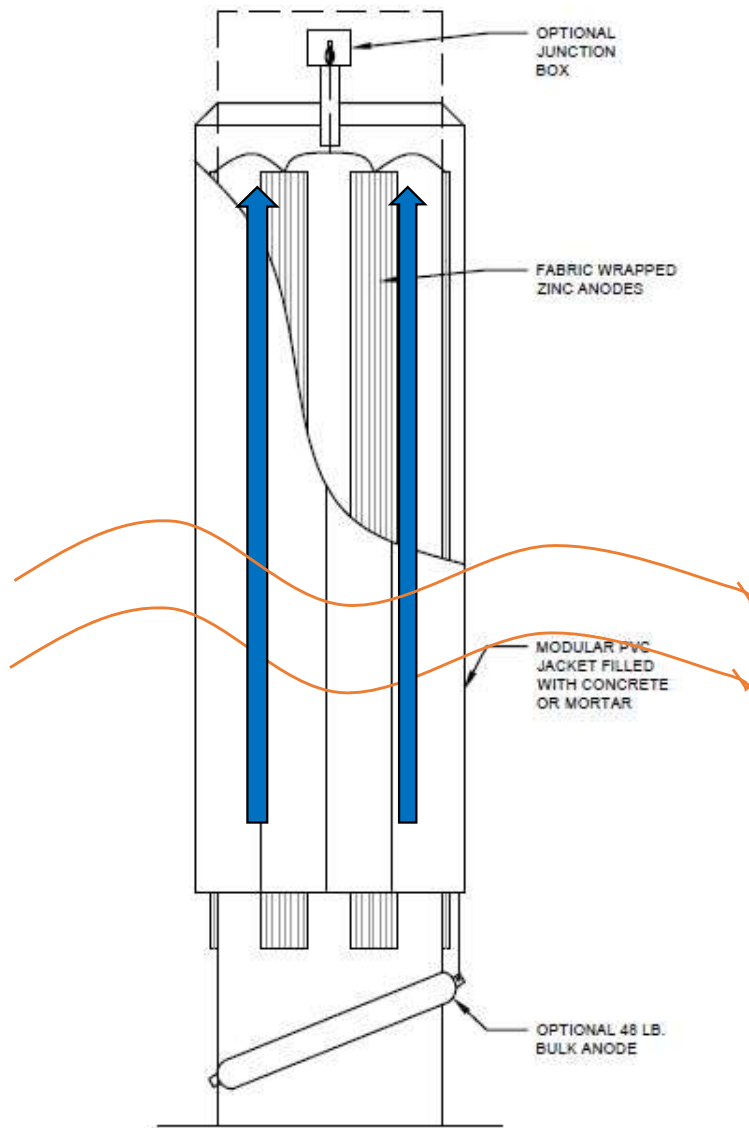
- Jacketing is the most common repair strategy
  - Critical to have cathodic protection in jackets
  - FDOT discovered accelerated corrosion in jackets without CP
    - Hartt, W.H. and Rapa, M., "Condition Assessment of Jackets Upon Pilings for Florida Bridge Substructures," Final Report, WPI No. 0510803, Florida Department of Transportation, Tallahassee, Florida, April 13, 1998



# Galvanic - Mesh

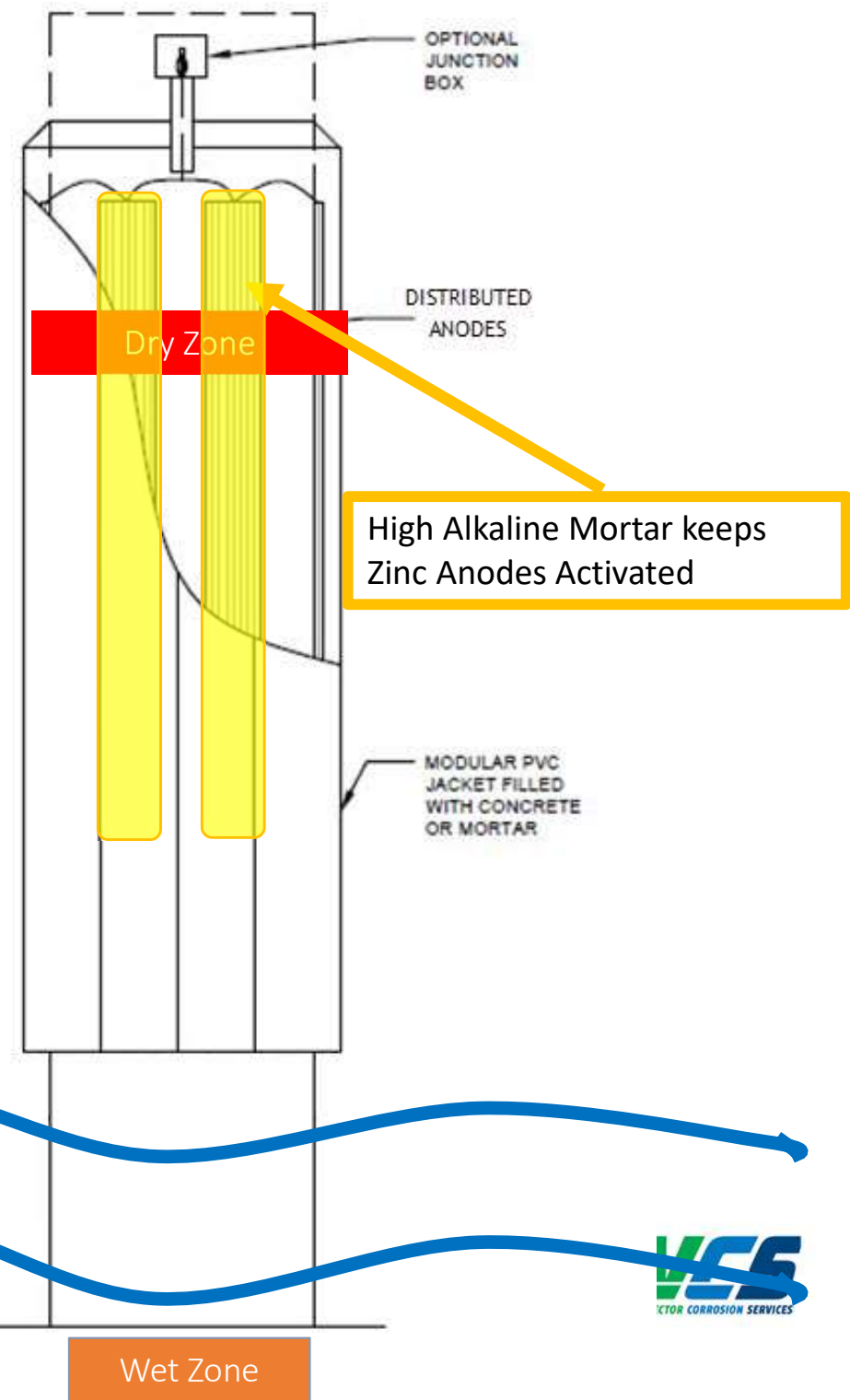


# Tidal Plus Jacket





# Self-Activated Galvashield DAS Jacket



# Port of Houston

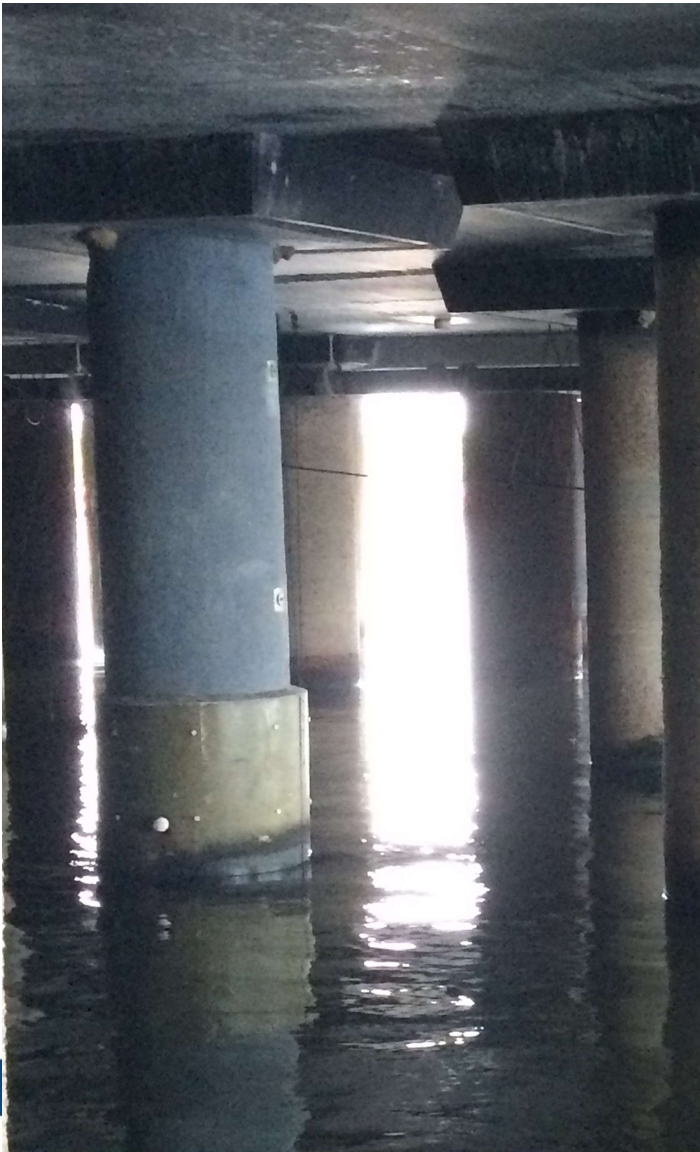




# Pile Repairs

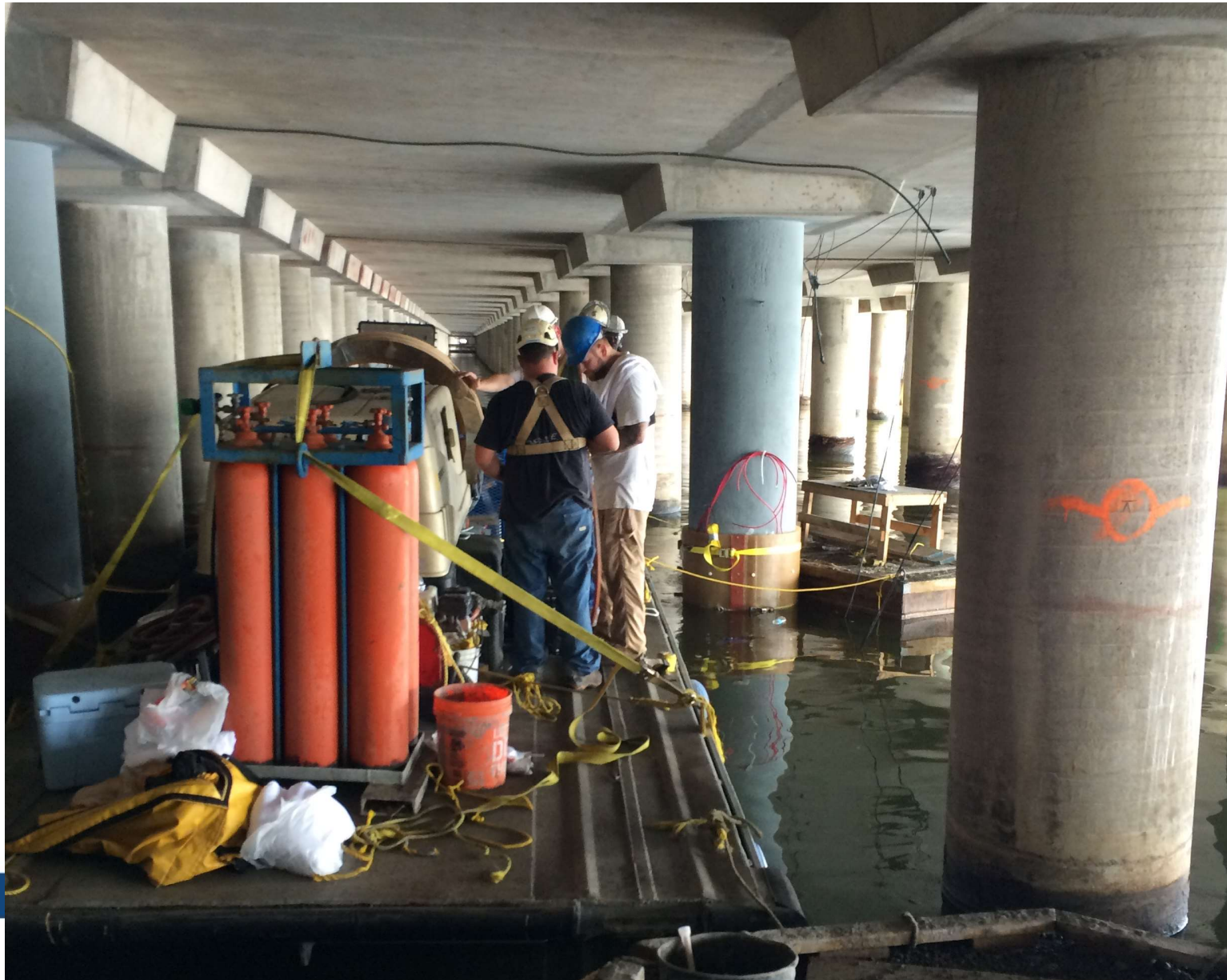


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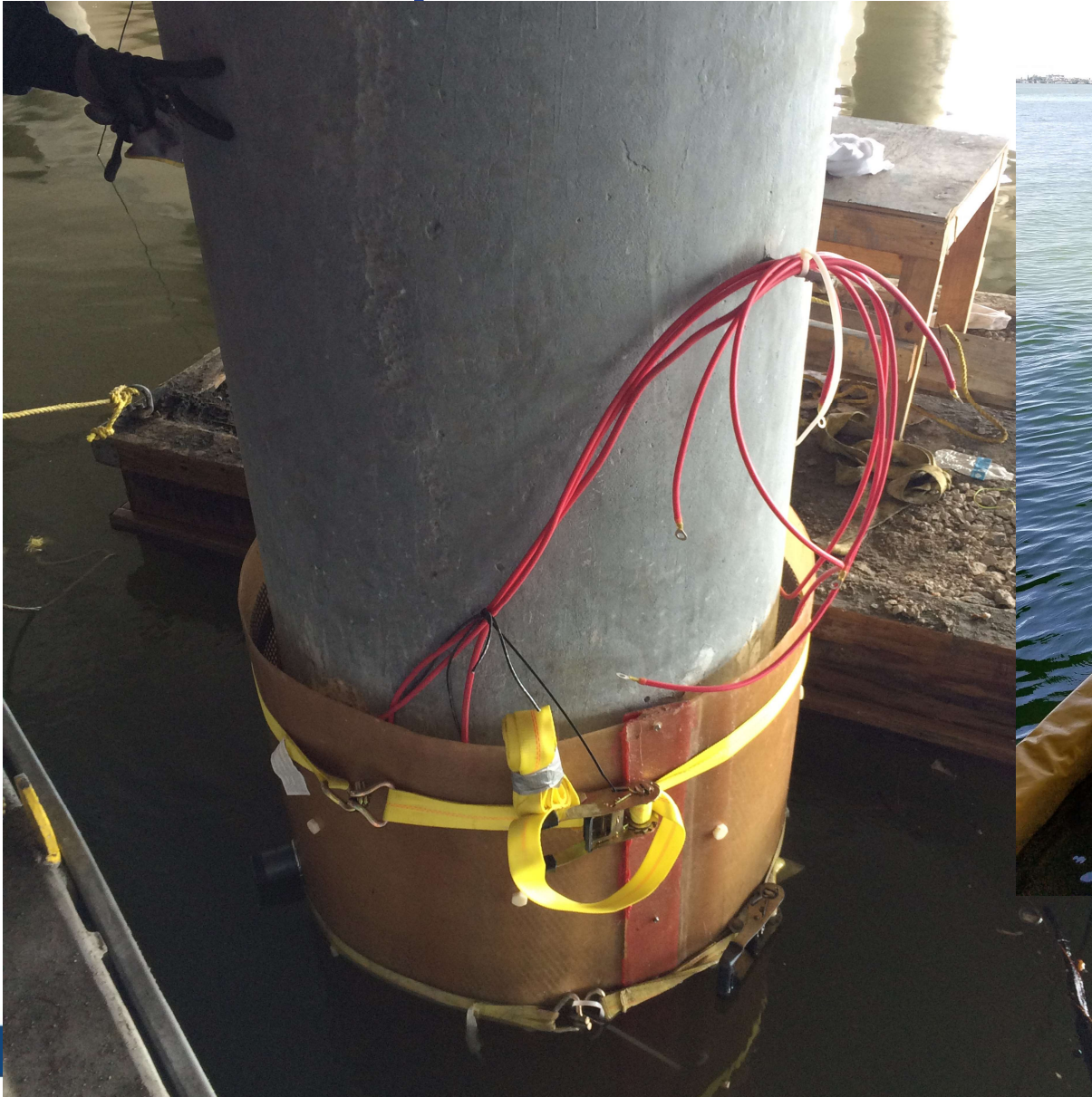


# Pile Repairs



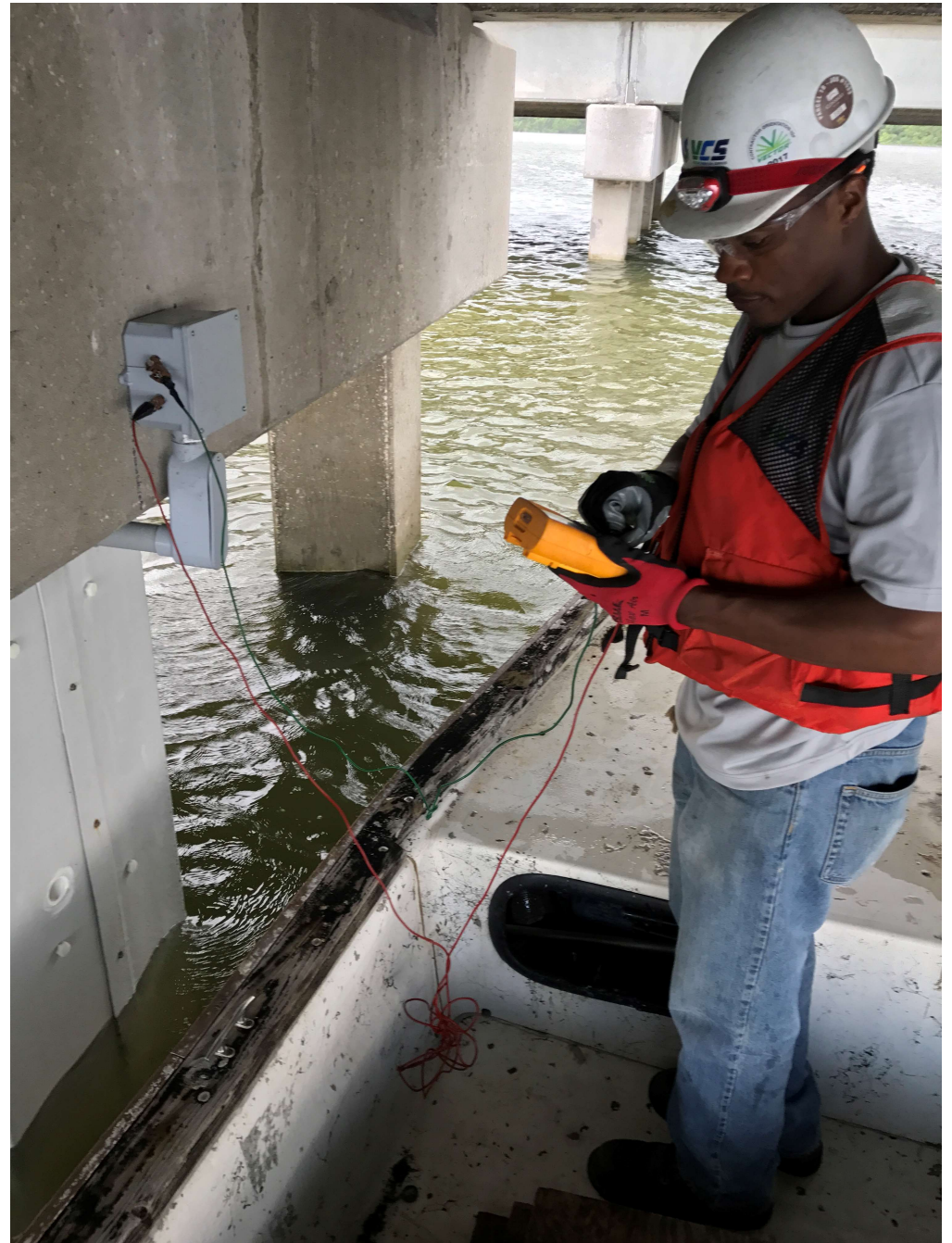
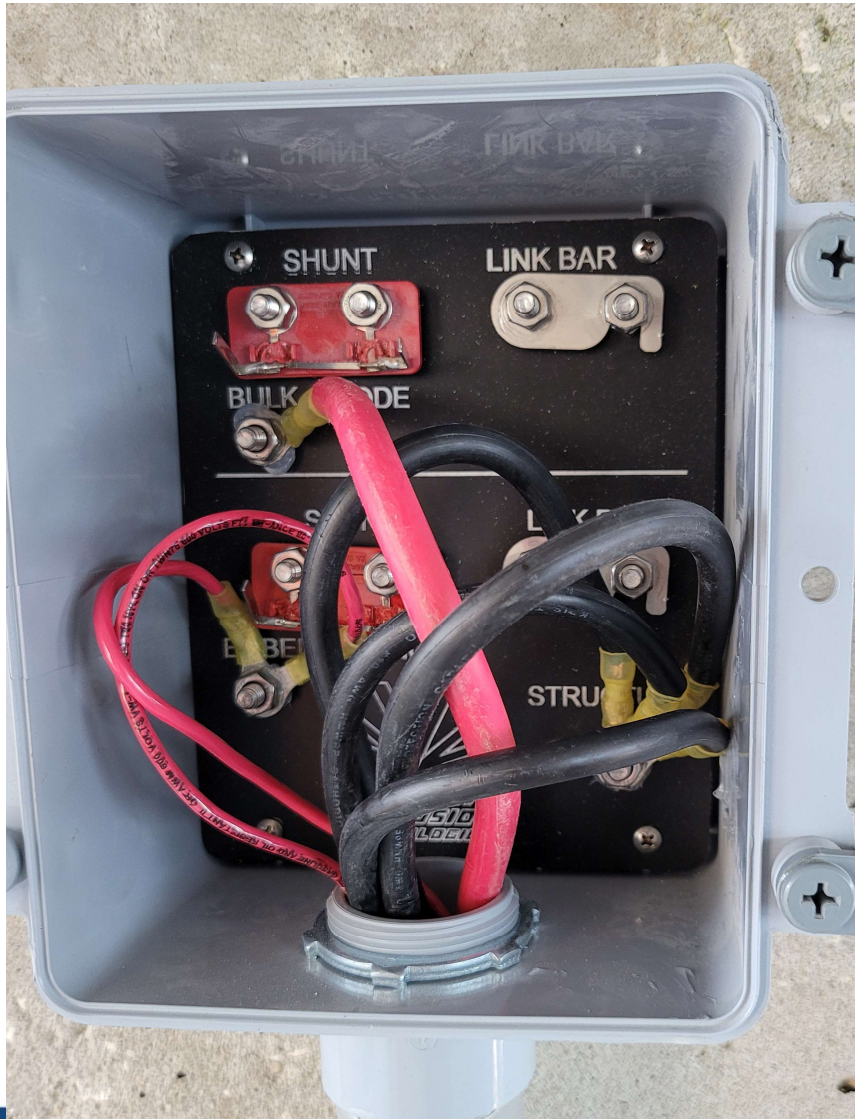


# Pile Repairs





# Pile Repairs





# Beam Repairs





# Beam Repairs



# Thank you!

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813-501-0050

# Questions?

