Improved Effectiveness of Corrosion Prevention and Control Systems for Hydraulic Steel Structures

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Project Team

- **ERDC-CERL**
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- **USACE Mobile District**
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- **USBR**
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Project Objectives

1. A better understanding of cathodic protection and coatings, and their interaction.
2. Development of integrated CPC monitoring system with predictive capability.
3. Holistic approach will provide an input to overall SHM system.

Big Payoffs!
What is CPC?

Corrosion Prevention and Control

Material Selection
1. Steel
2. Stainless Steel
3. Polymer
4. Etc.

Cathodic Protection
1. Impressed Current
2. Sacrificial Anode

Coatings
1. Coal Tar Epoxy
2. Epoxy
3. Vinyl
4. Urethane
“Why Do We Care?”

**Water Resources Infrastructure**

- Corps Navigation Mission:
  - Provide safe, reliable, efficient, effective and environmentally sustainable waterborne transportation systems for movement of commerce, national security needs, and recreation.

- Coastal Navigation
- Inland Navigation (12,000 miles of navigable waterways that touch 38 states)

**Economic**

- 565 million tons of freight valued at $214 billion (2012)

**Cost**

- $93,765,000 spent on corrosion M&R in FY15 (USACE)
- Reduced O&M costs

**Maintain National Assets**
Project Overview

Structural Health Monitoring System

Field Survey → Laboratory Research → Modeling → Data Acquisition & Analysis → Products & Guidance
Field survey shows every square inch of the structure is not protected from corrosion.

- Pintle socket during dewatering
- Coating failure
- Corrosion at Claiborne Lock due to inadequate CPC systems
- Corrosion around socket bolts
- Flame cut drain holes
- Weld corrosion
Laboratory Tests on Bare Steel Plates

Purpose: Use simple geometry in the lab to validate the modelling results.

Measurements taken using half-cell probe:
- Native Potential
- Instant On
- Instant Off Potential (IOP)

“T” Plate

Half Pipe
Bare Steel “T” Plate Schematic

4 separate impressed current anode locations: P1, P2, P3, P4.
Native Potential of Bare Steel “T” Plate

- Steel plate showing general corrosion and location of half-cell probe inside 280 gallon tank.
- Measurements taken after native potential stabilized.
- Cathodic protection is not active.

Average native potential of 720mV.
“On” Potential of Bare Steel “T” Plate

- DC potential was applied by mixed metal oxide anode with constant driving voltage of 20 VDC.

- Same half-cell measurement locations
- 4 different anode locations (P1, P2, P3, P4)
Polarization of Bare Steel “T” Plate

Results:

- Anode placement quantitatively shows an influence on the resulting surface polarization distribution.
- According to the 100 mV DC polarization criteria, it is shown that some locations are not protected.

Polarization = Instant Off Potential – Native Potential
Comparison between experimental measurements and model for “T” plate

Anode at 90 degrees (P1, P2).

Anode at 45 degrees (P3, P4).

NACE 850mV Criteria

Same Reduced Polarization Regions

Models generated using ANSYS Maxwell electromagnetic field simulation software.
Comparison between experimental measurements and model for “half-pipe” plate

IOP average (V)

Anode at 90°

NACE 850mV Criteria

Measurements

Model

Reduced polarization regions

Same Reduced Polarization Regions

Models generated using ANSYS Maxwell electromagnetic field simulation software.
Research Takeaway

- Effective application of cathodic protection is dependent on
  - Anode placement
  - Geometric complexity

- May also require changes to structure geometry
A state of the art sensor with built-in coupons will measure native potential and CP current density on a gate structure.

- Working with a commercial firm to develop a sensor which will measure the CP effectiveness and coating degradation simultaneously
  - A new application for lock gates.
Mobile District: Selden Lock and Dam on the Black Warrior River

Field Demonstration at Selden Lock and Dam

- Using rugged test probes, the field site will provide opportunity for long term data acquisition and analysis of CP system performance.
- Will be the first time in many years a sensor will be installed on a lock gate to monitor rectifier voltages/currents, and anode currents.

Installation on upper gates while lower gates are replaced.

Sensor located between anodes and below water level.
Field Demonstration System Schematic

One part of the holistic approach to Structural Health Monitoring of HSS.
Products & Guidance

Journal article: “Combined Structure Geometry and Anode Placement Effects on Cathodic Protection Effectiveness”

• Inspection procedures for both CP protected components and non-CP protected components
• System specifications
• Recommended updates to Corps of Engineers guidance documents such as EM 1110-2-2704
• Guidance for training
Conclusions

- Experiment and model provide insight into reduced polarization regions which influence the effectiveness of CP systems on complex structures.
- Field site data acquisition will confirm the presence of adequate or inadequate CP on a real gate with impress current CP.
- Updates to current guidance documents as well as other research results will be published.
- Improved effectiveness of CPC systems on hydraulic steel structures will help ensure that every square inch of the structure is cathodically protected.