

# CONCRETE REINFORCEMENT – CORROSION RESISTANT ALTERNATIVES



Florida Atlantic University

Department of Ocean Engineering



Florida Department of Transportation

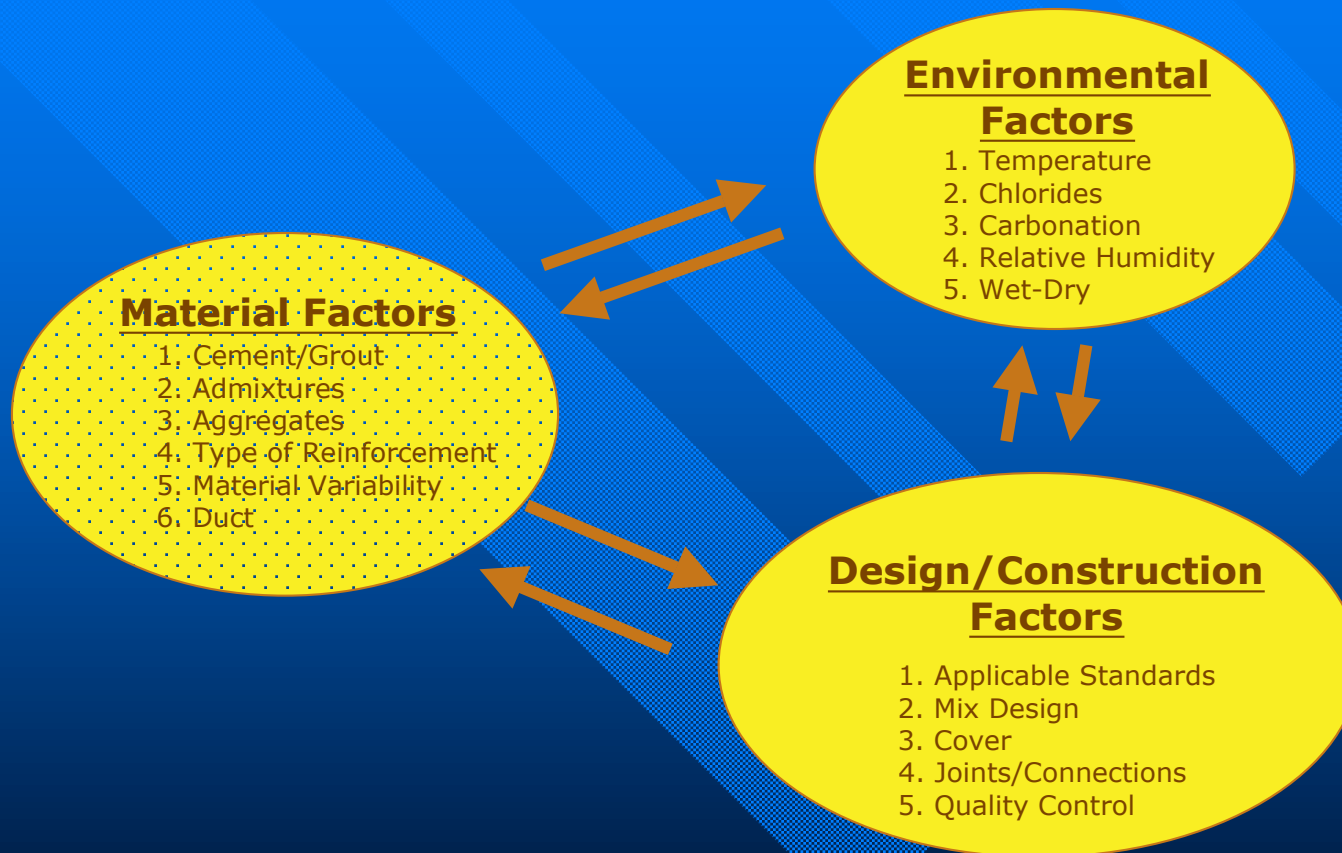


U.S. Department of Transportation

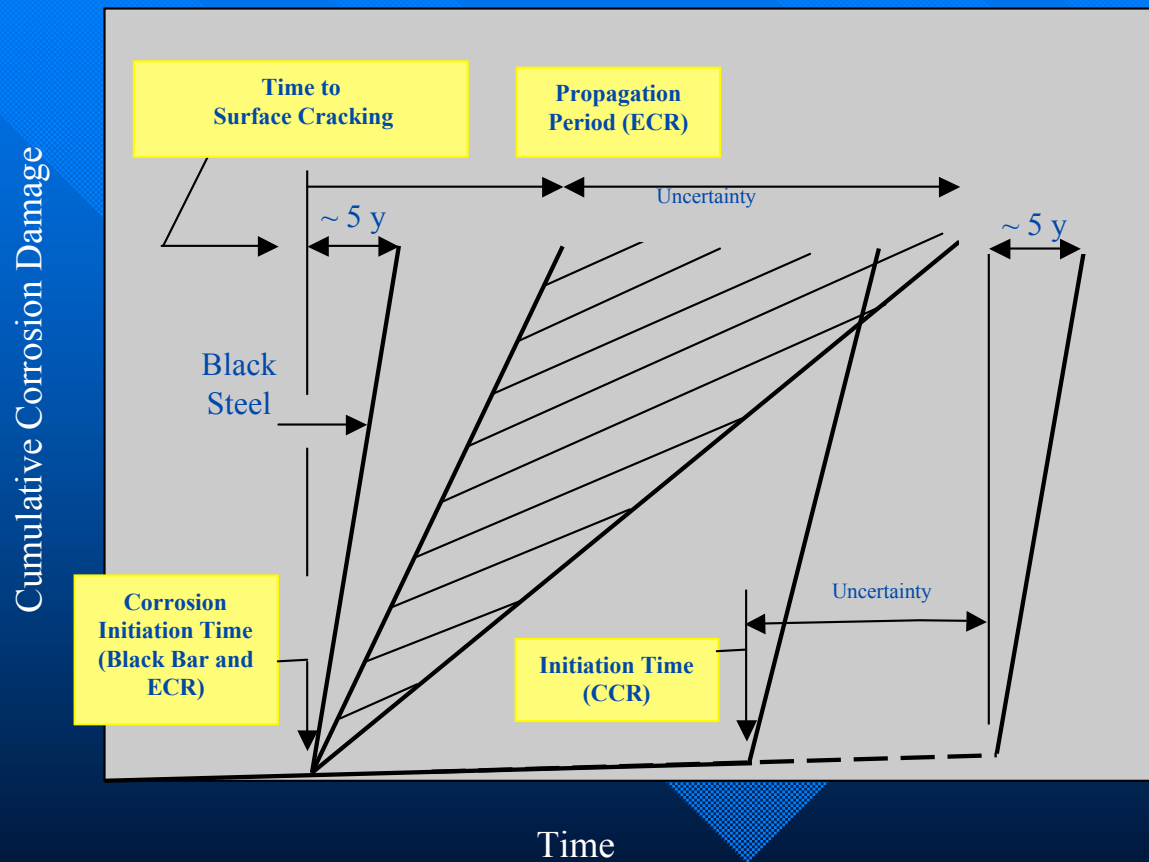
Federal Highway  
Administration

# Overview of Factors Affecting Durability of Concrete Bridge Structures

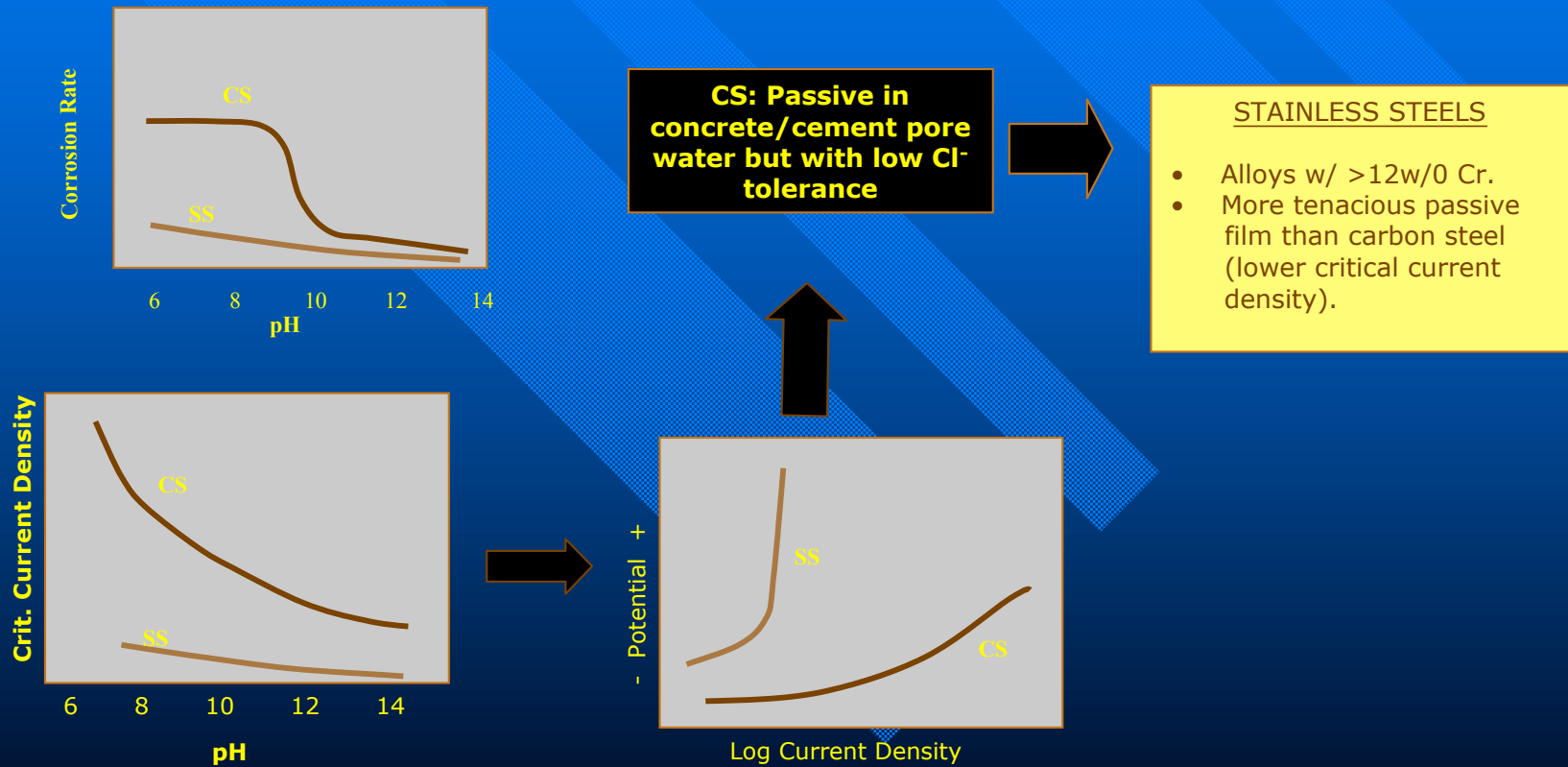
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# The Case for Corrosion Resistant Reinforcement



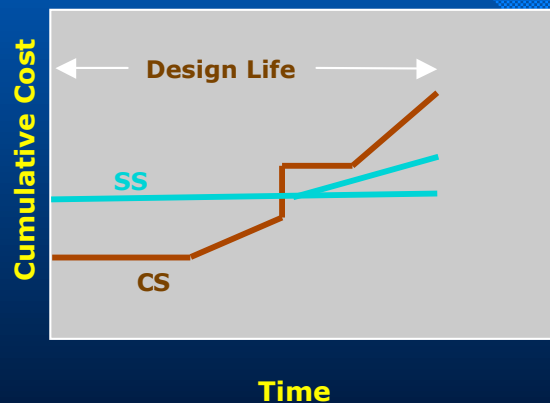
# The Case for Corrosion Resistant Alloys As Reinforcement



## Project Objective and Concerns

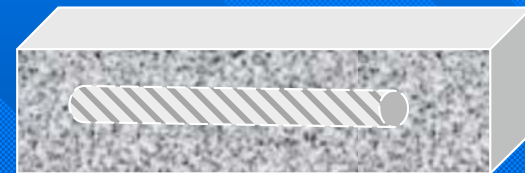
**Objective:** Characterize the performance of different corrosion resistant reinforcements in exposures relevant to northern and coastal bridge applications.

### Life Cycle Cost



### Susceptibility to Localized Corrosion

1. Pitting.
2. Crevice Corrosion.



### Concerns in Addition to Cl-

1. Carbonation.
2. Storage/Atm. Corrosion.
3. Galvanic Corrosion.
4. End Connections (Clad).
5. Torch Cuts/Welds.
6. Penetrations.
7. Product Variability.

# Candidate Alloys

- Type 304 SS
- Type 316 SS
- Type 2205 SS
- Type 2201 SS<sup>+</sup>
- Type 3Cr12 SS
- Clad Type 316 SS
  1. Stelax\*
  2. SMI\*
- MMFX-II\*<sup>+</sup>
- Black Bar

**Note: Default testing condition is with bars as-received.**

**\* Testing in the surface abraded and surface damaged conditions.**

**+ Testing in the pickled condition.**

# Project Tasks

## Short-Term Experiments:

- AST-1      Wet-Dry Exposure
- AST-2 A    Potentiostatic Tests
- AST-2 B    Potentiodynamic Polarization Scans
  
- Atmospheric Exposures

## Long-Term Experiments:

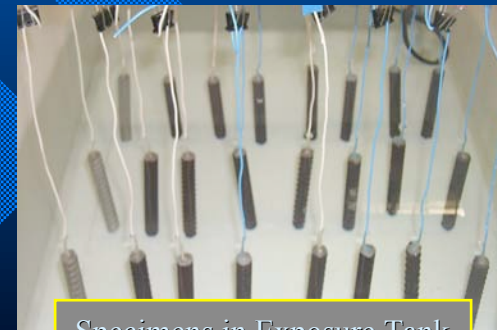
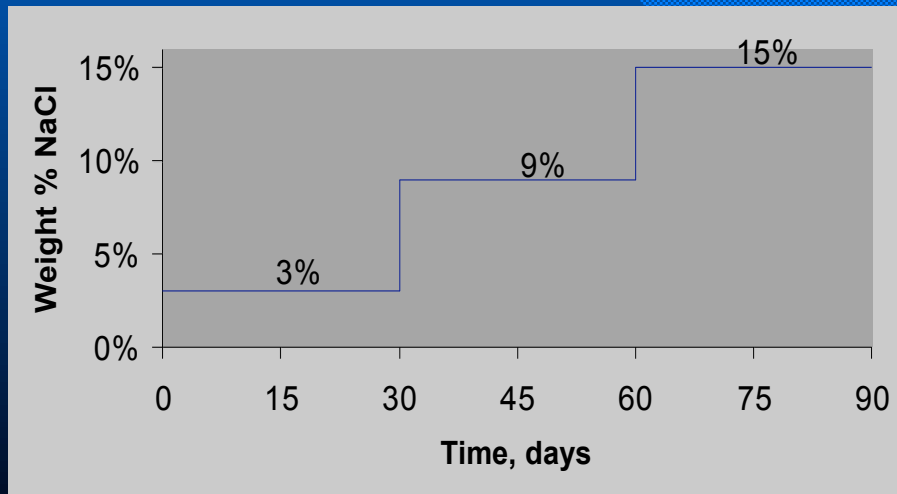
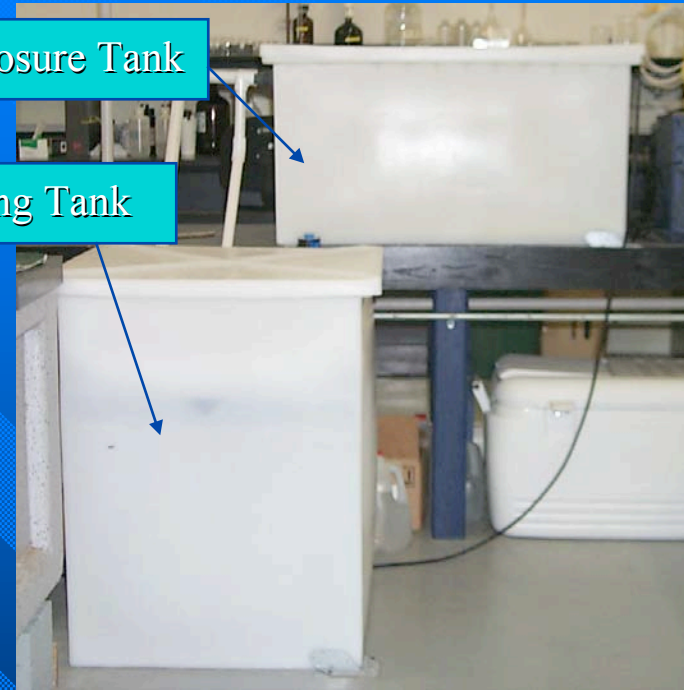
- Reinforced Concrete Slab Exposures

## AST-1 Wet-Dry Experiments (Modeled after Previous FHWA/WJE Program)

- Multiple 152 mm long #5 rebar specimens in as-received condition (selected materials bent, abraded, surface damaged, and pickled).
- Repetitive 1.75 hrs wet – 4.25 hrs dry cycle (four cycles per day) in simulated pore water (pH~13.2).
- Incrementally increasing NaCl concentration with time.
- Total exposure duration 84 days.

Exposure Tank

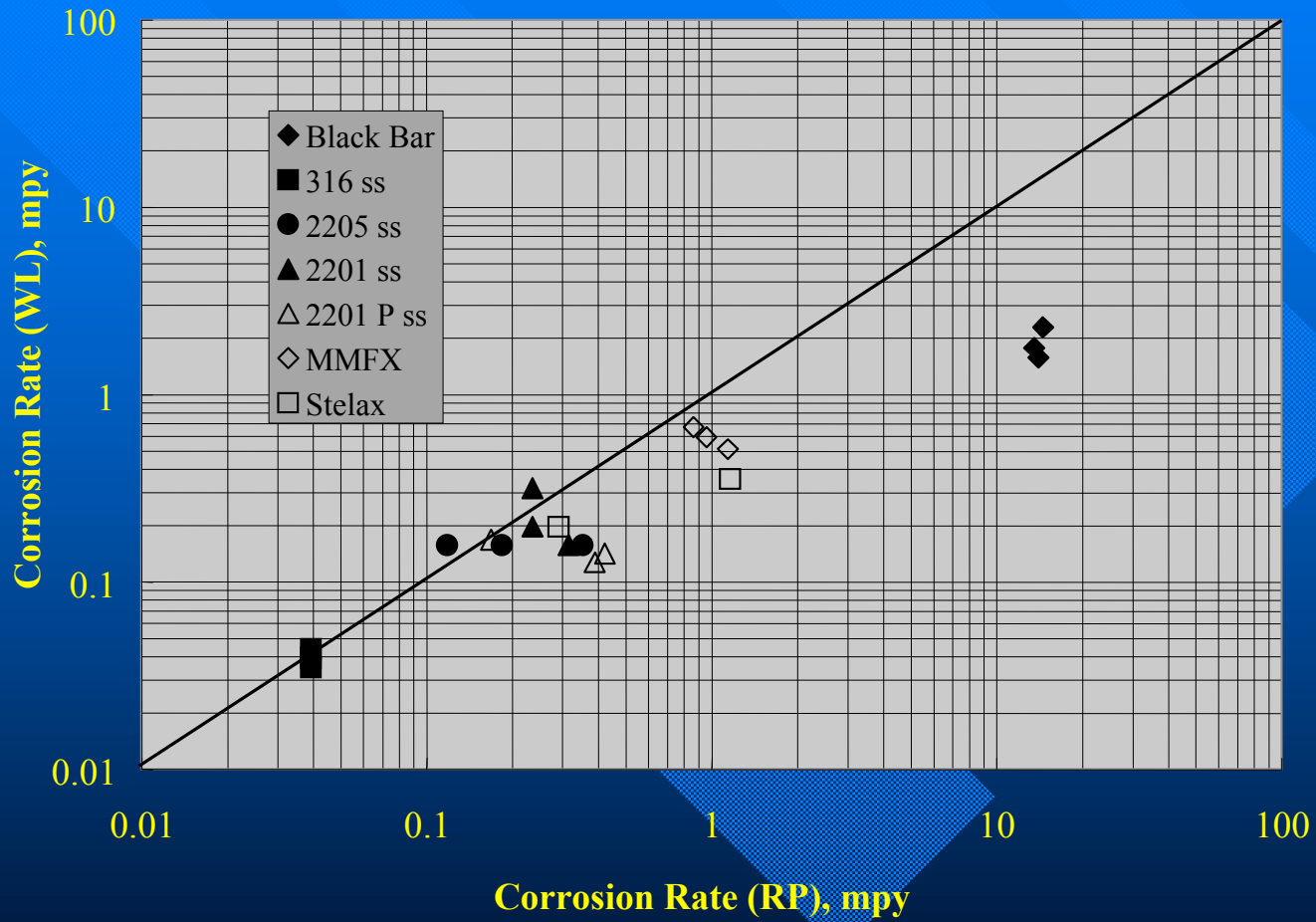
Holding Tank



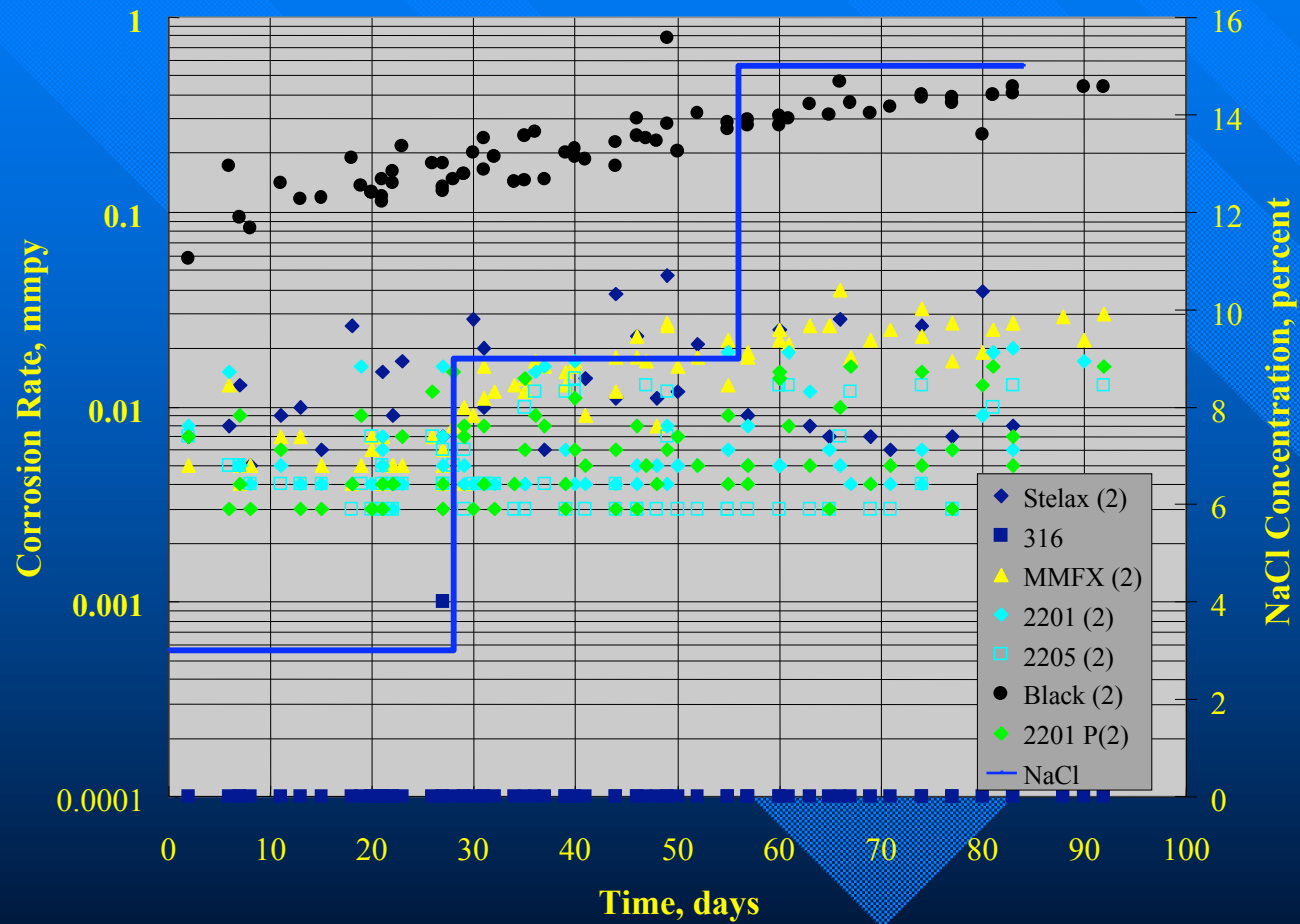
Specimens in Exposure Tank



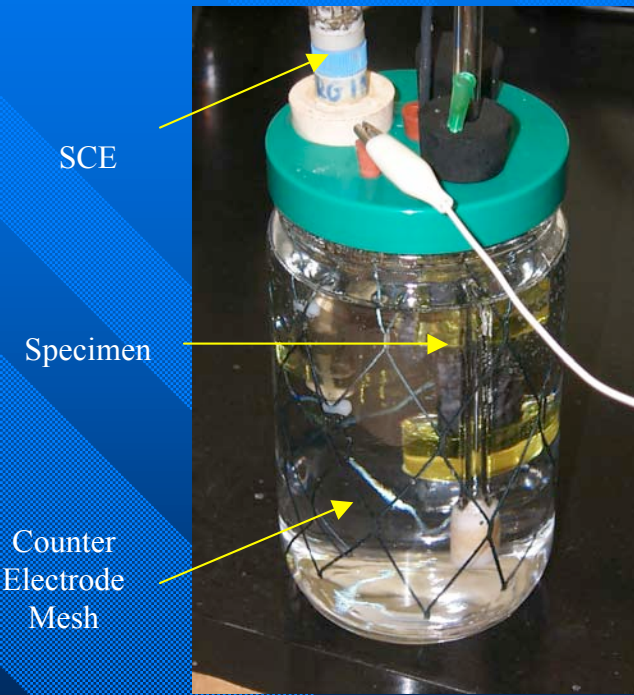
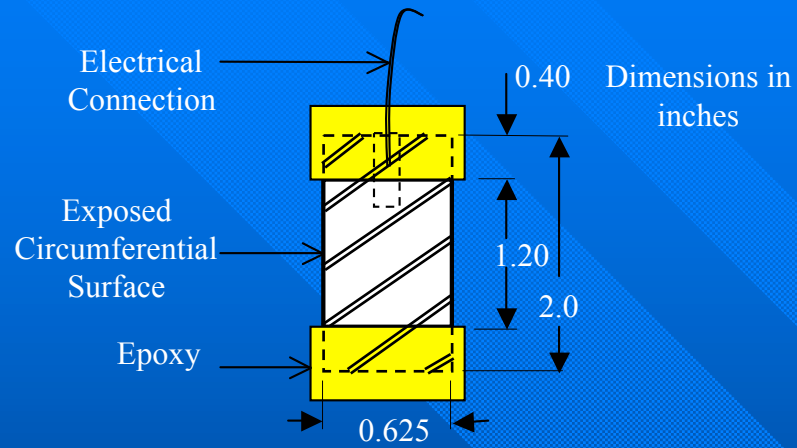
# AST-1 Data Correlation



# Corrosion Rate versus Time for Straight Bars: AST-1

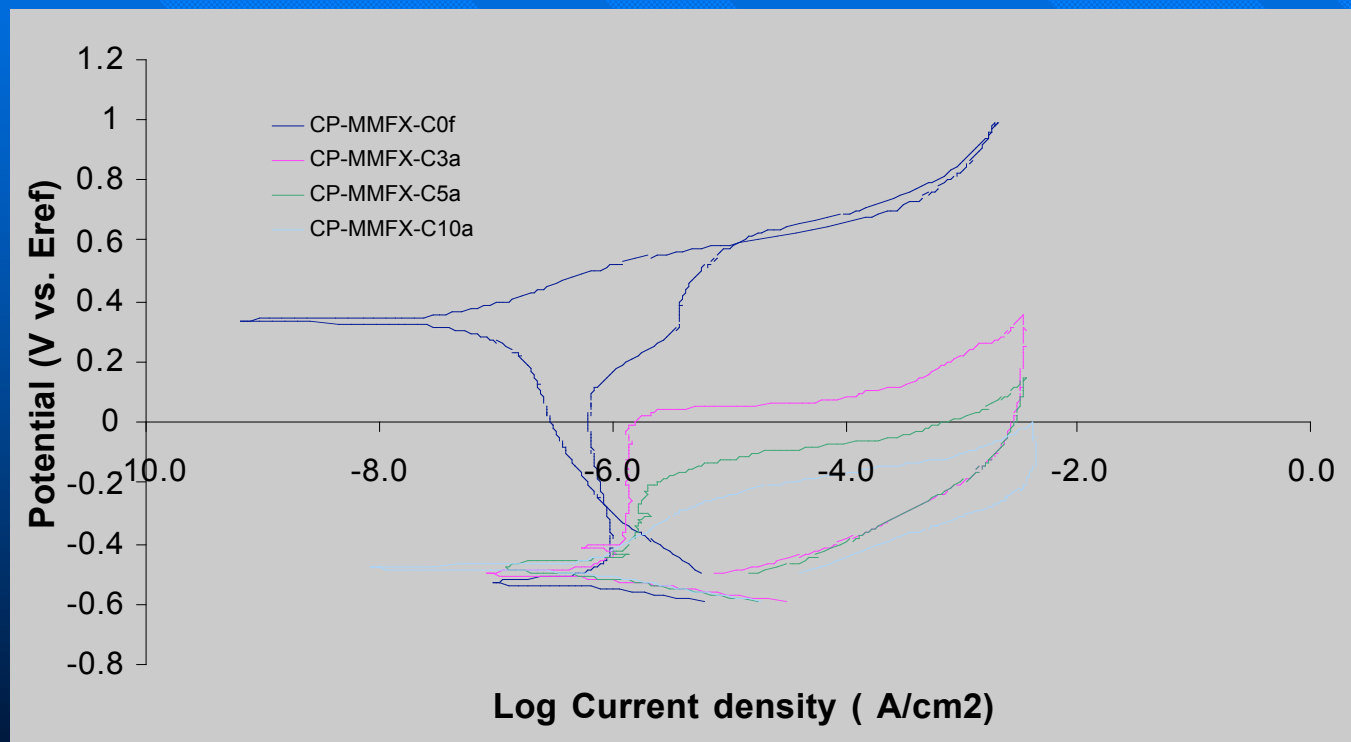


# AST-2 Specimen and Test Cell

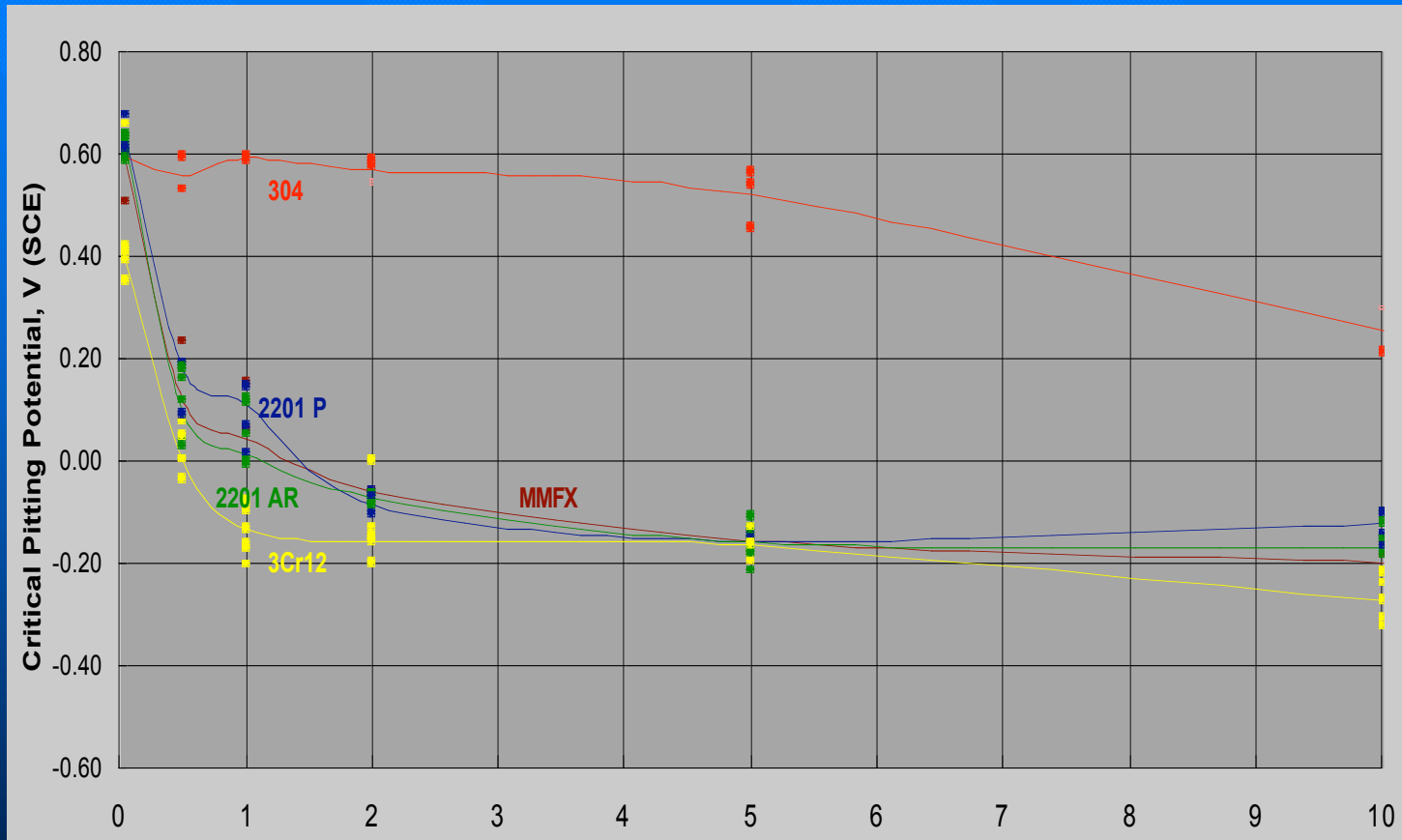


## AST-2 Potentiodynamic Polarization Experiments

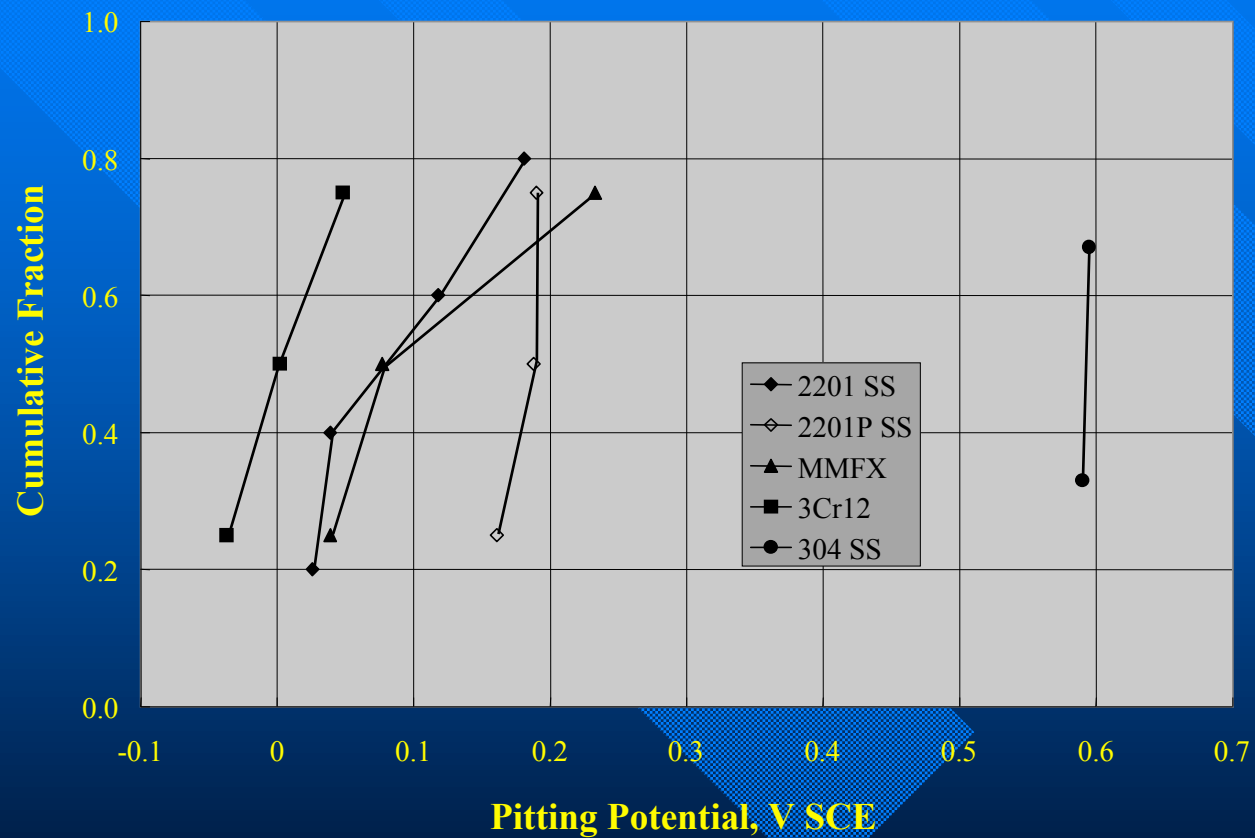
- Anodic scans performed on individual candidate specimens in saturated  $\text{Ca(OH)}_2$  with various chloride concentrations.



# AST-2B Potentiodynamic Polarization Scan Results



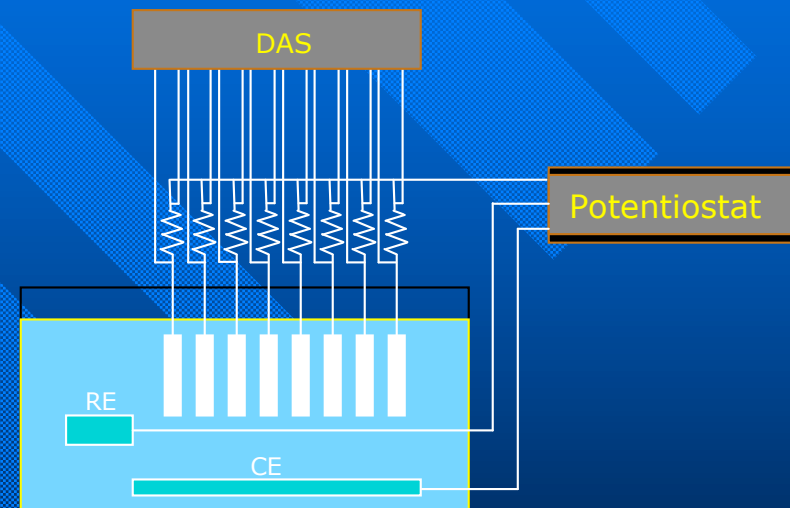
# Distributed Nature of the Critical Pitting Potential



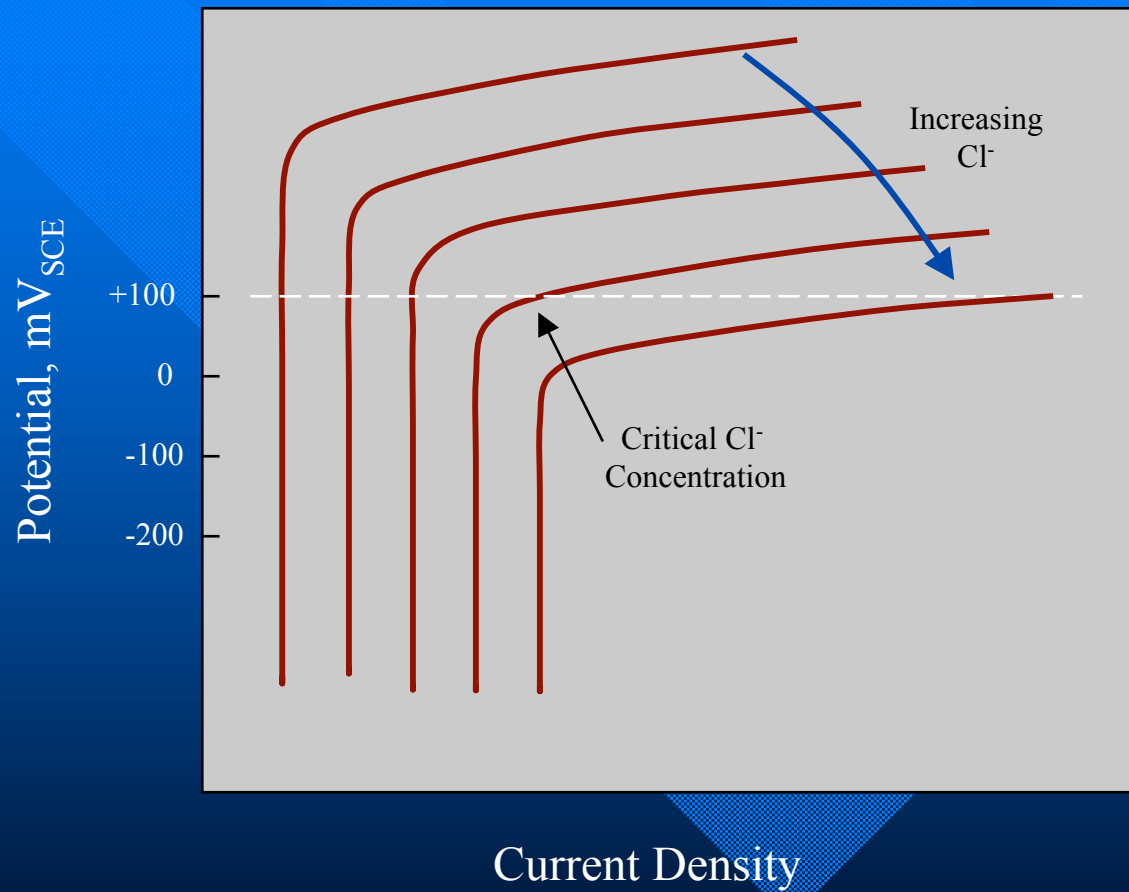
## Corrosion Resistance Reinforcement As an Alternative to Conventional Structural Steel for Corrosive Applications – AST-2 (Electrochemical Testing)

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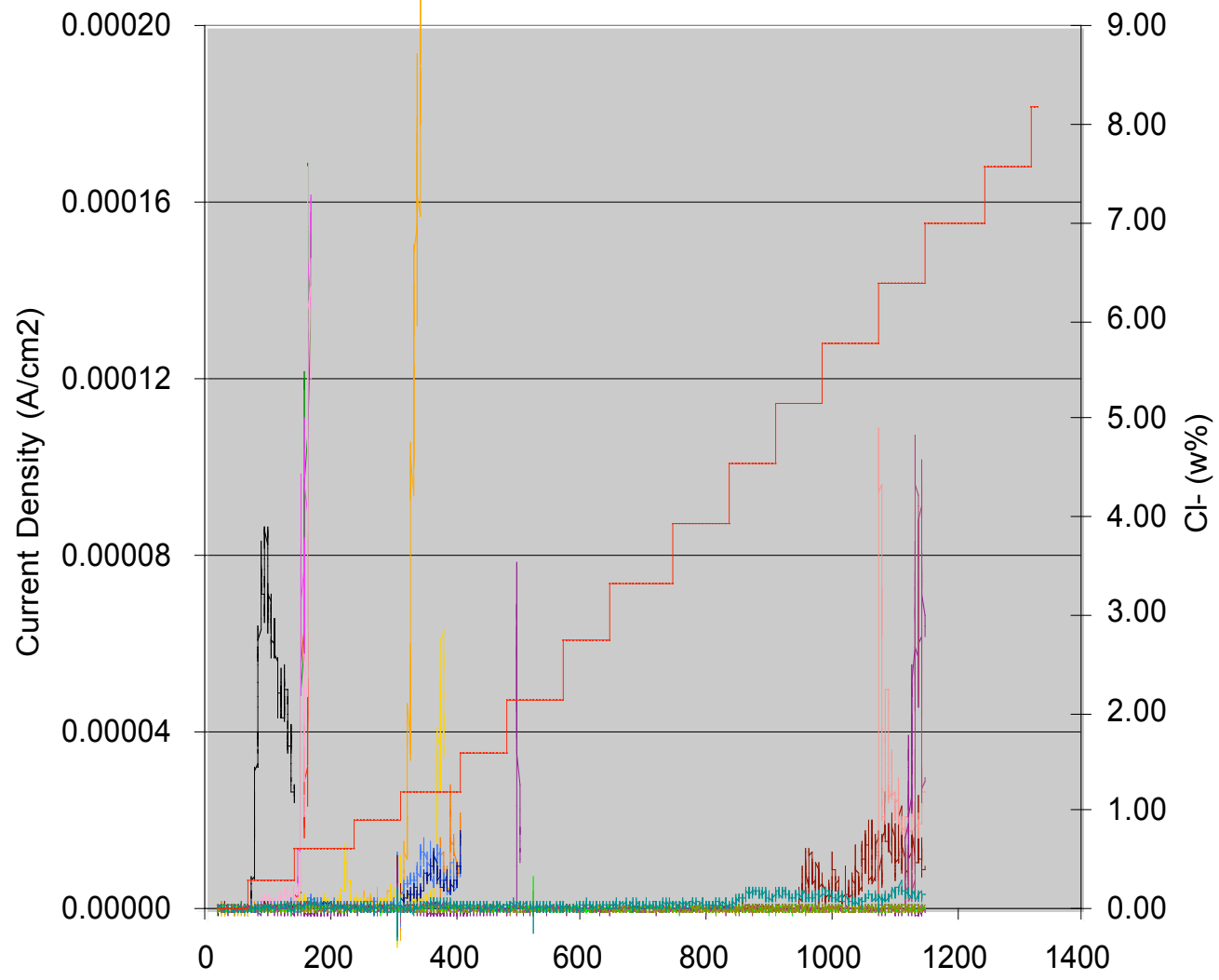
- A. Triplicate specimens in SPW+[Cl<sup>-</sup>]<sub>low</sub> at RT and constant potential. Monitor applied current. Incrementally increase [Cl<sup>-</sup>]. Retrieve bars once critical chloride concentration is reached.
  - B. Repeat (A) at pH = 9.
  - C. Repeat (A) and (B) at 40°C.
  - D. Correlate w/ results from 1) WJE test program, 2) AST-1, and 3) LLT.
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# AST-2 Rationale





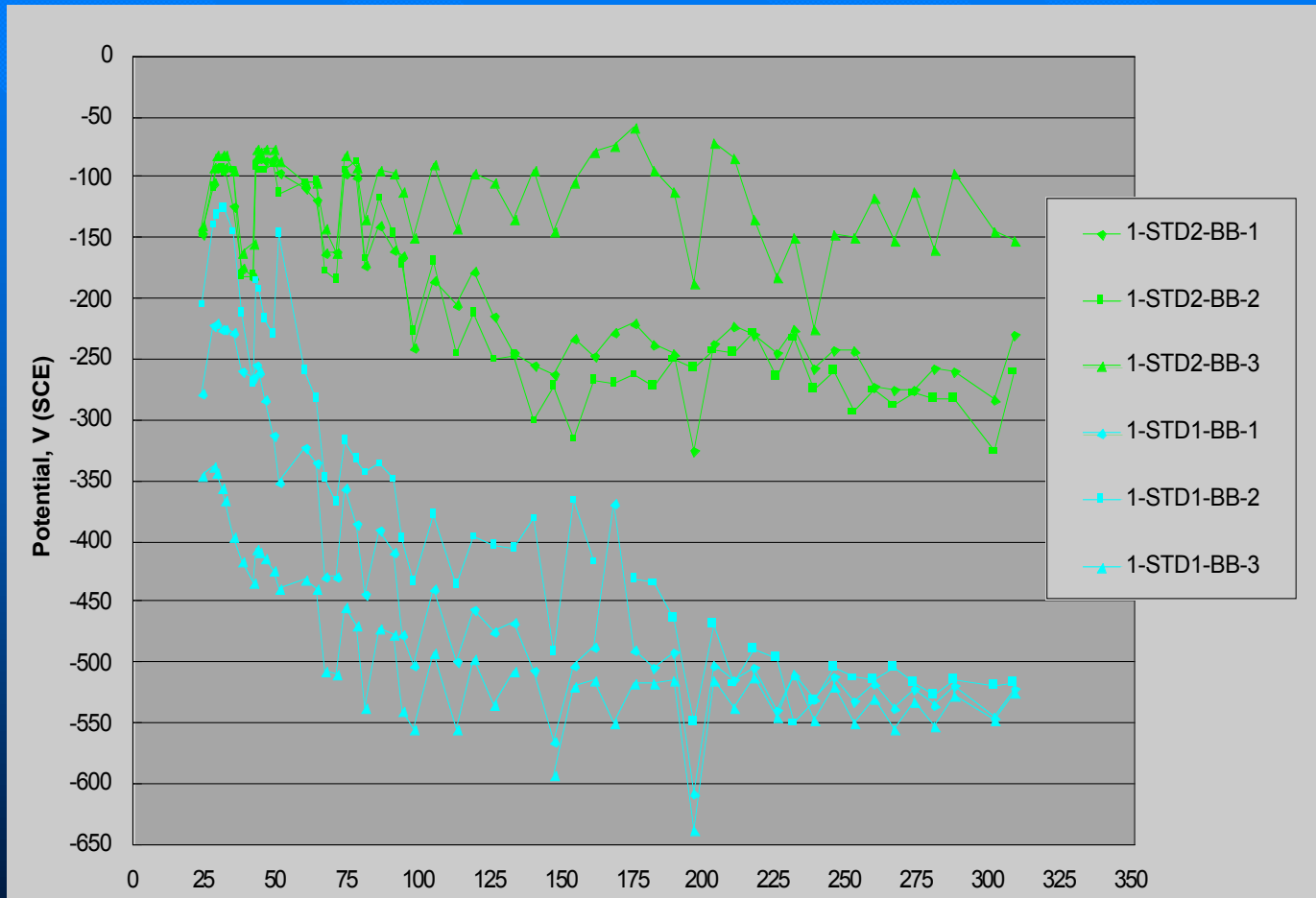


- BB
- 3Cr12
- MMFX B
- MMFX B D
- MMFX B A
- MMFX A
- MMFX
- MMFX D
- 2201
- 2201 P
- Stelax D
- SMI A
- SMI D
- SMI
- Stelax B
- Stelax A
- Stelax
- 316
- 304
- 2205
- Cl<sup>-</sup> (w%)

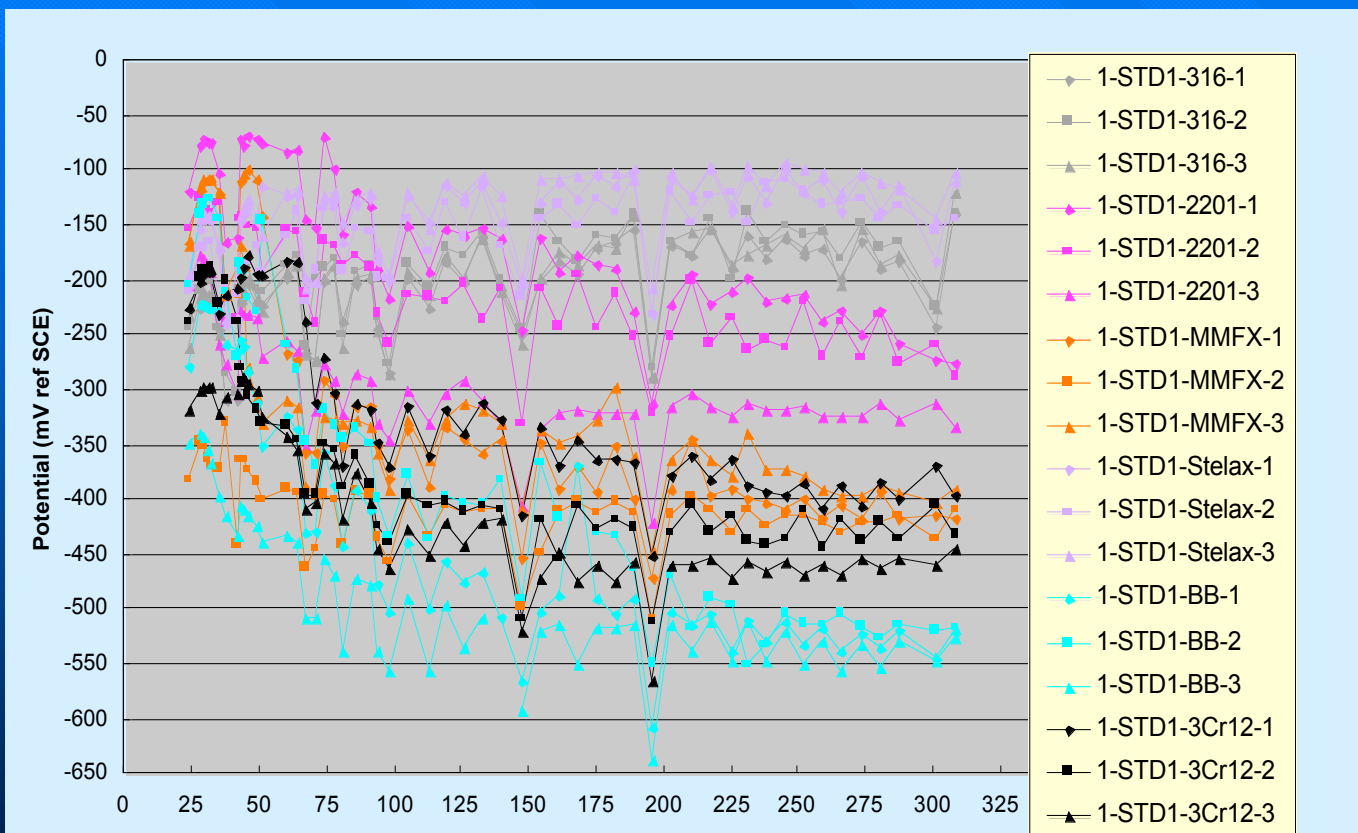
## Test Yard Exposure of Deck Slabs



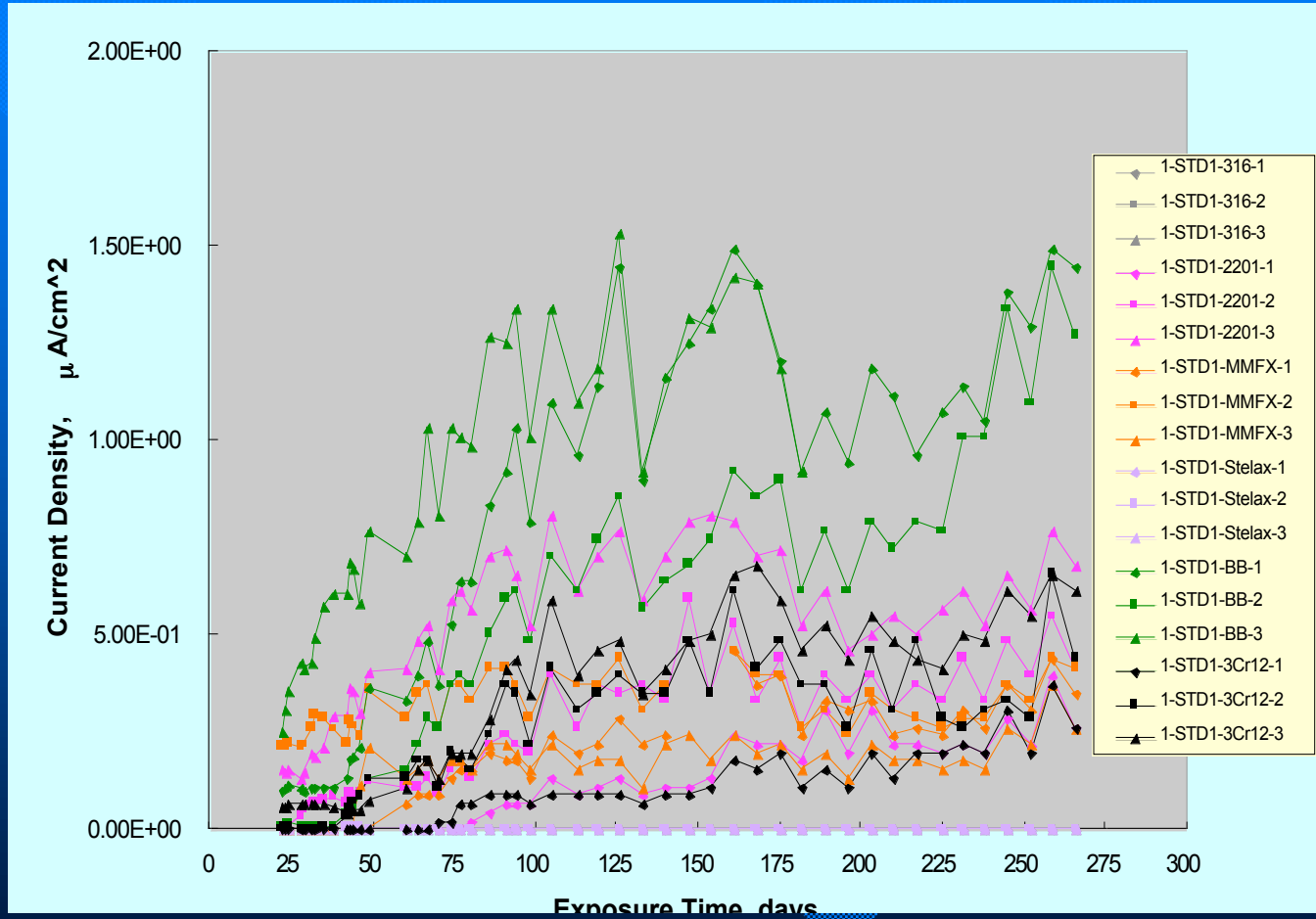
# Potential Data, Black Bar Set 1



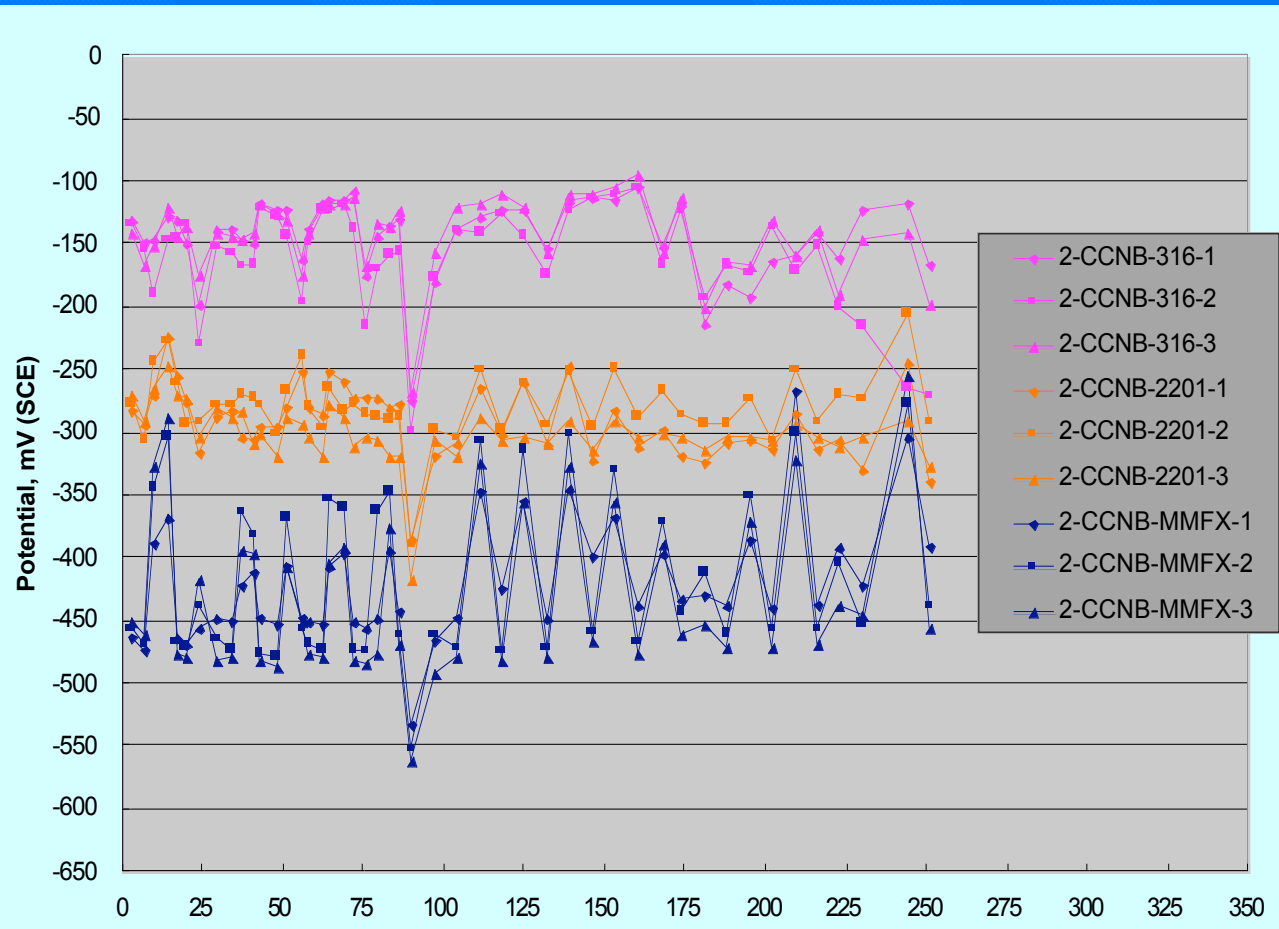
# Potential Data, Set 1 Straight Bars



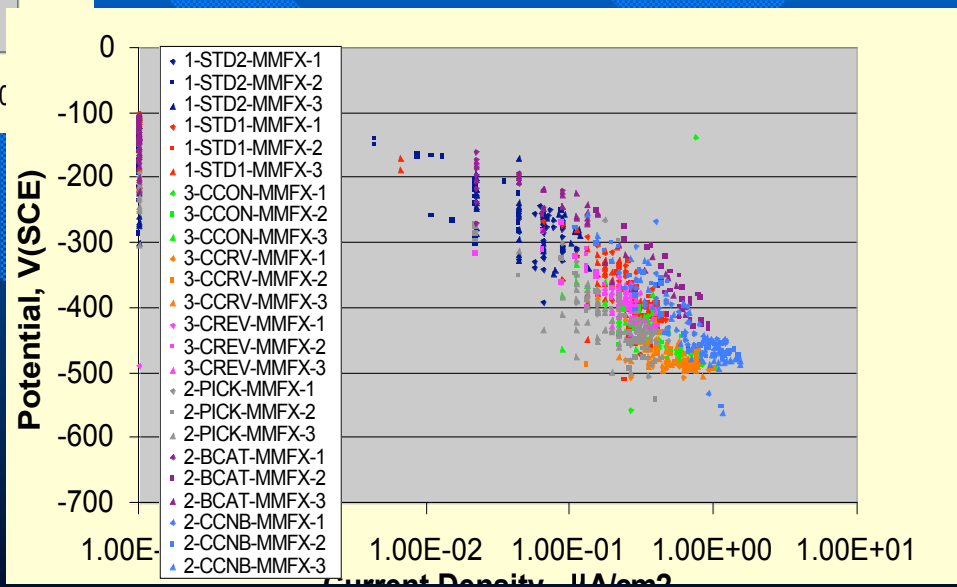
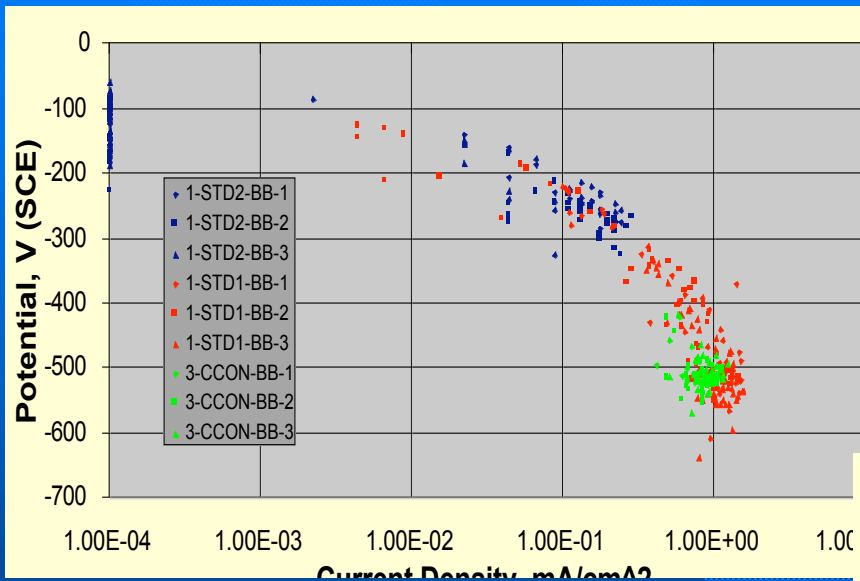
# Current Density Data, Set 1 Straight Bars



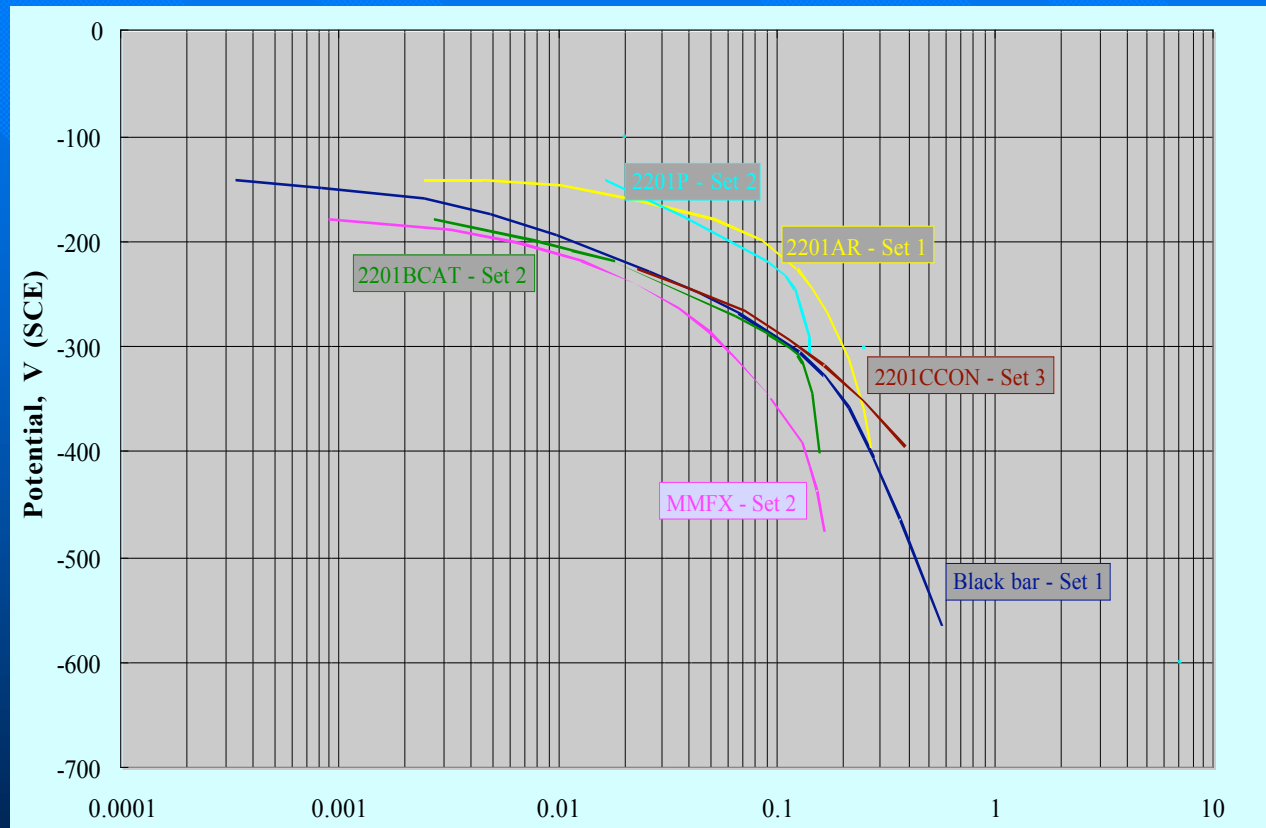
## Potential Data, Set 2 Cracked Concrete



# Potential-Current Density Format



# Potential – Current Density Trend





## Present Project Status

- Approximately 3 years into a six year effort.
- Atmospheric exposures to be initiated.
- AST-1 and -2A exposures to be completed.
- AST-2B exposures completed.
- Slab monitoring to continue.
- Correlations between accelerated, short-term exposures and long-term concrete slab exposures to be developed.
- Life cycle modeling as a function of HPMR type and exposure severity to be developed.