Evaluation of Reinforcing Bar Corrosion Performance

Dr. Matt O'Reilly
University of Kansas
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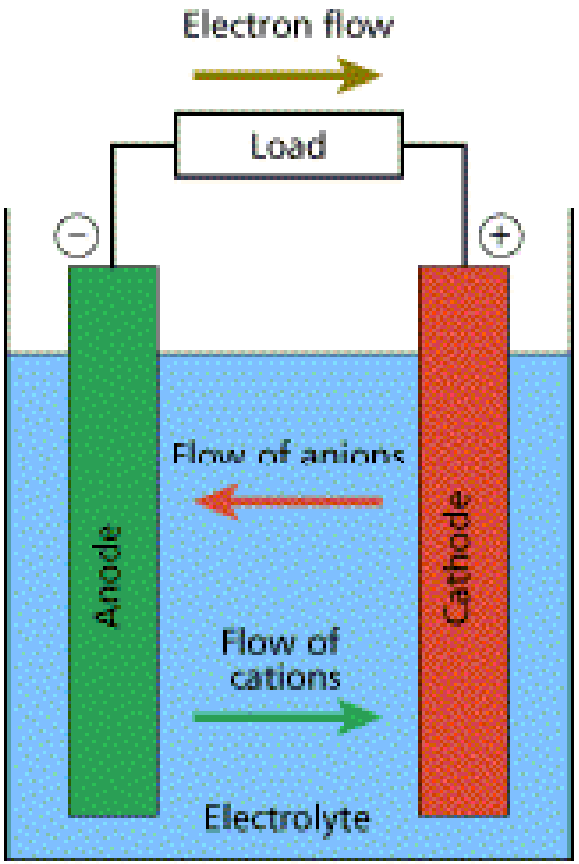
Outline

- Background
- Corrosion Resistance Testing
  - Rapid Macrocell Test
  - Cracked Beam Test
- Selected Results

Introduction to Corrosion

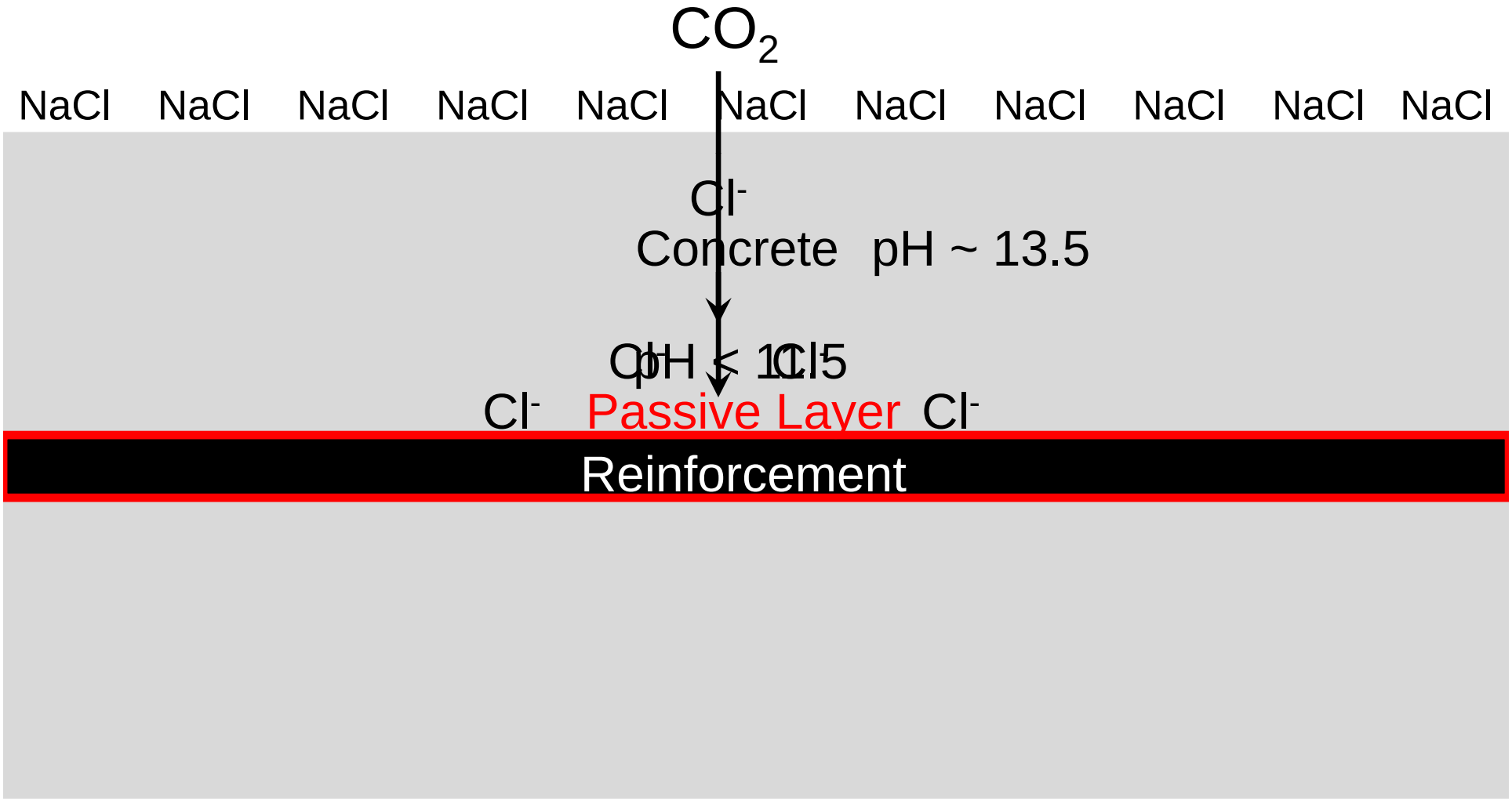
- Electrochemical process
  - Anode
    - Produces electrons
    - Location of corrosion
  - Cathode
    - Consumes electrons
  - Electrical connection
  - Electrolyte



Corrosion on Bridge Decks

- Significant increases in corrosion-related damage on bridge decks were first observed in the late 1960s and early 1970s.
- Corrosion accelerated by increasing use of deicing salts.

Corrosion of Steel in Concrete



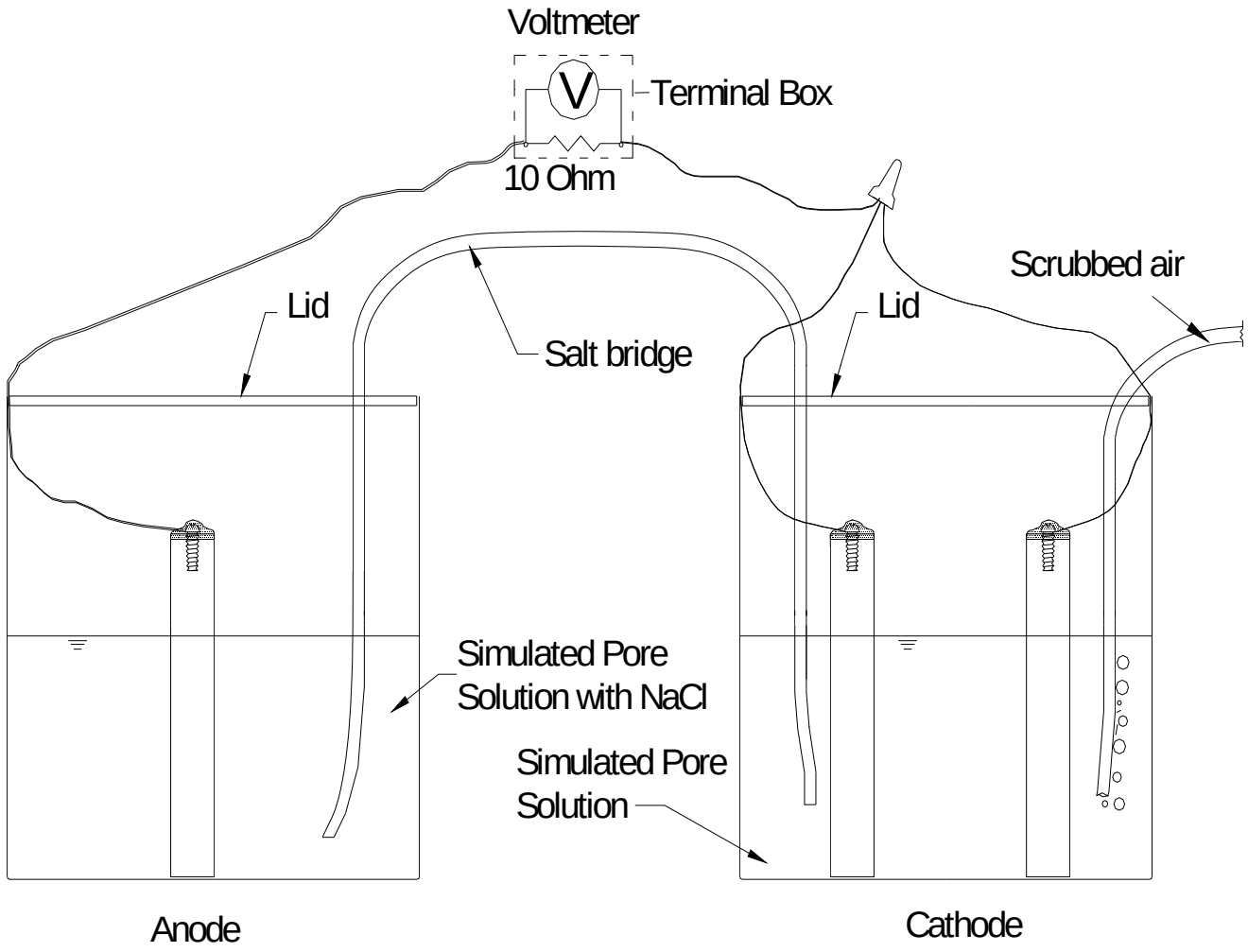
Corrosion Resistant Reinforcing Bars

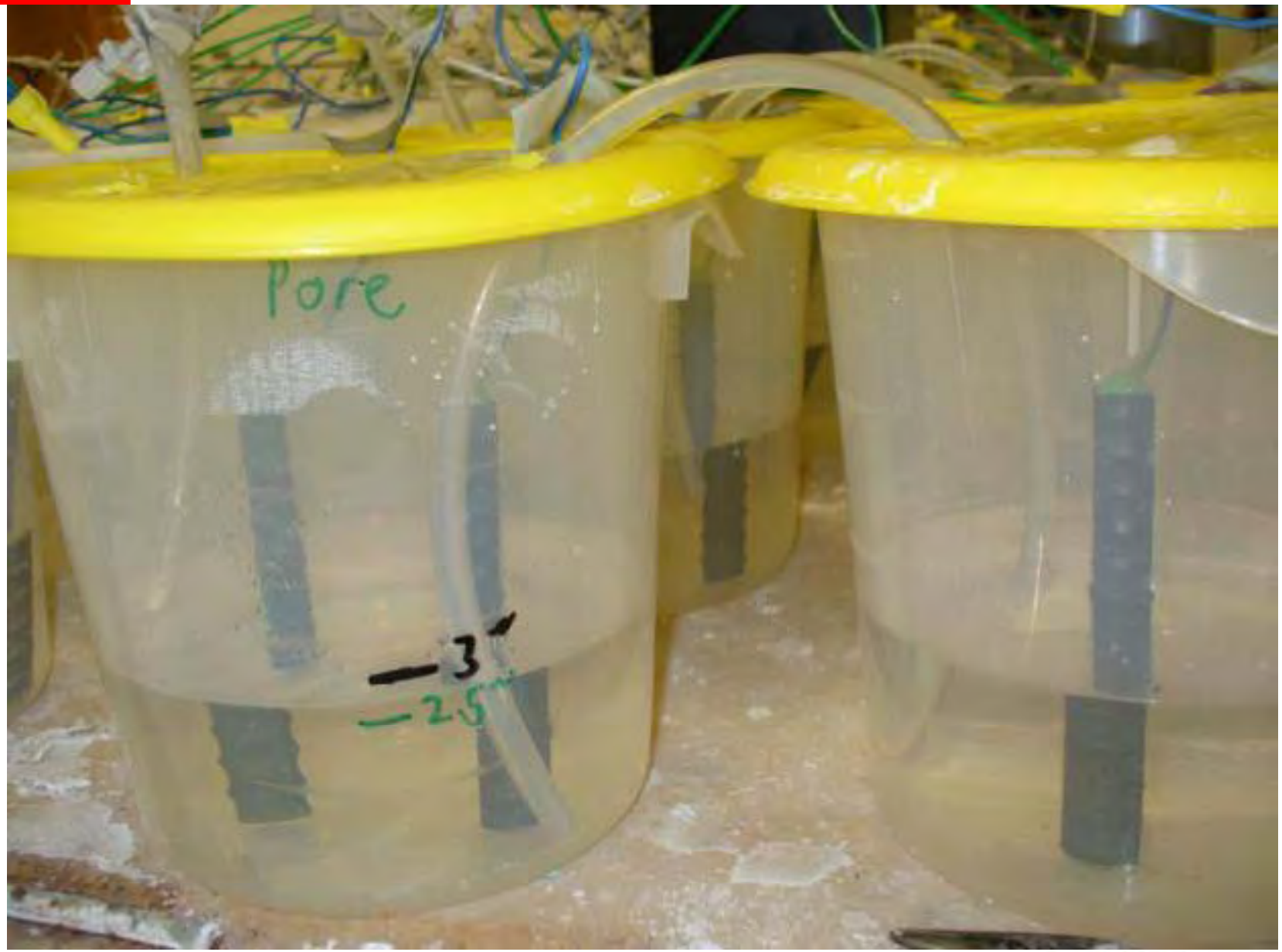
- Reinforcement can exhibit improved corrosion performance by:
  - Increasing the critical chloride corrosion threshold relative to conventional reinforcement
  - Decreasing the corrosion rate after corrosion initiation relative to conventional reinforcement

Test Methods

- Corrosion Initiation
  - Lab specimens with uncracked concrete (Southern Exposure)
  - Field tests
- Corrosion Rate
  - Southern Exposure
  - Cracked beam (ASTM A955)
  - Rapid Macrocell (ASTM A955)
  - Field tests

Rapid Macrocell Test

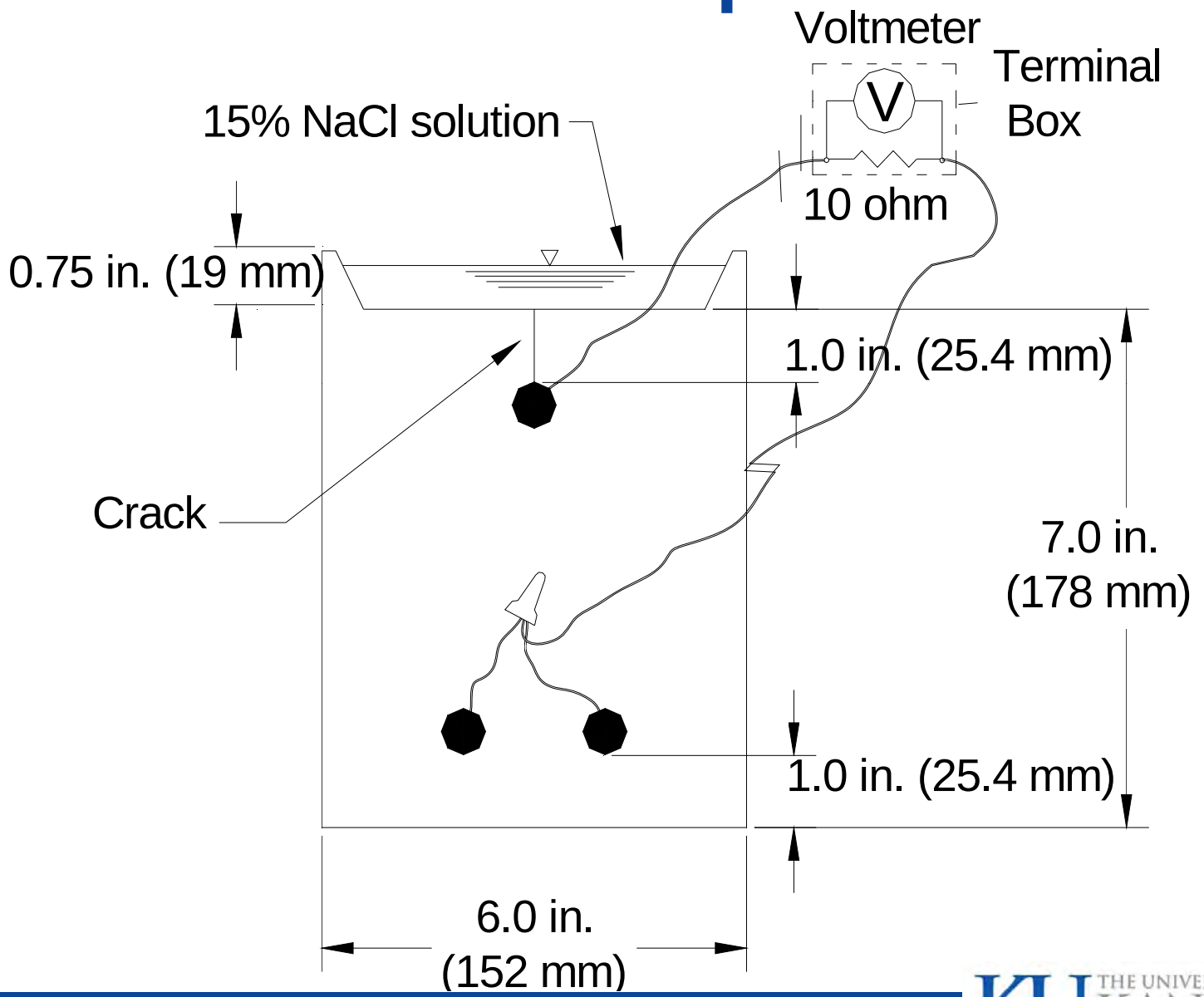



Pore
3"
2.5"

Rapid Macrocell Test Measurements

- Voltage drop
- Corrosion potential
- Measured daily for the first week, then weekly thereafter
- 15 week test; solution changed every 5 weeks

Cracked Beam Specimen



Cracked Beam Test Measurements

- Voltage drop
- Resistance
- Corrosion potential
- Measured weekly
- 60 week test with alternating 12-week cycles (KU extends test to 96 weeks)

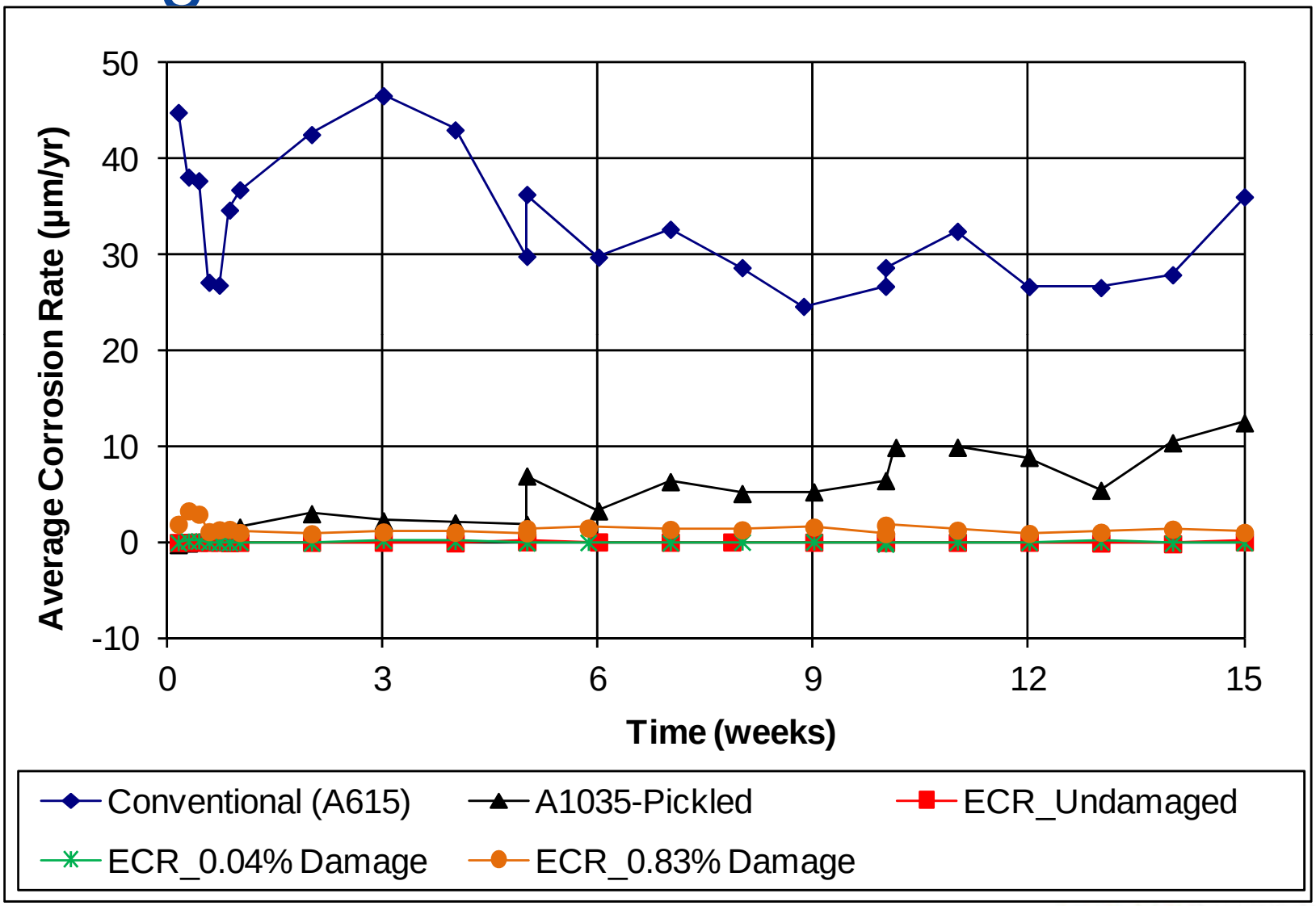
ASTM A955

- Qualify stainless steel based on corrosion rate limits in two tests:
  - Rapid Macrocell
    - Individual Corrosion Rate ≤ +0.50 µm/yr
    - Average Corrosion Rate ≤ +0.25 µm/yr
  - Cracked Beam
    - Individual Corrosion Rate ≤ +0.50 µm/yr
    - Average Corrosion Rate ≤ +0.20 µm/yr

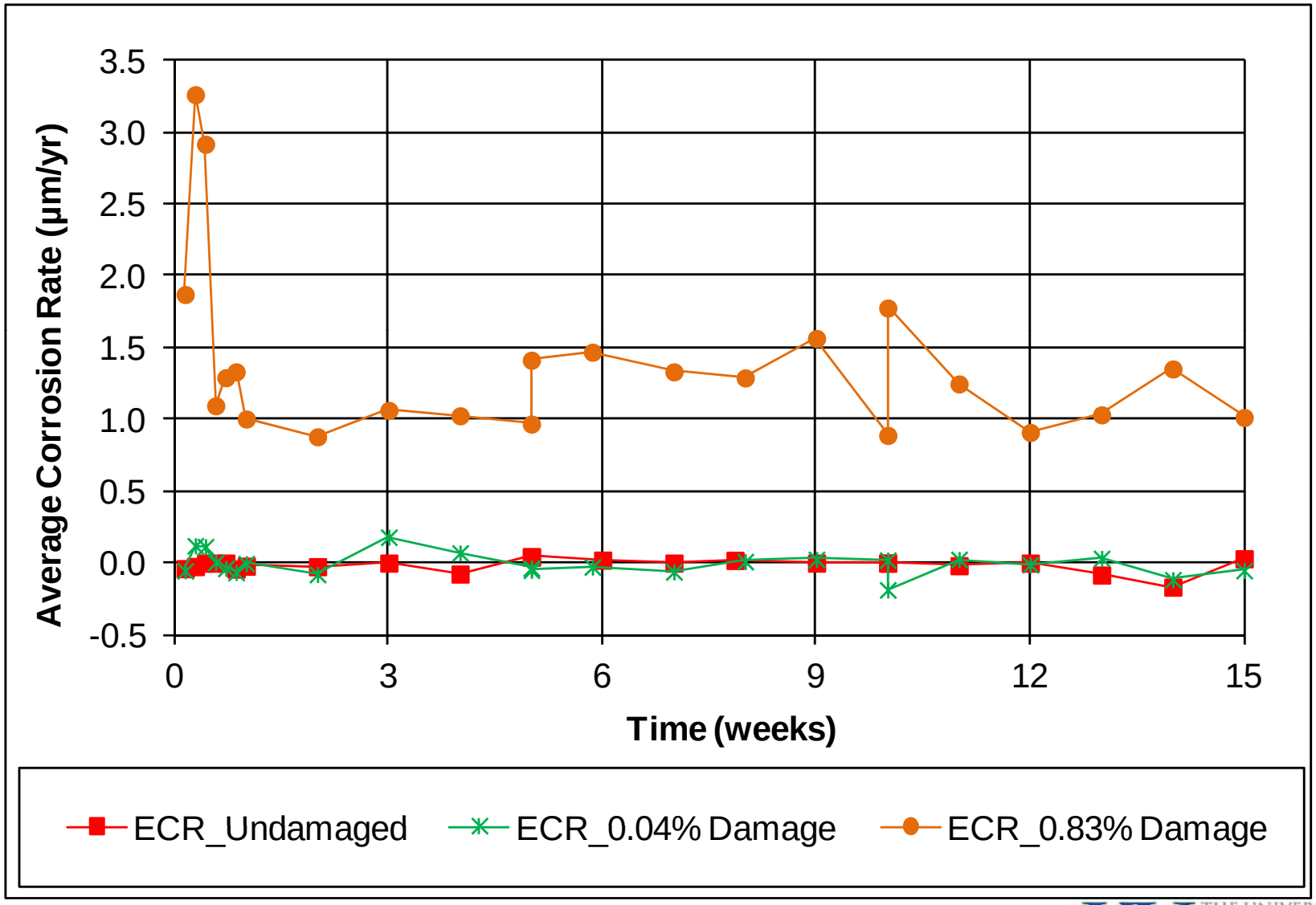
Selected Rapid Macrocell Results

- Conventional, ECR, A1035 Steel, 2205 Stainless Steel
- Stainless Steels
  - Effect of Pickling Stainless Steel Corrosion Resistance
  - Effect of Solution pH on Stainless Steel Corrosion Resistance

Average Corrosion Rates



Corrosion Rates-Different Scale

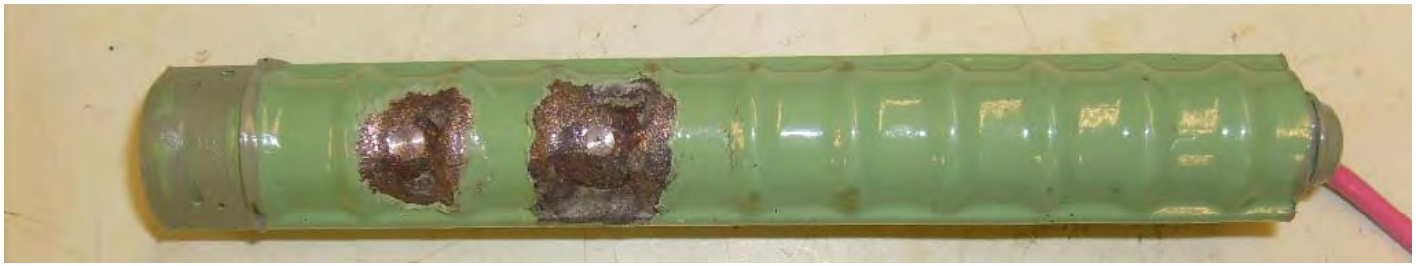


Conventional Reinforcement

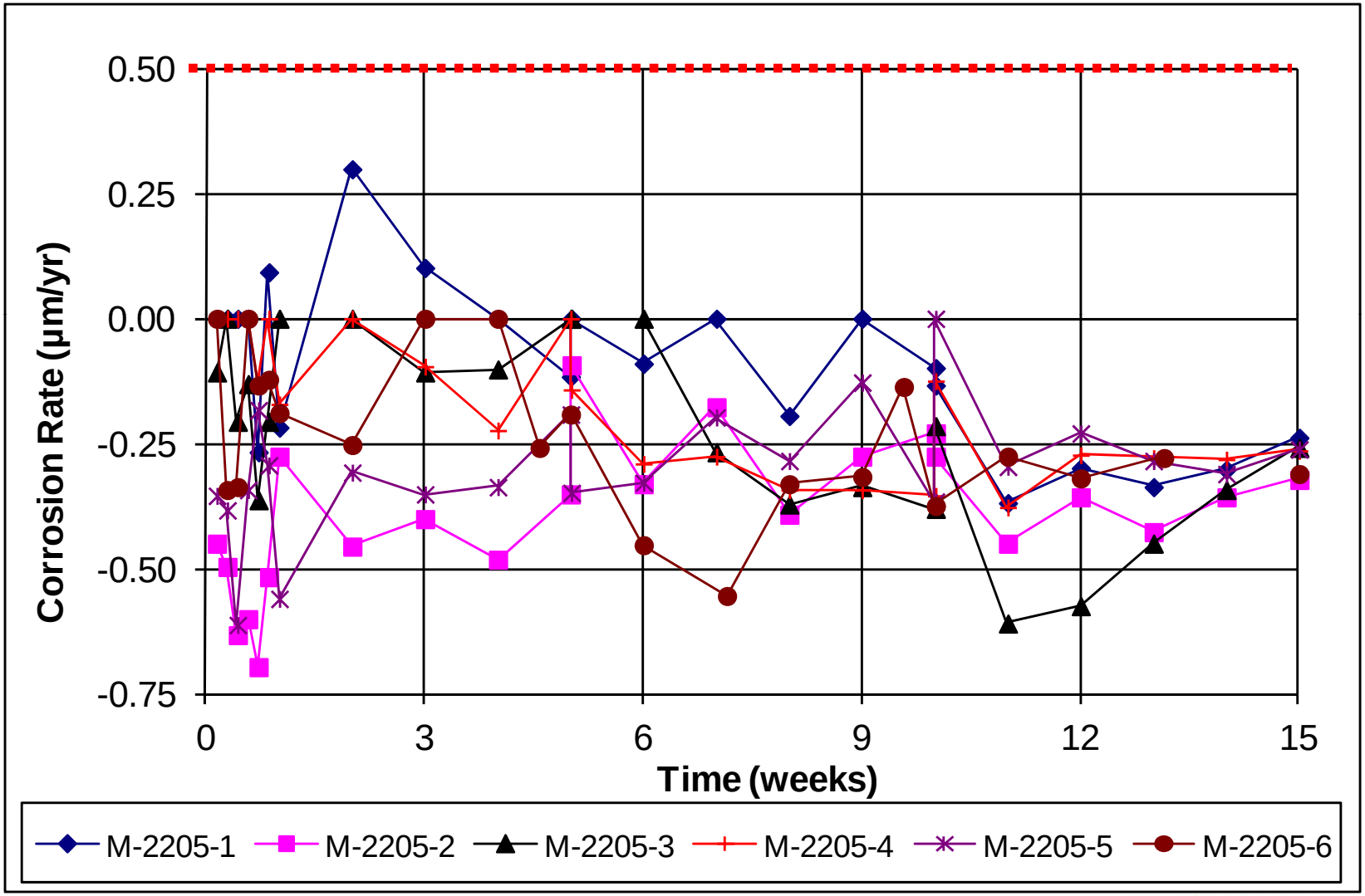
A1035-Pickled Reinforcement

Undamaged ECR

ECR - 0.83% Damage



2205 Stainless Steel



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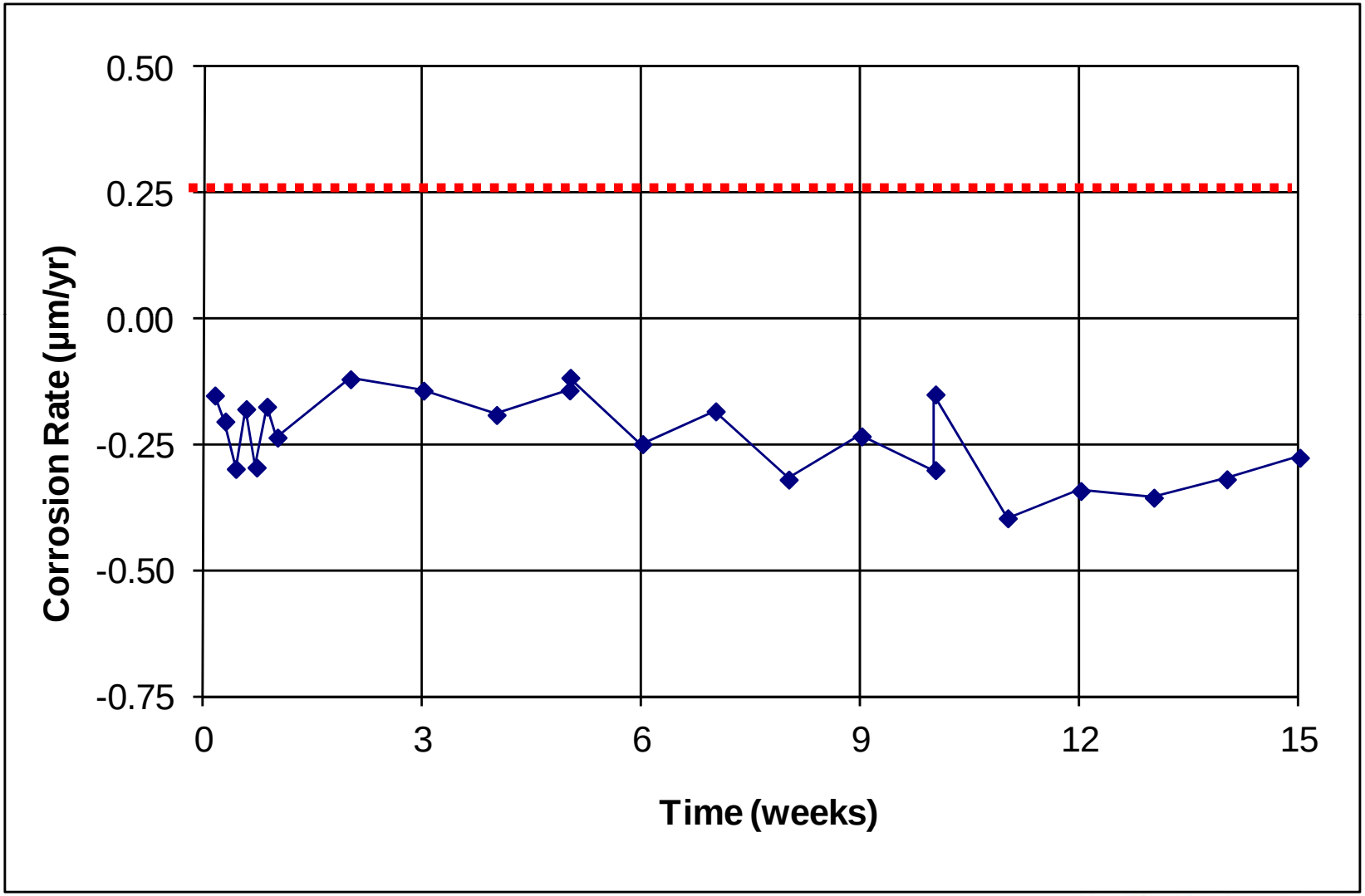


2205 After Testing

Effect of Pickling On Stainless Steel Corrosion Resistance

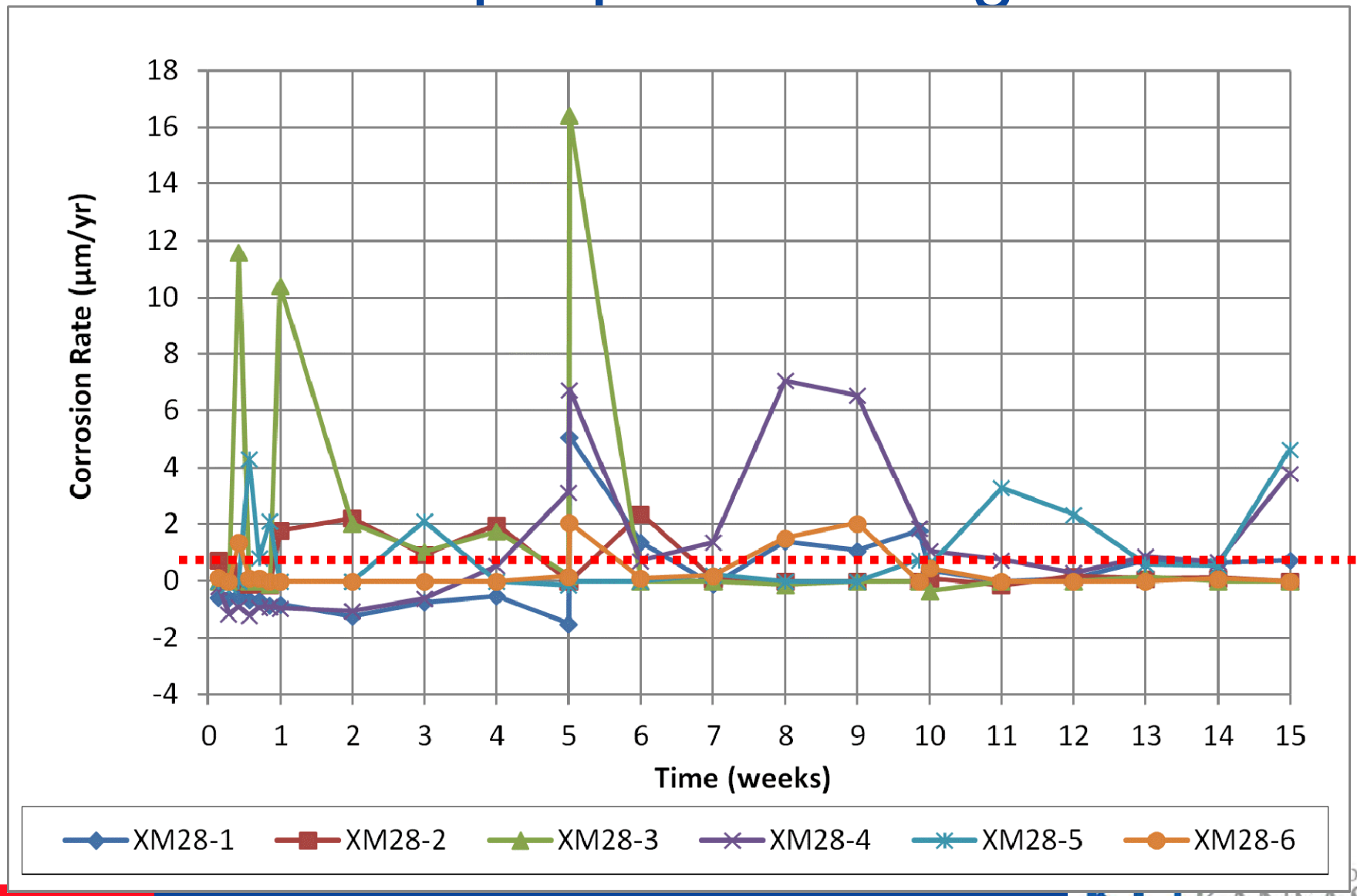
- For many stainless steels, a proper pickled finish is critical to developing a passive film

XM-28

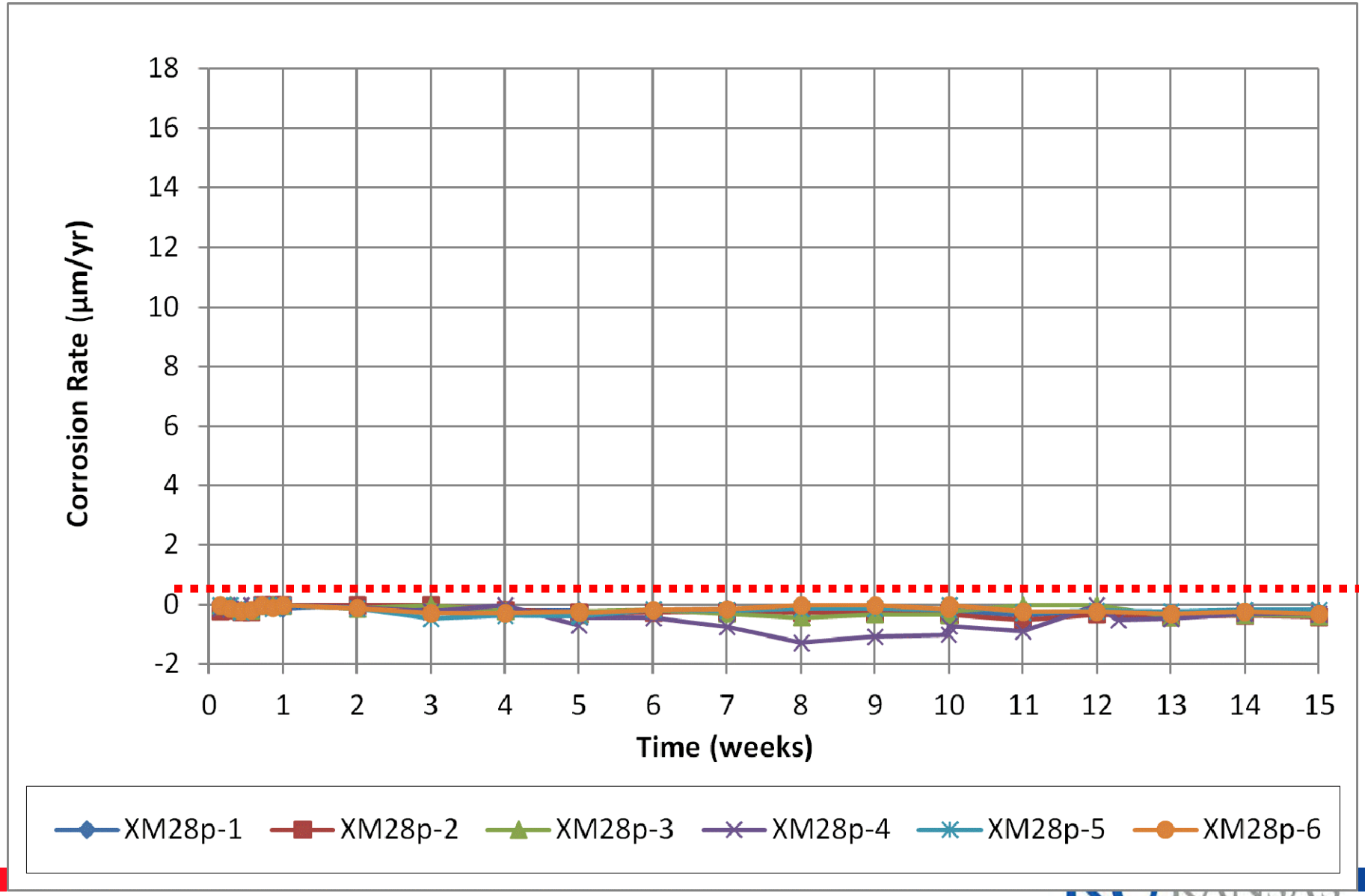
1st heat (improper pickling)

2nd heat (proper pickling)

XM-28 – Improper Pickling



XM-28 – Pickled



XM-28 Comparison

Improper Pickling

- Maximum individual corrosion rate of 16.4 µm/yr
- Maximum average (6 specimens) of 5.05 µm/yr

Pickled (New Heat)

- Individual & average rates remained at or below 0 µm/yr

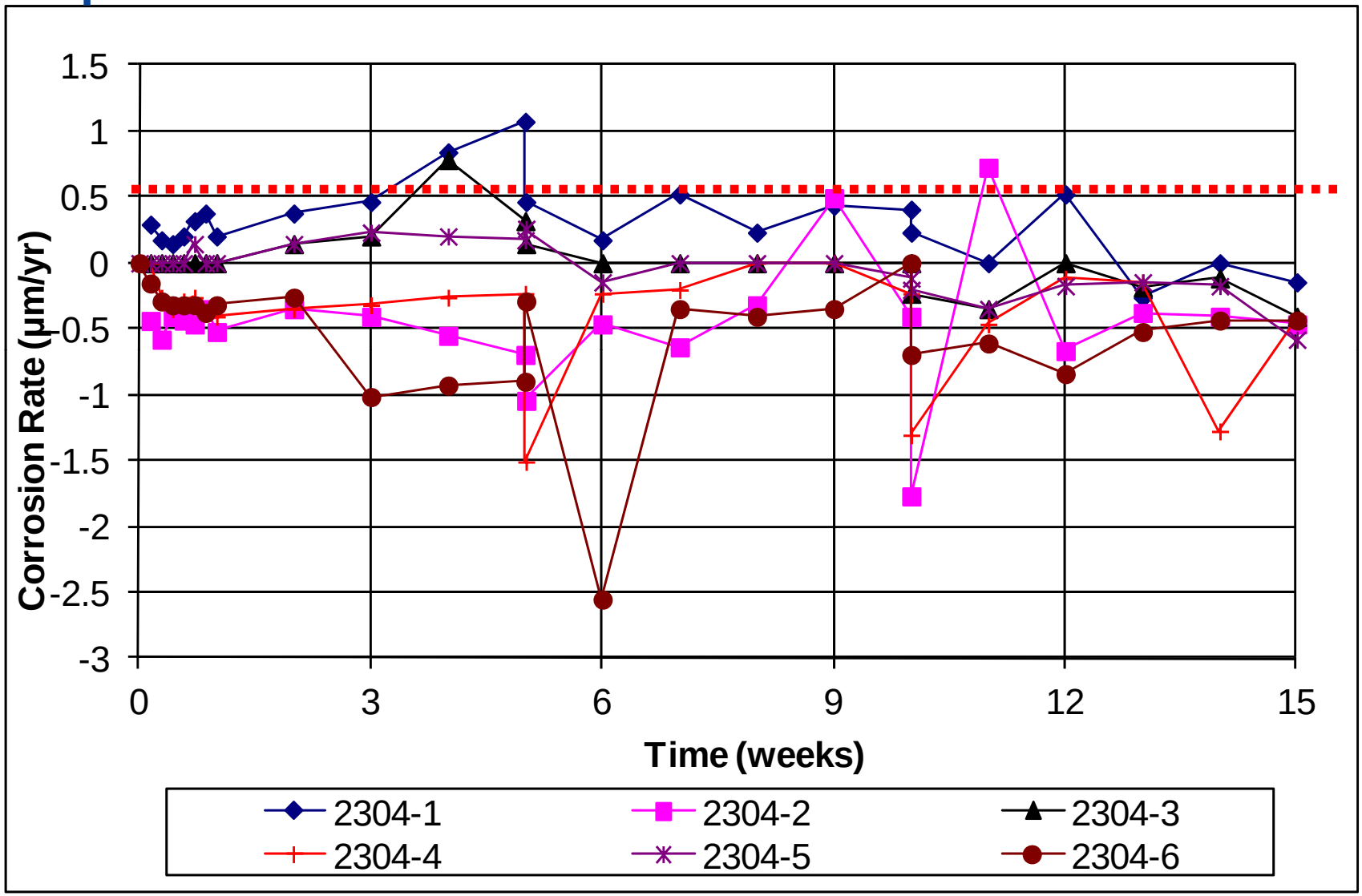
Autopsy photo of improperly pickled XM-28 specimen upon completion of test

Autopsy photo of properly pickled XM-28 specimen upon completion of test

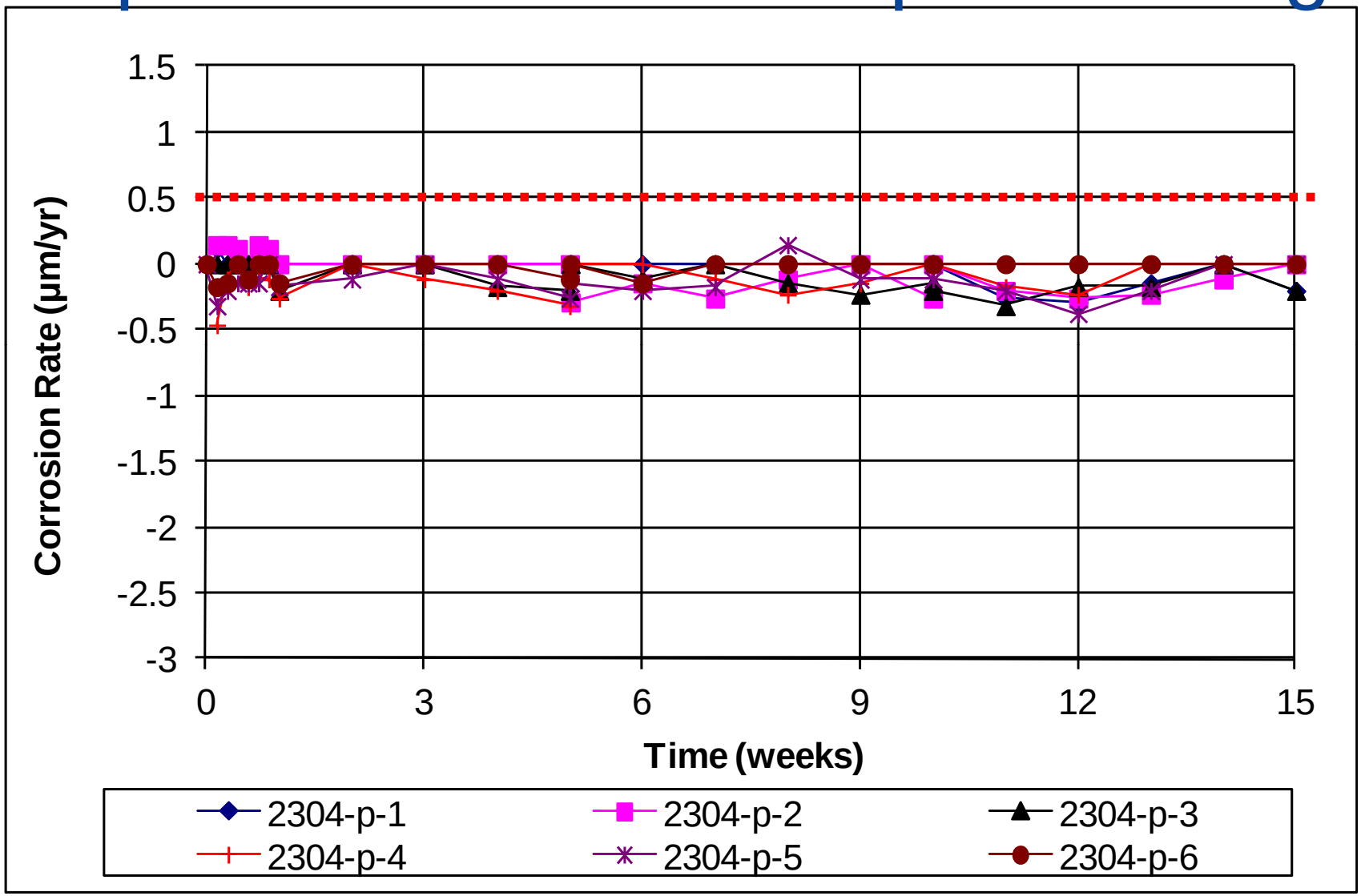
2304 Stainless Steel

Pickled 2304 Duplex Stainless Steel (Top),
2304 as-received (Bottom)

Rapid Macrocell – 2304 As-Received



Rapid Macrocells – Proper Pickling



2304 Comparison

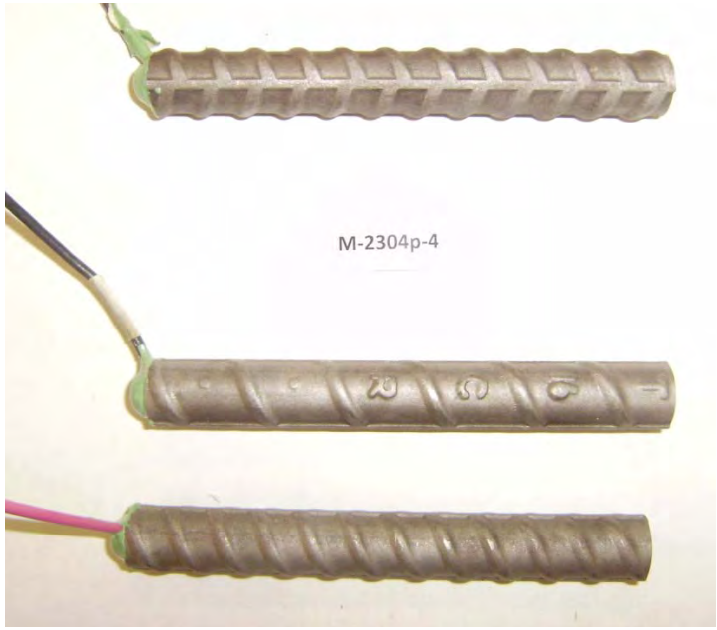
As-received specimens

- 2 specimens exceed 0.5 µm/yr at week 4

2304-1 (As-received) upon completion of test (anode on top, cathode on bottom)

Re-pickled specimens

- Maximum individual rate of 0.15 µm/yr

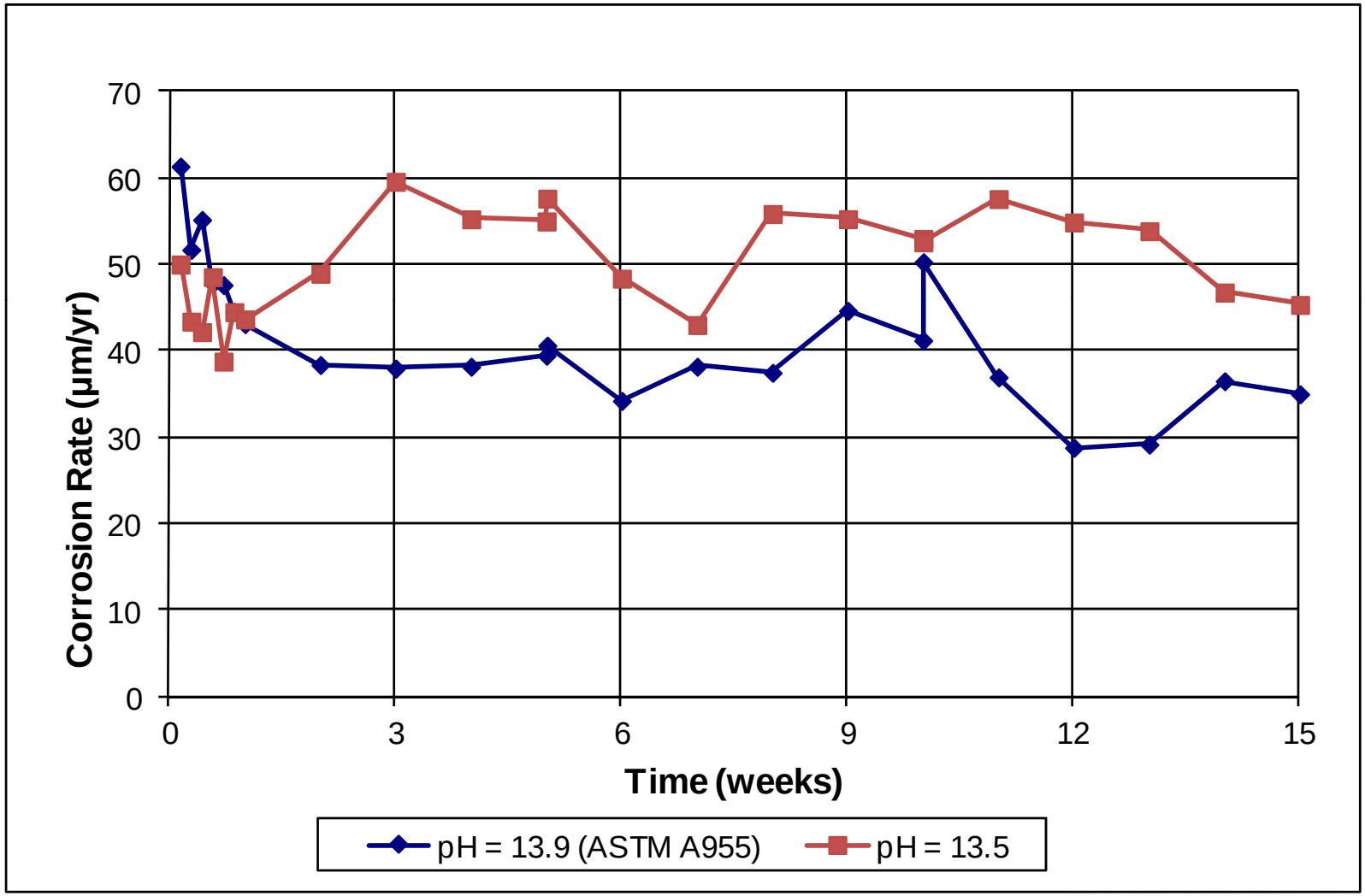


2304p-4 (Re-pickled) upon completion of test (anode on top, cathode on bottom)

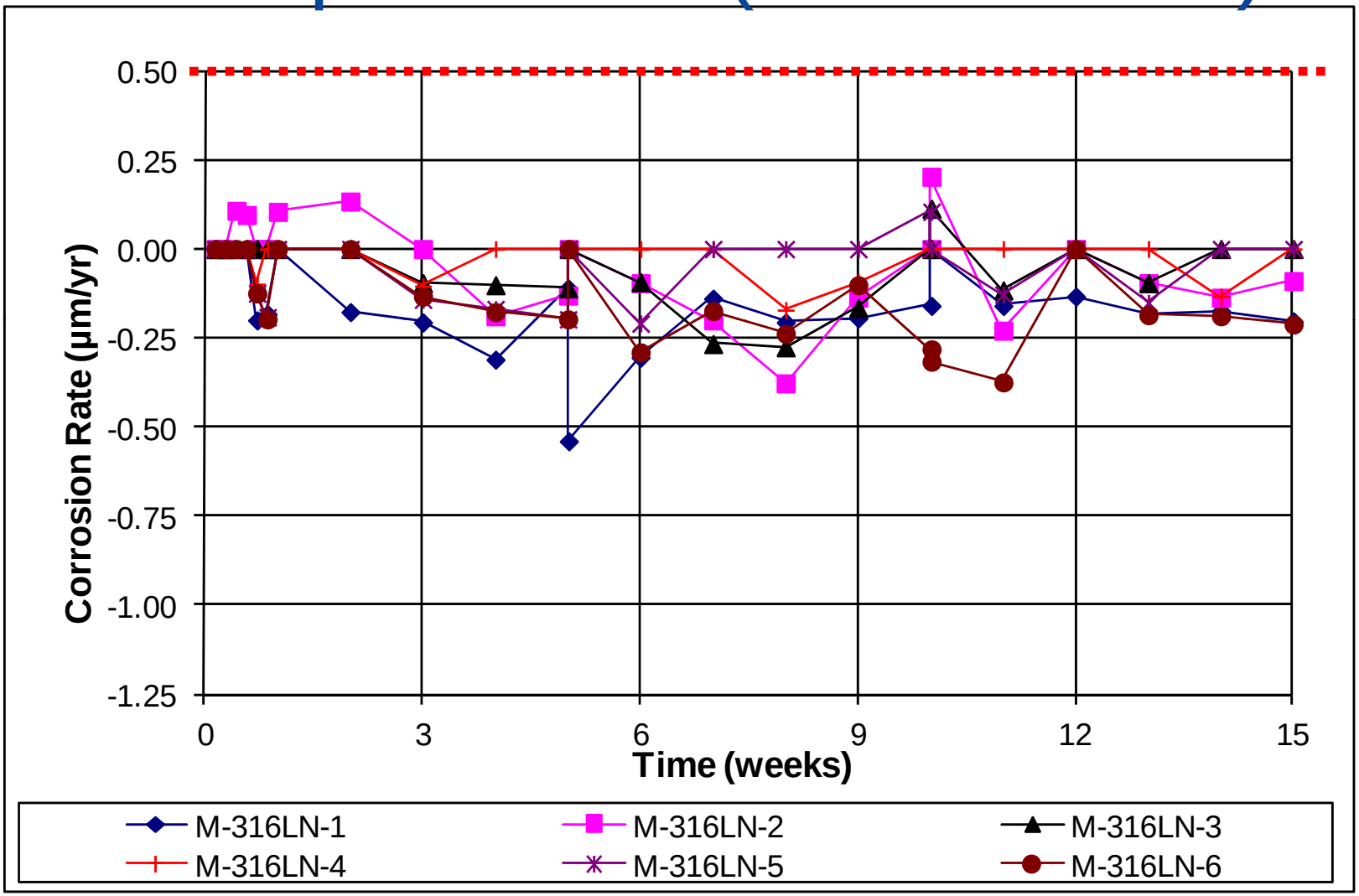
Effect of pH on Corrosion Resistance

- Pore solution in ASTM A955 has a high pH (~13.9)
- Actual concrete pore solution has a pH of ~13.5
- Higher pH helps stabilize the passive layer, improves corrosion resistance

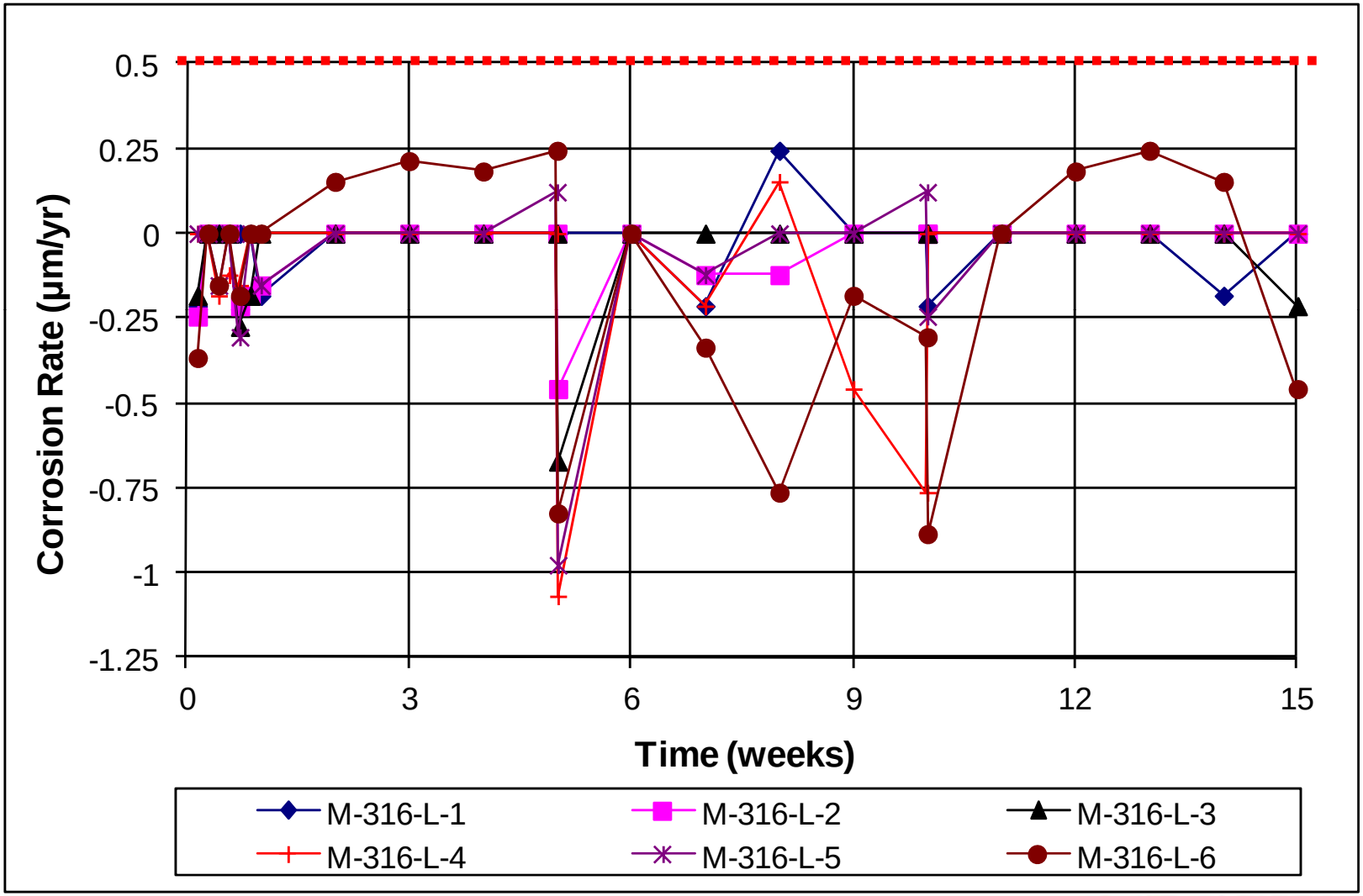
Conventional Reinforcement



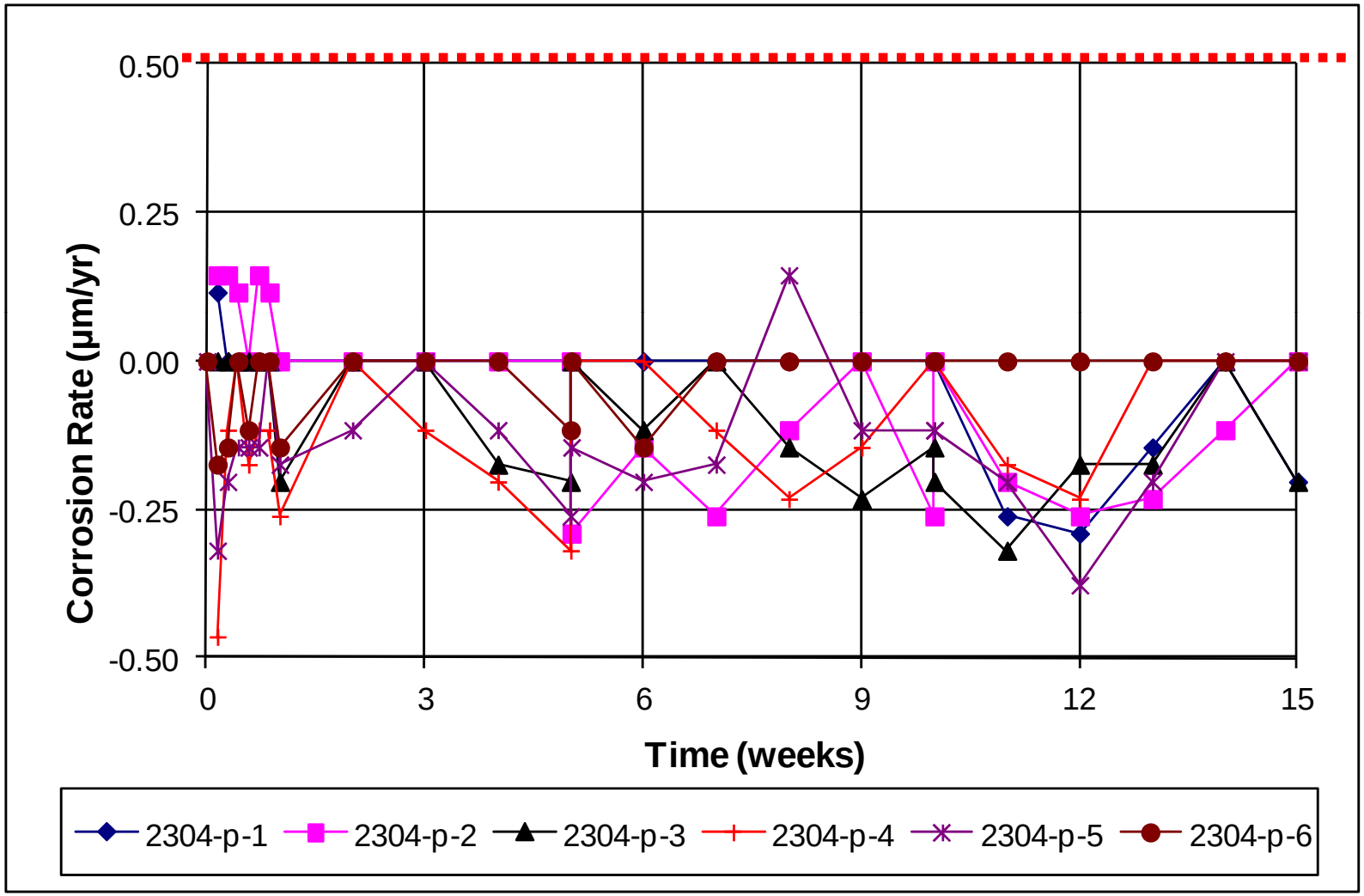
316LN in pH = 13.9 (ASTM A955)



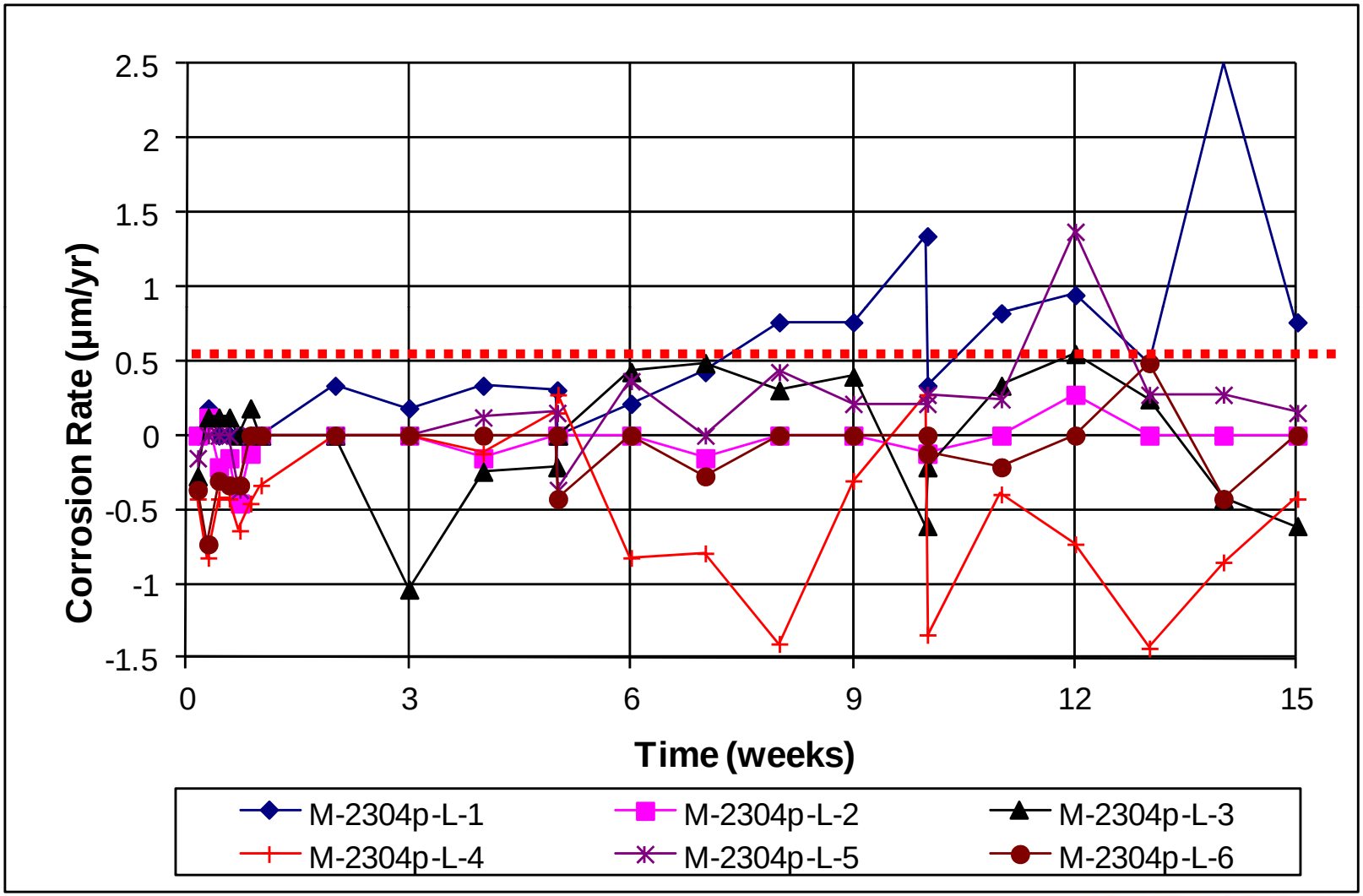
316LN in pH = 13.5



2304 in pH = 13.9 (ASTM A955)



2304 in pH = 13.5



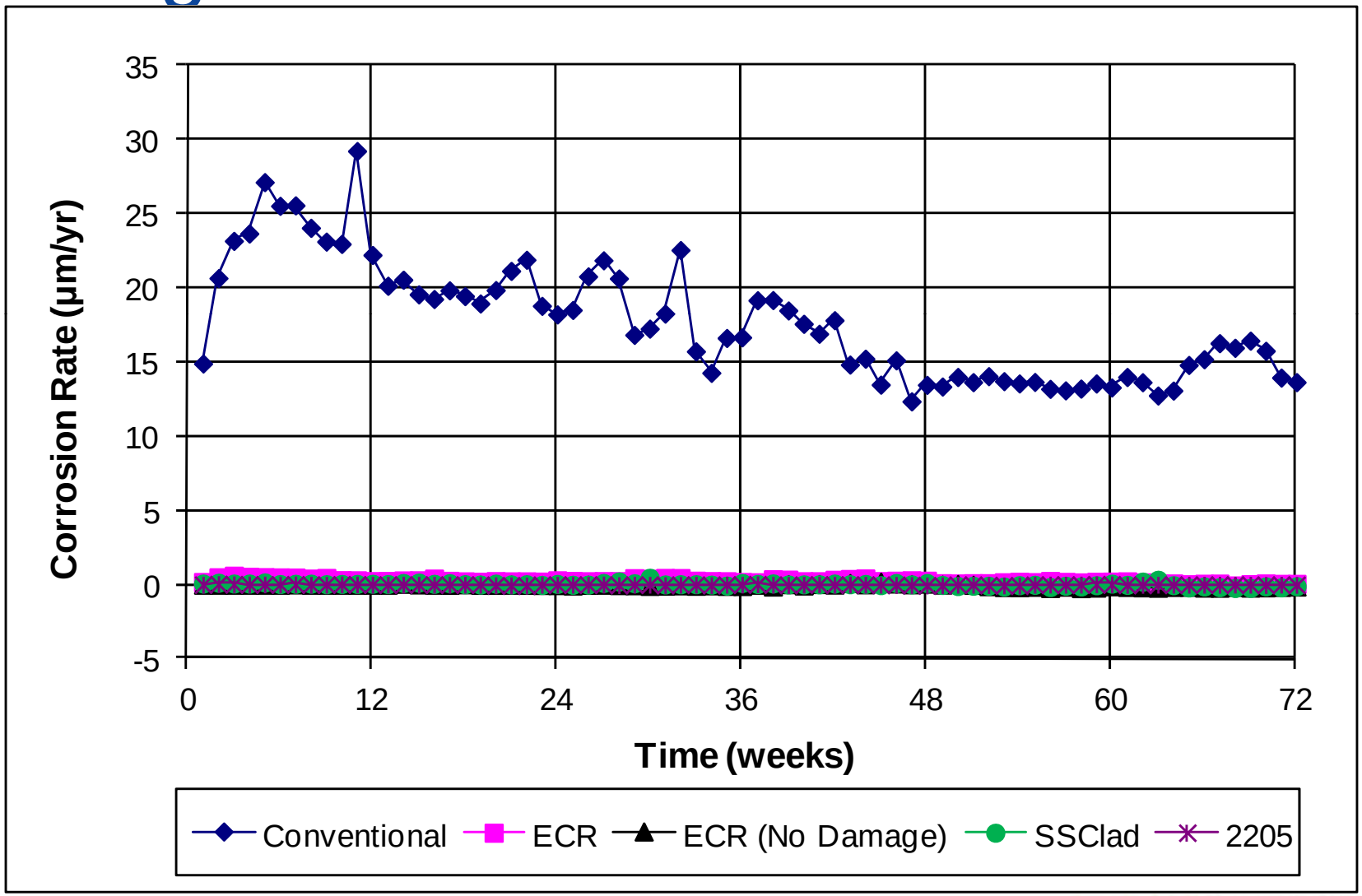
Effect of pH on Corrosion Resistance

- Currently testing 2101, 2205 stainless steels at lower pH (13.5)
- To date, both steels meet the individual and average corrosion rate limits of ASTM A955.

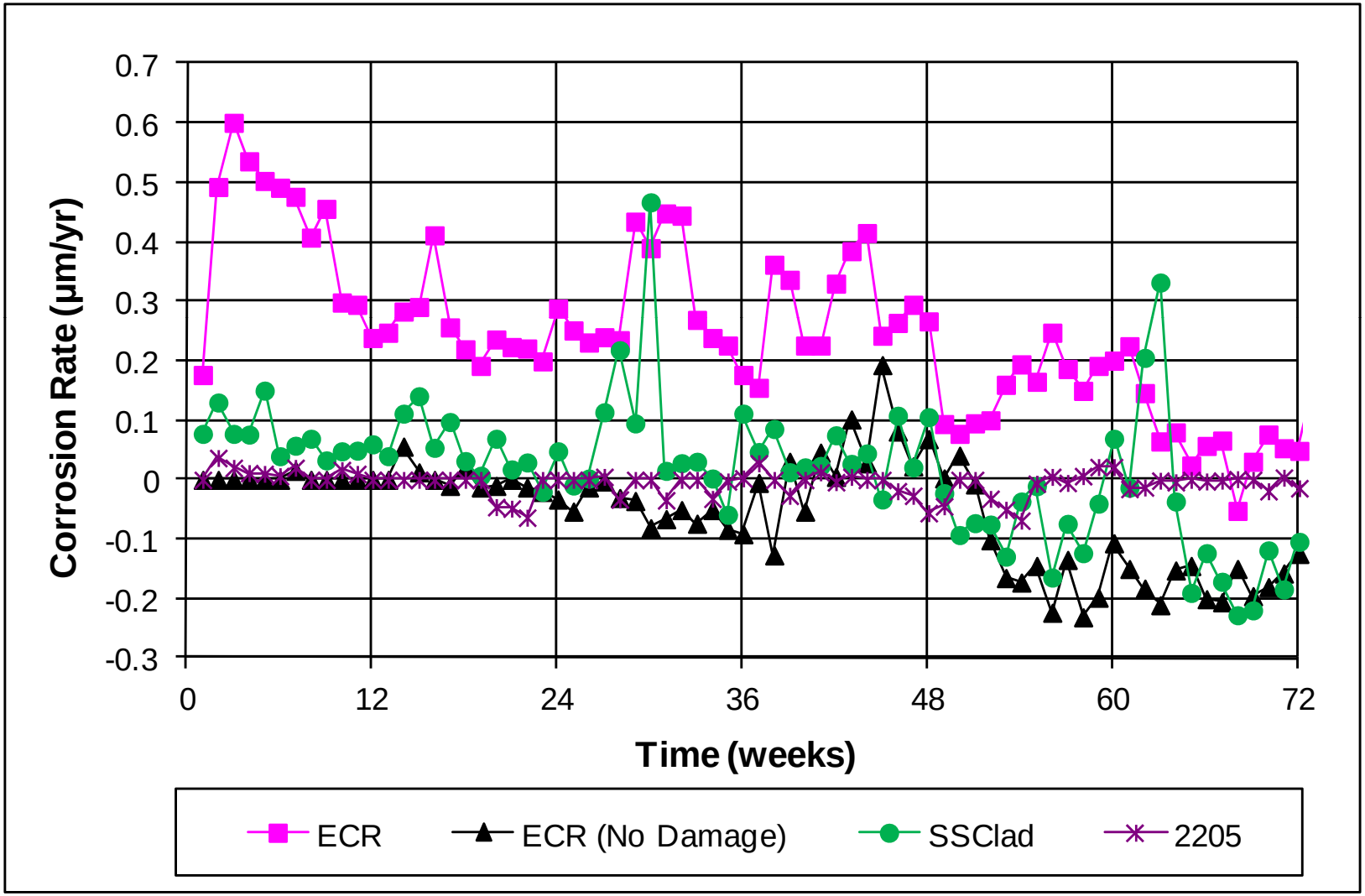
Selected Cracked Beam Results

- Conventional
- ECR
- Stainless Steel Clad
- 2205
- Effect of Pickling
  - 2205
  - 2304

Average Corrosion Rates

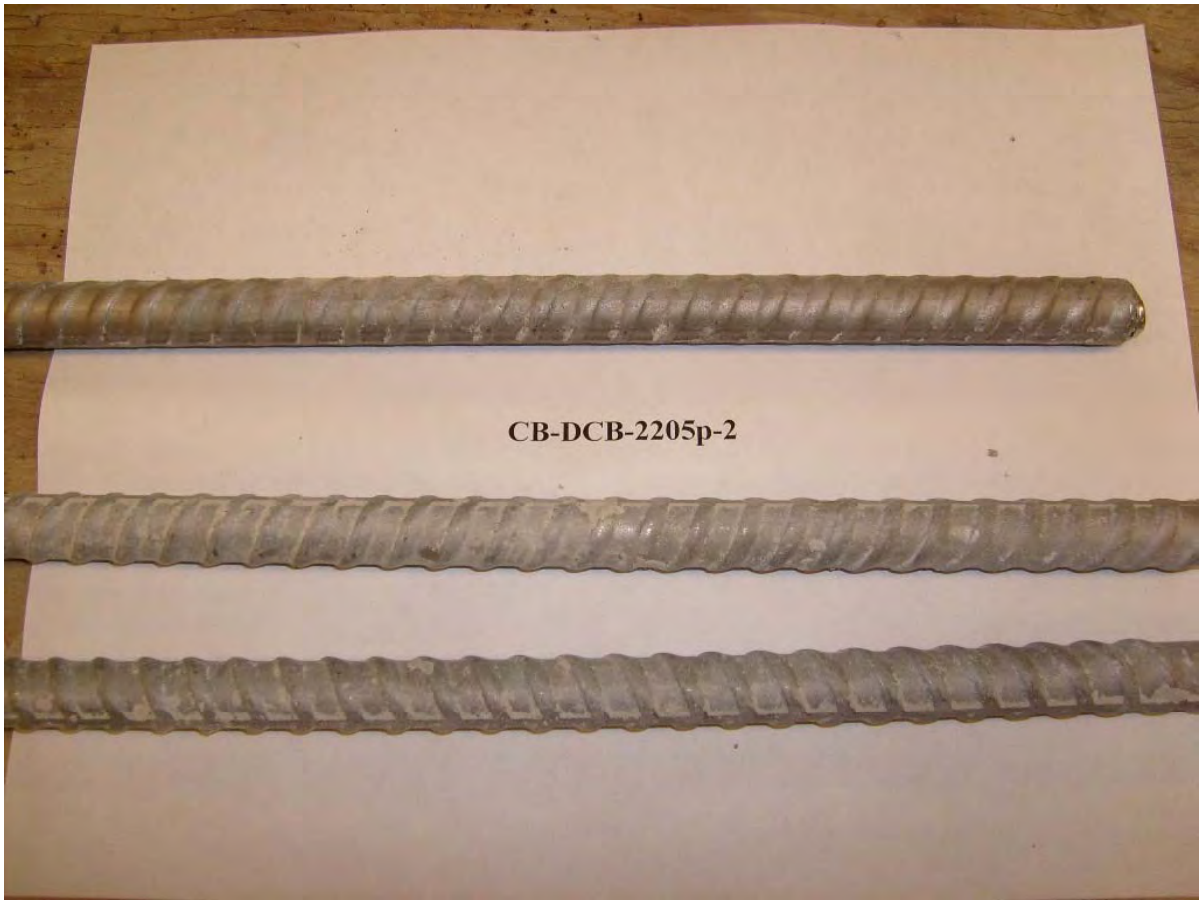


Corrosion Rates-Different Scale

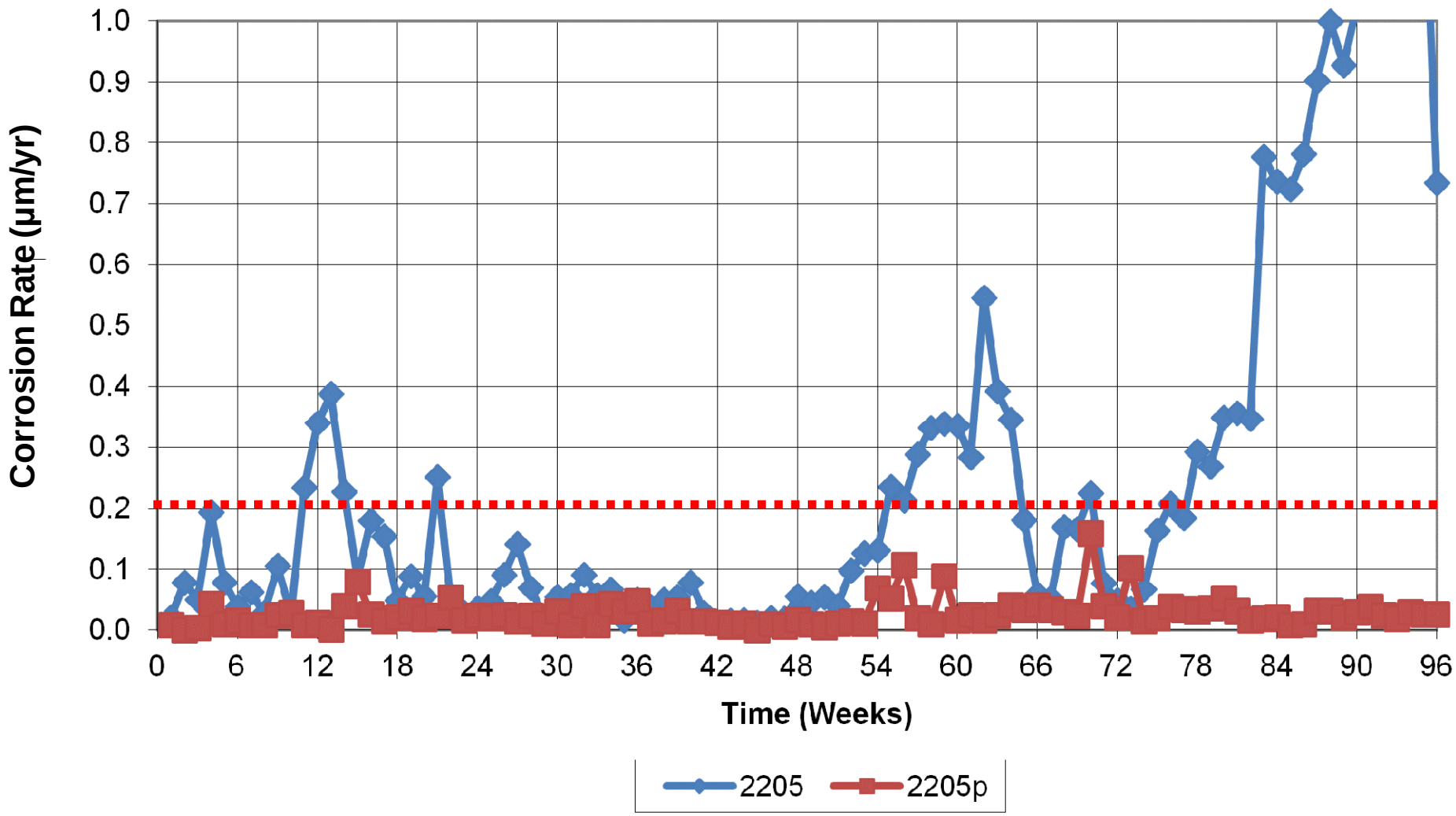


Conventional Cracked Beam, 96 weeks

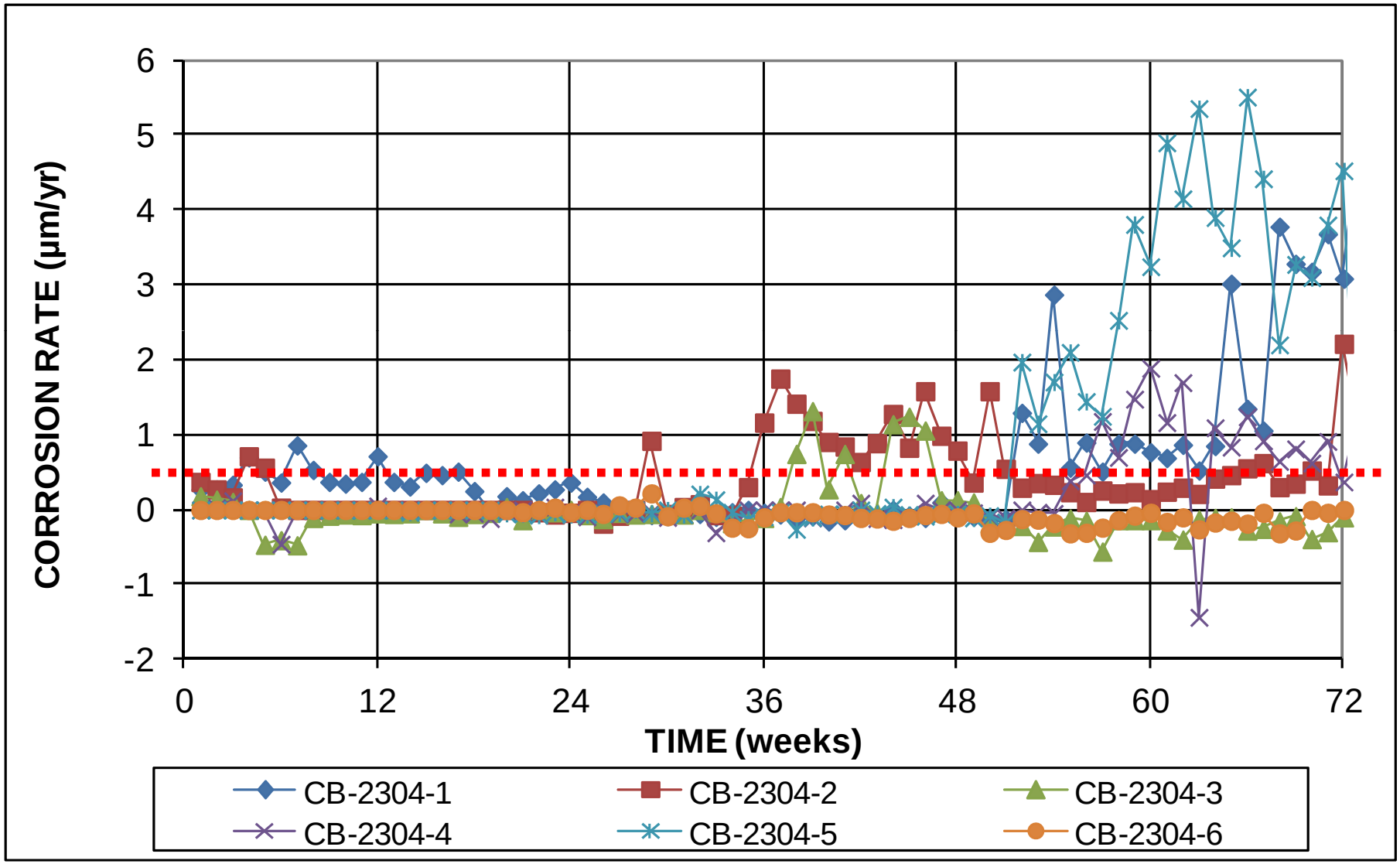
2205 Cracked Beam, 240 weeks



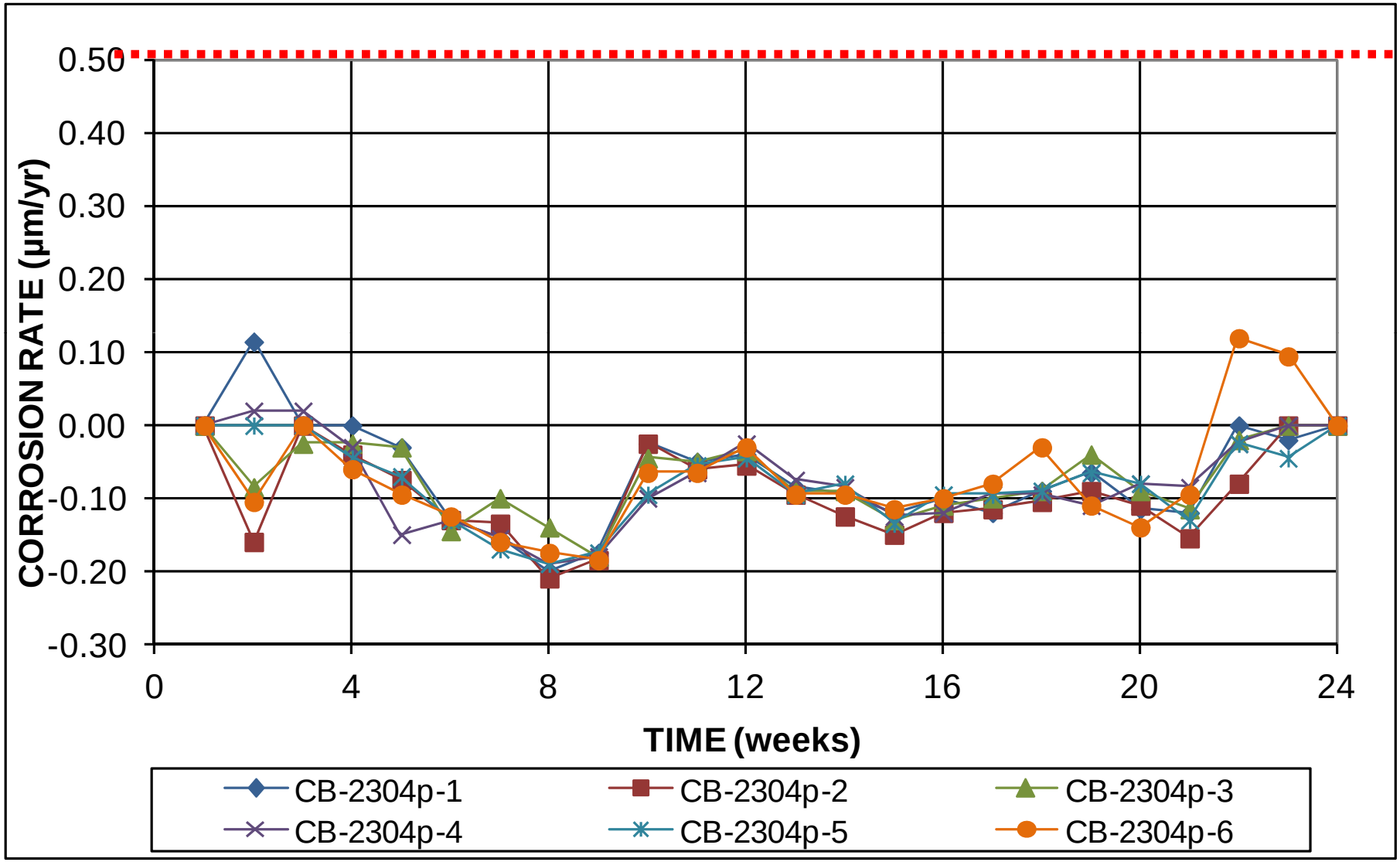
Cracked Beam – Non-Pickled v. Pickled



Cracked Beam – 2304 As-Received



Cracked Beam – Re-Pickled



Thank You

The University of Kansas

Matthew O'Reilly, Ph.D.

Lecturer/Research Engineer

Dept. of Civil, Environmental & Architectural Engineering
2142 Learned Hall
Lawrence, Kansas, 66045-7609
(785) 864-9017 Fax: (785) 864-5631

oreilly3@ku.edu

THE UNIVERSITY OF KANSAS