Fastener Corrosion Issues: Testing, Codes, and Design

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Overview

• Fundamentals of Corrosion
• Designing to Minimize Corrosion
• Codes & Standards
  • AWC
  • ICC-ES
  • AWPA E-12
• Current Research
  • Simpson Strong Tie
  • Forest Products Laboratory
Fundamentals

- All metals corrode
  - Metastable
- Corrosion rate
  - Reaction kinetics
  - Key figure of merit
  - Depends on
    - Chemical environment
    - Physical environment
    - Corrosion products
Fundamentals

- **Galvanic Series**
  - Only valid for seawater
  - Thermodynamic ranking
    - Does NOT rank corrosion rates

Low Alloy Steel
2.9 mils/year

Zinc 0.6 mils/year

ASM Handbook Vol 13b
Design Considerations

• **Protective Coatings**
  • **Metallic Coatings**
    • Anodic coatings (galvanizing)
      • “Self healing”
    • Cathodic coatings
      • Pitting corrosion at defects
  • **Corrosion performance**
    • Corrosion rate of coating
    • Defects in coating
Design Considerations

• Non-Metallic Coatings & Barriers
  • Coatings do not “corrode”
    • Subject to degradation
    • Pitting corrosion at defects
  • Currently researched at FPL
    • Based on epoxy coated rebar techniques
• Barriers
  • Same concerns as coatings
Codes & Standards

• **AF&PA AWC**
  • Corrosion fact sheet
    • *Minimum of hot-dip galvanized or equivalent*
  • *PWF Design Specifications (Draft)*
    • “Fasteners in contact with preservative treated wood shall be of Type 304 or 316 stainless steel”
    • *Exception: CCA treated wood, moisture content less than 19%,*
      • *hot-dip galvanized allowed*
Codes & Standards

• **AWPA E-12**
  - *Metal coupons held between wood blocks*
  - 49°C ± 1°C (120°F± 2°F) with RH of 90% ± 1%
    - Minimum 240 hours exposure
  - *Coupons cleaned, corrosion rate reported*
Codes & Standards

• ICC-ES Acceptance Criteria A326
  • Approved March 1, 2006
  • Min 10 replicates
  • Fasteners driven into wood
    • Then follows AWPA E12 exposures
  • Fasteners cleaned & visually inspected
  • Fastener shall pass if it has less than 25% surface corrosion
Current Testing

- **Simpson Strong Tie**
  - 1,800 AWPA E12 Tests
  - 3,000+ Modified E12 Tests
    - *Using actual fasteners*

![Figure 1](attachment://Figure_1.png)
Current Testing

• **Forest Products Laboratory**
  • **Electrical Impedance Spectroscopy (EIS)**

• **Pros**
  • Test at MC or T of interest
  • Measure diffusion controlled reactions
  • Prevent permanent polarization of preservative
  • Model corrosion via equivalent circuit

• **Cons**
  • Requires expensive equipment
  • Data analysis requires modeling

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Current Testing

- **Forest Products Laboratory**
  - DC methods
    - LPR, Polarization

- **Pros**
  - Simple data analysis
  - Rapid
  - Test at temperature of interest
  - Theory well studied

- **Cons**
  - Affected by solution resistance
  - Not well suited to solid wood
Current Testing

- Forest Products Laboratory
- Original DC Tests
  - Solutions of CCA, ACQ
  - Diluted to 0.25 pcf (etc.)
  - 1018 steel, 304 stainless, zinc, and 430 stainless
- Results
  - Steels < 4µm/yr
  - Zinc (no results)
- Conclusions
  - Preservatives change corrosiveness upon entering wood

New Testing
- “Extracts” of ACQ
- Real fasteners
- Wood matched to exposure tests
- Preliminary data well correlated to exposure results

Conclusions
- Preservatives change corrosiveness upon entering wood
Current Testing

• **Forest Products Laboratory**

• **Pros**
  - "Real world" data
  - Direct measurement

• **Cons**
  - Time consuming
  - Cleaning techniques cause additional uncertainties
  - Surface areas not well defined
Current Testing

- Forest Products Laboratory
- Surface Area Algorithm
Current Testing

- **Forest Products Laboratory**
- Andy Baker (1992 FPJ)
- 17 year exposure CCA-I, CCA-II, ACA
- 80°F~100% RH
- Reported % weight loss

Using algorithm, we converted to corrosion rate

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<th>Corrosion Rate (µm/yr)</th>
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- **CCA I**
- **CCA II**
- **ACA**
Current Testing

- Forest Products Laboratory
- Data Comparison
### Summary

- **Corrosion** - A kinetic phenomenon
- **Testing** - Quantitative methods being developed
- **Design**

<table>
<thead>
<tr>
<th>Product</th>
<th>Design Consideration</th>
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<tbody>
<tr>
<td>Stainless Steel</td>
<td>Combining with a different metal</td>
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<tr>
<td>Metallic Coatings (anodic)</td>
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<td>Corrosion rate of coating</td>
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<td>Construction damage to coatings</td>
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<td>Damage to coating during construction</td>
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<td>Barriers</td>
<td>Defects in barrier</td>
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