Corrosion of Galvanized Fasteners used in Cold-Formed Steel Framing

by

Ian N. Robertson Ph.D., P.E.

Steel Framing Alliance

and

University of Hawaii

Funded by

US Dept. of Housing and Urban Development (HUD)

& Steel Framing Alliance

November 2000 - November 2004
Outline

- HUD project overview
- Field study
- Laboratory study
- Field observations
- Recommendations
HUD Project Overview

- Concern over corrosion of CFS connection fasteners
- Initiated by HPSFA and UH in 2001
- Includes field and accelerated laboratory tests
  - Field tests - Evaluate rate of corrosion at various locations and climatic exposures on Oahu
  - Lab tests - Evaluate effect of various degrees of corrosion on connection strength
- Report results and prepare industry guideline
Field Enclosures

- Intended to represent typical housing construction
- Observe extent of corrosion on members and connections
- House test connection samples for future strength testing in laboratory
- Standard Steel and Zinc samples monitored for base corrosion rate
- Climatic conditions monitored
Panel Pre-fabrication
MCBH – Construction
Pre-Fabricated and stored at Hunt Building in Pearl City

Iroquois - Inland

Wheeler AAF

Iroquois - Coastal
Field enclosure locations

Windward Coastal:
1 - Kaneohe MCBH – 230 m

Windward near coast:
2 - Kaneohe MCBH – 535 m

Leeward Coastal:
3 - Iroquois Point – 55 m

Leeward near coast:
4 - Iroquois Point – 550 m

Inland:
5 – Wheeler AAF - > 1000 m
Kaneohe MCBH
Plywood with vinyl siding

Hardy Board with vapor barrier

Hardy Board without vapor barrier
Iroquois Point
Iroquois Coastal, Iroquois Inland and Wheeler AAF

![Diagram showing interior layout of Iroquois Coastal and Inland Wheeler AAF with labels for coupon locations and ceiling plan.]

**KEY:**
- Plywood sheathing with Insulation
- Plywood below joists
- Insulation between ceiling joists
- Coupon Location
- Relative Humidity and Temperature Sensors

**Interior Layout**
Iroquois Coastal and Inland Wheeler AAF

**Labels:**
- L5: External Coupon Rack
- L1: Back Wall H&T1
- L2: Ceiling Plan
- L3: Open Crawl Space H&T3
- L4: Covered Crawl Space H&T4
- H&T3

**Directions:**
- North at Wheeler
- North at Iroquois Coastal
- Front Wall
- Side Wall
- 8' dimension
Atmospheric Instrumentation

- UH College of Eng. - $25,000 funding
- Five identical weather stations
- One located at each site
- Campbell Scientific instruments and datalogger
  - Wind speed and direction
  - Rainfall
  - Solar radiation
  - Exterior RH and temperature
  - Interior RH and temperature
Atmospheric Chloride Candle

- Atmospheric chloride deposition rate
- Covered for rain protection
- Reported as mgCl/m²/day
Chloride Deposition Rates

- Wheeler AAF
- Iriquois Inland
- Iriquois Coastal
- MCBH Inland
- MCBH Coastal

Chloride Deposition Rate (mg/m²/day)
Field Test Connections

Connection Selection:
- (2) #10 screws
- In lap splice of 1.25" wide 16 ga (54 mil) G60 galvanized plates (Zinc coating approx. 12.5 μm)

Screw Selection:
- #10 Hex head galvanized screws
- Self-drilling, self-tapping
- Zinc coating approx. 3 - 4 μm
Observations at MCBH Coastal

Exterior Connections
MCBH Coastal – Exterior Connections
7 Months Exposure
The diagram illustrates the load-elongation behavior of different specimens and controls subjected to exterior exposure for 7 months. Key features include:

- **Axes:**
  - **Y-axis:** Load (kips)
  - **X-axis:** Elongation (in)

- **Legend:**
  - **Field Specimen 1**
  - **Field Specimen 2**
  - **Field Specimen 3**
  - **Control 1**
  - **Control 2**
  - **Control 3**
  - **Field Ave Strength**
  - **Field Peak Disp.**
  - **Control Ave Strength**
  - **Control Peak Disp.**

The graph shows the load-elongation curves for each specimen and control, indicating their performance under the specified conditions.
MCBH Coastal – Open Crawl Connections
7 Months Exposure
Average Peak Strength - 7 Month exposure

Control | MCBH Inland Exterior | MCBH Coast Open Crawl | Iroquois Coast Exterior | MCBH Coast Exterior | MCBH Coast Covered Crawl | MCBH Coast Ext 3M Open Crawl 4M

Strength Ratio

0.00 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 | 0.90 | 1.00 | 1.10
Average Displacement at Peak Load - 7 Months Exposure

Displacement Ratio

- Control
- MCBH Inland Exterior
- MCBH Coast Covered Crawl
- MCBH Coast Open Crawl
- Iroquois Coast Exterior
- MCBH Coast Exterior
- MCBH Coast Ext 3M Open Crawl 4M
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Accelerated Laboratory Testing

- 1100 liter Cyclic corrosion chamber installed at UH structures laboratory.
- Cyclic testing options include salt-solution spray, drying and high humidity periods in cycles.
- Test connections identical to those stored in field enclosures.
- Relate level of corrosion to strength reduction
- Attempt to correlate with field observations
Cyclic Routine

- Considered numerous industry standards (Salt spray, Auto industry, etc.)
- Require routine that simulates atmospheric conditions.
- Should produce the same ratio between corrosion rates for steel and zinc.
Research by Dr. Zhang

Figure 2  Corrosion ratios of steel/zinc in different natural corrosion environments
Figure 3 Corrosion rates of steel and zinc and their ratios in different corrosion tests
Cyclic Routine

- Selected cyclic routine recommended by Dr. Zhang of Teck Cominco.
  - Weak salt water solution (0.08% NaCl)
  - Salt spray for 15 minutes at 35º C
  - Drying for 30 minutes at 35ºC
  - Repeat
  - Best replicates 10:1 corrosion ratio for Steel:Zinc in atmospheric conditions
Steel and Zinc Coupons

Steel Coupon

Sand-Blasted Steel Coupon

Zinc Coupon
5 Days – 160 Cycles
Comparison of Steel and Zinc Corrosion Rates

- **Steel Coupons**

![Graph showing the comparison of steel and zinc corrosion rates. The graph plots weight loss (%) against the number of cycles. The data points for steel coupons show a steady increase in weight loss with increasing number of cycles.]
Comparison of Steel and Zinc Corrosion Rates

- **Steel Coupons**
- **Zinc Coupons**

![Graph showing weight loss (%) vs. number of cycles for Steel and Zinc coupons.](image-url)
Ratio of Steel/Zinc corrosion rates

Ratio of Steel/Zinc % Loss

Number of cycles
Comparison of Steel and Zinc Corrosion Rates

![Graph comparing mass loss to number of cycles for Steel and Zinc Coupons](image-url)
Connections after 1056 Cycles

Threads Down

Threads Up
Connection Tests - 1056 cycles - Threads down

Elongation (in) vs. Load (kips)

- Specimen 1
- Specimen 2
- Specimen 3
- Control 1
- Control 2
- Control 3
- Specimen Ave Strength
- Specimen Peak Disp.
- Control Ave Strength
- Control Ave Peak Disp.
Connections after 1979 Cycles

Threads Down

Threads Up
Connections after 2772 Cycles

Threads Down

Threads Up
Microscopic Inspection

Screw Threads - 1537 Cycles

Screw Threads - Original
Microscopic Inspection

Failed Connection – 1537 Cycles

Failed Connection - Original
## Preliminary Correlation with Field Sites

<table>
<thead>
<tr>
<th>Location</th>
<th>Exposure</th>
<th>1 year exposure equivalent to</th>
<th>1000 cycles (1 month) equiv to</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCBH Coastal</td>
<td>Exposed crawl space</td>
<td>1500 cycles</td>
<td>8 months</td>
</tr>
<tr>
<td></td>
<td>Vented attic</td>
<td>500 cycles</td>
<td>2 years</td>
</tr>
<tr>
<td></td>
<td>Vented Wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sealed crawl space or walls</td>
<td>250 cycles</td>
<td>4 years</td>
</tr>
<tr>
<td>MCBH Inland</td>
<td>Exposed crawl and vented attic</td>
<td>250 cycles</td>
<td>4 years</td>
</tr>
<tr>
<td>Iroquois Coastal</td>
<td>Sealed crawl space and walls</td>
<td>&lt; 250 cycles</td>
<td>&gt; 4 years</td>
</tr>
<tr>
<td>Iroquois Inland</td>
<td>All conditions</td>
<td>&lt; 250 cycles</td>
<td>&gt; 4 years</td>
</tr>
<tr>
<td>Wheeler AAF</td>
<td>All conditions</td>
<td>&lt; 250 cycles</td>
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Visual Inspection at Field Sites

- **Inspection:**
  - Crawl Space Framing – Posts and Cripple Wall
  - Floor Framing – Exposed and enclosed
  - Wall Framing – With or without vapor barrier
  - Roof Framing – Vented attic

- **Timeline (MCBH Enclosures):**
  - Panel Construction - June 2001
  - Enclosure Constr. - Nov-Dec 2001 Start
  - First Inspection - April 2002 5 Months
  - Second Inspection - Sept. 2002 10 Months
  - Third Inspection - March 2003 16 Months
  - Coupon Installation - August 2003 21 Months
  - Fifth Inspection - March 2004 28 Months
Exposed and Covered Floor Framing
Hardy Board lap-siding without vapor barrier
Hardy Board lap-siding with vapor barrier
Plywood sheathing and vinyl siding
Vented Attic
Observations at MCBH Inland

28 Months

56 Months
Observations at MCBH Inland

28 Months

56 Months
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28 Months

56 Months
Observations at MCBH Inland

28 Months

56 Months
Observations at MCBH Inland

7 Months

56 Months
Observations at MCBH Coastal

28 Months

56 Months
Observations at MCBH Coastal

28 Months

56 Months
Observations at MCBH Coastal

21 Months

56 Months
Observations at MCBH Coastal

21 Months

Covered Crawl Space
Observations at MCBH Coastal

56 Months

Covered Crawl Space
Observations at MCBH Coastal

42 Months Open Crawl Space

42 Months Covered Crawl Space
Observations at MCBH Coastal

Hardie Board without Vapor Barrier

28 Months

56 Months
Observations at MCBH Coastal

Hardie Board without Vapor Barrier

28 Months

56 Months
Observations at MCBH Coastal

Hardie Board with Vapor Barrier

28 Months

56 Months
Observations at MCBH Coastal

Hardie Board with Vapor Barrier

14 Months

42 Months
Observations at MCBH Coastal

Plywood without Vapor Barrier

28 Months

56 Months
Observations at MCBH Coastal

Plywood without Vapor Barrier

14 Months

42 Months
Observations at MCBH Coastal

16 Months

56 Months
Outline

- HUD project overview
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Recommendations

- Identify three exposure categories
  - Category A: Extreme exposure
  - Category B: Moderate exposure
  - Category C: Mild exposure

- Each building location assigned to one of these exposure categories based on
  - geographical location
  - surrounding features
  - meteorological records
Definitions

- **Distance from Shoreline**
  - Straight line distance, perpendicular to coast

- **Onshore and Offshore Wind**
  - Refers to predominant wind direction. If unknown, assume “Onshore Wind”.

- **Shielded**
  - Refers to presence of significant vegetation and/or structures, at least as tall as the proposed building, located between the coast and the proposed site

- **Unshielded**
  - Limited or no vegetation or structures between coast and proposed site
## Category Assignment

<table>
<thead>
<tr>
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Category C Recommendations

- Mild Exposure - Inland locations
  - Standard industry construction practices should be followed.
  - Permanent exposure of CFS members or fasteners to ambient atmospheric conditions should be avoided.
  - Exposure to atmospheric conditions during construction should be limited to 6 months.
  - Attic and crawl space framing should be inspected regularly for signs of corrosion. These inspections should be performed at least once every 5 years.
# Category B Recommendations

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Category B Recommendations

- Moderate Exposure
  - No CFS members or fasteners should be permanently exposed to ambient atmospheric conditions.
  - Exposure to atmospheric conditions during construction should be limited. If such exposure is expected to exceed 4 months, protective measures should be taken to prevent chloride accumulation on the CFS members.
  - Attics can be vented, but framing members and fasteners in the attic space should be provided with additional protection through the use of increased zinc coating thickness or the addition of zinc rich coatings after fabrication.
Category B Recommendations

- Moderate Exposure (Cont.)
  - Attic framing should be inspected regularly for signs of corrosion. These inspections should be performed at least once every 5 years.
  - Protection for CFS framing and fasteners in exterior walls can be achieved by providing an enclosed wall cavity.
  - Protection of CFS framing and fasteners in interior walls and floor systems is provided effectively by gypsum board coverings on both sides of the wall cavity, and as a ceiling below elevated floor framing.
# Category A Recommendations

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**Category A Recommendations**

- **Extreme Exposure**
  - No CFS members or fasteners should be exposed to ambient atmospheric conditions.
  - Exposure to atmospheric conditions during construction should be limited. If such exposure is expected to exceed 2 months, protective measures should be taken to prevent chloride accumulation on the CFS members.
  - No CFS framing should be exposed in sheltered locations such as crawl spaces or the interior of garages, carports and other unfinished spaces.
Category A Recommendations

- Extreme Exposure (Cont.)
  - Attic spaces require particular attention because of the need for venting to prevent moisture accumulation and potential mold development.
    - the attic space can be designed as a sealed environment with insulation placed directly under the roof sheathing (a.k.a. cathedral ceiling), and the area underneath designed as a conditioned space.
    - attic venting, particularly on the coastal elevation, can be kept to the minimum permitted by the applicable building code, while extra protection can be provided for the framing members and fasteners in the attic space through increased galvanizing thickness and/or the addition of zinc rich coatings after fabrication.
  - Attic framing should be inspected regularly for signs of corrosion. These inspections should be performed at least once every 2 years.
Extreme Exposure (Cont.)

- Protection for CFS framing and fasteners in exterior walls can be achieved by providing an enclosed wall cavity.
  - All openings, window and door framing, service penetrations, etc. must be sealed so as to prevent airflow into the wall cavity.
  - The top of the wall must be sealed from any vented attic space above.
- Protection of CFS framing and fasteners in interior walls and floor systems can be provided by gypsum board on both sides of the wall cavity, and as a ceiling below floor framing.
- Consideration should be given to increasing the thickness of galvanizing on CFS members and fasteners.
MCBH Housing

U.H. Dept. of Civil and Environmental Engineering  BSC Boston, August 1, 2017
MCBH Housing
Sealed Conditioned Attics

Continuous bead of sealant or caulking around vinyl soffit

MANUFACTURED COMPOSITION SHINGLE
30 YEAR ROOF. INSTALL PER MANUFACTURER RECOMMENDATIONS

ROOF SHEATHING - 5/8' 303 SIDING PLACED FACE DOWN OR OVERHANGS

9' WIDE MINERAL SURFACE STARTER STRIP

26 GA. CONTINUOUS PRE-COATED ALUM DRIP OR VINYL EAVES

PRE-COATED ALUM OR VINYL GUTTER WHERE APPLICABLE

SLOPED VINYL SOFFIT ATTACHED W/ CLIPS OR BLOCKING

5/4 X 8 CEMENTITIOUS TRIM

EXTERIOR FINISH (SEE ELEVATIONS)

EAVE @ 3 HOLE VENT BLOCKS

COMPOSITION SHINGLE

ALL MATERIALS SHALL BE INSTALLED PER MANUFACTURERS SPECIFICATIONS.
Minimized Venting of un-conditioned Attics
Seal Exterior Walls

1. **Insulation:**
   - 20 gage steel wall framing, refer to structural.

2. **Elevations for finish material:**

3. **Building Paper:**
   - 2 layers grade D' building paper over exterior sheathing or 'Tyvek' installed per mgr specifications.

4. **Gasket:**
   - Steel track with continuous gasket between track and concrete, refer to structural.

5. **Concrete Placement:**
   - Continuous bead of sealant applied to face of concrete prior to sheathing installation to seal opening between sheathing and concrete.

6. **Footing:**
   - Damp proofing footing, refer to structural.

7. **Supporting Wood:**
   - Foundations supporting wood shall extend 8' minimum above grade.

8. **Slope Grade:**
   - Slope grade away from building per civil plans.

9. **Concrete Line:**
   - Line of concrete.

10. **Vinly Siding at Foundation at Grade:**
    - All materials shall be installed per manufacturers specifications.
Seal Exterior Walls
Lanai Post Details

Refer to plan and elevations for material.

Caulk all exposed joints.

Refer to plan and elevations for material.

Post base, refer to structural for size and attachment.

Slope grade away from building.

See structural drawings for framing material.

Concrete slab.

Single wood post base.

Wood column.

Backing rod and continuous bead of sealant.

All materials shall be installed per manufacturers specifications.

1\1\0 1\1\0
Holddowns
Visit Hawaii!

Any Questions?