

Corrosion of Galvanized Fasteners used in Cold-Formed Steel Framing

by

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Steel Framing Alliance
and
University of Hawaii



Funded by

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& Steel Framing Alliance

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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

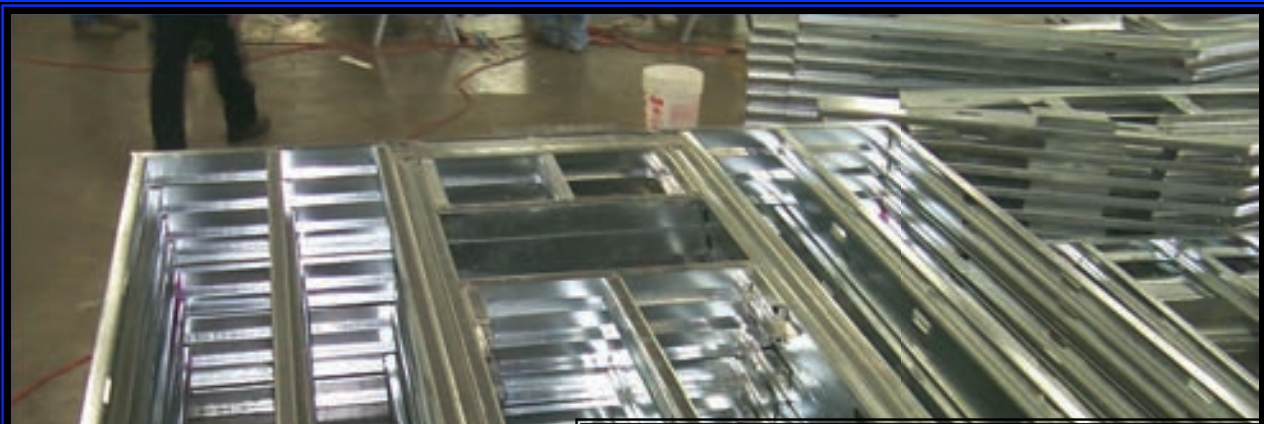
- Intended to represent typical housing construction
- Observe extent of corrosion on members and connections
- House test connection samples for future strength testing in laboratory
- Standard Steel and Zinc samples monitored for base corrosion rate
- Climatic conditions monitored

Typical field enclosure



Panel Pre-fabrication





MCBH – Construction





MCBH – Coastal Site

MCBH – Inland Site



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:

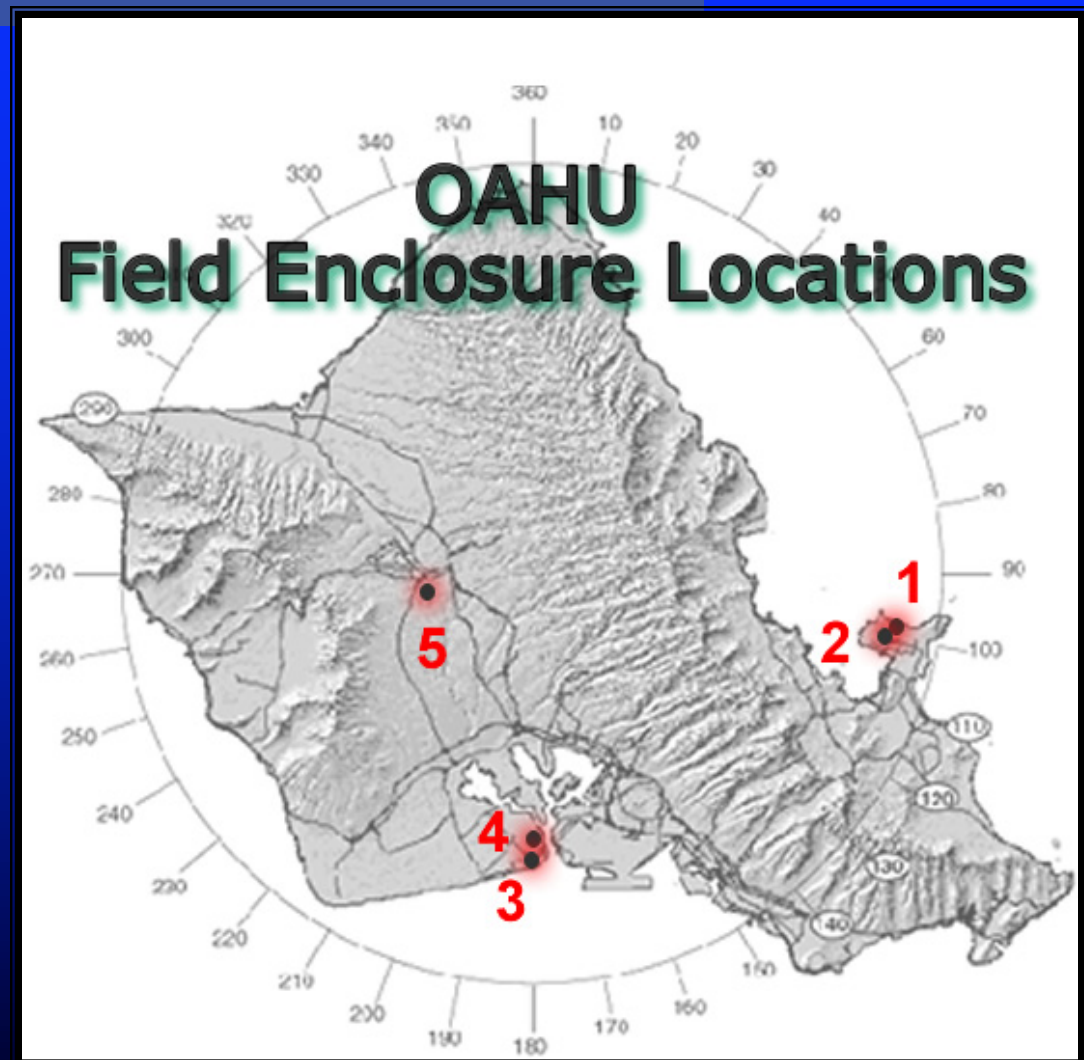
3 - Iroquois Point – 55 m

Leeward near coast:

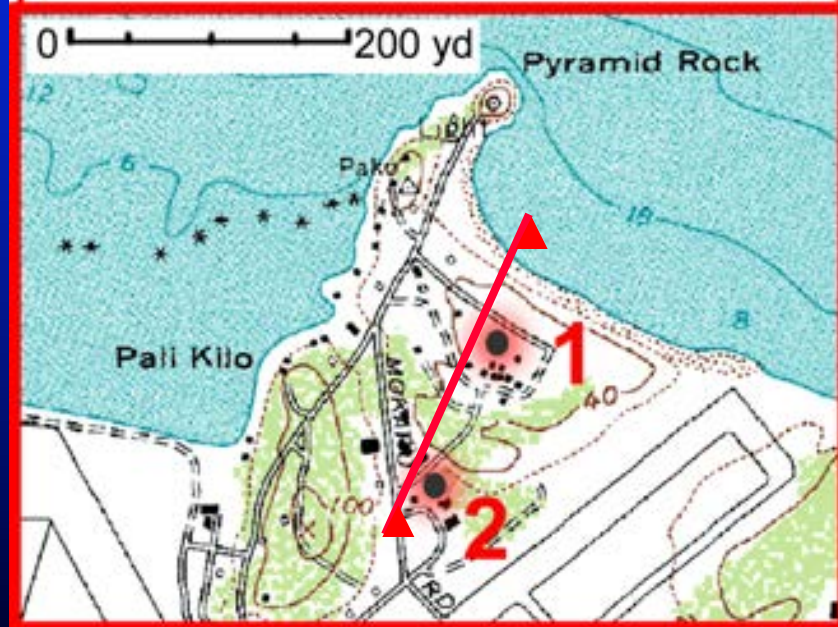
4 - Iroquois Point – 550 m

Inland:

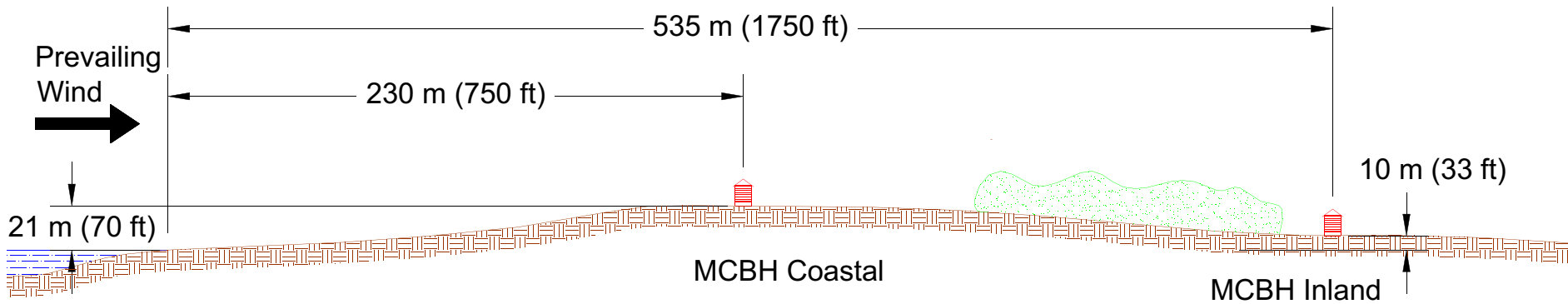
5 – Wheeler AAF - > 1000 m



Kaneohe MCBH



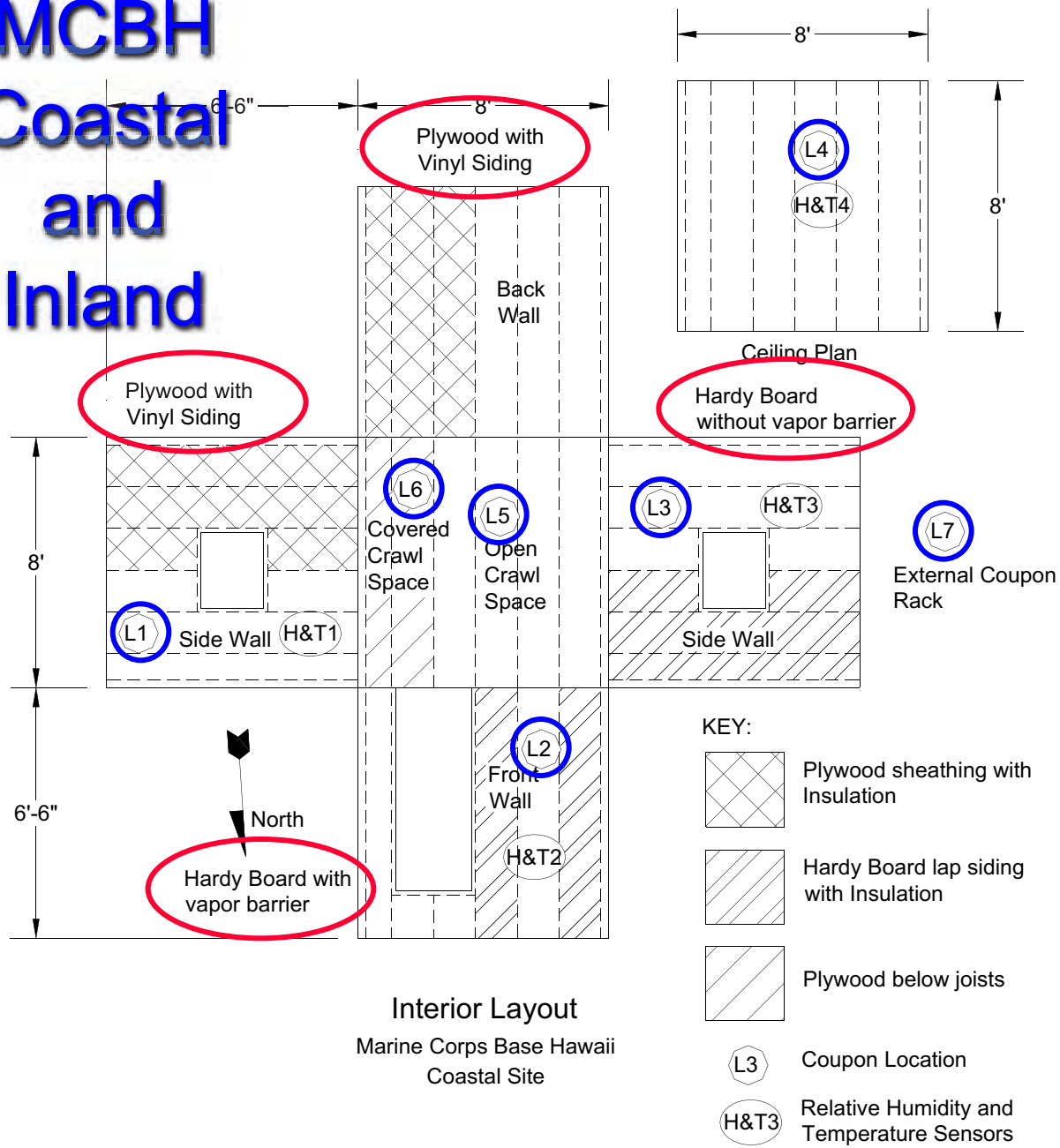
MCBH Profile



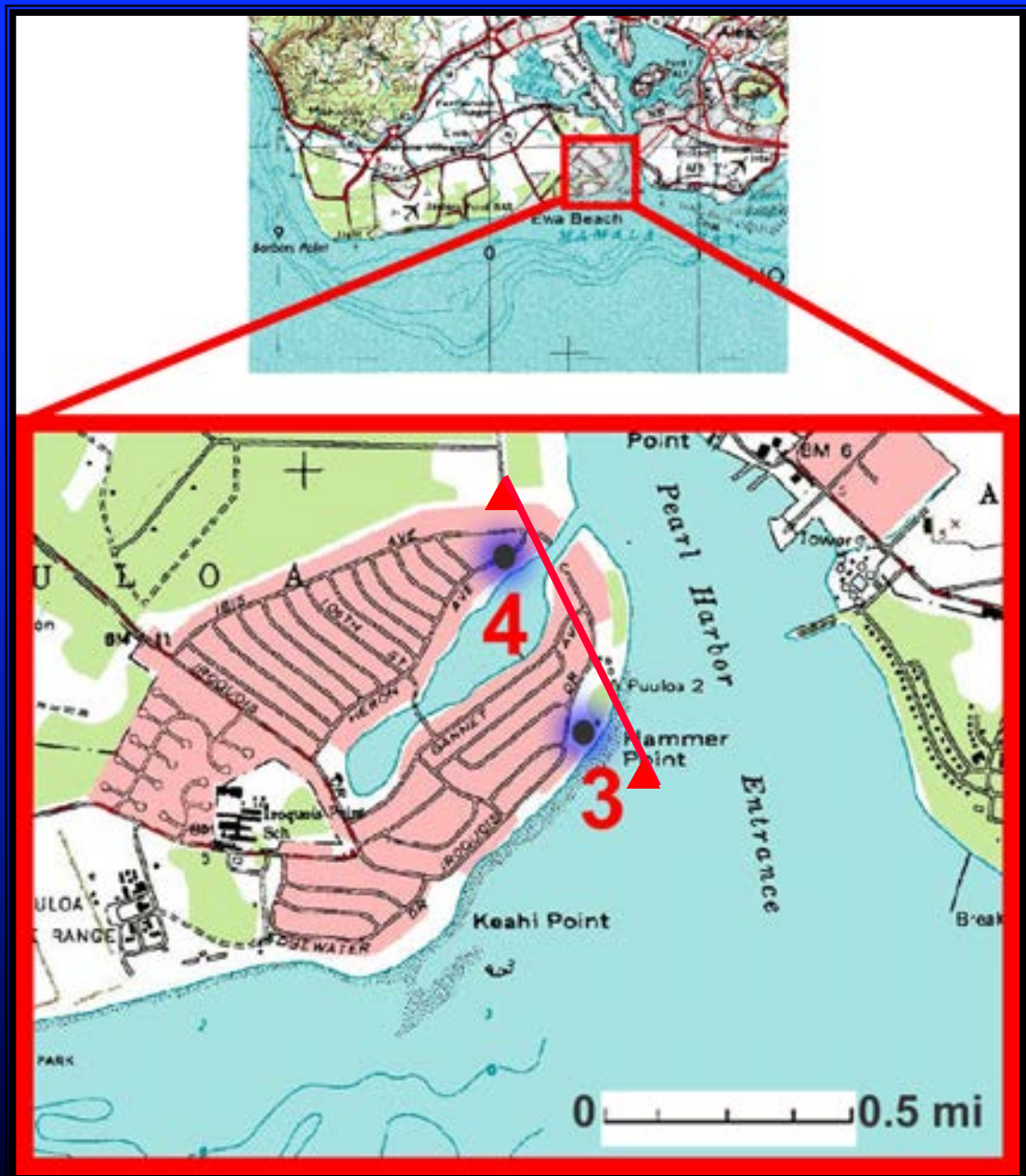
Kaneohe MCBH - Coastal



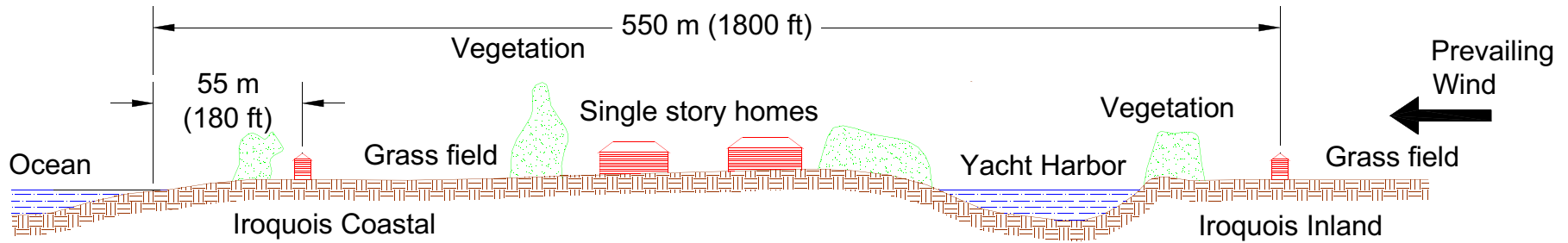
MCBH Coastal and Inland



Iroquois Point



Iroquois Profile



Iroquois Enclosures



Iroquois Coastal

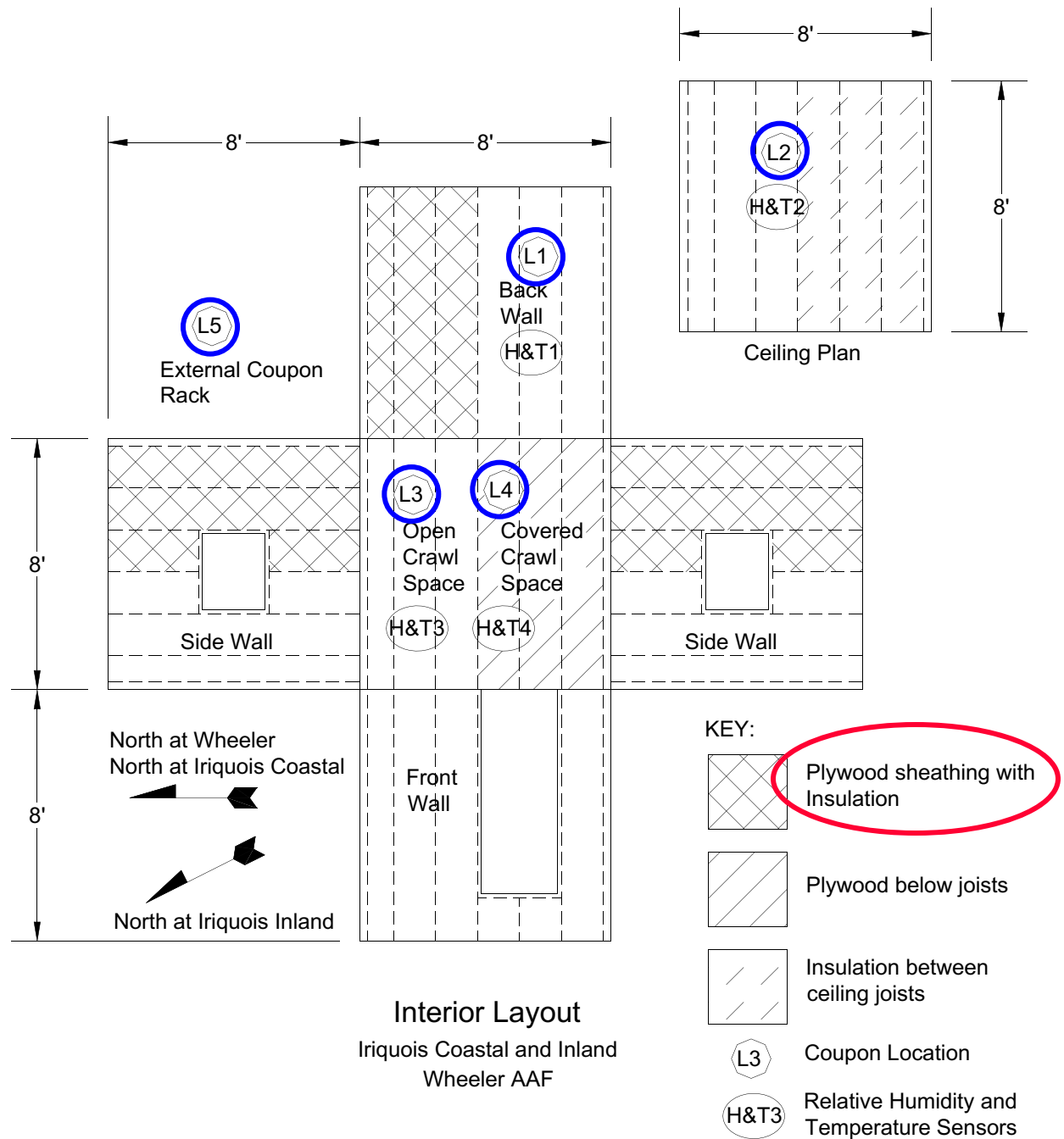


Iroquois Inland

Wheeler Army Airfield



Iroquois Coastal, Iroquois Inland and Wheeler AAF



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

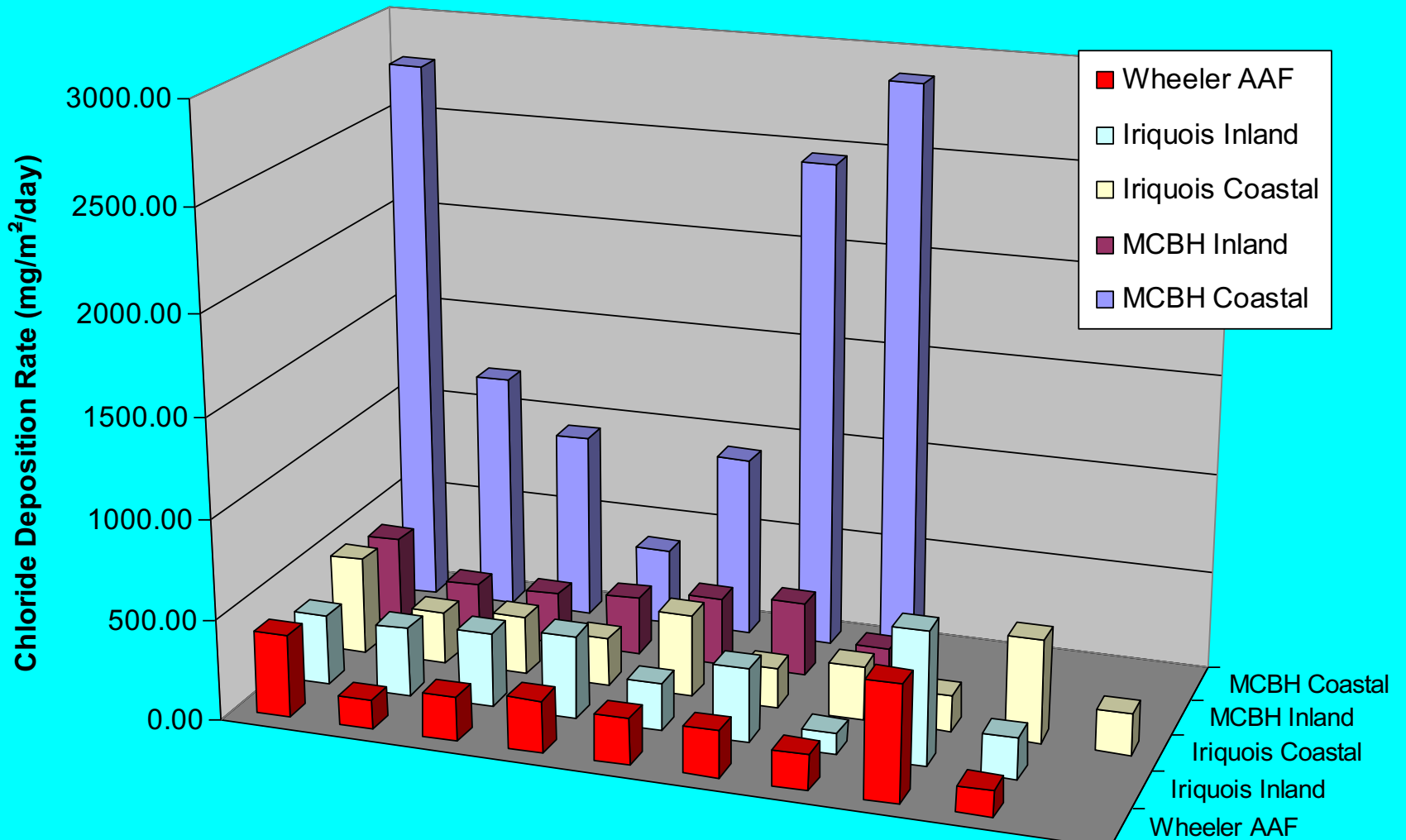


Atmospheric Chloride Candle

- Atmospheric chloride deposition rate
- Covered for rain protection
- Reported as $\text{mgCl}/\text{m}^2/\text{day}$



Chloride Deposition Rates



Field Test Connections

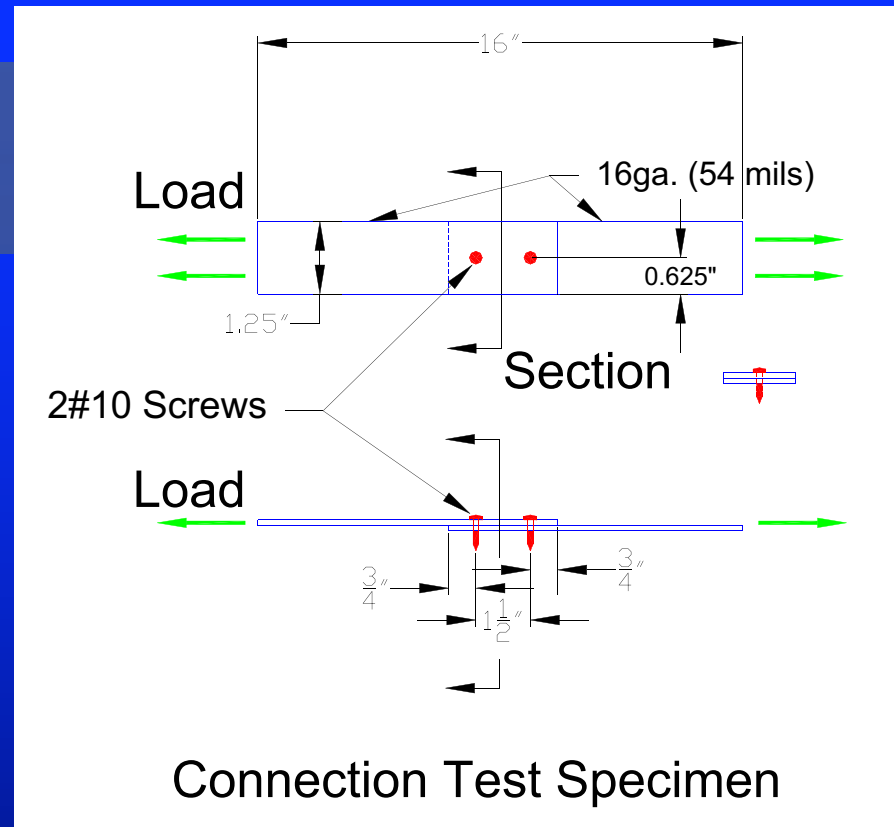
- Connection Selection:
 - (2) #10 screws
 - In lap splice of 1.25" wide 16 ga (54 mil) G60 galvanized plates (Zinc coating approx. 12.5 μm)



Lox-head



Hex-head



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

Observations at MCBH Coastal

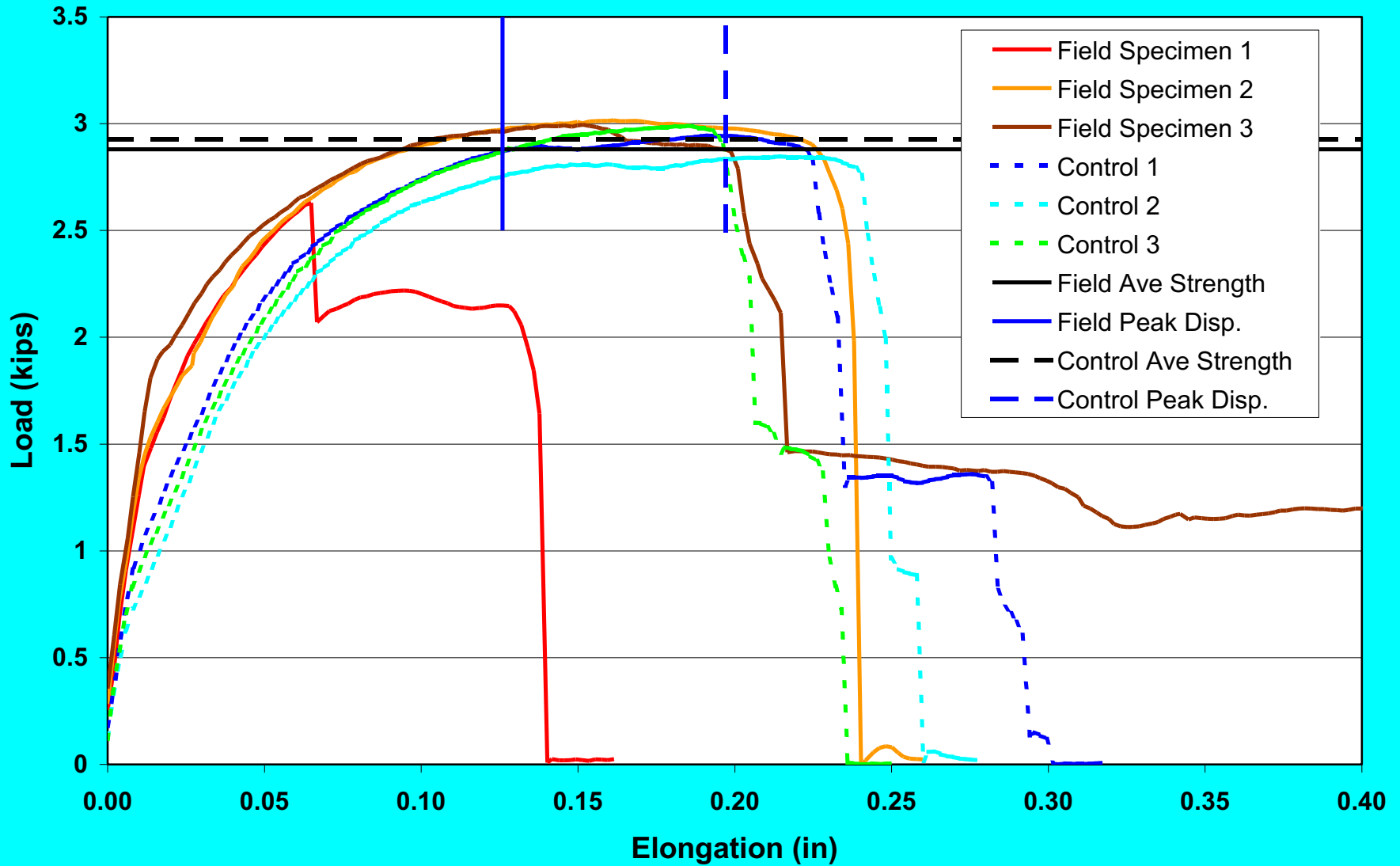
Exterior Connections



MCBH Coastal – Exterior Connections 7 Months Exposure



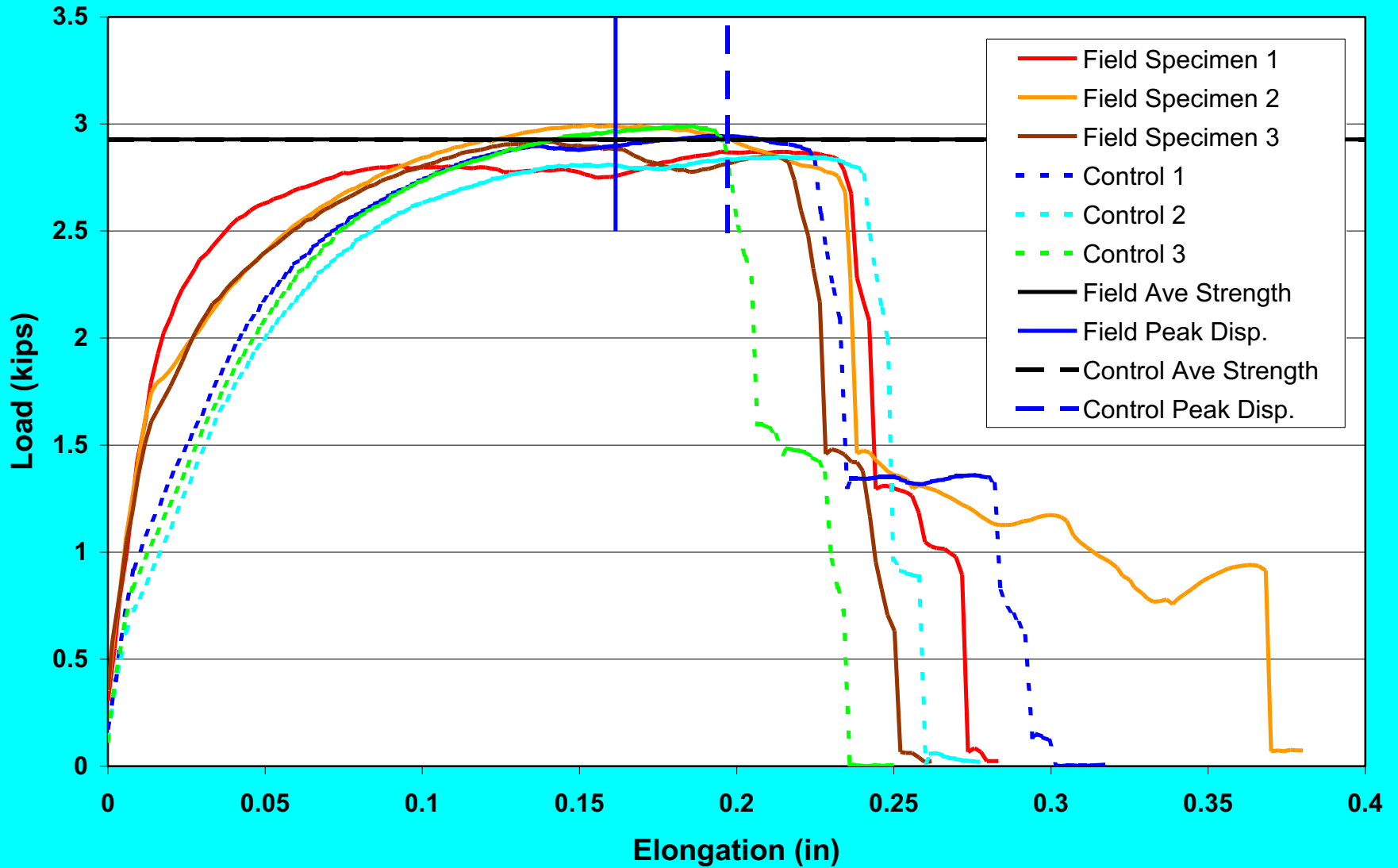
MCBH Coastal - Exterior exposure (L7) - 7 Months



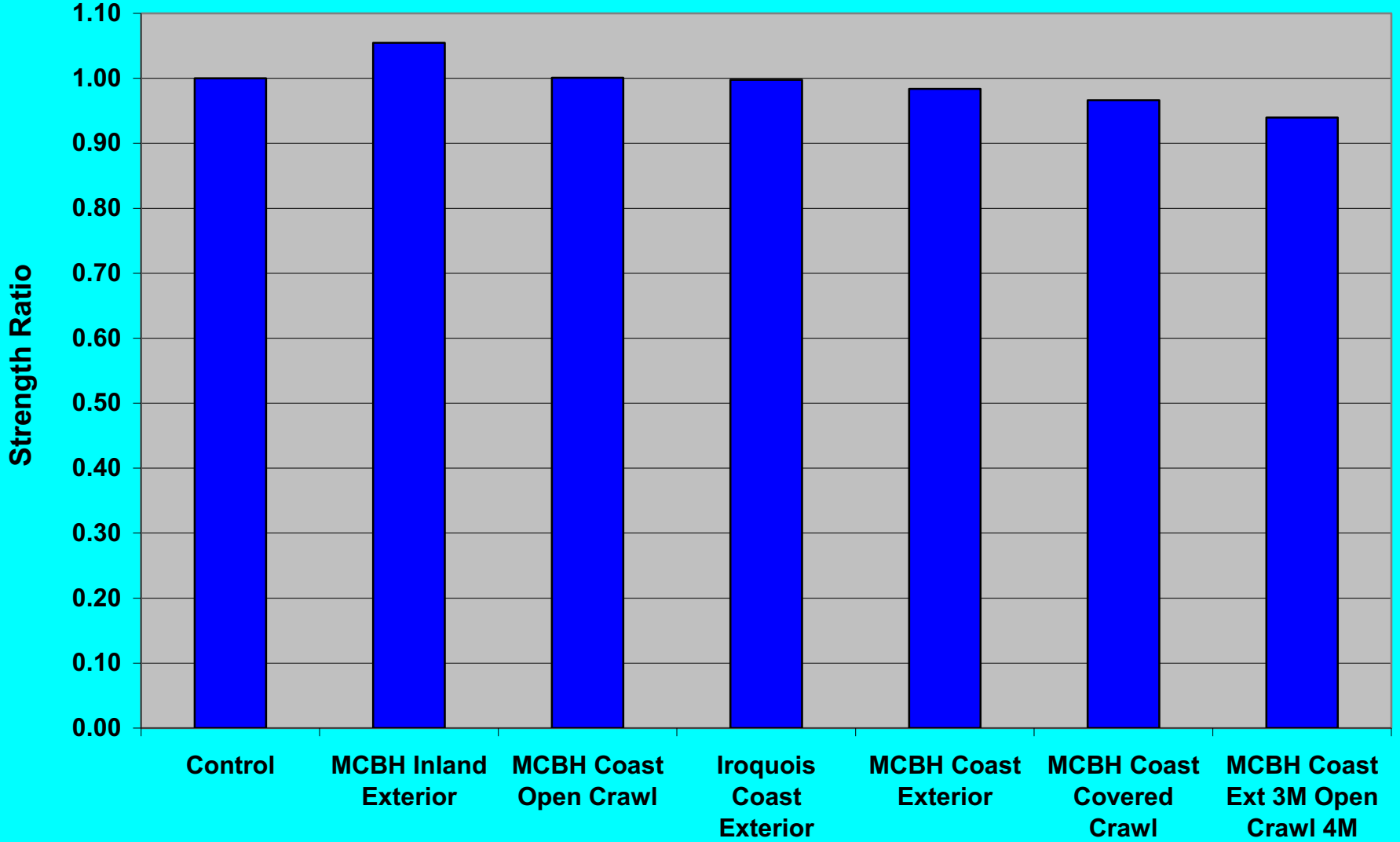
MCBH Coastal – Open Crawl Connections 7 Months Exposure



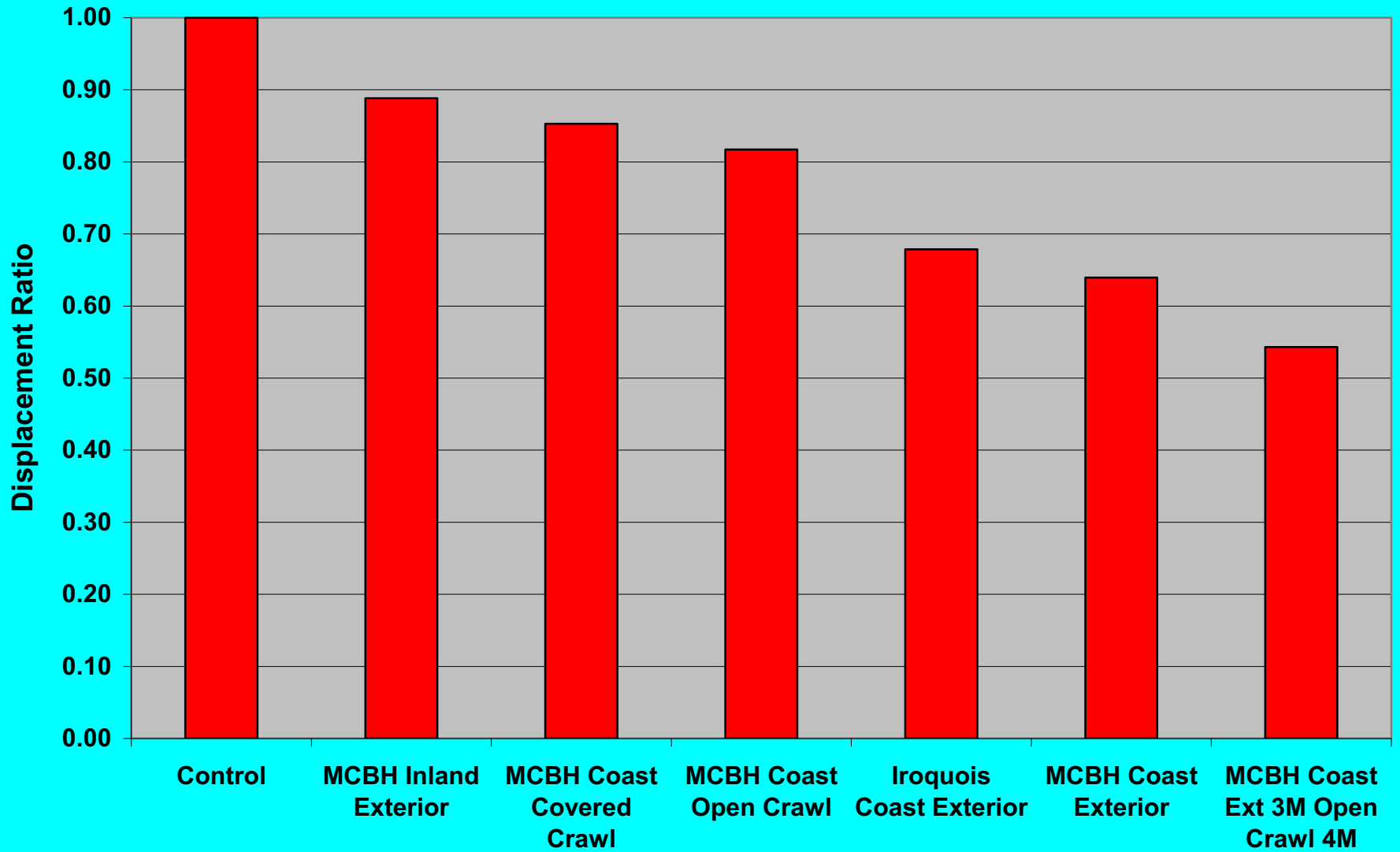
MCBH Coastal - Open Crawl exposure (L5) - 7 Months



Average Peak Strength - 7 Month exposure



Average Displacement at Peak Load - 7 Months Exposure



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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 Corrosion Chamber



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

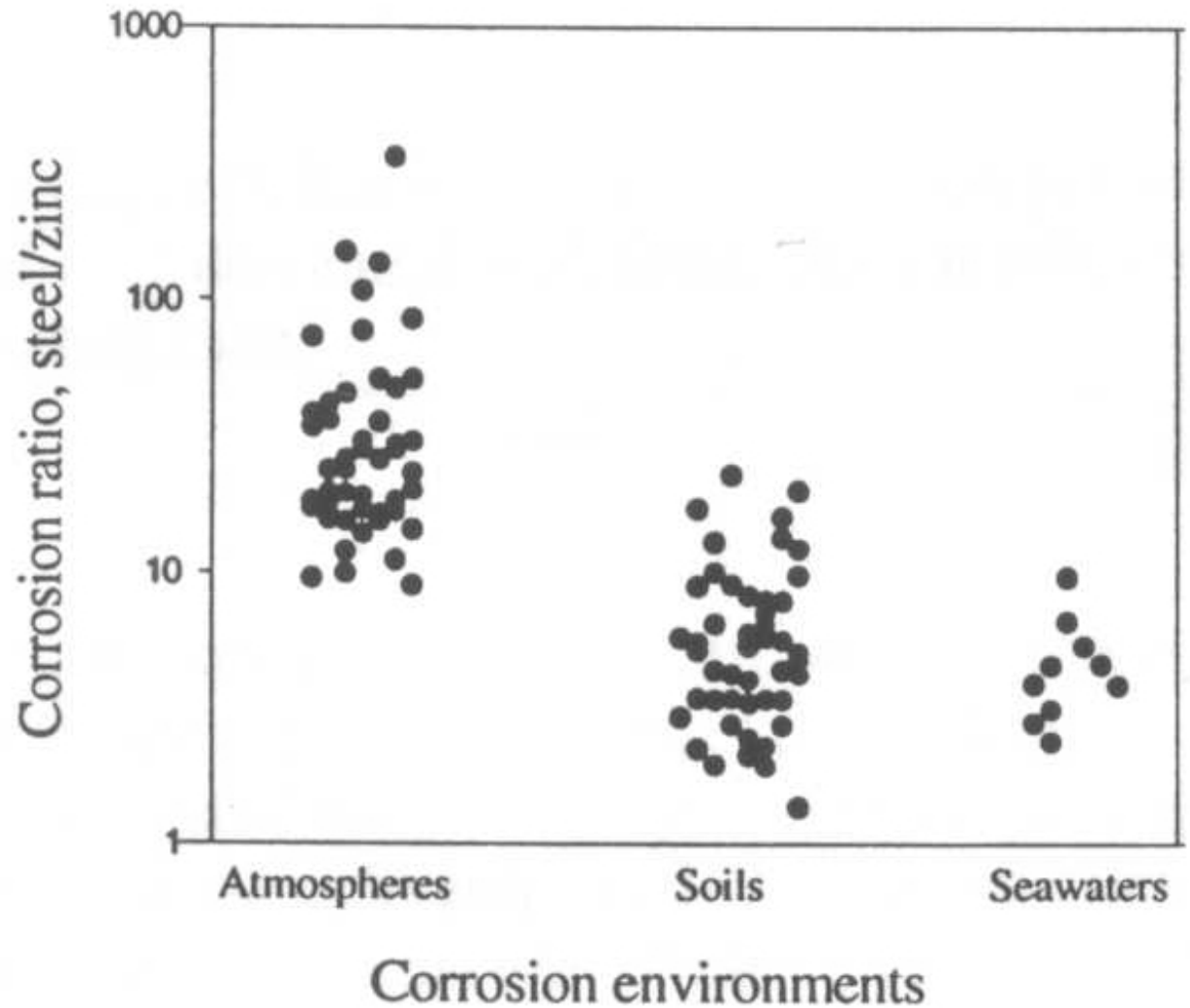


Figure 2 Corrosion ratios of steel/zinc in different natural corrosion environments

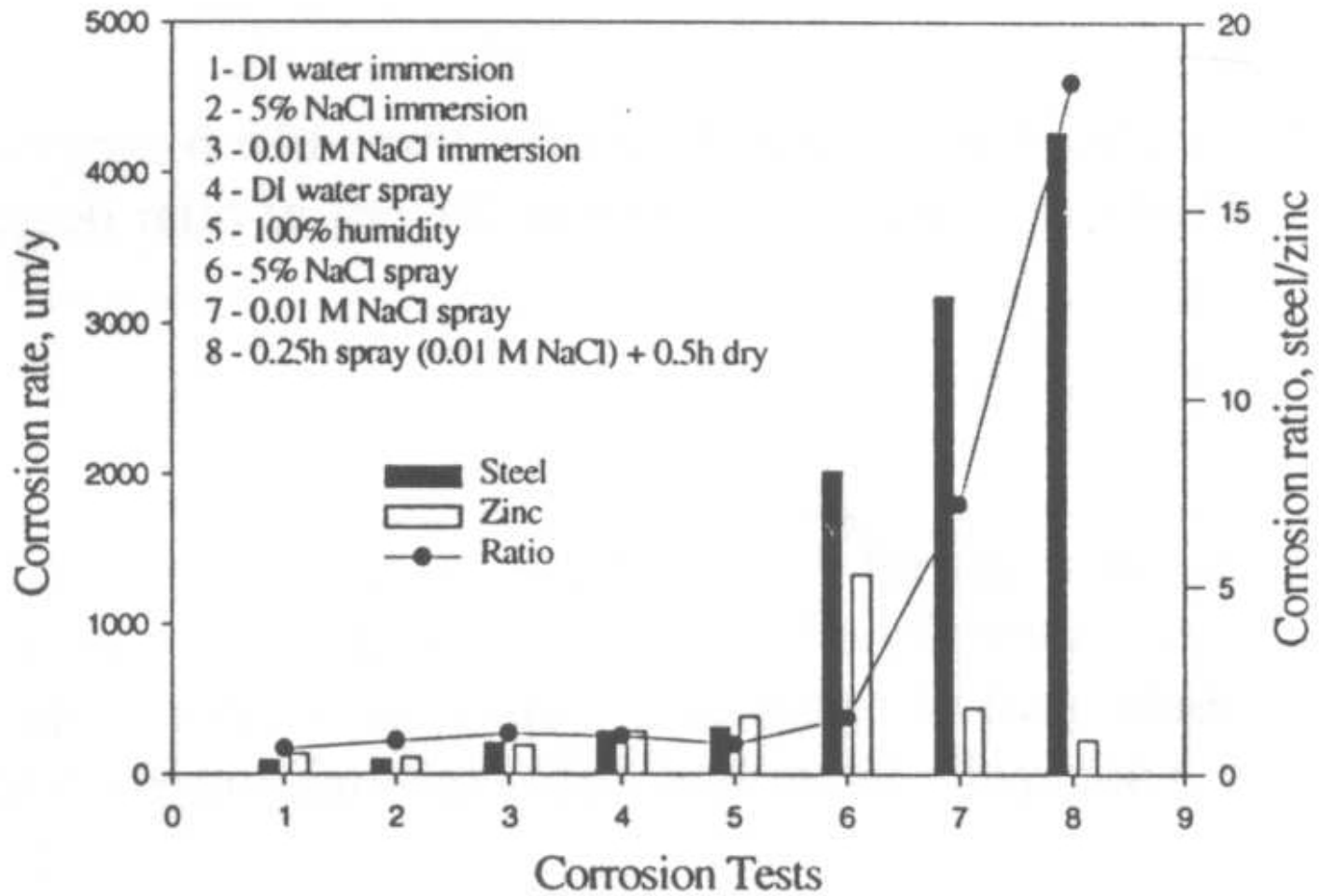


Figure 3 Corrosion rates of steel and zinc and their ratios in different corrosion tests

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 35° C
 - Drying for 30 minutes at 35°C
 - 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

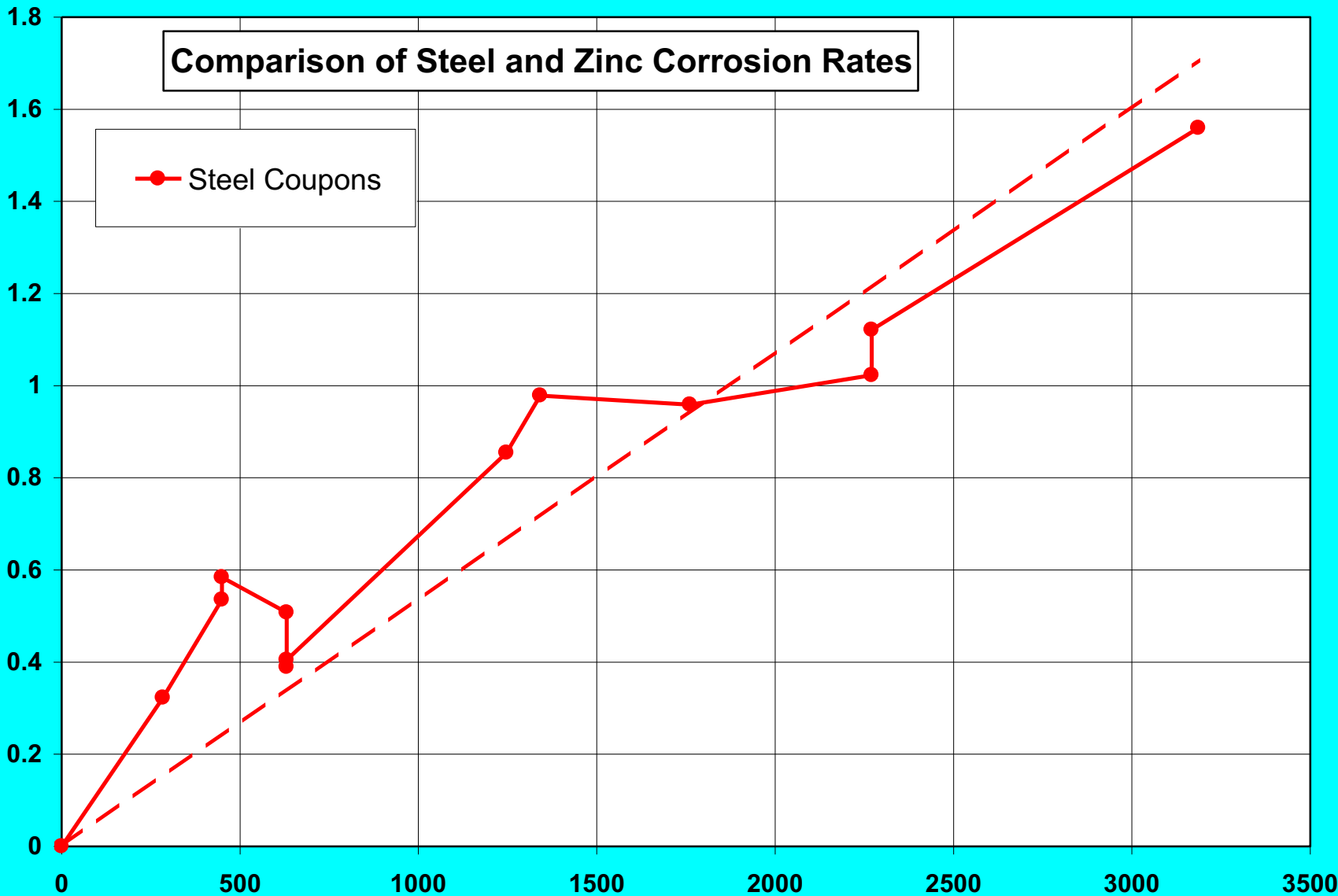


Comparison of Steel and Zinc Corrosion Rates

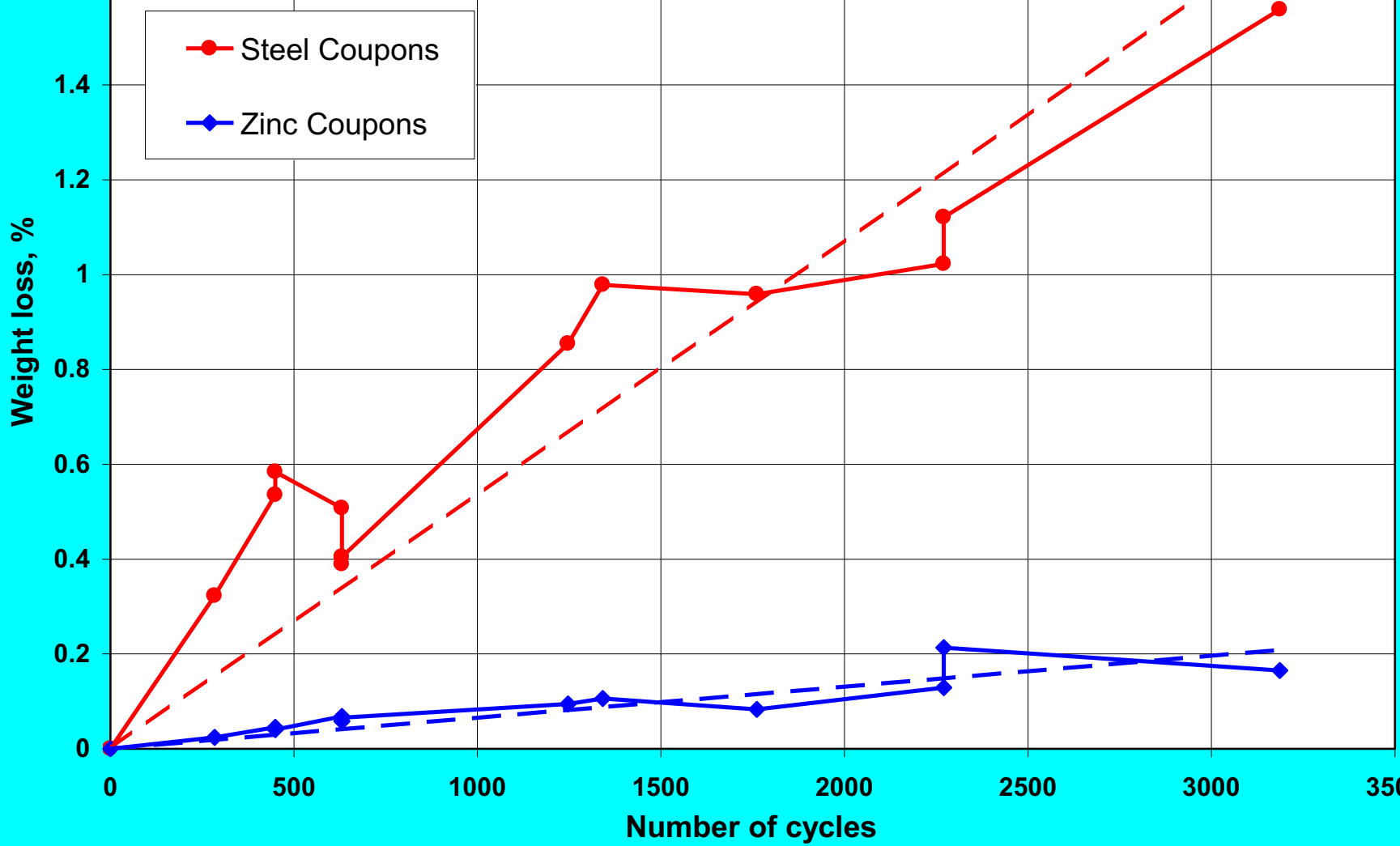
● Steel Coupons

Weight loss, %

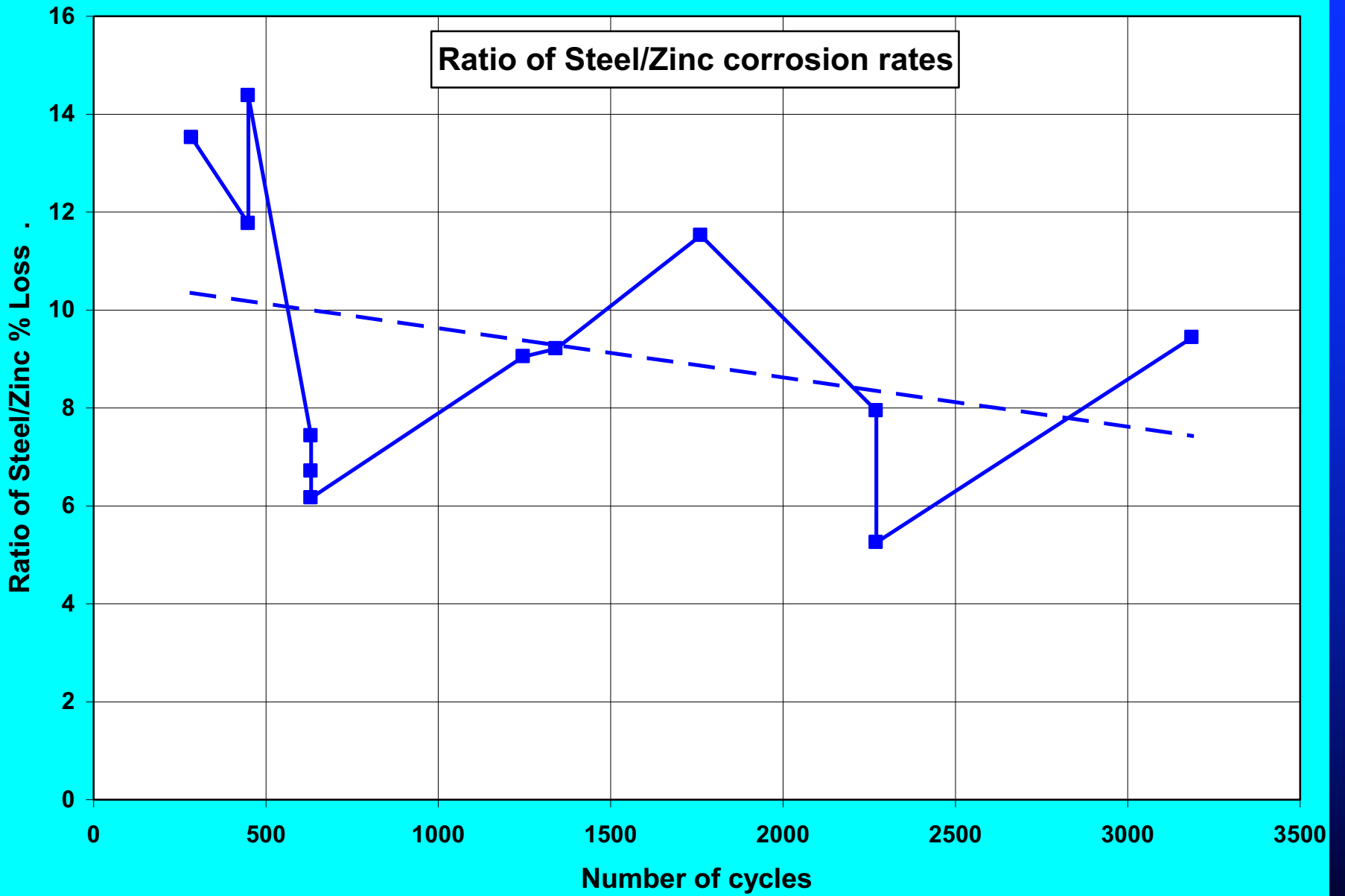
Number of cycles



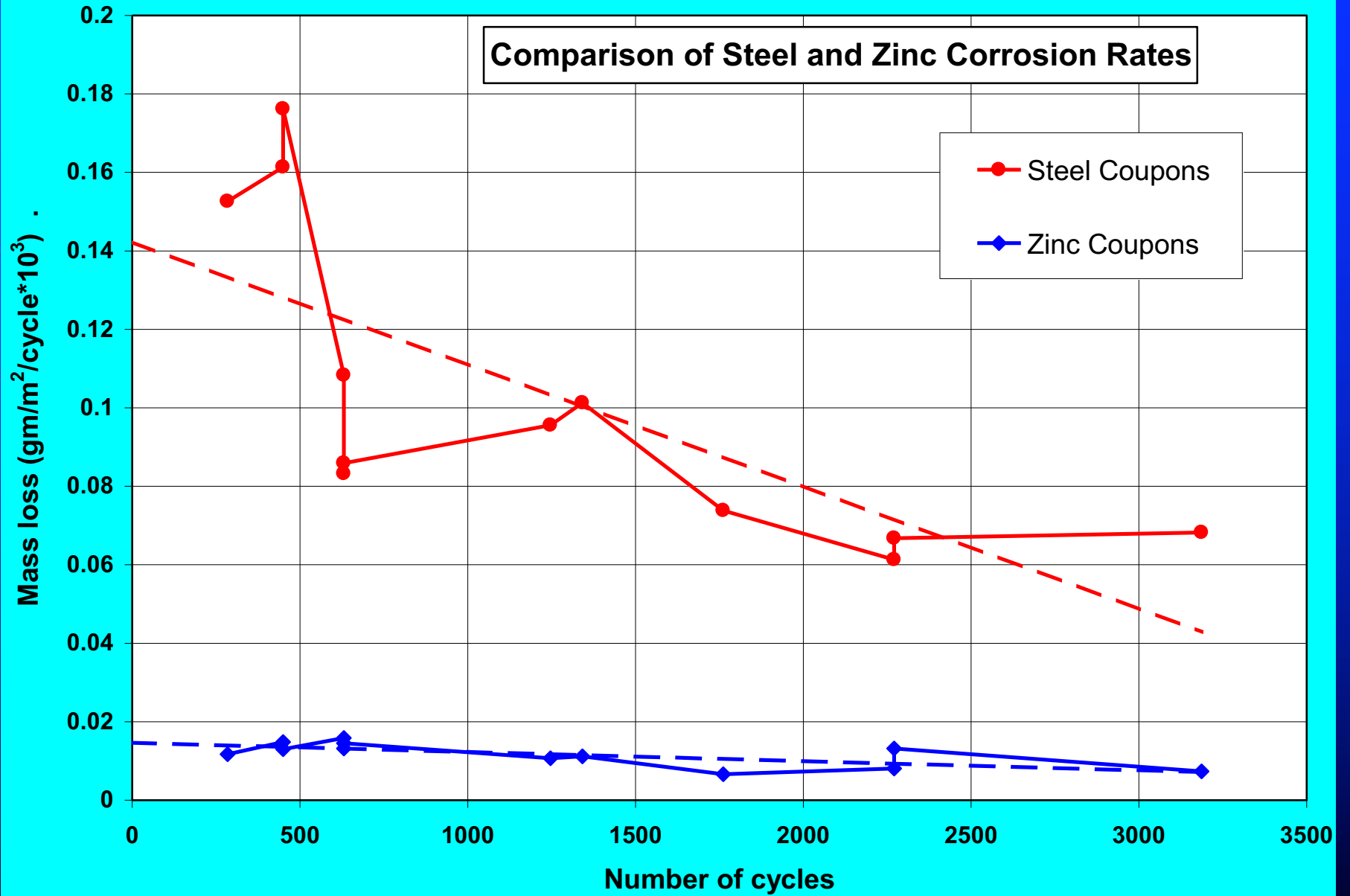
Comparison of Steel and Zinc Corrosion Rates



Ratio of Steel/Zinc corrosion rates



Comparison of Steel and Zinc Corrosion Rates



Connections after 1056 Cycles

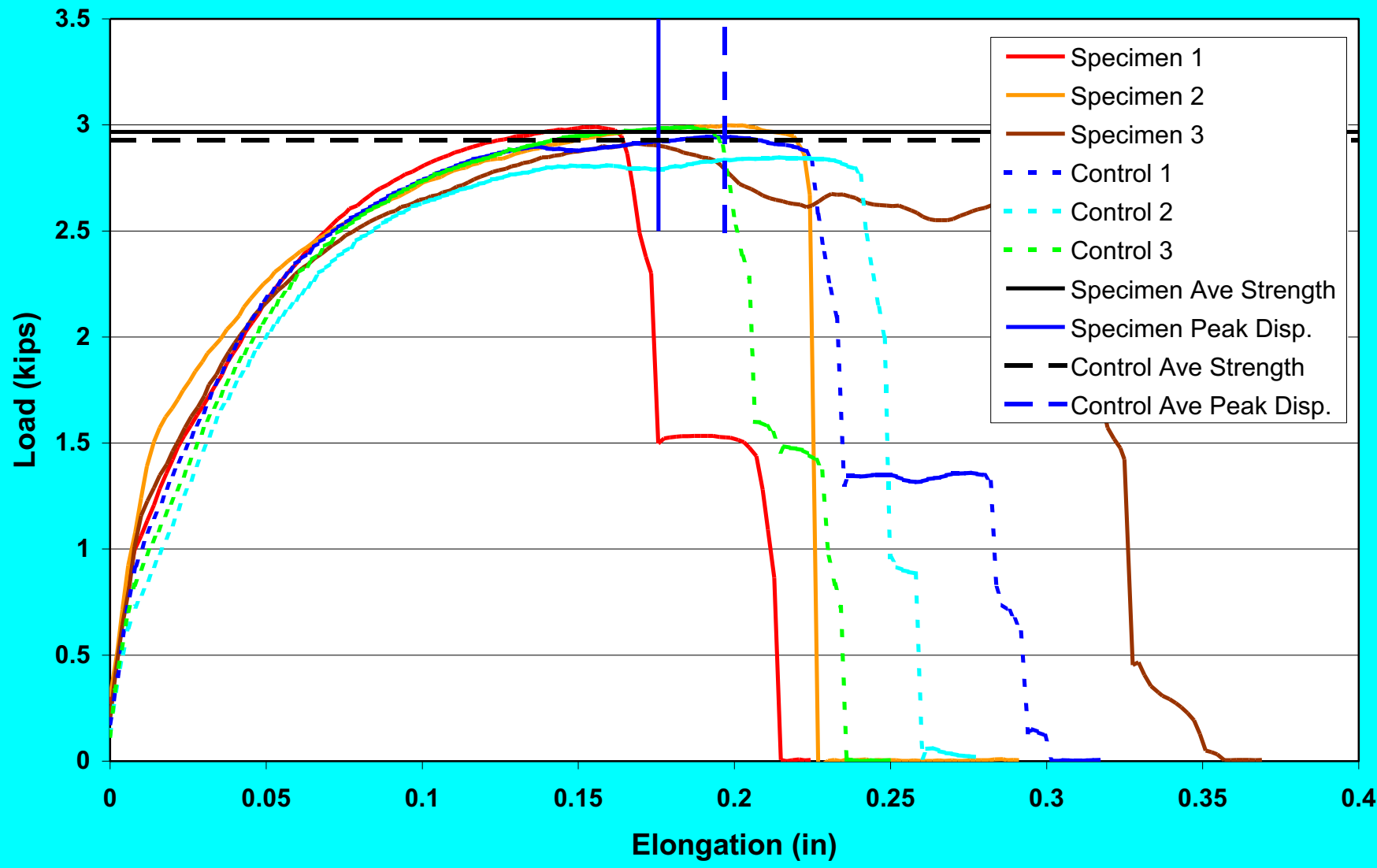


Threads Down

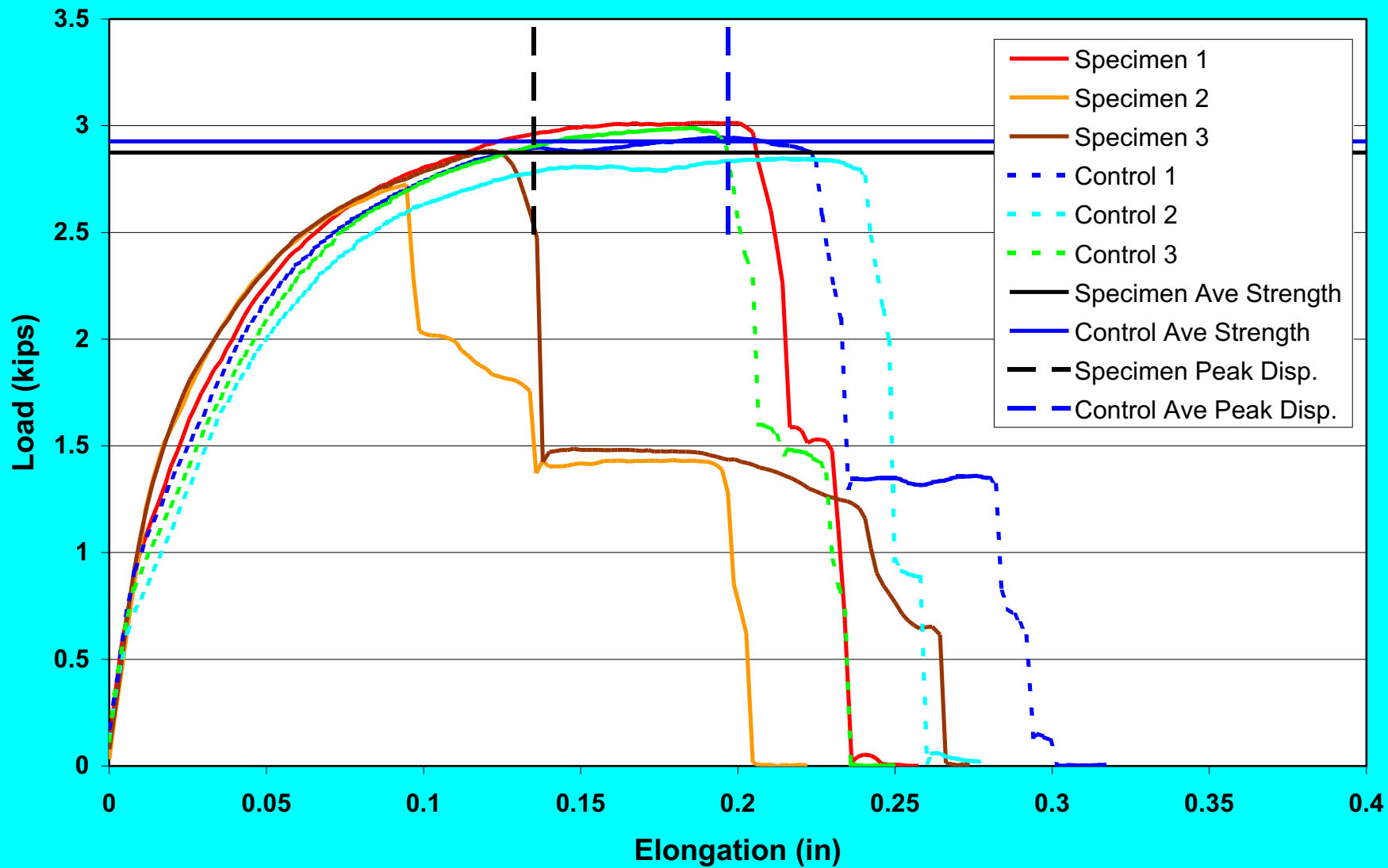


Threads Up

Connection Tests - 1056 cycles - Threads down



Connection Tests - 1056 cycles - Threads up



Connections after 1979 Cycles



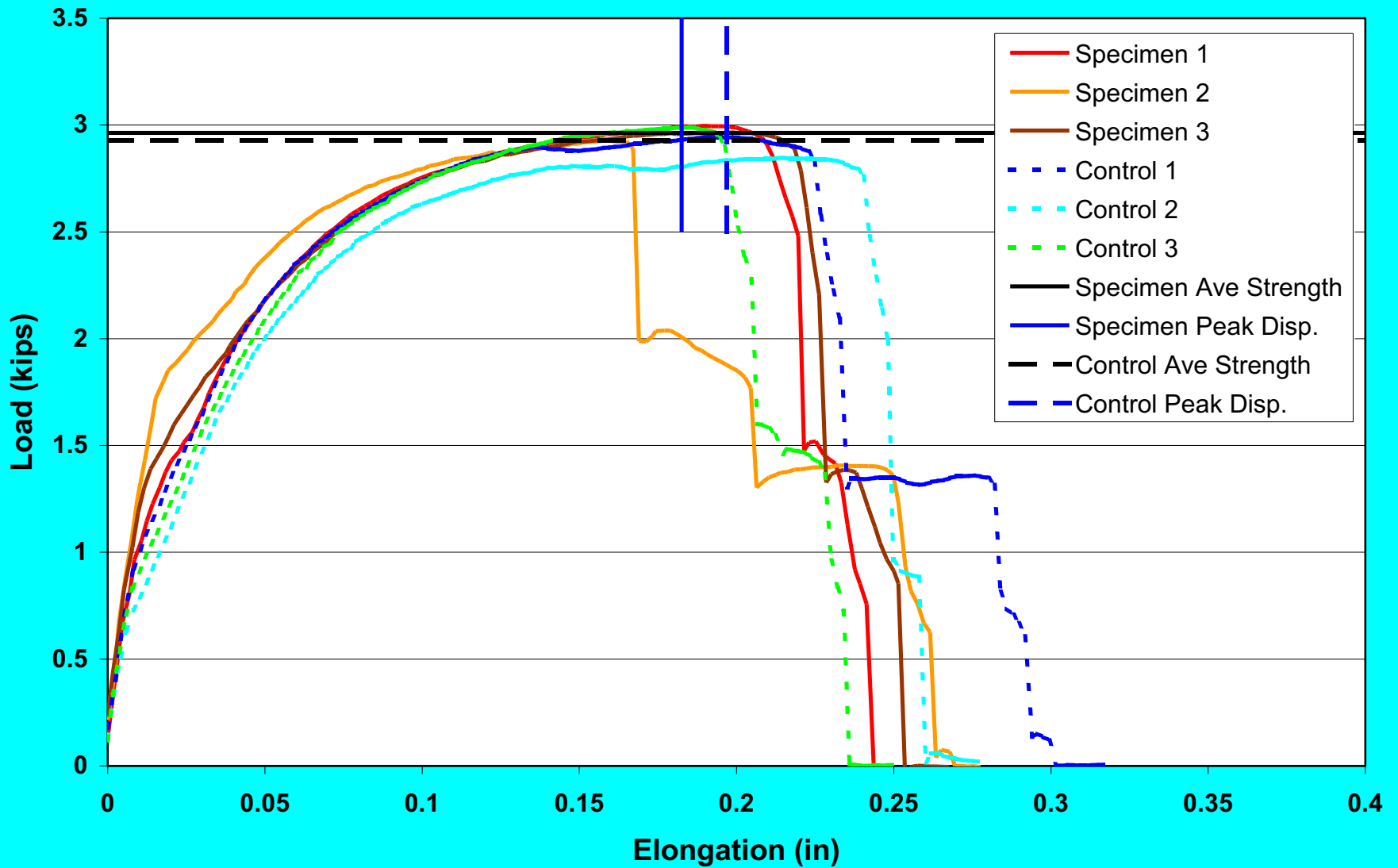
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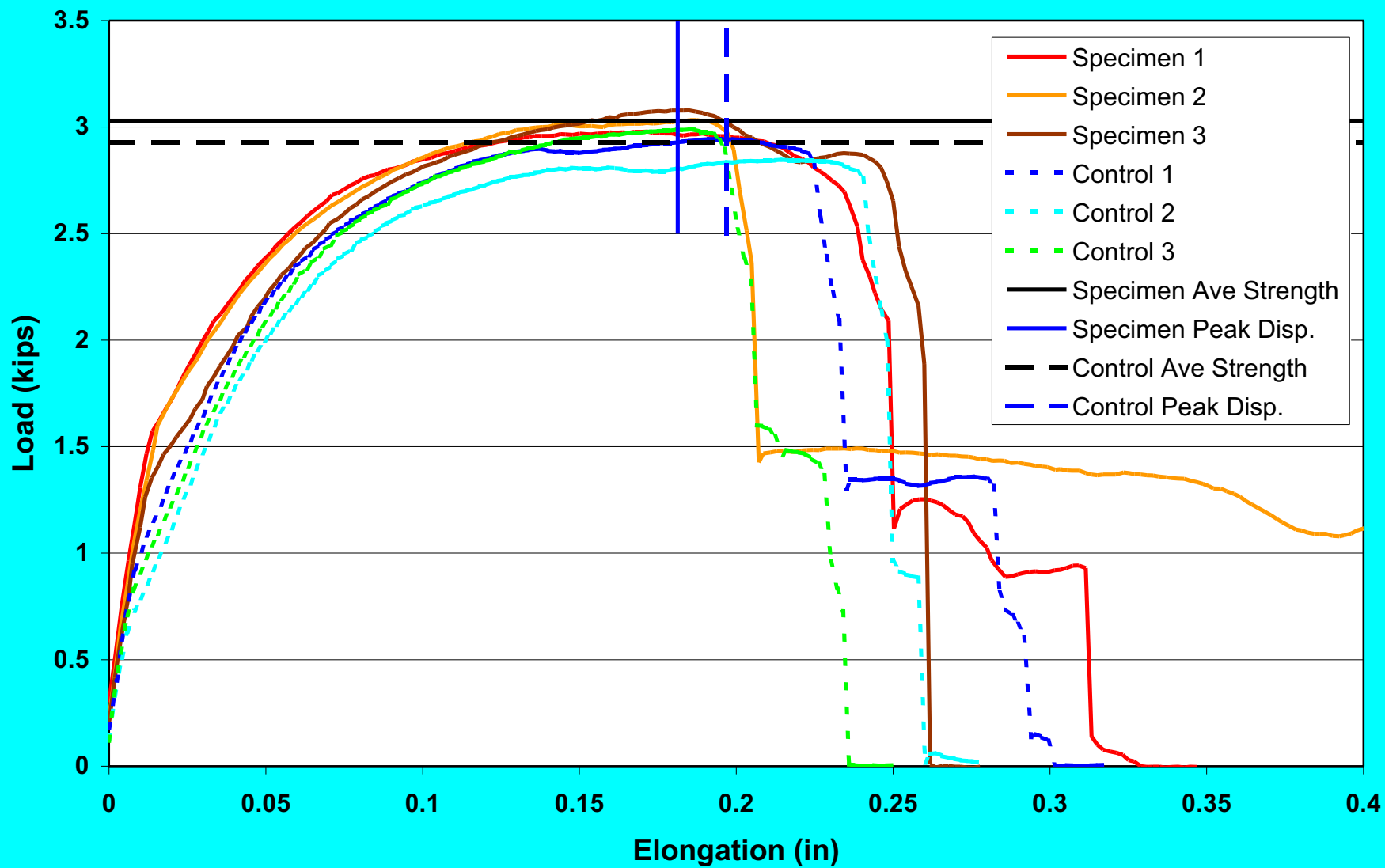
Threads Up



Connection Tests - 1979 cycles - Threads down



Connection Tests - 1979 cycles - Threads up



Connections after 2772 Cycles

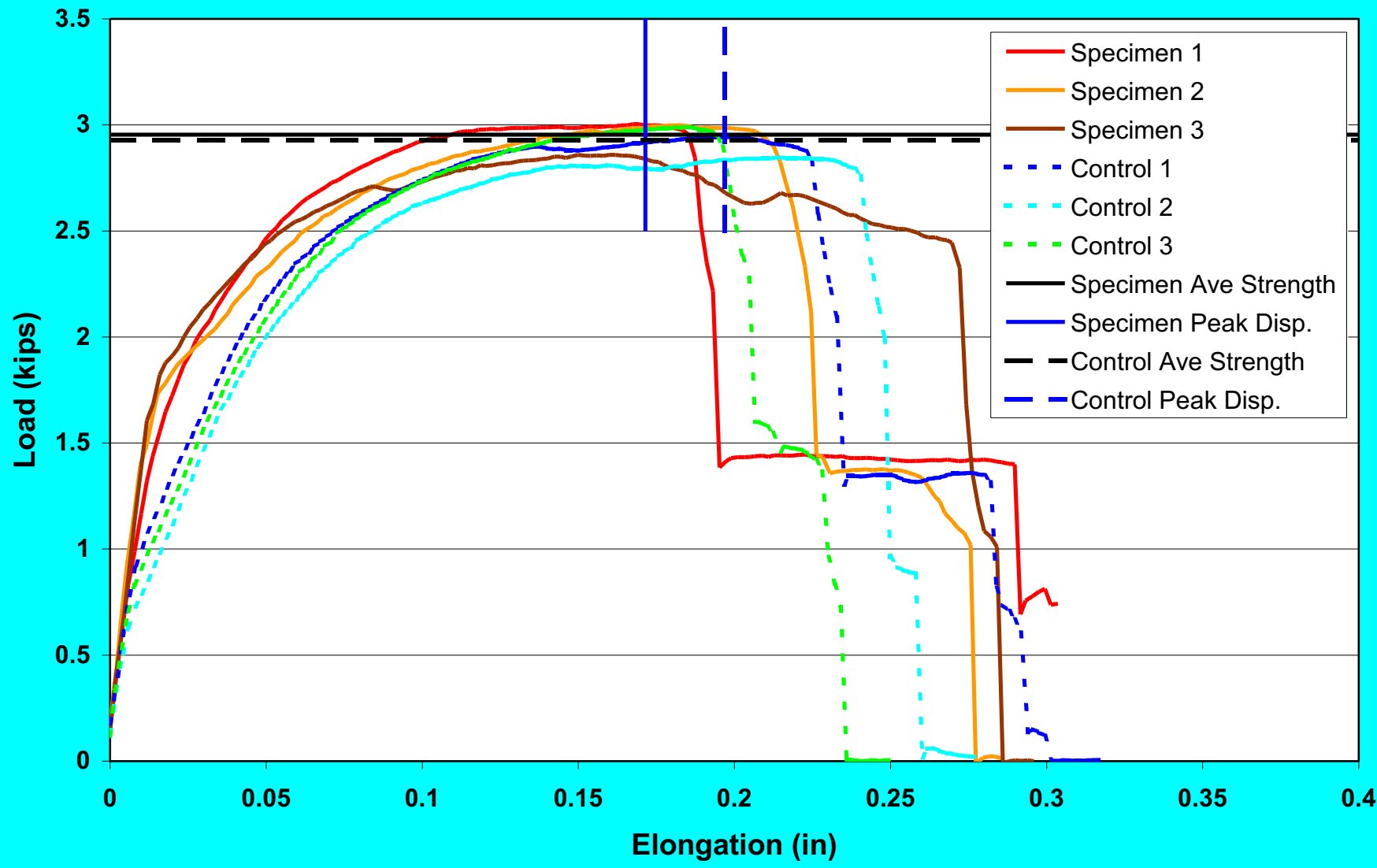


Threads Down

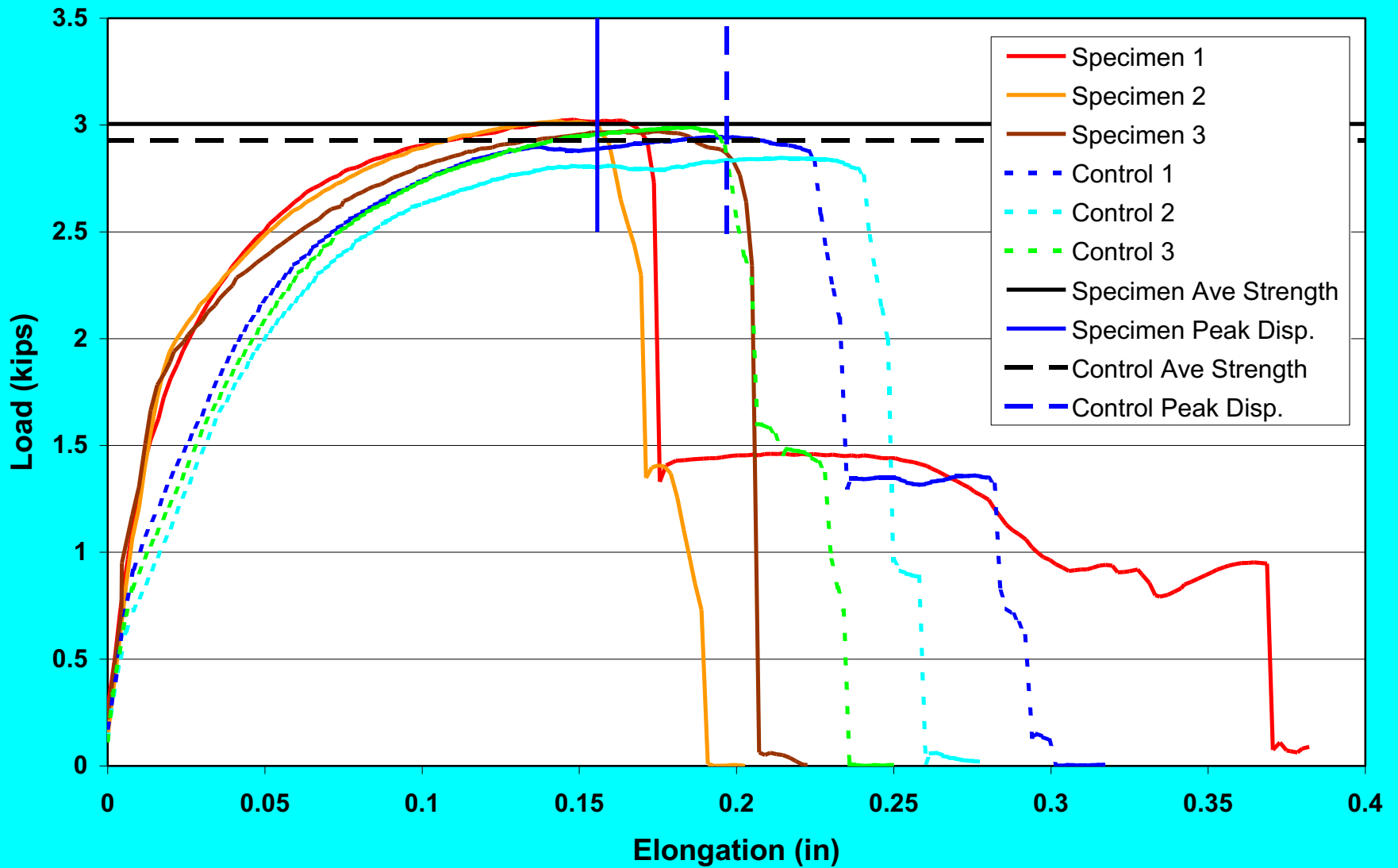


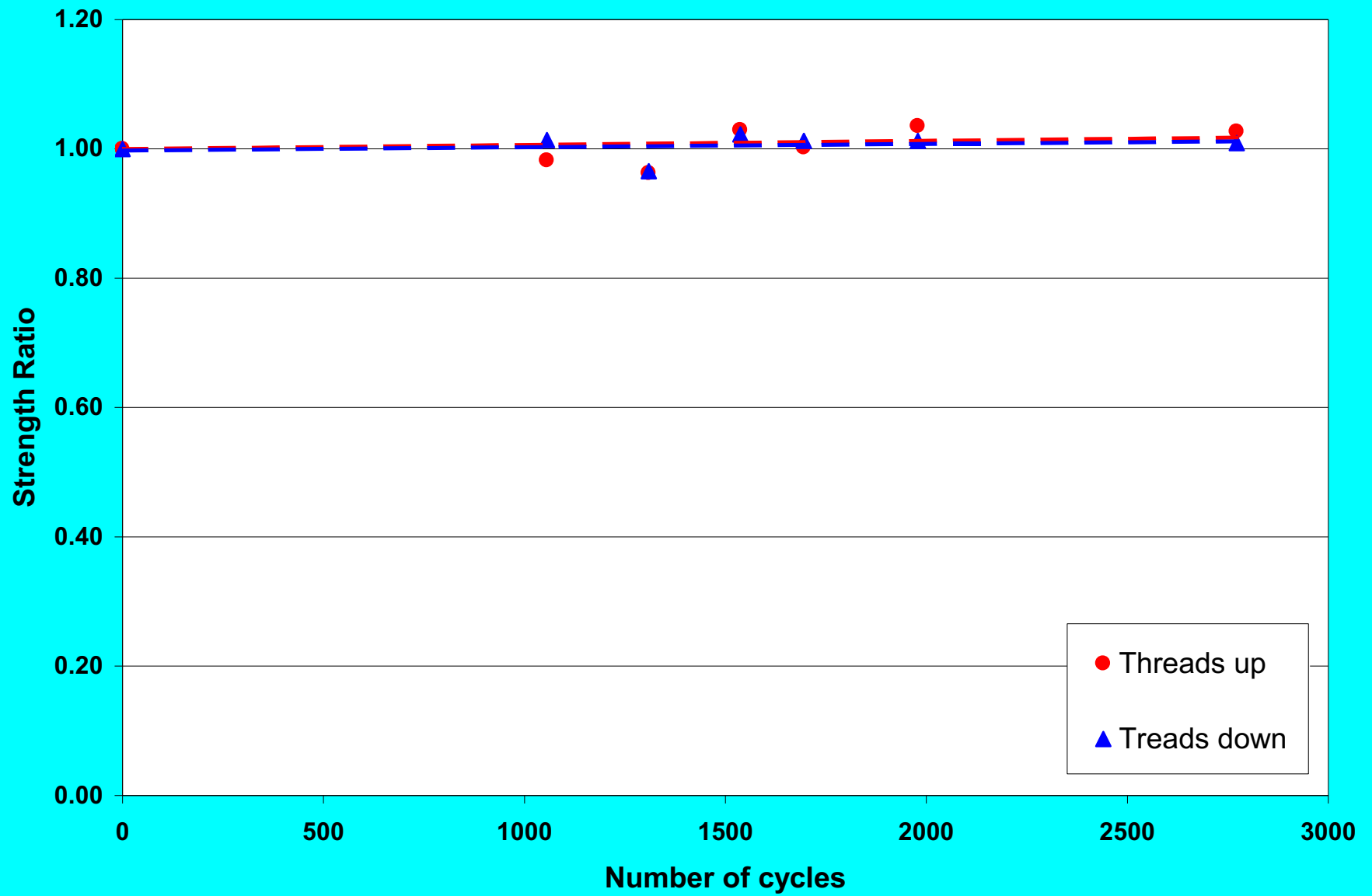
Threads Up

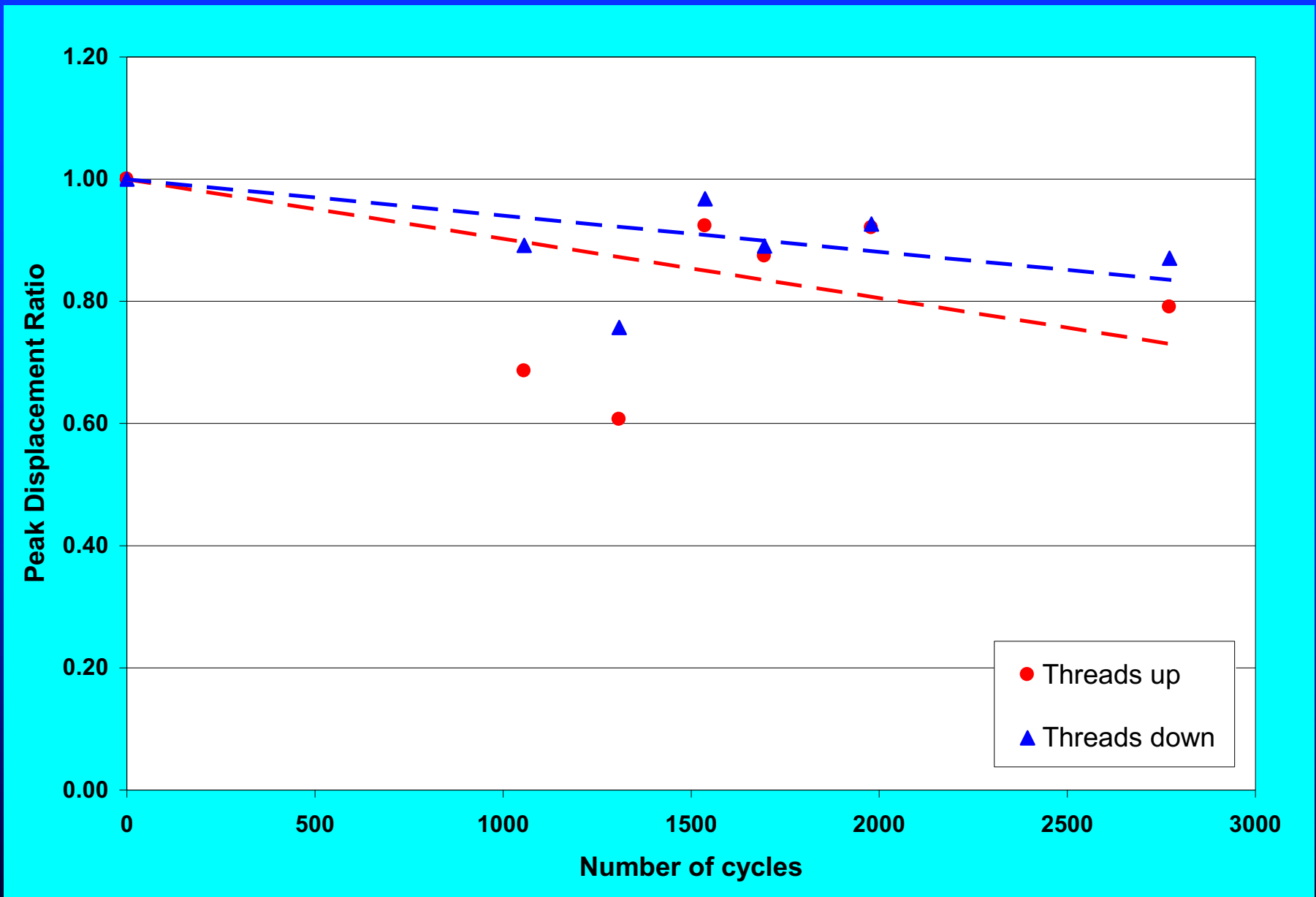
Connection Tests - 2772 cycles - Threads down



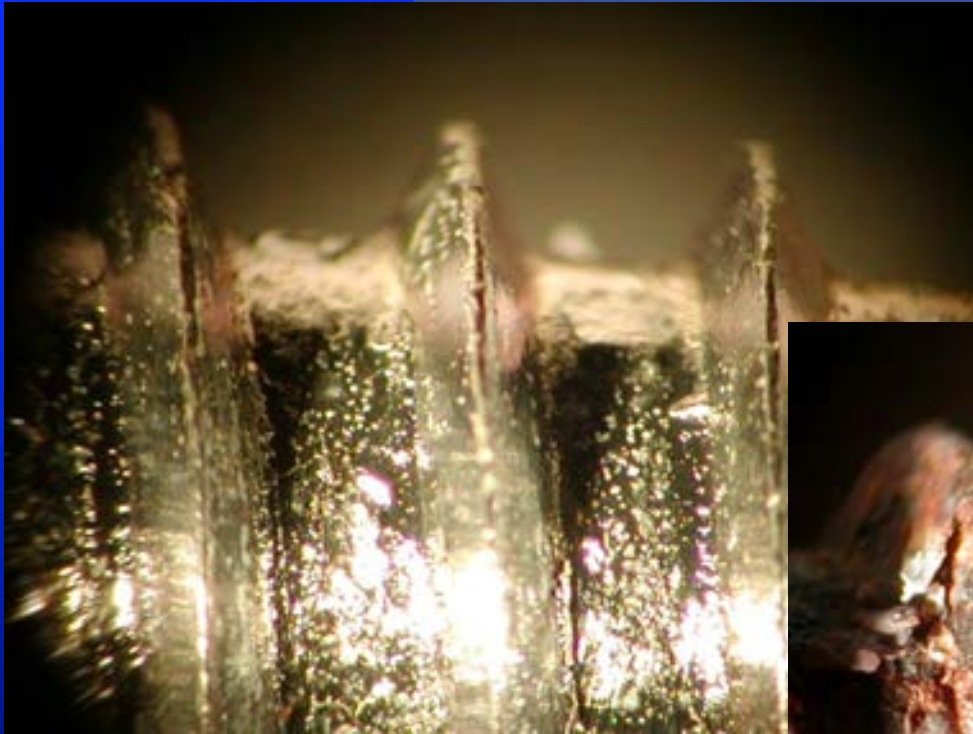
Connection Tests - 2772 cycles - Threads up







Microscopic Inspection

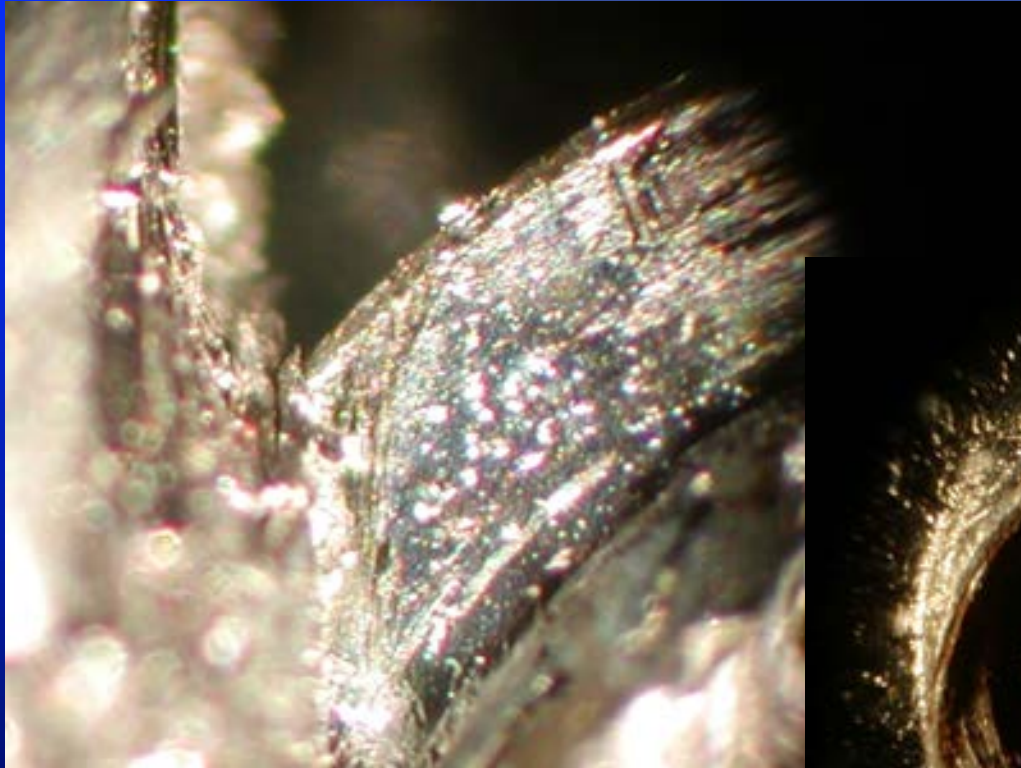


Screw
Threads -
Original



Screw
Threads -
1537 Cycles

Microscopic Inspection



Failed
Connection -
Original

Failed
Connection –
1537 Cycles



Preliminary Correlation with Field Sites

Location	Exposure	1 year exposure equivalent to	1000 cycles (1 month) equiv to
MCBH Coastal	Exposed crawl space	1500 cycles	8 months
	Vented attic Vented Wall	500 cycles	2 years
	Sealed crawl space or walls	250 cycles	4 years
MCBH Inland Iroquois Coastal Iroquois Inland	Exposed crawl and vented attic	250 cycles	4 years
	Sealed crawl space and walls	< 250 cycles	> 4 years
Wheeler AAF	All conditions	< 250 cycles	> 4 years

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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 |

Observations at MCBH Coastal



Crawl Space



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



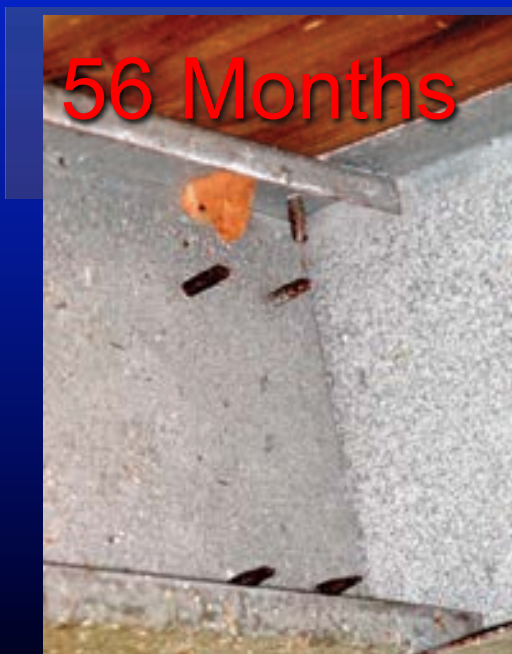
Observations at MCBH Inland



Observations at MCBH Inland



Observations at MCBH Inland



Observations at MCBH Inland



Observations at MCBH Inland



Observations at MCBH Inland



Observations at MCBH Inland



56 Months



Observations at MCBH Inland



28 Months



56 Months



Observations at MCBH Inland



Observations at MCBH Inland



Observations at MCBH Inland



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



Covered Crawl Space



21 Months



Observations at MCBH Coastal



56 Months



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



28 Months



56 Months



Observations at MCBH Coastal



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

Distance from Shoreline (m)	Site Characteristics			
	Onshore Wind		Offshore Wind	
	Unshielded	Shielded	Unshielded	Shielded
$L \leq 200$ m				
$200 \text{ m} < L \leq 500$ m				
$500 \text{ m} < L \leq 1000$ m				
$L > 1000$ m				

Category Assignment

Distance from Shoreline (m)	Site Characteristics			
	Onshore Wind		Offshore Wind	
	Unshielded	Shielded	Unshielded	Shielded
$L \leq 200$ m	A	A	A	
$200 \text{ m} < L \leq 500$ m	A			
$500 \text{ m} < L \leq 1000$ m				
$L > 1000$ m				

Category Assignment

Distance from Shoreline (m)	Site Characteristics			
	Onshore Wind		Offshore Wind	
	Unshielded	Shielded	Unshielded	Shielded
$L \leq 200$ m	A	A	A	
$200 \text{ m} < L \leq 500$ m	A			
$500 \text{ m} < L \leq 1000$ m			C	C
$L > 1000$ m	C	C	C	C

Category Assignment

Distance from Shoreline (m)	Site Characteristics			
	Onshore Wind		Offshore Wind	
	Unshielded	Shielded	Unshielded	Shielded
$L \leq 200$ m	A	A	A	B
$200 \text{ m} < L \leq 500$ m	A	B	B	B
$500 \text{ m} < L \leq 1000$ m	B	B	C	C
$L > 1000$ m	C	C	C	C

Category C Recommendations

Distance from Shoreline (m)	Site Characteristics			
	Onshore Wind		Offshore Wind	
	Unshielded	Shielded	Unshielded	Shielded
$L \leq 200$ m	A	A	A	B
$200 \text{ m} < L \leq 500$ m	A	B	B	B
$500 \text{ m} < L \leq 1000$ m	B	B	C	C
$L > 1000$ m	C	C	C	C

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

Distance from Shoreline (m)	Site Characteristics			
	Onshore Wind		Offshore Wind	
	Unshielded	Shielded	Unshielded	Shielded
$L \leq 200$ m	A	A	A	B
$200 \text{ m} < L \leq 500$ m	A	B	B	B
$500 \text{ m} < L \leq 1000$ m	B	B	C	C
$L > 1000$ m	C	C	C	C

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

Distance from Shoreline (m)	Site Characteristics			
	Onshore Wind		Offshore Wind	
	Unshielded	Shielded	Unshielded	Shielded
$L \leq 200$ m	A	A	A	B
$200 \text{ m} < L \leq 500$ m	A	B	B	B
$500 \text{ m} < L \leq 1000$ m	B	B	C	C
$L > 1000$ m	C	C	C	C

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.

Category A Recommendations

- 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



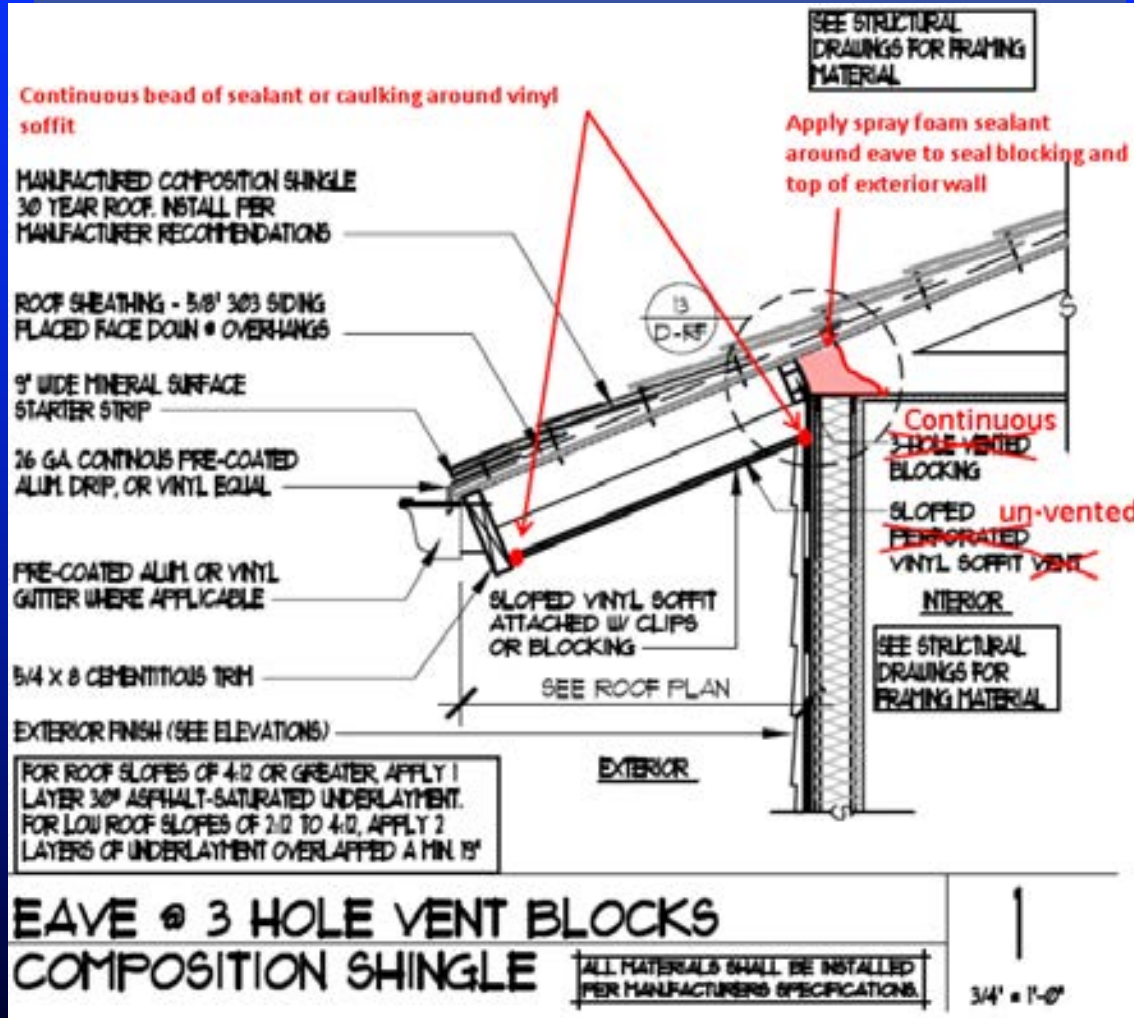
MCBH Housing



MCBH Housing



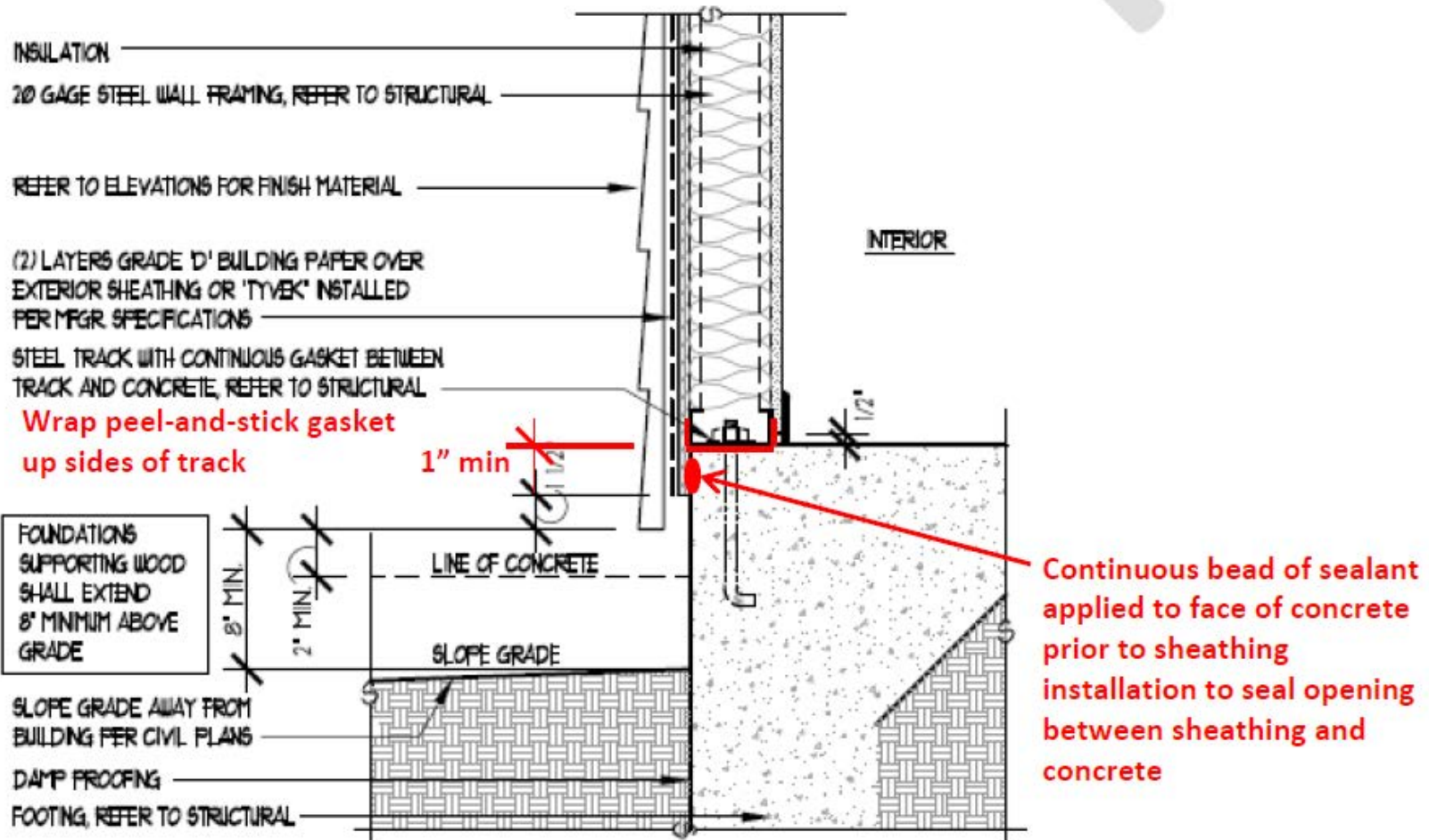
Sealed Conditioned Attics



Minimized Venting of un-conditioned Attics



Seal Exterior Walls



VINYL SIDING AT FOUNDATION AT GRADE

ALL MATERIALS SHALL BE INSTALLED PER MANUFACTURERS SPECIFICATIONS.

13

1/2" = 1'-0"

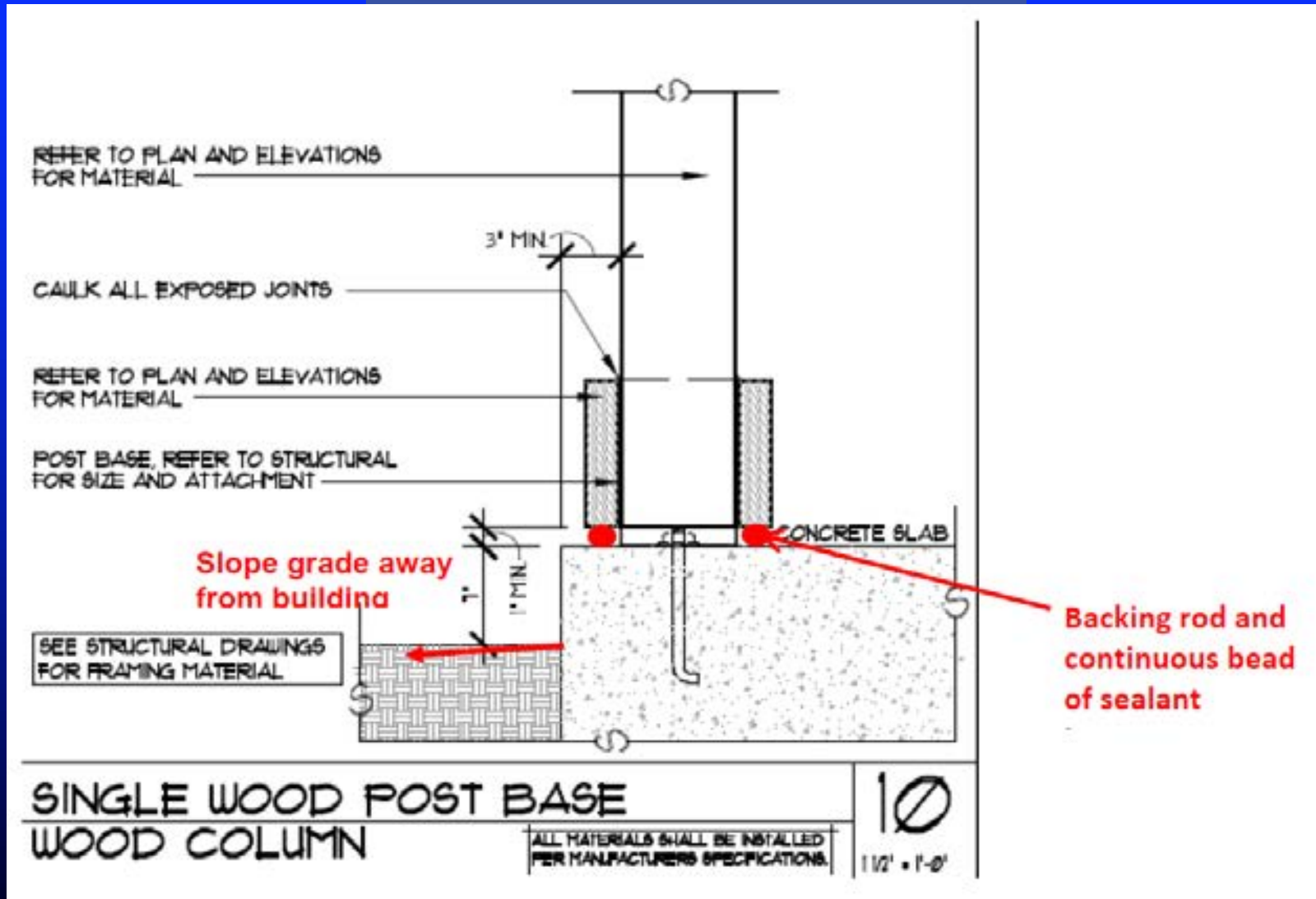
Seal Exterior Walls



Seal Exterior Walls



Lanai Post Details



Lanai Post Details



Holddowns



An aerial photograph of a tropical beach. The water is a vibrant turquoise color, transitioning to a deeper blue further out. A wide, white sandy beach is visible, dotted with people and umbrellas. Lush green palm trees and other tropical vegetation line the shore. In the foreground, several multi-story buildings with balconies are visible, suggesting a resort or hotel area. The sky is clear and blue.

Visit Hawaii!

Any Questions?