A. Appendix A

Wheeler Army Airfield - Field Enclosure Photographs

1. Construction – July 2002
2. Installed at site – May 2003
3. Full Structure Inspection – August 18, 2003 – 13 Months
4. Full Structure Inspection - March 18, 2004 - 20 Months

Wheeler Army Airfield – Construction – July 2002 and May 2003

Construction off-site and relocation

Figure A.1: Pre-fabrication in Pearl City – July 2002

Figure A.2: West elevation – May 2003

Figure A.3: North Elevation – May 2003

Figure A.4: South Elevation – May 2003

Wheeler Army Airfield – 13 Month Condition – August 18, 2003

Crawl Space – Cripple Wall

Figure A.5: Cripple Wall – NE end

Figure A.6: Cripple Wall – SE end

Figure A.7: Cripple Wall base – NE end

Figure A.8: Cripple Wall top – SE end

Figure A.9: Cripple wall base connection – NE end

Figure A.10: Cripple wall base – SE end

Wheeler Army Airfield – 13 Month Condition – August 18, 2003

Crawl Space - Posts


Figure A.11: NW Post


Figure A.12: SW Post


Figure A.13: NW Post base connection


Figure A.14: SW Post base connection

Wheeler Army Airfield – 13 Month Condition – August 18, 2003

Crawl Space - Floor Joists

Figure A.15: Exposed floor joists

Figure A.16: Exposed test connections – location 3

Figure A.17: Joist stiffener over cripple wall

Figure A.18: Joist connection over cripple wall

Figure A.19: Double edge joist with stiffener

Figure A.20: Covered crawl coupons – location 4

Wheeler Army Airfield – 13 Month Condition – August 18, 2003

Interior Wall Framing – East Wall – Plywood without vapor barrier


Figure A.21: East wall – North side


Figure A.22: East wall – South side


Figure A.23: East Wall – North Top Track


Figure A.24: East Wall – South Top Track


Figure A.25: East Wall – Top Track Connection


Figure A.26: East wall – Stud-track connection

Wheeler Army Airfield – 13 Month Condition – August 18, 2003

Interior Wall Framing – North Wall – Plywood without vapor barrier

Figure A.27: North Wall – West side

Figure A.28: North wall – Header west connection

Figure A.29: North Wall – Top track connection

Wheeler Army Airfield – 13 Month Condition – August 18, 2003

Vented Attic Framing

Figure A.30: Roof Trusses

Figure A.31: End Truss

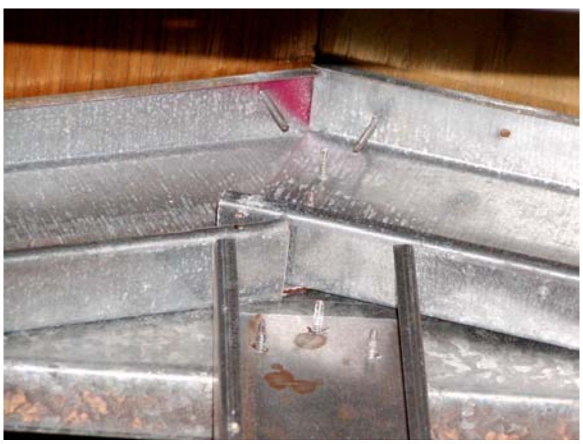

Figure A.32: Ridge connection

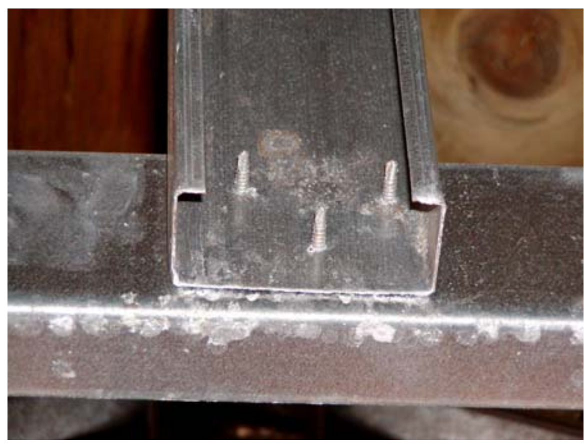

Figure A.33: King post base connection

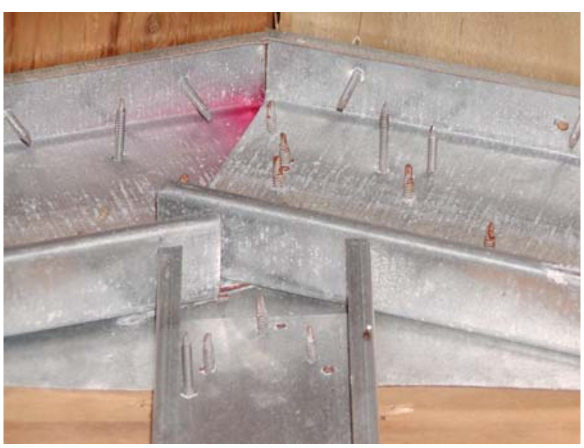

Figure A.34: Ridge connection fasteners

Figure A.35: Location 2 – Attic test connections

Wheeler Army Airfield – 13 Month Condition – August 18, 2003

Test Connection Locations

Figure A.36: Location 1 – Interior wall

Figure A.37: Location 5 – Exterior exposure

Figure A.39: Location 1 – Interior test connections

Figure A.38: Exterior test connection rack

Wheeler Army Airfield – 20 Month Condition – March 18, 2004

Crawl space cripple wall

Figure A.40: Cripple Wall – NE corner

Figure A.41: Cripple Wall – SE corner

Figure A.42: Cripple Wall – NE corner top

Figure A.43: Cripple Wall – SE corner top

Figure A.44: Cripple Wall – NE corner bottom

Figure A.45: Cripple Wall – SE corner bottom

Wheeler Army Airfield – 20 Month Condition – March 18, 2004

Crawl space posts


Figure A.46: SW Post


Figure A.47: NW Post


Figure A.48: SW Post top


Figure A.49: NW Post top


Figure A.50: SW Post base


Figure A.51: NW Post base

Wheeler Army Airfield – 20 Month Condition – March 18, 2004

Floor Joist Framing – Specimen exposure 7 Months

Figure A.52: Location 3 – Uncovered joists

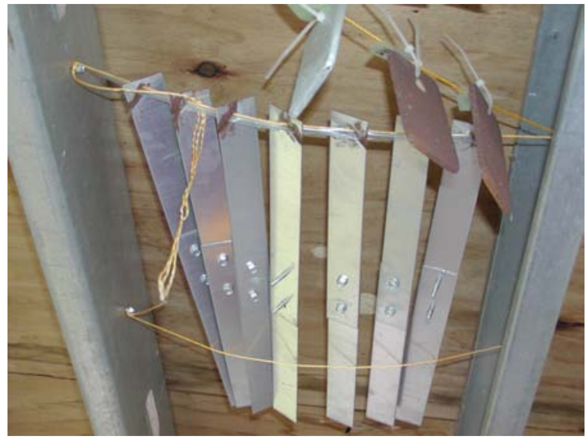

Figure A.53: Location 3 – test connections

Figure A.54: Location 3 – connection fasteners

Figure A.55: Location 4 – Enclosed joists

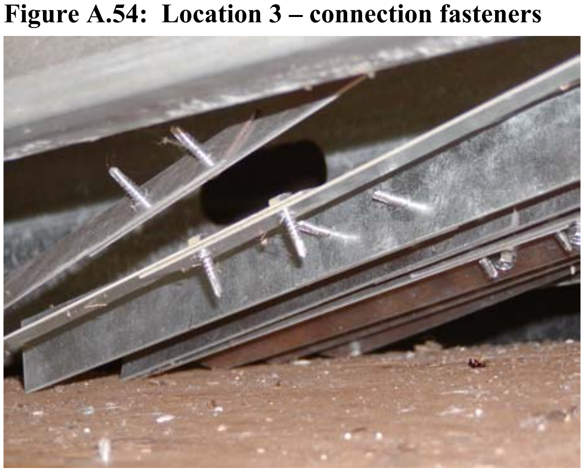

Figure A.56: Location 4 – connection fasteners

Figure A.57: Joist connection

Wheeler Army Airfield – 20 Month Condition – March 18, 2004

Interior Wall Framing – Specimen exposure 7 Months

Figure A.58: Location 1 – Interior wall

Figure A.59: Location 1 – Top track connections

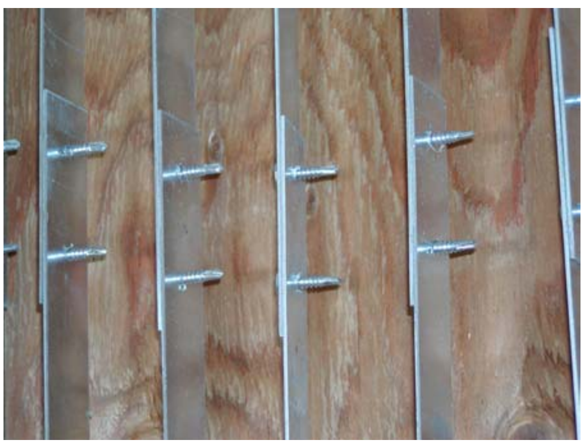

Figure A.60: Location 1 – connection fasteners

Figure A.61: Location 1 – zinc coupon

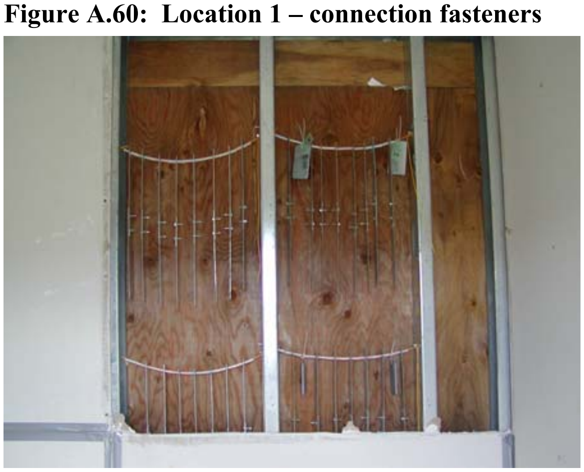

Figure A.62: 7 Month exterior connections added

Wheeler Army Airfield – 20 Month Condition – March 18, 2004

Vented Attic Framing – Specimen exposure 7 Months

Figure A.63: Location 2 – Attic test connections

Figure A.64: Location 2 – Truss top connection

Figure A.65: Location 2 – 7 Month conn. added

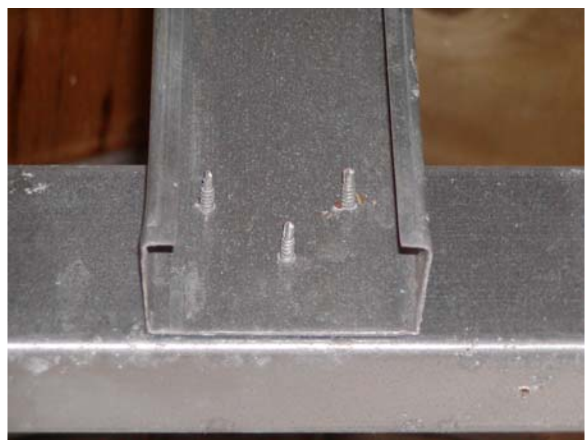

Figure A.66: Location 2 – Truss bottom connection

Figure A.67: 7 Month exterior connection set

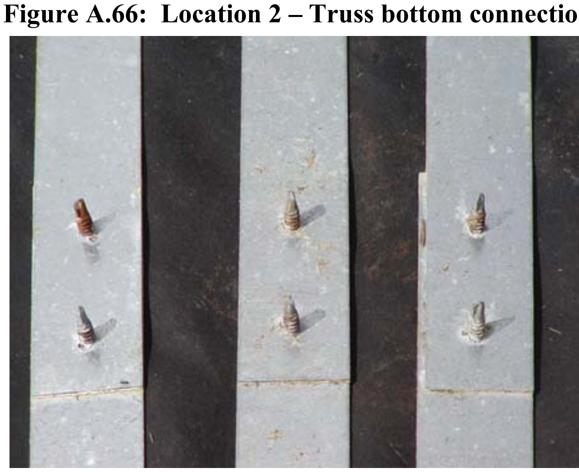

Figure A.68: 7 Month exterior connection fasteners

B. Appendix B

Iroquois Point Inland - Field Enclosure Photographs

1. Construction – July 2002
2. Installed at site – March 2003
3. Full Structure Inspection – August 13, 2003 – 13 Months
4. Full Structure Inspection - March 18, 2004 - 20 Months

Iroquois Point Inland – Construction – July 2002 and March 2003

Construction off-site and relocation

Figure B.1: Pre-fabrication in Pearl City – July 2002

Figure B.2: SW elevation – March 2003

Figure B.3: East Elevation – March 2003

Figure B.4: North Elevation – March 2003

Iroquois Point Inland – 13 Month Condition – August 13, 2003

Crawl Space – Cripple Wall

Figure B.5: East Cripple Wall

Figure B.6: Cripple Wall – SE end

Figure B.7: Cripple Wall – NE end top

Figure B.8: Cripple Wall – SE end top

Figure B.9: Cripple Wall – NE end base

Figure B.10: Cripple Wall – SE end base

Iroquois Point Inland – 13 Month Condition – August 13, 2003

Crawl Space - Posts

Figure B.11: NW Post

Figure B.12: SW Post

Figure B.13: NW Post Base

Figure B.14: SW Post Base

Iroquois Point Inland – 13 Month Condition – August 13, 2003

Crawl Space – Post Details

Figure B.15: SW Post Top – Interior view

Figure B.16: NW Post Top – Interior view

Figure B.17: SW Post Base – Interior view

Figure B.18: NW Post Base – Interior view

Figure B.19: SE Corner wall tie-downs

Iroquois Point Inland – 13 Month Condition – August 13, 2003

Crawl Space – Floor Joists

Figure B.20: Joists on Cripple Wall – NE corner

Figure B.21: Joists on cripple wall – East end

Figure B.22: Joist to track fasteners

Figure B.23: Exposed Joists

Figure B.24: Joist connections at West end

Figure B.25: Joist stiffener at West connection

Iroquois Point Inland – 13 Month Condition – August 13, 2003

Interior Wall Framing – East wall – Plywood without vapor barrier

Figure B.26: East Wall – North end framing

Figure B.27: East Wall – Top Track detail

Figure B.28: East Wall – Stud to track detail

Figure B.29: Test connections in East wall – Loc 1

Figure B.30: Test connections in East wall – Loc 1

Iroquois Point Inland – 13 Month Condition – August 13, 2003

Vented Attic Framing

Figure B.31: Attic Framing

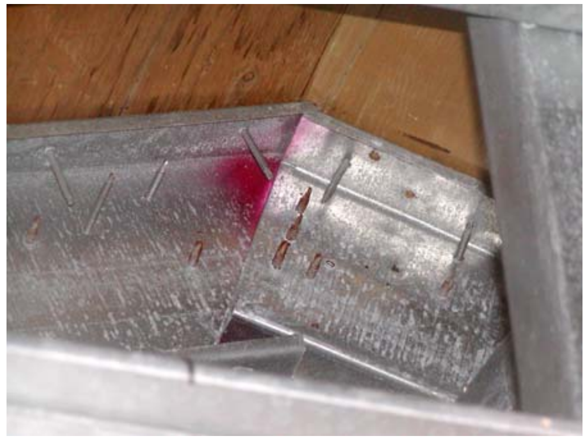

Figure B.32: Ridge connection fasteners

Figure B.33: King post base connection

Figure B.34: King post base connection

Figure B.35: King post top connection

Figure B.36: Test connections in attic – Location 2

Iroquois Point Inland – 13 Month Condition – August 13, 2003

Test Connection Locations

Figure B.37: Location 3 – Exposed crawl space

Figure B.38: Location 4 – Covered crawl space

Figure B.39: Location 5 – Exterior rack

Figure B.40: Location 5 – Exterior rack

Iroquois Point Inland – 20 Month Condition – March 18, 2004

Crawl space cripple wall

Figure B.41: Cripple Wall – NE corner

Figure B.42: Cripple Wall – SE corner

Figure B.43: Cripple Wall – NE corner top

Figure B.44: Cripple Wall – SE corner top

Figure B.45: Cripple Wall – NE corner bottom

Figure B.46: Cripple Wall – SE corner bottom

Iroquois Point Inland – 20 Month Condition – March 18, 2004

Crawl space posts

Figure B.47: SW Post

Figure B.48: NW Post

Figure B.49: SW Post top

Figure B.50: NW Post top

Figure B.51: SW Post base

Figure B.52: NW Post base

Iroquois Point Inland – 20 Month Condition – March 18, 2004

Floor Joist Framing – Specimen exposure 7 Months

Figure B.53: Location 3 – Uncovered joists

Figure B.54: Location 3 – test connections

Figure B.55: Location 3 – connection fasteners

Figure B.56: Location 4 – Enclosed joists

Figure B.57: Location 4 – connection fasteners

Figure B.58: Joist connection

Iroquois Point Inland – 20 Month Condition – March 18, 2004

Interior Wall Framing – Specimen exposure 7 Months

Figure B.59: Location 1 – Interior wall

Figure B.60: Location 1 – Top track connections

Figure B.61: Location 1 – connection fasteners

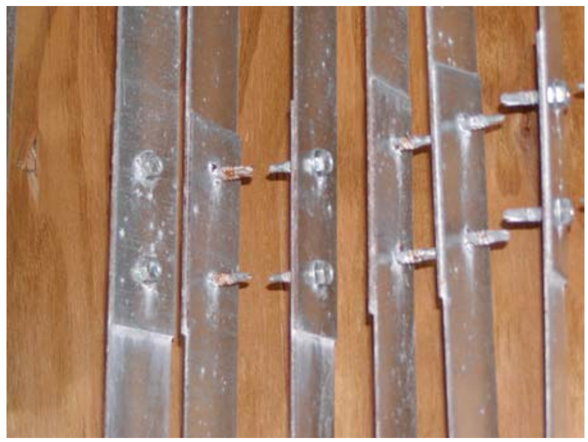

Figure B.62: 7 Month exterior connections added

Iroquois Point Inland – 20 Month Condition – March 18, 2004

Vented Attic Framing and Exterior – Specimen exposure 7 Months

Figure B.63: Location 2 – Attic truss connection

Figure B.64: Location 2 – connection fasteners

Figure B.65: Location 5 – Exterior connections

Figure B.66: Location 5 – connection fasteners

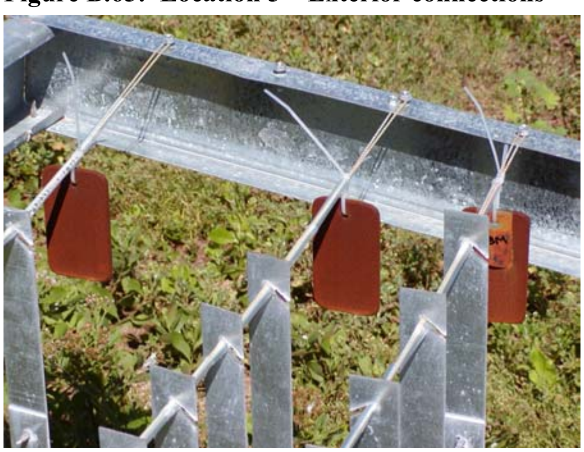

Figure B.67: Location 5 – steel coupons

Figure B.68: Location 6 – zinc coupon

C. Appendix C

Iroquois Point Coastal - Field Enclosure Photographs

1. Construction – July 2002
2. Installed at site – March 2003
3. Full Structure Inspection – August 13, 2003 – 13 Months
4. Full Structure Inspection - March 18, 2004 - 20 Months

Iroquois Coastal – Construction – July 2002 and March 2003

Construction off-site and relocation

Figure C.1: Prefabrication in Pearl City – July 2002

Figure C.2: West elevation – March 2003

Figure C.3: North elevation – March 2003

Figure C.4: West elevation – March 2003

Iroquois Point Coastal – 13 Month Condition – August 13, 2003

Crawl Space Cripple Wall

Figure C.5: Cripple Wall NE end

Figure C.6: Cripple Wall SE end

Figure C.7: Exposed joists on cripple wall – NE

Figure C.8: Covered joists on cripple wall - SE

Figure C.9: Cripple wall base - NE

Figure C.10: Cripple wall base - SE

Iroquois Point Coastal – 13 Month Condition – August 13, 2003

Crawl Space - Posts


Figure C.11: SW Post top


Figure C.12: NW Post top


Figure C.13: SW Post base - Interior


Figure C.14: NW Post base - Interior


Figure C.15: SW Post base – Exterior


Figure C.16: NW Post base - Exterior

Iroquois Point Coastal – 13 Month Condition – August 13, 2003

Crawl Space – Floor Joists

Figure C.17: Exposed and covered floor joists

Figure C.18: Joist connection over cripple wall

Figure C.19: Joist connection at South elevation

Figure C.20: Joist stiffener and fasteners

Figure C.21: Joist connection fasteners

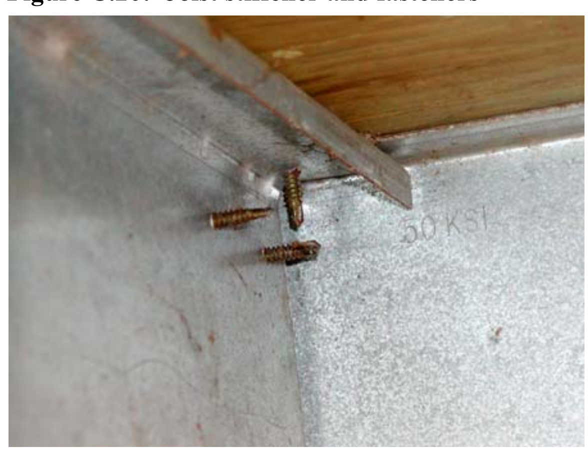

Figure C.22: Joist to track fasteners

Iroquois Point Coastal – 13 Month Condition – August 13, 2003

Interior Wall Framing – East Wall – Plywood without vapor barrier

Figure C.23: East Wall – North End

Figure C.24: East Wall – South End

Figure C.25: East Wall – North corner top track

Figure C.26: East Wall – Stud-track connection

Figure C.27: East Wall – Test Connections

Iroquois Point Coastal – 13 Month Condition – August 13, 2003

Interior Wall – South Wall – Plywood without vapor barrier

Figure C.28: South Wall – East End

Figure C.29: South Wall – West End

Figure C.30: South Wall – Header Connection E

Figure C.31: South Wall – Header Connection W

Figure C.32: South Wall – West corner fasteners

Iroquois Point Coastal – 13 Month Condition – August 13, 2003

Interior Walls – North and West Walls

Figure C.33: North Wall – West top corner

Figure C.34: North Wall – East End

Figure C.35: North Wall – Header connection W

Figure C.36: North Wall – Header connection E

Figure C.37: West Wall – North End

Figure C.38: West Wall – Door stud connection

Iroquois Point Coastal – 13 Month Condition – August 13, 2003

Vented Attic Framing

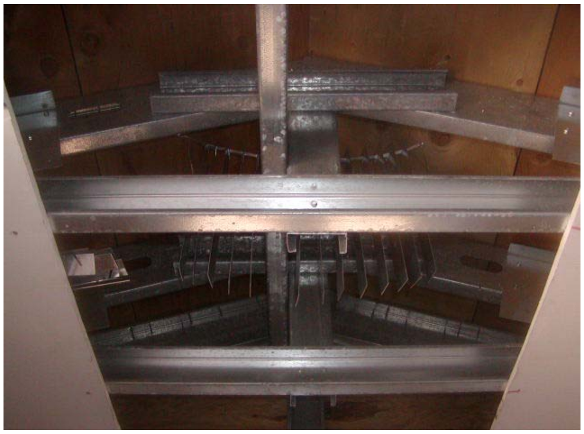

Figure C.39: Attic framing with test connections

Figure C.40: Post to ceiling joist connection

Figure C.41: Post to cross brace connection

Figure C.42: Eave connection

Figure C.43: Ridge Connection

Iroquois Point Coastal – 13 Month Condition – August 13, 2003

Test Connection Locations

Figure C.44: Location 1 – Interior Wall

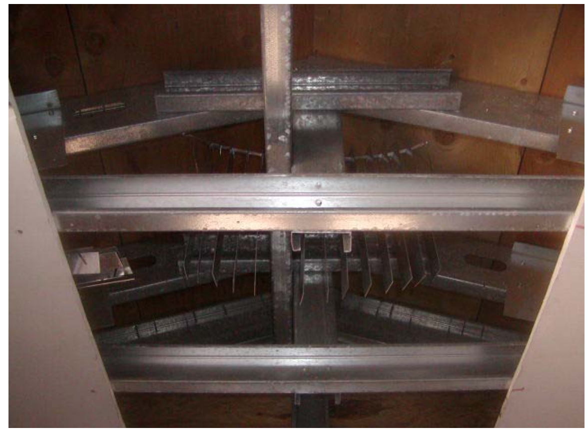

Figure C.45: Location 2 – Vented Attic

Figure C.46: Location 3 – Uncovered Crawl space

Figure C.47: Location 4 – Covered crawl space

Figure C.48: Location 5 – Exterior Rack

Figure C.49: Location 5 – Exterior Rack end view

Iroquois Point Coastal – 20 Month Condition – March 18, 2004

Crawl space cripple wall

Figure C.50: Cripple Wall – NE corner

Figure C.51: Cripple Wall – SE corner

Figure C.52: Cripple Wall – NE corner top

Figure C.53: Cripple Wall – SE corner top

Figure C.54: Cripple Wall – NE corner bottom

Figure C.55: Cripple Wall – SE corner bottom

Iroquois Point Coastal – 20 Month Condition – March 18, 2004

Crawl space posts

Figure C.56: SW Post

Figure C.57: NW Post

Figure C.58: SW Post top

Figure C.59: NW Post top

Figure C.60: SW Post base

Figure C.61: NW Post base

Iroquois Point Coastal – 20 Month Condition – March 18, 2004

Floor Joist Framing – Specimen exposure 7 Months

Figure C.62: Location 3 – Uncovered joists

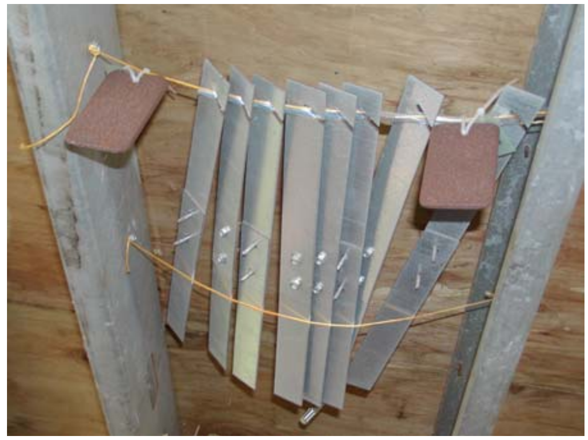

Figure C.63: Location 3 – test connections

Figure C.64: Location 3 – connection fasteners

Figure C.65: Location 4 – Enclosed joists

Figure C.66: Location 4 – connection fasteners

Figure C.67: Exposed joist connection

Iroquois Point Coastal – 20 Month Condition – March 18, 2004

Interior Wall Framing – Specimen exposure 7 Months

Figure C.68: Location 1 – Interior wall

Figure C.69: Location 1 – Top track connections

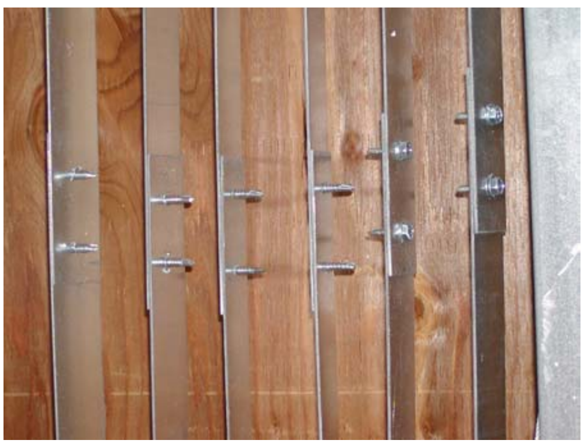

Figure C.70: Location 1 – connection fasteners

Figure C.71: 7 Month exterior connections added

Iroquois Point Coastal – 20 Month Condition – March 18, 2004

Vented Attic Framing – Specimen exposure 7 Months

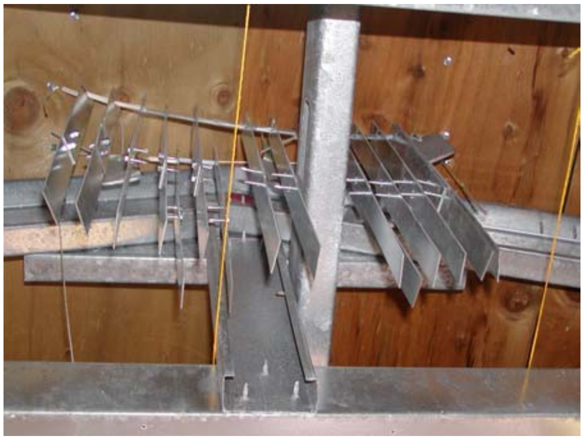

Figure C.72: Location 2 – Attic

Figure C.73: Location 2 – test connections

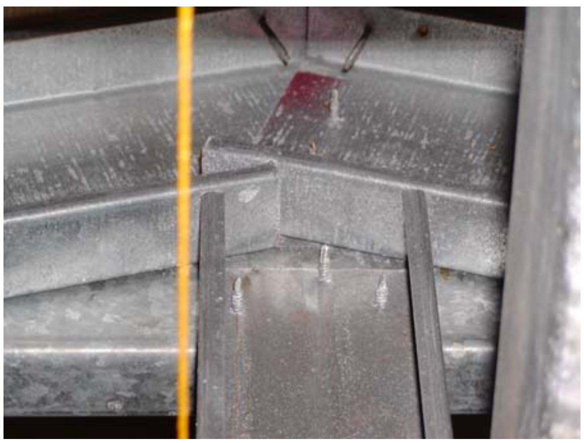

Figure C.74: Location 2 – Ridge truss connection

Figure C.75: Location 2 – Ridge truss connection

Figure C.76: Location 2 – Truss bottom connection

Figure C.77: Truss bottom connection

Iroquois Point Coastal – 20 Month Condition – March 18, 2004

Location 5 – Exterior specimen exposure 7 Months

Figure C.78: Location 5 – Test connections

Figure C.79: Location 5 – connection fasteners

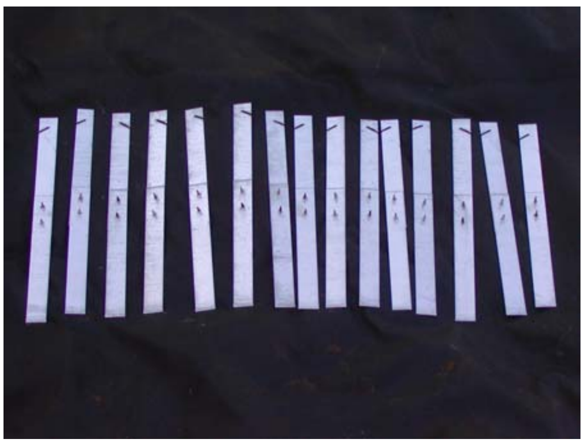

Figure C.80: 7 Month test connection set

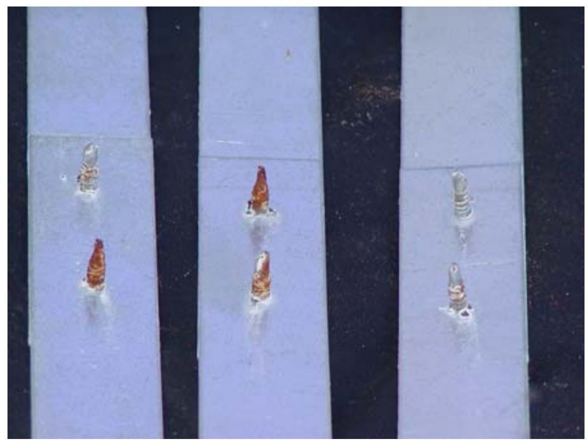

Figure C.81: 7 Month exterior exposure

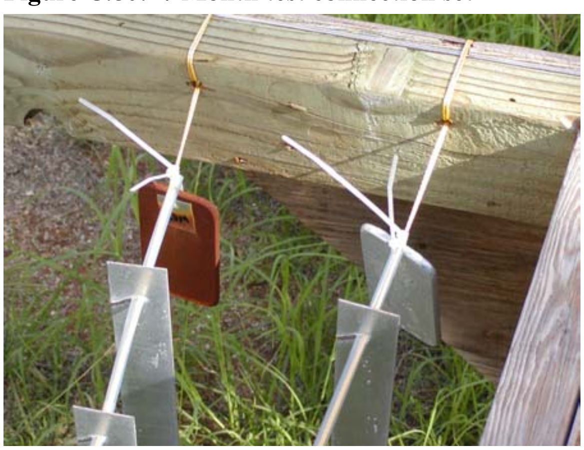

Figure C.82: Location 5 – Steel and zinc coupons

D. Appendix D

MCBH Inland - Field Enclosure Photographs

1. Construction – Nov – Dec 2001
2. Crawl Space Inspection – April 2, 2002 – 5 Months
3. Crawl Space Inspection – Sept, 2002 – 10 Months
4. Full Structure Inspection - March 6, 2003 - 16 Months
5. Full Structure Inspection – August 11, 2003 – 21 Months – Coupons installed
6. Connection Specimen Condition – September 23, 2003 – 1.5 Month exposure
7. Full Structure Inspection – March 11, 2004 – 28 Months
8. Connection Specimen Condition – March 11, 2004 – 7 Month exposure

MCBH Inland – Construction – Nov-Dec 2001

Figure D.1: NE elevation during construction

Figure D.2: SW elevation during sheathing

Figure D.3: SW cripple wall tie-down

Figure D.4: NW cripple wall tie-down

Figure D.5: Joist stiffeners on cripple wall

Figure D.6: Exposed and covered joists

MCBH Inland – Construction – Nov-Dec 2002

Figure D.7: NE post and brace

Figure D.8: Interior wall and roof framing

Figure D.9: Roof framing

Figure D.10: Roof truss eave connection

Figure D.11: NE elevation after completion

Figure D.12: East elevation with weather station

MCBH Inland – 5 Month Condition – April 2, 2002

Crawl Space – Posts and Cripple Wall


Figure D.13: SW end of cripple wall


Figure D.14: NW end of cripple wall


Figure D.15: NE post – top


Figure D.16: SE post - top


Figure D.17: NE post - base


Figure D.18: SE post - base

MCBH Inland – 5 Month Condition – April 2, 2002

Floor Framing

Figure D.19: Joist ends bearing on cripple wall

Figure D.20: Exposed and covered joist - West

Figure D.21: Exposed and covered joists - East

Figure D.22: Joist and double joist over post

MCBH Inland – 16 Month Condition – March 6, 2003

Crawl Space Posts and Cripple Wall

Figure D.23: SW corner cripple wall base

Figure D.24: NW corner cripple wall base

Figure D.25: NE corner post base

Figure D.26: SE corner post base

MCBH Inland – 16 Month Condition – March 6, 2003

Floor Joists

Figure D.27: SW corner exposed joists

Figure D.28: NW exposed and covered joists

Figure D.29: NE exposed and covered joists

Figure D.30: SE exposed joists

Figure D.31: Joist stiffener over cripple wall

Figure D.32: Joist midspan

MCBH Inland – 16 Month Condition – March 6, 2003

Interior Wall Framing – Lap siding without vapor barrier

Figure D.33: E wall – Lap siding w/o vapor barrier

Figure D.34: E wall – Studs and top track

Figure D.35: E wall – Stud to top track connection

Figure D.36: E wall – Load path tie-down

MCBH Inland – 16 Month Condition – March 6, 2003

Interior Wall Framing – Plywood sheathing without vapor barrier

Figure D.37: S wall – plywood w/o vapor barrier

Figure D.38: S wall – plywood with insulation


Figure D.39: S wall – East header connection


Figure D.40: S wall – West header connection


Figure D.41: S wall – Stud to top track connection

MCBH Inland – 16 Month Condition – March 6, 2003

Interior Wall Framing – Lap Siding with Vapor Barrier

Figure D.42: N wall – Lap siding with vapor barrier

Figure D.43: N wall – Lap siding with insulation

Figure D.44: N wall – Header connection

Figure D.45: N wall – Top track connections

Figure D.46: N wall – Stud to top track connection

MCBH Inland – 16 Month Condition – March 6, 2003

Vented Attic - Roof Framing

Figure D.47: Typical roof truss

Figure D.48: Roof truss ridge connection

Figure D.49: Roof truss connection

Figure D.50: Roof truss fasteners

Figure D.51: Roof truss eave connection

MCBH Inland – 21 Month Condition – August 11, 2003

Crawl Space

Figure D.52: SW corner cripple wall

Figure D.53: NW corner cripple wall

Figure D.54: SW Cripple Wall base connection

Figure D.55: NW Cripple Wall base connection

Figure D.56: NE Post base

Figure D.57: SE Post base

MCBH Inland – 21 Month Condition – August 11, 2003

Crawl Space – Floor Joists

Figure D.58: Exposed floor joists

Figure D.59: Floor joist end connections

Figure D.60: Test coupons in location 6 - exposed

Figure D.61: Test coupons in location 7 - enclosed

MCBH Inland – 21 Month Condition – August 11, 2003

Interior Wall Framing – without vapor barrier

Figure D.62: Loc. 2 – lap siding w/o vapor barrier

Figure D.63: Loc. 1 – plywood w/o vapor barrier

Figure D.64: Location 2 test connections

Figure D.65: Location 1 test connections

MCBH Inland – 21 Month Condition – August 11, 2003

Interior Wall and Roof Framing

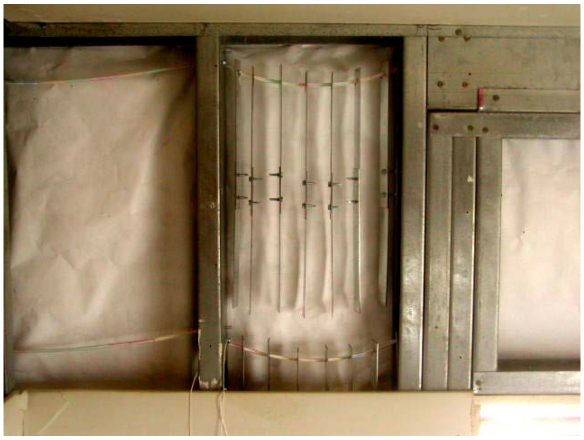

Figure D.66: Location 3 – wall with vapor barrier

Figure D.67: Location 4 – roof framing

Figure D.68: Location 3 – test connections

Figure D.69: Location 4 – test connections

MCBH Inland – 21 Month Condition – August 11, 2003

Exterior Test Connections


Figure D.70: Location 7 – exterior test connections


Figure D.71: Location 7 – exterior test connections


Figure D.72: Chloride Candle and shield


Figure D.73: Chloride Candle

MCBH Inland – 24 Month Condition – November 11, 2003

Exterior Test Connections – 3 Month Exposure

Figure D.74: Location 7 – 3 Month Exposure

Figure D.75: Location 7 – 3 Month exp fasteners

Figure D.76: Close-up of 3 Month exposure

Figure D.77: Steel and zinc coupons – 3 Months

MCBH Inland – 28 Month Condition – March 11, 2004

Crawl Space Cripple Wall

Figure D.78: Cripple Wall – SW corner

Figure D.79: Cripple Wall – NW corner

Figure D.80: Cripple Wall Top – SW corner

Figure D.81: Cripple Wall Top – Joist connection

Figure D.82: Cripple Wall Base – SW corner

Figure D.83: Cripple Wall Base – NW corner

MCBH Inland – 28 Month Condition – March 11, 2004

Crawl Space Posts

Figure D.84: Post – NE corner

Figure D.85: Post – SE corner

Figure D.86: Post Top – NE corner

Figure D.87: Post Top – SE corner

Figure D.88: Post Base – NE corner

Figure D.89: Post Base – SE corner

MCBH Inland – 28 Month Condition – March 11, 2004

Open Crawl Space Floor Joists

Figure D.90: Location 5 specimens - open crawl

Figure D.91: Joists and specimens – open crawl

Figure D.92: Joist end connection – open crawl

Figure D.93: Joist end stiffener- open crawl

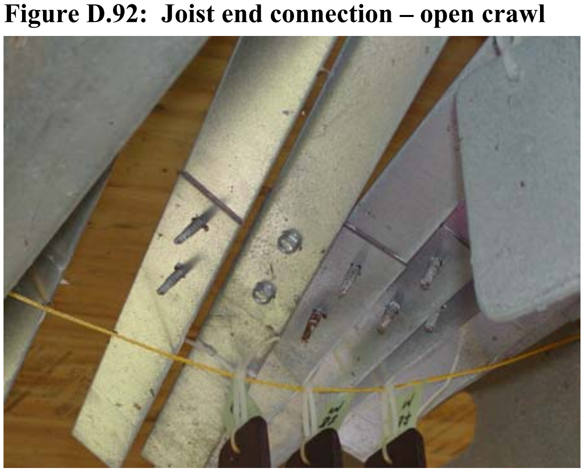

Figure D.94: Location 5 specimens – open crawl

Figure D.95: 7 Month exterior exposure specimens

MCBH Inland – 28 Month Condition – March 11, 2004

Covered Crawl Space Floor Joists

Figure D.96: Joists and specimens – covered crawl

Figure D.97: Joists and specimens – covered crawl

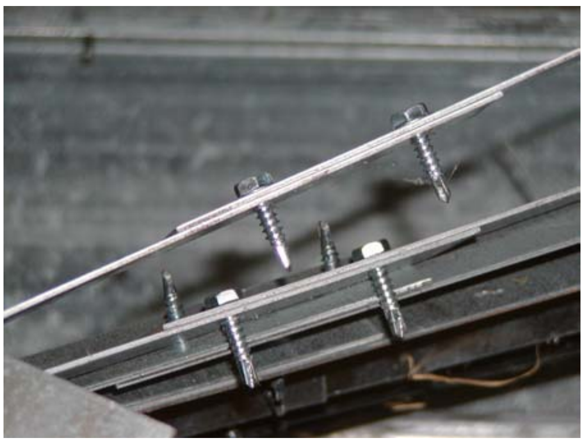

Figure D.98: Connection fasteners – covered crawl

Figure D.99: 7 Month exterior specimens added

Figure D.100: 7 Month exterior exposure specimens

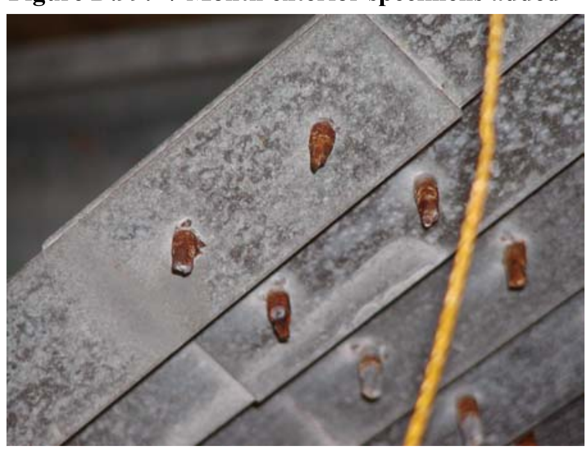

Figure D.101: 7 Month exterior fasteners

MCBH Inland – 28 Month Condition – March 11, 2004

Interior Wall Framing – Plywood with vinyl siding

Figure D.102: Location 1 - S wall - plywood

Figure D.103: Location 1 – corner connection

Figure D.104: Location 1 header connection

Figure D.105: Location 1 header connection

Figure D.106: Location 1 – test connections

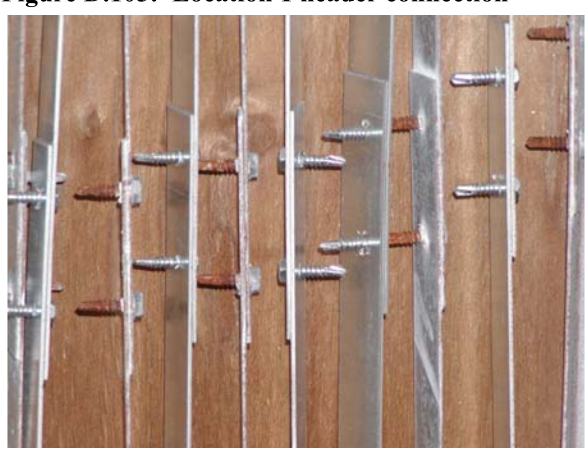

Figure D.107: 7 Month exterior connections added

MCBH Inland – 28 Month Condition – March 11, 2004

Interior Wall Framing – Lap siding without vapor barrier

Figure D.108: Location 2 - E wall – Lap siding

Figure D.109: Location 2 – test specimens

Figure D.110: Location 2 – top plate connection

Figure D.111: Location 2 – top plate connection

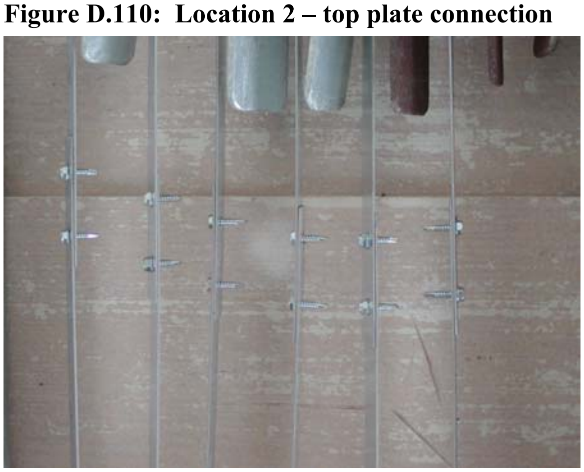

Figure D.112: Location 2 – test connections

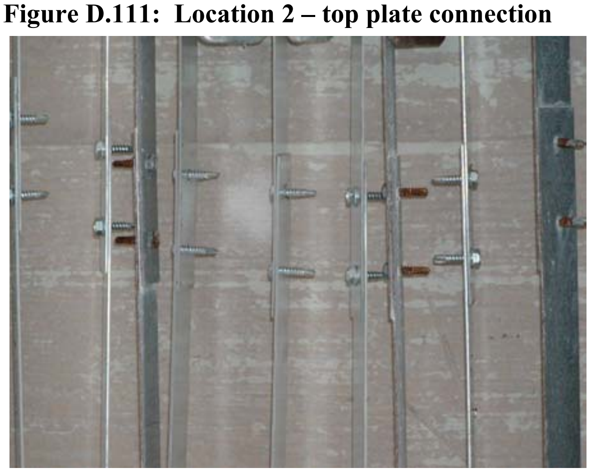

Figure D.113: 7 Month exterior connections added

MCBH Inland – 28 Month Condition – March 11, 2004

Interior Wall Framing – Lap siding with vapor barrier

Figure D.114: Location 3 - N wall – vapor barrier

Figure D.115: Location 3 – corner connection

Figure D.116: Location 3 – Header connection

Figure D.117: Location 3 – Header connection

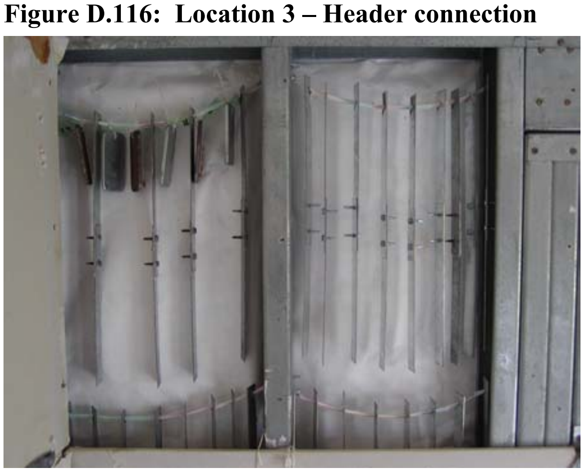

Figure D.118: Location 3 – ext connections added

Figure D.119: 7 Month exterior connections added

MCBH Inland – 28 Month Condition – March 11, 2004

Vented Attic Framing – Location 4

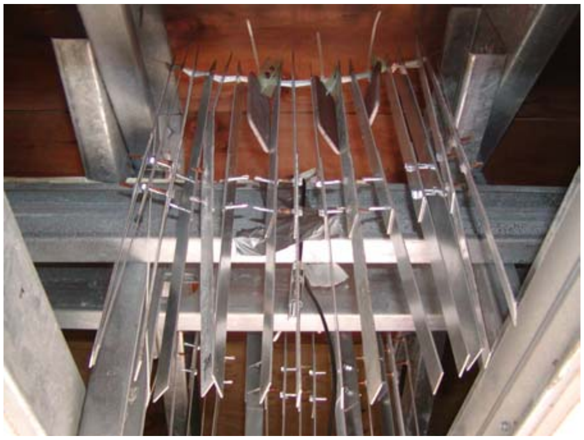

Figure D.120: Location 4 – test connections

Figure D.121: Location 4 – top truss connection

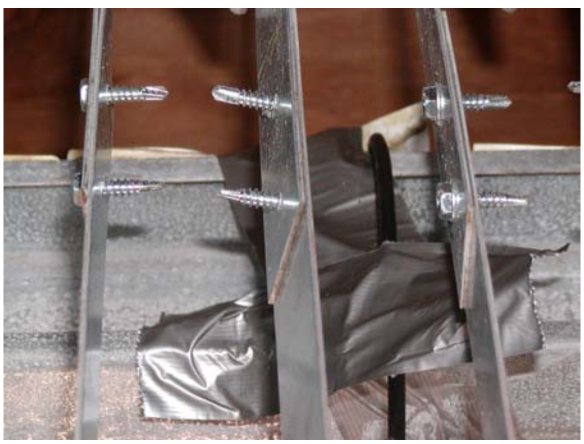

Figure D.122: Location 4 – connection fasteners

Figure D.123: Location 4 – bottom truss connection

Figure D.124: Location 4 – ext connections added

Figure D.125: 7 Month exterior connections added

MCBH Inland – 28 Month Condition – March 11, 2004

Exterior test connections – Location 7

Figure D.126: Location 7 – test connections

Figure D.127: Location 7 – fasteners threads

Figure D.128: Location 7 –fasteners heads

Figure D.129: Location 7 – test connection set

Figure D.130: Location 7 – test set fasteners

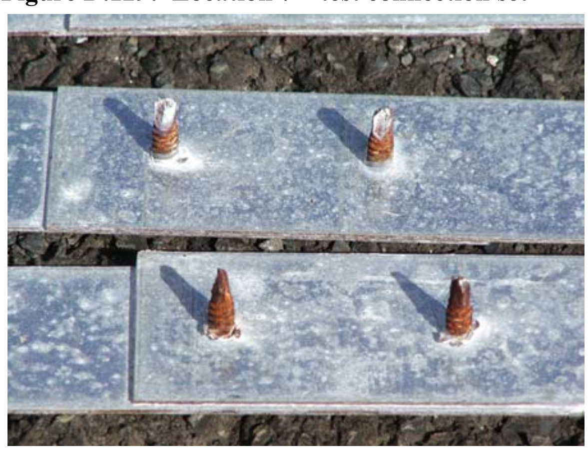

Figure D.131: 7 Month exterior fasteners

E. Appendix E

MCBH Coastal - Field Enclosure Photographs

1. Construction – Nov – Dec 2001
2. Crawl Space Inspection – April 2, 2002 – 5 Months
3. Crawl Space Inspection – Sept, 2002 – 10 Months
4. Full Structure Inspection - March 6, 2003 - 16 Months
5. Full Structure Inspection – August 11, 2003 – 21 Months – Coupons installed
6. Connection Specimen Condition – September 23, 2003 – 1.5 Month exposure
7. Full Structure Inspection – March 11, 2004 – 28 Months
8. Connection Specimen Condition – March 11, 2004 – 7 Month exposure

MCBH Coastal – Construction – Nov-Dec 2001


Figure E.1: Concrete Footings


Figure E.2: Foundation location


Figure E.3: Framing on site


Figure E.4: Foundation Tiedowns


Figure E.5: Completed Enclosure - NE Elevation


Figure E.6: Completed Enclosure – SE Elevation

MCBH Coastal – 5 Month Condition – April 2, 2002

Crawl Space – Posts and Cripple Wall

Figure E.7: Top of NW post

Figure E.8: Bottom of NE post

Figure E.9: Bottom of NW post

Figure E.10: Bottom of Cripple Wall - SW

Figure E.11: Bottom of Cripple Wall - SE

Figure E.12: Cripple Wall Tiedown

MCBH Coastal – 5 Month Condition – April 2, 2002

Crawl Space Joists


Figure E.13: Exposed Floor Joist – S Wall


Figure E.14: Exposed Floor Joist Stiffener


Figure E.15: Double Joist at SW corner


Figure E.16: Exposed Joist – N end - Center


Figure E.17: Exposed Joist – N end - E of center


Figure E.18: Exposed Joist - Midspan

MCBH Coastal – 10 Month Condition – September 2002

Crawl Space – Exposed Joists

Figure E.19: Exposed Joists and Cripple Wall

Figure E.20: Exposed Joists and Wall - SW

Figure E.21: Exposed Joists Midspan – West

MCBH Coastal – 16 Month Condition – March 6, 2003

Crawl Space Posts and Cripple Wall

Figure E.22: Post Base – NW corner

Figure E.23: Post Base – NE corner

Figure E.24: Cripple Wall Base – SE corner

Figure E.25: Cripple Wall Base – SW corner

MCBH Coastal – 16 Month Condition – March 6, 2003

Crawl Space Floor Joists


Figure E.26: Exposed Floor Joists - SE


Figure E.27: Exposed Floor Joists - South


Figure E.28: Exposed Floor Joists - SW


Figure E.29: Exposed Floor Joists - NW


Figure E.30: Exposed Floor Joists - NE

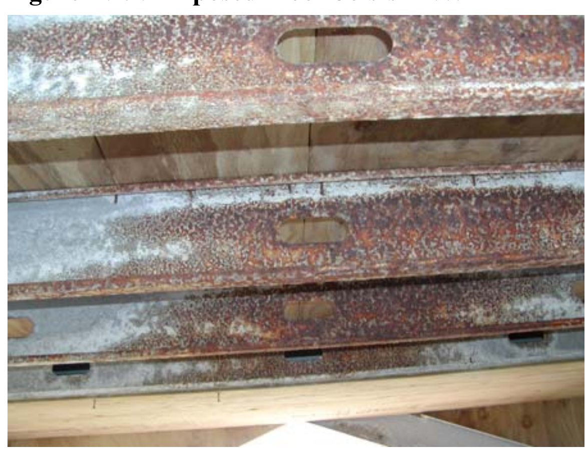
Figure E.31: Exposed Floor Joists – Midspan - E

MCBH Coastal – 16 Month Condition – March 6, 2003

Floor Joist Details


Figure E.32: Joist connection at cripple wall


Figure E.33: Joist stiffener at cripple wall


Figure E.34: Joist stiffener at South end


Figure E.35: Joist connection at South end


Figure E.36: Exposed joist detail at midspan


Figure E.37: Exposed joist soffit at midspan

MCBH Coastal – 16 Month Condition – March 6, 2003

Enclosed Floor Joists


Figure E.38: Enclosed floor joist punch-out


Figure E.39: Enclosed floor joist detail

MCBH Coastal – 16 Month Condition – March 6, 2003

Interior Wall Framing – Lap siding without vapor barrier

Figure E.40: W wall – Lap siding w/o vapor barrier

Figure E.41: W wall – Lap siding with insulation

Figure E.42: W wall header connection

Figure E.43: W wall top track

Figure E.44: W Wall top track connection

Figure E.45: W wall lap siding w/o vapor barrier

MCBH Coastal – 16 Month Condition – March 6, 2003

Interior Wall Framing – Plywood sheathing without vapor barrier

Figure E.46: E wall – Plywood w/o vapor barrier

Figure E.47: E wall – Header connection

Figure E.48: E wall – Top track

Figure E.49: E wall – Sheathing & stud fasteners

MCBH Coastal – 16 Month Condition – March 6, 2003

Interior Wall Framing - with vapor barrier

Figure E.50: N wall – vapor barrier & insulation


Figure E.51: N wall – top track


Figure E.53: N wall – stud and siding fasteners


Figure E.52: N wall – stud to top track connection

MCBH Coastal – 16 Month Condition – March 6, 2003

Vented Attic Framing

Figure E.54: Vented eave overhang

Figure E.55: Roof truss

Figure E.56: Ridge connection

Figure E.57: Ridge connection fasteners

Figure E.58: Eave connection fasteners

Figure E.59: Ceiling to king post fasteners

MCBH Coastal – 21 Month Condition – August 11, 2003

Crawl Space – Posts and Cripple Wall

Figure E.60: Post Base – NW corner

Figure E.61: Post Base – NE corner

Figure E.62: Cripple Wall Base – SE corner

Figure E.63: Cripple Wall Base – SW corner

Figure E.64: Close-up SE corner

Figure E.65: Close-up cripple wall tie-down

MCBH Coastal – 21 Month Condition – August 11, 2003

Crawl Space Floor Joists

Figure E.66: Exposed Joists – looking North

Figure E.67: Exposed Joists – looking South

Figure E.68: Exposed Joists – SW corner

Figure E.69: Exposed Joists - Midspan

Figure E.70: Exposed Joists – Close-up of fastener

Figure E.71: Exposed Joists – Midspan corrosion

MCBH Coastal – 21 Month Condition – August 11, 2003

Floor Joist Details

Figure E.72: Joists bearing on cripple wall

Figure E.73: Joist stiffener over cripple wall stud

Figure E.74: Joist stiffener at North end

Figure E.75: Double joist at cripple wall post

Figure E.76: Double joist at NW post

Figure E.77: Cripple wall below covered joists

MCBH Coastal – 21 Month Condition – August 11, 2003

Covered Floor Joists

Figure E.78: Exposed and covered floor joists

Figure E.79: Covered joist and fastener

Figure E.80: Covered Floor Joist – North end

Figure E.81: Covered Floor Joist – South end

Figure E.82: Corrosion around opening in joist

Figure E.83: Covered joist on exposed top track

MCBH Coastal – 21 Month Condition – August 11, 2003

Interior Wall Framing – Lap siding without vapor barrier

Figure E.84: W wall – Lap siding w/o vapor barrier

Figure E.85: W Wall – Lap siding with insulation

Figure E.86: W wall header connection - S

Figure E.87: W wall header connection - N

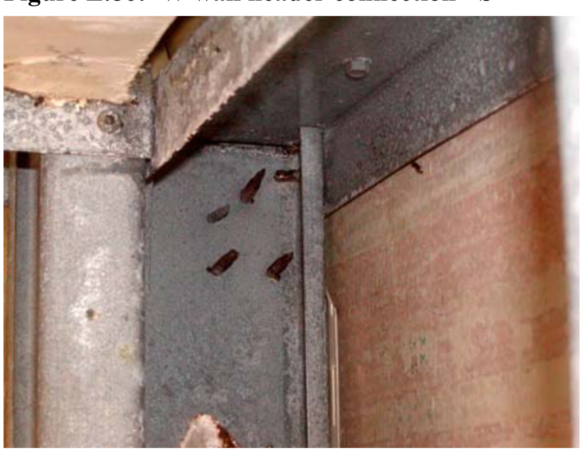

Figure E.88: W wall – S corner stud fasteners

Figure E.89: W wall – top track detail

MCBH Coastal – 21 Month Condition – August 11, 2003

Interior Wall Framing – Plywood sheathing without vapor barrier

Figure E.90: E wall – Plywood w/o vapor barrier

Figure E.91: E wall – Plywood with insulation

Figure E.92: E wall – Header and stud fasteners

Figure E.93: E wall – Header connection

Figure E.94: E wall – N corner stud fasteners

Figure E.95: E wall – top track fasteners

MCBH Coastal – 21 Month Condition – August 11, 2003

Interior Wall Framing – with vapor barrier

Figure E.96: N wall – vapor barrier & insulation

Figure E.97: N wall – with vapor barrier

Figure E.98: N wall – top track connection

Figure E.99: N wall – Truss tie-down connection

Figure E.100: N wall – Header and stud connection

MCBH Coastal – 21 Month Condition – August 11, 2003

Vented Attic Framing

Figure E.101: Truss Connection

Figure E.102: Truss Connection – fastener heads

Figure E.103: Ridge connection

Figure E.104: Ridge connection fasteners

Figure E.105: Eave connection fastener heads

Figure E.106: Eave connection fastener threads

MCBH Coastal – 21 Month Connection Placement – August 11, 2003

Placement of Test Connection Specimens

Figure E.107: Location 1 – East wall

Figure E.108: Location 2 – North wall

Figure E.109: Location 3 – West Wall

Figure E.110: Location 4 – Attic

MCBH Coastal – 21 Month Connection Placement – August 11, 2003

Placement of Test Connection Specimens

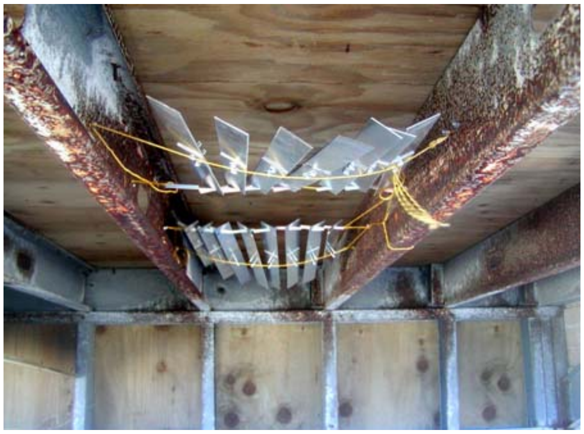

Figure E.111: Location 5 – Exposed crawl space

Figure E.112: Location 6 – Covered crawl space

Figure E.113: Location 7 – External specimens

Figure E.114: External connection specimen rack

Figure E.115: External specimen rack

MCBH Coastal – Connection Specimen Condition – September 23, 2003

42 Day exposure

Figure E.116: Location 1 – East Wall

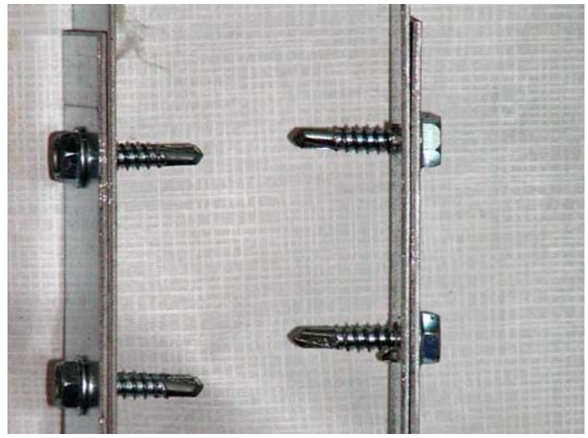

Figure E.117: Location 2 – North Wall

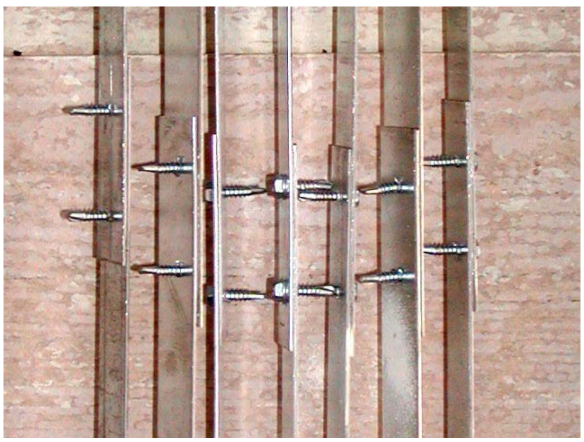

Figure E.118: Location 3 – West Wall

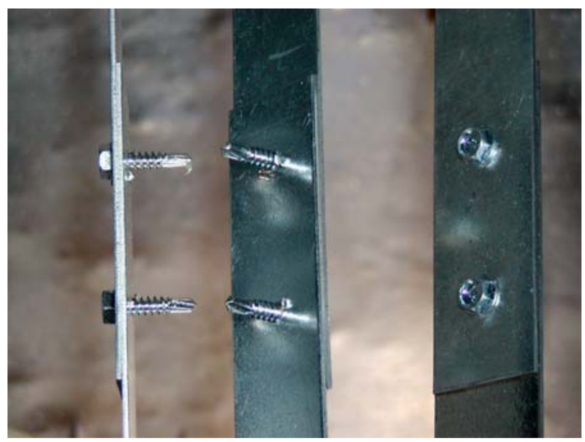

Figure E.119: Location 4 - Attic

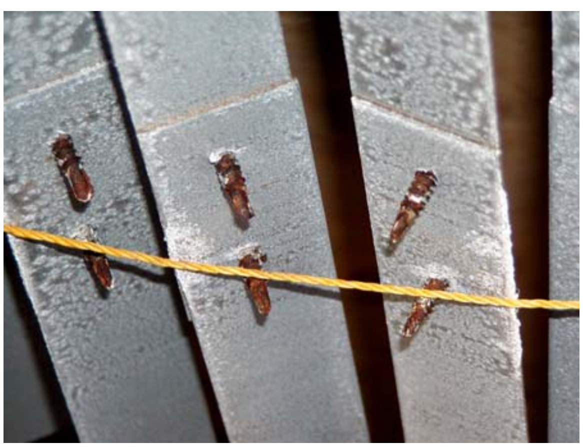

Figure E.120: Location 5 – Exposed Crawl Space

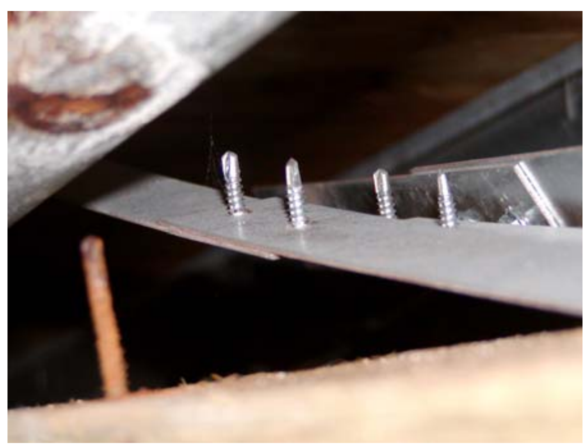

Figure E.121: Location 6 – Covered Crawl Space

MCBH Coastal – Connection Specimen Condition – September 23, 2003

42 Day exposure

Figure E.122: Location 7 – External screw threads

Figure E.123: Location 7 – External screw heads

Figure E.124: Location 7 – External specimens

MCBH Coastal – 28 Month Condition – March 11, 2004

Crawl Space Cripple Wall

Figure E.125: Cripple Wall - SE corner

Figure E.126: Cripple Wall – SW corner

Figure E.127: Cripple Wall Top – SE corner

Figure E.128: Cripple Wall Top – SW corner

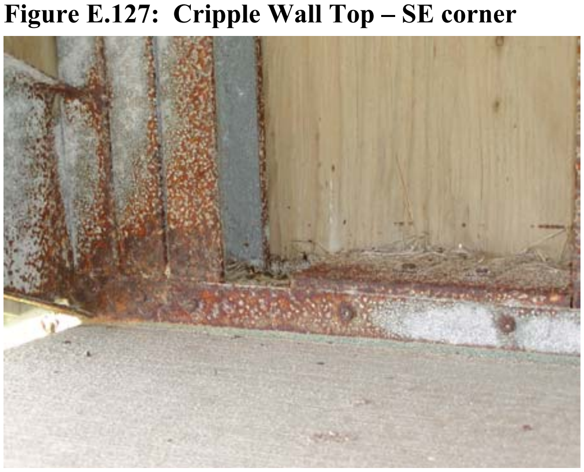

Figure E.129: Cripple Wall Base – SE corner

Figure E.130: Cripple Wall Base – SW corner

MCBH Coastal – 28 Month Condition – March 11, 2004

Crawl Space Posts

Figure E.131: Post – NW corner

Figure E.132: Post – NE corner

Figure E.133: Post Top – NW corner

Figure E.134: Post Base – NE corner

Figure E.135: Post Base – NW corner

MCBH Coastal – 28 Month Condition – March 11, 2004

Crawl Space Floor Joists

Figure E.136: Exposed Floor Joists - SW

Figure E.137: Exposed Floor Joists – Close-up

Figure E.138: Joist Connection at cripple wall

Figure E.139: Joist stiffener at cripple wall

Figure E.140: Joist stiffener at South end

Figure E.141: Joist connection at South end

MCBH Coastal – 28 Month Condition – March 11, 2004

Interior Wall Framing – Lap siding without vapor barrier

Figure E.142: W wall – Lap siding w/o barrier

Figure E.143: W wall- Lap siding with insulation

Figure E.144: W wall header connection - left

Figure E.145: W wall header connection - right

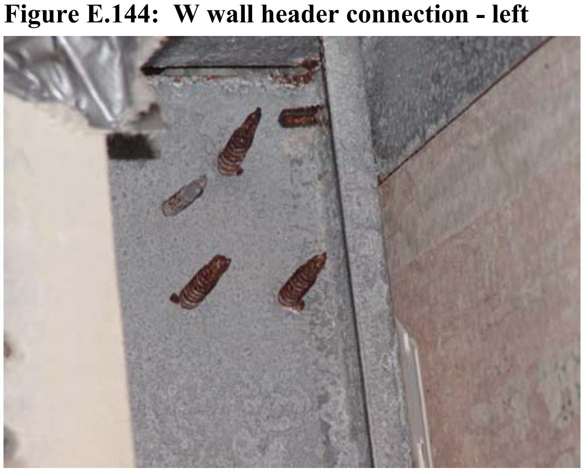

Figure E.146: W wall corner connection

Figure E.147: W wall top track connection

MCBH Coastal – 28 Month Condition – March 11, 2004

Interior Wall Framing – Plywood and lap siding with vapor barrier

Figure E.148: E wall – Plywood w/o barrier

Figure E.149: E wall - Header connection

Figure E.150: E wall – Test connections

Figure E.151: N wall – vapor barrier & insulation

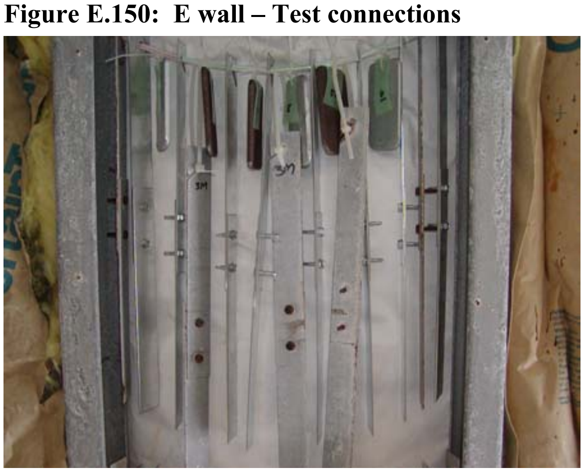

Figure E.152: N wall – Test connections

Figure E.153: N wall - top track connections

MCBH Coastal – 28 Month Condition – March 11, 2004

Vented Attic Framing

Figure E.154: Attic test connections

Figure E.155: Ridge connection

Figure E.156: Roof truss connection

Figure E.157: Ceiling to king post fasteners

Figure E.158: Roof truss connection

Figure E.159: Fastener heads at truss connection

MCBH Coastal – 7 Month Connection Condition – March 11, 2004

Test connections

Figure E.160: Open crawl space

Figure E.161: Open crawl space – close-up

Figure E.162: Open crawl space – steel coupons

Figure E.163: Open crawl space – zinc coupons

Figure E.164: Covered crawl space

Figure E.165: Covered crawl space – connections

MCBH Coastal – 7 Month Connection Condition – March 11, 2004

Exterior test connections

Figure E.166: Exterior connections – 7 months

Figure E.167: Exterior connections - Threads

Figure E.168: Exterior connections - Heads

F. Appendix F

Literature Review Report

December 27, 2000

LITERATURE REVIEW REPORT

December 27, 2000

SUBMITTED BY

NORTH AMERICAN STEEL FRAMING ALLIANCE
AND
UNIVERSITY OF HAWAII

HUD CONTRACT No.:	H-21248CA
PROJECT TITLE:	"Corrosion of Galvanized Fasteners used in Cold-Formed Steel Framing"
CONTRACTOR:	North American Steel Framing Alliance 1726 M Street, NW, Suite 601 Washington, DC 20036
Principal Investigator: Co/Investigators:	Tim Waite Don Moody, Kevin Bielat
SUB-CONTRACTOR:	University of Hawaii Dept. of Civil Engineering 2540 Dole Street, Holmes Hall 383 Honolulu, HI 96822
Principal Investigator	Dr. Ian N. Robertson
PROJECT PERIOD:	From 9/26/2000 to 11/25/2003
LITERATURE REVIEW REPORT:	December 27, 2000

CORROSION OF GALVANIZED FASTENERS USED IN COLD-FORMED STEEL FRAMING

LITERATURE REVIEW REPORT

December 27, 2000

Section I - Introduction

This research program will investigate the potential for corrosion of galvanized fasteners used in cold-formed steel framing (CFSF) by exposing test samples to a variety of environmental conditions frequently found in Hawaii. The results of this research will aid in the evaluation of galvanized CFSF fasteners in various exposure conditions.

The project was initiated on September 26, 2000 by an award from the Department of Housing and Urban Development (HUD) to the North American Steel Framing Alliance (NASFA). The project includes a research effort to study the effects of corrosion of galvanized fasteners on CFSF connection behavior, followed by a final report and development of a Practice Guide for use by industry. NASFA has subcontracted the research component of this study to the Civil Engineering Department at the University of Hawaii (UH), a non-profit State of Hawaii educational institution. The principal investigator at UH is Dr. Ian N. Robertson, Associate Professor of Structural Engineering.

The project has a two-year duration with various scheduled deliverables, including a literature review report and quarterly progress reports. This literature review report presents research literature relevant to this study. After a general introduction to galvanic corrosion and cathodic protection provided by zinc coatings on steel, the report focuses on research performed on connections in CFSF structures.

Section II - Galvanic Corrosion

Steel stores energy when it is changed from its natural state into the metallic form used in industry. This energy later returns in the form of corrosion. Corrosion is therefore the natural transformation of manmade metals to their original state (National Association of Corrosion Engineering, 1984).

Galvanizing of steel is the most economical and effective way to protect steel. This galvanizing is an adherent coating of zinc and zinc-iron alloys on the surface of steel that provides long term protection from corrosion. Galvanizing of steel is accomplished by immersing the member in molten zinc. This immersion forms a metallurgical bond between the steel and zinc coating. The standard galvanized coating is composed of pure zinc and a very small amount of aluminum. Zinc-rich paints that coat the steel framing must satisfy three important conditions for the galvanic process to occur. The zinc particles must be in electrical contact with each other. The zinc particles must also be in electrical contact with the steel. Finally, a continuous electrolyte must exist between the zinc particles and steel (AISI, 1996; Zhang, 1997).

The zinc coating applied to the steel provides a physical barrier as well as a cathodic protection against corrosion. In most environments, zinc corrodes less than steel. The rate of corrosion of zinc in atmospheric conditions is less than one tenth of that for steel (Zhang, 2000b). In fact, atmospheric conditions particularly detrimental to steel corrosion are those in which zinc coatings have been shown to be most effective (Zhang, 2000b). These conditions include marine and industrial atmospheric exposure.

As explained by Zhang (2000a), "galvanized (ie. zinc coated) steel is a typical example of metallic coating that provides a barrier layer to protect the steel and also sacrificially protects the locations where discontinuities occur in the coating." He adds that "... galvanic corrosion resulted in a reduction of the corrosion of steel by 3 times in rural, 40 times in industrial, and 300 times in seacoast industrial atmospheres." This galvanic effect is caused because zinc acts as the sacrificial anode protecting steel, the cathode. The zinc coating on the steel members carries out the cathodic protection because it becomes the sacrificial material. This sacrificial corrosion of the zinc coating is generated because zinc is more electronegative than steel.

This galvanic protection is effective over a short distance from a discontinuous edge of the zinc coating. This Galvanic Protection Distance (PD) varies depending on the environmental conditions. A PD of up to 5 mm was observed under full immersion in deionized water. In atmospheric conditions the PD is considerable smaller, and depends on the presence of an electrolyte to facilitate anodic sacrificial corrosion thus protecting neighboring cathodic material (Zhang, 2000c). In cold-formed steel framing there are often discontinuities in the zinc coating. This is particularly evident at cut ends, drilled holes and connections. It is important that the protection distance is adequate to prevent rapid corrosion of exposed steel surfaces.

Although a galvanized coating is a great protection and cathodic barrier, the zinc coating, that is part of the galvanized coating, corrodes slowly over time. The galvanic corrosion rate of zinc and extent of galvanic protection of steel is based on dimensions and environmental factors. The type of wetness and concentration of atmospheric pollutants affect the rate of corrosion of zinc. This corrosion directly affects the durability of the galvanized steel, because it leaves the steel underneath vulnerable to corrosion attack (AISI, 1996; Zhang, 1997). According to Zhang (2000d), "the high corrosion resistance of zinc is largely due to the formation of a stable, tenacious and compact corrosion product layer during the corrosion processes in atmospheric environments. The protective corrosion product layer is formed under the effect of cyclic weathering over a period of time." He points out that for accurate simulation of field conditions during accelerated laboratory testing, it is important that wetting and drying cycles be followed to allow the corrosion product layer to form. "The corrosion rates will be high under the conditions where tenacious and compact corrosion (products) cannot form" (Zhang, 2000d) such as during a continuous salt spray test.

Prediction of the life of a zinc coated steel member depends on various properties of the atmospheric environment. According to Zhang and Hwang (2000), "the corrosion rate of zinc in atmospheric environments may vary from as low as about 0.1 μm/year in indoor environments to as high as more than 10 μm/year in some industrial or marine environments .... This means that a G60 galvanized steel, about 13 μm coating each side, would have a corrosion life of more than 100 years in the least corrosive environment but only for about one year in an extremely corrosive environment."

Section III - Cold-Formed Steel Construction

Cold-formed light gauge steel frames have the same corrosion issues as other types of construction materials. Moisture and pollutants can reduce the life of the coated steel as well as the fasteners. The configuration of a steel track acts similar to a channel, which allows rainwater to collect prior to construction. After construction the steel track can be located in walls that collect moisture from the ambient relative humidity. This collection of the water can produce corrosion on the track. Corrosion of the steel in the frame of a building is undesirable deterioration and has adverse effects on the structural integrity of the framing (LGSEA, 1999).

Although most galvanized steel framing in residential homes is enclosed in walls, corrosion can still occur. In time, a moisture film can form on the galvanized steel on account of the relative humidity in the air. The degree of corrosion depends on the severity of the humidity in the atmosphere. When the humidity is above 70 percent, moisture will precipitate on the steel surface (Zhang, 1997).

Light gauge steel connections are primarily constructed with externally threaded fasteners. Tapping screws are capable of drilling holes into the metal with their own threads. There are two types of tapping screw that are used in the construction of residential framing, namely self-drilling screws and self-piercing screws. When choosing the screws for the structure, two basic questions must be answered.

The first question is what two materials are going to be joined. The two possible answers are steel to steel and steel to a rigid material. The answer to this question allows the engineer to choose a head style from the many different types available. The steel to steel connections requires a head with a bearing surface on the top of the material being connected. The hex washer head and the pancake head are the most frequently used in steel to steel construction.

The second question is what is the total thickness of the material being connected. The total thickness of the material that the screw is being fastened into is needed to determine the point type of the screw. The two most commonly used point types in construction are self-drilling and self-piercing (LGSEA, 1997).

The durability of the fasteners is hard to determine and design manuals do not offer substantial guidance. The life of the zinc coating on fasteners depends on the coating thickness and the environment to which it is exposed. Atmospheric and accelerated tests are good guides for the rating and coating of fasteners used in construction. Both of the atmospheric and accelerated tests should be performed, because some coating systems passed or performed well in accelerated tests did very poor in real world applications, and vise versa. (LGSEA, 1999; Roberts 1999).

Accelerated test methods for fasteners include the salt spray test. This is described in ASTM standard B-117. This practice provides a controlled corrosive environment, which produces relative corrosion resistance information for coated metals. The salt spray test apparatus consists of a fog chamber, a salt solution reservoir, a supply of compressed air, stabilizing nozzles, specimen supports, and necessary means of control. Continuous exposure to salt spray without drying periods to allow corrosion products to form a protective layer may not accurately represent atmospheric corrosion conditions (Zhang, 2000d).

The Mebon Prohesion test is similar to the Salt Spray (fog) test but it includes a drying cycle. This wetting and drying simulates long term natural exposure. The third test is the Kesternich test that is used to test heavy industrial exposure. The test involves hanging the samples in an environment of sulfur dioxide and warm water alternated with ambient conditions. The light gauge steel buildings however are exposed to a combination of the salt spray, Kesternich, and humidity all at the same time (LGSEA, 1999; ASTM, 1998).

Section IV - Atmospheric Exposure

Atmospheric corrosion is the most predominant type of corrosion for zinc coated steel. This type of corrosion can be tested in both exposure tests and simulated laboratory tests. The type of wetting, which includes duration and form of wetness, is important in determining corrosion. An outdoor type of wetting occurs when the coated steel is exposed to rain before erection. A metal that goes through cycles of wetting and drying will allow pollutants and corrosion products to dry on the exposed metal. In seacoast areas, sea salts are deposited on the zinc-coated metal by wind and raindrops (Zhang, 1997).

Exposure tests can be accomplished by building shelters at different distances from the ocean and observing these structures for a minimum of two years. The exposure sites should vary in topography, winds, and breaking surf conditions. A FEMA study of galvanized metal connectors used in timber framed housing construction identified three corrosion locations (FEMA 1996). Oceanfront buildings (less than 100 meters from the shore) have ocean salts and humidity that accelerate the corrosion rate of the cold-formed steel framing. Buildings that are 100 to 1000 meters from the shoreline are also prone to corrosion, but at a reduced rate. Buildings that are farther inland are not prone to ocean spray and therefore experience limited corrosion (FEMA 1996; Roberts 1999).

This report also identifies five types of corrosion exposure for metal connectors in a building. In order to study all possible exposure conditions, test shelters should be designed with each of these types of exposure.

The first type of corrosion exposure is the boldly exposed exterior portion of the shelter. This exposure consists of exterior connectors that are fully exposed to the elements. The side of the shelter that faces the ocean is likely to corrode faster than the sections facing away from the ocean. Although the connectors and exterior walls are coated with large amounts of salt spray, the exterior sections are also exposed to sunlight and rain. This exposure reduces the rate of corrosion because the walls and connectors are fully dried between wettings. Drying slows the rate of corrosion (FEMA 1996).

The second type of corrosion exposure is a partially sheltered exterior exposure. This exposure consists of crawl spaces, underneath exposed roof eaves, or exterior storage areas. The corrosion rate of this exposure is worse than that of the exterior exposure. Although the partially sheltered exterior exposures receive almost as much salt spray as bold exposures, they do not receive the cleansing rain. An additional factor causing the higher rate of corrosion is that this exposure condition has a higher duration of surface wetness. Certain levels of surface wetness can cause accelerated corrosion (FEMA 1996).

A vented enclosed exposure is classified as attic spaces. The corrosion in this area varies with the location of the connector. Connectors near the exterior vents behave similar to the partially sheltered exterior exposure. For connectors that are away from the vents, or covered by insulation; the corrosion rate is lower.

Unvented enclosed exposure similar to the wall framing and closed floor system has limited airflow and incoming salt spray. The corrosion rate for this unvented exposure is expected to be lower than the three previous exposure conditions.

The last enclosure condition is the interior living space exposure. In many locations, this area is sealed from most salt spray. The heated and cooling of this space reduces the interior humidity needed for corrosion. This exposure should have the lowest corrosion rate of all the exposures (FEMA 1996). However, in Hawaii and other tropical locations, through flow of air is used to moderate internal temperature rather than air-conditioning and heating. This will permit ingress of moisture and air-borne salt, and may accelerate corrosion of exposed connections.

Section V - Fastener Corrosion

Australian Standard 3566- Screws - Self Drilling – For the building and Construction Industries was recently adopted in Australia as the durability standard for building fasteners. This standard reviews the durability of fasteners and discourages the use of low-cost poor quality fasteners in buildings. The standard was developed and adopted because sheet metal protection systems had improved to the point where fastener life was often the determining factor in the longevity of a steel clad building.

This Australian standard evaluates the performance of fasteners by conducting accelerated weathering test. The various tests that fasteners must endure are fifteen cycles of Kesternick testing, one thousand hours of salt spray testing, two thousand hours of QUV and 1000 hours of humidity cabinet testing. Hot-dip Galvanized screws are exempt from the accelerated testing if they have an average 40 micron zinc thickness with a minimum zinc thickness of 35 microns. The standard also specifies that 40 micron zinc coated fasteners should be used for tropical high humidity environments. The standard classifies fasteners into three categories. Class 1 screws are used for internal applications only. Class two screws are used for general use, but not externally. Class three screws are for external use, but are not approved for corrosive external environments.

The Newcastle Branch of the Australian Corrosion Association conducted a major seminar on Preventing Corrosion of Building Fasteners in Australia to discuss the standards and important points in reducing the effects of atmospheric corrosion. Important presentations at this seminar are summarized in the August 1994 edition of Corrosion Management (1994).

Udo Buecher of BHP Sheet & Coil presented a paper on fasteners for steel cladding (Corrosion Management, 1994). Before the new standards, roofs were fixed with fasteners with yellow chromate 8 micron zinc-plated self-drilling screws, but they presented poor corrosion resistance. The yellow chromate zinc-plated fasteners presented a poor performance in one to five years. In certain environments, corrosion of cladding can occur near the fasteners. Low quality plated products with reduced zinc-coating thickness represent a weak link in connections; therefore, adequate corrosion resistance and compatibility should be used to choose the correct fasteners. Inadequate corrosion resistance of fasteners were found to be problematic when the screws were not compatible with the cladding material, and when the environment of the installation was highly corrosive (Corrosion Management, 1994).

A recent Japanese study tested the corrosion resistance of zinc-coated sheets and connections in steel-framed houses (Honda & Nomura, 1999). The researchers subjected various types of zinc-coated steel sheets to outdoor and indoor environments. They report that hot-dip galvanized steel sheet corrosion rate was low, as anticipated. The corrosion rate of the indoor sheets was considerably slower than that of the outdoor sheets. These results confirmed that a steel-framed house has a mild corrosion environment (Honda & Nomura, 1999).

The durability of joining methods applicable to steel-framed houses was also explored. Tests on the durability of self-tapping screw connections were conducted. Self-taping screws with a known coating thickness of 20 microns were used to join galvanized steel sheets. Each specimen consisted of two 150x 60mm steel sheets which were connected in a lap splice using two self-tapping screws. The maximum shear strength (from tension test on the connected plates) was measured before and after accelerated cyclic corrosion tests. The accelerated cyclic corrosion tests were conducted by exposing the specimens to daily cycles of salt spray, drying, wetting and freezing. The specimens were subjected to the cyclic corrosion testing for eight weeks. Every two weeks during this eight-week test the shear strength of the connected sheets was evaluated. The hot-dip galvanized steel sheets developed red rust after two weeks; and lost all zinc coating after four weeks. The self-tapping screws that connected the sheets showed signs of red rust after two weeks of testing. After four weeks of testing, the screws red rust had formed over the entire screw. However, the maximum shear strength of the tested connections only declined slightly after eight weeks of cyclic corrosion testing (Honda & Nomura, 1999).

Daudet (2000) reports on tests of cold-formed steel splice connections using self-drilling screws. The single-lap shear connections produced a failure normally known as tilting/bearing. The failure results from bearing failure of the steel plate adjacent to the screw and from tilting and eventual pull-out of the screw threads. Daudet reports a group effect which reduces the effectiveness of multi-screw connections from the strength anticipated for an equal number of individual screws. He found that connections with two screws oriented transverse to the loading direction had similar strength to single screw connections, while two screws oriented longitudinally had a 20 percent reduction in strength.

As similar study by LaBoube and Sokol (2000) also identified a significant group effect. However, varying the pattern in which the screws were arranged did not have a substantial effect on the connection strength. Failure of the steel plates is possible in connections with a large number of screws with minimum spacing and edge distances.

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