

Durability of Galvanized Steel Framing for Residential Building

Summary of the seven-year Progress Report produced by NAHB Research Center, a subsidiary of the National Association of Home Builders (NAHB) in the U.S.A. and sponsored by International Zinc Association



OVERVIEW

Durability of Galvanized Steel Framing for Residential Building is a study by the International Zinc Association (IZA) that measures actual zinc and zinc alloy coating corrosion rates of steel framing samples in four different home environments in the U.S.A. and Canada. The NAHB Research Center, a subsidiary of the National Association of Home Builders (NAHB) was the research contractor. Results presented in this summary report are based on the corrosion data presented in the Research Center's seven-year sample retrieval report that is available from IZA or from the Steel Framing Alliance's online store at www.steelframing.org.

The test sites were in Miami, Florida; Leonardtown, Maryland; and Long Beach Island, New Jersey in the U.S.A.; and Hamilton, Ontario in Canada. At each site, numerous test samples were installed in building

cavities where steel framing would typically be used (e.g.; attics, floor systems, walls). The corrosion test samples consisted of zinc-coated (galvanize), 55% aluminum-zinc alloy-coated (Galvalume®), and zinc-5%

aluminum alloy coated (Galfan®) flat plates and 1 in. (nominal) segments of C-section stud. Two sites were also equipped with electronic monitoring systems to measure surface temperatures, relative humidity, and



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time of wetness for a one-year period. This data was analyzed to determine if thermal and moisture conditions existed that would allow condensation to form on building components.

Samples were first installed in 1997: one-, three-, five-, and seven-year exposure samples were retrieved from the test sites. Coating loss measurements from the four sites have shown minor mass loss rates for all sample types (studs and plates), all sample coatings (galvanize, Galvalume®, and Galfan®), and all sample colonies (e.g., crawlspaces, walls, attics, joists). All retrieved samples had a measured mass loss of less than 0.05 grams and an estimated average life expectancy of more than 600 years. Sample colonies located in more aggressive environments, such as underneath an outdoor deck, did, exhibit higher corrosion rates.

The one-year environmental data from the Hamilton and New Jersey sites demonstrated that the surface temperatures of metal samples and actual building components remained above the local dew point with little exception. At one exterior wall location in Hamilton there were numerous instances

of wall component surface temperatures falling below the dew point. However, sample plates retrieved from this wall cavity after seven years of exposure showed an average mass loss of 0.02 grams, or a corrosion rate of less than 0.05 microns per year.

INTRODUCTION

This Report is the summary of the detailed seven-year Progress Report produced by the Research Center, revision 1, March 2007 for IZA's research program - Galvanized Steel Framing for Residential Building.

TEST SITES AND INSTALLATIONS

The four test sites are described in Table 1. (Additional details are provided in the Appendix.) They represented a range of climates and typical building types for each region. The

TABLE 1 – TEST SITES

SITE No.	LOCATION	ENVIRONMENT	FOUNDATION	DISTANCE TO WATER	EXTERIOR FINISH
1	Miami, Florida, U.S.A.	Humid, inland	Slab-on-grade	Several miles from Atlantic Ocean	Stucco
2	Leonardtown, Maryland, U.S.A.	Semi-marine with humid summers	Crawlspace	Less than 75 feet from Potomac River	Vinyl
3	Long Beach Island, New Jersey, U.S.A.	Marine	Piers with enclosed area under house	Less than 1/4 mile from Atlantic Ocean	Aluminum Siding
4	Hamilton, Ontario, Canada	Industrial with cold winters	Basement	Inland	Brick Veneer

For SI: 1 mile = 1.61 km

TABLE 2

MATERIAL	COATING SPECIFICATION ¹ (metric)	COATING SPECIFICATION ¹ (English)	NOMINAL COATING THICKNESS ² (microns)	MEASURED COATING THICKNESS ² (microns)	DENSITY OF COATING (g/cm ³)	COATING WEIGHT OF SOURCE MATERIAL ³ (g/m ²)
Galvanize 1	Z180	G60	25	38	7.14	273
Galvanize 2	Z180	G60	25	29	7.14	206
Galfan	ZGF275	AZ90	41	47	6.7	315
Galvalume 1	AZ180	AZ60	49	60	3.75	227
Galvalume 2	AZ180	AZ50	41	45	3.75	168

¹ Coating Specification is based on ASTM International standards for coated sheet products

² Total coating thickness for both sides of the steel coupon

³ Total coating weight for both sides of the steel coupon

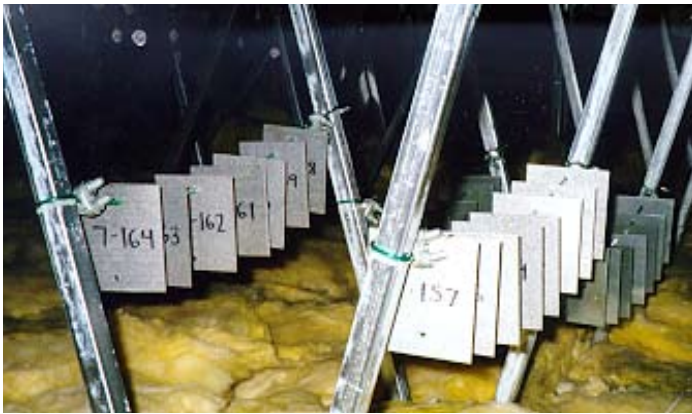


Figure 1 – Plate Samples

sites were chosen such that field results would be applicable to a large selection of homes and climates. At each site numerous test samples were installed in building cavities where steel framing would typically be used (e.g., attics, floor systems, walls). The Hamilton and Long Beach Island sites were also equipped with electronic monitoring systems that measured and recorded surface temperatures, relative humidity, and time of wetness during the first year of exposure. This data was collected to determine if thermal and moisture conditions existed that would allow condensation to form on building components.

CORROSION SAMPLES

The corrosion samples consisted of zinc-coated (galvanize), 55% aluminum-zinc alloy-coated (Galvalume®), and zinc-5% aluminum alloy coated (Galfan®) coatings in the form of 10 cm x 10 cm (3.9 in. x 3.9 in.) flat plates and 25 mm (1-in.) segments of C-section stud. The flat plates allowed for a more definitive determination of the specimen's area, and thus a more accurate

measure of coating corrosion rates calculated from mass reduction of the samples after exposure (Figure 1). The C-section samples were installed to investigate corrosion performance at the edges and bends of a stud. Both the plate and stud samples had both sides and all edges exposed. The coating thickness specifications for the samples are listed in Table

2. Nominal (column 4) refers to the calculated coating thickness according to the specification. Coating tests performed per ASTM A 90/A 90M¹ found that actual coating thicknesses were higher (column 5) than the nominal thicknesses. A sufficient number of samples were installed to allow for analysis in triplicates after one, three, five, and seven years of exposure. Additional

samples were also installed to allow for additional long-term corrosion data to be retrieved. An overview of where samples were installed in the four sites is provided in Table 3.

1. ASTM A 90/A 90M. Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings. American Society for Testing and Materials, West Conshohocken, PA

TABLE 3

SITE	SAMPLES/SENSORS BY COLONY			
	Crawlspace	Wall Cavity	Attic	Other
Miami, Florida, U.S.A.	N/A	Studs – all 3 coatings	Plates and studs – all 3 coatings	N/A
Leonardtown, Maryland, U.S.A.	Plates – all 3 coatings; studs – all 3 coatings and bare	Plates – all 3 coatings	Plates and studs – all 3 coatings	Studs – all 3 coatings and bare samples under outdoor deck
Long Beach Island, New Jersey, U.S.A.	Plates and studs – all 3 coatings; Sensors – metal surface temperature, and ambient relative humidity, temperature	Plates – all 3 coatings; Sensors – metal surface temperature, and ambient relative humidity, temperature	N/A	Plates – all 3 coatings under beachfront deck with metal surface temperature and ambient relative humidity, temperature, inside, and outdoor
Hamilton, Ontario, Canada	N/A	Plates – all 3 coatings; Sensors – metal surface temperature, ambient relative humidity, temperature, and condensation	Plates – all 3 coatings; Sensors – metal surface temperature, ambient relative humidity, temperature, and condensation	Outdoor relative humidity, temperature



RESULTS

Sample retrieval and corrosion rate calculations were conducted at one-, three-, five-, and seven-year intervals. The results of the seven-year sample retrievals are presented in Table 4.

Table 4 shows the expected life span of different coatings based on the average coating corrosion rates measured on seven-year samples from the different locations. Coating life was calculated based on the nominal coating weights listed in Table 2.

Coating corrosion rates were determined by removing the corrosion product from the samples and measuring the resulting weight loss, in accordance with ASTM G1².

CONCLUSION

Coating corrosion was minimal from all four sites for all sample types (studs and plates), all sample coatings (galvanize, Galvalume®, and Galfan®), and all sample colonies (e.g., crawlspaces, walls, attics, joists).

Coating mass loss and the resulting corrosion rate was determined based on the maximum sample exposure duration (seven years) using the ASTM G1 method. The

2. ASTM G1-03 Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens. American Society for Testing and Materials, West Conshohocken, PA.

**TABLE 4 – Corrosion Rates and Estimated Life Expectancy
(Plate Samples, Seven-Year exposure)**

SITE LOCATION	SAMPLE MATERIAL	SAMPLE LOCATION	MASS LOSS (grams)	EXPOSURE DURATION (months)	CORROSION RATE ¹ (μ/yr)	ESTIMATED LIFE EXPECTANCY ² (years)
Hamilton Ontario	Galvanize 2	Attic	0.013	98	0.0223	841
		Wall	0.020	98	0.0343	547
	Galvalume	Attic	0.017	98	0.0555	554
		Wall	0.020	98	0.0653	471
	Galfan	Attic	0.013	98	0.0238	1294
		Wall	0.020	98	0.0366	841
Miami Florida	Galvanize 2	Attic	0.017	99	0.0289	650
	Galvalume		0.013	99	0.0420	732
	Galfan		0.033	99	0.0597	515
Long Beach Island New Jersey	Galvanize 1	Wall	0.013	87	0.0251	747
		Floor	0.020	87	0.0386	485
		Under Deck	0.030	87	0.0580	324
	Galvalume	Wall	0.013	87	0.0478	643
		Floor	0.027	87	0.0993	310
		Under Deck	0.023	87	0.0846	363
	Galfan	Wall	0.013	87	0.0268	1149
		Floor	0.040	87	0.0823	373
		Under Deck	0.027	87	0.0556	553
Leonardtown Maryland	Galvanize 2	Attic	0.017	93	0.0307	610
		Wall	0.020	93	0.0361	519
		Crawl /Open	0.037	93	0.0669	280
	Galvalume	Attic	0.017	98	0.0555	554
		Crawl /Open	0.030	98	0.0980	314
	Galfan	Attic	0.017	98	0.0311	990
		Wall	0.033	98	0.0603	510
		Crawl /Open	0.023	98	0.0420	732

¹ Total corrosion rate for both surfaces of the plate. Single surface corrosion rate is half this corrosion rate.

² Life expectancy calculated using Nominal Coating thickness, Table 2

estimated life expectancy based on the average mass loss (using nominal coating weights) ranged from 280 to over 1000 years with an average of 611 years for all samples at all locations.

The fastest coating corrosion rates observed were in locations with exposures to higher levels of humidity and outdoor pollutants, such as

with samples installed in the floor above the carport of the New Jersey site or samples located in the crawl space ceiling of the Leonardtown site. Lower corrosion rates were generally found with samples installed in wall cavities and attics where the environments were more controlled with less exposure to humid conditions. The environmental data

collected from the Hamilton and New Jersey sites in the earlier years of this program indicated that the samples and their micro-environments (e.g., a wall cavity) remain dry throughout the year. This observation supports the low coating loss measurements reported for these two sites over one-, three-, five-, and seven-year exposure periods.

APPENDIX

Miami, Florida Test Site

The Miami site (Figure 2) was in a Habitat for Humanity Development in southwest Miami, where 16 of the 90 homes were framed with steel systems. The site was a single-story steel framed structure with a slab foundation. It had plywood sheathing with a stucco exterior finish. The wall interior was 5/8 in. (16 mm) painted drywall. The attic was kraft faced (facing the drywall) fiberglass batts with an R-30, while the walls have either R-11 or R-13 batts. The walls were 6 in. (152 mm) wide. The attic was vented with soffit vents [19 vents total, each is 22 in. x 4 in. (56 cm x 20.5 cm)]. No ridge vents were present, and one small gable end vent was visible in the front of the house.

The house was air conditioned and the type of environment could be classified as humid/inland. Although the site was in southern Florida it was several miles from any large water body. There was no shading of the house on the western exposure, where the wall cavity colonies were located.

Sample colonies were located in both the attic (see Figure 3) and an exterior wall. The attic colony samples were suspended from the roof framing. The attic was vented by soffit vents on the east and west sides of the house.

The wall cavity colony had a west-facing exposure, and contained samples which were accessible for retrieval through access panels. The samples were embedded into the fiberglass batt insulation in the wall cavity.

Leonardtown, Maryland Test Site

The Leonardtown, Maryland, house (Figure 4) was directly on the lower Potomac River before it empties into the Chesapeake Bay. The two-story home was roughly 75 feet (23 m) from the river, with strong winds often blowing spray towards the house from the brackish river water. The walls were framed with 0.043 in. (1.1 mm) thick steel C-section studs, while steel trusses were used for the roof framing. Steel floor joists were used in the crawlspace along with R-19 fiberglass batts. A layer of poly was installed on the crawlspace floor. The attic was insulated with 11 in. (28 cm) of blown cellulose and vented with a ridge vent and soffit vents. The walls consisted of 5/8 in. (16 mm) drywall, wet-blown cellulose (R-13), OSB sheathing, 1 in. (25 mm) of non-foil faced foam cladding (R-5), a Tyvek air infiltration barrier, and vinyl siding. The only notable interior moisture source is a large Jacuzzi tub in the master bathroom. All bathrooms were vented directly to the outside. The foundation was vented with perimeter vents in the block wall.

Specimens were installed in the attic, an exterior wall, the crawlspace, and under the outdoor deck.

The crawlspace contained a set of suspended samples fully exposed to the ambient crawlspace environment, including bare (stripped) stud-type specimens. The bare samples displayed extensive corrosion after just two months of exposure, indicating the aggressive environment in the crawlspace (see Figure 5).

Specimens were installed under the outdoor deck, which represented an extreme worst-case environment. The deck was boldly exposed to any river spray, and was actually framed with wood. The sample

colony under the decking provided performance data in an extremely aggressive environment. Corrosion results from this test site were found to be similar to the corrosion rates observed for the crawlspace colonies.



Figure 2 - Miami, Florida Corrosion Site



Figure 3 - Attic Specimens in Miami, Florida Site



Figure 4 - Leonardtown, Maryland, Site on Lower Potomac River



Figure 5 - Stud Specimen in Leonardtown Site Crawlspace

Hamilton, Ontario (Canada)
Test Site

The Hamilton, Ontario, site (Figures 6 and 7) was a single-story house in a retirement community. It was the end unit, with a walk-out basement. Three of the four basement walls were concrete block, with the fourth wall (east facing) being steel-framed. The framed walls were designed as follows: interior wall covering was 5/8 in. (15 mm) drywall, behind which a poly vapor barrier was installed. The walls were insulated with R-13 fiberglass batts. Beyond the framing was 1-1/4 in. (32 mm) of foam sheathing (R-7). Outside of the foam sheathing was a 1 in. (25.4 mm) air gap, with a brick veneer finish beyond this.

The block walls in the basement (3 of the 4) were 8 in. (203 mm) thick concrete, with the above-grade portions insulated on the interior by 6 in. (152 mm) of fiberglass batt insulation (R-19) that was covered by a poly vapor barrier. The below grade foundation walls were also protected on the exterior by a solid plastic membrane that was designed to shield the foundation walls from soil moisture. The slab edge insulation was an R-28 Isynene foam product. A poly damp proof course lies between the block foundation wall and the bottom track of the exterior basement wall. The basement was finished so there was no insulation in the basement ceiling. The attic was framed with wood roof trusses. An R-32 layer of blown-in fiberglass is in the attic. The attic was vented

with soffit vents and a ridge vent.

The attic samples were suspended in the air and thermistors were attached to one plate of each coating type to record the metal surface temperatures. The attic ambient temperature and relative humidity were also measured and a time of wetness sensor was mounted to a galvanized specimen to record the percentage of time that a moisture film was present. A similar installation was made in the exterior wall colony.

Long Beach Island, New Jersey Test Site

The Long Beach Island, New Jersey site (Figure 8) was the last addition to the research study with specimens being installed in 1998. The site was a beachfront house on the New Jersey shore, and was separated from the ocean by a low-lying dune roughly 1/4 mile (400 m) wide. The house was originally a one-story structure, and was remodeled to include a new second floor and roof that were both framed with cold-formed steel (Figure 9). The house was occupied primarily during the summer season, and was left vacant during the winter.

Three sample colonies were established in the New Jersey site. The first was a full set of stud and plate samples located between the joists that supported the first story. This location should carry some risk of corrosive conditions because it was not immune to infiltration air and outdoor conditions. The second colony was located on a cantilevered deck that



Figure 6 - Hamilton, Ontario Test Site (Rear View)



Figure 7 - Wall Cavity Specimens and Sensors in Hamilton, Ontario, Site



Figure 8 - New Jersey Site

hung off the second story of the home and faced the beach (Figure 9). The joist bays under the deck were vented, which presented an opportunity for ocean breezes to deposit salt and/or moisture on the samples. The third colony was in a steel-framed exterior wall on the second floor.

All three-sample colonies in the New Jersey site were also equipped with sensors that

measured the sample surface temperature for each coating type (galvanize, Galvalume®, Galfan®) as well as the ambient relative humidity and temperature. Building components such as wall studs and floor joists were also monitored for surface temperature, establishing a one-year long record of humidity and temperature conditions for the site.



Figure 9 - New Jersey Site Under Construction