Durability of Galvanized Steel Framing in Residential Buildings

Summary of a ten year report produced by NAHB Research Center, a subsidiary of the National Association of Home Builders (NAHB) in the US and sponsored by International Zinc Association

OVERVIEW

Durability of Galvanized Steel Framing in Residential Buildings was a study commissioned by the International Zinc Association (IZA) that measured actual zinc and zinc-alloy coating corrosion rates of steel framing samples in four different home environments in the US and Canada over a ten year period. The NAHB Research Center was the research contractor.

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INTRODUCTION

This summary report is based on the corrosion data presented in the NAHB Research Center's ten year sample retrieval report, January, 2009. The test sites were in Miami, Florida; Leonardtown, Maryland; and Long Beach Island, New Jersey in the US; and Hamilton, Ontario in Canada. At each site, numerous test samples were installed inside and in some cases, outside of the building (e.g.; roof trusses, floor systems, walls, decks).

The ten year coating loss measurements from the four sites have shown minor mass losses for all coating types in all sample colonies (e.g., walls, attics, floor joists). While calculating life expectancies based on the very low coating weight losses found in this study is inexact, the measured coating corrosion rates extrapolate to coating life predictions of 300 to over 1000 years in wall, floor, and roof framing. Sample colonies intentionally located in more aggressive exposures, such as underneath an outdoor deck and in an exposed crawl space located next to aggressive tidal waters, exhibited higher corrosion rates, but still had a coating life greater than 150 years. Steel is not recommended for outdoor use such as under decks. For an area near the coast or other aggressive bodies of water, steel in a vented or exposed crawl space would be specified with a heavier coating to significantly extend its life.

TABLE 1 – TEST SITES

Location	Environment	Foundation	Distance to Water	Exterior Finish
Miami, FL US	Humid, inland	Slab-on-grade	Several miles from Atlantic Ocean	Stucco
Leonardtown, MD US	Semi-marine with humid summers	Crawlspace	Less than 75 feet from tidal Potomac River	Vinyl
Long Beach Island, NJ US	Marine	Piers with enclosed area under house	Less than 1/4 mile from Atlantic Ocean	Aluminum Siding
Hamilton, ON Canada	Industrial with cold winters	Slab-on-grade	Inland	Brick veneer

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 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., roof trusses, 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 the steel 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

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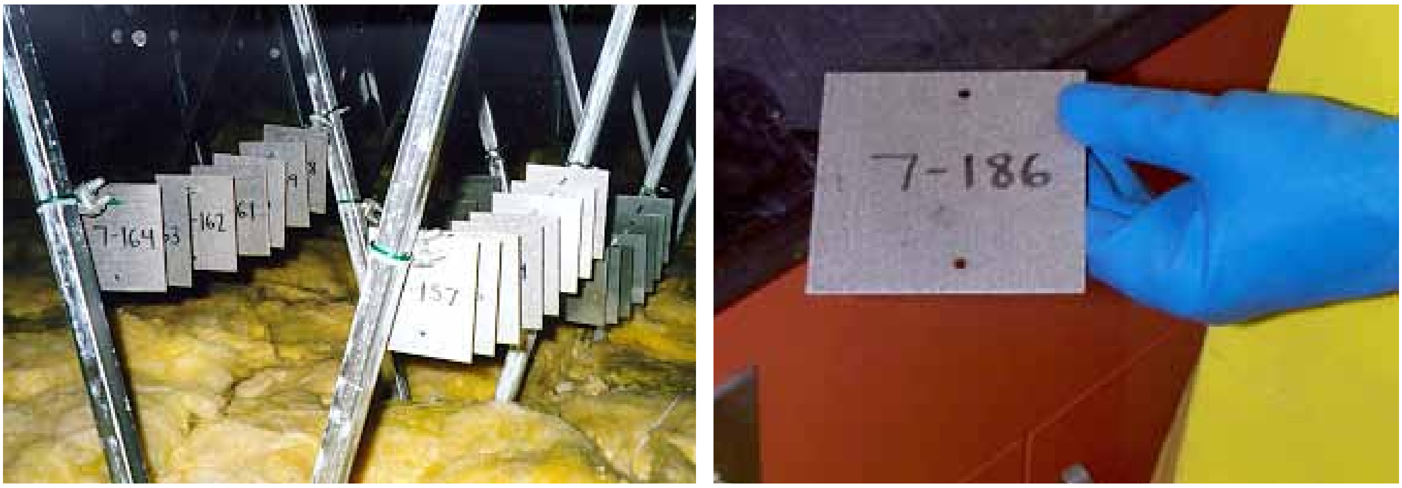

Figure 1 – Plate Samples

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 and measured coating weights of the samples are listed in Table 2. Coating Thickness (column 5) is the calculated coating thickness based on the measured coating mass in column 4. Coating tests performed per ASTM A90/A90M[1] determined that actual coating masses (column 4) were all above the minimum specification requirements. Samples were installed to allow for analysis after one, three, five, seven, and ten years of exposure. An overview of where samples were installed in the four sites is provided in Table 3.

TABLE 2 – SAMPLE COATING CHARACTERISTICS

Material	Coating Designation[A] (Metric [Inch-Pound])	Density of Coating (g/cm^3)	Coating Mass of Test Material[B] (g/m^2)	Coating Thickness[C] (microns)
Galvanize 1	Z180 [G60]	7.14	273	38
Galvanize 2	Z180 [G60]	7.14	206	29
Galfan	ZGF275 [ZF90]	6.84	315	46
Galvalume 1	AZM180 [AZ60]	3.75	227	60
Galvalume 2	AZM150 [AZ50]	3.75	168	45

[A] Coating Specification is based on ASTM International standards A653, A792, and A875 for coated sheet products
[B] Coating mass – total both sides of the test material
[C] Coating thickness – total both sides of the test material

RESULTS

Sample retrieval and corrosion rate calculations were conducted at one, three, five, seven, and ten year intervals. Corrosion rates were determined by removing the corrosion product from the samples and measuring the resulting weight loss, in accordance with ASTM G1[2]. The results of the ten year sample retrievals[3] show that the weight loss of the plates ranged from 0.02 to 0.06 grams for all coating types in the various locations in typical exposure conditions. As shown in Table 2, the amount of zinc or zinc-alloy coating on the sample plates is in the order of 2 to 3 grams ($100cm^2$ is 1/100 of a m^2). As such, over a 10 year period only 1-2% of the zinc or zinc-alloy coating was oxidized, indicating a very considerable life expectancy for the zinc and zinc-alloy coatings, and hence the underlying steel that the coating is protecting.

For samples that were semi-exposed in an aggressive environment, such as the Leonardtown open crawl space, or under an outdoor deck, coating losses were considerably greater, in the order of 0.05 to 0.15 grams after 10 years. Even in these exposed conditions, the zinc and zinc-alloy coatings can be expected to last over 150 years.

The environmental data collected from the Hamilton and New Jersey sites in the first year of the program indicated that the samples and their micro-environments (e.g., a wall cavity) remain dry throughout the year. This observation supports

the low weight loss measurements reported for these two sites over all exposure periods.

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., crawl spaces, walls, attics, joists).

Lower corrosion rates were found with samples installed in wall cavities and attics where the environments were more controlled with less exposure to humid conditions. Higher coating corrosion rates were found 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 of the Leonardtown site.

For enclosed locations (walls, attics, floors) the extrapolated coating life predictions ranged from 300 to over 1000 years. For exterior exposures or semi-exposed locations in an aggressive environment subject to higher humidity and exterior pollutants, the higher corrosion rates still extrapolated to over 150 years of coating life.

The life span of the zinc and zinc-alloy coated steel samples studied in this project was found to be well beyond the life expectancies of modern buildings. The results of this study agree with the results from a similar study conducted by Corus Research in the United Kingdom.[4]

TABLE 3 – SUMMARY OF INSTALLED SAMPLES

Site Location	Samples/Sensors By Colony			
	Floor Crawlspace	Wall Cavity	Attic	Other
Miami, FL.	none	Studs – all 3 coatings	Plates and studs – all 3 coatings	
Leonardtown, MD	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, NJ	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	none	Plates – all 3 coatings under beachfront deck with metal surface temperature and ambient relative humidity, temperature, inside and outdoor
Hamilton, ON	none	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

[1] ASTM A90/A90M Test Method for weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM, West Conshohocken, PA.

[2] ASTM G1 Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens, ASTM, West Conshohocken, PA.

[3] IZA Research Program ZC4, Galvanized Steel Framing for Residential Buildings, Ten Year Report, prepared by, NAHB Research Center, Inc., 400 Prince George Blvd., Upper Marlboro, MD 20774 USA, January 2009.

[4] Ten Year Corrosion Data of Zinc Coated Materials, Corus Research, Development & Technology, Swindon Technology Centre, Moorgate, Rotherham, South Yorkshire S60 3AR UK, June 2008.

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 on grade 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) R-30 fiberglass batt insulation, 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 soffitt 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 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 soffitt 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), an air infiltration barrier, and vinyl siding. 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 crawl space, 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 also installed under an 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.

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 specimens in Leonardtown Site crawl space. Note the uncoated C-sections in the background show red rust after just two months of exposure.

Hamilton, Ontario (Canada) Test Site

The Hamilton, Ontario, house (Figures 6 and 7) was a 2-storey townhouse block built on a concrete floor slab in a retirement community. It was the end unit, with a walkout on the ground floor. Three of the four 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 walls (3 of the 4) were 8 in. (203 mm) concrete block, 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 foam product. A poly damp proof course lies between the block foundation wall and the bottom track of the exterior wall. The ground floor was finished with no insulation in the 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 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 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 6 - Hamilton, Ontario Test Site (Rear View)

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

Figure 8 – New Jersey Site

Figure 9 – New Jersey Site Under Construction