

Durability of Cold-Formed Steel Framing Members

Summary: The purpose of this document is to give engineers, architects, builders and home and commercial building owners a better understanding of how galvanizing (zinc and zinc alloy coatings) provides long-term corrosion protection to cold-formed steel framing members. This document also suggests guidelines for selecting, handling and using these steels in framing applications.

1.0 DESIGN LIFE

A home is one of the few necessities that consumers expect to last a lifetime or more. For commercial property owners, each structure represents a significant investment. It is critical therefore, that the framing material performs its function for as long as other critical components, such as the roof structure, exterior and interior wall coverings, and flooring. For sufficient longevity, cold-formed steel framing needs proper corrosion protection.

Galvanizing is one of the most economical and effective ways to protect steel. Steel framing materials used in residential and light commercial construction can be effectively protected by a galvanized coating.

2.0 GALVANIZING

2.1 Definition

Galvanizing is a process whereby steel is immersed into a bath of molten zinc (865°F/460°C) to form a metallurgically bonded zinc coating. This same hot dip immersion process is also used to produce aluminum-zinc alloy coatings.

Most cold-formed steel is galvanized by unwinding coils of cold rolled steel and feeding the sheet continuously through a molten zinc bath at speeds up to 600 feet per minute (200 meters/minute). As the steel exits the molten zinc bath, air "knives" blow off the excess coating from the steel sheet and control the coating thickness to the specification requirement. The coated sheet steel is chemically treated (passivated) to protect against storage

stain and, if requested, oiled and recoiled for shipment to the fabricator¹.

Extensive information on the properties, performance and applications for zinc and zinc alloy coated steel sheet can be found on the GalvInfo Center web site at www.galvinfo.com.

2.2 Types of Coatings

The continuous galvanizing process can apply a number of different coatings that vary in thickness, appearance and alloy composition. A number of coating compositions are acceptable for cold-formed steel framing, as noted in ASTM A 1003/A 1003M². The common North American coatings, according to AISI S201³, are as follows:

- **Zinc-Coated (Galvanized):** The name, galvanized, usually refers to the "standard" continuous coating that is basically pure zinc. About 0.2% aluminum is added to the galvanizing bath to form a thin, inhibiting, iron-aluminum layer on the steel surface that ensures formation of a pure zinc coating. The finished coating has good formability and corrosion resistance, and provides excellent sacrificial protection (Section 4.2). For further details on coating specifications, refer to ASTM A 653/A 653M⁴.
- **55% Aluminum-Zinc Alloy-Coated:** This is a 55% aluminum, 43.5% zinc, and 1.5% silicon alloy coating that provides superior barrier corrosion resistance over galvanized coatings. For further details on coating specifications, refer to ASTM A 792/A 792M⁵.

Table 2.1
Zinc Coating Weights (Mass) / Thickness

Coating Designation	Minimum Requirement Total Both Sides		Thickness Nominal per Side	
	(oz/ft ²)	(g/m ²)	(mils)	(microns)
Zinc (Galvanized)				
G40/Z120	0.40	120	0.34	8.5
G60/Z180	0.60	180	0.51	12.7
G90/Z275	0.90	275	0.77	19.4
55% Aluminum-Zinc				
AZ50/AZM150	0.50	150	0.80	20.0

2.3 Types of Surface Finishes

Zinc and zinc alloy coatings can differ in appearance based on the size of spangle or type of surface finish. Spangle is the flowery pattern that results as molten zinc grains grow and are then frozen in place as the coating solidifies. Spangle size can be controlled or eliminated by various processing techniques. Spangle control does not effect coating thickness so the presence or absence of spangle has no influence on corrosion performance (Section 4.1).

2.4 Coating Weights and Thicknesses

The galvanizer controls how much coating is put on the steel. The amount of coating is measured by coating weight (ounces per sq. foot, grams per sq. meter) or by thickness (mils, microns). Table 2.1 lists the common commercially available continuously galvanized coatings used for cold-formed steel framing members.

Table 2.2 lists the minimum coating requirements for structural and non-structural framing members, as pre-

scribed by AISI S201³. For further details on coating specifications, refer to ASTM A 653/A 653M⁴ (zinc-coated) and A 792/A 792M⁵ (55% aluminum-zinc coated). Coating requirements for framing members also appear in ASTM C645⁶ and C955⁷.

A heavier coating may be advisable in applications where the environment is particularly corrosive. Section 3 contains more information on the performance of zinc coatings in various environments and identifies areas where additional protection may be required.

3.0 DURABILITY OF GALVANIZED STEEL FRAMING

The durability of zinc-based coatings is a function of time of wetness and composition of the atmosphere (refer to Section 4 for details). Since residential galvanized steel framing is intended for dry indoor environments, the corrosion rate of zinc should be very low. According to the corrosion rates in Section 3.1 and the minimum coating

Table 2.2
Minimum Coating Weight Requirements

Framing Member Designation	Zinc (Galvanized)	55% Aluminum-Zinc
Structural	G60/Z180	AZ50/AZM150
Non-Structural	G40/Z120	AZ50/AZM150

thicknesses specified in Table 2.2, zinc based coatings can protect steel for the design life of the structure.

Just as water leakage, excessive humidity or condensation will damage most construction materials over time, so will it accelerate the corrosion of zinc coatings. However, if a building is built to code and properly ventilated and maintained, moisture should not be a concern for galvanized steel framing.

Additional corrosion protection is recommended for structures built in particularly aggressive environments; i.e., humid coastal areas⁹.

3.1 Performance in Service

The corrosion rate of zinc coatings in an indoor atmosphere of a building's structure is generally low. According to a three-year British Steel study⁹, the corrosion of zinc is lower than 0.1 µm (microns) per 3-year period in houses located in different rural, urban, marine and industrial atmospheres (Figure 3.1). This indicates that under similar conditions a 10-µm (microns) zinc coating should last for more than 300 years.

A recent seven-year study conducted by the NAHB Research Center¹⁰ measured coating corrosion rates of test samples installed in the exterior wall cavities and ventilated crawl and attic spaces of four houses located in different geographic locations (inland, marine and industrial) in North America. Based on the corrosion rates measured, the estimated life expectancy of the coating varies from 325 years to over 1000 years.

Additionally, a survey was performed in May 1995 on a 20-year old steel-framed house in Stoney Creek, Ontario¹¹. The inspection revealed no visible signs of corrosion of the zinc coating or the steel studs. Coating thickness measurements taken on exterior and interior studs showed no measurable loss in coating thickness.

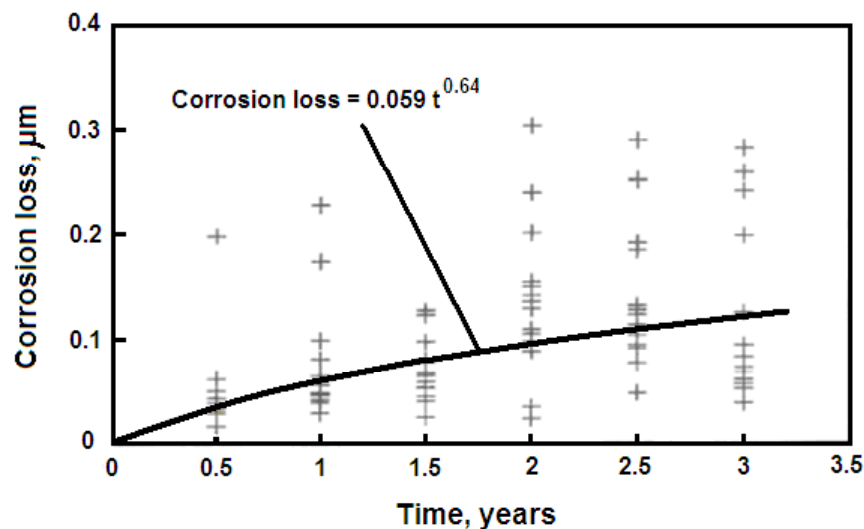
3.2 Interior Walls

Interior, non-load bearing walls will likely experience the most benign atmosphere in the structure. It is unlikely that these steel members will be subject to moisture on a regular basis and the coatings specified in Table 2.2 should give adequate protection.

Venting of rooms that generate considerable amounts of moisture (i.e., bathroom, kitchen) should be to the outside, not into wall or ceiling cavities.

3.3 Exterior Walls

Proper design and building practices which include vapor retarders, thermal breaks, and air barriers should eliminate significant moisture transfer into exterior wall cavities, and thus prevent the framing from being exposed to significant moisture accumulation. Galvanized cold-formed steel framing in accordance with Table 2.2, should adequately protect the framing when enclosed. Framing that is intentionally left exposed (e.g., supports for a balcony penetrating a wall, a garage with exposed framing, etc.) may require additional protection as the exterior environment is considered to have access to the framing. Heavier coatings will also be required for aggressive industrial and coastal environments⁸.



Corrosion loss of galvanized steel, exposed in the loft of 15 residential houses located in three different geographical areas in England, UK, as a function of exposure time (John, 1991). The data points are the mean values of 6 samples for each house; the equation in the figure is the best fit from linear regression analysis.

Figure 3.1

Particular attention should be paid to the bottom track of exterior walls that may collect moisture during installation or during the service life of the wall. A vapor barrier or sill gasket can be installed between the track and the foundation to prevent underside corrosion in the event that the concrete substrate gets wet.

3.4 Floor Framing

Floor joists contained within the controlled environment of a building or structure are not likely to be exposed to aggressive conditions, as a result the corrosion coating values specified in Table 2.2 should adequately protect the framing. Framing that is exposed to environments open to the outside, such as vented basements or crawlspaces, unconditioned basements, and the like should have greater protection. Floor joists installed in a basement or crawlspace not having a concrete slab floor or vapor barrier at the floor should be considered the same as having the framing exposed to the exterior environment. Greater corrosion protection is recommended in these applications due to the likelihood of exposure to extended periods of high humidity. Floor joists or tracks that are attached directly to the foundations made of concrete or pressure treated wood can include a vapor barrier or sill gasket under the joist or track to prevent underside corrosion in the event that the foundation gets wet. For all of the above scenarios, proper building design and building practices which include the installation of insulation, vapor retarders, thermal breaks, and air barriers should eliminate significant moisture transfer and accumulation into the floor assembly.

3.5 Roof Framing

Attics normally contain some form of cross ventilation due to the provisions of the locally adopted building code. Roof framing is generally considered to have more exposure to the exterior environment than other areas of the building's structure and increased corrosion protection may be advisable for buildings located near salt water or industrial environments where the atmosphere is more corrosive⁸. Also, a prolonged roof leak may cause localized corrosion of the affected roof members.

4.0 CORROSION PROPERTIES OF ZINC

It is well known that steel rusts when left unprotected in almost any environment. Applying a thin coating of zinc to steel is an effective and economical way to protect steel from corrosion. Zinc coatings protect steel by providing a physical barrier as well as cathodic protection to the underlying steel.

4.1 Barrier Protection

The main mechanism by which galvanized coatings protect steel is by providing an impervious barrier that does not allow moisture to contact the steel. Without moisture (the electrolyte) there is no corrosion. The nature of the galvanizing process ensures that the metallic zinc coating has excellent coating adhesion and abrasion resistance.

Galvanized coatings will not mechanically degrade (crack, de-bond or fade) over time as will other barrier coatings such as paint. However, zinc is a reactive material and will corrode slowly over time (Figure 3.1). For this reason, the protection offered by galvanized coatings is proportional to the coating thickness.

4.2 Cathodic Protection

Another important protection mechanism is zinc's ability to galvanically protect steel. When base steel is exposed, such as at a cut or scratch, the steel is cathodically protected by the sacrificial corrosion of the zinc coating adjacent to the steel. This occurs because zinc is more electronegative (more reactive) than steel in the galvanic series as shown in Table 4.1.

In practice, this means that when underlying steel is exposed by coating damage or at a cut edge, the zinc coating will not be undercut by rusting steel (Figure 4.1) because the steel cannot corrode adjacent to the zinc coating^{12,13}.

Table 4.1
Galvanic Series of Metals
and Alloys (in seawater)

<p>Corroded End - Anodic (Electronegative)</p> <p>Magnesium Zinc Aluminum Cadmium Iron or Steel Tin Copper Lead Silver</p> <p>Stainless Steel (passive) Gold</p> <p>Protected End - Cathodic or most noble (Electropositive)</p>
<p>Note: Any one of these metals and alloys will theoretically corrode while protecting any other that is lower in the series as long as both form part of an electric circuit.</p>

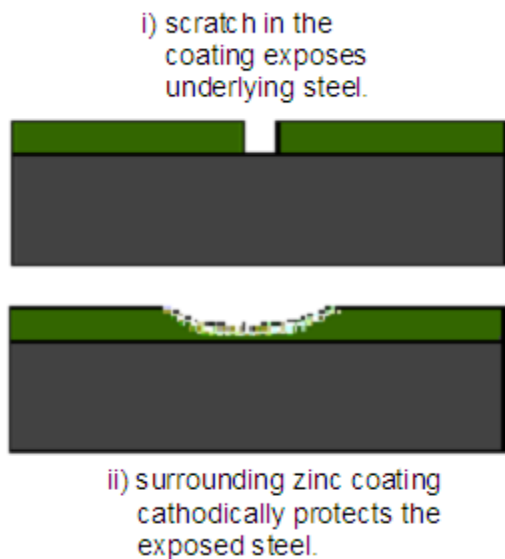


FIGURE 4.1 (A): ZINC COATING

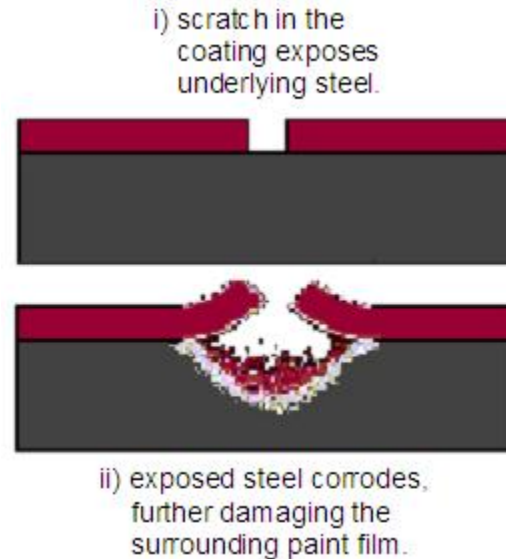


FIGURE 4.1 (B): PAINT COATING

4.3 Corrosion Process

The ability of a zinc coating to protect steel depends on zinc's corrosion rate. It is therefore important to understand zinc's corrosion mechanism and what factors affect zinc's corrosion rate.

Freshly exposed galvanized steel reacts with the surrounding atmosphere to form a series of zinc corrosion products. In air, newly exposed zinc reacts with oxygen to form a thin zinc oxide layer. When moisture is present, zinc reacts with water resulting in the formation of zinc hydroxide. A final common corrosion product to form in atmosphere is zinc carbonate as zinc hydroxide reacts with carbon dioxide in the air. Other zinc compounds containing sulfate or chloride can also be present in the corrosion products formed in industrial or marine environments. The zinc corrosion products formed in atmospheric environments are usually a thin, tenacious and stable layer that provides protection to the underlying zinc. These corrosion products are what give zinc its low corrosion rate in most environments.

Zinc corrosion rates correlate with two major factors; time of wetness, and concentration of air pollutants^{12,13}. Corrosion only occurs when the surface is wet. The effect of wetting on zinc's corrosion rate depends on the type of moisture. For example, while the moisture from rainfall may wash away zinc's corrosion products causing further zinc corrosion to occur, moisture formed by condensation usually can evaporate and leave the corrosion products in place. Since steel framing inside buildings should be dry almost all of the time, zinc's corrosion rate will be low.

The pH of the atmosphere, rain or other liquids that contact zinc have a significant effect on corrosion rate. Moderately acidic conditions or fairly strong basic conditions may increase zinc's corrosion rate. Most industrial atmospheres contain sulfur in the form of sulfur dioxide and sulfuric acid, which are corrosive to zinc.

Chloride environments (i.e. marine) have a lesser effect on zinc's corrosion rate than sulfur compounds. Nevertheless, because chlorides can be prevalent in coastal environments, chlorides may likely be of concern necessitating extra corrosion protection⁸.

4.4 Wet Storage Stain

"Wet Storage Stain" is a term traditionally used in the galvanizing industry to describe the white zinc corrosion product that sometimes forms on the galvanized steel surfaces during storage and transport.

When freshly galvanized steel is stored or installed with moisture trapped behind contacting surfaces and access to free-flowing air is restricted, zinc hydroxide may form. This is a voluminous, white, non-protective corrosion product. Zinc hydroxide can form during a single incident of wetting, by rain or condensation; however, once the affected areas are exposed and allowed to dry, it generally has little harmful effect on the long-term performance of galvanized steel. If the damp, restrictive conditions continue, then zinc corrosion may proceed rapidly down to the base steel. Most galvanized sheet products receive some form of surface treatment (passivation) to help prevent the formation of wet storage stain.

4.5 Contact with Non-Metallic Materials:

- **Mortar and Plaster:** Damp freshly prepared mortar and plaster may attack zinc and zinc alloy coatings, but corrosion ceases when the materials become dry. Since these materials absorb moisture, care should be taken to either keep them dry or isolate the steel framing from the plaster or mortar.
- **Wood:** Galvanized steel does not react with dry wood. Galvanized steel can be safely fastened to wood that is dry throughout most of its service life.
- **Pressure Treated Wood:** There are a variety of chemicals used to pressure-treat wood to help protect the components from attack by termites, other insects, and fungal decay. Recent testing has indicated copper-based products, i.e. A CQ, CA and A CZA are more corrosive to galvanized steel than the former CCA, which was voluntarily withdrawn from the market for many applications in 2003. Viable options for cold-formed steel framing that should be considered would seem to include specifying the less corrosive sodium borate (SBX/DOT) pressure treatment, isolating the steel and wood components, or avoiding use of pressure treated wood¹⁴.
- **Gypsum Sheathing (Drywall) and Insulation ducts:** Dry wall and various dry insulating products (mineral wool, cellulose and rigid foam) do not react with galvanized steel.
- **Concrete:** Freshly poured concrete may react with galvanized coatings because it is wet and highly alkaline (pH 12 to 13). However, as the concrete cures and dries, it becomes non-aggressive to these coatings. Since curing times are relatively short, the corrosion of the coating is minimal. Good quality concrete that is free of chlorides is not corrosive to zinc.

4.6 Contact with Other Metals

Bi-metallic interaction is an electrochemical reaction that can occur between some dissimilar metals or alloys that causes corrosion of one metal and protection of the

other. The reaction will only occur when the dissimilar metals are connected to form an electrical circuit and an electrolyte (such as moisture) is present. It is this reaction that is responsible for the galvanic protection of steel by zinc coatings at the place where the coating is damaged.

Based on outdoor atmospheric studies^{12,13}, Table 4.2 presents the relative galvanic corrosion rate of zinc when coupled to various metals. In normal indoor environments moisture levels are low and consequently the galvanic action between dissimilar metals is much lower than in outdoor environments. The galvanic interaction between dissimilar metals is complex and expert opinion should be sought on the advisability of combining different materials. The extent of the galvanic action depends on the metals coupled. Advice given should fall into one of three categories:

- 1) The choice is satisfactory and unlikely to cause a corrosion problem
- 2) Switch to a suitable combination
- 3) Use the materials selected but electrically insulate the bi-metallic couple.

According to Table 4.2, galvanic corrosion of zinc is the most severe when in contact with steel, copper or brass under moist conditions. If contact between galvanized coatings and copper/brass or bare steel cannot be avoided, then insulated, non-conductive gaskets should be used at the contact points to prevent localized consumption of the galvanized coating.

On the other hand, contact between galvanized coatings and aluminum or stainless steel results in less bi-metallic corrosion. However, insulating the materials may be advisable in humid environments.

Coupled Alloy	Zinc Corrosion Rate
Mild Steel	High
Stainless Steel	Low
Brass	High
Copper	High
Lead	Medium
Nickel	Medium
Aluminum	Low

Table 4.2

Galvanic Corrosion Rate of Zinc Coupled to Other Common Commercial Metals^{12,13}

5.0 BUILDING WITH GALVANIZED STEEL

5.1 Fabricating Galvanized Framing Members

Galvanized steel is shipped to fabricators as coils. The coils are slit lengthwise into individual “ribbons” of galvanized steel strip. These ribbons are roll-formed, cut to length and holes are often punched to produce the various steel sections used for framing.

Galvanized zinc coatings are metallurgically bonded to the steel sheet and will not spall or flake off during these forming operations. Zinc also cathodically protects any steel exposed at cut edges (Section 4.2).

5.2 Storage, Handling and Installation

A galvanized coating is adherent and abrasion resistant. As a result, normal handling during distribution, storage and installation should not damage the zinc coating. Coating damage that results from necessary job site procedures such as shearing, cutting or fastening is mitigated by zinc’s ability to cathodically protect any exposed steel at cut edges.

Precautions should be taken to avoid the formation of wet storage stain (Section 4.4) at all points in the distribution cycle and when storing galvanized steel at the job site. The galvanized steel should be stored to allow proper drainage and good ventilation so that all surfaces can dry after becoming wet.

In particularly aggressive conditions such as humid coastal environments, extra effort should be taken to minimize outdoor exposure of the galvanized framing members during storage and installation⁸. Material shall be received and stored in accordance with AISI Code of Standard Practice for Cold-Formed Steel Structural Framing, paragraph F3¹⁷.

5.3 Welding

Galvanized steel can be joined by spot or continuous welding. Welding may be an economical joining method when shop fabricating wall or roof assemblies. Although both welding operations volatilize the zinc coating at the weld site, spot welding is a much more localized process.

Spot welds and continuous welds will remove the zinc coating. Damaged areas should be repaired using zinc rich touch-up paint or by zinc metallizing in accordance with ASTM A 780¹⁵. Zinc metallizing is a thermal process that propels molten zinc particles onto the steel substrate producing a continuous metallic zinc coating.

5.4 Fasteners

Steel framing fasteners are usually protected against corrosion by electroplated zinc coating. Zinc plated coatings are typically thinner than and therefore not as protective as the galvanized coatings on the surrounding steel framing members⁶.

For more aggressive environments, improved fastener corrosion protection can be achieved with different organic, plated or even duplex (i.e. two or more combined coating systems) coatings. Fastener suppliers can provide further information on the level of corrosion protection that is recommended for particular environments and the level of protection provided by specific coating types.

6.0 CONCLUSIONS

Zinc and zinc alloy hot dip galvanized coatings are economical and recommended methods of providing long-term corrosion protection of steel framing members.

The galvanizing process produces a tough metallic coating that can withstand the physical demands created during fabrication, distribution, site storage and installation of the steel-framing members.

Time of wetness and concentration of air pollutants affect zinc’s corrosion rate and situations that expose steel framing to extended periods of wetness or aggressive atmospheres should be avoided. Thicker zinc coatings or additional topcoats can be specified for increased corrosion protection in areas where aggressive conditions cannot be avoided.

However, in most indoor or sheltered environments where steel framing is used (i.e. enclosed walls and floors, framing members that are not directly exposed to moisture and aggressive atmospheres (i.e. salty marine air etc.)) the corrosion rate of zinc and zinc alloy coatings is very low. With the use of recommended coating weights, as described AISI S201³, steel framing members will function for hundreds of years.

CONTRIBUTORS

This publication was developed by the Corrosion and Durability Task Group, a joint effort of the Committee on Framing Standards of the American Iron and Steel Institute and the Cold-Formed Steel Engineers Institute, a Council of the Steel Framing Alliance. This publication is intended to provide designers with guidance in selecting coated steels and enhancing durability in buildings that utilize cold-formed steel framing members.

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