

***DURABILITY OF COLD-FORMED STEEL
FRAMING MEMBERS***

American Iron and Steel Institute
1101 17th Street, NW, Suite 1300
Washington, DC 20036-4700

For more information on residential steel framing, call 800-79-STEEL.

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Durability of Cold-Formed Steel Framing Members
October 1996

INTRODUCTION

This publication was developed by the American Iron and Steel Institute with guidance from the Residential Advisory Group. This document is intended to provide designers with guidance in selecting coated steels and enhancing durability in residential buildings that utilize cold-formed steel framing members. AISI believes the information contained in this publication substantially represents industry practice and related scientific and technical information. However, the information herein is not intended to represent an official position of AISI or to restrict or exclude any other construction or design techniques.

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Scope

The purpose of this document is to give engineers, architects, builders and homeowners a better understanding of how galvanizing (zinc and zinc alloy coatings) provides long-term corrosion protection to steel framing members. This paper also suggests guidelines for selecting, handling and using these steels for steel framing.

1.0 Design Life

Residential homes are one of the few necessities that consumers expect to last a lifetime or more. It is critical therefore, that a home's framing material perform its function for as long as other critical components such as the roof structure, exterior and interior wall coverings, and flooring. To last a lifetime, light-gauge steel framing needs proper corrosion protection.

Galvanizing has proven to be the most economical and effective way to protect steel. All steel framing materials used in residential 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 (850°F/450°C) to form a metallurgically bonded zinc coating. This same hot dip immersion process is also used to produce zinc-aluminum alloy coatings.

Most light gauge 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 metres/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 passivated, oiled and recoiled for shipment to the fabricator (1).

2.2 Types of Coatings for Light Gauge Steel Framing

The continuous galvanizing process can apply a number of different coatings that vary in thickness, appearance and alloy composition.

2.2.1 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).

2.2.2 Galfan®

Galfan® is a 95% zinc - 5% aluminum/mischmetal coating. Galfan® is known for its improved corrosion resistance compared to galvanized.

2.2.3 Galvalume®

Galvalume® is a 55% aluminum, 1.5% silicon and 43.5% zinc alloy coating. Galvalume® provides superior barrier corrosion resistance over galvanized coatings.

2.2.4 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. The presence or absence of spangle has no influence on corrosion performance or other engineering properties of the coating.

2.3 Coating Weights and Thicknesses

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

Table 2.2 lists the recommended minimum coating requirements for load and non-load bearing (structural and non-structural) framing members. For further details on coating specifications, refer to ASTM A 653 (Galvanized), A 792 (Galvalume®) and A 875 (Galfan®). Coating requirements for framing members also appear in ASTM C 645 and C 955.

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.

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				
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
Galfan®				
GF45/ZGF135	0.45	135	0.39	9.8
GF60/ZGF180	0.60	180	0.53	13.3
GF90/ZGF275	0.90	275	0.79	19.8
Galvalume®				
AZ50/AZ150	0.50	150	0.80	20.0

Table 2.2 Recommended Coating Requirements

Framing Member Designation	Minimum Coating Designations		
	A 653/A 653M	A 792/ A 792M	A 875/875M
Load Bearing	G60/Z180	AZ50/AZ150	GF60/ZGF180
Non-Load Bearing	G40/Z120	AZ50/AZ150	GF45/ZGF135

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 involves dry indoor environments, the corrosion rate of zinc is very low. According to the corrosion rates in section 3.1 and the minimum coating thicknesses specified in Table 2.2, zinc based coatings can easily protect steel for the design life of the home.

Just as water leakage, excessive humidity or condensation will damage any construction material 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 will not be a concern for galvanized steel framing.

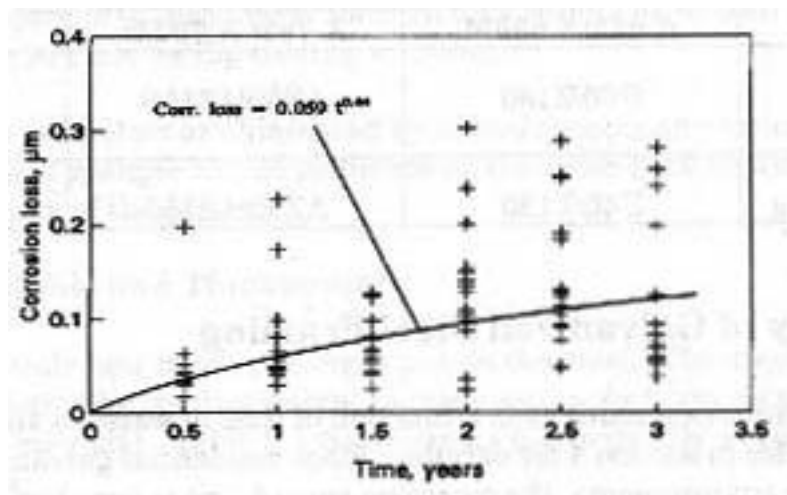
Additional corrosion protection is recommended for homes built in particularly aggressive environments (i.e., humid coastal).

3.1 Performance in Residential Homes

The corrosion rate of zinc coatings in an indoor atmosphere of a residential house is generally very low. According to a three-year British Steel study (2), the corrosion of zinc is lower than 0.1 μm 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 zinc coating should last for more than 300 years. This is similar to a G40/Z120 coating (10 μm = 0.39 mils).

Additionally, a survey was performed in May 1995 on a 20-year old steel-framed house in Stoney Creek, Ontario (3). 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.

Figure 3.1 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 (2). 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.



3.2 Environments in Residential Houses

3.2.1 Interior Walls

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

3.2.2 Exterior Walls

Proper building practices that include vapor barriers and thermal breaks should eliminate any significant moisture exposure to exterior wall framing. Poorly constructed walls could result in some moisture condensation. Galvanizing provides protection to the steel in this situation, but moisture cannot be allowed to collect.

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

For most applications, the minimum coatings specified in Table 2.2 are adequate. Heavier coatings may be considered for aggressive industrial and coastal environments.

3.2.3 Floor Joists and Roof Trusses

Second story floor joists as well as joists over enclosed basements are not likely to be exposed to aggressive conditions. For joist tracks that attach directly to concrete or exterior walls, precautions should be taken so that the environment remains dry and that a vapour barrier is installed between the joist track and concrete wall.

Floor joists installed in basements and crawl spaces not having a slab can be exposed to the outside environment. In these cases, greater corrosion protection is recommended due to the likelihood of exposure to extended periods of high humidity.

During normal ventilation, roof trusses will become more exposed to the surrounding environment than other areas of the house. This may be a concern in aggressive industrial or marine environments. A prolonged roof leak may cause localized corrosion of the affected roof truss.

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 degrade over time as with 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 a zinc coating will not be undercut by rusting steel (Figure 4.1) because the steel cannot corrode adjacent to the zinc coating. Any exposure of the underlying steel, because of severe coating damage or at a cut edge, will not result in corrosion of the steel and thus will not affect the performance of the coating or the steel structure.

Table 4.1 Galvanic Series of Metals and Alloys

Corroded End - Anodic

(Electronegative)

Magnesium

Zinc

Aluminum

Cadmium

Iron or Steel

Stainless Steels (active)

Lead

Tin

Copper

Gold

Protected End - Cathodic or most noble

(Electropositive)

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.

**Figure 4.1 (a)
Zinc Coating**



i) scratch in the coating exposes underlying steel



ii) surrounding zinc coating cathodically protects the exposed steel.

**Figure 4.1 (b)
Paint Coating**



ii) exposed steel corrodes, further damaging the surrounding paint film.

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.

4.3.1 Basic Factors and Mechanisms

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 very 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. Zinc carbonate is usually a thin, tenacious and stable (insoluble in water) 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.⁽⁴⁾ 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, that formed by condensation usually can evaporate and leave the corrosion products in place. Since residential steel framing should be dry almost all the time, zinc's corrosion rate will be very 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 far less an effect on zinc's corrosion rate than sulfur compounds. Nevertheless, because chlorides can be prevalent in residential environments (i.e. coastal homes), chlorides will likely be the most frequent environmental concern necessitating extra corrosion protection.

4.3.2 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 product receives some form of surface treatment to help prevent the formation of wet storage stain.

4.4 Galvanized Coatings in Contact with Building Materials

4.4.1 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 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 dry or most moderately damp woods. Galvanized nails and screws have been used successfully to join wood for years. The various chemicals in dry pressure-treated lumber are not corrosive to zinc and treated lumber does not require any special precautions.

Dry wall and Insulation Products: 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.

4.4.2 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 ⁽⁴⁾, Table 4.2 presents the relative galvanic corrosion rate of zinc when coupled to various metals. In normal indoor environments moisture levels are very 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 different materials. The extent of the galvanic action depends on the metals coupled. Advice given should fall into one of three categories:

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

Table 4.2 Galvanic Corrosion Rate of Zinc Coupled to Other Common Commercial Metals (ref. 4)

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

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.

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 punch-outs made 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 Erection and Handling

A galvanized metallic coating is very adherent and abrasion resistant. As a result, normal handling during distribution, storage and erection will not damage the zinc coating. Job site procedures such as shearing, cutting or fastening will expose bare steel, but, this is of no consequence because of zinc's ability to cathodically protect any cut edges.

Precautions should be taken to avoid the formation of white rust (4.3.2) 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 studs during storage and erection.

5.3 Welding

Galvanized steel can be joined by spot or continuous welding. Welding may be an economical joining method when shop fabricating standard wall or roof assemblies. Although both welding operations volatilize the zinc coating at the weld site, spot welding is a much more localized process and does not damage the surrounding zinc coating.

Continuous welding completely removes the zinc coating from relatively large and critical areas of the structure. In this case, the damaged areas need to be repaired with zinc rich touch-up paint (many commercially available products) or by zinc metallizing. Although zinc metallizing best matches, or even exceeds, the performance of the original galvanized coating, it requires special equipment and is time consuming to apply.

5.4 Fasteners

Steel framing fasteners are usually protected against corrosion by electroplated zinc coating. Zinc plated coatings are typically thinner and therefore not quite as protective as the galvanized coatings on the surrounding steel framing members. Type II coatings (per ASTM B633 - 96 hour salt spray test) are recommended as the minimal level of corrosion protection for zinc-coated residential steel framing fasteners. Other tests may be appropriate for other types of fasteners.

For more aggressive environments, improved fastener corrosion protection can be achieved with different organic, plated or even duplex (i.e. zinc base plus organic topcoat) 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 an economical, and recommended, method 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 distribution, site storage and erection of the steel-framing members.

In most indoor environments where steel framing is used, the corrosion rate of zinc and zinc alloy coatings are very low. By using the recommended coating weights, steel framing will remain protected for the life of the home.

Time of wetness and concentration of air pollutants, although very low, affect zinc's corrosion rate. Situations that expose steel framing to extended periods of wetness or aggressive atmospheres should be avoided. Thicker zinc coatings or organic topcoats can be specified for increased corrosion protection in areas where aggressive conditions cannot be avoided.

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