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TECHNICAL NOTE

On Cold-Formed Steel Construction

CFSEI
COLD-FORMED STEEL ENGINEERS INSTITUTE

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CORROSION PROTECTION FOR COLD-FORMED STEEL FRAMING IN COASTAL AREAS

Summary: Cold-formed steel framing may be subject to corrosion when exposed to moisture and salt, both of which are prevalent in coastal areas. The 2003 edition of this technical note, based on guidelines published by the Federal Emergency Management Agency (FEMA 1986) for metal connectors used in wood-framed construction, described the cause of accelerated corrosion in buildings located near the ocean and some larger saltwater bays, as well as the variation in the corrosive environments within a typical building. The 2007 update incorporated the results of a corrosion study by Dr. Ian Robertson of the University of Hawaii Department of Civil Engineering, funded by the U.S. Department of Housing and Urban Development (SFA 2006). The influence of terrain and wind direction on corrosion rates was added to the original document. This 2012 update includes revised referenced documents and improved guidance on the proper storage of materials. This technical note outlines available corrosion-resistant materials for cold-formed steel framing members and makes recommendations for buildings at various distances from the ocean and for different exposure conditions within an individual building

GALVANIZED STEEL

Cold-formed steel framing is fabricated from relatively thin steel sheet. Bare steel is subject to corrosion even in inland areas, and it corrodes rapidly in salt air. Therefore, cold-formed steel framing typically utilizes hot-dip galvanized steel sheet for corrosion protection. Hot-dip galvanizing is the process of coating steel with zinc. After careful cleaning, the steel sheet is fed continuously through a bath of molten zinc. The high temperature of the zinc bath enhances a reaction between steel and zinc, thereby creating a tight, metallurgical bond between the two metals. The coating of zinc still oxidizes, but *its corrosion rate is much lower* than that of steel in the same salt air environment.

Galvanizing is particularly effective for steel because, unlike most other coatings (such as paint), the zinc sacrificially protects any bare steel edges or scratches. The zinc surface near a scratch will oxidize slightly faster than the zinc surrounding it and will fill small scratches with zinc oxidation products, preventing the steel from corroding until the nearby zinc is consumed. Zinc also oxidizes at a relatively steady rate in most atmospheric exposures. Therefore, doubling the thickness of the zinc coating approximately doubles the protection period.

The American Society for Testing and Materials has established a national standard (ASTM A1003) for steel sheet for cold-formed steel framing members. Compliance with this standard is required by the building code adopted cold-formed steel framing standards of the American Iron and Steel Institute (AISI 2011 and 2012). The ASTM standard prescribes G60 for structural framing and G40 for nonstructural framing. Galvanizing thicknesses are identified by different G numbers. The G60 designation indicates a zinc coating of 0.60 oz/ft^2 (total on both sides) or a thickness of approximately 0.5 mil (1 mil = 0.001 inch) on each side of the steel. The numerical G designation increases or decreases proportionally with the coating thickness. For example, a G90 coating of zinc is 1.5 times thicker than a G60 coating.

CAUSES OF CORROSION NEAR THE OCEAN

Understanding the causes of accelerated corrosion can help identify some of the worst corrosion exposures that affect coastal buildings. Research has shown that local climate and geography have a significant impact on corrosion rates in close proximity to the coastline. The following factors contribute to different rates of corrosion.

Salt Spray

Salt Spray from breaking wave and onshore winds significantly accelerates the corrosion of metal. Ocean salts accumulate on the metal surfaces and accelerate the electrochemical reactions that cause corrosion.

The combination of salt accumulation on the surface and the high humidity common to many coastal areas significantly accelerates the corrosion rate of steel. The longer a surface remains damp during normal daily fluctuations in humidity, the higher the corrosion rate. This is especially true when salt chlorides are present. Onshore winds carry both salt and moisture inland. Therefore, corrosion rate along shorelines with predominately onshore winds will be higher than those along shorelines with predominately offshore winds.

Distance form the Ocean
Corrosion rates vary considerably from community to community. But the amount of salt spray in the air is greatest near the breaking waves and can decline rapidly in the first 300 to 3000 feet (roughly 100 to 1000 meters) landward of the shoreline. Farther landward, corrosion is akin to that which occurs in milder, inland conditions. The width of the high-corrosion zone will vary for each community. An inspection of local galvanized steel performance should given an indication of the limits of this zone.

Terrain
The concentration of airborne chlorides from salt spray largely influences corrosion near the ocean, so barriers to these chlorides (or lack thereof) will significantly impact the rate of corrosion. These obstacles can be natural, such as tress or other vegetation of same height as the structure or taller covering at least 50 feet between the ocean and the structure. Obstacles can also be man-made structures, such as two or more rows of housing between the ocean and the structure. If oceanfront buildings are experiencing severe corrosion over a typical useful lifetime of 50 to 70 years. The terrain of the coastline will also impact corrosion rates. A coastline with large, jagged rocks will generate more salt spray than a smooth, sandy coastline. These characteristics of local conditions will significantly vary the corrosion rates for different sites.

Elevation Corrosion
Elevation corrosion peaks at about 12 feet (3.6 meters) above the ground, approximately equal to the lowest floor elevation of an elevated building with lower level parking. For buildings farther inland, the overall corrosion rate is lower, but it is highest at an elevation above the roofs of small buildings.

Shelter and Orientation
Bold exposures such as building exteriors that are coated with large amounts of salt spray can be expected to suffer high corrosion rates. But partially sheltered exposures, such as underneath open, piling-supported buildings or underneath decks and walkways, can sustain even worse corrosion than bold exposures. Salt spray accumulations on bold exposures are rinsed periodically by rainfall, reducing the surface salt concentrations. Partially sheltered exposures receive almost as much incoming spray as bold exposures. However, the surface exposures. However, the surface concentrations remain high because of the shelter from cleansing rain. Sheltered exposures receive little salt spray. An additional factor is the duration of surface wetness. Accelerated corrosion occurs primarily when a certain level of surface wetness is exceeded, initiating electrochemical reactions among the metal, salts, and air. Bold exposures dry more rapidly because they are exposed to sunlight. Drying slows the corrosion rate. Partially sheltered exposures stay damp longer and therefore corrode faster. The effect of building orientation on corrosion is also important. The metals on the side of a building facing the ocean will corrode much faster than those facing away from the ocean.

Weather and Time
Weather affects the rate of corrosion in all exposures, both coastal and inland. Most chemical reactions, including corrosion rates, are affected by temperature and humidity. Like any weather-driven condition, the corrosion rate can vary considerably from year to year. Therefore, annual measurements of corrosion can be misleading unless compared to long-term averages for nearby locations.

IDENTIFYING CORROSION-PRONE BUILDINGS

In some communities, corrosion test facilities can predict the distance from the shoreline at which corrosion will be most severe. Unfortunately, in most communities, corrosion data will note be available. Estimates of the width of the zone where corrosion-resistant materials and methods are necessary should be based on local experience.

Classes of Exposure for Framing in a Building

Corrosion exposures for framing in most buildings can be grouped into five classes, four of which are shown in the figure on page 3. The five classes are listed below in order of decreasing corrosion severity.

Partially Sheltered Exterior Exposures
Examples include open, under-house storage and parking areas below a piling-, column-, or post-supported building and areas underneath roof overhangs, decks, and walkways. Corrosion can significantly affect framing after 5 to 10 years in these exposures on oceanfront buildings.

Boldly Exposed Exterior Exposures
Examples include exterior walls with the framing fully exposed. If the exposed framing is fully dried between wettings by the ocean spray, the corrosion rate will be lower than that in partially sheltered exterior exposures. Otherwise, the corrosion rate can match that in partially sheltered exterior exposures.

Vented Enclosed Exposures

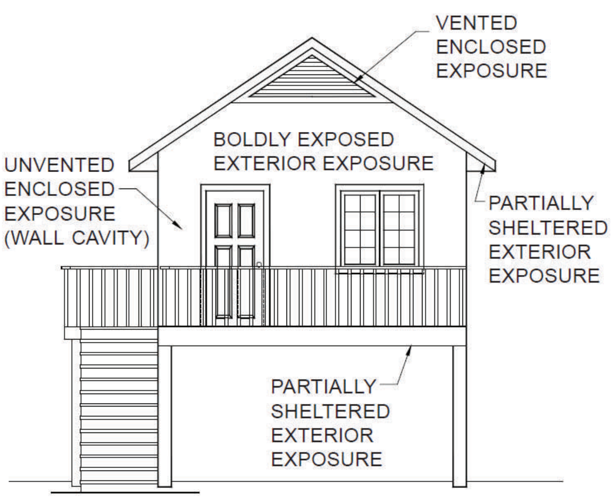
Attics, which must be vented to release excess heat and moisture, are typical examples of this type of exposure. Corrosion will vary with the location of the framing in the enclosed space. Corrosion rate for framing near exterior vents, where outside airflow is concentrated, is often similar to that for framing in partially sheltered exterior exposures. For framing that is away from the vents or covered by insulation, the corrosion rate is expected to be much lower.

Unvented Enclosed Exposures

Examples include enclosed floor systems with solid joists or trusses, and enclosed walls, both interior and exterior, where all penetrations are filled with expanding foam, covered with a properly applied and sealed air barrier, or other means to prevent air flow into the wall cavity. Because of the limited airflow and incoming salt spray, corrosion rates for framing in these exposures are expected to be lower than those for framing in the previous three exposures.

Interior Living Space Exposures

These spaces are sealed from most salt spray, and normal heating and cooling further reduce interior humidity below the threshold needed for rapid corrosion. Framing in these spaces should have the lowest corrosion rates.



CORROSION-RESISTANT MATERIALS AND COATINGS

Improved corrosion resistance can be obtained by fabricating cold-formed steel framing from more resistant steel sheet or by treating the framing members after they have been fabricated. The relative improvement in corrosion resistance for different options is estimated in this section.

Due to the much larger relative surface area of the cold-formed steel framing members to that of the fasteners typically used for connections, faster corrosion does not generally accelerate overall corrosion of the cold-formed steel framing member, but may lead to local corrosion at the fastening location. See CFSEI Tech Note D100-08 on Corrosion Protection of Screw Fasteners for more information (CFSEI 2008).

Thicker Galvanizing

Hot-dip galvanized sheet steel is available in a variety of coating thicknesses; thus, cold-formed steel framing members could be fabricated with thicker galvanizing. Several manufacturers now market cold-formed steel framing fabricated from G90 galvanized steel, which, compared to the standard G60, has a zinc coating that is 50 percent thicker. Since the corrosion resistance of zinc is proportional to the thickness of the zinc, these framing members should last approximately 1.5 times longer.

Paint Coatings

Painting standard galvanized steel framing members can significantly improve their corrosion resistance. Paint coatings provide an additional barrier coating that protects by blocking out water and oxygen, two necessary ingredients for corrosion. However many paints commonly used for buildings do not adhere well to galvanized surfaces. The Truss Plate Institute, in considering the use of galvanized truss plates in corrosive environments like coastal buildings, recommends that one of three types of industrial paint systems be applied by brush after delivery of the completed truss to the job site or after truss installation. The paints are specific formulations of (1) epoxy-polyamide, (2) coal-tar epoxy-polyamide, ad (3) zinc chromate-vinyl butyral primer with asphaltic mastic. These recommendations would seem to be appropriate for cold-formed steel framing, as well. However, the increased corrosion resistance provided by the recommended paint coatings in coastal buildings is difficult to estimate. Unlike changes in galvanizing thickness, changes in paint thickness do not proportionally change the corrosion resistance. Paint lifetimes are significantly affected by salt spray, as well as surface preparation and care in application.

GUIDANCE FOR FRAMING CORROSION CONTROL

All construction materials deteriorate with time. Continued use of a building requires that: (a) the original materials be durable enough to last the expected lifetime; (b) periodic maintenance be conducted to extend the life of original materials; or (c) the material be replaced one or more times during the lifetime of the building.

Avoid the problem

Most cold-formed steel framing is used for inland applications with mild corrosion and, under normal conditions, appears to last as long as or longer than other materials in the building. Many buildings in communities near the coast are likely to experience only slightly increased corrosion rates. Standard coatings appear appropriate for those buildings. But close to the ocean, drastically higher corrosion rates can be expected. The use of standard coatings in these areas may necessitate care in controlling the exposure. Otherwise, alternative materials should be used.

For some uses, corrosion can be partially avoided by altering the exposure of the framing. For example, on exteriors, framing should be fully covered if possible or otherwise protected from salt spray and moisture. Exterior siding and associated vapor retarder or air barrier should be designed to completely cover framing. Applying siding in this way changes the exposure form boldly exposed to unvented enclosed. An easy, but more costly, way to protect joists in the floors of piling-supported buildings is to sheath the underside of the floor joists to reduce the exposure to salt air. Adding such sheathing transforms one of the worst exposures, partially sheltered exterior, into a less corrosive, unvented enclosure but this also may hide the structural component, making it difficult or impossible to observe corrosion effects and repair or replace as necessary.

Proper Storage of Materials

When freshly galvanized steel is stored with moisture trapped between contacting surfaces and access to free-flowing air is restricted, zinc hydroxide (i.e., wet storage stain or white rust) may form. This is a voluminous, white, non-protective corrosion product that is most likely to form in bundled products as moisture remains trapped in the tightly strapped package and drying is prevented. Loose framing allows air drying of members. 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. Materials should be stored off the ground, shielded from rainwater and salt spray, and oriented or stacked in a manner to promote drainage/drying. Proper ventilation should be provided to prevent condensation build-up between members.

Maintenance and Replacement

In some uses where coastal area exposure may be a potential problem, framing may be placed where it is accessible and maintainable. In milder exposures, applying paint may be enough to extend the life of the framing. But in severe exposures, even annual painting may not prolong the life of framing to that of the rest of the building. In these exposures, accessible framing may be inspected for corrosion and, if necessary, repaired or replaced. ASTM has established a national standard (ASTM A780) for the repair of damaged and uncoated areas of galvanized coatings. The presence of more than thin corroded (red rust) edges indicates that the zinc coating has been consumed and the sacrificial effects have been lost. Without the zinc coating, corrosion of the thin, steel sheet will occur quickly and will rapidly deteriorate the structural integrity of the framing. Given the low likelihood of regular inspection by most building owners, repair or replacement is usually a poor option. Furthermore, most framing is a hidden structural component that is difficult or impossible to repair or replace. In such cases, repair or replacement are rarely viable options and more corrosion-resistant materials should be selected initially. Repair or replacement may be the only option in existing buildings where framing has already been damaged by corrosion.

SUMMARY OF RECOMMENDATIONS

For many framing applications in corrosion-prone areas, the use of standard galvanizing is the best solution. The choice of alternative framing materials or coating specifications should be guided by the location of the building relative to the observed corrosion hazards in each community and by the class of exposure in the building. Recommended materials for a typical community are listed in the table on page 5.

<table>
<tr><th colspan="5">Recommendations for Corrosion-Resistant Materials and Methods *</th></tr>
<tr><th rowspan="2">Class of Exposure **</th><th colspan="4">Building Location</th></tr>
<tr><th>Oceanfront Buildings</th><th>Intermediate Distance A</th><th>Intermediate Distance B</th><th>Buildings Farther Landward</th></tr>
<tr><td></td><td>(300 feet or less from the shoreline) ***</td><td>(300 to 1500 feet from shoreline) ***</td><td>(1500 to 3000 feet from shoreline) ***</td><td>(Greater than 3,000 feet from the shoreline) ***</td></tr>
<tr><td rowspan="2">Interior Living Space</td><td rowspan="2">Use standard (G40) galvanizing on non-structural and (G60) on structural framing members, and ensure that all drywall joints are taped and top of wall is sealed from attic spaces above to prevent air flow. [Note: The top of the top track is exposed to air flow in attic space, consider use of a wood top plate, sill sealer, or other barrier attached to top track to minimize its exposure to air in this space.]****</td><td>Conditions with onshore winds and unshielded exposure: Use standard (G40) galvanizing on non-structural and (G60) on structural framing members, and ensure that all drywall joints are taped and top of wall is sealed from attic spaces above to prevent air flow. ****</td><td rowspan="2">Use standard (G40) galvanizing on non-structural and (G60) on structural framing members. ****</td><td rowspan="2">Use standard (G40) galvanizing on non-structural and (G60) on structural framing members. ****</td></tr>
<tr><td>All other exposure conditions: Use standard (G40) galvanizing on non-structural and (G60) on structural framing members. ****</td></tr>
<tr><td>Unvented Enclosures</td><td colspan="3">Use standard galvanizing (G60) with all air flow prevented in wall cavity ****, or
Use heavier galvanizing with limited air flow in cavity (G90 minimum) ****, or
Use paint on galvanized framing members with limited air flow in cavity.
[Note: Exposure of top track is similar to condition noted in Interior Living Space Exposure Class.]</td><td>Use standard (G60) galvanizing. ****</td></tr>
<tr><td rowspan="2">Vented Enclosures</td><td rowspan="2">Avoid use of cold-formed steel framing unless a thorough study of the existing conditions is conducted. If favorable conditions exist, use coatings appropriate to those conditions. Minimize venting as allowed by local building code and place vents away from prevailing winds to minimize exposure to airborne chlorides. Perform periodic inspections for signs of corrosion.</td><td>Conditions with onshore winds and unshielded exposure: Avoid use of cold-formed steel framing unless a thorough study of the existing conditions is conducted. If favorable conditions exist, use coatings appropriate to those conditions. Minimize venting as allowed by local building code and place vents away from prevailing winds to minimize exposure to airborne chlorides. Perform periodic inspections for signs of corrosion.</td><td>Conditions with onshore winds:
Use heavier galvanizing on framing members near vents ****, or
Use paints on galvanized framing members near vents.
Perform periodic inspections of attic space for signs of corrosion</td><td rowspan="2">Use standard (G60) galvanizing. ****</td></tr>
<tr><td>All other exposure conditions:
Use heavier galvanizing on framing members near vents ****, or
Use paints on galvanized framing members near vents.</td><td>Conditions with offshore winds:
Use standard (G60) galvanizing ****, and
Perform periodic inspections of attic space for signs of corrosion.</td></tr>
<tr><td>Boldly Exposed Exteriors</td><td rowspan="2">Avoid use of cold-formed steel framing where possible.</td><td colspan="3" rowspan="2">Conditions with onshore winds and unshielded exposure: Avoid the use of cold-formed steel framing where possible.

All other exposure conditions: Use heavier galvanizing (G90 minimum) and perform periodic inspections for signs of corrosion. ****</td></tr>
<tr><td>Partially Sheltered Exteriors</td></tr>
<tr><td>On Site Material Storage</td><td>Limit exposure of material at job site to 2 months. Following proper storage guidelines and use of waterproof covering on exposed material is recommended. Prevent condensation accumulating under covering.</td><td>Limit exposure of material at job site to 2-4 months.</td><td>Limit exposure of material at job site to 4 months.</td><td>Limit exposure of material at job site to 6 months.</td></tr>
</table>

* Recommendations are based on available research and current industry practice.

** See Figure 1 for corrosion classes.

*** Distances may vary considerably depending on local climate. The width of the corrosion hazard area relative to the ocean should be determined in each community form field observations and any existing corrosion studies, such as those listed in References this tech note.

**** Standard and heavier galvanizing includes zinc-coated steel sheet as described in ASTM Specification A653/A653M, zinc-iron alloy-coated steel sheet as described in ASTM Specification A653/A653M, 55% aluminum-zinc alloy-coated steel sheet as described in ASTM specification A792/A792M, and zinc-5% aluminum alloy-coated steel sheet as described in ASTM Specification A875/A875M. Standard coating weight requirements are defined in ASTM A1003/A1003M. Alternative coatings can be used if proven to be equivalent.

References

1. FEMA Technical Note 8-86, *Corrosion Protection for Metal Connectors in Coastal Areas,* Federal Emergency Management Agency, Washington, D.C., 1986.
2. ASTM, A1003/A1003M, *Standard Specification for Sheet Steel, Carbon, Metallic and Non-Metallic Coated for Cold-Formed Framing Members,* American Society for Testing and Materials, West Conshohocken, PA, 2012.
3. AISI S200-07, *North American Standard for Cold-Formed Steel Framing - General Provisions,* American Iron and Steel Institute (AISI), Washington, D.C., 2007.
4. ASTM A780, *Standard for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings,* American Society for Testing and Materials, West Conshohocken, PA, 2009.
5. CFSEI Tech Note D100-08, Corrosion Protection of Screw Fasteners, Cold-Formed Steel Engineers Institute (CFSEI), Washington, D.C., 2008.
6. Robertson, I.N., *Corrosion of Galvanized Fasteners in Cold-Formed Steel Framing, Steel Framing Alliance, Washington,, D.C., 2006.*

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