GalvInfoNote
6.2

Successfully Designing Products made with Galvanized Steel Sheet

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Introduction

"*Mistakes in plant design are the most frequently cited (58%) cause of corrosion failure in chemical-process industries.*"[1] While this quote does not refer directly to products manufactured with galvanized sheet, design plays just as important role in corrosion failures of these products.

Reference 1 also lists and explains a number of general principles necessary for successful design. Those most applicable to products made with galvanized sheet are; minimize attack time, restrict galvanic cells, protect against environmental cells, and design for inspection and maintenance. Most importantly, zinc coatings corrode uniformly at known rates in atmospheric environments. This means that the coating thickness needed to last for the design life of an application can be easily calculated. The best designs take advantage of the uniform corrosion of zinc and avoid accelerated localized attack that results when the above principles are not followed.

This GalvInfoNote reviews the best practices to follow when designing products that use galvanized steel sheet.

Design for Uniform Corrosion

One definition of product failure is "not meeting the service expectations of its design life." If a building clad with galvanized sheet is designed to last for 20 years with no major maintenance, then it should show no signs of red rust before this time. As shown in Figure 1 on page 2 of *GalvInfoNote 1.6*, the atmospheric corrosion rates of zinc coatings are well known, so it's a relatively simple matter to select the appropriate coating weight for the application.

When zinc is exposed to wet/dry weather cycles it forms a very thin, protective zinc oxycarbonate patina. However, a very small amount of zinc is dissolved by rainwater and removed during each wetting event. This is the primary reason why zinc coatings are eventually consumed. In designing a structure, it is important to ensure that a particular exposed surface (roof elevation, side wall, etc.) always "sees" the same weather as uniformly as possible across the entire surface area. If some portion of, say, a roof receives extra water, draining from some higher, non-zinc coated surface, then that extra water also takes its share of zinc (in addition to that taken by the rain that fell directly on it). The end result is the area of impingement has its zinc coating removed at a higher rate. Such a situation is shown in the photo to the left. Water draining off the wood fascia on the higher elevation resulted in a rusted area at the drip point, and a stain trail down the slope. Once created, rusted areas cause an increased consumption rate of zinc from around their periphery and can grow in size relatively quickly.

This situation could have been avoided by cladding the wood fascia board with galvanized sheet. Water dripping off it would already be saturated with "its share" of zinc and would not have created the rust spot.

Similar situations can be seen on buildings with galvanized roofs that have translucent panel skylights installed, say, halfway down their slope. On many such roofs, the galvanized panel immediately below the skylight panel shows brown/red rust, which may be particularly severe right next to the skylight. One

[1] Bradford, S.A. *Corrosion Control*, 1993, Van Nostrand Reinhold International (UK), p. 265

way to prevent such corrosion is to install the translucent panels right down to the drip edge of the roof. In this manner, the rain that impinges on the skylight panels will not drain over galvanized areas.

Such situations do not usually happen on walls, as they do not receive as much rain impingement as roofs, but it is recommended that non-zinc areas not be installed above galvanized sheet areas on walls.

The design of a building, or any other structure that is subject to weather, should not have configurations where water drains incompletely and/or pools. The longevity of galvanized sheet exposed to weather depends on wet/dry cycles to form the protective zinc oxycarbonate patina. When it is subjected to long periods of wetness, this protective layer breaks down, increasing the zinc corrosion rate. Well-designed structures clad with galvanized sheet will dry uniformly and quickly after a rain event. This minimizes the chance of localized severe corrosion hotspots. Keep in mind that “protected exposure” surfaces, e.g., north-facing walls, do not dry as quickly as other orientations.

GalvInfoNote 4.2 that deals with prepainted galvanized sheet has a section on building design beginning on page 5. Many of the recommendations given there also apply to plain galvanized sheet.

Galvanic/Bimetallic Corrosion and Dissimilar Metals

When zinc and steel are in contact in the presence of an electrolyte, current will flow from the steel to the zinc, so that the zinc becomes an anodic electron-producing region while the steel is cathodic and consumes electrons, preventing it from combining with oxygen and forming rust. This property of zinc is used in many applications as a galvanic protector of steel.

Except for aluminum and magnesium, the corrosion of zinc is increased by electrically connecting it to other common non-ferrous metals. Depending on the connected metal and the type of atmosphere, this galvanic (bimetallic) corrosion can be as much as 5 times the normal corrosion rate of zinc in a rural atmosphere and 3 times that in a marine atmosphere. The corrosion rate of zinc decreases when it is connected to aluminum in urban and marine atmospheres and to magnesium in all atmospheres. Zinc and aluminum are galvanically compatible materials in atmospheric environments. That is, when these two metals are in direct contact there will be very little galvanic corrosion of either metal resulting from the coupling.

For more information on galvanic and bimetallic corrosion, see *GalvInfoNote 3.6*.

Galvanized sheet on buildings should not be allowed to come in electrical contact with other more noble (less electrochemically active) metals such as copper, lead and tin. Nor should rainwater be allowed to drain from these metals onto zinc surfaces. Rapid corrosion of zinc will occur in either situation. While zinc and aluminum are galvanically compatible as described above, it is not recommended that water be allowed to drain from aluminum surfaces to zinc surfaces for the reasons given earlier in this article.

Contact with Soil

This article deals with the corrosion of zinc in the atmosphere. Zinc corrosion in soil involves different chemical reactions than is the case in air. It is a very complex topic, due mostly to the myriad soil types and conditions that exist. Some soils are very corrosive to zinc.

Occasionally, however, galvanized sheet wall cladding, trim items, and stucco flashing comes into contact with soil at lower wall locations. If that happens and the soil gets wet from rain, snow, ice or irrigation, accelerated corrosion can occur as shown in the photo to the left.

This example is piece of flashing from the bottom of a stucco wall where soil adjacent to the wall was allowed to come into contact with and partially cover the flashing. With rain and irrigation, and the particular chemistry of the soil, first the zinc, then the steel was attacked from the bottom up.

To avoid such situations, design so that galvanized sheet on buildings is kept away from the ground. If it is necessary to bring it close to ground level, there should be a non-soil cover such as gravel, stones, pavement, etc.

Condensation Issues

Galvanized sheet used to clad some commercial and industrial buildings, and many farm buildings, is sometimes the only separation between the inside and outside "climate", i.e., there is no inner wall or ceiling structures separated from the outer wall by insulation, etc. This is the case in many animal confinement buildings.

If it becomes warm and humid inside such a building when it is cold outside, condensation can form on the inside of the wall and roof panels. Condensate can be present for long periods and will then accelerate corrosion of any zinc coating. If animal waste products become dissolved in the condensate, then corrosion can be dramatically accelerated.

The above two photos were taken from the same three-year-old animal confinement building. The G90 truss plates on the roof trusses (left photo) were severely corroded and the nearby roof sheeting had large perforated areas (right photo) that initiated from the inside. The cause of this very severe corrosion was quite likely an extreme buildup of warm, very moist air laden with chemicals from animal waste products. During cold winter weather, a very corrosive condensate formed on exposed metal surfaces high in the structure, resulting in the aggressive attack shown in the photos.

The solution to this problem is to have a building design that has sufficient and adequate ventilation, such that moisture cannot build up to the point where it can condense inside a structure. The exhaust system must both remove the moisture-laden air from inside the building, and not allow it to be entrained with replacement air.

Design for Maintenance

Good design can prevent many, but not all, corrosion problems from arising. Regular inspection and maintenance is necessary to identify and deal with issues as they arise. To ensure that it is easy to inspect and maintain all parts of, say, a building clad with galvanized sheet, it has to be considered during the design stage. Simple designs that allow easy inspection are important. Walkways may be needed on roofs or near other areas of a building that cannot be seen from the ground. Avoid areas of galvanized sheet that could be subject to corrosion but cannot be seen at all. Do not design configurations where there is no access or not enough room to perform maintenance. Consult with metal building manufacturers for recommendations on proper maintenance practices.

Summary

This GalvInfoNote covers some of the most important potential corrosion issues to be aware of when designing products made with galvanized sheet. There are undoubtedly many more. Perhaps the simplest approach is to remember that corrosion is a process that has four components, of which if any are absent, the process does not occur. One of these components is an electrolyte, e.g., water. When designing with galvanized sheet, one important question to be answered is:

"How might we minimize the time that water can be in contact with any part of the structure?"