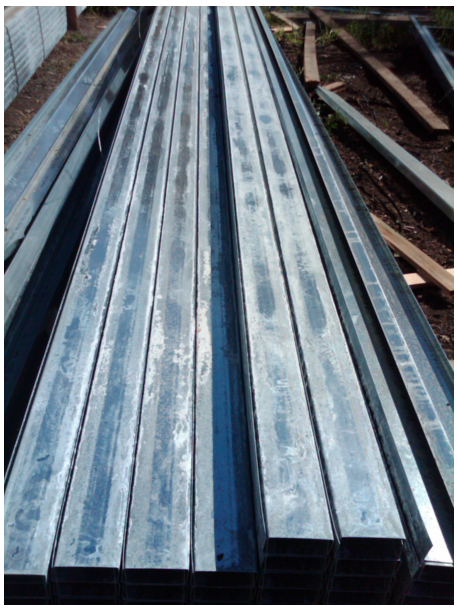
GalvInfoNote	Successfully Shipping and Storing Galvanized Steel Sheet
6.1	REV 1.0 DEC 2017

Introduction

When freely exposed to the atmosphere, galvanized sheet provides long-term freedom from corrosion to steel due to the slow corrosion rate of zinc. There are situations, however, during shipping and/or storage of this product where damage can occur to the zinc surface due to two different types of accelerated corrosion. This GalvInfoNote provides guidance on the precautions that can be taken to avoid damage due to storage staining and fretting corrosion.

Storage Stain



Storage stain on steel framing

Storage stain on galvanized sheet products is a corrosion product that is typically white, but which can also take the form of grey or black deposits on the surface. Since the most common form of discoloration is white in appearance, storage stain is often called *white rust.* It can occur when sheets of galvanized steel that are in close contact (in a coil or stacked in lifts/bundles) get wet, either by direct water intrusion, or condensation between the surfaces. The discoloration is due to the corrosion products that form after zinc reacts with moisture in the absence of free air circulation. For more information on storage stain, why it forms and preventive treatments, refer to *GalvInfoNotes 2.10 and 3.2.*

To prevent rejection of material, every precaution should be taken to avoid storage stain on galvanized sheet. Often, the end application requires the aesthetic appearance of a bright, galvanized surface, and no amount of storage stain is acceptable. Fortunately, practices have been developed that allow the shipment and storage of galvanized sheets without the formation of storage stain.

Passivation coatings have been in use for many years, and their performance has been exceptional with respect to minimizing the tendency for staining when the sheets get wet in coil or bundle form. Steel sheet manufacturers use the term “passivation treatment” or “chemical treatment” for this surface treatment. Both terms are used interchangeably. *When an order is placed, it is necessary to specify whether chemical treatment “is” or “is not” required.* It is important to remember that mill-applied passivation treatments *minimize* the tendency for storage stain; they *do not eliminate* its occurrence if the product is subjected to very adverse conditions. An example would be having a coil get wet during transit to a customer, and then allowing the coil to sit in a warehouse for a long period without any attempt to dry it. Even if the product is ordered with a chemical treatment, it is still important to keep moisture from between the wraps while in coil form, or stacks of sheets/blanks. For a number of reasons, some end uses for galvanized sheet require the use of unpassivated product. In such cases, protection against wetness during shipment/storage is paramount, and the best practice is to ensure that is it consumed by the user at the earliest opportunity.

Best Practices

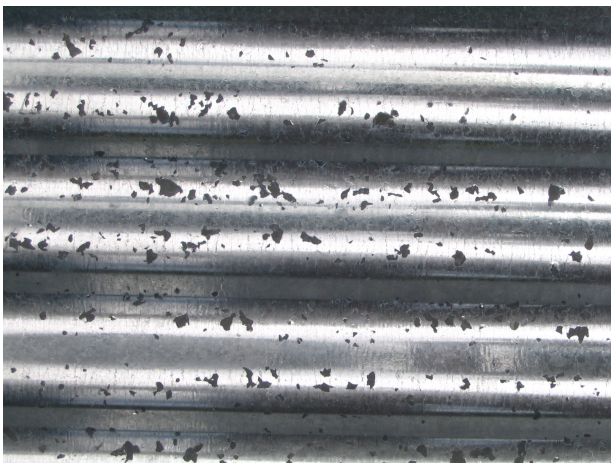
1. The steel manufacturer needs to apply the chemical treatment and/or oil in the specified manner to cover the entire surface area of the sheet.
2. When possible or required, wrap the coils with either paper or plastic that is specially made for this application.
3. The shipper needs to protect the steel during shipment to the customer's plant. Even if the coils/bundles are wrapped, ship only in covered watertight conveyances. If it is necessary to use an uncovered conveyance, wrap the load completely with a tarp to assure no water intrusion if it rains during shipment. Avoid tearing the paper.
4. The best practice is to store coils in a climate-controlled warehouse. Use the material promptly. Whenever possible, do not allow the product to remain in storage for extended periods of time (in excess of two months). Storing galvanized coils in unheated warehouses over the winter in the northern U.S.A or Canada carries the risk of condensation forming between the laps due to sudden temperature drops after a warm period. This can occur even when the coils are paper wrapped and encased inside metal shipping shrouds. In this circumstance, white rust can form after a few weeks, even on well-passivated sheet. Even in climate controlled warehouses there is a risk of condensation forming on between laps if cold steel is brought in below the dew point temperature in the storage area. See *GalvInfoNote 3.2* for more information on this issue.
5. For shipping from the manufacturing plant to the final location, the product again needs to be protected, especially if sheets/parts are in intimate contact with each other. When this is the case, the product is very susceptible to storage stain, as the zinc surfaces will not dry properly if they get wet.
6. Paper wrapping is one way to protect the sheets while in transit or during storage at a jobsite. Be careful to not wrap the bundle if the sheets are wet. This traps moisture in the bundle and prevents drying.
7. If bundles of galvanized sheets or blanks get wet, the only way of preventing or minimizing storage stain is to immediately separate all the pieces so they can individually dry. Unfortunately, if the material is unpassivated, it may be too late, as storage staining will occur immediately after becoming wet.
8. Do not wrap the sheets tightly in plastic. Allow the product to "breathe" by providing air circulation.
9. If outdoor storage is unavoidable, place bundles above ground by at least 12 inches to allow air circulation underneath. If bundles are stacked, ensure free circulation of air between bundles using cured lumber spacers.
10. Inspect frequently to assure that the panels have not become wet.
11. Elevate one end of a bundle of sheets to allow water to drain if moisture gets between the sheets. Make sure there are no low spots along the length so as to allow water to flow freely if necessary. If bundles have been found to be wet, separate all the sheets immediately.
12. When shipping manufactured parts or storing them outdoors, they must be dry and free of roll or press forming lubricants and protected from the weather. If not protected from the weather, then each part should be 'free standing' (not touching other parts), with any concave parts being placed so the concave side is down and not able to collect water.

Always keep in mind – if galvanize is kept dry, white rust will never be an issue.

Fretting Corrosion

Galvanized sheet surfaces sometimes exhibit a surface imperfection that appears as permanent black spots, marks, lines, or patches. This defect has many names, including transit abrasion, friction oxidation, wear oxidation, and chafing; all being terms for a form of erosion-corrosion known as fretting. It is a phenomenon that is more commonly seen on metal surfaces in mechanical assemblies (e.g., bolted, riveted, keyed, or pinned joints, bearings) and electrical contacts, but can occur on galvanized sheet

surfaces under certain conditions. While superficial, black fretting marks on galvanized sheet are almost impossible to remove, and are not the direct result of bulk water damage – which can also cause black (along with white) stains in its most severe form. When fretting occurs on galvanized sheet surfaces, liquid water is not necessary for its creation, although fretting can occur in the same areas of sheets that are additionally damaged by storage stain from entrapped moisture. For more information on fretting corrosion and how it is caused refer to *GalvInfoNote 3.5.*



On corrugated sheet

At the load-bearing point on coiled sheet

Fretting Corrosion Marks

The requirements for fretting corrosion are: the interface must be under load, vibration or repeated relative motion must occur, and the load and relative motion must be sufficient to produce deformation on the surface. Displacements as little as $4x10^{-9}$ in [10^{-4} μm] can cause fretting. It is seldom seen above amplitudes of 0.001 in [25 μm] and reaches a maximum at 0.0003 in [7.5 μm]. The reason fretting damage can be a severe problem is that it so often happens at the interface of two highly loaded surfaces that are not designed to move against each other.

For many years fretting problems have been observed on galvanized steel in both coil form and bundles of cut sheets. The defect is never seen at the production line and when found is almost always at customer facilities. It tends to be more prevalent on coil form and on material thicker than 0.030 in [0.8 mm]. Without fail, it is also characterized by a lower intensity mirror image on the reverse side of the sheet.

Minimizing Fretting Corrosion on Galvanized Sheet

There are a host of preventive measures that can be taken to minimize fretting corrosion. These include: lubricating with low viscosity oils or greases, optimizing the surface roughness to alter friction coefficients, isolating from vibration, increasing the recoiling tension or load to reduce slip, and decreasing the load at bearing surfaces.

All of the above measures are not practical in the case of galvanized sheet, but investigations at one steel supplier have indicated that some are effective to varying degrees. An action that has met with some success is redesigning support saddles to reduce concentrated point loading on the bottom of coils. By distributing the weight of the coil over the entire area of the saddle(s), there is less pressure at any one point, resulting in less transit damage given that vibration will always be present. A slightly less effective way of accomplishing the same result is to reduce the coil size, but this is perhaps not a desirable option for all situations. With either of these actions, care should be taken to avoid stacking coils during transit, as material on the bottom could become overloaded, even with well-designed saddles under them.

If large, heavy coils are required to be shipped as-is, then a third option is to ship in the “eye-to-the-sky” orientation. This way, relative motion between the surfaces is eliminated, thus fretting is not possible. However, this method requires specialized handling equipment at both ends of the shipping route to rotate the coils.

Still another option to reduce fretting is to oil the sheet, thereby reducing friction. However, oiling has been found not to be effective in all circumstances and has other drawbacks, such as telescoping of coil walls, oil oozing from the walls, and being unacceptable to the customer.

An obvious cure would be to eliminate the small amplitude vibration of horizontally oriented coiled or stacked galvanize sheet. Accomplishing this is very unlikely given the nature of long distance shipping methods.

Sheet with Fretting Marks – Suitability for Use

Fretting marks on galvanized sheet are a surface oxide phenomenon that can be a major aesthetic issue, but there is no evidence they have a negative affect on corrosion resistance. Bright galvanize has a covering layer of zinc oxide that is not visible, whereas any fretted spots have an oxide layer that is black. This being the case, the product can generally be used in situations where appearance is not a factor, e.g., hidden structural members. In fact, specification EN 10326 Continuously hot-dip coated strip and sheet of structural steels, technical delivery conditions; states in clause 11.2 that darks spots resulting from friction during shipping generally only impair the appearance.

Summary

Unsightly white/grey/black storage stains and black marks due to fretting corrosion can result in rejection of galvanized sheet and products made from it. With proper attention paid to shipping and storage practices, these rejections can be minimized or even eliminated.