Hot-Dip Galvanized Coating Appearance

Introduction

Hot-dip galvanized (HDG) steel is specified because it provides maintenance-free corrosion protection for decades. Aesthetics are important to nearly every construction project; however, some architects and engineers under-utilize HDG because of concerns about its appearance. Whether an artfully designed sculpture, architecturally exposed structural steel (AESS), bridge, bus station, or other infrastructure element, galvanized steel offers design flexibility, and an attractive, natural gray finish.

HDG steel may have a variety of different initial appearances, including bright and shiny, dull, spangled, mottled, or matte gray. This difference in initial appearance can occur between individual pieces and even between sections of the same piece. The initial appearance of hot-dip galvanized steel is hard to predict for a variety of reasons, including steel chemistry, cooling rate, and stress induced during steel processing.

Regardless of the initial appearance, all galvanized steel parts will take on a uniform matte gray appearance upon exposure to the environment, typically within six months to two years. As the coating is exposed to natural wet/dry cycles, it develops a protective zinc patina; the result is a soft gray appearance - evening out any differences in appearance that may have existed originally. Because superior corrosion protection depends on the thickness of the zinc coating rather than visual appearance, all coating appearances are acceptable upon inspection as long as they meet thickness requirements and don't interfere with the intended use. No matter the visual appearance of the product, the steel will still benefit from the superior corrosion protection provided by hot-dip galvanizing. This publication describes initial appearance differences that may occur for a variety of reasons.

Common Appearances on Newly Galvanized Parts

Spangle

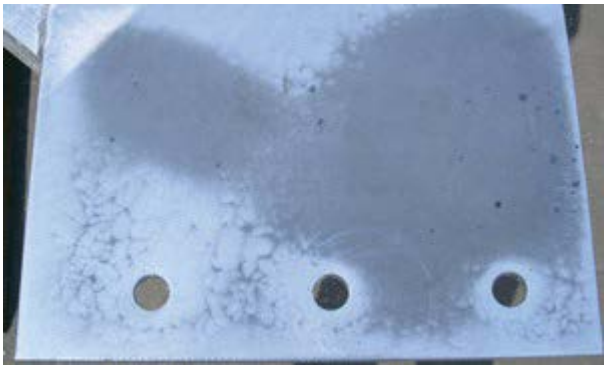
When many architects, designers, and other specifiers think of hot-dip galvanized coating appearance, they picture galvanized sheet metal coatings, common in ductwork, that have a spangled, metallic look. It is possible for hot-dip galvanized structural steel coatings to also have a spangled appearance, but it is not nearly as common as in sheet metal coatings. The occurrence of spangle on hot-dip galvanized coatings is the result of minor bath additions enhancing the appearance of zinc crystals on the coating surface. This coating phenomenon is not within full control of the galvanizer, but for steel grades within the recommended ranges for steel chemistry listed within Section 3.2 of ASTM A385/A385M, a spangled appearance can ultimately be controlled by adjusting cooling time, immersion time, and the concentration of optional alloying elements (typically tin, lead, and aluminum) by the galvanizer to the zinc bath. Generally, larger and more defined spangles are produced on smooth surfaces from minimized immersion times, the slowest possible cooling times, and higher amounts of the minor alloying elements in the galvanizing bath. To minimize the potential for a spangled appearance, request immediate quenching of articles after withdrawal from the galvanizing bath to ensure the zinc coating quickly cools to a temperature below which alloy crystals can form. Additionally, a spangled appearance cannot be achieved when choosing to hot-dip galvanize a reactive steel grade unless coating overgrowth is controlled.

Shiny Coating

A shiny coating appearance is achieved when a free zinc layer (eta layer) is formed atop the hot-dip galvanized coating. A shiny coating appearance is not within full control of the galvanizer. Although the addition of alloying elements such as aluminum and nickel to the zinc bath and performing quenching after galvanizing can influence the development of a shiny coating, steel chemistry has the greatest influence on the development of a free zinc layer and shiny surface appearance. To increase the likelihood of achieving an initial shiny coating appearance, select a steel grade which falls within the recommended limits and ranges for steel chemistry listed within Section 3.2 of ASTM A385/A385M, increase the withdrawal rate from the galvanizing kettle, and quench the newly galvanized articles immediately. For projects where a shiny coating is not preferred or a low reflectivity level is required, some galvanizers have the ability to perform a chemical post-treatment process for dulling of the surface immediately after galvanizing. Otherwise, the article can be left to weather naturally and become dulled over time, typically between six months to two years.

Matte Coating

A matte coating appearance occurs when the coating structure is comprised strictly of overgrown intermetallic layers and contains no free zinc layer (eta layer). The development of a matte coating is likely when hot-dip galvanizing "reactive" steels. Reactive steels contain elemental compositions beyond the recommended limits and ranges for galvanizing listed within Section 3.2 of ASTM A385/A385M and are often more rough in texture. Because steel chemistry has the greatest influence on the hot-dip galvanized coating structure, acquiring an initial matte surface appearance is not within the control of the galvanizer. To increase the likelihood of an initial matte appearance, select a reactive steel grade (Si content >0.22%) and skip quenching after galvanizing. It is important to note that all galvanized articles will eventually take on a matte appearance after natural weathering in environmental exposure.



Mottled Appearance

A mottled surface appearance is caused by uneven cooling rates of newly hot-dip galvanized articles after withdrawal from the zinc bath. During air cooling of the articles, the zinc/steel coating formation reaction can continue for a short time as long as the steel stays about 550 F. This continued reaction can consume some of the existing shiny zinc coating layer on top, leaving a matte gray appearance in thicker or internal areas of the article which are slow to cool, and a shiny appearance elsewhere. A mottled appearance can be greatly minimized by performing quench-cooling immediately upon removal from the galvanizing kettle. However, not all galvanizers have the ability to quench and sometimes quenching should be avoided for parts to be painted and powder coated, or those susceptible to warpage and distortion.

Mixed Appearance

Connecting different types or thicknesses of steel within the same assembly can result in a mixed appearance containing both shiny and matte surfaces. Another common place where a mixed appearance is found is in welded areas which can appear darker and thicker than the coating of the base steel. The processing of the steel can also create a mixed shiny and matte appearance in galvanized products. For example, the stresses in the steel corresponding to the fabrication process can affect the coating formation to create a striped or winding look. In order to avoid a mixed appearance, assemblies should be fabricated using steel of the same steel grade and of similar thickness. Furthermore, welding should be performed with a welding rod of similar silicon content to the base steel in order to ensure a consistent appearance.

Weathering

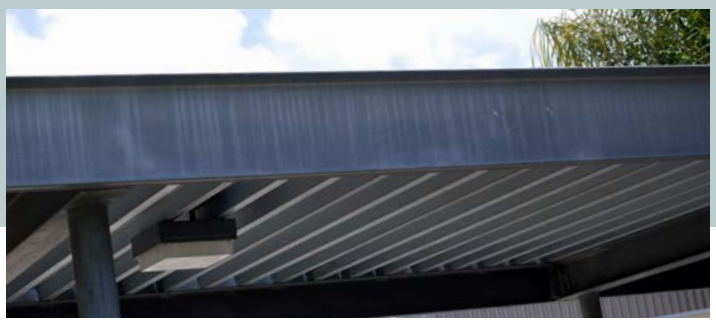
Regardless of the initial appearance (spangle, shiny, matte, mottled, or mixed), as galvanized steel weathers, initial variances will fade, producing a uniform matte gray coating. When exposed to the atmosphere, galvanized steel naturally develops a protective zinc patina on the surface which provides the uniform appearance. The time required for the change in appearance to occur is dependent on the exposure conditions.

A great example of this transformation is the canopied walkway at Mark Twain Elementary in Riverside, CA. The galvanized canopies were installed in October of 2006, and the initial coating appearance varied (see before photos) from bright and shiny to matte gray on the same beam. In June of 2009, the structure was revisited to examine the appearance and performance. The beams are now all uniformly matte gray with little to no visible difference in appearance. Additionally, as hot-dip galvanizing provides 75 years or more of maintenance-free corrosion protection, the beams show no signs of rust staining or corrosion damage.

Before: October 2006

After: June 2009

Before: October 2006

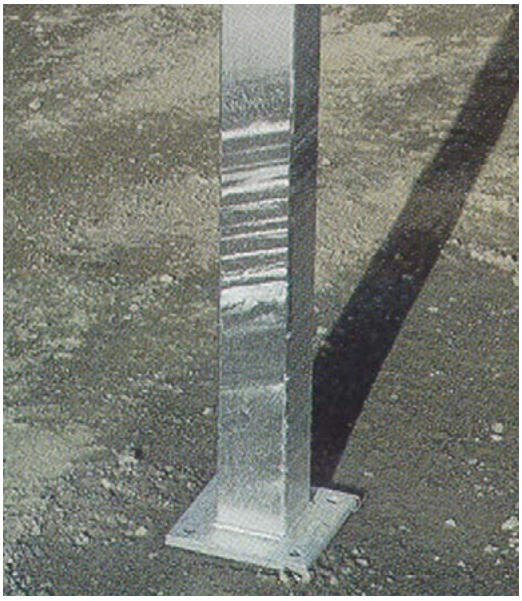


After: June 2009

Other Surface Appearance Conditions

Coating Overlap Line (Progressive Dip)

Progressively dipped pieces often have an overlap area that is visible on the piece. Progressive dipping is accomplished by dipping each end of the article sequentially to coat an entire item which is too large to fit directly into the galvanizing kettle. After bringing the first end though the galvanizing process, the coating is cleaned up and ground down near the center. Afterward, the second end is chemically cleaned and galvanized, where overlapping ensures full coating coverage of the article. The overlap area will most likely appear darker and develop a thicker coating. The color of the overlap area is not within the control of the galvanizer. However, the excess coating thickness can be buffed or ground down even with the surrounding coating for aesthetic purposes or if the area will be an important connection point with other pieces. To avoid the presence of an overlap line, consider a modular design comprised of articles which are able to fully fit within the galvanizing process tanks.



Oxide Lines

Oxide lines are light colored film lines on the galvanized steel surface created when a product is not withdrawn from the galvanizing kettle at a constant rate. Large articles, articles difficult to handle using the galvanizer's lifting equipment, and articles with poor drainage design may require the galvanizer to vary the withdrawal rate of the article and therefore increase the potential for oxide lines. In order to minimize the occurrence of oxide lines, ensure venting and drainage hole sizes for the article are optimized where possible, provide suitable lift points for galvanizing, and discuss lifting operations with the galvanizer prior to fabrication.

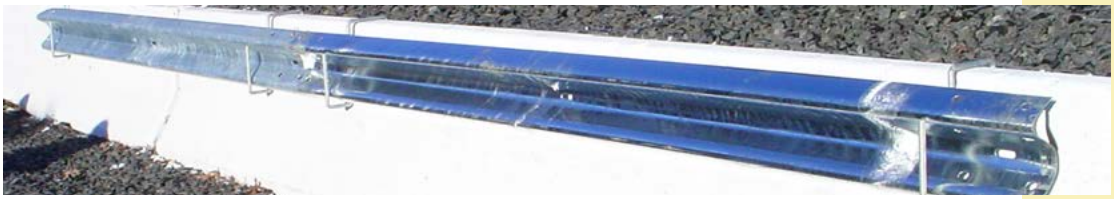
Touch-Up Areas

The use of touch-up materials can alter the appearance of the galvanizing finish as they are not usually an exact color match. Because the galvanized steel surface will weather and become a matte gray color over time (6 months to 2 years in the environment), touch-up performed using metalizing or a weathered-color zinc-rich paint will provide a more consistent final appearance to the product. Touch-up performed using bright/shiny zinc-rich paint will not weather in color similar to the surrounding coating. Differences in appearance from the use of touch-up materials is acceptable and not grounds for rejection. If required for aesthetic purposes, top-coating of the touched-up area with aluminum paint can be used to color-match newly galvanized steel. Areas of hot-dip galvanized steel previously touched-up either after the initial coating or erection should be inspected periodically and tested with a magnetic thickness gauge during the life of the structure.

Wet Storage Stain

Wet storage stain is a white, powdery surface deposit on freshly galvanized surfaces. It can occur when newly galvanized surfaces are exposed to fresh water, such as rain, dew, or condensation and have no air flow over the surface causing zinc oxide and zinc hydroxide to form. Wet storage stain is found most often on tightly stacked and bundled items, such as galvanized sheets, plates, angles, bars, and pipes. Wet storage stain can have the appearance of light, medium, or heavy white powder on the galvanized steel product. One method to avoid wet storage stains is to passivate the product after galvanizing by using a chromate quench solution. Another precaution is to avoid stacking products in poorly ventilated, damp conditions. Light or medium wet storage stain does not indicate reduction in the expected life of the product, and will weather uniformly over time upon storage or installation in standard conditions. For more information on preventing and/or removing wet storage stain, please see the AGA's publication *Wet Storage Stain*.

An example of wet storage stain weathering transformation is seen in the guardrail images below. The top image shows two pieces of guardrail, one shiny and one matte. These two pieces were galvanized in the same batch on the same day. The bottom image shows the same two guardrail sections after a little more than three months exposure. Both pieces have naturally weathered to develop the same stable zinc patina which provides hot-dip galvanized steel with its incredible resistance to corrosion. Hot-dip galvanized steel not only provides superior corrosion protection, but once in service will also sustain an aesthetically pleasing, uniform matte gray appearance for decades without maintenance.



Before natural weathering: Matte vs. shiny appearances

After natural weathering: Consistent appearances

Conclusion

Many specifiers erroneously equate the appearance of the coating with coating quality. It is important to note the durability of galvanized coatings is not determined by the appearance, but rather by the zinc coating thickness. Differences in appearance do not affect the corrosion protection of the galvanized coating and will fade over time as the coating weathers. Variations in coating appearance or finish are important only if they will affect the intended use of the article. The primary function of the galvanized coating is corrosion protection.

In summary, the biggest concerns in meeting the appearance requirements of ASTM galvanizing specifications address safety and quality. Although visual differences in the galvanized coating may exist, the coating will ultimately weather to a uniform matte gray and provide superior corrosion protection for decades.

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