Specifying and Detailing for Hot-Dip Galvanizing

AN OVERVIEW FOR ENGINEERS, ARCHITECTS, AND DETAILERS

By Philip G. Rahrig and John Krzywicki

High quality galvanized coatings are obtained when steel assemblies are designed to promote unrestricted flow of cleaning solutions and molten zinc during the hot-dip galvanizing process. A basic understanding of how steel is handled in the galvanizing plant and what the steel undergoes in the application of the galvanized coating will aid steel detailers in preparing drawings that will produce the best possible galvanized finish.

Keep the following details in mind when developing and reviewing structural details and shop drawings:

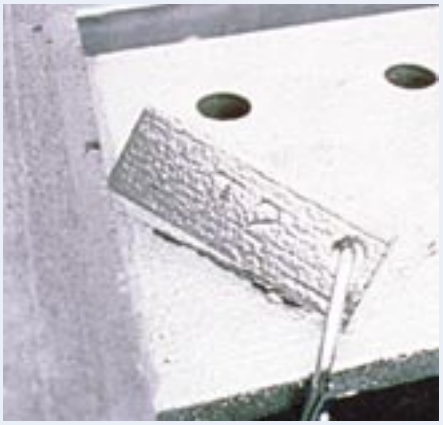
- ☑ Are the vent and drain holes of sufficient size and quantity?
- ☑ Are the vent and drain holes located properly? (One or more for drain and one or more for venting.)
- ☑ Are corners of gussets, stiffeners, and bracing cropped to allow free flow of zinc?
- ☑ If the fabrication is comprised of steel of two or more thicknesses, is it designed to promote minimal change in camber/straightness?
- ☑ Are welds at overlapping surfaces seal welded?
- ☑ Does the fabricator know to remove all weld flux and to use a weld material of suitable chemistry to produce good zinc coating?
- ☑ Have I accounted for marking/tracking of the parts through the galvanizing process and on to the job site?
- ☑ Have I planned for tapping of nuts or threaded holes after galvanizing?

The viscosity of liquid zinc at the galvanizing temperature plays a large role in which assemblies can be galvanized easily. The viscosity of molten zinc prevents it from entering gaps or crevices less than 3/32". Inside corners on steel fabrications also present quality issues if not properly designed for galvanizing. In general, the number of corners should be minimized. When applicable, corners should be cropped or enough space (3/32") must be provided for the molten zinc to easily flow in and out of tight spaces. When this issue is overlooked, zinc will tend to "pool" in these areas causing excessively thick coatings that may easily flake when subjected to rough handling. In addition, cleaning solutions are much less viscous than molten zinc and can enter tight spaces that the zinc cannot. Dried residue from cleaning solutions may remain trapped in the crevices after galvanizing and may bleed onto the surface if they come into contact with moisture. This will cause unsightly rust staining on the surface of the steel.

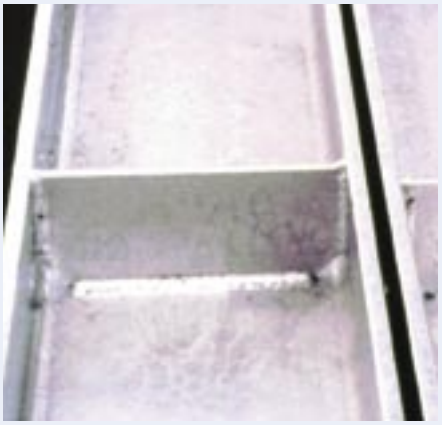
Arguably the most important components of galvanized steel design are vent and drain holes. Tubular or hollow fabrications must allow for cleaning solutions and zinc to freely flow on both the interior and exterior surfaces. To accomplish this, vent and drain holes should be placed near the ends of steel articles to allow zinc to penetrate the interior, as well as drain from the interior upon withdrawal from the galvanizing kettle.

Recommended Details for Hot-Dip Galvanized Structures, produced by the American Galvanizers Association (AGA), is a useful reference and can be downloaded from **www.galvanizeit.org/ref/details**. It includes working drawings containing the most commonly galvanized structures and includes the necessary details required for quality galvanizing. Another useful reference is *Designing with Hot-Dip Galvanized Steel*, an AGA-produced CD-ROM.

After choosing hot-dip galvanizing as the corrosion prevention system for your project, ASTM A123/A123M-02, *Standard Specification for Zinc (Hot-dip Galvanized) Coatings on Iron and Steel Products* should be the cornerstone of your project specification. ASTM A123 applies to structural



Identification marks or tags for each piece need to be sturdy enough to survive the galvanizing process.



Cropped corners allow molten zinc to flow in and out of tight spaces, avoiding "pooling" in these areas causing excessively thick coatings that may flake during rough handling.

Designers' and Detailers' Galvanizing Checklist

☑ **Will the steel surface exhibit extreme developments of mill scale, welding slag, or water-insoluble contaminants?**

These may not be removed by the cleaning chemicals in the galvanizing plant. Abrasive blasting or other types of mechanical cleaning may need to be employed to remove excessive developments of water-insoluble surface contaminants.

☑ **Has the steel been cold-formed?**

Avoid designs with notches, which increase stress. Flame-cutting or sawing is preferred, particularly for heavy sections, but other methods are acceptable. Drill, rather than punch, holes in material thicker than 3/4" (19 mm). If holes must be punched, they should be punched undersize and then reamed an additional 1/8" (3 mm) overall or drilled to size. Material between 1/4"-3/4" (6.5-19 mm) thick is not seriously affected by cold-punching if the punching is done under good shop practice. Materials up to 1/4" (6.5 mm) thick that have been cold-punched do not need stress-relieving operations before galvanizing.

☑ **Are there sharp bends in the steel fabrication?**

Best practice is to keep bend diameters as large as possible when parts are bent cold before galvanizing. A minimum bend radius of three times the section thickness will promote optimum galvanized coating properties (refer to ASTM A143, *Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement*, for additional information). If excessive cold bending or forming is necessary, the steel must be heat treated at 1100 °F (590 °C) for one hour, for every inch of section thickness to relieve stresses.

☑ **Are there thin sections of steel or varying thicknesses of steel that are going to be joined together by welding prior to galvanizing?**

Thin sections of steel (less than 1/8"), asymmetrical fabrications containing varying thickness steel, and articles that must be progressively dipped (aka "double-dip") have a higher susceptibility of warping (refer to ASTM A384, *Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies,* for additional information). To eliminate concerns over warping, bracing— permanent or temporary— can be used to provide stability during the thermal expansion and contraction cycle. Occasionally, when bracing is not used and warping and/or distortion occur, the part will return to its original shape during cool-down.

☑ **Does the steel assembly contain moving parts?**

During the galvanizing process, steel is immersed in molten zinc. Upon removal from the kettle, the once-molten zinc metal will solidify. As a result, the possibility exists for moving parts such as drop-handles, shackles, shafts, and hinges to freeze together.

☑ **Are there threaded holes or clearance holes in the design?**

Typical galvanized coatings range from 3-8 mils (75-200 microns) thick. When designing and detailing tapped holes, the increased thickness is important. Best practice suggests that the hole be tapped after galvanizing, removing the coating on the interior mating surface. If a galvanized component is used to mate with the hole (recommended to avoid galvanic corrosion), the galvanized coating on the mating surface will cathodically protect the bare steel of the interior threads. This also reduces the thickness loss of the hole and ensures a clean connection. On threaded assemblies with diameters greater than 1.5" (3.8 cm), it is often more practical, if design strength allows, to have the male thread cut 0.031" (0.8 mm) undersize before galvanizing so a standard tap can be used on the nut (refer to ASTM A563, *Standard Specification for Carbon and Alloy Steel Nuts*, for overtapping allowances).

☑ **Are there sections of the steel where wire or chain can be connected so that cranes can be used to lift the material?**

To ensure proper handling, lifting points should be incorporated into the fabrication's design. Lifting points provided only for hot-dip galvanizing purposes may be removed after galvanizing. For smaller parts (less than 18" in length, e.g. fasteners) baskets are used to handle the material and lifting points are not required. In some instances, the galvanizer may have specially designed racks to accommodate the galvanizing of certain products.

☑ **Have I provided the necessary vent and drain holes to produce a quality galvanized coating and ensure operator safety at the galvanizing plant?**

It is important to properly vent hollow, overlapped, and contacting surfaces to prevent trapped moisture or gas from flashing to steam in the heated galvanizing kettle, which may result in localized uncoated surfaces. Additionally, pressure increases resulting from trapped moisture flashing to steam can violently rupture the fabrication, endangering galvanizing plant personnel. ASTM A385 contains guidelines for properly venting numerous types of assemblies.

☑ **Have I used the proper weld metal?**

Silicon levels greater than 0.25% in the weld rod will cause thicker coatings to form in the weld areas. It is important to select welding rods that do not have excessive amounts of silicon.

☑ **Is the steel going to receive an additional coating on top of the galvanizing?**

Inform the galvanizer that the steel is going to be coated after galvanizing so they do not quench the material. After the article is removed from the kettle, it is often quenched to increase the rate of cooling and/or to coat the steel with a passivation layer to protect the galvanizing in transit and storage. This passivation layer may interfere with additional coating operations (refer to ASTM D6386, *Standard Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting*).

☑ **Is my fabrication going to fit in the galvanizing kettle?**

Throughout North America, a variety of sizes of hot-dip galvanizing kettles is available, allowing a wide size-range of structural fabrications to be galvanized (refer to **www.galvanizeit.org/ref/galvanizers** for a complete listing of AGA-member North American galvanizers and their kettle sizes). Designing and fabricating in modules suitable for the available galvanizing facilities allows almost any component to be galvanized. For oversized fabrications, best practice suggests that they be designed in modules or sub-units and assembled after galvanizing. In some instances, fabrications that are larger than the galvanizing kettle may be progressively dipped to obtain complete coating coverage on all surfaces.

Vent and drain holes prevent trapped moisture or gas from flashing to steam in the heated galvanizing kettle, which may result in localized uncoated surfaces or ruptured fabrications.

shapes, plate, strip, bar, castings, and all types of fabricated assemblies (grating, welded configurations, etc.). Pipe, tubing, and wire are also specified to ASTM A123 as long as they are not galvanized in a continuous process. Fasteners and any small parts that can fit into a perforated spinner basket are galvanized similarly, but the governing specification is ASTM A153/A153M-03, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*.

ASTM A123 requires a minimum average coating thickness by material type and thickness. For example, a ¼" thick piece of wide-flange beam must have a coating grade of 100 (3.9 mils, 2.3 oz/sq. ft, 100 microns) and a ¼" wall pipe or tube a coating grade of 75 (3.0 mils, 1.7 oz/sq. ft, 75 microns). There is no maximum coating thickness. The specification requires that the coating finish be continuous, reasonably smooth, and uniform, as galvanizing is generally specified for its corrosion protection and not its silver-gray appearance. If the appearance is of primary importance, or the galvanized steel is to be painted or powder coated, the specifier should communicate with the galvanizer to ensure certain steps are taken in the galvanizing process.

ASTM A385-03, *Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)* provides guidance to designers and fabricators for successful galvanizing projects. The most important paragraphs in ASTM A385 cover specific chemistries of steel that provide excellent zinc coating thickness and appearance. Specifically, there are ranges of phosphorous and silicon that yield high quality results. Other practices identified in the specification include continuous welding of overlapped surfaces, location and size of venting and drain holes, use of similar steels (chemistry, surface condition), cold forming, part identification, and weld material use/flux removal.

Thorough review of the referenced ASTM specifications will provide a basic understanding of hot-dip galvanizing. However, it is critical that the unique elements of a project are reviewed with the galvanizer and fabricator. ★

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Checklist for Galvanizing Specifications

1. Have I referenced all of the pertinent specifications that cover hot-dip galvanizing of steel after fabrication? (ASTM A123 or ASTM A153 and ASTM A385)
2. Is it practical to specify steel of certain chemistry in order to better control the coating thickness and appearance? (For small projects less than 20 tons, it is not likely that the fabricator has the selectivity to order steel of specific chemistry from a steel service center/warehouse. Larger projects that have schedule flexibility may allow for steel of a specific chemistry to be ordered from the mill.)
3. What sampling method will be used by the galvanizer? Have I specified a set number of thickness measurements or a random sampling?
4. Did I stipulate that a certificate of conformance be provided by the galvanizer?
5. Will the thickness of steel yield a zinc coating thickness appropriate for the intended use and environment of use?
6. Have I communicated with the fabricator and galvanizer about the intended use of the galvanized steel? (The intended use may dictate special post-galvanizing procedures.)
7. Are there any special packaging requirements to protect the galvanized steel during a long storage period? (Nested or tightly stacked galvanized steel does not allow the natural development of zinc's protective patina.)
8. What is my expectation for the coating appearance (matte gray, bright/shiny, spangled)? Do I care, or is corrosion protection my primary concern?
9. If there are any bare spots on the galvanized steel that result from contaminants on the black steel that prevent proper cleaning, what touch up method should be used in the galvanizer's plant (per ASTM A780-01, *Practice for Repair of Damaged and Uncoated Areas of Hot-dip Galvanized Coatings*)?
10. If there is damage in transit or during erection, which of the three approved touch up methods is to be used?