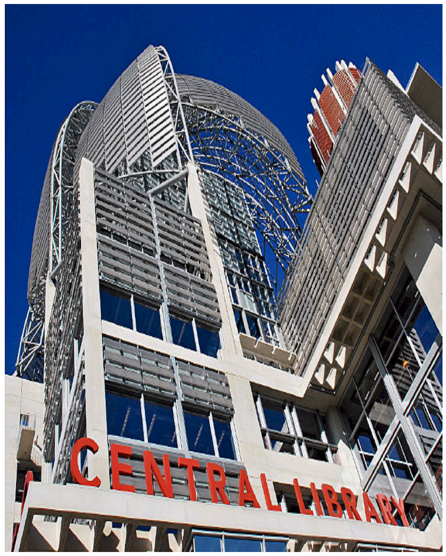
AESS for Specifiers



San Diego Central Library

Although not originally intended as an aesthetic finish, many architects turn to batch hot-dip galvanized Architecturally Exposed Structural Steel (AESS) to create artistic, durable, and sustainable showcase elements with a modern, industrial aesthetic. However, there are some misconceptions about the appearance of after fabrication batch hot-dip galvanized (HDG) steel that can lead to misaligned expectations between the architect, steel fabricator, and galvanizer. Some architects expect the shiny, smooth, or spangled finish of galvanized sheet metal common in ductwork or corrugated panels; however, most fabricators and galvanizers know after-fabrication batch HDG steel elements rarely yield this type of appearance.

Unlike painted or powder coated steel, stainless steel, concrete, or metal plating, the initial appearances of hot-dip galvanized steel is not consistent. Furthermore, the galvanizing process can produce uneven surface conditions (i.e. runs, inclusions, roughness, excess zinc) normally acceptable by ASTM specifications for steel products outside the architectural world, but unacceptable for showcase or feature elements without additional smoothing and filing after galvanizing. Despite these challenges, it is possible to achieve high-quality coatings when the necessary aesthetic requirements are clearly and directly communicated.

The intent of this publication is to explain how to use the AESS category systems developed by the American Institute of Steel Construction (AISC) and the Canadian Institute of Steel Construction (CISC) to facilitate such communication, minimize the cost premium for achieving galvanized AESS, and examine best practices to maximize hot-dip galvanizing appearance.

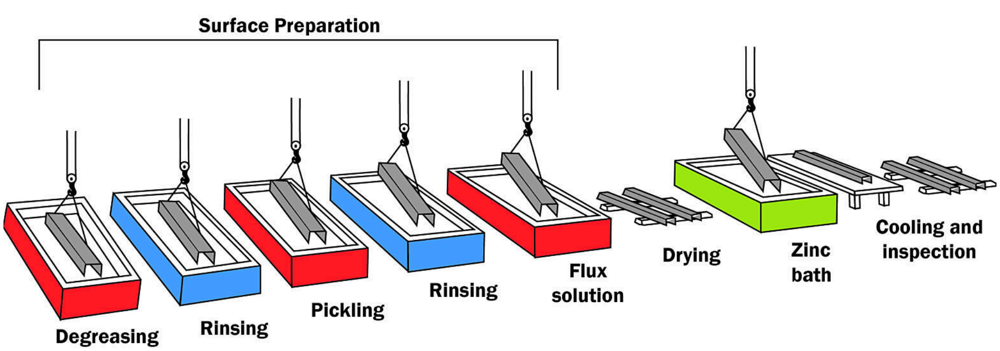
El Andaluz Commercial Offices & Residences

Upon Completion, you will be able to:

- Learn how to use the AESS category systems developed by the American Institute of Steel Construction (AISC) and the Canadian Institute of Steel Construction (CISC) to facilitate communication and minimize the cost premium for achieving galvanized AESS.
- Learn the best practices and procedures to obtain the desired aesthetic characteristics specified for AESS projects.
- Identify topics to discuss in a pre-bid or pre-job meeting with the general contractor, fabricator, galvanizer, and inspector to align expectations and ensure project success.

Batch Hot-Dip Galvanizing (HDG)

Hot-dip galvanizing produces a protective zinc coating by completely immersing the steel in a kettle filled with molten zinc (Figure 1). Prior to immersion in the zinc bath, the steel is chemically cleaned to remove all oils, greases, soil, mill scale, and oxides. The surface preparation consists of three steps: degreasing to remove organic contaminants, acid pickling to remove scale and rust, and fluxing, which inhibits oxidation of the steel before dipping in the molten zinc. After surface preparation, the steel is immersed in the molten (830-850 F) zinc bath. While in the galvanizing kettle, the molten zinc metallurgically reacts with the iron in the steel to form a durable and uniform corrosion resistant coating containing several layers harder than the base steel and a malleable outer layer of pure zinc.



Batch hot-dip galvanizing process

Initial Appearance

It is common for batch hot-dip galvanized steel to have a variety of different initial appearances, including bright and shiny, matte, spangled, mottled, or mixed (Figure 2). These differences can occur between individual pieces and even between sections of the same piece. The initial appearance of hot-dip galvanized steel is difficult to predict and control for a variety of reasons, including steel chemical composition, stress induced during steel processing, and cooling rates after galvanizing.

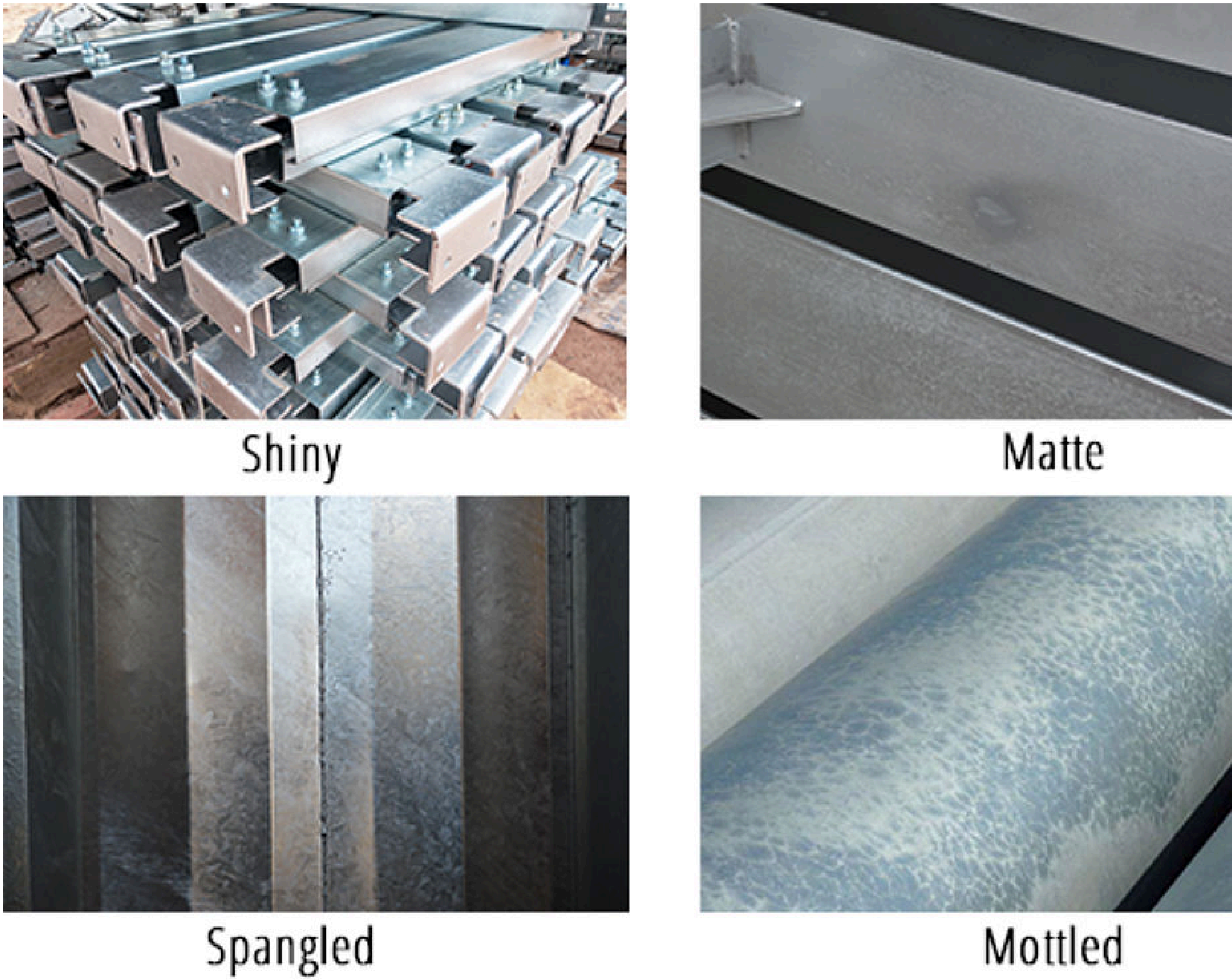


Figure 2: Examples of galvanized steel's initial appearance

Natural Weathering

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 depending on the exposure conditions. As the coating is exposed to natural wet/dry cycles, it develops a protective zinc patina; the result is a soft and weathered gray appearance - evening out many differences in initial appearance that may have existed originally (Figure 3). Conversely, interior AESS installed in a climate controlled area will not experience weathering, and the initial appearance is unlikely to weather significantly over time.

Post Treatments

Post treatments may be applied to batch hot-dip galvanized steel to assist with rapid cooling of the steel (quenching), passivation of the zinc surface to prevent formation of wet storage stain, or alter the appearance of the zinc coating. For most AESS projects post-treating or quenching galvanized steel is avoided when additional smoothing and/or painting is required after galvanizing. It is important to inform the galvanizer when specifying AESS on a project so they can avoid post treatments that can hinder additional surface treatment after galvanizing. Some post treatments may be intentionally applied to the galvanized surface to produce an alternative appearance. Passivation treatments are available that dull or create an attractive sheen to the surface of the galvanized steel, as well as secondary coatings in a traditional duplex system. A zinc-phosphate conversion coating can be applied to prematurely dull the coating when reflectivity of the zinc coating is a concern. Other proprietary color passivation treatments can be applied that augment the natural finish of the galvanized coating with a specific color.

Figure 3: Natural weathering of a canopied walkway at Mark Twain Elementary in Riverside, CA. The canopies were installed in October 2006, and the initial coating appearance varied from bright and shiny to matte gray on the same beam. In June 2009, the structure was revisited to examine the appearance and performance. The beams are now uniformly matte gray with little to no visible difference in appearance.

Duplex Systems: Painting or Powder Coating HDG

In addition to post treatments, paint or powder coatings can be applied to hot-dip galvanizing to achieve a desired color. In addition to a specified aesthetic, duplex systems provide improved longevity, 1.5 to 2.3 times the combined lifetimes of both systems, as the result of a synergistic effect between the coatings. Almost any liquid coating system can be applied over hot-dip galvanized coating, but the alkaline nature of the galvanized surface requires a tie coat to be specified for oil-based coatings such as alkyds to avoid saponification. When preparing hot-dip galvanized products for painting or powder coating, surface preparation is critical to the appearance and overall performance. The following surface preparation standards (and choices from the methods presented within), should be specified to clarify the steps necessary to prepare the galvanized surface for painting or powder coating:

- ASTM D6386 Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Products and Hardware Surfaces for Painting
- ASTM D7803 Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Products and Hardware Surfaces for Powder Coating

The coating manufacturer should be consulted for the best practice regarding application of their coatings over hot-dip galvanizing and the variety of preparation methods presented in ASTM D6386 or ASTM D7803. Although sanding and filing shall be performed to smooth high spots in the galvanized coating, it may also be desired to fill low spots or indentations. To achieve a smooth, paintable surface in these areas and meet AESS category 3 or 4 characteristics, specify a filler material such as caulk or putty be applied by the paint applicator. The coating manufacturer should be consulted regarding compatibility of the filler with the coating to be applied.

Specifying Batch Hot-Dip Galvanized AESS

The ASTM specifications that govern hot-dip galvanizing were written to ensure consistent, long-term corrosion protection. Therefore, meeting the specification requirements can be achieved without maximizing the appearance of the coating. When using HDG steel for AESS elements, there are important design details in supporting specifications and the AESS category system in the AISC Code of Standard Practice that should be followed to improve the HDG finish.

ASTM standards used to specify hot-dip galvanized steel:

- ASTM A123 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
- ASTM A153 Standard Specification for Zinc Coating (Hot-Dip) on Iron and

Hardware Supporting ASTM specifications contain best practices for design and fabrication as well as general quality and repair:

ASTM A143 Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement

- ASTM A384 Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
- ASTM A385 Practice for Providing High-Quality Zinc Coatings (Hot-Dip)
- ASTM A780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

When utilizing hot-dip galvanized steel in AESS projects, additional requirements beyond these specifications are necessary both before and after galvanizing to meet the aesthetic requirements for each AESS category. The majority of products galvanized to these standards do not require heightened aesthetics; therefore, the presence of unattractive surface conditions are allowed as long as they do not affect the corrosion resistance of the coating or intended use of the product. To maximize hot-dip galvanized appearance for AESS a combination of these ASTM standards and specific AESS practices are necessary.

Using the AESS C Category

The AESS categorical system was developed to provide clear expectations between the specifier and the fabricator to achieve the desired architectural finish. However, the requirements defined in the AISC/CISC categories (1, 2, 3, 4) do not address all the nuances of hot-dip galvanized coatings. Some practices required for each of these categories will have little to no effect on the initial galvanized coating appearance, whereas other, additional practices can greatly improve it (Figure 4). For example, the nature of the galvanizing process can result in aesthetic limitations in overall uniformity, smoothness, coating repairs, and the contouring and blending of mill markings, welds, and seams. These topics are discussed in the Best Design Practices section of this publication.

To define both practical exemptions and additional requirements necessary to achieve an equivalent aesthetic for each AESS category, it is recommended to use the Custom (AESS C) category. A modified AESS Category Matrix Table for HDG (Table 1) is provided as a guide and is modeled after the AISC/CISC AESS Category Matrix. The use of AESS C is not limited to these practices, but those noted using an "x" are highly recommended to maximize HDG appearance. Responsibility for each category characteristic in Table 1 shall be mutually determined by the galvanizer, fabricator, and erector prior to fabrication.

Figure 4: High resolution, closeup photos of these four AESS samples (from left to right, AESS 1, 2, 3, 4) are available from the AGA to supplement project meetings and allow invested parties to see the range of possible appearance levels corresponding to the characteristics of each AESS Category

Limitations to Batch HDG Visual Samples or Mockups

Visual samples are useful to determine whether the galvanizer and fabricator are capable of providing a galvanized part with suitable corrosion protection, smoothness, installation tolerances and overall quality. However, it is impractical to expect an aesthetic finish which exactly matches the sample for all the pieces galvanized in a project. It can be common to galvanize identical pieces which result in different finishes or overall appearance. Furthermore, the amount of detailing or smoothing required to bring the galvanized sample to the aesthetics requirements determined by each AESS category may not be representative of the amount of detailing or smoothing required for the final parts.

When requesting a visual sample, it is important to consider varieties of initial appearances and natural weathering of the galvanized coating so that realistic aesthetic criteria are established for the project.

Modified AESS Category Matrix for HDG		AESS C/4	AESS C/3	AESS C/2	AESS C/1
I.D	Category Characteristics	Custom Elements	Custom Elements	Custom Elements	Custom Elements
1.1	Surface preparation to SSPC-SP 6	x	x	x	x
1.2	Sharp edges ground smooth	x	x	x	x
1.3	Continuous weld appearance	waived	waived	waived	waived
1.4	Standard structural bolts	x	x	x	x
1.5	Weld splatters removed	x	x	x	x
2.1	Visual samples	mock-up required	mock-up required	optional	optional
2.2	One-half standard fabrication tolerances	x	x	x	
2.3	Fabrication marks not apparent	x	x	x	
2.4	Welds uniform and smooth	x	x	x	
3.1	Mill marks removed	x	x		
3.2	Butt/plug welds ground smooth & filled	x	x		
3.3	HSS weld seam oriented per contract documents	x	x		
3.4	Cross sectional abutting surface aligned	x	x		
3.5	Joint gap tolerances minimized	x	x		
3.6	All welded connections	waived	waived		
4.1	HSS seam not apparent	x	optional		
4.2	Welds contoured and blended	x			
4.3	Surfaces filled and sanded	x			
4.4	Weld show-through minimized	x			
Custom Characteristics for Batch Hot-Dip Galvanizing Beyond A123 Requirements					
C.1	Weld show-through minimized again after HDG	x	x	x	x
C.2	Flame cut edges grind 1/16” including cut faces	x	x	x	x
C.3	HDG skimmings removed	x	x	x	x
C.4	Washers underneath bolt heads	x	x	x	x
C.5	HDG repair material: TBC	x	x	x	x
C.6	Special care in fabrication and erection	x	x	x	x
C.7	HDG zinc splatter removed	x	x	x	optional
C.8	Plug and smooth round vent/drain holes	x	x	optional	optional
C.9	Wet storage stain prevention procedures	x	x	optional	optional
C.10	HDG cosmetic touch-ups using ZRP spray	x	optional	optional	optional
C.11	Low silicon welding electrodes	optional	optional	optional	optional
C.12	Increased venting/drainage designs for HDG	x	x	x	
C.13	HDG dross smoothed to projections <1/16”	x	x	optional	
C.14	HDG runs smoothed to projections <1/16”	x	x	optional	
C.15	Drilled vent/drain holes only	optional	optional	optional	
C.16	HDG handling marks smoothed to projections <16”	x	x		
C.17	Progressive dip galvanizing avoided	x	x		
C.18	Soft/padded slings, lifting devices, and rests	x	x		
C.19	HDG roughness smoothed to projections <1/16”	x	optional		
C.20	Welds contoured and blended again after HDG	x			

Table 1: Modified AESS Category Matrix Table for HDG (Modeled after the AISC/CISC AESS Category Matrix)

Commercial Blast Cleaning Before HDG

The specification of commercial blast cleaning (SSPC-SP 6/NACE No. 3) is primarily specified to roughen the steel surface before HDG and not to provide a specific degree of cleaning. This practice is necessary to achieve the elevated aesthetic quality expected for each AESS category because it promotes a more uniform initial appearance among variations in steel surface chemistry, minimizes the formation of excessively thick HDG coatings, and minimizes the formation of brittle coatings prone to delamination.

Surface Smoothing After HDG

The initial appearance of the galvanized coating cannot be altered and some variation in appearance is to be expected. However, many natural and common surface conditions can be reasonably ground, sanded or filed to minimize their appearance, improve uniformity, and achieve the desired aesthetics for featured or showcase elements. Though some of these surface conditions may not require removal for basic elements (AESS Category 1), the examples in Figure 5 are provided for guidance within the modified AESS Custom category matrix for HDG to address aesthetics above and beyond ASTM requirements and established AESS category requirements.

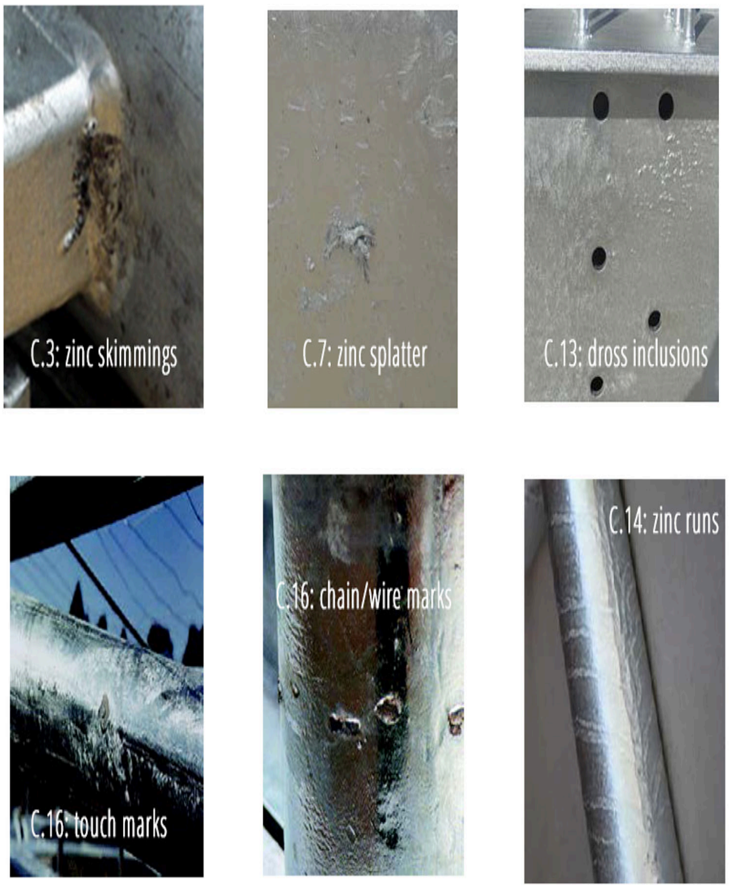


Figure 5: Areas that may need surface smoothing after HDG

Design Details and Fabrication Best Practices for HDG

The overall design of parts before fabrication is a primary factor in the initial galvanized finish. Many recommended design details for improving quality of the hot-dip galvanized coating are provided within ASTM A385 Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip). However, this standard is intended for general galvanizing purposes and additional requirements are necessary to achieve elevated aesthetics for AESS members. When specified in addition to ASTM A385, the following design and fabrication best practices allow the galvanizer to successfully implement process changes to maximize aesthetics while minimizing the time and cost of the surface smoothing to be performed after galvanizing.

Most iron-containing materials are suitable for galvanizing, but steel selection has the greatest influence on the hot-dip galvanized coating aesthetics and quality. Trace elements in the steel affect the thickness, structure, appearance, and overall quality of the galvanized coating. Specifically, steels with silicon or phosphorus levels outside of recommended ranges are known in the galvanizing industry as “reactive steels” and are known to produce thick and/or rough coatings. Reactive steels are galvanized on a regular basis, but the newly galvanized articles often appear matte gray as opposed to a bright and/or spangled appearance common when hot-dip galvanizing steels of recommended chemical composition. Consequently, combining steels of different material thickness, chemistries, or initial surface conditions in an assembly will result in a mixed appearance after hot-dip galvanizing.

Steel Selection

ASTM A385 contains the desired elemental ranges for steel composition to maximize quality for after-fabrication hot-dip galvanizing:

- Silicon levels either less than 0.04% or between 0.15% - 0.22%
- Phosphorus less than 0.04%
- Carbon less than 0.25%
- Manganese less than 1.35%

Although sometimes a reactive steel is desired to achieve greater zinc thickness and longevity of the hot-dip galvanized coating, other times an excessive coating thickness can lead to brittle coatings, poor adhesion and/or surface conditions unacceptable for AESS members. As the steel thickness of any reactive steels increase, or when thick steel (above 2-3 inches) is welded to reactive steels in an assembly, the potential for aesthetic and adhesion concerns increases significantly. Predicting steel reactivity is not an exact science. Element levels can vary +/- 0.02% and the values listed on a mill test report are only one sample taken from the heat. Element levels on individual pieces, and even on the same piece of steel, can vary to some degree. However, mill reports which state the estimated elemental composition typically lead to the most accurate evaluation.

Figure 6: Progressive dip overlap line (C.17)

Steel Size

Because hot-dip galvanizing is a total immersion process, the designer should take into consideration any steel parts must fit within the galvanizing bath while being suspended at a steep angle. This may require designing in modules or sub-units for connection by welding or bolting after galvanizing. Steel size limitations are governed by the galvanizing kettle dimensions, but the average kettle length in North America is 40 ft (12 m) and 50-60 ft (16-18 m) kettles are available. It is wise to verify all kettle constraints with your galvanizer early in the design process. Kettle dimensions for all AGA member galvanizers are available at galvanizeit.org/galvanizers.

Practical constraints regarding kettle depth should also be considered to significantly reduce time and cost for the surface smoothing of AESS members after hot-dip galvanizing. Natural and solid byproducts of the HDG process known as dross particles develop within the galvanizing bath and gradually settle at the bottom 3-12 inches of the kettle, known as the bottom dross layer. Large parts that reach near the bottom dross layer are more likely to develop rough galvanized coatings containing dross particle inclusions. For parts too large for total immersion in the galvanizing kettle, progressive dipping is a galvanizing method used to immerse each end of the article sequentially to coat the entire item. In practice, progressively dipped articles result in a notably dark and rough overlap area unlikely to weather uniformly over time (Figure 6). As a result, progressive dipping is not a recommended practice for unpainted galvanized AESS expected to meet category 3 or 4 characteristics. For galvanized AESS members that will be painted or powder coated, the excess coating thickness can be successfully buffed or ground down even with the surrounding coating.

Welding Before Batch HDG

When welded items are galvanized, two factors have the greatest impact on coating quality and aesthetics: cleanliness of the weld area and metallic composition of the weld. Welding slag, flux residues, and welding sprays (with the exception of water-soluble sprays) must be fully removed prior to galvanizing. Welding electrodes high in silicon (>0.25% Si) may cause excessively thick and/or darkened galvanized coatings to form over the weld. When smooth products are welded using high silicon electrodes, the coating over the weld material will be thicker than the surrounding coating, causing a raised weld in an otherwise smooth product. This appearance, sometimes referred to as a "raised weld" or "swollen weld," will require additional smoothing after galvanizing to meet AESS 3 and 4 characteristics (Figure 7). Specifying ground welds before galvanizing does not successfully prevent this condition, but is still necessary when raised welds are expected to be minimized.

Figure 7: Welding electrodes high in silicon result in a raised weld appearance (above) despite grinding prior to HDG (below). AESS Levels 3 and 4 may require additional smoothing after HDG (C.1 & C.20)

Specify a welding electrode with a chemical composition as close as possible to the parent metal to minimize differences in appearance and potential costs associated smoothing welds after galvanizing. A list of welding electrodes which are known to promote a more uniform appearance are provided in Table 2. In some welding processes (e.g. FCAW-G), the availability of low silicon welding electrodes may be uncommon. When designing for hot-dip galvanizing, the best practice is to avoid overlapping joints with narrow gaps. The resulting gap allows galvanizing pretreatment chemicals to enter, but molten zinc cannot enter gaps less than 3/32-in. Entrapped solutions rapidly expand at galvanizing temperatures and may result in blowout of overlapping areas 16 in2 or greater. Even if blowout is avoided, galvanizing pretreatment chemicals interact with the steel and moisture in the environment and cause rust to eventually bleed from the joint. To ensure structure integrity, galvanizing quality, and aesthetics near overlapped areas, the following methods are suggested:

- Fully seal weld and specify venting of the overlapping area to prevent weld blowout based on steel thickness and size of overlap area (ASTM A385 Tables 1 & 2).
- Intermittent weld, specify a minimum 3/32 in. gap between surfaces and increase weld size as required. One practical method utilizes 3/32 in. stainless steel wire spacers to minimize contact area. Maintaining a gap may become impractical for large areas.
- Where seal welding or stitch welding (described above) are impractical, specify venting of the overlap area to prevent weld blowout (ASTM A385 Table 1 & 2), clean any staining from rust bleeding from the HDG surface, and specify a caulking to seal the joint after galvanizing.

Welding Process	Lincoln Electric Welding Electrode	AWS Designation	Silicon (Weight %)
SMAW	Jetweld 2 Fleetwood 35 LS	E6027 E6011	0.22-0.26% 0.10-0.18%
SAW	L60-860	F6A2-EL12	0.24%
FCAW	NR-203 NiC+ NR 203 MP NR 233 NR 311	E71T8-K2 E71T-8J E71T-8 E70T-7	0.06% 0.22-0.26% 0.19-0.20% 0.12-0.13%

Table 2: Recommended welding electrodes for hot-dip galvanizing

Mill Markings, HSS Seams

In the galvanizing process, steel interacts with zinc in a diffusion reaction, meaning the coating grows perpendicular to all surfaces at a uniform rate. As a result, any initial imperfections in the steel surface will remain equally visible upon hot-dip galvanizing. For AESS 3 and 4 category requirements, the grinding and filing of HSS seams (Figure 8), mill markings (Figure 9), and other raised surface conditions will minimize their appearance after hot-dip galvanizing but it is unreasonable to expect they will be eliminated. Similarly, any divots or low spots in the steel surface will not be filled.

Figure 8: unground HSS seams are visibly apparent after HDG (left) but minimized when ground before (right) (4.1).

Figure 9: Typical appearance of mill markings if unground before HDG (3.1).

Especially for showcase elements with all sides exposed, design teams should determine whether seam grinding and smoothing of grinder marks before hot-dip galvanizing is necessary to achieve the desired aesthetic. Use the AESS Custom category characteristic 4.1 to clarify the seam preparation requirement(s), and then clearly specify seam orientations in the design documents. If not clearly indicated, fabricators are encouraged submit an RFI early in the project to determine seam preparation and orientation.

Thermally Cut Edges

Thermal cutting techniques can change the properties of the steel and increase the hardness at the edge of the plate. The increase in hardness changes the diffusion properties of the steel and makes it very difficult to form a galvanized coating of suitable aesthetics for AESS along the cut edge, particularly among flame cut edges on steels greater than ½ in. thick (Figure 10).

To achieve a high quality finish along thermally cut edges, the steps necessary are beyond the capabilities of the galvanizer. The fabricator must ensure the flat surface of all thermally cut edges are ground at least 1/16 in. into the parent material before galvanizing in addition to the grinding of sharp edges as outlined per AESS category requirements. Although grinding of thermally cut surfaces is often considered impractical and significant in terms of fabrication cost, this method is more efficient, cost-effective, and visually appealing compared to remedying the appearance after hot-dip galvanizing.

Figure 10: Galvanized coating formed over unground flame cut edge (C.2).

Designated Lift Points

Specifying designated lift points (temporary or permanent lifting lugs, 5/8 in. diameter holes, etc.) for hot-dip galvanizing allows the galvanizer to lift parts at an angle without the use of chains, thereby avoiding the presence of chain and wire mark indentations in the coating which are very difficult to smooth for increased aesthetics without damage. A fully optimized lifting configuration requires direct communication with the galvanizer and considers an angled lift, the location of venting/drainage holes, and the galvanizer's plant specific material handling capabilities.

Optimized Venting and Drainage

For successful hot-dip galvanizing, cleaning solutions and molten zinc must flow without undue resistance into, over, through, and out of the fabricated article. The minimum requirements for venting and drainage design details are provided in the standard ASTM A385 Practice for Providing High-Quality Zinc Coatings (Hot-Dip). However, these requirements do not necessarily provide sufficient venting and drainage details to maximize aesthetics for AESS. It is often necessary to specify additional design optimizations to improve quality, avoid bands of light colored oxide lines, and minimize the amount of smoothing and filing after galvanizing.

The larger and more complex the fabrication, the more critical the venting and drainage details are to the overall aesthetics of the part. It is strongly advised to consult directly with the galvanizer to optimize placement, quantity, and size of venting/drainage holes in relation to the handling orientation (Figure 11).

Figure 11: Optimizing the placement of vent/drain holes (left) is one method to improve galvanizing aesthetics and significantly reduce the appearance of zinc runs and other surface conditions unacceptable for AESS members (right) (C.12 & C.15).

For improved venting and drainage it is recommended to specify more and/or larger holes than defined by ASTM A385, place holes as close as possible to intersecting areas and welds (ideally within 1/2 in.), and specify drilled holes or smoothed holes to improve flow and ensure correct sizing. Vent holes can be plugged after galvanizing (Figure 12).

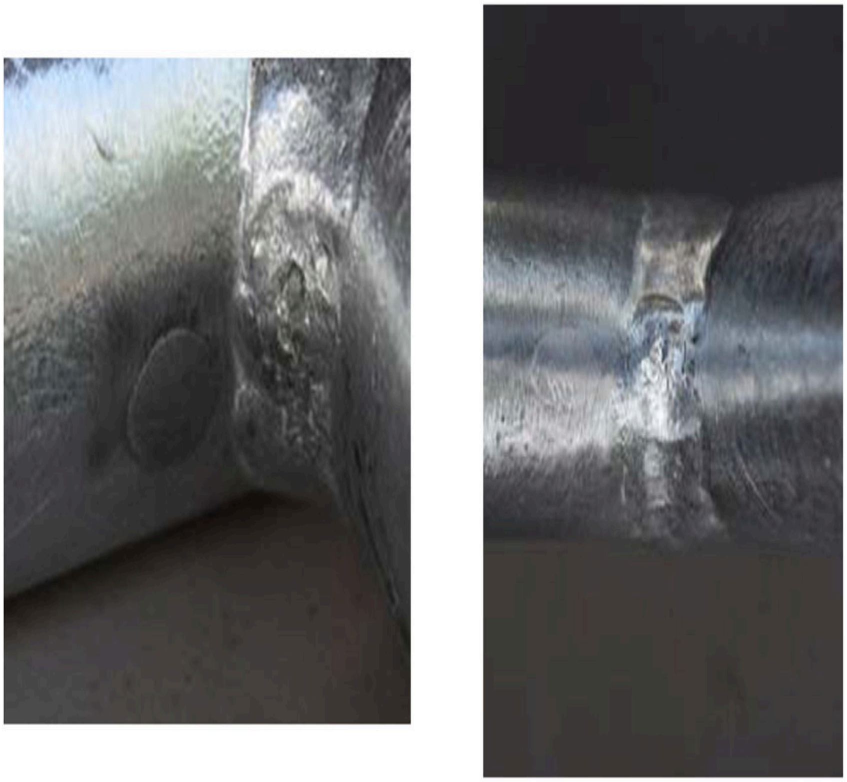


Figure 12: Round vent holes may be plugged with zinc (left) or aluminum (right) plugs after hot-dip galvanizing to minimize their appearance (C.8).

Dissimilar Metals

The combination of various building materials and metals can be used to achieve unique color, texture, and sheens, but efforts should be made to avoid galvanic corrosion with hot-dip galvanized steel. It is desirable to specify galvanized fasteners for galvanized connections, and nonconductive spacers when joining with other metals or metallic coatings. Generally, the combination of hot-dip galvanized steel and stainless steel or aluminum can be specified for interior AESS members or AESS in atmospheric environments with mild humidity and low air salinity.

High Strength Bolts

The Research Council on Structural Connections (RCSC) Specification for Structural Joints Using High-Strength Bolts excludes bolt Group 150 (ASTM F3125 Grade A490 and ASTM F3125 Grade F2280) from being hot-dip galvanized or mechanically galvanized. If the bolt is hot-dip galvanized, delayed brittle fracture in service is a potential concern due to the possible introduction of hydrogen during the pickling operation of the hot-dip galvanizing process. Research is in progress into whether this prohibition can be repealed. If dissimilar metals must be used to accommodate the specification of these fastener grades, it may be necessary mitigate against galvanic corrosion.

Post Galvanizing Concerns

There are a few areas of concern after galvanizing to be aware of that may impact the aesthetics of the part. At times following hot-dip galvanizing, there is a need for small areas of touch-up or repair in the plant or field. Repairs are performed in accordance with ASTM A780 Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings; however, this specification does not address appearance of repair materials. Another area of concern is proper storage and handling during shipment and erection. The following sections detail specific areas of attention when maximizing appearance for AESS projects.

Repair Material Selection

In the event small voids or defects in the coating occur during the galvanizing process or damage occurs during handling of the steel after galvanizing, ASTM A780 describes three acceptable methods to touch-up or repair hot-dip galvanized coatings:

- zinc-based solder
- zinc-rich paint
- thermal spray zinc (zinc metallizing)

Should the hot-dip galvanized coating need to be repaired at the galvanizing facility or at the job site, it is possible to specify a repair method for maximum aesthetics (Figure 13). Zinc-based solders and zinc-spray metallizing more closely match the appearance of hot-dip galvanized steel, but there are limitations to applying both materials which must be considered in addition to cost.

Zinc-rich paints can economically provide suitable aesthetics if a matte gray or weathered color repair paint is utilized. Although the initial appearance may contain a mixture of matte gray paint and shiny hot-dip galvanizing, exterior AESS members will weather and more closely match the repair paint over time. The use of a shiny or silver repair paint will result in a permanent mixed appearance upon natural weathering of the galvanizing. To assist specifiers, the AGA website contains a directory of hot-dip galvanizing repair material suppliers and instructional videos on touch-up and repair.

Occasionally, cosmetic repairs are required to address aesthetic concerns where the galvanizing is not compromised and localized removal of the coating is not advised to perform a repair. In such cases, a spray-applied zinc-rich paint may be specified to provide the desired aesthetics.

Figure 13: HDG repairs using brush-applied zinc-rich paint (top), zinc-based solder (middle), and zinc thermal spray (zinc metallizing) (bottom) (C.5)

Wet Storage Stain

Galvanized AESS members should be stored in a way to minimize the occurrence of wet storage stain, known as an accumulation of white/gray powdery corrosion products on zinc coated surfaces when articles are closely packed, deprived of freely moving air, and exposed to moisture (Figure 14). Information on preventing and removing wet storage stain is available in the AGA publication Wet Storage Stain, available at galvanizeit.org/WSS.

Figure 14: Example of wet storage staining (C.9)

The presence of light or medium wet storage stain does not negatively affect the level of corrosion protection, but for aesthetic purposes and for interior AESS installed in a climate controlled area, it is possible to specify removal using commercially available cleaners and a stiff nylon bristle brush. Alternatively, light or medium wet storage stain can be left to weather upon installation in an outdoor environment where a uniform appearance can be expected within six months to two years (Figure 15).

Figure 15: Over time, the appearance of wet storage stain weathers out. The photo on the left was taken upon initial installation with medium wet storage stain present on part of the product. The photo on the right was taken fourteen weeks later upon weathering in the environment.

Transportation, Handling, and Erection

Although the hot-dip galvanized coating is very resistant to damage, rough handling often results in cosmetic damage to the outermost, malleable zinc layer in the form of scratching or markings (Figure 16 & 17). Though these markings will weather out over time, their initial appearance can be minimized by specifying the use of soft or padded slings/chains in addition to padded lifting devices and rests.

Figure 16: Additional time and labor are required to provide adequate airflow during transportation and storage, either through the addition of spacers or sheltering until the parts can be installed. These

requirements should be clearly communicated to the logistics provider (C.9).

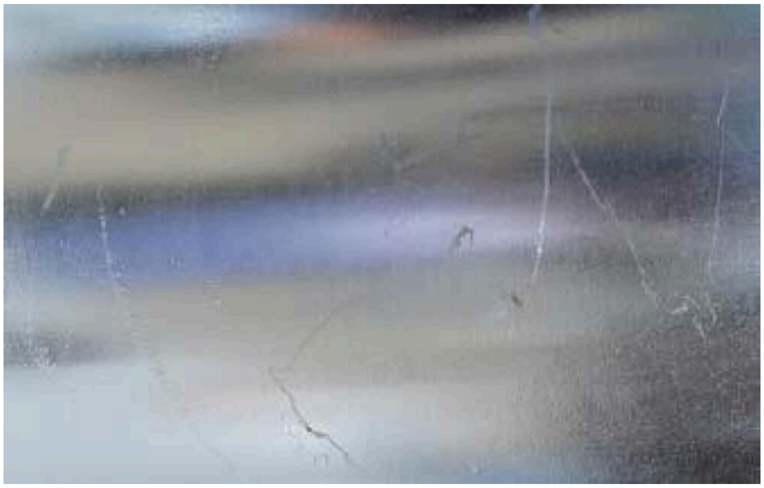
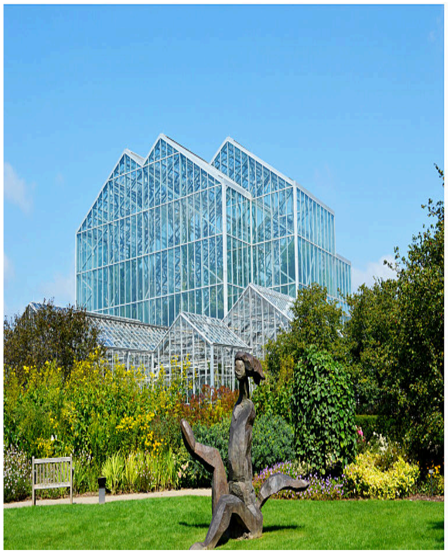


Figure 17: Light scratching of the hot-dip galvanized coating outer layer (C.6)

For bolted structural connections, regardless of joint type or tensioning requirements, the specification of washers underneath turning pieces avoids delamination or smearing of the hot-dip galvanized coating during tensioning (Figure 18).

Figure 18: Specify washers underneath the bolt head to prevent damage to the galvanized coating during bolt installation (C.4)

Summary

Frederik Meijer Botanical Garden & Sculpture Park

There are a number of factors that contribute to hot-dip galvanized steel's appearance that can lead to inconsistencies. However, it is possible to achieve high quality coatings that meet aesthetic requirements of Architecturally Exposed Structural Steel (AESS) when the designer, fabricator, and galvanizer work as a team. Clear, direct, and frequent communication as well as a detailed plan of best practices for each party will help to maximize appearance and minimize cost premiums to achieve hot-dip galvanized AESS.