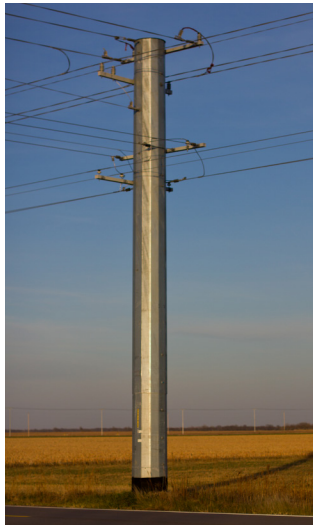
Hot-Dip Galvanized Steel vs. Weathering Steel



HDG Appearance



Stearns Bayou Bridge - Michigan
1966 - First HDG Bridge in U.S.
Picture taken 2017



HDG steel distribution pole

Hot-Dip Galvanized Steel (HDG)		Uncoated Weathering Steel (UWS)
Zinc coating applied to steel	Description	Steel alloy containing Cu, Cr, Ni, P, Si and Mn
Spangled silver/gray to Matte gray	Appearance	Deep-reddish brown to Light orange brown
3 types - barrier / cathodic / zinc patina	Corrosion Protection	Corrosion byproduct patina
0.5 - 2 years Insoluble layer of zinc carbonate	Patina Formation[1]	2 - 7 years Rust bleeding causes staining
Higher initial cost, lower life-cycle cost due to reduced maintenance and longer service life.	Cost	Lower initial cost, higher life-cycle cost due to increased maintenance and shorter service life.
Visual and/or magnetic gauge - Easily estimate remaining life (i.e. zinc thickness)	Inspection[1]	Visual - Difficult to estimate remaining life (i.e. distinguish patina from section thickness)
Considered for aesthetics or added protection Extends paint maintenance cycles by 1.5X	Painting[1,4]	Considered for aesthetics or added protection
Dependent on kettle capacity 90' L x 4' H possible in kettles 60' L x 8' D	Size Limitations[3]	None
Protected inside and out	Tubular Shapes	Trapped moisture leads to increased corrosion
	Corrosion Performance	
Easily estimated for most environments	Corrosion Rate[2]	Difficult to estimate in aggressive environments
Excellent	ISO - C1 (Very Low)[2]	Good
Excellent	ISO - C2 (Low)[2]	Good
Excellent	ISO - C3 (Medium)[2]	Fair
Good	ISO - C4 (High)[2]	Poor
Good	High Humidity/Fog[1]	Poor
Good protection of substrate steel	Road Salts[1]	Accelerated corrosion/loss of sectional thickness
Barrier coatings or concrete below grade for aggressive soils	Soil Embedment	Barrier coatings or concrete below grade for all soils
Good corrosion protection (consider proximity, sheltering, and wind direction)	Sea Coast (< 2miles)[1]	Not recommended for atmospheres with elevated humidity and chlorides.
Storage - Avoid In-Use - Little effect on corrosion	Vegetation (Dense)[1]	Storage - Avoid In-Use - Constant moisture accelerates corrosion



UWS Appearance



Moorestown Interchange - New Jersey
1964 - First UWS Bridge in the U.S.
Picture taken 2015



Weathering steel distribution pole

Notes & References

Definition

- HDG steel is produced by dipping steel in a bath of molten zinc forming a protective coating. The metallurgical reaction between iron and zinc provides both barrier and cathodic protection from corrosion. As it weathers, a zinc patina is formed to slow the corrosion rate.
- UWS has greater corrosion resistance than carbon steels due to the addition of Cu, Cr, Ni, P, Si and Mn. Its corrosion-resistance comes from the formation of a compact and well-adhering layer of corrosion products known as a patina.

History

- Hot-dip galvanizing after fabrication has been specified to combat steel corrosion in the harshest environments in various markets since the 1850s.
- UWS was first developed in the 1930s as a high strength steel, its corrosion resistant traits were later realized and has been used in various markets since the 1950s.

Appearance

- Hot-dip galvanized (HDG) steel initially exhibits a bright silver-gray appearance and then progresses within six to 24 months to a matte gray look that lasts for decades. The corrosion of zinc is slow, and the corrosion products are virtually invisible to the naked eye.
- Weathering steel will develop a dark brown, consistent patina over a three-to-five-year period. However, because the appearance often has an architecturally aesthetic purpose, it is necessary to blast or wire brush the surface in order to establish a uniform initial appearance. When exposed to moisture, the corrosion products of weathering steel bleed onto surrounding concrete and create unsightly stains.

Inspection

- HDG steel is inspected visually, and any substrate corrosion is obvious. Repairs can be made immediately to extend the life of the steel. To determine the expected life of the coating, a simple magnetic thickness measurement can be taken using inexpensive, hand-held tools to assess remaining zinc coating thickness.
- UWS is inspected visually to verify adherence, texture, and color of patina. It is difficult to distinguish between the patina that minimizes the corrosion rate of weathering steel and the voluminous rust that occurs when the weathering steel is losing significant mass. Extensive and expensive testing is required to determine if weathering steel has the design strength during the intended lifetime of the structure.

Painting

- HDG steel is painted for aesthetics or additional protection. The slow corrosion rate of zinc prevents underfilm corrosion and extends paint maintenance cycles by 1.5X, lowering life cycle cost compared with painting bare steel. HDG steel does require specific surface preparation depending on the age of the coating (See ASTM D6386 for specific preparation methods).
- UWS is painted for aesthetics or additional protection. Underfilm corrosion is not prevented. Targeted painting of steel members beneath and near joints where moisture can accumulate is recommended. Typical steel surface preparation steps can be employed to topcoat UWS.

Size Limitations

- HDG steel must be sized according to galvanizing kettle dimensions. See AGA Resources on "Progressive Dipping" to gauge maximum sizes
- UWS does not have any limitations on size.

Tubular & Hollow Shapes

- Regardless of moisture level, HDG steel provides corrosion protection both inside and out.
- Serious corrosion occurs on the inside of tubular/enclosed shapes of UWS. UWS will condense moisture inside, or design characteristics will allow moisture to enter the enclosure and accelerate corrosion.

Corrosion Rate

- Based on extensive studies of HDG steel in various, real-world atmospheric conditions for nearly a century, corrosion rates can easily be estimated. Zinc coating corrodes at 0.1 to 10 µm/year depending on environment (ISO C1 - C4). Development of the zinc patina slows corrosion over time.
- Estimating UWS corrosion is more difficult as corrosion accelerates when moisture is prevalent. Weathering steel needs a 50-50 wet/dry cycle in order to form the stable patina of tightly-bound corrosion products. UWS corrodes at 1.3 to 80 µm/year depending on environment (ISO C1 - C4). Development of the patina slows corrosion over time. Excessive moisture/humidity/salts can cause weathering steel to lose cross-sectional thickness that can compromise structural integrity. Regular inspections and subsequent washing of the steel surface can increase longevity.

High-Humidity / Fog Exposure

- HDG steel is unaffected because the stable zinc patina is unreactive.
- Weathering steel exhibits accelerated corrosion when frequent high humidity and/or fog conditions exist.

Chloride Resistance (i.e. road salts)

- The chlorides in road salts make an aggressive attack on the zinc coating of hot-dip galvanized steel; however, HDG has proven longevity for highway overpasses and guardrail exposed to road salting.
- Weathering steel is adversely affected by exposure to road salts. Corrosion rates are accelerated, and the design strength is lessened. Use thoughtfully for highway crossings with heavy road salting. Frequent inspection and washing may be required.

Sea Coast Exposure

- HDG provides good corrosion protection when taking into account proximity, sheltering, and yearly average wind direction. Use thoughtfully when < 1 mile from sea coast.
- Weathering steel performs poorly when exposed to salt air. Pitting and accelerated corrosion may compromise steel integrity. Not recommended for atmospheres with elevated humidity and chlorides.

Vegetation

- Avoid when storing HDG to prevent wet storage stain, but in-use there is little effect to the insoluble zinc patina and corrosion rate.
- Buildup of dense vegetation and organic material on and around UWS concentrates moisture and prevents UWS from drying. Constant exposure to moisture is adverse to the patina and vegetation must be regularly cleared.

References

Note: Additional HDG Steel Information can be found on galvanizeit.org with references

1 - **Corrosion Protection for Steel** - https://galvanizeit.org/hot-dip-galvanizing/why-specify-galvanizing/corrosion-protection
NSBA UWS Reference Guide - https://www.aisc.org/nsba/design-resources/uncoated-weathering-steel-reference-guide/
Weathering Steel Performance Data Collection - https://highways.dot.gov/sites/fhwa.dot.gov/files/FHWA-HRT-23-116.pdf

2 - **HDG Corrosion Rates for ISO Categories C1-C5/X**- https://galvanizeit.org/knowledgebase/article/hdg-corrosion-rates-for-iso-categories-c1-c5-x
Atmospheric Corrosivity Classifications for Weathering Steel https://www.newsteelconstruction.com/wp/atmospheric-corrosivity-classifications-for-weathering-steel

3 - **AGA Progressive Dipping Charts** - https://galvanizeit.org/pdcharts
AGA Progressive Dipping Calculator - https://galvanizeit.org/pdcalculator

4 - **Duplex Systems: Painting Over Hot-Dip Galvanized Steel** - https://galvanizeit.org/education-and-resources/publications/duplex-systems-painting-over-hot-dip-galvanized-steel-2012