



Plate

Weathering Steel: For unpainted bridges and general construction



Introduction

The rich patina of Weathering Steel is being seen more often in unpainted applications for bridges, utility and sign poles, structures and highway guardrails.

The aesthetic values of this weathered and textured material, and more importantly, the practical values of Weathering Steel make this steel particularly useful for applications where strength, ease of fabrication and appearance are paramount. This brochure provides owners, designers, structural engineers, bridge engineers and contractors important information about Weathering Steel including its use, handling, fabrication, availability, properties and specifications.

Design Considerations

Weathering Steel has a unique, natural oxide coating that when fully mature is dense, tightly adherent and relatively impervious to further atmospheric corrosion. Minor damage to this oxide coating heals itself; therefore, maintenance is greatly reduced.

Bare Weathering Steel is suitable for many atmospheric environments, including moderate industrial and select marine exposures. It is compatible with other construction materials – brick, stone and wood – when appropriate details are incorporated in the design.

Weathering Steel is available with yield strengths of 50 ksi, 70 ksi and 100 ksi allowing designs with relatively light sections. When combined with the fact little or no painting is required, Weathering Steel provides significant first cost and life cycle cost savings.

The Weathering Process

Alloy content and environmental conditions are key factors influencing the formation of an oxide film on steel. Under appropriate atmospheric conditions, Weathering steel develops a durable, tightly adherent protective oxide coating. The appearance, texture and maturity of this coating depend on three interrelated factors: time, degree of exposure and atmospheric environment.

With time, the oxide coating changes from a “rusty” red-orange to a dark purple-brown patina. The moderately rough texture becomes more distinct as the coating thickens. This weathering process extends over a period of time and depends on the following factors:

- Degree of exposure has a strong influence on the weathering process. Steel exposed to rain, sun and wind weathers more quickly than steel in a sheltered location. The oxide on a sheltered surface tends to be rougher, less dense and less uniform.

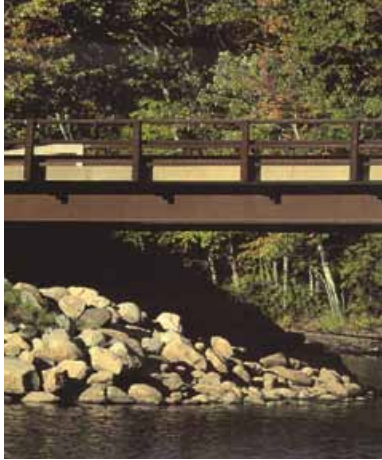


- Atmospheric environment also impacts oxide development. Frequent wet-dry cycles – for instance moisture in the form of rainfall and dew that is dried by wind and sun – are key to the weathering process.
- The degree of atmospheric contamination also has its effect. In moderate industrial environments, Weathering Steel usually matures rapidly and achieves the darkest possible tone. In rural locations, the oxide coating develops more slowly, and generally has a lighter tone. In arid climates, the weathering process is dramatically slower.

Today, corrosion engineers can use new analytical tools to identify the type of oxides formed in an environment. The presence of “good” or “bad” oxides can confirm whether the protective patina has or will be formed.

Weathering Steel has been successfully used in many applications. Growing use in bridges has resulted in over 40% of all structural steel used in bridges to be weathering steel. However, there are conditions where bare unpainted weathering steel may have problems developing a protective oxide patina. Examples of these conditions are:

- Atmospheres containing concentrated, corrosive industrial or chemical fumes
- Locations subjected to salt-water spray or salt-laden fog
- Applications where the steel is continuously submerged in water, buried in soil or installed where water run-off is contaminated with deicing salts (during winter months) or drains through leaky seals, open joints or expansion dams.
- Applications where the steel is in direct contact with timber decking. Timber retains moisture and may be treated with salt bearing preservatives.
- Bridges over enclosed highways where concentrated salt-laden road sprays under the bridge accumulate on the superstructure.



Questions also have been raised regarding the effect of acid rain on the corrosion resistance of uncoated weathering steel. Research conducted by ArcelorMittal USA laboratory indicates the effect of acid rain can be ignored. Wet deposition of sulfur dioxide, as in acid rain, actually has a beneficial effect on weathering steel because the acid rain washes away dry deposits that may increase corrosion.

Similarly, concerns regarding the effects of diesel engine exhaust gases on overhead structures have been expressed. An industry-sponsored study concluded the corrosive effect of these gases on uncoated Weathering Steel structures was negligible. The combustion products of diesel fuel, when combined with steam, are dissipated to the atmosphere. Only soot, unburned fuel and its decomposition products could be deposited on the steel, all of which are non-corrosive toward steel.



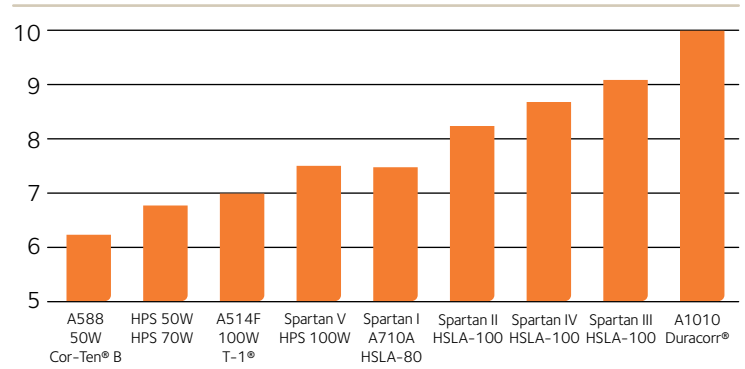
The FHWA has issued a technical advisory entitled “Uncoated Weathering Steel Structures” which provides the latest and most complete information available concerning the proper application of Weathering Steel in highway structures. Produced by the Federal Highway Administration (FHWA), ArcelorMittal USA has reprinted this advisory as Technical Bulletin TB-307, which is available upon request. This advisory applies not only to bridges, but also to all structures including light, sign and electrical distribution poles and structures. A precise evaluation of the suitability of uncoated Weathering Steel for a particular site may be obtained from a corrosion consultant and/or conducting standardized environmental tests.

In the past, long-term exposure testing of Weathering Steels indicated these steels have atmospheric corrosion resistance of approximately two times that of carbon structural steel with copper or about four times carbon structural steel without copper (copper 0.02 max.). ASTM now provides a standard guide (G101) describing more meaningful methods for estimating the atmospheric corrosion resistance of low-alloy Weathering Steels on the basis of chemical composition or alternative prediction of long-term performance on the basis of short-term data.

Weathering Steel Grades

The definition of what is a weathering steel is contained in ASTM G101. Two formulae are available for predicting performance. The most recent Townsend formula is applicable to the widest chemistry contents for structural steels. A summary of the ratings for a number of ArcelorMittal USA grades is given in the following figure:

*Weathering Steels Ranking
Townsend Weathering Index from G101*



The most popular weathering steel, ASTM A588, also known as Cor-Ten® B, is most widely used in bridges as ASTM A709 Grade 50W. New high performance steels (HPS) for bridges have predicted improved weathering performance. These grades are available as A709 Grades HPS 50W, HPS 70W and HPS 100W. U. S. Navy steels HSLA-80 and HSLA-100 produced to MIL-S-24645 and the new NAVSEA Technical Publication T9074-BD-GIB-010/0300 have significantly improved because of their high levels of copper (1.1%) and nickel (1.5 – 3.5%). They are dual certified to the ArcelorMittal USA Spartan™ family of Cu-Ni alloy steels. The 12% chromium, Duracorr®, is a utility stainless steel, which is finding applications in coal cars and coal handling equipment and most recently in bridge applications. Research is ongoing to confirm the performance of these highly alloyed improved weathering steels in short and long term testing.

Cleaning and Handling

Proper preparation of the surface of the steel by sand or grit blasting is necessary where rapid weathering and uniform appearance are desired. By removing all mill scale, the surface oxide will start forming on hot-rolled steel as it is exposed to air. This preparation is recommended especially for the highly visible exterior or fascia members of bridges.

Care should be taken while handling Weathering Steel in the field to avoid unsightly gouges and scrapes. The material should be kept as clean as possible away from mud, grease, oil, paint, concrete, mortar splatter and other foreign substances to minimize costly cleaning. Paint or crayon identification marks should be made in locations not visible on the finished structure. Otherwise, these marks must be removed from the visible surfaces during the final cleaning operation.

Storage in transit, yards or at job sites should be minimized. When storage is unavoidable, uneven weathering can be minimized by positioning the material in an exposed area with good drainage. Blocking, to avoid contact with the ground, is essential. Cover cloths also may prevent water staining and dirt accumulation, thus minimizing problems of an initial, non-uniform weathered appearance.

In general, the corrosion resistance and appearance of Weathering Steel is not affected by cleanliness. Mill scale and minor soilage will weather off naturally on exposed surfaces and need not be a concern for interior members of low visibility. However, cleanliness and surface preparation are important where an early, uniform appearance is desired.



Joining, Forming and Stiffening

Good connection, forming and stiffening details are important with Weathering Steel. Ledges, crevices and pockets that hold water, water-laden debris or condensation for an extended period time must be avoided. The oxide coating will not develop on surfaces that are continually wet or covered with debris. Under such circumstances, corrosion continues in these areas.

Welding

Weathering Steel is readily weldable by the submerged-arc, shielded metal-arc, gas metal-arc and flux-cored arc welding process. Procedures are similar to those used for other low-alloy structural steels. Low-hydrogen electrodes are specified by the American Welding Society for welding Weathering Steel. Suggestions on minimum preheat are contained in the latest revisions of ANSI/AWS "Structural Welding Code" D1.1 and the ANSI/AASHTO/AWS "Bridge Welding Code" D1.5.

For bare steel applications, when the weld is required to have strength, corrosion resistance and weathered appearance similar to that of the base metal, special electrodes must be used.

When matching strength is required, and color match and corrosion resistance are not important, E70, E80, E90, E100 or E110 low-hydrogen electrodes may be used. These electrodes also work for the underlying passes in multiple-pass welds. However, when color match and corrosion resistance are important, appropriate alloy electrodes must be used for the final two exposed top layers.

All welding should be consistent with AWS recommended procedures including adequate edge preparation and preheating, the selection of proper flux (when applicable) and the use of properly dried, low-hydrogen electrodes and fluxes.



Oxygen Cutting

Weathering Steel can be cut with conventional oxygen-gas equipment using the same general procedures for other structural steels. The workmanship requirements outlined in ANSI/AWS D1.1 and ANSI/AASHTO/AWS D1.5, Part 3 should be observed.

Mechanical Fasteners

Fasteners used to attach Weathering Steel to other materials should provide a corrosion resistance and weathered appearance comparable to the base material. High-strength structural bolts, including appropriate nuts and hardened washers, are available in Weathering Steel.

In certain circumstances, it may be desirable to use another type of fastener. For instance, galvanized fasteners have been used for highway guardrails. Whereas fundamental electrochemical and thermodynamic considerations predict a decreased life of the galvanized coating, this does not appear to be a limiting factor. Part of this success can be attributed to the thick coatings applied in hot-dip processing – typically 3 to 5 mils – giving a longer life expectancy. A light colored stain on the weathering steel, just beneath the galvanized fasteners, results from the rundown of zinc corrosion products. If appearance is critical, galvanized fasteners should not be used.

In bolted connections, the space between the two surfaces of Weathering Steel will usually seal itself with the typical tight oxide if the joint is tight and immobile. If the joint moves, both surfaces should be coated with protective material and filled with a suitable sealant to avoid progressive corrosion.

Bolt Spacing

In making a riveted, bolted or welding joint, fastener spacing should be such that the joint is tight and moisture cannot enter between the plies of material. If moisture enters the joint, corrosion may cause prying of the joint (also called “packout”) or fastener failure. AASHTO provides guidelines with respect to fastener patterns and spacing to prevent this problem.

Overlapping Surfaces

In overlapping joints, such as those common in utility distribution and high mast light poles, water can be drawn into the joint area by capillary action. This causes a breakdown of the normal oxide formation and “pack rust” forms. These joints should be sealed to prevent water intrusion or the lap area contact surfaces should be coated to prevent rust formation.



Forming and Fabricating

Weathering Steel can be fabricated with conventional equipment, tools and methods normally used for other steels with the same strength level.



Suggestions and Details for Bridges

Corrosion Control Study

Studies indicate the most important factor leading to excessive corrosion of bridges is the runoff of water contaminated with deicing salts through leaking deck seals, expansion dams or open joints. To minimize this problem, the following should be considered:

- Eliminate joints whenever possible. Jointless bridges up to 400 ft in length have been used successfully. Such designs incorporate integral abutments with piling flexible enough to accommodate girder translations. Bridges up to 1600 ft. in length with joints only at the abutments likewise have performed successfully. The combination of Weathering Steel and jointless or minimum joint decks offers owners structures of long-term durability and low maintenance cost.
- Use troughs beneath open finger-type joints as part of a system to discharge runoff away from the superstructure elements.
- Seal all other joints. Neoprene compression seals are commonly used in this application. However, experience indicates many of these do leak over time due to traffic and bridge movements.
- Recognize the potential for leakage through sealed joints and overflow from blocked troughs. Provide a second line of defense by coating the girders beneath deck joints. Typical distances for this partial painting are 1 to 1½ times the girder depth on either side of the joint.
- Control roadway drainage. Minimize scuppers to maximize flow and prevent blockage. Divert approach roadway drainage away from the bridge structure. Provide adequate drainage beneath overpass structures to prevent ponding and continual traffic spray from below.

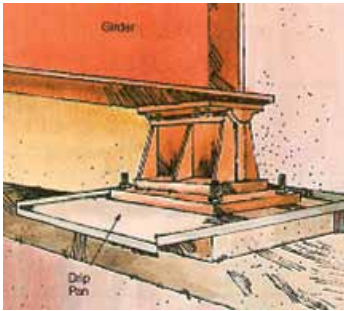
Another factor important to the success of Weathering Steel structures is the elimination of any details that prevent normal wet-dry cycles. The retention of water, dirt and other debris must be avoided and natural drainage should be designed into the structure. Tubular and box sections should be sealed or adequately vented to allow air circulation, prevent condensation and allow for drainage.

Methods of Minimize Staining

Like most steel compositions, Weathering Steel releases dissolved iron when water washes over exposed surfaces. The precipitation of the dissolved iron can cause staining on adjacent surfaces, particularly when the steel is subjected to frequent rainfall during its early months of exposure. If these adjacent surfaces are light in color and/or porous in nature, this staining may be objectionable. Although staining potential usually decreases as the oxide is formed, it may be present for an indefinite period, depending on environmental factors.

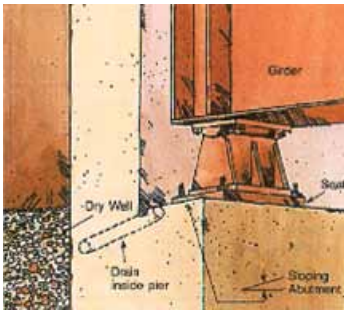
The best way to minimize staining is to incorporate permanent design details that divert water away from adjacent vulnerable materials. In bridge construction, the most severe staining occurs prior to deck placement. Designers use a number of details, and combinations thereof, to cope with staining. Temporary polyethylene coverings, gutter and downspout systems, adequate overhangs, drip plates and special flashing usually accomplish the job.

Applying liquid silicone or other type sealers is another method to reduce stain penetration into porous masonry. Some surface discoloration may occur, but may not be objectionable. These "stained" sealed coatings fade and weather off with time. Staining also can be removed by using proprietary chemical removers or, if necessary, sandblast cleaning. Caution should be exercised in using stain removers and manufacturer's recommendations should be followed.



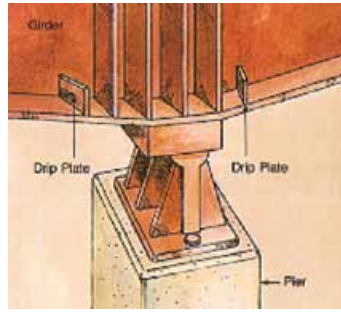
Drip Pans

In several installations, steel or fiberglass pans have been placed under the bearings and cantilevered out from the pier. These pans direct rust-laden water away from the piers to a location where major staining will not occur. However, where piers are very high, this system may permit winds to blow rust-laden water back onto the pier surface.



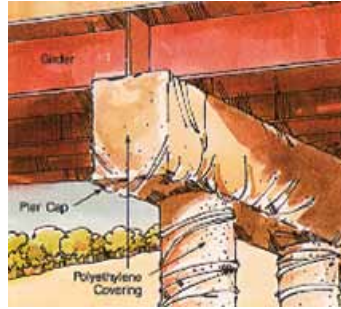
Sloping Abutments, Pier Details and Drains

On abutments and piers, various combinations of sloping and concave surfaces used in conjunction with drains provide an economical method of minimizing staining. The rust-laden runoff water is directed to areas that are not readily visible. Drains collect this water and carry it away.



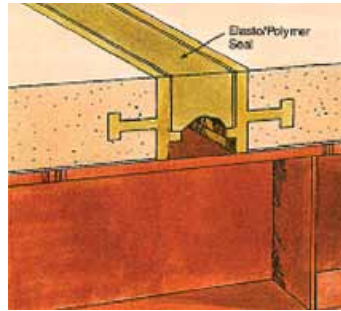
Drip Plates

A small plate attached to the bottom flange of a girder can divert water off the structure before it runs onto another bridge component.



Polyethylene Covering

One method of minimizing staining prior to deck placement is to cover the pier caps with a polyethylene sheet which will not be easily damaged by wind gusts and construction operations until the bridge deck is poured. Remove the sheet once the deck is in place and a system is installed to carry away the rust-laden water. This technique also has been used successfully with pier coatings.



Preformed Elastomeric Compression Joints

Preformed elastomeric compression joints, when installed and functioning properly, provide a thorough seal against deck surface water. These joints help prevent water from draining through and staining the substructure surfaces.

Pier Coatings

To reduce penetration by rust stain, liquid silicon sealers or other formulations can be applied to porous materials such as brick, stone and concrete. Designers using this method of protection must understand that the pier may be discolored by the treatment. Although the coating reduces stain penetration, some surface discoloration may occur because of oxide deposits. Coatings may disappear with time allowing the piers to develop a natural color.

Cleanup

Staining is not a new or unique problem for Weathering Steel. All structural materials stain. If all preventive measures fail, stained areas can be cleaned by sandblasting or use of several proprietary chemical stain removers.

Summary

Staining is most severe when Weathering Steel is subjected to prolonged rainfall during early months of exposure, and protection is most important during this initial phase. Nightly condensation is the best aging agent available and does not usually result in significant staining.

Inspection and Maintenance

Effective inspection and maintenance programs are essential to the performance of all structures, not just those built with Weathering Steel. Particular attention should be given to drainage systems on and beneath the structure and its approaches. Troughs must be kept open and sealed joints resealed. Debris and salt deposits should be periodically flushed from the structure particularly beneath joints and around the bearings. Vegetation should be cleared from pier and abutment areas to enhance air circulation and the subsequent weathering of the steel.

Fatigue

The issue of fatigue life of uncoated Weathering Steel has been addressed by the AASHTO Subcommittee on Bridges and Structures. The subcommittee concluded Weathering Steel could be considered the equivalent of painted steels in evaluating fatigue life for all AASHTO stress categories except Category A. The allowable stress ranges for Weathering Steel Category A details are noted separately by AASHTO in the current specification. Category A is essentially the base metal in either a rolled section or a plate. This is the area of the highest allowable ranges and typically does not control the design of a member.



Protective Coatings

In general, Weathering Steel is intended for and is most often used in a bare, uncoated, exposed condition. However, surfaces on which prolonged periods of moisture occur should be protected. A good quality, rust-inhibitive primer applied on cleaned material is usually adequate.

All submerged or buried members, or portions of members imbedded in concrete, soil or gravel pockets, should have an adequate protective coating like those used on carbon steel in the same environments. The protection should extend above the interface of the embedment for several inches.

Weathering Steel can be readily painted or coated as regular carbon steel. In its unweathered condition, a good wire brushing and solvent washdown is adequate to remove loose material, dirt and other contaminants before painting with a chromate oil-based paint. For synthetic resin paint (vinyl, epoxy, acrylic or alkyd) and inorganic zinc systems, blast cleaning or the equivalent is suggested.

Availability of Weathering Steel

Availability of Weathering Steel in small quantities is an important consideration. Minimum mill quantities are available, but quantities vary with the specific grade(s) required. We suggest you get in touch with the ArcelorMittal USA Plate sales office to determine minimum quantities of a product.

When developing design details, consideration also should be given to consolidation of sizes and thicknesses to overcome the problem of small quantity availability.

General Remarks

Cleaning the Steel

A clean steel surface is necessary for a more uniform weathered appearance. Mill scale and other foreign matter should be removed so that the steel surface is uniformly exposed to the atmosphere. This is particularly important if a uniform weathered appearance is desired as early as possible. The mill scale on Weathering Steel is much tighter than mill scale on ordinary carbon steels.

Removal of mill scale will require a greater effort than with plain carbon steel. Areas not cleaned properly will not oxidize in a uniform manner. The result will be a mottled appearance for several months or even years, depending upon degree of exposure and the local environment.

Cleaning is required only if the initial appearance of the steel is important. The steel's long-term corrosion properties are not affected measurably by surface preparation.

How Much is Enough?

For most applications, "Commercial Blast Cleaning" (SSPC-SP 6) is sufficient to provide somewhat uniform weathering of the fully exposed steel. "Blast Cleaning to White Metal" (SSPC-SP5) will provide a better surface than "Commercial Blast Cleaning", but will cost significantly more. "Blast Cleaning to White Metal" is not generally required and should be considered only where a high degree of uniformity is necessary during the early stages of weathering.

"Near-White Blast Cleaning" (SSPC-SP 10) provides for an intermediate level of surface preparation. This specification suggests the overall blast-cleaning should be not less than two-thirds nor more than 95% of that required to produce a white metal finish on the same surface

In some instances, it may be necessary to remove heavy coatings of oil or grease with a suitable solvent prior to the blast-cleaning operation. Removal of the oil and grease permits more efficient blast cleaning.

Additional Information

For more information please contact Alex Wilson at ArcelorMittal USA at +1 610 383 3105 or email technical questions to: alex.wilson@arcelormittal.com.

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