

## A Primer on Weathering Steel

By Bill McEleney

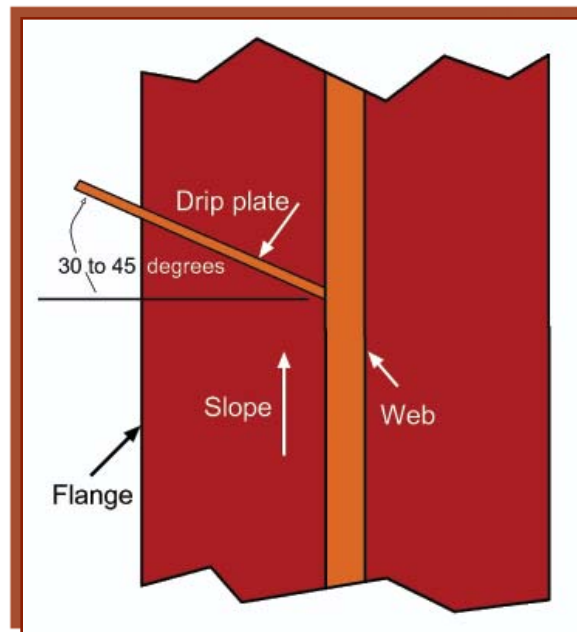
The availability of high performance steel (HPS) with 70 ksi yield strength, ASTM A709, Grade HPS-70W, has sparked renewed interest in weathering steel within the bridge marketplace. The new HPS material has weathering characteristics that are an incremental improvement over the Grade 50W material used to date. In general, weathering steels contain small amounts of copper, phosphorus, chromium, nickel, and silicon to attain their weathering properties.

### Useful Corrosion

In the past, weathering steels have been successfully applied to coal hopper cars, buildings, and electric transmission towers. They began appearing in bridges on a large scale in the mid-1960s. Currently, thousands of weathering steel bridges are in service in the U.S. Isolated misapplications of the technology gave the material a checkered reputation among many bridge engineers in the past.

However, unpainted weathering steel, properly designed and detailed, can realize bridge lifecycles up to 120 years with minimal maintenance. This high-strength, low-alloy steel forms a tightly adhering “patina” during its initial exposure to the elements. The patina is essentially an oxide film of corrosion by-products about the same thickness as a heavy coat of paint.

The initial corrosion of weathering steel depends on the presence of moisture and oxygen. But as corrosion continues, a protective barrier layer forms that greatly reduces further access to oxygen, moisture, and contaminants. This stable barrier layer greatly resists further corrosion, reducing it to a low value. Under appropriate conditions, weathering steel will generally corrode at a rate of less than 0.3 mils per year. Corrosion of conventional steels, on the other hand, forms rust layers that eventually disengage from the surface, exposing ‘fresh’ metal below, thereby continuing the corrosion cycle.



Plan view of drip plate. The plate is typically positioned at a 30 to 45 degree angle from the flange in the direction of the slope. Drawing courtesy of TxDOT.

Weathering steel bridges initially look orange-brown in color. However, the color will darken as the patina forms. In two to five years, depending on the climate, the steel will attain a dark, rich, purple-brown color that many think is attractive.

The protective patina will start to form during construction. Workers should avoid damaging the steel while it's being stored or handled. Otherwise, the weathering steel will appear mottled until the patina reforms to match the undamaged areas. If the beam ends are unpainted, constructors should wrap piers and abutments to protect them from staining.

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Texas Loop 360 Bridge (Pennybacker Bridge) taken from Lake Austin level. TxDOT photo.

## Benefits of Weathering Steels

Bridges constructed of weathering steel in suitable environments, and with proper detailing, have all the qualities of conventional steel, plus they offer the following benefits.

- Initial cost savings compared to conventional painted alternatives.
- Low maintenance consisting of periodic inspection and cleaning, which reduces direct operating costs.
- Minimal indirect costs from traffic delays for major maintenance operations.
- Faster construction resulting from elimination of shop and field painting.
- Good aesthetics, since weathering steel bridges eventually achieve an attractive dark brown color that blends well with the environment and improves with age.
- Low impact on the environment, compared to painted alternatives that emit undesirable volatile organic compounds (VOCs).
- Minimal health and safety issues relating to initial and future painting.
- A good track record for long-term performance based on various state and federal studies.



*Detail of support, Interstate 35 at U.S. Highway 290 in Austin, Texas, July 2005. Photo by Stan A. Williams, TxDOT.*

## Locating Weathering Steel Bridges

Several factors can impact the satisfactory performance of weathering steel. Experience has shown, for example, weathering steel requires alternating cycles of wet and dry conditions to form a tightly adhering protective layer. This would generally rule out areas of high rainfall and humidity, or persistent fog. Extreme marine conditions, the presence of roadway de-icing salts, pollution, surrounding vegetation, and “tunnel-like” conditions can also lead to unsatisfactory performance, as can poor detailing and maintenance.

Bridge engineers should avoid specifying weathering steel that will be exposed to sea water spray, salt fogs, and immediate coastal salt environments. The reason: salt film deposited on the metal surface, being hygroscopic, tends to maintain continuously damp conditions, preventing the formation of a proper patina.

Heavy use of de-icing salts over and under weathering steel bridges may cause problems. For example, salt-laden runoff that flows through leaking expansion joints and directly over the steel has been identified as a cause of poor weathering steel performance.

In all probability bridge expansion joints will eventually leak, so many states recommend painting the steel beam ends to a length 1.5 times the girder depth. Painting the ends also eliminates staining of the concrete piers below the joints. Fabricators and erectors should avoid marking

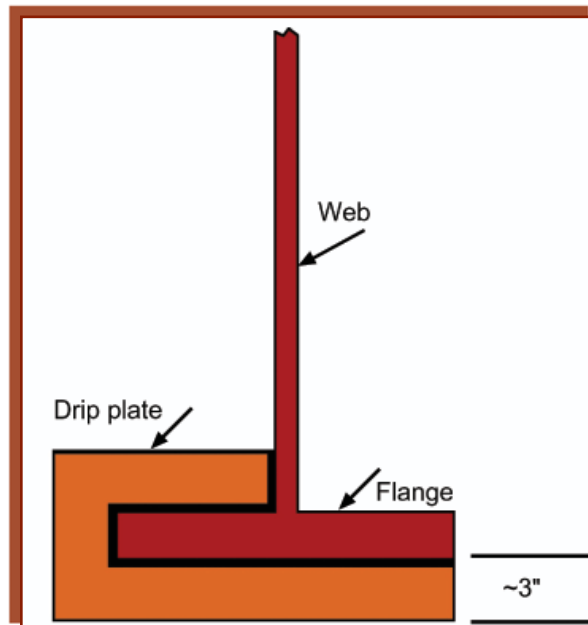


*Interstate 35 at U.S. Highway 290, Austin, Texas, July 2005. Photo by Stan A. Williams, TxDOT.*

blasted steel with paint, crayons, or wax, which will interfere with the forming of the desired patina. Painted ends, plus the requirement to shop blast mill scale from the weathering steel to promote a uniform patina, tend to reduce initial cost savings compared to painted steel.

Tunnel-like conditions result from a combination of a narrow road with minimum shoulders between vertical retaining walls, or a wide bridge with minimum headroom and full-height abutments. Such situations may be encountered at urban or suburban grade separations. In these cases, the lack of air currents to dispel roadway spray lead to excessive salt deposits on the bridge girders.

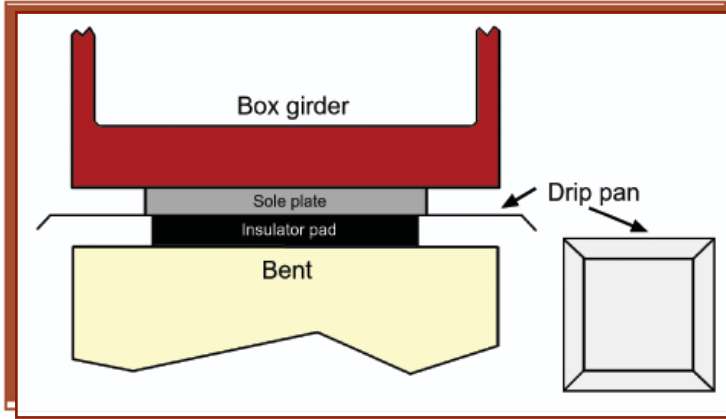
In addition, weathering steel bridges should not be located where ambient atmospheres contain high concentrations of pollution and industrial fumes, especially sulfur dioxide. But moderate industrial environments typically speed the weathering process and more quickly achieve the mature dark color.



*A drip plate diverts water from the steel girder before it runs onto another bridge component, such as a bearing pad or concrete pier. It consists of a small J-shaped plate slipped over the bottom flange of a girder. The plate is welded to both the top and bottom surfaces of the bottom flange and to the girder web. It typically has a 3-inch vertical profile above and below the flange. Drawing courtesy of TxDOT*



## Joining Weathering Steels



Drip pan helps to minimize staining of concrete bent below box girder made of weathering steel. The pan, typically about 1/8-inch stainless steel, should extend 4 to 6 inches beyond the sides of the bent. Drawing courtesy of TxDOT.

Weathering steels generally have higher carbon equivalent values (CEVs) than conventional steels. The higher CEVs can increase the possibility of hydrogen-induced cracking of welds. Proper preheating of the welds, however, eliminates this possibility.

Welders can use conventional electrodes for the body of multi-pass welds, but should switch to electrodes of a weathering composition matching the base metal to cap multi-pass welds. Conventional electrodes are also suitable for single pass welds because the melted base metal will sufficiently infuse the weld metal with the alloying elements and provide required corrosion behavior. Continuous welds are preferable since they avoid moisture traps.

Designers should specify weathering grade bolts, nuts and washers for joining weathering steel components. Tightening techniques should avoid load-indicating washers, as they are not typically available in weathering grades. Bolted connections inevitably result in crevices that can trap moisture. If detailing is such that close fit-ups are difficult, the joint should be sealed.

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## Wet/Dry Cycles

Detailing of weathering steel bridges must promote the wet/dry cycles necessary to form the protective patina and to avoid salt de-posits on the girders. In general, the detailing should permit all parts of the steelwork to dry, avoid moisture and debris retention, and promote adequate ventilation.

For example, designers should avoid closely spaced girders that inhibit ventilation. They should also avoid, or seal, overlaps and crevices that may attract moisture via capillary action. Drainage below an overpass should prevent ponding of water, which will otherwise result in continuous traffic spray.

What follows are recommendations on detailing based on those outlined in the FHWA Technical Advisory T-5140.22 (October 1989), *Uncoated Weathering Steel in Structures*.

- Eliminate bridge joints where possible through use of continuous girders and integral abutments.
- Control water on the deck near the expansion joints deck. Consider the use of a trough under the deck joint to divert water away from vulnerable elements.
- Paint all superstructure steel within a distance of 1½ times the depth of girder from bridge joints.
- Locate welded drip bars in areas of low stress.
- Minimize the number of bridge deck scuppers (holes cut near the edge of a deck to drain water below.) Fewer scuppers result in a higher amount of flow through each, minimizing the chance for blockage.
- Eliminate geometries that serve as water and debris "traps".
- "Hermetically seal" box members when possible, or provide weep holes to allow proper drainage and circulation of air.
- Cover or screen all openings in boxes that are not sealed.
- Consider protecting pier caps and abutment walls with drip pans and plates to minimize staining.



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## Inspection and Maintenance

The patina surface generally represents a good sign of performance. Laminations and flaking are bad signs, but a fine-grained adherent layer indicates expected weathering performance. Inspectors should specifically look for leaking expansion joints, blocked drains, build-ups of debris and other moisture traps, sealant failure, and bulging joints and overlaps.

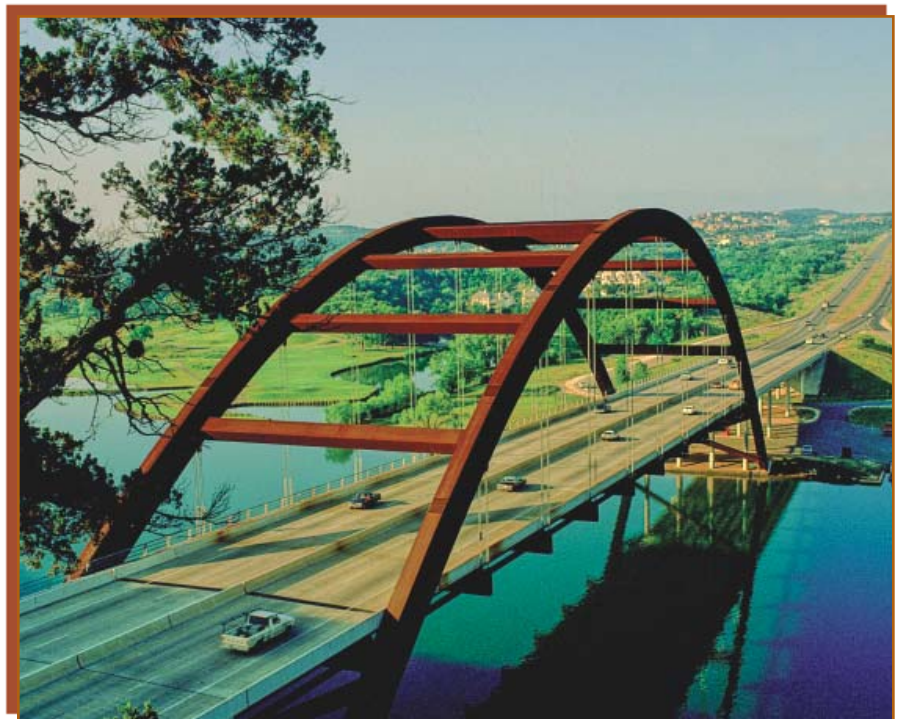
Of course, if inspectors discover any of the above conditions, appropriate maintenance should follow. In addition, TxDOT recommends periodic measures to:

- Flush debris, dirt, and bird and bat droppings from the bridge structure.
- Clear vegetation from pier and abutment areas to enhance air circulation.
- Reseal deteriorating joints.
- Unblock drains and troughs.

## Summary

Weathering steel bridges can save both initial and long-term maintenance costs compared to painted bridges. Many consider the rich brown color they ultimately attain attractive. Awareness of the climatic conditions, detailing, and maintenance necessary for formation of the protective patina will help ensure a successful application of the technology.■

*Bill McEleney is a Regional Director for the National Steel Bridge Alliance (NSBA), representing the steel bridge fabricating industry on matters of steel bridge fabrication and construction.*



*Texas Loop 360 bridge (Pennybacker Bridge) taken from hillside above the bridge. TxDOT photo.*

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