WEATHERING STEEL FOR HIGHWAY BRIDGES

By addressing corrosion concerns, weathering steel offers a sustainable and aesthetic solution for designers and owners.

BY ALEX WILSON AND BRIAN RAFF

APPROXIMATELY 40-45% of all steel bridges today are being built with some form of weathering steel. Weathering steel is typically a high-strength, low-alloy steel that, in suitable environments, forms a tightly adherent protective rust "patina" that acts as a skin to prevent further corrosion to the steel beneath. Since its development in the 1930s, many U.S. steel producers have offered corrosion-resistant, weathering steels as part of their product lines.

Current weathering steels are supported by the American Association of State Highway and Transportation Officials (AASHTO) Specification M270, which corresponds with ASTM A709, and can be acquired in grades 50W, HPS70W, and HPS100W where these numbers correspond to each grade's yield strength in ksi. A new generation of high-performance steel (those grades prefixed with HPS) provides weathering performance with a slightly greater resistance to atmospheric corrosion than its predecessors.

Tips to Ensure Success

Detailing: As with bridges built of any material, the performance of the structure often is controlled by the types of details used. Details for weathering steel bridges must be such that they will not trap water. If weathering steel remains wet more than 60% of the time—regardless of the cause of wetness—it will not perform as intended. Because it can be difficult and costly to prevent debris (e.g., pigeon nests) from building up on horizontal bridge components, it is imperative that bridge inspectors brush off this debris during their biennial inspections. This simple act will prevent the debris from holding moisture in contact with the steel, thus ensuring long-term performance.

Marine Environment Applications: The FHWA Technical Advisory 5140.22, "Uncoated Weathering Steel in Structures," (www.fhwa.dot.gov/bridge/t514022.cfm) provides guidance with regard to proper environment, location, design details and maintenance of weathering steel. It recommends the use of a "wet candle" test method to determine the level of airborne salts, with a limit above which the FHWA advises "caution." However, this test is very time consuming. A more practical approach is to evaluate performance of other types of steel structures in the general area of the proposed structures, and if excessive corrosion is not observed, then weathering steel will perform successfully. Chemical analysis by a corrosion specialist of the oxides/rust formed on other weathering steel structures in the vicinity of the location in question is also another technique to judge applicability. Since the mid-1970s, weathering steel has been performing well in applications literally within a few feet of bodies of salt water. Performance on these structures is more than adequate, and this performance level is expected to continue.

High Rainfall, Humidity or Fog: As with the performance of weathering steel when details trap water, if the environment is such that the steel will remain wet more than 60% of the time, then it will not perform as intended. An example of where the use of weathering steel is inappropriate is in the northwest U.S., where rainfall approaches 200 in. per year. However, in areas subjected to annual rainfall of even as much as 100 in. per year—and in areas with high humidity—structures with uncoated weathering steel are providing excellent performance

Alexander D. Wilson is chair of the Steel Marketing Development Institute's Steel Bridge Task Force and very active with NSBA members. He has been influential in the development of bridge material specifications and was influential in the development of the latest high-performance steel (HPS70W). He has been this generation's key resource for metallurgical information on steel bridges. Brian Raff is marketing director for the National Steel Bridge Alliance and is responsible for providing strategic leadership and executing the national marketing program that builds market share for steel bridges.

even after many years in service. The key is to provide an environment with a consistent wet/dry cycle because moisture activates the corrosion process, but the oxide layer obtains its nonporous state in its drying state. The faster the wet and dry states cycle, the more consistent and even the patina will be.

In both marine environments and those with high rainfall, humidity, or fog, a more in-depth evaluation can be made by following the wet candle method from ASTM G92, Characterization of Atmospheric Test Sites, and using ASTM G84, *Measurement of Time-of-Wetness on Surfaces Exposed to Wetting Conditions as in Atmospheric Corrosion Testing*, or by consulting with a corrosion specialist.

Bridge Joints: Regardless of the type of material used in the superstructure, a main cause of structure deterioration is the poor performance of bridge joints. The FHWA Technical Advisory referenced above also recommends use of "jointless" bridges wherever possible as a cure to this ever-present problem. Weathering steel used in conjunction with jointless bridge design has performed well. Integral and semi-integral abutments, in addition to just extending the deck slab over the abutment backwall, are ways to achieve the benefits of jointless bridges. Further guidance and details are available in "Performance of Weathering Steel in Highway Bridges—A Third Phase Report," available on the AISI website (**www.steel.org**) at **http://bit.ly/xuN5rO**. Where joints must be used, properly detailed troughs under all types of bridge joints must be used to ensure long-term protection.

Staining of Substructures: When weathering steel is directly exposed to rainfall—either temporarily during construction or permanently due to bridge detailing—concrete elements below will be stained by the rust-colored water that runs off. This problem is prevented during construction by simple and inexpensive techniques that include wrapping the substructure units with plastic until the deck slab is placed, precoating the concrete surfaces with a sealer, or requiring the stains to be removed by blast cleaning after construction. For areas where the steel is permanently exposed, detailing the tops of the substructure to channel the staining water into grooves in the concrete surface has been used successfully. This provides a streaked appearance that actually enhances the otherwise rather bland color of the concrete wall. Should staining occur that needs to be removed, there are commercial products available that are very successful in removing the stains.

Fatigue Cracking: State-of-the-art designs of steel structures, including those built with weathering steel, should be immune from the fatigue cracking that may occur on older structures that were built before a full understanding of the phenomenon emerged. However, sometimes a detail that is fatigue-sensitive still shows up on a newer bridge. Therefore, inspectors must be continually vigilant to ensure that fatigue cracks are discovered before they reach the point at which unstable crack growth can occur. Fatigue cracks in weathering steel are readily apparent because they exude an orange dust that contrasts with the deep brown color of the steel itself. These cracks may even be more

Ironworkers prepare to field splice the plate girders on the West Virgina approach to the Blennerhassett Island Bridge, which used high-strength, high-performance 70 ksi weathering steel for maximum durability and improved ductility.

Where appearance dictates a painted bridge, painting only the fascia side of exterior girders will provide most of the cost benefits of weathering steel while still satisfying aesthetic requirements.

The color of the weathering steel changes during the first few years as the protective patina is forming.

visible than ones that occur in painted structures.

Painting: The FHWA strongly recommends that the ends of beams and girders under bridge joints be painted for a minimum distance to protect against the certainty of joint leakage. The paint system used for weathering steel should be high-quality paint as would be used for any other steel bridge. Where the painted surface is exposed to view, the color of the paint should match the color of the "weathered" steel. Note that this color changes during the first several years of service as the protective patina forms on the steel. One recommended specification to achieve this is Federal Color number 30045. In some instances, aesthetic needs require a painted bridge. To provide most of the cost benefits of weathering steel while still satisfying aesthetic requirements, only the fascia side of exterior girders need be painted. For structures built with joints, and for those built before the FHWA Technical Advisory was issued with its recommendation to paint the steel below the joint, it may be necessary to paint steel that has been contaminated with the saltwater coming through the joint. Recommended paint systems for this application are included in the FHWA Research Report RD-92-055, *Maintenance Coating of Weathering Steel: Field Evaluation and Guidelines*, available online in the National Transportation Library, Bureau of Transportation Statistics, at **http://1.usa.gov/zPCjiK**.

Improvements and Research

The Federal Highway Administration (FHWA) is making an effort to develop a deeper understanding of weathering steel bridge performance and to provide more detailed guidance on proper application. Research is under way involving 3D numerical simulations of truck passage events at bridges using computation fluid dynamics (CFD) to quantify the amount of salt spray that is deposited on the girders and how this might be influenced by various geometric parameters. Also, FHWA has plans to perform a national study of weathering steel bridge performance in various micro and macro environments. These efforts will provide data for improving the guidance by better definition of "tunnel-like conditions" and/or "coastal environments" to name a few. FHWA is working with the American Iron and Steel Institute (AISI) Corrosion Advisory Group on other projects as well.

Engineers have expressed concern with section loss as part of the weathering process. However, the order of section loss expected to establish the protective patina amounts to around 100 mils (0.1 in.), a negligible amount when assessing structural performance. It is also important to keep in mind that because rolling tolerances generally result in a greater thickness than specified, even after many years in service, a weathering steel bridge will usually have a greater thickness than required by the origin design.

When excessive section loss does actually occur, it is very obvious and is in the form of "laminar" rusting of the surface. This occurs primarily under the all-too-common leaking bridge joints when deicing chemicals are used on the roadway above. Wherever laminar rusting is observed, it is imperative to locate the source of the corroding water, and if possible, seal it off. If it is not possible, then spot coating of the affected area may be necessary (see painting tips below).

Additional Resources

Much more information is available to assist those concerned with the use of weathering steel in highway bridges. Here are three recent publications that can be particularly helpful.

- "Uncoated Weathering Steel in Structures", FHWA Technical Advisory 5140.22, October 1989, **http://1.usa.gov/yhP3je**.
- "Improved Corrosion-Resistant Steel for Highway Bridge Construction Knowledge-Based Design," FHWA Tech-Brief, August 2009, **http://1.usa.gov/A8ddO3**.
- "Steel Plate Availability for Highway Bridges," *Modern Steel Construction*, September 2011, **http://bit.ly/wSVrqp**.
- "Weathering Steel: For unpainted bridges and general construction," ArcelorMittal USA, December 2012, **http://bit.ly/wNdMza**. MSC

This is the first in a series of updates to the Bridge Crossings columns originally published in MSC *beginning in 1996. The authors would like to acknowledge Robert L. Nickerson, P.E., who wrote the original column on this topic.*

The National Steel Bridge Alliance was formed in 1995 to enhance the design and construction of domestic steel bridges. A division of the American Institute of Steel Construction, NSBA assists fabricators, designers and owners in making the best design selections possible, while also establishing steel as the material of choice for bridges. Beyond our membership, NSBA brings together the agencies and groups who have a stake in the success of steel bridge construction, including representatives from AASHTO, FHWA, state DOTs, bridge consultants, and representatives of the coatings, fastener and welding industries. From more information, go to **www.steelbridges.org**.