Corrosion Protection and Connection Design

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Choosing which protection system to employ affects how you should design the connections.

THERE ARE A NUMBER of methods that can be used to protect structural steel from corrosive environments. As they are evaluated, designers must consider that the choice of corrosion protection system affects the best practices that should be followed in designing and detailing the connections for that structure. The difficulty is that a good practice for use with one system may cause problems if used with a different system.

Understanding the fundamentals will help engineers and detailers make the right choices in connection design and detailing. Good choices lead to economical and effective connections, while bad choices can lead to expensive connections that are ineffective in protecting against corrosion. The following article provides a brief overview of considerations for connections as they relate to three popular corrosion protection systems.

The Basics

Good corrosion protection design involves the proper selection of the protection system for the project's environment. Factors that impact this selection include the intended service life of the structure, severity of environmental exposure, cost of both the initial application and future renewals, owner's preference, and compatibility of the various components comprising the corrosion protection system. However, no method can overcome the effects of a design that does not consider corrosion and eliminate the details that are known to be troublesome.

Structural steel details that trap water and/or chemicals will suffer corrosion issues regardless of the corrosion protection method employed. Care must be taken to detail connections in corrosive environments to avoid crevices and gaps where water and/or chemicals can collect. See Chapter 1.2 of *Good Painting Practice*, *SSPC Painting Manual Vol. 1*, for more detailed information.

In addition, care must be taken by the designer to review the specification of materials used in the connection. There are instances where corrosive reactions can occur where two dissimilar metals come in contact. The reactions can cause corrosion or can increase the rate of corrosion for exposed elements. Typically the structural steel materials listed in Chapter A of the AISC *Specification* (ANSI/AISC 360-10) will not have increased corrosion due to contact of the connection materials. Table 2-6 of the 13th Edition AISC *Steel Construction Manual* contains an overview of the reactions of dissimilar metals in contact, and gives guidance about which combinations are the most suitable for structural steel. One method for avoiding corrosion of dissimilar metals is to put the contact surfaces of the dissimilar metals in a dry location so electrolytes will not be present in the contact areas. More information about the use of dissimilar metals is available in the commentary of AWS D1.6, *Structural Welding Code—Stainless Steel*.

Structural steel used in interior applications usually does not need corrosion protection but it may be painted for other reasons, such as aesthetics. Extra precaution to prevent crevices is not necessary in these controlled-climate conditions.

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Coated Steel—Painted

One of the most popular methods of protecting structural steel is painting the steel.

Connections using bolts in bearing may have the faying surfaces for the connection painted or unpainted prior to erection of the steel. Typically the faying surfaces of connections assembled at the fabrication shop are left unpainted to prevent the need to prepare and paint the members and parts prior to assembly. Bolted connections completed in

the field are often painted, eliminating the need to mask the faying surface.

For slip-critical bolted connections the faying surfaces of the connections may be clean mill scale or coated with a coating tested using Appendix A of the 2009 RCSC *Specification for Structural Joints Using High-Strength Bolts* (the RCSC *Specification*). Connections assembled at the fabrication shop that are required to be slip critical are rare; however, when they do occur the fabricator typically will use clean mill scale to avoid the cost of pre-blasting and pre-painting the members and parts. Slip-critical connections assembled in the field often are shipped with the faying surfaces painted with a primer. The zinc-rich paints often used for structural steel primers are typically qualified as Class B surfaces.

For welded connections of painted structural steel, the designer must be aware of both quality and safety considerations. If welding occurs prior to painting the steel at the fabrication shop, this means ensuring that the weld area is properly clear of slag and is clean of smoke residue from the welding process prior to painting. Solvent cleaning is defined in the standard SSPC-SP1 *Solvent Cleaning* and is a requirement of any of the other common surface preparation standards. When welding is to occur in the field, the connection may be masked from primer and top coat painting of the members at the fabrication shop, and the connection will be primed and painted after welding is performed in the field.

Welding can be completed through some paint systems; however, caution should be taken if this is to occur. Some paints interfere with the welding process causing undesirable results, and fumes from welding on some paints can be unsafe for the welder. If welding is to be performed on a painted surface, the procedure should be evaluated and the welder should be protected as directed by a safety professional. A better practice is to remove the paint by grinding prior to welding. In this case the welder still needs appropriate respiratory protection, and in both cases the joint will have to be touched up with paint after the weld is complete.

Coated Steel — Galvanized

Galvanizing structural steel is another popular method used to protect the steel. During the galvanizing process, the steel is immersed in pickling acid, flux and finally in molten zinc. Flux, acid, or water that is trapped in crevices or pockets in the steel assembly will weep from the galvanized product and can cause potentially dangerous pressure in the zinc bath. ASTM A385 and similar literature available from the American Galvanizers Association (**www.galvanizeit.org**) give guidance on how to avoid these problems. Common recommended procedures to avoid the build up of pressure are to either seal the liquids out of crevices and pockets or provide vent holes in the steel assembly to permit liquids to drain.

Seal welding will require variances from the provisions in AWS D1.1 *Structural Welding Code—Steel*. Variances to the welding provisions should be clear, understood, and accepted prior to fabrication of the steel to prevent conflicts during production. The article "Use Caution When Specifying 'Seal Welds,'" by Duane Miller, provides good guidance on the variances required for seal welding.

For bolted connections, whether bearing or slip-critical, the elements are individually galvanized and then assembled. The galvanizer will simply ensure that the bolt holes are not blocked with excessive amounts of zinc. The faying surfaces of galvanized slip-critical connections are then roughened prior to assembly. Roughening is done with a hand wire brush that leaves visible marks on the structural steel. Power wire brushing of the steel is not permitted by RCSC.

Unlike painted connections there is no common way to mask the area where welding is to occur to ensure that this area of is free of the zinc coating after galvanizing has occurred. Therefore, if welding is to occur in the field, the typical procedure is to galvanize the steel and remove the zinc coating from the area of the weld in the field by grinding. Welding may occur over the zinc coating; however, care should be taken to ensure cracking problems in the weld do not occur and the welder is properly protected.

Weathering Steel

The use of weathering steel is a popular outdoor corrosion protection method. With weathering steel, a protective patina forms on the surface of the steel that prevents corrosion. Weathering steel works well in most environmental conditions. However, it is not as effective in areas of aggressive chemistry, in tunnel like conditions (constant moisture in the air), immersed water conditions (consistently wet), and routine salt environments (coastal conditions).

Jacinda Collins

▲ This photo provides an example of two popular corrosion protection systems—painting and the use of weathering steel.

With weathering steel all of the elements can be blasted to provide an immediately consistent finish for all of the components. Blasting is not required if a period of inconsistent color is acceptable early in the life of the exposed structure. The weathering steel will then continue to form the patina and change color during and after erection of the structure.

Fastener components for connections of weathering steel are designated Type 3. Type 3 bolts, nuts, and washers should be specified for weathering steel bolted connections (e.g. ASTM A325 Type 3 bolt, with ASTM A563-C3 nut and ASTM F436 Type 3 washer).

AWS D1.1 Clause 3.7.3 provides for welds that have weathering characteristics or color matching. Alloy fillers are also available that will provide weathering properties similar to the weathering steel. Single-pass welds may not need the alloy filler because intermixing of alloy content from the base metal (weathering steel) has been shown to sufficiently protect single-pass welds. MSC

Resources

A number of resources are available not only for helping to select a corrosion protection system, but also to determine the impacts of the scheme on the design and detailing of the connections. The following were used in the creation of this article.

Specifications

ANSI/AISC 360-10, *Specification for Structural Steel Buildings* (available as a free download at **www.aisc.org/freepubs**)

2009 *Specification for Structural Joints Using High-Strength Bolts* (available as a free download at **www.boltcouncil.org**)

AWS D1.1/1.1M, 2010 *Structural Welding Code—Steel* (available for purchase at **www.awspubs.com**)

Websites

AISC Steel Solutions Center: **www.asic.org/ssc**

American Galvanizers Association: **www.galvanizeit.org**

American Institute of Steel Construction: **www.aisc.org**

American Welding Society: **www.aws.org**

The James F. Lincoln Arc Welding Foundation: **www.jflf.org**

Research Council on Structural Connections: **www.boltcouncil.org**

Publications

13th Edition AISC *Steel Construction Manual,* (available for purchase at **www.aisc.org/manual**)

AISC *Steel Design Guide 17, High-Strength Bolts—A Primer for Structural Engineers* (all AISC Steel Design Guides are available as free downloads for AISC members and for purchase by non-members at **www.aisc.org/dg**)

AISC *Steel Design Guide 21, Welded Connections—A Primer for Engineers*

AISC *Steel Design Guide 23, Constructability of Structural Steel Buildings*

Detailing for Steel Construction. 3rd Edition (available for purchase at **www.aisc.org/manual**)

Good Painting Practice, SSPC *Painting Manual Volume 1* (available for purchase at **www.sspc.org**)

Selected ASTM Standards for Structural Steel Fabrication (2011) (available for purchase at **www.aisc.org/astm**)

"Use Caution When Specifying 'Seal Welds,'" by Duane K. Miller, *Welding Innovation*, Vol. XVI, No. 2, 1999 (available online at **www.jflf.org/papers**)