Digging Through the Rubble

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The Northridge earthquake changed the way we weld, and a little guidance is helpful in navigating the current applicable welding requirements for seismic projects.

DISASTERS, NATURAL OR OTHERWISE, are well known for being catalysts for change in thinking and practice.

The 1994 Northridge (California) earthquake, for example, sparked more than 10 years of research and development in the field of high-seismic structural engineering and steel fabrication. In 1995 the SAC Joint Venture received funding through the Federal Emergency Management Agency (FEMA) to address both immediate and long-term needs to improve the seismic performance of welded, steel moment frame connections. The project culminated in several publications, including FEMA 350 and FEMA 353. As a result of this research, structural engineers are now equipped with better seismic design procedures.

In order to put this FEMA material into consensus codes and keep it up to date, AISC incorporated design provisions into the AISC *Seismic Provisions for Structural Steel Buildings* (AISC 341-05), and the American Welding Society (AWS) generated AWS D1.8 *Structural Welding Code—Seismic Supplement* (AWS D1.8). These documents supplement the standard specification for buildings and include much of the information presented in the FEMA documents as well as corresponding updated seismic requirements.

At the time that AISC released AISC 341-05, AWS had not yet released AWS D1.8. Thus, AISC 341-05 does not formally recognize AWS D1.8. Instead, Appendices W and X were included in AISC 341-05 to cover the seismic welding requirements, with the stipulation that these appendices were included on "an interim basis pending adoption of such criteria by AWS or other accredited organization." The 2010 AISC *Seismic Provisions* will not include Appendices X and W. Instead, it will simply reference AWS D1.8.

Testing requirements for qualification of connections and provisions for the prequalification of seismic connections are provided in Appendices S and P of AISC 341-05. AISC also assembled the Connection Prequalification Review Panel (CPRP), the committee responsible for prequalifying special moment frame (SMF) and intermediate moment frame (IMF) connections. The CPRP publishes and maintains AISC *Prequalified Connections for Special and Intermediate Moment Frames for Seismic Applications* (AISC 358-05), which specifies the design, detailing, fabrication, and quality criteria for prequalified connections for use with SMFs and IMFs.

Navigating the Resources

With the near nationwide adoption of the International Building Code (IBC), seismic design requirements now apply in almost all jurisdictions. Even today, some engineers and fabricators may be required to navigate through the seismic provisions for the first time in their careers. So, we've provided some guidelines on where to turn for more detailed information on the topic.

Because AISC and AWS have incorporated and built upon the FEMA documents in their current specifications, today there is no need to reference or specify the FEMA documents for requirements for steel construction projects. Specifying the current AISC and AWS documents in the contract documents is all that need be done.

For high-seismic applications (anytime the seismic framing is designed with an *R* other than 3), not only does the engineer need to design in accordance with AISC *Specification for Structural Steel Buildings* (AISC 360-05) and AWS D1.1 *Structural Welding Code—Steel* (AWS D1.1), but he/she also needs to meet the requirements of their seismic counterparts AISC 341-05 and AWS D1.8. When prequalified moment connections are to be used, the engineer can make use of AISC 358-05.

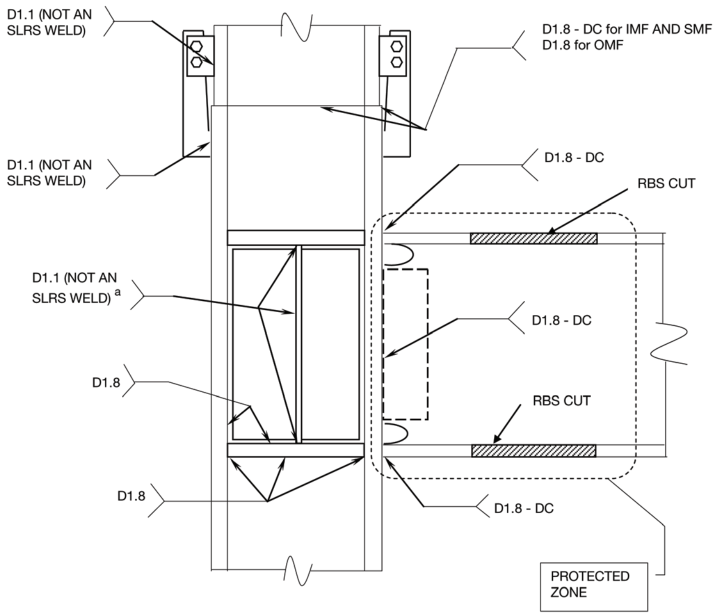
Another helpful resource for welding design is AISC Design Guide 21 *Welded Connections—A Primer for Engineers*; for seismic weld information, Chapter 10 "Seismic Welding Issues" is particularly helpful.

Three Welds

1. Non-seismic welds include all welds in a building where the lateral force resisting system is not specifically detailed for seismic resistance (referred to as non-seismic applications for the purposes of this article)—i.e., buildings designed with *R* = 3 in accordance with ASCE 7-05. In addition, welds that are not part of the seismic framing in buildings designed with *R* other than 3 are considered non-seismic welds. The design of non-seismic welds is subject to the requirements of AISC 360-05 and AWS D1.1.

2. Seismic welds include all welds that are part of the seismic framing in buildings specifically detailed for seismic resistance—i.e., buildings designed with *R* other than 3. AISC 341-05 and AWS D1.8 provide supplemental provisions for the design of seismic welds.

3. Demand-critical welds are seismic welds in the seismic framing that have been determined and specified by the engineer as demand-critical in the contract documents. Demand-critical welds generally are those that are subject to yield-level strains. The failure of a demand-critical joint would result in significant degradation in the strength and stiffness of the seismic framing. Demand-critical welds have additional require-



a As shown, the member connecting to the weak axis is not an SLRS member.

Notes:

- D1.8 - DC indicates welds commonly designated demand critical joints.
- D1.8 indicates joints subject to the requirements of D1.8, but not commonly designated demand critical welds.
- D1.1 indicates joints subject to the requirements of D1.1 only.

Figure 1 – Example RBS/Column Strong Axis Connection (AWS D1.8 Figure C-1.1, p. 58)

ments, such as the use of filler metals with heat input envelope tests and others as specified in AISC 341-05 and AWS D1.8.

The locations of demand-critical welds are described in general terms (i.e., conditions applicable in all cases) in Section 7.3b of AISC 341-05, and AISC 358-05 provides specific additional demand-critical joint locations for the prequalified connections. For example, in SMFs, typical examples of demand critical welds include the following cases when complete joint penetration (CJP) groove welds are used: beam flanges and beam webs to columns, single-plate shear connections where the beam web is not welded to the column, and column splices and bases. In addition to those that are established in the provisions as demand-critical welds, other similar welds included in the seismic framing should be considered and evaluated for demand-critical status, based upon the inelastic strain demand on the weld and the consequence of failure of the weld (AISC 341-05 Section 7.3b).

Following are some of the additional design and fabrication issues for the latter two groups of welds—seismic welds and demand-critical welds. Figure 1, above, taken from AWS D1.8, illustrates the three types of welds in a typical Reduced Beam Section (RBS) connection.

Protected Zone

The protected zone is the portion of a member of the seismic framing, designated by the engineer of record in the contract documents, in which inelastic straining is anticipated to occur. In the protected zone, restrictions on attachments and fabrication practices apply. Welded shear studs and decking attachments cannot be placed on beam flanges within the protected zones; however, decking arc spot welds to secure decking are permitted. Attachments for perimeter edge angles, exterior facades, partitions, duct work, and other construction should not be placed within the protected zone. Tack welds are prohibited outside the weld joint in the protected zone, unless specifically required or permitted by the engineer. Gouges and notches in the protected zone should be repaired by grinding or repair welding, as required by the engineer.

Similar to demand-critical weld locations, the locations and extents of the protected zones are dependent upon the seismic framing and the connection type used, as determined using AISC 341-05 and AISC 358-05. (Refer to the January 2007 Steelwise article "Prequalified Seismic Moment Connections," available at **www.modernsteel.com**, for a visual summary of two prequalified moment connections.

Filler Metal

All welds in the seismic framing must be made with a filler metal classified with a minimum Charpy V-notch (CVN) toughness of 20 ft-lb at 0 °F. Filler metals meeting this requirement are readily available and relatively operator friendly. For demand-critical welds, filler metals must be classified with a CVN toughness of 20 ft-lb at -20 °F (AISC 341-05) or 0 °F (AWS D1.8)—this discrepancy in temperature is in the process of being resolved between AISC and AWS—and heat input envelope tests must confirm a CVN toughness of 40 ft-lb at 70 °F. These requirements further limit the selection of filler metals for demand-critical welds, but they are still readily available. The filler metal specification for flux-cored carbon steel electrodes now includes the "-D" designator to denote wire tested with the heat input envelope CVN tests. The CVN toughness provisions apply to buildings in which the seismic framing is enclosed and maintained at a temperature of 50 °F or higher. If the seismic framing service temperature is lower than 50 °F, CVN testing of welds at lower temperatures is required.

All seismic welding electrodes and electrode-flux combinations must meet the requirements for H16 (16 mL maximum diffusible hydrogen per 100 grams deposited weld metal) as required in Section 6.3.2 of AWS D1.8. Specifying a maximum hydrogen content helps to prevent hydrogen-induced cracking.

When self-shielded flux-cored arc welding filler metals are used in combination with filler metals for other welding processes, supplemental notch toughness testing is required, in accordance with Section 6.3.4 and Annex B of AWS D1.8.

To be Continued…

Part Two of this article will appear in next month's MSC. There, we will discuss and highlight several more seismic welding requirements, including the removal of steel backing, weld access hole and weld tab requirements, welder qualification testing, and nondestructive examination requirements. MSC

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