

## conference preview

# CONNECTION DESIGN, DETAILING AND FABRICATION FOR SEISMIC RESISTANCE

BY ROBERT WHYTE, S.E., P.E.

A few important things to know when looking at a potential job for the first time.

**THE SEISMIC FORCE-RESISTING SYSTEM (SFRS)** is that part of the overall structural system that has been considered in design to provide the required resistance to the code-prescribed seismic forces.

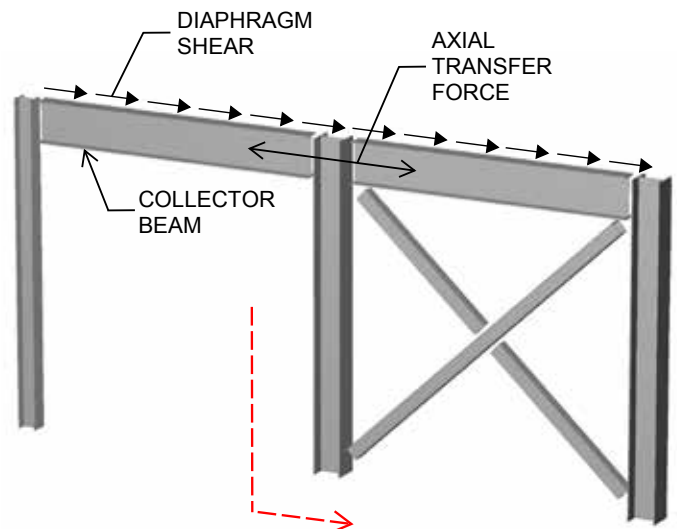
Originally known as the seismic load-resisting system (it was changed to SFRS in the 2nd Edition AISC *Seismic Design Manual*), it may consist of the following structural elements: the steel roof deck as designed as a diaphragm, the chord beams, collector beams, struts, trusses, horizontal bracing frames and the vertical frames (braced or moment). These elements are required to be indicated in both plan and elevation in the structural design drawings. Other non-steel elements such as concrete shear walls, for example, may be part of the SFRS. The steel members that connect to them should also be defined as SFRS and properly identified on the design drawings. If the SFRS is not clearly defined in the design drawings, this could result in an early RFI (request for information) on a job.

This is one of many items to keep in mind when initially exploring a structural steel project. And knowing what to look for early on can help get a project started off on the right foot and avoid potential questions or problems down the line. Below are several terms to consider from the outset.



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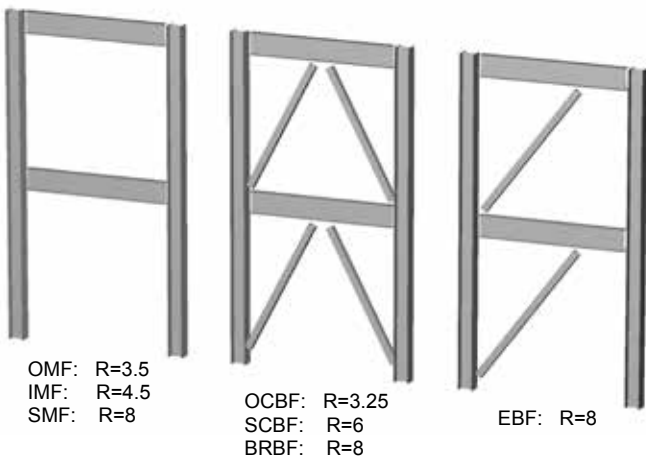


▲ Figure 1. An axial transfer force between the collector beam and the braced bay in an OCBF is something to keep an eye out for.

**BOLTED CONNECTIONS THIS SIDE OF LINE:**  
- 'CLASS A' FAYING SURFACES  
- FULLY PRETENSIONED BOLTS

**Response modification factor.** From a fabricator's and steel detailer's perspective, the first things to look at when estimating a job are the response modification factor, commonly referred to as the *R* factor, and the description of the lateral force-resisting system (LFRS). These are typically found in the design criteria section of the general notes. The *R* factor is an indicator of the ductility of the lateral system; the larger the *R* factor, the more ductile the system, which means larger deformations under seismic loading. If the *R* factor is greater than 3, all the requirements of *Seismic Provisions* immediately kick in.

**Seismic design category.** Another term that is good to be



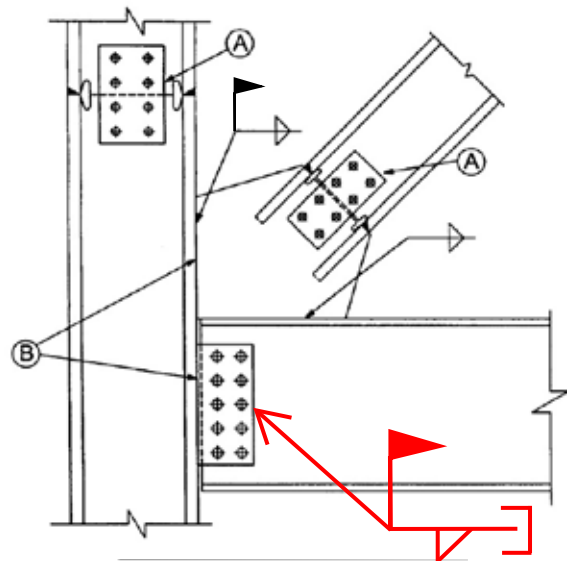
▲ Figure 2. Systems such as intermediate moment frames, special moment frames, special concentrically braced frames and eccentric braced frames have the most stringent detailing and fabrication requirements.

familiar with is the seismic design category (SDC), which is a direct measure of the seismicity of the structure due to its location and soil type supporting the structure. An SDC of A is the lowest and an F is the most severe; the most stringent steel detailing requirements kick in at an SDC of D and higher.

**Overstrength factor.** Designated as  $\Omega_o$ , overstrength factor is something that must be accounted for in the sizing of the structural members in the SFRS, and it is important to understand the reasoning behind it. Some elements of the SFRS are intended to dissipate earthquake energy by the ductility of certain “sacrificial” members in the form of yielding and buckling, while other components in the system are intended to remain elastic during the seismic event. The latter are those elements to which the overstrength factor has been applied. SFRS components that require application of the overstrength factor are defined in ASCE 7 *Minimum Design Loads for Buildings and Other Structures* and others are only found in the *Seismic Provisions*. Examples of these are: chord and collector beams and their connections, columns in an ordinary concentrically braced frame (OCBF), horizontal bracing and column splices. Connection design forces for structural members that have the overstrength factor should be clearly indicated in the design drawings.

**Bolted connections.** Due to the full load reversal nature of seismic loading, all bolted connections in the SFRS must be made with fully pretensioned bolts. The faying surfaces at these locations must be prepared with a Class A surface preparation, which may mean blocking paint. This requirement notwithstanding, bolts may still be designed as bearing. The surfaces to be blocked must clearly be identified in the shop drawings. Field bolted joints of the SFRS should be shown on the erection drawings and bolt pretensioning requirements noted. Exceptions to the surface preparation requirement are allowed for end-plate moment connections. For example, depending on the paint requirements of the structure, it may be less labor-intensive to fully paint an entire column with a coating system that achieves a minimum Class A or Class B surface rather than blocking every surface where a beam or a gusset plate connects to the column.

**No mixed connections.** Connections where bolts in combination with welds resist a common force are prohibited. Due to the potential of full load reversal and the likelihood of inelastic deformations in the connection plate elements, bolts may exceed their slip resistance under significant seismic loads. A problematic condition can occur at brace connections to columns with the gusset plate welded to the column and the beam web bolted to the column will transfer forces differently from all-welded or all-bolted connections. The welded joint of the gusset to the column will tend to resist the entire vertical force at the column face: the vertical component of the brace force plus the beam end reaction. This is due to the high stiffness of the welded connection versus the bolted connection. This can be a common mishap in the field when the bolts at the gusset plate-to-column interface happen to have been mis-drilled. The obvious fix would be to add welds and eschew the bolt strength at this interface. However, this would immediately require the addition of welds at the beam-to-column interface, which could get overlooked. The objective is to ultimately have proportional levels of connection stiffness at each interface.



▲ Figure 3. Both interfaces at the column flange must be all bolted or all welded, but not mixed.

**Width-to-thickness requirements.** Beam, column and brace sections in the SFRS that satisfy width-to-thickness requirements are grouped in the *Seismic Provisions* as moderately ductile or highly ductile. These are sections that ensure a required level of ductility that is dependent on the system cho-



sen. As the required level of system ductility is greater—e.g., in an system with an  $R$  factor of 6—the sections that satisfy these requirements become stockier. It is a good idea to be familiar with the member cross sections that are permitted under these requirements for a given lateral system.

**Protected zones.** Fabrication and erection work, and the subsequent work by other trades over the duration of the project, have the potential of causing discontinuities in locations of SFRS members where high inelastic strains are expected under a seismic event. Testing has demonstrated high sensitivity to these discontinuities, which can be anything from a small hole or a “nick” in the steel to a temporary handrail attachment that wasn’t properly repaired. Thus, regions where high inelastic strains are anticipated need to be identified and protected. It is a requirement of the *Seismic Provisions* to locate and dimension the protected zones for a given system in the structural drawings. Subsequently, they should be identified in the shop drawings and on the physical “as-built” structural members (in the field). Protected zones include moment frame hinging zones, links in EBF systems and the ends and center of braces in an SCBF system.

**Demand-critical welds.** Consideration for the high inelastic strain demands mentioned and the consequence of failure require that certain welds in the SFRS be designated as demand-critical. Demand-critical welds must be made with filler metals that meet certain Charpy V-notch toughness requirements using two test temperatures and specified test protocols. It is understood that low temperatures have an adverse effect on the ductility of these welds, thus the “lowest anticipated service temperature” (LAST) should be determined for the given location and use of the steel structure.

Keeping these areas in mind at the outset of a project will go a long way in helping it progress smoothly. ■

*This article is a preview of Session N11 “Connection Design, Detailing and Fabrication for Seismic Resistance” at NASCC: The Steel Conference, taking place April 13–15 in Orlando. Learn more about the conference at [www.aisc.org/nascc](http://www.aisc.org/nascc).*