steelwise

THE RIGHT MOMENT

BY JOE DARDIS, PE

What's so special about steel special moment frames?

A lot, actually.

DESIGNING A PROJECT in a high-seismic area? Have you thought about using steel special moment frames?

The SMF is one of a few select systems that U.S. building codes permit without restriction in buildings exceeding 160 ft in height. What truly makes the system "special" is the unique proportioning and detailing used for the beams, columns and beam-column connections. When following these special criteria, engineers can design SMFs for the most critical occupancies, even in areas with the highest mapped ground motions.

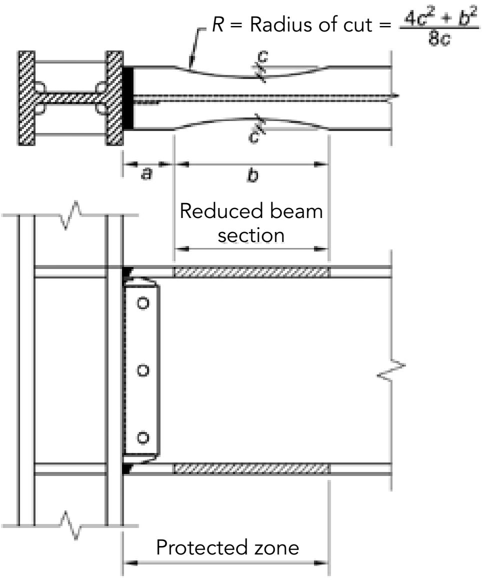
Aside from the absence of a height restriction in high seismic areas, SMFs can provide another huge benefit: architectural freedom with no braces or shear walls to hide or work around. This is also advantageous if the building ever goes through a remodel or retrofit, since the new layout will still be free from conflict with braces or shear walls. Open bays, unobstructed views and flexibility with initial and future layouts are all huge pluses.

In recent years, many tall buildings with core-style construction have taken advantage of using a dual system consisting of SMFs at the perimeter and either braced frames or shear walls in the core. If the SMFs are designed to provide at least 25% of the building's lateral strength, then the building is not subject to any code height restriction in high-seismic areas (per ASCE 7-10 12.2). Otherwise, the building height is limited to 240 ft.

Inelastic Deformation

SMFs are generally expected to experience significant inelastic deformation during large seismic events. If you're not too familiar with the AISC *Seismic Provisions for Structural Steel Buildings* (AISC 341), you may be asking yourself, "Why is this a good thing?" The answer is relatively simple: Large seismic events occur at average intervals of hundreds of years, and to design every structure to remain essentially elastic as they resist such rare events would be far too expensive and impractical. Instead, we allow structural damage to occur. This implies future repair costs in the event of an earthquake, but the expected return on the life of our building stock as a whole is much higher following this design philosophy. Additionally, there is a high level of uncertainty regarding earthquake demands on a building. Providing a ductile design provides an additional level of life safety.

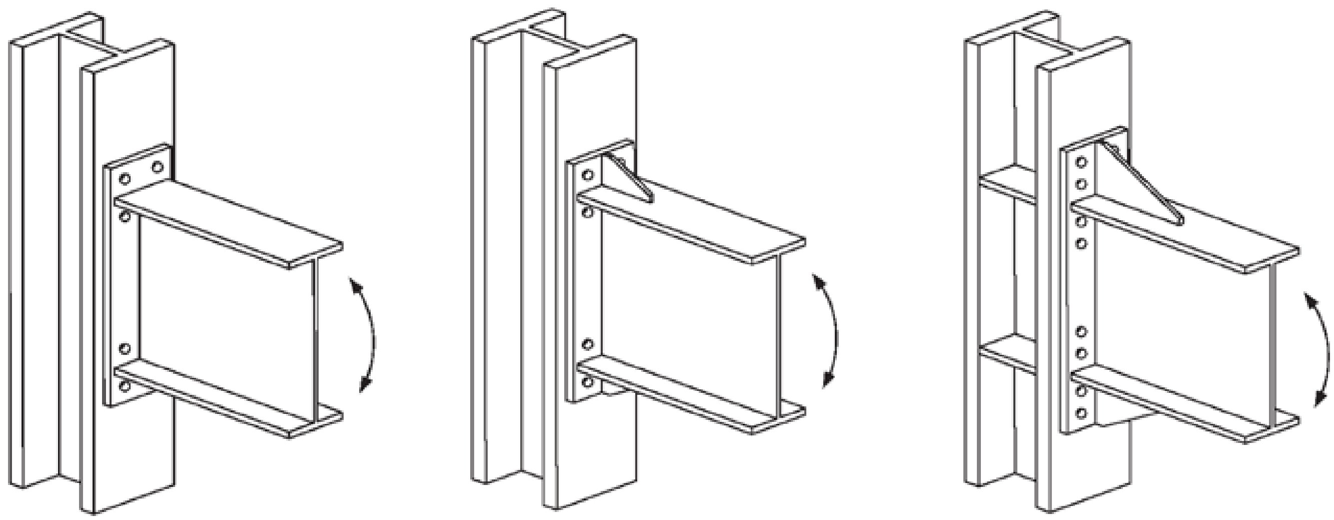
We also isolate inelastic deformation to occur at locations where it can be tolerated, usually in the beams at the beam-column joints and at column bases. AISC 358: *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* provides several connection options (shown in the various figures) that conform to AISC 341 requirements and accomplish location-specific deformation, and also explains in detail how to design each type of connection. Alternatively where desired, another connection detail can be qualified to meet the requirements in AISC 341.



A reduced beam section moment connection.

SMF members and connections are configured to achieve the so-called strong column-weak beam design philosophy AISC 341 states that the sum of column flexural strengths must exceed the sum of the beam flexural strengths at each joint. This promotes a more uniform distribution of lateral drift and beam hinging over the height of the structure. It functions as a check of the column's ability to remain elastic outside of the panel zone in a strong column-weak beam design, but we recognize that there may be some inelasticity in columns because the actual distribution of seismic effects may be different from our analyses.

Joe Dardis (dardis@aisc.org) is an advisor in AISC's Steel Solutions Center.



Extended end-plate moment connections. From left to right: four-bolt unstiffened, four-bolt stiffened and eight-bolt stiffened.

It is important to understand the strong column-weak beam design process in order to design an efficient SMF, particularly when considering drift. The sizing of steel beams in SMFs is typically drift controlled, and due to the requirements of strong column-weak beam design, the columns follow suit. When increasing beam and column sizes to control drift, one must balance the effect that increasing sizes has on tonnage and shape geometry.

Long-span frames that require deeper beam sections are more susceptible to lateral torsional buckling and therefore would typically require bracing, which makes frames with spans greater than 40 ft rarely practical. Additionally, longer-span frames are less stiff, making them more susceptible to drift. Similarly, frame spans of less than 20 ft can result in inelastic behavior in beams dominated by shear yielding as opposed to flexural yielding. AISC 358 conveniently provides span-to-depth limitations for several different connection types and also addresses the fact that deeper sections, when undergoing the same drift as a shallower section, experience larger levels of strain.

In addition to proportioning, redundancy and distributing the lateral forces over multiple moment frames will allow the use of lighter, more compact members with higher inelastic deformation capacity. In some cases, the reduced tonnage can offset the cost of the additional framework and provide additional clearance and floor space by using shallower beams and smaller columns.

Another technique used to control tonnage is the use of a deep-column section. A deep column is an economical choice that controls drift and satisfies strong column-weak beam design. AISC 358 allows the use of a column section up to 36 in. in depth. The strong axis of a deep-column section can typically provide as much capacity as a compact column section with a lower weight per foot of column length. Even after taking into account all of the great benefits of deep columns, architects are still sensitive to column depth in relation to floor space. However, the truth is that even a deep steel column will typically take up less space than a comparable concrete column.

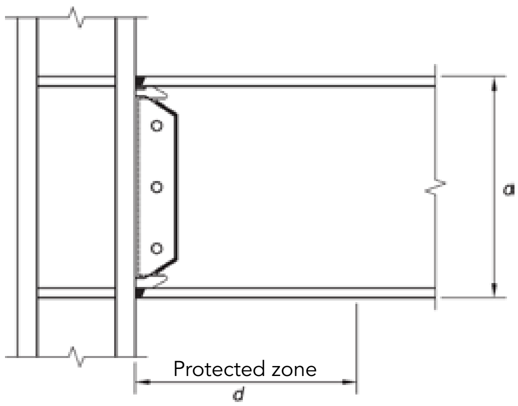
All About that Base

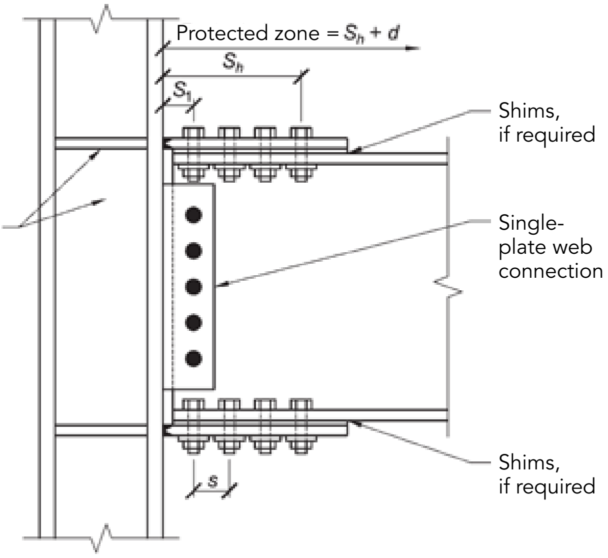
When trying to design the most economical SMF possible, it is important to consider the column base's contribution to drift. The first level of a building is typically taller than the higher floors, resulting in a larger story drift. Using a fixed-base column can significantly reduce drift at this level and subsequently overall building drift. Attention must be given to the fixed base requirements outlined in AISC 341, and following these requirements can prevent the need to increase member sizes at the first level. Similarly, if a pinned base is chosen, the engineer must still take into account large anticipated base rotations and design this connection accordingly. Note also that SMF systems typically impose smaller axial loads on foundations than other lateral systems, which may result in smaller foundation sizes.

Web doubler plates and continuity plates are other important considerations when designing for economy. Adding doubler plates will increase shop fabrication time, labor, inspection time and cost, which can be avoided by increasing the column size. As a general rule of thumb, a column size increase of 100 lb per ft will cost less than adding a doubler plate. This also will simplify the detailing of the continuity plate (stiffener) interface, which can become complicated when doubler plates also are present. Additionally, increasing size often eliminates the need for a continuity plate.

Talk to a Fabricator

You may think that moment frames are more expensive than alternative systems. Maybe so, but keep it all in perspective; a building's carpet usually costs more than the framing system! The key is to make the structural system as economical as it can be.





▲ A welded unreinforced flange/welded web moment connection.

➤ A bolted flange plate moment connection.

To do so, ask your fabricator for assistance. Is it more cost-effective to add redundancy and decrease member size? Will using a fixed base be more economical? Should I look at deep columns? What is the right balance between column size and doubler and continuity plates? Your fabricator can answer these and other questions and help you deliver the greatest value to a project.

You can also contact your AISC regional engineer or the Steel Solutions Center with any project-related inquiries, and we will be happy to put you in touch with a local AISC member fabricator. To find your regional engineer, visit **www.aisc.org/myregion**. And to contact the solutions center, email **solutions@aisc.org**, call 866.ASK.AISC or visit us on the web at **www.aisc.org/solutions**. ■