steelwise

CHOOSING THE MOMENT

Make your non-seismic moment connections better with these helpful tips.

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WHEN IT COMES TO SELECTING a lateral force resisting system for steel buildings, designers can select from a dizzying array of systems. A common—but often misunderstood—selection is the humble moment connection. With our *Manuals* bookmarked at Part 12—*Design of Fully Restrained Moment Connections*, we chatted with a few AISC-member, AISC-certified fabricators to gain some insight into three moment connection configurations commonly used in $R = 3$ construction.

An important takeaway from our fabricator discussions is that all three configurations make sense in a variety of situations, so the selection of connection configuration is largely dependent on shop and field costs—variables that are different with every project and every steel fabricator and erector.

Some of their tips may strike you as common sense, but they apply to all moment connections and bear repeating. For example:

- Always consider erection safety, constructability, and tolerances when designing moment connections.
- Consider shop welding short cantilevers to minimize field welding and the need for shoring during erection.
- For economy, detail stiffener plates only when they are required. Don't require stiffener plates (also known as continuity plates) when they are not needed—and if they are required, consider ¾-depth continuity plates for one-sided moment connections, a provision planned for the next edition of the AISC *Specification*.
- Do give extra thought to sloped and skewed connections. Angles can affect detailing and constructability, and sharper angles can affect the structural behavior of the moment connection.
- If you're working with moment connections in seismic construction (when R > 3), both AISC 341, *Seismic Provisions for Structural Steel Buildings*, and AISC 358, *Prequalified Moment Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* (free downloads at www.aisc.org/specifications) are useful references.

Now, let's take a closer look at our three moment connection types.

Directly Welded Flange Connections

In a directly welded flange moment connection, the beam flanges are welded to the column flanges in the field using CJP groove welds (see Figure 1a).

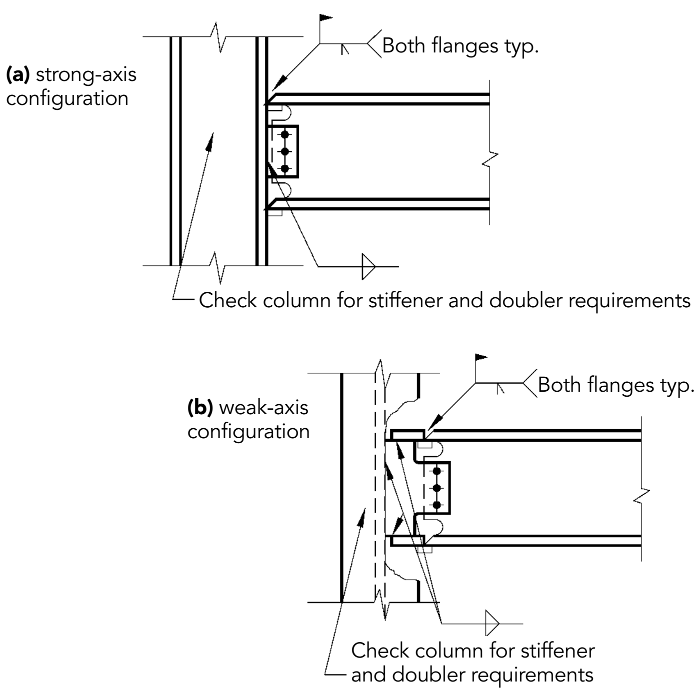

Figure 1 (adapted from Figure 12.4 in the 14th edition *Steel Construction Manual*).

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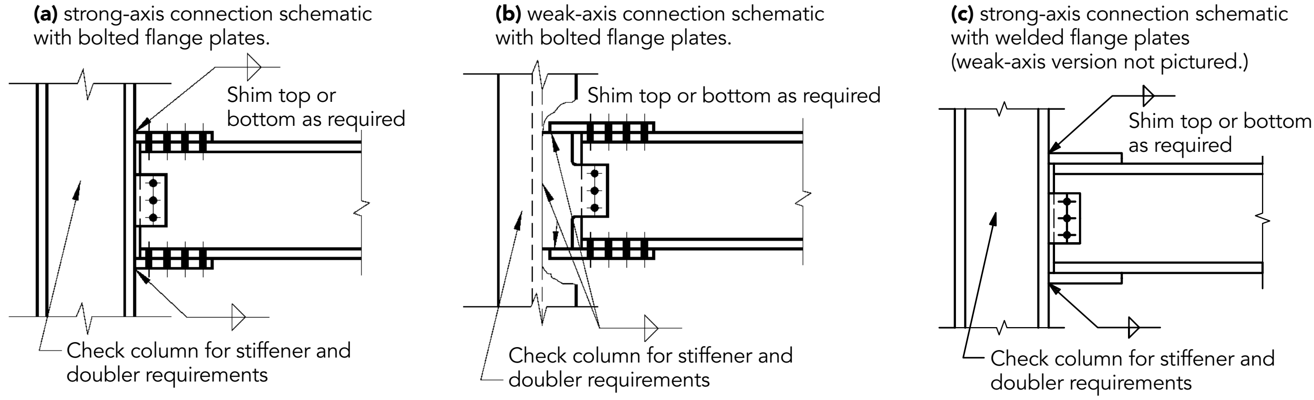


Figure 2 (adapted from Figure 12.2 in the 14th edition *Steel Construction Manual*).

The load path for flange forces in this connection is straightforward: beam flange forces are transmitted to the column through complete-joint-penetration (CJP) groove welds. This connection type can be used to connect to strong- and weak-axis column orientations. In the strong axis connection, the beam flanges are directly welded to the column flanges, and the column should be checked for stiffener and doubler plate requirements per Section J10 of the AISC *Specification*. In the weak-axis configuration, the beam flanges are welded to stiffeners fitted between the column flanges. These stiffeners must be detailed such that the welded flange connection is made beyond the face of the column flange tips. Also, it's necessary to detail the web connection to locate the bolts outside the column flanges to provide clearance for bolt installation. Figure 1b (previous page) illustrates the weak-axis configuration for this connection.

Fabricator tips for directly welded flange connections:

- Don't specify that weld access holes be filled with weld material: it creates regions of undesirable triaxial stresses. If weld access holes need to be concealed for appearance reasons, mastic materials (e.g. auto-body filler) are probably a better choice.
- Allow backing bars to be left in place when possible.
- Provide short slots for bolts in web to aid in erection alignment.
- Provide actual forces to avoid developing unnecessary extra capacity.
- For strong-axis moment connections, consider increasing the column size to eliminate the need for stiffeners or doublers.

Flange-Plated Connections

Flange-plated moment connections generally consist of top and bottom plates shop-welded to the column flanges. In the field, the beam slips between the top and bottom plates, and the beam's flanges are then either welded or bolted to the flange plates. These connections are usually detailed so any gap between flange plates and the beam flanges can be shimmed when the beam is erected. The flange forces in this connection are transferred into the top and bottom plates via weld material or bolts; the forces then transfer to the supporting member (the column flange) through welds.

Like the directly welded flange connection, this connection can be used for both strong- and weak-axis column connection (see Figure 2 for schematics of these configurations). And like the directly welded flange connection, column-flange-tilt tolerances can affect both the bolted and welded flange plate versions:

- The welded flange plate version can accommodate adjustability if enough weld shelf dimension is provided—in other words, if the flange plate details allow for a slight skew with respect to the column flanges.
- The bolted flange plate version accommodates some adjustability if oversized bolt holes are detailed in the flange plates.

Fabricator tips for flange-plated connections:

- Try to eliminate overhead welds in the field. For example, make the top flange plate narrower than the beam flange and the bottom flange plate wider than the beam flange. Refer to the recommended minimum shelf dimensions as shown in Figure 3.

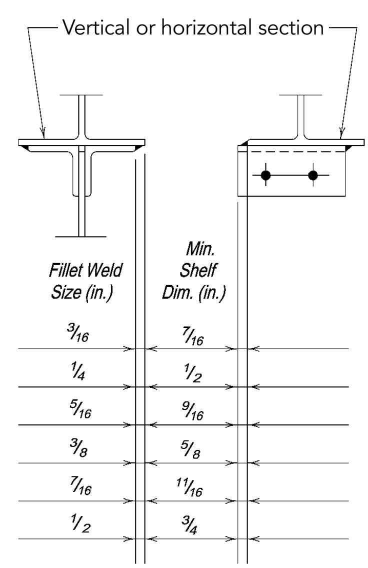
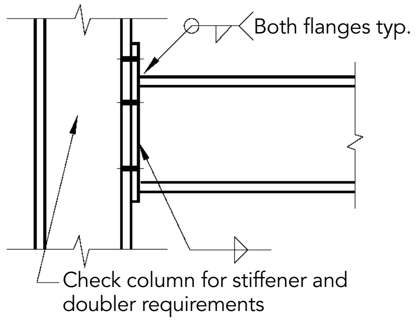


Figure 3: Recommended minimum shelf dimensions for SMAW fillet welds (adapted from Figure 8-11 in the 14th edition *Steel Construction Manual*).

- Don't forget to detail for deck bearing around the top flange plates. Unlike the directly welded flange connection, deck may not lie flat on top of the flange plates, especially of the flange plates are bolted.

(a) extended end plate moment connection



(b) stiffened extended end plate moment connection

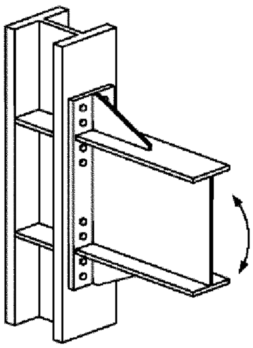


Figure 4 (adapted from Figures 12.5 and 12.6 in the 14th edition *Steel Construction Manual*).

- Keep in mind that, when designing for large moments, long flange plates with many bolt holes are common. This will reduce the beam flange net section area and may reduce the capacity of the beam to a point where it will not resist the intended loading. On top of that, those long plates can make shipping very challenging. Designing the connection for the actual beam reactions is key in such situations.
- Detail the beam a little short in order to avoid interference with the plate-to-column welds.
- Keep fillet welds 5⁄16 in. or smaller to minimize welding time and additional inspection requirements.

Extended End Plate Moment Connections

In extended end plate moment connections, plates are shop-welded to the ends of the beams. In the field, the beam/end-plate assembly is lifted in place between columns, and the end plates are field-bolted to the column flanges (see Figure 4a). There are end plate bolts within the depth of the beam as well as above and below the beam flanges, in the "extended" portion of the end-plate. If required by the loads, the "extended" portion of the plate can be lengthened and a stiffener added, creating the *stiffened* extended end plate moment connection (see Figure 4b).

The load path is quite different from the previously discussed moment connections, in that the beam flange forces are transferred into a plate that is perpendicular the beam span. Bolts in the end plates transfer tensile and shear forces into the column. Compression forces are transferred as the end plate bears directly on the column flange.

AISC's Design Guide 16, *Moment End Plate Connections*, is a handy guide for designing end-plated moment connections, which require the consideration of prying action—the amplification of the tensile forces in the bolts that occurs as the end plate rotates away from the column flange on the tension side of the moment connection. Design Guide 16 is a free download for AISC members at **www.aisc.org/designguides**.

End-plated moment connections are generally not a good idea at top-of-column (roof) locations because the column must extend past the top of the beam to accommodate the end-plate's top bolts. End-plates are probably not good choices for skewed connections (bolting can be impossible if the skew is sharp). Also, if loads are very high and bolts larger than 1¼ in. are indicated, other connections might be better choices.

Fabricator tips for extended end plates:

- Consider fillet welds at the beam-to-end plate connections when possible instead of CJP or PJP groove welds to save on welding costs.
- Stiffener and doubler plates on the columns complicate the detailing of the end-plate bolts and should be avoided if possible.
- Use fewer, larger diameter bolts instead of higher quantities of smaller diameter bolts.
- Detail beams ⅛ in. short, using shims between the end plate and the column to minimize fit-up issues.
- Think twice before using this connection type on a cambered beam—consult a fabricator first.
- End-plated connections may not work with larger beam sizes: the size and number of bolts can become a limiting factor.

Final Notes

A critical factor in any moment connection design is an understanding of the forces carried by the moment connection. A common misconception is that overdesigning moment connections isn't a big deal, when in reality designing the connections to carry only the required forces is the first step in economical design. If the connections are not designed on the drawings by the engineer of record (as is the case when Option 3 in Section 3.1.2 of the AISC *Code of Standard Practice* is selected—see sidebar), the drawings should specify the actual end reactions and moment cases. Doing so allows the fabricator's engineer to determine the most efficient connection.

A Word about the *Code of Standard Practice*

This article presupposes that the engineer is selecting either Option 1 (connections designed by the Engineer of Record) or Option 3 (connection design work delegated to a licensed engineer working for the fabricator) as given in Section 3.1.2 of the AISC *Code of Standard Practice*. There is also an Option 2 (basic connections left to be selected and completed by and experienced steel detailer).

One trend we noticed when talking to fabricators was a high proportion of fabricators noting that Option 2 is not used for moment connections. This makes sense because Option 2 does not allow for design work, and moment connections invariably involve design, not just selection and completion. Clearly this is consistent with what is stated in the *Code* and its Commentary:

"The intent of this method is that the steel detailer will select the connection materials and configuration from referenced tables or complete the specific connection configuration (e.g., dimensions, edge distances, and bolt spacing) based upon the connection details that are shown in the structural design drawings…It is not the intent that this method be used when the practice of engineering is required."

Download the complete AISC *Code of Standard Practice* for free at **www.aisc.org/specifications**.

Including forces on the drawings also helps determine if columns require reinforcing. Sometimes, increasing the column size by a few pounds per foot can eliminate the need for column reinforcing.

Also, it's never a good idea to overlook the cost implications of these two vague (and far too common) drawing notes:

- "provide column stiffeners and doublers as required"
- "detail for the maximum moment capacity of the beam"

If Option 3 is the connection design option of choice, these phrases will most certainly lead to lots of fabricator and detailer head-scratching and RFIs—not to mention extra costs—unless the end reactions are shown on the drawings for every moment connection.

Finally, remember to ask a fabricator for his/her advice when you encounter special situations. Even if they end up not being the actual fabricator, your project will benefit from their expertise. ■

For additional tips for designing moment connections, check out the June 2009 Modern Steel *article "In the Moment" by Victor Shneur (available at* ***www.modernsteel.com****).*