

## Tips for Designing Constructible Steel-Framed Structures

### Part 1

By Clifford W. Schwinger, P.E., SECB and Todd R. Campbell, P.E.

The term “constructability” defines the ease with which structures can be built. Why should designers care about constructability? They should care because a constructible design is an economical design. Thirty years ago there was little discussion about constructability. That was because most structural engineers were aware of the need to design buildings which could be easily built. Consideration of constructability was standard procedure. Attention to constructability diminished with the increased use of computers. Computer programs unfortunately do not print error messages warning of constructability flaws. Recently there has been renewed focus on constructability – what it is, how to achieve it and how to educate practicing engineers on this lost art. This article focuses on constructability of steel-framed structures.

There are four basic tenets to the practice of designing constructible steel structures. They are:

- 1) Simplicity = economy
- 2) Least weight does not always equate to least cost
- 3) The fewer the pieces, the more economical the design
- 4) Efficient connection design = economical design

Note that the terms *economy* and *constructible* are often used interchangeably in discussions of constructability. This is because the most economical design is usually one that is also highly constructible. Constructability problems fall into two general categories – constructability flaws due to framing configurations that are difficult to assemble (most often relating to connection issues) and constructability flaws due to framing configurations that are inefficient (such as a floor framing layout with beams spaced at 6 feet o.c. versus a layout with beams spaced at 12 feet o.c.)

Below is a list of suggestions which, if followed, will usually facilitate the fabrication and erection of steel structures. Some of these rules-of-thumb will vary depending on project location, labor cost and specific fabricator preferences based on available fabrication equipment. Designers should be familiar with

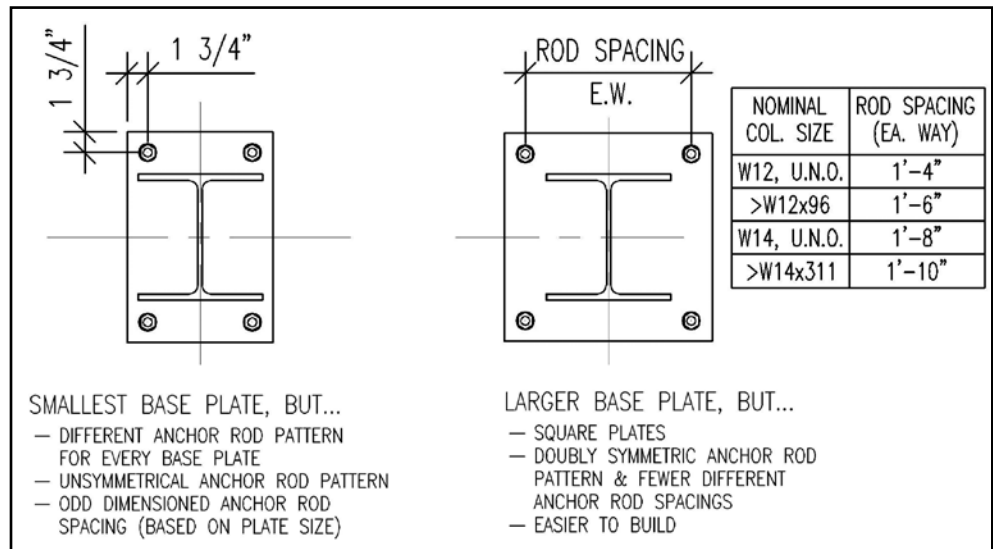


Figure 1: Simplify base plate geometry where possible.

preferred fabrication and construction practices common within the areas where their projects are located.

- 1) **Show all actual reactions, moments and axial loads for which connections must be designed, and permit fabricators to design and detail the connections to suit their preferences.** If readers follow only this rule, they will significantly enhance constructability of the buildings that they design. Showing reactions, moments and member forces, and allowing fabricators to design and detail their preferred connections, will result in the most competitive bids.
- 2) **Use square baseplates with symmetrical anchor rod patterns.** Square plates, and symmetrical and repetitive anchor rod patterns, are easy to detail, fabricate and erect. This is a classic example of “simplicity = economy”. (Figure 1)
- 3) **Frame girders to column flanges.** It’s easier to maneuver beams (which are usually smaller than girders) into position between column flanges than it is to frame girders to column webs. Likewise, beams usually have smaller reactions than girders. Economical

connections, such as single angle connections, can usually be used for light beam reactions. Single angle connections to column webs offer an additional benefit of eliminating shared bolts with the beam connections on the opposing side of the web.

- 4) **Do not prohibit “one-sided” shear connections, such as single angle connections, unless there are valid reasons for doing so.** Some designers arbitrarily prohibit the use of one-sided connections. Properly designed single-sided connections are cost effective, strong and safe to erect.
- 5) **Avoid complete joint penetration (CJP) welds when possible.** Some designers arbitrarily require welds to be complete joint penetration welds when alternative welds will work. When designers opt not to design and detail welded connections on the contract documents, the best alternative is to provide steel fabricators with the design forces at welded connections and permit the fabricator’s connection engineer to design the most cost-efficient weld to resist the applied forces.

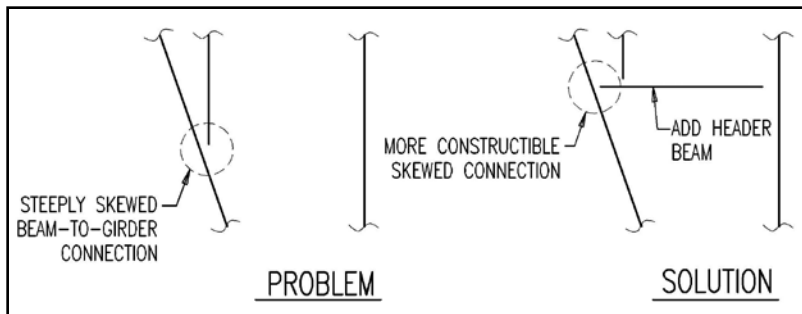


Figure 2: Head off steeply skewed beams to facilitate design and detailing of connections.

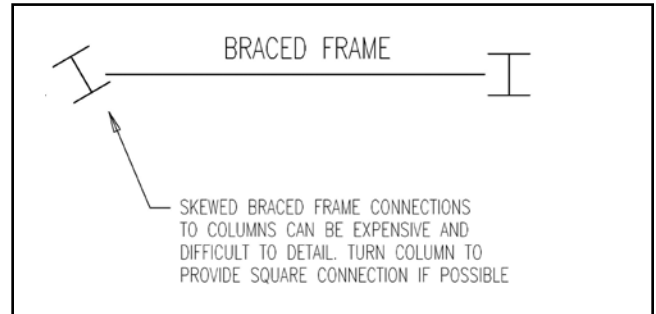


Figure 4: Orient columns in braced frames to enable square bracing connections.

- 6) **Avoid specifying that connections be designed for “full strength of member”.** Requiring that connections be able to support the full strength of the member is both vague and usually unnecessary. A better solution is to show the member reactions on the framing plans.
- 7) **Avoid using generic tables requiring beams of certain depths to be designed for conservative reactions.** The use of a table listing beam depths, minimum rows of bolts and minimum required connection shear capacities is widespread. A better solution is to show all beam reactions on the framing plans. Connection cost is a significant percentage of the total in-place cost of structural steel. Requiring connections to be designed to have capacities far greater than the actual reactions is wasteful of the owner's budget and resources.
- 8) **Size columns to avoid stiffener plates and web doubler plates.** Stiffener plates and web doubler plates are costly to install. A better alternative is usually to upsize columns so that these plates are not required.
- 9) **Favor bolted connections over welded connections.** Most large fabricators use computer controlled beam and angle drill line machinery.

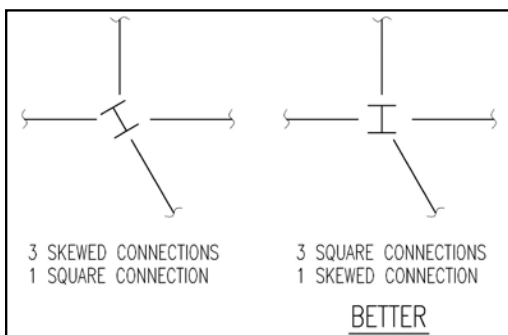


Figure 3: Orient columns to minimize the number of skewed connections.

- The only labor required is that of bolting connection angles to beams and columns. Welded connections introduce another level of complexity and increased chances for human error. While welded connections are fine where required, most fabricators with drill line machinery prefer bolted connections. Welded connections also require a greater level of inspection versus bolted connections.
- 10) **Favor connections that do not require field welding.** Field welding is generally more expensive than field bolting.
- 11) **Check that connections are constructible and that bolts or welds can be physically installed.** Engineers who delegate connection design to the steel fabricator are still obligated to make sure that their framing is configured in a manner that will permit the steel fabricators to efficiently detail and fabricate the connections.
- 12) **Minimize or avoid skewed connections where possible.** While skewed connections can be fabricated, they are generally more expensive than square connections.
- 13) **Avoid skewed connections with large reactions.** Beams with large end reactions are often most efficiently framed with double-sided connections – specifically double angle connections where the bolts are in double shear. Double sided skewed connections are more expensive than double-sided square connections, and bolt installation can be difficult depending on the angle of the skew.
- 14) **Avoid steeply skewed beam-to-girder connections with skew angles less than 30 degrees.** Steep skew angles often require very large beam copes, which can reduce the strength of the

member at the connection. Welds on the acute angle side of steeply skewed single plate connections can be difficult to install. Bolts can likewise be difficult to install. When steeply skewed beams cannot be avoided, heading them off will usually solve the connection problems that would otherwise occur. (Figure 2)

- 15) **Orient columns to minimize skewed connections to columns.** (Figure 3)

- 16) **Orient columns in braced frames square with braced frame members.** (Figure 4)

The next QA Corner article will continue the discussion of constructability of steel-framed structures, with 25 additional tips and suggestions. If you have any comments about this article, please email the authors. ■

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