Connection Design Options in the Real World

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The 2010 edition of the AISC *Code of Standard Practice* includes a new alternative.

THE 2010 AISC *CODE OF STANDARD PRACTICE* includes three options for connection design responsibility: 1) The Structural Engineer of Record (SER) designs the connections; 2) The SER provides adequate information so that the steel detailer need only select and detail the connections; and 3) The SER delegates connection design to another engineer employed or retained by the fabricator.

The third option is completely new to the *Code* and was discussed by Charles J. Carter, S.E., P.E., Ph.D., in the article "Connection Design Responsibility: Is the Debate Over?" (May 2009 *MSC*, available at **www.modernsteel.com/backissues**). This article provides guidance on applying each of the three connection design options in practice, including what to include in your design drawings and specifications and the contract documents (or CDs).

Drawing Requirements for All Options

The following items are required in the CDs for all three design alternatives:

- Size, section, material grade, and location of all members (*Code* Section 3.1)
- Geometry and working points (*Code* Section 3.1)
- Floor elevations (*Code* Section 3.1)
- Column centers and offsets (*Code* Section 3.1)
- Camber requirements—magnitude, direction, and location of camber (*Code* Sections 3.1 and 3.1.5)
- Joining requirements between elements of built-up members (*Code* Section 3.1)
- Clear representation of permanent bracing, column stiffeners, column web doubler plates, bearing stiffeners in beams and girders, web reinforcement, openings for other trades, and other special details where required (*Code* Section 3.1.1)
- Clear indication of connection design option(s) chosen—you may select different options for different connections or connection types (*Code* Section 3.1.2)
- Leveling plates—location, thickness, and size (*Code* Section 3.1.3)
- Identification of non-structural steel elements that interact with the structural steel frame (*Code* Section 3.1.4)
- Painting requirements—identification of members to be painted, surface preparation requirements, paint specifications, and minimum dry-film shop-coat thickness of paint required. (*Code* Section 3.1.6)

The shop drawing review and approval process is a crucial component for all steel construction projects. This process is outlined in Section 4.4 of the *Code* and is similar to previous editions. The SER reviews and approves the shop and erection drawings according to Section 4.4 regardless of what connection design option is specified.

As stated in Section 3.1.2, one of the three connection design options must be specified for each connection. Note, however, that it is acceptable to group connection types and utilize a combination of these options for the various connection types involved in a project.

Each of the three connection design options is presented below in a similar format—overview, drawing requirements, sample specification language, and helpful tips to consider for each option. Section 051200 of the American Institute of Architects (AIA) MasterSpec deals with structural steel framing, and Part 1.4 of that section outlines the performance requirements, including connection design responsibility.

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How to Optimize This Information

To get the most out of this article, first download and review the 2010 *Code of Standard Practice* for free at **www.aisc.org/freepubs** (particularly Section 3, Design Drawings and Specifications) and keep it handy.

Another good reference on this topic is Brian Dekker's NASCC 2010 presentation "Contract Documents: A Key to Economical Design." You can view this presentation (E23) and all 2010 NASCC sessions for free at **www.aisc.org/2010nascconline**.

For a thorough checklist of design document requirements for all structural materials, refer to the Council of American Structural Engineers (CASE) 2003 publication 962-D, "A Guideline Addressing Coordination and Completeness of Structural Construction Documents." It is available for purchase on the CASE website at **www.acec.org/case/publications.cfm**.

Other references include the 2010 MasterSpec, published by ARCOM for the American Institute if Architects (AIA), and the 13th Edition AISC *Steel Construction Manual*.

Connection Design Option 1– SER Designs the Connections

Overview

Option 1 under Section 3.1.2 of the 2010 *Code* is specified when the complete connection design is shown in the structural design drawings; in other words, when the SER designs the connections. The main advantage to this option is that the connections are fully communicated to the fabricator via the design drawings, which leaves little room for confusion. The main disadvantage is that it is harder to benefit from fabricator input, which may result in a less ideal use of the fabricator's resources, and thus a less economical project.

Drawing Requirements

Drawing requirements for Option 1 are outlined in subitem (1) in the Commentary to *Code* Section 3.1.2:

- All weld types, sizes, and lengths.
- All bolt sizes, locations, quantities, and grades.
- All plate and angle sizes, thicknesses and dimensions.
- All work point locations and related information.

With the complete connection design information provided on the CDs, the steel detailer will then be able to transfer this information to the shop and erection drawings, applying it to the individual pieces being detailed.

Sample Specification Language

Structural steel connection design for **[shear] [moment] [bracing] [all]** connections is shown in the Structural Drawings. No engineering is necessary for these connections.

Helpful Tips

When using Option 1, the SER has the responsibility to design economical and efficient connections. Here are some helpful tips to achieve that goal:

- Consider that labor costs (shop and field) are higher and more influential in connection economy than material costs.
- As a rule of thumb, minimize the number of pieces in connections.
- Use similar connection types throughout the project.
- Use single-plate connections, not through-plates, at HSS columns.
- Use single-sided connections wherever possible.
- Use the strength increase for welds loaded at an angle.
- Note that minimum weld size is now based on the thinner of the two connecting parts (see Section J2.2 in the 2005 AISC *Specification*).
- Use fillet welds wherever possible.
- Use snug-tightened joints whenever possible, pretensioned joints if not, and slip-critical joints only when necessary.
- Use the uniform force method for bracing connection design.
- Avoid stiffeners, doubler plates, and similar elements whenever possible
- Eliminate column splices when possible, but especially those that might create one-story or three-story tiers.
- Use $R = 3$ systems whenever possible.

Connection Design Option 2– The Steel Detailer Completes the Connections

Overview

For Option 2 under Section 3.1.2 of the 2010 *Code*, the connection is designated to be selected or completed by an experienced steel detailer; in other words, the SER provides the schematics and the steel detailer completes the details. This option also has pros and cons. The SER's effort is reduced to referencing or creating tabular information specific to the project that a steel detailer can use to select the specifics of each connection so designated in the project. The experienced steel detailer is skilled at optimizing the finer details like gages and angle sizes according to the fabricator's resources and capabilities, saving valuable time and money. However, this option is more difficult to implement for connections that aren't in the tables in the 13th Edition AISC *Manual* or other suitable literature. The SER must create such information for other connections if this method is used.

Drawing Requirements

Drawing requirements for Option 2 are outlined in *Code* Section 3.1.2 and described further in its Commentary subitem (2):

- Tables or schematic design information necessary to select and complete the connections, or reference to the tables in the *Manual* or other reference information.
- Any restrictions on the types of connections that are permitted.
- Data concerning the loads (including shears, moments, axial forces, and transfer forces) that are to be resisted by the individual members and their connections.
- Whether the above mentioned data is given at the service-load level or the factored-load level.
- Whether LRFD or ASD is to be used in the selection and completion of connection details.
- What substantiating connection information, if any, is required (note that substantiating information is rarely required for Option 2, particularly because there is no engineering required).

The intent of this method is that the steel detailer will select the connection materials and configuration from the referenced tables and/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 for connection design.

Sample Specification Language

- Structural steel connections shall be selected or completed by an experienced steel detailer for **[shear] [moment] [bracing] [all]** connections. No engineering is necessary for these connections.
- Detailer shall use the **[tables provided in the Drawings] [schematic information provided in the Drawings] [tables in the AISC *Steel Construction Manual*] [other reference]** in the selection or completion of the connections.
- Selection/completion criteria:
  - + Use **[LRFD; data are given at factored-load level] [ASD; data are given at service-load level]**
  - + Load data
    - Shear connections: **[see reactions shown in the Drawings] [see tables or schematic information in the Drawings]**
    - Moment connections: **[see reactions shown in the Drawings] [see tables or schematic information in the Drawings]**
    - Bracing connections: **[see reactions shown in the Drawings] [see tables or schematic information in the Drawings]**

Helpful Tips

Think in detail about the connections as you create the schematic information so that you are certain it is sufficient to allow the steel detailer to complete the specific connections you are describing. Also, note that providing accurate information to the fabricator and detailer is necessary to achieve economical connection designs with Option 2.

- Provide good schematic details and tables.
- Provide actual loads.
- Anticipate issues that will not work with the schematic details and reference tables, such as deep copes and skewed beams. Use Option 1 or 3 for these special connections.

Connection Design Option 3– SER Delegates Connection Design to the Fabricator

Overview

While the first two connection design options have appeared in previous editions of the *Code*, Option 3 is a new introduction in the 2010 *Code* (although its been commonly practiced in a wide variety of manners for decades). For Option 3 under Section 3.1.2 of the 2010 *Code*, the connection is designated to be designed by a licensed professional engineer working for the fabricator; in other words, the SER provides design criteria and a licensed professional engineer working for the fabricator designs the connections.

The advantages of Option 3 are similar to those for Option 2. The connection engineer works very closely with the fabricator to ensure the most economical connection designs for their shop. The main shortcoming of this method is overdesign, which can stem from the SER providing inadequate information or excessively conservative loading or other criteria to the connection engineer.

Drawing Requirements

Drawing requirements for Option 3 are outlined in *Code* Section 3.1.2 and described further in subitem 3 in its Commentary:

- Any restrictions on the types of connections that are permitted.
- Data concerning the loads (including shears, moments, axial forces, and transfer forces) that are to be resisted by the individual members and their connections.
- Whether the above mentioned data is given at the service-load level or the factored-load level.
- Whether LRFD or ASD is to be used in the design of connection details.
- What substantiating connection information, if any, is required.

Substantiating connection information can take many forms, such as hand calculations and/or software output. The SER may also request, for example, a signed and sealed cover letter with the shop and erection drawings and substantiating connection information. A requirement to sign and seal each sheet of the shop and erection drawings is discouraged—that may confuse the design responsibility between the SER and the licensed professional engineer performing the connection design. It is also recommended to use an early submittal and review process of sample substantiating connection information (such as sample calculations for typical connections) soon after the project award.

The fabricator has added responsibility with Option 3. The submittal and review process for the substantiating connection information is in addition to the traditional review and approval process of the shop and erection drawings as outlined in Section 4.4 of the *Code*, and thus, needs to be accounted for in the project schedule. The connection engineer has to review and confirm in writing that the shop and erection drawings properly incorporate their connection designs and the fabricator needs to provide a link between the substantiating connection information and the related connections on the shop and erection drawings.

Sample Specification Language

- Structural steel connections for **[shear] [moment] [bracing] [all]** connections shall be designed by a licensed **[professional] [structural]** engineer working for the fabricator.
- Design criteria:
  - + Use **[LRFD; data are given at factored-load level] [ASD; data are given at service-load level]**
  - + Load data
    - Shear connections: **[see reactions shown in the Drawings] [see tables or schematic information in the Drawings]**
    - Moment connections: **[see reactions shown in the Drawings] [see tables or schematic information in the Drawings]**
    - Bracing connections: **[see reactions shown in the Drawings] [see tables or schematic information in the Drawings]**
- At least **[XX]** days prior to submittal of the shop and erection drawings, provide sample substantiating connection information in the form of **[sample calculations for typical connections]**.
- With the shop and erection drawings, provide final substantiating connection information in the form of **[calculations for all Option 3 connections] [and a letter stating that the shop and erection drawings properly incorporate the connection designs]** signed and sealed by the licensed professional engineer in responsible charge of the connection design. Provide a means by which the substantiating connection information is referenced to the related connections on the shop and erection drawings for the purpose of review.

Helpful Tips

Communication between the SER, the fabricator, and the fabricator's engineer is key to the successful implementation of Option 3.

- Provide actual loads, including shear, moment(s), axial force, and/or torsion, as applicable.
- Let the fabricator's engineer do their job—don't unnecessarily restrict their connection designs.
  - + Only specify slip-critical and pretensioned bolts when necessary.
  - + Don't specify minimum weld sizes.
  - + Avoid specifying CJP groove welds when PJP groove welds will work.
  - + Don't specify through plates.
  - + Avoid specifying minimum bolt size or grade.
  - + Only specify weld all around if required structurally.

Final Thoughts

Regardless of which connection design option (or combination thereof) is implemented, the project team and owner will be best served by increased communication between the SER and the fabricator. Connection design can have a significant impact (both positive and negative) on the bottom line of the project. Early involvement of the fabricator can be extremely beneficial to the project schedule and economics. The sooner the SER can begin connection design discussions and debates with the fabricator and the fabricator's engineer in the case of Option 3, the sooner the benefits of collaboration will be evident.

Current design and construction industry trends, such as integrated project delivery and building information modeling, are all based on increased collaboration between the design team and the construction professionals. Collaboration in steel connection design certainly fits in well with these industry initiatives. MSC