Why care?

Engineers can reduce the cost of the connections even when delegating connection design.

A substantial percentage of structural steel cost is related to the connections.

Why delegate?

Less work for the engineer of record

Connection design is becoming a specialty

Fabricators have different preferences for preferred connection details

The wrong way:

“All shear connections shall be designed to develop the full shear strength of the member.”

“All moment connections shall be designed to develop the full plastic moment capacity of the member.”

But there is a right way and a wrong way to delegate connection design.
The wrong way:

"ALL SHEAR CONNECTIONS SHALL BE DESIGNED TO DEVELOP A SHEAR STRENGTH EQUAL TO \(0.6 \times F_y \times d \times t\)"

"ALL MOMENT CONNECTIONS SHALL BE DESIGNED TO DEVELOP THE FULL PLASTIC MOMENT CAPACITY \(0.9 \times M_p\) OF THE MEMBER."

The right way:

Follow the Code of Standard Practice

SECTION 3. DESIGN DRAWINGS AND SPECIFICATIONS

3.1. Structural Design Drawings and Specifications

Unless otherwise indicated in the contract document, the structural design drawings shall be based upon consideration of the design loads and forces to be resisted by the structural steel frame in the completed project. The structural design drawings shall clearly show the work that is to be performed and shall give the following information with sufficient dimensions to accurately convey the quantity and nature of the structural steel to be fabricated:

(a) The size, section, material grade and location of all members;
(b) All geometry and working points necessary for layout;
(c) Floor elevations;
(d) Column centers and offsets;
(e) The bearing requirements for members;
(f) Jointing requirements between elements of built-up members; and,
(g) The information that is required in Sections 3.1.1 through 3.1.6.

The structural steel specifications shall include any special requirements for the fabrication and erection of the structural steel. The structural design drawings, specifications and addenda shall be numbered and dated for the purposes of identification.
The owner's designated representative for design shall indicate one of the following options for each connection:

1. The complete connection design shall be shown in the structural design drawings;
2. In the structural design drawings or specifications, the connection shall be designated to be selected or completed by an experienced steel detailer, or;
3. In the structural design drawings or specifications, the connection shall be designated to be designed by a licensed professional engineer working for the fabricator.

When option (1) above is specified:

(a) The fabricator shall submit in a timely manner representative samples of the required connection information to the owner's designated representative for design and construction. The owner's designated representative for design shall confirm in writing to the fabricator that the samples are consistent with the requirements of the contract documents, or shall advise what modifications are required to bring the representative samples into compliance with the requirements in the contract documents. The initial submittal and review is in addition to the requirements in Section 4.4.

(b) The licensed professional engineer in responsible charge of the connection design shall review and confirm in writing as part of the substantiating connection information, that the shop and erection drawings properly incorporate the connection design. However, this review by the licensed professional engineer in responsible charge of the connection design does not replace the approval process of the shop and erection drawings by the owner's designated representative for design in Section 4.4.

(c) The fabricator shall provide a means by which the substantiating connection information is referenced in the related connections on the shop and erection drawings for the purpose of review.

When option (2) or (3) above is specified, the owner's designated representative for design shall provide the following information in the structural design drawings and specifications:

(a) Any restrictions on the types of connections that are permitted;
(b) Data concerning the loads, including shear, moments, axial forces and transfer forces, that are to be resisted by the individual members and their connections, sufficient to allow the selection, completion, or design of the connection details while preparing the shop and erection drawings;
(c) Whether the data required in (b) is given at the service-load level or the factored-load level;
(d) Whether LRF or ASD is to be used in the selection, completion, or design of connection details; and,
(e) What substantiating connection information, if any, is to be provided with the shop and erection drawings to the owner's designated representative for design.

The EOR has ultimate “...responsibility for the adequacy and safety of the entire structure....”

From the commentary of ATSC 303-10,
This is not connection design

Design of stiffeners is the responsibility of the engineer of record

Rule #2

Show the reactions
Wrong way #1

"ALL SHEAR CONNECTIONS SHALL BE DESIGNED TO DEVELOP THE FULL SHEAR STRENGTH OF THE MEMBER."

"ALL MOMENT CONNECTIONS SHALL BE DESIGNED TO DEVELOP THE FULL PLASTIC MOMENT CAPACITY OF THE MEMBER"

Wrong way #2

DESIGN SHEAR CONNECTIONS FOR THE FOLLOWING SHEAR STRENGTHS:

<table>
<thead>
<tr>
<th>Beam</th>
<th>Shear Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>W8</td>
<td>15 k</td>
</tr>
<tr>
<td>W10</td>
<td>30 k</td>
</tr>
<tr>
<td>W12</td>
<td>40 k</td>
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<td>W14</td>
<td>50 k</td>
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<td>60 k</td>
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<td>W24</td>
<td>120 k</td>
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<td>W27</td>
<td>150 k</td>
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<tr>
<td>W30</td>
<td>180 k</td>
</tr>
<tr>
<td>W33</td>
<td>210 k</td>
</tr>
<tr>
<td>W36</td>
<td>240 k</td>
</tr>
</tbody>
</table>

Wrong way #3

Do not specify connections be designed using Table 3A6

Relying on Table 3-6 will usually result in excessively conservative connection designs.

- From Table 3-6, 13th Edition ASD manual maximum uniform load capacity for W16x33 is 34k for I = 30°
- Connection requirement on contract documents: Design connections for 150% of the reaction from the uniform load capacity of the beams from Table 3-6 (0.75 x 34k = 25.5k)
- Required connection strength based on the arbitrary 1.5 x Table 3-6 value is 50% greater than required.
- Required connection strength based on the full shear capacity of the beam = 121k (more than 3 x required strength)

Relying on Table 3-6 will usually result in excessively conservative connection designs.

- From Table 3-6, 11th Edition AISC Manual maximum uniform load capacity for W24x76 is 35k for I = 45°
- Connection requirement on contract documents: Design connections for 150% of the reaction from the uniform load capacity of the beams from Table 3-6 (0.75 x 35k = 26.25k)
- Required connection strength based on the arbitrary 1.5 x Table 3-6 value is 50% greater than required.
- Required connection strength based on the full shear capacity of the beam = 235k (more than 3 x required strength)

But, relying on Table 3-6 can also result in connections with insufficient strength

- From Table 3-6, 14th Edition ASD Manual maximum uniform load capacity for W24x76 is 195k for I = 45°
- Connection requirement on contract documents: Design connections for 150% of the reaction from the uniform load capacity of the beams from Table 3-6 (0.75 x 195k = 146.25k)
- Actual reaction at right end is more than twice as big as connection strength.
Show member shear reactions on framing plans, moment connection design moments and axial loads in brace and truss members. (preferably factored)

Rule #3

Do not make up connection design requirements

Examples of arbitrary (and usually unnecessary) requirements,

“All bolts shall be slip-critical”

“All connections shall be designed for the full strength of the member”

“All holes shall be standard sized holes”

“Single-sided shear connections are prohibited”

Rule #4

Use R=3 (where permitted)

Rule #5

Limit “Strength Ratio” of tension members
Limit strength ratio

Strength ratio = \frac{\text{Required strength}}{\text{ASAGS}}

ASAGS = \text{Available strength at the gross section}

Limit strength ratio

Members must have sufficient strength at both the gross and net sections.

D2. TENSILE STRENGTH

The design tensile strength, \( F_u \), and the allowable tensile strength, \( F_{u,a} \), of tension members, shall be the lower value obtained according to the lower stress at net section yielding in the gross section and tensile rupture in the net section.

(a) For tensile yielding in the gross section:

\[
P_x - F_y A_x
\]

\( \phi = 0.50 \) (LRFD) \( \Omega = 1.67 \) (ASD)

(b) For tensile rupture in the net section:

\[
P_x - F_{y,a} A_x
\]

\( \phi = 0.75 \) (LRFD) \( \Omega = 2.00 \) (ASD)

Limit strength ratio

\[A_{c} = U \times A_{n}\]

\( A_{c} = \text{Effective net area} \)

\( A_{n} = \text{Net area} \)

\( U = \text{Shear lag factor} \)

Limit strength ratio

\[\varnothing_{c}F_{y}A_{c} = \varnothing_{u}F_{u}A_{u}\]

\[0.9\varnothing_{u}A_{n} = 0.75\varnothing_{u}A_{u}\]

\[
\frac{A_{c}}{A_{n}} = \frac{0.90F_{y}}{0.75F_{u}} = 1.2 \frac{F_{y}}{F_{u}}
\]

When \( \frac{A_{c}}{A_{n}} = 1.2 \frac{F_{y}}{F_{u}} \) Rupture strength = tension yield strength.

When \( \frac{A_{c}}{A_{n}} < 1.2 \frac{F_{y}}{F_{u}} \) Rupture strength at net section controls.

When \( \frac{A_{c}}{A_{n}} > 1.2 \frac{F_{y}}{F_{u}} \) Tension yield strength at gross section controls.

Limit strength ratio

ASTM A36:

\[
\varnothing_{u} = 98 \text{ ksi}
\]

\[
F_{y} = 58 \text{ ksi}
\]

\[
F_{u} = 60 \text{ ksi}
\]

ASTM A992:

\[
\varnothing_{u} = 98 \text{ ksi}
\]

\[
F_{y} = 50 \text{ ksi}
\]

\[
F_{u} = 65 \text{ ksi}
\]

ASTM A913 Grade 65:

\[
\varnothing_{u} = 98 \text{ ksi}
\]

\[
F_{y} = 65 \text{ ksi}
\]

\[
F_{u} = 80 \text{ ksi}
\]

When \( \frac{A_{c}}{A_{n}} < 0.75 \), 0.92 & 0.98 for ASTM A36, A992 & A913(Grade 65) respectively, then rupture strength at the net section will control.

Limit strength ratio

Suggestion

Limit \[
\frac{\text{Required strength}}{\text{Available strength}}\]
to 0.75 (max.)

(*Available strength at gross section)

Following this rule will reduce the likelihood that sections will require reinforcement at the net section.
Think about constructability and connection “designability”
Head off steeply skewed connections

Configure framing so that no more than one beam frames to any one side of a column
Designability

Be aware of connection interference where beams are slightly offset from columns.

Avoid skewed beam-to-column moment connections.

Rule #7

Issue complete, coordinated and well-detailed contract documents

Show details giving concept of design. Permit alternative details.
Rule #8

Permit consideration of alternative connection details

Summary

1. Understand and follow the Code of Standard Practice
2. Show the reactions
3. Do not specify requirements in excess of the building code
4. Use R = 3 for seismic design (if permitted)
5. Limit strength ratio in tension members to 0.75
6. Think about constructability and connection "designability"
7. Issue complete & coordinated contract documents with "designable" concept connection details
8. Permit alternative connection details

Thank you!

Questions?

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