

CVEN 446

Structural Steel Design

Module 16

Steel Connections I

April 22, 2015

Introduction to Steel Connections

In reviewing classical structural analysis, two types of support conditions are idealized: pinned and fixed.



The difference between the two support conditions is the magnitude of the moment that is transferred to the support by the connection. The pinned connection allows rotation, thus no moment can develop. The fixed connection prohibits rotation, thus the connection must be designed for bending moments.

Introduction to Steel Connections

In building frame construction, the AISC-LRFD Specification recognizes two basic types of connections: partially restrained and fully restrained.

Type PR - Partially Restrained

A partially restrained connection is insufficiently rigid to hold the angles between members unchanged. Therefore, the connection has an intermediate degree of moment capacity. A special case of a partially restrained connection is the "simple framing" connection. For this type of connection, it is assumed that only shear is transmitted through the connection.

A simple framing connection is used in braced frames.

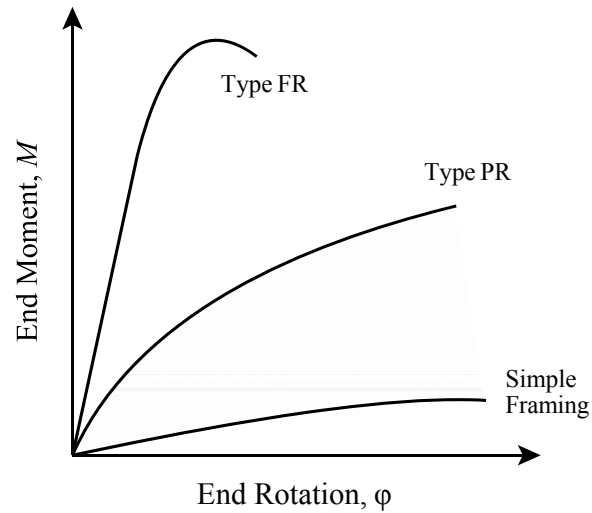
Introduction to Steel Connections

Type FR - Fully Restrained

A fully restrained connection transmits the calculated moments and shears. The connection is sufficiently rigid to provide full continuity and the angles between intersecting members remain unchanged during rotation (right-angles remain right-angles). Both moment and shear are transferred through the connection.

This type of connection is used in moment resisting frames that have to resist lateral loads (wind, earthquake, etc.).

Introduction to Steel Connections



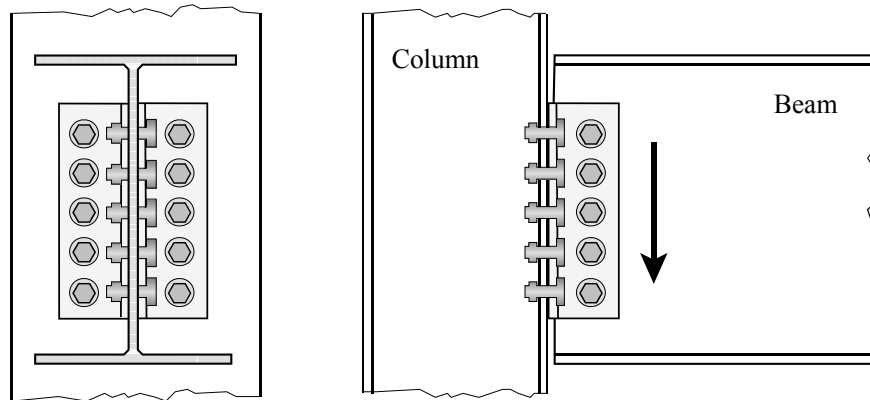
Bolted Clip Angle Connection

The bolted clip angle connection is one of the simpler beam-to-column connections to design and construct.

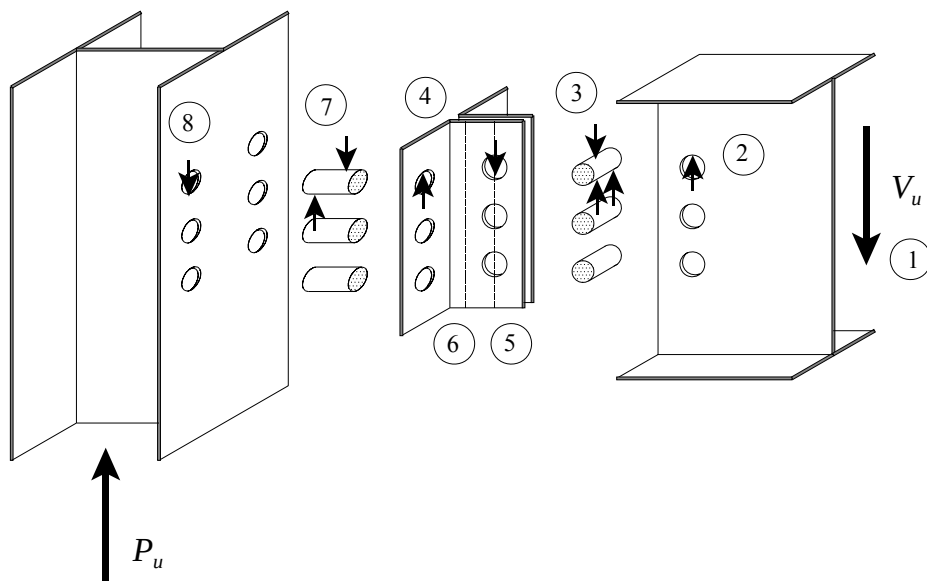


Bolted Clip Angle Connection

This simple connection consists of a single, or pair, of angles attached to the web of the beam. Since the flanges of the beams are not connected to the column, it is assumed that the connection only transfers shear from the beam to the column.



Bolted Clip Angle Connection



Bolted Clip Angle Connection - Analysis

1. The shear capacity of the beam web.

$$\phi V_n = 1.0(0.60) F_y d t_w$$

2. Bolt hole bearing strength for the beam web.

$$\phi R_n = n (0.75)(2.4) F_u t_w d_{bolt} \leq n (0.75) F_u (1.2) l_c t_w$$

3. Shear capacity of the bolts (single shear if one clip angle is used, double shear for a pair of clip angles)

$$\phi R_n = n \phi r_n$$

4. Bolt hole bearing strength for the angle.

$$\phi R_n = n (0.75)(2.4) F_u t d_{bolt} \leq n (0.75) F_u (1.2) l_c t$$

Bolted Clip Angle Connection - Analysis (cont.)

5. Net section shear capacity of the angle.

$$\phi V_n = 2[0.75(0.60) F_u (L - n d_{net}) t_{angle}]$$

6. Gross section shear capacity of the angle.

$$\phi V_n = 2[1.0(0.60) F_y L t_{angle}]$$

7. Shear capacity of the bolts at the clip angle-column connection (single shear).

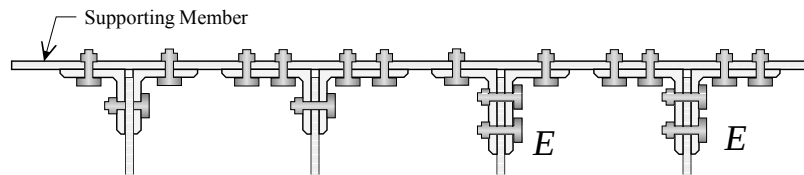
$$\phi R_n = n \phi r_n$$

8. Bolt hole bearing capacity of the column flange.

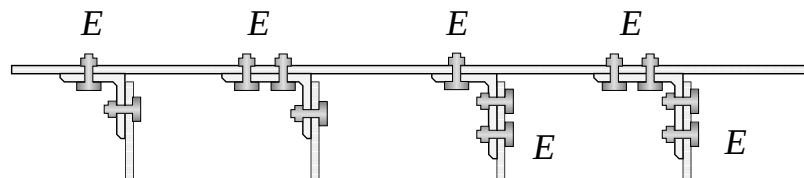
$$\phi R_n = n (0.75)(2.4) F_u t d_{bolt}$$

Bolted Clip Angle Connection

Eccentricity can be ignored except for bolt patterns designated by 'E'.



Eccentricity for Double-Angle Connections



Eccentricity for Single-Angle Connections

Bolted Double Clip Angle Connection - Design

1. Based on the required design shear capacity of the connection, V_u , determine the required number of bolts:

$$n_{req} = \frac{V_u}{\phi r_n}$$

The bolts are in double shear as a pair of clip angles are used.

2. Determine the required clip angle length using 3" spacing between bolts and 1-1/2" edge distance:

$$L = 3(n - 1) + 2(1.5) < T$$

Bolted Double Clip Angle Connection - Design

3. Determine required thickness of one clip angle based on net section shear rupture (usually controls):

$$t_{angle} = \frac{V_u}{[0.75(0.60)F_u (L - n(d_b + 1/8"))]2}$$

4. Check gross section shear yielding:

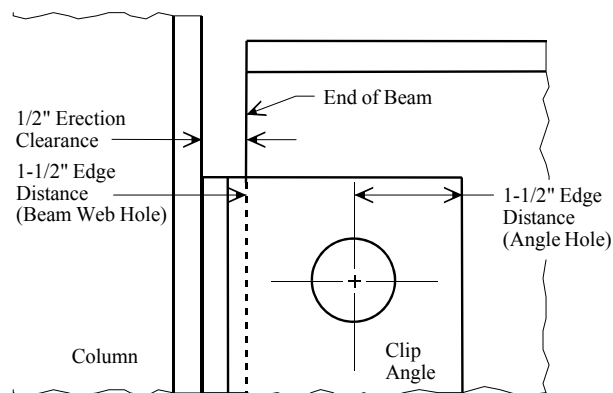
$$\phi V_n = 2[1.0(0.60) F_y L t_{angle}]$$

5. Checking bolt hole bearing strength in beam web, angles, and column flange (or web):

$$\phi R_n = n (0.75)(2.4) F_u t d_{bolt} \leq n (0.75) F_u (1.2) l_c t$$

Bolted Double Clip Angle Connection - Design

The lengths of the angle legs are determined by the spacing considerations shown. The outstanding leg dimension is typically 1/2" longer than the leg attached the column due to the 1/2" erection clearance.

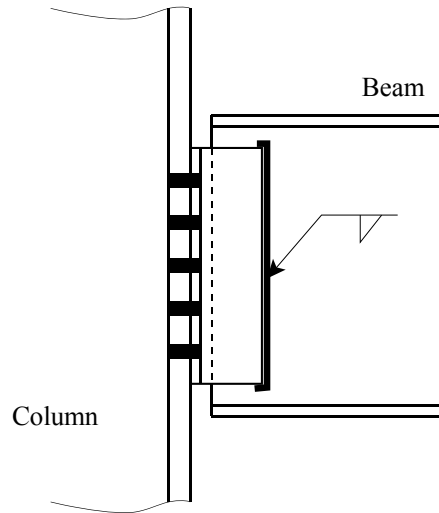


Welded Clip Angle Connection

Instead of bolting the clip angles to the beam flange, they are often fillet-welded.

This is done in the fabricating shop and is therefore more economical.

The clip angles are bolted to the column in the field during erection of the building.



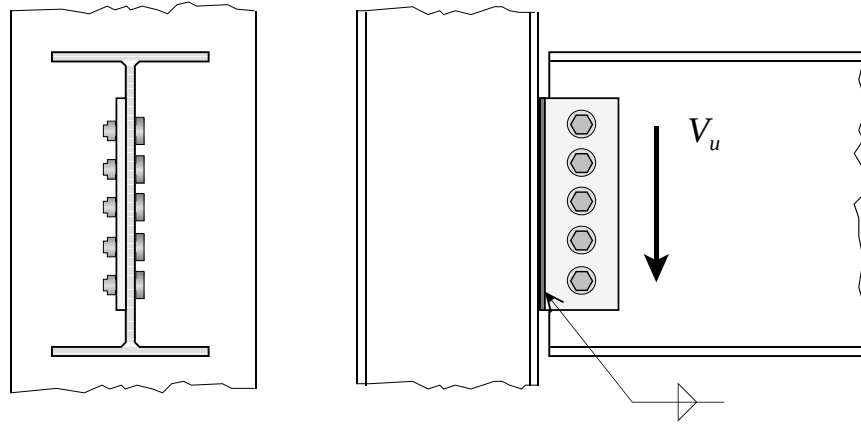
Single-Plate Shear Tab

The single-plate shear connection is comprised of a shear tab that is fillet welded to the supporting member (either a column or girder web) and bolted to the support member (beam).



Single-Plate Shear Tab

A single-plate shear tab connection is shop-welded to the column flange and field-bolted to the beam web. Fillet welds are used on both sides of the plate.



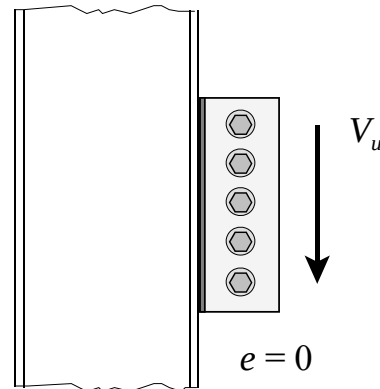
Single-Plate Shear Tab

The limit states that must be checked are given as:

- 1) Gross section shear yielding.
- 2) Net section shear rupture.
- 3) Bolt bearing in the shear tab and the beam web.
- 4) Bolt shear strength (single shear). Consider the effect of eccentricity on the bolt pattern.
- 5) Fillet welded shear strength.

Single-Plate Shear Tab

The bolt eccentricity is taken as zero when the shear tab has no more than 9 bolts in a single vertical row with standard holes.

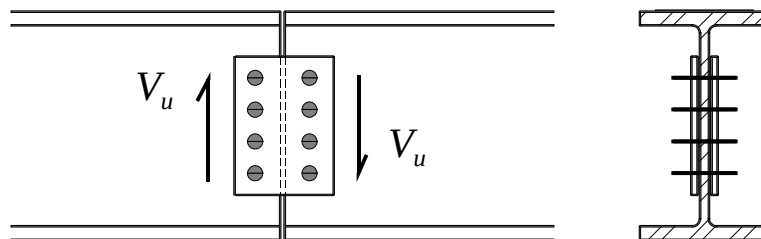


Beam Shear Splice

If a connection between beams is assumed to be pinned, then only shear is transferred:



The actual connection involves splicing the web plate:

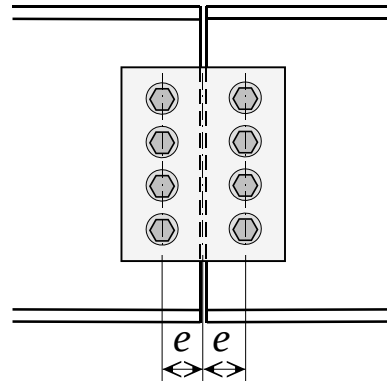


Beam Shear Splice

The eccentricity on the bolt pattern must be taken into account:

The eccentricity is taken as half the distance between the two bolt gage lines.

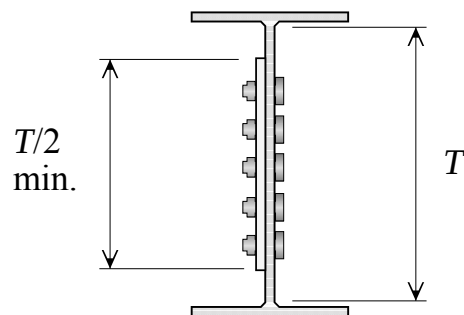
Typically, a 1/2" erection clearance is used between the ends of the beams.



T - Dimension

Any plate that is used to connect the web of a beam must fit between the fillets of the beam section. This dimension is given as T in the section property tables.

To provide lateral and torsional stability of the beam, the web connection plate should not be less than $T/2$.

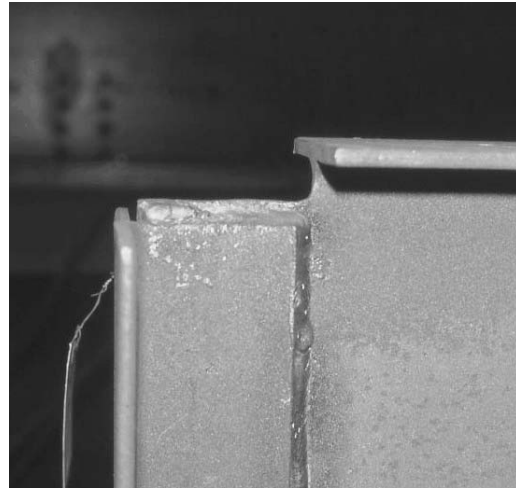


Coped Beam Flange

It may be necessary to cope the top flange of a beam so it doesn't interfere with the flange of the girder it is connecting to.

The cope reduces the shear capacity of the beam section (both gross and net section).

If the clip angle is bolted, block shear rupture may also control.



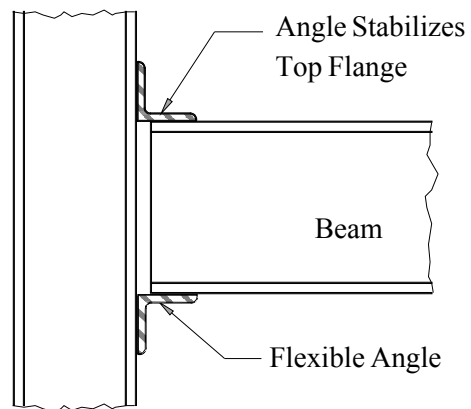
Unstiffened Beam Seat

An unstiffened beam seat connection has an angle projecting from the face of the column.

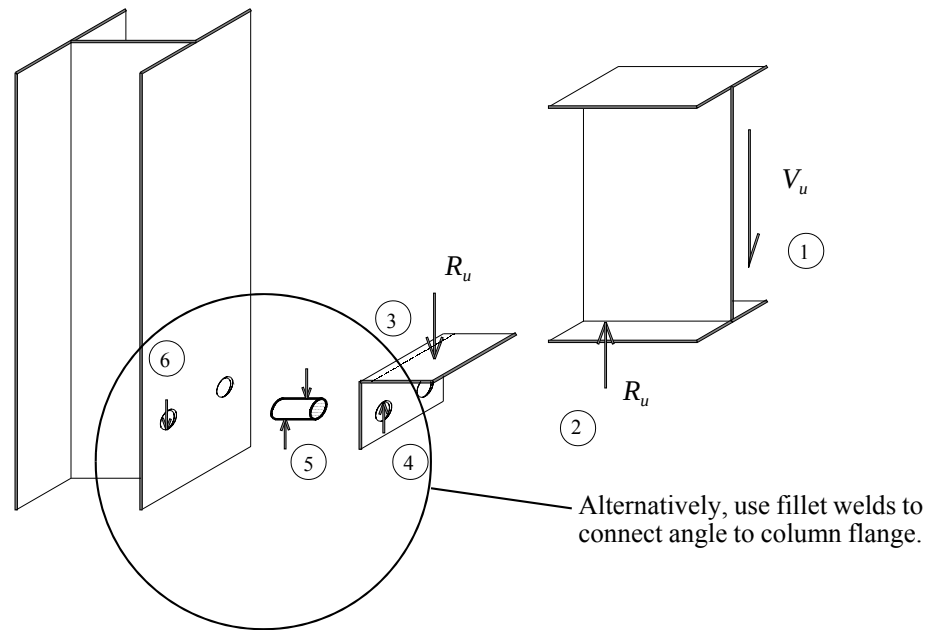
The beam shear is transferred to the beam shear in the form of the end reaction.

This is referred to as an unstiffened beam seat since the leg of the angle cantilevers out from the column without any support.

Column



Unstiffened Beam Seat



Unstiffened Beam Seat

The design or analysis of a beam seat connection detail must consider the following items:

1. The shear capacity of the beam web.
 2. Local web yielding and web crippling of the beam.
 3. Bending capacity of the angle.
 4. Bolt hole bearing capacity of the angle.
 5. Bolt shear strength at the angle-column connection.
 6. Bolt bearing capacity of the column flange.
- (Alternatively, the angle may be fillet-welded to the column.)

Unstiffened Beam Seat

The connection strength is usually controlled by the moment capacity of the angle leg.

The bending capacity of the outstanding leg of the angle is based on the development of a plastic hinge:

$$\begin{aligned}\phi M_n &= \phi M_p \\ &= \phi F_y Z \\ &= 0.90 F_y \left(\frac{bt^2}{4} \right)\end{aligned}$$

where

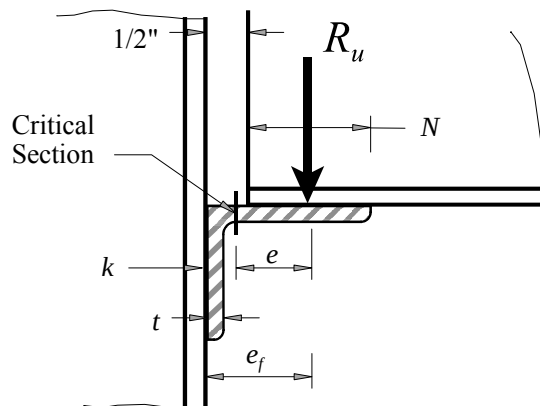
b = length of the angle section (generally taken as 6 or 8 in.)
 t = thickness of the angle

Unstiffened Beam Seat

The strength of the angle is controlled by the formation of a plastic moment at the critical section.

The critical section is at the end of the fillet of the outstanding leg.

The fillet size is given as k and varies with the angle thickness



Unstiffened Beam Seat

The moment that must be resisted by the outstanding leg is given as the support reaction times the eccentricity:

$$e = 1/2 + N/2 - k$$

where k is the thickness of the angle plus the fillet.

The size of the fillet varies for angles depending on the angle size:

- For the L4x3-1/2 series of angles the fillet is 7/16"
- For the L5x3-1/2 series of angles the fillet is 1/2"

The support reaction is assumed to act at $N/2$.

Unstiffened Beam Seat - Design

The design of an unstiffened beam seat is an iterative process since the unknown angle thickness determines the eccentricity.

By equating the required design moment to the moment capacity of the angle:

$$0.90F_y \left(\frac{bt^2}{4} \right) = R_u e$$

Solving for the angle thickness give:

$$t_{req} = \sqrt{\frac{4R_u e}{0.9F_y b}}$$

The eccentricity must be estimated as it contains the angle thickness. Iterate until the angle thicknesses converge.

Stiffened Beam Seats

As the magnitude of the end support reaction increases, the required thickness of an unstiffened beam seat angle exceeds the available shape sizes.

An alternative is to use a stiffened beam seat:

