Design of Shear Connections

An Online Continuing Education Course for Engineers

Course Number: S-4033

Credit: 4 Hours / 4 PDH / 4 CPD

Design of Shear Connections

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1. Introduction:

This course provides a comprehensive exploration of **shear connection design** in accordance with the **AISC Steel Construction Manual (16th Edition), Parts 9 and 10**, and **AISC 360-22, Chapter J**. All design methodologies are presented using both **LRFD and ASD** formats.

In keeping with our instructional philosophy, the curriculum prioritizes the **physical behavior and failure modes** of connection elements over exhaustive manual calculations. By focusing on how a connection actually fails, engineers develop a deeper **engineering sense** and a more intuitive understanding of how various design parameters influence code equations.

Shear connections are vital components designed to transfer gravity (shear) and axial loads from a beam to its support while maintaining a high **rotational capacity**. This flexibility ensures that the connection behaves as a "pinned" joint, preventing the transfer of unwanted moments. These connections are essential in various structural applications, including:

- Mezzanine framing.
- Secondary-to-primary beam intersections.
- Beam-to-column joints.
- End-wall column to gable rafter connections.

The course provides an in-depth analysis of three primary connection types: **Single-Plate (Fin Plate)**, **Double-Angle**, and **Shear End-Plate** connections. Participants will study the mechanical limits of each component, covering failure modes such as:

- **Connection Elements:** Bolt rupture, prying action, weld fracture, and plate buckling, etc.
- **Beam & Plate Limits:** Web yielding, block shear, plate rupture, and flexural yielding, etc.
- **Supporting Member Integrity:** Column flange local bending, web crippling, web yielding, and out-of-plane bending, etc.

The curriculum concludes with a specialized look at **coped beam stability**, focusing on web yielding, local buckling, and lateral-torsional buckling. By the end of this course, engineers will be equipped to design bolts, welds, and plates based on a fundamental understanding of **Chapter J** requirements, ensuring both safety and structural efficiency.

This course covers the following topics:

1. When do we use shear connections?
2. Types of shear connections, and how to choose the appropriate one.
3. Design of single plate shear connections.
4. Failure modes of single plate shear connections.
5. Design of double-angle shear connections.
6. Failure modes of double-angle shear connections.
7. Design of shear end plate connections.
8. Failure modes of shear end plate connections.
9. Checks of supporting members.
10. Checks of the coped beams.

2. When do we use shear connections?

The connections in steel structures are the main advantage of this industry. In contrast to the reinforced concrete structures, they give the engineers the benefit of fabricating the assemblies of the building in the workshop, then erecting the building in-situ using bolts. This accelerates the process of construction and eliminates as much as possible any potential delay in the schedule of the project.

For connections between two steel members, there are three types of connections:

- Moment connections: which transfer axial and shear forces, in addition to the moment. These connections do not provide rotation adequacy for the supported member at the ends. The applications of moment connections are:
    - In moment frames: to provide the framing action between the beam and the column of the frame, therefore, the frame becomes stable, and it can transfer the lateral forces (wind or seismic loads) to the ground.
    - Between secondary beams and main beams in floors that have no diaphragm systems (such as floors in industrial buildings where there is no type of floor coverage or horizontal bracing).
    - In cantilever beams.
- Shear connections: which transfer **ONLY** axial and shear forces. These connections should accommodate a rotation capacity for the supported member, and no moments are transferred through the connection. The applications of shear connections are:
    - In floor beams: where a diaphragm system is provided to the mezzanine, such as concrete on metal deck, checkered plates, single skin metal sheeting, or horizontal bracing.
    - When there is no need to use moment connections. The moment connections are more expensive than the shear connections. However, the moment connections decrease the moments in the formed continuous systems (such as continuous

beams), but for short spans, the use of moment connections has no valuable saving in the total weight (members and connections) of the system.

- Slotted connections: which transfer ONLY shear forces. They provide rotational capacity and longitudinal movements for the supported member. The applications of slotted connections are:
    - At expansion joints, to give the building the freedom to expand and contract under thermal variance. Therefore, no internal forces are generated in the members.
    - At the top connection between end wall columns and portal frame rafter in pre-engineered buildings, to prevent any transfer of forces from the roof to the end wall columns (the gravity loads are transferred from the rafter to the ground through the frame columns only).
    - For steel beams connected to concrete members, to prevent the beam from being a hinged-hinged system, therefore, no effect of thermal variance will occur in the steel beam or the concrete member.

3. Types of Shear Connections:

As per AISC Construction Manual (CM)-Part 10, there are many types of shear connections. The main idea is how to arrange the bolts, welds, connecting elements, and connected elements to satisfy the properties of shear connections:

- Transfer of shear forces.
- Transfer of axial forces (if any).
- Provide rotation capacity for the supported member.

The types mentioned in the CM are:

- Double-angle connections.
- Shear end-plate connections.
- Unstiffened seated connections.
- Stiffened seated connections.
- Single-plate connections.
- Single-angle connections.
- Tee connections.

In this course, three types of shear connections are addressed: single-plate connections, double-angle connections, and shear end-plate connections. We selected only these connections because:

- They are common and easy to design, fabricate, and erect.
- Each of them has an advantage from a design point of view.

The advantages of a single plate shear connection are:

- Suitable for moderate vertical reactions (not heavy ones).
- Economic option, because the thickness of the plate is usually thin.

- No attachments to the supported beam.
- Easy to fabricate.
- Easy to erect on the site.

The advantages of the shear end-plate connection are:

- Suitable for heavy vertical reactions, in addition to heavy axial reactions.
- Easy to fabricate.
- Easy to erect on the site.

The advantages of the shear double-angle connection are:

- Suitable for heavy vertical reactions.
- Easy to fabricate.
- Easy to erect on the site.

4. Design of Single-Plate Shear Connections:

A single plate shear connection is composed of:

1. Bolts connecting the beam web to the plate.
2. Single plate.
3. Weld between the plate to the supporting member.
4. Element of supporting member: beam web, column web, or column flange.

Figure (01) shows a typical single plate shear connection.

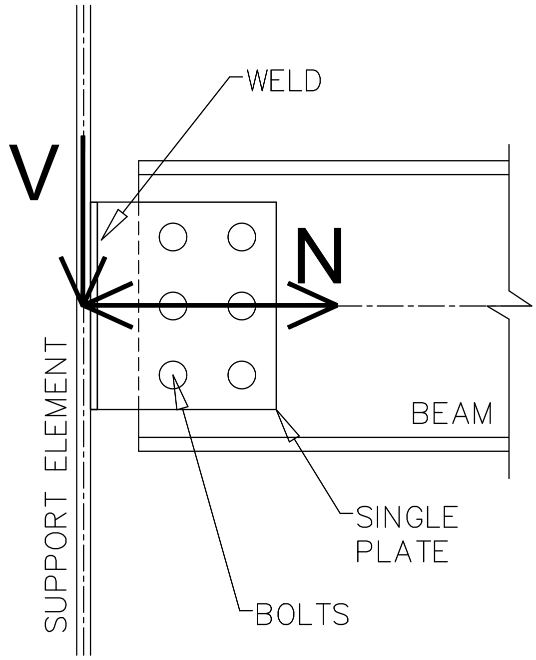

Figure (01). Typical Single-Plate Shear Connection Subject to Axial and Shear Force

In this section, we will study step-by-step the design checks of each element in this connection. In addition to understanding the modes of failure for each check in the real-life.

The design checks of the single-plate shear connection are:

1. Shear yielding of the beam web.
2. Tensile yielding of the beam.
3. Bolt rupture due to shear, tension, or both.
4. Bolt bearing/tearout at holes in the web of the supported beam.
5. Bolt bearing/tearout at holes in the single plate.
6. Shear rupture of the supported beam web due to shear (coped beam only with small eccentricity)
7. Tensile rupture of the supported beam web due to tension.
8. Shear rupture of a single plate due to shear at the bolts.
9. Tensile yielding of a single plate due to shear and flexure (single plate with large eccentricity).
10. Tensile rupture of a single plate due to shear and flexure at bolts (single plate with large eccentricity).
11. Block Shear Rupture of the beam web due to shear (for coped beams).
12. Block Shear Rupture of the beam web due to tension.

13. Block Shear Rupture of the beam web due to shear and tension.
14. Block shear rupture of a single plate due to shear.
15. Block shear rupture of a single plate due to tension.
16. Block Shear Rupture at a single plate due to shear and tension.
17. Rupture of the weld due to shear and tension.
18. Shear rupture of a single plate due to shear at the weld.
19. Tensile rupture of a single plate due to tension at the weld.
20. Shear yielding of a single plate due to shear.
21. Tensile yielding of a single plate due to tension.
22. Yielding of a single plate due to the combined effect of shear and tension.
23. Rotational Ductility.

For the supporting member, there are other check that depends on the type of element to which the single plate is welded.

For a single plate welded to the column flange:

1. Local yielding of the column web due to tension or compression.
2. Local crippling of the column web due to compression.
3. Buckling of Column Web due to com... sion at both sid... double-sided connections).

For a single plate weld...

1. Shea...
2. Shear...
3. Out-o... ession.

For a single plate w...

1. Shear yie...
2. Shear rup...
3. Out-of-pla... n.

- **Location of the...**

Shear connectio... support for a simply-supported beam. The location of t... determines the design force for each element in the connection. Generally, two concepts determine the location of the hinged support:

1. The hinging point is located at the centroid of the bolt group.
2. The hinging point is located at the intersection of the beam centerline with the support centerline (girder or column).