

Connecting HSS

By Donald R. Sherman

Making connections with HSS members is easier than you might think!

A frequent comment in the not-so-distant past was, "Tubes would make good structural members, but how can good connections be made?" The AISC *Hollow Structural Sections (HSS) Connections Manual* addressed this question in 1997. The *HSS Connections Manual* shows a variety of connections and contains numerous examples on how they can be designed, along with aids to facilitate the design. However, there are several nuances regarding HSS connections that should be of interest to designers and detailers.

There are four basic categories of HSS connections, with several types within each category. Some important aspects of detailing must be considered in selecting an appropriate type of HSS connection.

Simple Shear Connections

1. Shear connections in typical framing systems are made by shop-welding a connecting element to an HSS column or girder and field-bolting to a W-shape beam. If there are HSS beams, gussets or end tees can be used to provide a field-bolted connection similar to the web of a W-shape. The types of connections are:

→ Single plate (shear tab)

- Single angle
- Unstiffened seat
- Double angle
- WT
- Stiffened seat
- Through-plate

These are listed roughly in order of cost; however, this may vary depending on the fabricator's equipment and experience. The through-plate would have a less expensive placement if similar beams are framing into opposite sides of the column. Generally, through-plates are not recommended unless there are axial forces that have to be transferred through the support. Orthogonal through-plates are to be avoided in all cases.

2. In order to maintain rotational flexibility in the connection, transverse welds across the face of the HSS are used only in the stiffened seat and across the bottom of the single angle. The other connections use only vertical welds with small return. However, for single and through-plates, AISC recommends no weld across the thickness of the plate.

3. The through-plate is the only connection that is unique to HSS columns. All others are also used with W-shape columns, and design assumptions and criteria are the same (as noted in

the *HSS Connections Manual*) except for limit states involving the HSS wall. These limit states are shear in the HSS wall adjacent to the weld and punching shear in the case of single plate connections.

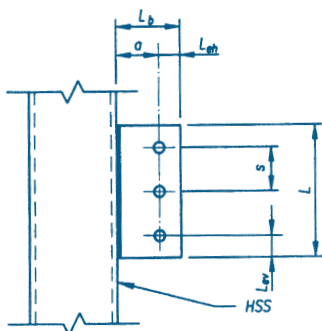
4. The single plate, through-plate, and stiffened seats are the only shear connections that can be used with round HSS columns. In the case of the stiffened seat, the seat plate must be cut to conform to the radius of the column.
5. The double angle connection is the only one that requires coping of the beam so that the web can be knifed between the outstanding angle legs during erection. In all the other connections, the beam is swung into position for bolting, which facilitates time and safety during erection.
6. For double angle and single angle connections, the HSS column width should be 12" or greater. This is necessary to accommodate the thickness of the beam web, the size of the typical 4 or 3.5" angle leg, the size of the fillet welds, and the corner radii of the HSS. Single plate and through-plate connections can be used with any width of HSS column. The width of the connection and HSS for the other types of connections are determined by the

Simple Shear Connections for HSS

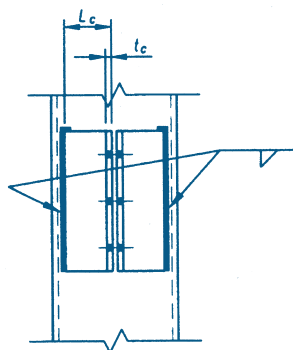
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MORE EXPENSIVE

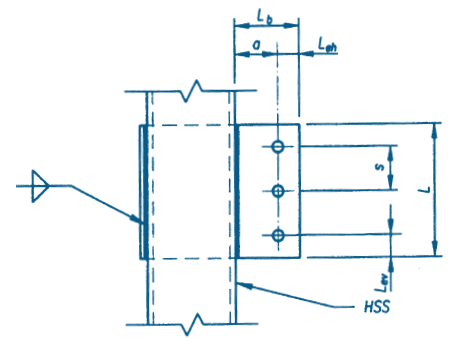
MOST EXPENSIVE



Single plate connection (shear tab)

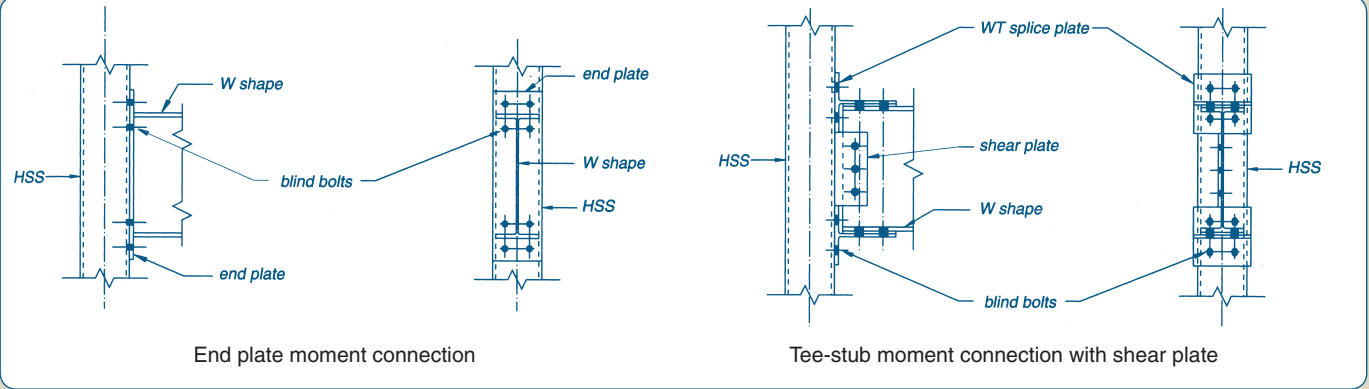


Double angle shear connection

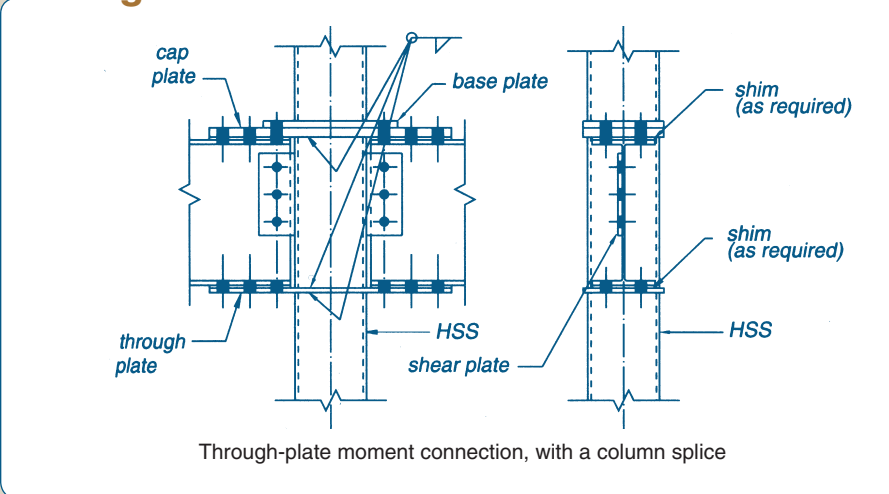


Through-plate shear connection

Bolted Moment Connections for HSS



Through-Plate Moment Connection for HSS



flange width of the beam. However, allowance must be made to permit a fillet weld on the flat of the HSS. If flare bevel welds are required for tees with flanges that are wider than the HSS, the cost of the connection increases dramatically.

7. Single plate connections can be used in place of through-plate connections without impairing the strength of the column due to distortion of the wall as long as the HSS section is not thin-walled ($b/t \leq 238/\sqrt{F_y}$ or $D/t \leq 3300/F_y$). Through-plates cannot be used in both planes for orthogonal shear connections.
8. All of the connections produce a moment on the column that must be considered in its design. In addition to the eccentricity from the face of the column to its centroid, there is an eccentricity of the shear force assumed in the design criteria for each of the types of connections, as noted in the *HSS Connections Manual*. Usually the shear is assumed to act at the weld or the bolt line. For single and through-plate connections, the eccentricity

varies with the length of the connection and will be outside the bolt line for long connections.

9. The stabilizing angles at the top of seated connections will probably require field welding since bolting to the HSS to accommodate the tilt in the flanges of the W-shape beam permitted by mill tolerances is impossible or difficult.

Moment Connections

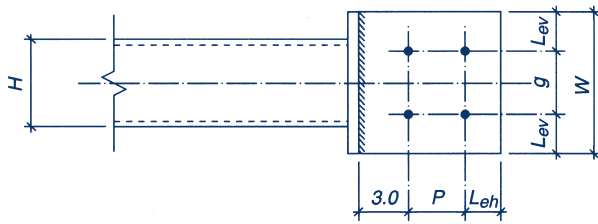
1. There are no standard types of moment connections between W-shape beams and HSS columns, and there is little information in published literature. However, the *HSS Connections Manual* describes several possibilities along with suggested design procedures.
 - Beam-over-column for single story construction
 - Beam through a column
 - Flange splice plate through the column
 - Flange splice plate around the column
 - Direct beam to column connections

The beam-over-column is the only one that is efficient and economical. The others are expensive, as is the case with most moment connections.

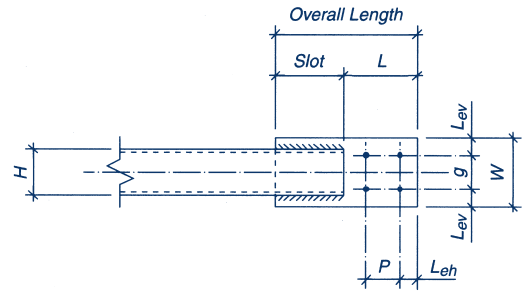
Four factors that dictate the critical limit states are important in selecting the type of connection:

- a. The magnitude of moment that must be transferred to the HSS.
 - b. The magnitude of the moment that must be transferred through the HSS.
 - c. The magnitude of the axial load in the HSS.
 - d. The requirements of orthogonal framing.
2. Due to the unique requirements of a particular job, a relative cost evaluation is not possible. However, the need for stiffeners and the degree of shop welding make moment connections expensive. They can all be detailed to avoid field welding.
 3. For W-shape beam-over-column construction, with lateral bracing at the top of the beam, there are column stability concerns due to the out-of-plane flexibility of the beam web. This pro-

End Connections for HSS



Welded-tee end connection



Slotted HSS/gusset plate end connection

duces a weakness between the brace point and the top of the HSS and allows sidesway in the column buckling mode. This must be resisted by stiffening the web or providing lateral bracing at the top of the HSS.

- When the beam passes through the HSS column, web stiffening must be provided to transfer the column axial load through the column. When flange splice plates pass through the column, a column stub is required between the plates to provide column continuity. Flange splice plates around the column permit the column to be continuous through the connection.
- Mill tolerances permit variations in beam depth and flange tilt, which must be recognized and provided for in the details for flange splice plates and beams through the column. This can be accomplished with field shims between the splice plates and beam flanges.
- When flange splice plates are used, single plate shear connections should be used to carry the shear force between the beam and column and to facilitate field erection.
- In direct connections, the beam flanges and web are welded directly to the HSS wall. The limit states in the HSS wall will determine the magnitude of moment that can be transferred, which will generally be less than the full moment capacity of the beam.

End Connections

- End connections are primarily used in bracing members. They can be made by using gussets, end tees, end plates, or welding around the perimeter.
- Welding around the perimeter can develop the full strength of the member, but only fillet or PJP welds should be specified. CJP welds are difficult

to make and inspect and are almost never needed to develop the required strength.

- Due to shear lag, gussets and end tees cannot efficiently develop more than 50% of the tensile strength of the HSS.
- The bolt layout for end plates should not use corner bolts that lie outside the projections of two sides of the HSS. Close length tolerances are required for fit-up and bolt tightening at both ends. Only fillet or PJP welds should be used to attach the end plate to the HSS.

Direct Connections

- Welded HSS-to-HSS connections are typically used in trusses to connect branch members to main members with welds around the perimeter of the branch. The types of connections are:
 - T or Y with a single branch perpendicular or at an angle to the main member.
 - K with two or three branches in a single plane; gapped or overlapping.
 - Cross where the load is transferred through the main member to the branch(es).
 - Butt splices.
 - Other types such as multiplanar and offset branches.

The new 2005 AISC *Specification* gives design criteria for rectangular and round HSS in T, Y, and K connections with axial loads or moments in the branches. T, Y, and gapped K-connections are discussed in the *HSS Connections Manual*. AISC does not consider multiplanar connections or offset branches. AWS D1.1 should be used.

- The design criteria specify the maximum load in the branch based on local limit states in the main member, which are obtained empirically through extensive testing. Member and connection design cannot be separated and

spreadsheets are useful design tools.

- Design rules for K-connections consider some eccentricity where the intersection of the branch centerlines does not lie on the centerline of the main member. If the intersection is within these limits, secondary moments in the connection do not have to be considered.
- Gapped K-connections are preferred to overlapped connections in order to avoid profiling of the overlapping branch, which is especially complex for round HSS.
- The weld between a sloping branch and main member may vary from a fillet weld to PJP weld depending on the position in the joint. CJP welds should not be specified.
- CJP welds may be necessary in tension butt splices, but PJP welds should be used in compression splices. If CJP welds use backing, it cannot be removed. Without backing, prequalified procedures, careful fit-up, and qualified welders must be used to ensure adequate root passes.
- When rectangular HSS have a branch and main member with the same width, there is a problem making the side welds due to the gap resulting from the corner radius of the main member. This requires either:
 - Profiling the transverse wall of the branch to the contour of the main member.
 - Using a backing which cannot be removed.
 - Placing a weld bead on the corner of the main member to act as a backing.
- Visual inspection is the best way to ensure sound welds, since no access to the inside and continually changing angles make radiographic and ultrasonic inspection difficult and unreli-

able. Visual inspection should include the fit-up before welding and compliance with the weld procedure, as well as examination of the final weld.

Direct Bolting to HSS

1. It is possible to use mechanical fasteners to make attachments to HSS.
 - Through-bolts, which cannot be fully tightened due to HSS wall flexibility.
 - Side access holes, which will weaken the HSS if not reinforced.
 - Commercially available expanding blind bolts, which are molly bolts for steel. (Read about available

blind bolt products on page 63 of this month's issue.)

- Welded threaded studs.
 - Self-tapping screws with thin HSS.
 - Flow-drilled and cold tapped holes, suitable for repetitive shop operations.
2. Fasteners can be used for unusual applications or atypical field repairs. ★

Donald R. Sherman is a Professor Emeritus of Civil Engineering and Mechanics, University of Wisconsin-Milwaukee.

Limit States in K-Connections for HSS

