Top Things to Know About HSS Connections

SEAAK
On-Line Presentation
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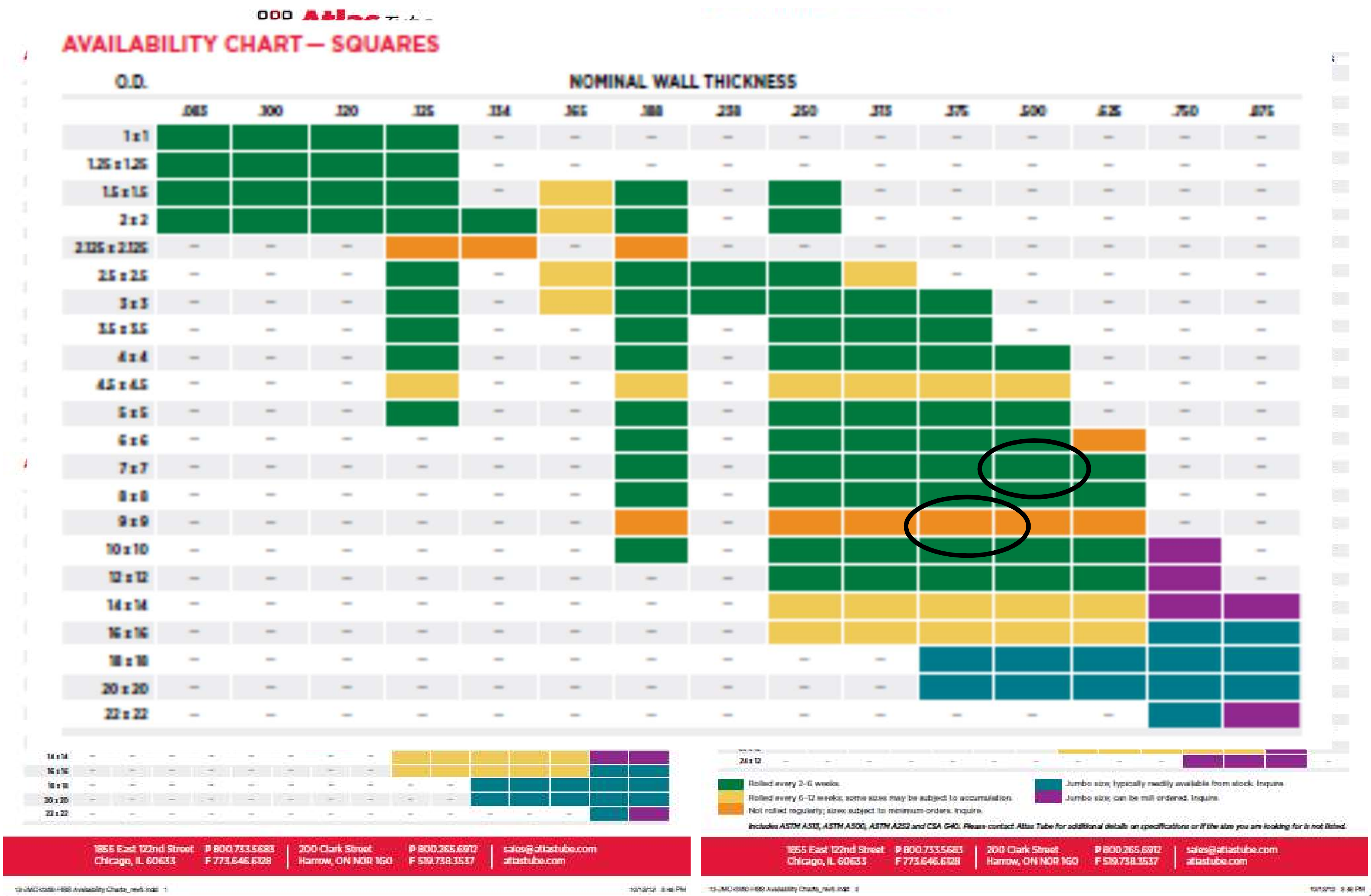
Atlas Tube – Market Leader

- **Largest size range in North America**
  - 1”–16” square, up to 5/8” wall
  - 1.25” – 20” round, up to 5/8” wall
  - Now offering Jumbo HSS
- **Shortest rolling cycle in the industry**
  - 2 – 3 weeks for common sizes
- **Able to roll custom lengths to minimize cost, waste, column splices**
  - Rolled lengths up to 135 ft. for rounds, up to 85 ft. for sq. & rect.
- **Five production facilities in North America**
- **Leading producer of ASTM A500, CSA G40 (Class C & H) and ASTM A1085**
- **In-House Heat Treating**
  - Leading producer of CSA Class H HSS
- **Products stocked by service centers across North America**

New Availability Charts



Jumbo HSS

Through a partnership with NSMP & Mitsui, Atlas is now offering large HSS

- 10" & 12" sq. x .750"
- 14" & 16" sq. x .750", .875"
- 18" & 20" sq. x .5", .625", .750", .875"
- 22" sq. x .750", .875"
- 20" x 12" x .750"
- 24" x 12" x .5", .625", .750"

Material stocked and readily available
Large quantities can be mill ordered
Available as A500 or CSA G40
Also available in new ASTM A1085

Jumbo HSS

Construction of the Largest Continuous ERW Tube Mill

CHICAGO (May 7, 2019) — Zekelman Industries announced today the construction of the world's largest continuous ERW tube mill. The mill will be capable of producing hollow structural sections (HSS) with a size range of 8″ square x 0.750″ wall up to 22″ square x 1″ wall. Atlas Tube, a division of Zekelman Industries, will produce square, rectangular and round structural sections in the mill. The largest rectangular section will be 34″ x 10″ x 1″ wall, and the largest round section will be 28″ OD x 1″ wall. The new mill will produce products to meet or exceed ASTM A500, ASTM A1085, CSA G40 and ASTM A252. This will be the first time ERW sections above 16″ square will be available domestically.

Jumbo HSS

Round HSS up to 28” OD

Square HSS up to 22” x 22”

Rectangle HSS up to 24” x 12” and 34” x 10”

Wall thickness up to 1.0”

Design Properties available on Atlas website

Available Fall 2021

Circular HSS	Wall Thickness (in)						
Outer Diameter (in)	0.375	0.500	0.675	0.690	0.750	0.875	1.000
14	■	■	■	■	■	■	■
16	■	■	■	■	■	■	■
18	■	■	■	■	■	■	■
20	■	■	■	■	■	■	■
24	■	■	■	■	■	■	■
28	–	■	■	■	■	■	■

Square HSS	Wall Thickness (in)						
Outer Diameter (in)	0.375	0.500	0.675	0.690	0.750	0.875	1.000
8 x 8	■	■	■	■	–	–	–
10 x 10	■	■	■	■	■	–	–
12 x 12	■	■	■	■	■	–	–
14 x 14	■	■	■	■	■	■	■
16 x 16	■	■	■	■	■	■	■
18 x 18	■	■	■	■	■	■	■
20 x 20	■	■	■	■	■	■	■
22 x 22	–	■	■	■	■	■	■

Rectangular HSS	Wall Thickness (in)						
B x H (in x in)	0.375	0.500	0.675	0.690	0.750	0.875	1.000
12 x 8	■	■	■	■	–	–	–
14 x 6	■	■	■	■	–	–	–
14 x 10	–	–	■	■	■	■	–
16 x 8	–	–	■	■	■	■	–
16 x 12	–	–	■	■	■	■	■
18 x 6	–	–	■	■	■	–	–
20 x 8	–	–	■	■	■	■	■
20 x 12	–	–	■	■	■	■	■
24 x 12	■	■	■	■	■	■	■
30 x 10	–	■	■	■	■	■	■
34 x 10	–	–	■	■	■	■	■

HSS Connections - Learning Objectives

- Learn about some of the most frequently asked questions about HSS connections
- Learn to avoid some of the pitfalls associated with HSS connections that can make them costly and difficult to fabricate
- Learn about unique solutions to common connection challenges
- Learn to appreciate the differences and similarities between HSS connections and other types of connections.

Why 0.93?

- **Per AISC 360-10, Section B4.2:**

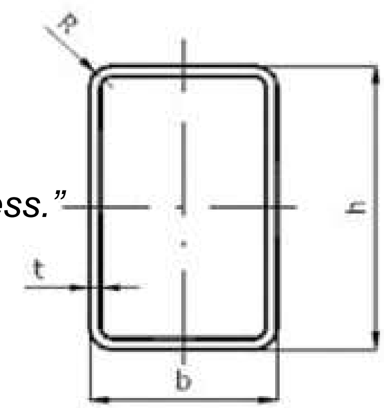
  "The design wall thickness, t, shall be used in calculations involving the wall thickness of hollow structural sections (HSS). The design wall thickness, t, shall be taken equal to 0.93 times the nominal wall thickness for electric-resistance-welded (ERW) HSS and equal to the nominal thickness for submerged-arc-welded (SAW) HSS."

  - ERW HSS – produced to ASTM A500 and A53
  - SAW HSS- typically sizes larger than permitted in the A500 (ASTM A1065)

- **Per AISC 360-16, Section B4.2:**

  "…..The design wall thickness, t, shall be taken as equal to the nominal thickness for box-sections and HSS produced according to ASTM A1065/A1065M or ASTM A1085/A1085M. For HSS produced according to other standards approved for use under this Specification, the design wall thickness, t, shall be taken as 0.93 times the nominal wall thickness."

- **Per CISC Handbook of Steel Construction**
  - *"…Design Wall Thickness is taken as 0.90 times the nominal thickness."*



- **Tolerances**
  - ASTM A500 – Wall thickness tolerance: +/- 10%
  - ASTM A53 – Wall thickness tolerance: -12.5%

Why 0.93?

Limit State: HSS Local Yielding
Plate Axial Load

$$R_n \sin\theta = F_y t^2 \left(\frac{5.5}{1 - 0.81 \frac{B_p}{D}} \right) Q_f \qquad \text{K1-1)}$$

AISC 360-10, Chp K, Section 1.1:

"t = design wall thickness of HSS, in. (mm)"

Limit State: Local Yielding
of HSS
Axial Load

$$R_n = 2F_y t\left(5t_p + l_b\right) \le F_y A \qquad \text{(K1-4)}$$

Limit State: HSS Shear Yielding (Punching),
When $0.85B \le B_p \le B - 2t$

$$R_n = 0.6F_y t\left(2t_p + 2B_{ep}\right) \qquad \text{(K1-8)}$$

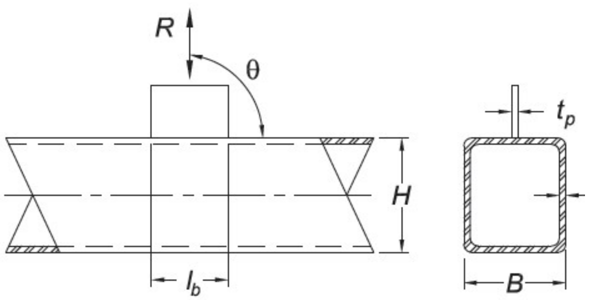
TABLE K1.1A
Limits of Applicability of Table K1.1

Plate load angle:	θ	$\ge 30°$
HSS wall	D/t	≤ 50 for T-connections under branch plate axial load or bending
slenderness:	D/t	≤ 40 for cross-connections under branch plate axial load or bending
	D/t	$\le 0.11E/F_y$ under branch plate shear loading
	D/t	$\le 0.11E/F_y$ for cap plate connections in compression
Width ratio:	0.2	$< B_p/D \le 1.0$ for transverse branch plate connections
Material strength:	F_y	≤ 52 ksi (360 MPa)
Ductility:	$F_y/F_u \le 0.8$	Note: ASTM A500 Grade C is acceptable.

Limit State: Local Crippling of HSS Sidewalls,
When $\beta = 1.0$ and Plate is in Compression,
for T-Connections

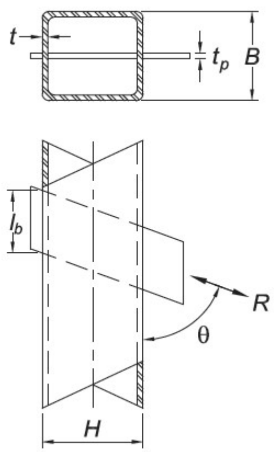
$$R_n = 1.6t^2\left(1 + \frac{3l_b}{H - 3t}\right)\sqrt{EF_y}\,Q_f \qquad \text{(K1-10)}$$

Welded Plate vs. Slotted Through Plate



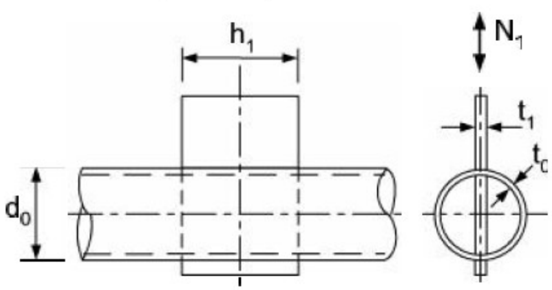
Limit State: HSS Plastification

$$R_n\sin\theta = \frac{F_y t^2}{1-\frac{t_p}{B}}\left(\frac{2l_b}{B}+4\sqrt{1-\frac{t_p}{B}}\,Q_f\right) \quad \text{(K1-12)}$$



Limit State: HSS Wall Plastification

$$R_n\sin\theta = \frac{2F_y t^2}{1-\frac{t_p}{B}}\left(\frac{2l_b}{B}+4\sqrt{1-\frac{t_p}{B}}\,Q_f\right) \quad \text{(K1-13)}$$



Limit State: HSS Plastification
Plate Axial Load

$$,\sin\theta = 5.5F_y t^2\left(1+0.25\frac{l_b}{D}\right)Q_f \quad \text{(K1-2)}$$

- For rect/sq HSS slotted through plate has twice the capacity compared to welded plate
- Slotted plate is more expensive to fabricate
- Is double the capacity needed and warrant the additional cost?
- Can this be applied to round HSS?

Slotted HSS Gusset Plate Connections

- **Check Limit States associated with HSS**
  - HSS Tensile Yielding (Gross Area)
  - HSS Tensile Rupture (Net Section) – Need to account for effective area (due to slot extending further than plate) and the effect of shear lag.
  - Base metal shear in HSS & gusset plate
  - Weld metal shear
  - Typical gusset plate limit states due to bolting
- **Cannot develop yield strength of bracing member due to shear lag**
  - Per AISC 360 Table D3.1 (Shear Lag Factor U)
  - Except Case 5 – Round HSS with weld length *l* $\geq$ 1.3D
- **Length of weld l should be $\geq$ H or D (distance between welds)**
  - This is implied with U factors in Table D3.1 (Cases 5 & 6)

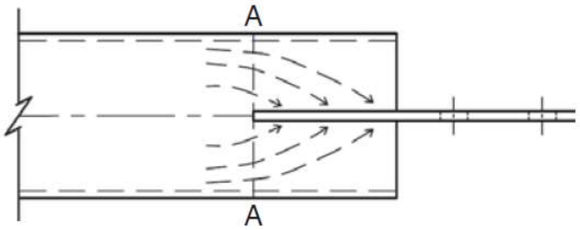
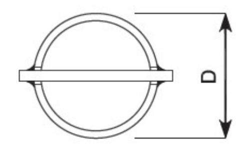
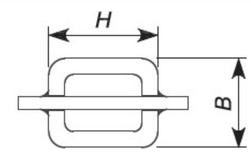
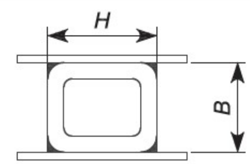


Fig. 5-2. Shear lag.

Slotted HSS Gusset Plate Connections

TABLE D3.1
Shear Lag Factors for Connections to Tension Members

Case	Description of Element		Shear Lag Factor, U	Example
5	Round HSS with a single concentric gusset plate		$l \geq 1.3D \ldots U = 1.0$ $D \leq l < 1.3D \ldots U = 1 - \bar{x}/l$ $\bar{x} = D/\pi$	
6	Rectangular HSS	with a single concentric gusset plate	$l \geq H \ldots U = 1 - \bar{x}/l$ $\bar{x} = \dfrac{B^2 + 2BH}{4(B+H)}$	
		with two side gusset plates	$l \geq H \ldots U = 1 - \bar{x}/l$ $\bar{x} = \dfrac{B^2}{4(B+H)}$	

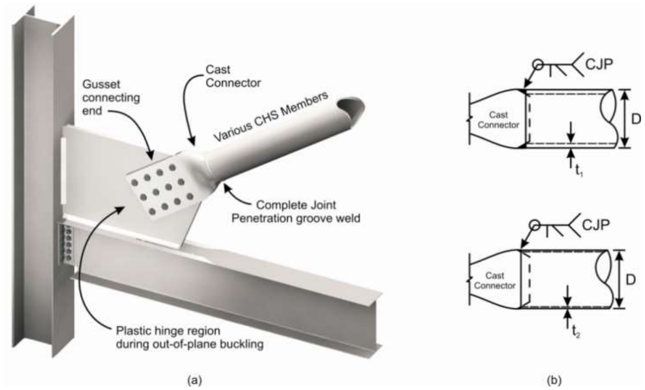
Changes coming in 2022 AISC 360

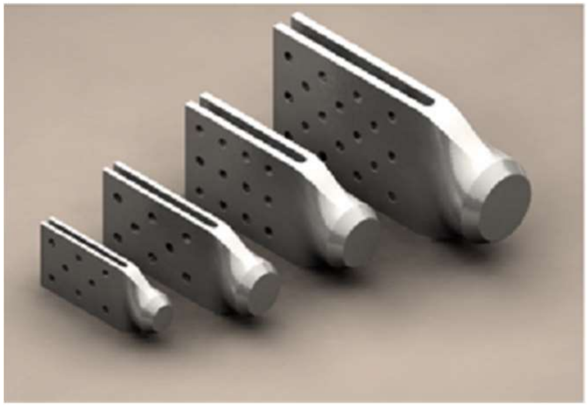
Cast Connections

- Can be a unique, highly aesthetic solution to the connection "problem"
- Typically custom made, project specific, expensive
- Usually thought of when dealing with nodes

Cast Connections – Cast Connex

- Can also be used for "everyday" connections such as diagonal bracing
- "Off the shelf" castings are becoming more popular
- Good, cost competitive solution for SCBFs in high seismic zones
- Energy-dissipative bracing system is designed to produce hinging at mid-length of the brace and in the gusset plates at each end, with the cast connector remaining elastic
- Extensively tested, ICC-ES in California

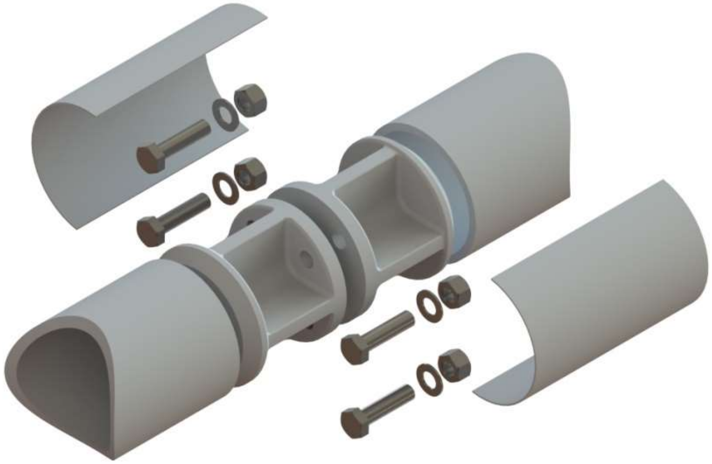


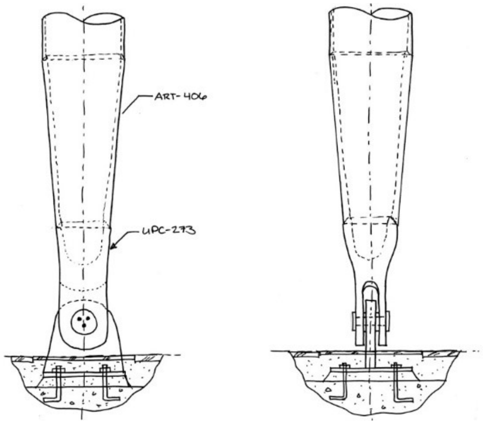


Cast Connections – Cast Connex

Other Options

- Tapered Connection
- Pinned Connection
- Diablo Connection

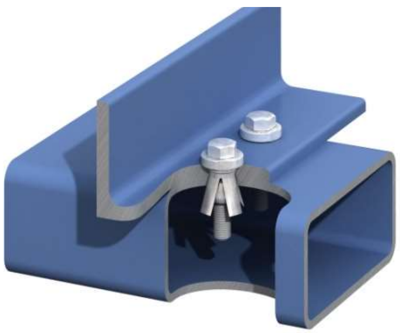


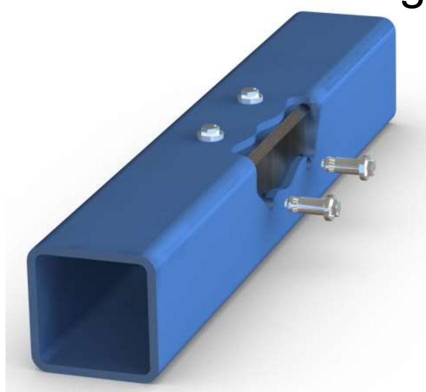


Single-Sided Bolts

Lindapter Hollo-Bolts

Exclusive ICC-ES Seismic Approval
Lindapter's Hollo-Bolt is the only expansion bolt ICC-ES approved for connecting structural steel in Seismic Design Categories (SDC) A through F, in compliance with the 2012 International Building Code.

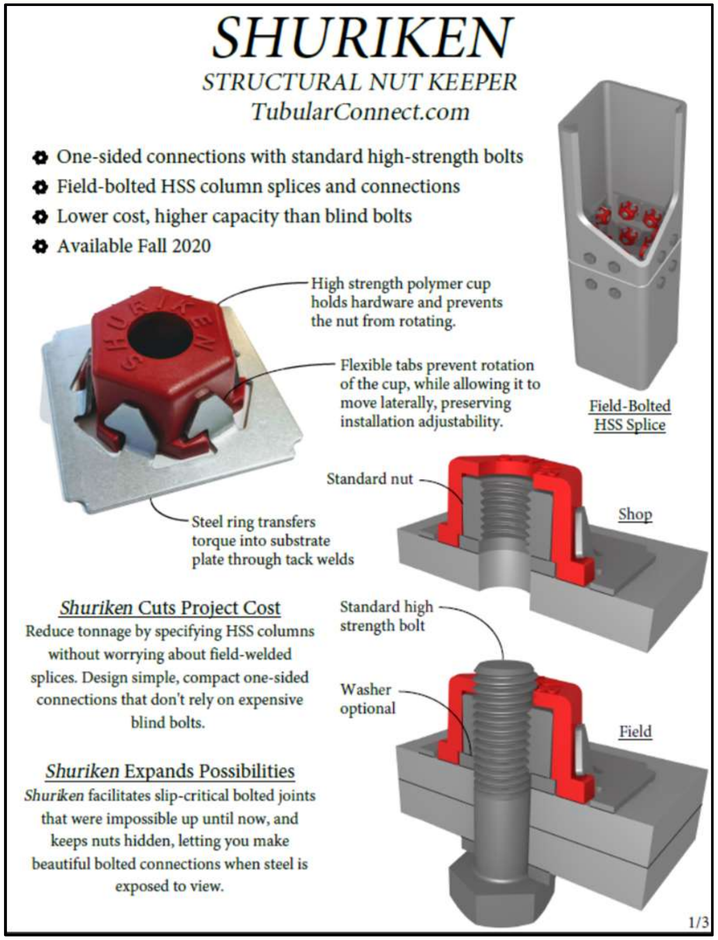




Single-Sided Bolts

Blind Bolt

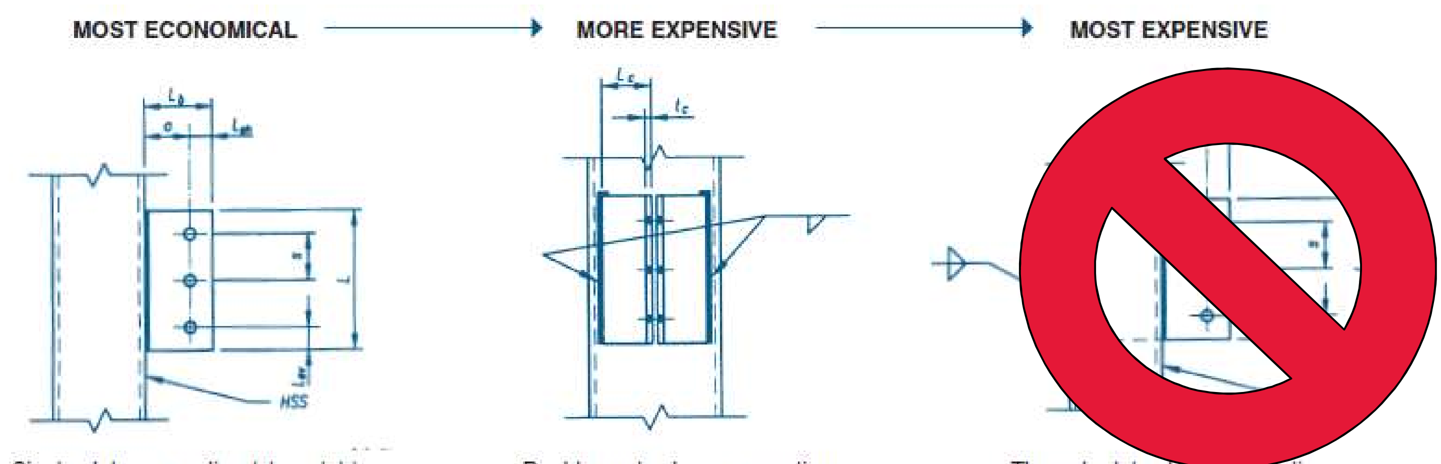
New Technology - Shuriken



- New technology to make HSS column splices easier

Shear Connections

- **All shear connections used to connect WF beams to WF columns can be used to connection WF beams to HSS columns.**
  - Single & Double Angles
  - Stiffened & Unstiffened Seats
  - Single shear plates (shear tabs)
  - Tee connections
- **Only unique HSS shear connection is through-plate**

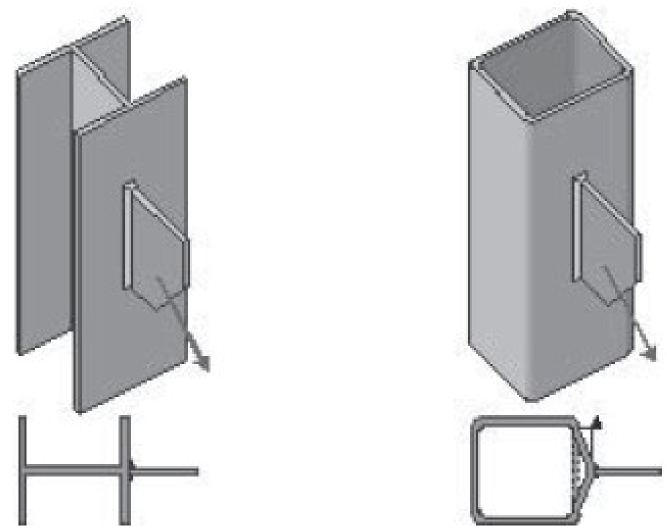


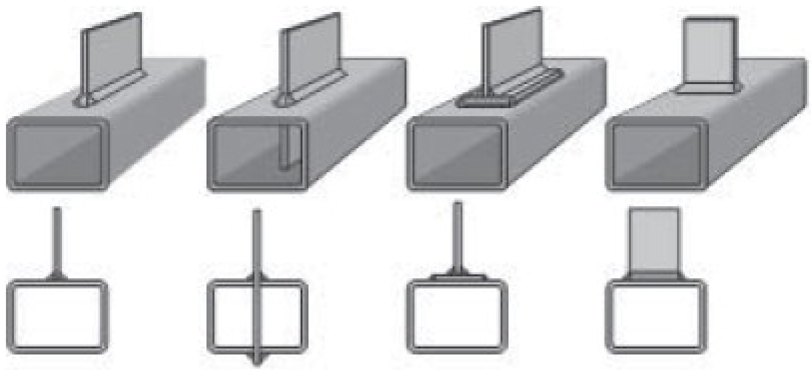
Single plate connection (shear tab) | Double angle shear connection | Through-plate shear connection

Connections – Line/Concentrated Loads

Plate-to-HSS welded

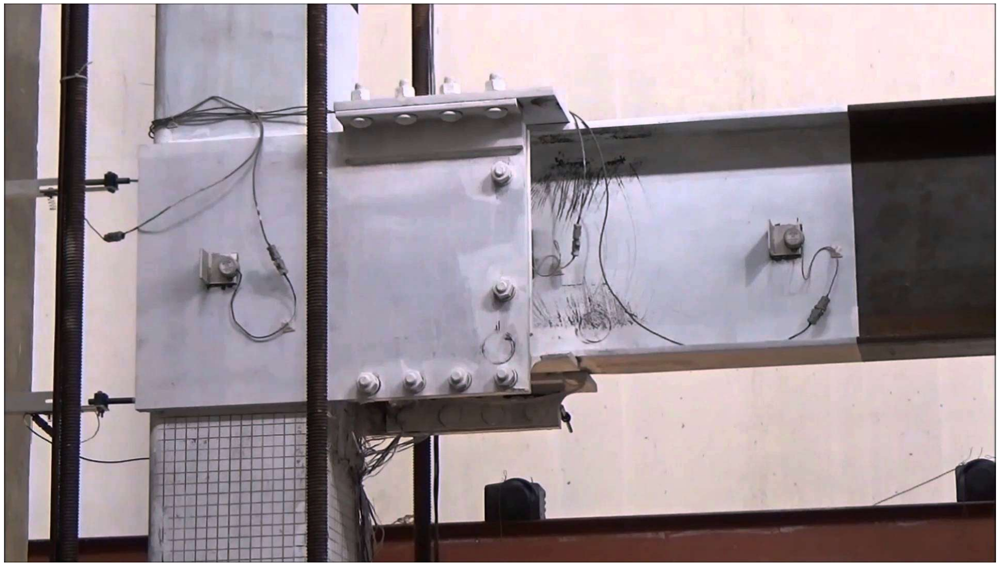
- More flexible than plate welded to W-shape
- Limit States
  - HSS wall plastification
  - Local plate yielding
  - HSS Shear yielding (punching)
  - HSS sidewall strength
- Use thicker HSS wall
- Connection reinforcing





Moment Connections - Seismic

- **Moment connections used in SMF and IMF need to be "pre-qualified" or tested in accordance with AISC 341-10, Chapter K.**
- **AISC 358-10 <u>Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications</u> lists all those connections that have met the criteria of 341-10, Chp K.**
- **Two moment connection listed directly pertains to HSS**
  - ConXtech ConXL connection
  - SidePlate Field Bolted connection



Moment Connections - Seismic

- SidePlate All-Bolted version debuted at 2020 virtual NASCC
- No welding – shop or field
- More cost effective using HSS.

Moment Connections - Seismic

How do you use HSS in SFRS?

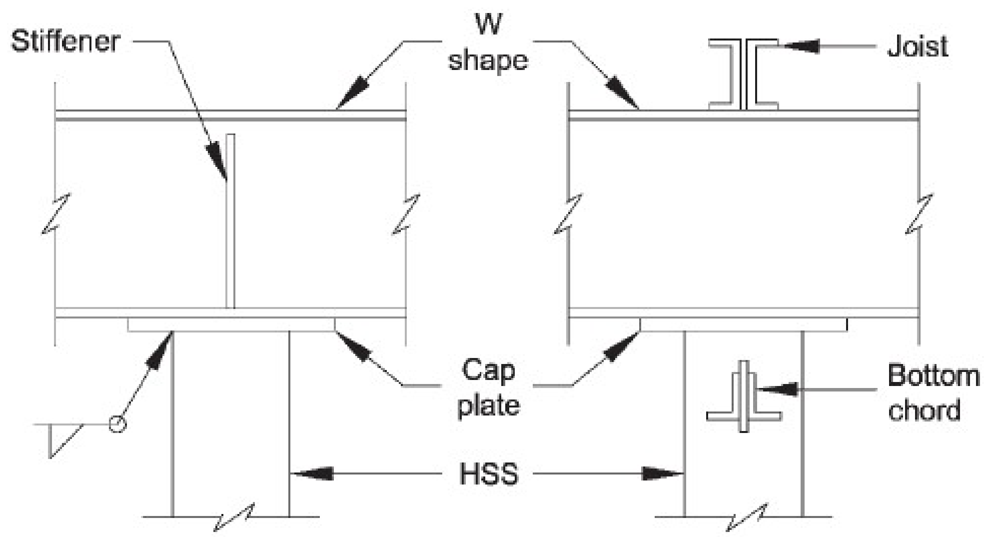
- Avoid using AISC 341-10 Seismic Provisions
  - Seismic Performance Category A
  - Seismic Performance Category B or C, with $R \leq 3$
  - Use OMF

- Prequalify (Develop & Test) a moment connection
  - Current research at Univ. of Michigan – HSS-to-HSS moment connections

Moment Connections — Types

Continuous Roof Beam

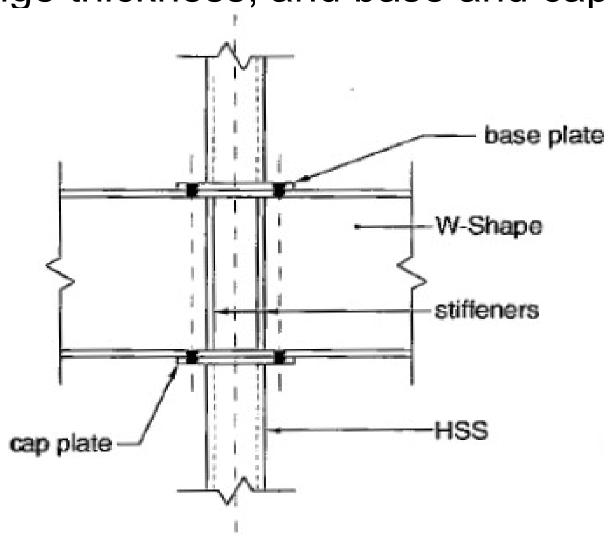
- Suitable for single-story structures
- Only top of beam is considered braced
- Additional stiffening or bracing required

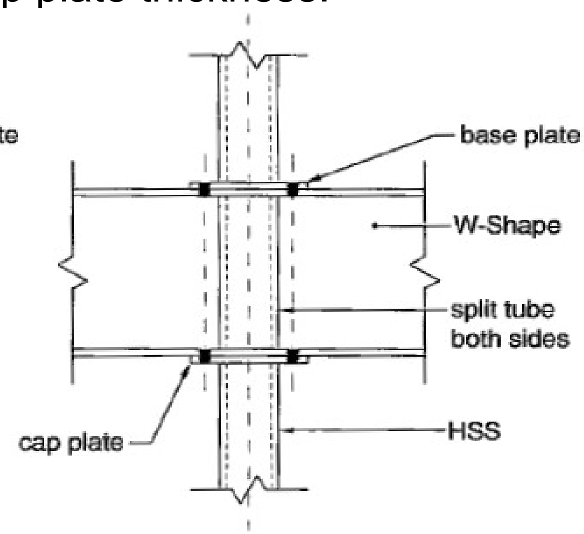


Moment Connections — Types

Continuous Beam at Column Splice

- HSS column is interrupted at continuous beam
- For lightly loaded columns, stiffener plates can be used to transfer axial forces
- Heavy loads may require a split HSS on either side of the beam web.
- Beam flange should be wider than HSS. Rectangular HSS may be required to fit base plate on beam.
- Moment transfer to HSS column is dependent on strength of bolts, beam flange thickness, and base and cap plate thickness.

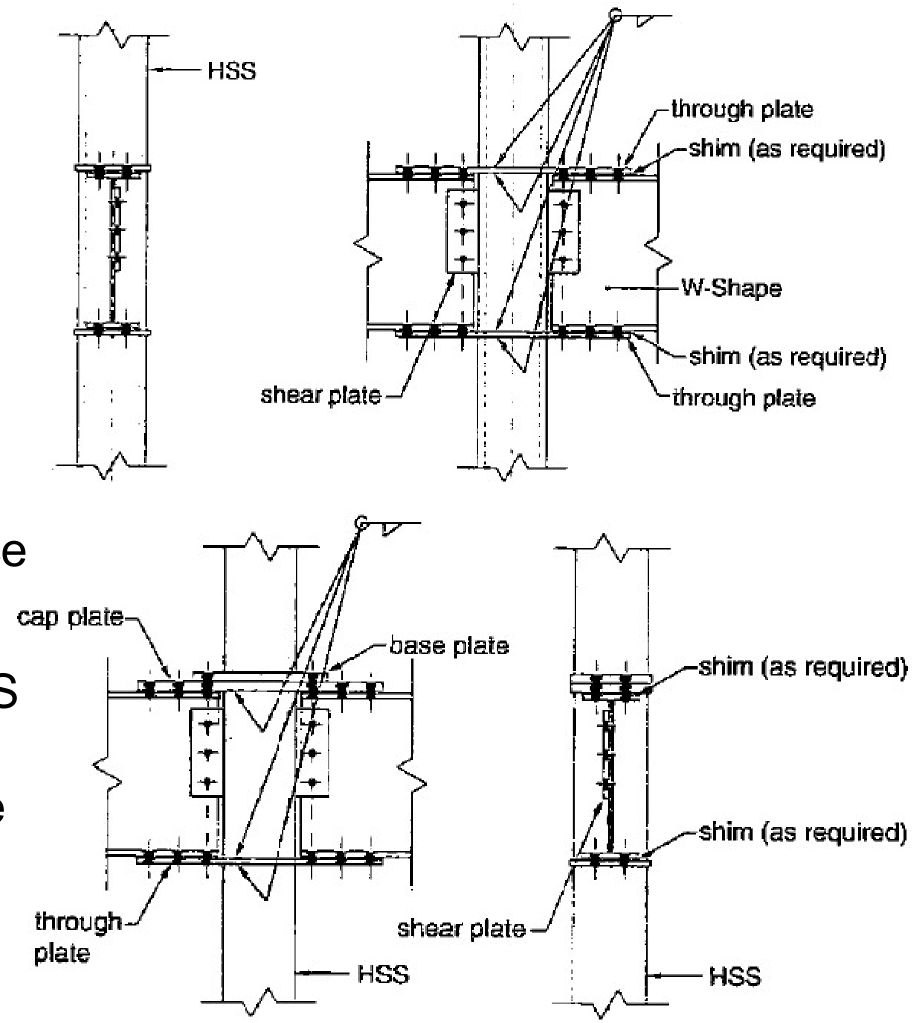




Moment Connections — Types

Through-Plate Diaphragm

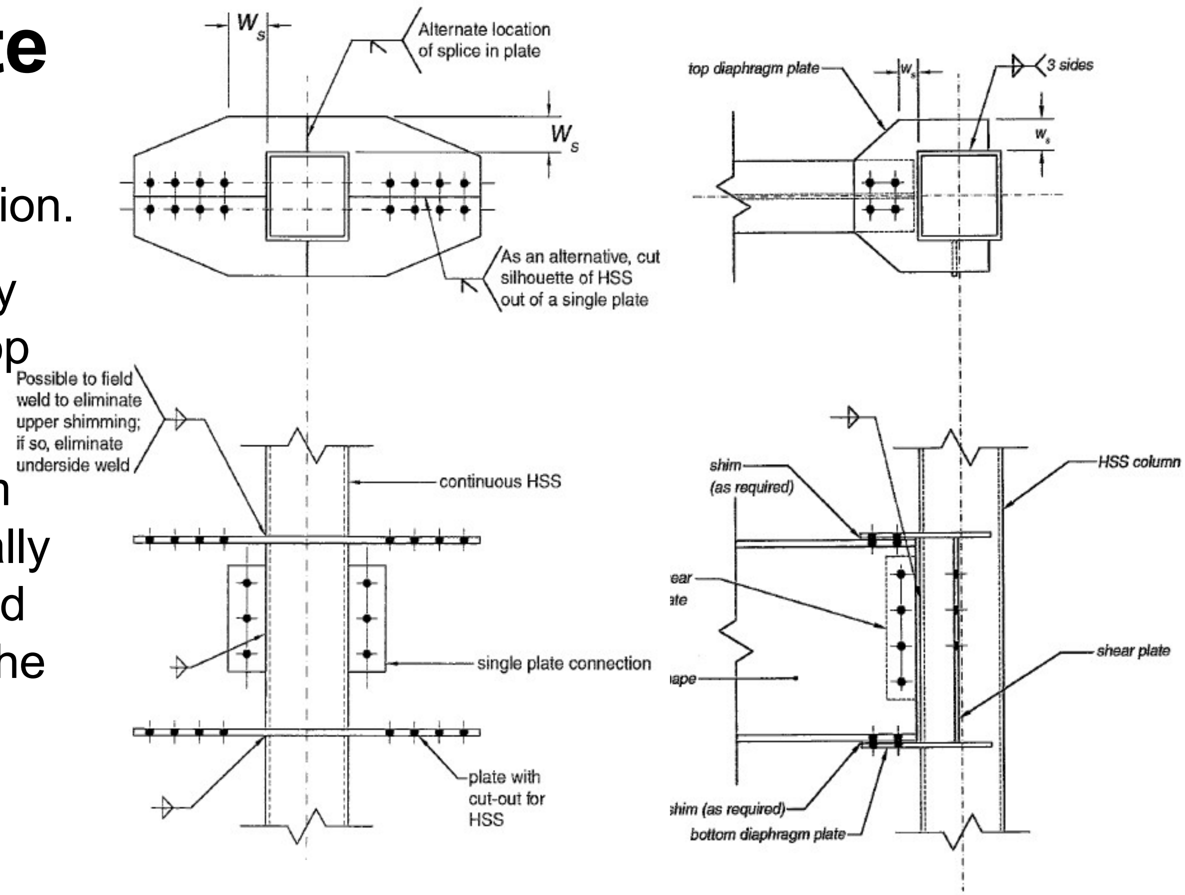
- Good for larger moment transfer through joint
- More difficult and costly to fabricate and erect
- Can be placed at column splice
- Column moment transfer is limited by fillet weld of the HSS to through plate. PJP or CJP welds can be used to increase connection strength.
- Good for two-way moment frame system.



Moment Connections — Types

Diaphragm Plate

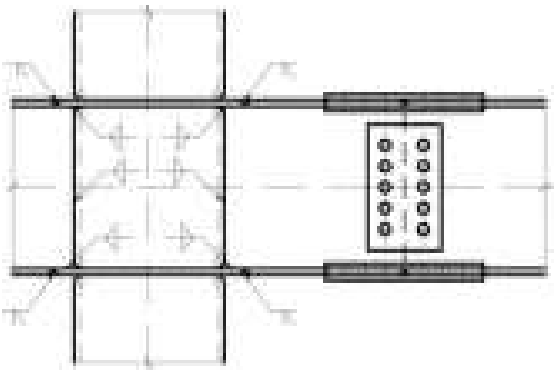
- An alternative to the through plate connection.
- Diaphragm plates may be field welded or shop welded.
- When used with beam on one side, additionally need to check the weld transferring shear to the HSS wall.

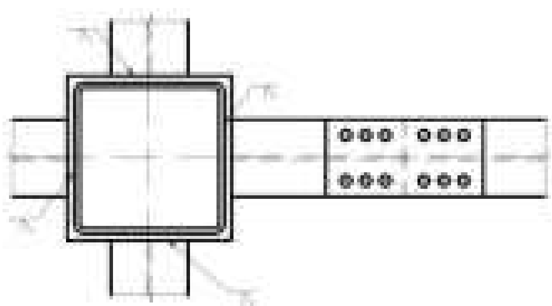


Moment Connections — Types

Diaphragm & through plate connections can be adapted to better facilitate erection.

Beam stubs can be shop attached to column to allow for field bolting or welding.

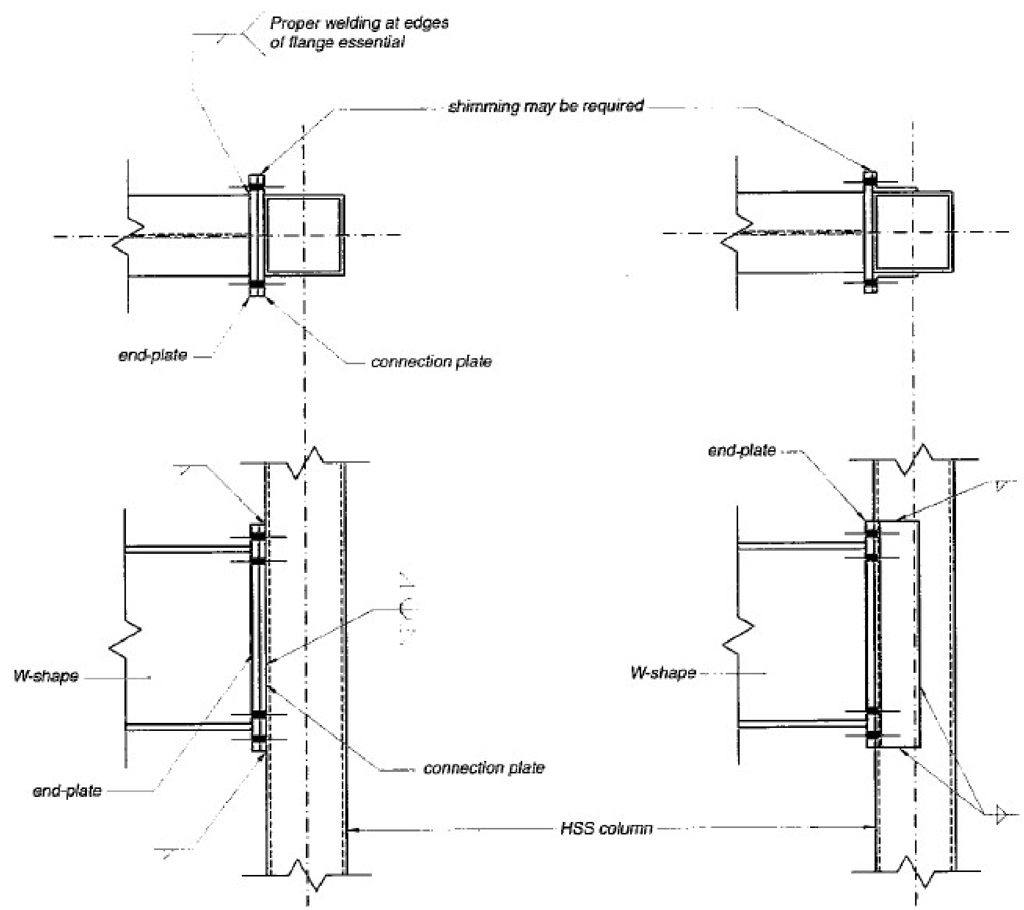




Moment Connections — Types

End Plate

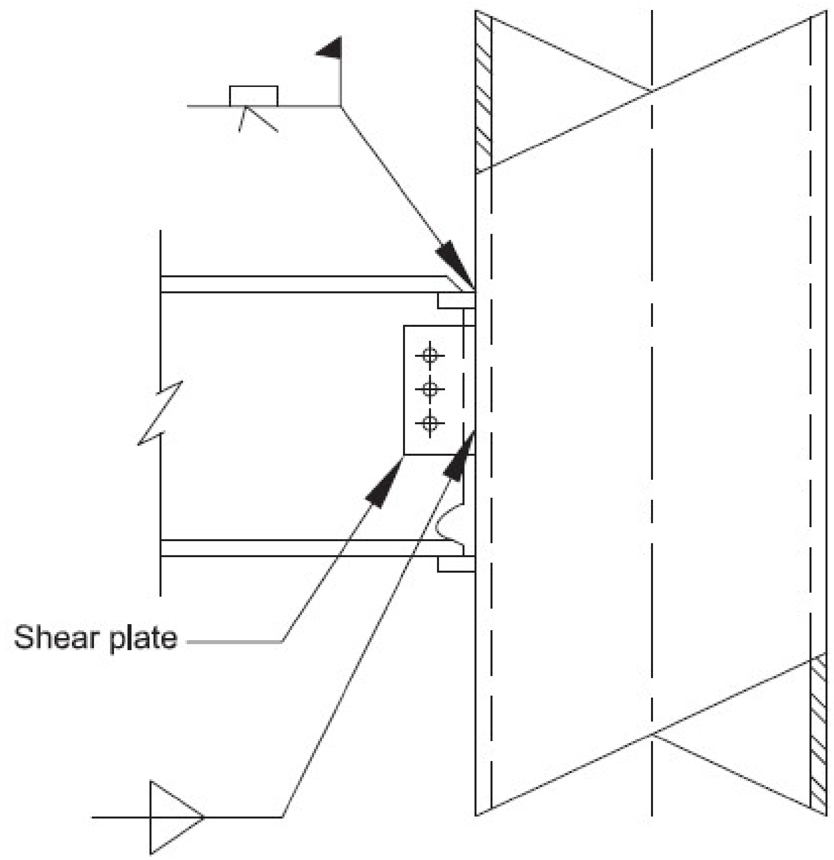
- Utilizes end plate or angles
- Need to consider/coordinate projection of plates beyond HSS
- Flange width of beam should be as large or larger than the HSS width to maximize efficiency
- Buckling strength of HSS side wall needs to be checked



Moment Connections — Types

Directly Welded

- May develop full flexural capacity of HSS
- Cannot develop full flexural capacity of W shape
- To achieve max efficiency, HSS wall should be thick and beam flange width should match HSS flat dimension (B-3t)

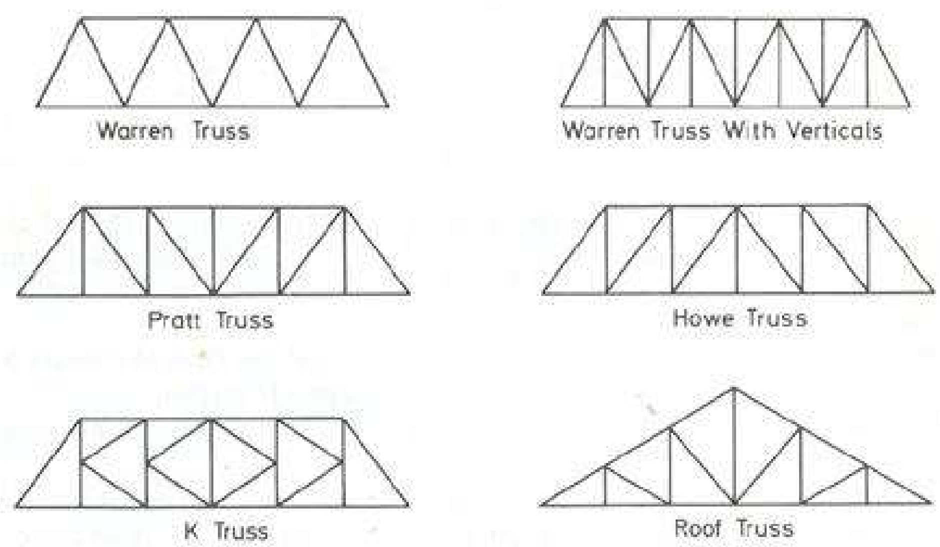


Truss Connections

Connections at the panel points of a planar truss

Trusses are typically analyzed with branch members "pinned"

Truss connections are designed as tension/compression connections



Types of simple Plane truss

Truss Connections - Nomenclature

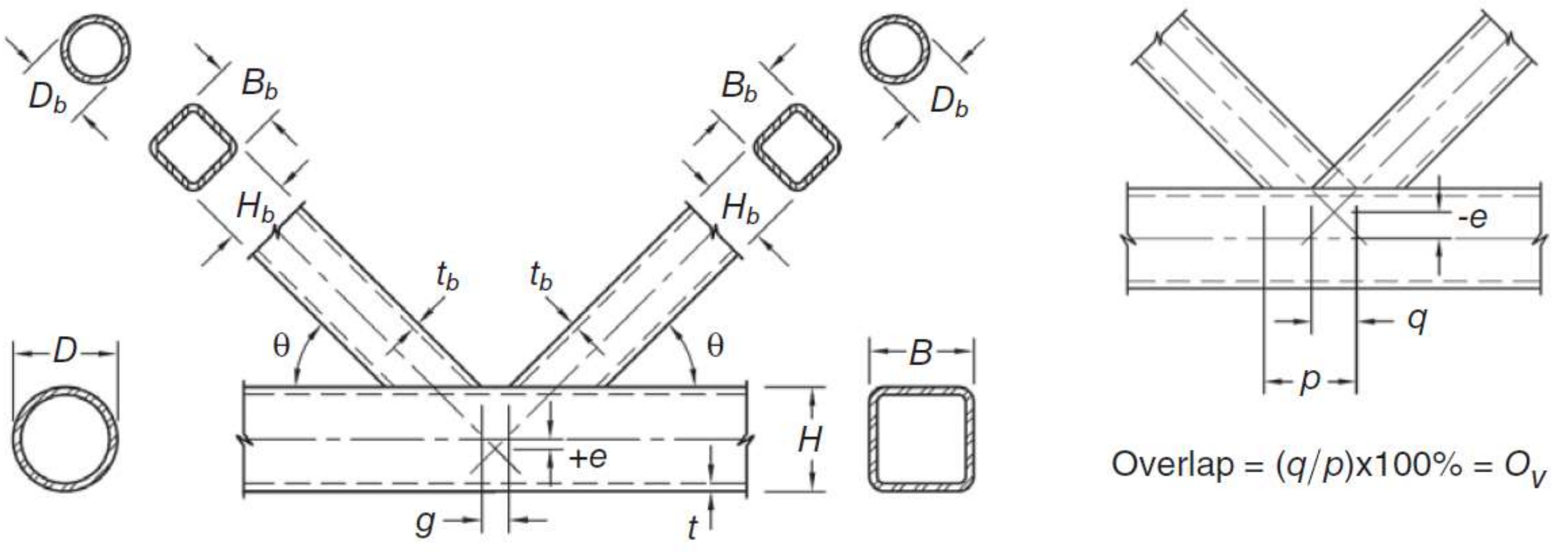
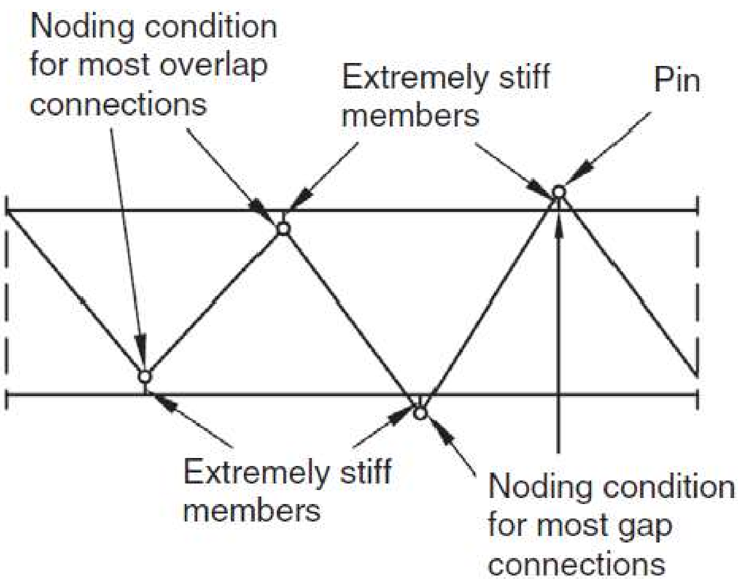


Fig. 8-1. Common notation for HSS truss connections.

Truss Connections - Analysis

Three options for analysis of planar welded HSS trusses:

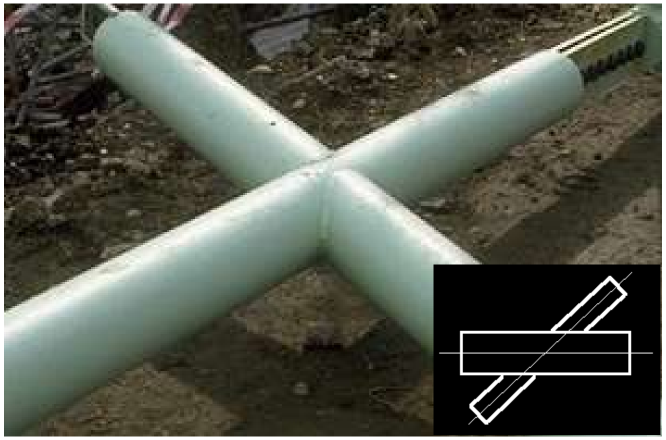
- ➢ Pin Jointed Analysis – All members pinned
- ➢ Pin Jointed Web Members, Continuous Chord Members
  - Extremely stiff members can be used to model the nodal eccentricity, e



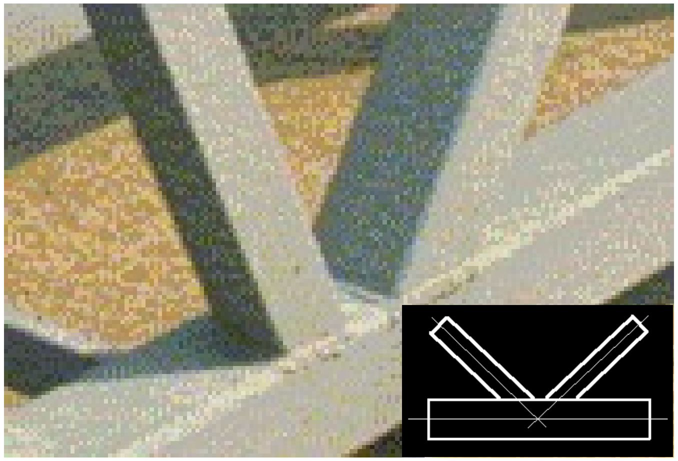
- ➢ Rigid Frame Analysis – Everything fixed

Truss Connections - Joint Types

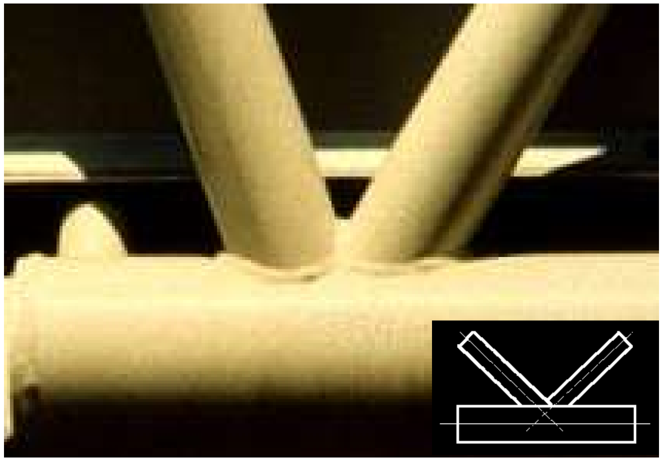
T or Y-Joint



X-Joint or Cross



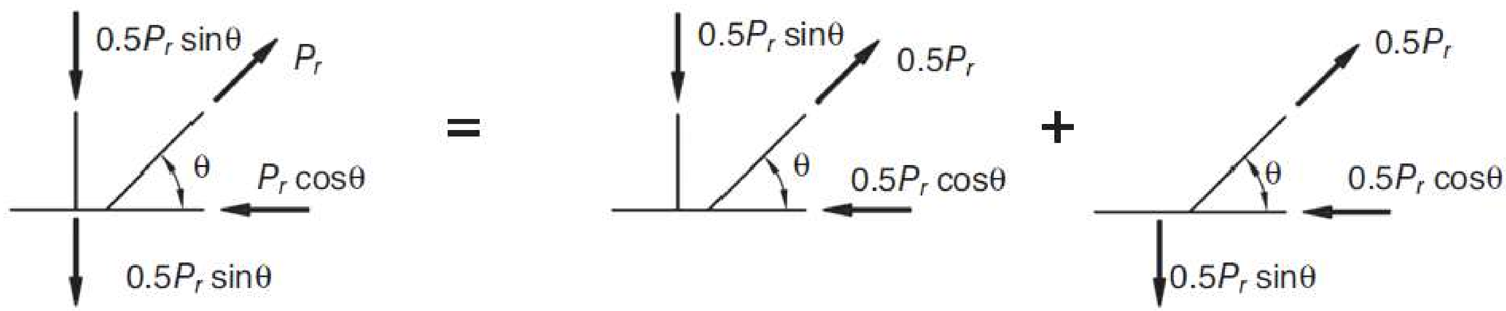
Gap K-Joint
(includes N)



Overlap K-Joint

Truss Connections - Joint Types

- Classification of joints is based on method of force transfer in the connection and not the physical appearance of the connection
- When branch members transmit part of their forces as one classification and part as another, then the adequacy of each branch is determined by linear interaction in proportion to how each portion is transferred.

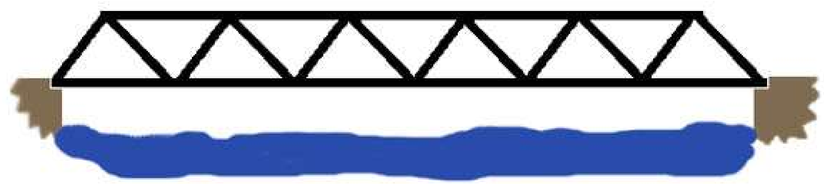


K Connection

Cross (X) Connection

Truss Connections - Fabrication Costs

- Minimum weight does not equal minimum cost
- Keep the number of different sizes small
- Try to minimize number of connections
  - ➔ Warren trusses



Understand effects of joint configuration and connection design criteria before analyzing truss and selecting member sizes!

Truss Fabrication Costs - Effect of Joint Type

Lowest Cost	RHS chord — gap joints	Lowest Joint Strength & Stiffness
↓	RHS chord — 100% overlap joints	↓
	CHS chord — gap joints	
	RHS chord — partial overlap joints	
	CHS chord — 100% overlap joints	
Highest Cost	CHS chord — partial overlap joints	Highest Joint Strength & Stiffness

Matched sizes will have higher fabrication cost versus unmatched

Welding

Generally for economics specify a fillet weld for tubular joints

Proper joint design should allow you to avoid complete joint penetration welds

For trusses subject to fatigue design, weld sequence is important. Overlap connections have been suggested for fatigue loading.

Truss Connections – Round Branch, Sq Chord

- Not covered by AISC 360-10, Chapter K
- However, Chp K Commentary states you can use "other verified design guidance…"
- Research by Packer, J.A., Mashiri, F.R., Zhao, X.L. and Willibald, S. ("Static and Fatigue Design of CHS-to-RHS Welded Connections using a Branch Conversion Method", Journal of Constructional Steel Research, Vol. 63, No.1, 2007, pp. 82-95.)
- For calculation purposes you "convert" the round sections to square sections and then use the Chp K equations.
- Branches of diameter D are replaced by members of width $B = (\pi/4)*D$ and the same wall thickness is used.

HSS Connections - Resources

AISC 360 — Chapter K

- 2005 & 2010

AISC Design Guide #24

CISC Design Guide 1997

CIDECT Design Guides

- Available for free on AISC website

Steel Tube Institute

- HSS CONNEX Online
- Connection Spreadsheets
- New HSS Design Manual

Questions?

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