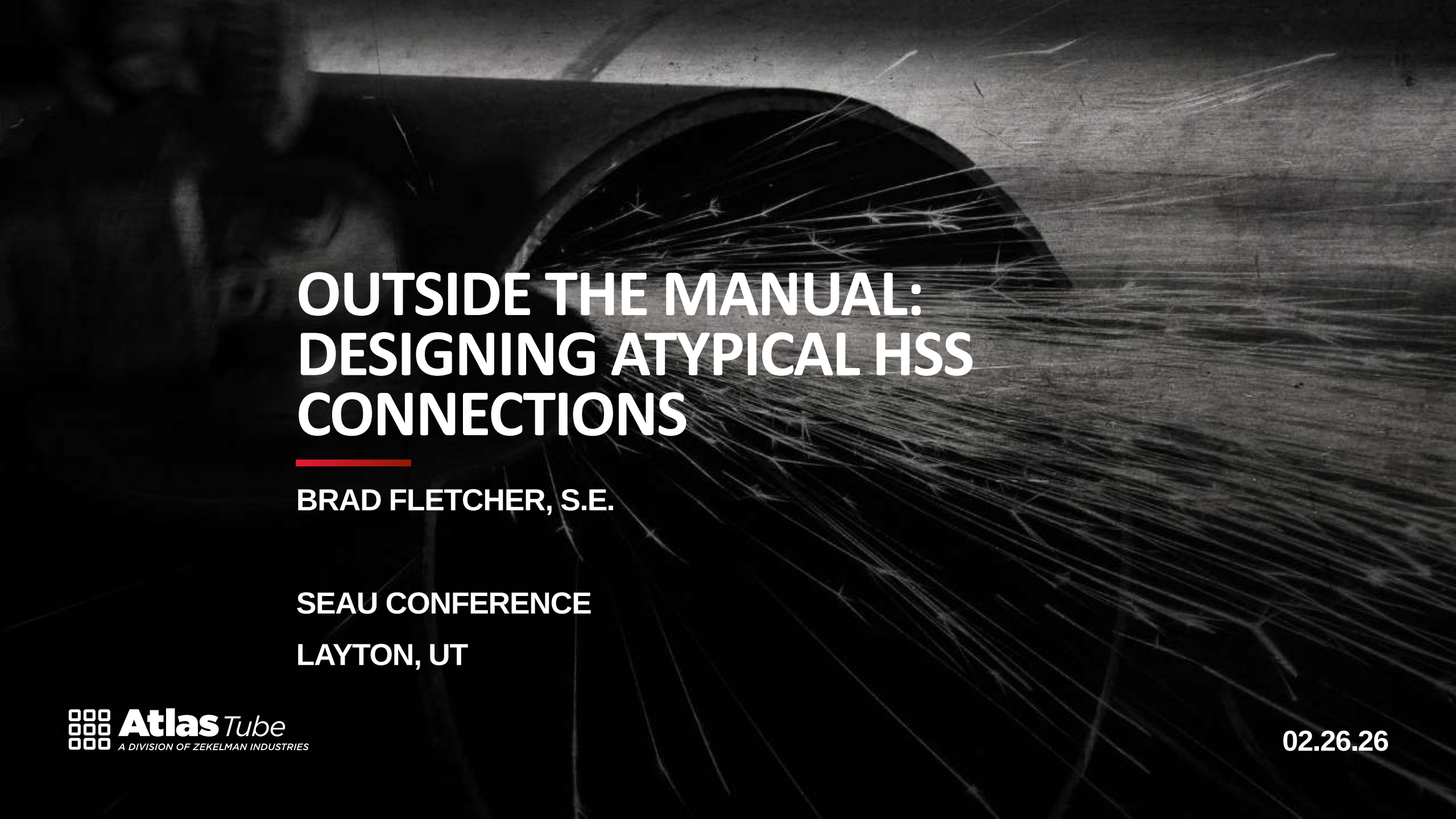


OUTSIDE THE MANUAL: DESIGNING ATYPICAL HSS CONNECTIONS

BRAD FLETCHER, S.E.

SEAU CONFERENCE

LAYTON, UT

Atlas Tube
A DIVISION OF ZEKELMAN INDUSTRIES

02.26.26

LEARNING OBJECTIVES

LEARNING OBJECTIVES

Identify what is in the current AISC Manual for HSS connections

Understand where to look for guidance on connections that are not expressly covered by the Manual

Adapt current resources to atypical connections

WHAT'S IN THE MANUAL?

Part 7 – Design Considerations for Bolts

Special consideration for HSS (pages 7-12 to 7-15)

Through Bolts

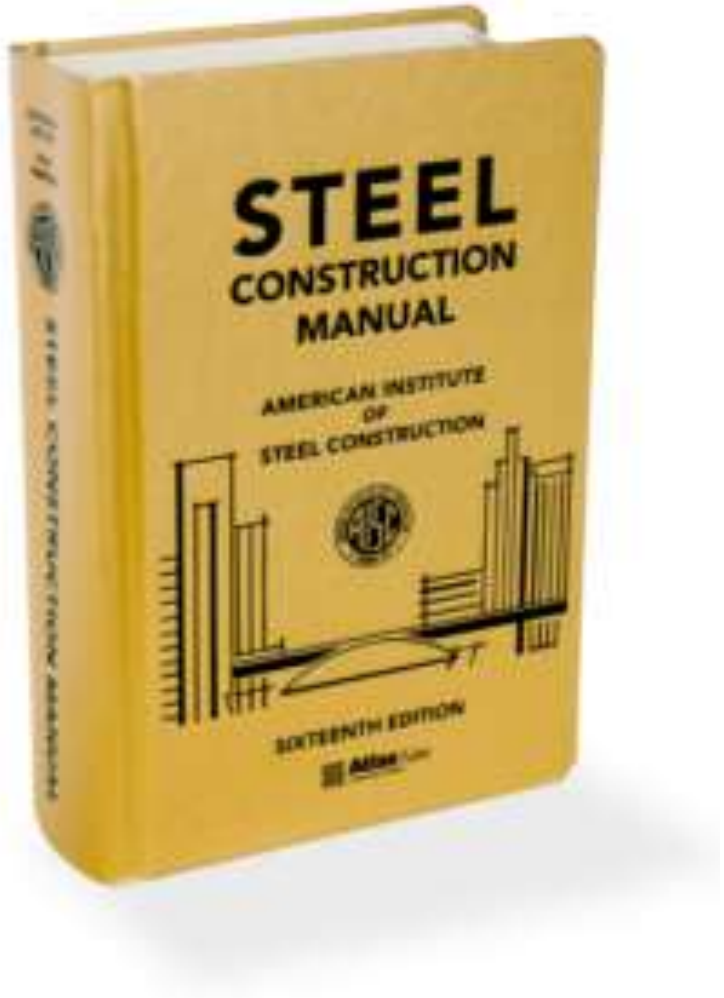
Single-Sided Bolts

Flow Drilling

Threaded Studs

Power Nails

Screws



WHAT'S IN THE MANUAL?

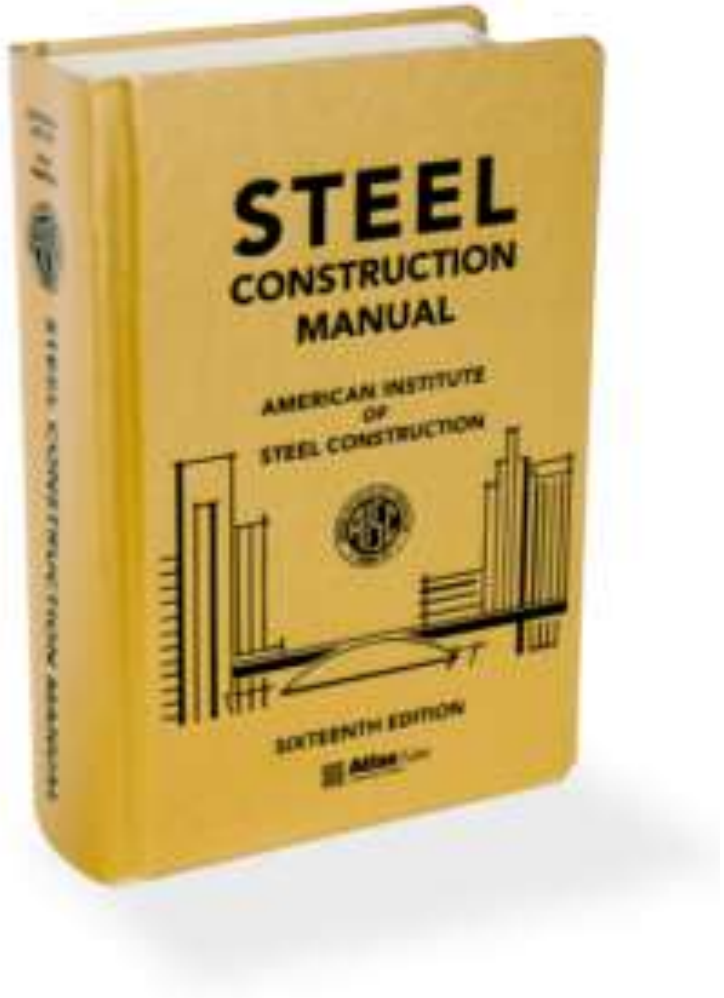
Part 8 – Design Considerations for Welds

Welding Considerations for HSS (pages 8-27 to 8-30

Summary of AWS D1.1, Clause 10

Weld Sizing For Uneven Distribution of Loads

Detailing Considerations



WHAT'S IN THE MANUAL?

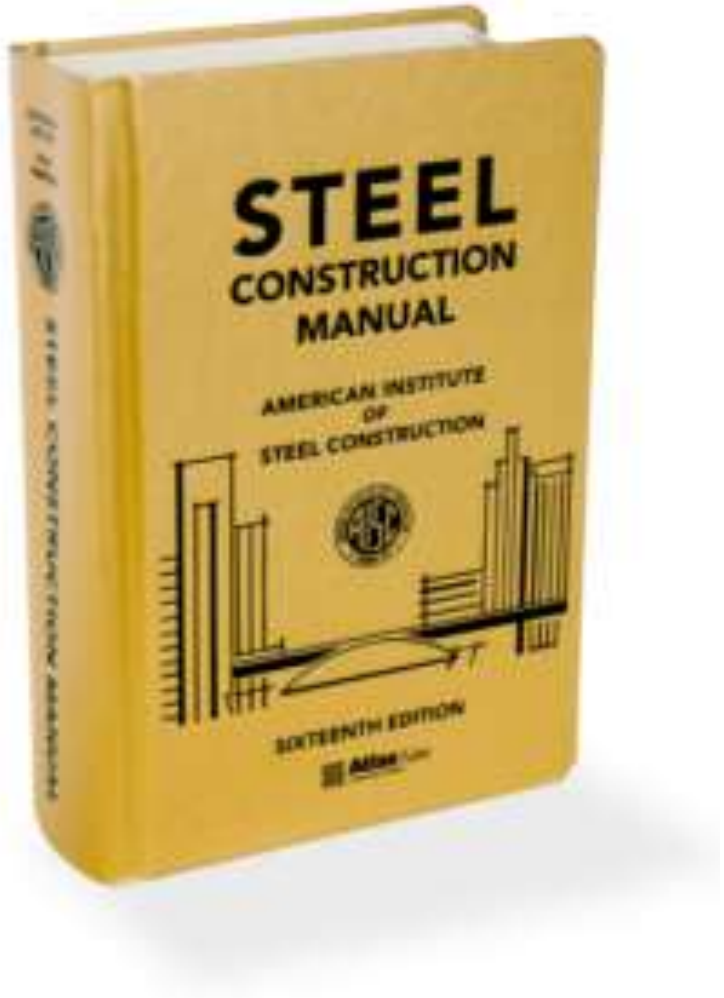
Part 9 – Design of Connecting Elements

Plate Elements Subjected to Out-of-Plane Loads

(pages 9-16 to 9-19)

Yield Line Theory

Effective width calculation, B_e



WHAT'S IN THE MANUAL?

Part 10 - Design of Simple Shear Connections

Design Considerations for Simple Shear Connections

to HSS (pages 10-95 to 10-99)

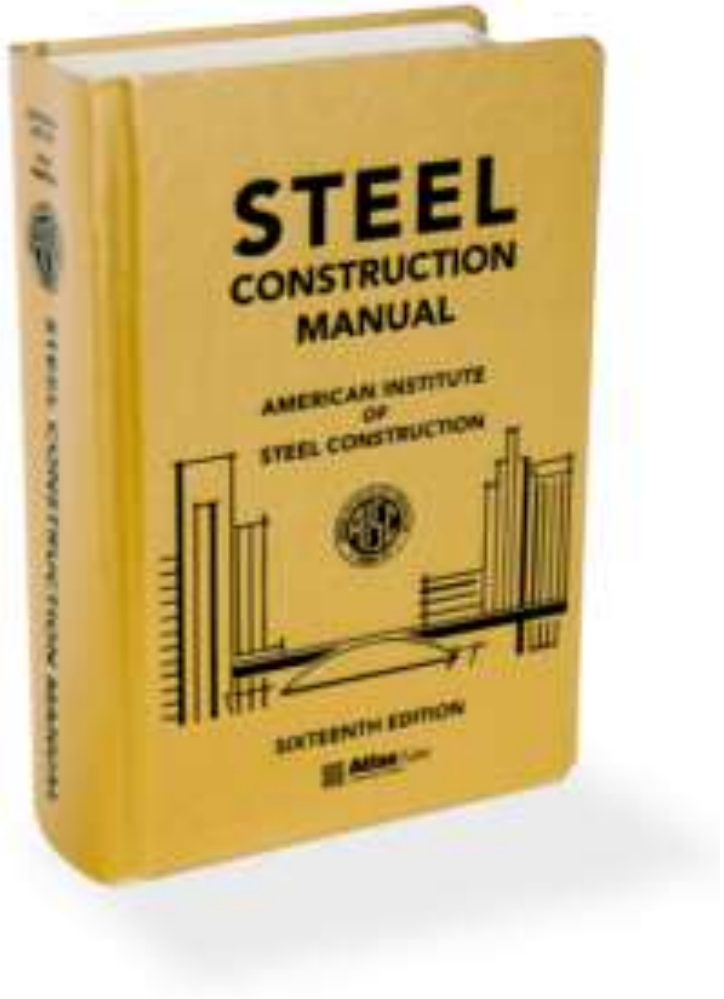
Double Angle Connections

Single Plate Connections

Seated Connections (Stiffened and Unstiffened)

Through Plate

Single Angle

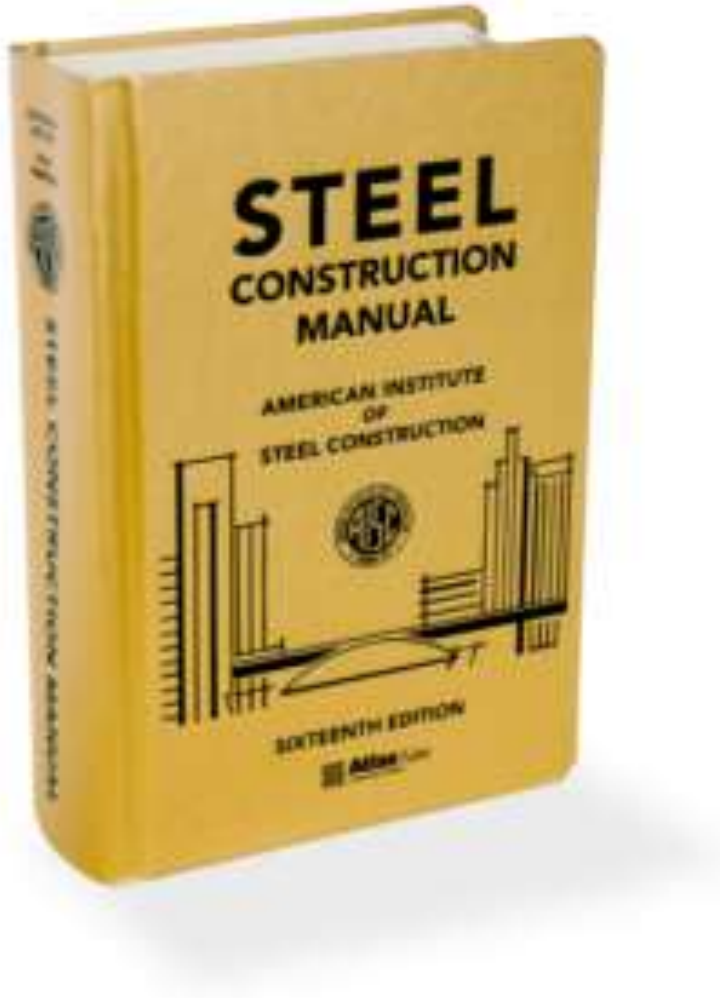


WHAT'S IN THE MANUAL?

Part 11 – Design of Moment Connections

FR Connections with HSS (pages 11-20 to 11-24)

Covers Wide Flange Beams to HSS Columns



WHAT'S IN THE MANUAL?

Part 12 – Design of Simple Connections For

Combined Forces

Connections to HSS Members with Combined Forces

(pages 12-8 to 12-9)

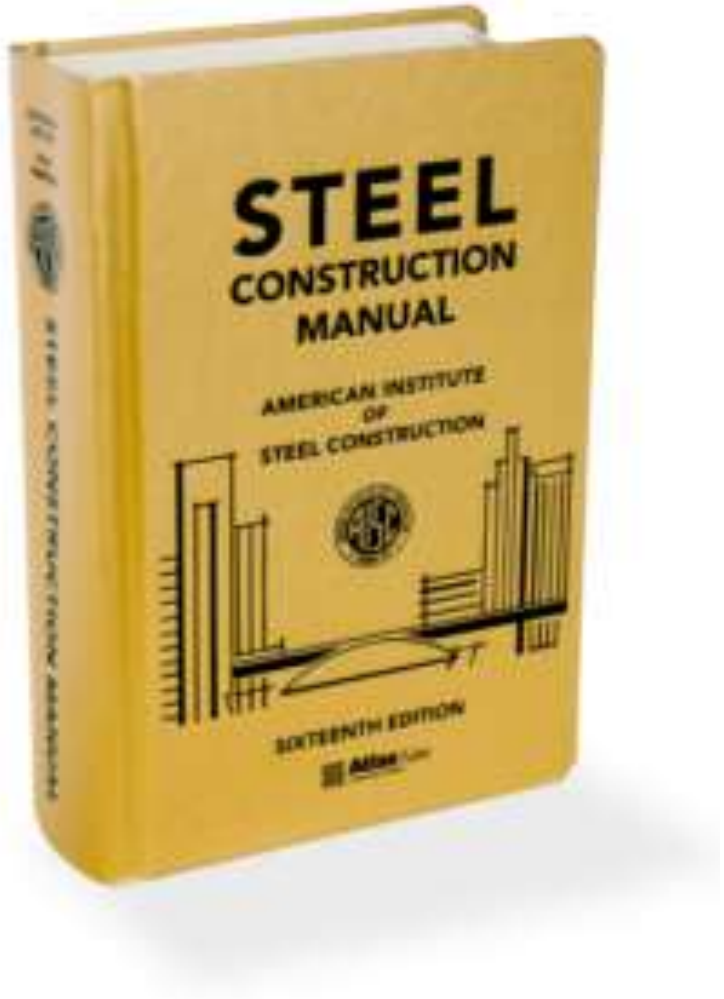
Single Plate

Through Plate

Stiffened Seated

End Plate

Tee and Double Angle



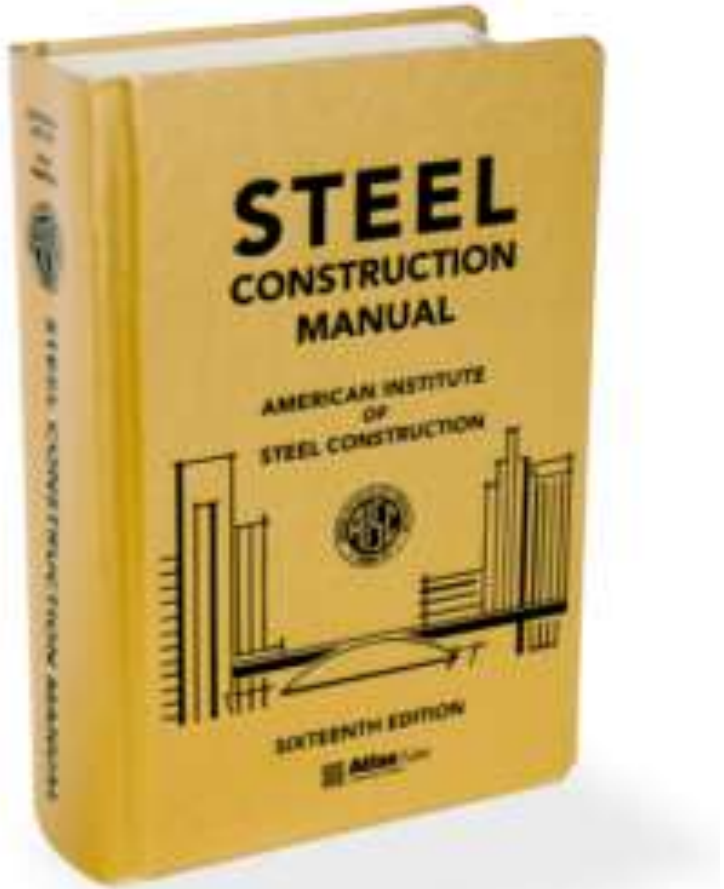
WHAT'S IN THE MANUAL?

Part 13 – Design of Bracing Connections and Truss Connections

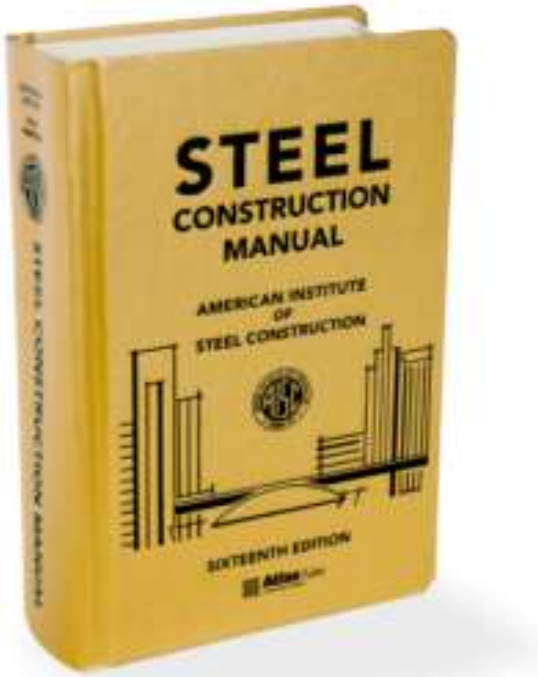
Design Considerations for HSS to HSS Truss Connections (page 13-28)

Refers to AISC Design Guide #24, 2nd Ed

Refers to CIDECT Design Guides



WHAT'S IN THE MANUAL?



AISC 360 Specification and Commentary

Chapter H, Section H3 - Torsion

Chapter J – Design of Connections

- Welding and Bolting requirements

Chapter K – Additional Requirements for HSS and Box-Section Connections

- Welding
- Requirements for T, K, Y, X Connections (truss connections)
- Limits of Applicability
- AISC Design Guide #24, 2nd Ed.

FLOOR FRAMING - COMPOSITE

Guidance from AISC

Use AISC 360, Chapter I with minor modifications

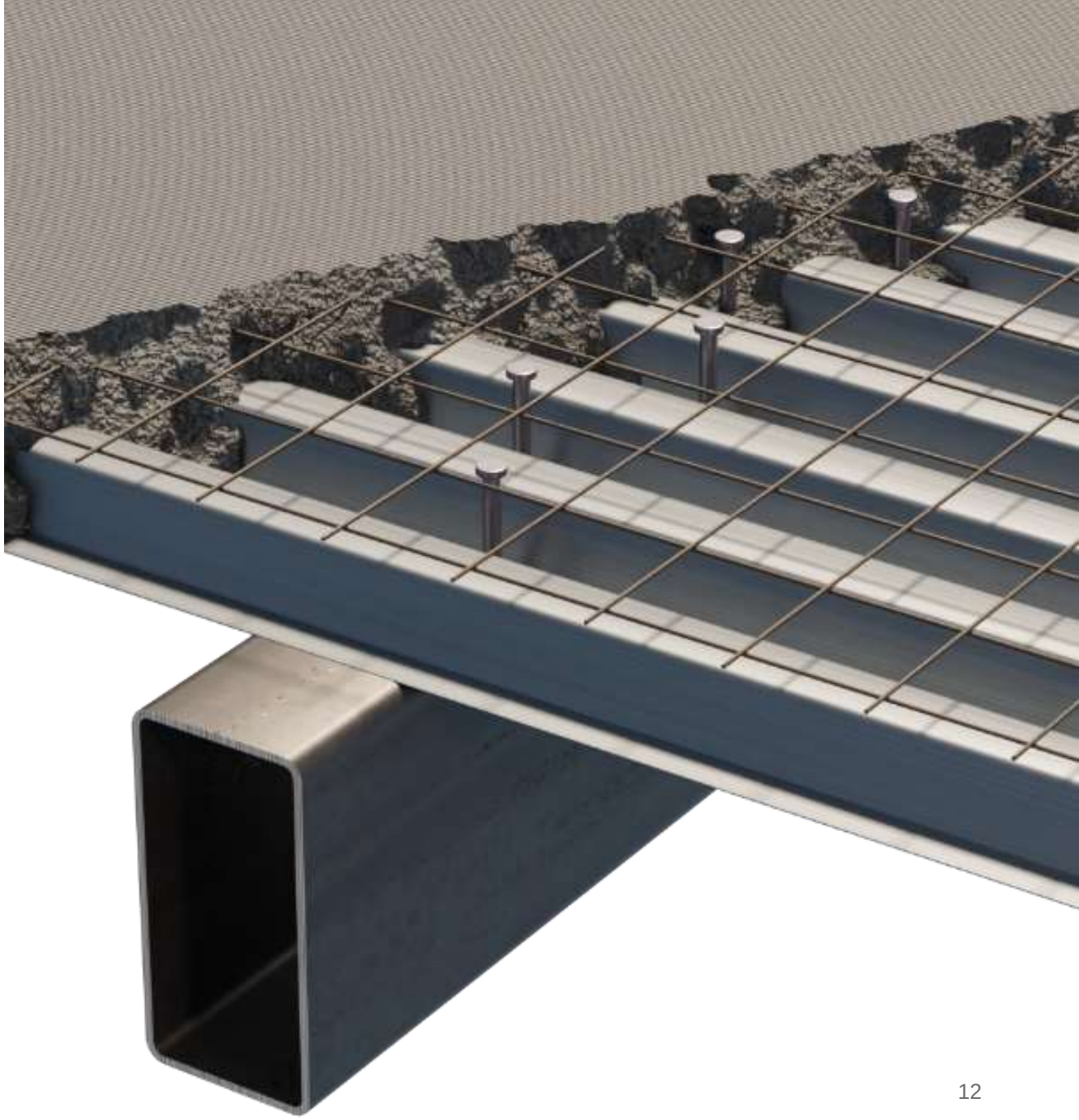
Section I3.2a(a) – use plastic stress distribution if webs are compact

- For HSS, Table B4.1b, Case 19
- Also, make sure compression flange is compact – Table B4.1, Case 17

Otherwise use elastic stress distribution, Section I3.2a(b)

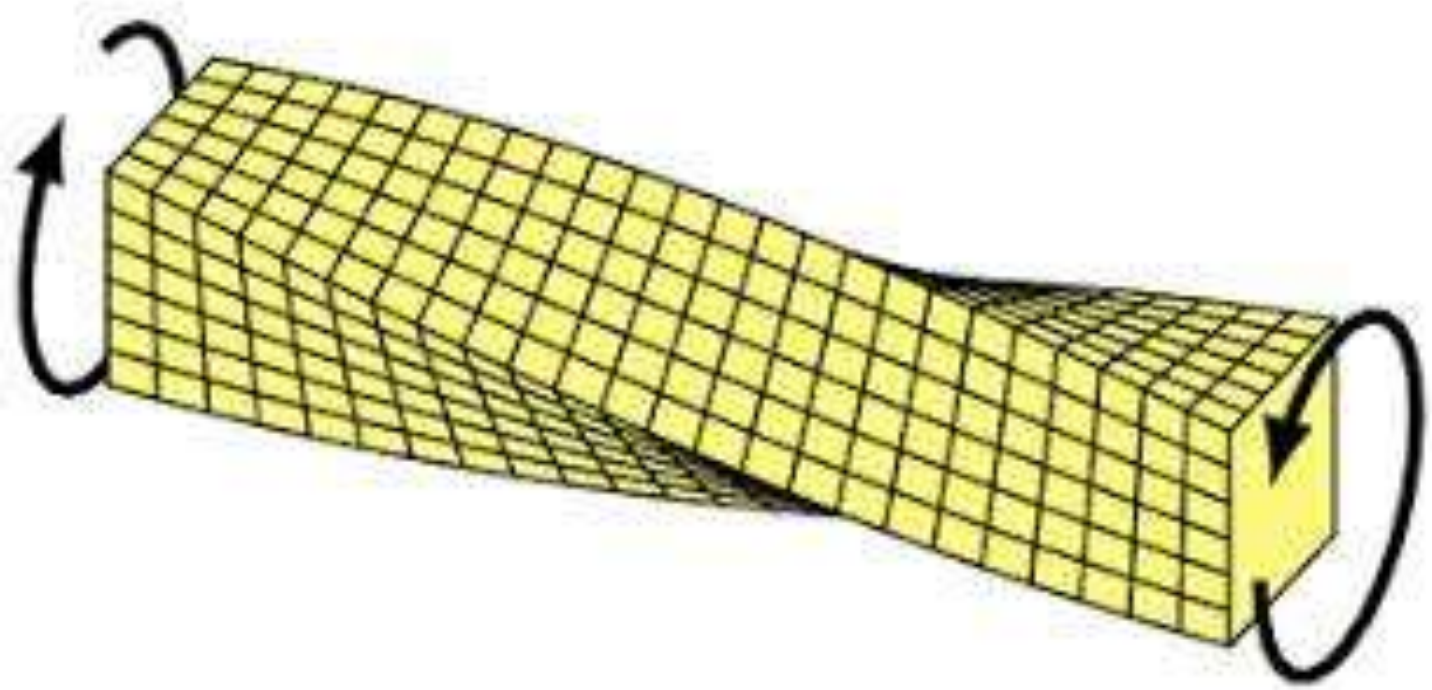
Min HSS wall thickness – Use Section I8.1

Consider stud location (closer to edge rather in the middle)



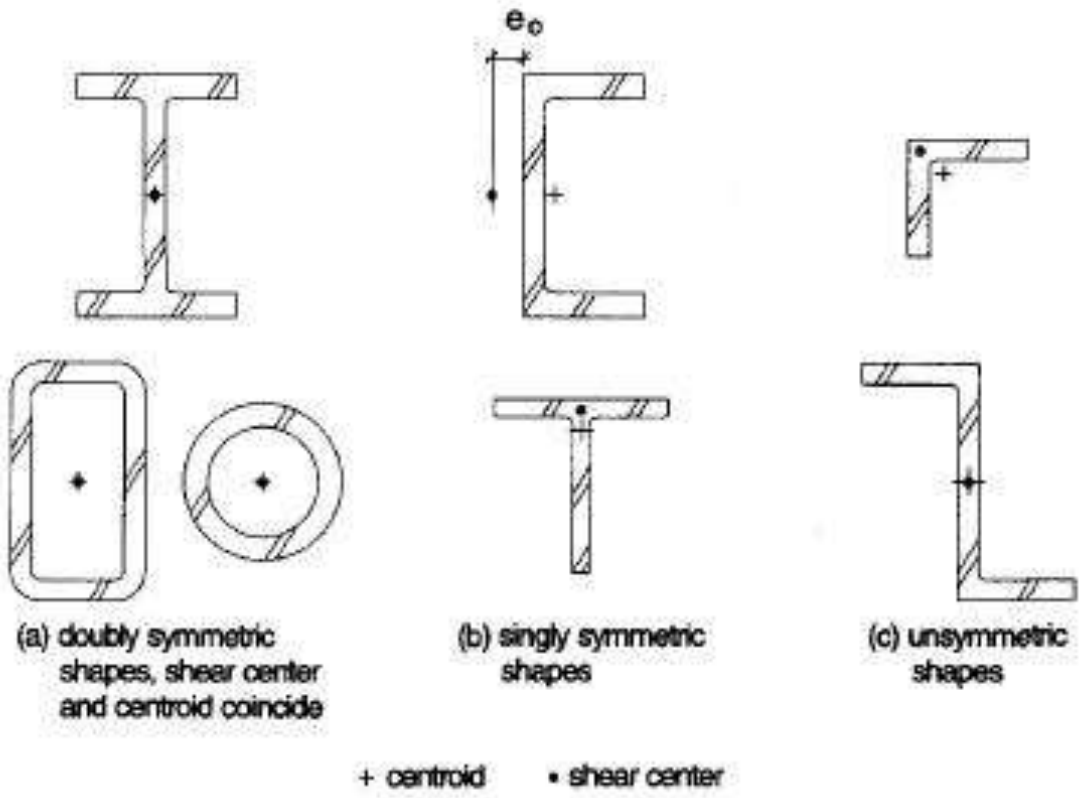
TORSION

In the Specification, but we are not given much guidance on how to deal with the connections



WHAT IS TORSION?

Torsion occurs when a load acts outside a member's shear center

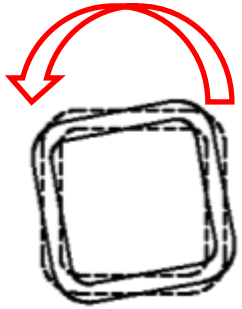


WHY TUBES?

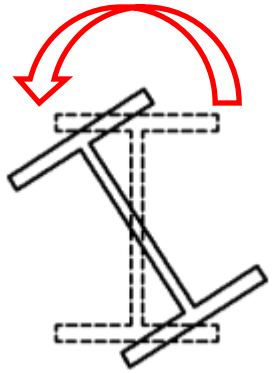
Torsional constant of an HSS is ≈200 times that of an open section

Calculation of torsional strength is a closed solution for HSS

Calculation for open sections is much more complex (see AISC Design Guide #9)

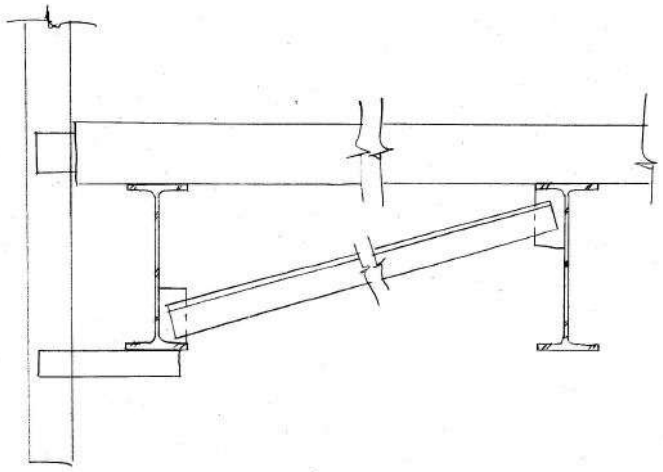


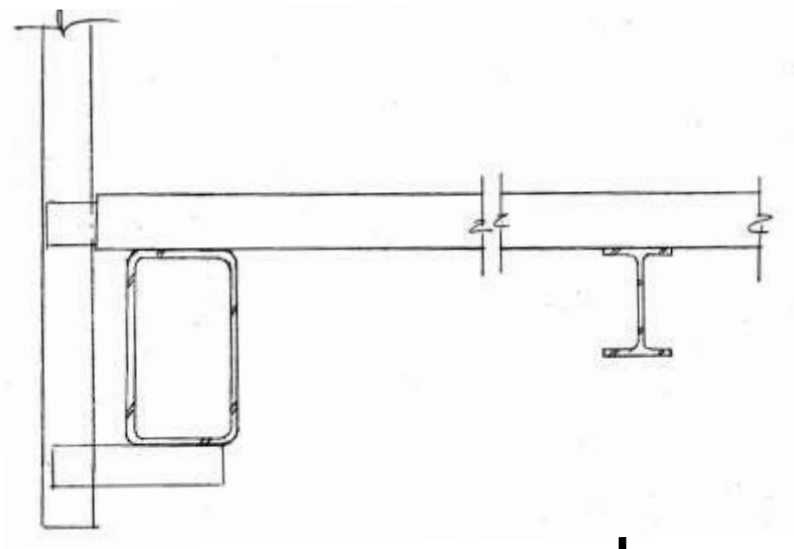
HSS

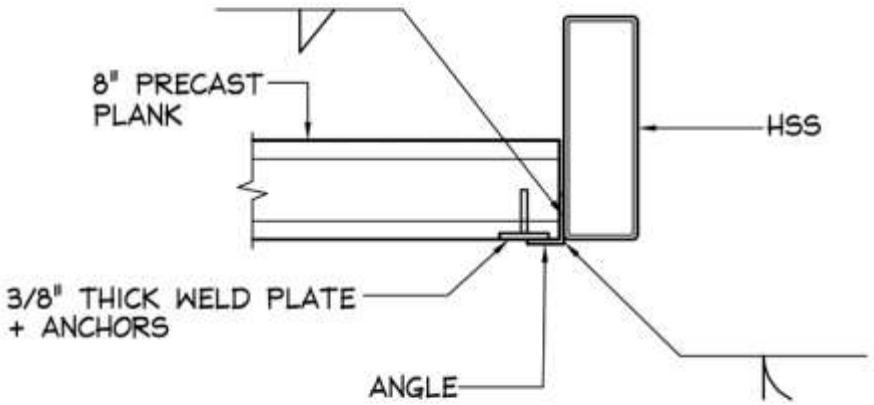


Wide Flange

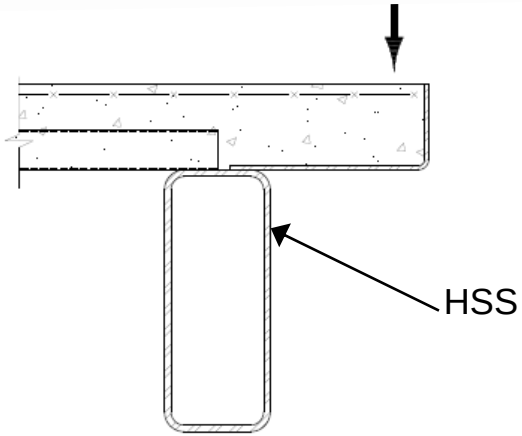
SPANDREL CONDITION





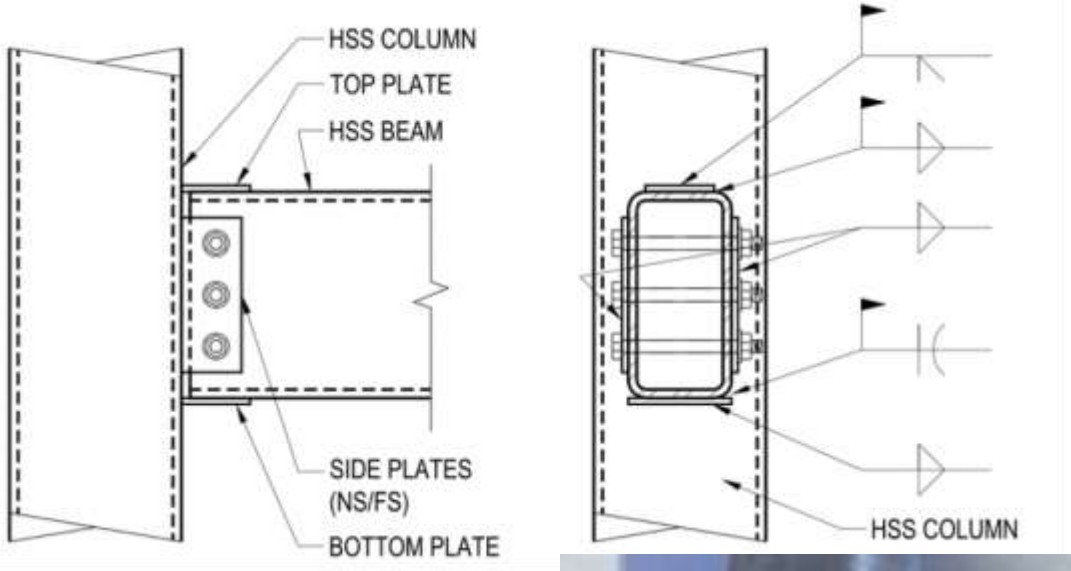


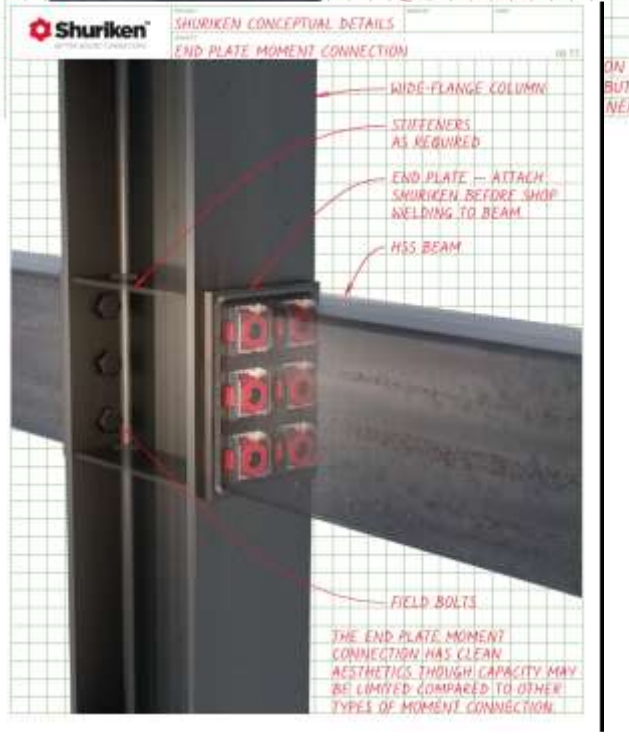
Source: Girder Slab



Spandrel Beam

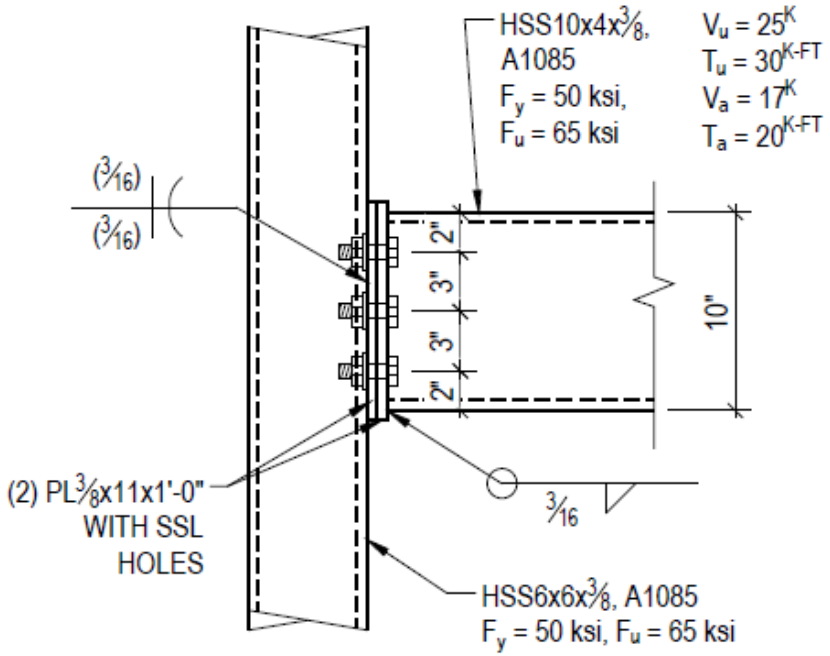
TORSIONAL CONNECTIONS

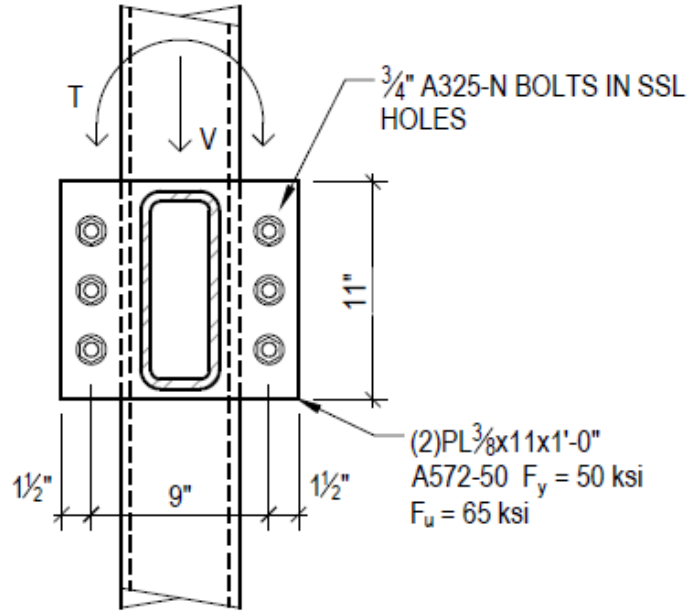




END PLATE CONNECTION

Design Example given in Steel Tube Institute's HSS Design Manual, Volume 3





LATERALLY OFFSET CONNECTIONS

Common for aesthetics

Girt applications

Bu, Wei, Packer, 2021

LATERALLY OFFSET CONNECTIONS

Manual Part 9 – “Plate Elements Subjected to Out-of-Plane Loads”

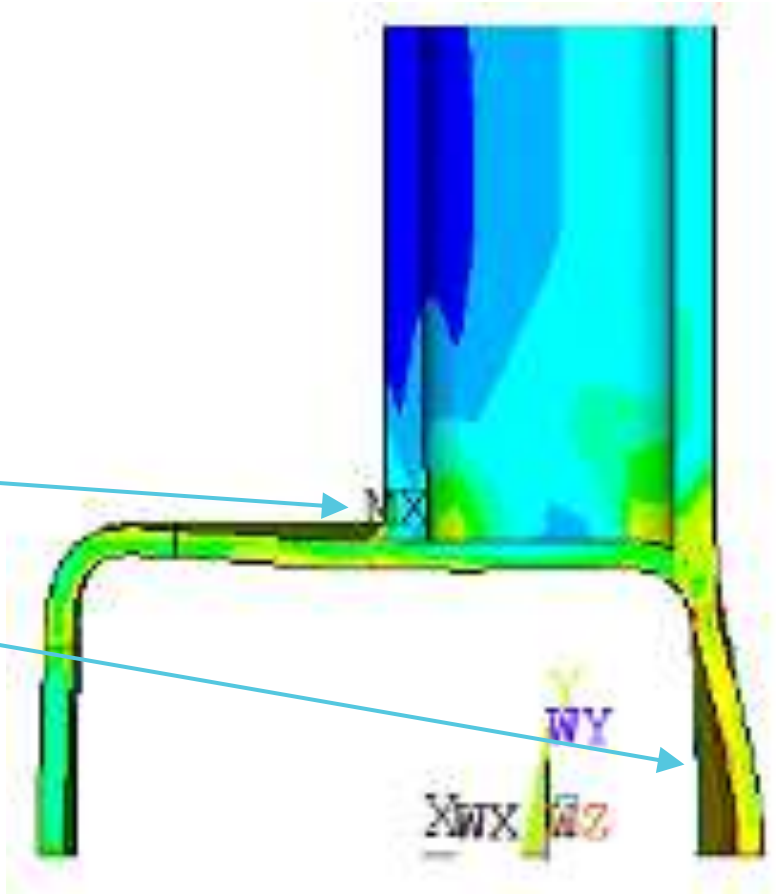
- Yield line mechanism
- Plastification of connecting face

Combination of traditional limit states

- Chord plastification
- Chord sidewall failure

Conservatively ignore connecting face contribution

- AISC 360, Eqn J10-2
- One sidewall



Bu, Wei, Packer, 2021

LATERALLY OFFSET CONNECTIONS

Limitations

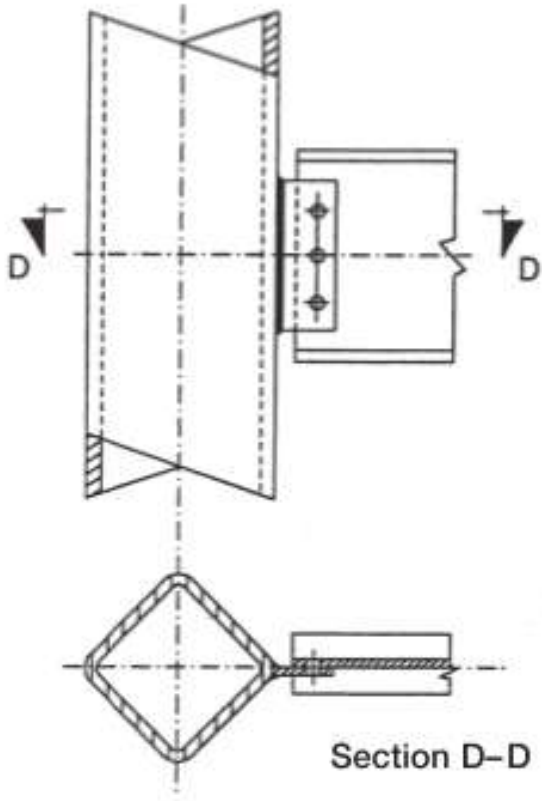
- Range of sizes studied
- Thin branch members
- Assumed lateral restraint

Additional Information:

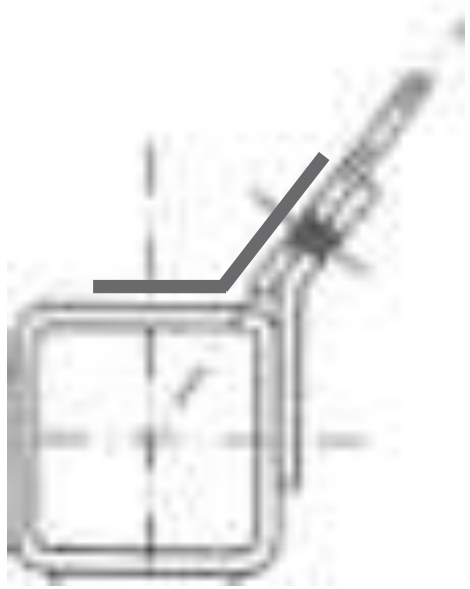
- “Laterally Offset HSS Connections”, by J.A. Packer, www.steeltubeinstitute.org
- “Laterally Offset RHS X-Connection”, Bu, Wei, & Packer, ASCE Journal of Structural Engineering
- “Rectangular hollow section webs under transverse compression”, Kuhn, Packer, & Fan, Canadian Journal of Civil Engineering, Vol 46

SKEWED CONNECTIONS

Don’t weld to corners



INSTEAD



Instead, use bent plate or double bent plate.

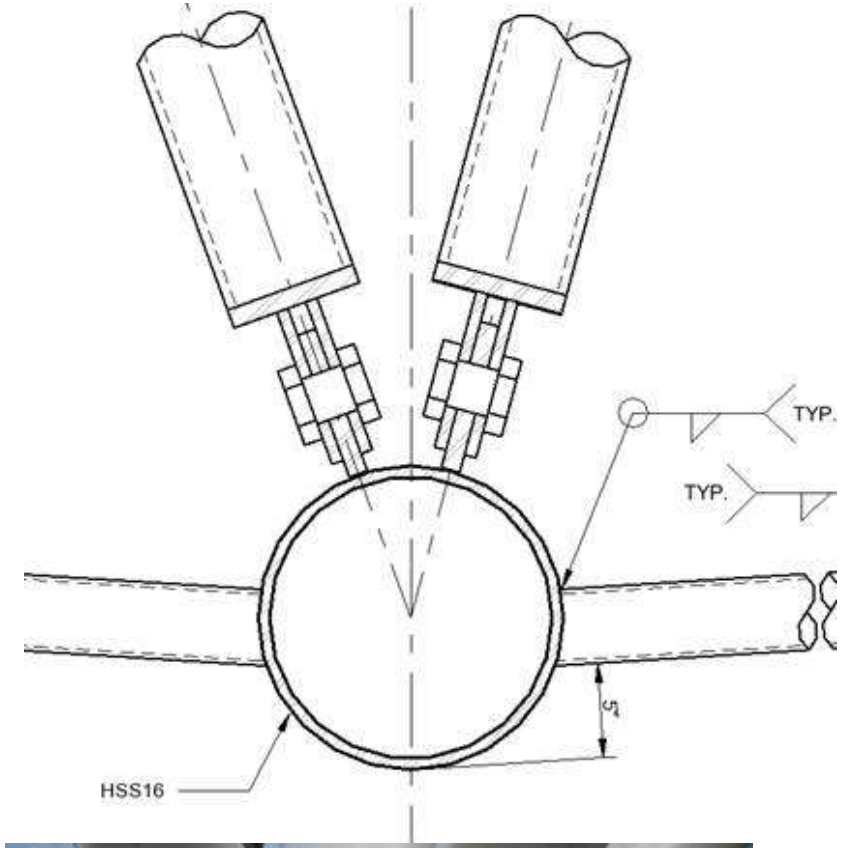
MULTIPLANAR LONGITUDINAL PLATES

How do you check plastification?

Vertical components of branches and apply total force to a single, central, longitudinal plate

What about skewed connections?

No effective width / area for longitudinal connections
Concentrate on the prime force affecting the connection = force component normal to the chord member



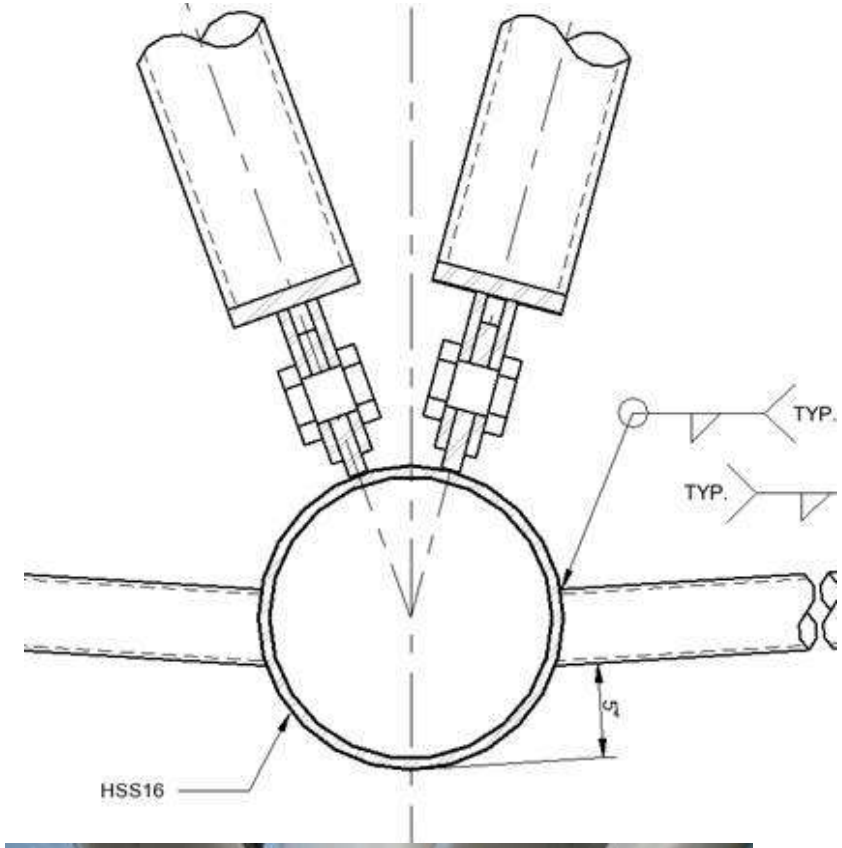
MULTIPLANAR LONGITUDINAL PLATES

Simple shear

Satisfy the min HSS wall requirement in Part 10 of the AISC Manual

Axial force

Consider global behavior of multi-planar trusses
For high loads, may need to use FEA



TRUSS CONNECTIONS

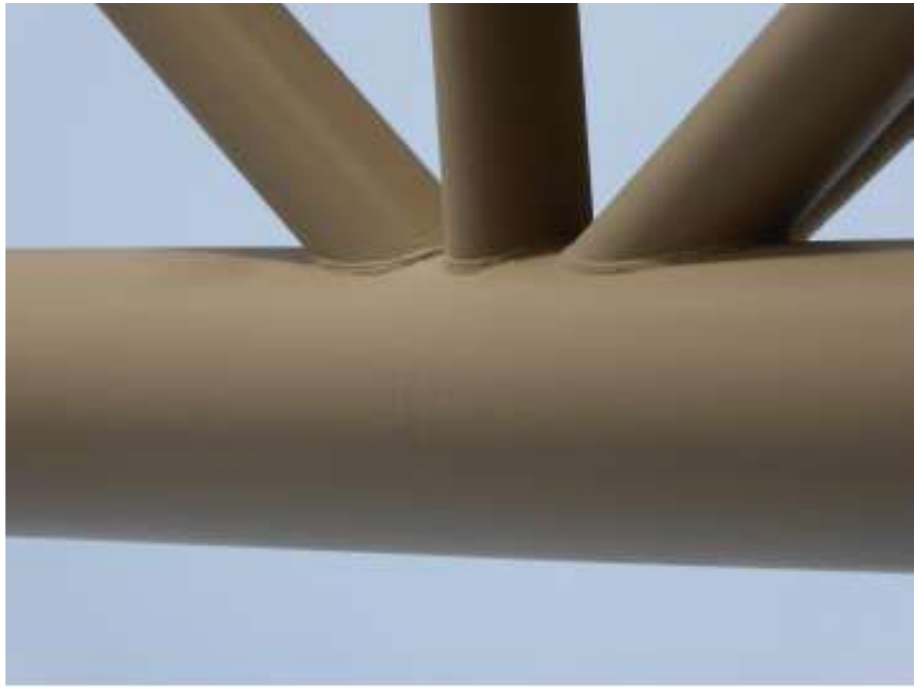
Joint types not addressed in Chapter K

TRUSS CONNECTIONS

KT joints occur in modified Warren truss where three branch members come together at a joint

Outside the scope of AISC 360, Chp K. *(Now covered by AISC Design Guide 24, 2nd Ed.)*

Suggested analysis and design technique in Engineering Journal paper: “HSS Truss Connections With Three Branches”, Jeffrey A. Packer, AISC Engineering Journal, 3rd Qtr, 2014



TRUSS CONNECTIONS

Round Branch, Square Chord

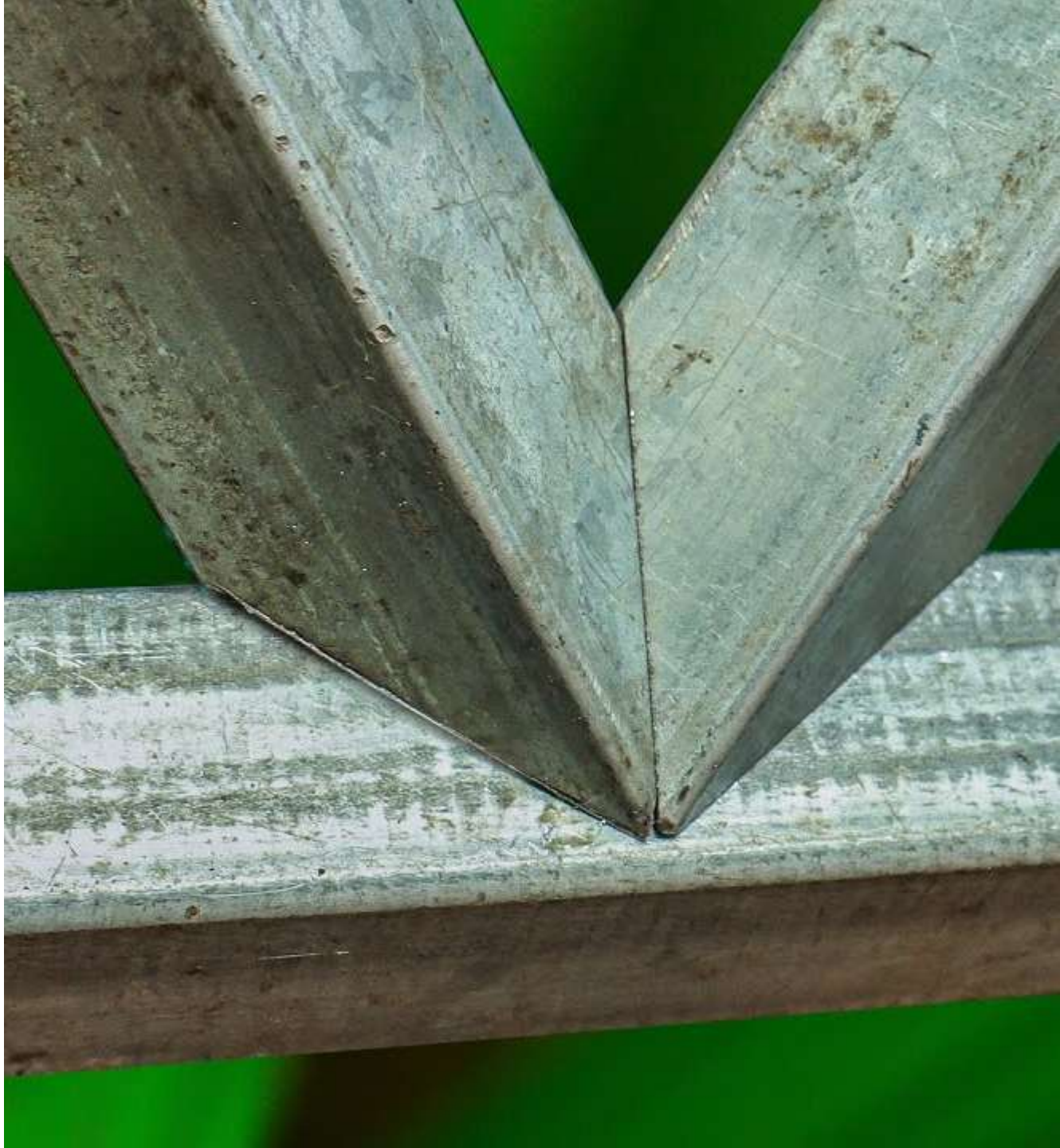
Not covered by AISC 360, Chapter K *(Now covered by AISC Design Guide 24, 2nd Ed.)*

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 = (π/4)*D and the same wall thickness is used.

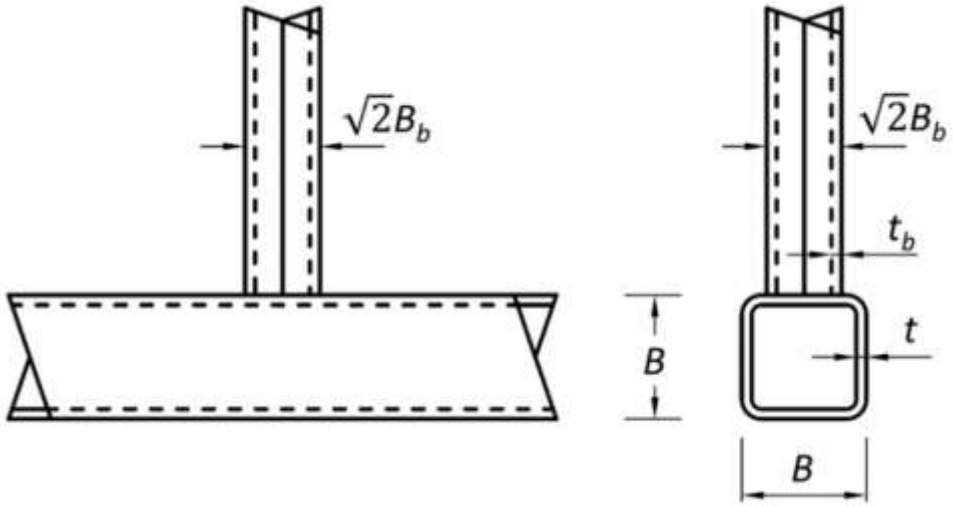
ROTATED HSS CONNECTIONS



ROTATED HSS CONNECTIONS

Branch Rotated 45 degrees

- Larger effective branch to chord width ratio ($\sqrt{2}$ (B_b/B)) – enhanced connection strength
- Footprint of branch is similar to round branch
- Treat as round branch to square chord and do “branch conversion” method
- Use guidance for T and X joints

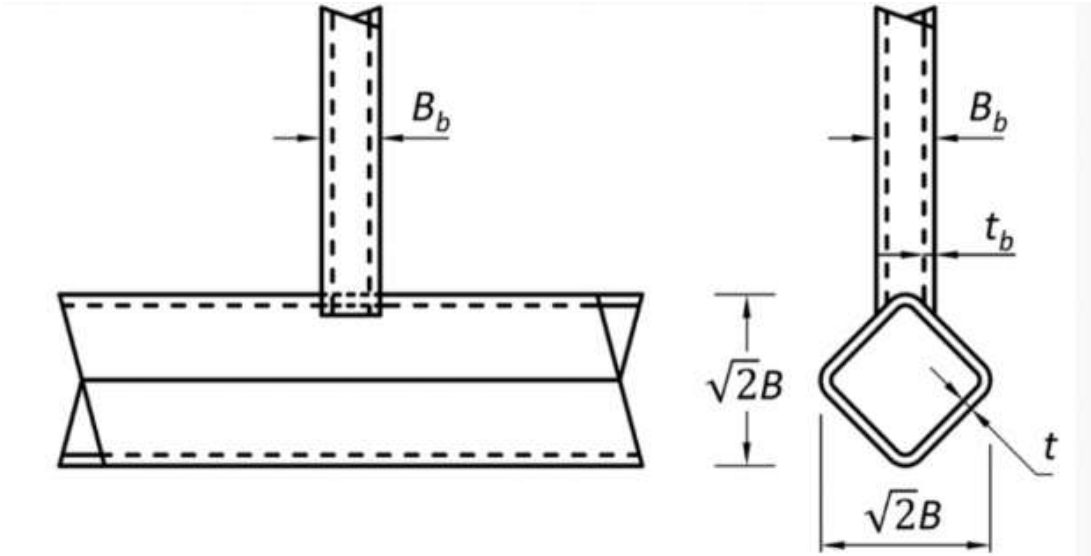


Branch-Rotated (BR) HSS connection

ROTATED HSS CONNECTIONS

Chord rotated 45 degrees

- More resistant to chord plastification
- No real design guidance
- Conservative approach is to treat as non-rotated chord and use Chapter K equations
- Special attention needed for prep for welding (profiling of branch)
- Use guidance for T and X joints

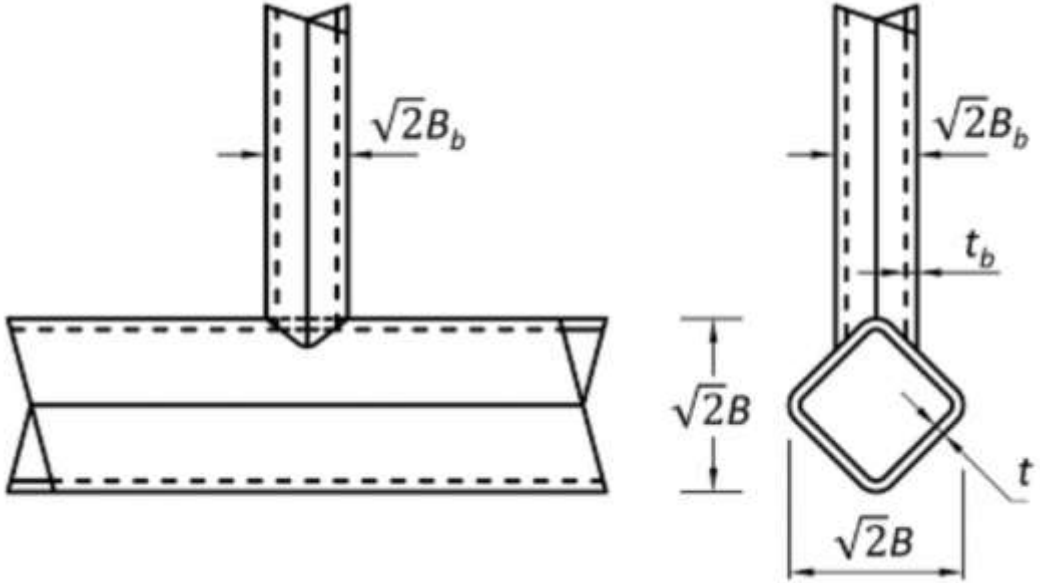


Square-Bird-Beak (SBB) HSS connection

ROTATED HSS CONNECTIONS

Chord and branch rotated 45 degrees

- Generally stronger connection than non-rotated squares and equivalent round HSS
- T and Cross joints behave similar to round HSS, so guidance is based on round HSS equations
- Gapped K joints limited to branch angle θ = 45 degrees
- Use guidance for T, X and K joints



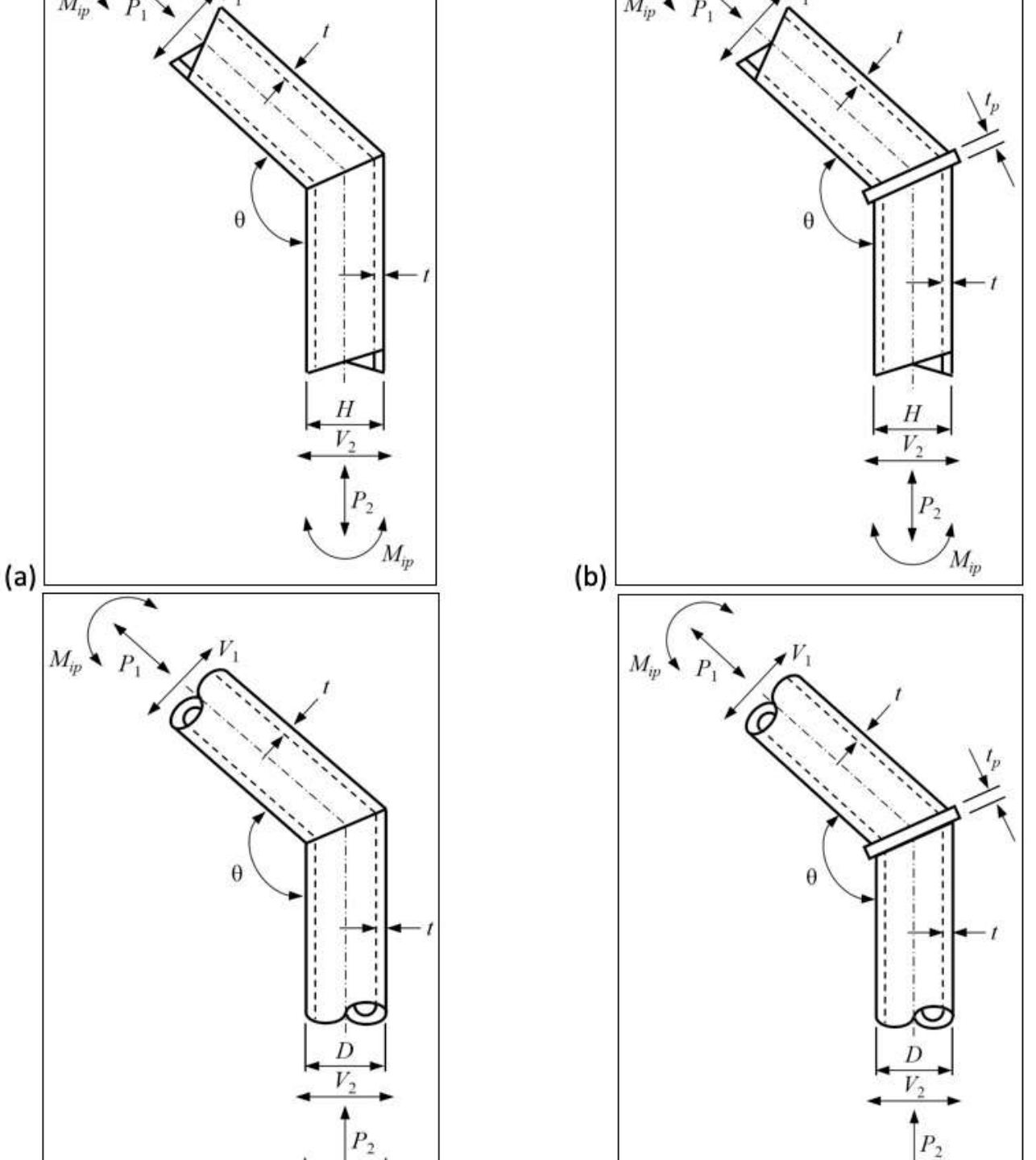
Diamond-Bird-Beak (DBB) HSS connection

ROTATED HSS CONNECTIONS

For more info

“HSS Connections with Rotated Members” by Jeffrey A. Packer at www.steeltubeinstitute.org

KNEE JOINTS

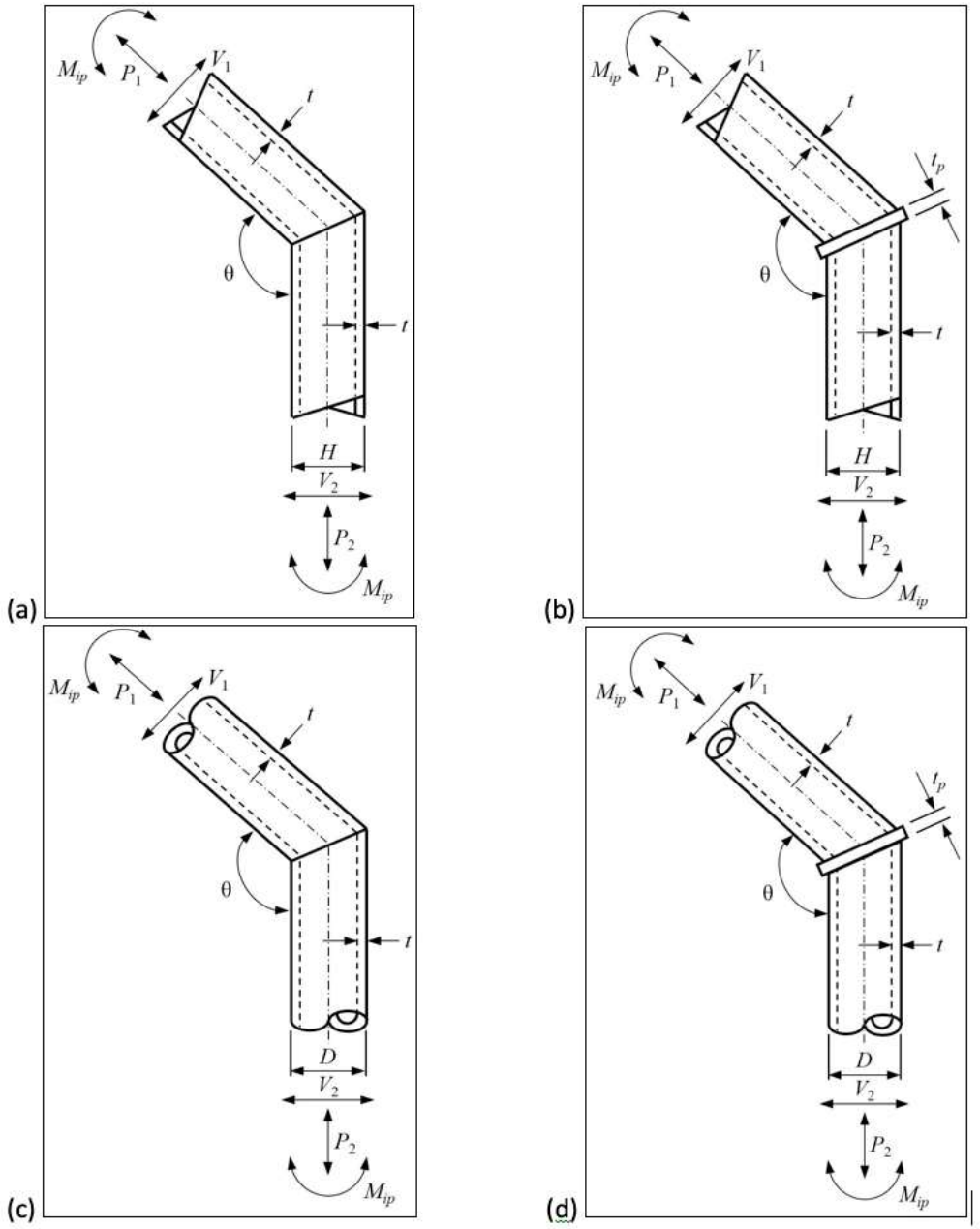


KNEE JOINTS

Behave primarily as a PR connection. Using stocky members and joint stiffening may allow FR behavior.

Best for elastically designed structures.

Compact sections required.



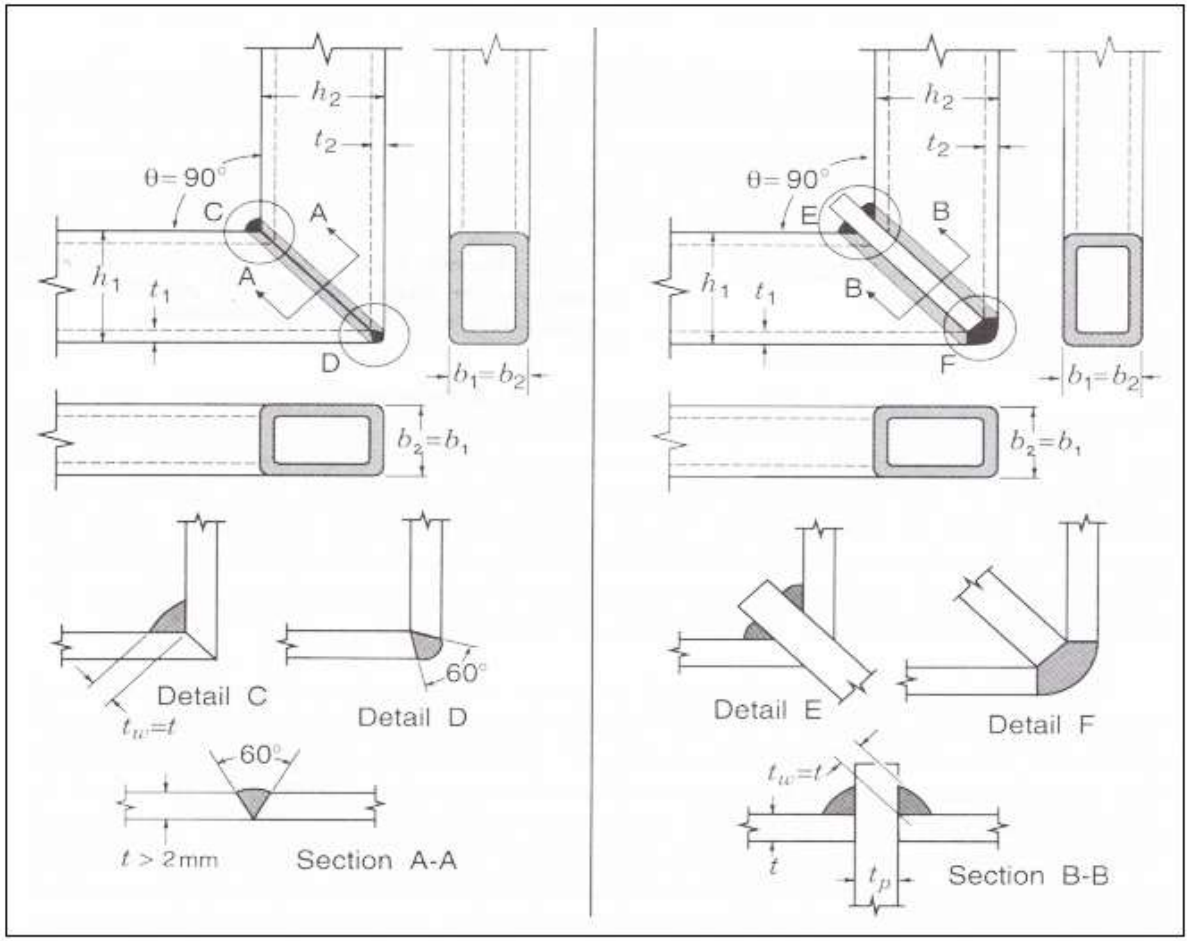
KNEE JOINTS

Stiffened joints are preferred

- Easier to fabricate as they allow fillet welds
- Results in stiffer, stronger connection
- Can use slightly different sized HSS

Unstiffened joints

- Edge prep and weld quality are critical
- Angle of joint will determine strength (obtuse angles are stronger than right angles)



From Packer and Henderson, 1997

KNEE JOINTS

For more info

"HSS Knee Connections" by Jeffrey A. Packer at www.steelinstitute.org

CIDECT Design Guides 1 (2nd Ed), 3 (2nd Ed) & 7

THANK YOU

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