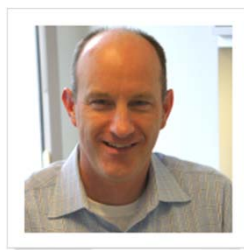




# ***Designing Connections to HSS***

## ***Introduction to Moment and Truss Connections***



*presented by*

**Brad Fletcher, S.E.**

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**Bradlee.Fletcher@atlastube.com**



# Topics

- **Introduction**
- **HSS General Overview**
- **Types of HSS Connections**
- **Truss Connections**
- **Moment Connections**

## About the Speaker



Brad Fletcher, S.E., is a structural engineer at Atlas Tube. In this role, Brad leverages his 20 years of experience in engineering design and the steel industry to provide technical expertise on the use of steel hollow structural sections (HSS) and pipe piling products to design engineers, detailers, fabricators and architects.

A registered structural engineer in the state of Illinois, Brad has held senior positions at leading architecture and engineering firms, Skidmore, Owings & Merrill; Sargent & Lundy; and Halvorson and Partners. Brad has contributed to notable projects, including the Guggenheim Museum in Spain and the Elysian Hotel. For the past six and a half years, most recently while working at Tata Steel (formerly known as Corus), Brad has focused his efforts on serving as a liaison between structural designers and the steel industry.

Brad holds a Bachelor of Science and a Master of Science in civil engineering (BSCE, MSCE) from Purdue University. He is active in many industry groups, including the American Institute of Steel Construction (AISC), the Structural Engineers Association of Illinois (SEAOI) and ASTM International. As chairman of the HSS Marketing Committee within the AISC, Brad upholds the institute's mission to promote the usage and understanding of steel and HSS. Brad is also on the Board of Governors for the Steel Structures Education Foundation (SSEF) in Canada and the S16 Technical Committee for the Canadian Standards Association (CSA).

# Corporate Overview



# Atlas Tube – Market Leader



## **Largest size range in North America**

- 1"–16" square, up to 5/8" wall (larger sizes listed on CISC website)
- 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 and waste**

- Rolled lengths over 100 ft.

## **Metallurgists and Structural Engineer on staff to assist with technical and product questions**

## **Products stocked by service centers across North America**



**CIDECT Member**

## **Four production facilities in North America**



# Atlas Tube products found in many markets



- **Solar Energy**
- **Mining Equipment**
- **Non-Residential Construction**
- **Transportation**
- **Agriculture & Construction Equipment**
- **Material Handling Equipment**
- **Water Treatment facilities**
- **Oil & Gas**



# Topics

- Introduction
- **HSS General Overview**
- Types of HSS Connections
- Truss Connections
- Moment Connections

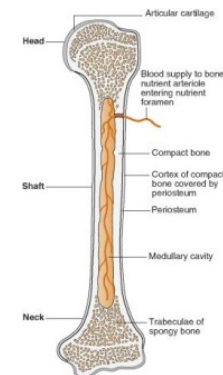


# What are HSS?

**The use of tube is extremely popular among engineers and throughout nature.**

**Tube-like structures are naturally occurring:**

- Bones of animals
- Bamboo
- Stems of flowers





# What are HSS?

Hollow structural sections are **cold-formed, welded steel tube** used for welded or bolted construction of buildings, bridges and other structures, as well as a wide variety of manufactured products.

Hollow structural sections are produced in **square, round and rectangular** shapes to meet structural design requirements.



# Why are HSS used?

## Aesthetics

## Economical

- Efficient in resisting torsional and compressive loads
- Less surface area
- Can have less weight

## Comes in a wide range of sizes and shapes

- 1"–22"
- Up to 7/8" wall thickness
- Square, rectangular, round and even elliptical



# Advantages of HSS

## Ease of handling

## Lower finishing costs

- Less surface area

## Excellent torsion resistance

- Torsional constant  
200 times greater than  
open section

## Increased unbraced length

- $r_x$  &  $r_y$  significantly higher than open sections
- Higher compression capacity for same unbraced length

## Robust structures / blast resistance

- Square / round HSS can resist loads from any direction
- Composite HSS (concrete-filled tubes)



# Topics

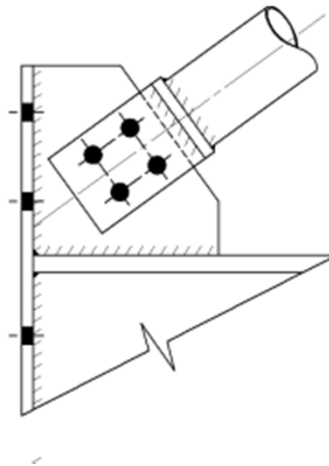
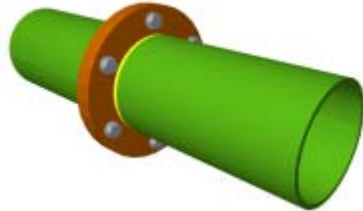
- Introduction
- HSS General Overview
- **Types of HSS Connections**
- Truss Connections
- Moment Connections

## Connection Design for HSS

- They are too hard
- They are too expensive
- There are not enough resources
- EOR does not design connections

## Tension & Compression

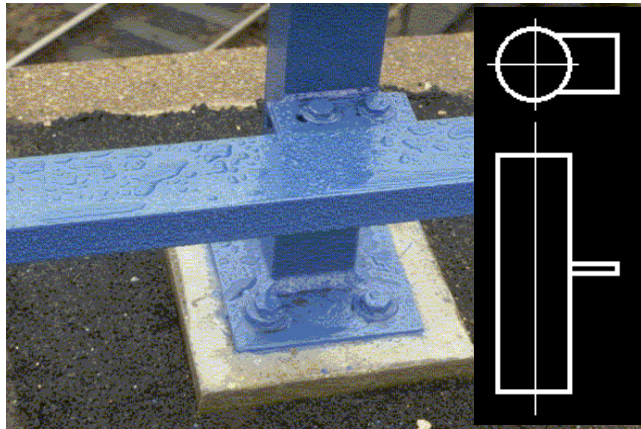
- Bracing
- Splices



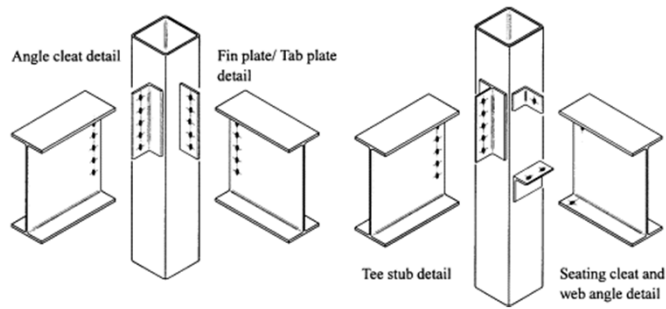


# HSS Connection Types

## Line Loads & Concentrated Loads



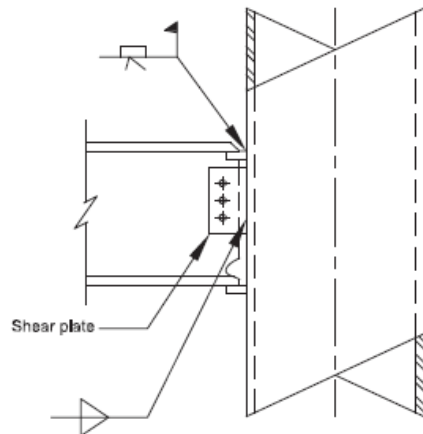
## Shear Connections





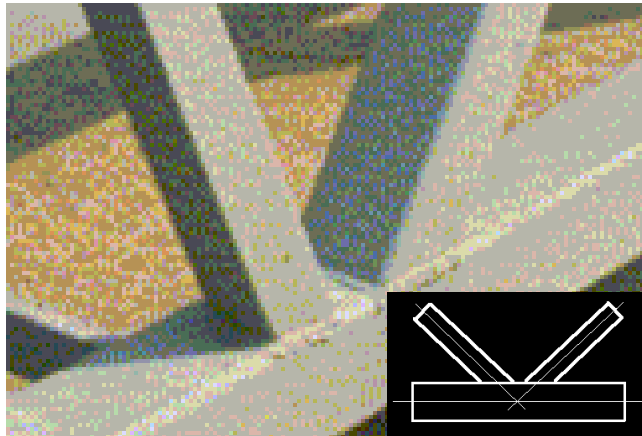
## Moment Connections

- Wide Flange to HSS



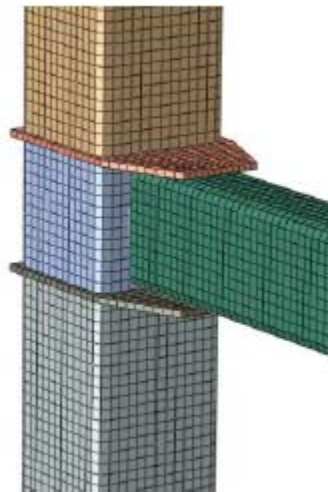
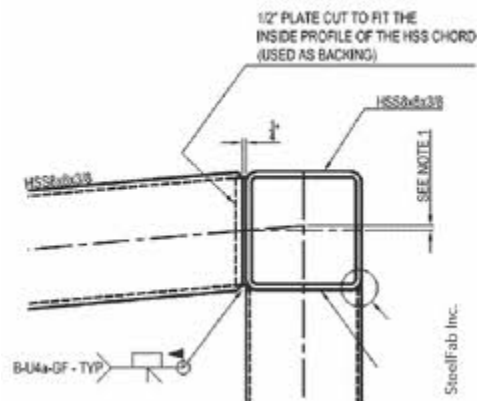
## HSS to HSS Truss Connections

- Tension & Compression



# HSS Connection Types

## HSS to HSS Moment Connections



# 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

## Atlas Website

- [www.atlastube.com](http://www.atlastube.com)



### International Institute of Welding (IIW)

- Subcomission XV-E published Design Recommendations on Static Strength of Tubular Joints
  - 1st Edition (IIW, 1981)
  - 2nd Edition (IIW, 1989)
  - 3rd Edition (IIW, 2009)

### CIDECT (International Committee for the Development and Study of Tubular Structures)

- An international association of HSS and pipe manufacturers dedicated to expanding knowledge of tubular sections through research and studies
  - 1st ed. Design Guides based on IIW, 1989
  - 2nd ed. Design Guides 1 & 3 based on IIW, 2009

## IIW 1989 is the basis for:

- Eurocode 3, Part 1-8
- AISC 360, Chapter K (2005 & 2010)
- AISC Design Guide 24
- CISC 1997 Design Guide
- 1st ed. CIDECT design guides

**The above all will have slight differences  
due to regional and code format factors**



All these design codes and guides will result in  
comparable designs

# HSS Connections

- Its important to note that local strength of HSS members is an integral part of HSS connection design.
- Understanding these local strength issues is important to member selection.
- Proper member selection by the EOR will have an effect on HSS connection design
- Reinforcing of connections is difficult and expensive and usually not an option due to architectural or fabrication restraints
- Even if EOR is not doing final connection design, some checks need to be done to ensure proper joint strength.
- Be sure to give good load information to the party responsible for final connection design.



# Joint Design Considerations

The joint strength is determined by the selected chord and bracing member sizes, grades and geometry

These are decided by the

**DESIGNER**



# Topics

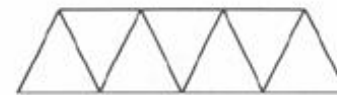
- Introduction
- HSS General Overview
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- **Truss Connections**
- Moment Connections

# Truss Connections

**Connections at the panel points of a planar truss**

**Trusses are typically analyzed with all members “pinned”**

**Truss connections are designed as tension/compression connections**



Warren Truss



Warren Truss With Verticals



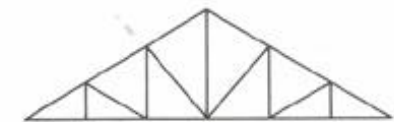
Pratt Truss



Howe Truss



K Truss



Roof Truss

Types of simple Plane truss



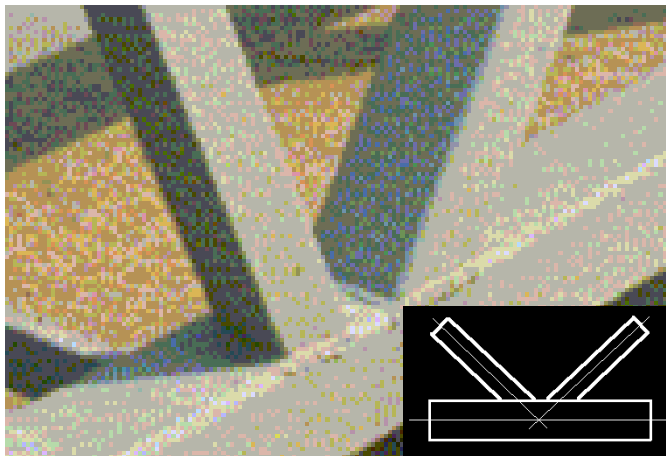
# Truss Connections — Joint Types



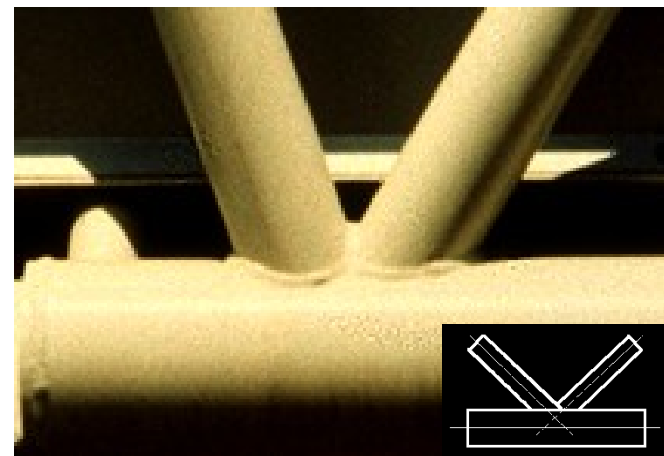
T or Y-Joint



X-Joint

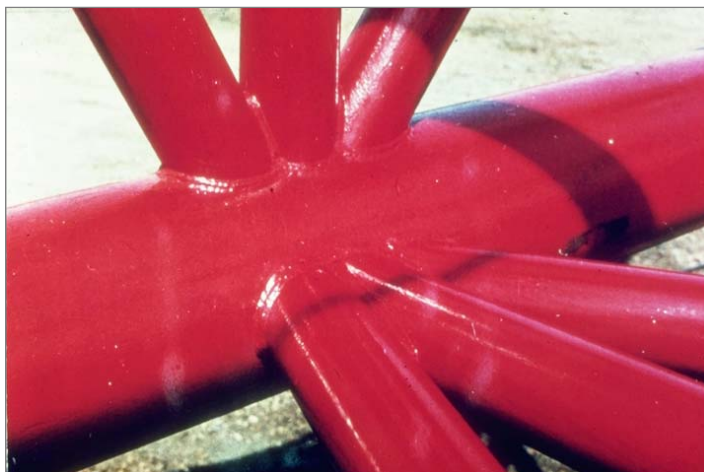


Gap K-Joint

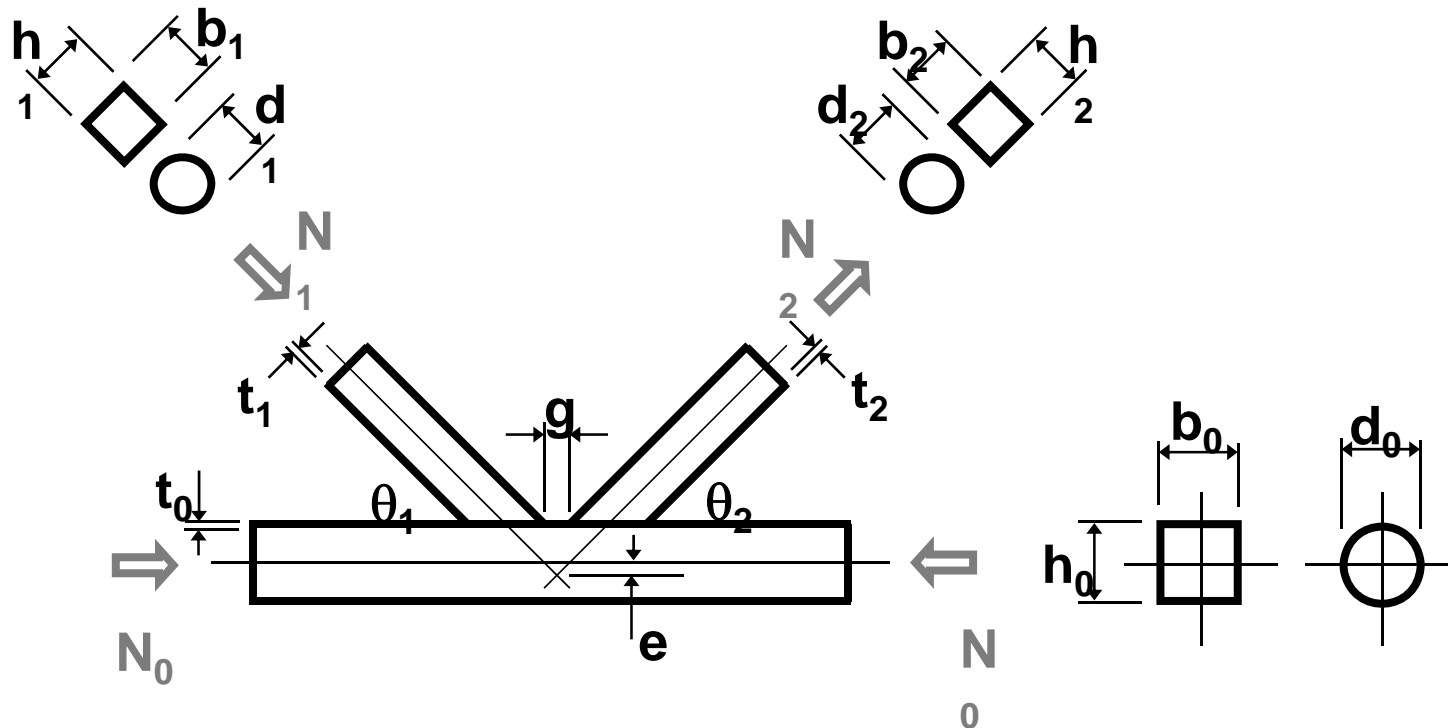


Overlap K-Joint

# Truss Connections — Multi-Planar



# Truss Connections — Nomenclature



Brace 1 usually compression brace



# Truss Fabrication Costs



**Minimum weight does not equal minimum cost**

**Keep the number of different sizes small**

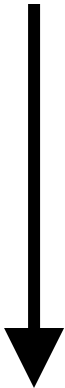
**Try to minimize number of connections**

**– 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

<b>Highest Cost</b>	<b>RHS chord — gap joints</b>
	<b>RHS chord — 100% overlap joints</b>
	<b>CHS chord — gap joints</b>
	<b>RHS chord — partial overlap joints</b>
	<b>CHS chord — 100% overlap joints</b>
<b>Lowest Cost</b>	<b>CHS chord — partial overlap joints</b>

## Gap Joints — Parametric Effects



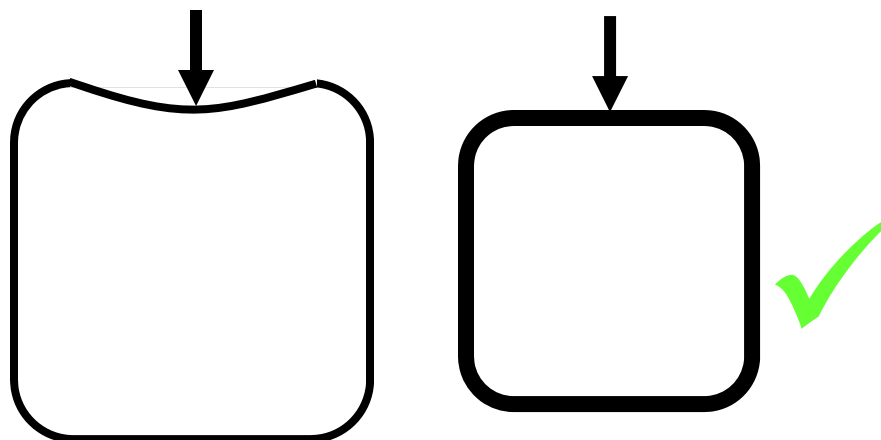
Parameter	Direction	Effect on Joint
Chord width to thickness ratio	Down	Capacity up
Bracing to chord width ratio	Up	Capacity up
Bracing angle	Down	Capacity up
Chord factored to yield stress ratio	Less compressive	Capacity up

# Overlap Joints – Parametric Effects

Parameter	Direction	Effect on Joint
Chord width to thickness ratio	Down	Capacity up
Bracing width to thickness ratio	Down	Capacity up
Overlap	Up	Capacity up
Chord factored to yield stress ratio	Less compressive	Capacity up
Bracing angle	Down	Capacity up

# Parameter Effects

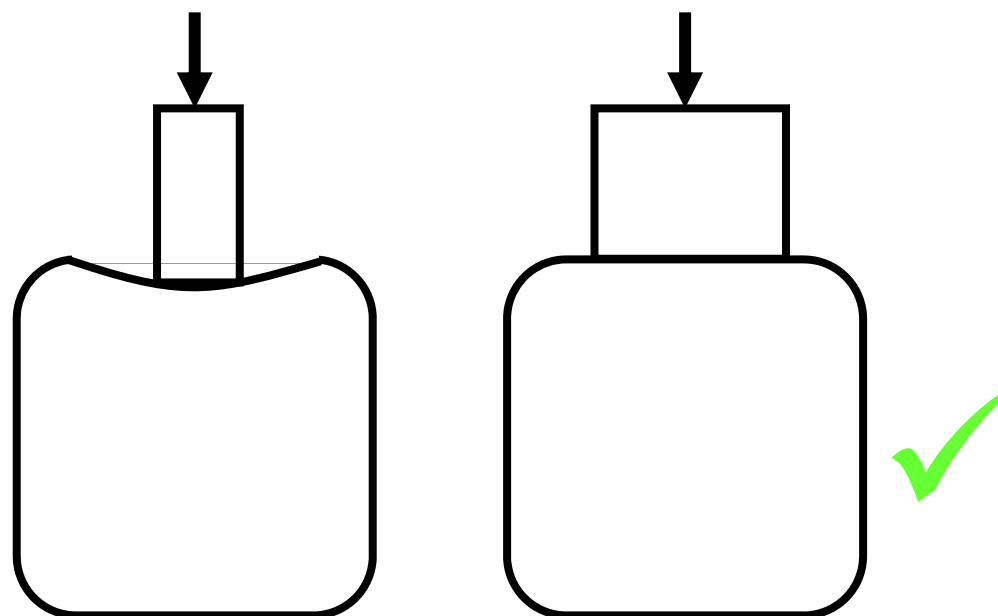
## Gap & Overlap Joints



Chord width to thickness ratio  
Keep ratio down to increase joint capacity  
Round HSS  $15 \leq D/t \leq 30$   
Square HSS  $15 \leq B/t \leq 25$

# Parameter Effects

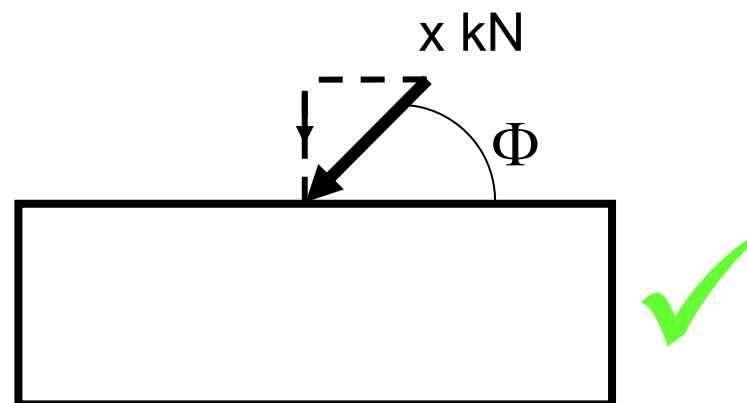
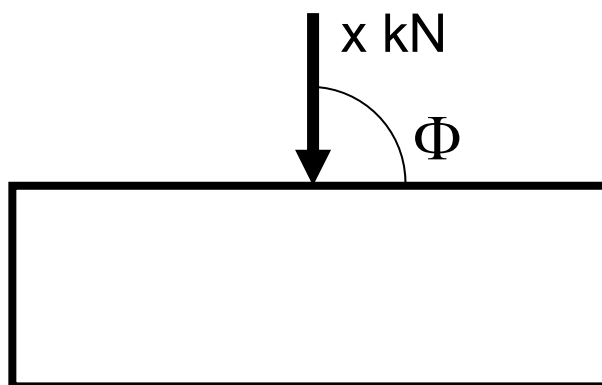
## Gap Joints



Bracing to chord width ratio  
Keep ratio up to increase joint capacity  
Keep  $B_b/B$  as high as possible and  
keep  $t_b/t$  as low as possible

# Parameter Effects

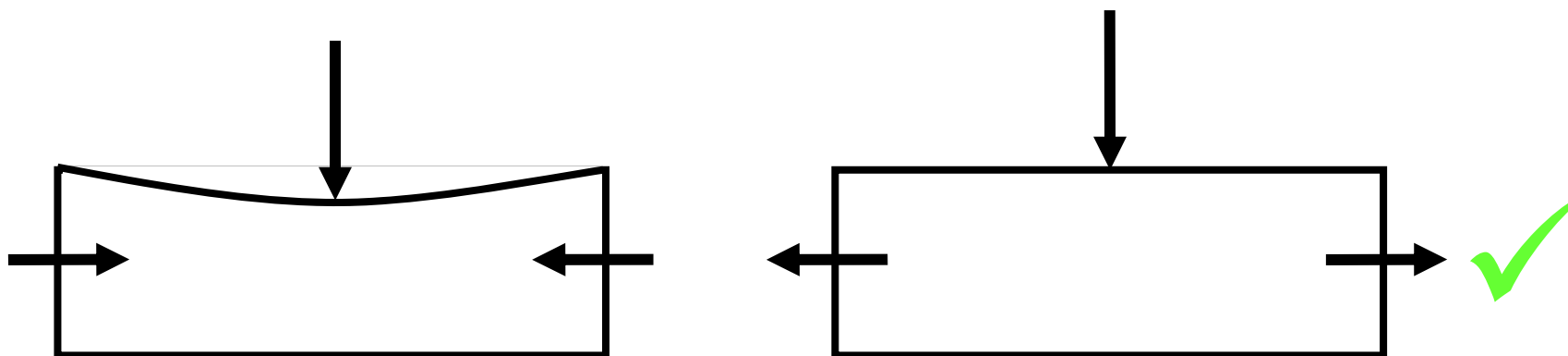
## Gap & Overlap Joints



**Bracing angle**  
Keep bracing angle  $\Phi$  down to increase  
joint capacity

# Parameter Effects

## Gap & Overlap Joints

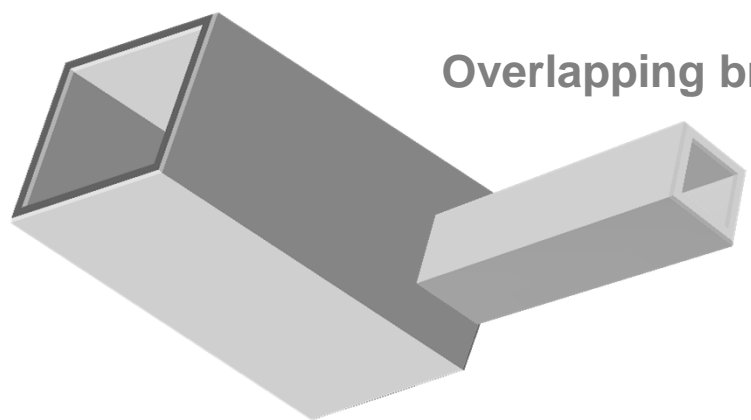


Chord factored to yield stress ratio  
Keep compressive stress down to  
increase joint capacity



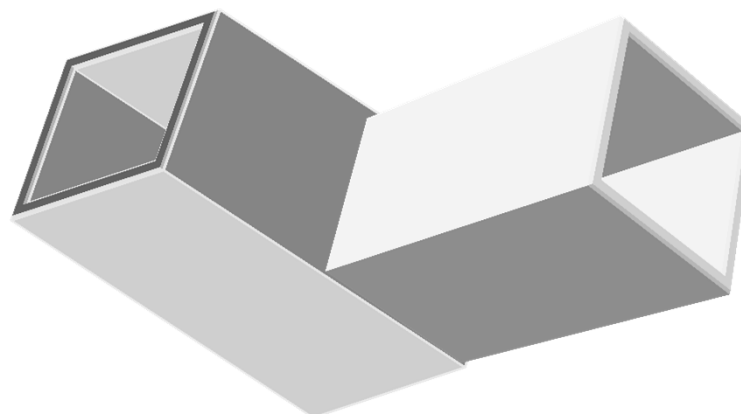
# Parameter Effects Overlap Joints

Overlapped brace



Overlapping brace

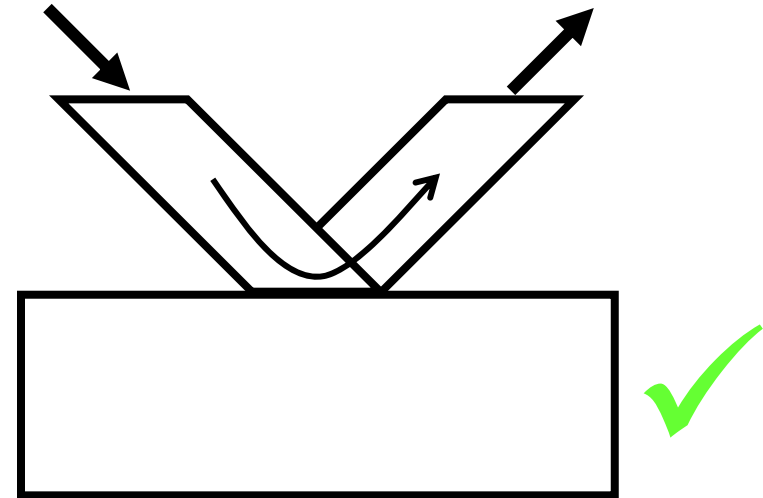
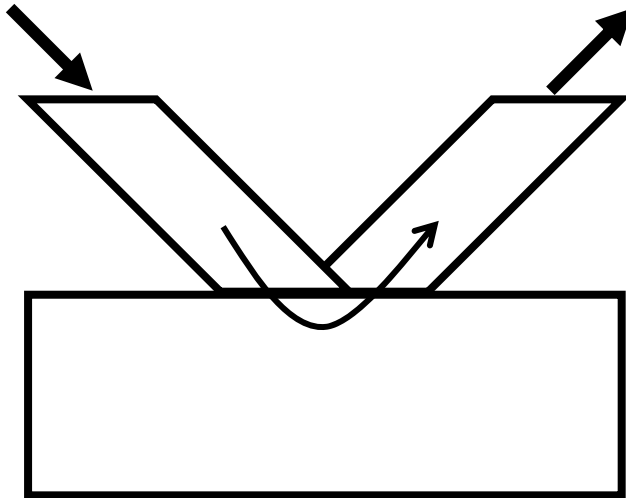
Overlapped brace



Overlapping brace

Bracing width to thickness ratio  
Try to match branch members width to  
increase joint capacity

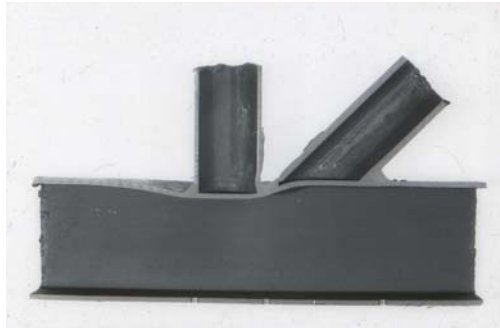
# Parameter Effects Overlap Joints



## Overlap

The higher percentage of overlap, the  
higher the joint strength

# Failure Modes



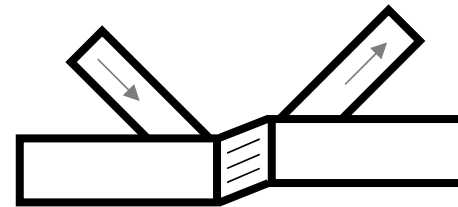
**Chord face deformation (yielding)**



**Chord or bracing localised buckling**



**Chord punching shear**



**Chord shear**



**Chord side wall buckling**



**Bracing effective width**

## Approach 1

Weld proportioned to develop yield strength of connected branch at all locations around the branch.

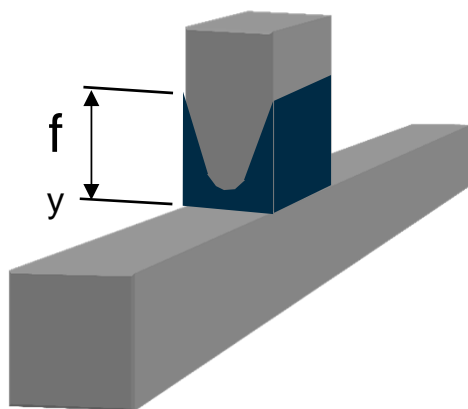
- Upper limit of weld size
- Conservative
- Appropriate if plastic stress redistribution is required in connection

## Approach 2

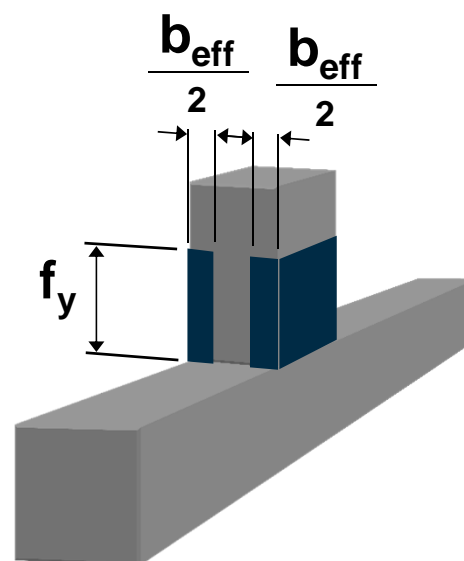
Weld proportioned to resist applied forces

- Need to account for effective weld lengths

# Bracing Effective Width RHS to RHS Chord

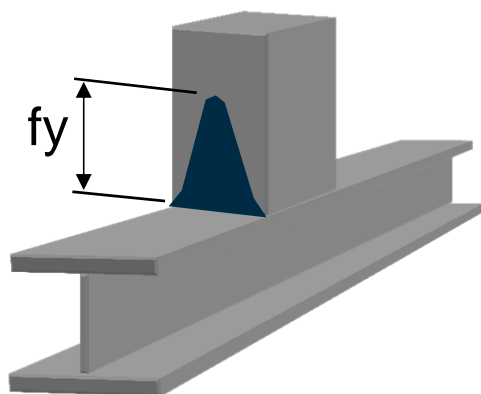


Axial stress distribution

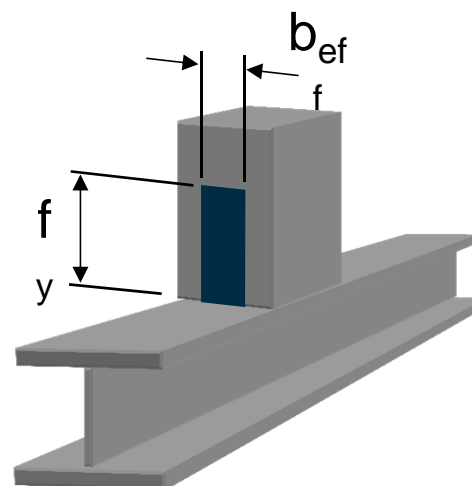


Hypothetical  
axial stress distribution

# Bracing Effective Width W Section Chord



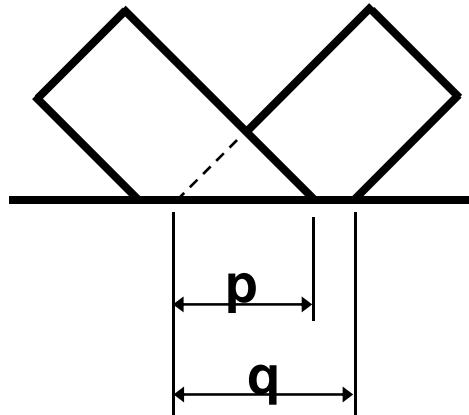
Axial stress distribution



Hypothetical  
axial stress distribution



# Overlap Detail

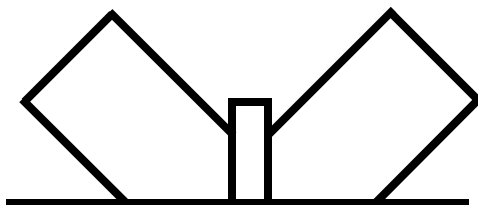
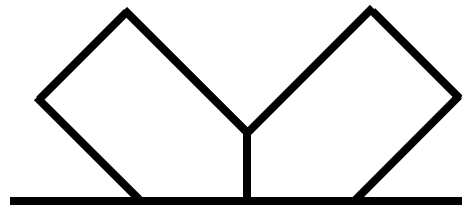


Overlap = p

Overlap % =  $p/q \times 100$

Overlap bracings should NEVER be made like this >

- Difficult to fabricate
- Up to 20% weaker



- Use division plate as alternative
- Helps to reinforce joint

# Welding

**Generally for economics  
specify a fillet weld for tubular  
joints**

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

**For dynamically loaded  
trusses, weld sequence is  
important**





## Joint capacity is dependant upon

- Brace angle
- Bracing width to chord width ratio
- Chord width to thickness ratio
- Gap or overlap bracings
- Chord compressive stress



# Topics

- Introduction
- HSS General Overview
- Types of HSS Connections
- Truss Connections
- **Moment Connections**

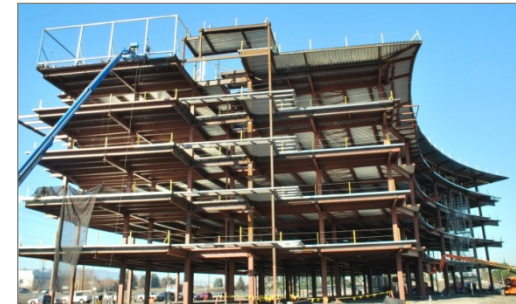
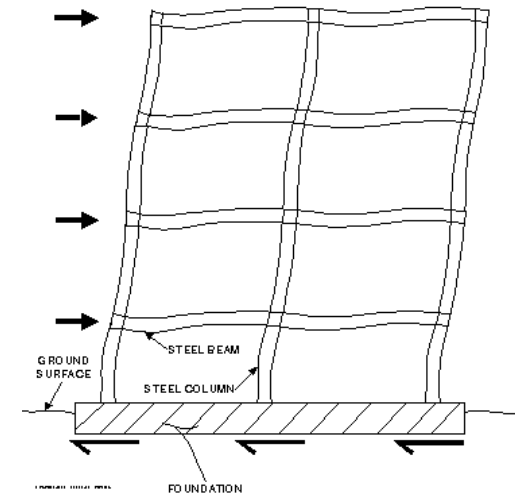
# Moment Connections

**Rigid frames**, or **moment frames**, are used to **resist lateral loads**, such as wind or seismic loads.

Moment connections are used to develop **continuity and rigidity between a beam and a column**.

Moment connections can either be designed as **partially restrained or fully restrained**.

**Fully restrained (FR)** moment connections possess sufficient rigidity to **maintain the angles** between connected members at the strength limit states.



# Moment Connections

## Rigid frames with HSS columns:

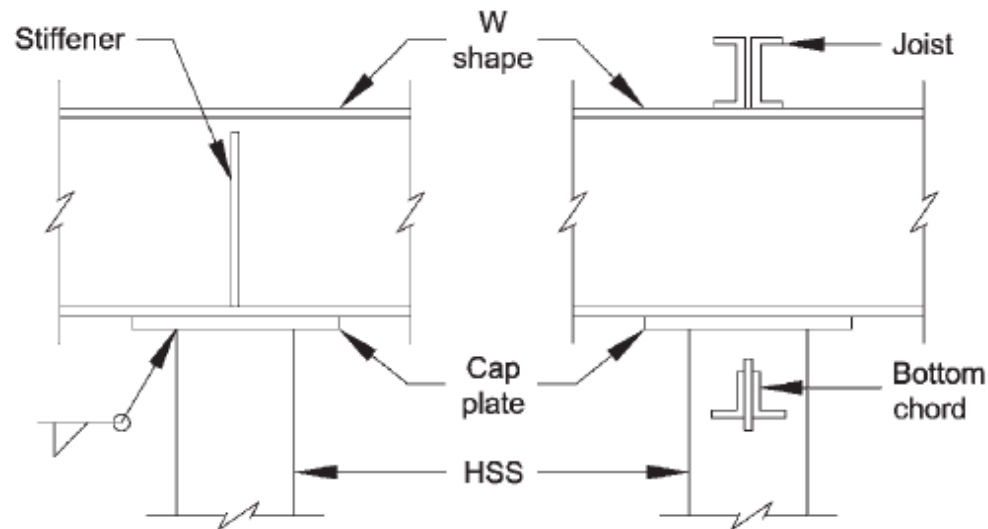
- Square HSS provide same resistance along both axes
- Provide clean columns when designed properly
- Provide efficient wide-open spaces



# Moment Connections — Types

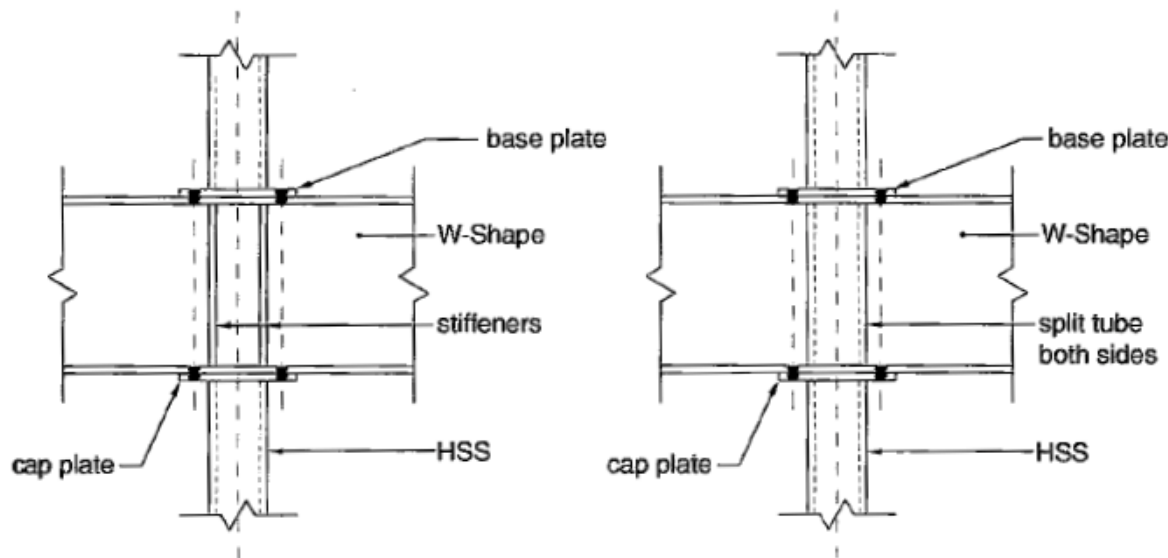
## Continuous Roof Beam

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



## Continuous Beam at Column Splice

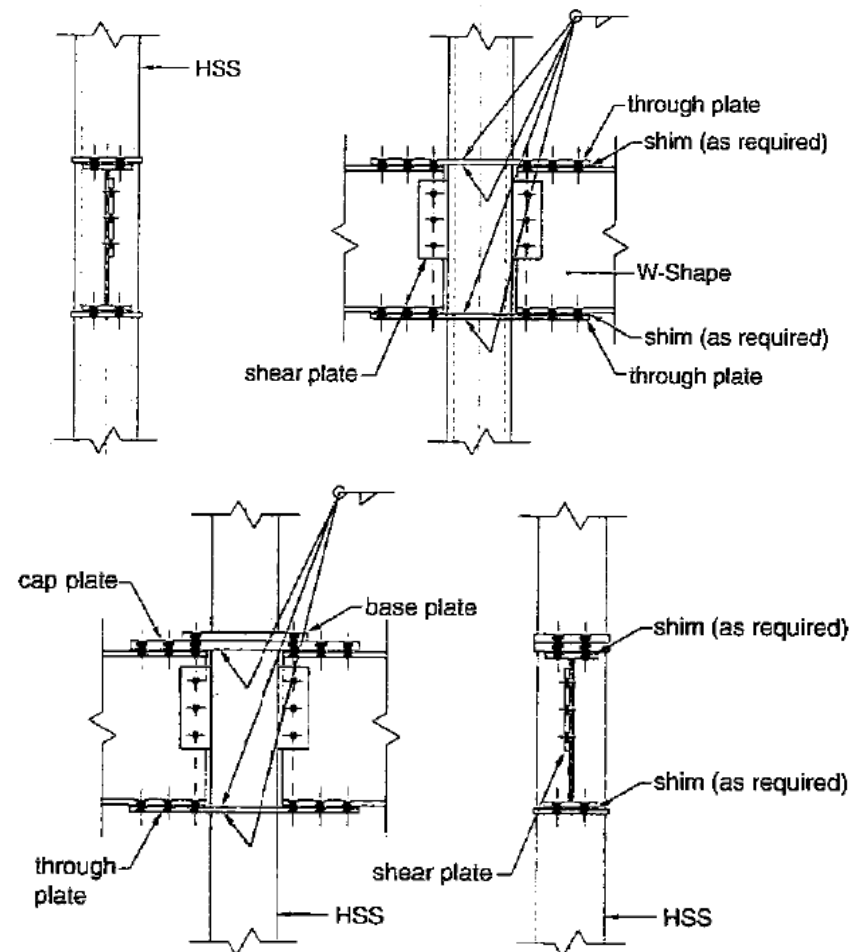
- HSS column is interrupted at continuous beam
- For lightly loaded columns, stiffener plates can be used to transfer axial forces
- Heavy loads may require a split HSS on either side of the beam web.
- Beam flange should be wider than HSS. Rectangular HSS may be required to fit base plate on beam.
-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

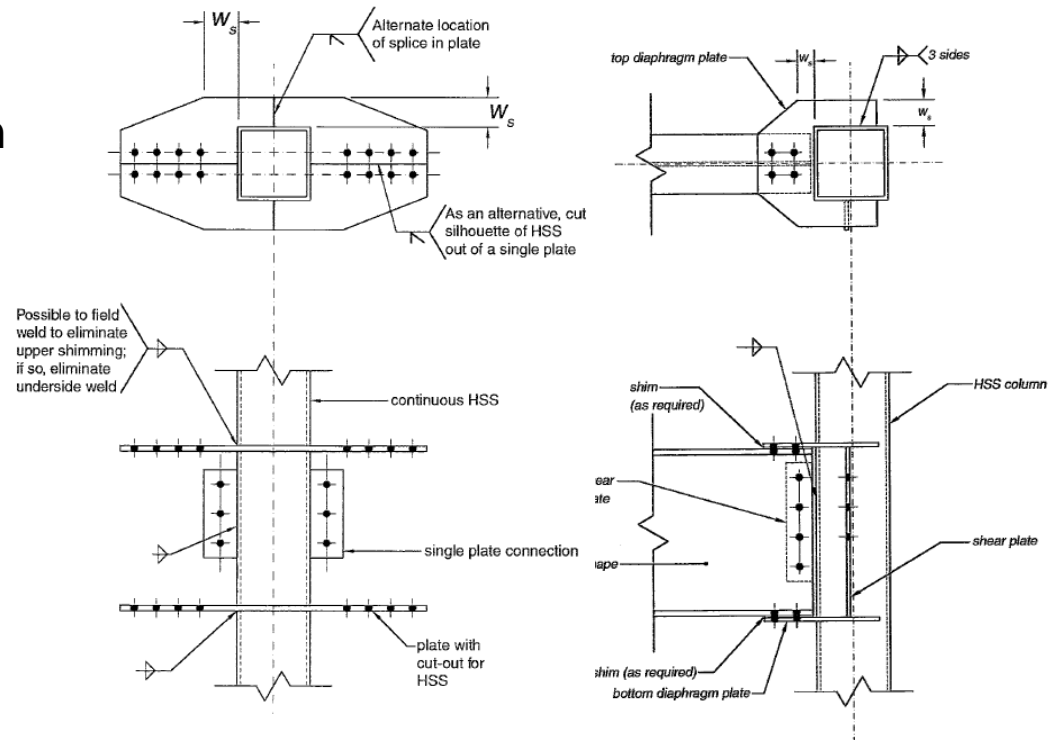
- Good for larger moment transfer through joint
- More difficult and costly to fabricate and erect
- Can be placed at column splice
- Column moment transfer is limited by fillet weld of the HSS to through plate. PJP or CJP welds can be used to increase connection strength.
- Good for two-way moment frame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

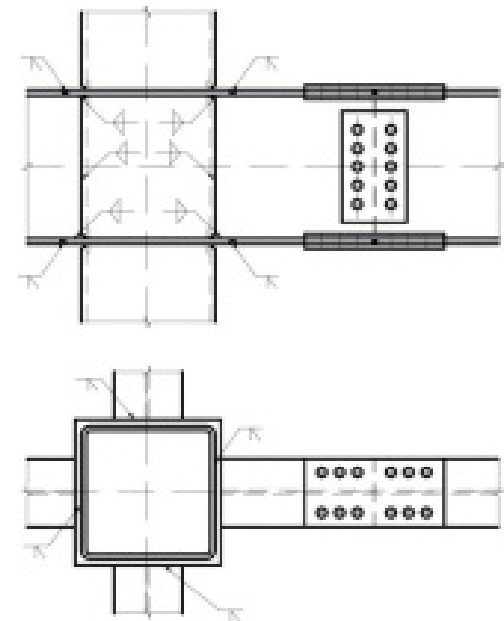




# Moment Connections — Types

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

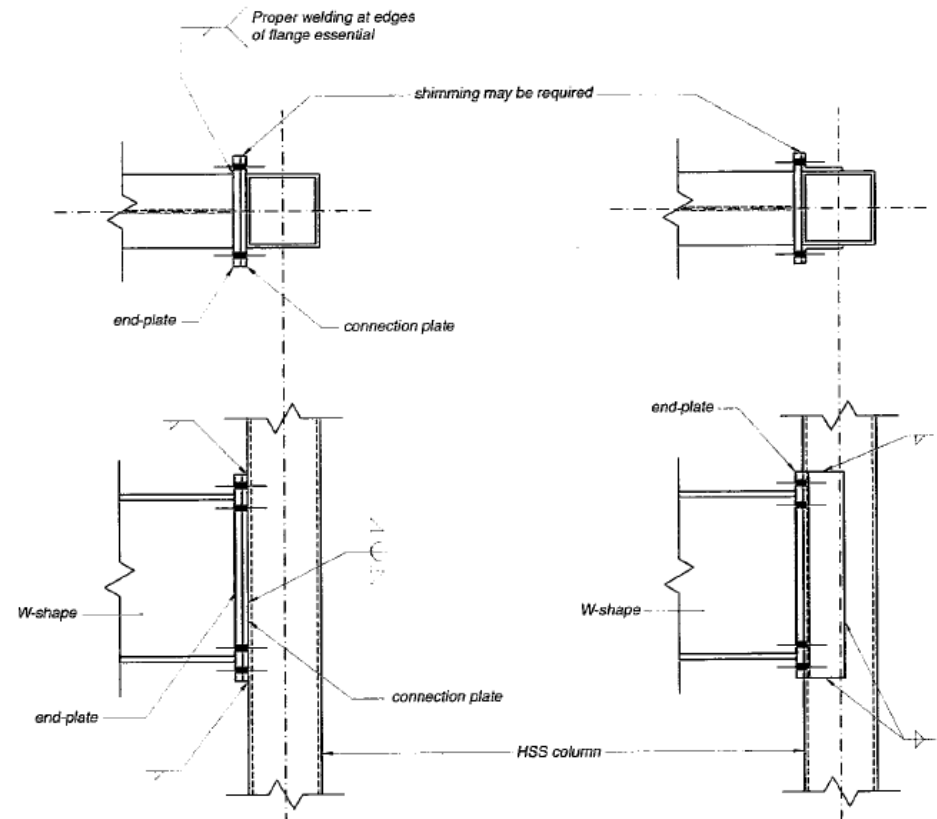
Beam stubs can be shop attached to column to allow for field bolting or welding.



# Moment Connections — Types

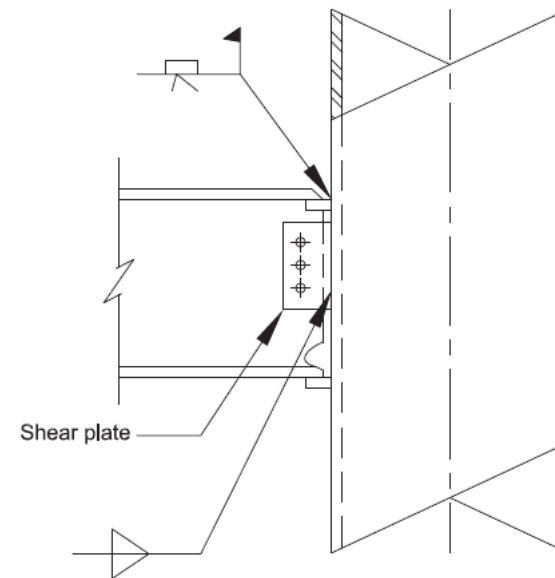
## End Plate

- 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



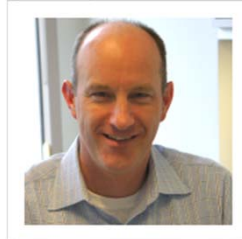
## Directly Welded

- 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 ( $B-3t$ )





## *Questions????*



*presented by*

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