

## AISC Live Webinars

Thank you for joining our live webinar today.  
We will begin shortly. Please standby.

Thank you.

Need Help?

Call ReadyTalk Support: 800.843.9166

**Kinked Connections**

July 25, 2019



**Smarter.  
Stronger.  
Steel.**

## AISC Live Webinars

**Today's live webinar will begin shortly. Please stand by.**

As a reminder, all lines have been muted. Please type any questions or comments through the chat feature on the left portion of your screen.

Today's audio will be broadcast through the internet.  
Alternatively, to hear the audio through the phone, dial:

(800)-289-0462  
Passcode: 988038



**Smarter.  
Stronger.  
Steel.**

## AISC Live Webinars

---

### Audio Options

Today's audio will be broadcast through the internet.

Alternatively, to hear the audio through the phone, dial:

(800)-289-0462  
Passcode: 988038



## AISC Live Webinars

---

### AIA Credit

AISC is a Registered Provider with The American Institute of Architects Continuing Education Systems (AIA/CES). Credit(s) earned on completion of this program will be reported to AIA/CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This program is registered with AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.



# AISC Live Webinars

---

## Copyright Materials

This presentation is protected by US and International Copyright laws. Reproduction, distribution, display and use of the presentation without written permission of AISC is prohibited.

© The American Institute of Steel Construction 2019

The information presented herein is based on recognized engineering principles and is for general information only. While it is believed to be accurate, this information should not be applied to any specific application without competent professional examination and verification by a licensed professional engineer. Anyone making use of this information assumes all liability arising from such use.



# AISC Live Webinars

---

## Course Description

Kinked Connections – What Are They And How to Deal With Them  
July 25, 2019

“Kinked connections” are those where loads flowing through the connections follow an eccentric load path, creating secondary moments and stresses. Kinked connections, if not properly addressed during design, can add unnecessary cost and complexity to a structure, and can lead to problems and headaches for designers, including RFIs and change orders. This webinar will review the need for engineers to find kinked connections in their models during design, and either eliminate the kinks or deal with them. Examples of various kinked connection configurations will be reviewed, and the role of the AISC Code of Standard Practice will be discussed.



# AISC Live Webinars

## Learning Objectives

- List connections that have well-established parameters for safely addressing eccentricity, as provided in the AISC *Steel Construction Manual*.
- List the two options for how to treat member reinforcing at connections, according to the AISC *Code of Standard Practice*.
- Describe the benefits of creating thoughtful conceptual details during the design phase of a project.
- Explain why engineers should be aware of the potential negative effects of eccentric structural load paths.



Smarter.  
Stronger.  
Steel.

# Kinked Connections

## What Are They and How To Deal With Them

July 25, 2019



Cliff Schwinger, PE

THE  
**HARMAN GROUP**  
structural engineering  
parking planning and design



PHILADELPHIA | NEW YORK



Smarter.  
Stronger.  
Steel.



## Seminar Objectives

- What are “kinked connections”?
- How to spot them
- How to deal with them
- Examples
- Review EOR’s responsibility (per ANSI/AISC 303-16) regarding how to deal with all connections, including kinked connections.



9

## Survey question

What is your primary role?

1. EOR
2. Fabricator
3. Erector
4. Connection designer
5. Contractor
6. Educator
7. Student
8. Other

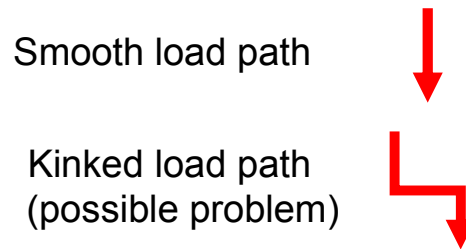


10



## What are Kinked Connections?

Connections where loads follow irregular, 3-dimensional, jogging load paths.



Kinked connections induce *secondary stresses* in members.



11

## What are Kinked Connections?

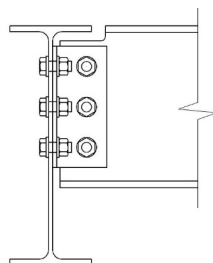
“Common eccentricities” versus “unusual eccentricities”

- Most standard shear connections have small eccentricities (common eccentricities) which are readily addressed by connection designers.
- The term “kinked connections” in this presentation focuses on connections with unusual eccentricities that are often not fully appreciated by the EOR during design.



12

## Common connection eccentricities



13

## Common connection eccentricities

### Double-Angle Connections

DESIGN TABLE DISCUSSION (TABLES 10-1, 10-2 AND 10-3)

10-9

The eccentricity on the supported side of double-angle connections may be neglected for connections with a single vertical row of bolts through standard or short-slotted holes with dimension  $a$  [see Figure 10-4(a)] not exceeding 3 in. The eccentricity should be considered for the design of double-angle connections with two or more vertical rows of bolts on the supported side of the connection and for the design of double-angle connections welded to the supported member.

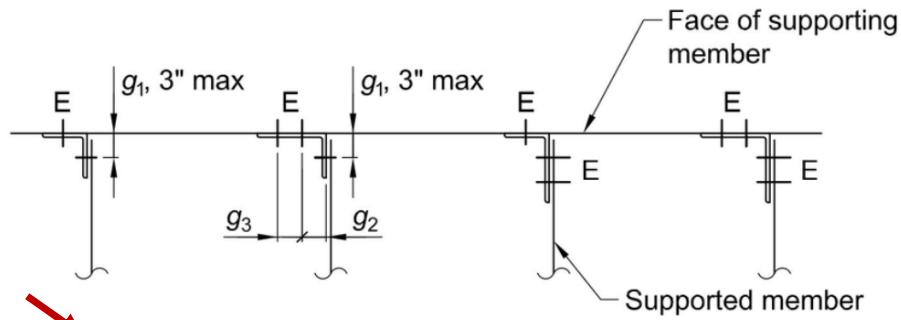
To provide for flexibility, the maximum angle thickness for use with workable gages should be limited to  $5/8$  in. Alternatively, the shear-connection ductility checks illustrated in Part 9 can be used to justify other combinations of gage and angle thickness.



14

## Common connection eccentricities

### Single-Angle Connections



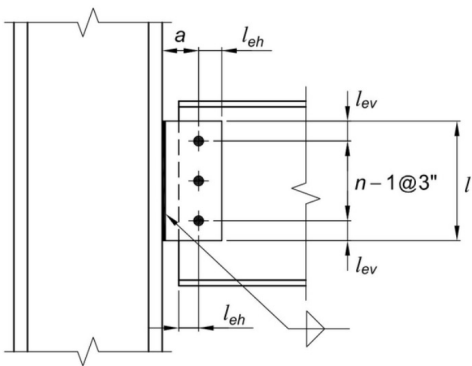
Notes: E indicates that eccentricity must be considered in this leg.  
 Gages  $g_1$ ,  $g_2$  and  $g_3$  are workable gages as shown in Table 1-7A.



Fig. 10-14. Eccentricity in angles.

## Common connection eccentricities

### Single-Plate Shear Connections



10-88

DESIGN OF SIMPLE SHEAR CONNECTIONS

Table 10-9  
 Design Values for Conventional  
 Single-Plate Shear Connections

$n$	Hole Type	$e$ , in.	Maximum $t_p$ or $t_w$ in.
2 to 5	SSLT	$a/2$	None
	STD	$a/2$	$d/2 + 1/16$
6 to 12	SSLT	$a/2$	$d/2 + 1/16$
	STD	$a$	$d/2 - 1/16$

Fig. 10-11. Single-plate connection—Conventional Configuration.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION



## Common connection eccentricities

### Extended Single-Plate Shear Connections

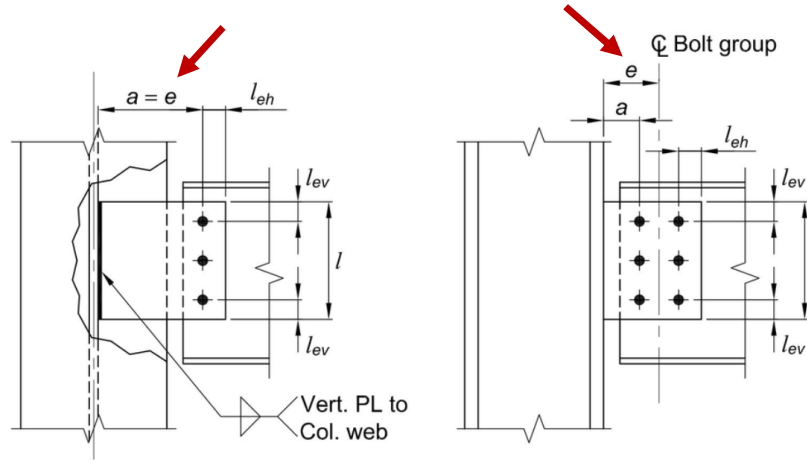


Fig. 10-12. Single-plate connection—Extended Configuration.



AMERICAN INSTITUTE OF STEEL CONSTRUCTION

## Common connection eccentricities

### Beam web shear splices

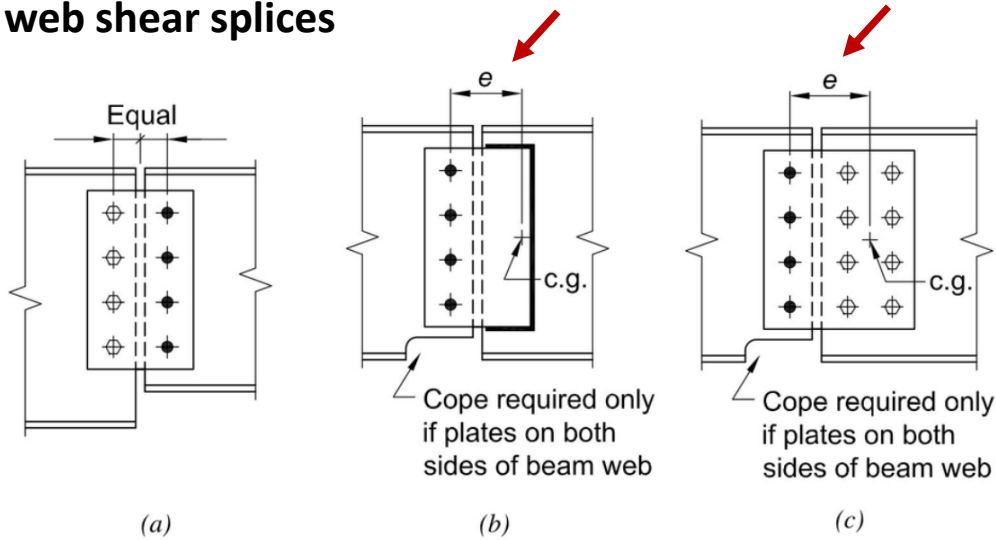
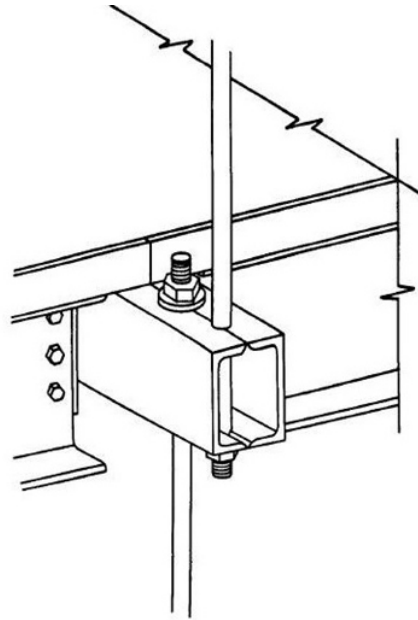


Fig. 10-16. Plate-type shear splices.





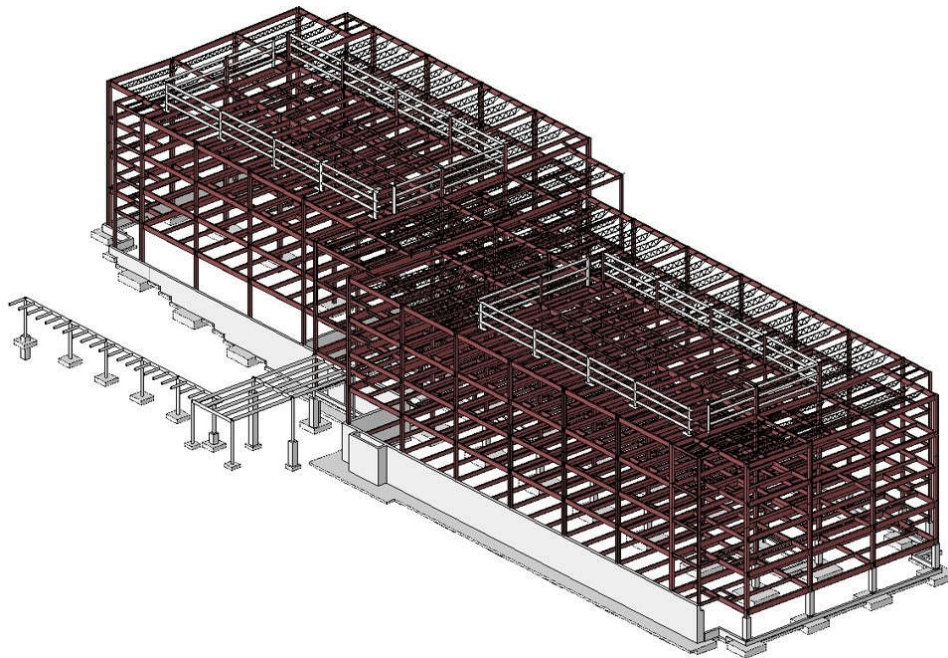
## What is a “kinked connection”?



As Built

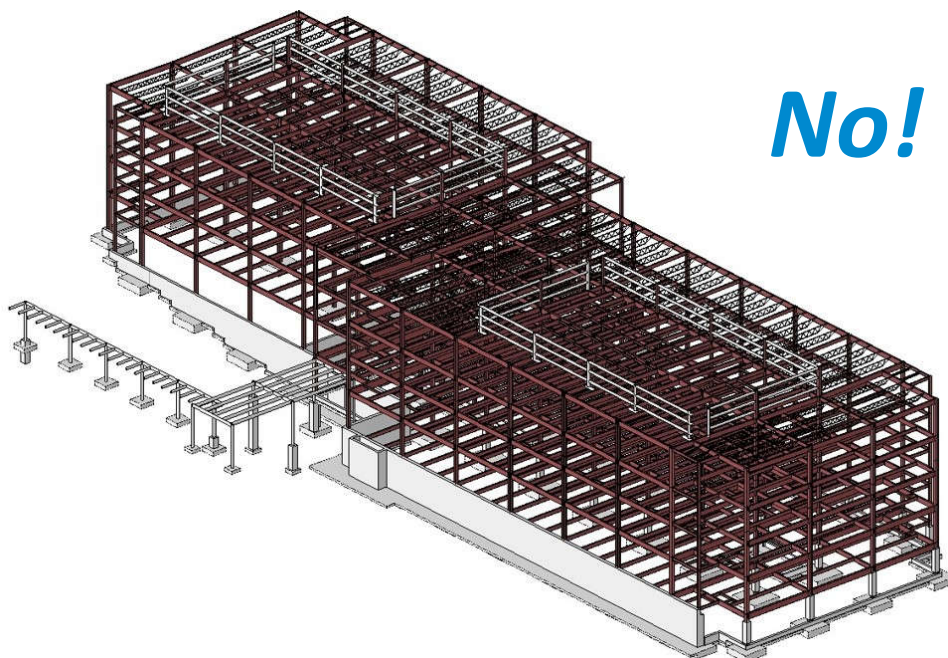
21

## Will your model flag the kinked connections?



22

Will your model flag the kinked connections?



23

Why is awareness of kinked connections important?

- Kinked connections induce secondary stresses in members.
- Failure to consider the secondary stresses can result in connection failure.
- Secondary stresses usually add complexity and cost to connection details.
- Failure to consider kinked connection details during design will lead to RFI's, arguments, and change orders during construction.

24

## Why the label, “kinked connections”?



25

## Why the label, “*kinked connections*” ?



- “It’s easy to spot a yellow car when you’re always thinking of a yellow car.”



26

## Why the label, "*kinked connections*" ?



- “It’s easy to spot a yellow car when you’re always thinking of a yellow car.”
- It’s easier to spot kinked connections when you’re always thinking of kinked connections



27

## Why the label, "*kinked connections*" ?



- “It’s easy to spot a yellow car when you’re always thinking of a yellow car.”
- It’s easier to spot kinked connections when you’re always thinking of kinked connections
- It’s easier to spot problems if they have a name.



28

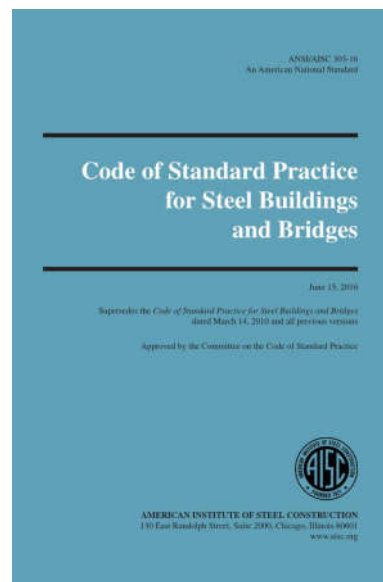
# Connection Design Responsibility



29

## Connection design responsibility

The Code of Standard Practice is the roadmap for navigating how to deal with connections on the contract documents.

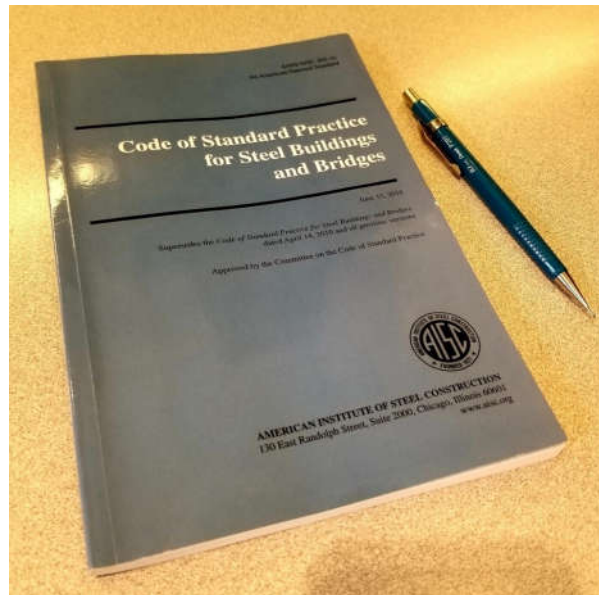


30



## Connection design responsibility

Recommended summer  
reading



31

## Survey question

Have you read the ANSI/AISC 303-16 Code of  
Standard Practice?

1. Yes
2. No
3. I read a few pages.



32

## Connection design responsibility

### From Section 1.9:

- 1.9.2. The structural engineer of record shall be responsible for the structural adequacy of the design of the structure in the completed project. The *structural engineer of record* shall not be responsible for the means, methods and safety of erection of the *structural steel* frame. See also Sections 3.1.4 and 7.10.



33

## Connection design responsibility

### From 4.4.1 Commentary:

From the inception of this Code, AISC and the industry in general have recognized that only the *owner's designated representative for design* has all the information necessary to evaluate the total impact of *connection* details on the overall structural design of the project. This authority traditionally has been exercised during the approval process for the *approval documents*. The *owner's designated representative for design* has thus retained responsibility for the adequacy and safety of the entire structure since at least the 1927 edition of this Code.



34

## Connection design responsibility

### 4.4. Approval

Except as provided in Section 4.5, the *approval documents* shall be submitted to the *owner's designated representatives for design* and construction for review and approval. The *approval documents* shall be returned to the *fabricator* within 14 calendar days.

Final *substantiating connection information*, if any, shall also be submitted with the *approval documents*. The *owner's designated representative for design* is the final authority in the event of a disagreement between parties regarding the design of *connections* to be incorporated into the overall *structural steel* frame. The *fabricator* and licensed engineer in responsible charge of *connection* design are entitled to rely upon the *connection* design criteria provided in accordance with Section 3.1.1. *Revisions* to these criteria shall be addressed in accordance with Sections 9.3 and 9.4.



35

## Three options for connection design

3.1.1. The *owner's designated representative for design* shall indicate one of the following options for each *connection*:

- (1) Option 1: the complete *connection* design shall be shown in the *structural design documents*.
- (2) Option 2: in the *structural design documents* or *specifications*, the *connection* shall be designated to be selected or completed by an experienced *steel detailer*.
- (3) Option 3: in the *structural design documents* or *specifications*, the *connection* shall be designated to be designed by a licensed engineer working for the *fabricator*.

In all of the above options,

- (a) The requirements of Section 3.1.2 shall apply.
- (b) The approvals process in Section 4.4 shall be followed.

*Code of Standard Practice for Steel Buildings and Bridges*, June 15, 2016  
AMERICAN INSTITUTE OF STEEL CONSTRUCTION



36



## Three options for connection design

- (2) When Option 3 in Section 3.1.1 is specified for a *connection*, two subsidiary options are available to the *owner's designated representative for design*; either:
- (a) Option 3A: member reinforcement at *connections* shall be designed by the *owner's designated representative for design* and shown in the structural *design documents* issued for bidding so that the quantity, detailing and fabrication requirements for member reinforcement at connections can be readily understood, or;
  - (b) Option 3B: the *owner's designated representative for design* shall provide a bidding quantity of items required for member reinforcement at connections with corresponding project-specific details that show the conceptual configuration of reinforcement appropriate for the order of magnitude of forces to be transferred. These quantities and project-specific conceptual configurations will be relied upon for bidding purposes. If no quantities or conceptual configurations are shown, member reinforcement at connections will not be included in the bid.

Subsequently, member reinforcement at *connections*, where required, shall be designed in its final configuration by the licensed engineer in responsible charge of the *connection* design.



37

## “Member reinforcement at connections”

- “Member reinforcement at connections” is usually reinforcement required to address secondary stresses.
- “Member reinforcement at connections” is member design, not connection design (however it can be delegated to the fabricator’s licensed connection design engineer when using Option #3B).



38

## “Concept connection details”

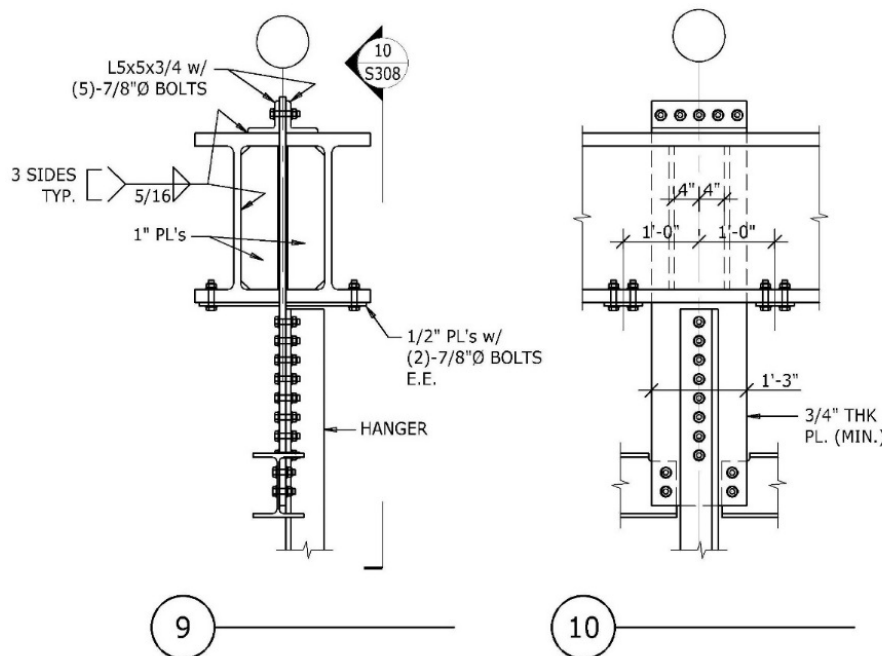
Details showing,

- Connection configurations
- Member reinforcement at the connections (“...conceptual configuration of reinforcement...”)

Concept connection details serve as a basis for connection design by the fabricator’s licensed connection design engineer and provide a way for fabricators bidding the project to estimate the cost of unusual connections.



## Concept connection detail



## Why provide concept connection details?



41

## Why provide “concept connection details”?

- Required by the Code of Standard Practice (“...conceptual configuration of reinforcement...”).
- Allows fabricators to better estimate cost and levels the playing field among all bidders.
- Provides guidance for connection designers.
- Gives EOR opportunity to find and resolve kinked connection issues (and constructability / connection designability issues) during design.



42

## Why provide “concept connection details”?

- The time to think about how connection details affect the performance and behavior of the structural framing is during design.
- The time to find kinked connections is during design – not during shop drawing review.
- EOR has options during design.
- The number of options for solving connection design problems is reduced if problems are not discovered until shop drawing review.



43

## Why provide “concept connection details”?

Concept connection details,

- Reduce RFI's
- Reduce arguments
- Reduce change orders
- Minimize chances of mistakes slipping through
- Enhance safety



44

## How to deal with kinked connections



45

## Dealing with kinked connections

- Remember: The engineer-of-record is ultimately responsible for the safe design of all connections – even when delegating connection design.
- Understand ANSI/AISC 303-16 rules regarding connection design responsibility.



46



## Dealing with kinked connections

- Find the kinked connections **during design** (*Do not* kick the can down the road)
- Eliminate the kinks if possible (by reframing) – or deal with them.



47

## Dealing with kinked connections

- Is member reinforcement at the connection required due to a kinked load path?
- EOR must either fully design and detail member reinforcement at the connections (Option #3A), or provide concept connection details and bidding quantities (Option #3B) on the structural drawings.  
(Note: Concept connection details should be provided for kinked connections, regardless of whether or not member reinforcement at the connections is required.)



48

## Dealing with kinked connections

- Can the connections be designed (connection designability)?
- Can the connections be built (constructability)?
- Is there anything unusual about how loads travel through the connections?
- Is member reinforcement at the connections required?



49

## Dealing with kinked connections

- Show reactions/member forces.
- Follow loads through the connections.
- Envision the *deflected shape!*
- Remember the fundamentals:

$$\sum F_{x,y,z} = 0$$

$$\sum M_{x,y,z} = 0$$

Kinked connections are *everywhere!*

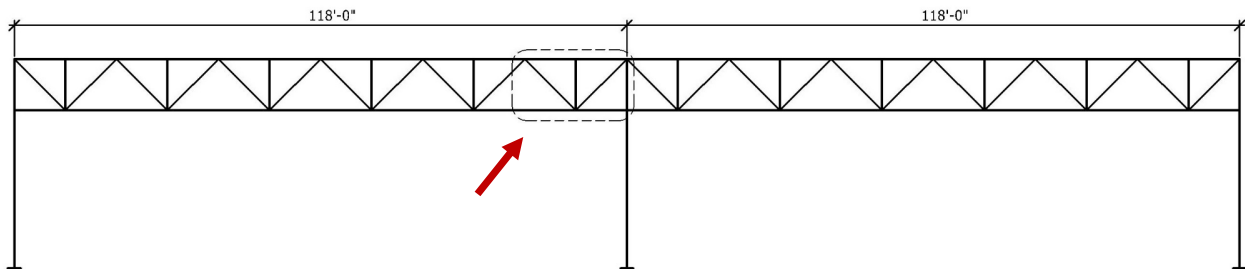


50

## The importance of concept connection details

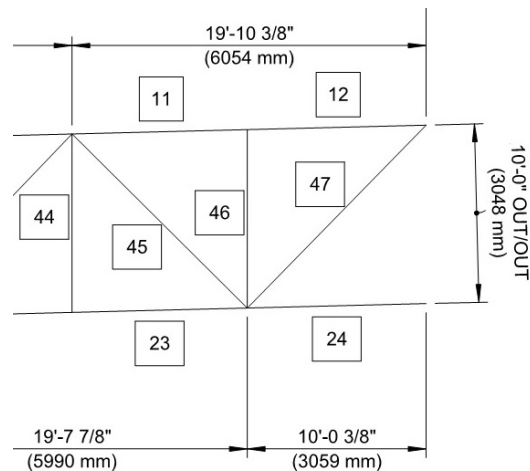
For all non-standard connections:

- How will the connections be configured?
- Can cost-effective connections be designed?
- Can the framing be easily erected?
- Provide concept connection details.



51

## The importance of concept connection details

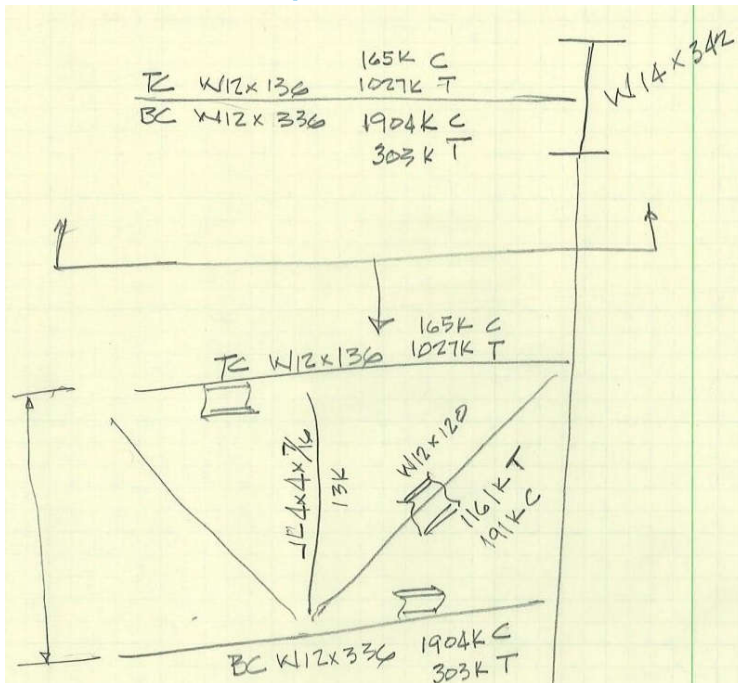


There were no concept connection details.



52

## The importance of concept connection details

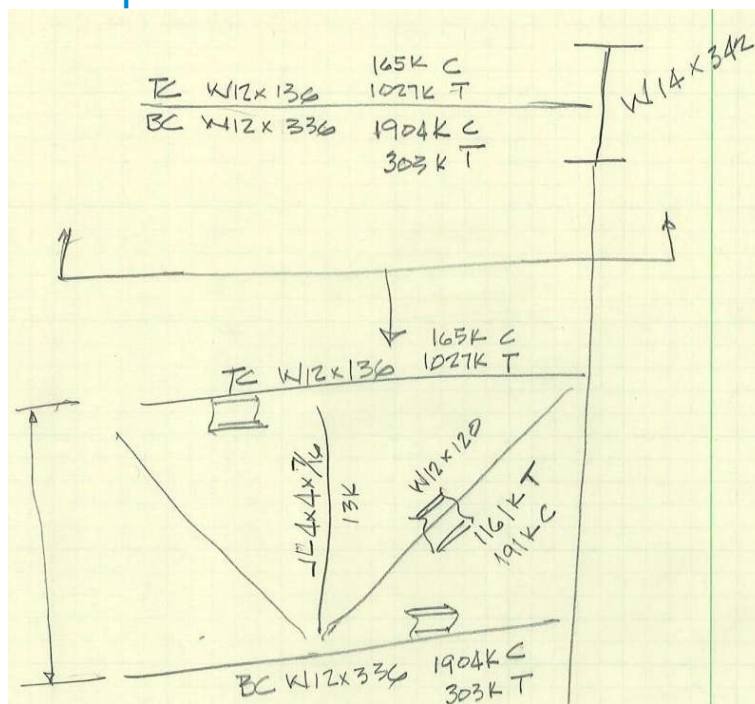


53

## The importance of concept connection details

Suggestions:

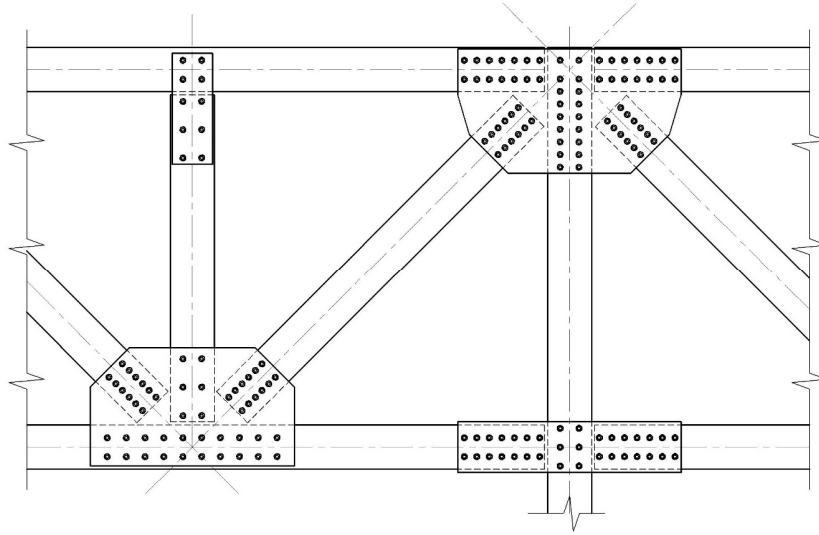
1. Make all members W14's
2. Rotate members and use bolted connections with gusset plates



54



## The importance of concept connection details



Don't kick the can down the road. The time to think about the connections is during design.



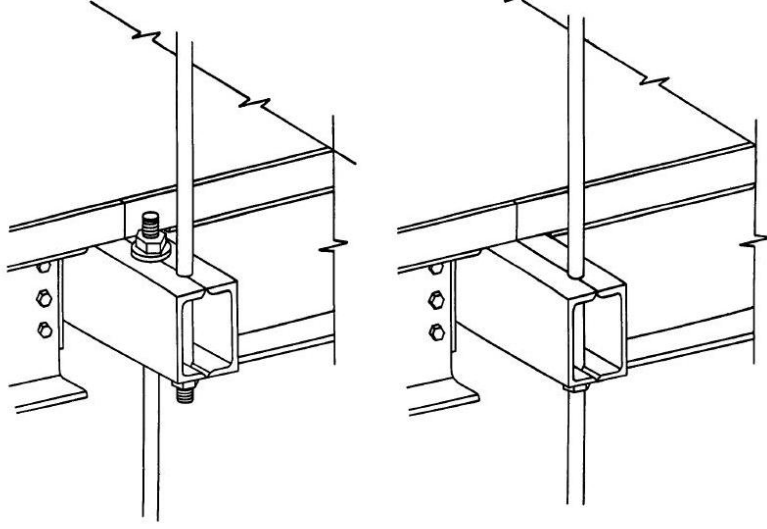
55

## Examples of kinked connections



56

### Hyatt Regency Connection Failure



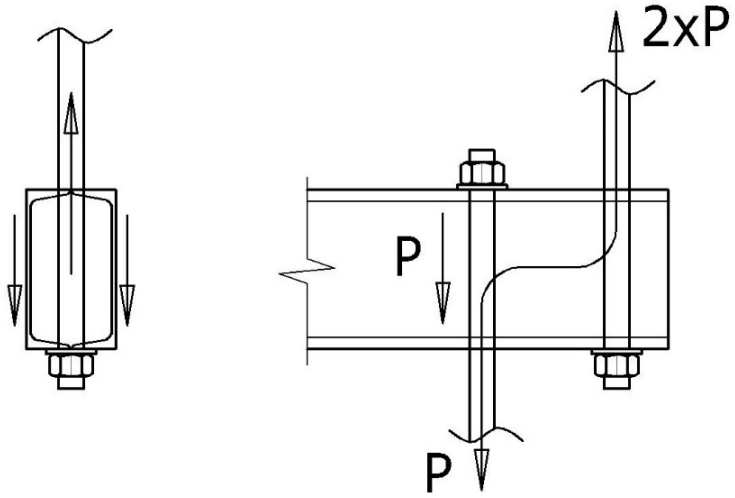
As Built

Original Detail



Figure 10.2 Comparison of interrupted and continuous hanger rod details.

### Hyatt Regency Connection Failure





## Hyatt Regency Connection Failure

NBS BUILDING SCIENCE SERIES 143

### Investigation of the Kansas City Hyatt Regency Walkways Collapse

R. D. Marshall  
E. O. Pfrang  
E. V. Leyendecker  
K. A. Woodward

Center for Building Technology  
National Engineering Laboratory

R. P. Reed  
M. B. Kasen  
T. R. Shives

Center for Materials Science  
National Measurement Laboratory

National Bureau of Standards  
Washington, DC 20234



U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, Secretary  
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Director

Issued May 1982

61



## Hyatt Regency Connection Failure

Based on measured weights of damaged walkway spans and on a videotape showing occupancy of the second floor walkway just before the collapse, it is concluded that the maximum load on a fourth floor box beam-hanger rod connection at the time of collapse was only 31 percent of the ultimate capacity expected of a connection designed under the Kansas City Building Code. It is also concluded that had the original hanger rod arrangement not been changed, the ultimate capacity would have been approximately 60 percent of that expected under the Kansas City Building Code. With this change in hanger rod arrangement, the ultimate capacity of the walkways was so significantly reduced that, from the day of construction, they had only minimal capacity to resist their own weight and had virtually no capacity to resist additional loads imposed by people.

Overstress in original connection detail: Strength ratio =  $1/0.6 = 1.67$

Overstress in revised connection detail: Strength ratio =  $1/0.31 = 3.23$

62



## Hyatt Regency Connection Failure

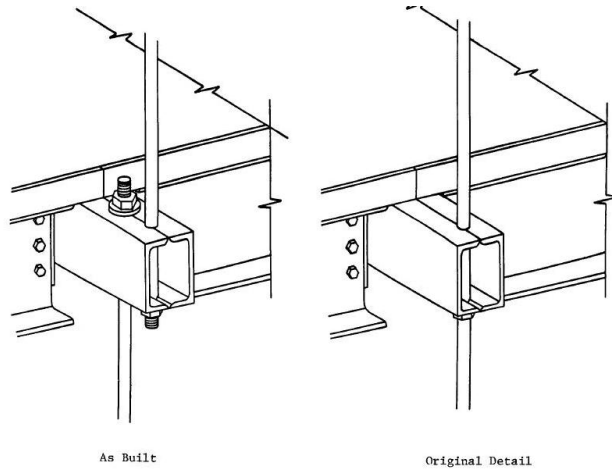


Figure 10.2 Comparison of interrupted and continuous hanger rod details.

Overstress in original connection detail: Strength ratio =  $1/0.6 = 1.67$   
 Overstress in revised paper connection detail: Strength ratio =  $1/0.31 = 3.23$



## Hyatt Regency Connection Failure

### CHRONOLOGY AND CONTEXT OF THE HYATT REGENCY COLLAPSE

By Gregory P. Luth<sup>1</sup>

**ABSTRACT:** This paper presents a brief chronology of the events that preceded the collapse of the walkways at the Kansas City Hyatt Regency Hotel, including the prior failure that occurred during construction and the evolution of the detail that caused the catastrophe. Many of the facts surrounding the case were not publicized, due to the litigation. Some were not brought out during the litigation. No attempt will be made to affix responsibility, as these issues were resolved years ago. The chronology is followed by a discussion of the events that contributed to the collapse and of the changes that have been made in the industry toward preventing a similar occurrence.

#### INTRODUCTION

On July 17, 1981, two walkways at the Hyatt Regency Hotel in the Crown Center development in Kansas City, Missouri, collapsed during a "tea dance." A full chronology of events is provided in table form (Table 1). The result of the collapse was that 114 people lost their lives and numerous others were injured. It is worthwhile to look back on the events leading up to the events of July 17 to determine what actions or omissions contributed to the tragedy and what actions might have averted the tragedy. The writer was a recent graduate working in the offices of the firm that performed the structural design of the Hyatt Regency. This paper presents a brief, objective, and factual summary of those events in chronological sequence in order to provide a context in which the profession might study and evaluate the lessons of the failure.

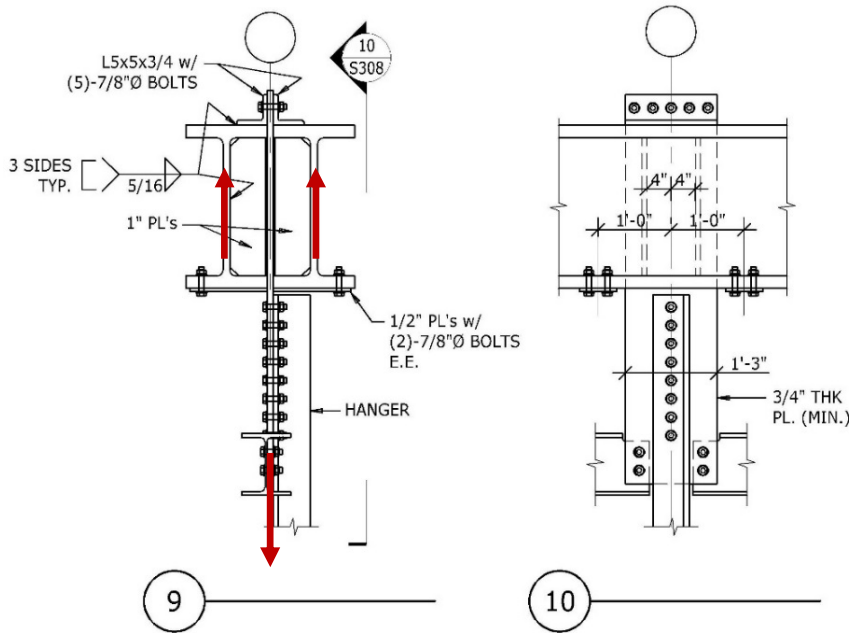
The project design was performed under the "fast track" method of delivery that came into vogue in the latter part of the 1970s. As with many projects delivered by this method, construction preceded design, structural design preceded architectural design, and both the design and construction phases

(120 ft), supported on slide bearings that rested on concrete corbels on the function block end. One side of the atrium roof structure would be supported on a system of vertical truss that formed a "sun screen" and also functioned to support a four-story glass wall. Communication between the function block and hotel floors was provided by a system of walkways at the 2nd, 3rd, and 4th floors.

Production of construction documents was ongoing between July 1977 and January 1978. Because of architectural constraints, the sunscreen structure evolved into a vertical truss that picked up loads at the roof on one chord and dropped them off at the first floor at the other chord in order to avoid loading the concrete floor system at the first floor. The inside chord of the sunscreen truss, which functions as a column, was designed to be provided with lateral support by structural tubes that also supported the curtain wall. Early schemes called for the walkways to be supported on posts off of the concrete floor at the first level. Later, the decision was made to suspend the walkways from the roof structure to give a light and airy feel to the atrium space. Fig. 1 shows floor plans of the roof and walkways. Fig. 2 shows a section through the sunscreen

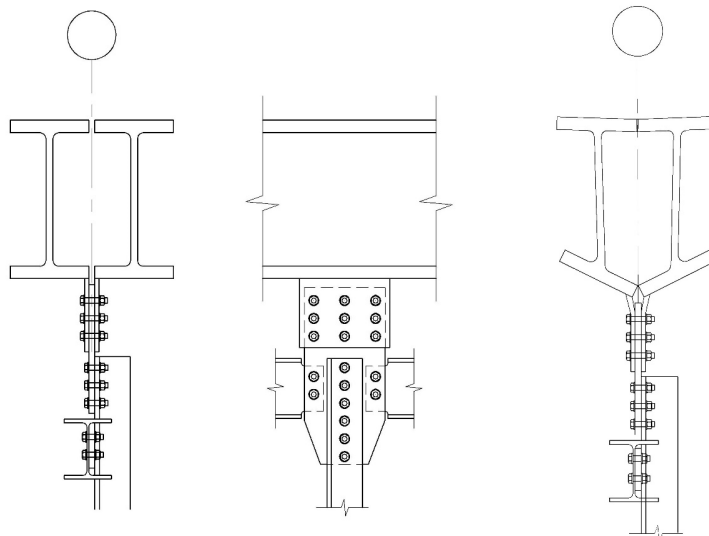


## Hanger below double beam



## Hanger below double beam

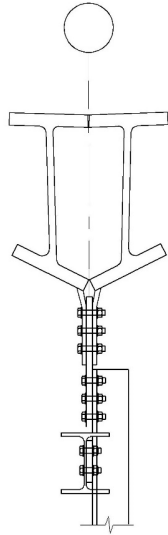
A possible result of not following the Code of Standard Practice and not providing "concept connection details"



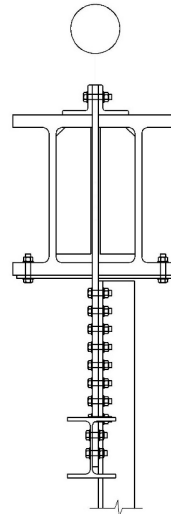
No!



## Hanger below double beam



Kink in load path inducing secondary stresses in members



Concept connection detail addressing secondary stresses



67

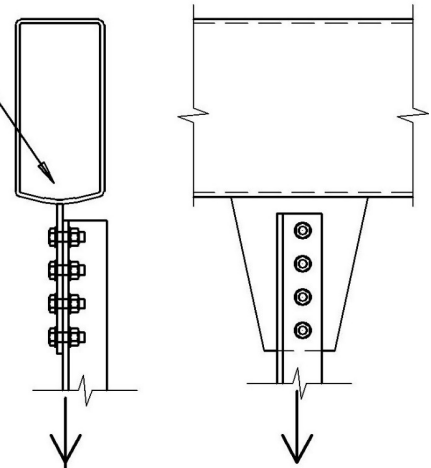
## Hanger below HSS beam

Who is responsible for checking the secondary stresses in the HSS?  
(Both the EOR and connection design engineer)

Who is ultimately responsible for the structural adequacy of the design of the completed project?  
(Section 1.9.2) (The EOR)

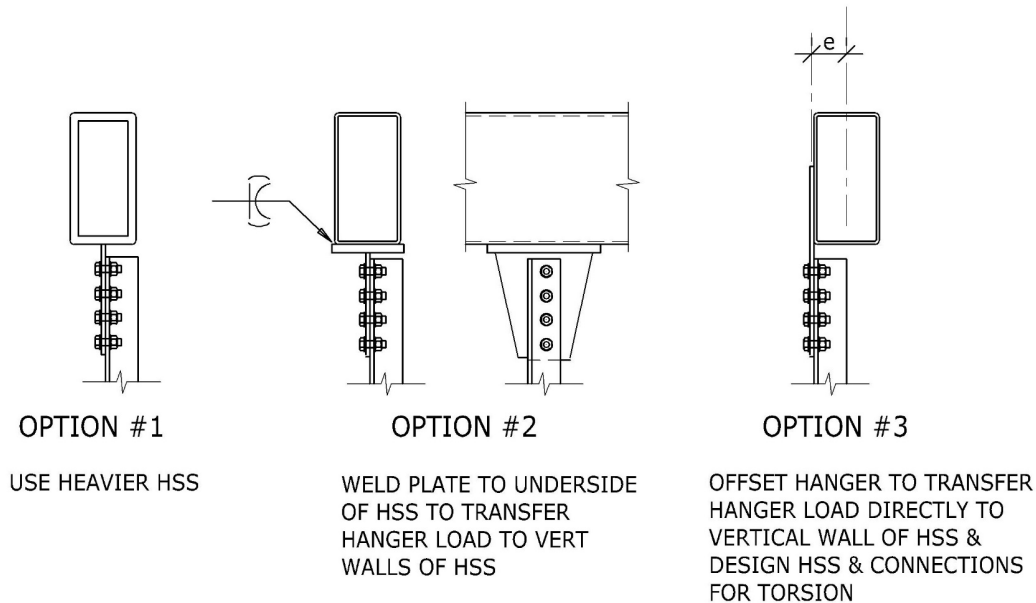
Who is responsible for providing project specific details showing conceptual configuration of reinforcement at the connections? (Section 3.1.2)  
(The EOR)

Secondary flexural stresses in bottom of HSS at hanger connection



68

## Hanger below HSS beam



Possible hanger options (there are more)

## HSS to HSS connections

See 15<sup>th</sup> Edition AISC Steel Construction Manual, pages 13-17 & 13-18

**Demand-to-capacity ratio** →

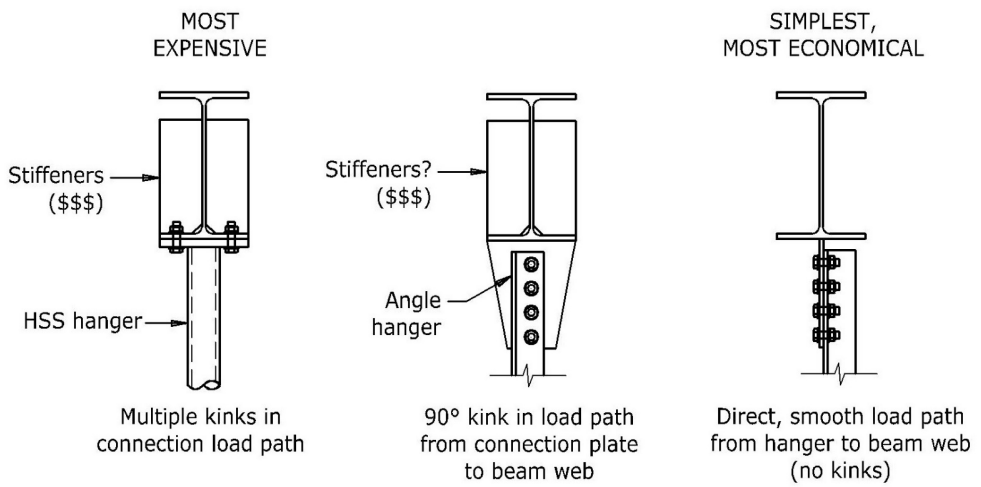
16.I-136 HSS-TO-HSS MOMENT CONNECTIONS [Sect. K4]

Connection Type	Connection Available Axial Strength
<p>Overlapped K-Connections</p> <p>Note that the force arrows shown for overlapped K-connections may be reversed, and j control member identification.</p>	<p>Limit State: Local Yielding of Branch/Branches due to Uneven Load Distribution</p> <p><math>\phi = 0.95</math> (LRFD) <math>\Omega = 1.58</math> (ASD)</p> <p>When <math>25\% \leq C_y &lt; 50\%</math></p> $P_{tj} = F_y A_{tj} \left[ \frac{C_y}{50} (2H_b - 4t_b) + B_{1j} + B_{2j} \right] \quad (K3-10)$ <p>When <math>50\% \leq C_y &lt; 80\%</math></p> $P_{tj} = F_y A_{tj} (2H_b - 4t_b + B_{1j} + B_{2j}) \quad (K3-11)$ <p>When <math>80\% \leq C_y \leq 100\%</math></p> $P_{tj} = F_y A_{tj} (2H_b - 4t_b + B_{1j} + B_{2j}) \quad (K3-12)$ <p>Subscript j refers to the overlapping branch Subscript i refers to the overlapped branch</p> $R_{tj} = P_{tj} \left( \frac{F_{y2} A_{t2}}{F_{y1} A_{t1}} \right) \quad (K3-13)$
<b>Functions</b>	
$Q_1 = 1$ for chord (connecting surface) in tension $= 1.3 - 0.4 \frac{U}{\beta} \leq 1.0$ (K3-14)	
$Q_2 = 1.3 - 0.4 \frac{U}{\beta_{ref}} \leq 1.0$ (K3-15)	
$Q_3 = 1.3 - 0.4 \frac{U}{\beta_{ref}} \leq 1.0$ for chord (connecting surface) in compression, for gapped K-connections.	
$U = \frac{P_{ro}}{F_c A_g} + \frac{M_{ro}}{F_c S} \quad (K2-4)$	
<p>where <math>P_{ro}</math> and <math>M_{ro}</math> are determined on the side of the joint that has the lower compression stress. <math>P_{ro}</math> and <math>M_{ro}</math> refer to required strengths in the HSS. <math>P_{ro} = P_r</math> for LRFD, and <math>P_r</math> for ASD, <math>M_{ro} = M_r</math> for LRFD, and <math>M_r</math> for ASD.</p>	
$\beta_{ref} = \left[ (B_1 + H_b)_{\text{compression branch}} + (B_2 + H_b)_{\text{tension branch}} \right] / AB \quad (K3-16)$	
$\beta_{ref} = \frac{50}{7} \leq \beta \quad (K3-17)$	

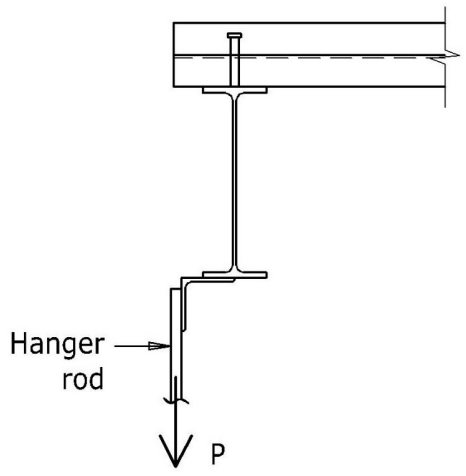
$$U = \left| \frac{P_{ro}}{F_c A_g} + \frac{M_{ro}}{F_c S} \right|$$



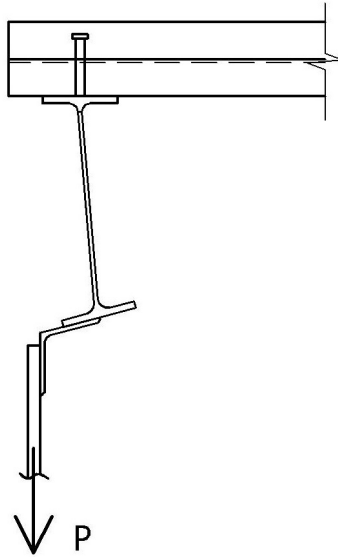
### Hanger below W shape



### Eccentric hangers

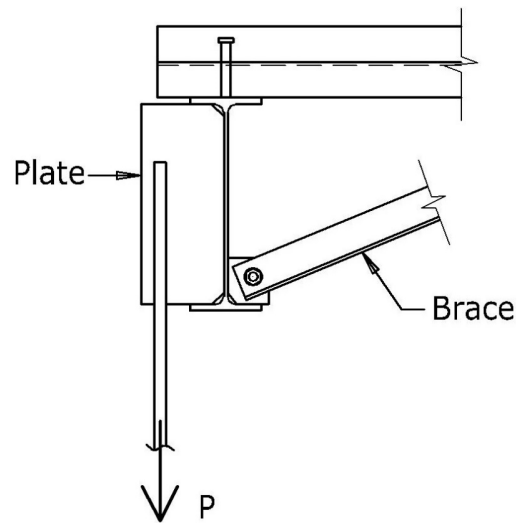


## Eccentric hangers



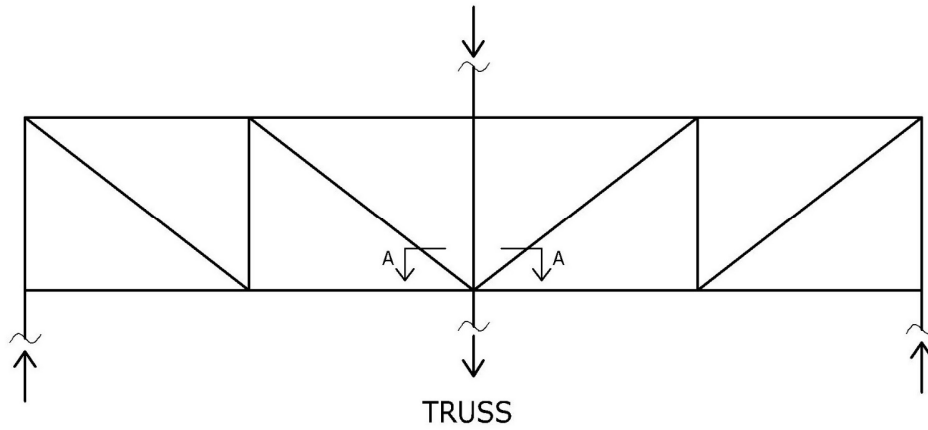
73

## Eccentric hangers



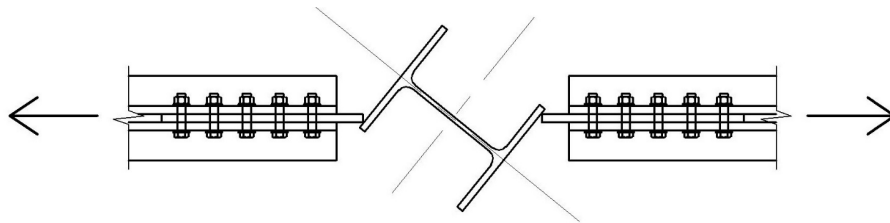
74

## Kink in tension connection



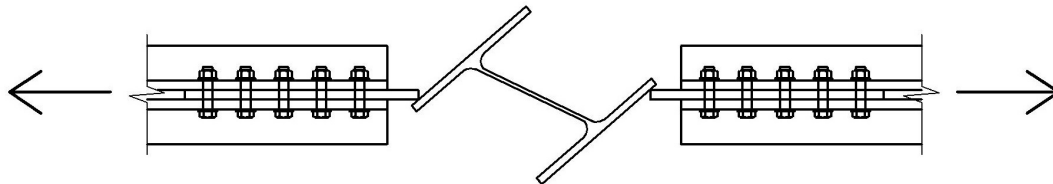
75

## Kink in tension connection



76

## Kink in tension connection

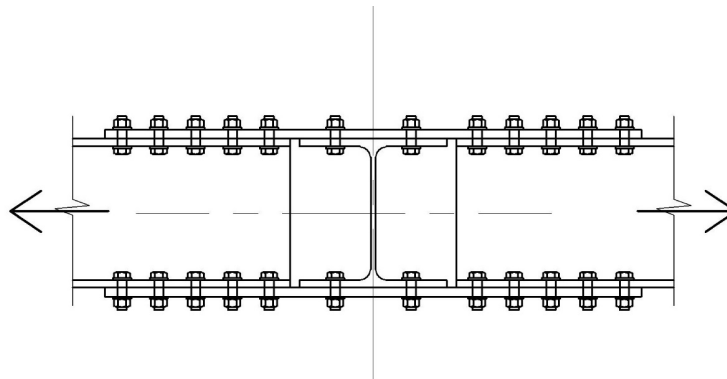


No good!



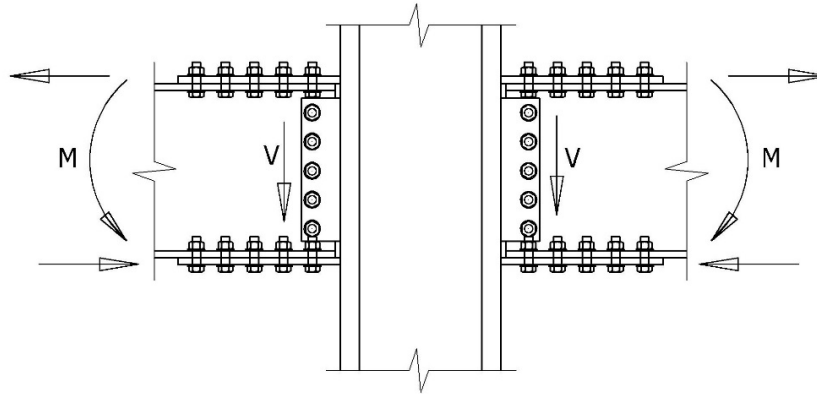
77

## Kink in tension connection



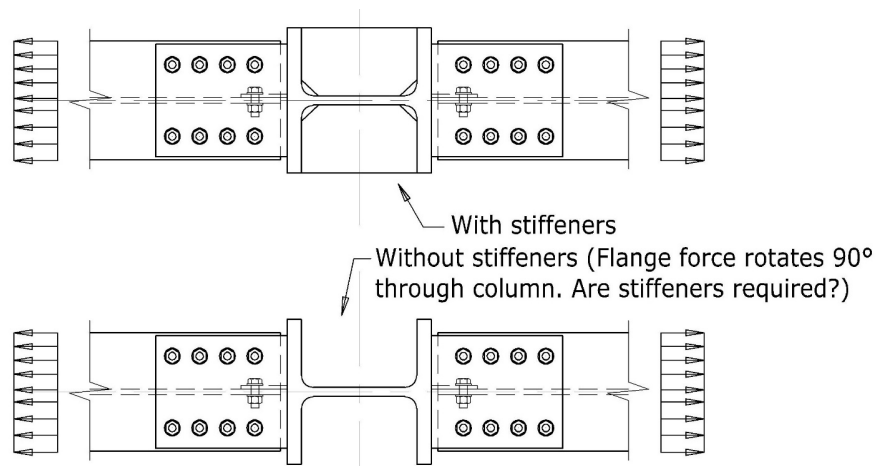
78

## Beam-to-column moment connection (w/o stiffeners)



79

## Beam-to-column moment connection (w/o stiffeners)

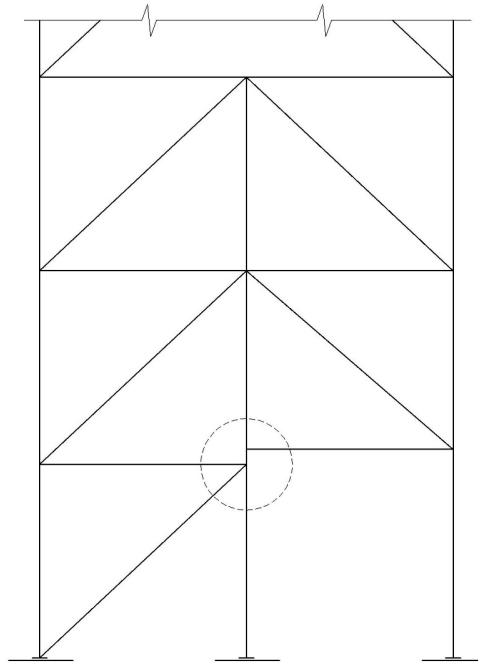


Check Specification Section J10 FLANGES AND WEBS WITH CONCENTRATED FORCES.  
(Stiffeners are expensive. Consider upsizing columns to avoid stiffeners.)



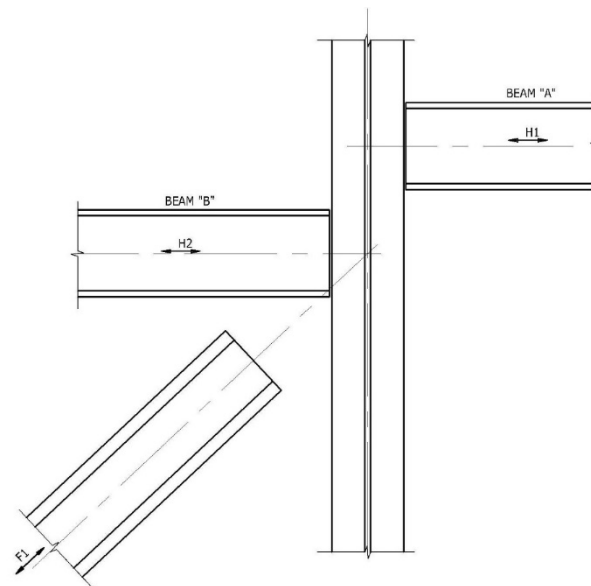
80

## Offset floor in braced frame



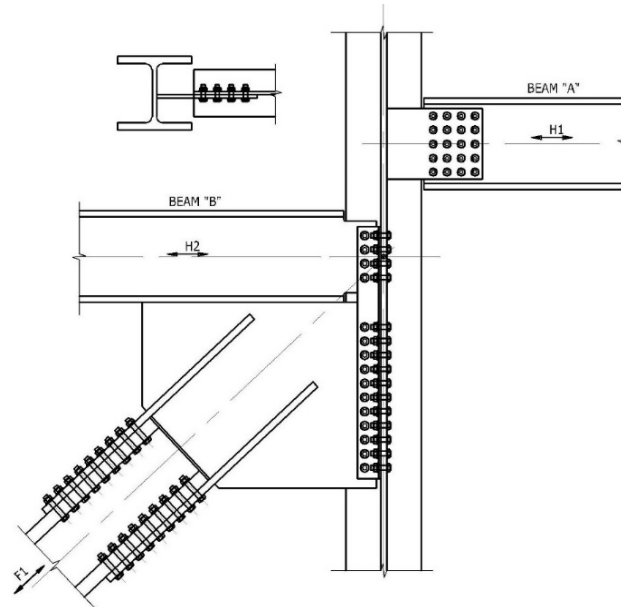
81

## Offset floor in braced frame



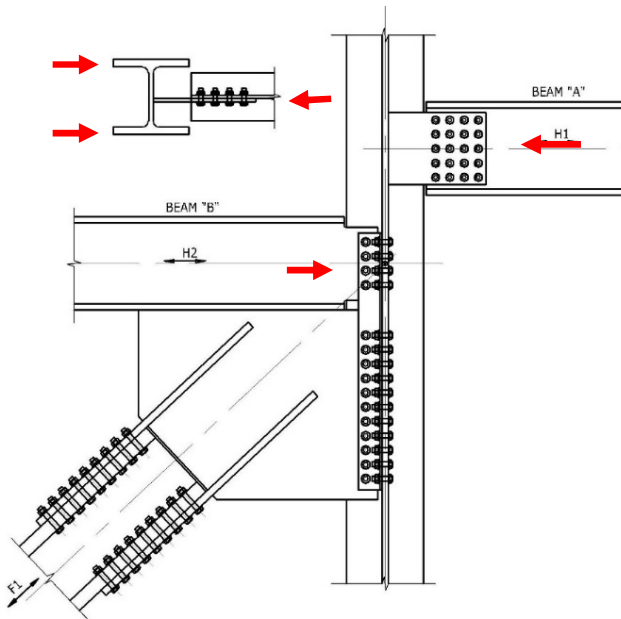
82

## Offset floor in braced frame



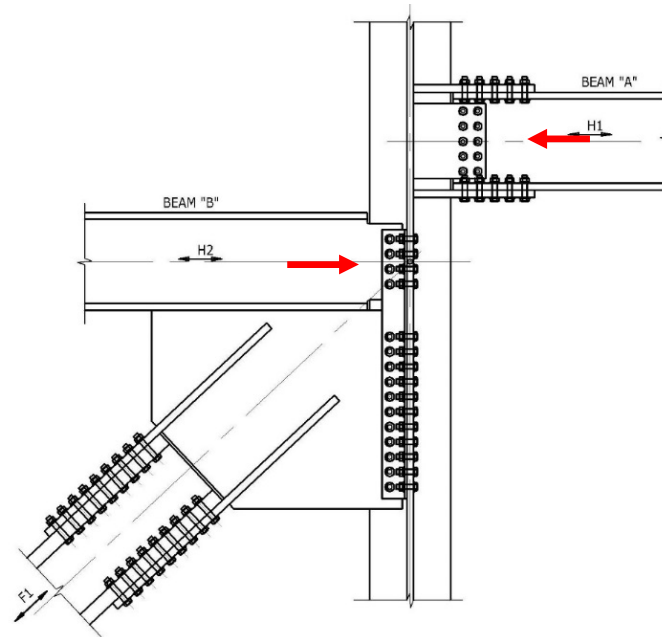
83

## Offset floor in braced frame



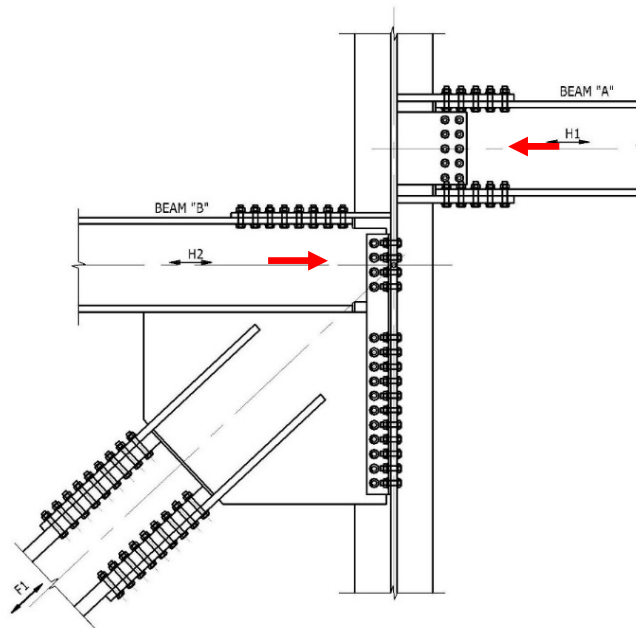
84

## Offset floor in braced frame



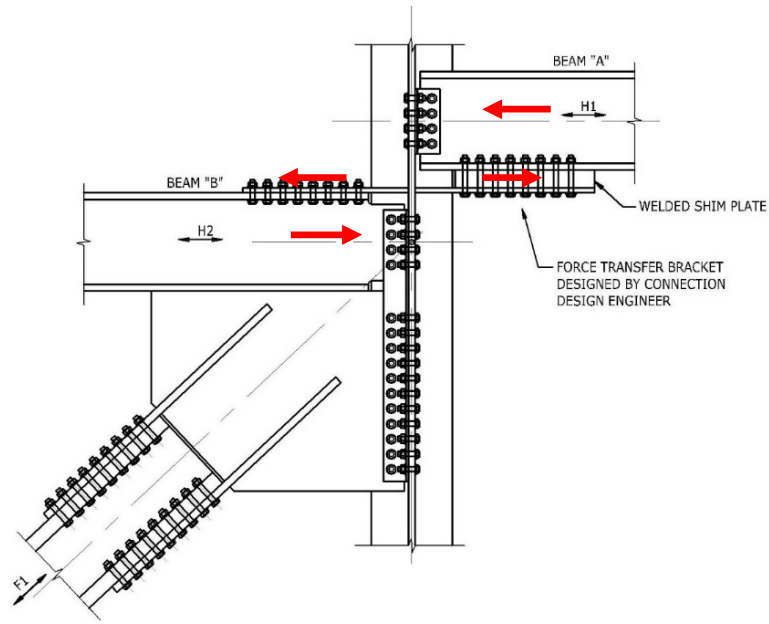
85

## Offset floor in braced frame

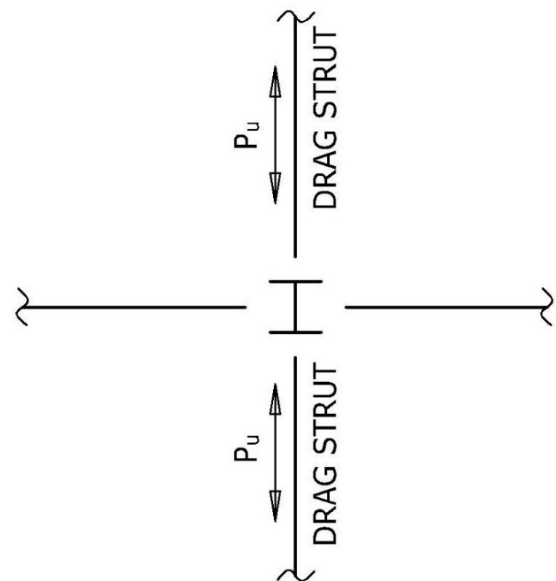


86

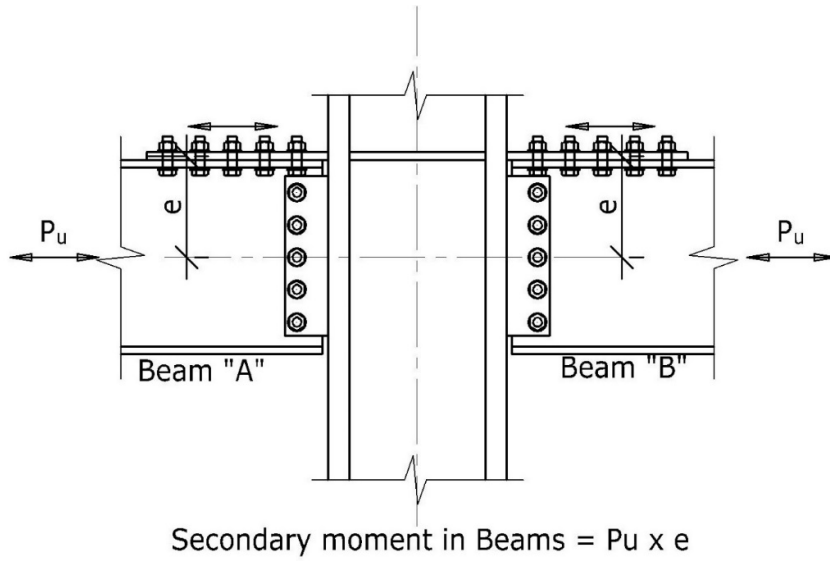
### Offset floor in braced frame



### Drag strut connections

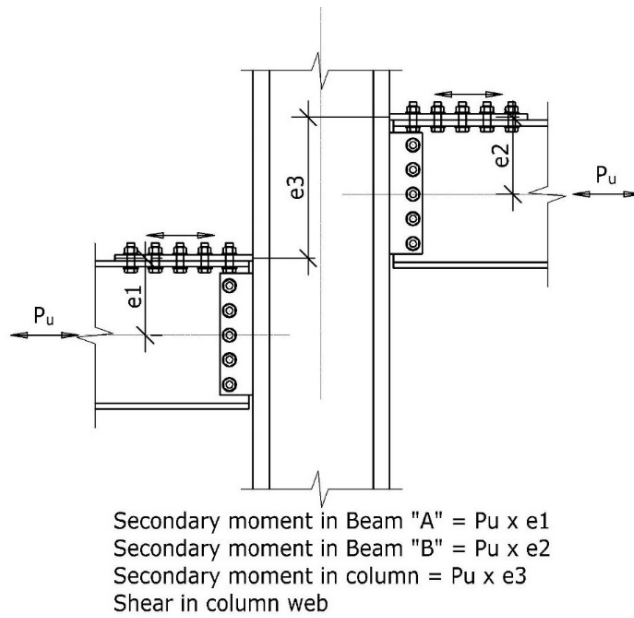


## Drag strut connections



89

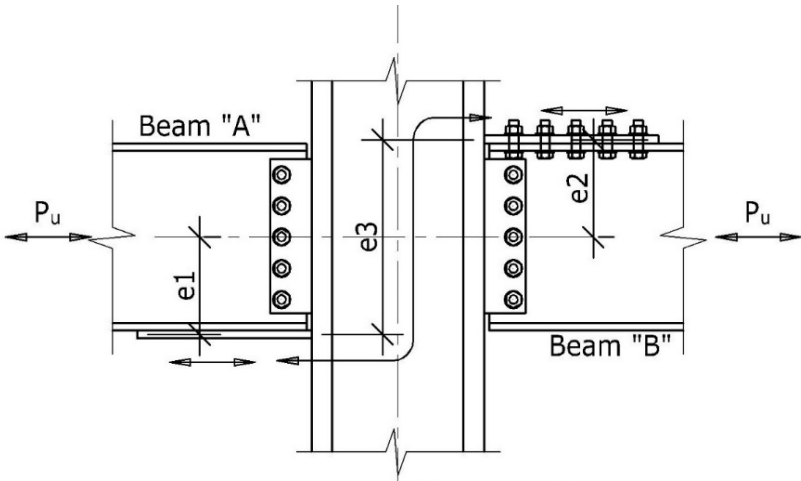
## Vertically offset drag strut



90



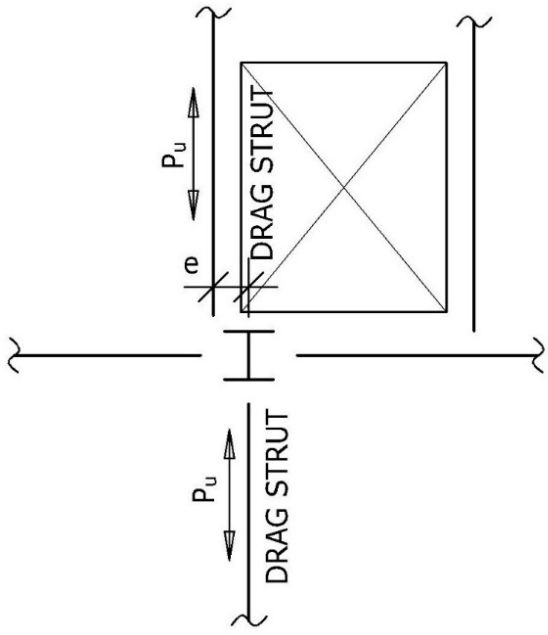
### Vertical offset in drag strut connection



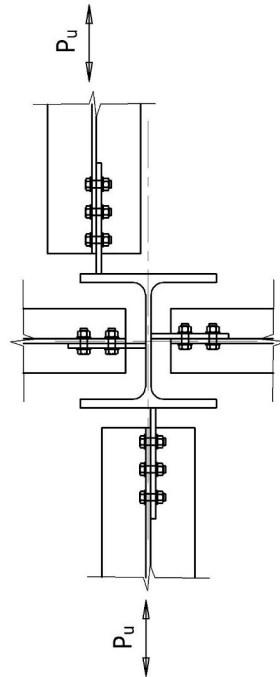
Secondary moment in Beam "A" =  $P_u \times e_1$   
 Secondary moment in Beam "B" =  $P_u \times e_2$   
 Secondary moment in column =  $P_u \times e_3$   
 Shear in column web



### Horizontally offset drag strut

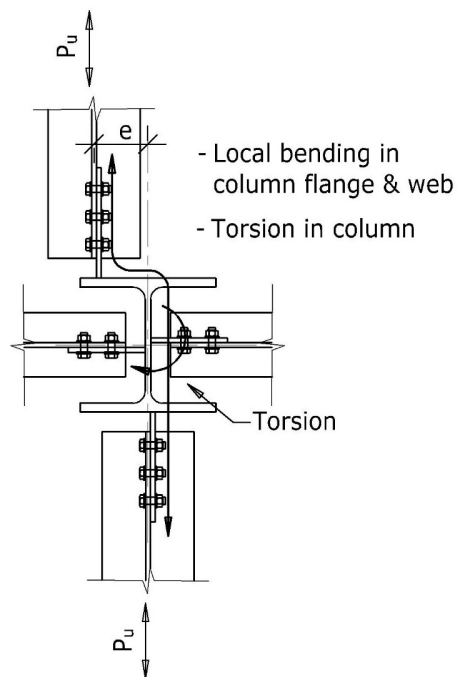


## Horizontally offset drag strut



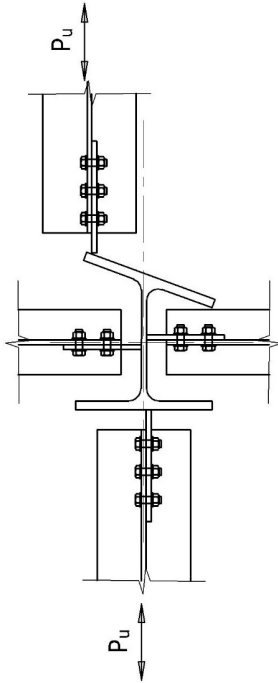
93

## Horizontally offset drag strut



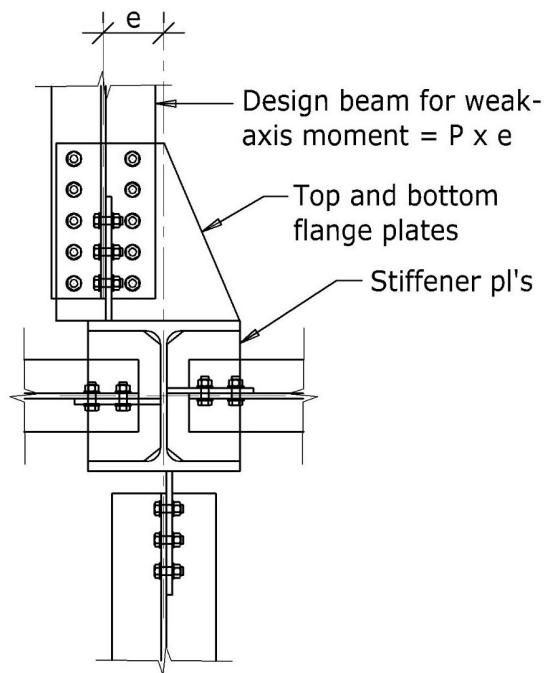
94

## Horizontally offset drag strut



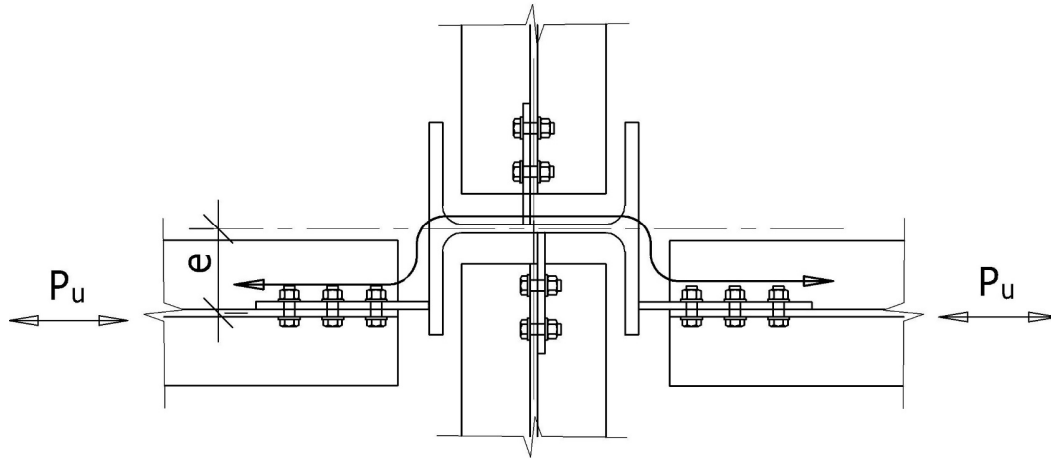
95

## Horizontally offset drag strut



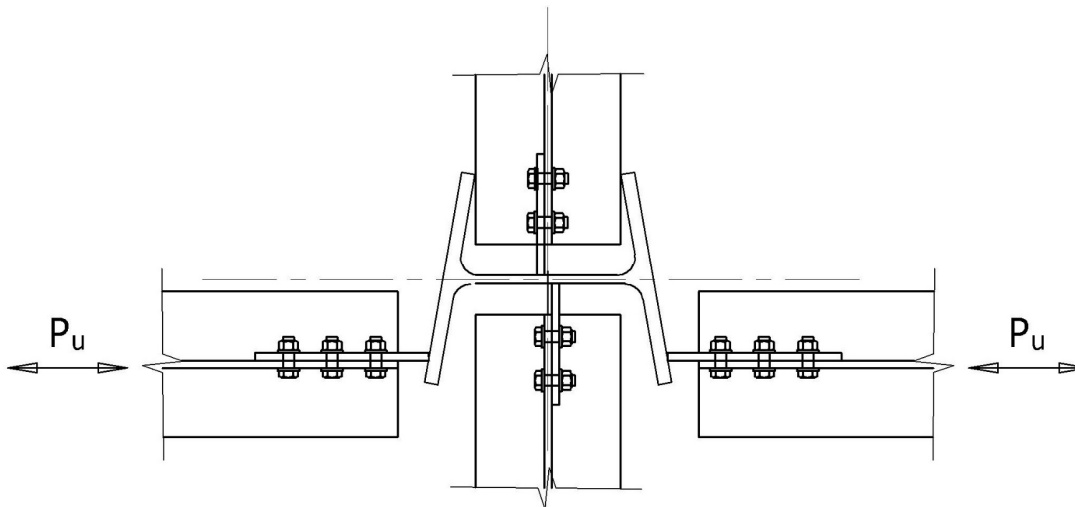
96

## Horizontally offset drag strut



97

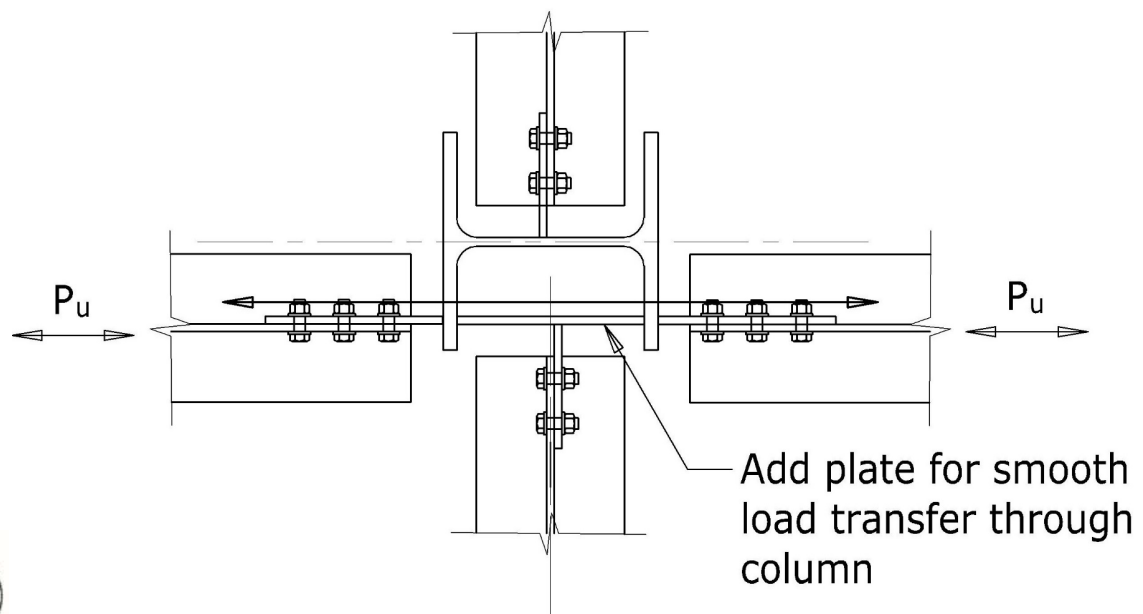
## Horizontally offset drag strut



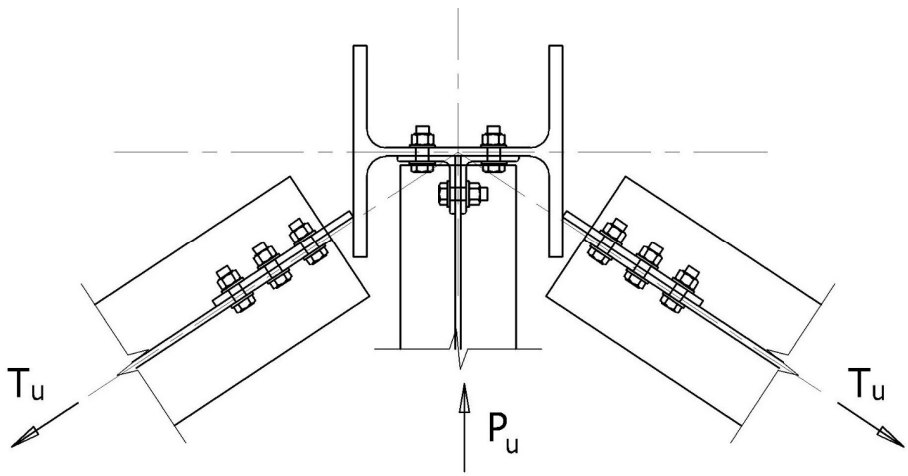
98



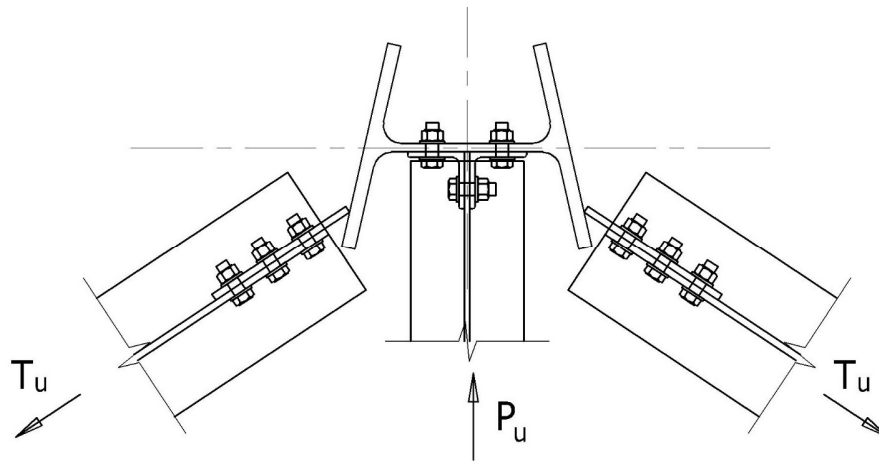
### Horizontally offset drag strut



### Tension ring connection



## Tension ring connection

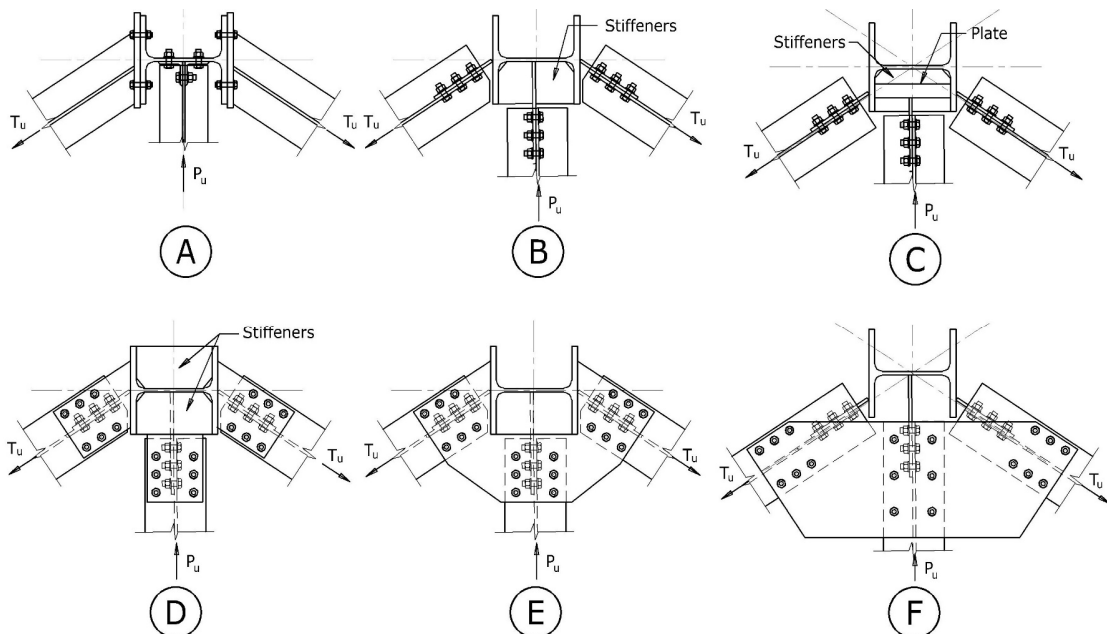


101

## Survey Question

Which detail is “best” for connecting tension ring members?

1. A
2. B
3. C
4. D
5. E
6. F



102

## Eccentric workpoint in truss



### Secondary Stress in Framed Structures

By E. W. Pittman \*

**S**ECONDARY stresses in framed structures are due, primarily, to faulty details. Attention will be directed to some of the more common faults and inconsistencies that are of frequent occurrence in structural details, and an effort made to illustrate their effects upon the strength of the structures.

In the general design of an articulated structure, such as a bridge or roof truss, it is assumed that the axes of the various members meeting at a joint are concurrent; that is, intersecting at a common point, and that they are free to rotate about this point as elastic deformation takes place.

(\*Manager, McClintic-Marshall Company, Pittsburgh Pa.)

103



## Eccentric workpoint in truss

The computation of the resulting bending moments in the members is a rather tedious process, as it involves the determination of the angular displacement of each joint. For bridge trusses of ordinary proportions, the deflection is small, and the resulting bending stresses in the members may be safely neglected, but for the shallow trusses with deep gusset plates, they should be considered.

This condition of secondary stress is sometimes further accentuated by faulty joints, such as shown in Fig. 1. The axes of the members are noncurrent, and a bending moment is, therefore, induced at the joint. All members are bent in opposite directions at their ends, and by approximately the same amounts. This places them in double curvature and makes a point of contra flexure, or zero moment, at their centers. All members, therefore, resist the bending moment due to eccentricity in proportion to their relative rigidities. The angular displacement of the

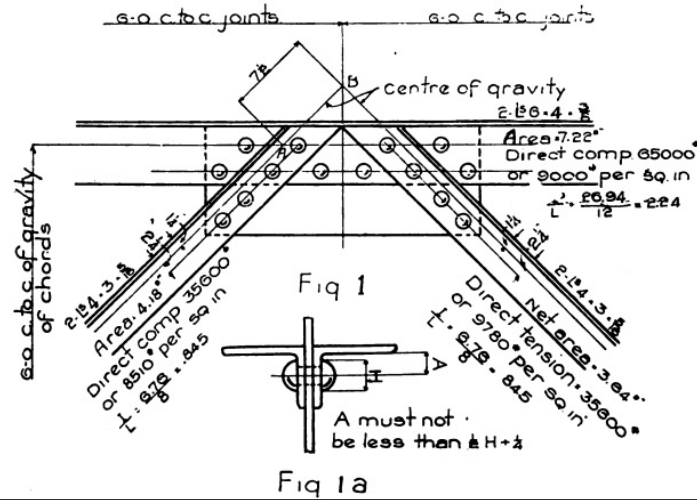
104



## Eccentric workpoint in truss

In order to make this result more tangible, and to illustrate the effect of this construction, let us assume an actual case and derive the numerical values of these secondary stresses.

Fig. 1 shows a joint in the top chord of a Warren truss. The make-up and properties of the several members are marked in the figure.



## Eccentric workpoint in truss

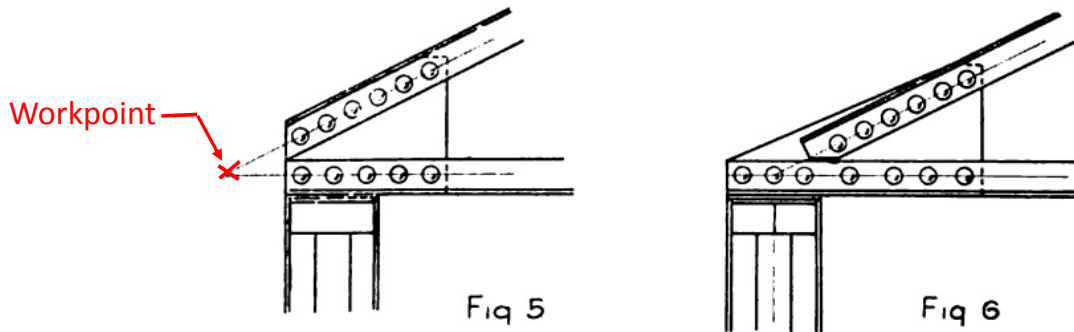
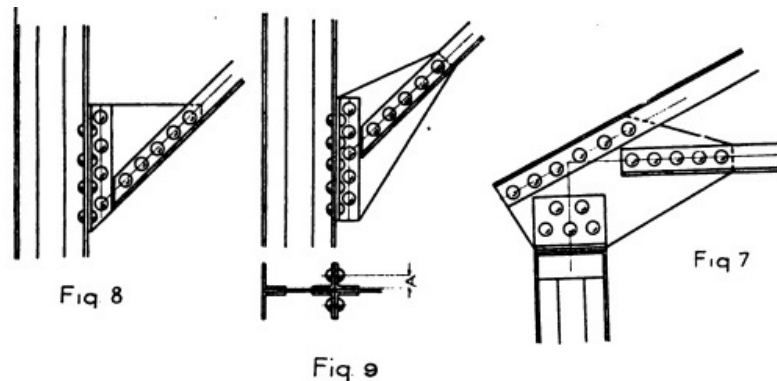


Fig. 5 shows the heel of a roof truss. This detail has been made familiar by its wide use, and yet the fault is pronounced. The three forces acting at the heel, namely the compression in the rafter, the tension in the bottom chord and the column, or wall, reaction are non-current. A bending moment results which induces large fibre stresses in the members. This detail is susceptible of the same analysis as the eccentric joint of the Warren truss.



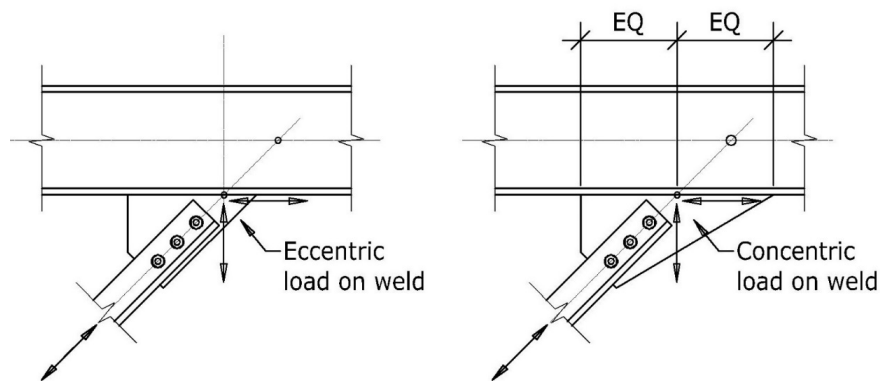
## Eccentric workpoint in braces



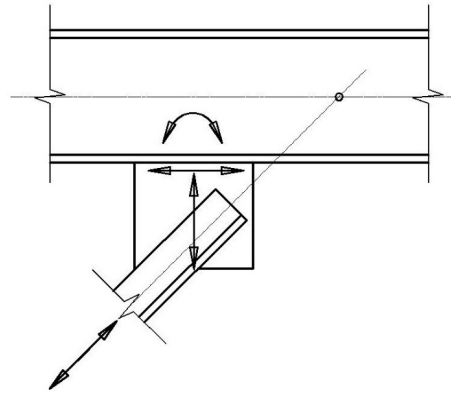
**Fig. 8** shows the detail of a knee brace connection to a column, which is not uncommon in mill building construction. This detail is open to the same criticism as the other eccentric connections already discussed. It is especially to be condemned in view of the fact that the knee brace is subject to tension, as well as compression, and when the knee brace is in tension, the entire stress must be resisted by two rivet heads. **Fig. 9** shows the proper detail for this connection. The gauge, *A*, for the rivets



## Eccentric workpoint in braces



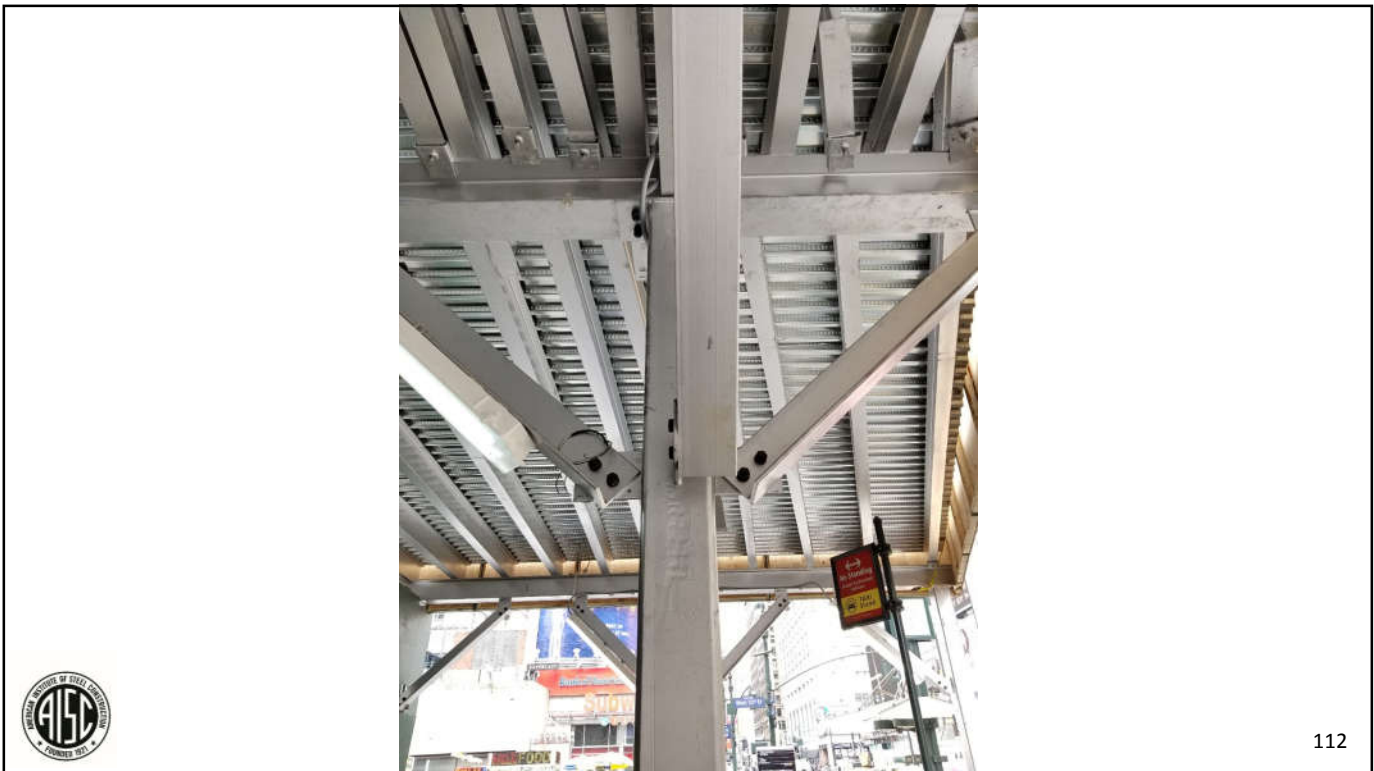
## Eccentric workpoint in braces



109

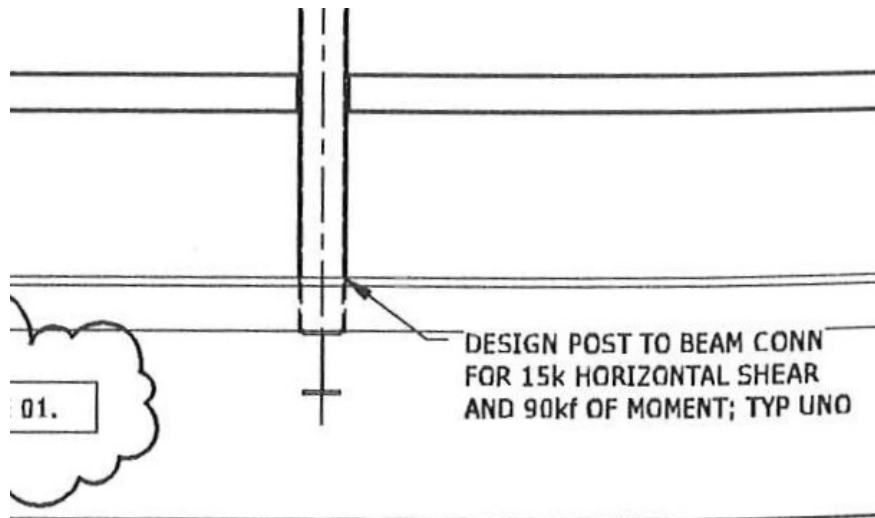


110

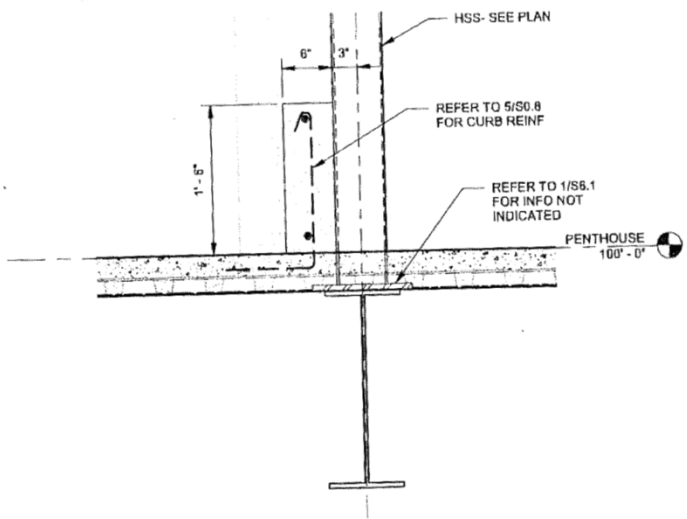




## Screen wall posts



### Screen wall posts

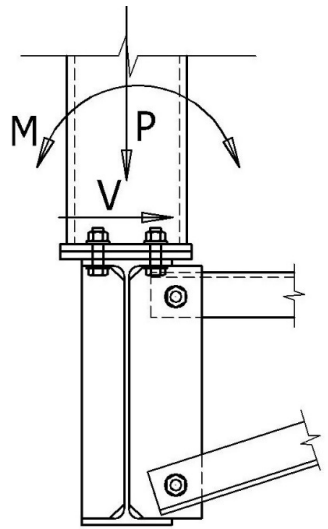


6 SECTION  
1" = 1'-0"

115



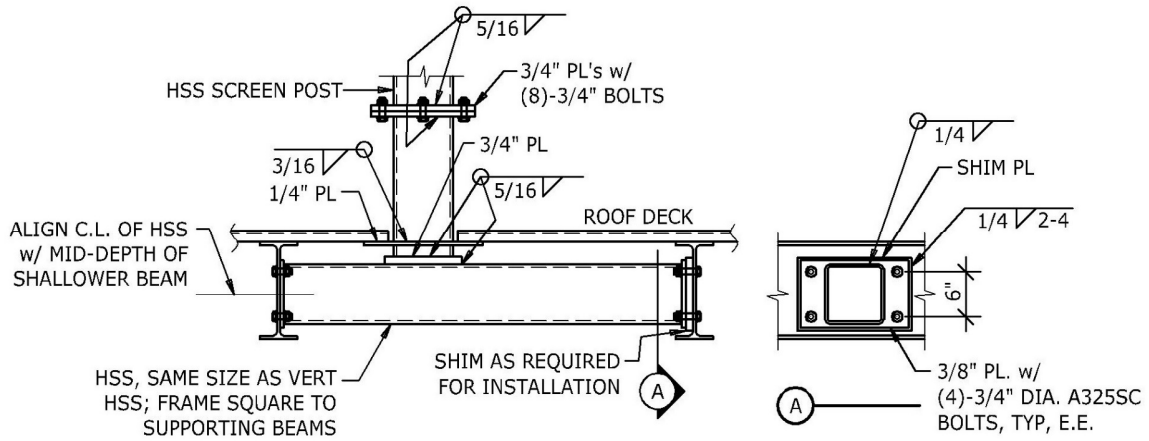
### Screen wall posts



116

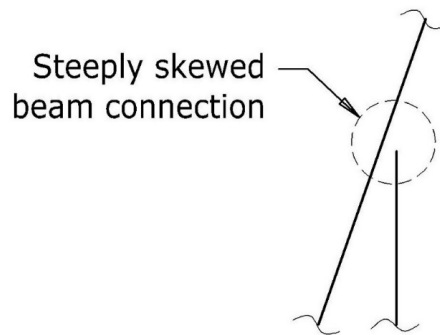


## Screen wall posts



117

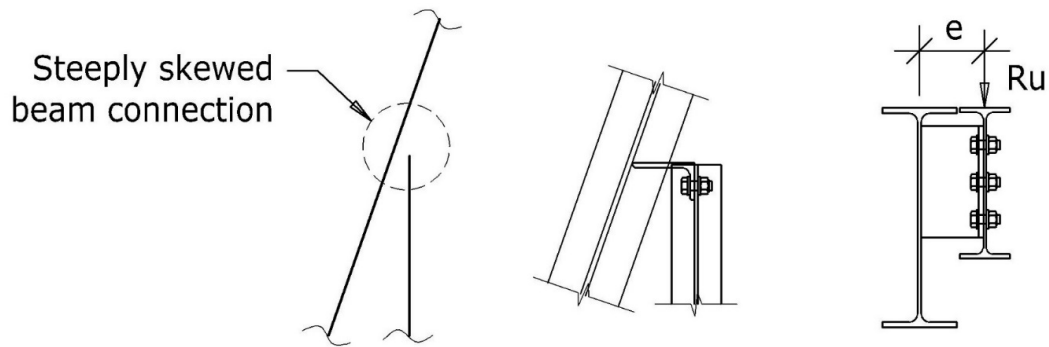
## Steeply skewed connections (w/ small reactions)



118

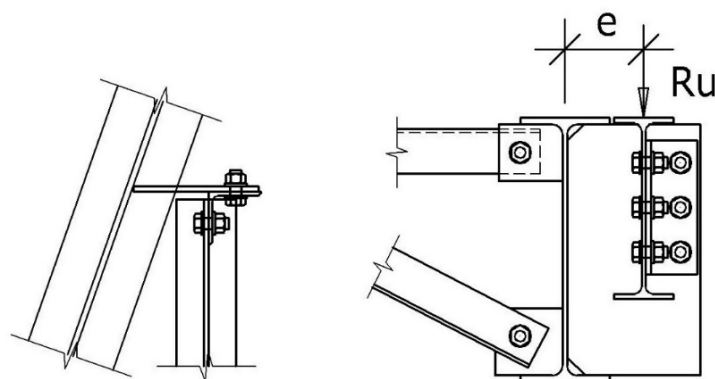


## Steeply skewed connections (w/ small reactions)



119

## Steep skewed connections (w/ small reactions)



120

## Summary

- The EOR is ultimately responsible for safe design of all connections
- Kinked connections are those with irregular, 3-dimensional jogged load paths
- The best load path is a smooth and direct load path
- Subtle changes can create kinked connections
- Computer models will not “find” the kinked connections



121

## Summary

- Look for kinked connections during design
- Alter framing to eliminate the kinks or consider their effects on members
- Provide concept connection details
- Read and understand the AISC Code of Standard Practice
- Kinked connections are common. Always be on the lookout for them!



122

# Thank you!

**AISC** | Questions?



## CEU / PDH Certificates

---

- You will receive an email on how to report attendance from:  
[registration@aisc.org](mailto:registration@aisc.org).
- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!



## CEU / PDH Certificates

---

- Reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.



**AISC** | Thank you

