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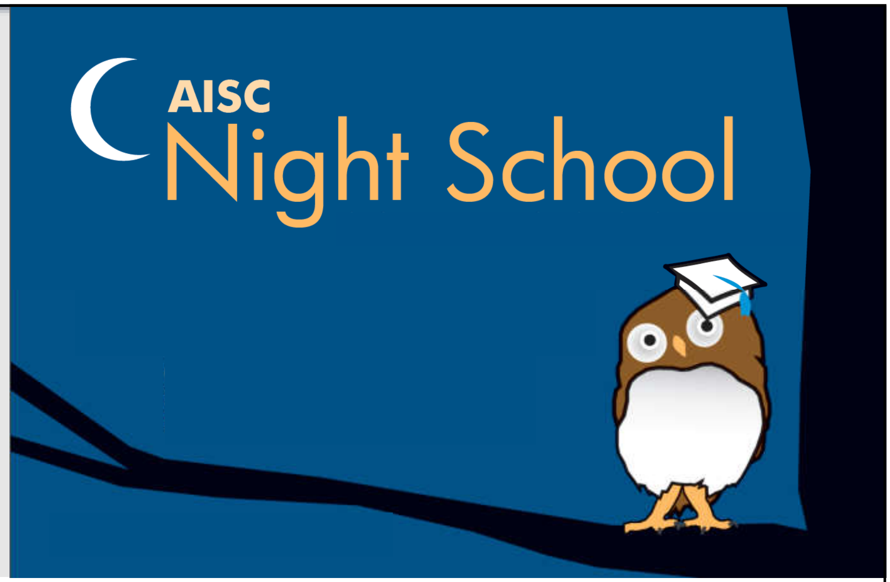

Connection Design

Tips, Tricks, and Lessons Learned

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Course Description

19.2 Delegating Connection Design
February 11, 2019

The cost of connections is a significant percentage of the total cost of steel-framed structures. This webinar reviews how designers can efficiently delegate connection design in a manner that saves time, reduces RFI's, reduces cost, and conforms with the requirements of the Code of Standard Practice. This session discusses the EOR's responsibility regarding delegation of connection design as stipulated by the COSP and reviews how decisions made relative to framing configuration during design can substantially affect connection cost. Tips, guidelines, suggestions, and examples will be presented to provide designers of all levels of experience a better understanding on how to properly delegate connection design in a manner that will result in safer, more constructable, and more economical steel-framed building structures.

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Learning Objectives

- Identify examples of improper general notes when delegating connection design.
- 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.

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Night School 19 Connection Design: Tips, Tricks, and Lessons Learned

Session 2: Delegating Connection Design
February 11, 2019

Cliff Schwinger, PE
THE HARMAN GROUP
structural engineering
parking planning and design
PHILADELPHIA | NEW YORK

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Seminar Objectives

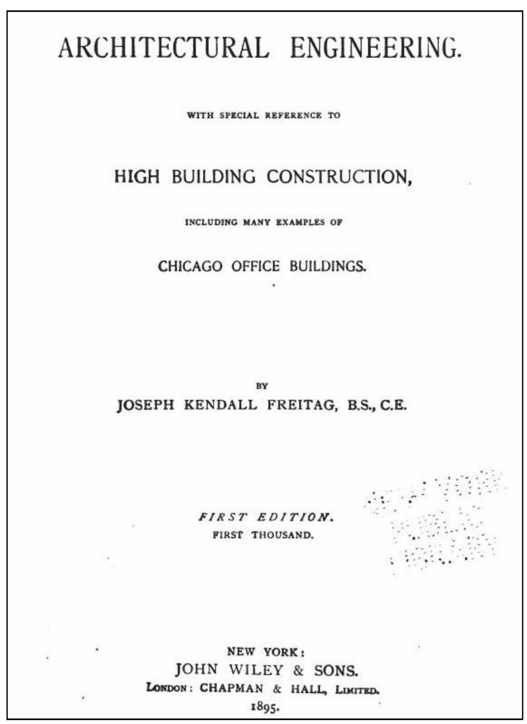
Review / Discuss

- Connection design responsibilities per AISC 303-16
- AISC 303-16 Options “3A” and “3B”
- “Member reinforcing” at connections
- “Concept connection details”
- “Connection constructability” and “connection designability”
- Unusual connections (including “kinked connections”) and things to consider when delegating connection design

9

Recommended reading

Delegation of connection design was discussed 124 years ago.



ARCHITECTURAL ENGINEERING.

WITH SPECIAL REFERENCE TO

HIGH BUILDING CONSTRUCTION,

INCLUDING MANY EXAMPLES OF

CHICAGO OFFICE BUILDINGS.

BY

JOSEPH KENDALL FREITAG, B.S., C.E.

FIRST EDITION.
FIRST THOUSAND.

NEW YORK:
JOHN WILEY & SONS.
LONDON: CHAPMAN & HALL, LIMITED.
1895.

10

Why delegate connection design?

- Delegating connection design is standard practice in some areas of the U.S.
- Schedules
- Connection design is a specialty
- Fabricator connection preferences

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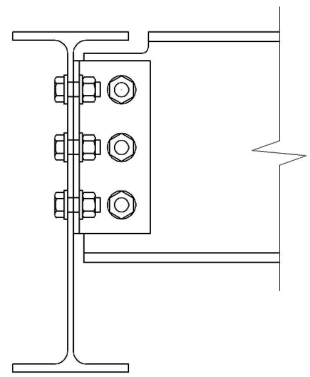
There’s a right way and a wrong way to delegate connection design

12

The wrong way

"Shear connections shall be designed to develop full shear strength of member."



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The right way

14

Follow AISC 303-16

The roadmap to navigating the proper way of delegating connection design

ANSI/AISC 303-16
An American National Standard

Code of Standard Practice for Steel Buildings and Bridges

June 15, 2016

Supersedes the *Code of Standard Practice for Steel Buildings and Bridges* dated March 14, 2010 and all previous versions

Approved by the Committee on the Code of Standard Practice

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Who is ultimately responsible for the safe design of all connections?

The "…owner's designated representative for design…" (the Engineer of Record)

16

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.

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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.

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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.

. . .

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SECTION 3. DESIGN DOCUMENTS AND SPECIFICATIONS

3.1. Structural Design Documents and Specifications

Unless otherwise indicated in the *contract documents*, the structural *design documents* shall be based upon consideration of the design loads and forces to be resisted by the *structural steel* frame in the completed project.

The structural *design documents* shall clearly show or note the work that is to be performed and shall give the following information with sufficient dimensions to accurately convey the quantity and complexity of the *structural steel* to be fabricated:

(a) The size, section, material grade and location of all members.
(b) All geometry and working points necessary for layout.
(c) Floor elevations.
(d) Column centers and offsets.
(e) The camber requirements for members.
(f) Preset elevation requirements, if any, at free ends of cantilevered members relative to their fixed-end elevations.
(g) Joining requirements between elements of built-up members.
(h) When the requirements of ANSI/AISC 341 are applicable, the information required in ANSI/AISC 341 Section A4.
(i) The information required in Sections 3.1.1 through 3.1.6.

. . .

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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

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(3.1.1 continued)

. . . When Option 2 is specified, the experienced *steel detailer* shall utilize information provided in the structural *design documents* in the selection or completion of the *connections*. When such information is not provided, tables in the AISC *Steel Construction Manual*, or other reference information as approved by the *owner's designated representative for design*, shall be used.

When Option 2 or 3 is specified, the *owner's designated representative for design* shall provide the following *connection* design criteria in the structural *design documents* and *specifications*:

(a) Any restrictions on the types of *connections* that are permitted.

(b) Data concerning the loads, including shears, moments, axial forces and transfer forces, that are to be resisted by the individual members and their *connections*, sufficient to allow the selection, completion, or design of the *connection* details while preparing the *approval documents*.

(c) Whether the data required in (b) is given at the service-load level or the factored-load level.

(d) Whether LRFD or ASD is to be used in the selection, completion, or design of *connection* details.

(e) What *substantiating connection information*, if any, is to be provided with the *approval documents* to the *owner's designated representative for design*.

. . .

22

(3.1.1. continued)

. . . When Option 3 is specified:

(a) The *fabricator* shall submit in a timely manner representative samples of the required *substantiating connection information* to the *owner's designated representatives for design* and *construction*. The *owner's designated representative for design* shall confirm in writing in a timely manner that these representative samples are consistent with the requirements in the *contract documents*, or shall advise what modifications are required to bring the representative samples into compliance with the requirements in the *contract documents*. This initial submittal and review is in addition to the requirements in Section 4.4.

(b) The licensed engineer in responsible charge of the *connection* design shall review and confirm in writing as part of the *substantiating connection information*, that the *approval documents* properly incorporate the *connection* designs. However, this review by the licensed engineer in responsible charge of the *connection* design does not replace the approval process of the *approval documents* by the *owner's designated representative for design* in Section 4.4.

(c) The *fabricator* shall provide a means by which the *substantiating connection information* is referenced to the related *connections* on the *approval documents* for the purpose of review.

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(3.1.2 continued)

. . . (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.

. . .

24

New term,

"…member reinforcement at connections…"

"Member reinforcement at connections" refers to stiffener plates, web doubler plates, and other elements required to deal with secondary stresses in members at connections.

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"…member reinforcement at connections…"

Option 3A

Per Section 3.1.2, the EOR is responsible for,

- Determining where member reinforcement is required at connections
- Designing and detailing all member reinforcing at connections
- Documenting all locations where member reinforcing is required on the contract documents

26

"…member reinforcement at connections…"

Option 3B

Per Section 3.1.2, the EOR is responsible for,

- Providing concept connection details showing the configuration and details of the member reinforcement at connections
- Providing a bidding quantity of items required for member reinforcement at connections referencing "…corresponding project-specific details that show the conceptual configuration of reinforcement appropriate for the order of magnitude of forces to be transferred..."
- Delegating design of the connection and member reinforcing at connections to the fabricator's connection design engineer

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"…member reinforcement at connections…"

Option 3B

From Section 3.1.2,

"…If no quantities or conceptual configurations are shown, member reinforcement at *connections* will not be included in the bid…".

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Another new term,

"Conceptual configuration of reinforcement"

or

"Concept connection details"

29

"Concept connection details"

Two purposes,

- They show connection design engineers how connections are to be configured
- They provide connection details to fabricators bidding the project so that everyone is accounting for the same things when estimating cost.

30

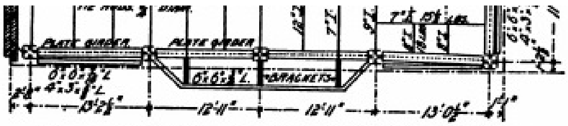


FIG. 19.—Typical Framing Plan of the Reliance Building.

with such license on the part of the contractor, and the best classes of work are made in accordance with definite details furnished by the engineer, after a careful considera-

SKELETON CONSTRUCTION. 45

tion of the conditions to be fulfilled. This does not mean that complete shop drawings are made, but rather such connections and special points in the design as need particular attention. The balance of the detailing may be made to suit the contractor, with the approval of the engineer, in conformity with the sizes of material marked on the plan, and the carefully drawn specifications.

The idea of allowing the manufacturer to prepare complete details after his own general scheme, and following specifications only, is not consistent with best results, in the judgment of the writer, though such an arrangement has often been advocated. It is true that it has been a

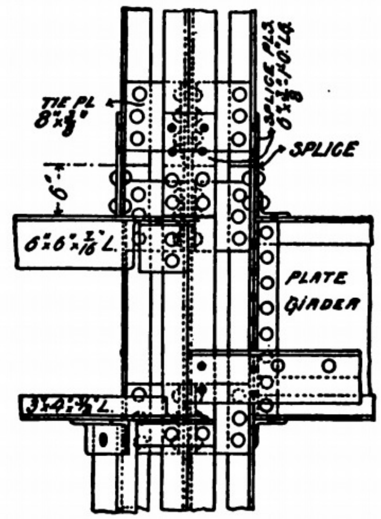
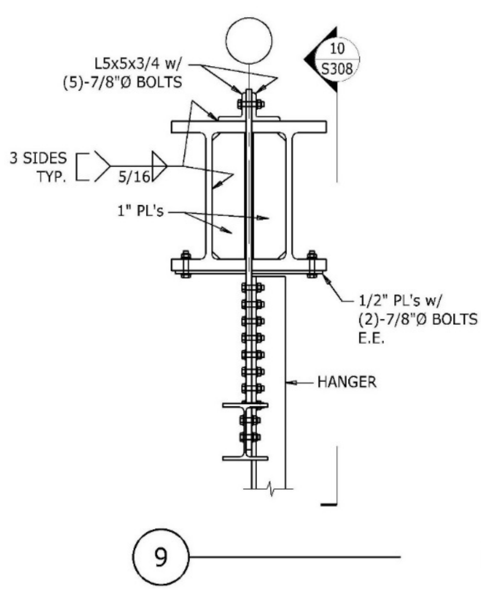


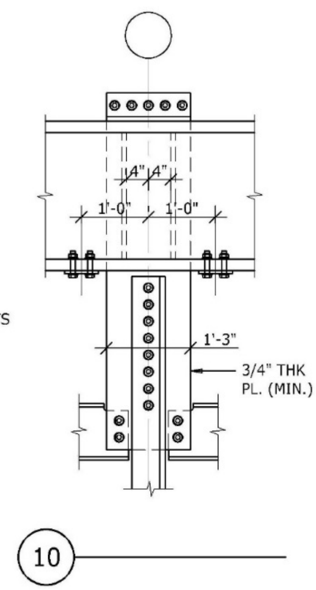
FIG. 104.

31

Concept connection detail

Note: The COSP does not specifically require that bolt sizes, weld sizes and plate sizes be shown in the "conceptual configuration of reinforcement" details





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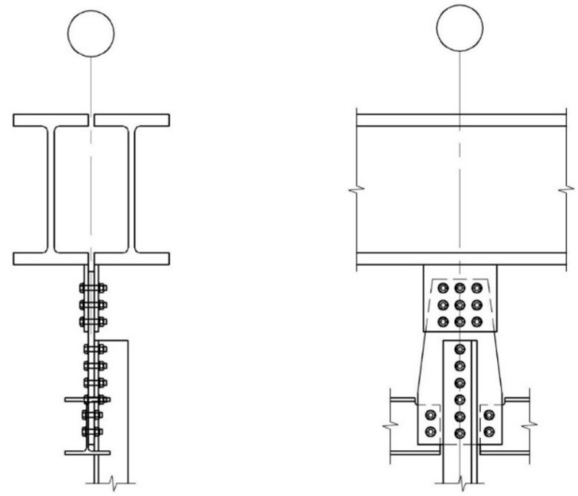
In the absence of a concept connection detail….

Concept connection details communicate the EOR's design intent, thereby avoiding time-consuming rejection of shop drawings, RFI's, arguments, mis-understandings between the EOR and the connection design engineer, and change orders.



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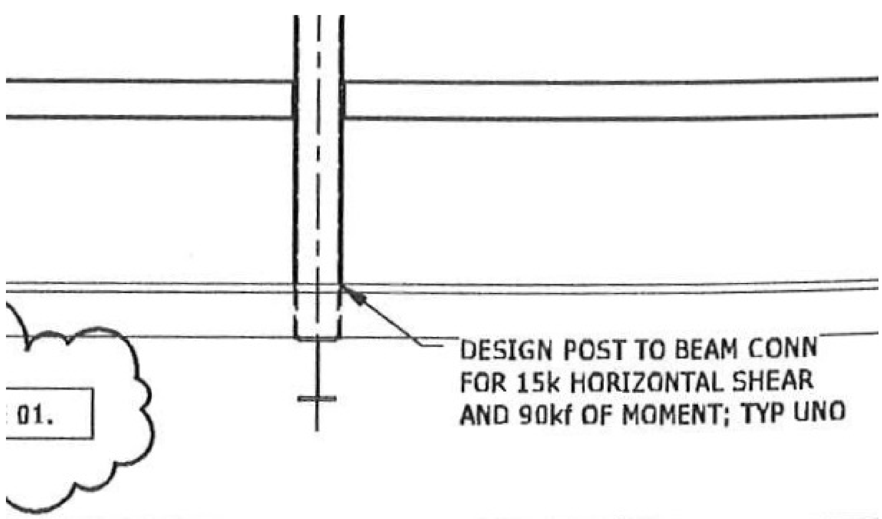
Not **an acceptable concept connection detail**



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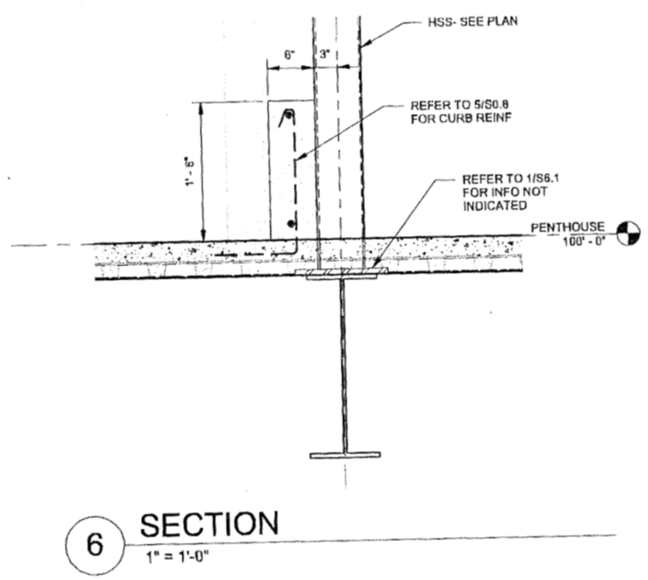
Not **an acceptable concept connection detail**



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Things to consider

- Can the connections be built? **(Constructability)**
- Can the connections be designed? **(Connection designability)**
- Is there anything unusual about how loads travel through the connections? Are there any transfer forces with ***eccentric*** load paths through any of the connections that will require member reinforcement? **(Kinked connections)**

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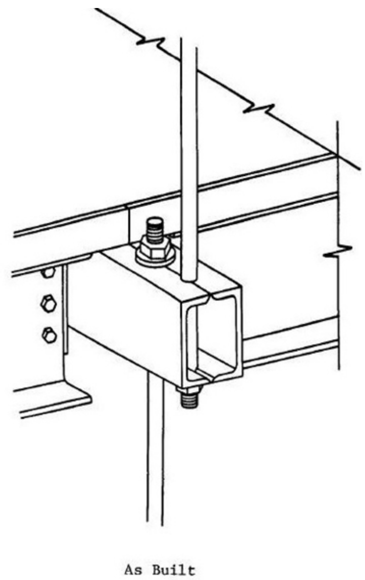
What's a "kinked connection"?

Connections where the transfer forces follow an ***eccentric*** load path through the connection inducing secondary stresses

One kink in original connection;
three kinks in final connection

1.6 strength ratio in original detail;
3.2 strength ratio in final (revised) detail



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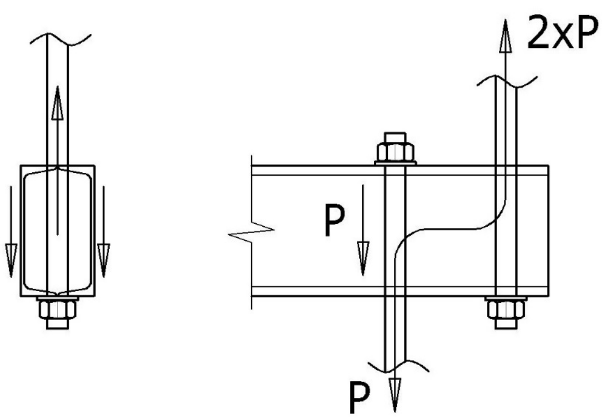
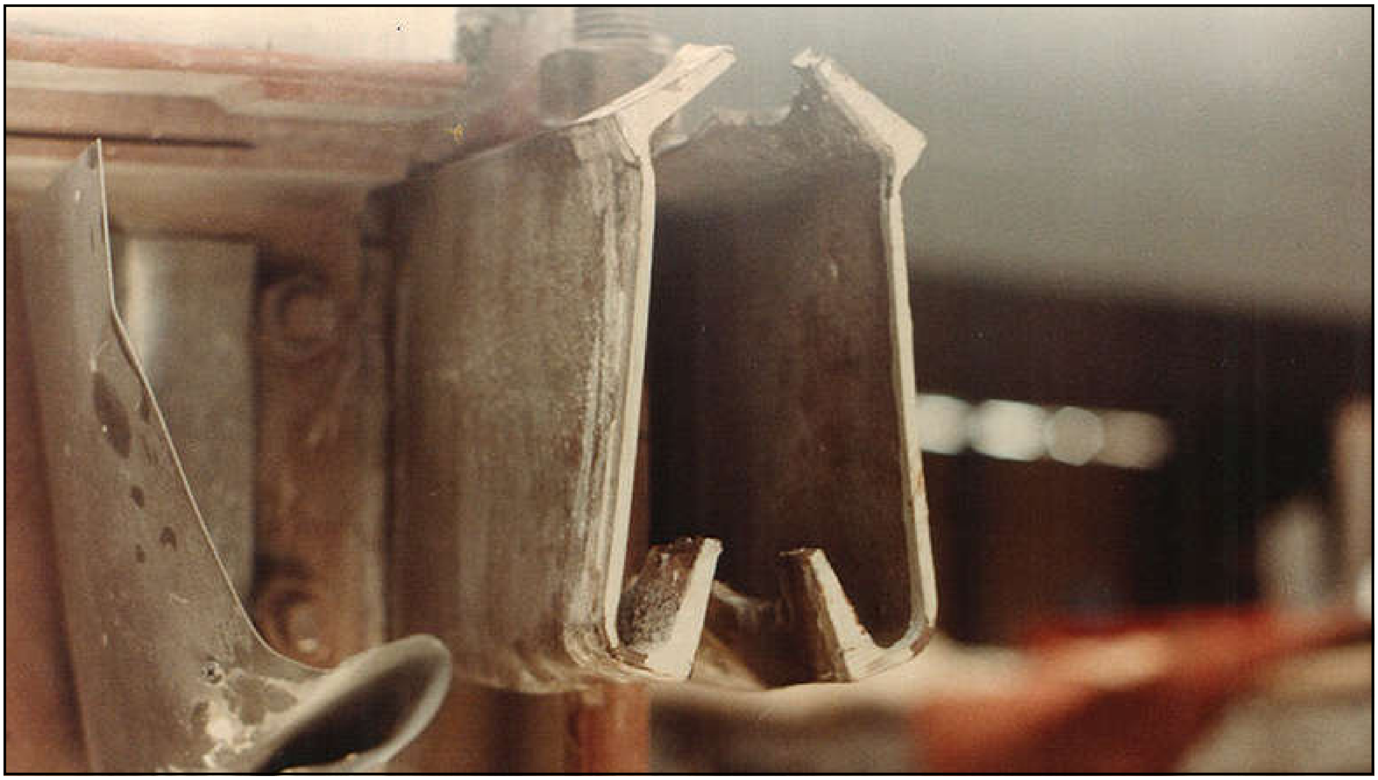
Always be on the lookout for kinked connections



Eccentric load paths through connections induce secondary stresses in the member(s)

38

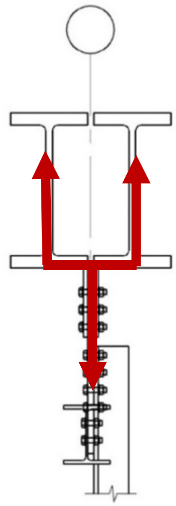


Dealing with kinked connections

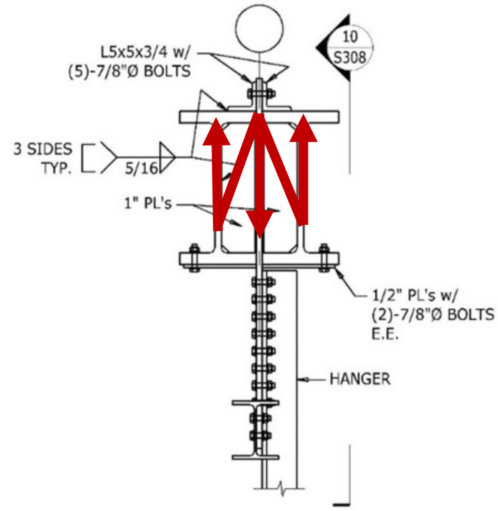
- Find the kinked connections ***during design***
- Eliminate kinks if possible – or deal with them
- Provide "concept connection details" on structural drawings

Kinked connections are *everywhere!*

40



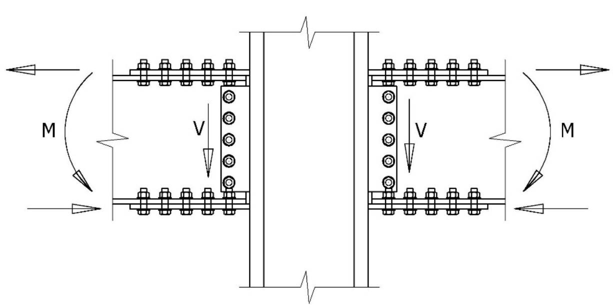
Kink in load path inducing secondary stresses in members



Concept connection detail addressing secondary stresses

41

Kinked connections



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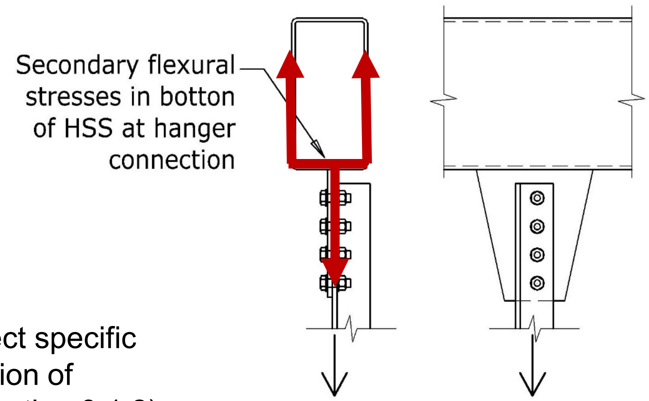
kinked connections

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)*

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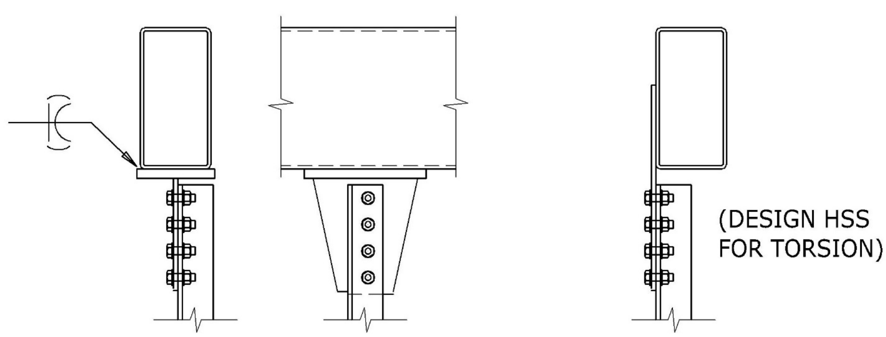
kinked connections



Two possible concept connection details to eliminate secondary stresses in HSS

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Why provide “concept connection details”?

- Required by the AISC Code of Standard Practice (“…conceptual configuration of reinforcement…”)
- Allows fabricators to better estimate cost, reducing the number of assumptions made by estimators and leveling the playing field among bidders
- Gives guidance and direction to connection designers
- Gives EOR opportunity to find and resolve constructability issues, connection designability issues, and kinked connection issues during design

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Why provide “concept connection details”?

- The time to find and resolve connection issues is during design
- EOR has options during design (revise framing)
- The number of economical options for solving connection design problems is reduced if problems are not discovered until shop drawing review
- Concept connection details reduce RFI’s, change orders, and disputes, *and* reduce the likelihood of mistakes slipping through
- Concept connection details make buildings safer!

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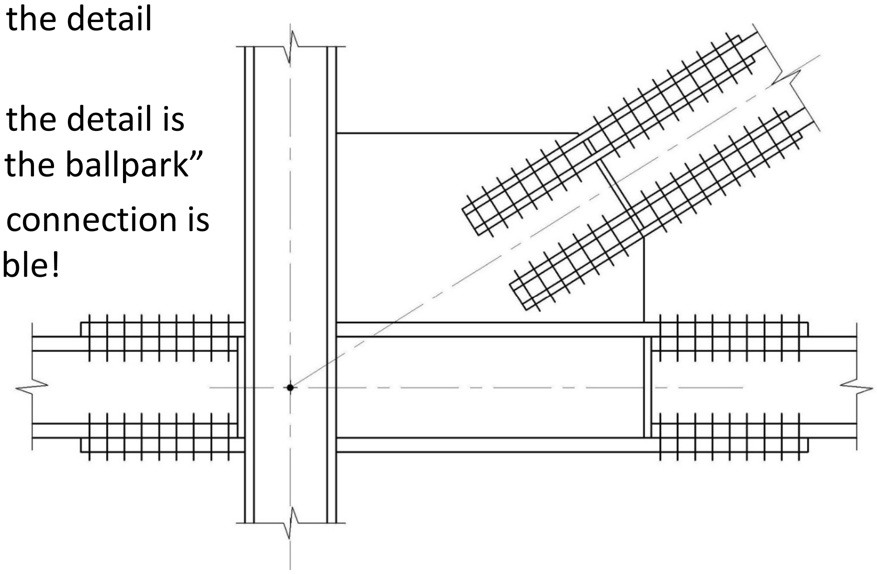
Perform quick and basic calculations to develop realistic concept connection details

- Be sure the detail works!
- Be sure the detail is "within the ballpark"
- Be sure connection is designable!



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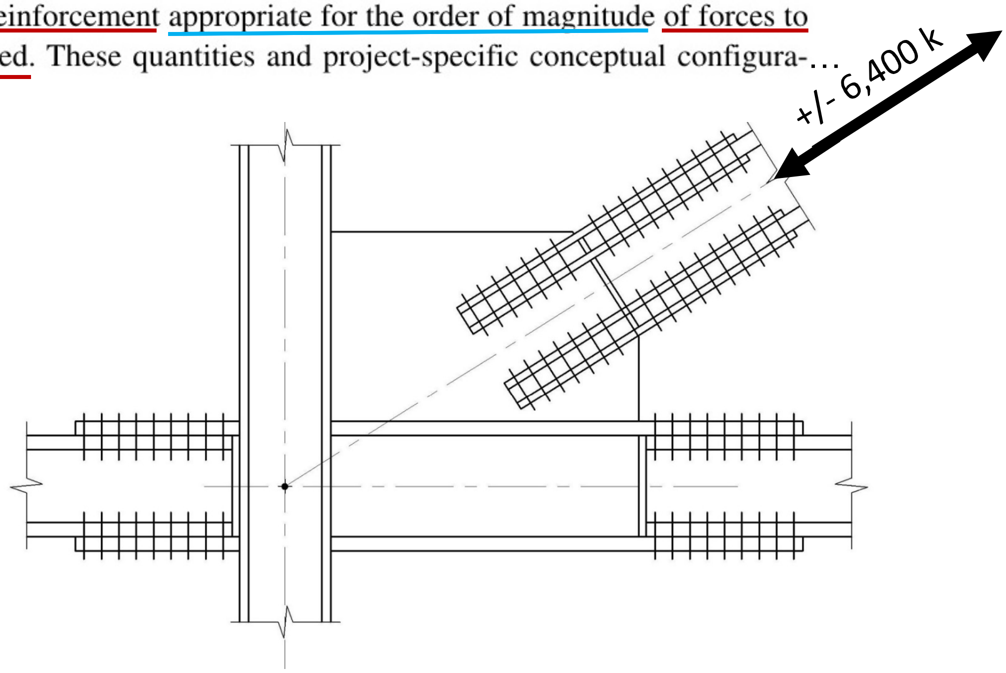
From 3.1.2 (2)

…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 configura-…



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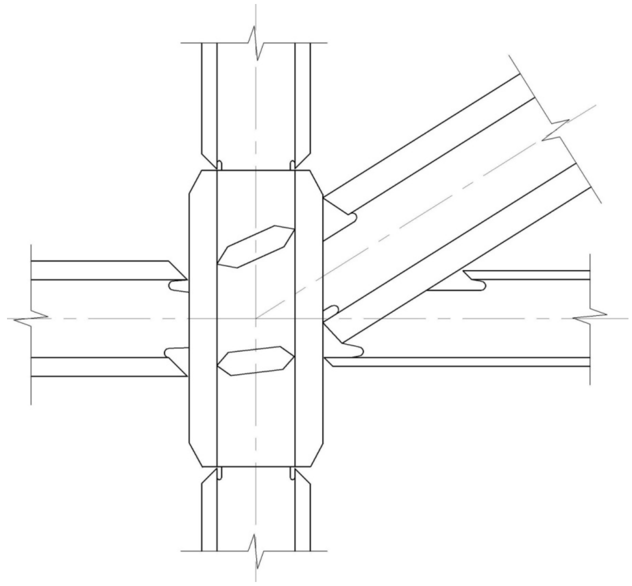
Provide realistic concept connection details



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Provide information on <u>Transfer Forces</u>

(What's a transfer force?)

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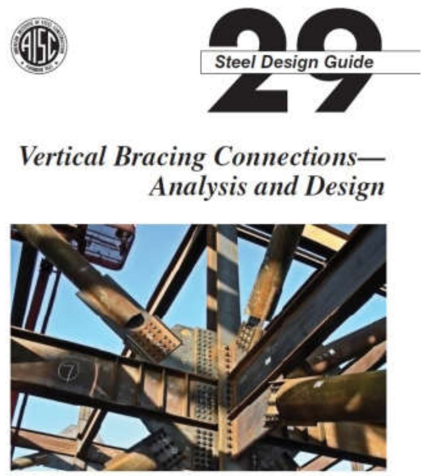
Transfer Forces



APPENDIX D
Transfer Forces

The AISC *Code of Standard Practice for Steel Buildings and Bridges* (AISC, 2010a), hereafter referred to as the AISC *Code of Standard Practice*, states that, when the fabricator is required to design connection details, the structural design drawings shall provide, among other things, "data concerning the loads, including shears moments, axial forces and transfer forces, that are to be resisted by the individual members and their connections, sufficient to allow the fabricator to select or complete connection details…"

This statement is most remarkable for what it does not require. It does not require the fabricator to be provided with all of the loads, or even loads that satisfy equilibrium. It merely requires that *sufficient* information be provided. It should also be noted that the term transfer force is not defined in the glossary for either the AISC *Code of Standard Practice* or the AISC *Specification*. In fact a survey of steel design handbooks will demonstrate that the term is neither ubiquitous nor well-understood. It is therefore useful to begin any discussion of transfer forces with a definition. A possible definition for a transfer force is a force that must be transferred from one element to another through connection elements and whose magnitude and direction cannot be ascertained from the maximum member end forces.

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Transfer Forces

zontal transfer is only a secondary concern. However, the magnitude of the vertical load that must be delivered to the column is unclear. Again, either statically consistent loadings

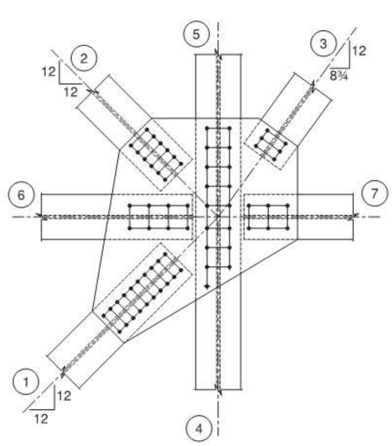

Fig. D-2. Alternate connection configuration.

D.2. PRESENTATION OF TRANSFER FORCES IN DESIGN DOCUMENTS

There are two possible methods that can be used to satisfy the AISC *Code of Standard Practice* requirement that sufficient load information be provided to complete the connection design. The first method involves providing a matrix of statically consistent load combinations that can be used to determine the required transfer force. An example of this type of presentation based on Table D-1 is shown in Figure D-3.

The procedure for generating such a matrix can be described as follows:

1. Define the assumed connection configuration.
2. Determine the load combinations that produce the maximum tension and maximum compression end forces for each member framing into a joint. Additionally, determine the load combinations that produce the maximum tension and maximum compression transfer forces.
3. For each load combination found in Step 1, give the axial forces in all members associated with that load combination so that joint equilibrium is provided for each. The maximum number of load cases will be equal to 2(n+1), where n is the number of members framing into the joint.

Possible advantages of this approach are as follows:

- Joint equilibrium is always provided for each load case, making the load paths very clear.

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Transfer Forces

All connections transfer forces, but…

The term “transfer forces” as used and described in DG 29, Appendix “D” refers to framing configurations where forces are transferred through nodes where multiple members converge, and where forces do not resolve if only maximum member forces are provided by the EOR in each member.

The most economical connections are achieved when the EOR provides forces in all members for various load combinations. (More work for EOR)

Heavier connections result when only maximum forces in each member are provided. (Less work for EOR)

(To be discussed further in Session #5 – “Vertical Bracing Connections”)

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Understand what is not connection design

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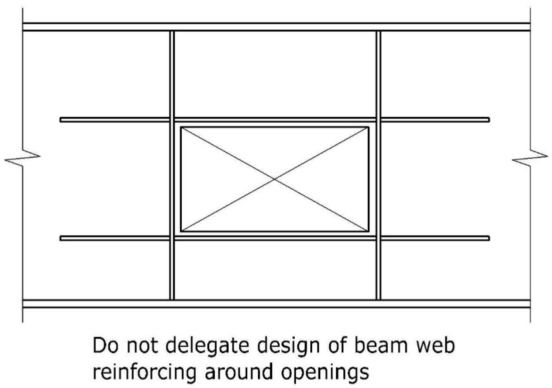
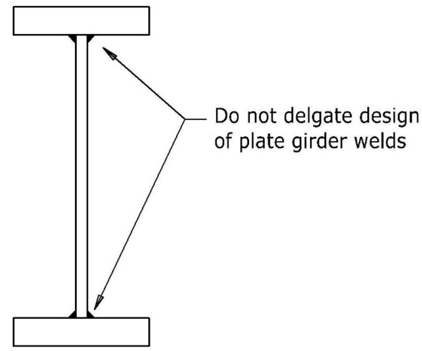
Understand what is not connection design





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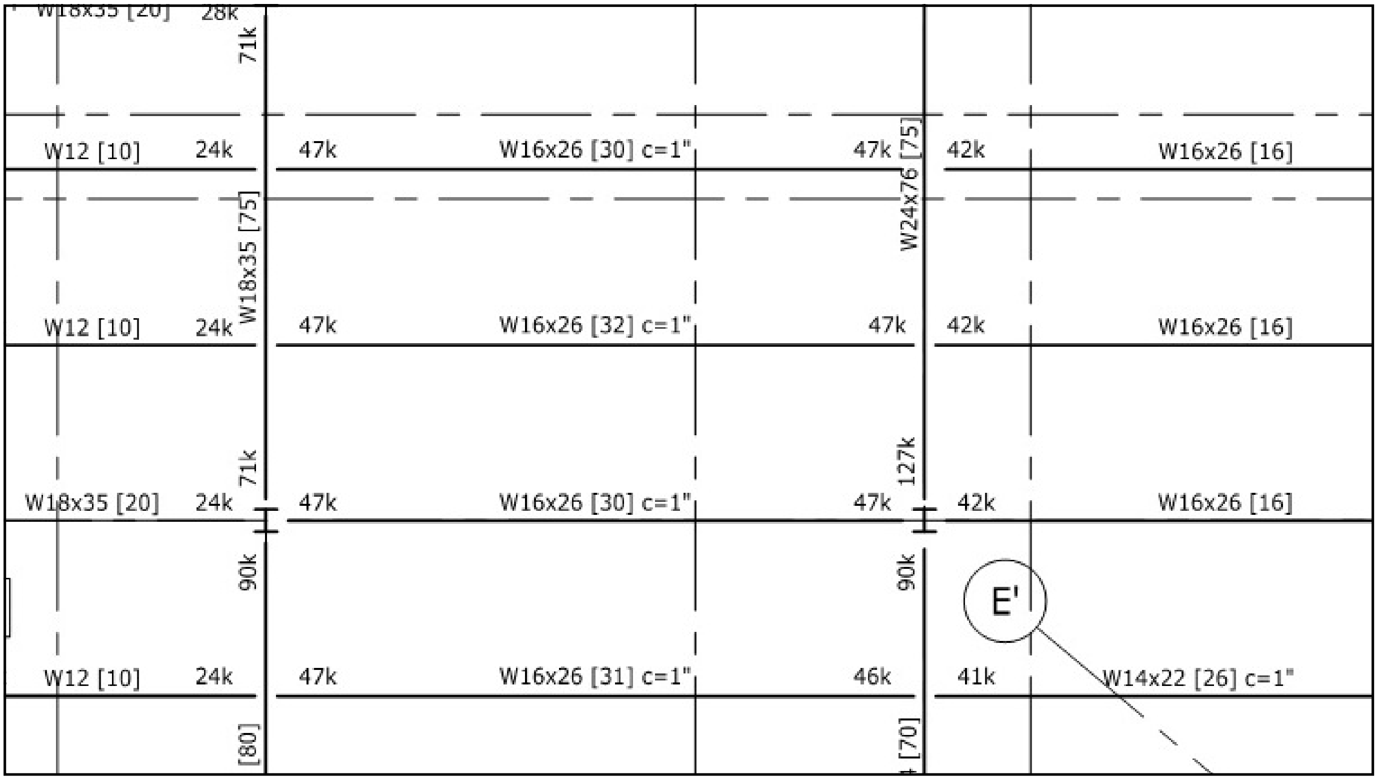
Show the reactions

Overly conservative connection design criteria do not make buildings safer

56



Wrong way #1

"All shear connections shall be designed to develop the full shear strength of the member."

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Wrong way #2

DESIGN SHEAR CONNECTIONS FOR THE FOLLOWING SHEAR STRENGTHS:

W8	15 k	W21	95 k
W10	30 k	W24	120 k
W12	40 k	W27	150 k
W14	50 k	W30	180 k
W16	60 k	W33	210 k
W18	75 k	W36	240 k

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Wrong way #3

Do not use Table 3-6 to specify the required beam shear connection strength

MAXIMUM TOTAL UNIFORM LOAD TABLES 3-59

F_y = 50 ksi

Table 3-6 (continued)
Maximum Total Uniform Load, kips
W-Shapes

W21

Shape	W21× 57		55		50		48[f]		44	
Design	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Span, ft 6					316	474			290	435
7	342	513			314	471	288	433	272	409
8	322	484	312	468	274	413	265	398	238	358
9	286	430	279	420	244	367	235	354	212	318
10	257	387	251	378	220	330	212	318	190	286
11	234	352	229	344	200	300	193	289	173	260
12	215	323	210	315	183	275	176	265	159	239
13	198	298	193	291	169	254	163	245	146	220
14	184	276	180	270	157	236	151	227	136	204
15	172	258	168	252	146	220	141	212	127	191
16	161	242	157	236	137	206	132	199	119	179
17	151	228	148	222	129	194	125	187	112	168
18	143	215	140	210	122	183	118	177	106	159
19	136	204	132	199	116	174	111	168	100	151
20	129	194	126	189	110	165	106	159	95.2	143
21	123	184	120	180	105	157	101	152	90.7	136
22	117	176	114	172	99.8	150	96.3	145	86.6	130
23	112	168	109	164	95.5	143	92.1	138	82.8	124
24	107	161	105	158	91.5	138	88.2	133	79.3	119
25	103	155	101	151	87.8	132	84.7	127	76.2	114
26	99.0	149	96.7	145	84.4	127	81.5	122	73.2	110
27	95.4	143	93.1	140	81.3	122	78.4	118	70.5	106
28	92.0	138	89.8	135	78.4	118	75.6	114	68.0	102
29	88.8	133	86.7	130	75.7	114	73.0	110	65.7	98.7
30	85.8	129	83.8	126	73.2	110	70.6	106	63.5	95.4
32	80.5	121	78.6	118	68.6	103	66.2	99.5	59.5	89.4
34	75.7	114	74.0	111	64.6	97.1	62.3	93.6	56.0	84.2
36	71.5	108	69.9	105	61.0	91.7	58.8	88.4	52.9	79.5
38	67.8	102	66.2	99.5	57.8	86.8	55.7	83.8	50.1	75.3
40	64.4	96.8	62.9	94.5	54.9	82.5	52.9	79.6	47.6	71.6
42	61.3	92.1	59.9	90.0	52.3	78.6	50.4	75.8	45.3	68.1
44	58.5	88.0	57.2	85.9	49.9	75.0	48.1	72.3	43.3	65.0
46	56.0	84.1	54.7	82.2	47.7	71.7	46.0	69.2	41.4	62.2
48	53.6	80.6	52.4	78.8	45.7	68.8	44.1	66.3	39.7	59.6
50	51.5	77.4	50.3	75.6	43.9	66.0	42.4	63.7	38.1	57.2
52	49.5	74.4	48.4	72.7	42.2	63.5				
Beam Properties										
W_c/Ω_b / $\phi_b W_c$, kip-ft	2570	3870	2510	3780	2200	3300	2120	3180	1900	2860
M_p/Ω_b / $\phi_b M_p$, kip-ft	322	484	314	473	274	413	265	398	238	358
M_r/Ω_b / $\phi_b M_r$, kip-ft	194	291	192	289	165	248	162	244	143	214
BF/Ω_b / $\phi_b BF$, kips	13.4	20.3	10.8	16.3	12.1	18.3	9.89	14.8	11.1	16.8
V_n/Ω_v / $\phi_v V_n$, kips	171	256	156	234	158	237	144	216	145	217
Z_x, in.^{3}	129		126		110		107		95.4	
L_p, ft	4.77		6.11		4.59		6.09		4.45	
L_r, ft	14.3		17.4		13.6		16.5		13.0	

ASD	LRFD
$\Omega_b = 1.67$	$\phi_b = 0.90$
$\Omega_v = 1.50$	$\phi_v = 1.00$

[f] Shape does not meet compact limit for flexure with F_y = 50 ksi; tabulated values have been adjusted accordingly.

Notes: For beams laterally unsupported, see Table 3-10.
Available strength tabulated above heavy line is limited by available shear strength.

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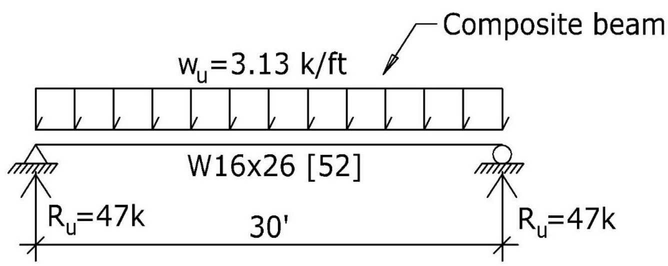
Using Table 3-6 can result in specification of undersized connection strength requirements



- From Table 3-6, 15th Edition AISC Manual maximum uniform load capacity for W16x26 (LRFD) is 44.2k for L=30'
- Connection requirement on contract documents: Design connections for 150% of the reaction from the uniform load capacity of the beams from Table 3-6 (0.75 x 44.2k = 33k)
- Specified connection strength based on the arbitrary 1.5 x Table 3-6 value is 42% less than required for actual loads. ← **Too low!!**

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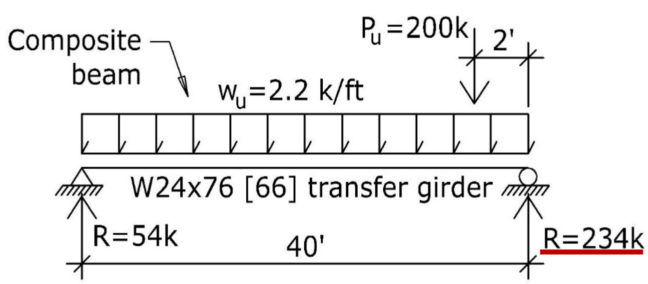
Using Table 3-6 can result in specification of undersized connection strength requirements



- From Table 3-6, 15th Edition AISC Manual maximum uniform load capacity for W24x76 (LRFD) is 150k for L=40'
- Connection requirement on contract documents: Design connections for 150% of the reaction from the uniform load capacity of the beams from Table 3-6 (0.75 x 150k = 113k)
- Actual reaction at right end is more than twice as big as specified connection strength!

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The right way…

Show member shear reactions on framing plans, moment connection design moments, and axial loads in braces and truss members.

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Do not mandate connection design requirements more stringent than required by the Building Code and AISC 360

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Examples of arbitrary (and unnecessary) connection requirements

- "All bolts shall be slip-critical"
- "All connections shall be designed for the full strength of the member"
- "All holes shall be standard sized holes"
- "Single-sided shear connections are prohibited"

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Use R=3 (where permitted)

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Limit tension yield strength ratio to 0.75 for tension members with bolted connections with $A_e > 0.75A_g$

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Limit tension yield strength ratio to 0.75 for tension members with bolted connections*

(*Provided that $A_e > 0.75A_g$)**

(** The use of $A_e = 0.75A_g$ in the AISC Manual Part 5 tension tables is only *an approximation* for bolted connections)

$$\text{Tension yield strength ratio} = \frac{\text{Required strength}}{\text{Tension yield strength}}$$

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Limit tension yield strength ratio to 0.75

D2. TENSILE STRENGTH

The *design tensile strength*, $\phi_t P_n$, and the *allowable tensile strength*, P_n/Ω_t, of tension members shall be the lower value obtained according to the *limit states* of *tensile yielding* in the gross section and *tensile rupture* in the net section.

(a) For tensile yielding in the gross section:

$$P_n = F_y A_g \quad \text{(D2-1)}$$

$$\phi_t = 0.90 \text{ (LRFD)} \qquad \Omega_t = 1.67 \text{ (ASD)}$$

(b) For tensile rupture in the net section:

$$P_n = F_u A_e \quad \text{(D2-2)}$$

$$\phi_t = 0.75 \text{ (LRFD)} \qquad \Omega_t = 2.00 \text{ (ASD)}$$

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Limit tension yield strength ratio to 0.75 for tension members with bolted connections*

(*Provided that $A_e > 0.75A_g$)

(Reduces likelihood that member reinforcement will be required at the net section at connections.)

Steel	Max suggested tension yield strength ratio for connections when Ae ≥ 0.75Ag
A36	1.0
A992	0.81 (use 0.75)
A913 (65)	0.77 (use 0.75)
A913 (70)	0.80 (use 0.75)

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Limit tension member strength ratio

ASTM A36:

Fy = 36 ksi
Fu = 58 ksi

$$\frac{A_e}{A_g} = 1.2\frac{F_y}{F_u} = 1.2\frac{36}{58} = 0.75$$

ASTM A992:

Fy = 50 ksi
Fu = 65 ksi

$$\frac{A_e}{A_g} = 1.2\frac{F_y}{F_u} = 1.2\frac{50}{65} = 0.92$$

ASTM A913 Grade 65:

Fy = 65 ksi
Fu = 80 ksi

$$\frac{A_e}{A_g} = 1.2\frac{F_y}{F_u} = 1.2\frac{65}{80} = 0.98$$

A_e/A_g ratios below which tension rupture strength < tension yield strength

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Limit tension member strength ratio

F_y = 50 ksi
F_u = 65 ksi

Table 5-1 (continued)
Available Strength in Axial Tension
W-Shapes

W14

Shape	Gross Area, A_g	$A_e = 0.75A_g$	Yielding kips		Rupture kips	
			P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$
	in.²	in.²	ASD	LRFD	ASD	LRFD
W14×873[h]	257	193	7690	11600	6270	9410
×808[h]	238	179	7130	10700	5820	8730
×730[h]	215	161	6440	9680	5230	7850
×665[h]	196	147	5870	8820	4780	7170
×605[h]	178	134	5330	8010	4360	6530
×550[h]	162	122	4850	7290	3970	5950
×500[h]	147	110	4400	6620	3580	5360
×455[h]	134	101	4010	6030	3280	4920
×426[h]	125	93.8	3740	5630	3050	4570
×398[h]	117	87.8	3500	5270	2850	4280

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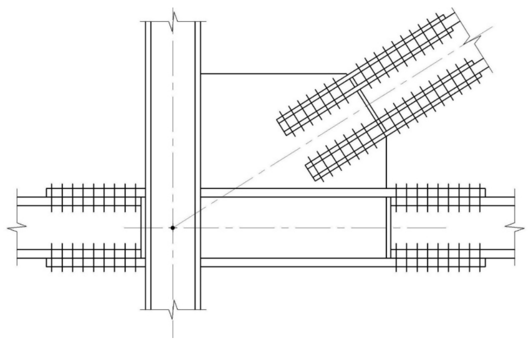
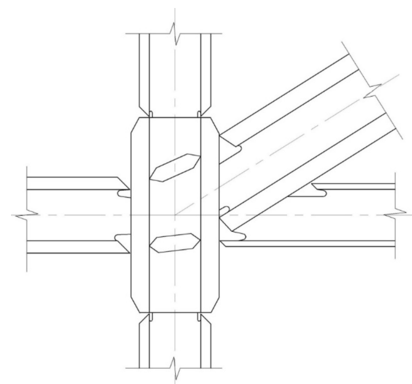
This may happen when tension rupture strength (and other things) are not considered during design…



Concept connection detail ignoring tension rupture strength (as well as other limit states)



Required connection detail

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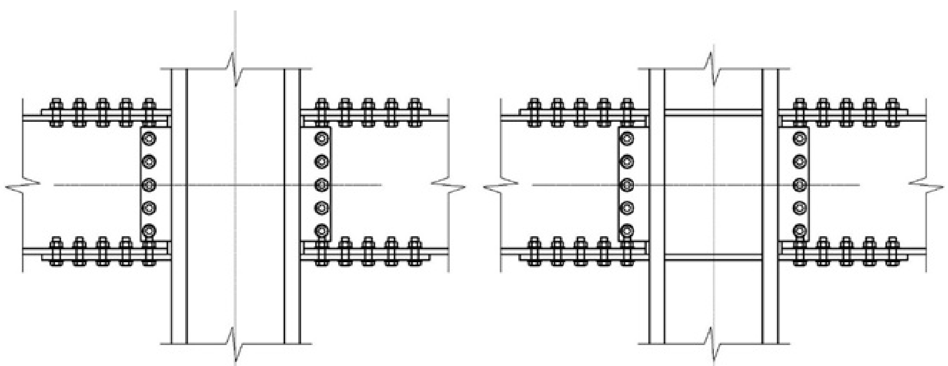
Think about connection economy



- "Least weight" does not always equate with "least cost"
- Stiffener plates and web doubler plates are expensive

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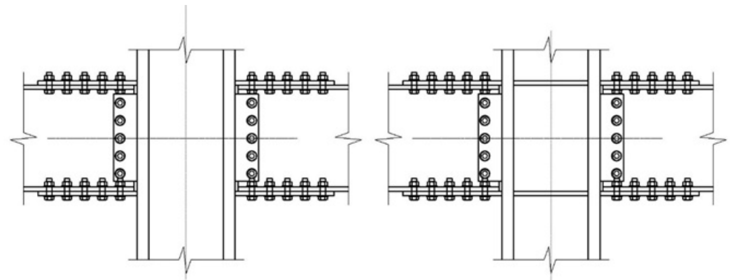
Think about connection economy

How expensive are
stiffeners & doublers?



References,

1. **"Connections: Art, Science, and Information in the Quest for Economy and Safety"** Dr. William Thornton, Engineering Journal, Fourth Quarter 1995
2. **"Stiffeners, Doublers, and Web Plates -- Oh my!"** , Carol Drucker, SE, PE, Peng, AISC Webinar, July 12, 2018 (Available on AISC website)

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Think about constructability and connection "designability"

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Think about constructability and connection "designability"

Connection designability

- How will the connections be designed and detailed?
- Are the connections "designable"?

Constructability

- Will the connections be easy and economical to fabricate?
- Will they be easy to install in the field?

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Connection "designability"

- EOR has options during design
- Configure the framing to improve the "designability" of connections

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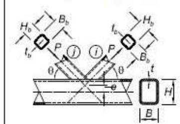
Connection "designability"

- Least weight ≠ least cost with HSS trusses.
- Think about the connections when selecting HSS truss member sizes. (See Part 13 of 15th Edition AISC Steel Construction Manual)

Demand-to-capacity ratio (see next slide)

16.1-156 HSS-TO-HSS MOMENT CONNECTIONS [Sect. K4.

TABLE K3.2 (continued)
Available Strengths of Rectangular HSS-to-HSS Truss Connections

Connection Type	Connection Available Axial Strength
Overlapped K-Connections	Limit State: Local Yielding of Branch/Branches due to Uneven Load Distribution
	$\phi = 0.95$ (LRFD) $\Omega = 1.58$ (ASD)
	When $25\% \le O_v < 50\%$
	$P_{n,i} = F_{ybi} t_{bi} \left[\frac{O_v}{50} (2H_{bi} - 4t_{bi}) + B_{ei} + B_{ej} \right]$ (K3-10)
	When $50\% \le O_v < 80\%$
	$P_{n,i} = F_{ybi} t_{bi} (2H_{bi} - 4t_{bi} + B_{ei} + B_{ej})$ (K3-11)
Note that the force arrows shown for overlapped K-connections may be reversed; *i* and *j* control member identification.	When $80\% \le O_v \le 100\%$
	$P_{n,i} = F_{ybi} t_{bi} (2H_{bi} - 4t_{bi} + B_{bi} + B_{ej})$ (K3-12)
	Subscript *i* refers to the overlapping branch Subscript *j* refers to the overlapped branch
	$P_{n,j} = P_{n,i} \left(\frac{F_{ybj} A_{bj}}{F_{ybi} A_{bi}} \right)$ (K3-13)

Functions

$Q_f = 1$ for chord (connecting surface) in tension

$$= 1.3 - 0.4 \frac{U}{\beta} \le 1.0 \quad \text{(K3-14)}$$

for chord (connecting surface) in compression, for T-, Y- and cross-connections

$$= 1.3 - 0.4 \frac{U}{\beta_{eff}} \le 1.0 \quad \text{(K3-15)}$$

for chord (connecting surface) in compression, for gapped K-connections

$$U = \left| \frac{P_{ro}}{F_c A_g} + \frac{M_{ro}}{F_c S} \right| \quad \text{(K2-4)}$$

where P_{ro} and M_{ro} are determined on the side of the joint that has the lower compression stress. P_{ro} and M_{ro} refer to required strengths in the HSS: $P_{ro} = P_u$ for LRFD, and P_a for ASD; $M_{ro} = M_u$ for LRFD, and M_a for ASD.

$$\beta_{eff} = \left[(B_b + H_b)_{compression\ branch} + (B_b + H_b)_{tension\ branch} \right] / 4B \quad \text{(K3-16)}$$

$$\beta_{eop} = \frac{5\beta}{\gamma} \le \beta \quad \text{(K3-17)}$$

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15th Edition AISC Steel Construction Manual, pages 13-17 & 13-18,

Design Considerations for HSS-to-HSS Truss Connections

HSS member sizes are often critical in connection design. Connection design, including weld requirements in AISC *Specification* Section K5, should be considered during main member selection as the connection limit states may force an increase in the member wall thickness over the main member design thickness. Compression chords should be sized such that the demand-to-capacity ratio is considerably less than one, such that the effects of web members do not cause the face of the chord to be overstressed. At initial design, Packer et al. (2010b) recommends that chords have thick walls rather than thin walls; web members have thin walls rather than thick walls; web members be wide relative to the chord members, but still able to sit on the "flat" face of the chord section if possible; and gap connections (for K and N situations) are preferred to overlap connections because the members are easier to prepare, fit and weld. Where a gap is provided between the web members, the gap should be equal to or greater than the sum of the thicknesses of the web members to facilitate welding. Where web members are overlapped, the thicker web member should run through to the chord, and the overlap length (measured along the connecting face of the

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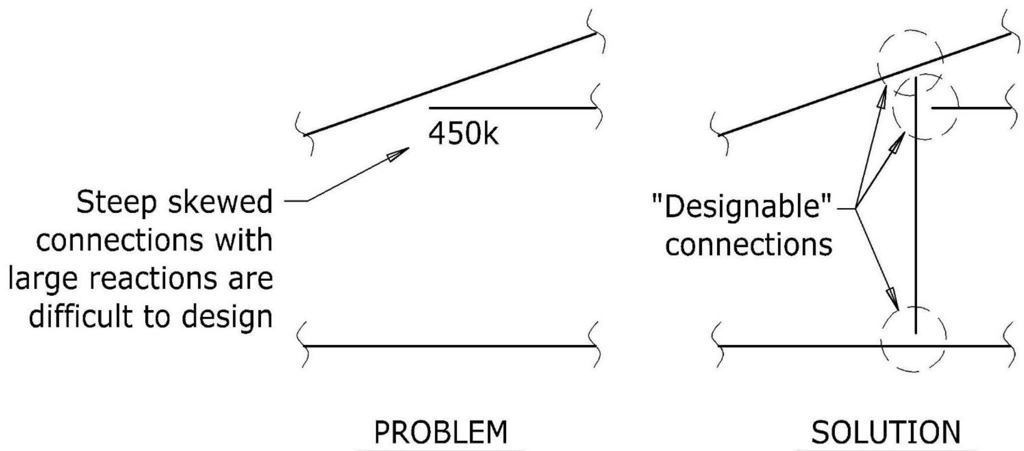
Connection "designability"



Head off steeply skewed connections

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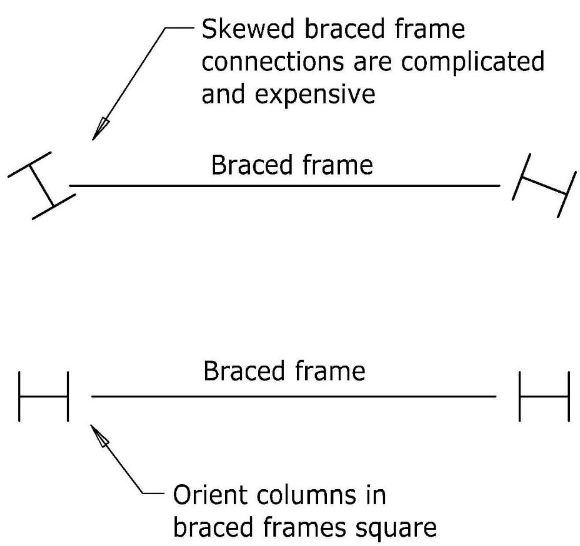
Connection "designability"



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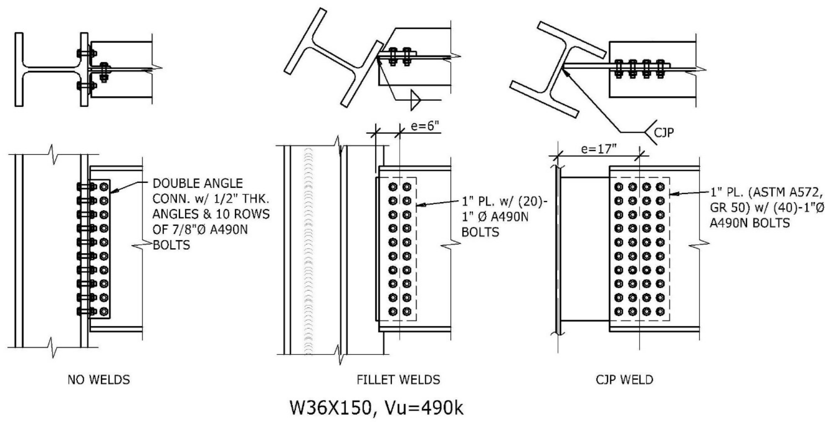
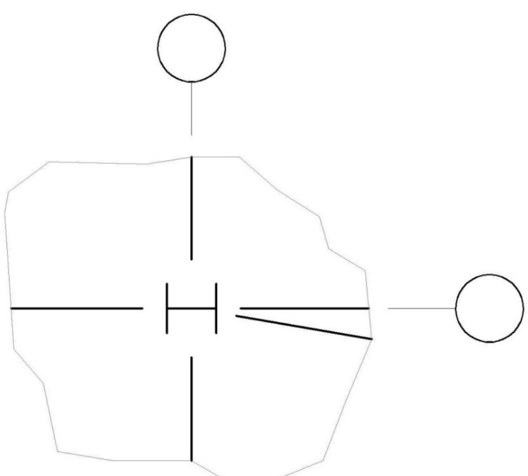
Connection constructability



Orient framing so that heavily loaded members frame square to the columns (preferably square to column flanges)

83

Connection "designability"



Configure framing so that no more than one beam frames to any one side of a column.

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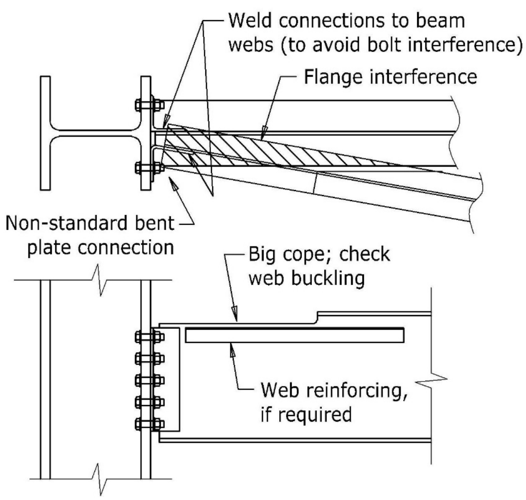
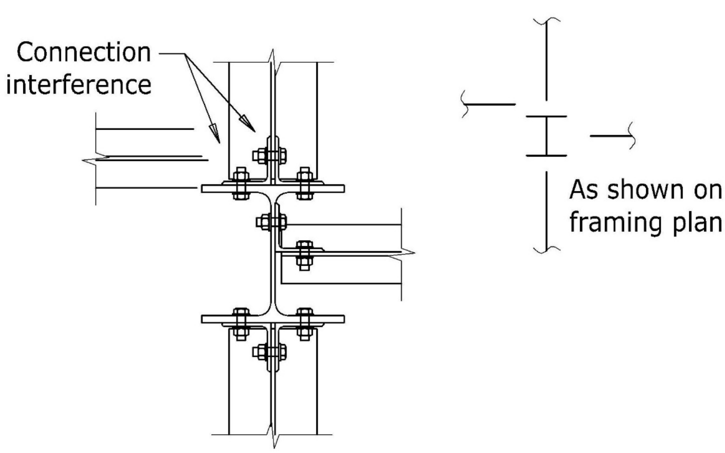
Connection "designability"



Configure framing so that no more than one beam frames to any one side of a column.

85

Connection "designability"



Be aware of connection interference where beams are slightly offset from columns.

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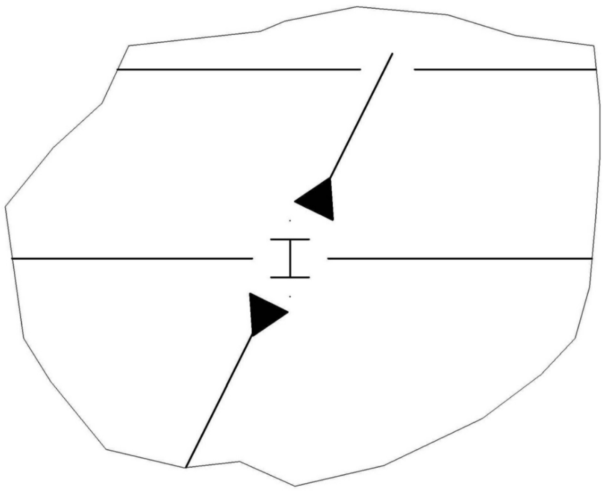
Connection "designability"



Avoid skewed beam-to-column moment connections

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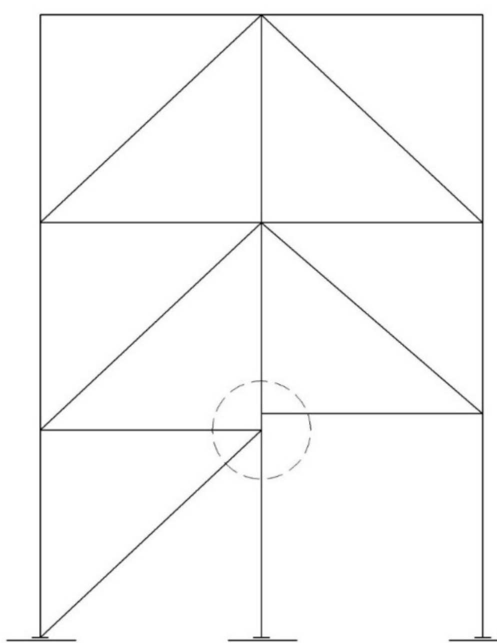
Kinked connections



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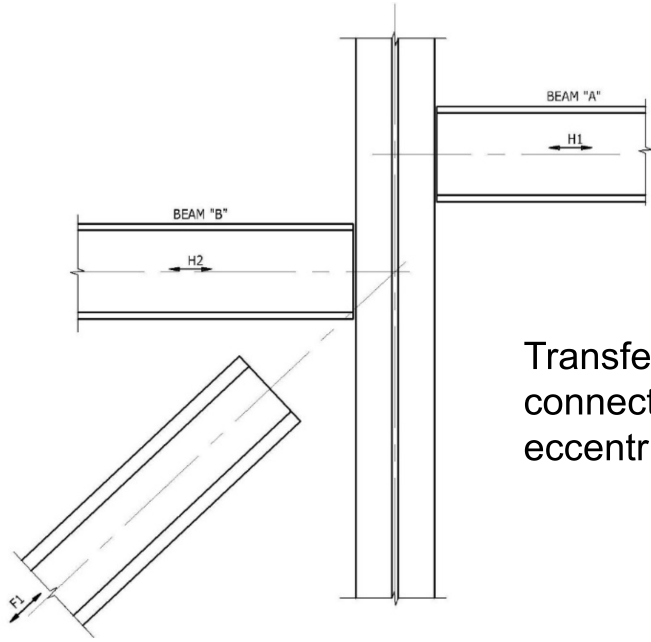
Kinked connections



Transfer forces through connection follow an eccentric load path

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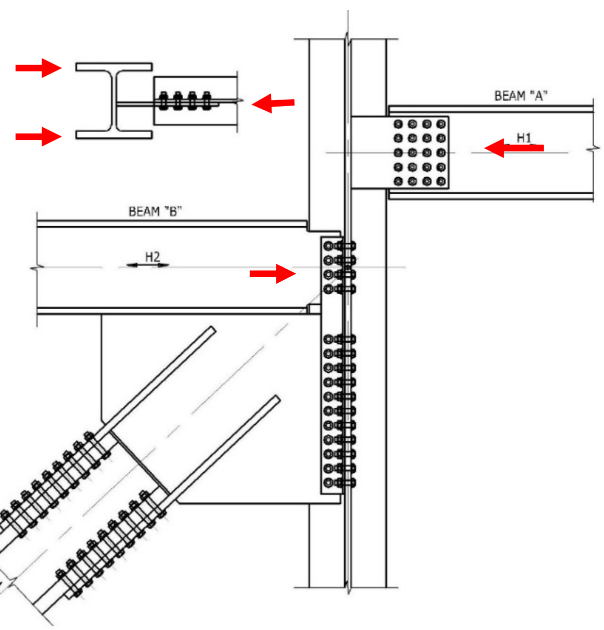
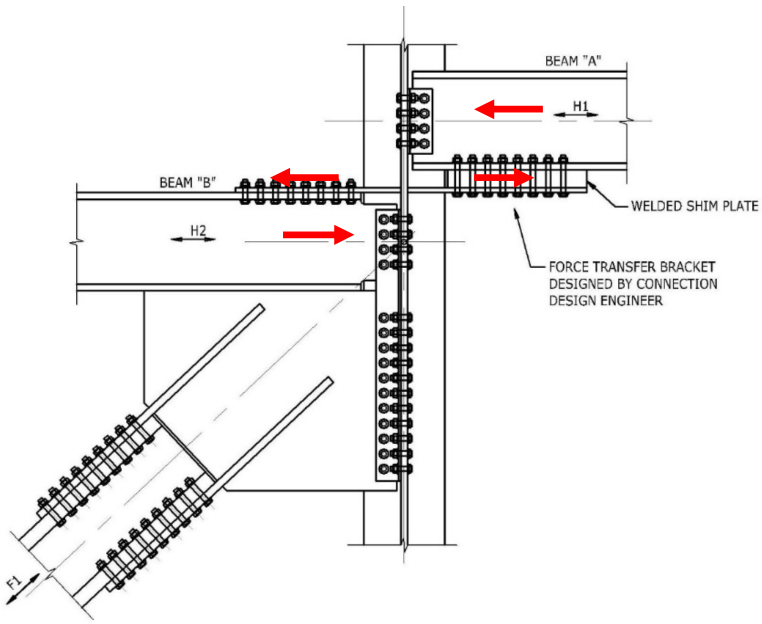
Kinked connections



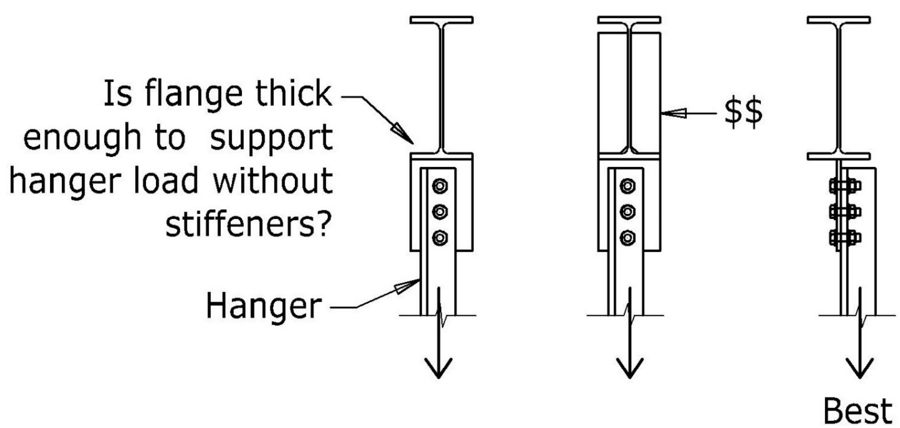
90

Kinked connections



91

Kinked connections



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Kinked connections

SECONDARY STRESSES IN FRAMED STRUCTURES

By E. W. Pittman.*

Secondary 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.

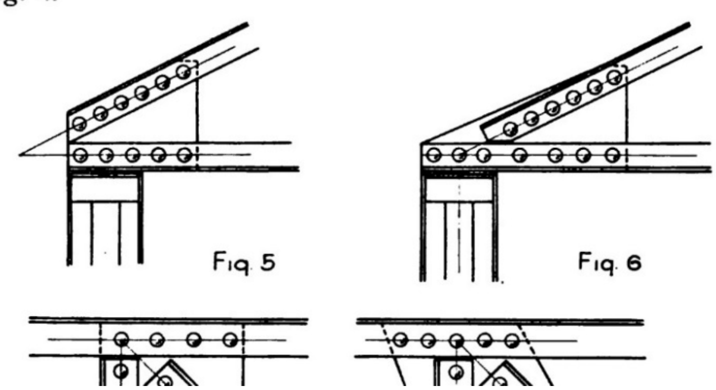
In the case of a pin connected truss, the assumed condi-

*** Chief Engineer, Pittsburgh Steel Construction Co.**
Presented before the Structural Section, January 5, 1909. Address of retiring Chairman.

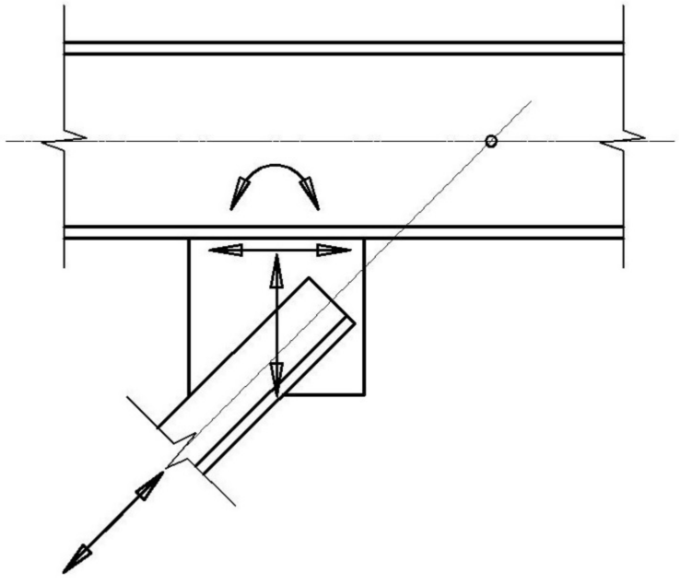
Kinked connections

PITTMAN—SECONDARY STRESSES IN FRAMED STRUCTURES 81

current, but the rivet connection through the chord is eccentric to the intersection of the lines of stress, and a bending moment results. The proper construction of this joint is as shown in Fig. 4.



Kinked connections



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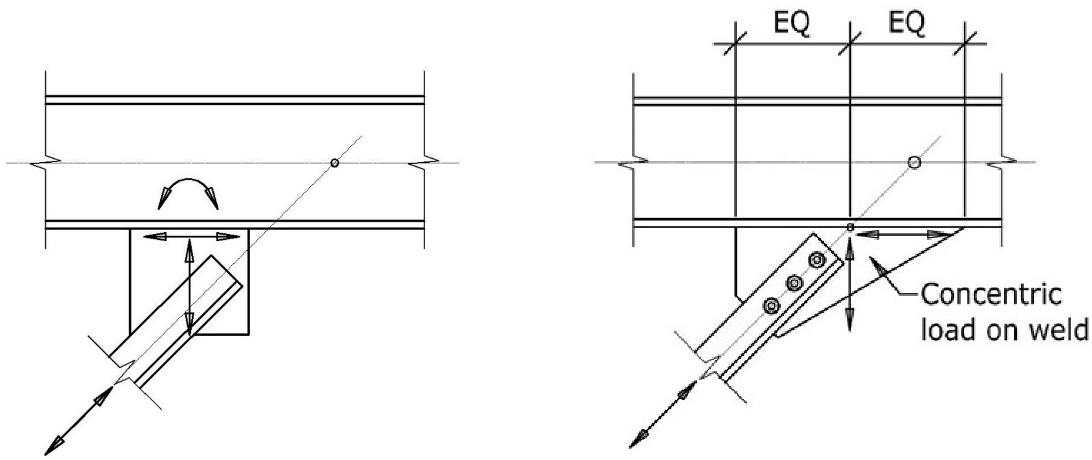
Kinked connections



Preferred detail (no secondary stresses in gusset and weld)

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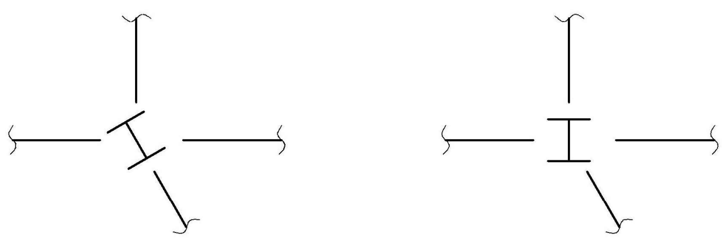
Connection constructability



3 SKEWED CONNECTIONS
1 SQUARE CONNECTION

3 SQUARE CONNECTIONS
1 SKEWED CONNECTION

Square connections cost less than skewed connections.

Orient columns to minimize skewed connections.

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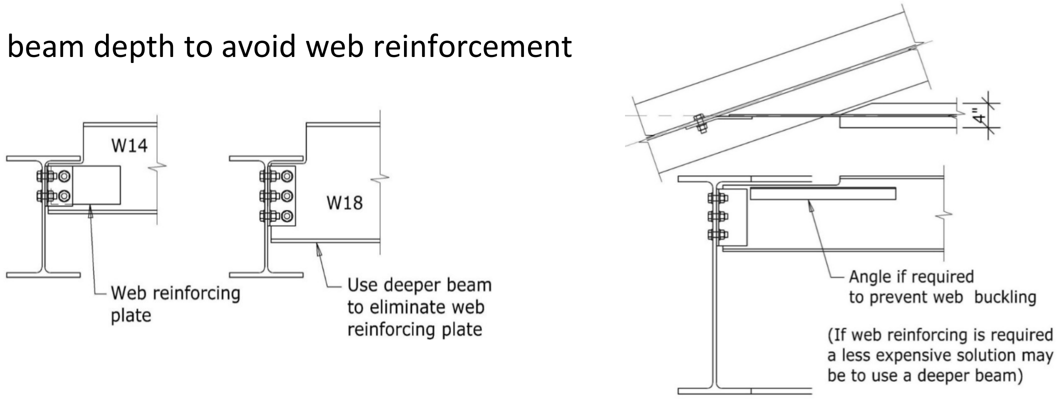
Connection constructability

Increase beam depth to avoid web reinforcement



Possible situations requiring web reinforcing:

- Large copes / heavy reactions
- High beams / low girders
- Skewed beams with long copes

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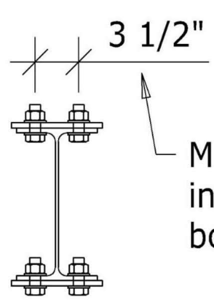
Connection constructability



Min. recommended flange width to install bolts through flange = 6"
(Don't forget to check net section.)

(End-plate moment connections are possible solutions to narrow flange moment connections to columns.)

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Allow fabricators to suggest alternative connection details

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Summary

1. Understand AISC 303-16 rules for delegating connection design
2. Provide **"concept connection details"** (details that work)
3. Provide bidding quantities where member reinforcement at connections is required
4. Consider **constructability and "connection designability"**
5. Look for (and detail) all unusual connections
6. Watch out for **"kinked connections"**
7. Show reactions, axial forces, and moments in moment connections
8. Provide **transfer force** connection design requirements

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Summary

9. Think about **connection economy** when framing the structure
10. Do not mandate connection design requirements in excess of the building code
11. Use R=3 for seismic design (when permitted)
12. Limit tension yield strength ratio to 0.75 in tension members (provided that $A_e > 0.75 \times A_g$)
13. Consider fabricator suggested alternative connection details
14. Issue complete and well-documented drawings. Good communication of design intent requires good drawings (Don't kick the can down the road.)
15. **Always** be thinking about the connections when you frame the structure - even when ***(especially when)*** delegating connection design.

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Thank you!

AISC | Questions?

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Individual Session Registrants

CEU / PDH Certificates

- You will receive an email on how to report attendance from: 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!

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Individual Session Registrants

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.

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8-Session Registrants

CEU / PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.

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8-Session Registrants

Access to the quiz

Information for accessing the quiz will be emailed to you by Wednesday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

Quiz and attendance records

Posted Tuesday mornings. www.aisc.org/nightschool -- Click on Current Course Details.

Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- CEUs/PDHs – If you watch a recorded session, you must pass quiz for CEUs/PDHs.
- REINFORCEMENT – Reinforce what you learn tonight. Get more out of the course.

Note: If you attend the live presentation, you do not have to take the quizzes to receive CEUS/PDHs

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8-Session Registrants

Access to the recording

Information for accessing the recording will be emailed to you by Wednesday. The recording will be available for three weeks. (For 8-session registrants only.) EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

CEUs / PDHs via recording

If you watch a recorded session, you must take *and pass* the quiz for CEUs/PDHs.

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8-Session Registrants

Night School Resources

Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!

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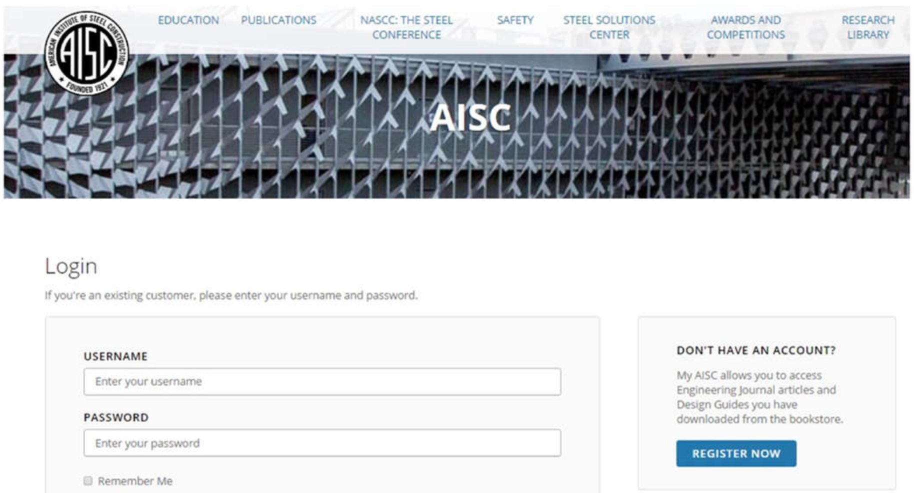
8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.



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8-Session Registrants

Night School Resources

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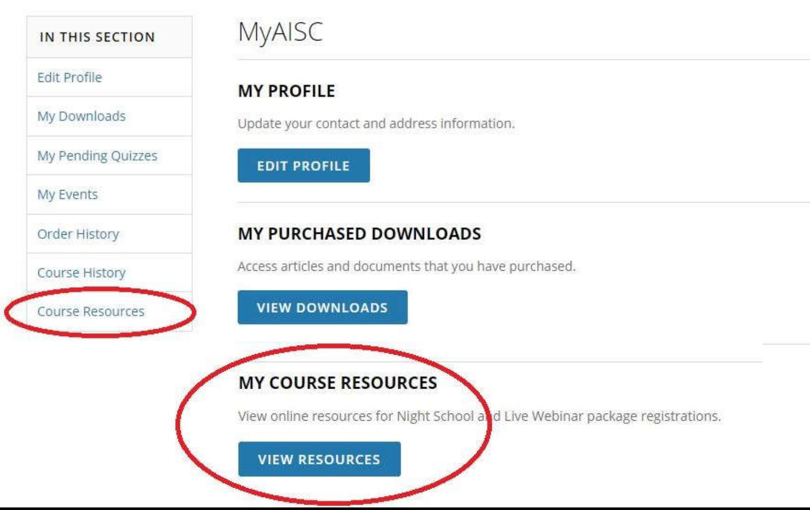

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8-Session Registrants

Night School Resources

AISC > MYAISC > COURSE RESOURCES

Course Resources

Event	Start Date
NS 13 8-Session Package-Night School 13 - Design of Industrial Buildings	1/30/2017 7:00:00 PM
NS 14 8-Session Package-Night School 14 - Fundamentals of Stability	6/5/2017 7:00:00 PM

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8-Session Registrants

Night School Resources

AISC > MYAISC > NIGHT SCHOOL RESOURCES > NS13 8-SESSION PACKAGE RESOURCES

Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending

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Night School Resources

- Weekly "quiz and recording" email.
- Weekly updates of the master quiz and attendance record, found at www.aisc.org/nightschool19. Scroll down to Quiz and Attendance records.
  - Updated on Tuesday mornings.

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8-Session Registrants

Night School Resources

- Webinar connection information
  - Found in your registration confirmation / receipt
  - Reminder email sent out Monday mornings
- Links to handouts also found here

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AISC | Thank you

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