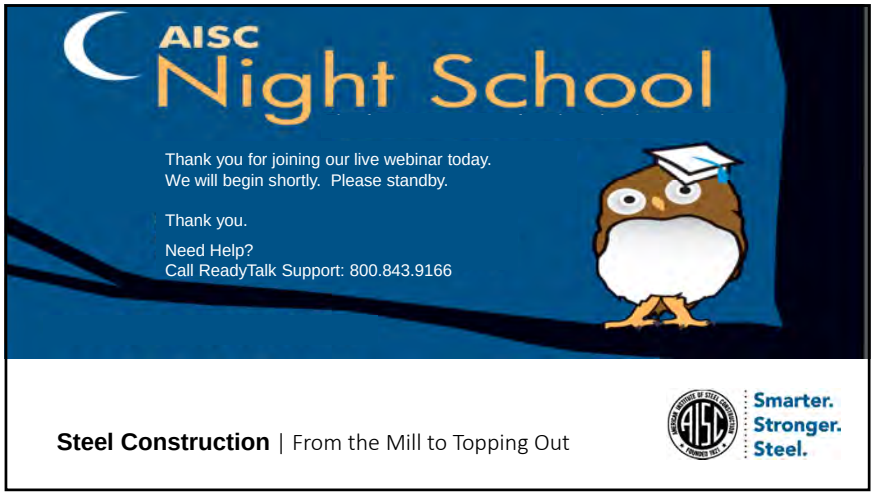

AISC Night School

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AISC Night School Session Description

18.4 Connection Design as the Fabricator's Representative
November 5, 2018

This session provides an overview of the steps taken by a Specialty Structural Engineer when the Structural Engineer of Record delegates design of the connections. Topics include:

- What does the Code of Standard Practice say about connection design
- Critical information provided on design drawings
- Request For Information (RFI) process
- Selection of standard connection types and materials
- Common challenges encountered
- Practical tips to facilitate shop and field efficiencies
- Helpful connection design references

AISC Night School Learning Objectives

- Describe the connection design option 3 found in the Code of Standard Practice.
- List the items required to be included on the design drawing per the Code of Standard Practice.
- Describe common challenges encountered by connection designers.
- List practical tips for constructable connection designs.

Night School 18: Steel Construction

From the Mill to Topping Out
Session 4: Connection Design as the Fabricator's Representative
November 5, 2018

Chad L Fox, PE, SE
Project Manager
Ruby + Associates Structural Engineers
Bingham Farms, MI

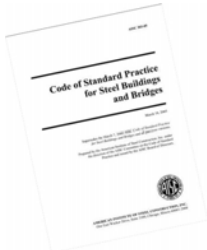
Smarter. Stronger. Steel.

Night School 18

• 18.1 Introduction to the Steel Construction Process	Oct. 15
• 18.2 The Manufacturing of Structural Steel Shapes	Oct. 22
• 18.3 A Virtual, Detailed Tour of the Steel Fabrication Process	Oct. 29
• **18.4 Connection Design as the Fabricator's Representative**	**Nov. 5**
• 18.5 It Doesn't Get Built Without the Erector	Nov. 19
• 18.6 Erection Engineering – Stability During Construction	Nov. 26
• 18.7 Field Fixes and Solutions	Dec. 3
• 18.8 Quality Control and Quality Assurance	Dec. 10

Smarter. Stronger. Steel.

4.1) Introduction



4.2) Code of Standard Practice
4.3) Process during bid phase
4.4) Process during project initiation
4.5) Common Challenges for SSE/Connection Design Engineer
4.6) Shop and Field Efficiencies
4.7) Helpful Resources

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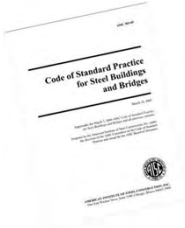
4.2) Code of Standard Practice - Connections

- 16.3 of AISC Manual

'Unless specific provisions to the contrary are contained in the contract documents, the existing trade practices that are contained herein are considered to be the standard custom and usage of the industry and are thereby incorporated into the relationships between the parties to a contract.'

11

Code of Standard Practice(COSP) - Definitions



The ODRD

Owner's Designated Representative for Design

- Engineer of Record (EOR)
- Responsible for structural adequacy of design

The ODRC

Owner's Designated Representative for Construction

- General Contractor (GC)
- Construction Manager (CM)

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Code of Standard Practice - Connections

- 3 Options per COSP Section 3.1.1
  - (1) The complete connection design shall be shown in the structural design drawings. (EOR designs)
  - (2) In the structural design drawings or specifications, the connection shall be designated to be selected or completed by an experienced steel detailer. (Detailer selects from AISC manual standards)
  - **(3A or B) In the structural design drawings or specifications, the connection shall be designated to be designed by a licensed professional engineer working for the fabricator. (Connection design delegated to Professional Engineer representing Fabricator)**

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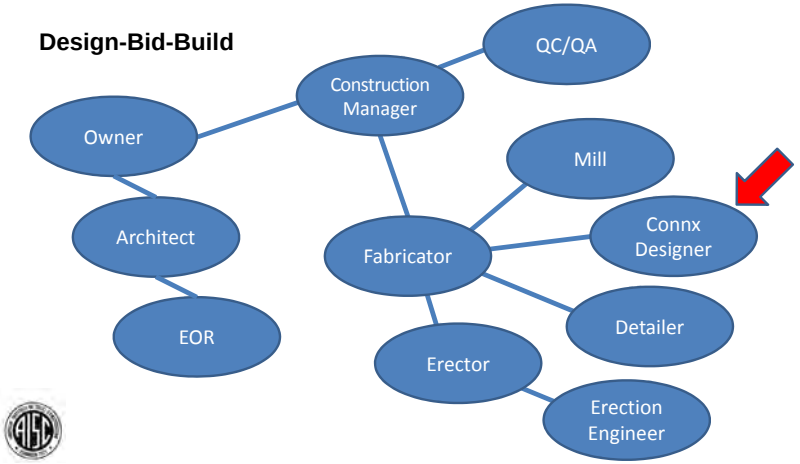
Design-Bid-Build



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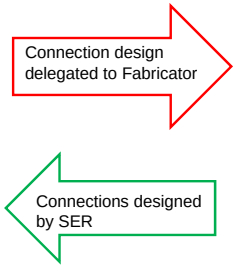
Code of Standard Practice - Connections



15

Code of Standard Practice - Connections

- When choosing Option #3, delegated design, what must the EOR provide per COSP Section 3?
- (3.1.2) Permanent bracing, openings in structural steel for other trades, and other special details….so that the quantity, detail and fabrication requirements for these items can be fully understood.
  - At locations away from connections, stiffeners, web doubler plates, bearing stiffeners, and other member reinforcements, where required shall be designed by ODRD (EOR).
  - At locations of connections, the following requirements shall apply to column stiffeners, web doubler plates, beam bearing stiffeners, and all other member reinforcement required to satisfy strength and equilibrium of forces through the connection:

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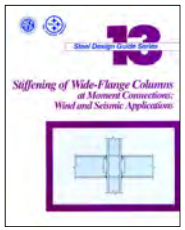
Option 3A/3B – Member Reinforcing Section 3

- Option 3A – EOR designs all member reinforcement at connections
- Option 3B – EOR provides project-specific conceptual details and estimated quantity for bidding purposes
- When actual quantity and/or details varies from those at bidding, contract price and schedule shall be adjusted per Sections 9.4 & 9.5.
- "Clean Columns" may save cost over reinforcing
  - AISC Spreadsheet at www.steeltools.org/column.php



Code of Standard Practice - Connections Section 3

- When choosing Option #3, delegated design, what must the EOR provide per COSP Section 3?
  - (a) Restrictions on the types of connections that are permitted;
  - Commentary: 'There are a variety of connections available in the AISC Steel Construction Manual for a given situation. Preference for a particular type will vary between fabricators and erectors. Stating these limitations, if any, in the structural design drawings and specifications will help to avoid repeat changes to the shop and erection drawings due to the selection of a connection that is not acceptable to the owner's designated representative for design,…
  - (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 shop and erection drawings;

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Code of Standard Practice - Connections Section 3

- Continued - When choosing Option #3, delegated design, what must the EOR provide per COSP Section 3?
  - (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; and,
  - (e) What substantiating connection information, if any, is to be provided with the shop and erection drawings to the owner's designated representative for design.
    - PE Sign and Seal Required? What specifically signed and sealed?

Commentary: 'A requirement to sign and seal each sheet of the shop and erection drawings is discouraged as it may serve to confuse the design responsibilities between the owner's designated representative for design and the licensed professional engineer's work in performing connection design.'

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Code of Standard Practice - Connections Section 4

- Per Option (3), what must the fabricator provide?
  - (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.

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Code of Standard Practice - Connections Section 4

- Per Option (3), what must the fabricator provide?
  - (b) The licensed professional engineer in responsible charge of the connection design shall review and confirm in writing as part of the substantiating connection information, that the shop and erection drawings properly incorporate the connections designs. However, this review by the licensed professional engineer in responsible charge of the connection design does not replace the approval process of the shop and erection drawings 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 shop and erection drawings for the purpose of review.

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Code of Standard Practice - Connections Section 4

- Per Option (3), what must the fabricator provide?
  - (Section 4.2.3) When the fabricator submits a request to change connection details that are described in the contract documents, the fabricator shall notify the owner's designated representatives for design and construction in writing in advance of the submission of the shop and erection drawings. The owners designated representative for design shall review and approve or reject the request in a timely manner.

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COSP Section 4) Approval Documents Summary Section 4

- Owner required to deliver design documents
- Fabricator required to produce approval documents
- Shop detail drawings and E-sheets – or model can be used as approval document and reviewed along with/instead of drawings
- Reviewed by ODRD(EOR) & ODRC (Sec. 4.4)
  - Confirmation fabricator has correctly interpreted contract documents
  - Confirmation ODRD(EOR) has reviewed & approved connection details
  - Release to begin fabrication
- Fabricator still responsible for accuracy of dimensions, general fitup

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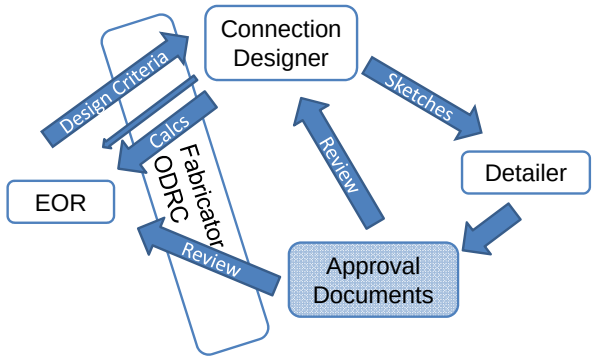
Option 3 – COSP Approval Documents Section 4)



24

Code of Standard Practice – Connections Section 4

- What does the COSP say about the Request for Information (RFI) Process?
  - Section 4.6) When requests for information (RFIs) are issued, the process shall include the maintenance of a written record of inquiries and responses related to the interpretation and implementation of the contract documents, including the clarifications and or revision to the contract documents that result, if any. RFI's shall not be used for the incremental release for construction of design drawings.

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Code of Standard Practice – Connections Section 4

- RFI Commentary Key Points:
  - May be used by the Fabricator or Erector in the event of an error and to develop corrective measures to resolve the errors.
  - Is not intended to replace all verbal communication.
  - Prepared in standardized format including RFI number, dated, author, reference to specific design drawing number or specification section, the needed response date, and a description of a suggested solution, and an indication of the possible schedule and cost impacts.
  - RFI's should be limited to one question each to facilitate the issue and minimize response time.
  - Unless otherwise noted, the fabricator and erector can assume that a response to an RFI constitutes a release for construction.

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4.3) Bid Phase Process

- Fabricator/Erector Team Receives RFP 'Request for Proposal' on a project where Option (3), delegated design, from AISC COSP is chosen for design of connections.

- Send Drawings to Specialty Structural Engineer and ask for Scope and Fee for Connection Design Services.

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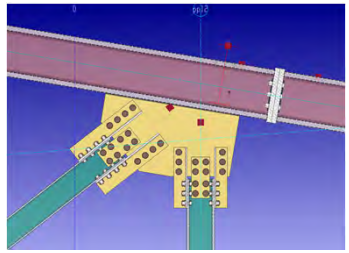
Bid Phase Process

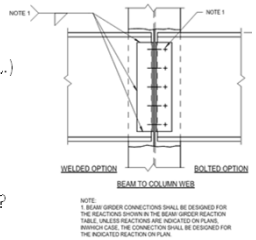
- Specialty Structural Engineer Reviewing & Providing Fee
  - Review with Fabricator which connections will need to be provided.
    - Most fabricators now use some type of detailing software which can run calculations and design a variety of connections.
    - Will detailing software output need to be reviewed and PE sealed?
    - Some fabricators have developed internal standards (simple shear) that have already been verified with supporting calculations.



28

Bid Phase Process

- Design Drawing Review
  - Review General Notes:
    - ASD or LRFD
    - Specific Welding or Bolting requirements (size, grades…)
    - Lateral Load Resisting System (COSP requirement)
  - Review Connection Details:
    - What has already been fully designed by EOR?
    - Did the EOR specifically provide guidance for this project or are details copied from previous project?
    - What details are missing?



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Bid Phase Process

- Design Drawing Review
  - Specific Requirements shown for:
    - Simple shear
    - Moment
    - Bracing
    - Trusses

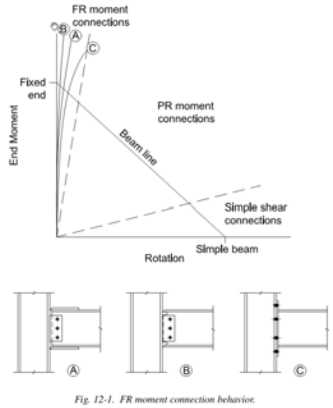

Fig. 12-1. FR moment connection behavior.

30

Bid Phase Process

- Design Drawing Review – Count
  - Framing and Elevation Review
    - Simple Shear:
      - ½ UDL vs Chart vs Specific
      - Look for high shears that may be outside of AISC standards
        - » Stocky Sections
      - Long Copes
      - Skews/Slopes
      - Multiple Members framing into Single location
      - TOS Differences
      - Thru Forces/Axial Loads in Beams

BEAM/ GIRDER REACTION TABLE - LRFD	
SIZE	REACTION
W8x10 THRU W8x35	30k
W8x40 THRU W8x67	38k
W10x12	18k
W10x15 THRU W10x26	24k
W10x30 THRU W10x45	34k
W10x49 THRU W10x60	38k
W10x68 THRU W10x88	53k

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Bid Phase Process

- Design Drawing Review – Count
  - Framing and Elevation Review
    - Bracing:
      - Different Loads
      - Different Sizes
      - Size of Support Beams (following UFM, this changes load distribution)
      - Framing into Column Flange or Web (following UFM, changes load distribution)
      - Options for field welding vs field bolting
      - Node Complexity – 90 degree inframing members

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Bid Phase Process

- Design Drawing Review – Count
  - Framing and Elevation Review
    - Moment Connections:
      - Different Loads
      - Different Beam Sizes (depths, flange widths)
      - Framing into Column Flange or Web
      - Options for field welding vs field bolting
      - Column Stiffeners Required? (COSP)
        - » Clean Columns
      - Node Complexity – 90 degree inframing members

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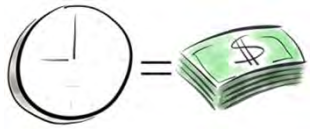
Bid Phase Process

- Design Drawing Review –Count
  - Count Each Connection Type and Assign Time (shear 2hrs, bracing 4hrs..etc)
  - Submit Pricing and Scope
  - Cost Impacts for Connection Designer
    - Lack of Information – results in many RFI's
    - Lack of Clarity – RFI's, multiple iterations
    - Obvious errors in EOR design
    - Repetition in Member sizes and Forces
    - Member Reinforcement (web doublers, column stiffeners) …cascading effect



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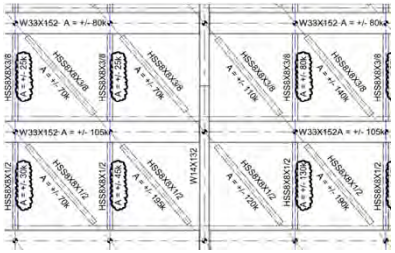
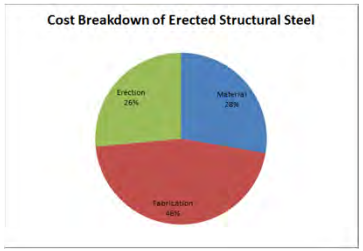
Bid Phase Process

- Design Drawing Review – Count Example





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4.4) Beginning Project

- Fabricator/Erector Team Awarded project and selects Specialty Structural Engineer for Connection Design
- Process for Connection Designer following project award

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Project Process

- Request for Information (RFI)
  - Loading Clarity
    - If shears seem excessive, request for actual loading
    - Complicated nodes – Envelope Forces
    - Loading provided does not reach equilibrium
    - Loads missing
  - Lateral Load System Identified
    - COSP Section 7.10: EOR shall identify:
      - "The LFRS and connecting diaphragm elements that provide for lateral strength and stability in the completed structure"

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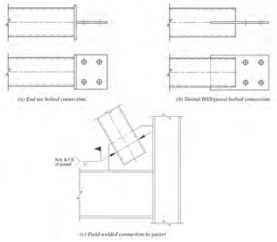
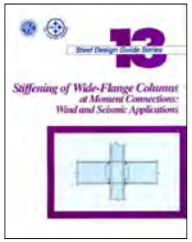
Project Process

- Request for Information (RFI)
  - Request for Alternates (Fabricator and Erector Efficiencies)
    - Field Bolted
    - Upsizing members (clean columns, high shears)
  - Clarity and Confirmation on Connection Types





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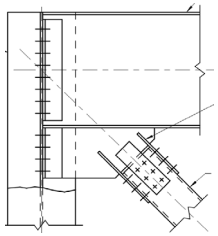
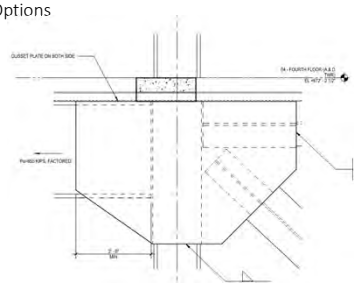
Project Process

- Request for Information (RFI)
  - Work Point Verifications
  - Eccentricities
  - Sample Concepts for Complicated Nodes/Options





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Project Process

- Fabricator Preferences
  - Preferred Simple Shear
    - Single angles, shear tabs (one sided)
    - Double angles (2 sided)
    - End Plates (2 sided)
    - Hole Types

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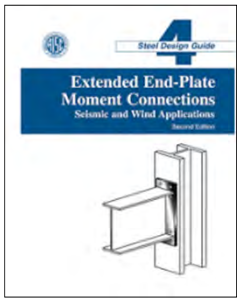
Project Process

- Fabricator Preferences
  - Preferred Moment Connection
    - Flange Plates (fills)
    - End Plates
    - Field Welded or Bolted
    - If bolted, then bolt and hole
      - STD, OVS
      - Bearing or Slip Critical



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Project Process

- Fabricator Preferences
  - Bracing
    - Bolted Options
    - Bolt Type & Hole Type
      - STD & Bearing vs OVS & SC
  - Bolt Selection
    - Typically (2) different… ie ¾" DIA ASTM F3125 Gr A325(Group A) & 1" DIA ASTM F3125 Gr A490 (Group B)
    - Separated by ¼" difference in diameter minimum
      - Avoid field Installation Errors
    - Installation Method …affects clearances
  - Repetitive Material Preferences

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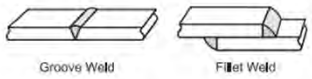
Project Process

- Fabricator Preferences
  - Welds
    - Fillet
      - Maximum single pass fillet weld size (typically 5/16")
      - ¾" Maximum size before PJP
    - Partial Joint Penetration (PJP)
      - Shop preference
      - Prequalified Procedures Available
      - Process = Effective (E) Size
    - Complete Joint Penetration (CJP)
      - Shop preference
      - Prequalified Procedures & Qualified Personnel Available



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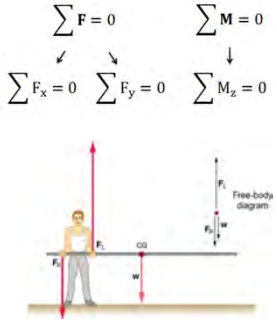
4.5) Common Challenges

- Describe some of the common issues connection designer encounters when performing design.
- Need to Know: (COSP)
  - Loads
  - Load Path…free body diagrams
  - Work Points
  - Design Restrictions



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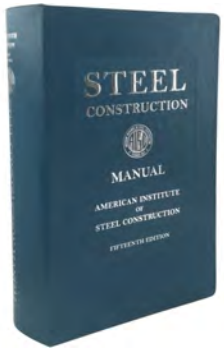
Connection Design Challenges

- Limit States – What needs to be checked? (Ch J)
  - Welds (J2)
    - Base Metal
    - Weld Metal
  - Bolts (J3)
    - Tensile & Shear Strength
    - Slip Critical Connections
    - Bearing
  - Connecting Elements (J4)
    - Tension Yielding & Rupture
    - Shear Yielding & Rupture
    - Block Shear
    - Compression Yielding & Buckling
    - Flexure



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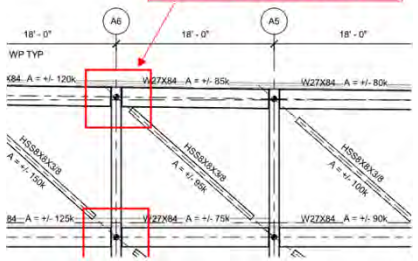
RFI: Loading Verification

Connection Design Challenges

- Envelope Loading

Are there transfer forces across these nodes?

What is the magnitude of the transfer forces at each node?



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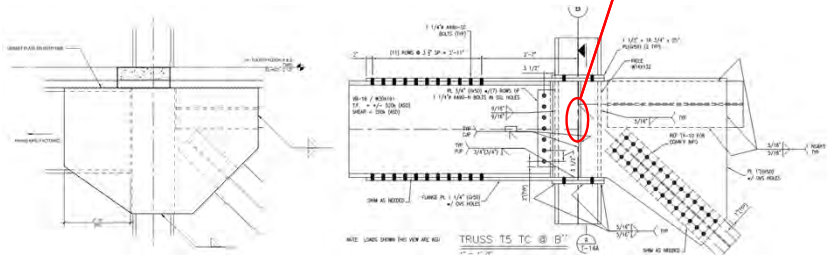
Connection Design Challenges

- Eccentric Worklines

A = 520k
e = 8 in
M = 347 ft-k to where?



RFI: Work Line Verification
RFI: Loading Verification

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Connection Design Challenges

- Long Copes
  - Smaller beams, W8, W10 framing into larger girders with wide flanges.
  - Limited room for connection material
  - Flexural buckling of coped section
  - Block Shear of Coped Section
  - May require web reinforcement
  - Reference Part 9 of Manual

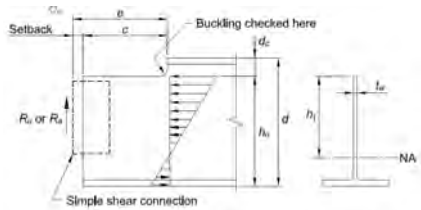

Fig. 9.2. Flexural local buckling of beam web coped at top flange only.

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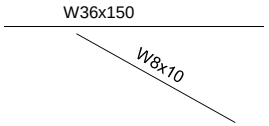
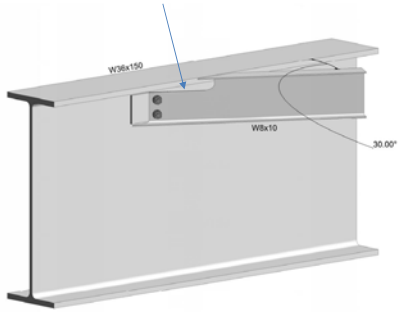
Connection Design Challenges

- Long Cope Example - Skew



Plan View

Cope Length = 12"
tw = 0.17"



Isometric View

RFI: Shape Substitution

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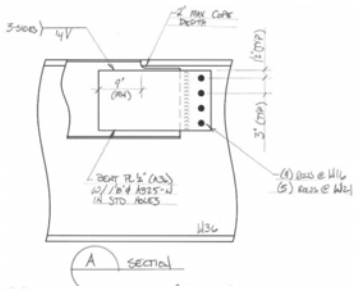
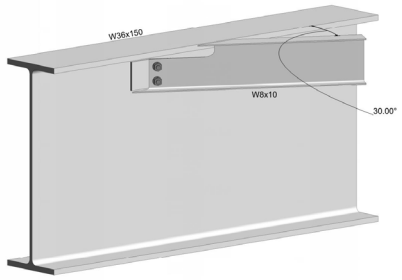
Connection Design Challenges

- Long Cope Example – Bent PL Connection Reinforces



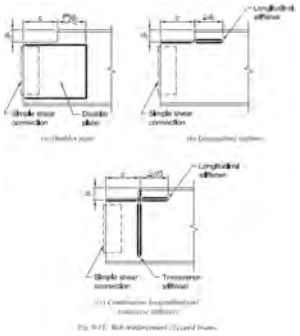


Isometric View

50

Connection Design Challenges

- Long Copes – AISC Manual Guidance, Part 9



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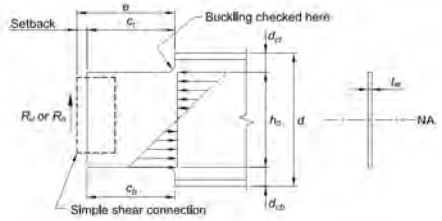
Connection Design Challenges

- Double Copes
  - In-framing members of equal or deeper section set.
  - Block Shear of Coped Section
  - May Require Web Reinforcement
  - Reference Part 9 Manual



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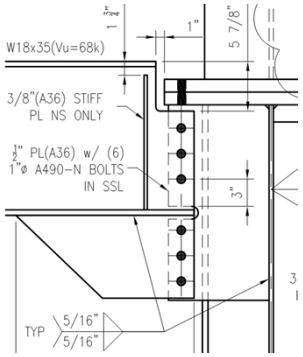
Connection Design Challenges

- High Shear
  - ½ UDL Short Beams
  - Stocky Section
  - May Require Web Reinforcement
  - May Require Multiple Bolt Columns
  - May Require Extension Below Flange

RFI: Actual Loads



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Connection Design Challenges

- Skewed Beams
  - Shear Tabs or Extended Shear Tabs up to 45 degrees
    - Reference AISC Table 10-14C for Welds for plates up to 5/8"
  - Bent Plate over 45 degrees
    - Limitation on plate thickness
  - Can Result in long copes
  - Watch bolt clearances
  - Skews into columns
    - Access Issues
    - Adjust Work Points – EOR RFI (example)

RFI: WP Adjustment

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Connection Design Challenges

- Beam to Girder Connections – Top of Steel Differences
  - Beam Frames in Above/Below Girder
    - Reduced Section – May Require Reinforcement for Bending and/or Shear
    - Seated Options – Knife PL, 2L

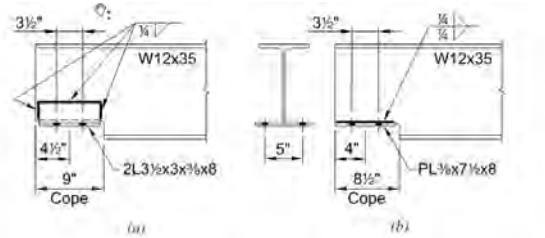

Fig 10-32

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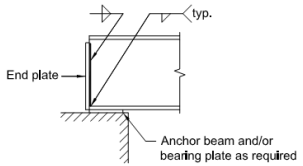
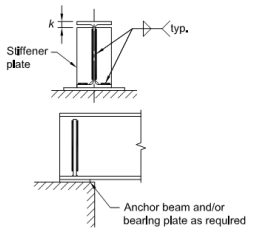
Connection Design Challenges

- Beam to Girder Connections – Top of Steel Differences
  - Beam Ends Bearing @ Bottom Flange
    - Caution: Top Flange Stability May Require Stiffener per AISC Section J10.7 & discussed in Part 2 of Manual.



(b) Stability provided with an end plate



(a) Stability provided with transverse stiffeners

Fig. 2-1. Beam end supported on bearing plate.

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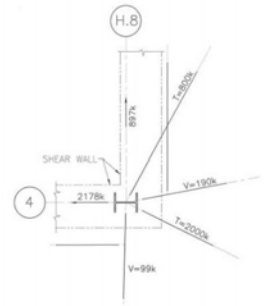
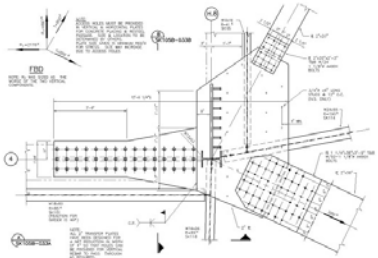
Connection Design Challenges

- Multiple Members @ Nodes – Example #1

RFI: Envelope Loading





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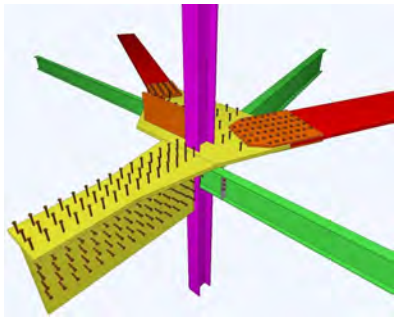
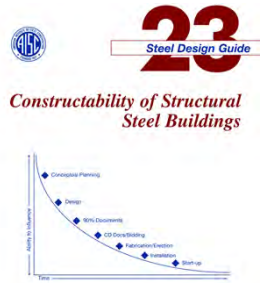
Connection Design Challenges

- Multiple Members @ Nodes – Example #1





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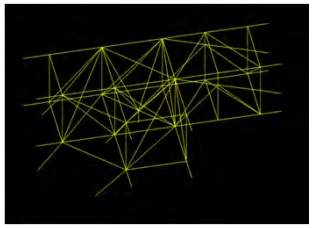
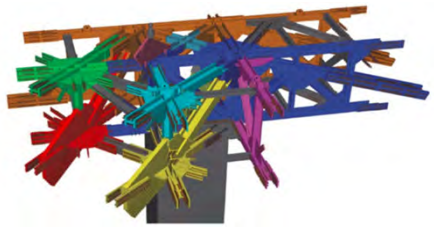
Connection Design Challenges

- Multiple Members @ Nodes – Model vs Reality
  - Use of BIM to help visualize





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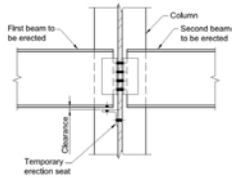
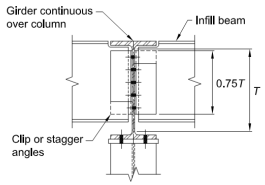
Connection Design Challenges

- Erectability Issues
  - Opposing beams framing into girders over columns or into column webs
    - OSHA Requirements
      - Included in Part 2 Manual
        - » Minimum Bolts
        - » Safety Connections





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Connection Design Challenges

- Erectability Issues
  - Column Base Plates
    - OSHA requirements for Freestanding Column
      - (4) Anchor Rods
      - 300 lbs @ 18" from Outer Face
      - Design Load Combination

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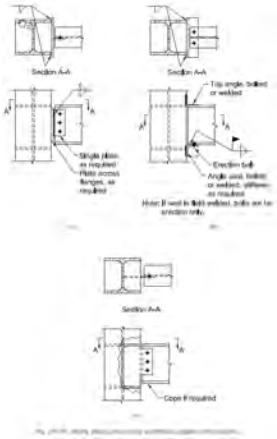
Connection Design Challenges

- Working Around Column Stiffeners
  - Limits Connection Types
  - Erectability Issues
  - Limits Bolt and Weld Access
  - Limits Connection Depths
  - Part 10 for Extended Shear Tabs
    - Discusses Eccentric Effect of Extended



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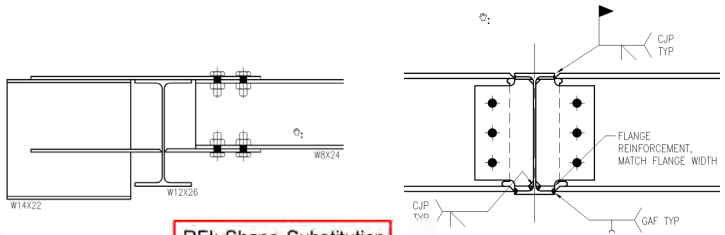
Connection Design Challenges

- Moment Connections
  - Moments thru Girders
    - Different Depths
    - 4" Flanges – No Room for Bolts(W12 & Shallower)



RFI: Shape Substitution

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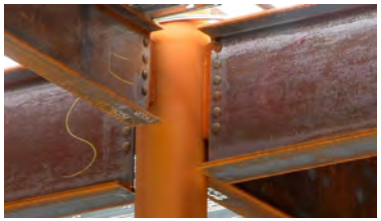
Connection Design Challenges

- Axial Loads in Beams & Girders
  - 2L or Extended Shear Tab for Smaller Axial
    - Watch Prying in 2L
    - Watch Bolt Hole Types for Bearing Bolts
  - Engage Flanges for Larger Axial Loads, ref AISC J3.2 for bolt hole types
    - Flange Plates
    - End Plates
    - EOR guidance



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4.6) Shop & Field Efficiencies

- Connection Materials
- Repetition
- Bolting
- Welds
- Clearances
- Shear Connections
- Moment Connections
- Bracing

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Shop & Field Efficiencies - Connections

- Wide Flange (WT) – ASTM A992
- A36 still default steel for:
  - Standard and Misc. I shapes
  - Channels and MCs
  - Angles
- Plate
  - ASTM A36 or ASTM A572 Gr. 50
  - Often no surcharge for 50 ksi plate
  - No reason not to take advantage of it!

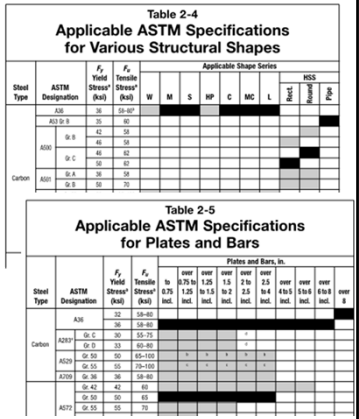

Table 2-4
Applicable ASTM Specifications for Various Structural Shapes

Steel Type	ASTM Designation	F_y Yield Stress* (ksi)	F_u Tensile Stress* (ksi)	Applicable Shape Series: W	M	S	HP	C	MC	L	HSS: Rect.	HSS: Round	Pipe
Carbon	A36	36	58–80[a]		■			■					■
	A53 Gr. B	35	60										
	A500 Gr. B	42	58										
	A500 Gr. C	46	58										
	A501	50	62								■	■	■
	Gr. A	36	58										
	Gr. B	50	70										

Table 2-5
Applicable ASTM Specifications for Plates and Bars

Steel Type	ASTM Designation	F_y Yield Stress* (ksi)	F_u Tensile Stress* (ksi)	Plates and Bars, in.: to 0.75 incl.	over 0.75 to 1.25 incl.	over 1.25 to 1.5 incl.	over 1.5 to 2 incl.	over 2 to 2.5 incl.	over 2.5 to 4 incl.	over 4 to 5 incl.	over 5 to 6 incl.	over 6 to 8 incl.	over 8
Carbon	A36	32	58–80										
		36	58–80										
	A283 Gr. C	30	55–75						[a]				
	A283 Gr. D	33	60–80						[a]				
	A529 Gr. 50	50	65–100	[a]	[a]	[a]	[a]	[a]	[a]				
	A709 Gr. 50	50	65–100	[a]	[a]	[a]	[a]	[a]	[a]				
	A709 Gr. 36	36	58–80										
	A572 Gr. 42	42	60										
	A572 Gr. 50	50	65										
	A572 Gr. 55	55	70										

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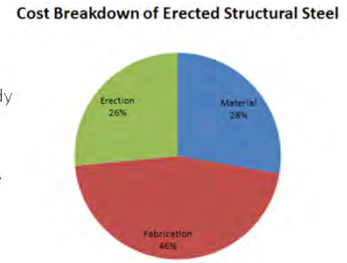
Shop & Field Efficiencies - Connections

- Shapes - Repetition
  - Utilize a couple 'groups' of angles, plates, WT shapes…may be overdesigned but more efficient overall
  - Note WT = Half W Shape, look for W shapes already used
  - Stiffeners & Plates
    - Maintain the same width, full width stiffeners not always needed
    - Full depth stiffeners not always needed
    - Standard Bar sizes, minimize cutting



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Shop & Field Efficiencies - Connections

- Field Work
  - Move as much of the fit-up and assembly time to shop
    - Typically means shop welding or bolting, field bolting
    - Be aware of shipping restrictions
      - May be able to shop attached - weld or bolt short cantilevers & similar framing

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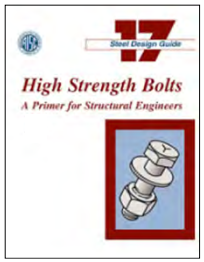
Shop & Field Efficiencies - Connections

- Bolting
  - Know the different advantages/disadvantages of Bearing vs SC bolts
    - Bearing
      - Advantages:
        - » Higher capacity
        - » Easier, cheaper to install
        - » Gr A325 re-used if not pretensioned
        - » Depending on installation technique - less access required for installation
      - Disadvantages:
        - » Bolt Hole Type Limitations – impacts erectability
        - » May not be suitable for load reversals/cyclical fatigue



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Shop & Field Efficiencies - Connections

- Bolting - continued
  - Slip Critical
    - Advantages
      - » May be used with all hole types
      - » Easier to erect
      - » Load reversals
    - Disadvantages
      - » Higher cost to install
      - » Faying surface preparation (and protection) required for installation; outlined in RCSC
      - » Lower capacities
      - » May not re-use Gr A490 bolts

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Shop & Field Efficiencies - Connections

- Welding
  - Fillets
    - Preferred by Fabricators
    - Cost efficient up to about 3/4"
    - Typically no 'cutting' prep required
    - Single Pass if possible

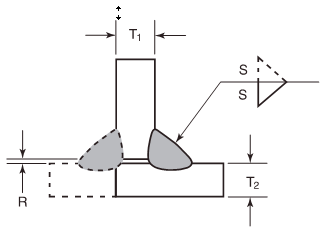

Table 8-12
Approximate Number of Passes for Welds

Weld Size* in.	Fillet Welds	Single-Bevel Groove Welds (Back-Up Weld not Included)		Single-V Groove Welds (Back-Up Weld not Included)		
		30 Bevel	45 Bevel	30 Groove Angle	60 Groove Angle	90 Groove Angle
1/4	1	–	–	–	–	–
5/16	1	1	1	2	3	3
3/8	1	1	1	2	3	3
1/2	3	2	2	3	4	6

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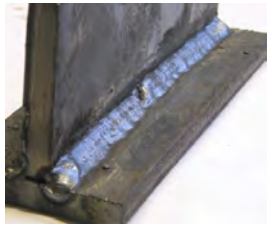
Shop & Field Efficiencies - Connections

- Welding
  - Make sure to use AISC J2.4 equation J2-5 (linear weld group increase based upon resultant load direction)
    - » (J2-5) $0.60F_{EXX}(1.0 + 0.50\sin^{1.5}(\theta))$



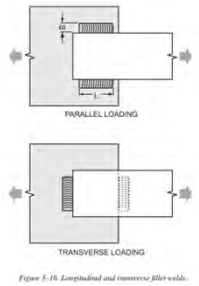


Figure 3-16. Longitudinal and transverse fillet welds.

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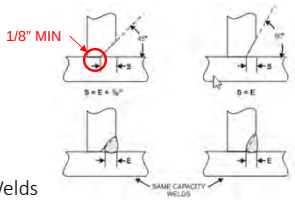
Shop & Field Efficiencies - Connections

- Welding
  - Partial Joint Penetration
    - Typically Preferred by Fabricators over CJP
    - Base material prep required
    - AISC Design Table 8.2 Shows Prequalified Welds
    - Effective weld thickness(Groove welds) depends upon weld process & angle
      - » Reference AISC Spec Table J2.1 – from Specification
    - Many times more efficient for fabricator to provide a groove weld with 1/8" land and increased material thickness than smaller thickness and CJP groove weld.
      - » No Backer for PJP



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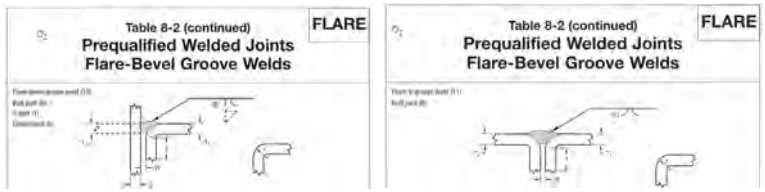
Shop & Field Efficiencies - Connections

- Welding
  - Partial Joint Penetration – Flare Groove Welds
  - Common at HSS Sections
  - Effective Weld (E) is a Function of Welding Process & Material Radius (which is a function of base material thickness)
    - Ref Table J2.2



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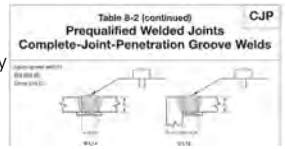
Shop & Field Efficiencies - Connections

- Welding
  - Complete Joint Penetration
    - Most Expensive for Fabricator
      - Cutting prep required
      - Backer Bars
      - Weld Inspection
      - AWS highly trained and certified welders
    - AISC Design Table 8.2 Shows Prequalified Welds
    - Easy for Designer, Capacity = Base Metal Capacity

Courtesy of Williams Enterprises



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Shop & Field Efficiencies - Connections

- Clearances
  - Welding Clearance
    - Min degree for access Ref Fig 8-11
  - Minimum Shelf for Fillets, Fig 8-14

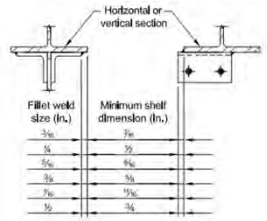

Fig. 8-13. Recommended minimum shelf dimensions for SMAW fillet welds.

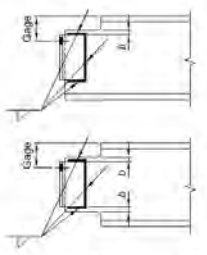

Fig. 8-14. Illustration of shelf dimensions for fillet welding.

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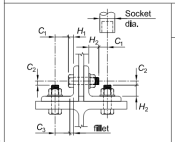
Shop & Field Efficiencies - Connections

- Bolting Clearances
  - Caution on Spacing, J3.2 = 2 2/3 x d, 3 x d recommended
  - Watch fillet radius of rolled shapes Reference AISC Table 7-14, 7-15 & 7-16

Table 7-15
Entering and Tightening Clearance, in.
ASTM F3125 Heavy Hex Bolts (A325 and A490)

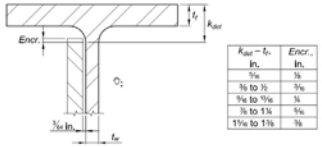
Aligned Bolts



Nominal Bolt Dia.	Socket Dia.	H_1	H_2	C_1	C_2	C_3 Circular	C_3 Clipped
5/8	2 1/8	25/64	1 1/4	1 3/16	1 1/16	1 1/16	5/8
3/4	2 1/8	15/32	1 3/8	1 3/16	3/4	3/4	1 1/16
7/8	2 1/4	35/64	1 1/2	1 1/4	7/8	7/8	1 3/16
1	2 1/2	39/64	1 3/4	1 3/8	15/16	1	7/8
1 1/8	2 3/4	11/16	2	1 1/2	1 1/16	1 1/8	1
1 1/4	3 1/8	25/32	2	1 13/16	1 1/8	1 1/4	1 1/8
1 3/8	3 1/2	27/32	2 1/4	1 7/8	1 1/4	1 3/8	1 1/4
1 1/2	3 3/4	15/16	2 1/4	2	1 5/16	1 1/2	1 3/8

Shop & Field Efficiencies - Connections

- Clearances
  - Material
    - Tight/Restricted Spaces
    - Riding the fillet allowance
    - Minimum Edge Distances



$k_{det} - t_f$, in.	Encr., in.
5/16	1/8
3/8 to 1/2	3/16
9/16 to 15/16	1/4
5/8 to 1 1/4	5/16
1 5/16 to 1 1/2	3/8

Fig. 10-3. Fillet encroachment (riding the fillet).

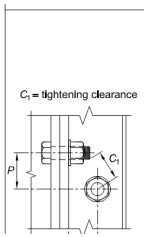
TABLE J3.4
Minimum Edge Distance [a] from Center of Standard Hole [b] to Edge of Connected Part
in.

Bolt Diameter	Minimum Edge Distance
1/2	3/4
3/4	1
7/8	1-1/8
1	1-1/4
1-1/8	1-1/2
1-1/4	1-5/8
Over 1-1/4	1-1/4 x d

[a] If necessary, lesser edge distances are permitted provided the applicable provisions from Sections J3.10 and J4 are satisfied, but edge distances less than one bolt diameter are not permitted without approval from the engineer of record.
[b] For oversized or slotted holes, see Table J3.5.

Shop & Field Efficiencies - Connections

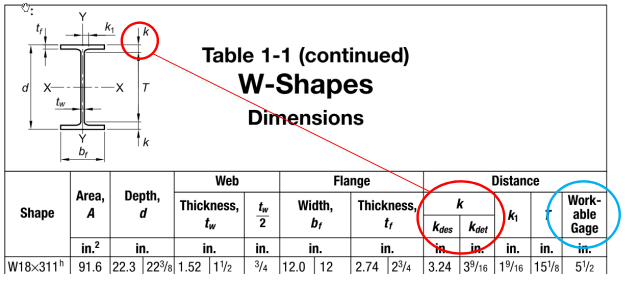
- Clearances
  - Material
    - Staggering, Table 7-15



F	Stagger P, in. — Nominal Bolt Diameter, in. 5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
1 1/4	1 5/8	1 13/16	2	–	–	–	–	–
1 3/8	1 1/2	1 3/4	1 15/16	2 1/4	–	–	–	–
1 1/2	1 1/2	1 9/16	1 7/8	2 3/16	2 1/2	–	–	–
1 5/8	1 7/16	1 9/16	1 11/16	2 1/8	2 7/16	–	–	–
1 3/4	1 3/8	1 1/2	1 11/16	2 1/16	2 3/8	–	–	–
1 7/8	1 5/16	1 7/16	1 5/8	1 7/8	2 5/16	2 7/8	3 1/16	–
2	1 1/4	1 3/8	1 9/16	1 7/8	2 1/4	2 13/16	3	3 5/16
2 1/8	1 1/8	1 5/16	1 1/2	1 13/16	2 1/16	2 7/16	2 15/16	3 1/4
2 1/4	1 5/16	1 3/16	1 7/16	1 3/4	2 1/16	2 7/16	2 7/8	3 3/16
2 3/8	1 1/16	1	1 5/16	1 3/4	2	2 3/8	2 9/16	2 3/4

Shop & Field Efficiencies - Connections

- Dimensioning
  - Use Kdet for clearances, Kdes for calculations
  - Standard 'Workable Gage' for W-Shape, WT & Angles

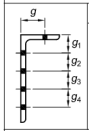


Shape	Area, A	Depth, d	Web Thickness, t_w	$\frac{t_w}{2}$	Flange Width, b_f	Flange Thickness, t_f	Distance k k_{des}	Distance k k_{det}	k_1	T	Work-able Gage
	in.^{2}	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
W18×311[h]	91.6	22.3	22 3/8	1.52	1 1/2	3/4	12.0	12	2.74	2 3/4	3.24	3 9/16	1 9/16	15 1/8	5 1/2

Shop & Field Efficiencies - Connections

- Dimensioning
  - Standard 'Workable Gage' for W-Shape, WT & Angles

Table 1-7A
Workable Gages in Angle Legs, in.

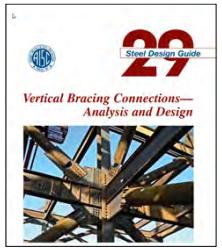


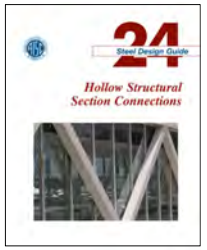
Leg	12	10	8	7	6	5	4	3½	3	2½	2	1¾	1½	1⅜	1¼	1
g	6	5	4½	4	3½	3	2½	2	1¾	1⅜	1⅛	1	⅞	⅞	¾	⅝
g1	3	3	3	2½	2¼	2	–	–	–	–	–	–	–	–	–	–
g2	2½	2½	3	3	2½	2	–	–	–	–	–	–	–	–	–	–
g3	2½	2½	–	–	–	–	–	–	–	–	–	–	–	–	–	–
g4	2½	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note: Other gages are permitted to suit specific requirements subject to clearances and edge distance limitations.

Shop & Field Efficiencies - Connections

- Brace Connections
  - Bolted Options for Brace Shapes:
    - Wide Flange
    - HSS





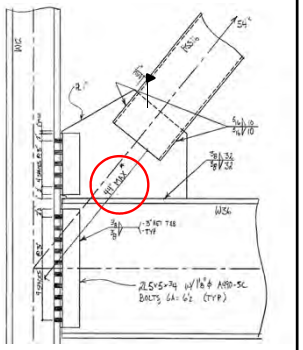
Shop & Field Efficiencies - Connections

- Brace Connections
  - Watch Setback Dimensions For Erection Clearances
  - Can impact buckling length
  - Bending in Gusset PL
    - Jump to Section F11, Section H1 for Combined Axial + Bending
  - K Factors Design Guide#29
  - AISC Table 4-14 – Critical Compression Stress

Table C-1. Summary of Effective Length Factors

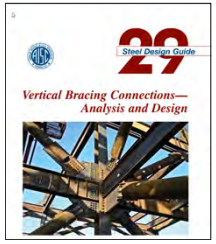
Gusset Configuration [a]	Effective Length Factor, K	Buckling Length, l [b]
Compact Corner [c]	– [d]	– [d]
Noncompact Corner [c]	1.0	l_{wg}
Extended Corner	0.6	l_1
Single Brace	0.7	l_1
Chevron	0.65	l_2

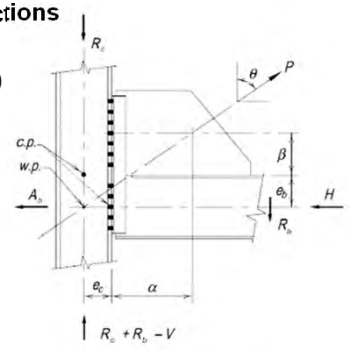
[a] See Figure C-2 for gusset configurations.
[b] See Figure C-3 for buckling length.
[c] See Figure C-4 for determination of compactness.
[d] Yielding is the applicable limit state for compact corner gusset plates; therefore, the effective length factor and the buckling length are not applicable.



Shop & Field Efficiencies - Connections

- Brace Connections
  - Uniform Force Method(DG & Part 13)
    - Static Equilibrium
    - Results in Efficient Designs

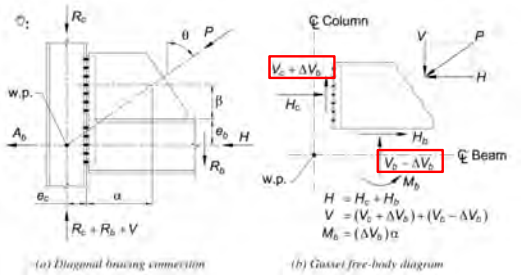




(a) Diagonal bracing connection and external forces

Shop & Field Efficiencies - Connections

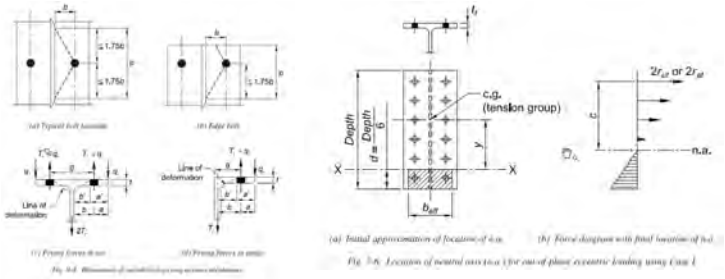
- Brace Connections
  - Uniform Force Method
    - Special Cases
    - Case #2 Valuable



(a) Diagonal bracing connection (b) Gusset free-body diagram

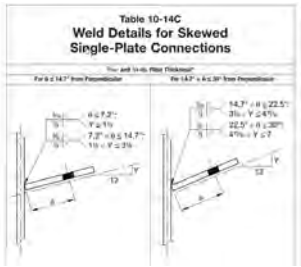
Shop & Field Efficiencies - Connections

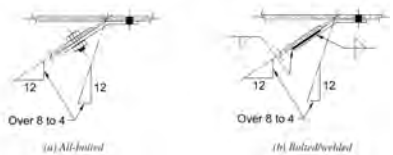
- Brace Connections
  - Uniform Force Method
    - Huc = Prying in Connection to Column (ref AISC Part 9 prying)
    - Bending Possible in 2L or End PL (ref AISC Part 7 for help with analysis)



Shop & Field Efficiencies - Connections

- Skewed Beams
  - Use Single Sided Shear Tab if Possible up to 45 degrees, Bent PL over 45 degrees
    - Ref 10-14C for Weld relative to tab thickness and angle





(a) All-bolted (b) Bolted/welded

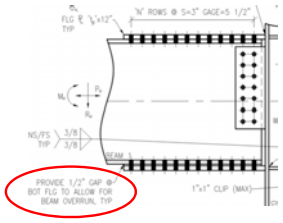
Fig 10-36

Shop & Field Efficiencies - Connections

- Skewed Beams
  - Ref Table 10-14A & 14B for Clearances
  - Ref Ch 10 for Design Recommendations Bent PL – Eccentricity
  - Ref Table 10-13 for Minimum Cold Bending Radius(Verify w/ Fabricator)

Shop & Field Efficiencies - Connections

- Moment Connections
  - Bolted Flange Plates
    - Shims/fills Top or Bottom (ref AISC fig 12-2). Due to roll/dim tolerance of shapes.
    - Caution – reduction factor for using fills in bearing joints (J5.2), SC Joints(J3.8)
    - Over or Under size PL width with respect to beam flange width
      - Allows field welding if bolts are misaligned



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Shop & Field Efficiencies - Connections

- Moment Connections
  - Bolted End Plate
    - Reference Design Guide #4
    - May Also Require Shims

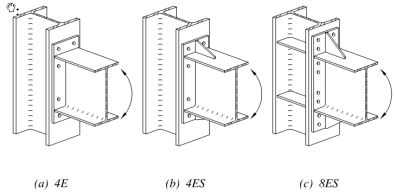
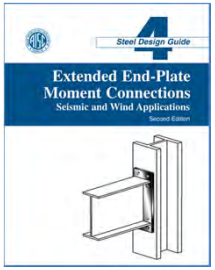


Fig. 12-6. Configurations of extended end-plate FR moment connections.



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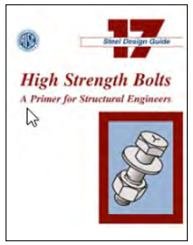
4.7) Connection Design References

- Bolts
  - **AISC Manual Part 7** – Design Considerations for Bolts
  - **AISC 360 Chapter J3** – Design of Connections
  - **RCSC** – Specification for Structural Joints Using High-Strength Bolts (16.2 AISC Manual)
  - **AISC Design Guide #17** – High Strength Bolts – A Primer for Structural Engineers



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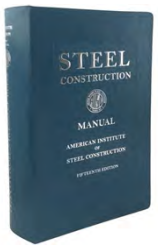
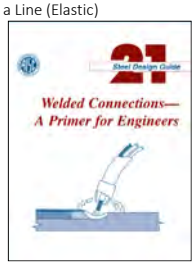
Connection Design References

- Welds
  - **AISC Manual Part 8** – Design Considerations for Welds
  - **AISC 360 Chapter J2** – Design of Connections
  - **AWS D1.1** – Structural Welding Code – Steel
  - **AISC Design Guide #21** – Welded Connections – A Primer for Structural Engineers
  - **Blodgett** – Weld as a Line (Elastic)





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Connection Design References

- Simple Shear
  - **AISC 360 Chapter J** – Design of Connections
  - **AISC Manual Part 9** – Design of Connecting Elements
  - **AISC Manual Part 10** – Design of Simple Shear Connections

- HSS Connections
  - **AISC 360 Chapter J –** Design of Connections
  - **AISC 360 Chapter K –** Additional Requirements for HSS and Box-Section Connections
  - **AISC Design Guide #24 –** Hollow Structural Section Connections

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Connection Design References

- Moment
  - **AISC Manual Part 9** – Design of Connecting Elements
  - **AISC Manual Part 11** – Design of Partially Restrained Moment Connections
  - **AISC Manual Part 12** – Design of Fully Restrained Moment Connections
  - **AISC 360 Chapter J** – Design of Connections
  - **AISC Design Guide #4** – Extended End Plate Moment Connections
  - **AISC Design Guide #13** – Stiffening of Wide-Flange Columns at Moment Connections
  - **AISC Design Guide #16** – Flush and Extended Multiple Row End-Plate Connections

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Night School 18: Steel Construction

From the Mill to Topping Out
Session 4: Connection Design as the Fabricator's Representative
November 5, 2018

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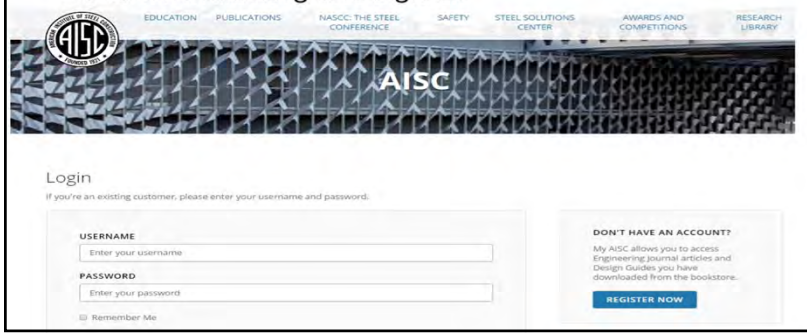

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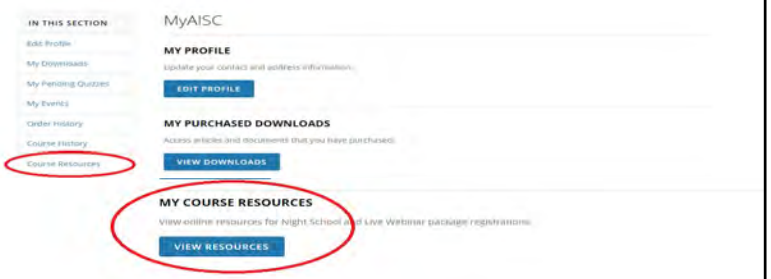

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Night School 13: Design of Industrial Buildings

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
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	Handouts	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending
NS13 - Final Exam	4/10/2017 7:00:00 PM			Available 04/12/2017 5pm EST	

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