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Course Description

Session 3: Lateral Load Systems and Details February 13, 2017

Lesson 3 deals with lateral load resisting systems which includes, roof horizontal bracing systems, braced frames, and rigid frames. Economical choices for the lateral load system are discussed. Moment connections details for connecting Joist Girders to columns are provided along with practical suggestions for the maximum moment resistance for each detail. Three examples are given, these include a braced frame using LRFD and ASD, and a rigid frame using ASD. The braced frame examples include the design of the roof diaphragm. The rigid frame example includes a "hand calculation" of a moment connection as well as a demonstration of a Spreadsheet solution.



Learning Objectives

- Explain the advantages and disadvantages of various lateral load systems.
- Describe girder to column moment connection details and how to maximize moment resistance in each.
- Determine (calculate) the forces that must be carried by the braced frame.
- List the steps for a designing a moment connection.



Design of Industrial Buildings Session 3: Lateral Load Systems and Details February 13, 2017



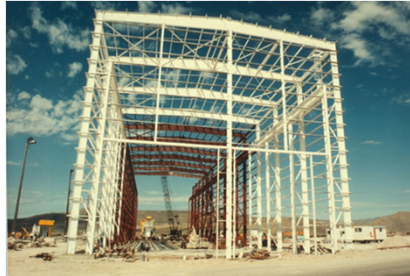
Presented by
James M. Fisher, PE, PhD
Emeritus Vice President, Computerized
Structural Design

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AISC Night School 13

Design of Industrial Buildings Lesson 3



Presenter:
Jim Fisher



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Buildings w/o Overhead Cranes

• Lesson 3

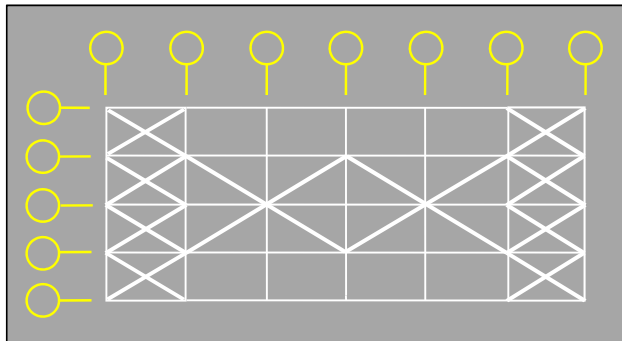
- Horizontal Bracing
- Braced Frames
- Rigid Frames
- Selection of the Lateral Load System
- Examples



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Horizontal Bracing

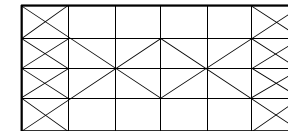


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Horizontal Bracing

- Required in One or Two Directions
- Bracing Forms
- Analysis Assumptions:
 1. Divide the Lateral Loads Equally (based on stiffness)
 2. Design for Pressure or Suction
 3. Model the Full Roof System



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Horizontal Truss



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Rigid Frames

- Determine if Rigid Frames are Required
 - Use W Shapes, Trusses or Joist Girders ?
- Consider Connection Types
 - Field welded or bolted?
 - End Plates?



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Rigid Frames

- The specifying professional shall provide the nominal loads and load combinations as stipulated by the applicable code under which the structure is designed and shall provide the design basis (ASD or LRFD).
- Type and magnitude of end moments and/or axial forces at the joist and Joist Girder end supports shall be shown on the structural drawings.
- A note shall be provided on the structural drawings stating that all moment resisting joists shall have all dead loads applied to the joist before the bottom chord struts are welded to the supporting connection whenever the moments provided do not include dead load.
- The top and bottom chord moment connection details shall be designed by the specifying professional. The joist designer shall furnish the specifying professional with the joist detail information if requested.

SJI Code of Standard Practice 6.1(a)



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Rigid Frames

GIRDER SCHEDULE USING ASD							
Mark	Designation	Live Load Moments, ft.-kip +		Wind or Seismic Moments, ft.-kip +		Applied Chord Forces, kips	
		+ 		+ 		+ 	
		Sign Convention		Sign Convention		Sign Convention	
		Left	Right	Left	Right	Top Chord	Bottom Chord
G1	48 inch depth	50	150	± 100	∓ 100	± 50	± 50



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Rigid Frames

GIRDER SCHEDULE USING LRFD							
Mark	Designation	Live Load Moments, ft.-kip ⁺		Wind or Seismic Moments, ft.-kip ⁺		Applied Chord Forces, kips	
		Sign Convention		Sign Convention		Sign Convention	
		Left	Right	Left	Right	Top Chord	Bottom Chord
G1	48 inch depth	50	150	± 100	∓ 100	± 50	± 50



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Moment Connections

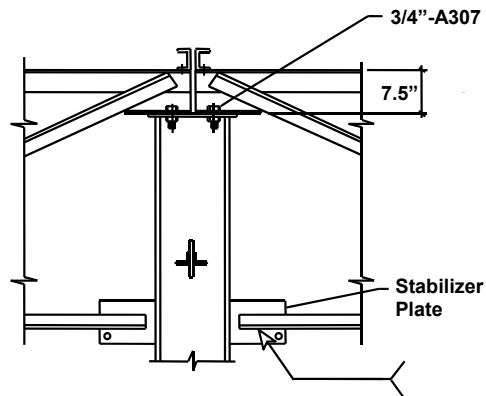
Joist Girders



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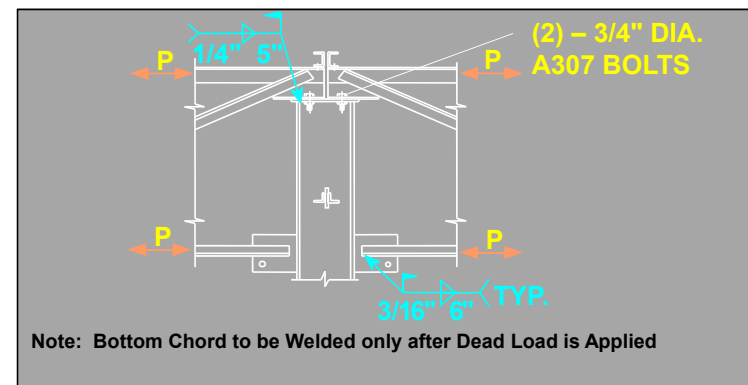
The Basic Connection



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The Welded Basic Connection



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The Welded Basic Connection

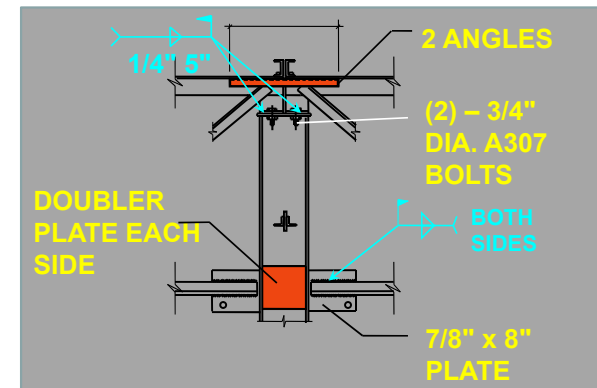
Joist Girder (7.5" seat) Top Chord Leg Size	ASD P_a	LRFD ϕP_n
2.5"	4 ^K	6 ^K
3.0"	8 ^K	12 ^K
3.5" and larger	10 ^K	15 ^K



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The Welded Basic Connection with Ties



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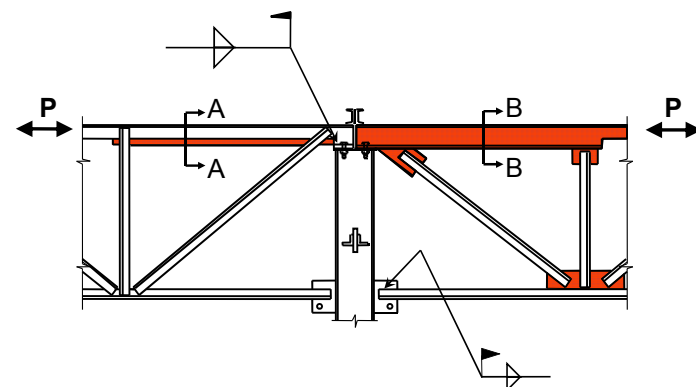
Top Chord Transfer Angles



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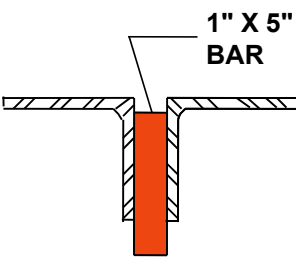
Reinforced Chords



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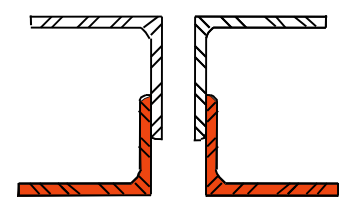
24

Reinforced Chords




1" X 5"
BAR

SECTION A-A



SECTION B-B



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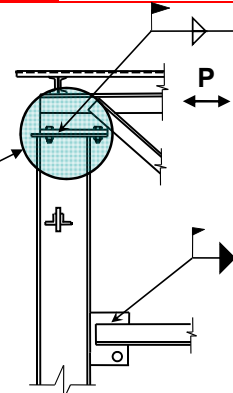
25

Rigid Seat Connection


$P_{max} = 50^k$ ASD

$P_{max} = 75^k$ LRFD

Special design required



BOTH SIDES



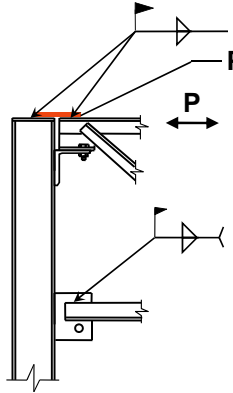
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Moment Plate Connection

$P_{max} = 200^k$ ASD

$P_{max} = 300^k$ LRFD



BOTH SIDES



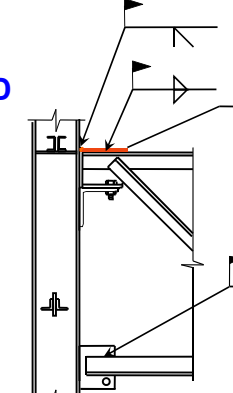
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Floor Moment Plate Connection

$P_{max} = 200^k$ ASD

$P_{max} = 300^k$ LRFD



BOTH SIDES



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Bottom Chord Extensions

Consider:

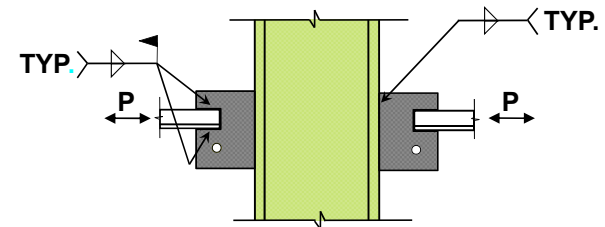
- Magnitude of Bottom Chord Force
- Geometrical Requirements
 - Chord Gap
- Welding
- Column Type



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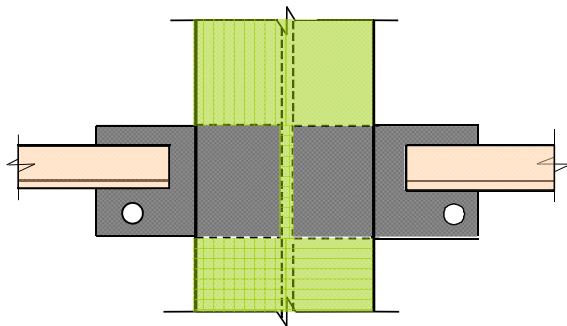
Bottom Chord Attachment to Flanges



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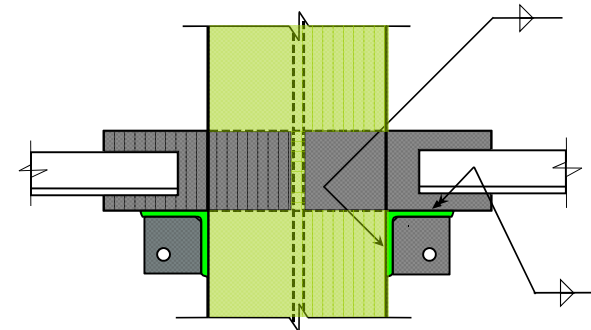
Framing to Column Web



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Angle Reinforcement to Stabilizer Plates

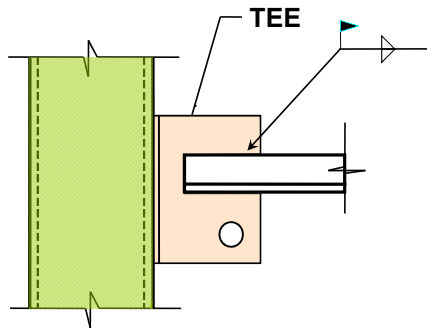


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HSS Column



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Rigid Frame Design

$$I_J = 26.767(W_{LL})(L^3)(10^{-6}) / 1.15$$

$$I_{JG \text{ approx}} = 0.027NPLd \text{ using ASD}$$

$$I_{JG \text{ approx}} = 0.018NPLd \text{ using LRFD}$$

where:

N = number of joist spaces

P = Panel point load, kips

L = Joist Girder length, ft.

d = effective depth of the Joist Girder, in. (total depth of the Joist Girder minus y_{bar})



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Examples

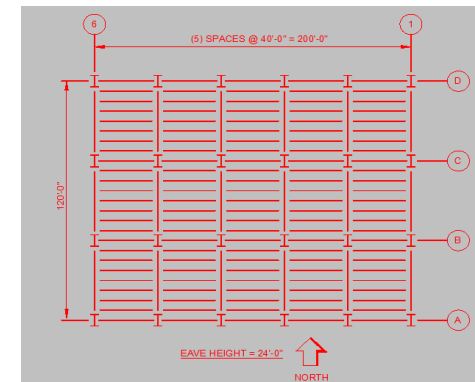
- EXAMPLE 1A
Building Braced at Walls using **ASD**
- EXAMPLE 1B
Building Braced at Walls using **LRFD**
- EXAMPLE 2
Rigid Frame Building using **ASD**



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Example 1A: Building Braced at Walls (**ASD**)



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Example 1A: Building Braced at Walls

Live Load	20 psf	Joists @ 5' - 0", o/c
Collateral	5 psf	Joist Girders at 40 ft. spacing
Dead Load	17 psf	22 gage Wide Rib Deck
Joist	3 psf	Load Combinations:
Joist Girders	1 psf	
Wind Load	= 32 psf	D + 0.6W

Factored Dead Load = 5 psf + 17 psf + 3 psf + 1 psf = 26 psf

Factored L_r Load = 1.0(20 psf) = 20 psf

Factored Wind Load = 0.6(32 psf) ≈ 20.0 psf



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Example 1A: Building Braced at Walls

Joist Load = (25 psf + 20 psf)(5 ft.) = 225 plf
From ASD Load Table for 40 ft. span,
Select 22K7 with Total load = 231 plf

Joist Girder Load - Interior = (0.230 klf)(40 ft.) = 9.2 kips
- Exterior = (0.230 klf)(40 ft.)/2 = 4.6 kips

Select Joist Girders:

JG1 42G8N4.6K (Exterior)

JG2 42G8N9.2K (Interior)

Live Load for Deflection (unfactored)

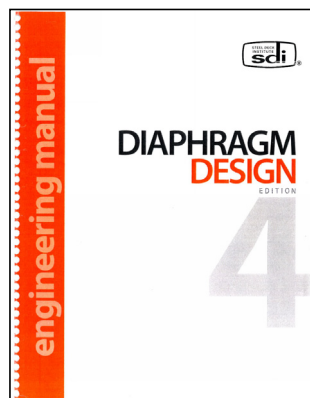
LL = (20 psf)(5 ft.)(40 ft.) = 4 kips Interior; 2 kips Exterior



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SDI Diaphragm Design Manual (4th Edition)



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Diaphragm Design

Determine the shear at each wall.

The shear wall force equals the eave force per foot times one half of the length of the wind loaded wall.

LINES 1 and 6:

$$V_1 = V_6 = (20 \text{ psf})(24/2 \text{ ft})(200/2 \text{ ft}) = 24,000 \text{ lbs}$$

LINES A and D:

$$V_A = V_D = (20 \text{ psf})(24/2 \text{ ft})(120/2 \text{ ft}) = 14,400 \text{ lbs}$$



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Diaphragm Design (cont'd)

Determine the maximum shear force per foot in the diaphragm.

The diaphragm shear equals the wall shear divided by the wall length.

LINES 1 and 6:

$$V_1 = V_6 = 24,000/120 = 200 \text{ plf}$$

LINES A and D:

$$V_A = V_D = 14,400/200 = 72 \text{ plf}$$



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Diaphragm Design (cont'd)

Select Fastening Pattern from SDI Diaphragm Design Manual 4th Ed. (2015)

For welded support fasteners and screwed side laps with 5' joist spacing (5/8 in. arc spot welds):

(Welded side laps are not recommended for 22 ga. decks)

36/4 weld pattern with (1) #10 Tek side lap screw.

$$V_{\text{allow}} = 555/2.35 = 236 \text{ plf where } \Omega \text{ (wind)} = 2.35$$

36/5 weld pattern without side lap screws.

$$V_{\text{allow}} = 625/2.35 = 266 \text{ plf where } \Omega \text{ (wind)} = 2.35$$



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Diaphragm Design Manual

1.5(WR, IR, NR)22
Design thickness = 0.0295 in.
Support fastening: 5/8 in. arc spot welds or equivalent
Side-lap fastening: #10 screws

Fastener Layout	Side-lap Conn/Span	Nominal Shear Strength, S_{ef} , plf ²								K_1	
		3	3.5	4	4.5	5	5.5	6	6.5		7
0	0	1775	1560	1390	1230	1100	1000	910	830	760	0.324
	1	1875	1650	1475	1325	1180	1065	970			0.272
36/4	0	770	675	600	530	475	430	390	360	330	0.726
	1	865	765	685	620	555	500	455			0.509
36/5	2	950	850	765	690	635	575	525	480	445	0.391
	3	1025	925	835	760	700	645	595	545	500	0.318
36/6	4	1095	995	905	825	760	705	655	610	560	0.267
	5	1155	1055	965	890	820	760	705	660	620	0.231
36/7	6	1210	1110	1025	945	875	810	750	710	665	0.203
	0	1030	885	765	675	605					0.647



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Diaphragm Design Manual

1.5(WR, IR, NR)22

Design thickness = 0.0295 in.

Support fastening: 5/8 in. arc spot welds or equivalent

Side-lap fastening: #10 screws

$F_u = 45 \text{ ksi}$

$F_y = 33 \text{ ksi}$

$F_{u,s} = 60 \text{ ksi}$

Loading	ϕ_{ef}	Ω_{ef}
Seismic	0.55	3.00
Wind	0.70	2.35
Other	0.60	2.65

Fastener Layout	Side-lap Conn/Span	Nominal Shear Strength, S_{ef} , plf ²								K_1	
		3	3.5	4	4.5	5	5.5	6	6.5		7
0	0	1775	1560	1390	1230	1100	1000	910	830	760	0.324
	1	1875	1650	1475	1325	1180	1065	970			0.272
36/4	0	770	675	600	530	475	430	390	360	330	0.726
	1	865	765	685	620	555	500	455			0.509
36/5	2	950	850	765	690	635	575	525	480	445	0.391
	3	1025	925	835	760	700	645	595	545	500	0.318
36/6	4	1095	995	905	825	760	705	655	610	560	0.267
	5	1155	1055	965	890	820	760	705	660	620	0.231
36/7	6	1210	1110	1025	945	875	810	750	710	665	0.203
	0	1030	885	765	675	605					0.647



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Diaphragm Design (cont'd)

For power driven fasteners:

36/4 Pneutek SDK63 drive pins with (1) #10 Tek side lap screw – support thickness 0.155" to 0.25".

$$V_{allow} = 590/2.35 = 251 \text{ plf where } \Omega(\text{wind}) = 2.35$$

36/4 Hilti ENP2K $V_{allow} = 530/2.35 = 225 \text{ plf}$

36/5 Pneutek SDK63 drive pins with no side lap screws – support thickness 0.155" to 0.25".

$$V_{allow} = 615/2.35 = 261 \text{ plf where } \Omega(\text{wind}) = 2.35$$

36/5 Hilti ENP2K $V_{allow} = 535/2.35 = 227 \text{ plf}$



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Diaphragm Design (cont'd)

Select Fastening Pattern from SDI Diaphragm Design Manual 4th Ed. (2015)

CHOOSE:

36/4 Weld Pattern

with (1) #10 Tek side lap screw.

NOTE: One side lap fastener is required at a 5 ft joist spacing to meet FM Global and SDI requirements.



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Diaphragm Design (cont'd)

Check the weld strength for combined uplift and shear. Uplift and shear forces are based on the MWFRS values.

Assume the uplift is 60 psf.
The diaphragm shear is 200 plf.

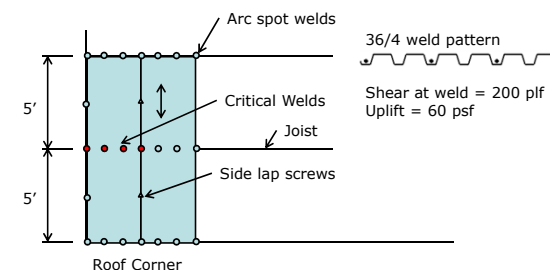
Determine the combined shear and uplift requirement Using the AISI Specification and Tables from the SJI Diaphragm Manual. ASD design.



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Combined Weld Shear and Uplift



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Combined Weld Shear and Uplift

Determine tension force per weld.



36/4 pattern

Number of effective welds across the sheet width, per SDI = 2.7 (edge welds are only 70% effective $2 + 0.7 = 2.7$).

$$\text{Tension per fastener, } T = (60 \text{ psf})(5 \text{ ft})(3\text{ft}) / (2.7) = 333 \text{ lbs/weld}$$



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Combined Weld Shear and Uplift

Table 9-8 Support Fastener Nominal Shear Strength (lbs)

Support Fastener	P _{nt} , lbs / Deck Gage											
	Form Deck			Roof Deck				Composite Deck				
	26	24	22	22	20	18	16	22	20	18	16	
5/8" arc spot weld - E60XX	--	--	2147	1739	2088	2710	3346	1943	2413	3132	3867	
3/4" arc spot weld - E60XX	--	--	--	↑ 1739	2531	3297	4086	1997	2857	3810	4722	
16 gage weld washer with 3/8" hole - E60XX	1455	1503	--	--	--	--	--	--	--	--	--	
#12 screw	647	864	1067	774	940	1244	1569	895	1086	1437	1814	



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Combined Weld Shear and Uplift

Table 9-15 Nominal Arc Spot Weld Uplift Strength (Concentric Loading)

Gage	Concentric Uplift Strength - lbs (Nominal)			
	Visible Diameter (Inches)			
	0.5	0.625	0.75	1
22	867	1098	1328	1789
20	1039	↑ 1298	1598	2157
18	1341	1708	2081	2822
16	1645	2112	2580	3514

Assumes F_{ax} = 60 ksi

Assumes F_y = 40 ksi; F_u = 50 ksi; which will give lower weld strength than 33/45 ksi



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Combined Weld Shear and Uplift

$$\Omega_t = 2.5, \Omega_r = 2.55$$

$$P_{nt} = 1098 \text{ lbs (available tensile strength)} \quad P_{nf} = 1739 \text{ lbs (available shear strength)}$$

$$\Omega_t T = (2.5)(333) = 833 \text{ lbs, (required tension)}$$

$$\text{If } \left(\frac{\Omega_t T}{P_{nt}} \right)^{1.5} \leq 0.15 \text{ then } P_{nft} = P_{nt}; \left(\frac{\Omega_t T}{P_{nt}} \right)^{1.5} = \left[\frac{833}{1098} \right]^{1.5} = 0.660 > 0.15 \quad (\text{AISI S310})$$

$$P_{nft} \neq P_{nt}$$

$$\text{Else } \left(\frac{P_{nft}}{P_{nf}} \right)^{1.5} + \left(\frac{\Omega_t T}{P_{nt}} \right)^{1.5} \leq 1.0 \quad (\text{AISI 310- Modified})$$

$$P_{nft} = P_{nf} \left[1 - \left(\frac{\Omega_t T}{P_{nt}} \right)^{1.5} \right]^{2/3} = P_{nf} \left[1 - \left(\frac{833}{1098} \right)^{1.5} \right]^{2/3} = 1739 (1 - 0.660)^{2/3} = 847 \text{ lbs} \leq 1098 \text{ lbs n.g.}$$

The SDI Diaphragm Manual outlines a method of checking the diaphragm shear to comply with the combined uplift and shear.



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Check Diaphragm Chord Forces

The edge joists are assumed to resist the diaphragm chord force. Determine diaphragm chord force in edge joist due to **wind** loadings:

$$M_{A\&D} = wL^2/8 = (0.020)(24/2)(200)^2 / 8 = 1200 \text{ ft.-kips}$$

$$P_{\text{chord}} = M / \text{diaphragm depth} = 1200 \text{ ft.-kips} / 120 \text{ ft} = 10 \text{ kips}$$



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Check Diaphragm Chord Forces (cont'd)

Determine top chord force in the joist due to **dead** load:

$$M_D = wL^2/8 = (17 \text{ psf} + 3 \text{ psf} + 5 \text{ psf})(5 \text{ ft} / 2)(40 \text{ ft})^2 / 8$$
$$= 12,500 \text{ ft.- lbs}$$

$$P_D = M/\text{depth} = (12,500)(12) / (22 \text{ in.} - 1.0 \text{ in.})$$
$$= 7,140 \text{ lbs}$$

$$P_r = 7.14 \text{ kips} + 10 \text{ kips} = 17.1 \text{ kips}$$



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Check Diaphragm Chord Forces (cont'd)

Determine allowable joist chord force for typical edge joist (22K7)

For the 22K7 the allowable gravity load = 231 plf

$$M_{\text{allow}} = (0.231)(40)^2 / 8 = 46.2 \text{ ft.-kips}$$

$$P_{\text{chord}} = (46.2 \text{ ft.-kips})(12) / 21 \text{ in.} = 26.4 \text{ kips}$$

$$26.4 \text{ kips} > 17.1 \text{ kips} \quad \text{ok}$$



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Check Diaphragm Chord Forces (cont'd)

- The 22K7 joist is adequate as the diaphragm chord at A and D, provided eccentric chord bending is eliminated.
- Don't try to pass the chord force through the joist seat.

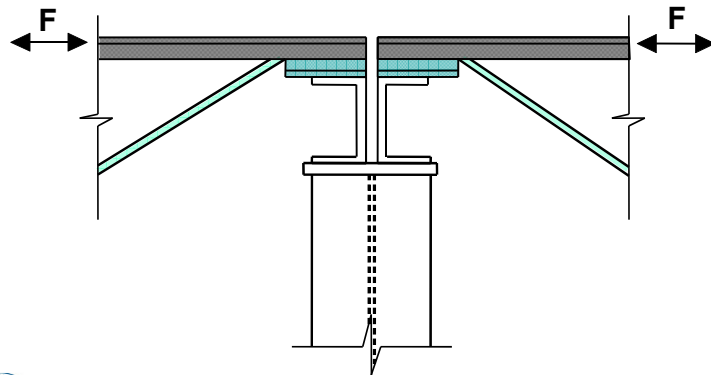


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Diaphragm Chord Force



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Check Diaphragm Chord Forces (cont'd)

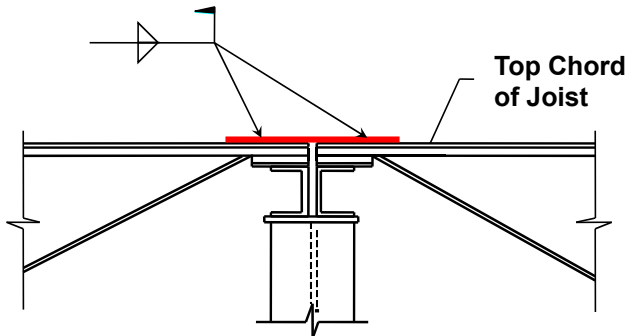
To eliminate bending stresses in the joist top chord use a tie plate between adjacent joists to transfer the chord force.



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Joist Tie Plate



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Size Top Plate and Weld

The chords may act in tension or compression, therefore design for compression case.

Try a 4" wide x 1/4" thick, A36 tie plate.

$$\text{Chord Force } P_{\text{chord}} = 17.1 \text{ kips}$$

Assume unwelded (unsupported) plate length of 4", check the buckling capacity of the plate:

Plate Properties:

$$A = 1.0 \text{ in.}^2$$

$$r_x = d/(12)^{.5} = 0.072 \text{ in.}$$

$$L / r_x = 56$$

$$F_{cr}/\Omega = 18.3 \text{ ksi (AISC Manual Table 4-22)}$$

$$P_a = (18.3)(1.0) = 18.3 \text{ kips}$$

$$18.3 > 17.1 \text{ ok}$$



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Size Top Plate and Weld (cont'd)

Use a 3/16 inch E70 fillet weld:

The allowable weld strength = 2.78 kips / in.

Weld length req'd = $17.1 / 2.78 = 6.2$ inches

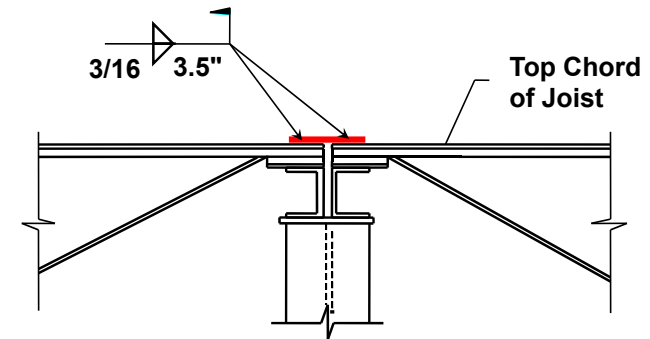
Therefore, use 7 inches of 3/16 inch fillet on each joist end.



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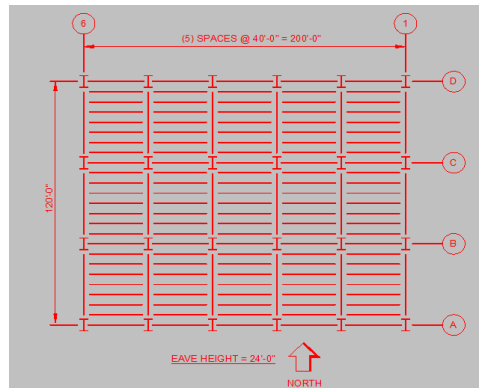
Joist Tie Plate



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Example 1B: Building Braced at Walls (LRFD)



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Example 1B: Building Braced at Walls

Live Load	20 psf	Joists @ 5' - 0", o/c
Collateral	5 psf	Joist Girders at 40' spacing
Dead Load	17 psf	22 gage Wide Rib Deck
Joist	3 psf	
Joist Girders	1 psf	
Wind Load	= 32 psf	

Load Combinations:

$1.2D + 1.6L_r$
 $1.2D + 1.0W + 0.5L_r$

Factored Dead Load = $1.2 (5 \text{ psf} + 17 \text{ psf} + 3 \text{ psf} + 1 \text{ psf})$
 = 31.2 psf

Factored Roof Live Load = $1.6(20) = 32.0 \text{ psf}$

Factored Wind Load = $1.0 (32 \text{ psf}) = 32.0 \text{ psf}$



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Example 1B: Building Braced at Walls

Joist Load = $(31.2 \text{ psf} + 32 \text{ psf})(5 \text{ ft.}) = 316 \text{ plf}$

From **LRFD** Load Table for 40 ft. span,

Select 22K7 with Total load = 346 plf

Joist Girder Load - Interior = $(0.316 \text{ klf})(40 \text{ ft.}) = 12.6 \text{ kips}$

- Exterior = $(0.316 \text{ klf})(40 \text{ ft.})/2 = 6.3 \text{ kips}$

Select Joist Girders:

JG1 42G8N6.3F (Exterior)

JG2 42G8N12.6F (Interior)

Live Load for Deflection (unfactored)

LL = $(20 \text{ psf})(5 \text{ ft.})(40 \text{ ft.}) = 4 \text{ kips Interior; } 2 \text{ kips Exterior}$



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Diaphragm Design

Determine the shear at each wall:

The shear wall force equals the eave force per foot times one half of the length of the wind loaded wall.

LINES 1 and 6:

$$V_1 = V_6 = (32 \text{ psf})(24 \text{ ft}/2)(200 \text{ ft}/2) = 38,400 \text{ lbs}$$

LINES A and D:

$$V_A = V_D = (32 \text{ psf})(24 \text{ ft}/2)(120 \text{ ft}/2) = 23,000 \text{ lbs}$$



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Diaphragm Design (cont'd)

Determine the maximum shear force per foot in the diaphragm.

The diaphragm shear equals the wall shear divided by the wall length.

LINES 1 and 6:

$$V_1 = V_6 = (38,400 \text{ lbs})/(120 \text{ ft}) = 320 \text{ plf}$$

LINES A and D:

$$V_A = V_D = (23,000 \text{ lbs})/(200 \text{ ft}) = 115 \text{ plf}$$



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Diaphragm Design (cont'd)

Select Fastening Pattern from SDI Diaphragm Design Manual 4th Ed. (2015)

For welded support fasteners and screwed side laps with 5' joist spacing:

(Welded side laps are not recommended for 22 ga. decks)

36/4 weld pattern with (1) #10 Tek side lap screw.

$$V_{\text{available}} = (555 \text{ plf})(0.7) = 389 \text{ plf } (\phi = 0.7)$$

36/5 weld pattern without side lap screws.

$$V_{\text{available}} = (626 \text{ plf})(0.7) = 438 \text{ plf}$$



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Diaphragm Design (cont'd)

Select Fastening Pattern from SDI Diaphragm Design Manual 4th Ed. (2015)

CHOOSE: 36/4 Weld Pattern with (1) #10 Tek
side lap screw.

NOTE: One side lap fastener is required at a 5 ft
joist spacing to meet Factory Mutual and
SDI requirements.



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Check Diaphragm Chord Forces

The edge joists are assumed to resist the diaphragm chord
force. Determine diaphragm chord force in edge joist due
to **wind** loadings:

$$M_{A\&D} = wL^2/8 = (32 \text{ psf})(24 \text{ ft}/2)(200)^2/8/1000$$

$$= 1,920 \text{ ft.-kips}$$

$$P_{\text{chord}} = M/\text{diaphragm depth} = 1,929 \text{ kips}/120 \text{ ft} = 16.0 \text{ kips}$$



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Check Diaphragm Chord Forces (cont'd)

From $1.2D + 1.0W + 0.5L_r$

$$M_D = (1.2)(25 \text{ psf})(2.5 \text{ ft.})(40 \text{ ft.})^2/8 = 15,000 \text{ ft.-lbs}$$

$$M_L = (0.5)(20 \text{ psf})(2.5 \text{ ft.})(40 \text{ ft.})^2/8 = 5,000 \text{ ft.-lbs}$$

$$P_{\text{chord } D} = M_D / \text{depth} = (15,000 \text{ ft.- lbs})(12)/(22 \text{ in.- } 1.0 \text{ in.})$$

$$= 8,570 \text{ lbs} = 8.6 \text{ kips}$$

$$P_{\text{chord } L} = M_L / \text{depth} = (5,000 \text{ ft.-lbs})(12)/(22 \text{ in.- } 1.0 \text{ in.})$$

$$2,860 \text{ lbs} = 2.9 \text{ kips}$$

$$P_{\text{chord } W} = 16 \text{ kips}; P_r = 8.6 \text{ kips} + 16 \text{ kips} + 2.9 \text{ kips} = 21.5 \text{ kips}$$



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Check Diaphragm Chord Forces (cont'd)

$$P_{22K7} = [wL^2/8] / \text{depth} = [0.346 \text{ klf } (40)^2 / 8](12)/(21)$$

$$= 39.5 \text{ kips}$$

Evaluate joist top chord forces:

$$P_{1.2D+1.5L+W} < P_{22K7}$$

$$21.5 \text{ kips} < 39.5 \text{ kips} \text{ ok}$$



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Size Top Plate and Weld

Try a 4" wide x 1/4" thick, A36 tie plate.

Factored Chord Force = 21.5 kips

Assume unwelded (unsupported) plate length of 4 in.,
check the buckling capacity of the plate:

Plate Properties:

$$A = 1.0 \text{ in.}^2$$

$$r_x = d/(12)^5 = 0.076 \text{ in.}$$

$$L / r_x = 56$$

$$\phi F_{cr} = 27.5 \text{ ksi}$$

$$P_a = (27.5)(1.0) = 27.5 \text{ kips}$$

$$27.5 > 21.5 \text{ ok}$$



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Size Top Plate and Weld (cont'd)

Use a 3/16 inch E70 fillet weld:

The design weld strength = 4.18 kips / in.

Weld length req'd = 21.5 kips / 4.18 = 5.14 inches

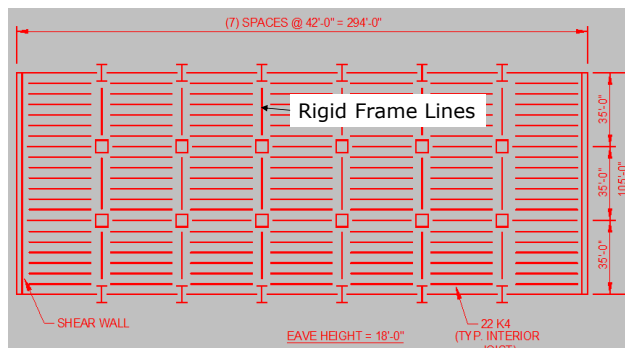
**Therefore, use 6 inches of 3/16 inch fillet
on each joist end.**



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Example 2: Rigid Frame Building (ASD)



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Example 2: Rigid Frame Building

Dead Load:	5 psf (Standing Seam Roof)
Collateral Load:	4 psf
Joist Girder:	1 psf
Live Load:	20 psf (Live load reduction allowed)
	12 psf – Reduced Live Load on Joist Girders only



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Example 2: Rigid Frame Building

Structure is Category II. From ASCE 7-10 Figure 26.5-1A the basic wind speed is 115 mph (3 second gust). For the 18 ft high structure with Exposure C the lateral load equals 32.7 psf. Roof Uplift: 27.4 psf (Suction).

By inspection the following load combination controls:

$$D + 0.6W; D = (10 \text{ psf})(42 \text{ ft}) = 420 \text{ plf}$$

$$\text{Eave strut load} = (0.6)(32.7)(42 \text{ ft})(18 \text{ ft}/2) = 7,420 \text{ lbs}$$

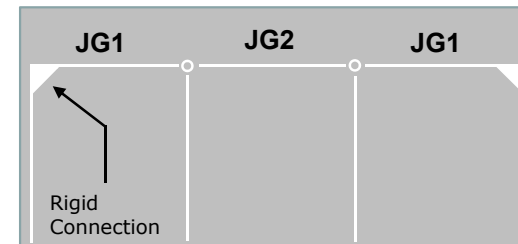
Since this is an ASD design, loads must be multiplied by 1.6 and after a second order analysis divided by 1.6.



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Design Joist Girder Rigid Frame (cont'd)



JG1 and JG2 are 36" deep, with 7 panel spaces



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Design Joist Girder Rigid Frame

Joist Girder Panel Point Load:

$$P = (DL + \text{Coll.} + LL_{\text{req'd}})(5)(42) = 4.6 \text{ kips}$$

Use a 36G7N4.6K Joist Girder

Determine the joist girder moment of inertia:

$$I_{JG} = 0.027 \text{ PNLd} = (0.027)(4.6)(7)(35)(36 - 2 \times 0.5^*) = 1065 \text{ in.}^4$$

* (0.5 in. is the estimated centroid distance for the chord angles)

Provide a rigid connection between the perimeter column and the Joist Girder. The connection is to be made after all dead loads are applied.

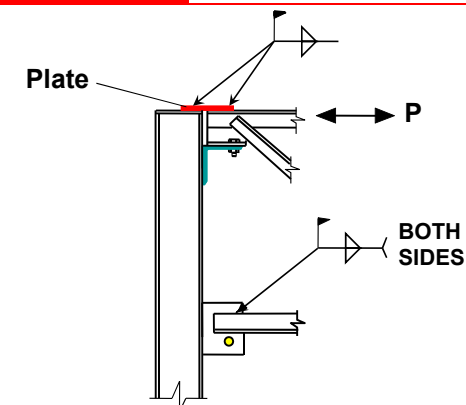
The Basic Connection is used for the Joist Girders at the interior columns.



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Moment Plate Connection



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Design Joist Girder Rigid Frame (cont'd)

Exterior Columns: Interior Columns:
Try W14x38 ($F_y = 50$ ksi) Try HSS 8x8x1/4 ($F_y = 46$ ksi)

$A = 11.2 \text{ in.}^2$	$A = 7.10 \text{ in.}^2$
$I_x = 385 \text{ in.}^4$	$I_x = 70.7 \text{ in.}^4$
$r_x = 5.87 \text{ in.}$	$r_x = 3.15 \text{ in.}$



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Design Joist Girder Rigid Frame (cont'd)

Joist Girder End Moments and Column Forces

Based on frame analysis:

$D + (.6)(W)$ Controls

$$M_r = -1005 \text{ in. kips} = 83.8 \text{ ft-kips}$$

$$P_r = 9.8 \text{ kips}$$

From the analysis, the eave deflection at full wind load is 1.9 inches. $H/100 = 2.2 \text{ in.}$ For a 10 year wind (using 75% of full wind) the deflection = 1.4 in.

$$= H/150$$



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Example 2: Rigid Frame Building

Use AISC Manual Table 6 - 1 to determine column size.

Try the W 14x38.

$$p \times 10^3 = 11.5, \quad b_x \times 10^3 = 10.9$$

$$pP_r = (0.0115)(9.8 \text{ kips}) = 0.11 \leq .2$$

$$\begin{aligned} 1/2pP_r + 9/8(b_x M_{rx}) &= (1/2)(0.11) + (9/8)(0.0109)(83.8) \\ &= 1.08 \text{ ng} \end{aligned}$$

Brace at mid-height: $p = 4.24 \times 10^3, \quad b_x = 6.61 \times 10^3$

$$1/2pP_r + 9/8(b_x M_{rx}) = (1/2)(0.00424)(9.8 \text{ kips})$$

$$+ (9/8)(0.00661)(83.8) = 0.64 \text{ ok}$$

Use W14x38



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Example 2: Rigid Frame Building

Support the girder on column bracket and use a top plate welded to Joist Girder and to the column cap plate to transfer the force.

$$\text{Top Chord: } M_{\text{end}} = 1005 \text{ in.-kips}$$

$$P_{\text{chord}} = M_{\text{end}}/d = 1005 \text{ in.-kips}/(36 \text{ in.} - 1.5 \text{ in.}) = 29.13 \text{ kips}$$

d is the distance from the top of the top chord to the half depth of the bottom chord leg.

$$\begin{aligned} A_{\text{req'd}} &= P_{\text{chord}}/F_t \quad (\text{where } F_t = F_y/\Omega) \\ &= 29.13/22 = 1.32 \text{ in.}^2 \end{aligned}$$

Use a 4 in. x 1/2 in. plate; $A = 2.00 \text{ in.}^2$



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Design Joist Girder End Connection (cont'd)

Check Plate for compression:
Controlling load case: $D + 0.6W$
 $P_{\text{chord}} = -29.13$ kips
 $L_x = 3$ in. (unbraced length)
 $r_x = 0.144$ in.
 $L/r_x = 20.8 \leq 25$
 $F_{cr}/\Omega_c = 21.6$ ksi
 $P_a = (F_{cr}/\Omega)(A) = (21.6 \text{ ksi})(2.0 \text{ in.}^2)$
 $= 43.2$ kips > 29.13 kips ok



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Design Joist Girder End Connection (cont'd)

Determine top plate weld:
 $P_r = 29.13$ kips
3/16 in. weld: $v_{\text{allow}} = 2.78$ kips/in.
Required weld length: $L = 29.13 \text{ kips} / 2.78 \text{ kips/in.} = 10.5$ in.
To eliminate shear lag effects on the plate use a weld equal to twice the width of the plate.
Use 10 in. of 3/16" weld each side at each end of plate



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Design Joist Girder End Connection (cont'd)

Determine bottom chord connection:

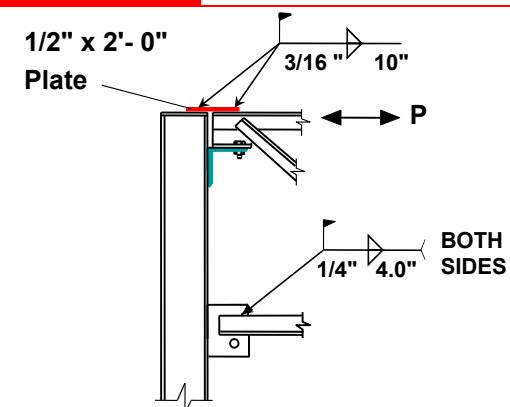
Try a 6" x 3/4" plate
 $A = 4.5$ in., $P_r = 36.5$ kips
 $P_a = (F_y)(A)/\Omega = (50)(4.5 \text{ ksi})/\Omega = 135$ kips
 $P_a < P_r$ ok
(Note: 1/4" minimum per AISC Sect. J)
 $v_{\text{allow}} = 3.71$ kips/in.
Required weld length, $L_w = 29.13 \text{ kips} / (3.71) = 7.85$ in.
Use 4 inches of 1/4 in. fillet weld each side of stabilizer



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Moment Plate Connection



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Design Joist Girder End Connection (cont'd)

Check column web for web yielding & web crippling:
(Requirements per AISC Sections J10.2 and J10.3)

Web Local Yielding: $\Omega = 1.5$

$$R_n/\Omega = F_{yw}t_w(5k + l_b)/\Omega$$

$$= (50 \text{ ksi})(0.31 \text{ in.})(5)(0.915 \text{ in.}) + 6 \text{ in.}/1.5 = 109.3 \text{ kips}$$

$$= 109.3 \text{ kips} > 29.13 \text{ kips} \text{ ok}$$



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Design Joist Girder End Connection (cont'd)

Web Local Crippling:

$$R_n = 0.80t_w^2 \left[1 + 3 \left(\frac{l_b}{d} \right) \left(\frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{\frac{EF_{yw}t_f}{t_w}}$$

$$R_n = (0.80)(0.31)^2 \left[1 + 3 \left(\frac{6}{14.1} \right) \left(\frac{0.31}{0.515} \right)^{1.5} \right] \sqrt{\frac{(29000)(50)(0.515)}{0.31}}$$

$$R_n = 190 \text{ kips} \quad \frac{R_n}{\Omega} = \frac{190}{2.00} = 95 \text{ kips} > 29.13 \text{ ok}$$



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SJI Spreadsheet Solutions

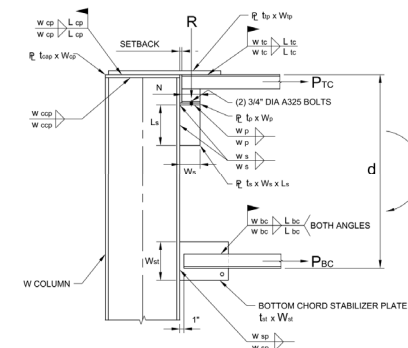
- Joist Girder Moment Connections to the Strong Axis of Wide Flange Columns
- Joist Girder Moment Connections to the Strong Axis of Wide Flange Columns- Intermediate Levels
- Joist Girder Moment Connections to the Weak Axis of Wide Flange Columns
- Joist Girder Moment Connections to HSS Columns- Top Plate
- Joist Girder Moment Connections to HSS Columns- Knife Plates
- Joist Girder Moment Connections to Strong Axis of WF Columns- Knife Plates



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SJI Spreadsheet Solution



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SJI Spreadsheet Solutions

All Spreadsheets are available for free
download from:
Steeljoist.org.



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End of Lesson 3



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Individual Webinar Registrants

PDH Certificates
Within 2 business days...

- 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 Webinar Registrants

PDH Certificates
Within 2 business days...

- New 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

PDH Certificates

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



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8-Session Registrants

QUIZZES

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 - scroll down to Quiz and Attendance Records.

Reasons for quiz:

EEU – must take all quizzes and final to receive EEU

PDHS – If you watch a recorded session you must take quiz for PDHS.

REINFORCEMENT – Reinforce what you learned tonight. Get more out of the course.

NOTE: If you attend the live presentation, you do not have to take the quizzes to receive PDHs.



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8-Session Registrants

RECORDINGS

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

PDHS – If you watch a recorded session you must take AND PASS the quiz for PDHS.



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Night School Resources for 8-session package Registrants

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



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Night School Resources for 8-session package Registrants

Go to www.aisc.org and sign in.

The screenshot shows the AISC website header with navigation links: EDUCATION, PUBLICATIONS, NASCC: THE STEEL CONFERENCE, SAFETY, STEEL SOLUTIONS CENTER, AWARDS AND COMPETITIONS, and RESEARCH LIBRARY. Below the header is a large banner with the AISC logo and the text "AISC". Underneath the banner is a "Login" section with a form for "USERNAME" and "PASSWORD", a "Remember Me" checkbox, and a "REGISTER NOW" button. To the right of the login form is a "DON'T HAVE AN ACCOUNT?" section with a brief description and a "REGISTER NOW" button.

Night School Resources for 8-session package Registrants

The screenshot shows the "MyAISC" user profile page. On the left is a sidebar menu with options: Edit Profile, My Downloads, My Pending Quizzes, My Events, Order History, Course History, and Night School Resources (circled in red). The main content area includes sections for "MY PROFILE", "MY PURCHASED DOWNLOADS", "MY ORDER HISTORY", and "MY NIGHT SCHOOL RESOURCES". The "MY NIGHT SCHOOL RESOURCES" section contains a "VIEW RESOURCES" button (circled in red).

Night School Resources for 8-session package Registrants

The screenshot shows the "Night School Resources" page on the AISC website. It features the same header and banner as the previous screenshot. Below the banner is a breadcrumb trail: "AISC > MYAISC > NIGHT SCHOOL RESOURCES". The main content area is titled "Night School Resources" and contains a table with the following data:

Event	Date
NS13 8-Session Package	1/30/2017 7:00:00 PM

At the bottom left is the AISC logo and the slogan "There's always a solution in steel!"

Night School Resources for 8-session package Registrants

The screenshot shows the "Night School 13: Design of Industrial Buildings" page. It features the same header and banner. Below the banner is a breadcrumb trail: "AISC > MYAISC > NIGHT SCHOOL RESOURCES > NS13 8-SESSION PACKAGE RESOURCES". The main content area is titled "Night School 13: Design of Industrial Buildings" and contains a section for "8-SESSION PACKAGE RESOURCES" with a table of resources:

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	Video	Passcode: NS13DCN Pins 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 Bridge Bracing Design	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	



Night School Resources for 8-session package Registrants

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



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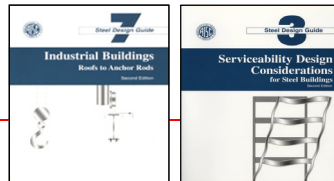
Night School Resources for 8-session package Registrants

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



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Design Guides



Design Guides are a FREE download for AISC Members.

For Night School registrants who are non-members, we are offering a discounted price on **Design Guide 3 and Design Guide 7 only**.

Non-members: Use the following discount codes to purchase the download for only \$10.



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Design Guides



Non-members: Use the following discount codes to purchase the download for only \$10.

Design Guide 3: Serviceability
Coupon Code: **NS13DG3TEN**

Design Guide 7: Industrial Buildings
Coupon Code: **NS13DG7TEN**

Note: Can only use one code per transaction.
Expires February 14, 2017!



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Thank You

Please give us your feedback!
Survey at conclusion of webinar.

