



**Night School 28:
Vertical Bracing
Connections**


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



Vertical Bracing Connections, Session 5: Uniform Force Method Part 2—Special Case IV and V
May 3, 2022 | William A Thornton





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Course Description

Vertical Bracing Connections

Session 5: Uniform Force Method Part 2—Special Case IV and V
May 3, 2022

This session will look at two cases of the uniform force method: Special Case IV, and Special Case V. A design example will be presented to demonstrate applicability.



Learning Objectives

- 1. Describe the Uniform Force Method – Special Case IV
- 2. Explain the advantages of Special Case IV
- 3. Describe the Uniform Force Method – Special Case V
- 4. Explain the advantages of Special Case V



Night School 28: Vertical Bracing Connections


Session 5: Uniform Force Method Part 2—Special Case IV and V
May 3, 2022

William A. Thornton, corporate consultant to Cives Steel



Vertical Bracing Connections


By: William Thornton, Rafael Sabelli, and Carol Drucker



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Course Outline


1. Basic Principles
2. Uniform Force Method Part 1
3. Bracing Connection Details and Prying Action
4. Vertical Bracing Corner Connection – Wind and Low-seismic
- 5. Uniform Force Method Part 2 (Special Case IV and V)**
6. Vertical Bracing Corner Connection – Seismic
7. Chevron Gussets Connection
8. Other Connection Topics and Case Study



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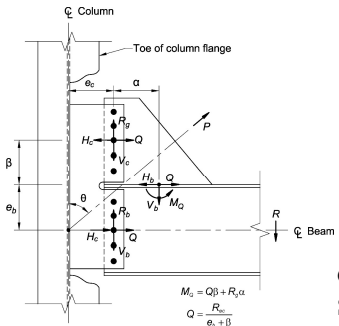
Session Outline

- Development of the Uniform Force Method Special Case IV
- Development of the Uniform Force Method Special Case V



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UFM Special Case IV



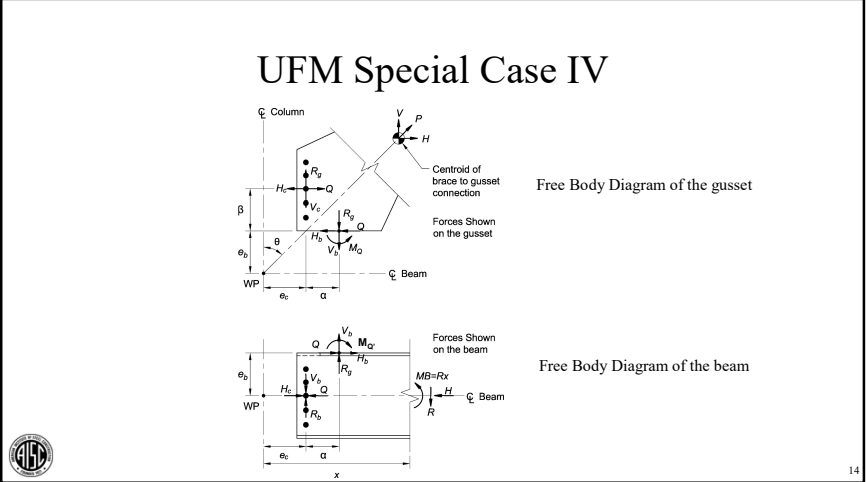
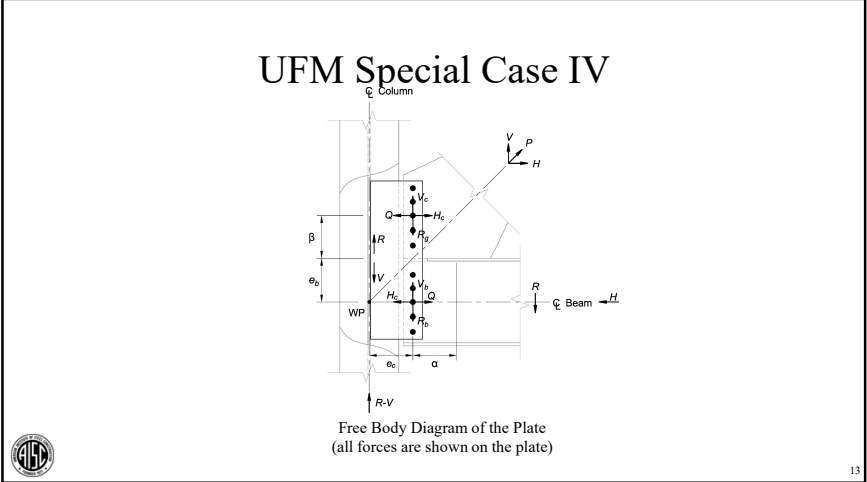
General notation for forces.
 See free body diagram on
 next two slides.

$$M_c = Q\beta + R_c\alpha$$

$$Q = \frac{R_c}{e_c + \beta}$$

$$R = R_c + R_b$$


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UFM Special Case IV

Derivation of Equations

Gusset

$$\sum M_{WP} = 0 = R_g e_c - R_g (\beta + \alpha) - Q \beta + M_Q = 0$$

$$0 = -R_g \alpha - Q \beta + M_Q$$

$$M_Q = Q \beta + R_g \alpha$$

Beam

$$\sum M_{WP} = 0 = -M_Q' - Q e_b + R_b e_c + R_g (e_c + \alpha) - R_b \alpha + R_g \alpha$$

$$M_Q' = -Q e_b + R_b e_c + R_g \alpha$$

$$= -Q e_b + R_b e_c + R_g \alpha$$

Using: $\alpha - \beta \tan \theta = e_b \tan \theta - e_c$

$$\text{and } Q = \frac{R_b e_c}{e_b + \beta}$$

UFM Special Case IV

Cont'd.

$$M_Q' = \frac{-R_b e_c e_b}{e_b + \beta} + R_b e_c + R_g \alpha$$

$$= \frac{R_b}{e_b + \beta} (-e_c e_b + e_c (e_b + \beta)) + R_g \alpha$$

$$M_Q' = \frac{R_b}{e_b + \beta} (-e_c e_b + e_c e_b + e_c \beta) + R_g \alpha$$

$$= \frac{R_b}{e_b + \beta} (e_c \beta) + R_g \alpha = Q \beta + R_g \alpha = M_Q \rightarrow \text{QED}$$

Example of Vertical Bracing Corner Connection Special Case IV



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Example Special Case IV

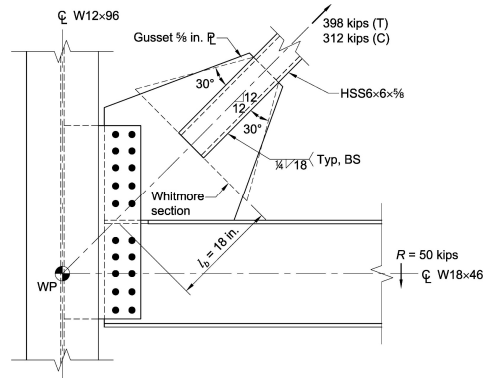
Given:

1. AISC 15th Edition *Manual*, LRFD
2. 1 in. diameter ASTM A325-N bolts
3. STD Holes, 1¹/₈ in. diameter
4. Brace Slope = 45°
5. Plate: ASTM A572 Gr. 50, $F_y = 50$ ksi, $F_u = 65$ ksi
6. HSS : ASTM A500 Gr. C, $F_y = 50$ ksi, $F_u = 62$ ksi



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Example Special Case IV



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Example Special Case IV

Weld (*Spec. Section J2.4*)

Use a 1/4" fillet weld to keep weld passes to one.

$$\begin{aligned} \phi R_n &= 0.75(0.6)(F_{EXX})t_e l n \\ &= 0.75(0.6)(70)\left(\frac{D}{16\sqrt{2}}\right) l n \\ &= 1.392 D l n \end{aligned}$$

D = no. of 16ths

l = length

n = no. of welds



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Example of Corner Connection Special Case IV

Brace-to-Gusset – Shear Lag (cont.):

AISC Specification Table D3.1, Case 6,

$$\bar{x} = \frac{B^2 + 2BH}{4(B+H)} = \frac{(6.0 \text{ in.})^2 + 2(6.0 \text{ in.})(6.0 \text{ in.})}{4(6.0 \text{ in.} + 6.0 \text{ in.})}$$

$$= 2.25 \text{ in.}$$

$$U = 1 - \frac{\bar{x}}{l_{conn}} = 1 - \frac{2.25 \text{ in.}}{18.0 \text{ in.}}$$

$$= 0.875$$

Case #	Description of Element	Shear Lag Factor, U	Example
6	Rectangular HSS with a single concentric gusset plate	$l \geq H, U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{B^2 + 2BH}{4(B+H)}$	
	with two side gusset plates	$l \geq H, U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{B^2}{4(B+H)}$	



Example of Corner Connection Special Case IV

Brace-to-Gusset – Shear Lag (cont.):

AISC Specification Eq. D3-1,

$$A_e = UA_n = 0.875(10.8 \text{ in.}^2)$$

$$= 9.45 \text{ in.}^2$$

$$\phi R_n = 0.75(62)(9.45)$$

$$= 439k > 398k \text{ – OK}$$



Determination of Interface Forces



Example of Corner Connection Special Case IV

Determination of Interface Forces – Uniform Force Method (Special Case IV):

Using the uniform force method (UFM), with $a = 8.875 \text{ in.}$ (AISC Manual

p. 10-103) take,

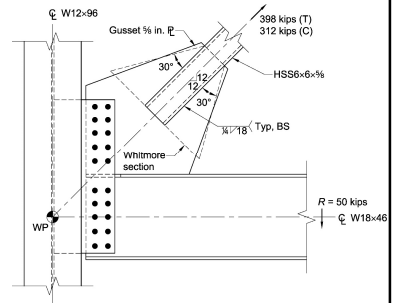
$$e_c = a + \frac{S_{bolts}}{2} = 8.875 \text{ in.} + \frac{3.0 \text{ in.}}{2}$$

$$= 10.375 \text{ in.}$$

The web connection is treated as a flange connection of an equivalent column at depth of $2(10.375 \text{ in.}) = 20.75 \text{ in.}$, that is a W21 column.

$$e_b = \frac{d_{beam}}{2} = \frac{18.1 \text{ in.}}{2}$$

$$= 9.05 \text{ in.}$$



Example of Corner Connection Special Case IV

Determination of Interface Forces (cont.): Tension Case

$$H_c = e_c \left(\frac{P}{r} \right) = 10.375 \text{ in.} (15.59 \text{ kips/in.})$$

$$= 162 \text{ kips}$$

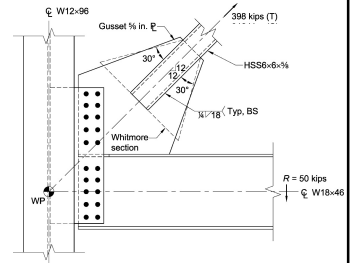
$$H_b = \alpha \left(\frac{P}{r} \right) = 7.675 (15.59 \text{ kips/in.})$$

$$= 120 \text{ kips}$$

$$\Sigma_H = 162 \text{ kips} + 120 \text{ kips}$$

$$= 282 \text{ kips} = 398 (\cos 45^\circ)$$

$$= 281 \text{ kips} \text{ -- OK due to rounding}$$



Example of Corner Connection Special Case IV

Determination of Interface Forces (cont.): Tension Case

$$V_c = \beta \left(\frac{P}{r} \right) = 9.0 \text{ in.} (15.59 \text{ kips/in.})$$

$$= 141 \text{ kips}$$

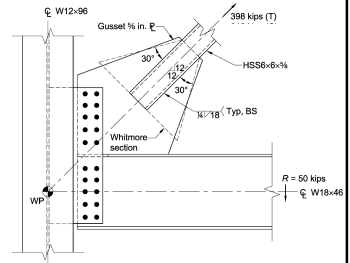
$$V_b = e_b \left(\frac{P}{r} \right) = 9.05 \text{ in.} (15.59 \text{ kips/in.})$$

$$= 141 \text{ kips}$$

$$\Sigma_V = 141 \text{ kips} + 141 \text{ kips}$$

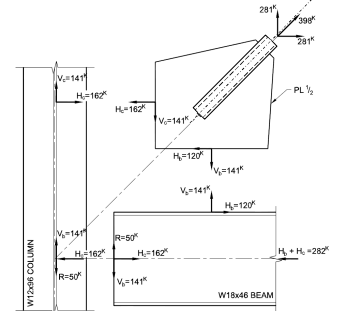
$$= 282 = 398 (\sin 45^\circ)$$

$$= 281 \text{ kips} \text{ -- OK due to rounding}$$



Example of Corner Connection Special Case IV

Exposition of Interface Forces: Tension Case



Example of Corner Connection Special Case IV

Exposition of Interface Forces: Tension Case

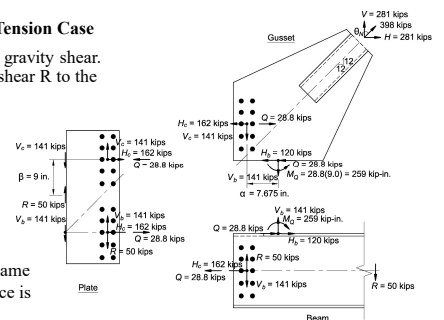
- The force, Q , is due to the beam gravity shear. It is required to move the brace force to the face of the column web.

$$M_Q = R\beta + R_g\alpha$$

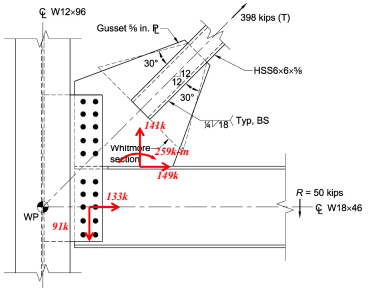
$$Q = \frac{R e_c}{e_b + \beta}$$

$$R = R_g + R_b$$

These forces always act in the same direction, whether the brace force is tension or compression.



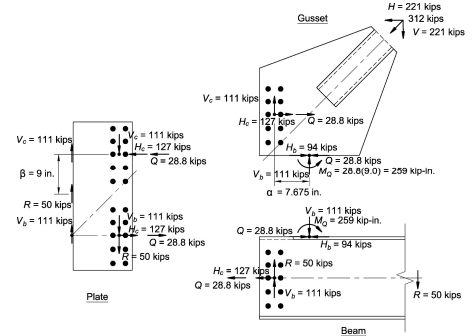
Example of Corner Connection Special Case IV



Net Interface Forces on Beam (Tension)



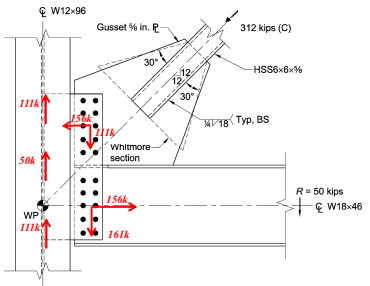
Example of Corner Connection Special Case IV



Interface Forces - Brace Compression



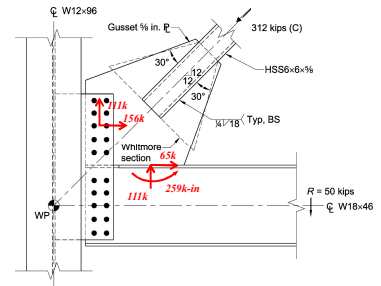
Example of Corner Connection Special Case IV



Net Interface Forces on Plate (Compression)



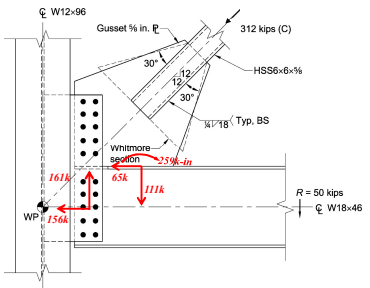
Example of Corner Connection Special Case IV



Net Interface Forces on Gusset (Compression)



Example of Corner Connection Special Case IV



Net Interface Forces on Beam (Compression)



Example of Corner Connection Gusset-to-Column

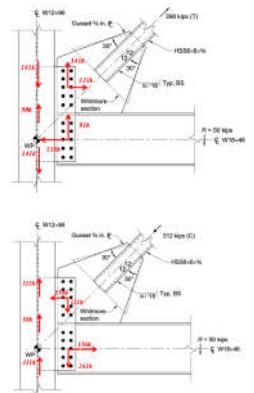


Example of Corner Connection Special Case IV

Plate: Gusset-to-Column – Bolt Shear: Table 7-1
 Brace Tension H=133k, V=141k
 Brace Compression H=156k, V=111k
 Tension controls
 $R = \sqrt{133^2 + 141^2} = 194k$

$$r_{bolt} = \frac{R}{n} = \frac{194 \text{ kips}}{10 \text{ bolts}} = 19.4 \text{ kips/bolt} < \phi_r = 31.8 \text{ kips/bolt} \quad \text{— OK}$$

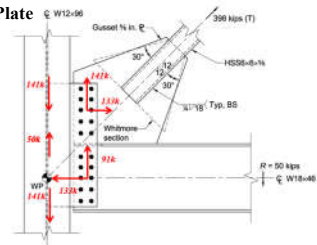
All bolts see 19.4 kips



Example of Corner Connection Special Case IV

Plate: Gusset to Column Bearing and Tearout of Plate

AISC Specification J3.10
 Tearout $\phi_{rto} = 0.75(1.2)(F_u)(l)(t_p)$
 Bearing $\phi_{rpb} = 0.75(2.4)(F_u)(d_b)(t_p)$
 Because of Special Case IV, all bolt groups are concentrically loaded



Net Interface Forces on Plate (Tension)



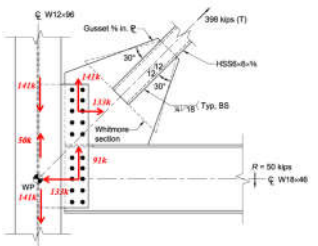
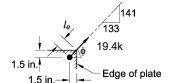
Example of Corner Connection Special Case IV

The critical bolt is the top right bolt

$$\phi = \tan^{-1} \frac{141}{133} = 46.7^\circ$$

Since $46.7^\circ > 45^\circ$, the distance to horizontal edge of plate controls

$$\cos \phi = \frac{1.5}{l_c} \rightarrow l_c = \frac{1.5}{\cos 43.3^\circ} = 2.06''$$



Net Interface Forces on Plate (Tension)



Example of Corner Connection Special Case IV

Tearout

$$l_c = l_e - \frac{1}{2}d_h$$

$$= 2.06 - \frac{1}{2}(1.125) = 1.50''$$

$$\phi r_{td} = 0.75(1.2)(65)(1.50)(t_p) \geq 19.4$$

$$t_p \geq 0.221 \rightarrow 3/8 \text{ plate ok, so far}$$

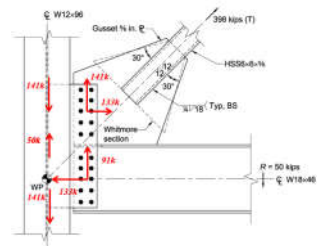
Bearing

$$\phi T_{pb} = 0.75(2.4)(65)(1.0)(0.375)$$

$$= 43.9 > 19.4k \text{ - OK}$$

3/8 plate ok, so far

Remember, gusset is 5/8 plate



Net Interface Forces on Plate (Tension)



Example of Corner Connection Special Case IV

Plate: Gusset-to-Column- Block Shear - Shear Plate (Vertical Load):

From AISC Specification Section J4.3

$$A_{gv} = [(n_b - 1)s_b + L_{cb}]t_{pl}$$

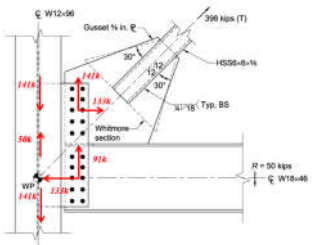
$$= [(2 - 1)(3.0 \text{ in.}) + 1.50 \text{ in.}](0.375 \text{ in.})$$

$$= 1.6875 \text{ in.}^2$$

$$A_{nt} = A_{gv} - (n_b - 0.5)d_{hole}t_{pl}$$

$$= 1.6875 \text{ in.}^2 - (2 - 0.5)(1.1875 \text{ in.})(0.375 \text{ in.})$$

$$= 1.019 \text{ in.}^2$$



Net Interface Forces on Plate (Tension)



Example of Corner Connection Special Case IV

Plate: Gusset-to-Column- Block Shear - Shear Plate (Vertical Load) (cont.):

From AISC Specification Eq. J4-3,

$$A_{gv} = [(n_v - 1)s_v + L_{cv}]t_{pl}$$

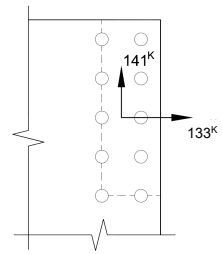
$$= [(5 - 1)(3.0 \text{ in.}) + 1.50 \text{ in.}](0.375 \text{ in.})$$

$$= 5.0625 \text{ in.}^2$$

$$A_{nt} = A_{gv} - (n_v - 0.5)d_{hole}t_{pl}$$

$$= 5.0625 \text{ in.}^2 - (5 - 0.5)(1.25 \text{ in.})(0.375 \text{ in.})$$

$$= 2.95 \text{ in.}^2$$



Example of Corner Connection Special Case IV

Plate: Gusset-to-Column– Block Shear – Shear Plate (Vertical Load) (cont.):

From AISC Specification Eq. J4-5,

$$\phi R_n = \phi [\min \{0.6F_u A_{nv}, 0.6F_y A_{gv}\} + U_{bs} F_u A_{nt}]$$

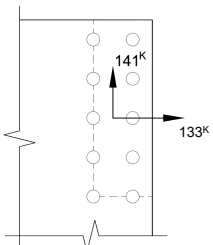
$$U_{bs} F_u A_{nt} = 1.0 (65 \text{ ksi}) (1.019 \text{ in.}^2) = 66.2 \text{ kips}$$

$$0.6F_y A_{gv} = 0.6 (50 \text{ ksi}) (5.0625 \text{ in.}^2) = 152 \text{ kips}$$

$$0.6F_u A_{nv} = 0.6 (65 \text{ ksi}) (3.06 \text{ in.}^2) = 119 \text{ kips}$$

$$\phi R_{bsv} = 0.75 (119 \text{ kips} + 66.2 \text{ kips})$$

$$= 138 \text{ kips} < V_c = 141 \text{ kips} \quad \text{—NG}$$



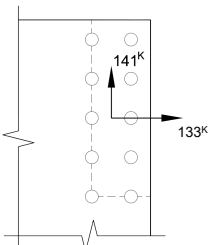
Example of Corner Connection Special Case IV

Plate: Gusset-to-Column– Block Shear – Shear Plate (Vertical Load) (cont.):

Try a 1/2 plate

$$\phi R_{bsv} = 134 \times \frac{0.5}{0.375} = 179 \text{ k} > 141 \text{ k} \quad \text{—OK}$$

Continue with 1/2 plate



Example of Corner Connection Special Case IV

Plate: Gusset-to-Column– Block Shear –
 Shear Plate (Horizontal Load):

From AISC Specification Eq. J4-5,

$$A_{gv} = [(n_v - 1)s_v + L_{gv}]t_{pl}$$

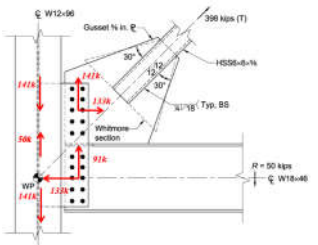
$$= [(5 - 1)(3.0 \text{ in.}) + 1.50 \text{ in.}](0.50 \text{ in.})$$

$$= 6.75 \text{ in.}^2$$

$$A_{nt} = A_{gv} - (n_h - 0.5)d_{hole}t_{pl}$$

$$= 6.75 \text{ in.}^2 - (5 - 0.5)(1.875 \text{ in.})(0.50 \text{ in.})$$

$$= 4.08 \text{ in.}^2$$



Net Interface Forces on Plate (Tension)



Example of Corner Connection Special Case IV

Gusset-to-Column– Block Shear – Shear Plate (Horizontal Load) (cont.):

From AISC Specification Eq. J4-5,

$$A_{gv} = [(n_h - 1)s_h + L_{gh}]t_{pl}$$

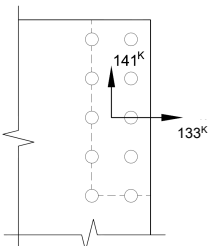
$$= [(2 - 1)(3.0 \text{ in.}) + 1.50 \text{ in.}](0.50 \text{ in.})$$

$$= 2.25 \text{ in.}^2$$

$$A_{nv} = A_{gv} - (n_h - 0.5)d_{hole}t_{pl}$$

$$= 2.25 \text{ in.}^2 - (2 - 0.5)(1.875 \text{ in.})(0.50 \text{ in.})$$

$$= 1.359 \text{ in.}^2$$



Example of Corner Connection Special Case IV

Plate: Gusset-to-Column – Block Shear – Shear Plate (Horizontal Load) (cont.):
 From AISC Specification Eq. J4-5,

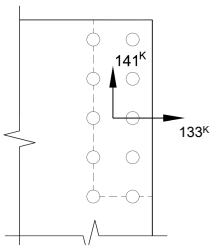
$$\phi R_n = \phi \left[\min \{ 0.6F_u A_{nt}, 0.6F_y A_{gv} \} + U_{ts} F_u A_t \right]$$

$$U_{ts} F_u A_{nt} = 1.0(65 \text{ ksi})(4.08 \text{ in.}^2) = 265 \text{ kips}$$

$$0.6F_y A_{gv} = 0.6(50 \text{ ksi})(2.25 \text{ in.}^2) = 67.5 \text{ kips}$$

$$0.6F_u A_{nt} = 0.6(65 \text{ ksi})(1.359 \text{ in.}^2) = 53.0 \text{ kips}$$

$$\phi R_{nbs} = 0.75(53.0 \text{ kips} + 265 \text{ kips}) = 238 \text{ kips} > H_c = 133 \text{ kips} \quad \text{—OK}$$

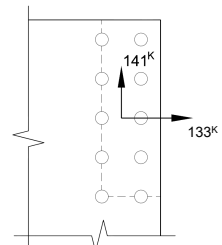


Example of Corner Connection Special Case IV

Gusset-to-Column – Block Shear – Shear Plate:
 Interaction of vertical and horizontal loading,

$$\left(\frac{V_c}{\phi R_{nv}} \right)^2 + \left(\frac{H_c}{\phi R_{nh}} \right)^2 = \left(\frac{141 \text{ kips}}{179 \text{ kips}} \right)^2 + \left(\frac{133 \text{ kips}}{238 \text{ kips}} \right)^2 = 0.93 < 1 \quad \text{—OK}$$

A 1/2" minimum shear plate is required.

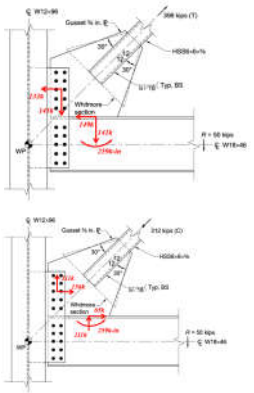


Example of Corner Connection Special Case IV

Gusset: Gusset-to-Column – Block Shear –
 The forces on the gusset act as shown.

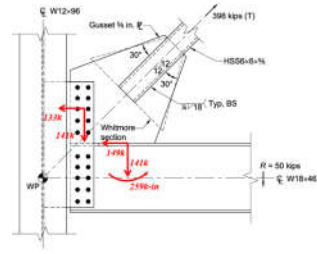
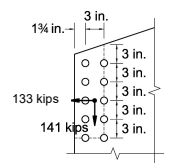
For Brace Tension:
 Only horizontal block shear is a limit state.

The gusset plate is 5/8". The shear plate has been checked for this load; therefore, 5/8" gusset is ok.



Example of Corner Connection Special Case IV

Gusset: Gusset-to-Column – Block Shear –
 The limit state was ok for the 1/2" plate.
 Therefore, 5/8" gusset ok for block shear.



Net Interface Forces on Gusset (Tension)



Example of Corner Connection Special Case IV Beam-to-Column



Example of Corner Connection Special Case IV

Plate: Beam-to-Column Connection:

Tension Case:
 H=133k V=91k R=161k
 Compression Case:
 H=156k V=161k R=224k -- Controls
 Bearing

$$\phi R_n = 0.75(2.4)F_u(d_b)(t_w)$$

$$= 0.75(2.4)(65)(1.0)(0.5)$$

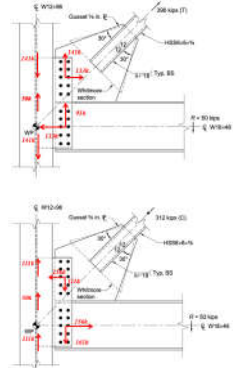
$$= 58.5k > 224k / 10 = 22.4k \text{ -- OK}$$

Tearout - worst case

$$\phi V_w = 0.75(1.2)(F_u)(l_c)(t_w)$$

$$= 0.75(1.2)(65)(1.50 - 0.5)(1.125)(0.50)$$

$$= 27.4k > 22.4k \text{ -- OK}$$

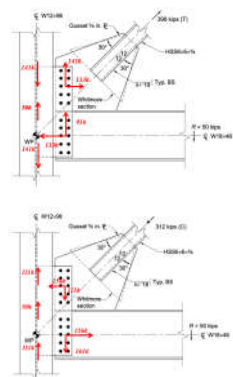


Example of Corner Connection Special Case IV

Plate: Beam-to-Column Connection:

Block shear is not a limit state for the brace tension case.

For the brace compression case, block shear is a limit state for the vertical plate force of 161k and the horizontal force of 156k.



Example of Corner Connection Special Case IV

Plate: Beam-to-Column – Block Shear:

Vertical force, V = 161 kips

$$A_{gv} = (13.5)(0.5) = 6.75 \text{ in.}^2$$

$$A_{nv} = 6.75 - 4.5(1.1875)(0.5) = 4.08 \text{ in.}^2$$

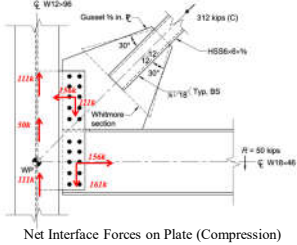
$$A_{nt} = (4.5 - 1.5(1.1875))(0.5) = 1.36 \text{ in.}^2$$

$$F_u A_{nt} = 65(1.36) = 88.4 \text{ kips}$$

$$0.6 F_y A_{gv} = 0.6(50)(6.75) = 203 \text{ kips}$$

$$0.6 F_u A_{nv} = 0.6(65)(4.08) = 159 \text{ kips} \leftarrow$$

$$\phi R_n = 0.75[1.0(88.4) + 159] = 186 \text{ kips} > 161 \text{ kips -- OK}$$



Example of Corner Connection Special Case IV

Plate: Beam-to-Column – Block Shear:

Horizontal force, $H = 156$ kips

$$A_{gv} = (4.5)(0.5) = 2.25 \text{ in.}^2$$

$$A_{nv} = 2.25 - 1.5(1.1875)(0.5) = 1.36 \text{ in.}^2$$

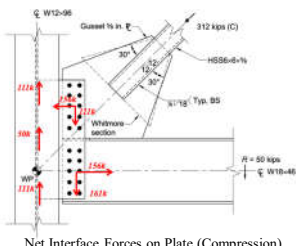
$$A_{nt} = (13.5 - 4.5(1.1875))(0.5) = 4.08 \text{ in.}^2$$

$$F_u A_{nt} = 65(4.08) = 265 \text{ kips}$$

$$0.6F_y A_{gv} = 0.6(50)(2.25) = 67.5 \text{ kips}$$

$$0.6F_u A_{nv} = 0.6(65)(1.36) = 53.0 \text{ kips}$$

$$\phi R_n = 0.75[1.0(265) + 53.0] = 239 \text{ kips} > 156 \text{ kips} \text{ -- OK}$$



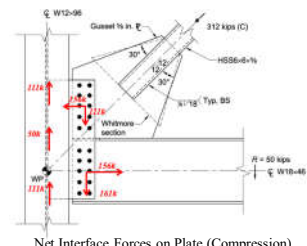
Example of Corner Connection Special Case IV

Plate: Beam-to-Column – Block Shear:
 Interaction

$$\left(\frac{161}{186}\right)^2 + \left(\frac{156}{239}\right)^2 = 1.18 > 1 \text{ -- NG}$$

$$1.18 \left(\frac{0.5}{t_p}\right)^2 \leq 1$$

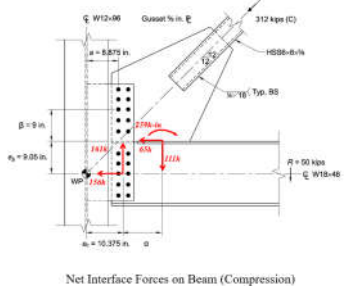
$$\rightarrow t_p \geq 0.543 \text{ in. -- Use a } 5/8\text{-in. plate.}$$



Example of Corner Connection Special Case IV

Beams: Beam-to-Column – Beam Web Shear:
 AISC Manual Table 3-2,
 $\phi V_n = 195 \text{ kips} > 161 \text{ kips, --OK}$

Table 3-2 (continued) W-Shapes Selection by Z_x											
$F_y = 50 \text{ ksi}$											
Shape	Z_x	M_u/F_u	M_u/F_u	M_u/F_u	M_u/F_u	M_u/F_u	M_u/F_u	M_u/F_u	M_u/F_u	M_u/F_u	M_u/F_u
		kip-ft	kip-ft	kip-ft	kip-ft	kip-ft	kip-ft	kip-ft	kip-ft	kip-ft	kip-ft
W12x64	85.4	238	338	143	214	113	163	6.65	13.2	843	217
W12x60	80.4	206	296	124	181	95.8	141	6.80	13.6	809	209
W12x56	75.4	174	246	105	151	81.6	121	7.00	14.0	775	201
W12x52	70.4	142	206	86	121	67.4	101	7.20	14.4	741	193
W12x48	65.4	110	166	67	96	53.2	76	7.40	14.8	707	185
W12x44	60.4	78	116	48	66	39.0	56	7.60	15.2	673	177
W12x40	55.4	46	66	29	36	24.8	36	7.80	15.6	639	169
W12x36	50.4	14	16	9	11	10.6	11	8.00	16.0	605	161



Example of Corner Connection Special Case IV

**Beam: Beam-to-Column – Bearing and Tearout of
 Beam Web: Tension**

Web is critical since: $t_w = 0.360 \text{ in.} < t_p = 0.50 \text{ in.}$
 There is no force acting towards the end of the beam.
 Therefore, tearout does not apply.

Shear per bolt:

$$R_w = \sqrt{133^2 + 91^2} = 161k$$

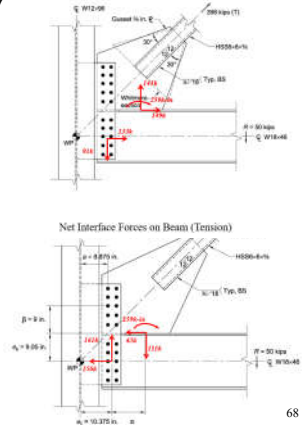
$$r_{bolt} = \frac{R_w}{n_{bolts}} = \frac{161}{10} = 16.1k / \text{bolt}$$

Bearing:

$$\phi r_{bs} = 0.75(2.4)F_u(d_b)(t_w)$$

$$= 0.75(2.4)(65)(1.0)(0.36)$$

$$= 48.9k > 16.1k \text{ -- OK}$$



Example of Corner Connection Special Case IV

Beam: Beam-to-Column – Bearing and Tearout

Compression controls

$$V = 161 \text{ kips} \quad H = 156 \text{ kips} \quad R = 224 \text{ kips}$$

Shear per bolt

$$224/10 = 22.4 \text{ kips} < 31.8 \text{ kips} \text{ -- OK}$$

Bearing

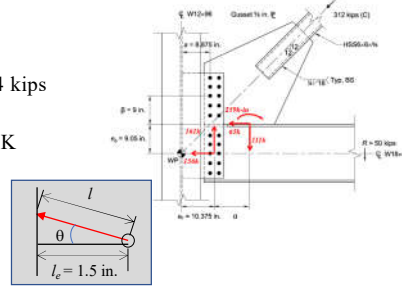
$$\phi r_n = 0.75(2.4)(65)(1.0)(0.360) = 42.1 \text{ kips} > 22.4 \text{ kips} \text{ -- OK}$$

Tearout

$$\tan \theta = (161/156 = 1.032) \rightarrow \theta = 45.9^\circ$$

$$\cos \theta = (1.5/l) \rightarrow l = 2.16 \text{ in.} \rightarrow l_c = 2.16 - 0.5(1.1875) = 1.57 \text{ in.}$$

$$\phi r_n = 0.75(1.2)(65)(0.360)(1.57) = 33.1 \text{ kips} > 22.4 \text{ kips} \text{ -- OK}$$



Example of Corner Connection Special Case IV

Beam: Beam-to-Column – Web Block Shear

Horizontal force, $H = 156$ kips

$$A_{gv} = 2(4.5)(0.360) = 3.24 \text{ in.}^2$$

$$A_{nv} = 2[4.5 - 1.5(1.1875)](0.360) = 1.96 \text{ in.}^2$$

$$A_{nt} = (12 - 4(1.1875))(0.360) = 2.61 \text{ in.}^2$$

$$F_u A_{nt} = 65(2.61) = 170 \text{ kips}$$

$$0.6 F_y A_{gv} = 0.6(50)(3.24) = 97.2 \text{ kips}$$

$$0.6 F_u A_{nv} = 0.6(65)(1.96) = 76.4 \text{ kips}$$

$$\phi R_n = 0.75[1.0(170) + 76.4] = 185 \text{ kips} > 156 \text{ kips} \text{ -- OK}$$



Example of Corner Connection Special Case IV

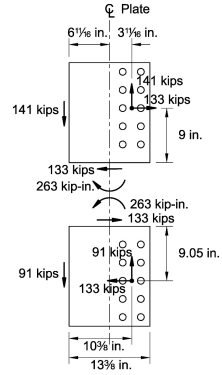
Plate Section Forces – Tension Case

$$V = 133 \text{ kips} \quad N_e = \frac{4(263)}{13.375} = 78.7 \text{ kips}$$

$$\phi V_n = 1.0(0.6)(50)(13.375)(0.625) = 251 \text{ kips} > 133 \text{ kips} \text{ -- OK}$$

$$\phi N_n = 0.9(1.0)(50)(13.375)(0.625) = 376 \text{ kips} > 78.7 \text{ kips} \text{ -- OK}$$

$$\left(\frac{133}{251}\right)^2 + \left(\frac{78.7}{376}\right)^2 = 0.32 < 1.0 \text{ -- OK}$$



Example of Corner Connection Special Case IV

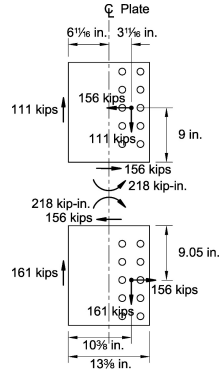
Plate Section Forces – Compression Case

$$V = 156 \text{ kips} \quad N_e = \frac{4(218)}{13.375} = 65.2 \text{ kips}$$

$$\phi V_n = 1.0(0.6)(50)(13.375)(0.625) = 251 \text{ kips} > 156 \text{ kips} \text{ -- OK}$$

$$\phi N_n = 0.9(1.0)(50)(13.375)(0.625) = 376 \text{ kips} > 65.2 \text{ kips} \text{ -- OK}$$

$$\left(\frac{156}{251}\right)^2 + \left(\frac{65.2}{376}\right)^2 = 0.42 < 1.0 \text{ -- OK}$$



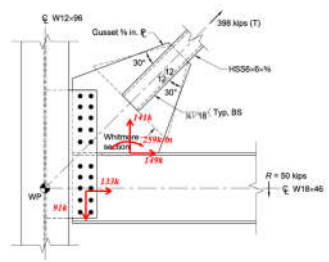
Example of Corner Connection Special Case IV

Gusset-to-Beam Connection – Gusset Checks:
 AISC Specification Eq. J4-4 – Shear Rupture

$$\begin{aligned} \phi R_n &= \phi 0.60 F_u A_{gv} \\ &= 0.75 (0.60) (65 \text{ ksi}) (0.625 \text{ in.}) (21.8 \text{ in.}) \\ &= 398 \text{ kips} > V = 149 \text{ kips} \quad \text{– OK} \end{aligned}$$

AISC Specification Eq. J4-2 – Tension Rupture

$$\begin{aligned} \phi R_n &= \phi F_u A_g \\ &= 0.75 (65 \text{ ksi}) (0.625 \text{ in.}) (21.8 \text{ in.}) \\ &= 664 \text{ kips} > N_e = 189 \text{ kips} \quad \text{– OK} \end{aligned}$$



Net Interface Forces on Beam (Tension)



Example of Corner Connection Special Case IV

Beam: Gusset-to-Beam Connection – Beam Checks:

AISC Specification Eq. J10-3 – Web Local Yielding

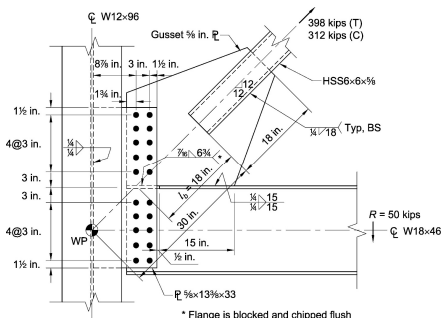
$$\begin{aligned} \phi R_n &= \phi F_y t_w (2.5k + l_b) \\ &= 1.0 (50 \text{ ksi}) (0.360 \text{ in.}) [2.5 (1.01 \text{ in.}) + 21.8 \text{ in.}] \\ &= 438 \text{ kips} > N_e = 189 \text{ kips} \quad \text{– OK} \end{aligned}$$

AISC Specification Eq. J10-4 – Web Local Crippling

$$\begin{aligned} \phi R_n &= \phi 0.80 t_w^2 \left[1 + 3 \left(\frac{l_b}{d} \right) \left(\frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{\frac{E F_y t_f}{t_w}} \\ &= \phi 0.80 (0.360)^2 \left[1 + 3 \left(\frac{21.8 \text{ in.}}{18.1 \text{ in.}} \right) \left(\frac{0.360 \text{ in.}}{0.605 \text{ in.}} \right)^{1.5} \right] \sqrt{\frac{29,000 \text{ ksi} (50 \text{ ksi}) (0.605 \text{ in.})}{0.360 \text{ in.}}} \\ &= 323 \text{ kips} > N_e = 189 \text{ kips} \quad \text{– OK} \end{aligned}$$



Example of Corner Connection Special Case IV



Final Design



UFM Special Case V – Bypass Method



UFM Special Case V – Bypass Method

- “Design for Local Web Shear at Brace Connections: An Adaptation of the Uniform Force Method”
 by Sabelli, Saxey, Li, and Thornton
AISC Engineering Journal, 2021, Vol. 58, No. 4, pp. 223-265
 Visit aisc.org/ej for access.



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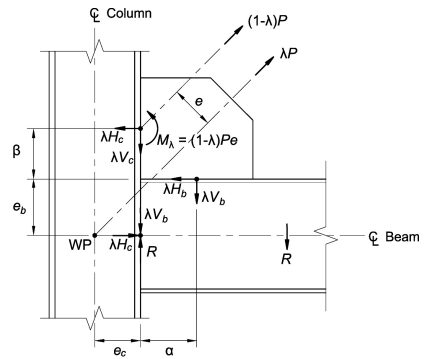
UFM Special Case V – Bypass Method

- When beam shear is high due to UFM component, V_b , and gravity shear, R ...
- If Special Case II cannot reduce beam shear enough to eliminate doubler...
 ...try the Bypass Method.



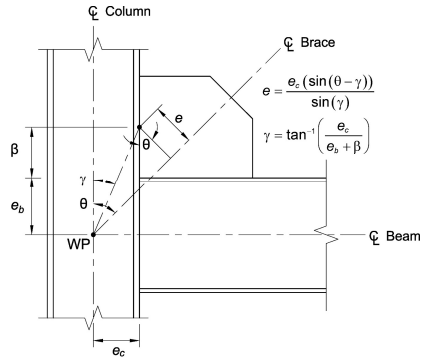
82

UFM Special Case V – Bypass Method



83

Calculation of Eccentricity, e



84

UFM Special Case V – Bypass Method

When $R + |V_b| > \phi R_n$

$$\text{set } \lambda = \frac{\phi R_n - R}{|V_b|}$$

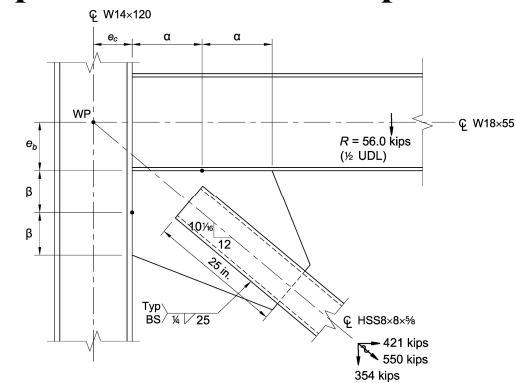
where

ϕR_n is the beam web strength or the web connection strength,
 whichever controls



85

Special Case V – Example



86

Special Case V – Example

Using the UFM

$$e_b = 9.05 \text{ in.} \quad e_c = 7.25 \text{ in.} \quad \tan \theta = \frac{12}{10.0625} = 1.1925 \rightarrow \theta = 50^\circ$$

$$\alpha - \beta \tan \theta = e_b \tan \theta - e_c$$

Choose $\beta = 8$, then $\alpha = (8 + 9.05)(1.1925) - 7.25 = 13.1 \text{ in.}$

$$r = \sqrt{(\alpha + e_c)^2 + (\beta + e_b)^2}$$

$$= \sqrt{(13.1 + 7.25)^2 + (8 + 9.05)^2} = 26.55 \text{ in.}$$

$$\frac{P}{r} = \frac{550}{26.55} = 20.72 \frac{\text{kips}}{\text{in.}}$$



87

Special Case V – Example

$$H_b = \alpha \frac{P}{r} = (13.1)(20.72) = 271 \text{ kips}$$

$$H_c = e_c \frac{P}{r} = (7.25)(20.72) = 150 \text{ kips}$$

$$\Sigma = 421 \text{ kips (OK)}$$

$$V_c = \beta \frac{P}{r} = (8)(20.72) = 166 \text{ kips}$$

$$V_b = e_b \frac{P}{r} = (9.05)(20.72) = 187 \text{ kips}$$

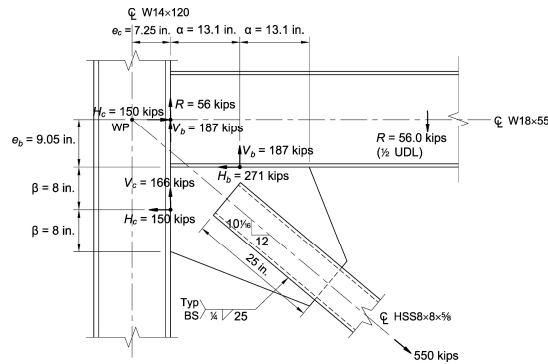
$$\Sigma = 353 \text{ kips (OK)}$$



Placing these forces on the connection...

88

Special Case V – Example



89

Special Case V – Example

The shear capacity at the beam

$$\phi V_n = 212 \text{ kips}$$

The shear demand is

$$187 + 56 = 243 \text{ kips} > 212 \text{ kips} \text{ -- No Good}$$

Could try Special Case 2 to reduce the shear by introduction of

$$\Delta V_b = 243 - 212 = 31 \text{ kips}$$

This will work for this problem

-- but --



I want to demonstrate **Special Case 5**.

90

Special Case V – Example

Special Case 5...

$$\text{Set } \lambda = \frac{\phi R_n - R}{|V_b|} = \frac{212 - 56}{187} = 0.834$$

If the brace force, $P = 550$, is reduced to

$$\lambda P = (0.834)(550) = 459 \text{ kips}$$

the beam shear will be reduced to

$$(187)(0.834) = 156 \text{ kips} < \phi R_n = 212 \text{ kips} \text{ -- OK}$$



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Special Case V – Example

The brace force, $P = 550$, is reduced to

$$\lambda P = (0.834)(550) = 459 \text{ kips}$$

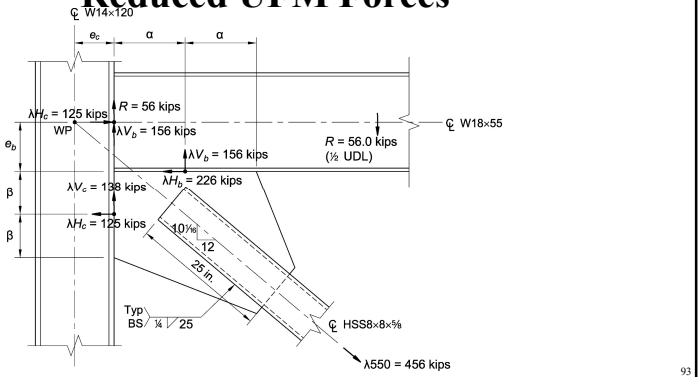
This brace force, $\lambda P = 459$ kips, is used in the UFD.

All the UFM forces are reduced by $\lambda = 0.834$ as shown in the next figure.



92

Special Case V – Example Reduced UFM Forces



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Special Case V – Example

The remainder of the brace force is applied to the gusset-to-column connection as

$$\bar{P} = (1 - \lambda) P$$

$$= (1 - 0.834)(550) = 91.3 \text{ kips}$$

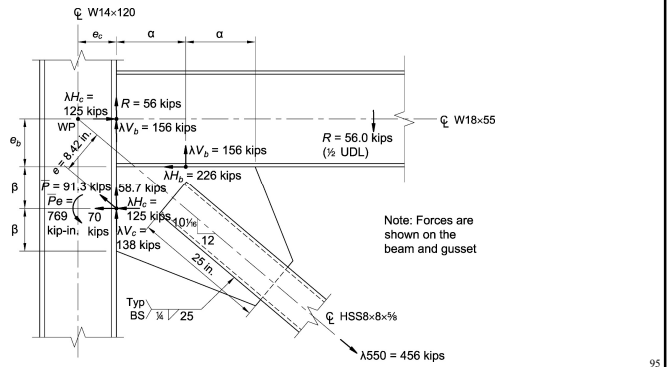
This force is eccentric to the W.P. and causes a moment

$$\bar{P}e = (91.3)(8.42) = 769 \text{ kips}$$



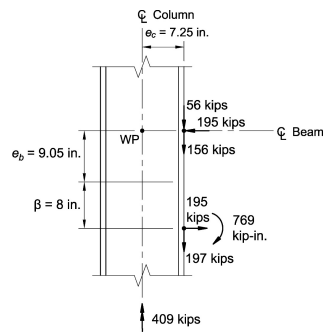
94

Special Case V – Example Special Case V Force Distribution



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Special Case V – Example Free Body Diagram



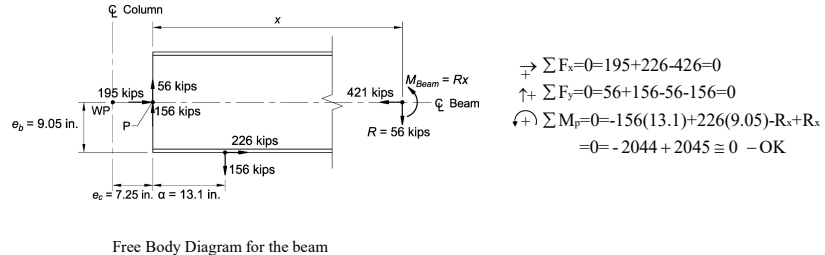
Beam shear is applied at column flange.
 There is a moment: $56k \times 7.25$
 Beam shear is applied at column flange.
 There is a moment:
 $56kips \times 7.25 = 406k-in \rightarrow$ ignored
 $\rightarrow \sum F_x = 0 = 195 - 195 = 0$
 $\uparrow \sum F_y = 0 = -56 - 156 - 197 + 409 = 0$
 $\curvearrowright \sum M_{wp} = 0 = -769 - (156 + 197)7.25 + 195(9.05 + 8) = -3.5 \approx 0 - OK$

Free Body Diagram for the column



96

Special Case V – Example Free Body Diagram

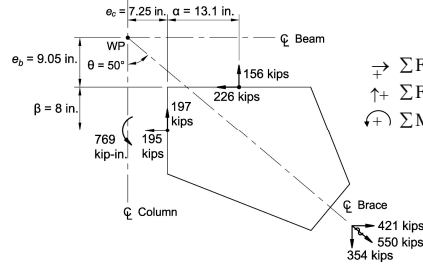


$$\begin{aligned} \rightarrow \sum F_x &= 0 = 195 + 226 - 426 = 0 \\ \uparrow \sum F_y &= 0 = 56 + 156 - 56 - 156 = 0 \\ \curvearrowright \sum M_P &= 0 = -156(13.1) + 226(9.05) - R_x + R_x \\ &= 0 = -2044 + 2045 \approx 0 \text{ - OK} \end{aligned}$$



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Special Case V – Example Free Body Diagram

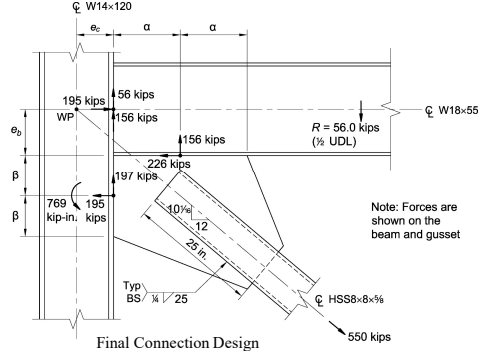


$$\begin{aligned} \rightarrow \sum F_x &= 0 = -226 - 195 + 421 = 0 \\ \uparrow \sum F_y &= 0 = 156 + 197 - 354 - 1 \approx 0 \rightarrow \text{O.K.} \\ \curvearrowright \sum M_{WP} &= 0 = 0 + 156(7.25 + 13.1) - 226(9.05) - 197(7.25) \\ &\quad - 195(9.05 + 8) + 769 \\ &= 3175 - 2045 + 1428 - 3325 + 769 = 2 \approx 0 \text{ - OK} \end{aligned}$$



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Special Case V – Example



99

The forces on all interfaces are now known.
 The connection design can now be completed.



Summary



Summary

- Uniform Force Method – Special Case IV
 - Provides concentrically loaded bolt groups
- Uniform Force Method – Special Case V
 - With heavy columns and light beams, provides an alternate method to avoid doubler plates



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Thank you!

AISC | Questions



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- All individuals attending at your connection: you will receive an email on how to report their 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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- EEU – You must take all quizzes and the final exam to receive EEU.
- PDHs – If you watch a recorded session, you must pass quiz for PDHs.
- REINFORCEMENT – Reinforce what you learn tonight. Get more out of the course.

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



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Course Resources

Event	Start Date
N13 8-Session Package Night School 1A - Design of Industrial Buildings	8/09/2017 7:00:00 PM
N13 8-Session Package Night School 1A - Fundamentals of Steeling	8/9/2017 7:00:00 PM

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Night School Resources



Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Minutes	Video	Quiz	Attendance
N13 - Design Criteria	3/30/2017 7:00:00 PM	30:00:00	Video	Pass Score: 80	Pending
N13 - Economic Considerations	2/6/2017 7:00:00 PM	30:00:00	Available	Available 02/08/2017 5pm EST	Pending
N13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	30:00:00	Available	Available 02/15/2017 5pm EST	Pending
N13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	30:00:00	Available	Available 03/01/2017 5pm EST	Pending
N13 - Crane Order Design and Frame Analysis	3/6/2017 7:00:00 PM	30:00:00	Available	Available 03/08/2017 5pm EST	Pending
N13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	30:00:00	Available	Available 03/15/2017 5pm EST	Pending
N13 - Transfer Crane Grease Is Compressive Brag Bracing Dpn	3/27/2017 7:00:00 PM	30:00:00	Available	Available 03/29/2017 5pm EST	Pending
N13 - Building Envelope and Bracing Design	4/10/2017 7:00:00 PM	30:00:00	Available	Available 04/05/2017 5pm EST	Pending

8-Session Registrants

Night School Resources

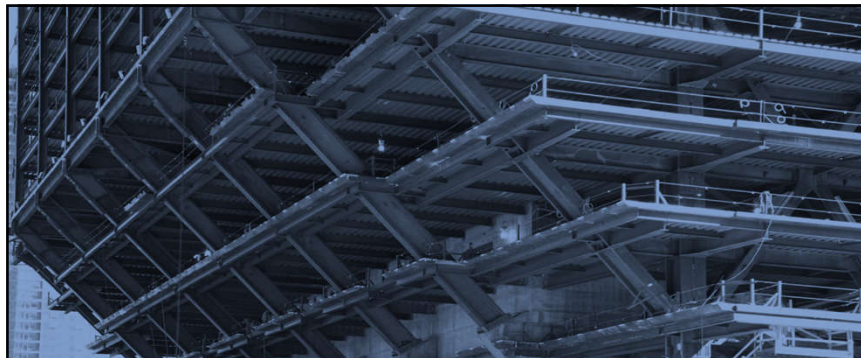
- Weekly “quiz and recording” email.
- Weekly updates of the master quiz and attendance record, found at www.aisc.org/nightschool28. Scroll down to Quiz and Attendance records.
 - Updated on Friday mornings.



8-Session Registrants

Night School Resources

- Webinar connection information
 - Reminder email sent out Monday mornings
- Links to handouts also found here



AISC | Thank you

