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Course Description

Vertical Bracing Connections – Corner Connection Part 2: High Seismic Systems

October 27, 2014

This session will be Part 2 of a two part session. Learn and understand the various steps and methodologies used for bracing connection design in high seismic areas. Become familiar with bracing connection design through illustrated design examples. Gain an understanding of practical design tips as well as addressing common design challenges.

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Learning Objectives

- Become familiar with designing a corner bracing connection using single plate shear connections for high seismic forces.
- Gain an understanding of the bracing connection design process through the presentation of a high seismic design example.
- Become familiar with the differences for designing for high seismic vs. low-seismic or wind controlled forces.
- Gain an understanding of expected yield stress, amplified seismic load, and protected zone and how these affect bracing connection design.

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Bracing Connections and Related Topics

Session 5: Vertical Bracing Connections – Corner Connection Part 2: High-Seismic Systems

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structural STEEL

Bracing Connections and Related Topics

By: William Thornton

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Course Outline

1. Basic Principles
2. Uniform Force Method
3. Bracing Connection Details and Prying Action
4. Vertical Bracing Connections – Corner Part 1
5. **Vertical Bracing Connections – Corner Part 2**
6. Chevron Gussets for Wind or Low-Seismic
7. Chevron Gussets for High Seismic
8. Additional Connection Topics

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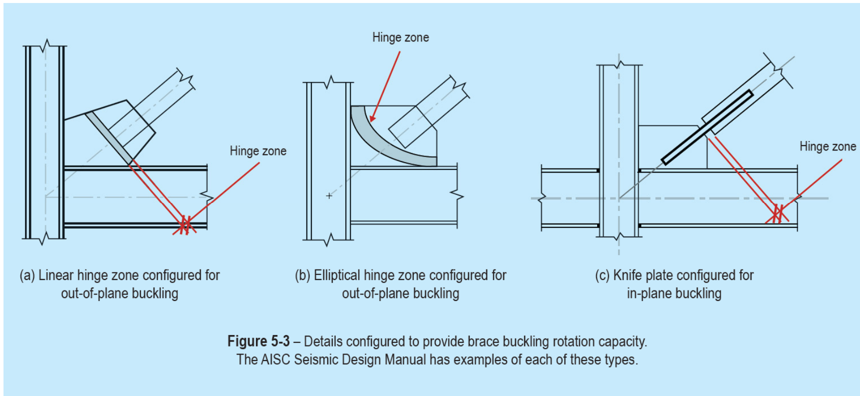
Seismic Vertical Brace Connection



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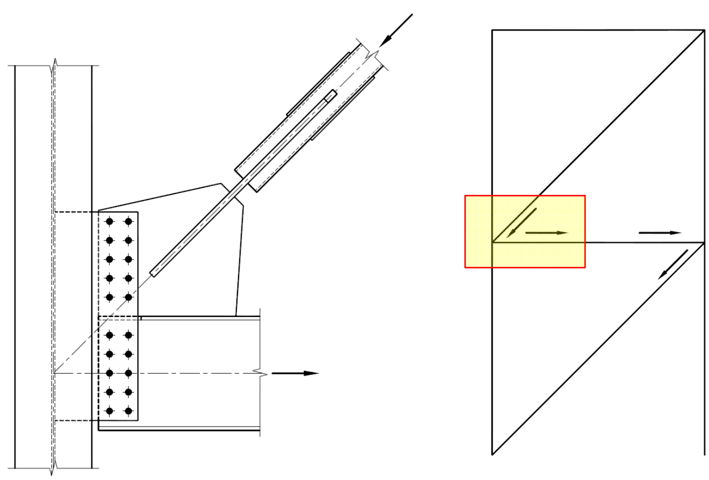
Seismic Vertical Brace Connection



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Session Outline

- Example of VB Corner Connection in High Seismic Systems
  - Brace-to-Gusset
    - Tensile and Compression Demand of Brace
    - Hinge Plate Design
    - Weld of Hinge Plate
    - Whitmore Section of Gusset
    - Shear Lag of Brace

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Session Outline

- Example of VB Corner Connection in High Seismic Systems (cont.)
  - Determination of Interface Forces
  - Shear Plate Ductility
  - Gusset to Column
    - Bolt Shear
    - Bearing and Tearout
    - Block Shear

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Session Outline

- Example of VB Corner Connection in High Seismic Systems (cont.)
  - Beam to Column Connections
    - Bolt Shear
    - Bearing and Tearout
    - Block Shear of Plate
    - Block Shear of Beam Web

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Session Outline

- Example of VB Corner Connection in High Seismic Systems (cont.)
  - Gusset to Beam Connection
    - Weld of Gusset to Beam
    - Gusset Checks
      - Shear Yielding
      - Tension Yielding
    - Beam Checks
      - Web Yielding
      - Local Beam Web Crippling

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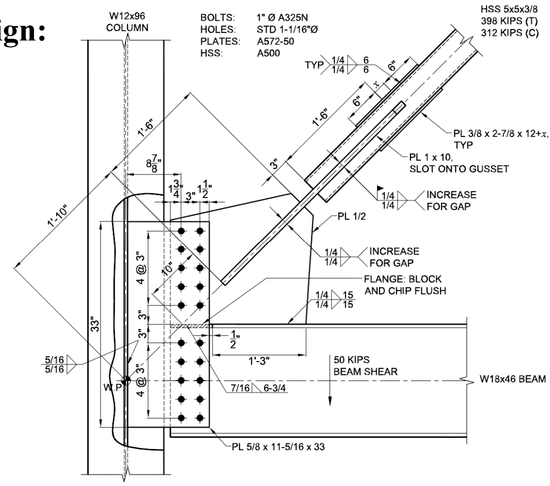
Example of High Seismic Corner Connection

Initial Design:



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Example of High Seismic Corner Connection (cont.)

Given:

1. AISC 14th Edition *Manual*, LRFD
2. AISC 341-10 *Seismic Provisions for Structural Steel Buildings*
3. 1 in. diameter ASTM A325-N bolts
4. STD Holes, $1^1/_{16}$ in. diameter
5. Brace Slope = 45°
6. Plate: ASTM A572 Gr. 50, $F_y = 50$ ksi
7. HSS : ASTM A500 Gr. B, $F_y = 46$ ksi

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Example of High Seismic Corner Connection Brace-to-Gusset

Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Tensile Demand of Brace:

AISC 341-10, Section F1.6a.(1),

$$T = R_y F_y A_g$$
$$= (1.4)(46 \text{ ksi})(6.18 \text{ in.}^2)$$
$$= 398 \text{ kips}$$

AISC 341-10, Table A3.1,

$$R_y = 1.4$$

TABLE A3.1
R_y and R_t Values for Steel and Steel Reinforcement Materials

Application	R_y	R_t
Hot-rolled structural shapes and bars:		
• ASTM A36/A36M	1.5	1.2
• ASTM A1043/1043M Gr. 36 (250)	1.3	1.1
• ASTM A572/572M Gr. 50 (345) or 55 (380), ASTM A913/A913M Gr. 50 (345), 60 (415), or 65 (450), ASTM A588/A588M, ASTM A992/A992M	1.1	1.1
• ASTM A1043/A1043M Gr. 50 (345)	1.2	1.1
• ASTM A529 Gr. 50 (345)	1.2	1.2
• ASTM A529 Gr. 55 (380)	1.1	1.2
Hollow structural sections (HSS):		
• ASTM A500/A500M (Gr. B or C), ASTM A501	1.4	1.3
Pipe:		
• ASTM A53/A53M	1.6	1.2
Plates, Strips and Sheets:		
• ASTM A36/A36M	1.3	1.2
• ASTM A1043/1043M Gr. 36 (250)	1.3	1.1
• A1011/A1011M HSLAS Gr. 55 (380)	1.1	1.1
• ASTM A572/A572M Gr. 42 (290)	1.3	1.0
• ASTM A572/A572M Gr. 50 (345), Gr. 55 (380), ASTM A588/A588M	1.1	1.2
• ASTM 1043/1043M Gr. 50 (345)	1.2	1.1
Steel Reinforcement:		
• ASTM A615, ASTM A706	1.25	1.25

Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Compression Demand of Brace:

$$Work\ Point\text{-}to\text{-}Work\ Point = \sqrt{(12\text{ ft-0 in.})^2 + (12\text{ ft-0 in.})^2}$$
$$= 17'-0"$$

$$L_{unbraced} = [(17\text{ ft-0 in.}) - 2(3\text{ ft-7 in.})](12\text{ in./ft})$$
$$= 118\text{ in.}$$

$$\frac{kL_{unbraced}}{r} = \frac{1.0(118\text{ in.})}{1.87} = 63.1\text{ in.} \le 4.71\sqrt{\frac{E}{R_y F_y}} = 4.71\sqrt{\frac{29{,}000\text{ ksi}}{(1.4)(46\text{ ksi})}} = 100$$

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Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Compression Demand of Brace (cont.):

From AISC *Specification* Eq. E3-4,

$$F_e = \frac{\pi^2 E}{(kl/r)^2} = \frac{\pi^2(29{,}000\text{ ksi})}{(63.1)^2}$$
$$= 71.9\text{ ksi}$$

From AISC *Specification* Eq. E3-2,

$$F_{cr} = \left[0.658^{R_y F_y / F_e}\right] R_y F_y = \left[0.658^{1.4(46\text{ ksi})/71.9\text{ ksi}}\right](1.4)(46\text{ ksi})$$
$$= 44.3\text{ ksi}$$

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Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Compression Demand of Brace (cont.):

From AISC 341-10, F1.6a.(2),

$$C = \min\left\{R_y F_y A_g,\ 1.14 F_{cr} A_g\right\}$$
$$= (1.14)(44.3\text{ ksi})(6.18\text{ in.}^2)$$
$$= 312\text{ kips}$$

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Example of High Seismic Corner Connection (cont.)

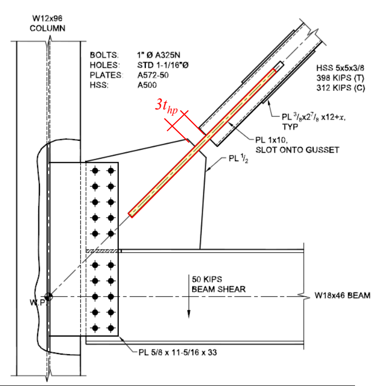
Brace-to-Gusset – Hinge Plate Design:

Choose a plate width not greater than the greater of the beam width or column depth

$$b_{f\,beam} = 6.0\text{ in.}$$
$$d_{column} = 12.75\text{ in.}$$

Choose a plate that's 10.0 in. wide

$$t_{min} = \frac{P_u}{\phi F_y b_p}$$
$$= \frac{398\text{ kips}}{0.90(50\text{ ksi})(10.0\text{ in.})}$$
$$= 0.884\text{ in.} - \textbf{Try a PL1}\times\textbf{10}$$



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Example of High Seismic Corner Connection (cont.)

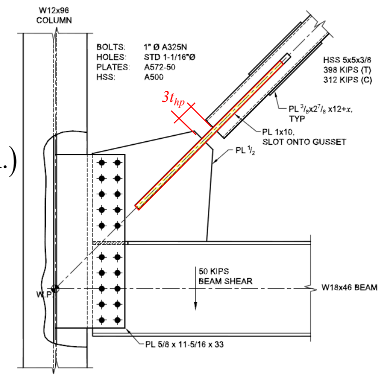
Brace-to-Gusset – Hinge Plate Design:

Rupture strength of the hinge plate at slot,

AISC *Specification* Eq. J4-2 – Tension Rupture

$$\phi R_n = \phi F_u A_n$$
$$= 0.75(65\text{ ksi})(10.0\text{ in.} - 0.625\text{in.})(1.0\text{ in.})$$
$$= 457\text{ kips} > 398\text{ kips} \quad \textbf{o.k.}$$

Note: $A_n = [b_{hp} - (t_g + 1/8\text{ in.})]t_{hp}$



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Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Buckling of Hinge Plate:

The yield line width should be 3 times the hinge plate thickness.

Assume hinge plate thickness at 1.0 in. and check.

$$\frac{kL_{unbraced}}{r} = \frac{1.2(3.0\text{ in.})\left(\sqrt{12}\right)}{1.0\text{ in.}} = 12.5 < 25$$

- Since $kl / r < 25$, per AISC *Specification* Section J4.4(a), yielding controls

$r = \frac{d}{\sqrt{12}}$ (from AISC Table 17-12 p. 17-36)

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Example of High Seismic Corner Connection (cont.)

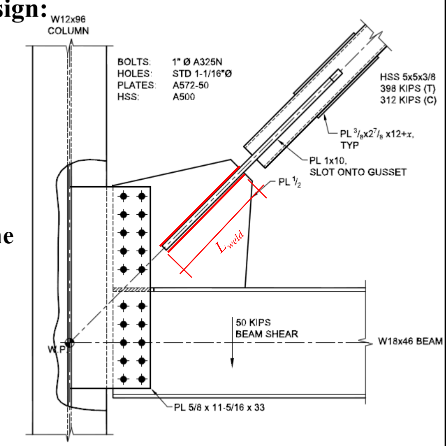
Brace-to-Gusset – Hinge Plate Weld Design:

Use 1/4 in. fillet welds (single pass)

$$L_{weld} = \frac{P_u}{1.392D(4\text{ lines})}$$

$$= \frac{398\text{ kips}}{1.392(4\text{ sixteenths})(4\text{ lines})}$$

$= 17.9$ in. – **Use 18.0 in. of weld per line**



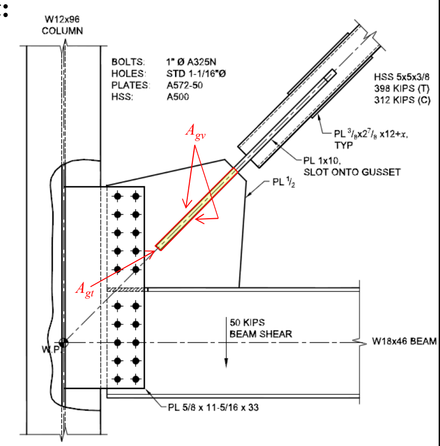
Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Block Shear of Gusset:

From AISC *Specification* Eq. J4-5,

$$A_{gv} = A_{nv} = 2L_{weld}t_g = 2(18.0\text{ in.})t_g$$

$$A_{gt} = A_{nt} = 1.0t_g$$



Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Block Shear of Gusset:

From AISC *Specification* Eq. J4-5,

$$\phi R_n = \phi\left(0.60 F_y A_{gv} + U_{bs} F_u A_{nt}\right) \geq R_u$$

$$= 0.75\left[0.60(50\text{ ksi})(36.0\text{ in.})t_g + 1.0(65\text{ ksi})(1.0\text{ in.})t_g\right] \geq 398\text{ kips}$$

$$= (859\text{ kips/in.})t_g \geq 398\text{ kips}$$

$$t_g = \frac{398\text{ kips}}{859\text{ kips/in.}}$$

$= 0.463$ in. - **Try ½ in. gusset**

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Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Whitmore Section:

$$l_{whit} = t_{pl} + L_{weld}\left(\tan 30°\right)(2)$$

$$= 1.0\text{ in.} + 18.0\text{ in.}\left(\tan 30°\right)(2)$$

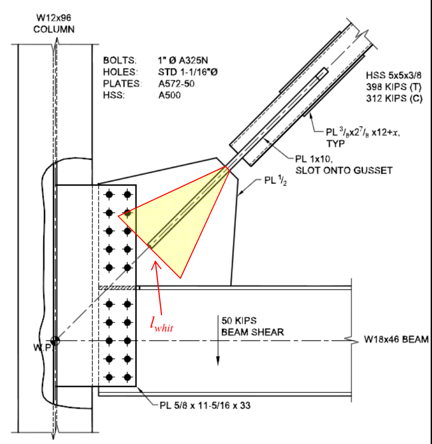
$$= 21.8\text{ in.}$$

Tension:

$$\phi R_n = \phi F_y t_g l_{whit}$$

$$= 0.90(50\text{ ksi})(0.50\text{ in.})(21.8\text{ in.})$$

$= 490$ kips $> P_u = 398$ kips, **o.k.**



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Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Whitmore Section (cont.):

Compression:

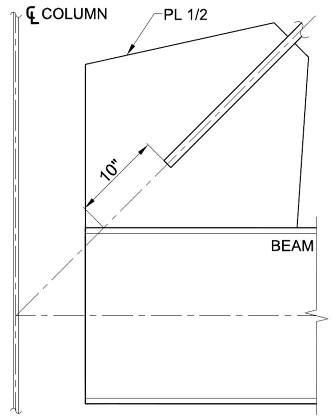
$k = 0.5$ (from AISC's 14th Edition *Design Examples*, Example II.C-2)

$$\frac{kL_{unbraced}}{r} = \frac{0.5(10.0\text{ in.})\left(\sqrt{12}\right)}{0.50\text{ in.}} = 34.6$$

From AISC *Manual* Table 4-22: $\phi F_{cr} = 41.2$ ksi

$$\phi P_{cr} = \phi F_{cr} t_g l_{whit}$$
$$= 41.2\text{ ksi}(0.50\text{ in.})(21.8\text{ in.})$$
$$= 449\text{ kips} > P_u = 312\text{ kips, \textbf{o.k.}}$$

→ ½" gusset o.k. so far



$r = \dfrac{d}{\sqrt{12}}$ (from AISC Table 17-12 p. 17-36)

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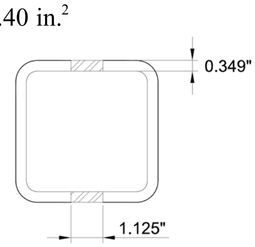
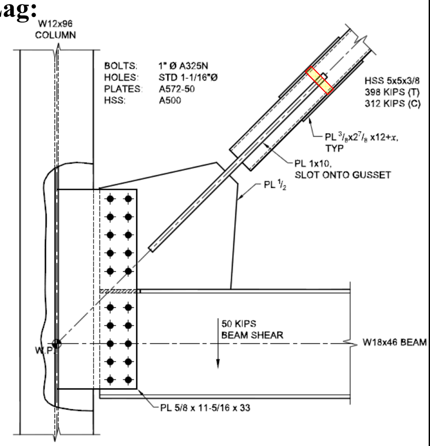
Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Brace Check – Shear Lag:

Effective Area:

$$A_g = 6.18\text{ in.}^2$$
$$A_n = A_g - 2t_{HSS\ wall}t_{slot}$$
$$= 6.18\text{ in.}^2 - 2(0.349\text{ in.})(1.125\text{ in.})$$
$$= 5.40\text{ in.}^2$$





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Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Shear Lag (cont.):

AISC *Specification* Table D3.1, Case 6,

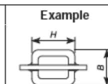
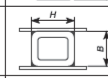
$$\bar{x} = \frac{B^2 + 2BH}{4(B+H)} = \frac{(5.0\text{ in.})^2 + 2(5.0\text{ in.})(5.0\text{ in.})}{4(5.0\text{ in.} + 5.0\text{ in.})}$$

$$= 1.87\text{ in.}$$

$$U = 1 - \frac{\bar{x}}{l_{conn}} = 1 - \frac{1.87\text{ in.}}{18.0\text{ in.}}$$

$$= 0.90$$

TABLE D3.1
Shear Lag Factors for Connections to Tension Members

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

Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Shear Lag (cont.):

AISC *Specification* Eq. D3-1,

$$A_e = UA_n = 0.90(5.40\text{ in.}^2)$$

$$= 4.86\text{ in.}^2 < A_g = 6.18\text{ in.}^2 \text{ - \textbf{reinforcement required}}$$

Estimate the required area of reinforcement needed,

$$(A_n + A_{re})U \geq A_g$$

$$A_{re} = \frac{A_g}{U} - A_n = \frac{6.18\text{ in.}^2}{0.90} - 5.40\text{ in.}^2$$

$$= 1.47\text{ in.}^2 \rightarrow \textbf{Try (2) PL } \tfrac{3}{8} \times 2\tfrac{7}{8}\textbf{"}$$

$$A_{re} = 2(0.375\text{ in.})(2.875\text{ in.}) = 2.16\text{ in.}^2 > 1.47\text{ in.}^2 \textbf{ o.k.}$$

Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Shear Lag (cont.):

$$A\bar{x} = \Sigma a_i x_i$$

$$a_1 = 0.375\text{ in.}(2.875\text{ in.}) = 1.08\text{ in.}^2$$

$$a_2 = 0.349\text{ in.}(5.0\text{ in.}) = 1.74\text{ in.}^2$$

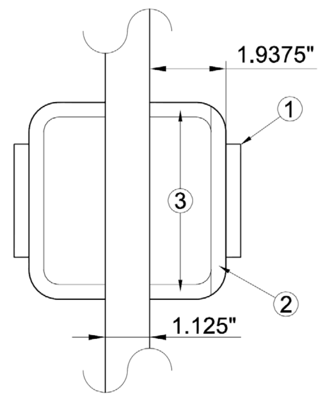
$$a_3 = (1.9375\text{ in.} - 0.349\text{ in.})(0.349\text{ in.})(2) = 1.11\text{ in.}^2$$

$$x_1 = 1.9375 + (0.375\text{ in.}/2) = 2.125\text{ in.}$$

$$x_2 = 1.9375 - (0.349\text{ in.}/2) = 1.76\text{ in.}$$

$$x_3 = (1.9375 - 0.349\text{ in.})/2 = 0.794\text{ in.}$$

$$a_{total} = a_1 + a_2 + a_3 = 3.93\text{ in.}^2$$



Example of High Seismic Corner Connection (cont.)

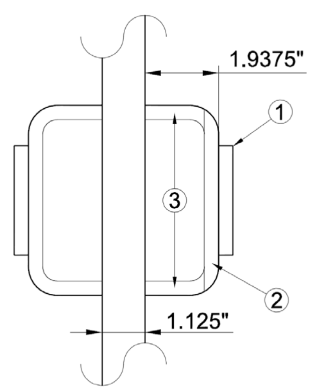
Brace-to-Gusset – Shear Lag (cont.):

$$A\bar{x} = a_1x_1 + a_2x_2 + a_3x_3 = 6.24\text{ in.}^3$$

$$\bar{x} = \frac{A\bar{x}}{a_{total}} = \frac{6.24\text{ in.}^3}{3.93\text{ in.}^2} = 1.59\text{ in.}$$

$$U = 1 - \frac{\bar{x}}{l_{conn}} = 1 - \frac{1.59\text{ in.}}{18.0\text{ in.}}$$
$$= 0.91$$

$$A_e = 2a_{total}U$$
$$= 2(3.93\text{ in.}^2)(0.91)$$
$$= 7.15\text{ in.}^2 > 6.18\text{ in.}^2$$ - **PL ⅜ × 2⅞" o.k. for reinforcement**



Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Shear Lag (cont.):

Expected strength of each reinforcement plate

From AISC 341-10, F2.5b.(3),

$$\phi R_n = R_y F_y (A_{re}/2)$$
$$= (1.1)(50 \text{ ksi})(1.08 \text{ in.}^2)$$
$$= 59.3 \text{ kips}$$

TABLE A3.1
R_y and R_t Values for Steel and Steel Reinforcement Materials

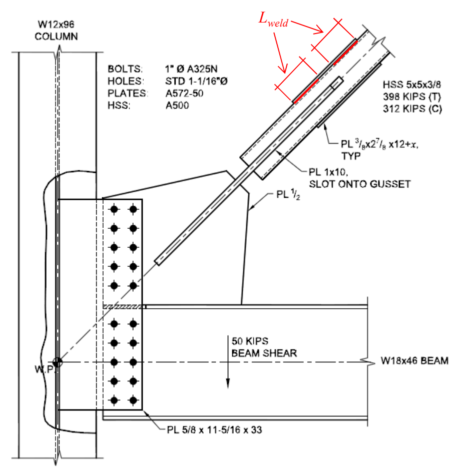
Application	R_y	R_t
Hot-rolled structural shapes and bars:		
• ASTM A36/A36M	1.5	1.2
• ASTM A1043/1043M Gr. 36 (250)	1.3	1.1
• ASTM A572/572M Gr. 50 (345) or 55 (380), ASTM A913/A913M Gr. 50 (345), 60 (415), or 65 (450), ASTM A588/A588M, ASTM A992/A992M	1.1	1.1
• ASTM A1043/A1043M Gr. 50 (345)	1.2	1.1
• ASTM A529 Gr. 50 (345)	1.2	1.2
• ASTM A529 Gr. 55 (380)	1.1	1.2
Hollow structural sections (HSS):		
• ASTM A500/A500M (Gr. B or C), ASTM A501	1.4	1.3
Pipe:		
• ASTM A53/A53M	1.6	1.2
Plates, Strips and Sheets:		
• ASTM A36/A36M	1.3	1.2
• ASTM A1043/1043M Gr. 36 (250)	1.3	1.1
• A1011/A1011M HSLAS Gr. 55 (380)	1.1	1.1
• ASTM A572/A572M Gr. 42 (290)	1.3	1.0
• ASTM A572/A572M Gr. 50 (345), Gr. 55 (380), ASTM A588/A588M	1.1	1.2
• ASTM 1043/1043M Gr. 50 (345)	1.2	1.1
Steel Reinforcement:		
• ASTM A615, ASTM A706	1.25	1.25

Example of High Seismic Corner Connection (cont.)

Brace-to-Gusset – Shear Lag (cont.):

Expected strength of reinforcement plate

$$L_{weld} = \frac{P_u}{1.392D(2 \text{ sides})}$$
$$= \frac{59.3 \text{ kips}}{1.392(4 \text{ sixteenths})(2 \text{ sides})}$$
$$= 5.33 \text{ in.}$$ **- Use 6 in. long ¼ in. fillet welds**



Example of High Seismic Corner Connection
Determination of Interface Forces

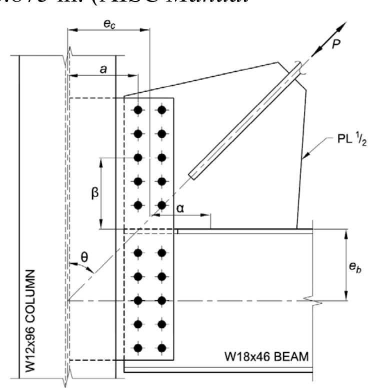
Example of High Seismic Corner Connection (cont.)

Determination of Interface Forces – Uniform Force Method (Special Case IV):
Using the uniform force method (UFM), with a = 8.875 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 in.) = 20.75 in., that is a W21 column.

$$e_b = \frac{d_{beam}}{2} = \frac{18.1 \text{ in.}}{2}$$
$$= 9.05 \text{ in.}$$



Example of High Seismic Corner Connection (cont.)

Determination of Interface Forces (cont.):

Using the brace to gusset connection as a guide, 5 rows of bolts will be required for the gusset to shear plate connection.

Strength calculations (not shown) require that there are 2 columns of bolts.

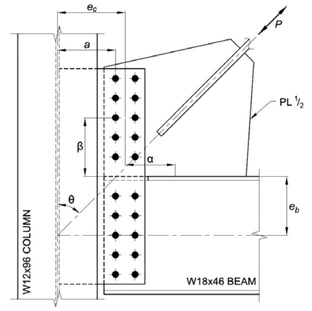
So choose,

$$\beta = \bar{\beta} = 9.0 \text{ in.}$$

Then,

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

$$\alpha = (9.05 \text{ in.} + 9.0 \text{ in.}) \tan 45° - 10.375 \text{ in.}$$
$$= 7.675 \text{ in.}$$



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Example of High Seismic Corner Connection (cont.)

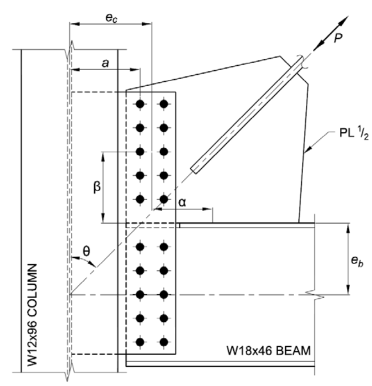
Determination of Interface Forces (cont.):

Choose the length of the gusset to beam connection such that the centroid of this connection falls at

$$\alpha = \bar{\alpha} = 7.675 \text{ in.}$$

Remember that α is measured from the face of the column flange, at

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



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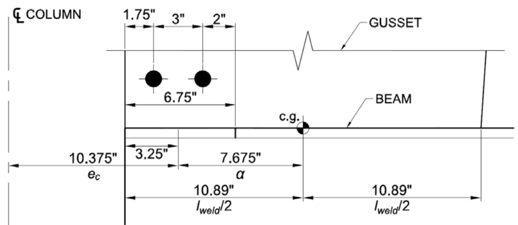
Example of High Seismic Corner Connection (cont.)

Determination of Interface Forces (cont.):

Length of the gusset to beam connection,



$$l_{weld} = 21.8 \text{ in.}$$

Distance from beam end to extent of blocking = 1.75 in.+ 3.0 in.+ 2.0 in.
= 6.75 in.

Length of weld beyond block = 21.8 in. – 6.75 in.
= 15.0 in

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Example of High Seismic Corner Connection (cont.)

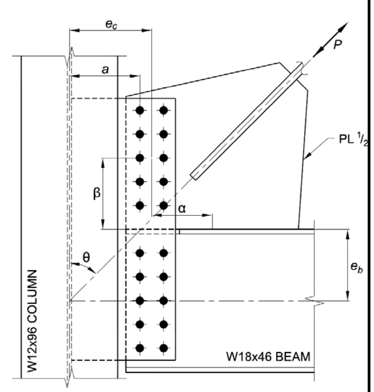
Determination of Interface Forces (cont.):

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

$$= \sqrt{(7.675 \text{ in.} + 10.375 \text{ in.})^2 + (9.0 \text{ in.} + 9.05 \text{ in.})^2}$$

$$= 25.53 \text{ in.}$$

$$\frac{P}{r} = \frac{398 \text{ kips}}{25.53 \text{ in.}} = 15.59 \text{ kips/in.}$$



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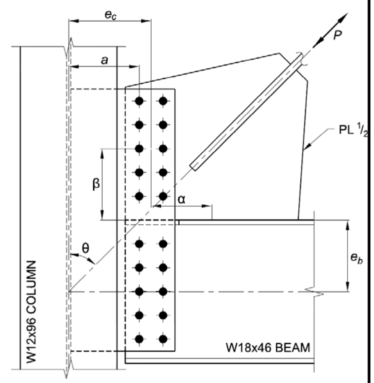
Example of High Seismic Corner Connection (cont.)

Determination of Interface Forces (cont.):

$$H_c = e_c\left(\frac{P}{r}\right) = 10.375\text{ in.}(15.59\text{ kips/in.})$$
$$= 162\text{ kips}$$

$$H_b = \alpha\left(\frac{P}{r}\right) = 7.675(15.59\text{ kips/in.})$$
$$= 120\text{ kips}$$

$$\Sigma_H = 162\text{ kips} + 120\text{ kips}$$
$$= 282\text{ kips} = 398(\cos 45°) = 281\text{ kips}$$ **o.k.** due to rounding



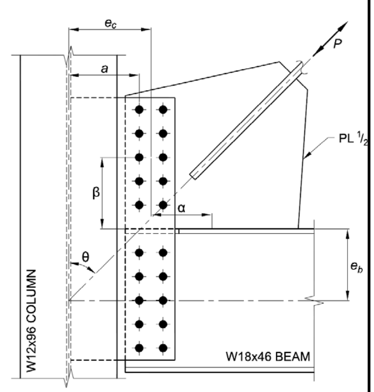
Example of High Seismic Corner Connection (cont.)

Determination of Interface Forces (cont.):

$$V_c = \beta\left(\frac{P}{r}\right) = 9.0\text{ in.}(15.59\text{ kips/in.})$$
$$= 141\text{ kips}$$

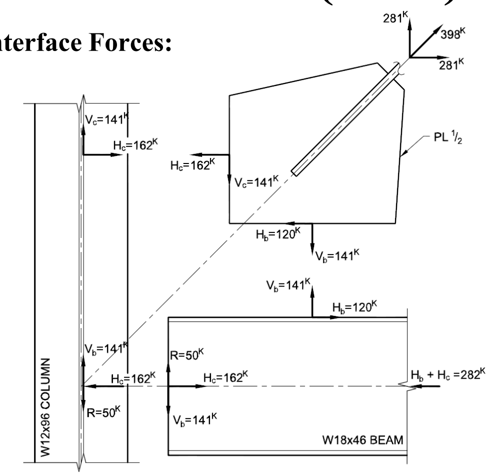
$$V_b = e_b\left(\frac{P}{r}\right) = 9.05\text{ in.}(15.59\text{ kips/in.})$$
$$= 141\text{ kips}$$

$$\Sigma_V = 141\text{ kips} + 141\text{ kips}$$
$$= 282 = 398\text{ kips}(\sin 45°) = 281\text{ kips}$$ **o.k.** due to rounding



Example of High Seismic Corner Connection (cont.)

Exposition of Interface Forces:



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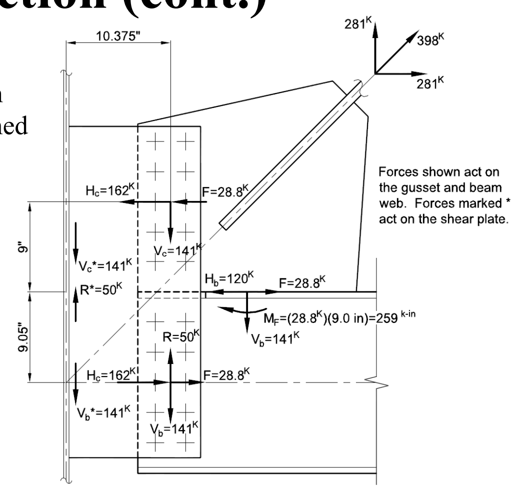
Example of High Seismic Corner Connection (cont.)

Exposition of Interface Forces:

- The force, *F*, is due to the beam gravity shear. It will be explained in the following slides.



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Example of High Seismic Corner Connection
Ductility of Shear Plate

Example of High Seismic Corner Connection (cont.)

Shear Plate Ductility:

AISC 341-10 F2.6(a):

- *"The connection shall be a simple connection meeting the requirements of AISC Specification Section B3.6(a) where the required rotation is taken to be 0.025 radians."*

AISC *Seismic Design Manual*, 2nd Edition, page 9-233:

- The simple shear connections of Part 10 of AISC Manual are deemed to satisfy provision F2.6(a).
- The extended shear plate used here for the gusset-to-column and beam-to-column connection is from the AISC Manual Part 10.
- Ductility is provided by requiring the plate to yield before the bolts or the weld fractures.

Example of High Seismic Corner Connection (cont.)

Shear Plate Ductility (cont.):

From AISC *Manual* Eq. 10-4, p.10-104,

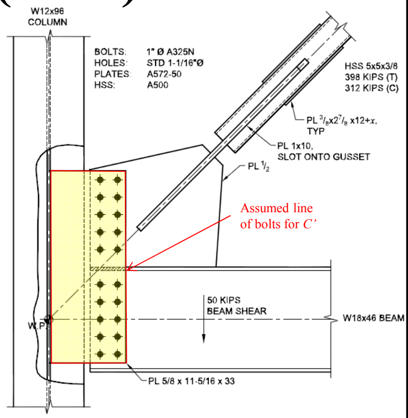
$$M_{max} = \frac{F_v}{0.90} A_b C'$$

$$= \frac{54 \text{ ksi}}{0.90}(0.785 \text{ in.}^2)(172)$$

$$= 8100 \text{ kip-in.}$$

F_v = From AISC *Specification* Table J3.2

C' = From AISC *Manual* Table 7-7 @ n = 11



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Example of High Seismic Corner Connection (cont.)

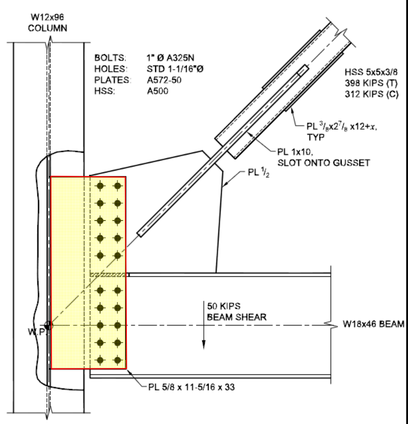
Shear Plate Ductility (cont.):

From AISC *Manual* Eq. 10-3, p.10-104,

$$t_{max} = \frac{6M_{max}}{F_y d^2} = \frac{6(8100 \text{ kip-in.})}{50 \text{ ksi}(33.0 \text{ in.})^2}$$

$$= 0.893 \text{ in.}$$

Therefore, for ductility, the maximum shear plate thickness is 7/8 in., try a 1/2 in. shear plate.



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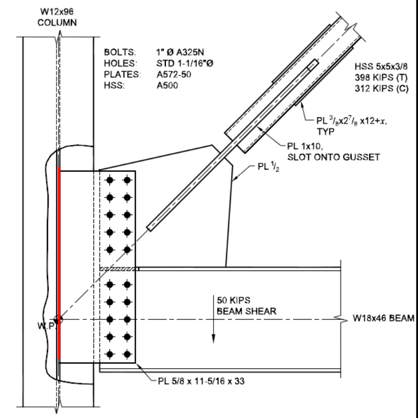
Example of High Seismic Corner Connection (cont.)

Shear Plate Ductility (cont.):

Weld Size to Column Web

$$D = \left(\tfrac{5}{8}\right) t_p = \left(\tfrac{5}{8}\right)(0.50 \text{ in.}) = \tfrac{5}{16}\text{" fillets}$$

Note: The plate thickness and welds size are tentative.



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Example of High Seismic Corner Connection (cont.)

<u>**Distribution of Forces (UFM + Effect of *R*):**</u>

The beam reaction acts at the face of the column web.

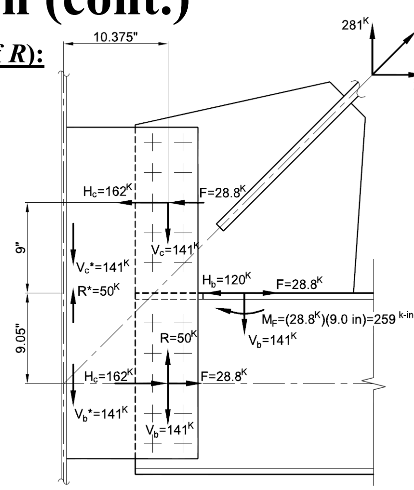
$$R(10.375 \text{ in.}) = F(18.01 \text{ in.})$$

$$F = \frac{50 \text{ kips}(10.375 \text{ in.})}{18.01 \text{ in.}} = 28.8 \text{ kips}$$

F increases H_c

F decreases H_b

F causes a moment, M_F



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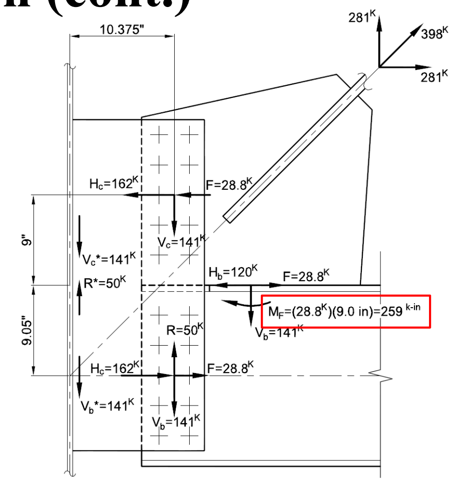
Example of High Seismic Corner Connection (cont.)

The moment caused by F is between the gusset and beam.

$$
\begin{aligned}
M_F &= F\beta \\
&= 28.8 \text{ kips}(9.0 \text{ in.}) \\
&= 259 \text{ kip-in.}
\end{aligned}
$$



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Example of High Seismic Corner Connection Gusset-to-Column

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Example of High Seismic Corner Connection (cont.)

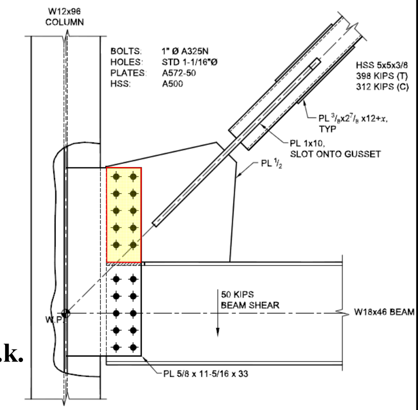
Gusset-to-Column – Bolt Shear:

$$V_c = 141 \text{ kips}$$

$$H_c + F = 162 \text{ kips} + 28.8 \text{ kips} = 191 \text{ kips}$$

$$R = \sqrt{(141 \text{ kips})^2 + (191 \text{ kips})^2}$$
$$= 238 \text{ kips}$$

$$r_{bolt} = \frac{R}{n} = \frac{238 \text{ kips}}{10 \text{ bolts}}$$
$$= 23.8 \text{ kips/bolt} < \phi r_v = 31.8 \text{ kips/bolt} \quad \textbf{o.k.}$$



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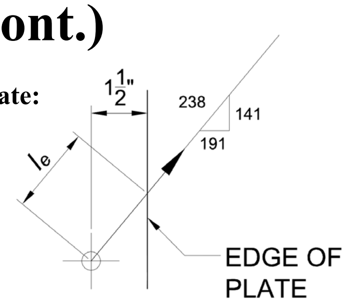
Example of High Seismic Corner Connection (cont.)

Gusset-to-Column – Bearing and Tearout of Plate:

$$\frac{l_e}{238 \text{ kips}} = \frac{1.50 \text{ in.}}{191 \text{ kips}}$$

$$l_e = 1.87 \text{ in.}$$



AISC *Specification* Eq. J3-6a,

$$\phi R_n = \phi 1.2 l_c t F_u \le \phi 2.4 d t F_u$$
$$= 0.75(1.2)\left[1.87 \text{ in.} - 0.5(1.06 \text{ in.})\right](0.50 \text{ in.})(65 \text{ ksi})$$
$$\le 0.75(2.4)(1.0 \text{ in.})(0.50 \text{ in.})(65 \text{ ksi})$$
$$= 39.2 \text{ kips/bolt} \le 58.5 \text{ kips/bolt}$$
$$= 39.2 \text{ kips/bolt} > \phi r_v = 31.8 \text{ kips/bolt} \quad \textbf{o.k.}$$

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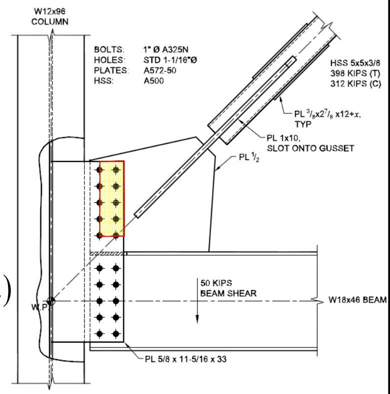
Example of High Seismic Corner Connection (cont.)

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

From AISC *Specification* Eq. J4-5,

$$A_{gt} = \left[(n_h - 1)s_h + L_{eh}\right]t_{pl}$$
$$= \left[(2-1)(3.0\text{ in.}) + 1.50\text{ in.}\right](0.50\text{in.})$$
$$= 2.25\text{ in.}^2$$

$$A_{nt} = A_{gt} - (n_h - 0.5)d_{hole}t_{pl}$$
$$= 2.25\text{ in.}^2 - (2-0.5)(1.125\text{ in.})(0.50\text{ in.})$$
$$= 1.41\text{ in.}^2$$



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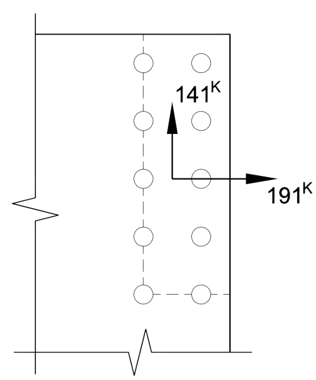
Example of High Seismic Corner Connection (cont.)

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

From AISC *Specification* Eq. J4-5,

$$A_{gv} = \left[(n_v - 1)s_v + L_{ev}\right]t_{pl}$$
$$= \left[(5-1)(3.0\text{ in.}) + 1.50\text{ in.}\right](0.50\text{in.})$$
$$= 6.75\text{ in.}^2$$

$$A_{nv} = A_{gv} - (n_v - 0.5)d_{hole}t_{pl}$$
$$= 6.75\text{ in.}^2 - (5-0.5)(1.125\text{ in.})(0.50\text{ in.})$$
$$= 4.22\text{ in.}^2$$



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Example of High Seismic Corner Connection (cont.)

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

From AISC *Specification* Eq. J4-5,

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

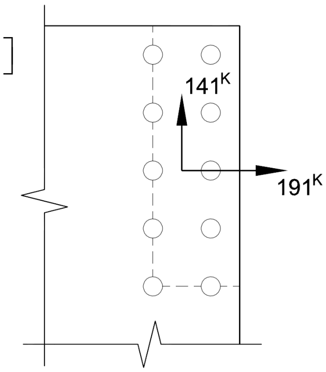
$$U_{bs}F_u A_{nt} = 1.0(65\text{ ksi})(1.41\text{ in.}^2) = 91.6\text{ kips}$$

$$0.6F_y A_{gv} = 0.6(50\text{ ksi})(6.75\text{ in.}^2) = 202\text{ kips}$$

$$0.6F_u A_{nv} = 0.6(65\text{ ksi})(4.22\text{ in.}^2) = 165\text{ kips}$$

$$\phi R_{bsv} = 0.75(165\text{ kips} + 91.6\text{ kips})$$

$$= 192\text{ kips} > V_c = 141\text{ kips} \quad \textbf{o.k.}$$



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Example of High Seismic Corner Connection (cont.)

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

From AISC *Specification* Eq. J4-5,

$$A_{gt} = \left[(n_v - 1)s_v + L_{ev}\right]t_{pl}$$

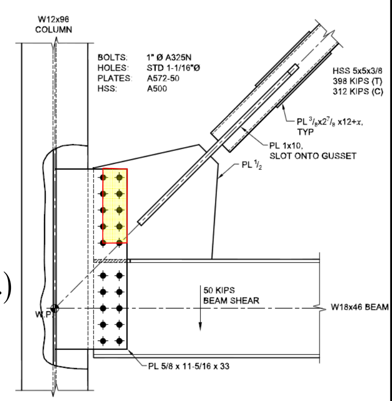
$$= \left[(5-1)(3.0\text{ in.}) + 1.50\text{ in.}\right](0.50\text{ in.})$$

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

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

$$= 6.75\text{ in.}^2 - (5-0.5)(1.125\text{ in.})(0.50\text{ in.})$$

$$= 4.22\text{ in.}^2$$



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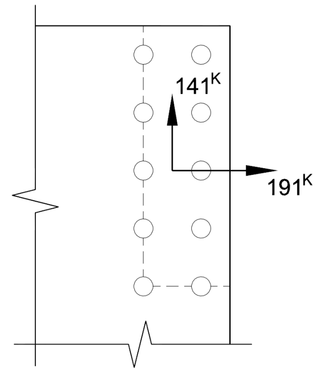
Example of High Seismic Corner Connection (cont.)

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

From AISC *Specification* Eq. J4-5,

$$A_{gv} = \left[\left(n_h - 1\right)s_h + L_{eh}\right]t_{pl}$$
$$= \left[\left(2-1\right)\left(3.0\text{ in.}\right)+1.50\text{ in.}\right]\left(0.50\text{in.}\right)$$
$$= 2.25\text{ in.}^2$$

$$A_{nv} = A_{gv} - \left(n_h - 0.5\right)d_{hole}t_{pl}$$
$$= 2.25\text{ in.}^2 - \left(2-0.5\right)\left(1.125\text{ in.}\right)\left(0.50\text{ in.}\right)$$
$$= 1.41\text{ in.}^2$$



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Example of High Seismic Corner Connection (cont.)

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

From AISC *Specification* Eq. J4-5,

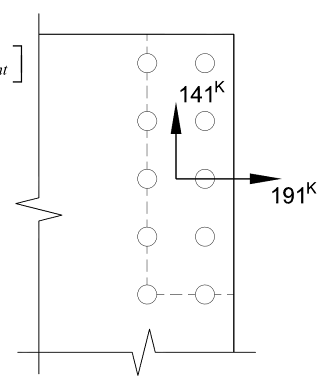
$$\phi R_n = \phi\left[\min\left\{0.6F_uA_{nv},\ 0.6F_yA_{gv}\right\} + U_{bs}F_uA_{nt}\right]$$

$$U_{bs}F_uA_{nt} = 1.0\left(65\text{ ksi}\right)\left(4.22\text{ in.}^2\right) = 274\text{ kips}$$

$$0.6F_yA_{gv} = 0.6\left(50\text{ ksi}\right)\left(2.25\text{ in.}^2\right) = 67.5\text{ kips}$$

$$0.6F_uA_{nv} = 0.6\left(65\text{ ksi}\right)\left(1.41\text{ in.}^2\right) = 55.0\text{ kips}$$

$$\phi R_{bsh} = 0.75\left(55.0\text{ kips} + 274\text{ kips}\right)$$
$$= 247\text{ kips} > H_c = 191\text{ kips} \quad \textbf{o.k.}$$



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Example of High Seismic Corner Connection (cont.)

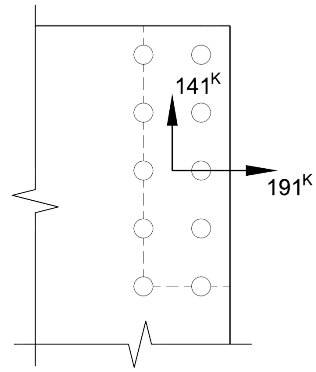
Gusset-to-Column – Block Shear – Shear Plate:

Interaction of vertical and horizontal loading,

$$\left(\frac{V_c}{\phi R_{bsv}}\right)^2+\left(\frac{H_c}{\phi R_{bsh}}\right)^2=\left(\frac{141\text{ kips}}{192\text{ kips}}\right)^2+\left(\frac{191\text{ kips}}{247\text{ kips}}\right)^2$$

$$=1.14>1\quad \textbf{N.G.}$$

A 5/8" minimum shear plate is required.



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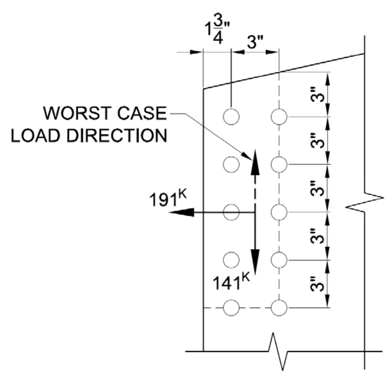
Example of High Seismic Corner Connection (cont.)

Gusset-to-Column – Block Shear – Gusset:

The forces on the gusset act as shown.

Only horizontal block shear is a limit state.

However, to cover the compression case and gusset at beam bottom flange, consider loads towards the edges.



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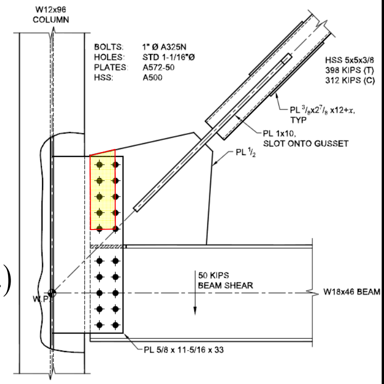
Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

$$A_{gt} = \left[\left(n_h - 1\right)s_h + L_{eh}\right]t_{pl}$$
$$= \left[\left(2-1\right)\left(3.0 \text{ in.}\right) + 1.75 \text{ in.}\right]\left(0.50 \text{in.}\right)$$
$$= 2.38 \text{ in.}^2$$

$$A_{nt} = A_{gt} - \left(n_h - 0.5\right)d_{hole}t_{pl}$$
$$= 2.38 \text{ in.}^2 - \left(2-0.5\right)\left(1.125 \text{ in.}\right)\left(0.50 \text{ in.}\right)$$
$$= 1.53 \text{ in.}^2$$



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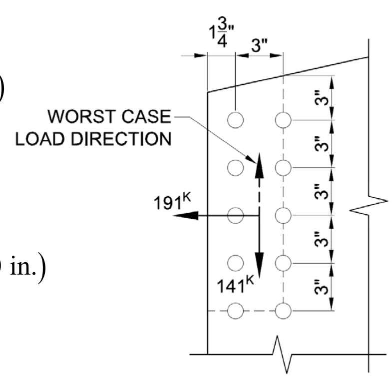
Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

$$A_{gv} = \left[\left(n_v - 1\right)s_v + L_{ev}\right]t_{pl}$$
$$= \left[\left(5-1\right)\left(3.0 \text{ in.}\right) + 3.00 \text{ in.}\right]\left(0.50 \text{in.}\right)$$
$$= 7.50 \text{ in.}^2$$

$$A_{nv} = A_{gv} - \left(n_v - 0.5\right)d_{hole}t_{pl}$$
$$= 7.50 \text{ in.}^2 - \left(5-0.5\right)\left(1.125 \text{ in.}\right)\left(0.50 \text{ in.}\right)$$
$$= 4.97 \text{ in.}^2$$



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Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

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

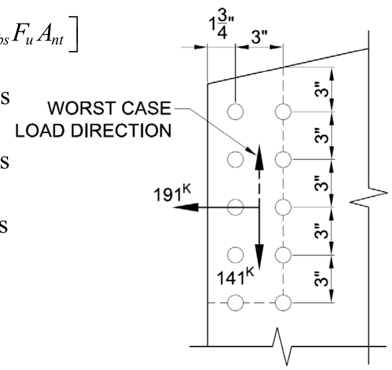
$$U_{bs} F_u A_{nt} = 1.0\left(65 \text{ ksi}\right)\left(1.53 \text{ in.}^2\right) = 99.4 \text{ kips}$$

$$0.6F_y A_{gv} = 0.6\left(50 \text{ ksi}\right)\left(7.50 \text{ in.}^2\right) = 225 \text{ kips}$$

$$0.6F_u A_{nv} = 0.6\left(65 \text{ ksi}\right)\left(4.97 \text{ in.}^2\right) = 194 \text{ kips}$$

$$\phi R_{bsv} = 0.75\left(194 \text{ kips} + 99.4 \text{ kips}\right)$$

$$= 220 \text{ kips} > V_c = 141 \text{ kips} \quad \textbf{o.k.}$$



Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

$$A_{gt} = \left[\left(n_v - 1\right)s_v + L_{ev}\right]t_{pl}$$

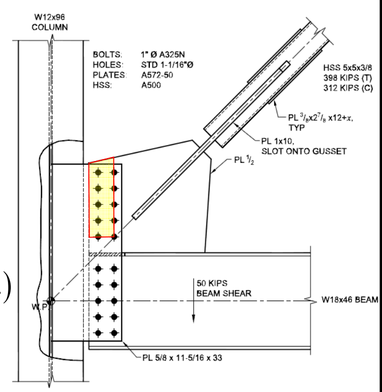
$$= \left[\left(5-1\right)\left(3.0 \text{ in.}\right) + 3.00 \text{ in.}\right]\left(0.50 \text{ in.}\right)$$

$$= 7.50 \text{ in.}^2$$

$$A_{nt} = A_{gt} - \left(n_v - 0.5\right)d_{hole}t_{pl}$$

$$= 7.50 \text{ in.}^2 - \left(5 - 0.5\right)\left(1.125 \text{ in.}\right)\left(0.50 \text{ in.}\right)$$

$$= 4.93 \text{ in.}^2$$



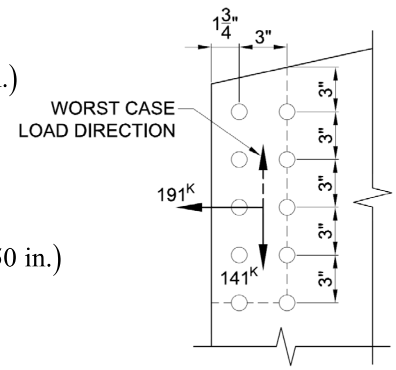
Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

$$A_{gv} = \left[(n_h - 1)s_h + L_{eh}\right]t_{pl}$$
$$= \left[(2-1)(3.0\text{ in.}) + 1.75\text{ in.}\right](0.50\text{ in.})$$
$$= 2.38\text{ in.}^2$$

$$A_{nv} = A_{gv} - (n_h - 0.5)d_{hole}t_{pl}$$
$$= 2.38\text{ in.}^2 - (2-0.5)(1.125\text{ in.})(0.50\text{ in.})$$
$$= 1.53\text{ in.}^2$$



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Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

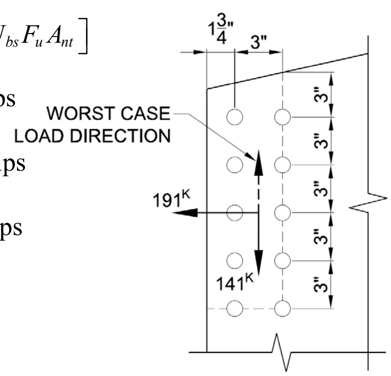
$$\phi R_n = \phi\left[\min\left\{0.6F_uA_{nv},\ 0.6F_yA_{gv}\right\} + U_{bs}F_uA_{nt}\right]$$

$$U_{bs}F_uA_{nt} = 1.0(65\text{ ksi})(4.93\text{ in.}^2) = 320\text{ kips}$$

$$0.6F_yA_{gv} = 0.6(50\text{ ksi})(2.38\text{ in.}^2) = 71.4\text{ kips}$$

$$0.6F_uA_{nv} = 0.6(65\text{ ksi})(1.53\text{ in.}^2) = 59.7\text{ kips}$$

$$\phi R_{bsh} = 0.75(59.7 + 320\text{ kips})$$
$$= 285\text{ kips} > H_c = 191\text{ kips}\ \ \textbf{o.k.}$$



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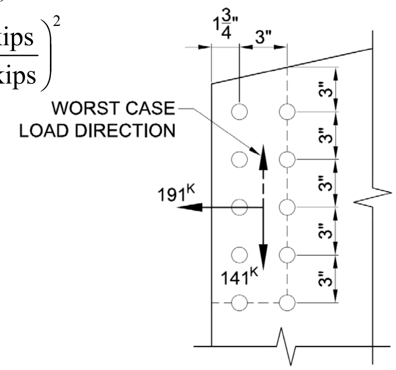
Example of High Seismic Corner Connection (cont.)

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

Interaction of vertical and horizontal loading,

$$\left(\frac{V_c}{\phi R_{bsv}}\right)^2 + \left(\frac{H_c}{\phi R_{bsh}}\right)^2 = \left(\frac{141\text{ kips}}{220\text{ kips}}\right)^2 + \left(\frac{191\text{ kips}}{285\text{ kips}}\right)^2$$

$$= 0.860 < 1 \quad \textbf{o.k.}$$



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Example of High Seismic Corner Connection Beam-to-Column

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Example of High Seismic Corner Connection (cont.)

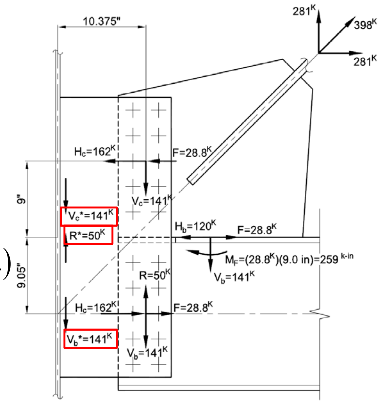
Beam-to-Column Connection:

Column Web Shear,

$V_u = 141\text{ kips} + 141\text{ kips} + 50\text{ kips} = 332\text{ kips}$

AISC *Specification* Eq. J4-3 – Shear Yielding

$$\phi R_n = \phi 0.60 F_y A_{gv}$$
$$= 1.0(0.60)(50\text{ ksi})(33\text{ in.})(2)(0.550\text{ in.})$$
$$= 1090\text{ kips} > V_u = 332\text{ kips} \quad \textbf{o.k.}$$



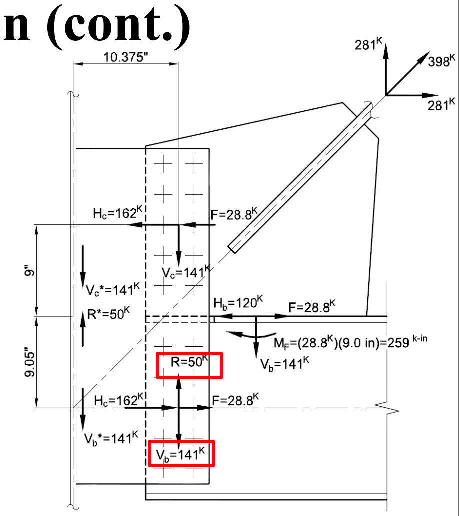
Example of High Seismic Corner Connection (cont.)

Beam-to-Column Connection:

Consider the worst case in which V_b and R are in the same direction.

This will occur for a beam bottom flange gusset or the top flange gusset of this example with a 312 kips compression force.

Use the worst case, V_b = 141 kips, R = 50 kips in the same direction



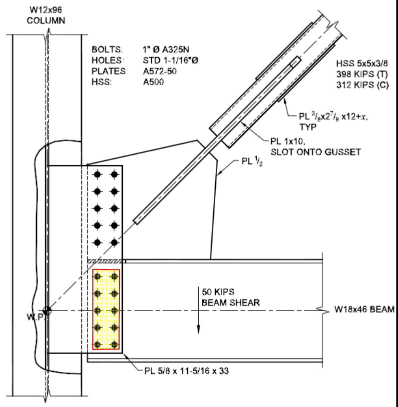
Example of High Seismic Corner Connection (cont.)

Beam-to-Column – Bolt Shear:

$$V_b + R = 141 \text{ kips} + 50.0 \text{ kips} = 191 \text{ kips}$$
$$H_c + F = 162 \text{ kips} + 28.8 \text{ kips} = 191 \text{ kips}$$

$$R_u = \sqrt{(V_b + R)^2 + (H_c + F)^2}$$
$$= \sqrt{(191 \text{ kips})^2 + (191 \text{ kips})^2}$$
$$= 270 \text{ kips}$$

$$r_{bolt} = \frac{R_u}{n_{bolts}} = \frac{270 \text{ kips}}{10 \text{ bolts}}$$
$$= 27.0 \text{ kips/bolt} < \phi r_v = 31.8 \text{ kips/bolt} \;\; \textbf{o.k.}$$



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Example of High Seismic Corner Connection (cont.)

Beam-to-Column – Beam Web Shear:

AISC *Manual* Table 3-2,

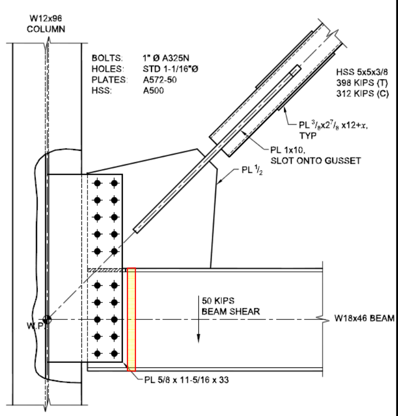
ϕV_n = 195 kips > 191 kips, **o.k.**

F_y = 50 ksi

Table 3-2 (continued)
W-Shapes
Selection by Z_x

Z_x

Shape	Z_x	M_{px}/Ω_b kip-ft	$\phi_b M_{px}$ kip-ft	M_{rx}/Ω_b kip-ft	$\phi_b M_{rx}$ kip-ft	BF/Ω_b kips	$\phi_b BF$ kips	L_p	L_r	I_x	V_{nx}/Ω_v kips	$\phi_v V_{nx}$ kips
W21×44	95.4	238	358	143	214	11.1	16.8	4.45	13.0	843	145	217
W16×50	92.0	230	345	141	213	7.69	11.4	5.62	17.2	659	124	186
W18×46	90.7	226	340	138	207	9.63	14.6	4.56	13.7	712	130	195



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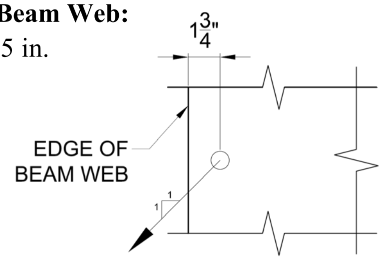
Example of High Seismic Corner Connection (cont.)

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

Web is critical since: $t_w = 0.360 \text{ in.} < t_p = 0.625 \text{ in.}$



$$l_e = l_{eh}\sqrt{2}$$
$$= 1.75 \text{ in.}\sqrt{2}$$
$$= 2.47 \text{ in.}$$

AISC *Specification* Eq. J3-6a,

$$\phi R_n = \phi 1.2 l_c t F_u \le \phi 2.4 d t F_u$$
$$= 0.75(1.2)\left[2.47 \text{ in.} - 0.5(1.0625 \text{ in.})\right](0.360 \text{ in.})(65 \text{ ksi})$$
$$\le 0.75(2.4)(1.0 \text{ in.})(0.360 \text{ in.})(65 \text{ ksi})$$
$$= 40.9 \text{ kips/bolt} \le 42.1 \text{ kips/bolt}$$
$$= 40.9 \text{ kips/bolt} > \phi r_v = 31.8 \text{ kips/bolt} \quad \textbf{o.k.}$$

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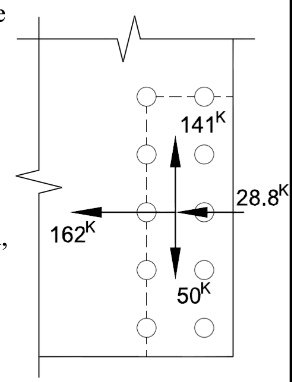
Example of High Seismic Corner Connection (cont.)

Beam-to-Column – Bearing and Tearout of Shear Plate:

These forces do not produce a force acting toward an edge but consider worst case, compression, bottom gusset, etc.



Note that the vertical force was taken as:

$$V_b + R = 141 \text{ kips} + 50.0 \text{ kips} = 191 \text{ kips}$$

For the compression case with $P = 312$ kips, they will add, but the sum will be smaller.

Rather than another loading analysis, it is conservative to proceed as above; as follows

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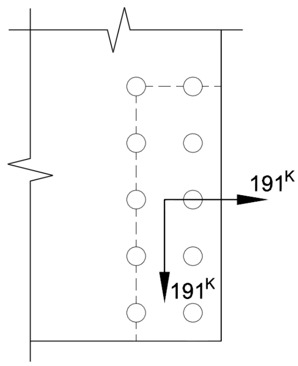
Example of High Seismic Corner Connection (cont.)

Beam-to-Column – Bearing and Tearout of Shear Plate (cont.):

For a bottom gusset and a compressive brace force the forces will act toward an edge.

Consider the case shown:



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Example of High Seismic Corner Connection (cont.)

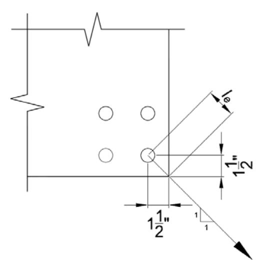
Beam-to-Column– Bearing and Tearout of Shear Plate (cont.):

Web is critical since: $t_w = 0.360 \text{ in.} < t_p = 0.625 \text{ in.}$

$$l_e = l_{eh}\sqrt{2}$$
$$= 1.50 \text{ in.}\sqrt{2}$$
$$= 2.12 \text{ in.}$$

AISC *Specification* Eq. J3-6a,

$$\phi R_n = \phi 1.2 l_c t F_u \le \phi 2.4 d t F_u$$
$$= 0.75(1.2)\left[2.12 \text{ in.} - 0.5(1.0625 \text{ in.})\right](0.625 \text{ in.})(65 \text{ ksi})$$
$$\le 0.75(2.4)(1.0 \text{ in.})(0.625 \text{ in.})(65 \text{ ksi})$$
$$= 58.1 \text{ kips/bolt} \le 73.1 \text{ kips/bolt}$$
$$= 58.1 \text{ kips/bolt} > \phi r_v = 31.8 \text{ kips/bolt} \quad \textbf{o.k.}$$



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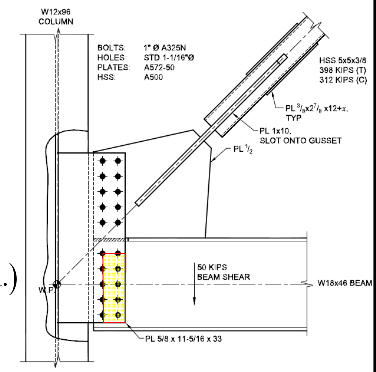
Example of High Seismic Corner Connection (cont.)

Beam-to-Column – Block Shear – Shear Plate (Vertical Load):

AISC *Specification* Eq. J4-5,

$$A_{gt} = \left[(n_h - 1)s_h + L_{eh}\right]t_{pl}$$
$$= \left[(2-1)(3.0\text{ in.}) + 1.50\text{ in.}\right](0.625\text{ in.})$$
$$= 2.81\text{ in.}^2$$

$$A_{nt} = A_{gt} - (n_h - 0.5)d_{hole}t_{pl}$$
$$= 2.81\text{ in.}^2 - (2-0.5)(1.125\text{ in.})(0.625\text{ in.})$$
$$= 1.76\text{ in.}^2$$



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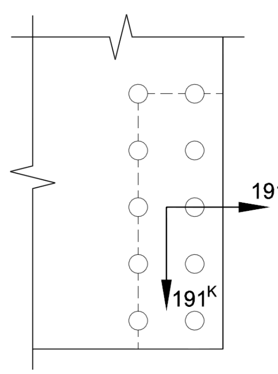
Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

$$A_{gv} = \left[(n_v - 1)s_v + L_{ev}\right]t_{pl}$$
$$= \left[(5-1)(3.0\text{ in.}) + 1.50\text{ in.}\right](0.625\text{ in.})$$
$$= 8.44\text{ in.}^2$$

$$A_{nv} = A_{gv} - (n_v - 0.5)d_{hole}t_{pl}$$
$$= 8.44\text{ in.}^2 - (5-0.5)(1.125\text{ in.})(0.625\text{ in.})$$
$$= 5.27\text{ in.}^2$$



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Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

$$\phi R_n = \phi\left[\min\left\{0.6F_uA_{nv},\ 0.6F_yA_{gv}\right\} + U_{bs}F_uA_{nt}\right]$$

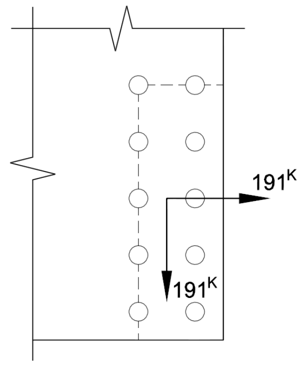
$$U_{bs}F_uA_{nt} = 1.0(65\text{ ksi})(1.76\text{ in.}^2) = 114\text{ kips}$$

$$0.6F_yA_{gv} = 0.6(50\text{ ksi})(8.44\text{ in.}^2) = 253\text{ kips}$$

$$0.6F_uA_{nv} = 0.6(65\text{ ksi})(5.27\text{ in.}^2) = 206\text{ kips}$$

$$\phi R_{bsv} = 0.75(206\text{ kips} + 114\text{ kips})$$

$$= 240\text{ kips} > V_c = 191\text{ kips} \quad \textbf{o.k.}$$



Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

$$A_{gt} = \left[(n_v - 1)s_v + L_{ev}\right]t_{pl}$$

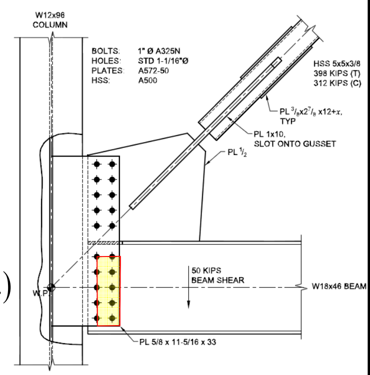
$$= \left[(5-1)(3.0\text{ in.}) + 1.50\text{ in.}\right](0.625\text{ in.})$$

$$= 8.44\text{ in.}^2$$

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

$$= 8.44\text{ in.}^2 - (5-0.5)(1.125\text{ in.})(0.625\text{ in.})$$

$$= 5.27\text{ in.}^2$$



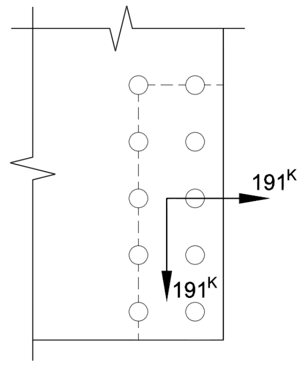
Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

$$A_{gv} = \left[(n_h - 1)s_h + L_{eh}\right]t_{pl}$$
$$= \left[(2-1)(3.0\text{ in.}) + 1.50\text{ in.}\right](0.625\text{ in.})$$
$$= 2.81\text{ in.}^2$$

$$A_{nv} = A_{gv} - (n_h - 0.5)d_{hole}t_{pl}$$
$$= 2.81\text{ in.}^2 - (2-0.5)(1.125\text{ in.})(0.625\text{ in.})$$
$$= 1.76\text{ in.}^2$$



Example of High Seismic Corner Connection (cont.)

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

AISC *Specification* Eq. J4-5,

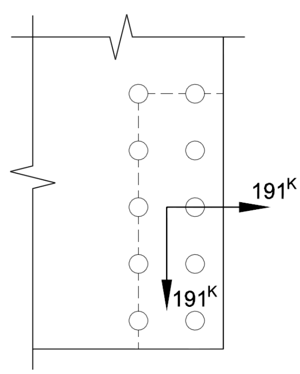
$$\phi R_n = \phi\left[\min\left\{0.6F_uA_{nv},\ 0.6F_yA_{gv}\right\} + U_{bs}F_uA_{nt}\right]$$

$$U_{bs}F_uA_{nt} = 1.0(65\text{ ksi})(5.27\text{ in.}^2) = 343\text{ kips}$$

$$0.6F_yA_{gv} = 0.6(50\text{ ksi})(2.81\text{ in.}^2) = 84.3\text{ kips}$$

$$0.6F_uA_{nv} = 0.6(65\text{ ksi})(1.76\text{ in.}^2) = 68.6\text{ kips}$$

$$\phi R_{bsh} = 0.75(68.6 + 343\text{ kips})$$
$$= 309\text{ kips} > H_c = 191\text{ kips}\quad \textbf{o.k.}$$



Example of High Seismic Corner Connection (cont.)

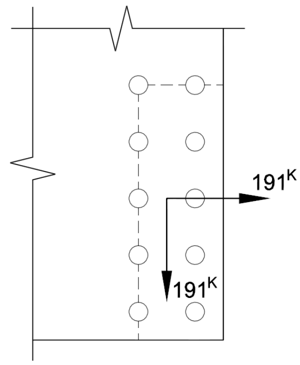
Beam-to-Column – Block Shear – Shear Plate (cont.):

Interaction of vertical and horizontal loading,

$$\left(\frac{V_c}{\phi R_{bsv}}\right)^2 + \left(\frac{H_c}{\phi R_{bsh}}\right)^2 = \left(\frac{191\text{ kips}}{240\text{ kips}}\right)^2 + \left(\frac{191\text{ kips}}{309\text{ kips}}\right)^2$$
$$= 1.02 > 1 \quad \textbf{N.G. – Try a PL}\tfrac{3}{4}$$

$$1.02\left(\frac{0.625\text{ in.}}{0.75\text{ in.}}\right)^2 = 0.705 < 1 \ \textbf{o.k.}$$

Ductility: $t_{max} = 0.734\text{ in.} < 0.893\text{ in.}$ **o.k.**



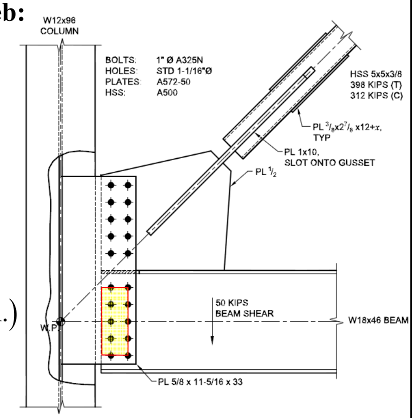
Example of High Seismic Corner Connection (cont.)

Beam-to-Column – Block Shear – Beam Web:

AISC *Specification* Eq. J4-5,

$$A_{gt} = (n_v - 1)s_v t_w$$
$$= (5-1)(3.0\text{ in.})(0.360\text{ in.})$$
$$= 4.32\text{ in.}^2$$

$$A_{nt} = A_{gt} - (n_v - 1)d_{hole}t_w$$
$$= 4.32\text{ in.}^2 - (5-1)(1.125\text{ in.})(0.36\text{ in.})$$
$$= 2.70\text{ in.}^2$$



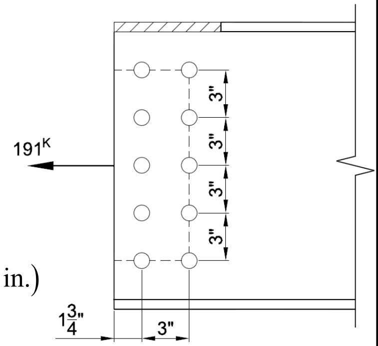
Example of High Seismic Corner Connection (cont.)

Beam-to-Column – Block Shear – Beam Web (cont.):

AISC *Specification* Eq. J4-5,

$$A_{gv} = 2\left[(n_h - 1)s_h + L_{eh}\right]t_w$$
$$= 2\left[(2-1)(3.0\text{ in.}) + 1.75\text{ in.}\right](0.360\text{ in.})$$
$$= 3.42\text{ in.}^2$$

$$A_{nv} = A_{gv} - 2(n_h - 0.5)d_{hole}t_w$$
$$= 3.42\text{ in.}^2 - 2(2-0.5)(1.125\text{ in.})(0.360\text{ in.})$$
$$= 2.20\text{ in.}^2$$



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Example of High Seismic Corner Connection (cont.)

Beam-to-Column – Block Shear – Beam Web (cont.):

AISC *Specification* Eq. J4-5,

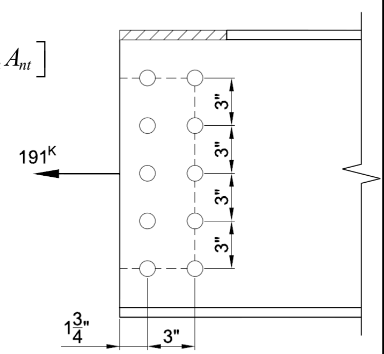
$$\phi R_n = \phi\left[\min\left\{0.6F_uA_{nv},\ 0.6F_yA_{gv}\right\} + U_{bs}F_uA_{nt}\right]$$

$$U_{bs}F_uA_{nt} = 1.0(65\text{ ksi})(2.70\text{ in.}^2) = 176\text{ kips}$$

$$0.6F_yA_{gv} = 0.6(50\text{ ksi})(3.42\text{ in.}^2) = 103\text{ kips}$$

$$0.6F_uA_{nv} = 0.6(65\text{ ksi})(2.20\text{ in.}^2) = 85.8\text{ kips}$$

$$\phi R_{bsv} = 0.75(85.8\text{ kips} + 176\text{ kips})$$
$$= 196\text{ kips} > H_c = 191\text{ kips} \quad \textbf{o.k.}$$



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Example of High Seismic Corner Connection Gusset-to-Beam

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Example of High Seismic Corner Connection (cont.)

Gusset-to-Beam Connection – Weld:

Shear: $H_b + F = 120\text{ kips} + 28.8\text{ kips}$

$= 149\text{ kips}$

Normal: $V_b = 141\text{ kips}$

Moment: $M_F = 28.8\text{ kips}(9.0\text{ in.})$

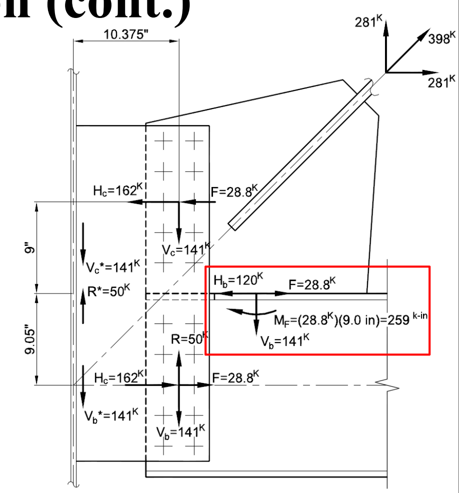
$= 259\text{ kip-in.}$

Equivalent normal force,

$$N_e = V_b + \frac{4M_F}{L_{weld}}$$

$$= 141\text{ kips} + \frac{4(259\text{ kip-in.})}{21.8\text{ in.}}$$

$$= 189\text{ kips}$$



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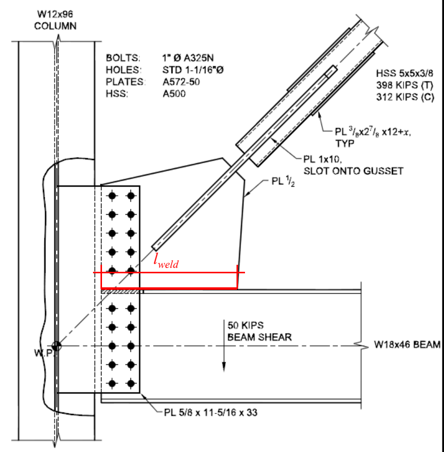
Example of High Seismic Corner Connection (cont.)

Gusset-to-Beam Connection – Weld (cont.):

$$R_u = \sqrt{(H_b + F)^2 + N_e^2}$$
$$= \sqrt{(149\text{ kips})^2 + (189\text{ kips})^2}$$
$$= 241\text{ kips}$$

$$\theta = \tan^{-1}\left(\frac{N_e}{H_b + F}\right) = \tan^{-1}\left(\frac{189\text{ kips}}{149\text{ kips}}\right)$$
$$= 51.75°$$

$$\mu = 1.0 + 0.50\sin^{1.5}\theta$$
$$= 1.0 + 0.50\sin^{1.5}51.75°$$
$$= 1.35$$



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Example of High Seismic Corner Connection (cont.)

Gusset-to-Beam Connection – Weld (cont.):

$$D_{req} = \frac{1.25R_u}{1.392\mu l_{weld}(2\text{ lines})}$$
$$= \frac{1.25(241\text{ kips})}{1.392(1.35)(21.8\text{ in.})(2\text{ lines})}$$
$$= 3.68\text{ sixteenths}$$ **- Use ¼ in. fillet welds for 15.0 in.**

Due to block on beam, weld single sided in this section.

$3.68\text{ sixteenths}(2) = 7.36\text{ sixteenths}$ **- Use 1 / 2 in. fillet welds for 6.75 in.**

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Example of High Seismic Corner Connection (cont.)

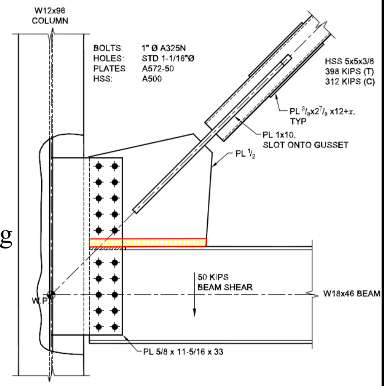
Gusset-to-Beam Connection – Gusset Checks:

AISC *Specification* Eq. J4-3 – Shear Yielding

$$\phi R_n = \phi 0.60 F_y A_{gv}$$
$$= 1.0(0.60)(50\text{ ksi})(0.50\text{ in.})(21.8\text{ in.})$$
$$= 327\text{ kips} > H_b + F = 149\text{ kips} \quad \textbf{o.k.}$$

AISC *Specification* Eq. J4-1 – Tension Yielding

$$\phi R_n = \phi F_y A_g$$
$$= 0.90(50\text{ ksi})(0.50\text{ in.})(21.8\text{ in.})$$
$$= 490\text{ kips} > N_e = 189\text{ kips} \quad \textbf{o.k.}$$



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Example of High Seismic Corner Connection (cont.)

Gusset-to-Beam Connection – Beam Checks:

AISC *Specification* Eq. J10-3 – Web Local Yielding

$$\phi R_n = \phi F_{yw} t_w (2.5k + l_b)$$
$$= 1.0(50\text{ ksi})(0.360\text{ in.})[2.5(1.01\text{ in.}) + 21.8\text{ in.}]$$
$$= 438\text{ kips} > N_e = 189\text{ kips} \quad \textbf{o.k.}$$

AISC *Specification* Eq. J10-4 – Web Local Crippling

$$\phi R_n = \phi 0.80 t_w^{\,2}\left[1 + 3\left(\frac{l_b}{d}\right)\left(\frac{t_w}{t_f}\right)^{1.5}\right]\sqrt{\frac{EF_{yw}t_f}{t_w}}$$
$$= \phi 0.80(0.360)^2\left[1 + 3\left(\frac{21.8\text{ in.}}{18.1\text{ in.}}\right)\left(\frac{0.360\text{ in.}}{0.605\text{ in.}}\right)^{1.5}\right]\sqrt{\frac{29{,}000\text{ ksi}(50\text{ ksi})(0.605\text{ in.})}{0.360\text{ in.}}}$$
$$= 323\text{ kips} > N_e = 189\text{ kips} \quad \textbf{o.k.}$$

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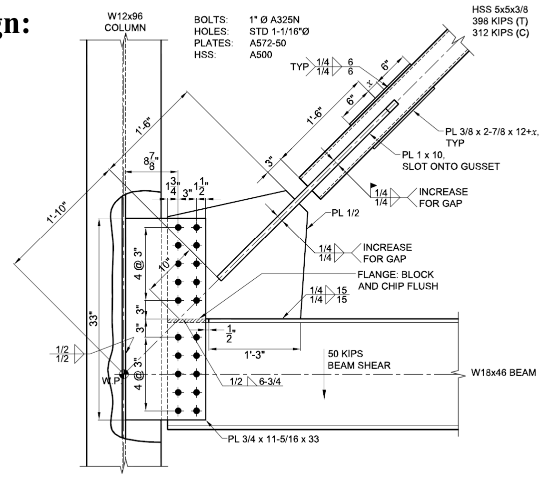
Example of High Seismic Corner Connection (cont.)

Final Design:



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Summary

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Summary

- Example of a Corner vertical bracing connection was reviewed for a High Seismic condition
- Uniform Force Method – Special Case IV
- Special Concentrically Braced Frame
  - Required Brace Tension Strength per AISC 341-10
  - Required Brace Compressive Strength per AISC 341-10
  - Accommodation for Brace Buckling, in this example, Hinge Plate Design
  - Required Rotational Capacity of the Connection

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Questions?

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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!

Individual Webinar Registrants

CEU/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.

8-Session Registrants

CEU/PDH Certificates

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

8-Session Registrants

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

Quiz and Attendance records: Posted Tuesday mornings. www.aisc.org/nightschool - click on Current Course Details.

Reasons for quiz:

- EEU – must take all quizzes and final to receive EEU
- CEUs/PDHS – If you watch a recorded session you must take quiz for CEUs/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 CEUs/PDHs.

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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.

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Thank You

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

structural STEEL