Night School 28: Vertical Bracing Connections

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

AISC Night School

Vertical Bracing Connections, Session 6: The Corner Connection (seismic)

May 10, 2022 | Rafael Sabelli

Smarter. Stronger. Steel.

AISC Night School

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Course Description

Vertical Bracing Connections

Session 6: The Corner Connection (seismic)
May 10, 2022

The various steps and methodologies used for bracing connection design will be highlighted as the presenter works through a seismic design example. The session will discuss the requirements for Special Concentrically Braced Frame (SCBF) and Buckling Restrained Braced Frame (BRBF) connections. It review the several alternatives for the gusset plate design: linear hinge, elliptical hinge and rotated gusset. Finally, a design example will be presented to demonstrate applicability.

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Learning Objectives

1. Understand the role of AISC 341 in bracing-connection design
2. Learn the bracing-connection requirements for Special Concentrically Braced Frames
3. Learn the bracing-connection requirements for Buckling Restrained Braced Frames
4. Learn to determine design forces for bracing connections that include both collector forces from ASCE 7 and bracing force from AISC 341

Night School 28:
Bracing Connections and Related Topics

From the First Principles to Design
Session 6: The Corner Connection (seismic)
May 10, 2022

Rafael Sabelli, PE, SE
Director of Seismic Design &
Senior Principal
Walter P Moore

Smarter.
Stronger.
Steel.

Learning Objectives

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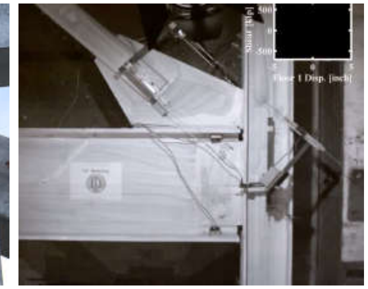
9

The Corner Connection—Seismic

BRBF



SCBF

10

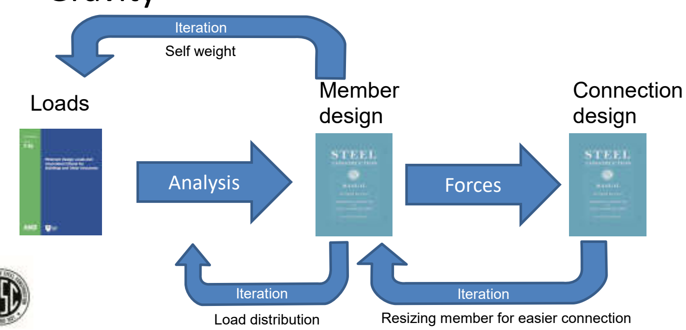
The Corner Connection—Seismic

- The process
- System types
  - SCBF
    - Buckling
    - Hinge types
    - Forces
  - BRBF
    - Forces
    - Stability
- Beam-to-column connection
  - Pinned
  - Fixed
  - Design cases
- Design example
  - Limit states
  - Analysis

11

ASCE 7, AISC 360, and AISC 341

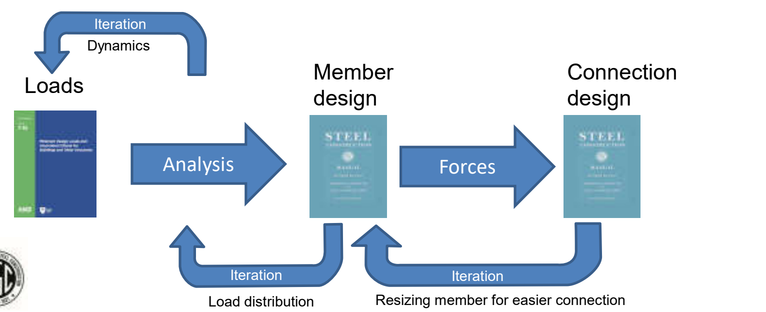
- Gravity



12

ASCE 7, AISC 360, and AISC 341

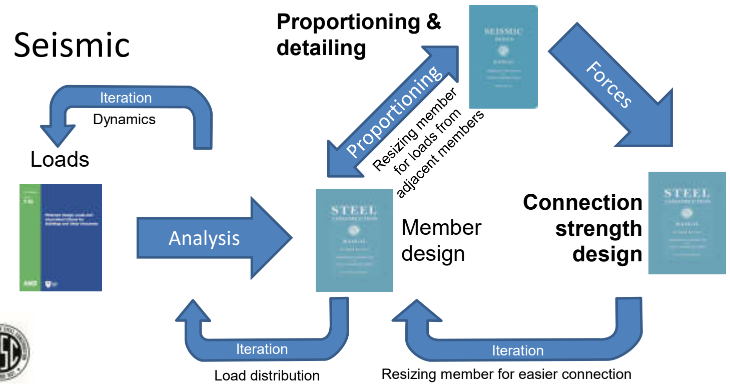
- Wind



13

ASCE 7, AISC 360, and AISC 341

Seismic



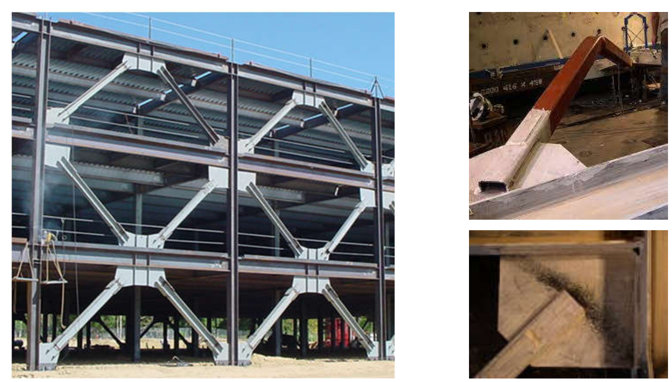
14

AISC 341 Bracing Connections

- Capacity Design
  - Brace expected tension strength
  - Brace expected compression strength
  - Accommodation of brace deformation
- Concurrent actions
  - Gravity
    - Shear in beam
  - Beam moment capacity (if fixed-end)
  - Collector force

15

Special Concentrically Braced Frames (SCBF)

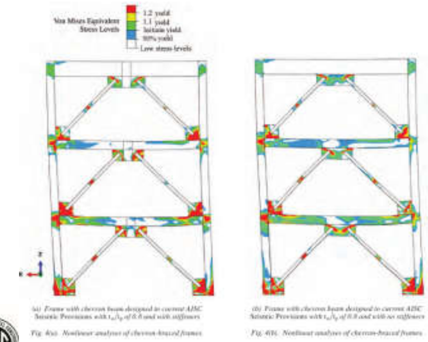


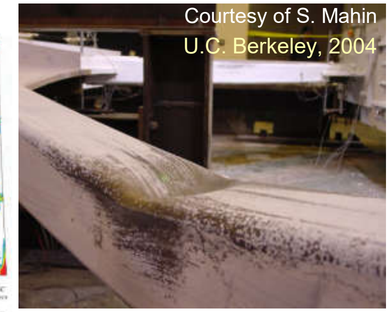
16

Special Concentrically Braced Frames (SCBF)

- System behavior
  - Member behavior
    - Brace buckling
      - Plane of buckling
      - End fixity
    - Brace tension yield
- Connection design
  - Fixed-end buckling
  - Gusset hinges
    - Linear hinge
    - Elliptical hinge
    - Knife-plate hinge

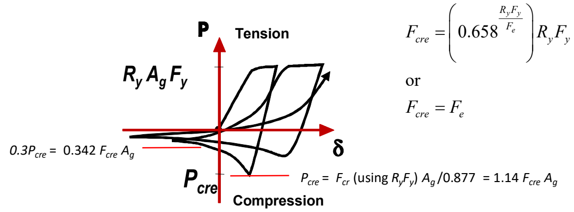
Brace Buckling and Yielding





https://www.aisc.org/globalassets/product-files-not-searched/engineering-journal/2021/ej-2021-q2-issue.pdf

Brace cyclic behavior (SCBF)



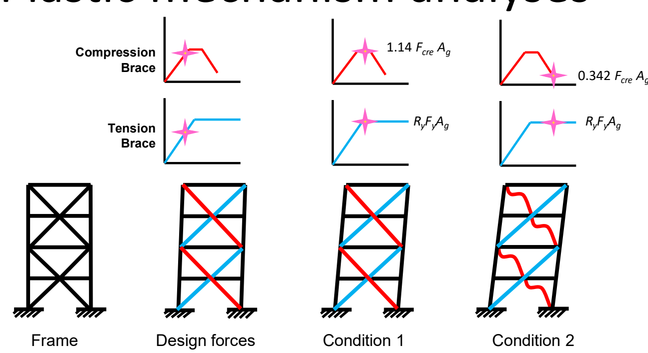
$$F_{cre} = \left(0.658^{\frac{R_y F_y}{F_e}}\right) R_y F_y$$

or

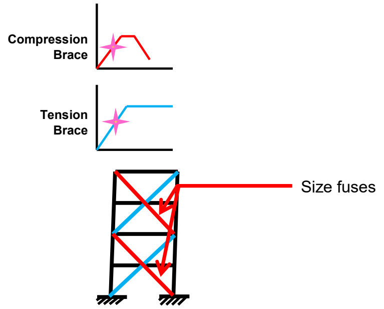
$$F_{cre} = F_e$$

Brace behavior is asymmetric with respect to tension and compression and is subject to strength and stiffness degradation

Plastic mechanism analyses



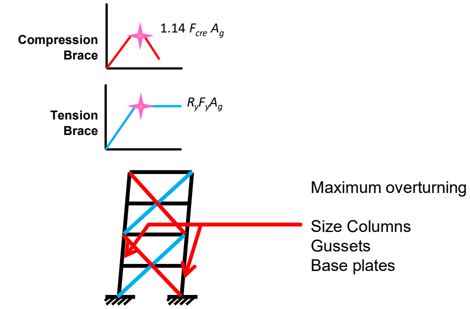
Design forces



Design forces

21

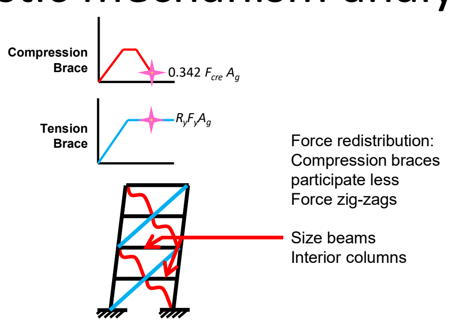
Plastic mechanism analyses



Condition 1

22

Plastic mechanism analyses



Condition 2

23

Basic SCBF Connection Requirements (Tension)

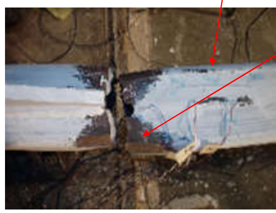
- Resist brace force (expected tension strength)
  - $R_y F_y A_g$
  - $R_y F_y$ is expected material yield stress
- Check all limit states discussed by Dr. Thornton
  - For limit states in gusset, etc.
    - $\phi F_y A_g$
    - $\phi F_u A_n$
  - For connection limit states in brace (net section rupture, block shear)
    - $\phi R_y F_y A_g$
    - $\phi R_t F_u A_n$

24

Basic SCBF Connection Requirements (Tension)

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/A1043M Gr. 36 (250)	1.3	1.1
• ASTM A992/A992M	1.1	1.1
• ASTM A572/A572M Gr. 50 (345) or 55 (380)	1.1	1.1
• ASTM A913/A913M Gr. 50 (345), 60 (415), 65 (450), or 70 (485)	1.1	1.1
• ASTM A588/A588M	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	1.4	1.3
• ASTM A500/A500M Gr. C	1.3	1.2
• ASTM A501/A501M	1.4	1.3
• ASTM A53/A53M	1.6	1.2
• ASTM A1085/A1085M	1.25	1.15



If the brace yields at 59 ksi here (R_yF_y =1.4*42ksi =59ksi)

It likely yields at 59 ksi here

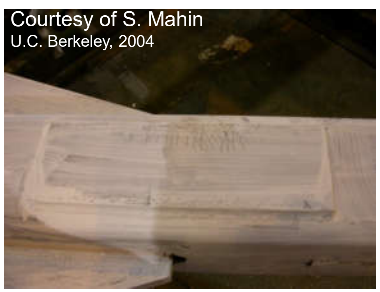
And also likely has higher-than-specified rupture strength

25

Facture at the Reduced Section

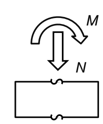
26

Brace Reinforcement

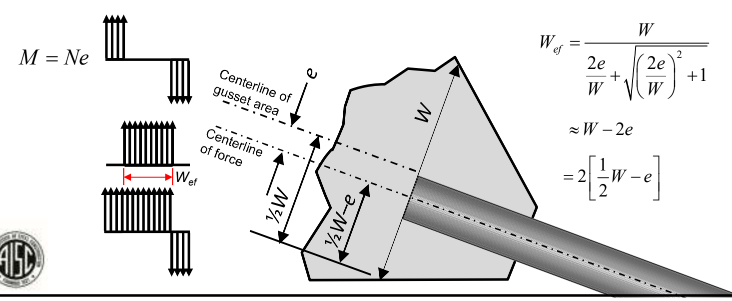


27

Tapered gussets



Tension may be applied eccentric to the critical section



$$W_{ef} = \frac{W}{\frac{2e}{W} + \sqrt{\left(\frac{2e}{W}\right)^2 + 1}}$$

$$\approx W - 2e$$

$$= 2\left[\frac{1}{2}W - e\right]$$

28

Basic SCBF Connection Requirements (Compression)

- Resist expected compression strength
  - Use real brace length (for upper-bound force)
  - $F_{cre}A_g/0.877 \le R_yF_yA_g$
- Check all limit states discussed by Dr. Thornton
  - Gusset buckling
  - Web crippling
- Provide accommodation of brace buckling without loss of tension strength

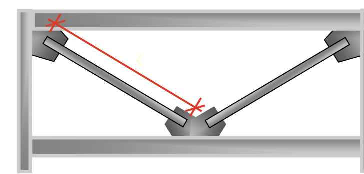
Check Detail for Compression

- Use realistic effective length
- Eliminate “conservative” assumptions that would reduce demand

$$F_{cre} = \left(0.658^{\frac{R_yF_y}{F_e}}\right)R_yF_y$$

or

$$F_{cre} = F_e$$

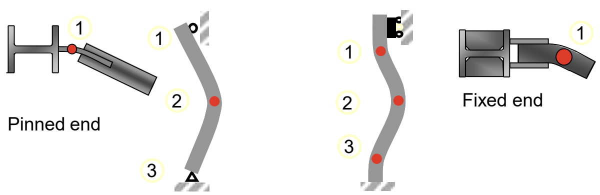


$$P_{cre} = F_{cre}A_g/0.877 = 1.14\,F_{cre}A_g$$

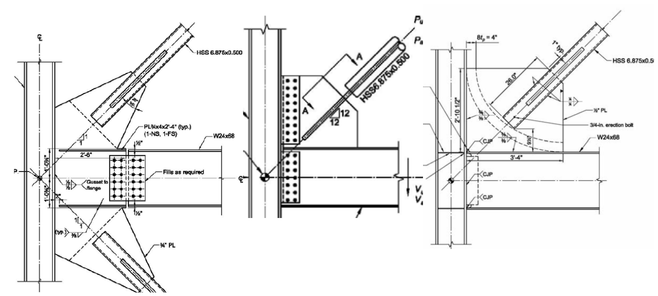
Brace Buckling

Flexural buckling (Compression)

Buckling: 3 hinges



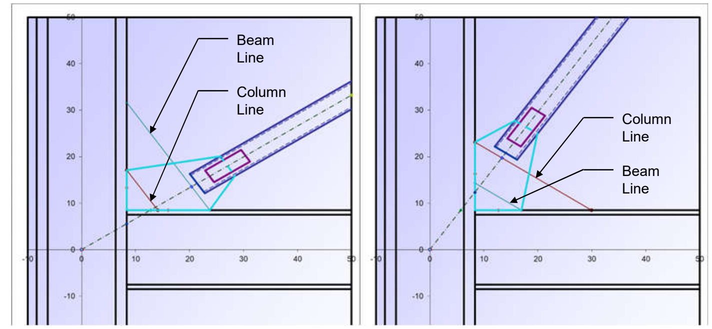
Accommodating buckling



Pinned-End Gusset Hinging

33

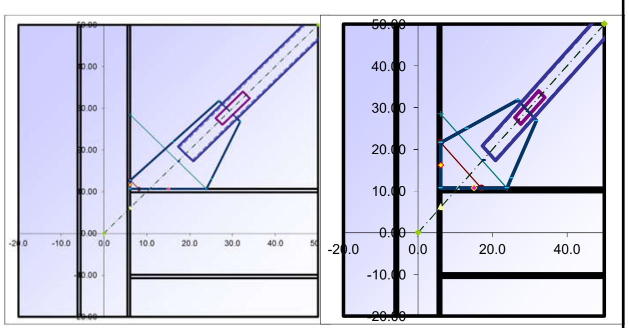
Folding of Gusset (Hinge Zone)



34

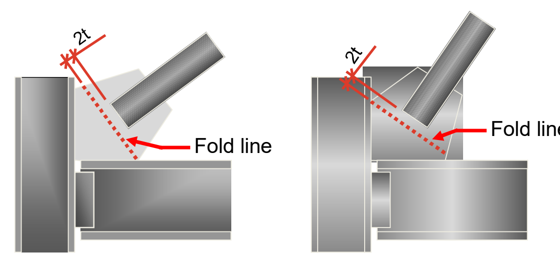
Folding of Gusset (Hinge Zone)

- Graph your design!
- Don't wait for shop drawings



35

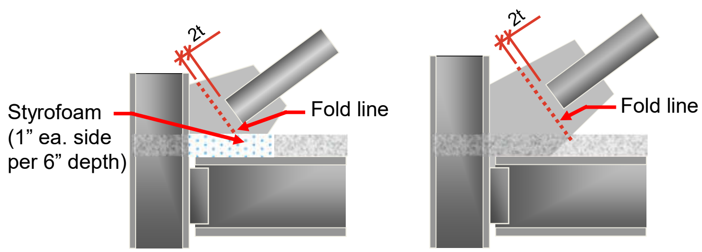
2t Offset



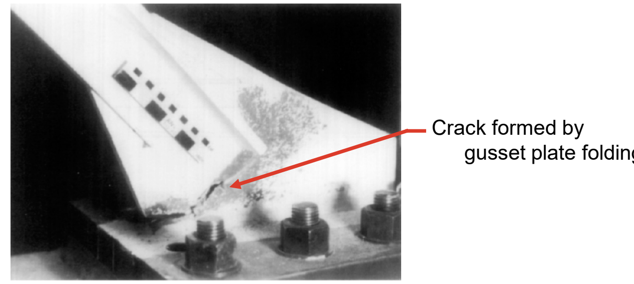
Provide accommodating detail (2t offset)
Recommendation: Detail: 2t + ¾" ± ¾"
Check gusset buckling: 2t + 1½"

36

2t Offset at Concrete Fill

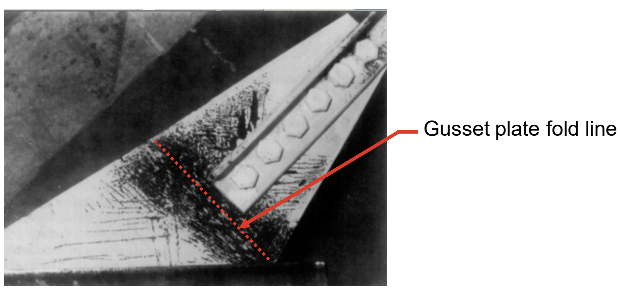


Tearing of Gusset (No Hinge Zone)



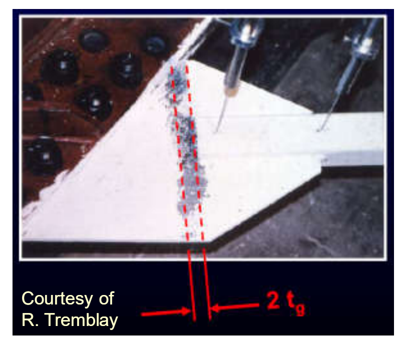
From Astaneh-Asl, Seismic Behavior and Design of Gusset Plates, Steel Tips 1998

Folding of Gusset (Hinge Zone)



From Astaneh-Asl, Seismic Behavior and Design of Gusset Plates, Steel Tips 1998

Folding of Gusset (Hinge Zone)



Welding in the vicinity of gusset hinging

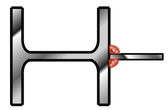
Weld from gusset to beam and column:

Minimum double fillet ~0.75 times gusset thickness

$$2\phi(0.6)F_{EXX}(0.707)(D/16) \geq 0.6R_yF_yt_{gusset}$$

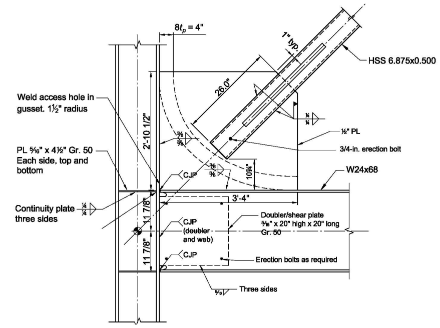
$$D/16 \geq 0.75t_{gusset}$$

Weld is stronger than plate; inelastic action occurs in plate



41

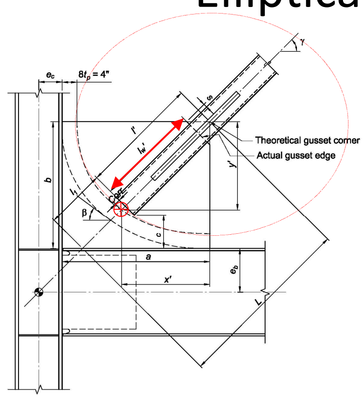
Elliptical Hinge



1. Size gusset using UFM
   a. Gusset limit states
   b. Web limit states
2. Determine brace-gusset lap length
   a. Weld
   b. Block shear
3. Check if brace intrudes into elliptical-hinge zone; resize gusset if necessary

42

Elliptical Hinge



Define ellipse

$$a' = a - 8t_p \qquad b' = b - 8t_p \qquad \rho = \frac{a'}{b'}$$

Determine intersection with brace axis

$$y' = a'\sqrt{\frac{1}{\cot^2\gamma + \rho^2}} \qquad x' = a'\sqrt{1 - \left(\frac{y'}{b'}\right)^2}$$

Correct for brace width

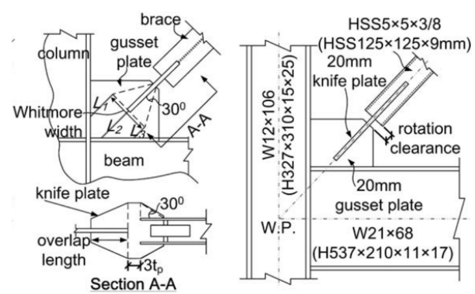
$$\beta = \tan^{-1}\left(\frac{x'}{y'\rho^2}\right) \qquad Corr = \frac{D_{brace}}{2}\tan(90° - \beta - \gamma)$$

Check lap length

$$l' = \sqrt{(x')^2 + (y')^2} - Corr \qquad l'_w = l' - \left(\frac{D_{brace}}{2} + s\right)\cot\gamma$$

43

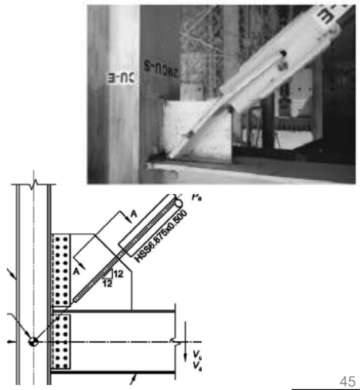
In-plane buckling detail



Seismic Design and Hybrid Tests of a Full-Scale Three-Story Concentrically Braced Frame Using In-Plane Buckling Braces
Ching-Yi Tsai, Keh-Chyuan Tsai, Pao-Chun Lin, Wai-Hang Ao, Charles W. Roeder, Stephen A. Mahin, Chih-Han Lin, Yi-Jer Yu, Kung-Juin Wang, An-Chien Wu, Jia-Chian Chen, and Te-Hung Lin

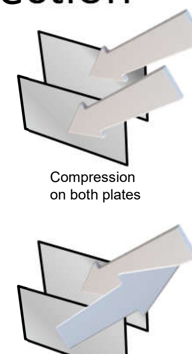
44

In-plane buckling detail



45

Fixed-End Brace Connection



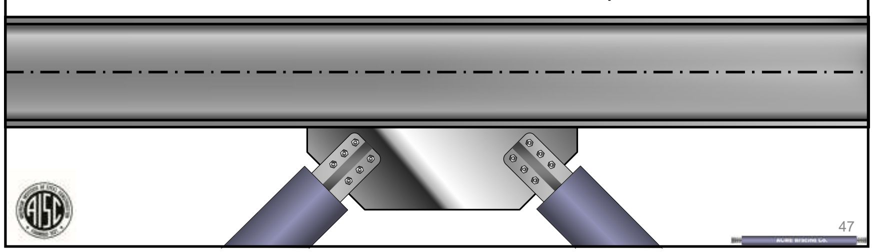
Compression
on both plates

Moment:
One plate in tension
One plate in compression

46

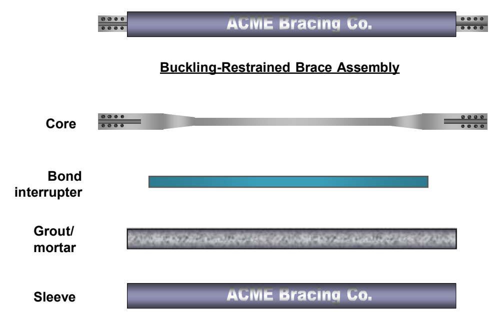
BRBF

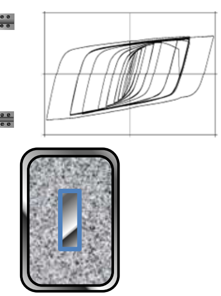
- System behavior
- Gusset design
  - Forces
  - Stability



47

Buckling Restrained Braces





48

Buckling-Restrained Brace Types

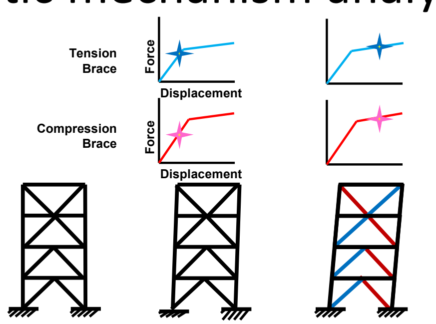
Buckling-Restrained Brace Types

Direct bolting of core

Courtesy of
CoreBrace

Courtesy of
STAR Seismic

Plastic mechanism analyses (BRBF)

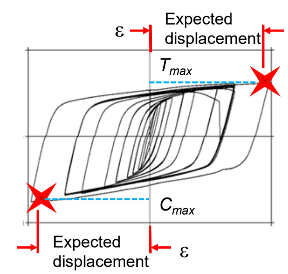


Frame Design forces Post-elastic case

Brace demands on frame

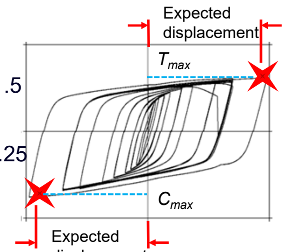
- Estimate fuse capacity
  - Expected material strength
  - Strain hardening
- Based on testing

Calculate deformation



Brace demands on frame

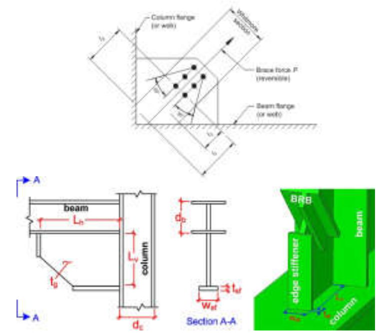
- Based on testing
  - $\omega = T_{max}/A_g F_y$
    - Typical $1.3 \leq \omega \leq 1.5$
  - $\beta\omega = C_{max}/A_g F_y$
    - Typical $1.1 \leq \beta \leq 1.25$
- For design
  - $R_{u\,(tension)} = \omega A_g R_y F_y$
  - $R_{u\,(compression)} = \beta\omega A_g R_y F_y$



AISC 341 F4.2

BRB Gusset stability

- Easy (conservative) path
  - Design gusset with K=2
  - or
  - Design gusset with edge stiffeners with K=0.65
    - Difficult to erect
    - Add stiffeners after brace

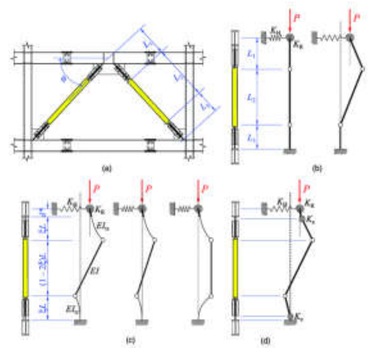


(K.C. Tsai)

BRB Gusset stability

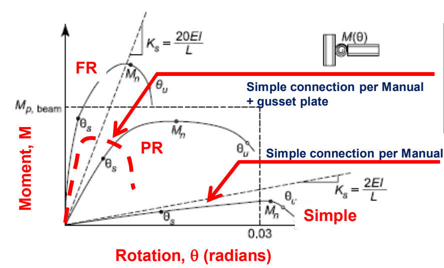
- Explicit path
  - Typically done by BRB manufacturers

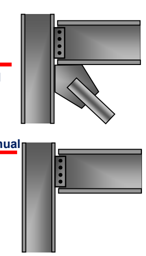
Work by:
- Takeuchi, et al (Tokyo Inst of Technology)
- *Zaboli, Clifton (Univ of Canterbury)*
- *2020 SEAOC Paper (Saxey et al.)*



Out-of-plane stability model: (a) chevron brace; (b) model for standard connections; (c) model proposed by Kinoshita et al. (2007); (d) model for alternative conditions

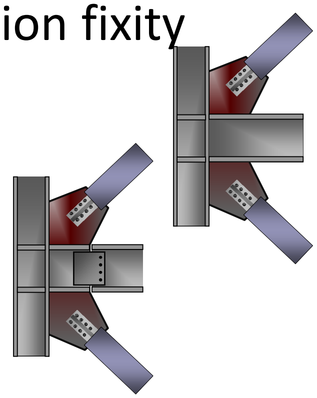
Rotation in gusseted beam-column connections (BRBF and SCBF)





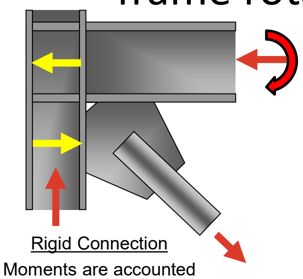
Connection fixity

- Ductile moment frames provide extra resistance
  - Lateral strength and stiffness
  - Resistance to story mechanisms
- Ductile moment connections require careful detailing



57

Method of accommodating frame rotations



Rigid Connection
Moments are accounted for in design

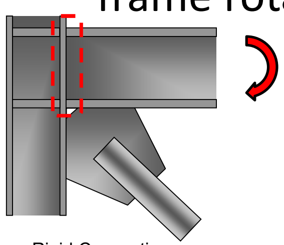
Connection strength exceeds beam strength

Consider brace and beam forces together

Consider brace and beam forces independently, too

58

Method of accommodating frame rotations

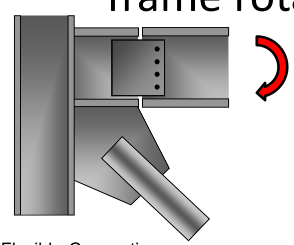


Rigid Connection
Moments are implicitly accounted for

Connection consists of Ordinary Moment Frame (OMF) connection, plus gusset

59

Method of accommodating frame rotations



Flexible Connection
Rotations are accommodated

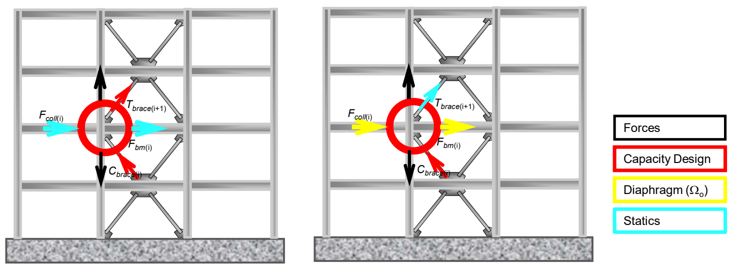
Connection typically provides rotation by means similar to shear connections in AISC manual

2.5% rotation (0.025 radians) required

60

Capacity Design Collector Forces

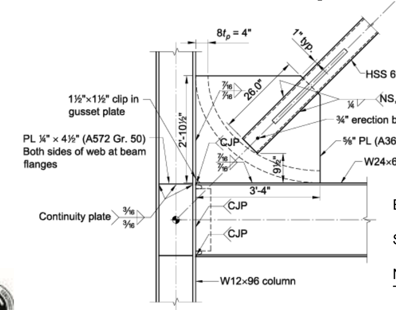
Make two cases:

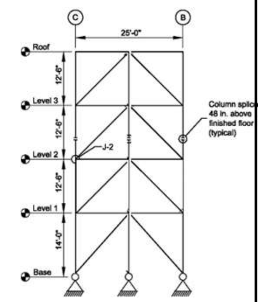


1. **Maximum brace forces**; statically consistent collector force
2. **Maximum collector force** and maximum brace force below; statically consistent brace force above

61

Design Example (SCBF)





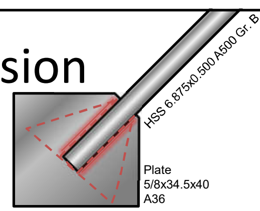
Example is from Seismic Design Manual

SDM uses "Ricker Method;" this example uses UFM

Note that SDM gusset is slightly oversized: ½" plate suffices. This example uses 5/8" plate, consistent with SDM.

62

Brace Forces: Tension

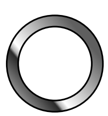


HSS 6.875x0.500 A500 Gr. B

t_{nom} = 0.500 in.
t_{des} = 0.465 in.
A = 9.36 in.^{2}
r = 2.27 in.

Tension demand

$$R_y = 1.4$$
$$P_{tension} = R_y F_y A_g = 1.4(42\text{ ksi})(9.36\text{ in.}^2) = 550\text{ kips}$$



Design brace-to-gusset weld

$$\frac{550\text{ kips}}{\phi 0.6 F_{EXX}\frac{\sqrt{2}}{2}4\left(\frac{1}{4}\text{ in.}\right)} = 24.6\text{ in.}$$

Check block shear (conservatively neglecting tension area)

$$\frac{550\text{ kips}}{\phi 0.6 F_y 2\left(\frac{5}{8}\text{ in.}\right)} = \frac{550\text{ kips}}{(0.9)0.6(36\text{ ksi})2\left(\frac{5}{8}\text{ in.}\right)} = 22.6\text{ in.}$$

Note that block shear addresses tension on the "Whitmore area"

63

Brace Forces: Tension

Net-section rupture

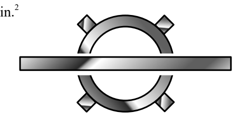
$$A_n = A_g - 2\left[t_{pl} + 2(gap)\right]t_{des}$$
$$U = 1.0$$
$$A_e = A_n$$
$$A_n = 9.36\text{ in.}^2 - 2\left[\frac{5}{8}\text{ in.} + 2\left(\frac{1}{16}\text{ in.}\right)\right](0.465\text{ in.})$$
$$= 8.66\text{ in.}^2 < A_g$$ Must reinforce!

Assume $U = 0.9$ (check after design)

$$A_r = A_g/U - A_n$$
$$A_r = 1.74\text{ in.}^2$$

Part	$\bar{x}$	A	$\bar{x}A$
	in.	in.^{2}	in.^{3}
Half-brace	2.19	4.33	9.48
2 bars	2.70	1.125	3.03
Σ		5.46	12.51

$$\bar{x} = \sum \bar{x} \Big/ \sum A = 2.29\text{ in.}$$
$$U = 1 - \bar{x}/L = 1 - 2.29/24.6 = 0.91$$



Use (4) 0.75x0.75 Grade 50 rods

Half-brace (conservative simplifications)

$$\bar{x} = r\frac{\sin\theta}{\theta} \approx 2r/\pi \approx OD/\pi$$

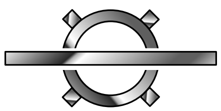
64

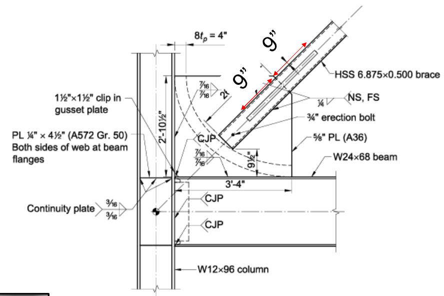
Brace Forces: Tension

$$R_yF_yA = 1.1(50\text{ ksi})\left(\frac{3}{4}\text{ in.}\right)^2 = 30.9\text{ kips}$$

$$\frac{30.9\text{ kips}}{\phi 0.6F_{EXX}\frac{\sqrt{2}}{2}2\left(\frac{1}{8}\text{ in.}\right)} = 5.5\text{ in.}$$

Use 18" long bars, centered on critical section





65

Corner gussets: UFM

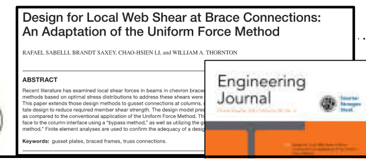
Optimal proportioning:

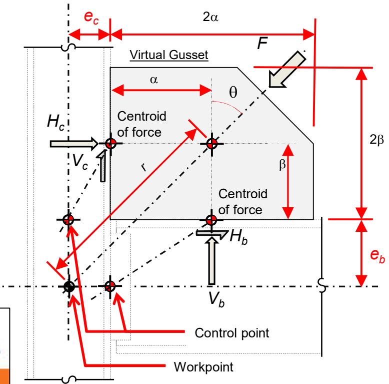
$$\alpha - \beta\tan\theta = e_b\tan\theta - e_c \qquad r = \sqrt{(e_c+\alpha)^2 + (e_b+\beta)^2}$$

$$\alpha = r\sin\theta - e_c \qquad \beta = r\cos\theta - e_b$$

$$H_c = \frac{e_c}{r}F \qquad H_b = \left(\sin\theta - \frac{e_c}{r}\right)F$$

$$V_b = \frac{e_b}{r}F \qquad V_c = \left(\cos\theta - \frac{e_b}{r}\right)F$$


Design for Local Web Shear at Brace Connections: An Adaptation of the Uniform Force Method



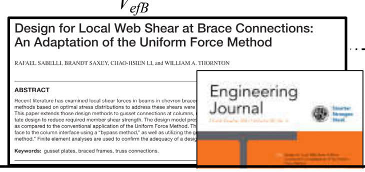
Minimum virtual gusset dimension

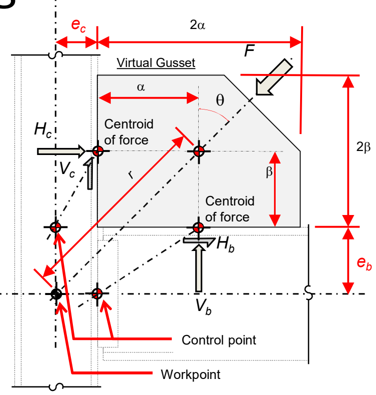
- Minimum dimension r necessary to limit column shear to its capacity

$$r \geq r_{minCol} = \frac{e_cP}{V_{efC}} = 16.7\text{ in.}$$

- Minimum dimension r necessary to limit beam shear to its capacity

$$r \geq r_{minBm} = \frac{e_bP}{V_{efB}} = 24.9\text{ in.}$$


Design for Local Web Shear at Brace Connections: An Adaptation of the Uniform Force Method



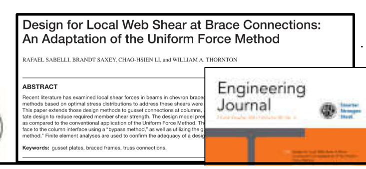
67

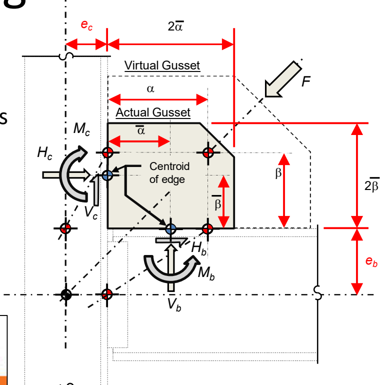
Minimum virtual gusset dimension

- Eccentricity between centroid of force (=centroid of virtual gusset) and centroid of actual gusset causes moment

$$M_b = V_b(\alpha - \bar{\alpha})$$

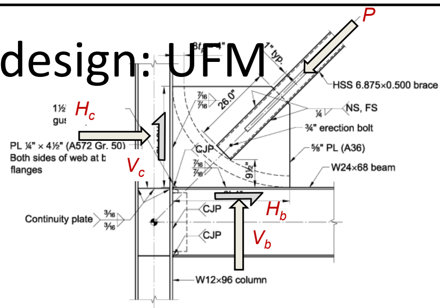
$$M_c = H_c(\beta - \bar{\beta})$$


Design for Local Web Shear at Brace Connections: An Adaptation of the Uniform Force Method



68

Gusset design: UFM



Select $\bar{\beta} = \beta$ $\quad \beta = \frac{1}{2}(2'\text{–}10.5") = 17.3 \text{ in.}$

$$r = \frac{e_b + \beta}{\cos\theta} = \frac{11.85 \text{ in.} + 17.3 \text{ in.}}{0.707} = 41.2 \text{ in.}$$

$$\alpha = r\sin\theta - e_c = (41.2 \text{ in.})(0.707) - 6.35 \text{ in.} = 22.8 \text{ in.}$$

$$V_c = \frac{\beta}{r}P = \frac{17.3 \text{ in.}}{41.2 \text{ in.}}(550 \text{ kips}) = 231 \text{ kips}$$

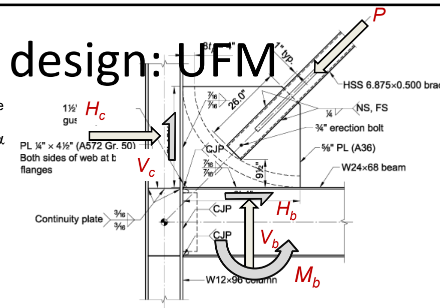
$$H_c = \frac{e_c}{r}P = \frac{6.35 \text{ in.}}{41.2 \text{ in.}}(550 \text{ kips}) = 85 \text{ kips}$$

$$V_b = \frac{e_b}{r}P = \frac{11.85 \text{ in.}}{41.2 \text{ in.}}(550 \text{ kips}) = 158 \text{ kips}$$

$$H_b = \frac{\alpha}{r}P = \frac{22.8 \text{ in.}}{41.2 \text{ in.}}(550 \text{ kips}) = 304 \text{ kips}$$

69

Gusset design: UFM



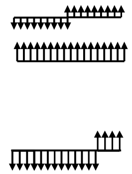
$\bar{\beta} = \beta$

$M_c = 0$

$$\bar{\alpha} = \frac{1}{2}(3'\text{–}4") = 20 \text{ in.}$$

$$M_b = V_b(\alpha - \bar{\alpha}) = 158 \text{ kips}(22.8 \text{ in.} - 20 \text{ in.}) = 442 \text{ in.-kips}$$

In reality, we would likely make $\bar{\alpha} = \alpha$



$$\frac{4M_b}{(3'\text{–}4")^2} = 1.11 \text{ kip/in.}$$

$$\frac{V_b}{(3'\text{–}4")} = 3.95 \text{ kip/in.}$$

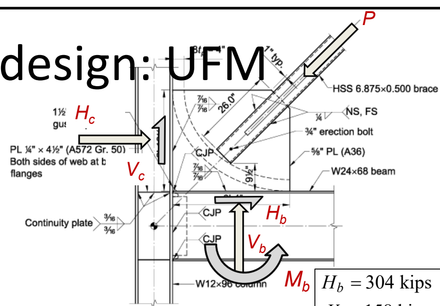
$$e = \frac{M_b}{V_b} = 2.80 \text{ in.}$$

$$W_{ef} = \frac{W}{\frac{2e}{W} + \sqrt{\left(\frac{2e}{W}\right)^2 + 1}} = \frac{40 \text{ in.}}{\frac{2(2.80 \text{ in.})}{40 \text{ in.}} + \sqrt{\left(\frac{2(2.80 \text{ in.})}{40 \text{ in.}}\right)^2 + 1}}$$

$$W_{ef} = 34.8 \text{ in.}$$

70

Gusset design: UFM



$H_c = 85$ kips
$V_c = 231$ kips
$M_c = 0$

$H_b = 304$ kips
$V_b = 158$ kips
$M_b = 442$ in.-kips

Same as low-seismic/wind:

- Check gusset interfaces
- Check beam shear, column shear
- Check beam WLY, column WLY
- Check beam WC, column WC
- Design beam-to-column connection (include V_b)

Weld from gusset to beam and column:
Minimum double fillet ~0.75 times gusset thickness

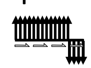
71

Plane stresses; rectangular plates

- Von Mises interaction

$$\sqrt{\left(\frac{f_n}{\phi F_y}\right)^2 + 3\left(\frac{f_v}{\phi F_y}\right)^2} \le 1$$

- Optimal plastic (with VM)



$$\sqrt{\left(\frac{M_u}{2\phi M_n} + \sqrt{\left(\frac{M_u}{2\phi M_n}\right)^2 + \left(\frac{P_u}{\phi P_n}\right)^2}\right)^2 + \left(\frac{V_u}{\phi V_n}\right)^2} \le 1$$

- Neal (approximation of OPM)

$$\frac{M_u}{\phi M_n} + \left(\frac{P_u}{\phi P_n}\right)^2 + \frac{\left(\frac{V_u}{\phi V_n}\right)^4}{1 - \left(\frac{P_u}{\phi P_n}\right)^2} \le 1$$

- Simplified by Astaneh

$$\frac{M_u}{\phi M_n} + \left(\frac{P_u}{\phi P_n}\right)^2 + \left(\frac{V_u}{\phi V_n}\right)^4 \le 1$$

72

Gusset design: Elliptical Hinge

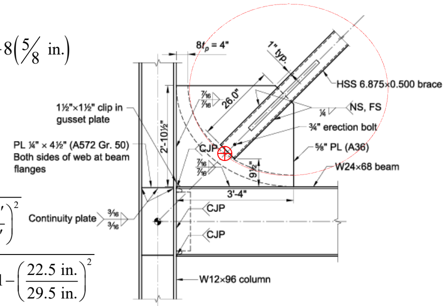
$$a' = a - 8t_p = 40.0\text{ in.} - 8\left(\tfrac{5}{8}\text{ in.}\right) = 35.0\text{ in.}$$

$$b' = b - 8t_p = 34.5\text{ in.} - 8\left(\tfrac{5}{8}\text{ in.}\right) = 29.5\text{ in.}$$

$$\rho = \frac{a'}{b'} = \frac{35.0\text{ in.}}{29.5\text{ in.}} = 1.19$$

$$y' = a'\sqrt{\frac{1}{\cot^2\gamma + \rho^2}} = 35.0\text{ in.}\sqrt{\frac{1}{\cot^2 45^\circ + (1.19)^2}} = 22.5\text{ in.}$$

$$x' = a'\sqrt{1 - \left(\frac{y'}{b'}\right)^2} = 35.0\text{ in.}\sqrt{1 - \left(\frac{22.5\text{ in.}}{29.5\text{ in.}}\right)^2} = 22.5\text{ in.}$$



73

Gusset design: Elliptical Hinge

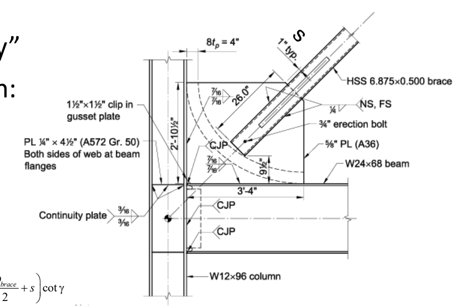
- Hold brace back "slightly"
- Or do explicit calculation:

$$\beta = \tan^{-1}\left(\frac{x'}{y'\rho^2}\right) = \tan^{-1}\left(\frac{(22.5\text{ in.})}{(22.5\text{ in.})(1.19)^2}\right) = 35.2^\circ$$

$$Corr = \frac{D_{brace}}{2}\tan(90^\circ - \beta - \gamma) = \frac{6.875\text{ in.}}{2}\tan(90^\circ - 35.2^\circ - 45.0^\circ) = 0.59\text{ in.}$$

$$l' = \sqrt{(x')^2 + (y')^2} - Corr = \sqrt{(22.5\text{ in.})^2 + (22.5\text{ in.})^2} - 0.59\text{ in.} = 31.2\text{ in.}$$

$$l'_w = l' - \left(\frac{D_{brace}}{2} + s\right)\cot\gamma = 31.2\text{ in.} - \left(\frac{6.875\text{ in.}}{2} + 1.0\text{ in.}\right)\cot 45^\circ = 26.8\text{ in.}$$



Allows for full 25" brace-to-gusset weld previously calculated

74

Brace Forces: Compression

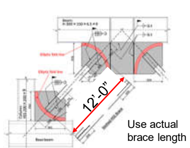
$$\frac{KL}{r} = \frac{1(12.0\text{ ft.})(12\text{ in./ft})}{2.27\text{ in.}} = 63.4$$

$$4.71\sqrt{\frac{E}{R_y F_y}} = 4.71\sqrt{\frac{29{,}000\text{ ksi}}{1.4(42\text{ ksi})}} = 105$$

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} = \frac{\pi^2(29{,}000\text{ ksi})}{(63.4)^2} = 71.2\text{ ksi}$$

$$F_{cre} = \left[0.658^{\frac{R_y F_y}{F_e}}\right] R_y F_y = 41.6\text{ ksi}$$

$$P_{compression} = 1.14 F_{cre} A_g = 1.14(41.6\text{ ksi})(9.36\text{ in.}^2) = 444\text{ kips}$$



Use actual brace length

75

Gusset Design: Compression

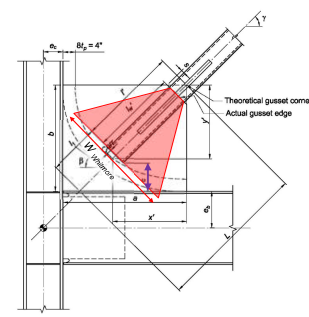
$$w_{Whitmore} = 2(\text{length of weld})\tan(30^\circ) + D_{brace} = 2(25\text{ in.})(\tan(30^\circ)) + 6.875\text{ in.} = 35.7\text{ in.}$$

Check Dowswell criterion for compact gusset

$$c = l_1 \sin\gamma - \tfrac{1}{2} D_{brace}\cos\gamma = 16.9\text{ in.}(\sin 45^\circ) - \tfrac{1}{2}(6.875\text{ in.})(\cos 45^\circ) = 9.52\text{ in.}$$

$$t_\beta = 1.5\sqrt{\frac{F_y c^3}{E l_1}} = 1.5\sqrt{\frac{(36\text{ ksi})(9.52\text{ in.})^3}{(29{,}000\text{ ksi})(16.9\text{ in.})}} = 0.378\text{ in.}$$

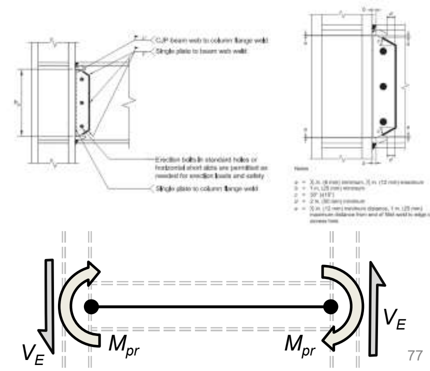
Gusset is sufficiently compact to preclude buckling



76

Beam-to-column connection

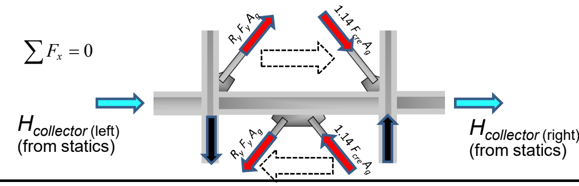
- Design as OMF
  - WUF-W
  - Prescriptive detailing
  - Check shear for Σ
    - V_b
    - $V_{gravity}$
    - V_E $=2M_{pr}/L_{cf}$ $=2(1.1R_yM_p)/L_{cf}$



77

Beam-to-column connection

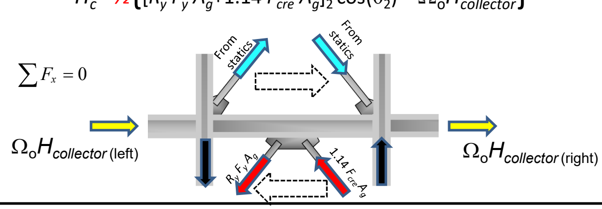
– Check adequacy for horizontal force (2 cases):
- Σ
  - H_c (from tension-capacity design)
  - $H_{collector}$= ½$\{[R_y F_y A_g$+1.14 $F_{cre} A_g]_2 \cos(\theta_2) - [R_y F_y A_g$+1.14 $F_{cre} A_g]_3 \cos(\theta_3)\}$



78

Beam-to-column connection

– Check adequacy for horizontal force (2 cases):
- Σ
  - $\Omega_o H_{collector}$ (from analysis)
  - H_c= ½$\{[R_y F_y A_g$+1.14 $F_{cre} A_g]_2 \cos(\theta_2) - \Omega_o H_{collector}\}$



79

Summary

- AISC 341 requires capacity design for bracing connections
- SCBF require connections to accommodate brace buckling
- BRBF require connections to stabilize the brace and prevent brace buckling
- Combining collector and bracing forces requires creation of additional load cases

80

AISC | Questions?

Smarter.
Stronger.
Steel.

Individual Session Registrants

PDH Certificates

- All WFH individuals associated with a group registration will be issued a certificate.
- 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!

8-Session Registrants

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 Wednesday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

Quiz and attendance records

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

Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- 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

8-Session Registrants

Access to the recording

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

PDHs via recording

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

8-Session Registrants

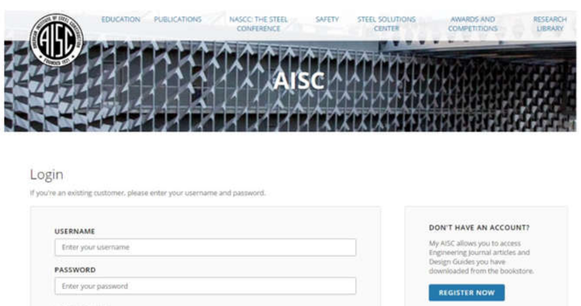
Night School Resources

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

8-Session Registrants

Night School Resources

Go to www.aisc.org and sign in.



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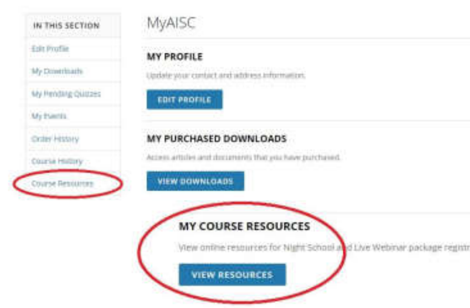
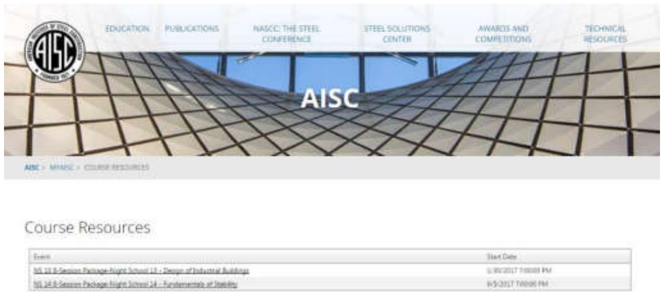


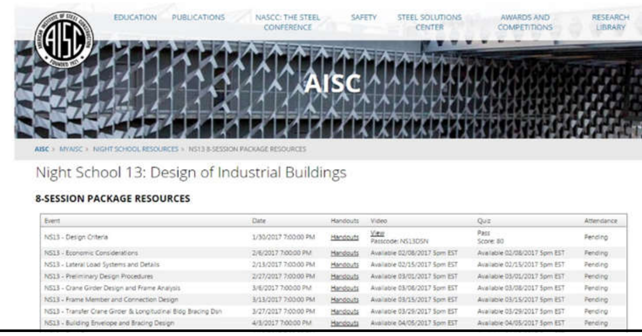
8-Session Registrants

Night School Resources



8-Session Registrants

Night School Resources



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
Smarter.
Stronger.
Steel.