Night School 28: Vertical Bracing Connections

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AISC Night School

Vertical Bracing Connections, Session 7: The Chevron Gusset Connection

May 17, 2022 | Rafael Sabelli

Smarter. Stronger. Steel.

AISC Night School

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Course Description

Vertical Bracing Connections

Session 7: The Chevron Gusset Connection
May 17, 2022

This session will review brace-to-beam connections away from the beam-to-column joint. Focusing on seismic force resisting systems where the brace vertical components are unequal, the presentation will demonstrate how to derive the forces imparted to the beam and evaluate the beam strength for those forces. It will also provide practical guidance on how the gusset plate geometry or stiffeners may be chosen to avoid beam web reinforcement.

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Learning Objectives

1. Learn how to determine forces acting on the beam at chevron connections.
2. Learn how frame configuration affects the intensity of the chevron effect.
3. Understand how assumed gusset stress distributions affect internal beam forces.
4. Learn how to apply the "Uniform Stress Method" to determine required gusset dimensions.
5. Learn how to apply the "Concentrated Stress Method" to determine required gusset dimensions.

Night School 28: Bracing Connections and Related Topics

From the First Principles to Design
Session 7: The Chevron Connection
May 17, 2022

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

Smarter.
Stronger.
Steel.

Learning Objectives

- Learn how to determine forces acting on the beam at chevron connections
- Learn how frame configuration affects the intensity of the chevron effect
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The Chevron Connection

- The frame
  - Configurations
  - Load path
  - Seismic design
- The connection
  - The "Chevron Effect"
  - Statics of the connection
  - Stress distributions
  - Complete plastic mechanism
- Design example
  - Statics of connection
  - Try Uniform Stress Method
  - Try Concentrated Stress Method
  - Gusset checks

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The Frame

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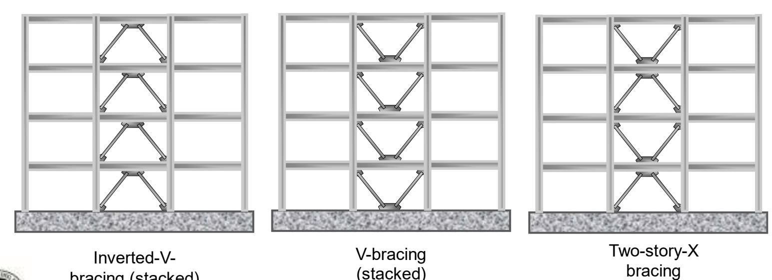
Configurations



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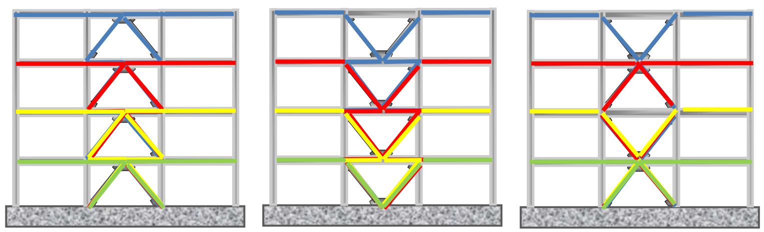
Load Path



Inverted-V-bracing (stacked)

V-bracing (stacked)

Two-story-X bracing

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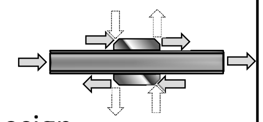
Seismic Design



- Wind design
  - Horizontal
    - Beam axial force loads braces
    - Braces above load braces below
  - Vertical
    - Beam loads braces
    - Bracing connection supports beam
- Seismic design
  - Horizontal
    - Beam axial force loads braces
    - Braces above load braces below
  - Vertical
    - Braces load beam
    - Beam spans full bay length

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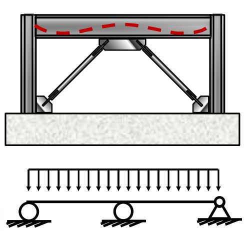
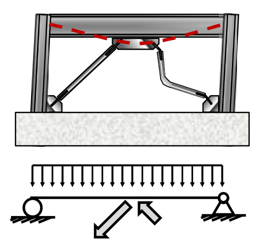
Beam support and loading

- Gravity load combinations
- Wind load combinations



- Seismic load combinations



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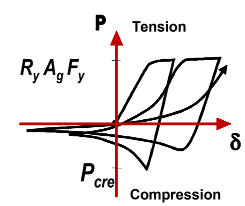
SCBF

- Special Concentrically Braced Frames (SCBF)
  - Brace tensile yield
  - Brace compression buckling
  - Post buckling loss of strength in brace



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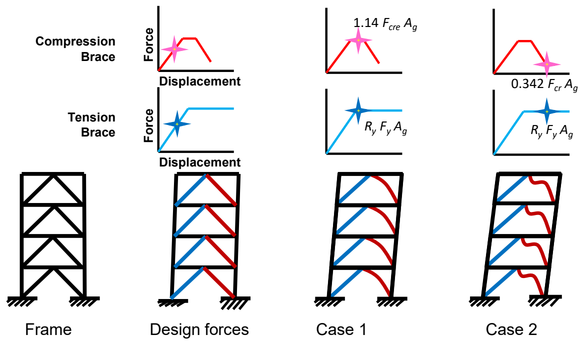
SCBF

SCBF

- Design for 2 events
  - Brace buckling
  - Brace tensile yielding
- Defined mechanism
- Strong connections required



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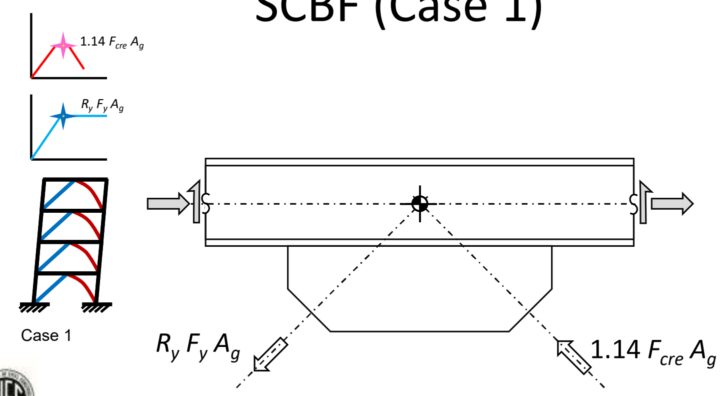
SCBF (Case 1)



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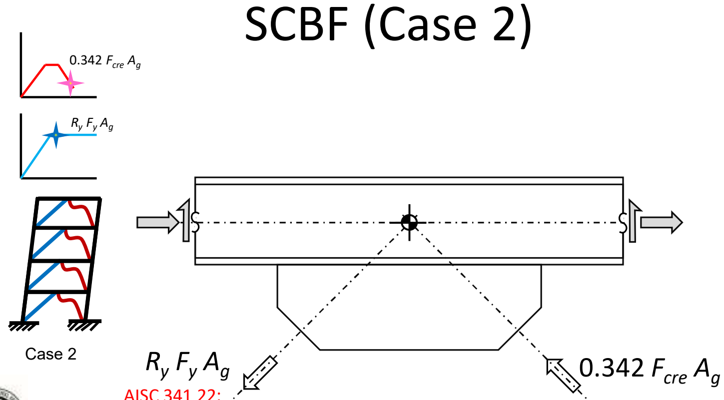
SCBF (Case 2)



AISC 341 22:
$\leq 1.14\ F_{cre}\ A_g$
for beams in V and Inverted-V braced frames

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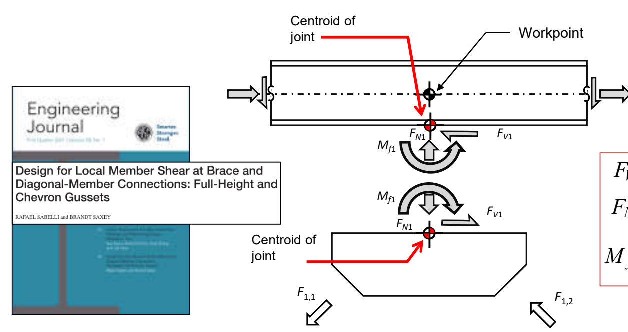
Statics of the connection



$$F_{V1} = (F_{1,1} + F_{1,2})\cos\theta$$
$$F_{N1} = (F_{1,2} - F_{1,1})\sin\theta$$
$$M_{f1} = (F_{1,1} + F_{1,2})\cos\theta \frac{d_b}{2}$$

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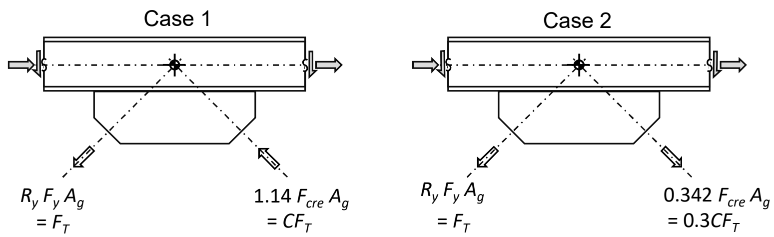
SCBF Case 1 vs. Case 2



Case 1:

$$F_{V1} = (F_{1,1}+F_{1,2})\cos\theta = (1+C)F_T\cos\theta$$

$$F_{N1} = (F_{1,2}-F_{1,1})\sin\theta = (C-1)F_T\sin\theta$$

$$M_{f1} = F_{V1}\frac{d_b}{2} = (1+C)F_T\cos\theta\frac{d_b}{2}$$

Case 2:

$$F_{V1} = (F_{1,1}+F_{1,2})\cos\theta = (1+0.3C)F_T\cos\theta$$

$$F_{N1} = (F_{1,2}-F_{1,1})\sin\theta = (0.3C-1)F_T\sin\theta$$

$$M_{f1} = F_{V1}\frac{d_b}{2} = (1+0.3C)F_T\cos\theta\frac{d_b}{2}$$

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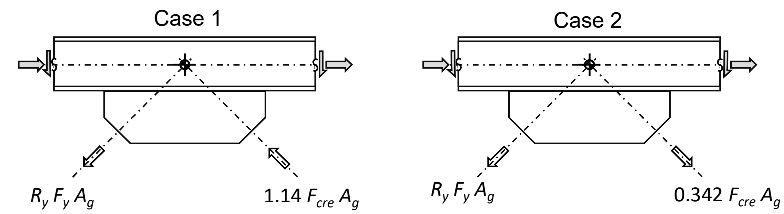
SCBF Case 1 vs. Case 2



Critical for connection

Critical for beam

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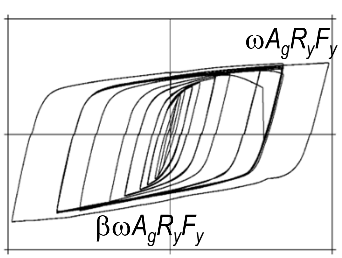
BRBF



- Buckling-Restrained Braced Frames (BRBF)
  - Tension and compression yielding
    - Strain hardening
  - (Almost) balanced tension and compression
    - Compression overstrength

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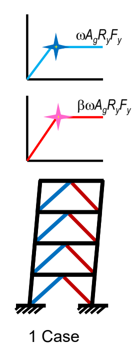
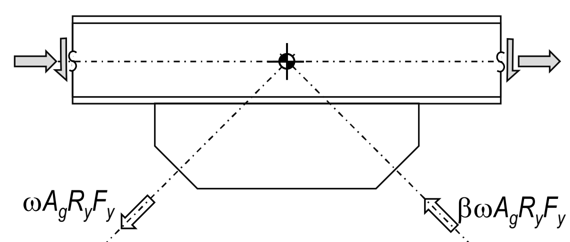
BRBF





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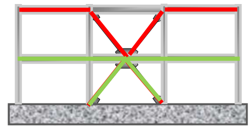
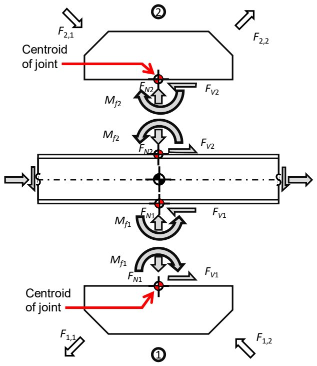
2-Story X





- Moments are additive
- Beam design axial force may be low
- Local connection effects may be more severe than member forces based on centerline analysis

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The Connection

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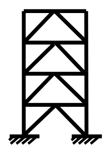
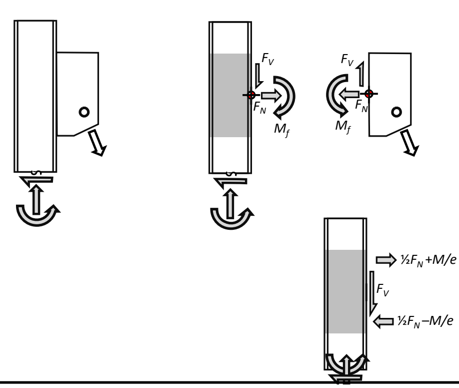
The “Chevron effect”





Force couple delivering moment:
Web local yielding
Web local crippling
Panel-zone shear

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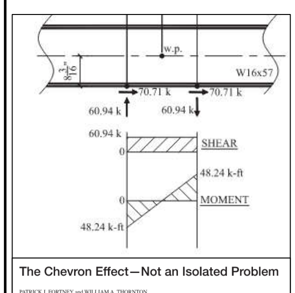
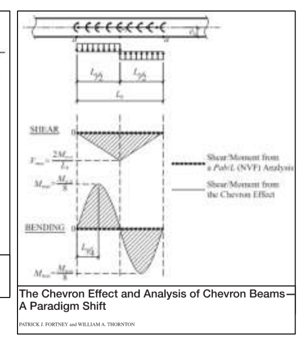
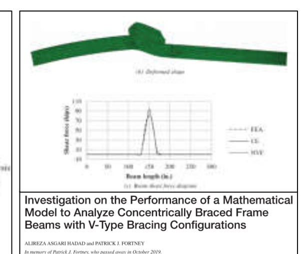
The “Chevron effect”







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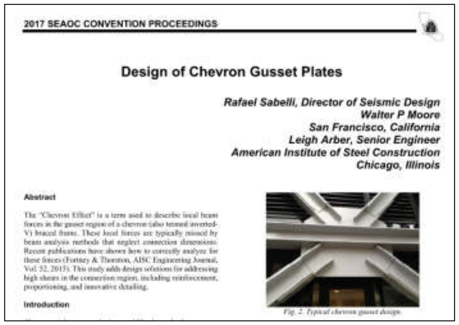
The "Chevron effect"


2017 SEAOC CONVENTION PROCEEDINGS

Design of Chevron Gusset Plates

Rafael Sabelli, Director of Seismic Design
Walter P Moore
San Francisco, California
Leigh Arber, Senior Engineer
American Institute of Steel Construction
Chicago, Illinois

Abstract

Introduction

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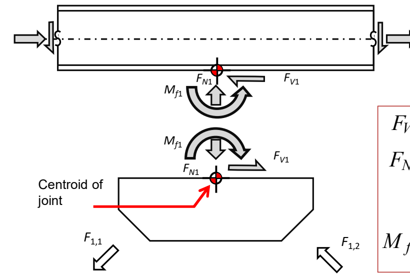
The "Chevron effect"



$$F_{V1} = \left(F_{1,1} + F_{1,2}\right)\cos\theta$$

$$F_{N1} = \left(F_{1,2} - F_{1,1}\right)\sin\theta$$

(compression positive)

$$M_{f1} = \left(F_{1,1} + F_{1,2}\right)\cos\theta \frac{d_b}{2}$$

Statics

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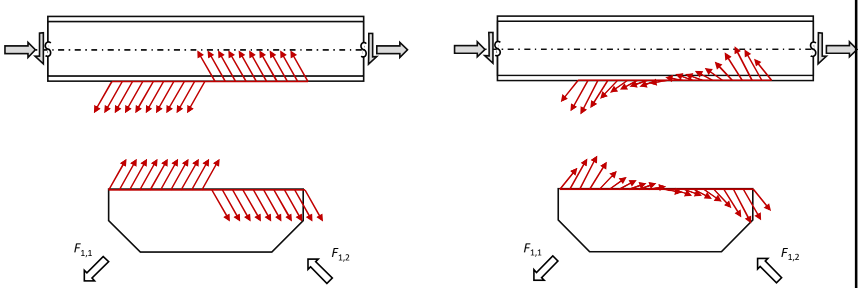
The "Chevron effect"



Distribution

Multiple stress distributions are "admissible"
(i.e, satisfy statics, consistent with Lower Bound Theorem)

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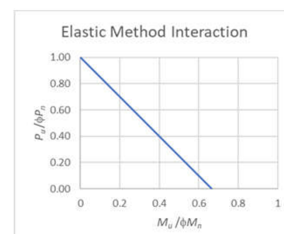
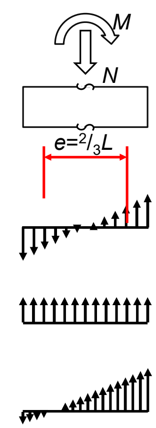
Axial-moment interaction on rectangular plates

- Elastic

$$\frac{M_u}{\phi M_y} + \frac{P_u}{\phi P_n} \le 1$$

$$\frac{6M_u}{t\phi F_y W^2} + \frac{P_u}{t\phi F_y W} \le 1$$



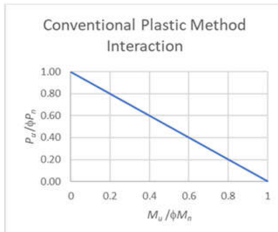


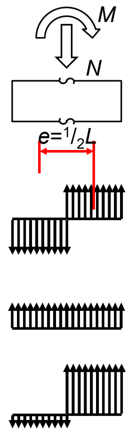
Axial-moment interaction on rectangular plates

- Conventional plastic

$$\frac{M_u}{\phi M_n}+\frac{P_u}{\phi P_n}\le 1$$

$$\frac{4M_u}{t\phi F_y W^2}+\frac{P_u}{t\phi F_y W}\le 1$$



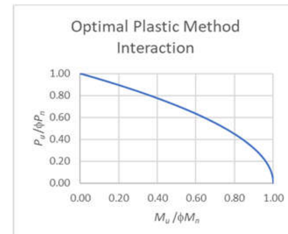


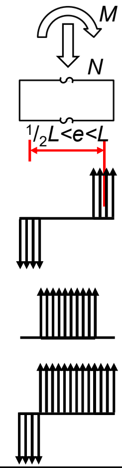
Axial-moment interaction on rectangular plates

- Optimal plastic

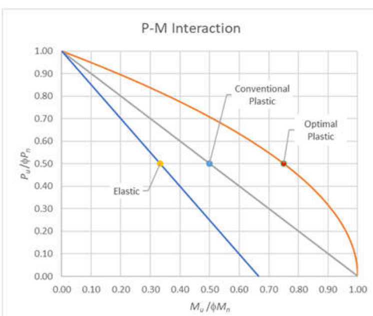
$$\frac{M_u}{\phi M_n}+\left(\frac{P_u}{\phi P_n}\right)^2\le 1$$

$$\frac{4M_u}{t\phi F_y W^2}+\left(\frac{P_u}{t\phi F_y W}\right)^2\le 1$$





Axial-moment interaction on rectangular plates



- Elastic $\frac{M_u}{\phi M_y}+\frac{P_u}{\phi P_n}\le 1$
- Conventional plastic $\frac{M_u}{\phi M_n}+\frac{P_u}{\phi P_n}\le 1$
- Optimal plastic $\frac{M_u}{\phi M_n}+\left(\frac{P_u}{\phi P_n}\right)^2\le 1$

The "Chevron effect"

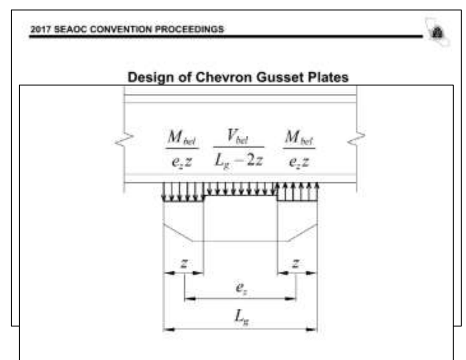


Fig. 6. Stress distribution for concentrated stress approach.

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The "Chevron effect"

Report No. SSRP-2018/02

Finite Element Evaluation of the Chevron Effect in Braced Frames

by

Paul Richards
Associate Professor
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Student Researcher
Jacob Linford
Student Researcher

Department of Civil and Environmental Engineering
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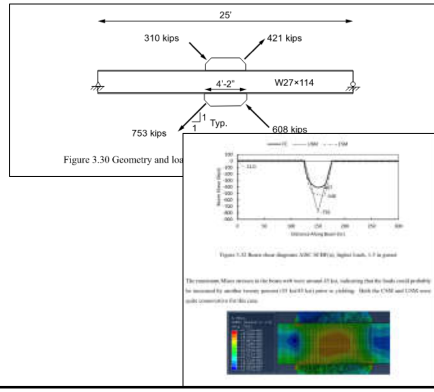

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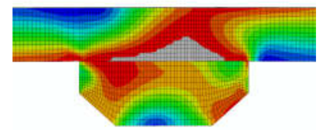
The "Chevron effect"

Design for Local Member Shear at Brace and Diagonal-Member Connections: Full-Height and Chevron Gussets

RAFAEL SABELLI and BRANDT SAXEY



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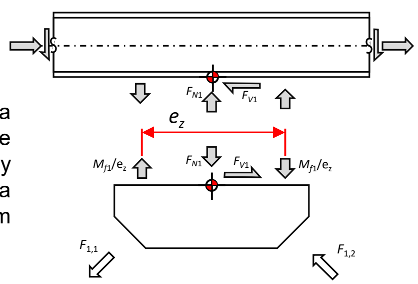
The "Chevron effect"

By selecting a distribution we are effectively selecting a moment arm



Distribution

The moment-arm length determines the magnitude of the vertical force

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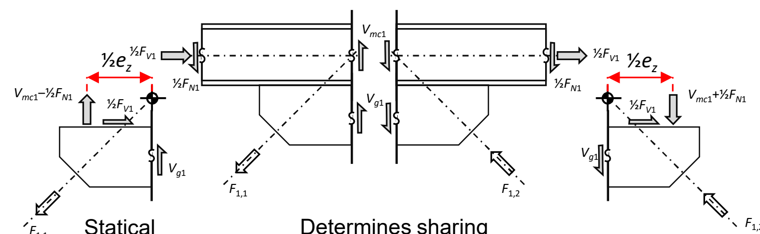
The "Chevron effect"



Statical equilibrium here

$$\sum M = 0$$

$$\left(V_{mc1} - \frac{1}{2}F_{N1}\right)\left(\frac{1}{2}e_z\right) = \left(\frac{1}{2}F_{V1}\right)\frac{d_b}{2}$$

Determines sharing of vertical force here

$$V_{g1} = F_{1,1}\sin\theta - \left(V_{mc1} - \frac{1}{2}F_{N1}\right)$$

$$= F_{1,1}\sin\theta - \left(\frac{1}{2}F_{V1}\right)\frac{d_b}{e_z}$$

To put more of the shear in the gusset, moment arm must be increased. Stiffening, thickening gusset is ineffective.

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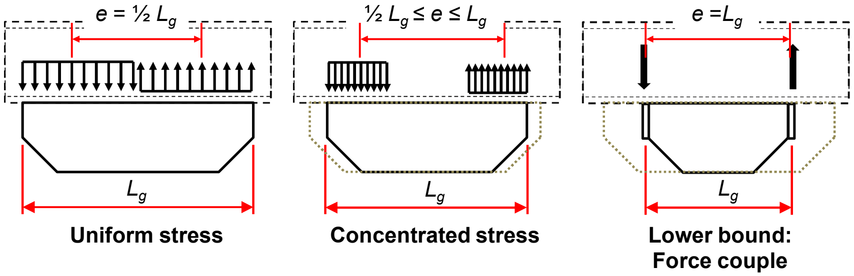
Increasing moment arm within gusset



$V = M/e = 2M/L_g$ $\quad$ $M/L_g \le V \le 2M/L_g$ $\quad$ $V = M/e = M/L_g$

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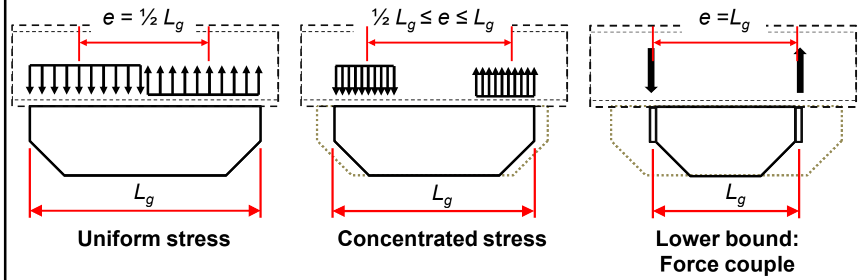
Increasing moment arm within gusset



$L_g \ge 2M/\phi V_n$ $\quad$ $2M/\phi V_n \ge L_g \ge M/\phi V_n$ $\quad$ $L_g \ge M/\phi V_n$

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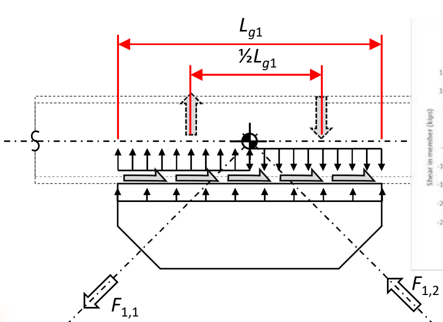
Uniform Stress Method (USM)



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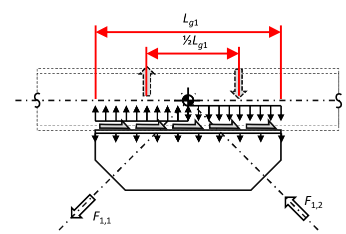
Uniform Stress Method



$$V_u = \frac{2M_{f1}}{L_{g1}} \qquad R_{u1} = \frac{F_{N1}}{2} \pm \frac{2M_{f1}}{L_{g1}}$$

Analysis

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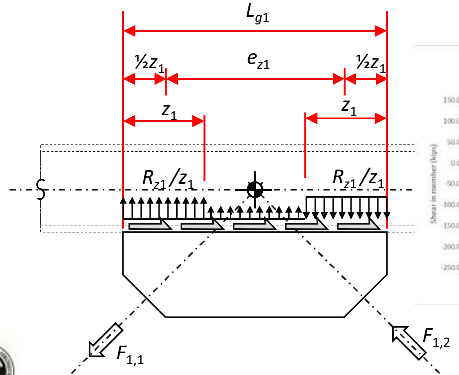
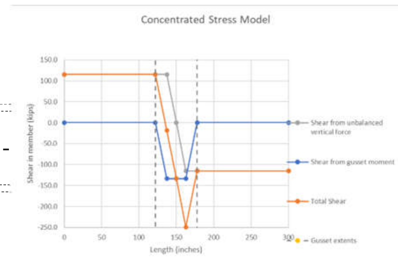
Concentrated Stress Method (CSM)





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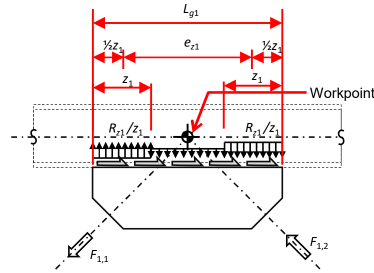
Concentrated Stress Method



Analysis

$$z_1 \geq \frac{L_{g1}}{2} - \sqrt{\frac{L_{g1}^{\ 2}}{4} - \frac{M_{f1}}{\phi_w F_y t_w}} - 5k$$ WLY

$$z_1 \geq \left[\frac{R_{z1}}{\phi_n 0.80 t_w^{\ 2}} \sqrt{\frac{t_w}{E F_y t_f}} - 1\right]\left(\frac{d_m}{3}\right)\left(\frac{t_f}{t_w}\right)^{1.5}$$ WLC

$$z_1 \geq \frac{L_{g1}}{2} - \sqrt{\frac{L_{g1}^{\ 2}}{4} - \frac{M_{f1}/\phi_t}{\sqrt{(F_y t_g)^2 - \left(\frac{F_{V1}}{\phi_v 0.6 L_{g1}}\right)^2}}}$$ Gusset yield

$$R_{z1} = \frac{M_{f1}}{L_{g1} - z_1} \qquad V_u = \frac{1}{2} F_{N1} + R_{z1}$$

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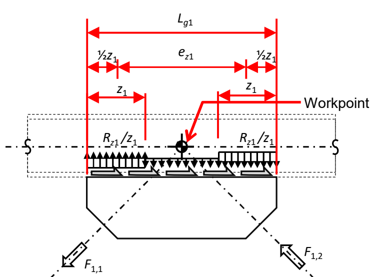
Concentrated Stress Method



Rough estimate
Not necessary
for design

Assume e_z = 0.75 L_g for a rough estimate

$$L_{g1} \approx 1.33 \frac{F_{V1} d_b}{\phi_v V_n}$$

$$\phi_v V_n \approx 0.75 \frac{F_{V1} d_b}{L_{g1}}$$

$$t_w \approx 0.75 \frac{F_{V1}/L_{g1}}{\phi_v 0.6 F_y}$$

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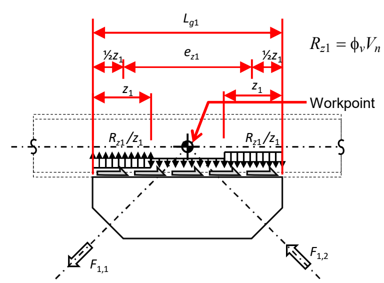
Concentrated Stress Method



Design

$$R_{z1} = \phi_v V_n - \frac{1}{2} F_{N1} \qquad L_{g1} \geq \frac{M_{f1}}{R_{z1}} + \frac{R_{z1}}{\phi_w F_y t_w} - 5k$$ WLY

$$L_{g1} > \frac{M_{f1}}{V_{ef1}} + \frac{R_{z1}}{t_{g1} \phi_t F_y}$$ Gusset yield (approximate)

WLC must be examined after selection of gusset length

$$t_{g1} \geq \sqrt{\left(\frac{F_{V1}}{\phi_v 0.6 F_y L_{g1}}\right)^2 + \left(\frac{R_{z1}}{\phi_t F_y \left(L_{g1} - \frac{M_{f1}}{R_{z1}}\right)}\right)^2}$$ Gusset yield (after length selection)

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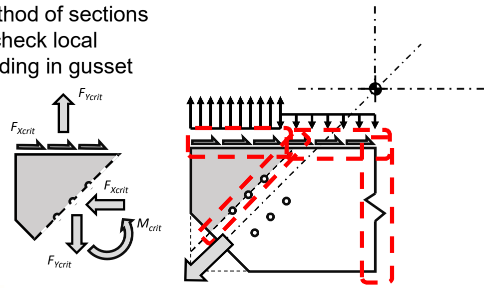
Concentrated Stress Method

Method of sections to check local yielding in gusset



Gusset sections

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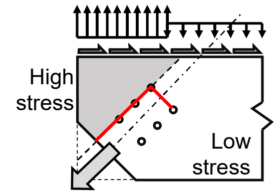
Concentrated Stress Method

CSM:
Nonuniform vertical stress at gusset-beam interface requires nonuniform stresses in gusset



Approximate method using partial block-shear area

Critical gusset section

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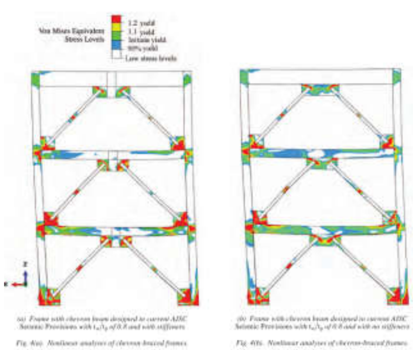
Looking beyond the connection



- Alternative load paths for moment
- Dependent on additional flexural strength in braces, beam

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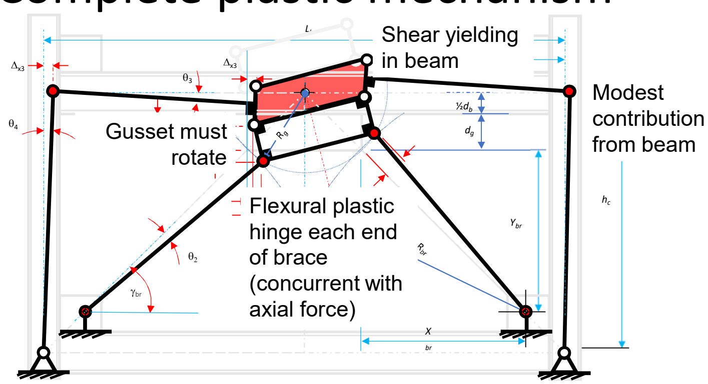
Complete plastic mechanism



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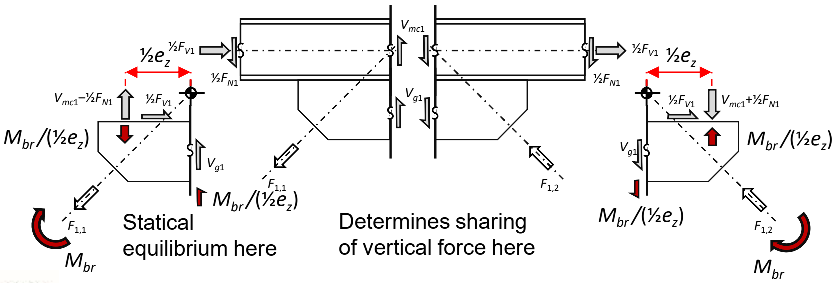
Brace engagement



Not recommended for new design!

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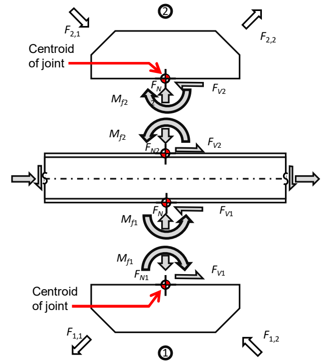
2 gussets, 4 braces



- Effects are additive
  - Similar to moment connection at column
- Maximum effects typically assumed to be simultaneous

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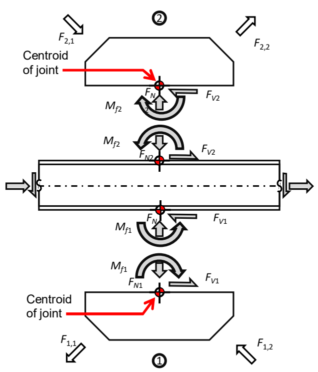
2 gussets, 4 braces



- Apportionment

$$V_{ef1} = \frac{M_{f1}}{M_{f1} + M_{f2}} \phi V_n$$

$$V_{ef2} = \frac{M_{f2}}{M_{f1} + M_{f2}} \phi V_n$$

- Design each gusset separately
  - Need not be same length

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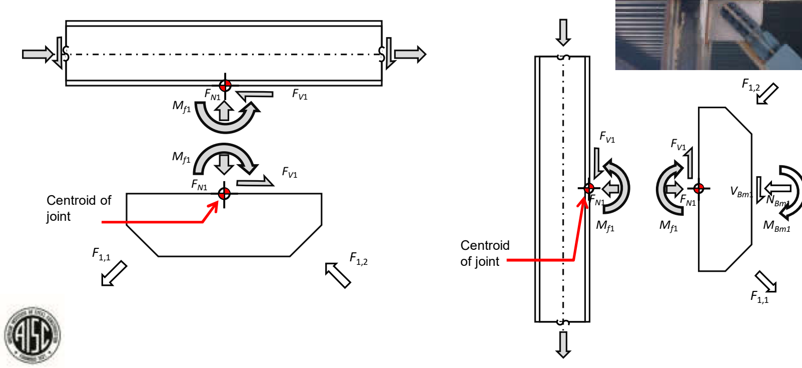
Megagussets



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Design

- Establish parameters
  - Determine F_V, F_N, and M_f
  - Determine the optimal gusset-plate length
  - Apportion shear strength between gussets (if applicable)
- Try USM
  - Check gusset length
  - (Consider reinforcement)
  - If no good….
- Try CSM
  - Check gusset length
- Check shear
- Design gusset and weld

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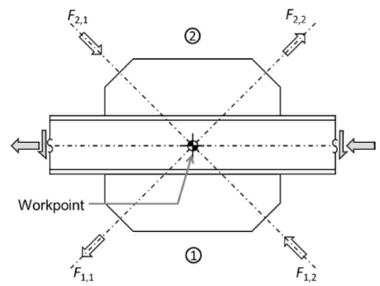
Design Example



	Brace Axial Force F (kips)	Shear Component $F\cos(\gamma)$ (kips)	Normal Component $F\sin(\gamma)$ (kips)
$F_{1,1}$	568	364	436
$F_{1,2}$	653	418	502
$F_{2,2}$	511	327	393
$F_{2,1}$	588	376	451

50.2° from horizontal

W24×94 (ϕV_n = 375 kips; A=27.7 in.^{2}; Z=254 in.^{3})

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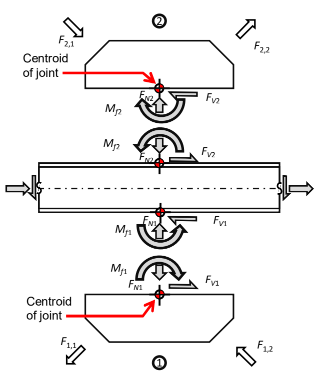
Collect forces



	Gusset 1 (below beam)	Gusset 2 (above beam)	Combination (total or difference)
$F_{V(i)}$ (kips)	782	703	78.5
$F_{N(i)}$ (kips)	65.5	58.9	6.6
$M_{f(i)}$ (kip-in.)	9500	8550	18,000
$V_{ef(i)}/V_{efTOT}$	0.526	0.474	1.0

$$V_{ef1} = \frac{M_{f1}}{M_{f1} + M_{f2}} \phi V_n$$

Optimum for brace attachment to gusset:
(2) $^3/_4$x21x48 gussets

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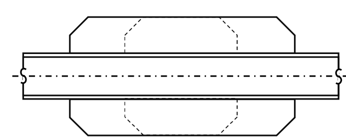
Try USM

- Determine gusset length that does not require reinforcement

$$L_g \geq \frac{2M_{Tot}}{V_{efTot}} = \frac{18{,}000 \text{ kip-in.}}{375 \text{ kips}} = 96.1 \text{ in.}$$

(2) 96” gussets (top and bottom)



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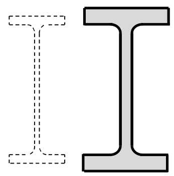
Try USM

- Determine beam size that does not require reinforcement for a 48" gusset

$$t_w \geq \frac{F_{V1}/L_{g1} + F_{V2}/L_{g2}}{\phi_v 0.6 F_y}$$
$$= \frac{F_{V1} + F_{V2}}{\phi_v 0.6 F_y L_g}$$
$$= \frac{782 \text{ kips} + 703 \text{ kips}}{(1.0)0.6(50 \text{ ksi})(48 \text{ in.})}$$
$$= 1.03 \text{ in.}$$

W24×250
(or a W21×248 or a W18×211)



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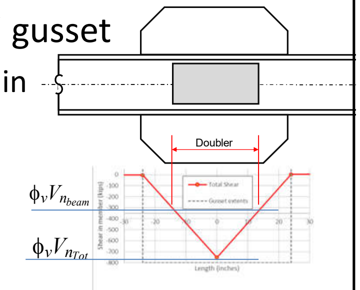
Try USM

- Determine a web doubler that works with the W24x94 and a 48" gusset
  - Try web doubler of 3/4 × 18 in



$$L_g \geq \frac{2M_{Tot}}{\phi_v V_{n_{Tot}}} = \frac{2M_{Tot}}{\left[\phi_v V_{n_{beam}} + \phi_v V_{n_{doubler}}\right]}$$
$$= \frac{2(18{,}000 \text{ kip-in.})}{\left[375 \text{ kips} + 1.0(0.6)(0.75 \text{ in.})(18 \text{ in.})(50 \text{ ksi})\right]} = 46.2 \text{ in.}$$

USM designs:
- Long gusset
- Heavy beam
- Web doubler

USM designs not acceptable; try CSM

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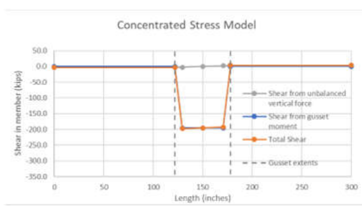
Try CSM

V_{efTOT} is reduced considering the net unbalanced force:

$$V_{efTot} = \phi_v V_n - \left|\frac{F_{N1}}{2} - \frac{F_{N2}}{2}\right|$$
$$= 375 \text{ kips} - \left|\frac{6.6 \text{ kips}}{2}\right|$$
$$= 372 \text{ kips}$$



Apportionment:

$$V_{ef1} = \frac{M_{f1}}{M_{Tot}} V_{efTot}$$
$$= \frac{9500 \text{ kip-in.}}{18{,}000 \text{ kip-in.}}(372 \text{ kips})$$
$$= 196 \text{ kips}$$

Shear available to Gusset 1

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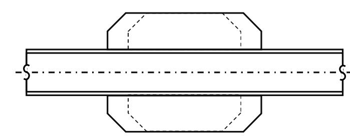
Try CSM

Preliminary design

$$L_{g1} > \frac{M_{f1}}{V_{ef1}} + \frac{V_{ef1}}{\phi_w F_y t_w} - 5k$$
$$= \frac{9500 \text{ kip-in.}}{196 \text{ kips}} + \frac{196 \text{ kips}}{(1.0)(50 \text{ ksi})(0.515 \text{ in.})} - 5(1.38 \text{ in.})$$
$$= 49.2 \text{ in.}$$

WLY



$$L_{g1} > \frac{M_{f1}}{V_{ef1}} + \frac{V_{ef1}}{\phi_t F_y t_{g1}}$$
$$= \frac{9500 \text{ kip-in.}}{196 \text{ kips}} + \frac{196 \text{ kips}}{(0.9)(50 \text{ ksi})(0.75 \text{ in.})}$$
$$= 54.3 \text{ in.}$$

Gusset yield

Use 56" minimum contact; 58" total

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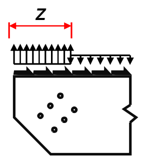
Try CSM

Determine z



$$z_1 \geq \frac{L_{g1}}{2} - \sqrt{\frac{{L_{g1}}^2}{4} - \frac{M_{f1}}{\phi_w F_y t_w}} - 5k$$

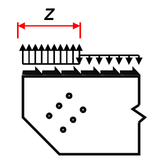
$$= \frac{56.0\text{ in.}}{2} - \sqrt{\frac{(56.0\text{ in.})^2}{4} - \frac{9500\text{ kip-in.}}{(1.0)(50\text{ ksi})(0.515\text{ in.})}} - 5(1.38\text{ in.})$$

$$= 0.73\text{ in.}$$

WLY

Try CSM

Determine z



$$z_1 \geq \left[\frac{V_{ef1}}{\phi_n 0.80{t_w}^2}\sqrt{\frac{t_w}{EF_y t_f}} - 1\right]\left(\frac{d_m}{3}\right)\left(\frac{t_f}{t_w}\right)^{1.5}$$

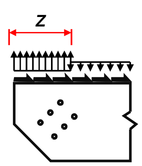
$$= \left[\frac{196\text{ kips}}{(0.75)0.80(0.515\text{ in.})^2}\sqrt{\frac{0.515\text{ in.}}{(29{,}000\text{ ksi})(50\text{ ksi})(0.875\text{ in.})}} - 1\right]\left(\frac{24.3\text{ in.}}{3}\right)\left(\frac{0.875\text{ in.}}{0.515\text{ in.}}\right)^{1.5}$$

$$= -3.87\text{ in.}$$

WLC

Try CSM

Determine z



$$z_1 = \frac{L_{g1}}{2} - \sqrt{\frac{{L_{g1}}^2}{4} - \frac{M_{f1}/\phi_t}{\sqrt{(F_y t_{g1})^2 - \left(\frac{F_{V1}}{\phi_v 0.6 L_{g1}}\right)^2}}}$$

$$= \frac{56.0\text{ in.}}{2} - \sqrt{\frac{(56.0\text{ in.})^2}{4} - \frac{9500\text{ kip-in.}/0.9}{\sqrt{[(50\text{ ksi})(0.75\text{ in.})]^2 - \left(\frac{782\text{ kip}}{(1.0)(0.6)(56\text{ in.})}\right)^2}}}$$

$$= 7.38\text{ in.}$$

Gusset yield

Use 7.38 in.

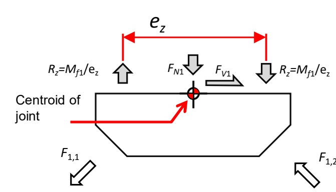
Try CSM

Force couple

$$R_{z1} = \frac{M_{f1}}{L_{g1} - z_1}$$

$$= \frac{9500\text{ kip-in.}}{56.0\text{ in.} - 7.38\text{ in.}}$$

$$= 195\text{ kips}$$



Maximum shear

$$V_{mc1} = V_{ma1} + R_{z1}$$

$$= \left(\frac{M_{f1}}{M_{Tot}}\right)\frac{F_{N1} - F_{N2}}{2} + R_{z1}$$

$$= 0.526\left(\frac{6.6\text{ kips}}{2}\right) + (195\text{ kips})$$

$$= 197\text{ kips}$$

$$\frac{V_{mc1}}{\phi_v V_n} = \frac{197\text{ kips}}{375\text{ kips}}$$

$$= 0.525 \leq 0.526 \quad \textbf{o.k.}$$

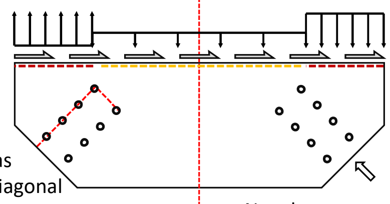
Design does not use more shear strength than apportioned

Design gusset

Gusset checks

$t_{g1} = 0.75$ in.
$d_{g1} = 21.0$ in.
$L_{g1} = 56.0$ in.

Check for portion of shear resisted by gusset, any normal force, and moment



Different welds possible in end and center region

Center region ≤ ½ L_g
Weld ≥ ½ end weld size (strain compatibility)

Block-shear check as approximation of diagonal section

Not shown:
Check stability
Check brace-to gusset connection

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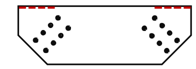
Design gusset



Gusset check at section parallel to the member axis at beam flange (*z* end regions)

- Implicitly checked by gusset-length selection
- Full utilization of gusset strength
- CJP (or fillet that can develop full gusset strength as gusset is fully utilized)

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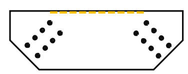
Design gusset



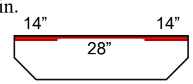
Gusset check at section parallel to the member axis at beam flange (center region)

$$\sqrt{\left(\frac{F_{V1}}{\phi_v 0.6 F_y t_{g1} L_{g1}}\right)^2 + \left(\frac{F_{N1}}{\phi_t F_y t_{g1}\left(L_{g1} - 2z_1\right)}\right)^2}$$
$$= \sqrt{\left(\frac{782 \text{ kips}}{0.6(50 \text{ ksi})(0.75 \text{ in.})(56.0 \text{ in.})}\right)^2 + \left(\frac{65.5 \text{ kips}}{(0.9)(50 \text{ ksi})(0.75 \text{ in.})(56.0 \text{ in.} - 2(7.38 \text{ in.}))}\right)^2}$$
$$= 0.622$$

- 62% utilization of gusset strength

$$L_{g1} - 2z_1 = 56.0 \text{ in.} - 2(7.38 \text{ in.}) = 41.2 \text{ in.}$$

Use $\frac{1}{2}(56.0 \text{ in.}) = 28$ in.



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Design gusset

Design weld (center region)

$$N_{weld} = F_{N1} = 65.5 \text{ kips}$$

$$V_{weld} = F_{V1}\frac{L_{g1} - 2z_1}{L_{g1}} = (782 \text{ kips})\frac{56 \text{ in.} - 2(7.38 \text{ in.})}{56.0 \text{ in.}} = 576 \text{ kips}$$

$$P_u = \sqrt{N_{weld}^2 + V_{weld}^2} = \sqrt{(65.5 \text{ kips})^2 + (576 \text{ kips})^2} = 579 \text{ kips}$$

$\tan^{-1}(65.5/576) = 6.5^{o}$

$$w \geq \frac{P_u}{\phi_n 0.6 F_{EXX}\left(1.0 + 0.5\sin^{1.5}\theta\right)\frac{\sqrt{2}}{2}2\left(L_{g1} - 2z_1\right)} = \frac{579 \text{ kips}}{(0.75)0.6(70 \text{ ksi})\left(1.0 + 0.5\sin^{1.5}(6.5°)\right)\sqrt{2}(41.2 \text{ in.})} = 0.310 \text{ in.}$$

Use (2) $^{5}/_{16}$-in. fillet welds

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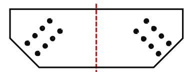
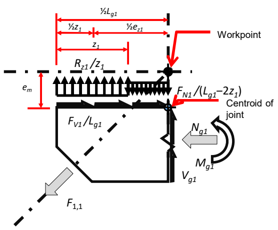
Design gusset



Gusset check at section perpendicular to the member axis



$$N_{g1} = \frac{1}{2}\left(F_{1,2}\cos\gamma_{1,2} - F_{1,1}\cos\gamma_{1,1}\right) = \frac{1}{2}(418\text{ kips} - 364\text{ kips}) = 27\text{ kips}$$

$$V_{g1} = F_{1,1}\sin\gamma_{1,1} - R_{z1} + \frac{F_{N1}}{2} = 436\text{ kips} - 195\text{ kips} + \frac{65.5\text{ kips}}{2} = 274\text{ kips}$$

$$M_{g1} = N_{g1}\left(e_m + \frac{d_{g1}}{2}\right) - \frac{F_{N1}}{2}\left(\frac{L_{g1}}{4} - \frac{z_1}{2}\right) = (27\text{ kips})\left(12.15\text{ in.} + \frac{21.0\text{ in.}}{2}\right) - \frac{65.5\text{ kips}}{2}\left(\frac{56\text{ in.}}{4} - \frac{7.38\text{ in.}}{2}\right) = 280\text{ kip-in.}$$

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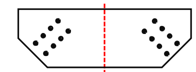
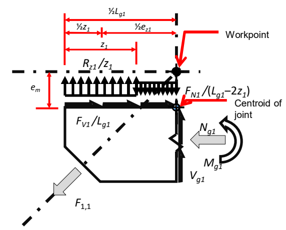
Design gusset



Gusset check at section perpendicular to the member axis



$$\phi_t P_n = 0.9F_y d_{g1} t_{g1} = (0.9)(50\text{ ksi})(21.0\text{ in.})(0.75\text{ in.}) = 709\text{ kips}$$

$$\phi_v V_n = 1.00(0.60F_y)d_{g1}t_{g1} = 1.00(0.60)(50\text{ ksi})(21.0\text{ in.})(0.75\text{ in.}) = 473\text{ kips}$$

$$\phi_b M_n = 0.9F_y\, d_{g1}^2 t_{g1}/4 = 0.9(50\text{ ksi})(21.0\text{ in.})^2(0.75\text{ in.})/4 = 3{,}720\text{ kip-in.}$$

$$\sqrt{\left(\frac{M_{g1}}{\phi_t M_n} + \frac{N_{g1}}{\phi_t P_n}\right)^2 + \left(\frac{V_{g1}}{\phi_v V_n}\right)^2} = \sqrt{\left(\frac{280\text{ kip-in.}}{3{,}720\text{ kip-in.}} + \frac{27\text{ kips}}{709\text{ kips}}\right)^2 + \left(\frac{274\text{ kips}}{473\text{ kips}}\right)^2} = 0.590$$

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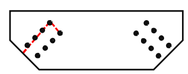
Design gusset



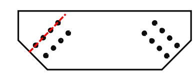
Gusset diagonal section by approximate block-shear method

$$R_u = 568\text{ kips}$$
$$A_{gv} = (0.75\text{ in.})(20\text{ in.}) = 15\text{ in.}^2$$
$$A_{gt} = (0.75\text{ in.})(12\text{ in.}) = 9\text{ in.}^2$$
$$A_{nv} = A_{gv} - (3.5)(0.75\text{ in.})\left(0.75\text{ in.} + \frac{1}{16}\text{ in.} + \frac{1}{16}\text{ in.}\right) = 12.375\text{ in.}^2$$
$$A_{nt} = A_{gt} - (0.75\text{ in.})\left(0.75\text{ in.} + \frac{1}{16}\text{ in.} + \frac{1}{16}\text{ in.}\right) = 8.25\text{ in.}^2$$

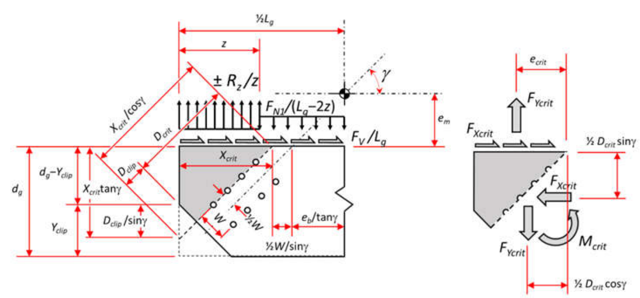
$$U_{bs} = 1.0$$
$$\phi R_n \le \phi\left(0.6A_{gv}F_y + U_{bs}A_{nt}F_u\right) = 0.75\left(0.6\left[15\text{ in.}^2\right][50\text{ ksi}] + 1.0\left[8.25\text{ in.}^2\right][65\text{ ksi}]\right) = 740\text{ kips, O.K.}$$
$$\phi R_n \le \phi\left(0.6A_{gv}F_u + U_{bs}A_{nt}F_u\right) = 0.75\left(0.6\left[12.375\text{ in.}^2\right][65\text{ ksi}] + 1.0\left[8.25\text{ in.}^2\right][65\text{ ksi}]\right) = 764\text{ kips, O.K.}$$

75

Design gusset



Gusset diagonal section (refer to paper for full geometry)



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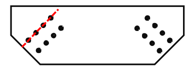
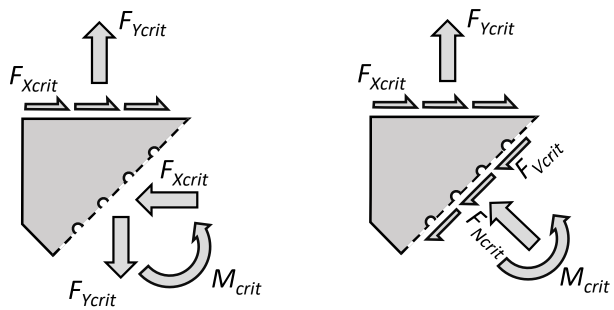
Design gusset



Gusset check at section parallel to the member axis at beam flange (*z* end regions)



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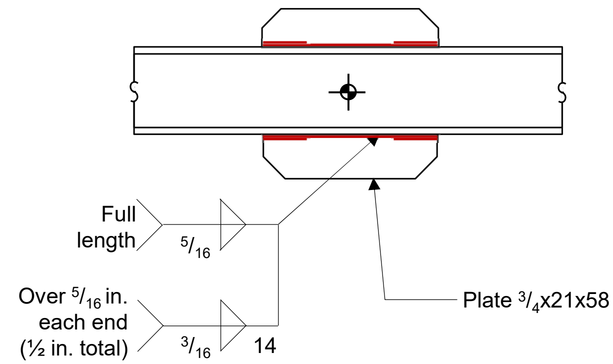
Design gusset



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Summary

- In seismic design, braces load the beam at chevron connections
- The chevron effect is similar to panel-zone shear
- The chevron effect may be significant for 4-brace connections
  - 2-brace connections typically have adequate beam shear strength
- Statics determines the forces acting on the beam, but multiple stress distributions are admissible
- Longer gussets will produce lower beam shear
- The USM is simpler and is typically the first choice
- The CSM is less conservative

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AISC | Questions?

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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

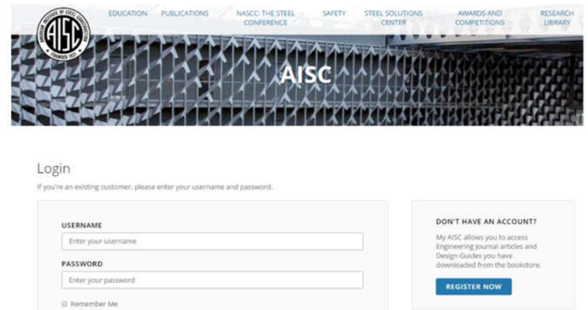
Night School Resources

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.



8-Session Registrants

Night School Resources

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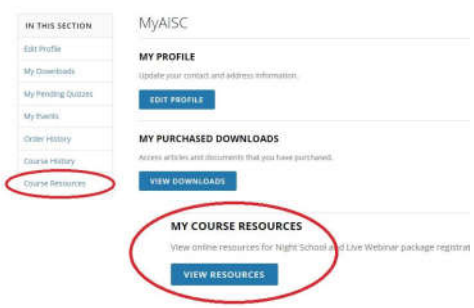
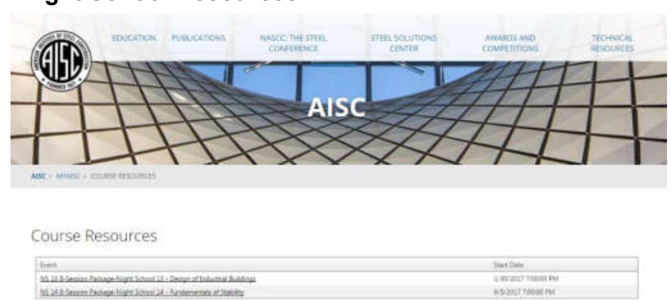


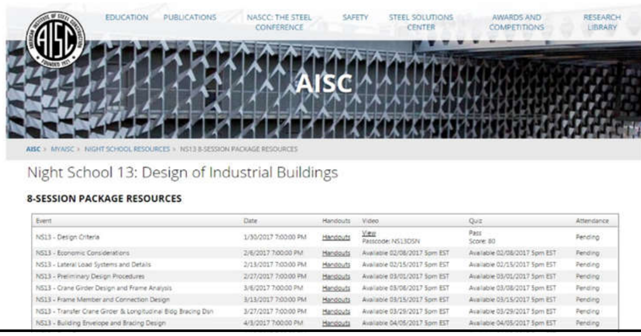
8-Session Registrants

Night School Resources



8-Session Registrants

Night School Resources


EDUCATION PUBLICATIONS NASCC: THE STEEL CONFERENCE SAFETY STEEL SOLUTIONS CENTER AWARDS AND COMPETITIONS RESEARCH LIBRARY

AISC

AISC > MYAISC > NIGHT SCHOOL RESOURCES > NS13 8-SESSION PACKAGE RESOURCES

Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	Handouts	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending

8-Session Registrants

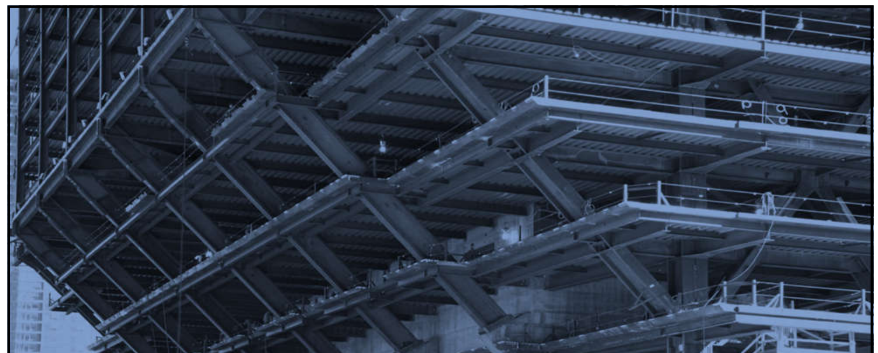
Night School Resources

- 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

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