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Course Description

Analysis and Design of Chevron Brace Connections with Flat Bar Gussets – Part 1: Non-Seismic Applications

April 9, 2015

Typically, chevron brace connections are detailed with one gusset plate used to connect all of the braces framing to a joint. When geometry permits, it may be more economical to provide a separate gusset for each brace. The analysis and design of chevron brace connections used in low seismic and wind applications are presented. The force distribution through the connection and the frame beam, and detailing considerations are presented. A design example will be used to support the discussion.

Learning Objectives

- Become familiar with analysis and design of chevron brace connections use in low seismic and wind applications.
- Gain an understanding of force distribution through the connection and the frame beam.
- Gain an understanding of chevron brace connection analysis and design through an in-depth design example.
- Become familiar with detailing considerations for chevron brace connections with separate flat bar gussets for each brace.

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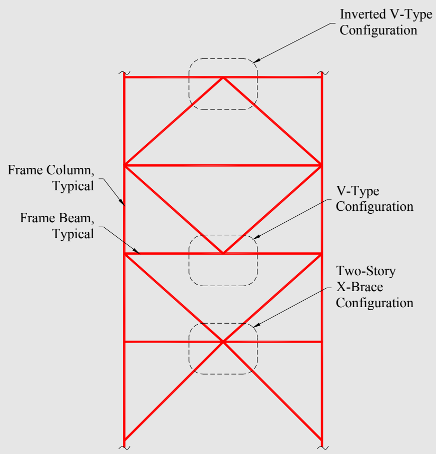
Analysis and Design of Chevron Brace Connections with Flat Bar Gussets

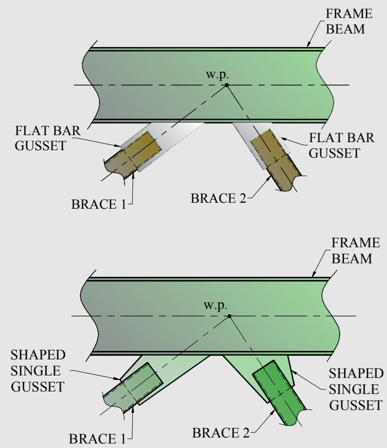
PART 1: Non-Seismic Applications

written and presented by
Patrick J. Fortney, Ph.D., P.E., S.E., P.Eng
President: Cives Engineering Corporation
Chief Engineer: Cives Steel Company

CHEVRON BRACE CONNECTIONS

Use of Flat Bar and Shaped Single Gussets





Presented by:
Patrick J. Fortney, Ph.D., P.E., S.E., P.Eng
President: Cives Engineering Corporation
Chief Engineer: Cives Steel Company

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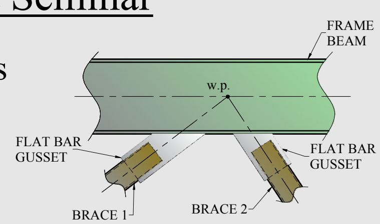
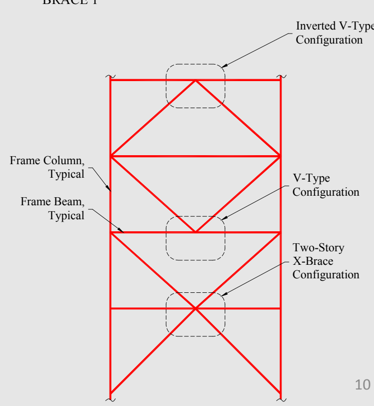
CHEVRON BRACE CONNECTIONS

A Two-Part Seminar

PART 1: Non-Seismic Applications

- The use of flat bar and shaped single gussets will be discussed
- A design example problem using flat bar gussets will be presented
  - Not to suggest that shaped single gussets cannot/should not be used in non-seismic applications





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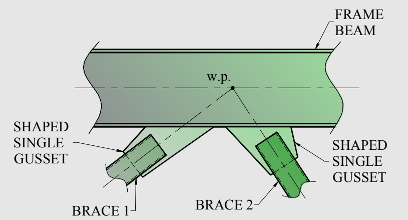
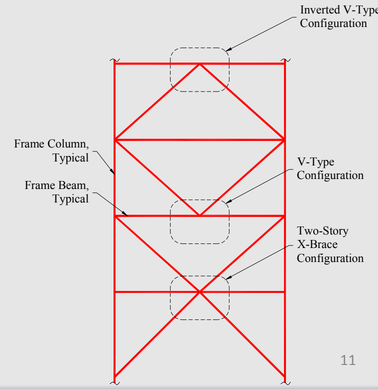
CHEVRON BRACE CONNECTIONS

A Two-Part Seminar

PART 2: Seismic Applications

- ❖ The use of shaped single gussets will be discussed
  - ➢ Typically, flat bar gussets do not work for the connection design requirements for seismic braced frames
- ❖ A design example problem using shaped single gussets will be presented





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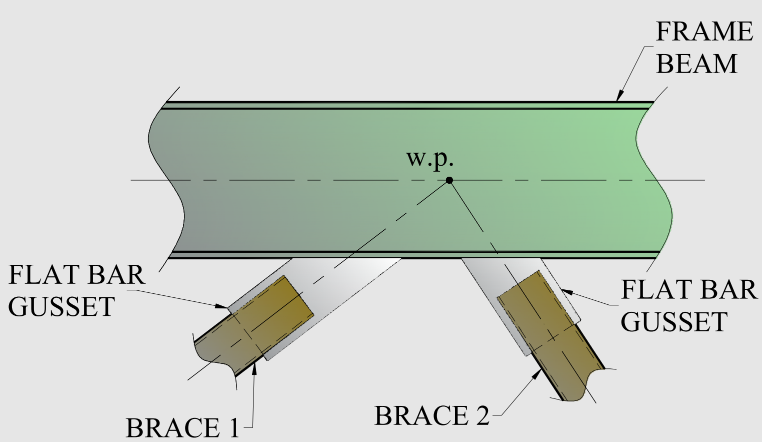
CHEVRON BRACE CONNECTIONS

Flat Bar and Individual Shaped Gussets

PART 1: Non-Seismic Applications



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AGENDA

PART 1: Non-Seismic Applications

- ❖ Introduction
  - ➢ Chevron Configurations
    - V-Type Configuration
    - Inverted V-Type Configuration
    - Two-Story X Configuration

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AGENDA

PART 1: Non-Seismic Applications

- ❖ Introduction
  - ➢ Connection Hardware
    - Combined Gussets
    - Individual Gussets
      - o Flat Bars
      - o Shaped
- ❖ Connection Geometry
- ❖ Brace Force Distribution

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AGENDA

PART 1: Non-Seismic Applications

- Impact on Beam
  - Shear Force Distribution
  - Bending Moment Distribution
- Limit State Checks
  - Connection Hardware
  - Frame Beam
- Example Problem

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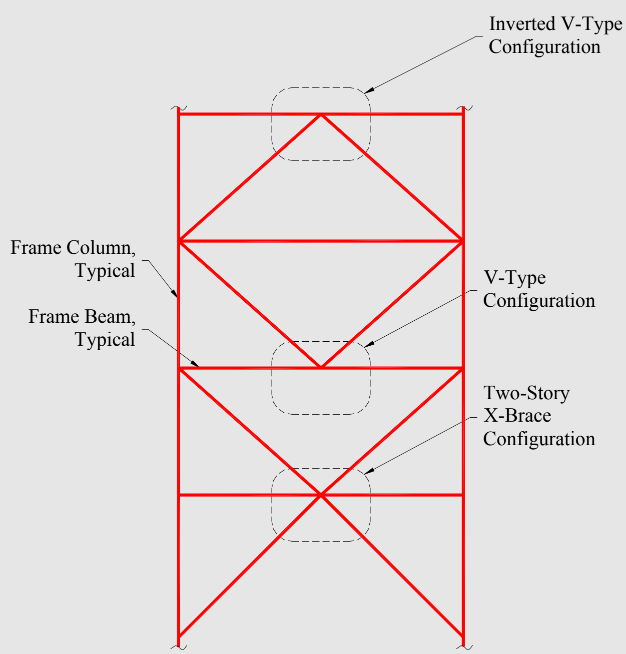
INTRODUCTION



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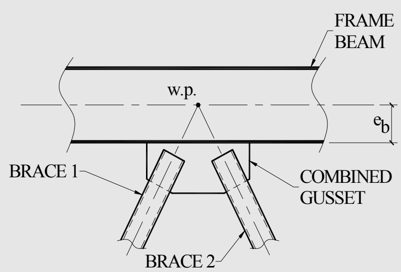
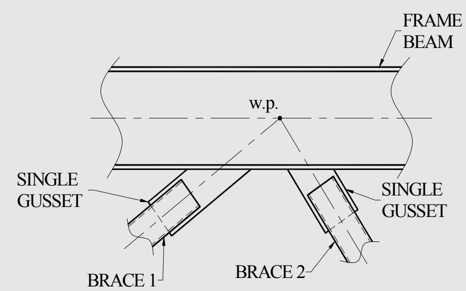
INTRODUCTION



Combined Gusset



Single Gussets

We'll focus on Single gussets, but it's important to recognize that the same concepts can be applied to the combined gusset configuration (with some slight differences)

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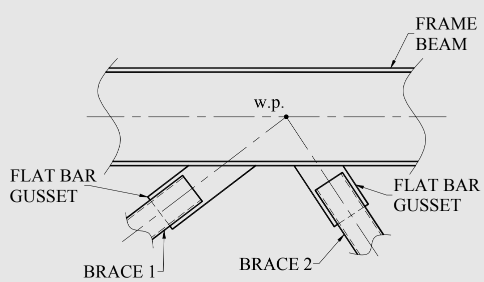
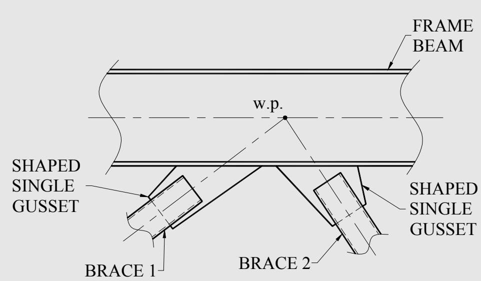
INTRODUCTION



Single Flat Bar Gussets



Single Shaped Gussets

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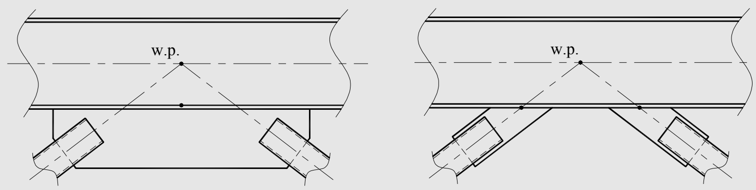
INTRODUCTION



Examples of When Flat Bars May be More Economical

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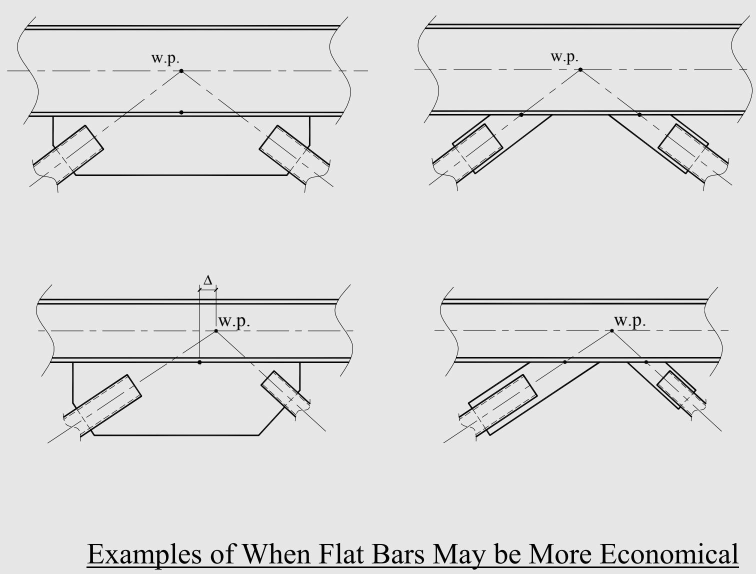

Examples of When Flat Bars May be More Economical

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INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

- ❖ Flat Bars
  - ➢ Generally available in:
    - A572-50 (more common)
    - Typically available in A36 and 529-50
    - Consult with your local service center(s) or producer(s)

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INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

- ❖ Flat Bars
  - ➢ Generally available in:
    - A572-50 (more common)
    - Typically available in A36 and 529-50
    - Consult with your local service center(s) or producer(s)
  - ➢ Width and thickness:
    - Up to 12" wide
    - Up to 2" thick
    - Consult with your local service center(s) or producer(s)

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INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

- Flat Bars
  - Width Increments:
    - < 3" wide; use ¼" increments
    - Between 3" and 6" wide; use ½" increments
    - Between 6" and 12" wide; use 1" increments
    - Consult with your local service center(s) or producer(s)

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INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

- Flat Bars
  - Thickness Increments:
    - Up to 1" thick; use 1/8" increments
    - Over 1: thick; use ¼" increments
    - Consult with your local service center(s) or producer(s)

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INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

- ❖ Flat Bars
  - ➢ Thickness Increments:
    - Up to 1" thick; use 1/8" increments
    - Over 1: thick; use ¼" increments
    - Consult with your local service center(s) or producer(s)
  - ➢ Typically used:
    - To eliminate moments on interface
    - When brace forces are relatively small (economical interface welds and gusset thickness)

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INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

- ❖ Shaped Single Gussets
  - ➢ Typically cut from plate material:
  - ➢ Typically available in:
    - A572-50 (most common)
    - Generally available in A36 and A529-50
    - Consult your local service center(s) and producer(s)

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INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

❖ Shaped Single Gussets

➢ Typically used:

- When brace forces are relatively large (economical interface welds and gusset thickness)
- Seismic applications

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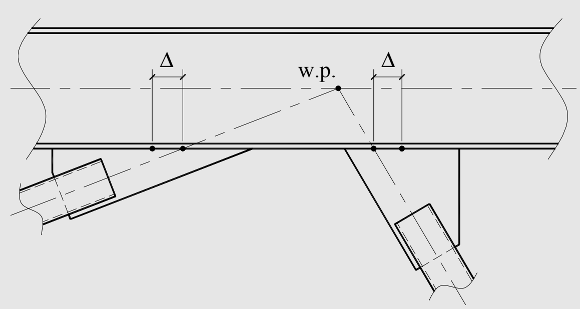
INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

❖ Shaped Single Gussets

➢ Try to Minimize eccentricities on shallow brace bevel connections:



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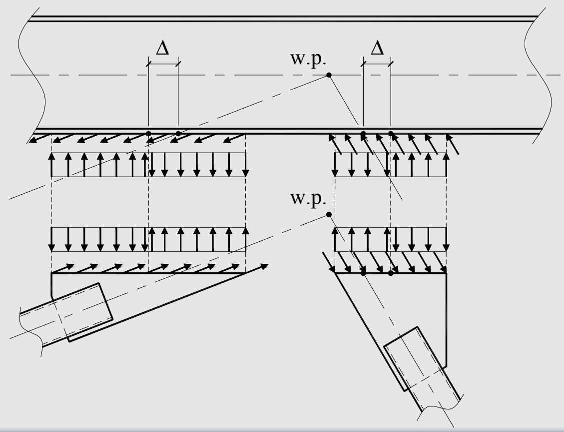
INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

❖ Shaped Single Gussets

➢ Try to Minimize eccentricities on shallow brace bevel connections:

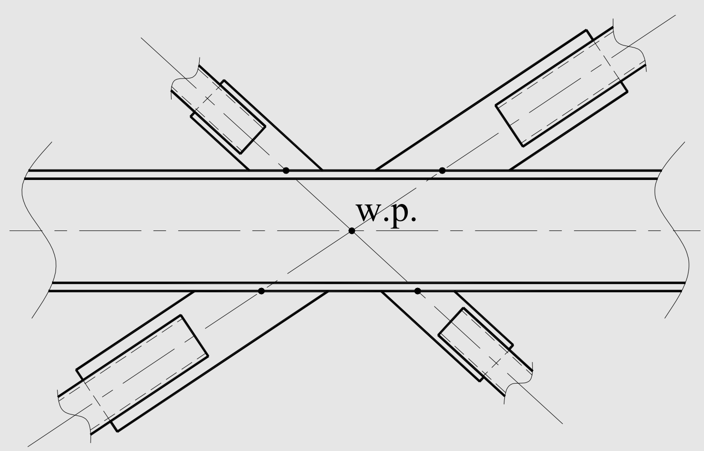


INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

❖ Shaped Single Gussets

➢ Try to minimize analysis efforts and impact on beam:



INTRODUCTION

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❖ Shaped Single Gussets

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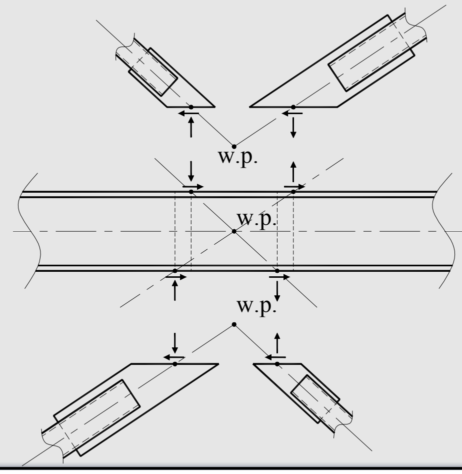

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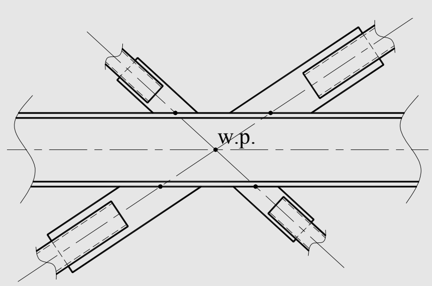
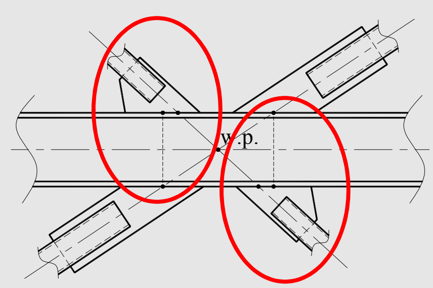
INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

❖ Shaped Single Gussets

➢ Try to minimize analysis efforts and impact on beam:





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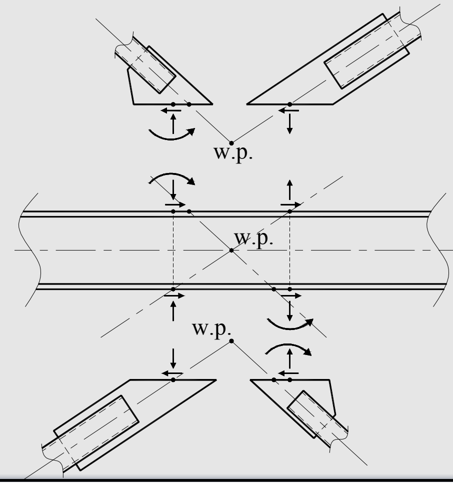
INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

❖ Shaped Single Gussets

➢ Try to minimize analysis efforts and impact on beam:



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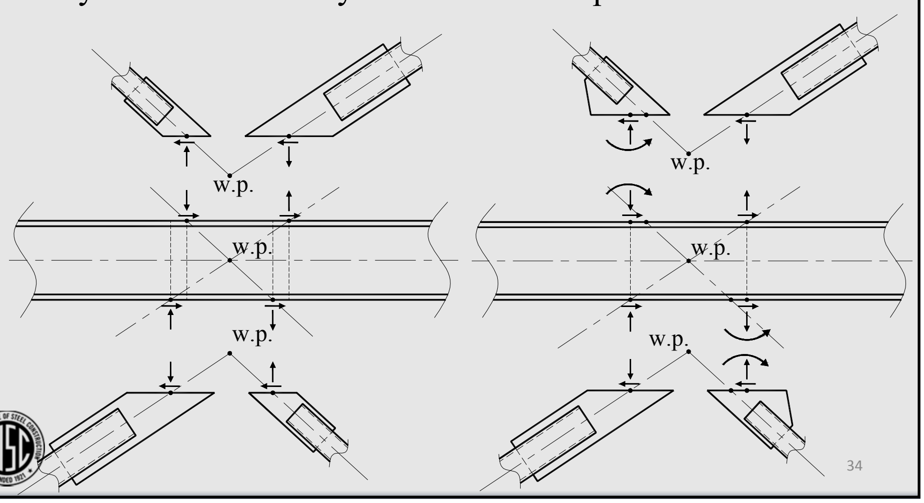
INTRODUCTION

Notes on Flat Bar and Shaped Single Gussets

❖ Shaped Single Gussets

➢ Try to minimize analysis efforts and impact on beam:



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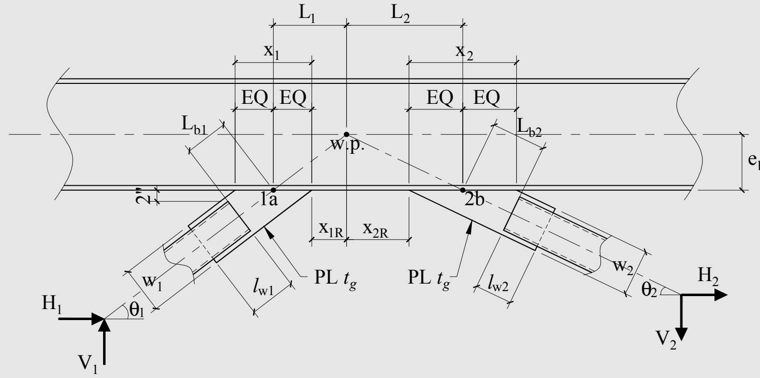
CONNECTION GEOMETRY

Flat Bar Gussets



x_1 = horizontal length of Brace 1 flat bar gusset-to-beam interface

x_2 = horizontal length of Brace 2 flat bar gusset-to-beam interface

x_{1R} = horizontal dimension between right egde of Brace 1 gusset to work point

x_{2R} = horizontal dimension between left egde of Brace 2 gusset to work point

e_b = one-half the depth of the frame beam

L_{wi} = length of brace-to-gusset weld at Brace 1 and 2

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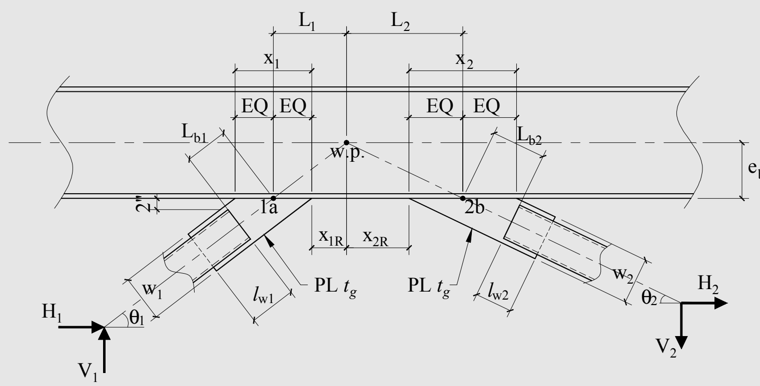
CONNECTION GEOMETRY

Flat Bar Gussets



H_i = horizontal components of Brace 1 and Brace 2 forces

V_i = vertical components of Brace 1 and Brace 2 forces

L_1 = horizontal dimension between Brace 1 interface centroid to work point

L_2 = horizontal dimension between Brace 2 interface centroid to work point

θ_i = Brace 1 and Brace 2 bevel angles measured off the horizontal

L_{bi} = unbraced bukling length of gussets on Braces 1 and 2

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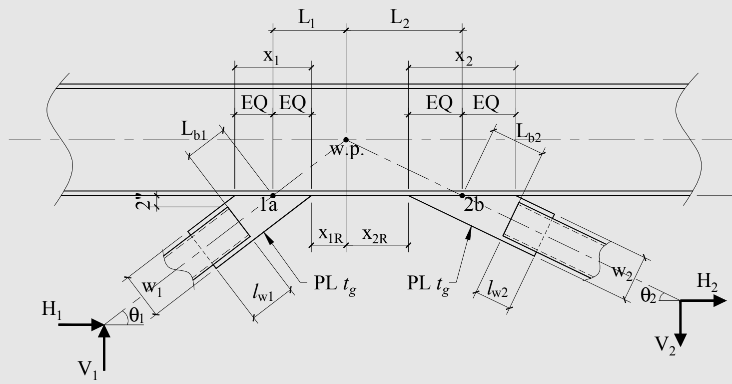
CONNECTION GEOMETRY

Flat Bar Gussets



Sign Convention

For Brace Tension;
H_i , V_i is (+)
For Brace Compression;
H_i , V_i is (-)

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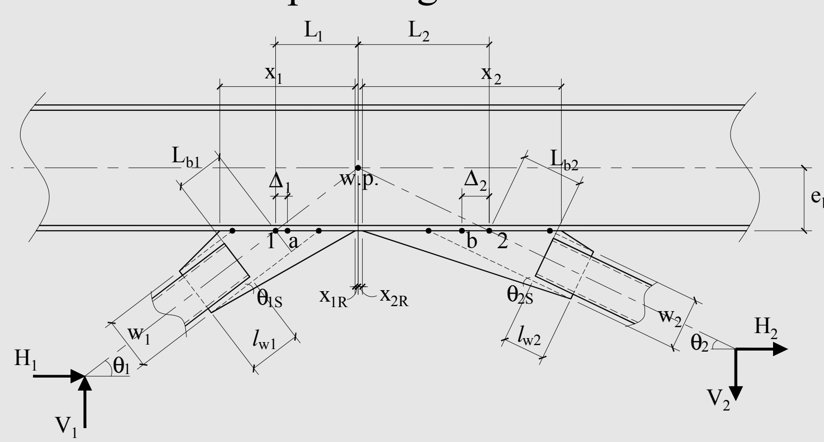
CONNECTION GEOMETRY

Shaped Single Gussets



θ_{iS} = angles formed by the shaped gussets measured between the edges of the theoretical flat bar line and the free edges of the shaped gussets

Δ_i = horizontal dimension measured at the face of the beam flange between the lines of action of Braces 1 and 2 and the centroids of the gusset-to-beam interface

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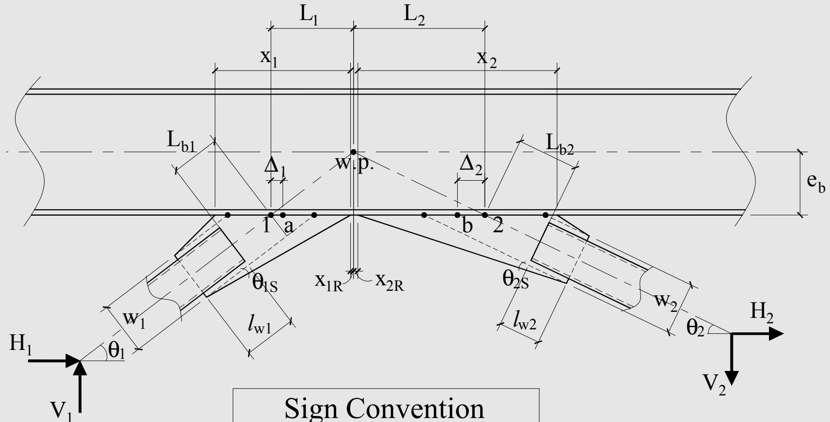
CONNECTION GEOMETRY

Shaped Single Gussets



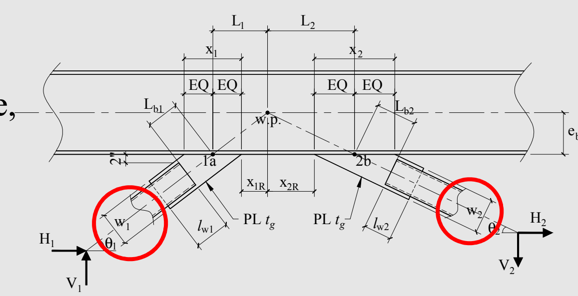
Sign Convention

For Brace Tension;
H_i , V_i is (+)
For Brace Compression;
H_i , V_i is (-)

CONNECTION GEOMETRY

Getting Started (Trial Geometry and Hardware)

- ❖ Will Flat Bars Work?
  - ➢ The brace bevel, size, and force impact the decision



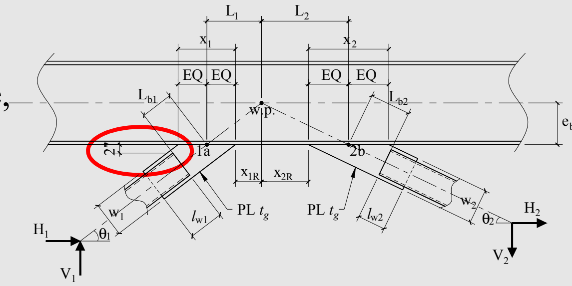
- Choose the bar width such that the there is room for a single pass brace-to-gusset fillet weld

$$\therefore w_i \simeq B_i + 2(0.5in) = B + 1in$$

CONNECTION GEOMETRY

Getting Started (Trial Geometry and Hardware)

- ❖ Will Flat Bars Work?
  - ➢ The brace bevel, size, and force impact the decision



- Make an assumption regarding the clear distance from the leading corner of the brace to the beam flange
  - o My standard is 2” but, use whatever you think is appropriate based on workmanship, inspection, access, etc.

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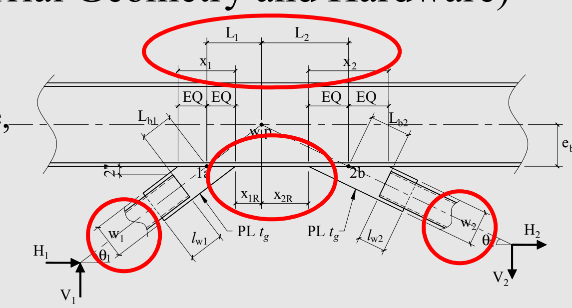
CONNECTION GEOMETRY

Getting Started (Trial Geometry and Hardware)

- ❖ Will Flat Bars Work?
  - ➢ The brace bevel, size, and force impact the decision



- $x_{1R}+x_{2R}$ must be greater than zero

$$L_1 = \frac{e_b \sin(90-\theta_1)}{\sin\theta_1} \qquad x_1 = \frac{w_1}{\sin\theta_1} \qquad x_{1R} = L_1 - \frac{1}{2}x_1$$

$$L_2 = \frac{e_b \sin(90-\theta_2)}{\sin\theta_2} \qquad x_2 = \frac{w_2}{\sin\theta_2} \qquad x_{2R} = L_2 - \frac{1}{2}x_2$$

$$x_{1R} + x_{2R} > 0$$

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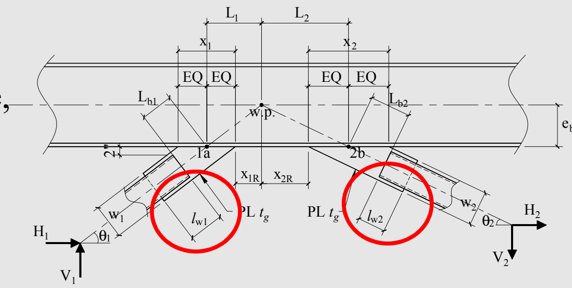
CONNECTION GEOMETRY

Getting Started (Trial Geometry and Hardware)

❖ Will Flat Bars Work?

➢ The brace bevel, size, and force impact the decision



- Estimate l_{wi} based on brace force (I typically start out assuming a single pass fillet weld (1/4"))

$$l_{wi} \geq B$$

$$l_{wi} \geq \frac{F_{bi}}{1.392Dn} \quad \text{(LRFD)}$$

$$l_{wi} \geq \frac{F_{bi}}{0.928Dn} \quad \text{(ASD)}$$

Assuming D=4 and with n=4 welds,

$$l_{wi} \geq B$$

$$l_{wi} \geq \frac{F_{bi}}{(1.392)(4)(4)} = \frac{F_{bi}}{22.3} \quad \text{(LRFD)}$$

$$l_{wi} \geq \frac{F_{bi}}{(0.928)(4)(4)} = \frac{F_{bi}}{14.8} \quad \text{(ASD)}$$

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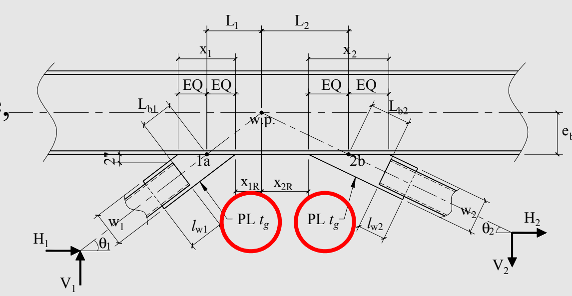
CONNECTION GEOMETRY

Getting Started (Trial Geometry and Hardware)

❖ Will Flat Bars Work?

➢ The brace bevel, size, and force impact the decision



- Estimate t_g based on gusset buckling:
  - Use K=0.70 (more on that later)
  - Use L=L_{bi}
  - r= simply calculated as $r = \dfrac{t_g}{\sqrt{12}}$

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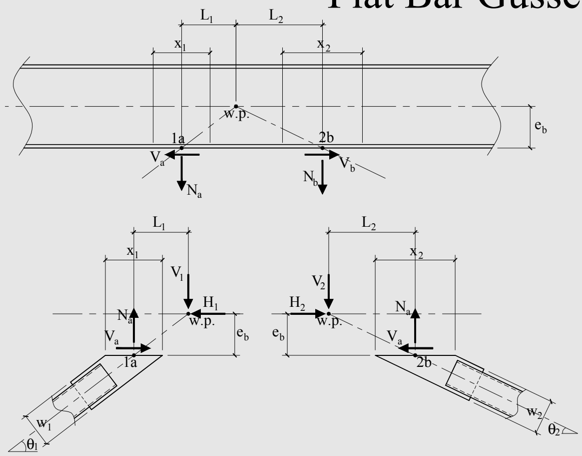
Brace Force Distribution

Flat Bar Gussets



The Normal and Shear forces acting at the gusset-to-beam interface are equal to the vertical and horizontal components of the brace forces, respectively.

Since the centroid of the gusset-to-beam interface coincides with the line of action of the brace (i.e., point 1 coincides with point a; point 2 coincides with point b), there is no moment acting on the interface, i.e.,

$$V_1 L_1 = H_1 e_b$$
$$V_2 L_2 = H_2 e_b$$

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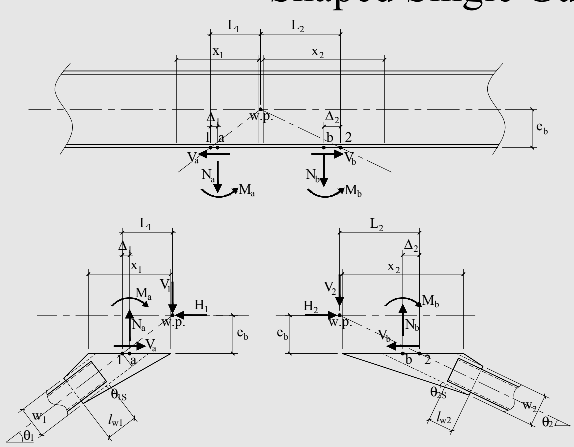
Brace Force Distribution

Shaped Single Gussets



The Normal and Shear forces acting at the gusset-to-beam interface are equal to the vertical and horizontal components of the brace forces, respectively.

Since the centroids of the gusset-to-beam interfaces do not coincide with the lines of action of the braces, there are moments acting on the interfaces, i.e., the <u>moments acting on the horizontal edges of the gussets are</u>…

$$M_a = H_1 e_b - V_1 \left(L_1 - \Delta_1 \right)$$
$$M_b = V_2 \left(L_2 - \Delta_2 \right) - H_2 e_b$$

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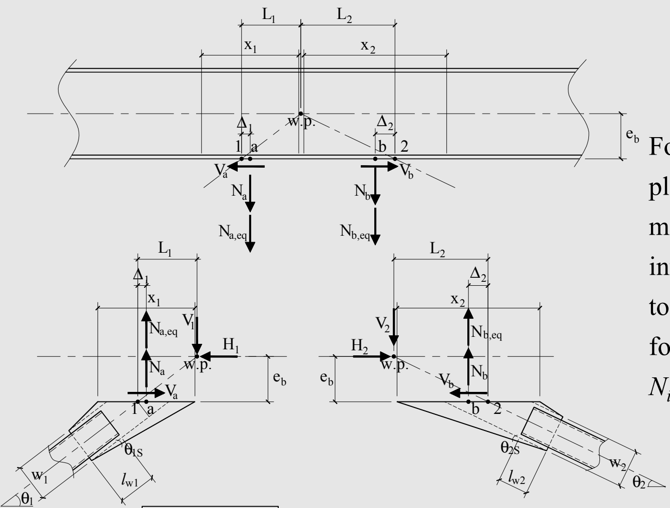
Brace Force Distribution

Shaped Single Gussets



For weld and gusset plate design, the moments acting on the interface are converted to equivalent normal forces and added to the N_i forces.

$$N_{i.eq} = \frac{4M_i}{x_i}$$

(see DG 29 App. B, Figure B-1 for discussion regarding N_{eq}).

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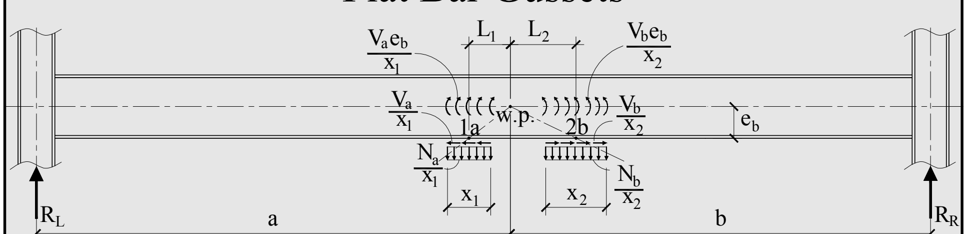
Distribution of Forces on Beam

Flat Bar Gussets



- The uniformly distributed moment acting along the gravity axis of the beam captures the eccentricity of the shear forces acting along the flange.

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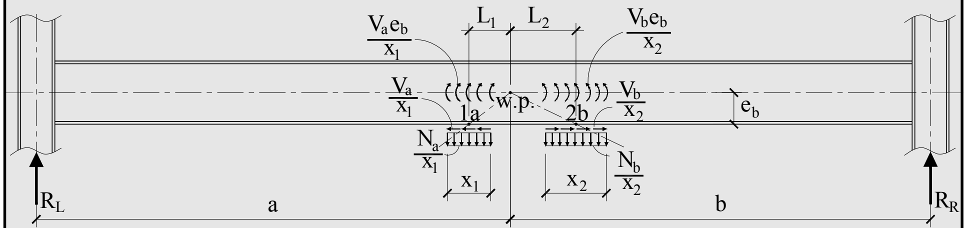
Distribution of Forces on Beam

Flat Bar Gussets



- The uniformly distributed moment acting along the gravity axis of the beam captures the eccentricity of the shear forces acting along the flange.
- Resultant interface welds work fine for sizing the gusset and weld…

  …but too conservative when evaluating beam shear and moment distribution!

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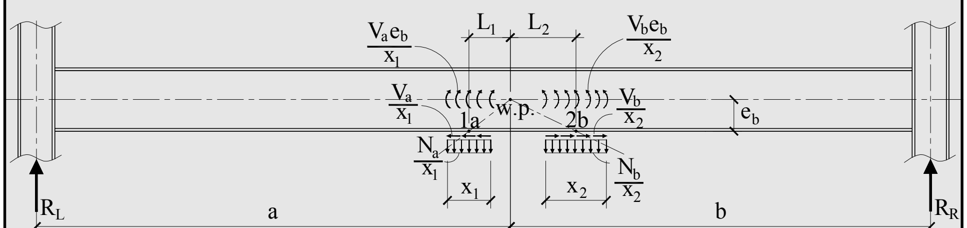
Distribution of Forces on Beam

Flat Bar Gussets



- The uniformly distributed moment acting along the gravity axis of the beam captures the eccentricity of the shear forces acting along the flange.
- Resultant interface welds work fine for sizing the gusset and weld…

  …but too conservative when evaluating beam shear and moment distribution!
- The interface forces and moments are treated as externally-applied loads and are used to determine the beam shear and moment distribution.

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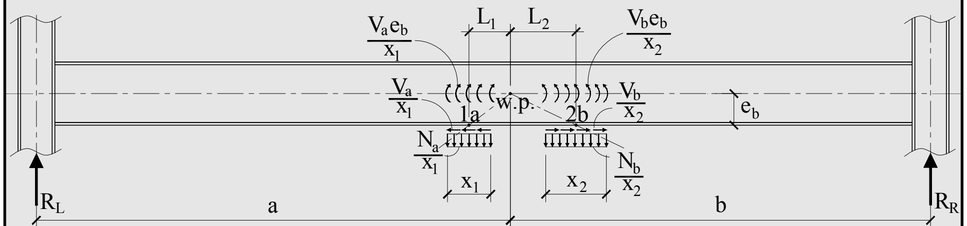
Distribution of Forces on Beam

Flat Bar Gussets



- The uniformly distributed moment acting along the gravity axis of the beam captures the eccentricity of the shear forces acting along the flange.
- Resultant interface welds work fine for sizing the gusset and weld…
  …but too conservative when evaluating beam shear and moment distribution!
- The interface forces and moments are treated as externally-applied loads and are used to determine the beam shear and moment distribution.
- Note that the resultant loads are used to check Chapter J limits states (e.g., web local yielding and web local crippling).

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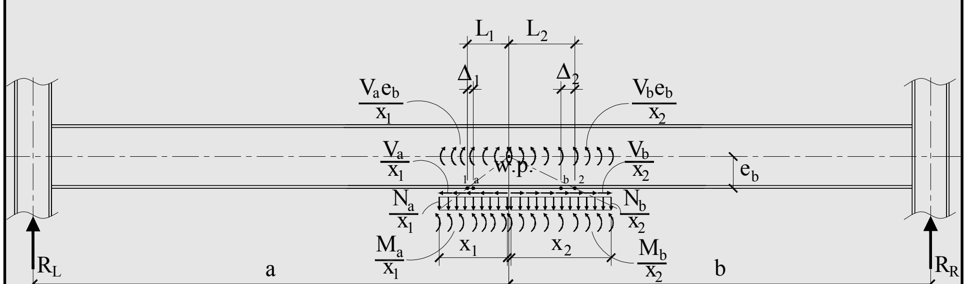
Distribution of Forces on Beam

Shaped Single Gussets



- The uniformly distributed moment acting along the gravity axis of the beam captures the eccentricity of the shear forces acting along the flange.

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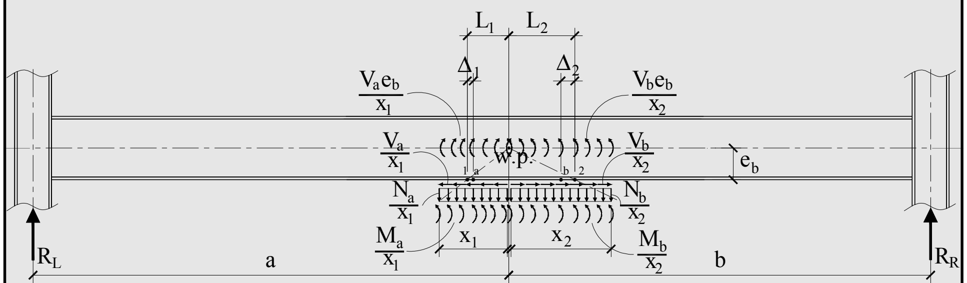
Distribution of Forces on Beam

Shaped Single Gussets



- The uniformly distributed moment acting along the gravity axis of the beam captures the eccentricity of the shear forces acting along the flange.
- Moments M_a and M_b are distributed uniformly along the interfaces

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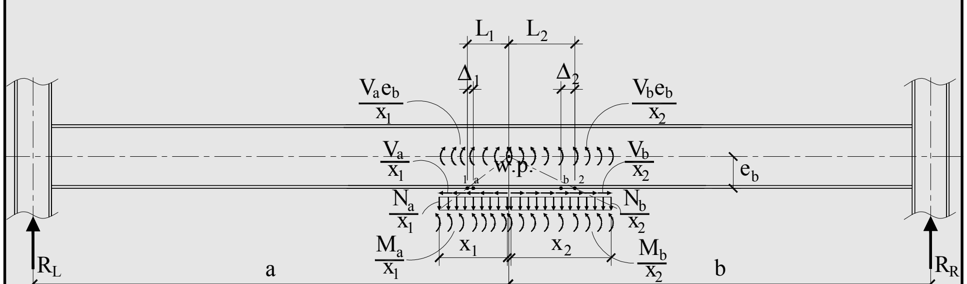
Distribution of Forces on Beam

Shaped Single Gussets



- The uniformly distributed moment acting along the gravity axis of the beam captures the eccentricity of the shear forces acting along the flange.
- Moments M_a and M_b are distributed uniformly along the interfaces
- The interface forces and moments are treated as externally-applied loads and are used to determine the beam shear and moment distribution.

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LIMIT STATE CHECKS

❖ CONNECTION

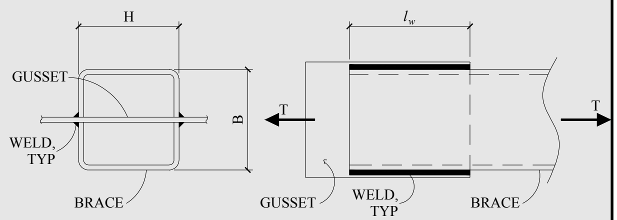
➢ Brace tensile rupture on net section (D2)

$P_n = F_u A_e$ (D2-2)

$A_e = A_n U$ (D3-1)

$P_n = F_u A_n U$

$\phi = 0.75, \Omega = 2.00$



I typically assume that the slot in the brace is 1/8" + the gusset thickness. However, you can calculate A_n based on your particular practice. Also, be sure to consult with your local fabricator/erector.

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LIMIT STATE CHECKS

❖ CONNECTION

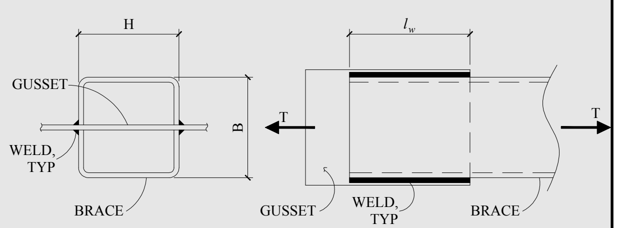
➢ Brace tensile rupture on net section (D2)

- Assuming a rectangular HSS brace, use Case 6 of Table D3.1

$$l = l_w \geq H$$

$$U = 1 - \frac{\bar{x}}{l_w}$$

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



- For other types of braces or gusset conditions, refer to table D3.1.

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LIMIT STATE CHECKS

❖ CONNECTION

- Assuming a rectangular HSS brace, use Case 6 of Table D3.1

6	Rectangular HSS	with a single concentric gusset plate	$l \ge H \ldots U = 1 - \bar{x}/l$ $\bar{x} = \frac{B^2 + 2BH}{4(B+H)}$	
		with two side gusset plates	$l \ge H \ldots U = 1 - \bar{x}/l$ $\bar{x} = \frac{B^2}{4(B+H)}$	

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

Case	Description of Element		Shear Lag Factor, U	Example
1	All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).		$U = 1.0$	—
2	All tension members, except plates and HSS, where the tension load is transmitted to some but not all of the cross-sectional elements by fasteners or longitudinal welds or by longitudinal welds in combination with transverse welds. (Alternatively, for W, M, S and HP, Case 7 may be used. For angles, Case 8 may be used.)		$U = 1 - \bar{x}/l$	
3	All tension members where the tension load is transmitted only by transverse welds to some but not all of the cross-sectional elements.		$U = 1.0$ and A_n = area of the directly connected elements	—
4	Plates where the tension load is transmitted by longitudinal welds only.		$l \ge 2w \ldots U = 1.0$ $2w > l \ge 1.5w \ldots U = 0.87$ $1.5w > l \ge w \ldots U = 0.75$	
5	Round HSS with a single concentric gusset plate		$l \ge 1.3D \ldots U = 1.0$ $D \le l < 1.3D \ldots U = 1 - \bar{x}/l$ $\bar{x} = D/\pi$	
6	Rectangular HSS	with a single concentric gusset plate	$l \ge H \ldots U = 1 - \bar{x}/l$ $\bar{x} = \frac{B^2 + 2BH}{4(B+H)}$	
		with two side gusset plates	$l \ge H \ldots U = 1 - \bar{x}/l$ $\bar{x} = \frac{B^2}{4(B+H)}$	
7	W, M, S or HP Shapes or Tees cut from these shapes. (If U is calculated per Case 2, the larger value is permitted to be used.)	with flange connected with 3 or more fasteners per line in the direction of loading	$b_f \ge 2/3d \ldots U = 0.90$ $b_f < 2/3d \ldots U = 0.85$	—
		with web connected with 4 or more fasteners per line in the direction of loading	$U = 0.70$	—
8	Single and double angles (If U is calculated per Case 2, the larger value is permitted to be used.)	with 4 or more fasteners per line in the direction of loading	$U = 0.80$	—
		with 3 fasteners per line in the direction of loading (With fewer than 3 fasteners per line in the direction of loading, use Case 2.)	$U = 0.60$	—

l = length of connection, in. (mm); w = plate width, in. (mm); $\bar{x}$ = eccentricity of connection, in. (mm); B = overall width of rectangular HSS member, measured 90° to the plane of the connection, in. (mm); H = overall height of rectangular HSS member, measured in the plane of the connection, in. (mm)

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AMERICAN INSTITUTE OF STEEL CONSTRUCTION

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LIMIT STATE CHECKS

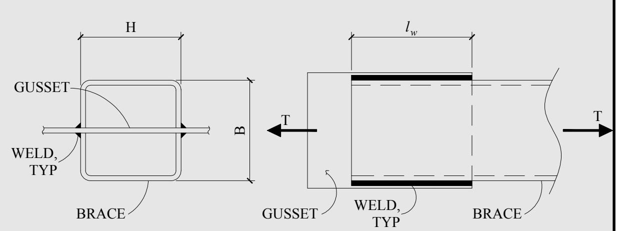
❖ CONNECTION

➢ Brace-to-Gusset Connection

- Brace-to-gusset weld (*Manual*, Part 8)

$$\phi R_n = 1.392Dl \qquad \text{(LRFD)}$$

$$\frac{R_n}{\Omega} = 0.928Dl \qquad \text{(ASD)}$$



D=weld size in sixteenths of an inch

l=weld length (in.)

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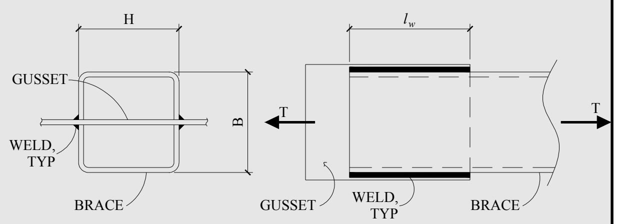
LIMIT STATE CHECKS

❖ CONNECTION

➢ Brace-to-Gusset Connection

- Shear rupture strength of brace wall

$$R_n = 0.6F_u A_{nv} \quad \text{(J4-4)}$$
$$\phi = 0.75,\ \Omega = 2.00$$
$$A_{nv} = 4lt_{des}$$



l=weld length

t_{des}=design tube wall thickness (*Manual*, Part 1)

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LIMIT STATE CHECKS

❖ CONNECTION

➢ Gusset Limit States

- Tensile yield on gross section (D2)

$$P_n = F_y A_g \quad \text{(D2-1)}$$
$$\phi = 0.90,\ \Omega = 1.67$$

- Tensile rupture on net section (D2)

$$P_n = F_u A_n \quad \text{(D2-2)}$$
$$\phi = 0.75,\ \Omega = 2.00$$

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LIMIT STATE CHECKS

❖ CONNECTION

➢ Gusset Limit States

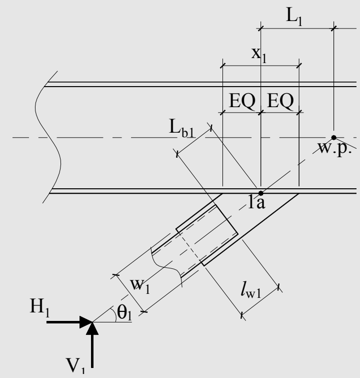
- Buckling (E3)

$P_n = F_{cr} A_g$ (E3-1)

$\phi = 0.90, \Omega = 1.67$

When $\frac{KL}{r} \leq 4.71\sqrt{\frac{E}{F_y}}$

$$F_{cr} = \left[0.658^{\frac{F_y}{F_e}}\right] F_y \qquad \text{(E3-2)}$$



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LIMIT STATE CHECKS

❖ CONNECTION

➢ Gusset Limit States

- Buckling (E3)

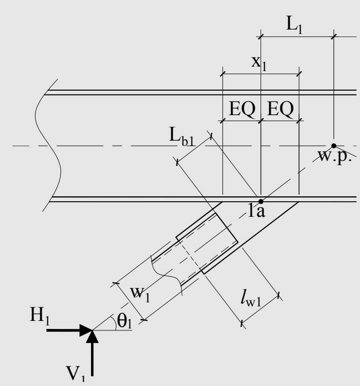
$P_n = F_{cr} A_g$ (E3-1)

$\phi = 0.90, \Omega = 1.67$

When $\frac{KL}{r} > 4.71\sqrt{\frac{E}{F_y}}$

$$F_{cr} = 0.877 F_e \qquad \text{(E3-3)}$$

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} \qquad \text{(E3-4)}$$



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LIMIT STATE CHECKS

❖ CONNECTION

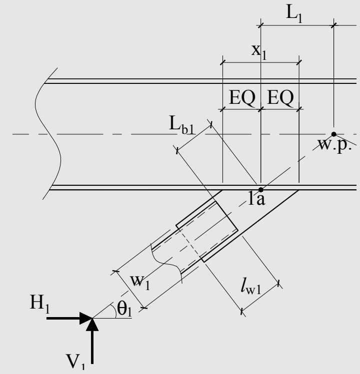
➢ Gusset Limit States

- Buckling (E3)

$P_n = F_{cr} A_g$ (E3-1)

$\phi = 0.90, \Omega = 1.67$

ϕF_{cr}, F_{cr}/Ω can be taken from Table 4-22 of the *Manual*, in lieu of crunching Equations E3-2 through E3-4.



LIMIT STATE CHECKS

❖ CONNECTION

➢ Gusset Limit States

ϕF_{cr}, F_{cr}/Ω can be taken from Table 4-22 of the *Manual*, in lieu of crunching Equations E3-2 through E3-4.

Table 4-22
Available Critical Stress for Compression Members

	F_y = 35 ksi			F_y = 36 ksi			F_y = 42 ksi			F_y = 46 ksi			F_y = 50 ksi	
$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD
1	21.0	31.5	1	21.6	32.4	1	25.1	37.8	1	27.5	41.4	1	29.9	45.0
2	21.0	31.5	2	21.6	32.4	2	25.1	37.8	2	27.5	41.4	2	29.9	45.0
3	20.9	31.5	3	21.5	32.4	3	25.1	37.8	3	27.5	41.4	3	29.9	45.0
4	20.9	31.5	4	21.5	32.4	4	25.1	37.8	4	27.5	41.4	4	29.9	44.9
5	20.9	31.5	5	21.5	32.4	5	25.1	37.7	5	27.5	41.3	5	29.9	44.9
6	20.9	31.4	6	21.5	32.3	6	25.1	37.7	6	27.5	41.3	6	29.9	44.9
7	20.9	31.4	7	21.5	32.3	7	25.1	37.7	7	27.5	41.3	7	29.8	44.8
8	20.9	31.4	8	21.5	32.3	8	25.1	37.7	8	27.4	41.2	8	29.8	44.8
9	20.9	31.4	9	21.5	32.3	9	25.0	37.6	9	27.4	41.2	9	29.8	44.7
10	20.9	31.3	10	21.4	32.2	10	25.0	37.6	10	27.4	41.1	10	29.7	44.7
11	20.8	31.3	11	21.4	32.2	11	25.0	37.5	11	27.3	41.1	11	29.7	44.6
12	20.8	31.3	12	21.4	32.2	12	24.9	37.5	12	27.3	41.0	12	29.6	44.5
13	20.8	31.2	13	21.4	32.1	13	24.9	37.4	13	27.2	40.9	13	29.6	44.4
14	20.7	31.2	14	21.3	32.1	14	24.8	37.3	14	27.2	40.9	14	29.5	44.4
15	20.7	31.1	15	21.3	32.0	15	24.8	37.3	15	27.1	40.8	15	29.5	44.3
16	20.7	31.1	16	21.3	32.0	16	24.8	37.2	16	27.1	40.7	16	29.4	44.2
17	20.7	31.0	17	21.2	31.9	17	24.7	37.1	17	27.0	40.6	17	29.3	44.1
18	20.6	31.0	18	21.2	31.9	18	24.7	37.1	18	27.0	40.5	18	29.2	43.9
19	20.6	30.9	19	21.2	31.8	19	24.6	37.0	19	26.9	40.4	19	29.2	43.8
20	20.5	30.9	20	21.1	31.7	20	24.5	36.9	20	26.8	40.3	20	29.1	43.7
21	20.5	30.8	21	21.1	31.7	21	24.5	36.8	21	26.7	40.2	21	29.0	43.6
22	20.4	30.7	22	21.0	31.6	22	24.4	36.7	22	26.7	40.1	22	28.9	43.4
23	20.4	30.7	23	21.0	31.5	23	24.3	36.6	23	26.6	40.0	23	28.8	43.3
24	20.3	30.6	24	20.9	31.4	24	24.3	36.5	24	26.5	39.8	24	28.7	43.1
25	20.3	30.5	25	20.9	31.4	25	24.2	36.4	25	26.4	39.7	25	28.6	43.0
26	20.2	30.4	26	20.8	31.3	26	24.1	36.3	26	26.3	39.6	26	28.5	42.8
27	20.2	30.3	27	20.7	31.2	27	24.0	36.1	27	26.2	39.4	27	28.4	42.7
28	20.1	30.3	28	20.7	31.1	28	24.0	36.0	28	26.1	39.3	28	28.3	42.5
29	20.1	30.2	29	20.6	31.0	29	23.9	35.9	29	26.0	39.1	29	28.2	42.3
30	20.0	30.1	30	20.6	30.9	30	23.8	35.8	30	25.9	39.0	30	28.0	42.1
31	20.0	30.0	31	20.5	30.8	31	23.7	35.6	31	25.8	38.8	31	27.9	41.9
32	19.9	29.9	32	20.4	30.7	32	23.6	35.5	32	25.7	38.6	32	27.8	41.8
33	19.8	29.8	33	20.4	30.6	33	23.5	35.4	33	25.6	38.5	33	27.7	41.6
34	19.8	29.7	34	20.3	30.5	34	23.4	35.2	34	25.5	38.3	34	27.5	41.4
35	19.7	29.6	35	20.2	30.4	35	23.3	35.1	35	25.4	38.1	35	27.4	41.2
36	19.6	29.5	36	20.1	30.3	36	23.2	34.9	36	25.2	37.9	36	27.2	40.9
37	19.5	29.4	37	20.1	30.1	37	23.1	34.8	37	25.1	37.8	37	27.1	40.7
38	19.5	29.3	38	20.0	30.0	38	23.0	34.6	38	25.0	37.6	38	26.9	40.5
39	19.4	29.1	39	19.9	29.9	39	22.9	34.4	39	24.9	37.4	39	26.8	40.3
40	19.3	29.0	40	19.8	29.8	40	22.8	34.3	40	24.7	37.2	40	26.6	40.0

ASD	LRFD
$\Omega_c = 1.67$	$\phi_c = 0.90$

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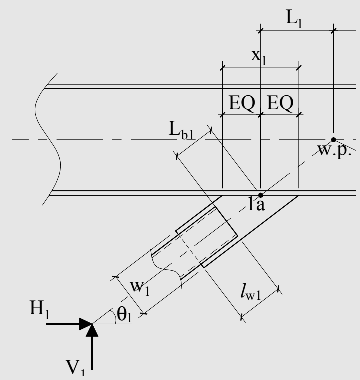
	F_y = 35 ksi			F_y = 36 ksi			F_y = 42 ksi			F_y = 46 ksi			F_y = 50 ksi	
$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD	$\frac{KL}{r}$	F_{cr}/Ω_c ksi ASD	$\phi_c F_{cr}$ ksi LRFD
1	21.0	31.5	1	21.6	32.4	1	25.1	37.8	1	27.5	41.4	1	29.9	45.0
2	21.0	31.5	2	21.6	32.4	2	25.1	37.8	2	27.5	41.4	2	29.9	45.0
3	20.9	31.5	3	21.5	32.4	3	25.1	37.8	3	27.5	41.4	3	29.9	45.0
4	20.9	31.5	4	21.5	32.4	4	25.1	37.8	4	27.5	41.4	4	29.9	44.9
5	20.9	31.5	5	21.5	32.4	5	25.1	37.7	5	27.5	41.3	5	29.9	44.9
6	20.9	31.4	6	21.5	32.3	6	25.1	37.7	6	27.5	41.3	6	29.9	44.9
7	20.9	31.4	7	21.5	32.3	7	25.1	37.7	7	27.5	41.3	7	29.8	44.8
8	20.9	31.4	8	21.5	32.3	8	25.1	37.7	8	27.4	41.2	8	29.8	44.8
9	20.9	31.4	9	21.5	32.3	9	25.0	37.6	9	27.4	41.2	9	29.8	44.7
10	20.9	31.3	10	21.4	32.2	10	25.0	37.6	10	27.4	41.1	10	29.7	44.7
11	20.8	31.3	11	21.4	32.2	11	25.0	37.5	11	27.3	41.1	11	29.7	44.6
12	20.8	31.3	12	21.4	32.2	12	24.9	37.5	12	27.3	41.0	12	29.6	44.5
13	20.8	31.2	13	21.4	32.1	13	24.9	37.4	13	27.2	40.9	13	29.6	44.4
14	20.7	31.2	14	21.3	32.1	14	24.8	37.3	14	27.2	40.9	14	29.5	44.4
15	20.7	31.1	15	21.3	32.0	15	24.8	37.3	15	27.1	40.8	15	29.5	44.3

LIMIT STATE CHECKS

❖ CONNECTION

➢ Gusset Limit States

- Buckling (E3)
  - L in KL/r taken as L_{bi}
  - For flat bar connections, the Whitmore width does not apply. Take the effective width as w_i $\therefore A_g = w_i t_g$
  - Use K=0.70 (see Dowswell 2006 and/or AISC DG29)



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LIMIT STATE CHECKS

❖ CONNECTION

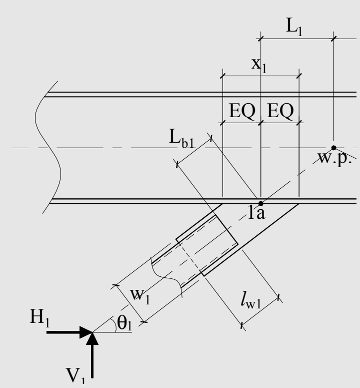
➢ Gusset Limit States

- Gross shear on horizontal section; sections *a* or *b* (J4)

$P_n = 0.6 F_y A_{gv}$ (J4-3)

$\phi = 1.00,\ \Omega = 1.50$

$A_{gv} = x_i t_g$



- Shear rupture on horizontal section; sections *a* or *b* (J4)

$P_n = 0.6 F_u A_{nv}$ (J4-4)

$\phi = 0.75,\ \Omega = 2.00$

$A_{nv} = x_i t_g$

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LIMIT STATE CHECKS

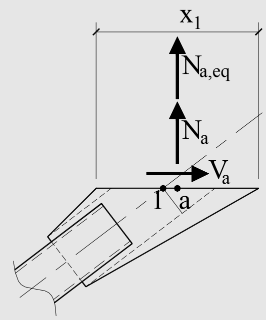
❖ CONNECTION

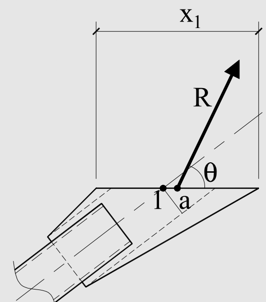
➢ Gusset Limit States

- Gusset-to-Beam Weld

$$\phi R_n = \frac{1.392DL\left(1+0.5\sin^{1.5}\theta\right)}{1.25} \quad \text{(LRFD)}$$

$$\frac{R_n}{\Omega} = \frac{0.928DL\left(1+0.5\sin^{1.5}\theta\right)}{1.25} \quad \text{(ASD)}$$





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LIMIT STATE CHECKS

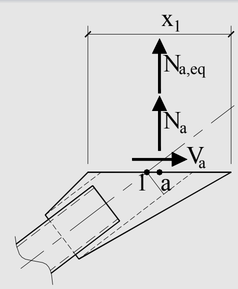
❖ CONNECTION

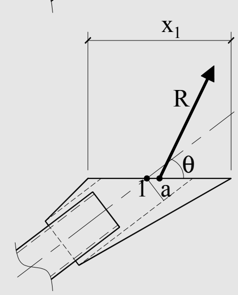
➢ Gusset Limit States

- Gusset-to-Beam Weld

$$\phi R_n = \frac{1.392DL\left(1+0.5\sin^{1.5}\theta\right)}{1.25} \quad \text{(LRFD)}$$

$$\frac{R_n}{\Omega} = \frac{0.928DL\left(1+0.5\sin^{1.5}\theta\right)}{1.25} \quad \text{(ASD)}$$





$$\theta = \tan^{-1}\left(\frac{N_{i,eq}+N_i}{V_i}\right) \qquad L = x_i$$

$$R = \sqrt{\left(N_{i,eq}+N_i\right)^2 + V_i^2}$$

The 1.25 factor is the ductility factor that accounts for non-uniform distribution of stresses along interface

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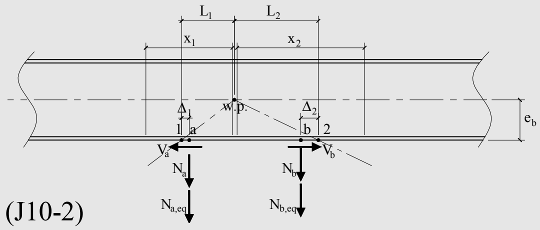
LIMIT STATE CHECKS

❖ BEAM

➢ Local Limit States From Concentrated Forces

- Web Yielding (J10)



$$R_n = F_{yw} t_w \left(5k + l_b\right) \qquad \text{(J10-2)}$$

$$\phi = 1.00,\ \Omega = 1.50$$

l_b=interface length, x_i

k=k_{des} (*Manual*, Part 1)

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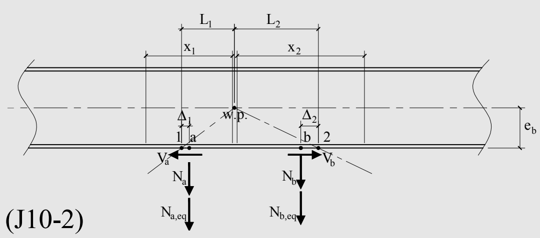
LIMIT STATE CHECKS

❖ BEAM

➢ Local Limit States From Concentrated Forces

- Web Yielding (J10)



$$R_n = F_{yw} t_w \left(5k + l_b\right) \qquad \text{(J10-2)}$$

$$\phi = 1.00,\ \Omega = 1.50$$

It is assumed in this presentation that points *a* and *b* are located a distance greater than the depth of the member from the end of the beam. If this is not the case, refer to Equation J10-3.

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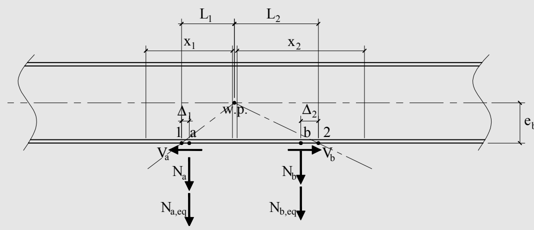
LIMIT STATE CHECKS

❖ BEAM

➢ Local Limit States From Concentrated Forces

- Web Crippling (J10)



$$R_n = 0.80 t_w^2 \left[1 + 3 \left(\frac{l_b}{d} \right) \left(\frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{\frac{E F_{yw} t_f}{t_w}} \qquad \text{(J10-4)}$$

$\phi = 0.75, \Omega = 2.00$

It is assumed in this presentation that points *a* and *b* are located a distance greater than one-half the depth of the member (d/2) from the end of the beam. If this is not the case, refer to Section J10.3 (Equations J10-5a and J10-5b).

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LIMIT STATE CHECKS

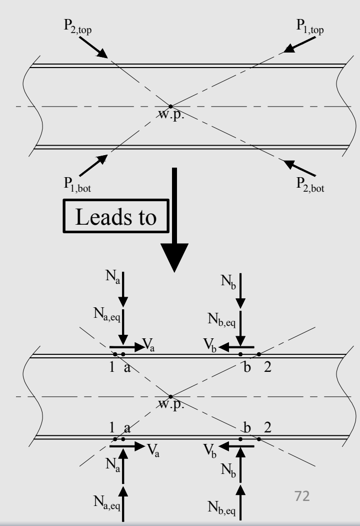
❖ BEAM

➢ Local Limit States From Concentrated Forces

- Web Compression Buckling (J10)

Needs to be checked when braces frame to both the top and bottom sides of the beam (two-story x-brace configuration) and a C-C load case needs to be considered (**RARE!**).

Refer to Section J10.5, Equation J10-8



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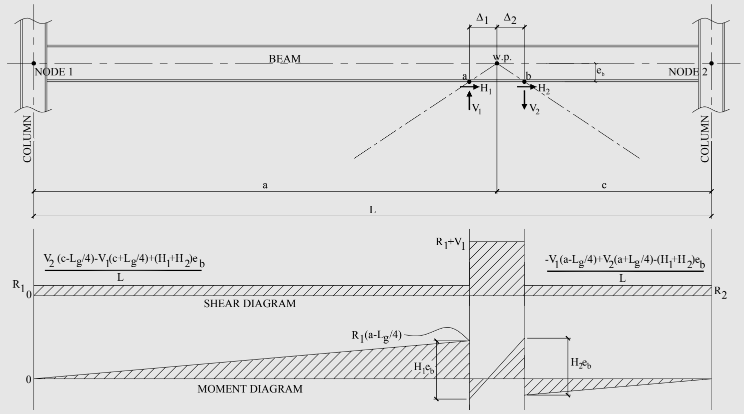
LIMIT STATE CHECKS

❖ BEAM

➢ Beam shear and bending distribution along the length of the beam



Representative beam shear and moment distribution using resultant loads

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LIMIT STATE CHECKS

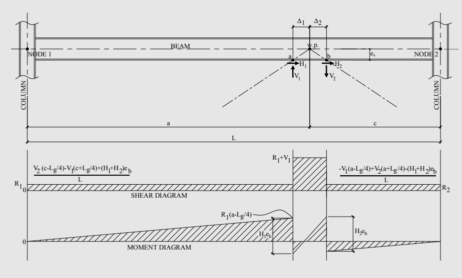
❖ BEAM

➢ Beam shear and bending distribution along the length of the beam

- Flexure (F2)

$$M_n = M_p = F_y Z_x \qquad \text{(F2-1)}$$

$$\phi = 0.90,\ \Omega = 1.67$$



Assume LTB is not applicable (i.e., compression flange is CLB)

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LIMIT STATE CHECKS

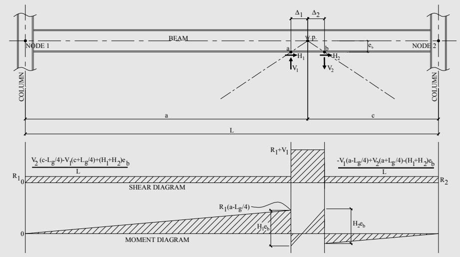
❖ BEAM

➢ Beam shear and bending distribution along the length of the beam

- Shear (G2)

$$V_n = 0.6F_y A_w C_v \qquad \text{(G2-1)}$$

$$\phi = 1.00,\ \Omega = 1.50$$



The ϕ and Ω factors given above assumes rolled I-shapes with

$$h/t_w \le 2.24\sqrt{E/F_y}$$

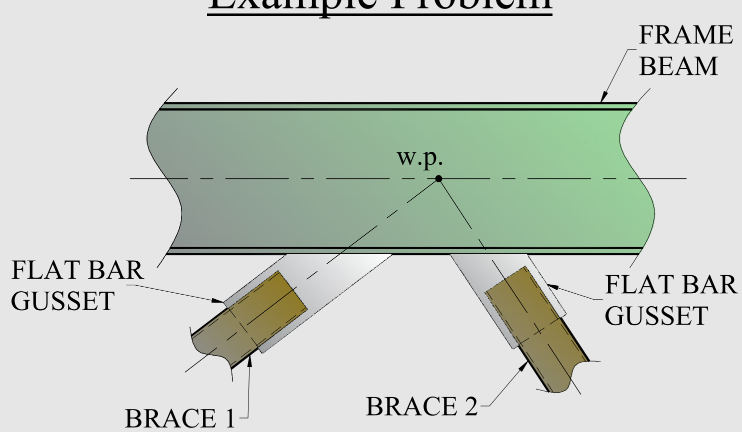
75

CHEVRON BRACE CONNECTIONS

Flat Bar Gussets

PART 1: Non-Seismic Applications

Example Problem



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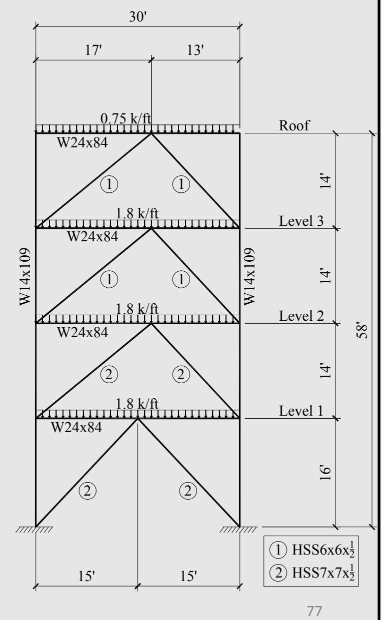
Example Problem

- ❖ The elevation of a braced frame is shown.
- ❖ The frame is used in a structure with design criteria such that the brace connections require no seismic strength or detailing.
- ❖ An analysis of the structure produces the following loading and brace forces.
- ❖ The brace forces shown are a result of factored LRFD load combinations



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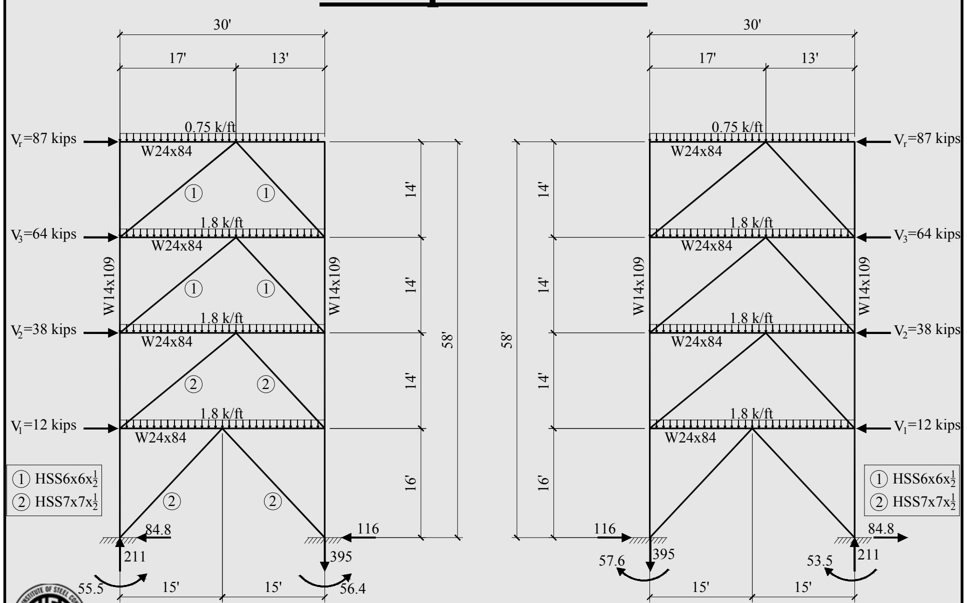
Example Problem



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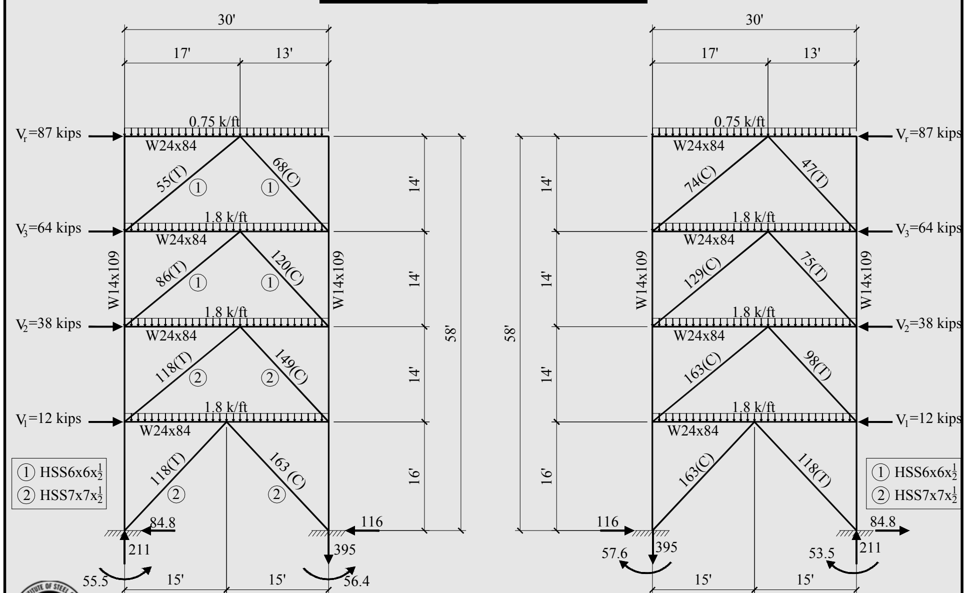
Example Problem



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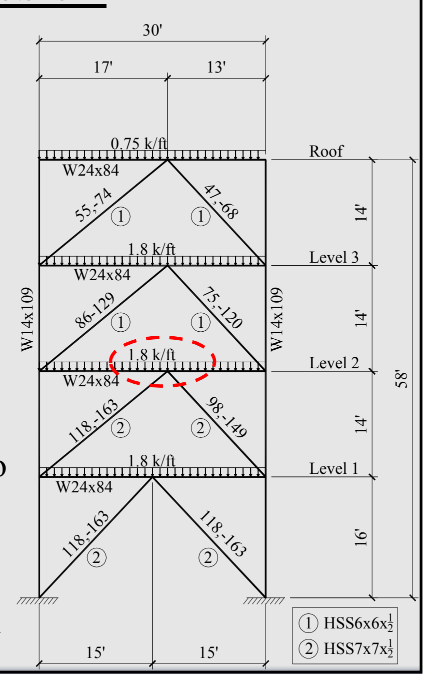
Example Problem

For the joint at Level 2,

1. Perform all of the appropriate limit state checks for the flat bar brace connection shown.
2. Draw the beam shear and moment diagrams for the beam considering the applied gravity loads and the loads determined to act at the gusset-to-beam interfaces.



Negative sign on brace forces indicates compression

Example Problem

For the joint at Level 2,

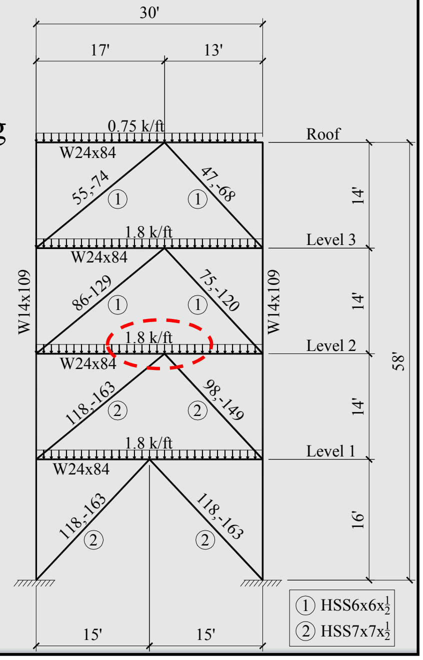
3. Check the beam for the following limits states:

   a) Web Local Yielding

   b) Web Local Crippling

   c) Beam Shear

   d) Beam Bending

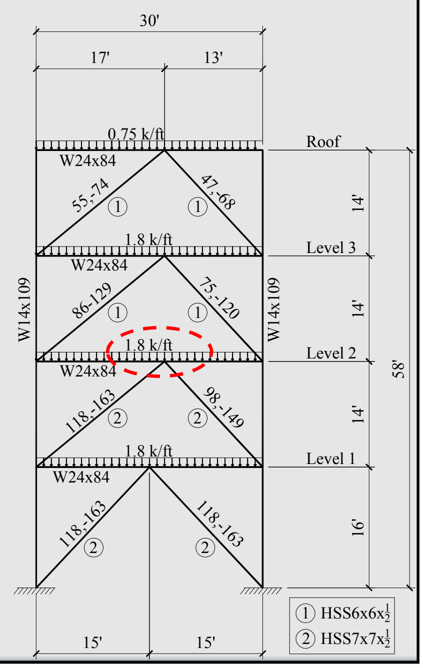


Negative sign on brace forces indicates compression

Example Problem

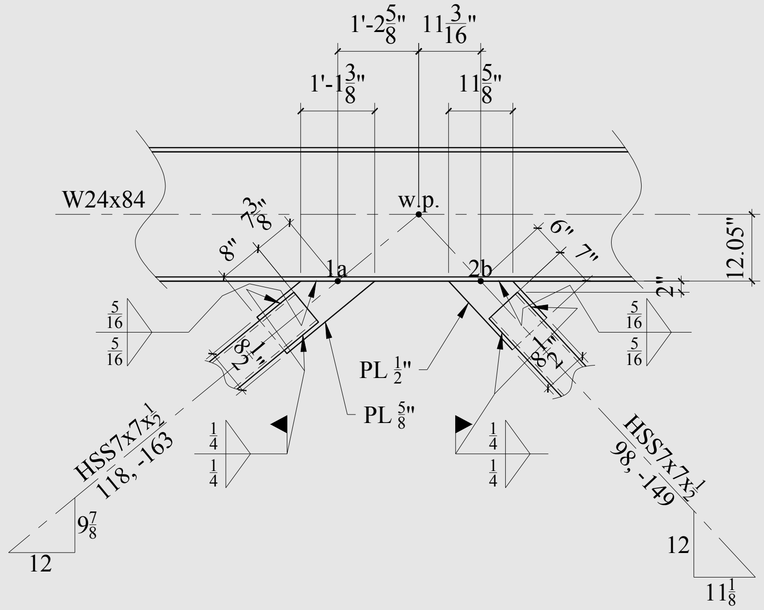
For the joint at Level 2,

4. Determine the required web doubler plate thickness if one is required, and provide all appropriate details for same.



Negative sign on brace forces indicates compression

Example Problem



Design Information for Level 2 Brace Connection

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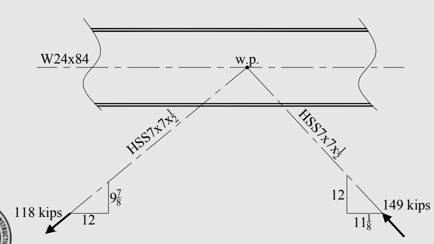
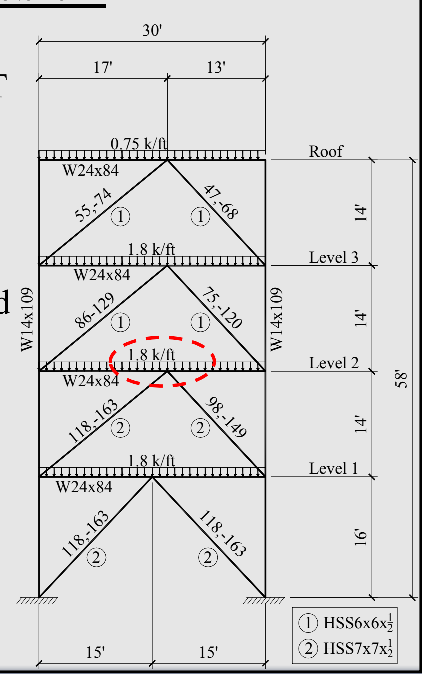
Example Problem

The brace connection design considers the worst case T-C and C-T load cases.

However, when checking beam limit states, check only the T-C load case as shown below. In practice both load cases need to be considered



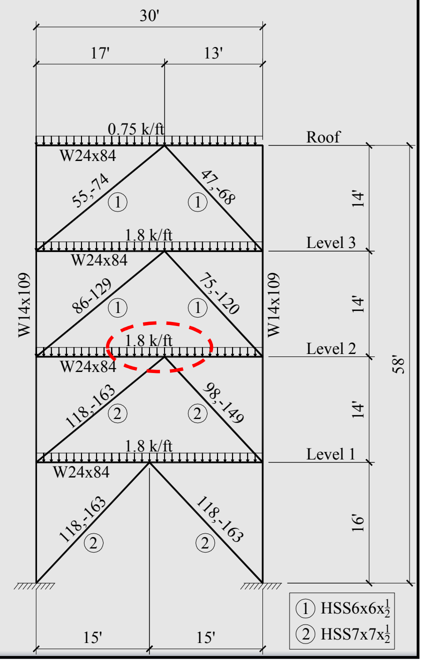
Load Case for check beam limit states



Example Problem

The following information is given:

- HSS shapes: A500-B
- Wide Flange shapes: A992-50
- Plate material: A572-50
- Flat bar material: A572-50

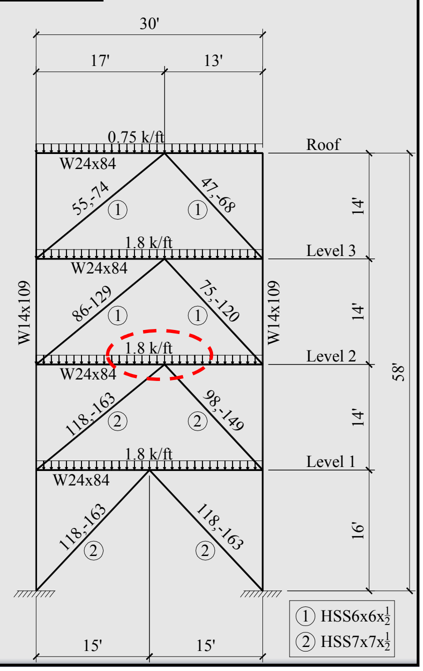


Example Problem

SOLUTION

Section and Material Properties

W24x84	HSS7x7x1/2
$F_y = 50ksi$	$F_y = 46ksi$
$F_u = 65ksi$	$F_u = 58ksi$
$d = 24.1in$	$A = 11.6in^2$
$t_f = 0.770in$	$r = 2.63in$
$b_f = 9.02in$	$b/t = h/t = 12.1$
$k_{des} = 1.27in$	$t_{des} = 0.465in$
$k_1 = 1-1/16in$	workable flat = $4.75in$

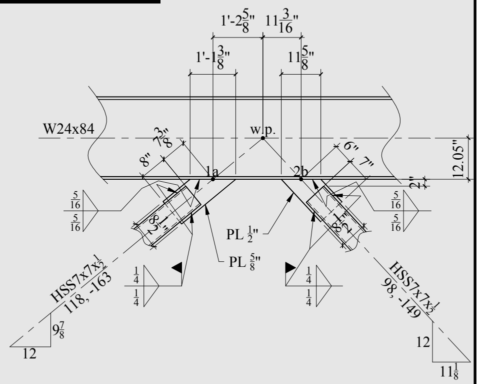


Example Problem

SOLUTION

BRACE 1 – Brace-to-Gusset

❖ Component Brace Forces



$$P_{rT} = 118kips$$

$$\theta_1 = \tan^{-1}\left(\frac{9.875}{12}\right) = 39.5^\circ$$

$$H_1 = \cos(39.5)(118) = 91.1kips$$

$$V_1 = \sin(39.5)(118) = 75.1kips$$

$$P_{rC} = 163kips$$

$$\theta_1 = \tan^{-1}\left(\frac{9.875}{12}\right) = 39.5^\circ$$

$$H_1 = -\cos(39.5)(163) = -126kips$$

$$V_1 = -\sin(39.5)(163) = -104kips$$

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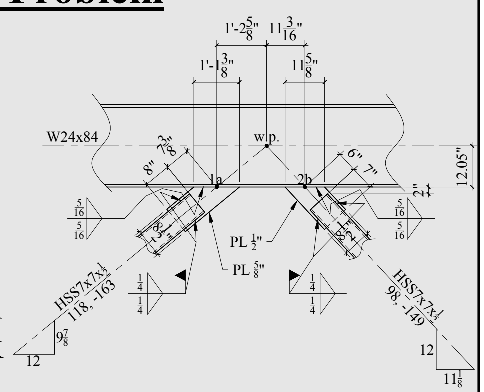
Example Problem

SOLUTION

BRACE 1 – Brace-to-Gusset

❖ Brace-to-gusset weld



$$\phi R_w = 1.392DL$$

$$\phi R_w = (1.392)(4)(4)(8)$$

$$\phi R_w = 178kips > 163kips \qquad \text{OK}$$

$$l = 8in > B = 7in \qquad \text{OK}$$

88

Example Problem

SOLUTION

BRACE 1 – Brace-to-Gusset

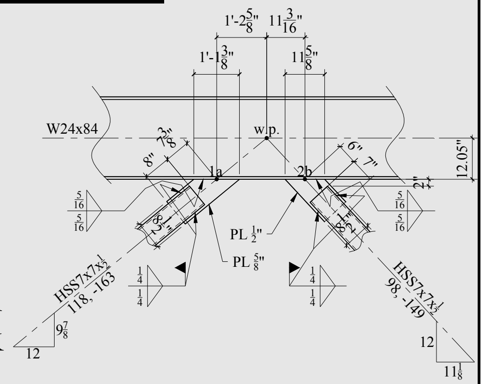
- Brace-to-gusset weld

$\phi R_w = 1.392DL$

$\phi R_w = (1.392)(4)(4)(8)$

$\phi R_w = 178kips > 163kips$ OK

$l = 8in > B = 7in$ OK



- Shear rupture of brace walls

$\phi R_n = \phi 0.6F_u 4lt_{des}$

$\phi R_n = (0.75)(0.6)(58)(4)(8)(0.465)$

$\phi R_n = 388kips > 163kips$ OK

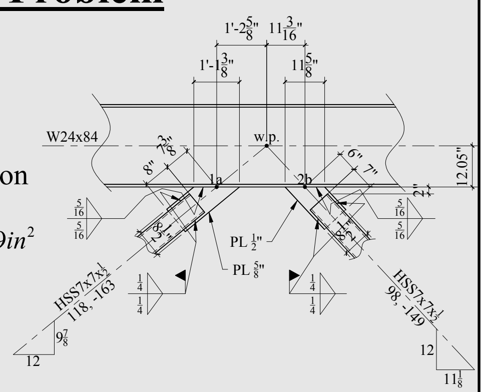
89

Example Problem

SOLUTION

BRACE 1 – Brace-to-Gusset

- Brace tensile rupture on net section



$A_n = 11.6 - (2)(0.5)(0.625 + 0.125) = 10.9in^2$

$\bar{x} = \frac{B^2 + 2BH}{4(B+H)} = \frac{7^2 + 2(7)(7)}{4(7+7)} = 2.625in$

$U = 1 - \frac{\bar{x}}{l} = 1 - \frac{2.625}{8} = 0.672$

$\phi R_n = \phi F_u A_n U$

$\phi R_n = (0.75)(58)(10.9)(0.672)$

$\phi R_n = 319kips > 118kips$ OK

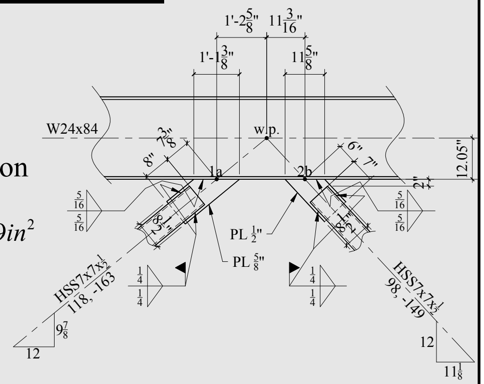
90

Example Problem

SOLUTION

BRACE 1 – Brace-to-Gusset

❖ Brace tensile rupture on net section



$$A_n = 11.6 - (2)(0.5)(0.625 + 0.125) = 10.9 in^2$$

$$\bar{x} = \frac{B^2 + 2BH}{4(B+H)} = \frac{7^2 + 2(7)(7)}{4(7+7)} = 2.625 in$$

$$U = 1 - \frac{\bar{x}}{l} = 1 - \frac{2.625}{8} = 0.672$$

$$\phi R_n = \phi F_u A_n U$$

$$\phi R_n = (0.75)(58)(10.9)(0.672)$$

$$\phi R_n = 319 kips > 118 kips \qquad \text{OK}$$

❖ Note that I use the nominal brace wall thickness to calculate A_n

❖ The 0.125 is to account for a slot width equal to t_g + 1/8”

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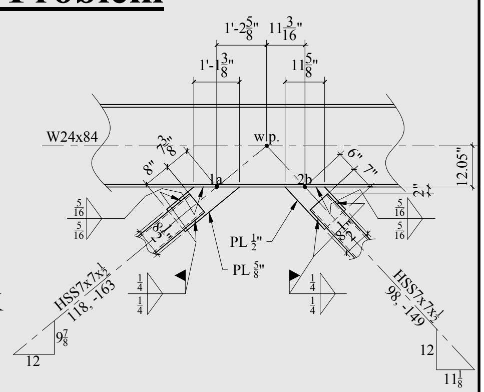
Example Problem

SOLUTION

BRACE 1 - Gusset

❖ Tensile yield



$$\phi R_n = \phi F_y A_g = \phi F_y w_1 t_g$$

$$\phi R_n = (0.90)(50)(8.50)(0.625)$$

$$\phi R_n = 239 kips > 118 kips \qquad \text{OK}$$

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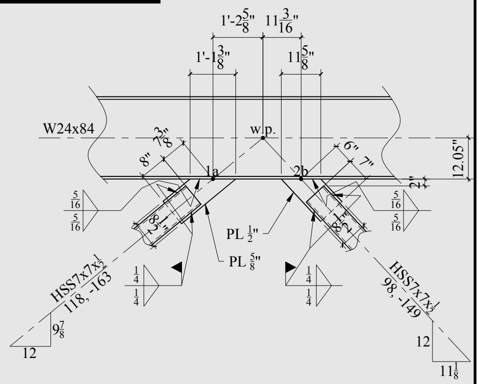
Example Problem

SOLUTION

BRACE 1 - Gusset



❖ Tensile yield

$$\phi R_n = \phi F_y A_g = \phi F_y w_1 t_g$$

$$\phi R_n = (0.90)(50)(8.50)(0.625)$$

$$\phi R_n = 239 kips > 118 kips \qquad \text{OK}$$

❖ Tensile rupture

$$\phi R_n = \phi F_u A_n = \phi F_n w_1 t_g$$

$$\phi R_n = (0.75)(65)(8.50)(0.625)$$

$$\phi R_n = 259 kips > 118 kips \qquad \text{OK}$$

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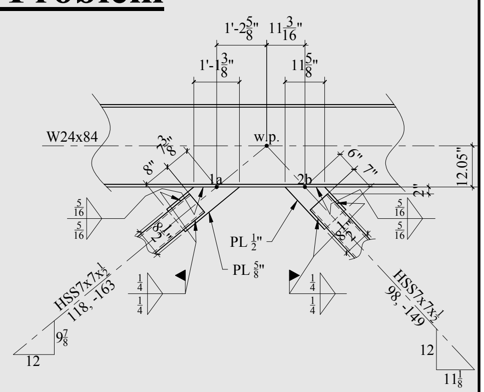
Example Problem

SOLUTION

BRACE 1 - Gusset



❖ Buckling

$$\phi R_n = \phi F_{cr} A_g = \phi F_{cr} w_1 t_g$$

$$K = 0.70$$

$$L = L_{b1} = 7.375 in$$

$$r = \frac{t_g}{\sqrt{12}} = \frac{0.625}{\sqrt{12}} = 0.180 in$$

$$\frac{KL}{r} = \frac{(0.70)(7.375)}{0.180} = 28.7$$

$$\phi F_{cr} = 42.3 \qquad (\textit{Manual} \text{ Table 4-22 with } KL/r = 29.0)$$

$$\phi R_n = (42.3)(8.50)(0.625)$$

$$\phi R_n = 225 kips > 163 kips \qquad \text{OK}$$

28	20.1	30.3	28	20.7	31.1	28	24.0	36.0	28	26.1	39.3	28	28.3	42.5
29	20.1	30.2	29	20.6	31.0	29	23.9	35.9	29	26.0	39.1	29	28.2	42.3
30	20.0	30.1	30	20.6	30.9	30	23.8	35.8	30	25.9	39.0	30	28.0	42.1

Example Problem

SOLUTION

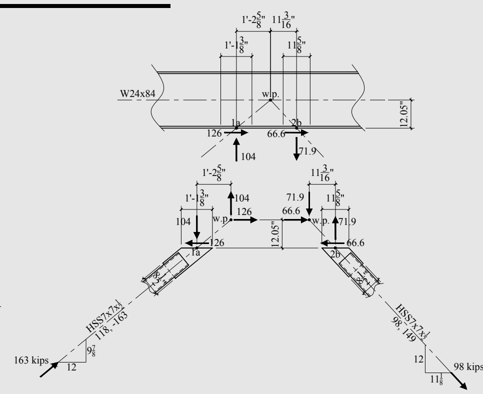
BRACE 1 - Gusset

❖ Shear yield on section *a*

$$\phi R_n = \phi 0.6 F_y A_g = \phi 0.6 F_y x_1 t_g$$

$$\phi R_n = (1.0)(0.6)(50)(13.375)(0.625)$$

$$\phi R_n = 251 kips > 126 kips \qquad \text{OK}$$



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Example Problem

SOLUTION

BRACE 1 - Gusset

❖ Shear yield on section *a*

$$\phi R_n = \phi 0.6 F_y A_g = \phi 0.6 F_y x_1 t_g$$

$$\phi R_n = (1.0)(0.6)(50)(13.375)(0.625)$$

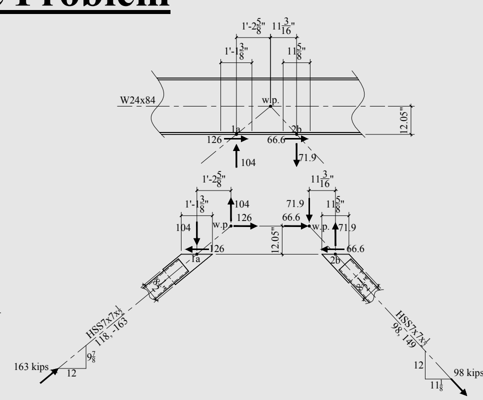
$$\phi R_n = 251 kips > 126 kips \qquad \text{OK}$$

❖ Shear rupture on section *a*

$$\phi R_n = \phi 0.6 F_u A_{nv} = \phi 0.6 F_u x_1 t_g$$

$$\phi R_n = (0.75)(0.6)(65)(13.375)(0.625)$$

$$\phi R_n = 244 kips > 126 kips \qquad \text{OK}$$



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Example Problem

SOLUTION

BRACE 1 - Gusset

❖ Weld at section *a*

$N = 104 kips$

$V = 126 kips$

$M = 0$

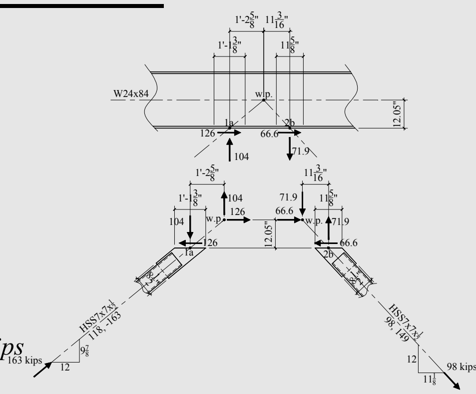
$R = \sqrt{N^2 + V^2} = \sqrt{104^2 + 126^2} = 163 kips$

$\theta = \tan^{-1}\left(\frac{104}{126}\right) = 39.5^\circ$

$u = 1 + 0.5\sin^{1.5}\theta = 1 + (0.5)\sin^{1.5}(39.5) = 1.25$

$\phi R_w = \frac{(1.392)(2)(5)(13.375)(1.25)}{1.25}$

$\phi R_n = 186 kips > 163 kips$ OK



97

Example Problem

SOLUTION

BRACE 2 – Brace-to-Gusset

❖ Component Brace Forces

$P_{rT} = 98 kips$

$\theta_2 = \tan^{-1}\left(\frac{12}{11.125}\right) = 47.2^\circ$

$H_2 = \cos(47.2)(98) = 66.6 kips$

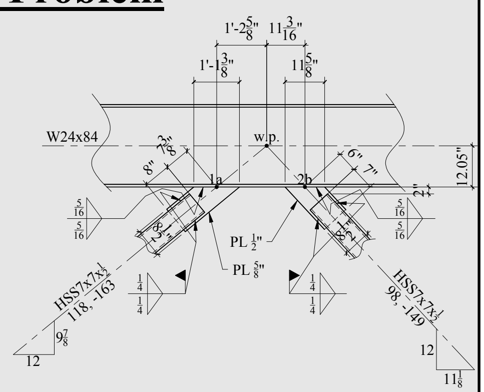
$V_2 = \sin(47.2)(98) = 71.9 kips$

$P_{rC} = 149 kips$

$\theta_2 = \tan^{-1}\left(\frac{12}{11.125}\right) = 47.2^\circ$

$H_2 = -\cos(47.2)(149) = -101 kips$

$V_2 = -\sin(47.2)(149) = -109 kips$



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Example Problem

SOLUTION

BRACE 2 – Brace-to-Gusset

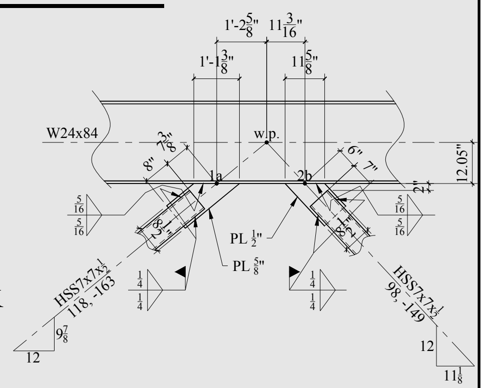
- Brace-to-gusset weld

$\phi R_w = 1.392DL$

$\phi R_w = (1.392)(4)(4)(7)$

$\phi R_w = 156kips > 149kips$ OK

$l = 7in \geq B = 7in$ OK



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Example Problem

SOLUTION

BRACE 2 – Brace-to-Gusset

- Brace-to-gusset weld

$\phi R_w = 1.392DL$

$\phi R_w = (1.392)(4)(4)(7)$

$\phi R_w = 156kips > 149kips$ OK

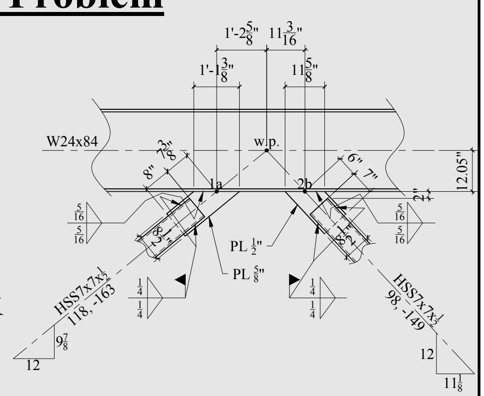
$l = 7in \geq B = 7in$ OK

- Shear rupture of brace walls

$\phi R_n = \phi 0.6 F_u 4 l t_{des}$

$\phi R_n = (0.75)(0.6)(58)(4)(7)(0.465)$

$\phi R_n = 340kips > 149kips$ OK



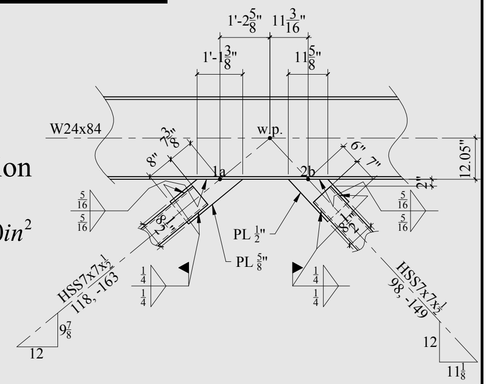
100

Example Problem

SOLUTION

BRACE 2 – Brace-to-Gusset

❖ Brace tensile rupture on net section



$$A_n = 11.6 - (2)(0.5)(0.50 + 0.125) = 11.0 in^2$$

$$\bar{x} = \frac{B^2 + 2BH}{4(B+H)} = \frac{7^2 + 2(7)(7)}{4(7+7)} = 2.625 in$$

$$U = 1 - \frac{\bar{x}}{l} = 1 - \frac{2.625}{7} = 0.625$$

$$\phi R_n = \phi F_u A_n U$$

$$\phi R_n = (0.75)(58)(11.0)(0.625)$$

$$\phi R_n = 299 kips > 98.0 kips \qquad \text{OK}$$

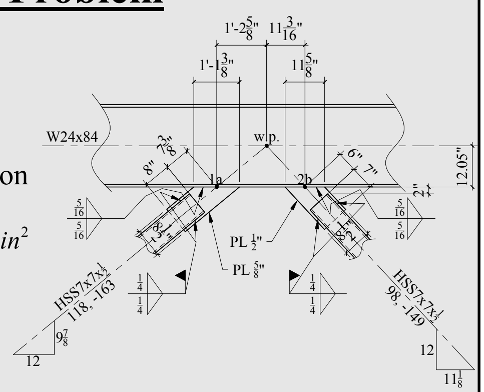
101

Example Problem

SOLUTION

BRACE 2 – Brace-to-Gusset

❖ Brace tensile rupture on net section



$$A_n = 11.6 - (2)(0.5)(0.50 + 0.125) = 11.0 in^2$$

$$\bar{x} = \frac{B^2 + 2BH}{4(B+H)} = \frac{7^2 + 2(7)(7)}{4(7+7)} = 2.625 in$$

$$U = 1 - \frac{\bar{x}}{l} = 1 - \frac{2.625}{7} = 0.625$$

$$\phi R_n = \phi F_u A_n U$$

$$\phi R_n = (0.75)(58)(11.0)(0.625)$$

$$\phi R_n = 299 kips > 98.0 kips \qquad \text{OK}$$

❖ Note that I use the nominal brace wall thickness to calculate A_n

❖ The 0.125 is to account for a slot width equal to t_g + 1/8”

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Example Problem

SOLUTION

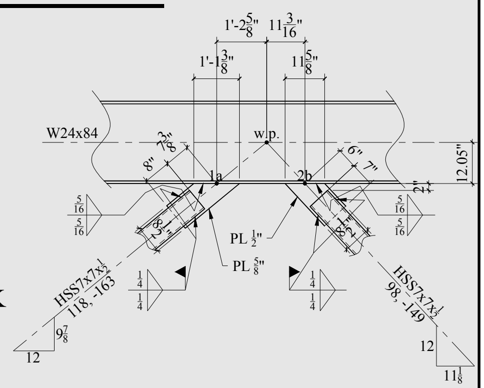
BRACE 2 - Gusset

❖ Tensile yield

$$\phi R_n = \phi F_y A_g = \phi F_y w_1 t_g$$

$$\phi R_n = (0.90)(50)(8.50)(0.50)$$

$$\phi R_n = 191 kips > 98.0 kips \qquad \text{OK}$$



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Example Problem

SOLUTION

BRACE 2 - Gusset

❖ Tensile yield

$$\phi R_n = \phi F_y A_g = \phi F_y w_1 t_g$$

$$\phi R_n = (0.90)(50)(8.50)(0.50)$$

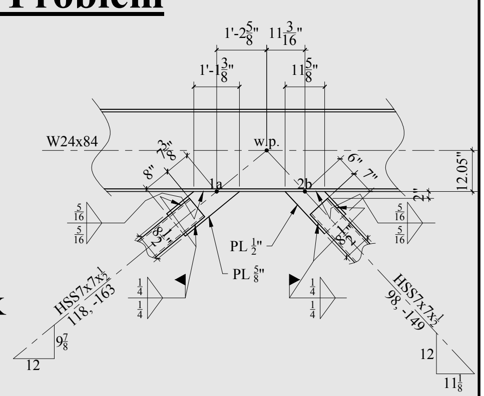
$$\phi R_n = 191 kips > 98.0 kips \qquad \text{OK}$$

❖ Tensile rupture

$$\phi R_n = \phi F_u A_n = \phi F_u w_1 t_g$$

$$\phi R_n = (0.75)(65)(8.50)(0.50)$$

$$\phi R_n = 207 kips > 98.0 kips \qquad \text{OK}$$



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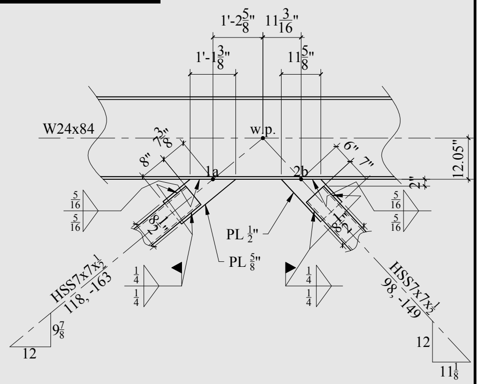
Example Problem

SOLUTION

BRACE 2 - Gusset

❖ Buckling



$$\phi R_n = \phi F_{cr} A_g = \phi F_{cr} w_2 t_g$$

$$K = 0.70$$

$$L = L_{b2} = 6.0in$$

$$r = \frac{t_g}{\sqrt{12}} = \frac{0.50}{\sqrt{12}} = 0.144in$$

$$\frac{KL}{r} = \frac{(0.70)(6.0)}{0.144} = 29.2$$

$\phi F_{cr} = 42.1$ (*Manual* Table 4-22 with KL/r=30.0)

$$\phi R_n = (42.1)(8.50)(0.50)$$

$\phi R_n = 179kips > 109kips$ OK

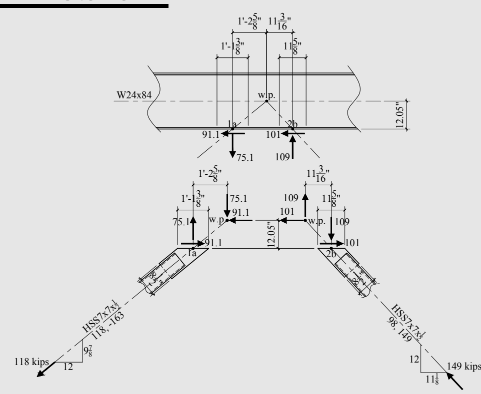
29	20.1	30.2	29	20.6	31.0	29	23.9	35.9	29	26.0	39.1	29	28.2	42.3
30	20.0	30.1	30	20.6	30.9	30	23.8	35.8	30	25.9	39.0	30	28.0	42.1

Example Problem

SOLUTION

BRACE 2 - Gusset

❖ Shear yield on section *b*



$$\phi R_n = \phi 0.6 F_y A_g = \phi 0.6 F_y x_2 t_g$$

$$\phi R_n = (1.0)(0.6)(50)(11.625)(0.50)$$

$\phi R_n = 174kips > 101kips$ OK

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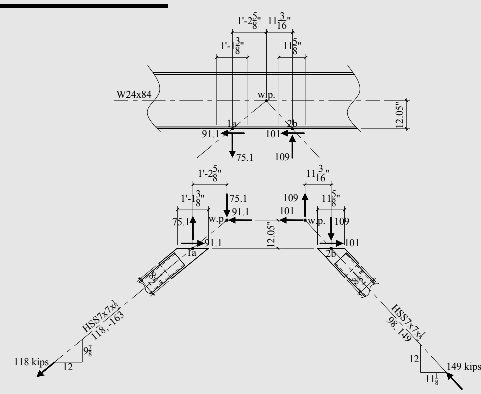
Example Problem

SOLUTION

BRACE 2 - Gusset



- Shear yield on section b

$$\phi R_n = \phi 0.6 F_y A_g = \phi 0.6 F_y x_2 t_g$$
$$\phi R_n = (1.0)(0.6)(50)(11.625)(0.50)$$
$$\phi R_n = 174 kips > 101 kips \qquad \text{OK}$$

- Shear rupture on section b

$$\phi R_n = \phi 0.6 F_u A_{nv} = \phi 0.6 F_u x_2 t_g$$
$$\phi R_n = (0.75)(0.6)(65)(11.625)(0.50)$$
$$\phi R_n = 170 kips > 101 kips \qquad \text{OK}$$

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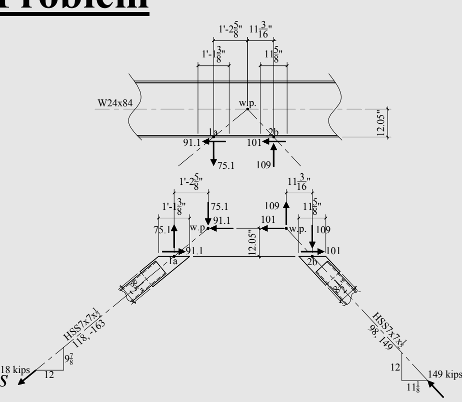
Example Problem

SOLUTION

BRACE 2 - Gusset



- Weld at section b

$$N = 109 kips$$
$$V = 101 kips$$
$$M = 0$$
$$R = \sqrt{N^2 + V^2} = \sqrt{109^2 + 101^2} = 149 kips$$
$$\theta = \tan^{-1}\left(\frac{109}{101}\right) = 47.2^\circ$$
$$u = 1 + 0.5\sin^{1.5}\theta = 1 + (0.5)\sin^{1.5}(47.2) = 1.31$$
$$\phi R_w = \frac{(1.392)(2)(5)(11.625)(1.31)}{1.25}$$
$$\phi R_n = 170 kips > 149 kips \qquad \text{OK}$$

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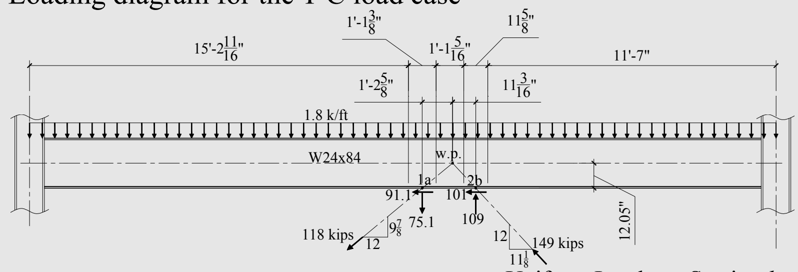
Example Problem

SOLUTION

Beam Limit States

❖ Loading diagram for the T-C load case



Uniform Loads on Section *a*

$$v_a = \frac{V_a}{x_1} = \frac{91.1kips}{13.375in}(12in/ft) = 81.7k/ft$$

$$n_a = \frac{N_a}{x_1} = \frac{75.1kips}{13.375in}(12in/ft) = 67.4k/ft$$

$$m_a = \frac{V_a e_b}{x_1} = \frac{(91.1kips)(12.05in)}{13.375in} = 82.1k-ft/ft$$

Uniform Loads on Section *b*

$$v_b = \frac{V_b}{x_2} = \frac{101kips}{11.625in}(12in/ft) = 104k/ft$$

$$n_b = \frac{N_b}{x_2} = \frac{109kips}{11.625in}(12in/ft) = 113k/ft$$

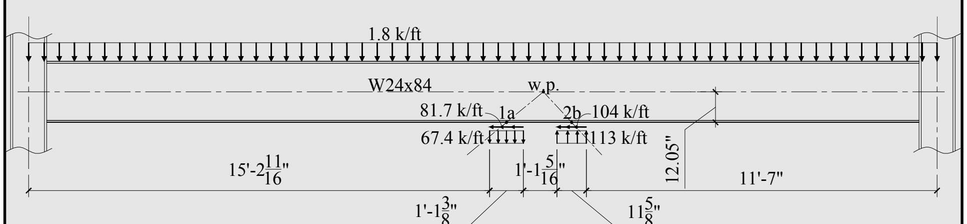
$$m_b = \frac{V_b e_b}{x_2} = \frac{(101kips)(12.05in)}{11.625in} = 105k-ft/ft$$

Example Problem

SOLUTION

Beam Limit States

❖ Loading diagram for the T-C load case



Load Diagram for T-C Load Case (uniformly distributed loads)

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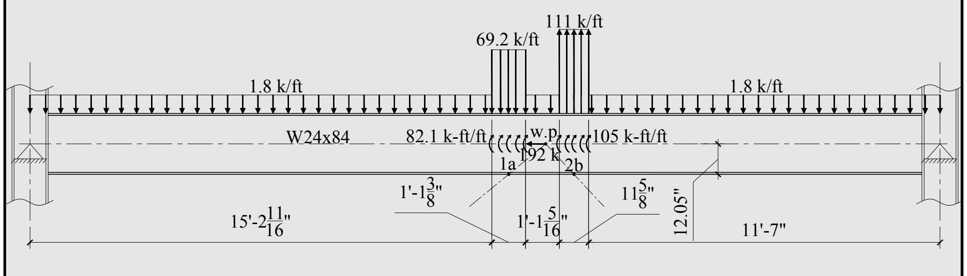
Example Problem

SOLUTION

Beam Limit States

❖ Loading diagram for the T-C load case



Equivalent Beam Model for T-C Load Case

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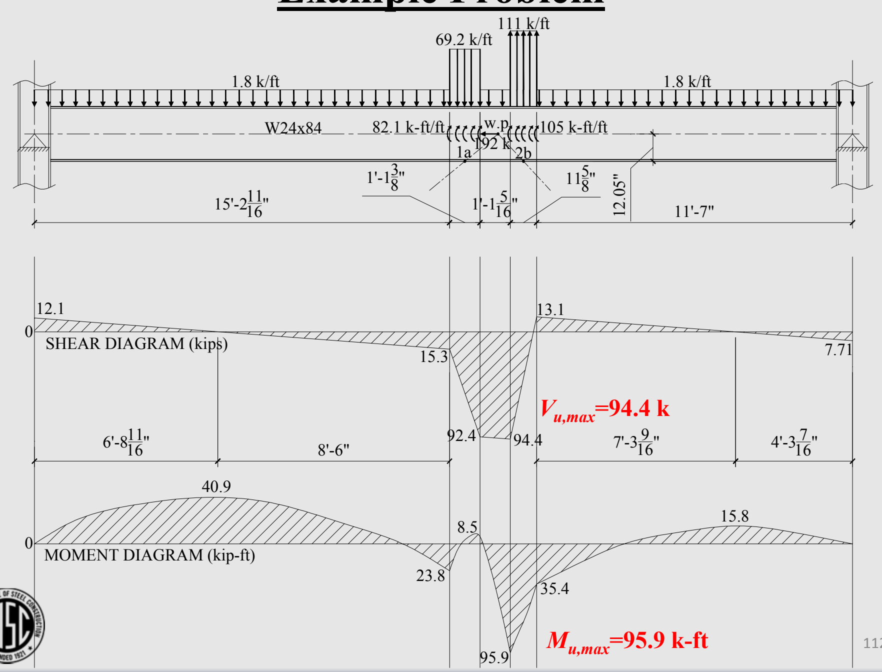
Example Problem



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Example Problem

SOLUTION

Beam Limit States

- Bending

  $\phi M_n = 840k - ft$ (*Manual* Table 3-6)

  $M_u = 95.9k - ft < \phi M_n = 840k - ft$ OK

- Shear

  $\phi V_n = 340k$ (*Manual* Table 3-6)

  $V_u = 94.4k < \phi V_n = 340k$ OK

Since the beam has sufficient available shear and bending strength, no web doublers or cover plates are required…Part 4 of this example problem needs no further consideration.

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Example Problem

SOLUTION

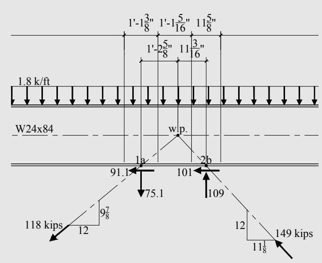
Beam Limit States

- Web Local Yielding

  $\phi R_n = \phi F_{yw} t_w \left(5k + l_b\right)$

  $\phi R_n = (1.00)(50)(0.470)\left[(5)(1.27) + 11.625\right]$

  $\phi R_n = 422k > 109k$ OK



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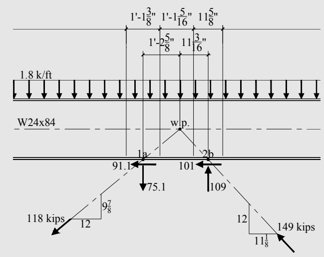
Example Problem

SOLUTION

Beam Limit States

❖ Web Local Crippling



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

$$\phi R_n = (0.75)(0.80)(0.47)^2 \left[1 + 3\left(\frac{11.625}{24.1}\right)\left(\frac{0.47}{0.77}\right)^{1.5} \right] \sqrt{\frac{(29{,}000)(50)(0.77)}{0.47}}$$

$$\phi R_n = 314k > 109k \qquad \text{OK}$$

Note that Web Local Crippling is checked against the 109*k* force because it is a compressive force acting on the flange…not because it is the larger of the two normal forces.

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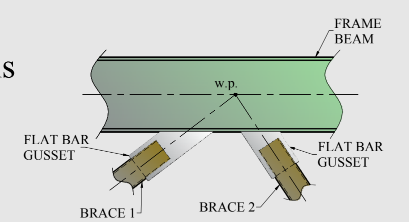
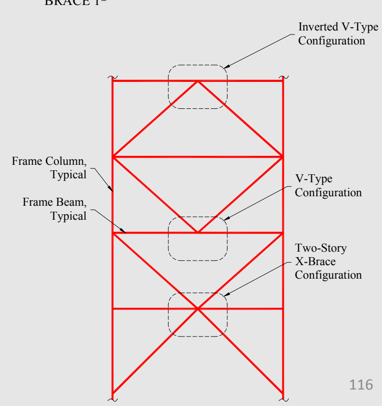
CHEVRON BRACE CONNECTIONS

PART 1: Non-Seismic Applications



This Concludes Part 1



Questions?
Comments

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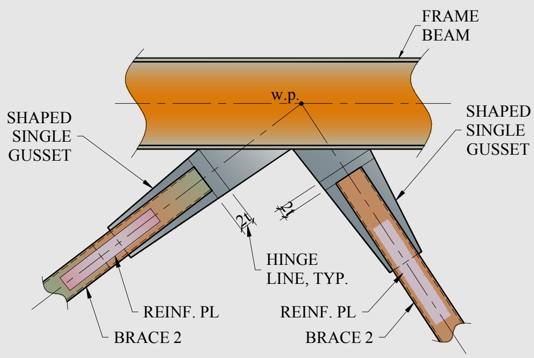
NEXT WEEK…

April 16, 2015
1:30 p.m. EDT

Flat Bar and Individual Shaped Gussets
PART 2: Seismic Applications



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CEU/PDH Certificates

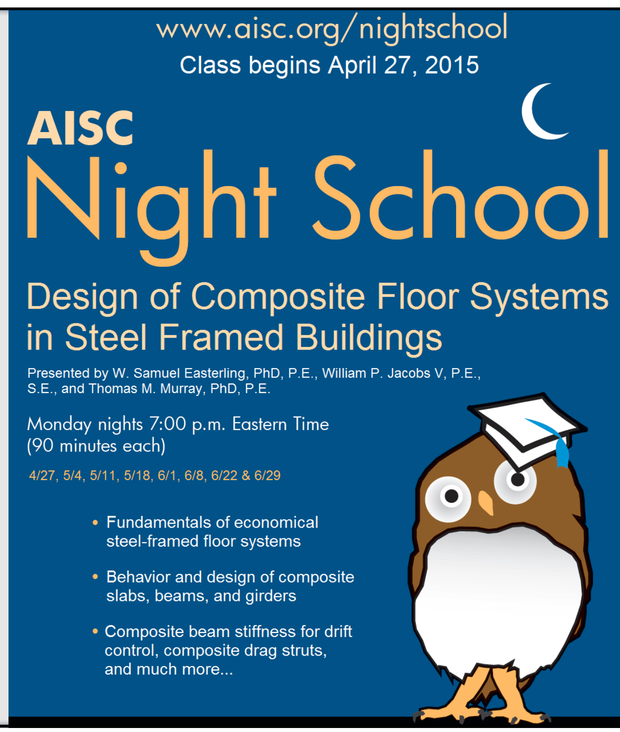
Within 2 business days…

- You will receive an email on how to report attendance from: registration@aisc.org.
- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

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.



There's always a solution in steel.

Thank You

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

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