

# CE 415

# DESIGN OF STEEL STRUCTURES

## LECTURE 2

## TENSION MEMBER

SEMESTER: SUMMER 2020

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# OUTLINE

- ASD and LRFD
- Yield of gross area and fracture of net area
- L-angle property table
- Staggered holes
- Staggered holes (Math Problems)

- ❑ **The two distinct procedures employed by designers are,**
  - **Allowable Strength Design (ASD) &**
  - **Load & Resistance Factor Design (LRFD).**

## Strength of Tension Members

**Yielding of gross cross section**

$$T_n = F_y A_g$$

**$T_n$  = Nominal tensile strength**

**$F_y$  = Yield stress**

**$A_g$  = Gross cross sectional area away from connection**

# Strength of Tension Members

## Strength of Tension Members Fracture of effective net area

$$T_n = F_u A_e$$

$T_n$  = Nominal tensile strength

$F_u$  = Specified minimum tensile strength

$A_e$  = Effective net area =  $UA_n$ ,

$A_n$  = net area

$U$  = Reduction coefficient (shear lag factor)

**Effective hole diameter = Actual hole diameter +  $\frac{1}{16}$ "**  
**= Bolt diameter +  $\frac{1}{8}$ "**

## Effective Net Area

The net area  $A_n$  gives the reduced section that resists tension but still may not correctly reflect the strength. That is particularly true when load does not pass through the centroid of the connection. Thus comes the concept of *effective net area*  $A_e$ .

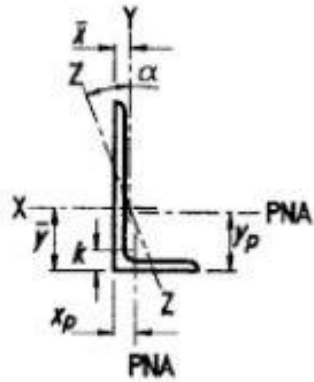
$$\text{Effective Net Area } A_e = UA_n$$

where  $U$  is Shear Lag Factor (a reduction co-efficient).

$$U = 1.0 - \bar{x}/L \text{ [except plates and HSS sections, AISC Table D3.1]}$$

$\bar{x}$  = distance between loading line (c.g. of tension member section) and connection plane.

$L$  = Length of connection



**Table 1-7  
Angles  
Properties**

Shape	k	Wt.	Area, A	Axis X-X						Flexural-Torsional Properties		
				<i>I</i>	<i>S</i>	<i>r</i>	$\bar{y}$	<i>Z</i>	$y_p$	<i>J</i>	$C_w$	$\bar{r}_o$
				in. <sup>4</sup>	in. <sup>3</sup>	in.	in.	in. <sup>3</sup>	in.	in. <sup>4</sup>	in. <sup>6</sup>	in.
L6×6×1	1½	37.4	11.0	35.4	8.55	1.79	1.86	15.4	0.918	3.68	9.24	3.18
×7/8	1¾	33.1	9.75	31.9	7.61	1.81	1.81	13.7	0.813	2.51	6.41	3.21
×¾	1¼	28.7	8.46	28.1	6.64	1.82	1.77	11.9	0.705	1.61	4.17	3.24
×5/8	1⅛	24.2	7.13	24.1	5.64	1.84	1.72	10.1	0.594	0.955	2.50	3.28
×9/16	1⅙	21.9	6.45	22.0	5.12	1.85	1.70	9.18	0.538	0.704	1.85	3.29
×½	1	19.6	5.77	19.9	4.59	1.86	1.67	8.22	0.481	0.501	1.32	3.31
×7/16	15/16	17.2	5.08	17.6	4.06	1.86	1.65	7.25	0.423	0.340	0.899	3.32
×3/8	7/8	14.9	4.38	15.4	3.51	1.87	1.62	6.27	0.365	0.218	0.575	3.34
×5/16	13/16	12.4	3.67	13.0	2.95	1.88	1.60	5.26	0.306	0.129	0.338	3.35



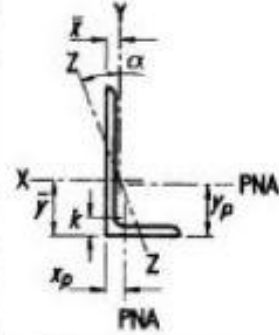
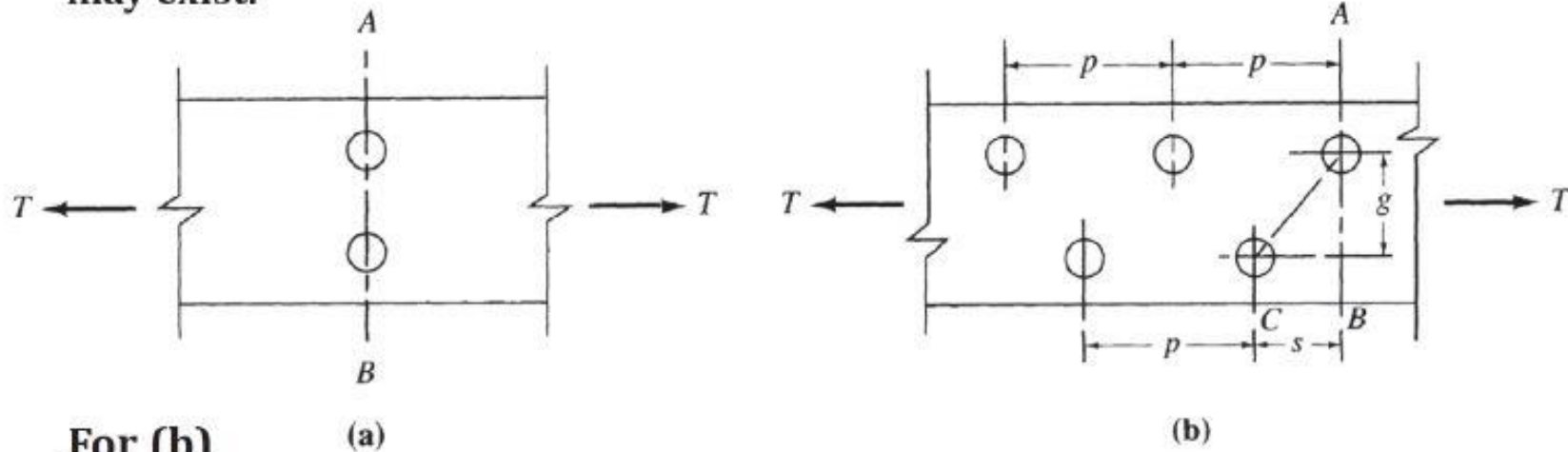


Table 1-7 (continued)  
Angles  
Properties

Shape	k	Wt.	Area, A	Axis X-X						Flexural-Torsional Properties		
				I	S	r	$\bar{y}$	Z	y <sub>p</sub>	J	C <sub>w</sub>	$\bar{r}_o$
				in. <sup>4</sup>	in. <sup>3</sup>	in.	in.	in. <sup>3</sup>	in.	in. <sup>4</sup>	in. <sup>6</sup>	in.
L4×3 <sup>1</sup> / <sub>2</sub> × <sup>1</sup> / <sub>2</sub>	<sup>7</sup> / <sub>8</sub>	11.9	3.50	5.30	1.92	1.23	1.24	3.46	0.497	0.301	0.302	2.03
× <sup>3</sup> / <sub>8</sub>	<sup>3</sup> / <sub>4</sub>	9.10	2.67	4.15	1.48	1.25	1.20	2.66	0.433	0.132	0.134	2.06
× <sup>5</sup> / <sub>16</sub>	<sup>11</sup> / <sub>16</sub>	7.70	2.25	3.53	1.25	1.25	1.17	2.24	0.401	0.0782	0.0798	2.08
× <sup>1</sup> / <sub>4</sub>	<sup>5</sup> / <sub>8</sub>	6.20	1.81	2.89	1.01	1.26	1.14	1.81	0.368	0.0412	0.0419	2.09
L4×3× <sup>5</sup> / <sub>8</sub>	1	13.6	3.89	6.01	2.28	1.23	1.37	4.08	0.810	0.529	0.472	1.91
× <sup>1</sup> / <sub>2</sub>	<sup>7</sup> / <sub>8</sub>	11.1	3.25	5.02	1.87	1.24	1.32	3.36	0.747	0.281	0.255	1.94
× <sup>3</sup> / <sub>8</sub>	<sup>3</sup> / <sub>4</sub>	8.50	2.48	3.94	1.44	1.26	1.27	2.60	0.683	0.123	0.114	1.97
× <sup>5</sup> / <sub>16</sub>	<sup>11</sup> / <sub>16</sub>	7.20	2.09	3.36	1.22	1.27	1.25	2.19	0.651	0.0731	0.0676	1.98
× <sup>1</sup> / <sub>4</sub>	<sup>5</sup> / <sub>8</sub>	5.80	1.69	2.75	0.988	1.27	1.22	1.77	0.618	0.0386	0.0356	1.99
L3 <sup>1</sup> / <sub>2</sub> ×3 <sup>1</sup> / <sub>2</sub> × <sup>1</sup> / <sub>2</sub>	<sup>7</sup> / <sub>8</sub>	11.1	3.25	3.63	1.48	1.05	1.05	2.66	0.466	0.281	0.238	1.87
× <sup>7</sup> / <sub>16</sub>	<sup>13</sup> / <sub>16</sub>	9.80	2.87	3.25	1.32	1.06	1.03	2.36	0.412	0.192	0.164	1.89
× <sup>3</sup> / <sub>8</sub>	<sup>3</sup> / <sub>4</sub>	8.50	2.48	2.86	1.15	1.07	1.00	2.06	0.357	0.123	0.106	1.90
× <sup>5</sup> / <sub>16</sub>	<sup>11</sup> / <sub>16</sub>	7.20	2.09	2.44	0.969	1.08	0.979	1.74	0.301	0.0731	0.0634	1.92
× <sup>1</sup> / <sub>4</sub>	<sup>5</sup> / <sub>8</sub>	5.80	1.69	2.00	0.787	1.09	0.954	1.41	0.243	0.0386	0.0334	1.93

## Staggered Holes

Whenever there is more than one hole and the holes are not lined up transverse to the loading direction, more than one potential failure line may exist.



**For (b)**

Net length of  $A-B$  = length of  $(A-B)$  - (width of hole +  $\frac{1}{16}$  in.)

Net length of  $A-C$  = length of  $(A-B)$  -  $2$ (width of hole +  $\frac{1}{16}$  in.) +  $\frac{s^2}{4g}$

**Length correction :  $s^2/4g$**

**$s$  = spacing of bolt in the direction of load.**

**$g$  = spacing of bolts in the direction perpendicular to load.**

# Staggered Holes: Example-1

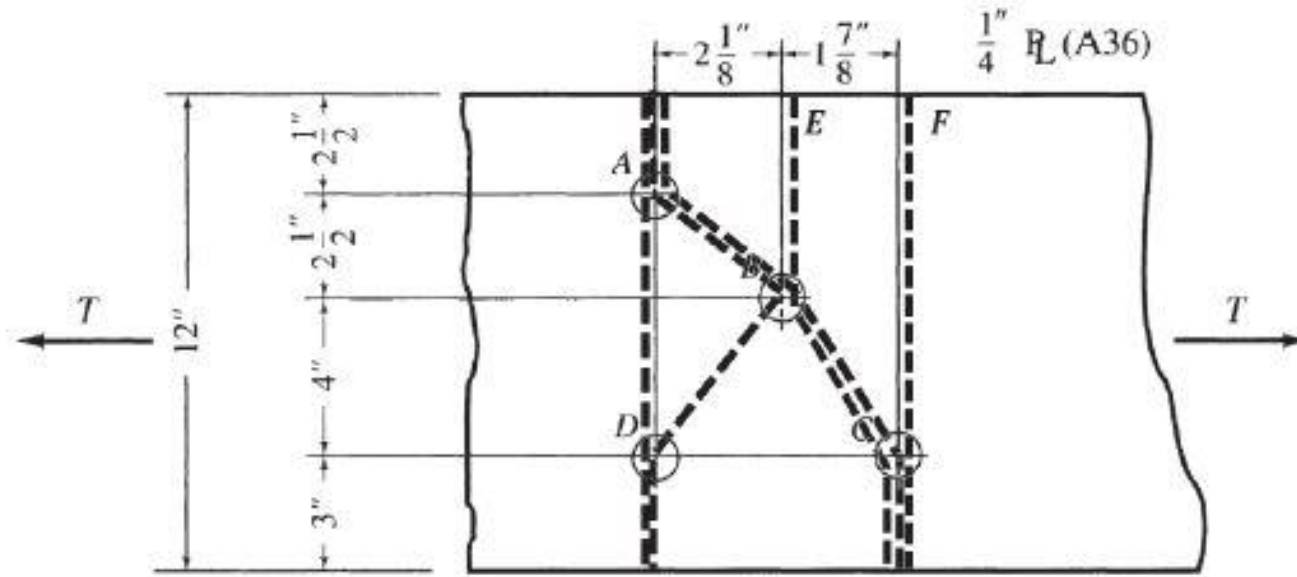


Plate is under tension from both sides. Failure line shall be investigated from both sides. Failure line shall be such that intact bolts may not be present on both sides of the failure line.

**Given:**  
Bolt hole  
dia.  $\frac{15}{16}$ "

$$\text{Path AD} \quad \left[ 12 - 2 \left( \frac{15}{16} + \frac{1}{16} \right) \right] 0.25 = 2.50 \text{ sq in.}$$

$$\text{Path ABD} \quad \left[ 12 - 3 \left( \frac{15}{16} + \frac{1}{16} \right) + \frac{(2.125)^2}{4(2.5)} + \frac{(2.125)^2}{4(4)} \right] 0.25 = 2.43 \text{ sq in.}$$

$$\text{Path ABC} \quad \left[ 12 - 3 \left( \frac{15}{16} + \frac{1}{16} \right) + \frac{(2.125)^2}{4(2.5)} + \frac{(1.875)^2}{4(4)} \right] 0.25 = 2.42 \text{ sq in. (controls)}$$

**Other possible paths: EBC and FC (do not control)**

## Staggered Holes: Example-2

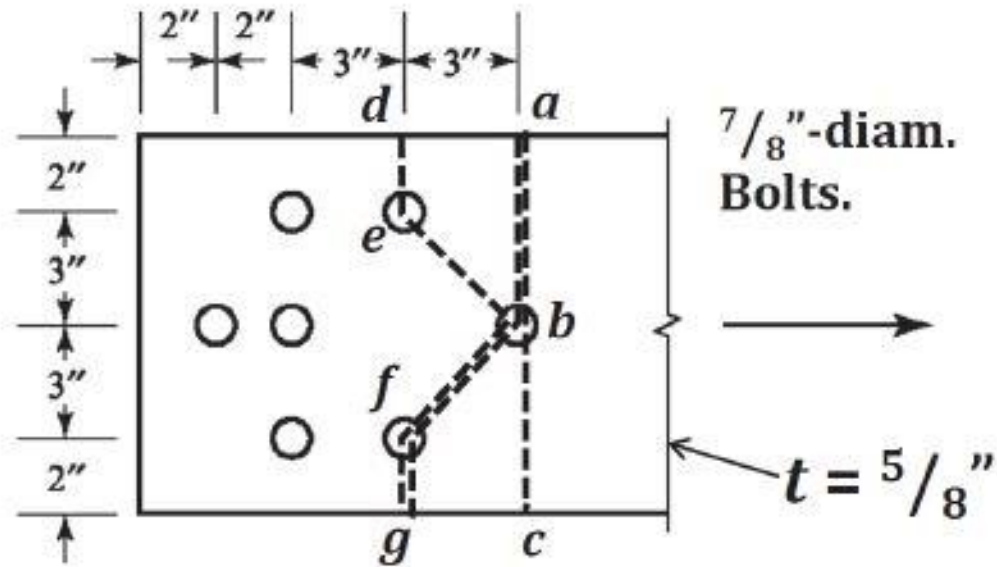


Plate is under tension from one side only. Failure line shall be investigated from loaded side only. Failure line shall be such that intact bolts may not be present on both sides of the failure line.

Valid failure lines/paths:

Path  $a-b-c$ :  $[10 - (7/8 + 1/8)]^{5/8} = 5.625 \text{ in}^2$ .

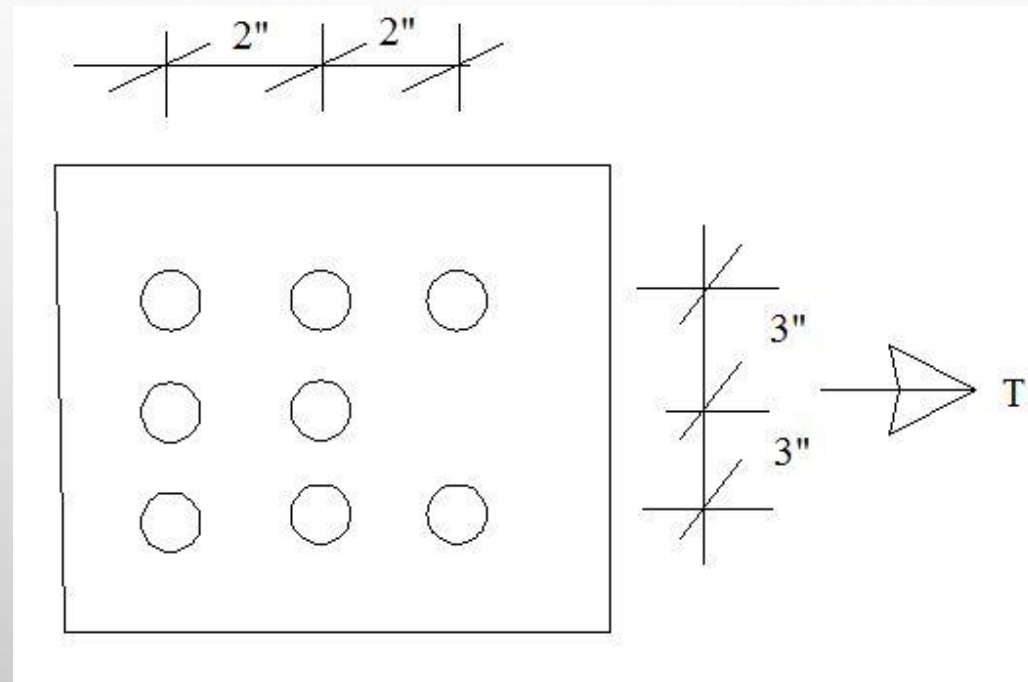
Path  $a-b-f-g$ :  $[10 - 2(7/8 + 1/8) + 3^2/(4 \times 3)]^{5/8} = 5.469 \text{ in}^2$ . (also  $d-e-b-c$ )

Path  $d-e-b-f-g$ :  $[10 - 3(7/8 + 1/8) + 2 \times 3^2/(4 \times 3)]^{5/8} = 5.313 \text{ in}^2$ . (Governs)

There is no other valid path since tension is from one side only.

# Assignment Problem

- L 12"X6"X1/2" steel section, bolt diameter = 5/8", width of L-section = 12", calculate failure path.



# □ SUBMIT THE ASSIGNMENT IN MOODLE

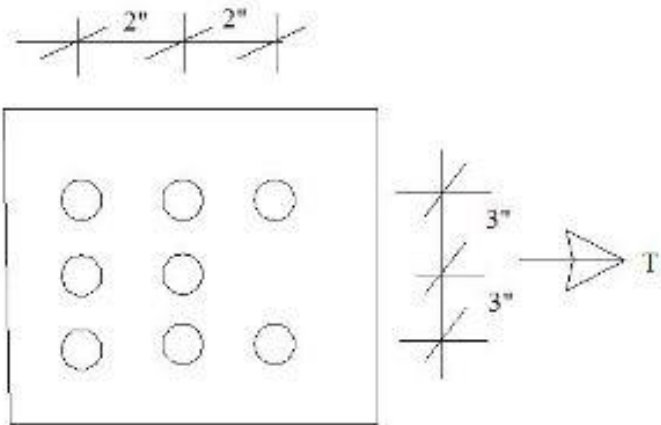
SB- Assignment on 18.5.20 Lecture

Edit

Not available unless any of:

- You belong to 172DE1
- You belong to 172DE2

L 12"x10"x1/2" steel section, bolt diameter = 5/8", width of L-section = 12", calculate failure path.



# SUBMIT THE ASSIGNMENT IN MOODLE

SOLVE THE MATH

WRITE STUDENT ID

TAKE PICTURE OF THE ASSIGNMENT

UPLOAD IT IN THE MOODLE SITE.