CE 415
DESIGN OF STEEL STRUCTURES

LECTURE 2
TENSION MEMBER

SEMESTER: SPRING 2021

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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)

$$\text{Effective hole diameter} = \text{Actual hole diameter} + {}^{1}/_{16}"$$
$$= \text{Bolt diameter} + {}^{1}/_{8}"$$

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.

Effective Net Area $A_e = UA_n$

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

$U = 1.0 - \bar{x}/L$ [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

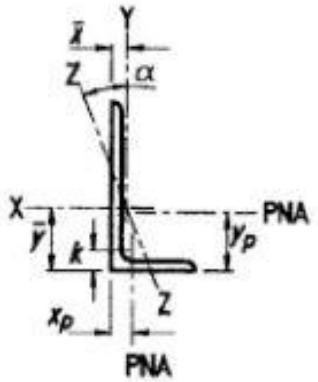


Table 1–7
Angles
Properties

Shape	k	Wt.	Area, A	Axis X-X						Flexural-Torsional Properties		
				I	S	r	$\bar{y}$	Z	y_p	J	C_w	$\bar{r}_o$
	in.	lb/ft	in.^{2}	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.	in.^{4}	in.^{6}	in.
L6×6×1	1 1/2	37.4	11.0	35.4	8.55	1.79	1.86	15.4	0.918	3.68	9.24	3.18
×7/8	1 3/8	33.1	9.75	31.9	7.61	1.81	1.81	13.7	0.813	2.51	6.41	3.21
×3/4	1 1/4	28.7	8.46	28.1	6.64	1.82	1.77	11.9	0.705	1.61	4.17	3.24
×5/8	1 1/8	24.2	7.13	24.1	5.64	1.84	1.72	10.1	0.594	0.955	2.50	3.28
×9/16	1 1/16	21.9	6.45	22.0	5.12	1.85	1.70	9.18	0.538	0.704	1.85	3.29
×1/2	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

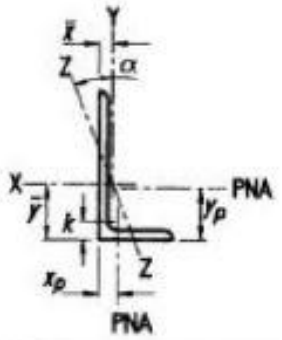
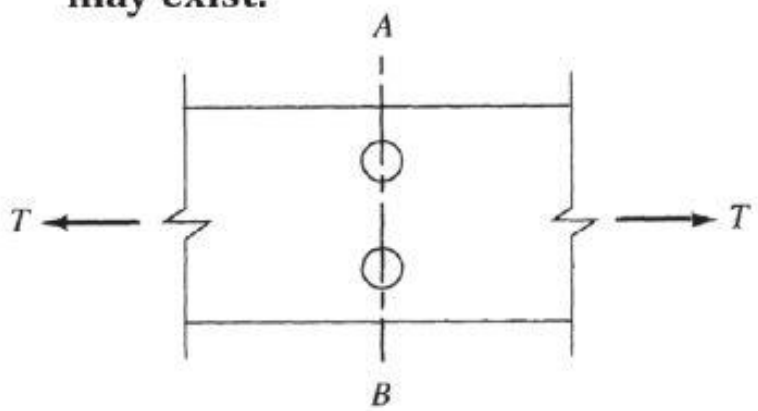


Table 1–7 (continued)
Angles
Properties

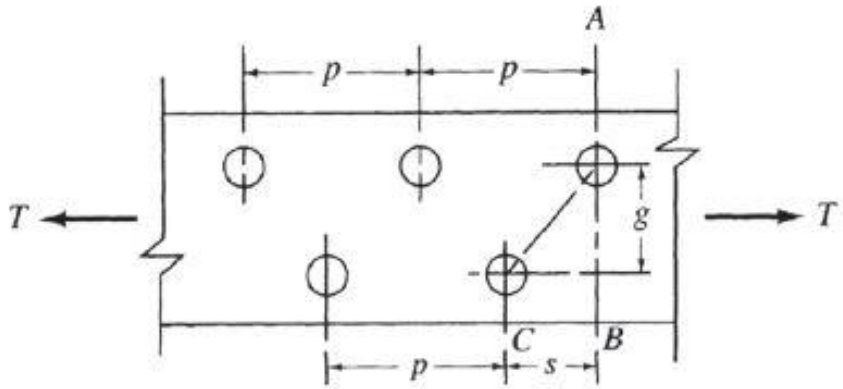
Shape	k	Wt.	Area, A	Axis X-X						Flexural-Torsional Properties		
				I	S	r	$\bar{y}$	Z	y_p	J	C_w	$\bar{r}_o$
	in.	lb/ft	in.^{2}	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.	in.^{4}	in.^{6}	in.
L4×3½×½	⅞	11.9	3.50	5.30	1.92	1.23	1.24	3.46	0.497	0.301	0.302	2.03
×⅜	¾	9.10	2.67	4.15	1.48	1.25	1.20	2.66	0.433	0.132	0.134	2.06
×5/16	11/16	7.70	2.25	3.53	1.25	1.25	1.17	2.24	0.401	0.0782	0.0798	2.08
×¼	⅝	6.20	1.81	2.89	1.01	1.26	1.14	1.81	0.368	0.0412	0.0419	2.09
L4×3×⅝	1	13.6	3.89	6.01	2.28	1.23	1.37	4.08	0.810	0.529	0.472	1.91
×½	⅞	11.1	3.25	5.02	1.87	1.24	1.32	3.36	0.747	0.281	0.255	1.94
×⅜	¾	8.50	2.48	3.94	1.44	1.26	1.27	2.60	0.683	0.123	0.114	1.97
×5/16	11/16	7.20	2.09	3.36	1.22	1.27	1.25	2.19	0.651	0.0731	0.0676	1.98
×¼	⅝	5.80	1.69	2.75	0.988	1.27	1.22	1.77	0.618	0.0386	0.0356	1.99
L3½×3½×½	⅞	11.1	3.25	3.63	1.48	1.05	1.05	2.66	0.466	0.281	0.238	1.87
×7/16	13/16	9.80	2.87	3.25	1.32	1.06	1.03	2.36	0.412	0.192	0.164	1.89
×⅜	¾	8.50	2.48	2.86	1.15	1.07	1.00	2.06	0.357	0.123	0.106	1.90
×5/16	11/16	7.20	2.09	2.44	0.969	1.08	0.979	1.74	0.301	0.0731	0.0634	1.92
×¼	⅝	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.



(a)



(b)

For (b)

$$\text{Net length of } A\text{–}B = \text{length of } (A\text{–}B) - \left(\text{width of hole} + \tfrac{1}{16}\text{ in.}\right)$$

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

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

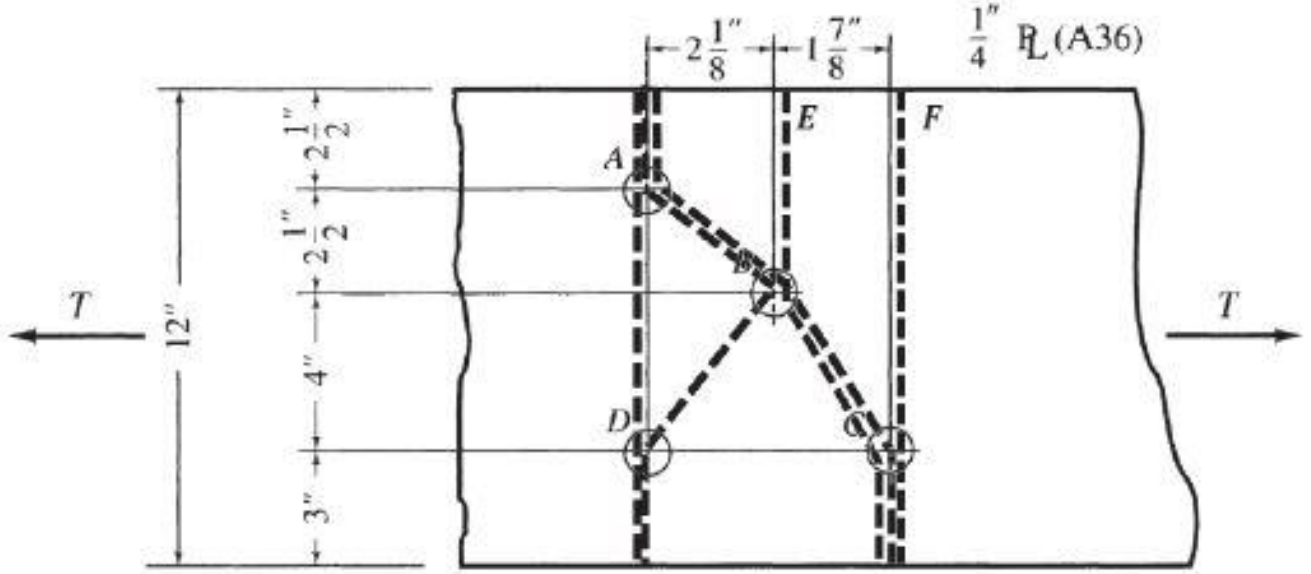


Plate is under tension form both sides. Failure line shall be investigated from both sides. Failure line shall be such that intact bolts may not be present on both sides of the failure line.

Given:
Bolt hole dia. $^{15}/_{16}$"

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

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

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

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

Staggered Holes: Example-2

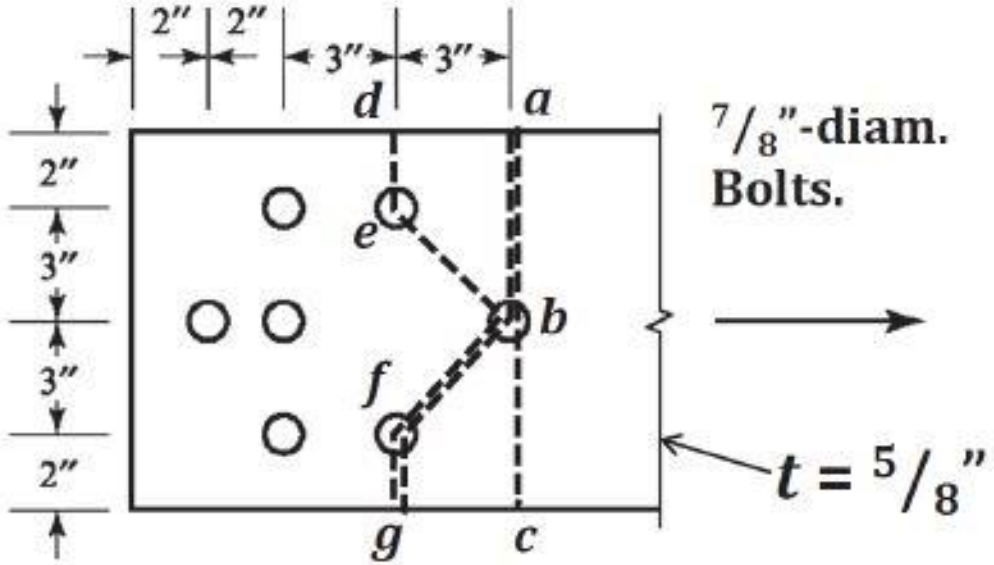


Plate is under tension form one side only. Failure line shall be investigated from loaded side only. Failure line shall be such that intact bolts may not be present on both sides of the failure line.

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*: $[10 - 2(7/8 + 1/8) + 3^2/(4\times3)]\,5/8 = 5.469\ \text{in}^2$. (also *d-e-b-c*)

Path *d-e-b-f-g*: $[10 - 3(7/8 + 1/8) + 2\times3^2/(4\times3)]\,5/8 = 5.313\ \text{in}^2$. (Governs)

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