EFFECTIVE NET AREA

Introduction to shear lag.

For some tension members, such as rolled shapes, that do not have all elements of the cross section connected to the supporting members, the failure load is less than would be predicted by the product $A_n F_u$. The phenomenon to which this situation is generally attributed is called *shear lag* and is illustrated in Figure 2-9. Note that the angle is connected along only one leg. This leads to a concentration of stress along that leg and leaves part of the unconnected leg unstressed or stressed very little. Studies have shown that the shear lag effect diminishes as the length of the connection is increased.

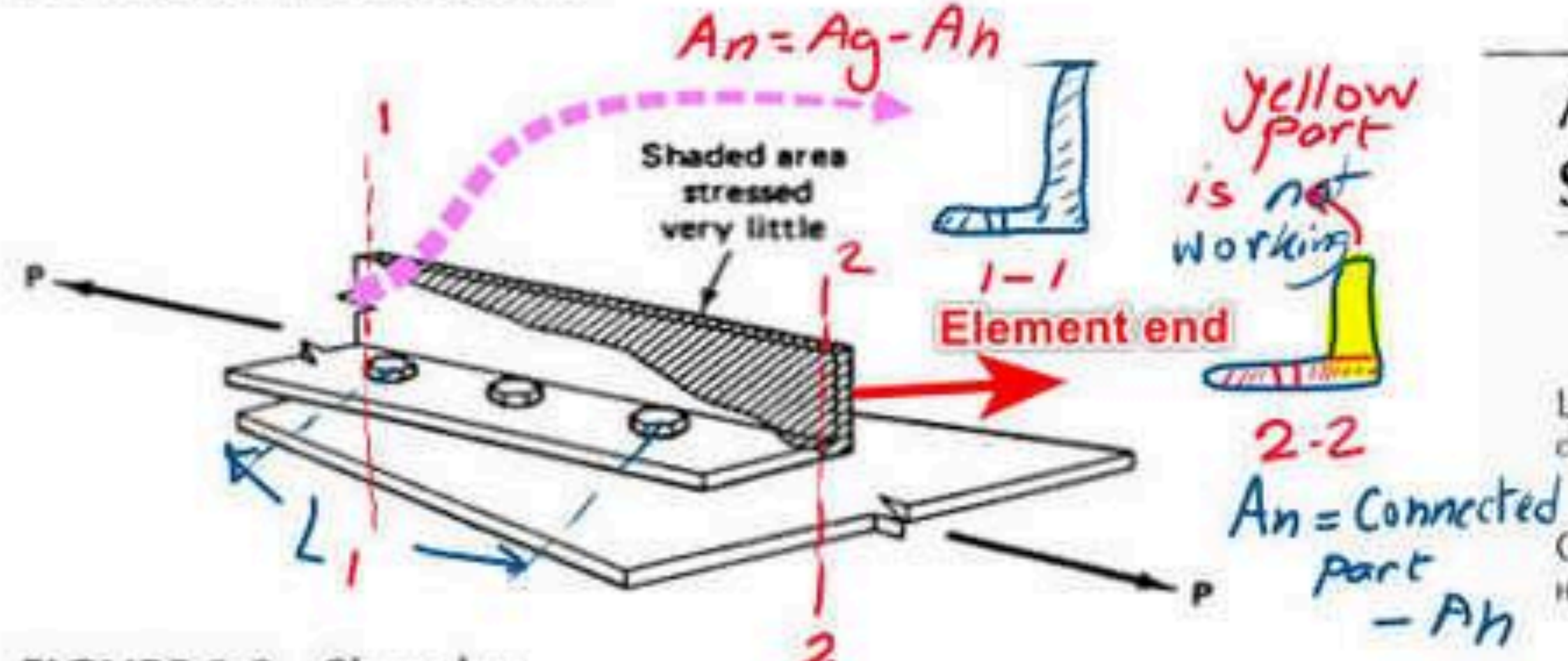

FIGURE 2-9 Shear lag.

Applied Structural Steel Design

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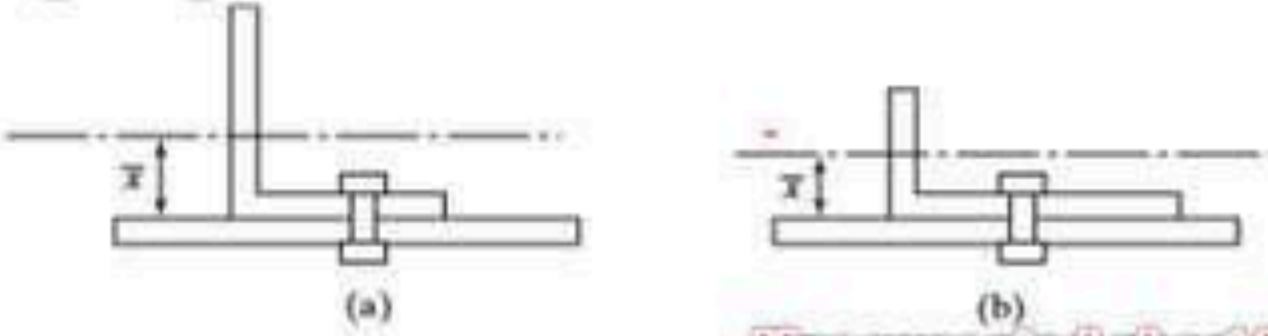
In the transition region the stress in the connected part of the member may very well exceed F_y and go into the strain-hardening range. Unless the load is reduced, the member may fracture prematurely. The farther we move out from the connection, the more uniform the stress becomes. In the transition region, the shear transfer has "lagged" and the phenomenon is referred to as *shear lag*.

Investigators have found that one measure of the effectiveness of a member such as an angle connected by one leg is the distance $\bar{x}$ measured from the plane of the connection to the centroid of the area of the whole section.[2,3] The smaller the value of $\bar{x}$, the larger is the effective area of the member, and thus the larger is the member's design strength.

Unconneted Longer leg decreases U value

FIGURE 3.10

Reducing shear lag by reducing length of unconnected leg and and thus $\bar{x}$.



Unconnected short leg improves U value

Another measure of the effectiveness of a member is the length of its connection, L. The greater this length, the smoother will be the transfer of stress to the member's unconnected parts. In other words, if 3 bolts at 3 inches on center are used, the effective area of the member will be less than if 3 bolts at 4 inches on center are used.

The effect of these two parameters, $\bar{x}$ and L, is expressed empirically with the reduction factor

Equation for shear lag factor U

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

specs

Min U value = Area Connected / Total area

D3. EFFECTIVE NET AREA

The gross area, A_g, and net area, A_n, of tension members shall be determined in accordance with the provisions of Section B4.3.

The effective net area of tension members shall be determined as

$$A_e = A_n U \qquad \text{(D3-1)}$$

where U, the shear lag factor, is determined as shown in Table D3.1.

For open cross sections such as W, M, S, C, or HP shapes, WTs, STs, and single and double angles, the shear lag factor, U, need not be less than the ratio of the gross area of the connected element(s) to the member gross area. This provision does not apply to closed sections, such as HSS sections, nor to plates.

open cross sections

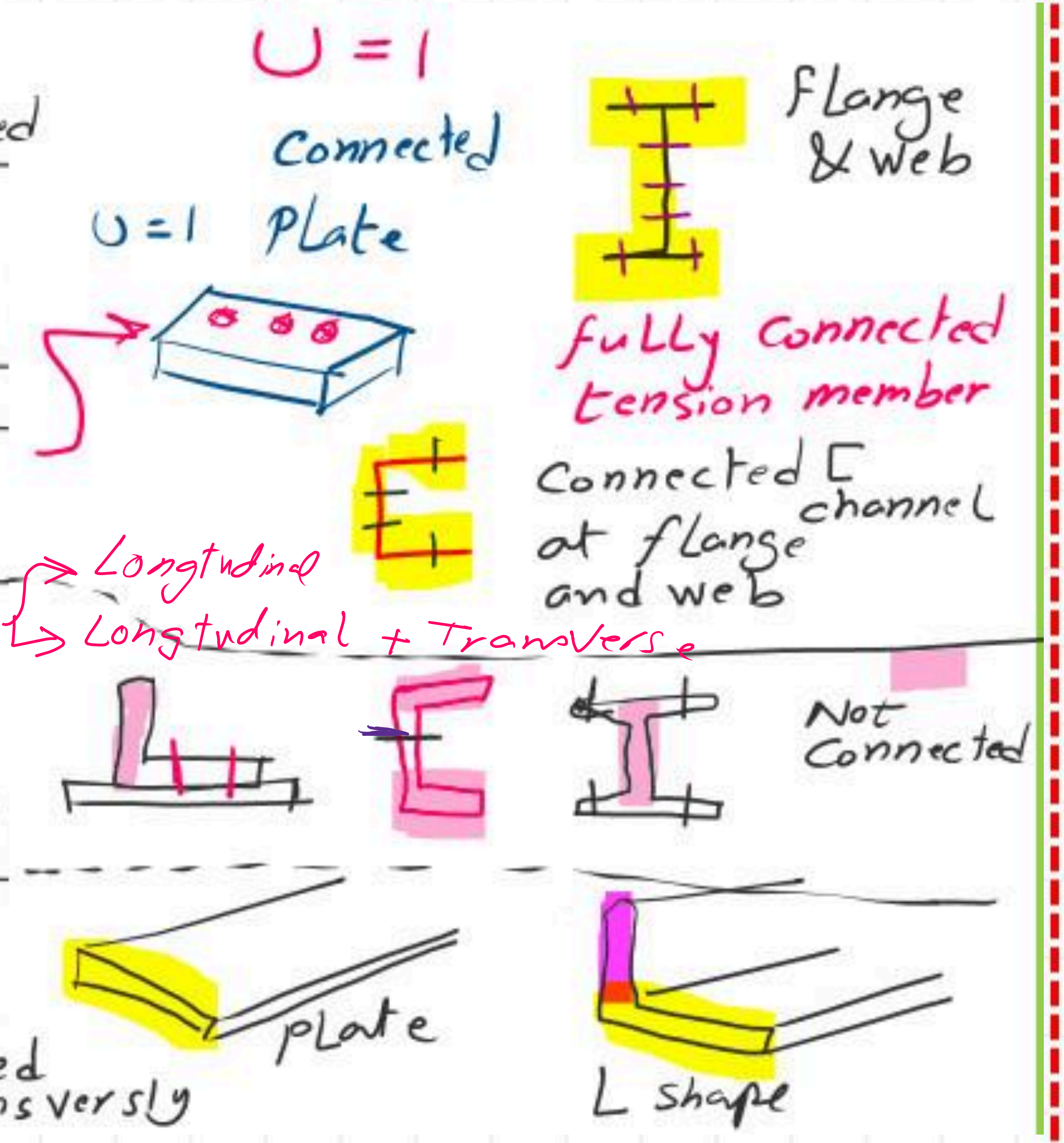
HSS

Not applicable to plates

CM # 14

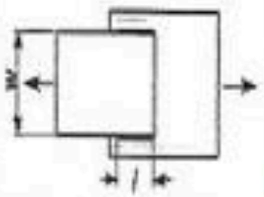
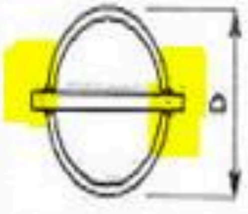
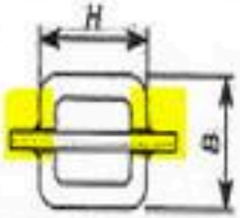
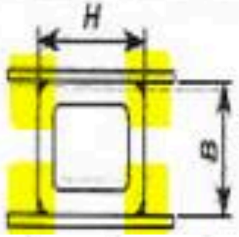
TABLE D3.1
Shear Lag Factors for Connections to Tension Members

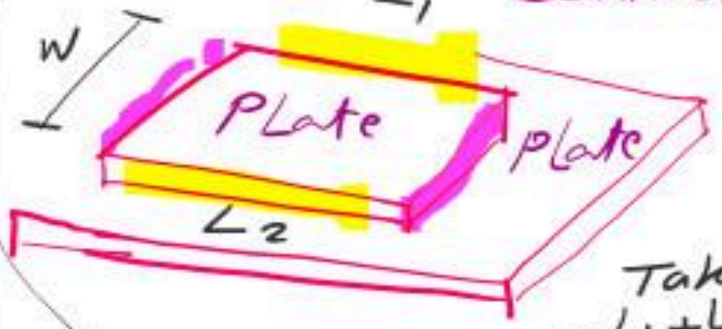
Case	Description of Element	Shear Lag Factor, U	Example
1	All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).	$U = 1.0$	—
2	All tension members, except plates and HSS, where the tension load 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	—



CM#14

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

Case	Description of Element	Shear Lag Factor, U	Example
4	Plates where the tension load is transmitted by longitudinal welds only.	$l \geq 2w ... U = 1.0$ $2w > l \geq 1.5w ... U = 0.87$ $1.5w > l \geq w ... U = 0.75$	
5	Round HSS with a single concentric gusset plate	$l \geq 1.3D ... U = 1.0$ $D \leq l < 1.3D ... U = 1 - \bar{x}/l$ $\bar{x} = D/\pi$	
6	Rectangular HSS — with a single concentric gusset plate	$l \geq H ... U = 1 - \bar{x}/l$ $\bar{x} = \frac{B^2 + 2BH}{4(B+H)}$	
	Rectangular HSS — with two side gusset plates	$l \geq H ... U = 1 - \bar{x}/l$ $\bar{x} = \frac{B^2}{4(B+H)}$	



Connected

Not Connected

Take L = $\frac{L_1 + L_2}{2}$ average

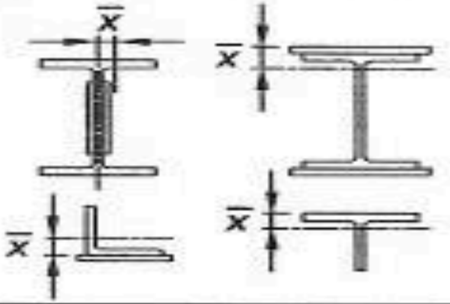
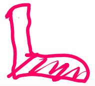
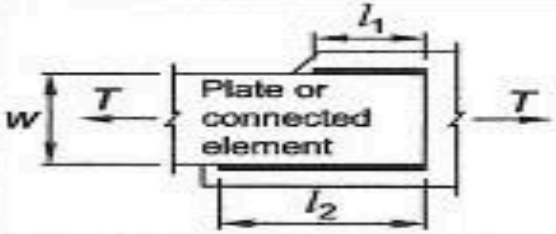
→ values were adapted in AISC-360-16

HSS

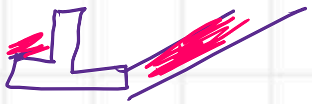
Hollow Structural Sections

CH #15 2016 specs → same as 2010

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

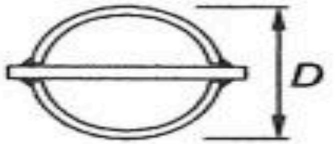
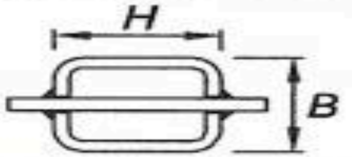
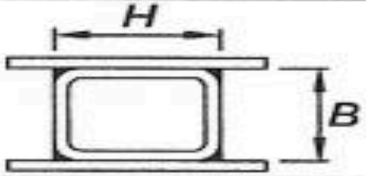
Case	Description of Element	Shear Lag Factor, U	Example
1	All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).	$U = 1.0$	—
2	All tension members, except HSS, where the tension load is transmitted to some but not all of the cross-sectional elements by fasteners or by longitudinal welds in combination with transverse welds. Alternatively, Case 7 is permitted for W, M, S and HP shapes. (For angles, Case 8 is permitted to be used.)	$U = 1 - \frac{\bar{x}}{l}$ Longtudinal + Transverse	
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[a]	Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of $\bar{x}$. Plates, angle, channel, WT, W section	$U = \frac{3l^2}{3l^2 + w^2}\left(1 - \frac{\bar{x}}{l}\right)$ Factor Change	

New item



CM # 14 & CM # 15

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

Case	Description of Element		Shear Lag Factor, U	Example
5	Round HSS with a single concentric gusset plate through slots in the HSS.		$l \geq 1.3D,\ U = 1.0$ $D \leq l < 1.3D,\ U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{D}{\pi}$	
6	Rectangular HSS.	with a single concentric gusset plate	$l \geq H,\ U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{B^2 + 2BH}{4(B+H)}$	
		with two side gusset plates	$l \geq H,\ U = 1 - \frac{\bar{x}}{l}$ $\bar{x} = \frac{B^2}{4(B+H)}$	
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 three or more fasteners per line in the direction of loading	$b_f \geq \frac{2}{3}d,\ U = 0.90$ $b_f < \frac{2}{3}d,\ U = 0.85$	–
		with web connected with four or more fasteners per line in the direction of loading	$U = 0.70$	–

CM # 14, CM # 15

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

Case	Description of Element		Shear Lag Factor, *U*	Example
8	Single and double angles. (If *U* is calculated per Case 2, the larger value is permitted to be used.)	with four or more fasteners per line in the direction of loading	$U = 0.80$	–
		with three fasteners per line in the direction of loading (with fewer than three fasteners per line in the direction of loading, use Case 2)	$U = 0.60$	–

Four Fastners in a Line

B = overall width of rectangular HSS member, measured 90° to the plane of the connection, in. (mm); D = outside diameter of round HSS, in. (mm); H = overall height of rectangular HSS member, measured in the plane of the connection, in. (mm); d = depth of section, in. (mm); for tees, d = depth of the section from which the tee was cut, in. (mm); l = length of connection, in. (mm); w = width of plate, in. (mm); $\bar{x}$ = eccentricity of connection, in. (mm).

[a] $l = \dfrac{l_1 + l_2}{2}$, where l_1 and l_2 shall not be less than 4 times the weld size.

EXAMPLE 4-1

U-Value for a Bolted Connection

For the bolted tension member shown in Figure 4-6, determine the shear lag factor, U; the net area, A_n; and the effective area, A_e.

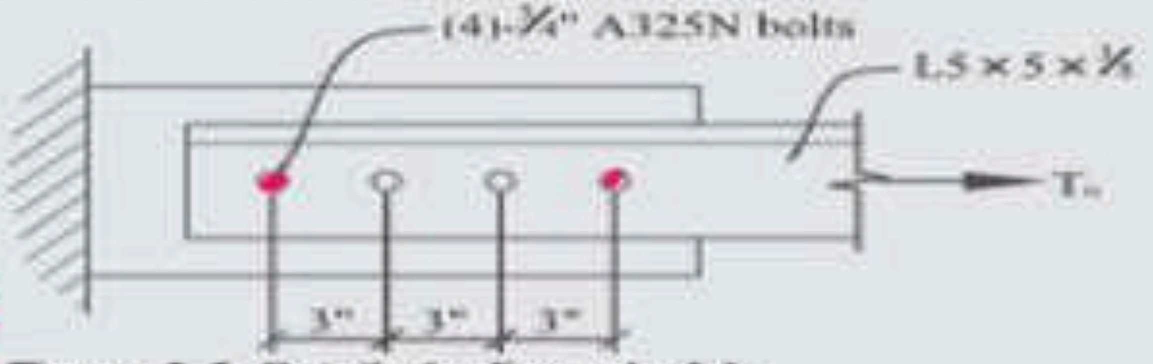
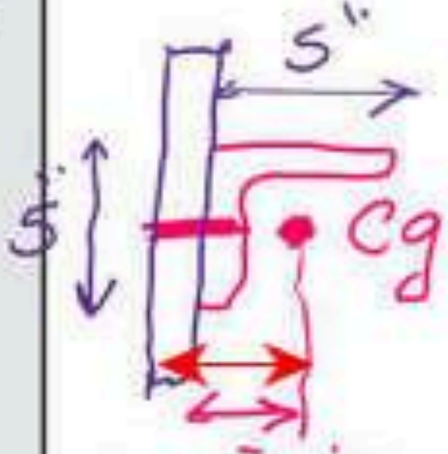


Figure 4-6 Details for Example 4-1.

L → 1st → Last Fastner



Solution $d_b = 3/4"$ ← L → diameter for design ⇒ $d_h = \frac{3}{4} + \frac{1}{8} = 7/8"$

x // Unconnected Leg $5" \times 5" \times \frac{3}{8}"$ $A = 3.65$ inch²

$\bar{x}$ c.g to connected part part edge

$U = \left(1 - \frac{\bar{x}}{L}\right) = \left(1 - \frac{1.37}{3(3)}\right) = 0.848$ shear lag factor

U from table = 0.80

Select the Larger Value

Prepared by Eng.Maged Kamel.

L 5x5x3/8

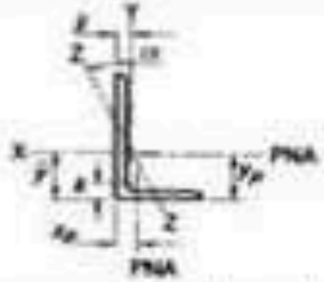
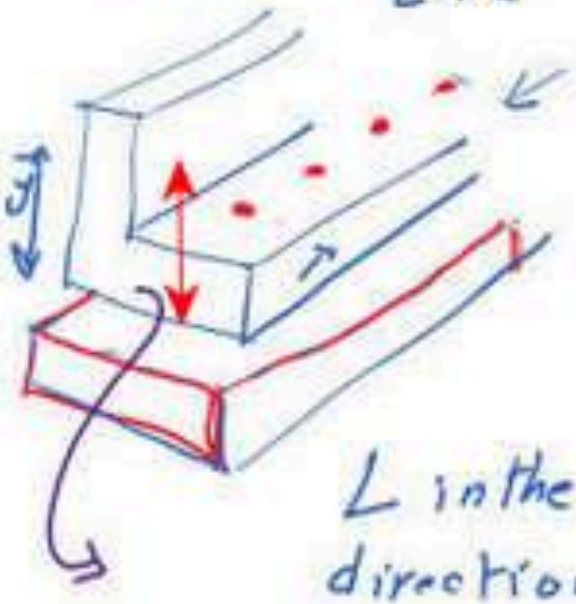


Table 1-7 (continued)
Angles
Properties

Data

Shape	k	Wt.	Area, A	I	S	r	$\bar{y}$	Z	y_p	J	C_w	$\bar{r}_o$
				Axis X-X						Flexural-Torsional Properties		
	in.	lb/ft	in.^{2}	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.	in.^{4}	in.^{6}	in.
L5×5×7/8	1 3/8	27.2	8.00	17.8	5.16	1.49	1.56	9.31	0.800	2.07	3.53	2.64
×3/4	1 1/4	23.6	6.98	15.7	4.52	1.50	1.52	8.14	0.698	1.33	2.32	2.67
×5/8	1 1/8	20.0	5.90	13.6	3.85	1.52	1.47	6.93	0.590	0.792	1.40	2.70
×1/2	1	16.2	4.79	11.3	3.15	1.53	1.42	5.66	0.479	0.417	0.744	2.73
×7/16	15/16	14.3	4.22	10.0	2.78	1.54	1.40	5.00	0.422	0.284	0.508	2.74
×3/8	7/8	12.3	3.65	8.76	2.41	1.55	1.37	4.33	0.365	0.183	0.327	2.76
×5/16	13/16	10.3	3.07	7.44	2.04	1.56	1.35	3.65	0.307	0.108	0.193	2.77

$\bar{y}$ ⊥er to Connectio Line



L in the direction of Force.

1.37"

↳ Use as $\bar{x}$ in Equation

$\bar{y}$ Distance to Connected part

Prepared by Eng.Maged Kamel.

$L\ 5 \times 5 \times 3/8''$ $\quad t = 3/8''$

$A_{eff} = U \cdot A_{net}$ for bolted.

$d_h\ t\ L$

$A_{net} = A_{gross} - \phi t = 3.65 - (1)(\frac{7}{8})(\frac{3}{8}) = 3.32\ \text{inch}^2$

$U \quad A_{net}$

$A_{eff} = 0.848(3.32) = 2.82\ \text{inch}^2$

↳ Higher value

> 0.80 from

↳ Table item 8

Final effective area