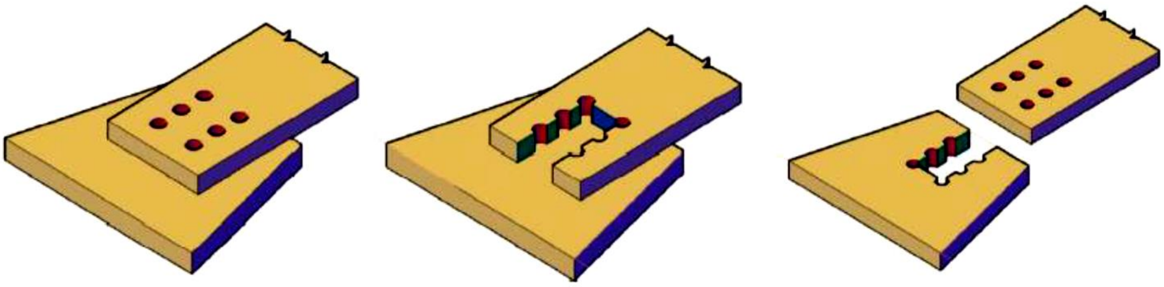
2.4 Block shear failure

For certain connection configurations, a segment or "block" of material at the end of the member can tear out.



Tension member   Block shear in Member   Block shear in Gusset Plate

The available strength according to AISC Specifications is:

$$R_n = 0.6\, F_u\, A_{nv} + U_{bs}\, F_u\, A_{nt} \;\leq 0.6\, F_y\, A_{gv} + U_{bs}\, F_u\, A_{nt}$$

$$P_{bs} = \emptyset\, R_n$$

where:

$\emptyset = 0.75$

R_n: block shear available strength

P_{bs}: block shear rupture strength

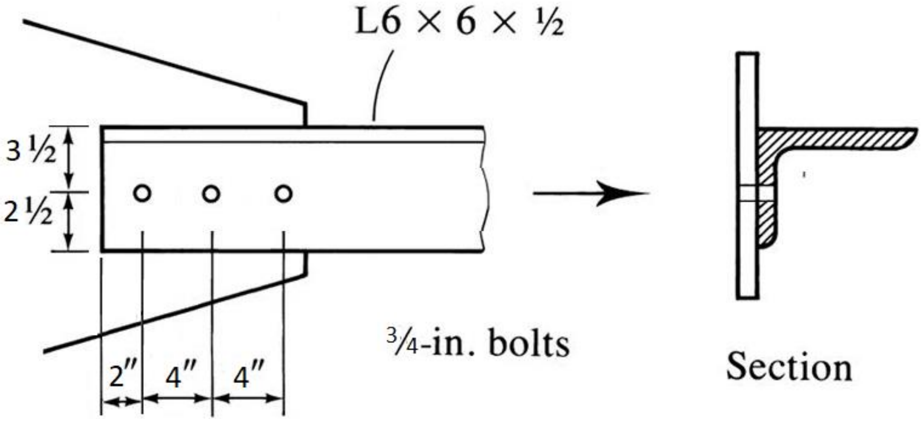
A_{gv}: Gross area subjected to shear

A_{nv}: Net area subjected to shear

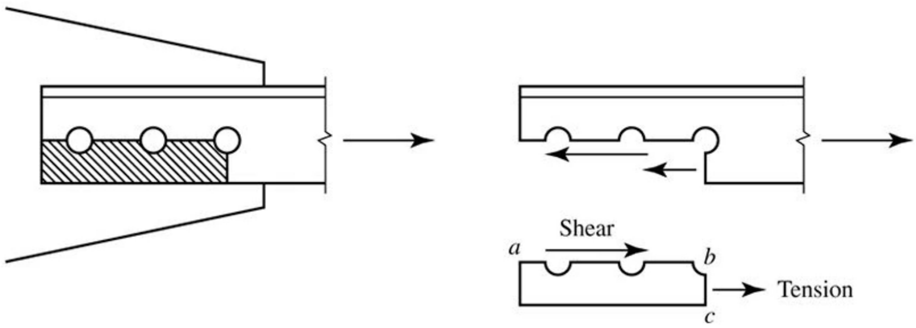
A_{nt}: Net area subjected to tension

U_{bs}: Block shear factor always equal 1.

Example No. 1: A steel angle $\boldsymbol{L6 \times 6 \times \frac{1}{2}}$ using **A36** steel is subjected to tensile load. Determine the block shear rupture strength.

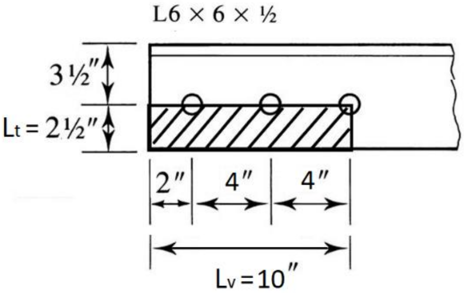


Solve:



Steel and Section Properties

$Fy = 36\ ksi, Fu = 58\ ksi\ (Table\ 2-3)$



$L_v = 2 + 4 + 4 = 10''$

$L_t = 2.5''$

$\boldsymbol{A_{gv}} =$ **gross area subjected to shear** $(\boldsymbol{in^2})$

$$A_{gv} = L_v \cdot t = 10 \times \frac{1}{2} = 5\ in^2$$

$\boldsymbol{A_{nv}} =$ **net area subjected to shear** $(\boldsymbol{in^2})$

$$A_{nv} = \boldsymbol{A_{gv}} - \boldsymbol{A_{hole}} = L_v \cdot t - n\ d_h \cdot t$$

$$A_{nv} = 5 - 2.5\left(\frac{3}{4}+\frac{1}{8}\right)\times\frac{1}{2} = 3.91\ in^2$$

$\boldsymbol{A_{nt}} =$ **net area subjected to tension** $(\boldsymbol{in^2})$

$$\boldsymbol{A_{nt}} = \boldsymbol{A_{gt}} - \boldsymbol{A_{hole}} = L_t \cdot t - n\, d_h \cdot t$$

$$A_{nt} = 2.5\times\frac{1}{2} - 0.5\left(\frac{3}{4}+\frac{1}{8}\right)\times\frac{1}{2} = 1.03\ in^2$$

$\boldsymbol{R_n}$**: block shear available strength**

$$R_n = 0.6\,F_u\,A_{nv} + U_{bs}\,F_u\,A_{nt} = 0.6\times 58\times 3.91 + 1\times 58\times 1.03$$

$$R_n = 195.8\ kips$$

OR

$$R_n = 0.6\,F_y\,A_{gv} + U_{bs}\,F_u\,A_{nt} = 0.6\times 36\times 5 + 1\times 58\times 1.03$$

$R_n = 167.7\ kips$ (***Control***)

Choose small value $R_n = 167.7\ kips$

$\boldsymbol{P_{bs}}$**: block shear rupture strength**

$$P_{bs} = \emptyset\,R_n = 0.75\times 167.7 = 125.8\ kips$$

2.5 Slenderness Ratio

To prevent the local sagging of the tension member, there is a maximum limitation to the length (L) of the member which depends on the minimum radius of gyration (r).

$$\frac{\boldsymbol{L}}{\boldsymbol{r_{min}}} \le \mathbf{300}$$

Example: For the previous example, compute the maximum permissible length of the tension member.

Solve:

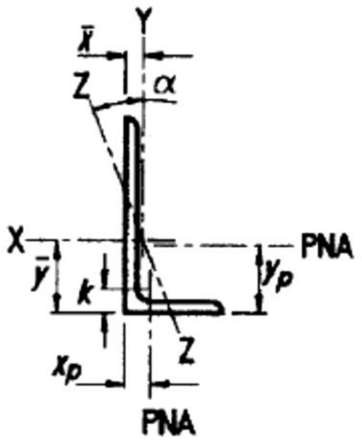
Section properties $\boldsymbol{L6\times 6\times \frac{1}{2}}$

$r_x = 1.86\ in$

$r_y = 1.86\ in$

$r_z = 1.18\ in$

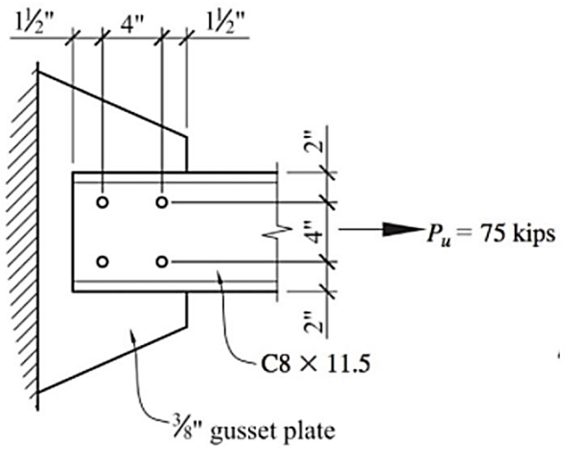
$L_{maximum} \le 300 \times 1.18 = 354\ in = 29.5\ ft$

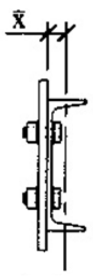


Example No. 2: The channel is ASTM **A36**; it is connected with four **5/8 ''** diameter bolts.

a) Determine if the channel is adequate for the applied tension load shown in Figure. Neglect block shear.

b) Determine if the channel is adequate for the applied tension load considering block shear.





Solve:

a) If the channel is adequate for the applied tension load. Neglect block shear.

1) Steel and Section Properties

$Fy =\ 36\ ksi, Fu =\ 58\ ksi\ (Table\ 2-3)$

$Ag =\ 3.37\ in^2,\ \ tw =\ 0.22'',\ \ \bar{x} = 0.572\ ''$

2) Ultimate Applied Load

$Pu = 75\ kips$

3) Design strength

$\emptyset t\ Pn \geq\ Pu$

From gross area:

$\emptyset t\ Pn = 0.9\ Fy\ Ag = 0.9 \times 36 \times 3.37$

$\emptyset t\ Pn = 109\ kips > 75\ kips \quad \therefore$ ***ok***

From effective area:

$\emptyset t\ Pn = 0.75\ Fu\ Ae$

$Ae = U \cdot An$

$$U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{0.572}{4} = 0.857''$$

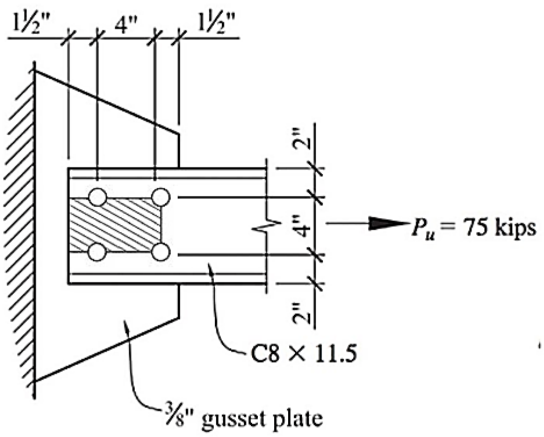
$An = Ag - n\ d_h\ t$

$$An = 3.37 - 2 \times \left(\frac{5}{8} + \frac{1}{8}\right) \times 0.22 = 3.04\ in^2$$

$Ae = 0.857 \times 3.04 = 2.61\ in^2$

$\emptyset t\ Pn = 0.75 \times 58 \times 2.61 = 113 > 75\ kips \quad \therefore$ ***ok***

b) If the channel is adequate for the applied tension load considering block shear.



1) Steel and Section Properties

$Fy = 36\ ksi, Fu = 58\ ksi\ (Table\ 2-3)$

$L_v = 2(4+1.5) = 11''$

$L_t = 4''$

$A_{gv} = L_v \cdot t = 11 \times 0.22 = 2.42\ in^2$

$A_{nv} = \boldsymbol{A_{gv}} - \boldsymbol{A_{hole}}$

$A_{nv} = L_v \cdot t - n\ d_h \cdot t$

$= 2.42 - 3\left(\frac{5}{8}+\frac{1}{8}\right) \times 0.22 = 1.92\ in^2$

$\boldsymbol{A_{nt}} = \boldsymbol{A_{gv}} - \boldsymbol{A_{hole}}$

$A_{nt} = L_t \cdot t - n\ d_h \cdot t$

$= 4 \times 0.22 - 1\left(\frac{5}{8}+\frac{1}{8}\right) \times 0.22 = 0.715\ in^2$

$R_n = 0.6\ F_u\ A_{nv} + U_{bs}\ F_u\ A_{nt} = 0.6 \times 58 \times 1.92 + 1 \times 58 \times 0.715$

$R_n = 108.3\ kips$

OR

$R_n = 0.6\ F_y\ A_{gv} + U_{bs}\ F_u\ A_{nt} = 0.6 \times 36 \times 2.42 + 1 \times 58 \times 0.715$

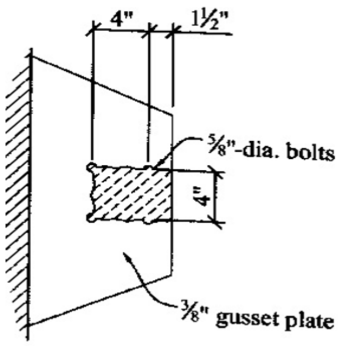
$R_n = 93.74\ kips$ (***Control***)

$P_{bs} = \emptyset\ R_n = 0.75 \times 93.74 = 70.31\ kips < 75\ kips$ ***Not ok***

∴ So the channel is not adequate in block shear

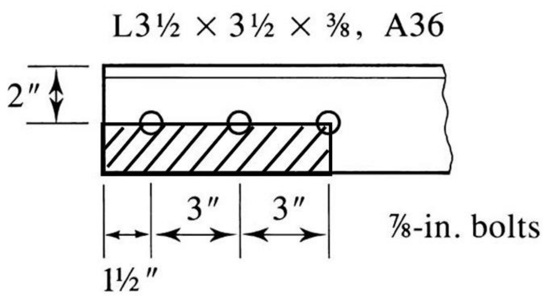
H.W:

1) For the previous example **(b)**, Determine if the gusset plate is adequate for the applied tension load considering block shear.



Ans: $P_{bs} = 119\ kips\ >\ 75\ kips$

2) Determine the block shear strength for the following section.



Ans: $P_{bs} = 61.88\ kips$