All problems are to be done according to the AISC Steel Construction Manual, 13th Edition. Assume fastener strength is adequate and does not control. All holes are standard holes. Values of yield stress $F_Y$ and tensile strength $F_u$ are available in AISC p. 2-39. Where needed, assume distances from center of hole to end of piece are 1-1/2 in. When the load is transmitted through some but not all cross-sectional elements be sure to use the correct reduction coefficient $U$ according to AISC D3.3.

### Workable gages in angle legs, in.

<table>
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<th>1.375</th>
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3.1 A WT8x25 tension member is to carry a tension load $T$ that is comprised of 25 percent dead load and 75 percent live load. It is connected using one gage line of six 3/4-in.-diameter bolts in standard holes spaced 3 in. on centers in the stem of the tee as shown. Compute the permissible tension load $T$ according to AISC LRFD requirements. Consider the limit states of (a) gross section yielding, (b) net section fracture, and (c) block shear rupture. Use A572 Grade 50 steel.

3.2 Determine the tensile load $T$ permitted by AISC ASD for a pair of angles L 5 x3-1/2 x1/4 attached to a gusset plate as shown in the accompanying figure. Use A36 steel and ¾-in. diameter bolts in standard holes at the locations shown on standard gage lines. Consider (a) gross section yielding, (b) net section fracture, and (c) block shear rupture.

3.3 Determine the tensile load $T$ (comprised of 40 percent dead load and 60 percent live load) permitted by AISC LRFD for a pair of channels C8x13.7 attached to a 3/8-in. gusset plate as shown in the accompanying figure. Use A572 Grade 50 steel for both the channels and the gusset plate and ¾-in. diameter bolts in standard holes at the locations shown. Consider the following limit states (a) gross section yielding of channels, (b) net section fracture of channels, (c) block shear rupture of channels, and (d) block shear rupture of gusset plate.
3.1 \quad A_g = 7.37 \text{ in}^2 \quad t_w = 0.380 \quad (\rho = 1-58)

\underline{A_g-yielding:} \quad \phi P_n = 0.9 (50) \times 7.37 = 331.65 \text{k}

\underline{A_e-fracture:} \quad \frac{x}{L} = 4.5 - 4.5 - 1.89 = 2.61''

\[ U = 1 - \frac{x}{L} = 1 - \frac{2.61}{15} = 0.826 \]

\[ A_n = A_g - dt_w = 7.37 - \frac{7}{8} (0.380) = 7.04 \text{ in}^2 \]

\[ \phi P_n = 0.75 (65) \times 0.826 (7.04) = 283.38 \text{k} \]

**Block Shear Rupture**

\[ A_{gu} = 16.5 (0.380) = 6.27 \text{ in}^2 \]

\[ A_{nt} = \left[3.63 - 0.5 \left(\frac{7}{8}\right)\right] 0.380 \]

\[ A_{nt} = 1.21315 \text{ in}^2 \]

\[ A_{nV} = \left[16.5 - 5.5 \left(\frac{7}{8}\right)\right] 0.380 = 4.44125 \text{ in}^2 \]

\[ R_n = \text{smaller of} \quad \begin{cases} 0.6 (65) 4.44125 + (1) 65 (1.21315) = 252.06 \text{k} \leq \text{controls} \\ 0.6 (50) 6.27 + (1) 65 (1.21315) = 266.95 \text{k} \end{cases} \]

\[ \phi R_n = 0.75 (252.06) = 189.05 \text{k} \quad \text{controls} \]

Since smaller than 331.65 and also 283.38 k,

\[ T_w \leq \phi R_n \]

\[ 1.2 (0.25T) + 1.6 (0.75T) \leq 189.05 \text{k} \]

\[ 1.5 T \leq 189.05 \text{k} \]

\[ T \leq 126.03 \text{k} \quad \text{is the permissible tension} \]
\[ A_g = 2(2.06) = 4.12 \text{ in}^2 \]
\[ 2L = 5 \times 3 \frac{1}{2} \times \frac{1}{4} \]

**Ag - yielding:**
\[ P_{a} = \frac{A_g F_y}{2} = \frac{4.12(36)}{1.67} = 88.814 \text{ k} \]

**Ae - fracture:**
\[ \bar{x} = 0.80 \text{ in} \]
\[ 1 \left( 1 - \frac{\bar{x}}{2} \right) = 1 - \frac{0.80}{2} = 0.9196 \]
\[ A_n (1 \text{ hole}) = 4.12 - \frac{7}{8} \left( \frac{1}{4} \right) 2 = 3.6825 \text{ in}^2 \]
\[ A_n (2 \text{ holes}) = 4.12 - 2 \left( \frac{7}{8} \right) \frac{1}{4} (2) + \frac{2^2}{4} (2) = 3.531 \text{ in}^2 \]

\[ P_{n, \text{ fracture}} = A_n U F_u = 3.531 \left( 58 \right) 0.9196 = 188.32 \text{ k} \]
\[ P_{a, \text{ fracture}} = \frac{P_n}{2} = 94.15 \text{ k} > 88.814 \text{ k} \]

\[ \therefore \text{ yielding is more critical than Ae fracture} \]

**Block shear rupture:**
\[ A_{g v} = (11.5 + \sqrt{2^2 + 1.75^2}) \frac{1}{4} (2) \]
\[ A_{g v} = 7.079 \text{ in}^2 \]
\[ A_{nt} = (1.25 - 0.5 \frac{3}{8}) \frac{1}{4} (2) \]
\[ A_{nt} = 0.40625 \text{ in}^2 \]
\[ A_{nv} = 7.079 - 3.5 \left( \frac{7}{8} \right) \frac{1}{4} (2) = 5.548 \text{ in}^2 \]
3.2 Continued:

\[ R_h = \text{smaller} \left\{ \begin{array}{l}
0.6 (58) 5.548 + (1) 58 (0.40625) = 216.63 \text{k} \\
0.6 (36) 7.079 + (1) 58 (0.40625) = 176.47 \text{k}
\end{array} \right. \]

\[ R_n = \frac{176.47}{2} = 88.23 \text{ k} \quad \text{controls} \]

Allowable loads based on limit states (so far):

- Gross section yielding \( \rightarrow T_a = 88.81 \text{ k} \)
- Net section fracture \( \rightarrow T_a = 98.21 \text{ k} \)
- Block shear rupture \( \rightarrow T_a = 88.23 \text{ k} \)

Block shear rupture controls since 88.23 k is less than the other two.

\[ T = 88.23 \text{ k permitted based on full block shear} \]

Check alternative block shear path with \( \left( \frac{5}{6} \right) T \):

- \( A_{yu} = (7.5 + \sqrt{2^2 + 1.75^2}) \frac{1}{2} (2) = 5.079 \)
- \( A_{ht} = 0.40625 \)
- \( A_{nv} = 5.079 - 2.5 (\frac{7}{8}) \frac{1}{2} (2) = 3.985 \)

\[ R_n = \left\{ \begin{array}{l}
0.6 (58) 3.985 + 58 (0.40625) = 162.24 \rightarrow R_n = \frac{6}{5} (133.27) \\
0.6 (36) 5.079 + 58 (0.40625) = 133.27
\end{array} \right. \]

\[ R_n = 160.0 \text{ k controls} \]

\[ \frac{160}{2} = 80 \text{ k controls} \]

Permissible load is \( T = 80 \text{ k based on } \frac{5}{6} \text{ Block Shear} \)
Check with alternative Block Shear Path on $\frac{3T}{6}$

\[ A_{\sigma} = 9.5 \left( \frac{1}{4} \right)^2 = 4.75 \]
\[ A_{nt} = 0.40625 \]
\[ A_{nu} = \left[ 9.5 - 2.5 \left( \frac{2}{3} \right) \right] \frac{1}{4}(2) = 3.65625 \]

\[ \frac{3}{6} R_n = \begin{cases} 0.6(58)3.65625 + 58(0.40625) = 150.8 \\ 0.6(36)4.75 + 58(0.40625) = 126.1625 \end{cases} \]

\[ R_n = \frac{6}{3}(126.16) = 252.33 \text{ k} \text{ does not control} \]
3.3 \( A_g = 2(4.04) = 8.08 \text{ in}^2 \) (p. 1-34)

Ag-yielding: \( \Phi P_h = 0.9 (50) 8.08 = 363.6 \text{ k} \)

Ae-fracture: \( x = 0.1554 '' \rightarrow U = 1 - \frac{x}{L} = 1 - \frac{0.1554}{6} = 0.9076 \)

\( \Phi P_h = 0.75 (65) 0.9076 (8.08 - 2 \left( \frac{7}{8} \right) 0.303(2)) = 310.6 \text{ k} \)

Net section fracture more important than yielding.

Block shear rupture of channels

\[ A_{qv} = 16(0.303)2 = 9.696 \text{ in}^2 \]
\[ A_{nt} = \left( 4 - \frac{7}{6} \right) (0.303)2 = 1.894 \text{ in}^2 \]
\[ A_{nv} = 9.696 - 5 \left( \frac{7}{8} \right) (0.303)2 \]
\[ A_{ntc} = 7.04475 \text{ in}^2 \]

\[ R_h = \begin{cases} 0.6(65)7.04475 + (1)65(1.894) = 397.86 \text{ k} & \text{smaller governs} \cr 0.6(50)9.696 + (1)65(1.894) = 414.0 \text{ k} & \end{cases} \]

\( \Phi R_h = 0.75 (397.86) = 298.4 \text{ k} \) controls so far

Block shear rupture of gusset plate

\[ A_{qv} = 18 \left( \frac{3}{8} \right) = 6.75 \text{ in}^2 \]
\[ A_{nt} = \left( 4 - \frac{7}{6} \right) \left( \frac{3}{8} \right) = 1.172 \text{ in}^2 \]
\[ A_{nv} = \left[ 18 - 5 \left( \frac{3}{8} \right) \right] \frac{3}{8} = 5.109 \text{ in}^2 \]

\[ R_h = \begin{cases} 0.6(65)5.109 + 65(1.172) = 275.43 \text{ k} & \text{controls} \cr 0.6(50)6.75 + 65(1.172) = 278.68 \text{ k} & \end{cases} \]

\( \Phi R_h = 275.43(0.75) = 206.6 \text{ k} \) Gusset plate block shear controls.

\[ 1.2(0.40) + 1.6(0.67) = 206.6 \text{ k} \] or \( 1.44 T = 206.6 \text{ k} \)

\[ T = 143.45 \text{ k} \text{ is permissible} \]

Need at least \( 9/16 '' \) thick gusset plate to develop member strength.