Solution to Homework 5:

Problem 1:

Given and Required:

7.3-2 The tension member shown in Figure P7.3-2 is a PL ½ × 5½ of A242 steel. It is connected to a ⅜-inch-thick gusset plate (also A242 steel) with ¾-inch-diameter bolts.

a. Check all spacing and edge-distance requirements.

b. Compute the design strength in bearing.

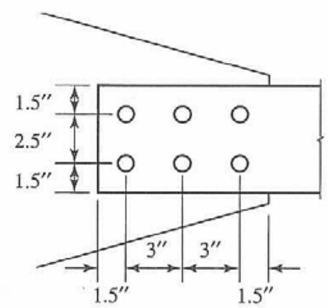

FIGURE P7.3-2

Solution:

a) Edge distance given = 1.5 in > minimum = 1 in. (AISC Table J3.4)

Spacing given = 3.0 in or 2.5 in. > minimum = $2.67d_b$ = 2.0 in.

Spacing given = 3.0 in or 2.5 in. > preferred = $3d_b$ = 2.25 in.

Therefore, all conditions are satisfied.

b) Given in lecture, F_y = 50 ksi, F_u = 70 ksi

For the bearing strength associated with the plate:

$t := 0.5$ in $\quad Fu := 70$ ksi $\quad db := 0.75$ in

At Edges: $Lce := 1.5 - \dfrac{\left(db + \frac{1}{16}\right)}{2}$ $\quad Lce = 1.094$ in

$\phi Rn := 0.75 \cdot (1.2 \cdot Lce \cdot t \cdot Fu)$ $\quad \phi Rn = 34.453$ kips

But: $\phi Rnmax := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu)$ $\quad \phi Rnmax = 47.25$ kips

Therefore $\quad \phi Rn = 34.453$ kips

At Other Holes: $Lce := 3 - \left(db + \frac{1}{16}\right)$ $\quad Lce = 2.188$ in

$\phi Rn := 0.75 \cdot (1.2 \cdot Lce \cdot t \cdot Fu)$ $\quad \phi Rn = 68.906$ kips

But: $\phi Rnmax := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu)$ $\quad \phi Rnmax = 47.25$ kips

Therefore $\quad \phi Rn := \phi Rnmax$ $\quad \phi Rn = 47.25$ kips

$Bearing\_Strength := 2 \cdot 34.453 + 4 \cdot 47.25$ $\quad Bearing\_Strength = 257.906$ kips

For the bearing strength associated with the gusset plate:

If we assume that Le for gusset = Le for plate, Then:

$t := \frac{3}{8}$ in $Fu := 70$ ksi $db := 0.75$ in

At Edges: $Lce := 1.5 - \frac{\left(db + \frac{1}{16}\right)}{2}$ $Lce = 1.094$ in

$\phi Rn := 0.75 \cdot (1.2 \cdot Lce \cdot t \cdot Fu)$ $\phi Rn = 25.84$ kips

But: $\phi Rnmin := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu)$ $\phi Rnmin = 35.437$ kips

Therefore $\phi Rn = 25.84$ kips

At Other Holes: $Lce := 3 - \left(db + \frac{1}{16}\right)$ $Lce = 2.188$ in

$\phi Rn := 0.75 \cdot (1.2 \cdot Lce \cdot t \cdot Fu)$ $\phi Rn = 51.68$ kips

But: $\phi Rnmax := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu)$ $\phi Rnmax = 35.437$ kips

Therefore $\phi Rn := \phi Rnmax$ $\phi Rn = 35.437$ kips

$Bearing\_Strength := 2 \cdot 25.84 + 4 \cdot 35.437$ $Bearing\_Strength = 193.428$ kips

This is the acceptable answer:

However, if we assume that Le for gusset is long as it appears to be from drawing, Then

$\phi Rnmax := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu)$ $\phi Rnmax = 35.437$ kips

Therefore $\phi Rn = 35.437$ kips

$Bearing\_Strength := 6 \cdot 35.437$ $Bearing\_Strength = 212.622$ kips

In both cases, the gusset plate controls

Problem 2

Given and Required:

7.6-2 A double-angle tension member, 2L4 × 3 × ½ LLBB, is connected to a ⅜-inch-thick gusset plate with ⅞-inch-diameter A325 bolts as shown in Figure P7.6-2. Both the tension member and the gusset plate are of A36 steel. Does the connection have enough capacity based on shear and bearing? It is not known whether the bolt threads will be in shear.

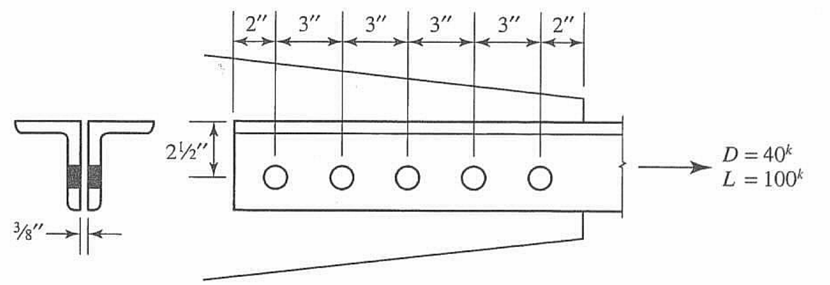

FIGURE P7.6-2

Solution:

Step I: Determine Factored Load:

$D := 40$ kips $\qquad 1.4D = 56$ kips

$L := 100$ kips $\qquad 1.2D + 1.6L = 208$ controls

Step II: Check the bolts for shear capacity:

$db := \frac{7}{8}$ in $\quad Ab := \pi \cdot \frac{db^2}{4} \quad Ab = 0.601$ in^2 $\quad Fn := 48$ ksi $\quad \phi := 0.75$

Design Shear Strength 1 bolt: $Vb := \phi \cdot Fn \cdot Ab \qquad Vb = 21.648$ kips

Shear Strength of Connection: $5 \cdot 2 \cdot Vb = 216.475$ kips

Step III: Check bearing at strength of bolt holes in angles:

$t := 0.5$ in $Fu := 58$ ksi (A36 steel)

$Le := 2$ in Use Table 7-13

$s := 3$ in Use Table 7-12

$$Lce := Le - \frac{\left(db + \frac{1}{16}\right)}{2} \qquad Lce = 1.531 \text{ in}$$

$\phi Rn := 0.75 \cdot (1.2 \cdot Lce \cdot t \cdot Fu)$ $\phi Rn = 39.966$ kips

But: $\phi Rnmax := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu)$ $\phi Rnmax = 45.675$ kips

Check from Table $79.9 \cdot t = 39.95$ ok

$\phi Rn = 39.966$ kips

$$Lcs := s - \frac{\left(db + \frac{1}{16}\right)}{1} \qquad Lcs = 2.063 \text{ in}$$

$\phi Rn := 0.75 \cdot (1.2 \cdot Lcs \cdot t \cdot Fu)$ $\phi Rn = 53.831$ kips

But: $\phi Rnmax := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu)$ $\phi Rnmax = 45.675$ kips

Check from Table $91.3 \cdot t = 45.65$ ok

$\phi Rn := \phi Rnmax$ $\phi Rn = 45.675$ kips

$Bearing\_Strength := 2 \cdot 39.966 + 8 \cdot 45.675$ $Bearing\_Strength = 445.332$ kips

Step IV: Check bearing at strength of bolt holes in gusset:

$t := \frac{3}{8}$ in $Fu := 58$ ksi (A36 steel)

$Le := 2$ in Use Table 7-13

$s := 3$ in Use Table 7-12

$$Lce := Le - \frac{\left(db + \frac{1}{16}\right)}{2} \qquad Lce = 1.531 \text{ in}$$

$\phi Rn := 0.75 \cdot (1.2 \cdot Lce \cdot t \cdot Fu)$ $\phi Rn = 29.974$ kips

But: $\phi Rnmax := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu)$ $\phi Rnmax = 34.256$ kips

Check from Table $79.9 \cdot t = 29.963$ ok

$\phi Rn = 29.974$ kips

$$Lcs := s - \frac{\left(db + \frac{1}{16}\right)}{1} \qquad Lcs = 2.063 \text{ in}$$

$\phi Rn := 0.75 \cdot (1.2 \cdot Lcs \cdot t \cdot Fu)$ $\phi Rn = 40.373$ kips

But: $\phi Rnmax := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu)$ $\phi Rnmax = 34.256$ kips

Check from Table $91.3 \cdot t = 34.237$ ok

$\phi Rn := \phi Rnmax$ $\phi Rn = 34.256$ kips

$Bearing\_Strength := 29.974 + 4 \cdot 34.256$ $Bearing\_Strength = 166.998$ kips

This is less than the factored load of 208 kips, not acceptable

Problem 3

Given and Required:

A WT7x19 of A572 Grade 50 steel is used as a tension member. It is connected to a 3/8 gusset plate, also of A572 steel, with 7/8 inch diameter bolts. The connection is through the flange of the tee. The connection must resist a service live load of 90 kips and a service dead load of 45 kips. Assume, the nominal bearing strength will be $2.4d_btF_u$ and answer the following questions.

a) How many A307 bolts are required?
b) How many A325 bolts are required?
c) How many A490 bolts are required?
d) If relative costs of A307, A325, and A490 bolts are in ratio of 1.0:1.7:2.6, which type of bolt is most economical for connection?

Solution:

The thickness of the gusset plate is lower than the thickness of the flange. Therefore,

bearing strength of the gusset will govern:

Step I: Determine Factored Load:

$D := 45$ kips $\quad 1.4D = 63$ kips

$L := 90$ kips $\quad 1.2D + 1.6L = 198$ controls

Step III: Determine number of bolts based on bearing of gusset:

$t := \frac{3}{8}$ in $\quad Fu := 65$ ksi (A36 steel) $\quad db := \frac{7}{8}$ in

1 bolt: $\phi Rn := 0.75 \cdot (2.4 \cdot db \cdot t \cdot Fu) \quad \phi Rn = 38.391$ kips

Number of bolts required $n := \frac{198}{\phi Rn} \quad n = 5.158$ Round up to Even Number 6 bolts

Step III: Determine number of bolts bases on shear capacity of connection:

$db := \frac{7}{8}$ in $\quad Ab := \pi \cdot \frac{db^2}{4} \quad Ab = 0.601$ in^2 $\quad \phi := 0.75$

a) $Fn := 24$ ksi

Design Shear Strength 1 bolt: $Vb := \phi \cdot Fn \cdot Ab \quad Vb = 10.824$ kips

Number of bolts required $n := \frac{198}{Vb} \quad n = 18.293$ Round up to Even Number 20 bolts

b) $Fn := 48$ ksi

Design Shear Strength 1 bolt: $Vb := \phi \cdot Fn \cdot Ab \quad Vb = 21.648$ kips

Number of bolts required $n := \frac{198}{Vb} \quad n = 9.147$ Round up to Even Number 10 bolts

c) $Fn := 60$ ksi

Design Shear Strength 1 bolt: $Vb := \phi \cdot Fn \cdot Ab \quad Vb = 27.059$ kips

Number of bolts required $n := \frac{198}{Vb} \quad n = 7.317$ Round up to Even Number 8 bolts

d) For A307 bolts, Nominal cost: $20 \cdot 1 = 20$ units

For A325 bolts, Nominal cost: $10 \cdot 1.7 = 17$ units

For A325 bolts, Nominal cost: $8 \cdot 2.6 = 20.8$ units

<u>Therefore, A325 bolts are most economical for this connection</u>: