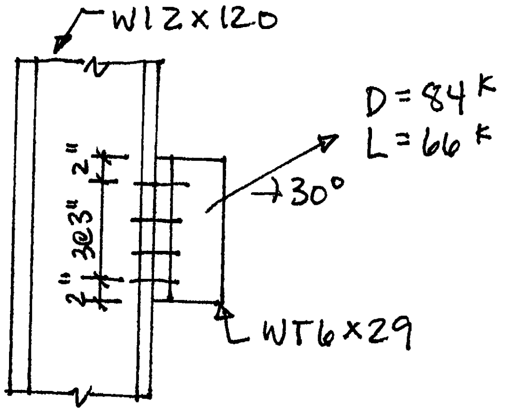
CE470 SPRING 2009 HW #4 DUE 2/26/09
Segui 7.9-1(a), 7.9-3(a), 7.9-4(a), 7.9-5(a)

Problem 7.9-1(a)

A bracket must support the service loads shown, which act through the center of gravity of the connection. The connection to the column flange is with eight 7/8-in-dia., A325 bearing-type bolts. A992 steel is used for all components. Is the connection adequate? Use LRFD.



$P_u = 1.4D = 1.4(84^k) = 117.6^k$

$P_u = 1.2D + 1.6L = 1.2(84^k) + 1.6(66^k)$
$= 206.4^k$ controls.

W12X120 $t_f = 1.11''$
WT6x29 $t_f = 0.64''$ ← controls
$b_f = 10''$

$V_u = P_u \sin 30° = (206.4^k)\sin 30°$
$= 103.2^k$

$T_u = P_u \cos 30° = 179^k$

Check shear strength of bolts, assume A325N

$\phi R_n = 0.75(1)(0.4)(120\text{ksi})(0.6013\text{in}^2)(8\text{ bolts}) = 173^k > 103.2^k$ ✓ok

Check bearing
assume def. IS design consideration

edge bolts $L_c = 2'' - \frac{1}{2}(\frac{15}{16}'') = 1.531''$
others $L_c = 3'' - \frac{15}{16}'' = 2.063''$

$\phi R_n = \phi 1.2 L_c t F_u \le \phi 2.4 d t F_u$
$\le 0.75(2.4)(7/8'')(0.64'')(65\text{ksi}) = 65.5^k$

edge $\phi R_n = 0.75(1.2)(1.531'')(0.64'')(65\text{ksi}) = 57.3^k \le 65.5^k$

others $\phi R_n = 0.75(1.2)(2.063'')(0.64'')(65\text{ksi}) = 77.2^k \le 65.5^k$

total $\phi R_n = 2(57.3^k) + 6(65.5^k) = 508^k \gg 103.2^k$ ✓ok.

Check combined shear and tension

Tension $\frac{179^k}{8 \text{ bolts}} = 22.4\ ^k/\text{bolt}$

→

Shear $\frac{103.2^k}{8 \text{ bolts}} = 12.9\ ^k/\text{bolt}$

Problem 7.9-1(a), cont'd.

$f_t = \dfrac{22.4^k}{0.6013\ in^2} = 37.3\ ksi$ $\qquad f_v = \dfrac{12.9^k/bolt}{0.6013\ in^2} = 21.5\ ksi$

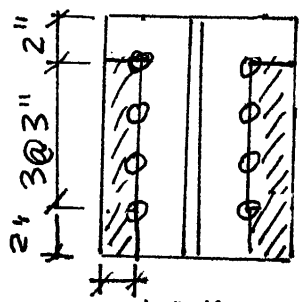
$f_t \le \phi F'_{nt} = \phi\left(1.3F_{nt} - \dfrac{F_{nt}}{\phi F_{nv}} f_v\right) \le \phi F_{nt}$

$= 0.75\left(1.3(90ksi) - \dfrac{90ksi}{0.75(48ksi)}(21.5ksi)\right) \le 0.75(90ksi)$

$\phi F'_{nt} = \underline{44.75\ ksi} \le 67.5\ ksi$

$37.3\ ksi < 44.7\ ksi$ ✓ OK.

Block shear of WT? due to V_u. (FYI only – not required for your HW solution; not enough info given)



not given. Cannot really check block shear

$\phi R_n = \phi\left(0.6F_u A_{nv} + U_{bs}F_u A_{nt}\right)$
$\le \phi\left(0.6F_y A_{gv} + U_{bs}F_u A_{nt}\right)$

$A_{gv} = 2(11")(0.64") = 14.1\ in^2$

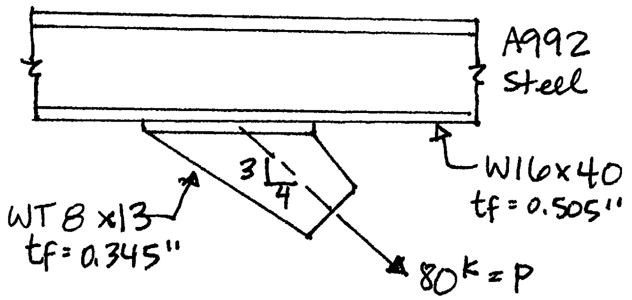
$\phi\, 0.6F_y A_{gv} = 0.75(0.6)(50ksi)(14.1\ in^2)$
$= 317.3^k \gg 103.2^k$

∴ block shear not likely to be a problem

$\boxed{\text{Yes, connection is adequate.}}$

Problem 7.9-3(a)

In this connection, how many 7/8-inch diameter A325 bearing-type bolts are needed? The 80^k load is a service load, consisting of 20^k dead load and 60^k live load. Assume that the bolt threads are in the plane of shear and bearing strength is controlled by the upper limit of $2.4dtF_u$. Use LRFD.



$$P_u = 1.2(20^k) + 1.6(60^k) = 120^k$$

$$V_u = 120^k\left(\tfrac{4}{5}\right) = 96^k$$

$$T_u = 120^k\left(\tfrac{3}{5}\right) = 72^k$$

$$f_t \le \phi F'_{nt} = \phi\left(1.3F_{nt} - \frac{F_{nt}}{\phi F_{nv}} f_v\right) \le \phi F_{nt}$$

$\times A_{bt}$ (total Area of bolts)

$$\underbrace{f_t A_{bt}}_{T_u} \le \phi\, 1.3F_{nt}A_{bt} - \frac{\phi F_{nt}}{\phi F_{nv}}\underbrace{f_v(A_{bt})}_{V_u} \le \phi F_{nt}A_{bt}$$

$$72^k \le 0.75(1.3)(90ksi)(A_{bt}) - \frac{90ksi}{48ksi}(96^k) \le 0.75(90ksi)A_{bt}$$

$$72^k \le 87.75A_{bt} - 180 \le 67.5A_{bt}$$

$$A_{bt} \ge 2.87\ in^2 \qquad N_b = \frac{2.87 in^2}{0.6013 in^2/bolt} = 4.77 \text{ bolts}$$

TRY 6 bolts (2 rows of 3)

Check upper limit. $A_{bt} = 6(0.6013 in^2/bolt) = 3.61\ in^2$

$67.5(3.61 in^2) = 244^k \gg 72^k$ ✓ok

Check shear $\frac{V_u}{A_{bt}} = \frac{96^k}{3.61 in^2} = 26.6\ ksi < \phi 48ksi$?

$= 0.75(48ksi)$

$26.6 = 36ksi$ ✓ok

Check bearing (WT flange controls) $\phi 2.4dtF_u = 0.75(2.4)(7/8")(0.345")(65ksi)$

$\phi R_n = 35.3\ ^k/bolt$

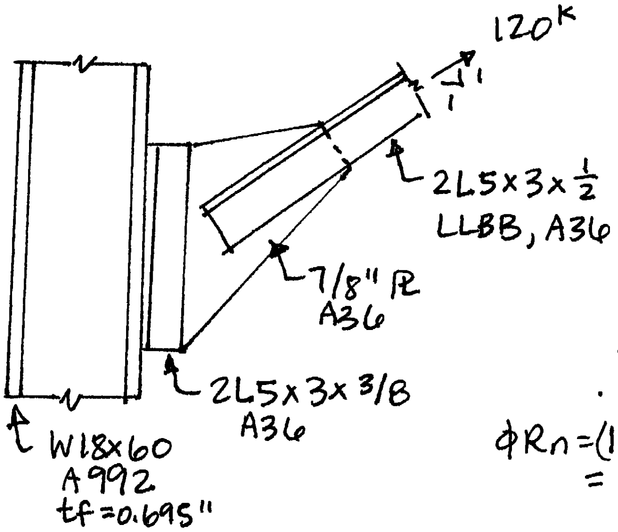
$\frac{V_u}{6} = 16\ ^k/bolt < 35.3\ ^k/bolt$ ✓ok.

$\boxed{\text{USE 6 bolts.}}$

not enough information to check block shear of WT.

Problem 7.9-4 (a)

A double-angle tension member is attached to a 7/8" gusset plate, which in turn is connected to a column flange with another pair of angles. The given load is a service load consisting of 25% dead load and 75% live load. All connections are made with 7/8"-dia. A490 slip critical bolts. Assume that the threads are in shear. Determine the required number of bolts and show their location on a sketch. The column is of A992 steel and the angles and plate are A36. Use LRFD.



$P_u = 1.2\left(\frac{120^k}{4}\right) + 1.6\left(\frac{3}{4}(120^k)\right)$

$= 180^k$

$V_u = T_u = 180^k\left(\frac{1}{\sqrt{2}}\right) = 127.3^k$

- First, choose # bolts for tension member., slip-critical for serviceability

$\phi R_n = \phi \mu D_u h_{sc} T_b N_s$

- assume Class A, standard holes

$\phi R_n = (1.0)(0.35)(1.13)(1.0)(49^k)(2)$

$= 38.76\ ^k/\text{bolt}$ ← controls

bearing on gusset plate controls., assume upper limit controls

$\phi R_n = 0.75(2.4)(7/8")(7/8")(58\text{ksi}) = 79.9\ ^k/\text{bolt}$

bolt shear

$\phi R_n = 0.75(2)(0.4)(150\text{ksi})(0.6013\text{ in}^2) = 54.1\ ^k/\text{bolt}$

$\#\text{ bolts} = \frac{180^k}{38.76\ ^k/\text{bolt}} = 4.64$ bolts → USE 5 bolts.

- Double check bearing for spacing & edge distances (min.)

J3.3 min $s = 2\frac{2}{3}d = 2\frac{2}{3}(7/8") = 2.33"$ USE $2\frac{1}{2}"$

Table J3.4 min $L_e = 1.5"$ for sheared edge.

edge $L_c = 1.5" - \frac{1}{2}\left(\frac{15}{16}"\right) = 1.031"$

$\phi R_n = 0.75(1.2)(1.031")(7/8")(58\text{ ksi})$

$= 47.1^k < 79.9^k$

others $L_c = 2.5" - 15/16" = 1.563"$

$\phi R_n = 0.75(1.2)(1.563")(7/8")(58\text{ksi}) = 71.4\ ^k/\text{bolt} < 79.9^k$

total $\phi R_n = 47.1^k + 4(71.4\ ^k/\text{bolt})$

$= 333^k \gg 180^k$ ✓ ok

Problem 7.9-4(a), cont'd.

Second, choose # bolts for double angle to column connection

Slip critical $\phi R_n = 19.48\,^k/\text{bolt}$ (half previous value, $N_s = 1$)

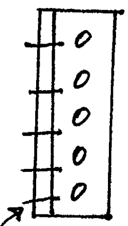
AISC J3.9 $K_s = 1 - \dfrac{T_u}{D_u T_b N_b} = 1 - \dfrac{127.3^k}{(1.13)(49^k)(N_b)}$

$= 1 - \dfrac{2.299}{N_b}$

$127.3^k \le N_b\,(19.5\,^k/\text{bolt})\left(1 - \dfrac{2.299}{N_b}\right)$

$\le 19.5\,N_b - 44.8$

$N_b \ge 8.9$ use 10 bolts, 2 rows of 5



$P_u = 180^k$

2 rows of 5 to column, offset from bolts in connection to gusset

ALSO would use 5 bolts in angle to gusset (same as for tension member) 5 bolts in double shear, resisting 180^k, so use 10 bolts (2 rows of 5) to match. ✓

Check shear $(27.1\,^k/\text{bolt})(10\text{ bolts}) = 271^k > 127.3^k$ ✓ok. (1 shear plane)

Check bearing, assume def. is design consideration, min. spacing, Le for conn. to column $t = 3/8''$ (angles) controls, assume same s & Le as before

edge $L_c = 1.031''$ → $\phi R_n = 0.75(1.2)(1.031'')(3/8'')(58\text{ksi})$

others $L_c = 1.563''$ $\le 0.75(2.4)(7/8'')(3/8'')(58\text{ksi})$

$\phi R_n = \underline{20.2^k} \le 34.3^k$

→ $\phi R_n = 0.75(1.2)(1.563'')(3/8'')(58\text{ksi}) \le 34.3^k$

$= \underline{30.6^k} \le 34.3^k$

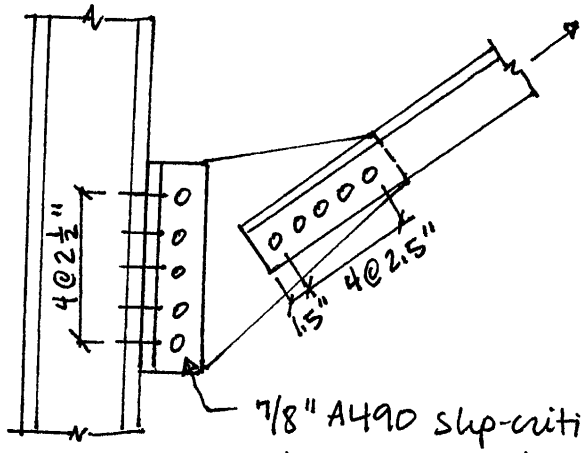
$\phi R_n = 20.2^k(2) + 8(30.6^k) = 285^k > 127.3^k$ ✓ok

for connection of angles to gusset plate (at column), angles control again ($2 \times 3/8'' = 6/8'' < 7/8''$ gusset). bearing on 2 angles for $180^k \sin 45°$; by inspection, capacity ok.

Check tension $\dfrac{127.3^k}{10\text{ bolts}} = 12.7$ kips. →

$\phi R_n = \phi F_t A_b = 0.75(113\text{ksi})(0.6013\text{in}^2) = 51^k$ ✓ok.

Problem 7.9-4(a), cont'd.

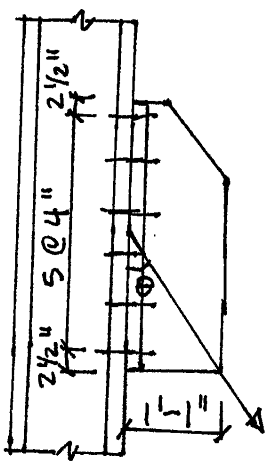


7/8" A490 slip-critical bolts.
All spaced @ 2½"; assume edge distances of 1½" (although bolts will be slightly offset in connection to column to provide clearance for tightening.)

10 bolts in connection to column
5 in angle-to-gusset connection at column
5 in tension member to gusset plate

Problem 7.9-5(a)

A bracket cut from a W12×120 is connected to a W12×120 column flange with 12 A325 bearing-type bolts. A992 Steel is used. The line of action of the load passes through the center of gravity of the connection. What size bolt is required? Use LRFD.



D=55k
L=145k

$P_u = 1.2(55^k) + 1.6(145^k) = 298^k$

$\theta = \tan^{-1}\left(\frac{13''}{12.5''}\right) = 46.1°$ angle from vertical

$V_u = P_u\cos\theta = 298^k(\cos 46.1°) = 207^k$

$T_u = P_u\sin\theta = 298^k(\sin 46.1°) = 215^k$

$f_t \le \phi F_{nt}'$ AISC J3.7

× A_{bt} (total area of bolts)

Assume A325 N

$\underbrace{f_t A_{bt}}_{T_u} \le \phi F_{nt}' A_{bt} = \phi 1.3 F_{nt} A_{bt} - \frac{\phi F_{nt}}{\phi F_{nv}} \underbrace{f_v A_{bt}}_{V_u} \le \underbrace{\phi F_{nt} A_{bt}}_{\text{check later.}}$

$215^k \le 0.75(1.3)(90\text{ksi})A_{bt} - \frac{90\text{ksi}}{48\text{ksi}}(207^k)$

$215^k \le 87.75 A_{bt} - 388.1^k$

$A_{bt} \ge 6.87 \text{ in}^2 \rightarrow \frac{6.87\text{in}^2}{12 \text{ bolts}} = 0.573 \text{ in}^2/\text{bolt}$

$\therefore d_b \ge \sqrt{\frac{0.573\text{in}^2(4)}{\pi}} = 0.854''$

TRY 7/8" dia. bolts ($A_b = 0.6013 \text{ in}^2$)

Check upper limits on f_t, f_v

$f_t = \frac{215^k}{12(0.6013\text{in}^2)} = 29.8 \text{ ksi} < \phi F_{nt} = 0.75(90\text{ksi}) = 67.5 \text{ ksi}$ ✓ok.

$f_v = \frac{207^k}{12(0.6013\text{in}^2)} = 28.7 \text{ ksi} < \phi F_{nv} = 0.75(48\text{ksi}) = 36 \text{ ksi}$ ✓ok.

→

Problem 7.9-5(a), cont'd.

Check bearing; assume deformation is a design consideration

$\phi R_n = \phi 1.2 L_c t F_u \leq \phi 2.4 d t F_u$

W12x120
$t_f = 1.11''$

$0.75(2.4)(7/8'')(1.11'')(65ksi)$
$= 113.6^k$

edge bolts on bracket $L_c = 2.5'' - \frac{1}{2}(\frac{15}{16}'') = 2.031''$
other bolts $L_c = 4'' - 15/16'' = 3.063''$

edge $\phi R_n = 0.75(1.2)(2.031'')(1.11'')(65ksi) = 131.9^k \leq \underline{113.6^k}$
others $\phi R_n = 0.75(1.2)(3.063'')(1.11'')(65ksi) = 199^k \leq \underline{113.6^k}$
total $\phi R_n = 12(113.6^k) = 1363^k \gg \underset{V_u}{207^k}$ ✓ok

block shear? not enough information. (need transverse spacing between 2 rows).

Also $\phi 0.6 F_y A_{gv} = 0.75(0.6)(50ksi)(2)(22.5'')(1.11'')$
$= 1124^k \gg \underset{V_u}{207^k}$ ✓ok
block shear will not control

$$\boxed{\begin{array}{l}\text{Required } d_b = 0.854'' \\ \text{USE } 7/8''\text{-dia. bolts.}\end{array}}$$