Name: N. Holtz

Tension Member

Design Example 1

N. Holtz
[signature]
Feb 5, 2018

DESIGN EXAMPLE 1 - TENSION MEMBER

Design a typical tension member similar to one of the diagonal braces shown above.

Given $T_f = 650 \text{ kN}$

Design to include main member and connection, but not the end gusset plates.

Basic Steps are as follows:

1. Choose a configuration (member & connection type).
2. Estimate member size.
3. Estimate # of bolts.
4. Estimate plate size.
5. Estimate weld size and length.
6. Check plate size. (depends on 3, 4, 5)
7. Check bolts (depends on 4, 6)
8. Check welds (depends on 5)
9. Check member (depends on all of the above)

(See lecture 2017-01-26, 2017-10-31)

CARLETON UNIVERSITY
Department of Civil and Environmental Engineering

Name: N. Holtz

CIVE 3205

ID#:

Assign#: T.M. DX-1

Date: Feb 5/8

① Configuration

Try HSS main member.

Slotted & welded to single plate each end.

Double lap plate bolted to gusset.

Material:

HSS: G40.21 350W (Table 6-8)

$F_y = 350$ MPa (Table 6-3)

$F_u = 450$ MPa

Plates: G40.21 300W

$F_y = 300$ MPa ($t \leq 65$mm) (Table 6-3)

$F_u = 440$ MPa

Bolts: ASTM A325

$F_u = 825$ MPa ($d \leq 1"$) (§ 13.12.1.2)

Welds: E49xx electrodes (S16 Table 4 - matching)

$X_u = 490$ MPa

② Estimate HSS Size

Guess $A_{ne} = 0.85 A_g$ (typical range 0.75 - 0.95)

A_{ne} often governs strength

i) Gross area yield

$$0.9 \times A_g \times 350 \frac{N}{mm^2} \times 10^{-3} \frac{kN}{N} \geq 650\ kN$$

$$A_g \geq 2060\ mm^2$$

iii) Net section fracture

$$0.75 \times 0.85 A_g \times 450 \frac{N}{mm^2} \times 10^{-3} \frac{kN}{N} \geq 650\ kN$$

$$A_g \geq 2270\ mm^2$$

From HB p 6-98

Section	A	
HSS 76 x 76 x 9.5	2310	← try
HSS 89 x 89 x 7.9	2410	
HSS 102 x 102 x 6.4	2320	
HSS 127 x 127 x 4.8	2280	

Normally, choose lightest
but 4.8 mm is thin for welding

Try: HSS 76 x 76 x 9.5

Name: N. Holtz

③ # of bolts

$\frac{3}{4}''$ ASTM A325 $F_u = 830$ MPa (§ 13.12.1.2 c))

$A_b = (0.75 \times 25.4)^2 \frac{\pi}{4}$

$A_b = 285\ mm^2$

Double shear, threads intercepted

for 1 bolt:

$V_r = 0.6\ \phi_b n m A_b F_u \times 0.7$ (§13.12.1.2 c))

$= 0.6 \times 0.8 \times 1 \times 2 \times 285 mm^2 \times 830 \frac{N}{mm^2} \times 0.7 \times 10^{-3} \frac{kN}{N}$

$V_r = 158$ kN

bolts reqd $= \frac{670}{158} = 4.24$

do not use 5

∴ try 6 bolts per side, lap plate

④ Plate Sizes

bolts: min pitch $= 2.7 \times \frac{3}{4} \times 25.4$ (§ 22.3.1) 22.3.5.1 hole size

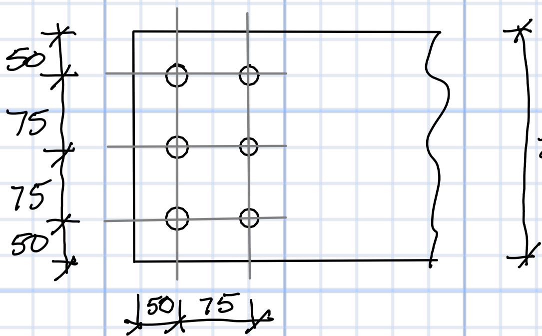
$= 51.4$ mm

min edge dist $= 32$ mm (§ 22.3.2, Table 6)

min end dist $= 1.5 \times \frac{3}{4} \times 25.4$ (§ 22.3.4)

$= 29$ mm

use pitch 75 mm
edge dist 50 mm
end dist 50 mm



holes 22 mm punched
(ok by §22.3.5.1)
hole allow. = 24 mm

Reqd. Thickness

Gross Yield: $0.9 \times 250\,mm \times t \times 0.350\,\frac{kN}{mm^2} \geq 650\,kN$

$t \geq 8.2\,mm$

Net Fracture: $0.75 \times (250 - 3 \times 24)\,t\,mm \times 0.440\,\frac{kN}{mm^2} \geq 650\,kN$

$t \geq 11.1\,mm$ ← governs

Try 12 mm plate (HB p 6-154)

6a Check Plate Size

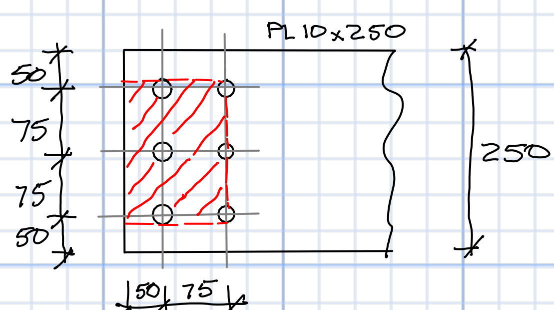
Check Block Shear (§13.11)

$$T_r = \phi_u \left[U_t A_n F_u + 0.6 A_{gv} \frac{F_y + F_u}{2} \right]$$

$$= 0.75 \left[U_t A_n \times 0.35 + 0.6 A_{gv} \frac{.35 + .44}{2} \right]$$

$$= 0.2625\, U_t A_n + 0.237 A_{gv}$$

i)



$A_{gv} = (50 + 75) \times 12 \times 2$

$= 3000\,mm^2$

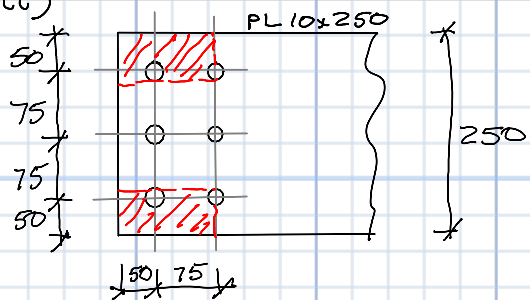
$A_n = (150 - 4 \times \frac{24}{2}) \times 12$

$= 1224\,mm^2$

$U_t = 1.0$

$$T_r = 0.2625 \times 1.0 \times 1224 + 0.237 \times 3000$$
$$= \underline{1030\,kN > 650\,kN} \quad O.K.$$

ii)



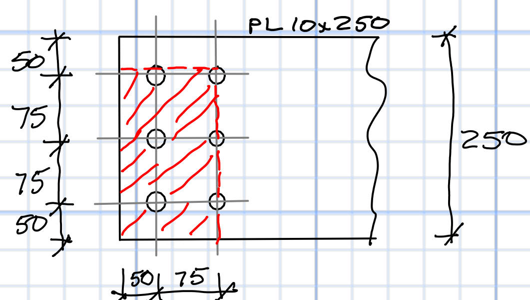
$A_{gv} = 3000\,mm^2$ (as above)

$$A_n = 2 \times \left(50 - \frac{24}{2}\right) \times 12$$
$$= 912\ mm^2$$

$U_t = 0.9$ (#8, Figure 2-26)

$$T_r = 0.2625 \times 0.9 \times 912 + 0.237 \times 3000$$
$$T_r = \underline{926\,kN > 670\,kN} \quad OK$$

iii)



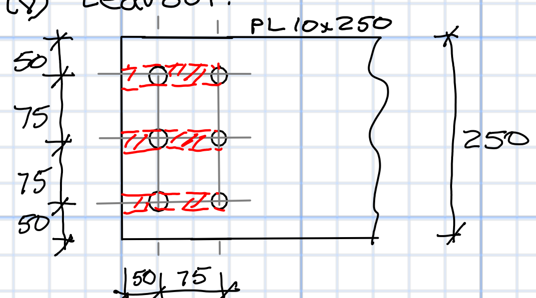
$$A_{gv} = (50+75) \times 12$$
$$= 1500\ mm^2$$

$$A_n = \left(75 + 75 + 50 - 5 \times \frac{24}{2}\right) \times 12$$
$$= 1680\ mm^2$$

$U_t = 0.9$

$$T_r = 0.2625 \times 0.9 \times 1680 + 0.237 \times 1500$$
$$= \underline{752\,kN > 650\,kN} \quad \underline{O.K.}$$

iv) tearout:



$$A_{gv} = (50+75) \times 12 \times 6 = 9000\ mm^2$$

$A_n = 0$

$$T_r = .237 \times 9000$$
$$= 2133\ kN \gg 650\,kN \quad OK$$

<u>Bolted End is Adequate</u>

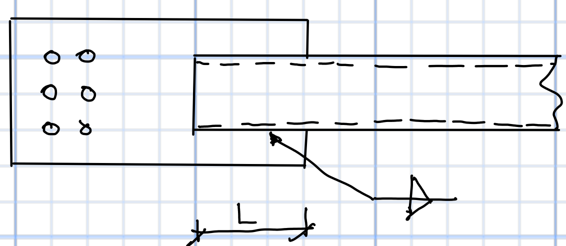
(5) Weld size

for $t = 12$ mm min weld size = 5 mm (p 6-186)

no essential weld max size in this case.

weld should be long to reduce shear lag effects.

∴ try 6 mm fillet weld E49xx electrodes



HSS 76x76x9.5

HSS 350W
PL 300W

E49xx - matching electrode (S16 Table 5)
$X_u = 490$ MPa
4 welds:

$$A_w = 4 \times .707 \times 6 \times L = 17L \text{ mm}$$

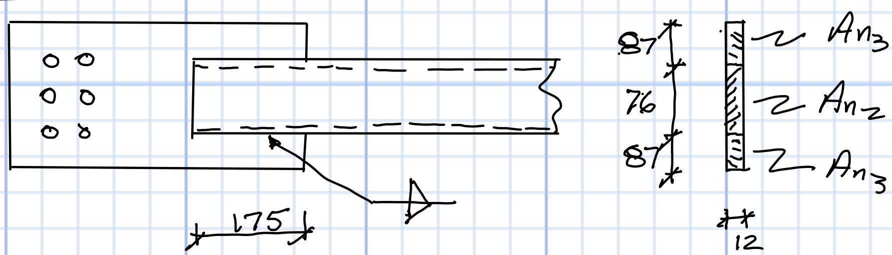
$$V_r = 0.67\,\phi_w A_w X_u \cancel{(1 + 0.5\sin^{1.5}\theta)}^{\,1}\,\cancel{M_w}^{\,1}$$

$$= 0.67 \times 0.67 \times 17L \times 0.490 > 650$$

$L > 174$ mm

try $L = 175$ mm

(6b) Plate – welded end



A_{n_2}: $w = 76$, $t = 12$, $L = 175$

$L > 2w$

$175 > 2 \times 76$

$\therefore A_{n_2} = 1.00\, wt$

$= 1.0 \times 76 \times 12$

$= 912\ mm^2$

A_{n_3} $w = 87$ $t = 12$ $L = 175$

$L > w$

$\bar{x} = \frac{87}{2} = 43.5\ mm.$

$A_{n_3} = \left(1 - \frac{43.5}{175}\right) \times 87 \times 12$

$= 784\ mm^2$

$A_{ne} = 912 + 2 \times 784$

$= 2480\ mm^2$

$T_r = 0.75 \times 2480 \times 0.440$

$= 818\ kN > 650\ kN$ O.K.

Welded end is adequate

(7) Bolts

- V_r (shear) ok (see (3) above)

Bearing: $B_r = 3\phi_{br}\, n t d F_u$ (§ 13.12.1.2)

$= 3 \times 0.8 \times 6 \times 12 \times 19 \times 0.450$

$= 1477\ kN \gg 650\ kN$ O.K.

Bolts are adequate

8 Welds

Welds are adequate (see 5 above)

9 HSS

HSS 76x76x9.5 G40.20

$F_y = 350$ MPa

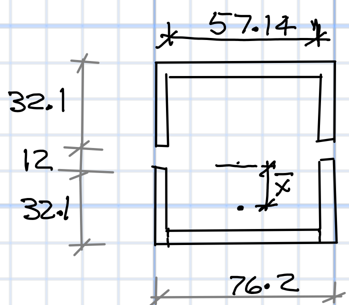
$F_u = 450$ MPa

$A = 2310 \text{ mm}^2$

$t = 9.53$ mm

$b = d = 76.2$ mm

$L_w = 175$ mm



$$\text{Area of } \tfrac{1}{2} = 2 \times 9.53 \times 32.1 + 9.53 \times 57.14$$

$$= 1156 \text{ mm}^2$$

$$\bar{x} = \frac{2 \times 9.53 \times 32.1 \times \frac{32.1}{2} + 9.53 \times 57.14 \times \left(32.1 - \frac{9.53}{2}\right)}{1156}$$

$$\bar{x} = 21.4 \text{ mm}$$

$$\frac{\bar{x}}{L_w} = \frac{21.4}{175} = 0.12$$

$$A_n = 2310 - 2 \times 12 \times 9.53$$

$$= 2081 \text{ mm}^2$$

$$A_{ne} = (1.1 - 0.12) \times 2081$$

$$A_{ne} = 2039 \text{ mm}^2 \quad > 0.8 A_n$$

Net section fracture:

$$T_r = \phi_u A_{ne} F_u$$

$$= 0.75 \times 2039 \times 0.450$$

$$= 688 \text{ kN} \quad > \quad 650 \text{ kN}$$

O.K.

Gross Area Yield (OK from ② above)
but repeat here for clarity

$$T_r = \phi A_g F_y$$
$$= 0.9 \times 2310 \times 0.350$$
$$= 728 \text{ kN} > 650 \text{ kN} \qquad \text{O.K.}$$

HSS Adequate

⑯ Lap Plates

Use 2 - 6 x 250 plates

- adequate - by inspection (same total thickness as main plate)

Summary