CIVE 3205

Problem Set CPS

Solutions

Feb. 26, 2020

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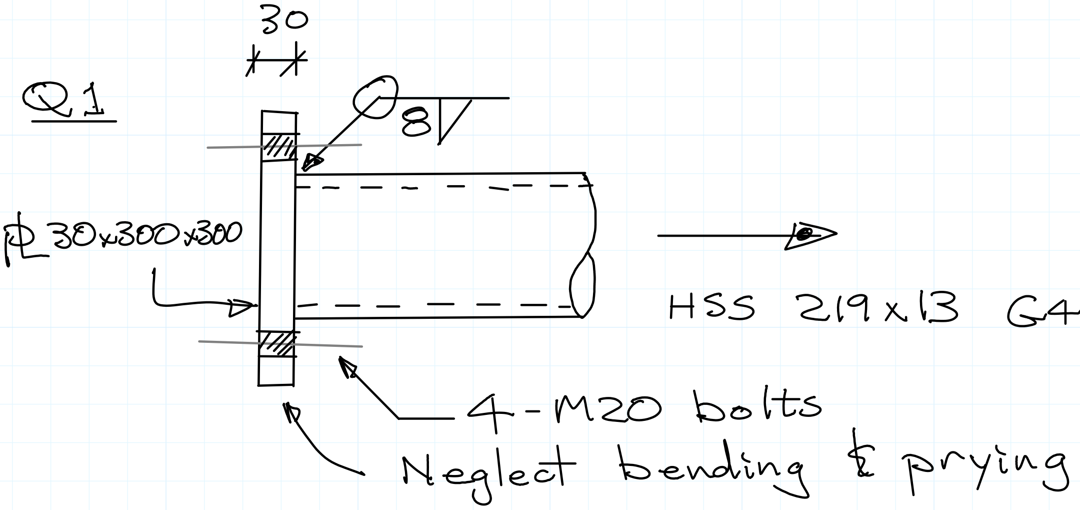
Revisions:

- Feb 26/20: new posting.

Q1



300 W Steel
E49XX electrodes
A325M bolts

HSS 219x13: $A_g = 8230 \text{ mm}^2$
$t = 12.7 \text{ mm}$

i) HSS strength:

$$T_r = \phi A_g F_y$$
$$= 0.9 \times 8230 \times 300 \times 10^{-3}$$
$$= 2220 \text{ kN}$$

ii) Weld:

$L = \pi \times 219 = 688.0$ mm

min thickness = 8 mm (p 6-172, PL > 20mm) OK

max thickness = N.A. OK

300 W steel E49xx electrodes
∴ matching electrodes (Table 4)

weld metal: (§ 13.13.2.2)

$$V_r = 0.67 \phi_w A_w X_u (1.0 + 0.5 \sin^{1.5}\theta) M_w$$

$A_w = 0.707 \times 8 \times 688$
$M_w = 1.0$
$\theta = 90°$

$$V_r = 0.67 \times 0.67 \times .707 \times 8 \times 688.0 \times 490 \times (1 + 0.5 \times 1^{1.5}) \times 1 \times 10^{-3}$$

$$\underline{V_r = 1290 \text{ kN}}$$

iii) Bolts in tension: (§ 13.12.1.3)

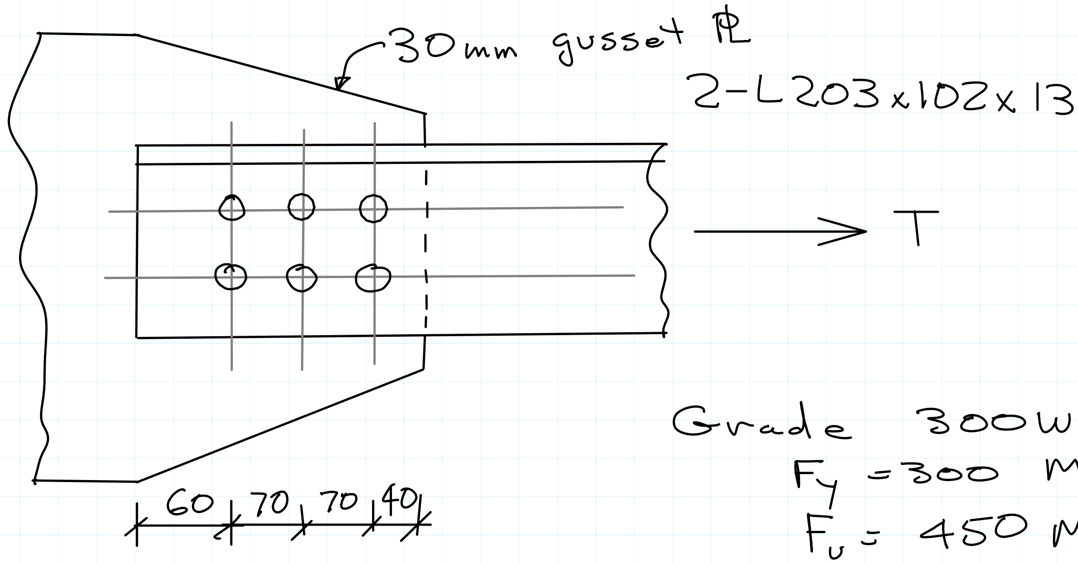
$F_u = 830\,MPa$

$$T_r = 4 \times 0.75 \times 0.80 \times \frac{\pi \times 20^2}{4} \times 830 \times 10^{-3}$$

$$= \underline{625.8\,kN} \longleftarrow \text{governs}$$

$$\therefore \quad \underline{\underline{T_r = 626\,kN}} \longleftarrow$$

Q2)



Grade 300W
$F_y = 300$ MPa
$F_u = 450$ MPa

ASTM A325M
$F_u = 830$ MPa

1-L203x102x13:
$A = 3710\ mm^2$
$t = 12.7\ mm$

i) angle - gross section yielding (§ 13.2 (a))

$$T_r = \phi A_g F_y$$
$$= 0.9 \times 3710 \times 300 \times 10^{-3}$$
$$= \underline{1002\ kN}$$

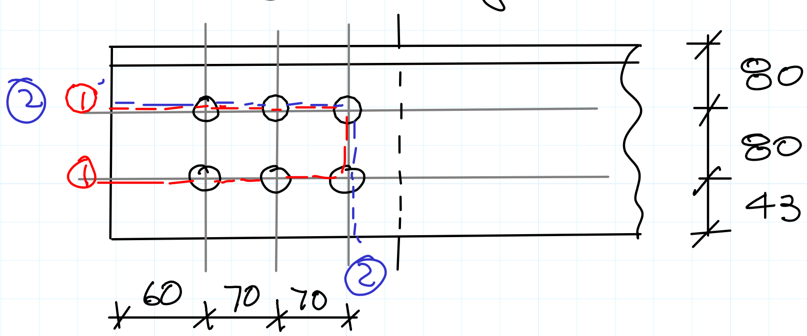
ii) angle - net section fracture (§ 13.2 (a)(ii) & (iii))

$$A_n = 3710 - 2 \times (20+4) \times 12.7$$
$$= 3100\ mm^2$$

$$A_{ne} = 0.6 A_n \qquad (§\ 12.3.3.2\ (b)\ (ii))$$
$$= 0.6 \times 3100$$
$$= 1860\ mm^2$$

$$T_r = 0.75 \times 1860 \times 450 \times 10^{-3} \qquad (§ 13.2\ (a)(iii))$$
$$= \underline{628\ kN} \longleftarrow \text{governs (angle)}$$

iii) Block shear, angle (§ 13.11)



Path 1-1:

$$A_n = (80 - 24) \times 12.7 = 711.2 \ mm^2$$

$$A_{gv} = (60 + 70 + 70) \times 12.7 \times 2 = 5080 \ mm^2$$

$$U_T = 0.6 \quad \text{(conservative)}$$

$$T_r = 0.75\left[0.6 \times 711.7 \times 450 + 0.6 \times 5080 \times \frac{300 + 450}{2}\right] \times 10^{-3}$$

$$= \underline{1001 \ kN}$$

Path 2-2:

$$A_n = (80 + 43 - 1.5 \times 24) \times 12.7 = 1105 \ mm^2$$

$$A_{gv} = (60 + 70 + 70) \times 12.7 = 2540 \ mm^2$$

$$U_T = 0.6$$

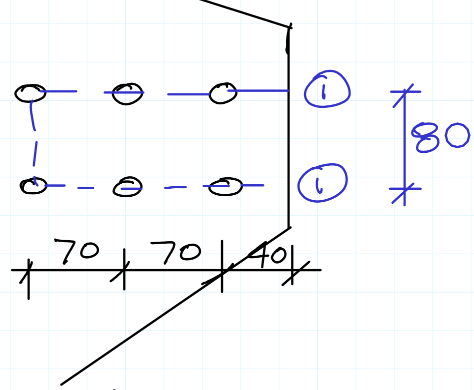
$$T_r = 0.75\left[0.6 \times 1105 \times 450 + 0.6 \times 2540 \frac{300 + 450}{2}\right] \times 10^{-3}$$

$$= \underline{652.4}$$

(All of the above are for 1 angle)
(ii governs - thus, for angles:)

$$T_r = 628 \frac{kN}{angle} \times 2 \, angle = 1256 \ kN$$

iv) Check block shear in gusset



By inspection, only 1 path

$$A_n = (80 - 24) \times 30 = 1680 \ mm^2$$

$$A_{gv} = (70 + 70 + 40) \times 30 \times 2 = 10800 \ mm^2$$

$$U_T = 1.0$$

$$T_r = 0.75\left[1.0 \times 1680 \times 450 + 0.6 \times 10800 \times \frac{300+450}{2}\right] \times 10^{-3}$$

$$= 2390 \text{ kN} \quad > 1256$$

∴ Gusset Plate does not govern

v) Bolts:

grip = $80 + 2 \times 12.7 = 55.4$ mm

p 6-161	L = 80 mm	Unthreaded L = 80 − (36 + 7.5) = 36.5
	L = 85 mm	" = 85 − 43.5 = 41.5
	L = 90 mm	" = 90 − 43.5 = 46.5

min. unthreaded length for no intercept
= 30 + 12.7 = 42.7
∴ only the 90 mm bolt would have threads excluded

∴ <u>Assume threads intercepted</u>

(§ 22.3)
min pitch = 2.7 × 20 = 54 mm < 70 O.K.
min edge dist = 26 mm < 43 O.K.
min end dist = 34 mm < 60 O.K.

Bolts, bearing ($\S$13.12.1.2 (a))

$t = 2 \times 12.7 = 25.4$ mm.
$n = 6$
$d = 20$mm
$F_u = 450$ MPa

$B_r = 3 \times 0.80 \times 6 \times 25.4 \times 20 \times 450 \times 10^{-3}$

$B_r = 3292$ kN

Bolts, double shear ($\S$13.12.1.2 (c))

$n = 6$
$m = 2$
$A_b = \frac{\pi \times 20^2}{4} = 314.2$ mm^2

$V_r = 0.7 \times 0.6 \times \phi_b\, n\, m\, A_b\, F_u$ (threads intercepted)

$= 0.7 \times 0.6 \times 0.8 \times 6 \times 2 \times 314.2 \times 830 \times 10^{-3}$

$= 1051$ kN

Connection length, $L = 140 < 15 \times 20$
∴ no reduction necessary

Bolt Shear governs

$\underline{\underline{T_r = 1050 \text{ kN}}}$ ← ans.

Note: if threads are excluded from shear plane, by using 90 mm bolts, bolt shear strength will be $\frac{1050}{0.7} = 1500$
& angle strength of 1260 kN will govern.
- increase of 210 kN for almost negligible cost (except for inspection).

Q3

1) L178×102×13

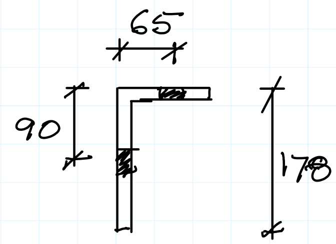
$F_y = 300$ $F_u = 450$

$A_g = 3390\ mm^2$

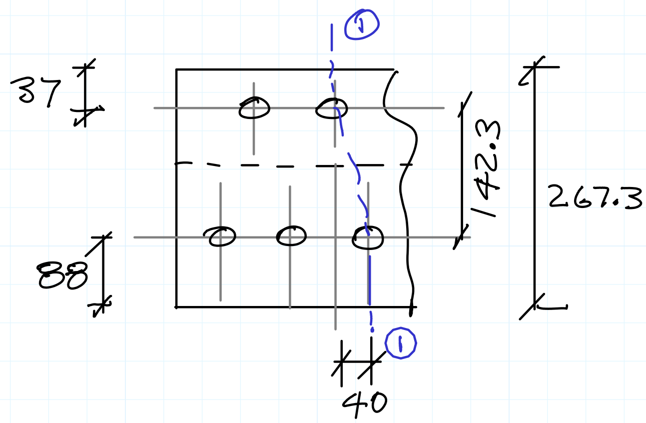
$t = 12.7\ mm$

M20 bolts punched holes

x-sect



std. gauges, p6-168



$w = 178 + 102 - 12.7 = 267.3$

$$w_n = 267.3 - 2\times(20+2+2) + \frac{40^2}{4\times 142.3}$$
$$= 222.1\ mm$$

$$A_n = w_n t$$
$$= 222.1 \times 12.7$$
$$= 2821\ mm^2 \quad (= 0.83 A_g)$$

$A_{ne} = 2821\ mm^2$ (no shear lag)

gross section yielding:

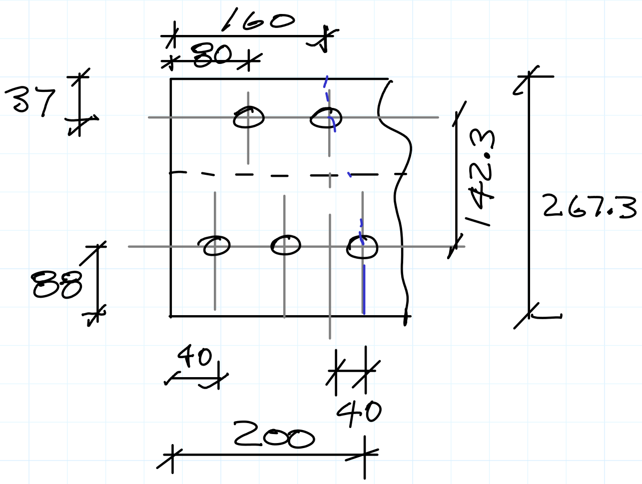
$$T_r = \phi A_g F_y$$
$$= 0.9 \times 3390 \times 300 \times 10^{-3}$$
$$= 915\ kN$$

← governs for overall capacity

net section fracture

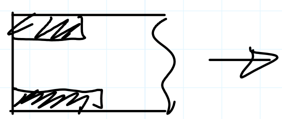
$$T_r = \phi_u A_{ne} F_u$$
$$= 0.75 \times 2821 \times 450 \times 10^{-3}$$
$$= 952\ kN$$

2) Block shear



$t = 12.7$

i)



$A_n = (37 + 88 - 24) \times 12.7 = 1283 \ mm^2$

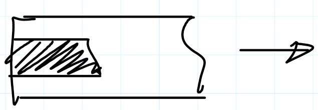
$A_{gv} = (160 + 200) \times 12.7 = 4572 \ mm^2$

$U_T = 0.9$

$T_r = 0.75 \left[0.9 \times 1283 \times 450 + 0.6 \times 4572 \times \frac{300 + 450}{2} \right] \times 10^{-3}$

$= 1161 \ KN$

ii)



$A_n = (142.3 - 24) \times 12.7 = 1502 \ mm^2$

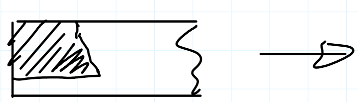
$A_{gv} = 4572 \ mm^2$

$U_t = 1.0$

$1.0 \times 1502 > 0.9 \times 1283 \quad \therefore$ will not govern

Note: we did not allow for the 'tension face' not being perpendicular to the load, but the difference is small.

iii)



$A_n = ((267.3 - 88) - 1.5 \times 24) \times 12.7 = 1820 \ mm^2$

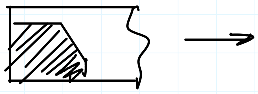
$A_{gv} = 200 \times 12.7 = 2540 \ mm^2$

$U_t = 0.6$

$T_r = 0.75 \left[0.6 \times 1820 \times 450 + 0.6 \times 2540 \times 375 \right] \times 10^{-3}$

$= 797$ ← governs for block shear

iv)



$A_n = (267.3 - 37 - 1.5 \times 24) \times 12.7 = 2468 \text{ mm}^2$

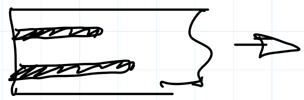
$A_{gv} = 160 \times 12.7 = 2032$

$U_t = 0.6$

$T_r = 0.75 [0.6 \times 2468 \times 450 + 0.6 \times 2032 \times 375] \times 10^{-3}$

$\underline{T_r = 843 \text{ kN}}$

v)



$A_{gv} = (2 \times 160 + 2 \times 200) \times 12.7 = 9144 \text{ mm}^2$

$A_n = 0$

$T_r = 0.75 [.6 \times 9144 \times 375] \times 10^{-3}$

$\underline{= 1543 \text{ kN}}$

3) fastener capacity

5 A325 M20 bolts $F_u = 830$ MPa.

i) Shear (threads intercepted)

$$V_r = 0.6\,\phi_b\, n\, m\, A_b F_u$$

$$= 0.6 \times 0.8 \times 5 \times 1 \times \frac{20^2 \times \pi}{4} \times 0.7 \times 830 \times 10^{-3}$$

$$V_r = 438 \text{ kN.}$$ ← governs, fastener cap.

ii) Bearing

- angle thickness governs (12.7 mm < 20 mm)

$$B_r = 3\phi_{br}\, n\, t\, d\, F_u$$

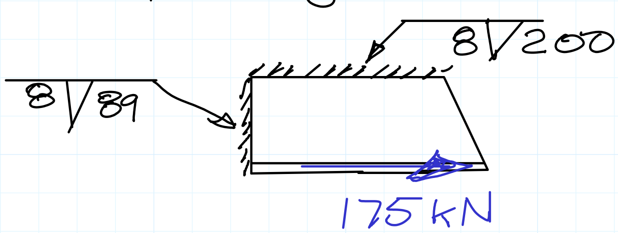
$$= 3 \times 0.80 \times 5 \times 12.7 \times 20 \times 450 \times 10^{-3}$$

$$B_r = 1372 \text{ kN}$$

Capacity is 438 kN if clip angle capacity is sufficient to develop force in 2 bolts

$$V_f = \frac{2}{5} \times 438 = 175 \text{ kN}$$

4) Clip angle



$X_u = 490$ MPa

This is an eccentrically loaded welded connection, but we will ignore eccentricity for now.

transverse weld

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

$\theta = 90°$, $M_w = 1$

$$= 0.67 \times 0.67 \times 8 \times .707 \times 89 \times 490 \times 1.5 \times 1 \times 10^{-3}$$

$$= 166 \text{ kN}$$

longit weld $\theta = 0°$, $M_w = 0.85$

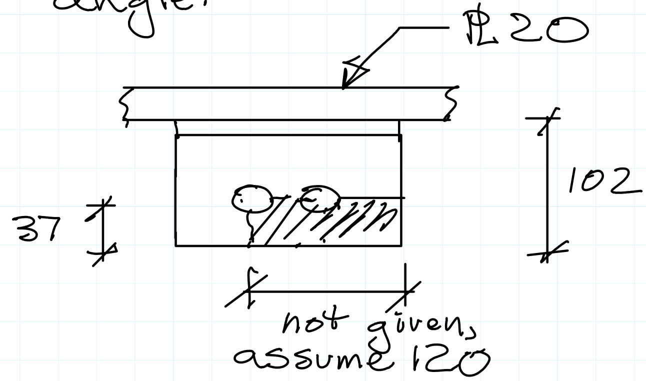
$$V_r = .67 \times .67 \times 8 \times .707 \times 200 \times 490 \times 1 \times 0.85 \times 10^{-3}$$

$$= 211 \text{ kN}$$

Total weld capacity

$= 166 + 211 = 388 \gg 175$ OK

- this is so far above the 175 req'd that we are justified in ignoring the small eccentricity.
- we should also check block shear of two bolts in the outstanding leg of the clip angle.



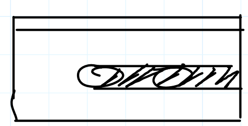
$A_n = (37 - 0.5 \times 24) \times 12.7 = 317.5$

$A_{gv} = 120 \times 12.7 = 1524$

$U_t = 0.6$

$V_r = 0.75\left[.6 \times 317.5 \times 450 + 0.6 \times 1524 \times 375\right] \times 10^{-3}$

$= 321 \gg 175$ O.K.



$A_n = 0$

$A_{gv} = 3048$

$V_r = .75 \times .6 \times 3048 \times 375 \times 10^{-3}$

$= 514 \gg 175$ O.K.

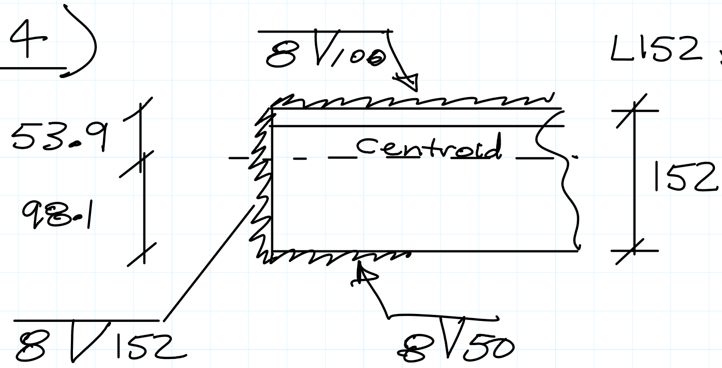
$\therefore$ Clip angle can develop sufficient strength

$\therefore$ $\underline{\underline{T_r = 438 \text{ kN}}}$

(governed by shear capacity of bolts)

Q4)

L152 x 89 x 16



$A_g = 3580\ mm^2$

$t = 15.9\ mm$

$X_u = 490\ MPa$

1) Welds

Transverse weld

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

$\theta = 90^\circ \qquad M_w = 1$

$$= 0.67 \times 0.67 \times 8 \times .707 \times 152 \times 490 \times 1.5 \times 1 \times 10^{-3}$$

$$= 283.7\ kN$$

Longit weld

$\theta = 0^\circ \qquad M_w = 0.85$

$$T_r = .67 \times .67 \times 8 \times .707 \times 150 \times 490 \times 1 \times 0.85 \times 10^{-3}$$

$$= 158.6\ kN$$

Total

$$T_r = 283.7 + 158.6$$

$$\underline{T_r = 442\ kN}$$

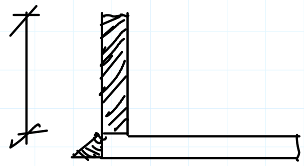
2) Angle

i) 152 mm leg — welded transversely

$A_{n1} = 152 \times 15.9 = 2417 \text{ mm}^2$

ii) 89 mm leg — weld along 1 edge

$w = 73$



$\bar{x} = 44.45$

$L = 100$ mm

$L > w$

$\therefore A_{n3} = \left(1 - \frac{\bar{x}}{L}\right) wt$

$= \left(1 - \frac{44.45}{100}\right) \times 73 \times 15.9$

$= 645 \text{ mm}^2$

$A_{ne} = A_{n1} + A_{n3}$

$= 2417 \text{ mm}^2 + 645 \text{ mm}^2$

$= 3062 \text{ mm}^2$

net section fracture

$T_r = \phi_u A_{ne} F_u$

$= 0.75 \times 3062 \times 450 \times 10^{-3}$

$= 1033$ kN

gross section yielding

$T_r = \phi A F_y$

$= 0.9 \times 3580 \times 300 \times 10^{-3}$

$= 967$ kN

$\therefore$ Welds govern

$\underline{\underline{T_r = 442 \text{ kN}}}$