**Faculty of Engineering**

# CIVE 3205: Steel I

**Mid-Term Examination 2 A, March 12, 2012**

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**Name** (Last, First): SOLUTION A

**Student No.:** 1

**Notes:**

1) Time limit: **1 hr 20 minutes**
2) This examination paper has 7 pages, including this title page.
3) Answer all 4 questions. There is no choice.
4) Answer all questions in the space provided **on this examination paper**. You may use the reverse side of these pages for rough work.
5) Write your name and student number on the top of **each page**. We will not discuss grading later if that has not been done.
6) Do not separate the pages.
7) Show **all** necessary steps to support your answers.
8) If you feel that any information is incorrect or incomplete, make a reasonable assumption, state it clearly, and proceed. **DO NOT ASK QUESTIONS: 2 marks will be deducted for each question answered.**
9) Authorized memoranda: calculator (without document-storage capability), one letter-size page, steel handbook.
10) Do not write below.

| **Question** | 1 | 2 | 3 | 4 | **Total** |
|---|---|---|---|---|---|
| **Mark** | | | | | |
| **Max** | 10 | 10 | 10 | 10 | **40** |

## Question 1 (10 marks)

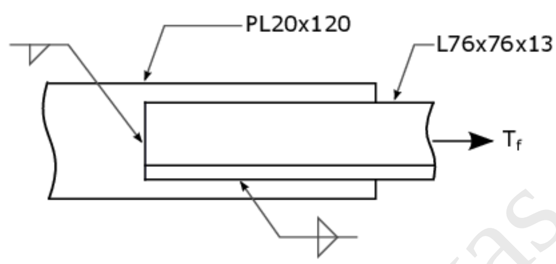
The following angle is of CSA G40.21 300W steel and is to be fillet welded to the plate using E49xx electrodes. Choose the length of weld for two different configurations:

(i) Weld across the 76mm end and on the two parallel sides.

(ii) Weld only along the two parallel sides.

For both cases, choose the *maximum* size of fillet weld. $T_f$ shall be equal to the maximum factored tensile resistance for the angle, *not* reduced for shear lag. The welds on the parallel sides must be "balanced" so as to minimize the eccentricity of loading with respect to the centroidal axis.

Summarize each design on a simple sketch.




min weld size (governed by 20mm PL) = 6mm

max weld size = $\frac{3}{4} \times 12.7$mm = 9.5 say 8mm

(weld sizes are commonly 5, 6, 7, 8, 10, 12 mm – p 3-40)

Use 8mm weld E49xx electrodes

Compute $T_r$ of angle

$A = 1770\ mm^2$

$T_r = \phi A_g F_y$

$= 0.9 \times 1770\ mm^2 \times 300 \frac{N}{mm^2} \times 10^{-3} \frac{kN}{N}$

$= 478\ kN$ ← governs

$T_r = \phi_u A_n F_u$

$= 0.75 \times 1770\ mm^2 \times 450 \frac{N}{mm^2} \times 10^{-3} \frac{kN}{N}$

$= 597\ kN$

$T_f = 478\ kN$

case i)

for end weld:

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

$\theta = 90°$ $M_w = 1$

$V_r = 0.67 \times 0.67 \times 8mm \times 76mm \times .707 \times 490 \frac{N}{mm^2} \times 1.5 \times 1 \times 10^{-3} \frac{kN}{N}$

$= 142\ kN$

for edge welds

$\theta = 0°$ $M_w = 0.85$

$V_r = 0.67 \times 0.67 \times 8mm \times L \times .707 \times 490 \frac{N}{mm^2} \times 1.0 \times 0.85 \times 10^{-3} \frac{kN}{N}$

$= 1.06 L \frac{kN}{mm}$

$1.06 L \frac{kN}{mm} = 478kN - 142\ kN$

$L = 317\ mm$

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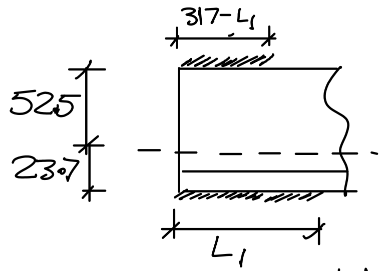
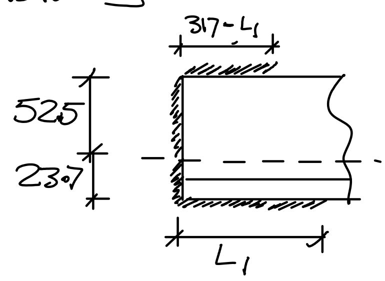



$$52.5(317 - L_1) = 23.7L_1$$
$$16600 = 76.2L_1$$
$$L_1 = 219\text{ mm}$$
$$317 - L_1 = 98\text{ mm}$$

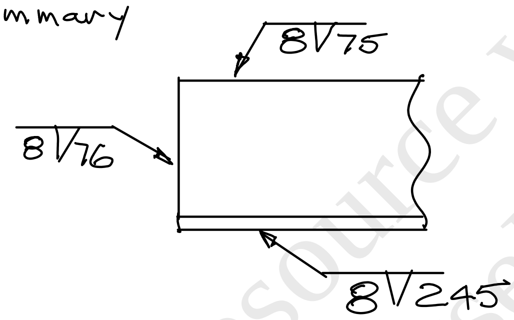
Including end welds




$$52.5(317 - L_1)\times .85 + 52.5\times\frac{52.5}{2}\times 1.5 = 23.7L_1\times .85 + 23.7\times\frac{23.7}{2}\times 1.5$$

$$L_1 = 244$$
$$317 - L_1 = 73$$

Summary



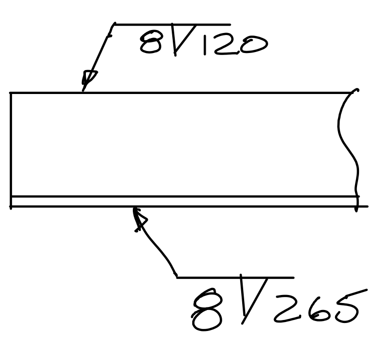

case ii) parallel sides only

$\theta = 0^\circ$ $M_w = 1.0$

$$V_r = 0.67\times 0.67\times 8\text{mm}\times L\times .707\times 490\frac{N}{mm^2}\times 1\times 1\times 10^{-3}\frac{kN}{N}$$
$$= 1.24L\frac{kN}{mm}$$
$$1.24L\frac{kN}{mm} = 478\text{ kN}$$
$$L = 384\text{ mm}$$

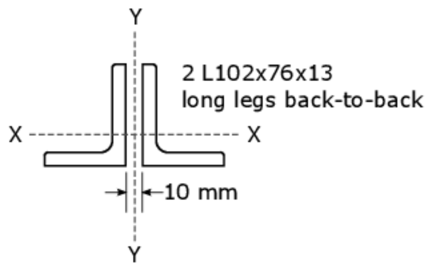
balancing

$$23.7\times L_1 = 52.5(385 - L_1)$$
$$76.2L_1 = 20200$$
$$L_1 = 265\text{ mm}$$
$$385 - L_1 = 120\text{ mm}$$



## Question 2 (10 marks)

A double angle strut is 6m long and is pin connected at its ends. End connections are by bolts to a 10mm gusset plate. Interconnection is by means of snug tight bolts with 10mm spacers, through the long legs. Determine how many interconnections are required and where they should be placed. Determine the slenderness ratios ($KL/r$ terms) about both axis for use in clause 13.3.2. Do not compute axial strength.




$r_x = 31.8$ mm
$r_y = 34.0$ mm

built-up shape

$$\left(\frac{KL}{r}\right)_x = \frac{1.0 \times 6000}{31.8} = 189$$

Single angle
$r_{min} = 16.2$ mm

$$\frac{KL'}{16.2} \leq 189$$

$$L' \leq 3061 \text{mm}$$

Try 1 interconnection @ centre ($L' = 3000$ mm)

from §19.1.4

$$\rho_o = \frac{1 \times 6000}{34.0} = 176.5 \text{ mm}$$

$$\rho_i = \frac{1 \times 3000}{16.2} = 185.2 \text{mm}$$

$$\rho_e = \sqrt{\rho_o^2 + \rho_i^2} = \sqrt{176.5^2 + 185.2^2} = 256.$$

$$\left(\frac{KL}{r}\right)_y = 256$$

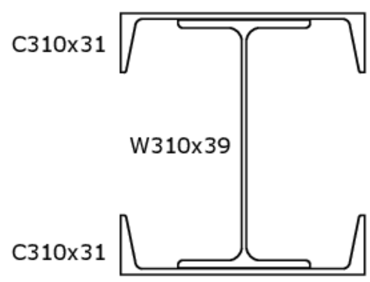
(note this exceeds the limit of 200 of §10.4.2.2

$$\left(\frac{KL}{r}\right)_x = 189 \quad \leftarrow$$

$$\left(\frac{KL}{r}\right)_y = 256 \quad \leftarrow$$

## Question 3 (10 marks)

Compute the cross-sectional properties ($A$, $I$, $r$) needed in order to compute the strength of the following built-up member when used as an axially loaded column. The flanges of the W310x39 are continuously welded to the webs of the C310x31s.




W310x39

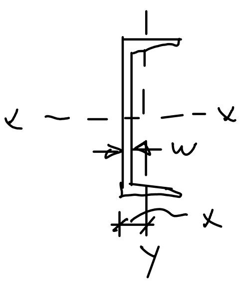
$A = 4940\ mm^2$

$I_x = 85.1\times10^6\ mm^4$

$I_y = 7.27\times10^6\ mm^4$

$d = 310\ mm$

C310x31




$I_x = 53.5\times10^6\ mm^4$

$I_y = 1.59\times10^6\ mm^4$

$A = 3920\ mm^2$

$x = 17.6\ mm$

$w = 7.2\ mm$

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B.U. Shape

$A = 4940 + 2\times3920 = 12800\ mm^2$

$I_x = 85.1\times10^6 + 2\left(1.59\times10^6 + 3920\left(\frac{310}{2} + 7.2 - 17.6\right)^2\right)$

$= 252\times10^6\ mm^4$

$I_y = 7.27\times10^6 + 2\times53.5\times10^6$

$= 114\times10^6\ mm^4$

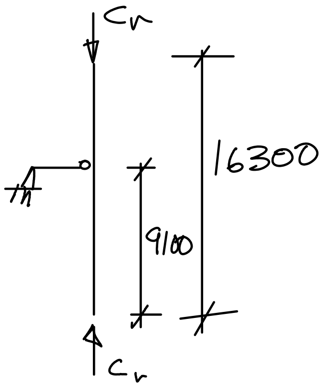
$r_x = \sqrt{\frac{252\times10^6}{12800}} = 140\ mm$

$r_y = \sqrt{\frac{114\times10^6}{12800}} = 94.4\ mm$

| |
|---|
| $A = 12800\ mm^2$ |
| $I_x = 252\times10^6\ mm^4$ |
| $r_x = 140\ mm$ |
| $I_y = 114\times10^6\ mm^4$ |
| $r_y = 94.4\ mm$ |

## Question 4 (10 marks)

A pin-ended column is a W310x143 of CSA G40.21 350W steel. Its length is 16300mm and it has lateral bracing against bending about the weak axis 9100mm up from the bottom. Determine the factored axial compressive resistance of the column.




$KL_x = 16300$

$KL_y = 9100$

W310 × 143:

$b = 309$ $r_x = 138$ mm

$t = 22.9$ $r_y = 78.6$ mm

$w = 14.0$

$h = d - 2t = 277$ $A = 18200$ mm$^2$

local buckling

flange $\frac{b_{el}}{t} = \frac{309}{2 \times 22.9} = 6.75$ limit: $\frac{200}{\sqrt{350}} = 10.7$ O.K.

web $\frac{h}{w} = \frac{277}{14.0} = 19.8$ limit: $\frac{670}{\sqrt{350}} = 35.8$ O.K.

$\frac{KL_x}{r_x} = \frac{16300}{138} = 118.1$ ← governs

$\frac{KL_y}{r_y} = \frac{9100}{78.6} = 115.8$

$F_e = \frac{\pi^2 \times 200\,000}{118.1^2} = 141.5$

$\lambda = \sqrt{\frac{350}{141.5}} = 1.573$

$n = 1.34$

$C_r = \phi A F_y \left(1 + \lambda^{2n}\right)^{-1/n}$

$= 0.9 \times 18200 \times 350 \left(1 + 1.573^{2.68}\right)^{-1/1.34} \times 10^{-3}$

$C_r = 1910$

$C_r = 1910$ kN ←

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