

Faculty of Engineering  
CIVE 3205: Steel I  
Mid-Term Examination 2 A, March 12, 2015

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Name (Last, First): Solutions

Student No.: \_\_\_\_\_

**Notes:**

- 1) Time limit: **1 hr 30 minutes**
- 2) This examination paper has 9 pages, including this title page.
- 3) Answer all 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	5	Total
Mark						
Max	10	15	20	20	15	<b>80</b>

**Note - prob 2 - if h/w NG than can either reduce h or reduce Fy. If you have reduced Fy and not been given proper credit, see me.**

**Question 1 (10 marks)**

An axially loaded column is 2m long, is pin-ended in both directions, and is made of a W360x64 section of CSA G40.20 400W steel. Compute  $C_r$  for this column.

W360x64

$$A = 8140 \text{ mm}^2$$

$$b = 203 \text{ mm}$$

$$h = 320 \text{ mm}$$

$$r_x = 148 \text{ mm}$$

$$t = 13.5 \text{ mm}$$

$$w = 7.7 \text{ mm}$$

$$r_y = 48.1 \text{ mm}$$

local buckling

$$\frac{b}{2t} = \frac{203}{2 \times 13.5} = 7.52 \quad \text{limit} = \frac{200}{\sqrt{400}} = 10 \quad \text{O.K.}$$

$$\frac{h}{w} = \frac{320}{7.7} = 41.6 \quad \text{limit} = \frac{670}{\sqrt{400}} = 33.5 \quad \text{N.G.}$$

use reduced x-section (13.3.5(a))

$$h_e = w \times 33.5 = 258.0 \text{ mm.}$$

$$A_e = 8140 - (320 - 258) \times 7.7 \\ = 7663 \text{ mm}^2$$

$$\left(\frac{KL}{r}\right)_{\max} = \frac{1 \times 2000}{48.1} = 41.58$$

$$F_e = \frac{\pi^2 \times 20000}{41.58^2} = 1142$$

$$\lambda = \sqrt{\frac{400}{1142}} = 0.592$$

$$n = 1.34$$

$$(1 + \lambda^{2n})^{-1/n} = (1 + 0.592^{2.68})^{-1/1.34} \\ = 0.849$$

$$C_r = 0.9 \times 7663 \times 400 \times 0.849 \times \frac{1}{1000}$$

$$\underline{\underline{C_r = 2340 \text{ kN}}}$$

Alt. - use  $F_{ye}$  as per 13.3.5 (b)

$$\frac{h}{w} \leq \frac{670}{\sqrt{F_{ye}}} \quad F_{ye} = \left(\frac{670}{h/w}\right)^2 \\ = \left(\frac{670}{41.6}\right)^2 \\ = 259.4$$

$$F_e = 1142 \text{ (as before)}$$

$$\lambda = \sqrt{\frac{259.4}{1142}} = 0.477$$

$$P = (1 + \lambda^{2n})^{-1/n} \\ = (1 + 0.477^{2.68})^{-1/1.34} = 0.908$$

$$C_r = 0.9 \times 8140 \times 259.4 \times 0.908 \\ = 1730$$

too conservative  
- penalizes flange  
too much &  
unnecessarily

**Question 2 (15 marks)**

A axially loaded column is 4.2m long and is pin-ended in both directions. Lateral bracing is provided at mid-height for buckling about the weak axis. Select an economical W section of 350W steel to support a factored load,  $C_f$  of 2550 kN. Clearly show the value of  $C_r$  for the selected column.

$$KL = 2100 \text{ mm (weak axis)}$$

use  $KL=2250$  in W column tables

$$W310 \times 74 \quad (2480)$$

$$W250 \times 73 \quad (2640)$$

$$W200 \times 71 \quad (2440) \leftarrow \text{try}$$

$$A = 9100 \text{ mm}^2$$

$$r_y = 52.8 \quad r_x = 91.7$$

Width Thickness

$$W200 \times 71$$

$$b = 206$$

$$t = 17.4$$

$$\frac{b_{el}}{t} = \frac{206}{2 \times 17.4} = 5.91$$

$$\text{limit} = \frac{200}{\sqrt{350}} = 10.7 > 5.9 \quad \text{OK}$$

$$h = 181$$

$$w = 10.2$$

$$\frac{h}{w} = \frac{181}{10.2} = 17.7$$

$$\text{limit} = \frac{670}{\sqrt{350}} = 35.8 > 17.7 \quad \text{OK}$$

Axial Strength

$$\frac{KL_y}{r_y} = \frac{1 \times 2100}{52.8} = 39.77$$

$$\frac{KL_x}{r_x} = \frac{1 \times 4200}{91.7} = 45.80 \leftarrow \text{governs}$$

$$F_e = \frac{\pi^2 \times 200000}{45.80^2} = 941.0$$

$$\lambda = \sqrt{\frac{350}{941.0}} = 0.6099$$

$$(1 + 0.6099^{2.68})^{-1/1.34} = 0.8387$$

$$C_r = 0.9 \times 9100 \times 0.350 \times 0.8387$$

$$= 2404 \text{ kN} < 2550 \text{ N.G. !!}$$

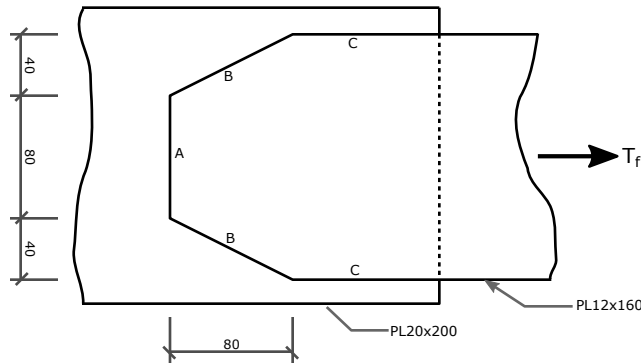
Try W250x73

Solutions	$C_r$
W250x73	2610
W310x74	2570
W310x79	2740
W250x80	2880
W200x86*	2920
W310x86*	3200
W250x89*	3220
W360x91*	3360
W310x97*	3620

\* - not good solutions

## Question 3 (15 marks)

A 12x160 plate tension member is cut on an angle over part of its end and is fillet welded to a 20x200 plate underneath. It is welded completely along the 80mm edge A, and as much on the other two edges, B and C, as is necessary to support a factored tension force,  $T_f$  of 590 kN. Assuming E49xx electrodes and 350W steel, specify the size and length of weld required. Show your results on a sketch.



$$\text{min weld size} = 6\text{mm} \quad \text{CP 6-172, thicker part} = 20\text{mm}$$

$$\text{max weld size} = 12 - 2 = 10\text{mm}$$

$$\text{Try } D = 10\text{mm weld} \quad X_u = 490\text{ MPa}$$

$V_r$  for edge A - welded along entire side

$$L = 80\text{mm} \quad D = 10\text{mm}$$

$$A_w = 0.707 \times 80 \times 10 = 565.6\text{ mm}^2$$

$$M_w = 1.0$$

$$1 + 0.5(\sin 90^\circ)^{1.5} = 1.5$$

$$V_{rA} = 0.67 \times 0.67 \times 565.6 \times 0.49 \times 1.5 \times 1.0$$

$$= 186.6\text{ kN}$$

$V_r$  for 2 edges B - welded along entire side

$$L = \sqrt{40^2 + 80^2} = 89.44\text{mm}$$

$$A_w = 2 \times 0.707 \times 89.44 \times 10 = 1265\text{ mm}^2$$

$$\theta = \sin^{-1} \frac{40}{89.44} = 26.57^\circ$$

$$M_w = \frac{0.85 + 26.57/600}{0.85 + 90/600} = 0.8943$$

$$1 + 0.5(\sin 26.57^\circ)^{1.5} = 1.150$$

$$V_{rB} = 0.67 \times 0.67 \times 1265 \times 0.49 \times 1.15 \times 0.8943$$

$$= 286.2\text{ kN}$$

Edge C

$$\text{Must resist } 590 - (186.6 + 286.2) = 117.2\text{ kN}$$

$$\theta = 0^\circ$$

$$M_w = \frac{0.85 + 0/600}{0.85 + 90/600} = 0.85$$

$$1 + 0.5(\sin 0^\circ)^{1.5} = 1.0$$

For 1 mm of weld

$$v_r = 0.67 \times 0.67 \times (1 \times 0.707 \times 10) \times 0.49 \times 1.0 \times 0.85$$

$$= 1.322\text{ kN/mm}$$

(Workspace for Question 3)

Length of weld reqd

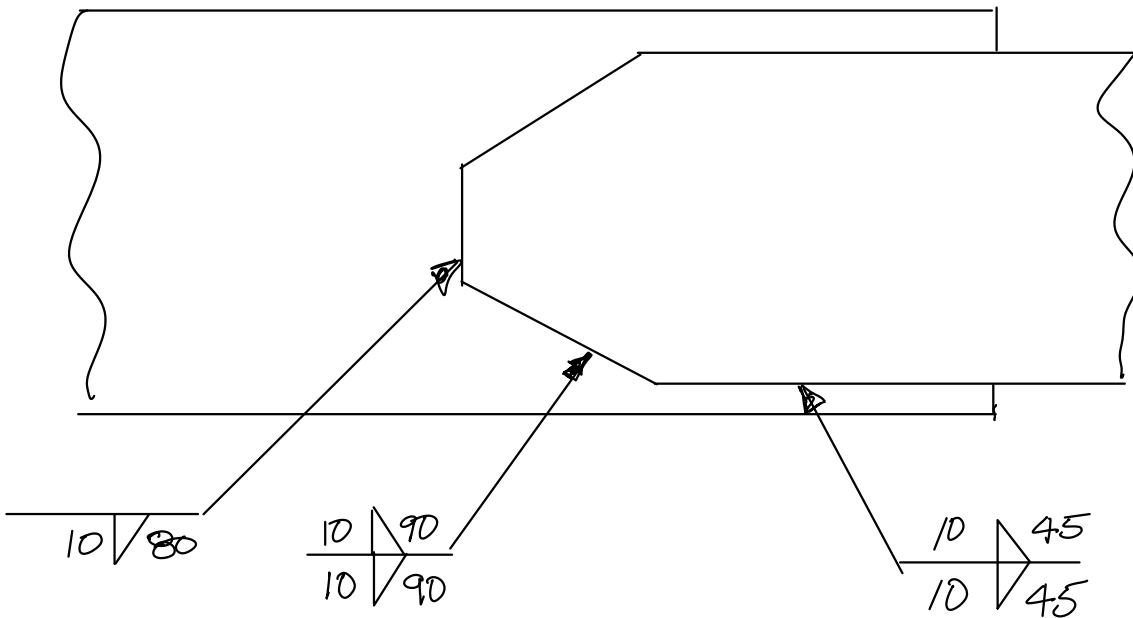
$$= \frac{117.2 \text{ kN}}{1.322 \text{ kN/mm}}$$

$$= 88.65 \text{ mm}$$

Length/side

$$= \frac{88.65 \text{ mm}}{2} = 44.3 \text{ mm}$$

Use 45 mm/side.

Other solutions

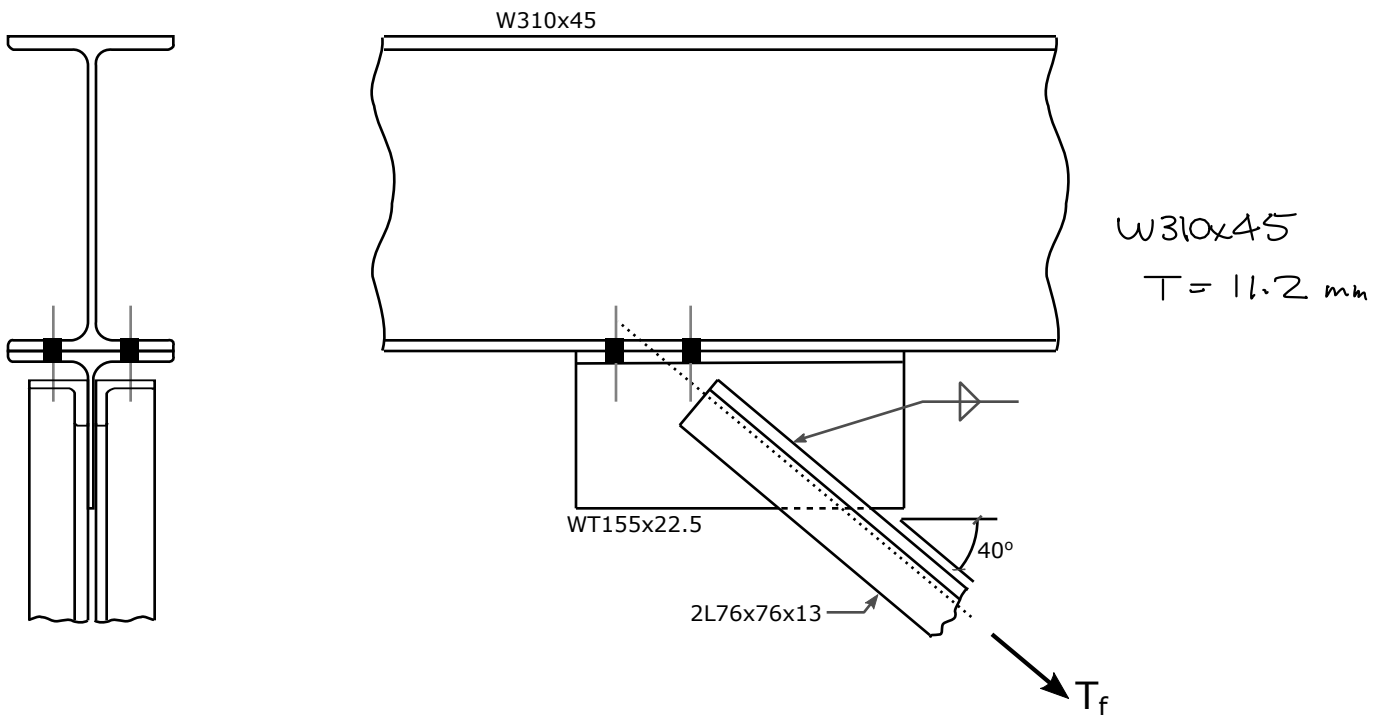
D	L <sub>c</sub>
6	195
7	140
8	100
10	45

## Question 4 (15 marks)

A cross-brace in a building is subject to a factored tension force of  $T_f = 650$  kN. It is welded to a WT155x22.5 bracket, which in turn is bolted to the underside of a W310x45 beam. The cross brace itself is made of 2 L76x76x13 angles.

Select an adequate and economical number of bolts for the tee-to-beam connection, designed as a bearing-type connection. Specify the size, type and number of bolts. Assume 350W steel in the beam, tee and angles.

You need not consider block shear failure of the tee.



$$T_f = 650 \text{ kN} \quad \theta = 40^\circ$$

$$V_f = 650 \cos 40^\circ = 497.9 \text{ kN}$$

$$T_f = 650 \sin 40^\circ = 417.8 \text{ kN}$$

Try 6 M20 A325M bolts, threads intercepted  
d=20

$$F_y = 350 \quad F_u = 450 \quad F_u = 830$$

$$A_b = \frac{\pi \times 20^2}{4} = 314.2 \text{ mm}^2$$

$$V_r = 0.6 \times 0.8 \times 6 \times 1 \times 314.2 \text{ mm}^2 \times 0.830 \frac{\text{kN}}{\text{mm}^2} \times 0.7$$

$$= 525.7 \text{ kN}$$

$$T_r = 0.75 \times 0.8 \times 314.2 \text{ mm}^2 \times 0.83 \frac{\text{kN}}{\text{mm}^2} \times 6$$

$$= 938.7 \text{ kN}$$

$$B_r = 3 \times 0.8 \times 11.2 \times 20 \times \frac{45 \text{ kN}}{\text{mm}^2} \times 6$$

$$= 1451 \text{ kN}$$

(Workspace for Question 4)

$$B_r > V_f$$

$$1451 > 497.9$$

$\therefore$  bearing OK

### Combined Shear & Tension

$$\left(\frac{497.9}{525.7}\right)^2 + \left(\frac{417.9}{938.7}\right)^2 = 1.10 > 1 \text{ N.G.}$$

$\therefore$  6 M20 N.G.

Try 6 M22

### Solutions

<u>d</u>	<u>N</u>	<u><math>V_r</math></u>	<u><math>T_r</math></u>	<u><math>B_r</math></u>	<u><math>\left(\frac{V_f}{V_d}\right)^2 + \left(\frac{T_f}{T_w}\right)^2</math></u>	
20	4	351	626	968	2.4	NG
20	6	526	939	1452	1.1	NG
20	8	701	1252	1935	0.6	OK
22	4	424	757	1064	1.7	NG
22	6	636	1136	1597	0.74	good
22	8	848	1514	2129	0.42	
24	4	505	901	1161	1.2	NG
24	6	757	1352	1742	0.53	
24	8	1009	1802	2322	0.3	
27	4	639	1141	1306	0.74	good
27	6	958	1711	1960	0.3	
27	8	1277	2281	2613	0.19	

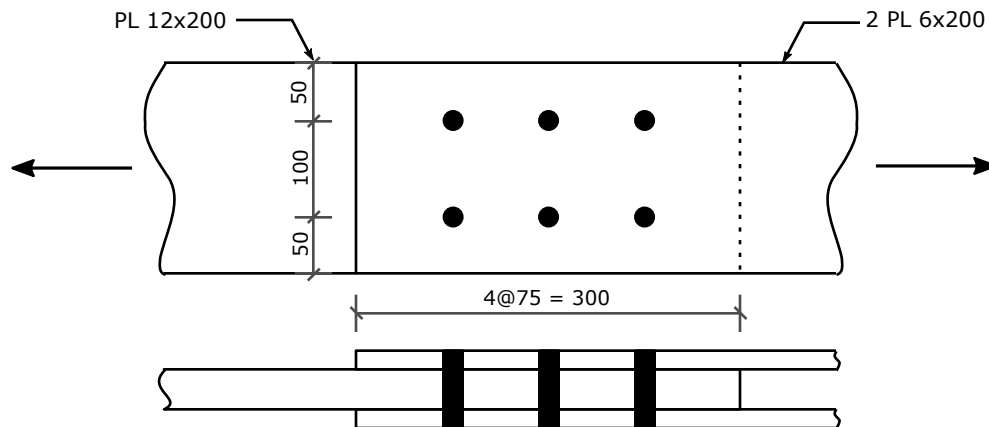
**Question 5 (15 marks)**

A double lap plate connection joins 2 6x200 plates to 1 12x200 plate, all of 350W steel. The connection is by means of 6 M24 A490M bolts in punched holes.

Is this connection adequate as a slip-resistant connection? Justify your answers for all relevant provisions.

The specified dead load is 400kN (tension), the specified live load is 800kN (tension) and the factored load is  $400 \times 1.25 + 800 \times 1.5 = 1700$ kN.

You may assume class B surfaces for the purpose of Table 3. You need only check the applicable provisions of S16 Section 13.12. You need not check the tensile strength provisions of Section 13.2, nor the bolting details of Section 22.5.



350 W Steel:  
 $F_y = 350$  MPa  
 $F_u = 450$  MPa  
 A490M Bolts  
 $F_{ub} = 1040$  MPa

Class B Surface  
 $K_s = 0.5$   
 $C_v = 0.85$

$m = 2$  faying surfaces  
 $n = 6$  bolts

Check Slip Resistance

$$A_b = \pi \times \frac{24^2}{4} = 452.4 \text{ mm}^2$$

$$V_s = 0.53 \times 0.85 \times 0.5 \times 2 \times 6 \times 452.4 \times 1.040$$

$$= 1271 \text{ kN} > 400 + 800$$

$\therefore$  Slip Resistance OK

Check Bolt Shear (threads intercepted)

$$V_r = 0.6 \times 0.8 \times 2 \times 6 \times 452.4 \times 1.040 \times 0.7$$

$$= 1897 \text{ kN} > T_f = 1700$$

$\therefore$  Shear Resistance OK

Check Bearing

$$t = \min(2 \times 6, 12) = 12 \text{ mm}$$

$$B_r = 3 \times 0.8 \times 12 \times 24 \times 0.450 \times 6$$

$$= 1866 \text{ kN} > T_f = 1700 \text{ OK.}$$

$\therefore$  Bolts are adequate

Note -  $V_s$  should be compared to total service load, not just live. live was accepted for this exam

Name: \_\_\_\_\_

Student No.: \_\_\_\_\_

**CIVE 3205 Steel I**

*Mid-Term Examination 2 A, March 12, 2015*

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(Workspace for Question 5)