

CIVE 3205

Example C4

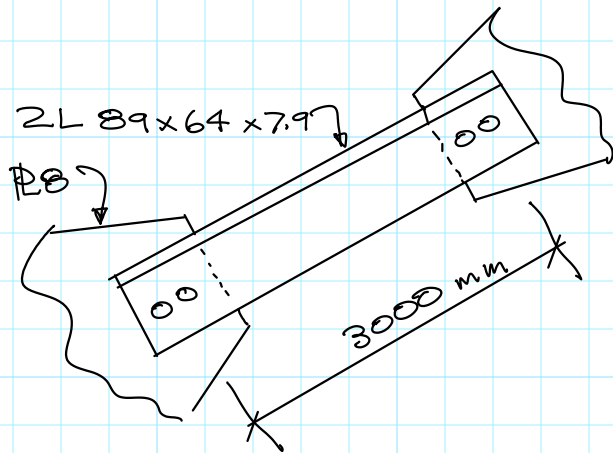
Built-Up Sections
(Double Angle Struts)

March 1, 2013

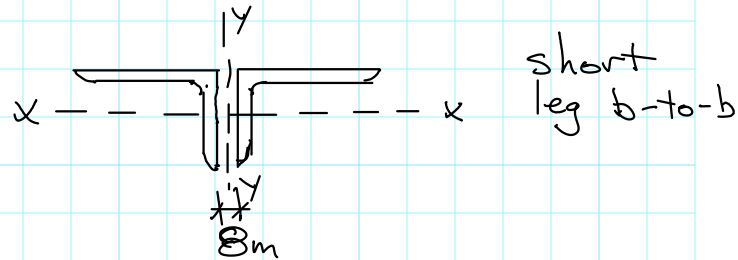
Revisions:

- Apr 4, 2013 - added explanatory note, page 6
- Mar 1, 2013 - original posting

Example C4 - Built-up sections (§ 19 & 19.1.4) 1/6 (Lecture 2012-03-01)



Grade 300W
 $F_y = 300 \text{ MPa}$



Find factored axial capacity

From p. 6-132 2L89x64x7.9 short legs back-to-back

$$A = 2290 \text{ mm}^2$$

$$r_x = 18.5 \text{ mm}$$

$$r_y = 43.3 \text{ mm}$$

(spacing = 8 mm)

From p. 6-76 L89x64x7.9

$$b = 88.9 \text{ mm}$$

$$t = 7.94 \text{ mm}$$

A) Check local buckling

$$\text{largest } \frac{b_{el}}{t} = \frac{88.9}{7.94} = 11.2$$

$$\text{limit} = \frac{200}{\sqrt{300}} = 11.5 > 11.2 \quad \text{O.k.}$$

B) Interconnection

- the angles must be interconnected s.t. the $\frac{KL}{r}$ of a single angle is not greater than the $\frac{KL}{r}$ of the built up section

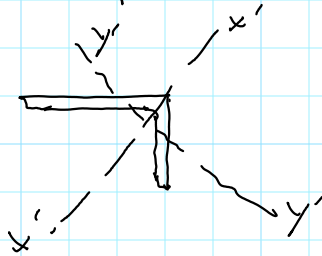
- for $\frac{KL}{r_y}$ of whole, we must calculate an effective ρ_e (see § 19.1.4 & below)

- however $r_x < r_y$ so probably $\frac{KL}{r_x}$ will govern for the whole

Assume governing r will be $r_x = 18.5 \text{ mm}$ 2/6

$$\therefore \left(\frac{KL}{r} \right)_{\text{whole}} = \frac{KL_x}{r_x} = \frac{1.0 \times 3000}{18.5} = 162.2$$

$$\text{thus } \left(\frac{KL}{r} \right)_{\text{part}} \leq 162.2$$



from p. 6-76

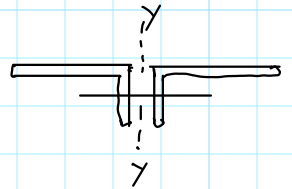
$$r_{\min} = r_{y'} = 13.7$$

$$\frac{1 \times L}{13.7} \leq 162.2$$

$$L \leq 2222 \text{ mm} \quad (\text{max length of 1 angle})$$

\therefore connect with 1 snug tight bolt + 8mm spacer thru short legs at center

$$L_{\text{part}} = 1500 \text{ mm}$$



c) Overall Slenderness

Bending about y -axis causes shear in the connector

\therefore by § 19.1.4

$$\rho_e = \sqrt{\rho_o^2 + \rho_i^2}$$

$$\rho_o = \left(\frac{KL}{r_y} \right)_{\text{whole}} = \frac{1.0 \times 3000}{43.3} = 69.28$$

$$\rho_i = \left(\frac{KL}{r_{\min}} \right)_{\text{part}} = \frac{1.0 \times 1500}{13.7} = 109.5$$

$$P_e = \sqrt{69.28^2 + 109.5^2}$$

$$= 129.6 \quad \leftarrow \text{effective } \frac{KL}{r} \text{ for } y\text{-axis buckling}$$

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$$\left(\frac{KL}{r}\right)_{x\text{-axis}} = 162.2$$

(\therefore our assumption under interconnection above is O.K.)

D)

Compressive Resistance wrt axis x-x
(flexural mode: § 13.3.1 applies)

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} = \frac{\pi^2 \times 200000}{162.2^2}$$

$$= 75.03$$

$$\lambda = \sqrt{\frac{F_y}{F_e}} = \sqrt{\frac{300}{75.03}}$$

$$= 2.000$$

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

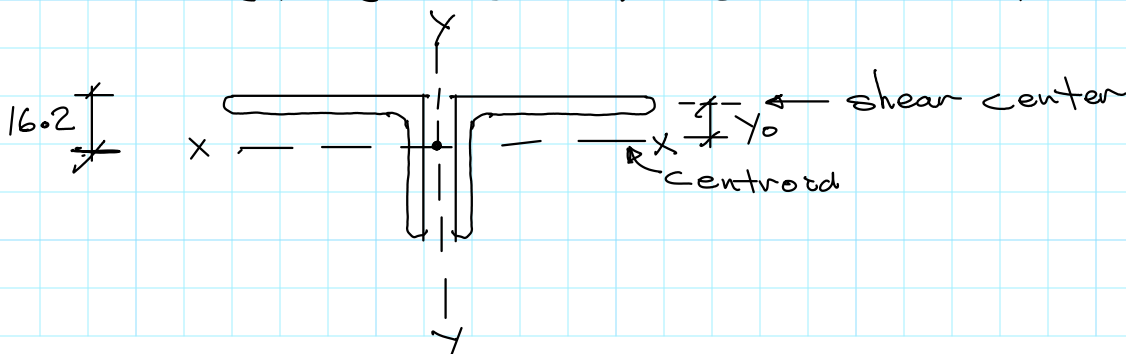
$$= 0.9 \times 2290 \times 300 (1 + 2^{2.68})^{-1/1.34}$$

$$= 139 \text{ kN}$$

$$\underline{\underline{C_r = 139 \text{ kN}}}$$

E)

Compressive Resistance wrt to axis y-y
(Torsional Flexural Mode: § 13.3.2)



Shear-centre location

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In x direction, shear centre coincides with centroid (as y-axis is axis of symmetry)

$$X_0 = 0$$

In y direction, shear centre is mid-depth of leg (ref: Torsional Section Properties of Steel Shapes, cisc and Formulas for Stress and Strain, Roark & Young)

$$Y_0 = 16.2 - \frac{7.9}{2} = 12.2 \text{ mm}$$

Torsional-flexural section properties

$$\begin{aligned}\bar{r}_0^2 &= x_0^2 + y_0^2 + r_x^2 + r_y^2 \\ &= 0^2 + 12.2^2 + 18.5^2 + 43.3^2\end{aligned}$$

$$\bar{r}_0^2 = 2366 \text{ mm}^2$$

$$\begin{aligned}\Omega &= 1 - \left(\frac{x_0^2 + y_0^2}{\bar{r}_0^2} \right) \\ &= 1 - \left(\frac{0^2 + 12.2^2}{2366} \right) \\ &= 0.937\end{aligned}$$

Equivalent Buckling Stresses

$$\begin{aligned}F_{ey} &= \frac{\pi^2 E}{\left(\frac{k_y L_y}{r_y} \right)^2} \\ &= \frac{\pi^2 E}{\rho_e^2} \quad (\S 19.1.4) \\ &= \frac{\pi^2 \times 200000}{129.6^2} \\ &= 118 \text{ MPa}\end{aligned}$$

for single L 89x64x7.9

$$C_w = 11.5 \times 10^6 \text{ mm}^6 \quad (\text{p 6-76})$$

$$J = 24.1 \times 10^3 \text{ mm}^4$$

From "Torsional Section Properties of Steel Shapes", CISC, 2002

for pair:

$$C_w = 11.5 \times 10^6 \times 2 = 23 \times 10^6 \text{ mm}^6$$

$$J = 24.1 \times 10^3 \times 2 = 48.2 \times 10^3 \text{ mm}^4$$

§13.3.2:

$$F_{ez} = \left(\frac{\pi^2 E C_w}{(K_z L_z)^2} + GJ \right) \frac{1}{A r_o^2}$$

$$= \left(\frac{\pi^2 \times 200000 \times 23 \times 10^6}{(1.0 \times 3000)^2} + 77000 \times 48.2 \times 10^3 \right) \frac{1}{2290 \times 2366} \times 10^3$$

$$F_{ez} = 685 \text{ MPa}$$

$$F_{eyz} = \frac{F_{ey} + F_{ez}}{2\Omega} \left[1 - \sqrt{1 - \frac{4F_{ey}F_{ez}\Omega}{(F_{ey} + F_{ez})^2}} \right]$$

$$= \frac{118 + 685}{2 \times 0.937} \left[1 - \sqrt{1 - \frac{4 \times 118 \times 685 \times 0.937}{(118 + 685)^2}} \right]$$

$$= 116 \text{ MPa}$$

$$F_{ex} = \frac{\pi^2 E}{\left(\frac{K_x L_x}{r_x} \right)^2} = \frac{\pi^2 \times 200000}{\left(\frac{1 \times 3000}{18.5} \right)^2}$$

$$= 75.0 \text{ MPa}$$

$$\therefore F_e = \text{lesser of } F_{ex}, F_{eyz}$$

$$= 75.0 \text{ MPa}$$

But that's what we used in D), above.

\therefore x-x axis governs

$$\underline{\underline{C_r = 139 \text{ kN}}}$$



Notes:

- § 13.3.1 is used for axis X-X buckling (flexural only)
- § 13.3.2 is used for axis Y-Y buckling.

References:

- Commentary, page 2-31, paragraph 6.
"... while for singly symmetric sections two potential compressive buckling modes (one flexural & one flexural torsional) exist..."
- Handbook, page 4-4 (notes on double angle struts)
- Handbook, page 4-142 (design example)