CIVE 3205
Example AC40

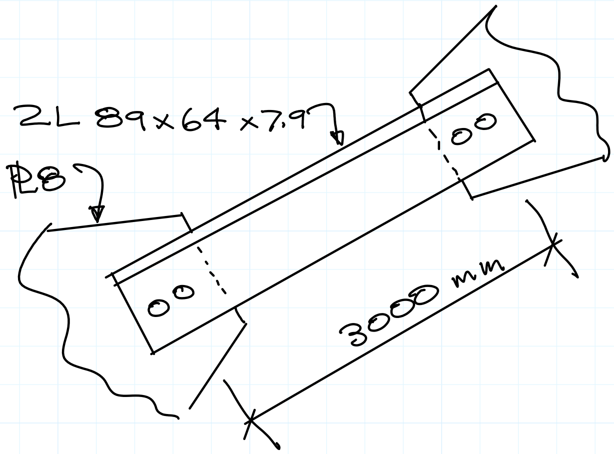
Built-Up Sections
(Double Angle Struts)

Feb 26, 2020

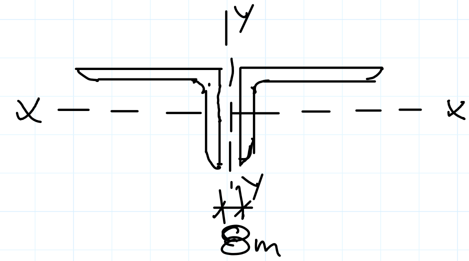
N.M. Holtz

Revisions:
- Feb 26/20 - original posting

Example AC40 - Built-up sections (§ 19 & 19.1.4)



Grade 300W
$F_y = 300$ MPa



Find factored axial capacity

From p. 6-130 2L89x64x7.9 short legs back-to-back

$\frac{2300}{2290}$

$A = 2300\ mm^2$
$r_x = 18.5$ mm
$r_y = 43.3$ mm (spacing = 8 mm)

From p. 6-76 L89x64x7.9
$b = 88.9$ mm
$t = 7.94$ mm

A) Check local buckling

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

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

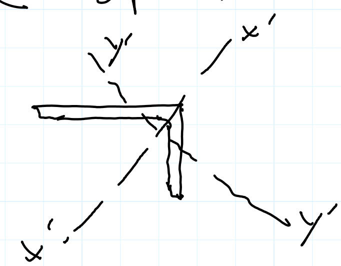
B) Interconnection

- 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 $r_x = 18.5$ mm.

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

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



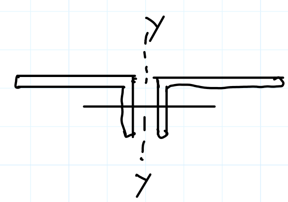
from p 6-76
$r_{min} = r_{y'} = 13.7$

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

$L \leq 2222$ mm (max length of 1 angle)

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

$L_{part} = 1500$ mm



c) <u>Overall Slenderness</u>

Bending about y-axis causes shear in the connector

$\therefore$ by § 19.1.4

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

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

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

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

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

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

(∴ our assumption under interconnection above is O.K.)

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

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

$$= 75.03$$

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

$$= 2.000$$

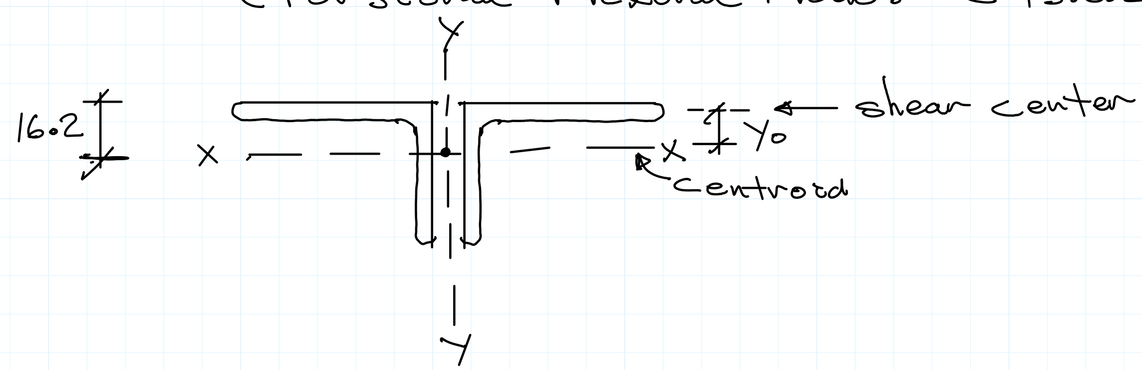
$$C_r = \phi A F_y \left(1 + \lambda^{2n}\right)^{-1/n}$$

$$= .9 \times 2300 \times 300 \left(1 + 2^{2.68}\right)^{-1/1.34}$$

$$= 139 \text{ kN}$$

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

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



Shear-centre location

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

$$X_o = 0$$

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)

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

Torsional-flexural section properties

$$\bar{r}_o^2 = x_o^2 + y_o^2 + r_x^2 + r_y^2$$

$$= 0^2 + 12.2^2 + 18.5^2 + 43.3^2$$

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

$$\Omega = 1 - \left(\frac{x_o^2 + y_o^2}{\bar{r}_o^2}\right)$$

$$= 1 - \left(\frac{0^2 + 12.2^2}{2366}\right)$$

$$= 0.937$$

Equivalent Buckling Stresses

$$F_{ey} = \frac{\pi^2 E}{\left(\frac{K_y L_y}{r_y}\right)^2}$$

$$= \frac{\pi^2 E}{\rho_e^2} \qquad (\S\, 19.1.4)$$

$$= \frac{\pi^2 \times 200\,000}{129.6^2}$$

$$= 118 \text{ MPa}$$

for single L 89x64x7.9

$C_w = 11.5 \times 10^6 \text{ mm}^6$ (p 6-74)

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

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

for pair:

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

$J = 24.1 \times 10^6 \times 2 = 48.2 \times 10^3 \text{ mm}^4$

§13.3.2:

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

$$= \left(\frac{\pi^2 \times 200\,000 \times 23 \times 10^6}{(1.0 \times 3000)^2} + 77000 \times 48.2 \times 10^3 \right) \frac{1}{2290 \times 2366} \times 10^{-3}$$

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

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

$$= \frac{118 + 685}{2 \times 0.937} \left[1 - \sqrt{1 - \frac{4 \times 118 \times 685 \times .937}{(118 + 685)^2}} \right]$$

$= 116 \text{ MPa}$

$$F_{ex} = \frac{\pi^2 E}{\left(\frac{K_x L_x}{r_x} \right)^2} = \frac{\pi^2 \times 200\,000}{\left(\frac{1 \times 3000}{18.5} \right)^2}$$

$= 75.0 \text{ MPa}$

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

$= 75.0 \text{ MPa}$

But thats 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 8.

  "... while for singly symmetric sections two potential compressive buckling modes (one flexural & one flexural torsional) exist ..."

- Handbook, page 4-115 (notes on double angle struts)
- Handbook, page 4-150 (design example)