CIVE 3205

Example Set C1

Axially Loaded Columns

March 1, 2012
March 1, 2013
March 4, 2019

Revisions:

- March 4, 2019 - Revised C1-3, Added C1-4
- March 1, 2012 - original posting.

C1-1 (Example of lecture 2013-02-27)

Find capacity of axially loaded W250x73, L=8m, pinned end (K=1.0). Grade 350W - $F_y = 350$ MPa.

From page 6-52

W250x73:

$A = 9280 \text{ mm}^2$ $\quad b = 254$ mm $\quad t = 14.2$ mm

$r_x = 110$ mm $\quad d-2t = h = 225$ mm $\quad w = 8.6$ mm

$r_y = 64.6$ mm

i) check local buckling

flange: $\dfrac{b_{el}}{t} = \dfrac{254}{2 \times 14.2} = 8.94$

Table 1 limit $= \dfrac{200}{\sqrt{350}} = 10.7 > 8.94$ o.k.

web: $\dfrac{h}{w} = \dfrac{225}{8.6} = 26.2$

Table 1 limit $= \dfrac{670}{\sqrt{350}} = 35.8 > 26.2$ o.k.

∴ local buckling reqments are met.

ii) overall strength

$$\frac{K_x L_x}{r_x} = \frac{1.0 \times 8000}{110} = 72.7$$

$$\frac{K_y L_y}{r_y} = \frac{1.0 \times 8000}{64.6} = 123.8 \longleftarrow \text{governs}$$

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2} = \frac{\pi^2 \times 200\,000}{123.8^2} = 128.8 \text{ MPa}$$

$$\lambda = \sqrt{F_y/F_e} = \sqrt{350/128.8} = 1.648$$

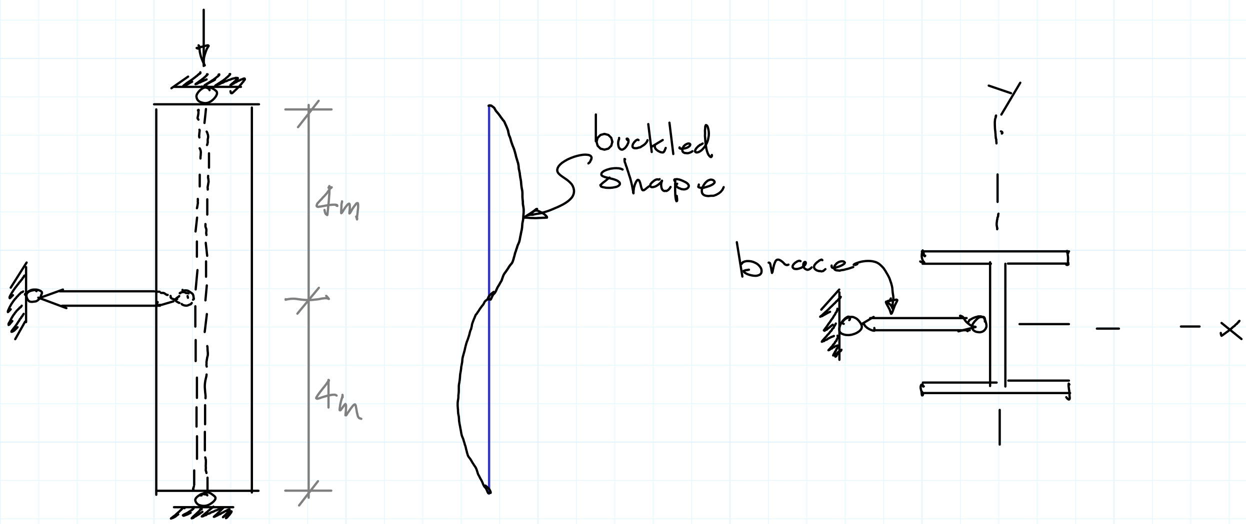
$n = 1.34$

$$C_r = 0.9 \times 9280 \text{ mm}^2 \times 350 \frac{N}{mm^2} \times 10^{-3} \frac{kN}{N} \times \left(1 + 1.648^{2.68}\right)^{-1/1.34}$$

$$\underline{\underline{C_r = 905 \text{ kN}}} \longleftarrow \text{Ans.}$$

C1-2 (Class Example 2013-03-01)

The W250 x 73 of example C1-1 is to be braced at mid-height against buckling about the weak axis, as shown:



i) local buckling – as before o.k.

ii) overall strength

$$\frac{K_x L_x}{r_x} = \frac{1.0 \times 8000}{110} = 72.7 \longleftarrow \text{governs}$$

$$\frac{K_y L_y}{r_y} = \frac{1.0 \times 4000}{64.6} = 61.9$$

$$F_e = \frac{\pi^2 \times 200000}{(72.7)^2} = 373.5 \text{ MPa}$$

$$\lambda = \sqrt{\frac{350}{373.5}} = 0.9680$$

$$n = 1.34$$

$$C_r = 0.9 \times 9280 \times .35 \times \left(1 + .9680^{2.68}\right)^{-1/1.34}$$

$$C_r = 1799 \text{ kN}$$

$$\underline{\underline{C_r = 1800 \text{ kN}}} \longleftarrow$$

C1-3 (In-class example ~~2013-03-01~~ 2019-03-04)

Select a column to carry $C_f = 4000$ kN as an axially loaded pin-ended col. $L = 4900$ mm $K = 1.0$ ~~350W~~ A992 steel $F_y = \cancel{350}$ 345 MPa.

Use a W profile.

For a trial section, calc. smallest area:

$$A_{reqd} > \frac{C_f}{\phi F_y} = \frac{4000 \times 10^3}{0.9 \times 345} = 12880 \text{ mm}^2$$

Typical W column sections are W310 & W360 (sometimes W200 or W250) and roughly square in cross section (b & d roughly equal).

Try W310x158

$A = 20\,100$ mm^2 $b = 310$ mm $t = 25.1$ mm

$r_x = 139$ mm $d - 2t = 277$ mm $w = 15.5$ mm

$r_y = 78.9$ mm

i) check local buckling

flange: $\frac{b_{el}}{t} = \frac{310}{2 \times 25.1} = 6.18 \leq \frac{200}{\sqrt{345}} = 10.8$ o.k.

web: $\frac{h}{w} = \frac{277}{15.5} = 17.9 \leq \frac{670}{\sqrt{345}} = 36.1$ o.k.

ii) overall capacity

$$\left(\frac{KL}{r}\right)_{max} = \frac{K_y L_y}{r_y} = \frac{1.0 \times 4900}{78.9} = 62.10$$

$$F_e = \frac{\pi^2 \times 200\,000}{62.10^2} = 511.9$$

$$\lambda = \sqrt{\frac{345}{511.9}} = 0.8210$$

$n = 1.34$

$$C_r = 0.9 \times 20\,100 \times .345 \times \left(1 + 0.8210^{2.68}\right)^{-1/1.34}$$

$$C_r = 4416 \text{ kN}$$

10% overdesign – try smaller section.

C1-3 (continued.)

Use Handbook Factored Axial Compressive Resistance tables (green pages 4-21 to 4-113) to select trial section.
(Note: values in table are for $F_y = 345$ MPa)

Using row for $KL = 5000$ mm

Try W310 x 143 $\quad (C_r = 3930$ for $L = 5000$, $F_y = 345)$

$A = 18\,200$

$r_x = 138 \qquad b = 309 \qquad t = 22.9$

$r_y = 78.6 \qquad d - 2t = 277 \qquad w = 14.0$

i) local buckling

flange: $\frac{b_{el}}{t} = \frac{309}{2 \times 22.9} = 6.75 < 10.8$ o.k.

web: $\frac{h}{w} = \frac{277}{14.0} = 19.8 < 36.1$ o.k.

ii) overall strength

$$\frac{KL}{r} = \frac{1.0 \times 4900}{78.6} = 62.34$$

$$F_e = \frac{\pi^2 \times 200\,000}{62.34^2} = 507.9 \text{ MPa}$$

$$\lambda = \sqrt{\frac{345}{507.9}} = 0.8242$$

$$n = 1.34$$

$$C_r = 0.9 \times 18200 \times 0.345 \left(1 + 0.8242^{2.68}\right)^{-1/1.34}$$

$= 3987 < 4000$ but o.k. (0.3% under)

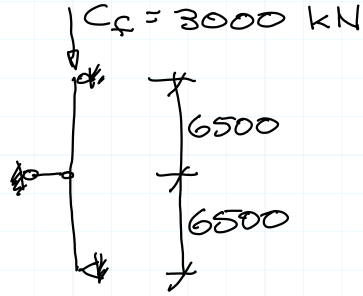
Use $\underline{\underline{\text{W310 x 143}}}$ ←

C1 -3 (continued)

The following sections would likely work & should be checked

		mass kg/m
W360 x 134		134
HSS 406 x 13	Class C	123

Example C1-4



Select a W section
ASTM A992 steel

Pin ends, both direction

Mid point brace one direction

Note: Factored Axial Compressive Resistance Tables

1. C_r values are computed using L_y - length associated with weak axis buckling.
   i.e using $\frac{K_y L_y}{r_y}$ as the slenderness ratio

2. Sometimes, as perhaps in this case, buckling about the strong axis will govern

$$\frac{K_x L_x}{r_x} > \frac{K_y L_y}{r_y}$$

3. Find a section of length such that strength wrt weak axis is the same

4. Do that by equating slenderness ratios

$$\frac{K_y L_y}{r_y} = \frac{K_x L_x}{r_x}$$

or $$L_y = \left(\frac{K_x}{K_y}\right) \frac{L_x}{(r_x / r_y)}$$

if $K_x = K_y$, then

$$L_y = \frac{L_x}{(r_x / r_y)}$$

1^{st} estimate:

Use $L_y = 6500$ mm & $C_f = 3000$ to get 1^{st} trial.

W310 × 143 has $C_f = 3070$ for $L_y = 6500$

for that section $r_x/r_y = 1.76$

∴ find a section with $L_y = \frac{13000}{1.76} \doteq 7390$ mm

Look at row for $L = 7500$

try: W310 x 179 $\frac{r_x}{r_y} = 1.76$ $L_y = 7390$

$3560 > C_f > 3270$

or W360 x 162 $\frac{r_x}{r_y} = 1.66$ $L_y = 7831$

$3650 > C_f > 3400$ will work

(but not readily available)

W360 x 134 $\frac{r_x}{r_y} = 1.66$ $L_y = 7831$

$2990 > C_f > 2780$ N.G.

W360 x 122 $\frac{r_x}{r_y} = 2.44$ $L_y = \frac{13000}{2.44} = 5330$ mm

$2730 > C_f > 2450$ N.G.

Use W310 x 179