CIVE 3205
Structural Steel Components

Example BC10
Eccentrically-Loaded Column Strength

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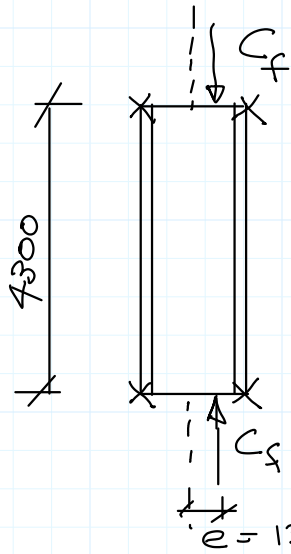
Revisions:

- Mar 27/20 – initial posting.

Beam Column Example BC10



W310 x 86
Grade 350W

x - lateral brace

Is section adequate?

- braced frame
- compr. flange laterally supported only at ends.
- pinned both ends, both directions
- sway effects included in analysis (§10.3.2)

C_f = 1250 kN

M_{fx} = 1250 x .13 = 162 kN-m

M_{fy} = 0

W310 x 86:

d = 310 mm
b = 254 mm
t = 16.3 mm
w = 9.1 mm
h = d - 2t = 277 mm
I_x = 198 x 10^6 mm^4
Z_x = 1420 x 10^3 mm^3

r_x = 134 mm
r_y = 63.6 mm
I_y = 44.5 x 10^6 mm^4
J = 874 x 10^3 mm^4
C_w = 961 x 10^9 mm^6

1) check local buckling against class 2

flange: $\frac{b}{2t} = \frac{254}{2 \times 16.3} = 7.8$

$\text{limit} = \frac{170}{\sqrt{350}} = 9.1 > 7.8$ O.K.

web:

$\phi C_y = \phi A F_y$
$= 0.9 \times 11000 \times 350 \times 10^{-3}$
$= 3465$ kN

$\text{limit} = \frac{1700}{\sqrt{350}} \left(1 - 0.61 \frac{1250}{3465}\right) = 70.9$

$\frac{h}{w} = \frac{277}{9.1} = 30.4 < 70.9$ O.K.

∴ section is at least class 2

2) Strength & Stability: §13.8.2

$$\frac{C_f}{C_r} + \frac{0.85 U_{1x} M_{fx}}{M_{rx}} \le 1.0 \qquad (M_{fy} = 0)$$

(a) cross-section strength

$C_r = \phi A F_y$ (§13.3, $\lambda = 0$)

$= 0.9 \times 11000 \times 350 \times 10^{-3}$

$= 3465$ kN

$M_{rx} = \phi Z F_y$ (§13.5(a))

$= 0.9 \times 1420 \times 10^{-3} \times 350 \times 10^{-6}$

$= 447.3$ kN-m

$U_{1x} = \frac{\omega_1}{1 - \frac{C_f}{C_e}} \not< 1.0$ (§13.8.4)

$\omega_1 = 0.6 - 0.4\kappa \ge 0.4$ (§13.8.5(a))

$\kappa = -1$ (§13.6)

$\omega_1 = 0.6 - 0.4 \times -1$

$= 1.0$

$C_e = \frac{\pi^2 EI}{L^2}$

$= \frac{\pi^2 \times 200\,000 \times 198 \times 10^6}{4300^2} \times 10^{-3}$

$= 21140$ kN

$U_{1x} = \frac{1.0}{1 - \frac{1250}{21140}} \ge 1.0$

$= 1.063$

Check:

$$\frac{1250}{3465} + \frac{0.85 \times 1.063 \times 162.5}{447.3} \le 1.0$$

$0.689 < 1.0$ O.K.

(b) overall member strength

$K_x = 1.0$ (regardless of "real" K_x)

in addition, we have uniaxial strong-axis bending, so

$C_r = C_{rx}$

$= \phi A F_y \left(1 + \lambda^{2n}\right)^{-1/n}$ (§ 13.3.1)

$F_e = \dfrac{\pi^2 E}{\left(\frac{KL}{r_x}\right)^2} = \dfrac{\pi^2 \times 200\,000}{\left(\frac{1.0 \times 4300}{134}\right)^2} = 1917$

$\lambda = \sqrt{\dfrac{F_y}{F_e}} = \sqrt{\dfrac{350}{1917}}$

$= 0.4273$

$n = 1.34$

$C_r = 3465 \left(1 + 0.4273^{2.68}\right)^{-1/1.34}$

$= 3222$ kN

$M_{rx} = 447.3$ kN-m, as above (§ 13.5(a))

$U_{1x} = 1.063$ as above (§ 13.8.4)

check:

$$\frac{1250}{3222} + \frac{0.85 \times 1.063 \times 162.5}{447.3} \leq 1.0$$

$0.716 < 1.0$ O.K.

(c) lateral torsional buckling strength

$C_r = C_{ry}$ (§ 13.8)

$$\frac{kL}{r_y} = \frac{1.0 \times 4300}{63.6} = 67.61$$

$$\lambda = \sqrt{\frac{350}{\frac{\pi^2 \times 200\,000}{67.61^2}}}$$

$$= 0.9003$$

$$C_{ry} = 0.9 \times 11000 \times 350 \times \left(1 + 0.9003^{2.68}\right)^{-1/1.34} \times 10^{-3}$$

$$= 2278 \text{ kN}$$

M_{rx} (§ 13.6)

$L = 4300$

$$\omega_2 = 1.75 + 1.05 \times -1 + 0.3 \times (-1)^2$$

$$= 1.0$$

$$M_u = \frac{1.0 \times \pi}{4300} \sqrt{200\,000 \times 44.5 \times 10^6 \times 77\,000 \times 874 \times 10^3 + \left(\frac{\pi \times 200000}{4300}\right)^2 \times 44.5 \times 10^6 \times 961 \times 10^9} \times 10^{-6}$$

$$= 898 \text{ kN-m}$$

$$M_p = ZF_y = 1420 \times 10^3 \times 350 \times 10^{-6}$$

$$= 497 \text{ kN-m}$$

$$0.67 M_p = 333 \text{ kN-m}$$

$M_u > 0.67 M_p$

$$\therefore M_r = 1.15 \times 0.9 \times 497 \left(1 - \frac{.28 \times 497}{898}\right) < 0.9 \times 497$$

$$= 434.7 < 447.3$$

$M_r = 434.7$ kN-m

$U_{1x} = 1.063 > 1.0$ as above

Check:

$$\frac{1250}{2278} + \frac{0.85 \times 1.063 \times 162.5}{434.7} \leq 1.0$$

$$0.886 < 1.0 \quad \text{O.K.}$$

Check also

$$\frac{M_{fx}}{M_{rx}} + \frac{M_{fy}}{M_{ry}} \leq 1.0 \qquad (\S 13.8.2)$$

$$\frac{162.5}{434.7} < 1.0 \qquad \text{O.K.}$$

$\therefore$ Section W310x86 is adequate