CARLETON UNIVERSITY
Department of Civil and Environmental Engineering

Name:

ID#: Assign#: Date:

CIVE 3205

Steel 1

Example BC30

Beam Column Strength

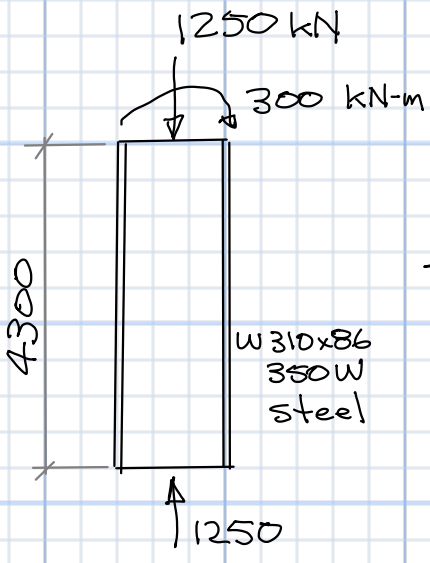
Braced Frame

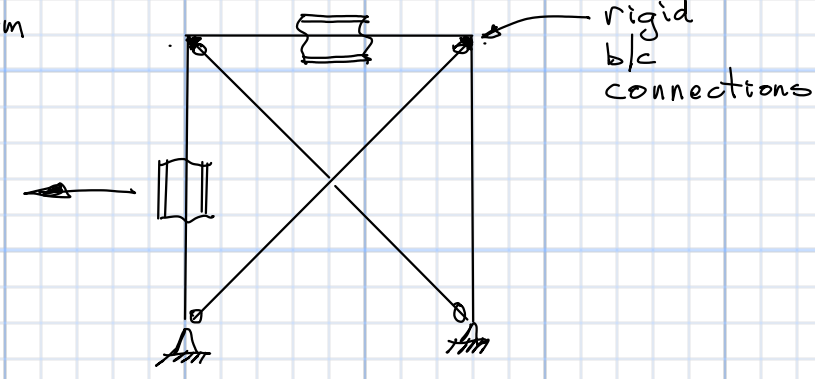
March 27, 2020

6 pages

Revisions:

- March 27/20 - initial posting





Braced Frame

Col pinned both ends about its y-axis

Col pinned @ bot, rigidly connected to girder @ top for bending about its x-(strong) axis

$C_f = 1250\ kN$

$M_{fx} = 300\ kN\text{-}m$

$M_{fy} = 0$

W310x86:

$d = 310\ mm$
$b = 254\ mm$
$t = 16.3\ mm$
$w = 9.1\ mm$
$d - 2t = 277\ mm$

$I_x = 198 \times 10^6\ mm^4$
$Z_x = 1420 \times 10^3\ mm^3$
$I_y = 44.5 \times 10^6\ mm^4$
$J = 874 \times 10^3\ mm^4$
$C_w = 961 \times 10^9\ mm^2$

$A = 11000\ mm^2$
$r_x = 134\ mm$
$r_y = 63.6\ mm$

Check local buckling / section class:

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

class 2 limit $= \frac{170}{\sqrt{350}} = 9.1 > 7.8$ ok

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

class 2 limit $= \frac{1700}{\sqrt{350}} \left(1 - 0.61 \frac{1250}{3465}\right) = 70.9$

$\frac{h}{w} = \frac{277}{9.1} = 30.4 < 70.9$ ok

∴ section meets class 2 requirements

(a) cross-section strength (§ 13.8.2 a))

$$C_r = \phi A F_y$$
$$= 0.9 \times 11000\ mm^2 \times 350\ \frac{N}{mm^2} \times 10^{-3}\ \frac{kN}{N}$$
$$= 3465\ kN$$

for U_{1x}:

$$\alpha = \frac{0}{300} = 0$$
$$w_1 = 0.6 - 0.4 \times 0$$
$$= 0.6$$
$$C_{ex} = \frac{\pi^2 \times 200000 \times 198 \times 10^6}{4300^2}$$
$$C_{ex} = 21140\ kN$$
$$U_{1x} = \frac{0.6}{1 - \frac{1250}{21140}} = 0.6377$$

use $U_{1x} = 1.0$

$$M_{rx} = \phi Z_x F_y$$
$$= 0.9 \times 1420 \times 10^3 \times 350 \times 10^{-6}$$
$$= 447.3\ kN\text{-}m$$

$$\frac{C_f}{C_r} + \frac{0.85 U_{1x} M_{fx}}{M_{rx}} = \frac{1250}{3465} + \frac{0.85 \times 1 \times 300}{447.3}$$
$$= 0.931 < 1 \qquad \text{O.K.}$$

b) overall strength (13.8.2 b))

C_r: $K = 1$, $L = 4300$

$$\frac{KL}{r_x} = \frac{1 \times 4300}{134} = 32.09$$
$$F_e = \frac{\pi^2 \times 200000}{32.09^2} = 1917\ MPa$$

$$\lambda = \sqrt{\frac{350}{1917}} = 0.4273$$

$$C_r = \frac{0.9 \times 11000 \times 350}{(1 + 0.4273^{2.68})^{1/1.34}}$$

$$= 3222 \text{ kN}$$

M_r:

$M_{rx} = 447.3$ kN-m (as above)

$U_{1x} = 0.6377$ (see above)

$$\frac{1250}{3222} + \frac{0.85 \times 0.6377 \times 300}{447.3}$$

$$= 0.7515 < 1.0 \quad \text{O.K.}$$

c) lateral torsional strength (13.8.2c))

C_r: - based on weak axis buckling

@ top $G_{uy} = \infty$ (because no girders rigidly attached wrt bending about y-axis)

@ bot $G_{Ly} = 10$ (annex G.4)

$\therefore K = 0.98$ (Fig G.1)

Alternatively: col is pinned top & bot wrt y-axis bending, $\therefore K = 1$ would be perfectly acceptable

$$\frac{KL}{r_y} = \frac{0.98 \times 4300}{63.6}$$

$$= 66.26$$

$$F_e = \frac{\pi^2 \times 200000}{66.26^2}$$

$$= 449.6$$

$$\lambda = \sqrt{\frac{350}{449.6}} = 0.8823$$

$$C_r = \frac{0.9 \times 11000 \times 350}{(1 + 0.8823^{2.68})^{1/1.34}}$$

$$C_r = 2317 \text{ kN}$$

M_r:

$$x = \frac{0}{800} = 0$$

$$\omega_2 = 1.75 \quad (\S 13.6 \text{ a)})$$

$$P = EI_y GJ = 200000 \times 44.5 \times 10^6 \times 874 \times 10^3 \times 77000$$

$$= 599.0 \times 10^{21}$$

$$Q = \left(\frac{\pi \times 200000}{4300}\right)^2 \times 44.5 \times 10^6 \times 961 \times 10^9$$

$$= 913.1 \times 10^{21}$$

$$M_o = \frac{1.75 \times \pi}{4300} \sqrt{599.0 \times 10^{21} + 913.1 \times 10^{21}} \times 10^{-6}$$

$$= 1572 \text{ kN-m}$$

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

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

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

$$M_o > 0.67 M_p$$

$$\therefore M_{r_x} = 1.15 \phi M_p \left(1 - \frac{0.28 M_p}{M_o}\right) \leq \phi M_p$$

$$= 1.15 \times 0.9 \times 497 \left(1 - \frac{0.28 \times 497}{1572}\right)$$

$$= 468.9 \leq 447.3$$

$M_{r_x} = 447.3$ kN-m

$U_{1x} = 1.0$ (calc as 0.6377 above)

$$\frac{1250}{2317} + \frac{0.85 \times 1.0 \times 300}{447.3}$$

$= 1.11 \not\leq 1.0$ N.G.

Section inadequate wrt l.t.b.

§13.8.2 c) vi)

$$\frac{M_{fx}}{M_{r_x}} = \frac{300}{447.3} < 1$$ O.K.