CARLETON UNIVERSITY
Department of Civil and Environmental Engineering

Name:

ID#:

Assign#:

Date:

CIVE 3205

Steel 1

Example BC35

Beam Column Strength

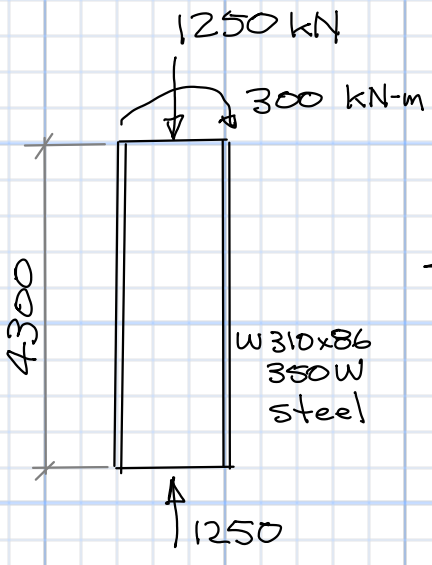
Unbraced Frame

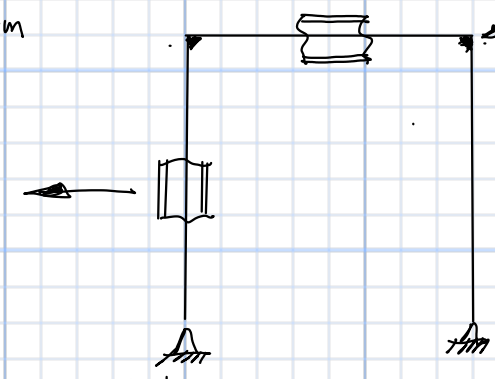
March 27, 2020

6 pages

Revisions:

- March 27/20 - initial posting





Unbraced Frame

See BC30 for braced frame version.

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

$M_{f_x} = 300$ kN-m

$M_{f_y} = 0$

P-Δ effects included in analysis.

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))

-not necessary to check, will not govern for unbraced frames.

(b) overall strength (13.8.2 b))

C_r: $K = 1$

$L = 4300$

$$\frac{KL}{r_x} = \frac{1 \times 4300}{134} = 32.09$$

$$F_e = \frac{\pi^2 \times 200000}{32.09^2} = 1917 \text{ MPa}$$

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

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

$$= 3222 \text{ kN}$$

$$M_{rx} = \phi Z_x F_y$$

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

$$= 447.3 \text{ kN-m}$$

$U_{1x} = 1.0$ (13.8.2 b) iii)

$$\frac{1250}{3222} + \frac{0.85 \times 1.0 \times 300}{447.3}$$

$$= 0.958 < 1.0 \quad \text{O.K.}$$

c) lateral torsional strength (13.8.2c))

Cr: - based on weak axis buckling

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

(remember, those girders would be perpendicular to page)

@ 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:

$\lambda = \frac{0}{300} = 0$

$\omega_2 = 1.75$ (§ 13.6 a))

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

$= 599.0 \times 10^{21}$

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

$= 913.1 \times 10^{21}$

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

$= 1572$ kN-m

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

$= 497$ kN-m

$0.67 M_p = 333$ kN-m

$M_u > 0.67 M_p$

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

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

$= 468.9 \leq 447.3$

$M_{r_x} = 447.3$ kN-m

$U_{1x} = 1.0$ (unbraced frame)

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

$$= 1.11 \not\leq 1.0 \qquad \text{N.G.}$$

Section inadequate wrt l.t.b.

§13.8.2 c) vi)

$$\frac{M_{fx}}{M_{rx}} = \frac{300}{447.3} < 1 \qquad \text{O.K.}$$

Compare Braced vs Unbraced

	Braced	Unbraced
a) cross-sectional		
C_r	3465	na
U_{1x}	1.0	na
M_{rx}	447.3	na
b) overall		
C_r	3222	3222
U_{1x}	0.6377	1.0
M_{rx}	447.3	447.3
c) LTB		
C_r	2317	2317
U_{1x}	1.0	1.0
M_{rx}	447.3	447.3