Beam- column — 1

1/ • check the interaction formula:

A992 steel, $f_y = 50$ ksi

W 10×49, LRFD Approach Use করতে হবে।

Interaction Formula:

① $\frac{P_u}{\Phi_c P_n} + \frac{8}{9}\left[\frac{M_{ux}}{\Phi_b M_{nx}} + \frac{M_{uy}}{\Phi_b M_{ny}}\right] \leq 1.0$; $\frac{P_u}{\Phi_c P_n} \geq 0.2$

② $\frac{P_u}{2\Phi_c P_n} + \left[\frac{M_{ux}}{\Phi_b M_{nx}} + \frac{M_{uy}}{\Phi_b M_{ny}}\right] \leq 1.0$; $\frac{P_u}{\Phi_c P_n} < 0.2$

• কোন formula ব্যবহার করতে হবে সেইটা বের করতে হবে।

$$\frac{KL}{r_y} = \frac{1\times17\times12}{2.54} = 80.31 \, , \; 4.71\sqrt{\frac{E}{F_y}} = 113.43$$

$$\frac{KL}{r_y} < 4.71\sqrt{\frac{E}{F_y}} \, , \; F_{cr} = \left(0.658^{F_y/F_e}\right)\times F_y$$

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r_y}\right)^2} = \frac{\pi^2 E}{80.31^2} = 44.4 \text{ ksi}$$

$$F_{cr} = 0.658^{50/44.4} \times 50 = 31.21 \text{ ksi}$$

$$P_n = F_{cr} A_g = 31.21 \times 14.4 = 449.40 \text{ k}$$

$$P_u = \Phi_c P_n = 0.9\times449.40 = 404.5^k$$

$$P_u (\text{factored load}) = 1.2\times D + 1.6\times L = 1.2\times35 + 1.6\times99$$
$$= 200.4$$

so, $\frac{P_u}{\phi_c P_n} = \frac{200.4}{407.5} = 0.49 > 0.2$

so, formula :

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9}\left[\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}\right] \leq 1.0$$

→ Bending About strong Axis. It is considered as '0'.

• Section check করতে হবে, এটা কি compact নাকি non-compact। কারণ Section এর property অনুযায়ী M_n এর formula change হবে।

$\frac{b_f}{2t_f} = \frac{10}{2\times 0.56} = 8.93$; $0.38\sqrt{\frac{E}{F_y}} = 9.15$

$\frac{b_f}{2t_f} < 0.38\sqrt{\frac{E}{F_y}}$ → flange Compact.

$\frac{h}{t_w} = 23.10$; $3.76\sqrt{\frac{E}{F_y}} = 90.6$

$\frac{h}{t_w} < 3.76\sqrt{\frac{E}{F_y}}$ → web Compact.

so, Section is Compacted and $L_b = 17' = 17\times 12$
$= 204''$

$L_p = 1.76 r_y \sqrt{E/F_y} = 1.76 \times 2.54 \times \sqrt{\frac{29000}{50}} = 108''$

$L_r = 1.95 r_{ts} \frac{E}{0.7F_y} \sqrt{\frac{Jc}{S_x h_o}} \times \left\{ 1 + \sqrt{1 + 6.76 \times \left(\frac{0.7 F_y S_x h_o}{E \; Jc} \right)^2} \right\}^{\frac{1}{2}}$

so, $1.95 \times 2.84 \times \frac{29000}{0.7 \times 50} \times \sqrt{\frac{1.39 \times 1}{54.6 \times 9.42}} = 2385.44$

and

$\left\{ 1 + \sqrt{1 + 6.76 \times \left(\frac{0.7 \times 50 \times 54.6 \times 9.42}{29000 \times 1.39 \times 1} \right)^2} \right\}^{\frac{1}{2}} = 1.59$

so, $L_r = 238.544 \times 1.59 = 379.3''$

$L_p < L_b < L_r$, $M_p = Z_x F_y = 60.4 \times 50 = 3020$

so, $M_n = C_b \left[M_p - (M_p - 0.7 S_x F_y) \frac{L_b - L_p}{L_r - L_p} \right] \leq M_p$

$= 1.32 \left[3020 - (3020 - 0.7 \times 54.6 \times 50) \left(\frac{204 - 108}{379.3 - 108} \right) \right]$

$M_{nx} = 3532.16$ kip'' $> M_p$; $\boxed{M_{nx} = M_p}$

$\phi_b M_{nx} = 0.9 \times 3020 = 2718^{k}$-in

so, $\phi_b M_{nx} = 2718$ kip-in

$M_{ux} = \frac{PL}{4} = \frac{(1.2 \times 5 + 1.6 \times 12)}{4} \times 17 = 1285.2$ kip-in

• Strong Axis এর perpendicular loading এর জন্য Mux পাওয়া যাবে। Moment Amplification factor consider করতে বলা হয় না।

So,

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9}\left[\frac{M_{ux}}{\phi_b M_{nx}}\right]$$

$$= 0.49 + \frac{8}{9} \times \frac{1285.2}{2718} = 0.91 < 1.0$$

(OK)

Interaction formula Satisfied.

Beam Column - 2

- Previous Problem → Considering Moment Amplification factor and 2nd order effect

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9} \frac{M_{ux}}{\phi_b M_{nx}}$$

$$\frac{P_u}{\phi_c P_n} = 0.49 \; ; \quad \phi_b M_{nx} = 2718 \text{ kip-in.}$$

Considering Moment Amplification factor M_{ux} is changed,

$$M_{max} = B \times M_o \; ; \quad M_o = M_{ux}$$

$$B = \frac{1}{\left(1 - \frac{P_u}{P_e}\right)}$$

$$P_e = F_e \times A_g \; , \quad F_{cr} = \left[0.658^{F_y/F_e}\right] F_y$$

$$F_e = \frac{\pi^2 E}{\left(\frac{kL}{r_x}\right)^2} = \frac{\pi^2 E}{\left(\frac{1 \times 204}{4.35}\right)^2} = 130.14 \text{ ksi}$$

$$P_e = 130.14 \times 14.4 = 1874 \text{ kip}$$

$$B = \frac{1}{1 - \frac{200.4}{1874}} = 1.12$$

So; Modified $M_{ux} = 1.12 \times 1285.2$

$= 1439.424$ kip-inch

* Bending About Q Loads are in strong Axis. Therefore moment magnification, Euler load for strong Axis buckling is needed.

$$\frac{P_u}{\phi P_c} + \frac{8}{9}\frac{M_{ux}}{\phi_b M_{nx}} = 0.49 + \frac{8}{9} \times \frac{284.84}{2718}$$

$$= 0.96 < 1.0.$$

SO, Interaction formula Satisfied.

Beam- Column - 3

- check the adequacy of (W 12×65) Member.
- কোন formula ব্যবহার করতে হবে।

⇒ Factored load, $P_u = 1.2 \times P_D + 1.6 \times P_L$

$$= 1.2 \times 70 + 1.6 \times 210 = 420^k$$

$$4.71\sqrt{\frac{E}{F_y}} = 4.71 \times \sqrt{\frac{29000}{50}} = 113.43$$

$$\frac{KL}{r_y} = \frac{1 \times 14}{3.02} \times 12 = 55.63$$

$$\frac{KL}{r_y} < 4.71\sqrt{\frac{E}{F_y}} \quad \text{so, } F_{cr} = \left(0.658^{F_y/F_e}\right) \times F_y$$

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r_y}\right)^2} = \frac{\pi^2 E}{55.63^2} = 92.50$$

$$\therefore F_{cr} = \left(0.658^{50/92.50}\right) \times 50 = 39.9^k$$

$$P_n = F_{cr} \times A_g = 39.9 \times 19.10 = 761.6^k$$

$$P_u = \phi P_n = 0.9 \times 761.6 = 685.5^k$$

$$\frac{P_u}{\phi_c P_n} = \frac{420}{685.5} = 0.61 > 0.2$$

so;

Formula: $\frac{P_u}{\phi_c P_n} + \frac{8}{9}\left[\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}\right] \leq 1.0$

→ Bending is about strong axis. So it is '0'.

So, $\frac{P_u}{\phi_c P_n} + \frac{8}{9}\frac{M_{ux}}{\phi_b M_{nx}} \leq 1.0$

- Section Property check করতে হবে।

$\frac{b_f}{2t_f} = 9.9$; $0.38\sqrt{\frac{E}{F_y}} = 9.15$; → flange nc

$\frac{h}{t_w} = 31.02$, $3.76\sqrt{\frac{E}{F_y}} = 90.55$; → web c

section is non-compacted.

$M_p = Z_x F_y = 96.8 \times 50 = 4840$ kip-in

$\lambda_p = 0.38\sqrt{\frac{E}{F_y}} = 9.15$

$\lambda_f = \frac{b_f}{2t_f} = 9.9$

$\lambda_p < \lambda_f < \lambda_r$

$\lambda_r = 1\sqrt{\frac{E}{F_y}} = 24.1$

$$M_n = \left[M_p - (M_p - 0.7 S_x F_y) \frac{\lambda_f - \lambda_p}{\lambda_r - \lambda_p} \right] \leq M_p$$

$$= 4840 - (4840 - 0.7 \times 87.9 \times 50) \frac{0.75}{14.95}$$

$= 4751.5$ kip in $< M_p$

SO, $M_{nx} = 4751.5$ kip inch

Here unbraced length, $L_b = 14 \times 12 = 168$ inch

so, check this moment for LTB.

$$L_p = 1.76\, r_y \sqrt{\frac{E}{F_y}} = 1.76 \times 3.02 \times \sqrt{\frac{29000}{50}} = 128 \text{ inch}$$

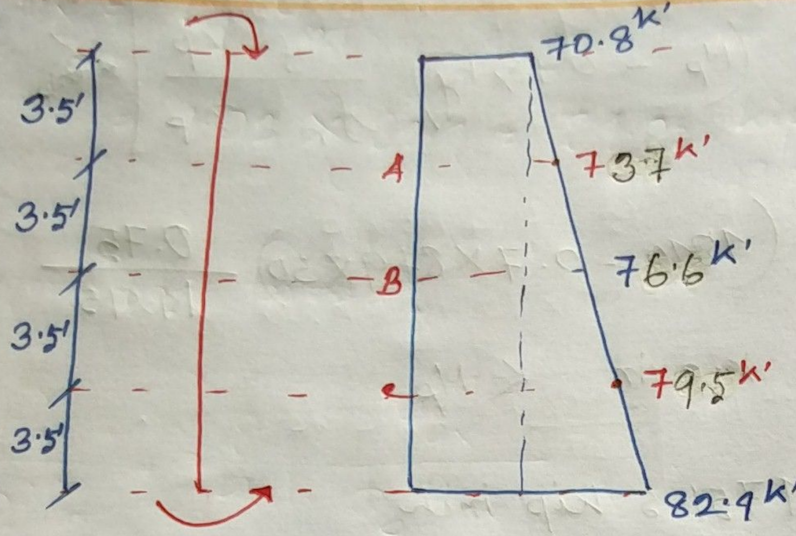
$$L_r = 1.95\, r_{ts} \frac{E}{0.7 f_y} \sqrt{\frac{Jc}{S_x h_o}} \times \left\{ 1 + \sqrt{1 + 6.76 \times \left(\frac{.7 S_x h_o f_y}{E\, Jc} \right)^2} \right\}^{\frac{1}{2}}$$

$= 253.61 \times 1.66 = 421.75$ inch

$$\boxed{L_p < L_b < L_r}$$

$$M_n = C_b \left\{ M_p - (M_p - 0.7 S_x F_y) \frac{L_b - L_p}{L_r - L_p} \right\}$$

$M_1 = 1.2 \times 11 + 1.6 \times 36 = 70.8^{k'}$



$M_2 = 1.2 \times 19 + 1.6 \times 41 = 82.4^{k'}$

$$C_b = \frac{12.5 \times M_{max}}{2.5 \times M_{ax} + 3M_A + 3M_C + 4M_B}$$

$$= \frac{12.5 \times 82.4}{2.5 \times 82.4 + 3 \times (73.7 + 79.5) + 4 \times 76.6}$$

$$= 1.06.$$

$$\therefore M_n = 1.06 \times \left(4840 - (4890 - 3076.5) \times 0.14\right)$$

$$= 4869 \text{ k-in} > M_{nx}$$

so, $M_{nx} = 4751.5$ kip-in $= 395.96$ k-ft

$\phi_b M_{nx} = 0.9 \times M_{nx} = 356.4$ k-ft

(*) Section is a Member of Braced frame and Moment Amplification factor should be considered.

(*) Mux should be Amplified.

$M_{ux} = B_1 M_{nt} + B_2 M_{lt}$ → No traverse load $M_{lt} = 0$.

$B_1 = \frac{C_m}{\left(1 - \frac{P_u}{P_{e1}}\right)}$; $M_{nt} = M_o = 82.4$ kip-ft

$\therefore C_m = 0.6 - 0.4\left(\frac{M_1}{M_2}\right) = 0.6 + 0.4 \frac{70.8}{82.4} = 0.94$

P_u = factored Load = 420^k.

$P_{e1} = F_{e1} \times A_g$

$F_{e1} = \frac{\pi^2 E}{\left(\frac{KL}{r_x}\right)^2} = \frac{\pi^2 \times E}{\left(\frac{14 \times 12}{5.28}\right)^2} = 282.71$ ksi

$P_{e1} = 282.71 \times 19.1 = 5399.8^k$

$B_1 = \frac{0.94}{\left(1 - \frac{420}{5399.8}\right)} = 1.02$.

$M_{ux} = B_1 M_{nt}$

$= 1.02 \times 82.4 = 84.05$ kip-ft

Interaction formula:

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9} \frac{M_{ux}}{\phi_b M_{nx}}$$

$$= \frac{8 \times 84.05}{356.4 \times 9} + 0.61 = 0.82 < 1.0$$

so, formula satisfied

W 12×65 ⟶ adequate.