DESIGN OF THE SLENDER COLUMN

—* Problem:

Design a braced slender column for the following data:

* Size of column = 300 mm x 400 mm.
* Grade of Concrete = M_{30}
* Grade of Steel = Fe_{415}
* Effective length for bending parallel to larger dimension L_{ex} = 6M
* Effective length for bending parallel to shorter dimension L_{ey} = 5M
* Unsupported length = 7M.
* Factored load = 1500 KN.
* Factored Bending moment in the direction of larger dimension = 40 KN-m at top & 22.5 KN-m at bottom.
* Factored Bending moment in the direction of shorter dimension = 30 KN-m at top & 20 KN-m at Bottom.

Solution: → Assumptions:

* The column bends in double curvature
* Reinforcement is distributed equally on 4 sides.
* The percentage of reinforcement p = 2.5%.

→ STEP: ① Calculation of Additional Moments:

[clause: 39.7.1]

Slenderness ratio:

Along larger dimension = $\frac{L_{ex}}{D} = \frac{6000}{400} = 15$ [>12]

Along shorter dimension $= \frac{L_{ey}}{b} = \frac{5000}{300} = 16.7 \; [>12]$

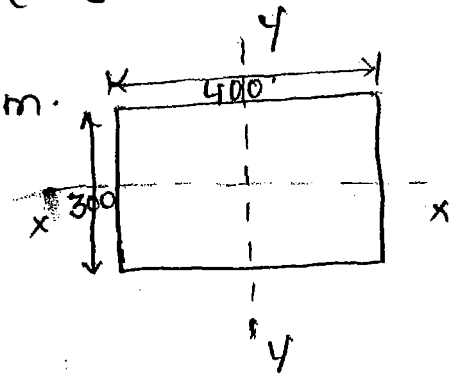
$\therefore$ The column is slender about both the axis.

Additional moments:

Along larger dimension $= M_{ax} = \frac{P_u D}{2000}\left[\frac{L_{ex}}{D}\right]^2$

$\Rightarrow M_{ax} = \frac{1500 \times 0.4}{2000}\left[15\right]^2$

$\Rightarrow M_{ax} = 67.5$ KN-m.



Along shorter dimension =

$\Rightarrow M_{ay} = \frac{P_u b}{2000}\left[\frac{L_{ey}}{b}\right]^2$

$= \frac{1500 \times 0.300}{2000}\left[16.7\right]^2$

$\Rightarrow M_{ay} = 62.75$ KN-m

The above calculated additional moments are to be reduced by multiplying a factor 'k' according to clause: 39.7.1.1 of IS: 456-2000.

$\therefore k = \frac{P_{uz} - P_u}{P_{uz} - P_b} \leq 1.$

Where $P_{uz} = 0.45 f_{ck} \cdot A_c + 0.75 f_y \cdot A_{sc}$

$A_g = 300 \times 400 = 120000 \text{ mm}^2$

$A_{sc} = \frac{p \times b \times D}{100} = \frac{2.5 \times 300 \times 400}{100}$

$= 3000 \text{ mm}^2$

$\therefore P_{uz} = 0.45 \times 30 \times [120000 - 3000] + 0.75 \times 415 \times 3000$

$= 2513 \text{ KN}.$

Calculation of 'P_b': [Table : 60 of SP-16]

P_b along larger dimension

For 25 mm dia bars effective cover $d' = 40 + \frac{25}{2}$

$\Rightarrow d' = 52.5 \text{ mm}.$

$$\frac{d'}{D} = \frac{52.5}{400} = 0.13$$

For rectangular section, $\frac{d'}{D} = 0.15$, $k_1 = 0.196$ & $k_2 = 0.203$.

$$\therefore P_{bx} = \left[k_1 + k_2\left(\frac{p}{f_{ck}}\right)\right] f_{ck}\, bD$$

$$= \left[0.196 + 0.203\left(\frac{2.5}{30}\right)\right] 30 \times 300 \times 400$$

$$P_{bx} = 766.5 \text{ KN}$$

$$\therefore k_x = \frac{P_{uz} - P_u}{P_{uz} - P_{bx}} = \frac{2513 - 1500}{2513 - 766.5} = 0.58$$

P_b along shorter dimension

$$d'/b = \frac{52.5}{300} = 0.175$$

For rectangular section $\frac{d'}{b} = 0.2$, reinforcement equally distributed on 4 sides & fe_{415} steel, $k_1 = 0.184$, $k_2 = 0.028$.

$$\therefore P_{by} = \left[k_1 + k_2\left(\frac{p}{f_{ck}}\right)\right] f_{ck}\, bD$$

$$P_{by} = 670.8 \text{ KN}$$

$\therefore k_y = \frac{P_{uz} - P}{P_{uz} - P_{by}} = \frac{2513 - 1500}{2513 - 670.8} = 0.55$

Reduced moments:

$M_{ax\,red} = M_{ax} \times k_x = 67.5 \times 0.58 = 39.15$ KN-m.

$M_{ay\,red} = M_{ay} \times k_y = 62.75 \times 0.55 = 34.51$ KN-m.

STEP: 2 Calculation of Initial Moments [Cl: 39.7.1]

Note: Along larger dimension

$M_{ix} = 0.6 M_2 - 0.4 M_1$

$= 0.6[40] - 0.4[22.5]$

$M_{ix} = 15$ kN-m

$[< 0.4 M_2 < 0.4(40) < 16$ kN-m$]$

Note: Along shorter dimension.

$M_{iy} = 0.6 M_2 - 0.4 M_1$

$= 0.6(30) - 0.4(20)$

$M_{iy} = 10$ KN-m

$[< 0.4 M_2 < 0.4 \times 30 < 12$ KN-m$]$

STEP: 3 Calculation of moments due to minimum Eccentricity. [Cl: 25.4]

① Along larger dimension.

$e_{min} = \frac{L}{500} + \frac{D}{30} = \frac{7000}{500} + \frac{400}{30} = 14 + 13.3$

$\Rightarrow e_{min} = 27.33$ mm > 20 mm

$$M_{ex} = P_u \times e_{min} = \frac{1500 \times 27.3}{1000} = 40.95 \text{ KN-m}$$

$$> M_{ix}.$$

(2) Along shorter dimension

$$e_{min} = \frac{L}{500} + \frac{b}{30} = \frac{7000}{500} + \frac{300}{30} = 14 + 10 = 24 \text{ mm}$$

$$> 20 \text{ mm}.$$

$$M_{ey} = P_u \times e_{min} = \frac{1500 \times 24}{1000} = 36 \text{ KN-m}$$

$$> M_{iy}.$$

* The greater value of initial moment & moment due to minimum Eccentricity is added to the reduced additional moment to obtain the final design moment on column, to which the column is to be designed.

STEP : (4) Calculation of final Moments :

$$M_{ux} = M_{ax,red} + M_{ex} = 39.15 + 40.95$$

$$= 80.1 \text{ KN-m}$$

$$M_{uy} = M_{ay,red} + M_{ey} = 34.51 + 36$$

$$= 70.51 \text{ KN-m}$$

STEP : (5) Calculation of Moment capacities :

* $\frac{P}{f_{ck}} = \frac{2.5}{30} = ~~0.125~~ \; 0.083$

* $\frac{P_u}{f_{ck} bD} = \frac{1500 \times 10^3}{30 \times 300 \times 400} = ~~0.625~~ \; 0.416. \simeq 0.42$

① Along larger dimension

$$\frac{d'}{D} = 0.13$$

Refering to chart no: 45 of SP: 16, $\frac{d'}{D} = 0.15$, Fe 415 Steel & reinforcement on '4' sides.

$$\frac{M_{ux_1}}{f_{ck}\, b D^2} = 0.09$$

$$\Rightarrow M_{ux_1} = 0.09 \times 30 \times 300 \times 400^2$$

$$= 129.6 \text{ kN-m}$$

② Along shorter dimension

$$\frac{d'}{b} = 0.175$$

Refering to chart no: 46 of SP: 16, $\frac{d'}{b} = 0.2$, Fe 415 Steel & reinforcement on 4 sides

$$\frac{M_{uy_1}}{f_{ck}\, D b^2} = 0.083$$

$$\Rightarrow M_{uy_1} = 0.083 \times 30 \times 400 \times 300^2$$

$$= 89.64 \text{ kN-m}$$

STEP: ⑥ Check for Biaxial Bending [Cl: 39.6]

$$P_{uz} = 2513$$

$$\therefore \frac{P_u}{P_{uz}} = \frac{1500}{2513} = 0.59$$

$$\therefore \alpha_n = 1.65$$ [By linear interpolation]

$$\therefore \left[\frac{M_{ux}}{M_{ux1}}\right]^{\alpha_n} + \left[\frac{M_{uy}}{M_{uy1}}\right]^{\alpha_n} \leq 1.0$$

$$\Rightarrow \left[\frac{80.1}{129.6}\right]^{1.65} + \left[\frac{70.51}{89.64}\right]^{1.65} \leq 1.0$$

$$\Rightarrow [0.618]^{1.65} + [0.786]^{1.65} \leq 1.0$$

$$\Rightarrow 0.451 + 0.672 \leq 1.0$$

$$\Rightarrow 1.12 \leq 1.0 \quad \text{[Not satisfied]}$$

So, the assumed percentage of steel is not satisfactory.

$\therefore$ Revise the percentage of reinforcement and ~~the~~ repeat the ~~proce~~ steps from step-②.

STEP:⑦ Calculation of Reinforcement:

* Longitudinal reinforcement:

~~$A_{sc} = 2.6/100 \times 300/4$~~

$$A_{sc} = \frac{2.6}{100} \times 300 \times 400$$

$$\Rightarrow A_{sc} = 3120 \text{ mm}^2$$

$$\text{No. of bars} = \frac{3120}{491} = 6.35 \simeq 8 \text{ bars.}$$

* Lateral ties:

Diameter:

① $\frac{1}{4} \times 25 = 6.25$ mm

② 6 mm

→ Adopt 8 mm dia lateral ties.

Pitch :

① 300 mm.

② 16 × 25 = 400 mm

③ 300 mm.

~~Notes~~ ∴ provide 8 mm dia lateral ties @ 300 mm c/c