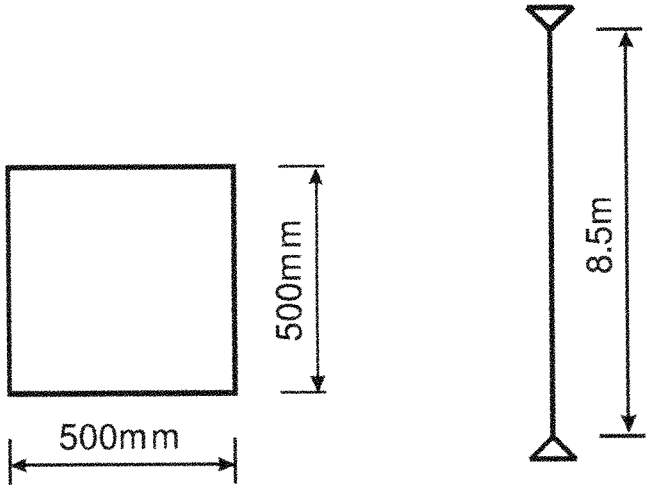
**The University of Ottawa**

**Department of Civil Engineering**

**CVG 3148 REINFORCED CONCRETE DESIGN I**

**Assignment No. 3**

A square concrete column is part of a braced frame, with ends assumed to be simply supported (hinge-hinge). The unsupported column height is 8.5 m. The column is subjected to 175 kN.m of end moment at both ends, making the column bend in double curvature. Factored axial load on the column is $P_f$ = 2900 kN. Design a 500 mm square column with reinforcement on all four sides. $f'_c$ = 30 MPa; $f_y$ = 400 MPa. Cover to the ties = 40 mm.



## Solution

$P_f = 2900$ kN

$|M_1| = |M_2| = 175$

Double curvature $\longrightarrow$ $-1 \leq \frac{M_1}{M_2} \leq 0$ (Note: $\frac{M_1}{M_2} \geq -0.5$)

$b = h = 500$ mm

$f'_c = 30$ MPa

$f_y = 400$ MPa

$l_u = 8.5$ m , hinge-hinge connection

Cover to ties: 40 mm

### * Slenderness check to determine if the column is slender

$k = 1.0$ $\longrightarrow$ hinge-hinge

$r = 0.3h = 0.3 \times 500 = 150$ mm

$\frac{M_1}{M_2} = -1 \xrightarrow[\text{at all times}]{\geq -0.5} \frac{M_1}{M_2} = -0.5$

$$\frac{k l_u}{r} \leq \frac{25 - 10\left(\frac{M_1}{M_2}\right)}{\sqrt{\frac{P_f}{f'_c A_g}}}$$

$$\frac{1.0 \times 8500}{150} \leq \frac{25 - 10(-0.5)}{\sqrt{\frac{2900 \times 10^3}{30 \times 500^2}}}$$

$56.67 \not\leq 48.24$ $\longrightarrow$ The column is slender.

### * Calculate Magnified Moment ($M_c$)

$$M_c = \frac{C_m \cdot M_2}{1 - \frac{P_f}{\phi_m P_c}} \geq M_2$$

$$C_m = 0.6 + 0.4\frac{M_1}{M_2} \geq 0.4$$

$C_m = 0.6 + 0.4(-0.5) = 0.4 \geq 0.4$ ok.

$\varphi_m = 0.75$

$EI = 0.25\, E_c I_g$ (Used in Euler formula)

$$EI = 0.25\,(4500\sqrt{30})\left(\frac{500^4}{12}\right) = 3.2\times10^{13}\ N.mm^2$$

$$P_c = \frac{\pi^2 EI}{(klu)^2} = \frac{\pi^2 \cdot 3.2\times10^{13}}{[(1.0)(8500)]^2}\times10^{-3} = 4371\ kN$$

$$* M_c = \frac{0.4\times175}{1-\frac{2900}{0.75\times4371}} = 606\ kN.m \quad > M_2 \rightarrow OK$$

$< 2M_2 \rightarrow$ N.G. $\rightarrow$ Section should be enlarged.

*Select 600×600 square section:

$r = 0.3\times600 = 180\ mm$

slenderness check

$$\frac{1.0\times8500}{180} \leq \frac{25-10(-0.5)}{\sqrt{\frac{2900\times10^3}{30\times600^2}}}$$

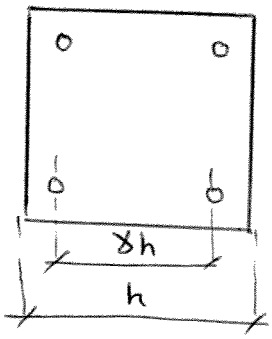
$47.2 \leq 57.89 \rightarrow$ It is not slender. This is a short column.

No need to amplify the moment. use $M_2$ to do the design.

*Select the colum reinforcement

Use No.25M rebars.

equal reinf. on all four faces.




$$\gamma = \frac{600 - 2(40 + 10 + \frac{25}{2})}{600} = 0.792 \simeq 0.8$$

$$\frac{P_f}{A_g} = \frac{2900 \times 10^3}{600^2} = 8.06 \quad MPa$$

$$\frac{Mc}{A_g . h} = \frac{175 \times 10^6}{(600)^2 . 600} = 0.81 \quad MPa$$

use Table 7.4.3 $\longrightarrow$ $\rho < 0.01$ $\longrightarrow$ Use minimum allowable steel of 1%.

$$\rho = 1\%$$

$$A_S = \rho . A_g = 0.01 * (600)^2 = 3600 \ mm^2$$

use 8 No.25M $\Rightarrow$ $A_S = 4000 \ mm^2$