UNIT-V

UNIT- V

COLUMNS + FOOTINGS

INTRODUCTION:

A column is an important component of RC structures. A column may be defined as a member carrying direct axial load which causes compressive stresses. A column or strut is a compression member, the effective length of which exceeds three times the least lateral dimension.

concrete is strong in compression. However, longitudinal steel rods are always provided to assist in carrying the direct load. A minimum area of longitudinal steel is provided in the column whether required or not from load point of view or not. There is also an upper limit of amount of reinforcement in RC columns because higher percentage of steel may cause difficulties in placing and compacting the concrete. Longitudinal reinforcing bars are tied laterally by ties or stirrups at suitable interval so that the bars do not buckle.

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Pedestal: If the eff. length does not exceed three times the least lateral dimension, it is known as known as pedestal.

SHORT COLUMN & LONG COLUMN:

→ If $\frac{l_{ex}}{D}$ & $\frac{l_{ey}}{b} < 12$. (Short columns)

Slenderness ratio = $\frac{l_{ex}}{D}$ or $\frac{l_{ey}}{b}$.

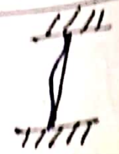
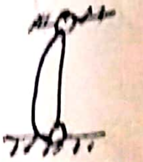
→ If $\frac{l_{ex}}{D}$ & $\frac{l_{ey}}{b} \geq 12$ (long columns)

where

len = Effective length in bending w.r.t. major axis (i.e x-axis)

ley = Eff. length in bending w.r.t minor axis (i.e y axis)

Effective length of columns Annex E IS 456-(94)

End Restraint of column	symbol	Theoretical Eff length	Recommended Eff. length
i) Effective held in position 		0·50l	0·65l
		0·70l	0·80l
		1·00l	1·00l

eq. eff length of col. is defined as that length ~~of column~~ b/w the points of contraflexure of the buckled column

* Diff b/w Short & long col.

TYPE I : AXIALLY LOADED COLUMNS

Steps

1. Given: the load acting on column, type of steel & concrete

2. From IS 456- (pg 71)

$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

→ Adopt $A_{sc} = 0.8\%$ of A_c (pg 48)

$= 0.008 A_c$

→ substitute A_{sc} in 'P_u' Eqn and find the value of A_c.

Step 3:- Decide dimensions of column

Step 4: calculate A_{sc} and provide longitudinal bars with dia ≮ 12mm.

Step 5: Provide lateral ties as per IS 456.

Problem:- 1) Design an RCC column carrying an axial load of 610 kN, the unsupported length of the column is 3m, and it is fixed at both ends. The column is to be designed as short column. Adopt M_{25} concrete & Tor steel

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Note: Short column with lateral ties shall be design by the following Eqn $P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$ if eccentricity does not Exceed 0.05 D i.e.) $e_{min} = \frac{L}{500} + \frac{D}{30} \geq 20mm$

$e_{min} \not> 0.05D$

sol

Step 1: Given: P = 600 kN ⇒ $P_u = 1.5 \times 600 = 900 kN$

$l_{unsupp} = 3m$ ⇒ $l_{eff} = 0.65 \times 3 = 1.95m$

(**Note:** If $e_{min} > 0.05D$ col. is designed for combined axial load & bending)

Let A_c = given area of column.

Step 2: $P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

$$900 \times 10^3 = (0.4 \times 25 A_c) + (0.67 \times 415 \times 0.008 A_c)$$

$$\Rightarrow \boxed{A_c = 73623.2 \ mm^2}$$

Assuming square column

⇒ size of col = $\sqrt{73623.2} = 272mm$

∴ Provide a column of size 280×280 mm

Step 3 Area of longitudinal Steel A_{sc}

0·8 % – 4 %

$A_{sc} = 0.008 \times 280 \times 280 = 589 \ mm^2$

∴ provide 12 mmϕ bars.

No: of bars required = $\frac{589}{\pi(12)^2/4} = 5.2$

∴ Provide 6 bars of 12mmϕ.

Maximum slenderness limit λ_{max}

$\lambda_{max} \leq 60 \times$ least lateral dimension of column

Minimum Eccentricity

All column shall be designed for min. eccentricity

$e_{min} = \frac{l}{500} + \frac{b}{30}$ subjected to a minimum value of 20mm.

Where biaxial bending is considered, it is sufficient to ensure that eccentricity exceeds the minimum value about one axis at a time.

Based on Stresses, Columns are classified as:

① Axially Loaded Columns (square, rect., circular)
② Axially loaded columns with uniaxial Bending
③ Axially loaded columns with Bi-axial bending.
(4) Axially loaded circular columns with helical reinforcement

Reinforcement in Columns:

Longitudinal reinforcement: (IS 456 - ㊽)

@ $A_{min} \not< 0.8\%$ gross c/s area of column

$A_{smax} \not> 6\%$ " " " "

(Note But from practical difficulties $A_{smax} \not> 4\%$)

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b) Min. no: of longitudinal bars in Columns shall be <u>four</u> in rectangular & square column and six in circular columns.

c) dia. of longitudinal bars $\nless$ 12mm.

d) spacing of longitudinal bars measured along the periphery of the column $\ngtr$ 300mm.

e) In any column that has larger c/s area than required, the min. percentage of steel shall be based on actual area required not on the area provided.

f) In Pedestal longitudinal steel $\nless$ 0.15% of c/s area.

<u>Transverse Reinforcement</u>:

i) dia of transverse reinforcement $\nless$ $\frac{1}{4}$th of the dia. of largest longitudinal bar and in no case less than 6mm.

ii) pitch of lateral ties shall be least of the following (a) least lateral dimension of the column

(b) Sixteen times the dia. of longitudinal bar

(C) 300mm

Step: 4 Design of Transverse reinforcement

Check for slenderness ratio.

$$\frac{l_{eff}}{b} = \frac{1.95}{0.28} = 6.96 < 12$$

∴ The column is short column.

Transverse Reinforcement:

→ dia. of reinforcement ≮ $\frac{1}{4} \times 12 = 3mm$

~~Further~~ dia ≮ 6mm

Provide 6mm dia stirrups.

spacing :- should be least of

a) least lateral dimension = 280mm c/c

b) $16 \times \phi = 16 \times 12 = 192mm$ c/c

c) 300mm c/c.

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∴ Adopt a spacing of 190mm c/c for stirrups of 6mm ϕ.

#2 A RCC column of unsupported length 4.5m is fixed at one end and hinged at the other. It is subjected to a factored load of 550kN. The size of the column is 300mm × 400mm. Design the column using M_{20} & Fe 415 grades.

Sol Steps : 1 Given: $P_u = 550kN$; $l_{unsup} = 4.5m$

$\Rightarrow l_{eff} = 0.8 \times 4.5 = 3.6m$; $b = 300mm$; $D = 400mm$

$A_c = 300 \times 400 = 12 \times 10^4 mm^2$; $f_{ck} = 20N/mm^2$; $f_y = 415N$

From I.S 456 : $P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

$$550 \times 10^3 = (0.4 \times 20 \times 12 \times 10^4) + (0.67 (415) A_{sc})$$

$$A_{sc} = \frac{-410000}{0.67 \times 415}$$

-ve A_{sc} i.e Concrete is taking more than 550kN load.

However provide min. % of longitudinal steel $A_{sc} = \frac{0.8}{100} \times 12 \times 10^4$

$= 960 mm^2$

Provide 16mm ϕ - 5 bars

Chk for Slenderness Ratio : $\lambda = \frac{3.6}{0.3} = 12$

$\therefore$ long column.

Transverse Reinforcement:

more ductile.

TYPE II

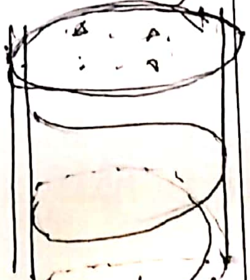
CIRCULAR COLUMN WITH HELICAL REINFORCEMENT

The load carrying capacity of a circular column is increased by a factor 1.05 (i.e 5% more) if following condition is satisfied (7i) 39.4 IS456

$$\frac{V_H}{V_K} \quad \frac{\text{Volume of helical Reinforcement}}{\text{Vol. of core.}} \not< 0.36\left(\frac{A_g}{A_k}-1\right)\frac{f_{ck}}{f_{yh}}$$

$$\Rightarrow \boxed{P_u = 1.05(0.4 f_{ck} A_c + 0.67 f_y A_{sc})}$$

(Note:- Code permits larger load in short compression members with helical reinforcement because columns with helical reinforcement have greater ductility or toughness when they are loaded concentrically or with small eccentricity)



A_g = gross area of c/s

A_K = area of core of the helically reinforced col. measured to the outside dia. of helix =

$$= \frac{\pi D_k^2}{4} - A_s$$

D_K = dia. of concrete core = D − 2× clear cover. *Typoo centre of helix

f_{yh} = characteristic strength of helical reinforcement $\not> 415\ N/mm^2$

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#3 Design a helically circular column to carry an axial working load of 900 kN use helical Reinforcement as latual Reinforcement.

Adopt M_{20} & Fe415 grades

sol

step1 Given $P = 900\,kN \Rightarrow P_u = 1.5 \times 900 = 1350\,kN$

$f_y = 415\,N/mm^2$; $f_{ck} = 20\,N/mm^2$

step2

$$P_u = 1.05(0.4 f_{ck} A_c + 0.67 f_y A_{sc})$$

$\Rightarrow$ provide $A_{sc} = 0.8\%$ of A_c

$= 0.008\,A_c$

$$1350 \times 10^3 = 1.05\,(0.4 \times 20 \times A_c) + (0.67 \times 415 \times 0.008 A_c)$$

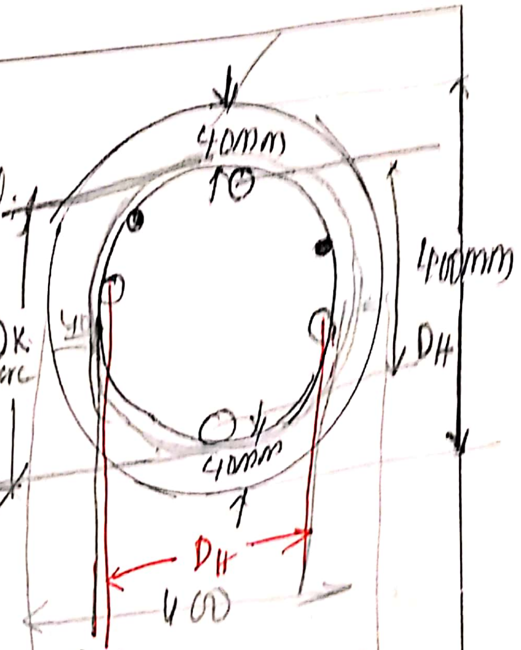
$$\Rightarrow \boxed{A_c = 125750\,mm^2}$$

Let D = dia. of column

$$\Rightarrow A_c = \frac{\pi D^2}{4}$$

$$\Rightarrow \boxed{D = 400\,mm}$$

Step 3 Area of Longitudinal Steel:



$A_{sc} = 0.008\,A_c$

$= 0.008 \times 125750$

$\boxed{A_{sc} = 1006\,mm^2}$

Provide 16mmφ-4bars ⇒ $A = 804$

\+

12mmφ-2bars ⇒ $A = 226$

A_{sc} 1130mm²

Step 4

~~Helical~~ LATERAL Reinforcement : (IS 456)

→ dia of helix $= \frac{1}{4} \times$ dia. of longitudinal bar

$= \frac{1}{4} \times 16 = 4\,mm < 6mm.$

∴ Provide 6mm dia MS helical Reinforcement.

Let S = pitch of helical Reinforcement

As per IS 456 $\frac{V_H}{V_K} \not< 0.36\left(\frac{A_g}{A_k} - 1\right)\frac{f_{ck}}{f_{yH}}$ D_H = dia. upto centre of helix

$A_K = \frac{\pi}{4} D_K^2$

$D_K = D - 2\,cover$

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To find V_H & V_K

Consider 1m length of column:

$V_H = \frac{\pi d_H}{S} \times \frac{\pi d^2}{4} \times 1$ where d_H = dia. of helix

$= 400 - 40 - 40 + 6 - 6$

$= 326mm$ 314mm

$D - 2\,cover - {}^{6}\phi_s$

$$V_H = \frac{\text{circumference of spiral} \times \text{Area of spiral}}{\text{pitch of spiral}} = \frac{\pi D_H \times \pi \phi_s^2}{p}$$

$$V_H = \frac{\pi \overset{314}{(326)}}{S} \times \frac{\pi (6)^2}{4}$$

d = 6mm ϕ

d_k = dia of core upto

= 400-40-40+(2×6)

out side dia of helix

= 326+6 = 332 mm

$$= \frac{28953}{S}\ \text{mm}^3$$

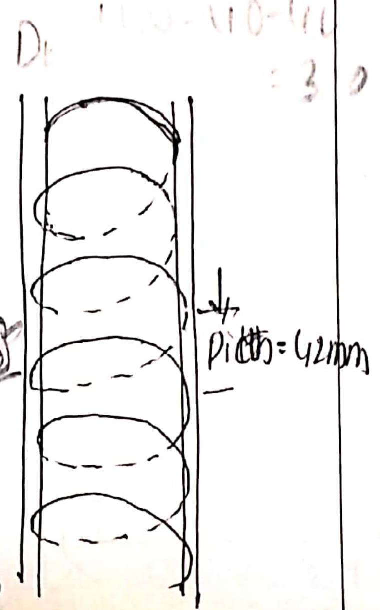
volume of core per mm height of col,

$$V_K = \frac{\pi d_k^2}{4} \times 1$$

$$= \frac{\pi \overset{320}{(332)}^2}{4} \times 1 = 86570\ \text{mm}^3$$

A_g = gross C/s area = 125750 mm²

A_K = Area of core = 86570 mm² $\frac{\pi(320)^2}{4}$



Substituting the values of V_H, V_K, A_g & A_k

$$\frac{28953}{S} \Big/ 86570 = 0.36\left(\frac{125750}{86570} - 1\right)\frac{20}{\overset{415}{250}} \; f_{yh}$$

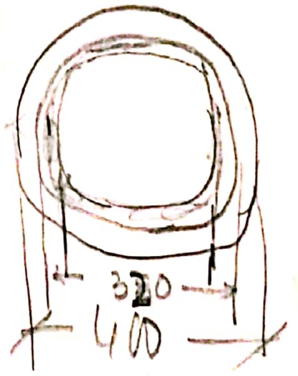
$$\Rightarrow \boxed{S = 42\ \text{mc/c}}$$

M9

pitch ≯ 75mm &

≯ $\frac{1}{6}$ dia of core = $\frac{1}{6}$ × 332

= 55mm c/c



∴ Provide 6mm ϕ (Fe415) grade Steel

@ pitch 42mm c/c .

Note:- Since helically Reinforced cols are very ductile, more desirable in highly seismic zones.

Type III Columns with Axial load and Uniaxial Bending

Methods of Design of eccentrically loaded Short Columns: can be done by two methods

i) using equations

2) using interaction curves

Design Steps using interaction curve method

1) Decide the column dimensions (bxD), cover ratio (d'/D) and mode of placement of reinforcing bars.

2) compute $P_u/f_{ck} b \cdot D$ & $\frac{M_u}{f_{ck} bD^2}$

3) Referring the interaction diag. of SP.16, locate the above values on y-axis & x-axis respectively.

4) The point of intersection will fall b/w any two curves of p/f_{ck}; Interpolate the value of p/f_{ck} corresponding to this point of intersection

5) Compute $A_{sc} = \frac{p}{100} \times bxD$. & design longitudinal & Transverse reinforcement.

#3) Find the Reinforcement Required for a circular column (RCC) of diameter 400mm Subjected to a factored load of 1200kN and a factored moment of 75 kN-m. use M_{20} + Fe 415 Grades. Design Transverse reinforcement for a) ~~Hoop rein-forcement~~ b) Lateral ties.

Sol

Step 1: Given ; $P_U = 1200kN$; $M_U = 75 kN\cdot m$

$f_{ck} = 20N/mm^2$; $f_y = 415 N/mm^2$

Assume Eff. cover $d' = 40mm \Rightarrow \frac{d'}{D} = \frac{40}{400} = \underline{\underline{0.1}}$

Step 2

$$\underset{(Rec)}{\frac{P_U}{f_{ck}bD}} = \underset{(CIR)}{\frac{P_U}{f_{ck}D^2}} = \frac{1200\times10^3}{20\times400^2} = \underline{\underline{0.375}}$$

$$\frac{M_U}{f_{ck}bD^2} = \frac{M_U}{f_{ck}D^3} = \frac{75\times10^6}{20\times400^3} = \underline{\underline{0.06}}$$

$$\frac{d'}{D} = \underline{\underline{0.1}}$$

Ref. SP16 Charts $\frac{p}{f_{ck}} = 0.08$

$\Rightarrow p = 0.08\times20 = 1.6\%$

Step 3 Area of Longitudinal Reinforcement

$A_s = \frac{1.6}{100} \times \frac{\pi D^2}{4} = \frac{1.6}{100} \times \frac{\pi (400)^2}{4} = 2011 \text{ mm}^2$

$n = \frac{2011}{\frac{\pi (22)^2}{4}} \simeq 5.3$

Provide 6 bars of 22 mm ϕ.

Step 4: TRANSVERSE REINFORCEMENT

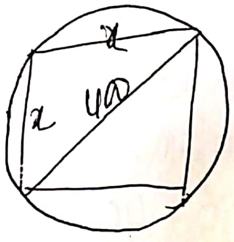
(A) Lateral ties:

→ dia of ties, $d \nless \frac{1}{4}\phi$ or 6mm

$\nless \frac{1}{4} \times 22$ or 6mm

∴ provide 6mm ϕ lateral ties.

→ pitch $\ngtr$ least lateral dim. 'x'



$x^2 + x^2 = 400^2$

$\Rightarrow x = 282$ mm c/c

∴ $\ngtr 16\phi = 16 \times 22 = 352$ mm c/c

$\ngtr 300$mm

∴ Provide hoop ties of 6mm ϕ @ 282 mc/c

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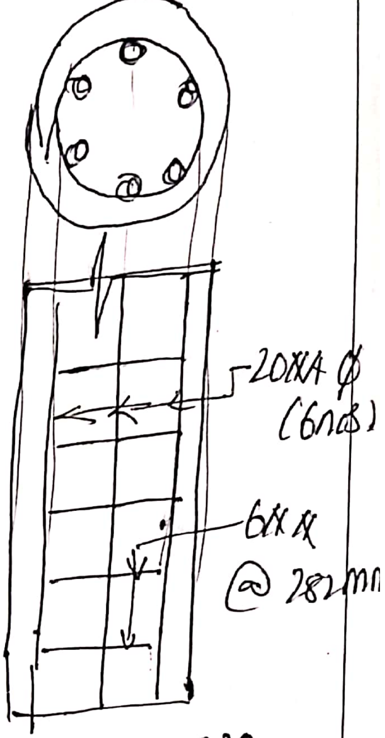
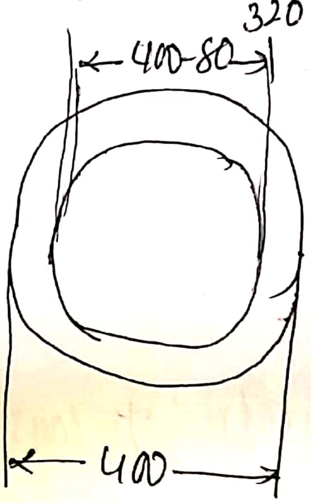
B) HOOP/Helical Reinforcement



Let us provide ~~8mm~~ 6mm ϕ M.S bars for helical reinforcement.
or from IS

dia $\not< \frac{1}{4}\phi = \frac{1}{4} \times 22 = 5.5$ mm or 6mm ✓

→ core diameter, $D_k = 400-40-40+2\times6$
$= 332$mm



$\Rightarrow A_k = \frac{\pi(332)^2}{4} = 86570\text{mm}^2$

$A_g =$ ~~$\frac{6\times\pi(20)^2}{4}$~~ $\frac{\pi(400)^2}{4} = 1,25663.7$

→ D_h = dia. of core upto centre of helix
$= 400-40-40+6 = 326$mm

→ Let the pitch of the spiral be 's' mm

$$V_h = \frac{\pi d_h}{s} \times \frac{\pi(d)^2}{4} = \frac{\pi\times326}{s} \times \frac{\pi(6)^2}{4} = \frac{28957.42}{s}$$

$$V_k = \frac{\pi(332)^2}{4}\times1 = 86,570$$

$$\frac{V_H}{V_K} = 0.36\left(\frac{A_g}{A_K}-1\right)\frac{f_{ck}}{f_{yH}}$$

$$\frac{28957.5/s}{86570} = 0.3\left(\frac{1,25,663.7}{86570}-1\right)\frac{20}{250}$$

$\Rightarrow S = 31mc/c$

However pitch $\ngtr 75mm$

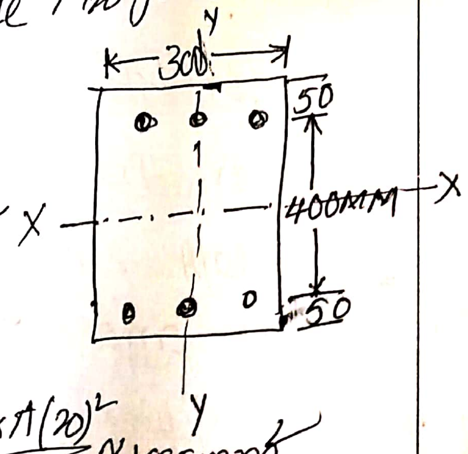
$\ngtr \frac{1}{6}D_k\ (\frac{1}{6}\times\overset{55.33}{332}) \ngtr 55.33\,mm$

Hence o.k.

$\nless 3\times\overset{6}{\phi} = 18mm$

∴ Keep a pitch equal to 31mc/c.

~~Determine~~ A short RC column 300mm wide and 500mm deep is reinforced with 6-20mmφ arranged as shown in fig. Determine B.M, M_u (M_{ux}) about an axis bisecting the depth when it is subjected to $P_u = 800kN$. Assume M20 grade & Fe415 grade...



Sol $\frac{d'}{D} = \frac{50}{500} = 0.1$ & f_y 415

Refer chart (32) $f_{ck} = 20N/m^2$

$\frac{P_u}{f_{ck}bD} = \frac{800\times10^3}{20\times300\times500} = 0.267$

& $A_{sc} = \frac{6\times\pi(20)^2}{4} \approx 1885mm^2$

$\Rightarrow p = \frac{A_{sc}}{bD} \times 100 = \frac{1885}{300 \times 500} \times 100 \approx 1.257.$

$\Rightarrow \frac{p}{f_{ck}} = \frac{1.257}{20} = \underline{\underline{0.063}}$

Ref a chart with $\frac{d'}{D} = 0.1$, $\frac{P_u}{f_{ck}bD} = 0.267$ &

$\frac{p}{f_{ck}} = 0.063$,

we get $\frac{M_u}{f_{ck}bD^2} \simeq 0.13$

$\Rightarrow M_u = \frac{0.13 \times 20 \times 300 \times 500^2}{10^6} = \underline{\underline{195 \text{ kN.m}}}$

TYPE IV COLUMNS WITH AXIAL LOAD & BIAXIAL BENDING

columns with axial load and biaxial bending are found in corner columns, external facade columns under combined vertical and horizontal loads. Also columns supporting helical stairs etc.

STEPS FOR DESIGN:

1) Given: Axial load P_u, Moments M_{ux} & M_{uy}

2) Adopt suitable dimensions of column bxD and percentage of longitudinal steel 'p'

3) Determine the moment Capacities M_{ux1} and M_{uy1} of the column from interaction diagrams.

4) find the Coefficient α_n depending upon P_u/P_{uz} from IS 456 Page (71). ; $\boxed{P_{uz} = 0.45 f_{ck} A_c + 0.75 f_y A_{sc}}$ cont..)

5) For the column to be Safe the following Conditions must be Satisfied

$$\left(\frac{M_{ux}}{M_{ux1}}\right)^{\alpha_n} + \left(\frac{M_{uy}}{M_{uy-1}}\right)^{\alpha} \leq 1$$

(cont..) for $\frac{P_u}{P_{uz}} = 0.2$ to 0.8, $\alpha_n \to 1$ to 2

for $\frac{P_u}{P_{uz}} < 0.2$; $\alpha_n = 1.0$

$\frac{P_u}{P_{uz}} > 0.8$; $\alpha_n = 2.0$

Design an RCC Column to Carry a working load of 700kN and working moments of 30kN-m & 45kN-m about x and y-axis. Adopt M25 concrete & Tor steel.

Design: $P_u = 1.5 \times 700 = 1050\text{kN}$

$M_{ux} = 1.5 \times 30 = 45$ kN-m

$M_{uy} = 1.5 \times 45 = 67.5$ kN-m

Step 2 Adopt Size of column 230×550 mm

→ percentage of Steel $p = 2.5\%$

Assume $d' = 55$ mm.

Step 3 For safety of column, $\left(\frac{M_{ux}}{M_{ux-1}}\right)^{\alpha_n} + \left(\frac{M_{uy}}{M_{uy-1}}\right)^{\alpha_n} \leq 1$

$\rightarrow \dfrac{P_u}{f_{ck}bD} = \dfrac{1050\times10^3}{25\times230\times550} = 0.33$

$\dfrac{p}{f_{ck}} = \dfrac{2.5}{25} = 0.1$ & $\dfrac{d'}{D} = \dfrac{55}{550} = 0.1$

from interaction diagrams

$\rightarrow \dfrac{M_{ux-1}}{f_{ck}b^2D} = 0.18 \Rightarrow M_{ux1} = \dfrac{0.18\times25\times230^2\times550}{10^6}$

$= \underline{130.92}$ kN-m

$\rightarrow \dfrac{M_{uy-1}}{f_{ck}bD^2} = 0.18 \Rightarrow M_{uy1} = 0.18\times25\times230\times550^2/10^6$

$= 313\times10^6$ N-mm or $\underline{313}$ kN-m

step3 :

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

$= \left(0.45\times25\times230\times550\right) + \left(0.75\times415\times\dfrac{2.5}{100}\times230\times550\right)/10^3$

$= 2407$ kN

$\Rightarrow \dfrac{P_u}{P_{uz}} = \dfrac{1050}{2407} = 0.43$

From IS456-(71) for

P_u/P_{uz}	α_n
0.2-0.8	1.02
0.6	1.0

0.23 — ?

For $\frac{P_u}{P_{uz}} = 0.43$, $\alpha = \underline{0.2} + \underline{0.23}$

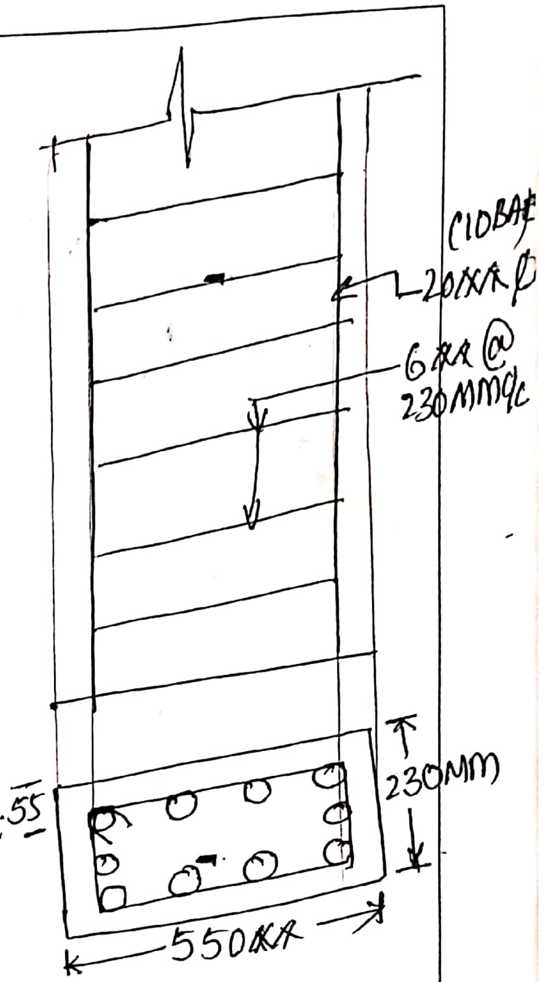
$$\alpha_n = 1 + \frac{0.2}{0.6} \times 1$$

$$\boxed{\alpha_n = 1.38}$$

Substituting

$$\left(\frac{45}{130}\right)^{1.38} + \left(\frac{67.5}{3133}\right)^{1.38} = 0.35 < 1$$

∴ column is safe.



Step 4 Area of longitudinal Steel :

$$A_{sc} = \frac{2.5}{100} \times 230 \times 550$$

$$\boxed{A_{sc} = 3163 \text{ mm}^2}$$

provide 20mm ϕ bars , $n = \frac{3163}{\pi(20)^2/4} = \underline{10}$

Step 5 TRANSVERSE STEEL :

→ dia ≮ $\frac{1}{4} \times 20 = 5$mm & ≮ 6mm ✓

→ spacing of ties : least of the following,

(i) least lateral dimension = 230mm c/c

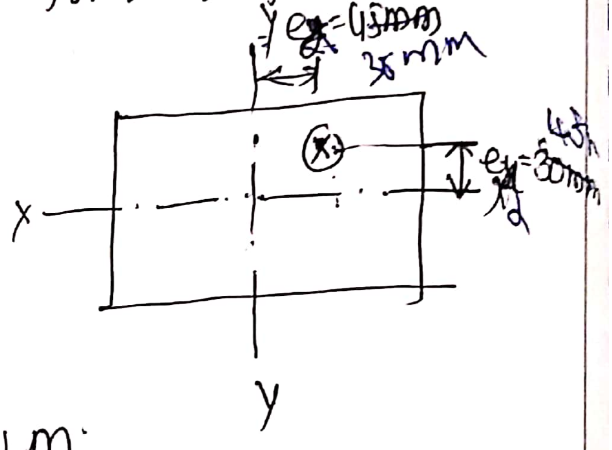
(ii) 16×20 = 320mm c/c or (iii) 300mm c/c

∴ provide 6mm ϕ MS ties @ 230mm c/c .

(fig ↑)

HW.

An RCC Column Carries a working load of 600 kN at an eccentricities $e_x = 300mm$ & $e_y = 45mm$. Design the Column; Check it for safety and draw Reinforcement details



sol

Step1 $P = 600$ kN ⇒ $P_u = 900$ kN

$M_{ox} = $ ~~(600~~ $900 \times \frac{30}{1000} \simeq 27$ kN.m

$M_{oy} = 900 \times \frac{45}{1000} \simeq 40.5$ kN.m

Adopt M_{20} Concrete & Fe 415 Steel.

(Assume) ⇒ $f_{ck} = 20 N/mm^2$ & $f_y = 415 N/mm^2$

provide a column of size: 300mm × 400mm.

percentage of steel $p = 2.5\%$

Step2 For Safety

$$\left(\frac{M_{ox}}{M_{ox-1}}\right)^{\alpha_n} + \left(\frac{M_{oy}}{M_{oy-1}}\right)^{\alpha_n} \leq 1.0$$

Proceed same.

DESIGN OF R.C.C. FOOTINGS

Footing is the part of structure that transfers the load from super structure to the sub soil safely.

Different types of Footings:

- Isolated: square footing, Rectangular, Circular.
- Combined footings (provided on two/more columns)
- Raft or Mat foundation, which is provided when more than 50% of the plot is occupied by the footing and also when the soil loose.
- pile foundation
- well foundation

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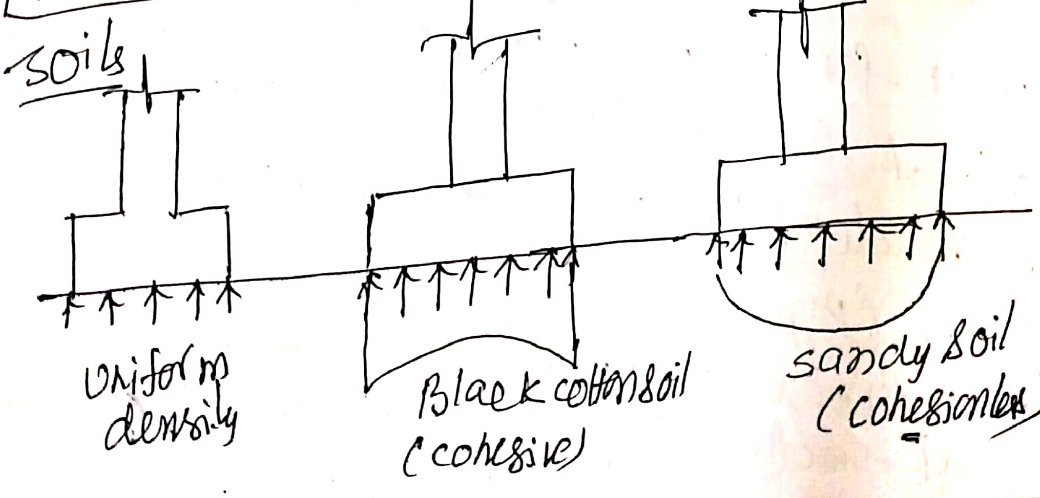
Pressure distribution in different types of soils



Steps for the Design of Footing:

1) Given the load 'p' acting on the column and the safe bearing capacity (SBC) of soil.

2) Find total load P_{total} acting on footing.

$$P_{total} = (P + 10\% \text{ of } P)$$

3) Calculate the area of the footing 'A'

$$A = \frac{P_{total}}{SBC}$$ and side of footing $= \sqrt{A}$

4) Determine the net upward pressure intensity (NUPI)

$$w = \frac{P}{A}$$

5) Determine max. BM at the face of the column.

~~5)~~ ~~PG~~ IS 456 recommends that max BM occurs at the face of the column.

6) Determine thickness of footing and Area of steel required.

7) Check for one way Shear: IS 456 recommends critical section occurs at a distance equal to the depth 'd' of footing from the face of column. (Page 65)

8) Check for two way Shear: IS 456 (57) recommends critical section occurs at a dist. '$\frac{d}{2}$' from the face of column.

Design an isolated RCC footing for a Rectangular column 230×380 mm carrying a working load of 500kN. The SBC of soil is 175 kN/m², Adopt M_{20} Conc. & Fe415 Steel.

Design: $b = 230mm$ $D = 380mm$; $P = 500kN$

$SBC = 175 kN/m^2$

$\Rightarrow P_u = 1.5 \times 500$

$= 750kN$

$P_{Total} = P_u + 10\% \text{ of } P_u$

$= 750 + \frac{10}{100} \times 750$

$= 825kN$

$\rightarrow$ Area, $A = \frac{P_{Total}}{SBC} = \frac{825}{175} = 4.71 m^2$

$\rightarrow$ The ratio of 'L' and 'B' of footing shall be approximately same ~~$\frac{b}{D}$~~ $\frac{D}{b}$ ratio of column.

$\frac{L}{B} = \frac{380}{230} \Rightarrow L = 1.65B$

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$A = L \times B = 4.71$

$\Rightarrow 1.65B \times B = 4.71$

$B^2 = \frac{4.71}{1.65} \Rightarrow B = 1.689m \sim 1.69m$

$L = 2.787m \sim 2.79m$

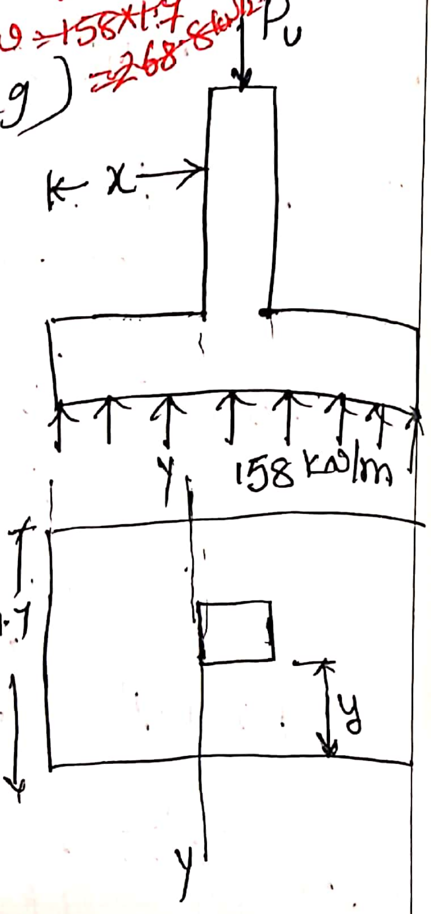
$\Rightarrow$ Provide footing of size $1.7m \times 2.8m$

→ Netupward pressure intensity, NUPI $= \frac{P}{A}$

$$\omega = \frac{750}{2.8 \times 1.7} = \simeq 158\,kN/m^2$$

~~for 1m wide~~

~~ω = 158×1.7 = 268.8 kN/m~~



→ Design for flexure (Bending)

$$x = \frac{(2.8 - 0.38)}{2} = \overset{1.21m}{\cancel{0.96m}}$$

Factored Moment

$$M_U = \cancel{1.5}\,\frac{\omega . x^2}{2} = \frac{\cancel{1.5} \times \overset{268.8}{\boxed{158}} \times \overset{1.21^2}{\cancel{0.96}}}{2}$$

$$\boxed{M_{UL} \equiv \boxed{115.66\ kN\text{-}m}}\ \ \cancel{196.63\,kNm}$$

TRANSVERSE MOMENT:

$$y = \frac{1.7 - 0.23}{2} = 0.735\,m.$$

$$M_{U\text{-}tiv} \overset{\omega l^2/2}{=} \frac{\boxed{158 \overset{\cancel{\times 1.7}}{\times} 0.735^2}}{2} = \underline{\underline{42.67\ kN\text{-}m}}\ \ \cancel{\times 1.7}\ \ \boxed{\cancel{71.54}\,kN\text{-}m}$$

Effective depth (thickness) of footing

$$\cancel{M_U = 0.36\,b\,x_{umax}\,f_{ck}\,(d - 0.42\,x_{umax})}$$

$$\cancel{115.66 \times 10^6 = 0.36 \times 1000 \times 0.48\,d\,(d - 0.42 \times 0.48\,d)}$$

$$\boxed{196.63}\ M_{UL} = 0.36\,\frac{x_{umax}}{d}\left(1 - 0.42\,\frac{x_{umax}}{d}\right) f_{ck}\,b\,d^2$$

$$\boxed{115.66} \times 10^6 = 0.36 \times 0.48\,(1 - 0.42 \times 0.48)\,20 \times \overset{1700}{\cancel{1000}} \times d^2$$

⇒ $\boxed{d = 205 mm}$ 8445

Accounting for one way & two-way shear,

Provide $\boxed{d = 350 mm}$ + cover = 50 mm

$\therefore \boxed{D = 400 mm}$

⇒ Area of Steel: (Main)

$M_{UL} = 0.87 f_y A_{st} (d - 0.42 x_{um})$

$115.66 \times 10^6 = 0.87 \times 415 \, A_{st} (350 - 0.42 \times 0.48 \times 350)$

⇒ $\boxed{A_{st} = 1088 mm^2}$

Provide 12mm ϕ dia for steel bars @

Spacing $= \frac{\pi (12)^2/4}{1088} \times 1000 = 103$ mm c/c.

⇒ ~~to~~ Transverse Steel: (Along width of footing)

$42.67 \times 10^6 = 0.87 \times 415 \, A_{stv} (350 - 0.42 \times 0.48 \times 350)$

$\boxed{A_{stv} = 397 mm^2}$

Provide 10mm ϕ bars @

Spacing $= \frac{\pi (10)^2/4}{397} \times 1000$

$= 196$ mm c/c.

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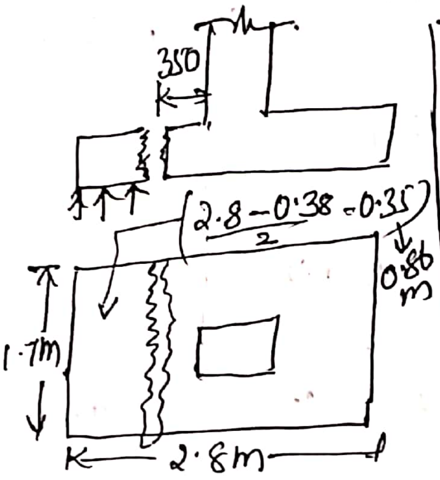
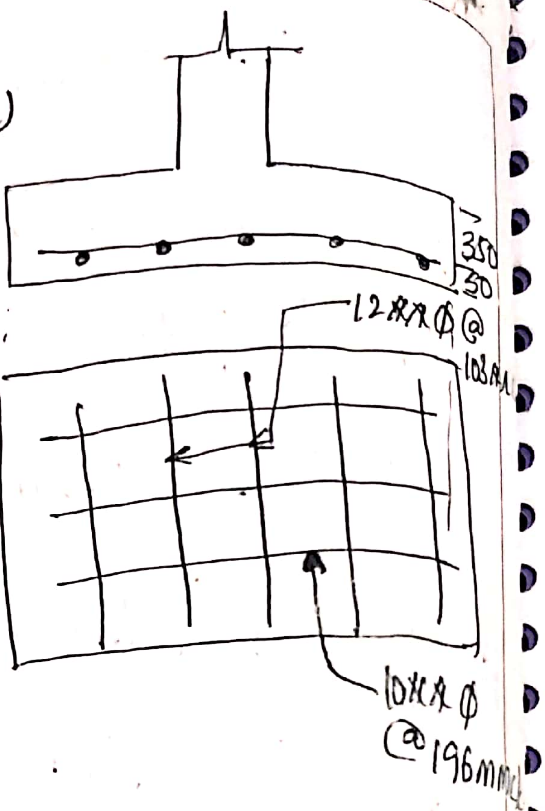
Check for one-way Shear (Beam Shear)

→ Critical sec. occurs at a dist. d = 350mm from the face of col.





SF = 1·[illegible] load in shaded area

= 1·[illegible] (1·7 × 0·86 × 15~~9~~8)

= 3[illegible] 253·36

⇒ Shear stress $\tau_v = \frac{V_u}{bd} = \frac{\overset{255·36}{3[illegible]8} \times 10^3}{1700 \times 350}$ = [illegible]

<u>per. shear stress:</u>

$\frac{A_{st}}{bd} \times 100 = \frac{1088}{1000 \times 350} \times 100 = 0.31\ \%$

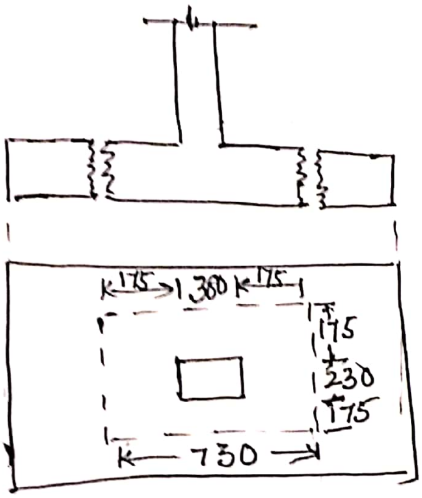
From Table ⑲ $\tau_c \simeq$ . . .

$\tau_v \approx$ . . .

∴ Section is safe in one way shear.

Check for Punching Shear:

As per IS 456, critical section occurs at a distance $\frac{'d'}{2}$ ~~from~~ = $\frac{350}{2}$ = 175mm from the face of column.



Load Causing Punching Shear

$V = P_u -$ Load in shaded area

$= 750 - (0.58 \times 0.73 \times 158)$

$= 682.68\text{ kN}$.

→ Punching Stress $= \frac{682.68 \times 10^3}{2(730 + 580)\,350}$

$= 0.74\text{ N/mm}^2$

Pg 58

→ per. stress $= K_s \tau_c$

$= (0.5 + \beta_c)\ 0.25\sqrt{\overset{f_{ck}}{20}}$

$= \left(0.5 + \frac{0.23}{0.38}\right) 1.11$

$= 1.105 \times 1.11$ ($K_s \ngtr 1$)

$= 1 \times 1.11 = 1.11\text{ N/mm}^2$

∴ Punching stress < Per. stress.

∴ Section is safe in Punching.