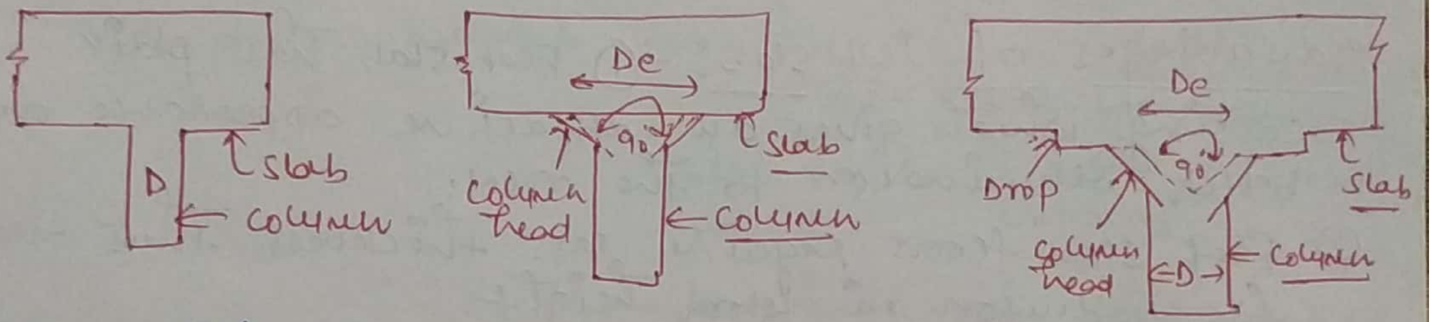
Unit – III^rd (Flat slab)

Introduction:- ✡ A flat slab means a reinforced slab with or without drops supported directly on columns without beams.

✡ The minimum thickness of a flat slab should be 125MM.

✡ The thickness of a flat slab is controlled by consideration of span to effective depth ratio.

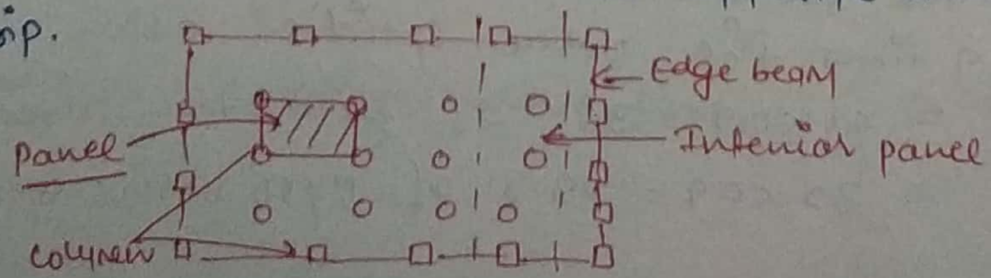


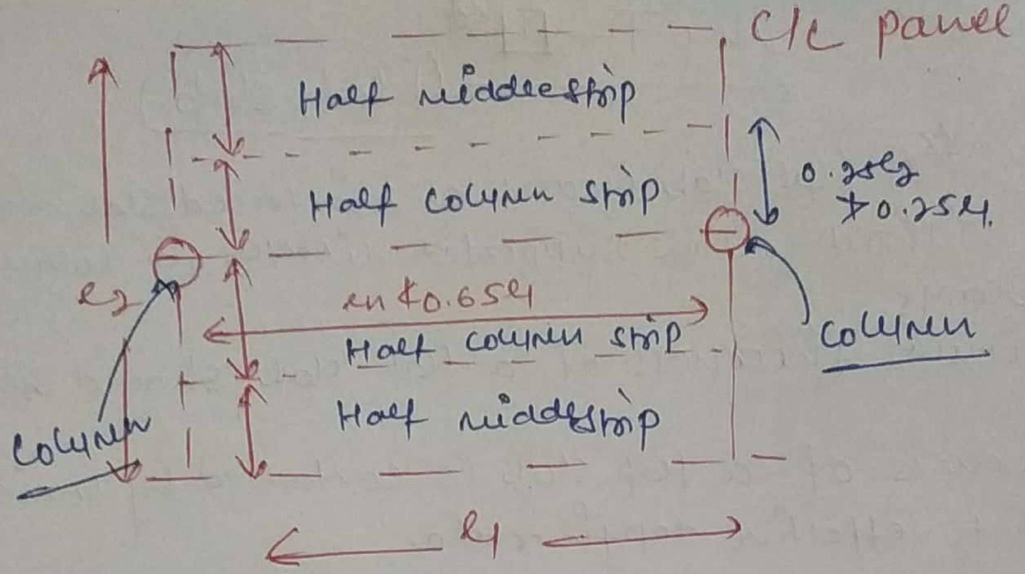
Drops:- The thickened part of the slab over the column is called drops. The drops when provided shall be rectangular in plan and have a length in each direction not less than one third of the panel in that direction.

Column head:- The widened area at the top of column to provide more support area to slab is called column head or column capital.

Column Strip:- Column strip means a design strip having a width of $0.25l_2$ but not greater than $0.25l_1$ on each side of column c/c line, where l_1 is the direction in the direction of moments.

Middle strip:- Middle strip means a design strip bounded on each of its opposite sides by column strip.





Advantages of flat slab:- ① Flat slab has plain ceiling which gives an attractive appearance and better illumination to the room.

② Flat slab floors require less thickness thus allowing for reduction in story height.

③ Since no beams are required are provided in flat slab. hence form-work required is simple.

④ Reduced load on foundations because of less thickness and less height of structure.

⑤ curing is easy because of flat surface.

✡ Thickness of flat slab:- Acc. of IS:456-2000 the max.m value of ratio of larger span to thickness shall be

= 40, if mild steel is used

= 32, if Fe415 or Fe500 (HYSD) is used

If drops are not provided or size of drops do not satisfy the specification 1.4.1. Then the ratio shall not exceed 0.9 times the value specified above

$= 40 \times 0.9 = 36$ if mild steel is used

$= 32 \times 0.9 = 28.8$ if HYSD bars is used.

Methods for determination of Bending moments and shear force:- For this IS-456:2000 permits use of any one of the following

I. Direct design method
II. Equivalent frame method

(1) Direct design method:- (1) There shall be min^m of three continuous spans in each directions.

Total design moment $M_0 = \frac{W L_n}{8}$

M_0 → Total moment

W → Design load on the area $L_2 \times L_n$

L_n → clear span extending from face to face of columns.

L_2 = length of span transverse to L_1.

distribution of Total design moment into –ve and +ve moments:

In an Interior span

–ve design moment = $0.65 M_0$

+ve design moment = $0.35 M_0$

In an end span

Interior –ve design moment $M_1 = \left[0.75 - \frac{0.10}{1+\frac{1}{\alpha_c}}\right] M_0$

+ve design moment $M_2 = \left[0.63 - \frac{0.28}{1+\frac{1}{\alpha_c}}\right] M_0$

Exterior –ve design moment $M_3 = \left[\frac{0.65}{1+1/\alpha_c}\right] M_0$

where α_c is the ratio of flexural stiffness at exterior column to the flexural stiffness of the slab at a joint.

$$\alpha_c = \frac{\Sigma k_c}{\Sigma k_s}$$

Σk_c → Sum of flexural stiffness of columns meeting at joint

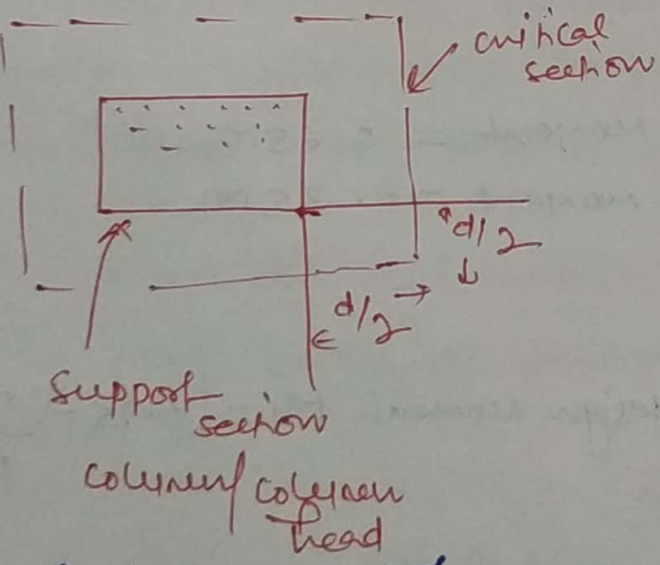
Σk_s → flexure stiffness of the slab

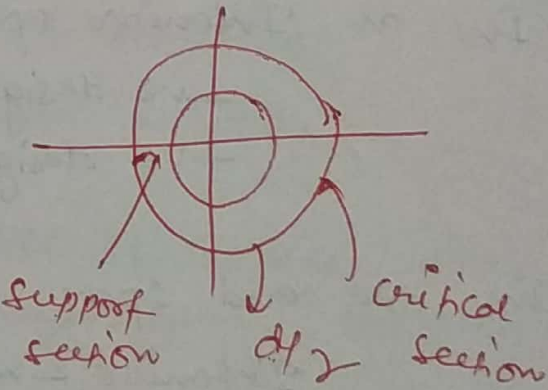
Moments in column:-

$$M = 0.08 \frac{(w_d + 0.5 w_l) l_2 l_n^2 - w_d' l_2' (l_n')^2}{1 + \frac{1}{\alpha_c}}$$

Shear in flat slabs:-

The critical section for shear shall be at a distance d/2 from the periphery of the column capital drop panel, hence of drops are provided there are two critical section near columns.





The nominal shear stress may be calculated

$$\tau_v = \frac{V}{b_o \cdot d}$$

V → design shear force

d → Eff. depth

b_o → periphery of the section

$k_s = 0.5 + \beta_c$ $\tau_c = 0.25\sqrt{f_{ck}}$

$\tau_v < \tau_c$

Equivalent Frame Method :- IS 456:2000 recommends the analysis of flat slab and column structure as a rigid frame to get design moment and shear force with the following assumptions. I to given in the IS 456 code (5)

Loading pattern – When the live load does not exceed 3/4 th of dead load, the max^m. moments maybe assumed to occur at all sections when full design live load is on the entire slab.

Slab reinforcement :- ① Spacing – The spacing of the bars in a flat slab shall not exceed 2 times the slab thickness.

② Area of a Reinforcement – When the drop panels are used, the thickness of drop panel for determining area of reinforcement shall be the lesser of the following :-

i) Thickness of drop.
ii) Thickness of slab + one quarter distance b/w edge of drop and edge of capital

③ Min^m. length of Reinforcement :- at least 50% of the bottom bars should be from support to support. The rest maybe bent up.

Que :- Design an Interior panel of a flat slab of size 5m x 5m without providing drop and column head. Size of column is 500 x 500 mm and live load on the panel is 4 kN/m². Take floor finishing load as 1 kN/m². Use M20 & Fe415 steel.

Solutions – Step-I Thickness of flat slab
span to eff depth ratio (when drop is not provided)

$= \frac{1}{0.9 \times 32} = \frac{1}{28.8}$

min^m depth required $d_{reg} = \frac{span}{28.8}$

$= \frac{5000}{28.8} = 173.6 MM$

Assuming cover as 15 MM & using 12 MM φ bars

∴ over all depth $D = d + d'$

$= 175 + 15 + \frac{12}{2} = 196 MM$

$\simeq 200 MM$

Hence provide thickness of slab, $T = D = 200 MM$.

Step: 2 Load calculation:

Self weight of slab, $W_d = 0.20 \times 25 = 5 KN/M^2$

finishing load $W_f = 1 KN/M^2$

live load $W_L = 4 KN/M^2$

Total working load, $W = 10 KN/M^2$

Factored load $W_u = 1.5 \times 10 KN/M^2$

$= 15 KN/M^2$

$L_n = 5 - 0.5 = 4.5 M$

∴ Total design load in a panel $W = 15 L_2 L_n$

$= 15 \times 5 \times 4.5$

$= 337.5 KN.$

Step: 3 Design moments & its distribution:

Total design moment; $M_0 = \frac{W L_n}{8} = \frac{337.5 \times 4.5}{8}$

$= 189.84 KNM$

$M_o = 189.84$ kNm

Panel -ve moment = $0.65 \times 189.84 = 123.40$ kNm

" +ve moment = $0.35 \times 189.84 = 66.44$ kNm

Distribution of moment into column strips & middle strip

	Column strip	Middle strip
-ve moment	$0.75 \times 123.40 = 92.55$	$0.25 \times 123.4 = 30.85$
+ve moment	$0.60 \times 66.44 = 39.86$	$0.40 \times 66.44 = 26.58$

Step 4: checking the thickness selected

since Fe 415 steel is used

$M_{ulim} = 0.138 f_{ck} b d^2$

width of column strip $= 0.5 \times 5000 = 2500$ mm

$M_{ulim} = 0.138 \times 20 \times 2500 \times 175^2 = 211.3125$ kNm.

since $M_o < M_{ulim}$ hence depth 200 mm is safe

Step 5: check for shear: the critical section for shear is taken at a distance $d/2$ from the column face.

Periphery of critical section around a column is square size $= 500 + d = 500 + 175 = 675$ mm

Shear to be resisted by critical section

$V = 15 \times 5 \times 5 - 15 \times 0.675 \times 0.675$

$= 368.166$ kN

Nominal shear stress, $\tau_v = \frac{368.166 \times 1000}{4 \times 675 \times 175}$

$= 0.799 \ N/mm^2$

$k_s = 1 + \beta_c$

$\beta_c = \frac{L_1}{L_2} = \frac{5}{5} = 1$

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Design shear strength, $\tau_c = 0.25 \sqrt{f_{ck}}$

$= 0.25 \sqrt{20} = 1.118 \ N/mm^2$

Since $\tau_v < \tau_c$ hence the design is safe against shear.

Step:6 Reinforcement calculations

For -ve moment in column strip

$M_u = 92.55 \ kNm$

$$A_{st} = 0.5 \frac{f_{ck}}{f_y} bd \left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} bd^2}}\right]$$

$$\frac{M_u}{bd^2} = \frac{92.55 \times 10^6}{2500 \times 175^2} = 1.209$$

$A_{st} = 1583.75 mm^2$

This is to be provided in a column strip of width 2500 mm. Hence using 12 mm bars then spacing of 12 mm ϕ bars is given by

$$s = \frac{\pi/4 \times 12^2}{1583.74} \times 2500 = 178 mm$$

Hence provide 12 mm bars @ 175 mm c/c.

or +ve moment in column strip

$$A_{st} = \frac{0.5 f_{ck}}{f_y} bd \left[1 - \sqrt{1 - \frac{4.6}{f_{ck}} \frac{M_u}{bd^2}}\right]$$

$$\frac{M_u}{bd^2} = \frac{39.86 \times 10^6}{2500 \times 175^2} = 0.521$$

$$A_{st} = 651.9\ mm^2$$

using 10mm ϕ bars. spacing of 10mm ϕ bar is-

$$s = \frac{\pi/4 \times 10^2}{651.5} \times 2500$$

$$= 301.4\ mm < 2 \times \text{thickness of slab}$$

$$< 2 \times 200$$

$$301.4\ mm < 400\ mm$$

Hence provide 10 mm bars @ 300 mm c/c.