

Square panel, with drop

Example → Design an interior panel of a flat slab with panel size $6\text{m} \times 6\text{m}$ supported by columns of size $500\text{mm} \times 500\text{mm}$. Provide suitable drop. Take live load as 4kN/m^2 . Use M20 concrete and Fe 415 steel.

Solution →

Step-1 → Calculation of depth of Slab & panel drop →

$$\frac{l}{d} = 26 \times \text{M.F.}$$

$$f_s = 0.58 f_y \frac{\text{Area of c/s of steel required}}{\text{Area of c/s of steel provided}}$$

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$$f_s = 0.58 \times 415 = 240.7 \frac{\text{N}}{\text{mm}^2}$$

Assuming $p_t = 0.12\%$, M.F. = 1.7 fig no - 4, Page no 38

$$\frac{6000}{d} = 26 \times 1.7$$

$$d = 135.75 \text{ mm}$$

provide effective depth $> 136 \text{ mm}$

assume $d = 170 \text{ mm}$

$$D = 170 + 20 + 30 = 220 \text{ mm}$$

$$\text{length of drop} \geq \frac{\text{length of panel in that direction}}{3}$$

Page no 53, clause no - 31.2.2

$$\text{length of drop} \geq \frac{6000}{3} = 2000 \text{ mm} \Rightarrow \text{Provide } 3000 \text{ mm}$$

$$\text{Depth of drop} \approx \frac{D}{4} \text{ to } \frac{D}{2}$$

$$\text{depth of drop} \approx \frac{220}{4} \text{ to } \frac{220}{2} \approx 55 \text{ to } 110$$

Let us assume depth of drop = 60 mm

Step-2 → Loading Calculation →

$$\text{Self weight of flat slab} = 0.22 \times 25 = 5.5 \text{ kN/m}^2$$

$$\text{Self weight of drop} = \frac{\left(\frac{3}{2} \times \frac{3}{2} \times 4\right) \times 25 \times 0.060}{6 \times 6} = 1.5 \text{ kN/m}^2$$

$$\text{Live load} = \frac{4 \text{ kN}}{\text{m}^2}$$

$$\text{Floor finish} = 1 \text{ kN/m}^2$$

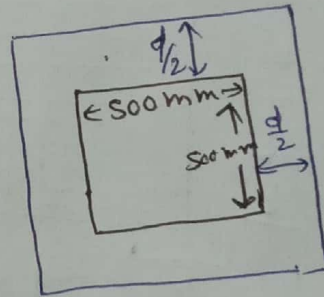
$$\text{Total load} = 5.5 + 1.5 + 4 + 1 = 12 \text{ kN/m}^2$$

$$\text{Factored load} = 1.5 \times 12 = 18 \text{ kN/m}^2$$

Step-3 → Check for 2-way shear →

available depth at distance of $\left(\frac{170+60}{2}\right) = 115$ mm from the face of column is = effective depth + depth of drop

$$= 170 + 60 = 230 \text{ mm}$$



$$\text{Length of critical section} = 500 + \frac{230}{2} + \frac{230}{2} = 730 \text{ mm}$$

$$\text{Perimeter of critical section} = 730 \times 4 = 2920 \text{ mm}$$

$$\% \text{ area available} = 6000 \times 6000 - 730 \times 730 = 35467100 \text{ mm}^2$$

$$\text{Total } V_u = \frac{18 \times 35467100}{1000} = 638407.8 \text{ N}$$

$$Z_v = \frac{V_u}{bd} = \frac{638407.8}{2920 \times 230} = 0.951 \frac{\text{N}}{\text{mm}^2}$$

$$P_c = \frac{\text{Short side of Column}}{\text{long side of Column}} = \frac{500}{500} = 1$$

$$k_s = 0.5 + P_c = 0.5 + 1 = 1.5 \neq 1$$

$$k_s = 1$$

$$Z_c = 0.25 \sqrt{f_{ck}} = 0.25 \times \sqrt{20} = 1.118 \frac{\text{N}}{\text{mm}^2}$$

$$z'_c = k_s z_c = 1 \times 1.18 \frac{N}{\text{mm}^2} = 1.18 \frac{N}{\text{mm}^2}$$

$$z_v < z'_c \rightarrow \text{OK}$$

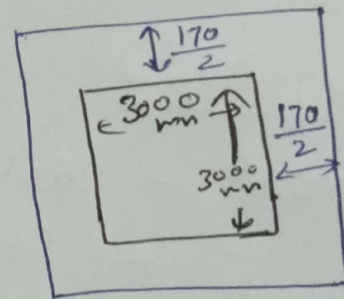
Another critical section will be at a distance of $\frac{d}{2}$ from column drop portion.
depth available at this section = 170mm

Total periphery at critical section

$$= 4 \left(3000 + \frac{170}{2} + \frac{170}{2} \right) = 12680 \text{ mm}^2$$

$$V_u = \frac{18}{1000} [6000 \times 6000 - (3000 + 170)^2]$$

$$V_u = \cancel{644023.8} \text{ N} = 467119.8 \text{ N}$$



$$z_v = \frac{V_u}{bd} = \frac{\cancel{644023.8}}{\cancel{12680} \times 170} = \frac{467119.8}{12680 \times 170} = 0.2167 \frac{N}{\text{mm}^2}$$

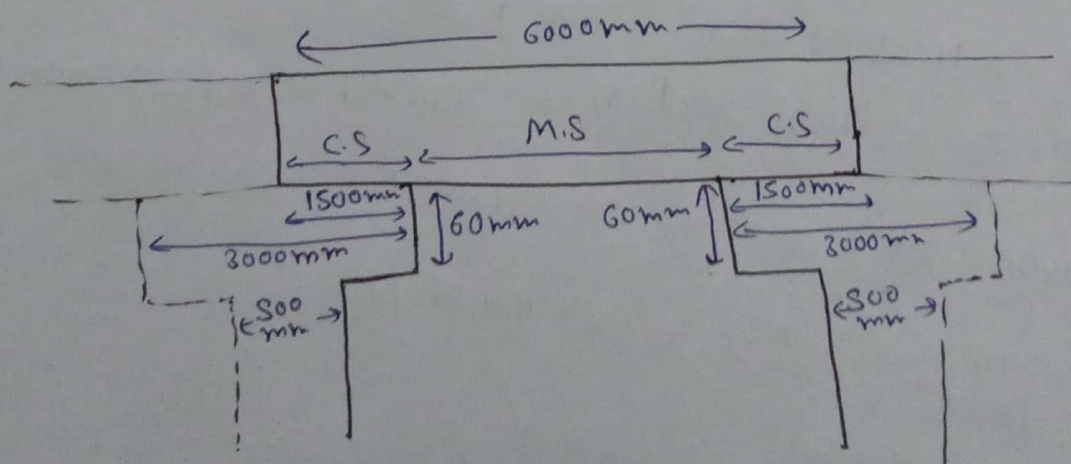
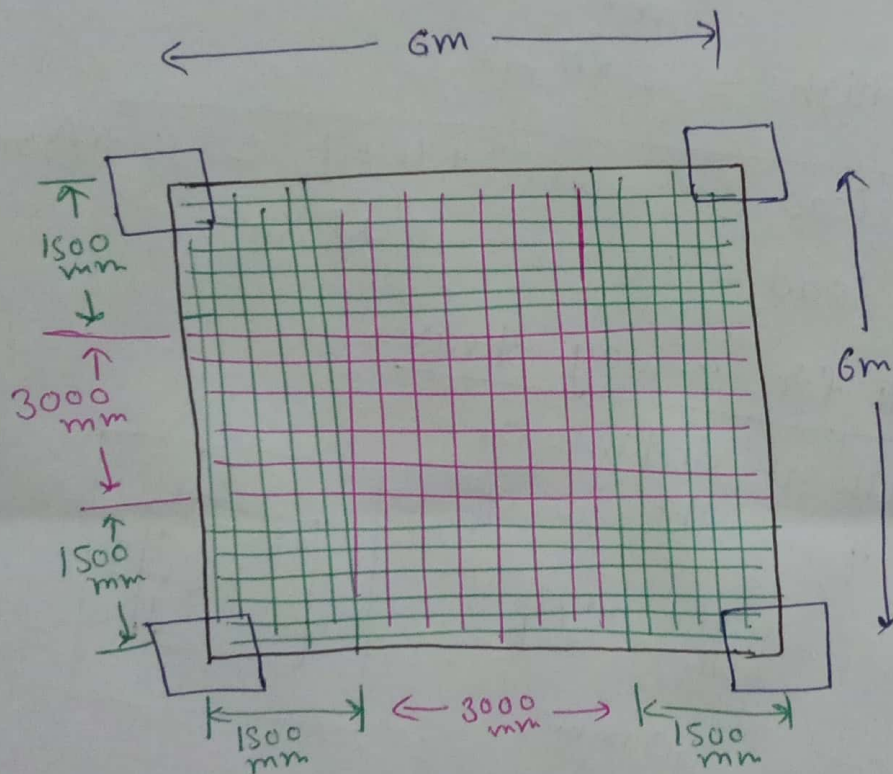
$$z_v < z'_c \rightarrow \text{Safe.}$$

Step-4 → Calculate length and size of column strip and middle strip →

$$l_1 = l_2 = 6000 \text{ mm}$$

$$\text{column strip thickness} = 0.25l = 0.25 \times 6000 = 1500 \text{ mm}$$

$$\text{middle strip thickness} = 6000 - 2 \times 1500 = 3000 \text{ mm}$$



Step-5 → Calculate moments in all strips -

$$l_n = 6000 - \left(\frac{500}{2} + \frac{500}{2} \right)$$

$$l_n = 5500 \text{ mm}$$

$$0.65 l_1 = 0.65 \times 6000 = 3900 \text{ mm}$$

$$0.65 l_2 < l_n \rightarrow \text{OK}$$

$$W = w l_2 l_n$$

$$= \frac{18}{1000} \times 6000 \times 5500 = 594000 \text{ N}$$

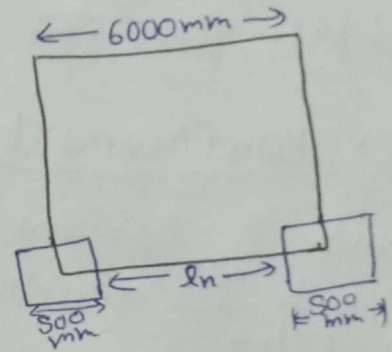
$$M_o = \frac{W l_n}{8} = \frac{594000 \times 5500}{8} = 40837500 \text{ Nmm}$$

Total -ve design moment = $0.65 M_o$ Page no (55)
 $\Rightarrow 0.65 \times 40837500$ clause no - 31.4.3.2
 $= 26544375 \text{ Nmm}$

Total +ve design moment = $0.35 M_o$
 $= 0.35 \times 40837500$
 $= 14293125 \text{ Nmm}$

Column Strip -

-ve moment = $0.75 \times \text{Total -ve moment}$
 $= 0.75 \times 26544375$
 $= 19908281.25 \text{ Nmm}$



$$+ve \text{ moment} = 0.60 \times \text{Total } +ve \text{ moment} \\ = 0.60 \times 14293125 = 8575875 \text{ Nmm}$$

middle strip →

$$-ve \text{ moment} = 26544375 - 19908281.25 \\ = 6636093.75 \text{ Nmm}$$

$$+ve \text{ moment} = 14293125 - 8575875 \\ = 5717250 \text{ Nmm}$$

$$M_{ulim} = K b d^2 \\ = 2.76 \times 3000 \times (170)^2 = 239292000 \text{ Nmm}$$

$$M_{ulim} > \begin{matrix} +M \\ -M \end{matrix} \rightarrow \text{OK}$$

So depth provided is safe in BM criteria.

Step-6 → Reinforcement along longer and shorter direction -

because $l_1 = l_2 = 6\text{m}$ so same $\bar{x}/f$ would be provided in both the directions.

$$\text{Column Strip} \rightarrow \frac{A_{stmin}}{100} = \frac{0.12}{100} \times b D = \frac{0.12}{100} \times 3000 \times (220 + 60) = 1008 \text{ mm}^2$$

$$\text{spacing}_{max} = 2D = 2 \times 220 = 440 \text{ mm}$$

$$\bar{x}/f \text{ for } -ve \text{ M in Column Strip} \rightarrow d = 170 + 60 = 230 \text{ mm}$$

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d} \right)$$

$$19908281.25 = 0.87 \times 415 \times A_{st} \times 230 \left(1 - \frac{415 \times A_{st}}{20 \times 3000 \times 230} \right)$$

$$239.74 = A_{st} - 3 \times 10^{-5} A_{st}^2$$

$$3 \times 10^{-5} A_{st}^2 - A_{st} + 239.74 = 0$$

$$A_{st1} = 33091.84 \text{ mm}^2 \text{ (reject)}$$

$$A_{st2} = 241.49 \text{ mm}^2 \text{ (accept)} < A_{stmin}$$

$$\text{provide } A_{st} = 1008 \text{ mm}^2$$

$$\text{take dia of bars} = 10 \text{ mm}$$

$$\text{spacing} = \frac{\frac{\pi}{4} (10)^2 \times 3000}{1008} = 233.75 \text{ mm} < \text{spacing}_{max} \rightarrow \text{OK}$$

provide 10 mm dia bars @ 230 mm c/c

σ/f for +ve M in column strip →

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d} \right)$$

$$8575875 = 0.87 \times 415 \times A_{st} \times 230 \left(1 - \frac{415 \times A_{st}}{20 \times 3000 \times 230} \right)$$

$$3 \times 10^{-5} A_{st}^2 - A_{st} + 103.27 = 0$$

$$A_{st1} = 33229.74 \text{ mm}^2 \text{ (reject)}$$

$$A_{st2} = 103.59 \text{ mm}^2 \text{ (accept)} < A_{stmin}$$

$$\text{Provide } A_{st} = 1008 \text{ mm}^2$$

take dia of bars = 10 mm

$$\text{Spacing} = \frac{\frac{\pi}{4} \times (10)^2 \times 3000}{1008} = 233.75 \text{ mm} < \text{spacing}_{max} \rightarrow \text{OK}$$

provide 10 mm dia bars @ 230 mm c/c

middle strip → $b = 3000 \text{ mm}$, $D = 220 \text{ mm}$, $d = 170 \text{ mm}$

$$A_{stmin} = \frac{0.12}{100} \times b D = \frac{0.12}{100} \times 3000 \times 220 = 792 \text{ mm}^2$$

σ/f for -ve M in middle strip →

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d} \right)$$

$$6636093.75 = 0.87 \times 415 \times A_{st} \times 170 \left(1 - \frac{415 \times A_{st}}{20 \times 3000 \times 170} \right)$$

$$4.069 \times 10^{-5} A_{st}^2 - A_{st} + 108.12 = 0$$

$$A_{st1} = 24467.46 \text{ mm}^2 \text{ (reject)}$$

$$A_{st2} = 108.60 \text{ mm}^2 \text{ (accept)} < A_{stmin}$$

$$\text{Provide } A_{st} = 792 \text{ mm}^2$$

dia = 8 mm

$$\text{Spacing} = \frac{\frac{\pi}{4} \times (8)^2 \times 3000}{792} = 190.40 \text{ mm}$$

provide 8 mm dia bars @ 190 mm c/c

σ/f for +ve M in middle strip →

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d} \right)$$

$$5717250 = 0.87 \times 415 \times A_{st} \times 170 \left(1 - \frac{415 \times A_{st}}{20 \times 3000 \times 170} \right)$$

$$4.069 \times 10^{-5} A_{st}^2 - A_{st} + 93.147 = 0$$

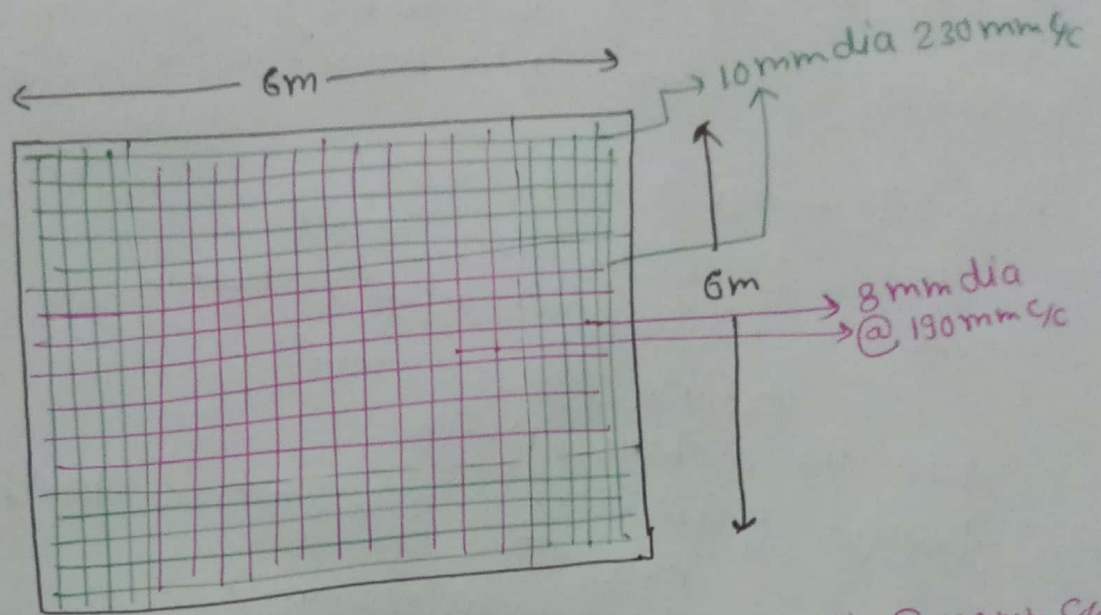
$$A_{st1} = 24482.56 \text{ mm}^2 \text{ (reject)}$$

$$A_{st2} = 93.50 \text{ mm}^2 \text{ (accept)} < A_{stmin}$$

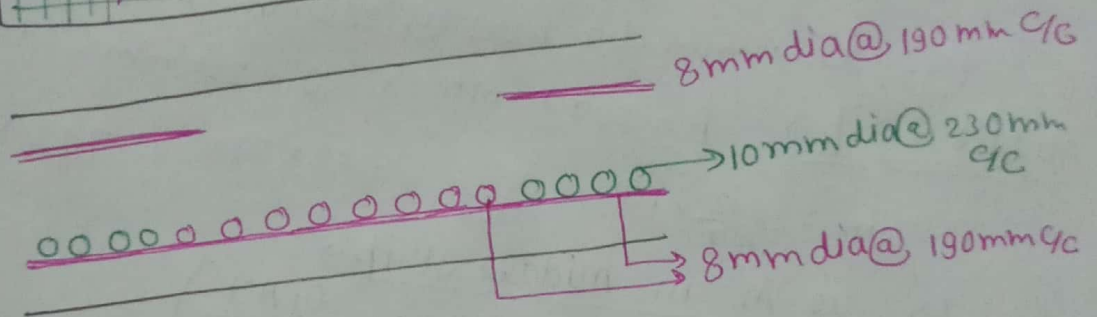
provide 8mm dia bars @ 190mm c/c

Step-7 → Detailing diagram →

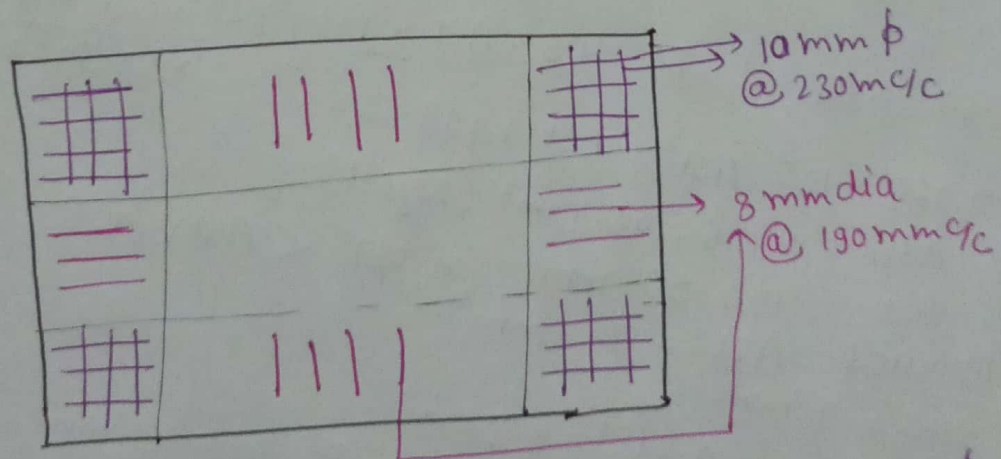
Down side panel →



Middle Strip →



up side panel →



Column Strip →

