Square panel, with drop

Example → Design an interior panel of a flat slab with panel size 6m x 6m supported by columns of size 500 mm x 500 mm. Provide suitable drop. Take live load as 4KN/m². Use M20 concrete and Fe 415 steel.

Solution →

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

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

$$f_s = 0.58 f_y \frac{\text{Area of c/s of steel required}}{\text{Area of c/s of steel provided}}$$ Page (38)

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

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

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

$d = 135.75$ mm

provide effective depth > 136 mm

assume $d = 170$ mm

$D = 170 + 20 + 30 = 220$ mm

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

Page no 53, clause no - 31.2.2

Length of drop $\geq \frac{6000}{3} = 2000$ mm ⇒ Provide 3000mm

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

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

Let us assume depth of drop = 60 mm

Step-2 → Loading Calculation →

Self weight of flat slab = $0.22 \times 25 = 5.5\ KN/m^2$

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

Live load = $\frac{4\ KN}{m^2}$.

Floor finish = $1\ KN/m^2$

Total load = $5.5 + 1.5 + 4 + 1 = 12\ KN/m^2$

Factored load = $1.5 \times 12 = 18\ KN/m^2$

Step-3 → Check for 2-way shear →

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

$= 170 + 60 = 230\ mm$

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

perimeter of critical section = $730 \times 4 = 2920\ mm$

c/s area availiable = $6000 \times 6000 - 730 \times 730 = 35467100\ mm^2$

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

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

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

$k_s = 0.5 + \beta_c = 0.5 + 1 = 1.5 \not> 1$

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$K_S = 1$

$\tau_c = 0.25\sqrt{f_{ck}} = 0.25 \times \sqrt{20} = 1.118\ N/mm^2$

$\tau_c' = k_s \tau_c = 1 \times 1.118 \frac{N}{mm^2} = 1.118 \ N/mm^2$

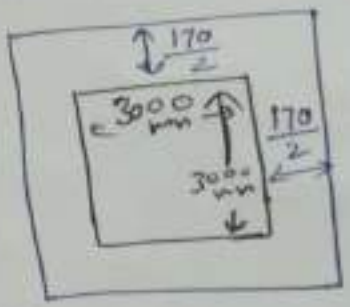
$\tau_v < \tau_c' \rightarrow OK$

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

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



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

$V_u = 467119.8 \ N$

$\tau_v = \frac{V_u}{bd} = \frac{467119.8}{12680 \times 170} = 0.2167 \frac{N}{mm^2}$

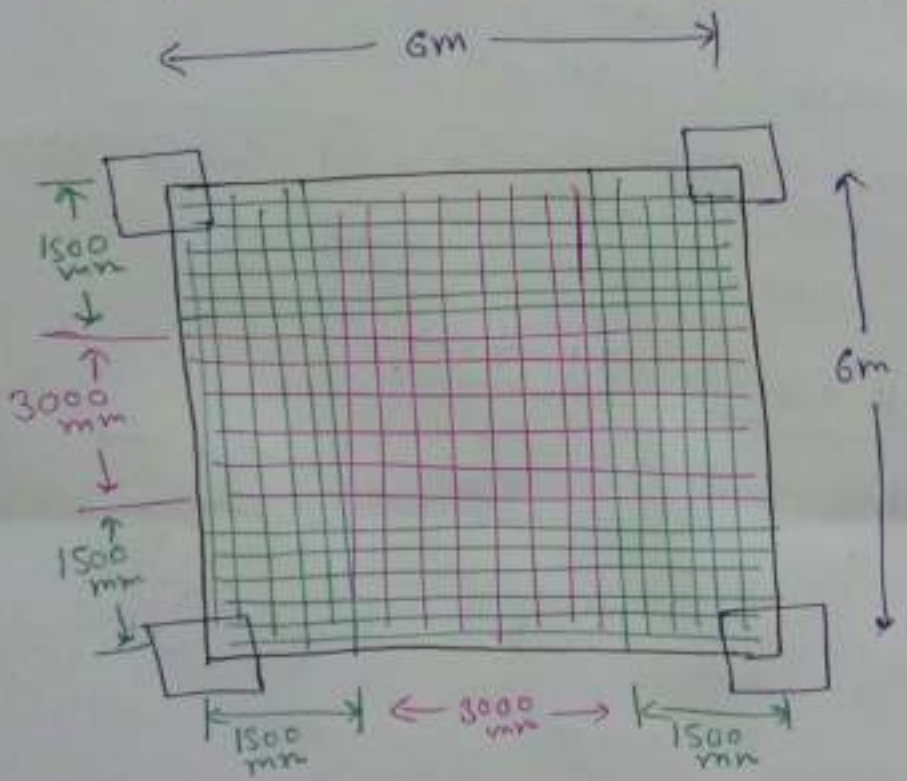
$\tau_v < \tau_c' \rightarrow$ Safe.

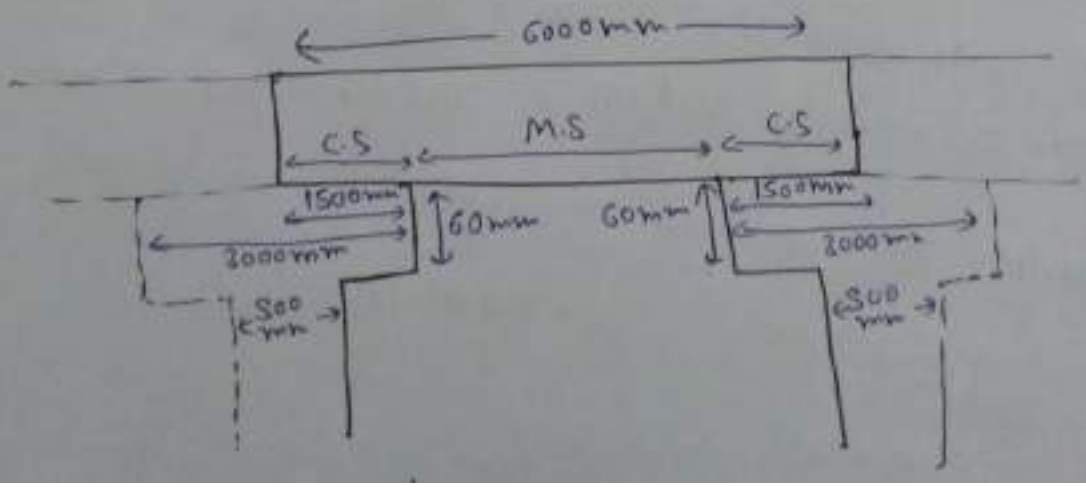
Step-4 → Calculate length and size of column strip and middle strip →

$l_1 = l_2 = 6000$ mm

Column strip thickness $= 0.25l = 0.25 \times 6000 = 1500$ mm

Middle strip thickness $= 6000 - 2 \times 1500 = 3000$ mm





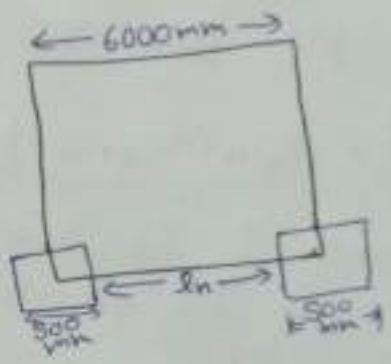
Step-5 → Calculate moments in all strips -

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

$l_n = 5500$ mm

$0.65 l_1 = 0.65 \times 6000 = 3900$ mm

$0.65 l_2 < l_n \rightarrow$ OK



$W = w\, l_2\, l_n$

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

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

Total -ve design moment = $0.65 M_o$ Page no (55)

$\Rightarrow 0.65 \times 40837500$ clause no - 31.4.3.2

$= 26544375$ Nmm

Total +ve design moment = $0.35 M_o$

$= 0.35 \times 40837500$

$= 14293125$ Nmm

Column Strip-

-ve moment = $0.75 \times$ Total -ve moment

$= 0.75 \times 26544375$

$= 19908281.25$ Nmm

+ve moment = 0.60 × Total +ve moment
= 0.60 × 14293125 = 8575875 Nmm

Middle strip →

-ve moment = 26544375 - 19908281.25
= 6636093.75 Nmm

+ve moment = 14293125 - 8575875
= 5717250 Nmm

$M_{u\,lim} = K b d^2$
$= 2.76 \times 3000 \times (170)^2 = 239292000$ Nmm

$M_{u\,lim} > {}^{+M}_{-M}$ → OK

So depth provided is safe in BM criteria.

Step-6 → Reinforcement along longer and shorter direction.

because $l_1 = l_2 = 6m$ so same s/f would be provided in both the directions

Column Strip →

$A_{st\,min} = \frac{0.12}{100} \times bD = \frac{0.12}{100} \times 3000 \times (220+60) = 1008$ mm²

$Spacing_{max} = 2D = 2 \times 220 = 440$ mm

s/f for -ve M in Column Strip → d = 170 + 60 = 230 mm

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

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

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

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

$A_{st_1} = 33091.84$ mm² (rejected)

$A_{st_2} = 241.49$ mm² (accept) < $A_{st\,min}$

provide $A_{st} = 1008$ mm²

take dia of bars = 10 mm

Spacing = $\frac{\frac{\pi}{4}(10)^2 \times 3000}{1008} = 233.75$ mm < $Spacing_{max}$ → OK

provide 10 mm dia bars @ 230 mm c/c

R/f for +ve M in column strip →

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

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

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

$A_{st_1} = 33229.74 \text{ mm}^2$ (reject)

$A_{st_2} = 103.59 \text{ mm}^2$ (accept) $< A_{st\,min}$

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

take dia of bars = 10mm

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

provide 10mm dia bars @ 230 mm c/c

middle strip → $b = 3000$ mm, $D = 220$ mm, $d = 170$ mm

$A_{st\,min} = \frac{0.12}{100} \times bD = \frac{0.12}{100} \times 3000 \times 220 = 792 \text{ mm}^2$

R/f for -ve M in middle strip →

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

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

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

$A_{st_1} = 24467.46 \text{ mm}^2$ (reject)

$A_{st_2} = 108.60 \text{ mm}^2$ (accept) $< A_{st\,min}$

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 8mm dia bars @ 190 mm c/c.

R/f for +ve M in middle strip →

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

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

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

$A_{st_1} = 24482.56 \text{ mm}^2$ (reject)

$A_{st_2} = 93.50 \text{ mm}^2$ (accept) $< A_{st\,min}$

provide 8 mm dia bars @ 190 mm c/c

Step-7 → Detailing diagram →