(Q1) Design a simply supported roof slab for a room 7.5m X 3.5m clear in size. The slab is carrying an imposed load of 5KN/m². Use M20 grade and Fe415 steel.

Sol:- Given data :- Size of slab = 7.5m X 3.5m, ~~Live load = 5KN/~~

Live load = 5 KN/m²,

$\frac{l_y}{l_x} = \frac{7.5}{3.5} > 2 \rightarrow$ designs as one way slab

Design the one slab [d, Ast].

Assuming total depth = D = 150mm

(i) Effective depth, $d = D - \text{clear cover} - \frac{\phi}{2}$

$d = 150 - 20 - \frac{10}{2}$

$d = 125mm$

(ii) Effective span (l_{eff}):-

(a) l_{eff} = clear span + width of support] whichever is less

l_{eff} = clear span + d

Assume support width = 200mm = 0.2m

$l_{eff} = 3.5 + 0.2 = 3.7m$

or $= 3.5 + 0.125 = 3.625m$

adopt, $l_{eff} = 3.625m$

(2) Factored Bending Moment: M_{UD}:

load for 1m width of slab:-

~~Self~~ Self wt. of slab = b × D × 25

= 1 × 0.15 × 25 = 3.75 KN/m

Live load = 5 KN/m

Total load = 5 + 3.75 = 8.75 KN/m

Design load, w_u = 1.5 × 8.75 = 13.125 KN/m

Factored Moment, $M_{uD} = \frac{w l_{eff}^2}{8} = \frac{13.125 \times (3.625)^2}{8}$

= 21.60 KN-m

Factored shear force, $V_u = \frac{w_u l}{2} = \frac{13.125 \times 3.5}{2}$

= 22.97 KN

(3) Check for effective depth: d:

$$d = \sqrt{\frac{M_u}{0.36 f_{ck} b}}$$

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

$M_{uD} = 0.36 f_{ck} b \times 0.48d\, (d - 0.42 \times 0.48d)$

$M_{uD} = 0.36 f_{ck} b \times 0.48 d^2 (1 - 0.42 \times 0.48)$

$$d^2 = \frac{M_{uD}}{0.36 f_{ck} b \times 0.48 (1 - 0.42 \times 0.48)}$$

$$d = \sqrt{\frac{M_{uD}}{0.36 \times 20 \times 1000 \times 0.48 (1 - 0.42 \times 0.48}} = \sqrt{\frac{21.6 \times 10^6}{2.}}$$

$$d = \sqrt{\frac{21.6 \times 10^6}{0.36 \times 20 \times 1000 \times 0.48(1 - 0.42 \times 0.48)}}$$

$d = 88.5\,mm < 125\,mm$ (OK)

④ <u>Area of tensile steel</u>: <u>Ast</u> (Main reinforcement)

$$M_{uD} = 0.87 f_y A_{st} d \left[1 - \frac{A_{st}}{bd}\frac{f_y}{f_{ck}}\right]$$

$$21.6 \times 10^6 = 0.87 \times 415\, A_{st} \times 125 \left[1 - \frac{A_{st} \times 415}{1000 \times 125 \times 20}\right]$$

~~$21.6 \times 10^6 = 361.05\, A_{st} - 0.06\, A_{st}^2$~~

~~$A_{st}^2 - 6024\, A_{st} + \frac{21.6 \times 10^6}{360 \times 10^6} = 0$~~

$$21.6 \times 10^6 = 45131.25\, A_{st} - 7.49\, A_{st}^2$$

$$7.49\, A_{st}^2 - 45131.25\, A_{st} + 21.6 \times 10^6 = 0$$

$A_{st} = 524.2\,mm^2$

using 10 mm ϕ diameter bars

$$\text{Spacing of bars} = \frac{1000 \times \text{Area of one bar}}{A_{st}}$$

$$= \frac{1000 \times \frac{\pi}{4}(10)^2}{524.2} = 150\,mm$$

Provide 10mm φ diameter bar @ 150mm c/c spacing.

Bent up of alternate bars at $\frac{l_{eff}}{7} = \frac{3625}{7} = 517mm \simeq 520mm$ from face of support

(5) <u>Distribution Steel</u>: Distribution steel is provided in longer direction

$= 0.12\%$ of cross sectional area

$= \frac{0.12}{100} \times bD = \frac{0.12}{100} \times 1000 \times 150$

$= 180 mm^2$

using 6mm φ bar

$$\text{spacing} = \frac{1000 \times \frac{\pi}{4}(6)^2}{180} = 157.22mm \simeq 150 mm \text{ c/c}$$

Provide 6mm φ bar @ 150 mm c/c in the longer direction.

(6) <u>check for shear</u>:

i) Factored shear force $= V_u = 22970$ KN

Nominal shear stress, $\tau_{v} = \frac{V_u}{bd} = \frac{22970}{1000 \times 125} = 0.184 N/mm^2$

<u>Design shear strength of concrete τ_c</u>

$$P_t = \frac{100 \times A_{st}/2}{bd} = \frac{100 \times 524.2/2}{1000 \times 125} = 0.21\%$$

$$\tau_c = 0.28 + \left(\frac{0.36-0.28}{0.25-0.15}\right)(0.21-0.15)$$

$$= 0.328 \ N/mm^2$$

$\tau_v < \tau_c$ → hence the design is safe in shear

⑦ check for deflection:

$$p_t = \frac{100 A_{st}}{bd} = \frac{100 \times 524.2}{1000 \times 125} = 0.42\%$$

$$f_s = 0.58 f_y \left[\frac{A_{st} \text{ required}}{A_{st} \text{ provided}}\right]$$

$$= 0.58 \times 415 \left[\frac{524.2}{524.2}\right] = 240 \ N/mm^2$$

for $p_t = 0.42\%$, $f_s = 240 \ N/mm^2$, $K_t = 1.55$

$$\left(\frac{l}{d}\right)_{max^m} = 20 \times K_t = 20 \times 1.55 = 31$$

$$\left(\frac{l_{eff}}{d}\right)_{provided} = \frac{3625}{125} = 29$$

$\left(\frac{l}{d}\right)_{max^m} > \left(\frac{l}{d}\right)_{provided}$, Hence the design is safe in deflection

(8) Check for development length: **SLAB**

Moment of resistance at support by 10mm diameter bars @ 300mm c/c

Reinforcement at support $= \frac{524.2}{2} = 262.1 mm^2$

$$M_r = 0.87 f_y A_{st} d \left[1 - \frac{A_{st}}{bd}\frac{f_y}{f_{ck}}\right]$$

$$M_r = 0.87 \times 415 \times 262.1 \left[1 - \frac{262.1 \times 415}{1000 \times 125 \times 20}\right]$$

$$= 11.31 \times 10^6 \ N\text{-}mm$$

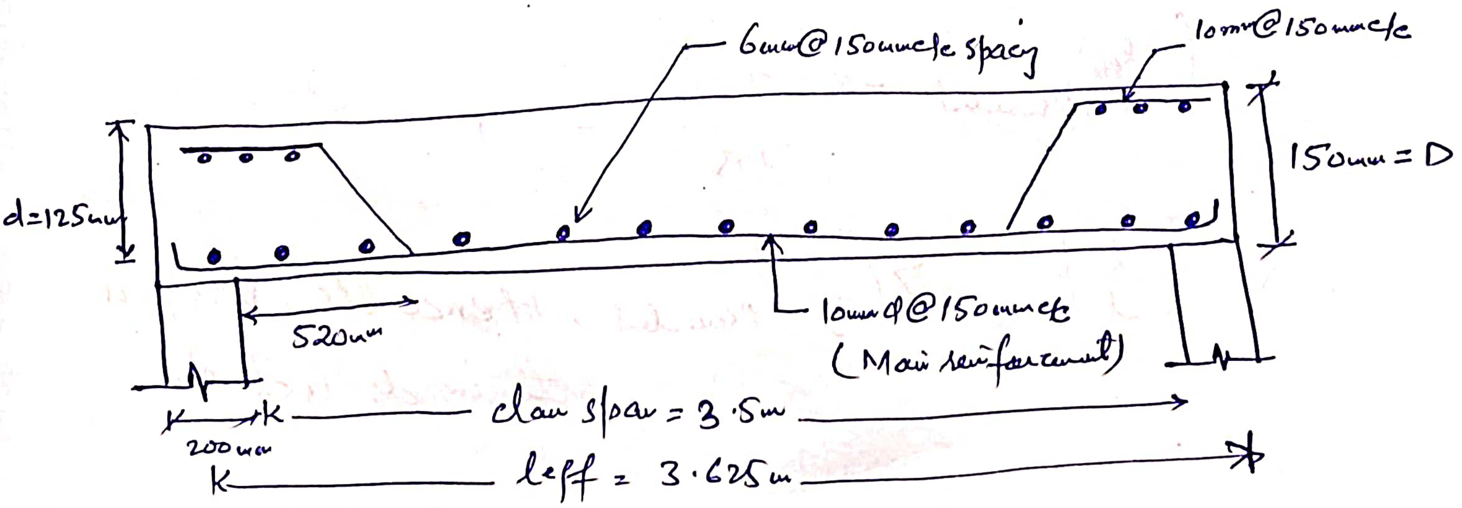
Factored shear force, $V_u = 22970 N$

Providing no hooks, $l_o = 0$

$$\frac{M_r}{V} + l_o = \frac{11.31 \times 10^6}{22970} + 0 = 492 mm$$

$$L_d = \frac{0.87 f_y \phi}{4 \tau_{bd}} = \frac{0.87 \times 415 \times 10}{4 \times 1.2 \times 1.6} = 470 mm$$

$\frac{M_r}{V_u} + l_o > L_d$ → Hence slab is safe.



bd 1000 X 125

Two way slab: When the ratio of $\frac{l_y}{l_x} \leq 2$, then the slab ~~is does~~ will be designed as two ~~dwo~~ way slab.

(a) Two way slab with corners not held down / free to lift

(b) Two " " " " held down / prevent to lift.

(Q2): Design a simply supported slab for a room 4000mm × 3500mm clear in size if the superimposed load is 3 KN/m² and floor finish of 1 KN/m². The edges of the slab are not held down. Use M20 grade concrete and Fe 415 steel?

Sol:-

$$\frac{l_y}{l_x} = \frac{4}{3.5} = 1.14 < 2$$

Hence, the slab is to be designed as a two way slab.

1) Given Data:-

Shorter span, l_x = 3.5 m

Long span, l_y = 4 m

Live load = 3 KN/m²

Floor finish = 1 KN/m²

f_{ck} = 20 N/mm²

f_y = 415 N/mm²

2) **Thickness of slab:**

Assume effective depth, d =

Assume % of steel, p_t = 0.2%

α = 20 [Simply supported slab]

Modification factor, $\gamma = 1.68$

$$\left(\frac{L}{d}\right) = \alpha \gamma$$

$$\frac{3.5 \times 10^3}{d} = 20 \times 1.68$$

$$\frac{3500}{20 \times 1.68} = d$$

$$\boxed{104.2 \text{ mm} = d}$$

Take, $d = 105$ mm

Total depth, $D = d + 20 + \frac{\phi}{2}$ (c.c)

$$D = 105 + 20 + \frac{10}{2} = 130 \text{ mm}$$

③ Effective span: $(l_x)_{eff}$

$(l_x)_{eff}$ = clear span + width of support

or = clear span + d

$(l_x)_{eff} = 3.5 + 0.3$ [Assumed, width of support = 300mm]

$= 3.8$ m

$(l_x)_{eff} = 3.5 + 0.105 = 3.605$ m

Adopt, $(l_x)_{eff} = 3.605$ m

④ **Loads:** load per unit area of slab.

Self wt. of slab = 0.13 × 25 = 3.25 KN/m²

Live load = 3 KN/m²

floor finish load = 1 KN/m²

Total load = 7.25 KN/m²

Total load/m = 7.25 × 1 = 7.25 KN/m

Factored load, W_u = 1.5 × 7.25 = 10.875 KN/m

⑤ **Design Moments:** $\left[\frac{l_y}{l_x} = 1.14\right]$

$$\alpha_x = 0.074 + \left(\frac{0.084 - 0.074}{1.2 - 1.1}\right) \times (1.14 - 1.1)$$

$$= 0.078$$

$$\alpha_y = 0.061 - \left(\frac{0.061 - 0.059}{1.2 - 1.1}\right)(1.14 - 1.1)$$

$$\alpha_y = 0.06$$

$$M_{ux} = \alpha_x w l_x^2 = 0.078 \times 10.875 \times (3.605)^2$$

$$= 11.02 \text{ KN-m}$$

$$M_{uy} = \alpha_y w l_x^2 = 0.06 \times 10.875 \times (3.605)^2$$

$$= 8.48 \text{ KN-m}$$

⑥ **Minimum depth required:**

$$M_{uo} = 0.36 f_{ck} b x_{umax} (d - 0.42 x_{umax})$$

$$11.02 \times 10^6 = 0.36 \times 20 \times 1000 \times 0.48 \times d \, (d - 0.42 \times 0.48 d)$$

$d = 63.2\,mm < 105\,mm$, Hence, the design is Safe.

⑦ Reinforcement in Middle strip: Along shorter direction

$$M_{ux} = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{b d f_{ck}}\right]$$

$$11.02 \times 10^6 = 0.87 \times 415 A_{st} \times 105 \left[1 - \frac{A_{st}}{1000 \times 105} \times \frac{415}{20}\right]$$

$$11.02 \times 10^6 = 37910.25 A_{st} - 7.49 A_{st}^2$$

$$7.49 A_{st}^2 - 37910.25 A_{st} + 11.02 \times 10^6 = 0$$

$$A_{st} = 309.63\,mm^2$$

using 8mm ϕ bars.

$$c/c \text{ Spacing of bars} = \frac{1000 \times \frac{\pi}{4} \times (8)^2}{309.63} = 162.34\,mm$$

$\simeq 160\,mm$ c/c

Max^m spacing (i) $3d = 3 \times 105 = 315$ or 300mm (whichever is less)

Hence, provide 8mm ϕ @ 160 mm c/c spacing along shorter direction

Along longer direction: effective depth for longer direction.

$$d = 105 - 8 = 97\,mm$$

$$M_{uy} = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{b d f_{ck}}\right]$$

$$8.48\times10^6 = 0.87\times415\,A_{st}\times97\left[1-\frac{A_{st}}{1000\times97}\times\frac{415}{20}\right]$$

$$8.48\times10^6 = 35021.85\,A_{st} - 7.49\,A_{st}^2$$

$$7.49\,A_{st}^2 - 35021.85\,A_{st} + 8.48\times10^6 = 0$$

$$A_{st} = 256.2\ mm^2$$

using 8mm bars

$$c/c\ \text{spacing} = \frac{1000\times\frac{\pi}{4}(8)^2}{256.2} = 196.2\ mm$$

Max^m spacing, (i) $3d = 3\times105 = 315$ mm, (ii) 300mm [whichever is less]

Hence, provide 8mm Φ @ 190mm c/c spacing along longer direction

⑧ Reinforcement in edge strip :-

$$A_{st} = 0.12\%\ \text{of}\ bD = \frac{0.12}{100}\times1000\times130 = 156\ mm^2$$

using 6mm Φ bars, spacing of bars $= \frac{1000\times\frac{\pi}{4}(6)^2}{156} = 181.2$ mm

≃ 180mm c/c

(i) $5d = 5\times105 = 525$ mm
(ii) 450 mm
{whichever is less}

Hence, provide 6mm Φ @ 180mm c/c spacing in edge strip

⑨ Width of edge strip :-

width of edge strip along shorter direction $= \frac{l_x}{8} = \frac{3500}{8} = 437.5$ mm

" " " " " longer " $= \frac{l_y}{8} = \frac{4000}{8} = 500$ mm length of middle strip along shorter direction = $\frac{3}{4} l_x = \frac{3}{4} \times 3500$

$= 2625 \text{ mm}$

" " " " " longer direction = $\frac{3}{4} l_y = \frac{3}{4} \times 4000 = 3000$ mm

⑨ check for deflection :-

$$P_t = \frac{\frac{\pi}{4}(8)^2 \times 100}{160 \times 105}$$

$P_t = 0.3\%$

$f_s = 0.58 f_y = 0.58 \times 415$

$= 240 \text{ N/mm}^2$

$\gamma = 1.68$

$\left(\frac{l}{d}\right)_{max} = 1.68 \times 20 = 33.6$

$\left(\frac{l}{d}\right)_{Provided} = \frac{3605}{105} = 34.33$

Hence, the slab is not safe in deflection so, increase the depth of slab and redesign the slab.