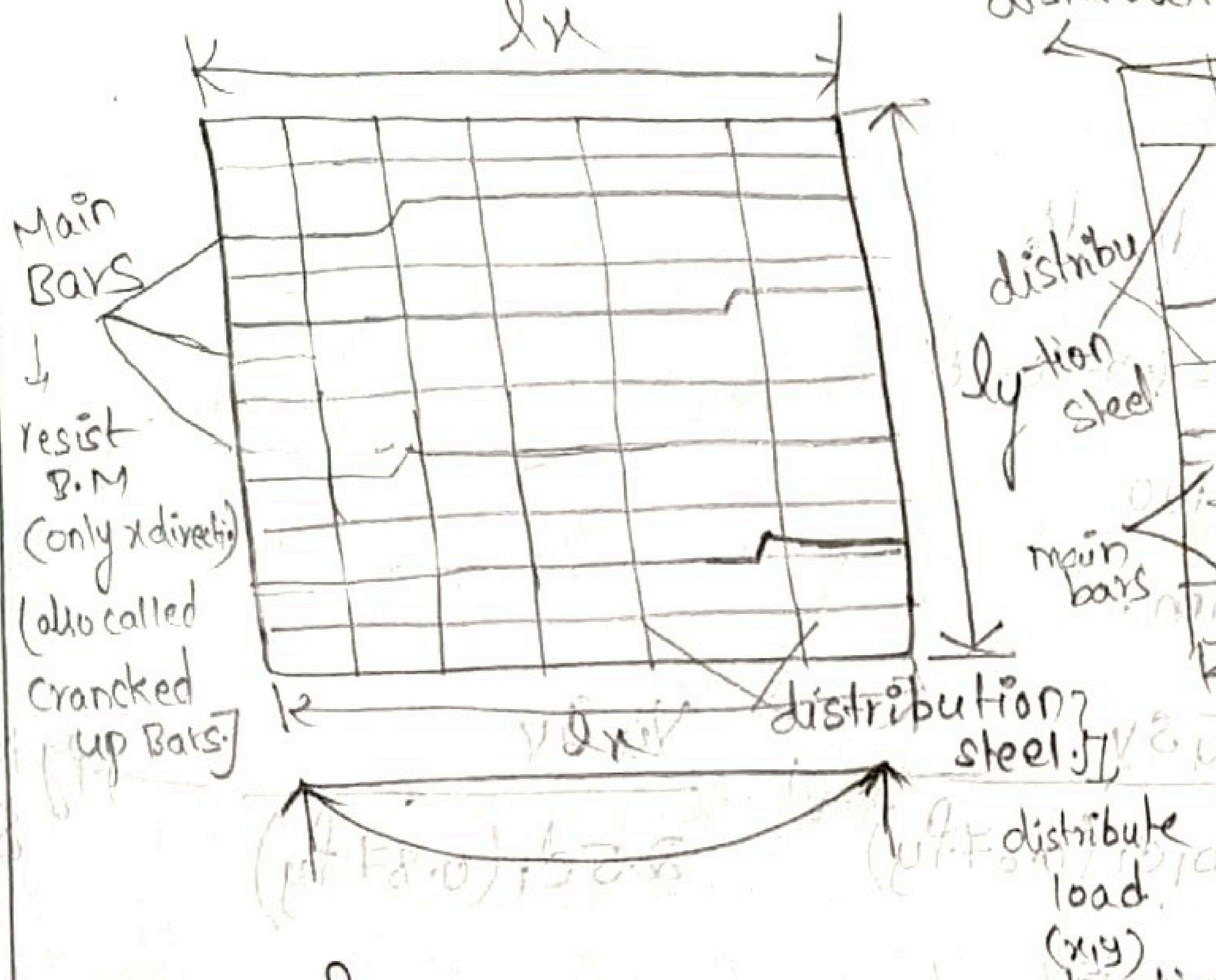
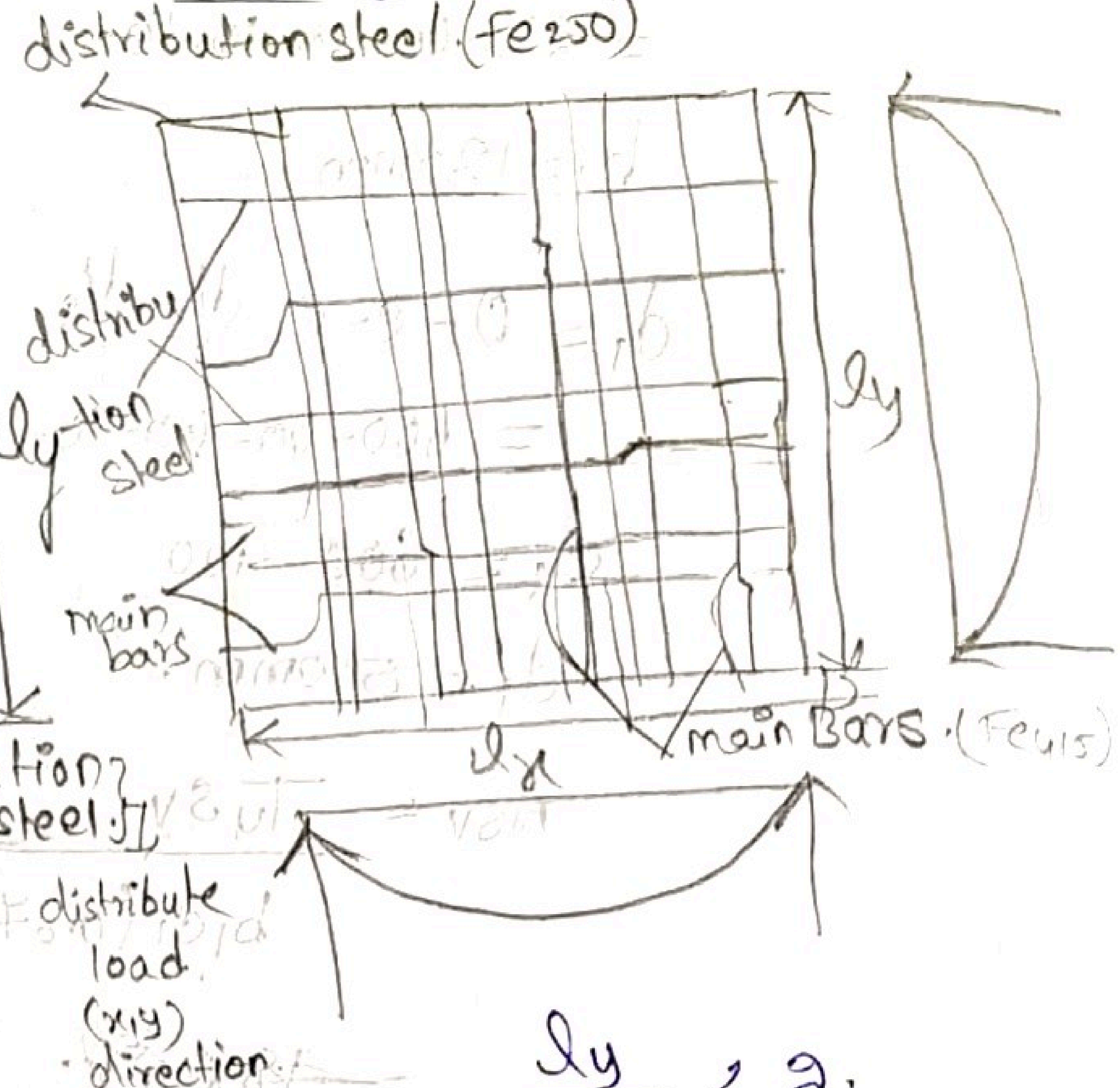
Unit-IV SLABS

Slabs:- One-way Slab. Two way slab



$$\frac{l_y}{l_x} > 2$$



$$\frac{l_y}{l_x} < 2$$

$$\text{Spacing} = \frac{A_{st}\,\text{required}}{A_{st}\,\text{provided}} \times 1000$$

[l/30 to l/40]

Slabs:- A slab is a plane structural member having the depth 'D' much lesser when compared to the length and width. They are classified based on the system of supports as follows.

① One way slab. ② Two-way slab. ③ Grid slab ④ Flat slab
⑤ Circular slab. ⑥ Waffle slab (or) Ribid slab.

① One-way slab:- A slab which is supported on all the four edges and the ratio of $\frac{l_y}{l_x}$ ratio.

$\frac{l_y}{l_x} > 2$ is called one way slab.

One way slab bends in only in one direction [Shorted span side].

Hence it needs the main reinforcement in one direction.

→ However minimum reinforcement that is distribution steel is placed along ly direction to distribute the loads equally and to resist temperature and shrinkage effects.

(2) Two way slab:- The slab supported on all the four edges and the ratio $\frac{l_y}{l_x} < 2$. is called as two way slab.

The slab bends in two-directions. So that the main reinforcement provided in both directions to resist the bending moment and distribution steel is placed along two direction to resist the shrinkage effects.

(3) General design requirements for slabs:-

(1) Calculation of effective depth.

for simply supported → $d = l/25$ to $l/30$.

(2) Calculation of effective span.

l_e = clear span + effective depth (or) center to center distance b/w two supports } less.

for cantilever, l_e = length of face of support + $\frac{\text{effective depth}}{2}$.

for continuous, l_e = center to center distance b/w supports.

(3) limiting stiffness:- (Refer class No. 23.2

(4) Minimum reinforcement:- (Refer class No 26.5.2.1 Pg No-48 of IS 456]

→ for mild steel → ≮ 0.15% of gross cross sectional area.

→ H.Y.S.D → ≮ 0.12% of gross cross sectional area.

(5) Maximum diameter of bar:- (Refer class No. 26.5.2.2 Pg No 48 of IS 456]

φ ≯ 1/8 (thickness of slab).

(6) Spacing of main reinforcement:- [refer class 26.3.3 Pg No-46].

≯ 3d
≯ 300mm } less value.

$S = \frac{a_{st}}{A_{st}} \times 1000$

7) Spacing of distribution steel:-

$\not> 5d$ } less.
$\not> 450mm$

8) Cover to reinforcement :-

(1) At each end of the reinforcement bar should not be less than 25mm and should not be less than 2 times of the diameter of bar. [$\not< 25mm$, $\not< 2\phi$]

(2) At bottom of reinforcement the cover should not be less than 20mm and should not less than diameter of bar.

[$\not< 20mm$, $\not< \phi$].

Design steps for one-way slab:-

(1) The Design of one-Way slab as same as that of beam of
- 1m width (or) 1000mm width.

(1) calculation effective depth (d) $d = l/25$ to $l/30$

(2) Assume some diameter of bar and cover to reinforcement then calculate 'D'.

(2) Calculation of effective span.

(3) Calculation of w_u, V_u, M_u. [load, shear, Moment].

(4) Check for depth. $M_u = M_{u limit}$

$M_u = 2.76 bd^2$ [b=1000mm]

~~$M_u = 2$~~

(5) Calculation of Ast :- $M_u = 0.87 f_y A_{st} d \left[1 - \frac{f_y A_{st}}{f_{ck} \cdot b \cdot d}\right]$

(6) Calculation of Minimum reinforcement.

(7) Spacing of main reinforcement

$$S = \frac{a_{st}}{A_{st}} \times 1000.$$

$\not> 3d$ and $\not> 300mm$. Which one is less.

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8) Spacing of distribution steel :-

$\not> 5d$ } less.
$\not> 450mm$

~~Retaining of~~

9.) Reinforcement details :-

1) Check for deflection.

2) Check for shear.

3) Check for development length.

~~12) check for deflection.~~

1) Design a simply supported Reinforced Concrete slab has to be provided for the roof of a room of a clear dimensions 3m x 8m. width of the supporting wall 300mm the weight of weathering coarse $1 KN/m^2$ over the slab and the live load is $2 KN/m^2$. Use M_{20} grade of Concrete and Fe_{415} steel.

Beam width, b = 300mm

Sol:- Given → $l_x = 3m$, $l_y = 8m$

$$\frac{l_y}{l_x} = \frac{8}{3} = 2.66$$

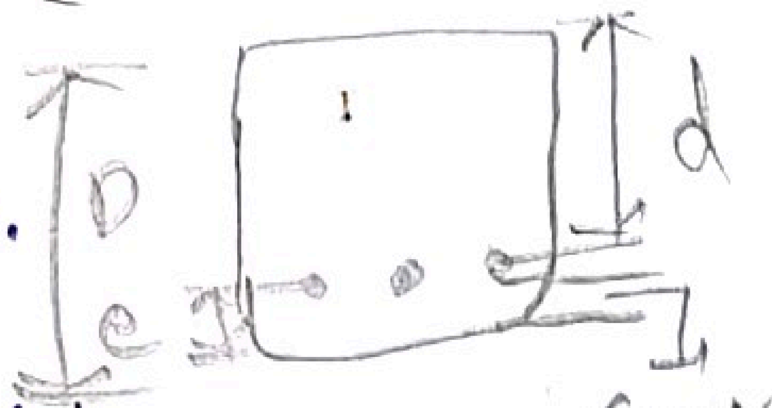
$$\frac{l_y}{l_x} > 2 \text{ one way slab.}$$

live load $= 2 KN/m^2$.

weathering coarse $= 1 KN/m^2$.

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

In one way slab → the deflection only in (x direction) shorter side. So the l is taken as 3m, $l = 3m$.



1) Calculation of depth :- $l/25$ to $l/30$

$$\frac{3000}{25} \text{ to } \frac{3000}{30}$$

120 to 100

$d = 120mm$. greater value

Choose 10ϕ of clear cover 20mm.

~~D = d + c = 120 + 20 = 140mm.~~

$D = 120 + 20 + 10/2 = 120 + 20 + 5 = 145mm$

② Calculation of effective span:—

l_e = clear span + effective depth

= 3000 + 120

= 3120

= 3.12m

l_e = center to center distance b/w support.

= $3000 + \frac{300}{2} + \frac{300}{2}$

= 3000+150+150

= 3300

= 3.3m

less value.

l_e = 3.12m

③ Calculation of load:—

D.L = b×D× unit weight.

= 1×0.145×25

D.L = 3.62 KN/m²

L.L = 2KN/m².

W.C = 1 KN/m²

Total Load = D.L + L.L + W.C

= 3.62+2+1

= 6.62 KN/m².

Factored load = 6.62×1.5

We = 9.93 KN/m².

B.M = $\frac{W_u l_e^2}{8} = \frac{9.93 \times (3.12)^2}{8}$

B.M = 12.08 KN/m.

$V_u = \frac{W_e l_e}{2} = \frac{9.93 \times 3.12}{2}$ = 15.49 KN.

④ check for depth:-

$$M_u = M_{u\,limit}$$

$$12.08 \times 10^6 = 2.76 b d^2$$

b = 1m
b = 1000mm.

$$12.08 \times 10^6 = 2.76 \times 1000\, d^2$$

$$d = 66.15\text{mm}.$$

$$66.15 < 120\text{mm}$$

check ok.

⑤ Calculation of Ast:-

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

$$12.08 \times 10^6 = 0.87 \times 415 \times A_{st} \times \cancel{66.15}\,120 \left[1 - \frac{415 \times A_{st}}{20 \times 1000 \times \cancel{66.15}\,120}\right]$$

$$12.08 \times 10^6 = \cancel{23883.45}\,43326 A_{st} - 7.49 A_{st}^2.$$

$$7.49 A_{st}^2 - \cancel{23883.45}\,43326 A_{st} + 12.08 \times 10^6 = 0.$$

less value.

$$\boxed{A_{st} = \cancel{299.73}\,293.73\text{mm}}$$

$$\boxed{A_{st} = 293.73\text{mm}^2}\ \text{req}$$

Main bars

10mm ϕ

$$293.73 = n \times \pi/4\,(10)^2$$

$$n = 3.73$$

$$\boxed{n = 4}$$

$$A_{st} = 4 \times \pi/4\,(10)^2$$

$$\boxed{A_{st} = 314.15\text{mm}^2}\ \text{provided}.$$

$$S = \frac{A_{st}}{A_{st}} \times 1000 = \frac{293.73}{314.15} \times 1000$$

$$\cancel{S = 934.99}$$

$$S = \frac{a_{st}}{A_{st\,req}} \times 1000$$

$$S = \frac{1 \times \pi/4 \times 10^2}{293.73} \times 1000$$

$$S = 267.38\text{mm}$$

$$\ngtr 3d = 3(120) = 360\text{mm}$$

$$\ngtr 300\text{mm}$$

s = 267.38mm.

6) Minimum reinforcement :- distribution bars

Fe415 = 0.12 % Gross cross section.

$b \times D$

$= 1000 \times 145 \left(\frac{0.12}{100}\right)$

$= 1000 \times 145 mm \left(\frac{0.12}{100}\right)$

$= ~~0.174~~\ 174 mm^2$.

7.) Spacing of distribution bars:-

choose 8mm dia.

$Ast = n \times \pi/4 d^2$

$174 = n \times \pi/4\, 8^2$

$n = 4$ bars.

$Ast = 4 \times \pi/4 \times 8^2$

$Ast = 201.06$

$Ast = n\pi/4 (d^2)$

~~293.73 = n × π/4 (8)²~~

$S = \frac{ast}{Ast} \times 1000$

$= \frac{1 \times \pi/4 (8)^2}{174} \times 1000$

$S = 288.8 mm$, $S \not> 5d$, $S \not> 450mm$ } less value

$S \not> 5 \times 120$

$S \not> 600$

Provide 4 - 8mm ϕ @ 288.8mm. $S = 288.8 mm$.

8. Check for deflection:-

~~l/d = 20.~~

$\left[fy = 0.85 \times fck \times \frac{Ast\ req}{Ast\ provided} \right]$

$\frac{3100}{120} = 25.8$

$l/d = 20$

$Pt = \frac{100 \times Ast}{bd} = \frac{100 \times 314.15}{1000 \times 120}$

$Pt = 0.26 \%$.

$fs = 0.58 fy \times \frac{\text{area of c/s of steel required}}{\text{area of c/s of steel provided}}$

$= 0.58 \times 415 \times \frac{293.73}{314.15}$

$fs = 225.05 N/mm^2$

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$l/d = 20 \times 1.9$

$l/d = 38$

$\frac{l}{d} = \frac{3120}{120}$

$= 26$

$38 > 26$,

Check ok.

9.) check for shear Reinforcement :-

$\tau_v = \frac{V_u}{bd}$

$V_u = \frac{wl}{2} = 15.49 KN$

$\tau_v = \frac{15.49 \times 10^3}{1000 \times 120} = 0.12 N/mm^2$ [pg no-73]

$\tau_c =$ M20, Fe415

$pt = \frac{100 Ast}{bd} = \frac{100 \times 314.15}{1000 \times 120} = 0.26\%$

0.25	0.36
0.26	
0.50	0.48

$\tau_c = 0.48 + \left[\frac{0.48 - 0.36}{0.50 - 0.25}\right] \times [0.26 - 0.50]$

$\tau_c = 0.46 N/mm^2$

$\tau_c > \tau_v$.

need not be provided shear reinforcement.

10.) check for Ld :-

$Ld = \frac{0.87 f_y \phi}{4 \tau_{bd}}$

$60\% = 100 + 60$

$= 160\% = \frac{160}{100}$

$= 1.6$

$\tau_{bd} = 1.2 \times 1.6$

$= 1.92 N/mm^2$

$\phi = 10mm$.

$= \frac{0.87 \times 415 \times 10}{4 \times 1.92}$

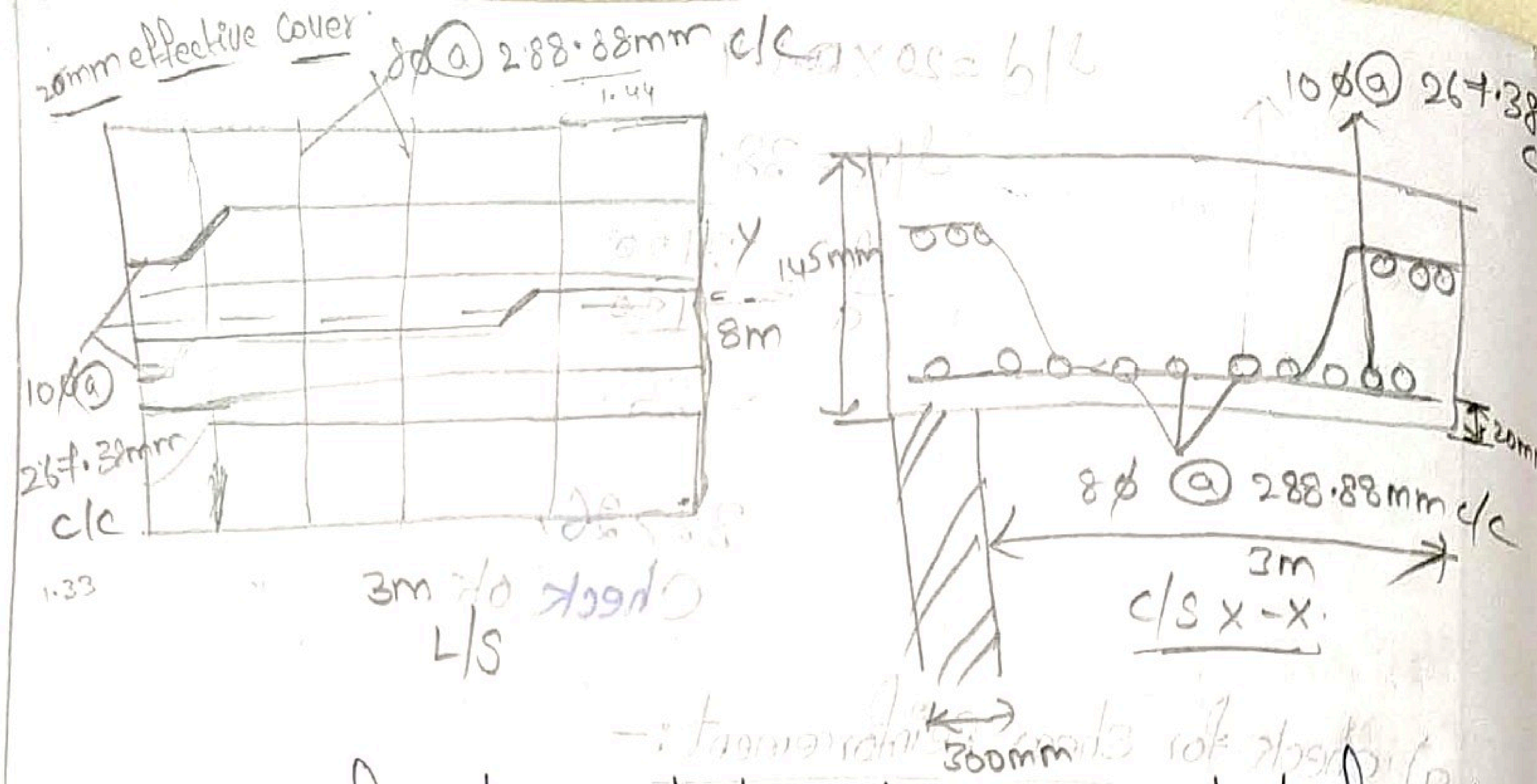
$Ld = 470.11mm$

$Ld \not> \frac{M_1}{V} + L_0$

$= \frac{12.08 \times 10^6}{15.49 \times 10^3} + 3120$

$= 3899.85$

$470.11 \not> 3899.85$. check ok.



2) Design a reinforced Concrete beam to carry a live load of $3 kN/m^2$ over an effective span of 3.5m use M_{20} grade of Concrete and Fe_{415} Sketch the reinforcement details for the roof of a room of clear dimensions 4m x 9m, Support width 300mm.

Given that:- effective span = 3.5m, $f_{ck} = 20 N/mm^2$, $f_y = 415 N/mm^2$, $L.L = 3 kN/m^2$

Sol:- $\frac{l_y}{l_x} = \frac{9}{4} = 2.25$

$\frac{l_y}{l_x} > 2$. One way slab.

① Effective depth:- $l/25$ to $l/30$ — l is taken as 4m

~~$\frac{3500}{25}$ to $\frac{3500}{30}$~~

$\frac{4000}{25}$ to $\frac{4000}{30}$

160 to 133.33

d = 160mm

Choose 10ϕ of clear cover 20mm.

$D = d + 20 + 10/2 = 160 + 20 + 5$

$D = 185 mm$.

② Effective Span is 3.5m. $l_e = 3.5m$

③ Calculation of load:- $L.L = 3 kN/m^2$

$D.L = b \times D \times$ unit wg of material

$= 1 \times 0.185 \times 25$

$= 4.625 kN/m^2$

Floor finish = 1 KN/m^2.

Total Load = D.L + L.L + F.F

= 4.625 + 3 + 1

= 8.625 KN/m^2.

factored load = T.L × 1.5

= 8.625 × 1.5

W_e = 12.93 KN/m^2.

$$B.M = \frac{W_e l_e^2}{8} = \frac{(12.93)(3.5)^2}{8}$$

M = 19.79 KN/m^2.

$$V_u = \frac{wl}{2} = \frac{12.93 \times 3.5}{2} = 22.62 KN.$$

(4) check for depth:-

$M_u = M_{u\,limit}$

$= 2.76 bd^2$

$19.79 \times 10^6 = 2.76 \times 1000 d^2$

d = 84.67 mm.

84.67 mm < 160 mm

check ok.

(5) Calculation of Ast:-

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

$$M_u = 0.87 \times 415 \times A_{st} \times 160 \left(1 - \frac{415 \times A_{st}}{20 \times 1000 \times 160}\right)$$

$19.79 \times 10^6 = 57768 A_{st} - 7.49 A_{st}^2$

$7.49 A_{st}^2 - 57768 A_{st} + 19.79 \times 10^6 = 0$. Ast less value.

Ast = 359.31 mm

(6)

10 mm ϕ

$359.31 = n \times \pi/4 (10)^2$

n = 4.57

n = 5 bars.

$A_{st} = 5 \times \pi/4 (10)^2$

Ast = 392.69 mm.

$$S = \frac{ast}{Ast} \times 1000$$

$$= \frac{1 \times \pi/4 \times 10^2}{359.31} \times 1000 = 218.58$$

S ≯ 3d = 3(160) = 420 mm

S ≯ 300 mm

S less value

S = 218.58 mm

6) Minimum reinforcement:- distribution bars.

$Fe415 = 0.12\%$ Gross cross section.

$= \frac{0.12}{100} \times b \times D$

$= \frac{0.12}{100} \times 1000 \times 185$

$= 222 mm^2$

7) Spacing of distribution bars:-

Choose 8m dia.

$Ast = n \times \pi/4 d^2$

$222 = n \times \pi/4 \, 8^2$

$n = 4.41$

$n = 5$ bars.

$S = \frac{ast}{Ast} \times 1000$

$S = \frac{1 \times \pi/4 (8^2)}{222} \times 1000$

$S = 226.42 mm$.

$S \ngtr 5d = 5 \times 160 = 800 mm$

$S \ngtr 450 mm$

} which one is less.

~~S = 450mm~~

$S = 226.42 mm$.

Provide 5 - 8mm ø @ 226.42mm.

8) Check for deflection:-

$P_t = \frac{100 \times Ast}{bd} = \frac{100 \times 392.69}{1000 \times 160}$

$P_t = 0.24\%$.

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

$f_s = 0.58 \times 415 \times \frac{359.31}{392.69}$

$f_s = 220.23 N/mm^2$.

$l/d = 20 \times 1.8$

$l/d = 36$.

$\frac{l}{d} = \frac{3500}{160} = 21.87$

$21.87 < 36$. check ok

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9) Check for Shear reinforcement:-

$$\tau_v = \frac{V_u}{bd}$$

$$\tau_v = \frac{22.62\times10^3}{1000\times160}$$

$$\tau_v = 0.14\ N/mm^2$$

τ_c = M20, Fe415

$$P_t = \frac{100A_{st}}{bd} = \frac{100\times392.69}{1000\times160}$$

$$P_t = 0.24\%$$

0.15 — 0.28

0.24

0.25 — 0.36

$$\tau_c = [0.36] + \left[\frac{0.36-0.28}{0.25-0.15}\right]\times[0.24-0.25]$$

$$\tau_c = 0.35\ N/mm^2$$

$\tau_c > \tau_v$

need not to provide shear Reinforcement

10) Check for Ld:-

$$L_d = \frac{0.87 f_y \phi}{4\tau_{bd}}$$

$\tau_{bd} = 1.2\times1.6$
$= 1.92\ N/mm^2$

$$L_d = \frac{0.87\times415\times10}{4\times1.92} \Rightarrow 470.11mm$$

$$L_d \ngtr \frac{M_1}{V} + L_0 = \frac{19.79\times10^6}{22.62\times10^3} + 3500$$

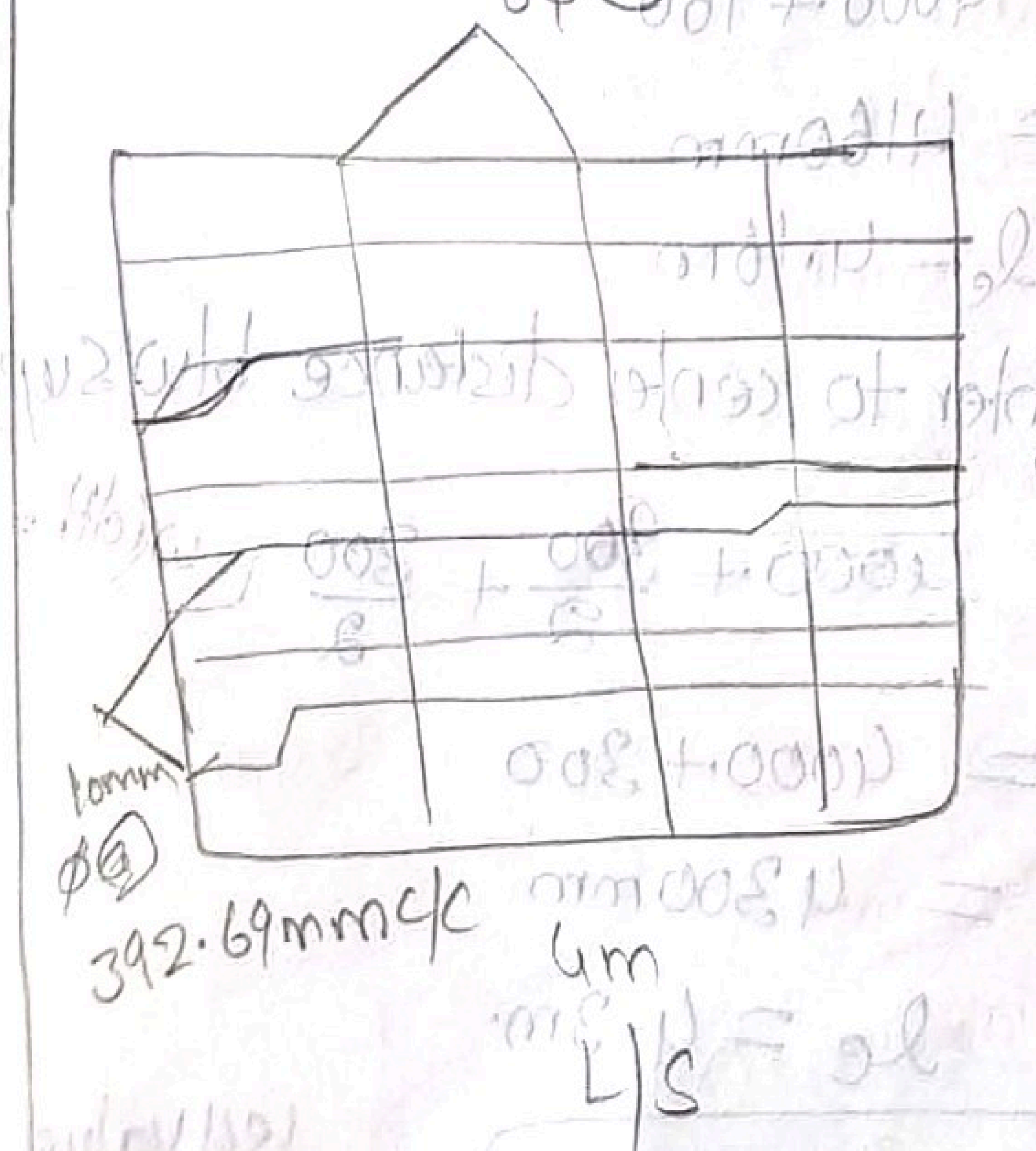
= ~~6174.88mm~~. 5030.54mm.

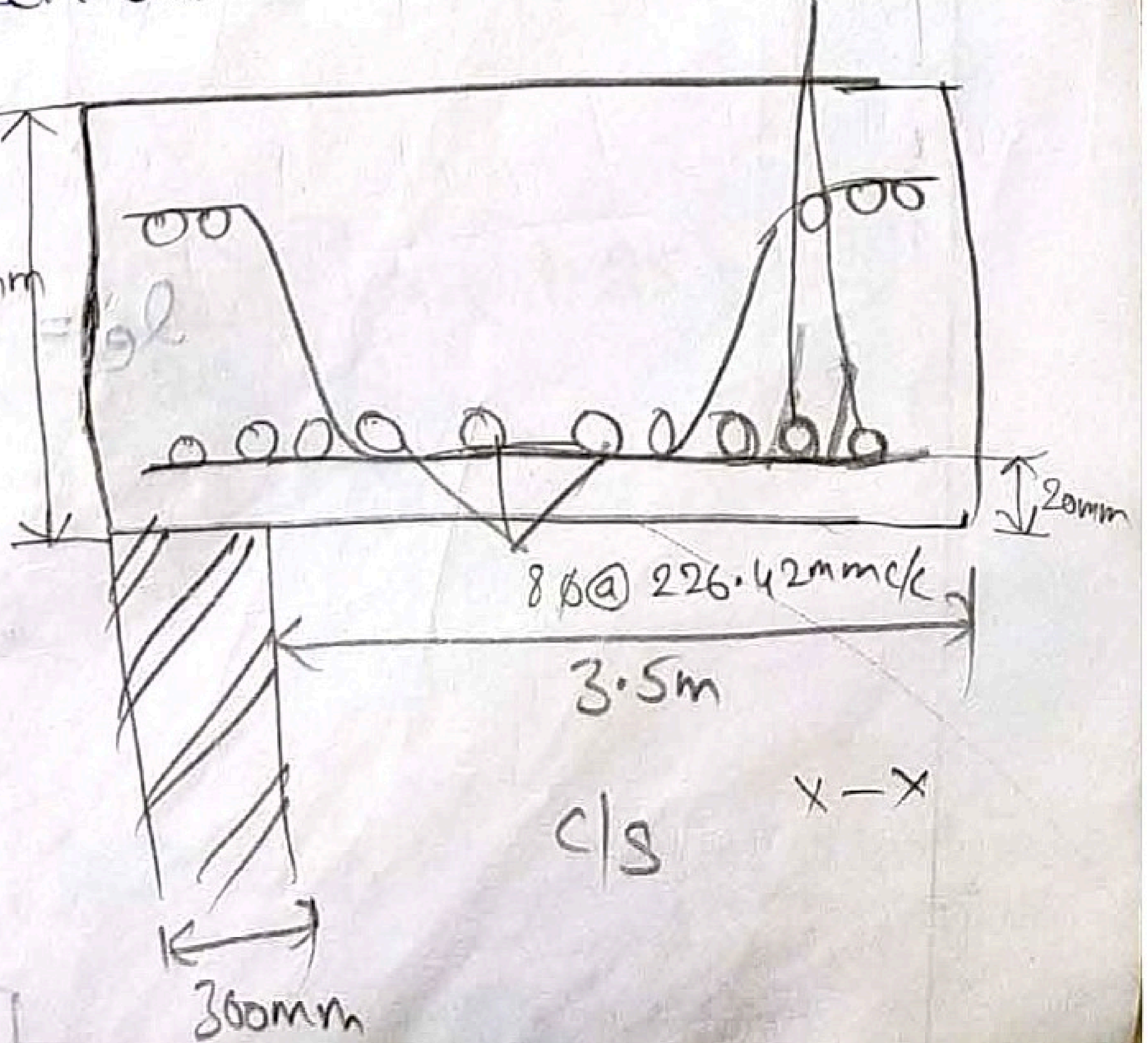
470.11 ≯ ~~6174.88~~ 5030.54

check ok.

8φ @ 226.42mm c/c

10φ @ 392.69mm c/c





3) Two way slab :-

1) Design a two way slab for a room of size 4m×5m dimensions with discontinuous and simply supported edges on all the sides with corners prevented from lifting to the support a live load of 4kN/m². Use M20 grade of concrete and Fe415 steel.

Sol:-

$$\frac{l_y}{l_x} = \frac{5}{4} = 1.25.$$

$$\frac{l_y}{l_x} < 2 \text{ two way slab.}$$

① **Effective depth:-**

$$l/25 \text{ to } l/30.$$

$$\frac{4000}{25} \text{ to } \frac{4000}{30}$$

$$160 \text{ to } 133.33$$

$$d = 160mm.$$

choose 10 ϕ of clear cover 20mm.

$$D = 160 + 20 + 10/2$$

$$D = 160 + 20 + 5$$

$$D = 185mm.$$

② **Effective span:-**

l_e = clear span + effective depth

$$= 4000 + 160$$

$$= 4160mm$$

$$l_e = 4.16m$$

l_e = Center to center distance b/w supports.

$$= 4000 + \frac{300}{2} + \frac{300}{2} \quad \text{width} = 300mm$$

$$= 4000 + 300$$

$$= 4300mm$$

$$l_e = 4.3m.$$

$$\boxed{l_e = 4.16m}$$ less value.

3) calculation of load:-

$D.L = b \times D \times$ unit wt of material

$= 1 \times 0.185 \times 25$

$= 4.625 \ KN/m^2$.

live load $= 4 KN/m^2$.

Floor finish $= 1 KN/m^2$

$T.L = D.L + L.L + F.F = 4.625 + 4 + 1$

$= 9.625 \ KN/m^2$.

factored load $=$ T.L×1.5 $= 9.625 \times 1.5$

$w_e = 14.43 \ KN/m^2$.

$$M_u = \frac{w l^2}{8} = \frac{14.43 \times (4.16)^2}{8} = 31.21 \ KN\text{-}m.$$

(4) check for depth:-

$M_u = M_{u limit}$

$M_u = 2.76 \, bd^2$

$31.21 \times 10^6 = 2.76 \times d^2 \times 1000$

$d = 106.33 mm$

$106.33 < 160 mm$

Check ok.

(5) calculation of Ast:- From edge conditions → $l_y/l_x = 1.25$.

[four edges discontinuous].

$\alpha_x \Rightarrow$ 1.2 0.072

1.25

1.3 0.079

$$0.079 + \left[\frac{0.079 - 0.072}{1.3 - 1.2}\right] \times (1.25 - 1.3)$$

$\alpha_x = 0.0755$.

$\alpha_y = 0.056$

$M_x = \alpha_x w_u \cdot l_{ex}^2 = 0.0755 \times 14.43 \times 4.16^2$

$= 18.85 \ KN\text{-}m$.

$M_y = \alpha_y w_u l_x^2$

$= 0.056 \times 14.43 \times 4.16^2$

$= 13.98 kN\text{-}m.$

Calculation of Ast :-

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

$18.85 \times 10^6 = 0.87 \times 415 \times A_{st} \times 160 \left[1 - \frac{415 \times A_{st}}{20 \times 1000 \times 160}\right]$

$18.85 \times 10^6 = 57768 A_{st} - 7.49 A_{st}^2$

$7.49 A_{st}^2 - 57768 A_{st} + 18.85 \times 10^6 = 0.$

$A_{st} = 7371.26$ } less value.
$A_{st} = 341.41$

$A_{st} = 341.41 mm^2.$

Spacing. for 10ϕ

$341.41 = n \times \pi/4 (10)^2$

$n = 4.34$

$n = 5$

$A_{st} = 5 \times \pi/4 \times 10^2$

$A_{st \text{ provided}} = 392.69 mm^2.$

$Spacing = \frac{a_{st}}{A_{st}} \times 1000$

$= \frac{1 \times \pi/4 (10)^2}{341.41} \times 1000.$

$S = 230.04 mm$

$S \ngtr 3d = 3(160) = 480 mm$ } less value
$S \ngtr 300 mm$

$S = 230.04 mm$

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

$$13.98 \times 10^6 = 0.87 \times 415 \times A_{st} \times 160 \left[1 - \frac{415 \times A_{st}}{20 \times 1000 \times 160}\right]$$

$$13.98 \times 10^6 = 57768 A_{st} - 7.49 A_{st}^2$$

$$7.49 A_{st}^2 - 57768 A_{st} + 13.98 \times 10^6 = 0.$$

$$A_{st} = 250.11 mm^2$$

for 10ϕ

$$250.11 = n \times \pi/4 (10^2)$$

$$n = 3.18$$

$$n = 4$$

$$A_{st} = 4 \times \pi/4 (10)^2$$

$$A_{st} = 314.15 mm^2$$

$$\text{Spacing} = \frac{a_{st}}{A_{st}} \times 1000$$

$$= \frac{1 \times \pi/4 (10)^2}{250.11} \times 1000$$

$S = 314.02$ mm
$S \not> 3d = 3 \times 160 = 480$ mm } less value.
$S \not> 300$ mm

$S = 300.02$ mm.

7) Minimum reinforcement :-

Fe415 = 0.12 % Gross Cross Section.

$$= \frac{0.12}{100} \times b \times D$$

$$= \frac{0.12}{100} \times 1000 \times 185$$

$$= 222 mm^2$$

Choose 8mm dia $A_{st} = n \times \pi/4 (8)^2 \Rightarrow 222 = n \times \pi/4 \, 8^2$

$$n = 4.41$$

$n = 5$ bars.

$$S = \frac{a_{st}}{A_{st}} \times 1000 = \frac{1 \times \pi/4 \, 8^2}{222} \times 1000$$

$S = 226.42$ mm
$S \not> 5d = 5 \times 160 = 800$ mm } less value. $S = 226.42$ mm.
$S \not> 450$ mm

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8) Check for deflection:-

$$P_t = \frac{100 \times A_{st}}{bd} = \frac{100 \times 392.69}{1000 \times 160}$$

$$P_t = 0.24\%$$

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

$$f_s = 0.85 \times 415 \times \frac{341.41}{392.69}$$

$$f_s = 209.26 \text{ N/mm}^2$$

$$l/d = 20 \times 1.8$$
$$= 36$$

$$\frac{4160}{160} = 26$$

$$26 < 36$$

Check ok.

9) Check for shear reinforcement:-

$$\tau_v = \frac{V_u}{bd} = \frac{V_u}{1000 \times 160} = \frac{30.01 \times 10^3}{1000 \times 160}$$

$$V_u = \frac{W_e l}{2} = \frac{14.43 \times 4.16}{2}$$
$$= 30.01 \text{ KN}$$

$$\tau_v = 0.18 \text{ N/mm}^2$$

$\tau_c \Rightarrow M_{20}$, Fe_{415}

$$P_t = \frac{100 A_{st}}{bd} = \frac{100 \times 392.69}{1000 \times 160}$$

$$P_t = 0.24\%$$

0.15	0.28
0.24	
0.25	0.36

$$0.36 + \left(\frac{0.36 - 0.28}{0.25 - 0.15}\right) \times \left[0.24 - 0.25\right]$$

$$\tau_c = 0.35 \text{ N/mm}^2$$

$$\tau_c > \tau_v$$

Need not be provided shear reinforcement

10) Check for Ld:-

$$L_d = \frac{0.87 f_y \phi}{4 \tau_{bd}}$$

$\tau_{bd} = 1.2 \times 1.6$
$= 1.92\ N/mm^2$

$$= \frac{0.87 \times 415 \times 10}{4 \times 1.92}$$

$L_d = 470.11 mm$

$$L_d \ngtr \frac{M_1}{V} + L_0 = \frac{31.21 \times 10^6}{30.01 \times 10^3} + 4160$$

$= 5199.98 mm$

$470.11 \ngtr 5199.98$

11) Check for Torsion:-

$M_x = \alpha_x w l_x^2$
$M_x = ?$
Ast provided = ?
75% for torsion.
distance $\frac{l_x}{5}$

Area of steel = $0.75 \times Ast_{x-x}$ provided
$= 0.75 \times 392.69$
$= 294.51 mm^2$

Choose 8mm dia.
$294.51 = \pi/4 \times n(8)^2$
$n = 5.85$
$n = 6$ bars.
$A_{st} = 6 \times \pi/4 (8)^2$
$A_{st} = 301.59 mm^2$

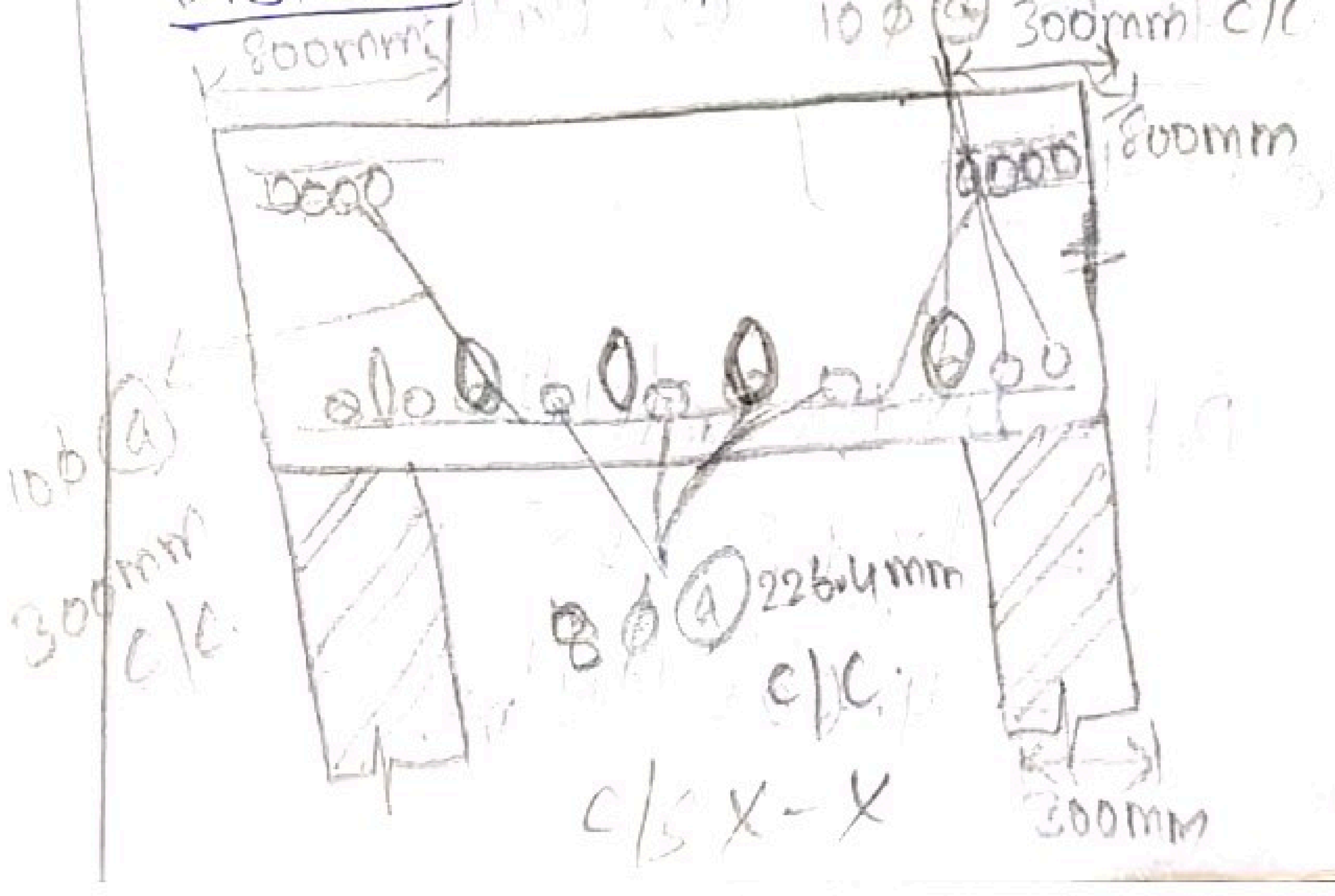
$$S = \frac{a_{st}}{A_{st}} \times 1000$$

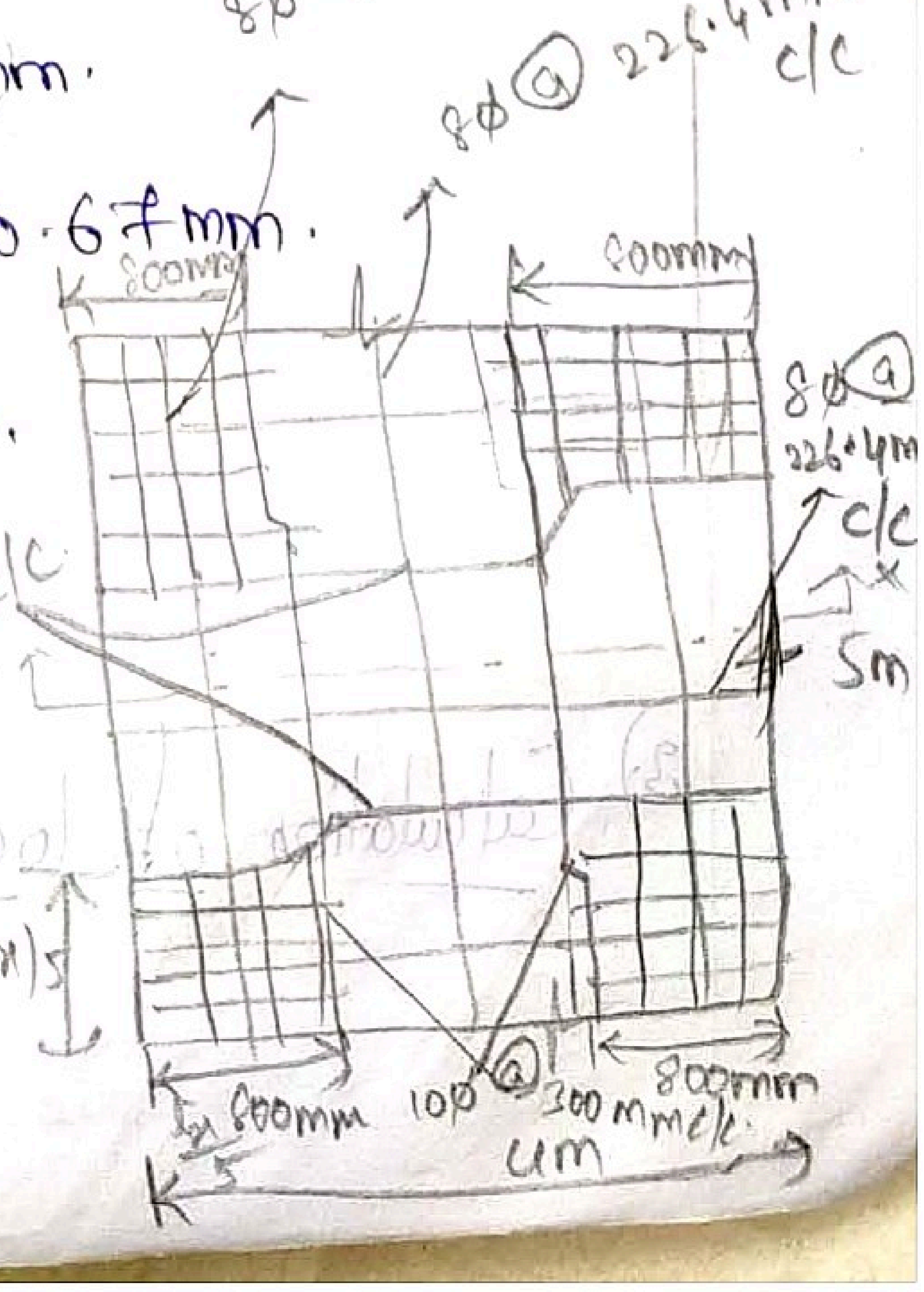
$$= \frac{\pi/4 \times (8)^2}{294.51} \times 1000$$

$S = 170.67 mm$

Provide 6 - 8ϕ @ 170.67mm.

Distance:- $l_x/5 = \frac{4000}{5} = 800mm$.





2) Design a two way slab for a office floor to suitable the following data. Size of office floor 4m x 6m edge condition, two adjacent edges are discontinuous. Use M_{20} grade of concrete and Fe_{415} steel.

Sol:- $\frac{l_y}{l_x} = \frac{6}{4} = 1.5 < 2.$

$\frac{l_y}{l_x} < 2$ two way slab.

1.) Calculation of depth:-

live load for IS 875 code book. part-2
Residensial → 3KN/m²
office - 4KN/m²
School → 1to2KN/m²

$l/25$ to $l/30$

$\frac{4000}{25}$ to $\frac{4000}{30}$

160 to 133.33

d = 160mm.

choose 10 ϕ of clear cover 20mm.

D = 160 + 20 + 10/2

D = 160 + 20 + 5

D = 185mm.

2) Effective span:-

l_e = clear span + effective depth.

= 4000 + 160

= 4160

l_e = 4.16m

l_e = Center to center distance b/w support

width = 300mm

$= 4000 + \frac{300}{2} + \frac{300}{2}$

= 4300mm

l_e = 4.3m

less value.

l_e = 4.16m

3) Calculation of load:-

D.L = b x D x unit wt

= 1 x 1.85 x 25

= 4.625 KN/m².

Live load = $4 KN/m^2$.
office
Floor finish = $1 KN/m^2$.

$T.L = D.L + L.L + F.F = 4.625 + 4 + 1$
$= 9.625 KN/m^2$

factored load $= T.L \times 1.5 = 9.625 \times 1.5$
$w_e = 14.43 KN/m^2$

$M_u = \frac{w_e l_e^2}{8} = \frac{14.43 \times 4.16^2}{8} = 31.21 KN\text{-}m.$

4) check for depth:-

$M_u = 2.76 bd^2$

$31.21 \times 10^6 = 2.76 \times d^2 \times 1000$

$d = 106.33 mm.$

$106.33 mm < 160 mm$

Check ok.

5) Calculation of Ast_x:-

(Ast x.)

$M_x = \alpha_x \cdot w_u l_x^2$

$\frac{l_y}{l_x} = 1.5$

[two adjacent edges are discontinuous]

$-ve\ \alpha_x = +0.075$
$+ve\ \alpha_x = +0.056$
$-ve\ \alpha_y = +0.047$, $+ve\ \alpha_y = 0.035$.

$M_x = \alpha_x w_e l_{ex}^2 = +0.075 \times 14.43 \times (4.16)^2$

(-ve) $M_x = +18.72 KN\text{-}m.$

$M_x = 0.056 \times 14.43 \times 4.16^2$

(+ve) $M_x = 13.98 KN\text{-}m.$

$M_x (-ve) = 0.87 f_y Ast\, d \left[1 - \frac{f_y Ast}{f_{ck} \cdot b \cdot d}\right]$

$+18.72 \times 10^6 = 0.87 \times 415 \times Ast \times 160 \left[1 - \frac{415 \times Ast}{20 \times 1000 \times 160}\right]$

$18.72 \times 10^6 = 57768 Ast - 7.49 Ast^2$

$7.49 Ast^2 - 57768 Ast + 18.72 \times 10^6 = 0.$

$Ast = 338.95 mm^2.$

$$M_{x(+ve)} = 0.87 f_y A_{st} d \left[1 - \frac{f_y A_{st}}{f_{ck} \cdot b \cdot d}\right]$$

$$13.98 \times 10^6 = 0.87 \times 415 \times A_{st} \times 160 - \left[1 - \frac{415 \times A_{st}}{20 \times 1000 \times 160}\right]$$

$$7.49 A_{st}^2 - 57768 A_{st} + 13.98 \times 10^6 = 0$$

$$\boxed{A_{st} = 250.11\ mm^2}$$

+ve, spacing 10ϕ.

$$250.11 = n \times \pi/4 (d^2) \Rightarrow 250.11 = n \times \pi/4 \times 10^2$$

$n = 3.18$

$n = 4$ bars.

$$A_{st} = 4 \times \pi/4 (10)^2$$

$$A_{st\,pro} = 314.15\ mm^2$$

$$\text{Spacing} = \frac{a_{st}}{A_{st}} \times 1000 = \frac{1 \times \pi/4 \times 10^2}{250.11} \times 1000$$

$S = 314.02$ mm.

$S \ngtr 3d = 3(160) = 480$ mm $\}$ less value.

$S \ngtr 300$ mm

$$\boxed{S = 300\ mm}$$

-ve, spacing, 10ϕ.

$$338.95 = n \times \pi/4 \times 10^2$$

$n = 4.31$

$n = 5$ bars.

$$A_{st} = 5 \times \pi/4 \times 10^2$$

$$A_{st\,Provided} = 392.69\ mm^2$$

$$\text{Spacing} = \frac{a_{st}}{A_{st}} \times 1000 = \frac{1 \times \pi/4 \times 10^2}{338.95} \times 1000$$

$S = 231.71$ mm.

$S \ngtr 3d = 3 \times 160$ mm $= 480$ mm

$S \ngtr 300$ mm

$$\boxed{S = 231.71\ mm}$$

(b) Calculation A_{sty}

+ve. $M_y = \alpha_y l_e^2 \cdot w_e = 0.035 \times 4.16^2 \times 14.43$

+ve $M_y = 8.74$ KN-m.

-ve $M_y = \alpha_y l_e^2 w_e = 0.047 \times 4.16^2 \times 14.43 = 11.73$ KN-m.

+ve $M_y = 0.87 f_y A_{st} d \left[1 - \frac{f_y \times A_{st}}{f_{ck} \cdot b \cdot d}\right] \Rightarrow 8.74 \times 10^6 = 0.87 \times 415 A_{st} \times 160 \left[1 - \frac{415 \times A_{st}}{20 \times 1000 \times 160}\right]$

$7.49 A_{st}^2 - 57768 A_{st} + 8.74 \times 10^6 = 0.$

$A_{st} = 154.38 mm^2.$

-ve $M_y = 0.87 f_y A_{st} d \left[1 - \frac{f_y A_{st}}{f_{ck} \cdot b \cdot d}\right] \Rightarrow 11.73 \times 10^6 = 0.87 \times 415 A_{st} \times 160 \left[1 - \frac{415 A_{st}}{20 \times 1000 \times 160}\right]$

$7.49 A_{st}^2 - 57768 A_{st} + 11.73 \times 10^6 = 0.$

$A_{st} = 208.70 mm^2$

+ve spacing 10ϕ

$154.38 = n \times \pi/4 (10)^2$

$n = 1.96 = 2$

$A_{st} = 2 \times \pi/4 (10)^2$

$A_{st} = 157.07 mm^2.$

$\text{Spacing} = \frac{a_{st}}{A_{st}} \times 1000 = \frac{1 \times \pi/4 \times 10^2}{154.38} \times 1000$

$S = 508.74 mm$

$S \ngtr 3d = 3 \times 160 = 480 mm$ } less

$S \ngtr 300 mm$

$S = 300 mm$

-ve spacing.

$208.70 = n \times \pi/4 (10)^2 \Rightarrow n = 2.65, n = 3$

$A_{st} = 3 \times \pi/4 (10)^2$

$A_{st} = 235.61 mm^2.$

$\text{Spacing} = \frac{a_{st}}{A_{st}} \times 100 = \frac{1 \times \pi/4 \times 10^2}{208.70} \times 1000$

$S = 376.32$

$S \ngtr 3d = 3 \times 160 = 480 mm.$

$S \ngtr 300 mm$

$S = 300 mm$

(7) Minimum reinforcement :- $Fe_{415} = 0.12\%$ Gross cross Section.

$= \frac{0.12}{100} \times b \times D$

$= \frac{0.12}{100} \times 1000 \times 185 = 222 mm^2.$

Choose 8mm dia $A_{st} = n \times \pi/4 (8)^2 = 222 = n \times \pi/4\, 8^2$

$n = 4.41$

$n = 5$ bars.

$S = \frac{a_{st}}{A_{st}} \times 1000 = \frac{1 \times \pi/4 (8)^2}{222} \times 1000 = 226.42 mm.$

$S \ngtr 5d = 5 \times 160 = 800 mm$ less value.

$S \ngtr 450 mm$

$S = 226.42 mm.$

8) Check for deflection:- $P_t = \frac{100 \times A_{st}}{b \times d} = 100 \times \frac{314.15}{1000 \times 160}$

$P_t = 0.19$

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

$f_s = 0.58 \times 415 \times \frac{250.11}{314.15}$

$f_s = 191.63\ N/mm^2$

$l/d = 20 \times 1.8$

$= 36$

$\frac{4160}{160} = 26.$

$26 < 36$

Checkok.

9) Check for Shear reinforcement:-

$\tau_v = \frac{V_u}{bd} = \frac{30.01 \times 10^3}{1000 \times 160} = 0.18\ N/mm^2.$

$V_u = \frac{wl}{2}$

$= \frac{14.43 \times 4.16}{2}$

$V_u = 30.01 kN$

$\tau_c \Rightarrow M_{20}, Fe_{415}$

$P_t = \frac{100 A_{st}}{bd} = \frac{100 \times 314.15}{1000 \times 160} = 0.19\%$ ~~0.24%~~

~~0.15 0.28~~
~~0.24~~
~~0.25 0.36~~
~~$0.36 + \left[\frac{0.36 - 0.28}{0.25 - 0.15}\right] \times (0.24 - 0.25)$~~
~~$\tau_c = 0.35$~~

0.15 0.28

0.19

0.25 0.36

$0.36 + \left[\frac{0.36 - 0.28}{0.25 - 0.15}\right] \times \{0.19 - 0.25\}$

$\tau_c = 0.31\ N/mm^2.$

$\tau_c > \tau_v.$

need not be provided shear reinforcement.

10) Check for Ld:-

$L_d = \frac{0.87 f_y \phi}{4 \tau_{bd}} = \frac{0.87 \times 415 \times 10}{4 \times 1.92}$

$\tau_{bd} = 1.2 \times 1.6$
$= 1.92 N/mm^2$

$L_d = 470.11 mm.$

$L_d \ngtr \frac{M_1}{V} + L_o \Rightarrow \frac{~~13.98 \times 10^6~~\ 31.21 \times 10^6}{30.01 \times 10^3} + 4160$

$=$ ~~4625.84 mm.~~ 5199.98mm

$470.11 \ngtr$ ~~4625.84~~ 5199.98mm.

Check for Torsion:-

Area of steel $= 0.75 \times A_{st}\ x\text{-}x$ provided

$= 0.75 \times 314.15$

$= 235.61\,mm^2$

Choose 8mm dia.

$235.61 = \pi/4 \times n \times 8^2$

$n = 4.68$

$n = 5$

$A_{st} = 5 \times \pi/4 (8)^2$

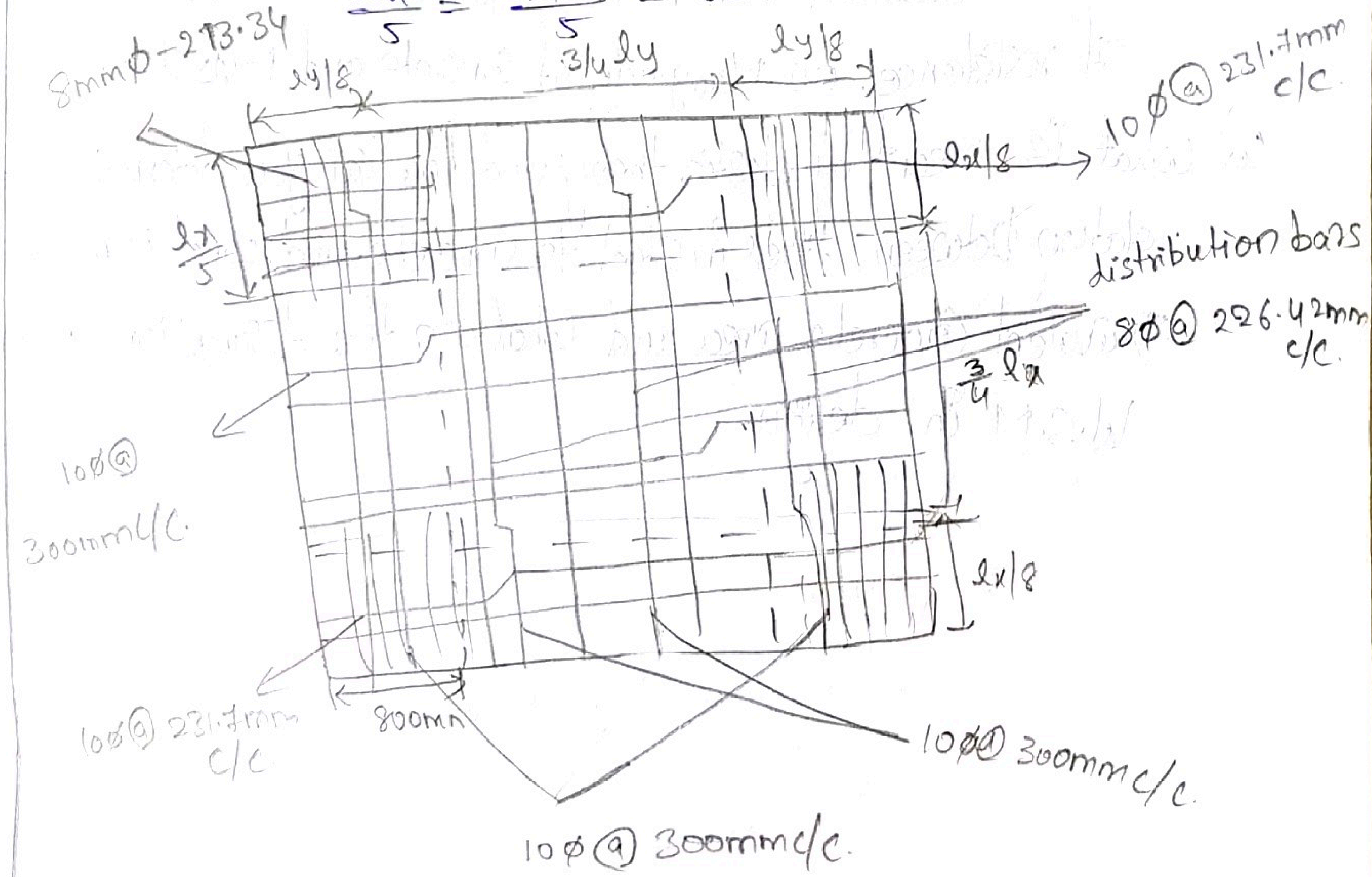
$A_{st} = 251.32\,mm^2$

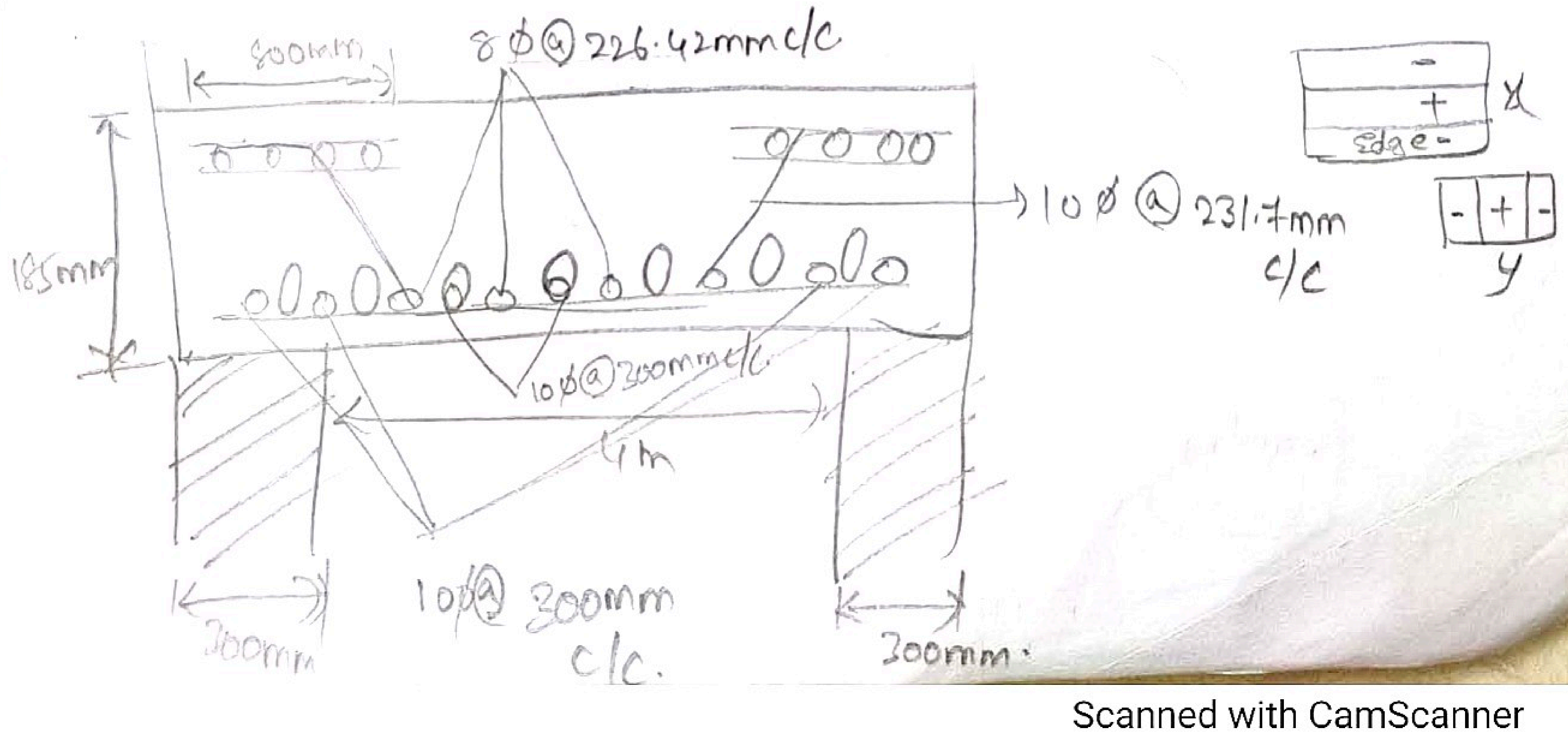
$S = \frac{a_{st}}{A_{st}} \times 1000 = \frac{\pi/4 \times 8^2}{235.61} \times 1000$

$S = 213.34\,mm.$

8mmφ provide 5-8φ @ 213.34mm.

$\frac{l_x}{5} = \frac{4000}{5} = 800mm.$





One-Way Slab Continuous:-

1.) Design one way continuous slab for an office floor. The slab is continuous over T-beams at center to center span of 4m. Take live load as $4 KN/m^2$. Use M_{20} grade of concrete and Fe_{415} steel.

Sol:- 1.) Calculation of effective depth:-

$\frac{l}{25}$ to $\frac{l}{30}$

For Continuous → $l/30 = \frac{4000}{30}$

$d = 133.33mm$

choose clear cover 20mm, 10mm ϕ

$D = 133.33 + 20 + \frac{10}{2}$

$D = 158.33$

$D = 160 mm$

2.) Effective span = 4m.

3.) Calculation of loads:-

$D.L = b \times D \times 25$

$= 1 \times 0.16 \times 25$

$= 4 KN/m^2.$

$L.L = 4 KN/m^2.$

$F.F = 1 KN/m^2$

$T.D.L = 4 + 1 = 5 KN/m^2.$

$L.L = 4 KN/m^2.$

factor of safety - 1.5

-ve moment @ Support next to end support $= 1.5 \left[\frac{1}{10}(5) + \frac{1}{9}(4) \right] \times 4^2.$

$= 22.66$ KN-m.

+ve moment @ near middle span $= 1.5 \left[\frac{1}{12}(5 \times 4^2) + \frac{1}{10}(4 \times 4^2) \right] = 19.6$ KN-m

S.F @ Support next to end Support

$= 1.5[0.6 \times (5+4) \times 4]$.

$= 32.4$ KN.

M_u is higher value $\rightarrow$ 22.66 KN-m

4) <u>check for depth</u>:-

$M_u = M_{u limit}$

$22.66 \times 10^6 = 2.76 bd^2$

$22.66 \times 10^6 = 2.76 \times 1000 \times d^2$

$d = 90.60$ mm.

90.60 mm < 133.33 mm.

Check ok.

5) <u>Calculation for Ast</u>:-

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

$$22.66 \times 10^6 = 0.87 \times 415 \times A_{st} \times 133.33 \left[1 - \frac{415 \times A_{st}}{20 \times 1000 \times 133.33}\right]$$

$$7.49 A_{st}^2 - 48138.79 A_{st} + 22.66 \times 10^6 = 0$$

$\boxed{A_{st\,req} = 511.41 mm^2}$ less value.

Choose 10mm ϕ

$511.41 = n \times \pi/4 (10^2)$

$n = 6.5$

$n = 7$

$A_{st} = 7 \times \pi/4 (10^2)$

$\boxed{A_{st\,provided} = 549.77 mm^2}$

6) Spacing of Main reinforcement:-

$$S = \frac{a_{st}}{A_{st}} \times 1000$$

$$S = \frac{1 \times \pi/4 \times (10^2)}{511.41} \times 1000$$

$$S = 153.57 mm.$$

$$S \ngtr 3d = 3(133.33) = 399.99 mm$$

$$S \ngtr 300 mm$$

$$\boxed{S = 153.57 mm}$$

7) Minimum reinforcement:-

Fe = 0.12% Gross Cross sectional area.

$$= \frac{0.12}{100} \times b \times D$$

$$= \frac{0.12}{100} \times 1000 \times 160$$

$$A_{st} = 192 mm^2$$

Choose 8mm ϕ:

$$192 = n \times \pi/4 (8^2)$$

$$n = 3.81$$

$$n = 4$$

$$A_{st} = 4 \times \pi/4 (8^2)$$

$$A_{st} = 201.06 mm^2$$

$$S = \frac{a_{st}}{A_{st}} \times 1000$$

$$= \frac{1 \times \pi/4 (8^2)}{192} \times 1000$$

$$S = 261.79 mm$$

$$S \ngtr 5d = 5(133.33) = 666.65 mm$$

$$S \ngtr 450 mm$$

$$\boxed{S = 261.79 mm}$$

8) check for deflection:-

$$P_t = \frac{100 A_{st}}{b \times d} = \frac{100 \times 549.77}{1000 \times 133.33}$$

$$= 0.41\%$$

$$F_s = f_y \times 0.58 \times \frac{\text{Area of c/s of steel req}}{\text{Area of c/s of steel provided}}$$

$$F_s = 0.58 \times 415 \times \frac{511.41}{549.77}$$

$$F_s = \frac{0.58 \times 415 \times 511.41}{549.77}$$

$$F_s = 223.90\ N/mm^2$$

$l/d = 26 \times 1.5$ Continuous.

$l/d = 39$

$$l/d = \frac{4000}{133.33} = 30.$$

$30 < 39$

check ok.

9.) Check for shear reinforcement:-

$$\tau_v = \frac{V_u}{bd} = \frac{32.4 \times 10^3}{1000 \times 133.33}$$

$V_u = \frac{wl}{2} = 32.4 KN$ $\tau_v = 0.24\ N/mm^2$

$$\tau_c,\ \%\ pt = \frac{100\ Ast}{bd} = \frac{100 \times 549.77}{1000 \times 133.33}$$

$Pt = 0.41\%.$

0.25	0.36
0.41	
0.50	0.48

$$0.48 + \left[\frac{0.48 - 0.36}{0.50 - 0.25}\right] \times (0.41 - 0.50)$$

$\tau_c = 0.43\ N/mm^2$

$\tau_c > \tau_v.$

need not be provided shear reinforcement.

10.) Check for Ld:-

$$L_d = \frac{0.87 f_y \phi}{4 \tau_{bd}}$$

$$\tau_{bd} = 1.2 \times 1.6 = 1.92 \, N/mm^2$$

$$= \frac{0.87 \times 415 \times 10}{4 \times 1.92}$$

$$L_d = 470.11 mm$$

$$L_d \ngtr \frac{M_1}{V} + L_0$$

$$\frac{22.66 \times 10^6}{32.4 \times 10^3} + 4000$$

$$L_d \ngtr 4699.38 mm$$

Check ok.