8/11/21

2)

# * UNIT- II DESIGN OF SLABS *

* Types of slabs: Based on slab dimension and load distribution slabs are classified into 2 types.

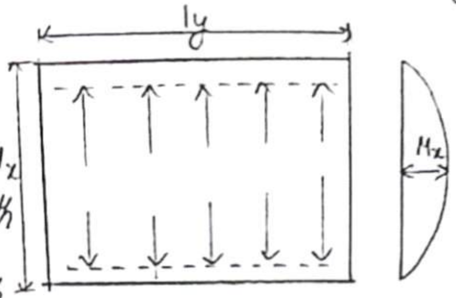
1) One way slab.
2) Two way slab.

1) One way slab: In one way slab, the slabs are supported by beams in 2 supports sides.

$$\boxed{\frac{l_y}{l_x} \ngtr 2}$$

Where, $L_y$ = longer span length

$l_x$ = Short span length




→ The load on the slab is transvered to the 2 support walls. this types of slab bend only in one direction. (∴ shorter span) is "one way slab".

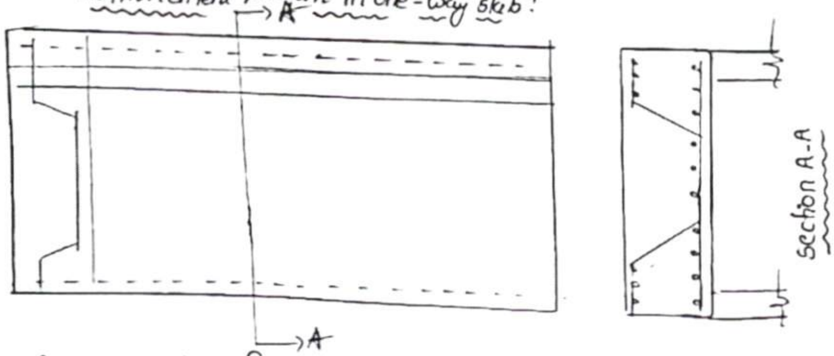
→ 50% of main bars on shorter side are cranked or bend.

→ Compared to two way slab is less economical and gives more thickness

→ Main reinforcement is mainly provided in shorter span

→ Distribution bars (straight bars) provided in longer span.

Reinforcement pattern in one-way slab:

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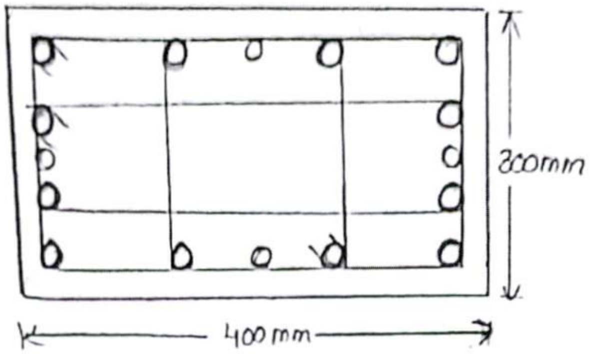
* Design procedure for one way slab:

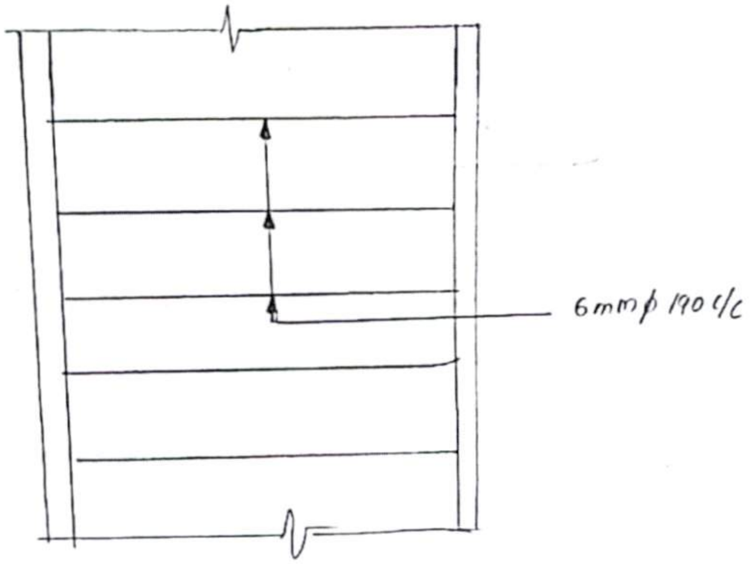
1) Step 1: Given data, type of slab

— $l_x$, $l_y$, live load, dead load, support width, $f_{ck}$, $f_y$

→ $\frac{l_y}{l_x} \geq 2$ design as one way slab.

Step 9: Detailing of reinforcement :



2) step 2 : To find factored bending moment shear force.

a) overall depth:

- As per cl no : 23.2.1 (A) IS 456 : 2000

- span to depth ratio $\Rightarrow \dfrac{\text{Span (shorter)}}{\text{Effective depth(d)}} \leq 20$ [for S.S slab]

$\dfrac{\text{Span (}}{\text{Effective depth}} \leq 25$ [Assumed for SS slab]

- Assume dia of main bars & nominal cover [Table 16]

- Overall depth (D) = $d + \phi_m$ + clear cover [ $\phi_m$ - dia of main bar]

b) Factored load ($w_u$):

- Live load = ______ $kN/m^2$

- dead load : ______ $kN/m^2$

- Sf. wt of the slab = $\gamma$ × overall depth $kN/m^2$

- Total load ($w$) =

- Factored load ($w_u$) = $1.5 \times w$.

c) Effective span:

- $l_{eff}$ = least of $(l_x + d)$ (or) ($l_x$ + width of the supports).

d) Factored bending moment:

- $M_u = \dfrac{w_u l_{eff}^2}{8}$

- Shear force $V_u = \dfrac{w_u l_{eff}}{2}$

3) Step 3: Check for effective depth

for Fe415 - $M_{u\,lim} = 0.138 f_{ck} bd^2$

Fe 250 - $M_{u\,lim} = 0.148 f_{ck} bd^2$

Fe 500 - $M_{u\,lim} = 0.133 f_{ck} bd^2$

- 'd' required < 'd' provided.

4) Step 4 : Design of main reinforcement.

- Main reinforcement is designed for 1 m width and provided same for entire length. [Refer cl no : 456 : 2000].

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

- Check for Ast

$\Rightarrow$ Ast min $= \frac{0.12}{100 \cancel{bd}} bD$ [ Ref 26.5.2.1, Pg - 48 ]

- Spacing of main bars -

$\Rightarrow \frac{a_{st}}{A_{st}} \times 100$ [ $\phi_m < \frac{D}{8}$ ]

(As per 26.3.3.b) - slabs

- Ast provided $= \frac{a_{st}}{\text{Spacing}} \times 1000$ - 3 x effective depth

5) Step5: Distribution reinforcement

- for one way slab provided minimum reinforcement as distributio reinforcement.

- $A_{st} \min = \frac{0.12}{100} \times bD$

- spacing $= \frac{a_{st}}{A_{st}} \times 1000$

$\rightarrow$ 5 x Effective depth

- Ast provide $= \frac{a_{st}}{\text{spacing}} \times 1000$

6) Step6: Check for shear

$\tau_v = \frac{V_u}{bd}$ [ As per table 19, 72 pg ]

$\tau_v$ should be $< k \times \tau_c$

- Hence the section safe in shear, for 'K' [ Ref cl no 40.2, Pg

- $P_t = \frac{100 A_{st}}{bD}$ ; $A_{st} = \frac{a_{st}}{2}$.

7) Step 7: Check for deflection [ 37 pg, 23

- $\frac{l_{eff}}{d\,(\text{pro})}$ should be $< \frac{l_{eff}}{d\,(\text{basic})} \times \alpha \times \beta \times \gamma \times \eta$

8) Step8: Check for development length [ As per cl no - 26.2.3.3 pg 44

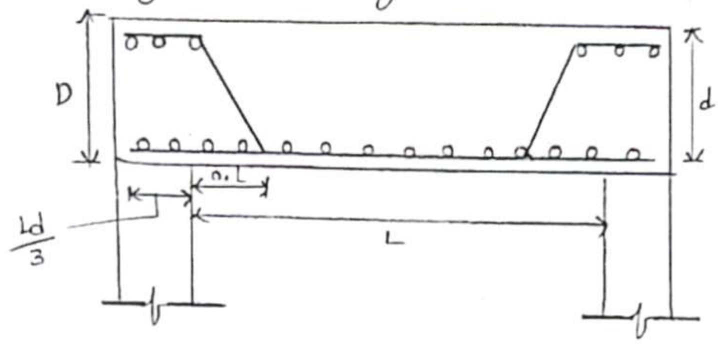
- The reinforcement shall extend along the face of the member int support to a length equals to $L_d/3$.

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

- $\tau_{bd}$ - values are taken by the cl no : 26.2.1.1 pg 43

9) Step 9: Reinforcement details

One-way slab c/s along shorter span.




1) Design a floor slab a room of size 3.5 x 12 m, the slab is resting on 230 mm thick masonary walls, assume live load as 4.0 km/m² and dead load due to finish, partian etc, at 1.5 kN/m². Use $M_{25}$ & Fe 415 steel.

Sol: Step 1: Given data & Type of slab:

$l_x = 3.5 m$

$l_y = 12 m$

Support thickness = 230 mm

Live load = 4 kN/m²

Dead load = 1.5 kN/m²

$f_{ck} = 25 N/mm^2$

$f_y = 415 N/mm^2$

→ Type of slab = $\frac{l_y}{l_x} = \frac{12}{3.5} > 2$

Designed as one way slab

* Step 2: Finding Factor B.M & S.F:

(a) Overall depth of slab: [cl no: 23.2.1 for 6.5]

$$\frac{Span}{d} \leq 20 mm \quad (for\ beam)$$

→ Assuming for slabs $\frac{Span (l_x)}{d} \leq 25$

$$\frac{3500}{d} = 25$$

$$d = 140 mm$$

Assuming 10 mm ϕ min bars

Nominal cover = 20 mm (mild) — [Table-16]

For bar $\phi_m < 12$

Nominal cover = 20 - 5 = 15 mm

→ overall depth (D) = 140 + 15 + 10/2 = 160 mm

(b) Factored load ($w_u$) :

- Live load = 4 kN/m²
- Dead load = 1.5 kN/m²

→ Self weight of slab = 25 × 0.16 = 4 kN/m²

Total load (w) = 9.5 kN/m²

→ Factored load ($w_u$) = 1.5 × w

= 1.5 × 9.5 = 14.25 kN/m²

(c) Effective Span ($L_{eff}$) :

$L_{eff}$ = Length of ($l_x$ + d) (or) ($l_x$ + support width)

= (3.5 + 0.14) (or) (3.5 + 0.23)

= 3.64 (or) 3.73

→ Take $l_{eff}$ = 3.64 m

(d) Factored B.M & S.F :

- $M_u = \frac{w_u l_{eff}^2}{8} = \frac{14.25 \times 3.64^2}{8}$ = 23.6 kN.m
- $V_u = \frac{w_u l_{eff}}{2} = \frac{14.25 \times 3.64}{2}$ = 25.9 kN.m

* Step 3 : Check for depth :

For Fe 415, $M_{u\,lim} = 0.138 f_{ck} b d^2$

$23.6 \times 10^6 = 0.138 \times 25 \times 1000 \times d^2_{req}$

$d_{req}$ = 82.70 mm

$d_{pro}$ = 140 mm

$d_{req} < d_{prov}$

Hence the design is safe.

* Step4 : Design of main reinforcement : [ Ref G.1.1 b ]

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

$$23.6 \times 10^6 = 0.87 \times 415 \times A_{st} \times 140 \left[1 - \frac{415\, A_{st}}{25 \times 1000 \times 140}\right]$$

$$23.6 \times 10^6 = 50547\, A_{st} \left[1 - 1.1857 \times 10^{-4} A_{st}\right]$$

$$23.6 \times 10^6 = 50547 A_{st} - 5.99343 A_{st}^2$$

$$5.99343 A_{st}^2 - 50547 A_{st} + 23.6 \times 10^6$$

$$A_{st\,req} = 496.07\ mm^2$$

Check for $A_{st}$ :

→ $A_{st\,min} = \frac{0.12}{100}\, bD \Rightarrow \frac{0.12}{100} \times 1000 \times 160$

$\Rightarrow 192\ mm^2$

→ Dia of main bar $< \frac{D}{8}$

$\phi_m = 10 < \frac{160}{8}$ $\left[a_s = \frac{\pi}{4} \times 10^2 = 78.5\right]$

① spacing $= \frac{a_{st}}{A_{st\,req}} \times 1000$

$= \frac{78.5}{496} \times 1000 = 158.2\ mm$

② 3 x effective depth $= 3 \times 140 = 420\ m$

③ 300 mm

(provide 10mm $\phi$ @ 150 c/c)

→ $A_{st\,prov} = \frac{a_{st}}{spacing} \times 1000 = \frac{78.5}{150} \times 1000 = 523.3\ mm^2$

* Step 5: Distribution reinforcement :

For one way slab provide $A_{st\,min}$ as distribution

$\therefore$ $A_{st\,min} = 192\ mm^2$

Assume 8mm $\phi$ distribution bar $a_{st} = \frac{\pi}{4} \times 8^2 = 50.2\ mm^2$

① spacing $= \frac{50.2}{192} \times 1000 = 261.77\ mm^2$

② 5d $= 5 \times 140 = 700$

③ 450 mm

(provided 8mm $\phi$ @ 250 c/c)

## * Step 6 : Check for shear :

$$\rightarrow \tau_v = \frac{V_u}{bd} = \frac{25.43 \times 10^3}{1000 \times 140} = 0.18\ N/mm^2$$

For, $\tau_c$ – [ Table - 19 ]

$$\rightarrow P_t = \frac{100\ A_{st}}{bd} \Rightarrow \frac{100 \times \frac{523.3}{2}}{1000 \times 140}$$

$$\Rightarrow 0.18\ \%$$

{ for slab simply supported on half of Ast is in supports tension zone.

$$\Rightarrow \frac{0.25 - 0.15}{0.36 - 0.29} = \frac{0.18 - 0.15}{\tau_c - 0.29}$$

| M25 | $\tau_c$ |
|---|---|
| 0.15 | 0.29 |
| 0.18 | $\tau_c$ |
| 0.25 | 0.36 |

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

$$\left[\therefore \tau_c = 0.29 + \frac{(0.18-0.15)(0.3}{(0.25-0.15)}\right.$$

$$\tau_v < k\tau_c$$

[ For 'k' cl no - 40.2 , Pg - 72 ]

For D = 160mm , k = 1.3

$$\tau_v < k \cdot \tau_c$$

$$0.18 < 1.3 \times 0.31$$

$$0.18 < 0.4$$

Hence the slab is safe for shear

## * step 7 : Check for deflection :

$$\left(\frac{l_{eff}}{d}\right)_{prov} < \left(\frac{l_{eff}}{d}\right)_{basis} \times \alpha \beta \gamma \delta$$

[ $\alpha$ – Cl No : 23.2.1 , Pg no - 37 ]

$$\alpha = 1 \; ; \; \beta = 1 \; ; \; \delta = 1$$

$\beta$ → Modification factore – [Pg no 38 - fig 4]

$$F_s = 0.58 f_y \frac{A_{st\ requi}}{A_{st\ prov}}$$

$$= 0.58 \times 415 \times \frac{496.06}{523}$$

$$= 228\ N/mm^2$$

$$P_b = \frac{100\ A_{st}}{bD} = \frac{100 \times 523.3}{1000 \times 160} = 0.37\ \%$$

$$\beta = 1.4$$

$$\left(\frac{3.64}{0.14}\right) < (25) \times 1 \times 1.4 \times 1 \times 1$$

$$26 < 35$$

Hence the slab is safe for deflection.

*** Step 8 : Check for development length :**

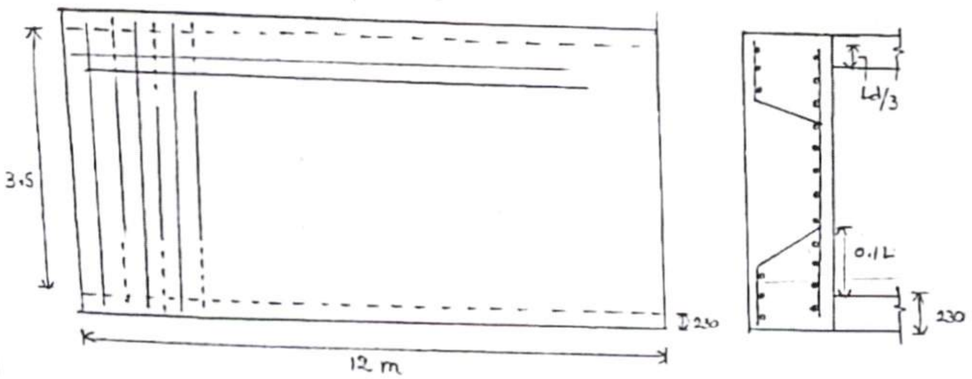
$$L_d = \frac{0.87 f_y \phi_m}{4 \tau_{bd}}$$

$$= \frac{0.87 \times 415 \times 10}{4(1.4 \times 1.6)} = 402\ mm$$

$$\rightarrow \frac{L_d}{3} = \frac{402.9}{3} = 134.3\ mm$$

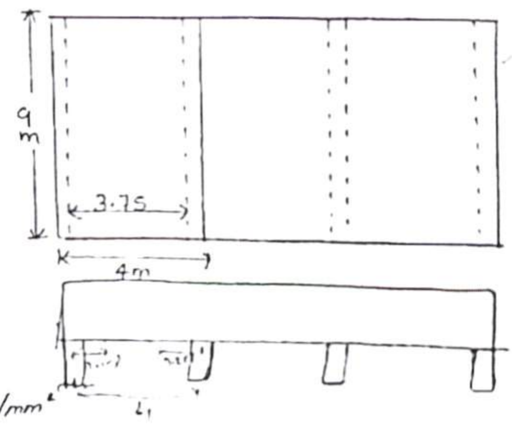
Main reinforcement should be placed 135 mm inside supports

*** Step 9 : Detailing of reinforcement :**




2) Design a one-way continuous slab for all in building. The slab is supported on 250 mm wide 60cm beam spaced at 4m c/c. Clear span of the beam is 9m. live load on the slab is 3 kN/m². Dead load due to finish, partition etc.., is 1.5 kN/m². Use $M_{20}$ concrete and Fe415 steel, Doe the neccessary check. Draw to a scale the reinforcement detailes.

Ans: **Step-1: Given data & Type of slab :**




Width of support = 250mm

$l_x = 4 - 0.25 = 3.75m$

$l_y = 9m$

Dead load = $1.5\ kN/m^2$

Live load = $3\ kN/m^2$

$f_{ck} = 20\ N/mm^2$ ; $f_y = 415\ N/mm^2$

$\frac{l_y}{l_x} = \frac{9}{3.75} > 2$

Design for a one way continuous slab

Step 2 : factored bending moment & shear force :

(a) Overall depth of slab :

$\frac{Span}{d} \leq 20mm$

for simply supported $= \frac{l}{d} \leq 20$

for continuous $= \frac{l}{d} \leq 25$

Average $\frac{l}{d} \leq 25$

for continuous slab $\frac{l}{d} \leq 25$

$\frac{3750}{d} = 25$

$d = 150\ mm$

⟹ Assume 10mm ϕ main bars

Nominal cover = 15mm

Overall depth $= (D) = d + \phi/2 + 15$

$= 150 + \frac{10}{2} + 15 \Rightarrow 170mm$

(b) factored load :

• Dead load : Dead load $= 1.5\ kN/m^2$

Self weight of the slab $= \gamma \times D$

$= 25 \times 0.17$

$= 4.25\ kN/m^2$

Total dead load $= 5.75\ kN/m^2$

factored dead load $= 1.5 \times 5.75$

$(W_{u\,D.L}) = 8.625\ kN/m^2$

• Live load :

Live load $= 3\ kN/m^2$

$(W_{uLL})$ factored load live $= 1.5 \times 3\ kN/m^2 = 4.5\ kN/m^2$

factored dead load $= 1.5 \times 5.75 = 8.625\ kN/m^2$

(c) Effective span :

$L_{eff}$ = least of $(l_x + d)$ (or) $(l_x$ + support width$)$

$= 3.75 + 0.15$ (or) $3.75 + 0.25$

$L_{eff} = 3.9m$

(d) Factored Bending moment & shear force:

Ref IS 456 : 2000 , Pg No : 36 - Table no 12 & 13

⇒ Factored Bending moment = Maximum moment coefficient × $W_u l_{eff}^2$

$$M_u = \frac{1}{10}(W_{u D.L} \times l_{eff}^2) + \frac{1}{9}(W_{u L.L}\, l_{eff}^2)$$

$$= \frac{1}{10}(8.625 \times 3.9^2) + \frac{1}{9}(4.5 \times 3.9^2)$$

$$= 20.7 \text{ KN.m}$$

⇒ Shear force $V_u$ = Maxi" shear coefficient × $W_u l_{eff}$

$$= 0.6\left[W_{u D.L}\, l_{eff}\right] + 0.6\left[W_{u L.L} \cdot l_{eff}\right]$$

$$= 0.6\left[8.625 \times 3.9\right] + 0.6\left[4.5 \times 3.9\right]$$

$$= 30.71 \text{ KN}$$

Step 3: Check for depth:

$$d_{req} = \sqrt{\frac{M_u}{0.138 f_{ck} b}} \Rightarrow \sqrt{\frac{20.7 \times 10^6}{0.138 \times 20 \times 1000}}$$

$$= 86.60 < d_{prov}.$$

Step 4: Design of main Reinforcement:

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

$$20.7 \times 10^6 = 0.87 \times 415 \times A_{st} \times 150\left[1 - \frac{415 A_{st}}{20 \times 150 \times 1000}\right]$$

$$20.7 \times 10^6 = 54157.5 A_{st}\left[1 - 1.3833 \times 10^{-4} A_{st}\right]$$

$$20.7 \times 10^6 = 54157.5 A_{st} - 7.4917875 A_{st}^2$$

$$7.4917875 A_{st}^2 - 54157.5 A_{st} + 20.7 \times 10^6$$

$$A_{st_{req}} = 404.8471 \text{ mm}^2$$

Check for Ast:

→ $A_{st\,min} = \frac{0.12}{100} bD = \frac{0.12}{100} \times 1000 \times 170$

$$= 204 \text{ mm}^2$$

→ Dia of main bars < $\frac{D}{8}$

$\phi m = 10 < \frac{170}{8}$ [$a_s = 78.5$]

① spacing $= \frac{a_{st}}{A_{st\,req}} \times 1000$

$= \frac{78.5}{204} \times 1000 = \cancel{384.8}$ 194. mm

② 3 × effective depth = 3 × 150 = 450 mm

③ 300mm

$\Rightarrow A_{st\,prov} = \frac{a_{st}}{spacing} \times 1000 \Rightarrow \frac{78.5}{190} \times 1000$

$\Rightarrow 413.15\ mm^2$

**Step5: Distribution reinforcement:**

For one way slab continuous Ast min as distribution

$A_{st}\ min = 204\ mm^2$

Assume 8mm $\phi$ distribution bar, $a_{st} = \frac{\pi}{4} \times 8^2 = 50.2 mm^2$

① spacing $= \frac{50.2}{204} \times 1000 = 246.07\ mm^2$

② 5d $= 5 \times 150 = 750$

③ 450 mm

(Provide 8mm $\phi$ 240 c/c

**Step6: check for shear:**

$\rightarrow \tau_v = \frac{V_u}{bd} = \frac{30.71 \times 10^3}{1000 \times 150} = 0.20\ N/mm^2$

For,

$\tau_c$ — [table - 19]

$\Rightarrow P_t = \frac{100 A_{st\,pro}}{bd} = \frac{100 \times 413.15}{1000 \times 150} = 0.27\ \%$

$\Rightarrow \frac{0.50 - 0.25}{0.48 - 0.36} = \frac{0.27 - 0.25}{\tau_c - 0.36}$

| M20 | $\tau_c$ |
|---|---|
| 0.25 | 0.36 |
| 0.27 | $\tau_c$ |
| 0.50 | 0.48 |

$\tau_c = 0.36\ N/mm^2$

$\tau_v < k\,\tau_c$

[For 'k' cl no - 40.2 pg 72] ; D = 170 mm

$\tau_v < k \cdot \tau_c$

$0.20 < 1.3 \times 0.36$

$0.20 < 0.46$

Hence the slab is safe for shear

Step 7: Check for deflection :

$$\left(\frac{l_{eff}}{d}\right)_{prov} < \left(\frac{l_{eff}}{d}\right)_{basics} \times \alpha \beta \gamma \xi$$

[ $\alpha$ - Cl no : 23.2.1 , Pg no : 37 ]

$\beta$ = Modification factor - [ Pg no 38 - fig 4 ]

$$F_s = 0.58 f_y \frac{A_{st\ requ}}{A_{st\ prov}}$$

$$= 0.58 \times 415 \frac{404.8}{413.1} = 235.86 \ N/mm^2$$

$$P_b = \frac{100 A_{st}}{bD} = \frac{100 \times 413}{1000 \times 150} = 0.27\%$$

$\beta = 1.5$

$\alpha = 1 \quad \gamma = 1 \quad \xi = 1$

$$\left(\frac{3.9}{0.150}\right) < (25 \times 1 \times 1.5 \times 1 \times 1)$$

$26 < 37.5$

Hence the slab is safe for deflection.

Step 8: Check for development length :

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

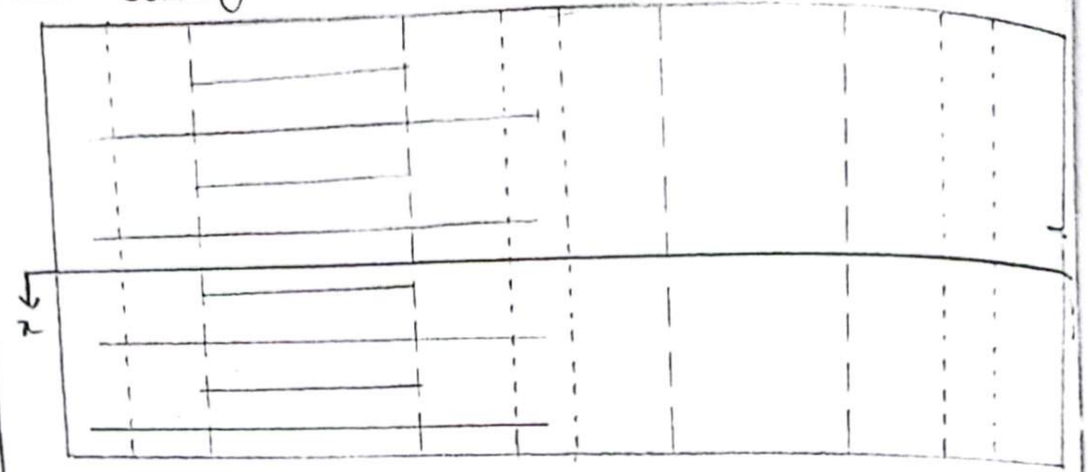
$$= \frac{0.87 \times 415 \times 10}{4 (1.2 \times 1.6)}$$

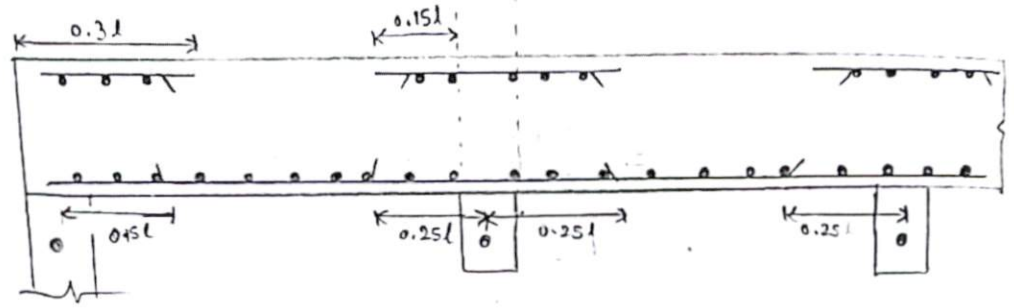
$= 470$

$\rightarrow \frac{L_d}{3} = \frac{470}{3} = 156 \ mm \simeq 155 mm$

Main rainforcement should be place 155mm inside supports.

Step 9: Detailing of reinforcement:






3) Design a floor slab of room dimensions resting on beams on width 300mm carries live load of 4 kN/m² & the floor finish of 1 kN/m² design for $M_{20}$ grade of concrete and Fe 415 steel.

Ans: Step 1: Given data:

Room dimensions

$l_x = 4m$

$l_y = 5m$

$f_{ck} = 20\ N/mm^2$

$f_y = 415\ N/mm^2$

Live load $= 4\ kN/m^2$

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

$\frac{l_y}{l_x} = \frac{5}{4} < 2$ → Design as two way slab

Step 2: factored Bending moment and shear force:

(a) Overall Depth ref Cl. no 24 note - 2

for span upto 35 no. bar & Fe 250

simply supported $\frac{\text{span } (l_x)}{\text{Overall depth}} = 35$

for Fe 415 $\frac{l_x}{b} = 35 \times 0.8 = 28$

Assume for spans more than 3m

$$\frac{l_{cx}}{D} = 25$$

$$\frac{4000}{D} = 25$$

$$D = 160 \text{ mm}$$

(b) factored load

- Live load = 4 kN/m²
- Floor finish = 1 kN/m²
- Self weight = $\gamma \times D \Rightarrow 25 \times 0.6 = 4$

$w = 9 \text{ kN/m}^2$

$\therefore$ factored load $w_u = 1.5 \times w$

$= 1.5 \times 9 \Rightarrow 13.5 \text{ kN/m}^2$

(c) Effective span:

$L_{eff}$ = least of $(l_x + d)$ & $(l_x$ + support width$)$

$d = D - \phi/2$ - nominal cover ( Table -16)

$= 160 - \frac{10}{2} - 15 = 140 \text{mm}$

$L_{eff} = 4 + 0.14$ & $[4 + 0.3]$

$= 4.14$ & $4.3$

$L_{eff} = 4.14$ mter

(d) factored Bm & S.F

For two way slab simply supported Ref tabe 26 - Pg (no -91)

$M_x = \alpha_x w_u l_x^2$ ; $M_y = \alpha_y w_u l_x^2$

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

$1.2 \longrightarrow 0.084$ ; $\boxed{1.25 \longrightarrow \alpha_x}$ ; $1.3 \longrightarrow 0.093$

$$\frac{1.3 - 1.2}{1.25 - 1.2} = \frac{0.093 - 0.084}{\alpha_x - 0.084}$$

$\alpha_x = 0.088$

Similarly $\alpha_y = 0.057$

$M_x = 0.088 \times 13.5 \times 4^2 = 19$ KN

$M_y = 0.057 \times 13.5 \times 4^2 = 12.31$ KN

$V_u = \frac{W_u l_{eff}}{2} = \frac{13.5 \times 4.14}{2}$

$= 27.94$ KN

Step3: check for depth:

for Fe415, $M_{ulim} = 0.138\, f_{ck}\, bd^2$

Fe415; $d_{req} = \sqrt{\frac{M_{ulim}}{0.138 \cdot f_{ck}\, b}}$

$= \sqrt{\frac{19 \times 10^6}{0.138 \times 20 \times 1000}}$

$d_{req} = 82.9$

Step4: Design for main reinforcement: (shorter):

Reff cl no 38.1

$M_{ux} = 0.87 f_y\, Ast\, d_x \left[1 - \frac{Ast_x f_y}{bd\, f_{ck}}\right]$

$19 \times 10^6 = 0.87 \times 415 \times Ast_{req} \times 140 \left[1 - \frac{Ast_{req_x} \times 415}{1000 \times 140 \times 20}\right]$

$Ast\ req_x = 399.6 mm^2$

Check for Ast:

$Ast\ min = \frac{0.12}{100} \times bD$

$= \frac{0.12}{100} \times 1000 \times 160 = 192$

i) Spacing $= \frac{ast}{Ast_{req}} \times 1000 \Rightarrow \frac{\pi/4 \times 10^2}{399.6} \times 1000 = 196.54$

ii) $3 \times d = 3 \times 140 = 420$ mm

iii) 300mm

[$\because$ provide 10mm $\phi$ @ 192 c/c]

$\Rightarrow$ Ast req y (longer span):

$d_y = 160 - \frac{10}{2} - 15 - 10 = 130$

$12.31 \times 10^6 = 0.87 f_y\, Ast\, d_y \left[1 - \frac{Ast_y f_y}{f_{ck}\, bd}\right]$

$$12.31 \times 10^6 = 0.87 \times 415 \times Ast_y \times 130 \left[1 - \frac{Ast_y \times 415}{20 \times 1000 \times 130}\right]$$

$$243.535 = Ast_y \left(1 - 1.48 \times 10^{-4}\right)$$

$$Ast_y = 274.2 \ mm^2$$

<u>check for $Ast_y$:</u>

$$Ast_y \ min = \frac{0.12}{100} \times 1000 \times 160 = 192 \ mm^2$$

Dia of main bar $< \frac{D}{f}$

$$\phi m = 10 < \frac{160}{8} \qquad \left[\because ast = \frac{\pi}{4}(10)^2 = 78.5\right]$$

i) spacing $= \frac{78.5}{274.2} \times 1000 = 286.28$

ii) 3d $> 3 \times 130 = 390$

iii) 300 mm

$$\Rightarrow Ast_x \ prov = \frac{ast}{spacing} \times 1000 = \frac{78.5}{190} \times 1000$$

$$= 413.15 mm^2$$

$$\Rightarrow Ast_y \ prov = \frac{ast}{spacing} \times 1000 = \frac{78.5}{286.28} \times 1000$$

$$= 274.09 \ mm^2 \quad (or) \quad (280.5)$$

<u>steps: check for shear:</u>

$$\tau_v < k \tau_c$$

$$\tau_v = \frac{V_u}{bd} = \frac{27.9 \times 10^3}{1000 \times 140} = 0.199 \ N/mm^2$$

For $\tau_c \longrightarrow$ Table - 19

$$P_t = \frac{100 \ Ast_x/2}{1000 \times 140}$$

$$= \frac{100 \times \frac{413.15}{2}}{1000 \times 140}$$

$$P_t = 0.29$$

$$\tau_c = 0.28 \ N/mm^2$$

$$[\tau_v < k \tau_c]$$

$$k = 1.3 \qquad \left\{ \begin{array}{l} \text{ref Pg no - 72} \\ \text{cl no - 40.2.1.1} \end{array} \right\}$$

Hence the safe

Step6: check for deflection :

$$\left(\frac{l_{eff}}{d}\right)_{prov} < \left(\frac{l_{eff}}{d}\right)_{basic} \times \alpha \beta \gamma \xi$$

$$\left(\frac{4.14}{0.14}\right)_{prov} < (25) \times 1 \times \beta \times 1 \times 1$$

$\beta \rightarrow$ fig 4 of IS (456 : 2000)

$$f_s = 0.88 \times f_y \; \frac{Ast\, req}{Ast \times prov}$$

$$= 0.88 \times 415 \; \frac{399.50}{413.50}$$

$$= 232.8$$

$$\beta = 1.5$$

$$\left(\frac{4.14}{0.14}\right) < (25 \times 1 \times 1 \times 1 \times 1.5)$$

$$29.57 < (25 \times 1.5 \times 1 \times 1)$$

$$29.57 < 37.5$$

Hence the slab is safe for deflection

Step7: check for development length :

$$l_d = \frac{0.87 \times f_y \times \phi_m}{4 \tau_{bd}}$$

$$= \frac{0.87 \times 415 \times 10}{4\,(1.2 \times 1.6)}$$

$$l_d = 470.117$$

$$\frac{l_d}{3} = \frac{470.117}{3} = 156.70$$

4) Design a floor slab of room dimensions resting on beams on width 300mm caries live load of 4 kN/m² the floor finish of 1 kN/m² design for M20 grade of concrete & Fe 415 steel. $l_y = 6m$ ; $l_x = 4m$

Ans: Step 1: Given data & type of slab :

$l_x = 4m$

$l_y = 6m$

Live load := 4 kN/m²

Assume Floor finish = 1 kN/m²

$f_{ck} = 20 \, N/mm^2$

$f_y = 415 \, N/mm^2$

Edge condition ⇒ one long edge discontinuous

$$\frac{l_y}{l_x} = \frac{6}{4} = 1.5$$

Design a two way slab

Step 2: Factored B.M & S.F :

(a) Overall depth : [Ref pg no - 39 , NOTE - 2]

For span > 3.5m

$$\frac{\text{Span}}{D} = 25$$

$$\frac{4000}{D} = 25$$

$D = 160mm$ ( Assume 10mm ϕ bars).

→ $d_x = 160 - 15 - \frac{10}{2} = 140mm$

→ $d_y = 160 - 15 - 10 - \frac{10}{2} = 130mm$

(b) Factored load :

- Live load = 4 kN/m2
- Floor finish = 1 kN/m²
- Self weight = 0.16 × 25 = 4 kN/m²

Total = 9 kN/m²

$W_u = 1.5 \times 4 = 13.5$ kN/m²

(c) Effective span :

$L_{eff} = 4 + 0.14$ (or) $4 + 0.3$

Take = 4.14 mm

(d) Factored B.M & S.F :

Ref - table 26 pg no - 91 — from $\frac{l_y}{l_x} = 1.5$

$\alpha x_1 = 0.062$ , $\alpha y_1 = 0.032$

$\alpha x_2 = 0.061$ $\alpha y_2 = 0.028$

$M_{x_1} = \alpha x_1 W_u l_x^2 = 14.47$ kNm

$M_{x_2} = \alpha x_2 W_u l_x^2 = 11.01$ kN.m

$M_{y_1} = \alpha y_1 W_u l_x^2 = 7.9$ kNm

$M_{y_2} = \alpha y_2 W_u l_x^2 = 6.02$ kNm

$$V_u = \frac{W_u l_{eff}}{2} = \frac{13.5 \times 4.14}{2} = 27.94 \text{ kN}$$

Step3: Check for depth :

$$d = \sqrt{\frac{M_u}{0.138 f_{ck} b}}$$

$$d = \sqrt{\frac{14.47}{0.138 \times 20 \times 1000}}$$

$d_{req} = 72.4$ mm $< d_{prov}$

Step4: Short span main reinforcement :

(i) $M_{x_1} = 0.87 f_y A_{stx_1} d_x \left[1 - \frac{A_{stx_1} f_y}{f_{ck} b d_x}\right]$

$14.47 \times 10^6 = 0.87 f_y\, 415 \times A_{stx_1} \times 140 \left[1 - \frac{A_{stx_1}\, 415}{20 \times 140 \times 1000}\right]$

$14.47 \times 10^6 = 50547 A_{stx_1} \left[1 - 1.4821 \times 10^{-4} A_{stx_1}\right]$

$14.47 \times 10^6 = 50547 A_{stx_1} - 7.4917875 A_{stx_1}^2$

$$\boxed{A_{stx_1} = 299.56 \text{ mm}^2}$$

Check for $A_{stx_1}$ :

$A_{stx_1}$ min $= \frac{0.12}{100} \times bD$

$= \frac{0.12}{100} \times 1000 \times 160 = 192$

i) spacing $= \frac{ast}{Ast_{req}} \times 1000 \Rightarrow \frac{\pi/4 (10)^2}{299.5} \times 1000 = 262.2$

ii) $3 \times d$ - $3 \times 140 = 420\,mm$ [∵ provide 10 mm @ 190 c/c]

iii) 300 mm

(ii) $M_{x_2} = 0.87 f_y Ast_{x_2} \times d_x \left[1 - \frac{Ast_{x_2} f_y}{f_{ck}\, b d_x}\right]$

$$11.01 \times 10^6 = 0.87 \times 415 \times Ast_{x_2} \times 140 \left[1 - \frac{Ast_{x_2}\, 415}{20 \times 140 \times 1000}\right]$$

$$11.01 \times 10^6 = Ast_{x_2}\, 50547 \left[1 - 1.48214 \times 10^{-4} Ast_{x_2}\right]$$

$$11.01 \times 10^6 = 50547\, Ast_{x_2} - 7.4917875\, Ast_{x_2}^2$$

$$\boxed{Ast_{x_2} = 225.34\ mm^2}$$

(iii) (longer span) :-

$M_{y_1} = 0.87 f_y\, Ast_{y_1}\, d_y \left[1 - \frac{Ast_{y_1} f_y}{f_{ck}\, b d_y}\right]$

$$7.9 \times 10^6 = 0.87 \times 415 \times 130 \times Ast_{y_1} \left[1 - \frac{Ast_{y_1}\, 415}{20 \times 1000 \times 130}\right]$$

$$7.9 \times 10^6 = 46936.5\, Ast_{y_1} \left[1 - 1.596153 \times 10^{-4} Ast_{y_1}\right]$$

$$7.9 \times 10^6 = 46936.5\, Ast_{y_1} - 7.4917875\, Ast_{y_1}^2$$

$$\boxed{Ast_{y_1} = 173.09\ mm^2}$$

→ spacing $= \frac{ast}{Ast_{y_1, req}} \times 1000 = \frac{\pi/4 (10)^2}{173.09} \times 1000 = 453.75$

→ $3 \times d = 3 \times 130 = 390$

→ 400 mm

$M_{y_2} = 0.87 f_y\, Ast_{y_2}\, d_y \left[1 - \frac{Ast_{y_1} f_y}{f_{ck}\, b d_y}\right]$

$$6.02 \times 10^6 = 0.87 \times 415 \times Ast_{y_2} \times 130 \left[1 - \frac{Ast_{y_2}\, 415}{20 \times 1000 \times 130}\right]$$

$$6.02 \times 10^6 = 46936.5\, Ast_{y_2} \left[1 - 1.596153 \times 10^{-4} Ast_{y_2}\right]$$

$$6.02 \times 10^6 = 46936.5\, Ast_{y_2} - 7.4917835\, Ast_{y_2}$$

$$\boxed{Ast_{y_2} = 130.99\ mm^2}$$

Step5: check for shear:

$$\tau_v = \frac{V_u}{bd} = \frac{27.94}{1000 \times 140} = 0.19 \ N/mm^2$$

For $\tau_b$ - Table 19

$$P_t = \frac{100\ Ast}{bd}$$

$$= \frac{100 \times 299.56}{1000 \times 140}$$

$$= 0.21\%$$

$\tau_c = 0.30 \ N/mm^2$

| M20 | $\tau_c$ |
|---|---|
| 0.15 | 0.28 |
| 0.21 | $\tau_c$ |
| 0.25 | 0.36 |

$\tau_v < k.\tau_c$

For cls no: 48.2.1, $k = 1.3$

$\therefore \tau_v < 1.3 \times 0.30$

$0.18 < 0.39$

$\therefore$ Hence the slab is safe for shear

Step6: check for deflection:

$$\left(\frac{d_{eff}}{d}\right)_{prov} < \left(\frac{L_{eff}}{d}\right)_{basic} \times \alpha \times \beta \times \gamma \times \delta$$

$\alpha \rightarrow$ cl no: 23.2.1, pg no 37

$\alpha = 1, \ \gamma = 1, \ \delta = 1$

$$f_s = 0.85\, f_y \frac{Ast}{Ast\ prov}$$

$$= 0.85 \times 415 \ \frac{299.56}{413}$$

$$= 255.63$$

$$P_t = \frac{100\ Ast}{bd} \Rightarrow \frac{100 \times 299.56}{1000 \times 140}$$

$\Rightarrow 0.21\%$

$\boxed{\beta = 1.6}$

Step5: chek for shear:

$$\tau_v = \frac{V_u}{bd} = \frac{27.94}{1000 \times 140} = 0.19\ N/mm^2$$

For $\tau_b$ - Table 19

$$P_t = \frac{100\ Ast}{bd}$$

$$= \frac{100 \times 299.56}{1000 \times 140}$$

$$= 0.21\%$$

$\tau_c = 0.30\ N/mm^2$

| $M_{20}$ | $\tau_c$ |
|---|---|
| 0.15 | 0.28 |
| 0.21 | $\tau_c$ |
| 0.25 | 0.36 |

$\tau_v < k \cdot \tau_c$

For cls no: 48.2.1, $k = 1.3$

$\tau_v < 1.3 \times 0.30$

$0.18 < 0.39$

∴ Hence the slab is safe for shear

Step6: check for deflection:

$$\left(\frac{d_{eff}}{d}\right)_{prov} < \left(\frac{L_{eff}}{d}\right)_{basic} \times \alpha \times \beta \times \gamma \times \delta$$

$\alpha \rightarrow$ cl no: 23.2.1, pg no 37

$\alpha = 1,\ \gamma = 1,\ \delta = 1$

$$f_s = 0.85\ f_y\ \frac{Ast}{Ast\ prov}$$

$$= 0.85 \times 415\ \frac{299.56}{413}$$

$$= 255.63$$

$$P_t = \frac{100\ Ast}{bd} \Rightarrow \frac{100 \times 299.56}{1000 \times 140}$$

$\Rightarrow 0.21\%$

$\boxed{\beta = 1.6}$

$\left(\frac{4.14}{0.14}\right) < 47.31$

$\therefore$ Hence slabe is safe for deflection.

step 7: check for development length:

$$l_d = \frac{0.87 f_y \phi_m}{4 \tau_{bd}}$$

$$= \frac{0.87 \times 415 \times 10}{4 \times 1.2 \times 1.6}$$

$$l_d = 470.117$$

$$\Rightarrow \frac{l_d}{3} = \frac{470.1}{3} = 156.70$$