UNIT –III DESIGN OF SLABS AND STAIRCASE

3.3 DESIGN OF SIMPLY SUPPORTED AND CONTINUOUS SLABS USING IS CODE

DESIGN EXAMPLES

1.A slab has clear dimensions 4 m x 6 m with wall thickness 230 mm the live load on the slab is 5 kN/m^2 and a finishing load of 1kN/m^2 may be assumed. Using M20 concrete and Fe415 steel, design the slab

Given data

Dimension = 4 x 6

Shorter span 1_x = 4m

Longer span 1_y = 6m

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

= 1.5 < 2

It is a two way slab.

Width of support = 230 mm

Live load = 5 kN/m^2

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

F_y = 415 N/mm^2

Depth of slab:

Effective depth d = $\frac{span}{25}$

= $\frac{4000}{25}$

= 160 mm

Assume cover 20mm, 10mm diameter rod

Overall depth D = 160 + 20 + $\frac{10}{2}$

=185mm

D = 200 mm

Effective span:

1. c/c of supports $l_e = \frac{wall\ thickness}{2} + shorter\ span + \frac{wall\ thickness}{2}$

$$= \frac{0.23}{2} + 4 + \frac{0.23}{2}$$

$$= 4.23 \text{ m}$$

2. clear span + effective depth = 4 + 0.24

$$= 4.24\text{m}$$

Take least value, 1_e = 4.23 m

Load calculation:

Self weight= B X D X γ

= 1 X 0.2 X 25

= 5 kN/ m

Live load = 5 kN/m

Floor finish = 1 kN/m

Total load = 5 + 5 + 1

= 11 kN/ m

Factor load = 1.5 x 11

= 16.5 kN/ m

Bending moment & shear force:

$$M_X = \alpha_X W_U l_e^2$$

$$M_y = \alpha_y W_U l_e^2$$

From table 26 of IS 456: 2000

$$\frac{ly}{\text{lx}} = 1.5$$

Four edges are discontinuous,

α_X = 0.089

α_y =0.056

Bending moment:

$$M_X = 15.59\text{x}4.2^2\text{x}0.089$$

$= 25.01$ kNm

$M_Y = 0.056 \times 15.93 \times 4.2^2$

$= 15.73$ kNm

Shear force :

$$SF = \frac{Wule}{2}$$

$$= \frac{15.93 \times 4.2}{2}$$

$= 33.45$ KN

Check for Depth :

$M_U = 0.138\, f_{ck} b d^2$

$$d = \sqrt{\frac{25 \times 10^6}{0.138 \times 20 \times 1000}}$$

$= 95.17$ mm

$d_{prov} > d_{req}$

Hence the design is safe.

Area of reinforcement:

For shorter span:

$$M_U = 0.87\, f_y \times A_{st} \times d\, [1 - \frac{Ast \times fy}{b \times d \times fck}]$$

$$25 \times 10^6 = 0.87 \times 415 \times A_{st} \times 160\, [1 - \frac{Ast \times 415}{1000 \times 160 \times 20}]$$

$$25 \times 10^6 = 57768\, A_{st} - 7.4\, A_{st}^2$$

$A_{st} = 459.85\ mm^2$

$A_{st\ min} = 0.12\% \times bd$

$$= \frac{0.12}{100} \times 1000 \times 200$$

$= 240\ mm^2$

Provide 10mm dia bar.

Spacing :

$$i.\ \frac{ast}{Ast} \times 1000 = \frac{\pi/_4 \times 10^2}{459.85} \times 1000$$

$= 170.79$ mm ≈ 170mm

ii. 3d = 3 x 160 = 480 mm

take the least value = 170 mm

provide 10 mm dia bar 170 mm c/c.

For longer span:

$$M_U = 0.87\, f_y \times A_{st} \times d\, [1 - \frac{Ast \times fy}{b \times d \times fck}]$$

$$15.73 \times 10^6 = 0.87 \times 415 \times A_{st} \times 160\, [1 - \frac{Ast \times 415}{1000 \times 160 \times 20}]$$

$$A_{st} = 282.52\ mm^2$$

Spacing :

$$i)\ \frac{ast}{Ast} \times 1000 = \frac{\pi/_4 \times 10^2}{282.52} \times 1000 = 277.99mm \approx 300\ mm$$

ii) 3d = 3×160

= 480mm

Take the least value for spacing = 300mm,

provide 10mm diameter bar, 300m

Check for shear:

Permissible shear stress, $\tau_v = \frac{Vu}{bd}$

$$= \frac{33.45 \times 10^3}{1000 \times 160} = 0.2 N/mm^2$$

Nominal shear stress = $\tau_c \times K$

To find τ_c ,

Percentage of steel, $p_t = 100 \times \frac{Ast}{b \times d}$

$$= 100 \times \frac{459.85}{1000 \times 160}$$

$$= 0.28\%$$

The value lies between 0.25 and 0.50, use interpolation

X_1	0.25	Y_1	0.36	X	0.28
X_2	0.5	Y2	0.48	Y	?

$$Y = \tau_c = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)}(x - x_1)$$

$$= 0.36 + \frac{0.48-0.36}{0.50-0.25}(0.28 - 0.25)$$

$$= 0.37 N/mm^2$$

To find K ,

Overall depth, D = 185mm

Refer pg no:73 of IS 456-2000

This value lies between 150 to 175, use interpolation

X_1	150	Y_1	1.3	X	185
X_2	175	Y2	1.25	Y	?

$$Y = K = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)}(x - x_1)$$

$$= 1.3 + \frac{1.25-1.3}{175-150}(185 - 150)$$

$$= 1.27$$

$\tau_c \times K = 0.38 \times 1.27$

$$= 0.48 N/mm^2$$

$\tau_v < \tau_c \times K$,

Hence the design is safe.

Check for deflection:

$$\frac{l}{d}_{max} = \frac{l}{d}_{basic} \times K_b \times K_c$$

$$= 20 \times 1.4 \times 1 = 30$$

$$\frac{l}{d}_{pro} = \frac{\text{Effective span}}{\text{Effective depth}}$$

$$= \frac{4000}{160} = 26.25mm$$

$$(\frac{l}{d})_{max} > (\frac{l}{d})_{pro}$$

Hence the design is safe for deflection.

Check for crack control:

1. Reinforcement provided must be greater than minimum percentage of reinforcement provided as per IS 456-2000.

$A_{st\,min}$ = 0.12% of cross section area

$= 0.12/100 \times 1000 \times 185$

$= 222\ mm^2$

$A_{st\ pro} > A_{stmin}$,

Hence it is safe.

2. Spacing is not greater than 3d.

$3d = 3 \times 160$

$= 480mm$

Spacing < 3d,

Hence it is safe.

3. Diameter of reinforcement should be less than $\frac{D}{8}$

$d < \frac{D}{8}$

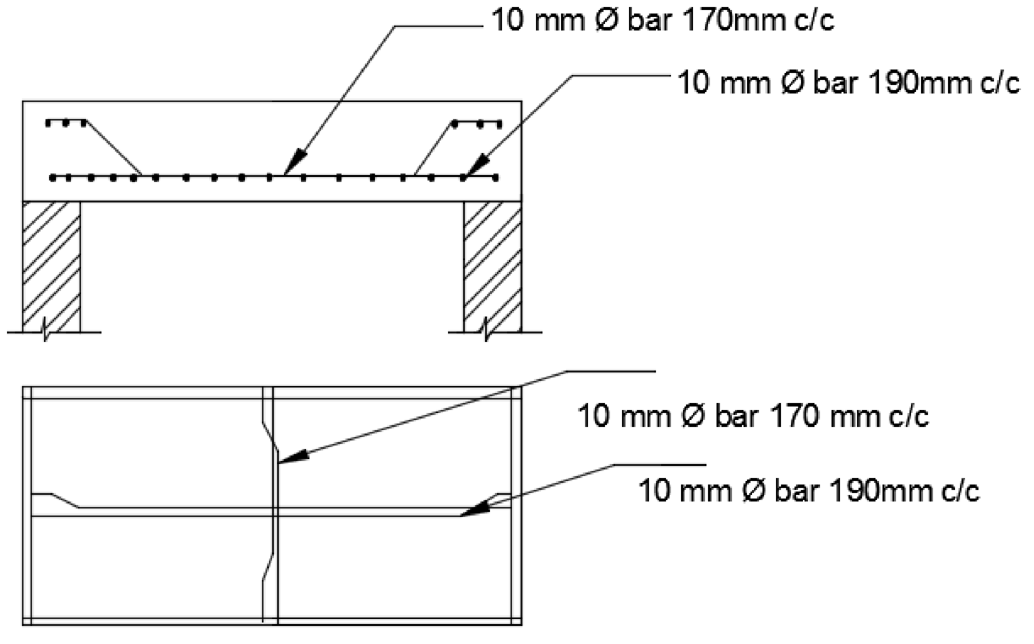
$\frac{D}{8} = \frac{185}{8}$

$= 28.12mm$

$d < \frac{D}{8}$

Hence it is safe.

Reinforcement detailing:



2.A slab has clear dimensions 3.5 m x 6 m with wall thickness 230 mm the live load on the slab is 5 kN/m^2 and a finishing load of 1kN/m^2 may be assumed. Using M20 concrete and Fe415 steel, design the slab

Given data

Dimension = 3.5 x 6

Shorter span 1_x = 3.5

Longer span 1_y = 6

$$\frac{ly}{lx} = \frac{6}{3.5}$$

= 1.7 < 2

It is a two way slab

Width of support = 230 mm

Live load = 5 kN/m^2

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

F_y = 415 N/mm^2

Depth of slab,

Effective depth, d $= \frac{span}{25}$

$= \frac{3500}{25}$

Assume cover 20mm, 10mm diameter rod

Overall depth, D = 140 + 20 + 10/2

=165mm

= 125 mm

Effective span:

i. c/c of supports $l_e = \frac{wall\ thickness}{2} + shorter\ span + \frac{wall\ thickness}{2}$

$$= \frac{0.23}{2} + 3.5 + \frac{0.23}{2}$$

= 3.73 m

ii. clear span + effective depth = 3.5 + 0.14

= 3.64

Take least value, 1_e = 2.6 m

Load calculation:

Self weight = B X D X γ

= 1 X 0.165 X 25

= 4. 13 KN/ m

Live load = 5 KN/m

Floor finish = 1 KN/m

Total load = 4.13 + 5 + 1

= 10.13 KN/ m

Factor load = 1.5 x 10.13

= 15.2 KN/ m

Bending moment & shear force:

$$M_X = \alpha_X W_U l_e^2$$

$$M_y = \alpha_y W_U l_e^2$$

From table 26 of IS 456: 2000

$$\frac{ly}{lx} = 1.7$$

Four edges are discontinuous,

α_X = 0.098

α_y =0.056

Bending moment:

M_X = 0.098 x 15.2 x 3.64^2

= 19.74 KNm

M_Y = 0.056 x 15.2 x 3.64^2

$= 11.24$ KNm

Shear force :

$$SF = W_U l_e/2$$
$$= (15.2 \times 3.64)/2$$
$$= 27.66 \text{ KN}$$

Check for Depth :

$$M_U = 0.138 f_{ck} bd^2$$
$$d = \sqrt{\frac{19.74\times10^6}{0.138\times20\times1000}}$$
$$= 84.57 \text{ mm}$$
$$d_{prov} > d_{req}$$

Hence the design is safe

Area of reinforcement:

For shorter span:

$$M_U = 0.87 f_y \times A_{st} \times d \left[1 - \frac{Ast \times fy}{b\times d\times fck}\right]$$
$$19.74 \times 10^6 = 0.87 \times 415 \times A_{st} \times 140 \left[1 - \frac{Ast \times 415}{1000\times140\times20}\right]$$
$$19.74 \times 10^6 = 50547 A_{st} - 7.49 A_{st}^2$$
$$A_{st} = 416.19 \text{ mm}^2$$
$$A_{st\,min} = 0.12\% \times bd$$
$$= \frac{0.12}{100} \times 1000 \times 165$$
$$= 198 \text{ mm}^2$$

Provide 10mm dia bar

Spacing :

$$i \ \frac{ast}{Ast} \times 1000 \qquad = \frac{\pi/4 \times 10^2}{416.9} \times 1000$$
$$= 188.7 \text{ mm}$$
$$\approx 180 \text{mm}$$

ii. 3d = 3 x 140

= 420 mm

Take the least value for spacing

provide 10 mm dia bar 180 mm c/c

For longer span:

$$M_U = 0.87\, f_y \times A_{st} \times d\, [1 - \frac{Ast \times fy}{b \times d \times fck}]$$

$$11.24 \times 10^6 = 0.87 \times 415 \times A_{st} \times 140\, [1- \frac{Ast \times 415}{1000 \times 100 \times 20}\ ]$$

A_{st}= 230.2mm^2

Spacing :

i. $\frac{ast}{Ast} \times 1000$ $= \frac{\pi/4 \times 10^2}{230.2} \times 1000$

= 323.72mm

≈ 300mm

ii. 3d = 5 ×140

= 800mm

iii. 300 mm

Take the least value for spacing

provide 10mm diameter bar, 300mm c/c

Check for shear:

Permissible shear stress, $\tau_v = {}^{V_u}/_{b \times d}$

$= \frac{27.66 \times 10^3}{1000 \times 140}$

$= 0.19 \mathrm{N/mm^2}$

Nominal shear stress $= \tau_c \times K$

To find τ_c ,

Percentage of steel, $p_t = 100 \times \frac{Ast}{b \times d}$

$= 100 \times \frac{416.69}{1000 \times 140}$

= 0.29%

The value lies between 0.25 and 0.50, use interpolation

X_1	0.25	Y_1	0.36	X	0.29
X_2	0.5	Y2	0.48	Y	?

$$Y = \tau_c = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)}(x - x_1)$$

$$= 0.36 + \frac{0.48 - 0.36}{0.50 - 0.25}(0.29 - 0.25)$$

$$= 0.38 N/mm^2$$

To find K ,

Overall depth, D = 165mm

This value lies between 150 to 175, use interpolation

X_1	150	Y_1	1.3	X	165
X_2	175	Y2	1.25	Y	?

$$Y = K = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)}(x - x_1)$$

$$= 1.3 + \frac{1.25 - 1.3}{175 - 150}(165 - 150)$$

$$= 1.27$$

$\tau_c \times K$ $= 0.38 \times 1.27$

$$= 0.48 N/mm^2$$

$$\tau_v < \tau_c \times K,$$

Hence the design is safe.

Check for deflection:

$({}^{l}/_{d})_{max}$ $= ({}^{l}/_{d})_{basic} \times K_b \times K_c$

$$= 20 \times 1.5 \times 1$$

$$= 30$$

$({}^{l}/_{d})_{pro}$ $= \frac{\text{Effective span}}{\text{Effective depth}}$

$$= \frac{3.64}{0.14}$$

$= 26mm$

$({}^{l}/_{d})_{max} > ({}^{l}/_{d})_{pro}$

Hence the design is safe for deflection.

Check for crack control:

4. Reinforcement provided must be greater than minimum percentage of reinforcement provided as per IS 456-2000.

$A_{st\mathbf{min}}$ = 0.12% of cross section area

$= 0.12/100 \times 1000 \times 165$

$= 198\ mm^2$

$A_{st\ pro} > A_{stmin}$,

Hence it is safe.

5. Spacing is not greater than 3d.

$3d = 3 \times 140$

$= 420mm$

Spacing < 3d

Hence it is safe.

6. Diameter of reinforcement should be less than ${}^{D}/_{8}$

$d < D/8$

${}^{D}/_{8} = {}^{165}/_{8}$

$= 20.62mm$

$d < D/8$

Hence it is safe.

Torsion reinforcement in corners:

Area of reinforcement in each corners is,

$A_{st\ torsion} = 0.75 \times 416.19$

$= 312.14$ mm

Spacing,

Provide 8 mm Ø bar

$\frac{ast}{Ast} \times 1000 \qquad = \frac{\pi/4 \times 8^2}{312.14} \times 1000$

$= 161mm$

$\approx 160mm$

Length over which the torsion steel is provided,

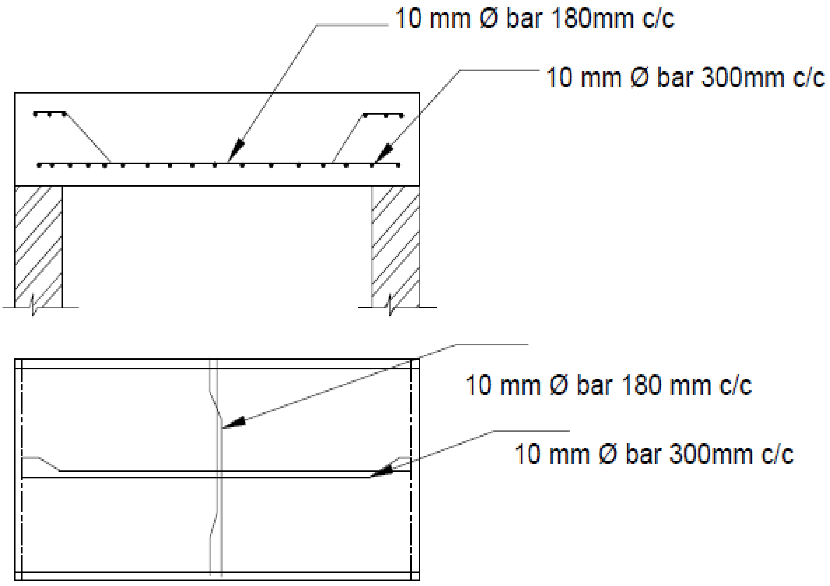
$= \frac{1}{5} \times \text{shorter span}$

$= \frac{1}{5} \times 3500$

$= 700 \text{ mm}$

Provide 8 mm Ø bar 160mm c/c , for the length of 700 mm at the corners

Reinforcement details



CONTINUOUS SLAB DESIGN

Design a one-way slab for an office floor which is continuous over T beams at 3.5m intervals. Assume a live load 4kN/m² adopt M_{20} grade concrete and Fe_{415} steel HYSD bars.

Given:

$L = 3.5$ m

$q = 4$ kN/m²

$f_{ck} = 20$ N/mm²

$f_y = 415$ N/mm²

Step: 1 Depth of slab

Assuming a span/depth ratio of 26 (Clause 23.2.1 of IS 456)

Effective depth $d = (\text{span}/26)$

$= 3500/26 = 135$ mm

Adopt $d = 140$ mm

$D = 160$ mm

Step: 2 Load calculation

Self-weight of slab $= 0.165 \times 25 = 4.125$ kN/m²

Finishes = 0.875 kN/m^2

Total working load (g) = 5.000 kN/m^2

Service live load (q) = 4 kN/m^2

Step: 3 Bending moment calculation

Referring to Tables 12 and 13, IS 456-2000 code, maximum negative BM at support next to the end support is:

$$M_u\ (\text{-ve}) = 1.5\left[\frac{gL^2}{10} + \frac{qL^2}{9}\right]$$

$$= 1.5\left[\frac{5 \text{ x } 3.5^2}{10} + \frac{4 \text{ x } 3.5^2}{9}\right]$$

$$= 17.35 \text{ kNm}$$

Positive BM at centre of span

$$M_u\ (\text{+ve}) = 1.5\left[\frac{gL^2}{12} + \frac{qL^2}{10}\right]$$

$$= 1.5\left[\frac{5 \text{ x } 3.5^2}{12} + \frac{4 \text{ x } 3.5^2}{10}\right]$$

$$= 15 \text{ kNm}$$

Step: 4 Shear force calculation

Maximum shear force at the support

$$V_u = 1.5 \text{ x } 0.6\ (g + q)\ L$$

$$= (1.5 \text{ x } 0.6)\ (5 + 4)\ 3.5$$

$$= 28.35 \text{ kN}$$

Step: 5 Check for Depth of the slab

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

$$= (0.138 \text{ x } 20 \text{ x } 10^3 \text{ x } 140^2)\ 10^{-6}$$

$$= 54.1 \text{ kNm}$$

Since $M_u < M_{u\,lim}$,

Section is under – reinforced.

Step: 6 Reinforcement details

$$M_u = 0.87\, f_y\, Ast\, d\, (1 - \frac{f_y Ast}{f_{ck} bd})$$

$$17.35 \times 10^6 = 0.87 \times 415 \times Ast \times 140\, (1 - \frac{140\ Ast}{20 \times 1000 \times 140})$$

Solving Ast = $360\ mm^2$

Provide 10 mm diameter bars at 150 mm centers (Ast = $524\ mm^2$). The same reinforcement is provided for positive BM at mid-span.

Distribution steel = $0.0012 \times 10^3 \times 165$

= $198\ mm^2$

Provide 10 mm diameter bars at 300 mm centers (Ast = $262\ mm^2$).

Step: 7 Check for shear stress

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

$$= \frac{28.35 \times 10^3}{10^3 \times 140}$$

$$= 0.20\ N/mm^2$$

$$p_t = \frac{100 \times Ast}{bd}$$

$$= \frac{100 \times 262}{10^3 \times 140}$$

$$= 0.187$$

Refer to Table 19, IS 456 and readout:

$$k\tau_c = 1.27 \times 0.30 = 0.38\ N/mm^2$$

Since $\boldsymbol{\tau_c} > \boldsymbol{\tau_v}$, the sab is safe against shear stresses.

Step: 8 Check for Deflection

Considering the end and inferior spans

$$\left(\frac{L}{d}\right)_{max} = \left(\frac{L}{d}\right)_{Basic} \times k_t \times k_c \times k_f$$

Also $k_c = k_f = 1.00$

$$\mathbf{p_t} = \frac{\mathbf{100 \times 393}}{\mathbf{10^3 \times 140}}$$

$$= 0.28$$

From Fig.8.1, read out k_t = 1.5

$$\left(\frac{L}{d}\right)_{max} = \left(\frac{20+26}{2}\right)1.5 = 34.5$$

$$\left(\frac{L}{d}\right)_{Actual} = \frac{3500}{140} = 25 < 34.5$$

Hence the slab is safe against deflection control.