Catalog

DESIGN OF SLABS

Difference between One Way Slab and Two Way Slab

Sr No.	One Way Slab	Two Way Slab
1	The one way slab is supported by a beam on two opposite side only.	The two way slab is supported by the beam on all four sides.
2	In one way slab, the load is carried in one direction perpendicular to the supporting beam.	In two way slab, the load is carried in both directions.
3	One way slab two opposite side support beam /wall	Two Way Slab four side mins all side supported beam /wall
4	One way slab is bend only in one spanning side direction while load transfer	Two way slab is bend both spanning side direction while load transfer
5	One way slab is bend only in one spanning side direction while load transfer	In two-way slab, the crank is provided in four directions.
6	If L/b the ratio is greater than or equal 2 or then it is considered a one-way slab.	If L/b the ratio is less than 2 then it is considered a two-way slab.
7	In one-way slab, the load is carried in one direction perpendicular to the supporting beam.	In two-way slab, the load is carried in both directions.
8	The deflected shape of the one-way slab is cylindrical.	Whereas the deflected shape of the two-way slab is a dish or saucer-like shape.
9	Chajja and Varandha are practical examples of one-way slab.	Whereas two-way slabs are used in constructive floors of the Multistorey building.
10	In one-way slab quantity of steel is less.	In two-way slab quantity of steel is more as

		compared to the one-way slab.
11	Main Reinforcement is in provide short span due to banding.	Main Reinforcement is in provide short span due to banding
12	Ly/Lx ≥ 2 one way slab spanning.	Ly/Lx < 2 two way slab spanning
13	One way slab near about 100mm to 150mm based on the deflection.	two way slabs is in the range of 100mm to 200mm depending upon
14	one way slab economical near about 3.5 m.	Two way slab may economical for the panel sizes near about 6m x 6m.

ANALYSIS AND DESIGN OF CANTILEVER SLABS

INTRODUCTION

A slab is like a flat plate loaded transversely and supported on its edges. Under the loads, it bends and the directions of its bending depend on its shape and support conditions. A beam bends only in one direction, i.e. in its own plane; where as a slab may have multidirectional bending. Therefore, slabs may have different names depending upon its bending, support conditions and shapes. For example, a slab may be called

(a) One-way simply supported rectangular slab,
(b) Two-way simply supported or restrained rectangular slab,
(c) Cantilever rectangular slab,
(d) Fixed or simply supported circular slab, etc

One-way slab means it bends only in one direction and, therefore, reinforcement for bending (i.e. main reinforcement) is provided only in that direction. A slab supported on all sides bends in all the directions so the main reinforcements provided shall be such that they may be effective in all directions. For ease of analysis and convenience of reinforcement detailing, the bending moments in a slab are calculated in two principal directions only and, therefore, such a slab is called a two-way slab.

A slab is designed as a beam of unit width in the direction of bending. In this unit, only the most commonly used rectangular slabs, with uniformly distributed load is described.

Objectives

After studying this unit, you should be able to

- describe the design and detailing of cantilever slabs,
- design and explain detailing of one-way and two-way simply supported slabs, and
- explain the design and detailing of two-way restrained slabs

GENERAL PRINCIPLES OF DESIGN AND DETAILING OF SLABS

Following are the general principles for design and detailing applicable to all types of slabs

(a) The maximum diameter of reinforcing bars shall not exceed1/8 th of total thickness (D) of the slab.

(b) Normally, shear reinforcement is not provided in slabs. The shear resistance requirements may, then, be complied either by increasing the percentage of tensile reinforcement or by increasing the depth of slab, but the latter is preferred as it is economical. For solid slabs, the design shear strength for concrete slab shall be τ ,c, K, , where K has the values given IS 800.

(c) To take care of temperature and shrinkage stresses, minimum reinforcement in either direction shall not be less than 0.15 percent and 0.12 percent of total cross section area of concrete section for mild steel and high strength deformed bars, respectively.

(d) To meet the requirement for limit state of cracking the following two rules are observed:

  (i) The horizontal distance between parallel main reinforcement shall not be more than 3 times the effective depth of slab or 300 mm whichever is smaller.

  (ii) The horizontal distance between parallel bars provided against temperature and shrinkage shall not be more than 5 d or 450 mm, whichever is smaller

DESIGN OF SLAB

Definition :

Slab is a thin flexural member used as a floor of structure to support the imposed load

Loads on slab :

Generally in design of horizontal slab two types of loads are considered.

- Dead load
- Imposed load

Dead load :

The dead load in slab comprises of the immovable partitions. Floor finishes weathering courses and primarily its weight .The dead loads are to be determined based on the weight of the materials .

Imposed loads:

Imposed load is the load induced by the intent use or occupancy of the building including the weight of movable partitions load due to impact vibrations.

Basic rules for the design of the slab :

The two main factors to be considered while designing the slab are:

- Strength of the slab against flexure, shear, twisted.
- Stiffness against deflection

One way slab – codal requirements :

When the ratio of the longer span to shorter span is greater than 2, it is called one way slab and bending takes place along one direction. The loads on the slab is transferred to the supports only on the main reinforcement. Hence main reinforcement is provided in the shorter span.

Minimum requirement in slab :

As per clause 26.5.2.1 of IS 456:2000, the reinforcement in either direction ,in slabs shall not be less than 0.12% of the total cross sectional area , when HYSD bars Fe415 are used.

Maximum size of bars in slabs

As per clause 26.5.2.2 of IS 456 :2000 , the reinforcing bars shall not exceed 1/8 of the total thickness of the slab.

DESIGN OF CANTILEVER SLAB

Design a cantilever chajja slab projecting 1m from the support using M20 grade concreteand Fe415 HYSD bars. Adopt a live load of 3kN/m^2.

i. Given

$L = 1$ m

$q = 3$ kN/m^2

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

$f_y = 415$ N/mm^2

$\tau_{bd} = 1.2$N/mm^2 for plain bars for

M20grade concrete

ii. Depth of slab

Effective depth d = (span/7)

= 1000/7 = 142.8 mm

Adopt d = 150 mm

D = 175 mm

Adopt maximum depth of 150 mm at support gradually reducing to 100 mm at the free end.

iii. Loads

Self-weight of slab = 0.5 (0.15 + 0.10) 2.5

= 3.125 kN/m

Live load = 3.000

Finishes = 0.875 kN/m

Total working load = 7.000 kN/m

Design ultimate load w_u = (1.5 x 7.00)

= 10.5 kN/m

iv. Ultimate design moments and shear forces

M_u = $0.5\ w_u L^2$

= $0.5 \times 10.5 \times 1^2$

= 5.25 kNm

V_u = $w_u\ l$

= 10.5 x 1

= 10.50 kN

v. Check for depth

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

= $(0.138 \times 20 \times 10^3 \times 150^2)\ 10^{-6}$

$= 62.10$ kNm

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

Section is under – reinforced.

vi. Reinforcements

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

$$5.25 \times 10^6 = 0.87 \times 415 \times Ast \times 150 \left(1 - \frac{140 \, Ast}{20 \times 1000 \times 150}\right)$$

Solving Ast $= 105 \text{ mm}^2 < Ast_{min}$

Hence provide 10 mm diameter bars at 300 mm centres (Ast = 262 mm^2) in the span direction and the same as distribution reinforcement.

vii. Anchorage length

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

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

$= 470$ mm

viii. Check for deflection control

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

And $k_c = k_f = 1.00$

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

$$= \frac{100 \times 262}{10^3 \times 150}$$

$= 0.174$ mm

$k_t = 1.8$

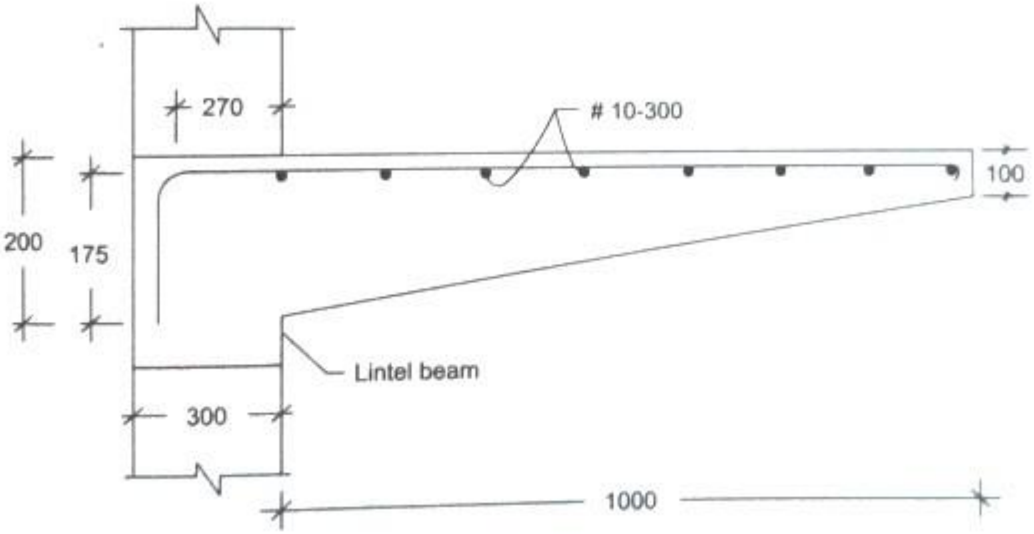
Hence $\left(\frac{L}{d}\right)_{max} = 2.7 \times 1.8 = 12.6$

$$\left(\frac{L}{d}\right)_{Actual} = \frac{1000}{150} = 6.66 < 12.6$$

Hence the slab satisfies the deflection criteria.

ix. Reinforcement details

The reinforcement details in the cantilever slab is shown in fig.



ONE WAY SLAB DESIGN

Design a simply supported one–way slab over a clear span of 3.5 m. It carries a live load of 4kN/m^2 and floor finish of 1.5kN/m^2. The width of supporting wall is 230 mm. Adopt M-20 concrete & Fe-415 steel.

Step: 1 Depth of slab

Assume approximate depth d = L/26

3500/26 = 134 mm

Assume overall depth D = 160 mm

& clear cover 15mm for mild exposured = 160 – 25 = 140mm

Effective span is lesser of the two

i. l = 3.5 + 0.23 (width of support) = 3.73 m

ii. l = 3.5 + 0.14 (effective depth) = 3.64 m

Effective span = 3.64 m

Step: 2 Load on slab

Self-weight of slab = 0.16 x 25 = 4.00

Live load = 4.00

Floor finish = 1.50

Total Load W = 9.5 kN/m^2

Ultimate load Wu = 9.5 x 1.5 = 14.25 kN/m^2

Step 3: Design bending moment and check for depth

$$M_u = \frac{W_u l^2}{8}$$

$$= \frac{14.25 \text{ x } 3.64^2}{8}$$

$$M_u = 23.60 \text{ kN/m}$$

Minimum depth required from BM consideration

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

$$= \sqrt{\frac{23.60 \text{ x } 10^6}{0.138 \text{ x } 20 \text{ x } 1000}}$$

$$d = 92.4 > 140 \quad \text{(OK)}$$

Step: 4 Area of Reinforcement

Area of steel is obtained using the following equation

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

$$23.60 \text{ x } 10^6 = 0.87 \text{ x } 415 \text{ x Ast x } 140 \, (1 - \frac{415 \text{ Ast}}{20 \times 1000 \times 140})$$

$$23.60 \text{ x } 10^6 = 50547 \text{ Ast} - 7.49 \text{ Ast}^2$$

$$\text{Solving Ast} = 504 \text{ mm}^2$$

OR

$$\text{Ast} = \frac{0.5 f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 \, M_u}{f_{ck} \, bd^2}} \right] \text{bd}$$

$$\text{Ast} = \frac{0.5 \text{ x } 20}{415} \left[1 - \sqrt{1 - \frac{4.6 \times 23.60 \times 10^6}{20 \times 1000 \times 140^2}} \right] 1000\text{x}140$$

$$= 505 \text{ mm}^2$$

$$\text{Spacing of 10mm } S_v = \frac{\text{ast}}{\text{Ast}} \text{ x } 1000$$

$$S_v = \frac{78}{505} \text{ x } 1000 = 154\text{mm}$$

Provide 10mm @ 150C/C.

Distribution steel@ 0.12% of the Gross area

$$\frac{0.12}{100} \text{ x } 1000 \text{ x } 160 = 192 \text{ mm}^2$$

$$\text{Spacing of 10mm } S_v = \frac{50}{192} \text{ x } 1000 = 260 \text{ mm}$$

Provide 8mm @ 260mm

Step: 5 Check for shear

$$\text{Design shear } V_u = \frac{W_u \, l}{2}$$

$$= \frac{14.25 \text{ x } 3.64}{2}$$

$$= 25.93 \text{ kN}$$

$$\tau_v = \frac{25.93 \times 10^3}{1000 \times 140}$$

$$= 0.18 \text{ N/mm}^2 \qquad (<\tau_{c\,max} = 28 \text{ N/mm}^2)$$

Shear resisted by concrete $\boldsymbol{\tau_c}$ = 0.42 for $\mathbf{p_t}$ = 0.37 (Table 19, IS 456-2000)

$$\boldsymbol{\tau_c} > \boldsymbol{\tau_v}$$

Step: 6 Check for Deflection

$$\left(\frac{l}{d}\right)_{\text{Actual}} < \left(\frac{l}{d}\right)_{\text{Allowable}}$$

$$\left(\frac{l}{d}\right)_{\text{Allowable}} = \left(\frac{l}{d}\right)_{\text{Basic}} \text{ x } k_1 \text{ x } k_2 \text{ x } k_3 \text{ x } k_4$$

k_1 - Modification factor for tension steel

k_2 - Modification factor for compression steel

k_3 - Modification factor for T-sections

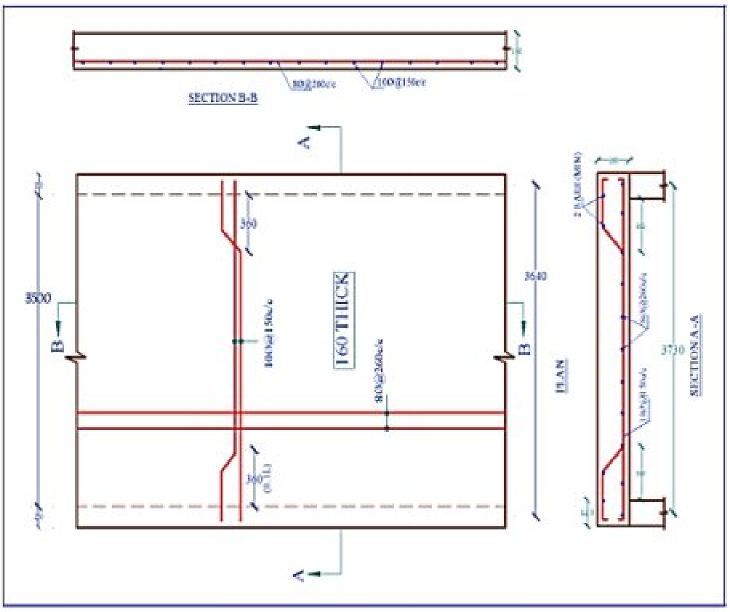
if span exceeds 10 m (10/span)

$\mathbf{k_1}$ = 1.38 for $\mathbf{p_t}$ = 0.37 (Fig. 4, cl.32.2.1)

$$\left(\frac{l}{d}\right)_{\text{Allowable}} = 20 \text{ x } 1.38 = 27.6$$

$$\left(\frac{l}{d}\right)_{\text{Actual}} = 3630/140 = 25.92$$

$$\left(\frac{l}{d}\right)_{\text{Actual}} < \left(\frac{l}{d}\right)_{\text{Allowable}} \quad \text{(OK)}$$



DESIGN OF TWO WAY SLAB

Definition :

Slab is a thin flexural member used as a floor of structure to support the imposed load

Loads on slab :

Generally in design of horizontal slab two types of loads are considered.

- Dead load
- Imposed load

Dead load :

The dead load in slab comprises of the immovable partitions. Floor finishes weathering courses and primarily its weight .The dead loads are to be determined based on the weight of the materials .

Imposed loads:

Imposed load is the load induced by the intent use or occupancy of the building including the weight of movable partitions load due to impact vibrations.

Basic rules for the design of the slab :

The two main factors to be considered while designing the slab are:

- Strength of the slab against flexure, shear, twisted.
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One way slab – codal requirements :

When the ratio of the longer span to shorter span is greater than 2, it is called one way slab and bending takes place along one direction. The loads on the slab is transferred to the supports only on the main reinforcement. Hence main reinforcement is provided in the shorter span.

Minimum requirement in slab :

As per clause 26.5.2.1 of IS 456:2000, the reinforcement in either direction ,in slabs shall not be less than 0.12% of the total cross sectional area , when HYSD bars Fe415 are used.

Maximum size of bars in slabs

As per clause 26.5.2.2 of IS 456 :2000 , the reinforcing bars shall not exceed 1/8 of the total thickness of the slab.

TWO WAY SLAB DESIGN

Design a R.C Slab for a room measuring 6.5mx5m. The slab is cast monolithically over the beams with corners held down. The width of the supporting beam is 230 mm.The slab carries superimposed load of 4.5kN/m^2. Use M-20 concrete and Fe-500 Steel.

Since, the ratio of length to width of slab is less than 2 and slab is resting on beam, the slab is designed as two way restrained slab.

Step: 1 Depth of slab and effective span

Assume approximate depth d = l/30

= 5000/30 = 166mm

Assume D = 180 mm

& clear cover 15 mm for mild exposured

= 180-20 = 160 mm.

Effective span is lesser of the two

i) ly = 6.5+0.23 = 6.73 m ,

lx = 5.0+0.23 = 5.23 m

ii) ly = 6.5+0.16 = 6.66 m,

lx = 5+0.16 = 5.16 m

ly = 6.66 m

lx = 5.16 m

$$\alpha = \frac{l_y}{l_x} = \frac{6.66}{5.16} = 1.3$$

Step 2: Load Calculation

Self-weight of slab = 0.18X25 = 4.50 kN/m^2

Super imposed load = 4.50

Total load = 9.0 kN/m^2

Ultimate load Wu = 9X1.5 = 13.5 kN/m^2

Step 3: Design bending moment and check for depth

The boundary condition of slab in all four edges discontinuous

(case 9, Table 9.5.2)

$$M_x = \propto_x W_u l_x^2$$

$$M_y = \propto_y W_u l_x^2$$

$$\text{For} \quad \frac{l_y}{l_x} = 1.3,$$

$$\propto_x = 0.079$$

$$\propto_y = 0.056$$

Positive moment at mid span of short span M_x $= 0.079 \text{ x } 13.5 \text{ x } 5.16^2$

$= 28.40$ kNm

Positive moment at mid span of longer span M_x $= 0.056 \text{ x } 13.5 \text{ x } 5.16^2$

$= 20.13$ kNm

Minimum depth required from maximum BM consideration

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

$$= \sqrt{\frac{28.40 \text{ x } 10^6}{0.138 \text{ x } 20 \text{ x } 1000}}$$

$$d = 103 \text{ mm}$$

However, provide $d = 160$ mm

Step: 4 Area of Reinforcement

Area of steel is obtained using the following equation.

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

Steel along shorter direction (M_x)

$$28.40 \text{ x } 10^6 = 0.87 \text{ x } 500 \text{x Ast x } 160 \left(1 - \frac{500 \text{ Ast}}{20 \times 1000 \times 160}\right)$$

$$28.40 \text{ x } 10^6 = 69600 \text{ Ast} - 10.875 \text{ Ast}^2$$

Solving Ast $= 438 \text{ mm}^2$

Provide 10 mm @ 175 C/C ($P_t = 0.27\%$)

Steel along shorter direction (M_y)

Since long span bars are placed above short span bars d = 160-10 = 150

$$20.13 \times 10^6 = 0.87 \times 500 \times Ast \times 150 \left(1 - \frac{500\ Ast}{20 \times 1000 \times 150}\right)$$

$$20.13 \times 10^6 = 65250\ Ast - 10.875\ Ast^2$$

Solving, $Ast = 327\ mm^2$

Spacing at 10 mm;

$$\frac{79}{327} \times 100 = 241$$

Provide 10 mm @ 240 mm C/C (<3d = 450)

Step: 5 Check for shear

$$\text{Design shear } V_u = \frac{W_u\, l}{2}$$

$$= \frac{13.5 \times 5.16}{2}$$

$$= 34.83\ kN$$

$$\tau_v = \frac{34.83 \times 10^3}{1000 \times 160}$$

$$= 0.217\ N/mm^2 \qquad (<\tau_{c\,max} = 28\ N/mm^2)$$

Shear resisted by concrete $\boldsymbol{\tau_c} = 0.42$ for $\mathbf{p_t} = 0.37$ (Table 19, IS 456-2000)

$$\boldsymbol{\tau_c > \tau_v}$$

Step: 6 Check for Deflection

$$\left(\frac{l}{d}\right)_{Allowable} = \left(\frac{l}{d}\right)_{Basic} \times k_1$$

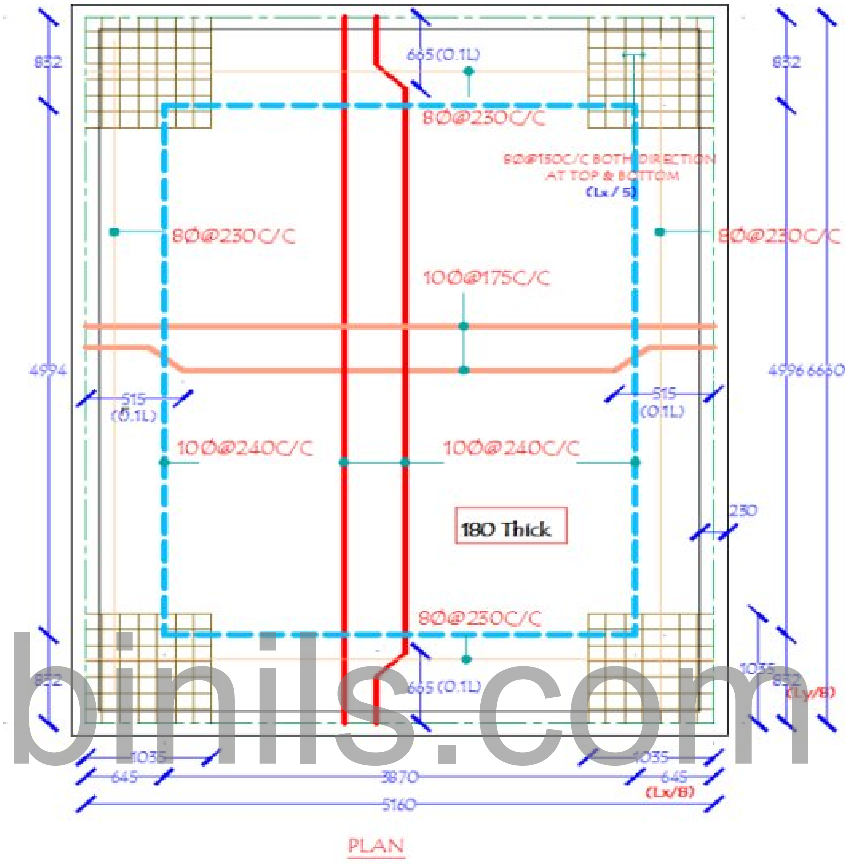
$\mathbf{k_1}$ = 1.5 for $\mathbf{p_t}$ = 0.27% & $f_s = 0.58 \times f_y = 240$

(Fig. 4, cl.32.2.1, IS 456-2000)

$$\left(\frac{l}{d}\right)_{Allowable} = 26 \times 1.5 = 39$$

$$\left(\frac{l}{d}\right)_{Actual} = 5.16/0.16 = 32$$

$$\left(\frac{l}{d}\right)_{\text{Actual}} < \left(\frac{l}{d}\right)_{\text{Allowable}} \quad \text{(OK)}$$



Reinforcement Detail of Two way Restrained slab

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 m

2. clear span + effective depth = 4 + 0.24

= 4.24m

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

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

Four edges are discontinuous,

α_X = 0.089

α_y =0.056

Bending moment:

M_X = 15.59x4.2^2x0.089

= 25.01 kNm

M_Y = 0.056 x 15.93 x 4.2^2

$$= 15.73 \text{ kNm}$$

Shear force :

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

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

$$= 33.45 \text{ KN}$$

Check for Depth :

$M_U = 0.138 f_{ck} bd^2$

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

$$= 95.17 \text{ mm}$$

$$d_{prov} > d_{req}$$

Hence the design is safe.

Area of reinforcement:

For shorter span:

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

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

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

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

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

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

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

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 :

$$i)\ \frac{ast}{Ast} \times 1000 = \frac{\pi/4 \times 10^2}{282.52} \times 1000 = 277.99mm \approx 300\ mm$$

$$ii)\ 3d = 3 \times 160$$

$$= 480mm$$

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	?

$$Y = \tau_c = y_1 + \frac{(y2 - y1)}{(x_2 - x_1)}(x - x_1)$$

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

$$= 0.37 N/mm^2$$

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.

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

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

$$= 222 \text{ mm}^2$$

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

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 $\frac{D}{8}$

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

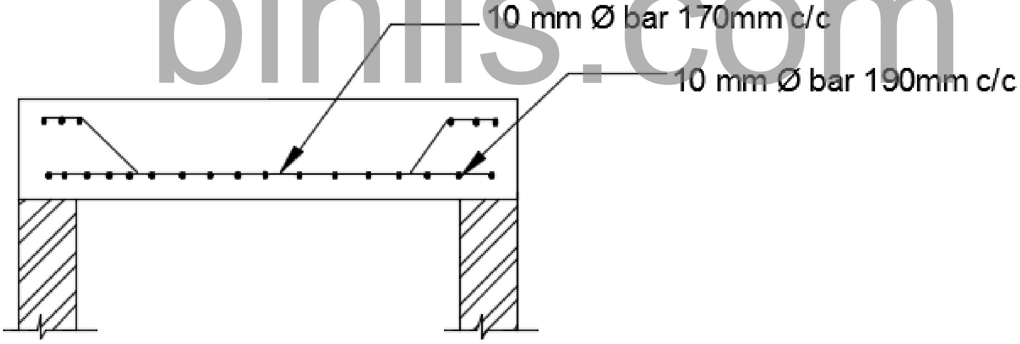
$$\frac{D}{8} = \frac{185}{8}$$

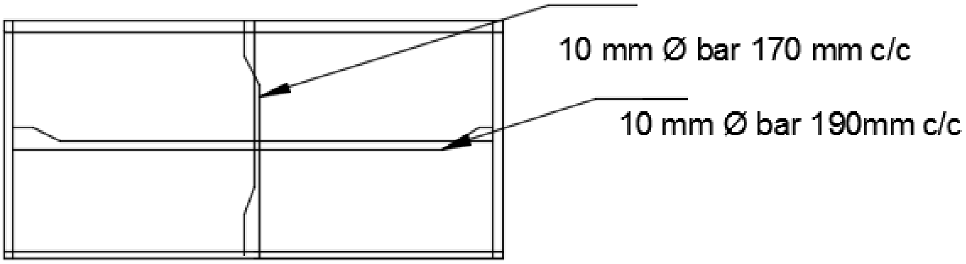
$$= 28.12mm$$

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

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,

$\alpha_X = 0.098$

$\alpha_y = 0.056$

Bending moment:

$M_X = 0.098 \text{ x } 15.2 \text{ x } 3.64^2$

= 19.74 KNm

$M_Y = 0.056 \text{ x } 15.2 \text{ x } 3.64^2$

= 11.24 KNm

Shear force :

$SF = W_U l_e/2$

= (15.2 x 3.64)/2

= 27.66 KN

Check for Depth :

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

$$d = \sqrt{\frac{19.74\times10^6}{0.138\times20\times1000}}$$

$$= 84.57 \text{ mm}$$

$$d_{prov} > d_{req}$$

Hence the design is safe

Area of reinforcement:

For shorter span:

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

$$19.74 \times10^6 = 0.87 \times 415 \times A_{st} \times 140 \left[1 - \frac{Ast \times 415}{1000\times140\times20}\right]$$

$$19.74 \times 10^6 = 50547\, A_{st} - 7.49\, A_{st}^2$$

$$A_{st} = 416.19 \text{ mm}^2$$

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

$$= \frac{0.12}{100} \times 1000 \times 165$$

$$= 198 \text{ mm}^2$$

Provide 10mm dia bar

Spacing :

$$i \quad \frac{ast}{Ast} \times 1000 \qquad = \frac{\pi/4 \times 10^2}{416.9} \times 1000$$

$$= 188.7 \text{ mm}$$

$$\approx 180\text{mm}$$

ii. 3d $\quad = 3 \text{ x } 140$

$$= 420 \text{ mm}$$

Take the least value for spacing

provide 10 mm dia bar 180 mm c/c

For longer span:

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

$$11.24 \times10^6 = 0.87 \times 415 \times A_{st} \times 140 \left[1 - \frac{Ast \times 415}{1000\times100\times20}\right]$$

$A_{st} = 230.2\text{mm}^2$

Spacing :

i. $\frac{ast}{Ast} \times 1000$ $= \frac{\pi/_4 \times 10^2}{230.2} \times 1000$

$= 323.72\text{mm}$

$\approx 300\text{mm}$

ii. 3d $= 5 \times 140$

$= 800\text{mm}$

iii. 300 mm

Take the least value for spacing

provide 10mm diameter bar, 300mm c/c

Check for shear:

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

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

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

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	?

$$Y = \tau_c = y_1 + \frac{(y2 - y1)}{(x_2 - x_1)}(x - x_1)$$

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

$$= 0.38\text{N/mm}^2$$

To find K ,

Overall depth, D $= 165\text{mm}$

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	?

$$Y = K = y_1 + \frac{(y2 - y1)}{(x_2 - x_1)}(x - x_1)$$

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

$$= 1.27$$

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

$$= 0.48 N/mm^2$$

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

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

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

$$= 198\ \text{mm}^2$$

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

Hence it is safe.

5. Spacing is not greater than 3d.

$$3d = 3 \times 140$$

$$= 420\text{mm}$$

$$\text{Spacing} < 3d$$

Hence it is safe.

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

$$d < D/8$$

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

$$= 20.62\text{mm}$$

$$d < D/8$$

Hence it is safe.

Torsion reinforcement in corners:

Area of reinforcement in each corners is,

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

$$= 312.14\ \text{mm}$$

Spacing,

Provide 8 mm Ø bar

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

$$= 161\text{mm}$$

$$\approx 160\text{mm}$$

Length over which the torsion steel is provided,

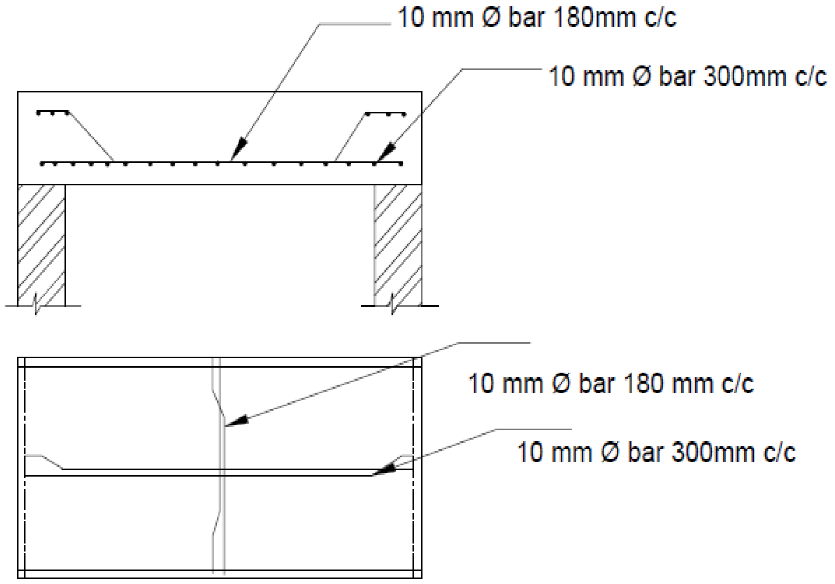
$$= \frac{1}{5} \times \text{shorter span}$$

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

$$= 700\ \text{mm}$$

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/m^2 adopt M$_{20}$ grade concrete and Fe$_{415}$ steel HYSD bars.

Given:

L = 3.5 m

q = 4 kN/m^2

f_{ck} = 20 N/mm^2

f_y = 415 N/mm^2

Step: 1 Depth of slab

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

Effective depth d = (span/26)

= 3500/26 = 135 mm

Adopt d = 140 mm

D = 160 mm

Step: 2 Load calculation

Self-weight of slab = 0.165 x 25 = 4.125 kN/m^2

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:

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

$$= 1.5 \left[\frac{5 \text{ x } 3.5^2}{}\right.$$

Positive BM at centre of span

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

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

$$= 15\ \text{kNm}$$

Step: 4 Shear force calculation

Maximum shear force at the support

$$V_u = 1.5 \times 0.6\ (g + q)\ L$$

$$= (1.5 \times 0.6)\ (5 + 4)\ 3.5$$

$$= 28.35\ \text{kN}$$

Step: 5 Check for Depth of the slab

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

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

$$= 54.1\ \text{kNm}$$

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

Section is under – reinforced.

Step: 6 Reinforcement details

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

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

Solving $Ast = 360\ \text{mm}^2$

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

$$\text{Distribution steel} = 0.0012 \times 10^3 \times 165$$

$$= 198\ \text{mm}^2$$

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

Step: 7 Check for shear stress

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

$$= \frac{28.35 \text{ x } 10^3}{10^3 \text{ x } 140}$$

$$= 0.20 \text{ N/mm}^2$$

$$p_t = \frac{100 \text{ x Ast}}{\text{bd}}$$

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

$$= 0.187$$

Refer to Table 19, IS 456 and readout:

$$k\tau_c = 1.27 \text{ x } 0.30 = 0.38 \text{ N/mm}^2$$

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

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

Also $k_c = k_f = 1.00$

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

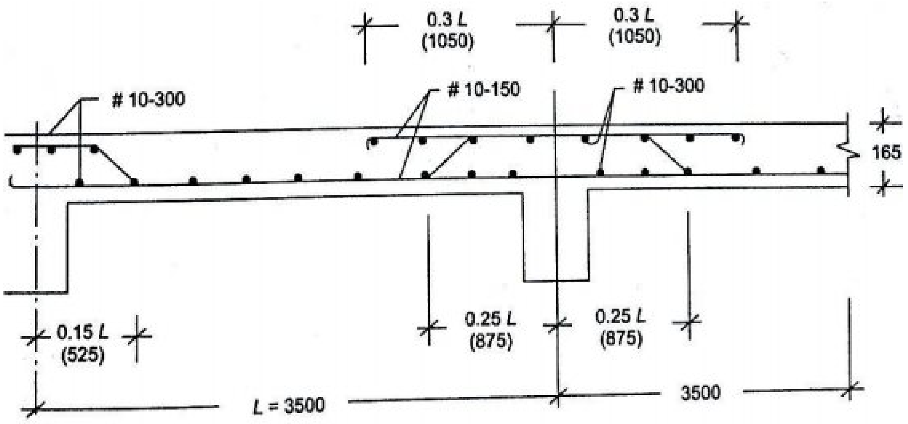
$$= 0.28$$

From Fig.8.1, read out $k_t = 1.5$

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

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

Hence the slab is safe against deflection control.



3.4 TYPES OF STAIRCASE

General

Staircases are generally provided connecting successive floors of a building and in small buildings. They are only means of access between the floors. The staircase comprises of flight of step generally with one or more intermediate landings provides between the floors level.

Dog-legged staircase is the most common type used in all types of buildings . it comprises of two adjacent flights running parallel with a landing slab at mid height.

Loads on staircases

The various types of loads to be resisted by the staircases are grouped under dead and live load

1. Dead load which includes the self-weight of the stair , tread and risers and self weight of finishes
2. Live load to be considered are specified in IS 875-1987 for residential buildings a uniformly distributed live load of 2 to 3 KN/m^2 depending upon the users and for public buildings, a uniformly distributed load of 5KN/m^2 is specifies in the code

TYPES OF STAIRCASE

- Straight stairs
- Quarter turn stairs
- Half turn stairs
- Spiral stairs
- Curved stairs
- Dog legged stair

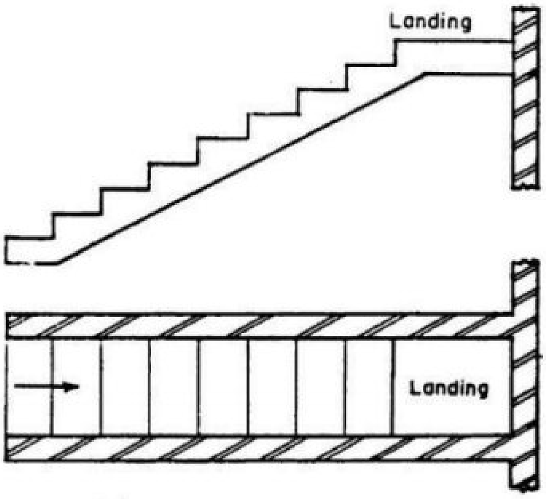
STRAIGHT STAIRS

These are the stairs along which there is no change in direction on any flight between two successive floors. The straight stairs can be of following types.

- Straight run with a single flight between floors
- Straight run with a series of flight without change in direction
- Parallel stairs
- Angle stairs

- Scissors stairs

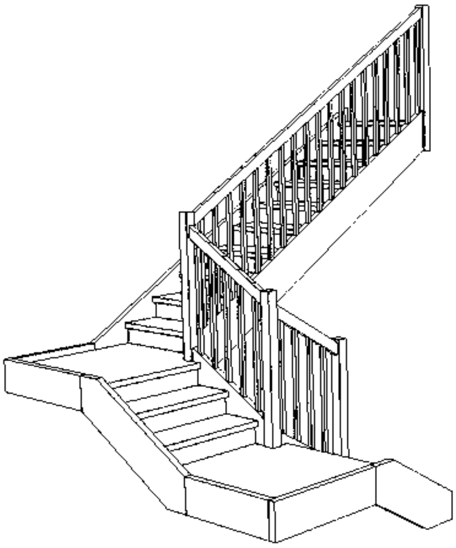
Straight stairs can have a change in direction at an intermediate landing. In case of angle stairs, the successive flights are at an angle to each other. Scissor stairs are comprised of a pair of straight runs in opposite directions and are placed on opposite sides of a fire resistive wall.



Straight Stair with Single Flight

QUARTER TURN STAIRS

They are provided when the direction of flight is to be changed by 90^0. The change in direction can be effected by either introducing a quarter space landing or by providing winders at the junctions.



HALF TURN STAIRS

These stairs change their direction through 180^0. It can be either dog-legged or open newel type. In case of dog legged stairs the flights are in opposite directions and no space is provided between the flights in plan. On the other hand in open newel stairs, there is a well or opening between the flights and it may be used to accommodate a lift. These stairs are used at places where sufficient space is available.

SPIRAL STAIRS

These stairs are similar to circular stairs except that the radius of curvature is small and the stairs may be supported by a center post. Overall diameter of such stairs may range from 1 to 2.5 m.

CURVED STAIRS

These stairs, when viewed from above, appear to follow a curve with two or more centre of curvature, such as ellipse.

DOG LEGGED STAIRCASE:

Dog legged staircase is the simplest type of stairs by which a flight of stairs moves one-half step before 180 degrees and persevering upwards. Due to its appearance in sectional elevation, it is a very common and popular stair consisting of two flights that run in opposite directions separated by a landing in the middle space. These staircases are used when the available space is equal to twice the width of the stairs and stairs lie in their compact layout that has better circulation from a design point of view.