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DESIGN OF STAIRCASES







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INTRODUCTION

STAIRS CONSIST OF STEPS ARRANGED IN A SERIES FOR THE PURPOSE OF GIVING ACCESS TO DIFFERENT FLOORS OF BUILDING.SINCE STAIR IS OFTEN THE ONLY MEANS OF COMMUNICATION BETWEEN THE VARIOUS FLOORS OF BUILDING,THE LOCATION REQUIRES GOOD AND CAREFUL CONSIDERATION.





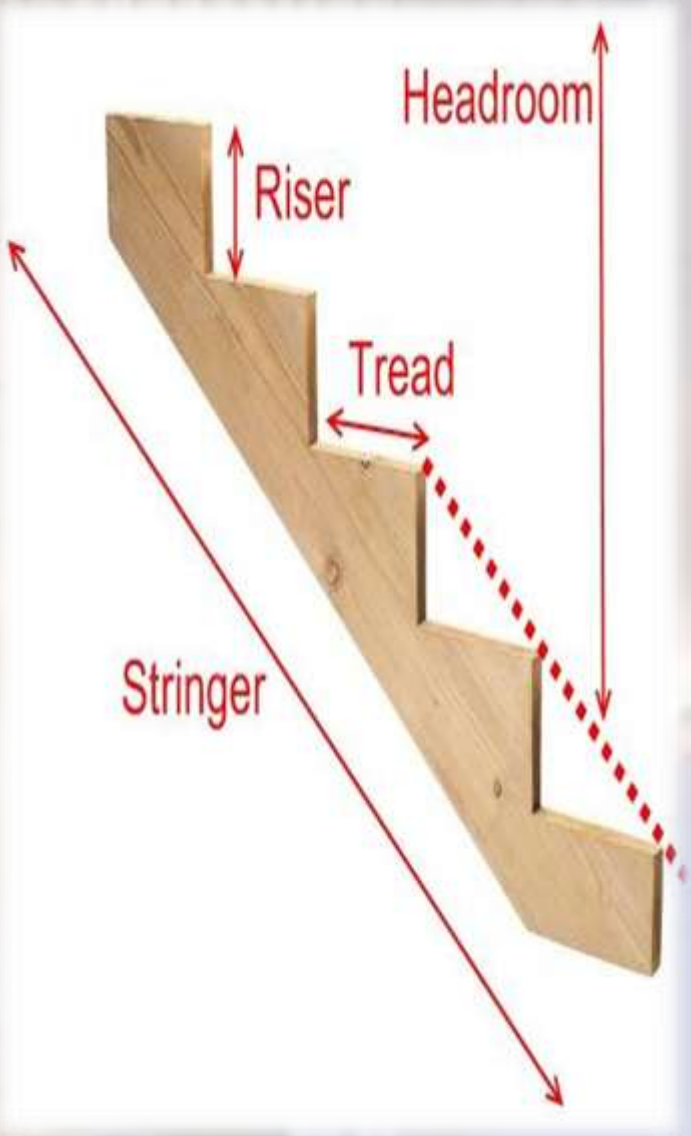


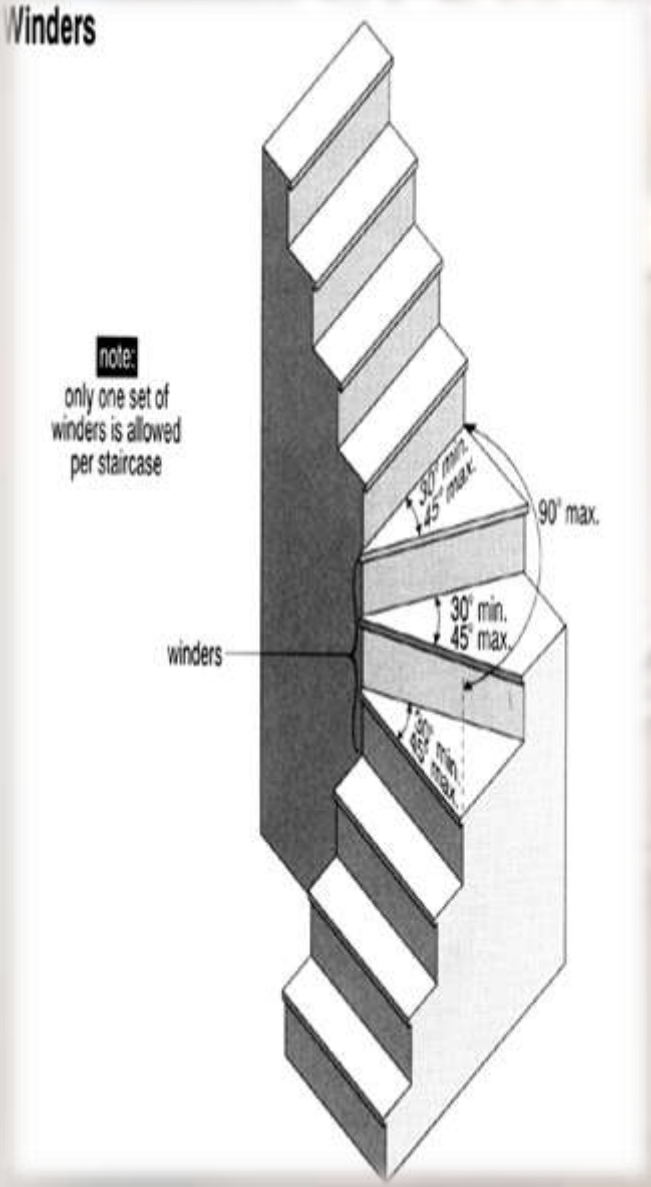
COMPONENTS OF STAIRCASES

TREAD:-THE UPPER HORIZONTAL PORTION OF STEP OVER WHICH FOOT IS PLACED DURING ASCENDING AND DESCENDING A STAIRWAY.

RISER:-THE VERTICAL MEMBER OF STEP.IT IS USED TO SUPPORT AND CONNECT SUCCESSIVE TREADS.

HEADROOM:-THE VERTICAL HEIGHT BETWEEN THE TREAD OF ONE FLIGHT AND CEILING OF OVERHEAD CONSTRUCTION.IT SHOULD BE SUFFICIENT SO AS NOT TO CAUSE ANY DIFFICULTY TO PERSON USING THE STAIRS.





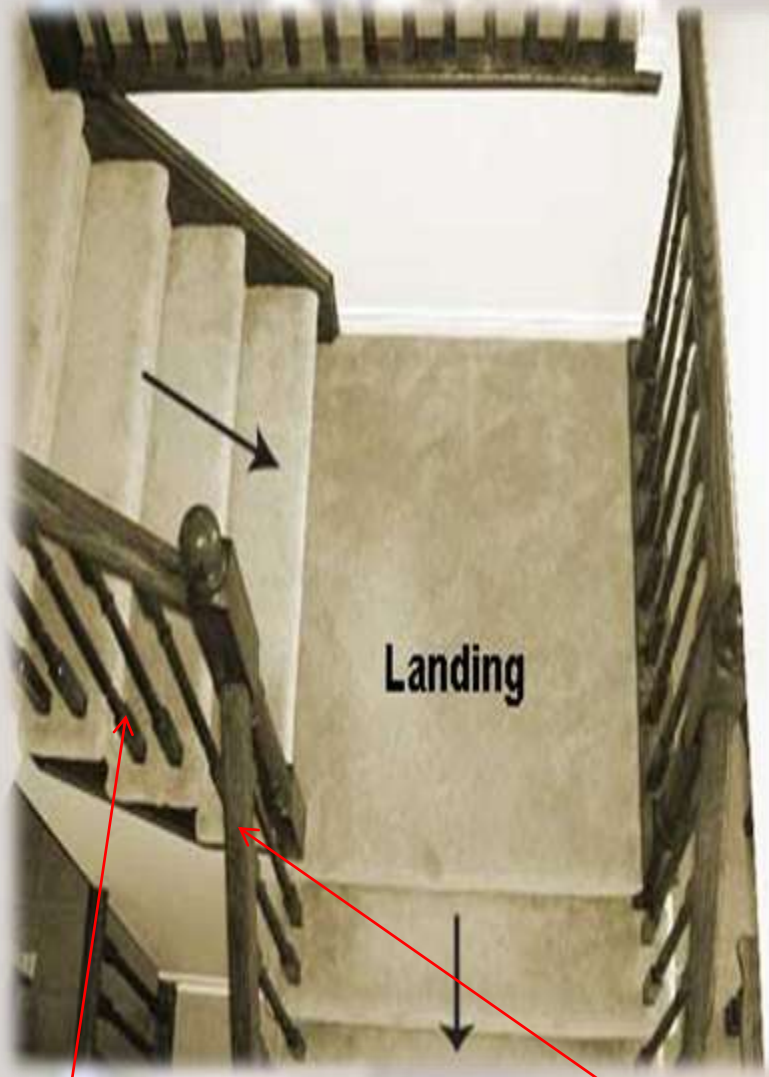
STRINGERS:-THESE ARE THE SLOPING MEMBERS OF THE STAIR,USED TO SUPPORT THE END OF STEPS

WINDERS:-THESE ARE THE STEPS USED FOR CHANGING THE DIRECTION OF STAIRS .THESE ARE USUALLY TRIANGULAR IN PLAN.

FLIGHT:-THIS CONSIST OF SERIES OF STEPS PROVIDED BETWEEN LANDINGS

RUN OR GOING:-TOTAL LENGTH OF STAIRS IN HORIZONTAL PLAIN INCLUDING LENGTH OF LANDINGS

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LANDING:-THIS IS THE HORIZONTAL PLATFORM PROVIDED AT THE HEAD OF SERIES OF STEPS .IT IS USED AS A RESTING PLACE DURING USE OF STAIRS .IT FACILITATES CHANGE OF DIRECTION OF FLIGHT

HAND RAIL:-IT IS AN INCLINED RAIL PROVIDED AT CONVINIENT HEIGHT OVER STEPS .IT SERVES AS GUARD RAIL AND PROVIDE ASSISTANCE TO USER OF STAIRS .

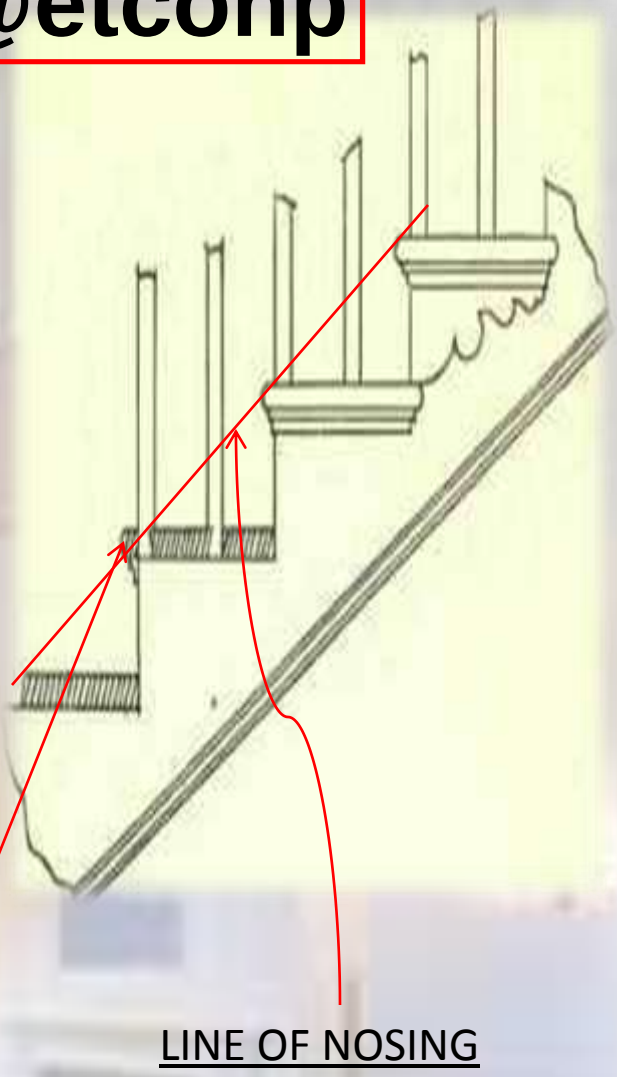
BALUSTERS:-IT IS INDIVIDUAL VERTICAL MEMBER MADE OF TIMBER,METAL OR MASONARY FIXED BETWEEN STRING AND HAND RAIL TO GIVE SUPPORT TO HAND RAIL.

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NOSING:-IT IS THE PROJECTING PART OF TREAD BEYOND THE FACE OF RISER.IT IS USUALLY ROUNDED TO GIVE PLEASING EFFECT TO TREAD AND MAKE STAIRCASE CONVINIENT AND EASY TO USE.

LINE OF NOSING:-THIS IS THE STRAIGHT LINE TOUCHING THE NOSING OF VARIOUS STEPS AND PARALLEL TO SLOPE OF LINE.

PITCH OR SLOPE:-VERTICAL ANGLE MADE BY LINE OF NOSING WITH HORIZONTAL

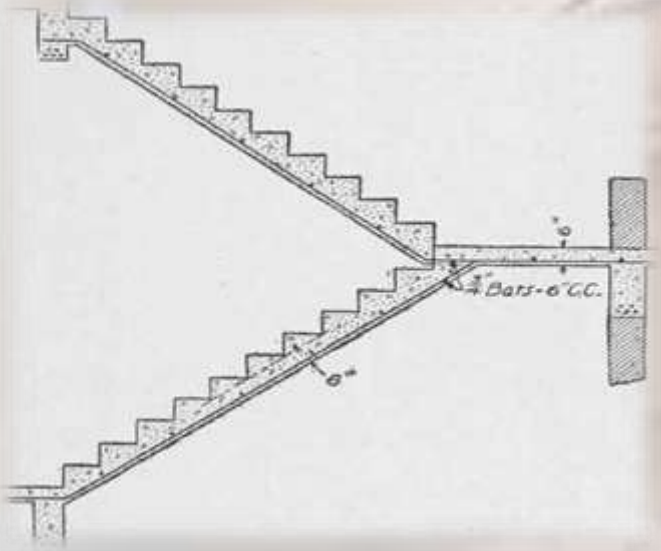


TYPES OF STAIRCASES

STRAIGHT STAIRS:-

- ✓ALL STEPS LEAD IN ONE DIRECTION
- ✓THIS MAY BE CONTINUOUS WITH TWO FLIGHTS WITH AN INTERMIDIATE LANDING
- ✓ADOPTED WHEN STAIRCASE IS NARROW AND LONG
- ✓PROVIDED MOSTLY IN PORCH,ENTRANCE ETC





DOG-LEGGED STAIRS:-

- ✓CONSIST OF TWO STRAIGHT FLIGHTS RUNNING IN OPPOSITE DIRECTIONS
- ✓THERE IS NO SPACE BETWEEN THE FLIGHTS IN PLAN
- ✓LANDING IS PROVIDED AT LEVEL WHICH DIRECTION OF FLIGHT CHANGES



QUARTER TURN NEWEL:-

✓A STAIR TURNING THROUGH 90° WITH THE HELP OF LEVEL LANDING

✓USED IN SHOPS AND PUBLIC BUILDINGS

OPEN NEWEL STAIRS:-

✓POPULARLY KNOWN AS OPEN WELL STAIRS

✓A WELL OR OPENING IS LEFT BETWEEN FORWARD AND BACKWARD FLIGHT

✓THE OPENING IS GENERALLY USED FOR INSTALLATION OF LIFT

✓A SHORT FLIGHT MAY OR MAY NOT PROVIDED IN THESE STAIRS

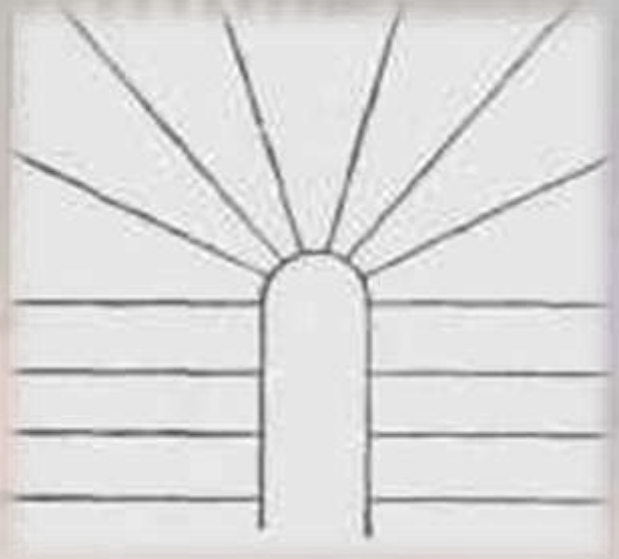


GEOMETRICAL STAIRS :-

✓THESE STAIRS MAY HAVE ANY GEOMETRICAL SHAPE AND THEY REQUIRE NO NEWEL POST

✓THIS TYPE OF STAIR IS SIMILAR TO OPEN NEWEL STAIR EXCEPT THE WELL FORMED BETWEEN FORWARD AND BACKWARD FLIGHT IS CURVED

✓CHANGE OF DIRECTION IN SUCH STAIRS IS ACHIEVED BY WINDERS AND NOT BY LANDINGS





CIRCULAR STAIRS:-

✓ALL THE STEPS ARE RADIATE FROM A NEWI POST OR WELL HOLE

✓ALL THE STEPS ARE WINDERS

✓THIS IS PROVIDED WHERE SPACE IS LIMITED AND TRAFFIC IS CASUAL

✓MOSTLY LOCATED AT REAR OF BUILDING

STRUCTURAL BEHAVIOR OF STAIRCASES

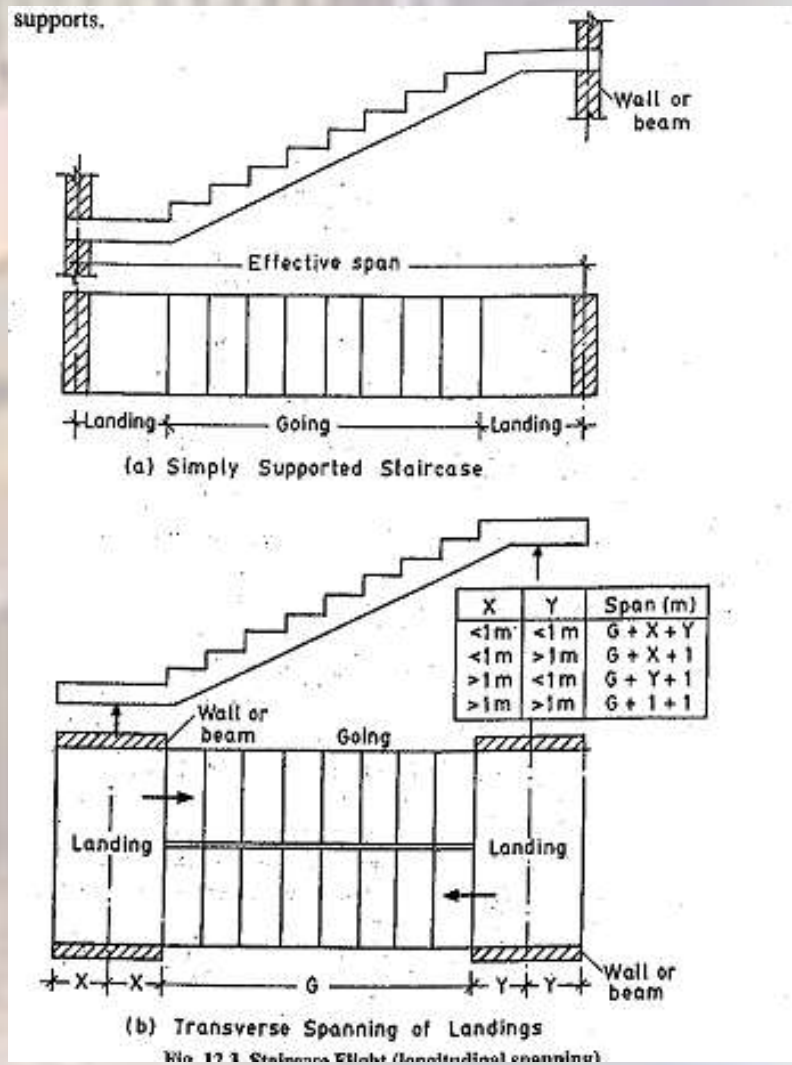
1)STAIRS SPANNING IN LONGITUDINAL DIRECTION:-

✓INCLINED STAIR FLIGHT TOGEATHER WITH LANDING ARE SUPPORTED ON WALL & BEAMS

✓IN FIG (a) THE EFFECTIVE SPAN IS CONSIDERED BETWEEN THE CENTRE TO CENTRE OF SUPPORTS

✓IN FIG (b) OF TRANSVERSE SPANNING OF LANDINGS SPAN IS TAKEN AS SSHOWN IN FIG

✓IN CASE OF OPEN WELL STAIRS WHERE SPAN PARTLY CROSS AT RIGHT ANGLES THE LOAD ON COMMEN AREA MAY DISTRIBUTED AS ONE HALF IN EACH DIRECTION IN FIG (C)



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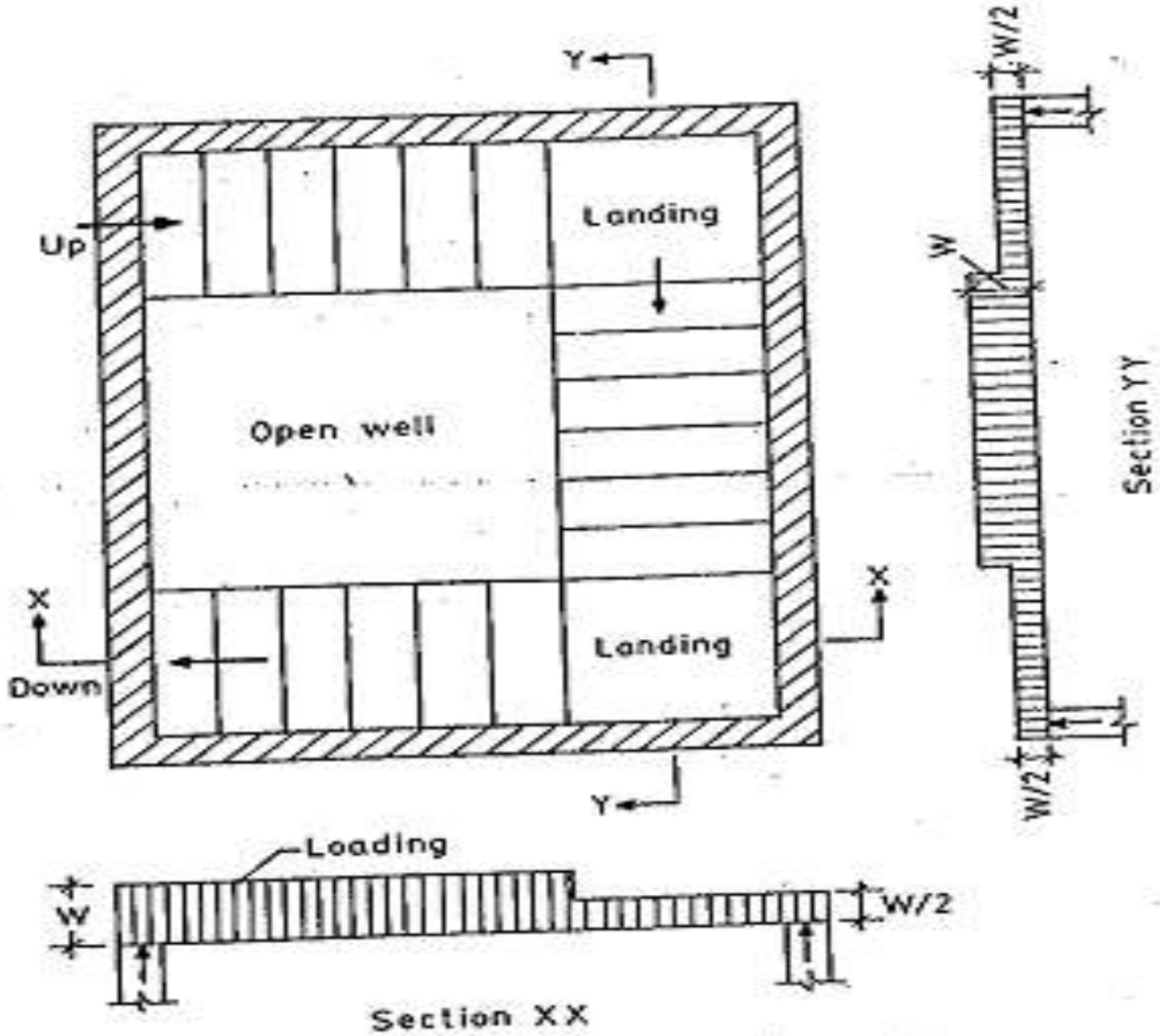


Fig. 12.4 Loading on Stairs With Open Wells

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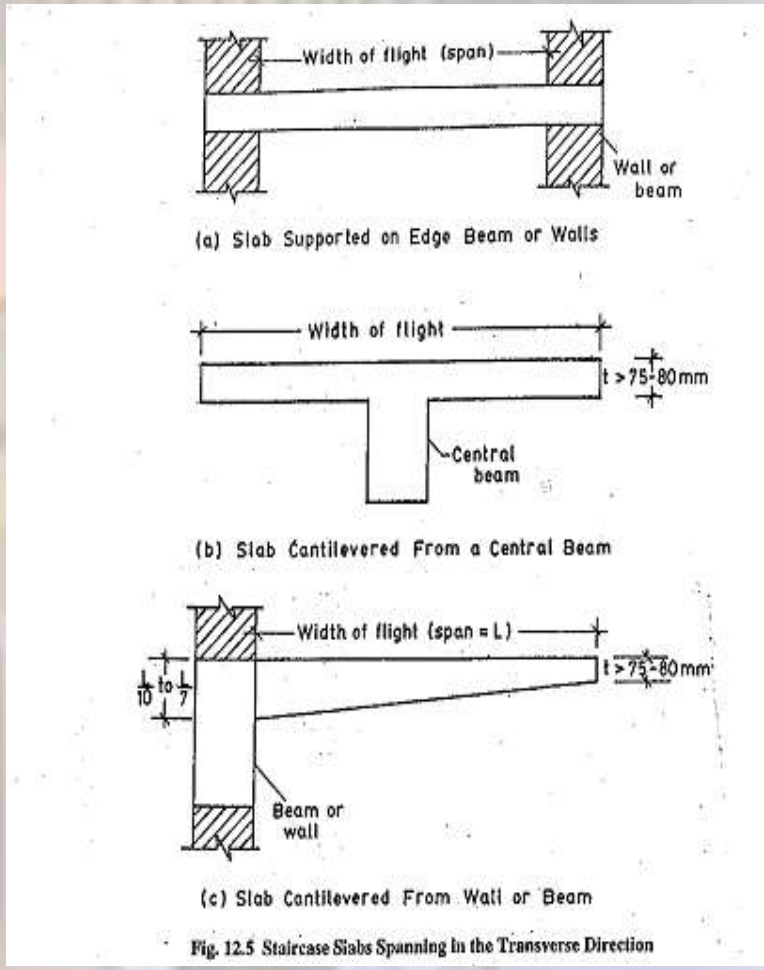
2)STAIR SLAB SPANNING IN THE TRANSVERSE DIRECTION:-

✓FOLLOWING ARE THE MOST COMMON EXAMPLES OF SLAB SPANNING IN TRANSVERSE DIRECTION AS SHOWN IN FIGURE

✓IN THESE SLABS WIDTH OF FLIGHT BEING SMALL(1-1.5M)

✓MINIMUM THICKNESS OF 75 TO 80 MM SHOULD BE PROVIDED

✓MINIMUM PERCENTAGE REINFORCEMENT TO RESIST MAX BENDING MOMENT SHOULD BE PROVIDED



POINTS OF CONSIDERATIONS

✓LANDING

THE WIDTH OF THE LANDING SHOULD NOT BE LESS THAN THE WIDTH OF STAIRS

✓WIDTH OF STAIRS

RESIDENTIAL:-0.8 TO 1 M

PUBLIC :- 1.8 TO 2 M

✓TREAD

RESIDENTIAL:-220-250 MM

PUBLIC:- 250-300MM

NOT LESS THAN 200MM IN ANY CASE

✓ RISER

RESIDENTIAL:-150-180 MM

PUBLIC:- 120-150MM

NOT MORE THAN 200MM IN ANY CASE

✓PITCH

SHOULD NOT BE MORE THAN 38°

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✓HEAD ROOM CLEARENCE

SHOULD NOT BE LESS THAN 2.1M

✓LENGTH OF FLIGHT

NO OF STEPS SHOULD BE MINIMUM 3 AND MAXIMUM 12

DESIGN STEPS

1) GEOMETRICAL DESIGN:-

ASSUME SUITABLE TREAD AND RISER

NO OF RISER= (F/F HEIGHT)/ RISE

NO OF RISERS IN ONE FLIGHT=0.5×(NO OF RISERS)

NO OF TREAD = (NO OF RISERS —1)

GOING DISTANCE= (NO OF TREAD) × (TREAD WIDTH)

WIDTH OF LANDING ≥ WIDTH OF STAIR

2) STRUCTURAL DESIGN:-

2.1) EFFECTIVE SPAN CALCULATION:-

EFFECTIVE SPAN CALCULATION=C/C DISTANCE BETWEEN SUPPORTS

IF NOT GIVEN WIDTH OF SUPPORT CAN BE TAKEN IN BETWEEN 200 TO 300 MM

2.2)TRIAL DEPTH OF WAIST SLAB:-

ACCORDING TO IS 456:2000 ARTICLE 23.2.1 BY CALCULATING RATIO OF SPAN TO EFFECTIVE DEPTH AND AFTER THAT RATIO IS MULTIPLYING BY THE MODIFICATION FACTOR

Table 7.1 Basic Span-Effective depth Ratios for Beams and Slabs.
(Clause 23.2.1 of IS: 456-2000)

Type of Support	Rectangular Sections	Flanged Sections
Cantilever	7	Multiply Values for rectangular sections by factor K_f (Refer Fig. 7.4)
Simply supported	20	
Continuous	26	

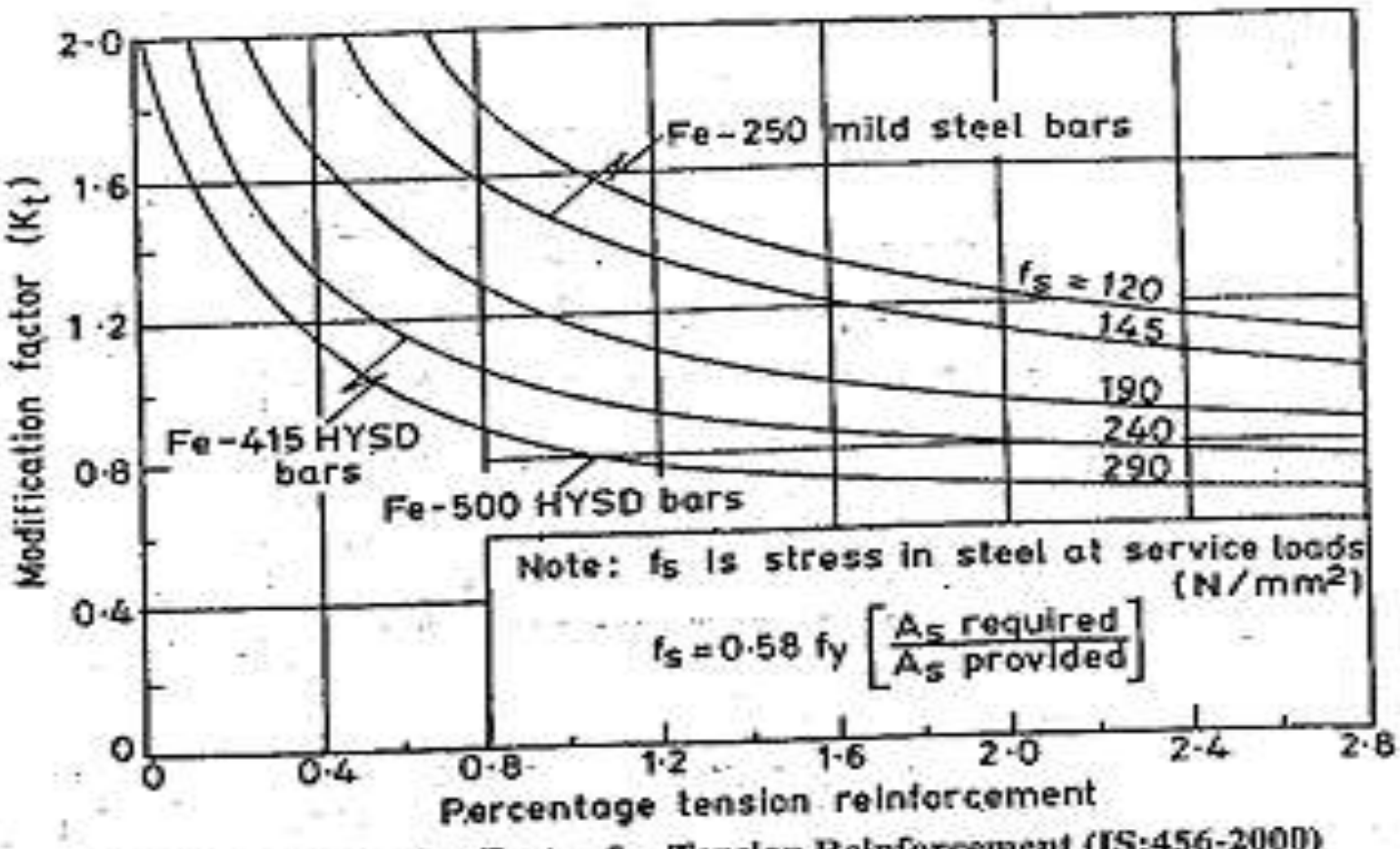
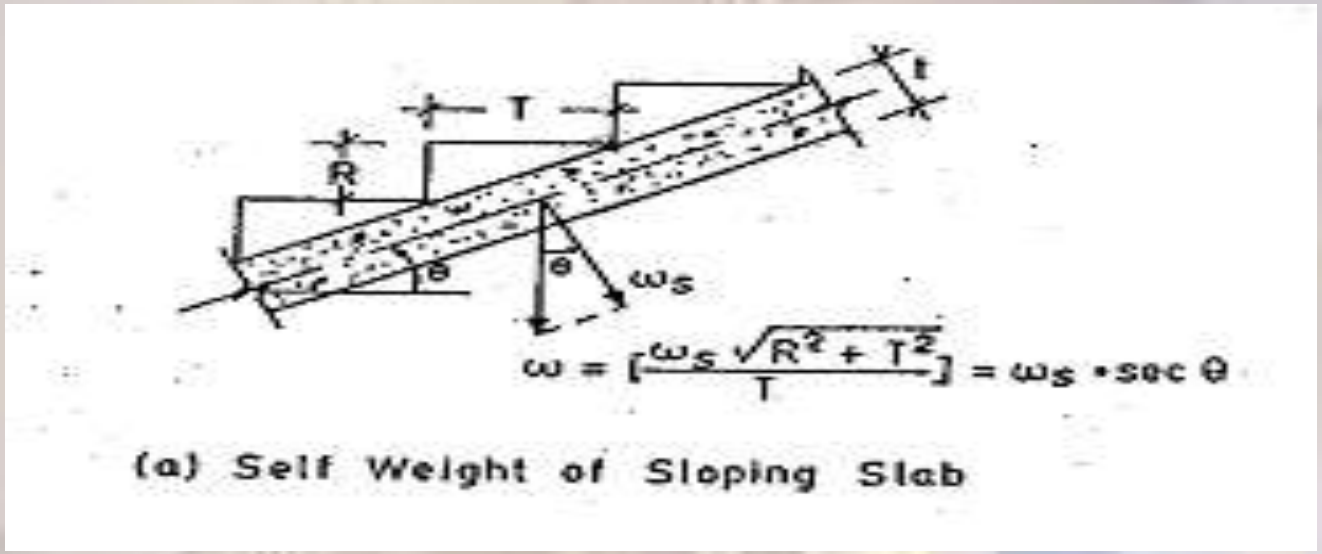


Fig. 7.2 Modification Factor for Tension Reinforcement (IS:456-2000)

MODIFICATION FACTOR CAN BE CALCULATED BY ASSUMING % OF TENSION REINFORCEMENT

ALTERNATE METHOD:-

1) THE THICKNESS OF WAIST SLAB(t) NORMAL TO SLOPE CAN BE ASSUMED AS (L/20) FOR SIMPLY SUPPORTED SLAB (L/25) FOR CONTINUOUS SLAB WHEN WAIST SLAB SPANNING IN LONGITUDINAL DIRECTION



(a) Self Weight of Sloping Slab

2) IN CASE OF TREAD-RISER STAIRS SPANNING LONGITUDINALLY THE THICKNESS OF RISER & TREAD SLAB KEPT SAME WITH VALUES OF (SPAN/25) FOR SIMPLY SUPPORTED AND (SPAN/30) FOR CONTINUOUS STAIRCASES

(MINIMUM THICKNESS OF 80 MM SHOULD BE PROVIDED)

3) LOAD CALCULATION:-

CALCULATIONS SHOULD BE MADE BY CONSIDERING WIDTH OF SLAB EQUAL TO 1 METRE

3.1) SELF WEIGHT OF SLAB = $25 \times D \times \sqrt{(R^2+T^2)}/T$ (KN-M)

3.2)WT OF STEPS = $25 \times 0.5 \times R$ (KN-M)

3.3)WT OF FLOOR FINISH = 1×1 (KN-M) (ASSUME)

3.4)LIVE LOAD = 3 KN/M² (RESIDENTIAL BUILDING)
= 4-5 KN/M² (PUBLIC BUILDING)

3.5) NET LOAD(W) = $W_1 + W_2 + W_3 + W_4$

3.6)FACTORED LOAD = $W' = 1.5 \times W$

4) CALCULATION OF DESIGN MOMENTS:-

FIND MAX BENDING EITHER BY DRAWING SHEAR FORCE AND BENDING MOMENT DIAGRAM OR BY CONSIDERING IT EQUALS TO ($0.125W' \times L^2$)

5)CHECK FOR EFFECTIVE DEPTH:-

$$d = \sqrt{(M/(Ru \times b))} \leq d \text{ provided}$$

6)CHECK FOR REINFORCEMENT:-

6.1)CALCULATE MAIN STEEL(Ast)

$$Ast = 0.5Fck/Fy \times (1 - \sqrt{(1 - (4.6M/Fckbd^2))})bd$$

$Ast \geq Ast\ minimum$

FOR Fe 250 — Ast min = 0.12 % of GROSS AREA

FOR Fe 415 — Ast min = 0.15 % of GROSS AREA

6.2) PROVIDE SUITABLE DISTRIBUTION STEEL=Ast min

7) CHECK FOR SHEAR:-

7.1)CALCULATE MAX DESIGN SHEAR FORCE:-

$$Vud = 0.5 \times W'L$$

7.2)CALCULATE SHEAR RESISTED BY CONCRETE:-

$$Vuc = k \times \tau c \times b \times d$$

$$Vud < Vuc$$

VALUES OF "τc" AND "k" CAN BE OBTAINED BY THE FOLLOWING TABLES

Overall depth of slab (mm)	300 or more	275	250	225	200	175	150 or Less
k	1.00	1.05	1.10	1.15	1.20	1.25	1.30

Table 6.14 Design Shear Strength of Concrete (τ_c, N/mm^2)
(Table-19 of IS: 456-2000)

$100A_s/bd$	Concrete Grade					
	M-15	M-20	M-25	M-30	M-35	M-40 and above
(1)	(2)	(3)	(4)	(5)	(6)	(7)
≤ 0.15	0.28	0.28	0.29	0.29	0.29	0.30
0.25	0.35	0.36	0.36	0.37	0.37	0.38
0.50	0.46	0.48	0.49	0.50	0.50	0.51
0.75	0.54	0.56	0.57	0.59	0.59	0.60
1.00	0.60	0.62	0.64	0.66	0.67	0.68
1.25	0.64	0.67	0.70	0.71	0.73	0.74
1.50	0.66	0.72	0.74	0.76	0.78	0.79
1.75	0.71	0.75	0.78	0.80	0.82	0.84
2.00	0.71	0.79	0.82	0.84	0.86	0.88
2.25	0.71	0.81	0.85	0.88	0.90	0.92
2.50	0.71	0.82	0.88	0.91	0.93	0.95
2.75	0.71	0.82	0.90	0.94	0.96	0.98
3.00 and above	0.71	0.82	0.92	0.96	0.99	1.01

Notes: The term A_s is the area of longitudinal tension reinforcement which continues at least one effective depth beyond the section being considered except at support where the full area of tension reinforcement may be used provided the detailing conforms to Clauses 26.2.2 and 26.2.3

8) PROVISION OF DEVELOPMENT LENGTH:-

$$Ld\ req = (0.87 \times Fy \times \Phi)/4 \times \tau$$

WHERE

Φ = DIAMETRE OF BAR PROVIDED

τ = DESIGN BOND STRESS

9) CHECK FOR DEFLECTION:-

CALCULATE ACTUAL % OF REINFORCEMENT

L/d provided < L/d max

10) SUMMARY AND DETAILING

NUMERICAL PROBLEM

12.4.1 Design one of the flights of stairs of a school building spanning between landing beams to suit the following data.

a) Data

Type of staircase:- Waist slab type
Number of steps in flight = 12
Tread T = 300 mm
Riser R = 160 mm
Width of landing beams = 400 mm
Materials: M-20 Concrete and Fe-415 HYSD bars

b) Effective span

Effective span = $L = \{(12 \times 300) + 400\} = 4000$ mm

Thickness of waist slab $= \left(\frac{\text{span}}{20}\right) = \left(\frac{4000}{20}\right) = 200$ mm

c) Loads

Dead load of slab (on slope) = $w_s = (0.2 \times 1 \times 25) = 5$ kN/m
Dead load of slab on horizontal span is expressed as,

$$w = \left(\frac{w_s\sqrt{R^2 + T^2}}{T}\right) = \left(\frac{5\sqrt{160^2 + 300^2}}{300}\right) = 5.66 \text{ kN/m}$$

Dead load of one step = $(0.5 \times 0.16 \times 0.3 \times 25) = 0.6$ kN/m
Load of steps/m length = $[0.6 \times (1000/300)] = 2$ kN/m
Finishes = 0.6 kN/m
∴ Total dead load = $(5.66 + 2 + 0.6) = 8.26$ kN/m
Live load (liable of over crowding) = 5 kN/m
∴ Total service load = 13.26 kN/m
∴ Total Ultimate load = $w_u = (1.5 \times 13.26) = 19.89$ kN/m

d) Bending Moments

Maximum B.M at Centre of span is given by

$$M_u = 0.125\, w_u.L^2 = (0.125 \times 19.89 \times 4^2) = 39.78 \text{ kN.m}$$

e) Check for depth of waist slab

$$d = \sqrt{\frac{M_u}{0.138 f_{ck} b}} = \sqrt{\frac{39.78 \times 10^6}{0.138 \times 20 \times 10^3}} = 120\text{mm}$$

Assuming a clear cover of 20 mm and using 12 mm diameter bars,
Effective depth = $d = [200 - 20 - 6] = 174$ mm
Hence, the effective depth provided is greater than the required depth.

f) Reinforcements

Reinforcements are computed using the relation,

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

Where $f_y = 415\ \text{N/mm}^2$
$f_{ck} = 20\ \text{N/mm}^2$ and $M_u = (39.78 \times 10^6)\ \text{N.mm}$
$d = 174\ \text{mm}$
$b = 1000\ \text{mm}$

Or by using Table-2 of SP:16, read out the percentage reinforcement corresponding to

$$\left(\frac{M_u}{bd^2}\right) = \left(\frac{39.78 \times 10^6}{10^3 \times 174^2}\right) = 1.31$$

$$\therefore \quad p_t = 0.40 = \left(\frac{100 A_{st}}{bd}\right)$$

$$\therefore \quad A_{st} = \left(\frac{0.40 \times 10^3 \times 174}{100}\right) = 696\ \text{mm}^2$$

Provide 12mm diameter bars at 160mm centres ($A_{st} = 707\ \text{mm}^2$) as main reinforcement.

Distribution reinforcement = $(0.0012 \times 10^3 \times 200) = 240\ \text{mm}^2/\text{m}$

Provide 8 mm diameter bars at 200 mm centres ($A_{st} = 251\ \text{mm}^2$)

[illegible] reinforcements in the staircase flight is shown in Fig. 12.9.

The details of reinforcements in the staircase flight is shown in Fig. 12.9.

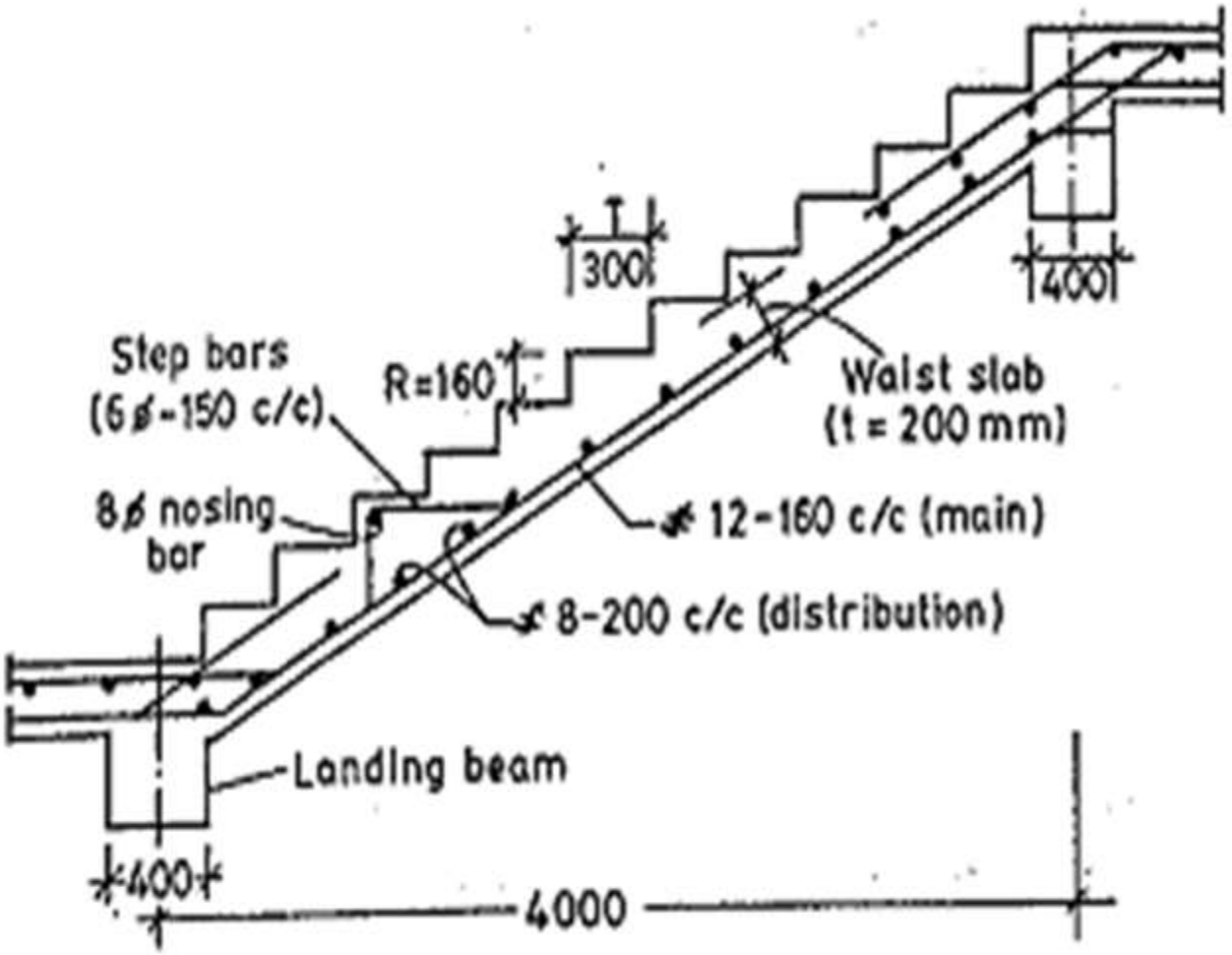


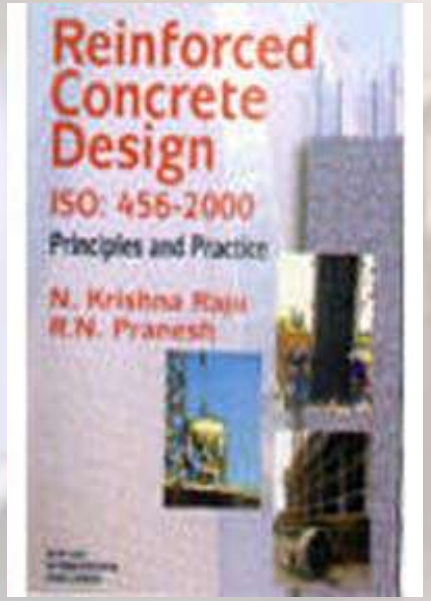
Fig. 12.9 Reinforcement in staircase Flight

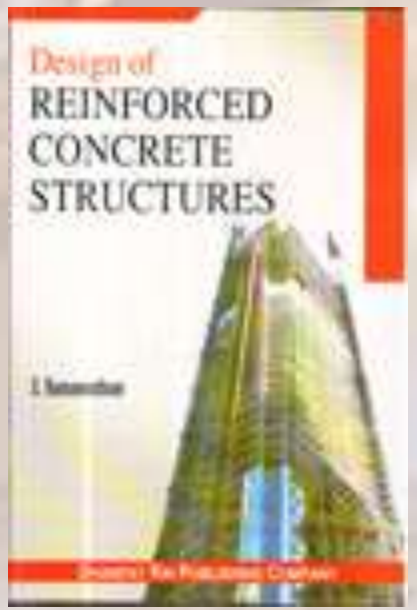
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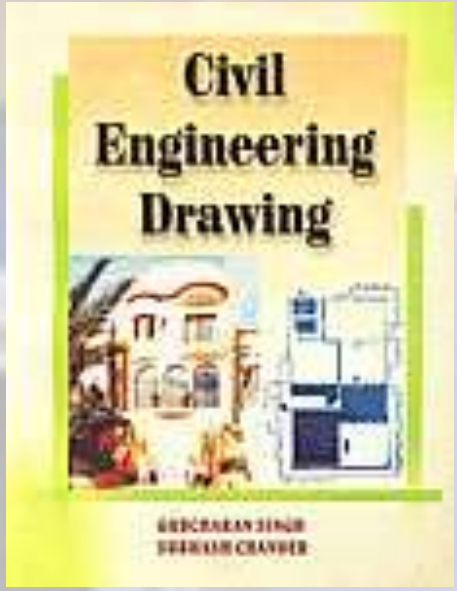
✓REINFORCED CONCRETE DESIGN- N.KRISHNA RAJU,R.N.PRANESH

✓DESIGN OF REINFORCED CONCRETE STRUCUTRES- S.RAMAMRUTHAM

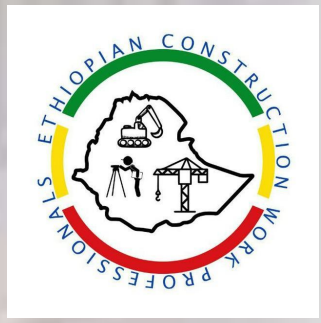
✓CIVIL ENGINEERING DRAWING- GURCHARAN SINGH,SUBHASH CHANDER







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