



SRI VIDYA COLLEGE OF ENGINEERING & TECHNOLOGY
VIRUDHUNAGAR



QUESTION BANK WITH ANSWER

DEPARTMENT: CIVIL **SEMESTER: 06**
SUBJECT CODE /NAME: CE 6601/DESIGN OF REINFORCED CONCRETE AND BRICK
MASONRY STRUCTURES
YEAR: III

UNIT III – SELECTED TOPICS

Design of staircases (ordinary and doglegged staircase)-Design of flat slabs-Design of reinforced concrete walls-principles of design of mat foundation, box culverts and road bridges.

PART - A (2 marks)

1. What are the types of staircases?

(AUC May/Jun-2012) (AUC Nov/Dec-2012) (AUC Nov/Dec-2011)

They are broadly classified as

- Quarter turn stair
- Half turn stair Dog
- legged stair
- Open newer stair with quarter space landing
- Geometrical stairs such as circular stair, spiral stair, etc.

2. Define flat slab.

(AUC May/Jun-2013)

A flat slab is a typical type of construction in which a reinforced slab is built monolithically with the supporting columns and is reinforced in two or more directions, without any provision of beams.

3. What is the thickness of flat slab with drops and without drops? (AUC May/Jun-2013)

- The thickness of the drop shall be 1.25 to 1.5 times the thickness of the slab. The
- thickness of the flat slab without drop is less than 125mm.

4. Distinguish between one way shear and punching shear in flat slabs.

(AUC Nov/Dec-2013)

- The one way shear is located near the column head due to the shear force on the joint. Punching
- shear is located the panels for the shear is created by the loads.

5. What are the load cases for which a box culvert should be designed to remain safe? (AUC Nov/Dec-2013)

- The box culvert is subjected to soil load from outside and water load from inside.

- No water flowing in the drain. The box culvert will be dry from inside, and the sidewalls will be subjected to earth pressure from outside.
- Water in box, which will be subjected to earth pressure from outside and water pressure from inside.

6. What are the limitations of direct design method of flat slabs? (AUC May/Jun-2012)
(AUC Nov/Dec-2011)

- There must be at least three continuous spans in each direction.
- The panels should be rectangular and the ratio of longer span to shorter span within a panel shall not be greater than 2.0.
- The successive span length in each direction shall not differ by more than one third of the longer span. The end spans may be shorter but not longer than the interior spans.
- The design live load should not exceed three times the design dead load.

7. Write the different types of flat slabs? (AUC May/Jun-2013)

- Slabs without drops
- Slab with drops and column with column head

8. What do you mean by column strip and middle strip in flat slab? (AUC Nov/Dec-2012)

Column strip is a design strip having a width of $0.25L_2$ but not greater than $0.25 L_1$ on each side of the column center line where L_1 is the span in the direction, moments are being determined, measured center to center of supports and L_2 is the span traverse to L_1 measured center to center of the support.

Middle strip is a design strip bounded on each of its opposite sides by the column strip.

9. What is a stair case?

A staircase consists of a number of steps arranged in a series, with landings at appropriate locations, for the purposes of giving access to different floors of a building.

10. Define tread

The horizontal portion of a step where the foot rests is referred to, as tread. 250 to 300 mm is the typical dimensions of a tread. Riser is the vertical distance between the adjacent treads or the vertical projection of the step with value of 150 to 190 mm depending upon the type of building.

11. Define Going

Going is the horizontal projection of an inclined flight of steps between the first and last riser.

12. What is a flight?

A flight is the length of the staircase situated between two landings. The number of steps in a flight may vary between 3 to 12.

13. What is the minimum rise and tread in residential buildings?

In residential buildings, the rise may vary between 150mm to 180mm tread between 200mm to 250mm.

14. What is the minimum rise and tread in public buildings?

In public buildings, the rise may vary between 120mm to 150mm tread between 200mm to 300mm.

15. Mention the places where the following staircase can be used

Single flight staircase is used in cellars or attics where the height between floors is small and the frequency of its use is less. Quarter turn staircase flight generally runs adjoining the walls and provides uninterrupted space at the center of the room.

Generally used in domestic houses where floor heights are limited to 3m. Dog legged staircase is generally adopted in economical utilization of available space.

Open well staircases are provided in public buildings where large spaces are available. In congested locations, where space availability is small, Spiral stairs are provided.

16. What are all the components of flat slab?

- Drop of flat slab
- Capital or column head

17. Define drop of flat slab.

Drop is that part of the slab around the column, which is of greater thickness than the rest of the slab.

18. Define capital or column head.

Sometimes the diameter of a supporting column is increased below the slab. This part of column with increased diameter is called column head.

19. Define panel of flat slab.

It is the area enclosed between the center lines connecting adjacent columns in two direction and the outline of the column heads.

20. What are the methods of analysis of flat slab?

- The direct design method
- The equivalent frame method

21. What are all the assumptions made in equivalent frame method?

- The structure is considered to be made of equivalent frames longitudinally and transversely.
- Each frame is analyzed by any established method like moment distribution method.
- Iii The relative stiffness is computed by assuming gross cross section of the concrete alone in the
- Any variation of moment of inertia along the axis of the slab on account of provision of drops
- Slabs without drops and column heads calculation of the moment of inertia should be considered.

22. What are all the assumptions made in direct design method?

- There shall be minimum of three continuous spans in each direction.
- The panel shall be rectangular, and the ratio of the longer span to the shorter span within a panel shall not be greater than 2.0.

23. Explain about box culvert shortly.

Slabs are cast monolithic. A box culvert is used where a small drain crosses a high embankment of a road or a railway or a canal- especially when bearing capacity of soil is low. A box culvert is continuous rigid frame of rectangular section in which the abutment and the top and bottom.

24. Give the names of various types of bridges.

- Solid Slab Bridge or deck slab bridge.
- Deck Girder Bridge or T-beam Bridge.
- Balanced cantilever bridge
- Rigid frame culvert. Bowstring
- Girder Bridge. Continuous girder or
- arch bridge.

PART-B (16 MARKS)**1. Design the interior panel of a flat slab with drops for an office floor to suit the following data:**

Size of office floor=25mx25m

Size of panels=5mx5m Loading

class=4kN/m²

Materials: M20 grade concrete

Fe415 steel

(AUC May/Jun-2013, 2012) (AUC Nov/Dec-2011)

1. Data :

Size of office floor = 25 m by 25 m

Size of panels = 5 m by 5

Loading class = 4 kN/m²

Materials : M-20 grade concrete

Fe-415 HYSD bars

2. Slab thickness

According to IS : 456 code, for two way continuous slabs :

Thickness of slab = (span/40) = (5000/40) = 125 mm

Adopt thickness of slab in middle strip = 150 mm

Thickness of slab at drops = (150 + 50) = 200 mm

Column head diameter is computed as :

$$D \geq 0.25 L = (0.25 \times 5) = 1.25 \text{ m}$$

Length of drop $\leq (L/3)$ in either direction

$$\leq (5/3) = 1.66 \text{ m}$$

Adopt drop width = 2.5 m

 \therefore Column strip = Drop width = 2.5 m

Middle strip width = 2.5 m

Span of flat slab = $L_1 = L_2 = 5 \text{ m}$ **3. Loads**Self weight of slab = $(0.15 \times 25) = 3.75 \text{ kN/m}^2$ in middle stripDead load due to extra thickness of slab at drops = $(0.05 \times 25) = 1.25 \text{ kN/m}^2$

Live load = 4.00

Finishes = 1.00

Working load = $w = 10.00 \text{ kN/m}^2$ Design ultimate load = $w_u = (1.5 \times 10) = 15 \text{ kN/m}^2$

4. *Ultimate bending moment*

$$M_o = \left(\frac{W L_n}{8} \right)$$

where $L_n = (5 - 1.25) = 3.75 \text{ m} > 0.65 L_1 > (0.65 \times 5) = 3.25$

and $L_1 = L_2 = 5 \text{ m}$

$$\therefore W = (w_u L_2 L_n) = (15 \times 5 \times 3.75) = 281.25 \text{ kN}$$

$$M_o = \left(\frac{281.25 \times 3.75}{8} \right) = 132 \text{ kN.m}$$

For interior panels with drops

Column strip moments

$$\begin{aligned} \text{Negative B.M.} &= 49 \text{ per cent of } M_o \\ &= (0.49 \times 132) = 65 \text{ kN.m} \end{aligned}$$

$$\begin{aligned} \text{Positive B.M.} &= 21 \text{ per cent of } M_o \\ &= (0.21 \times 132) = 28 \text{ kN.m} \end{aligned}$$

Middle strip moments

$$\text{Negative B.M.} = 15 \text{ per cent of } M_o = (0.15 \times 132) = 20 \text{ kN.m}$$

$$\text{Positive B.M.} = 15 \text{ per cent of } M_o = (0.15 \times 132) = 20 \text{ kN.m}$$

5. *Check for thickness of slab*

(a) Thickness of slab required at drops :

$$d = \sqrt{\frac{M_u}{0.138 f_{ck} b}} \quad \text{where } b = 2500 \text{ mm}$$

$$\begin{aligned} &= \sqrt{\frac{65 \times 10^6}{0.138 \times 20 \times 2500}} \\ &= 97 \text{ mm} \end{aligned}$$

Effective depth provided = $d = 170 \text{ mm}$

Overall depth = $D = 200 \text{ mm}$

(b) Thickness of slab required in middle strips :

$$d = \sqrt{\frac{20 \times 10^6}{0.138 \times 20 \times 2500}} = 53.8 \text{ mm}$$

Effective depth provided = $d = 120 \text{ mm}$

Overall depth = $D = 150 \text{ mm}$

6. *Check for shear stress*

Shear stress is checked near the column head at section $(D + d)$.

Total load on the circular area with $(D + d)$ as diameter is given by :

$$\begin{aligned} W_1 &= (\pi/4) (D + d)^2 w_u \\ &= (\pi/4) (1.25 + 0.17)^2 15 \\ &= 23.74 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Shear force} &= [(\text{Total load}) - (\text{load on circular area})] \\ &= [(15 \times 5 \times 5) - (23.74)] \\ &= 351.26 \text{ kN} \end{aligned}$$

Shear force/metre width of perimeter

$$V_u = \left[\frac{351.26}{(1.25 + 0.17)} \right] = 78.8 \text{ kN/m}$$

$$\begin{aligned} \therefore \text{Shear stress} &= \tau_v = (V_u / b d) = [(78.8 \times 10^3) / (10^3 \times 170)] \\ &= 0.46 \text{ N/mm}^2 \end{aligned}$$

According to clause 31.6.3.1 of IS : 456-2000

Permissible shear stress $= (k_s \tau_c)$

where $k_s = (0.5 + \beta_c)$ and $\beta_c = (L_1/L_2) = (5/5) = 1$

$$\therefore k_s = (0.5 + 1) = 1.5 > 1.0$$

$$\therefore k_s = 1.0$$

$$\tau_c = 0.25 \sqrt{f_{ck}} = 0.25 \sqrt{20} = 1.12 \text{ N/mm}^2$$

$$k_s \tau_c = (1 \times 1.12) = 1.12 \text{ N/mm}^2$$

Hence $\tau_v < k_s \tau_c$

Hence the slab is safe against shear failure.

7. Reinforcement in column and middle strips

(a) Column strip

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

$$(65 \times 10^6) = (0.87 \times 415 A_{st} \times 170) \left[1 - \left(\frac{415 A_{st}}{2500 \times 170 \times 20} \right) \right]$$

Solving $A_{st} = 1122 \text{ mm}^2$ for negative bending moment

$$\therefore A_{st}/\text{metre} = (1122 / 2.5) = 449 \text{ mm}^2$$

Adopt 12 mm diameter bars at 250 mm centres ($A_{st} = 452 \text{ mm}^2$)

A_{st} for positive moment is :

$$(28 \times 10^6) = (0.87 \times 415 A_{st} \times 170) \left[1 - \frac{415 A_{st}}{(2500 \times 170 \times 20)} \right]$$

Solving $A_{st} = 672 \text{ mm}^2$

$$A_{st}/\text{metre} = (1122 / 2.5) = 449 \text{ mm}^2$$

Provide 10 mm diameter bars at 270 mm centres ($A_{st} = 285 \text{ mm}^2$)

(b) *Middle strip*

A_{st} for positive and negative moments is computed as :

$$(20 \times 10^6) = (0.87 \times 415 A_{st} \times 120) \left[1 - \frac{415 A_{st}}{(2500 \times 120 \times 20)} \right]$$

Solving $A_{st} = 474 \text{ mm}^2$

$$\therefore A_{st}/\text{metre} = (474 / 2.5) = 190 \text{ mm}^2$$

Provide 10 mm diameter bars at 300 mm centres ($A_{st} = 262 \text{ mm}^2$)

3. *Reinforcement details*

The details of reinforcement in the flat slab is shown in Fig. 7.7.

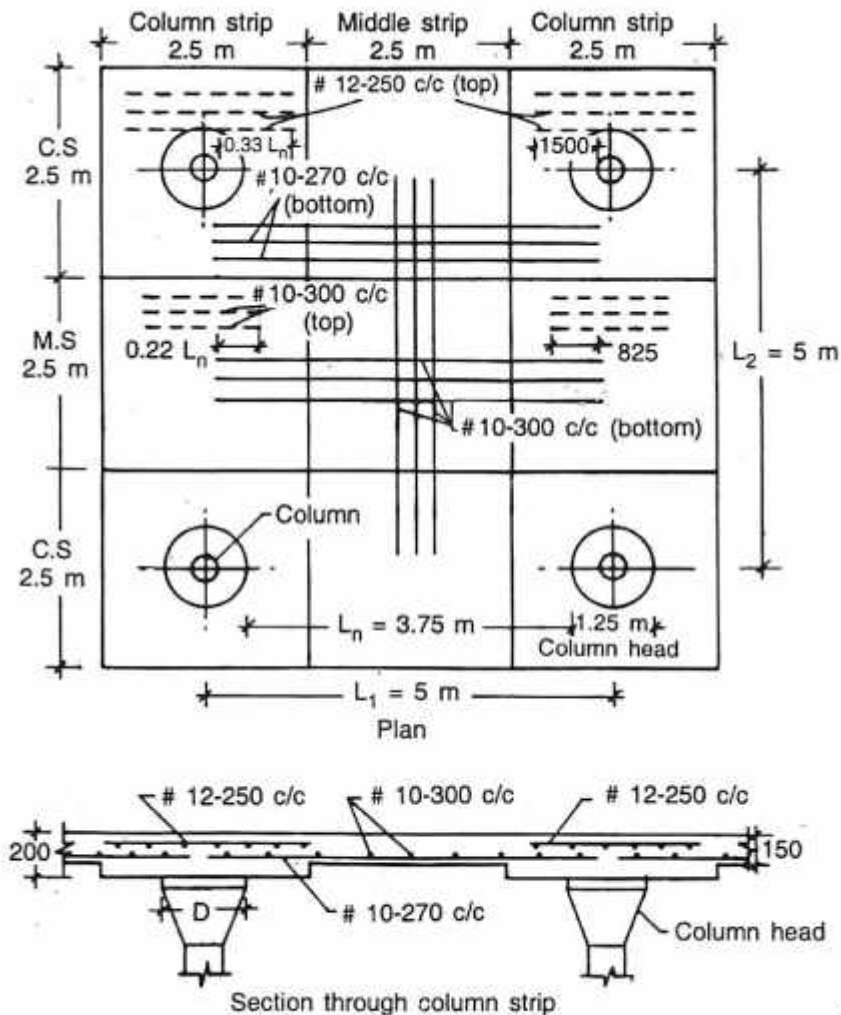


Fig. 7.7. Reinforcement details in flat slab.

2. A straight stair in a residential building is supported on wall at one side and by stringer beam on the other side, with a horizontal span of 1.2m. the risers are 150mm and tread 300mm. design the steps. Use M20 concrete and Fe415 steel. Take live load as 3 kN/m^2 .
(AUC Nov/Dec-2012)

Solution :

$$\begin{array}{lll} R = 150 \text{ mm} & T = 300 \text{ mm} & l = 1.2 \text{ m} \\ f_{ck} = 20 \text{ N/mm}^2 & \text{and} & f_y = 415 \text{ N/mm}^2. \end{array}$$

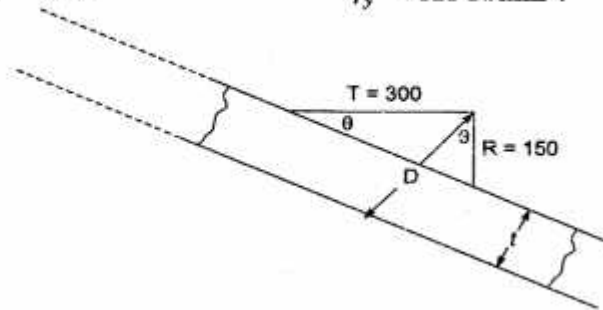


Fig. 10.10.

Referring to Fig. 10.10,

$$b = \sqrt{R^2 + T^2} = \sqrt{150^2 + 300^2} = 335.4 \text{ mm.}$$

$$D = t + R \cos \theta = t + R \frac{T}{b}$$

Taking waist slab thickness t as $\frac{1}{20}$ th span plus cover, we have

$$\begin{aligned} t &= \frac{1}{20} \times 1200 + \text{cover} \\ &= 80 \text{ mm.} \end{aligned}$$

$$\therefore D = 80 + 150 \times \frac{300}{335} = 214 \text{ mm.}$$

$$\therefore \text{Effective depth } d = \frac{D}{2} = \frac{214}{2} = 107 \text{ mm.}$$

Loads:

Loads on each step are calculated as shown below:

D.L of waist slab per metre width of stairs

$$w_1 = 0.080 \times 0.335 \times 1 \times 25 = 0.67 \text{ kN/m}$$

D.L. of each step per metre width of stairs

$$w_2 = \frac{1}{2} \times 0.15 \times 0.30 \times 25 = 0.5625 \text{ kN}$$

Taking finishing load at a rate of 1 kN/m , its value per step $= 1 \times 0.30 = 0.3 \text{ kN/m}$.

$$\begin{aligned} \therefore \text{Total } DL &= 0.67 + 0.5625 + 0.3 \\ &= 1.5325 \text{ kN/m} \end{aligned}$$

Live load $= 0.30 \times 1 \times 3 = 0.90 \text{ kN/m.}$

Total load per metre width of a step

$$= 1.5325 + 0.90 = 2.4325 \text{ kN/m.}$$

$$M_u = 1.5 \times 2.4325 \times \frac{1.2^2}{8} = 0.657 \text{ kN-m.}$$

$$M_{u\text{lim}} = 0.36 f_{ck} b x_{u\text{lim}} (d - 0.42 x_{u\text{lim}})$$

$$x_{u\text{lim}} \text{ for Fe 415 steel} = 0.48 d$$

$$M_{u\text{lim}} = 0.36 f_{ck} b \times 0.48 d (d - 0.42 \times 0.48 d)$$

$$= 0.138 f_{ck} b d^2$$

$$= 0.138 \times 20 \times 335 \times 107^2$$

$$= 10.59 \text{ kN-m.} > M_u.$$

It can be designed as singly reinforced section. Hence tensile reinforcement A_{st} is obtained by

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

$$0.657 \times 10^6 = 0.87 \times 415 A_{st} \times 107 \left[1 - \frac{A_{st}}{335 \times 107} \times \frac{415}{20} \right]$$

$$17.00 = A_{st} \left[1 - \frac{A_{st}}{1727.5} \right]$$

$$A_{st}^2 - 1727.5 A_{st} + 17.00 \times 1727.5 = 0$$

$$A_{st} = 17.17 \text{ mm}^2$$

But minimum steel required is

$$= \frac{0.12}{100} \times 107 \times 335 = 43.0 \text{ mm}^2$$

\therefore Provide one bar of 8mm for each step. Thus

$$A_{st} \text{ provided} = \frac{\pi}{4} \times 8^2 = 50 \text{ mm}^2$$

Distribution Steel:

Distribution steel required per metre width of steps

$$= \frac{0.12}{100} \times 107 \times 1000 = 64.2 \text{ mm}^2.$$

Using 8 mm bars, spacing

$$s = \frac{\frac{\pi}{4} \times 8^2}{64.2} \times 1000 = 778 \text{ mm.}$$

\therefore Provide 8 mm bars at 300 mm c/c.

The details of reinforcements are shown in Fig. 10.11.

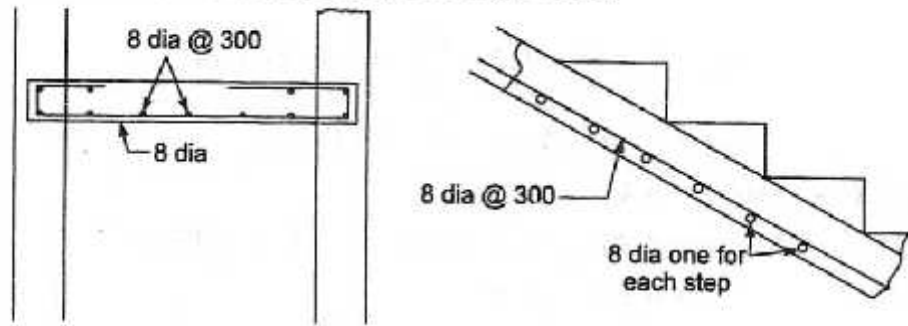


Fig. 10.11.

3. Design a dog legged stairs for an office building in a room measuring 2.8m x 5.8m clear. Vertical distance between the floors is 3.6m. width of flight is to be 1.25m. allow a live load of 3kN/m². sketch the details of the reinforcements. Use M20 concrete and Fe415 steel. Assume the stairs are supported on 230mm walls at the end of outer edges of landing slabs. (AUC May/Jun-2012)

Solution :

Let us select steps of rise 150 mm.

Floor to floor height = 3.6 m

∴ Height of one flight = $\frac{3.6}{2} = 1.8\text{m} = 1800\text{ mm.}$

∴ Number of Risers = $\frac{1800}{150} = 12.$

Hence number of treads required = 12 - 1 = 11.

As width of stairs is 1.25 m, minimum landing width required = 1.25 m.

For 11 treads we need a length of 11 × T. Selecting tread T = 300mm, the steps may be arranged as shown in Fig. 10.12.

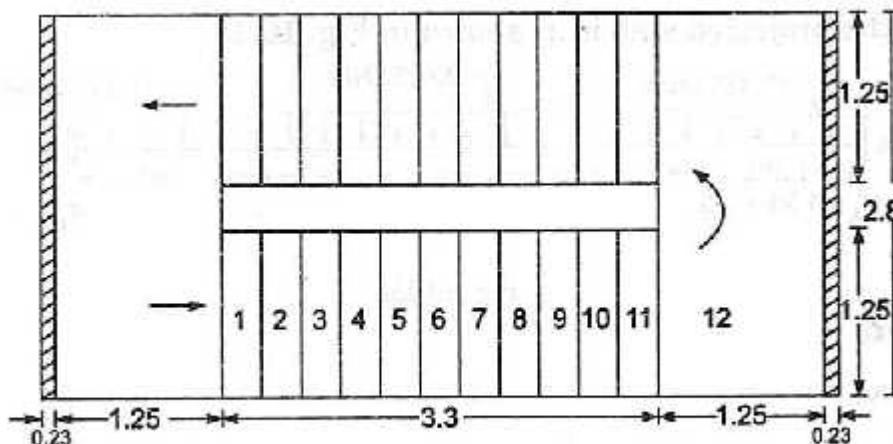


Fig. 10.12.

Effective span:

the stairs slab span longitudinally

$$\begin{aligned}\text{Effective span} &= \text{Centre to centre distance of walls} \\ &= 1.25 + 3.3 + 1.25 + 0.23 \\ &= 6.03 \text{ m}\end{aligned}$$

Loads:

Thickness of waist slab is to be $\frac{1}{20}$ th to $\frac{1}{25}$ th span *i.e.*, 300 to 240 mm.

Let us take $t = 250$ mm and $D = 280$ mm.

Let us find load per metre horizontal width of stairs.

$$\begin{aligned}\therefore \text{Weight of waist slab} &= 0.28 \sqrt{1 + \left(\frac{150}{300}\right)^2} \times 25 \\ &= 7.83 \text{ kN/m}\end{aligned}$$

$$\text{Weight of steps} = \frac{1}{2} \times \frac{0.15 \times 0.25}{0.25} \times 25 = 1.875 \text{ kN/m}$$

$$\therefore \text{Dead load} = 7.88 + 1.875 = 9.7 \text{ kN/m}$$

In going portion with finishing load, let us take

$$DL = 10.5 \text{ kN/m}$$

In landing portion

$$DL = 0.25 \times 1 \times 25 = 6.25 \text{ kN/m}$$

With finishing material, it may be taken as $= 7.25 \text{ kN/m}$

$$\text{Live load} = 3 \text{ kN/m}^2$$

$$\begin{aligned}\therefore \text{Factored load on going per meter horizontal width} \\ &= 1.5 (10.5 + 3) = 20.25 \text{ kN/m}\end{aligned}$$

and on landing slab per metre width total load

$$= 1.5 (7.25 + 3) = 15.375 \text{ kN/m}$$

\therefore Loading on the projected slab is as shown in Fig. 10.13.

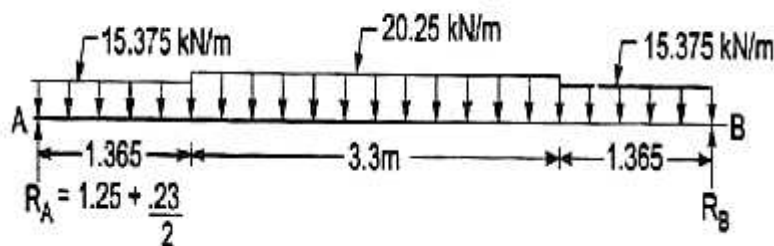


Fig. 10.13.

Design Moment:

Due to symmetry,

$$\begin{aligned} R_A = R_B &= \frac{1}{2} \times \text{total load} \\ &= \frac{1}{2} \times [15.375 \times 1.365 + 3.3 \times 20.25 + 15.375 \times 1.365] \\ &= 54.40 \text{ kN} \end{aligned}$$

Maximum moment occurs at mid span and its value is

$$\begin{aligned} M_u &= 54.40 \times \frac{6.03}{2} - 15.375 \times 1.365 \left(\frac{6.03 - 1.365}{2} \right) - \frac{3.3}{2} \times 20.25 \times \frac{3.3}{4} \\ &= 87.5 \text{ kN-m} \end{aligned}$$

$$M_{u \text{ lim}} = 0.36 f_{ck} b x_{u \text{ lim}} (d - 0.42 x_{u \text{ lim}})$$

For Fe 415,

$$x_{u \text{ lim}} = 0.48d$$

∴

$$\begin{aligned} M_{u \text{ lim}} &= 0.36 f_{ck} b 0.48 d (d - 0.42 \times 0.48 d) \\ &= 0.138 f_{ck} b d^2 \\ &= 0.138 \times 20 \times 1000 \times 250^2 \\ &= 172.5 \times 10^6 \text{ N-mm} > M_u \end{aligned}$$

Hence the section can be designed as singly reinforced.

Reinforcement:

Let A_{st} be the area of reinforcement required.

Then,

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

$$87.5 \times 10^6 = 0.87 \times 415 \times A_{st} \times 250 \left[1 - \frac{A_{st}}{1000 \times 250} \times \frac{415}{20} \right]$$

$$969.39 = A_{st} \left[1 - \frac{A_{st}}{12048} \right]$$

$$\text{i.e., } A_{st}^2 - 12048 A_{st} + 969.39 \times 12048 = 0$$

$$A_{st} = 1063 \text{ mm}^2$$

Using 16mm bars, spacing required

$$S = \frac{\pi/4 \times 16^2}{1063} \times 1000 = 189 \text{ mm}$$

∴ Provide 16mm bars at 180 mm c/c

Distribution steel

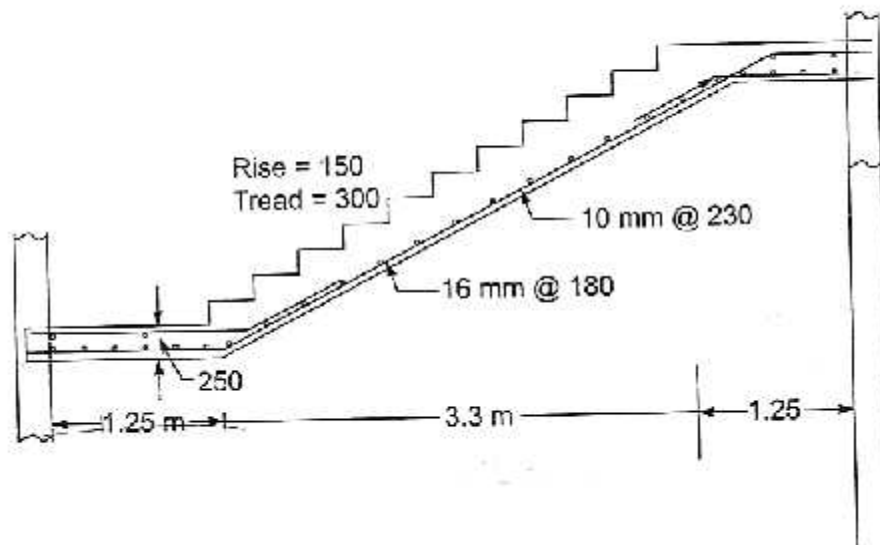
$A_{st} = 0.12$ percent of gross sectional area

$$\frac{0.12}{100} \times 1000 \times 280 = 336 \text{ mm}^2$$

Using 10mm bars, Spacing required

$$S = \frac{\pi/4 \times 10^2}{336} \times 1000 = 233 \text{ mm}$$

Provide 10mm bars at 230 mm c/c



4. Design one of the flights of a dog legged stairs spanning between landing beams using the following data:

Type of staircase: dog legged with waist slab, treads and risers

Number of steps in the flight=10

Rise R=150mm

Tread T=300mm

Width of landing beams=300mm

M20 grade concrete and Fe415 steel.

(AUC May/Jun-2013) (AUC
Nov/Dec-2011)

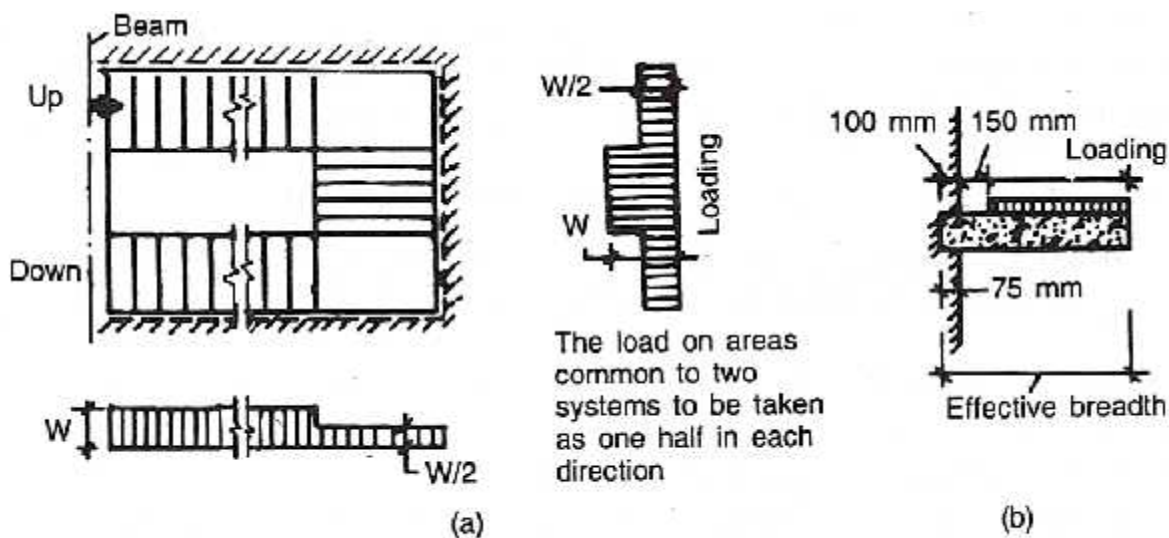


Fig. 9.3. Distribution of loads on stairs (IS : 456-2000).

1. *Data*

Type of stair cases : Dog-legged with waist slab, treads and risers

Number of steps in the flight = 10

Tread $T = 300$ mm

Rise $R = 150$ mm

Width of landing beams = 300 mm

M-20 grade concrete ($f_{ck} = 20$ N/mm²)

Fe-415 HYSD bars ($f_y = 415$ N/mm²)

2. *Effective span*

Effective span = $(10 \times 300) + 300 = 3300$ mm = 3.3 m

Thickness of waist slab = $(\text{span} / 20) = (3300 / 20) = 165$ mm

Adopt overall depth = $D = 165$ mm

Effective depth = $d = 140$ mm

3. *Loads*

Dead loads of slab on slope = $w_s = (0.165 \times 1 \times 25) = 4.125$ kN/m

Dead load of slab on horizontal span is :

$$w = \left[\frac{w_s \sqrt{R^2 + T^2}}{T} \right] = \left[\frac{4.125 \sqrt{150^2 + 300^2}}{300} \right] = 4.61 \text{ kN/m}$$

Dead load of one step = $(0.5 \times 0.15 \times 0.3 \times 25) = 0.56 \text{ kN/m}$

Load of steps per metre length = $\left(\frac{0.56 \times 1000}{300} \right) = 1.86 \text{ kN/m}$

Finishes etc. = 0.53 kN/m

Total dead load = $(4.61 + 1.86 + 0.53) = 7 \text{ kN/m}$

Service live load (liable for over crowding) = 5 kN/m^2

\therefore Total service load = $(7 + 5) = 12 \text{ kN/m}$

Factored load = $w_u = (1.5 \times 12) = 18 \text{ kN/m}$

4. Bending moments

Maximum bending moment at centre of span is :

$$\begin{aligned} M &= 0.125 w_u L^2 \\ &= (0.125 \times 18 \times 3.3^2) \\ &= 24.5 \text{ kN.m} \end{aligned}$$

5. Check for depth of waist slab

$$\begin{aligned} \therefore d &= \sqrt{\frac{M_u}{0.138 f_{ck} b}} = \sqrt{\frac{195 \times 10^6}{0.138 \times 20 \times 10^3}} = 266 \text{ mm} \\ &= 94.2 \text{ mm} < 140 \text{ mm provided (hence safe).} \end{aligned}$$

6. Main reinforcements

$$\begin{aligned} M_u &= (0.87 f_y A_{st} d) \left[1 - \left(\frac{A_{st} f_y}{b d f_{ck}} \right) \right] \\ (24.5 \times 10^6) &= (0.87 \times 415 A_{st} \times 140) \left[1 - \left(\frac{415 A_{st}}{10^3 \times 140 \times 20} \right) \right] \end{aligned}$$

Solving $A_{st} = 530 \text{ mm}^2/\text{m}$

Provide 12 mm diameter bars at 200 mm centres ($A_{st} = 565 \text{ mm}^2$) as main reinforcement.

7. Distribution reinforcement

$$\begin{aligned} \text{Distribution reinforcement} &= 0.12 \text{ per cent of cross section} \\ &= (0.0012 \times 1000 \times 165) \\ &= 198 \text{ mm}^2/\text{m} \end{aligned}$$

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

The details of reinforcements in the stair case is shown in Fig. 9.4.

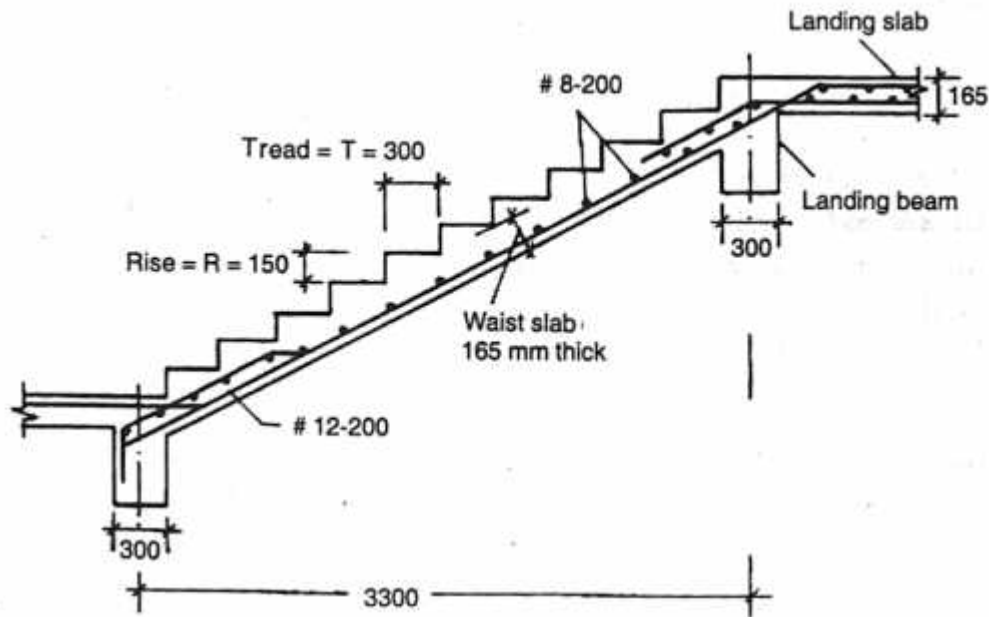


Fig. 9.4. Reinforcement details in a flight of dog legged stair case.

8. Design using SP : 16 design charts

Compute the design parameter :

$$\left(\frac{M_u}{b d^2} \right) = \left(\frac{24.5 \times 10^6}{10^3 \times 140^2} \right) = 1.25$$

Refer Table 2 of SP : 16 design tables corresponding to $f_{ck} = 20 \text{ N/mm}^2$ and read out the percentage of reinforcement as :

$$p_t = 0.376$$

$$\therefore A_{st} = \left(\frac{p b d}{100} \right) = \left(\frac{0.376 \times 10^3 \times 140}{100} \right) = 527 \text{ mm}^2/\text{m}$$

The reinforcement quantity is the same as that obtained by analytical method.

5. the general arrangement of stair case in a multistory housing complex is as shown in fig. the risers are 150mm and treads are 250mm. the stair slab is embedded into the wall by 200mm. the height between floors is 3m. the service live load is 3 kN/m^2 . adopting M20 grade concrete and Fe415 steel bars are used. Design the stair case flight and draw a longitudinal section showing the details of reinforcements in the flight of the stair case.

(AUC Nov/Dec-2013)

1. Data

Risers= $R=150\text{mm}$

Tread= $T=250\text{mm}$

Service live load= 3kN/m^2

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

$F_y=415 \text{ N/mm}^2$

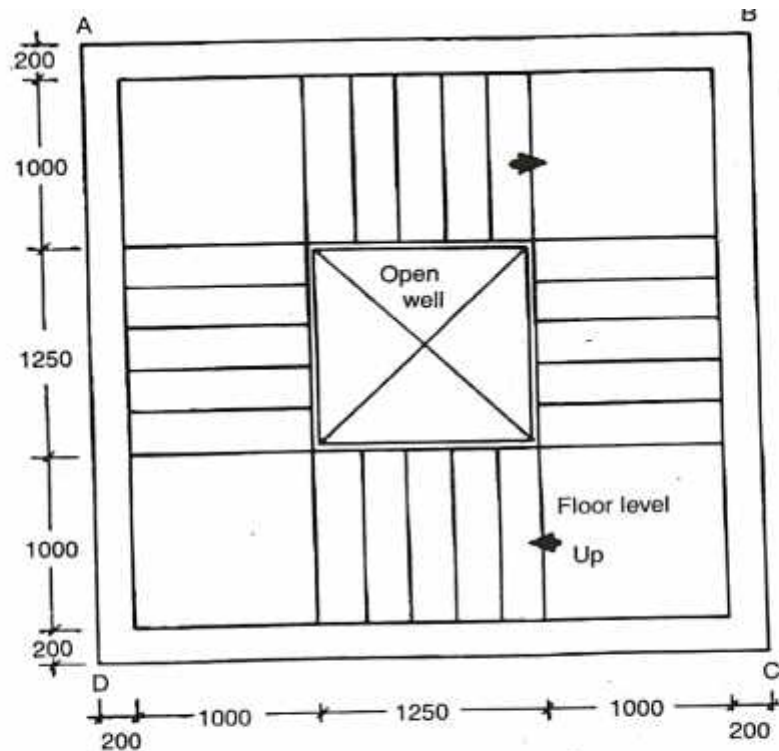


Fig. 9.5. Open well stair case.

2. Effective span

The flights AB, BC, CD and DA are equal in length.

Effective span with 200 mm load bearing wall is computed as :

$$L = (1.00 + 1.25 + 1.00 + 0.2) = 3.45 \text{ m}$$

3. Thickness of waist slab

For simply supported slabs the span to effective depth ratio is equal to 20. Since a portion of the slab (landing slab) is spanning both ways, the ratio can be increased to 25.

Hence $(L/d) = 25$

$$d = (3450 / 25) = 138 \text{ mm}$$

Adopt effective depth = $d = 135 \text{ mm}$ and overall depth = $D = 160 \text{ mm}$

4. Loads

Self weight of slab on horizontal area is computed as :

$$w = \left[(0.16 \times 25) \sqrt{\frac{150^2 + 250^2}{250}} \right] = 4.66 \text{ kN/m}^2$$

Self weight of steps	$= (0.5 \times 0.15 \times 1 \times 25) = 1.87 \text{ kN/m}^2$
Live load	$= 3.00$
Finishes etc.	$= 0.47$
Total load	$= 10.00 \text{ kN/m}^2$
Self weight of landing slab	$= (0.16 \times 25) = 4.00 \text{ kN/m}^2$
Weight of finishes etc.	$= 1.00$
Live load	$= 3.00$
Total load	$= 8.00 \text{ kN/m}^2$

5. *Bending moments and shear forces*

Fig. 9.6 shows the service loads acting on the slab on one of the flights.

$$R_A = [(4 \times 1.1) + (0.5 \times 10 \times 1.25)] = 10.65 \text{ kN}$$

$$M_{\max} = (10.65 \times 1.725) - (4 \times 1.1 \times 1.175) - (0.625 \times 10 \times 0.5 \times 0.625)$$

$$= 11.25 \text{ kN.m}$$

$$V_{\max} = R_A = 10.65 \text{ kN}$$

$$\text{Factored moment} = M_u = (1.5 \times 11.25) = 16.875 \text{ kN.m}$$

$$\text{Factored shear} = V_u = (1.5 \times 10.65) = 15.975 \text{ kN}$$

6. *Check for depth of waist slab*

$$d = \sqrt{\frac{M_u}{0.138 f_{ck} b}} = \sqrt{\frac{16.875 \times 10^6}{0.138 \times 20 \times 10^3}} = 78.19 \text{ mm}$$

Adopted effective depth $= d = 135 \text{ mm}$ (hence safe)

7. *Reinforcements*

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

$$(16.875 \times 10^6) = (0.87 \times 415 A_{st} \times 135) \left[1 - \left(\frac{415 A_{st}}{10^3 \times 140 \times 20} \right) \right]$$

Solving $A_{st} = 530 \text{ mm}^2/\text{m}$

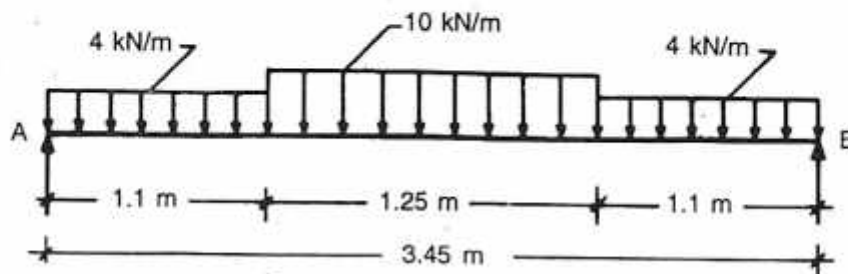


Fig. 9.6. Loads on stair case flight.

Adopt 10 mm diameter bars at 200 mm centres ($A_{st} = 393 \text{ mm}^2$).

Distribution bars = $(0.0012 \times 10^3 \times 160) = 192 \text{ mm}^2$

Adopt 8 mm diameter bars at 250 mm centres ($A_{st} = 201 \text{ mm}^2$).

8. Reinforcement details

The details of reinforcements in one of the flights of stair case is shown in Fig. 9.7.

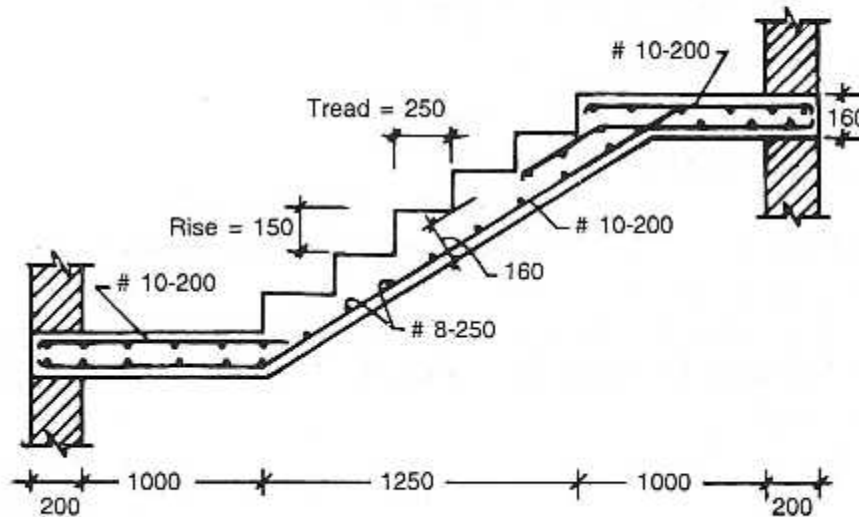


Fig. 9.7. Reinforcement details in stair case flight.

6. Design a reinforced concrete wall 3m height, 100mm thick, and 4m in length between cross walls. It has to carry a factored load of 600kn per meter length. (AUC Nov/Dec-2013)

Step 1

Determine slenderness

$$L_0 = 3 \text{ m}, \quad L_e = 0.75L_0$$

$$\frac{L_e}{h} = \frac{(0.75)(3000)}{100} = 22.50 > 12 < 40$$

From table 17.4

Wall is slender
Case (2)

Step 2

Calculate minimum accidental eccentricity

$$e_x = e_{\min} = \frac{h}{20} \quad \text{or} \quad 20 \text{ mm}$$

$$\frac{h}{20} = \frac{100}{20} = 5 \text{ mm}$$

Adopt $e_x = 20 \text{ mm}$

Design as slender column.

Step 3

Additional eccentricity (e_a as in R.C. column)

$$e_a = \frac{(L_e)^2}{2000h} = \frac{(2250)^2}{2000 \times 100} = 25.3 \text{ mm}$$

Calculate M and P for design

Assume total eccentricity = $(e_x + e_a) = 45.3$

$$M = Pe = \frac{600 \times 45.3}{1000} = 27.18 \text{ kNm}$$

$$P = 600 \text{ kN}$$

Determine steel from interaction diagram

$$\frac{d'}{D} = \frac{20}{100} = 0.2, \quad \frac{P}{f_{ck} bD} = \frac{600 \times 10^3}{20 \times 1000 \times 100} = 0.30$$

$$\frac{M}{f_{ck} bD^2} = \frac{27.18 \times 10^6}{20 \times 1000 (100)^2} = 0.14 \quad \begin{array}{l} \text{SP 16} \\ \text{Chart 34} \end{array}$$

$$\frac{p}{f_{ck}} = 0.12, \quad p = 0.12 \times 20 = 2.4 \%$$

Detail the steel

$$(a) \text{ Vertical steel} = \frac{2.4 \times 1000 \times 100}{100} = 2400 \text{ mm}^2$$

Provide 16 mm at 16 cm spacing on each face.

- (b) *Horizontal steel*—As vertical steel is more than 2 per cent, provide 0.25 per cent horizontal steel for both faces (6 mm at 200 mm spacing).
Maximum allowed spacing = $3h = 300$

Table 17.7

- (c) *Links*—As vertical steel is more than 2 per cent, provide links—6 mm at 200 mm.
[Min. diameter = 6 mm, spacing $2h = 200$ in either direction: Vertical spacing $\geq 16 \times$ diameter of main steel]

7.Design a reinforced concrete wall of height 5m, which is restrained in position and direction at both ends and has to carry at its top a factored load $p_u=600\text{kN}$ and factored moment $M_u=25\text{kNm}$, at right angles to the plane of the wall. (AUC May/Jun-2012)

Determine thickness of wall

Assume a moderate height to thickness ratio say 22.

$$h = \frac{5000}{22} = 225 \text{ mm (approx.)}$$

Adopt an R.C. wall as the load is large.

$$L_e = 0.65 L_0 = 3250 \text{ mm}$$

Determine slenderness of wall

$$\frac{L_e}{h} = \frac{0.65 L_0}{h} = \frac{0.65 \times 5000}{225} = 14.4 > 12 < 40 \quad \text{Slender R.C. wall Case 2.}$$

Calculate minimum accidental eccentricity

$$e_{\min} = \frac{h}{20} \text{ or } 20 \text{ mm}$$

$$\frac{h}{20} = \frac{225}{20} = 11.25. \text{ Adopt } 20 \text{ mm}$$

Calculate e_x

$$\begin{aligned} \text{Eccentricity due to } M &= \frac{M}{P} = \frac{25 \times 10^6}{600 \times 10^3} \\ &= 41.6 \text{ mm} \end{aligned}$$

$$e_{\min} < e_x. \text{ Hence adopt } e_x = 41.6 \text{ mm} \quad e_x = 41.6 \text{ mm}$$

Additional eccentricity as in R.C. columns

$$e_a = \frac{(L_e)^2}{2000h} = \frac{(3250)^2}{2000 \times 225} = 23.5 \text{ mm} \quad e_a = 23.5 \text{ mm}$$

Calculate design P and M

$$\text{Total eccentricity} = e_x + e_a = 41.6 + 23.5 = 65.1$$

$$M_t = \frac{600 \times 65.1}{1000} = 39.1 \text{ kNm}$$

Determine percentage of steel from SP 16

$$P = 600, \quad M = 39.1$$

$$d' = 40(\text{cover}) + 6 (\text{for } 12 \text{ mm rods}) = 46 \text{ mm}$$

$$\frac{d'}{D} = \frac{46}{225} = 0.20$$

$$\frac{P}{f_{ck} bD} = \frac{600 \times 10^3}{20 \times 1000 \times 225} = 0.13$$

$$\frac{M}{f_{ck} bD^2} = \frac{39.1 \times 10^6}{20 \times 1000 \times (225)^2} = 0.04$$

$$\frac{P}{f_{ck}} = 0. \text{ Provide minimum 0.4 per cent}$$

SP 16

Chart 34

Detail the reinforcement

- (a) *Vertical steel.* 6 mm at 250 centres on both faces satisfies maximum spacing of $3h$ or 450 mm as vertical steel. Table 17.7
- (b) *Horizontal steel.* Minimum 0.2 per cent. Providing 6 mm diameter steel at 450 mm spacing on both faces satisfies conditions for maximum spacing.
- (c) *Links.* No links required as vertical steel is less than 2 per cent.