King Faisal University
College of Architecture and Planning
Dept. of Building Science & Technology

Building Structure I
Reinforce Concrete Design
0525 – 351

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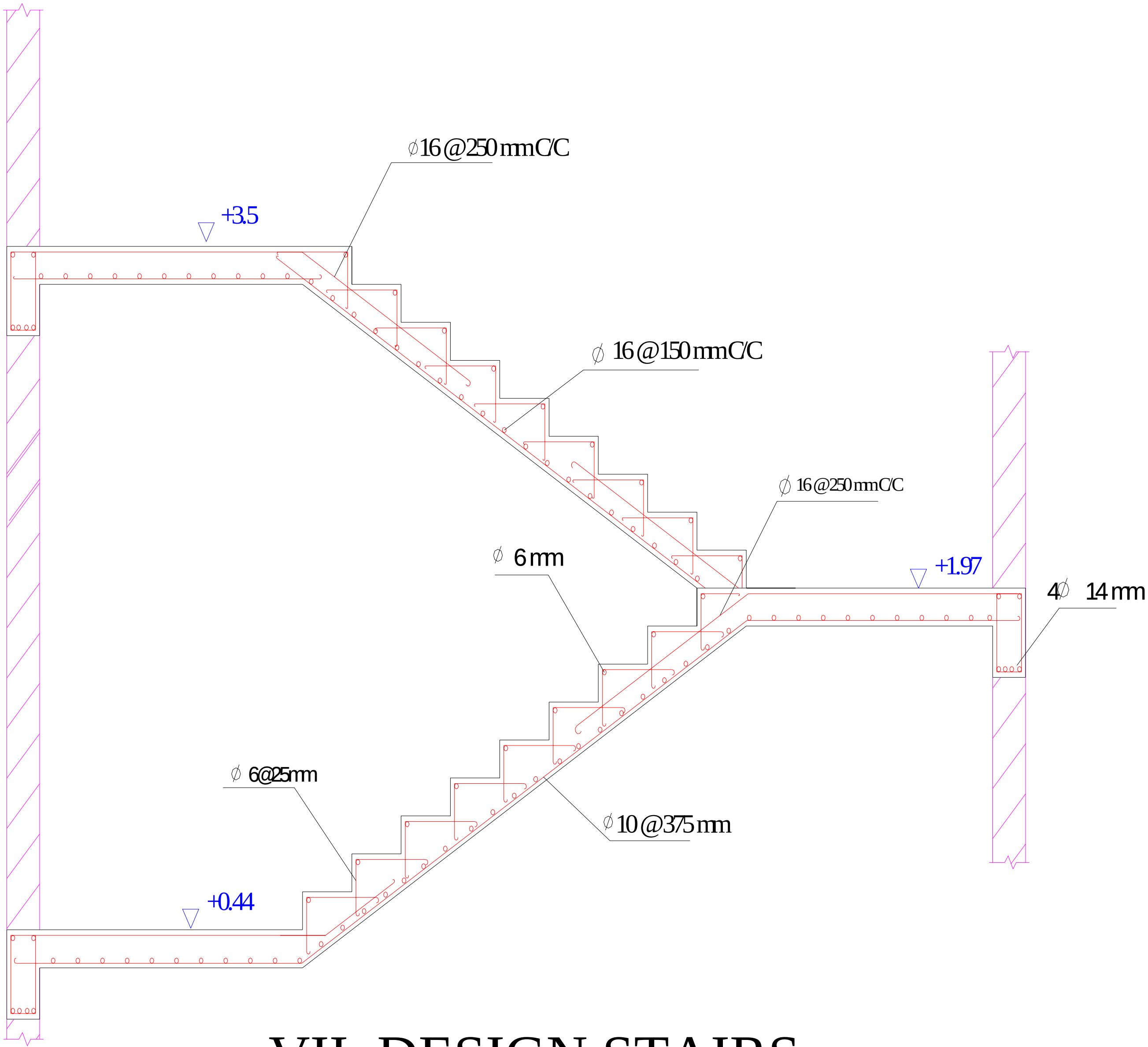


VII. DESIGN STAIRS

CHAPTER VII

Design Of Reinforced Concrete Stairs

Stairs are constructed to provide access to the different floor levels, within buildings. They consist of a number of steps arranged in series.

Most of stairs are designed as supported one-way slabs

7.1. DEFINITIONS

The definitions of some technical terms which are used in connection with the planning and design of stairs are shown in Figure (7.1).

1. Going (G): The horizontal distance of the upper surface of a step.
2. Rise (R): The vertical distance between horizontal of two consecutive steps.
3. Waist (h) : The least thickness of the stairs slab.
4. Landing : The horizontal platform which is usually provided at the beginning and the end of series of steps.
5. Flight : Comprised of a number of steps provided between two consecutive landing.

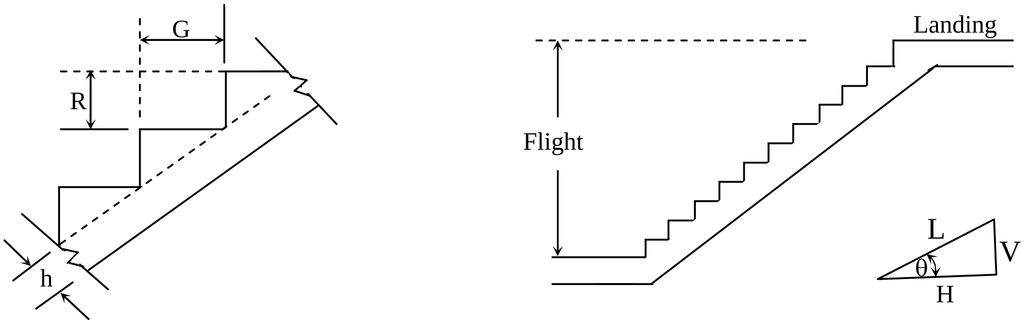


Figure (7.1) Particulars of stairs

7.2. GENERAL REQUIREMENTS:

1. There should be an equal number of steps between consecutive floors, and steps should have identical rises and goings.
2. Rise should not be greater than 17 cm, and the going not les than 22.5 cm $R \le 17\ cm$

$$G \ge 22.5\ cm$$

3. The slope to exterior from 0.2 to 0.3 for reduce the horizontal surface of stairs

7.3. TYPE OF STAIRS:

For the purpose of analysis and design, stairs may classify in two groups:

1) ***Stairs Spanning Transversely***, characterize be:
    a) Stairs simply supported at each side by a wall or beam.
    b) Stairs cantilevering from a wall or beam at one side only.
    c) Stairs cantilevering across a central sloping beam.
2) ***Stairs Spanning Longitudinally,***

Supported at the top and bottom of the flight and are unsupported along the sides.

Referring to Figure (7.2), which shows four common supporting systems of a typical staircase involving two flights, the supporting elements may be:

1) ***Beams provided at the top and bottom of the actual stairs***,

As shown in Fig.(7.2.a), Naturally these beams must be supported in some manner.

2) ***Beams or walls provided at both outside edges of the landings,***

As shown in Fig.(7.2.b), A beam is usually available at the edge of the floor landing, but a special beam or wall has to be provided at the edge of the intermediate landing,

3) ***Landing slabs which span transversely and are supported by beams or walls at their outsider edges,***

As shown in Fig.(7.2.c), Normally, beams are available at the two edges of the floor landing, but special provision have to be mad support intermediate landings at their edges.

4) ***A combination of a beam, or a wall, at one edge and transversely supported slab the other edge***

As shown in Fig.(7.2.d)

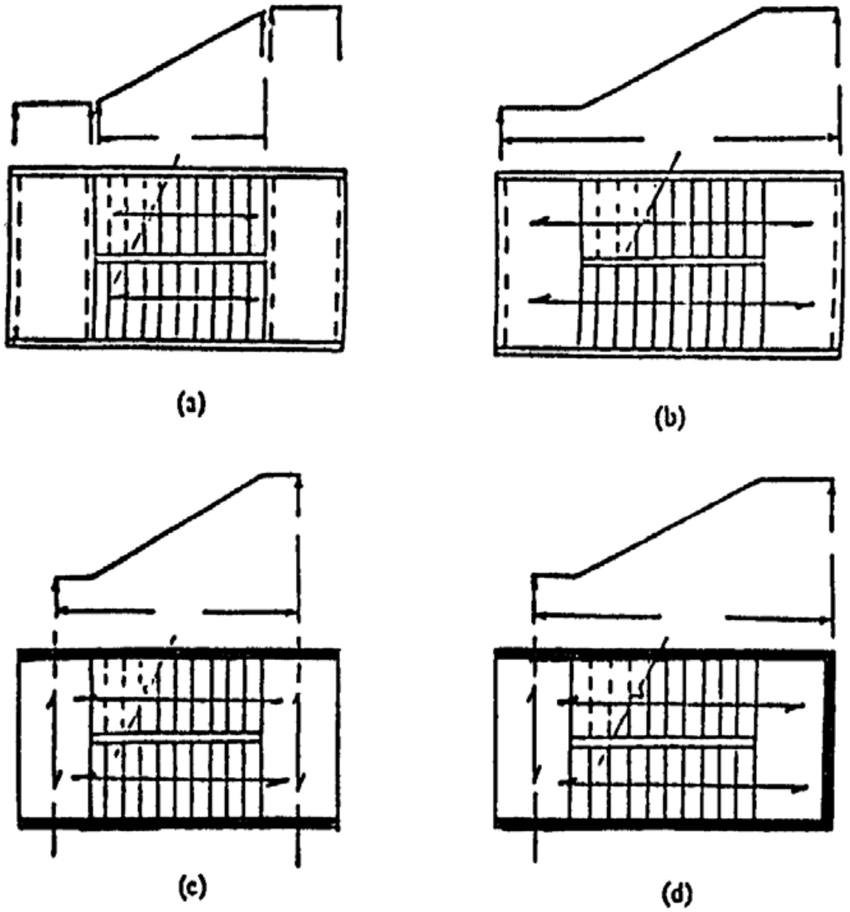


Figure (7.2); Common supporting systems of longitudinally supported stairs

7.4. PRINCIPAL STAIRS

Figure (7.3) and Figure (7.4) show a typical staircase of an Office building. The story height is 3.00 m and a typical step has a rise R=15 cm, and a going G= 30 cm. Design the stairs for the flowing data:

- Live load= 5 kN/m^2
- $f_c' = 25\ MPa,\quad f_y = 400\ MPa\ \ cc = 20\ mm$

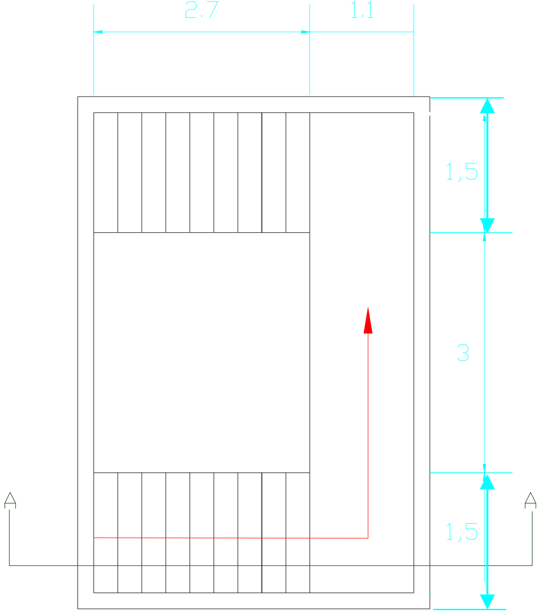


Figure (7.3): Horizontal Stair Dimensions

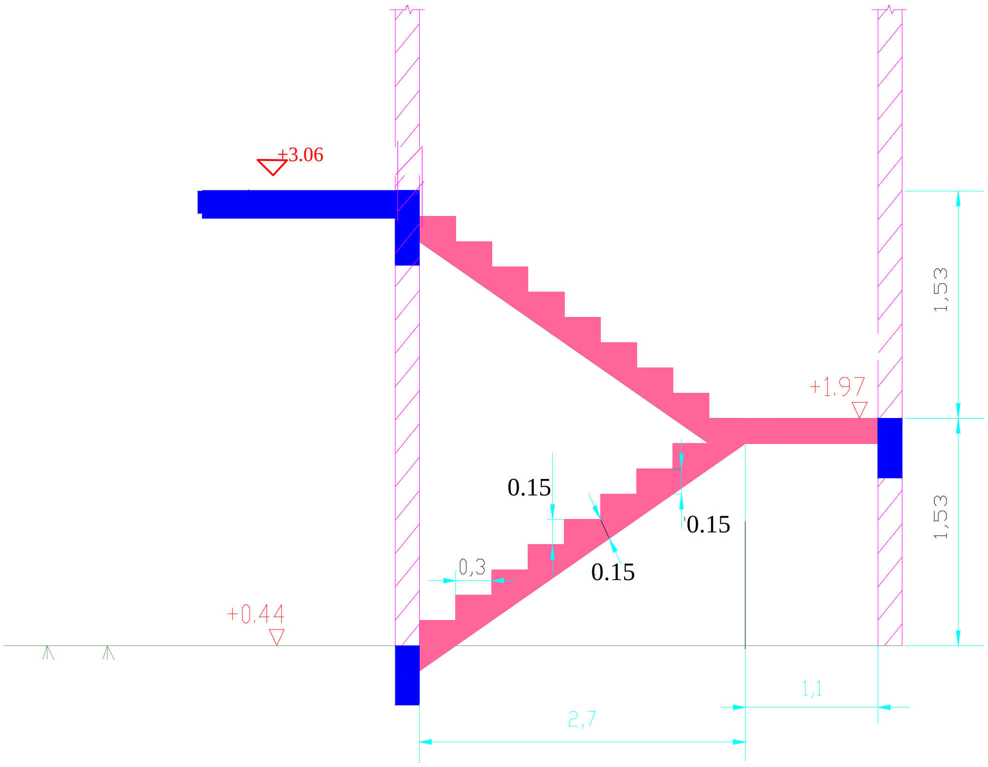
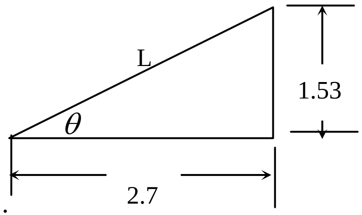


Figure (7.4): Heights of Stair

I. DIMENSIONS:

I.1. Slope Angle of the Stair Slab:

$$\theta = \tan^{-1}\frac{V}{H} = \tan^{-1}\frac{1.53}{2.70} = 29.54^{0} \quad O.K$$



I.2. Length of Stair:

$$L = \sqrt{(1.53)^2 + (2.7)^2} = 3.1m = 3100\,mm$$

I.3. Thickness of Stair :

For control the deflection (h) .Using ACI Code Deflection Conditions

$$h_{\min} = \frac{L}{24} \qquad \text{(one end continuous slab)}$$

$$h_{\min} = \frac{3100}{24} = 129.2\,mm \approx 130\,mm$$

$$Use\ \ h = 150\,mm = 15\ \ cm$$

II. LOAD CALCULATIONS:

II.1. Load on the Stair Landing:

Weight of landing: $= 0.15 \times 1\ \ x1\ \ x\ \ 24 = 3.6\,kN/m^2$

Finishing:

Tiles $= 0.44\ kN/m^2$

Cement mortar $= 0.4\ kN/m^2$

Plaster $= 0.4\ kN/m^2$

Additional load: $= 0.46\ \ kN/m^2$

$$\sum DL = 5.30\,kN/m^2$$

$$\sum L.L = 5\ \ kN/m^2$$

Design load:

$$U \ \ = (1.2 \times DL) + (1.6 \times LL)$$

$$U_1 = (1.2 \times 5.30) + (1.6x5) = 14.306\,kN/m^2$$

II.2. Load on Stair Slab:

Weight of slab: $= 0.15\ \ x\ \ 1\ \ x\ \ 1\ \ x\ \ 24 = 3.6\ kN/m^2$

Weight of steps:

$$= \frac{1}{2} \times 0.3 \times 0.15 \times 24 = 0.54\,kN/m^2$$

Finishing:

Tiles $= \ 0.44\ kN/m^2$

Cement mortar: $= \ 0.4\ kN/m^2$

Plaster $= 0.4\ kN/m^2$

Additional load $= 0.5\,kN/m^2$

Total load

$$\sum DL = 5.88\ kN/m^2$$

$$\sum L.L = 5\ kN/m^2$$

Design load:

$$U = (1.2 \times DL) + (1.6 \times LL)$$

$$U_2 = (1.2 \times 5.88) + (1.6x5) = 15.56\ kN/m^2$$

III. STRUCTURAL ANALYSIS

III.1. Reactions:

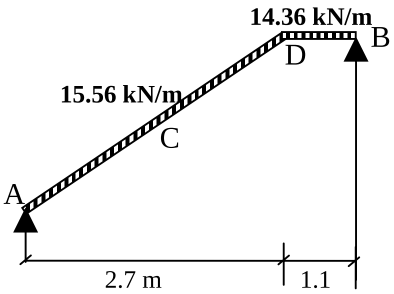
$$\sum M_A = 0 = (15.56x2.7)x1.35 + (14.36x1.1)x3.25 - 3.8R_B$$

$$0 = 56.716 + 51.337 - 3.8R_B$$

$$R_B = \frac{108.05}{3.8} = 28.44\ kN$$

$$\sum Y = 0 = 15.56x2.7 + 14.36x1.1x - 28.44 - R_A$$

$$R_A = 57.808 - 28.44 = 29.37\ kN$$



III.2. Moments:

- The positive moment at C

$$M_c = -(15.56x1.35)x0.675 + 29.37x1.35$$

$$= -14.179 + 39.65 = 25.47\ kN.m$$

III.3. Diagrams:

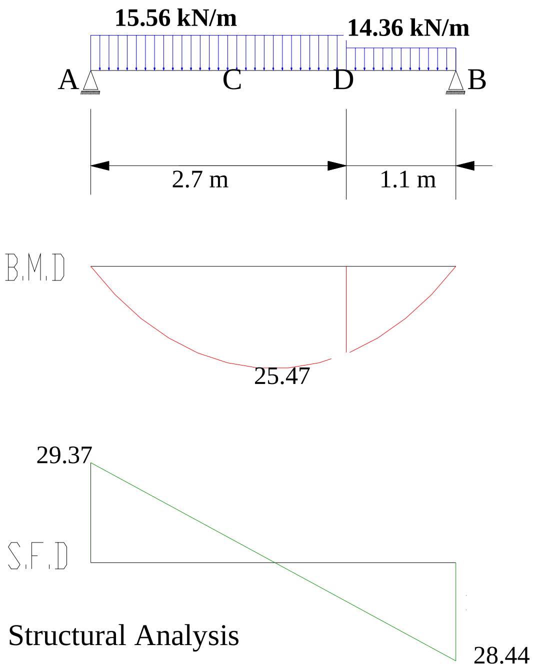


Figure (7.5): Structural Analysis

IV. CALCULATION OF STEE REINFORCEMENT:

IV.1. Positive Moment (Main Reinforcement):

$Use\ \ \phi_b = 14\,mm\ \ ,\ Concrete\,Cover = 20\,mm\,,\qquad M_u = 25.47\ \ kN.m\,,$

$M_n = \frac{M_u}{\phi} = \frac{25.47}{0.9} = 28.3\ \ kN.m \qquad f_c^{'} = 25\ \ MPa \quad f_y = 400\ \ MPa$

Effective depth:

$$d = h - \frac{\phi_b}{2} - cc$$

$$d = 150 - \frac{14}{2} - 20 = 123mm$$

Area of steel:

$$m = \frac{f_y}{0.85 f_c^{'}} = \frac{400}{0.85x25} = 18.81$$

$$R_n = \frac{M_n}{bd^2} = \frac{28.3}{1000x(0.124)^2} = 1.841$$

$$\rho = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2mR_n}{f_y}}\right]$$

$$\rho = \frac{1}{18.81}\left[1 - \sqrt{1 - \frac{2\ x18.81\ x1.841}{400}}\right]$$

$$\rho = 0.0048$$

Check ρ

$$\rho_{\min} = \frac{1.4}{f_y} = 0.0035$$

$$\rho_{\max} = 0.75\left[0.85 \times 0.85 \times \frac{25}{400} \times \left(\frac{600}{600 + 400}\right)\right] = 0.02$$

$$\rho_{\min} = 0.0035 < \rho = 0.0048 < \rho_{\max} = 0.02$$

$$A_s = \rho\,.b.d = 0.0048 \times 1000 \times 124 = 595.2\ \ mm^2$$

Number of bars:

$$A_b = \pi\frac{(14)^2}{4} = 153.94\ \ mm^2$$

$$n = \frac{595.2}{153.94} = 3.87 \approx 4$$

$Use\quad 4\ \ \phi\,14mm/m'$

Spacing:

$$S = \frac{1000}{3.87} = 258 \ mm$$ Use S=250 mm

Check Spacing:

$$S_{\max} \leq 3 \ h$$

$$S_{\max} = 3x150 = 450 \ mm$$

$$S = 250 \prec S_{\max} = 450 \ mm$$ OK

$$Use \quad S = 250mm$$

$$Use \quad \phi 14mm @ 250mm$$

IV.2. Negative Moment Reinforcement:

The connection zone (slab-landing) should be reinforced as a equal: a *half quantity of Positive moment*

$$A_s = \frac{595.2}{2} = 297.6 \ mm^2$$

Use $\phi = 12 \ mm$ $$A_b = \frac{\pi (12)^2}{4} = 113 \ mm^2$$

$$n = \frac{297.6}{113} = 2.63 \approx 3$$

$$Use \ 3\phi 12 mm / m'$$

Spacing

$$S = \frac{1000}{2.63} = 380 \ mm$$

$$Use \quad \phi \, 12 mm @ 380 \ \ mm$$

Check Spacing:

$$S_{\max} \leq 3 \ h$$

$$S_{\max} = 3x150 = 450 \ mm$$

$$S = 380 \prec S_{\max} = 450 \ mm$$ OK

$$Use \quad S = 380mm$$

$$Use \quad \phi 12mm @ 380mm$$

IV.3. Temperature and Shrinkage Reinforcement:

$$Use \quad \phi \, 10 \ mm$$

Steel Ratio:

$$\rho_{\min} = \frac{0.0018 \times 400}{f_y}$$

$$\rho_{\min} = \frac{0.0018 \times 400}{400} = 0.0018$$

Effective Depth:

$$d = h - cc - \phi_b(main) - \frac{\phi_b(temp)}{2}$$

$$d = 150 - 20 - 14 - \frac{10}{2} = 111\,mm$$

Steel Area:

$$A_s = \rho_{\min} \times b \times d$$

$$= 0.0018 \times 1000 \times 111 = 199.8 \;\; mm^2$$

Number of bars

$$A_b = \pi \frac{(10)^2}{4} = 78.5 \;\; mm^2$$

$$n = \frac{199.8}{78.5} = 2.54 \approx 3$$

$$Use \quad 3\phi\, 10\, mm / m'$$

Spacing:

$$S = \frac{1000}{2.54} = 393 \;\; mm$$

Use s=380 mm

Check spacing

$$S_{\max} \le 3h = 3x150 = 450 \;\; mm$$

$$S = 380 \le S_{\max} = 450 \;\; mm$$

$$Use \qquad \phi\, 10\; mm @ 380 \;\; mm$$

IV.4. Shear:

$$\phi V_C = \phi \left[\frac{\sqrt{f_c^{'}}}{6} \right] \times b_w \times d$$

$$= 0.85 \times \frac{\sqrt{25}}{6} \times 1000 \times 124 \times 10^{-3} = 87.83\, kN$$

$$V_u = R_A = 31\, kN$$

$$V_u < \phi \; V_C \qquad \Rightarrow \qquad o.k$$

No shear stirrups need

V. BEAM STEEL REINFORCEMENT

V.1. Dimension of Beam:

Deflection conditions.

$$h_{\min} = \frac{L}{16} \quad \text{(Simply supported beam)}$$

$$h_{\min} = \frac{6000}{16} = 375\,mm\; Use \quad h = 400\,mm$$

$$d = h - cc - \phi_{sb} - \frac{\phi_b}{2}$$

$$d = 400 - 20 - 10 - \frac{16}{2} = 362 \; mm$$

$$\left(\frac{h}{3} < b < \frac{2h}{3}\right)$$

$$\left(\frac{400}{3} < b < \frac{2x400}{3}\right) = (133.3 \quad \prec b \prec \quad 266.6)$$

$$Use \quad b = 200 \; mm$$

V.2. Loads on the Beam

Reaction of R. stair slab: $= 28.45\; kN/m$

Load from landing: $0.15 \times 1.1 \times 24 = 43.96\, kN/m$

Own weight $0.4 \times 0.2 \times 24 = 1.92\, kN/m$

Weight of wall: $= 7.5 \; kN/m$

Total dead load $= 28.45 + 3.96 + 1.92 + 7.5 = 41.83 \quad kN/m$

$$U \; = (1.2 \times DL) + (1.6 \times LL)$$

$$U_3 = (1.2 \times 41.83) + (1.6 \times 5) = 58.2 \quad kN/m$$

V.3 Structural Analysis for Beam

- *Reaction:*

$$R = \frac{Ul}{2} = \frac{58.2x6}{2} = 174.6 \; kN$$

- *Moments:*

$$M = \frac{Ul^2}{24} = \frac{58.2(6)^2}{24} = 87.3 \; kN.m \qquad \text{(Continuous beam)}$$

- *Diagrams:*

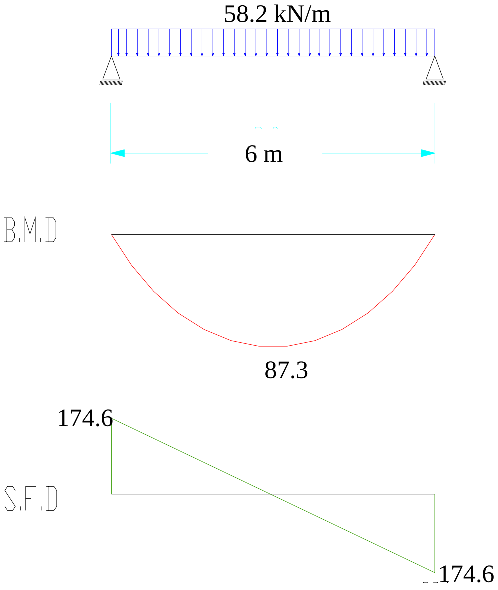


Figure: (7.6): Structural Analysis of Stair Beam

V.4. Structural Design for beam:

$$M_u = 87.3 \ kN.m$$

$$M_n = \frac{M_u}{0.9} = \frac{87.3}{0.9} = 97 \ kN.m$$

$$d = 362 \ mm \qquad b = 200 \ mm$$

$$f_c^{'} = 25 \ MPa \qquad f_y = 400 \ MPa$$

Area of Steel:

$$m = \frac{f_y}{0.85 f_c^{'}} = \frac{400}{0.85x25} = 18.81$$

$$R_n = \frac{M_n}{bd^2} = \frac{97}{1000(0.2)x(0.362)^2} = 3.7$$

$$\rho = \frac{1}{m}\left[1-\sqrt{1-\frac{2mR_n}{f_y}}\right]$$

$$\rho = \frac{1}{18.81}\left[1-\sqrt{1-\frac{2x18.81x3.7}{400}}\right]$$

$$\rho = 0.010 \approx 0.010$$

Check ρ

$$\rho_{\min} = \frac{1.4}{f_y} = 0.0035$$

$$\rho_{\max} = 0.75\left[0.85\times 0.85\times\frac{25}{400}\times\left(\frac{600}{600+400}\right)\right] = 0.02$$

$$\rho_{\min} = 0.0035 < \rho = 0.010 < \rho_{\max} = 0.02$$

$$A_s = \rho.b.d = 0.010\times 200\times 362 = 724\ mm^2$$

$$A_b = \pi\frac{(16)^2}{4} = 201\ mm^2$$

Number of steel:

$$n = \frac{724}{201} = 3.6 \approx 4$$

$$Use\quad 4\ \phi 16 mm/m'$$

Spacing:

$$S = \frac{b-2cc-2\phi_{sb}-n\phi_b}{n-1}$$

$$S = \frac{200-2x25-2x10-4x16}{3} = \frac{66}{3} = 22\ mm$$

S=22 mm

VI. STRUCTURAL DESIGN:

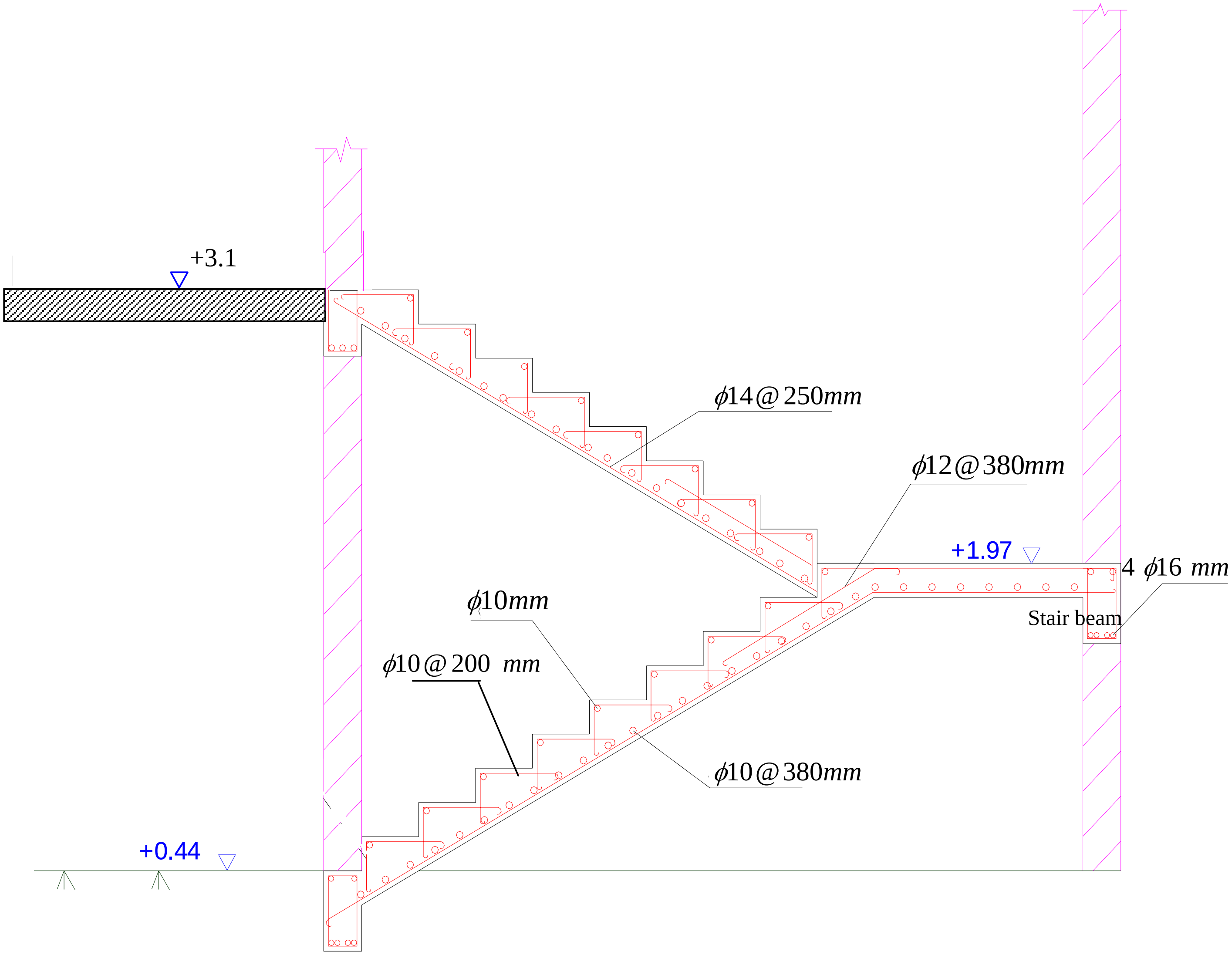


Figure (7.7): Reinforcement Detailing of Principal stair

7.5. EMERGENCY STAIR

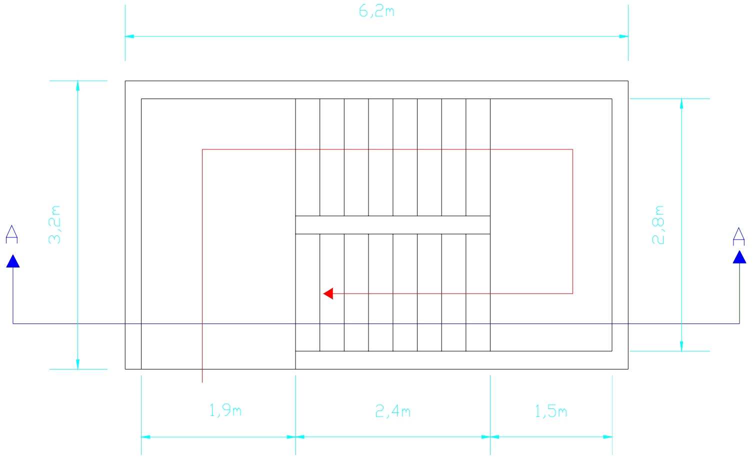


Figure (7.8): Horizontal of an Emergency Stair Dimensions

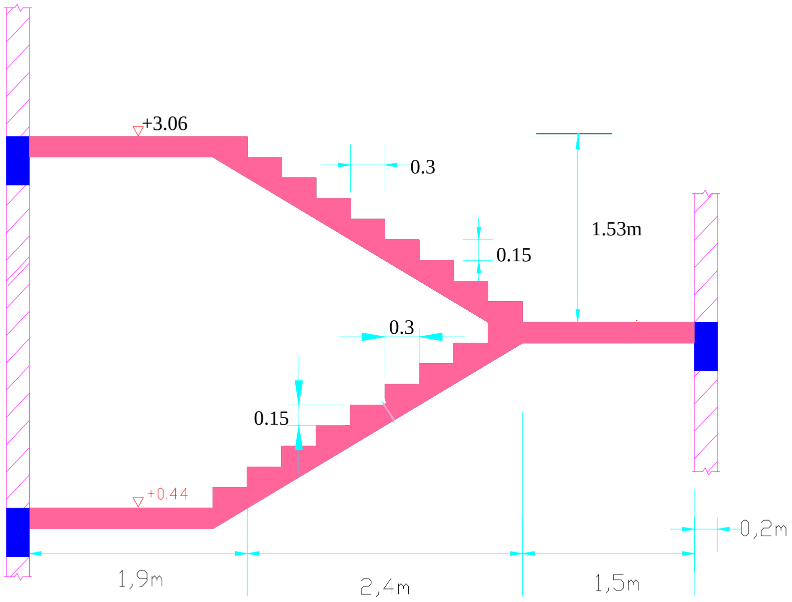


Figure (7.9): Heights of Emergency Stair

I. DIMENSIONS:

I.1. Slope Angle of the Stair Slab:

$$\theta = \tan^{-1}\frac{1.53}{2.4} = 32.5^0$$

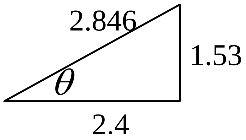
I.2. Length of Stair:

$$L = 2846\ mm$$

I.3. Thickness of Stair:

$$h = \frac{L}{21} = \frac{2846}{21} = 135.5\ mm$$ (Both end continuous slabs)

$$Use\ \ h = 150\,mm$$



II. LOAD CALCULATIONS

II.1. Calculation of Load of Stair Slab

Weight of stair slab:

$$= 0.15x1x1x24 = 3.6\ kN./m^2$$

Weight of steps:

$$= \frac{1}{2}\times 0.3\times 0.15\times 24 = 0.54\,kN/m^2$$

Finishing:

$$= 1.24\,kN/m^2$$

Additional load: $= 0.62\ \ kN/m^2$

Total load:

$$\sum DL = 6\ kN/m^2$$

$$\sum L.L = 5\ kN/m^2$$

$$U_1 = 1.2\times 6 + 1.6x5 = 15.2\ kN/m^2$$

II.2. Calculation of Load of Stair Landing

Weight of landing:

$$= 0.15x1x1x24 = 3.6\ kN/m^2$$

Finishing: $= 1.25\,kN/m^2$

Additional weight: $= 0.45\,kN/m^2$

$$\sum DL = 5.30\ kN/m^2$$

$$\sum L.L = 5\ kN/m^2$$

Design load:

$$U_2 = 1.2 \times 5.3 + 5 \times 1.6 = 14.36\ kN/m^2$$

III. STRUCTURAL ANALYSIS:

III.1. Reactions

$$\sum M_A = 0 = (14.36x1.9)x0.95 + (15.2x2.4)x3.1 + (14.36x1.5)x5.05 - 5.8R_B$$

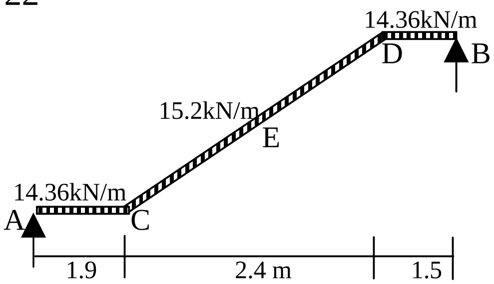
$$0 = 25.92 + 113.088 + 108.78 - 5.8R_B$$

$$R_B = \frac{247.788}{5.8} = 42.722\ \ kN$$

$$\sum Y = 0 = (14.36x1.9) + (15.2x2.4) + (14.36x1.5)x46.68 - 42.722 - R_A$$

$$R_A = 27.284 + 36.48 + 21.54 - 42.722$$

$$R_A = 42.582\ \ kN$$



III.2. Moments

- The positive moment

$$M_C = -(14.36x1.9)x0.95 + 42.722x1.9$$

$$= -25.92 + 80.91 = 54.99\ \ kN.m$$

$$M_E = (14.36x1.9)x(0.95 + 1.2) + (15.2x1.2)x0.6 - 42.722x3.1$$

$$= (14.36x1.9)x2.15 + (15.2x1.2)x0.6 - 42.722x3.1$$

$$= 58.661 + 10.944 - 132.438 = -62.83\ \ kN.m$$

$$M_u = 62.82\ kN.m$$

$$M_n = \frac{M_u}{0.9} = \frac{62.83}{0.9} = 69.815 kN.m$$

III.3. Diagrams

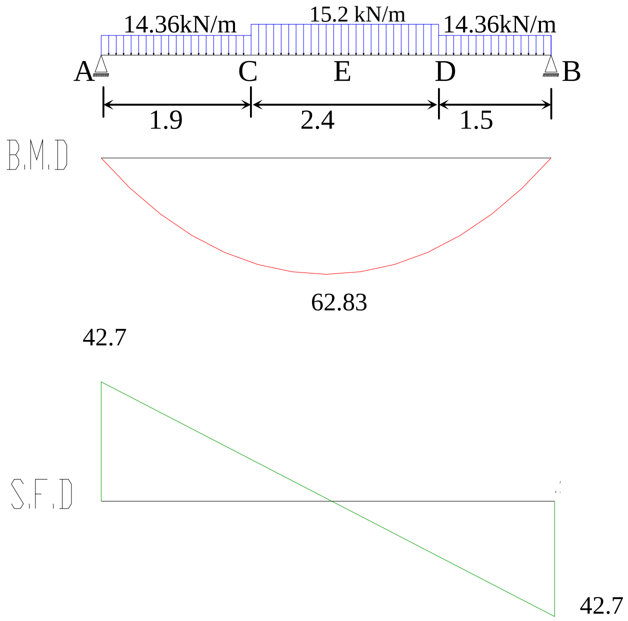


Figure (7.10): Structural Analysis of Emergency Stair Slab

IV. Calculation of Steel Reinforcement

IV.1. Design for Positive Moment:

$$Use\ \phi 16mm,\quad concrete over\ 20mm$$

$$f_c^{'} = 25\ MPa \quad , \quad f_y = 400\,MPa \quad , M_n = 69.83\ kN.m$$

Effective depth:

$$d = h - \frac{\phi_b}{2} - cc$$

$$= 150 - \frac{16}{2} - 20 = 122\,mm$$

Area of steel:

$$m = \frac{f_y}{0.85 f_c^{'}} = \frac{400}{0.85x25} = 18.81$$

$$R_n = \frac{M_n}{bd^2} = \frac{69.83}{1000x(0.122)^2} = 4.69$$

$$\rho = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2mR_n}{f_y}}\right]$$

$$\rho = \frac{1}{18.81}\left[1 - \sqrt{1 - \frac{2\,x\,18.81\,x\,4.69}{400}}\right]$$

$$\rho = 0.0134$$

Check ρ

$$\rho_{\min} = \frac{1.4}{f_y} = 0.0035$$

$$\rho_{\max} = 0.75\left[0.85 \times 0.85 \times \frac{25}{400} \times \left(\frac{600}{600+400}\right)\right] = 0.02$$

$$\rho_{\min} = 0.0035 < \rho = 0.0134 < \rho_{\max} = 0.02$$

$$A_s = \rho\,.b.d = 0.0134 \times 1000 \times 122 = 1634.8\,mm^2$$

Number of bars:

$$A_b = \pi\frac{(16)^2}{4} = 201\ mm^2$$

$$n = \frac{1635}{201} = 8.13 \approx 8$$

$$Use\quad 8\phi\,16\,mm/m'$$

Spacing:

$$S = \frac{1000}{8.13} = 123\ mm$$

Use S=125 mm

Check Spacing:

$$S_{\max} \le 3\ h$$

$$S_{\max} = 3x150 = 450\ mm$$

$$S = 125 \le S_{\max} = 450\ mm \qquad \text{OK}$$

$$Use\quad S = 125\,mm$$

$$Use\quad \phi 16mm@125\,mm$$

IV.2. Negative Moment Reinforcement:

Reinforcement connection zone (slab-landing) to *be half quantity of Positive moment*

$$A_s = \frac{1635}{2} = 817.5 \ \ mm^2$$

$$A_b = \pi \frac{(16)^2}{4} = 201 \ \ mm^2$$

$$n = \frac{817.5}{201} = 4.07 \approx 4$$

$$Use \quad 4\phi\, 16\, mm/m'$$

Spacing:

$$S = \frac{1000}{4.07} = 245 \ \ mm$$

Use S=250 m

Check Spacing:

$$S_{\max} \le 3 \ h$$

$$S_{\max} = 3x150 = 450 \ \ mm$$

$$S = 250 \le S_{\max} = 450 \ \ mm \qquad \text{OK}$$

$$Use \quad S = 250 \ mm$$

$$Use \quad \phi 16 mm @ 250\, mm$$

IV.3. Reinforcement Temperature and Shrinkage:

$$Use \ \ \phi\, 10\, mm$$

$$\rho = \frac{0.018 \times 400}{f_y} = 0.018$$

$$d = 150 - 20 - 16(main) - \frac{10}{2} = 109\, mm$$

$$A_s = 0.0018 \times 1000 \times 109 = 196.2\, mm^2$$

$$n = \frac{196.2}{78.5} = 2.5 \approx 3$$

$$Use\ 3\phi\, 10\, mm/m'$$

Spacing:

$$S = \frac{1000}{2.5} = 400 \ \ mm$$

Use S = 400 mm

$$\phi\, 10 @ \ \ 400 \ \ mm$$

IV.4. Shear

$$\phi\ V_C = 0.85 \times \frac{\sqrt{25}}{6} \times 1000 \times 142 \times 10^{-3} = 100.6\ kN$$

$$V_u = 50\ kN$$

$$V_u < \phi\ V_C \quad o.k$$

V. BEAM STEEL REINFORCEMENT:

V.1. Dimensions

$$h_{\min} = \frac{L}{16}$$

$$h_{\min} = \frac{3200}{16} = 200\ mm$$

$$Use\ h = 400\,mm$$

Effective depth and width :

$$d = h - cc - \phi_{sb} - \frac{\phi_b}{2}$$

$$= 400 - 20 - 10 - \frac{14}{2} = 363\,mm$$

$$\left(\frac{h}{3} < b < \frac{2h}{3}\right)\left(\frac{400}{3} < b < \frac{2x400}{3}\right) = \left(133.3\,mm \prec b \prec 266.7\,mm\right)$$

$$Ue\ b = 200\,mm$$

V.2. Loads Acting on Beam

Reactions of R. slab and landing:	$= 42.7\ \ kN/m$
Own Weight	$0.2 \times 0.4 \times 24 = 1.92\ kN/m$
Weight of wall	$= 7.5\,kN/m$
Total dead load:	=52.12 kN/m

V.3 Structural Analysis for Beam

- Reaction:

$$R = \frac{U\,l}{2} = \frac{52.12x3.2}{2} = 83.39\ \ kN$$

- Moments:

$$M\ = \frac{U\,l^2}{24} = \frac{52.12(3.2)^2}{24} = 66.72\ \ kN.m$$

- Diagrams:

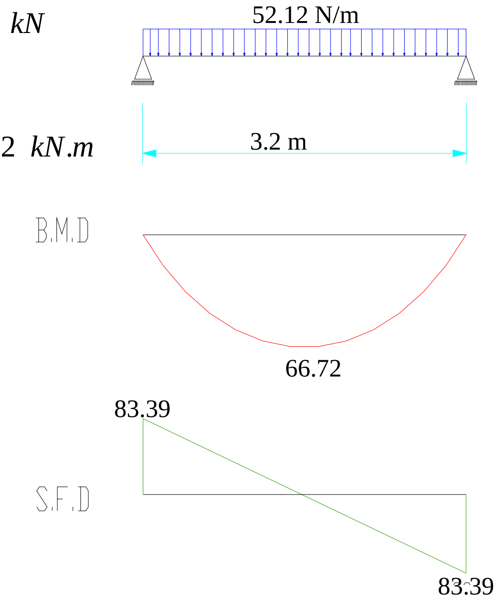


Figure (7.11): Structural Analysis of Emergency Stair Beam

V.4. Structural Design

$$d = 400 - 20 - 10 - 7 = 363\ mm$$

$$M_n = \frac{66.12}{0.9} = 73.47\ kN.m/m$$

Area of steel:

$$m = \frac{f_y}{0.85\,f_c^{'}} = \frac{400}{0.85x25} = 18.81$$

$$R_n = \frac{M_n}{bd^2} = \frac{88}{1000x0.200x(0.363)^2} = 2.94$$

$$\rho\ = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2\,mR_n}{f_y}}\right]$$

$$\rho\ = \frac{1}{18.81}\left[1 - \sqrt{1 - \frac{2\,x18.81\,x2.94}{400}}\right]$$

$$\rho\ \ =\ 0.009$$

Check ρ

$$\rho_{\min} = \frac{1.4}{f_y} = 0.0035$$

$$\rho_{\max} = 0.75\left[0.85 \times 0.85 \times \frac{25}{400} \times \left(\frac{600}{600+400}\right)\right] = 0.02$$

$$\rho_{\min} = 0.0035 < \rho = 0.0079 < \rho_{\max} = 0.02$$

$$A_s = \rho .b.d = 0.0079 \times 200x363 = 573.54 \ \ mm^2$$

Number of bars:

$$A_b = \pi \frac{(14)^2}{4} = 153.9 \ \ mm^2$$

$$n = \frac{573.54}{153.9} = 3.7 \approx 4$$

$$Use \quad 4\phi\, 14\, mm / m'$$

Spacing:

$$S = \frac{b - 2cc - 2\phi_{sb} - n\phi_b}{n-1}$$

$$S = \frac{200 - 2x25 - 2x10 - 4x14}{3} = 24.7 \ \ mm$$

S=25 mm

VI. STRUCTURAL DESIGN:

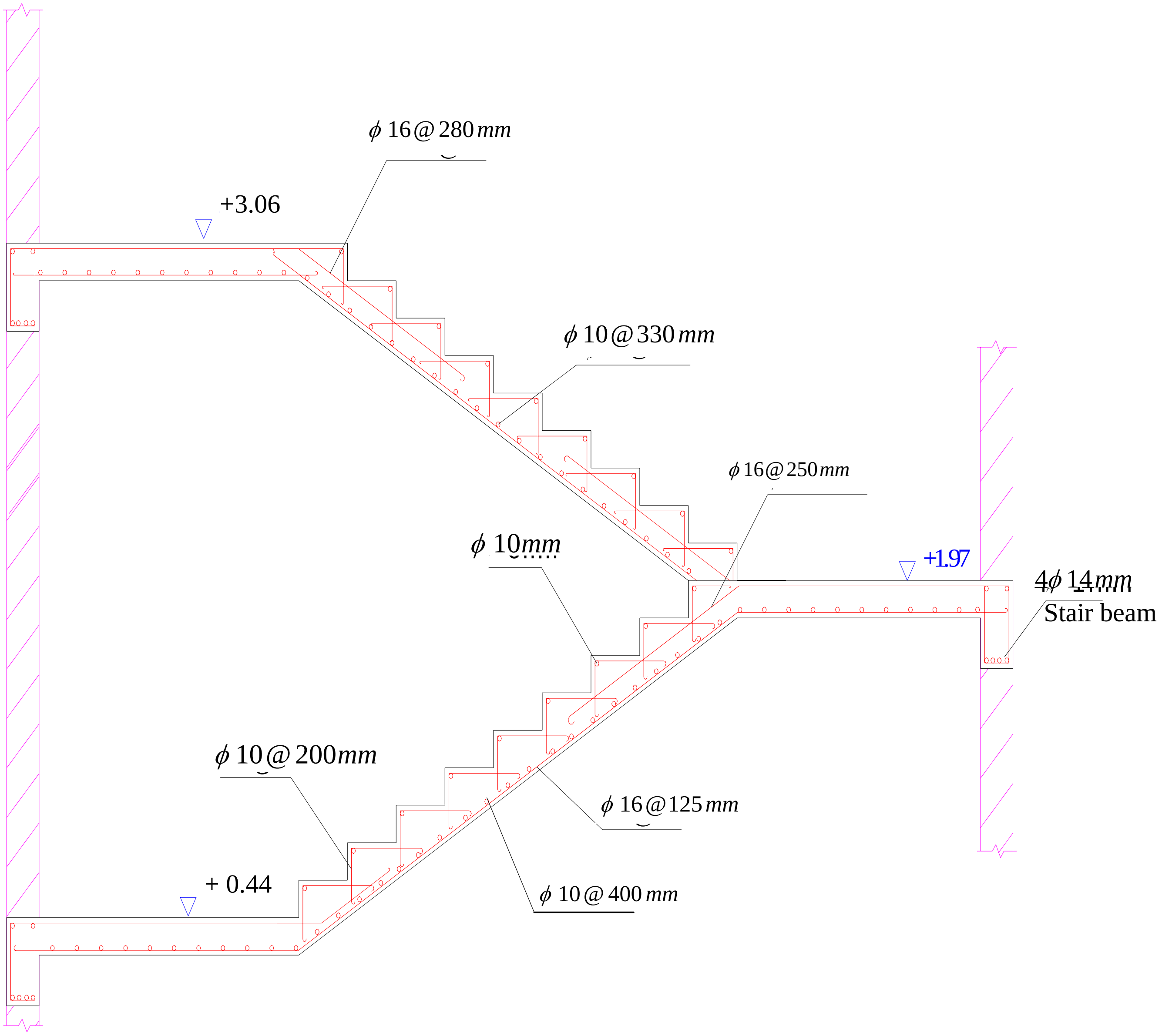


Figure (7.12): Details of Emergency Reinforcement Stairs