

4

Chapter Four

Structural Analysis and Design

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4-1 Introduction

Many structures are built of reinforced concrete: bridges, buildings, retaining walls, tunnels and others.

Reinforced concrete is logical union of two materials: plain concrete, which possesses high compressive strength but little tensile strength, and steel bars embedded in the concrete, which can provide the needed strength in tension.

Plain concrete is made by mixing cement, fine aggregate, coarse aggregate, water, and frequently admixtures.

Understanding of reinforced concrete behavior is still far from complete, building codes and specifications that give design procedures are continually changing to reflect latest knowledge.

Structural concrete can be classified into:-

- ☐ Lightweight concrete with unit weight from about 1350 to 1850 kg/m³.
- ☐ Normal weight concrete with unit weight from about 1800 to 2400 kg/m³.
- ☐ Heavyweight concrete with unit weight from about 3200 to 5600 kg/m³.

4-2 Design Method and Requirements

The design strength provided by a member is calculated in accordance with the requirements and assumptions of **ACI_code (318_11)**.

✓ Strength design method:-

In ultimate strength design method, the service loads are increased by factors to obtain the load at which failure is considered to be occurring.

This load called factored load or factored service load. The structure or structural element is then proportioned such that the strength is reached when factored load is acting. The computation of this strength takes into account the nonlinear stress-strain behavior of concrete.

The strength design method is expressed by the following,

$$\text{Strength provided} \geq \text{strength required to carry factored loads.}$$

NOTE:-

The statically calculation and the key plans dependent on the architectural plans.

- **Code:-**

ACI 2011

- **Material:-**

Concrete:-B300

$f_c' = 30 \text{ N/mm}^2 (\text{MPa})$ For circular section

but for rectangular section ($f_c' = 30 * 0.8 = 24 \text{ MPa}$).

Reinforcement steel:-

The specified yield strength of the reinforcement $\{f_y = 420 \text{ N/mm}^2 \text{ (MPa)}\}$.

✓ Factored loads:-

The factored loads for members in our project are determined by:-

$$W_u = 1.2 D_L + 1.6 L_L \quad \text{ACI-code-318-08(9.2.1)}$$

4.3 Check of Minimum Thickness of Structural Member

Table 4-1 :- Minimum Thickness of Non-prestressed Beam or One-Way Slabs Unless Deflections are Calculated. (ACI 318M-11).

Minimum thickness (h)				
Member	Simply supported	One end continuous	Both end continuous	Cantilever
solid one way slabs	L/20	L/24	L/28	L/10
Beams or ribbed one way slabs	L/16	L/18.5	L/21	L/8

Table (4.1): Check of Minimum Thickness of Structural Member.

For Rib :-

$$H_{\min} \text{ for (one end continuous) } = L/18.5 = 5.75/18.5 = 31.1 \text{ cm}$$

$$H_{\min} \text{ for (both end continuous) } = L/21 = 4.15/21 = 19.76 \text{ cm}$$

$$H_{\min} \text{ for (one end continuous) } = L/18.5 = 6.12/18.5 = 33.1 \text{ cm}$$

Take h = 35 cm

27 cm block + 8 cm topping = 35cm

For Beam :-

$$H_{\min} \text{ for (one end continuous)} = L/18.5 = 6.96/18.5 = 37.62 \text{ cm}$$

$$H_{\min} \text{ for (both end continuous)} = L/21 = 3.93/21 = 18.71 \text{ cm}$$

$$H_{\min} \text{ for (both end continuous)} = L/21 = 6.33/21 = 30.1 \text{ cm}$$

$$H_{\min} \text{ for (one end continuous)} = L/18.5 = 4.85/18.5 = 26.21 \text{ cm}$$

Take $h = 45 \text{ cm}$

4.4 Design of Topping

✓ Statically System For Topping :-

Consider the topping as strip of (1m) width, and span of mold length with both end fixed in the ribs.

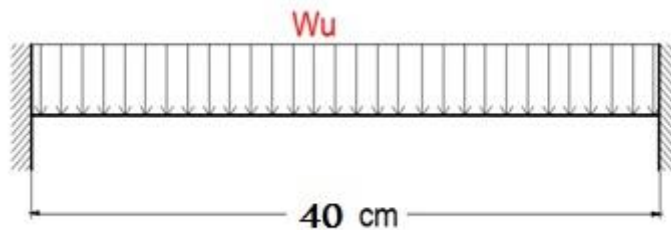


Fig 4.1: Topping Load.

✓ Load Calculations:-

Dead Load:-

No.	Parts of Rib	Calculation
1	Tiles	$0.03 \times 23 \times 1 = 0.69 \text{ KN/m}$
2	Mortar	$0.02 \times 22 \times 1 = 0.44 \text{ KN/m}$

3	Coarse Sand	$0.07 \times 17 \times 1 = 1.19 \text{ KN/m}$	
4	Topping	$0.08 \times 25 \times 1 = 2.0 \text{ KN/m}$	
		Sum =	4.32KN/m

Table (4.2): Dead Load Calculation of Topping.

Live Load :-

$$L_L = 4 \text{ KN/m}^2$$

$$L_L = 4 \text{ KN/m}^2 \times 1\text{m} = 4\text{KN/m}$$

Factored Load :-

$$W_U = 1.2 \times 4.32 + 1.6 \times 4 = 11.59 \text{ KN/m}$$

Check the strength condition for plain concrete, $\phi M_n \geq M_u$, where $\phi = 0.55$

$$M_n = 0.42 \lambda \sqrt{f'_c} S_m \text{ (ACI 22.5.1, equation 22-2)}$$

$$S_m = \frac{b \cdot h^2}{6} = \frac{1000 \cdot 80^2}{6} = 1066666.67 \text{ mm}^2$$

$$\phi M_n = 0.55 \times 0.42 \times 1 \times \sqrt{24} \times 1066666.67 \times 10^{-6} = 1.21 \text{ KN.m}$$

$$M_u = \frac{W_u L^2}{12} = \frac{11.59 \times 0.4^2}{12} = 0.155 \text{ KN.m} \quad (\text{negative moment})$$

$$M_u = \frac{W_u L^2}{24} = \frac{11.59 \times 0.4^2}{24} = 0.077 \text{ KN.m} \quad (\text{positive moment})$$

$$\phi M_n >> M_u = 0.155 \text{ KN.m}$$

No reinforcement is required by analysis. **According to ACI 10.5.4**, provide $A_{s,\min}$ for slabs as shrinkage and temperature reinforcement.

$$P_{\text{shrinkage}} = 0.0018 \quad \text{ACI 7.12.2.1}$$

$$A_s = \rho \times b \times h_{\text{topping}} = 0.0018 \times 1000 \times 80 = 144 \text{ mm}^2/\text{m}$$

Step (s) is the smallest of:

1. $3h = 3 \times 80 = 240 \text{ mm}$ **control ACI 10.5.4**
2. 450mm.
3. $S = 380 \left(\frac{280}{f_s} \right) - 2.5C_c = 380 \left(\frac{280}{\frac{2}{3} \cdot 420} \right) - 2.5 \cdot 20 = 330 \text{ mm}$ **ACI 10.6.4**

Take $\phi 8 @ 200 \text{ mm}$ in both direction

Take 5 $\phi 8$ in 1m, $A_{s_{\text{provided}}} = 5 \times 50.27 = 251.35 \text{ mm}^2/\text{m}$

$A_{s_{\text{provided}}} = 251.35 \text{ mm}^2/\text{m} > A_{s_{\text{req}}} = 144 \text{ mm}^2/\text{m}$ ok

$S = 200 \text{ mm} < S_{\text{max}} = 240 \text{ mm}$ ok

4.5 Design of One Way Rib Slab

Requirements For Ribbed Slab Floor According to ACI- (318-08) .

$b_w \geq 10 \text{ cm}$**ACI(8.13.2)**

Select $b_w = 12 \text{ cm}$

$h \leq 3.5 \cdot b_w$ **ACI(8.13.2)**

Select $h = 35 \text{ cm} < 3.5 \cdot 12 = 42 \text{ cm}$

$t_f \geq L_n/12 \geq 50 \text{ mm}$ **ACI(8.13.6.1)**

Select $t_f = 8 \text{ cm}$

❖ Material :-

⇒ concrete B300 $F_c' = 24 \text{ N/mm}^2$

⇒ Reinforcement Steel $f_y = 420 \text{ N/mm}^2$

❖ Section :-

⇒ $B = 520 \text{ mm}$

⇒ $B_w = 120 \text{ mm}$

⇒ $h = 350 \text{ mm}$

⇒ $t = 80 \text{ mm}$

⇒ $d = 350 - 20 - 10 - 12/2 = 314 \text{ mm}$

✓ Statically System and Dimensions:-

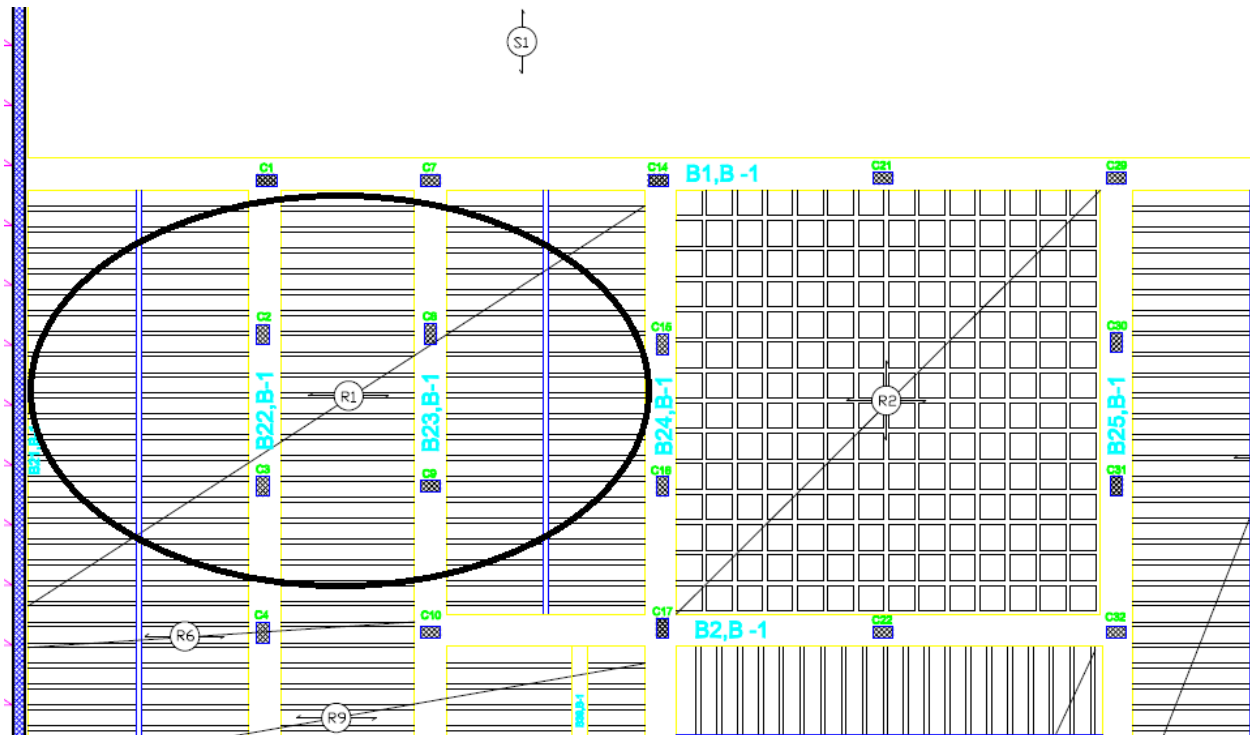
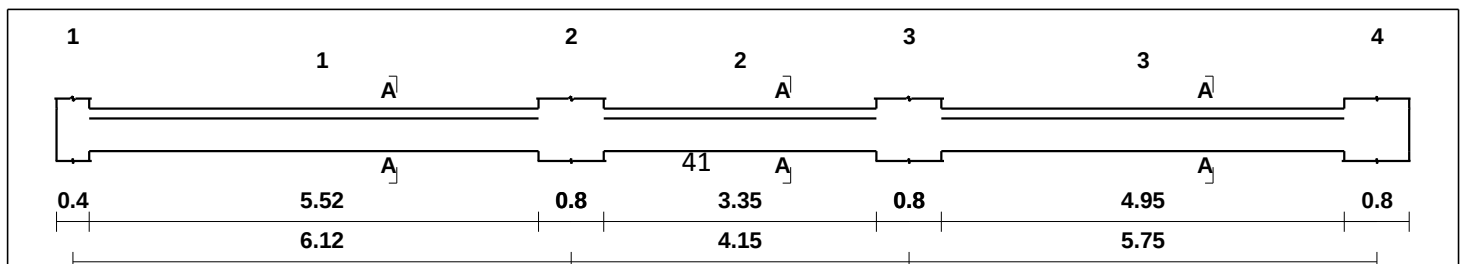
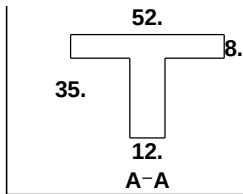


Fig 4.2: One Way Rib Slab (R1).

Geometry Units: meter, cm

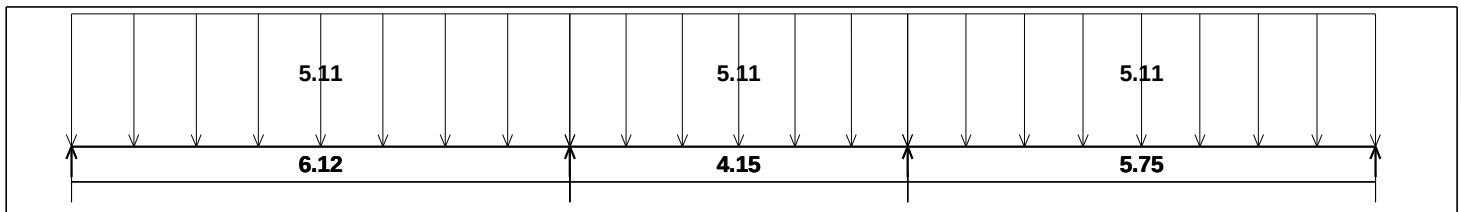




Loading

load group no. 1
Dead load - Service

Units:kN,meter



Live load - Service

Load factors: 1.20,1.20/1.60,0.00

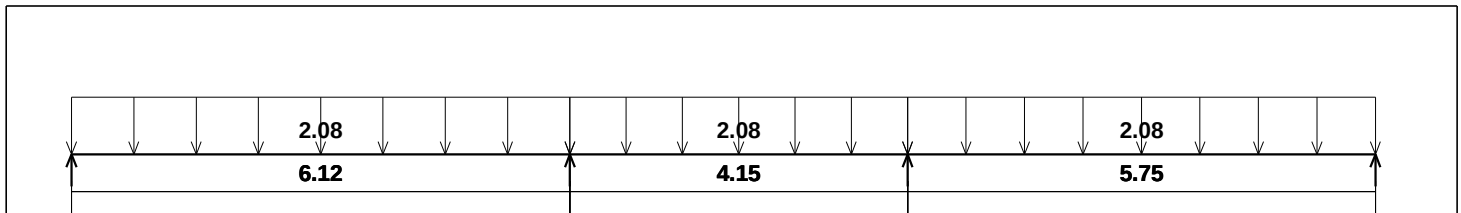


Fig 4.3: Statically System and Loads Distribution of Rib (R1).

✓ Load Calculation:-

Dead Load:-

No.	Parts of Rib	Calculation
1	Tiles	$0.03 \times 23 \times 0.52 = 0.359 \text{ KN/m/rib}$
2	Mortar	$0.03 \times 22 \times 0.52 = 0.229 \text{ KN/m/rib}$
3	Coarse Sand	$0.07 \times 17 \times 0.52 = 0.620 \text{ KN/m/rib}$
4	Topping	$0.08 \times 25 \times 0.52 = 1.04 \text{ KN/m/rib}$

5	RC. Rib	$0.27 \times 25 \times 0.12 = 0.81 \text{ KN/m/rib}$
6	Hollow Block	$0.27 \times 10 \times 0.4 = 1.08 \text{ KN/m/rib}$
7	plaster	$0.02 \times 22 \times .52 = 0.229 \text{ KN/m/rib}$
8	partitions	$1.5 \times 0.52 = 0.78 \text{ KN/m/rib}$
		Sum = 5.11 KN/m/rib

Table (4.3): Dead Load Calculation of Rib(R1).

Dead Load /rib = 5.11 KN/m

Live Load:-

Live load = 4 KN/M^2

Live load /rib = $4 \text{ KN/m}^2 \times 0.52 \text{ m} = 2.08 \text{ KN/m}$.

❖ **Effective Flange Width (b_E):-** ACI-318-11 (8.10.2)

b_E For T- section is the smallest of the following:-

$$b_E = L / 4 = 335 / 4 = 83.75 \text{ cm}$$

$$b_E = 12 + 16 t = 12 + 16 (8) = 140 \text{ cm}$$

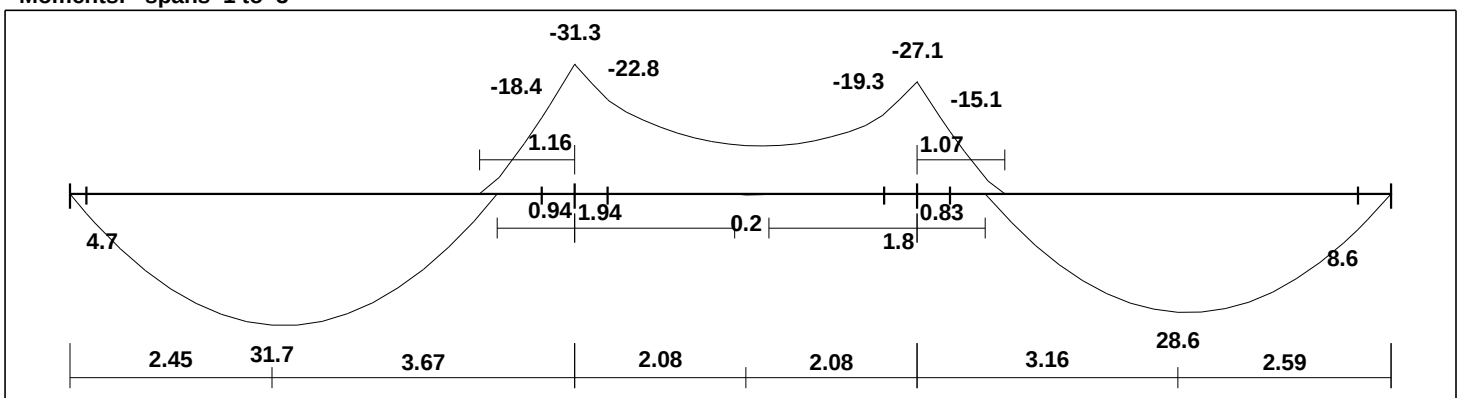
$$b_E = b_e \leq \text{center to center spacing between adjacent beams} = 52 \text{ cm}.$$

Control

b_E **For T-section = 52cm .**

Moment / Shear Envelope (Factored) Units:kN,meter

Moments: spans 1 to 3



Shear

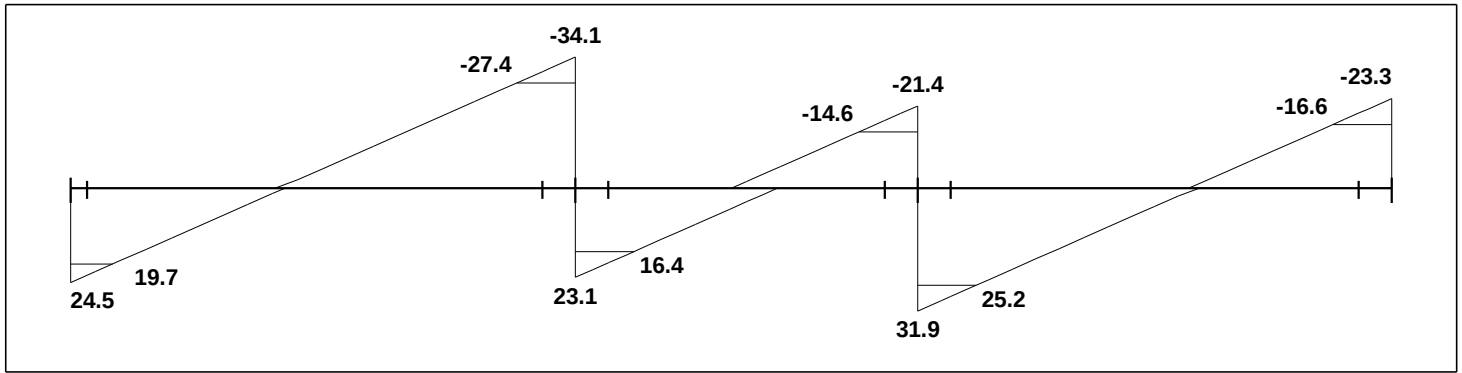


Fig 4.4: Shear and Moment Envelope Diagram of Rib (R1).

✓ Moment Design for (R 1):-**Design of Positive Moment for (Rib1) :***** Mu=31.7 KN.m**Assume bar diameter ϕ 12 for main positive reinforcement

$$d = h - \text{cover} - d_{\text{stirrups}} - \frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314 \text{ mm}$$

Check if $a > h_f$ to determine whether the section will act as rectangular or T- section.

$$M_{nf} = 0.85 \cdot f'_c \cdot b_e \cdot h_f \cdot \left(d - \frac{h_f}{2}\right)$$

$$= 0.85 \times 24 \times 520 \times 80 \times \left(314 - \frac{80}{2}\right) \times 10^{-6} = 232.5 \text{ KN.m}$$

$$M_{nf} = 232.5 \text{ KN.m} \gg \frac{M_u}{\phi} = \frac{31.7}{0.9} = 35.22 \text{ KN.m}$$

the section will be designed as rectangular section with $b_e = 520 \text{ mm}$.

$$R_n = \frac{M_u}{\phi b d^2} = \frac{31.7 \times 10^6}{0.9 \times 520 \times 314^2} = 2.977 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 2.977}{420}} \right) = 0.005398$$

$$A_{s, \text{req}} = \rho \cdot b \cdot d = 0.005398 \times 520 \times 314 = 290.06 \text{ mm}^2$$

Check for As min:-

$$A_s \min = \frac{\sqrt{f_c'}}{4(f_y)}(bw)(d) \quad \text{ACI-318 (10.5.1)}$$

$$A_s \min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110 \text{ mm}^2$$

$$A_s \min = \frac{1.4}{(f_y)}(bw)(d)$$

$$A_s \min = \frac{1.4}{420}(120)(314) = 125.6 \text{ mm}^2 \quad \text{- controls}$$

$$A_{s\text{req}} = 290.06 \text{ mm}^2 > A_{s\min} = 125.6 \text{ mm}^2 \quad \text{OK}$$

Use 2 ø 14 , $A_{s\text{provided}} = 307.8 \text{ mm}^2 > A_{s\text{required}} = 290.06 \text{ mm}^2$ Ok

$$S = \frac{120 - 40 - 20 - (2 \times 14)}{1} = 32 \text{ mm} > d_b = 14 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f_c'} = \frac{307.8 \times 420}{0.85 \times 520 \times 24} = 52.809 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f_c' \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{52.809}{0.85} = 62.128 \text{ mm}$$

$$\epsilon_s = 0.003 \left(\frac{d - c}{c} \right) = 0.003 \left(\frac{314 - 62.128}{62.128} \right) = 0.01216 > 0.005 \quad \text{Ok}$$

Design of Positive Moment for (Rib1) :-

***Mu = 28.6 KN.m**

$$d = h - \text{cover} - d_{\text{stirrups}} - \frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314 \text{ mm}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{28.6 \times 10^6}{0.9 \times 520 \times 314^2} = 2.686 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f_c'} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 2.686}{420}} \right) = 0.006883$$

$$A_{s\text{req}} = \rho \cdot b \cdot d = 0.006883 \times 520 \times 314 = 259.33 \text{ mm}^2$$

Check for A_s min:-

$$A_s \min = \frac{\sqrt{f_c'}}{4(f_y)}(bw)(d) \quad \text{ACI-318 (10.5.1)}$$

$$A_s \min = \frac{\sqrt{24}}{4(420)}(120)(314) = 110 \text{ mm}^2$$

$$A_s \min = \frac{1.4}{(f_y)}(bw)(d)$$

$$A_s \min = \frac{1.4}{420}(120)(314) = 125.6 \text{ mm}^2 \quad \text{- controls}$$

$$A_{s\text{req}} = 290.06 \text{ mm}^2 > A_{s\text{min}} = 125.6 \text{ mm}^2 \quad \dots \quad \text{OK}$$

$$\text{Use } 2 \text{ } \phi 14, A_{s\text{provided}} = 307.8 \text{ mm}^2 > A_{s\text{required}} = 259.33 \text{ mm}^2 \quad \dots \quad \text{Ok}$$

$$S = \frac{120 - 40 - 20 - (2 \times 14)}{1} = 32 \text{ mm} > d_b = 14 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f_c'} = \frac{307.8 \times 420}{0.85 \times 520 \times 24} = 52.809 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f_c' \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{52.809}{0.85} = 62.128 \text{ mm}$$

$$\epsilon_s = 0.003 \left(\frac{d - c}{c} \right) = 0.003 \left(\frac{314 - 62.128}{62.128} \right) = 0.01216 > 0.005 \quad \text{Ok}$$

Design of Negative Moment for (Rib1) :-

*** $M_u = -22.8 \text{ KN.m}$**

Assume bar diameter $\phi 12$ for main negative reinforcement

$$d = h - \text{cover} - d_{\text{stirrups}} - \frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314 \text{ mm}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{22.8 \times 10^6}{0.9 \times 120 \times 314^2} = 2.141 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f_c'} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 2.141}{420}} \right) = 0.005398$$

$$A_{s, \text{req}} = \rho \cdot b \cdot d = 0.005398 \times 120 \times 314 = 203.4 \text{ mm}^2$$

Check for As min:-

$$A_{s \text{ min}} = \frac{\sqrt{f_c'}}{4(f_y)} (bw)(d) \quad \text{ACI-318 (10.5.1)}$$

$$A_{s \text{ min}} = \frac{\sqrt{24}}{4(420)} (120)(314) = 110 \text{ mm}^2$$

$$A_{s \text{ min}} = \frac{1.4}{(f_y)} (bw)(d)$$

$$A_{s \text{ min}} = \frac{1.4}{420} (120)(314) = 125.6 \text{ mm}^2 \quad - \text{ controls}$$

$$A_{s, \text{req}} = 203.4 \text{ mm}^2 > A_{s, \text{min}} = 125.6 \text{ mm}^2 \quad \text{..... OK}$$

Use 2 ø 12 , $A_{s, \text{provided}} = 226.1 \text{ mm}^2 > A_{s, \text{required}} = 203.4 \text{ mm}^2 \dots \text{Ok}$

$$S = \frac{140 - 40 - 20 - (2 \times 12)}{1} = 56 \text{ mm} > d_b = 12 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f_c'} = \frac{226.1 \times 420}{0.85 \times 120 \times 24} = 38.792 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f_c' \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{38.792}{0.85} = 45.637 \text{ mm}$$

$$\epsilon_s = 0.003 \left(\frac{d - c}{c} \right) = 0.003 \left(\frac{314 - 45.637}{45.637} \right) = 0.017641 > 0.005 \quad \text{Ok}$$

Design of Negative Moment for (Rib1) :-

***Mu= - 19.3KN.m**

Assume bar diameter ø 12 for main negative reinforcement

$$d = h - \text{cover} - d_{\text{stirrups}} - \frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 314 \text{ mm}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{19.3 \times 10^6}{0.9 \times 120 \times 314^2} = 1.812 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2mR_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 1.812}{420}} \right) = 0.004526$$

$$A_{s, \text{req}} = \rho \cdot b \cdot d = 0.004526 \times 120 \times 314 = 170.55 \text{ mm}^2$$

Check for As min:-

$$A_s \text{ min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) \text{ ACI-318 (10.5.1)}$$

$$A_s \text{ min} = \frac{\sqrt{24}}{4(420)} (120)(314) = 110 \text{ mm}^2$$

$$A_s \text{ min} = \frac{1.4}{(f_y)} (b_w)(d)$$

$$A_s \text{ min} = \frac{1.4}{420} (120)(314) = 125.6 \text{ mm}^2 \quad - \text{ controls}$$

$$A_{s, \text{req}} = 170.55 \text{ mm}^2 > A_{s, \text{min}} = 125.6 \text{ mm}^2 \quad \text{OK}$$

Use 2 #12, $A_{s, \text{provided}} = 226.1 \text{ mm}^2 > A_{s, \text{required}} = 170.55 \text{ mm}^2 \dots \text{ Ok}$

$$S = \frac{120 - 40 - 20 - (2 \times 12)}{1} = 36 \text{ mm} > d_b = 12 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{226.1 \times 420}{0.85 \times 120 \times 24} = 38.792 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{38.792}{0.85} = 45.637 \text{ mm}$$

$$\epsilon_s = 0.003 \left(\frac{d - c}{c} \right) = 0.003 \left(\frac{284 - 45.637}{45.637} \right) = 0.017641 > 0.005 \quad \text{Ok}$$

✓ Shear Design for (R 1):-

V_u at distance d from support = 27.4 kN

Shear strength V_c , provided by concrete for the joists may be taken 10% greater than for beams. This is mainly due to the interaction between the slab and closely spaced ribs. (ACI, 8.13.8).

$$V_c = \frac{1.1}{6} \sqrt{f'_c} b_w d = \frac{1.1}{6} \sqrt{24} \times 120 \times 314 \times 10^{-3} = 33.84 \text{ kN}$$

$$\phi V_c = 0.75 \times 33.84 = 25.38 \text{ kN}$$

$$\phi V_c < V_u$$

$$V_{s_{\min}} = \frac{1}{16} \sqrt{f'_c} b_w d \geq \frac{1}{3} b_w d$$

$$V_{s_{\min}} = \frac{1}{16} \sqrt{24} \times 120 \times 314 = 11.54 \text{ kN}$$

$$V_{s_{\min}} = \frac{1}{3} b_w d = \frac{1}{3} \times 120 \times 314 = 12.56 \text{ kN} \quad - \text{ control}$$

$$\phi(V_c + V_{s_{\min}}) = 0.75(33.84 + 12.56) = 34.8 \text{ kN}$$

$$\phi(V_c + V_{s_{\min}}) > V_u > \phi V_c$$

Case 3 :

for shear design, minimum shear reinforcement is required ($A_{v, \min}$), Reinforcement.

Use stirrups (2 leg stirrups) $\phi 8 @ 150 \text{ mm}$, $A_v = 2 \times 50.24 = 100.5 \text{ mm}^2$

$$A_{v_{\min}} = \frac{1}{16} \sqrt{f'_c} \frac{b_w s}{f_{yt}} \geq \frac{1}{3} \frac{b_w s}{f_{yt}}$$

$$A_{v_{\min}} = 100.5 = \frac{1}{16} \sqrt{24} \frac{120s}{420} \rightarrow s = 1.145 \text{ m}$$

$$100.5 = \frac{1}{3} \frac{120s}{420} \rightarrow s = 1.055 \text{ m}$$

$$s_{\max} \rightarrow \frac{d}{2} = 157 \text{ mm} - \text{ control}$$

$$s_{\max} \rightarrow \leq 600 \text{ mm}$$

Take (2 leg closed stirrups) $\phi 8 @ 150 \text{ mm}$

$$A_v = \frac{2 \times 50.3}{0.15} = 670.67 \text{ mm}^2/\text{m}_{\text{strip}}$$

4.6 Design of Beam

❖ Material :-

- ⇒ concrete B300 $F_c' = 24 \text{ N/mm}^2$
- ⇒ Reinforcement Steel $f_y = 420 \text{ N/mm}^2$

❖ Section :-

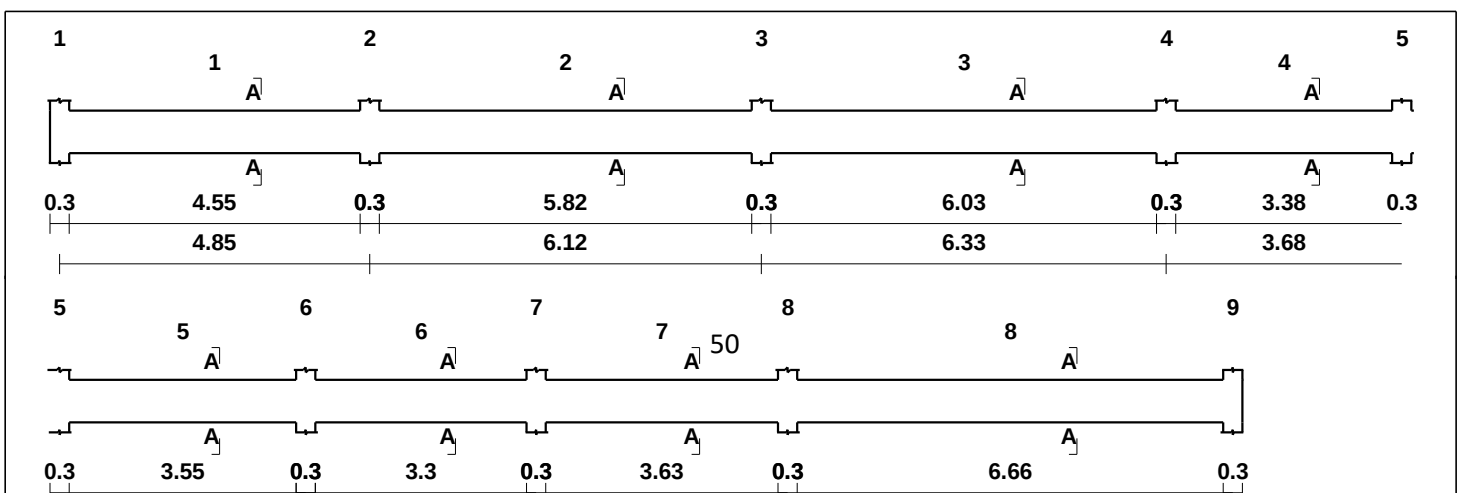
- ⇒ $B = 80 \text{ cm}$

- ⇒ $h = 40 \text{ cm}$

- ⇒ $d = 450 - 40 - 10 - 18/2 = 391 \text{ mm}$

✓ Statically System and Dimensions:-

Geometry Units: meter, cm



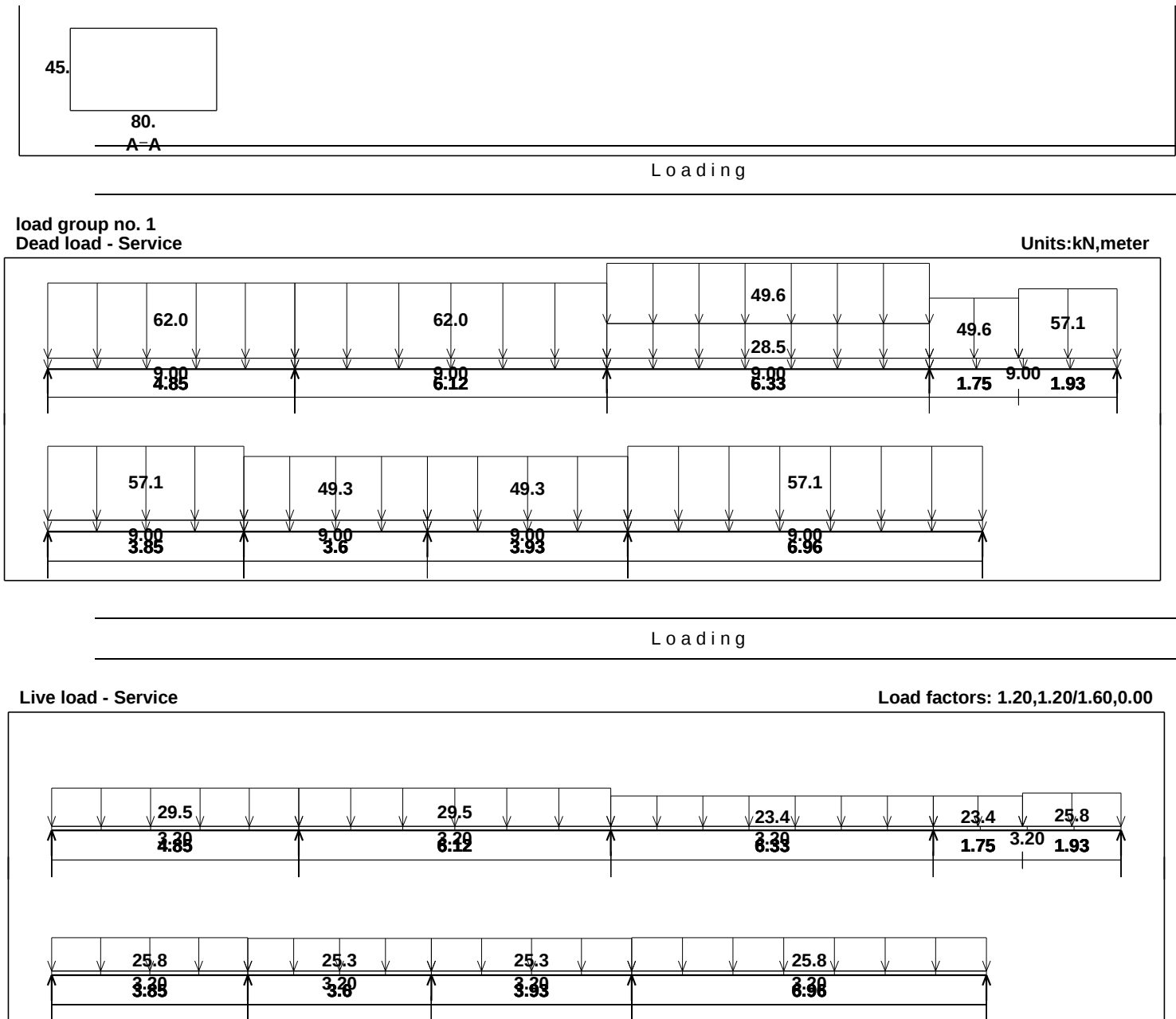


Fig 4.5: Statically System and Loads Distribution of Beam (B4,B-1) .

Moment/Shear Envelope (Factored) Units:kN,meter

Moments: spans 1 to 8

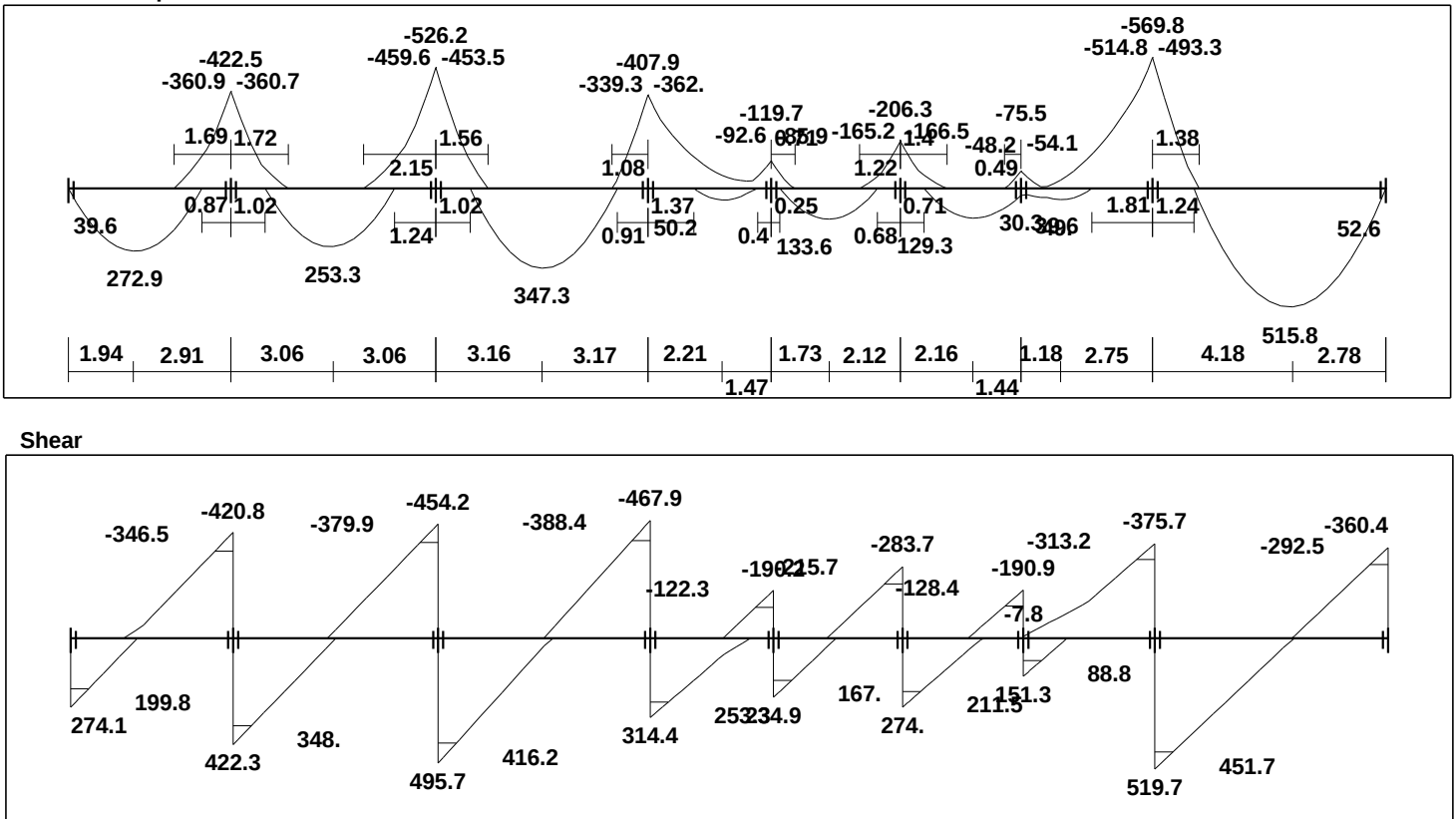


Fig 4.6: Shear and Moment Envelope Diagram of Beam (B4.B-1).

✓ Load Calculations:-**Dead Load Calculations for Beam (B4,B-1) :-**

The distributed Dead and Live loads acting upon Beam 4 can be defined from the support reactions of the R12, R13, R14, and R15.

From Rib12

The support reaction from Dead Loads and live load for R12 upon B4 is 22.57 KN and 14.35 KN respectively.

The service distributed Dead Load and Live load from the R12 on B4 in span 1,2 .

$$DL = (32.26 \text{ KN} / 0.52) = 62.03 \text{ KN} / \text{m}$$

$$LL = (14.35 \text{ KN} / 0.52) = 29.52 \text{ KN} / \text{m}$$

From Rib 13

The support reaction from Dead Loads and live load for R13 upon B4 is 25.8 KN and 12.21 KN respectively.

The service distributed Dead Load and Live load from the R12 on B4 in span 3,4 .

$$DL = (25.8 \text{ KN} / 0.52) = 49.61 \text{ KN} / \text{m}$$

$$LL = (12.21 \text{ KN} / 0.52) = 23.48 \text{ KN} / \text{m}$$

From Rib14

The support reaction from Dead Loads and live load for R14 upon B4 is 29.73 KN and 13.42 KN respectively.

The service distributed Dead Load and Live load from the R12 on B4 in span 4,5,8 .

$$DL = (29.73 \text{ KN} / 0.52) = 57.17 \text{ KN} / \text{m}$$

$$LL = (13.42 \text{ KN} / 0.52) = 25.8 \text{ KN} / \text{m}$$

From Rib15

The support reaction from Dead Loads and live load for R15 upon B4 is 25.68 KN and 13.17 KN respectively.

The service distributed Dead Load and Live load from the R12 on B4 in span 6,7 .

$$DL = (25.68 \text{ KN} / 0.52) = 49.38 \text{ KN} / \text{m}$$

$$LL = (13.17 \text{ KN} / 0.52) = 25.32 \text{ KN} / \text{m}$$

From concrete wall height = 3.8 m :

Dead load from the concrete wall act on span 3 on beam 4 :

$$DL = 25 * 0.3 * 3.8 = 28.5 \text{ KN/m}$$

Self weight of the beam 4 :

$$DL = 25 * 0.8 * 0.45 = 9 \text{ kN/m}$$

Live load acting directly upon the beam 4 :

$$LL = 4 \text{ kN/m}^2$$

$$LL = 4 * 0.8 = 3.2 \text{ KN/m}$$

✓ Moment Design for (B4,b-1):-

Determine of $M_{n,max}$ To decide if the beam will design singly or doubly :

$$d = 450 - 40 - 10 - 18/2 = 391 \text{ mm}$$

$$c = \frac{3}{7}d = \frac{3}{7} \cdot 391 = 167.57 \text{ mm}$$

$$a = \beta_1 c = 167.57 \cdot 0.85 = 142.44 \text{ mm}$$

$$M_{n,max} = 0.85 \cdot f'_c \cdot a \cdot b \left(d - \frac{a}{2} \right) = 0.85 \cdot 24 \cdot 124.22 \cdot 800 \cdot (391 - 142.44/2) \cdot 10^{-6} = 548.28 \text{ KN.m}$$

$$\phi M_{n,max} = 0.82 \cdot 565.4 = 531.59 \text{ KN.m} > M_u \text{ max } 515.8 \text{ KN.m} .$$

Design as singly reinforcement.

Flexural Design of Positive Moment for (B4):-

$$M_u = 272.9 \text{ KN.m}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{272.9 \times 10^6}{0.9 \times 800 \times 391^2} = 2.479 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 2.479}{420}} \right) = 0.006313$$

$$A_s = \rho \cdot b \cdot d = 0.006313 \times 800 \times 391 = 1974.7782 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \cdot 420} \cdot 800 \cdot 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} \cdot 800 \cdot 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 1974.7782 \text{ mm}^2 > A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{OK}$$

$$\text{Use 5 } \phi 25 \text{ Bottom, } A_{s,provided} = 2454.37 \text{ mm}^2 > A_{s,required} = 1974.7782 \text{ mm}^2 \dots \text{ Ok}$$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - (5 \times 25)}{4} = 143.75 \text{ mm} > d_b = 25 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{2454.37 \times 420}{0.85 \times 800 \times 24} = 63.16 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{63.61}{0.85} = 74.31 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-74.31}{74.31} \right) = 0.012785 > 0.005 \quad \text{OK}$$

Flexural Design of Positive Moment for (B4):-

Mu=253.3 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{253.3 \times 10^6}{0.9 \times 800 \times 391^2} = 2.301 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 2.301}{420}} \right) = 0.005829$$

$$A_s = \rho \cdot b \cdot d = 0.005829 \times 800 \times 391 = 1823.2216 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} * 800 * 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} * 800 * 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 1823.2216 \text{ mm}^2 > A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{OK}$$

Use 4 ø 25 Bottom, $A_{s,provided} = 1963.495 \text{ mm}^2 > A_{s,required} = 1974.7782 \text{ mm}^2 \dots \text{Ok}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - (4 \times 25)}{3} = 200 \text{ mm} > d_b = 25 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{1963.495 \times 420}{0.85 \times 800 \times 24} = 50.531 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{63.61}{0.85} = 59.448 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-59.448}{59.448} \right) = 0.0167314 > 0.005 \quad \text{OK}$$

Flexural Design of Positive Moment for (B4):-

Mu=347.3 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{347.3 \times 10^6}{0.9 \times 800 \times 391^2} = 3.155 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 3.155}{420}} \right) = 0.008205$$

$$A_s = \rho \cdot b \cdot d = 0.008205 \times 800 \times 391 = 2566.6224 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} * 800 * 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} * 800 * 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 2566.6224 \text{ mm}^2 > A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{OK}$$

Use 6 ø 25 Bottom, $A_{s,provided} = 2945.243 \text{ mm}^2 > A_{s,required} = 2566.6224 \text{ mm}^2 \dots \text{Ok}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - (6 \times 25)}{5} = 110 \text{ mm} > d_b = 25 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{2945.243 \times 420}{0.85 \times 800 \times 24} = 75.797 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{75.797}{0.85} = 89.173 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-89.173}{89.173} \right) = 0.010154 > 0.005 \quad \text{Ok}$$

Flexural Design of Positive Moment for (B4):-

Mu=133.6 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{133.6 \times 10^6}{0.9 \times 800 \times 391^2} = 1.214 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2mR_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 1.214}{420}} \right) = 0.002981$$

$$A_s = \rho \cdot b \cdot d = 0.002981 \times 800 \times 391 = 932.556 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} * 800 * 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} * 800 * 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 932.556 \text{ mm}^2 < A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{- not OK}$$

$$\text{Take } A_{s,req} = A_{s,min} = 1042.7 \text{ mm}^2$$

Use 4 ϕ 20 Bottom, $A_{s,provided} = 1256.6 \text{ mm}^2 > A_{s, required} = 1042.7 \text{ mm}^2 \dots \text{Ok}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - (4 \times 20)}{3} = 206.66 \text{ mm} > d_b = 20 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{1256.6 \times 420}{0.85 \times 800 \times 24} = 32.34 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{32.34}{0.85} = 38.047 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-38.047}{38.047} \right) = 0.0278 > 0.005 \quad \text{OK}$$

Flexural Design of Positive Moment for (B4):-

Mu=129.3 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{129.3 \times 10^6}{0.9 \times 800 \times 391^2} = 1.175 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 1.175}{420}} \right) = 0.002882$$

$$A_s = \rho \cdot b \cdot d = 0.002882 \times 800 \times 391 = 901.594 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} \times 800 \times 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} \times 800 \times 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 932.556 \text{ mm}^2 < A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{- not OK}$$

Take $A_{s,req} = < A_{s,min} = 1042.7 \text{ mm}^2$

Use 4 ϕ 20 Bottom, $A_{s,provided} = 1256.6 \text{ mm}^2 > A_{s, required} = 1042.7 \text{ mm}^2 \dots \text{Ok}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - (4 \times 20)}{3} = 206.66 \text{ mm} > d_b = 20 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{1256.6 \times 420}{0.85 \times 800 \times 24} = 32.34 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{32.34}{0.85} = 38.047 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-38.047}{38.047} \right) = 0.0278 > 0.005 \quad \text{OK}$$

Flexural Design of Positive Moment for (B4):-

Mu=515.8 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{515.8 \times 10^6}{0.9 \times 800 \times 391^2} = 4.686 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 4.686}{420}} \right) = 0.012859$$

$$A_s = \rho \cdot b \cdot d = 0.012859 \times 800 \times 391 = 4022.3532 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} \times 800 \times 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} \times 800 \times 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 4022.3532 \text{ mm}^2 > A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{OK}$$

Use 7 ϕ 28 Bottom, $A_{s,provided} = 4310.3 \text{ mm}^2 > A_{s,required} = 4022.3532 \text{ mm}^2 \dots \text{Ok}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - (7 \times 28)}{6} = 84 \text{ mm} > d_b = 28 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{4310.3 \times 420}{0.85 \times 800 \times 24} = 110.927 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{110.927}{0.85} = 130.502 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-130.502}{130.502} \right) = 0.05988 > 0.005 \quad \text{OK}$$

Flexural Design of negative Moment for (B4):-

Mu= -360.9 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{360.9 \times 10^6}{0.9 \times 800 \times 391^2} = 3.279 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 3.279}{420}} \right) = 0.008561$$

$$A_s = \rho \cdot b \cdot d = 0.008561 \times 800 \times 391 = 2677.8342 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} * 800 * 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} * 800 * 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 2677.8342 \text{ mm}^2 > A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{OK}$$

Use 6 Ø 25 Top , $A_{s,provided} = 2945.243 \text{ mm}^2 > A_{s, required} = 2677.8342 \text{ mm}^2 \dots \text{ Ok}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - 6 \times 25}{5} = 110 \text{ mm} > d_b = 28 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{2945.243 \times 420}{0.85 \times 800 \times 24} = 75.797 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{110.927}{0.85} = 89.173 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-89.173}{89.173} \right) = 0.0101542 > 0.005 \quad \text{Ok}$$

Flexural Design of negative Moment for (B4):-

Mu= -459.6 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{459.6 \times 10^6}{0.9 \times 800 \times 391^2} = 4.175 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 4.175}{420}} \right) = 0.011242$$

$$A_s = \rho \cdot b \cdot d = 0.011242 \times 800 \times 391 = 3516.6328 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} * 800 * 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} * 800 * 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 3516.6328 \text{ mm}^2 > A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{OK}$$

Use 6 ø 28 Top, $A_{s,provided} = 3694.512 \text{ mm}^2 > A_{s, required} = 3516.6328 \text{ mm}^2 \dots \text{Ok}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - 6 \times 28}{5} = 53.6 \text{ mm} > d_b = 28 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{3694.512 \times 420}{0.85 \times 800 \times 24} = 95.079 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{95.079}{0.85} = 111.858 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-111.858}{111.858} \right) = 0.00748651 > 0.005 \quad \text{Ok}$$

Flexural Design of negative Moment for (B4):-

Mu= -362 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{362 \times 10^6}{0.9 \times 800 \times 391^2} = 3.289 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 3.289}{420}} \right) = 0.008590$$

$$A_s = \rho \cdot b \cdot d = 0.008590 \times 800 \times 391 = 2686.8725 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} \times 800 \times 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} \times 800 \times 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 2686.8725 \text{ mm}^2 > A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{OK}$$

Use 6 ϕ 25 Top, $A_{s,provided} = 2945.243 \text{ mm}^2 > A_{s, required} = 2686.8725 \text{ mm}^2 \dots \text{Ok}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - 6 \times 25}{5} = 110 \text{ mm} > d_b = 28 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{2945.243 \times 420}{0.85 \times 800 \times 24} = 75.797 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{110.927}{0.85} = 89.173 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-89.173}{89.173} \right) = 0.0101542 > 0.005 \quad \text{Ok}$$

Flexural Design of negative Moment for (B4):-

Mu= -92.6 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{92.6 \times 10^6}{0.9 \times 800 \times 391^2} = 0.841 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 0.814}{420}} \right) = 0.002046$$

$$A_s = \rho \cdot b \cdot d = 0.002046 \times 800 \times 391 = 640.0110 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} \times 800 \times 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} \times 800 \times 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 640.0110 \text{ mm}^2 < A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{- not OK}$$

$$\text{Take } A_{s,req} = A_{s,min} = 1042.7 \text{ mm}^2$$

$$\text{Use 4 } \phi 20 \text{ Top, } A_{s,provided} = 1256.6 \text{ mm}^2 > A_{s, required} = 1042.7 \text{ mm}^2 \dots \text{ Ok}$$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - (4 \times 20)}{3} = 206.66 \text{ mm} > d_b = 20 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{1256.6 \times 420}{0.85 \times 800 \times 24} = 32.34 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{32.34}{0.85} = 38.047 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-38.047}{38.047} \right) = 0.0278 > 0.005 \quad \text{OK}$$

Flexural Design of negative Moment for (B4):-

Mu= -166.5 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{166.5 \times 10^6}{0.9 \times 800 \times 391^2} = 1.513 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 31.513}{420}} \right) = 0.003746$$

$$A_s = \rho \cdot b \cdot d = 0.003746 \times 800 \times 391 = 1171.7201 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} \times 800 \times 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} \times 800 \times 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 1171.7201 \text{ mm}^2 > A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{OK}$$

Use 4 Ø 20 Top, $A_{s,provided} = 1256.6 \text{ mm}^2 > A_{s, required} = 1171.7201 \text{ mm}^2 \dots \text{OK}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - (4 \times 20)}{3} = 206.66 \text{ mm} > d_b = 20 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{1256.6 \times 420}{0.85 \times 800 \times 24} = 32.34 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{32.34}{0.85} = 38.047 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391-38.047}{38.047} \right) = 0.0278 > 0.005 \quad \text{OK}$$

Flexural Design of Negative Moment for (B4):-

Mu=514.8 KN.m

$$R_n = \frac{M_u}{\phi b d^2} = \frac{515.8 \times 10^6}{0.9 \times 800 \times 391^2} = 4.677 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.6$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 4.677}{420}} \right) = 0.01283$$

$$A_s = \rho \cdot b \cdot d = 0.01283 \times 800 \times 391 = 4013.1547 \text{ mm}^2$$

Check for $A_{s,min}$:-

$$A_{s,min} = \frac{\sqrt{f'_c}}{4(f_y)} (b_w)(d) = \frac{\sqrt{24}}{4 \times 420} \times 800 \times 391 = 912.1 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{(f_y)} (b_w)(d) = \frac{1.4}{420} \times 800 \times 391 = 1042.7 \text{ mm}^2 \quad \text{- Controls}$$

$$A_{s,req} = 4013.1547 \text{ mm}^2 > A_{s,min} = 1042.7 \text{ mm}^2 \quad \text{OK}$$

Use 7 ϕ 28 Top, $A_{s,provided} = 4310.3 \text{ mm}^2 > A_{s, required} = 4013.1547 \text{ mm}^2 \dots \text{Ok}$

Check spacing :-

$$S = \frac{800 - 40 \times 2 - 20 - (7 \times 28)}{6} = 84 \text{ mm} > d_b = 28 > 25 \text{ mm} \quad \text{OK}$$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{4310.3 \times 420}{0.85 \times 800 \times 24} = 110.927 \text{ mm}$$

$$B_1 = 0.85 \text{ for } f'_c \leq 28 \text{ Mpa}$$

$$c = \frac{a}{B_1} = \frac{110.927}{0.85} = 130.502 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d-c}{c} \right) = 0.003 \left(\frac{391 - 130.502}{130.502} \right) = 0.05988 > 0.005 \quad \text{OK}$$

✓ Shear Design for (B4,B-1):-

1. $V_u = 346.5 \text{ KN}$

$$V_c = \frac{1}{6} \sqrt{f'_c} b_w d = \frac{1}{6} \sqrt{24} * 800 * 391 = 255.4 \text{ KN}$$

$$\Phi V_c = 0.75 * 255.4 = 191.55 \text{ KN}$$

$$\Phi V_{smin} \geq 0.75 \left(\frac{1}{3} \right) * b_w * d = 0.75 * \left(\frac{1}{3} \right) * 800 * 391 * 10^{-3} = 78.2 \text{ KN} - \text{Controls}$$

$$\Phi V_{smin} \geq 0.75 \left(\frac{\sqrt{f'_c}}{16} \right) * b_w * d = 0.75 * \left(\frac{\sqrt{24}}{16} \right) * 800 * 391 * 10^{-3} = 71.83 \text{ KN}$$

$$\Phi (V_c + V_{smin}) = 269.75 \text{ KN}$$

$$\Phi (V_c + V_{smin}) < V_u$$

Calculate v_s'

$$v_s' = \frac{1}{3} \sqrt{f'_c} b_w d = \frac{1}{3} \sqrt{24} * 800 * 391 = 518.638 \text{ KN}$$

$$\Phi (v_c + v_{s,min}) < v_u \leq \Phi (v_c + v_s')$$

$$0.75(255.4 + 104.26) < 346.5 < 0.75(255.4 + 518.638)$$

$$269.745 < 346.5 < 580.528$$

Case 4 :

shear reinforcement are required

Use 2 leg Φ 12

$$A_s = 226 \text{ mm}^2$$

$$V_s = V_n - V_c = \frac{346.5}{0.75} - 255.4 = 206.6 \text{ KN}$$

$$S = \frac{A_v f_{yt} d}{v_s} = \frac{226 * 420 * 391}{206.6 * 1000} = 179.64 \text{ mm} \quad \textbf{control}$$

$$s_{max} \leq \frac{d}{2} = \frac{391}{2} = 195.5 \text{ mm}$$

$$\text{or} \quad s_{max} \leq 600 \text{ mm}$$

Use 2 leg Φ 12 @150mm

2- $V_u = 379.9 \text{ KN}$

$$V_c = \frac{1}{6} \sqrt{f'c} b_w d = \frac{1}{6} \sqrt{24} * 800 * 391 = 255.4 \text{ KN}$$

$$\Phi V_c = 0.75 * 255.4 = 191.55 \text{ KN}$$

$$\Phi V_{smin} \geq 0.75 \left(\frac{1}{3} \right) * b_w * d = 0.75 * \left(\frac{1}{3} \right) * 800 * 391 * 10^{-3} = 78.2 \text{ KN} - \textbf{Control}$$

$$\Phi V_{smin} \geq 0.75 \left(\frac{\sqrt{f'c}}{16} \right) * b_w * d = 0.75 * \left(\frac{\sqrt{24}}{16} \right) * 800 * 391 * 10^{-3} = 71.83 \text{ KN}$$

$$\Phi (V_c + V_{smin}) = 269.75 \text{ KN}$$

$$\Phi (V_c + V_{smin}) < V_u$$

Calculate v_s'

$$v_s' = \frac{1}{3} \sqrt{f'c} b_w d = \frac{1}{3} \sqrt{24} * 800 * 391 = 518.638 \text{ KN}$$

$$\phi(v_c + v_{s,\min}) < v_u \leq \phi(v_c + v_{s'})$$

$$0.75(255.4 + 104.26) < 379.9 < 0.75(255.4 + 518.638)$$

$$269.745 < 379.9 < 580.528$$

Case 4 :

shear reinforcement are required

Use 2 leg Φ 12

$$A_s = 226 \text{ mm}^2$$

$$V_s = V_n - V_c = \frac{379.9}{0.75} - 255.4 = 251.13 \text{ KN}$$

$$S = \frac{A_v f_{yt} d}{v_s} = \frac{226 * 420 * 391}{251.13 * 1000} = 147.78 \text{ mm} \quad \textbf{control}$$

$$s_{max} \leq \frac{d}{2} = \frac{391}{2} = 195.5 \text{ mm}$$

$$\text{or} \quad s_{max} \leq 600 \text{ mm}$$

Use 2 leg Φ 12 @125mm

$$\mathbf{3-V_u = 416.2 \text{ KN}}$$

$$V_c = \frac{1}{6} \sqrt{f'c} b_w d = \frac{1}{6} \sqrt{24} * 800 * 391 = 255.4 \text{ KN}$$

$$\phi V_c = 0.75 * 255.4 = 191.55 \text{ KN}$$

$$\phi V_{s\min} \geq 0.75 \left(\frac{1}{3} \right) * b_w * d = 0.75 * \left(\frac{1}{3} \right) * 800 * 391 * 10^{-3} = 78.2 \text{ KN} - \textbf{Controls}$$

$$\phi V_{s\min} \geq 0.75 \left(\frac{\sqrt{f'c}}{16} \right) * b_w * d = 0.75 * \left(\frac{\sqrt{24}}{16} \right) * 800 * 391 * 10^{-3} = 71.83 \text{ KN}$$

$$\phi (V_c + V_{s\min}) = 269.75 \text{ KN}$$

$$\phi (V_c + V_{s\min}) < V_u$$

Calculate $v_{s'}$

$$v_{s'} = \frac{1}{3} \sqrt{f'c'} b_w d = \frac{1}{3} \sqrt{24} * 800 * 391 = 518.638 \text{ KN}$$

$$\phi(v_c + v_{s,\min}) < v_u \leq \phi(v_c + v_{s'})$$

$$0.75(255.4 + 104.26) < 416.2 < 0.75(255.4 + 518.638)$$

$$269.745 < 416.2 < 580.528$$

Case 4 :

shear reinforcement are required

Use 2 leg Φ 12

$$A_s = 226 \text{ mm}^2$$

$$V_s = V_n - V_c = \frac{416.2}{0.75} - 255.4 = 299.53 \text{ KN}$$

$$S = \frac{A_v f_{yt} d}{v_s} = \frac{226 * 420 * 391}{299.53 * 1000} = 123.9 \text{ mm} \quad \textbf{control}$$

$$s_{max} \leq \frac{d}{2} = \frac{391}{2} = 195.5 \text{ mm}$$

$$\text{or} \quad s_{max} \leq 600 \text{ mm}$$

Use 2 leg Φ 12 @120 mm

$$\mathbf{4-V_u = 313.2 \text{ KN}}$$

$$V_c = \frac{1}{6} \sqrt{f'c'} b_w d = \frac{1}{6} \sqrt{24} * 800 * 391 = 255.4 \text{ KN}$$

$$\phi V_c = 0.75 * 255.4 = 191.55 \text{ KN}$$

$$\phi V_{s\min} \geq 0.75 \left(\frac{1}{3} \right) * b_w * d = 0.75 * \left(\frac{1}{3} \right) * 800 * 391 * 10^{-3} = 78.2 \text{ KN} - \textbf{Controls}$$

$$\phi V_{s\min} \geq 0.75 \left(\frac{\sqrt{f'c'}}{16} \right) * b_w * d = 0.75 * \left(\frac{\sqrt{24}}{16} \right) * 800 * 391 * 10^{-3} = 71.83 \text{ KN}$$

$$\phi (V_c + V_{s\min}) = 269.75 \text{ KN}$$

$$\Phi (V_c + V_{s_{\min}}) < V_u$$

Calculate $v_{s'}$

$$v_{s'} = \frac{1}{3} \sqrt{f'c'} b_w d = \frac{1}{3} \sqrt{24} * 800 * 391 = 518.638 \text{ KN}$$

$$\Phi(v_c + v_{s,\min}) < v_u \leq \Phi(v_c + v_{s'})$$

$$0.75(255.4 + 104.26) < 313.2 < 0.75(255.4 + 518.638)$$

$$269.745 < 313.2 < 580.528$$

Case 4 :

shear reinforcement are required

Use 2 leg Φ 12

$$A_s = 226 \text{ mm}^2$$

$$V_s = V_n - V_c = \frac{313.2}{0.75} - 255.4 = 162.2 \text{ KN}$$

$$S = \frac{A_v f_{yt} d}{v_s} = \frac{226 * 420 * 391}{162.2 * 1000} = 288.81 \text{ mm} \quad \textbf{control}$$

$$s_{\max} \leq \frac{d}{2} = \frac{391}{2} = 195.5 \text{ mm}$$

$$\text{or} \quad s_{\max} \leq 600 \text{ mm}$$

Use 2 leg Φ 12 @175 mm

$$\mathbf{5-V_u = 451.7 \text{ KN}}$$

$$V_c = \frac{1}{6} \sqrt{f'c'} b_w d = \frac{1}{6} \sqrt{24} * 800 * 391 = 255.4 \text{ KN}$$

$$\Phi V_c = 0.75 * 255.4 = 191.55 \text{ KN}$$

$$\Phi V_{s\min} \geq 0.75 \left(\frac{1}{3} \right) * b_w * d = 0.75 * \left(\frac{1}{3} \right) * 800 * 391 * 10^{-3} = 78.2 \text{ KN} - \textbf{Controls}$$

$$\Phi V_{s\min} \geq 0.75 \left(\frac{\sqrt{f'c'}}{16} \right) * b_w * d = 0.75 * \left(\frac{\sqrt{24}}{16} \right) * 800 * 391 * 10^{-3} = 71.83 \text{ KN}$$

$$\Phi (V_c + V_{s_{\min}}) = 269.75 \text{ KN}$$

$$\Phi (V_c + V_{s_{\min}}) < V_u$$

Calculate $v_{s'}$

$$v_{s'} = \frac{1}{3} \sqrt{f'c'} b_w d = \frac{1}{3} \sqrt{24} * 800 * 391 = 518.638 \text{ KN}$$

$$\Phi(v_c + v_{s,\min}) < v_u \leq \Phi(v_c + v_{s'})$$

$$0.75(255.4 + 104.26) < 451.7 < 0.75(255.4 + 518.638)$$

$$269.745 < 451.7 < 580.528$$

Case 4 :

shear reinforcement are required

Use 2 leg $\Phi 12$

$$A_s = 226 \text{ mm}^2$$

$$V_s = V_u - V_c = \frac{451.7}{0.75} - 255.4 = 346.86 \text{ KN}$$

$$S = \frac{A_v f_{yt} d}{v_s} = \frac{226 * 420 * 391}{346.86 * 1000} = 106.99 \text{ mm} \quad \text{control}$$

$$s_{\max} \leq \frac{d}{2} = \frac{391}{2} = 195.5 \text{ mm}$$

$$\text{or} \quad s_{\max} \leq 600 \text{ mm}$$

Use 2 leg $\Phi 12$ @100 mm

$$6-V_u = 128.4 \text{ KN}$$

$$V_c = \frac{1}{6} \sqrt{f'c'} b_w d = \frac{1}{6} \sqrt{24} * 800 * 391 = 255.4 \text{ KN}$$

$$\Phi V_c = 0.75 * 255.4 = 191.55 \text{ KN}$$

$$\Phi V_{smin} \geq 0.75 \left(\frac{1}{3} \right) * b_w * d = 0.75 * \left(\frac{1}{3} \right) * 800 * 391 * 10^{-3} = 78.2 \text{ KN} - \text{Controls}$$

$$\Phi V_{smin} \geq 0.75 \left(\frac{\sqrt{f_c'}}{16} \right) * b_w * d = 0.75 * \left(\frac{\sqrt{24}}{16} \right) * 800 * 391 * 10^{-3} = 71.83 \text{ KN}$$

$$\Phi V_c > V_u > 0.5 \Phi V_c$$

$$191.55 > 128.4 > 95.77$$

Case 2 :

minimum shear reinforcement is required ($A_{v,min}$), Reinforcement.

Use stirrups (2 leg stirrups) $\emptyset 8@150 \text{ mm}$, $A_v = 2 \times 50.24 = 100.5 \text{ mm}^2$

$$A_{vmin} = \frac{1}{16} \sqrt{f_c'} \frac{b_w s}{f_{yt}} \geq \frac{1}{3} \frac{b_w s}{f_{yt}}$$

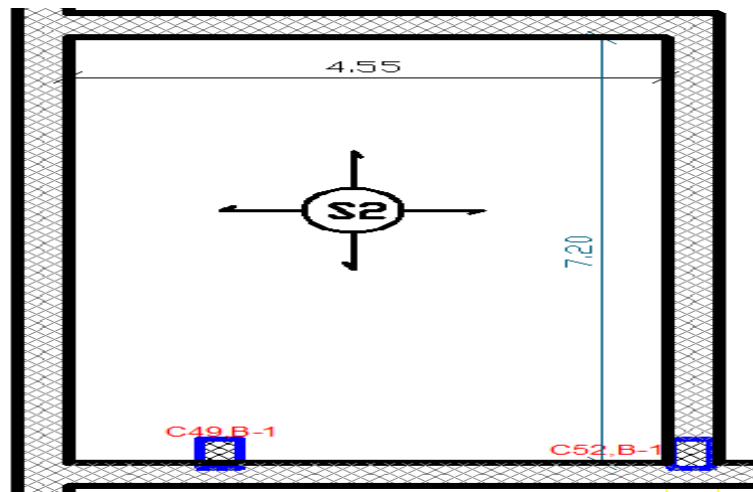
$$A_{vmin} = 100.5 = \frac{1}{16} \sqrt{24} \frac{800s}{420} \rightarrow s = 0.172 \text{ m}$$

$$100.5 = \frac{1}{3} \frac{800s}{420} \rightarrow s = 0.158 \text{ m}$$

$$S_{max} \rightarrow \frac{d}{2} = 157 \text{ mm} - \text{control}$$

$$S_{max} \rightarrow \leq 600 \text{ mm}$$

4. 7 Design of Two Way Solid Slab:



Fig(4-7):Plan Of Solid Slab

(4.12.2) Dead load calculations:

Table(4-4) calculation of the Dead load solid

Dead load from:	$\delta \times \gamma$	KN/m
Tiles	$0.03 \times 23 \times 1$	0.69
Mortar	$0.03 \times 22 \times 1$	0.66
Coarse sand	$0.07 \times 17 \times 1$	1.19
Slab	$0.2 \times 25 \times 1$	5
Plaster	$0.02 \times 22 \times 1$	0.44
Partitions	1.5×1	1.5
		9.48

Dead load = 9.48 KN/m^2 .

Live load = 4 KN/m^2 .

$$W_{uD} = 1.2 * \text{Dead load} = 1.2 * 9.48 = 11.38 \text{ KN/m}^2.$$

$$W_{uL} = 1.6 * \text{live load} = 1.6 * 4 = 6.4 \text{ KN/m}^2.$$

$$W_u = 11.03 + 6.4 = 17.8 \text{ KN/m}^2$$

(4.12.3) Shear Design :

$$l_a/l_b = 0.63$$

$$W_b = 0.28$$

$$W_a = 0.72$$

The total load on the panel being ($7.2 * 4.55 * 17.43$) = 571.01 KN

The load at face of the long beam is ($0.72 \times 571.1 / (2 * 7.2)$) = 28.55 KN

Assume the Φ 16

$$d = 200 - 20 - 12/2 = 174 \text{ mm}$$

$$V_c = (\sqrt{24} * 1000 * 174 * 10^{-3}) / 6 = 145 \text{ KN}$$

$$\phi V_c = 0.75 \times 145 = 108.75 \text{ KN}$$

$$V_u < \phi V_c.$$

The thickness of the slab is adequate enough

(4.12.4) Flexural Design:

$$(l_a/l_b = 0.632)$$

Positive moments :

$$C_{da} = 0.068$$

$$C_{la} = 0.073$$

$$C_{db} = 0.0132$$

$$C_{lb} = 0.0127$$

$$M_{a+ve,Dl} = C_a * W * L_a^2 = 0.068 * 11.38 * 4.55^2 = 16.05 \text{ KN.m/m}$$

$$M_{a+ve,L} = C_a * W * L_a^2 = 0.073 * 6.4 * 4.55^2 = 9.67 \text{ KN.m/m}$$

$$M_{a+ve} = M_{a+ve,L} + M_{a+ve,D} = 25.8 \text{ KN.m/m}$$

$$M_{b+ve,D} = C_b * W * L_b^2 = 0.0132 * 11.38 * 7.2^2 = 7.78 \text{ KN.m/m}$$

$$M_{b+ve,L} = C_b * W * L_b^2 * b = 0.0127 * 6.4 * 7.2^2 = 4.21 \text{ KN.m/m}$$

$$M_{b+ve} = M_{b+ve,L} + M_{b+ve,D} = 12 \text{ KN.m/m}$$

(4.12.5) Positive Moment:

$$*M_{u,b} = 25.8 \text{ KN.m/m}$$

Assume the $d_{Bar} = 14 \text{ mm}$

$$d = h - \text{cover} - (d_{Bar}/2) = 200 - 20 - 7 = 173 \text{ mm}$$

$$R_n = \frac{M_n}{b \cdot d^2} = \frac{25.8 * 10^6 / 0.9}{1000 * 173^2} = .958 \text{ MPa}$$

$$m = \frac{f_y}{0.85 \times f_c'} = \frac{420}{0.85 \times 24} = 20.59$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2mK_n}{f_y}} \right) = \frac{1}{17.64} \left(1 - \sqrt{1 - \frac{2 * 17.64 * 1.25}{420}} \right) = 0.002234$$

$$A_{s_{req}} = 0.00229 * 1000 * 173 = 404.33 \text{ mm}^2/\text{m}$$

$$A_{s_{min}} = 0.0018 * b * h = 0.0018 * 1000 * 200 = 360 \text{ mm}^2/\text{m}$$

$$A_s = 404.33 \text{ mm}^2 \geq A_{s_{min}} = 360 \text{ mm}^2/\text{m}$$

Use 4Φ 12 with $A_s = 452.4 \text{ mm}^2/\text{m}$

$$*M_{ua} = 12 \text{ KN.m/m}$$

Assume the $d_{Bar} = 12 \text{ mm}$

$$d = h - \text{cover} - (d_{Bar}/2) = 200 - 20 - 6 = 174 \text{ mm}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{12 \times 10^6}{0.9 \times 1000 \times 174^2} = 0.4403 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 \times f_c'} = \frac{420}{0.4403 \times 24} = 20.59$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2mR_n}{f_y}} \right) = \frac{1}{20.59} \left(1 - \sqrt{1 - \frac{2 \times 20.59 \times 0.4403}{420}} \right) = 0.00105$$

$$A_{s_{req}} = 0.002 \times 1000 \times 174 = 183 \text{ mm}^2/\text{m}$$

$$A_{s_{min}} = 0.0018 \times b \times h = 0.0018 \times 1000 \times 200 = 360 \text{ mm}^2/\text{m}$$

$$A_s = 183 \text{ mm}^2 < A_{s_{min}} = 360 \text{ mm}^2/\text{m}$$

$$A_s = 360 \text{ mm}^2/\text{m}$$

$$\text{Use } 4 \Phi 12 \text{ } A_s = 452.38 \text{ mm}^2/\text{m}$$

(4.12.5) Negative Moment:

$$*M_{u,a} = 26.05 \text{ KN.m/m}$$

Assume the $d_{Bar} = 14 \text{ mm}$

$$d = h - \text{cover} - (d_{Bar}/2) = 200 - 20 - 7 = 173 \text{ mm}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{26.05 \times 10^6}{0.9 \times 1000 \times 173^2} = 0.97 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 \times f_c'} = \frac{420}{0.85 \times 24} = 20.58$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2mR_n}{f_y}} \right) = \frac{1}{20.6} \left(1 - \sqrt{1 - \frac{2 \times 20.6 \times 0.97}{420}} \right) = 0.00237$$

$$A_{s_{req}} = 0.00224 * 1000 * 173 = 409.6 \text{ mm}^2/\text{m}$$

$$A_{s_{min}} = 0.0018 * b * h = 0.0018 * 1000 * 200 = 360 \text{ mm}^2/\text{m}$$

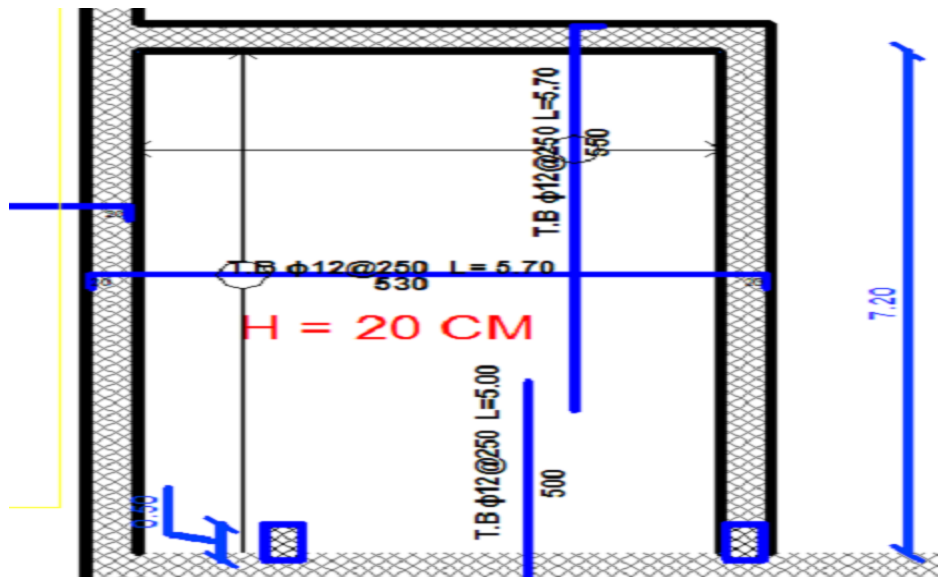
$$A_s = 409.5 \text{ mm}^2 \geq A_{s_{min}} = 360 \text{ mm}^2/\text{m}$$

Use 4 Φ 12 $A_s = 452.4 \text{ mm}^2/\text{m}$

Note: other moments requires areinforcement less than minimum, Use Φ 8 \ 12.5cm with $A_s = 400 \text{ mm}^2/\text{m}$

Check the max spacing:

1. $3h = 3 * 20 = 60$
2. 450mm
3. $S = 380 * (280/\text{FS}) - 2.5C_c = 330 \dots \text{Control.}$



Fig(4-8) : Reinforcement of solid slab

4.8 Design of two way ribbed slab (R5)

4.8.1 Minimum thickness for Waffle (R2) slab $h = 35 \text{ cm}$:

Check for the minimum thickness of the slab:

-All Exterior and interior beams have a rectangular section of 60 cm width and 60 cm depth:

$$I_b = \frac{b * h^3}{12} = \frac{0.8 * 0.35^3}{12} = 28.58 * 10^{-4} m^4$$

The moment of inertia for the ribbed slab:

$$y_c = \frac{52 * 8 * 4 + 27 * 12 * 21.5}{52 * 8 + 27 * 12} = 11.66 cm$$

$$I_{rib} = 52 * \frac{11.66^3}{3} - 40 * \frac{3.66^3}{3} + 12 * \frac{23.33^3}{3} = 77616.86 cm^4$$

Short direction $l = 10.6 m = 1060 cm$

Long direction $l = 10.63 m = 1063 cm$

$$I_{s1} = \frac{I_{rib} * (\frac{l}{2} + bw)}{b_f} = \frac{77616.86 * 610}{52} = 910505.47$$

$$I_{s2} = \frac{I_{rib} * (\frac{l}{2} + bw)}{b_f} = \frac{77616.86 * 611.5}{52} = 912744.42$$

$$I_{s3} = \frac{I_{rib} * (\frac{l}{2} + bw)}{b_f} = \frac{77616.86 * 1140}{52} = 1701600.392$$

$$I_{s4} = \frac{I_{rib} * (\frac{l}{2} + bw)}{b_f} = \frac{77616.86 * 1143}{52} = 1706078.288$$

$$\alpha_{f1} = \frac{I_b}{I_s} = \frac{285833.33}{910505.47} = 0.314$$

$$\alpha_{f2} = \frac{I_b}{I_s} = \frac{285833.33}{1706078.288} = 0.167$$

$$\alpha_{f3} = \frac{I_b}{I_s} = \frac{285833.33}{1701600.392} = 0.167$$

$$\alpha_{f4} = \frac{I_b}{I_s} = \frac{285833.3}{1706078.288} = 0.1675$$

$$\alpha_m = \frac{(3 * 0.1675 + 0.314)}{4} = 0.204 < 2.0$$

The minimum slab thickness will be:

$$h = \frac{L_n(0.8 + \frac{f_y}{1400})}{36 + 5\beta(\alpha_m - 0.2)} = \frac{10.63 * (0.8 + \frac{420}{1400})}{36 + 5 * \frac{10.63}{10.6} * (0.204 - 0.2)} = 0.3246 \text{ m}$$

$$h = 35 \text{ cm} > 32.46 \text{ cm} - \text{OK}$$

4.8.2 Load calculation for (R5):

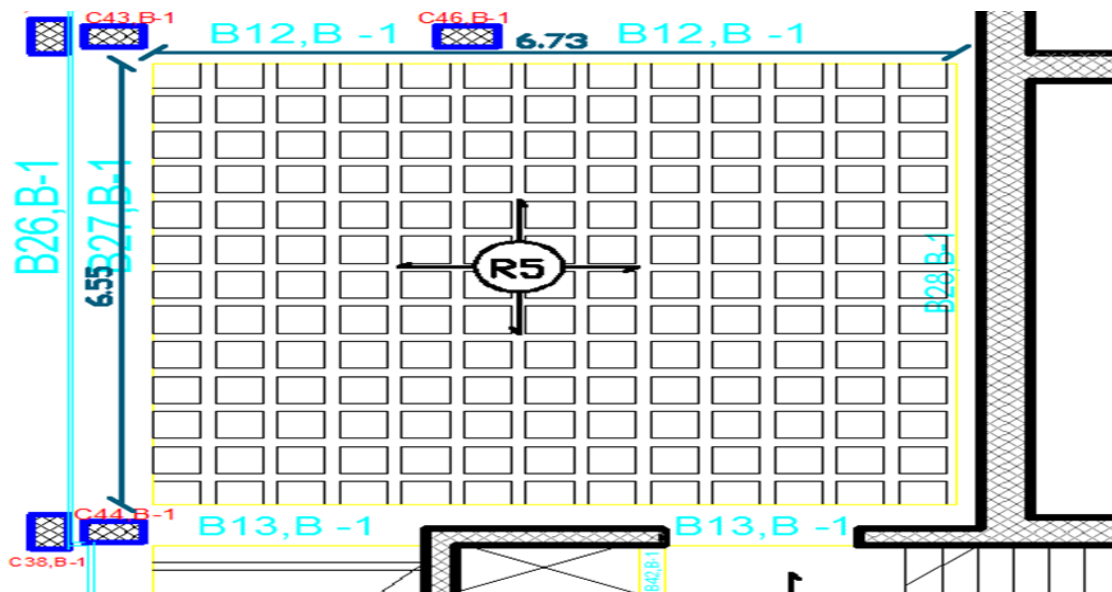


fig.(4.9): Two way Ribbed slab.

For the two-way ribbed slabs, the total dead load to be used in the analysis and design is calculated as follows:

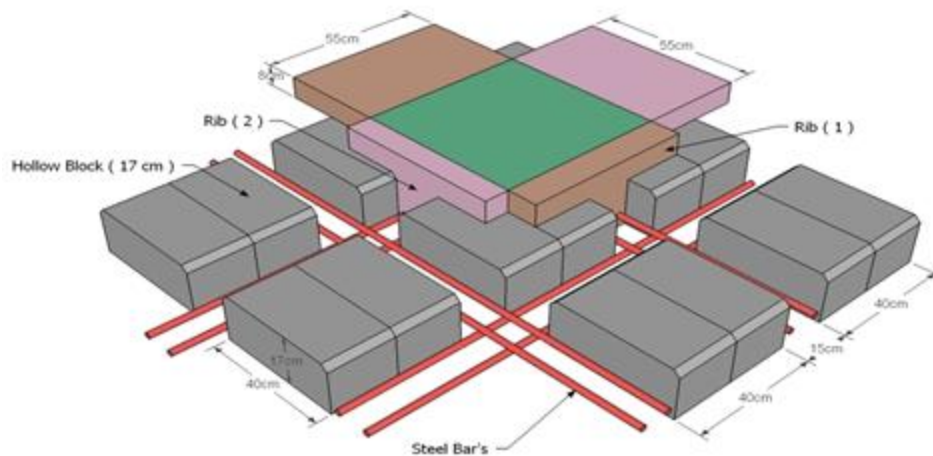


Fig.(4.10): Two way ribbed slab

Table (4-3) Calculation of the total dead load for two way rib slab (25). **Table (4**

No.	Material	Quality Density KN/m ³	Calculation			
1	Topping	25	0.52×0.52×0.08×25 = 0.54			
2	Rib	25	(0.4+0.52)0.27×0.12×25 = 0.745			
3	Sand	16	0.52×0.52×0.07×17= 0.322			
4	Mortar	22	0.52×0.52×0.02×22 =0.119			
5	Tile	22	0.52×0.52×0.03×23 =0.1866			
6	Plaster	22	0.52×0.52×0.02×22 =0.119			
7	Block	9	0.4×0.4×0.27×9 = 0.388			
8	Partitio	1.5	1.5×0.52*.52 = 0.41			
			<table><tr><td>Σ =</td><td>2.8267</td><td>KN/unit</td></tr></table>	Σ =	2.8267	KN/unit
Σ =	2.8267	KN/unit				

Dead Load of slab:

$$DL = \frac{2.8267}{0.52 * 0.52} = 10.45 \text{ KN/m}^2$$

$$w_D = 1.2 * 10.45 = 12.54 \text{ KN/m}^2$$

$$LL = 4 \text{ KN/m}^2$$

$$w_L = 1.6 * 4 = 6.4 \text{ KN/m}^2$$

$$w = 12.54 + 6.4 = 18.85 \text{ KN/m}^2$$

4.8.3 Moments calculations:

$$\text{Ratio} = 6.55/6.73 = 0.973$$

$$M_a = C_a w l a^2 b f \quad \text{and} \quad M_b = C_b w l b^2 b f$$

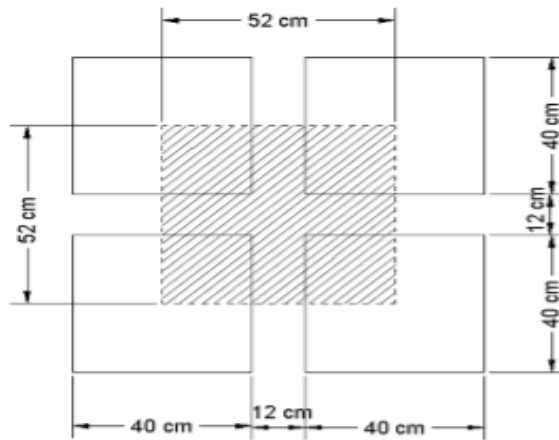


Fig.(4.11): Two way ribbed slab

***Negative moment**

$$C_{a,neg} = 0.075$$

$$M_{a,neg} = (0.075 * 18.83 * 6.55^2) * 0.52 = 31.5 \text{ KN.m}$$

***Positive moment**

$$C_{aD,pos} = 0.0345$$

$$C_{bD,pos} = 0.0255$$

$$C_{aL,pos} = 0.0365$$

$$C_{bL,pos} = 0.0305$$

$$M_{a,pos,(dl+ll)} = (0.0345 * 12.54 * 6.55^2 + 0.0365 * 6.4 * 6.55^2) * 0.52 = 14.86 \text{ KN.m}$$

$$M_{b,pos,(dl+ll)} = (0.0255 * 12.54 * 6.73^2 + 0.0305 * 6.4 * 6.73^2) * 0.52 = 12.13 \text{ KN.m}$$

Design of positive moment

*Short direction ($M_u = 14.86 \text{ KN.m}$)

$$bf = 520 \text{ mm}$$

Assume bar diameter $\phi 14$ for main positive reinforcement.

$$d = h - \text{cover} - d_{stirrups} - \frac{d_b}{2} = 350 - 20 - 10 - \frac{14}{2} = 313 \text{ mm.}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{14.86 \times 10^6}{0.9 \times 120 \times 313^2} = 1.4 \text{ MPa}$$

$$m = \frac{f_y}{0.85 f_c'} = \frac{420}{0.85 * 24} = 20.59$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{20.59} \left(1 - \sqrt{1 - \frac{2 \times 20.59 \times 1.4}{420}} \right) = 0.00345$$

$$A_s = \rho \cdot b \cdot d = 0.00345 \times 120 \times 313 = 129.8 \text{ mm}^2$$

Check for $A_s, \min$.

$$A_{s, \min} = 0.25 \frac{\sqrt{f_c'}}{f_y} b_w * d \geq \frac{1.4}{f_y} b_w * d$$

$$A_{s, \min} = 0.25 * \frac{\sqrt{24}}{420} 120 \times 313 = 109.53 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{420} * 120 \times 313 = 125.2 \text{ mm}^2 \dots \text{Control.}$$

$$A_{s,required} = 129.6 \text{ mm}^2 > A_{s,min} = 125.2 \text{ mm}^2 \quad (OK)$$

Use 2Ø12, with $A_s = 227 \text{ mm}^2 > A_{s,required} = 129.9 \text{ mm}^2$

Check for strain: ($\epsilon_s \geq 0.005$)

Tension = Compression

$$A_s * f_y = 0.85 * f'_c * b * a$$

$$227 * 420 = 0.85 * 24 * 120 * a$$

$$a = 37.388 \text{ mm}$$

$$x = \frac{a}{\beta_1} = \frac{52.48}{0.85} = 43.98 \text{ mm}$$

$$\epsilon_s = 0.003 * \left(\frac{d - x}{x} \right)$$

$$= 0.003 * \left(\frac{313 - 43.98}{43.98} \right) = 0.018 > 0.005 \therefore \phi = 0.9 \dots OK.$$

Long direction ($M_u = 12.1 \text{ KN.m}$) -

$$bf = 520 \text{ mm}$$

Assume bar diameter Ø12 for main positive reinforcement.

$$d = h - \text{cover} - d_{stirrups} - \frac{d_b}{2} = 350 - 20 - 10 - \frac{12}{2} = 313 \text{ mm.}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{12.1 \times 10^6}{0.9 \times 120 \times 313^2} = 1.14 \text{ MPa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 * 24} = 20.59$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2mR_n}{420}} \right) = \frac{1}{20.59} \left(1 - \sqrt{1 - \frac{2 \times 20.59 \times 1.14}{420}} \right) = 0.00279$$

$$A_s = \rho . b . d = 0.00248 \times 120 \times 313 = 104.968 \text{ mm}^2$$

Check for $A_{s,min}$ •

..

$$A_{s,min} = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w * d \geq \frac{1.4}{f_y} b_w * d$$

$$A_{s,min} = 0.25 * \frac{\sqrt{24}}{420} 120 \times 313 = 109.53 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{420} * 120 \times 310 = 125.2 \text{ mm}^2 \dots \textbf{Control.}$$

$$A_{s,min} = 125.2 \text{ mm}^2 > A_{s,required} = 104.83 \text{ mm}^2 \text{ ..ok}$$

Use 2Ø12, with $A_s = 227 \text{ mm}^2 > A_{smin} = 125.2 \text{ mm}^2$

Check for strain: ($\epsilon_s \geq 0.005$)

Tension = Compression

$$A_s * f_y = 0.85 * f'_c * b * a$$

$$227 * 420 = 0.85 * 24 * 120 * a$$

$$a = 38.9 \text{ mm}$$

$$x = \frac{a}{\beta_1} = \frac{38.9}{0.85} = 45.82 \text{ mm}$$

$$\epsilon_s = 0.003 * \left(\frac{d - x}{x} \right)$$

$$= 0.003 * \left(\frac{313 - 45.82}{45.82} \right) = 0.017 > 0.005 \therefore \phi = 0.9 \dots \textbf{OK.}$$

Design of negative moment ($M_u = 31.5 \text{ KN.m}$)

$$bf = 520 \text{ mm}$$

Assume bar diameter $\phi 14$ for main positive reinforcement.

$$d = h - \text{cover} - d_{stirrups} - \frac{d_b}{2} = 350 - 20 - 10 - \frac{16}{2} = 312 \text{ mm.}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{31.5 \times 10^6}{0.9 \times 120 \times 312^2} = 3 \text{ MPa}$$

$$m = \frac{f_y}{0.85 f_c'} = \frac{420}{0.85 * 24} = 20.59$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2mR_n}{420}} \right) = \frac{1}{20.59} \left(1 - \sqrt{1 - \frac{2 \times 20.59 \times 3}{420}} \right) = 0.00776$$

$$A_s = \rho \cdot b \cdot d = 0.00773 \times 120 \times 312 = 273.3 \text{ mm}^2$$

heck for $A_{s, \min}$..

$$A_{s, \min} = 0.25 \frac{\sqrt{f_c'}}{f_y} b_w * d \geq \frac{1.4}{f_y} b_w * d$$

$$A_{s, \min} = 0.25 * \frac{\sqrt{25}}{420} 120 \times 312 = 111.43 \text{ mm}^2$$

$$A_{s, \min} = \frac{1.4}{420} * 120 \times 312 = 125 \text{ mm}^2 \dots \textbf{Control.}$$

$$A_{s, \text{required}} = 273.3 \text{ mm}^2 > A_{s, \min} = 125.2 \text{ mm}^2 \dots \textbf{OK}$$

Use 2Ø18, with $A_s = 508.9 \text{ mm}^2 > A_{s, \text{required}} = 273.3 \text{ mm}^2$

Check for strain: ($\epsilon_s \geq 0.005$)

Tension = Compression

$$A_s * f_y = 0.85 * f_c' * b * a$$

$$402.1 * 420 = 0.85 * 25 * 120 * a$$

$$a = 66.22 \text{ mm}$$

$$x = \frac{a}{\beta_1} = \frac{52.48}{0.85} = 78 \text{ mm}$$

$$\epsilon_s = 0.003 * \left(\frac{d-x}{x} \right) = 0.003 * \left(\frac{312-78}{78} \right) = 0.009 > 0.005 \therefore \phi = 0.9 \dots \textbf{OK.}$$

Check shear strength: 4.8.4

$$W_a = 0.73$$

$$W_b = 0.27$$

Short direction

$$Au_a = 18.83 * 6.55 * 6.73 * 0.75 * 0.5 * \frac{0.52}{6.73} = 24.1 \text{ KN}$$

$$Vu = Au_a - W * 0.52 * Wa = 24.1 - 18.83 * 0.52 * 0.73 = 17 \text{ KN}$$

$$\phi * V_c = 1.1 * \frac{0.75}{6} * \sqrt{f_c'} * bw * d = 1.1 * \frac{0.75}{6} * \sqrt{25} * 120 * 313 = 25.82 \text{ KN}$$

Case 1

$$Vu < \frac{1}{2} * \phi * V_c$$

$$Vu = 17. \text{KN} > \frac{1}{2} * \phi * V_c = 13. \text{KN} \dots \text{Not OK}$$

Case 2

$$\frac{1}{2} * \phi * V_c < Vu < \phi * V_c$$

$$\frac{1}{2} * \phi * V_c = 13. \text{KN} < Vu = 17. \text{KN} < \phi * V_c = 25.82 \text{ KN} - \text{OK}$$

provide minimum shear reinforcement

$$Vs_{\min} \geq \frac{1}{16} * \sqrt{f_c'} * bw * d = \frac{1}{16} * \sqrt{25} * 120 * 313 * 10^{-3} = 11.73 \text{ KN.}$$

$$\phi Vs_{\min} = 8.8$$

$$\leq \frac{1}{3} * b_w * d = \frac{1}{3} * 0.12 * 0.313 * 10^3 = 12.52 \text{ KN}$$

$$\phi Vs_{\min} = 8.8 \dots \dots \dots \text{control}$$

$$\phi V_c = 25.82 \text{ KN} < Vu = 17 \text{ KN} \leq \phi (V_c + Vs_{\min}) = 25.8 \text{ KN} \dots \dots \text{satisfy}$$

∴ Case (3) is satisfy shear reinforcement is required.

Use 2 Legφ8 for stirrups with $A_v = 100.53 \text{ mm}^2$

$$Vs_{\min} = \frac{\phi Vs_{\min}}{\phi} = \frac{8.8}{0.75} = 11.73$$

$$s = \frac{A_v * f_y * d}{Vs_{\min}} = \frac{100.53 * 420 * 313}{11.73} * 10^{-3} = 1126.6 \text{ Vmm}$$

$$S_{\max} \leq \frac{d}{2} = \frac{313}{2} = 157 \text{ mm.} \leq 600 \text{ mm.}$$

Select 2 leg $\phi 8$ @ 15cm

4-9 Design of Stair

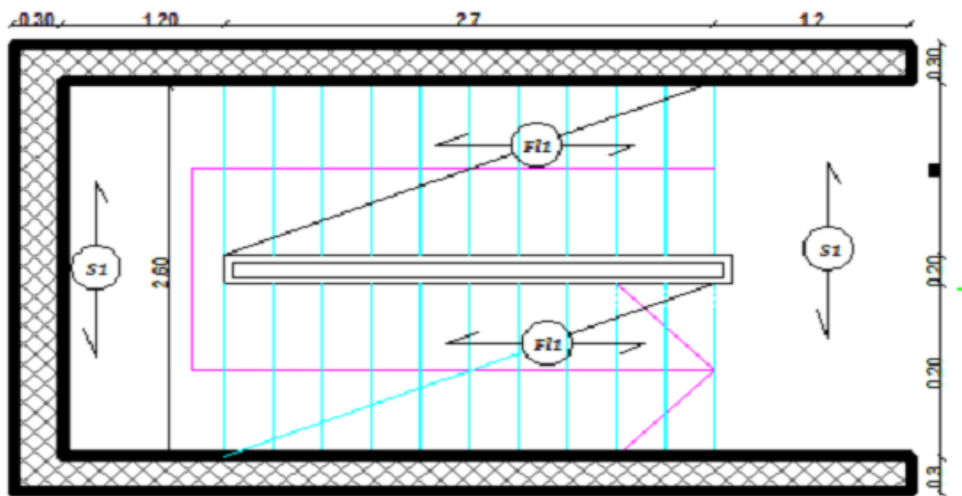


Fig 4.12: Stair Plan.

❖ **Material :-**

⇒ concrete B300 $F_c' = 24 \text{ N/mm}^2$

⇒ Reinforcement Steel $F_y = 420 \text{ N/mm}^2$

1- Design of Flight :-

✓ **Determination of Thickness:-**

$$h_{\min} = L/20$$

$$h_{\min} = 520/20 = 26 \text{ cm}$$

Take $h = 30 \text{ cm}$

The Stair Slope by $\theta = \tan^{-1}(17/30) = 28.07^\circ$

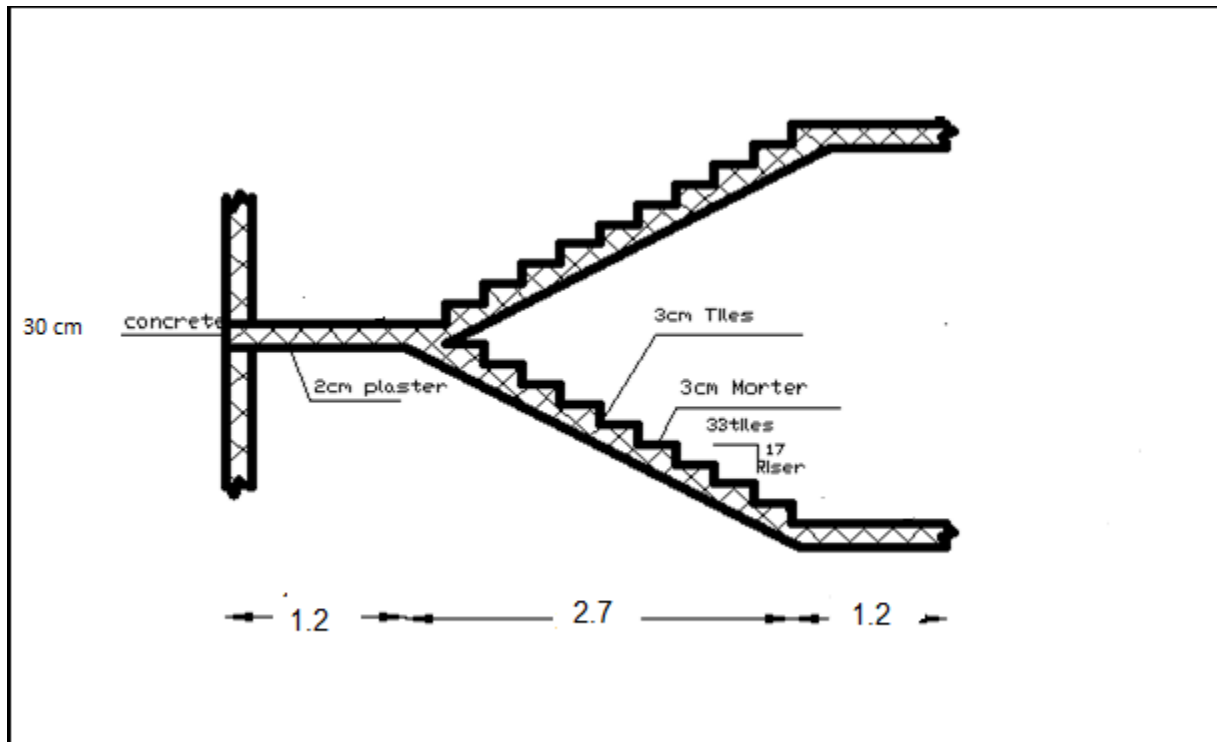
✓ Load Calculation:-

Fig 4.13: Stair Section.

Dead Load For Flight For 1m Strip:-

No.	Parts of Flight	Calculation
1	Tiles	$23 \times 0.03 \times 1 \times (0.35 + 0.16) / 0.3 = 1.173 \text{ KN/m}$
2	Mortar	$22 \times 0.03 \times 1 \times (0.3 + 0.16) / 0.3 = 1.012 \text{ KN/m}$
3	Stair	$25 / 0.3 \times (0.3 \times 0.16 / 2) \times 1 = 2 \text{ KN/m}$
4	R.C	$25 \times 0.3 \times 1 / \cos 28.07 = 8.5 \text{ KN/m}$
5	Plaster	$22 \times 0.02 \times 1 / \cos 20.07 = 0.499 \text{ KN/m}$
Sum		13.184 KN/m

Table (4.5): Dead Load Calculation of Flight.

Live Load For Landing For 1m Strip = $4 \times 1 = 4 \text{ KN/m}$

Factored Load For Flight :-

$$W_U = 1.2 \times 13.184 + 1.6 \times 4 = 22.22 \text{ KN/m}$$

✓ System of Flight:-

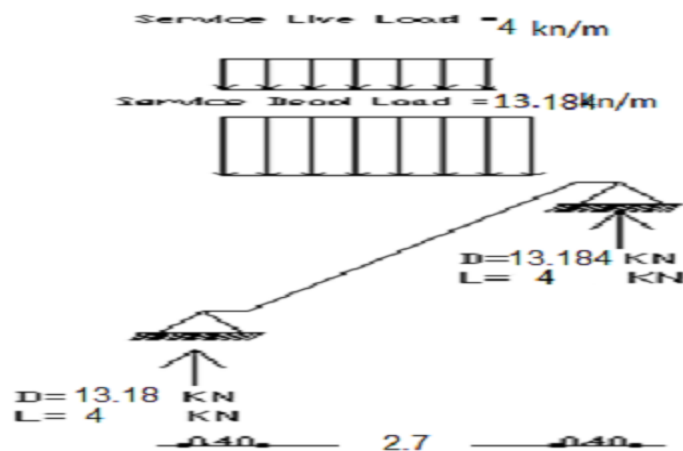
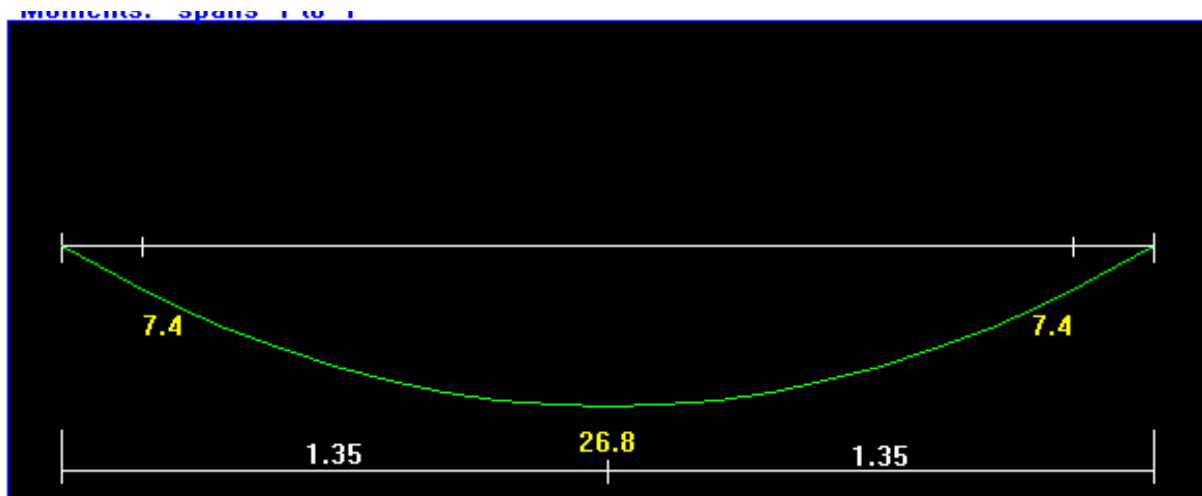


Fig 4.14: Statically System and Loads Distribution of Flight.



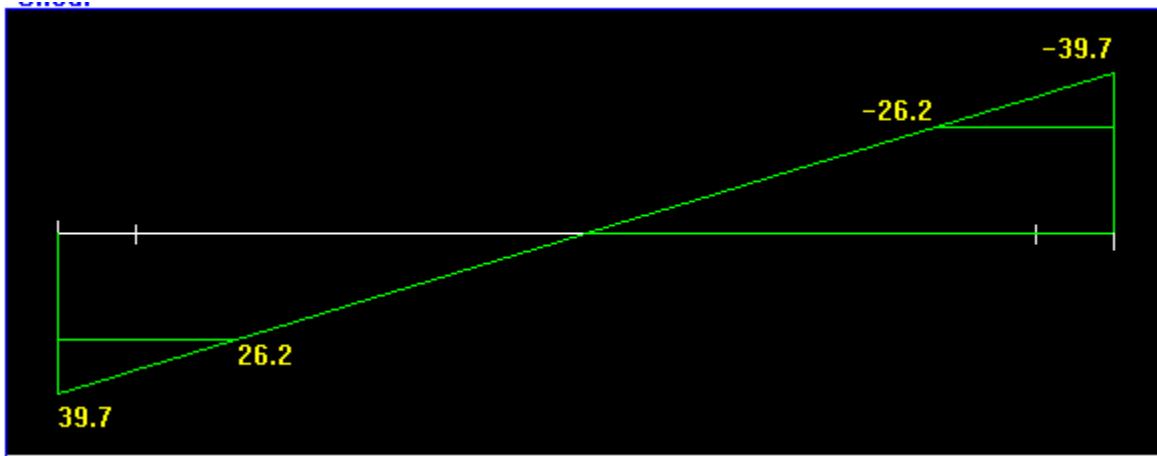


Fig 4.15: Shear and Moment Envelope Diagram of Flight

1- Design of Shear for Flight :- ($V_u=42.5$ KN.m)

Assume bar diameter ϕ 12 for main reinforcement

$$d = h - \text{cover} - \frac{d_b}{2} = 300 - 20 - \frac{12}{2} = 274 \text{ mm}$$

$$V_c = \frac{1}{6} \sqrt{f_c'} b_w d = \frac{1}{6} \sqrt{24} * 1000 * 274 = 224 \text{ KN}$$

$\Phi V_c = 0.75 * 224 = 167.7 \text{ KN} > V_u = 28 \text{ KN} \dots \dots \text{No shear reinforcement are required}$

2- Design of Bending Moment for Flight :- ($M_u=27$ KN.m)

$$R_n = \frac{M_u}{\phi b d^2} = \frac{27 \times 10^6}{0.9 \times 1000 \times 274^2} = .399 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f_c'} = \frac{420}{0.85 \times 24} = 20.59$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{17.65} \left(1 - \sqrt{1 - \frac{2 \times 20.59 \times .399}{420}} \right) = 0.0012$$

$$A_{s, \text{req}} = \rho \cdot b \cdot d = 0.00123 \times 1000 \times 274 = 262.9 \text{ mm}^2$$

$$A_{s, \text{min}} = 0.0018 * 1000 * 300 = 540 \text{ mm}^2$$

$A_s = 540 \text{ mm}^2 \dots \dots \dots \text{is ok}$

Use 12 @ 150mm , $A_{s, \text{provided}} = 678.558 \text{ mm}^2 > A_{s, \text{required}} = 540 \text{ mm}^2 \dots \text{Ok}$

Check for Spacing :-

$$S = 3h = 3 \times 300 = 900 \text{ mm}$$

$$S = 450 \text{ mm}$$

$$S = 450 \text{ mm} \dots\dots\dots \text{is control}$$

Use $\phi 14$ @ 150mm ,

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{678.5 \times 420}{0.85 \times 1000 \times 24} = 14 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{14}{0.85} = 16.5 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d - c}{c} \right) = 0.003 \left(\frac{274 - 16.5}{16.5} \right) = 0.0468 > 0.005 \dots\dots \mathbf{Ok}$$

3- Lateral or Secondary Reinforcement For Flight :-

$$A_{s, \text{req}} = A_{s, \text{min}} = 0.0018 \times 1000 \times 300 = 540 \text{ mm}^2$$

Use $\phi 10$ @ 150mm , $A_{s, \text{provided}} = 5.65 \text{ mm}^2 > A_{s, \text{required}} = 540 \text{ mm}^2 \dots \text{Ok}$

Table (4.6): Dead Load Calculation of Landing.

No.	Parts of Landing	Calculation
1	Tiles	$22 \times 0.03 \times 1 = 0.66 \text{ KN/m}$
2	Mortar	$22 \times 0.03 \times 1 = 0.66 \text{ KN/m}$
4	R.C	$25 \times 0.3 \times 1 = 7.5 \text{ KN/m}$
5	Plaster	$22 \times 0.02 \times 1 = 0.44 \text{ KN/m}$
Sum		9.3KN/m

2- Design of Landing :- (For First One Meter)

Determination of Thickness:-

$$h_{\min} = L/20$$

$$h_{\min} = 3.1/20 = 15.5 \text{ cm}$$

$$\text{Take } h = 30 \text{ cm}$$

✓ Load Calculation:-

Dead Load For Landing For 1m Strip:-

Live Load For Landing For 1m Strip = $4 \times 1 = 4 \text{ KN/m}$

Reaction From Flight:-

$$DL = 29.63 \text{ KN/m}$$

$$LL = 11 \text{ KN/m}$$

$$\text{Total Dead Load} = 9.3 + 29.63 = 38.93 \text{ KN/m}$$

$$\text{Total Live Load} = 4 + 11 = 15 \text{ KN/m}$$

Factored Load For Landing :-

$$W_U = 1.2 \times 38.93 + 1.6 \times 15 = 69.6 \text{ kN/m}$$

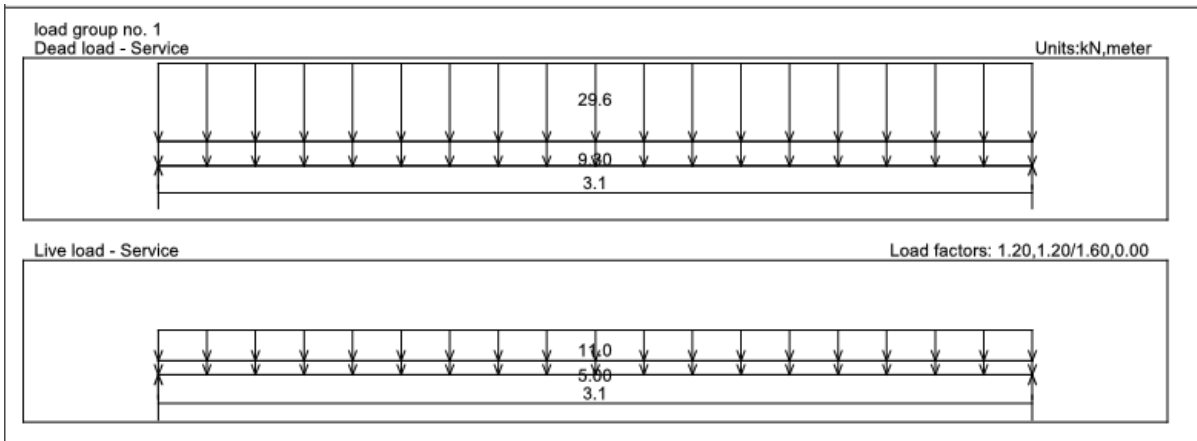
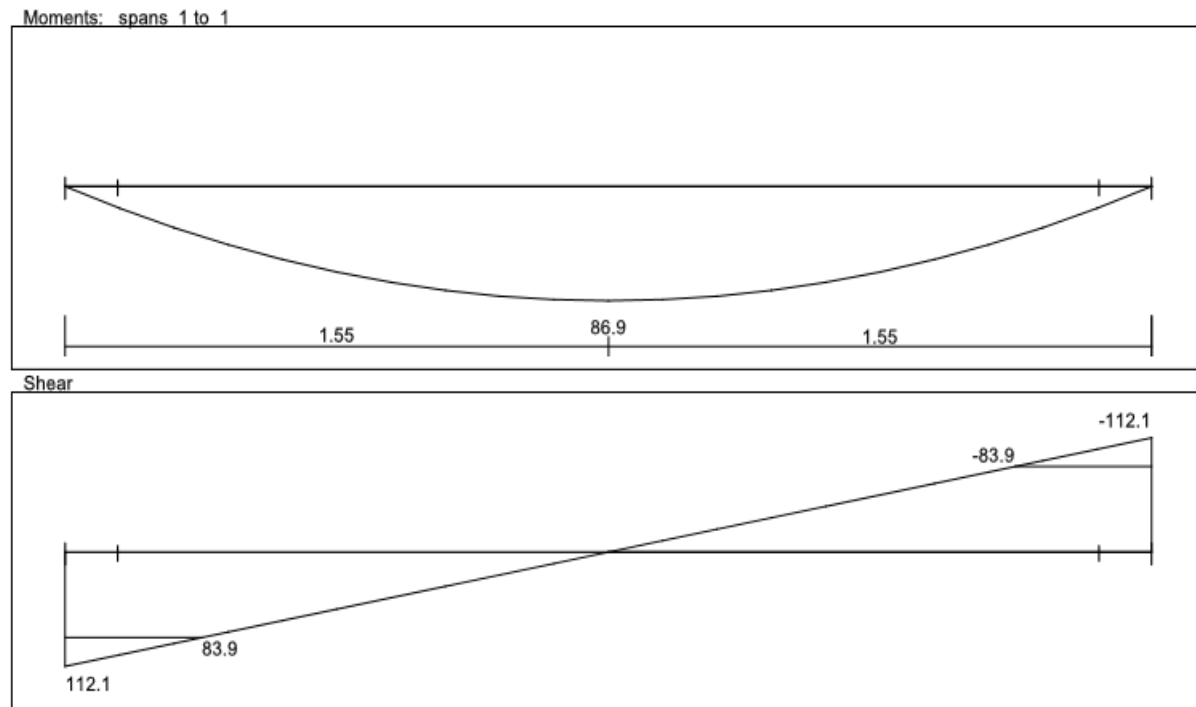
✓ System of Landing:-**Fig 4.16: Statically System and Loads Distribution At First 1m Of Landing**

Fig 4.17: Shear and Moment Envelope Diagram At First 1m of Landing.

1- Design of Shear:- ($V_u=83.9$ KN)

Assume bar diameter ϕ 12 for main reinforcement

$$d = h - \text{cover} - \frac{d_b}{2} = 300 - 20 - \frac{12}{2} = 274 \text{ mm}$$

$$V_c = \frac{1}{6} \sqrt{f_c'} b_w d = \frac{1}{6} \sqrt{28} * 1000 * 274 = 242 \text{ KN}$$

$\Phi * V_c = 0.75 * 242 = 181.5 \text{ KN} > V_u = 83.9 \text{ KN} \dots\dots \text{No shear reinforcement are required}$

2- Design of Bending Moment :- ($M_u=86.9$ KN.m)

Assume bar diameter ϕ 12 for main reinforcement

$$d = h - \text{cover} - \frac{d_b}{2} = 300 - 20 - \frac{12}{2} = 274 \text{ mm}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{83.9 \times 10^6}{0.9 \times 1000 \times 274^2} = 1.242 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f_c'} = \frac{420}{0.85 \times 28} = 20.59$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.59} \left(1 - \sqrt{1 - \frac{2 \times 20.59 \times 1.242}{420}} \right) = 0.003039$$

$$A_{s, \text{req}} = \rho \cdot b \cdot d = 0.003039 \times 1000 \times 274 = 832.58 \text{ mm}^2$$

$$A_{s, \text{min}} = 0.0018 * 1000 * 300 = 540 \text{ mm}^2$$

$$A_{s, \text{req}} = 832.58 \text{ mm}^2$$

Check for Spacing :-

$$S = 3h = 3 * 300 = 900 \text{ mm}$$

$$S = 450 \text{ mm} \dots\dots\dots \text{is control}$$

Use $\phi 12 @ 125 \text{ mm}$, $A_{s, \text{provided}} = 904.8 \text{ mm}^2 > A_{s, \text{required}} = 832.58 \text{ mm}^2 \dots \text{Ok}$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f_c'} = \frac{855.5 \times 420}{0.85 \times 1000 \times 28} = 15.1 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{15.1}{0.85} = 17.765 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d - c}{c} \right) = 0.003 \left(\frac{274 - 17.76}{17.76} \right) = 0.0433 > 0.005 \dots \dots \mathbf{Ok}$$

1- Lateral or Secondary Reinforcement For Landing :-

$$A_{s,req} = A_{s,min} = 0.0018 * 1000 * 300 = 540 \text{ mm}^2$$

$$\text{Use } \phi 10 @ 150 \text{ mm} , A_{s,provided} = 549.7 \text{ mm}^2 > A_{s,required} = 540 \text{ mm}^2 \dots \text{ Ok}$$

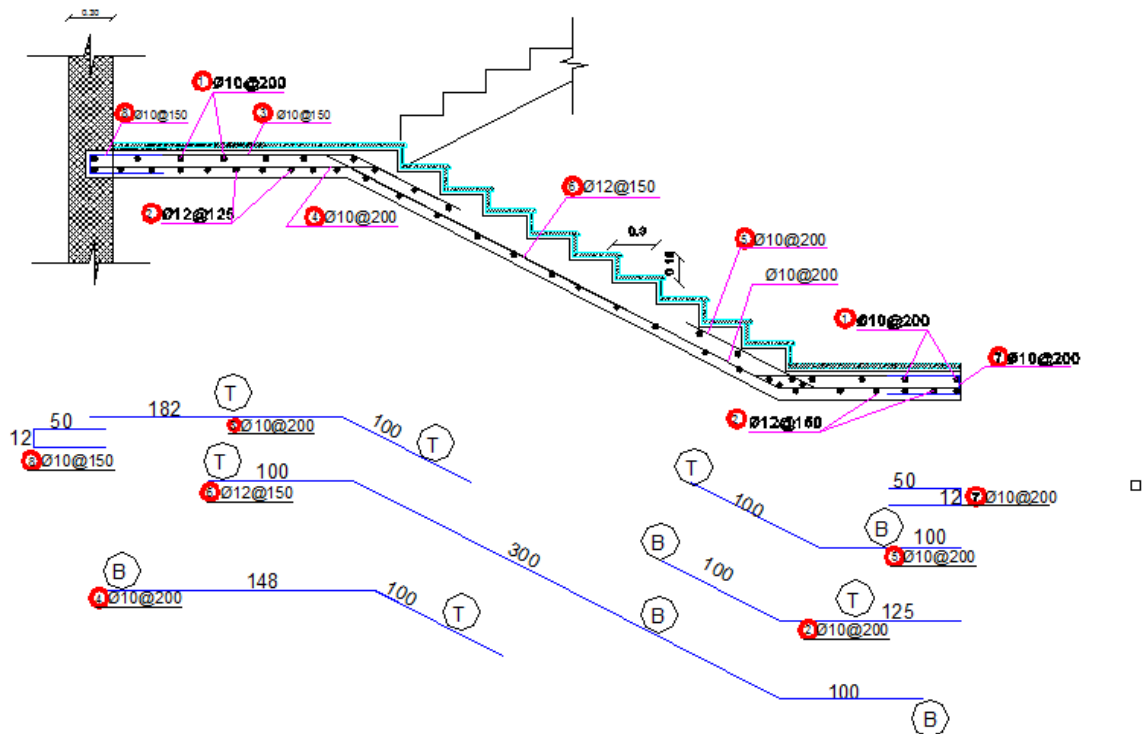


Fig 4.18: Stair Reinforcement

4.10 Design of Column

❖ Material :-

⇒ concrete B350 $F_c' = 28 \text{ N/mm}^2$

⇒ Reinforcement Steel $F_y = 420 \text{ N/mm}^2$

✓ Load Calculation:- (From Column Group H)

Service Load:-

Dead Load = 2146 KN

Live Load = 225 KN

Factored Load:-

$$P_U = 1.2 \times 2146 + 1.6 \times 225 = 3703 \text{ KN}$$

✓ Dimensions of Column:-Assume $\rho_g = 0.01$

$$\phi * P_n = 0.65 \times 0.8 \times A_g \{0.85 f_c' (1 - \rho_g) + \rho_g * F_y\}$$

$$3707 \times 1000 = 0.65 \times 0.8 \times A_g \{0.85 * 28 (1 - 0.01) + 0.01 * 420\}$$

$$A_g = 248784.315 \text{ mm}^2$$

Assume square column with $a = 500 \text{ mm}$ **✓ Check Slenderness Parameter:-**

$$\frac{klu}{r} < 34 - 12 \frac{M_1}{M_2} \leq 40$$

Lu: Actual unsupported (Unbraced) length.

K: effective length factor

R: radius of gyration = $\sqrt{\frac{I}{A}} \approx 0.3 h$ For rectangular section

$$L_u = 4.1 \text{ m}$$

$$M_1/M_2 = 1$$

K=1 for braced frame.

about X-axis (b= 0.7m)

$$\frac{klu}{r} < 34 - 12 \frac{M_1}{M_2} \leq 40$$

$$\frac{1 \times 3.2}{0.3 \times 0.5} = 21.33 < 22$$

Column Is Short About X-axis and y- axis

$$3707 \times 1000 = 0.65 \times 0.8 \times 500 \times 500 \{0.85 \times 28(250000 - A_s) + A_s \times 420\}$$

$$A_s = 2120 \text{ mm}^2$$

$$A_{s_{\min}} = 0.01 \times 500 \times 500 = 2500 \text{ mm}^2$$

$$A_{s_{\min}} \geq A_{s_{\text{req}}} \quad \text{so use } A_s = 2500 \text{ mm}^2$$

Use 8 Φ 20 with $A_s = 2513 \text{ mm}^2$

✓ **Design of the Stirrups:-**

Use Φ 10 for ties

The spacing of ties shall not exceed the smallest of :-

$$\text{spacing} \leq 16 \times d_b = 16 \times 20.0 = 32.0 \text{ cm}$$

$$\text{spacing} \leq 48 \times d_s = 48 \times 1.0 = 48 \text{ cm}$$

$$\text{spacing} \leq \text{least dim} = 50 \text{ cm}$$

Use $\phi 10 @ 20 \text{ cm}$

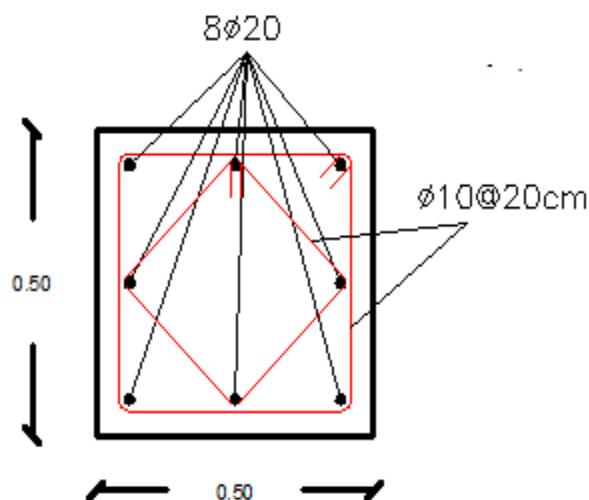


Fig 4.19: Column Reinforcement

4.12 Design of Footing

❖ Material :-

⇒ concrete B350 $F_c' = 28 \text{ /mm}^2$

⇒ Reinforcement Steel $F_y = 420 \text{ N/mm}^2$

✓ Load Calculations :- (From foundation cat2)

Dead Load = 1180KN, Live Load = 177 KN

Total services load = 1180+ 177 = 1357 KN

Total Factored load = 1.2*1180+ 1.6*177= 1699.2 KN

Column Dimensions (a*b) = 30*50 cm

Soil density = 18 Kg/cm³

Allowable Bearing Capacity = 500 KN/m²

Assume h = 55cm

$$q_{net-allow} = 400 - 18 = 382.3 \text{ kn/m}^2$$

✓ Area of Footing :-

$$A = \frac{Pt}{q_{net-allow}} = \frac{1357}{382.} = 3.55 \text{ m}^2$$

Assume Square Footing

B required = 1.9 m

✓ Bearing Pressure :-

$$q_u = 1699.2/1.9 \times 1.9 = 470.7 \text{ KN/m}^2$$

✓ Design of Footing :-

1- Design of One Way Shear Strength :-

Critical Section at Distance (d) From The Face of Column

Assume $h = 55\text{cm}$, bar diameter $\phi 20$ for main reinforcement and 7.5 cm Cover

$$d = 550 - 75 - 20 = 455 \text{ mm}$$

$$V_u = q_u \left(\frac{B-a}{2} - d \right) * L$$

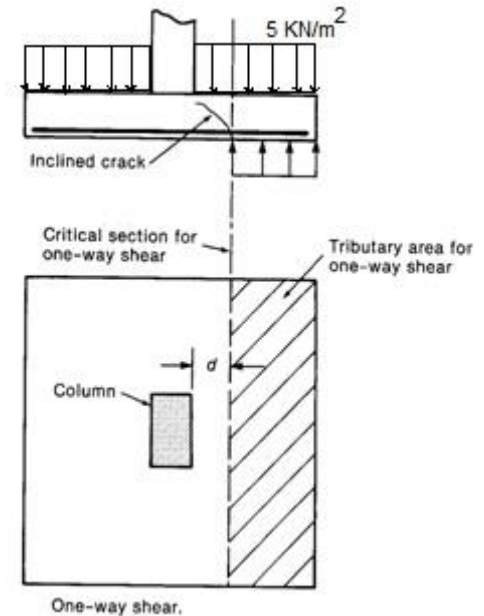
$$V_u = 470.7 * \left(\frac{1.9 - 0.3}{2} - 0.455 \right) * 1.9 = 308.54 \text{ Kn}$$

$$\phi.V_c = \phi \cdot \frac{1}{6} * \sqrt{f_c'} * b_w * d$$

$$\phi.V_c = 0.75 * \frac{1}{6} * \sqrt{28} * 1900 * 455 = 571.81 \text{ Kn}$$

$$\phi.V_c = 571.81 \text{ Kn} > V_u = 308.54 \text{ Kn}$$

∴ Safe



2- Design of Two Way Shear Strength :-

$$V_u = P_u - FR_b$$

$$FR_b = q_u * \text{area of critical section}$$

$$V_u = 470.7 - 1.9 * 1.9 - [(0.5 + 0.455) * (0.3 + 0.455)] = 1359.84 \text{ Kn}$$

The punching shear strength is the smallest value of the following equations:-

$$\phi.V_c = \phi \cdot \frac{1}{6} \left(1 + \frac{2}{\beta_c} \right) \sqrt{f_c'} b_o d$$

$$\phi.V_c = \phi \cdot \frac{1}{12} \left(\frac{\alpha_s}{b_o/d} + 2 \right) \sqrt{f'_c} b_o d$$

$$\phi.V_c = \phi \cdot \frac{1}{3} \sqrt{f'_c} b_o d$$

Where:-

$$\beta_c = \frac{\text{Column Length (a)}}{\text{Column Width (b)}} = \frac{50}{30} = 1.67$$

b_o = Perimeter of critical section taken at (d/2) from the loaded area

$$b_o = 2 * (.455 + .5) + 2 * (.455 + .3) = 3.42m$$

$\alpha_s = 40$ for interior column

$$\phi.V_c = \phi \cdot \frac{1}{6} \left(1 + \frac{2}{\beta_c} \right) \sqrt{f'_c} b_o d = \frac{0.75}{6} * \left(1 + \frac{2}{1.67} \right) * \sqrt{24} * 3420 * 455 = 2094.125Kn$$

$$\phi.V_c = \phi \cdot \frac{1}{12} \left(\frac{\alpha_s}{b_o/d} + 2 \right) \sqrt{f'_c} b_o d = \frac{0.75}{12} * \left(\frac{40 * 455}{3420} + 2 \right) * \sqrt{24} * 3420 * 455 = 3488.44Kn$$

$$\phi.V_c = \phi \cdot \frac{1}{3} \sqrt{f'_c} b_o d = \frac{0.75}{3} * \sqrt{28} * 3744 * 511 = 1905.825Kn$$

$\Phi V_c = 1905.825 Kn > V_u = 1359.84Kn$ safe .

3- Design of Bending Moment :-

Critical Section at the Face of Column

$$M_u = 470.7 * 1.9 * .8 * .8 / 2 = 286.2KN$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{286.2 \times 10^6}{0.9 \times 1900 \times 455^2} = .808 Mpa$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.59$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_n}{420}} \right) = \frac{1}{17.6} \left(1 - \sqrt{1 - \frac{2 \times 17.65 \times 1.147}{420}} \right) = .000196$$

$$A_{s,req} = \rho \cdot b \cdot d = 0.00196 \times 1900 \times 455 = 1697.44 \text{ mm}^2$$

$$A_{s,min} = 0.0018 \times 1900 \times 550 = 1881 \text{ mm}^2$$

$$A_{s,req} = 1881 \text{ mm}^2$$

Use 13ø14 in Both Direction, $A_{s,provided} = 2001.2 \text{ mm}^2 > A_{s,required} = 1881 \text{ mm}^2 \dots \text{Ok}$

Check for Spacing :-

$$S = 3h = 3 \times 55 = 165 \text{ cm}$$

$$S = 380 \times \left(\frac{\frac{280}{2} \times 420}{3} \right) - 2.5 \times 75 = 192.5 \text{ cm}$$

$$S = 450 \text{ cm} \dots\dots\dots \text{is control}$$

Use 13ø14 in Both Direction, $A_{s,provided} = 2001.2 \text{ mm}^2 > A_{s,required} = 1881 \text{ mm}^2 \dots \text{Ok}$

Check for strain:-

$$a = \frac{A_s f_y}{0.85 b f'_c} = \frac{2001.2 \times 420}{0.85 \times 1900 \times 24} = 21.68 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{21.68}{0.85} = 25.51 \text{ mm}$$

$$\varepsilon_s = 0.003 \left(\frac{d - c}{c} \right) = 0.003 \left(\frac{511 - 30.58}{30.58} \right) = 0.05 > 0.005 \dots\dots \text{Ok}$$

Critical Section at the Face of Column

$$M_u = 470.7 \times 1.9 \times 0.7 \times 0.7 / 2 = 219.11 \text{ kN}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{219.11 \times 10^6}{0.9 \times 1900 \times 455^2} = .6189 \text{ Mpa}$$

$$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 24} = 20.59$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2 m R_n}{420}} \right) = \frac{1}{20.59} \left(1 - \sqrt{1 - \frac{2 \times 20.59 \times .6189}{420}} \right) = .000149$$

$$A_{s,req} = \rho \cdot b \cdot d = 0.00196 \times 1900 \times 455 = 1293.83 \text{ mm}^2$$

$$A_{s,min} = 0.0018 \times 1900 \times 550 = 1881 \text{ mm}^2$$

$$A_{s,req} = 1881 \text{ mm}^2$$

Use 13 ϕ 14 in Both Direction, $A_{s,provided} = 2001.2\text{mm}^2 > A_{s,required} = 1881\text{mm}^2 \dots \text{Ok}$

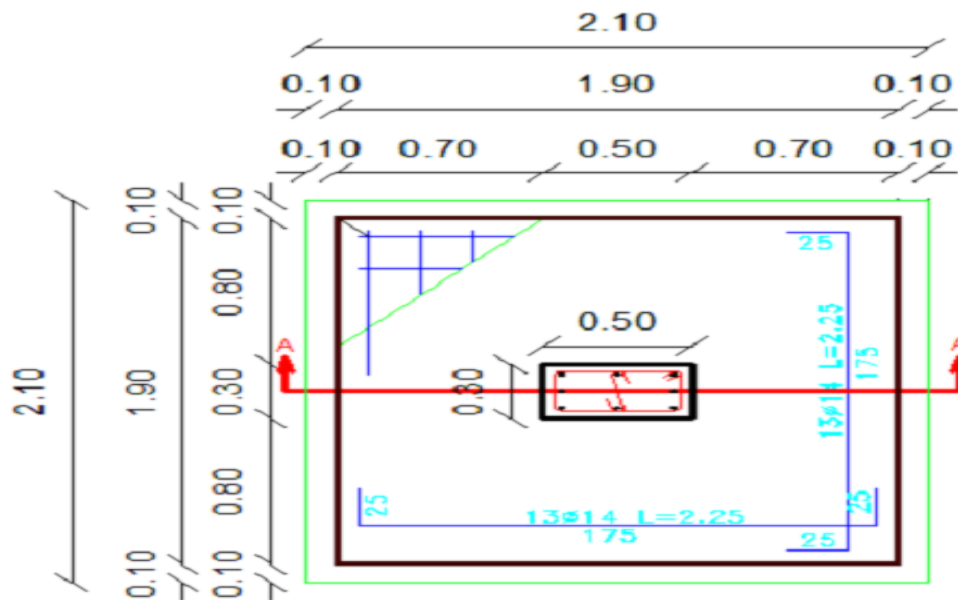
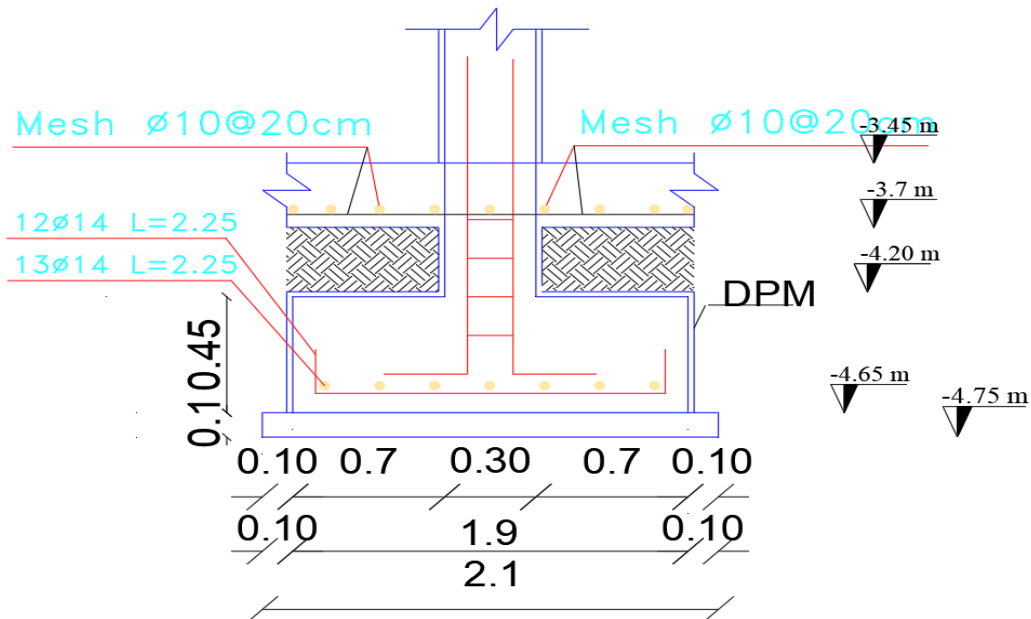


Fig 4.20 :Foot Reinforcement Details.

4.13 Design of Basement Wall:

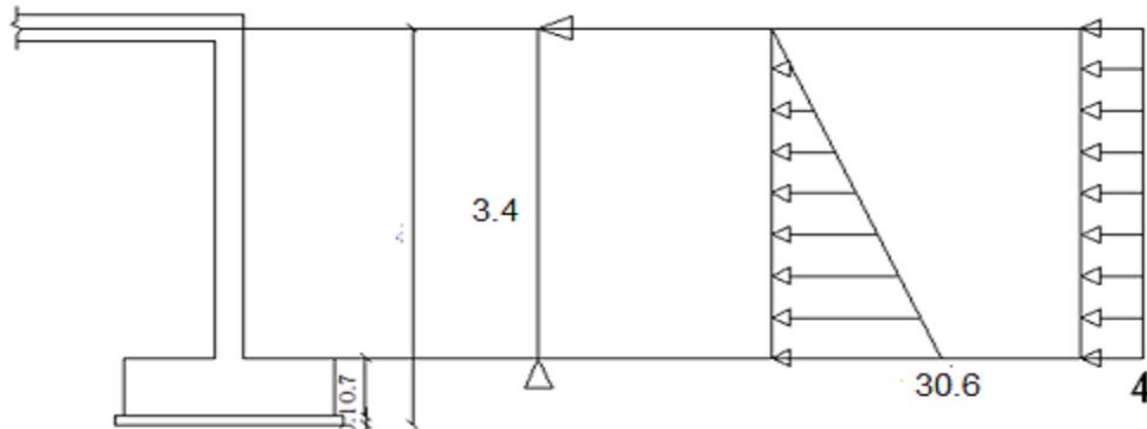


Figure (4-21): Geometry of basement.

$$F_c' = 24 \text{ Mpa} \quad F_y = 420 \text{ Mpa}$$

$$\phi = 30^\circ \quad \gamma = 18.00 \text{ KN/m}^3$$

$$K_o = 1 - \sin \phi$$

$$= 1 - \sin 30$$

$$= 0.50$$

4.11.1 Load on basement wall:

For 1m length of wall:

* **Weight of backfill:**

$$q_1 = K_o * \gamma * h$$

$$= 0.50 * 18.0 * 3.4 = 30.6 \text{ KN/m}$$

$$q_1 \text{ (Factored)} = 1.6 * 30.6 = 48.96 \text{ KN/m}$$

* **Load from live load (CAR) :**

$$LL = 2.5 \text{ KN/m}^2$$

$$q_2 = K_o * LL$$

$$= 0.50 * 2.5 = 1.25 \text{ KN/m}$$

$$q_2 (\text{Factored}) = 1.6 * 1.25 = 2.0 \text{ KN/m}$$

4.11.2 Design of the shear force:

Assume $h = 300 \text{ mm}$,

$$d = 300 - 20 - 16 = 268 \text{ mm}$$

$$V_{\max} = 47.7 \text{ KN}$$

$$\phi V_c = \frac{\phi \sqrt{f'_c} * b_w * d}{6}$$

$$\phi V_c = \frac{\phi \sqrt{24} * 1000 * 264}{6} = 161.66 \text{ KN}$$

$$V_u < \phi V_c$$

No shear Reinforcement is required.

4.11.3 Design of bending moment:

$$M_{u \max} = 49.9 \text{ KN.m}$$

$$M_n = \frac{M_u}{0.9} = \frac{49.9}{0.9} = 55.44 \text{ KN.m}$$

$$R_n = \frac{M_n * 10^6}{b * d^2} = \frac{55.44 * 10^6}{1000 * 264^2} = 0.772 \text{ Mpa}$$

$$m = \frac{F_y}{0.85 * f'_c} = \frac{420}{0.85 * 24} = 20.59$$

$$\begin{aligned} \rho &= \frac{1}{m} * \left(1 - \sqrt{1 - \frac{2 * R_n * m}{F_y}} \right) \\ &= \frac{1}{17.65} * \left(1 - \sqrt{1 - \frac{2 * 1.0468 * 17.65}{420}} \right) \\ &= 0.00187 \end{aligned}$$

$$A_{s \text{ req}} = \rho * b * d = 2.55 * 10^{-3} * 1000 * 266 = \mathbf{502.3 \text{ mm}^2/\text{m}}$$

$$A_{min} > A_{req}$$

Select 4Ø16 Vertical reinforcement at compression face

A Check for $A_{s,min}$

$$A_{s,min} = 0.25 \frac{\sqrt{f'_c}}{f_y} b_w * d \geq \frac{1.4}{f_y} b_w * d$$

$$A_{s,min} = 0.25 * \frac{\sqrt{24}}{420} 1000 \times 266 = 772.6 \text{ mm}^2$$

$$A_{s,min} = \frac{1.4}{420} * 120 \times 310 = 886.6 \text{ mm}^2 \dots\dots \text{Control.}$$

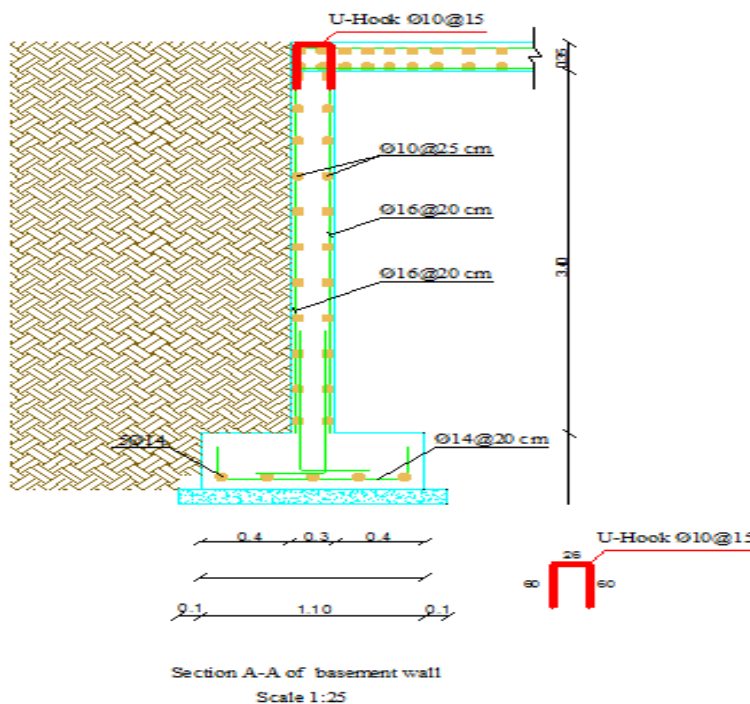
$$A_{min} > A_{req}$$

Select 5Ø16 Vertical reinforcement at compression face:

4.10.4 Design of the horizontal reinforcement:

$$A_{smin} = 0.0012 * b * h = 0.002 * 1000 * 300 = 360 \text{ cm}^2/\text{m}$$

Select Ø10@20cm/m, in two layer.



4.14 Design of shear wal



❖ Material and Sections:- (From Shear Wall 2)

- ⇒ concrete B350 $F_c' = 28 \text{ N/mm}^2$
- ⇒ Reinforcement Steel $F_y = 420 \text{ N/mm}^2$
- ⇒ Shear Wall Thickness $h = 25 \text{ cm}$
- ⇒ Shear Wall Width $L_w = 6 \text{ m}$
- ⇒ Shear Wall Height $H_w = 29.5 \text{ m}$

✓ Design of Horizontal Reinforcement:-

$$\sum F_x = V_u = 3850.8 \text{ KN}$$

The critical Section is the smaller of:

$$\frac{l_w}{2} = \frac{29.5}{2} = 14.75m$$

$$\frac{h_w}{2} = \frac{29.5}{2} = 14.75m$$

storyheight(H_w) = 29.5m.....Control

$$d = 0.8 \times L_w = 0.8 \times 6 = 4.8m$$

$$\begin{aligned}\phi V_{nmax} &= \phi \frac{5}{6} \sqrt{f_c'} h d \\ &= 0.75 * 0.83 * \sqrt{28} * 250 * 4800 = 3952.8 KN > V_u = 3850.8KN\end{aligned}$$

V_c is the smallest of :

$$1 - V_c = \frac{1}{6} \sqrt{f_c'} h d = \frac{1}{6} \sqrt{28} * 250 * 4800 = 1058.3 \dots\dots\dots \text{Control}$$

$$2 - V_c = 0.27 \sqrt{f_c'} h d + \frac{N_u d}{4 l_w} = 0.27 \sqrt{28} * 250 * 4800 + 30.4 = 1617.9KN$$

$$3 - V_c = \left[0.05 \sqrt{f_c'} + \frac{l_w \left(0.1 \sqrt{f_c'} + 0.2 \frac{N_u}{l_w h} \right)}{\frac{M_u}{V_u} - \frac{l_w}{2}} \right] h d = 3239.41KN$$

$$\frac{6123.1 - 3637.3}{3.6} = \frac{M_u - 3637.3}{3.6 - 2.75} \Rightarrow M_u = 4224.22KN.m$$

$$\frac{M_u}{V_u} - \frac{l_w}{2} = \frac{32457.2 * 10^3}{3850.8} - \frac{6000}{2} = 5428.69 mm$$

$$V_c = 1058.3KN$$

$$\phi * v_c + \phi v_s = v_u$$

$$\phi * v_s = v_u - \phi * v_c$$

$$V_s = v_u / \phi - v_c$$

$$V_s = 3850.8 / 0.75 - 1058.3 = 5067.73KN \quad \text{No need reinforcement}$$

Minimum shear reinforcement is required:

$$\begin{aligned}\text{Min}(A_v h / S_h) &= 0.0025 * h \\ &= 0.0025 * 250 = 0.625\end{aligned}$$

Select $\phi 10 @ 200mm$, two layers

$$A_v h = 2 * \pi * 10^2 / 4 = 157 mm^2$$

$$157/S_h = 0.625$$

$$S_h = 157/0.625 = 251.2$$

$$\text{Select } S_h = 200 \text{ mm} \leq S_{\max} = L_w/5 = 600/5 = 120 \text{ cm.}$$

$$= 3 \cdot h = 3 \cdot 25 = 75 \text{ cm.}$$

✓ Design of Vertical Reinforcement:-

$$\frac{A_{vv}}{S_v} = \left[0.0025 + 0.5 \left(2.5 - \frac{h_w}{L_w} \right) \left(\frac{A_{vh}}{S_h \cdot h} - 0.0025 \right) \right] \cdot 250$$

$$\frac{A_{vv}}{S_v} = \left[0.0025 + 0.5 \left(2.5 - \frac{29.5}{6} \right) \left(\frac{157}{200 \cdot 250} - 0.0025 \right) \right] \cdot 250$$

$$\frac{A_{vv}}{S_v} = 0.736$$

Select Ø10 in Two Layer

$$A_{vh} = \frac{2 \cdot \pi \cdot 10^2}{4} = 157 \text{ mm}^2$$

$$\frac{157}{S_v} = 0.621375$$

$$S_v = 252 \text{ mm}$$

- Maximum spacing is the least of :

$$\frac{L_w}{3} = \frac{6000}{3} = 2000 \text{ mm}$$

$$3 \cdot h = 3 \cdot 250 = 750 \text{ mm}$$

450 mm Control

Use Ø14/200 mm for two layers

✓ Design of Bending Moment:-

$$A_{st} = \left(\frac{6000}{200}\right) * 2 * 79 = 4710 \text{ mm}^2$$

$$w = \left(\frac{A_{st}}{L_w h}\right) \frac{f_y}{f_c'} = \left(\frac{4710}{6000 * 250}\right) \frac{420}{28} = 0.0471$$

$$\alpha = \frac{P_u}{l_w h f_c'} = 0$$

$$\frac{C}{l_w} = \frac{w + \alpha}{2w + 0.85\beta_1} = \frac{0.0471 + 0}{2 * 0.0471 + 0.85 * 0.85} = 0.0576$$

$$\phi M_n = \phi \left[0.5 A_{st} f_y l_w \left(1 + \frac{P_u}{A_{st} f_y} \right) \left(1 - \frac{c}{2l_w} \right) \right]$$

$$= 0.9 [0.5 * 4710 * 420 * 6000 (1 + 0) (1 - 0.0576/2)] = 5170.223 \text{ KN} \\ \geq 32457.2 \text{ KN.m}$$

$$M_{ub} = M_u - \phi M_n = 32457.2 - 5170.223 = -69.83 \text{ KN.m}$$

$$X \geq \frac{l_w}{600 * \frac{\Delta h}{h_w}} = \frac{6000}{600 * 0.007} = 1428.57 \text{ mm}$$

$$L_b \geq \frac{X}{2} = 714 \text{ mm}$$

$$M_{ub} \text{ (moment carried by boundary steel)} = 27287 \text{ KN.m}$$

$$A_{sb} = M_n / \{F_y * (L_w - L_b)\} = \frac{(27287 * 10^6) / 0.9}{420 * (6000 - 750)} = 1375 \text{ mm}^2$$

select 8Ø 16 with $A_s = 1608 \text{ mm}^2$ for each boundary element

