STRUCTURAL DESIGN PROJECT REPORT

Design & Analysis of G+1 Residential Building

Submitted in partial fulfillment of the requirements for the course:

CE353P: Structural Design Lab

SUBMITTED BY (GROUP 12)

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Contents

Introduction

1.1 Project Scope

This report details the architectural planning and structural arrangement of a proposed G+1 residential building. The structure is designed as a Reinforced Concrete Cement (RCC) frame. The design philosophy follows the Limit State Method as per IS 456:2000.

1.2 Structural System

- **Columns:** RCC columns at grid intersections.
- **Beams:** Rectangular sections transferring loads to columns.
- **Slabs:** Two-way slab systems.
- **Foundation:** Isolated footings.

Architectural Design

2.1 Floor Plans

The layout maximizes space efficiency while maintaining privacy.

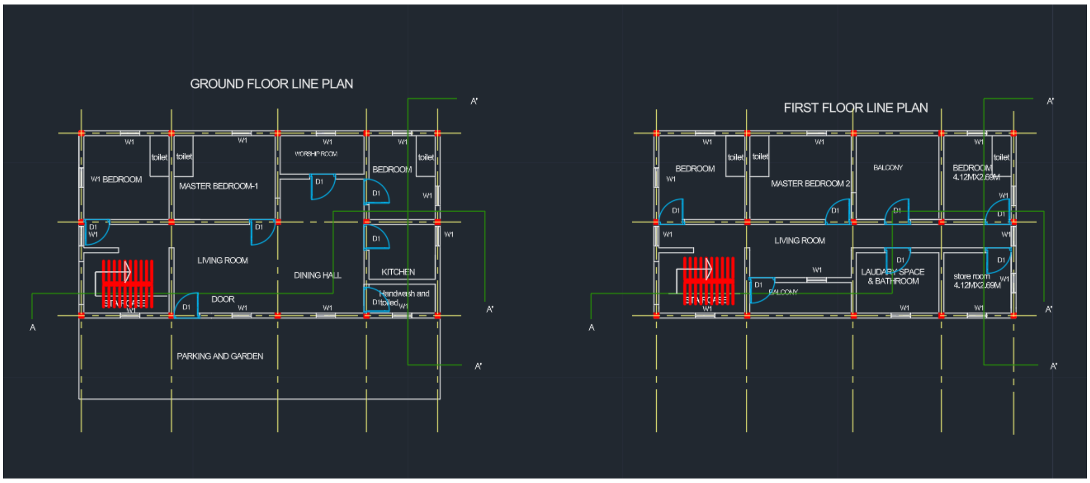

Figure 2.1: Ground and First Floor Line Plans

2.2 Elevations Sections

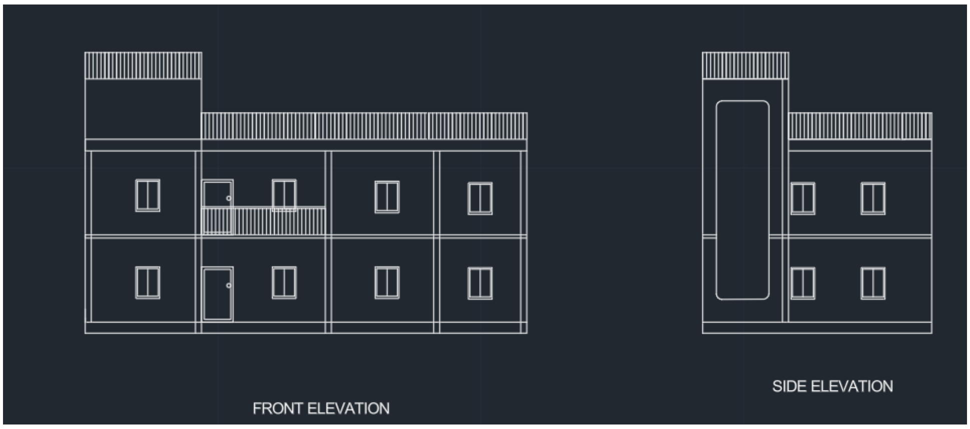

Figure 2.2: Front and Side Elevations

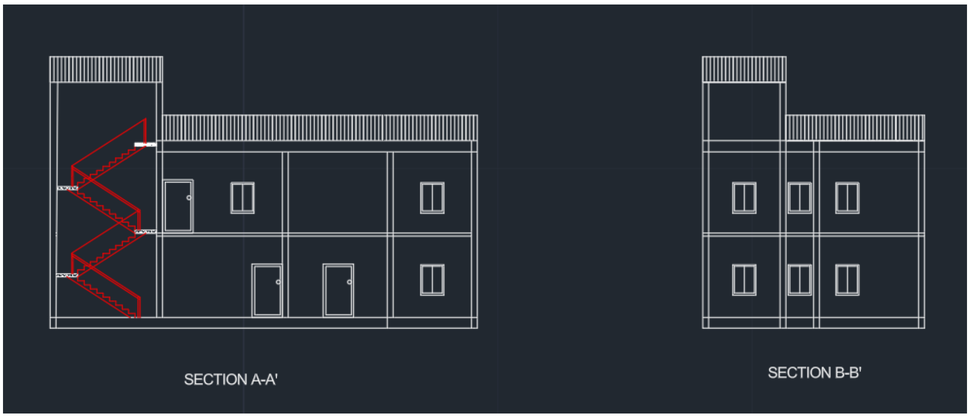

Figure 2.3: Building Sections A-A' and B-B'

Structural Layout

3.1 Grid Column Positioning

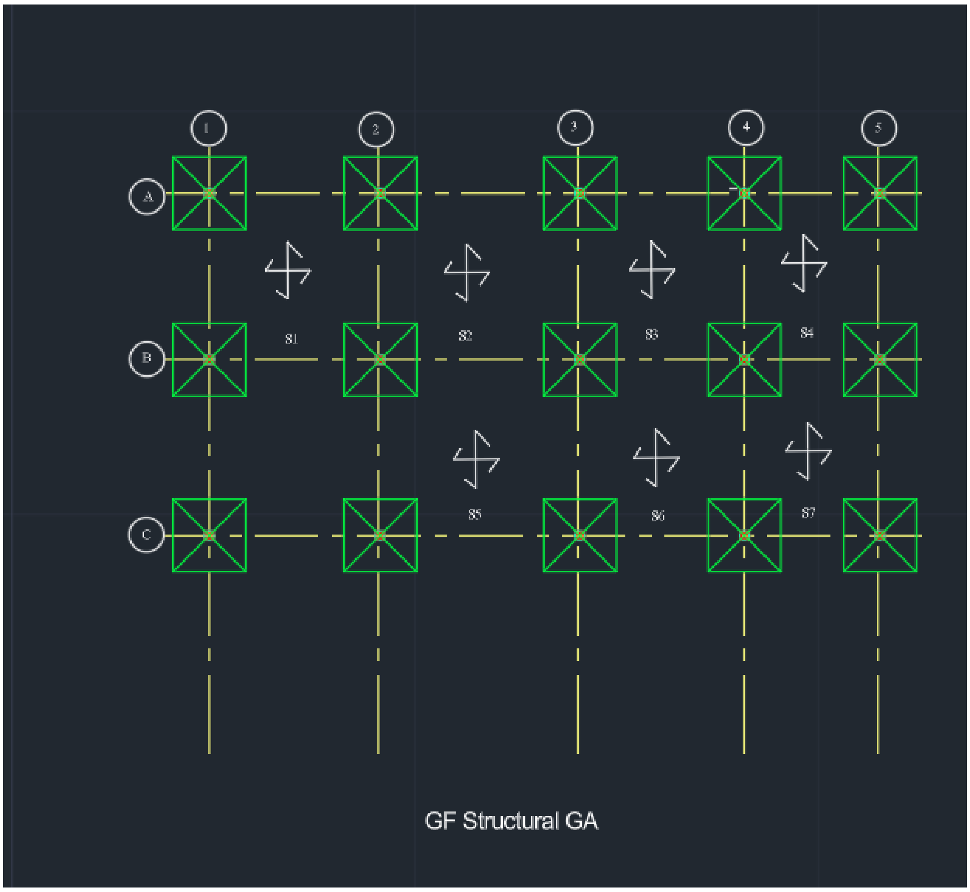

Figure 3.1: Ground Floor Structural GA

3.2 Beam Slab Arrangement

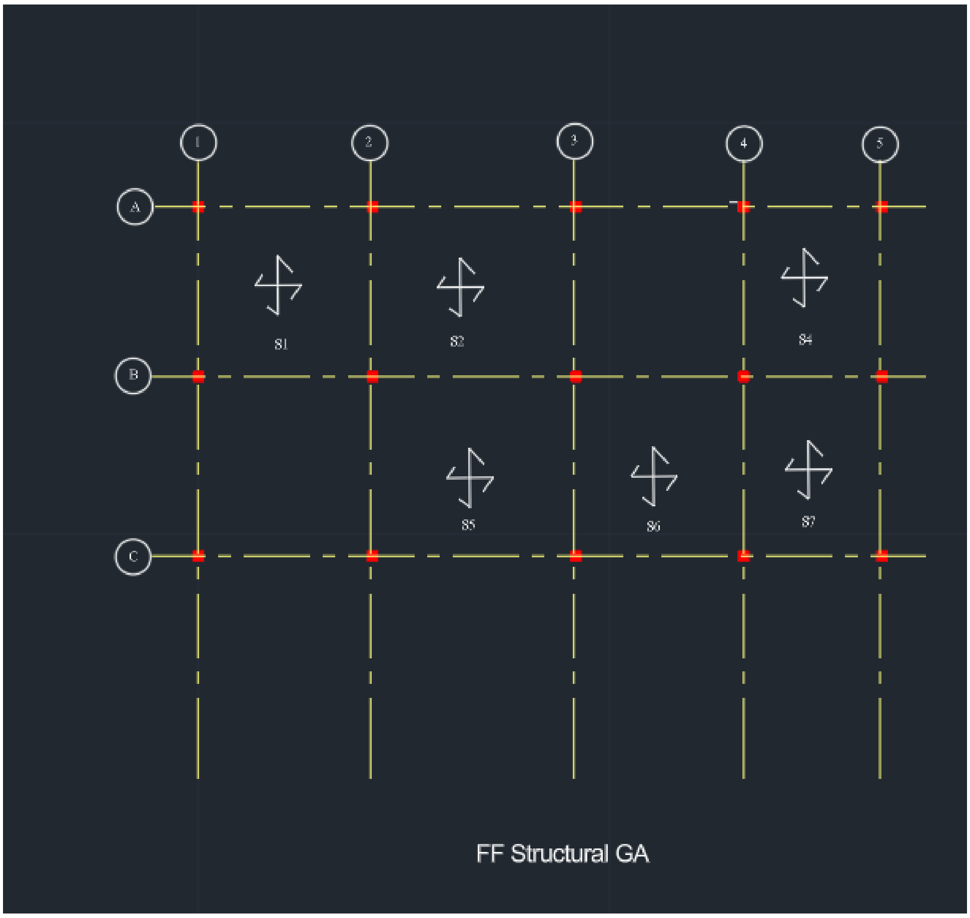

Figure 3.2: First Floor Structural GA

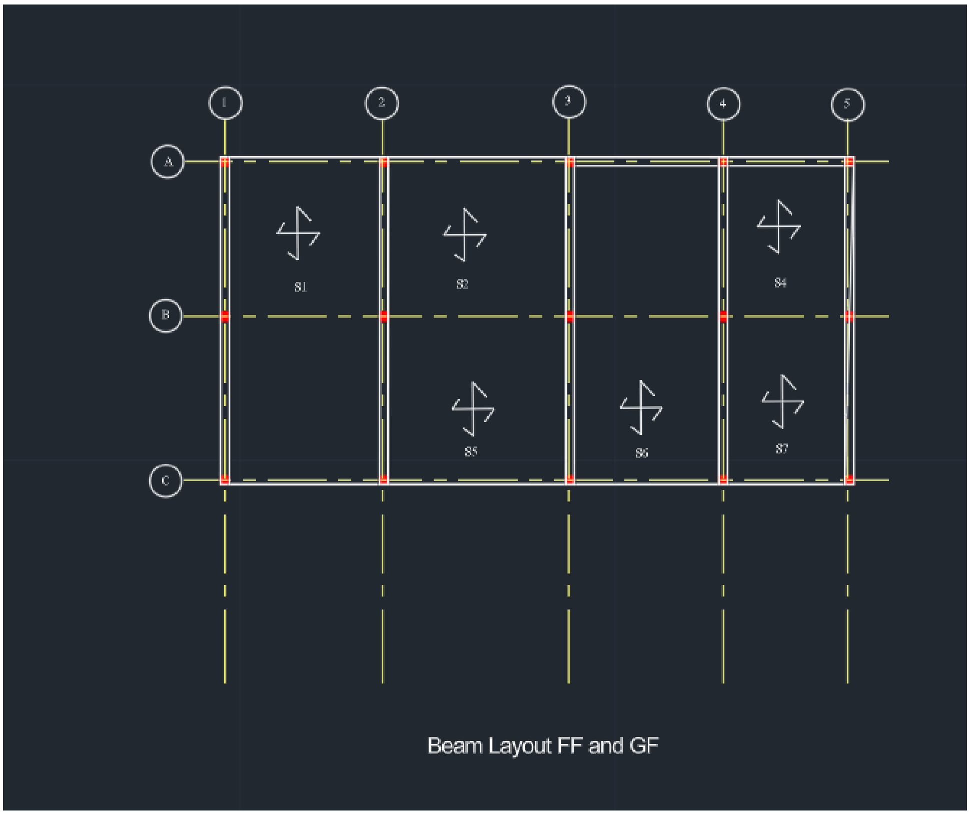

Figure 3.3: Beam Layout Plan

3.3 Terrace Level

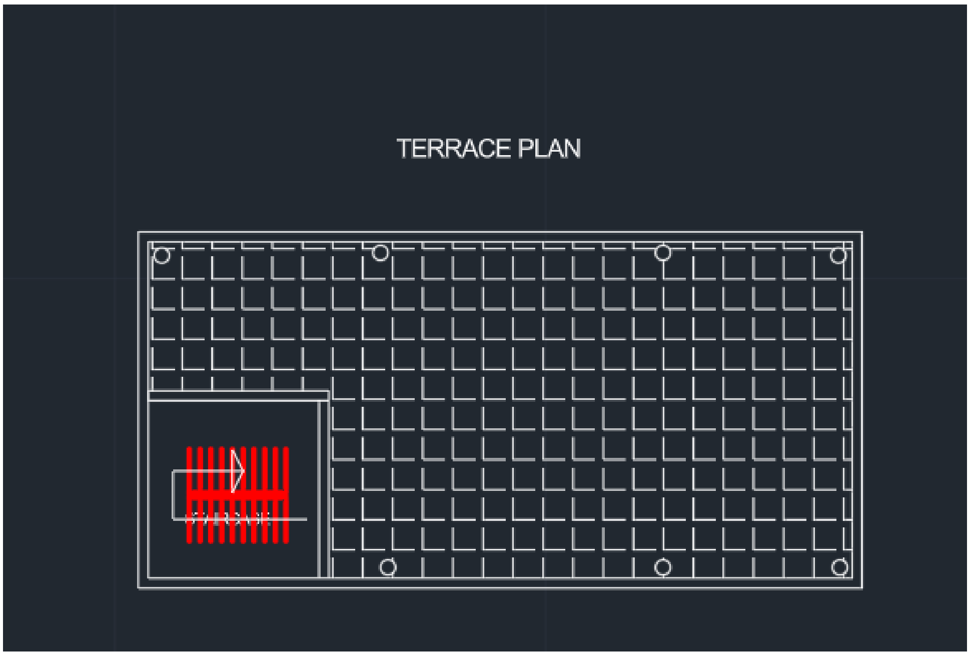

Figure 3.4: Terrace Plan Details

Structural Analysis (STAAD.Pro)

The structure was modeled using STAAD.Pro CONNECT Edition.

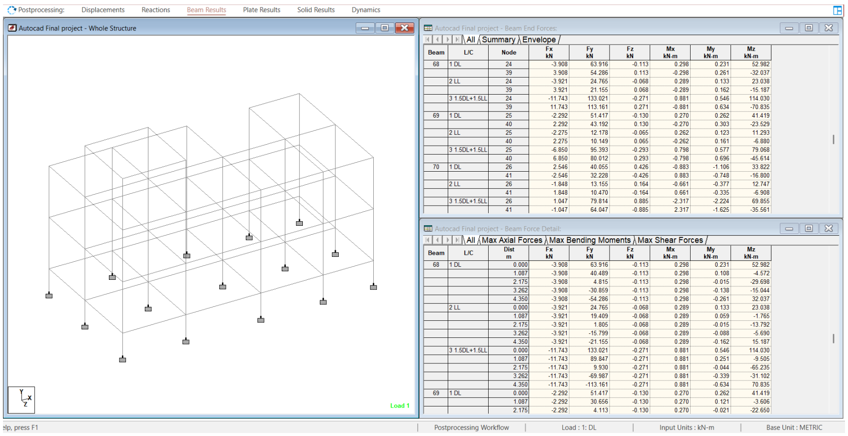

Figure 4.1: STAAD Wireframe Model

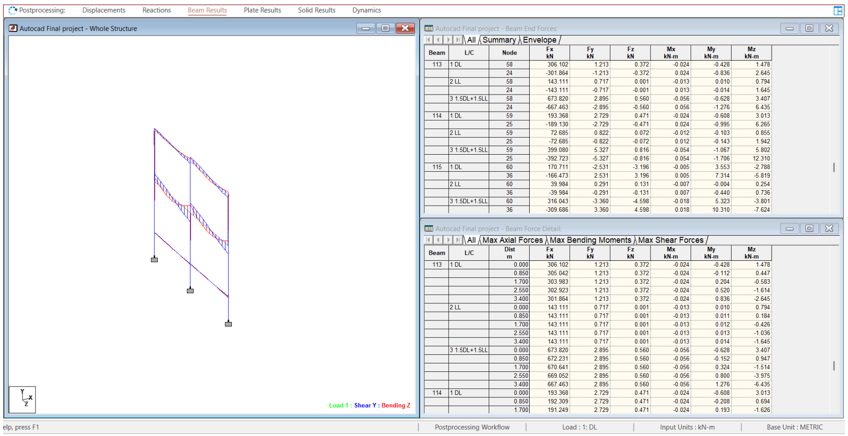

Figure 4.2: 3D Rendered View

Detailed Component Design: Slab S3

5.1 1. Input Data

- Panel Size ($L_x \times L_y$): 4.13 m × 4.13 m
- Concrete: M30 ($f_{ck} = 30$ N/mm^2)
- Steel: Fe415 ($f_y = 415$ N/mm^2)
- Clear Cover: 25 mm
- Total Depth (D): 200 mm

5.2 2. Effective Depth Calculation

Assuming 8mm ϕ bars as main reinforcement:

$$d_{prov} = D - \text{Cover} - \frac{\phi}{2}$$
$$d_{prov} = 200 - 25 - \frac{8}{2} = \mathbf{171}\ \text{mm} \quad (\text{Use } d = 175 \text{ mm for design safety})$$

5.3 3. Load Calculation

Consider a 1m wide strip ($b = 1000$ mm):

$$\text{Self Weight } (DL) = D \times 25 \text{ kN/m}^3 = 0.20 \times 25 = 5.0 \text{ kN/m}^2$$
$$\text{Floor Finish } (FF) = 1.0 \text{ kN/m}^2$$
$$\text{Live Load } (LL) = 4.0 \text{ kN/m}^2 \quad (\text{Residential/Corridor})$$
$$\text{Total Load } (w) = 5.0 + 1.0 + 4.0 = 10.0 \text{ kN/m}^2$$
$$\text{Factored Load } (w_u) = 1.5 \times w = 1.5 \times 10.0 = \mathbf{15.0} \text{ kN/m}^{\mathbf{2}}$$

5.4 4. Bending Moment Calculation

Aspect Ratio: $L_y/L_x = 4.13/4.13 = 1.0 < 2.0 \implies$ **Two-Way Slab**. Using IS 456 Coefficients (Table 26) for Interior Panel:

$$\alpha_x(+ve) = 0.028, \quad \alpha_x(-ve) = 0.037$$
$$M_{u,x}(+ve) = \alpha_x w_u L_x^2 = 0.028 \times 15 \times 4.13^2 = \mathbf{7.16} \text{ kNm}$$
$$M_{u,x}(-ve) = 0.037 \times 15 \times 4.13^2 = \mathbf{9.47} \text{ kNm}$$

5.5 5. Check for Effective Depth

For Fe415, $M_{u,lim} = 0.138 f_{ck} b d^2$.

$$d_{required} = \sqrt{\frac{M_{u,max}}{0.138 f_{ck} b}}$$
$$d_{required} = \sqrt{\frac{9.47 \times 10^6}{0.138 \times 30 \times 1000}} = \sqrt{\frac{9470000}{4140}} = \mathbf{47.8} \text{ mm}$$

Check: Since $d_{prov}(175 \text{ mm}) > d_{req}(47.8 \text{ mm}) \implies$ **SAFE**.

5.6 6. Reinforcement Calculation

Using the approximation formula for under-reinforced sections ($M_u = 7.16$ kNm):

$$A_{st} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} b d^2}}\right] bd$$

$$\frac{4.6 M_u}{f_{ck} b d^2} = \frac{4.6 \times 7.16 \times 10^6}{30 \times 1000 \times 175^2} = 0.0358$$
$$A_{st} = \frac{0.5 \times 30}{415}\left[1 - \sqrt{1 - 0.0358}\right] \times 1000 \times 175$$
$$A_{st} = 0.0361 \times [1 - 0.9819] \times 175000 = \mathbf{114.3} \text{ mm}^\mathbf{2}$$

Safety Check 1: Minimum Steel

$$A_{st,min} = 0.12\% bD = \frac{0.12}{100} \times 1000 \times 200 = \mathbf{240} \text{ mm}^\mathbf{2}$$

Since $A_{st,calc}(114.3) < A_{st,min}(240)$, **Provide Minimum Steel = 240 mm**^{2}.

Spacing (Using 8mm ϕ):

$$S = \frac{1000 \times 50.26}{240} = 209 \text{ mm} \implies \textbf{Provide 8mm @ 200mm c/c}.$$

Safety Check 2: Deflection

$$\%p_t = \frac{100A_{st,prov}}{bd} = \frac{100 \times 251}{1000 \times 175} = 0.14\%$$

$$\text{Service Stress } (f_s) = 0.58 \times 415 \times \frac{240}{251} = 230 \text{ N/mm}^2$$

$$\text{Modification Factor } (k_t) \approx 2.0 \text{ (from IS 456 Fig 4)}$$

$$(L/d)_{max} = 26 \times k_t = 26 \times 2.0 = 52$$

$$(L/d)_{actual} = 4130/175 = 23.6$$

$$23.6 < 52 \implies \textbf{SAFE in Deflection}$$

Safety Check 3: Shear

$$V_u = 0.5 w_u L_x = 0.5 \times 15 \times 4.13 = 30.97 \text{ kN}$$

$$\tau_v = \frac{V_u}{bd} = \frac{30970}{1000 \times 175} = \mathbf{0.177} \text{ N/mm}^{\mathbf{2}}$$

$$\text{For M30, min } \tau_c = 0.28 \text{ N/mm}^2\text{. With slab factor } k = 1.2:$$

$$k\tau_c = 1.2 \times 0.28 = 0.336 \text{ N/mm}^2$$

$$0.177 < 0.336 \implies \textbf{SAFE in Shear}$$

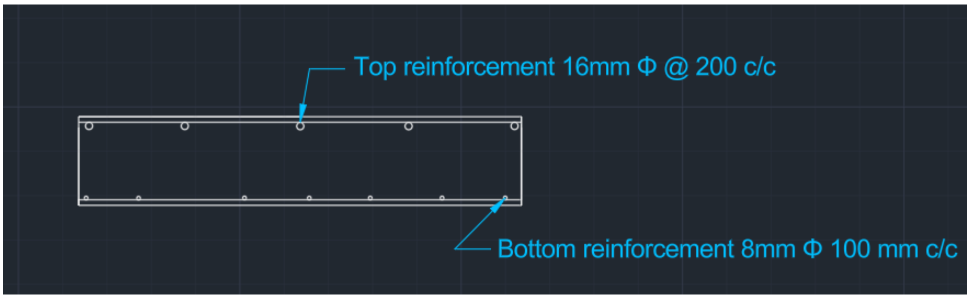

Figure 5.1: Slab Reinforcement Detail

Detailed Component Design: Beam 68

6.1 1. Section Properties

- Size: 230×350 mm ($b = 230, D = 350$)
- Effective Depth $d = 310$ mm
- Design Moment $M_u = 114.03$ kNm (Support)

6.2 2. Limiting Moment Calculation

$$M_{u,lim} = 0.138 f_{ck} b d^2$$
$$M_{u,lim} = 0.138 \times 30 \times 230 \times 310^2$$
$$M_{u,lim} = 91,503,060 \text{ Nmm} = \mathbf{91.50} \text{ kNm}$$

6.3 3. Main Steel Design (Doubly Reinforced)

Since $M_u(114.03) > M_{u,lim}(91.50)$, section is Doubly Reinforced.

$$M_{u2} = M_u - M_{u,lim} = 114.03 - 91.50 = \mathbf{22.53} \text{ kNm}$$

Compression Steel (A_{sc}):

$$d'/d = 40/310 = 0.13 \implies f_{sc} \approx 353 \text{ N/mm}^2$$

$$A_{sc} = \frac{M_{u2}}{f_{sc}(d - d')} = \frac{22.53 \times 10^6}{353(310 - 40)} = \mathbf{236.4} \text{ mm}^{\mathbf{2}}$$

Provide: 2 Nos 16mm ϕ ($A_{sc,prov} = 402$ mm^2).

Tension Steel (A_{st}):

$$A_{st1} = \frac{M_{u,lim}}{0.87 f_y (d - 0.42 x_{u,max})} = \frac{91.5 \times 10^6}{0.87 \times 415 \times 0.798 \times 310} = 1023 \text{ mm}^2$$

$$A_{st2} = \frac{A_{sc} f_{sc}}{0.87 f_y} = \frac{236.4 \times 353}{0.87 \times 415} = 231 \text{ mm}^2$$

$$A_{st,total} = 1023 + 231 = \mathbf{1254} \text{ mm}^{\mathbf{2}}$$

Provide: 4 Nos 20mm ϕ ($A_{st,prov} = 1256$ mm^2).

Safety Check 1: Steel Limits

$$A_{st,min} = \frac{0.85bd}{f_y} = \frac{0.85 \times 230 \times 310}{415} = 146 \text{ mm}^2$$

$$A_{st,max} = 0.04bD = 0.04 \times 230 \times 350 = 3220 \text{ mm}^2$$

$$146 < 1256 < 3220 \implies \textbf{SAFE}$$

6.4 4. Shear Reinforcement

- Design Shear $V_u = 133.02$ kN

$$\tau_v = \frac{V_u}{bd} = \frac{133020}{230 \times 310} = \mathbf{1.86} \text{ N/mm}^{\mathbf{2}}$$

$$\%p_t = \frac{100 \times 1256}{230 \times 310} = 1.76\%$$

From IS 456 Table 19 (M30, $p_t = 1.76$), $\tau_c = 0.82$ N/mm^2.

$$V_{us} = V_u - \tau_c bd = 133020 - (0.82 \times 230 \times 310) = \mathbf{74,554} \text{ N}$$

Spacing Calculation (8mm 2-Legged, $A_{sv} = 100.5$ mm^2):

$$S_v = \frac{0.87 f_y A_{sv} d}{V_{us}} = \frac{0.87 \times 415 \times 100.5 \times 310}{74554} = \mathbf{150.8} \text{ mm}$$

Safety Check 2: Maximum Spacing

$$S_{max} = \min(0.75d, 300) = \min(0.75 \times 310, 300) = 232.5 \text{ mm}$$

Since $150.8 < 232.5$, **Provide 8mm @ 150mm c/c**.

Safety Check 3: Deflection

$$(L/d)_{actual} = 4350/310 = 14.03$$

$$k_t \approx 1.0, k_c \approx 1.1$$

$$(L/d)_{max} = 26 \times 1.0 \times 1.1 = 28.6$$

$$14.03 < 28.6 \implies \textbf{SAFE}$$

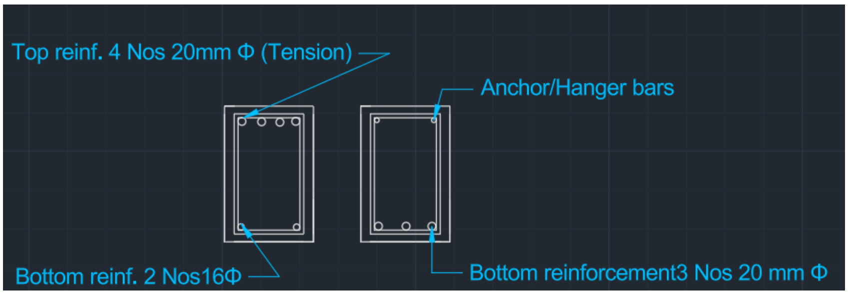

Figure 6.1: Beam Reinforcement Detail

Detailed Component Design: Column 113

7.1 1. Calculations

- $P_u = 673.82$ kN
- $M_u = 13.48$ kNm
- $D = 230$ mm, $L = 3400$ mm

Safety Check 1: Slenderness

$$\lambda = \frac{L_{eff}}{D} = \frac{1.0 \times 3400}{230} = 14.78 > 12 \implies \text{Slender (Design for additional moments)}$$

Safety Check 2: Minimum Eccentricity

$$e_{min} = \frac{L}{500} + \frac{D}{30} = \frac{3400}{500} + \frac{230}{30} = 6.8 + 7.66 = 14.46 \text{ mm}$$
$$e_{min,code} = 20 \text{ mm}$$
$$\text{Design Moment } M_{min} = P_u \times 0.02 = 673.8 \times 0.02 = \mathbf{13.47} \text{ kNm}$$

The applied moment matches the minimum eccentricity moment.

7.2 2. Longitudinal Steel Design

Using SP-16 Charts:

$$\frac{P_u}{f_{ck} b D} = \frac{673820}{30 \times 230 \times 230} = 0.42$$
$$\frac{M_u}{f_{ck} b D^2} = \frac{13.48 \times 10^6}{30 \times 230 \times 230^2} = 0.037$$

From Chart 44 (Fe415, d'/D=0.15): Required $p \approx 1.2\%$.

$$A_{st,req} = \frac{1.2}{100} \times 230 \times 230 = 634 \text{ mm}^2$$

Provided: 4 Nos 16mm ϕ.

$$A_{st,prov} = 4 \times 201 = 804 \text{ mm}^2$$

Safety Check 3: Ultimate Capacity (P_{uz})

$$A_c = A_g - A_{st} = (230 \times 230) - 804 = 52096 \text{ mm}^2$$

$$P_{uz} = 0.45 f_{ck} A_c + 0.75 f_y A_{st}$$
$$P_{uz} = (0.45 \times 30 \times 52096) + (0.75 \times 415 \times 804)$$
$$P_{uz} = 703,296 + 250,245 = 953,541 \text{ N} = \mathbf{953.5} \text{ kN}$$

$$P_{uz}(953.5) > P_u(673.8) \implies \textbf{SAFE}$$

7.3 3. Transverse Reinforcement

- **Diameter:** $\max(16/4, 6) = 6\text{mm} \rightarrow$ Provide 8mm.
- **Pitch:** $\min(230, 16 \times 16, 300) = \min(230, 256, 300) = 230\text{mm}$.

Provide 8mm ties @ 200mm c/c.

[Image of reinforced concrete column cross section detailing]

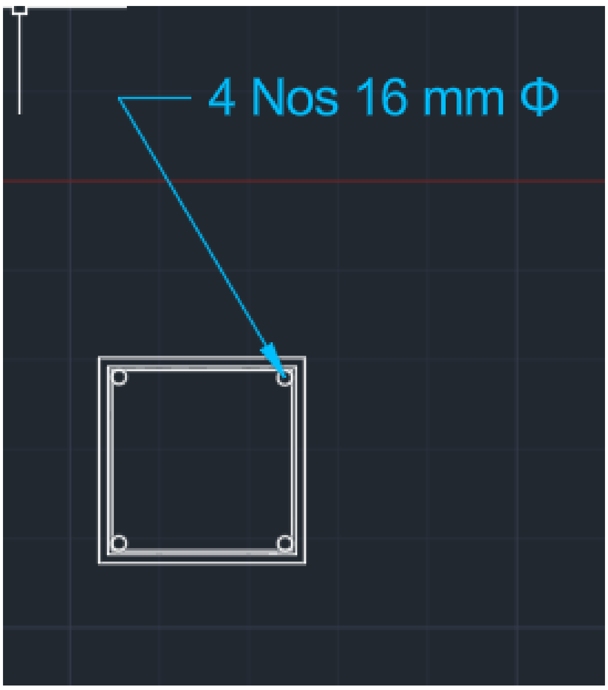

Figure 7.1: Column Reinforcement Detail

Detailed Component Design: Staircase

8.1 1. Load Calculations

- Waist Slab (D) = 150 mm
- Riser (R) = 160 mm, Tread (T) = 250 mm

Dead Load on Plan:

$$\text{Slope Factor} = \frac{\sqrt{R^2 + T^2}}{T} = \frac{\sqrt{160^2 + 250^2}}{250} = 1.187$$
$$w_{slab} = 25 \times 0.15 \times 1.187 = 4.45 \text{ kN/m}^2$$
$$w_{steps} = 25 \times \frac{R}{2} = 25 \times \frac{0.16}{2} = 2.00 \text{ kN/m}^2$$
$$w_{finish} = 1.00 \text{ kN/m}^2$$
$$w_{DL} = 4.45 + 2.00 + 1.00 = 7.45 \text{ kN/m}^2$$

Total Factored Load:

$$w_u = 1.5 \times (DL + LL) = 1.5 \times (7.45 + 3.00) = \mathbf{15.68 \text{ kN/m}^2}$$

8.2 2. Moment Calculation

Assuming effective span $L = 3.5$ m:

$$M_u = \frac{w_u L^2}{8} = \frac{15.68 \times 3.5^2}{8} = \mathbf{24.01} \text{ kNm}$$

8.3 3. Steel Calculation

$$d = 150 - 20 - 6 = 124 \text{ mm}$$
$$\frac{4.6 M_u}{f_{ck} b d^2} = \frac{4.6 \times 24.01 \times 10^6}{30 \times 1000 \times 124^2} = 0.239$$

$$A_{st} = \frac{0.5 \times 30}{415}[1 - \sqrt{1 - 0.239}] \times 1000 \times 124 = \mathbf{574} \ \mathrm{mm}^{\mathbf{2}}\mathbf{/m}$$

Spacing for 12mm bars ($A_\phi = 113$ mm^2):

$$S = \frac{1000 \times 113}{574} = 196 \text{ mm} \implies \text{Provide } \mathbf{12}\phi\mathbf{@150} \text{ c/c}$$

Safety Check 1: Anchorage Length

For the connection between the stair slab and floor slab:

$$L_d = \frac{0.87 f_y \phi}{4\tau_{bd}} = \frac{0.87 \times 415 \times 12}{4 \times 1.6 \times 1.25} = 541 \text{ mm}$$

Requirement: Bars must extend **600mm** into the supporting floor beam/slab.

Project Contributions

The project work was distributed among the group members as follows:

Member Name	Contribution / Tasks
Sathvika Nambiar	• Architectural Line Diagrams and Floor Plans • Roof Plan, Elevations, and Sections
Akshat Gupta	• Structural GA (Column, Footing, Centerline) • STAAD.Pro Modeling & Analysis • Slab S3 Design & Calculation • Beam 68 Design & Calculation • Column 113 Design & Calculation • Staircase Architectural Design • Staircase Structural Design & Calculation • Report Compilation • Final Report Formatting
Kartik Gupta	• Beam General Arrangement (GA) • Reinforcement Drawings/Detailing

Table 9.1: Distribution of Project Responsibilities

References

Codes and Standards

1. **IS 456:2000** - Plain and Reinforced Concrete - Code of Practice. Bureau of Indian Standards, New Delhi.
2. **IS 875 (Part 1):1987** - Code of Practice for Design Loads (Dead Loads).
3. **IS 875 (Part 2):1987** - Code of Practice for Design Loads (Live Loads).
4. **SP 16:1980** - Design Aids for Reinforced Concrete to IS 456:1978.
5. **SP 34:1987** - Handbook on Concrete Reinforcement and Detailing.

Software Used

1. **STAAD.Pro CONNECT Edition** - For Structural Analysis and Design.
2. **AutoCAD** - For Architectural and Structural drafting.