Indian Institute of Technology Mandi
Kamand, Himachal Pradesh - 175075

Design of Reinforced Concrete G+1 Residential Building

CE 353P: Civil Engineering Drawing
Academic Year 2025-26 (Odd Semester)

Submitted by Group 1:

Role	Roll No.	Name
Member	B23059	Abhinav Singh
Member	B23065	Aman Raj Verma
Member	B23102	Sumit Yadav

Date of Submission: 26 November 2025

Contents

1 Project Overview **3**

2 Architectural Design Phase **3**
2.1 Design Concept 3
2.2 Architectural Drawings 3

3 Structural General Arrangement Phase **10**

4 Structural Analysis Phase **11**

5 Reinforced Concrete Design Phase **15**
5.1 Design of Continuous Beam (First Floor) 15
5.1.1 1. Design Data & Properties 15
5.1.2 2. Limiting Moment Capacity Check 15
5.1.3 3. Support Design (Hogging Moment) 16
5.1.4 4. Mid-Span Design (Sagging Moment) 16
5.1.5 5. Shear Reinforcement Design 17
5.1.6 6. Development Length (L_d) 17
5.1.7 7. Deflection Check (Serviceability) 18
5.1.8 8. Final Schedule of Reinforcement 18
5.2 Design of Ground Floor Column 18
5.2.1 1. Design Data & Properties 18
5.2.2 2. Step 1: Slenderness Check 18
5.2.3 3. Step 2: Minimum Eccentricity & Design Moments 19
5.2.4 4. Step 3: Longitudinal Reinforcement 19
5.2.5 5. Step 4: Check for Biaxial Safety (Cl. 39.6) 20
5.2.6 6. Step 5: Transverse Reinforcement (Lateral Ties) 20
5.3 Design of Slab Panel (First Floor) 21
5.3.1 1. Design Constants & Parameters 21
5.3.2 2. Depth & Effective Span 21
5.3.3 3. Load Calculations 21
5.3.4 4. Bending Moments (IS 456 Table 26) 22
5.3.5 5. Check for Effective Depth 22
5.3.6 6. Reinforcement Design 22
5.3.7 7. Check for Shear 23
5.3.8 8. Check for Deflection 23
5.3.9 9. Torsion Reinforcement (Corners) 23
5.3.10 10. Final Summary of Slab Design 23

6 Reinforcement Detailed Drawings **24**
6.1 Beam Reinforcement Details 24
6.2 Column Reinforcement Details 25
6.3 Slab Reinforcement Details 26

7 Conclusion **27**

8 Key Insights and Learnings **27**
8.1 Contribution of Group Members 28

9 References **28**

1 Project Overview

The objective of this project is to plan, model, analyze, and design a G+1 residential building ("Dream Home") in accordance with Indian Standard (IS) codes. The project encompasses Architectural Planning, Structural General Arrangement, Structural Analysis using STAAD.Pro, and detailed Reinforced Concrete (RC) Design.

2 Architectural Design Phase

2.1 Design Concept

The building is designed with functionality and aesthetics in mind, adhering to local building codes. The layout maximizes natural light and ventilation.

2.2 Architectural Drawings

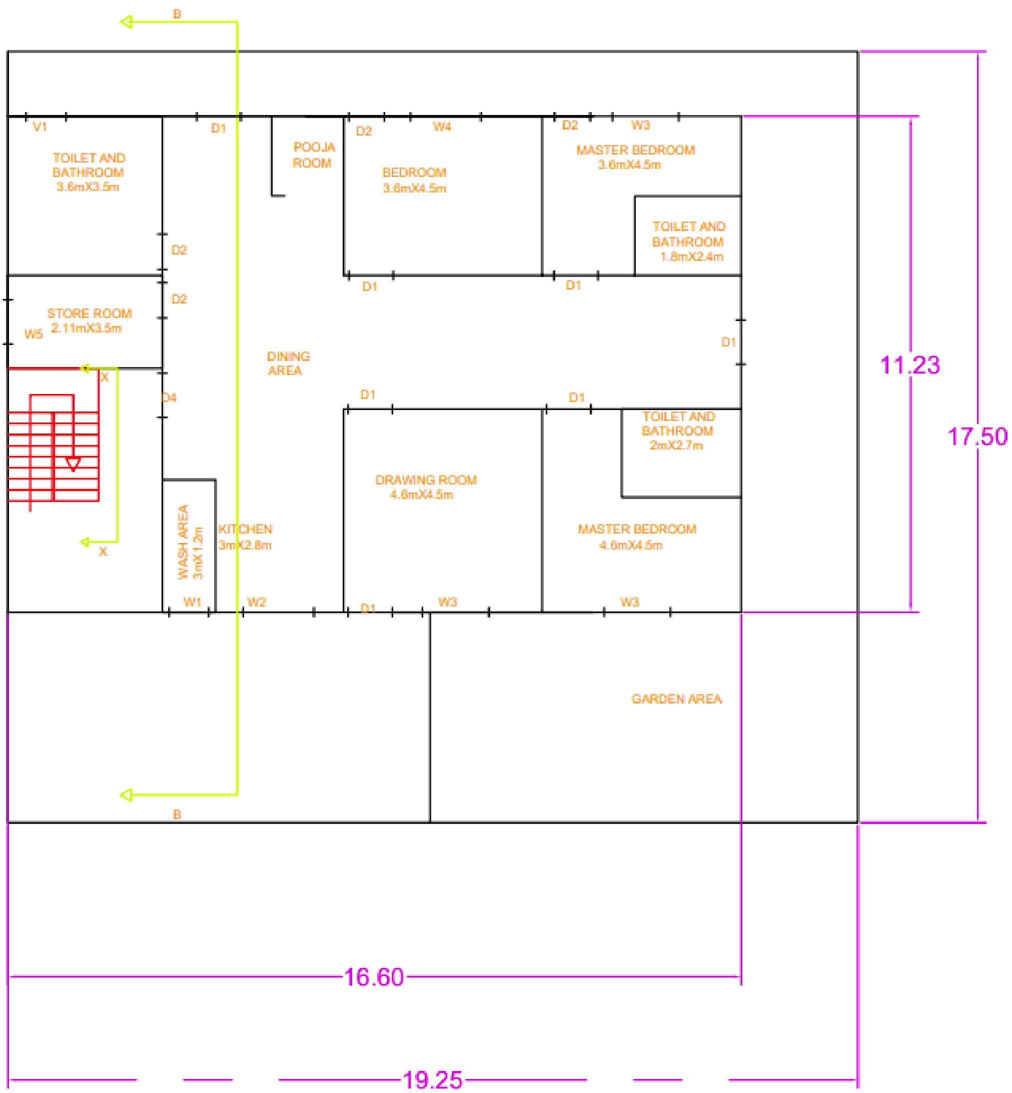

Figure 1: Ground Floor Line Plan

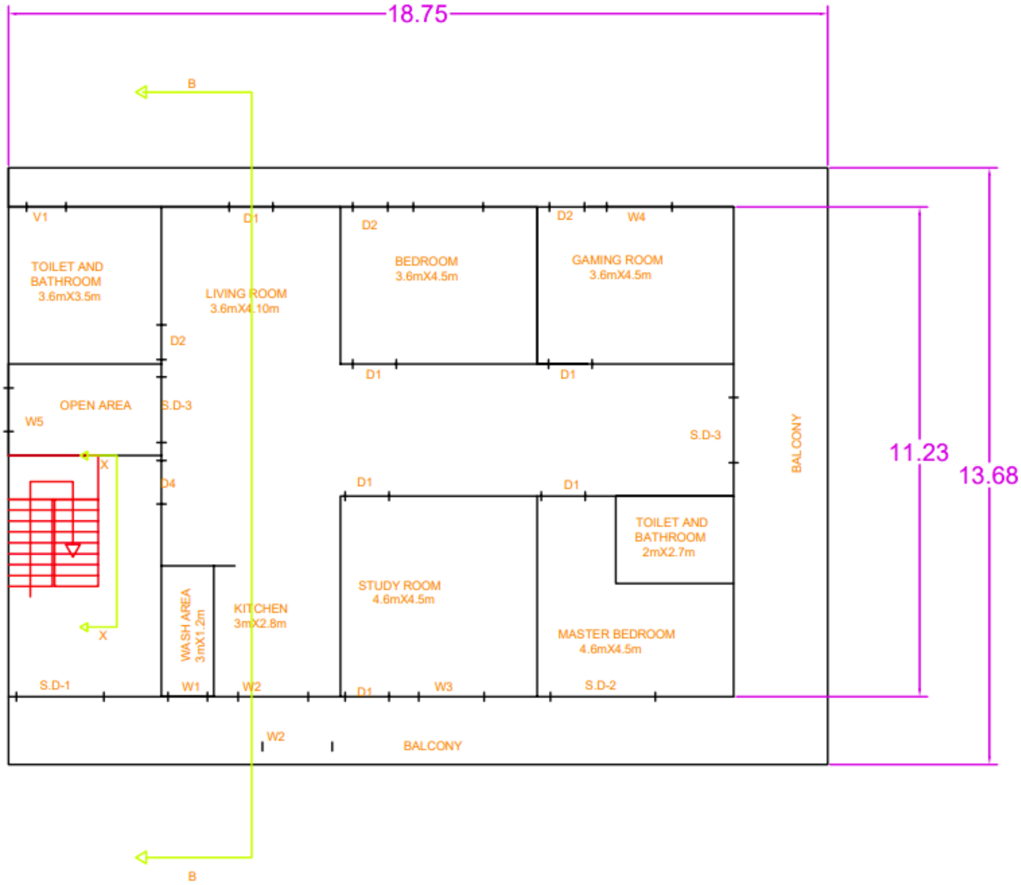

Figure 2: First Floor Line Plan

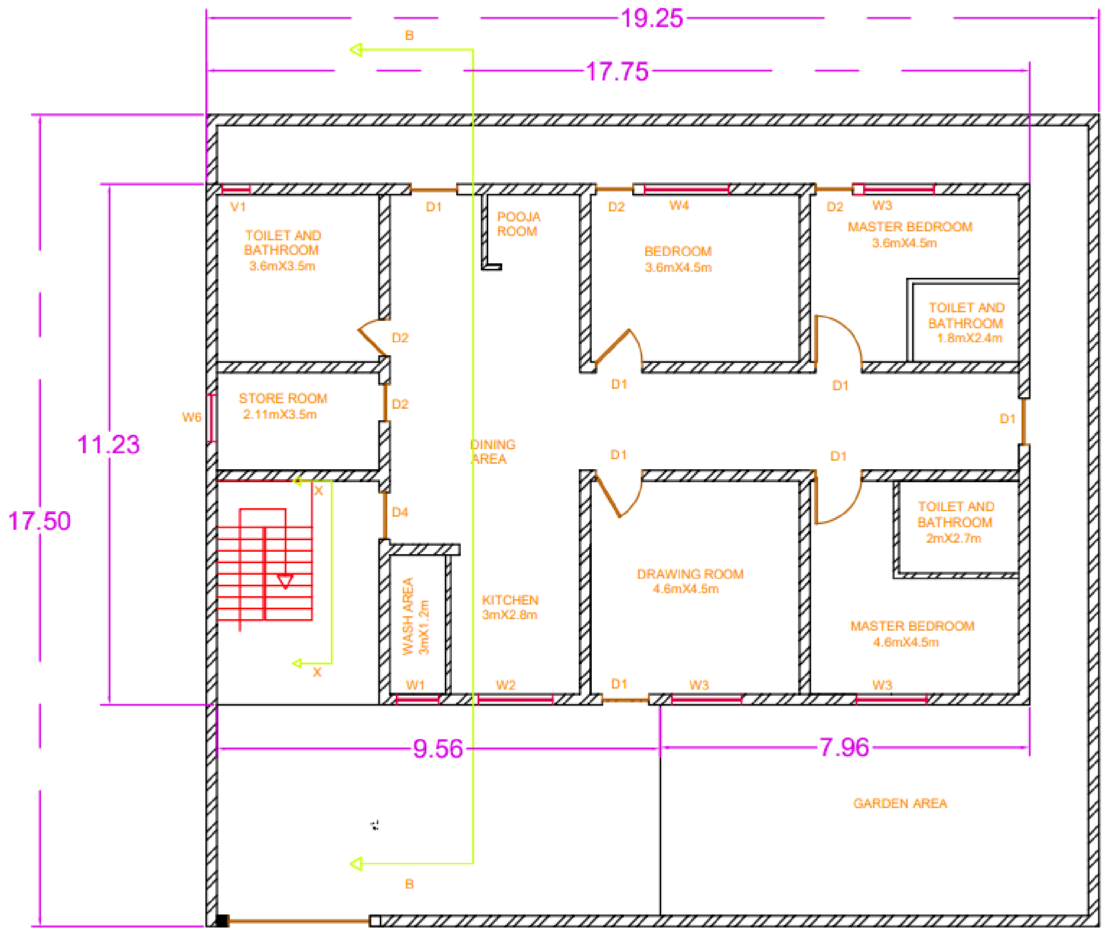

Figure 3: Ground Floor Architectural Plan

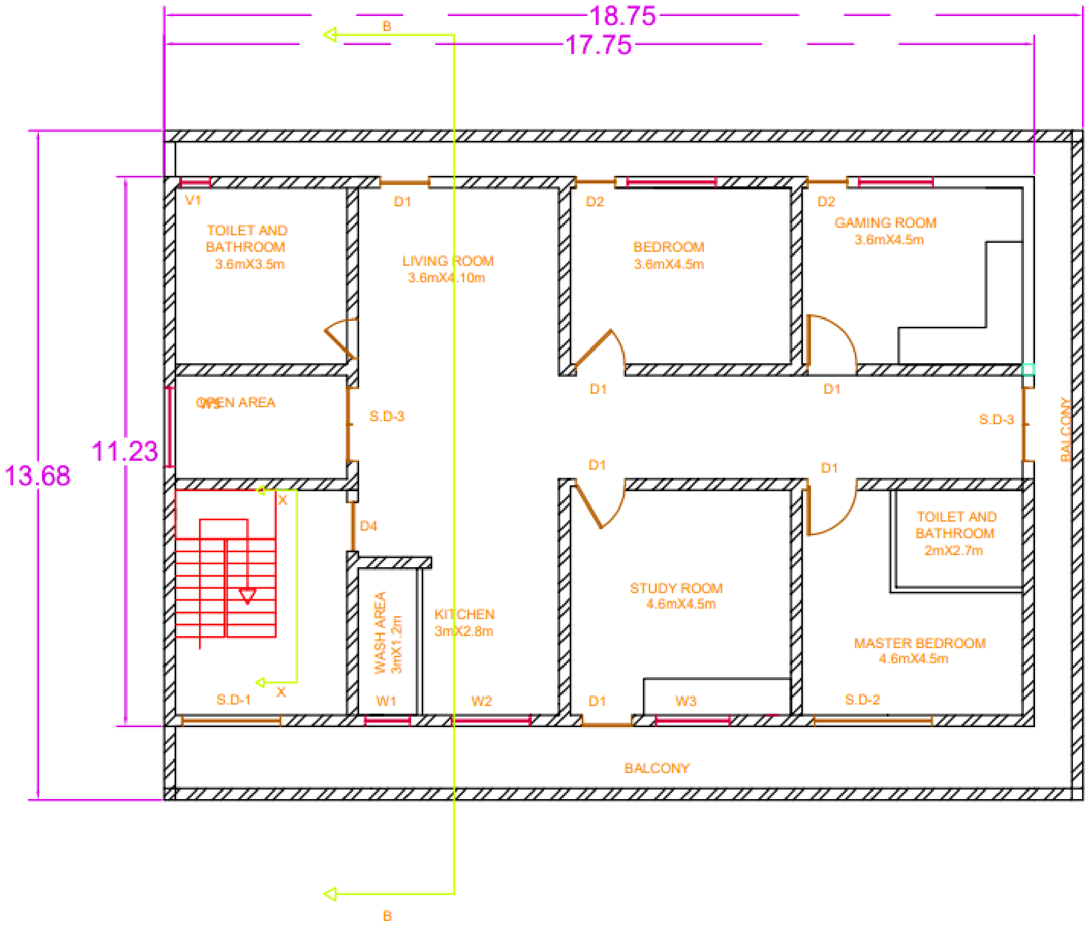

Figure 4: First Floor Architectural Plan

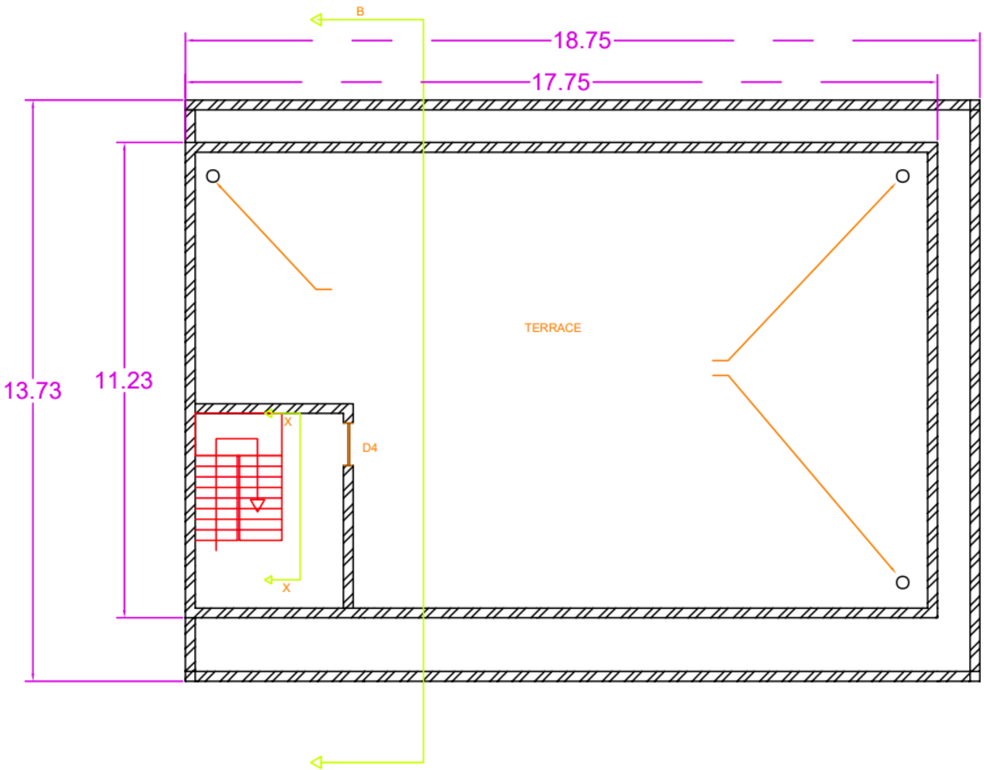

Figure 5: Terrace Architectural Plan

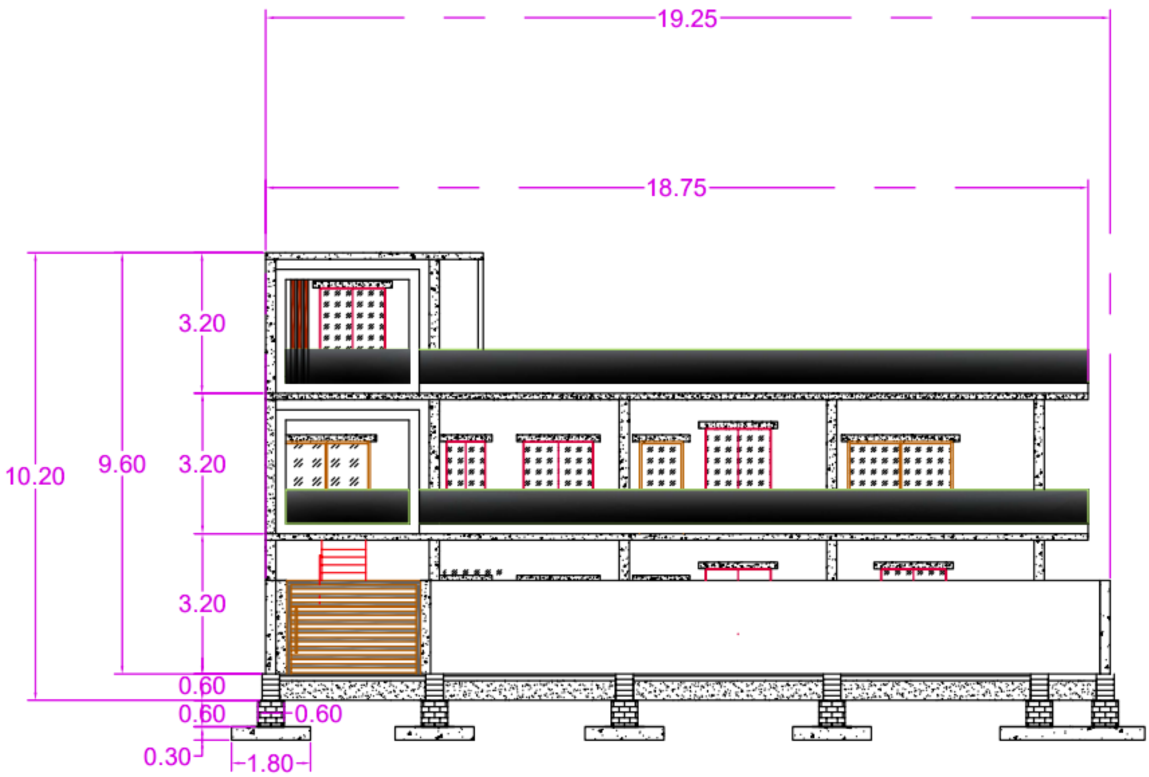

Figure 6: Building Elevation (Front View)

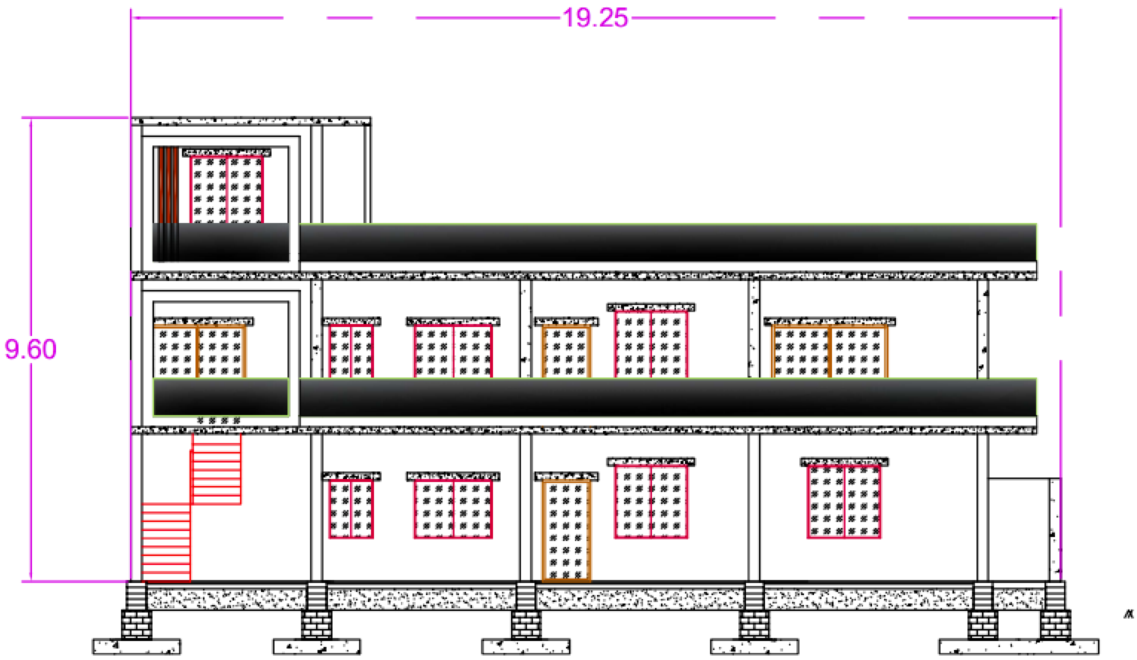

Figure 7: Building Section (A-A)

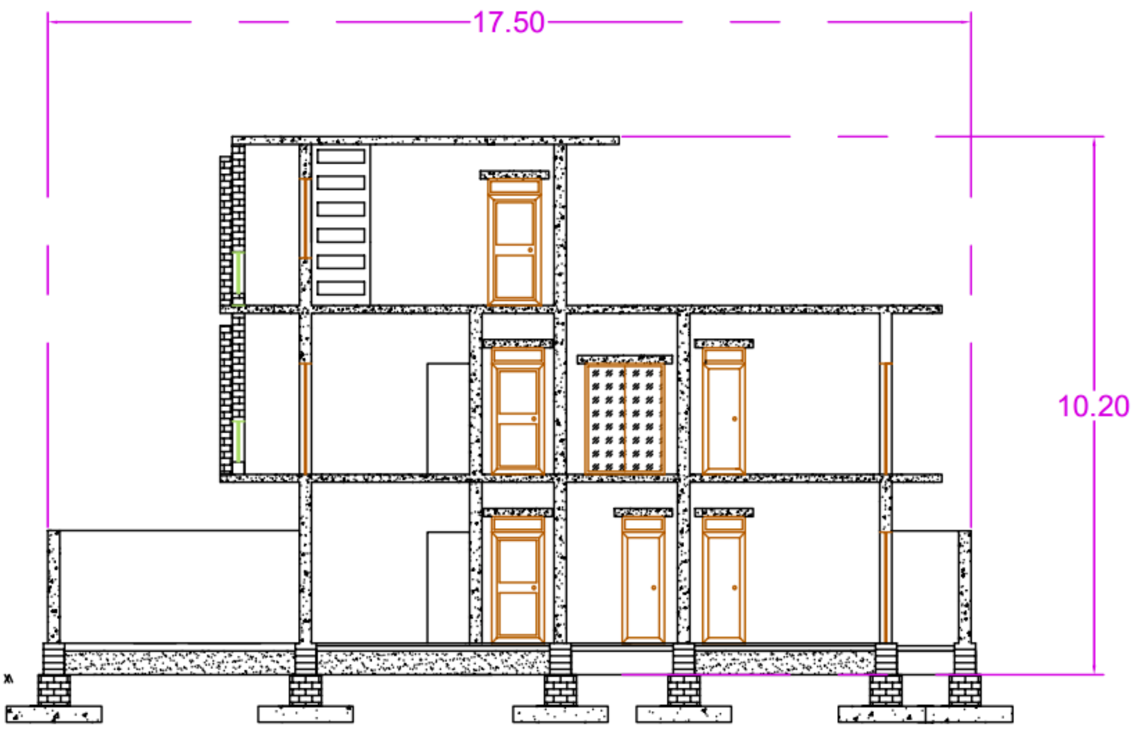

Figure 8: Building Section (B-B)

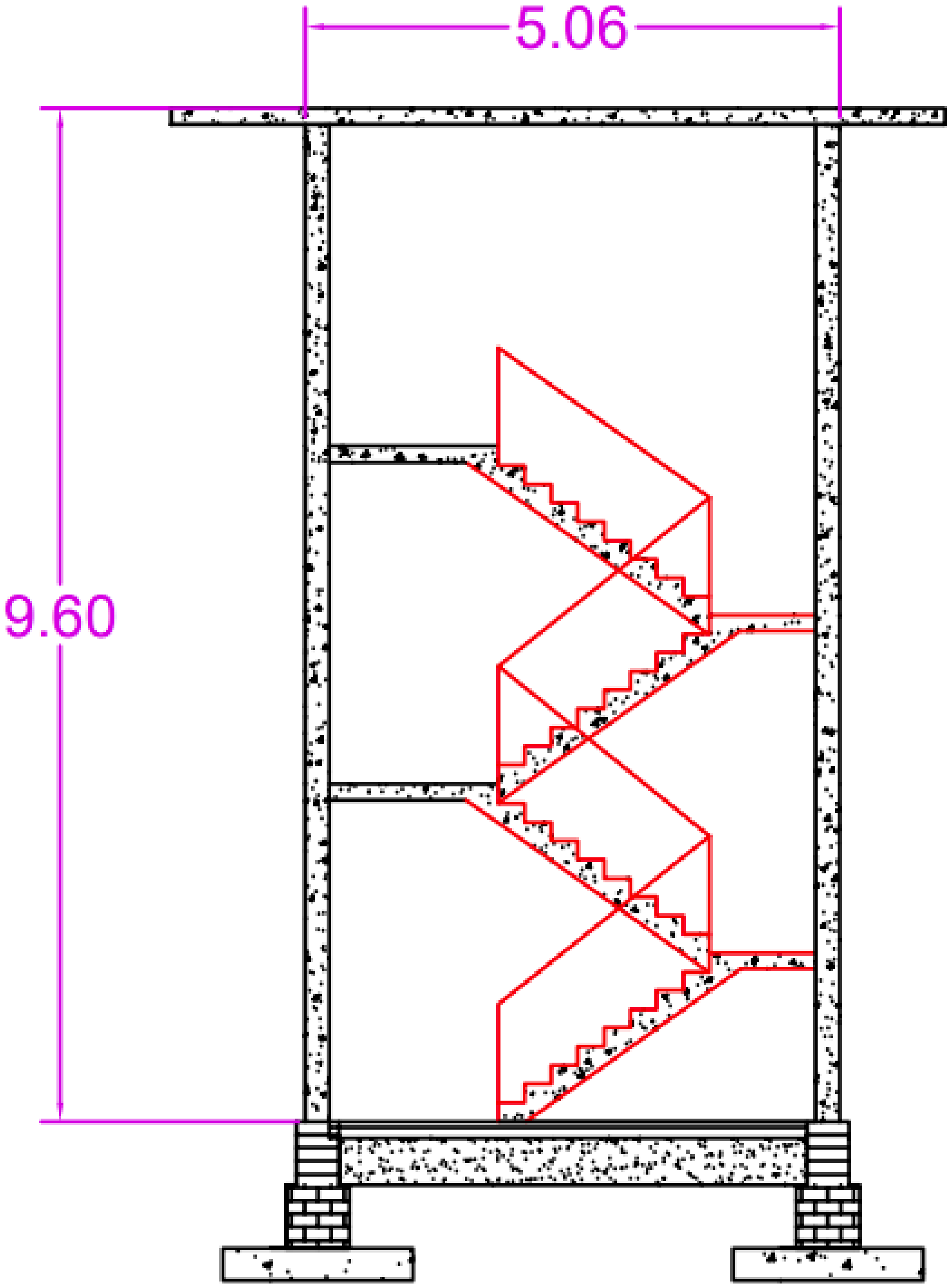

Figure 9: Staircase Section (X-X)

3 Structural General Arrangement Phase

The following drawings illustrate the positioning of structural members including columns, beams, and slabs.

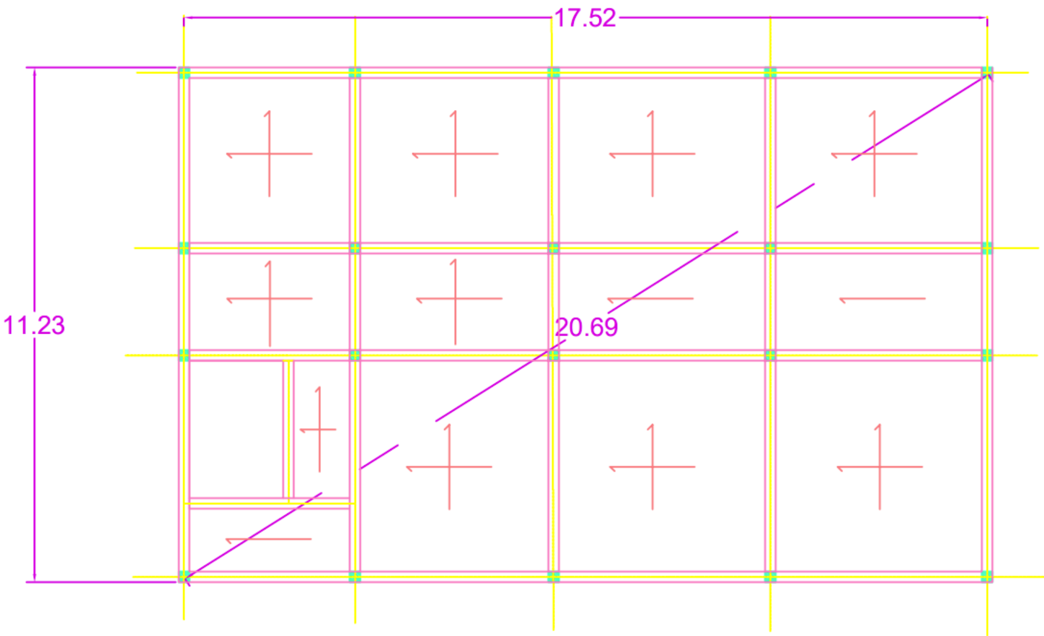

Figure 10: Beam and Slab Layout Plan

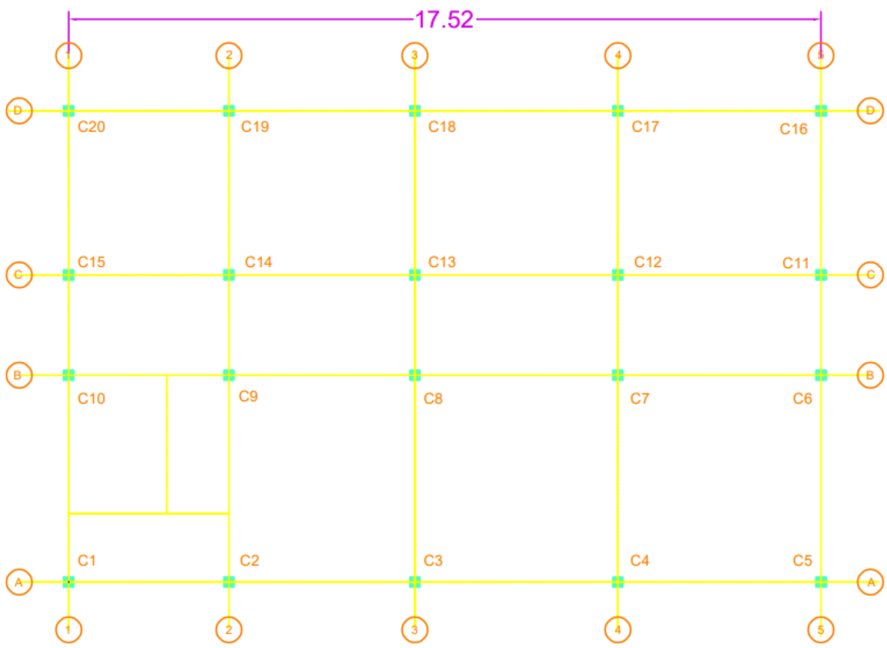

Figure 11: Centre Line Plan

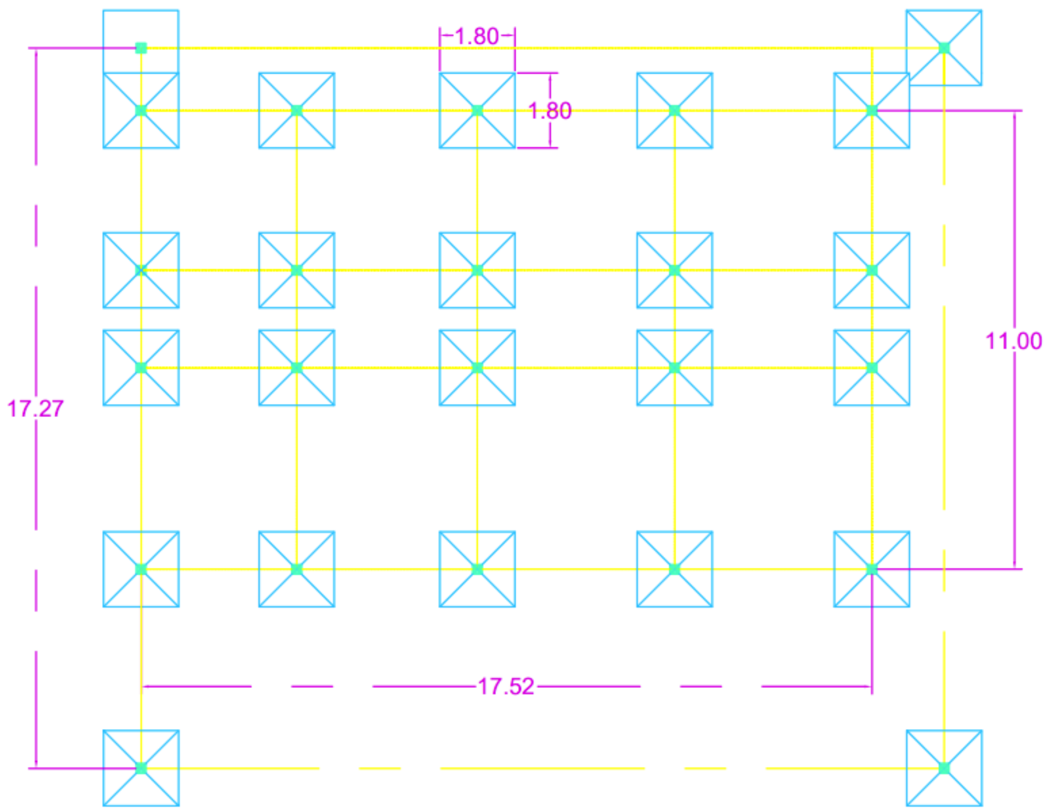

Figure 12: Foundation Layout

4 Structural Analysis Phase

The structure was modeled and analyzed using STAAD.Pro.

- **Load Combination:** 1.5 DL + 1.5 LL
- **Frame Selected:** The selected internal frame is marked by the node numbers and beam numbers as shown in the following diagrams. Similarly the beam, column, and the slab which have to be designed are represented by their respective nodes and element numbers.
  - **Selected Beam:** Continuous beam joining the beams 19, 20, 21 and 22 (using the maximum span and end moments of the beam 21).
  - **Selected Column:** Beam 27
  - **Selected Slab:** Plate 136

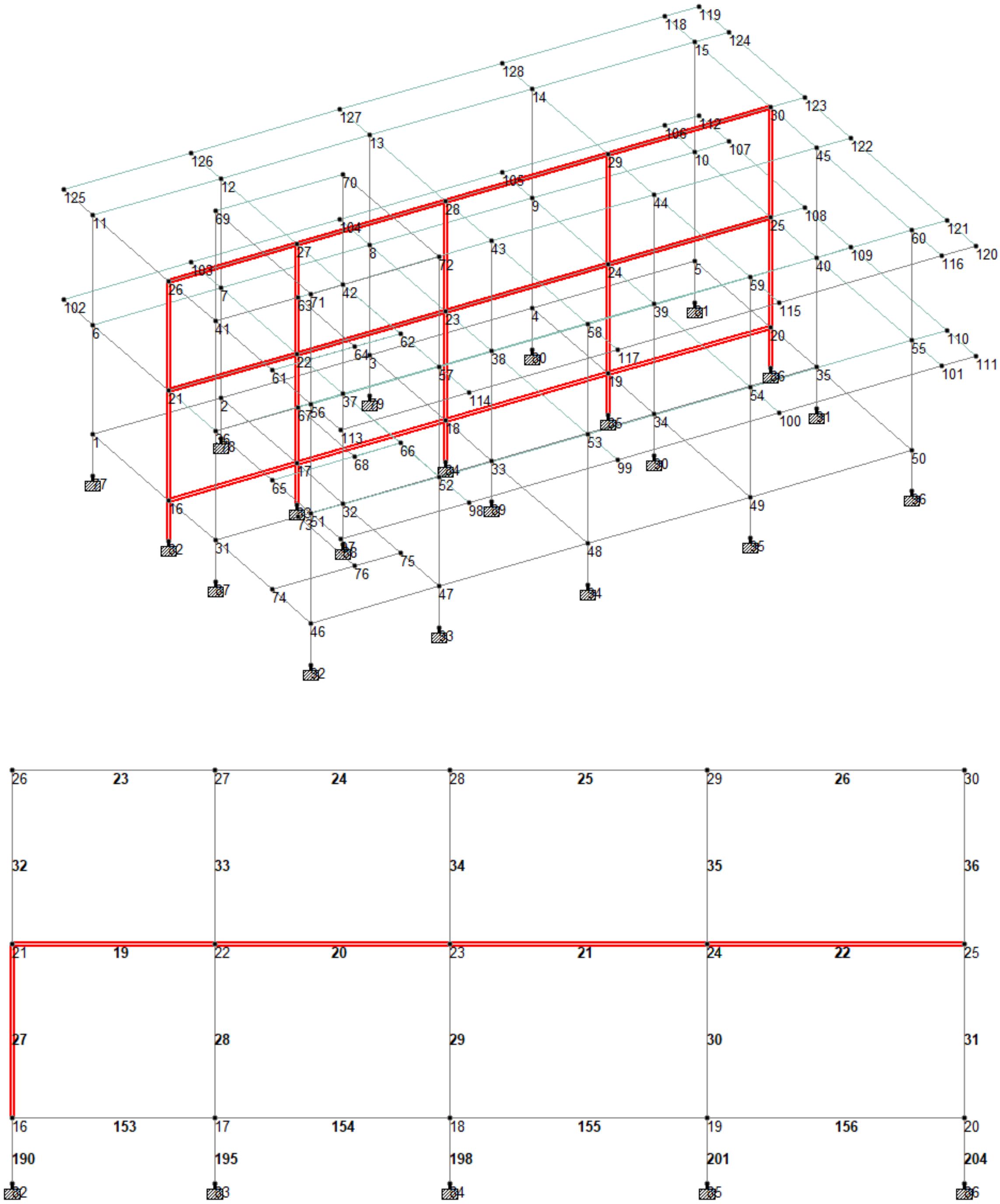

Figure 13: Selected Internal Frame in STAAD.Pro (top), Selected Beam and Column in the Internal Frame (bottom)

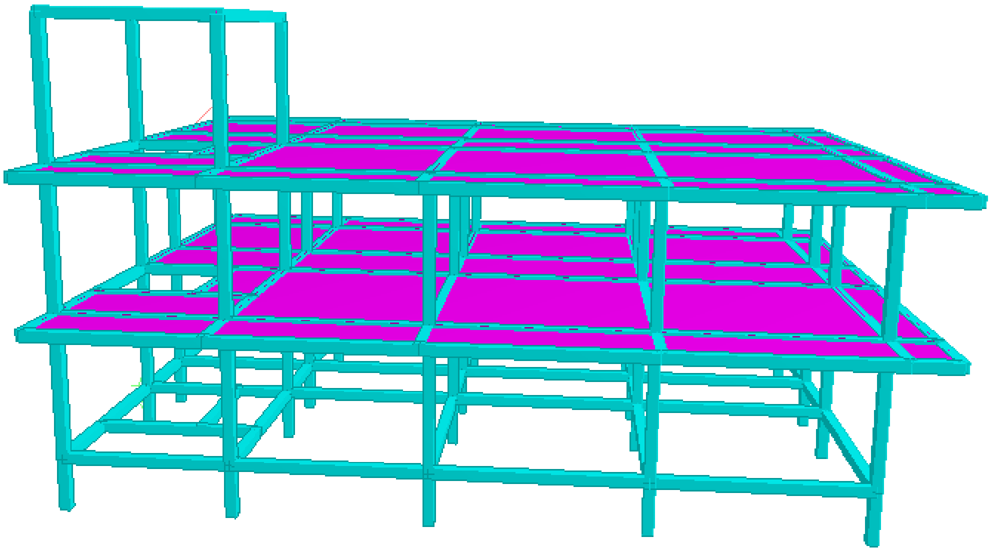

Figure 14: STAAD Model - 3D Render

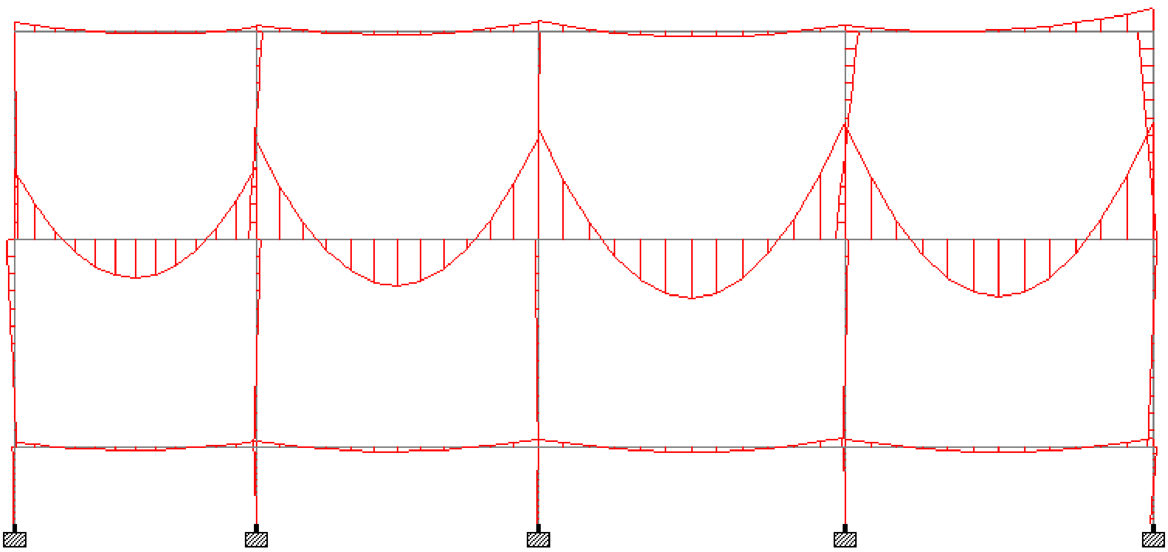

Figure 15: Bending Moment Diagram (BMD) for the Internal Frame (1.5 DL + 1.5 LL)

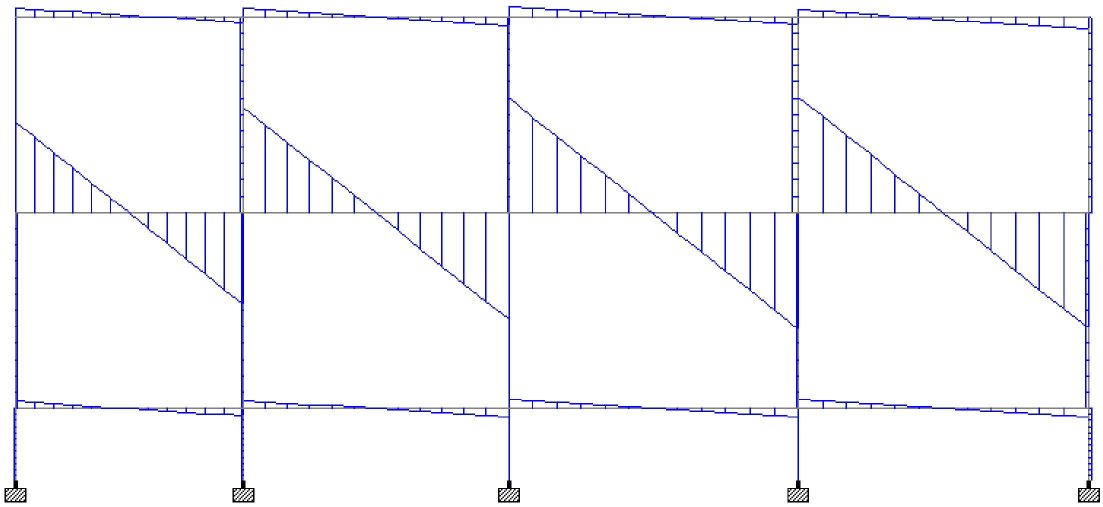

Figure 16: Shear Force Diagram (SFD) for the Internal Frame (1.5 DL + 1.5 LL)

5 Reinforced Concrete Design Phase

Note: The detailed structural design calculations presented in this section are based on the forces and moments extracted from STAAD.Pro model of our structure.

5.1 Design of Continuous Beam (First Floor)

5.1.1 1. Design Data & Properties

- **Span (Center to Center):** 4.73 m
- **Cross Section ($b \times D$):** 230 mm × 230 mm
- **Concrete Grade:** M25 ($f_{ck} = 25$ N/mm^2)
- **Steel Grade:** Fe500 ($f_y = 500$ N/mm^2)
- **Factored Forces:**
  - Max Support Moment ($M_{u,\text{supp}}$): 45.443 kNm (Hogging)
  - Max Span Moment ($M_{u,\text{span}}$): 22.740 kNm (Sagging)
  - Max Shear Force (V_u): 57.150 kN
- **Effective Depth Calculation:**
  - Nominal Cover: 25 mm
  - Stirrup Diameter: 8 mm
  - Main Bar Diameter (Assumed max): 20 mm
  - $d = 230 - 25 - 8 - \frac{20}{2} = \mathbf{187}$ mm

5.1.2 2. Limiting Moment Capacity Check

Determining if the section requires double reinforcement. Limiting Moment ($M_{u,\text{lim}}$) for Fe500:

$$M_{u,\text{lim}} = 0.133 f_{ck} b d^2$$

$$M_{u,\text{lim}} = 0.133 \times 25 \times 230 \times 187^2$$

$$M_{u,\text{lim}} = 26.74 \times 10^6 \text{ Nmm} = \mathbf{26.74} \text{ kNm}$$

Check:

- $M_{u,\text{supp}}(45.44) > M_{u,\text{lim}}(26.74) \Rightarrow$ **Doubly Reinforced Section Required at Support.**
- $M_{u,\text{span}}(22.74) < M_{u,\text{lim}}(26.74) \Rightarrow$ **Singly Reinforced Section Sufficient at Span.**

5.1.3 3. Support Design (Hogging Moment)

Moment: 45.443 kNm (Tension at Top)

A. Excess Moment Calculation

Moment to be resisted by compression steel and additional tension steel:

$$M_{u2} = M_{u,\text{supp}} - M_{u,\text{lim}}$$

$$M_{u2} = 45.443 - 26.74 = \mathbf{18.70} \text{ kNm}$$

B. Tension Reinforcement (A_{st}) - Top

Total $A_{st} = A_{st1} + A_{st2}$

A_{st1} (for $M_{u,\text{lim}}$):

$$A_{st1} = \frac{M_{u,\text{lim}}}{0.87 f_y (d - 0.42 x_{u,\max})} \approx \frac{26.74 \times 10^6}{0.87 \times 500 \times 0.79 \times 187} = \mathbf{416} \text{ mm}^{\mathbf{2}}$$

A_{st2} (for M_{u2}):

Assume effective cover to compression steel $(d') = 40$ mm.

$$A_{st2} = \frac{M_{u2}}{0.87 f_y (d - d')} = \frac{18.70 \times 10^6}{0.87 \times 500 \times (187 - 40)} = \mathbf{292} \text{ mm}^{\mathbf{2}}$$

Total Required A_{st}: $416 + 292 = \mathbf{708}$ $\text{mm}^{\mathbf{2}}$

Provide: 2 Nos. 20mm ϕ + 1 No. 12mm ϕ

Area Provided: $628 + 113 = \mathbf{741}$ $\text{mm}^{\mathbf{2}}$ (Safe).

C. Compression Reinforcement (A_{sc}) - Bottom

Strain Ratio (d'/d): $40/187 = 0.21$

Stress in Steel (f_{sc}): From SP16 for Fe500 at $d'/d = 0.2$, $f_{sc} = 353$ N/mm^2.

Required Area:

$$A_{sc} = \frac{M_{u2}}{f_{sc}(d - d')} = \frac{18.70 \times 10^6}{353 \times 147} = \mathbf{360} \text{ mm}^{\mathbf{2}}$$

Provide: 2 Nos. 16mm ϕ

Area Provided: **402** $\text{mm}^{\mathbf{2}}$ (Safe).

Note: These bars will extend into the span to serve as main tensile reinforcement for the sagging moment.

5.1.4 4. Mid-Span Design (Sagging Moment)

Moment: 22.740 kNm (Tension at Bottom)

Required A_{st}:

Since $M_u < M_{u,\text{lim}}$, use singly reinforced formula (approximate):

$$A_{st} = \frac{M_u}{0.87 f_y (0.9d)} = \frac{22.74 \times 10^6}{0.87 \times 500 \times 0.9 \times 187} = \mathbf{310} \text{ mm}^{\mathbf{2}}$$

Check Minimum Steel (IS 456 Cl 26.5.1.1):

$$A_{st,\min} = \frac{0.85 bd}{f_y} = \frac{0.85 \times 230 \times 187}{500} = 73 \text{ mm}^2$$

(Check Passed)

Provide: 2 Nos. 16mm ϕ (Bottom)

Area Provided: 402 mm^2.

Note: This matches the compression steel required at supports, ensuring continuity.

5.1.5 5. Shear Reinforcement Design

Factored Shear (V_u): 57.150 kN
Nominal Shear Stress (τ_v):

$$\tau_v = \frac{V_u}{bd} = \frac{57150}{230 \times 187} = \mathbf{1.33} \text{ N/mm}^{\mathbf{2}}$$

$\tau_{c,\max}$ for M25 = 3.1 N/mm^2. Since $\tau_v < \tau_{c,\max}$, section size is OK.

Concrete Shear Strength (τ_c):
Percentage of steel at support tension zone (p_t):

$$p_t = \frac{100 A_{st,\text{prov}}}{bd} = \frac{100 \times 741}{230 \times 187} = 1.72\%$$

From IS 456 Table 19 (M25): $\tau_c \approx \mathbf{0.76}$ N/mm$^{\mathbf{2}}$

Shear Reinforcement Calculation:
Since $\tau_v > \tau_c$, shear reinforcement is required.
Shear taken by stirrups (V_{us}):

$$V_{us} = V_u - \tau_c bd = 57150 - (0.76 \times 230 \times 187) = \mathbf{24463} \text{ N}$$

Spacing (s_v) for 2-legged 8mm Stirrups ($A_{sv} = 100$ mm^2):

$$s_v = \frac{0.87 f_y A_{sv} d}{V_{us}} = \frac{0.87 \times 500 \times 100 \times 187}{24463} = 332 \text{ mm}$$

Maximum Spacing Criteria:

- $0.75d = 0.75 \times 187 = \mathbf{140}$ mm
- 300 mm
- Calculated (332 mm)

Adopt: 130 mm c/c (rounded down for safety).

5.1.6 6. Development Length (L_d)

Reference: IS 456 Cl 26.2.1

$$L_d = \frac{\phi \sigma_s}{4 \tau_{bd}}$$

$\sigma_s = 0.87 f_y = 435$ N/mm^2
τ_{bd} (Bond stress for M25) = 1.4 N/mm^2
For Deformed bars (Fe500), increase τ_{bd} by 60%: $\tau_{bd,\text{design}} = 2.24$ N/mm^2

$$L_d = \frac{\phi \times 435}{4 \times 2.24} \approx 48.5\phi$$

- 20mm Bars: $L_d = 48.5 \times 20 = \mathbf{970}$ mm
- 16mm Bars: $L_d = 48.5 \times 16 = \mathbf{776}$ mm
- 12mm Bars: $L_d = 48.5 \times 12 = \mathbf{582}$ mm

5.1.7 7. Deflection Check (Serviceability)

Reference: IS 456 Cl 23.2.1
Basic L/d ratio for continuous beam = 26.
Actual L/d ratio = 4730/187 = **25.29**.
25.29 < 26 ⇒ **Safe against deflection.**

5.1.8 8. Final Schedule of Reinforcement

Location	**Reinforcement**	**Remarks**
Support Top	2-20ϕ + 1-12ϕ	Extend 970 mm into span
Span Bottom	2-16ϕ	Continuous throughout
Support Bottom	2-16ϕ	Same as Span Bottom
Shear Stirrups	8mm ϕ @ 130mm c/c	2-Legged

5.2 Design of Ground Floor Column

5.2.1 1. Design Data & Properties

- **Column Dimensions ($b \times D$):** 230 mm × 230 mm
- **Unsupported Length (L):** 3.20 m = 3200 mm
- **Material Properties:**
  - Concrete Grade (f_{ck}): 25 N/mm^2 (M25)
  - Steel Grade (f_y): 500 N/mm^2 (Fe 500)
- **Loads (Factored):**
  - Axial Load (P_u): 219.363 kN
  - Applied Moment (M_{ux}): 0.515 kNm
  - Applied Moment (M_{uy}): 2.901 kNm

5.2.2 2. Step 1: Slenderness Check

First, we determine if the column is "Short" or "Slender" (Long). Assuming the column is effectively held in position at both ends but not restrained against rotation (hinged-hinged).

$$l_{eff} \approx 1.0 \times L = 3200 \text{ mm}$$

Slenderness Ratio (λ):

$$\lambda = \frac{l_{eff}}{D} = \frac{3200}{230} = 13.91$$

According to IS 456 Cl. 25.1.2: Since $\lambda > 12$, this is a **Slender (Long) Column**. We must calculate additional moments due to deflection.

5.2.3 3. Step 2: Minimum Eccentricity & Design Moments

A. Minimum Eccentricity (e_{min})
According to Cl. 25.4:

$$e_{min} = \frac{L}{500} + \frac{D}{30} = \frac{3200}{500} + \frac{230}{30} = 6.4 + 7.67 = 14.07 \text{ mm}$$

Subject to a minimum of 20 mm. Therefore, $e_{min} = 20$ mm.

B. Moments due to Minimum Eccentricity

$$M_{min} = P_u \times e_{min} = 219.363 \text{ kN} \times 0.020 \text{ m} = 4.387 \text{ kNm}$$

C. Check Governing Initial Moments The code requires we design for the greater of the Applied Moment or M_{min}.

- $M_{ux,applied} = 0.515$ kNm < 4.387 kNm. Use 4.387 kNm.
- $M_{uy,applied} = 2.901$ kNm < 4.387 kNm. Use 4.387 kNm.

D. Additional Moments (Due to Slenderness) Since it is a slender column, we add M_{add} (Cl. 39.7.1):

$$M_{add} = \frac{P_u D}{2000} \left(\frac{l_{eff}}{D} \right)^2$$

$$M_{add} = \frac{219.363 \times 0.230}{2000} \times (13.91)^2$$

$$M_{add} = 0.0252 \times 193.49 = \mathbf{4.88} \text{ kNm}$$

E. Total Design Moments (M_u)

$$M_{ux} = M_{min} + M_{add} = 4.387 + 4.88 = 9.267 \text{ kNm}$$

$$M_{uy} = M_{min} + M_{add} = 4.387 + 4.88 = 9.267 \text{ kNm}$$

Summary of Design Loads: $P_u = 219.363$ kN, $M_{ux} = 9.27$ kNm, $M_{uy} = 9.27$ kNm

5.2.4 4. Step 3: Longitudinal Reinforcement

A. Check Required Steel Percentage
Check non-dimensional parameters to see if Minimum Steel controls. Cover (d') = 40mm (nominal) + 8mm (link) + 6mm (center of bar) $\approx$ 54mm. $d'/D \approx 0.2$.

$$\frac{P_u}{f_{ck} b D} = \frac{219.363 \times 10^3}{25 \times 230 \times 230} = 0.166$$

$$\frac{M_u}{f_{ck} b D^2} = \frac{9.27 \times 10^6}{25 \times 230 \times 230^2} = 0.030$$

These values are very low. Even with minimum steel, the capacity will be much higher than required.

B. Provide Minimum Steel
According to Cl. 26.5.3.1: Minimum steel = 0.8% of Gross Area (A_g).

$$A_{sc,min} = \frac{0.8}{100} \times 230 \times 230 = 423.2 \text{ mm}^2$$

Trial: Provide 4 bars of 12 mm diameter.

$$A_{sc,provided} = 4 \times \frac{\pi}{4}(12)^2 = 4 \times 113 = \mathbf{452}\ \mathrm{mm}^{\mathbf{2}}$$

$$452 > 423.2 \quad \text{(Safe)}$$

Percentage provided $(p) = 0.85\%$

5.2.5 5. Step 4: Check for Biaxial Safety (Cl. 39.6)

We must ensure the section passes the interaction check:

$$\left(\frac{M_{ux}}{M_{ux1}}\right)^{\alpha_n} + \left(\frac{M_{uy}}{M_{uy1}}\right)^{\alpha_n} \leq 1.0$$

A. Calculate P_{uz} (Pure Axial Capacity)

$$P_{uz} = 0.45 f_{ck} A_c + 0.75 f_y A_{sc}$$

$$A_c = 52900 - 452 = 52448\ \mathrm{mm}^2$$

$$P_{uz} = (0.45 \times 25 \times 52448) + (0.75 \times 500 \times 452)$$

$$P_{uz} = 590040 + 169500 = 759540\ \mathrm{N} = \mathbf{759.54}\ \mathrm{kN}$$

B. Calculate α_n exponent Ratio $\frac{P_u}{P_{uz}} = \frac{219.363}{759.54} = 0.288$. Since the ratio is between 0.2 and 0.8:

$$\alpha_n = 1.0 + \frac{0.288 - 0.2}{0.8 - 0.2}(2.0 - 1.0) = 1.0 + \frac{0.088}{0.6} = \mathbf{1.15}$$

C. Determine Uniaxial Moment Capacity (M_{u1}) Using SP:16 Charts (Chart 44 for Fe 500, d'/D=0.2): $P_u/f_{ck}bD = 0.166$, $p/f_{ck} = 0.85/25 = 0.034$. From chart: $\frac{M_{u1}}{f_{ck}bD^2} \approx 0.09$.

$$M_{ux1} = M_{uy1} = 0.09 \times 25 \times 230 \times 230^2 = 27.38\ \mathrm{kNm}$$

D. Interaction Check

$$\left(\frac{9.27}{27.38}\right)^{1.15} + \left(\frac{9.27}{27.38}\right)^{1.15}$$

$$(0.338)^{1.15} + (0.338)^{1.15} = 0.286 + 0.286 = \mathbf{0.572} \leq 1.0$$

Result: The section is SAFE in biaxial bending.

5.2.6 6. Step 5: Transverse Reinforcement (Lateral Ties)

A. Diameter of Links (Cl. 26.5.3.2)

Greater of: $\frac{1}{4} \times 12 = 3$ mm or 6 mm. Use **8 mm** diameter ties.

B. Pitch (Spacing) of Links

Least of:

1. Least Lateral Dimension = 230 mm
2. 16 × Smallest Long. Bar = 16 × 12 = 192 mm
3. 300 mm

Result: Provide 8 mm ϕ ties @ 190 mm c/c.

5.3 Design of Slab Panel (First Floor)

5.3.1 1. Design Constants & Parameters

- Concrete: M25 ($f_{ck} = 25$ N/mm^2)
- Steel: Fe415 ($f_y = 415$ N/mm^2)
- Unit Weight of Concrete: 25 kN/m^3
- **Dimensions (Center to Center):**
  - $L_x = 4.73$ m (Shorter Span)
  - $L_y = 4.83$ m (Longer Span)
- **Aspect Ratio:**

$$r = \frac{L_y}{L_x} = \frac{4.83}{4.73} = 1.02$$

  Since $\frac{L_y}{L_x} < 2$, it is designed as a **Two-Way Slab**.

5.3.2 2. Depth & Effective Span

- Overall Depth (D): 150 mm
- Nominal Cover: 20 mm (Mild Exposure)
- Assumed Bar Diameter (ϕ): 10 mm
- **Effective Depth (d):**
  - Short Span (d_x): $D - \text{Cover} - \frac{\phi}{2} = 150 - 20 - 5 = \mathbf{125}$ mm
  - Long Span (d_y): $d_x - \phi = 125 - 10 = \mathbf{115}$ mm

5.3.3 3. Load Calculations

- **Dead Load (DL):**
  - Self Weight: $0.150 \times 25 = 3.75$ kN/m^2
  - Floor Finish: 1.00 kN/m^2
  - Total DL: 4.75 kN/m^2
- **Live Load (LL):** 2.50 kN/m^2
- **Total Design Load (w_u):**

$$w_u = 1.5 \times (4.75 + 2.50) = 1.5 \times 7.25 = \mathbf{10.875}\ \text{kN/m}^{\mathbf{2}}$$

5.3.4 4. Bending Moments (IS 456 Table 26)

Condition: Two Adjacent Edges Discontinuous (Case 4). Ratio = 1.02.

- Short Span Neg. (α_x^-): 0.0482
- Short Span Pos. (α_x^+): 0.0360
- Long Span Neg. (α_y^-): 0.0470
- Long Span Pos. (α_y^+): 0.0350

Constant Factor $(K) = 10.875 \times 4.73^2 = 243.29$
Moments:

- $M_{u,x}$ (Negative - Support): $0.0482 \times 243.29 = \mathbf{11.73}$ kNm
- $M_{u,x}$ (Positive - Midspan): $0.0360 \times 243.29 = \mathbf{8.76}$ kNm
- $M_{u,y}$ (Negative - Support): $0.0470 \times 243.29 = \mathbf{11.43}$ kNm
- $M_{u,y}$ (Positive - Midspan): $0.0350 \times 243.29 = \mathbf{8.51}$ kNm

5.3.5 5. Check for Effective Depth

Check required depth for $M_{u,max} = 11.73$ kNm.

$$M_{u,lim} = 0.138 f_{ck} b d^2$$
$$11.73 \times 10^6 = 0.138 \times 25 \times 1000 \times d_{req}^2$$
$$d_{req} = 58.3 \text{ mm}$$

Check: $d_{provided}(125 \text{ mm}) > d_{req}(58.3 \text{ mm}) \Rightarrow$ **SAFE**.

5.3.6 6. Reinforcement Design

Minimum Steel: $A_{st,min} = 0.12\%$ of $bD = 180$ mm^2.
Formula: $A_{st} \approx \frac{M_u}{0.87 f_y (0.9d)}$

A. Short Span Reinforcement (Along 4.73m)

- **Continuous Edge (Top):** $M_u = 11.73$ kNm

$$A_{st} = 289 \text{ mm}^2 \Rightarrow \text{Provide: 10mm } \phi \text{ @ 270 mm c/c}$$

- **Mid-Span (Bottom):** $M_u = 8.76$ kNm

$$A_{st} = 216 \text{ mm}^2 \Rightarrow \text{Provide: 8mm } \phi \text{ @ 230 mm c/c}$$

B. Long Span Reinforcement (Along 4.83m) (Use $d = 115$mm)

- **Continuous Edge (Top):** $M_u = 11.43$ kNm

$$A_{st} = 305 \text{ mm}^2 \Rightarrow \text{Provide: 10mm } \phi \text{ @ 250 mm c/c}$$

- **Mid-Span (Bottom):** $M_u = 8.51$ kNm

$$A_{st} = 227 \text{ mm}^2 \Rightarrow \text{Provide: 8mm } \phi \text{ @ 220 mm c/c}$$

5.3.7 7. Check for Shear

Max Shear (V_u): $0.5 \times w_u \times L_x = 25.72$ kN.

$$\tau_v = \frac{25.72 \times 1000}{1000 \times 125} = \mathbf{0.21} \text{ N/mm}^{\mathbf{2}}$$

Permissible Shear (τ_c): M25, low steel % + Slab Factor 1.3 = 0.39 N/mm^2. Result: $\tau_v < \tau_c \Rightarrow$ **Shear is SAFE**.

5.3.8 8. Check for Deflection

Actual $L/d = 4730/125 = 37.8$. Allowable = Basic (26) $\times k_t(1.6) = 41.6$. Result: $37.8 < 41.6 \Rightarrow$ **Deflection is SAFE**.

5.3.9 9. Torsion Reinforcement (Corners)

Mesh Size: $L_x/5 = 950$ mm.

- **Discontinuous Corner:** Provide 4 layers. Area = $0.75A_{st,max} = 162$ mm^2. Provide 8mm ϕ @ 200 mm c/c mesh.
- **Other Corners:** Provide minimum mesh 8mm ϕ @ 200 mm c/c.

5.3.10 10. Final Summary of Slab Design

Component	**Details**
Slab Thickness	150 mm (M25 / Fe415)
Short Span (Bottom)	8mm @ 230 mm c/c
Short Span (Top @ Support)	10mm @ 270 mm c/c
Long Span (Bottom)	8mm @ 220 mm c/c
Long Span (Top @ Support)	10mm @ 250 mm c/c
Corner Mesh	8mm @ 200 mm c/c (950x950mm)

6 Reinforcement Detailed Drawings

Note: The reinforcement details of the beam and column are generated based on the design of the structural elements using RCDC Software.

6.1 Beam Reinforcement Details

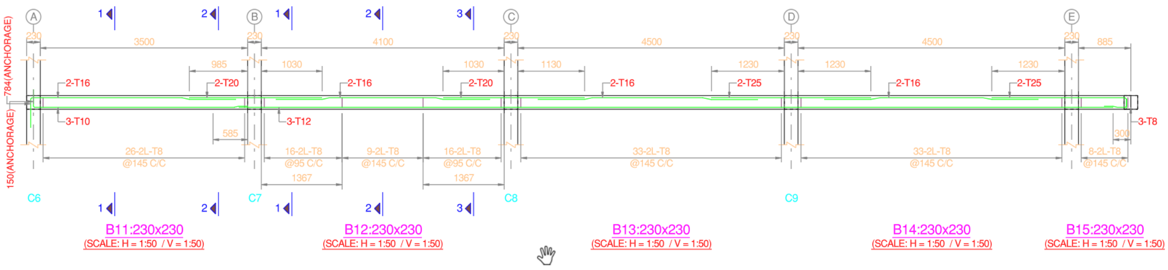

Figure 17: Beam Elevation

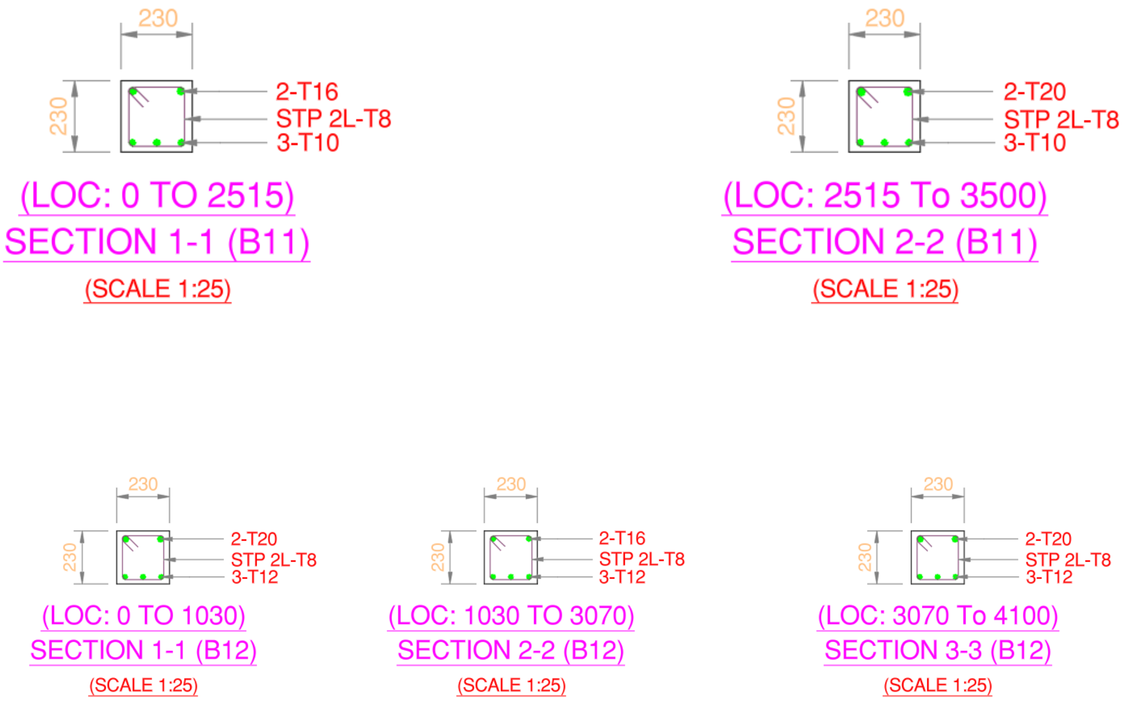

Figure 18: Beam Cross Sections

6.2 Column Reinforcement Details

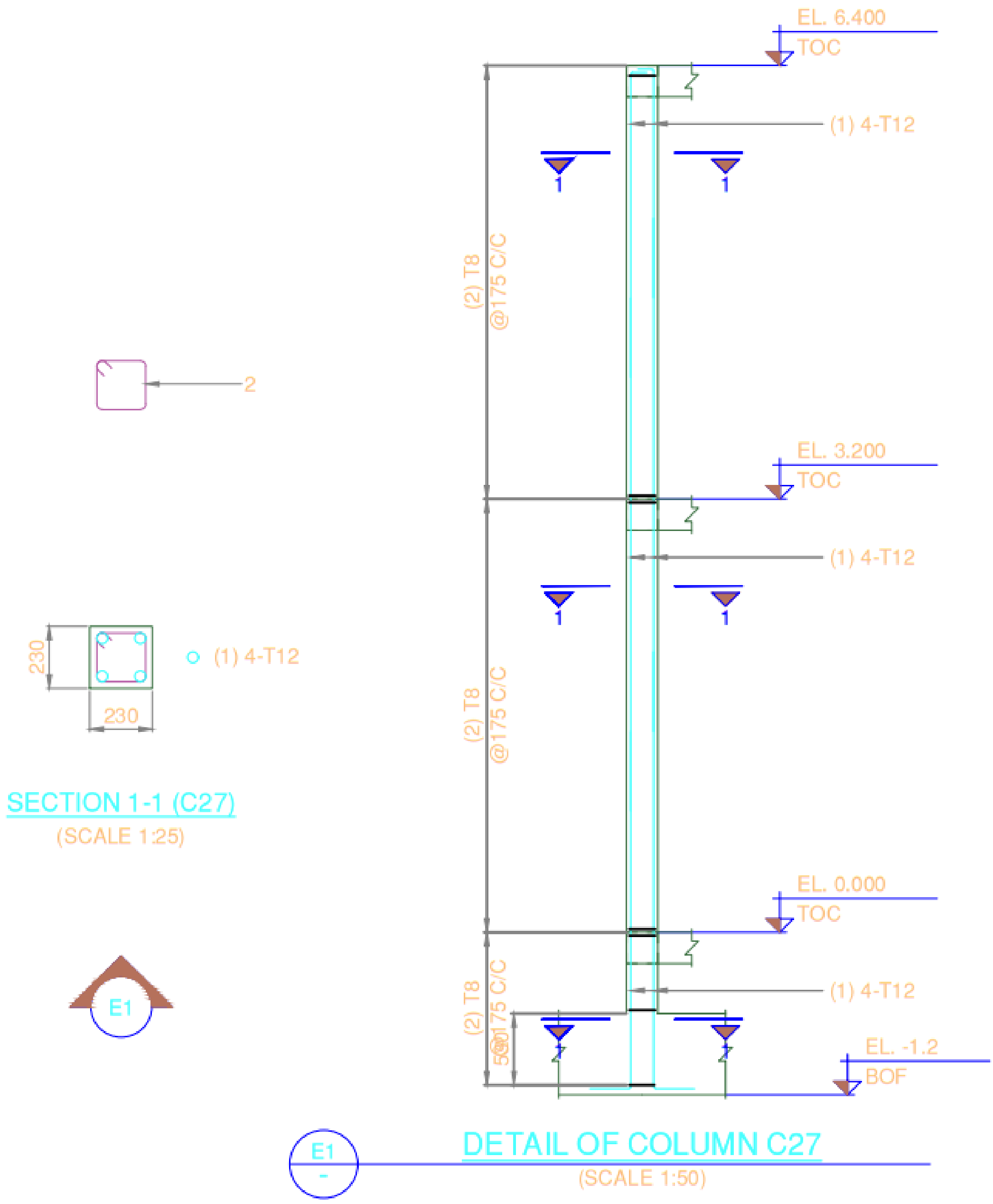

Figure 19: Columnn Elevation and Cross Section

6.3 Slab Reinforcement Details

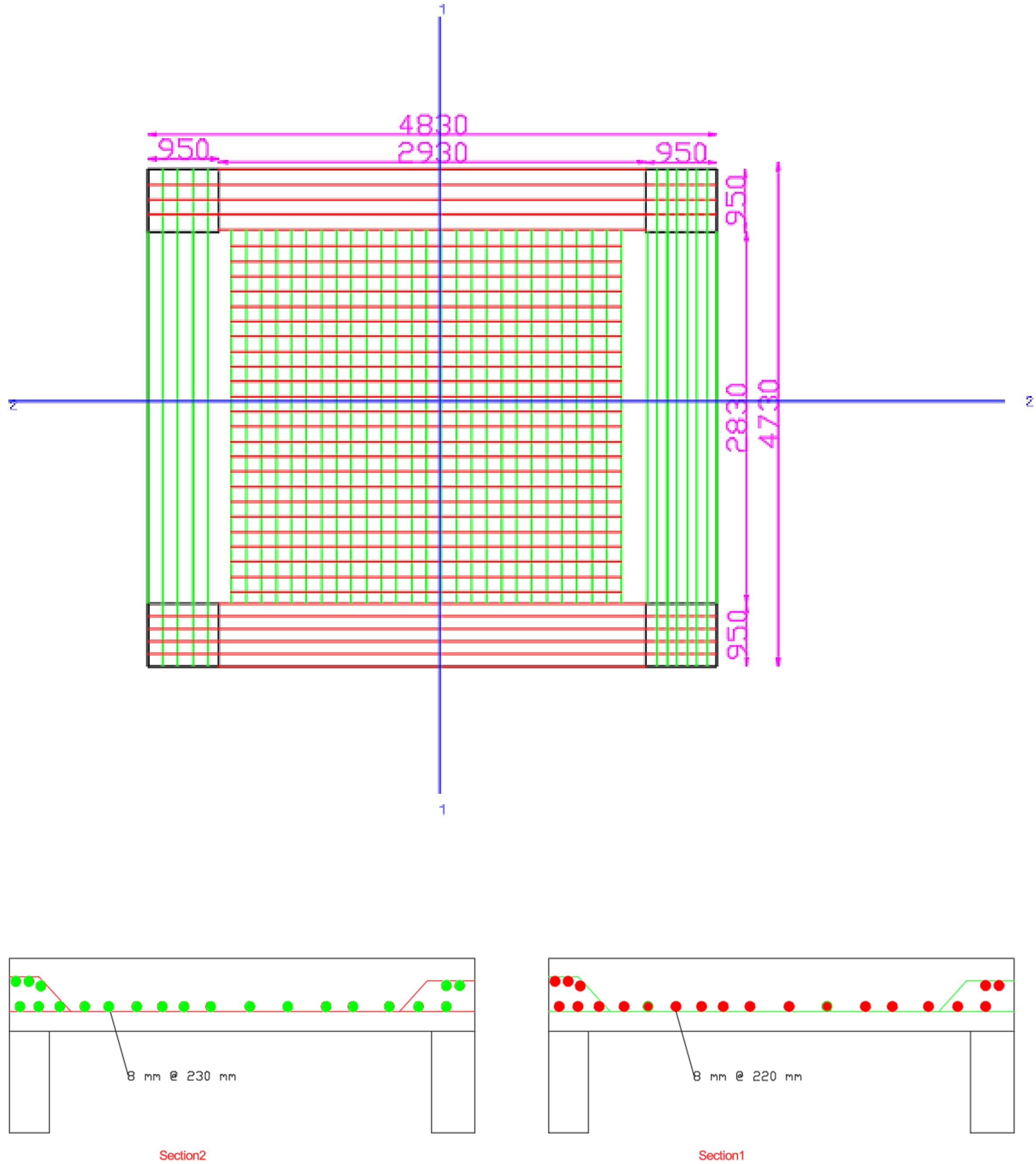

Figure 20: Slab Reinforcement Diagrams

7 Conclusion

The G+1 residential building was successfully designed using M25 concrete and Fe500/415 steel.

- The critical continuous beam required a doubly reinforced section at the supports due to high hogging moments.
- The columns were identified as slender due to their length-to-depth ratio and were designed for additional moments.
- The slab acted as a two-way slab and was safe in deflection and shear without shear reinforcement.

The design ensures safety, serviceability, and economy adhering to IS 456:2000 and SP:16.

8 Key Insights and Learnings

This project served as a comprehensive exercise in bridging the gap between theoretical structural engineering concepts and practical application. Through the design of the G+1 residential building, the group gained significant insights into the following areas:

- **The Language of Civil Engineering:** This course emphasized that drawings are the universal language of construction. We learned that precision in drafting—correct line weights, standard symbols, and clear dimensioning—is as critical as the design calculation itself to ensure errors are avoided during site execution.
- **Translation of Theory to Practice:** While theoretical courses taught us *how* to calculate reinforcement, this subject taught us *where* and *how* to place it. We gained a practical understanding of concepts like curtailment, development length, and cranking of bars, which are essential for monolithic structural behavior.
- **Holistic Design Workflow:** The subject provided a complete overview of the project lifecycle. We learned how to navigate the iterative process of moving from an Architectural Plan to a Structural General Arrangement (GA), and finally to detailed structural analysis and design.
- **Navigating Indian Standards (IS Codes):** We developed proficiency in using IS 456:2000, IS 875, and SP:16. We learned that these codes are not just rulebooks but frameworks for safety, teaching us how to balance economy with safety requirements in real-world scenarios.
- **Visualization of Load Paths:** Creating the structural drawings helped us visualize how loads transfer from slabs to beams, beams to columns, and finally to the foundation. This visualization is crucial for intuition in structural engineering, preventing major conceptual errors in design.
- **The Role of Computer-Aided Design:** By combining manual calculations with software tools (like STAAD.Pro), we learned that while software ensures speed and handles complexity, manual design checks are indispensable for verifying accuracy and maintaining engineering control over the structure.

8.1 Contribution of Group Members

The successful completion of this project was a collaborative effort, with tasks distributed to leverage individual strengths. The specific contributions are detailed below:

Roll No.	Name	Key Contributions & Responsibilities
B23065	**Aman Raj Verma**	**Structural Design Lead** • Performed detailed manual design calculations for Beams, Columns, and Slabs. • Verified structural safety checks (Deflection, Shear, and Bond). • Compiled the Design Calculation Sheets.
B23059	Abhinav Singh	**Architectural Planning & Modeling** • Developed the Architectural Plans, Elevations, and Sections. • Created the initial 3D model in STAAD.Pro. • Prepared the Building Line Plan.
B23102	Sumit Yadav	**Structural Analysis & Detailing** • Executed the Structural Analysis (Load combinations and Force extraction). • Drafted the Structural General Arrangement (GA) drawings. • Prepared final Reinforcement Detailing drawings.

Table 1: Distribution of Work Responsibilities

9 References

1. IS 456:2000 - Plain and Reinforced Concrete - Code of Practice.
2. SP 16:1980 - Design Aids for Reinforced Concrete to IS 456.
3. IS 875 (Parts 1 & 2) - Code of Practice for Design Loads.
4. SP 34 - Handbook on Concrete Reinforcement and Detailing.