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Planning, Analysis and Design of G+2 Residential Building Using STAAD.Pro (V8i)

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Abstract - This study presents a preliminary structural design of a ground-plus-two-storey reinforced concrete residential building by combining three-dimensional modelling in STAAD.Pro V8i with manual limit-state design. One-way and two-way slabs, a T-beam, columns under uniaxial and biaxial bending, an isolated footing, and a dog-legged staircase were assessed under factored gravity loads using IS 456:2000. The member calculations adopted M25 concrete and reinforcement with a nominal yield strength of 500 MPa. Minimum reinforcement governed the one-way slab, for which 201 mm²/m was provided against a minimum of 150 mm²/m. The two-way slab had a calculated shear stress of 0.14 MPa and a span-to-effective-depth ratio of 27.9, compared with the reported limits of 0.37 MPa and 32, respectively. The representative beam had a calculated factored bending moment of 123.9 kN·m and a shear force of 117.2 kN. For the 1.50 m square isolated footing, the service bearing pressure due to the column load alone was 186.7 kPa against an assumed allowable bearing pressure of 200 kPa. The results document the preliminary gravity-load design of selected members. Building-level assessment requires verification of the biaxial column interaction, reconciliation of the footing depth and shear calculations, and evaluation of the seismic response of the three-dimensional model

Key Words: Reinforced cement concrete, G+2 residential building, STAAD.Pro V8i, structural analysis, slab design, column design, isolated footing

1. INTRODUCTION

he structural design of low-rise reinforced concrete (RC) residential buildings links the analysis of the structural system to the design of its individual members. Under gravity loading, floor and wall loads are transferred through slabs and beams to columns and foundations. A three-dimensional frame model represents these load paths and provides estimates of member forces, support reactions, and displacements. These estimates depend on how member stiffness, slab load transfer, and support restraints are represented. For RC columns subjected to lateral loading, Elwood and Eberhard (2009) showed that accounting for anchorage slip, in addition to flexural and shear deformations, improved estimates of effective stiffness. Their findings illustrate how modelling assumptions can influence the interpretation of structural response.

Previous case studies have used computer-based analysis to support the design of low-rise residential buildings. Naidu et al. (2024) integrated architectural drafting in AutoCAD with STAAD.Pro analysis and quantity estimation for a ground-plus-two-storey (G+2) building. Mabula et al. (2023) compared manual and STAAD.Pro calculations for a residential building of the same height. These studies illustrate two applications of numerical modelling in residential design. A related issue is the traceability of member-design decisions. To reproduce a reinforcement calculation, the reader needs the adopted geometry, load combination, design action, and governing limit-state criterion.

This study documents the preliminary gravity-load design of a G+2 RC residential building. The architectural layout was developed in AutoCAD, and a three-dimensional structural model was created in STAAD.Pro V8i. Manual limit-state calculations followed IS 456:2000 (Bureau of Indian Standards, 2000) for representative one-way and two-way slabs, a T-beam, columns under uniaxial and biaxial bending, an isolated footing, and a dog-legged staircase. The assessment reports the adopted loads and factored design actions, compares required and provided reinforcement, and presents selected shear and span-to-effective-depth checks.

The contribution of the case study is a documented design basis for the selected members that allows individual calculations to be reviewed and reproduced. The assessment also identifies two issues that affect interpretation of the results. The limiting moments used in the biaxial column interaction require independent verification, and the adopted footing depth must be reconciled with the effective depth used in the shear calculation. Although seismic loading was defined in the model, the reported results address gravity-load design. Building-level seismic assessment requires documented lateral response and verification of the governing load combinations.

2. LITERATURE REVIEW

Mehta et al. (2016) investigated the optimisation of structural member sizes and materials in multi-storey residential buildings. The study showed that changing structural member dimensions affects the quantity of construction materials and hence the overall structural cost. Optimisation of member sizes can therefore contribute to economical structural design while satisfying all safety requirements.

Wadekar and Dahake (2020) studied the analysis and design of multi-storey buildings using STAAD.Pro. Their methodology involved structural planning, manual load calculations, and subsequent analysis using STAAD.Pro. Dead, imposed, and wind loads were considered along with appropriate load combinations. The study highlighted that STAAD.Pro can efficiently obtain structural responses such as shear force, bending moment, and torsion.

Sravan Kumar et al. (2024) investigated the analysis and design of a G+2 residential building using STAAD.Pro. The

study considered dead and live loads and obtained the design of beams, columns, and slabs using the software, demonstrating the practical application of STAAD.Pro for low-rise residential building analysis and design.

Meshram et al. (2026) examined the use of STAAD.Pro for low-rise residential RCC structures in a recent review. Previous studies reviewed in the work considered gravity, wind and earthquake loads according to Indian Standards and evaluated bending moments, shear forces, axial forces, storey displacement and deflection. The review concluded that software-based structural analysis can improve analysis efficiency and assist in material-use assessment. Related comparison studies also show that software output depends on geometry, support conditions, stiffness assumptions, load distribution and load combinations; therefore, it should be checked against independent calculations wherever possible.

Naidu et al. (2024) integrated architectural planning, structural design and estimation for a G+2 residential building using AutoCAD and STAAD.Pro. **Mabula et al. (2023)** compared manual and software-based analysis using responses such as support reactions, deflections, axial forces, shear forces and bending moments. **Khandelwal et al. (2021)** similarly highlighted the importance of comparing manual procedures with STAAD.Pro results. These studies support the present paper's emphasis on traceable assumptions and independent member-level checks rather than accepting software output without model verification.

3. OBJECTIVES

1. To model and analyse a G+2 residential building using STAAD.Pro (V8i).
2. To evaluate the structural behaviour of beams, columns, and slabs under dead, live, and seismic loads.
3. To design structural members that satisfy the flexure, shear, and serviceability requirements of IS 456:2000.
4. To optimise member sizes and reinforcement for a safe and economical structure.

4. SCOPE AND DESIGN BASIS

The building considered is a ground-plus-two-storey residential RCC frame with a nominal floor-to-floor height of 3.00 m. The project workflow covers architectural planning, AutoCAD drawing preparation, three-dimensional STAAD.Pro modelling, manual design of selected members and preparation of a consolidated design record. The principal dimensions used in the project calculations include a 3.23 × 6.40 m two-way slab panel, a 1.067 × 3.048 m one-way slab panel, a 4.00 m clear-span beam, a 400 × 450 mm column and a 1.50 m square isolated footing.

M25 concrete and Fe500 reinforcement are adopted for the principal member calculations, with Fe500D specified in the staircase calculation. The concrete unit weight is 25 kN/m³. Residential floor live load is taken as 2.0 kN/m², staircase live load as 3.0 kN/m², floor finish as 1.0 kN/m² and one-way-slab waterproofing as 0.5 kN/m². A service safe bearing capacity of 200 kN/m² is used for the preliminary footing sizing. These values reproduce the project basis and must be confirmed against the final drawings, occupancy, site investigation and applicable standard editions.

5. METHODOLOGY

The project followed a systematic workflow beginning with a review of relevant literature and national codes (NBC, IS 456:2000, IS 875, IS 1893). Architectural planning and drawing were carried out using AutoCAD to produce floor plans, column layout, and sectional details. The structural model was then developed in STAAD.Pro and analysed for the applicable load cases. Finally, individual members were designed manually using IS 456:2000 and SP 16 design aids, and a comprehensive project report was prepared.

Methodology flowchart:

Literature Review
↓
Planning (NBC)
↓
Drawing (AutoCAD)
↓
Analysis (STAAD.Pro)
↓
Design of Members
↓
Project Report

6. STRUCTURAL PLANNING AND DRAWING

6.1 Floor Plans

The building comprises a ground floor, first floor, and second floor with identical column grids. Figures 1 to 3 show the ground, first and second floor plans produced in AutoCAD. The column centre-to-centre distances govern the effective spans used in member design.

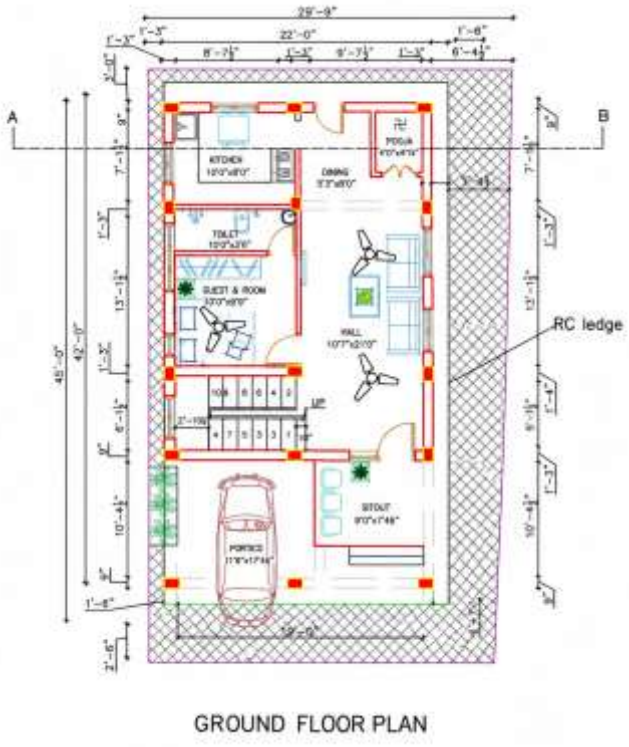


Fig. 1: Ground Floor Plan (dimensions shown in architectural feet-inches notation)

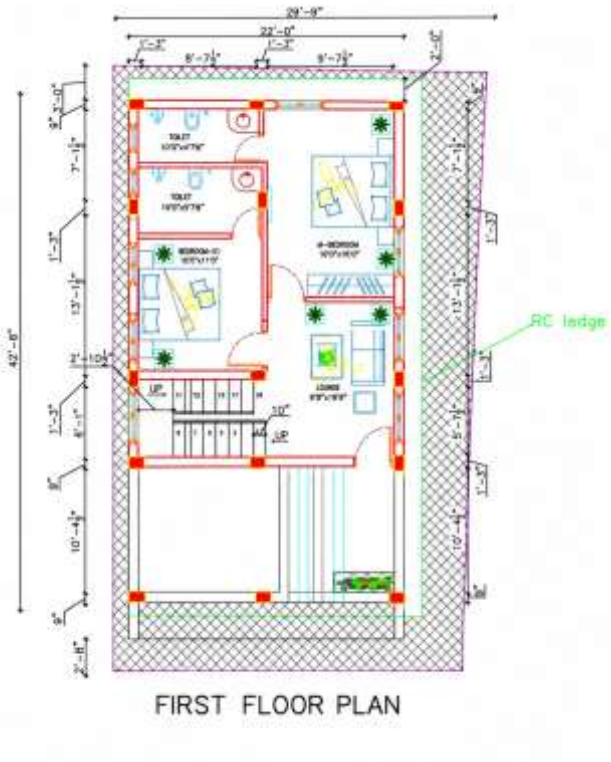


Fig. 2: First Floor Plan (dimensions shown in architectural feet-inches notation)

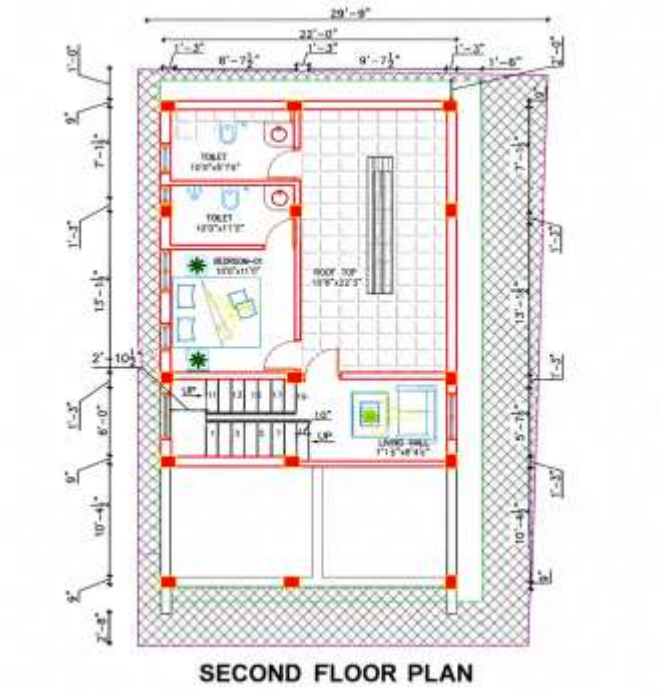


Fig. 3: Second Floor Plan (dimensions shown in architectural feet-inches notation)

6.2 Column and Footing Layout

Column positions were fixed based on architectural requirements and structural continuity. Figure 4 shows the column marking plan and Figure 5 shows the footing marking plan. The sectional plan is presented in Figure 6.

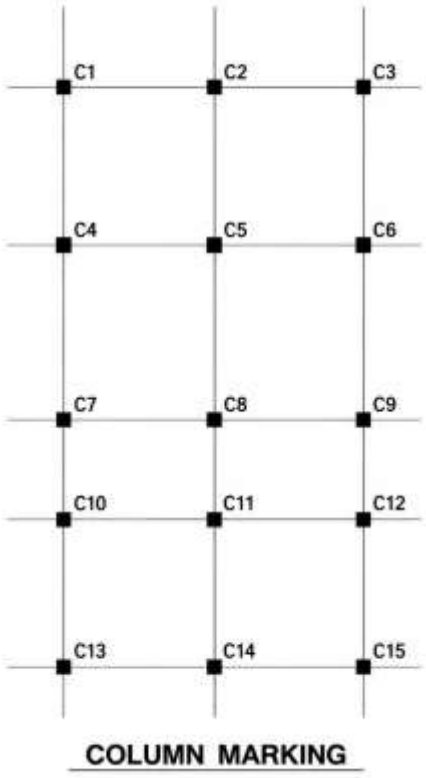


Fig. 4: Column Marking Plan

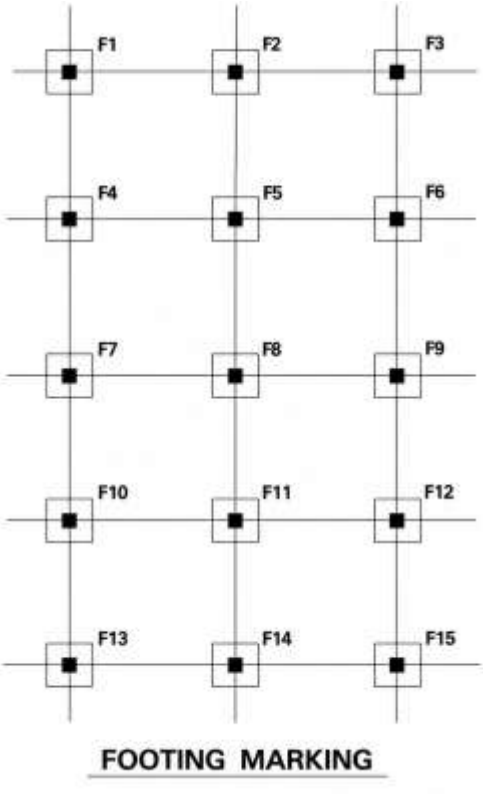


Fig. 5: Footing Marking Plan

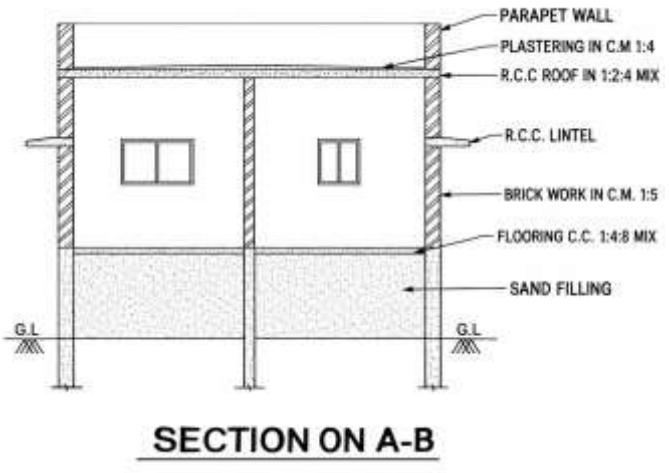


Fig. 6: Sectional Plan

7. STRUCTURAL ANALYSIS USING STAAD.PRO

7.1 Project Description and Design Basis

The study considers a three-storey residential RCC frame comprising a ground floor and two upper floors, with a nominal floor-to-floor height of 3.00 m. The planning and design workflow follows five stages: review of literature and applicable codes, architectural and structural drawing preparation in AutoCAD, three-dimensional modelling and analysis in STAAD.Pro, manual design of slabs, beams, columns, footing and staircase, and preparation of the project report. The principal design dimensions adopted from the project drawings are a 3.23 × 6.40 m slab panel, a 1.067 × 3.048 m one-way slab panel, and a 4.00 m clear-span beam. A 1.50 m square isolated footing is proportioned for the representative 400 × 450 mm column.

The design uses M25 concrete (f_{ck} = 25 N/mm², unit weight 25 kN/m³) and Fe500D reinforcement (f_y = 500 N/mm²). Residential floor live load is taken as 2.0 kN/m², staircase live load as 3.0 kN/m², floor finish as 1.0 kN/m², and waterproofing on the one-way slab as 0.5 kN/m². The isolated footing is checked for a service safe bearing capacity of 200 kN/m². These assumptions provide a consistent basis for comparing software actions with the subsequent code-based member calculations.

7.2 Structural Model

The three-dimensional frame was modelled in STAAD.Pro (V8i) with beam and column members, slab and support idealisations, and foundation-level support conditions representing the adopted structural scheme. Material properties correspond to M25 concrete and Fe500D steel. Figures 7 and 8 show the isometric and rendered views of the STAAD.Pro model.

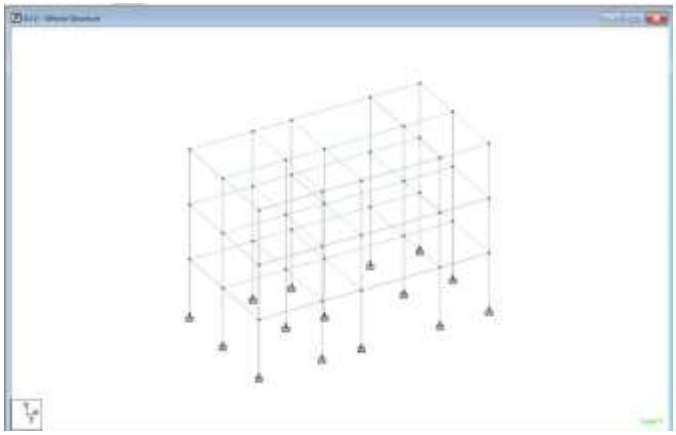


Fig. 7: Isometric view of STAAD.Pro model



Fig. 8: Rendered view of structural model

7.3 Load Cases

Three primary load cases were considered:

1. Dead Load (DL) - self-weight of structural members plus superimposed dead load (floor finish, wall loads). Figure 9 shows the total dead load diagram.
2. Live Load (LL) - 2.0 kN/m² for residential floors per IS 875 (Part 2). Figure 10 shows the total live load diagram.
3. Seismic Load (EQ) - as per IS 1893 (Part 1):2016.

The principal ultimate gravity-load combination used in the manual checks is 1.5(DL + LL). Seismic effects are defined separately in accordance with IS 1893 (Part 1):2016; the final seismic member actions and storey-response checks should be confirmed from the completed STAAD.Pro analysis before construction.

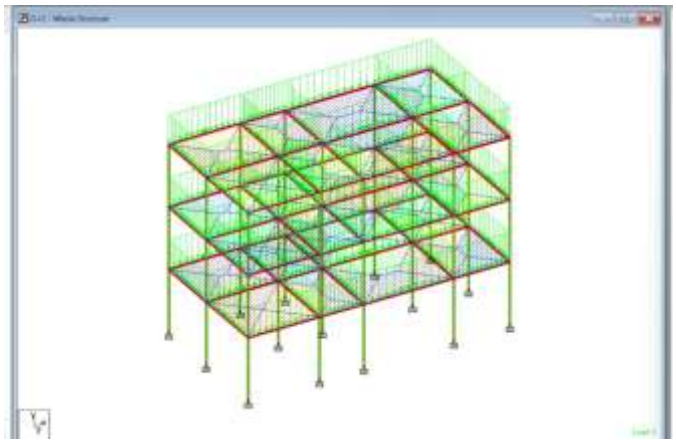


Fig. 9: Total dead load on structural model

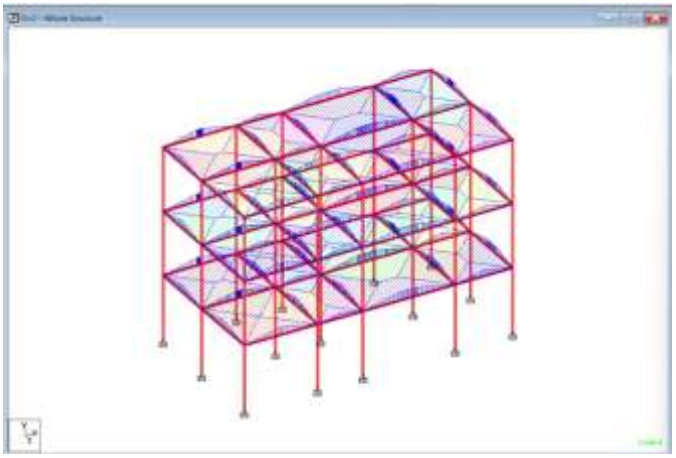


Fig. 10: Total live load on structural model

8. DESIGN OF STRUCTURAL MEMBERS

All members are designed using the Limit State Method of IS 456:2000. Material grades adopted throughout: f_{ck} = 25 N/mm² (M25), f_y = 500 N/mm² (Fe500D).

8.1 Design of Two-Way Slab

Design Data:

Short span, lx = 3.23 m
Long span, ly = 6.40 m
Wall thickness = 0.22 m
Live load = 2.0 kN/m²
Floor finish = 1.0 kN/m²

Classification:

$l_y/l_x = 6.40/3.23 = 1.98 < 2 \Rightarrow$ Two-way slab

Depth:

d_{min} = span/35 = 3230/35 = 92 mm
Provided D = 150 mm; clear cover = 25 mm;
bar dia = 10 mm.
d = 150 - 25 - 10/2 = 120 mm

Effective Span:

lx = min(3.23 + 0.22, 3.23 + 0.12) = 3.35 m

Loading:

Self-weight = 1.0 × 0.150 × 25 = 3.75 kN/m²
W = 3.75 + 2.00 + 1.00 = 6.75 kN/m²
W_u = 6.75 × 1.5 = 10.13 kN/m²

Bending Moments (IS 456 Annex D):

Moment coefficients are taken from IS 456:2000 Annex D, Table 26, Case 9 (all four edges discontinuous), at ly/lx = 2.0.

$M_{ux} = \alpha_x \times W_u \times l_x^2 = 0.118 \times 10.13 \times 3.35^2 = 13.41$ kNm

$M_{uy} = \alpha_y \times W_u \times l_x^2 = 0.030 \times 10.13 \times 3.35^2 = 3.41$ kNm

Check for Depth:

$d_{req} = \sqrt{(M_u / (0.138 \times f_{ck} \times b))} = \sqrt{(13.41 \times 10^6 / (0.138 \times 25 \times 1000))} = 62.35$ mm

d_{prov} = 120 mm > 62.35 mm ✓

Main Reinforcement:

Using the quadratic relationship of IS 456 Cl. G-1.1:

$M_u = 0.87 f_y A_{st} d [1 - (A_{st} f_y) / (b d f_{ck})]$

A_{st} = 269 mm²/m

$s = (a_{st} / A_{st}) \times 1000 = (78.54 / 269) \times 1000 = 292$ mm

Provide 10 mm dia @ 250 mm c/c.

Check for Shear:

$V_u = W_u l_x / 2 = 10.13 \times 3.35 / 2 = 16.97$ kN

$\tau_v = V_u / (b d) = 16.97 \times 10^3 / (1000 \times 120) = 0.14$ N/mm²

$p_t = 100 A_{st} / (b d) = 100 \times 314 / (1000 \times 120) = 0.26\% \Rightarrow \tau_c = 0.37$ N/mm²

$\tau_v = 0.14 < \tau_c = 0.37$ N/mm² ✓

Check for Deflection:

$f_s = 0.58 \times 500 \times 269/314 = 248$ N/mm²

$K_t = 1.6$, $K_c = 1$, $K_f = 1$

$(l/d)_{max} = 20 \times 1.6 = 32$

$(l/d)_{actual} = 3350/120 = 27.92 < 32$ ✓

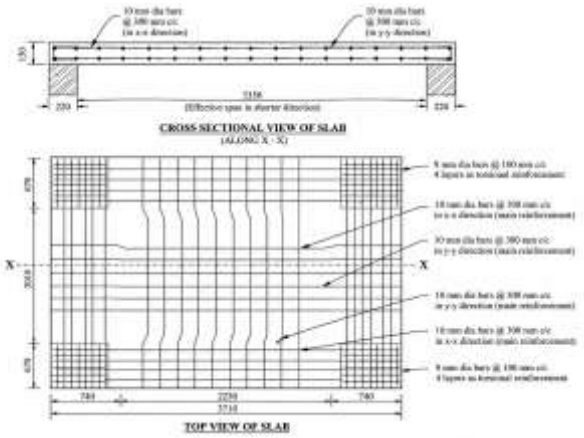


Fig. 11: Reinforcement details - Two-way slab

8.2 Design of One-Way Slab

Design Data:

Short span, Lx = 1.067 m
Long span, Ly = 3.048 m
Live load = 2.0 kN/m²
Floor finish = 1.0 kN/m²
Waterproofing = 0.5 kN/m²

Classification:

$L_y/L_x = 3.048/1.067 = 2.86 > 2 \Rightarrow$ One-way slab

Depth:

D = Lx/35 = 1067/35 = 30.5 mm ⇒ Provided D = 125 mm
d = 125 - 15 - 8/2 = 106 mm

Loading:

W = 3.125 + 2.00 + 1.00 + 0.50 = 6.625 kN/m²
W_u = 1.5 × 6.625 = 9.94 kN/m²

Effective span l = 1.173 m.

Design Bending Moment:

$M_u = W_u l^2 / 8 = 9.94 \times 1.173^2 / 8 = 1.71$ kNm/m

Check for Depth:

$d_{req} = \sqrt{(1.71 \times 10^6 / (0.138 \times 25 \times 1000))} = 22.2$ mm < 106 mm ✓

Reinforcement:

Required A_{st} = 37.3 mm²/m; minimum A_{st} = 0.12% × 1000 × 125 = 150 mm²/m (governs).

Provided 8 mm dia @ 250 mm c/c ($A_{st,prov}$ = 201 mm²/m > 150 mm²/m ✓).

Shear:

$\tau_v = 5.83 \times 10^3 / (1000 \times 106) = 0.055$ N/mm² < τ_c ✓

Deflection:

(l/d)actual = 1173/106 = 11.07 < 20 ✓

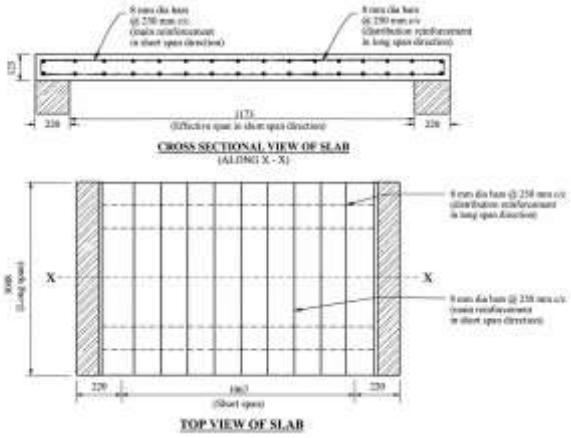


Fig. 12: Reinforcement details - One-way slab

8.3 Design of Beam

Design Data:

Clear span = 4.0 m
bw = 230 mm
D = 500 mm, d = 460 mm
Effective span = min(4.0 + 0.23, 4.0 + 0.46) = 4.23 m.

Loading:

Load from slab = 6.75 × 3.0 = 20.25 kN/m
Beam self-weight = 0.23 × 0.50 × 25 = 2.88 kN/m
Wall load = 0.23 × 3.0 × 20 = 13.80 kN/m
W = 36.93 kN/m; W_u = 55.40 kN/m

Bending Moment and Shear Force:

$M_u = W_u l^2 / 8 = 55.40 \times 4.23^2 / 8 = 123.91$ kNm

$V_u = W_u l / 2 = 55.40 \times 4.23 / 2 = 117.17$ kN

Check for Depth:

$d_{req} = \sqrt{(123.91 \times 10^6 / (0.138 \times 25 \times 230))} = 395.2$ mm < 460 mm ✓

Effective Flange Width (T-beam):

$b_f = l/6 + b_w + 6D_f = 4230/6 + 230 + 6(150) = 1835$ mm

$d_{req} = \sqrt{(123.91 \times 10^6 / (0.138 \times 25 \times 1835))} = 139.9$ mm < 460 mm ✓

Area of Reinforcement:

A_{st} = 629 mm² ⇒ Provided 2-32 mm dia bars (A_{st} = 1608.5 mm²)

Shear Design:

$\tau_v = 117.17 \times 10^3 / (230 \times 460) = 1.11$ N/mm²

$p_t = 100 \times 1608.5 / (230 \times 460) = 1.52\%$ ⇒ $\tau_c = 0.74$ N/mm²

$V_{us} = V_u - \tau_c b_w d = 117.17 - 78.29 = 38.88$ kN

$s_v = 0.87 f_y A_{sv} d / V_{us} = 0.87 \times 500 \times 100.53 \times 460 / (38.88 \times 10^3) = 517$ mm

Check: 0.75d = 345 mm governs; maximum spacing limit = 300 mm.

Provided 8 mm dia 2-legged stirrups @ 300 mm c/c.

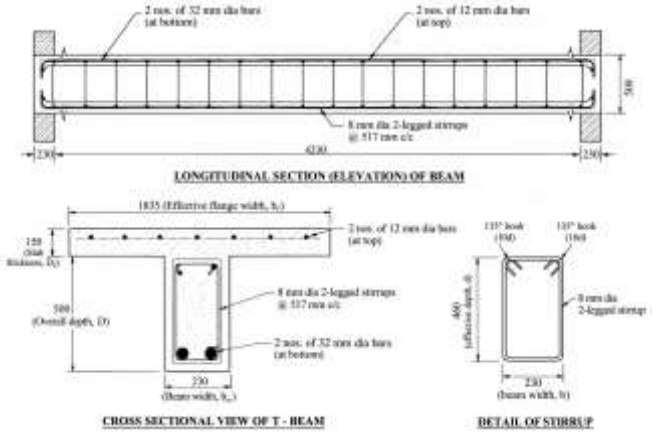


Fig. 13: Reinforcement details - Beam

8.4 Design of Uniaxial Column

Design Data:

Size: 400 mm × 450 mm

Factored load, P_u = 630 kN

Factored moment, M_u = 50 kNm

Non-Dimensional Parameters:

Assume 20 mm dia bars; d' = 40 + 10 = 50 mm; d'/D = 0.11.

$P_u / (f_{ck} b D) = 630 \times 10^3 / (25 \times 400 \times 450) = 0.140$

$M_u / (f_{ck} b D^2) = 50 \times 10^6 / (25 \times 400 \times 450^2) = 0.0247$

Reinforcement (using SP-16, Chart 44):

$p / f_{ck} = 0.060$ ⇒ p = 1.50%

$A_{st} = 1.50 \times 400 \times 450 / 100 = 2700$ mm²

n = 2700 / 314.16 = 8.59 ⇒ Provided 10 bars of 20 mm dia

Lateral Ties:

Pitch = min(400, 16 × 20, 300) = 300 mm

Provided 8 mm dia ties @ 300 mm c/c.

8.5 Design of Biaxial Column

Design Data:

Size: 400 mm × 450 mm
P_u = 630 kN

M_{ux} = 50 kNm, M_{uy} = 30 kNm

Equivalent Uniaxial Moment:

$M_u = 1.15\sqrt{(M_{ux}^2 + M_{uy}^2)} = 1.15\sqrt{(50^2 + 30^2)} = 67.06$ kNm

Reinforcement:

$P_u / (f_{ck}\, b\, D) = 0.140$; $M_u / (f_{ck}\, b\, D^2) = 67.06 \times 10^6 / (25 \times 400 \times 450^2) = 0.0331$

From SP-16 Chart 46, p/fck = 0.032 (minimum) ⇒ p = 0.8%.

$A_{sc,req} = 0.8\% \times 400 \times 450 / 100 = 1440$ mm²

Provided 10 bars of 20 mm dia (A_{sc} = 3141.6 mm²).

Safety Check under Biaxial Bending (IS 456 Cl. 39.6):

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

$= 0.45(25)(176858) + 0.75(500)(3141.6) = 3167.75$ kN

$P_u / P_{uz} = 630 / 3167.75 = 0.199 \leq 0.2 \Rightarrow \alpha_n = 1.0$

$M_{ux1} = 0.140 \times 25 \times 400 \times 450^2 \times 10^{-6} = 283.50$ kNm

For y-axis bending, d'/b = 50/400 = 0.125; from SP-16 Chart 44 interpolated at Pu/(fck D b) = 0.140, Muy1/(fck D b²) = 0.120:

$M_{uy1} = 0.120 \times 25 \times 450 \times 400^2 \times 10^{-6} = 216.00$ kNm

$(M_{ux}/M_{ux1})\alpha n + (M_{uy}/M_{uy1})\alpha n = 50/283.50 + 30/216.00 = 0.315 < 1.0$ ✓

Lateral ties: 8 mm dia @ 300 mm c/c.

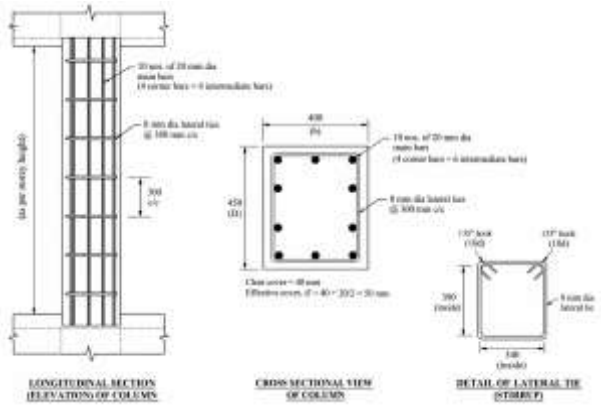


Fig. 14: Reinforcement details - Column (Uniaxial and Biaxial)

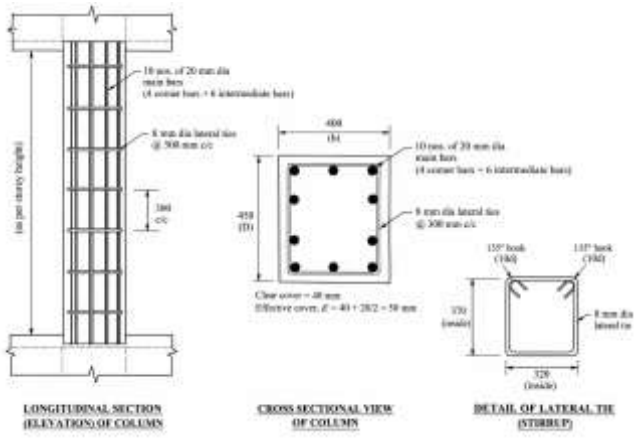


Fig. 15: Reinforcement details - Biaxial column check

8.6 Design of Isolated Footing

Design Data:

Column size: 400 mm × 450 mm
Total column load = 420 kN
Safe bearing capacity = 200 kN/m²

Size of Footing:

$A = P / q_{safe} = 420 / 200 = 2.10$ m² ⇒ $\sqrt{2.10} \approx 1.45$ m

Adopt 1.50 m × 1.50 m footing.

Factored Upward Soil Pressure:

$P_u = 420 \times 1.5 = 630$ kN; $q_u = 630 / 1.50^2 = 280$ kN/m²

Service pressure: $w = 420 / 1.50^2 = 186.67$ kN/m²

Bending Moment:

Cantilever projection = (1500 - 400)/2 = 550 mm = 0.55 m.

$M = w\, Lc^2 / 2 = 186.67 \times 0.55^2 / 2 = 28.23$ kNm

$M_u = 1.5 \times 28.23 = 42.35$ kNm

Depth Check:

$d_{req} = \sqrt{(42.35 \times 10^6 / (0.138 \times 25 \times 1000))} = 110.8$ mm

Provided d = 300 mm (D = 356 mm, adopt 350 mm) > 110.8 mm ✓.

Tension Reinforcement:

A_{st} = 332 mm², s = 113.1 / 332 × 1000 = 340 mm

Provided 12 mm dia @ 300 mm c/c in both directions

($A_{st,prov}$ = 377 mm²/m > 332 mm²/m ✓).

Shear Check:

$\tau_v = 70 \times 10^3 / (1000 \times 300) = 0.23$ N/mm² < 0.29 N/mm² ✓

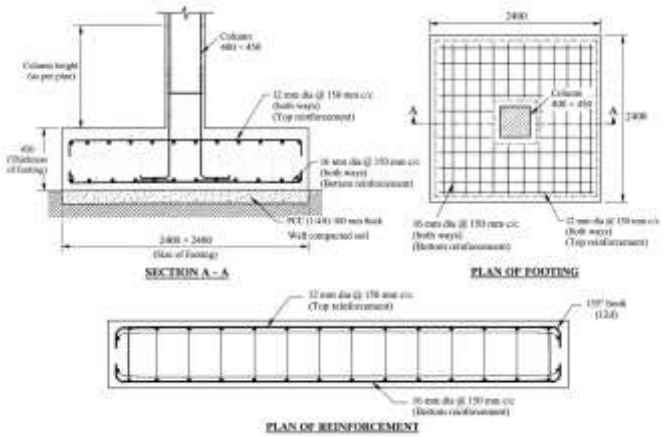


Fig. 16: Reinforcement details - Isolated footing

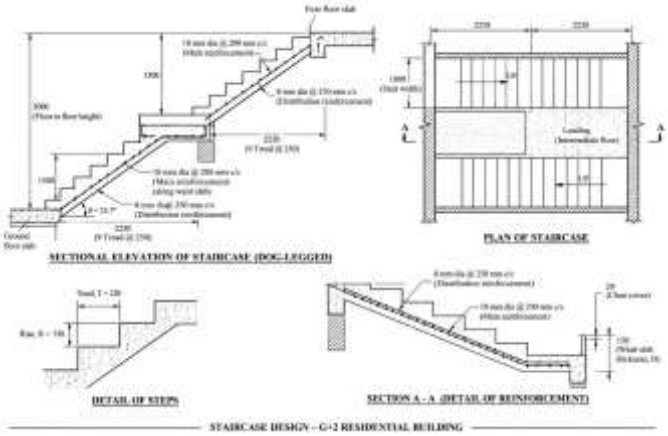


Fig. 17: Reinforcement details - RCC dog-legged staircase

8.7 Design of RCC Dog-Legged Staircase

Design Data:

Type: Dog-legged RCC
Stair width = 1.00 m
Floor-to-floor height = 3.00 m
Rise, R = 150 mm
Tread, T = 250 mm
No. of risers per flight = 10

Proportion Check:

$2R + T = 2(150) + 250 = 550$ mm (acceptable: 550-600 mm)

Geometry:

$L = \sqrt{(2.25^2 + 1.50^2)} = 2.70$ m (inclined span)

Depth:

Waist slab D = 150 mm; d = 150 - 20 - 5 = 125 mm.

Loading:

Waist slab SW = $0.15/\cos(33.7°) \times 25 = 4.51$ kN/m²
Step weight = $25 \times 0.15/2 = 1.88$ kN/m²
Floor finish = 1.00 kN/m²
Live load = 3.00 kN/m²
$W_u = 1.5(4.51 + 1.88 + 1.00 + 3.00) = 15.57$ kN/m²

Design Bending Moment:

$M_u = W_u L^2 / 8 = 15.57 \times 2.70^2 / 8 = 14.23$ kNm/m

$d_{req} = \sqrt{(14.23 \times 10^6 / (0.138 \times 25 \times 1000))} = 64.2$ mm < 125 mm ✓

Main Reinforcement:

$A_{st,req} = 274$ mm²/m; minimum = $0.12\% \times 1000 \times 150 = 180$ mm²/m.

Provided 10 mm dia @ 200 mm c/c ($A_{st} = 393$ mm²/m > 274 mm²/m ✓).

Distribution steel: 8 mm dia @ 250 mm c/c.

Shear:

$\tau_v = 21.06 \times 10^3 / (1000 \times 125) = 0.168$ N/mm² < τ_c ✓

Deflection:

$f_s = 0.58 \times 500 \times 274/393 = 202$ N/mm²; $p_t = 0.31\% \Rightarrow K_t = 1.7$

$(l/d)_{allow} = 20 \times 1.7 = 34 > 2700/125 = 21.63$ ✓

9. RESULTS SUMMARY

Table 1 summarises the design results for all structural members.

Member	Adopted Size	Reinforcement Provided
Two-way slab	D = 150 mm	Main: 10 mm ø @ 250 mm c/c; Dist.: 10 mm ø @ 250 mm c/c
One-way slab	D = 125 mm	8 mm ø @ 250 mm c/c (both directions)
Beam	230 × 500 mm	Bottom: 2–32 mm ø; Top: 2–16 mm ø; Stirrups: 8 mm ø 2L @ 300 mm c/c
Uniaxial col.	400 × 450 mm	10–20 mm ø bars; Ties: 8 mm ø @ 300 mm c/c
Biaxial col.	400 × 450 mm	10–20 mm ø bars; Ties: 8 mm ø @ 300 mm c/c
Footing	1500 × 1500 mm	12 mm ø @ 300 mm c/c (both ways); depth/shear verification required
Staircase	D = 150 mm	Main: 10 mm ø @ 200 mm; Dist.: 8 mm ø @ 250 mm

9.1 Results and Discussion

The calculated results provide a preliminary comparison of the selected dimensions with the reported manual design actions. For the two-way slab, the provided effective depth of 120 mm exceeds the reported required 62.35 mm, while the reported shear stress is 0.14 N/mm² against a stated concrete shear strength of 0.37 N/mm²; the actual span-to-depth ratio is 27.92, below the reported allowable value of 32. The one-way slab is governed by minimum reinforcement rather than flexural demand: 201 mm²/m is provided against the reported 150 mm²/m minimum, and its actual span-to-depth ratio is 11.07 against the basic limit of 20. These comparisons remain dependent on the stated support conditions, design coefficients and code provisions.

The 230 mm wide, 500 mm deep beam requires an effective depth of 395.2 mm for the web check and 139.9 mm using the reported effective T-beam flange width; the provided effective depth is 460 mm. The adopted two 32 mm bottom bars provide 1608.5 mm² against a reported required area of 629 mm². This excess must be justified through minimum reinforcement, detailing, continuity, anchorage and section-capacity checks before it is described as optimized. The reported 8 mm two-legged stirrups at 300 mm c/c are a detailing choice below the theoretical shear spacing and require confirmation against all applicable limits. Both column

cases use the same 400 × 450 mm section and ten 20 mm longitudinal bars. For the biaxial column, the reported interaction value is 0.315, less than unity, but its intermediate limiting-moment derivation requires independent reproduction.

For the isolated footing, the adopted 1.50 × 1.50 m plan area gives a preliminary service pressure of 186.67 kN/m² when footing self-weight and other soil-pressure effects are neglected, below the assumed 200 kN/m² bearing capacity. The corrected spacing calculation gives s = 340 mm, so 12 mm bars at 300 mm c/c provide approximately 377 mm²/m, exceeding the reported 332 mm²/m requirement. The project still records an effective depth of 300 mm but also gives an overall depth of 356 mm and mentions 350 mm; these depth values and the shear check require final verification. The staircase satisfies the proportion check 2R + T = 550 mm and has an actual span-to-depth ratio of 21.63 against a reported allowable value of 34. These comparisons do not replace verification of the final seismic analysis, detailing requirements and site investigation.

10. LIMITATIONS AND REQUIRED VERIFICATION

1. The final STAAD.Pro file must be checked for geometry, member connectivity, supports, section assignments, material properties and load-transfer assumptions.
2. All dead-load, imposed-load and lateral-load cases should be documented, including confirmation that automatically generated self-weight has not been duplicated manually.
3. The complete load-combination list and the governing combinations for reported member forces must be traceable in the analysis output.
4. The applicable editions and amendments of the Indian Standards must be confirmed before final submission; the historical project code basis alone does not establish current compliance.
5. The two-way slab support conditions and moment coefficients or analysis source should be recorded so that the reported moments can be reproduced.
6. Beam reinforcement selection should be justified through minimum and maximum reinforcement, section capacity, anchorage, spacing and continuity checks.
7. Column chart-based reinforcement percentages and the biaxial limiting moments should be independently recalculated from documented expressions.
8. Footing overall depth, effective depth, soil pressure and one-way or punching shear checks must be made mutually consistent; the corrected 12 mm bars at 300 mm c/c provide the reported required steel area.
9. If seismic adequacy is claimed, the site parameters, seismic weight, lateral-force procedure, response quantities, storey drift and ductile detailing must be reported. Gravity-load calculations alone are insufficient.
10. The adopted soil bearing capacity must be supported by site-specific geotechnical information before the footing design is finalized.

These items affect whether the reported numerical results can be interpreted as verified design outcomes; they are not merely editorial refinements.

11. CONCLUSIONS

This study combined three-dimensional modelling in STAAD.Pro V8i with manual limit-state calculations to document the preliminary gravity-load design of a ground-plus-two-storey reinforced concrete residential building. The calculations identified the governing criteria for selected members and quantified the difference between required and provided reinforcement.

Minimum reinforcement governed the one-way slab, for which 201 mm²/m was provided against a minimum requirement of 150 mm²/m. The two-way slab developed a calculated shear stress of 0.14 MPa against a reported resistance of 0.37 MPa. Its span-to-effective-depth ratio was 27.9, below the adopted limit of 32. For the 1.50 m square isolated footing, the calculated service bearing pressure was 186.7 kPa against an assumed allowable pressure of 200 kPa. This estimate accounts for the column load alone. The footing reinforcement provided approximately 377 mm²/m in each direction against the reported requirement of 332 mm²/m.

These findings apply to the selected members under the adopted gravity-load assumptions. The biaxial column interaction requires verification of the limiting moments about both axes. The footing assessment requires a consistent effective depth for the flexural, one-way shear, and punching shear checks, together with site-specific confirmation of the allowable bearing pressure. Although seismic loading was defined in the model, the reported results establish only the preliminary gravity-load design basis. A building-level assessment requires documented lateral response, governing load combinations, and verification of ductile detailing.

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