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Planning, Analysis and Design of Multi-Purpose Building Using STAAD.Pro (V8i)

Iyappan G[1] , Kathiresan M[2], Surendharraj S[2] and Sri Harish GJ[2]

[1] Assistant Professor, Department of Civil Engineering, Kongunadu College of Engineering and Technology (Autonomous), Tiruchirappalli – 621 215, Tamil Nadu, India
[2] UG Student · Department of Civil Engineering, Kongunadu College of Engineering and Technology (Autonomous), Tholurpatti (P.O), Thottiam-T.K, Tiruchirappalli – 621 215, Tamil Nadu, India

Email: guruiyappan5@gmail.com

Abstract - The increasing demand for multifunctional infrastructure necessitates the development of structurally efficient, safe, and sustainable building systems that integrate architectural functionality with reliable engineering design. This study presents an integrated approach to the planning, three-dimensional structural analysis, and design of a ground-plus-two-storey (G+2) reinforced concrete (RC) multi-purpose building using AutoCAD and STAAD.Pro V8i. Architectural planning was undertaken considering spatial efficiency, accessibility, functional requirements, and structural continuity. A three-dimensional analytical model was developed by incorporating structural geometry, material properties, member characteristics, support conditions, and relevant loading parameters. M25-grade concrete and Fe500D reinforcement steel were adopted, while gravity and seismic loading provisions were considered with reference to applicable Indian Standards, including IS 456:2000, IS 875, and IS 1893 (Part 1):2016. Structural responses were evaluated in terms of axial forces, bending moments, shear forces, support reactions, and deflections. The design methodology incorporated limit-state principles and member-level calculations for slabs, beams, columns, isolated footings, and staircases. The illustrative design results included a 230 × 500 mm reinforced concrete beam subjected to a factored bending moment of 123.91 kN·m and a factored shear force of 117.17 kN, together with a 400 × 450 mm column subjected to a factored axial load of 630 kN. The study establishes a systematic framework for integrating computer-aided structural analysis with conventional reinforced concrete design procedures. However, comprehensive verification of seismic response, structural detailing, and foundation performance remains necessary before practical implementation. The proposed methodology provides a basis for the preliminary structural assessment and design development of multi-purpose reinforced concrete buildings.

Keywords: Multi-Purpose Buildings; Reinforced Concrete Structures; STAAD.Pro V8i; Structural Analysis; Limit State Design; Seismic Loading; Structural Performance; Computer-Aided Design.,

1. INTRODUCTION

The rapid expansion of urban infrastructure and the increasing demand for multifunctional buildings have intensified the need for structurally efficient, economically feasible, and functionally adaptable construction systems. Reinforced concrete (RC) framed structures are extensively adopted in residential, commercial, institutional, and multi-purpose buildings owing to their structural versatility, durability, fire resistance, and ability to accommodate diverse architectural configurations. The structural performance of these buildings depends on the appropriate integration of architectural planning, material selection, structural configuration, loading assessment, and engineering design. Ensuring adequate strength, stiffness, stability, and serviceability under different loading conditions remains a fundamental requirement of reinforced concrete structural design (Bureau of Indian Standards [BIS], 2000, 2016a).

The planning and design of multi-purpose buildings involve several interconnected engineering considerations, including effective space utilization, functional accessibility, structural continuity, load distribution, and long-term durability. Multi-purpose buildings may accommodate different functional spaces with varying imposed loads and architectural requirements. Such variations influence the arrangement of structural members, column spacing, beam dimensions, slab configurations, and foundation systems. Consequently, selecting an appropriate structural framework is essential for maintaining continuous load transfer and limiting excessive structural deformation. The National Building Code of India provides a framework for building planning and structural safety, while relevant Indian Standards establish requirements for reinforced concrete design and loading assessment (BIS, 1987a, 1987b, 2016a).

Structural analysis is a critical stage in engineering design because it enables the determination of internal forces, support reactions, displacements, and deformation characteristics resulting from applied loads. Although conventional analytical methods provide a fundamental understanding of structural behaviour, their application to complex three-dimensional building configurations can become computationally demanding. Computer-aided structural analysis facilitates the development of numerical models representing interconnected structural members, material characteristics, geometric properties, and boundary conditions. Such models enable systematic evaluation of structural responses under different loading scenarios. However, the reliability of numerical predictions depends on the accuracy of modelling assumptions, load idealizations, structural connectivity, and the interpretation of analytical results (Bathe, 1996; Chopra, 2020).

The application of structural engineering software has substantially influenced the analysis and design of reinforced concrete buildings. STAAD.Pro is a structural analysis and design platform that supports three-dimensional structural modelling, load assignment, analysis of structural members, and evaluation of internal forces and displacements. The software provides an integrated computational environment for examining structural responses under gravity and lateral loading conditions. When combined with computer-aided drafting applications such as AutoCAD, it facilitates coordination between architectural layouts and structural configurations.

Nevertheless, software-generated results must be interpreted using established structural engineering principles and independently verified against relevant design provisions (Bathe, 1996; Bentley Systems, n.d.).

The structural behaviour of reinforced concrete framed buildings is significantly influenced by the magnitude, distribution, and combination of applied loads. Dead loads originate from the self-weight of structural and permanent non-structural components, whereas imposed loads arise from occupancy and functional requirements. Wind and earthquake actions introduce additional lateral demands that may affect structural stability, member forces, inter-storey displacement, and overall building response. Indian Standards provide provisions for the assessment of gravity, wind, and earthquake loads. Seismic analysis requires particular attention to structural mass, lateral stiffness, dynamic characteristics, and the distribution of earthquake-induced forces. The interaction among these parameters influences the structural response and the demands imposed on individual reinforced concrete members (BIS, 1987a, 1987b, 2015, 2016b; Chopra, 2020).

The limit state design philosophy provides a systematic basis for evaluating the strength and serviceability of reinforced concrete structural elements. Under this approach, structural members are proportioned to resist factored design actions while satisfying prescribed performance requirements. The design of slabs and beams primarily involves the assessment of flexural resistance, shear capacity, reinforcement requirements, and deflection control. Reinforced concrete columns require consideration of axial compression, uniaxial or biaxial bending, reinforcement configuration, and stability. Similarly, isolated foundations must transfer structural loads safely to the supporting soil without exceeding permissible bearing pressures or violating structural strength requirements. The Indian Standard IS 456:2000 establishes fundamental provisions for the design and detailing of reinforced concrete structural components (BIS, 2000).

The integration of numerical structural analysis with conventional design calculations is important for ensuring consistency between predicted structural responses and adopted member dimensions. Although computer-aided modelling enables efficient calculation of internal forces and displacements, numerical outputs alone do not establish structural adequacy. Independent verification of critical bending moments, shear forces, axial forces, reinforcement quantities, and serviceability parameters is necessary to identify potential modelling inconsistencies and design limitations. Furthermore, foundation performance depends on soil-bearing characteristics, while earthquake-resistant performance requires appropriate consideration of lateral response and ductile detailing requirements (Bathe, 1996; BIS, 2000, 2016b).

In the present study, an integrated methodology is adopted for the architectural planning, structural analysis, and preliminary design of a ground-plus-two-storey (G+2) reinforced concrete multi-purpose building using AutoCAD and STAAD.Pro V8i. The structural system consists of reinforced concrete slabs, beams, columns, isolated footings, and staircases. A three-dimensional analytical model is developed by defining structural geometry, member properties, material characteristics, support conditions, and relevant loading parameters. M25-grade concrete and Fe500D reinforcement steel are considered for structural design. Gravity loading and relevant seismic design provisions are incorporated into the design framework with reference to applicable Indian Standards. Structural responses are examined through bending moments, shear forces, axial forces, support reactions, and deflections, followed by member-level design calculations using the limit state method.

The principal objective of this investigation is to establish a systematic procedure for integrating architectural planning, three-dimensional numerical modelling, structural response evaluation, and reinforced concrete member design within a unified engineering workflow. Particular emphasis is placed on the relationship between computationally obtained structural actions and the corresponding design requirements of individual structural components. The study also identifies verification requirements associated with seismic response, foundation adequacy, and reinforcement detailing. Rather than proposing a new numerical analysis technique, the investigation demonstrates an integrated computer-aided structural design procedure applied to a representative low-rise reinforced concrete building. The resulting framework is intended to support preliminary design development, structural assessment, and engineering decision-making for comparable multi-purpose building configurations.

2. LITERATURE REVIEW

Dunnala Lakshmi Anuja & V.S Nagasai in (2019) the analysis and design of a building that has four floors above ground. They used STAAD.Pro for their work. The study showed that using computer tools for analysis is better than old ways. STAAD.Pro was used to check how the building would behave under conditions. The authors said that using software makes calculations faster and helps create reliable designs, for homes.

Adhiraj A. Wadekar & Ajay G.Dahake in (2020) Their study highlights the use of modern engineering software for analysing and designing reinforced cement concrete structures. The research emphasizes the need for proper planning and selection of structural components to achieve a safe and economical building. Different structural elements, such as beams, columns, slabs, and foundations, are considered during the design process. Various loads, including dead loads, live loads, wind loads.

Grande Sharan Kumar, S. Zubeeruuddin in (2021) . Their research highlights the role of proper planning in developing safe, stable, and economical building structures. The study emphasizes the application of modern structural engineering software for analysing reinforced cement concrete buildings. Different structural elements, such as beams, columns, slabs, and foundations, are considered during the design process.

Rohini Khandelwal, Kunal Bhimte in (2021), Their study highlights the need for proper structural design to ensure the safety and stability of buildings. The research emphasizes the use of computer-based software for analysing reinforced cement concrete structures. Different structural components, such as beams, columns, slabs, and foundations, are considered in the design process. Various loading conditions, including dead loads, live loads, wind loads, and earthquake loads, are taken into account. Structural modelling helps engineers understand the behaviour of buildings under different loading conditions.

Sonal Kachhwwaha, Srishti Verma & Prahallad Choudhari (2024),) Their study highlights the need for proper

architectural planning and efficient utilization of available space. It emphasizes the selection of suitable structural components such as beams, columns, slabs, and foundations to ensure structural stability. Different types of loads, including dead loads, live loads, wind loads, and seismic loads, are considered during structural analysis. member-level checks rather than accepting software output without model verification.

3. OBJECTIVES

1. To prepare an efficient architectural plan for multipurpose building.
2. To develop a three-dimensional structural model using STAAD.Pro V8i.
3. To analyse structural members under various loading conditions.
4. To design safe and economical RCC structural components.

4. SCOPE AND DESIGN BASIS

.The scope of this project involves the planning, structural analysis and design of a multi-purpose building using STAAD.Pro V8i software. The project aims to develop a safe, stable, durable and economical building structure by applying fundamental civil engineering principles. The architectural plan is prepared by considering the functional requirements, proper space utilization, accessibility, ventilation and lighting. A three-dimensional structural model is created in STAAD.Pro V8i by defining the building geometry, member properties, material specifications and support conditions.

The structural analysis is carried out by considering various loads acting on the building, such as dead load, live load, wind load and earthquake load wherever applicable. The load calculations and combinations are considered according to the relevant Indian Standard Codes. The structural components, including slabs, beams, columns and foundations, are analysed to determine bending moments, shear forces, axial forces, support reactions and deflections. Based on the analysis results, the structural members are designed to satisfy the required strength and serviceability conditions.

5. METHODOLOGY

The methodology adopted for the planning, analysis and design of a multi-purpose building involves a systematic procedure to achieve a safe, stable and economical structural design using STAAD.Pro V8i software. Initially, the architectural plan is prepared by considering the building requirements, space utilization, room dimensions, accessibility and functional arrangements. Based on the architectural drawings, the structural layout is developed by selecting suitable locations for beams, columns, slabs and foundations..

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

A ground floor plan is a detailed architectural drawing lowest level of a building. It typically shows that thearrangement of rooms, walls, doors, windows, and other structural elements, helping to visualize the spatialorganizationof a structure above.

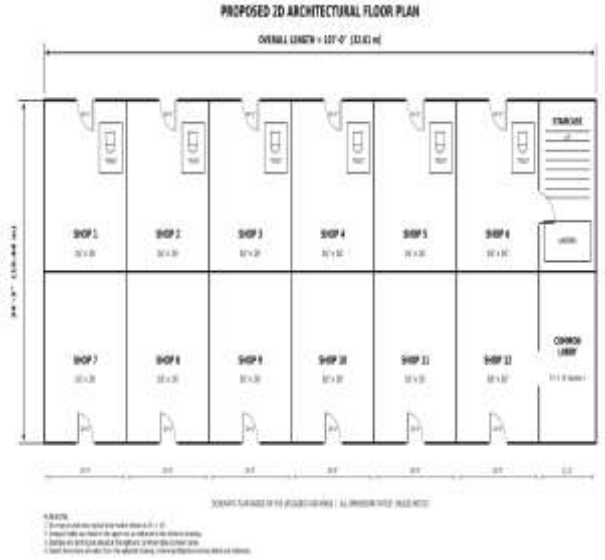


Fig. 1: Ground Floor Plan (dimensions shown in architectural feet-inches notation)



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.

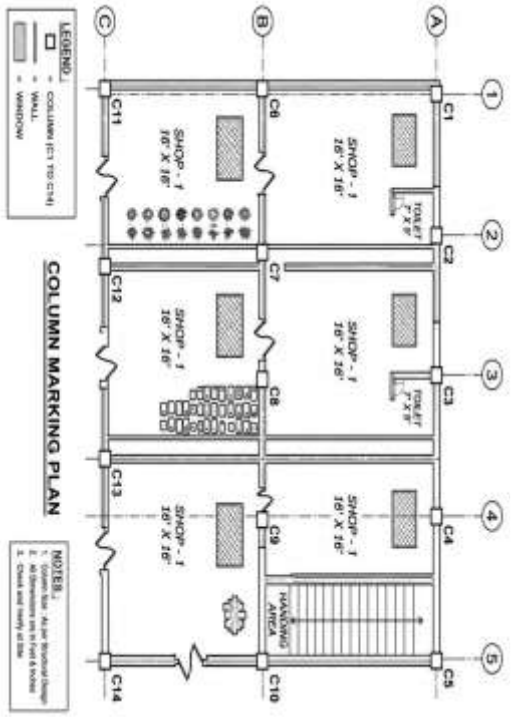


Fig. 4: Column Marking Plan

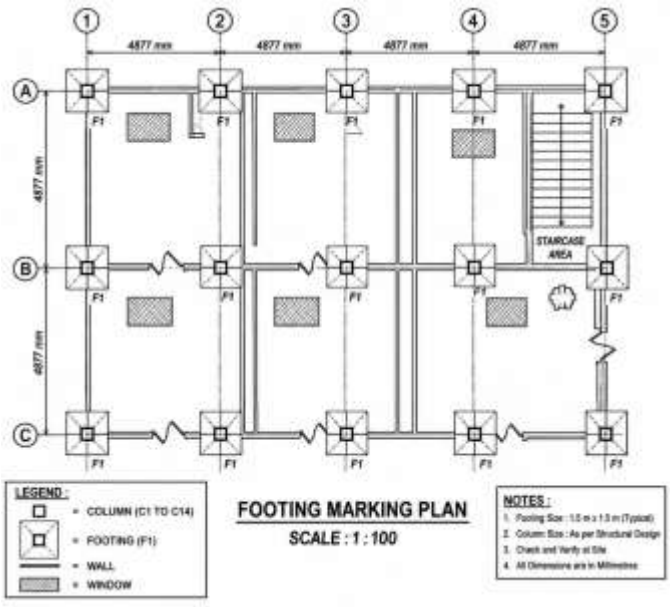


Fig. 5: Footing Marking Plan

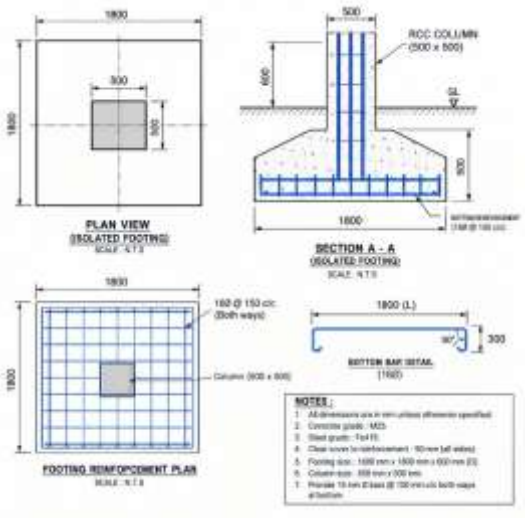


Fig. 6: Sectional Plan

7. STRUCTURAL ANALYSIS USING STAAD.PRO

7.1 Project Description and Design Basis

he proposed project deals with the planning, structural analysis and design of a multi-purpose building using STAAD.Pro V8i software. The building is planned to accommodate various activities and facilities based on functional requirements and effective space utilization. The structural system is considered as a reinforced cement concrete (RCC) framed structure consisting of slabs, beams, columns and foundations. The building dimensions, number of floors, floor-to-floor height and structural member sizes are adopted based on the architectural and structural drawings prepared for the project.

The planning and design procedure involves five major stages: collection of project data and review of relevant design codes, preparation of architectural and structural drawings using AutoCAD, three-dimensional structural modelling and analysis using STAAD.Pro V8i, design and checking of RCC structural components, and preparation of the final project report.

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.

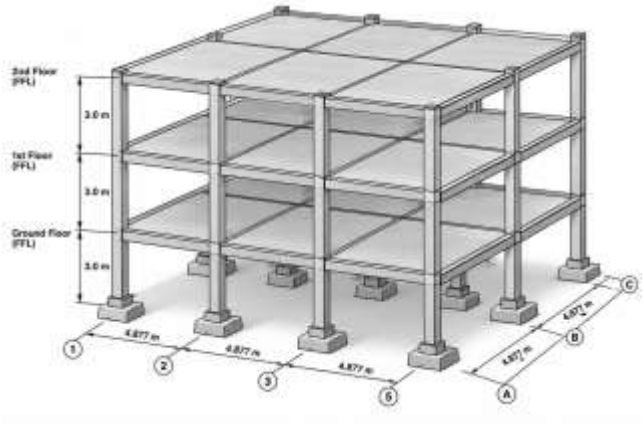


Fig. 7: Isometric view of STAAD.Pro model



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.

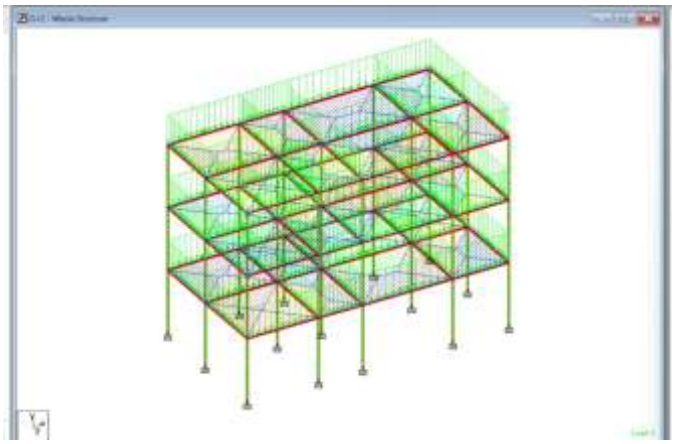


Fig. 9: Total dead load on structural model

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

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

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

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

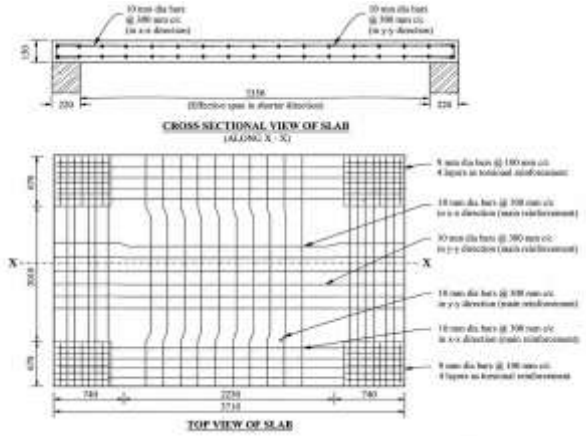


Fig. 11: Reinforcement details - Two-way slab

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 $\Rightarrow$ 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
$W_u = 1.5 \times 6.625 = 9.94$ 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 $A_{st} = 0.12\% \times 1000 \times 125 = 150$ 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:

$(l/d)_{actual} = 1173/106 = 11.07 < 20$ ✓

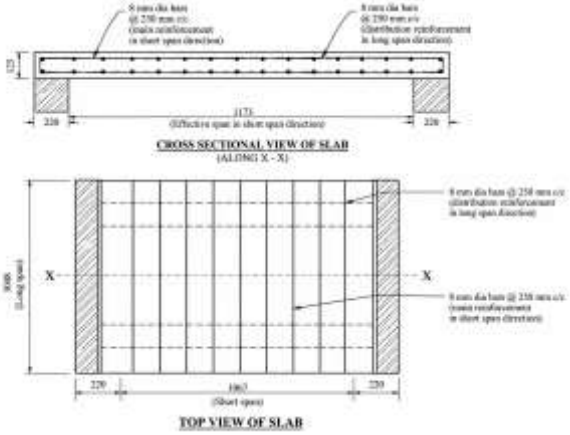


Fig. 12: Reinforcement details - One-way slab

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

$p_t = 100 \times 1608.5 / (230 \times 460) = 1.52\% \Rightarrow \tau_c = 0.74$ 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.

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):

$p / f_{ck} = 0.060 \Rightarrow p = 1.50\%$

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

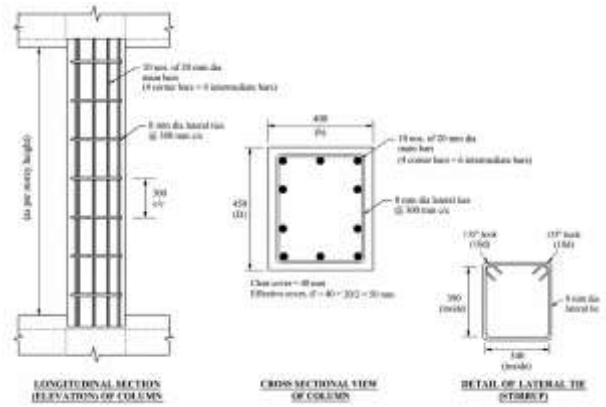


Fig. 14: Reinforcement details - Column (Uniaxial and Biaxial)



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.

$M = w L_c^2 / 2 = 186.67 \times 0.55^2 / 2 = 28.23$ 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:

τ_v = 70 × 10³ / (1000 × 300) = 0.23 N/mm² < 0.29 N/mm² ✓

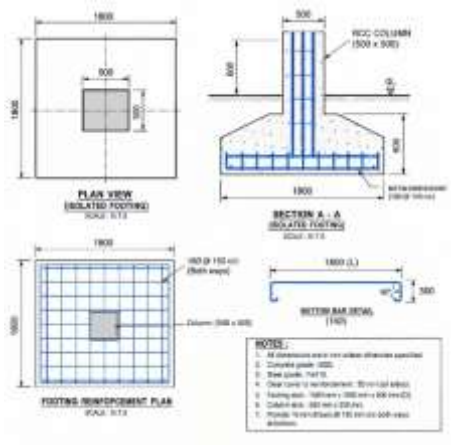


Fig. 16: Reinforcement details - Isolated footing

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 = √(2.25² + 1.50²) = 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°) × 25 = 4.51 kN/m²
Step weight = 25 × 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 × 2.70² / 8 = 14.23 kNm/m

d_{req} = √(14.23 × 10⁶ / (0.138 × 25 × 1000)) = 64.2 mm < 125 mm ✓

Main Reinforcement:

$A_{st,req}$ = 274 mm²/m; minimum = 0.12% × 1000 × 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:

τ_v = 21.06 × 10³ / (1000 × 125) = 0.168 N/mm² < τ_c ✓

Deflection:

f_s = 0.58 × 500 × 274/393 = 202 N/mm²; p_t = 0.31% ⇒ K_t = 1.7

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

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

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 planning, structural analysis and design of the G+2 residential building are carried out using STAAD.Pro V8i software. The building is modelled as a reinforced cement concrete (RCC) framed structure consisting of a ground floor and two upper floors. The structural model is developed by defining the building geometry, material properties, beam and column specifications, support conditions and loading parameters.

The analysis is performed by considering dead load, live load, wall load and other applicable loads as per relevant Indian Standard Codes. The software provides important structural results, including support reactions, bending moments, shear forces, axial forces and deflections.

The analysis results help identify critical structural members that require careful design and detailing. Beams are checked for bending and shear stresses, while columns are checked for axial loads and bending moments. Slabs are designed to resist the applied floor loads, and foundations are designed to safely transfer the structural loads to the soil..

The STAAD.Pro V8i analysis provides a clear understanding of the structural behaviour of the G+2 residential building under different loading conditions. The results indicate how loads are distributed from slabs to beams, beams to columns, and columns to foundations.The bending moment and shear force diagrams help identify critical sections in beams and assist in determining the required reinforcement. The axial force results are useful for checking the strength and stability of columns. Similarly, the

support reactions are considered during foundation design to ensure safe transfer of loads to the soil.The deflection results are examined to verify that the building satisfies the applicable serviceability requirements. Proper load combinations are considered to identify the most critical structural conditions. The analysis results are also reviewed to identify modelling errors and ensure that the structural system behaves as expected.

10. LIMITATIONS AND REQUIRED VERIFICATION

1. Structural modelling dimensions must be verified carefully against the approved architectural drawings before performing analysis.
2. Material properties, including concrete grade and reinforcement strength, must be checked against the actual project specifications.
3. Dead loads, live loads and wall loads must be calculated accurately according to applicable Indian Standard Codes.
4. Wind load and earthquake load calculations must be verified based on the building location and applicable design requirements.
5. Support conditions and boundary assumptions must be reviewed to ensure realistic representation of actual structural behaviour.
6. Beam dimensions and reinforcement details must be independently checked for bending moment, shear force and deflection requirements.
7. Column design must be verified for combined axial loads, bending moments, slenderness effects and structural stability.
8. Slab thickness and reinforcement requirements must be checked manually to satisfy strength and serviceability requirements.
9. Foundation dimensions and reinforcement details must be verified using the actual soil investigation and safe bearing capacity.
10. Staircase dimensions, loading conditions and reinforcement details must be checked according to relevant structural design provisions.

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

11. CONCLUSIONS

The present study investigated the integrated planning, structural analysis, and preliminary design of a ground-plus-two-storey (G+2) reinforced concrete multi-purpose building using AutoCAD and STAAD.Pro V8i. The investigation demonstrated the application of three-dimensional numerical modelling and limit state design principles to evaluate structural behaviour under prescribed loading conditions. Based on the analytical procedures and reported design calculations, the following conclusions were drawn.

The integration of architectural planning and structural modelling provided a systematic framework for developing the G+2 reinforced concrete building. The adopted structural configuration incorporated slabs, beams, columns, isolated footings, and staircases to establish the intended gravity-load transfer mechanism.

The three-dimensional structural model developed using STAAD.Pro V8i facilitated the evaluation of structural responses, including bending moments, shear forces, axial forces, support reactions, and deflections. These parameters formed the basis for identifying structural demands and determining preliminary member dimensions and reinforcement requirements.

The reinforced concrete beam with a cross-sectional dimension of 230 × 500 mm was designed for a factored bending moment of 123.91 kN·m and a corresponding shear force of 117.17 kN. The reported design adopted longitudinal reinforcement and transverse stirrups based on the calculated flexural and shear demands.

The reinforced concrete columns, with adopted cross-sectional dimensions of 400 × 450 mm, were evaluated under axial compression and uniaxial or biaxial bending conditions. The reported factored axial load of 630 kN and associated bending moments were used to determine the required reinforcement and assess the interaction between axial and flexural resistance.

The slab design calculations considered one-way and two-way bending behaviour, with adopted thicknesses of 125 mm and 150 mm, respectively. The reported calculations included flexural reinforcement, shear resistance, and deflection-control checks in accordance with the adopted limit state design approach.

The isolated footing design adopted a plan dimension of 1.50 × 1.50 m based on an assumed safe bearing capacity of 200 kN/m². The reported calculations provided a preliminary assessment of soil pressure, bending resistance, and reinforcement requirements. However, the adequacy of the foundation remains subject to verification of punching shear, one-way shear, actual geotechnical conditions, and reinforcement detailing.

The combined application of computer-aided structural analysis and conventional design calculations established a practical workflow for preliminary structural design. Nevertheless, comprehensive verification of seismic response, load combinations, structural detailing, and foundation

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