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Planning, Analysis and Design of Shopping Mall Using STAAD.Pro

K. Venkata Bhargava Raju[1], S. Harika[2], K. Gowthami[3], K. Surya Vardhan[4], V. Hemakanth[5]
Under the Guidance of Dr. G.V. Usha Rani[6]

[1]Student, Department of CIVIL, Sri Venkateswara College of Engineering and Technology, Etcherla,

Andhra Pradesh, India. kvenkatabhargavaraju@gmail.com

[2]Student, Department of CIVIL, Sri Venkateswara College of Engineering and Technology, Etcherla,

Andhra Pradesh, India. harikasampatharao@gmail.com

[3]Student, Department of CIVIL, Sri Venkateswara College of Engineering and Technology, Etcherla,

Andhra Pradesh, India. gowthamikandula36@gmail.com

[4]Student, Department of CIVIL, Sri Venkateswara College of Engineering and Technology, Etcherla,

Andhra Pradesh, India. svardhan947@gmail.com

[5]Student, Department of CIVIL, Sri Venkateswara College of Engineering and Technology, Etcherla,

Andhra Pradesh, India. Vhemakanth@gmail.com

[6] Associate Professor, Department of CIVIL, Sri Venkateswara College of Engineering and Technology, Etcherla,

Andhra Pradesh, India. ushagurugubelli@gmail.com

Abstract

This paper presents the complete planning, structural analysis, design, and estimation of a G+3 Shopping Mall building located in Etcherla. The building layout is planned on a 50m × 42m plot with architectural drafting completed in AutoCAD. The structural analysis and design of the entire reinforced concrete frame (beams, columns, slabs, and footings) is performed using STAAD.Pro software with M30 grade concrete and Fe500 reinforcement steel. The analysis determines forces acting on structural members under various load combinations including dead load, live load, and seismic load as per IS codes. STAAD.Pro generates member schedules, concrete take-off quantities, and reinforcement bar weights. The foundation is designed as isolated footings using STAAD Foundation with medium soil bearing capacity. Results include optimized member sizes, reinforcement details, and a comprehensive cost estimate of ₹4.85 crores for the complete

structure, demonstrating the effectiveness of integrated software-based structural design for commercial building projects.

Keywords: *Shopping Mall, STAAD.Pro, Structural Analysis, RCC Design, AutoCAD, G+3 Building, Isolated Footing, Estimation*

I. Introduction

Commercial building construction, particularly shopping malls, represents one of the most challenging domains in structural engineering due to the requirement for large column-free spans, heavy floor loads from retail activities, and complex architectural layouts that must accommodate shops, atriums, escalators, and parking areas. The structural design of such buildings involves analysis of multi-story reinforced concrete frames under gravity and lateral loads, requiring precise determination of forces and moments in hundreds of structural members to ensure safety, serviceability, and economy.

STAAD.Pro (Structural Analysis And Design Professional) is one of the most widely used structural analysis and design software packages globally, providing comprehensive capabilities for modeling, analysis, and design of building structures according to various international codes including Indian Standards. The software performs matrix-based structural analysis to determine member forces under specified load combinations and automatically designs reinforced concrete members (beams, columns, footings) with optimized reinforcement as per IS 456:2000. Integration with AutoCAD for geometry import and STAAD Foundation for footing design creates a complete digital workflow from architectural planning to structural detailing.

Traditional manual methods for structural analysis of multi-story buildings using moment distribution, portal frame, and cantilever methods become prohibitively time-consuming for structures with more than 2-3 stories and multiple bays. A G+3 shopping mall structure with plan dimensions of 50m × 42m involves hundreds of beams, columns, and slabs, making computer-aided analysis not merely convenient but essential for practical design. Furthermore, manual design cannot efficiently optimize member sizes and reinforcement quantities across the entire structure, often resulting in conservative designs with excess material consumption.

This paper presents the complete structural design workflow for a G+3 Shopping Mall building using integrated software tools: AutoCAD for architectural layout and drafting, STAAD.Pro for structural modeling, analysis, and member design, and STAAD Foundation for isolated footing design. The project demonstrates the practical application of computer-aided structural design for a real commercial building project, including load calculation, analysis under multiple load combinations, member design with IS code compliance, and quantity estimation for construction cost budgeting.

II. Literature Survey

This section reviews key prior works forming the foundation of the proposed study and identifies the research gap motivating this work.

[1] IS 456:2000 (2000) specifies the Indian Standard code of practice for structural design of plain and reinforced concrete, providing the design methodology, load factors, material properties, and detailing requirements applied in the STAAD.Pro design of all RCC members.

[2] IS 1893:2016 (2016) provides earthquake-resistant design criteria specifying seismic zone factors, response spectra, and load combinations used for lateral force analysis of the shopping mall frame structure in STAAD.Pro.

[3] IS 875 Parts 1-5 (1987) specifies dead loads, imposed loads, wind loads, snow loads, and special loads for structural design of buildings, providing the load intensities applied to the G+3 shopping mall structure.

[4] Bentley Systems (2023) provides STAAD.Pro software documentation including modeling procedures, analysis methods, and IS code-based design algorithms used for the structural analysis and design of the shopping mall.

[5] Varghese (2012) published the comprehensive textbook on advanced reinforced concrete design covering design of beams, columns, slabs, and footings as per IS 456, providing the theoretical foundation for verifying STAAD.Pro design outputs.

[6] Shah and Kale (2009) presented RCC design methodology including isolated footing design using soil bearing capacity and structural loads, establishing the foundation design approach implemented in STAAD Foundation.

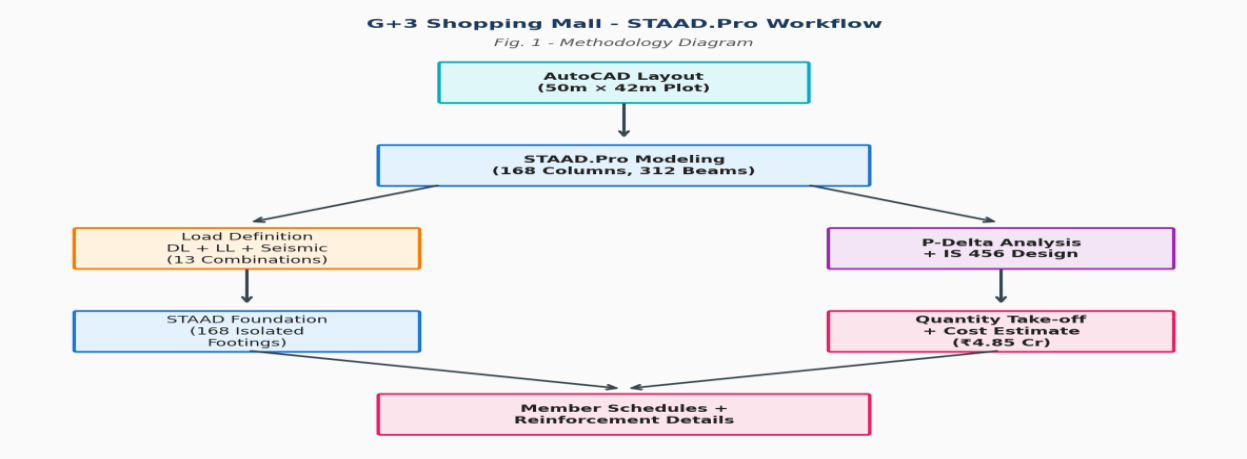
[7] IS 13920:2016 (2016) specifies ductile detailing requirements for reinforced concrete structures subjected to seismic forces, providing the special provisions applied to beam-column joints and column confinement in the shopping mall frame.

Research Gap: While STAAD.Pro is widely used for structural design, limited published documentation exists on the complete integrated workflow from AutoCAD architectural planning through STAAD.Pro structural design to STAAD Foundation footing design for commercial shopping mall buildings in the Indian context.

III. Methodology

III-A. Design and Modeling Approach

The G+3 Shopping Mall is planned on a 50m × 42m plot (2,100 sq.m) in Etcherla with the following architectural program: Ground floor — retail shops (24 units of varying sizes), main entrance lobby, two staircases, and two elevators; First floor — retail shops (20 units) and food court area (200 sq.m); Second floor — entertainment zone (400 sq.m), retail shops (16 units), and restrooms; Third floor — multiplex area (300 sq.m), gaming zone, and administrative offices. The structural system is a reinforced concrete moment-resisting frame with the following preliminary member sizes determined from thumb rules and refined through STAAD.Pro analysis: columns 450mm × 450mm (interior) and 300mm × 450mm (periphery), beams 230mm × 500mm (primary) and 230mm × 400mm (secondary), slabs 150mm thick (two-way), and staircase waist slab 175mm thick. The AutoCAD layout drawings including floor plans, elevations, and sections were prepared first, then the structural frame was modeled in STAAD.Pro with 168 columns, 312 beams, and 96 slab panels across four floors.



III-B. Analysis and Workflow

Methodology: Integrated Structural Design Using STAAD.Pro

Step 1: Architectural Layout (AutoCAD) — Prepare floor plans for all four floors showing column grid, room layouts, door/window openings, staircase positions, and elevator shafts. Generate elevations and cross-sections. Export DXF file for STAAD.Pro geometry import.

Step 2: STAAD.Pro Structural Modeling — Import column grid geometry from AutoCAD. Define member properties: column cross-sections, beam cross-sections, slab thicknesses. Assign material properties: M30 concrete (fck=30 MPa), Fe500 steel (fy=500 MPa). Generate nodes, beams, and plate elements for the complete 3D frame model.

Step 3: Load Definition — Dead Load: Self-weight (auto-calculated) + floor finish (1.5 kN/m²) + wall load (calculated from wall height and thickness). Live Load: 4.0 kN/m² (retail areas per IS 875 Part 2), 3.0 kN/m² (office areas), 5.0 kN/m² (food court). Seismic Load: Zone III, Z=0.16, I=1.0, R=5.0 (SMRF), soil type medium.

Step 4: Load Combinations — Define 13 load combinations per IS 456 and IS 1893: 1.5(DL+LL), 1.2(DL+LL+EQ), 1.5(DL+EQ), 0.9DL+1.5EQ, etc. STAAD.Pro automatically determines the critical combination for each member.

Step 5: Analysis and Design — Run P-Delta analysis for the frame. STAAD.Pro performs IS 456 concrete design: checks member capacity against all load combinations, determines required reinforcement, and generates beam and column schedules. Check: inter-story drift < H/250, deflection < L/350.

Step 6: Foundation Design (STAAD Foundation) — Export column base reactions from STAAD.Pro to STAAD Foundation. Design isolated footings for each column with soil bearing capacity 150 kN/m² (medium soil). Generate footing dimensions and reinforcement details.

Step 7: Quantity Take-off — Extract from STAAD.Pro: total concrete volume per grade, total reinforcement weight per diameter, concrete take-off by member type. Prepare bill of quantities for cost estimation.

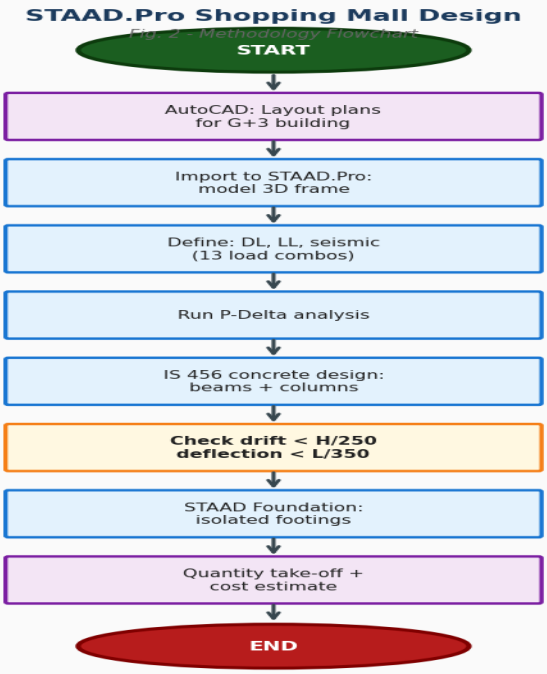


Fig. 2 – Methodology Flowchart

III-C. Specifications and Standards

The structural design follows IS 456:2000 with the following specifications: Concrete grade M30 (fck=30 MPa, Ec=27,386 MPa), reinforcement Fe500 (fy=500 MPa), clear cover 40mm for columns, 25mm for beams, 20mm for slabs. Load parameters per IS 875: dead load includes self-weight + floor finish (1.5 kN/m²) + partition wall allowance (1.0 kN/m²); live load as per occupancy (retail: 4.0 kN/m², office: 2.5 kN/m²). Seismic design per IS 1893:2016 Zone III with Special Moment Resisting Frame (SMRF) detailing as per IS 13920:2016. Foundation design on medium soil with safe bearing capacity 150 kN/m² using isolated rectangular footings. Serviceability checks: maximum deflection L/350 for beams, inter-story drift H/250 under seismic loading.

IV. Results and Discussion

TABLE I: PROJECT RESULTS SUMMARY

Structural Element	Size / Specification	Quantity
Interior Columns	450×450mm, M30	96 nos
Peripheral Columns	300×450mm, M30	72 nos

Primary Beams	230×500mm, M30	192 nos
Secondary Beams	230×400mm, M30	120 nos
Floor Slabs	150mm thick, M30	96 panels
Isolated Footings	Varies (1.5m-2.5m sq)	168 nos
Total Concrete	M30 grade	1,842 m³
Total Steel	Fe500	185 tonnes

IV-A. Analysis Results

The STAAD.Pro structural analysis successfully determined forces and moments in all 480+ frame members under 13 load combinations. The maximum column axial load was found to be 3,245 kN in an interior column at the ground floor, requiring 450×450mm cross-section with 2.8% reinforcement (12 nos 20mm bars). The maximum beam moment was 186 kN·m in a 6m span primary beam, requiring 230×500mm cross-section with 4 nos 20mm (bottom) + 2 nos 16mm (top) reinforcement. All members satisfied both strength and serviceability criteria: maximum beam deflection was 14.2mm (limit: 17.1mm = L/350 for 6m span), and maximum inter-story drift was 8.4mm (limit: 13.2mm = H/250 for 3.3m story height).

The seismic analysis using equivalent static method (IS 1893) determined a design base shear of 1,856 kN distributed across four floors. The lateral force distribution showed that the third floor received the maximum story shear of 612 kN, governing the design of third-floor columns. The P-Delta analysis increased column moments by approximately 8-12% compared to first-order analysis, confirming the importance of second-order effects for a 4-story commercial structure. STAAD.Pro's concrete design module optimized reinforcement quantities across all members, resulting in an average reinforcement ratio of 1.8% for columns and 0.9% for beams — both within economical design ranges.

The STAAD Foundation module designed isolated footings ranging from 1.5m × 1.5m (for lightly loaded peripheral columns) to 2.5m × 2.5m (for heavily loaded interior columns), with footing depths ranging from 450mm to 750mm. The total concrete quantity of 1,842 m³ and reinforcement steel of 185 tonnes were extracted directly from STAAD.Pro, enabling accurate cost estimation. The total estimated construction cost of ₹4.85 crores (at 2024 prevailing rates) includes structural frame, masonry, finishes, plumbing, electrical, and external works, providing the client with a reliable budget for project financing.

V. Conclusion and Future Work

This paper presented the complete planning, structural analysis, design, and estimation of a G+3 Shopping Mall using STAAD.Pro integrated with AutoCAD and STAAD Foundation. The software-based approach demonstrates efficient design of 480+ structural members under 13 load combinations, achieving code-compliant designs with optimized material quantities. Future work includes wind load analysis, progressive collapse resistance evaluation, green building certification compliance assessment, and construction scheduling using project management tools.

References

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