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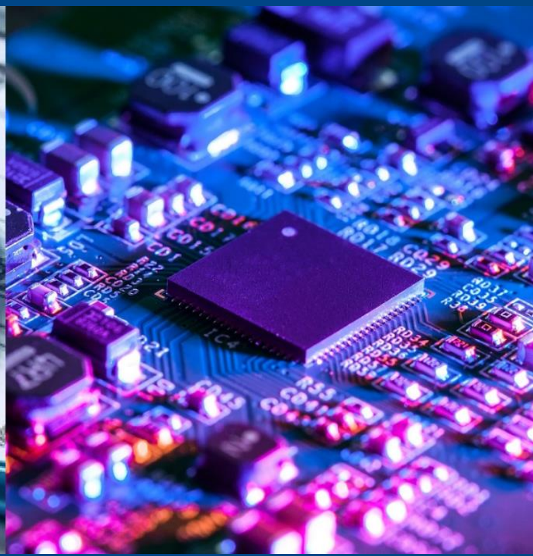

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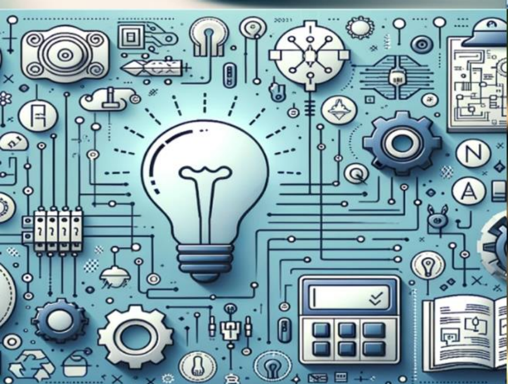

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Analysis and Design of a Multi-Storey Residential Building using ETABS and STAAD Foundation

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ABSTRACT: This project focuses on the structural analysis and design of a G+3 residential building using ETABS and STAAD Foundation software. The study aims to assess the building's structural performance in terms of strength, stability, and serviceability, in compliance with relevant Indian Standards (IS codes). ETABS was employed to model, analyze, and design the superstructure, including gravity and lateral load systems, while STAAD Foundation was used to design the substructure based on soil conditions and load transfer from the superstructure. The integration of these tools enabled a comprehensive understanding of the structural behaviour under various loading conditions. The study highlights the importance of precise load distribution, effective foundation design, and optimization of structural components to enhance safety and cost efficiency. It also emphasizes the significance of adhering to local building codes and regulations. The research demonstrates a practical and systematic approach to designing multistory residential buildings, offering valuable insights for future civil engineering practices. By analyzing the entire building structure from foundation to uppermost floors, engineers can identify potential weak points, optimize load transfer mechanisms, and ensure optimal performance of each structural element within the overall system. The study underscores the critical role of specialized software in structural analysis and design, and the need for advanced numerical modeling techniques to tackle complex geotechnical issues

KEYWORDS: Structural analysis, ETABS, STAAD Foundation, Multistorey residential building, Indian Standards (IS codes), Structural design, Load distribution, Foundation design, Structural optimization.

I. INTRODUCTION

The swift expansion of urban populations has heightened the demand for secure, efficient, and economical multistory residential buildings. Contemporary high-rise construction requires sophisticated design approaches to ensure structural soundness, occupant safety, and cost-effectiveness. With progress in computational tools, structural analysis and design have become more accurate and time-saving, enabling engineers to simulate real-world scenarios and evaluate performance prior to construction. This research focuses on the structural analysis and design of a G+3 multistory residential building using the ETABS and STAAD Foundation. ETABS was employed to model, analyze, and design the superstructure, including gravity and lateral load systems, whereas the STAAD Foundation was used to design the substructure based on soil conditions and the transfer of loads from the superstructure. By integrating these tools, a thorough understanding of the structural behavior under various loading conditions was achieved.

The aim of this study was to assess the structural performance of buildings in terms of strength, stability, and serviceability in compliance with relevant Indian Standards (IS codes). This research also highlights the significance of precise load distribution, effective foundation design, and optimization of structural components to enhance both safety and cost efficiency. Through this project, a practical and systematic approach to designing multistory residential buildings was demonstrated, offering valuable insights for future civil engineering practices, which allowed for a comprehensive analysis of the entire building structure from the foundation to the uppermost floors. This holistic approach enables engineers to identify potential weak points, optimize load transfer mechanisms, and ensure that each structural element is designed to perform optimally within the overall system.Furthermore, the study's emphasis on compliance with Indian Standards underscores the importance of adhering to local building codes and regulations. By aligning the design process with these standards.

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II. LITERATURE REVIEW

2.1 Overview of Multistorey Building Design Considerations
In modern structural engineering, effective design strategies are essential to satisfy increasing market needs while maintaining structural integrity [1]. Tools like STAAD.Pro facilitate the thorough analysis of multistory structures under diverse loading scenarios, greatly enhancing design productivity [1]. The adoption of analytical software has transformed structural engineering by automating intricate calculations that were once done manually.

2.2 The Role of Software in Structural Analysis
Today's structural analysis heavily depends on specialized software like STAAD.Pro and ETABS [2]. These applications offer precise calculations for shear forces, bending moments, and deflections, while also automatically producing reinforcement details in accordance with design codes [2]. The compatibility between STAAD.Pro and CAD software, such as AutoCAD, boosts the efficiency of the design process [1]. Additional tools like MATLAB serve as complements for element-specific designs [2].

2.3 ETABS: Features and Applications
ETABS has become a favored choice for structural engineers due to its user-friendly interface, adherence to codes (including Indian standards), and optimization features [3]. This software allows for accurate material quantity assessments and aids in precise cost estimation during the design stage [3]. Researchers have employed ETABS for comparative analyses of various slab systems and for evaluating the seismic performance of buildings with geometric irregularities [4,5].

2.4 STAAD.Pro: Features and Applications
STAAD.Pro is highly effective in conducting seismic analysis for multistorey buildings, offering extensive features for load application and element design [6]. The software is capable of handling various structural irregularities and performs dynamic analysis to assess storey drift, displacement patterns, and base shear [7]. Its powerful analytical engine makes it particularly well-suited for complex structural configurations.

2.5 Comparison of Software Capabilities
Both ETABS and STAAD.Pro cater to structural analysis needs, but ETABS is noted for its superior optimization features and user experience [3], while STAAD.Pro is recognized for its advanced seismic analysis tools [6]. Choosing between these platforms depends on the specific requirements of the project and the preferences of the engineer.

2.6 Importance of Pile Foundations
Pile foundations are crucial for transferring structural loads to stable soil layers, especially in challenging ground conditions [8]. Urban construction projects in areas with complex soil profiles, such as Nur-Sultan, often require advanced pile foundation solutions [9].

III.METHODOLOGY

3.1 Floor plan:
This study employs a mixed-methods approach to analyze a selected residential building, that has incorporated green building principles. The methodology involves a combination of qualitative and quantitative data collection and analysis to provide a comprehensive understanding of the project's design, implementation, and performance.

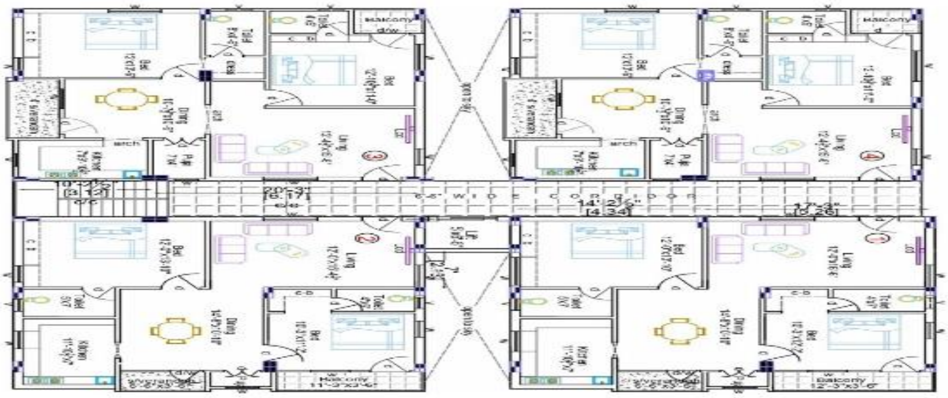

Figure 1: Floor Plan

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3.2 Statement of Project:

Salient features: the design data shall be as follows.
1. Type of Building: Residential building
2. No.of storey: G+3
3. Dimensions of building: Length-68'-9.5", Breadth-68'11.5"
4. No.of lifts: one
5. Infill wall: Brick Masonry
(a) Main wall: 0.23m
(b) Partition wall: 0.11m
6. Type of construction: RCC Framed Structure
7. Type of Foundation: Pile Foundation
8. Geometric Details:
(a) Height of Plinth: 0.6m above G.L
(b) Floor-To-Floor Height: 3m
9. Design Criteria: As per Indian Standard Codes
10. Size of Structural Elements
(a) Main Beam: 300 x 420mm
(b) Main Column: 300 x 600 mm
(c) Secoundary Column: 300 x 450 mm
(d) Slab Thickness: 120 mm

3.4 Etabs Analysis and Design Procedure

3.4 Desc2.322.3 Description Of Loads

- All moving loads comes under live loads.

Live load (on floors): 4 KN/m^2
Live load (on roof): 2 KN/m^2

- Floor finishes are the super imposed dead loads

Floor finishes (in floors): 1.5 KN/m^2
Floor finishes (on roof): 2 KN/m^2

- Dead loads are the loads of bricks used in construction

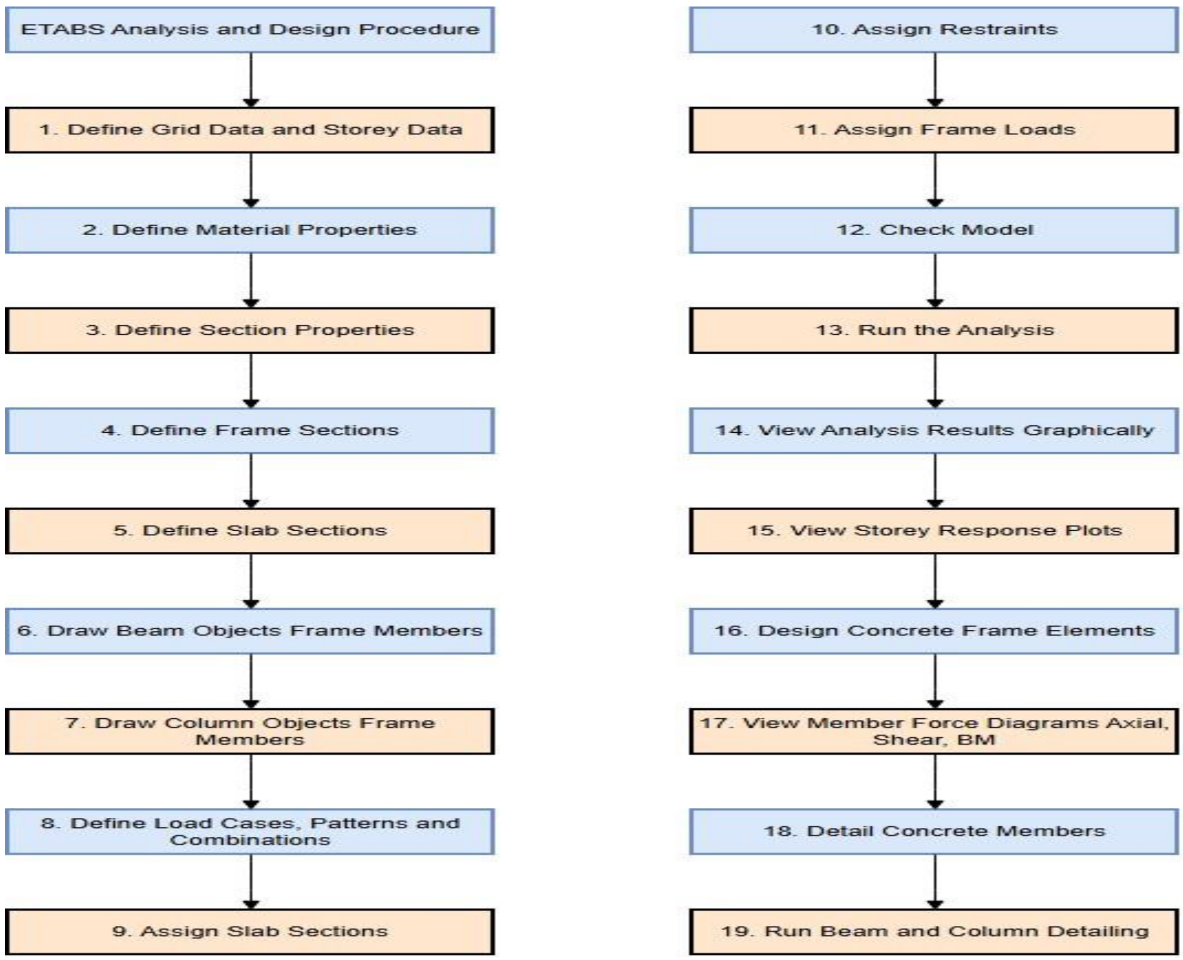
For 9" wall (outer wall): 15 KN/m
For 4.5" wall (inner wall): 7.5 KN/m

- Seismic loads are given so that the building shall be earthquake resistant.

Zone: III
Zone Factor: 0.36
Importance factor: 1.0
Response Reduction Factor: 5.0 (SMRF)

- Wind load is the force of wind

Wind Speed: 50 m/s



3.5 Grid and Storey Data:

In ETABS modeling, the grid system forms the structural skeleton by defining column locations through intersecting horizontal and vertical reference lines, while storey data establishes the building's vertical hierarchy by specifying floor-to-floor heights, slab levels, and material properties for each level - together they create the 3D framework that accurately represents the building's structural geometry before analysis.

3.6 Material Properties:

Table -1: Material Properties

Material	Type	Grade
M30	**Concrete**	**M30**
HYSD550	**Rebar**	**HYSD550**

3.7 Section Properties:

In ETABS, section properties define the geometric and material characteristics of structural elements like beams, columns, and slabs, which directly influence their strength and stiffness. The software allows engineers to specify precise cross-sectional dimensions, material grades, and reinforcement details for each member, ensuring accurate simulation of real-world structural behavior under various loads. These properties - including moment of inertia, cross-sectional area, and torsional constants - are automatically calculated by ETABS based on the defined shapes and materials, enabling proper analysis of how each component will perform in the actual structure.

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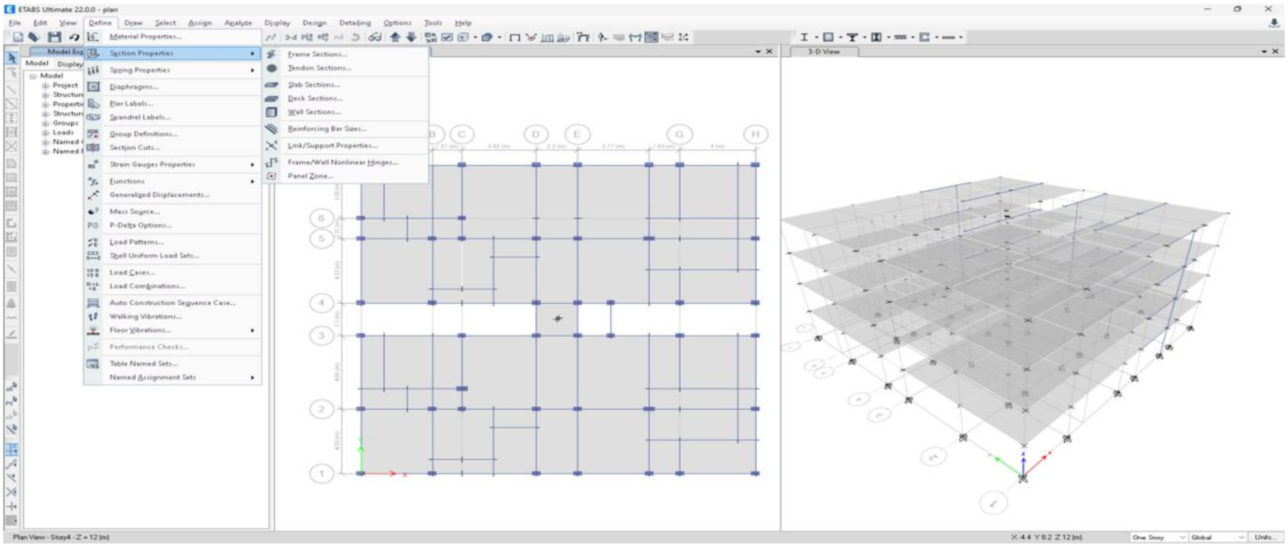

Figure-2: SECTION PROPERTIES

3.8 Frame Sections:

Table -2: Frame Sections

Name	Type	Size(mm)	Material	Shape
Beam	Frame section	300 X 420	M30	Rectangular
Column -1	Frame section	300 X 450	M30	Rectangular
Column -2	Frame section	300 X 600	M30	Rectangular

3.9 Slab Section:

Table-3: Slab Section

Name	Type	Material	Thickness
Slab	Slab section	M30	120 mm

3.10 Load Patterns:

Table-4: Load Patterns

Name	Type	Self-Weight Multiplie	Auto Load
Dead	Dead	1	
EQ-X	Seismic	0	IS 1893:2016
EQ-Y	Seismic	0	IS 1893:2016
Live Load	Live	0	
WLX	Wind	0	IS 875:2015
WLY	Wind	0	IS 875:2015

3.11 Load Cases:

Load cases represent different force conditions acting on the structure, including dead loads (permanent structural weight), live loads (temporary occupancy loads), wind loads (lateral pressure), and seismic loads (earthquake forces). The software allows engineers to define customized load combinations as per building codes, automatically calculating their combined effects on beams, columns, and slabs. Proper load case setup ensures the structure is analyzed for worst-case scenarios, verifying its safety against both everyday use and extreme events while optimizing material efficiency

Table-5: Load Cases

Name	Type
Dead	Linear Static
Live	Linear Static
WX	Linear Static
WY	Linear Static
EQX	Linear Static
EQY	Linear Static

3.12 Assigning Frame Loads:

To apply frame loads in ETABS, first select the beams or columns where the load will be assigned, then navigate to the "Assign" menu and choose "Frame Loads." Specify the load type (such as uniformly distributed, point, or trapezoidal), enter the magnitude and direction (positive for downward gravity loads), and define the load case (dead, live, or other custom cases). The software automatically distributes these loads across the selected structural members, which can be verified in the analysis results to ensure proper load transfer through the building's framing system.

3.13 Load Combinations:

ETABS automatically generates and analyzes critical load combinations to evaluate structural performance under various loading scenarios, combining dead, live, wind, and other loads with appropriate safety factors as per design codes. The software allows engineers to customize combinations to assess different structural responses, ensuring all potential load interactions are considered while optimizing material efficiency and maintaining safety margins. These combinations help identify governing load cases for each structural element, enabling precise reinforcement design and deflection checks throughout the building framework.

3.14 Restraints and Diaphragm:

In ETABS, restraints and diaphragms play crucial roles in simulating real structural behavior—restraints control how joints move or remain fixed (like pinned supports preventing rotation or fixed supports locking all movement), while diaphragms (typically assigned as rigid or semi-rigid) ensure floors and roofs distribute lateral forces properly, mimicking how concrete slabs or steel decks actually stiffen a building against wind or seismic loads. Properly defining these elements ensures accurate load paths and realistic structural responses in the analysis.

IV. RESULTS AND DISCUSSION

4.1 Analysis Results:

After analyzing the G+3 residential structure in ETABS, I've generated comprehensive diagrams showing critical structural behaviors - shear force diagrams reveal maximum stress points near beam-column joints, bending moment diagrams highlight peak moments at mid-spans and supports, axial force diagrams indicate load distribution through columns, and displacement diagrams illustrate story-wise lateral movement under loads. These visual representations help identify vulnerable zones requiring reinforcement while verifying the structure's stability against vertical and lateral forces as per design codes.

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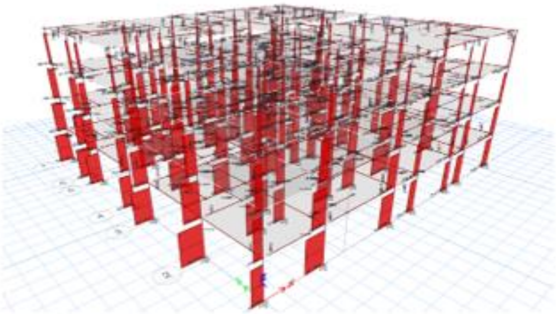

Figure 3: Axial Force

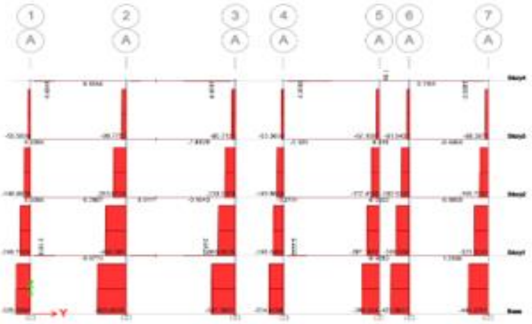

Figure 4: Elevation View of Axial Force Diagram

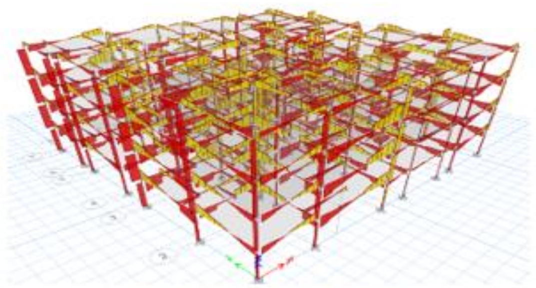

Figure 5: Shear Force Diagram

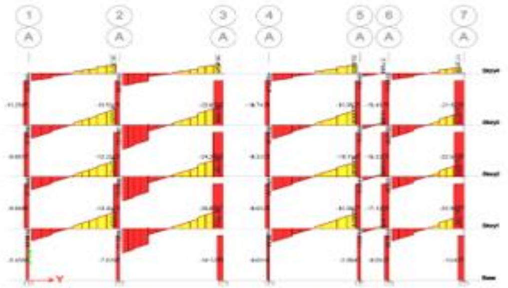

Figure 6: Elevation View of Shear Force Diagram

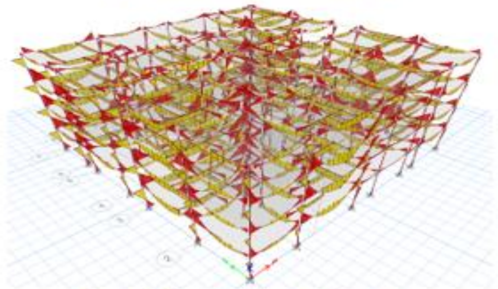

Figure 7: Bending Moment Diagram

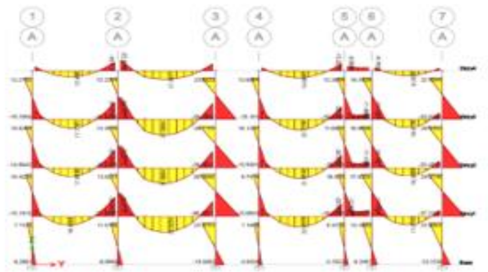

Figure 8:Elevation View of Bending Moment Diagram

4.2. Design Results of RC Building:

The fundamental goal of structural design is ensuring buildings can reliably serve their purpose while safely enduring all expected loads and environmental effects throughout their lifespan. We account not just for typical forces but also temperature changes, ground movements, and other real-world factors that impact structural performance. For this reinforced concrete project, we've chosen the limit state design approach - a modern method that balances strength requirements with practical serviceability needs like controlling cracks and deflections. This philosophy requires us to examine all potential failure scenarios, then design for the most critical conditions while verifying other performance limits remain within safe thresholds, creating structures that are both strong enough to withstand extreme events and comfortable for everyday use.

4.3 Detailing of Concrete Members:

The detailing of concrete structural elements requires precise specification of reinforcement arrangements to ensure code compliance and structural safety. For beams, we define both longitudinal bars and stirrup spacing while maintaining proper clear cover and development lengths as per IS 456:2000. Column detailing focuses on confinement reinforcement and lap splice requirements for axial load transfer, while slab reinforcement addresses proper distribution around openings and supports. ETABS assists this process by generating detailed bar bending schedules

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and reinforcement drawings that specify bar diameters, quantities, spacing, and special requirements like hooks or bends. The accompanying diagram illustrates these details through rebar profiles and elevation views, showing exact bar placements, beam dimensions, and other critical construction information that bridges the gap between design calculations and practical execution on site.

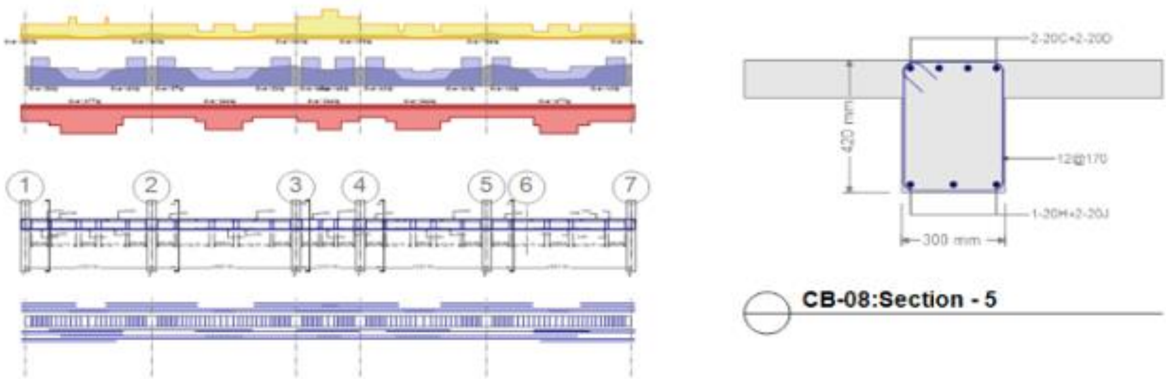

Figure 9: Detailing of a Beam with Rebars and its Section

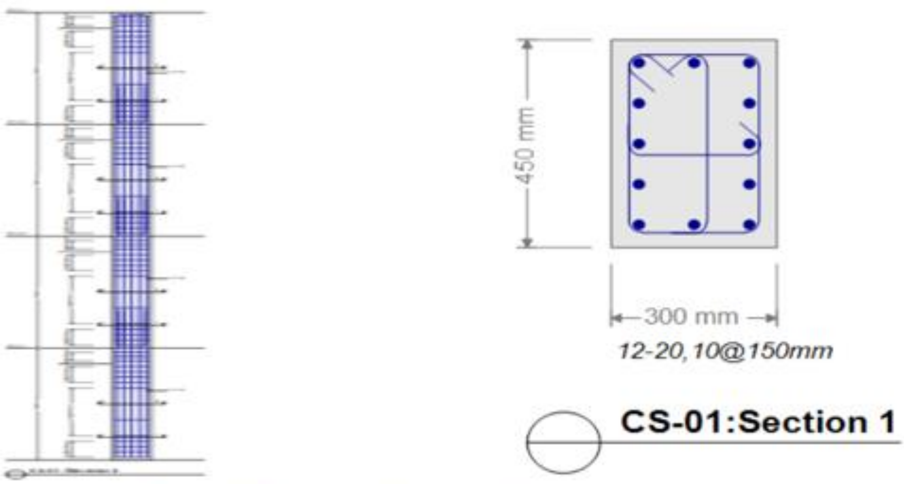

Figure 10: Detailing of a Column with Rebars and its Section

4.4 Foundation Design with Pile Cap:

Pile caps are thick concrete mats that distribute column loads to multiple piles, creating a stable foundation system for structures in weak soil conditions. Using STAAD Foundation software, the design process begins by importing column forces from structural analysis, then automatically calculates optimal pile arrangements (maintaining 3D center-to-center spacing per IS 2911) and cap dimensions. The software performs critical checks for bending moments (IS 456 Cl. 34), punching shear (Cl. 31.6), and reinforcement development lengths while generating construction-ready drawings with precise bar placements and material schedules. Here is the detailed design output, concluding a complete engineered solution that satisfies all safety requirement

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Detailing Of Pile Cap Design

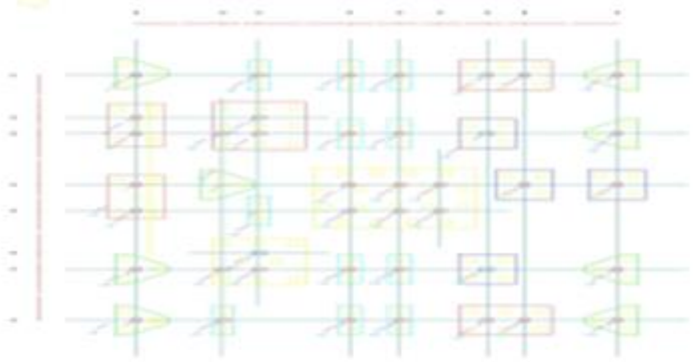

Figure 11: Plan View of Foundation Design

V.CONCLUSION

This Project represented a comprehensive structural analysis and design of a G+3 residential building using ETABS for superstructure modeling and STAAD Foundations for pile cap design. The study successfully applied the limit state method to design all structural elements, including beams, columns, slabs, and foundations, in full compliance with IS 456:2000 and IS 2911 standards. The software integration proved particularly effective, with ETABS generating optimized reinforcement details and STAAD Foundations ensuring proper load transfer to the pile foundation system. The complete design package, from structural calculations to construction-ready drawings, demonstrates how modern engineering software can deliver safe, economical, and efficient solutions for multi-storey residential construction while maintaining strict adherence to building codes and practical construction requirements.

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