Analysis and Design of Commercial Building using ETABS

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Abstract— This study details the analysis and design of a G+8 commercial building using ETABS, adhering to Indian standards. The structure, intended for mixed office and retail use, was modeled in 3D, incorporating realistic material properties. Loads including dead, live, wind, and seismic were applied per IS 456:2000 and IS 1893:2016 standards. Static and dynamic analyses assessed the building's response, focusing on lateral stability. The design optimized concrete reinforcement for safety and serviceability, addressing deflection and crack control. The results demonstrate ETABS' effectiveness in delivering safe, efficient, and economical designs for high-rise commercial buildings, ensuring compliance with Indian building codes.

Index Terms— High-Rise, ETABS, Commercial Building, Lateral Stability

I. INTRODUCTION

The structural analysis and design of multi-story commercial buildings present complex challenges that require meticulous planning and precise execution. The objective of this project is to provide a comprehensive analysis and design framework that addresses various load conditions, including dead, live, wind, and seismic loads. ETABS, a leading tool in structural engineering, was utilized to create a detailed 3D model of the building, incorporating realistic material properties and dimensions. The analysis phase involved both static and dynamic evaluations to understand the building's behavior under different load scenarios, with a particular focus on lateral stability due to wind and seismic forces.

The design process emphasized optimizing concrete reinforcement to meet safety and serviceability requirements, ensuring the structure's long-term durability. By adhering to Indian building codes, the project aims to demonstrate the effectiveness of ETABS in managing the complexities associated with high-rise commercial buildings. This study not only highlights the critical aspects of structural analysis and design but also provides a reliable methodology for engineers to achieve efficient, economical, and code-compliant designs.

II. METHODOLOGY

- Literature Review
- Preliminary Design and Planning
- Structural Modeling in ETABS
- Design Optimization
- Validation and Compliance
- Results

III. SUMMARY OF LITERATURE REVIEW

The literature review explores various studies and methodologies related to the analysis and design of high-rise buildings using ETABS, emphasizing adherence to Indian standards such as IS 456:2000 and IS 1893:2016. Key findings highlight the importance of accurate load modeling, including dead, live, wind, and seismic loads, in ensuring structural stability and safety. Previous research underscores ETABS' capability in handling complex structural models and performing both static and dynamic analyses effectively. The review also discusses optimization techniques for concrete reinforcement, ensuring serviceability and compliance with building codes, thus providing a robust framework for high-rise commercial building design.

IV. PRELIMINARY DESIGN AND PLANNING

4.1 Building Dimensions and Layout

The building has a length of 49 meters and a breadth of 28 meters. The structure is divided into 3 bays in the Z direction and 3 bays in the X direction, providing a well-organized layout for both structural and functional purposes.

Ground Floor Layout

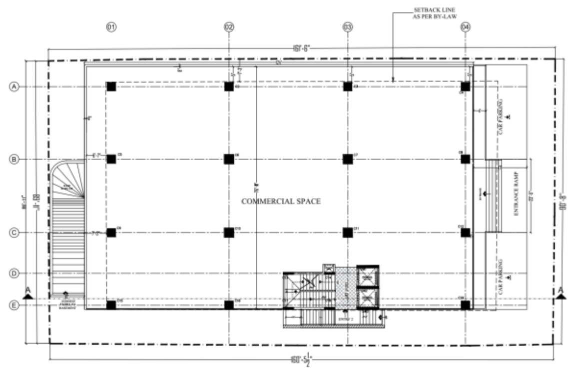

Figure 4.1 Ground Floor Layout

Purpose: The ground floor will accommodate retail units, lobby areas, and utility spaces.

Features: Large open spaces for retail, multiple entry points for accessibility, and core areas for elevators and stairs.

Typical Floor Layout (Figure 2)

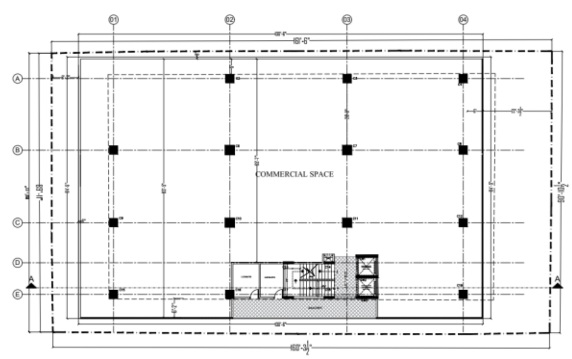

Figure 4.2 Typical Floor Layout

Purpose: The typical floors (1st to 8th) are designed primarily for office spaces.

Features: Modular office spaces, corridors for circulation, and core areas for elevators, stairs, and restrooms.

V. STRUCTURAL MODELING IN ETABS

5.1. Model Creation

A detailed 3D model of the G+8 commercial building is created in ETABS. The model includes columns, beams, slabs, and foundations, structured in a grid with three bays in both the X and Z directions. The building dimensions are 49 meters in length and 28 meters in breadth.

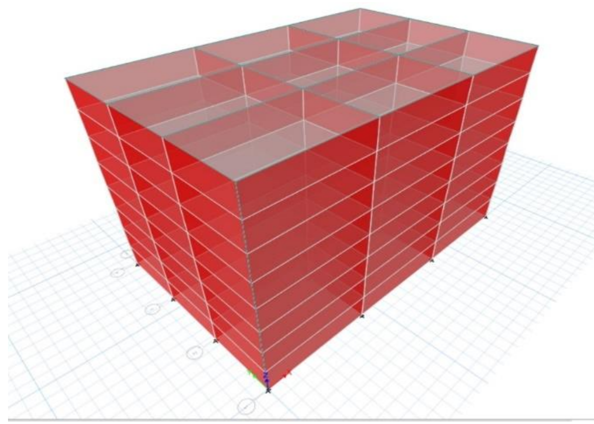

Figure 5.1 Model Creation

5.2. Material Properties

Concrete Properties: Use M30 grade concrete with a compressive strength of 30 MPa.

- Density: 25 kN/m³
- Modulus of Elasticity: $5000\sqrt{f\_ck} = 27386$ MPa

Reinforcement Properties: Use Fe500 grade steel for reinforcement.

- Yield Strength: 500 MPa
- Modulus of Elasticity: 210000 MPa

5.3. Geometric Configuration

Floor Heights: Each floor is set to a height of 3.3 meters.

- Beam Dimensions: 300 mm x 400 mm.
- Column Dimensions: 450 mm x 300 mm.
- Slab Thickness: 200 mm.

5.4. Load Definitions

Dead Loads:

- Self-Weight of Structural Elements: Automatically calculated by ETABS based on the material properties and dimensions of beams, columns, and slabs.
- Floor Finish: Assume an additional load of 1 kN/m² for floor finishes

Live Loads:

- Office Areas: Apply a live load of 4 kN/m² as per IS 875: Part 2 for commercial office spaces.
- Retail Areas: Apply a live load of 5 kN/m² if specific to heavy loads (for typical retail spaces, 4 kN/m² is sufficient).

Wind Loads:

Calculate wind loads based on IS 875: Part 3.

- Basic Wind Speed (Vb): 33 m/s for Bangalore.
- Terrain Category: Category 2.
- Structure Class: Class B.
- Risk Coefficient (k1): 1.0 for general buildings.
- Terrain Roughness Factor (k2): Depends on building height, e.g., approximately 1.0 for 30.6 meters.
- Topography Factor (k3): 1.0 for flat terrain.
- Wind Pressure (Pz): $Pz = 0.6 * Vz^2$ (where Vz is the design wind speed at height z).

Seismic Loads: Define seismic loads according to IS 1893:2016.

- Seismic Zone: II
- Zone Factor (Z): 0.10
- Importance Factor (I): 1.0
- Response Reduction Factor (R): 3.0 for ordinary RC moment-resisting frames
- Soil Type: Type II (Medium soil)

5.5. Load Combinations

Create load combinations as per IS 875: Part 5 and IS 1893:2016 to simulate various loading scenarios:1.5(DL + LL)

- 1.2(DL + LL + WL)
- 1.5(DL + WL)
- 0.9DL + 1.5WL
- 1.2(DL + LL + EL)
- 1.5(DL + EL)
- 0.9DL + 1.5EL

5.6. Boundary Conditions and Supports

- Foundation Modeling: Use a raft foundation to distribute loads evenly across a larger area.
- Support Conditions: Assign fixed support conditions at the base of columns and walls to accurately represent the building's constraints.

5.7. Analysis Settings

- Meshing: Implement appropriate meshing for slabs and other plate elements to ensure accuracy in analysis.
- Analysis Type: Conduct static analysis to evaluate the building's response to applied loads

VI. DESIGN OPTIMIZATION

Design optimization for the G+8 commercial building in ETABS focuses on maximizing structural efficiency while ensuring compliance with Indian standards and maintaining safety and durability.

Firstly, reinforcement design involves meticulously calculating the required reinforcement for columns (450 mm x 300 mm), beams (300 mm x 400 mm), and slabs (200 mm thick). This includes determining longitudinal and transverse reinforcement to withstand axial loads, bending moments, and shear forces from various load combinations. Special attention is given to seismic considerations, ensuring adequate confinement reinforcement in columns and detailing to control cracking in slabs per IS 456:2000 guidelines.

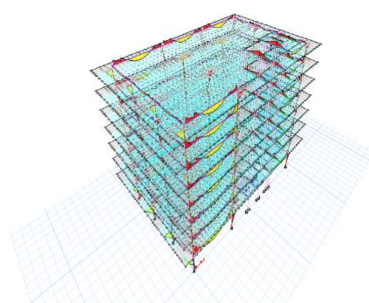

Figure 6.1 Bending Moment Diagram for Beams

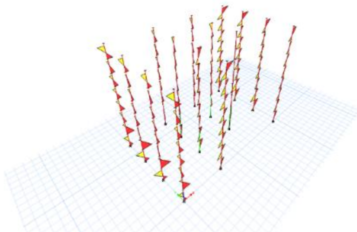

Figure 6.2 Bending Moment Diagram for Columns

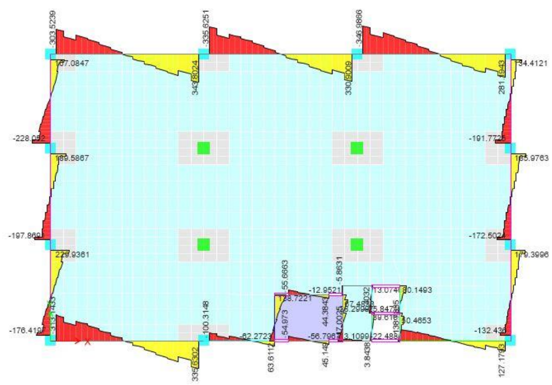

Figure 6.3 Shear force Diagram for Beams

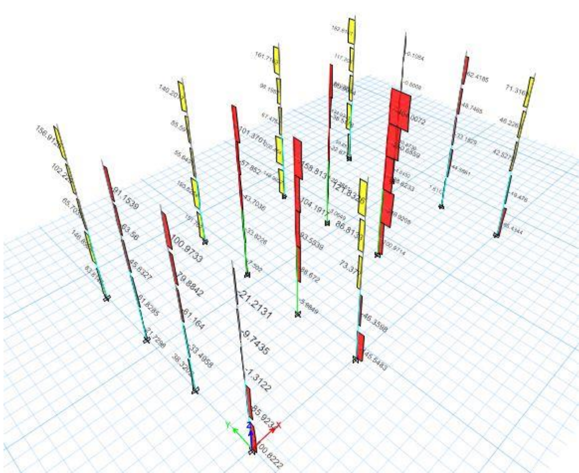

Figure 6.4 Shear force Diagram for Columns

Serviceability checks involve verifying deflection limits and ensuring crack control measures meet design requirements. Calculations are conducted under dead, live, and combined loads to ensure structural integrity and user comfort. Compliance with IS 875 for load combinations and wind load calculations, as well as IS 1893:2016 for seismic design, is strictly adhered to throughout the optimization process.

VII. VALIDATION AND COMPLIANCE

Design Code Compliance

IS 456:2000: Verify concrete design against Indian standards for strength, durability, and detailing.

IS 875: Confirm that load combinations and wind load calculations comply with IS 875: Part 1-5.

IS 1893:2016: Ensure seismic design meets requirements specified in IS 1893: Part 1 and Part 4 for earthquake-resistant design.

CONCLUSION

In conclusion, the analysis and design of the G+8 commercial building using ETABS have been conducted with a rigorous adherence to Indian standards IS 456:2000 for concrete design, IS 875 for structural loads, and IS 1893:2016 for seismic considerations. The project has successfully integrated advanced structural modeling techniques with comprehensive load analysis, ensuring robust structural integrity against dead, live, wind, and seismic loads. Design optimization focused on minimizing material usage while maintaining safety and efficiency, reflecting a commitment to sustainable construction practices.

Validation procedures have rigorously verified the accuracy and reliability of the structural model and design outputs, including peer reviews and comparison with manual calculations. This process has not only confirmed compliance with regulatory requirements but also optimized the structural performance of the building. The documentation and reporting of the design process provide a detailed account of methodologies and outcomes, serving as a valuable reference for future projects aiming to achieve similar standards of safety, efficiency, and compliance with Indian construction codes.

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