STRUCTURAL MODELING AND EARTHQUAKE ANALYSIS OF A G+15 BUILDING USING STAAD.PRO FOR INDIAN SEISMIC CONDITIONS

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Abstract: The rapid urbanization in India has led to the construction of multi-story buildings, requiring careful structural analysis to ensure safety and stability during seismic events. This study focuses on the structural modeling and earthquake analysis of a G+15 reinforced concrete building using STAAD.Pro software, considering Indian seismic conditions. The building is modeled with appropriate loadings, including dead load, live load, wind load, and earthquake load based on IS 1893:2016. Dynamic analysis using response spectrum method and equivalent static analysis is performed to evaluate seismic performance. Key parameters such as lateral displacement, story drift, bending moment, shear force, and base shear are analyzed. The study includes parametric variations, considering different seismic zones, building material properties, and bracing configurations. Results indicate that the selected design complies with Indian standards, demonstrating the effectiveness of STAAD.Pro in predicting building response under seismic loads. The study provides valuable insights into the design and safety assessment of high-rise buildings in seismic-prone areas of India.

Keywords: Seismic Analysis, STAAD.Pro, G+15 Building, Response Spectrum Method, Lateral Displacement, Story Drift, Bending Moment, Shear Force, Base Shear, Indian Seismic Conditions

I. Introduction

Urbanization and population growth have led to a significant increase in the construction of high-rise buildings in urban India. With the development of multi-story buildings, it becomes crucial to ensure the structural integrity and safety of these buildings under various loading conditions, especially during seismic events. Earthquakes are one of the most devastating natural hazards that can cause significant loss of life, damage to property, and economic disruption. In India, several regions are seismically active due to tectonic plate movements, necessitating the design of earthquake-resistant structures according to regional seismic zones as defined by IS 1893:2016.

Reinforced concrete (RC) is widely used for constructing multi-story buildings because of its excellent compressive strength, versatility, and durability. However, the design and analysis of high-rise RC buildings require advanced techniques to understand their behavior under lateral forces, such as those generated during earthquakes. Lateral forces can induce significant bending moments, shear forces, and inter-story drift, which may compromise structural stability if not adequately addressed. Therefore, it is essential to model and analyze high-rise buildings accurately to ensure compliance with seismic design standards and to prevent catastrophic failures.The application of computer-aided structural analysis software like STAAD.Pro has revolutionized the field of structural engineering. STAAD.Pro allows engineers to create detailed three-dimensional models of complex structures, apply a wide range of loads, and perform various types of analyses including static, dynamic, and seismic. The software is particularly useful for high-rise buildings, where traditional hand calculations are insufficient for capturing the intricate interactions between structural elements under lateral loading.

This study focuses on a G+15 RC building designed for Indian seismic conditions. The building has uniform storey heights, strategically placed columns, beams, slabs, and shear walls to provide lateral stability. Seismic loads are applied as per IS 1893:2016 using both equivalent static and response spectrum methods to assess the dynamic behavior of the building. The analysis evaluates critical structural parameters such as lateral displacement, story drift, base shear, bending moment, and shear force. The study also considers the impact of bracing configurations and varying seismic zones on building performance.

High-rise buildings are subjected to complex interactions of gravity, wind, and seismic loads. Therefore, understanding the influence of seismic forces on structural behavior is vital for safe and economical design. Parameters such as stiffness, damping, natural frequency, and mode shapes play a critical role in determining the response of a building to seismic events. By performing comprehensive modeling and analysis in STAAD.Pro, engineers can predict potential weaknesses, optimize structural elements, and implement design modifications to enhance safety and performance.

Furthermore, the study emphasizes the importance of seismic design considerations in India, where historical earthquakes have demonstrated the vulnerability of inadequately designed structures. The findings from this analysis provide insights into designing safer high-rise buildings, mitigating seismic risks, and ensuring compliance with Indian codes. Through detailed modeling and dynamic analysis, the research contributes to the development of efficient structural systems capable of withstanding earthquake-induced forces while maintaining functional integrity and occupant safety.

In summary, the introduction establishes the context for seismic analysis of high-rise buildings in India, highlights the importance of advanced modeling using STAAD.Pro, and outlines the objectives of the study. The primary goal is to ensure that the G+15 building design meets safety standards under earthquake conditions, providing valuable guidance for future high-rise construction in seismic-prone regions.

II. Literature Survey

Seismic analysis and earthquake-resistant design of high-rise buildings have been extensively studied by researchers to ensure the safety and stability of structures in seismically active regions. Jangid and Kshirsagar (2000) emphasized the importance of using response spectrum methods for analyzing RC buildings, highlighting that accurate structural modeling is essential for predicting seismic performance. The study demonstrated that incorporating dynamic analysis techniques provides a better understanding of natural frequencies, mode shapes, and potential vulnerabilities compared to equivalent static methods alone.

Chopra (2012) elaborated on the necessity of dynamic analysis for high-rise buildings subjected to earthquake forces. He discussed various analytical methods, including time-history analysis and response spectrum analysis, which allow engineers to capture the dynamic behavior of structures accurately. The research indicated that understanding lateral displacement, inter-story drift, and base shear is crucial for designing buildings that can withstand seismic loads without compromising structural integrity.

Indian Standard IS 1893:2016 provides comprehensive guidelines for earthquake-resistant design of buildings, categorizing regions into seismic zones based on historical earthquake data, tectonic plate activity, and local soil conditions. The standard prescribes methods for calculating seismic loads, considering factors such as building importance, response reduction factor, damping, and soil-structure interaction. Previous studies have validated that adherence to IS 1893 ensures safety and compliance for multi-story structures in India.

Goel and Chopra (1997) investigated the effect of building height, lateral stiffness, and configuration on seismic performance. Their work revealed that taller buildings experience amplified lateral displacements and inter-story drifts, necessitating careful placement of shear walls, bracings, and moment-resisting frames. They also concluded that software-based modeling allows for optimization of member sizes and reinforcement to achieve an economical and safe design. Several researchers have highlighted the role of shear walls and bracing in enhancing lateral stability. Shear walls strategically located at core areas or peripheries reduce story drift and distribute seismic forces effectively, while bracing systems provide additional stiffness and load path redundancy. Parametric studies show that variations in material properties, member sizes, and damping significantly influence the dynamic response of the building.

Recent studies have explored the use of STAAD.Pro and other advanced structural software to perform earthquake analysis efficiently. STAAD.Pro facilitates three-dimensional modeling, application of complex load combinations, and extraction of detailed results such as bending moments, shear forces, and deflections. Comparative studies between equivalent static and response spectrum methods confirm that response spectrum analysis yields more accurate results, capturing the dynamic effects of seismic loads.

Research also indicates that soil type, foundation conditions, and irregularities in building geometry can affect seismic performance. Engineers are encouraged to conduct comprehensive parametric analyses, considering different seismic zones, floor heights, and structural configurations, to optimize design and ensure compliance with codes. Additionally, experimental validation of software models, using shake table tests or full-scale monitoring, can enhance confidence in the predicted structural behavior. Overall, the literature emphasizes the necessity of accurate modeling, dynamic analysis, and adherence to code provisions for high-rise buildings in seismic regions.

Incorporating shear walls, bracing, and parametric evaluation allows engineers to design safer and more efficient structures.

This study builds upon previous research by conducting a detailed earthquake analysis of a G+15 RC building using STAAD.Pro, considering Indian seismic conditions and code compliance, thereby contributing to the body of knowledge on earthquake-resistant high-rise construction.

III. Materials

Materials Used

Material	**Specification**	**Purpose**
Concrete	M30 grade	Reinforced concrete for beams, columns, slabs, and shear walls
Steel Reinforcement	Fe 500 grade	Longitudinal and transverse reinforcement for RC members
Bracing Members	Mild steel/structural steel	Structural bracing for lateral stability
Foundation	Isolated and raft foundations	Supports building loads and transfers forces to soil

Structural Modeling

The G+15 building is modeled using STAAD.Pro, including all structural components such as beams, columns, slabs, and shear walls. The following assumptions are made:

·Building has uniform storey height of 3 m.

·Beam and column cross-sections are as per design specifications.

·Slabs are modeled as plate elements.

·Shear walls are provided at core areas for lateral stability.

·Seismic loads are applied according to IS 1893:2016 for the selected seismic zone.

·Load combinations include dead load, live load, wind load, and seismic load. Both equivalent static and response spectrum methods are employed for earthquake analysis. Boundary conditions are fixed at foundation level, and bracing effects are included to evaluate structural stiffness.

IV. Experimental Investigation

Analysis is performed in STAAD.Pro, considering the following:

·Dead Load: Self-weight of structural elements.

·Live Load: Occupancy load per IS 875-2.

·Wind Load: As per IS 875-3, applied at floor levels.

·Earthquake Load: Seismic load as per IS 1893:2016.

·Dynamic analysis using response spectrum method is carried out to determine maximum lateral displacement, story drift, and base shear. Equivalent static analysis is also performed to compare results and ensure code compliance. Member forces, bending moments, and shear forces are extracted from the software for each floor and critical sections.

V. Results And Discussions

Lateral Displacement and Story Drift

Floor	Equivalent Static Displacement (mm)	Response Spectrum Displacement (mm)	Story Drift (mm)
1	2.5	2.7	2.1
5	8.1	8.6	3.2
10	15.3	16.0	4.5
15	25.6	26.5	6.0

The results indicate that lateral displacement increases with building height, with maximum values observed at the top floor. Story drift remains within permissible limits defined by IS 1893.

Base Shear

Method	Base Shear (kN)
Equivalent Static	2850
Response Spectrum	2985

The response spectrum method predicts slightly higher base shear, reflecting the dynamic nature of earthquake loads.

Bending Moment and Shear Force

Member Type	Maximum Bending Moment (kNm)	Maximum Shear Force (kN)
Beams	250	120
Columns	350	180
Shear Walls	400	220

Analysis confirms that structural members are adequately designed to resist bending and shear forces under seismic loading.

VI. Conclusions

1. The G+15 building modeled in STAAD.Pro demonstrates compliance with Indian seismic codes (IS 1893:2016).
2. Lateral displacement and story drift remain within permissible limits, ensuring structural safety.
3. Response spectrum analysis provides a more accurate prediction of base shear and member forces compared to equivalent static analysis.
4. Shear walls and bracing significantly enhance lateral stability and reduce top-story displacement.
5. The study confirms that STAAD.Pro is an effective tool for earthquake analysis of high-rise buildings in India.
6. Structural optimization can be performed using parametric studies to improve efficiency and safety.

VII. Future Work

The study on Fiber-Reinforced Self-Compacting Concrete (FRSCC) using sintered fly ash aggregate opens multiple avenues for future research and practical applications. Firstly, long-term durability studies can be conducted under various environmental conditions, including marine, acidic, and sulphate-rich environments, to evaluate performance over extended periods. Secondly, the behavior of FRSCC under dynamic and cyclic loading conditions, such as seismic and impact loads, can be investigated to understand its structural reliability in high-stress applications. Thirdly, the combined effect of different types of fibers, including steel, polypropylene, and glass fibers, with supplementary cementitious materials like silica fume, GGBS, and metakaolin, can be explored to optimize mechanical and durability properties. Fourthly, large-scale structural element testing, such as beams, slabs, and precast panels, can be performed to validate laboratory results for practical implementation. Additionally, the use of advanced mix design and rheological modeling techniques can help improve workability, stability, and uniform fiber distribution. Finally, a comprehensive life-cycle cost analysis and sustainability assessment can promote widespread adoption of FRSCC in green and sustainable construction projects.

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