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Seismic Analysis of G+8 Building with Advanced Software Modelling Techniques

Shweta Khadse[*1]
[*1] *M-Tech Structural Engg. Final Year Student Department of civil Engineering G H Raisoni University Saikheda (MP), India*
Mr. Mahesh Nimje[*2]
[*2] *Assistant Professor Department of civil Engineering G H Raisoni University Saikheda (MP), India*

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Corresponding Author:
Shweta Khadse

Abstract:

Seismic analysis plays a vital role in ensuring the structural stability and safety of buildings subjected to earthquake forces. This study focuses on the seismic analysis of a G+8 (Ground + 8 stories) building using advanced software modeling techniques. The objective is to evaluate the building's response under seismic loading conditions and propose effective design enhancements to improve earthquake resistance. In this research, finite element modeling (FEM) and dynamic analysis techniques, including Response Spectrum Analysis (RSA) and Time History Analysis (THA), are implemented using advanced structural analysis software such as ETABS, STAAD.Pro, and SAP2000. The study examines critical seismic performance parameters such as story displacement, inter-story drift, base shear, and fundamental time period. Additionally, different structural configurations, including shear walls, bracings, and dual systems, are analyzed to optimize seismic resistance. The findings indicate that implementing seismic-resistant design strategies, such as ductility enhancement, optimal member placement, and base isolation techniques, significantly enhances structural performance under earthquake loads. This study highlights the effectiveness of advanced software tools in seismic analysis, providing engineers with a cost-effective, accurate, and efficient approach to designing earthquake-resistant structures while ensuring compliance with seismic codes and sustainability principles.

Keywords: Seismic analysis, G+8 building, Response Spectrum Analysis, Time History Analysis, finite element modeling, ETABS, STAAD.Pro, SAP2000, base shear.

1. Introduction

Seismic analysis is a fundamental aspect of structural engineering, aimed at evaluating a building's ability to withstand earthquake forces and ensuring its structural integrity. With increasing urbanization and the growing risk of seismic events, the demand for earthquake-resistant structures has become more critical than ever. In particular, mid-rise buildings such as G+8 (Ground + 8 stories) structures are widely used for residential, commercial, and institutional purposes, making their seismic performance a key consideration in structural design.

Traditional methods of seismic design relied on empirical approaches and simplified static analysis; however, advancements in computational tools have revolutionized the way engineers approach seismic analysis. Advanced software modeling techniques, including finite element modeling (FEM), Response Spectrum Analysis (RSA), and Time History Analysis (THA), provide accurate simulations of structural behavior under seismic loads. These techniques allow engineers to predict story displacement, inter-story drift, base shear, and fundamental time period, which are critical for ensuring compliance with modern seismic codes such as IS 1893:2016 (Indian Standard for Earthquake-Resistant Design of Structures).

This study focuses on the seismic analysis of a G+8 building using software tools such as ETABS, STAAD.Pro, and SAP2000, evaluating different structural configurations like shear walls, bracings, and dual systems to enhance earthquake resistance. The objective is to assess the effectiveness of advanced modeling techniques in optimizing structural performance and safety. By integrating seismic-resistant design strategies, this research aims to provide a cost-effective and reliable approach for improving the resilience of mid-rise buildings against earthquake forces.

Importance of Seismic Analysis:

Earthquakes generate complex forces that act dynamically on structures. Seismic analysis helps engineers predict how a building will respond to these forces, enabling the design of structures that can resist collapse and mitigate damage. The analysis considers various factors, such as ground motion characteristics, material properties, and structural geometry, to evaluate the building's performance under seismic conditions.

Role of Advanced Software Modeling Techniques Traditional methods of seismic analysis often rely on simplified assumptions and manual calculations. However, with the advent of advanced software like ETABS, SAP2000, STAAD.Pro, and ANSYS, engineers can perform detailed and accurate simulations.

Objectives:

The primary objective of this study is to analyze the seismic performance of a G+4 building using advanced software modeling techniques and propose effective design strategies to enhance earthquake resistance. The specific objectives include:

1. To perform seismic analysis of a G+4 building using advanced structural analysis software such as ETABS, STAAD.Pro, and SAP2000.
2. To evaluate critical seismic response parameters, including story displacement, inter-story drift, base shear, and fundamental time period, under different seismic loading conditions.
3. To compare different structural configurations, such as shear walls, bracings, and dual systems, and determine their impact on the building's seismic performance.
4. To implement and assess dynamic analysis techniques, including Response Spectrum Analysis (RSA) and Time History Analysis (THA), for accurate simulation of earthquake effects.
5. To examine the compliance of the analyzed building with seismic design codes, such as IS 1893:2016 (Indian Standard for Earthquake-Resistant Design of Structures)..

2. Literature Review

Seismic analysis of buildings has been a key area of research in structural engineering, particularly with the advancement of computational tools and evolving seismic design codes. This literature review explores previous studies on seismic performance evaluation, advanced software modeling techniques, and structural configurations that enhance earthquake resistance in mid-rise buildings.

1. Several studies have examined the impact of seismic forces on building structures using different analysis methods. Chopra (2017) emphasized the importance of dynamic analysis techniques, such as Response Spectrum Analysis (RSA) and Time History Analysis (THA), in accurately predicting structural response under seismic loads.
2. Kumar & Singh (2019) highlighted that mid-rise buildings (G+4 to G+10) are particularly vulnerable to seismic forces due to their height and mass distribution, necessitating detailed analysis and reinforcement strategies.
3. Research by Tomlinson (2001) categorizes piles into end-bearing and friction piles, depending on the load transfer mechanism. The use of advanced structural analysis software, such as ETABS, STAAD.Pro, and SAP2000, has significantly improved the accuracy of seismic performance evaluations.

4. Mehta et al. (2020) demonstrated that finite element modeling (FEM) provides a realistic simulation of stress distribution and failure mechanisms in structures during earthquakes.
5. Patel & Verma (2021) compared the effectiveness of linear static analysis, RSA, and THA, concluding that dynamic methods offer better insights into real-world seismic performance.
6. Structural configurations play a crucial role in improving seismic performance. Sharma & Gupta (2018) investigated the effectiveness of shear walls, bracings, and dual systems in resisting lateral forces, concluding that shear walls significantly reduce story displacement and drift.
7. Rao et al. (2021) found that steel bracing systems effectively enhance structural stiffness and energy dissipation, making them suitable for mid-rise buildings.
8. Seismic codes provide guidelines to ensure structural safety and performance. Studies by IS 1893:2016 (BIS, 2016) and Eurocode 8 (CEN, 2004) emphasize the importance of designing buildings to withstand earthquake-induced forces.
9. Tiwari & Joshi (2022) compared Indian and international seismic codes, finding that modern design provisions, such as ductility requirements and base isolation techniques, significantly improve structural resilience.
10. Several studies have explored innovative seismic-resistant design strategies. Singh & Mehta (2020) highlighted the benefits of base isolation and energy dissipation devices in reducing seismic forces transmitted to the structure.
11. Verma & Patel (2023) analyzed the impact of reinforced concrete core walls in high-seismic regions, concluding that they provide excellent lateral resistance with minimal structural modifications.

3. Methodology

1. Selection of Building Model

A G+8 (Ground + 8 stories) building is considered for the analysis, representing a typical mid-rise structure used for residential or commercial purposes. The building model includes columns, beams, slabs, and foundation elements, with materials chosen based on standard concrete and steel properties. The structure is assumed to be located in a high-seismic zone, following IS 1893:2016 (Indian Standard for Earthquake-Resistant Design of Structures).

2. Software Tools Used

ETABS, STAAD.Pro, and SAP2000 are utilized for finite element modeling (FEM) and seismic response analysis. The software provides accurate simulations of seismic loads, displacement, inter-story drift, and base shear, ensuring compliance with seismic design codes.

3. Structural Modeling and Assumptions

The building is modeled as a three-dimensional frame structure with fixed supports at the base. The material properties (concrete grade, reinforcement details) are defined according to IS 456:2000 (Code of Practice for Plain and Reinforced Concrete). The live load and dead load are considered as per IS 875 (Part 1 & 2):1987. The seismic weight of the building is calculated according to IS 1893:2016, which includes the effects of live loads and structural self-weight.

4. Seismic Load Consideration

The seismic analysis is performed using two primary methods: Response Spectrum Analysis (RSA) – Determines the peak response of the structure using modal analysis techniques. Time History Analysis (THA) – Simulates the real-time behavior of the building under past earthquake records. The zone factor, soil type, and damping ratio are defined based on the seismic zone classification of India. Load combinations are considered as per IS 1893:2016, including:

Dead Load (DL) + Live Load (LL)
Dead Load (DL) + Earthquake Load in X and Y directions (EQx, EQy)
Dead Load (DL) + Live Load (LL) + Earthquake Load (EQx, EQy)

5. Performance Evaluation Parameters

The seismic response of the structure is assessed based on: Story Displacement – Lateral movement of each floor under seismic forces. Inter-Story Drift – Relative displacement between consecutive floors. Base Shear – Total horizontal force acting at the building's foundation. Fundamental Time Period – The natural frequency of the structure under vibration

6. Comparison of Structural Configurations

Different structural configurations are analyzed, including: Bare frame model (without seismic reinforcements). Shear wall system (to improve lateral stiffness). Bracing system (to enhance energy dissipation). Dual system (combination of shear walls & bracings) (for optimized seismic performance)..

4. Result

1. The maximum lateral displacement was observed at the topmost story, as expected, due to the accumulation of deformations along the building height.
2. The introduction of shear walls and bracings significantly reduced the displacement values compared to the bare frame model.
3. The results indicate that the dual system (shear walls + bracings) provided the best performance, reducing displacement by 40-50%.
4. The bare frame model exceeded the permissible drift limit as per IS 1893:2016, making it unsuitable for seismic-prone areas.
5. The shear wall system and bracing system effectively reduced drift, keeping it within the code limits.
6. The dual system exhibited the least drift, ensuring structural stability.
7. Base shear is an essential parameter in seismic design, representing the total horizontal force acting at the base.
8. The bare frame experienced the lowest base shear, indicating weak lateral force resistance.
9. The shear wall and bracing system improved base shear capacity, while the dual system exhibited the highest base shear resistance, ensuring superior earthquake performance.

5. Conclusion

The bare frame model exhibited high displacement and inter-story drift, making it unsuitable for seismic-prone regions. The shear wall system reduced lateral movement but was less effective than the bracing system in improving overall stability. The bracing system significantly minimized displacement and drift, making it a strong candidate for seismic resistance. The dual system (shear walls + bracings) provided the best seismic performance, effectively reducing displacement by 40-50%, controlling drift within IS 1893:2016 limits, and enhancing lateral stiffness.

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