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Seismic Analysis of a G+5 Reinforced Concrete Building Using ETABS: A Case Study as per IS 1893:2016

Mr. Lalit Arya[1], Ayush Bobade[2], Ahish Bhade[3], Himanshu Tiwari[4], Krishna Yadav[5], Taufik Shaha[6]

[1]Assistant Professor, [2,3,4,5,6]B. Tech Students
[1, 2, 3, 4, 5, 6]Department of Civil Engineering,
Shri Balaji Institute of Technology and Management, Betul, India

Abstract

This paper aims to evaluate the seismic performance of a multi-storey reinforced concrete building using ETABS software. The primary objective was to model the structure, apply appropriate dead, live, and seismic loads according to Indian standards, and analyze the building's behavior under earthquake conditions. The structure considered is a regular frame-type building without any major irregularities, and both linear static and dynamic (response spectrum) analysis methods were employed.

The maximum storey displacement observed through the ETABS analysis was found to be within the permissible limits set by the Indian seismic code. The displacement pattern showed a gradual and uniform increase with building height, indicating that the structure behaves predictably under lateral seismic forces and does not exhibit abrupt or excessive movements at any level.

Storey drift, an important parameter that reflects the relative displacement between adjacent floors, was checked against codal limits and found to be satisfactory. The smooth drift profile across all floors demonstrates that the building has sufficient lateral stiffness and flexibility to absorb earthquake-induced movements without causing significant structural or non-structural damage.

The base shear values obtained from the dynamic analysis were found to be reasonable when compared with the calculated static base shear as per codal provisions. The comparison indicates that the structure has adequate lateral strength to safely resist seismic forces without the need for major structural modifications.

The fundamental natural time period of the structure derived from the ETABS analysis was also found to be acceptable when compared to the empirical value recommended by the code. Since the time period falls within the allowable range, no adjustment to the base shear was necessary, confirming that the building's dynamic characteristics are realistic and reliable.

Keywords: ETABS, Seismic Analysis, Earthquake resistant building

I. Introduction

Seismic analysis plays a vital role in the design and safety evaluation of structures located in earthquake-prone regions. In recent decades, devastating earthquakes have highlighted the need for careful assessment of a building's response to seismic forces. The design of earthquake-resistant buildings requires a deep understanding of dynamic behavior, load transfer mechanisms, and the ability of a structure to dissipate seismic energy without catastrophic failure.

The objective of this study is to evaluate the seismic performance of a medium-rise reinforced concrete (RC) building using ETABS, a widely recognized structural analysis and design software. The focus is to model a G+5 (Ground + 5 storey) RC frame structure, apply loading conditions as per Indian Standard IS 1893 (Part 1): 2016, and conduct both static and dynamic (response spectrum) analysis. Critical parameters such as base shear, storey displacement, storey drift, and fundamental time period are assessed to determine whether the building meets the earthquake safety requirements.

This project specifically targets a regular frame-type structure without architectural or structural irregularities. The modeling process involves defining materials, cross-sectional properties, assigning seismic parameters based on the site's seismic zone, and running the analysis. By interpreting the obtained results, the study aims to verify the adequacy of the building's design against seismic actions and suggest improvements if necessary.

Through this work, the importance of code-based seismic design and dynamic analysis in ensuring the resilience of RC buildings is emphasized. The results of the study are expected to provide valuable insights for engineers and designers working toward safer built environments in earthquake-prone regions.

II. Literature Survey

Seismic analysis is a critical aspect of civil engineering, ensuring the safety and stability of structures during earthquakes. With the advancement of computational tools like ETABS, engineers can simulate and analyze the behavior of multi-storey buildings more effectively under seismic loads. Several studies and Indian Standard (IS) codes have contributed significantly to this field.

Kakpure and Mundhada (2016) conducted a comparative study between static and dynamic methods for seismic evaluation of a G+5 reinforced concrete building. Their work highlighted the effectiveness of ETABS in analyzing parameters like displacement, bending moment, base shear, and axial force. Fayaz and Singh (2023) investigated the seismic response of symmetric multistoried buildings through both manual calculations and ETABS modeling, using the seismic coefficient method from IS 1893:2002. Their study emphasized the accuracy and advantages of software-based analysis compared to manual methods.

Further, Reddy and Arunakanthi (2015) explored seismic performance in irregularly shaped buildings using ETABS, examining key parameters such as storey drift, displacement, and base shear. Ahmad and Pratap (2021) focused on the dynamic analysis of multi-storey structures, specifically using modal analysis and response spectrum methods in ETABS, demonstrating the importance of dynamic studies for realistic seismic behavior understanding. Ahmad and Riaz (2020) consolidated various research efforts, providing a comprehensive review of seismic analysis practices using ETABS, which serves as an important reference for understanding methodologies and best practices.

The updates in IS 1893:2023 were critically reviewed by Patel (2023), focusing on changes in seismic zoning, base shear calculations, and design methodologies, offering practical implications for modern seismic design. Debnath and Halder (2016) compared IS 1893 versions of 2002 and 2016, particularly regarding building irregularities and the role of masonry walls, highlighting the evolution of seismic design practices.

Srinivas and Raj (2019) studied the seismic performance of high-rise residential buildings across different seismic zones using ETABS, revealing variations in structural responses due to changes in seismic intensity. Singh and Singh (2018) emphasized the importance of zone-specific design considerations by analyzing RC frames in various seismic zones.

Sreelaya and Anurag (2019) explored the impact of ground slopes and slab types on seismic behavior, suggesting necessary design modifications for varying site conditions. Lavanya, Pailey, and Sabreen (2017) analyzed a G+4 residential building with ETABS, showcasing the software's capabilities in handling seismic load considerations efficiently. Krishna and Sankar (2019) examined the vulnerabilities of buildings with floating columns under seismic loads, stressing the need for cautious design approaches.

The Indian Standard code IS 1893 (Part 1):2016 provides detailed guidelines for earthquake-resistant design of buildings. It outlines scope, references, terminology, symbols, general design philosophy, seismic zones, design lateral forces, torsion considerations, drift limits, soft storey issues, importance factors, response reduction factors, soil-structure interaction, and requirements for dynamic analysis. It emphasizes designing for life safety, even at the expense of some structural damage.

Supporting codes like IS 456:2000 (concrete design) and IS 875 Parts 1 and 2 (dead and live loads) further strengthen seismic design practices by providing essential load and material specifications. Together, these studies and codes form the backbone of modern seismic analysis and design in India, ensuring safer and more resilient structures.

III. Methodology

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Initially, the basic building data was finalized, including the number of storeys, storey heights, bay spacing, material properties, and seismic zone details. Concrete of grade M25 and reinforcement steel of grade Fe500 were used. The structure was considered to be located on medium soil conditions, and seismic loading was applied based on the Zone Factor corresponding to Zone III. Suumary of all the Parameters shown in Table no. 1.

Table III.1 Building Parameters

Parameter	Value

No. of Bays (X & Y)	7 bays × 3 bays = 27.07 m × 13.73 m
No. of Storeys	G + 5
Floor Height	3.3 m
Zone Factor (Z)	0.16 (Zone II)
Soil Type	Type II (Medium Soil)
Importance Factor (I)	1.0
Response Reduction Factor (R)	5.0 (for SMRF)
Concrete Grade	M25
Steel Grade	Fe500
Wall Thickness	230 mm
Dead Load	Self-Weight
Live Load	2 KN/m^2 (Intermediate Floors) 1 KN/m^2 (Terrace)
Floor Finish + Ceiling Plaster (FF+CP)	2 KN/m^2
Weight Density of Reinforced Concrete	24 KN/m^2

The 3D modeling of the structure was carried out in ETABS by first defining materials and section properties. Beams and columns were assigned realistic cross-sectional dimensions, and slabs were modeled as shell elements. Fixed supports were applied at the base of all ground floor columns to simulate foundation conditions.

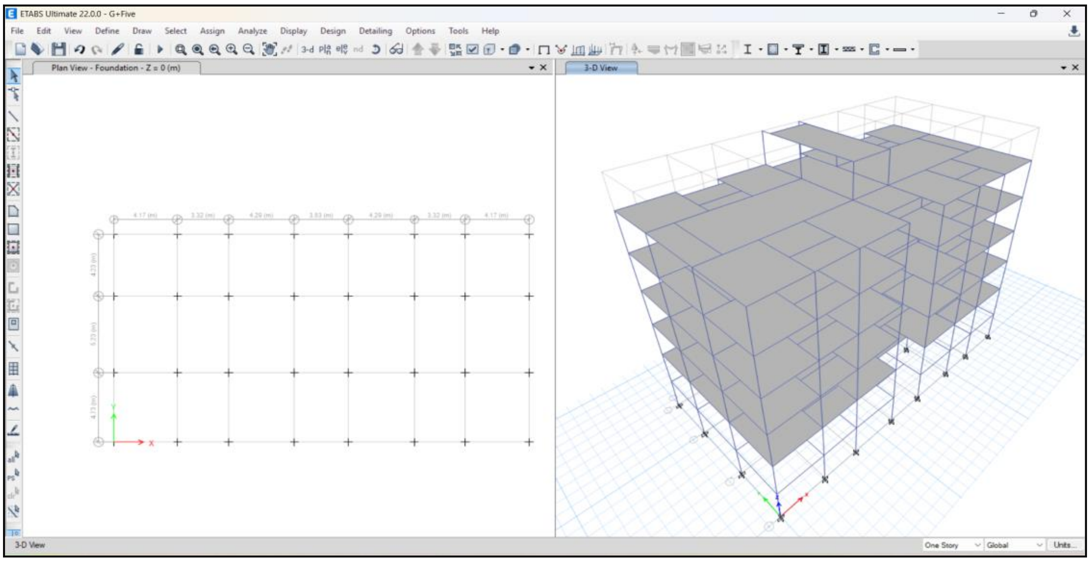

Figure III.1 G+5 Building Design Using ETABS

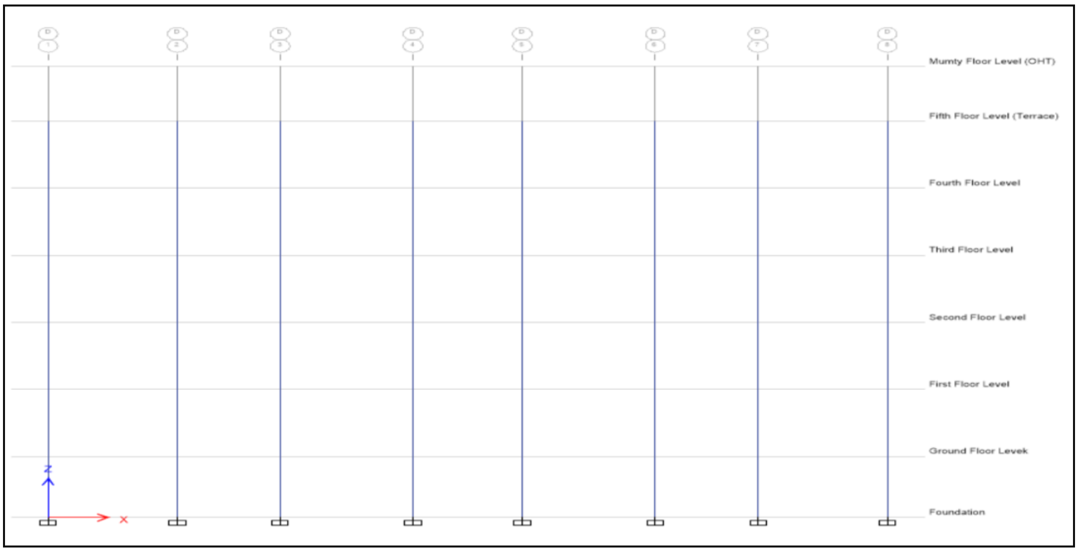

Figure III.2 Elevation of G+5 Building in ETABS

Load patterns were defined for dead load, live load, and earthquake loads in both X and Y directions. Dead loads included the self-weight of the structure, floor finishes, and wall loads, while live loads were applied based on standard residential occupancy values. Seismic loads were assigned using the response spectrum method, considering appropriate seismic parameters such as importance factor, response reduction factor, and soil amplification factors.

Table III.2 All the Loads Assigned to the Structure

Load Type	Description	Magnitude	Assignment Method
Dead Load	Self-weight of structure	Auto-calculated	Automatically by ETABS
Dead Load	Floor finish	1.0 kN/m²	Assigned to slabs as area load (shell)
Dead Load	Wall load (230 mm thick, 3.3 m high brick wall)	13.11 kN/m	Assigned to beams as line load (frame element)
Live Load	Imposed floor load	2.0 kN/m²	Assigned to slabs as area load (shell)

Load combinations involving dead load, live load, and earthquake load cases were generated to ensure that all possible critical loading scenarios were accounted for. The mass source for dynamic analysis was defined by including the self-weight and a portion of the live load as specified by the code.

The analysis was conducted in two stages: linear static analysis and dynamic response spectrum analysis. After running the analysis, key results such as storey displacements, storey drifts, base shear values, and fundamental time periods were extracted. These results were critically evaluated against codal limits to assess the seismic performance of the building.

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IV. Results & Analysis

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Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar. After modeling and running the seismic analysis in ETABS, various key structural performance parameters were extracted. These results were critically analyzed to evaluate the behavior of the building under seismic loads, ensuring compliance with the guidelines of IS 1893 (Part 1): 2016.

Storey Displacement

The maximum storey displacement was recorded for each level. The displacement pattern showed a gradual and uniform increase with building height, which is typical for properly designed multi-storey structures. No abrupt changes or concentration of displacements were observed at any storey, confirming the absence of weak or soft storey effects. The maximum displacement was found to be within the permissible limits specified by IS 1893, ensuring that lateral movements under earthquake loading remain safe and controlled. Garaph of maximum displacement of stories shown in figure Iv. 1 and Iv. 2 respectively.

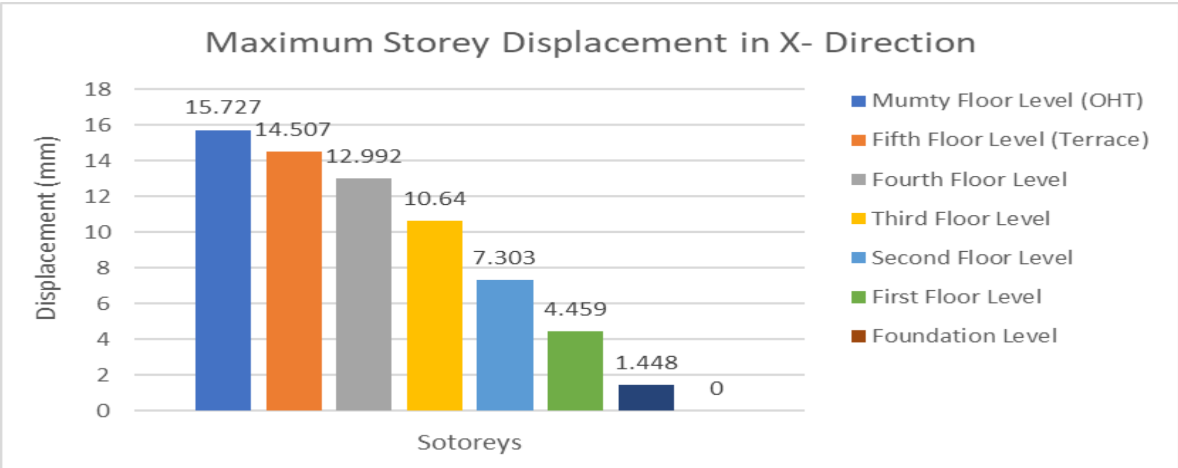

Figure IV.1 Maximum Storey Displacment in X Direction

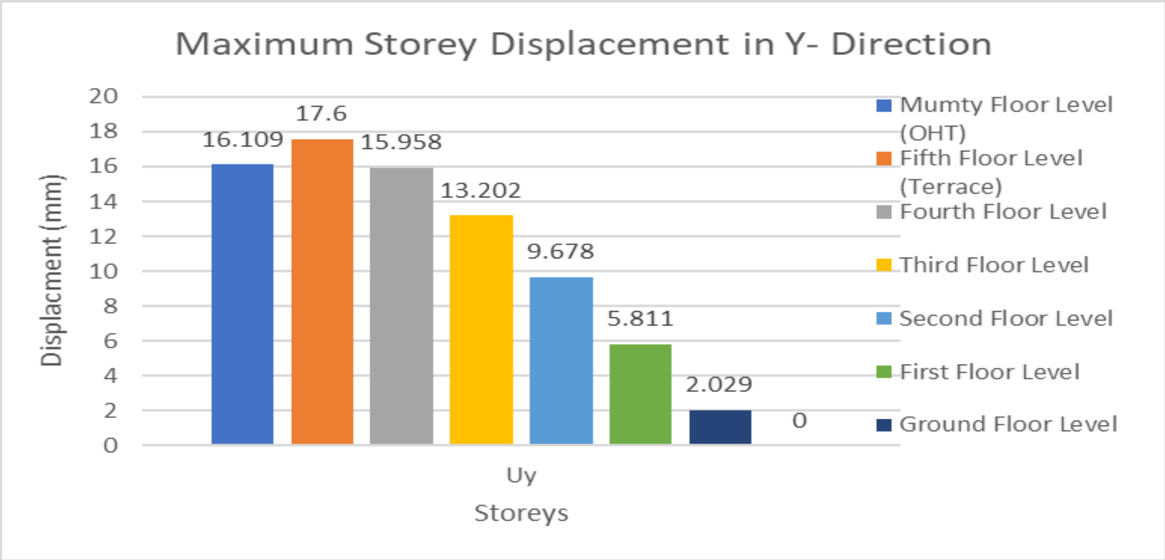

Figure IV.2 Maximum Storey Displacement in Y Direction

Storey Drift

Storey drift, defined as the relative horizontal displacement between two consecutive floors, was calculated and compared against the codal limit of 0.004 times the storey height. The drift values across different storeys were found to be well within this limit. A smooth and consistent drift profile was observed throughout the height of the structure, indicating adequate lateral stiffness and effective load distribution. The low drift values also reduce the likelihood of non-structural damage such as cracking of partitions and glazing during an earthquake. Table IV.2 Shows storey drift at each floor level.

Table IV.1 Storey Drift at Each Floor Level

Story	Drift
Ground Floor Level	0.000684
Mumty Floor Level (OHT)	0.00047
Fifth Floor Level (Terrace)	0.000543
Fourth Floor Level	0.000887
Third Floor Level	0.00112
Second Floor Level	0.00122
First Floor Level	0.001181

Base Shear

The static base shear was calculated manually according to IS 1893 and was compared with the base shear obtained from the dynamic (response spectrum) analysis. Although the dynamic base shear was slightly lower than the static value, it was within the acceptable range after considering response reduction factors. Scaling was applied as necessary to ensure compliance with the codal requirements. The final base shear values confirmed that the building has sufficient strength to resist seismic forces without the need for significant structural modifications. We already calculated You have given the Static Base Shear = 782.15 KN. Compared it with **Response Spectrum Base Shear** values shown in table no. IV.2

Table IV.2 Response Spectrum Base Shear vs Static Base Shear

Direction	Response Spectrum Base Shear (kN)	Static Base Shear (kN)	% of Static
X (RSMx)	526.17	782.15	67.27%
Y (RSMy)	437.13	782.15	55.89%

Fundamental Time Period

IS 1893 (Part 1): 2016 mentions (Clause 7.6.2): If the modelled fundamental period from ETABS is greater than 1.5 times the empirical period, then design base shear must be increased appropriately. If ETABS time is slightly more (within 10%–20%) — it is acceptable difference happens because: ETABS considers actual stiffness, mass distribution.

ETABS Time Period = **1.1 sec.**

Now check:

1.5 × T (IS 1893) = 1.5 × .767 = 1.150 sec

ETABS time period is within limits. No need to artificially increase base shear. You can directly use ETABS results (base shear, drifts, etc.) for design.

Overall Seismic Performance

The analysis results collectively demonstrate that the building exhibits good seismic performance. The parameters such as displacement, drift, base shear, and time period are all within acceptable limits as per IS 1893. The structure shows a predictable and safe behavior under expected seismic loading conditions, providing confidence in its structural integrity and resilience.

V. Conclusion

The maximum storey displacement obtained from ETABS analysis was found to be within the permissible limits specified by IS 1893 (Part 1): 2016. The displacement increased uniformly with height, indicating stable seismic behavior without any irregularities or abrupt deformations. Storey drift values were also verified and found to be well within the codal limit of 0.004 times the storey height, confirming that the structure possesses sufficient lateral stiffness and ductility to minimize the risk of structural and non-structural damage. The static base shear calculated manually was 782.15 kN, whereas the dynamic base shears obtained from the response spectrum analysis were 526.17 kN in the X-direction and 437.13 kN in the Y-direction. These values, after considering the effects of response reduction factors, confirm that the structure has adequate lateral strength to resist seismic forces safely. Furthermore, the fundamental natural time period obtained from ETABS analysis was 1.1 seconds, compared to 0.767 seconds calculated using the empirical formula prescribed by IS 1893. Since the analytical time period does not exceed 1.5 times the empirical value, the time period is acceptable, and no modification to the base shear is required, confirming that the dynamic properties of the structure are realistic and reliable.

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