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EARTHQUAKE RESISTANT DESIGN OF IRREGULAR MULTISTOREY (G+10) STRUCTURE WITH FLOATING COLUMNS

[1] Baral. S. M, [2] Bere. V. S, [3] Tarangre P. S, [4] Pandhare R. S, [5] Tonape A.R

[1]Assist. Prof. Department of Civil Engineering, S. B Patil College of Engineering, Indapur, Pune, Maharashtra, India

[2]Assist. Prof. Department of Civil Engineering, S. B Patil College of Engineering, Indapur, Pune, Maharashtra, India

[3,4,5.] Student Department of Civil Engineering, S. B Patil College of Engineering, Indapur, Pune, Maharashtra, India

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Abstract: Many high-rise buildings are practically irregular, as perfectly regular high-rise buildings rarely exist. Structural irregularities increase the uncertainty regarding a building's ability to meet design requirements during an earthquake. Structural failure often begins at points of weakness, which arise due to discontinuities in mass, stiffness, and geometry. A vertically irregular structure refers to discontinuities in the vertical profile of the building. To ensure safety, cost-effectiveness, and adherence to standards, it is essential to analyze and design these buildings using advanced software such as ETabs. The analysis of a G+7Reinforced Cement Concrete (RCC) irregular framed structure in this project involves the consideration and application of live loads, dead loads, seismic loads, and wind loads.

Keywords: *Storey Building, Reinforced Concrete, Storey Drift, Storey Shear, Storey Stiffness, Storey Displacement, Overturning Moment*

I.INTRODUCTION:

General introduction

Earthquakes are generated by tectonic movements in the crust of a planet. When tectonic plates collide, one plate may ride over the other, leading to the formation of earthquakes and volcanoes. These earthquakes result from vibrations in the Earth's crust that radiate in all directions from the point of disturbance. While some earthquakes are man-made, most are natural. Regardless of origin, all earthquakes are triggered by imbalances within the Earth's crust.

ETABS

(Extended 3D Analysis of Building Systems) is a powerful software developed by Computers and Structures, Inc. (CSI) for the structural analysis and design of buildings. It is widely used by civil and structural engineers for modeling, analyzing, and designing multi-story buildings under various loads, including seismic and wind forces

ETABS is an integrated software package that combines:

- 3D modeling tools
- Linear and nonlinear analysis capabilities
- Design modules for concrete, steel, and composite structures
- Graphical visualization and reporting features

Floating Column

A floating column (also called hanging column) is a column that does not transfer load directly to the foundation. Instead, it rests on a beam, which then transfers the load to other columns and ultimately to the foundation. This design is often adopted due to architectural or functional requirements, such as creating open spaces on lower floors. A floating column is a vertical structural element that rests on a beam instead of directly connecting to the foundation. It's commonly used in multi-story buildings to optimize space, especially for parking or open lobbies.

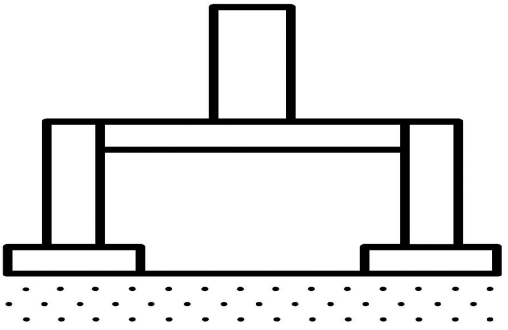

Fig. 1. Floating Column

II.LITERATURE REVIEW

1. **Sanjay Sabu-[2022]** Irregular structures exhibit higher displacement and storey drift compared to regular ones, especially at the top levels. Base shear values vary significantly depending on the shape and irregularity of the structure. The displacements, shear and stiffness of building in flat surface as well as sloped surface (1:25) of different stories is successfully evaluated with the help of this software. The comparative study should be done after further analysis and preparations. TABS proves to be a robust and reliable tool for modeling and analyzing complex structural geometries. Vertical irregularities negatively impact seismic performance, and careful design considerations are essential.
2. **Akhilesh rathi1, Dr. Ashwin Raut (October 2018)** investigate the seismic performance of regular and vertically irregular buildings using E-TABS software. They

model two structures—one with uniform geometry and another with setbacks—to analyze how vertical irregularities affect structural behavior under earthquake loads. The analysis follows IS 1893:2002 guidelines and considers parameters like storey drift, displacement, base shear, and time period. Their findings reveal that irregular buildings experience higher drift and displacement, especially at setback levels, making them more vulnerable during seismic events. Regular buildings, by contrast, show better energy dissipation and structural stability. The study emphasizes the importance of uniform mass and stiffness distribution in seismic design. Ultimately, they conclude that vertical irregularities must be carefully addressed to ensure safety and resilience in earthquake-prone zones.

3. **B Sri Kalyan1 et al., (Mar-Apr-2025)** This study evaluates how irregularities in building structures affect their seismic performance using E-TABS software. The authors model various irregular building configurations to assess their behavior under seismic loads, focusing on parameters like storey drift, displacement, and base shear

4. **Shaik Akbar Vali1 et.al., (2024)** This study explores how vertical genetic irregularities affect the seismic performance of reinforced concrete buildings using ETABS software. The authors, Shaik Akbar Vali, S. Sekhar, and Maddikera Lokanath Reddy, model both regular and vertically irregular buildings to assess their behavior under seismic loads. The analysis is conducted in accordance with IS 1893:2002, focusing on parameters such as storey displacement, drift, base shear, and time period. The results indicate that vertically irregular buildings exhibit greater lateral displacements and inter-storey drifts, especially at the points of irregularity. These irregularities disrupt the uniform distribution of mass and stiffness, leading to stress concentrations and potential failure zones during earthquakes.

5. **Vamsi Jagannath Bankuru and B. Krishna Naik (2022)** The analysis reveals that such configurations are more prone to torsional effects and stress concentrations, especially at re-entrant corners. Despite these challenges, the study demonstrates that with proper design and adherence to seismic codes, irregular buildings can be made safe and functional. The use of STAAD Pro allows for precise modeling and analysis, helping engineers understand the impact of geometry on stability. In conclusion, while irregular shapes pose design complexities, they can be effectively managed through advanced software tools and thoughtful structural planning

6. **Sanjay Sapkota, Sunil Kumar Yadav (2022)** This study analyzes the dynamic behavior of regular and irregular buildings using ETABS software. The authors simulate various structural configurations to evaluate seismic responses under lateral loads. Irregular buildings show higher storey drift and displacement due to uneven mass and stiffness distribution. Regular buildings maintain better stability and energy dissipation during earthquakes. The response spectrum method reveals that irregularities increase vulnerability to torsional effects. Proper design and reinforcement can mitigate these risks in irregular structures. The study concludes that regular buildings are more reliable under seismic conditions, while irregular ones demand careful engineering.

7. **Sahil Khandare, et.al., (2023)** The authors examine the accuracy and reliability of automated analysis versus traditional hand methods in evaluating structural components like beams, columns, slabs, and footings. ETABS provides efficient modeling and rapid results, while manual calculations ensure deeper understanding and validation of design principles. The study highlights discrepancies that may arise due to assumptions or modeling limitations in software. It emphasizes the importance of cross-verification to maintain safety and compliance with IS codes. By integrating both approaches, engineers can achieve more robust and error-free designs. In conclusion, the paper advocates for a hybrid method combining software efficiency with manual precision to enhance structural integrity and design confidence.

8. **Yuvabharathi.G,VenkateswaraRao.P(2020)**
The investigates the seismic response of irregular buildings using linear static analysis in ETABS. The authors model structural irregularities to assess their impact on displacement, drift, and base shear under earthquake loads. The analysis reveals that irregular buildings exhibit higher vulnerability due to uneven force distribution, leading to the conclusion that careful design and reinforcement are essential to ensure seismic safety.

9. **Siva Naveen, et al., (2019)** This study examines the seismic performance of irregular structures subjected to earthquake loads using analytical methods. The authors focus on how geometric and mass irregularities influence structural responses like displacement and base shear. They conclude that irregularities significantly increase vulnerability during seismic events, emphasizing the need for careful design and detailing to enhance structural resilience.

10. **Chethana1, Sowmya K B (2018)** this study explores the impact of shear wall placement on the seismic performance of regular and irregular buildings using ETABS. Chethana and Sowmya K B analyze various configurations to assess parameters like storey drift, displacement, and base shear. The results conclude that optimal shear wall positioning significantly enhances structural stability, especially in irregular buildings, improving their resistance to earthquake forces.

11. **Anil Mitkar, H. Hararwala (2025)** the examines how the placement of shear walls affects the seismic behavior of irregular structures. The study analyzes various

configurations to understand changes in displacement, drift, and structural stability. It concludes that strategically altering shear wall locations can significantly improve the performance of irregular buildings under earthquake loads.

12. **Jain Pritam Anil, Vaibhav. V. Shelar(2020)** The analyzes the impact of vertical and horizontal irregularities on building performance under earthquake loads. Jain Pritam Anil and Vaibhav V. Shelar highlight how asymmetry in mass and stiffness affects seismic response, increasing drift and stress concentrations. The study concludes that irregular structures require enhanced design strategies to ensure safety and compliance in seismic zones.
13. **Varsha Kare ,et al.,(2018)** They investigated the seismic response of 3D building frames with strap footings while incorporating soil-structure interaction (SSI). They challenged the conventional assumption of fixed-base structures by modeling soil flexibility using two SSI approaches: spring stiffness replacement and full soil mass modeling. The study used dynamic analysis to evaluate how strap footings influence load distribution and structural behavior during earthquakes. Results showed that SSI significantly alters internal forces, moments, and displacements compared to fixed-base models. Strap footings helped reduce differential settlement and improved load sharing between columns. The elastic continuum method provided more realistic results than the equivalent static method. They concluded that incorporating SSI and strap footing design leads to safer and more accurate seismic performance predictions for real-world structures

III.METHOD OF ANALYSIS

seismic analysis: Seismic analysis is one of the major tools in earthquake engineering which is mainly used to understand the seismic response of structure. In the past the buildings were designed only for the gravity. seismic analysis is a recent development. It is a component of structural analysis and structural design in regions where earthquakes are widespread. There are various methods for evaluating earthquakes. Some of them were used in the project are as follows

1. **Response spectrum method:** Multiple modes of vibration of a structure can be used in this concept. This analysis can be applied in numerous building regulations for all constructions except simple & complex structures. The vibration of a building is defined as the combination of many various modes that correspond to "harmonics" in a vibrating string. Employing computer-aided structural analysis, various mode shapes for the structure are generated. For each mode shape, design spectrum responses are evaluated, using characteristics such as modal participation mass and modal frequency, and then they are combined to produce an evaluation of the structure's total responses.
2. **Time history analysis**:

This is referred to as Time history analysis. It is a key technique for seismic structural analysis, especially when the assessed structural response is nonlinear. To execute such a study, a structure being analyzed must have a representative earthquake time history. Time history analysis is a step-by-step investigation of the time-varying dynamic response of a structure to a specific loading. Employing time history analysis, the seismic response of a structure under the dynamic loading of a representative earthquake is calculated.

IV.METHODOLOGY

Overview

The seismic response of reinforced concrete frame structures with different configurations is evaluated using numerical simulation. The modeling and analysis are performed using a finite element software package (ETABS). All regular and irregular frame configurations are analyzed with the same procedure, ensuring consistency in comparison and validation.

Software & Modelling Tool

- The modelling and analysis are carried out in ETABS, a finite-element based structural analysis & design software.
- The analytical model is created by defining frame geometry, assigning material and section properties, applying loads, performing dynamic analysis, and retrieving response outputs.

Inputs & Parameters

Parameter	Value / Description
Geometry	Frame configuration (storeys, bays, column positions), number of stories, dimensions of columns and beams
Mass distribution	Total mass at each floor level assigned as lumped/semi-lumped mass
Material properties	Modulus of elasticity = **20,000 MPa** (for concrete or steel as appropriate)
Damping	Rayleigh damping with damping ratio = **4 %**
Initial Conditions	Structure is assumed to be at rest before load application (initial displacements / velocities = zero)
Earthquake Load	Seismic data (ground motion input / design spectrum / time history as applicable)

Analysis Procedure

1.Model creation

- Create the structural layout (grid, members, stories, bays) in ETABS.
- Define cross-sectional properties (column / beam sizes), material assignments.
- Assign mass to floor levels (dead + live / any super-imposed mass as per design assumptions).

2.Defining Material & Damping

- Set material modulus of elasticity = 20,000 MPa.
- Apply damping via Rayleigh-type damping in ETABS to achieve 4 % modal damping.

3.Loading & Dynamic Input

- Apply seismic loads (either response spectrum, code spectrum, or ground motion time-history).
- Ensure that the ground motion input is appropriate for location / seismic zone.

4.Analysis

- Run dynamic analysis / response spectrum analysis / time-history analysis (depending on your study).
- Store outputs such as story-wise displacements, story drifts, base shear, overturning moments.

5.Validation

- For regular (benchmark) configurations, compare the ETABS-obtained results with published results in literature to check correctness.
- Once validated, use same modelling approach for irregular/ variant configurations to carry out comparative analysis.

6.Post-Processing & Interpretation

- Extract outputs: storey displacement & drift profiles, base shear values, overturning moment diagrams.
- Compare across configurations to understand the effect of irregularities on seismic behaviour.

Future Scope of Earthquake-Resistant Design for Irregular Structures

Irregular structures:those with asymmetry in plan or elevation pose special challenges in seismic regions. As urban architecture becomes more intricate, ensuring earthquake resistance in such buildings is increasingly important. The following directions offer potential areas for further research and innovation:

- Advanced Modelling & Simulation Techniques
- Smart Materials & Adaptive Control Systems
- Performance-Based & Risk-Informed Design
- Retrofitting & Resilient Urban Planning
- Sustainability, Multi-Hazard & Integrated Safety Design

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