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Reviewing of Seismic Analysis of Multi Story Building on Sloping Ground and Flat Ground by Using ETABS

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Abstract**: Using ETABS software and a variety of analytical techniques, this review paper investigates the seismic performance of high-rise structures with irregular shapes and vertical irregularities. The evaluated research examines regular and irregular models with vertical, plan, stiffness, and mass irregularities, as well as various configurations, such as H, O, and L-shaped structures. In accordance with IS: 1893-2016recommendations, linear static, linear dynamic, response spectrum, and time history studies are used to analyze buildings with 5, 10, and 15 stories that are located in various seismic zones and soil conditions. Important conclusions show that irregular structures draw greater seismic pressures, which causes stress concentrations and makes them more vulnerable. Soft story irregularities revealed considerable inter-story drift and damage, while H-shaped buildings performed better, particularly in lower-rise combinations. Research also emphasizes the impact of shear stresses, bending moments, and mass transfer, especially in O-shaped structures. Furthermore, it has been demonstrated that applying energy dissipation devices—like fluid viscous dampers—improves earthquake resilience. The review highlights the need of implementing advanced design solutions to prevent earthquake-induced damage and the need for dynamic analysis for irregular buildings to enable accurate performance assessment.**

Keywords**: Seismic analysis, Irregular structures, ETABS, Response spectrum, Time history, Story drift, Base shear, Modal analysis, Pushover, Dynamic response.**

1. Introduction

Overview of earthquakes: They are the most dangerous and devastating natural disasters, making it extremely difficult to preserve life and engineering structures. We must assess the seismic performance of the structures using a variety of analytical techniques to make sure they can endure sporadic small earthquakes and take the necessary safety measures in the event of a tragedy. Overview

A. Overview of Earthquakes

A building's ability to withstand seismic activity is contingent upon a number of elements, including enough lateral strength, stiffness, flexibility, and a straightforward, consistent design. Snow load, living load, and dead load are often utilized loads for gravitational effects.

Compared to a structure with an irregular layout, one with orderly geometry and uniformly distributed stiffness and mass in elevation and plan sustains far less damage. Because the building's bulk, stiffness, and strength all exhibit structural anomalies.

The part of the building that withstands seismic forces is called a lateral force resisting system (L.F.R.S.). Shear walls, frame-shear wall dual systems, and unique moment resisting systems are some of the various types of lateral force resisting systems that are frequently utilized in constructions.

14 computer-based software apps created by various software businesses can be used to solve problems more successfully. ETABS represents the extended three-dimensional assessment of a building. Indeed, it is a design-focused computer tool made especially for analyzing multi-story buildings.

ETABS analyzes complex high-rise systems rapidly using advanced numerical techniques. Steel frames, reinforced concrete frames, composite beams and columns, steel joists, and shear walls can all be designed with ETABS.

Irregularities in buildings causes eccentricity between the building mass and stiffness centers, give rise to damaging effect on building.

The safety and stability of structures, especially those with irregular configurations, are seriously threatened by earthquakes. Planar or elevational structural imperfections can result in a concentration of loads and dynamic reactions that are very different from those found in regular structures. These anomalies could cause partial or complete collapse due to poor performance during seismic events.

In modern structural engineering, irregular frame structures are increasingly common due to architectural and functional requirements. However, their complex dynamic behavior demands careful seismic analysis. Traditional hand calculations and simplified methods are often insufficient to predict the real-time response of such buildings under earthquake loads.

ETABS (Extended 3D Analysis of Building Systems), a powerful finite element software developed by Computers and Structures, Inc. (CSI), offers a comprehensive platform for

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modeling, analyzing, and designing structures under various loading conditions, including earthquakes. With its advanced capabilities like response spectrum analysis, time history analysis, and pushover analysis, ETABS enables engineers to study the seismic response of irregular structures with high precision.

This study focuses on evaluating the seismic performance of irregular frame structures using ETABS. The analysis considers different types of irregularities as defined in major seismic codes and examines their impact on key parameters such as story drift, base shear, natural period, and mode shapes. The goal is to provide insights into how irregularities influence structural behavior during earthquakes and to highlight the importance of accurate modeling and dynamic analysis in earthquake-resistant design

1. Krishna Prasad Chaudhary, Ankit Mahajan 2021: They studied on Response spectrum analysis of irregular shaped high rise buildings under combined effect of plan and vertical irregularity using csi etabs .- :In this research work several high rise buildings were analyzed using CSI ETABS under the influence of the response spectrum analysis over it. Several different shaped high rise buildings such as H shaped, O shaped and C shaped buildings were taken into consideration for carrying out the research work.
2. K Veera Babu, S Siva Rama Krishna, Venu Malagavelli, 2022: They studied on 'Seismic analysis of Multi storey Building on Sloping Ground and Flat Ground by using ETABS' (2022). Due to urbanization and industrialization, which paved the door for the development of tall, multi-story structures on mountainous terrain, land is scarce in emerging nations like India. Buildings built on hilly terrain differ from those built on flat terrain due of their uneven and asymmetrical vertical and horizontal structures. These buildings are also significantly more vulnerable to earthquake pressures when located in mountainous terrain. On Flat ground, setback building attracts less action forces as comparing with other configurations on sloping ground which make it more stable and it would not tolerate more damages due to the lateral load action
3. Yash Chhatani, Prashant Y Pawade, Kuldeep R. Dabhekar, Isha P Khedikar, 2021: They studied on 'Seismic Analysis of Plan Regular and Irregular Buildings' The patterns of sporadic structure development have quickly expanded because of tasteful and restricted accessibility of land. Past examinations have indicated that the structures with design abnormality are harmed under solid ground movement. Auxiliary inconsistencies are significant elements which decline the seismic exhibition of the structures. Structures having basic anomalies bring about the lopsided circulation of the story float, exorbitant twist, etc. The irregularity discussed here are about plan irregularity which is available in re-participant corners and torsional anomaly which is caused by abrupt changes in firmness and twist enhancement factor in building
4. P. Prashanthkumar, A. Jyothirmai, They studied on 'Seismic studies on energy dissipation device performance for irregular steel structure in different soil conditions using ETABS' 2023. Earthquakes are sudden loads that occur and cause low to severe damage to the structure. Based on the intensity of an earthquake, the zones are divided into II, III, IV and V as per IS code 1893:2016(Part-1). Regular, Stiffness Irregular and Mass Irregular G+7 steel building is designed for four zones in ETABS software. Linear Static and Linear Dynamic analyses are performed on all zones for different conditions of soils. In this work, a steel G+7 storeyed structure is developed in ETABS and subjected to seismic loading.
5. Anjeet Singh Chauhan, Rajiv Banerjee, 2021: They studied on 'Seismic Analysis of Irregular Building on Hilly Area' 2021 The RC buildings' construction has increased in the preferred location of north & eastern hilly areas during the last few decades due to population increase, urbanization, and tourists. The buildings located in the hilly areas are more susceptible to seismic loading as compared to the location of the flat surface building. The shape of the building on the sloping ground differs from the flat surface situated buildings. So, the construction of the building on hilly areas are irregular both vertically & horizontally, thus this type of building is susceptible to severe damage when applied to the seismic condition.
6. Nadeem Hussain, M. Shahria Alam, Aman Mwafy, 2024. They studied on 'Seismic design coefficients verification of regular and vertically irregular high-rise shear wall buildings using bidirectional horizontal ground motions and 3D modeling' (2024)- Recommended seismic design coefficients in design codes were based on previous research primarily on regular low- to medium-rise building configurations using two-dimensional analysis. Thus, the present study addresses these limitations by validating these design coefficients for high-rise buildings, considering different heights, structural systems, and irregularities using three-dimensional (3D) dynamic response simulation and bidirec tional earthquake records.
7. M. T. Raagavi, S. Siddhartha: They studied on 'A Study on Seismic Performance of Various Irregular Structures' The buildings constructed in the present scenario are mostly irregular in geometry and elevation for aesthetic view. These irregularities may also be due to economical feasibility, land availability and other factors. From the past earthquake, researches says that regularly configured structures stay safe in Earthquakes, but irregularly configured structures could not able to withstand effectively during an earthquake. Structures experience lateral deflections under earthquake loads.
8. Xun Zhang, he studied on 'Design optimization of

irregularity RC structure based on ANN-PSO'(2024) Seismic design principles advocate for simple and regular structures to minimize earthquake damage. However, this frequently does not lead to unique and aesthetically pleasing designs, leading some engineers to select irregular structures despite the potential risks. The primary aim of this investigation is to achieve the optimal design of torsional irregularity coefficients for planar irregular reinforced concrete (RC) frames under static and dynamic loads, utilizing a 3D 6- layer model. Structural ground vibration analysis was conducted using the ETABS software.

9. Sujeet Patil, Pooja Matnalli, Priyanka S. V., Rooparani, Rajamma: They studied on 'Seismic Analysis of Plan Regular and Irregular Buildings, 2019: Reinforced concrete structures are mostly used in India since this is the most convenient and economic system for low rise buildings. However, for medium to high rise building this type of structure is no longer economic because of increases dead load, less stiffness, span restriction. So the structural engineers are facing the challenge of striving for the most efficient and economic design solution.
10. Arvind reddy, R. J. Fernandes: They studied on 'Seismic analysis of RC regular and irregular frame structures', 2015. Reinforced concrete multi storey buildings are subjected to most dangerous earthquakes. It was found that main reason for failure of RC building is irregularity in its plan dimension and its lateral force resisting system. this paper an analytical study is made to find response of different regular and irregular structures located in severe zone V. Analysis has been made by taking 15 storey building by static and dynamic methods using ETABS 2013 and IS code 1893-2002 (part1). Linear Equivalent Static analysis is performed for regular buildings up 90m height in zone I and II, Dynamic Analysis should be performed for regular and irregular buildings in zone IV and V. Dynamic Analysis can take the form of a dynamic Time History Analysis or a linear Response Spectrum Analysis. Behaviour of structures will be found by comparing responses in the form of storey displacement for regular and irregular structures

2. Aim

Using ETABS software, the study's objective is to assess and analyze the seismic response of irregular frame structures. It focuses on how different structural irregularities, both in plan and elevation, affect important seismic performance metrics like story drift, base shear, mode shapes, and natural period. Understanding how these abnormalities affect dynamic behavior under earthquake stress and showcasing how well ETABS models and evaluates seismic performance in intricate structural systems are the goals.

1. To analyze the seismic performance of irregular frame structures using ETABS software.
2. To study the effect of different irregularities (plan, vertical, or mass irregularities) on the dynamic behavior of structures.
3. To evaluate key seismic parameters such as displacement, base shear, storey drift, and time period.
4. To compare the performance of regular vs. irregular structures under seismic loading.
5. To identify critical structural elements that are most affected by irregularities during seismic events.
6. To assess the compliance of irregular frame structures with relevant seismic design codes (e.g., IS 1893, UBC, IBC).
7. To optimize structural design by recommending modifications to improve seismic resilience.
8. To validate modeling techniques and response analysis methods in ETABS for real-world applications.
9. To enhance safety and performance of irregular structures in seismic zones through analytical insights.

3. Objectives

1. To use response spectrum analysis to compare the seismic performance of high-rise buildings with different shapes (H, O, and C) under earthquake loads [Response spectrum analysis of irregular shaped high-rise buildings under combined effect of plan and vertical irregularity using csi etabs].
2. To study the performance of various building forms subjected to earthquake loadings and assess the seismic response of irregular buildings taking vertical abnormalities into consideration [Evaluation of Seismic Response of Irregular Buildings:
   A study] current approaches will be highlighted, and potential areas for future research will be discussed.
3. To evaluate, using ETABS, how energy dissipation devices affect the seismic performance of irregular steel structures under various soil conditions. [Using ETABS, seismic investigations on the performance of energy dissipation devices for irregular steel structures in various soil conditions.
4. To examine the displacement and shear force responses of regular and irregular frame structures under different loading scenarios and compare their seismic behaviour. RC regular and irregular frame structures: seismic analysis.
5. To ascertain the efficacy of various analysis techniques and examine the structural behaviour of G+14 multistorey buildings with irregular plans under seismic loading. Regular and irregular plan buildings: seismic analysis

4. Problem Statement

The lateral displacement of a floor relative to the floor below, known as storey drift, along with the storey drift ratio—calculated as the product of storey drift and storey height—are critical parameters in assessing structural performance during seismic events. Structures built on sloped or inclined ground face a significantly higher risk of damage when subjected to seismic forces. Furthermore, irregularities in a building's stiffness, strength, and mass distribution can cause severe structural deterioration or collapse during earthquakes. Specifically, mass irregularities can lead to eccentricities between the centers of mass and stiffness, resulting in harmful torsional effects. Sudden changes in geometry, mass, or stiffness amplify these vulnerabilities, making irregular structures more susceptible to failure due to uneven load distribution and stress concentrations. Despite advances in structural analysis software, accurately predicting the seismic response of such irregular frames remains a challenge for engineers. This study seeks to address these issues by analyzing and understanding the seismic behavior of various irregular frame structures using ETABS, a robust structural analysis and design tool. By simulating different irregular configurations and comparing their seismic responses with those of regular structures, the research aims to identify the most vulnerable cases and provide valuable insights for designing safer, more resilient buildings in earthquake-prone areas.

5. Research Methodology

This study aims to examine the impact of irregular plan arrangement on a model of a multistorey reinforced concrete building. The examination of a multistorey building (G+14) with an irregular layout is the primary focus of this project. The ETABs 2022 software will be used to model and analyze a 15-story R.C.C. building.

We are examination of structures like Base Shear, Storey Drift, and Maximum Storey Displacement.

Praveen J V, Sanjith J, Ranjith A, Likhitharadhya Y R, et al. Although buildings are usually constructed on flat terrain, construction has started on slopes due to the scarcity of level land.

1. The study uses pushover analysis to determine seismic susceptibility and lateral load analysis in compliance with seismic codes to evaluate the effects of seismic loads [1].
2. To ascertain the impacts of a concrete shear wall in different earthquake-prone zones, a 3D analytical model of an eight-story structure was analyzed using ETabs.
3. In accordance with IS:1893 (part 1): 2002, the study uses reaction spectrum studies to perform seismic analysis.
4. To assess their seismic performance, a variety of models were examined, including those with mass imperfections and various plan forms.
5. There are two distinct construction designs for sloping land: step back and step back setback. A G+ ten-story RCC building with a ground slope between 100 and 300 was considered in this study. It has been likened to a building that is situated on flat ground. Studies of literature: The results included top storey displacement, storey acceleration, base shear, and mode period. Short columns may be more adversely affected by earthquakes. To determine the seismic demands, pushover analysis was done using various lateral load instances in all three directions. various components that collectively inform the analysis and synthesis of the literature.

6. Conclusion

This paper presented a review of seismic analysis of multi-story building on sloping ground and flat ground by using ETABS.

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