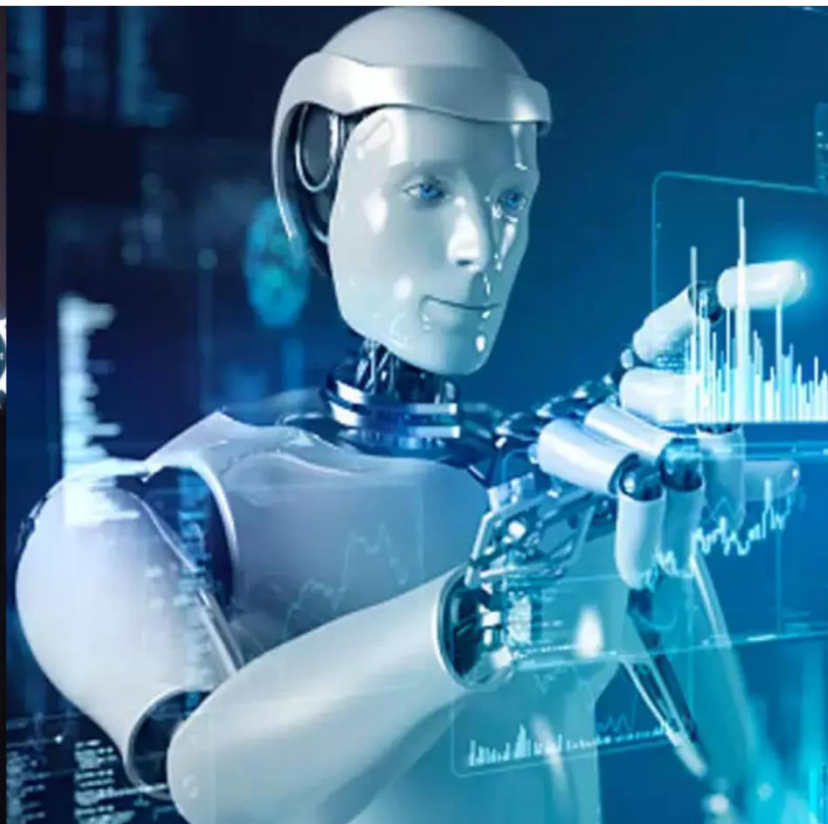




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# Structural Assessment of Regular and Irregular Building Designs: A Review

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**ABSTRACT:** The structural configuration of a building whether regular or irregular plays a crucial role in its behavior under lateral loads such as wind and seismic forces. Regular buildings, with uniform mass and stiffness distributions, typically exhibit predictable and uniform responses. In contrast, irregular buildings, characterized by asymmetry in plan or elevation, tend to experience stress concentrations, torsional effects, and amplified displacements, making their structural assessment more complex and crucial. This review paper synthesizes recent developments in the analysis, modeling, and performance evaluation of regular and irregular structures. Key methodologies such as linear and nonlinear static analysis, time-history analysis, and performance-based design frameworks are examined. The review highlights that while simplified models suffice for regular structures, irregular buildings demand more advanced assessment tools and careful design considerations. Despite progress, significant research gaps persist, including limited consideration of soil-structure interaction, multi-hazard scenarios, and non-structural components. Future work should focus on integrated analytical models, digital twin technologies, and AI-driven predictive frameworks to enhance the resilience of irregular structures. This review underscores the need for updated design guidelines tailored specifically for irregular configurations, especially in high-risk seismic zones.

**KEYWORDS:** Seismic analysis, Mass irregularity, Etabs 17, Story and base shear plots

## I. INTRODUCTION

The structural integrity and performance of buildings are highly influenced by their geometric configuration and distribution of mass and stiffness. Buildings are generally categorized as regular or irregular based on the uniformity of their plan and elevation features. Regular buildings possess a symmetrical and uniform layout, resulting in a more predictable and efficient load path during lateral forces such as wind or earthquakes. In contrast, irregular buildings—characterized by discontinuities in mass, stiffness, or geometry—exhibit complex and often unpredictable responses under dynamic loading conditions, leading to increased vulnerability (Chopra, 2012). The increasing architectural demand for innovative and asymmetric structures has made the study of irregular buildings crucial, especially in seismic-prone regions. Studies have shown that irregularities in building design, especially in plan and elevation, can cause significant amplification of seismic forces, stress concentrations, and torsional effects (Habibi & Asadi, 2014). As a result, modern seismic codes such as IS 1893:2016 and FEMA 451B (2006) emphasize rigorous analysis methods, such as pushover and time-history analysis, for the accurate structural assessment of irregular buildings. This study aims to explore the differences in performance between regular and irregular buildings under lateral loads, highlighting the critical role of structural assessment in improving safety, serviceability, and design optimization.

## II. LITERATURE REVIEW

**Haque Mahi et al. BNBC 2020 Analysis – Plan Irregularity (Mar 2025)** compared 7 plan forms— including regular rectangle/square vs irregular T, U, W, H, L shapes—under BNBC 2020 seismic code using ETABS with ESFP. They observed markedly higher lateral displacement and drift in irregular designs, especially above seven stories. ResearchGate.

**Paudel et al. Nepal (2024)** Seismic Vulnerability in Vertical Irregularities – analyzed 2- and 3-story RCC buildings—both regular and vertically irregular—in Nepal using pushover and time-history analyses. They quantified increased seismic risk: failure probability rose from 1.8% to 5.7% in non-engineered irregular buildings. MDPI+10SpringerLink+10Journal UMY+10Jurnal Universitas Gadjah Mada.

**Santos, Melo & Varum Eurocode 8 Framework – Elevation Irregularity (2024)** conducted extensive analysis using five-storey moment-resisting frames per Eurocode 8. They found elevation irregularities (varying storey heights, column sizes) significantly elevate inter-storey drift and base shear. MDPI+1SpringerLink+1.

**Elnish Fiqhunissa et al. Auditorium with Torsional Irregularity – ASCE 41-23 (Sept 2024)** evaluated an irregular auditorium (with cantilevers, inclined/transfer configurations) using Tier-3 linear dynamic (RSA & LTHA). While torsional irregularity flagged some component failures, overall performance met IO/LS targets—though max performance didn't fully satisfy criteria.

**Md. Sabbir Hossain, S.K. Singh (2022)** The earthquake is the most devastating and unexpected natural phenomenon, causing massive damage to both human lives and infrastructure. In this study, two different irregulars Reinforced Cement Concrete (RCC) building plans of 25th story buildings with the ground floor (G+25) and 9th storey buildings with the ground floor (G+9) were subjected to four different zones making a total of eight model structures to test their ability to withstand gravity and seismic loads. The design was response spectrum method (RSM) then subjected to an earthquake load in accordance with Indian Standard (IS) 1893.

### 2.1 Linear Static Analysis

Linear static analysis, also known as the Equivalent Lateral Force (ELF) method, is one of the most fundamental procedures for evaluating structural response under seismic loading. It is primarily suitable for regular, low- to mid-rise buildings located in low to moderate seismic zones, where dynamic effects are minimal and structural symmetry ensures uniform load distribution. This method simplifies the seismic assessment by applying a lateral force distribution based on the building's mass and height, assuming linear elastic behavior. For regular buildings, this approach can provide reasonably accurate estimations of internal forces, base shear, and story drifts (IS 1893:2016). However, in the case of irregular buildings, this method has notable limitations. Irregularities in mass, stiffness, or geometry introduce torsional responses and localized stress concentrations, which the linear static method does not effectively capture. According to Chopra (2012), linear static analysis may underestimate displacement demands and internal forces in such structures, leading to unconservative design assumptions. Thus, for buildings with significant plan or vertical irregularities, it is recommended to adopt dynamic analysis methods—such as response spectrum or time-history analysis—for more accurate and realistic assessment.

### 2.2 Nonlinear Static (Pushover) Analysis

Nonlinear static analysis, commonly known as pushover analysis, is a performance-based evaluation method used to assess the structural capacity of buildings under lateral loads. Unlike linear methods, pushover analysis captures material nonlinearity, enabling the identification of plastic hinge formations, sequential member failures, and post-elastic behavior of a structure. In this method, a building model is subjected to incrementally increasing lateral loads (representing seismic forces) until a target displacement is reached. This process generates a capacity curve (base shear vs. roof displacement), which provides valuable insight into the structural performance levels—such as immediate occupancy, life safety, and collapse prevention (FEMA 356, 2000). Pushover analysis provides insight into performance levels (IO, LS, CP) for both regular and irregular structures. However, it is less accurate for higher-mode dominated systems or those with severe irregularities.

### 2.3 Nonlinear Dynamic Time-History Analysis

This method offers the most accurate predictions, particularly for highly irregular buildings subjected to site-specific ground motions (Krawinkler, 2001).

### III. NATIONAL AND INTERNATIONAL SCENARIO

Several case studies in recent years have provided valuable insights into the structural performance of regular and irregular buildings, particularly under seismic and wind loading conditions. In a comparative study conducted by Kumar et al. (2021), a pushover analysis was performed on G+9 RC frame structures with vertical irregularities such as soft stories and mass irregularity. The results indicated that irregular buildings experienced higher inter-story drift and base shear values than regular configurations, highlighting their vulnerability during seismic events. Karthika and Prabhavathy (2017) analyzed different plan irregular building shapes (L, U, T, and H-types) and compared them with regular rectangular buildings. Using linear dynamic analysis in ETABS software, they found that L- and U-shaped buildings exhibited maximum lateral displacement and storey drift, indicating a need for additional seismic reinforcement in such geometries. A notable case study by Habibi and Asadi (2014) involved nonlinear time-history analysis of torsionally irregular RC buildings subjected to bi-directional ground motion. Their findings revealed concentration of damage at the corners of irregular plans, with significantly increased torsional rotation compared to regular layouts. In the field of wind engineering, Huang et al. (2007) conducted a wind tunnel study on high-rise buildings with irregular geometries. Their investigation showed that buildings with sharp corners and irregular setbacks had higher wind-induced torsional responses, affecting occupant comfort and structural safety.

Table - Feature	Regular Buildings	Irregular Buildings
Load Distribution	Uniform and predictable	Complex with stress concentrations
Torsional Behavior	Minimal	Significant, especially in plan irregularity
Analysis Simplicity	Suitable for linear/static analysis	Requires nonlinear/dynamic methods
Code Compliance	Easily satisfies basic code provisions	Needs advanced compliance checks
Collapse Risk	Lower under lateral loading	Higher under seismic/wind loads

These case studies emphasize the importance of accounting for irregularities in both design and assessment stages. While modern analysis tools can predict the behavior of complex structures, irregular buildings consistently show a greater demand for detailed structural evaluation and performance-based design approaches.

Banerjee (2025) presents a compelling review of AI-enabled structural evaluation techniques in irregular medical facilities. While the primary focus is on healthcare infrastructure, the study highlights adaptable AI methods—such as machine learning and anomaly detection—that can be applied to various irregular structural forms. The paper contributes to advancing intelligent structural health monitoring in complex building geometries. However, it could be strengthened by including broader case studies beyond the healthcare domain and addressing data governance issues more thoroughly. Polizzi (2024) delivers an engaging exploration of how ancient civilizations ingeniously integrated water into the structural and aesthetic fabric of irregular architecture. The paper, *Solonte et l'eau: Structural Use of Water in Ancient Architecture*, provides rich archaeological evidence—drawn from sites like Solonte—demonstrating innovative water management techniques that shaped and stabilized unconventional building forms. Polizzi's work deepens our understanding of the interplay between natural environments and architectural ingenuity in the ancient world, though it might benefit from further comparative analysis across different regions. The paper by Sanghai and Ninawe (2025) investigates the use of base isolation systems in reinforced concrete (RCC) buildings that exhibit mass and plan irregularities. The study highlights how conventional seismic design strategies may fall short in such irregular configurations due to uneven force distribution and stress concentrations. Through dynamic analysis using the Time History Method in SAP2000, the authors demonstrate that base-isolation techniques significantly reduce base shear and floor acceleration, leading to better seismic performance and enhanced occupant safety. The study provides valuable insights for structural engineers dealing with irregular urban structures in seismic zones. Verma and Jain (2017) conducted a comparative study using ETABS to analyze the seismic performance of G+10 RCC buildings with varying plan and vertical irregularities. Their findings revealed that irregular buildings experienced significantly higher lateral displacements and inter-story drifts—up to 40% more than their regular counterparts. This study highlights the critical impact of structural irregularities on seismic response and underscores the need for special design considerations in irregular configurations.

## IV. CONCLUSION

The structural performance of a building is highly influenced by its geometric configuration. Regular buildings, due to their symmetry and uniformity, show better seismic and structural performance. Irregular buildings, while often architecturally necessary, demand more comprehensive assessment and specialized retrofitting strategies. Adoption of advanced modeling techniques, adherence to seismic codes, and continuous innovation in materials and methods are essential for improving the safety of such structures.

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