COMPARATIVE STUDY OF SEISMIC ANALYSIS OF VERTICALLY IRREGULAR R.C. FRAME USING INDIAN AND EURO CODE

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Abstract –

This study explores the impact of various International Standard Codes on the durability, stability, and safety of buildings through dynamic structural analysis. This study meticulously compares the design outcomes influenced by Eurocode 8 and the Indian Standard Code IS 1893:2016, shedding light on their distinct structural characteristics and implications for building design. Key findings include a significant increase in design base shear by up to 67% when employing Eurocode 8 over IS 1893, leading to higher story displacement, particularly at the top of the building, and a marked increase in story drift by up to 65%. Despite these differences, the analysis revealed that the Indian Code yields better structural factor values, indicating superior structural criteria and safety. Notably, the first story experiences the most drift under both codes, with the Indian Standard demonstrating performance within allowable limits for building parameters across spectrum load cases. This comparison highlighted the importance of selecting appropriate standard codes to enhance the structural integrity and safety of buildings in various geographical contexts.

Keywords: **Dynamic structural analysis, IS 1893:2016, Eurocode8 Response reduction factors, Structural safety, Storey drift, Design base shear**

1. INTRODUCTION

In India, seismic activity threatens more than half of the geographical area, underscoring the critical need for earthquake-resistant construction. Historical data have revealed that buildings with structural anomalies are particularly susceptible to seismic damage. This necessitates a comprehensive understanding of the seismic response of a structure, particularly in low seismic zones, to mitigate structural failures. Irregular construction, characterized by discontinuities in mass, stiffness, and geometric configuration, presents significant challenges in achieving seismic resilience. These irregularities, often resulting from architectural demands or functional requirements, can lead to adverse lateral and torsional responses during earthquakes, making a detailed structural analysis imperative. This study focused on the impact of vertical irregularities, such as soft stories and setbacks, on a building's seismic performance by employing a probabilistic approach to evaluate the relative performance of common vertically irregular structures. With urban infrastructure increasingly featuring such designs, understanding and addressing these vulnerabilities are paramount for enhancing earthquake preparedness and structural safety.

2. OBJECTIVE OF STUDY

1. Investigate and assimilate diverse specifications and recommendations encapsulated within both national and international building codes, with a particular focus on Indian and European standards.

2. Execute dynamic computational analyses of a 23-story building exhibiting vertical irregularities, employing methodologies outlined in both Indian and Eurocode standards.

3. The ETABS 2016 software was used to conduct Response Spectrum Analysis (RSA) or Dynamic Analysis on various models designed with Vertical Geometric irregularities to thoroughly understand the structural responses.

4. A detailed comparative evaluation of the outcomes derived from critical parameters such as displacement, base shear, story displacement, and story drift during seismic events, considering structures with comparable irregularities and geographic specifications under both coding standards.

3. LITERATURE REVIEW

Our planet hosts many natural calamities, among which earthquakes stand out as particularly perilous, inflicting profound social and economic impacts. The ability of earthquakes to devastate infrastructure and essential services is alarming. Consequently, significant destruction, mortality, and property loss following such tremors have prompted scholars to reconsider architectural and engineering designs. Current demands for architectural aesthetics and functionality often lead to structures with various irregularities. This section focuses on the effects of vertical irregularities in buildings subjected to seismic forces.

2.2 BUILDINGS WITH VERTICAL IRREGULARITIES

Structural irregularities are categorized as plan and vertical irregularities. Plan irregularity arises from various factors, including torsional effects or discontinuities in the horizontal load-resisting mechanisms of a building. Vertical irregularity is observed when significant differences occur in the stiffness, strength, mass, dimensions, or discontinuities of the structure in its vertical load-resisting framework. There were five primary types of vertical irregularities.

1.Stiffness irregularity

2.Geometric irregularity in the vertical plane

3.Mass irregularity

4.Discontinuity within vertical elements that resist lateral forces

5.Strength irregularity, also known as weak storey irregularity

This study examines how these vertical irregularities affect the seismic behavior of reinforced concrete (RC) moment-resisting frames. The subsequent sections detail the definitions and standards for these irregularities, as outlined in modern seismic design guidelines.

2.3 DEFINING VERTICAL IRREGULARITY STANDARDS IN VARIOUS SEISMIC REGULATIONS

The approach used to identify vertical irregularities across seismic codes is non-uniform. Each code established its own set of guidelines for different types of vertical deformities. The following sections briefly discuss standards for identifying vertical irregularities.

2.3.1 As Defined by IS 1893:2016

Five classifications of vertical irregularities were identified.

a) Stiffness irregularity - soft story: refers to a level where the lateral stiffness is notably lower than the level above.

Illustration 2.1: Stiffness Irregularity [14]

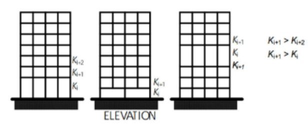


Figure 2.1: Stiffness Irregularity [14]

b) Mass Irregularity: Occurs when the seismic weight of a level surpasses 150 percent of the weight of its adjacent levels. Roofing irregularity is excluded from consideration.

Illustration 2.2: Mass Irregularity [14]

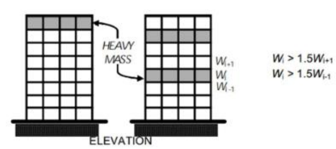


Figure 2.2: Mass Irregularity [14]

c) Vertical Geometric Irregularity: Identified when the horizontal dimension of any level's lateral force resisting system is more than 125 percent of its adjacent level.

Illustration 2.3: Vertical Geometric Irregularity [14]

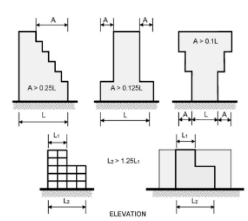
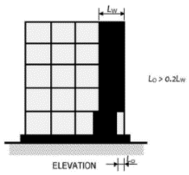


Figure 2.3: Vertical Geometric Irregularity [14]

d) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force: Present when there is an in-plane offset in a lateral force resisting element exceeding 20 percent of its length.

Illustration 2.4: In-Plane Discontinuity [14]



e) Capacity Discontinuity - Weak Storey: A storey is considered weak if its lateral strength is below that of the storey above.

Illustration 2.5: Capacity Discontinuity [14]

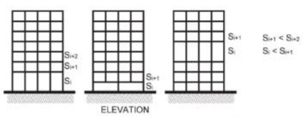


Figure 2.5: Discontinuity in Capacity [14]

2.3.2 As per EC 8

Eurocode 8 introduces criteria for differentiating between "regular" and "irregular" vertical structures, defining irregular structures as those with significant variations in parameters such as mass or strength between adjacent stories. A structure is considered vertically irregular if it satisfies the following conditions:

a) For structures with various setback heights, all lateral load-resisting elements must extend continuously from the base to the top or the respective zone of the building.

b) There must be a consistent or gradually decreasing pattern in the mass and lateral stiffness from the base to the top without abrupt changes.

c) The ratio of actual to required story resistance must not vary significantly among adjacent stories.

Additional criteria for structures with setbacks include the following.

a) Setbacks must not surpass 20 percent of the building's plan dimension in the direction of the setback for symmetrically progressive setbacks, as depicted in Illustrations 2.2(a) and (b).

b) For a single setback located within the lowest 15 percent of the building's height, it must not exceed 50 percent of the prior plan dimensions, as shown in Illustration 2.2(c). The base zone of the building within the projected perimeter of the upper stories should be designed to withstand at least 75 percent of the horizontal shear stress compared with a structure without base enlargement.

c) For asymmetric setbacks, the total setbacks at all levels on each face at the base above the foundation or a rigid basement must not exceed 30 percent of the plan dimension, and individual setbacks should not surpass 10 percent of the previous plan dimension, as shown in Illustration 2.2(d). [8]

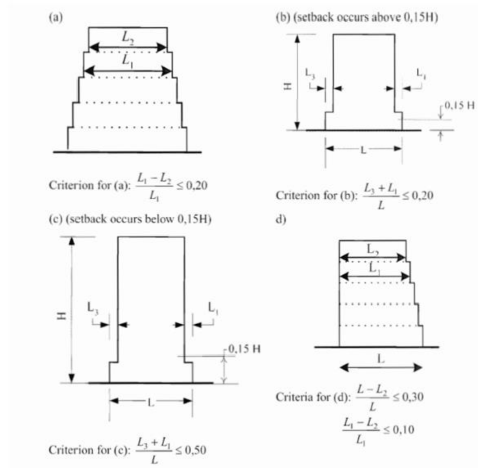


Figure 2.6: Vertical irregularities as per EC 8 [16]

2.4 IMPACT OF VERTICAL IRREGULARITY ON STRUCTURES IN PREVIOUS EARTHQUAKES

"Vertical geometry irregularity in building" refers to the reduction of a structure's lateral dimension along its height. These sorts of structures are favoured in modern multi-story building construction due to their functional and attractive architecture. The key advantages of this sort of structure are that it provides appropriate ventilation and sunlight to the lower levels,according to Sarkar et al (2011). This style of structure also complies with 'floor area ratio' constraints imposed by local building codes. Stepped buildings are used to increase the heights of masonry structures by dispersing the gravity loads generated by construction materials such as bricks and stones. These structures also allow natural erosion to occur without jeopardizing their structural integrity.

More than 1000 people are believed to have died after a huge earthquake jolted towns and villages across South Asia, including numerous villages in Pakistan. In India's Jammu and Kashmir earthquakes, a magnitude 7.6 earthquake killed 157 people. Hundreds of people were believed to have been murdered or trapped in two 12-story apartment buildings in Islamabad, as seen in

The vertical geometry irregularity in building (Time ball Station in Christchurch) at New

Zealand is one of the many buildings and landmarks in the city that has been diminished to ruins because of a 6.3 magnitude earthquake rocked in New Zealand that caused widespread damage and killed at least 65 people. Their fitness is determined by selecting pairs of individuals from the current population, and they are mated by recombination and mutation operators to generate new individuals in place of the least-fit population [70]. This iteration process is continued until it reaches the termination criteria and the maximum number of generations is reached.

2.5 Past studies on vertically irregular building

Recent research on vertically irregular buildings has provided insightful comparisons and analyses of their seismic performances under different international codes. In 2015**, Tapkire and Birajdar** evaluated high-rise buildings using Indian and European standards, revealing significant variations in structural responses owing to different load combinations prescribed by each code. They highlighted the influence of the Response Reduction Factor, noting that the design base shear under IS 1893 tended to be lower than that calculated using Eurocode 8, underlining the importance of simplicity, symmetry, uniformity, and redundancy in earthquake-resistant structures.

Sirisha and Tejaswi's 2019 study further examined multistory buildings using the ETABS 2015 software, emphasizing the impact of bracing on reducing base shear, lateral displacement, and story drift. Their findings suggest that European standards tend to predict higher displacement and story drift compared to Indian codes, pointing towards greater stiffness and resilience against seismic forces when bracing is utilized.

Wagh et al. (2018) compared the seismic behavior across Indian, European, and New Zealand codes for a G+24 structure. Their research identified key factors affecting high-rise building performance during earthquakes, demonstrating lower base shear values according to Indian standards compared to European and New Zealand norms owing to the different Response Reduction Factors employed.

Ravikumar et al.'s 2012 analysis of building models with plan and vertical irregularities used various analytical methods to understand seismic demands. Their work underlined the limitations of static methods and the need for empirical approaches to accurately predict the seismic responses of irregular structures.

Finally, Bhavsar, Choksi, Bhatt, and Shah (2014) analyzed a reinforced concrete building under Indian and Eurocode standards, noting differences in design parameters based on each code's load combinations. Their study indicated a larger permitted story drift under Eurocode 8 than under IS 1893, suggesting a need for a nuanced understanding and application of international seismic standards to enhance structural safety and resilience.

These studies collectively emphasize the critical need for tailored seismic analysis and design approaches that consider the unique challenges posed by vertically irregular structures. They advocate for the nuanced application of international codes to ensure the safety and durability of such buildings in seismic zones.

4. CONCLUSION

This study conducted a comprehensive dynamic analysis of how various structural characteristics affect a building's durability, stability, and safety according to different International Standard Codes. This study's findings provide several key insights.

The Indian code's higher response reduction factors result in significantly lower design base shear values when compared to Eurocode 8 by up to 67%; however, both codes yield similar values for story shear in both the X and Y directions.

Designs based on Eurocode 8 exhibit greater story displacement at the top of the building, escalating with the height of the structure owing to the increased base shear.

Storey drift predicted by Eurocode 8 exceeds that of IS 1893:2016 by up to 65%, highlighting a stark contrast in design outcomes between the two codes.

Upon comparison, structures analyzed under IS 1893:2016 demonstrated superior performance in terms of structural evaluation factors, thereby indicating the Indian Code's enhanced structural criteria and safety measures.

The first story experienced the most drift under both the Indian and Euro codes, emphasizing a critical area for structural reinforcement.

When juxtaposed with Euro Standards, the structures assessed under the Indian code not only exhibited lower values but also remained well within permissible limits for analyzed building parameters against spectrum load cases, showcasing the Indian code's better performance in ensuring structural integrity and safety.

Future Research Directions

This study paves the way for further research, suggesting a deeper comparison between the Indian and Euro Standards. This encourages exploration of the efficacy of Equivalent Static Analysis and Response Spectrum Analysis. Future investigations could extend to employing Pushover Analysis and Time History Analysis, offering a more nuanced understanding of both the plan and vertical irregularities within structures. Additionally, the incorporation of bracings and shear walls presents a promising avenue for enhancing the structural analysis and optimizing building designs to withstand seismic forces.

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