Seismic Analysis of Vertical Setback Irregularity in RCC Building

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Abstract:
Earthquake-resistant design of structures has become a critical aspect in civil engineering due to increasing seismic activities and urbanization. This research focuses on the seismic performance of reinforced cement concrete (RCC) buildings with vertical setback irregularities. Setback structures, where the building geometry changes along height, lead to irregular distribution of mass, stiffness, and strength, making them more vulnerable to seismic forces. In this study, a G+10 storey RCC building is analyzed using the Equivalent Static Method as per IS 1893 (Part 1): 2016. Multiple models with different setback configurations are considered and compared based on parameters such as storey displacement, storey drift, base shear, and torsional effects. The results indicate that vertical irregularities significantly influence seismic behavior and must be carefully considered during design.

Keywords: Earthquake, Seismic analysis, structure performance, torsional stresses, deformation

1. INTRODUCTION

Rapid urban development has led to the construction of complex building structures with irregular geometries. Among these, vertical setback buildings are commonly used due to architectural aesthetics, ventilation benefits, and compliance with urban regulations. However, such irregularities adversely affect the seismic performance of structures. During an earthquake, the response of a building depends on the distribution of mass, stiffness, and strength. Any abrupt change in these parameters results in stress concentration and potential structural failure. Vertical irregularity occurs when there is a sudden change in geometry, stiffness, or mass along the height of the building. Setback buildings are a typical example, where upper storeys are reduced in size compared to lower ones.

Here in this work the seismic behavior of RCC buildings with vertical setback irregularity is carried out. And to compare different setback models (M1 to M6). Identified the most efficient structural configuration and the effect of irregularity on seismic performance.

2. METHODOLOGY

Previous studies have shown that irregular buildings are more vulnerable to earthquake damage compared to regular structures. Researchers observed that sudden variation in stiffness and mass leads to higher seismic forces and damage concentration. Studies using ETABS software demonstrated that setback buildings experience higher displacement and drift. Some research introduced indices like the Geometric Regularity Index (GRI) to evaluate irregularity. It has been concluded that both magnitude and location of setback influence structural behaviour.

Overall, literature emphasizes the need for careful design of irregular structures.

- A G+10 RCC structure is modelled using ETABS.
- Building has a 5×5 grid with 5 m spacing and uniform storey height.
- Materials used: M30 concrete and Fe500 steel.
- Loads considered:
  - Dead load
  - Live load
  - Seismic load (IS 1893:2016)
- Seismic parameters:
  - Zone V (Z = 0.36)

  - Importance factor = 1.5
  - Response reduction factor = 5
- Analysis method: Equivalent Static Method
- Models used:
  - M1 (regular)
  - M2–M6 (setback irregular models)

3. RESULT AND DISCUSSION

This study analyzes the seismic behavior of G+10 RCC setback buildings using ETABS software. Six different models (M1 to M6) with varying vertical irregular configurations are considered to evaluate the effect of setbacks on structural performance. Each model has a square plan of 10 m × 10 m with a ground floor height of 4 m and remaining storeys of 3 m. The analysis is carried out using the Equivalent Static Method as per IS 1893 (Part 1): 2016. All models are subjected to seismic loading, and key parameters such as storey displacement, storey drift, base shear, and torsion are studied. The comparison of results helps in understanding how changes in mass, stiffness, and geometry due to setbacks influence the seismic response and identifies the most efficient structural configuration.

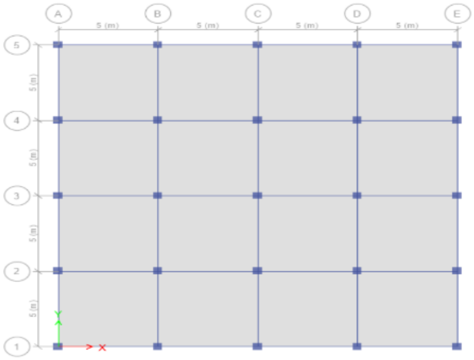


Fig 1plan view of M1 square plan building

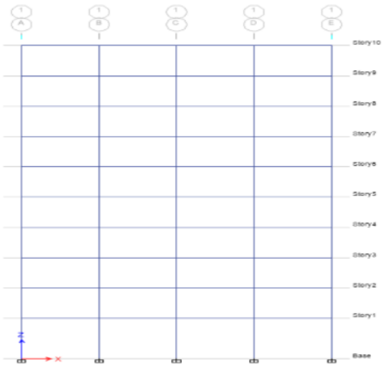


Fig 2 elevation view of M1 model

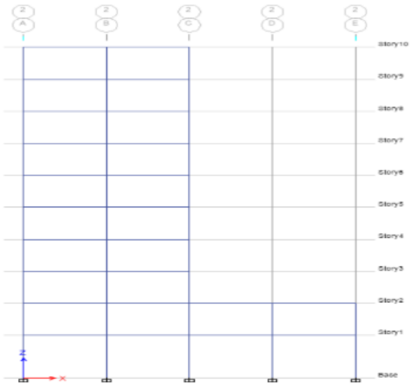


Fig 3 elevation view of M2 model

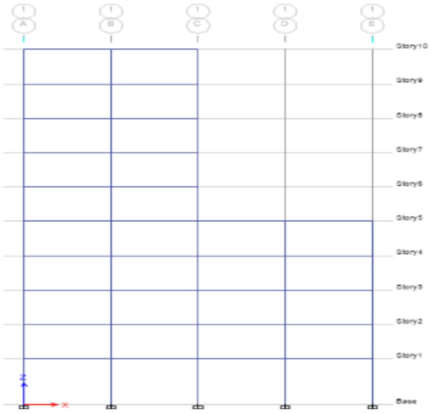


Fig 4 elevation view of M3 model

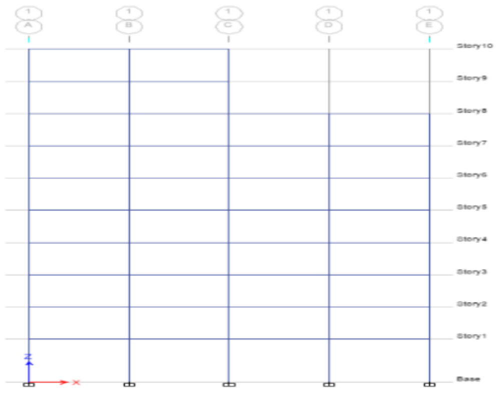


Fig 5 elevation view of M4 model

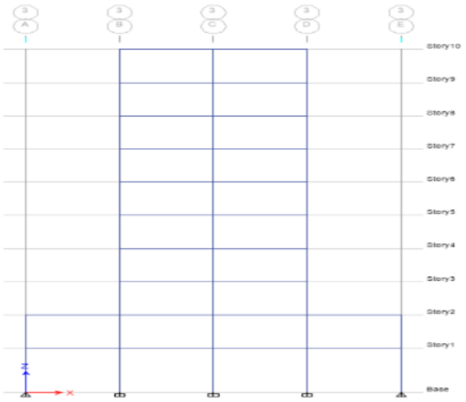


Fig 6 elevation view of M5 model

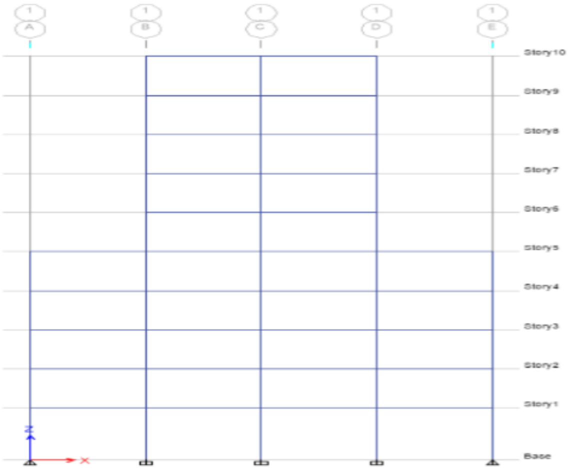
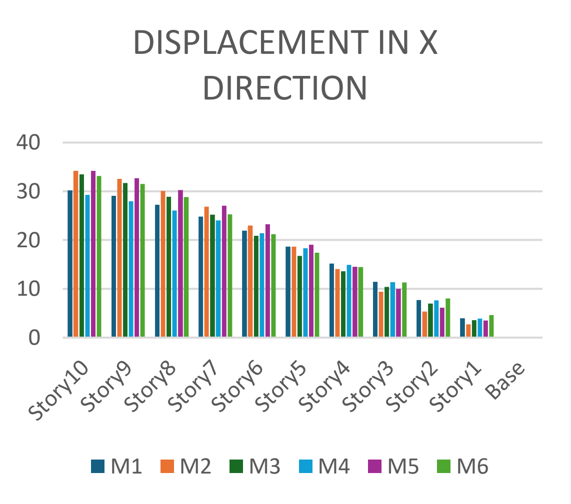
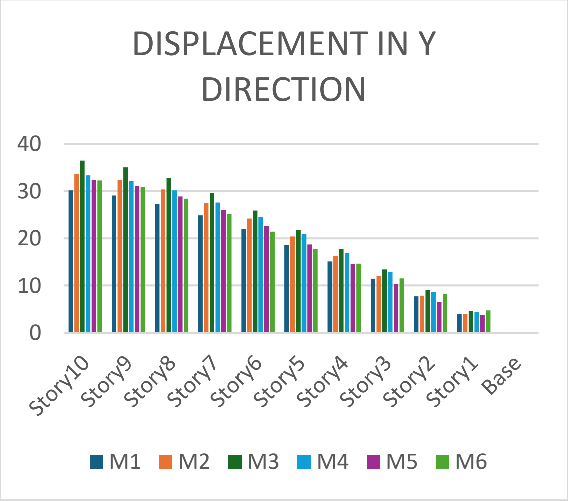


Fig 7 elevation view of M6 model

Displacement values in x direction

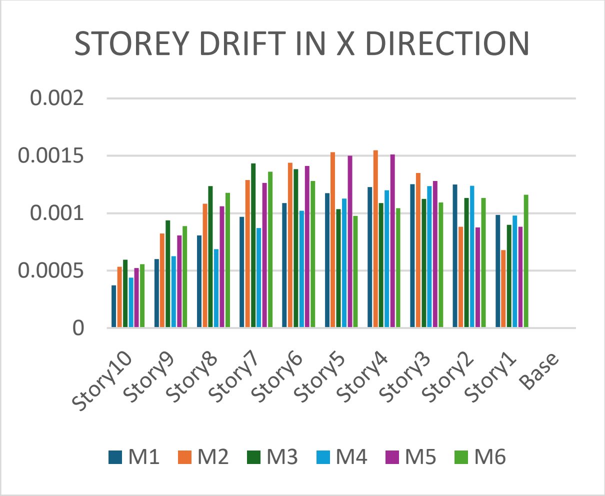


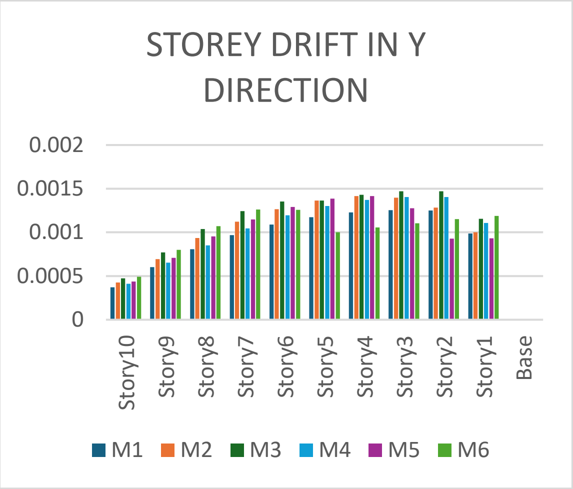
Displacement values in Y direction



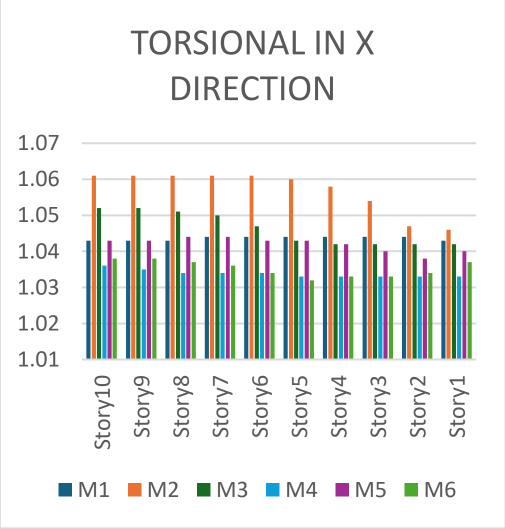
Story drift in x direction

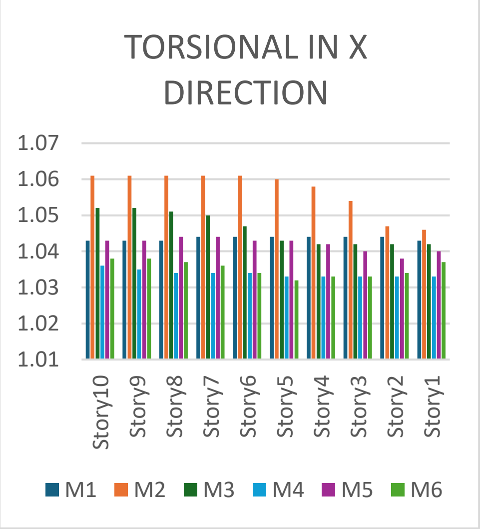
Story drift in Y direction





TORSIONAL IN X DIRECTION TORSIONAL IN Y DIRECTION





The results show that all models (M1–M6) exhibit increasing displacement with height, with maximum values at the top storey. Among them, M2 and M5 show higher displacement, indicating more flexibility, while M1 and M4 show comparatively better stiffness. Storey drift in both X and Y directions increases up to mid-height and then decreases towards the top, indicating maximum deformation occurs in middle storeys. M3 and M5 show higher drift values, while M4 shows more uniform and stable behavior. Overturning moment increases linearly from top to base in all models, with M1 having the highest values and M5–M6 the lowest, indicating better performance in resisting overturning. Torsional values in X direction remain within safe limits for all models, while in Y direction, M2 and M3 show higher torsional irregularity compared to others. Storey shear is maximum at lower storeys and decreases towards the top, with M4 showing higher shear values indicating more flexibility. Overall, M5 and M6 perform better in terms of lower torsion and overturning, while M4 shows balanced behavior, and M2–M3 are more affected by irregularity.

4. CONCLUSION

Seismic analysis shows displacement increases from base to top in all models. Models **M2 and M3** have higher displacement and torsional irregularity (less stable). Models **M5 and M6** show better performance with low torsion and overturning. Model **M4** provides balanced behavior with good stiffness distribution. Overall, proper symmetry and stiffness distribution improve seismic performance.

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