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# Analysis of an RCC Irregular and Setback Building under Dynamic Loading Using ETABS

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***Abstract**: Vertical irregularities such as setbacks, abrupt changes in stiffness, mass distribution, and geometric discontinuities are increasingly common in reinforced cement concrete (RCC) buildings due to architectural and functional requirements. However, these irregularities significantly influence the seismic response of structures and often lead to concentration of damage during strong ground motions. This paper presents a comprehensive review of research studies published between 2015 and 2025 on the seismic analysis of vertically irregular and setback RCC buildings subjected to dynamic loading. Emphasis is placed on analytical investigations conducted using ETABS, including response spectrum analysis, time history analysis, and nonlinear performance-based approaches. The reviewed literature highlights the impact of different types of vertical irregularities on key seismic response parameters such as natural period, storey displacement, inter-storey drift, base shear, torsional effects, and damage distribution. Comparative insights from code-based studies, experimental investigations, and seismic vulnerability assessments are also discussed. The review identifies consistent trends indicating increased seismic demand and reduced performance in irregular buildings compared to regular configurations. Furthermore, existing research gaps related to combined irregularities, nonlinear dynamic analysis, and mitigation strategies are summarized. The findings of this review aim to support researchers and practicing engineers in understanding the seismic behavior of irregular RCC buildings and in adopting appropriate analysis and design approaches.*

***Keyword**: Vertical irregularity; Setback buildings; Reinforced concrete structures; Seismic response; Dynamic analysis; ETABS; Response spectrum analysis; Time history analysis.*

## I. INTRODUCTION

The rapid growth of urbanization and limited availability of land have led to the widespread construction of multistorey reinforced cement concrete (RCC) buildings with complex architectural forms. To satisfy functional, economic, and aesthetic requirements, modern buildings often incorporate features such as open ground storeys for parking, setbacks at upper floors, floating columns, and large openings for commercial use. Although these configurations enhance usability and appearance, they introduce structural irregularities that significantly influence the seismic performance of buildings. Past earthquakes have demonstrated that irregular RCC buildings are far more vulnerable to damage and collapse compared to regular, symmetric structures, particularly when subjected to strong dynamic loading. Structural irregularities disrupt the uniform distribution of mass, stiffness, and strength within a building. As a result, seismic forces are unevenly transferred through the structural system, leading to stress concentrations, excessive inter-storey drifts, and localized failures. According to IS 1893:2002 (Part I), irregularities are broadly categorized into vertical irregularities and plan irregularities. Vertical irregularities include soft storeys, extreme soft storeys, mass irregularities, and stiffness discontinuities along the height of the building, while plan irregularities arise due to asymmetry, re-entrant corners, and setbacks in the horizontal configuration. Among these, setback buildings are particularly critical as the sudden reduction in floor area at higher levels causes abrupt changes in stiffness and mass, thereby amplifying seismic demands in the lower storeys.

In RCC framed structures, setback irregularities significantly alter dynamic characteristics such as natural period, mode shapes, and lateral force distribution. During an earthquake, these buildings tend to develop torsional effects and concentration of damage near the setback levels, making them prone to premature failure. Therefore, a realistic assessment of the seismic behavior of such buildings requires advanced dynamic analysis techniques rather than simplified static methods.

With the availability of powerful structural analysis software such as ETABS, it has become feasible to perform detailed dynamic analyses using response spectrum and time-history methods to capture the true behavior of irregular structures under earthquake loading. ETABS provides an efficient platform for modeling complex geometries, evaluating modal properties, and estimating seismic responses with high accuracy.

In this context, the present study focuses on the dynamic analysis of an RCC irregular and setback building using ETABS. The objective is to investigate how setback irregularity influences key seismic response parameters such as storey displacement, storey drift, base shear, and modal participation. The outcomes of this study aim to provide useful insights for the safe and economical design of irregular RCC buildings in seismic regions.

## II. METHODOLOGY

### *A. Overview*

Structural irregularities significantly affect the dynamic behavior of multistorey buildings under earthquake excitation. Past seismic events have shown that buildings with nonuniform distributions of mass, stiffness, and strength tend to suffer concentration of damage and excessive deformation at critical storeys, leading to premature failure . Therefore, modern seismic design codes emphasize the need to explicitly account for such irregularities during analysis and design.

In this study, a comprehensive numerical framework is adopted to quantify the influence of vertical irregularities on the seismic response of RCC buildings. Sixteen three-dimensional building models, including both regular and irregular configurations, are developed and analyzed using CSI-ETABS. Four types of vertical irregularities—infill, stiffness, mass, and setback—are considered, reflecting common construction practices in urban RCC buildings. The seismic performance of each irregular model is evaluated relative to a reference regular building. Dynamic behavior is assessed through response spectrum analysis (RSA) in accordance with IS 1893:2002 (Part I), which is widely accepted for estimating design-level seismic demands in linear dynamic analysis.

Storey displacement, inter-storey drift, storey shear, overturning moment, and storey stiffness are extracted as primary response indicators [1].

### *B. Description of Building Models*

A regular RCC moment-resisting frame with uniform mass and stiffness distribution is used as the baseline model. All irregular configurations are derived from this model by introducing controlled variations in vertical stiffness, mass, and geometry while maintaining identical plan dimensions.

#### *1) Infill Irregularity*

Masonry infill walls, although often treated as non-structural elements, significantly contribute to lateral stiffness and force transfer during earthquakes . Eight G+10 building models are developed, including a bare frame, a fully infilled frame, and six partially infilled frames with infill walls terminating at different storey levels. To realistically capture infill behavior, each panel is modeled as an equivalent diagonal strut with pinned ends, neglecting shear interaction with the RC frame. RSA is carried out to evaluate the influence of discontinuous infill distribution on seismic demand [2].

#### *2) Stiffness Irregularity*

Vertical stiffness irregularity is introduced by creating **extreme soft storeys** at selected levels—ground, fourth, and seventh storeys. As per IS 1893:2002, a storey is classified as extreme soft if its lateral stiffness is less than 60% of the storey above or less than 70% of the average stiffness of the three storeys above . This is achieved by increasing the storey height to 4.5 m, reducing column rigidity and simulating practical conditions such as open parking or commercial floors [3].

#### *3) Mass Irregularity*

Mass irregularity is defined when the weight of a storey exceeds 200% of that of an adjacent storey. In this study, refuge floors are introduced at the fourth and eighth levels with an imposed load of 15 kN/m², while the remaining geometry remains unchanged. The seismic response of this configuration is compared with the regular bare-frame model to quantify the impact of vertical mass concentration [4].

#### *4) Setback Irregularity*

Setback buildings involve sudden reductions in plan area at certain heights, resulting in discontinuities in stiffness, mass, and strength . Three setback configurations with setbacks at the second, fifth, and eighth storeys are analyzed alongside a regular model. All buildings are G+10 RCC frames with four bays in each principal direction, ensuring consistency in base geometry.

*5) Loading and Seismic Parameters*

Dead loads include self-weight and masonry wall loads, taken as 12 kN/m for external and 6 kN/m for internal walls. The imposed load is assumed as 3 kN/m². Seismic forces are computed as per IS 1893:2002, considering 25% of imposed load for floor loads up to 3 kN/m². The structure is assumed to lie in Seismic Zone V with a zone factor Z=0.36Z = 0.36Z=0.36, medium soil, importance factor I=1I, and damping ratio of 5%. A response reduction factor **R=5.0R = 5.0R=5.0** is adopted for the Special RC Moment Resisting Frame (SMRF). The fundamental natural period is estimated using codal expressions for bare and infilled frames, enabling accurate RSA input [5][].

## III. RESULTS AND DISCUSSION

### *A. Infill Irregular Building*

1) *Storey Displacement:* The bare frame (B1) exhibits the maximum storey displacement, while the fully infilled frame (R) shows the minimum. Abrupt changes in the displacement profile occur at storeys without infill, as presented in Figure 1.

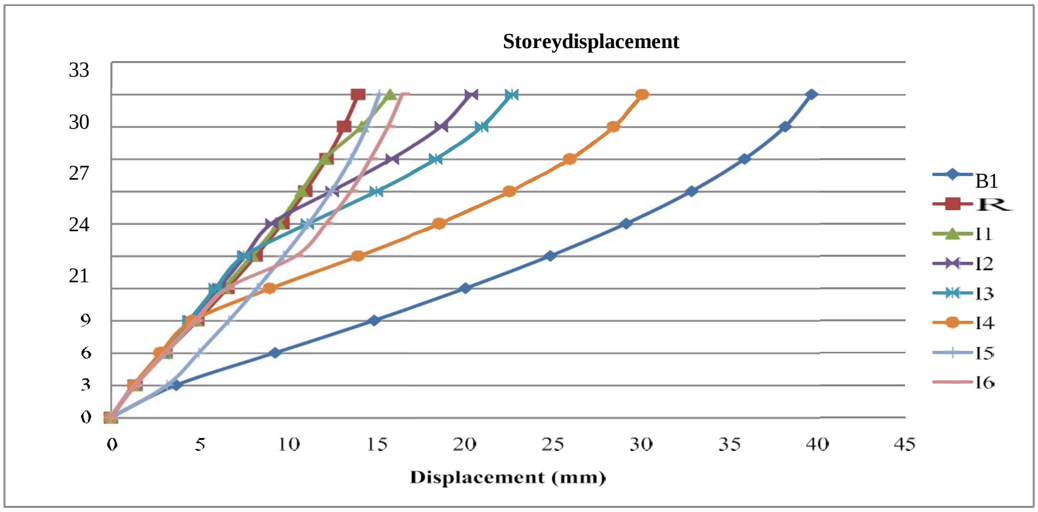


Figure 1 Comparison of storey displacement of infill irregular buildings

2) Orey Drift: The maximum storey drift values listed in the bare frame (B1) exhibits the highest drift, with abrupt increases at storeys lacking infill, as illustrated in Figure 2.

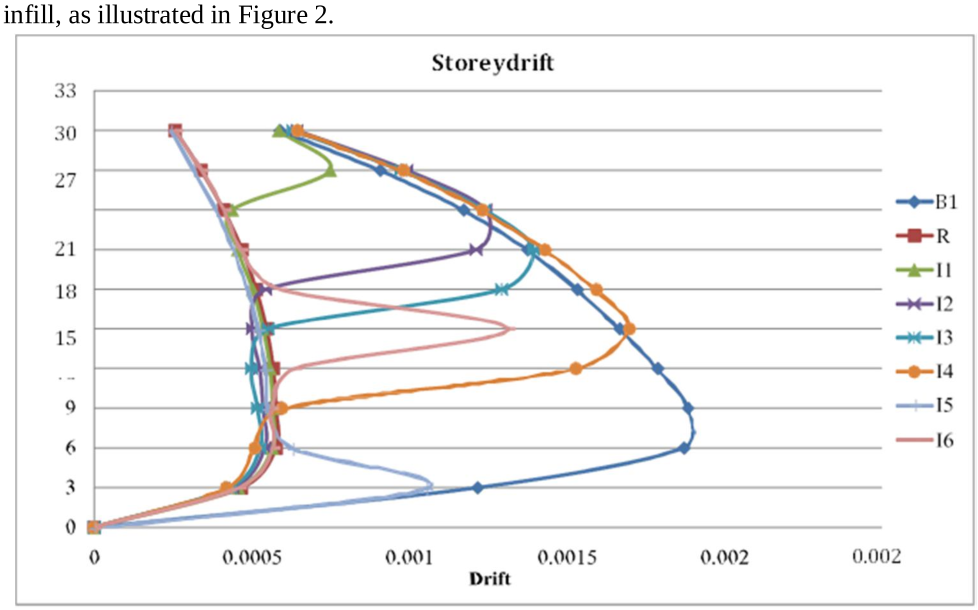


Figure 2 Comparison of storey drift of infill irregular buildings

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*3)* Overturning Moment: Figure 3 show that the fully infilled frame (R) develops the highest overturning moment, which progressively decreases with reduction in infill percentage across the storeys.

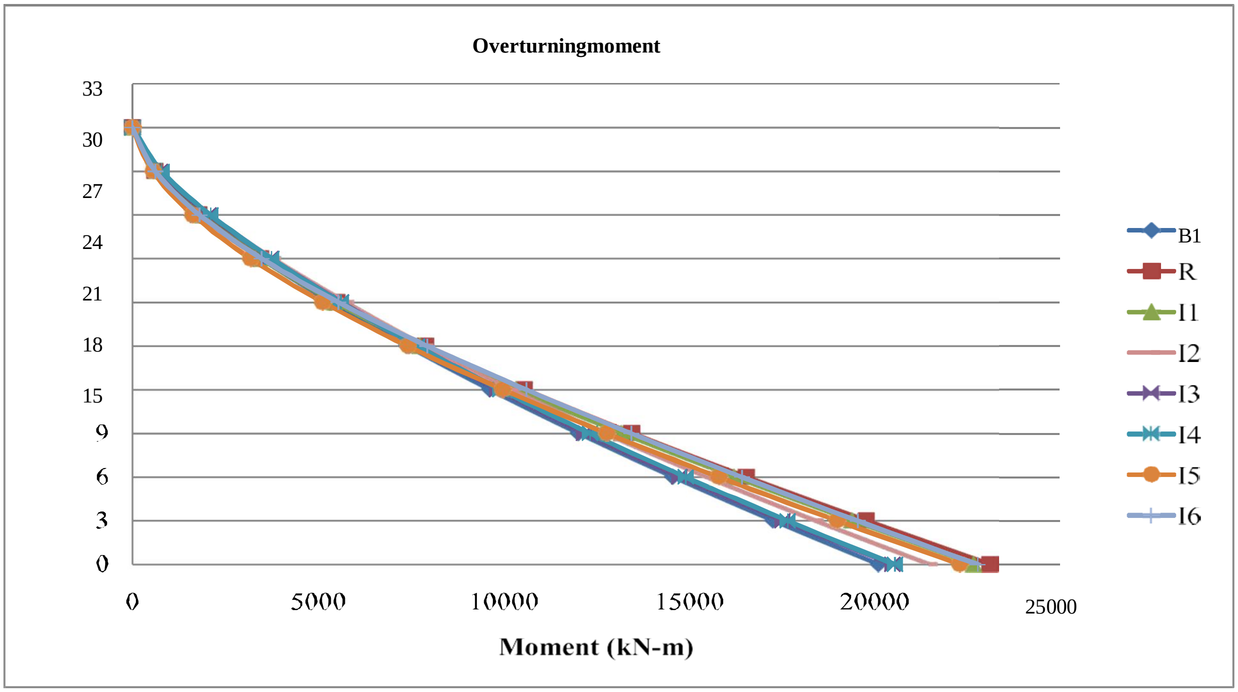


Figure 3 Comparison of overturning moment of infill irregular buildings

*4)* Storey Shear: As shown in Table 4 and Figure 4, the fully infilled frame (R) develops the highest storey shear, which decreases progressively with a reduction in infill percentage.

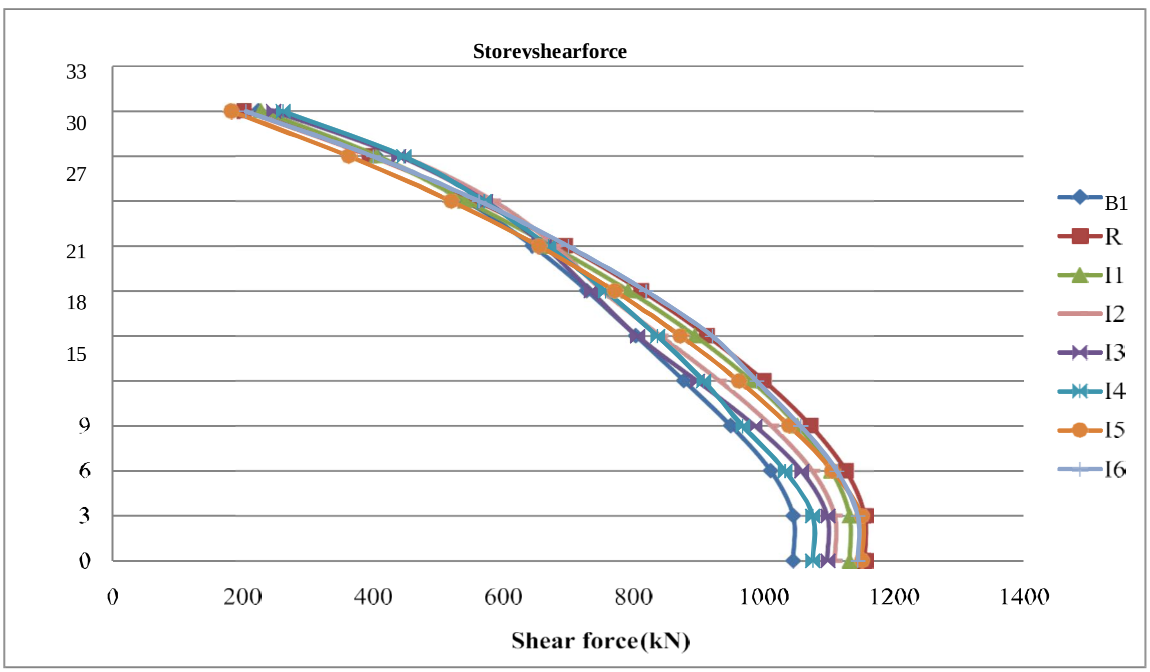


Figure 4 Comparison of storey shear force of infill irregular buildings

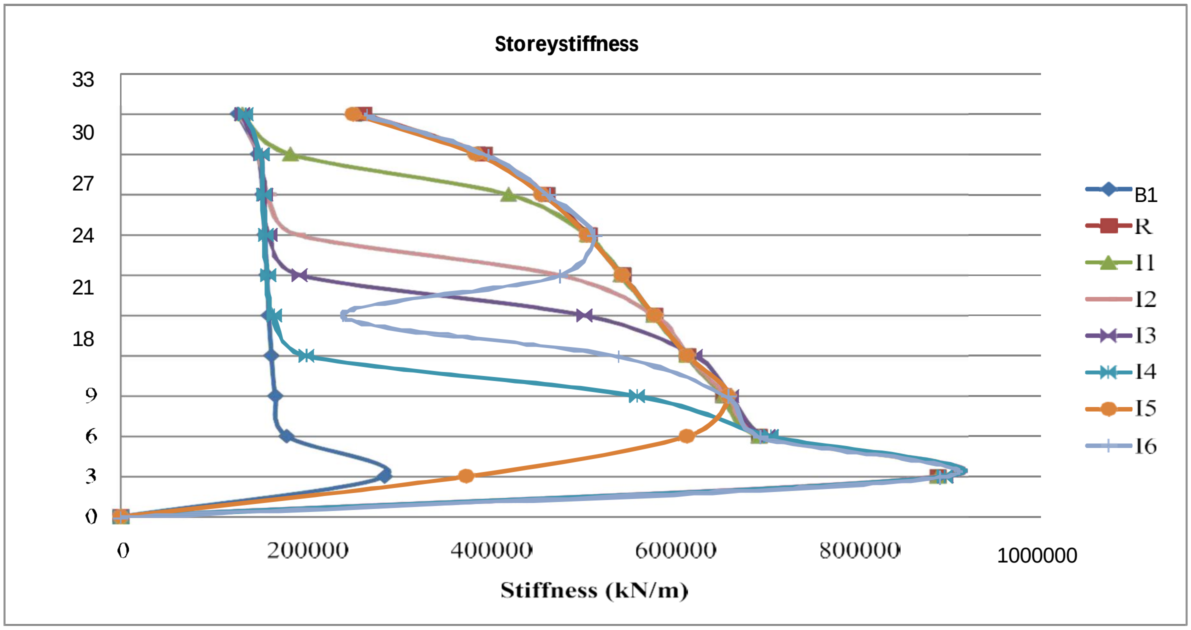


Figure 5 Comparison of storey stiffness of infill irregular buildings

*B. Stiffness Irregularity*

*1)* Storey displacement As in Figure 6, stiffness-irregular models exhibit significantly higher displacements than the regular building, with the soft-ground-storey model (S1) showing about 1.5 times greater displacement at the base and abrupt slope changes at the soft storey levels.

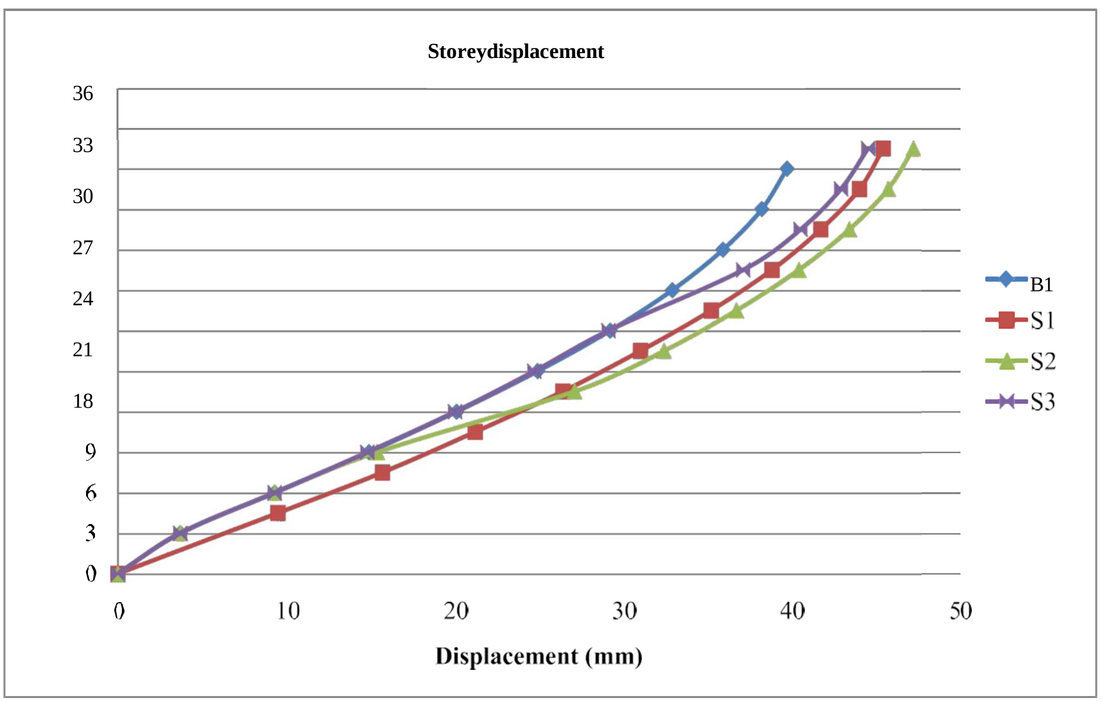


Figure 6 Comparison of storey displacement of stiffness irregular buildings

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2) Storey Drift: Figure 7 that stiffness irregularity causes sudden and pronounced increases in storey drift compared with the regular building.

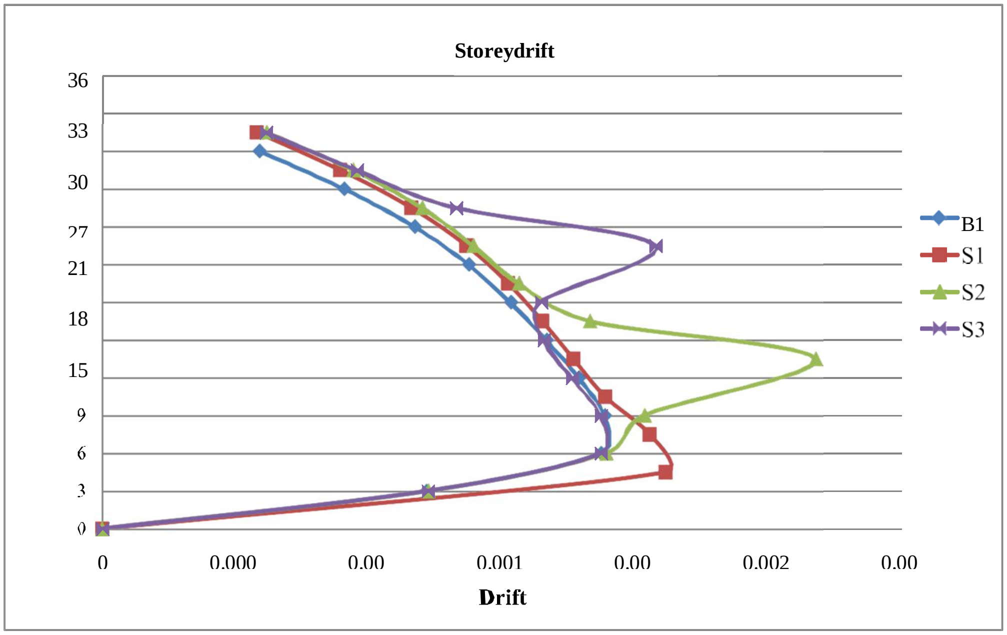


Figure 7 Comparison of storey drift of stiffness irregular buildings

3) Overturning moment Figure 8 show that stiffness-irregular buildings develop slightly higher overturning moments than the regular frame, with model S2 producing the maximum value at the ground storey.

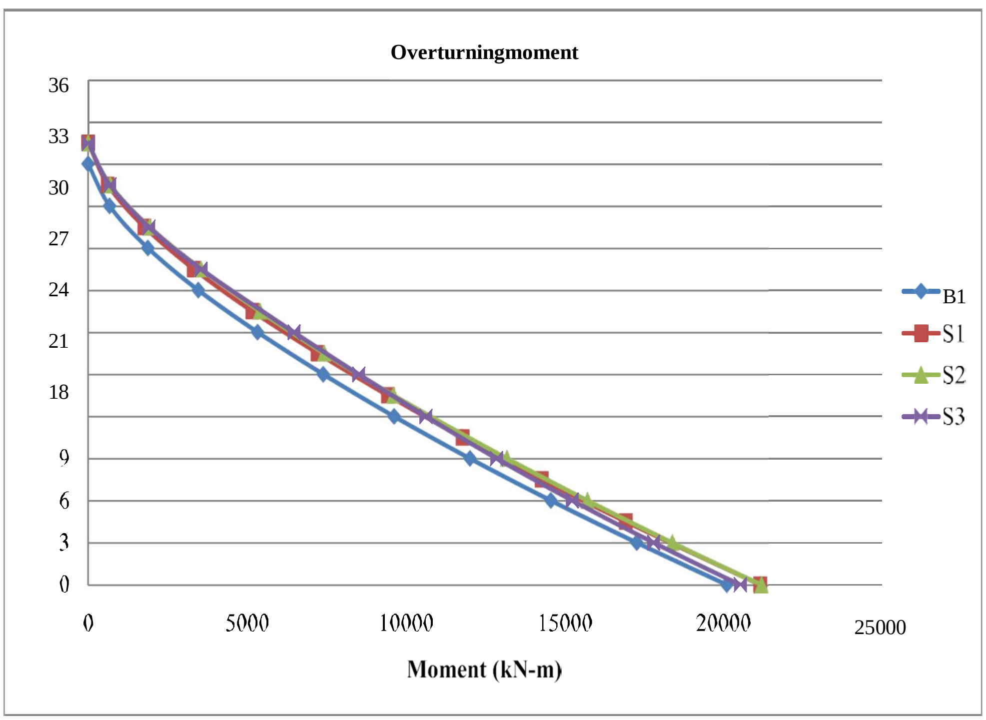


Figure 8 Comparison of overturning moment of stiffness irregular buildings

*4)* Storey Shear: As indicated Figure 9, stiffness-irregular buildings experience higher storey shear than the regular model, with the maximum occurring in model S2 at the ground storey and noticeable slope changes at the irregular levels.

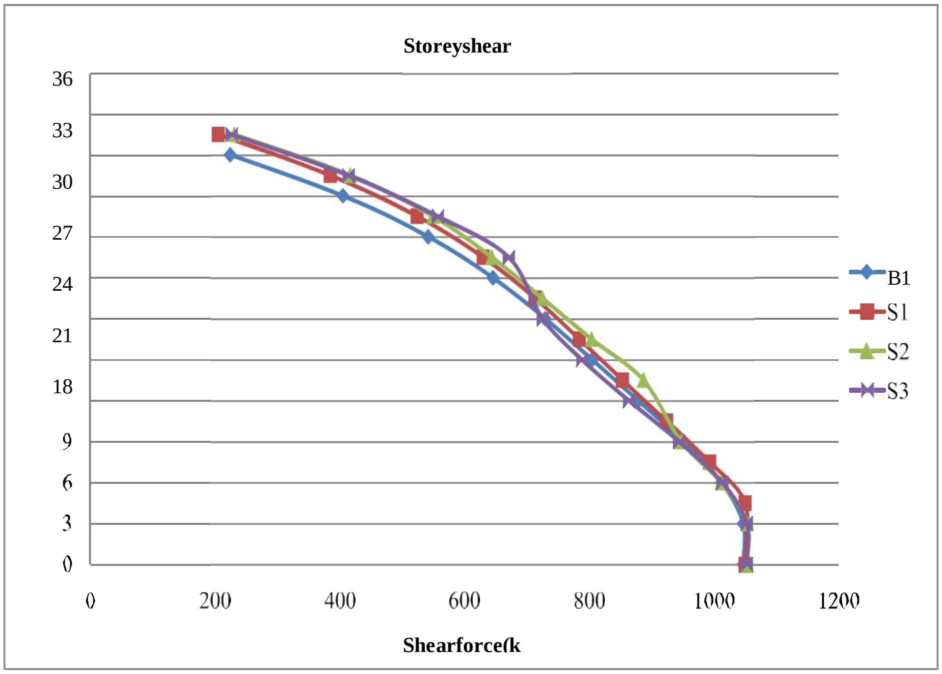


Figure 9 Comparison of storey shear force of stiffness irregular buildings

*5)* Storey Stiffness: Figure 5.10 show abrupt and significant changes in storey stiffness at the irregular levels due to stiffness discontinuity.

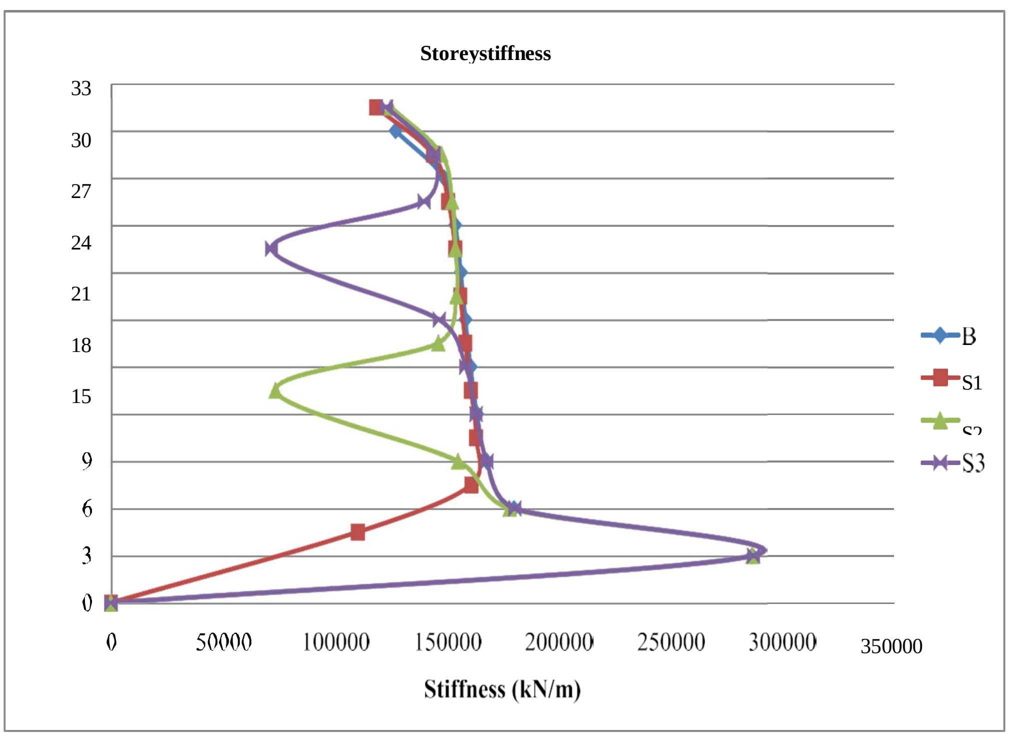


Figure 10 Comparison of storey stiffness of stiffness irregular buildings

*C. Mass Irregularity*

1) Storey Displacement: The top node displacement in case of mass irregular building is greater than that of the regular building. But in lower storeys it is approximately same as that of regular building as shown in Figure 11

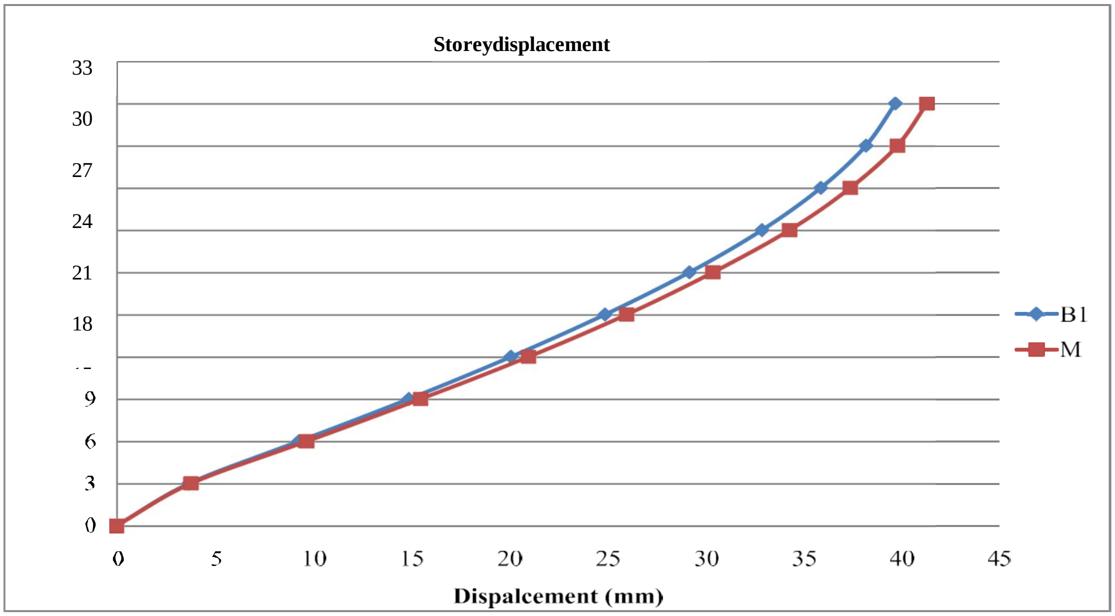


Figure 11 Comparison of storey displacement of mass irregular buildings

2) Storey drift: The storey drift is greater in case of mass irregular building in the intermediate storeys, but in top and bottom storeys it is same as that of regular building as shown in Figure 5.12

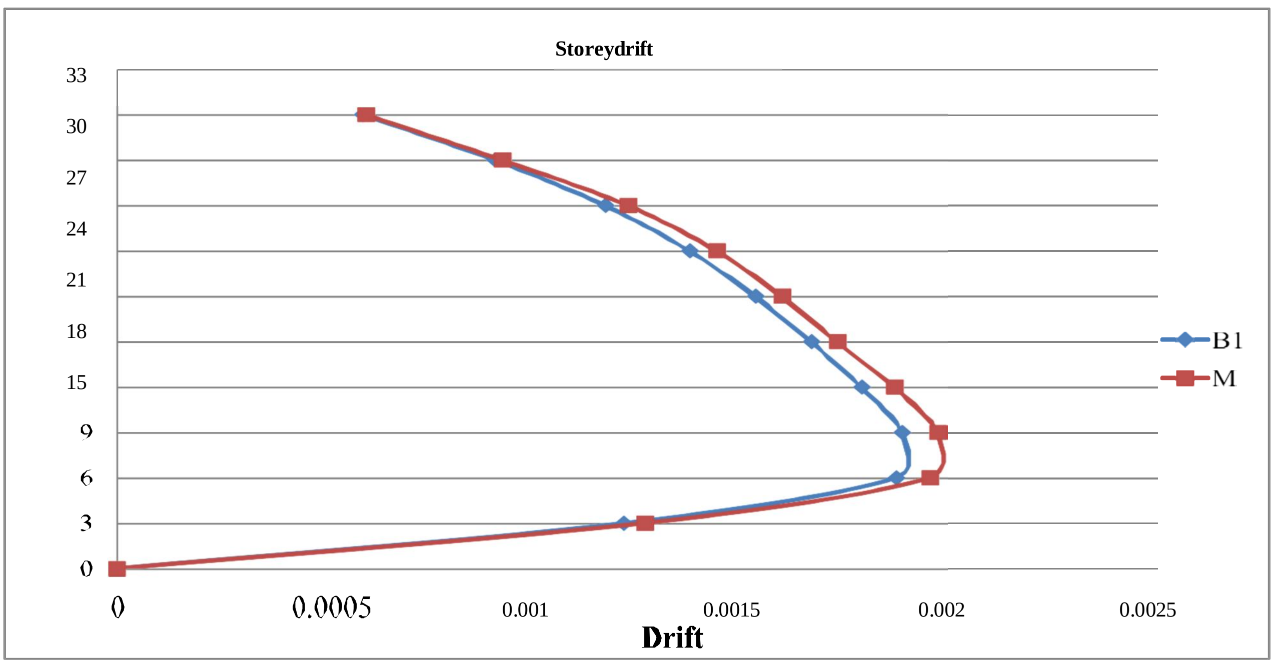


Figure 12 Comparison of storey drift of mass irregular buildings

*3)* Overturning Moment: The maximum overturning moment at each storey for the regular and mass irregular buildings is given in Table

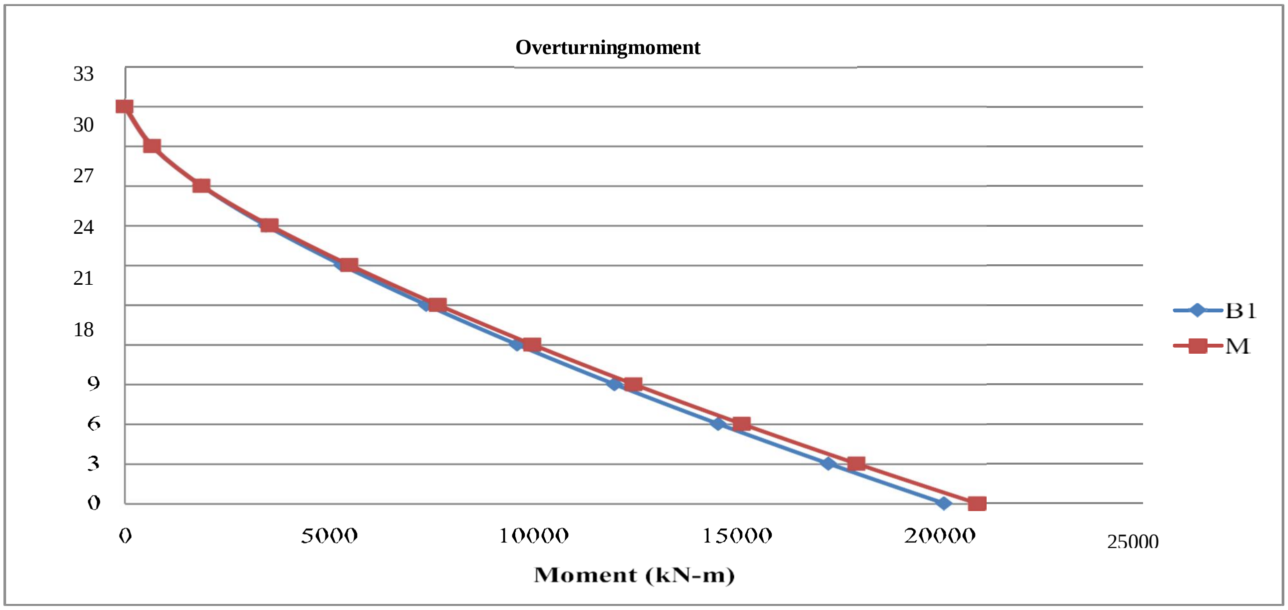


Figure 13 Comparison of overturning moment of mass irregular buildings

*4)* Storey Shear: The storey shear force in case of mass irregular building is greater than that of regular building in the bottom storeys, but towards the top of the building it is almost same as that of regular building as shown in Figure 14

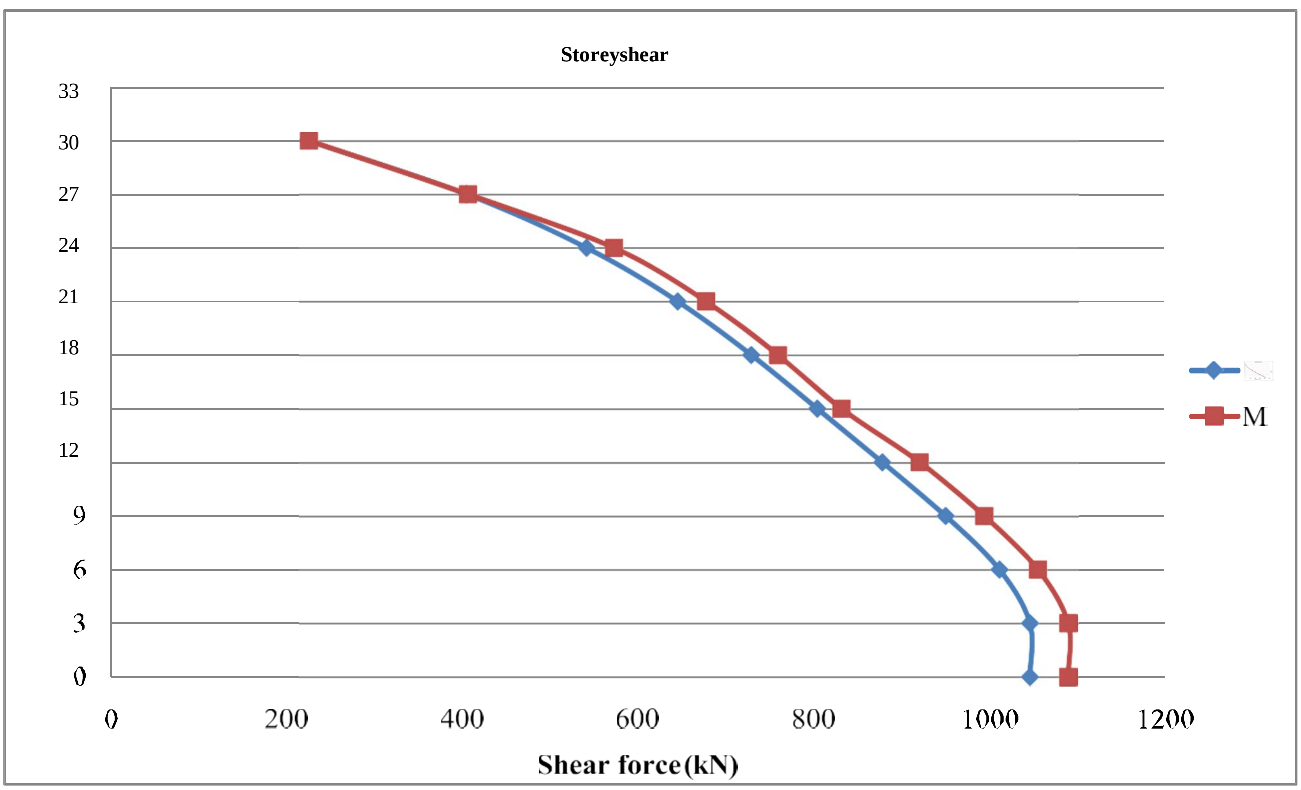


Figure 14 Comparison of storey shear force of mass irregular buildings

*5)* Storey Stiffness: Figure 15 shows that due to mass irregularity the stiffness of the irregular building gets marginally affected in the top storeys. But in the bottom storeys,

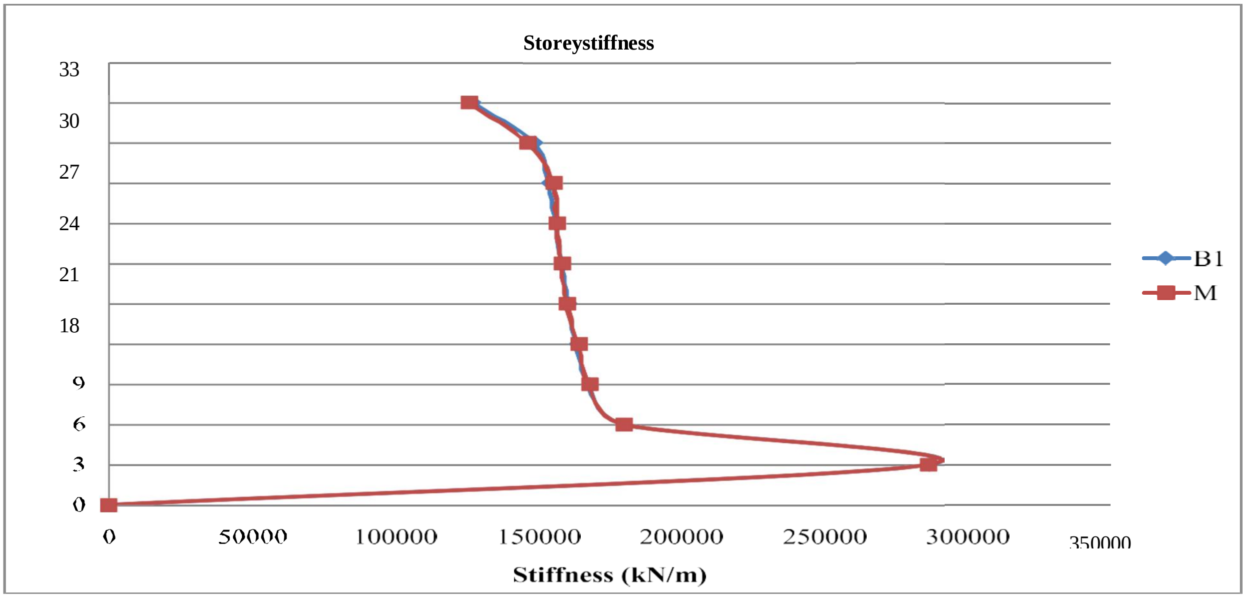


Figure 15 Comparison of storey stiffness of mass irregular buildings

*D. Setback Irregularity*

*1)* Storey Displacement: The storey displacement curve shown in Figure 16.

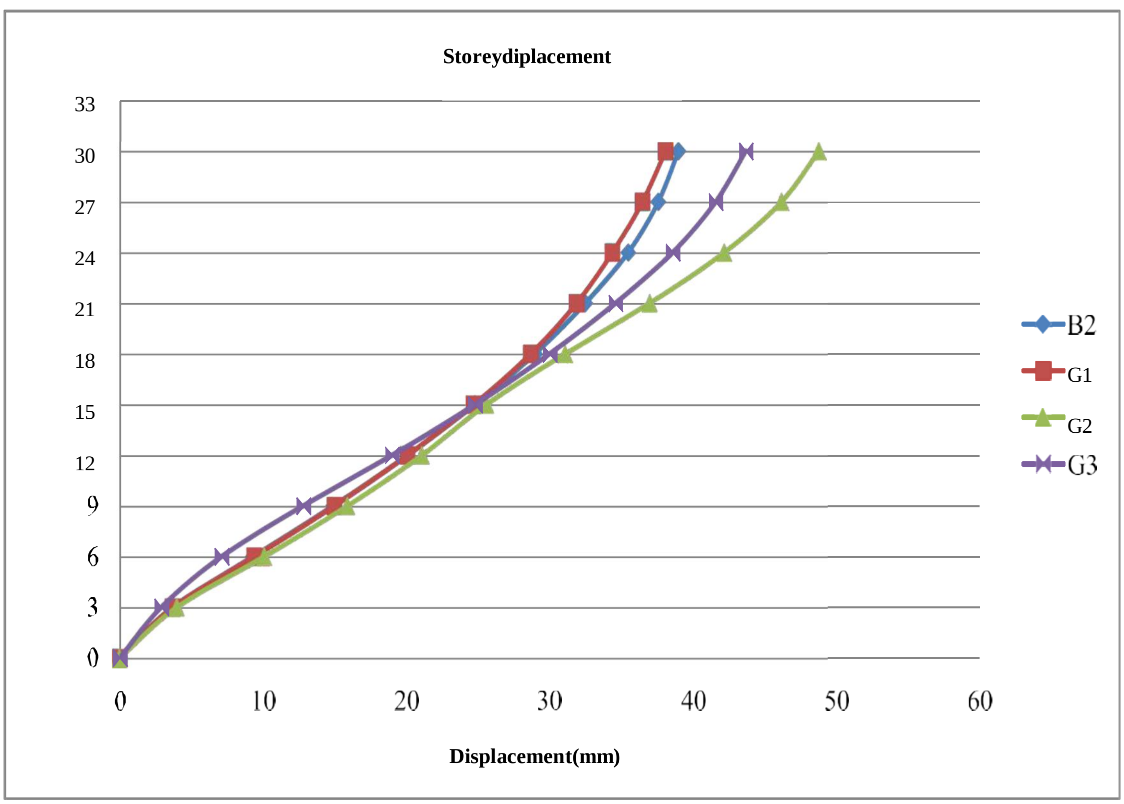


Figure 16 Comparison of storey displacement of setback irregular buildings

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2) Storey Drift: From Figure 17 it is observed that there is a sudden extreme change in storey drift due to setback. The slope of the storey drift curve first decreases before setback, and then increases suddenly just after setback.

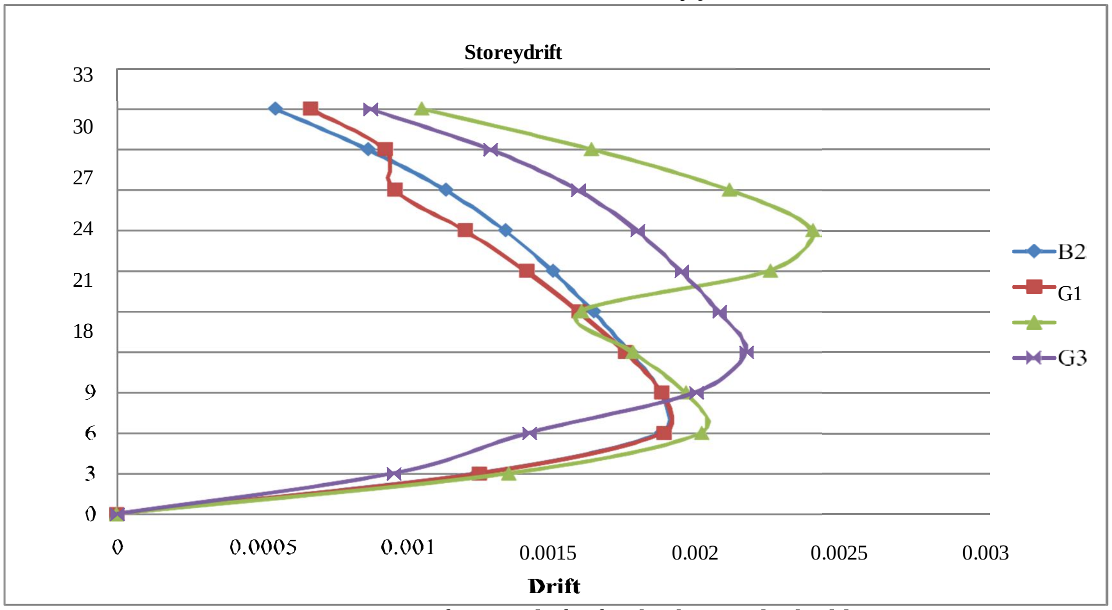


Figure 17 Comparison of storey drift of setback irregular buildings

3) Overturning Moment: Figure 18 indicate that setback buildings develop lower overturning moments than the regular building across all storeys.

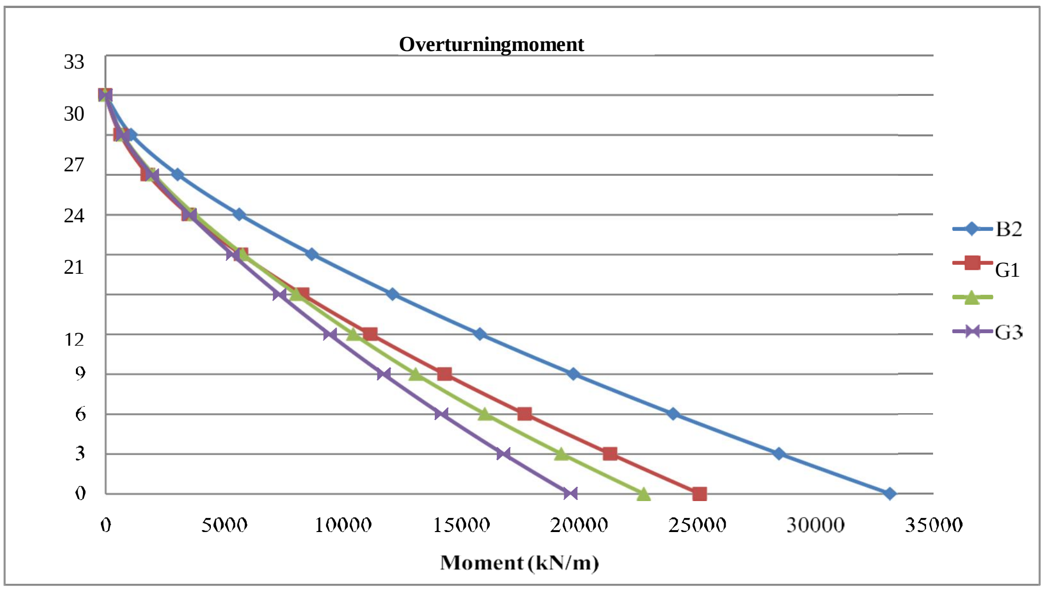


Figure 18 Comparison of overturning moment of setback irregular buildings

## IV. DISCUSSION AND CONCLUSION

This study examined the seismic behavior of RCC buildings with four types of vertical irregularities—partial infill, stiffness, mass, and setback—while maintaining plan symmetry. A total of sixteen regular and irregular building models were developed and analyzed using CSI ETABS 2015. Response spectrum analysis was performed in accordance with IS 1893:2002 (Part I) for Seismic Zone V and medium soil conditions. Key response parameters, including storey displacement, inter-storey drift, storey shear, overturning moment, and storey stiffness, were evaluated and compared with those of a regular building.

The results indicate that masonry infill significantly enhances structural stiffness and strength, reducing roof displacement and storey drift; however, partial infill causes abrupt drift concentrations, making such configurations undesirable in high seismic zones. Stiffness irregularity, particularly soft storeys, leads to excessive local drift and higher displacement demand, with a noticeable drop in storey stiffness at the irregular levels. Mass irregularity increases roof displacement, inter-storey drift, and base shear, thereby degrading seismic performance. Setback irregularity reduces overall stiffness and induces sudden drift variations near the setback levels, although the regular building consistently exhibits superior performance.

Overall, the regular RCC building demonstrates the most favorable seismic behavior, highlighting the importance of avoiding vertical irregularities in earthquake-prone regions.

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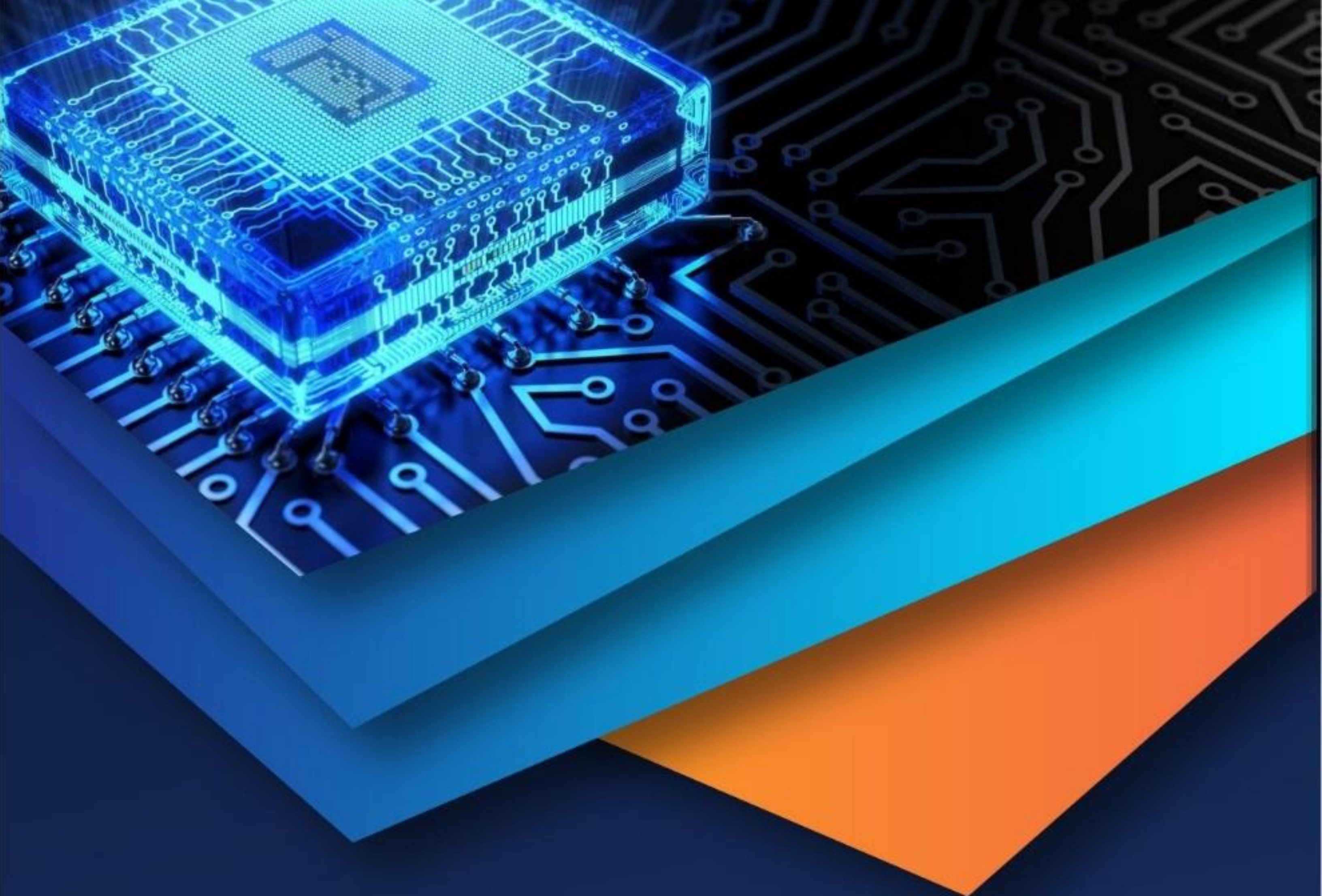

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