

Comparative Seismic Performance of RCC Buildings with Varying Plan Irregularities

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Abstract - Earthquakes are one of the most destructive natural hazards affecting structures worldwide. The seismic behavior of buildings is significantly influenced by structural configuration, mass distribution, stiffness, and geometry. Plan irregularities may lead to stress concentration and non-uniform structural response, increasing the vulnerability of buildings during seismic events. This study presents the seismic analysis of a Reinforced Cement Concrete (RCC) building with different plan shapes, namely rectangular, L-shape, C-shape, T-shape, and U-shape, using ETABS. An 11-storey RCC building located in seismic zone III is considered for analysis. The Equivalent Static Method is adopted in accordance with IS 1893 (Part 1): 2016. Key response parameters such as storey displacement, storey drift, and base shear are evaluated in both principal directions. The results are compared to assess the influence of plan configuration on seismic performance. It is observed that building geometry has a significant effect on structural response. Among the configurations studied, the C-shape building shows comparatively lower displacement and drift, while the U-shape and T-shape buildings exhibit higher values due to plan irregularity.

Keywords -Seismic Analysis, RCC Buildings, Plan Irregularity, ETABS, Equivalent Static Method, Structural Behavior.

I. INTRODUCTION

Earthquakes are among the most destructive natural hazards, caused by the sudden release of energy within the Earth's crust, generating seismic waves. These ground motions impose dynamic forces on structures, which may lead to significant damage or collapse if not adequately designed. In India, where a large region lies within seismic zones, earthquake-resistant design has become essential. The primary objective of seismic design, as per IS 1893 (Part 1), is to ensure structural safety by minimizing damage and preventing failure during seismic events.

Reinforced Cement Concrete (RCC) buildings are extensively used in modern construction due to their strength, durability, and cost-effectiveness. Although RCC structures perform well under gravity loads, their behaviour under seismic loading is complex due to the dynamic and lateral nature of earthquake forces. These forces generate inertia effects throughout the structure, making proper analysis and design crucial for ensuring stability.

Plan configuration plays a significant role in determining the seismic performance of a building. Structures with regular and symmetrical plans exhibit better performance due to uniform distribution of mass and stiffness. In contrast, irregular configurations such as L-shaped, T-shaped, and other asymmetrical layouts result in torsional effects, stress concentration, and uneven force distribution. These factors increase the susceptibility of buildings to damage during earthquakes.

Accurate seismic analysis is therefore necessary to evaluate structural response. Conventional manual methods are inefficient for multi-storey buildings with complex geometries, leading to the adoption of advanced computational tools. ETABS (Extended Three-Dimensional Analysis of Building Systems) is widely used for this purpose, offering efficient modelling and analysis of structures under various loading conditions, including seismic forces.

In recent construction practices, irregular plan configurations are increasingly adopted due to architectural and functional requirements. However, their seismic performance is often not fully understood, which may compromise structural safety. This necessitates a comparative study to assess the behaviour of different plan shapes under earthquake loading.

In this study, RCC buildings with various plan configurations are analysed using ETABS in

accordance with IS 1893 (Part 1). Both regular and irregular models are evaluated based on key response parameters such as storey displacement, storey drift, and base shear.

The objective of this research is to investigate the influence of plan configuration on seismic response and to identify structurally efficient configurations. The findings aim to support engineers in selecting appropriate building layouts, thereby enhancing safety and performance in seismic regions.

II. AIM AND OBJECTIVES

The aim of this study is to evaluate and compare the seismic performance of multi-storey RCC buildings with different plan configurations, focusing on the influence of structural geometry on key response parameters such as lateral deflection, storey drift, and base shear under earthquake loading using ETABS.

The objectives of this study are:

1. To develop analytical models of an 11-storey RCC building with various plan shapes, namely Rectangular, L-shape, C-shape, T-shape, and U-shape, using ETABS software.
2. To perform seismic analysis using the Equivalent Static Method as per IS 1893 (Part 1): 2016.
3. To evaluate key seismic response parameters, including lateral deflection, storey drift, and base shear in both principal directions (EQX and EQY).
4. To carry out a comparative study of different plan configurations based on the obtained response parameters.
5. To identify the most efficient building configuration that exhibits improved seismic performance with reduced lateral deflection, minimum storey drift, and optimum base shear.

III. LITERATURE REVIEW

Jose et al. (2021) [1] reviewed the structural behavior of irregular buildings with different plan shapes such as rectangular, L, C, and I-shape using ETABS software. The analysis considered parameters like maximum shear force, bending moment, and storey displacement for a 15-storey RCC building. The findings revealed that irregular buildings experience higher displacement and structural forces compared to regular configurations.

Shah and Singh (2024) [2] conducted a comparative study on a multi-storeyed RC framed building to analyze the effects of wind and earthquake loads using ETABS. Parameters such as base shear and storey displacement were examined, and the results indicated that seismic loads produce significantly higher structural response than wind loads.

Rahman and Mamun (2025) [3] investigated RCC buildings with various plan configurations including rectangular, L-shape, I-shape, C-shape, and hexagonal. The study evaluated storey shear, bending moments, and lateral displacement, and observed that regular shapes such as rectangular and hexagonal performed better, whereas irregular shapes exhibited higher displacement.

Ugale and Pagar (2023) [4] analyzed a G+8 RCC building under different loading conditions using ETABS. The study examined storey displacement, base shear, and internal forces, demonstrating the effectiveness of ETABS in evaluating structural performance.

Manduskar and Shingade (2023) [5] carried out analysis of a multi-storeyed RCC building to study its response under seismic loading. The results indicated that parameters such as storey drift and base shear are critical in assessing structural safety.

Ladiya et al. (2026) [6] examined the seismic behavior of irregular and setback buildings under dynamic loading conditions. The study highlighted that such configurations exhibit higher deformation and concentration of seismic forces compared to regular structures.

Patidar and Pandey (2022) [7] performed dynamic analysis of multi-storey RCC buildings with different plan shapes. The results confirmed that plan configuration significantly influences seismic performance, with irregular buildings showing higher displacement.

Pandey et al. (2025) [8] focused on vertically irregular RC frame buildings and observed that vertical irregularities have a considerable impact on storey drift and displacement.

Mahi et al. (2025) [9] analyzed the seismic performance of regular and irregular RC buildings and concluded that irregular buildings exhibit higher drift, torsional effects, and instability.

Manoj and Varghese (2022) [10] studied irregular buildings using the response spectrum method and found that such structures experience higher seismic

response compared to regular buildings.

Anilkumar and Jose (2023) [11] conducted a comparative study on regular and irregular plan configurations and reported that irregular buildings show increased displacement and drift under seismic loading.

From the above studies, it is evident that plan irregularity has a significant influence on the seismic performance of RCC buildings, often resulting in increased displacement and storey drift due to irregular distribution of mass and stiffness. However, most previous studies are limited to specific configurations or particular types of irregularities, and a detailed comparative assessment under consistent conditions is lacking. Hence, there is a need to systematically study multiple plan configurations to better understand their relative performance and structural behavior under seismic loading.

IV. METHODOLOGY

This study focuses on the seismic analysis of RCC buildings with different plan configurations using ETABS. Five building models, representing both regular and irregular plan shapes, are developed for comparative evaluation.

All models are assigned the same structural properties, material characteristics, and loading conditions, with plan configuration as the only variable parameter. The buildings are modelled as multi-storey RCC framed structures with uniform storey height and consistent member dimensions. Material grades and sectional properties of beams, columns, and slabs are selected based on standard design practice and applied consistently across all models.

4.1 Building Specification

The building considered in this study is an RCC structure modelled as a multi-storey moment-resisting frame. The geometric and structural parameters are selected based on standard design practices applicable to mid-rise buildings. The model is developed to represent typical residential construction, ensuring realistic behaviour under seismic loading conditions. Key assumptions related to structural configuration, boundary conditions, and modelling approach are incorporated to achieve accurate analytical results.

The building consists of a regular plan with defined dimensions and uniform storey height throughout its

elevation. Structural components such as slabs, beams, and columns are modelled using appropriate element types to simulate actual behaviour. In addition, suitable assumptions are made for diaphragm action and support conditions to ensure proper load transfer and stability of the structure.

The detailed building specifications adopted for the analysis are summarized in Table 1.

Table 1: Building Specification

Parameter	Value
Building Type	Residential RCC
Plan Area	15m x 18m
Number of Storeys	11 storeys
Total Height of Structure	33 m
Storey Height	3 m
Floor Diaphragm	Rigid
Slab Type	Thin Shell
Parapet Wall Height	1 m
Support Condition	Fixed

The structure comprises G+10 storeys with a total height of 33 m and a uniform storey height of 3 m. A rigid diaphragm is assigned at each floor level to facilitate proper distribution of lateral loads. The slab is modeled as a thin shell element, and the base is assumed to be fixed. A parapet wall height of 1 m is also considered in the analysis.

4.2 Material and Section Properties

The building is modelled as a reinforced concrete (RCC) moment-resisting frame comprising beams, columns, slabs, and walls. The selection of appropriate material properties and sectional dimensions plays a crucial role in ensuring the strength, stiffness, and overall performance of the structure under loading conditions. In this study, the material grades and member sizes are chosen based on standard design practices applicable to residential buildings.

To maintain consistency and ensure a fair comparison of results, these properties are kept constant for all building models, so that the variation in response is influenced only by differences in plan configuration.

The material properties and sectional dimensions adopted in the study are summarized in Table 2.

Table 2: Material and Section Properties

Parameter	Value
Grade of Concrete	M25 & M30
Grade of Steel	Fe415
Beam Size	230mm x 350 mm
Column Size	350mm x 400 mm
Slab Thickness	150 mm
Wall Thickness	230 mm

Concrete of grade M25 is used for beams and slabs, while M30 is adopted for columns to achieve higher strength and improved load-carrying capacity. Reinforcing steel of grade Fe415 is used throughout the structure. The material properties such as modulus of elasticity, density, and Poisson’s ratio for concrete, along with yield strength and modulus of elasticity for steel, are considered as per standard provisions of IS 456:2000.

The selected member dimensions are suitable for maintaining structural stability and serviceability requirements. These parameters are kept constant to ensure that variations in seismic response are influenced only by changes in plan configuration.

4.3 Loading Conditions

The structural models are subjected to gravity loads representing typical service conditions, including dead load and live load. These loads are assigned in accordance with standard design practices for residential buildings to ensure realistic structural behaviour.

The loading details adopted in the analysis are presented in Table 3.

Table 3: Loading Details

Load Type	Value
Dead Load	Self-Weight (Auto)
Wall Load	11.58 kN/m ²
Floor Finish Load	1 kN/m ²
Water Proofing Load	2 kN/m ²
Floor Live Load	2 kN/m ²
Roof Live Load	1.5 kN/m ²

Dead load includes the self-weight of structural elements, which is automatically calculated by ETABS based on assigned material properties and section dimensions. Additional permanent loads such as wall load, floor finish, and waterproofing are considered as uniformly distributed loads.

Live load is assigned as per IS 875 (Part 2): 1987 for residential buildings, considering both floor and roof levels.

Seismic load is applied in accordance with IS 1893

(Part 1): 2016 and is defined separately based on relevant seismic parameters.

4.4 Seismic Parameters

Seismic analysis of the building models is carried out in accordance with IS 1893 (Part 1): 2016 using the Equivalent Static Method. The earthquake forces are evaluated based on specified seismic parameters that govern the intensity and response of the structure.

The seismic parameters adopted for the study are summarized in Table 4.

Table 4: Seismic Parameters

Parameters	Value
Seismic Zone	III
Zone Factor	0.16
Importance Factor	1
Response Reduction Factor	5
Soil Type	II (Medium)
Damping Ratio	0.05

The zone factor represents the seismic intensity of the region, while the importance factor reflects the functional importance of the structure. The response reduction factor accounts for the ductility and energy dissipation capacity of the structural system. Soil type influences the dynamic response of the building under seismic loading.

4.5 Load Combinations

The structural response is evaluated using standard load combinations to account for the combined effects of gravity and seismic loads. These combinations are defined in accordance with IS 456:2000 and IS 1893 (Part 1): 2016. The load combinations considered in the analysis are as follows:

- 1.5 DL
- 1.5 (DL + LL)
- 1.2 (DL + LL ± EQX)
- 1.2 (DL + LL ± EQY)
- 1.5 (DL ± EQX)
- 1.5 (DL ± EQY)
- 0.9 DL ± 1.5 EQX
- 0.9 DL ± 1.5 EQY

These combinations are used to assess the structural performance under both gravity-dominated and earthquake-dominated conditions. Seismic loads are applied in both X and Y directions to capture the critical response of the structure.

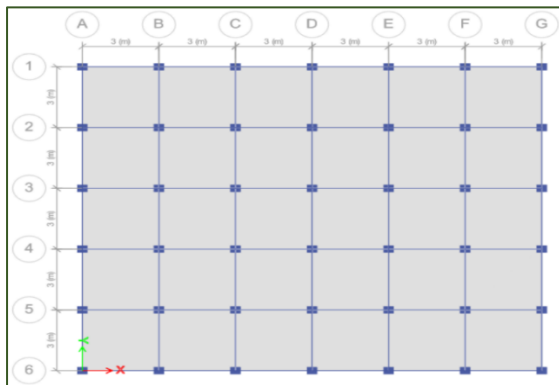
4.6 Modelling in ETABS

The structural models are developed and analysed using ETABS. The modelling process involves defining the building geometry, grid layout, and storey data corresponding to the selected plan configurations.

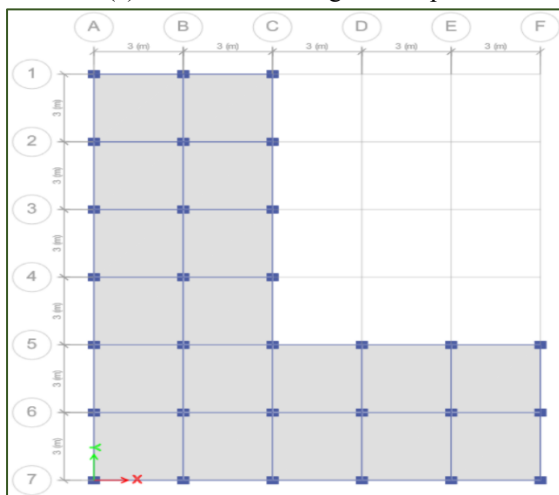
Structural elements such as beams, columns, and slabs are assigned appropriate section properties, with slabs modelled as thin shell elements. A rigid diaphragm is assigned at each floor level to ensure effective lateral load distribution. The base of the structure is assumed to be fixed.

Load cases for dead load, live load, and seismic load are defined and applied as per codal provisions. After completing the modelling and load assignment, analysis is carried out to obtain the structural response.

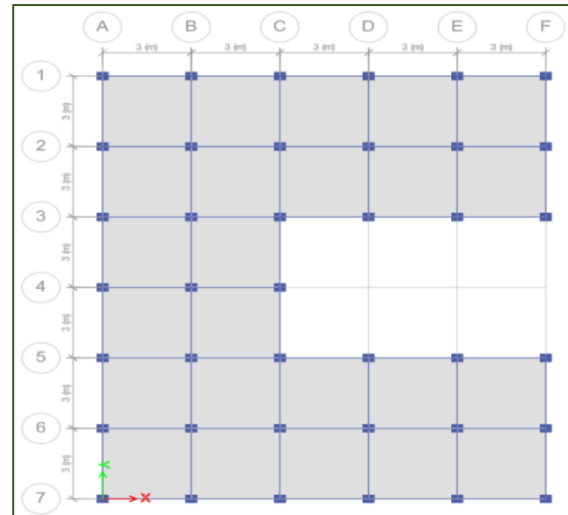
The plan configurations and three-dimensional views of the models are presented below.



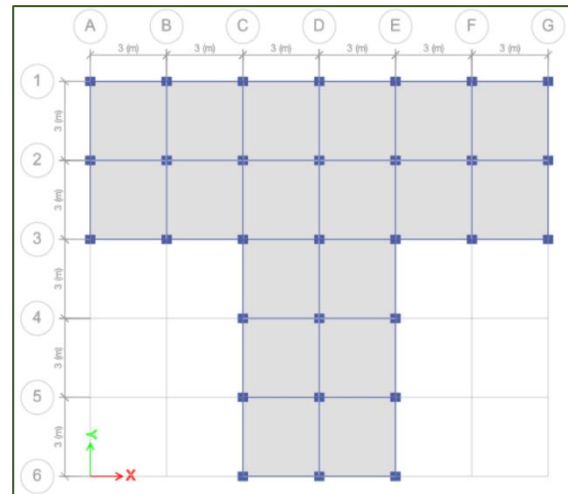
(a) Model 1 - Rectangular Shape



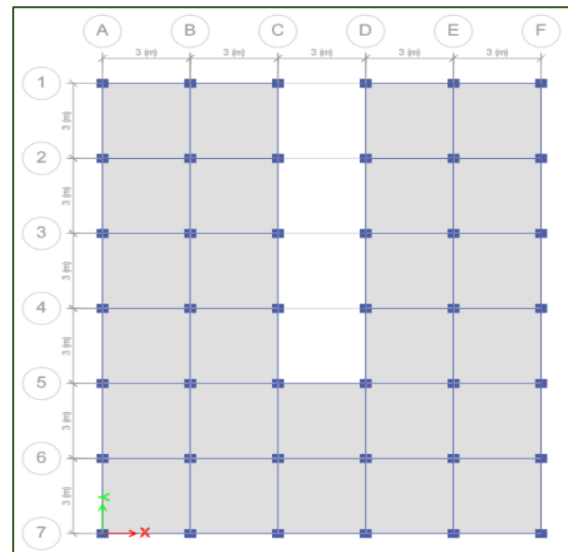
(b) Model 2 - L Shape



(c) Model 3 - C Shape



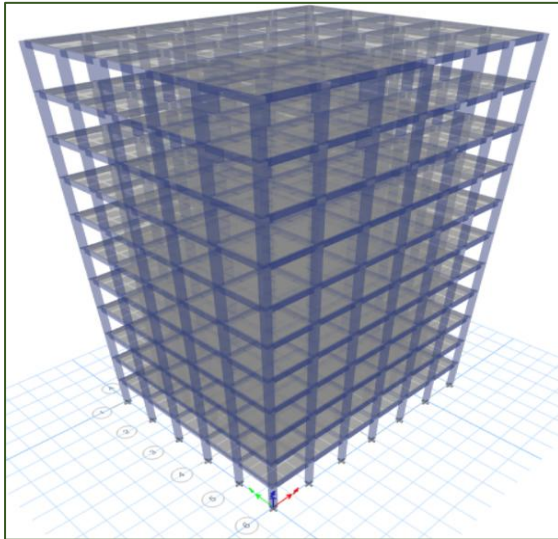
(d) Model 4 - T Shape



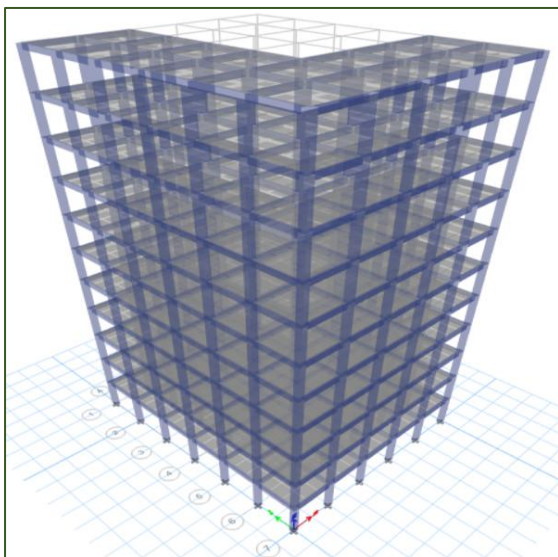
(e) Model 5 - U Shape

Figure 1: Plan Configurations of Building Models

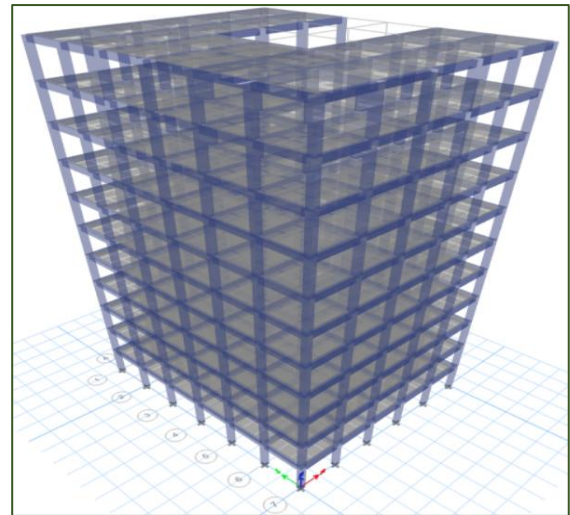
Figure 1 illustrates the plan configurations of the building models considered in the study, including rectangular, L-shaped, C-shaped, T-shaped, and U-shaped layouts. The rectangular configuration represents a regular plan, whereas the L, C, T, and U-shaped layouts represent irregular geometries with asymmetric distribution of mass and stiffness. These configurations are considered to evaluate the effect of plan shape on the seismic response of the structures.



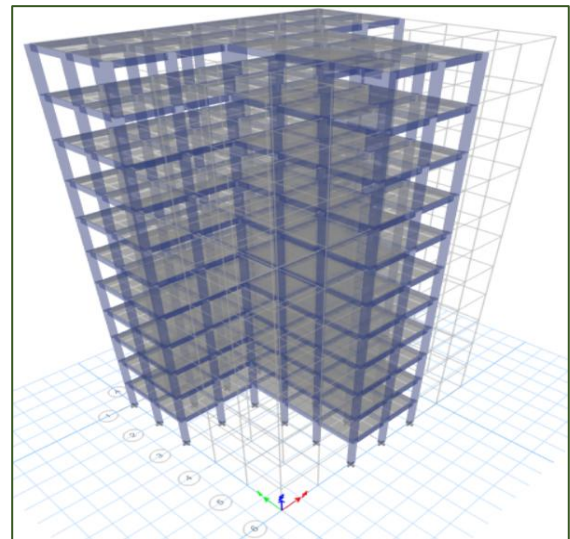
(a) Model 1 - Rectangular Shape



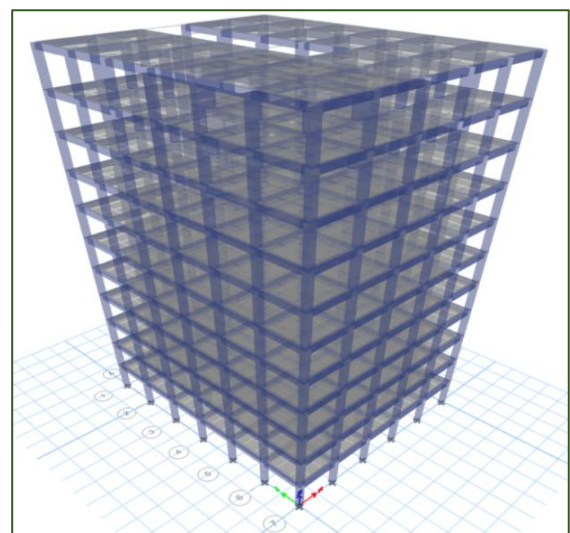
(b) Model 2 - L Shape



(c) Model 3 - C Shape



(d) Model 4 - T Shape



(e) Model 5 - U Shape

Figure 2: Three-Dimensional (3D) Views of

Building Models

Figure 2 presents the three-dimensional view of the RCC building model developed in ETABS, illustrating the spatial arrangement of structural elements such as beams, columns, and slabs. It provides a clear representation of the overall structural system considered for analysis.

4.7 Analysis Method

Seismic analysis of the building models is carried out using the Equivalent Static Method in accordance with IS 1893 (Part 1): 2016. This method represents earthquake effects in the form of equivalent lateral forces acting on the structure.

The total seismic base shear is calculated based on the seismic weight and relevant seismic parameters, and is distributed along the height of the building at each storey level. Lateral forces are applied in both principal directions to evaluate the structural response.

The analysis is performed using ETABS, and the response is obtained in terms of storey displacement, storey drift, and base shear, which are used to compare the performance of different plan configurations.

This method is suitable for regular and mid-rise buildings, providing a simplified yet reliable approach for seismic analysis.

V. RESULTS AND DISCUSSION

The seismic response of RCC building models with different plan configurations is evaluated and presented in this section. The analysis is carried out using ETABS, and the structural performance is assessed in terms of storey displacement, storey drift, and base shear.

A comparative study of all models is performed to examine the influence of plan configuration on seismic behaviour. The results are presented through tabular and graphical representations, enabling

identification of variations in response among different configurations.

A comparative study of all models is performed to examine the influence of plan configuration on seismic behaviour. The results are presented through tabular and graphical representations, enabling identification of variations in response among different configurations.

4.8 Storey Displacement

Storey displacement is a key parameter used to evaluate the lateral response of a structure under seismic loading. It represents the horizontal movement of each storey due to earthquake forces and reflects the stiffness characteristics of the building. Higher displacement values indicate increased flexibility and potential vulnerability under seismic action.

In this study, storey displacement is obtained for all models in both principal directions using ETABS. The variation in displacement along the height provides insight into the distribution of lateral forces and the influence of structural configuration on overall performance.

The displacement results in the X-direction indicate a significant influence of plan configuration on structural response. Taking Model 1 (rectangular configuration) as the reference, Model 2 (L-shape) and Model 4 (T-shape) show an increase in displacement of approximately 12.0% and 6.5%, respectively, indicating higher flexibility due to plan irregularity. In contrast, Model 3 (C-shape) and Model 5 (U-shape) exhibit a reduction of about 39.2% and 31.1%, respectively, reflecting improved stiffness characteristics.

Displacement increases progressively from the base to the top storey for all models, with variation in the rate depending on the plan configuration.

The graphical trend shows that displacement increases with height for all models; however, the rate of increase varies with configuration. Models 2 and 4 exhibit steeper variation, while Models 3 and 5 maintain lower displacement throughout the

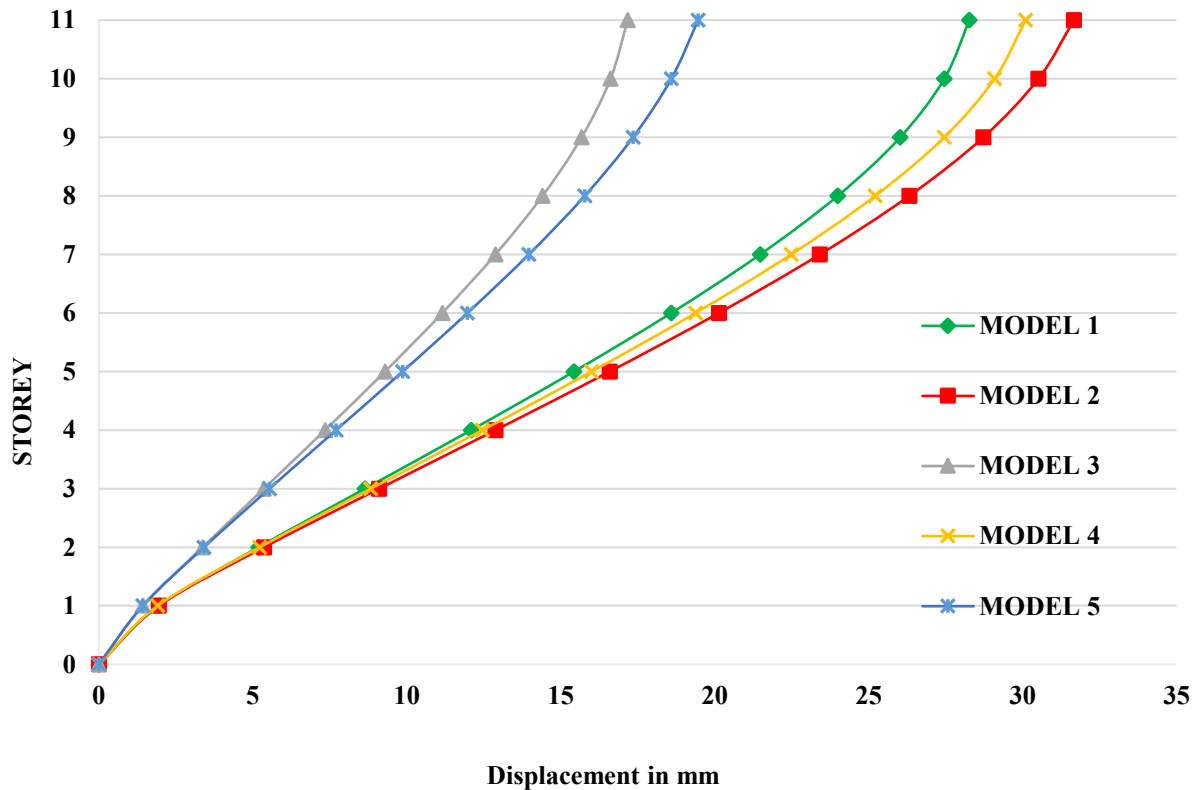


Figure 3: Storey Displacement in X-Direction

height. The divergence between models becomes more prominent at higher storeys, indicating the increasing influence of plan configuration.

The higher displacement observed in Models 2 and 4 is attributed to torsional effects and stiffness irregularity, whereas Models 3 and 5 demonstrate better performance due to relatively uniform stiffness distribution. Overall, the results confirm that plan configuration significantly affects displacement behaviour.

The displacement pattern in the Y-direction follows a trend similar to the X-direction, with comparatively smaller variation among models. Relative to Model 1, Models 2 and 4 show a marginal increase of approximately 3.1% and 1.7%, respectively, while Models 3 and 5 exhibit a reduction of about 36.8% and 42.3%, indicating better performance.

The graphical representation shows a gradual increase in displacement with height for all models, with relatively closer variation between

configurations. Models 2 and 4 follow a slightly higher trend, whereas Models 3 and 5 maintain lower displacement values throughout. The separation between models becomes noticeable at upper storeys, highlighting the influence of configuration.

The reduced variation in this direction suggests a more balanced stiffness distribution. However, the improved response of Models 3 and 5 indicates higher structural efficiency, while the slightly increased values in Models 2 and 4 are associated with minor irregularities. Overall, consistent behaviour is observed in both directions, with comparatively lower variation in the Y-direction.

4.9 Storey Drift

Storey drift is a critical parameter used to assess the deformation behaviour of a structure under seismic loading. It represents the relative horizontal displacement between two consecutive storeys and is an important indicator of structural stability and damage potential.

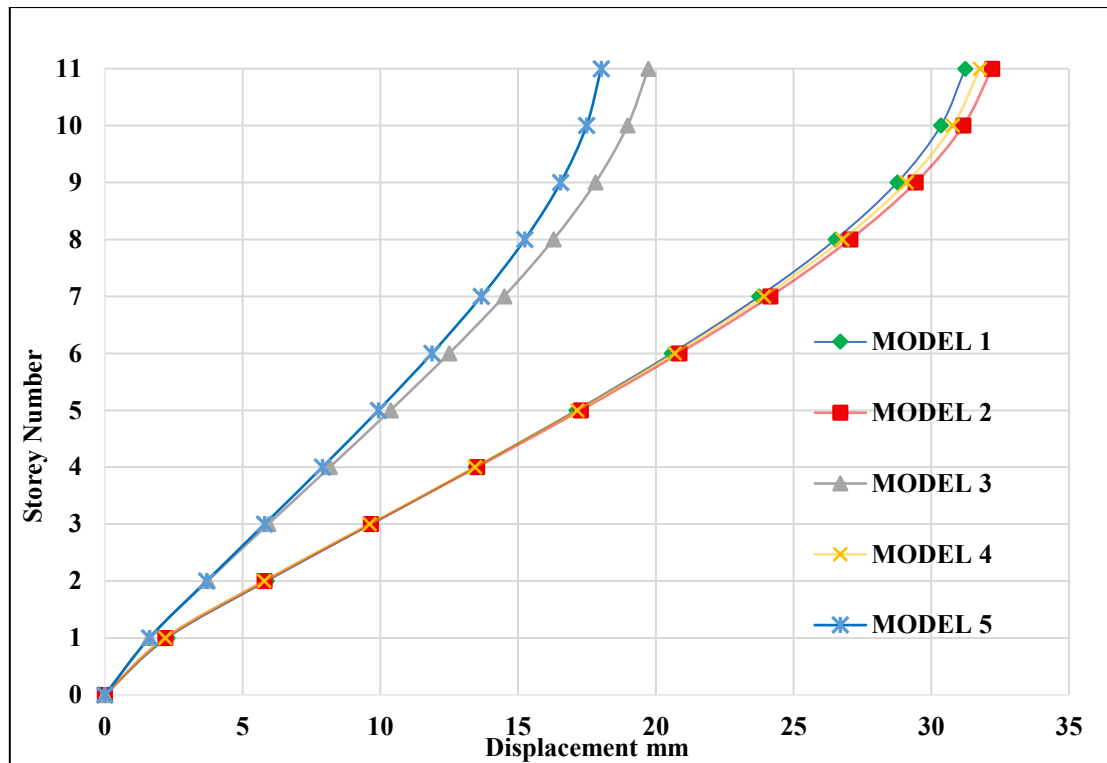


Figure 4: Storey Displacement in Y-Direction

In this study, storey drift values are obtained for all models in both principal directions using ETABS. The variation of drift along the height is analysed to evaluate the influence of plan configuration and to check compliance with the permissible limits specified in IS 1893 (Part 1): 2016.

The storey drift values in the X-direction exhibit a typical parabolic variation along the building height, with drift increasing from the base to mid-storey levels and decreasing towards the top. The maximum drift is observed at intermediate storeys, indicating the critical zone of lateral deformation.

Taking Model 1 as the reference, Model 2 shows a moderate increase in drift (approximately 5–10%), while Model 4 exhibits a slight increase (3–7%), reflecting the influence of plan irregularity and associated stiffness variation.

In contrast, Model 3 and Model 5 demonstrate a significant reduction in drift (about 35–45% and 30–40%, respectively), indicating improved stiffness distribution and better seismic performance.

The maximum storey drift obtained is approximately 0.126%, which corresponds to about 3.78 mm for a storey height of 3 m. This value is significantly lower than the permissible limit of 0.4% (12 mm) specified in IS 1893 (Part 1): 2016. Hence, all models satisfy the drift criteria, indicating adequate lateral stiffness and safe structural performance under seismic loading.

The graph shows that storey drift in the X-direction follows a parabolic trend, increasing from the base to mid-height and decreasing towards the top. Models 2 and 4 exhibit comparatively higher drift, while Models 3 and 5 show lower values, indicating better stiffness. The maximum drift occurs at mid-storey levels, highlighting the critical zone of deformation.

The storey drift values in the Y-direction show a parabolic variation along the height, with drift increasing from the base to mid-storey levels and decreasing towards the top.

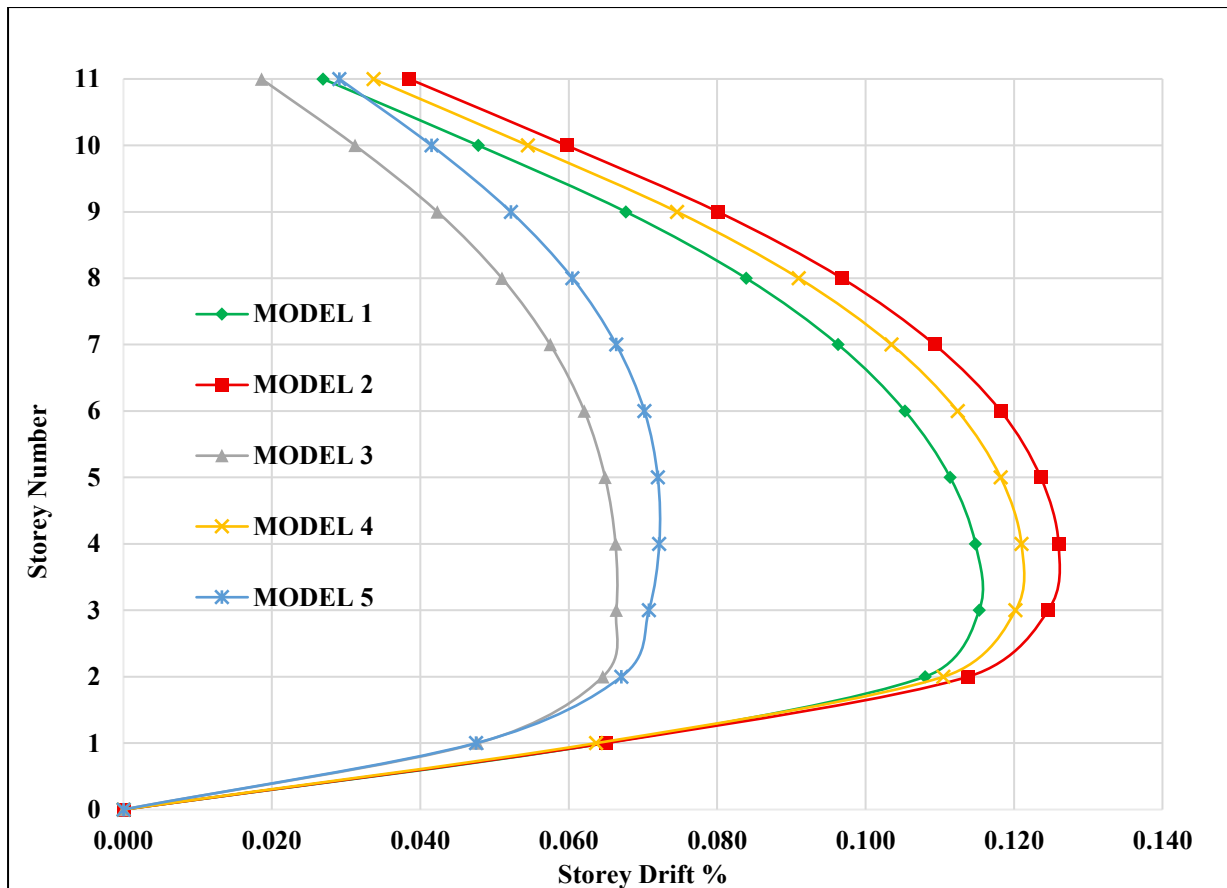


Figure 5: Storey Drift in X-Direction

The maximum drift occurs at intermediate storeys, indicating the critical zone of deformation under seismic loading.

Taking Model 1 as the reference, Model 2 shows a slight increase in drift (approximately 2–5%), while Model 4 exhibits negligible variation (0–3%), indicating similar stiffness characteristics. In contrast, Model 3 and Model 5 demonstrate a significant reduction in drift (about 35–50%), reflecting improved stiffness distribution and enhanced seismic performance.

The maximum storey drift observed is approximately 0.129%, which corresponds to about 3.87 mm for a storey height of 3 m. This value is well within the permissible limit of 0.4% (12 mm) specified in IS 1893 (Part 1): 2016. Hence, all models satisfy the drift criteria and exhibit adequate lateral stiffness.

The graph shows that storey drift in the Y-direction follows a similar parabolic pattern, increasing from the base to mid-height and decreasing towards the top. The variation among models is relatively

smaller, with Models 2 and 4 showing slightly higher drift, while Models 3 and 5 exhibit lower values. The maximum drift occurs at mid-storey levels, indicating the critical region of deformation.

4.10 Base Shear

Base shear is a key parameter in seismic analysis representing the total lateral force acting at the base of a structure due to earthquake excitation. It depends on factors such as seismic zone, structural mass, natural period, and lateral stiffness. In this study, base shear is used to evaluate the overall seismic demand and to compare the performance of different plan configurations.

The base shear values in the X-direction show significant variation among different configurations when compared with the reference model. Models 2 and 4 exhibit a considerable reduction of approximately 35%, while Models 3 and 5 show an increase of about 6% and 8.5%, respectively, with Model 5

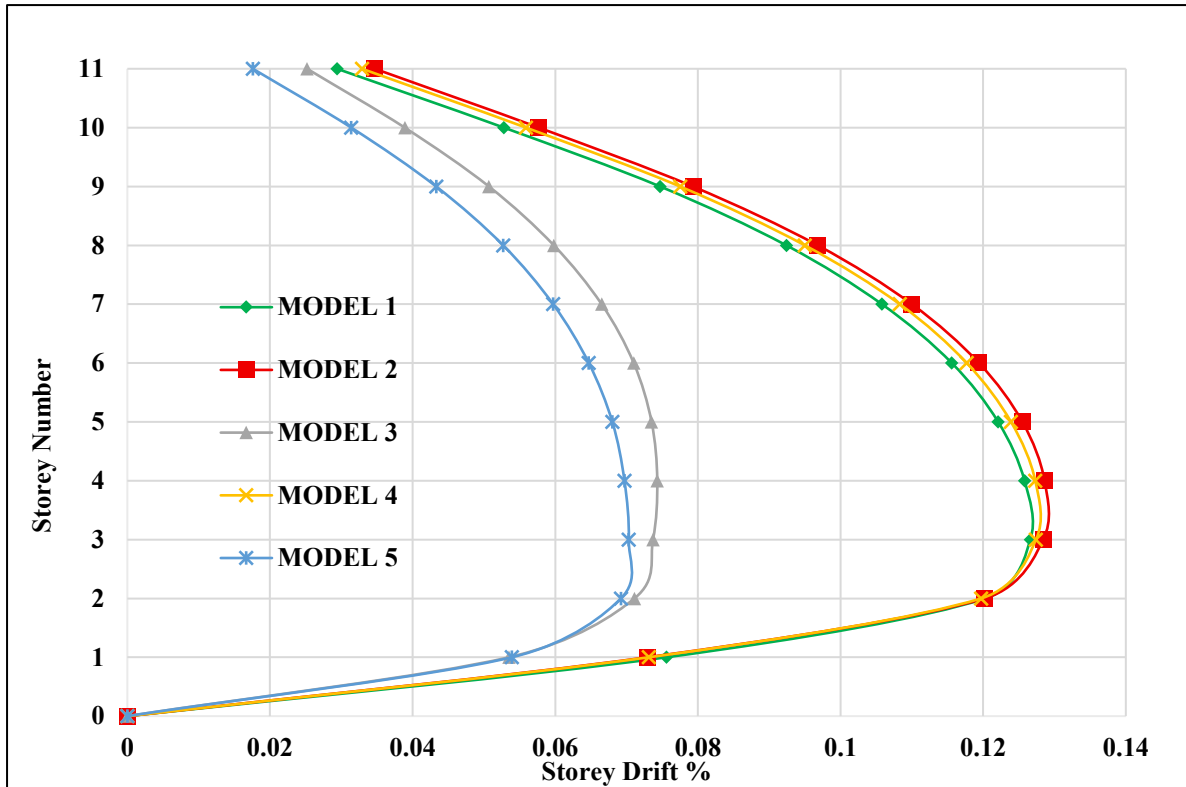


Figure 6: Storey Drift in Y-Direction

recording the highest value.

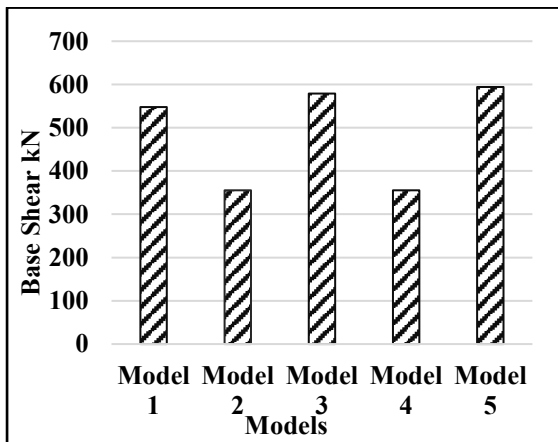


Figure 7: Base Shear in x-Direction

The graph shows the variation of base shear in the X-direction for different plan configurations. Model 5 exhibits the highest base shear, followed by Model 3 and Model 1, indicating higher seismic force demand due to increased stiffness. In contrast, Models 2 and 4 show significantly lower base shear, reflecting relatively flexible behavior.

This variation highlights the influence of plan configuration on seismic force distribution.

The base shear values in the Y-direction also show a distinct variation among the models. Compared to

Model 1, Models 2 and 4 exhibit a reduction of approximately 35%, while Model 3 shows a slight decrease of about 4%. In contrast, Model 5 shows an increase of nearly 8%, indicating the highest base shear in this direction.

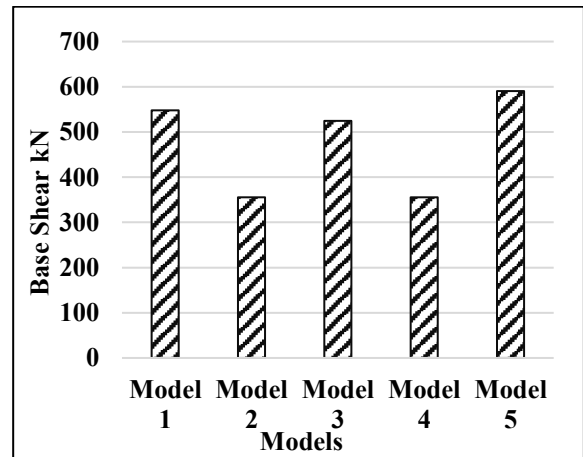


Figure 8: Base Shear in Y-Direction

The graphical trend is consistent with the tabulated results, with Models 2 and 4 showing lower values and Model 5 showing higher seismic demand. This behavior is influenced by stiffness variation along the Y-direction, where flexible configurations attract less force, whereas stiffer configurations resist higher lateral loads.

VI. CONCLUSION

1. The seismic analysis demonstrates that plan configuration significantly influences the dynamic response of RCC buildings. Irregular geometries tend to induce torsional effects and uneven stiffness distribution, leading to adverse seismic behaviour.
2. Storey displacement is observed to be higher in L-shaped and T-shaped models, indicating greater lateral flexibility. In contrast, C-shaped and U-shaped configurations show reduced displacement, reflecting better control over lateral movement.
3. Storey drift results follow a similar trend, with L-shaped models exhibiting the highest drift and C-shaped models the lowest. All models satisfy the permissible drift limits specified in IS 1893 (Part 1): 2016, indicating adequate structural performance.
4. Base shear is highest in the U-shaped model, followed by the C-shaped model, indicating higher seismic force demand due to increased stiffness. In contrast, L-shaped and T-shaped models show lower base shear but experience higher displacement and drift.
5. Among the considered configurations, the C-shaped model demonstrates comparatively better overall performance, with reduced displacement and drift along with acceptable base shear values. However, this observation is specific to the present study.
6. The study highlights the importance of selecting appropriate plan configurations in seismic regions. A balanced design approach considering stiffness, displacement control, and seismic force demand is essential for achieving safe and efficient structures as per IS 1893 (Part 1): 2016.

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