© April 2025 | IJIRT | Volume 11 Issue 11 | ISSN: 2349-6002

Performance Evaluation of Different Building Shapes Under Wind and Seismic Forces: A Structural Response Analysis

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***Abstract*—This Study focuses on comparing various building shapes—Square, C-shaped, H-shaped, L-shaped, and Rectangular—by evaluating their structural performance under extreme conditions, such as high wind and earthquake forces. The increasing global demand for structures that can endure severe atmospheric and seismic challenges, driven by urbanization, forms the basis of this investigation. The study aims to analyze how different building geometries respond to dynamic forces like wind and earthquakes.**

The main aim of this research is to assess the impact of different architectural shapes on the structural behavior of buildings when exposed to extreme loads. This is achieved through computer simulations combined with a thorough analysis of the shapes. Critical performance indicators such as stress distribution, displacement, and structural stability under wind and earthquake forces are closely examined to evaluate the buildings' overall performance in these conditions.

The research provides detailed insights into the deformation behavior of buildings under extreme loading conditions, demonstrating that specific shapes offer superior performance under certain circumstances. For example, rectangular and square buildings exhibit better lateral stability under wind forces, while H-shaped and C-shaped buildings show enhanced torsional stability during earthquakes. Additionally, the study evaluates the efficiency of different geometric forms in load transmission and their vulnerability to damage caused by external forces.

The findings highlight the importance of considering shape during the design phase of buildings, revealing that certain shapes are better suited to resist specific external forces. This information serves as a practical guide for architects and civil engineers to optimize building designs for greater safety and efficiency, particularly in regions prone to severe seismic and wind conditions.

***Index Terms*—Comparative analysis, Structural performance, Building shapes, Seismic, Wind pressure, Earthquake force, Simulation models, load analysis, Lateral displacement, stress distribution, Structural stability.**

I. INTRODUCTION

High-rise buildings are tall structures, typically starting at 12–14 stories or about 50 meters (164 feet) in height, designed to accommodate large populations. They require specialized construction techniques to ensure stability and safety, addressing factors like wind loads, seismic activity, and structural integrity. Commonly found in densely populated urban areas, these buildings maximize space in limited environments.

The construction of structures, including high-rise buildings, involves considering various factors such as stability and resistance to environmental forces. Key concerns include the significant loads caused by earthquakes and winds, which can place substantial strain on structures. High-rise buildings face a variety of loads affecting their safety and stability, which must be addressed during the design and construction phases. Below are the primary load factors relevant to high-rise structures.

A building's shape plays a critical role in determining its response to external forces such as wind and earthquakes. Common configurations like square, rectangular, C-shaped, L-shaped, and H-shaped buildings exhibit unique characteristics that influence their behavior under dynamic loads. Understanding these responses is essential for identifying optimal designs suited to different environmental conditions. The increasing frequency of severe weather events and heightened seismic activity in urban areas has highlighted the need for structures capable of withstanding extreme wind and earthquake forces.

This thesis aims to evaluate the impact of geometric configurations—square, rectangular, H-shaped, C-shaped, and L-shaped—on structural performance under wind and seismic loading. The analysis focuses on each shape's dynamic response and the resulting structural behavior, examining factors such as force distribution, displacement, and overall integrity. The study employs computational simulations and analytical models to assess these parameters comprehensively.

Objectives

- To analyze the structural performance of different building shapes (Rectangular, Square, H-shaped, C-shaped, and L-shaped) under peak wind and seismic loads.
- To evaluate the influence of building geometry on lateral displacement, stress distribution, and overall stability when subjected to extreme dynamic forces.
- To compare the wind pressure distribution and earthquake-induced forces across various building shapes using advanced simulation models.
- To identify the most resilient building shape in terms of structural integrity under peak loading conditions.
- To assess the role of geometric configurations in mitigating seismic and wind-induced stresses in high-risk regions.
- To provide design recommendations for architects and engineers on optimizing building shapes for enhanced safety and performance.
- To contribute to the development of more robust architectural solutions that minimize structural risk and improve resilience against natural hazards.

II. LITERATURE REVIEW

The literature review for title "Comparative analysis of different shape building i.e. Rectangular, Square, H shape, C and L shape corresponding to Peak wind and Earthquake loads" are as follows:

Vivek Mishra et al., (2025) analyzed the design of a 50-story high-rise building using geometric shapes like triangular, square, rectangular, circular, and elliptical, focusing on seismic and wind loads. The findings showed that elliptical shapes offer the best stability and safety, while triangular shapes perform the worst, providing insights for designing resilient buildings in critical zones. Amgoth Sujith Singh et al., (2024) examined the vulnerability of irregular-shaped structures to earthquake damage, especially in high seismic zones, using a 15-story building in four distinct shapes modeled in ETABS 9.7.1. Irregular shapes experienced greater deformation and reduced overturning moments, while regular shapes had higher base shear, highlighting the importance of regularity in seismic performance. Pritesh Jiwane et al., (2024) assessed the impact of geometric configurations on seismic performance using circular and rectangular building models simulated in STAAD Pro Software. Circular buildings demonstrated superior displacement, stability, and support reactions compared to rectangular ones, emphasizing the influence of shape on earthquake resilience. Ms. Tanmayee V. Dixit et al., (2024) investigated the effects of vertical winds on various building shapes, including square, rectangular, C-shaped, T-shaped, L-shaped, and hollow rectangular, in cyclone-prone zones. Square buildings performed best with minimal displacements and storey drifts, while C and T shapes also showed significant improvements, stressing the importance of shape in wind resistance. Shikha Tyagi et al., (2024) focused on wind loads affecting rectangular high-rise structures using CFD and ANSYS, considering wind incidence angles and pressure coefficients. The research highlighted the role of shape and height in determining wind load effects and provided insights for designing stable tall structures. Pavankumar M. Bavaskar et al., (2024) utilized advanced simulations to analyze the impact of form, height, and materials on the structural performance of tall buildings in wind-prone areas. The research explored adjustable facades and tuned mass dampers to reduce wind forces, offering strategies for economical and efficient designs in windy regions.

Sachin Vasantrao Kendre et al., (2023) evaluated the effects of wind loads on tall buildings, identifying that square and circular shapes experience lower wind stress and better stability. It emphasized the importance of efficient structural systems, lateral bracing, and shear walls to mitigate wind loads. Raju Mudassani et al., (2023) Using ETABS software, this research analyzed seismic forces on buildings with varying vertical geometries. The results showed that storey displacement increases with building height, highlighting the importance of design considerations for seismic resistance.

Kamlesh Raikwar et al., (2022) designed a 50-story high-rise building in different shapes, including rectangular, square, triangular, circular, and elliptical, to assess their performance under seismic and wind loads. Elliptical shapes were identified as the most stable, while triangular shapes performed the worst, guiding optimal designs for challenging conditions. Rahul Kumar Meena et al., (2022) compared wind-induced responses in four building models with regular and irregular shapes using CFD. The Y-shaped model with rounded corners exhibited the lowest base moment and drag coefficient, making it the most efficient design for resisting wind loads.

Kamlesh Mehta et al., (2020) analyzed the aerodynamic performance of circular, elliptical, and hexagonal buildings under wind loads. Rounded corners reduced drag forces, while sharp-edged shapes experienced higher drag, highlighting the need for aerodynamic designs in wind-prone areas. Mahendra Balasheb Shelke et al., (2019) examined the effect of aspect ratios on high-rise buildings under wind and earthquake loads. It emphasized the significance of wind-earthquake-structure interactions in determining structural performance, providing crucial insights for designing stable buildings. Kiran Kumar J et al., (2018) addressed the challenges of constructing tall buildings in limited spaces, analyzing the wind resistance of C-shaped, PLUS-shaped, and rectangular buildings. The PLUS shape demonstrated superior wind resistance, followed by the C shape, while the rectangular shape performed the worst. Mahendra Balasaheb Shelke et al., (2018) study explored how varying aspect ratios influence the seismic and wind performance of buildings, emphasizing the importance of aspect ratio in maintaining stability and safety under external forces. Kiran Kumar et al., (2018) examined the resistance of different building shapes to wind loads, concluding that non-angular shapes provide better resistance. It evaluated the impact of geometric configurations on structural behavior in tall buildings.

III. METHODOLOGY

In this study, the structural behavior of high-rise steel buildings (G+24) with different geometric configurations—Rectangular, Square, L-shaped, C-shaped, and H-shaped—is analyzed under the influence of peak wind and seismic loads.

Table 1 Building Parameters

Variables	Description	
Plan Shapes	Rectangular, Square, L-shaped, C-shaped, and H-shaped	
No. of stories	G+24	
Dimensions	Length	36m
	Height	80m
Floor height	3.2m	
Column (B*D)	G-4 Floor	1.2m*1.2m
	4-8 Floor	1.05m*1.05m
	8-12 Floor	0.9m*0.9m
	12-16 Floor	0.75m*0.75m
	16-20 Floor	0.6m*0.6m
	21-24 Floor	0.45m*0.45m
Beam (B*D)	G-4 Floor	0.45m*0.6m
	12-16 Floor	0.45m*0.45m
	16-20 Floor	0.3m *0.45m
Slab thickness	0.150m	
Grade of concrete	M30	
Grade of steel	Fy550	
Seismic Zone	V	
Wind speed	55	

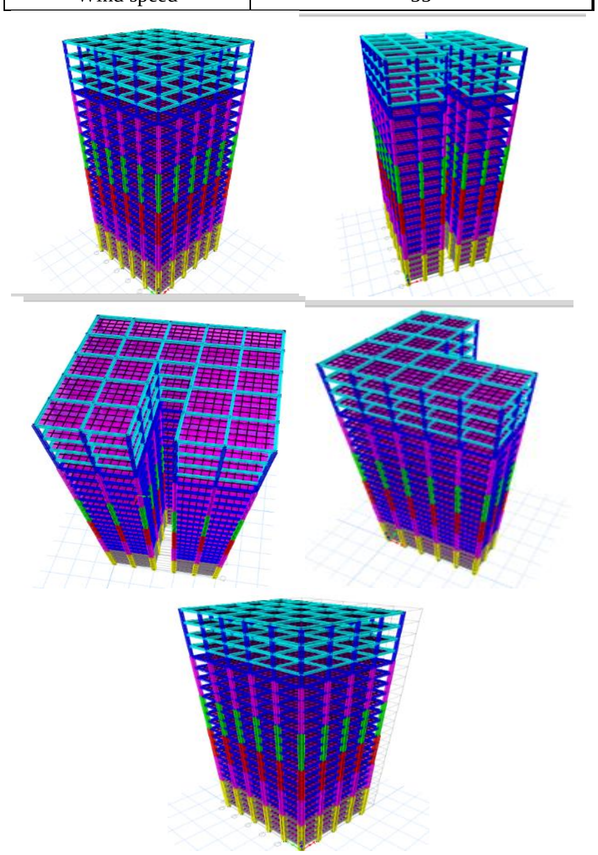

Fig 1: (a) SQUARE Shaped (b) H Shaped (c) L Shaped (d) C Shaped (e) Rectangle Shaped Building

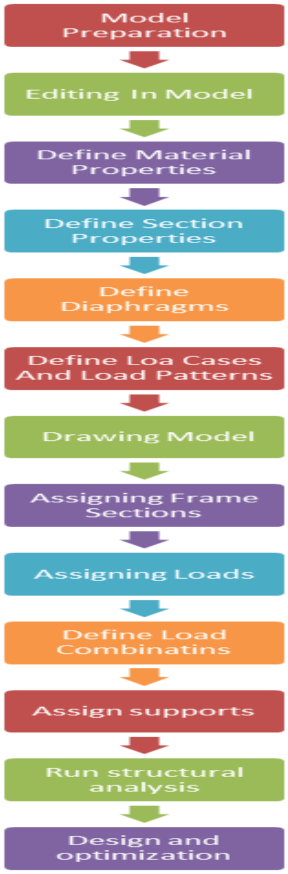

Fig 2: Modelling Steps

IV. RESULTS AND DISCUSSION

The effects of base shear, shear force, bending moment, storey drift, and displacement differ significantly in different shape structure.

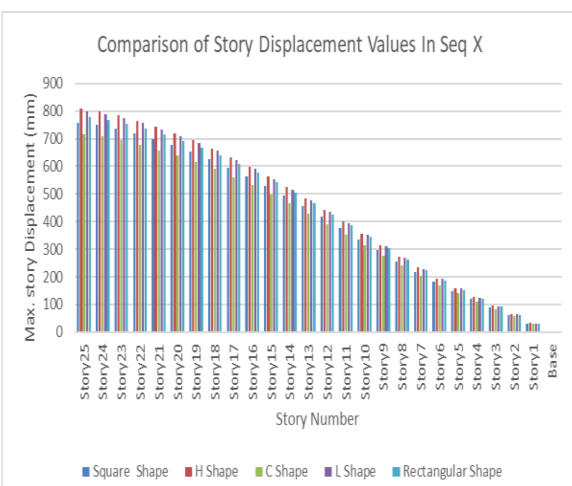

Fig. 3 Comparison of Story Displacement Values in Seq X

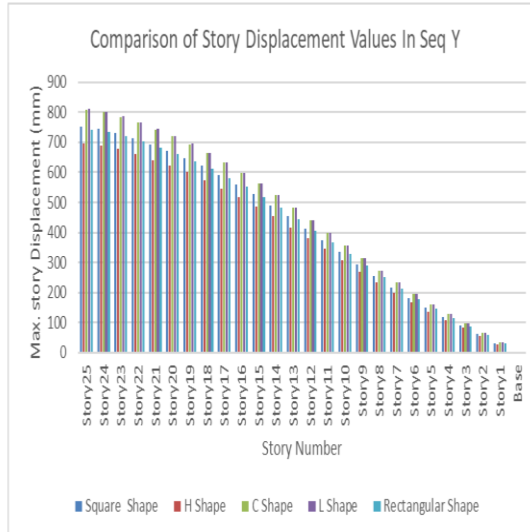

Fig. 4 Comparison of Story Displacement Values in Seq Y

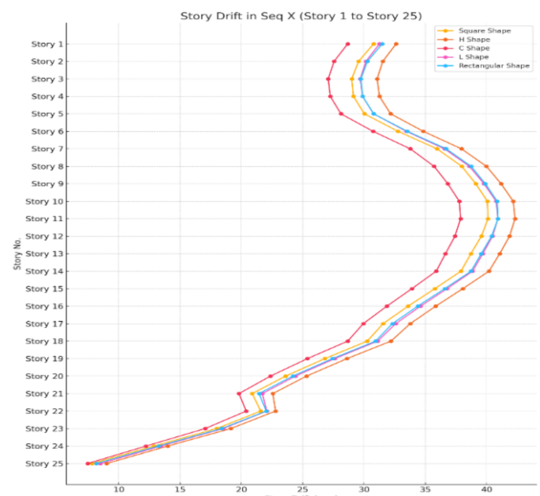

Fig. 5 Comparison of Story Drift Values in Seq X

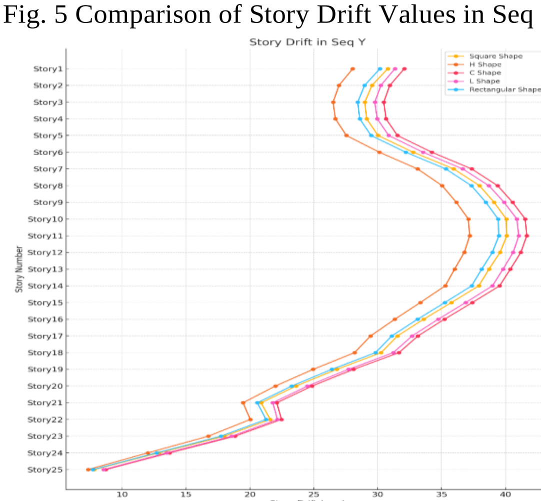

Fig. 6 Comparison of Story Drift Values in Seq Y

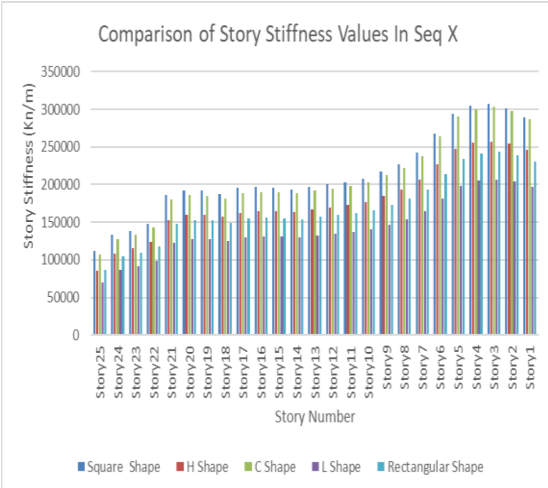

Fig. 7 Comparison of Storey Stiffness Values in Seq X

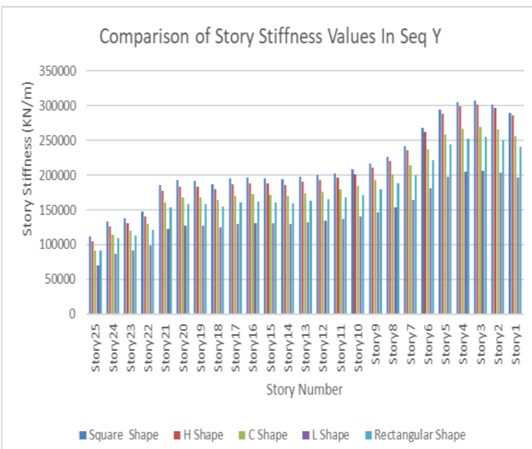

Fig. 8 Comparison of Storey Stiffness Values in Seq Y

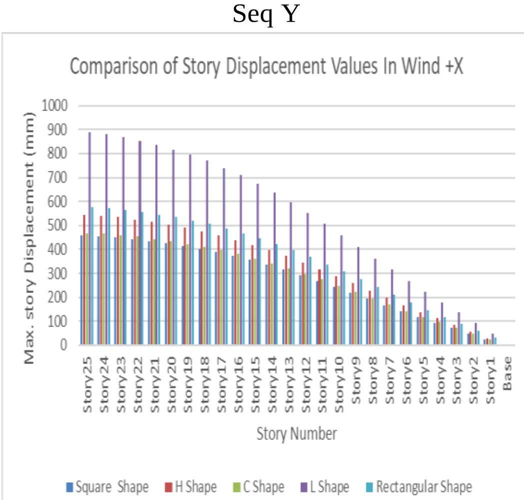

Fig. 9 Comparison of Storey displacement Values in Wind X

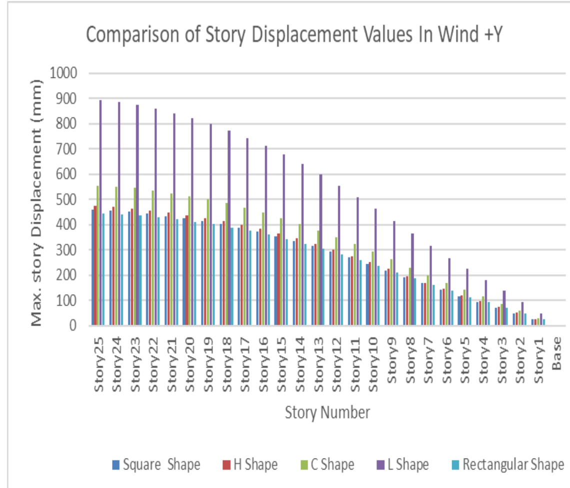

Fig. 10 Comparison of Storey displacement Values in Wind Y

V. CONCLUSIONS

This study systematically evaluated the structural performance of various building shapes Rectangular, Square, H-shaped, C-shaped, and L-shaped—under peak wind and seismic loads using advanced simulation models. Studying the geometry's effect on building strength provides helpful information on the provided structure flexibility by geometry. The geometry's effect has been analyzed based on key structural parameters like lateral displacement, stress distribution, and stability.

Based on numerical performance indicators, the following conclusions were drawn:

- Lateral Displacement: While symmetrical shapes (Rectangular and Square) showed lower lateral displacement which improved their seismic resilience, irregular shapes (H, C, and L) exhibited higher displacement making them more susceptible to dynamic forces.
- Wind Pressure Distribution: Wind resistance was higher in rectangular and streamlined structures because they experienced low aerodynamic drag as sharp-edged geometries suffered from high wind-induced stress.
- Seismic Base Shear: Uniform mass and stiffness (like Rectangular & Square shapes) provided better performance in load distribution and thus had lower base shear forces in comparison to the irregular geometry structures.

- Story Drift: Asymmetrical shaped buildings had higher story drift, which increased likelihood of collapse, while compact geometries showed less risk of structural instability.
- Stress Concentration: Joints and edges of Irregular structures (H, C, and L) had a higher tendency to accumulate stresses that eventually lead to localized structural failure when subjected to extreme loads.
- Structural Stiffness: The degree of deformation for square and rectangular buildings with higher overall stiffness was significantly lower, resulting in a more stable structure.
- Load Distribution Efficiency: In compact geometries, wind and seismic forces were observed to be more uniformly distributed, whereas more irregular shapes needed extra support in order to be stable.
- Design Optimization: These results indicate that improper building shape design selection may be detrimental in high-risk area performance. While compact shapes and symmetrical forms are favorable in high seismic zones, more aerodynamic shapes are helpful in regions exposed to strong winds.

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