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# Time History Analysis of Irregular Shape Building

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**Abstract**

Irregular-shaped buildings have become increasingly common in modern construction due to architectural innovation, yet they pose significant challenges in seismic design because of their complex dynamic behavior. This study investigates the seismic performance of various irregular building configurations L-shaped, C-shaped, T-shaped, rectangular, and square—using Time History Analysis (THA). Structural models of G+20 reinforced concrete buildings are developed in ETABS following IS 456:2000 and IS 1893 (Part 1):2016 standards. The 1940 El-Centro earthquake record is used as seismic input and scaled to multiple intensities to assess building response under varying levels of ground motion. Key parameters such as storey displacement, inter-storey drift, torsional irregularity, base shear, and floor accelerations are analyzed to understand the influence of geometric and stiffness irregularities. Results indicate that irregular buildings experience higher torsional effects and amplified lateral displacement compared to regular structures, making them more vulnerable during strong seismic events. The study highlights the limitations of conventional linear analysis methods, such as Response Spectrum Analysis (RSA), in capturing nonlinear dynamic interactions. Findings provide important insights for structural engineers and contribute to developing improved design strategies for enhancing the seismic resilience of irregular-shaped buildings.

***Keywords:*** *Time History Analysis, Irregular Buildings, Seismic Performance, ETABS, Torsional Irregularity*

## 1. Introduction

The seismic performance of buildings plays a critical role in determining the safety, resilience, and long-term reliability of structures in earthquake-prone regions. Traditional engineering practice has long favored regular and symmetrical building configurations due to their predictable dynamic behavior and ease of analysis. Such buildings typically possess uniform stiffness and mass distribution, enabling them to better withstand lateral loads generated during seismic events. However, with increasing demands for architectural innovation, urban space optimization, and functional flexibility, the construction of irregular shape buildings has become more prevalent. These structures, though visually appealing and functionally efficient, pose significant challenges in seismic design due to their complex geometry and non-uniform mass and stiffness characteristics. Irregular buildings exhibit deviations in plan configuration, vertical alignment, or mass distribution, resulting in asymmetrical shapes such as L-shaped, T-shaped, or U-shaped layouts. Additionally, features like soft stories, varying floor heights, and eccentric mass distribution introduce complexities in the structural response during earthquakes. These irregularities often shift the center of mass away from the center of rigidity, leading to torsional effects and differential floor displacements. Such behavior increases the vulnerability of these buildings to excessive drift, internal stresses, and localized failures, making their seismic analysis more challenging compared to regular structures.

Time History Analysis (THA) has emerged as one of the most reliable and accurate techniques for evaluating the seismic performance of irregular buildings. Unlike simplified methods such as Response Spectrum Analysis, THA captures the real-time response of the structure under actual earthquake ground motion records. This allows for a detailed understanding of transient effects, resonance behaviors, torsional responses, and potential nonlinear deformations that typically occur in irregular configurations. By analyzing the complete duration of seismic excitation, engineers gain deeper insights into critical weaknesses and response patterns that may not be evident through conventional linear analysis methods. This study aims to investigate the seismic behavior of irregular shape buildings using Time History Analysis, focusing on the influence of plan irregularity, vertical irregularity, and mass eccentricity on overall structural performance. The findings of this research will provide valuable guidance for seismic design, retrofitting strategies, and improved safety standards for irregular buildings, thereby contributing to safer and more resilient infrastructures in earthquake-sensitive regions. In alignment with this research focus, the study is guided by the following objectives:

- To perform a time history analysis of irregularly shaped buildings using ETABS and compare their seismic performance with that of regular buildings.
- To examine the effects of different seismic forces on the dynamic behavior of irregularly shaped buildings, including the impact of ground motion variations.
- To identify key factors that influence the dynamic response of irregular buildings, such as geometry, stiffness, and mass distribution, and their effect on seismic performance.
- To propose recommendations for enhancing the seismic resilience of irregular buildings based on the findings from the time history analysis results.

## 2. Literature Review

**V. S. Shingade (2022)** this study focuses on the Non-linear Time History Analysis of Irregular Shaped Buildings, emphasizing the impact of ground motion characteristics on seismic performance. Earthquake behavior, influenced by parameters such as PGA, frequency, and duration, plays a vital role in determining structural response. The research evaluates G+30 buildings with normal, L-shaped, and C-shaped floor plans using the 1940 El-Centro earthquake record, assuming Zone V and medium soil conditions. ETABS is used to analyze story displacement, drift, and base shear. Results indicate that low-frequency vibrations significantly affect RC structures, with irregular buildings showing higher variability, highlighting the need for improved earthquake-resistant design. **Mr. Saurabh P. Agrawal (2021)** this study centers on the Time History Analysis of Irregular Shape Concrete Buildings using SAP2000, examining the nonlinear dynamic behavior of a ten-story RCC structure under varying seismic intensities. Five time-history records corresponding to MMI intensities V to X are applied to evaluate structural response. The analysis reveals a consistent variation in base shear and storey displacement with increasing intensity levels, demonstrating clear sensitivity of the building to seismic loading. The findings highlight the importance of using Time History Analysis for multistoried RCC buildings and emphasize the need to consider multiple seismic intensities to ensure safety and resilience in earthquake-prone regions. **Mr. Vivek Asati (2021)** this study focuses on the Time History Analysis of Irregular Shape Buildings, emphasizing the need to understand ground motion characteristics for effective seismic evaluation. Earthquakes result from the sudden release of strain energy in the Earth's crust, producing seismic waves that can severely damage structures. Key dynamic parameters—Peak Ground Acceleration, frequency content, and duration—play a crucial role in determining structural response. Linear Time History Analysis offers advantages over modal response spectrum analysis when nonlinear behavior is absent, as it provides detailed, time-dependent response data. Its ability to preserve the relative signs of response quantities makes it especially valuable for assessing interaction effects in structural design. **Nandini M Naganur (2018)** this study focuses on the Seismic Analysis of Plan Irregular Buildings, emphasizing the vulnerability of structures with geometric discontinuities during earthquakes. Irregularities cause force concentration and deformation at junctions, increasing the risk of structural failure. While Equivalent Static Analysis is commonly used for low- to mid-rise regular buildings, it lacks accuracy in capturing true dynamic behavior. Response Spectrum Analysis provides a more realistic assessment by considering multiple modes of vibration. This project conducts a comparative analysis of G+10 regular and irregular RCC buildings using ETABS 2019, evaluating the effectiveness of various seismic analysis methods in predicting structural performance under seismic loading.

**Sahil Tomer (2022)** this study presents a comprehensive review titled "Evaluation of Seismic Response of Irregular Buildings", addressing the growing trend of constructing irregular-shaped structures that are highly vulnerable to seismic forces. Emphasis is placed on vertical irregularity, which significantly influences structural performance during earthquakes. Both linear and nonlinear time history analyses are examined to evaluate seismic behavior in various irregular configurations. Findings indicate that buildings with soft stories, characterized by reduced stiffness at lower levels, experience higher inter-storey drifts and greater damage compared to other irregularities. The review underscores the necessity of addressing such irregularities in seismic design to enhance structural safety and reduce earthquake-induced failures. **V. S. Shingade (2022)** this study, titled "Non-Linear Time History Analysis of an Irregular Shaped Building," investigates the seismic performance of L-shaped and C-shaped G+30 RCC structures using ETABS 2018. Both building models are analyzed under Zone V seismic conditions on medium soil, with ground motion data from the 1940 El-Centro earthquake. Key response parameters—displacement, storey drift, base shear, floor acceleration, and time period—are evaluated to understand the behavior of irregular buildings under strong seismic loading. The findings emphasize the significance of accounting for structural irregularities and dynamic response characteristics to enhance earthquake-resistant design in high-risk seismic regions. **Uttam Jadhav Shubham (2025)** this study, titled "Dynamic Analysis of Irregular Shape Structures Using Time History and Response Spectrum Methods," highlights the vulnerability of modern irregular buildings to dynamic loads such as wind and earthquakes. Architectural complexity often leads to irregular planning, increasing the risk of collapse under seismic forces. Using ETABS, the study analyzes a G+20 Marcos 3-D model with asymmetric vertical configuration, following IS 1893:2016 guidelines. Both Time History and Response Spectrum Analyses are employed to determine displacement, lateral forces, and shear demands. Three RC building frames are modeled individually, emphasizing the significant effects of plan irregularity and vertical discontinuities on structural performance under dynamic loading.

### 2.1 Research gap

Despite advancements in seismic analysis methods, a significant research gap remains in the comprehensive evaluation of irregular-shaped buildings using Time History Analysis (THA). Existing studies and design guidelines largely emphasize regular structures, overlooking the complex dynamic responses of irregular buildings caused by asymmetry, mass eccentricity, and stiffness variations. Research has examined isolated issues—such as torsional effects, soft stories, and inter-storey drifts—but lacks an integrated assessment under time-varying seismic loads. Additionally, limited studies evaluate the effectiveness of mitigation strategies specifically for irregular buildings. Therefore, a deeper investigation using THA is essential to understand seismic vulnerabilities and improve resilience in irregular structures.

## 3. Proposed Methodology


**Fig 1. Methodology Flowchart**

This study employs a quantitative, analytical, and simulation-based methodology to investigate the seismic performance of irregular-shaped buildings using Time History Analysis (THA) and to compare their behavior with regular building configurations. The methodology is structured into four key stages: model development, seismic input selection, dynamic analysis execution, and comparative evaluation. In the first stage, three-dimensional structural models of both regular and irregular buildings are developed in ETABS. The selected irregularities include plan irregularities (L-shaped and C-shaped configurations) and vertical irregularities such as setbacks and mass discontinuities. All models are designed as G+20 reinforced concrete structures using IS 456:2000 and IS 1893 (Part 1):2016 provisions. Material properties, load combinations, mass source, damping ratio, and boundary conditions are defined uniformly to ensure comparability. In the second stage, the 1940 El-Centro ground motion record is adopted as the primary seismic input due to its reliability and extensive use in seismic engineering research. The ground motion data is scaled to reflect different seismic intensities, enabling assessment under varying earthquake scenarios. This provides a realistic representation of how buildings respond to real-time dynamic loading.

The third stage involves performing Time History Analysis in ETABS for each building configuration. Key parameters such as lateral displacement, inter-storey drift, torsional rotation, storey shear, and floor accelerations are extracted to understand the influence of irregularities on seismic response. Additionally, Response Spectrum Analysis (RSA) is conducted to compare linear dynamic behavior and validate the THA results. In the final stage, results are analyzed using graphical interpretation, statistical comparison, and sensitivity analysis. Critical factors influencing seismic behavior—such as geometry, stiffness irregularity, and mass eccentricity—are identified. The study operates under controlled assumptions, excluding soil–structure interaction, non-structural elements, and P-delta effects. Overall, this methodology provides a systematic and comprehensive framework for evaluating the seismic vulnerabilities of irregular-shaped buildings and supports the development of improved design recommendations for enhancing structural resilience.

## 4. Problem Statement and Modeling

**Building models**

Modelling a building entails designing and assembling its numerous load-bearing components. The model should ideally reflect mass distribution, strength, stiffness, or deformability. Plan and 3-D view of building of various shapes are shown below.

**Models**

Model 1: Square shape building

Model 2: Rectangular shape building

Model 3: C shape building

Model 4: L shape building

Model 5: T shape building

**Buildings description**

**Table 1.** Building components and details

| Name of parameter | Value | Unit |
|---|---|---|
| No. of storey | G+15 | Nos. |
| Bottom storey height | 1.5 | m |
| Storey height | 3 | m |
| Soil type | Medium | |
| Plan area | 2500 | $m^2$ |
| Grid size | 5x5 | m |
| Thickness of slab | 150 | mm |
| Size of beam | 300 X 450 | mm |
| Size of column | 650 X 650 | mm |
| **Material properties** | | |
| Grade of concrete | M40 | $N/mm^2$ |
| Grade of steel | Fe500 | $N/mm^2$ |
| **Dead load intensities** | | |
| FF on floors | 1.5 | $kN/m^2$ |
| **Live load intensities** | | |
| LL on floors | 3 | $kN/m^2$ |

**Modeling images**

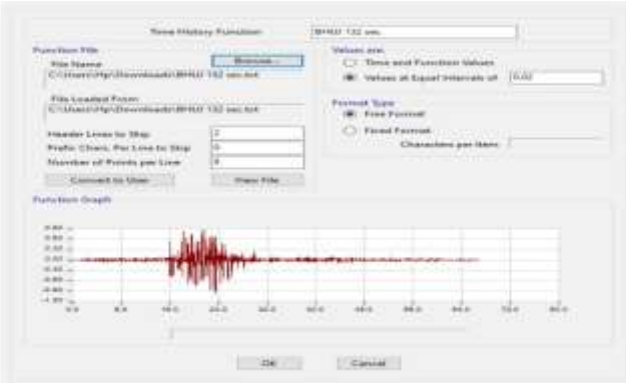

Fig 2. Time History Function Setup for Seismic Data Analysis

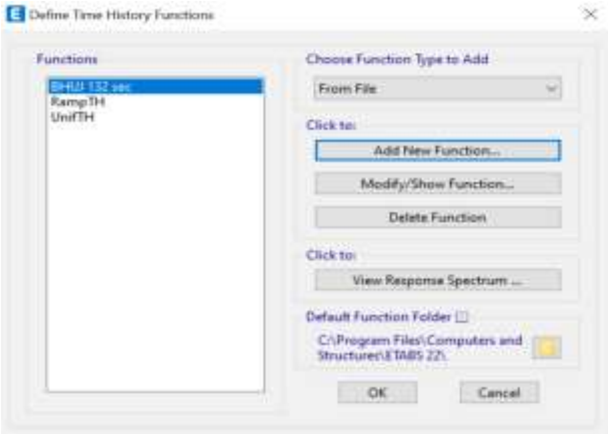


Fig 3. Defining Time History Functions in ETABS

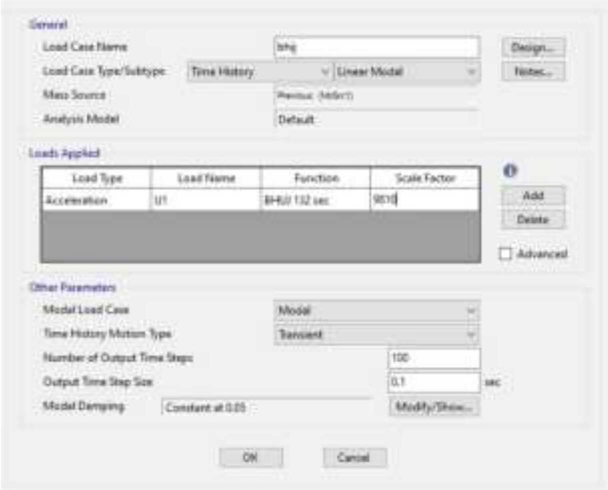


Fig 4. Defining Time History Load Case in ETABS

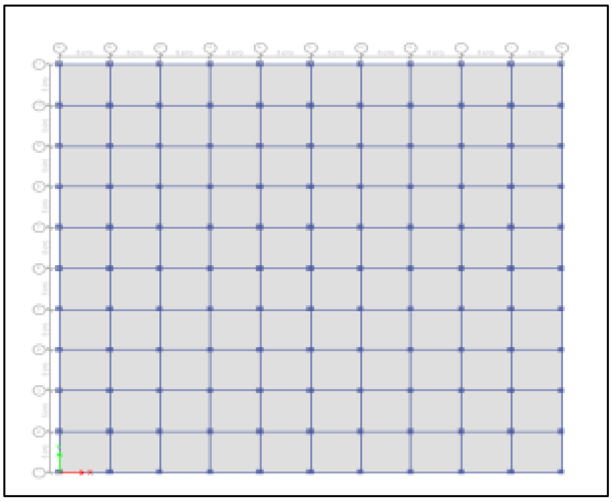

Fig 5. Plan view of square shape building

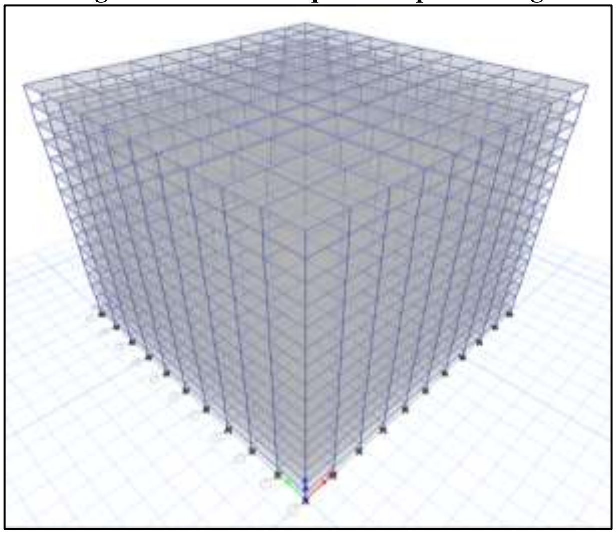

Fig 6. 3D view of square shape building

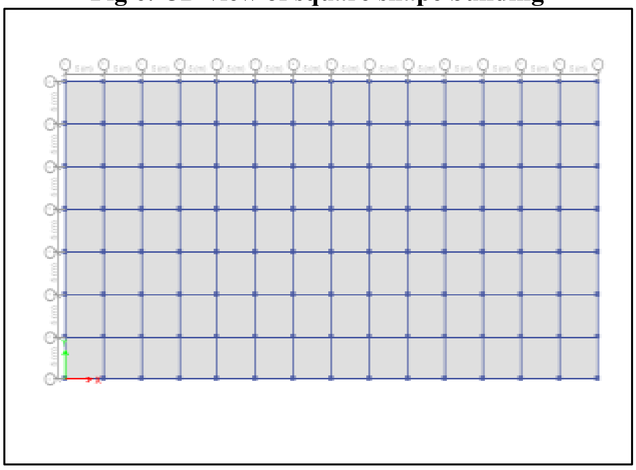

Fig 7. Plan view of rectangular shape building

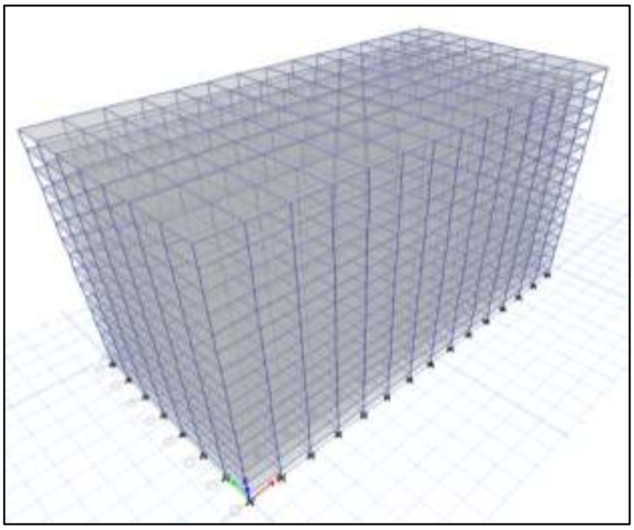

Fig 8. 3D view of rectangular shape building

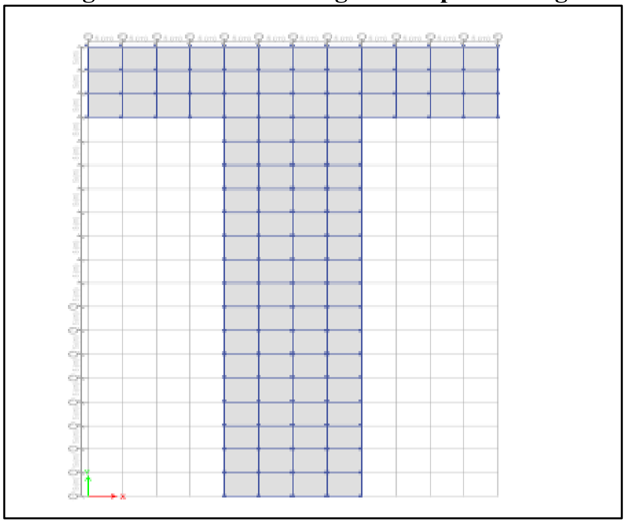

Fig 9. Plan view of T shape building

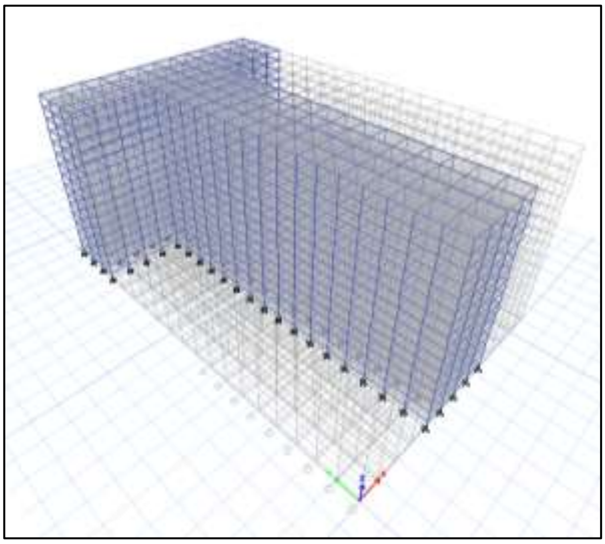

Fig 10. 3D view of T shape building

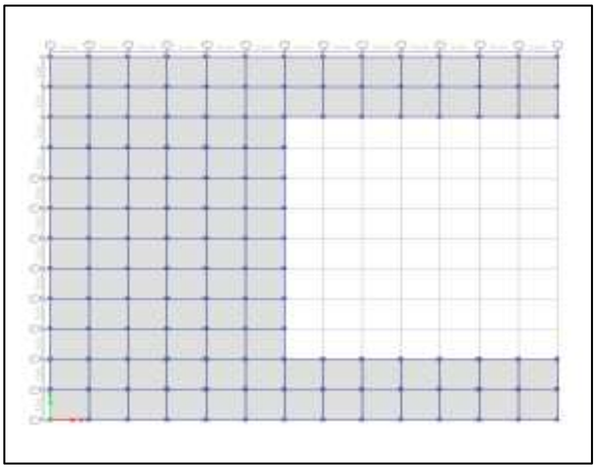

Fig 11. Plan view of C shape building

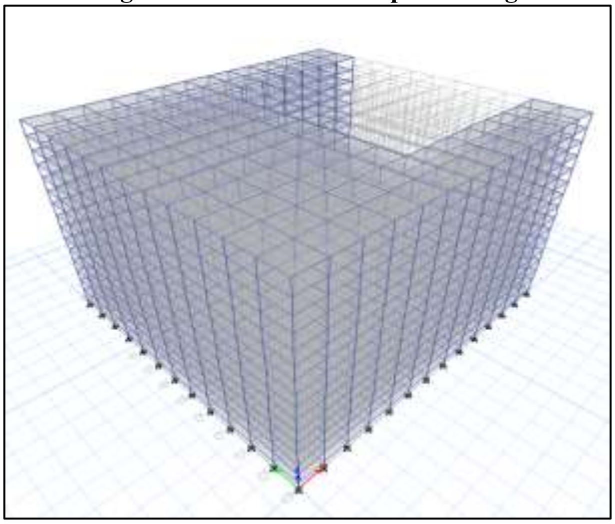

Fig 12. 3D view of C shape building

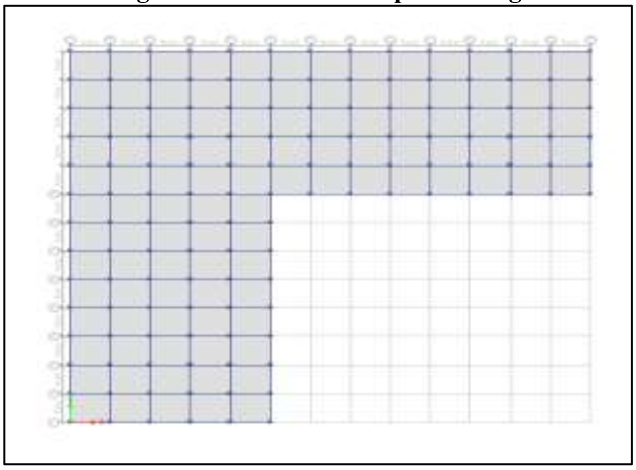

Fig 13. Plan view of L shape building

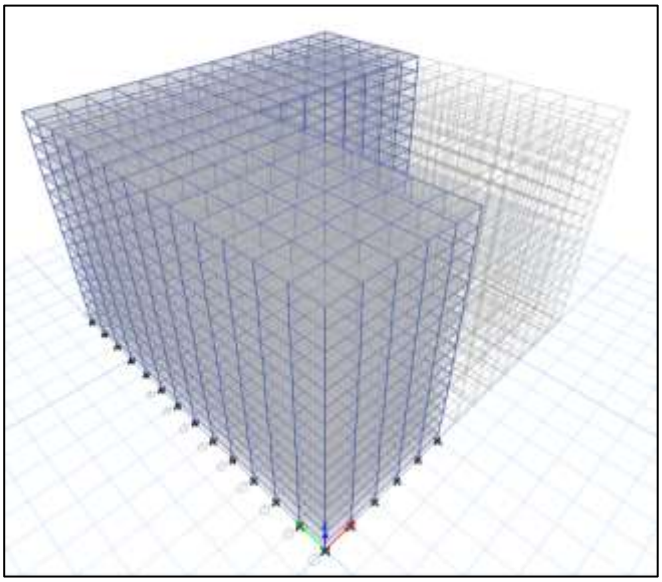

Fig 14. 3D view of L shape building

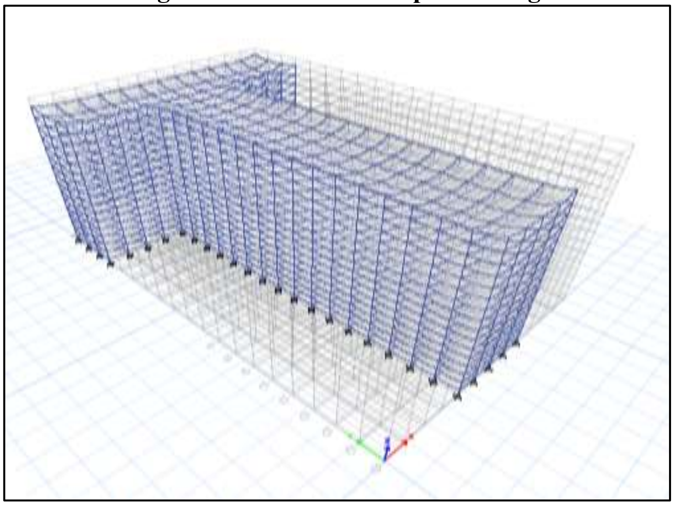

Fig 15. Run model

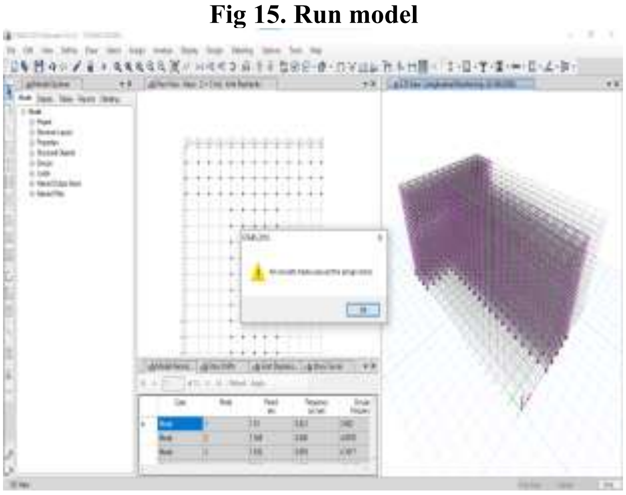

Fig 16. All members passed for load combinations

## 5. Result and Discussion

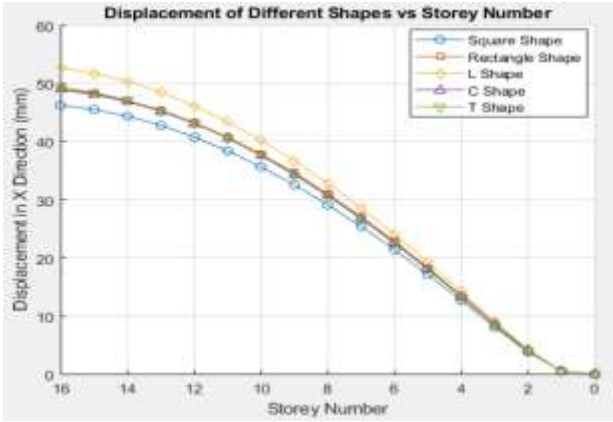


**Fig 17. Displacement of Different Shapes vs Storey Number**

The graph illustrates the comparison of storey displacements in the X direction for different aerodynamic building shapes—Square, Rectangle, L, C, and T. The highest displacement occurs at Story 16, where the L-shaped building exhibits a maximum value of 52.748 mm, which is 14.0% higher than the square shape (46.278 mm), 7.5% higher than the rectangle shape (49.057 mm), 7.8% higher than the C shape (48.931 mm), and 6.8% higher than the T shape (49.389 mm). The square shape consistently demonstrates the least displacement across all stories, highlighting its superior aerodynamic efficiency in mitigating lateral forces. At the lower levels, such as Story 1, the displacements converge with minimal differences between shapes; however, the square shape still shows slightly lower values. This trend emphasizes that the square shape provides better structural stability and aerodynamic performance, particularly in upper stories, compared to other configurations.

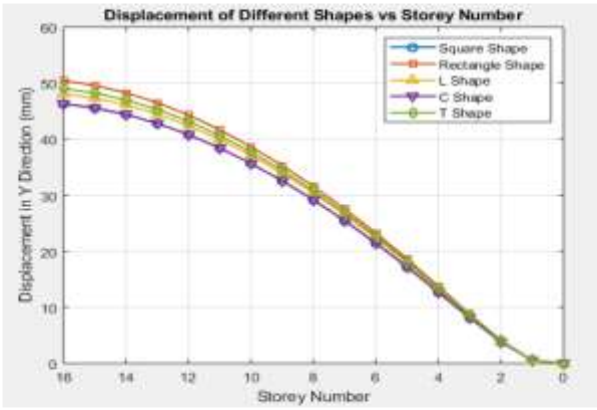


**Fig 18. Displacement of Different Shapes vs Storey Number (Y Direction)**

The graph compares storey displacements in the Y direction for various aerodynamic building shapes—Square, Rectangle, L, C, and T. At the topmost level, Story 16, the Rectangle-shaped building exhibits the highest displacement of 50.448 mm, which is 9.0% higher than the Square shape (46.278 mm), 4.9% higher than the L shape (48.103 mm), 8.8% higher than the C shape (46.34 mm), and 2.9% higher than the T shape (48.996 mm). The Square-shaped building consistently demonstrates the least displacement, showcasing its aerodynamic efficiency and structural stability. At lower storey levels, such as Story 1, the differences in displacement among shapes converge, with values such as 0.55 mm for the Square shape, 0.594 mm for the Rectangle shape, and 0.577 mm for the L shape. This trend highlights the minor impact of aerodynamic forces at the base of the structure. Overall, the analysis indicates that the Square-shaped building outperforms the other configurations in minimizing displacements across all stories, particularly in the upper stories, making it the most stable and efficient design for mitigating lateral forces in the Y direction.

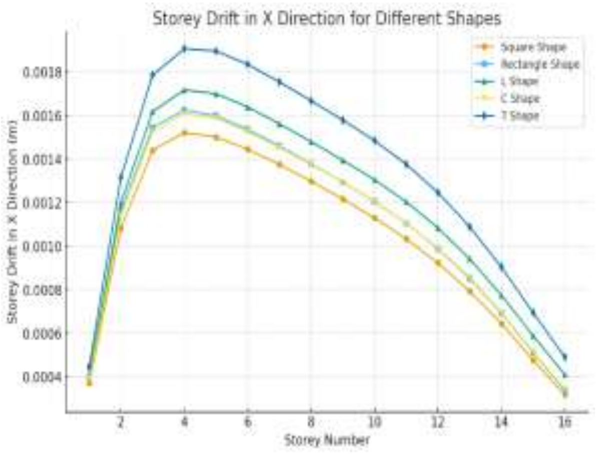


**Fig 19. Storey Drift in X Direction for Different Shapes**

The graph illustrates the storey drift in the X direction for different aerodynamic building shapes—Square, Rectangle, L, C, and T. Storey drift is highest at intermediate levels, with variations in performance among the shapes. In Story 10, which shows peak drift for most shapes, the T-shaped building exhibits the highest storey drift of 0.001485 m, which is 31.5% higher than the Square shape (0.00113 m), 23.2% higher than the Rectangle shape (0.001205 m), 17.9% higher than the C shape (0.001203 m), and 13.8% higher than the L shape (0.001305 m). The Square-shaped building consistently demonstrates the least drift across all stories, highlighting its aerodynamic and structural stability. At the lower stories, such as Story 1, the storey drift values for all shapes are minimal and closely aligned, with the Square shape recording a drift of 0.000371 m, which is 16.6% lower than the T shape (0.000445 m). The difference between shapes becomes more pronounced at the intermediate and upper stories. This analysis emphasizes that the Square-shaped building is the most efficient in minimizing storey drift, particularly at critical heights, making it the most stable configuration under lateral forces in the X direction.

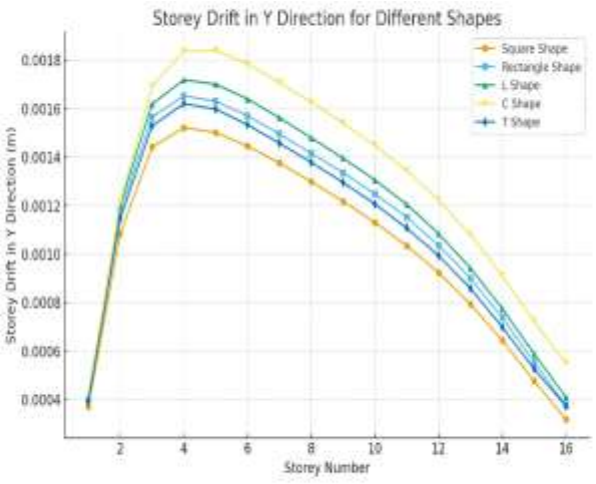


**Fig 20. Storey Drift in Y Direction for Different Shapes**

The graph compares the storey drift in the Y direction for different aerodynamic building shapes—Square, Rectangle, L, C, and T. Storey drift reaches its maximum at intermediate levels before decreasing toward the base and top of the structure. At Story 11, the C-shaped building exhibits the highest drift of 0.001344 m, which is 30.0% higher than the Square shape (0.001034 m), 16.7% higher than the Rectangle shape (0.001151 m), 11.6% higher than the L shape (0.001204 m), and 21.4% higher than the T shape (0.001107 m). The Square-shaped building consistently demonstrates the least drift across all stories, highlighting its aerodynamic stability and efficient structural behavior under lateral forces. At lower levels, such as Story 1, the drift values for all shapes converge, with the Square shape recording a drift of 0.000371 m, the lowest among all configurations, while the C shape is marginally higher at 0.000402 m, showing only an 8.4% Overall, the Square-shaped building outperforms the other shapes in minimizing storey drift, particularly at intermediate and upper stories, making it the most effective configuration for ensuring structural stability under lateral loads in the Y direction.

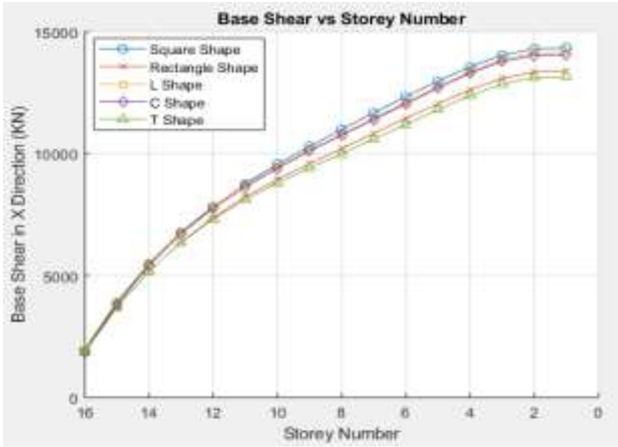


**Fig 21. Base Shear in X Direction vs Storey Number**

The graph illustrates the base shear in the X direction for different aerodynamic building shapes—Square, Rectangle, L, C, and T. Base shear increases progressively from the topmost storey to the base, with variations in performance across the different shapes. At the base (Story 1), the Square-shaped building experiences the highest base shear of 14,342.5339 kN, which is 7.4% higher than the Rectangle shape (13,384.9472 kN), 1.2% higher than the L shape (14,174.1968 kN), 1.9% higher than the C shape (14,069.4926 kN), and 9.0% higher than the T shape (13,161.0346 kN). This trend is consistent across lower stories, emphasizing the square shape's structural rigidity in resisting lateral loads. In contrast, at the topmost story (Story 16), the L-shaped building exhibits the highest base shear of 1,989.8784 kN, which is 2.4% higher than the Square shape (1,942.6884 kN) and significantly higher than the Rectangle (1,857.516 kN), T shape (1,857.8791 kN), and C shape (1,876.804 kN). The data highlights that while the Square-shaped building generally experiences the highest base shear at lower stories due to its stable geometry, the L-shaped building demonstrates higher shear forces at upper levels, potentially indicating increased stress concentrations in irregular geometries. These insights are critical for optimizing building designs to manage base shear efficiently across different configurations.

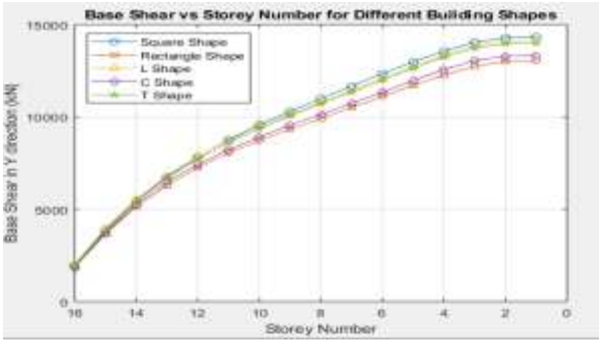


**Fig 22. Base Shear in Y Direction vs Storey Number for Different Building Shapes**

The graph illustrates the base shear in the Y direction for different aerodynamic building shapes—Square, Rectangle, L, C, and T. The base shear increases progressively from the topmost story to the base, reflecting the cumulative effects of lateral loads along the height of the structure. At the base (Story 1), the Square-shaped building experiences the highest base shear of 14,342.5318 kN, which is 10.7% higher than the Rectangle shape (13,042.9384 kN), 1.2% higher than the L shape (14,174.1978 kN), 7.7% higher than the C shape (13,321.272 kN), and 2.5% higher than the T shape (14,005.06 kN). This trend underscores the higher lateral load resistance of the square shape at the lower levels. In contrast, at the topmost level (Story 16), the L-shaped building exhibits the highest base shear of 1,989.8787 kN, which is 2.4% higher than the Square shape (1,942.6886 kN), 7.6% higher than the Rectangle shape (1,853.1382 kN), 8.4% higher than the C shape (1,836.2261 kN), and 6.3% higher than the T shape (1,871.2838 kN). The analysis reveals that while the Square-shaped building consistently demonstrates superior performance in resisting base shear at the lower levels, the L-shaped building incurs higher base shear at upper stories due to its irregular geometry, which likely concentrates stress. These findings emphasize the importance of shape selection in managing lateral forces effectively across the height of the structure.

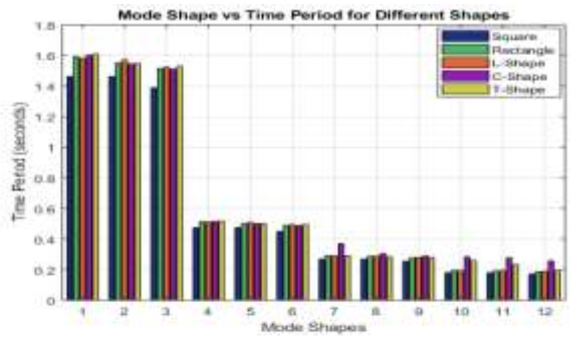


**Fig 23. Mode Shape vs Time Period for Different Shapes**

The above graph shows the time periods (seconds) for different mode shapes of various aerodynamic building configurations—Square, Rectangle, L, C, and T. The x-axis represents the mode shapes (1 to 12), while the y-axis shows the time periods in seconds. The highest time period observed is 1.61 seconds for Mode Shape 1 in the T-shaped building, indicating lower stiffness. In contrast, the lowest time period is 0.18 seconds for Mode Shape 12 in the Square-shaped building, highlighting higher stiffness. The Square shape consistently demonstrates shorter time periods across all mode shapes, indicating superior structural rigidity and stability compared to the other shapes, with the C and T shapes displaying relatively higher time periods in several modes.

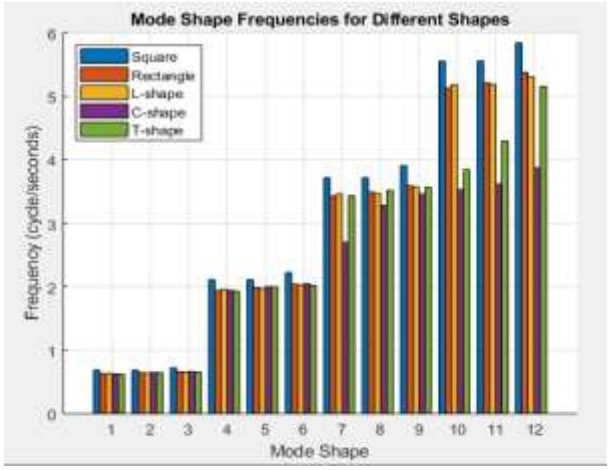


**Fig 24. Mode Shape Frequencies for Different Shapes**

The above graph shows the natural frequencies (cycles/second) for different mode shapes of various aerodynamic building configurations—Square, Rectangle, L, C, and T. The x-axis represents the mode shapes (1 to 12), while the y-axis shows the frequencies in cycles per second. The highest frequency observed is 5.841 cycles/second for Mode Shape 12 in the Square-shaped building, indicating superior stiffness. In contrast, the lowest frequency for Mode Shape 12 is 3.871 cycles/second in the C-shaped building, reflecting reduced stiffness. For Mode Shape 1, the Square shape also demonstrates the highest frequency at 0.684 cycles/second, which is 9.1% higher than the T shape. These results highlight the Square shape's dynamic efficiency compared to other configurations.

## 6. Conclusion

This study focused on the seismic performance of irregular-shaped buildings, specifically L-shaped, C-shaped, T-shaped, rectangular, and square structures, using Time History Analysis (THA). The results revealed significant variations in the seismic behavior of the different building configurations under dynamic earthquake loading. Among the shapes analyzed, the square-shaped building consistently showed superior performance in terms of minimal storey displacement, drift, and base shear across most stories, especially at the upper levels, highlighting its stability under lateral forces. In contrast, irregular buildings, such as the L-shape and T-shape, exhibited higher displacement and drift, particularly at the higher stories, indicating their vulnerability to torsional movements and stress concentrations. The study also demonstrated that base shear increased with height, with the square-shaped building offering the most efficient distribution of forces. The L-shaped building, while showing higher shear forces at upper levels, had a more pronounced response due to its asymmetry. Additionally, natural frequency analysis highlighted the superior stiffness of the square building, contributing to better resistance to seismic forces. Overall, the findings emphasize the importance of considering building geometry in seismic design, especially for irregular-shaped structures. The insights gained from this study will guide engineers and architects in improving the earthquake resilience of irregular buildings through design modifications and retrofitting strategies, ensuring safer urban infrastructure in seismic regions.

## 7. Future Scope

This study provides valuable insights into the seismic performance of irregular-shaped buildings, but several avenues for future research remain. First, further investigations can explore the impact of different seismic intensities by using a wider range of earthquake ground motion data, including both real and synthetic earthquake records. An expanded dataset could help simulate various seismic scenarios, enhancing the robustness of the analysis. Additionally, the study could incorporate a broader range of building types, including more complex irregular shapes, to assess how unique architectural features influence seismic behavior. Future research could also delve into the effects of soil-structure interaction (SSI), as this study assumes standard soil conditions. Incorporating different soil types and their impact on seismic performance would provide a more comprehensive understanding of building behavior in real-world conditions. Another potential area for exploration is the integration of non-linear analysis, which would capture more realistic post-yield behaviors, especially for materials used in irregular buildings. Moreover, the application of advanced retrofitting techniques and their effectiveness in enhancing the seismic resilience of irregular buildings could be studied. The development of more precise and tailored design recommendations, supported by these findings, would provide engineers with more effective tools for mitigating seismic risks. Incorporating these additional parameters will help refine seismic design strategies and offer more practical solutions for improving the earthquake resilience of irregular-shaped buildings in urban environments.

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