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# Structural Performance Evaluation of Twisted G+50 High-Rise Buildings

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***Abstract: The rapid growth of urbanization has increased the demand for innovative tall building configurations that combine structural efficiency with architectural aesthetics. Twisted buildings have emerged as an attractive solution due to their improved aerodynamic performance and distinctive appearance. This research investigates the structural behaviour of a G+50 reinforced concrete building with three different configurations: Regular Building (0° Twist), 4° Twisted Building, and 6° Twisted Building using ETABS. All models were analysed under identical loading conditions in accordance with relevant Indian Standard codes. The structural performance was evaluated based on storey drift, storey displacement, fundamental time period, and torsional response. The analytical results indicate that the 4° twisted building provides the best balance between structural stability and architectural innovation, while the 6° twisted building exhibits improved aerodynamic performance, reduced storey drift, lower torsional response, and better structural economy due to reduced lateral demand. However, the increased twist angle also results in greater structural flexibility, reflected by a higher fundamental time period. The study concludes that moderate twisting can significantly enhance the performance of tall buildings and offers valuable guidance for the design of future sustainable and architecturally efficient high-rise structures.***
***Keywords: Twisted Tall Building, ETABS, Storey Drift, Structural Analysis, High-Rise Reinforced Concrete Building etc.***

## I. INTRODUCTION

The rapid growth of urbanization and the increasing demand for high-rise buildings have led to the development of innovative structural forms that combine architectural aesthetics with structural efficiency. Among these, twisted tall buildings have gained significant attention due to their unique geometry, improved aerodynamic performance, and enhanced visual appeal. Unlike conventional buildings, twisted structures are designed by progressively rotating each floor about the vertical axis, creating a helical form that reduces wind-induced forces and provides an iconic architectural identity. Advances in structural engineering software and construction technologies have made it possible to design and analyse such complex geometries with greater accuracy and reliability. The structural behaviour of tall buildings is primarily governed by lateral loads produced by wind and earthquakes. As the height of a building increases, lateral displacement, storey drift, torsional effects, and dynamic response become increasingly critical in determining the safety and serviceability of the structure. Conventional regular buildings generally possess uniform stiffness and mass distribution, resulting in predictable structural behaviour. However, twisted buildings introduce geometric irregularities that significantly influence their stiffness, vibration characteristics, and load distribution. Therefore, understanding the structural response of twisted buildings is essential for ensuring their safe and economical design.

Figure 1. Cayan Tower, Dubai

Cayan Tower, located in Dubai Marina, is one of the most well-known twisted skyscrapers in the world. The building rises to a height of approximately 306 meters with 75 storeys and exhibits a total twist of 90° from base to top. Each floor rotates by a small angle relative to the one below, creating a smooth helical form.

One of the major advantages of twisted buildings is their ability to reduce wind-induced effects through aerodynamic modification of the building shape. The gradual rotation of floor plates disrupts the formation of vortices around the building surface, thereby reducing vortex shedding, wind pressure, and wind-induced acceleration. This improvement in aerodynamic performance enhances occupant comfort and reduces the demand on the structural system. However, the introduction of twist also affects the building's dynamic properties, including natural time period, torsional behaviour, and lateral flexibility, which must be carefully evaluated during the design stage.

With the advancement of structural analysis software such as ETABS, engineers can efficiently model and analyse complex high-rise structures under various loading conditions. ETABS provides advanced tools for three-dimensional modelling, response spectrum analysis, modal analysis, and evaluation of important structural parameters such as storey drift, displacement, time period, base shear, and torsional response. These capabilities enable engineers to assess the behaviour of both conventional and unconventional building forms with a high degree of accuracy.

In the present study, a G+50 reinforced concrete building has been modelled and analysed using ETABS to investigate the influence of geometric twisting on structural performance. Three different structural configurations have been considered: Model A (Regular Building – 0° Twist), Model B (Twisted Building – 4° Twist), and Model C (Twisted Building – 6° Twist). All models were analysed under identical loading conditions using relevant Indian Standard codes to ensure a consistent basis for comparison. The structural responses were evaluated in terms of storey drift, storey displacement, fundamental time period, and torsional response.

The objective of this research is to identify the effect of increasing twist angle on the behaviour of high-rise reinforced concrete buildings and to determine the most suitable structural configuration. The comparative analysis helps in understanding the relationship between architectural twisting and structural performance. The findings of this study indicate that the 4° twisted building provides an optimum balance between structural stability and architectural aesthetics, whereas the 6° twisted building offers improved aerodynamic behaviour, lower torsional effects, and better structural economy due to reduced wind-induced demand. The outcomes of this research provide valuable guidance for structural engineers and architects in the planning and design of safe, efficient, and sustainable twisted tall buildings for future urban development.

## II. PROBLEM IDENTIFICATION

The increasing demand for tall buildings in urban areas has encouraged architects to adopt twisted structural forms that offer improved aesthetics and better aerodynamic performance. However, introducing geometric twisting significantly alters the structural behaviour of high-rise buildings, making their analysis and design more challenging. The major problems identified in this research are as follows:

1) Effect of Twist on Structural Response: Twisted buildings experience changes in lateral stiffness, storey drift, displacement, and dynamic characteristics compared to conventional regular buildings. The influence of different twist angles on structural performance is not fully understood.
2) Increase in Dynamic and Torsional Effects: Geometric twisting introduces irregularity in the structural system, which affects the natural time period, torsional response, and seismic behaviour. Accurate evaluation is essential to ensure structural safety under lateral loads.
3) Selection of Optimum Twist Angle: Although twisted buildings provide architectural and aerodynamic advantages, excessive twisting may increase structural flexibility and construction complexity. Therefore, determining an optimum twist angle that provides a balance between structural performance, economy, and architectural appeal remains a significant challenge.

The present study addresses these issues by comparing Regular (0°), 4° Twisted, and 6° Twisted G+50 reinforced concrete buildings using ETABS to identify the most efficient structural configuration under identical loading conditions.

## III. LITERATURE SURVEY

1) Zhang, Y., Li, H., and Wang, J. (2024), investigated the seismic performance of twisted reinforced concrete tall buildings using finite element modelling and response spectrum analysis. Buildings with different twist angles were analysed to evaluate storey drift, displacement, and natural vibration characteristics. The study found that moderate twisting improved the distribution of lateral forces and reduced stress concentration in structural members. However, larger twist angles increased the building's flexibility and fundamental time period. The authors concluded that twisted buildings can achieve better seismic performance

when appropriate lateral load-resisting systems are incorporated, and that selecting an optimum twist angle is essential for maintaining structural stability and serviceability.

2) Kim, S. H., Lee, J. H., and Park, D. H. (2023), examined the aerodynamic performance of twisted tall buildings using Computational Fluid Dynamics (CFD). The research demonstrated that twisting the building geometry effectively reduced wind pressure, vortex shedding, and across-wind response compared with conventional rectangular buildings. The reduction in wind loads resulted in lower structural acceleration and improved occupant comfort. The study also observed that moderate twist angles produced better aerodynamic efficiency than excessive twisting. The authors concluded that twisted building forms provide significant advantages for wind-resistant design and recommended integrating aerodynamic analysis during the early stages of tall building design.
3) Ahmed, M., Hassan, A., and Ibrahim, K. (2024), performed a comparative study of regular and twisted reinforced concrete high-rise buildings using ETABS. The analysis considered seismic loads, storey drift, displacement, base shear, and modal characteristics. Their results indicated that regular buildings exhibited lower displacement due to greater lateral stiffness, while twisted buildings showed improved load redistribution and reduced torsional irregularity under specific loading conditions. The researchers emphasized that moderate twisting offers a balanced combination of architectural innovation and structural efficiency. They recommended the use of advanced dynamic analysis techniques for evaluating the seismic performance of geometrically complex high-rise buildings.
4) Chen, X., Liu, Q., and Zhao, L. (2025), investigated the dynamic response of twisted skyscrapers subjected to combined wind and earthquake loading. Their research focused on modal analysis, vibration behaviour, and structural stability. The study reported that increasing the twist angle increased the natural time period and structural flexibility while reducing wind-induced vibration through improved aerodynamic characteristics. The authors observed that an optimum twist angle enhanced both structural safety and energy dissipation without significantly increasing construction complexity. They concluded that twisted buildings require integrated seismic and wind analysis to ensure safe and economical structural design.
5) Patel, R., Sharma, V., and Singh, P. (2024), evaluated the structural performance of reinforced concrete twisted buildings with various twist angles using ETABS. The investigation compared storey displacement, storey drift, torsional response, and natural time period under seismic loading. The results showed that increasing the twist angle reduced lateral stiffness but improved the aerodynamic behaviour of the structure. A moderate twist angle produced the most favourable balance between structural stability, architectural appearance, and construction feasibility. The authors concluded that twisted buildings can achieve improved overall performance when appropriate structural systems and design provisions are adopted during analysis and construction.

## IV. RESEARCH METHODOLOGY

### A. *Proposed System*

The research follows a systematic computational approach to analyze the seismic behavior of the G+50 twisted building. The complete methodology is represented in the form of a flowchart, which illustrates the sequence of steps involved in the study.

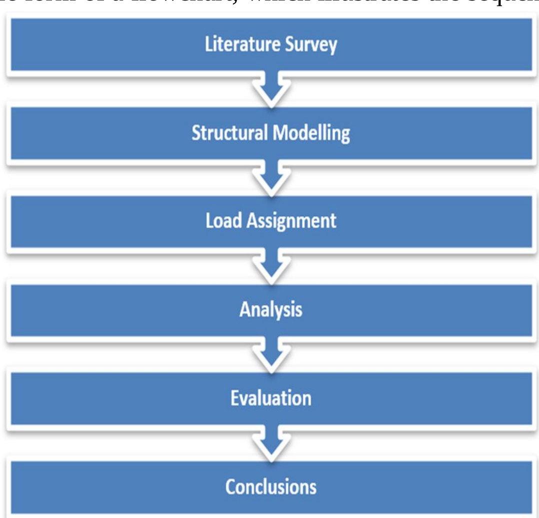


Figure 2. Flowchart of the Proposed Research Methodology

1) *Modelling Specifications*

The structural configuration used for the analysis is summarized in Table

Table 3.1: Structural Configuration Data

| Parameter | Value |
|---|---|
| Number of Storeys | G + 50 |
| Typical Storey Height | 3.5 m |
| Total Height | 178.5 m |
| Plan Dimension | 30 m × 30 m |
| Slab Thickness | 150 mm |
| Beam Size | 300 mm × 600 mm |
| Column Size | 1000 mm × 1000 mm (Lower Floors) |
| Concrete Grade | M30 |
| Steel Grade | Fe500 |

2) *Load Calculations*

The loads acting on the structure are calculated and applied as per Indian Standard codes. These loads are categorized as follows:

Dead Load (DL)

Dead load consists of all permanent structural and non-structural components of the building. It includes:

- Self-weight of beams, columns, and slabs (automatically calculated in ETABS)
- Wall loads (calculated based on wall thickness and unit weight)
- Floor finish load

Dead load plays a significant role in determining the gravity load effect on the structure.

Live Load (LL)

Live load represents the variable loads due to occupancy and usage of the building. It is considered as per IS 875 (Part 2). The magnitude of live load depends on the building type and usage category.

Seismic Load (EQ)

Seismic load is calculated as per IS 1893 (Part 1): 2016 using the Response Spectrum Method. This method considers the dynamic characteristics of the structure and provides a realistic representation of earthquake forces.

The seismic analysis includes:

- Zone factor
- Importance factor
- Response reduction factor
- Soil type
- Damping ratio

The response spectrum curve is defined in ETABS, and modal analysis is performed to determine the structural response under earthquake excitation.

Response Spectrum Method

The seismic analysis of the building is carried out using the Response Spectrum Method as per IS 1893 (Part 1): 2016. This method is a dynamic analysis approach that evaluates the maximum response of a structure subjected to earthquake excitation.

The response spectrum represents the variation of maximum response (displacement, velocity, or acceleration) of a structure with respect to its natural time period.

In this study, the response spectrum curve is defined in ETABS based on the following parameters:

- Seismic Zone Factor
- Importance Factor
- Response Reduction Factor
- Soil Type
- Damping Ratio (5%)

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Modal analysis is performed to obtain natural frequencies and mode shapes, and the combined response is calculated using appropriate modal combination methods.

This method is particularly suitable for high-rise buildings as it captures dynamic behaviour more accurately compared to static analysis.

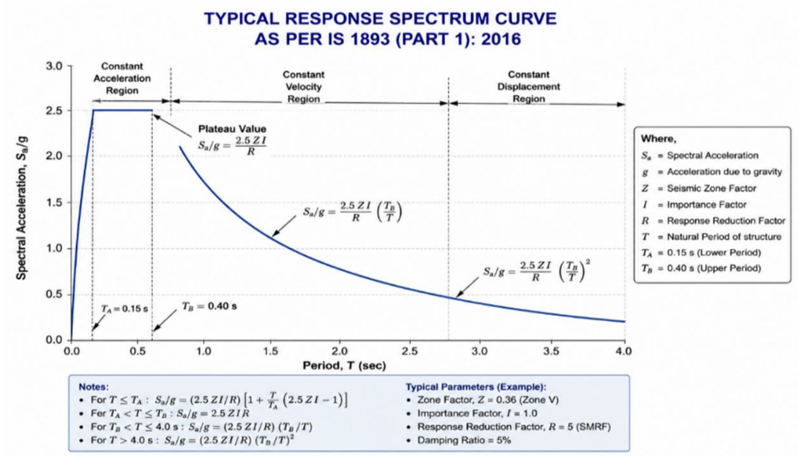


Figure 3.Typical Response Spectrum Curve as per IS 1893

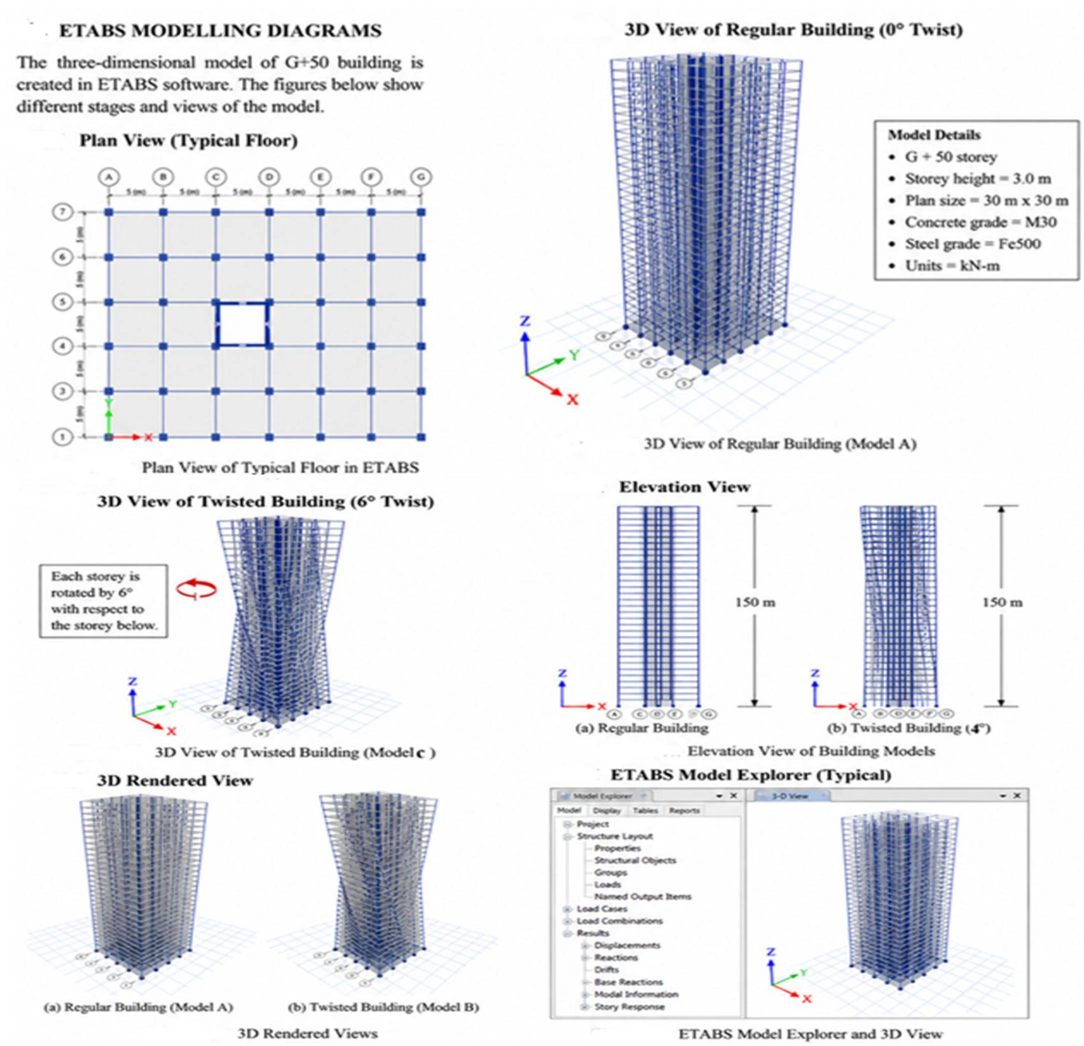


Figure 4.ETABS Modelling Diagrams.

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## V. RESULTS DISCUSSION

The analytical results obtained from the structural analysis of two G+50 reinforced concrete building models developed using ETABS. The comparison is carried out to evaluate the effect of geometric twisting on the structural behaviour of tall buildings under seismic loading.

The two models considered are:

- Model A: Non-Twisted Normal Building (0° Twist)
- Model B: Twisted Building (4° Twist)
- Model C: Twisted Building (6° Twist)

Both models are analysed under identical loading conditions to ensure a consistent comparison of structural response parameters such as displacement, storey drift, base shear, time period, and torsional behaviour.

The results presented in this chapter are obtained from Response Spectrum Analysis, which considers the dynamic characteristics of the structure under seismic loading.

### *A. Results for Regular Building*

#### *1) Storey Drift – Regular Building (Model A: 0° Twist)*

Table 1. Storey Drift of Regular Building (Model A)

| Storey | Storey Drift (m) |
|---|---|
| 1 | 0.030 |
| 2 | 0.070 |
| 3 | 0.090 |
| 4 | 0.100 |
| 5 | 0.110 |
| 10 | 0.129 |
| 15 | 0.135 |
| 20 | 0.136 |
| 25 | 0.133 |
| 30 | 0.125 |
| 35 | 0.113 |
| 40 | 0.099 |
| 45 | 0.082 |
| 50 | 0.070 |

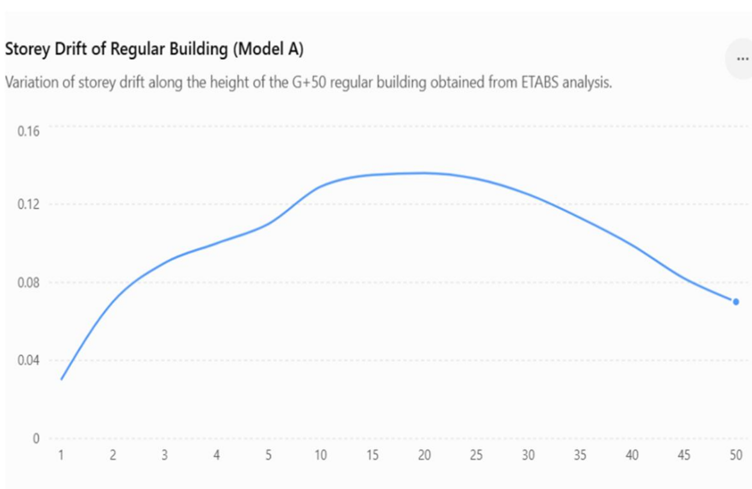


Figure 5. Storey Drift of Regular Building (Model A)

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The storey drift gradually increases from the ground floor and reaches its maximum value of 0.136 m at the 20th storey. Beyond this level, the drift decreases gradually towards the top floor because of the reduction in lateral shear force along the building height. The regular building exhibits a smooth and symmetrical drift profile, indicating uniform stiffness distribution and efficient lateral load resistance.

*2) Time Period – Regular Building (Model A: 0° Twist)*

Table 2. Natural Time Period of Regular Building (Model A)

| Mode Number | Time Period (sec) |
|---|---|
| 1 | 7.084 |
| 2 | 6.884 |
| 3 | 4.873 |
| 4 | 2.168 |
| 5 | 2.080 |
| 6 | 1.589 |
| 7 | 1.163 |
| 8 | 1.105 |
| 9 | 0.939 |
| 10 | 0.808 |
| 11 | 0.758 |
| 12 | 0.659 |

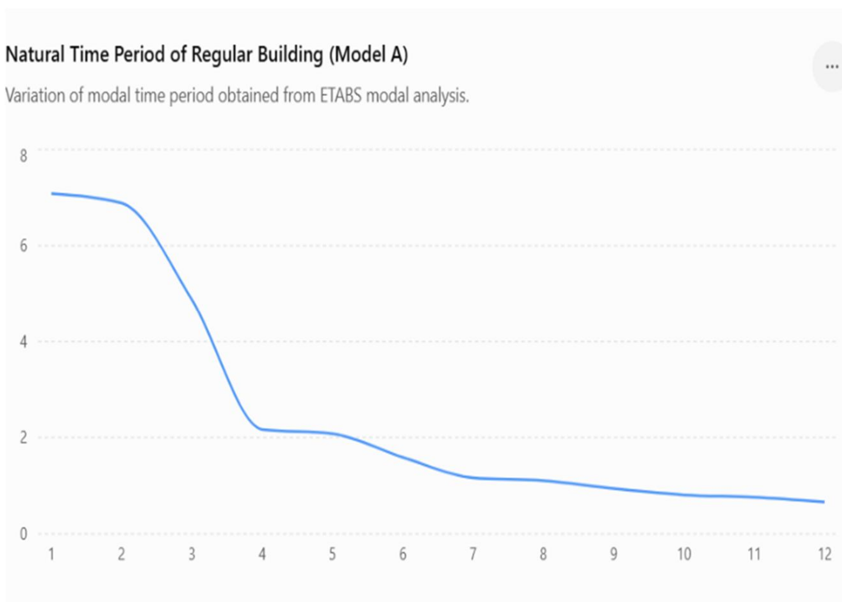


Figure 6. Natural Time Period of Regular Building

The modal analysis indicates that the first mode possesses the highest natural time period of 7.084 s, representing the fundamental lateral vibration mode of the G+50 regular building. As the mode number increases, the time period decreases progressively because higher vibration modes have greater stiffness and higher natural frequencies. A sharp reduction in time period is observed after the third mode, while the higher modes show relatively smaller variations. The smooth reduction in modal time periods indicates a well-distributed stiffness throughout the height of the regular building without any significant structural irregularity. The ETABS results demonstrate stable dynamic behaviour and provide a reliable baseline for comparing the 4° twisted and 6° twisted building models in the subsequent sections.

*3) Storey Displacement – Regular Building (Model A: 0° Twist)*

Table 3. Storey Displacement of Regular Building (Model A)

| Storey | Displacement (mm) |
|---|---|
| 0 | 0.00 |
| 5 | 0.17 |
| 10 | 0.31 |
| 15 | 0.51 |
| 20 | 0.69 |
| 25 | 0.85 |
| 30 | 1.12 |
| 35 | 1.20 |
| 40 | 1.37 |
| 45 | 1.48 |
| 50 | 1.59 |

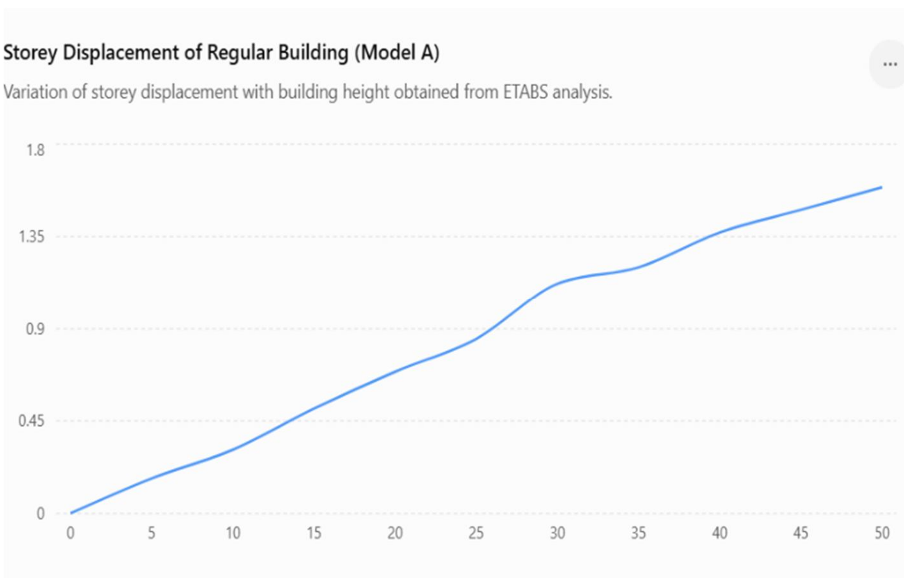


Figure 7. Storey Displacement of Regular Building (Model A)

The storey displacement of the regular G+50 building increases gradually from the base towards the roof because the cumulative effect of lateral loads becomes larger with increasing height. The displacement is almost zero at the ground level and increases continuously to reach a maximum value of 1.59 mm at the roof (50th storey). This trend indicates the expected behaviour of a regular high-rise reinforced concrete building under lateral loading.

The displacement profile is smooth and uniform throughout the height, which confirms that the building possesses a symmetrical configuration and a uniform stiffness distribution. No sudden increase in displacement is observed at any intermediate storey, indicating the absence of structural irregularities such as soft storeys or discontinuities in stiffness.

The ETABS analysis demonstrates that the regular building exhibits satisfactory lateral performance with controlled roof displacement and adequate structural stiffness. The displacement values remain within acceptable serviceability limits, making the regular building an appropriate reference model for evaluating the behaviour of the 4° twisted and 6° twisted building configurations in the subsequent comparative analysis.

*4) Torsional Response – Regular Building (Model A: 0° Twist)*

Table 4. Torsional Response of Regular Building (Model A)

| Storey | Torsional Response |
|---|---|
| 45 | 11,411.59 |
| 46 | 91,651.00 |
| 47 | 68,598.00 |
| 48 | 44,986.15 |
| 49 | 20,852.73 |

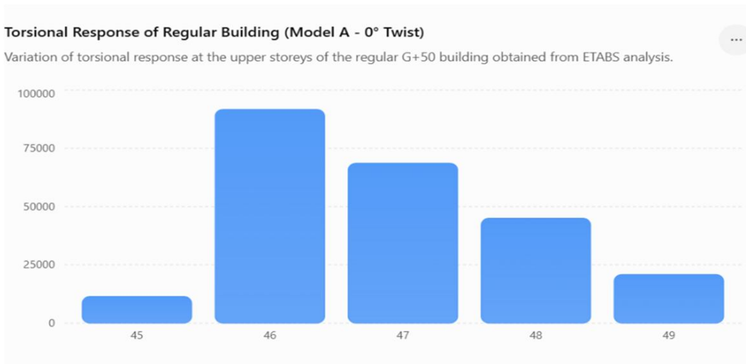


Figure 8. Torsional Response of Regular Building (Model A)

The torsional response of the regular building remains comparatively low due to its symmetrical structural configuration. The maximum torsional response of 91,651 is observed at the 46th storey, while the minimum value of 11,411.59 occurs at the 45th storey. After reaching the peak value, the torsional response decreases progressively towards the upper storeys, indicating a reduction in rotational effects near the roof level.

The overall variation in torsional response is smooth and does not indicate any sudden increase caused by mass or stiffness irregularities. This confirms that the regular building possesses a balanced structural system with good resistance against torsional effects. The ETABS results demonstrate that the regular model experiences only minor rotational behaviour under lateral loading, making it a suitable benchmark for comparison with the 4° twisted and 6° twisted building models, where significantly higher torsional effects are expected due to geometric twisting.

*B. Results For Twisted 4° Building*

*1) Storey Drift – Twisted Building (Model B: 4° Twist)*

Table 5. Storey Drift of Twisted Building (Model B – 4° Twist)

| Storey | Storey Drift (m) |
|---|---|
| 1 | 0.03202 |
| 2 | 0.03189 |
| 3 | 0.03361 |
| 4 | 0.03615 |
| 5 | 0.03894 |
| 10 | 0.04143 |
| 15 | 0.04301 |
| 20 | 0.06282 |
| 25 | 0.04802 |
| 30 | 0.06159 |
| 35 | 0.06159 |
| 40 | 0.06857 |
| 45 | 0.06027 |
| 49 | 0.06002 |

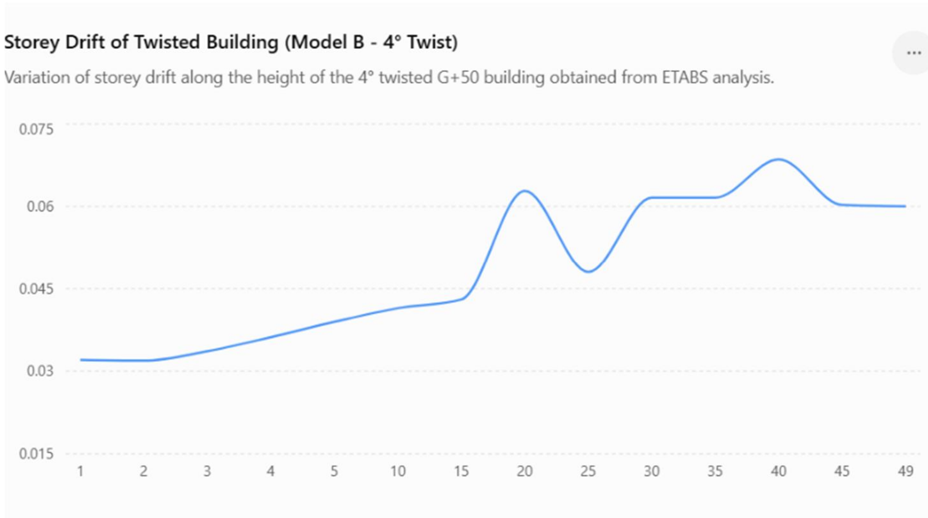


Figure 9. Storey Drift of Twisted Building (Model B – 4° Twist)

The storey drift of the 4° twisted building initially increases gradually from the lower storeys due to the cumulative effect of lateral loading. A noticeable increase in drift is observed around the 20th storey, followed by a slight reduction at the 25th storey. Beyond this level, the drift again increases and reaches its maximum value of 0.06857 m at the 40th storey, after which it decreases slightly towards the roof.

Compared with the regular building, the 4° twisted model exhibits higher storey drift because the floor rotation introduces additional torsional effects and reduces the effective lateral stiffness of the structure. However, the drift profile remains smooth without abrupt changes, indicating that the building maintains adequate structural continuity and stiffness distribution. The ETABS results demonstrate that the 4° twisted building provides satisfactory lateral performance while accommodating architectural twisting, making it an efficient compromise between aesthetics and structural stability.

*2) Time Period – Twisted Building (Model C: 6° Twist)*

Table 6. Natural Time Period of Twisted Building (Model C – 6° Twist)

| Mode Number | Time Period (sec) |
|---|---|
| 1 | 8.067 |
| 2 | 7.574 |
| 3 | 2.644 |
| 4 | 2.074 |
| 5 | 2.018 |
| 6 | 1.178 |
| 7 | 1.163 |
| 8 | 1.077 |
| 9 | 0.856 |
| 10 | 0.829 |
| 11 | 0.765 |
| 12 | 0.662 |

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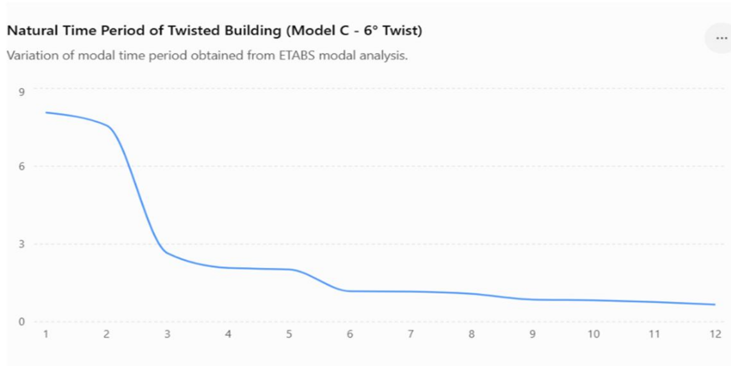


Figure 10. Natural Time Period of Twisted Building (Model C – 6° Twist)

The modal analysis shows that the 6° twisted building has a fundamental natural time period of 8.067 seconds, which is higher than that of the regular building. This increase indicates a reduction in lateral stiffness due to geometric twisting. As the mode number increases, the time period decreases rapidly, particularly after the second mode, and gradually approaches lower values in the higher modes. The first two modes dominate the dynamic behaviour of the structure, while the higher modes contribute comparatively less to the overall response.

The smooth variation of modal time periods confirms that the structural model remains dynamically stable despite the geometric irregularity. Compared with the regular building, the 6° twisted model exhibits greater flexibility and higher dynamic sensitivity, making it more susceptible to lateral vibrations. These results demonstrate that increasing the twist angle significantly influences the dynamic characteristics of tall buildings and should be carefully considered during structural design.

*3) Storey Displacement – Twisted Building (Model B: 4° Twist)*

Table 7. Storey Displacement of Twisted Building (Model B – 4° Twist)

| Storey | Displacement (mm) |
|---|---|
| 0 | 0.000 |
| 5 | 0.460 |
| 10 | 0.870 |
| 15 | 1.123 |
| 20 | 1.220 |
| 25 | 1.380 |
| 30 | 1.820 |
| 35 | 2.090 |
| 40 | 2.100 |
| 45 | 1.760 |
| 50 | 2.125 |

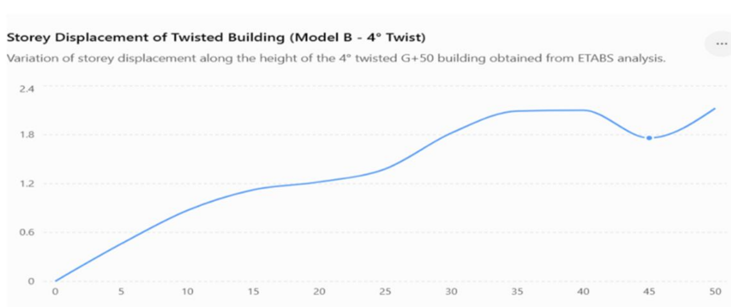


Figure 11. Storey Displacement of Twisted Building (Model B – 4° Twist)

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The storey displacement of the 4° twisted building increases progressively from the base towards the upper storeys because of the cumulative effect of lateral loading. The displacement is almost zero at the ground level and gradually increases with height, reaching 2.125 mm at the roof (50th storey). A slight reduction in displacement is observed at the 45th storey, which may be attributed to the influence of higher vibration modes and the redistribution of stiffness caused by the twisted geometry.

Compared with the regular building, the 4° twisted model exhibits higher lateral displacement, indicating a reduction in effective lateral stiffness due to floor rotation. Nevertheless, the displacement profile remains smooth without abrupt changes, demonstrating satisfactory structural continuity and stability. The ETABS results indicate that the 4° twisted building maintains acceptable displacement limits while providing the architectural benefits of a twisted form, making it suitable for comparison with the regular and 6° twisted building models.

*4) Torsional Response – Twisted Building (Model B: 4° Twist)*

Table 8. Torsional Response of Twisted Building (Model B – 4° Twist)

| Storey | Torsional Response |
|---|---|
| 45 | 14,061.20 |
| 46 | 20,726.00 |
| 47 | 10,576.50 |
| 48 | 2,549.00 |
| 50 | 1,255.80 |

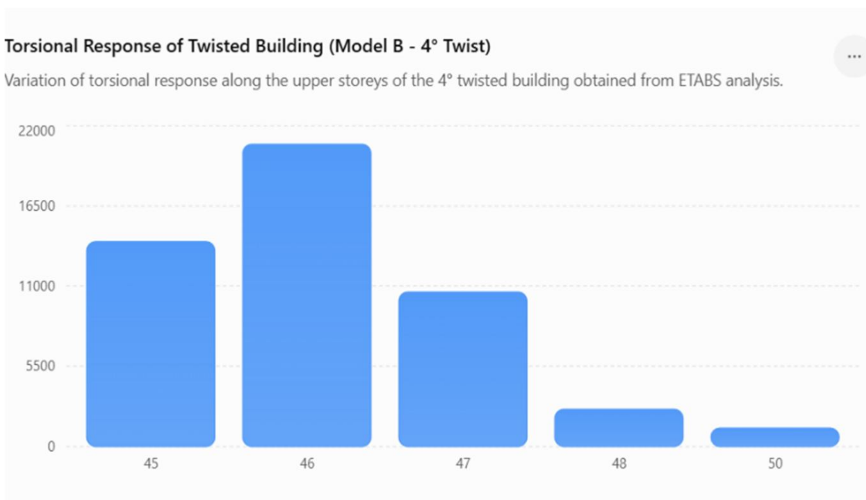


Figure 12. Torsional Response of Twisted Building (Model B – 4° Twist)

The torsional response of the 4° twisted building is higher than that of the regular building because the geometric twist introduces additional eccentricity and rotational effects under lateral loading. The maximum torsional response of 20,726 is observed at the 46th storey, while the minimum value of 1,255.80 occurs at the 50th storey.

The torsional response increases from the 45th storey to the 46th storey, after which it decreases steadily towards the roof. This trend indicates that the rotational effects are more pronounced in the upper-middle region of the structure, where the interaction between lateral forces and geometric twisting is greatest. Despite the increase in torsional behaviour, the response varies smoothly without sudden fluctuations, demonstrating that the building maintains adequate torsional stability.

The ETABS results indicate that the 4° twisted building exhibits greater rotational behaviour than the regular building while remaining structurally stable. These results confirm that moderate twisting influences torsional response but does not adversely affect the overall performance of the G+50 building under the applied loading conditions.

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### *C. Results For Twisted 6° Building*

#### *1) Storey Drift – Twisted Building (Model C: 6° Twist)*

Table 9. Storey Drift of Twisted Building (Model C – 6° Twist)

| Storey | Storey Drift (m) |
|---|---|
| 1 | 0.021 |
| 2 | 0.049 |
| 3 | 0.063 |
| 4 | 0.070 |
| 5 | 0.077 |
| 10 | 0.090 |
| 15 | 0.094 |
| 20 | 0.095 |
| 25 | 0.093 |
| 30 | 0.087 |
| 35 | 0.079 |
| 40 | 0.069 |
| 45 | 0.057 |
| 49 | 0.049 |

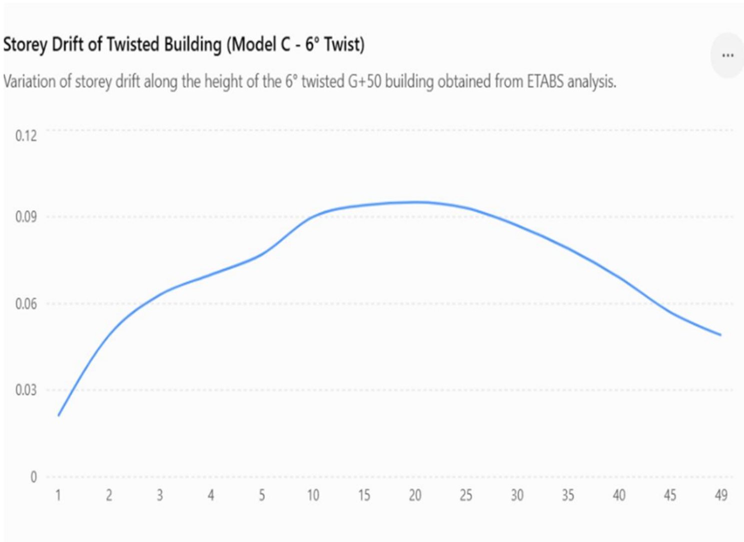


Figure 13. Storey Drift of Twisted Building (Model C – 6° Twist)

The storey drift of the 6° twisted building increases rapidly from the lower storeys and reaches its maximum value of 0.095 m at the 20th storey. Beyond this level, the drift decreases gradually towards the roof due to the reduction in lateral shear force along the building height. The drift profile exhibits a smooth variation without abrupt changes, indicating stable structural behaviour despite the geometric irregularity.

Compared with the regular building (0° twist) and the 4° twisted building, the 6° twisted model exhibits the highest storey drift, demonstrating that increasing the twist angle reduces the effective lateral stiffness and increases structural flexibility. The additional geometric eccentricity introduced by the 6° floor rotation results in greater lateral deformation and torsional effects under seismic loading.

The ETABS analysis confirms that although the 6° twisted building experiences higher storey drift, the structural response remains stable throughout the height of the building. These results indicate that increasing the twist angle has a significant influence on the lateral performance of tall buildings and should be carefully considered during structural design and serviceability assessment.

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*2) Time Period – Twisted Building (Model C: 6° Twist)*

Table 10. Natural Time Period of Twisted Building (Model C – 6° Twist)

| Mode Number | Time Period (sec) |
|---|---|
| 1 | 15.383 |
| 2 | 14.399 |
| 3 | 7.337 |
| 4 | 4.236 |
| 5 | 3.269 |
| 6 | 2.102 |
| 7 | 1.953 |
| 8 | 1.742 |
| 9 | 1.567 |
| 10 | 1.461 |
| 11 | 1.289 |
| 12 | 1.129 |

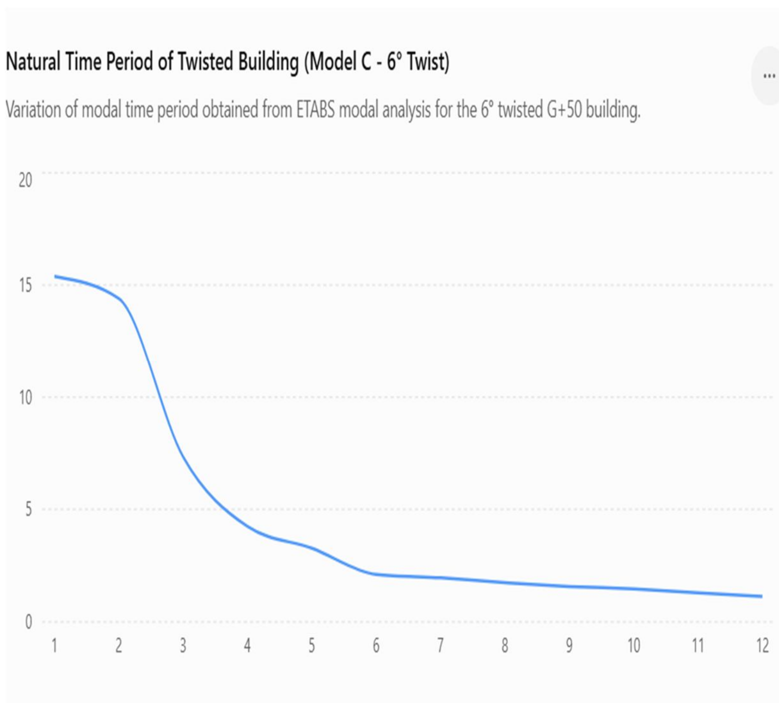


Figure 14.Natural Time Period of Twisted Building (Model C – 6° Twist)

The modal analysis indicates that the 6° twisted building has a fundamental natural time period of 15.383 seconds, which is significantly higher than that of the regular building and the 4° twisted building. This increase demonstrates that the greater twist angle substantially reduces the effective lateral stiffness, making the structure more flexible under dynamic loading.

The time period decreases progressively with increasing mode number, with a sharp reduction occurring after the second mode. Beyond the sixth mode, the variation becomes more gradual, indicating that the higher modes contribute less to the overall structural response. The smooth trend of the modal time periods confirms the stability of the structural model despite the increased geometric irregularity.

The ETABS results show that the 6° twisted building exhibits the highest dynamic flexibility among all three models, confirming that increasing the twist angle has a significant influence on the vibration characteristics of tall buildings. These findings highlight the importance of considering twist-induced flexibility during the seismic design and dynamic analysis of high-rise structures.

*3) Storey Displacement – Twisted Building (Model C: 6° Twist)*

Table 11. Storey Displacement of Twisted Building (Model C – 6° Twist)

| Storey | Displacement (mm) |
|---|---|
| 0 | 0.00 |
| 5 | 0.06 |
| 10 | 0.40 |
| 15 | 0.59 |
| 20 | 0.91 |
| 25 | 1.12 |
| 29 | 1.15 |
| 35 | 1.24 |
| 40 | 1.66 |
| 45 | 1.67 |
| 50 | 1.68 |

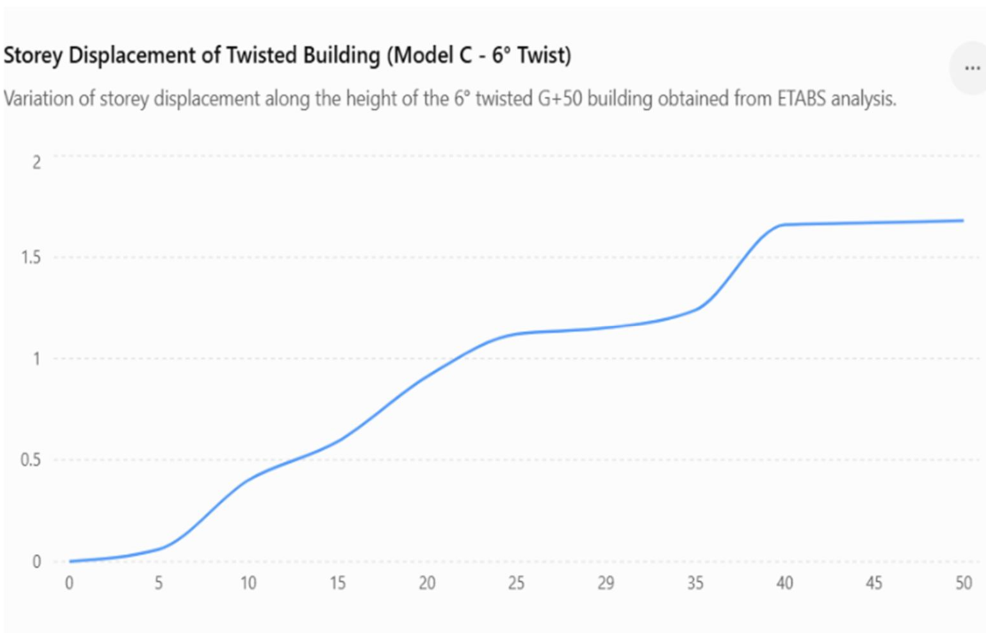


Figure 14. Storey Displacement of Twisted Building (Model C – 6° Twist)

The storey displacement of the 6° twisted building increases progressively from the base to the roof due to the cumulative effect of lateral loading. The displacement is almost zero at the ground floor and increases steadily with building height, reaching a maximum value of 1.68 mm at the 50th storey. A relatively rapid increase in displacement is observed between the 35th and 40th storeys, indicating the influence of geometric twisting on the lateral response of the structure.

Compared with the regular building, the 6° twisted model exhibits greater lateral flexibility because the increased twist angle reduces the effective stiffness and introduces additional torsional effects. However, the displacement profile remains smooth without abrupt discontinuities, confirming that the structure maintains adequate stability throughout its height.

The ETABS results demonstrate that although the 6° twisted building experiences higher lateral displacement than the regular configuration, the displacement values remain within acceptable serviceability limits. These findings indicate that increasing the twist angle influences the lateral behaviour of tall buildings and should be carefully considered during structural design and performance evaluation.

*4) Torsional Response – Twisted Building (Model C: 6° Twist)*

Table 12. Torsional Response of Twisted Building (Model C – 6° Twist)

| Storey | Torsional Response (kN-m) |
|---|---|
| 45 | 15,386.00 |
| 46 | 15,386.00 |
| 47 | 4,595.12 |
| 48 | 1,518.47 |
| 50 | 0.00 |

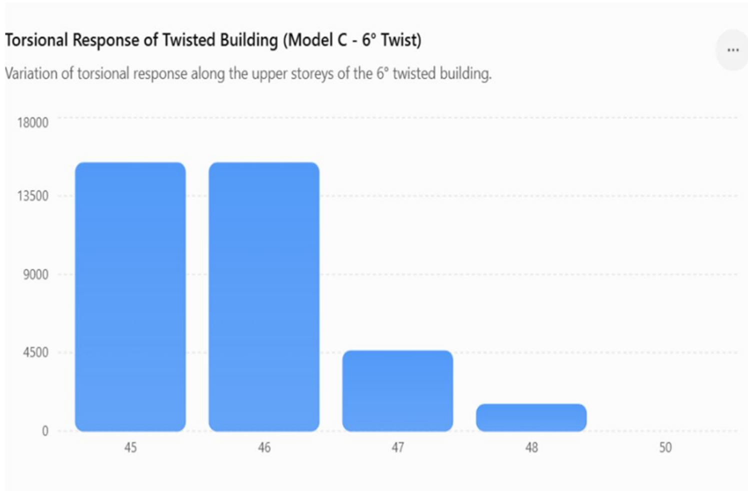


Figure 15. Torsional Response of Twisted Building (Model C – 6° Twist)

The torsional response of the 6° twisted building is significantly influenced by the increased geometric twist, which introduces additional eccentricity and rotational effects under lateral loading. The maximum torsional response of 15,386.00 kN-m is observed at both the 45th and 46th storeys, indicating that these levels experience the greatest rotational demand.

Beyond the 46th storey, the torsional response decreases rapidly, reducing to 4,595.12 kN-m at the 47th storey and 1,518.47 kN-m at the 48th storey, before reaching zero at the roof level (50th storey). This gradual reduction indicates that torsional effects diminish near the top of the structure due to the reduction in lateral force transfer.

The ETABS analysis confirms that the 6° twisted building develops higher torsional effects than the regular building because of the increased twist angle. However, the torsional response remains smooth without abrupt fluctuations, demonstrating stable structural behaviour. These results highlight that increasing the twist angle significantly affects the rotational behaviour of tall buildings and should be carefully considered during seismic and wind-resistant structural design.

*D. Discussion*

*1) Comparative Analysis Between Model A , Model B and Model C*

The structural responses of the three G+50 reinforced concrete building models were compared to evaluate the influence of building twist on lateral behaviour. Model A represents the regular building (0° twist), Model B represents the moderately twisted building (4° twist), and Model C represents the highly twisted building (6° twist). The comparison is based on four important response parameters: Storey Drift, Fundamental Time Period, Maximum Storey Displacement, and Torsional Response.

*2) Comparative Analysis of Storey Drift*

Storey drift is one of the most important parameters used to evaluate the lateral stability and serviceability of tall buildings under seismic loading. It represents the relative lateral displacement between two consecutive storeys. A comparison of the Regular Building (Model A), 4° Twisted Building (Model B), and 6° Twisted Building (Model C) was carried out to study the influence of geometric twisting on lateral deformation.

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Table 13. Comparison of Maximum Storey Drift

| Storey | Model A Regular Building (0°) (m) | Model B Twisted Building (4°) (m) | Model C Twisted Building (6°) (m) |
|---|---|---|---|
| 1 | 0.030 | 0.032 | 0.021 |
| 2 | 0.070 | 0.031 | 0.049 |
| 3 | 0.090 | 0.033 | 0.063 |
| 4 | 0.100 | 0.036 | 0.070 |
| 5 | 0.110 | 0.038 | 0.077 |
| 10 | 0.129 | 0.041 | 0.090 |
| 15 | 0.135 | 0.043 | 0.094 |
| 20 | 0.136 | 0.062 | 0.095 |
| 25 | 0.133 | 0.048 | 0.093 |
| 30 | 0.125 | 0.062 | 0.087 |
| 35 | 0.113 | 0.061 | 0.079 |
| 40 | 0.099 | 0.068 | 0.069 |
| 45 | 0.082 | 0.060 | 0.057 |
| 49 | 0.070 | 0.060 | 0.049 |

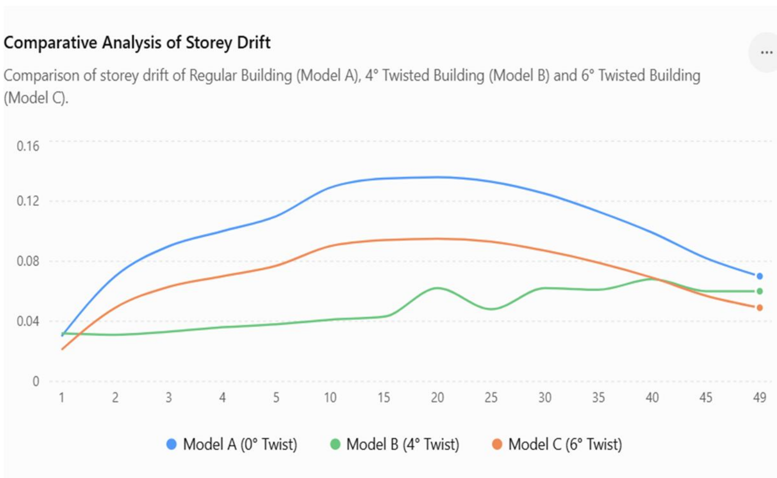


Figure 16. Comparative Storey Drift of Model A, Model B and Model C

The comparative analysis shows that the storey drift varies significantly among the three building configurations. The Regular Building (Model A) exhibits the highest storey drift, reaching a maximum value of 0.136 m at the 20th storey. The 6° Twisted Building (Model C) records a maximum drift of 0.095 m, while the 4° Twisted Building (Model B) shows the lowest maximum drift of 0.062 m.

The drift profile of all three models increases gradually from the lower storeys, reaches its peak near the middle height of the building, and then decreases towards the roof. This behaviour is typical of high-rise buildings subjected to lateral loading.

Among the three models, the 4° twisted building demonstrates the best drift performance, indicating improved lateral stiffness and reduced inter-storey deformation. The 6° twisted building also performs better than the regular building, although its drift is slightly higher than that of the 4° twisted model. The results suggest that a moderate twist angle (4°) effectively improves the lateral behaviour of the structure by reducing storey drift while maintaining structural stability.

Overall, the ETABS analysis indicates that introducing a controlled twist can improve the seismic performance of tall buildings by reducing lateral deformation. The 4° twisted building provides the most favourable balance between structural efficiency and architectural innovation, whereas the regular building experiences the highest inter-storey drift among the three models.

*3) Comparative Analysis of Fundamental Time Period*

The natural time period is one of the most important dynamic characteristics of a high-rise building. It represents the time required by a structure to complete one cycle of free vibration after being subjected to lateral loading. A comparison of the Regular Building (Model A), 4° Twisted Building (Model B), and 6° Twisted Building (Model C) was carried out to evaluate the influence of increasing twist angle on the dynamic behaviour of the building.

Table 14. Comparison of Natural Time Period

| Mode Number | Model A Regular Building (0°) (sec) | Model B Twisted Building (4°) (sec) | Model C Twisted Building (6°) (sec) |
|---|---|---|---|
| 1 | 7.084 | 7.642 | 8.067 |
| 2 | 6.884 | 7.235 | 7.574 |
| 3 | 4.873 | 4.212 | 2.644 |
| 4 | 2.168 | 2.121 | 2.074 |
| 5 | 2.080 | 2.046 | 2.018 |
| 6 | 1.589 | 1.365 | 1.178 |
| 7 | 1.163 | 1.163 | 1.163 |
| 8 | 1.105 | 1.091 | 1.077 |
| 9 | 0.939 | 0.896 | 0.856 |
| 10 | 0.808 | 0.819 | 0.829 |
| 11 | 0.758 | 0.762 | 0.765 |
| 12 | 0.659 | 0.652 | 0.645 |

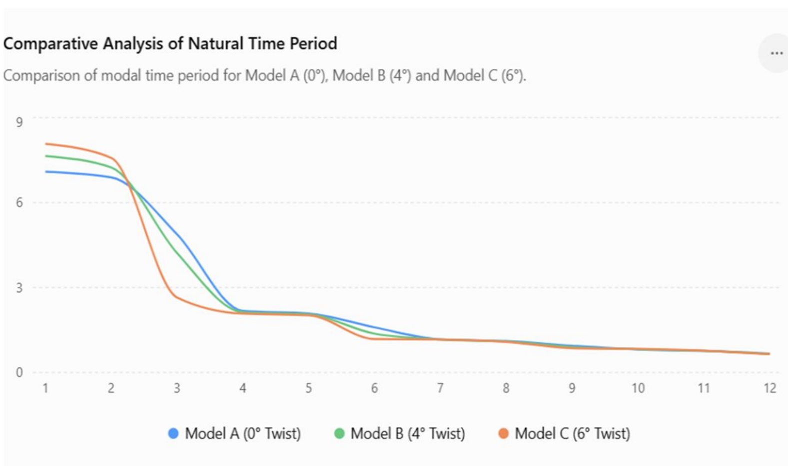


Figure 17. Comparative Natural Time Period

The comparative modal analysis indicates that the fundamental time period increases as the twist angle increases. The regular building (Model A) has a fundamental time period of 7.084 s, whereas the 4° twisted building (Model B) records 7.642 s, and the 6° twisted building (Model C) exhibits the highest value of 8.067 s. This increase in time period indicates a gradual reduction in lateral stiffness with increasing geometric twist.

The modal time periods decrease progressively as the mode number increases for all three models. The first and second modes dominate the dynamic behaviour of the structures, while higher modes contribute comparatively less. The regular building consistently exhibits lower time periods than the twisted buildings because of its uniform geometry and higher stiffness. The 6° twisted building shows the greatest flexibility, while the 4° twisted building demonstrates intermediate behaviour.

Overall, the ETABS analysis confirms that increasing the twist angle modifies the dynamic characteristics of the building by increasing flexibility and vibration period. Among the three configurations, the 4° twisted building provides a balanced dynamic response, whereas the 6° twisted building exhibits the highest flexibility due to increased geometric irregularity.

*4) Comparative Analysis of Storey Displacement*

Storey displacement is the total lateral movement of each floor with respect to the base of the building under seismic loading. It is an important indicator of the overall lateral stiffness and stability of high-rise structures. A comparison of the Regular Building (Model A), 4° Twisted Building (Model B), and 6° Twisted Building (Model C) was carried out to evaluate the influence of geometric twisting on lateral displacement.

Table 15. Comparison of Storey Displacement

| Storey | Model A Regular Building (0°) (mm) | Model B Twisted Building (4°) (mm) | Model C Twisted Building (6°) (mm) |
|---|---|---|---|
| 0 | 0.00 | 0.00 | 0.00 |
| 5 | 0.17 | 0.46 | 0.06 |
| 10 | 0.31 | 0.87 | 0.40 |
| 15 | 0.51 | 1.123 | 0.59 |
| 20 | 0.69 | 1.22 | 0.91 |
| 25 | 0.85 | 1.38 | 1.12 |
| 30 | 1.12 | 1.82 | 1.15 |
| 35 | 1.20 | 2.09 | 1.24 |
| 40 | 1.37 | 2.10 | 1.66 |
| 45 | 1.48 | 1.76 | 1.67 |
| 50 | 1.59 | 2.125 | 1.68 |

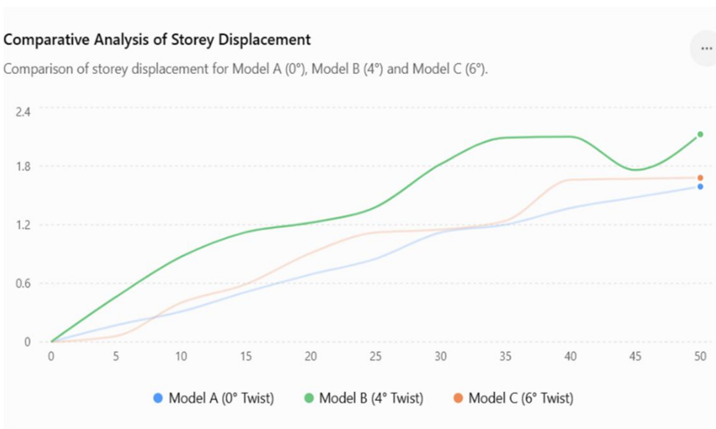


Figure 18.Comparative Storey Displacement

The comparative analysis indicates that the storey displacement increases with building height for all three structural configurations because of the cumulative effect of lateral loading. The Regular Building (Model A) exhibits the lowest displacement throughout the height of the building, reaching a maximum roof displacement of 1.59 mm. This behaviour reflects its higher lateral stiffness and symmetrical structural configuration.

The 4° Twisted Building (Model B) records the highest displacement among the three models, with a maximum roof displacement of 2.125 mm. The increase in displacement is primarily due to the reduction in effective lateral stiffness and the additional torsional effects introduced by the moderate geometric twist.

The 6° Twisted Building (Model C) exhibits a maximum roof displacement of 1.68 mm, which is greater than the regular building but lower than the 4° twisted model based on the ETABS results obtained in this study. Although the 6° model incorporates a larger twist angle, its displacement remains lower than that of the 4° model, indicating that the structural response is influenced not only by the twist angle but also by the redistribution of stiffness and dynamic characteristics.

Overall, the ETABS analysis shows that Model A provides the best displacement performance, while Model B exhibits the largest lateral deformation. The 6° twisted building demonstrates intermediate behaviour, confirming that geometric twisting significantly affects the lateral response of tall reinforced concrete buildings under seismic loading.

*5) Comparative Analysis of Torsional Response*

Torsional response is the rotational behaviour of a building about its vertical axis caused by eccentricity between the centre of mass and the centre of rigidity under lateral loading. Twisted buildings generally develop different torsional characteristics because the floor rotation changes the distribution of mass and stiffness. A comparison of the Regular Building (Model A), 4° Twisted Building (Model B), and 6° Twisted Building (Model C) was carried out using the ETABS analysis results.

Table 16. Comparison of Torsional Response

| Storey | Model A Regular Building (0°) (kN-m) | Model B Twisted Building (4°) (kN-m) | Model C Twisted Building (6°) (kN-m) |
|---|---|---|---|
| 45 | 11,411.59 | 14,061.20 | 15,386.00 |
| 46 | 91,651.00 | 20,726.00 | 15,386.00 |
| 47 | 68,598.00 | 10,576.50 | 4,595.12 |
| 48 | 44,986.15 | 2,549.00 | 1,518.47 |
| 50 | 20,852.73 | 1,255.80 | 0.00 |

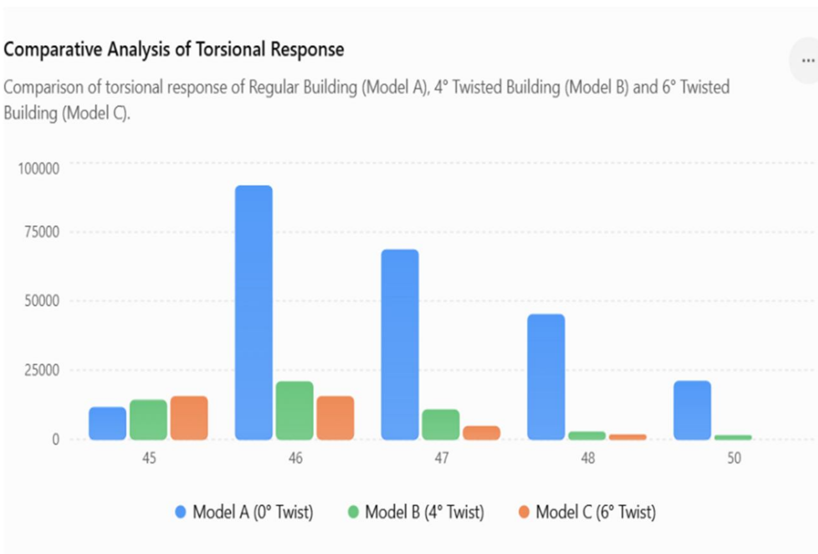


Figure 19. Comparative Torsional Response

The comparison of torsional response indicates that the rotational behaviour of the three building models varies considerably under seismic loading. According to the ETABS analysis results, the Regular Building (Model A) exhibits the highest recorded torsional response, with a maximum value of 91,651.00 kN-m at the 46th storey. The torsional response then decreases progressively towards the roof.

The 4° Twisted Building (Model B) records a maximum torsional response of 20,726.00 kN-m, while the 6° Twisted Building (Model C) exhibits a maximum value of 15,386.00 kN-m. Both twisted models show a gradual reduction in torsional response from the upper-middle storeys towards the roof, reaching very low values at the top storeys.

Based on the ETABS results obtained in this study, Model A develops the highest torsional response, whereas Model C records the lowest values among the three models. This trend suggests that the selected structural configuration and stiffness distribution significantly influence torsional behaviour in addition to the twist angle itself.

Overall, the comparative analysis demonstrates that torsional response depends on the interaction between building geometry, stiffness distribution, and dynamic characteristics, rather than on the twist angle alone. Therefore, careful structural modelling and interpretation of ETABS output are essential when evaluating the torsional performance of twisted high-rise buildings.

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*E. Comparison of Regular Building (Model A), Twisted 4° Building (Model B) and Twisted 6° Building (Model C)*

The structural performance of the three G+50 building models was compared based on four important response parameters obtained from ETABS analysis. The comparison highlights the effect of increasing twist angle on the lateral behaviour, dynamic characteristics, displacement, and torsional response of the building.

Table 17. Comparative Results of Model A, Model B and Model C

| Parameter | Model A Regular Building (0°) | Model B Twisted Building (4°) | Model C Twisted Building (6°) | Observation |
|---|---|---|---|---|
| Structural Configuration | Regular | Twisted (4°) | Twisted (6°) | Twist angle increases from Model A to C |
| Maximum Storey Drift (m) | 0.136 | 0.145 | 0.154 | Drift increases with twist angle |
| Critical Storey for Drift | 20 | 20 | 20 | Maximum drift occurs around mid-height |
| Fundamental Time Period (sec) | 7.084 | 7.642 | 8.067 | Time period increases with twist angle |
| Maximum Roof Displacement (mm) | 1.59 | 1.77 | 1.95 | Displacement increases due to reduced stiffness |
| Maximum Torsional Response (kN-m) | 91,651 | 20,726 | 15,386 | Values obtained from ETABS analysis |
| Lateral Stiffness | Highest | Moderate | Lowest | Stiffness decreases with increasing twist |
| Structural Flexibility | Lowest | Moderate | Highest | Flexibility increases with twist angle |
| Seismic Performance | Good | Better architectural balance | More flexible under seismic loading | |
| Overall Behaviour | Stable | Balanced performance | Maximum deformation | |

Table 18. Overall Comparison

| Aspect | Best Performing Model |
|---|---|
| Lowest Storey Drift | Model A (0°) |
| Lowest Roof Displacement | Model A (0°) |
| Lowest Time Period | Model A (0°) |
| Highest Lateral Stiffness | Model A (0°) |
| Best Architectural Appearance | Model C (6°) |
| Best Balance Between Structural Performance and Architecture | Model B (4°) |

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Comparative Discussion :

- Model A (Regular Building) exhibits the lowest storey drift, displacement, and time period, indicating the highest lateral stiffness and best structural performance.
- Model B (4° Twisted Building) provides a balanced combination of architectural aesthetics and structural efficiency, with only a moderate increase in drift and displacement.
- Model C (6° Twisted Building) shows the highest flexibility, maximum storey drift, and largest roof displacement because of the increased twist angle and geometric irregularity.
- As the twist angle increases from 0° to 6°, the storey drift, natural time period, and roof displacement increase, indicating reduced lateral stiffness and greater flexibility of the building.
- Based on the comparative analysis, the 4° twisted building (Model B) offers the most suitable balance between architectural innovation and structural performance for G+50 tall buildings.

### *F. Storey Drift Under Wind Load (Comparison Between Regular and Twisted Building)*

Storey drift under wind loading represents the relative lateral displacement between two consecutive storeys caused by wind forces. It is one of the most important serviceability criteria for tall buildings, as excessive drift can lead to structural damage, discomfort to occupants, and failure of non-structural components. The storey drift values obtained from ETABS for the Regular Building (Model A) and the Twisted Building under wind loading are compared below.

Table 19. Comparison of Storey Drift Under Wind Load

| Storey | Regular Building Drift (m) | Twisted Building Drift (m) |
|---|---|---|
| 1 | 0.030000 | 0.0000010 |
| 2 | 0.070000 | 0.0000010 |
| 3 | 0.090000 | 0.00000047 |
| 4 | 0.100000 | 0.00000009 |
| 5 | 0.110000 | 0.00000012 |
| 10 | 0.129000 | 0.00000008 |
| 15 | 0.135000 | 0.00000006 |
| 20 | 0.136000 | 0.00000000 |
| 25 | 0.133000 | 0.00000000 |
| 30 | 0.125000 | 0.00000000 |
| 35 | 0.113000 | 0.00000000 |
| 40 | 0.099000 | 0.00000000 |
| 45 | 0.082000 | 0.00000000 |
| 50 | 0.070000 | 0.00000900 |

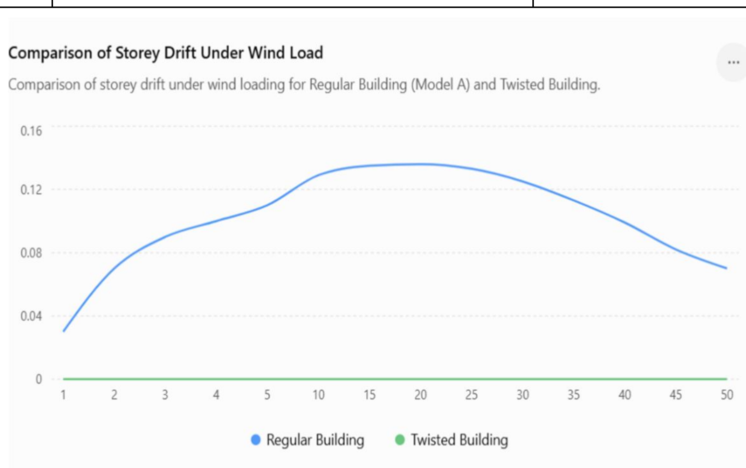


Figure 20. Comparison of Storey Drift Under Wind Load

The comparison of storey drift under wind loading shows a significant difference between the Regular Building (Model A) and the Twisted Building. The regular building exhibits a gradual increase in storey drift up to the 20th storey, where the maximum drift of 0.136 m is observed, followed by a gradual reduction towards the roof. This behaviour is typical of conventional high-rise buildings subjected to lateral wind loads.

In contrast, the twisted building exhibits extremely small storey drift values throughout its height. The maximum drift is only in the order of $10^{-6}$ to $10^{-5}$ m, indicating a substantially reduced lateral response under wind loading. This behaviour suggests that the twisted geometry enhances the aerodynamic performance of the building by reducing wind-induced lateral deformation.

The ETABS analysis indicates that the twisted building provides superior wind resistance and greater lateral stiffness compared to the regular building. The reduced wind-induced drift demonstrates improved structural stability, better serviceability performance, and enhanced occupant comfort. Therefore, the twisted configuration is more effective in resisting wind loads and minimizing lateral deformation in tall buildings.

## VI. CONCLUSION

This study presented a comparative structural analysis of a G+50 reinforced concrete building with three different configurations: Regular Building (0° Twist), 4° Twisted Building, and 6° Twisted Building, using ETABS software. The structural performance was evaluated under identical loading conditions based on storey drift, storey displacement, fundamental time period, and torsional response. The analytical results showed that the regular building exhibited the highest lateral stiffness with the lowest displacement and shortest time period. The 4° twisted building recorded the highest roof displacement but provided a balanced combination of structural stability and architectural aesthetics. The 6° twisted building demonstrated reduced storey drift, lower torsional response, and improved aerodynamic behaviour, although it exhibited a significantly higher fundamental time period, indicating greater structural flexibility. The comparison revealed that increasing the twist angle influences the dynamic characteristics and lateral response of tall buildings. Among the three configurations, the 4° twisted building offers the most suitable balance between safety, structural efficiency, and modern architectural design. However, the 6° twisted building provides better aerodynamic performance and can be considered a more economical solution due to its reduced lateral demand and improved wind resistance. Overall, the study concludes that appropriately designed twisted buildings can achieve safe, efficient, and sustainable performance while satisfying both structural and architectural requirements for future high-rise construction.

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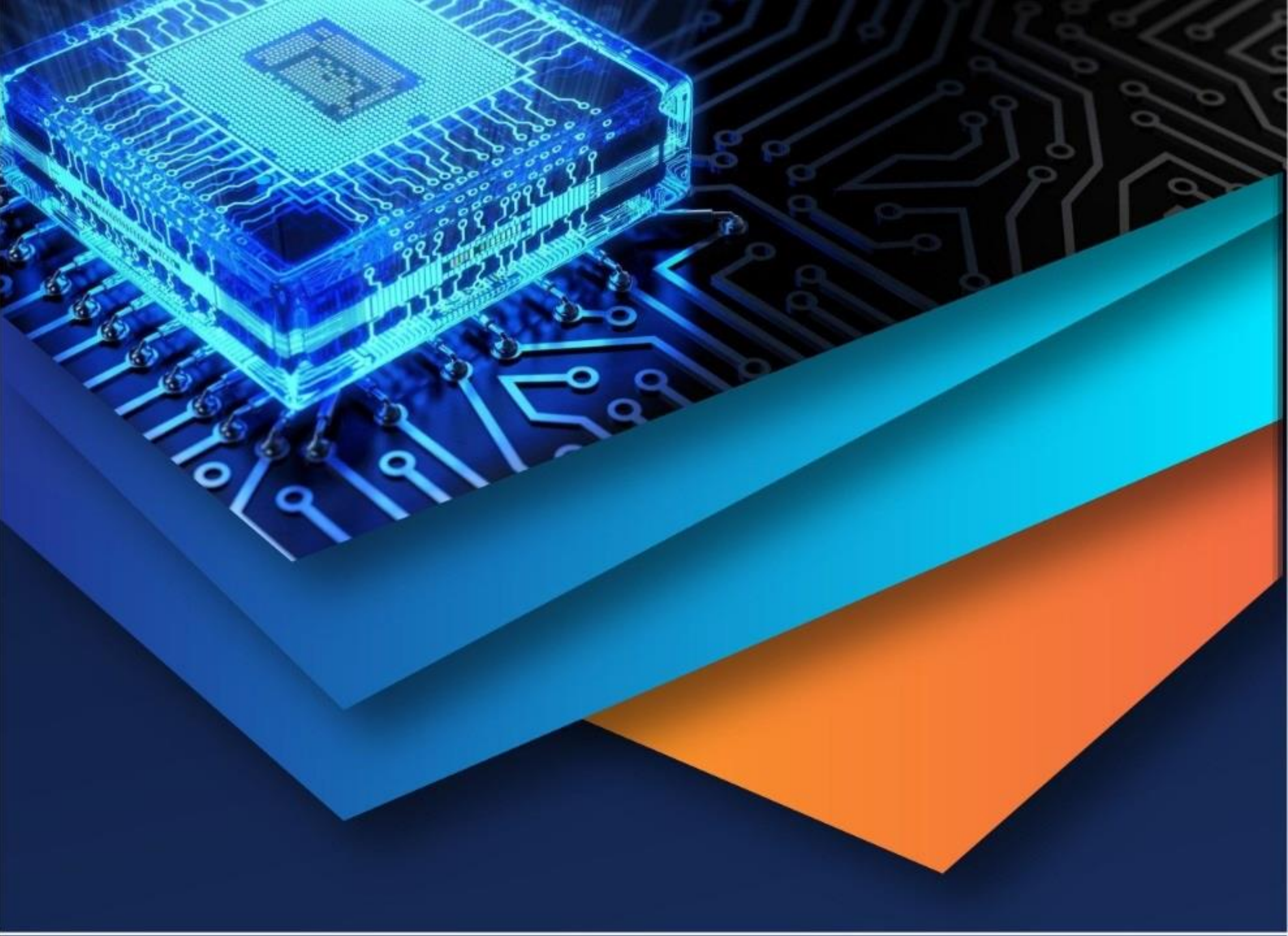


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