PERFORMANCE BASED DESIGN OF TALL BUILDING WITH CORNER MODIFICATION BY USING ETABS SOFTWARE

Avinash Joshi[1], Banoth Venkat[2], Elluri Arjun Goud[2], Jupally Divya[2], Kamaneri Anusha[2]

ABSTRACT

The behaviour of tall buildings under wind loads is significantly influenced by their geometric configuration, particularly the shape of building corners. This study investigates the effect of different corner modifications—namely square (base model), rounded, and chamfered (25%, 50%, and 100%)—on the wind-induced displacement of a G+21 tall building. Structural analysis is performed under load combinations 1.2 (DL + LL + WLX) and 1.2 (DL + LL + WLY), focusing on maximum storey displacement at critical elevations.

The results indicate that the Rounded Model exhibits superior performance by significantly reducing displacement in both X and Y directions. The displacement reduces from 39.35 mm to 22.17 mm in X-direction and from 18.16 mm to 9.92 mm under the respective load combinations. In Y-direction, displacement reduces from 43.93 mm to 34.71 mm and from 103 mm to 84.60 mm compared to the Base Model. These reductions correspond to 27.93%, 29.34%, 11.73%, and 9.80%, respectively, demonstrating improved aerodynamic behaviour and reduced wind pressure concentration.

In contrast, the Chamfer 25% Model shows the highest displacement, increasing from 39.35 mm to 81.48 mm and from 18.16 mm to 81.48 mm, with percentage increases of 34.86% and 77.64%, respectively. The Chamfer 50% Model increases displacement from 39.35 mm to 68.75 mm and from 18.16 mm to 68.75 mm, while the Chamfer 100% Model increases displacement from 39.35 mm to 55.85 mm and from 103 mm to 146.02 mm, indicating reduced structural efficiency due to disturbed airflow and stiffness variation.

Furthermore, the study highlights that displacement increases with building height and varies with wind direction, with higher values generally observed in the Y-direction. The findings emphasize that aerodynamic shaping plays a crucial role in enhancing the stability and serviceability of tall buildings.

Overall, the study concludes that rounded corner modification is the most effective strategy for minimizing wind-induced displacement, thereby improving structural performance and safety. These results provide valuable insights for the optimal design of tall buildings subjected to wind loads.

KEYWORDS: Tall Building, Wind Load Analysis, Storey Displacement, Corner Modification, Rounded Geometry, Chamfer Building, ETABS Analysis

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Research Paper

1. INTRODUCTION:

In recent years, the rapid growth of urbanization and population has led to an increased demand for vertical construction, resulting in the development of tall buildings. These structures are not only designed to accommodate large populations but also to optimize land use in densely populated cities. However, as the height of buildings increases, they become more susceptible to lateral loads such as wind and earthquake forces, which significantly influence their structural behavior.

Traditionally, structural design has been carried out using code-based design methods, where buildings are designed to satisfy minimum requirements specified in design codes. While this approach ensures safety, it does not explicitly predict how a building will perform under different levels of loading, especially during extreme events like earthquakes.

To overcome these limitations, the concept of Performance-Based Design (PBD) has emerged as a modern and efficient design philosophy. Performance-based design focuses on evaluating how a structure behaves under real loading conditions and ensures that it meets specific performances like immediate occupancy, life safety, collapse prevention.

This approach allows engineers to design structures that are not only safe but also economical and efficient. One of the critical aspects affecting the performance of tall buildings is their geometric configuration, particularly the shape of the building plan. Most buildings are commonly constructed in rectangular or square shapes due to simplicity in design and construction. However, these shapes often lead to stress concentration at the corners, increased wind pressure, and torsional irregularities during seismic events.

Corners of buildings play a significant role in determining how forces are distributed throughout the structure. Sharp corners tend to attract higher stresses and may cause structural inefficiencies. To address these issues, corner modification techniques such as chamfer-ed corners, rounded corners, and setbacks are increasingly being adopted in modern high-rise construction. Corner modifications help in reducing wind pressure effects, minimizing stress concentration, improving aerodynamic behavior, enhancing overall structural performances with the advancement of structural analysis software like ETABS, engineers can now model complex geometries and accurately analyze the behavior of buildings under various loading conditions. ETABS provides powerful tools for modeling, analysis, and design of multi-storey buildings, making it an essential tool for performance-based design studies.

This project focuses on the performance-based design of tall buildings by considering different corner modifications using ETABS software, and aims to evaluate how these modifications influence the structural behavior under lateral loads.

1.1 Literature Review

a. **MANEESHA YOGA et al.** (2025) studied the aerodynamic shape optimization of G+21 buildings using ETABS. The study considered both micro and macro modifications such as corner cuts, recessions, and vertical fins. The results showed that these modifications reduced top storey displacement by up to 30%. Parameters like storey drift, displacement, and storey shear were analyzed, and it was found that square plans performed better due to symmetry. The study concluded that aerodynamic shaping significantly improves wind resistance, structural stability, and occupant comfort.

b. **MOHAMMED ABDUL SAMI:** (2024) investigated the effectiveness of tapering and corner modification in 50- and 100-storey buildings under wind loads. The study analyzed parameters such as storey displacement, drift, base shear, and time period. It was found that increasing tapering ratios along with chamfered corners leads to significant reduction in wind-induced vibration. The results demonstrated improved aerodynamic behavior and structural performance. The study concluded that combining geometric modifications enhances both efficiency and safety.

c. **SUJAN M AND SHIVARAJ G. NAYAK** (2023) analyzed G+24 buildings with both minor and major aerodynamic modifications. The study focused on parameters such as storey drift, displacement, and base shear under wind loading. It was observed that corner geometry has a direct influence on wind response and structural behavior. Modified shapes showed reduced vibration and improved stability compared to conventional buildings. The study concluded that aerodynamic optimization is an economical and effective solution for tall buildings.

d. HAMIDREZA ALILEJAD, BYEONGUK AHN, AND THOMUS H. K. KANG (2024) studied the performance-based wind design of 160 m tall buildings with different corner configurations. The study compared sharp, chamfered, and recessed corners and found that approximately 10% corner modification significantly reduces wind loads and vibrations. The research also considered inelastic behavior and energy dissipation under wind loading. The results showed improved performance and reduced material demand. The study concluded that aerodynamic modification combined with performance-based design enhances structural efficiency.

e. RAHUL KUMAR MEENA, RITU RAJ, AND S. ANBU KUMAR (2022) conducted a CFD-based study on buildings with different corner configurations. The research analyzed airflow patterns, pressure distribution, and vortex formation around the structure. It was observed that rounded and chamfered corners reduce drag and lift forces by minimizing vortex shedding. Rounded corner buildings showed the best aerodynamic performance among all models. The study concluded that corner modification significantly improves wind stability and reduces turbulence effects.

2. OBJECTIVE AND METHODOLOGY

2.1. Objective:

- To study how different corner modifications (square, rounded, chamfered) influence the lateral displacement behaviour of tall buildings under wind loads.
- To evaluate and compare storey displacement values between the base model and modified models such as rounded, chamfer 25%, 50%, and 100% and to assess how varying levels of chamfering, influence displacement and structural efficiency under wind loading conditions.
- To analyse how displacement varies with wind acting in X and Y directions and identify directional sensitivity of tall buildings.
- To compare displacement at different elevations (60 m and 63 m) and understand how height affects structural response.
- To determine the optimal corner configuration that provides maximum stability, minimum displacement, and improved structural performance under wind loads

2.2 Methodology –

The methodology of this project focuses on analyzing the performance of tall buildings with different corner configurations using ETABS software. The entire process is carried out in a systematic manner to ensure accurate modelling, analysis, and comparison of results.

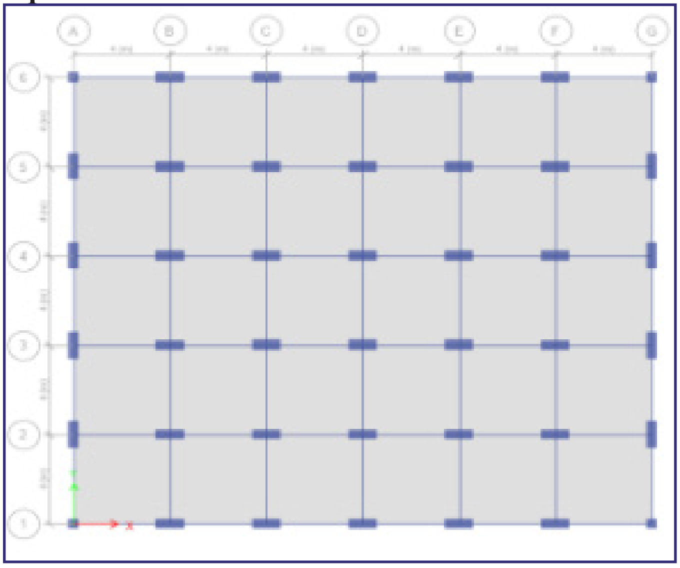
- Objective → ETABS Model Generation → Analysing the Buildings for Different Cases → Presentation and comparison of results in the form of graphs and tables → Results and Conclusion

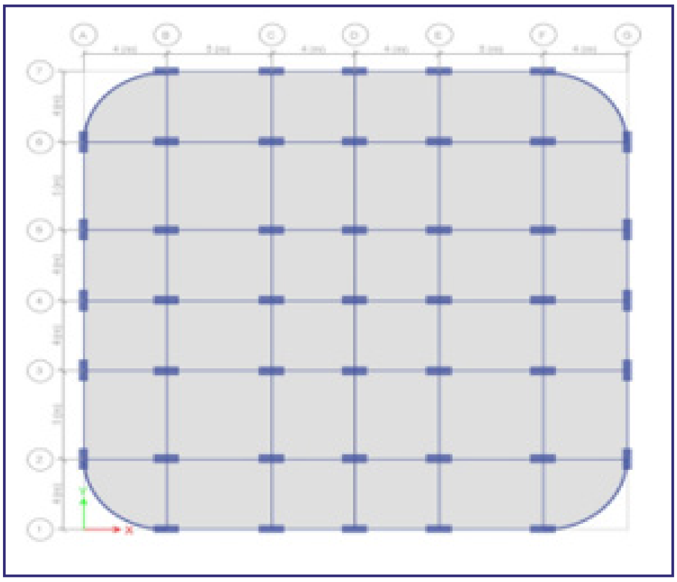
2.3 Geometry:

Table-1: Building details for the models Building Shape	Square, Round & Chamfer
Building Dimension	24m x 20m
Total Storey	G+21
Total Height of Building	66m
Grade of Concrete	For BEAM, SLAB: M 35N/mm2 For COLUMN: M 40 N/ mm2
Grade of Steel	Fe 500 N/ mm2
Nominal cover of Structural elements	Beam – 25 mm, Slab – 25 mm, Column -60mm.
Beam Dimensions	B1 230x600 mm B2 230x230 mm
Column Dimensions	C1 450x450mm C2 450x1200mm C3 500x1200mm
Slab Thickness	150 mm
Wind Speed	33 m/s
Terrain Category	2
Windward Coefficient, Cp	0.8
Leeward Coefficient, Cp	0.25
Type of Load	Load Calculation

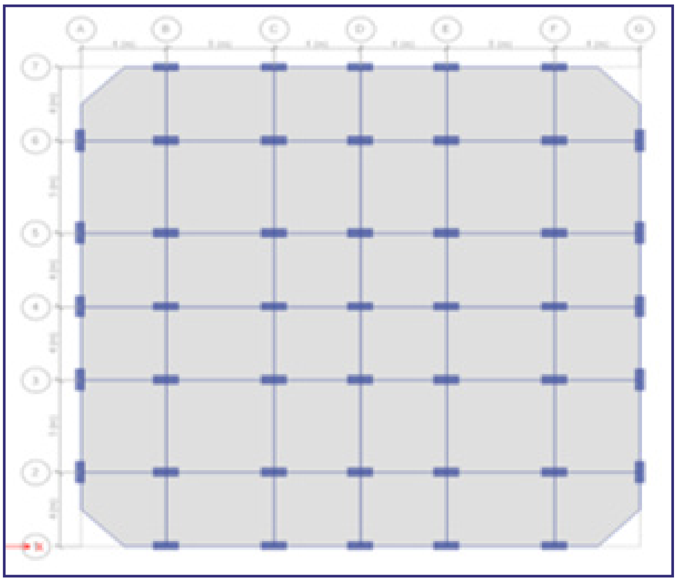
Total Live load applied	2 KN/ m2
Floor Finish Load	1 KN/ m2
Main Wall Load	15.24 KN/m
Partition Wall Load	2.78 KN/m

Square Model:





Chamfer Model:



3. RESULTS AND DISCUSSION:

3.1. Base Model vs Rounded Model

- The maximum storey displacement along the X-direction for the base model is 39.35 mm, whereas for the rounded model, it is 22.17 mm at storey 21 (63 m) under 1.2 (DL + LL + WLX). By modifying the building shape from square to rounded, the displacement is reduced by (39.35 – 22.17) = 17.18 mm, then the percentage reduction in displacement is 27.93%
- The maximum storey displacement along the Y-direction for the base model is 43.93 mm, whereas for the rounded model, it is 34.71 mm at storey 21 (63 m) under 1.2 (DL + LL + WLX). By modifying the building shape from square to rounded, the displacement is reduced by (43.93 – 34.71) = 9.22 mm, then the percentage reduction in displacement is: 11.73 %
- The maximum storey displacement along the X-direction for the base model is 18.16 mm, whereas for the rounded model, it is 9.92 mm at storey 21 (63 m) under 1.2 (DL + LL + WLY). By modifying the building shape from square to rounded, the displacement is reduced by (18.16 – 9.92) = 8.24 mm, then the percentage reduction in displacement is 29.34%
- The maximum storey displacement along the Y-direction for the base model is 103 mm, whereas for the rounded model, it is 84.60 mm at storey 21 (63 m) under 1.2 (DL + LL + WLY). By modifying the building shape from square to rounded, the displacement is reduced by (103 –

84.60) = 18.40 mm, then the percentage reduction in displacement is 9.80%

3.2. Base Model vs Chamfer 100% Model

- The maximum storey displacement along the X-direction for the base model is 39.35 mm, whereas for the chamfer 100% model, it is 55.85 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 100%, the displacement is increased by (55.85 – 39.35) = 16.50 mm, then the percentage increase in displacement is:17.32%
- The maximum storey displacement along the Y-direction for the base model is 43.93 mm, whereas for the chamfer 100% model, it is 84.31 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 100%, the displacement is (43.93 – 84.31) = -40.38 mm, so it is increased, then the percentage increase in displacement is:31.49%
- The maximum storey displacement along the X-direction for the base model is 18.16 mm, whereas for the chamfer 100% model, it is 34.20 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 100%, the displacement is (18.16 – 34.20) = -16.04 mm, so it is increased, then the percentage increase in displacement is 30.64%
- The maximum storey displacement along the Y-direction for the base model is 103 mm, whereas for the chamfer 100% model, it is 146.02 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 100%, the displacement is (103 – 146.02) = -43.02 mm, so it is increased, then the percentage increase in displacement is 17.28%

3.3. Base Model vs Chamfer 25% Model

- The maximum storey displacement along the X-direction for the base model is 39.35 mm, whereas for the chamfer 25% model, it is 81.48 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 25%, the displacement is increased by (81.48 – 39.35) = 42.13 mm, then the percentage increase in displacement is 34.86 %
- The maximum storey displacement along the Y-direction for the base model is 43.93 mm, whereas for the chamfer 25% model, it is 77.45 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 25%, the displacement is (43.93 – 77.45) = -33.52 mm, so it is increased, then the percentage increase in displacement is:27.61%
- The maximum storey displacement along the X-direction for the base model is 18.16 mm, whereas for the chamfer 25% model, it is 81.48 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 25%, the displacement is (18.16 – 81.48) = -63.32 mm, so it is increased, then the percentage increase in displacement is 77.64%
- The maximum storey displacement along the Y-direction for the base model is 103 mm, whereas for the chamfer 25% model, it is 77.45 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 25%, the displacement is (103 – 77.45) = 25.55 mm, so it is reduced, then the percentage reduction in displacement is 14.61%

3.4. Base Model vs Chamfer 50% Model

- The maximum storey displacement along the X-direction for the base model is 39.35 mm, whereas for the chamfer 50% model, it is 68.75 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 50%, the displacement is increased by (68.75 – 39.35) = 29.40 mm, then the percentage increase in displacement is: 27.20%
- The maximum storey displacement along the Y-direction for the base model is 43.93 mm, whereas for the chamfer 50% model, it is 65.14 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 50%, the displacement is (43.93 – 65.14) = -21.21 mm, so it is increased, then the percentage increase in displacement is:19.45%
- The maximum storey displacement along the X-direction for the base model is 18.16 mm, whereas for the chamfer 50% model, it is 68.75 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 50%, the displacement is (18.16 – 68.75) = -50.59 mm, so it is increased, then the percentage increase in displacement is 58.22%
- The maximum storey displacement along the Y-direction for the base model is 103 mm,

whereas for the chamfer 50% model, it is 65.14 mm at storey 21 (63 m). By modifying the building shape from square to chamfer 50%, the displacement is (103 – 65.14) = 37.86 mm, so it is reduced, then the percentage reduction in displacement is 22.51%

3.5. Rounded Model vs Chamfer 100% Model

- The maximum storey displacement along the X-direction for the rounded model is 22.17 mm, whereas for the chamfer 100% model, it is 55.85 mm at storey 21 (63 m). The displacement increases by (55.85 – 22.17) = 33.68 mm, then the percentage increase is: 43.17%
- The maximum storey displacement along the Y-direction for the rounded model is 34.71 mm, whereas for the chamfer 100% model, it is 84.31 mm at storey 21 (63 m). The displacement is (34.71 – 84.31) = -49.60 mm, so it is increased, then the percentage increase is:41.67%
- The maximum storey displacement along the X-direction for the rounded model is 9.92 mm, whereas for the chamfer 100% model, it is 34.20 mm. The displacement is (9.92 – 34.20) = -24.28 mm, so it is increased, then the percentage increase is 71.67%
- The maximum storey displacement along the Y-direction for the rounded model is 84.60 mm, whereas for the chamfer 100% model, it is 146.02 mm. The displacement is (84.60 – 146.02) = -61.42 mm, so it is increased, then the percentage increase is 26.64%

3.6. Rounded Model vs Chamfer 25% Model

- The maximum storey displacement for the rounded model is 22.17 mm, whereas for the chamfer 25% model, it is 81.48 mm. The displacement increases by (81.48 – 22.17) = 59.31 mm, then the percentage increase is 57.22%
- The maximum storey displacement along the Y-direction for the rounded model is 34.71 mm, whereas for the chamfer 25% model, it is 77.45 mm. The displacement is (34.71 – 77.45) = -42.74 mm, so it is increased, then the percentage increase is 38.45%
- The maximum storey displacement along the X-direction for the rounded model is 9.92 mm, whereas for the chamfer 25% model, it is 81.48 mm. The displacement is (9.92 – 81.48) = -71.56 mm, so it is increased, then the percentage increase is 87.78 %
- The maximum storey displacement along the Y-direction for the rounded model is 84.60 mm, whereas for the chamfer 25% model, it is 77.45 mm. The displacement is (84.60 – 77.45) = 7.15 mm, so it is reduced, then the percentage reduction is 4.41%

3.7. Rounded Model vs Chamfer 50% Model

- The maximum storey displacement for the rounded model is 22.17 mm, whereas for the chamfer 50% model, it is 68.75 mm. The displacement increases by (68.75 – 22.17) = 46.58 mm, then the percentage increase is 51.26%
- The maximum storey displacement along the Y-direction for the rounded model is 34.71 mm, whereas for the chamfer 50% model, it is 65.14 mm. The displacement is (34.71 – 65.14) = -30.43 mm, so it is increased, then the percentage increase is 30.46%
- The maximum storey displacement along the X-direction for the rounded model is 9.92 mm, whereas for the chamfer 50% model, it is 68.75 mm. The displacement is (9.92 – 68.75) = -58.83 mm, so it is increased, then the percentage increase is 85%
- The maximum storey displacement along the Y-direction for the rounded model is 84.60 mm, whereas for the chamfer 50% model, it is 65.14 mm. The displacement is (84.60 – 65.14) = 19.46 mm, so it is reduced, then the percentage reduction is 13%

CONCLUSION

1. The study confirms that corner geometry significantly affects wind-induced storey displacement for all models: Base Model (Square), Rounded Model, Chamfer 25% Model, Chamfer 50% Model, and Chamfer 100% Model under load combinations 1.2 (DL + LL + WLX) and 1.2 (DL + LL + WLY).
2. The Rounded Model shows the best performance under 1.2 (DL + LL + WLX), reducing X-direction displacement is 27.93% (Base Model), and under 1.2 (DL + LL + WLY), the rounded model reduces X-direction displacement 29.34% (Base Model), showing significant improvement. In Y-direction, the Rounded Model displacement under the load

combination of 1.2 (DL + LL + WLX) reduced 11.73%, and under 1.2 (DL + LL + WLY) reduced 9.80% compared to the Base Model.
3. The Chamfer 100% Model increases displacement under 1.2 (DL + LL + WLX) load combination 17.32%, and under 1.2 (DL + LL + WLY) 30.64%.
4. The Chamfer 50% Model also shows higher displacement, increasing 51.26 % under 1.2 (DL + LL + WLX) and 85% under 1.2 (DL + LL + WLY).
5. The Chamfer 25% Model shows the worst performance, with displacement increasing 57.22% under 1.2 (DL + LL + WLX) and 87.78% under 1.2 (DL + LL + WLY).
6. For all models (Base, Rounded, Chamfer 25%, Chamfer 50%, Chamfer 100%), the maximum displacement occurs at storey 21 (63 m) under both load combinations, confirming increase in displacement with height Based on overall performance under 1.2 (DL + LL + WLX) and 1.2 (DL + LL + WLY), the ranking is: Base Model > Rounded Model > Chamfer 50% Model > Chamfer 100% Model > Chamfer 25% Model. Hence, the Rounded Model is the most efficient configuration for minimizing displacement and improving structural performance under wind loads.

FUTURE SCOPE

The study can be extended by considering seismic load analysis along with wind loads for combined effect evaluation. Dynamic analysis methods such as Time History Analysis, Response Spectrum Analysis and Computational Fluid Dynamics (CFD) analysis can be used to study detailed wind flow behavior around modified geometries.

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