Evaluation Of Wind Effects on Slender Tall Buildings Using the Gust Factor Method Considering Corner Modification

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***Abstract*—Two building heights, G+40 and G+60 storeys, are considered to represent moderately tall and highly slender structures. For each height, three aspect (slenderness) ratios 8, 9, and 10 are studied to evaluate the effect of increasing slenderness on wind response. Four plan configurations are analysed: a conventional sharp-corner model and three aerodynamically modified models incorporating corner rounding, chamfering, and corner recession. Structural modelling and analysis are performed to determine key response parameters, including top-storey displacement, storey drift, fundamental time period, storey stiffness, and base shear. The results indicate that the sharp-corner configuration consistently produces the highest wind-induced responses across all slenderness ratios and building heights. Aerodynamic modifications significantly improve performance, with rounded corners emerging as the most effective strategy**

***Index Terms*—Slender tall buildings, Gust factor method, Corner modification, Aerodynamic effect.**

I. INTRODUCTION

Slender tall buildings often referred to as super-slender or ultra-slim towers are characterized by their high aspect ratios, typically exceeding 7:1 (height to width). These buildings present unique challenges and opportunities from an architectural standpoint. Evaluating their architectural design involves multiple parameters such as form, function, structural integration, aesthetics, and performance. In CTBUH's 2016 Awards lineup, 432 Park Avenue was highlighted as a finalist from the Americas region, noted for pushing slenderness limits with its 1:15 ratio. CTBUH defines "super-slender" high-rises generally as those exceeding 10:1 or 12:1 slenderness ratio, aligning with engineering convention

- To develop and analyses structural models of slender tall buildings with varying aspect ratios (8, 9, and 10) in order to evaluate the influence of slenderness on wind-induced response.
- To examine the effectiveness of aerodynamic corner modifications, namely corner rounding, chamfering, and corner recession, in mitigating wind-induced forces and dynamic responses.
- To perform a comparative assessment between conventional sharp-corner configurations and aerodynamically modified models under equivalent wind loading conditions as per Indian Standard provisions.
- To quantify the percentage reduction in wind-induced loads and structural responses achieved through each type of corner modification, and to provide practical design recommendations for improving the aerodynamic performance of tall buildings.

II. LITERATURE REVIEW

S. A Fawzy et.al (2024): The construction of high-rise buildings with increasing slenderness ratios presents both economic and engineering challenges. This study investigates the effect of slenderness ratio on the seismic performance of high-rise buildings in various seismic zones across the United States. This research aims to contribute to the development of safer, more resilient, and cost-effective high-rise construction practices in earthquake-prone regions. The research employs non-linear and linear static analysis to assess the seismic response of slender high-rises subjected to ground motions representative of different US seismic zones

Qingshan Yang et.al (2024): The crosswind responses of tall slender structures play an important role for the wind-resistant design, and they can be significantly influenced by the wind fields. There was a prevailing belief that the aero elastic response of tall-slender structures was mostly observed under low-turbulent suburban flow. Nevertheless, aero elastic response of tall-slender structures with substantially higher height and aspect ratio in high-turbulent urban flow may occur, remains unverified in the absence of empirical evidence. Moreover, the aeroelastic instability of vortex resonance and galloping of square-section tall-slender structures should be carefully addressed, especially the combined vortex resonance and galloping may occur.

Patrick Walsh et.al (2024): The paper by Patrick Walsh, Ali Saleh and Harry Far (2024) was published in the Proceedings of the Australian Journal of Structural Engineering. With the rapid population growth and scarcity of developable space, especially in large cities, there is a need for increased density in both commercial and residential housing, and hence a strong demand to maximize floor space by constructing not only tall, but also slender buildings. This study considers different structural systems available for constructing slender high-rise buildings and evaluates their feasibility in terms of the lateral deformation being one of the key governing design criteria for very tall buildings.

Chandradhara G. P et.al (2024): The paper by Chandradhara G. P1, Vikram. M. B2 (2024) was published ISOR journal of mechanical and civil engineering. In the recent past many tall buildings are being built in India. The impact of wind loads is to be considered for the design of tall multi-storied buildings. Several failures of structures have occurred in India due to wind. The IS 875 Part-3 deals with wind loads on different types of structures. Modern Tall buildings designed to satisfy lateral drift requirements, still may oscillate excessively during wind storm. These oscillations can cause some threats to the tall building as buildings with more and more height becomes more vulnerable to oscillate at high-speed winds. This study presents the wind effects on buildings with different aspect ratio using ETABS

M.S. REFAEY et.al (2023): According to research historically, humans constructed temples, castles, and pyramids. Skyscrapers arose due to urban growth, limited land, and high costs. They represent power and prestige. New designs attract planners and architects to vertical cities as urban populations increase. The problem: Tall buildings are at higher risk of wind-induced damage to non-structural elements. To study this, we analyzed structural systems for vertical expansion in high-altitude building design. This study analyses tall building shapes to study wind forces and stability. It focuses on aerodynamic alterations to reduce wind excitation

III. MODEL INFORMATION

Model	Corner Configuration	Slenderness Ratio (Aspect Ratio)	Storeys
M1	Sharp Corner (Baseline)	8, 9, 10	G+40, G+60
M2	Rounded Corner	8, 9, 10	G+40, G+60
M3	Chamfered Corner	8, 9, 10	G+40, G+60
M4	Recessed Corner	8, 9, 10	G+40, G+60

40 Storey Building Dimensions as Per Slender Ratios

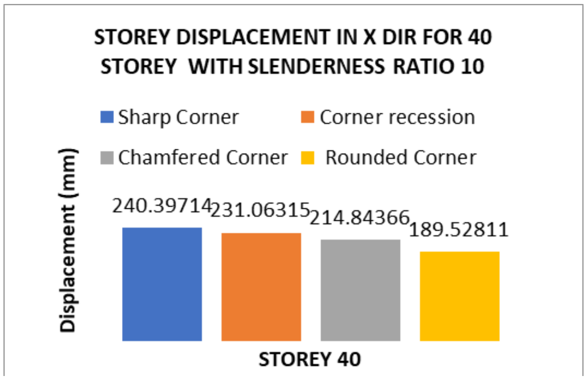
Slenderness Ratio	Width (m)	Length (m)	Area (sq.m)
8	15.000	20.000	300
9	13.333	22.500	300
10	12.000	25.000	300

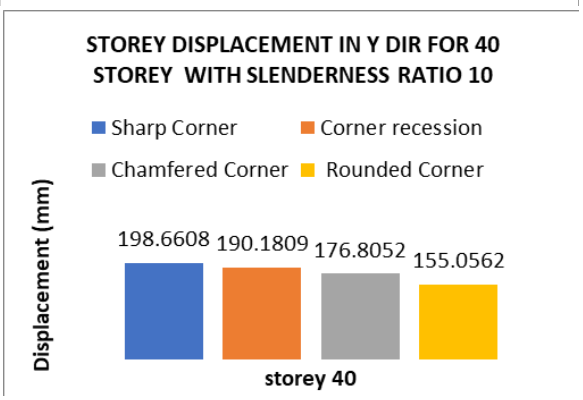
60 Storey Building Dimensions as Per Slender Ratios

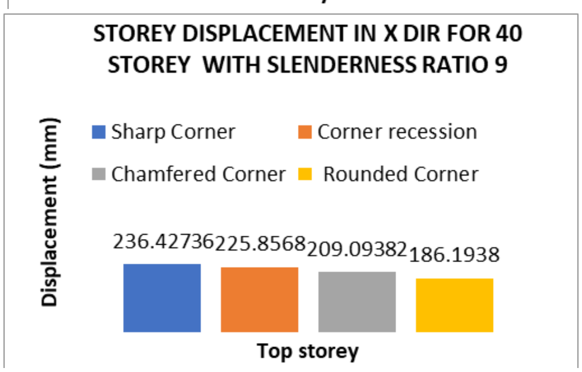
Slenderness Ratio	Width (m)	Length (m)	Area (m²)
8	22.50	13.33	300
9	20.00	15.00	300
10	18.00	16.67	300

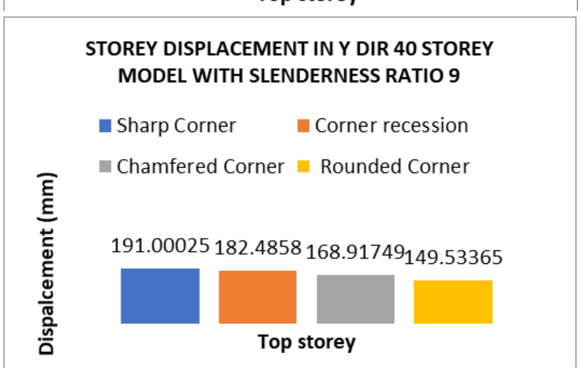
IV. RESULTS AND DISCUSSION

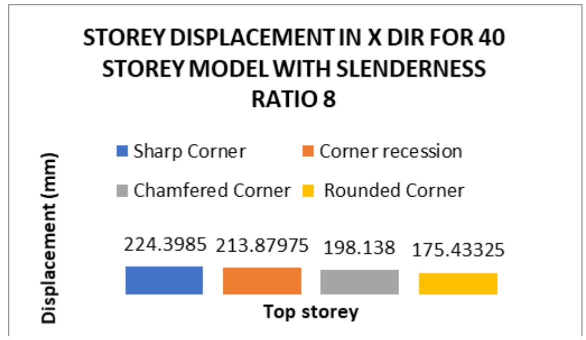
4.1 Displacement results for 40 storey with slenderness ratio 10, 9&8

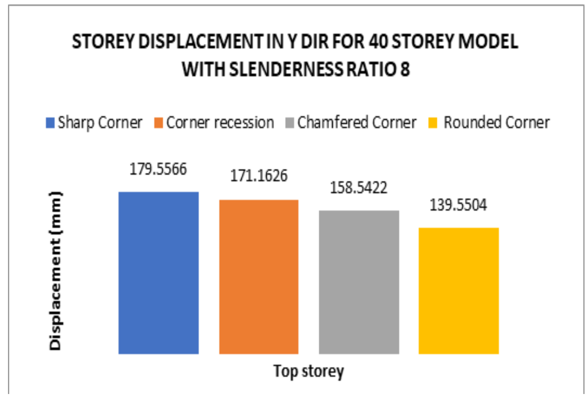




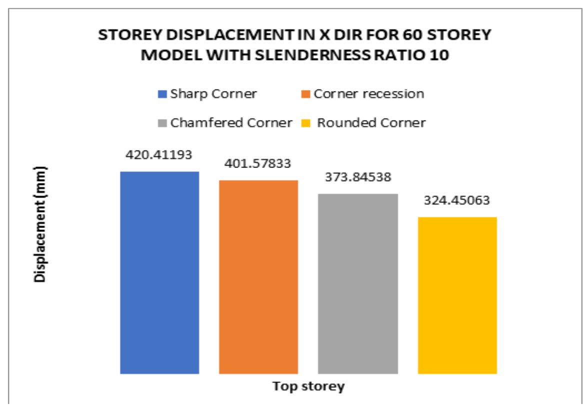


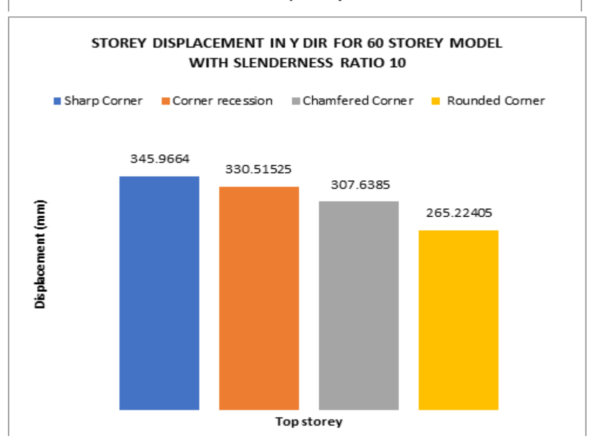


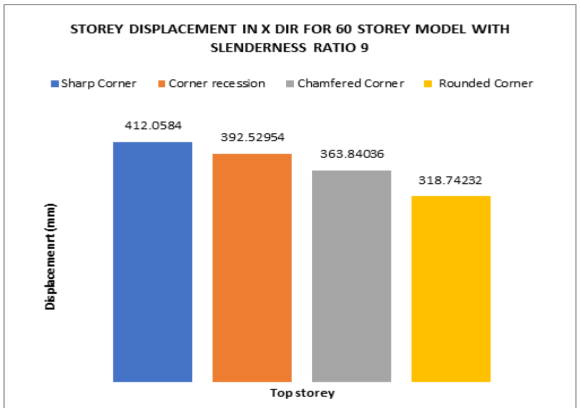


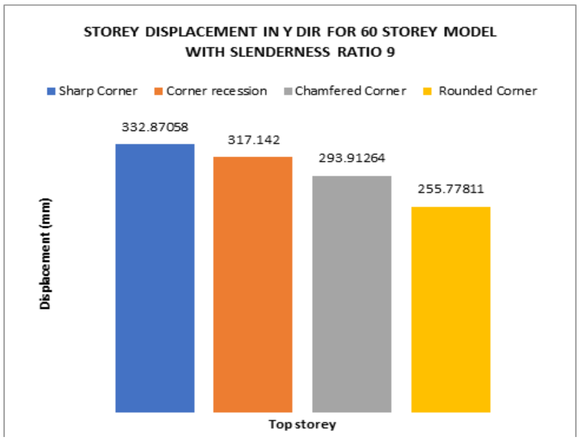


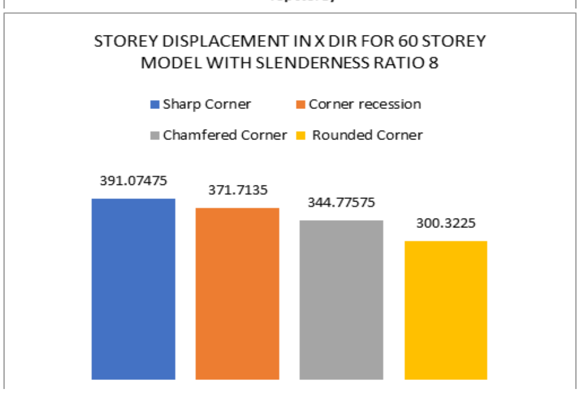
4.2 Displacement results for 60 storey with slenderness ratio 10

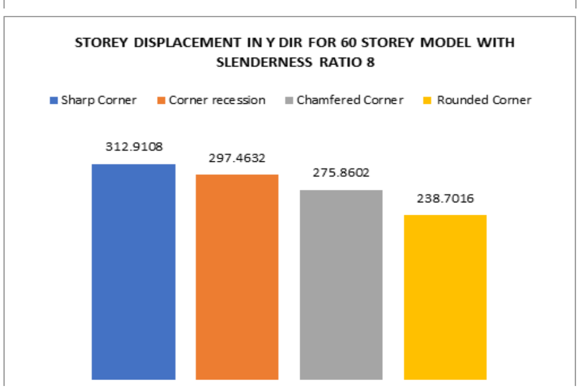






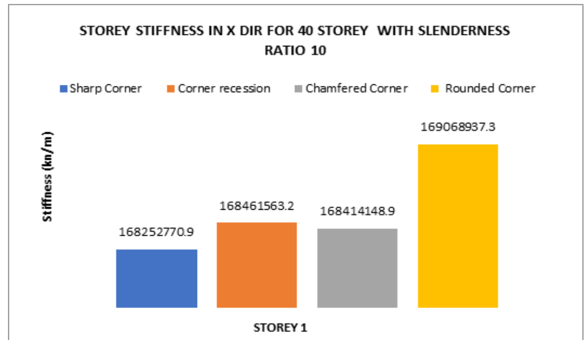


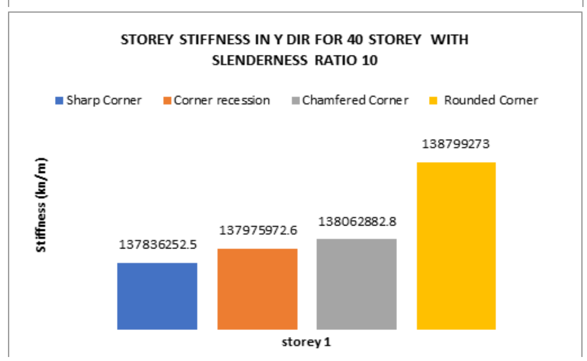


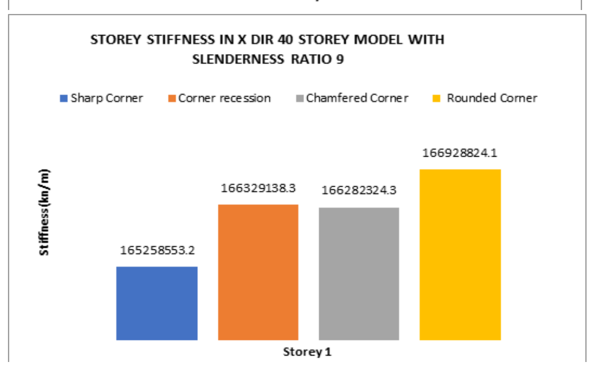


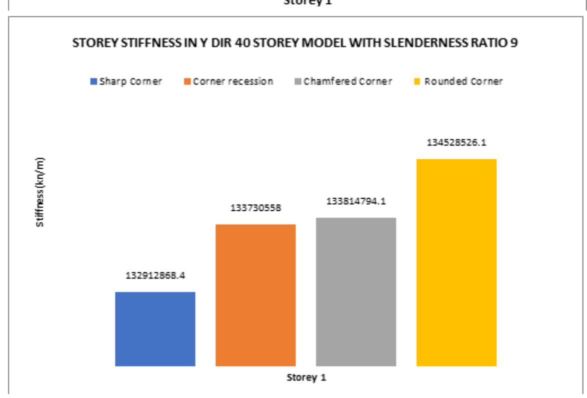
For a 60-storey building, storey displacement is significantly higher because of the increased height and slenderness ratio. The building becomes more flexible, leading to larger lateral movements and greater inter-storey drift, especially in the upper levels. This typically requires enhanced lateral load-resisting systems such as shear walls, bracing, or outrigger systems to control displacement within permissible limits.

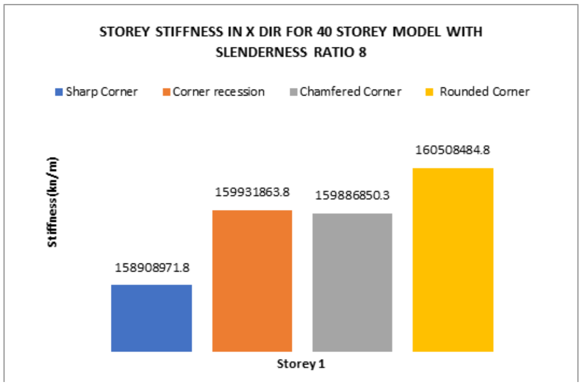
4.3 Storey stiffness result of 40 storey with slenderness ratio 10, 9 &8

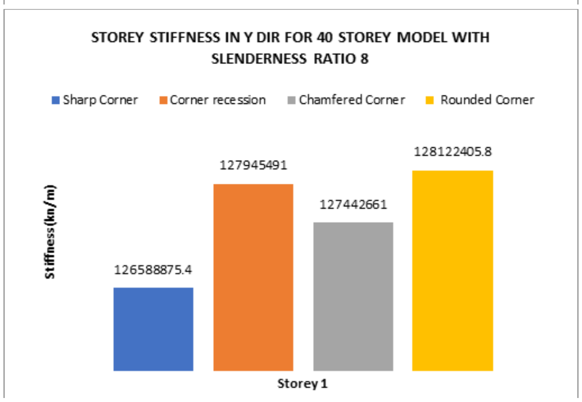






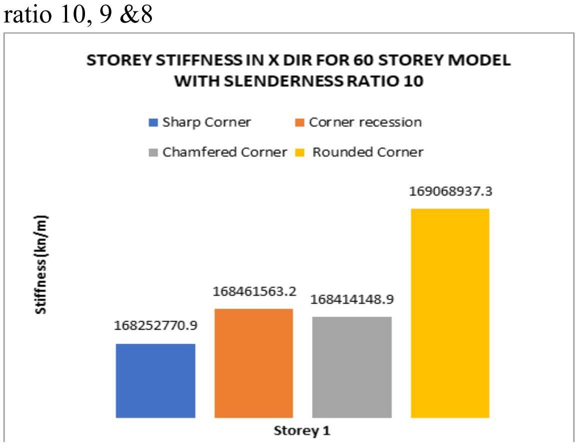


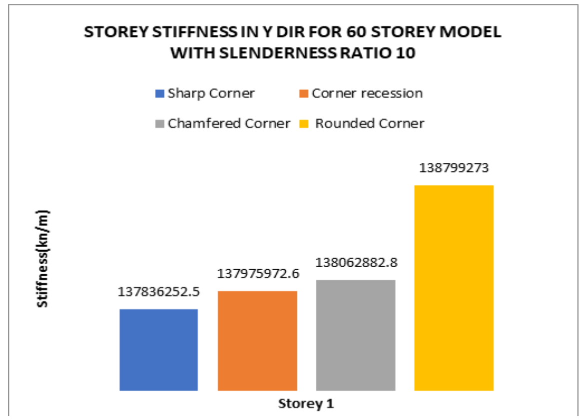


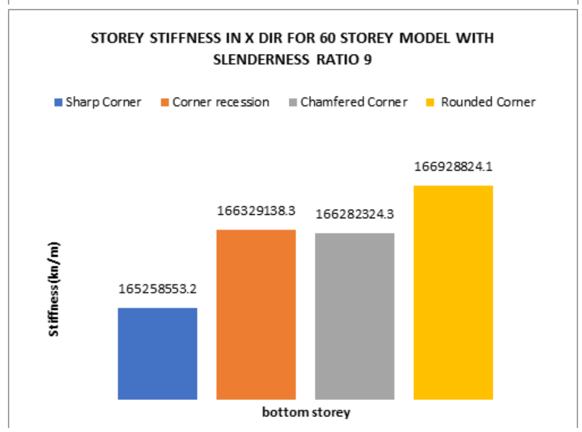


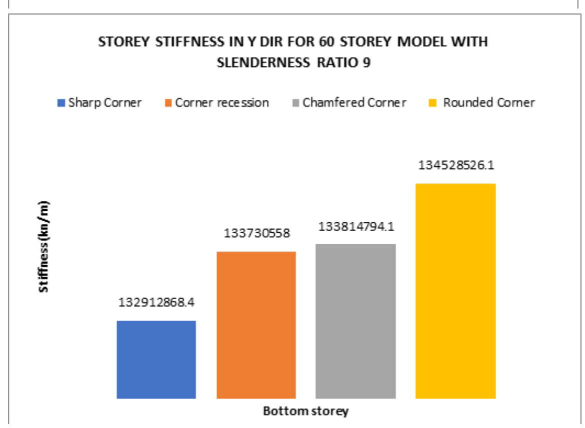
In a 40-storey building, storey stiffness decreases as the slenderness ratio increases, making the structure more flexible under lateral loads. Corner shape significantly affects this behavior: sharp corners experience higher wind effects and relatively lower stiffness, while corner recession slightly improves performance by reducing wind impact. Chamfered corners provide better stiffness due to smoother load distribution, and rounded corners perform the best by minimizing wind forces, resulting in the highest storey stiffness and lowest lateral drift.

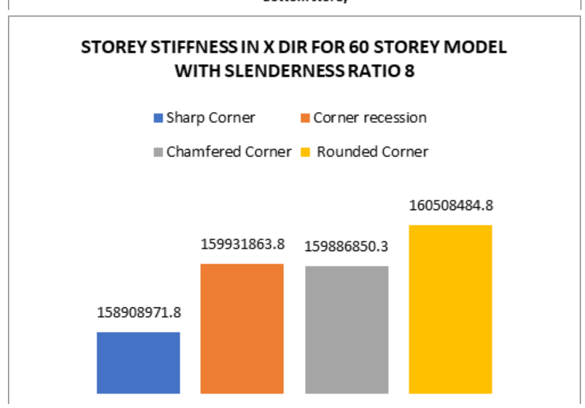
4.4 Storey stiffness result of 60 storey with slenderness ratio 10, 9 &8

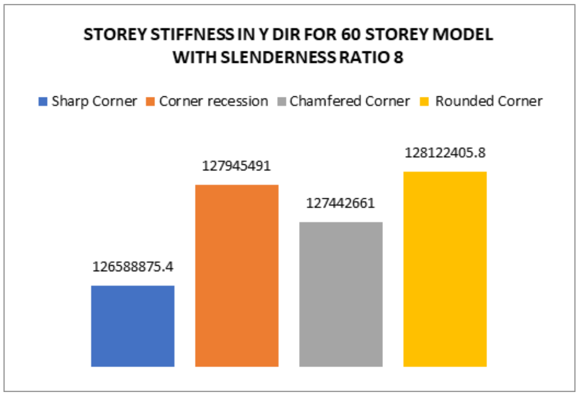






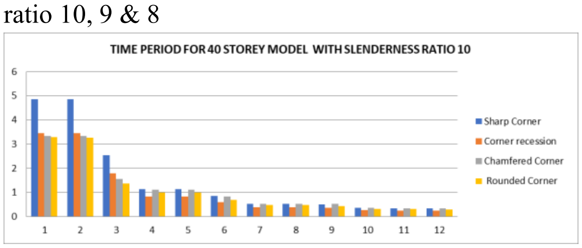


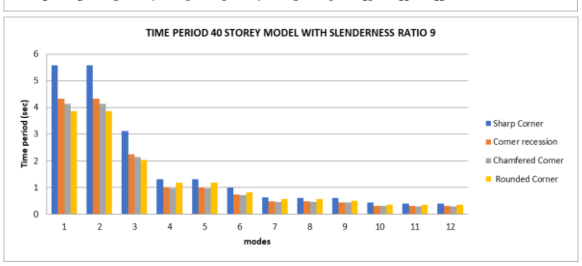


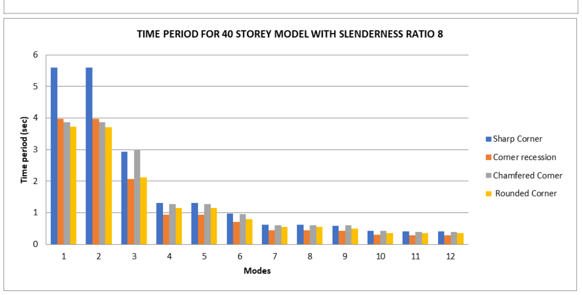


For a 60-storey building, storey stiffness is relatively lower compared to shorter structures due to the higher slenderness ratio and increased flexibility. Stiffness is highest at the lower storeys where structural elements are larger and gradually decreases toward the top as member sizes reduce and cumulative deformation increases. This reduction in stiffness makes the building more sensitive to lateral loads such as wind and earthquakes, often resulting in higher storey drift. To maintain adequate stiffness and control displacement, advanced systems like shear walls, braced frames, or outrigger systems are typically required.

4. 5 Time period results for 40 story with slenderness ratio 10, 9 & 8

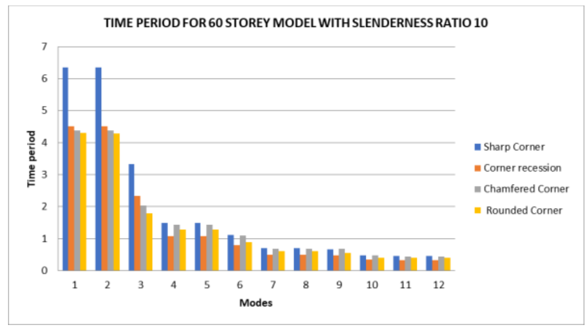


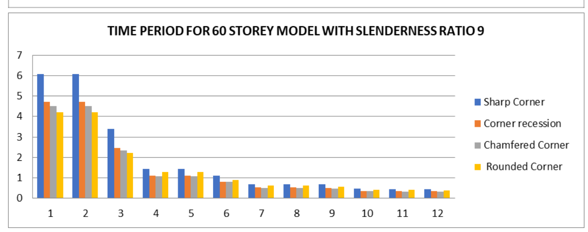


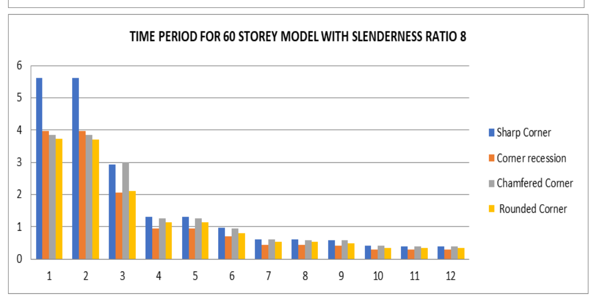


For a 40-storey building, the fundamental time period is lower compared to taller structures because of higher overall stiffness and reduced slenderness. Typically, the time period falls in the range of about **3** to 5 seconds, depending on the structural system, material type, and lateral load-resisting elements used. Buildings with shear walls or bracing will have a shorter time period, while more flexible moment-resisting frame systems will have a slightly higher value within this range.

4.6 Time period results for 60 story with slenderness ratio 10, 9 & 8







For a 60-storey building, the fundamental time period is relatively high due to increased height and slenderness, which makes the structure more flexible. As a general approximation, the time period of such tall buildings typically falls in the range of 5 to 8 seconds, depending on the structural system, material (RC or steel), and stiffness. More flexible systems (with higher slenderness) will have a longer time period, while stiffer systems with shear walls or outriggers will have a comparatively shorter time period.

V. CONCLUSION

A. Displacement Results (40- and 60-Storey Buildings)
For both 40-storey and 60-storey buildings, lateral displacement is found to be maximum in the sharp-corner configuration and decreases consistently with corner modification and reduction in slenderness ratio. Compared with the sharp-edge model, the rounded-corner configuration reduces the top-storey displacement by approximately 21–22% for the 40-storey buildings and 22–25%

For the 60-storey buildings across slenderness ratios 10, 9, and 8 in both principal directions. Chamfered corners and corner recession show intermediate reductions in the range of 10–14% and 4–8%, respectively.

In addition, reducing the slenderness ratio from 10 to 8 further decreases displacement due to increased global stiffness, with the effect being more pronounced in the 60-storey models because of their higher flexibility. As per IS 875 (Part 3) and IS 16700, the permissible lateral displacement limit of H/500 is satisfied by all models.

However, the sharp-corner configurations lie closer to the limit, whereas rounded-corner buildings provide a significantly higher margin of safety and improved serviceability performance.

B. Storey Drift Results (40- and 60-Storey Buildings)
The storey drift response shows a clear dependence on both slenderness ratio and corner geometry for 40- and 60-storey buildings.

For all slenderness ratios, the sharp-corner configuration produces the highest drift, while the rounded-corner model achieves the maximum reduction, ranging from 20–24% in 40-storey buildings to 24–28% in 60-storey buildings relative to the sharp-edge case.

Chamfered and corner-recession configurations show moderate reductions of approximately 8–15%. A reduction in slenderness ratio from 10 to 8 consistently lowers storey drift due to increased lateral stiffness.

All models comply with the IS 16700 inter-storey drift limit of 0.004h, with rounded-corner configurations remaining well below the permissible limit, indicating improved deformation control and occupant comfort.

C. Storey Stiffness Results (40- and 60-Storey Buildings)
Storey stiffness increases marginally but consistently with corner modification and reduction in slenderness ratio for both building heights.

When compared with the sharp-corner configuration, the rounded-corner models show an increase in stiffness of about 0.5–1.0% for SR = 10**,** 1.0–1.3% for SR = 9, and up to 1.5% for SR = 8, with slightly higher gains observed in the 60-storey buildings.

Although the percentage increase is modest, it plays a crucial role in reducing displacement, drift, and time period, supporting the stiffness requirements emphasized in IS 16700 for tall buildings subjected to wind loading.

D. Time Period
The fundamental time period is strongly influenced by both slenderness ratio and corner geometry. For both 40- and 60-storey buildings, the sharp-corner models exhibit the highest Mode-1 time periods, indicating greater flexibility.

In contrast, rounded-corner configurations reduce the fundamental time period by approximately 29–34% in 40-storey buildings and 30–37% in 60-storey buildings relative to the sharp-edge case.

A decrease in slenderness ratio from 10 to 8 further shortens the time period due to increased global stiffness. This reduction in time period aligns with the objectives of IS 16700, as lower flexibility leads to improved control of wind-induced vibrations and serviceability response.

Based on the detailed analytical results, it is recommended that rounded-corner configurations be preferred for slender tall buildings, particularly for higher aspect ratios and greater heights. This approach leads to improved aerodynamic performance, enhanced structural efficiency, better occupant comfort, and economical compliance with wind design requirements as per Indian Standards.

VI LIMITATIONS

The following are the limitations of the present study

A. Idealized Structural Models:
The building models considered in this study are simplified and regular in plan and elevation. Real-world tall buildings often exhibit architectural irregularities, setbacks, and asymmetrical mass

distributions, which can significantly influence their dynamic behavior.

B. Limited Structural Systems Studied:
Only three structural systems Structural Wall + Moment Frame, Structural Wall + Perimeter Frame, and Structural Wall + Framed Tube were analyzed. Other high-performance lateral systems such as outrigger systems, braced tubes, and diagrid were not considered, which may provide alternative solutions for very slender configurations.

VII FUTURE SCOPE

A. Inclusion of Additional Structural Systems
Future investigations can incorporate other advanced structural systems such as outrigger and belt truss systems, diagrid, braced tubes, and hybrid systems. Comparing these systems with the ones studied here would provide a broader understanding of stiffness enhancement strategies for extremely slender towers.

B. Integration of Seismic Analysis
Extending the study to include earthquake load effects in combination with wind loads, as per IS 1893 (Part 1): 2016, would make the findings more comprehensive, especially for tall buildings in seismic-prone regions of India.

C. Nonlinear and Time-Dependent Analysis
Future work can include nonlinear dynamic analysis, P–Δ effects, and time-dependent deformations such as creep and shrinkage to capture realistic long-term behavior of slender reinforced concrete structures.

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