Investigating the effectiveness of tapering and corner modification in mitigating Wind-Induced Vibrations In high rise Structure

Mohammed Abdul Sami

Mohammed Abdul Sami, Nawab Shah Alam Khan College of Engineering and technology

Abstract: **Wind forces significantly influence the design of high-rise structures, especially as buildings become taller and more flexible. This research investigates the effectiveness of tapering and corner modifications in mitigating wind-induced vibrations in high-rise structures. The study analyzes two composite building models, a 50-story and a 100-story structure, subjected to a wind speed of 44 m/s. Different tapering ratios (0%, 5%, 10%, 15%, and 20%) and corner modifications (chamfered and corner cut) are analyzed using ETABS 2021 software. The results, including story displacement, story drift, base shear, and time period, are compared across different models. The findings indicate that tapering and corner modifications effectively reduce wind-induced vibrations, with higher tapering ratios generally leading to better performance. The study highlights the importance of considering aerodynamic modifications in the design of high-rise buildings to ensure structural safety and occupant comfort.**

I. INTRODUCTION

One of the most important factors that influence the responses of tall buildings is wind force acting on it. The gradient of wind profile goes on increasing with respect to height of the building. Though tall buildings seem to be immovable, a degree of flexibility should be considered while designing a tall building, as impact of wind loads is higher as building becomes taller. Additionally, as wind flows around the building, formation of vortices takes place.

The present work aims to demonstrate the wind Response of structures positioned on the (G+50) low tall structure and (G+100) very tall structure. In order to maximize their capacity to resist wind load tapering along height are used from 0,5,10,15 and 20 tapering ratio and aerodynamic modifications are done as corner chamfer and corner cut for tapering models. It is studied using dynamic wind analysis considered Wind speed (Vb)= 44 m/s constructed for gravity and wind using IS 875-2015 Part-3. Moreover, it will be analyzed with Etabs 2021 tools. In the analysis, Story's Displacement, Story's Drift, Base Shear, and the time Period of the Structure were analyzed and contrasted with others.

These design modifications are essential not only for structural stability but also for functional and aesthetic purposes. By combining practical engineering with innovative architectural designs, these techniques help create efficient, safe, and visually appealing high-rise buildings. This study investigates the impact of tapering and corner modifications across various ratios, highlighting their effects on parameters like story drift, displacement, base shear, and time periods using dynamic wind analysis and computational modeling tools.

In the context of the above study, aerodynamic refers to the way a building's shape and design interact with wind forces to minimize their impact. By modifying the geometry of tall structures—such as tapering the shape, chamfering edges, or cutting corners—engineers can reduce wind-induced pressures, vortex shedding, and vibrations. These aerodynamic adjustments improve the building's stability, safety, and comfort under strong wind conditions.

II. OBJECTIVE OF THE STUDY

To study the wind response of composite buildings by comparing structures of different heights with tapering and corner modifications.

To assess the wind performance of the high-rise structures considering different types of tapering ratio (0,5,10,15 and 20) with corner modifications and discussing the obtained results.

To study the effect of corner modification on structure considering corner chamfered, and corner cut with tapering model.

Creating a reliable analytical model capable of simulating the wind-induced response of composite high-rise structures, considering both tapering and corner modifications.

III. NEED OF STUDY

Today, due to progress in construction techniques, engineering technology, and computational design tools for architecture, supertall buildings can now be built in unique and unconventional shapes.

Architectural and practical considerations remain crucial in shaping supertall buildings; however, wind-induced excitations significantly impact their aerodynamic behavior, becoming a critical design factor

Tall buildings need to work well and resist the forces of nature, like strong winds. We use various techniques to achieve this, including changing the shape of the building to improve its aerodynamics. Tapering the building, making it narrower towards the top, is a very common and effective method used in modern skyscrapers. This not only helps the building withstand wind forces but also has a big impact on its overall architectural design.

IV. SCOPE OF THE STUDY

Numerically investigate of the wind response of high-rise buildings to extreme wind events.

Acquire wind loading data and studying the effect of building's realistic environment (such as the building's shape) on the dynamic wind loading characteristics for an existing high-rise building. • This study investigates wind load impacts on 50 and 100-story composite structures, considering various tapering ratios and building responses under wind and gravity loads.

The study emphasizes the importance of aerodynamic design for tall buildings, highlighting the influence of wind effects on building shape alongside architectural and practical considerations

V. METHODOLOGY

This study analyzes two composite building models: a 50-story and a 100-story structure. The models are subjected to a wind speed of 44 m/s, and the analysis is performed using ETABS 2021 software. Different tapering ratios (0%, 5%, 10%, 15%, and 20%) and corner modifications (chamfered and corner cut) are investigated. The primary parameters evaluated include story displacement, story drift, base shear, and the time period of the structure.

VI. MODEL INFORMATION

Model 1: First building is modelled with regular steel beams, composite Columns, Shear Core with mega column, and Slabs. The lateral load resisting structural system is adopted by studying IS 1893:2016 and labelled as regular model without any tapering ratio.

- Model without tapering ratio for G+50 model
- Model without tapering ratio for G+100 model

Model 2: Second building is modelled with lateral load resisting structural system with mega column system with tapering ratio as (5 percent).

- Model with tapering ratio as (5 percent) for G+50 model
- Model with tapering ratio as (5 percent) for G+100 model

Model 3: Third building is modelled with lateral load resisting structural system with mega column system with tapering ratio as (10 percent).

- Model with tapering ratio as (10 percent) for G+50 model
- Model with tapering ratio as (10 percent) for G+100 model

Model 4: Fourth building is modelled with lateral load resisting structural system with mega column system with tapering ratio as (15 percent).

- Model with tapering ratio as (15 percent) for G+50 model
- Model with tapering ratio as (15 percent) for G+100 model

Model 5: Fifth building is modelled with lateral load resisting structural system with mega column system with tapering ratio as (20 percent).

- Model with tapering ratio as (20 percent) for G+50 model
- Model with tapering ratio as (20 percent) for G+100 model

Model 6: sixth building is modelled with lateral load resisting structural system with mega column system with corner chamfered.

- Model with corner chamfered for G+50 model without tapering
- Model with corner chamfered for G+50 model with 5% tapering
- Model with corner chamfered for G+50 model with 10% tapering
- Model with corner chamfered for G+50 model with15% tapering
- Model with corner chamfered for G+50 model with 20% tapering
- Model with corner chamfered for G+100 model without tapering
- Model with corner chamfered for G+100 model with 5% tapering
- Model with corner chamfered for G+100 model with 10% tapering
- Model with corner chamfered for G+100 model with 15% tapering
- Model with corner chamfered for G+100 model with 20% tapering

Model 7: seventh building is modelled with lateral load resisting structural system with mega column system with corner cut.

- Model with corner cut for G+50 model without tapering
- Model with corner cut for G+50 model with 5% tapering
- Model with corner cut for G+50 model with 10% tapering
- Model with corner cut for G+50 model with15% tapering
- Model with corner cut for G+50 model with 20% tapering
- Model with corner cut for G+100 model without tapering
- Model with corner cut for G+100 model with 5% tapering
- Model with corner cut for G+100 model with 10% tapering
- Model with corner cut for G+100 model with 15% tapering
- Model with corner cut for G+100 model with 20% tapering.

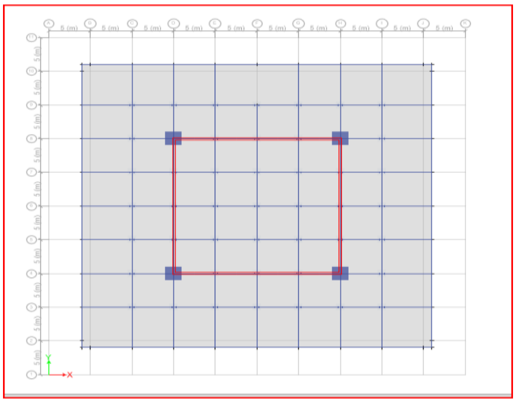

Figure: 1 Top View for the 5% tapering ratio

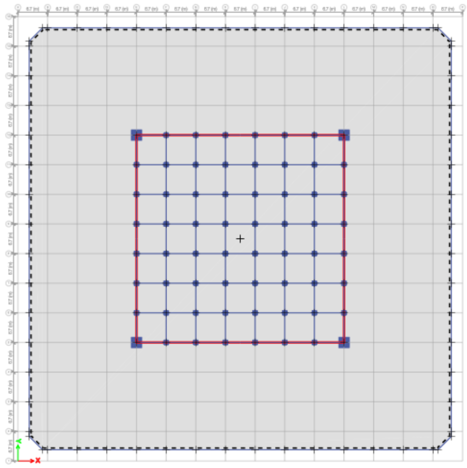

Figure:2 Top View for the 5% tapering Combined with chamfered edge modification

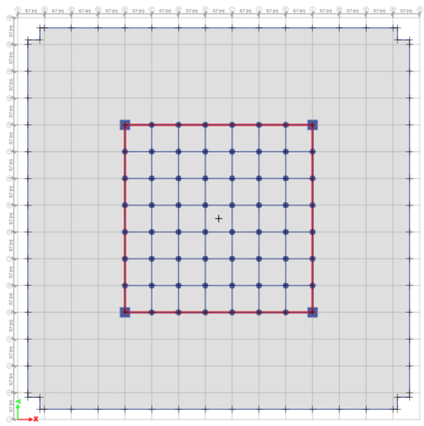

Figure:3 Top View for 5% tapering ratio with corner cut modification.

VII. RESULTS AND DISCUSSION

Lateral Displacement: In the G+50 model, tapering alone led to reductions of 3%, 5.32%, 8%, and 11% for 5°, 10°, 15°, and 20° tapers, respectively. Combining tapering with chamfering resulted in reductions of 1.5%, 6%, 9.5%, 12%, and 14% for the same angles. Tapering with corner cutting yielded the most significant reductions: 2%, 10.5%, 15.36%, 19.2%, and 23.78% for 0°, 5°, 10°, 15°, and 20° tapering ratios.

In the G+100 model, tapering alone led to reductions of 4.7%, 6.5%, 8%, and 12% for the same angles. Combining tapering with chamfering resulted in reductions of 1%, 5.7%, 7.8%, 9.3%, and 12.68%. Tapering with corner cutting led to reductions of 2%, 6.7%, 8.5%, 10.3%, and 14%.

Story Drift: For the G+50 model, tapering alone resulted in decreases of 1% at 5°, 2.5% at 10°, 4.2% at 15°, and 10% at 20°. Tapering with chamfering led to reductions of 1.9% at 0°, 2.5% at 5°, 4.8% at 10°, 8% at 15°, and 9.1% at 20°. Tapering with corner cutting provided the most significant reductions: 2% at 0°, 5.5% at 5°, 12% at 10°, 17.4% at 15°, and 19.1% at 20°.

In the G+100 model, tapering alone led to decreases of 1% at 5°, 1.6% at 10°, 3.2% at 15°, and 8% at 20°. Tapering with chamfering led to reductions of 1% at 0°, 2.8% at 5°, 4.1% at 10°, 8.1% at 15°, and 13% at 20°. Tapering combined with corner cutting again provided the most significant reductions: 1% at 0°, 4.5% at 5°, 6.4% at 10°, 8.3% at 15°, and 14% at 20°.

Time Period: In the G+50 model with tapering, decreases were 9.4% at 5°, 18.6% at 10°, 37.8% at 15°, and 51.2% at 20°. For the chamfered edge and corner cut model with tapering, decreases started at 0% for 0° and rise to 18% at 5°, 35.8% at 10°, 38% at 15°, and 50% at 20°.

In the G+100 model with tapering, decreases were 28% at 5°, 31% at 10°, 32% at 15°, and 46% at 20°. For the chamfered edge and corner cut model, decreases started at 0% for 0° and rise to 29% at 5°, 32% at 10°, 33% at 15°, and 47% at 20°.

Base Shear: In the G+50 model, tapering alone led to reductions of 8.76% at 5°, 16.42% at 10°, 24.64% at 15°, and 32.85% at 20°. The chamfered edge and corner cut models started with a 10% reduction at 0° and rise to 32.85% at 5°, 41.6% at 10°, 42.16% at 15°, and 43% at 20°.

In the G+100 model, tapering alone led to reductions of 3.4% at 5°, 9.8% at 10°, 14.8% at 15°, and 30% at 20°. The chamfered edge and corner cut models started with a 2.5% reduction at 0° and rise to 5.7% at 5°, 12.3% at 10°, 16.62% at 15°, and 32.4% at 20°.

VIII. CONCLUSION

This study examined the wind response of composite mega-frame buildings of varying heights with different aerodynamic shapes. Aerodynamic shape modifications, like chamfered and corner cut, effectively reduced wind loads. The study suggests that combining mega frames with aerodynamic optimization is a promising approach for designing wind-resistant composite buildings.

Models with tapered, chamfered, and corner-cut, the average reduction in displacement was around 2-3%, 3-4%, and 4-5%, respectively, for both G+50 and G+100 structures. For storey drift, the reduction ranged from 2-4% for tapered models, 3-5% for chamfered models, and 4-6.5% for corner-cut models, with similar patterns in G+100 structures. The time period decreased by 9-12% in tapered models and 14-17% in chamfered and corner-cut models for G+50 structures, while for G+100 structures, it reduced by 7-11% and 7-12% respectively. Additionally, base shear reductions for G+50 models were 5-8% for tapered, and 6-8% for chamfered and corner-cut model. In G+100 models, base shear reduced by 3-5% with tapered and 7-10% with chamfered and corner-cut modifications.

In chamfered and corner cut modification the reduction in lateral displacement was 12% and 14% comparing with non-tapered structure and similar reduction was noticed in other parameters for different heights of the buildings.

By comparing the G+50 and G+100 models with different tapering ratios lead to significant reductions in different parameters was noticed. The most effective reductions occur when tapering is combined with chamfering or corner cutting, especially at higher tapering ratio 20°, with the corner cutting combination offering the greatest structural improvements.

IX. FUTURE SCOPE

1) Further research can be carried out by considering the effect of wind loads on irregular shaped structures
2) Further we can also adopt different advanced materials like high-performance concrete or fiber-reinforced polymers, along with innovative construction techniques, could be explored to further optimize the structural performance and wind resistance of tall buildings.

3) Further research can be carried by using the same system with soil interaction properties.

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