Corner Modifications and Their Effect on Wind-Induced Forces in High-Rise Structures

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Abstract- Tall buildings are a hallmark of modern architecture and urbanization, providing efficient use of limited land and serving as iconic landmarks in cities around the world. However, the complex interaction of wind and structural loads can pose significant challenges for designers and engineers, particularly at building corners where turbulence and vortex shedding can cause vibrations and structural fatigue. This study investigates the impact of corner modification on highrise buildings. The objective of this study is to evaluate the impact of corner modification on the overall performance of tall buildings in terms of structural integrity, wind resistance, and aesthetic appeal. Corner modification techniques include chamfers, setbacks, and curves, and their impacts on the structural integrity and wind-induced responses of tall buildings. Corner modification can significantly affect the structural behavior and wind loads of tall buildings. Chamfered corners, for instance, can reduce the wind loads on the building while also improving its aesthetic appeal. Rounding off corners can also reduce wind loads, but may increase the complexity of the structural design. On the other hand, cutting off corners can increase the wind loads on the building and may require additional structural reinforcement. Overall, the results of this study suggest that corner modification can be an effective way to improve the performance and aesthetics of tall buildings, but the specific type of modification must be carefully chosen based on the building's structural design and location.

Keywords– Wind load, corner modification, AUTODESK ROBOT

1. INTRODUCTION

A building having a height of more than 15m is called a high-rise building according to National Building Code 2005 of India but, due to the scarcity of land in urban areas high buildings are in demand. Tall buildings have to resist gravity loads as well as lateral loads such as Earthquakes, Wind load, etc. The wind load is a more powerful force which causes more dangerous effects on tall buildings. To make a safe enough tall building to resist these loads, there are a lot of studies done and many researchers have done research on tall buildings and their design.

Tall buildings are subject to high wind loads that can affect their structural performance and occupant comfort. The outer shape of the building is a critical parameter in determining the structural responses and loads. Nevertheless, modern architecture is increasingly characterized by the development of taller structures with more intricate geometrical forms, which serve as distinctive designs that become a distinctive feature of the global landscape. Consequently, the assessment and prediction of wind-induced motions on such structures becomes increasingly difficult.[1]

Tall buildings are exposed to high wind loads that can affect their structural performance and occupant comfort and can cause dangerous damage. One of the ways to reduce the wind-induced effects on tall buildings is to modify their shape, especially at the corners. Corner modifications, such as cuts, chamfers, venting, and fins, can alter the flow patterns around the building and reduce the wind forces and pressures on the building surfaces. However, the optimal design of corner modifications depends on various factors, such as the building height, aspect ratio, orientation, and wind climate.

This report aims to investigate the impact of corner modifications on a high-rise building. The report will contrast various forms of corner modifications and their ratios and evaluate their impact on the mean and dynamic response of the building under different wind directions.

However, different types of corner modifications may have different impacts on the aerodynamic characteristics of tall buildings, depending on their size, location, and orientation relative to the wind direction. Therefore, it is important to investigate the effects of incremental corner adjustment on a tall building with a horizontal cross-section.

This research aims to present a comprehensive study of the influence of corner modifications on the wind loading and responses of a tall building with a square plan. The report will use wind tunnel experiments and computational fluid dynamics simulations to measure and analyse the mean and dynamic wind effects on the building models with different corner chamfers. The report will also compare the acceleration levels and structural safety of the idealized building with and without corner modifications for different wind climates.

2. GEOMETRIC DESIGN

For the analysis three different configurations of building shapes are selected on the basis of building corners, 90º Corner, Chamfer corner and fillet corner.[2,4] Each model has two towers with same dimesndions for the analysis of wind tunnel effect. All three models have the same properties. All models have same plan dimension of 30 x 40 m,[13] G+19 storeys and size of beam is 350x700 mm and size of column is 500x700 mm. Grade of concrete used for beam and column is M45.[8] Models are in the categoroy of tall buildings so shear wall are provided in models. The thickness of the shear wall is 230 mm and grade of concrete for the shear wall is M45. The distance between the towers is 15m. Dead load and live load(consider as residential buildings) applied on building models. [9,10]

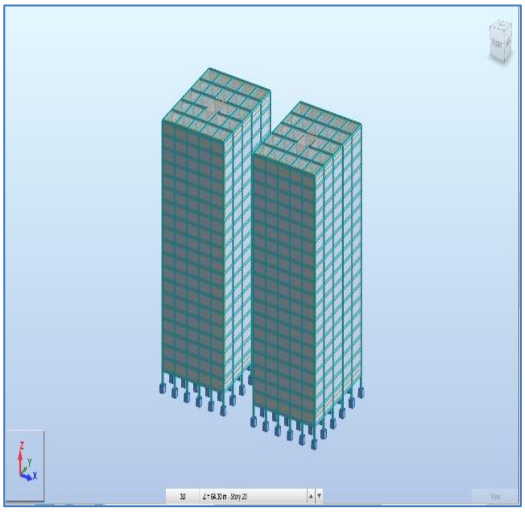

Figure 1: 3D View Model 1

Wind speed is 50m/s and terrain cateogory is 4 for all the models (Building model situated in a metrocity which is in eastern cost of india.) for the analysis from IS: 875-2015 (Part-3)[11] and dead and live also consider from code IS: 875 Part 1 and Part 2 respectively.

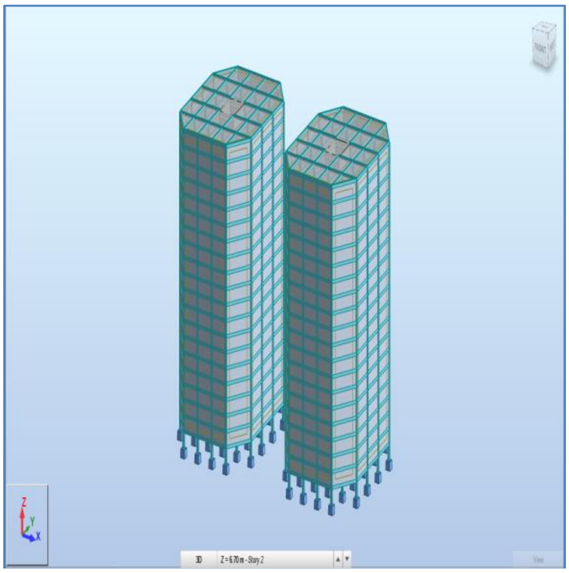

Figure 2: 3D View Model 2

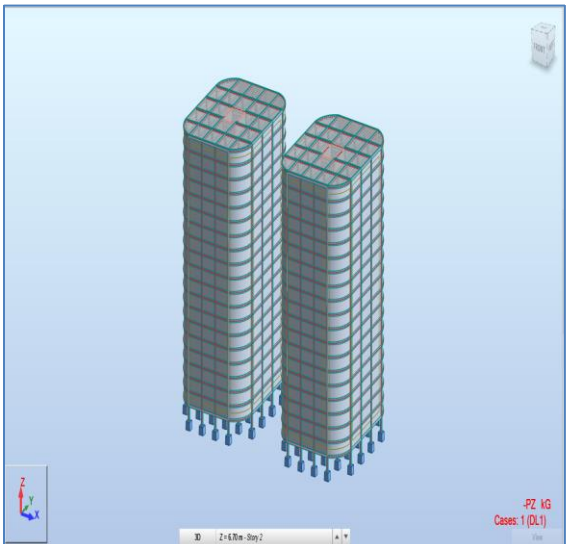

Figure 3: 3D View Model 3

for analysis load combinations are used as per Indian standard code provisions, 1.5 safety factor is used[1.5(DL+LL)] with a combination of dead load and live load, and 1.2 safety factor multiplied with dead load and live load along with the combination of wind in x and y direction. [1.2(DL+LL+WLx, 1.2 (DL+LL+WLy)].[12]

3. ANALYSIS

For the analysis AUTODESK ROBOT software is used. All three modesl were analysed for same wind conditions. From analysis storey displacement, drift, shear and moment forces are calculated and wind pressure also measure from the analysis.

3.1 Displacement

Comparing the displacements of a building is crucial for assessing its structural integrity and performance to lateral loads. Displacement refers to the movement or shifting of a building under various loading conditions.

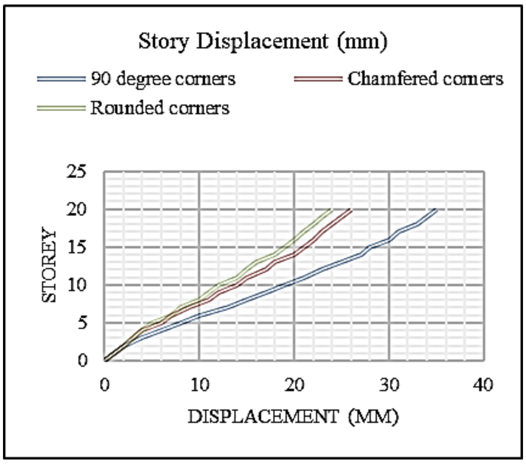

Figure 4: Storey Displacement (mm)

By comparing the displacement results of three models, Model-1 (90-degree corners) demonstrates significant displacement in multiple locations, indicating a relatively weaker response to external loads. The high displacement values raise concerns about the structure stability and potential vulnerabilities. Model-2 (chamfered corners) exhibits minimal displacement across all measured points, indicating a high level of stiffness and rigidity. This suggests that model-2 is well-designed and can effectively resist external forces. Its low displacement values signify a stable and reliable structure, capable of maintaining its original position even under significant loads. Model-3 (rounded corners) shows moderate displacement across various points, indicating a degree of flexibility in its response to external loads.[3] While not as rigid as model-2, the displacement values remain within an acceptable range(l/500 according to IS: 16700:2017).[14]

The displacement reduction percentage between model-1 (90-degree corners) and model-2 (chamfered corners) at story 20 is approximately 25.71%. Also, the displacement reduction percentage between model-1 (90-degree corners) and model-3 (rounded corners) at story 20 is approximately 31.42%.[7]

3.2 Storey Drift

The drift ratio refers to the horizontal displacement or deflection experienced by different parts of a building relative to its height. Model-1 (90-degree corners) demonstrates significant story drift values across multiple levels, suggesting a relatively weaker response to lateral loads. The high story drift values raise concerns about the structures ability to withstand and distribute lateral forces effectively. Model-2 (chamfered corners) shows moderate story drift values at various levels, indicating a certain degree of flexibility in its response to lateral forces. While not as rigid as model-3, the moderate story drift values remain within an acceptance range. Model-3 (rounded corners) exhibits minimal story drift values across all levels, indicating high level of stiffness and resistance to lateral loads. This suggests that model-3 is well designed and capable of effectively distributing and resisting lateral forces. The minimal story drift indicates a stable structure that can maintain its overall shape even under significant wind loads or other lateral loading conditions.

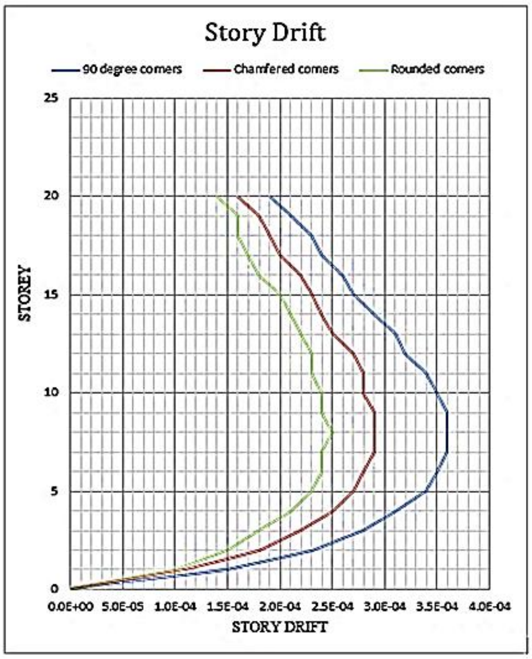

Figure 5: Storey Drift

The drift ratio reduction percentage between model-1 (90-degree corners) and model-2 (chamfered corners) at story 8 is approximately 19.44%. The drift ratio reduction percentage between model-1 (90-degree corners) and model-3 (rounded corners) at story 8 is approximately 30.55%.[5]

3.3 Shear Force

Comparing the shear force results of three corners modified building models in the X, Y, and Z directions provides insights into their respective structural behaviors and their ability to withstand and distribute lateral loads effectively in different orientations.

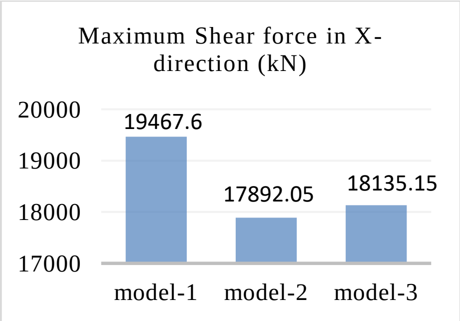

Figure 6: Maximum shear forec in X- Direction

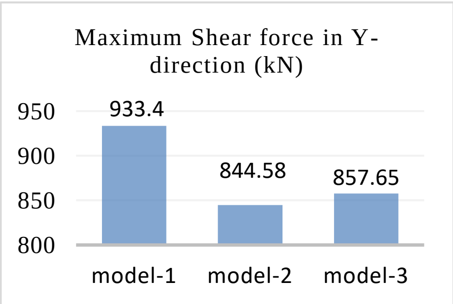

Figure 7: Maximum shear forec in Y- Direction

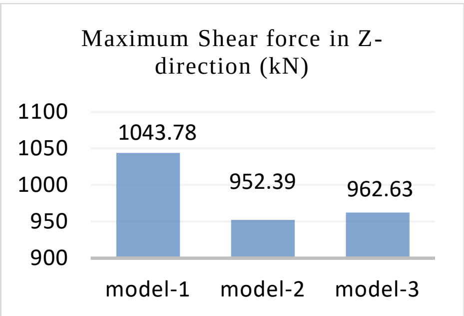

Figure 8: Maximum shear forec in Z- Direction

By comparing the shear force results, Model-1, Model-2, and Model-3 exhibit higher shear forces in the X direction compared to the Y and Z directions. This suggests that the building is more susceptible to lateral forces acting in the X direction, which could be due to the configuration of the structure. Considering the shear force in X direction, the shear force reduction percentage between mode-1 (90-degree corners) and model-2 (chamfered corners) is approximately 8.1% Also, the shear force reduction percentage between model-1 (90-degree corners) and model-3 (rounded corners) is approximately 6.84%.

3.4 Bending Moment

Comparing the bending moment results of three building models in the X, Y, and Z directions

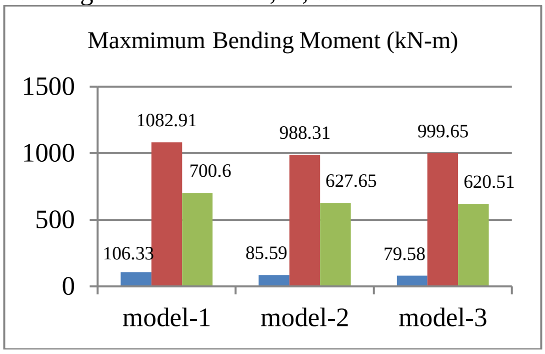

Figure 9: Maximum bending moment (kN-m)

Provides insights to the distribution of internal moments and the structural behavior of the buildings in different orientations**.**

Model-1, Model-2, and Model-3 demonstrate varying bending moment distributions in the X, Y, and Z directions.[6] Bending moments in the Y direction experience significantly higher bending moments compared to the X and Z directions, indicating potential weak points or areas of concern. Considering the bending moment in the Y direction, the bending moment reduction percentage between model-1 (90-degree corners) and model-2 (chamfered corners) is approximately 8.73%. Also, the bending moment reduction percentage between model-1 (90degree corners) and model-3 (rounded corners) is approximately 7.68%

3.5 Wind Pressure

Comparing the wind pressure results of three corner-modified buildings provides insights into their respective abilities to withstand and respond to wind loads at their corners, which are typically vulnerable areas. Figures no. 4,5 and 6 show the wind pressure on the wall surface of building models.

Comparing the wind pressure results of three corner-modified buildings provides insights into their respective abilities to withstand and respond to wind loads at their corners, which are typically vulnerable areas. Model-1 (90-degree corners) shows higher wind pressures of 1.1 kPa at the corners compared to the other two buildings. This suggests that the 90-degree corners in this building might not be as effective in reducing the wind loads at the corners. Model-2 (chamfered corners) wind pressure of 0.28 kPa indicates a well-balanced distribution of forces at the corners. According to the wind pressures, suggesting that the building's corner modifications effectively mitigate the wind loads. This indicates a well-designed structure that can withstand wind forces and maintain its stability. Model-3 (rounded corners) demonstrates varying wind pressure of 0.415kpa distributions at the corners. Some corners may experience significantly higher wind pressures compared to others, indicating potential weak points in the building's modifications. This raises concerns about the building's ability to resist wind forces uniformly at all corners.

Table 1: Pressure table

Colour	Pressure (kPa)
	1.65
	138
	1.1
	0.82
	0.55
	0.28
	0
	-0.28
	-0.55
	-0.82
	-1.1
	-1.38
	-1.65

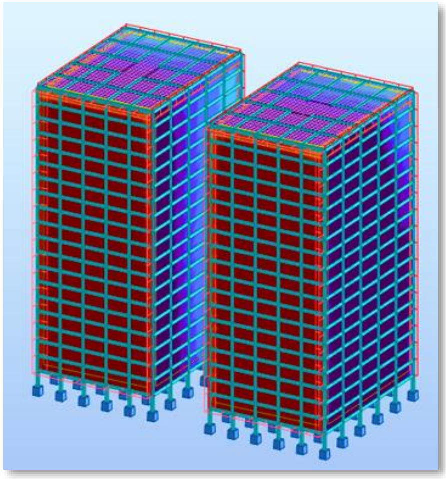

Figure 10: Model 1 (pressure on building's exterior surface)

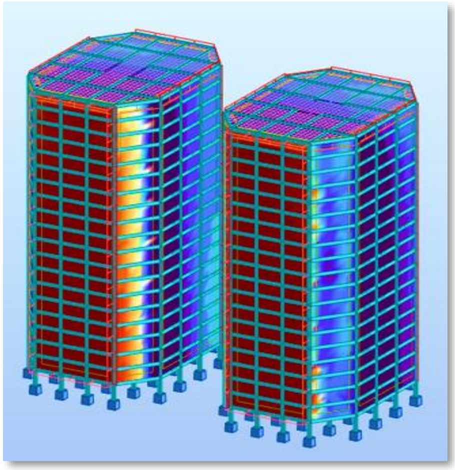

Figure 11: Model 2 (pressure on building's exterior surface)

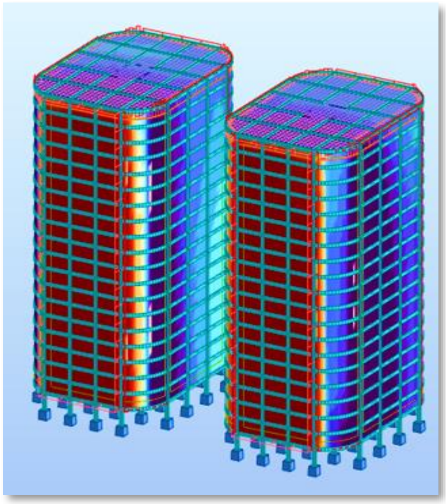

Figure 12: Model 3 (pressure on building's exterior surface)

4. CONCLUSION

In conclusion, the impacr of corner modifications on high-rise buildings under wind load can significantly impact the performance and safety of the structures. Through corner modifications, the adverse effects of wind pressure can be mitigated, resulting in improved structural stability and reduced deformations.

- The analysis conducted in this study demonstrated that corner modifications such as chamfered corners, and rounded corners can effectively reduce the wind pressure on tall buildings.
- The results indicate that corner modifications can lead to a noticeable reduction in displacements, drift ratios, and

wind-induced stresses in the structural elements. By reducing these adverse effects, the overall structural integrity of tall buildings is enhanced, ensuring a higher level of safety and reducing the potential for damage or failure during severe wind events.

- Wind pressure in Model 1(90-Degree) is highest in all three models at the corners of the building which is 1.1 kPa and lowest is 0.28 kPa in Model 2(chamfer conrner) and in Model 3(rounded corner) wind pressure in the corner is 0.415kPa which is slightly higher than model 2. So wind pressure distribution is batter than in model 2.
- The displacement reduction percentage between model-1 (90 degree corners) and model-2 (chamfered corners) at story 20 is approximately 25.71%. Also, the displacement reduction percentage between model-1 (90 degree corners) and model-3 (rounded corners) at story 20 is approximately 31.42%.
- The drift ratio reduction percentage between model-1 (90 degree corners) and model-2 (chamfered corners) at story 8 is approximately 19.44%. Also, the drift ratio reduction percentage between model-1 (90 degree corners) and model-2 (rounded corners) at story 8 is approximately 30.55%
- The shear force reduction percentage in X direction between model-1 (90 degree corners) and model-2 (chamfered corners) is approximately 8.1%, and between model-1 (90 degree corners) and model-3 (rounded corners) is approximately 6.84%
- The bending moment reduction percentage in Y direction between model-1 (90 degree corners) and model-2 (chamfered corners) is approximately 8.73%, and between model-1 (90 degree corners) and model-3 (rounded corners) is approximately 7.68%

5. REFERENCES

[1] Prasenjit Sanyal & Sujit Kumar Dalai, 2020, "Effect of Corner Modification on 'Y' plan shaped Tall Building under Wind Load."

[2] Ms. Ameena. Mr. M V Varkey & Ms. Jiji Thomas, 2017, "Aerodynamic Modification and Shape Optimization of Tall Building."

[3] Yanyu Ke, Guohui Shen, Hangcong Yu and Jiming Xie, 2022, "Effect of Corner Modification on the Wind-Induced Responses of High-Rise Buildings."

[4] Mugahed Amran, Mohammed Abdo Albaaom & Wan Inn Goh, 2022, "Computation Aerodynamic Optimization of Wind-Sensitive Irregular Tall Building."

[5] K.T. Tse, Gang Hu, Jie Song, Hyo Sean Park, Bubryur Kim, 2020, "Effect of Corner Modifications on Wind Loads and Local Pressure on Walls of Tall Buildings."

[6] J D Holmes, M Kasperski, 1996, "Effective Distributions of Fluctuating and Dynamic Wind Loads." B.Sc. (Engg), Ph.D., FIE Aust

[7] Suchana S, Telrandhe, A.M. Pande, 2019, "Dynamic Wind Analysis for High-Rise Building – Typical Observations."

[8] IS 456 (2000) : Plain and Reinforced Concrete – Code of Practice

[9] IS 875-1 (1987) : Code of Practice for Design Loads (Other than Earthquake) for buildings and structures, Part 1: Dead loads – Unit weights of building material and stored materials

[10] IS 875-2 (1987) : Code of Practice for Design Loads (Other than Earthquake) for buildings and structures, Part 2: Imposed loads

[11] IS 875-3 (2015) : Design loads (Other than Earthquake) for buildings and structures, Part 3: Wind loads

[12] IS 875-5 (1987): Code of Practice for Design Loads (Other than Earthquake) for buildings and structures, Part 5: Special loads and combinations

[13] National building code of india:2016.

[14] IS: 16700:2017 Criteria for Structural Safety of Tall Concrete Buildings.