Aerodynamic Modification of Mega Frame Structure with Various Tapering Ratio

Mrs. P.Sai Leela [(1)], Mohammed Parvez Affani [(2)], Mohammed Omer Farooq [(3)]
M.Tech Student, Department of Civil Engineering, Global institute of engineering and technology
Guide, Associate Professor, Department of Civil Engineering, Global institute of engineering and technology

Abstract: 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. The present work aims to demonstrate the dynamic wind Response of structures positioned on the (G+50) low tall structure (G+75) tall structure and (G+100) very tall structure. In order to maximize their capacity to resist wind load outriggers and tapering along height are used from 0, 5, 10, 15 and 20 tapering ratio. It is studied using dynamic wind analysis considered Vb= 44 m/s constructed for gravity and wind using IS 875-2015. 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.

Keywords: dynamic wind analysis, tapering along height, mega column with frame system.

1. INTRODUCTION

Tall buildings are increasingly vulnerable to vibration caused by wind as they rise in height. Many strategies have been devised to lessen this negative impact of the wind, and one of them is altering the building's aerodynamics. Depending on how this adjustment affects the structural and architectural concepts, it can be divided into two categories. Consequently, the main alteration, which has a significant impact on the architectural and structural design of tall buildings, consists of apertures, sculptured building shapes, twisting buildings, tapering, or setbacks along the height, and openings. According to building regulations, elliptical or circular buildings can have wind pressure design loads that are up to 40% lower than those of rectangular buildings (Schueller 1977).

Aerodynamic shaping of a building has great relevance in the design of tall buildings, and architects must be aware of this fact. The scope of this research is to numerically investigate the dynamic response of high-rise buildings to extreme wind events; acquire wind loading data; study the effect of a building's realistic environment (such as the building's shape) on the dynamic wind loading characteristics of an existing high-rise building; and so forth.

The present work aims to show how dynamic wind loads influence composite construction. Designed for Gravity, Designed for Gravity, and Wind Loads, the present study investigates the behavior of composite structures for various tapering ratios along the heights, subjected to dynamic wind loads (G+50, G+75, and G+100 stories). The structure is evaluated using the wind code IS875 Part 3 of 2015. Regarding forces, first-time period, story displacement, story drift, and story stiffness, these buildings respond accordingly.

LITERATURE REVIEW

FU Ji-yang, WU Jiu-rong, and XU An (2022): Tall buildings are highly flexible and therefore highly vulnerable to wind loading because of their long natural vibration periods and little damping. The wind load is the primary controllable load for the structural design of extremely tall buildings near coasts. Tall buildings must be planned to be both cost-effective and efficient, in addition to meeting design codes' safety criteria in the event of a typhoon or heavy wind. Thus, research on wind-resistant optimized design and wind-induced vibration management of tall structures is highly relevant to real-world applications.

K. T. Tse, Gang Hu, Jie Song, Hyo Seon Park & Bubryur Kim (2022) : The aerodynamic properties of tall structures with modified corners were investigated in this work. These properties included local wind force coefficients, mean pressure distributions, normalized power spectrum density, and extreme local pressure. To assess the wind pressures on building models with varying heights and recessed corners of varying ratios, wind tunnel tests were carried out. Corner changes successfully decreased wind forces in every situation when the wind direction was a = 0° or when the wind was blowing directly on top of a building. Specifically, tiny corner modification ratios lowered wind forces more successfully than their larger equivalents. Corner alterations, on the other hand, caused tremendous local strain on the buildings' surfaces.

Mohammed Abdo Albaom, Fadi Alkhatib (2022): When designing tall structures and associated lateral structural systems, wind-induced loads and motions are crucial considerations. One important factor in determining these loads and structural responses is the building configuration, which is reflected in its external shape. On the other hand, modern architecture tends to focus on larger structures with intricate geometric shapes in order to provide distinctive designs that leave their mark on global maps. As a result, it becomes increasingly difficult to assess and forecast wind-induced motions on such structures. This work proposes an aerodynamic optimization based on computational performance, with small imposed adjustments that do not significantly affect the intended structural and architectural design.

2. Module And Building Configuration

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

- Mega column and outrigger belt truss system with tapering ratio as (5 percent) for G+50 model
- Mega column and outrigger belt truss system with tapering ratio as (5 percent) for G+75 model
- Mega column and outrigger belt truss system 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)

- Mega column and outrigger belt truss system with tapering ratio as (10 percent) for G+50 model
- Mega column and outrigger belt truss system with tapering ratio as (10 percent) for G+75 model
- Mega column and outrigger belt truss system 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)

- Mega column and outrigger belt truss system with tapering ratio as (15 percent) for G+50 model
- Mega column and outrigger belt truss system with tapering ratio as (15 percent) for G+75 model
- Mega column and outrigger belt truss system 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)

- Mega column and outrigger belt truss system with tapering ratio as (20 percent) for G+50 model
- Mega column and outrigger belt truss system with tapering ratio as (20 percent) for G+75 model
- Mega column and outrigger belt truss system with tapering ratio as (20 percent) for G+100 model

The load combinations considered are as given below.
a. 1.5(DL +LL)
b. 1.5(DL-EQX)
c. 1.2(DL+LL+EQX)
d. 1.2(DL+LL-EQX)

The plan and 3D view of the building used for the modelling is as below:

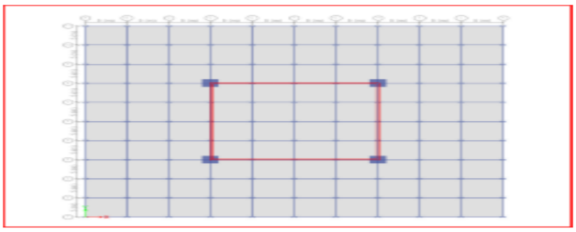


Figure 1: Plan view of G+50 storey building

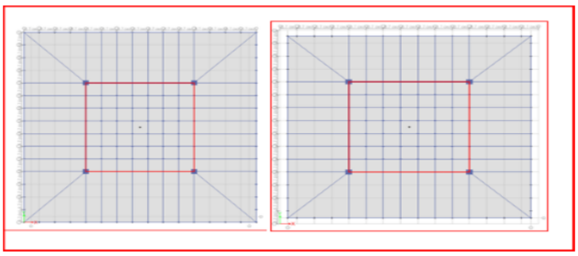


Figure 2: Isometric view of 5% tapering ratio

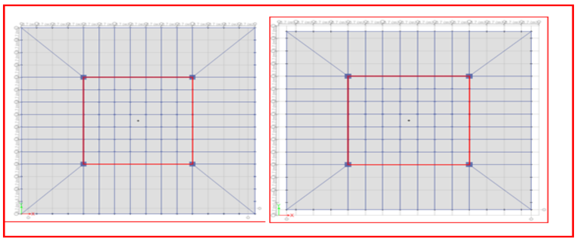


Figure 3: Isometric view of 10% tapering ratio

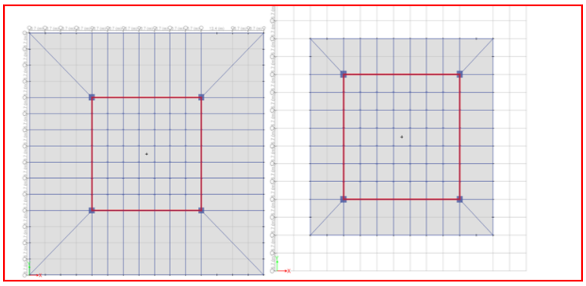


Figure 4: Isometric view of 15% tapering ratio

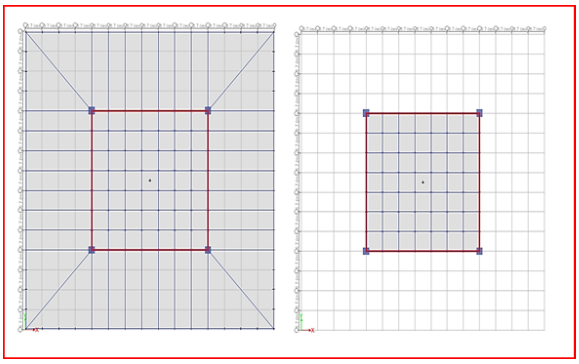


Figure5: Isometric view of 20% tapering ratio

3. RESULTS FOR MODELS STORY DISPLACEMENT

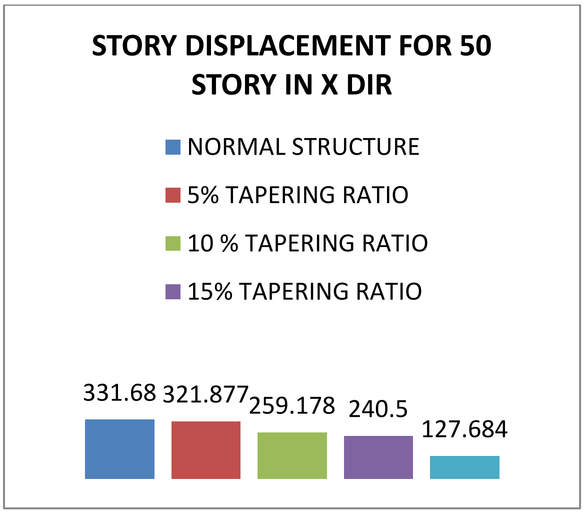


Figure 6: story displacement G+50 in the X direction

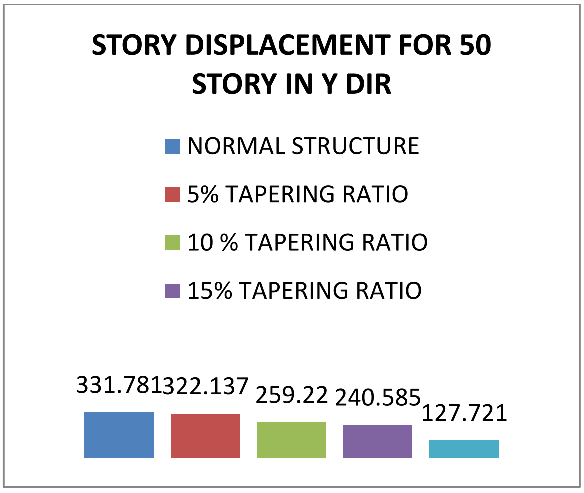


Figure 7: story displacement G+50 in Y direction

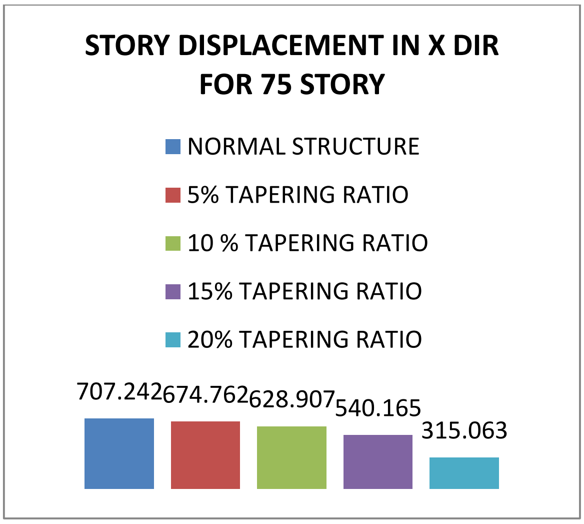


Figure 8: story displacement G+75 in the X direction

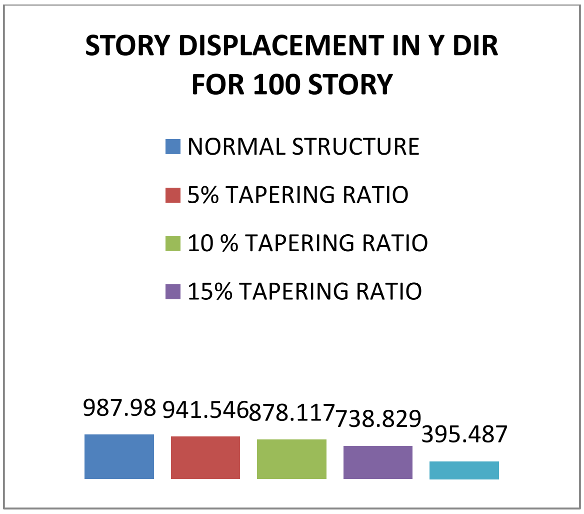


Figure 9: story displacement G+75 in Y direction

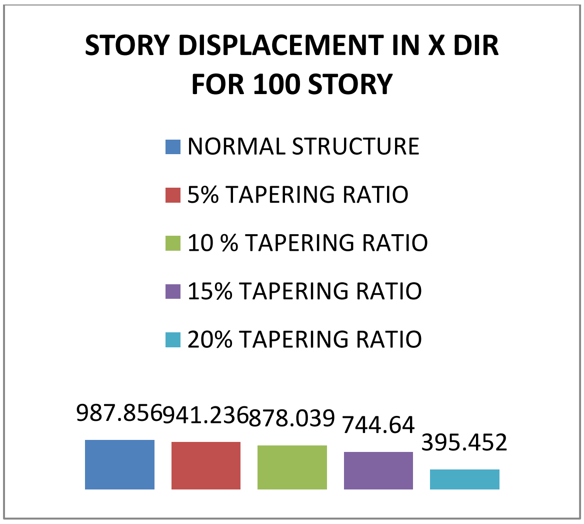


Figure 10: story displacement G+100 in the X direction

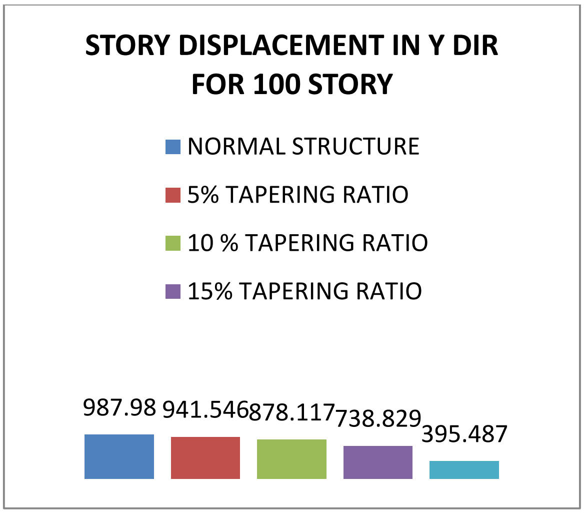
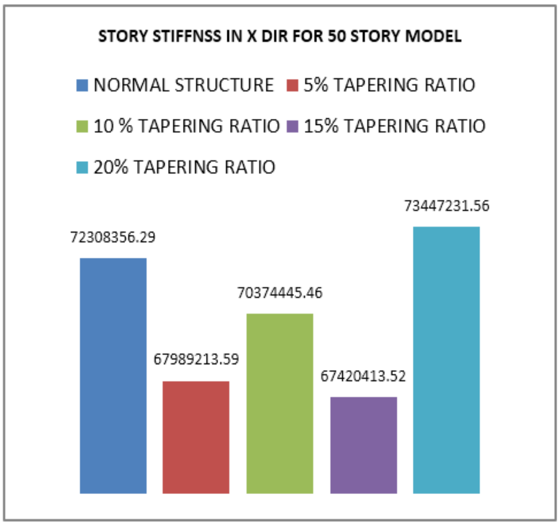


Figure 11: story displacement G+100 in Y direction

STORY STIFFNESS



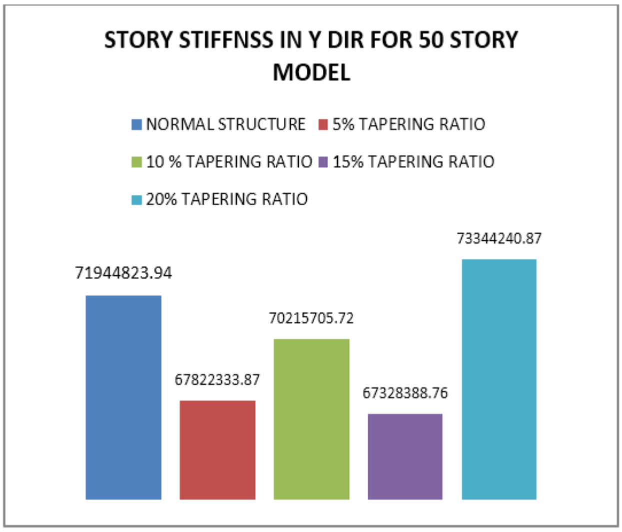
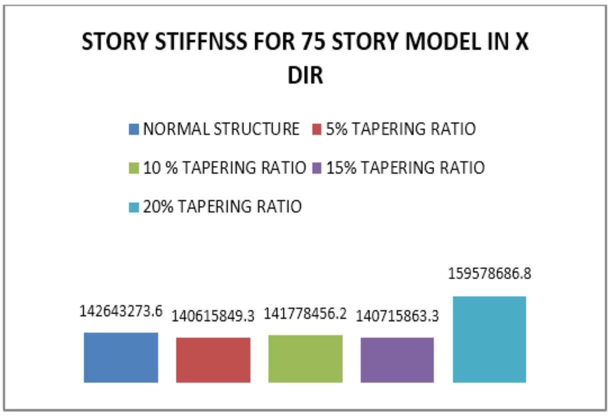


Figure 12: story Stiffness for G+50



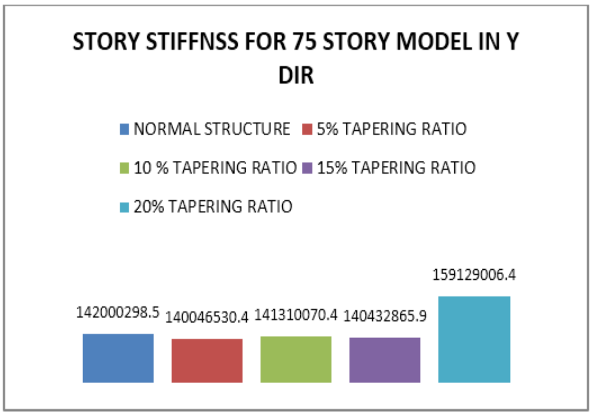


Figure 13: story Stiffness for G+75

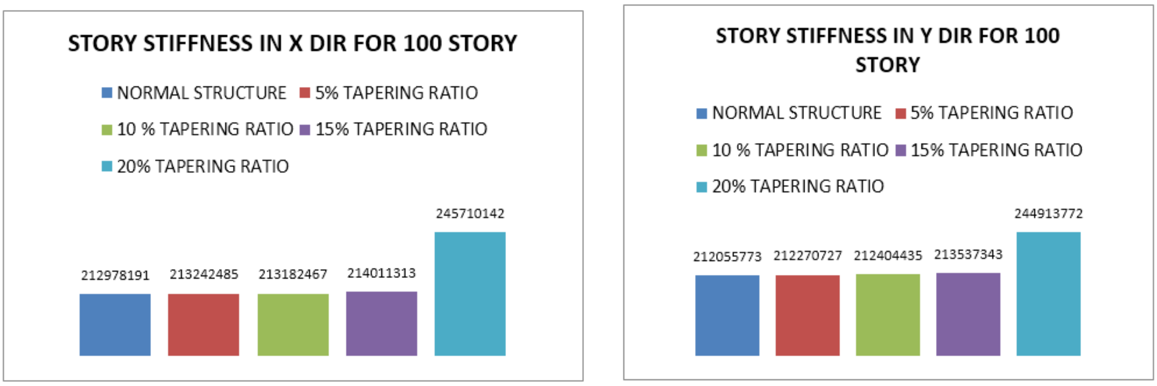


Figure 14: story Stiffness for G+100

TIME PERIOD RESULTS

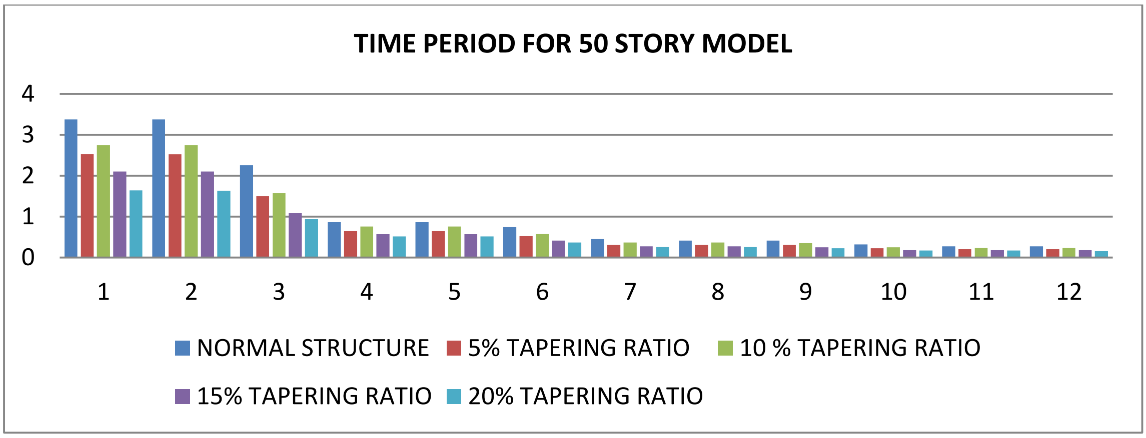


Figure 15: Time period for G+50

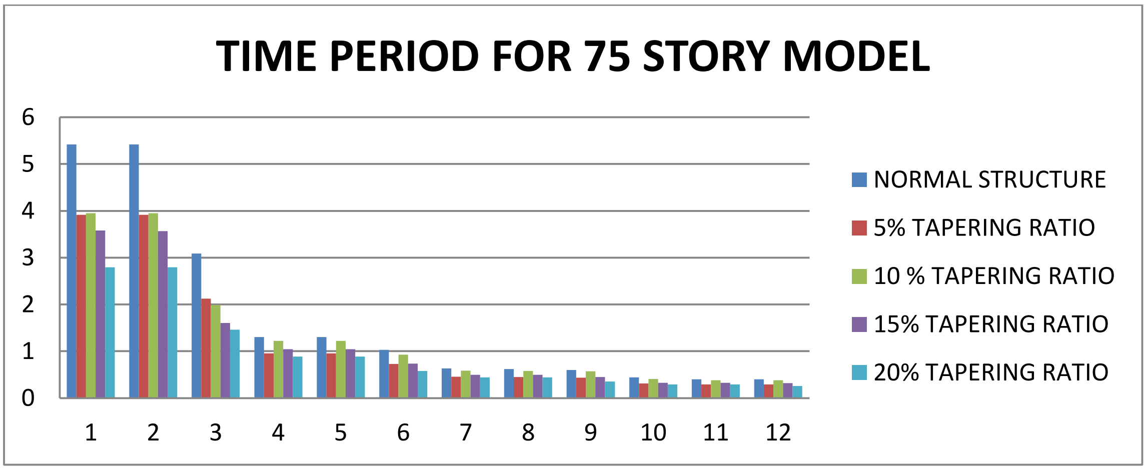


Figure 16: Time period for G+75

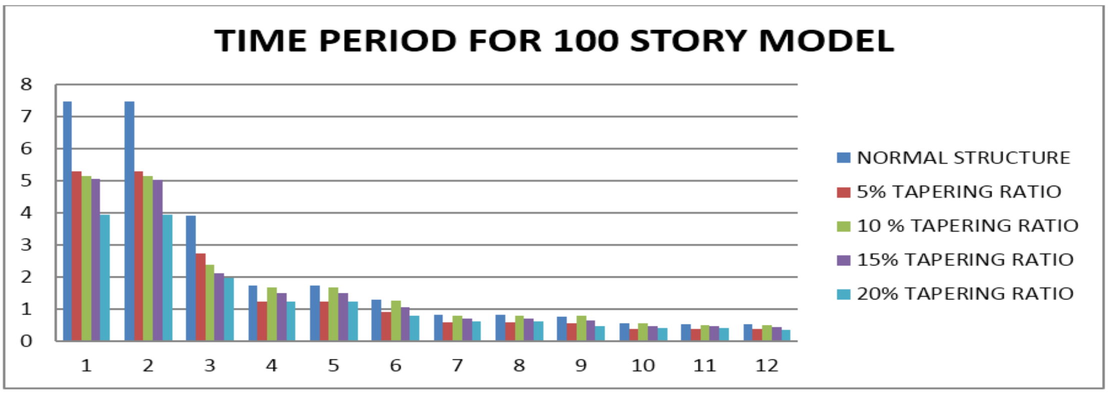


Figure 17: Time period for G+100

4. CONCLUSION

This dissertation investigates the comparison of the high rise buildings with considering 50, 75 and 100 Storey buildings with different tapering ratio from (0, 5, 10, 15 and 20 degree), all the buildings are with floor size 50mX50m for 50 story model and 100x100 m for 100 story model and typical Storey height as 3m.

- In this study, using different height of tall buildings, interrelationships between tapered building forms and main planning criteria, considering the aerodynamic design concerns of the tapering effect in contemporary supertall buildings were analyzed.
- This is because even a small change in geometric shape can provide a significant advantage over wind-induced lateral loads. In this context, the tapered form is one of the most preferred building forms and enables the supertall tower to exhibit an effective behavior against wind loads.
- Tapered forms mitigate the drag force owing to their geometric properties. Due to the increased size in the downward direction, the downwash phenomenon slows down less rapidly, and the upward flow accelerates at a higher speed due to the smaller width. These results in a lower pressure coefficient near the bottom and a larger pressure coefficient at the upper level compared to the reference square form.
- Tapered forms help prevent tall and supertall towers from shedding organized alternating vortices, due to the constantly changing plan dimensions across the height of the building. Thus, tapered structures are less sensitive to across-wind direction vibrations than high-rise towers with square cross sections.
- When a tower is tapered, it's outer surface area, where the wind load is exposed, decreases at higher levels, and increases at lower levels. As wind pressure increases slowly upwards and decreases rapidly downwards, lateral shear forces and overturning moments decrease as the tapered angle increases.
- We can conclude that the aerodynamic efficiency of high-rise buildings with rectangular forms is enhanced by the increased tapering ratio.
- The percentage of reduction in displacement when different tapering ratio is used on regular model is 50 % when tapering is 20 percent and 4-5% for tapering is 5 percent, 11-12% for tapering 10 percent and 23-27 % when tapering is 15 percent compared to normal model.
- Tapered structures have been increasingly used in buildings in recent decade. Due to their excellent lateral stiffness and aesthetic features, they have the potential to become a more widely- used structural system in high- rise buildings.

5. SCOPE OF FURTHER STUDY

Further research can be carried out by considering the effect of wind loads on irregular shaped structures and also by considering the impact effects due to the seismic loading on structure. Further research can be carried by using the same system with soil interaction properties.

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