ANALYSIS OF WIND LOAD ON TALL BUILDINGS OF VARIOUS ASPECT RATIO

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ABSTRACT: The rapid increase in the population in developing countries such as India has an acute shortage of land and space. To get rid of all these problems, people have resorted to multi-story or tall buildings both for commercial as well as for residential purposes. As the weight of the building increases wind flow is an important consideration for the designers. Tall building considering categories like relative height, proportion, and structural design. Under the Relative height categories, we call a building is tall depending upon the height relative to the surrounding structures. Most importantly from the structural design point of view, those buildings which are subjected to gravity loads are not considered as tall buildings only those which are additionally subjected to lateral loads like wind loads, etc. are referred to as tall buildings. But when we go higher wind excitation becomes one of the most precarious forces acting on the surface of the structure and if the plan geometry is irregular Also direction of wind plays a very vital role in the behaviour of the structure. In this Research paper, we study the various types of the aspect ratios of the building and the effect of wind forces on the building and also we study about, five-building models having different Horizontal Aspect ratios viz. 1, 1.5, 2, 2.5 and 3, height of the building is 53.6m.

1. INTRODUCTION

Due to bracketed range of features that span all form circumstances, resulting in diverse aerodynamic reactions, primary impacts of wind on buildings may be generalized to some degree. There is a restricted range of modifications in the construction of certain buildings due to their rigid structures. Circular eddies of varied diameters and rotational properties make up the fluid wind. Wind becomes more turbulent and gusty as a result of these eddies, which has a major impact on whatever it encounters. There is a resistance to the fluid's passage across the building's surface. Force exerted by the fluid's exit velocity on the structure is known as drag. The building is subjected to extreme stress from the wind's vortex shedding, which varies depending on the structure's geometry and the direction of the wind's flow. We know that non-streamlined body shapes, such as cubes and cylinders, have much more resistance for the same fluid velocity, and the Reynolds number, when exhibiting turbulent flow characteristics, will be roughly around this value. Building forms with a lower drag coefficient are thus considered by engineers when they construct tall buildings. The Skyscraper the construction of reinforced concrete buildings is known to be affected by vibrations and oscillations caused by high-speed wind forces. Several changes in form occur in all structures when they are loaded.

The definition of wind is the movement of air in relation to Earth's surface. Both time and space have an impact on it. The unpredictable nature of wind makes it all the more important to design tall buildings with wind's vital impacts in mind. A structure's exposed area determines the wind force. The building's dynamic qualities, the size and form of the structure, the kind of wind, and the surrounding terrain and topography all contribute to the wind force. The ever-changing nature of wind pressure must be carefully considered throughout the design process. A new generation of buildings has emerged as a consequence of advancements in current building processes and materials. These structures are frequently very lightweight, extremely flexible, and have low damping levels, qualities that were previously unimaginable. Such constructions are often more vulnerable to wind damage. The structural engineer's job is to make sure the building can withstand wind loads without compromising safety or functionality throughout the duration of its expected lifespan. For freestanding, tall buildings, wind is the main force exerted.

1.1 Definition of high rise building: Typically, a building will include walls, floors, a roof, and windows. The majority of people who live, work, or visit a multi-story building rely on elevators (lifts) to go from one floor to another. Typically, "high-rise" refers to the tallest structures in an area. At least one structure with a height more than fifteen stories is considered a high rise, under the 2005 Indian National Building Code.

1.2 Aspect Ratio: There are two kinds of aspect ratios: horizontal and vertical. We focus upon horizontal aspect ratio in our study paper. Ratio of a length (L) to its base (B) is known as horizontal aspect ratio (L/B). Ratio of horizontal to vertical dimensions is known as plan aspect ratio.

1.3 Calculation of wind load on building:

The building's wind load is calculated using

a. Analytical approach, stated in IS-875-Part III-1987, is the procedure in question. This strategy, which relies on the geometric qualities of buildings rather than taking into account the influences of surrounding structures, is used when the building's form and scale are regular.
b. Secondly, utilization of a so-called building model for wind tunnel testing to evaluate wind loads. Both cladding design & dynamic study of scaled model building are carried out in wind tunnel using Balendras's technique and a pressure measuring device, respectively.
   To account for interference impact on buildings, impacts of surrounding structures have been included into models of isolated buildings.

1.4 Terrain: Proper consideration will be given to the influence of inhibit, which is comprised of the roughness of ground surface, while classifying territories. A building's blueprint may call for a different land type depending on direction of wind. Any building or structure may be suitably oriented in relation to wind if sufficient weather data is available.

Evaluated terrain must fall into one of following categories depending on kind of structure it is located on.

1. Terrain category-1
2. Terrain category-2
3. Terrain category-3
4. Terrain category-4

2. LITERATURE REVIEW

1. **Barkha Verma, et.al:** This research article examines the effects of wind forces on four building models with varying horizontal aspect ratios (1, 2.25, 4, and 9) at a height of 96 meters, as well as other building kinds. A 30-story structure was used for the study, and the model was produced in Etabs. Storey drift, shear, and displacement are the parameters chosen for comparison. The models show that the storey displacement grows in direct proportion to the building's aspect ratio. This provides a crucial consideration when creating a structure to withstand high wind loads, which is particularly important in regions where wind load effects are more noticeable than earthquake effects, since it shows maximum wind load which structure meeting a certain specification can withstand.
2. **Chandradhara G. et.al:** Utilizing ETABS, this research shows how wind affects structures with varying aspect ratios. Models are classified according to building's aspect ratio and number of stories. In order to study the influence of wind load upon gravity load, frame models with aspect ratios rising from 0.25 to 2 are taken into consideration. Also, by adjusting number of storeys from three to twenty, we can study influence of wind load on building height. Program ETABS is used for analysis of all idealized 3D models of frame. It is possible to investigate behavior of frames by considering variations of axial force and bending moment in columns. Researchers found that wind impact decreases with decreasing building aspect ratios.

3. **Ankit Panjwani et.al**: Utilizing parameters such as base shear, overturning moment, maximum story displacement, and maximum story drift, this paper studies effects on buildings of changing terrain categories 2 and 4, and then suggests best approach that corresponds to each terrain category. Along wind and across wind loads at different building heights are calculated using MS-Excel. ETABS software is used for frame modeling and analysis. According to results, while deciding between 2 methods, terrain category is crucial. According to the results, a dynamic approach is more important than a static one in terrain category 2, whereas the opposite is true in terrain category 4.
4. **K. Vishnu Haritha , et.al:** This research analyzes wind loads on structures with various aspect ratios using the equivalent static approach. By adjusting number of bays, the aspect ratio may be adjusted. Consideration for the current research was given to aspect ratios 1, 2, and 3. Staad Pro is used to do the analysis.
   The following findings are derived from the STAAD PRO study of the building frames: Deformation of frame is reduced when member's stiffness is increased. Up to a particular height, aspect ratio is determining factor for the displacements.
5. **Venkanna, Potlapelli. Avinash:** This research analyzes wind loads on structures with various aspect ratios using the equivalent static approach. By adjusting number of bays, the aspect ratio may be adjusted. Consideration for the current research was given to aspect ratios 1, 2, and 3. We use STAAD PRO to do analysis. This research analyzes wind loads on structures with various aspect ratios using the

equivalent static approach. By adjusting number of bays, aspect ratio may be adjusted. In this investigation, aspect ratios were taken into account. We use STAAD PRO to do the analysis.

6. **Miss. Homeshwari V. Gedam , Mrs. Gitadevi B. Bhaskar:** Current research examines impact of wind loads on structures with varying aspect ratios, or H/B ratios, using STADD PRO. Here, H is the overall height of the structure and B is its base width. This study shows how changing the number of storeys with increasing aspect ratio affects impact of wind load upon structure height. Class A and Class B wind zones in terrain categories TC2 & TC3 are included in examination of multi-story buildings. The G+5 and G+11 multistory buildings have their STAAD-Pro 3D models ready.
   The research led them to the conclusion that
   a. As the terrain category changes from 2 to 1, axial force, shear force, torsion, bending moment, and displacements created in columns diminish due to the wind force.
   b. Wind forces are shown to grow as one climbs higher, yet they diminish noticeably when one increases the base size.
   c. When height of a structure is raised, the shear at the top level is much greater than the floor directly below it in the event of a windstorm.
7. **Jamaluddeen, et.al:** Modern times have seen the construction of an abundance of skyscrapers and other tall buildings, and this study article examines the impact of wind loads on these structures. Two-story structure is often symmetrical. The building's height varies, and the symmetry amongst wings isn't preserved adequately, all because of technical or architectural considerations. Research on building displacement, duration, base shear, and base moment coefficients for various tall building shapes. Buildings ranging from sixteen to twenty stories in height do this. Due to its ever-changing nature, wind plays a significant influence in the construction of tall buildings. According to building's location and height, towering buildings are particularly vulnerable to the wind's destructive power. In order to analyze wind loads on buildings, this article compresses structures according to their height and various shapes.
8. **Ashish Singh, Sasankasekhar Mandal:** This research aims to assess the influence of wind and structural characteristics on the across wind load of a super high-rise structure within a conceivable realistic range. Exponent of mean velocity profile, turbulence intensity, background peak factor, and peak factor for resonant response are the wind characteristics taken into account in this research. Also taken into account are structural characteristics like structural damping ratio and natural frequency that impact the wind load throughout the structure. In order to conduct the research, an analytical approach is used to assess the across wind loads. The findings show that when evaluating various wind stresses, the natural frequency of the structure is the most important structural characteristic. From a wind parameter standpoint, the across wind load is largely affected by the exponent of the mean wind profile. The magnitude of turbulence has no effect on the across wind load. When evaluating across-wind loads, this research helps designers choose the best values for wind and structural factors.
9. **Vikram.M.B , et.al:** Wind load is considered a vital loading for structures with long spans, such as bridges, tall buildings, and towers or masts. Tall multi-story structures must take wind loads into account throughout design process. Utilizing ETABS, this research shows how wind affects structures with varying aspect ratios. As 3D models, all of the frame models are idealized. It is possible to investigate behavior of frames by considering variations of axial force and bending moment in columns. The current research shows that wind effects are more noticeable than gravity impacts for lower aspect ratios, but dynamic impacts are less noticeable than static impacts for symmetrical frames.
10. **Neela Viswanath , et.al:** There are a lot of skyscrapers and other towering buildings going up all over place these days.Due to its ever-changing nature, wind has significant influence in the construction of tall buildings. Based on factors such as building's location and height, wind tends to have a more significant impact on tall buildings. This research analyzes wind loads on structures with various aspect ratios using the equivalent static approach. By adjusting the number of bays, aspect ratio may be adjusted. Consideration for the current research was given to aspect ratios 1, 2, and 3.

3. OBJECTIVES AND SCOPE OF WORK

3.1 Objectives:

1. For the purpose of researching how tall structures react when exposed to wind stresses.
2. So that we may learn how the building's form in the blueprint affects its operation.
3. In order to compare and contrast different construction aspect ratios that occupy the same space.
4. In order to find out how the wind affects a number of building factors, such as the maximum displacements, maximum story drift, and bending moment.
5. This study aims to compare several aspect ratios in tall structures in order to determine the optimal one for providing safe wind loads.

3.2 Scope of work:

1. RC framed structure was the subject of the modeling.
2. This analysis took the infill wall mass into account.
3. Story drift, displacement, and the application of wind force
4. For Story Drift and Story, we examine actions of five different models. Every story undergoes displacement to account for wind forces.
5. This research shows how aspect ratio matters.

4. METHODOLOGY

An examination of tall buildings with different aspect ratios may be done using the following methods: Books, technical papers, and research papers are all part of the literature review that must be completed in order for us to grasp the subject's foundational ideas. After then, the need of doing research is determined. Planning the steps to be taken in order to complete the next analytical task. Data collecting is then complete. After that, we get ETABS models ready. An examination is conducted on a 16-story skyscraper. Afterwards, a variety of building aspect ratio designs are created. The assignment of all loads, including dead load, live load, and load combinations, follows completion of models. The building's wind loads were determined utilizing the different parameters in accordance with IS-875 part 3. The next step is to apply predicted wind loads to the virtual structures. Once that is done, we can begin analyzing and designing our model. Perform the analysis and verify the layout. Verify findings Research into the findings is followed by calculations of wind intensity, story displacement, shear, and drift, as well as the structural efficiency of the structure as a whole, taking into account the model's aspect ratio. After all efforts interpretation of findings and conclusion.

4.1 Description of models:

1. Model-1: A RC framed building of G+15 storey with aspect ratio 1.0
2. Model-2: A RC framed building of G+15 storey with aspect ratio 1.5
3. Model-3: A RC framed building of G+15 storey with aspect ratio 2.0
4. Model-4: A RC framed building of G+15 storey with aspect ratio 2.5
5. Model-5: A RC framed building of G+15 storey with aspect ratio 3.0

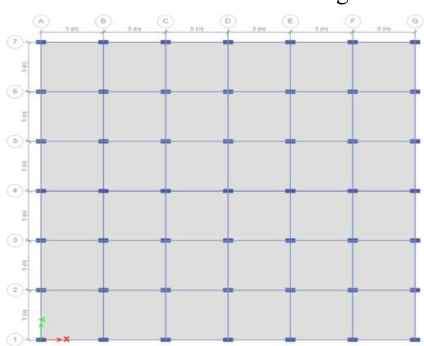


Fig-1a: Plan of RC framed building with aspect ratio-1

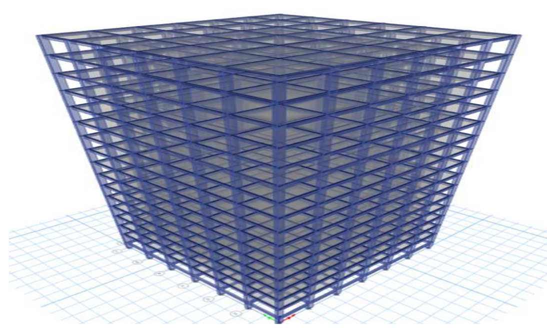


Fig-1b: 3D View of RC framed building having aspect ratio-1

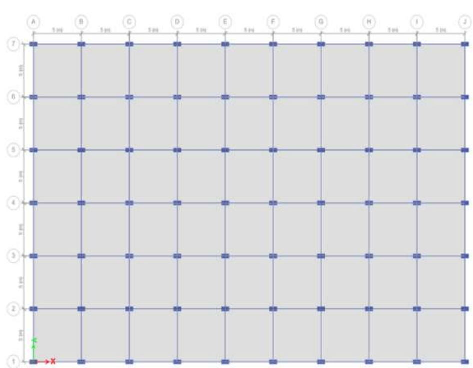


Fig-2a: Plan of RC framed structure having aspect ratio-1.5

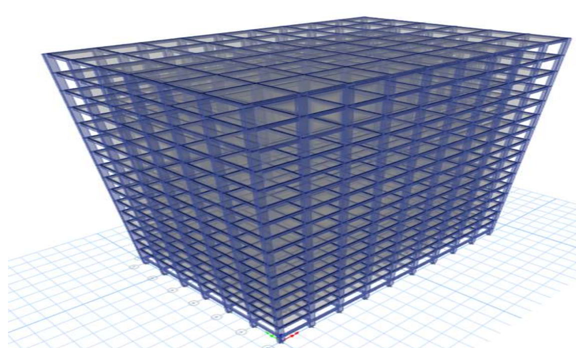


Fig-2b: 3D View of RC framed building with aspect ratio-1.5

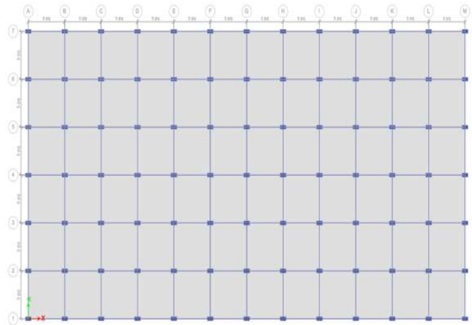


Fig-3a: Plan of RC framed structure having aspect ratio-2.0

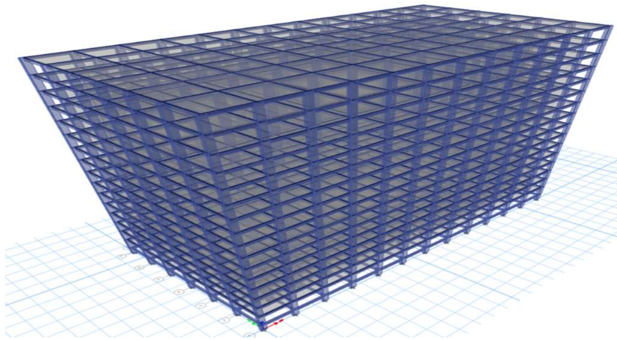


Fig-3b: 3D View of RC framed structure having aspect ratio-2.0

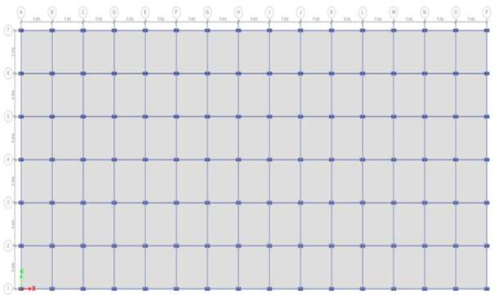


Fig-4a: Plan of RC framed structure having aspect ratio-2.5

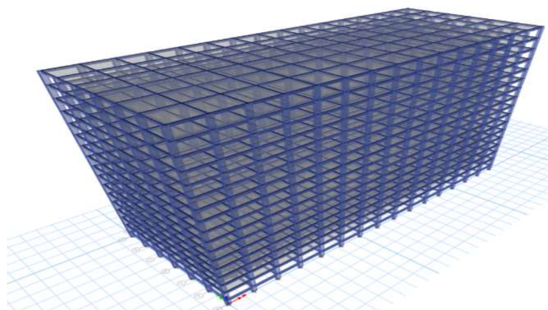


Fig-4b: 3D View of RC framed structure having aspect ratio-2.5

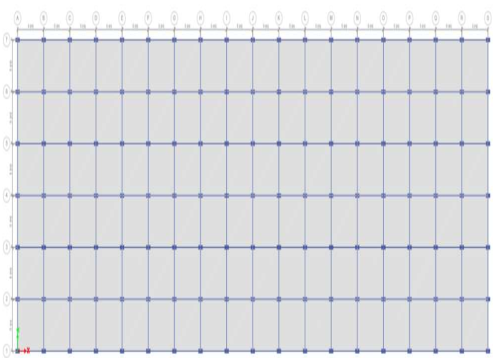


Fig-5a: Plan of RC framed structure having aspect ratio-3.0

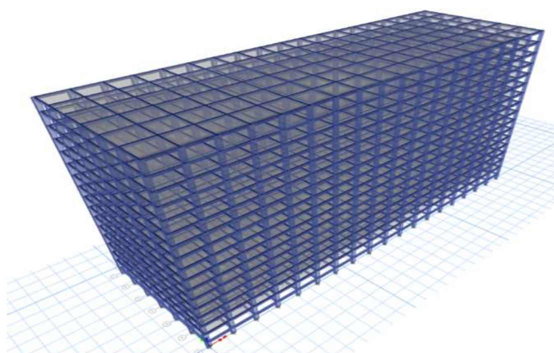


Fig-5b: 3D View of RC framed structure having aspect ratio-3.0

4.3 Details of Structure's:

Building type	Commercial Building	
Frame type	Special moment resisting frame	
Total storeys	16 (G+15)	
Each storey height	3.35m	
Bottom storey height	2.0m	
Full height of building	53.60 m	
Size of building	1. 30mx30m	Aspect ratio -1.0
	2. 45mx30m	Aspect ratio -1.5
	3. 60mx30m	Aspect ratio -2.0
	4. 75mx30m	Aspect ratio -2.5

	5. 90mx30m	Aspect ratio -3.0
Wall thickness	230mm	
LL (live load)	$4KN/m^2$	
FF(floor finish)	1.0 KN/m^2	
Concrete grade	M40	
Steel grade	500 N/mm^2	
Density of Brick masonry	18 KN/m^3	
Size of column	C- 400 x 800 mm	
Size of Beam	300mm x 450mmm	
Thickness of slab	150mm	
Terrain Category	I	
Wind speed considered	50Km/h	
Type of soil	Medium	

4.4 LOAD ANALYSIS:

When analyzing RC framed buildings, the following loads are taken into account.

4.4.1: DL as per IS 875- 1987 part-1

The term "dead load" describes a load that does not change during the course of a structure's lifetime. Before considering active loads, there are dead loads, such as the strength of the plan or other permanent components.

4.4.2 Live load as per IS 875(part II)- 1987

Occupancy of a design often causes live loads, which may change over time and are sometimes known as applied or imposed burdens, changeable activities, or simply loads. People, wind at a height, furniture, cars, a library's weight in volumes, etc. are all examples of common live loads.

4.4.3 Wind load as per IS-875 Part-III-1987

The term "wind load" describes the amount of stress that wind causes on a building's outside layers. In order to avoid collapse, it is crucial that the building's structural design efficiently and securely absorbs wind forces and transfers them to the foundations.

5. Linear Analysis

5.1 Pressure coefficients:

The design of cladding and structural components like walls and roofs are both affected by pressure coefficients. To get the ultimate wind loading, procedure involves adding Cpe and Cpi algebraically. Direction of the wind, building's layout, ratio of height to breadth, and the roof's features and form all influence external pressure coefficient. Both the proportion of apertures in walls and their positioning with respect to direction of wind significantly impact internal pressure coefficients.

5.2 Force coefficients:

Pd is the total wind load, which is the result of multiplying the force coefficients applied to structure by its effective frontal area. A multiplied by the chosen wind speed and pressure.

5.3 Parameters considered for linear analysis:

Design Wind Speed (Vz): The chosen structure's design wind velocity at any height (Vz) may be determined by using the basic wind speed (Vb) recorded at each site according to IS: 875 Part-III-1987 and taking into consideration the following consequences.

a) Risk level;

b) Terrain roughness, height and size of structure; and

c) Local topography.

It can be mathematically expressed as follows: where

$$V_z = V_b x K_1 x K_2 x K_3$$

Where Vz = Design wind speed at any height z in m/s

K_1 = Probability factor

K_2 = Terrain height and structure size factor

K_3 = Topography factor

Design Wind Pressure: Design wind pressure can be determined by applying the following formula at any height above mean level: $P_z = 0.6\ (V_z)^2$

Where, P_z = Design wind pressure in N/m^2 at height 'z' m

V_z = design wind velocity in m/s at height "z" m

Wind Load on Individual Members: (IS: 875 (Part 3)

$F = (C_{pe} – C_{pi})\ AP_Z$

Where, C_{pe} = external pressure coefficient,

C_{pi} = internal pressure- coefficient,

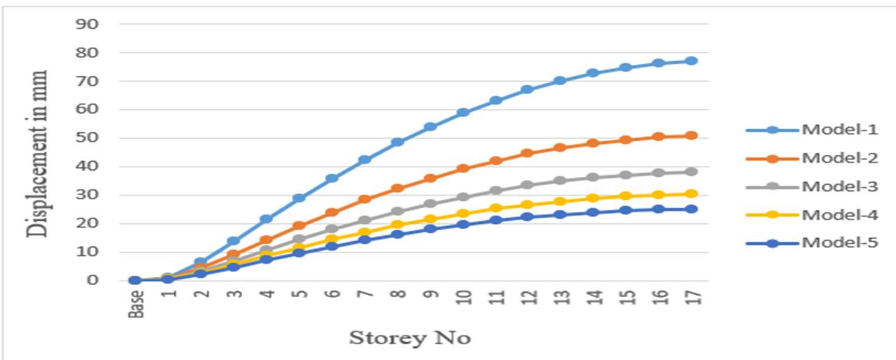
A = surface area of structural or cladding unit and

Pz = design wind pressure.

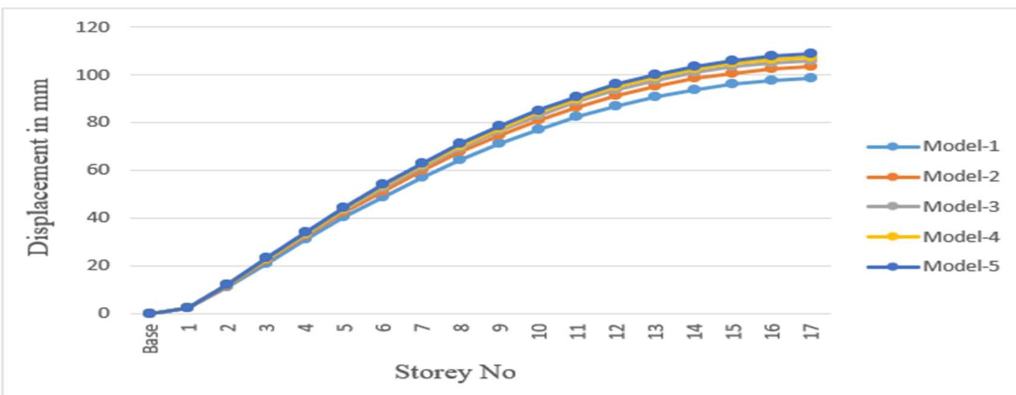
6. RESULT AND DISCUSSION

6.1 General: Five models of RC-framed buildings with varying aspect ratios were subjected to wind loads for evaluating their performance. In order to evaluate each construction model, ETABs 2020 software is employed. Displacements, storey drifts, storey shear, and overturning moment are all included in the assessment outcomes of the building models.

6.2 Displacement: Storey displacement is the change in height of floor being considered in relation to the ground or other foundation of structure. Height of structure, denoted as hs, divided by 500 is maximum allowable displacement in multi-story buildings, as stated in Article 7.11.1.2 of Part 1 of the 1893 Code of Standards. There is a 56.3% tolerance for error, which works out to 0.1126 m, or 112.60 mm.

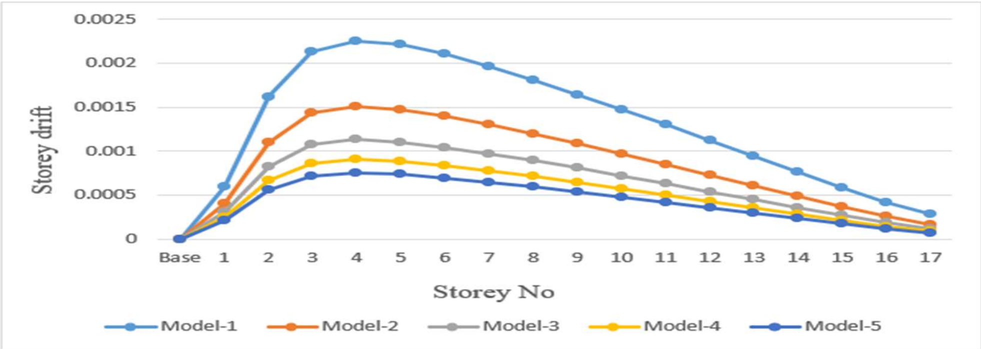


Graph 6.1: Displacement in mm of all models due to wind load along X-direction.

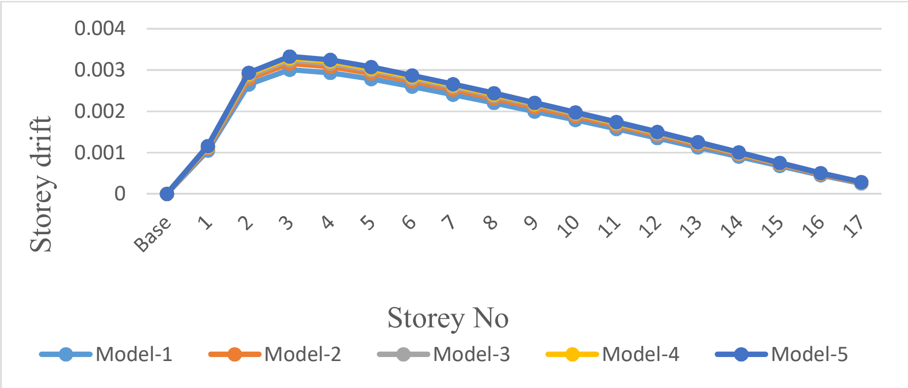


Graph 6.2: Displacement in mm of all models due to wind load along Y-direction.

6.3 Storey drift: Drift is nothing but lateral deflection of one storey relative to the other level storey above or below. Maximum allowable story drift in any given storey is 0.004 times height of that storey, according to IS 1893: 2002.



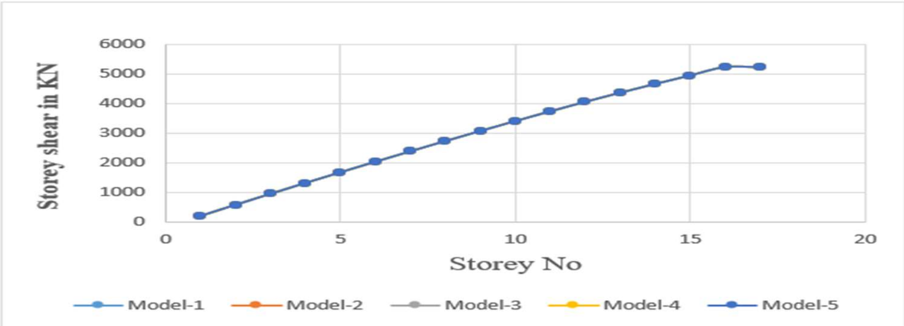
Graph 6.3: Storey Drift of all models due to wind load along X-direction.



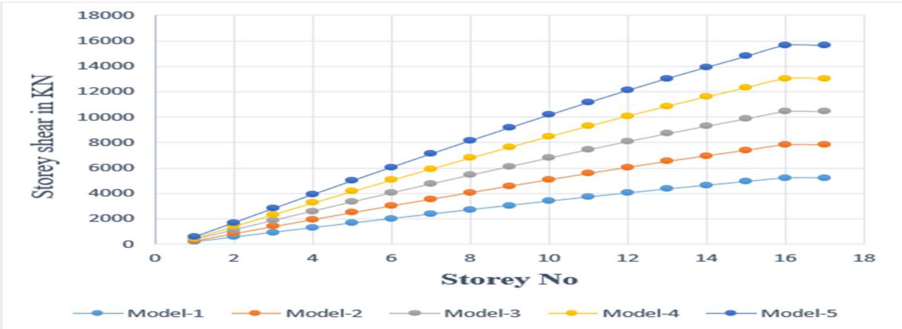
Graph 6.4: Storey Drift of all models due to wind load along Y-direction.

6.4 Story Shear:

It is the lateral load or horizontal load due to wind or seismic acting per story of the building.

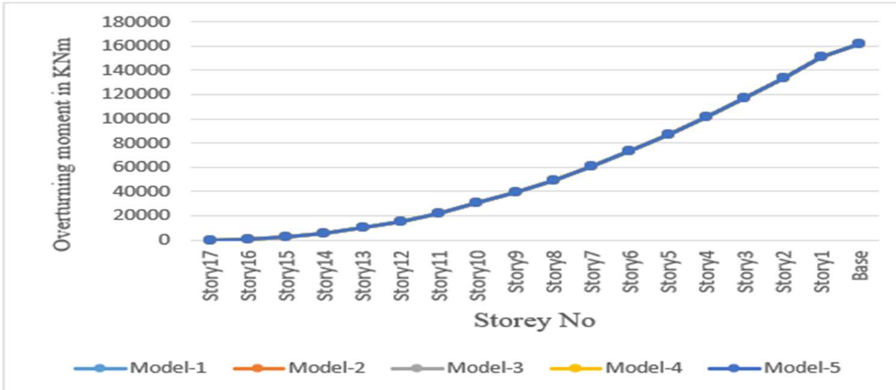


Graph 6.5: Storey shear of all models because of wind load along X-direction

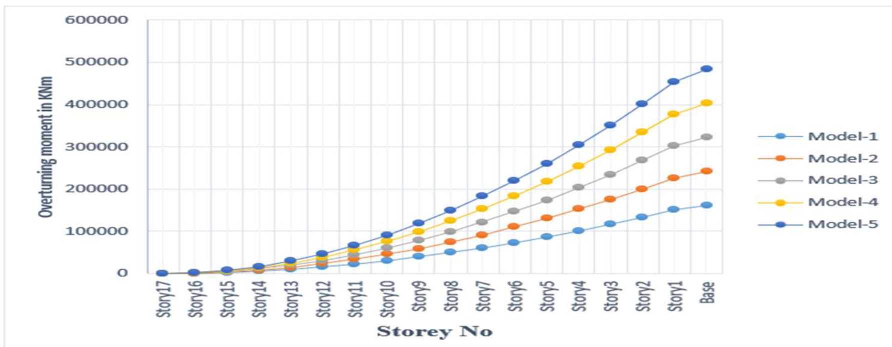


Graph 6.6: Storey shear of all models because of wind load along Y-direction

6.5 Overturning Moment: Torque that results from applied forces around base or point of contact is called overturning moment.



Graph 6.7: Overturning moment of all models due to wind load along X-direction



Graph 6.8: Overturning moment of all models due to wind load along Y-direction

7. OBSERVATION AND CONCLUSION

1. For buildings with an aspect ratio of 1.0, the displacement is found to be maximal.
2. It is observed that the displacement reduces with increasing aspect ratio.
3. While the length of the structure was altered in this thesis, the breadth remained fixed. Therefore, it was observed that displacement reduces with increasing building width and rises with decreasing building length.
4. The storey drift was shown to decrease with increasing aspect ratio.
5. All models show that the storey shear along the x-axis stays constant as the aspect ratio grows.
6. Along the Y-axis, we see that the storey shear grows in proportion to the aspect ratio.
7. Even when the building's aspect ratio rises in the x-direction, the overturning moment stays the same.
8. As the aspect ratio grows, the overturning moment similarly increases, provided that the building width remains constant in the y-direction.

7.1 Scope for further study:

1. In this thesis the length of building was change and width of building kept constant. Hence further study can be carried out by keeping length of building constant and width of building varied.
2. In this thesis wind load is applied further work can be carried out by applying seismic load.
3. The current work is finished for M40 grade concrete further work may be accomplished for higher grade of concrete.
4. In this thesis the building was taken symmetry. Hence further work may extend for irregular building.

REFERENCES

1. **Barkha Verma, Bhavika Baghel, Aditi Chakradhari, Abhishek Agrawal, Prince Wanjari:** Analysis of Wind Load on Tall Building of Various Aspect Ratios, International Research Journal of Engineering and Technology (IRJET) Volume: 09 Issue: 01 | Jan 2022.
2. **Chandradhara G. P , Vikram.M.B:** Effect of wind load on the aspect ratio of the building, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), International Conference on Innovations in Civil Engineering.
3. **Ankit Panjwani, Vipin Kumar Tiwari**: Comparative analysis of tall buildings subjected to wind loads using force coefficient method and gust factor method, International Journal of Creative Research Thoughts (IJCRT), Volume 9, Issue 11 November 2021 | ISSN: 2320-2882.
4. **K. Vishnu Haritha , Dr.I. Yamini Srivalli:** Effect of Wind on Tall Building Frames - Influence of Aspect Ratio, International Journal of Research in Civil Engineering, Architecture & Design Volume 1, Issue 1, July-September, 2013.
5. **Venkanna, Potlapelli. Avinash:** Effect of wind on tall building frame – influence of aspect ratio, International Journal of innovative Research in science and engineering, volume No-2 issue 10 October 2016.
6. **Miss. Homeshwari V. Gedam , Mrs. Gitadevi B. Bhaskar:** Effect of Wind Load on High Rise Buildings Considering Aspect Ratio, International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 6 Issue VI, June 2018- Available at www.ijraset.com.
7. **Jamaluddeen, Rajiv Banerjee:** AN ANALYTICAL STUDY ON EFFECT OF WIND LOAD FOR TALL BUILDING, International Journal of Structural Engineering (IJSE) Volume 3, Issue 1, January-December 2021.
8. **Ashish Singh, Sasankasekhar Mandal:** Effect of wind and structural parameters on across wind load of super high-rise buildings, Research on Engineering Structures & Materials, DOI: http://dx.doi.org/10.17515/resm2023.727st0403 Res. Eng. Struct. Mat. Vol. 9 Iss. 4 (2023) 1459-1475.
9. **Vikram.M.B , Chandradhara G. P, Keerthi Gowda B.S:** A study on effect of wind on the static and dynamic analysis, International Journal of Emerging Trends in Engineering and Development, Issue 4, Vol.3 (May 2014).
10. **Neela Viswanath , Cirisala Gowthami , A. Rakesh Varma , P. Anusha , M. D. Doulath , Mohd Arshad Lateef:** Design and Analysis of Commercial Building under Wind Load Analysis Using Staad.Pro, International Journal of Scientific Engineering and Technology Research Volume.07, IssueNo.03, March-2018.