

Effect Of Wind On Tall Building Frames-Influence Of Aspect Ratio

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Abstract- *The natural wind loads significantly impact the design and structural integrity of tall buildings. The aspect ratio, defined as the ratio of a building's height to its width, plays a crucial role in determining the extent of wind-induced forces on buildings. This study examines the influence of aspect ratio on wind loads by analyzing buildings with varying aspect ratios using STAAD Pro software tools.*

The impact of wind on tall building frames is a critical factor in structural design, as the forces exerted by wind can significantly influence the stability and performance of the building. This study is to examine whether the buildings with higher aspect ratios are more susceptible to wind-induced stresses, affecting both structural safety and serviceability. The study underscores the importance of considering wind loads and optimizing the design of tall buildings to ensure their stability, safety, minimize structural damage, and improve performance in wind-prone areas throughout their anticipated lifespan.

Keywords- Aspect Ratio, Story drift, Tall Buildings, Wind Analysis,

I. INTRODUCTION

In modern urban landscapes, the construction of tall buildings has become increasingly prevalent due to rapid urbanization, population growth and the demand for efficient land use. As cities expand vertically, engineers face new challenges in ensuring the stability and safety of these towering structures. One of the most critical factors influencing the design of tall buildings is the impact of wind loads, which can cause significant structural responses, affecting safety, serviceability and long-term performance.

Among the factors affecting a building's wind response aspect ratio is an important factor and plays a crucial role. The aspect ratio, is defined as the ratio of a building height to its width. Higher aspect ratios, typically result in more slender structures, which are more susceptible to wind-induced stresses, lateral movements, and aerodynamic instabilities.

Designing tall buildings to withstand wind loads is not just about structural integrity but also about ensuring occupant comfort and minimizing structural damage over time. Excessive lateral sway can cause discomfort to occupants, especially in upper floors and over time, repetitive wind-induced movements may lead to structural fatigue. Therefore, understanding the relationship between a building's aspect ratio and its wind load response is vital for developing efficient design strategies that ensure safety, comfort and durability.

This study proposes to focus on investigating the influence of aspect ratio due to wind loads on tall buildings by utilizing equivalent static methods with STAAD Pro software tools. The objective is to evaluate how varying aspect ratios impact the distribution of wind-induced forces and the overall structural response. By analysing these effects, the research aims to offer insights into optimizing building design for enhanced stability, minimizing structural damage and ensuring good performance in wind-prone areas throughout the building's lifespan. The findings of this study are expected to contribute valuable knowledge for engineers and architects involved in the design and construction of tall buildings. Incorporating the influence of aspect ratio into wind load assessments can lead to more resilient structures, better occupant safety and improved serviceability, ultimately ensuring that tall buildings safely withstand wind forces while maintaining long-term performance.

II. OBJECTIVES

This defines the purpose of study, aligns literature review with goal and meaningful contribution.

- Study the response of tall buildings when exposed to wind force.
- Study the response of tall buildings for different aspect ratios of buildings with the same height but different base areas.
- Assess the impact of wind forces on various parameters such as maximum displacement, maximum story drift, shear force & bending moment.

- Based on the study of wind load on different buildings with aspect ratio, recommend best suitable Aspect ratio for adoption in designs.

III. METHODOLOGY

The methodology will consist of Literature survey and identifying Research Need for a specific topic. Based on the topic identified, problem statement is formulated. The approach to the problem analysis is defined. The necessary data is collected and exact building Configurations (Width, Length, Height and column beam frame work) is finalized. The Structural Modeling of building is done in Staad pro software. The physical structure for different Aspect Ratios is finalized. The loads are assigned as per applicable IS Codes. The model integrity is checked. The Program is Run for analysis. In post analysis, the results studied, compared and conclusion is made on the results. The recommendations are made for the suitable parameter (Aspect Ratio) to be adopted for the design.

IV. LITERATURE REVIEW

Literature survey was conducted in detail to identify the Research Need of a subject. Based on these searches, the problem statement was formulated. This was followed by Data collection for the problem.

1. Guleria, 1481–1485 (2014) :- The structural behavior of multi-story buildings for various plan configurations such as rectangular, C, L, and I-shape was concluded in his research article. Maximum shear forces, bending moments, and maximum narrative displacement are computed and compared. The displacement of stories grew with story height up to the sixth story, reaching a maximum value, and then began to decrease.

2. Muley, P. V, Senghani, J. M. & Radke, A. S. 2460–2464 (2019) :- In this study, the performance of high-rise buildings under seismic and wind excitation for various plan configurations in the same area was studied. Finite Element Analysis is used to create and analyze all of the models. As the Plan aspect ratio grows in the Y direction, the displacement of the top story increases. The building's stability, on the other hand, appears to be rising as the $L_y : L_x$ ratio rises. For high-rise buildings, the plan aspect ratio $L_y : L_x$ is critical.

3. Pawan Pandey & Dilip Kumar (2014) :- Studied in Seismic load Effect on Building Configuration, that the behavior of building during earthquake depends critically on its overall shape, size and geometry.

4. Sanjay Kumar Sadhu and Dr. Umesh Pendharkar. :- In their study on the effect of aspect ratio and plan configurations on the seismic performance of multistoried regular R.C.C. buildings, it was observed that seismic parameters escalate with an increase in the number of bays and stores. Additionally, they concluded that a square configuration (horizontal aspect ratio=1) yields superior performance, and it is advisable to maintain a vertical aspect ratio of less than 4.

5. Dr D.P.Joshi:- The paper focuses on studying various cases of aspect ratios of buildings under wind and earthquake forces. It examines the analysis and design of a G+30 storey building with different aspect ratios. By considering different aspect ratios, the study aims to draw concluding remarks based on the results obtained from the analysis. The research aims to provide insights into how aspect ratio influences the structural response to wind and earthquake forces, ultimately informing optimal design practices for high-rise buildings to ensure structural integrity and safety.

6. Lekhraj k pandit, swapnil jadhav (2017) :- The analysis and design of a G+9 story building with various aspect ratios, all having the same area of 2000 square meters, were considered in the study. It was observed that as the aspect ratio increases, the story displacement also increases. Particularly, the displacement in the x-direction was found to be significantly greater than the displacement in the y-direction when subjected to earthquake loads. This observation underscores the importance of considering aspect ratio in structural design to accurately assess and mitigate potential displacement and deformation under seismic forces, ensuring the structural integrity and safety of the building.

Summary of Literature review

1. The aspect ratio of a building is a crucial factor in analysis and design of tall buildings. Irregularly shaped buildings experience more deformation, highlighting the preference for regular-shaped structures.

2. Seismic parameters such as base shear, story overturning moment, story drift, story displacement, and model period of vibration increase with plan aspect ratio. Higher numbers of bays lead to excessively increased values of these parameters.

3. Buildings with a square configuration, having an aspect ratio of 1, perform well based on various seismic parameters and may be considered a suitable plan configuration option.

There is publication on similar study of tall buildings on Wind and seismic loads. There are studies made for Aspect ratios by varying all related parameters. However no specific paper isolating the effect of wind for different aspect ratios with same height are not available. Hence it is chosen to work on this topic and the same is selected for study.

VI. STRUCTURAL ANALYSIS

6.1 Building Configuration

The structural analysis covered finalisation of Beam Column frame for the building configuration with 5 x 5 m grid. The sizes adopted are, Beam: 0.50 x 0.50 column: 0.90 x 0.90 m, slab thickness: 0.15 m, no of floors G+30 with 3.20 m as each floor height, with grade of concrete as M45 for Beams and M50 for Columns. The building height is 99.20 m for all combination base areas of: 80x80, 140x60, 100x50 and 150x40m, steel grade: Fe 500.

6.2 Modelling

Based on building configuration, the Modelling is carried out in Staad Pro Software. Depth of Foundation is at 5 m from GL. Plinth is at GL. The Footings are fixed base. Plates adopted for Slab. The structural components likely to affect the analytic purpose of study like Shear wall, Braces. are intentionally not included.

6.3 Loads:

Loads on Building adopted for analysis are Wind Load, Dead Load, wind load, all as per IS 875 part (1), (2) and (3)-2015.

6.3.1 Wind Load. The wind load is as per IS 875 Part 3-2015 are adopted for Dharwad, Karnataka location with Basic Speed-33 m/sec, K1, K2, K3 and K4 as per IS Code, Kc, Kd, Ka as per IS code. Wind load is applied as per Column Spacing and Height and on full face.

6.3.2 Dead Load. The dead loads cover self-weight as Dead Load for Columns, Beams, Slab excluding Footings. Floor finish loads as dead load on Plate. The wall weight is Dead Load on all beams as UDL. No wall load on Terrace. The density adopted for Brick wall is 20 KN/Cum and concrete is 25 KN/Cum.

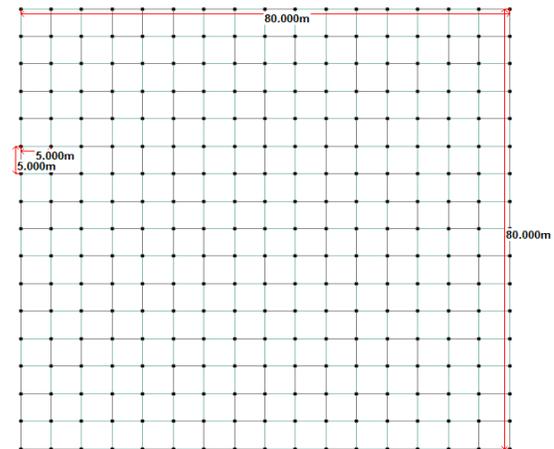
6.3.3 Live Load. The live load is applied as Pressure on Slab Plate.

6.3.4 Conditions: Seismic loads are not included, as only wind effects are under study. All the analysis are carried out for serviceability condition. The outcomes from Analysis are adopted for study. No structure components are designed. The analysis for wind is uniform static. The wind load is considered uniform for all floors and over the period. The dynamic analysis is not adopted, as the main purpose study of effect due to Aspect Ratio ONLY could be compromised.

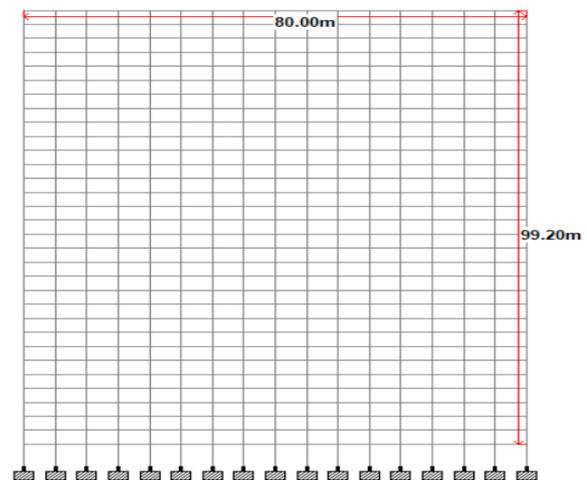
6.3.5 Structure Figures

1) Model A 80.0M X 80.0M

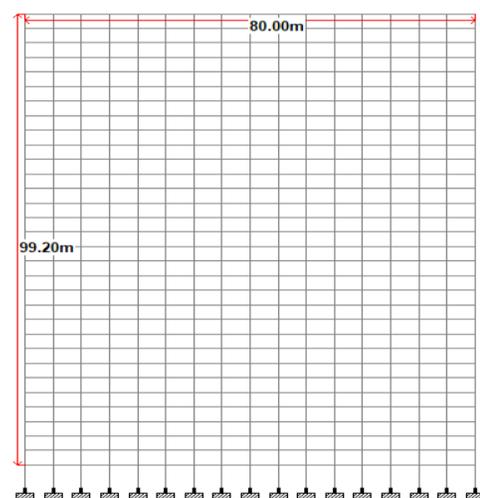
a) Plan



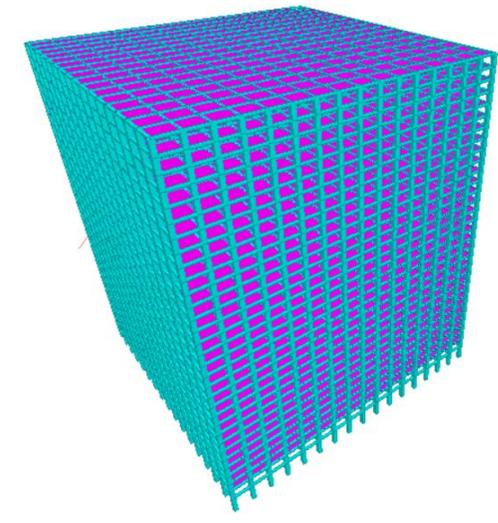
b) FRONT ELEVATION



c) SIDE ELEVATION



d) 3D VIEW



influence of wind load on structure and are only compared for study.

SL.NO	MODEL	BASE AREA	ASPECT RATIO	SF-Z (KN)	BM - MY (Kn-m)	MAX. DISPLACEMENT IN Z(mm)	MAX. STOREY DRIFT (mm)	REMARKS
1	A	80X80	1.24	88.8	187.75	7.525	1.53	
2	B	140X60	1.65	89.1	188.62	11.03	1.56	
3	C	100X50	1.98	91.2	189.19	13.22	1.59	
4	D	150X40	2.48	93.5	191.47	17.04	1.65	

The results for analysis as tabulated above indicate that the Aspect Ratio has inverse effect on all critical parameters for study. The values are for study and are not in any way indicate the design values.

The Bending moments in column are very important along with shear force for the design purpose. The study clearly indicates the increase in Aspect ratio has positive effect on stability of the buildings. The reduced displacement and story drifts for higher Aspect ratio can form the basis for design of tall structures. The reduced sway gives a great comfort for the occupants and forms critical user parameter for design. The analysis has taken in to consideration only the influence of Aspect ratio and uniform wind in static analysis. Hence the results clearly indicate the strong influence of these parameters to be adopted for economical design.

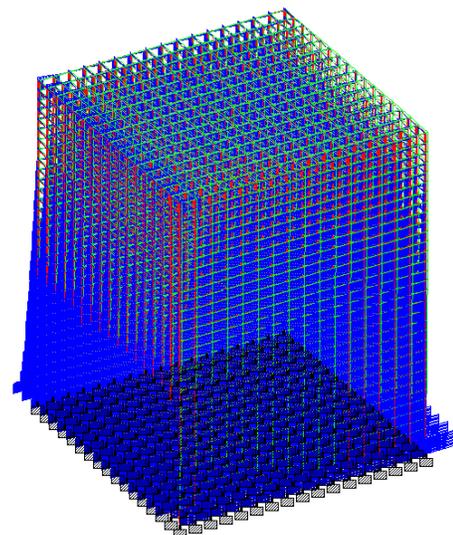
6.4 Load Combinations :- The comparison of results is predominantly for service conditions such as displacement and drift. No designs are carried out under limit state. Hence the factors adopted for analysis in 1 only. Hence Only Service load combinations are used for analysis. Combination 1: DL+LL, Combination 2: DL+WL, Combination 3: DL+LL+WL

6.5 Models for Comparative Analysis: Four models are adopted for study have common height of 99.20 m with G+30 Story building with 3.20 m floor heights. The column and beam size as mentioned earlier are common. Loading is also common. Only base area is changed for different models leading to different Aspect Ratios.

Model Comparison

Sl. No	Model No.	No. of Floors	Floor Ht (m)	Column Grid	Column Size (m)	Beam Size (m)	Slab Thickness (m)	Base Area (mxm)	Aspect Ratio
1	A	G+30	99.2	5.0x5.0	0.9 x 0.9	0.5 x 0.5	0.15	80X80	1.24
2	B	G+30	99.2	5.0x5.0	0.9 x 0.9	0.5 x 0.5	0.15	140X60	1.65
3	C	G+30	99.2	5.0x5.0	0.9 x 0.9	0.5 x 0.5	0.15	100X50	1.98
4	D	G+30	99.2	5.0x5.0	0.9 x 0.9	0.5 x 0.5	0.15	150X40	2.48

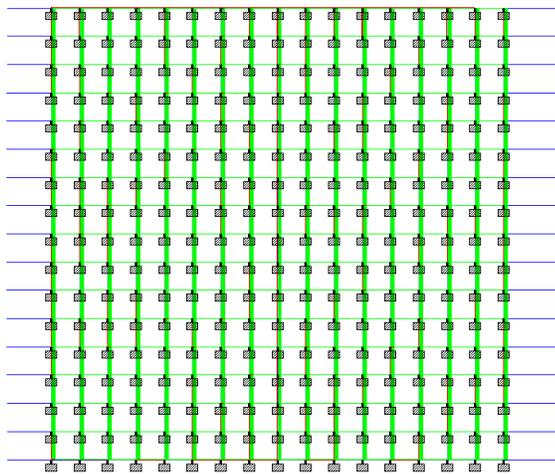
8. Shear Force and Bending Moment Diagram of Model 80m X 80m.



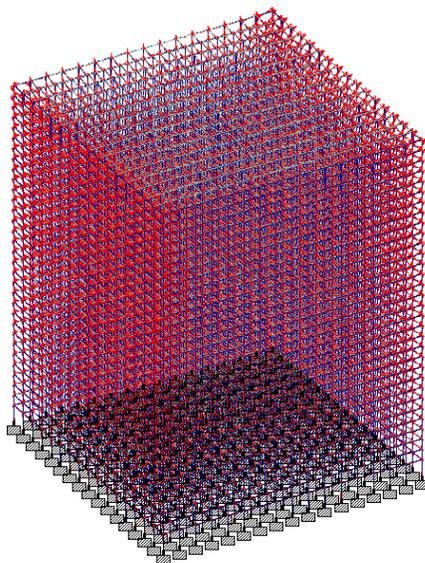
Shear Force (Elevation View)

VII. RESULTS AND DISCUSSIONS

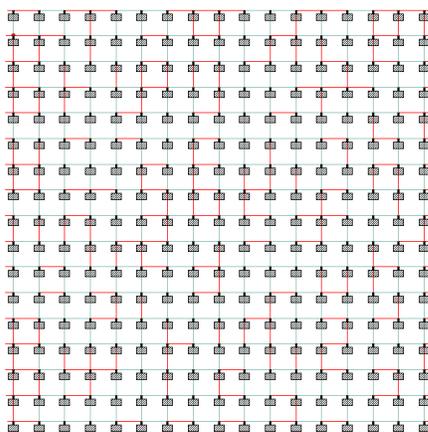
The buildings as conceptualized are loaded accordingly and analyzed in software as per the standard practices. The parameters under study are identified as Bending Moment in columns, Shear Force in columns, Maximum Displacement of nodes and maximum Story Drifts. These are the indicative parameters which indicate the



Shear Force (Plan View)



Bending Moment (Elevation View)



Bending Moment (Plan View)

VIII. CONCLUSION AND RECOMMENDATION

The study of different configuration models with different aspect ratio are clearly indicating the trend of directions of critical parameters adopted for study viz Bending Moment, Shear Force, Displacement and Story Drift.

This can be conclusively recommended to adopt lower Aspect Ratios for Tall buildings to specifically reduce the adverse effect purely due to wind load.

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