Analytical Study of Shape of Tall Building Subjected to Wind Load for Steel Frame Structures

Shital.A. Patage, Abhay.B. Shelar, Supriya B Shinde, Rakesh Kumar
Department of Civil Engineering, Anantrao Pawar College of Engineering & Research, Parvati, Pune

Article Info
Page Number:12854 - 12860
Publication Issue:
Vol 71 No. 4 (2022)

Article History
Article Received: *15 September 2022*
Revised: *25 October 2022*
Accepted: *14 November 2022*
Publication: *21 December 2022*

Abstract
Shapes like rectangles, circles, hexagons, and pentagons at different heights are used to assess the stability of skyscrapers. Using a wind rise diagram and the STADD pro for Steel Frames design program, the experimental investigation will examine the impact of a building's shape on wind load. An FEM study is used as the foundation for the load calculations. Consequently, several research and investigations have been conducted to lessen the possibility of such an excitation and to strengthen tall buildings' resilience to the consequences of wind loads and earthquake loads. The architectural design of tall buildings relies heavily on the early integration of aerodynamic form and structural system choices in order to lessen the building's sensitivity to wind excitations.

Keywords: High-rise Building, Wind load Effect, Earthquake load effect.

1 Introduction

The growth of urban populations as a consequence of increased industrialization points to a prosperous future for the construction of high-rise housing and office buildings. There are already 3.5 billion people residing in urban areas, and it is anticipated that this number will increase by an additional 3 billion during the next 30 years. An unprecedented number of skyscrapers have been built in India's largest cities as a result of the enormous increase in the country's population as well as the scarcity of accessible land. This indicates that there is not enough flat land available to accommodate the urban population of the globe at its present density. Therefore, it is vital to acquire knowledge about the examination of high-rise buildings.

Wind effects on tall buildings

Tall buildings are especially susceptible to damage from the wind, which may come from unexpected directions and be very severe. A tall building may be likened to a mast, which is firmly planted in the ground yet moves and twists in response to the wind. This form of movement is known as wind drift, and it has to be managed in order to prevent damage. In addition, the wind drift for a high-rise structure that has been thoughtfully designed shouldn't be any more than the height of the building divided by 500. The amount of wind pressure that is put on a structure may be significantly affected by the height of the building. In addition to this, the wind pressure rises according to the cube of the wind speed, and wind speeds increase with increasing altitude. Due to the existence of turbulent flow, which can be described analytically, the wind speed profile within this layer may be calculated.

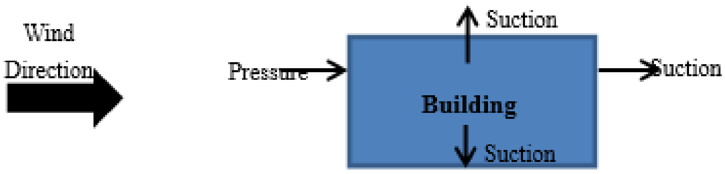

Figure1: Effect of wind loads on a structure

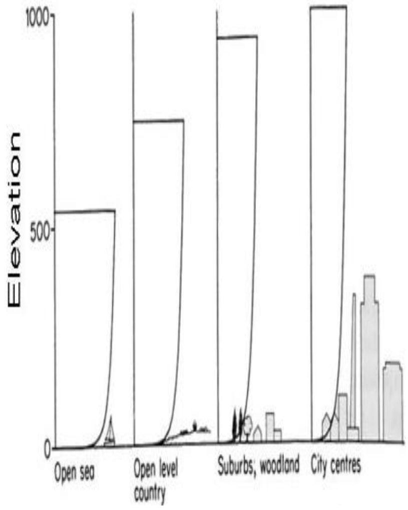

Figure 2: Mean wind profiles for different terrains.

Vortex-shedding phenomenon

Along the wind and across the wind are the two primary directions that are employed when describing the phenomena known as "vortex shedding." The forces that cause drag are often referred to as along wind, wind, or just wind. A motion that takes place in a plane that is perpendicular to the direction that the wind is blowing is referred to as the across wind response. The lines of the wind stream, which were originally parallel, are displaced on both transverse sides of the building when a structure is exposed to a wind flow, which creates what are known as vortices (Fig. 2).

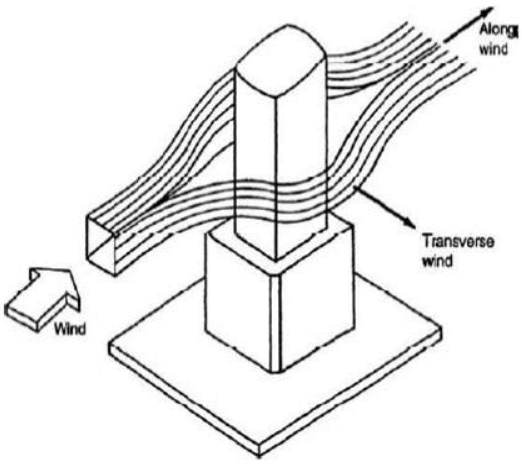

Figure 3: Simplified wind flow

When the wind speed is relatively modest (Fig. 3 a), the vortices are shed symmetrically on each transverse side of the structure, preventing the building from swaying in the direction perpendicular to the wind.\

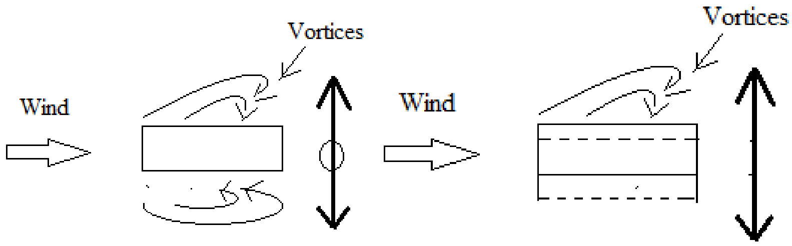

Fig. 3 shows vortices at a range of wind speeds, from low-speed vortices (where there is no vibration in the across wind direction) to high-speed vortices (where there is such vibration) due to the vortex-shedding phenomena. The vortices, on the other hand, lose their energy alternately from one side and then the other as the wind speeds increase. When anything like this takes place, there will be a force acting in both the along- and across-wind directions. The gusts of wind coming from the opposite direction are first given to the left side, and then they are switched over to the right side. In the field of fluid mechanics, this kind of structural vibrations in the flow and across the wind direction is referred to as "vortex-shedding," and it is a well-known phenomenon. The phenomenon of the shedding of vortices alternatively may be seen in Figure 2b, which depicts the performance of a rectangular high-rise building. These findings are highly shape-dependent. As a consequence of this, architects are beginning to think about the aerodynamics of the design of ultra-tall structures a great deal earlier on in the process of developing these skyscrapers. Curtain wall loads have a tendency to grow with height as a result of the general increase in wind speeds that occurs with height, as well as the increase in winds that occur at ground level and on terraces or balconies. All of these effects will be obvious to architects and developers who have experience working on tall structures, and they will identify them as potential problems that can be solved by wind tunnel testing.

When designing a structure, architects and engineers need to be aware of the expected wind loads on the building so that they can create resistance systems that are both efficient and effective. According to Suresh Kumar (2011), the prevalent practice in India is to avoid carrying out any wind tunnel research and instead to base building design only on the wind load requirements of the IS 875 (1987) Standard. This is done under the incorrect assumption that the calculations provided by the code offer the definitive answer. In contrast to what is stated in the codes and standards, it is possible to physically model and anticipate the aerodynamic influence of the actual shape of the structure by using wind tunnel testing. Davenport (1971) conducted wind tunnel tests on aerodynamic models in order to investigate the consequences of form from a wind engineering point of view. Hayashida and Iwasa (1990) also explored the influence of building shape on extremely tall buildings by using rigid models. They did this research. Dutton and Isyumov (1990), Kawai (1998), and Tamura and Miyagi (1999) all conducted in-depth study on the issue of changing corners and the impact that this had on the aerodynamic forces exerted by the vehicle. In this inquiry, our primary emphasis is on determining how the wind loading changes across a variety of geometric shapes depending on the direction of the wind. Additionally, the standards of IS:875-

1987 and ASCE 7-2005 are compared to the computed wind loads in order to evaluate the accuracy of the results.

According to Zhou et al. (2003)'s suggestion, commercial wind tunnel assessments of buildings in their actual surroundings have the potential to give useful new loading data. In the ASCE 7-05 comments, there are some encouraging references to the use of databases for preliminary design, such as http://aerodata.ce.nd.edu/interface/ interface.html. These references are quite encouraging.

In this inquiry, we analyze the impact of the building's shape under wind load by using the design tool STADD pro for RCC and for Steel Frames, and we compute the loads based on a finite element model.

Objectives:

I. To explore the effect of building shape on wind induced response of structure through FEM analysis for Steel Frames

II. To provide base line values for wind load, computed response against the value given in IS 875(1893)

III. To compare square, rectangular, circular, pentagon and Hexagon.

IV. To analyze the different shapes and their effects on building by using design software.

Literature Review:

In 2015, Anupam Rajmani and Priyabrata Guha(2) carried out wind and seismic load assessments for a wide range of high-rise building configurations. The authors claim that flexible structures are particularly susceptible to the impacts that wind stimulation may have on the individuals who are inside of them. As a result, a wide variety of research and investigations have been carried out in order to mitigate the impacts of such an excitation and to improve the resistance of tall buildings to the stresses imposed by wind and earthquakes.

SanhikKar Majumder and Priyabrata Guha(21) conducted a study in 2014 to examine the effects of wind and seismic loads on a variety of building designs. In this research, lateral loads from wind and earthquakes are evaluated and contrasted in order to inform the design of reinforced concrete structures, with an emphasis on tall buildings, in accordance with the Codes IS: 875(PART - 3), IS:-1893-2002(PART-1), and IS:875(PART-1 AND PART-2) respectively. The purpose of this study is to inform the design of reinforced concrete structures that can withstand extreme lateral loads. Software is developed in order to do studies of different kinds of buildings that are exposed to wind loads and seismic shaking in accordance with relevant building codes. The evolution of different structures in terms of lateral loads is discussed along with some ideas for development. According to the findings of the study, each and every structure is susceptible to the forces of the wind, and the requirements of the code for wind speed and direction vary depending on the location and orientation of the building. The constructions will be more adaptive and cost-effective in the case of Load instances 5, 2, and 1 based on the basic wind speed of 50 meters per second and the zone factor of zone 2. They aim to broaden their study to discover which structures will be the most cost-effective in the event that the basic wind speed and zone factor in any region of India is changed. This is because they are concerned about the possibility of climate change.

Methodology

In this investigation, five different architectural forms for a (G+20) structure were selected for analysis. The seed structures' cross-sections all resembled one of the five study forms, but the seeds' heights and widths were different. It was important to standardize the data to reflect a common building form so that it could be compared and loading patterns for specific shapes could be identified. Standard architectural forms were used for this analysis. Pictured in Figure 1 is a seed construction of each of the investigated forms. It was important that the sample seeds be located in an open area, free of nearby buildings and other obstacles that may alter the wind conditions. Four structures were found in the database for each of the five fundamental building footprints studied. It's important to remember that the research accounted for seeds with a wide range of Reynold's numbers (Re) in its analysis. Each experiment's Re variation was capped to 150,000.

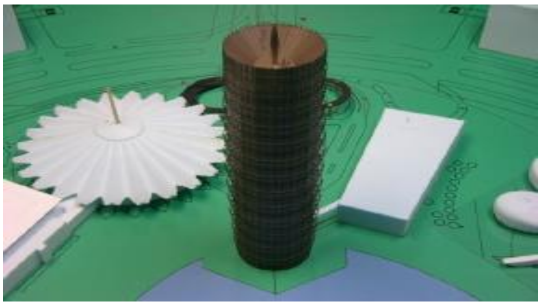

Fig.1 circular shape building

Fig.2 square shape building

Fig3 Rectangular shape building

Fig4 Triangular shape building

Fig5 Elliptical shape building

For the present study loads considered are as:

DEAD LOAD: Dead loads shall be calculated on basis of unit weights which shall be established taking into consideration the materials specified for construction. This consists of walls, partitions, roofs, floors including the weights of all other permanent structure. It may be calculated on the basis of unit weights of material given in IS 875(PART-I)

IMPOSED LOADS: Imposed loads are produced from the weight of movable partitions of building, uniformly distributed and concentrated loads. For structure carrying live loads which induced impact and vibration. Imposed loads shall be assumed in accordance with IS 875(PART-2)

WIND LOAD: The IS 875(part-3) deals with wind loads to be considered when designing building, structure and components thereof,

CONCLUSION- In this investigation, we use the design program STADD pro for RCC to examine the impact of the building's form under wind load, and we calculate the loads based on a finite element model. The results of a wind load calculation performed in line with IS 875: Part-3 are as follows:

1.Load displacement in the +VE and -Ve X directions is reduced by 25% compared to rectangular and pentagonal shapes.

2. Rectangular displacement is 15% less than that of square or pentagonal under the same +VE and -Ve Z loading conditions.

References:

[1] American Society of Civil Engineers. 2005. "ASCE 7-05 Standard Minimum Design Loads for Buildings and Other Structures". Reston, Virginia.

[2] Kumar, A., Dhabliya, D., Agarwal, P., Aneja, N., Dadheech, P., Jamal, S. S., & Antwi, O. A. (2022). Research Article Cyber-Internet Security Framework to Conquer Energy-Related Attacks on the Internet of Things with Machine Learning Techniques.

[3] Gupta, S. K., Lanke, G. R., Pareek, M., Mittal, M., Dhabliya, D., Venkatesh, T., & Chakraborty, S. (2022). Anamoly Detection in Very Large Scale System using Big Data. 2022 International Conference on Knowledge Engineering and Communication Systems (ICKES), 1–6. IEEE.

[4] Joshi, K., Kumar, V., Sundaresan, V., Karanam, S. A. K., Dhabliya, D., Shadrach, F. D., & Ramachandra, A. C. (2022). Intelligent Fusion Approach for MRI and CT Imaging using CNN with Wavelet Transform Approach. 2022 International Conference on Knowledge Engineering and Communication Systems (ICKES), 1–6. IEEE.

[5] AnupamRajmani and Prof PriyabrataGuha "Analysis of wind & earthquake load for different shapes of high rise building" International Journal of Civil Engineering and Technology. 2015, 38-45

[6] Davenport, A.G. 1971. "The Response of Six Building Shapes to Turbulent Wind". Philosophical Transactions of the Royal Society of London. 1199, 385-394.

[7] Davenport, A.G. 1971. "The Response of Six Building Shapes to Turbulent Wind". Philosophical Transactions of the Royal Society of London. 1199, 385-394.

[8] Dutton R. and N. Isyumov. 1990. "Reduction of Tall Building Motion by Aerodynamic Treatments" Journal of Wind Engineering and Industrial Aerodynamics. 36, 739-747.

[9] Eswara Kumar Bandi , Yukio Tamura, Akihito Yoshida, Yong ChulKim, Qing shan Yang "Experimental investigation on aerodynamic characteristics of various triangular-section high-rise buildings" Journal of Wind Engineering and Industrial Aerodynamics 2013,60–68

[10] Hayashida, H. and Y. Iwasa. 1990. "Aerodynamic Shape Effects of Tall Building for Vortex Induced Vibration",Journal of Wind Engineering and Industrial Aerodynamics. 33, 237-242.

[11] HosseinMoravej, Mahdi Hatami, Reza Naghshbandi, YaserMousaviSiamakani "Wind load analysis of buildings in hill-shape zone" International Journal of Applied Sciences and Engineering Research.2015,1-14

[12] I.Venanziand A.L. Materazzi "Across wind aeroelastic response of square tall buildings: A semi-analytical approach based of wind tunnel tests on rigid models" Wind and Structures.2012, 1-14.