A Critical Review on Effect of the Wind Load on Different Type and Shape of the Building

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Abstract

The force that results from the wind blowing against a building acting on the elevations is known as the "wind load." In order to prevent structural collapse, the building's structural design must safely and effectively absorb wind forces and transfer them to the foundations. It can be challenging to anticipate wind loads with accuracy because they often rely on the wind speed and the shape (and surface) of the building. Any consequences of over- or under-pressure could be made worse by the design of the building. Windows may be blown out on the leeward side (sheltered from the wind) by under-pressure (suction), whereas windows may be blown in on the windward side (facing the wind). Similar to how a circular building will deflect the wind more successfully than a square one, a glass-clad structure with a very smooth profile will typically do so. In order to identify the gaps in the existing literature, we have studied the material that is currently accessible on the design and analysis of steel-framed structures for wind loading with variously shaped buildings and roof types. The purpose of this research is to investigate, via a review of the literature, the effects of wind loading on building shape and roofing system type in steel framed structures.

Keywords: *wind load, mono slope roof, flat roof, rectangular building, steel frame structure.*

1. INTRODUCTION

Any building's structure is subject to a variety of loads, starting with the weight of the structure itself, which is brought on by gravity. Similar to this, the structure must be able to withstand the "living load" that comes from people, furniture, fixtures, etc. The structure must be able to withstand its own weight as well as wind, earthquake, and other loads. Buildings, other structures, other parts, and cladding must all be built and engineered to withstand wind loads. [1]

In general, wind speed in the atmospheric boundary layer rises with height, reaching a maximum at what is known as the gradient height from zero at ground level. The Code ignores the Ekman effect, a minor change in direction that frequently occurs. The topography factors most heavily into the change in height. It has been found convenient to resolve the wind speed's instantaneous magnitude into an average or mean value and a fluctuating component around this average value because the wind speed at any height never stays constant. The average number is dependent on the length of time used to average the meteorological data, which might range from a few seconds to several minutes. The length of the average period affects the size of the variable component of wind speed, which symbolises wind gustiness. The magnitude of the wind speed increases as the average interval decreases.

The fundamental wind speed is defined by code as the max gust wind speed averaged over a 3 second period. It includes the turbulent wind's mean and fluctuation components. You can multiply the 3-second value by 0.65 to get the hourly mean wind speed. The conditions for which Vb is defined have been described in this clause for the open terrain category because, in addition to the location of the country, wind speed varies with height, ground roughness, local topography, and storm return time. Six wind zones have been established for the nation, and certain coastal areas are susceptible to cyclonic storms as described in IS 875 2015 clause 5.3.4. [2]

Table 1.1: Wind speed in various zones in India

Zone 1	33 m/sec
Zone 2	39 m/sec
Zone 3	44 m/sec
Zone 4	47 m/sec
Zone 5	50 m/sec
Zone 6	55 m/sec

1.1 Mechanism of Wind Loads on Structures

Any sort of structure's design must take wind load into account. The load that the wind places on a structure's exterior, measured in kN per square metre, is known as the wind load. This is dependent upon:

The angle at which the wind strikes the structure
The shape of the structure (height, width, etc.)
Strengthening vulnerable building areas is necessary to prevent wind damage. Strong and secure connections must be made between the walls, roof, and foundation as well as between each of these components. A structure must have connections that connect all structural parts and can withstand different types of wind loads that could push and pull on the building in a storm in order to be able to withstand hurricane and weak tornadic winds. These connections must run continuously from the roof to the foundation.
Wind exerts three types of forces on a structure:
Uplift load - winds with high lift pressures, similar to what happens to an airplane's wings. Wind flow over a roof pulls upward while wind flow under a roof pushes that direction.
Shear load – Horizontal wind pressure that could cause racking of walls, making a building tilt.
Lateral load – Vertical pushing and pulling pressure that could cause a structure to topple over or fall off its base.
Doors, windows, roofing, and roof decking can all be destroyed by strong winds, in addition to gable end walls. Particularly vulnerable to harm are roof overhangs and other characteristics that have a propensity to trap air beneath them, producing strong uplift forces. Building contents can sustain substantial damage from internal wind pressures and water infiltration due to broken windows and doors. [3]

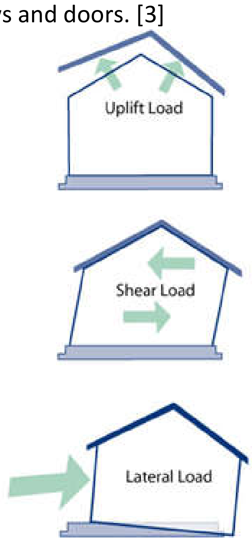

Figure 1.2 Loads acting on structures due to wind loads[4]

2. LITERATURE REVIEW

Here we have reviewed the past literature available related to wind load analysis of framed structure and also the effects of aspect ratio and roofing type on building wind loading has been reviewed.

Aditya Kumar Jha et. al. (2022) used Ansys CFX fluid flow software to carry out the simulations using a standard k-ε turbulence model. The simulations had been run for 7 different wind incidence angles, spaced 30 degrees apart. On the roofs, pressure, force, moment, drag, and lift coefficients were compared. Although the variance in these coefficients with respect to the wind incidence angles was identical for both types of roofs, it was discovered that the pitched roof's steep rooftop contributed to higher magnitudes of these coefficients than the smooth arch roof. In order to obtain the face average of pressure coefficients, associated pressures, and forces for each given wind incidence angle, mathematical modules between the face average of pressure coefficients and the wind incidence angles were developed in a polynomial form. [5]

Barkha Verma et. al. (2022) studied the various types of the aspect ratios of the building and the impact of wind pressures on the structure as well as four building models with various Horizontal Aspect Ratios, including 1, 2.25, 4, and 9. The height of the building is 96 metres. In the terrain category, a comparison of regular and irregular constructions was made using the criteria of storey displacement, storey drift, and storey shear. They came to the conclusion that the base shear gradually increases as the number of spans increased. Additionally, the base shear was higher for buildings with 20 spans than it was for those with 2 spans. The 2 bay (square) building had the lowest value, while the 20 bay (rectangular) building had the highest value. [6]

Seung Yong Jeong et. al. (2021) studied extensive nonlinear analysis including the generation of 1,000 wind load time histories and they produced elaborate design techniques. For the preliminary design (PBWD) of tall and/or irregular buildings, the suggested approach of producing wind load time histories based on PSD functions can be especially helpful. During the initial elastic design, the resonant component was diminished by the RW factor to induce inelastic behaviour. They came to the conclusion that time-history wind load derived by PSD functions can be used for preliminary PBWD. In order to calculate time-history wind loads for an NTHA, factors such as progressive loading and unloading, vertical distribution of mean and background rather than the mode form of the resonant component, and maximum load occurrence must be taken into account. 3. Although it is inexpensive to generate wind load time histories, it is still advisable to confirm final performance using the results of wind tunnel tests due to certain limitations, such as the absence of precise PSD functions for various structure shapes and wind directions, uncertainties in the local wind pressure, and aerodynamic instability (an aeroelastic wind tunnel test is occasionally required). [7]

Juliya Mironova (2020) aimed to model wind flows to determine maximum aerodynamic wind effects on multi-storey buildings and their surroundings. Additionally, they sought to enhance the formula for calculating maximum wind load in relation to building height and proximity. They investigated numerical studies on simulating the distribution of wind flows for an existing low-rise building in a virtual wind tunnel. Based on their findings, a proposal was made to add an increasing coefficient to the expression used to calculate the wind load based on the height and proximity of multi-story buildings. When putting multi-story and high-rise buildings inside of existing structures, the results can be utilised to calculate the wind loads during the reconstruction of low-rise buildings and for their verification calculations. [8]

Abba M. Alkali et. al. (2019) provided an assessment for high-rise building wind design using both software's and they also aimed to improve the maximum wind load formula in respect to building height and closeness. In a fictitious wind tunnel, they looked into computer calculations that simulated the distribution of wind flows for an existent low-rise building. According to their research, it was suggested that the formula used to determine the wind load based on the height and proximity of multi-story buildings be modified to include an increasing coefficient. The results can be used to determine the wind loads during the reconstruction of low-rise buildings and for their verification calculations when placing multi-story and high-rise buildings inside of existing structures. [9]

Jagbir Singh and Amrit Kumar Roy (2019) studied twenty-four models with different roof slopes (α), i.e. 0°, 10°, 20°, and 30°, with various wind incidence angles (Ɵ), i.e. 0°, 15°, 30°, 45°, 60° and 75° were investigated. In this study, the effects of roof slope and wind incidence angle are examined. The pressure coefficient (Cp) contours on the roof surface and the velocity streamlines of the flow field of the various scenarios have been used to show the results. Different wind incidence angles for structures may be taken into account to optimize the roof slope so that they can better withstand wind force in a particular area. When wind pressure coefficients from buildings with and without openings were analyzed, it was shown that the pressure coefficients for buildings without openings are about twice as high as the pressure coefficients for buildings with openings. [10]

Gregory A. Kopp et.al. (2018) examined the component and Using measured pressure data from an aerodynamic database, cladding wind load provisions for low-sloped roofs on low-rise buildings in ASCE 7–10. The dimensions of the roof zones in ASCE 7–10 as well as the design pressure coefficients were discovered to be substantially smaller than what the evidence suggested. According to the statistics, the size of the roof zones are most significantly influenced by building height, but the impact of plan dimensions on this class of buildings is rather small. The development of recommendations for improved roof zones resulted in changes to the corner zone's outline, the addition of a new inner zone far from the roof edges, and a definition of zone size that is solely dependent on building height. The collected data revealed that the design pressure coefficients must be raised in the corners and edges even with larger roof zone widths. [11]

Kiran Kumar and U. Dhiyaanesh (2018) compared the effect of wind loads on some of the commonly used non-circular shapes. C Shape, Plus Shape, and Rectangle Shape are the chosen shapes for comparison. The architecture of the structures should be such that they are both cost-effective and have enough wind resistance. The size of structural members is kept as small as possible to attain these outcomes without compromising the stability of the system. All three of the plans' areas are the same across the three. To determine the effectiveness of the structures, the raised structures' responses to the ground and deflections were compared. In order to provide future structures with a reference for the sizes of the columns and beams, each building was built to three heights: four stories, ten floors, and fifteen floors. They found that plus shapes, followed by C shapes and rectangles, and were the most wind-resistant section types. The C form segment was the most cost-effective, followed by Rectangle and Plus shape. [12]

Mohammed Ali et. al. (2018) presented story drift, story shear, and support reactions in different storey Buildings (Low Rise Buildings, Medium Rise Buildings, and High Rise Buildings) due to wind in different terrain category. A total of 12 G+5, G+10, and G+15 models were examined using the ETABSv9.7.4 software. They provide a reliable source of information regarding variations in drift and shear, which are compared as changes in model height and percentages of drift and shear in various terrain categories. They came to the conclusion that the values of storey drifts in G+5 building designs were consistent in all terrain categories up to the second story and declined to the first storey, indicating that the wind had less of an impact on short rise buildings. [13]

A. D. John, A. K. Roy and A. Gairola (2012) a wind tunnel research was conducted to evaluate the wind loads on 25 degree low-rise gable building walls as a result of interference with freestanding boundary walls built on the upstream side at various locations. On the building's wall surfaces that had been prepared at a geometric scale of 1:25, mean and fluctuation pressures were monitored. Design pressures given in wind standards and critical values of positive and negative pressures measured on an isolated gable building accord well. Based on the results of the wind tunnel experiment, it has been determined that shielding occurs when the pressure coefficients on the building dramatically decrease at various distances from the interfering wall. [14]

Alok David John et. al. (2009) established a wider scope to investigate influence of architectural features on wind load in low-rise buildings. The wind's impact on buildings is a challenging issue because of variations in architectural characteristics and the impact of topography features. Further tests with documentation must be conducted in order to obtain more comprehensive information on pressure on low-rise gable buildings. The knowledge at hand was yet insufficiently complete to allow for the formulation of definitive laws on the impact of various architectural aspects on wind loads in low-rise buildings. [15]

John D. Holmes et. al. (2008) described a comparison of wind load calculations on three buildings using up to fifteen different wind loading codes and standards from the Asia-Pacific Region. The low-rise structure was a typical industrial warehouse structure made of steel portal frames that was most likely situated in a rural region. A 48-meter-high office building in a tropical city makes up the medium-sized structure. The 183-meter-tall high-rise structure was situated in an urban area. Other wind characteristics, such as turbulence intensity, and the design wind speeds at the top of each building were specified. There were various levels of agreement amongst the comparisons. They came to the conclusion that there was no significant link between the along-wind load effects, such as base shears and base bending moments, and dynamic response factors or gust loading factors for the medium-rise building (Building 2). However, there was some link found between the net peak cladding force coefficients and the cladding pressures. It was also acknowledged with clarity that some clusters exhibit almost identical or comparable behaviour as a result of the sharing of some common standards and source codes. The coefficients of variation for both along-wind overall load impacts and cladding pressures were estimated to be between 22 and 23 percent using the mean values and coefficients of variation of the fifteen codes and standards in the Asia-Pacific area. The calculation was performed under a well-harmonized condition, where the design wind speed, the intensity of the turbulence at the building's top, the first mode damping ratio, and the natural frequency were all provided. As a result, the calculation's relatively high coefficient of variation is somewhat unexpected. It should also be emphasized that the interrelation of the codes/standards renders the estimated statistical values, such as mean value or coefficient of variation, to be of only limited significance. [16]

Deepak Prasad, Tuputa Uliate, and M. Rafiuddin Ahmed (2008) carried out wind tunnel testing of low-rise building models with flat, gabled and hip roof configurations in a boundary layer wind tunnel. The average height of each model was the same. The pitch angles that were looked at for gabled and hip roofs were 15, 20, 30, and 45 degrees. In order to calculate the values of the pressure coefficient, pressure measurements were taken on all the walls and the roof of the building models that were exposed to a turbulent wind of 7 m/s. It was discovered that the roof configuration has a substantial impact on the suction over the roof. Under the same wind circumstances, the 45-degree gabled and hip structure models performed the best. When compared to the flat roof, the peak suction over the roof is reduced by 85 and 91 percent, respectively. In addition, compared to their gabled counterparts, the hip roof models registered less suction. [17]

Kai Wang et. al. (2006) investigated the low building wind load fluctuation over various terrain configurations, paying great attention to localized small-scale changes in roughness. It was discovered that the terrain configurations a short distance upwind of the site dominate the peak wind loads. The main findings of this study are presented in this report along with comparisons to the ASCE 7 requirements for low buildings. [18]

Yin Zhou et. al. (2002) investigated the value of CFs in assessing different load effects. A non-ideal mode shape was found to have little effect on the displacement response and base bending moment, but not on other load effects, such as base shear and generalized wind load. The current methods worked well at adjusting the intended response component, but they shouldn't be applied arbitrarily to other load effects. A loading structure that was particularly appealing for implementation in codes and standards, design practice, as well as for the accurate interpretation of wind tunnel results, was also offered by them as a corrective process for the influence of mode shapes on the ESWLs. [19]

3. CONCLUSIONS

As per the research done in the past, lots of researches have focused on wind load effect in steel framed structure to reduce the effect of lateral loading for instance seismic loads and wind loads. So we can conclude following conclusions from the literature review studied:

- Studies on steel structures by the past researchers have shown that aspect ratio of building plays a vital role in the design of the structure.
- Each type of roof configuration has a different effect of wind loads acting on it and load transferred mechanism id is different for each types of roofing systems.
- Roof slope angles plays an important role in the design of structures as the wind directional angels changes, the pattern load transmission in the structure's changes.
- Very few have studies the effect of aspect ratio along with different types of roofing systems. Combine action of shape of building and roofing system still needs though research.
- Most of the studies are on high rise building, not much literature is available on low rise building and also shape of building roof shape was not considered in most of the past research work. More focus was on flat and pitched roof in past research.

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