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A Literature Study of Wind Assessment between two tall buildings for pedestrian wind comfort

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Abstract - *with issue of scarcity of land people wants to win the race of designing beautiful and complex structures and it is today's necessity to go higher and higher vertical and construct high rise structures. But as we go higher, wind excitation becomes one of the most precarious force acting on the surface of the structure which in turn has a great impact on pedestrian comfort around the building. to assess the pedestrian wind comfort and safety, wind assessment around the tall building is required. Therefore, this study concluded that the analysis of wind behaviour along the centreline of the passage at the pedestrian level between the two tall buildings through wind tunnel experiments is important.*

Key Words: **wind assessment, tall buildings, spacing between tall buildings, wind behaviour, Pedestrian level wind comfort, wind tunnel experiment**

1. INTRODUCTION

Wind forces in atmosphere are random in nature and vary with space and time. Wind speed in atmospheric boundary layer increases with height from zero at ground level to maximum up to a height called gradient wind height, where the wind speed conditions are independent of the ground surface friction. The variation of wind speed with height primarily depends upon the terrain conditions. The wind speed at any height never remains constant and resolving an instantaneous velocity magnitude gives a mean and fluctuating component of velocity at that instant of time. The magnitude of fluctuating component of the wind speed is called gust. Wind velocity, wind direction, turbulence intensity and turbulence spectrum of fluctuating wind are the main wind characteristics.

Evaluation of pedestrians wind conditions has developed as a sub branch of computational wind engineering, which covers loads on constructions, simulating boundary conditions for indoor climate problems and building heat losses, ventilation of urban spaces etc. The evaluation of pedestrians wind conditions as a tool for urban planning is scattered by the broad range of other parameters influencing the quality of urban spaces. In general, urban spaces should be designed as a compromise between all these parameters, but the task of taking all parameters into account is still too comprehensive.

The study of pedestrians level environment around a building generally focuses on the comfort and safety of pedestrians for a range of wind conditions. Measurements of wind speeds for different wind directions are made at various locations on main pedestrians routes on a scaled model of the project site. Since, only wind conditions near the ground have a direct effect on pedestrians, a low measurement height is normally adopted for pedestrians wind studies. Most commonly used heights are in the range of 1.5m to 2m above the ground at full scale. The pedestrians level wind environment around tall buildings is mainly affected by the following factors:

- Inflow characteristics (mean velocity and turbulence intensity)
- Angle of wind incidence
- Shape of the buildings
- Orientation of the buildings (converging, diverging, perpendicular, parallel, tandem, staggered etc.)
- Passage or spacings between the buildings
- Surrounding structures
- Geometric proportions (plan ratio and height ratio) and characteristics (building width and height, cross-section etc.)
- Use of podium (height and width of podium, modification along the height etc.)

2. LITERATURE STUDY

WIREN (1975) conducted a wind tunnel study of wind velocities in passages between and through buildings, placing the buildings either in a row or perpendicular to each other, and varying the width of the passage between the models. A great number of arrangements, intended to reduce the wind speed in the passage, has been studied. Based on the test results it was concluded that, the wind speed in a passage between two buildings increases with increasing building dimensions, building height having the strongest influence. The effect of increasing the passage width is a slight reduction of the wind speed in passages between the buildings, in passages through a building the wind speed is practically independent of the passage width. In a passage between two buildings placed at right angle to each other, a considerable reduction of the passage wind speed may be achieved by staggering the buildings.

MELBOURNE et al. (1977) Paper noted that it is the forces caused by peak gust wind speeds and associated gradients which people feel most and discusses the relation between peak gust and mean wind speeds. To define a range of wind-speed probabilities, in particular, the frequency of occurrence of mean wind speeds, Melbourne's criteria, which have been stated in terms of maximum gust speeds per annum, were shown which then facilitates comparison between the various published criteria and shown that, in spite of the apparent numerical differences in published wind speed criteria and the various subjective assumptions used in their development, there is remarkably good agreement when they are compared on a proper probabilistic basis.

Stathopoulos and Storms (1986) carried out wind tunnel investigations to determine wind velocity and turbulence intensities in a passage between two rectangular buildings. The experiments were done under open terrain conditions for different wind directions. The investigated parameters are the height of the two buildings and the passage width. The results showed that the most critical wind velocity condition occurs for buildings of different heights and the most critical turbulence conditions are found for the wind direction perpendicular to the passage centre line. The wind velocity in the passage increases with the decrease in the passage width. The turbulence intensity decreases with the decrease in the passage width.

Paterson et al. (1986) developed two computer programs, they are, WIND and COMPLEX to compute the turbulent flows over three-dimensional rectangular surface mounted bluff bodies. Program WIND computes symmetric flow field over a single rectangular building, whereas program COMPLEX computes the asymmetric flow field over a group of buildings. In this computer modelling k-ε turbulence model was used to solve the steady state RANS equation and SIMPLE algorithm was used to solve partial differential equations.

Uematsu et al. (1992) studied the effects of the corner shape of a high-rise building on the mean and rms wind speed distributions at pedestrian level experimentally using wind tunnel. The experiment was carried out on 4 types of corner shapes. Shape of the corner affected both mean and rms values. It was concluded that the flow characteristics around the building usually changes with a small change in the shape of the corner of the buildings and that the degree of effect depends on the direction of the wind.

Hanquing Wu et al. (1993) investigated some characteristics related to Irwin's surface wind sensor performance like calibration of the sensor for measuring mean and rms wind speeds, the effect of sensor height on measurement of errors, the interference between nearby sensors and the response of sensor to turbulent wind conditions. Experiments were carried out to examine some important features for the performance of surface wind sensor. The major findings were considerable errors have been found when a short sensor is used to measure the flow at a higher level above the ground. The sensor may overestimate low frequency fluctuations of wind flow at the measurement level since the inlet on the base captures the wind signals below the sensor height where low frequency turbulence exists. The interference between sensors could be estimated as functions of the diameter of sensors.

Ted Stathopoulos et al. (1995) established some generic models with the empirical relations between wind conditions and building configurations. These models were applied for the preliminary estimation of pedestrian level wind environmental conditions in built up regions. The parameters considered are spatial density and height of the buildings, location of the building and wind direction. From this study it was concluded that the blockage ratio can be used to find the average wind speed. Also, the maximum speed amplification is a function of difference between height of tall building and the surrounding buildings.

Lam et al. (1995) investigated wind environment around the base of a row of identical tall buildings in the wind tunnel. The experiments were conducted under open terrain category on a square model (1:200) for three test cases (isolated building, four buildings arranged in a row and wind flow direction perpendicular to the row, wind flow along the row of buildings). The three conclusions made for the three test cases are: 1. The presence of adjacent buildings affects mean, rms wind speed and turbulence intensity. 2. Flow channelling is observed if the wind direction is perpendicular to the row. 3. Strong sheltering is observed for the downwind buildings if the wind blowing in the direction along the row of buildings.

Blocken et al. (2008a) conducted a wind tunnel test on two long and narrow buildings of converging and diverging type, simulating the open terrain wind speed profile to understand the wind passage. The results showed that the wind speed increased with increasing street canyon width and the wind speed of the diverging passage was higher than that of the converging passage.

The main purpose of the **Tetsu Kubota et al. (2008)** study is to reveal the relationship between the building density and the average wind velocity at pedestrian level in residential neighborhoods. Firstly, a series of wind tunnel tests on 22 residential neighborhoods selected from actual Japanese cities were carried out. The results showed that there is a strong relationship between the gross building coverage ratio and the mean wind velocity ratio. Secondly, by using the wind tunnel results and the climatic conditions of several major Japanese cities, the wind environment evaluation for case study areas is performed. By using the gross building coverage ratio, the development method of guidelines for realizing acceptable wind environment in residential neighbourhoods was proposed.

Hemant Mittal et al. (2018) presented a review of the methods for the assessment of pedestrian level wind climate, different wind comfort criterion and various techniques to evaluate the wind speed at the pedestrian level and also presented a brief review for the influence of different parameters related to building design and configuration on pedestrian level wind in later sections. Coming to the wind tunnel measurement techniques, use of Irwin probe is simple and accurate compared to hot-wire anemometry and it can be installed at numerous locations for simultaneous measurement of pedestrian level wind speed. Reynolds Averaged Navier Stokes based technique has been used by various researchers for numerical simulation, although this technique is not accurate as much as large eddy simulation and detached eddy simulation. The results from this review study are summarized as the wind climate statistics obtained from nearby weather station are obligatory for selecting the building shape, orientation and alignment of streets in urban planning and these wind statistics are compared with suitable wind comfort criterion and to simulate pedestrian level wind (PLW) environment, steady RANS method is the best choice economically, however, LES and DES provide more accurate results. Further to improve the accuracy of steady RANS using standard k-ε model, the effect of different model closure coefficient needs to be investigated in detail. Several parameters related to building design e.g. height & width of buildings have an adverse effect on PLW environment, however, building depth does not affect PLW environment significantly.

3. NEED FOR THE STUDY

India has seen unprecedented growth of tall buildings in recent years. This has mainly centred in cities like Mumbai, Delhi, Bangalore, Hyderabad and Chennai. Case studies of many buildings in Delhi Greater Noida and Mumbai have shown that there exists the potential for adverse wind effects in the vicinity of tall buildings in the country. The geometry of buildings, the proximity of surrounding buildings, the relative height of buildings and the effect of architectural features can all influence the wind environment in the vicinity of tall buildings. Hence, the pedestrians environment needs to be studied to avoid or minimize pedestrians discomfort around tall buildings. Also, the Indian wind code IS: 875 (part 3) – 2015 does not contain any references to pedestrians wind environment and there are no ordinances, urban design guidelines for the assessing the pedestrians level winds.

4. CONCLUSIONS

Review of Literature has been carried out on various aspects of wind related to the assessment of wind environment around tall buildings. An overview of tall buildings, pedestrian wind environment, comfort and safety proposed by various researchers, instrumentation, and techniques for carrying out wind tunnel investigations and numerical investigations using CFD has been studied. From the literature review conducted, importance of wind effects on tall buildings was revealed. Due to lack of proper codal provisions, all the studies conducted were problem specific and therefore discrepancies in the results were clear. There are many factors that affect the wind environment between tall buildings. One among those factors i.e., spacing between the buildings is considered and the magnitude of wind velocity along the centre line of two tall buildings were measured at pedestrian level for different spacings using Wind Tunnel.

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