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Pedestrian level Wind Characteristics around Tall Buildings: Effect of building Shape and Wind direction

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Abstract

Wind flow pattern in urban area strongly affects the comfort level of pedestrians, natural ventilation and pollutant dispersion. Wind flow pattern is influenced by many parameters, such terrain condition of building location, architecture of buildings, wind direction and arrangements of neighbouring buildings. In this study effect of building shape (square, tapered and setback) and wind direction on pedestrian level wind has been investigated.

Introduction

Rapid population growth and limited available land resources has led to urbanization particularly in metro cities. While designing dense urban areas natural ventilation and pedestrian comfort is an important factor. Generally building forms comprises of low rise medium rise and high rise buildings with complex shapes. So it is necessary to understand PLW environment around these building forms.

The wind flow pattern around buildings has been studied extensively in past by various researchers. Blocken and Careliet [1] conducted a review study since 1960 focused on pedestrian comfort. Stathopoulos [2] examined various comfort criteria, such as wind speed, air temperature and relative humidity. Stathopoulos [3] investigated the effect of corner chamfering on PLWs for different building heights (60-180m) Asfour S.O. [4] performed numerical simulation for the prediction of wind environment in different grouping patterns of housing blocks with the objective of ventilation potential of buildings.
Recently Tsang. C.W. et al [5] performed comprehensive wind tunnel study of PLWs around tall buildings with the effects of building dimensions, separation and podium. Tse. K.T. et al [6] investigated the effect of twisted wind environment on PLW flow around an isolated building for different aspect ratio.
With the advancement of computation power, CFD methods has been used to study wind flow around buildings. Blocken B. et al [7] performed CFD simulation for the evaluation of wind speed conditions in passages between parallel buildings at pedestrian height. Janseen W.D. et al [8] has conducted CFD simulation of PLWs for the campus of Eindhoven University of Technology and made a comparison of different wind comfort criteria. Zheng C. et al [9] performed wind tunnel and CFD simulation of PLW environment on outdoor platforms of a mega tall building. Iqbal Q. M. Z. et al [10] investigated the effect of building shape, separation and orientation on PLW environment
Du Y. et al [11] studied similar effect on different shape (-, L, U and, ■) of buildings using CFD under different wind direction and concludes that the lift-up design helps in improving the PLW comfort around lift up area.
Present study focuses on effect of building shape and wind direction on PLW environment. In this work isolated buildings has been considered to study their effects.

Experimental setup

The experiments were carried out in boundary layer wind tunnel at Department of Civil Engineering, Indian Institute of Technology, Roorkee, India. The tunnel is open circuit type with continuous flow of wind at variable speed. The wind tunnel test section is 15 m in length with a cross section of 2 m x 2 m.

The building models were fabricated at a length scale of 1/200 shown in Figure 1. Square model has dimensions 20m*20m*100m (b*d*h). Tapered and setback model has same base dimensions and height with tapering and setback ratio of 10%. So comparison has been made on the basis of same base area of the building models.

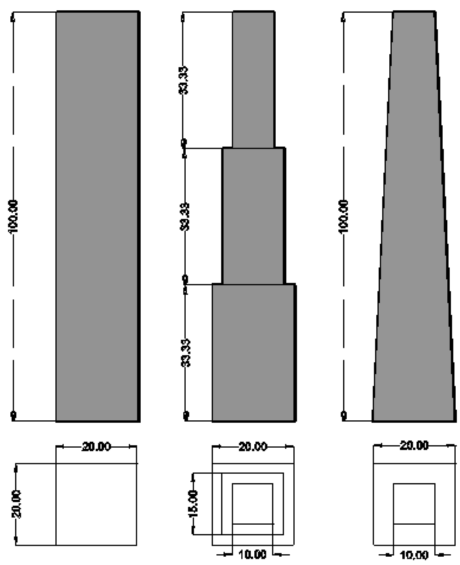

Figure 1. Details of building models

The mean wind speed profile of the approaching turbulent flow has power law exponent of 0.17, generated using a series of roughness blocks. Fig.2 shows the profile of normalised mean wind seed, U/Ur and turbulence intensity. Where Ur represents the reference wind speed at 100m height. All wind tunnel experiments were carried out at reference wind speed of approximately 9.5m/s.

The distribution of wind speed at pedestrian level was measured using modified Irwin sensors [12] installed at a height equivalent to 2m above the ground (10mm at model scale). The sensors covered an area of 1.5d in upstream, 2d laterally and 10d downstream of the building. . Sensors spacing near the building is kept 10m near the building and up to 50m away. For farther downstream area sensor spacing is 20m.

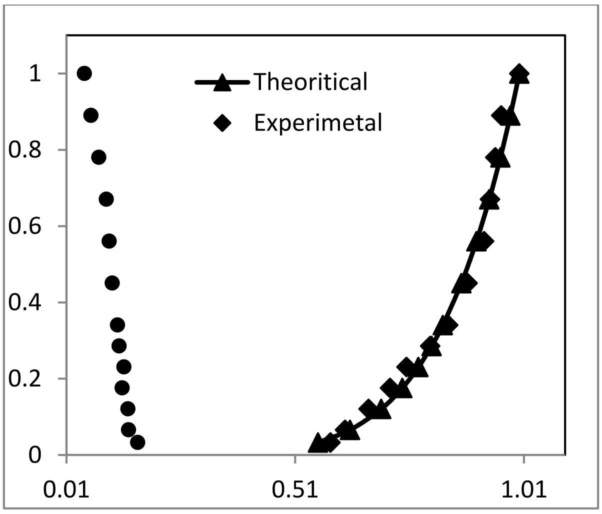

Figure 2. Profile of approaching wind

Irwin probe has been successfully used for practical wind environment study. It is axisymmetric about vertical axis and consists of sensor tube that protrude above ground surface. The pressure difference is measured between the top of sensor tube and sensor hole. A linear simplified relation between pressure difference Δp , and the wind speed,u was proposed by Irwin [3],

$$u = \alpha + \beta\sqrt{\Delta p} \qquad (1)$$

Where the constants in equation (1), are the function of sensor dimension. In current research the sensor has same dimension as used by Tsang C.W. et al[5] Which has been calibrated using robust Pitot tube for mean wind speed and found $\alpha = 0.54$, and $\beta = 1.62$, comparable to Tsang CW et. al.

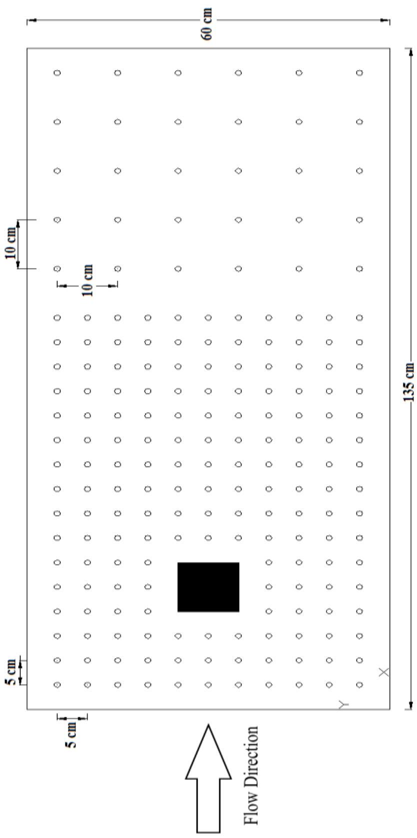

Figure.3 distribution of Irwin probes

Results and discussion

Velocity Ratio (VR):

The velocity ratio has been defined as the ratio of velocity (U) at a location with building to velocity (U0) at that location without building.

$$VR = U/Uo \qquad (2)$$

Contours of velocity ratio for square, tapered and setback building models under different wind direction (0, 22.5 and 45 degree) is shown in following Figure 4, 5 and 6. In which it clearly depicted different VR zones. For square building model, maximum and minimum VR was observed to 1.7 and 0.8 respectively under 0 degree wind incident angle. For 22.5 degree the maximum VR is also 1.7 but for a weak zone and minimum VR is 0.7. Area under VR<1, for this angle is more because of higher blockage. For 45 degree, the maximum value of VR is observed to be 1.8. In this case the area under VR>1 is higher than 0 degree.

For tapered building configuration the contours of VR is shown in Figure 6, for 0 degree angle of incident, a more strong zone for VR =1 to 1.1, is observed. The maximum VR is 1.6 and minimum VR is 0.8 for weak zone because of less blockage as in case of square model. For 22.5 degree, minimum VR is 0.6 and area under VR<1, is more as compare to Square model for this angle. For 45 degree the maximum VR is 1.5, but there is more strong zone for VR<1.

For setback model the maximum VR at 0 degree is 1.6 and minimum value is 0.70. Area under VR>1, is more as compare to square model but less as compare to tapered model. For 22.5 degree, area under VR<1 is more as square model and tapered model

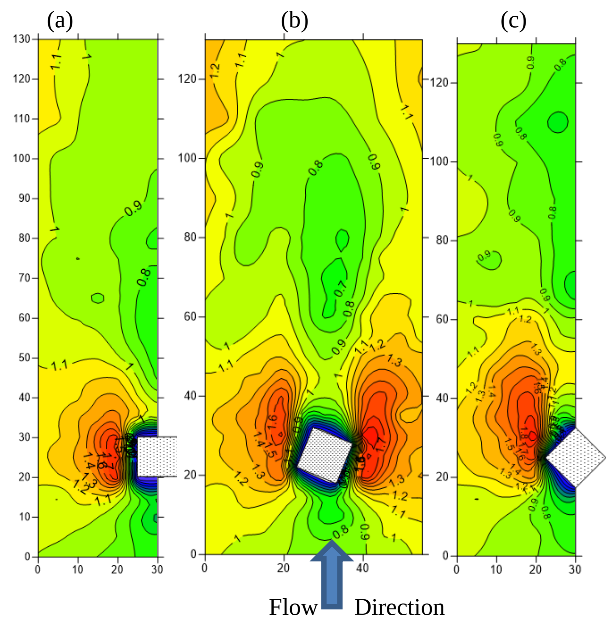

Figure 4. (a) Shows contours of velocity ratio (VR) for square model at 0 degree, (b) contours of VR at 22.5 degree (c) contours of VR at 45 degree

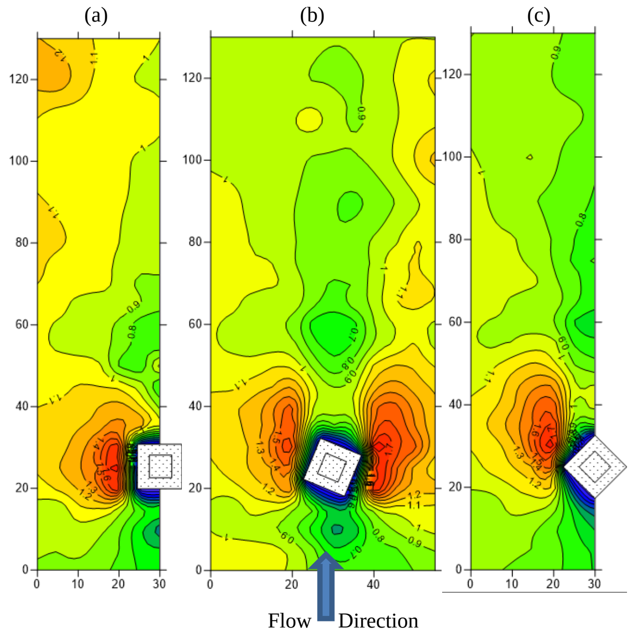

Figure 5. (a) Shows contours of velocity ratio (VR) for Tapered model at 0 degree, (b) contours of VR at 22.5 degree (c) contours of VR at 45 degree

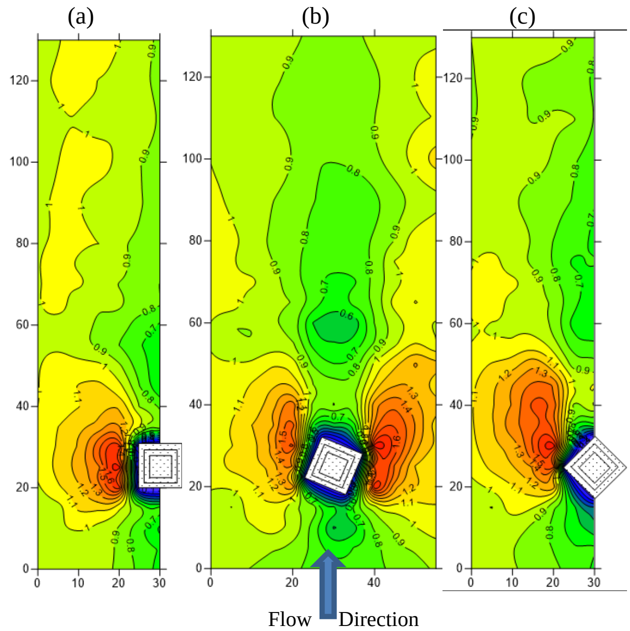

Figure 6. (a) Shows contours of velocity ratio (VR) for setback model at 0 degree, (b) contours of VR at 22.5 degree (c) contours of VR at 45 degree

Conclusions

As building designer are more interested in area of normalised wind speed ratio (VR) regarding ventilation efficiency and pedestrian comfort. This study gives insight view for decision making of building shape and their orientation.

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