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Original Research Article

Effects of upstream terrain characteristics on aerodynamic coefficients of structures

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ABSTRACT

Most research investigations and standards have not emphasized the effects of upstream terrain characteristics on aerodynamic coefficients of structures. Hence in this investigation, pressure measurements study on a 1:2:3 rectangular building model has been simulated through wind tunnel test under uniform, open and suburban terrain condition for 0° and 90° angles of wind incidence. From the variation of pressure and force coefficient values of present study, it is seen that the mean pressure and force coefficient values of all levels of uniform flow condition are on higher side by about 15–40% than the open and suburban terrain values for 0° angles of wind incidence as expected. However the mean pressure and force coefficient values of uniform flow condition are also showed that the values of all levels for 90° angle of wind incidence are on lower side with 20–40% difference than the boundary layer flow values when compared to the values of 0° angle of wind incidence. In addition, the mean pressure and force coefficients of present study has been compared with the Indian and international guidelines to highlight the limitations of codal standards.

1. Introduction

The rapid growth of urban population has lead to increase of vertical construction of high rise buildings. High rise buildings are predominantly affected due to lateral forces of the wind than other loads. The magnitude of intensity of these wind loads acting on the structure is significantly affected by terrain conditions than other parameters. The actual exposure condition of structures subjected to wind load is usually different from uniform condition drafted in most wind standards since most such structures erected in cities are embedded in boundary layer flow. In the present study, the effect of terrain on structures against wind load has been considered. While considerable research has been reported for wind induced load effects regarding the effect of side ratio, angle of wind incidence and the slenderness effect of tall rectangular building models. Only limited researches are reported for boundary layer flow conditions. Amin and Ahuja [1] carried out wind tunnel studies on 1:300 scaled-down models of rectangular buildings having same plan area and height but different side ratios ranging from 0.25 to 4 under open terrain for the mean velocity of 15 m/s. Effectiveness of the side ratios of models in changing the surface pressure distribution was assessed at wind incidence angle of 0° to 90° at an interval of 15°. Quan et al. [2] studied the influence of side

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ratio and terrain category on area-averaged most unfavorable wind pressure coefficients (MUWPCs) acting on various regions of building surface based on the wind tunnel test data of 1:250 scale models of typical high-rise buildings with rectangular cross-sections for three different side ratios1.0, 2.0 and 0.5 respectively. Based on the test, the relation between pressure coefficients in the form of a nondimensional parameter was arrived. No unique pattern of variation was found for the effect of terrain category because of complex interaction between the high-rise building and the 3D wind field. Lin et al. [3] tested nine models (1:500) with different rectangular cross-sections in a wind tunnel to study the characteristics of wind forces acting on tall buildings under open terrain condition. Based on experimental results, side ratio, aspect ratio and elevation effect on wind force coefficients, spectra and spanwise cross-correlation were discussed by the authors. Most of the investigations reported in the literature are correspond to open terrain simulations. The effect of terrain characteristics on the aerodynamic coefficients are recently addressed by some of the international standards for conservative open terrain condition but the current Indian standard and some of the international standards do not even specify any provision for aerodynamic coefficients calculation under nonuniform flow conditions and are yet to be revised for atmospheric boundary layer flow condition. However research work investigating the importance of upstream terrain characteristics on wind induced load effects has not been focused on these studies and is limitedly discussed in literatures. Therefore an in depth study would have to be adopted for the understanding of effect of terrain on the aerodynamic characteristics of structures against wind load. Hence, the present investigation is focused on the terrain effects on aerodynamic pressure distributions and on mean drag forces characteristics of rectangular building model in three different flow conditions. Besides to highlight the codal limitations, a comparison has been made with the values of Indian standard and international guidelines.

2. Simulation of atmospheric boundary layer in wind tunnel

The experiments are performed in the boundary layer wind tunnel (BLWT) facility available at CSIR-SERC. The size of the test section of the tunnel is 18 m × 2.5 m × 1.8 m. The maximum wind speed attainable at the upstream side of the test section is 55 m/s. In order to translate the results of the boundary layer wind tunnel tests to corresponding proto type conditions, proper simulation of wind characteristics and wind flow field in the boundary layer wind tunnel are essential. Based on the simulated mean velocity profile, the power law coefficient arrived for the simulated terrains are 0.165 and 0.205 and the measured turbulence intensity at the height of the model are 16 and 20%. The simulated mean velocity and turbulence intensity profiles are shown in Fig. 1. The spectrum of the horizontal wind speed is also simulated and compared with Von Karman spectrum. Based on flow scale conditions, a geometric scale of 1:300 has been selected.

3. Model fabrication with instrumentation details

The present study has adopted rigid model study of tall rectangular building for the measurement of pressure acting on various faces of the building. The scale ratio between the model and the prototype depends on the cross sectional area of the wind tunnel. The original dimension of the tall building for which the study was being conducted, is 30 m × 60 m × 90 m. The prototype is modeled to a scale of 1:300 for the pressure measurement study. Hence the dimension of the model is 10 cm × 20 cm × 30 cm with an aspect ratio of 1:2:3. The rigid model has been fabricated using acrylic sheets. This material is chosen for its reasonable transparency, ease to work with and to avoid any kinks while connecting the pressure tubes to the pressure sensors. The acrylic sheets used are of thickness 3 mm considering that the model of height 30 cm will be able to remain stable as a rigid model when exposed to wind pressures. The base plate is made thicker to provide a rigid base connectivity. The base plate is 10 mm thick. For the measurement of wind induced pressures on the rigid model, it is instrumented for pressures at five different levels namely, $z = 0.10H$, $0.30H$, $0.50H$, $0.70H$ and $0.90H$, where 'z' is the height of each level from the bottom plate of the model and 'H' is the height of the model. Typical locations of pressure taps along the perimeter of the rectangular model in plan with numbering corresponding to level 1 are shown in Fig. 2a. At each level, twenty eight

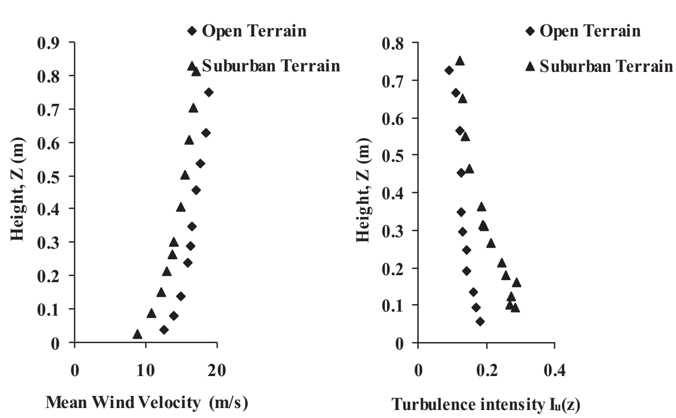

Fig. 1 – Simulated mean wind velocity and turbulence intensity profile for open and suburban terrain condition.