Non-Gaussian Features of Local Wind Pressure for Typical Gable Roof of Low-rise Building

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Keywords: Low-rise building, Wind tunnel test, Non-gaussian, Correlation, Skewness, Kurtosis.

Abstract. The non-Gaussian characteristics of local wind pressure of typical gable roof of low-rise building with a slop angle of 18.4° were monitored by means of the wind tunnel test under terrain roughness regimes of A, B and C. The probability density distribution features of wind pressure coefficient series are investigated, the characteristics of non-Gaussian zones distribution of wind pressure relative to different wind angles and different terrain conditions are analyzed and the relationships between non-Gaussian pressure and distinctions of flow field on roof are discussed. The studying results indicate that GEV distribution and Gamma distribution fit the probability density distribution of wind pressure coefficient better than Gaussian distribution and Lognormal distribution, but the fitting effect for long trailing tail part is undesirable, when skewness and kurtosis are large in magnitude (absolute value). The variation of terrain roughness and wind direction have significant influence on the distribution of non-Gaussian pressure regions on low-rise building roof. Under the oblique wind direction, the Gaussian pressure zone is divided into three sections along the approaching wind direction, along which the areas move with the change of terrain roughness regimes. The non-Gaussian features of wind pressure is positively related to mutual correlation coefficient of it’s time-history.

Introduction

As we all known, the low-rise buildings located in the lower part of the atmospheric boundary layer are subjected to the complex fluctuating wind due to the influence of the terrain roughness regimes such as the surrounding structures and trees. Consequently, the wind pressure acting on the building surface no longer follow the hypothesis of Gaussian distribution, but present significant non-Gaussian feature. Kareem et al.[1] used numerical simulation methods to compare the feasibility and effects of different computational models and analytical methods on the non-stationary, non-Gaussian, non-linear process of wind pressure on low-rise buildings under turbulent flow. The non-Gaussian wind pressure and its influence on the wind load on the side of a square building were studied by Ko et al[2]. A full-size low-rise building was constructed to monitor the non-Gaussian features of wind pressure under the action of the typhoon ‘plum blossom’, which show that the wind pressure on the roof exhibits obvious non-Gaussian, especially at the windward leading edge[3]. The wind pressure characteristics and the distribution of non-Gaussian regions on low-rise building with different roof slopes and heights have been studied widely recent years by varying wind direction angle and terrain category[4,5]. Meanwhile, the law of non-Gaussian pressure on high-rise building was also developed by some investigators such as Han N, et al[6]. The major objective of this paper is to expound the distribution of non-Gaussian regions affected by terrain roughness and the relationship between wind pressure correlation rule and non-Gaussian pressure counterpart.

Wind Tunnel Test

The wind tunnel test is implemented in the atmospheric boundary layer DC wind tunnel of the Wind Engineering Experimental Research Center of Hunan University of Science and Technology. The
pressure measuring equipment adopted in the test includes American PSI electronic pressure scanning valve system, three-dimensional pulsating anemometer, pitot tube et al. The sampling frequency of the pressure measurement signal is 333.2 Hz, the sampling time is 30 s, corresponding to the actual building sampling time is 10 min. The number of samples per test point in the test is 10,000. The wind fields required in Chinese standard GB50009-2012 for the wind tunnel test of low-rise building are simulated by using the passive simulation devices. Fig.1 shows the picture of the wind tunnel test. The dimensions of this low-rise building model are 600mm (length)×400mm (width)×400 (eave height) and its roof slope is 18.4°. The model scale ratio is 1:20, the test wind speed is 10m/s, and the wind speed scale ratio is 1:1. Fig.2 illustrates the arrangement of the pressure taps with a total number of 130 on the roof of the building.

Research Contents

Probability Distribution of Wind Pressure Time History

Figure 3 shows the wind pressure probability density distribution fitting results of the typical measuring points on the windward roof under the wind angle of 45° in the suburban terrain condition. As shown in the figure, the wind pressure coefficient of tap1 and tap7, in the corner area of the roof, are greatly affected by the cone vortex, so that the statistical characteristics deviate from the Gaussian distribution and both are negatively skewed. It is statistically stated that the probability of the actual wind suction in this area is greater than the Gaussian assumption and is more vulnerable to damage. The Gamma distribution and the Generalized Extreme Value distribution (GEV) have a better fitting effect to the probability density distribution of wind pressure time history of the taps near roof corner in the oblique wind direction, but it is difficult to fit the long tail region when the kurtosis is large. Tap13 and 19 are located in the middle of the windward roof, where the influence of cone vortex is weak, therefore, the probability density distribution of wind pressure is closer to the Gaussian. The skewness and kurtosis of the wind pressure time history of the measuring point 13 are 0.05 and 3.56, and the measuring points 19 are 0.14 and 3.12, respectively, which are close to the theoretical skewness value 0 and the kurtosis value 3 under the Gaussian distribution.

Non-Gaussian Wind Pressure Distribution Characteristics

In this section, the characteristics of non-Gaussian wind pressure distribution on roofs under different wind directions and different terrain roughness are discussed. Figure 4 shows the distribution of the non-Gaussian wind pressure on the building roof exposed at suburban terrain under different wind directions, and reveals the influence of the wind direction on the non-Gaussian partition of the low-rise building roof. In the figure, the wind pressure at the solid point is Gaussian, and the hollow point is non-Gaussian. The wind direction angle has a significant influence on the non-Gaussian distribution, especially under the oblique wind direction (such as 20°, 30°, 45°, 60°). The Gaussian area distribution is generally consistent with the wind direction angle, while the non-Gaussian area is mainly distributed in the both side of Gaussian area. Figure 5 presents the distribution of the
non-Gaussian wind pressure on the building roof exposed at different categories of terrains under wind direction angles of 0° and 45° respectively. It can be seen from the figure that the categories of terrain under the same wind direction angle has a significant influence on the distribution of the non-Gaussian area of the roof. The Gaussian region gradually moves forward along the incoming flow direction with the change of turbulence intensity in different wind field. This is because the vortex shedding in the airflow separation zone is expanded as the increased airflow turbulence, resulting in an increase in the non-Gaussian range of the separation zone.

Figure 3. Probability density of wind pressure coefficients for typical taps.

Figure 4. The distribution of non-Gaussian zones on roofs at various wind angles.

Figure 5. The distribution of non-Gaussian regions under typical wind angle in different terrains.
Relationship between Local Non-Gaussian Wind Pressure and Features of Roof Flow Field

Figure 6. shows the skewness and kurtosis curve of the along-wind direction measured on the roof under wind angle of 0°(Due to length limitation, only the curves under suburban terrain are given in this section). Under different categories of terrains, extreme points of the skewness and kurtosis appear at the windward roof with a distance from the windward front about 0.2 times the height of the eaves. From the trend of change, the trend of skewness under different field configurations is generally consistent with the “M” shape trend and the overall decline trend, while the kurtosis shows a “W” shape trend and the overall trend is upward. The skewness and kurtosis generally show obvious asynchrony, and the probability of occurrence of small skewed high peak state and large skewed low peak state is low. Figure 7. only shows the correlation between the along-wind direction and the crosswind direction under the wind direction of 0°. The legend in the figure represent reference point and the last point of the target measurement point sequence in the correlation calculation. The wind pressure correlation is the weakest at about 0.2 times the height of the eaves and then the correlation coefficient increases, reaching another peak near the ridge area. The wind pressure correlation value at the area of the leeward roof is slightly attenuated compared to the ridge region. It can be seen from Figure 7(b) that the crosswind correlation curve basically conforms to the negative exponential rate model and has a large difference from the downwind wind pressure correlation curve. The correlation of the 3-63 measurement points sequence at the height of about 0.2 times of the eaves under different terrains is the weakest. The correlation features of the cross wind direction measurement points indicate that the area at about 0.2 times the height of the eaves is the least affected by the characteristic turbulence resulted in the weakest non-Gaussian.

Figure 6. The curves of skewness and kurtosis change in wind direction angle of 0°.

Figure 7. The curves of wind spatial correlation under the wind direction of 0°.
Summary
This paper analyzes non-Gaussian features of local wind pressure of a typical low-rise building with a slope angle of 18.4° under different condition. The specific conclusions are as follows:
(1) Under the oblique wind direction, the wind pressure at the windward corner tend to be non-Gaussian, and the pressure at the area far from the windward angle is closer to the Gaussian distribution. Gamma and GEV distribution fit the wind pressure time history probability distribution more better, but can’t fit long tail region effectively when the kurtosis is large.
(2) Under the wind direction of 0°, the Gaussian zones move forward along the incoming flow direction as the increasing of turbulence intensity. Under the wind angle of 45°, the Gaussian zones in open and suburb flow field are mainly divided into three parts along the inflow direction and move along the approaching wind direction with the regional range reduction.
(3) Under different terrains, the Curve trend of skewness is approximate "M" shaped with the overall trend downward, while that of the kurtosis is "W" shaped with the overall trend upward. The skewness and kurtosis are obviously asynchronous. In areas with large correlation coefficients, wind pressure belong to non-Gaussian.

Acknowledgement
Financial support was from National Nature Science Foundation of China Project (No: 51578237)

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