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Gorge Wind Characteristics in Mountainous Area in South-West China Based on Field Measurement

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ABSTRACT

Gorge wind characteristics in mountainous area in south-west China is obtained based on wind field measurement at Beipan River Bridge and Qingshui River Bridge. The direction and distribution of wind as well as turbulence intensity was statistically analyzed. Non-stationarity and non-Gaussian of fluctuating wind are extracted to verify the turbulence of wind. The similarity of these characteristics shows feasibility to study on the general model for gorge wind in mountainous area in south-west China.

1. INTRODUCTION

Large span bridges own greater flexibility and lower vibration frequencies than general bridges, which leads to higher sensitivity to wind. Therefore, wind-resistant design is necessary to ensure bridge safety. Wind characteristics on the bridge site along with aerodynamic performance of the bridge are the basis for the design.

The present code for bridge wind-resistant design in China stipulates wind load for isotropic wind at flat topography. Yet for complex terrain, for instance gorge in mountainous area, the code designates field measurement or terrain model wind tunnel tests for wind load determination, not to mention quantitative description of turbulence characteristics. The basic reason for these uncertainties is the complexity of airflow motion caused by various terrains. The turbulence characteristics are hard to define by uniformed standard. However, there is still some similarity presented on wind characteristics in mountainous area. The influence mechanisms of terrain to wind speed of atmospheric boundary layer are mainly classified as: 1) the increasing or decreasing of average wind speed caused by the narrowing or broadening of gorge, 2) large-scale wake caused by separation when airflow climbs over the hillside, 3) wind speed reduction due to the block of terrain ahead. Large span bridges are often built across the narrowest position of gorges, which increases the similarity of wind

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characteristics. The study for gorge wind characteristics in mountainous area is therefore become more feasible.

The existing research on wind characteristics in mountainous area started at the mid-1970s, mainly based on Jackson's linear theory (Jackson 1975). Tumipseed et al (2003) investigated the effect of complex terrain on turbulent measurement accuracy, and obtained characteristics of fluctuating wind. Carrem (2009) studied canyon effect based on wind speed data from weather station and reanalysis database of North America. Pang (2010) analyzed the turbulence characteristics of Sidu river valley bridge site and found them different with the code-recommended models. Zhu (2011) used a phased array sodar wind profiler at the Balinghe bridge site and found that the regular profiles are different from the power law specified in codes for common flat terrains, and show variation patterns of exponential law.

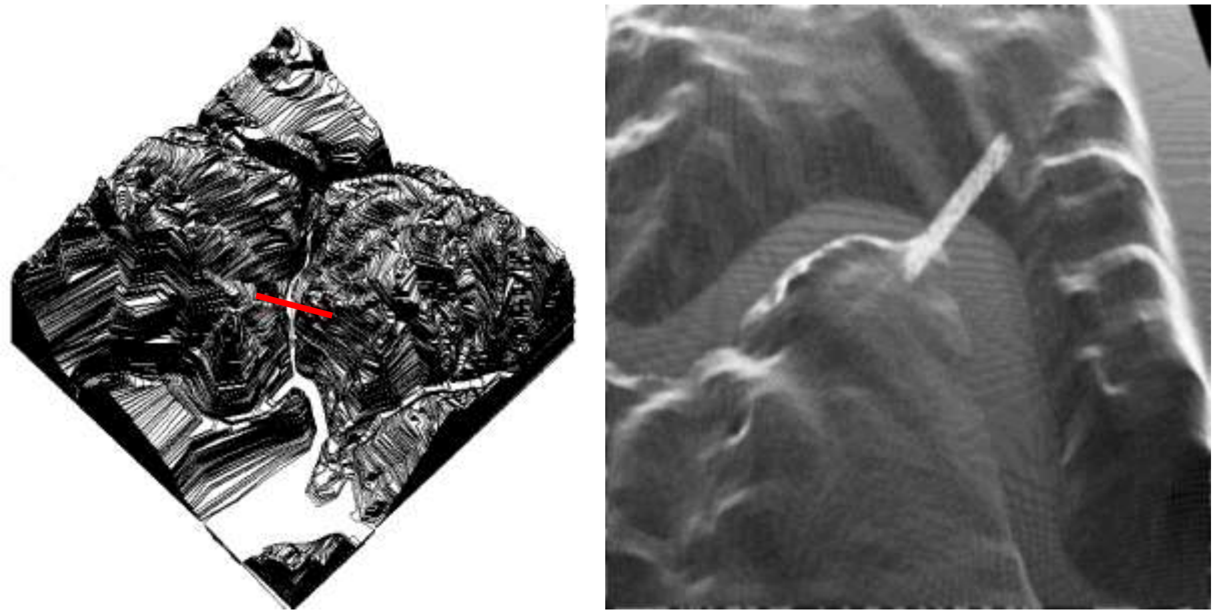
This paper analyzes gorge wind characteristics based on field measurement data at Beipan River Bridge and Qingshui River Bridge site, both located in mountainous area in south-west China. The similarities of wind characteristics for these two locations are hopefully present the whole trend for south-west mountainous gorge wind in China.

Beipan River Bridge located near the Shuicheng County in Guizhou Province, built across the Beipan River gorge, 1500 meters elevation above sea level, 1341.4m full bridge length, 720m main span length. Qingshui River Bridge located in Longjing Village of Kaiyang County in Guizhou Province, lays across Qingshui River gorge, 1018 meters elevation above sea level, 2171.4m full bridge length, 1130m main span length. Both two bridge sites own typical southwest mountainous gorge terrain, with cliff gorge sides, see in Fig.1.

The average wind speed anemometers are selected as NRG # 40C Maximum mechanical anemometer, with measurement range of 1 ~ 96m/s. Wind direction sensors are NRG # 200P wind vane, with the resolution of 1° and measurement range of 0 ~ 360°, the sampling frequency of which is Hz. RM Young 81000 ultrasonic anemometers are adopted to measure the turbulence characteristics. The anemometers could measure three-dimensional instantaneous wind speed. The sampling frequency is 4-32Hz; the wind speed measurement range is 0~40m/s and the measurement accuracy is 1% rms±0.05m/s.

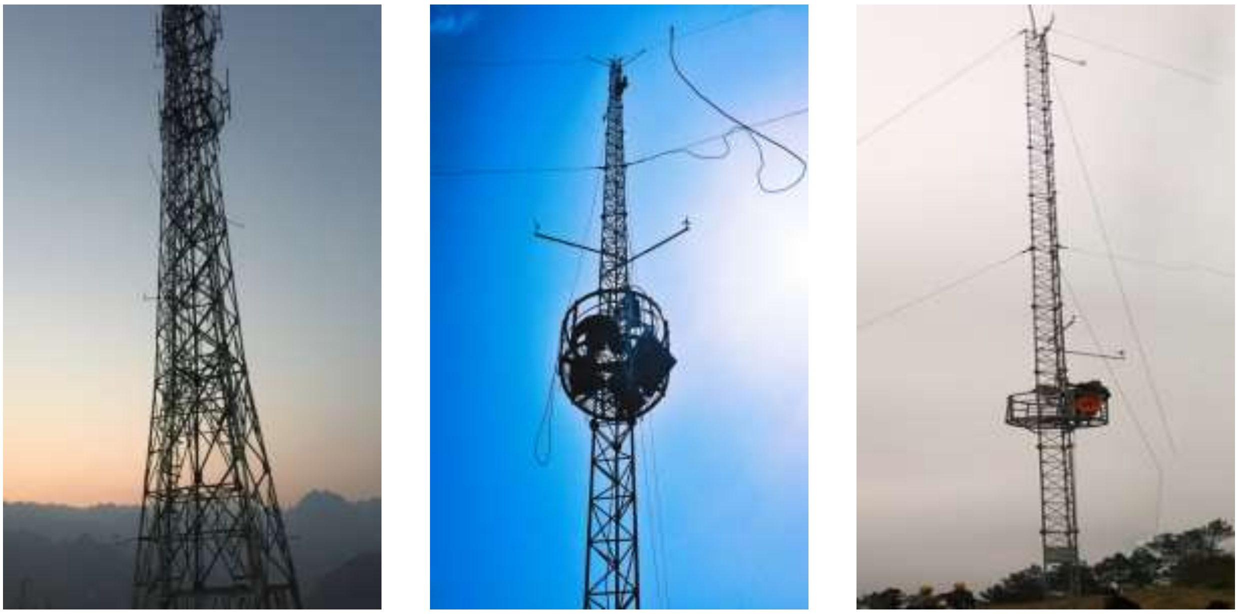
The observation tower of Beipan River Bridge at Guizhou bank is 100m from the nearest bridge tower. Average wind speed anemometers are installed at the height of 10m, 30m from the bridge deck. Two three-dimensional ultrasonic anemometers are installed at the height of 25m, 45m from the deck. Taking the local terrain condition at the bridge site into account, the observation tower of Beipan River Bridge at Yunnan bank is 500m from the nearest bridge tower. Average wind speed anemometers are installed at the height of 10m, 30m from the observation tower foundation. One three-dimensional ultrasonic anemometer is installed at the height of 45m from the observation tower foundation.

Qingshui River observation tower at Weng'an bank locates 200m far from the nearest bridge tower. Average wind speed anemometers are installed at the height of 10m, 30m from the observation tower foundation. One three-dimensional ultrasonic anemometer is installed at the height of 45m from the observation tower foundation. The installation position of anemometers are shown in Fig. 2.



(a) Beipan River Bridge site (b) Qingshui River Bridge site

Fig. 1 Surrounding topography of wind field measurement



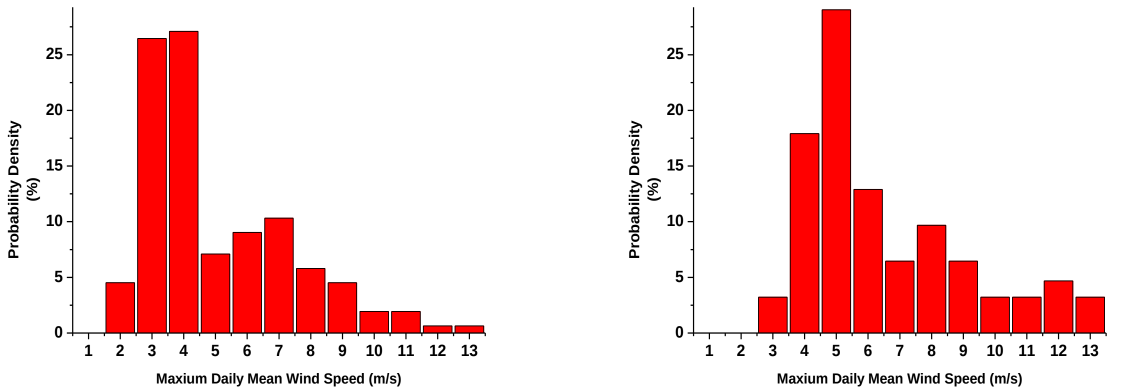
(a)Guizhou bank tower (b)Yunnan bank tower (c) Qingshui River tower

Fig. 2 Installation position of anemometers

2. MEAN WIND CHARACTERISTICS

2.1 Mean wind speed

The mean wind speed in 10 minutes is adopted to analyze the probability density of maximum daily mean wind speed, see in Fig. 3. The data obtained on observation towers at two banks of Beipan River is combined to calculate the wind speed. It is shown that the daily maximum mean wind speed at 3-4m/s stands the highest probability on Beipan River Bridge site while Qingshui River Bridge site at 4-6m/s. Both two sites present as lognormal probability density distribution.

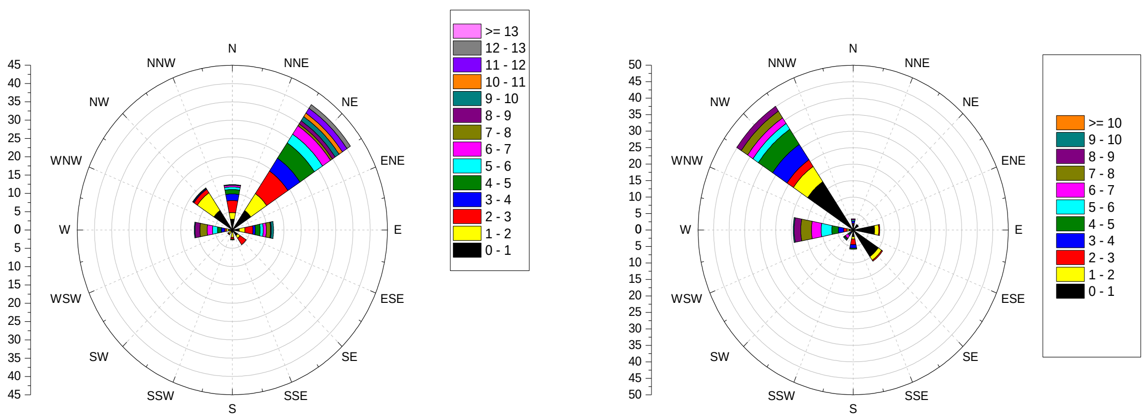


(a) Beipan River Bridge site (b) Qingshui River Bridge site

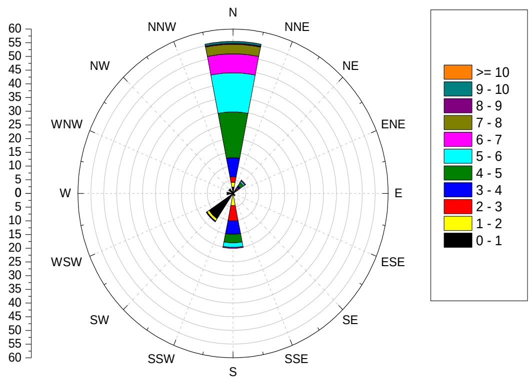
Fig. 3 Maximum daily mean wind speed

2.2 Mean wind direction

The direction of mean wind in 10 minutes is shown Fig. 4. The two towers of Beipan River Bridge has a difference of 90°. The terrain might be the main reason which changed wind direction. Qingshui River gorge near measurement site runs from North to South, which determines the main direction of mean wind.



(a) Yunnan bank tower (b) Guizhou bank tower



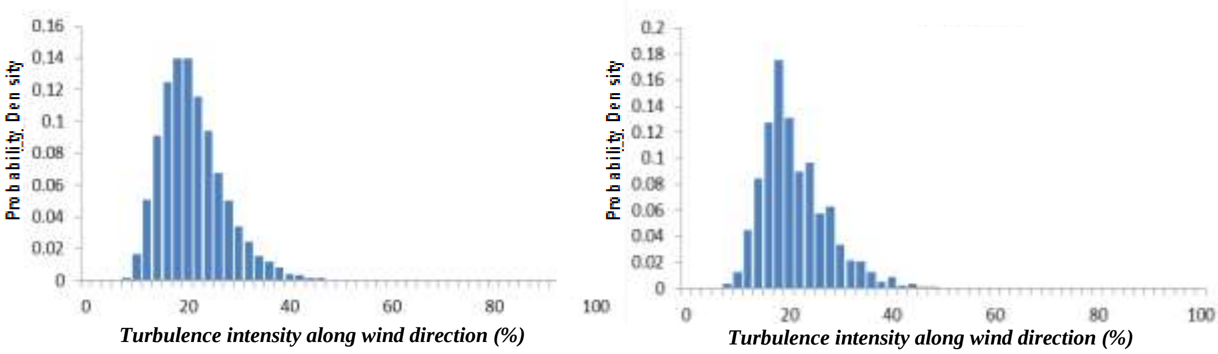
(c) Qingshui River tower

Fig. 4 Mean wind direction

3. TURBULUENCE CHARACTERISTICS

3.1 Turbulence intensity

The probability densities of turbulence intensity along wind direction of two sites are shown in Fig. 5. The turbulence intensity of two measurement sites at two banks of Beipan River has not much difference. Therefore the data is analyzed together. Noted that mean wind speed is limited to 4m/s and above in order to ensure data efficiency.

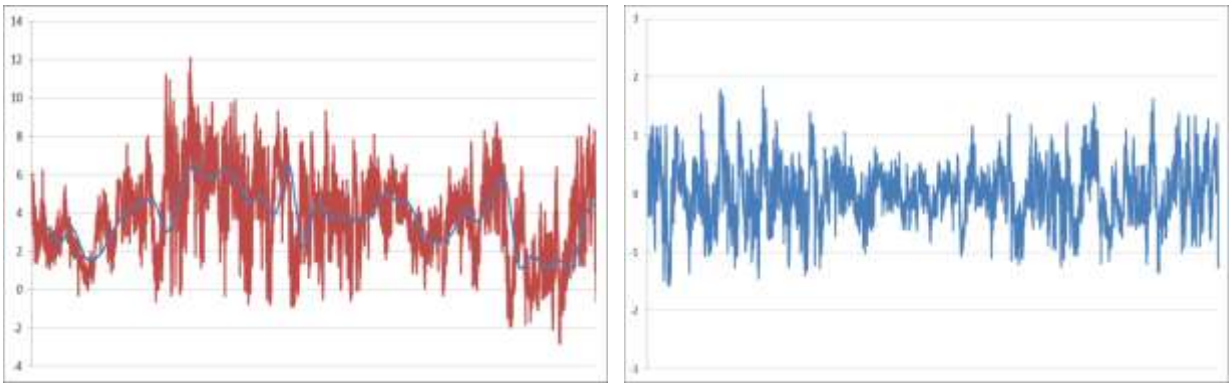


(a) Beipan River Bridge site (b) Qingshui River Bridge site

Fig. 5 Probability density of turbulence intensity along wind direction

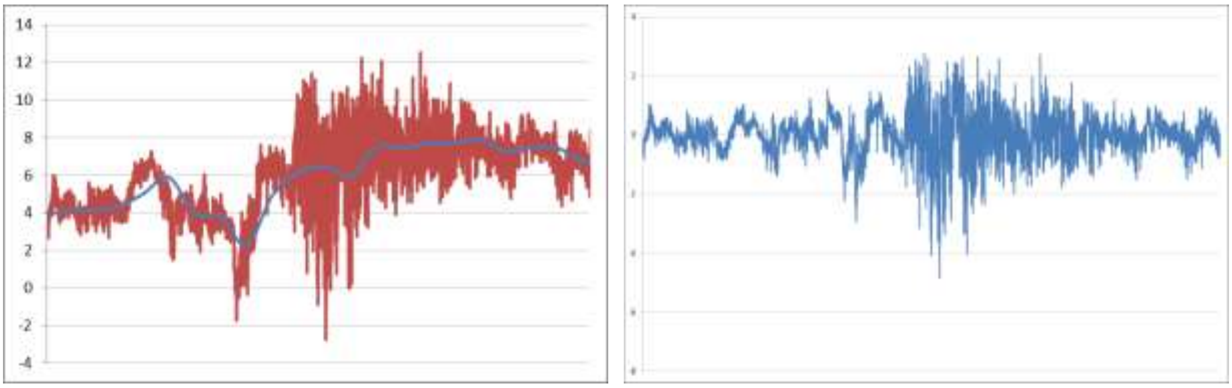
3.2 Nonstationary Gaussian and Nonstationary non-Gaussian Time History

The typical nonstationary Gaussian time history is shown in Fig. 6. Nonstationary non-Gaussian time history is shown in Fig. 7. Fig. 8 shows PDF of different fluctuations, nonstationary non-Gaussian process owns higher dispersion than nonstationary Gaussian process.



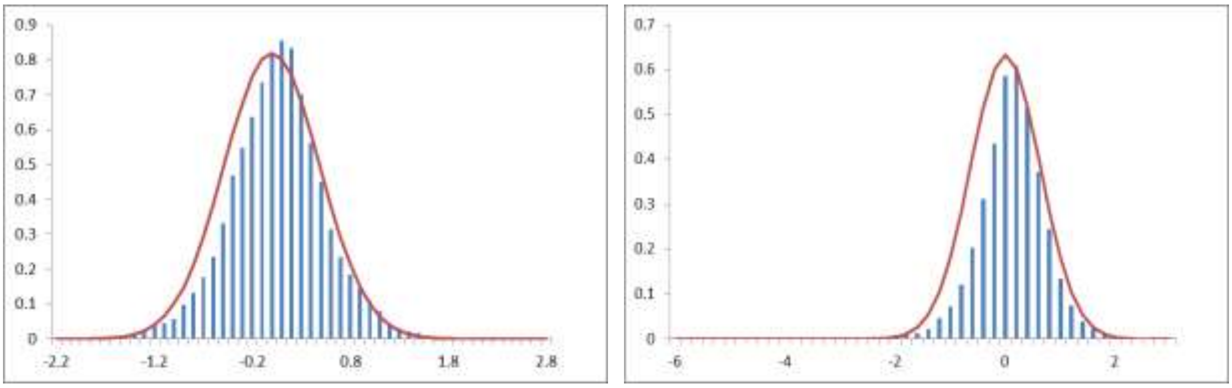
(a) Instantaneous and time-varying mean wind speed (b) Turbulence time history

Fig. 6 Nonstationary Gaussian time history



(a) Instantaneous and time-varying mean wind speed (b) Turbulence time history

Fig. 7 Nonstationary non-Gaussian time history



(a) Nonstationary Gaussian process (b) Nonstationary non-Gaussian process

Fig. 8 PDF of fluctuation

3. CONCLUSIONS

The maximum daily mean wind speed presents similar regularity at both sites on Beipan River Bridge and Qingshui River Bridge. Mean wind direction are shown influenced greatly by terrain. Turbulence density also presents similarity at both sites. Nonstationary Gaussian and nonstationary non-Gaussian time history are extracted to verify the turbulence of gorge wind in south-west mountainous area.

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