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Research on the wind speed distribution at the height of long-span bridge deck in U-shaped valley

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SUMMARY:
It is of great significance to determine the span-wise distribution of wind speed at the deck height of long-span bridges in valleys. In this paper, a U-shaped valley and a long-span suspension bridge to be built are taken as the research objects. In order to study the wind speed distribution in the spanwise direction of the main girder, the lidar measurement and numerical simulation are used to carry out the research. It is found that lidar can measure wind parameters in the range of 810 m×1400 m without contact. The measured results show that the probability of gale from January to April is 87%, and the correlation of wind speed at different locations of main girder is related to distance, location, season, wind direction and wind speed. Numerical simulation shows that when the oncoming flow is blocked by a wide range of mountains, the wind speed at the mid-span of the main girder is even only 50% of the wind speed at the bridge tower. The mid-span acceleration effect is not obvious, and the spanwise wind speed of main girder can be considered conservatively according to uniform distribution.

Keywords: wind speed distribution, field measurement, numerical simulation

1. INTRODUCTION

Many long-span bridges built in mountainous valley area, which have the characteristics of long span and low damping, and are wind-induced sensitive structures. Verification of wind resistance is an important issue in design, construction and operation of such bridges. Before the wind resistance design of long-span bridges in mountainous areas, the wind environment at the bridge site is worthy of attention. In particular, it should be noted that the spanwise distribution characteristics of wind speed at the height of bridge deck are the basis for the study of wind resistance of bridges. In studying the distribution of wind speed along the spanwise direction of the main girder of the bridge, Xie et al. (Xie and Xiang, 1985 , Zhang, 2007) proposed a wind speed formula for the bridge site area based on the measured data, considering the equivalent flow tube width and symmetry of the incoming wind field, and the length of the main span of the bridge. However, there is no clear method for determining the incoming flow characteristics. Li et al. (Li et al., 2017) used numerical simulation and wind tunnel test methods to compare the spanwise distribution results of wind speed at the main girder position under different incoming flows. The study showed that the results of numerical simulation were not consistent with the experimental results.

In summary, scholars used a single or diversified method to study the distribution characteristics of wind speed along the spanwise direction at the main girder position of bridges in mountainous valleys, and obtained rich research results. However, the current research results have the characteristics of low universality and large difference in results, which also shows that the complexity of the wind field characteristics in the valley region has brought challenges and difficulties to the research. In this paper, a proposed long-span suspension bridge in a U-shaped valley is taken as the research object. Firstly, the wind parameters of gale weather are collected by lidar which can monitor large-scale data, and the data of 5 virtual wind measuring towers are analysed. Then, the spanwise distribution characteristics of wind speed at the height of bridge girder are compared and studied by numerical simulation. The research means and results can provide reference for bridge design in similar areas.

2. DESCRIPTION OF THE VALLEY AND BRIDGE

2.1. U-shaped Velley

A U-shaped valley is located in southwest China, with many peaks and valleys, and its climate is dominated by northern subtropical montane monsoon climate. In addition, the main wind direction in this region is southwesterly all the year, and the gale weather appears from November to April. and the water surface width is about 700 m, as shown in Fig. 1.

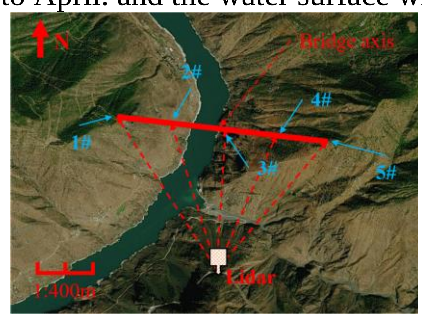

Figure 1. U-shaped valley and lidar setting

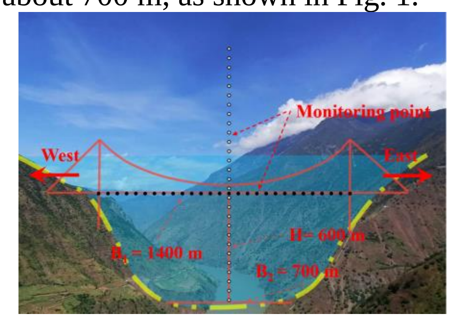

Figure 2. Bridge and monitoring points

2.2. Long-span Bridge

A suspension bridge with a main span of 1400 m will be built here, with an elevation of about 2000 m and a height of about 600 m above the river, as shown in Fig. 2.

3. RESEARCH METHODS

3.1. Field measurement

Compared with traditional wind measurement instruments, such as anemometers and sodars, the wind measuring lidar has the advantages of higher measurement accuracy, higher spatial and temporal resolution, and lower detection blind area, as shown in Fig. 3. The setup details of the lidar system is as follows:

(1) Site selection: after the preliminary field investigation, the lidar is installed beside the highway, the site was open and unobstructed, as shown in Fig. 1 and Fig. 3. (2) Installation: the lidar system is equipped with power supply, monitoring and 4G network to facilitate data transmission and site monitoring. (3) Measuring scheme: in order to measure the distribution characteristics of wind speed of the bridge, measuring points are arranged in 5 key positions, respectively, west bridge tower, 1/4 span, mid-span, 3/4 span and east bridge tower. 5 virtual wind measuring towers are set up, namely, form 1# ~ 5#, as shown in Fig. 1. (4) Debugging:

after field debugging, the lidar system runs normally, with little interference from surrounding environment, the signal-to-noise ratio (SNR) is greater than 10, and the wind parameter measurement is normal and reliable. (5) Testing: according to the gale season over the years, from October 25, 2020 to May 6, 2021, and continuous 193 days of data was measured and recorded.

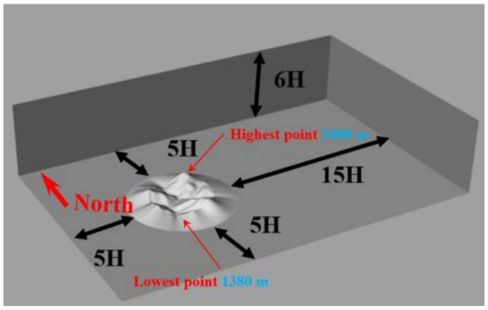

Figure3. Picture of the Lidar **Figure 4.** Calculation domain in numerical simulation

3.2. Numerical simulation

According to the suggestion of Blocken (Blocken, 2015), the size rectangular calculation domain size is (18.975 km width)×(58.7 km length)×(12.45 km height), as shown in Fig. 4. Due to the measured data, the incoming flow is mainly north wind and south wind, a total of three working conditions are designed, which are denoted as 90°, 102° and 270°, respectively, as shown in Fig. 5.

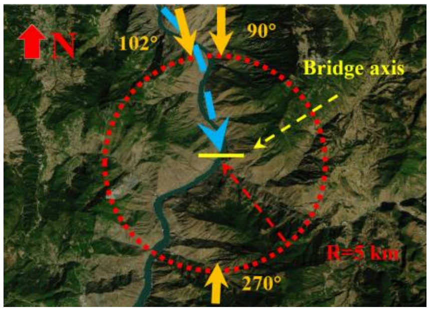

Figure 5. Working condition layout

4. RESULTS AND DISCUSSION

It can be seen that the wind speed at the height of the main girder is larger, no less than 9 m/s, and the wind speed fluctuation is small, especially the position of 3# ~ 4# virtual tower, as shown in Fig. 6.

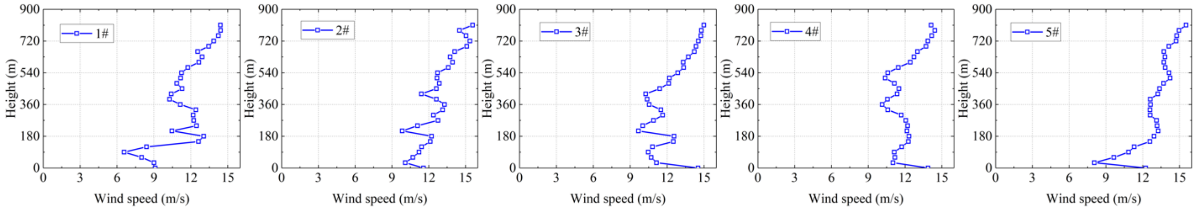

Fig. 6. The spanwise distribution of wind speed on April 1, 2021

It can be seen from Fig. 7 that the incoming flow and wind direction have a significant impact on the wind speed at the height of the bridge deck.

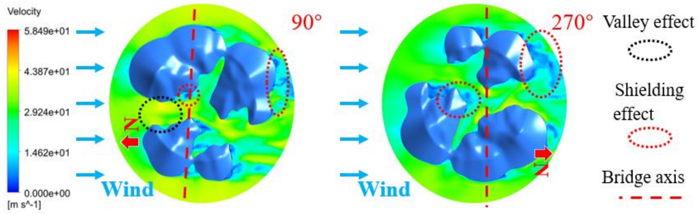

Figure 7. Velocity contour of valley at the height of bridge deck: (a) 90° (b) 270°

It can be seen that the data range of 2# virtual tower at 350 m is from 0.94 to 1.03, and the numerical simulation results are highly consistent with the measured data, which are closest to the results of 90° and 102°. At the position of 1050 m and the position of 4# virtual tower have strong fluctuation, ranging from 0.84 to 1.06, as shown in Fig. 8.

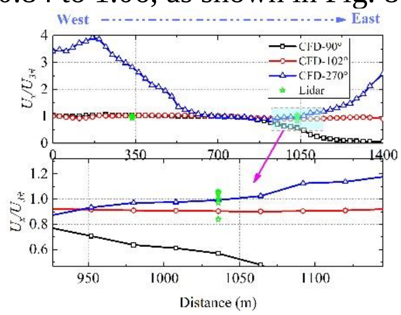

Figure 8. Non-dimensional wind speed along wind direction at the height of bridge deck, comparison of measured results with CFD results

5. CONCLUSION

(1) The wind speed is related to distance, terrain, wind speed and season. The closer the distance is, the less the incoming flow is blocked by the upstream mountains, and the greater the wind speed is, the stronger the correlation is.

(2) The wind speed along the span direction of the main girder is affected by the upstream terrain and the valley compression, showing uneven distribution characteristics, the wind speed at the mid-span of the girder is not always the largest, even only 50% of the wind speed on both sides. Conservative estimation, the spanwise wind speed of the main girder can be considered according to the uniform distribution of the maximum wind speed.

ACKNOWLEDGEMENTS

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REFERENCES

BLOCKEN, BERT 2014. 50 years of computational wind engineering: past, present and future. Journal of Wind Engineering & Industrial Aerodynamics [J], 129: 69-102.

LI Y L, XU X Y, ZHANG M J, et al. 2017. Wind tunnel test and numerical simulation of wind characteristics at a

ZHANG M, JISHENG Y, ZHANG J, et al. 2019. Study on the wind-field characteristics over a bridge site due to the shielding effects of mountains in a deep gorge via numerical simulation. Advances in Structural Engineering [J], 22: 3055-3065.

XIE J M, XIANG H F 1985. Three flutter analysis for bridge by state-space approach. Journal of Tongji University (Natural Science) [J]: 1-13.