STUDY OF WIND TUBULENCE BASED ON STRONG WIND MEASUREMENT

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1. INTRODUCTION

The information on the features of atmospheric turbulence is useful in structural engineering applications. The structures and members are subjected to time dependent load with fluctuation; resonant amplification effects induce by velocity fluctuations and the aerodynamic behavior may depend strongly upon the turbulence in the air flow. In this study, the turbulent flows are of interest in various applications: the turbulence intensity; the integral length scale of turbulence; power-spectral density functions and spatial correlation.

2. RECORDED DATA

The data used in this paper are taken from the full-scale measurement on the Akashi-Kaikyo Bridge during 9918 typhoon. In the process of the measurement, five anemometers are installed on the deck in the middle of the main span and the altitude is approximately 108m [1].

3. WIND TURBULENCE

3.1 Turbulence Intensity

As the simplest key parameters determine the turbulence wind load acting on structures, turbulence intensity describe the intensity of fluctuating wind. The longitudinal turbulence intensity $I_u(z)$ is defined as:

$$I_u(z) = \frac{\sigma_u(z)}{U(z)} \quad (1)$$

Where U(z) is the mean wind speed at elevation z; σ_u (z) is the standard deviation of the fluctuating components. During the typhoon, the along wind turbulence intensity were calculated with time interval of 10 minutes, and the results demonstrate in Fig.1. As, the mean wind speeds range from 14 to 24 m/s and the turbulence intensity from 4% to 16%.

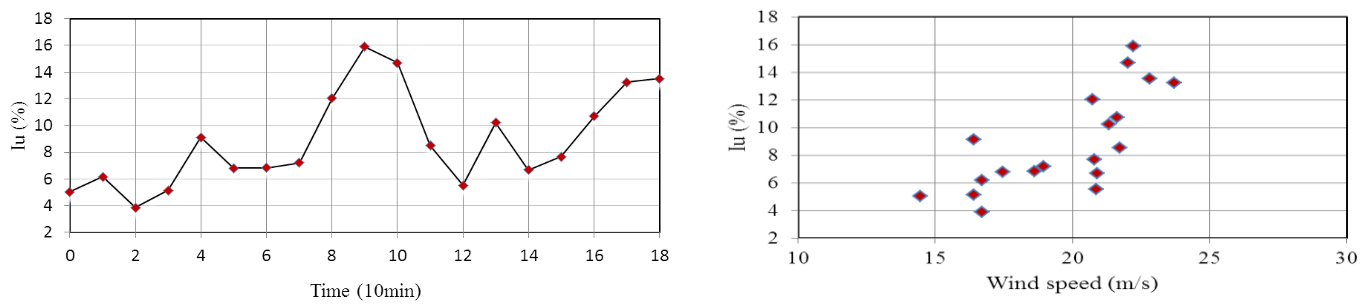

Fig. 1: 10 min turbulence intensity of typhoon.

3.2 Turbulence Integral Length Scale

Integral Scales of turbulence are a measure of the average size of the turbulence eddies of the flow. Assumes that Taylor's hypothesis is normally considered in natural wind, thus the cross-correlation function can be estimated from a single point measurement.

$$L_u^x = \frac{U}{\sigma_u^2}\int_0^\infty R_u(\tau)d\tau \quad (2)$$

Where $R_u(\tau)$ is the autocorrelation function of turbulence component u. In order to integrate to ∞, a signal of infinite length would be required and standard practice is to integrate to the first zero crossing of autocorrelation with x axis.
Fig. 2 depicts the L_u^x based on the measured wind speed with time interval 10 minutes. As in Fig. 2 shown that L_u^x is very sensivity and for the most part of the L_u^x values range from 80m to 280m.

3.3 Turbulence Power Spectrum Density Function

The frequency distribution of turbulent along-wind velocity component u is described by the non-dimensional power spectral density function R_N (z, f) defined as:

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$$R_N(z, f) = \frac{fS_u(z, f)}{\sigma_u^2(z)} \quad (3)$$

Where f is frequency in hertz and $S_u(z, f)$ is the power spectrum for the along-wind turbulent component

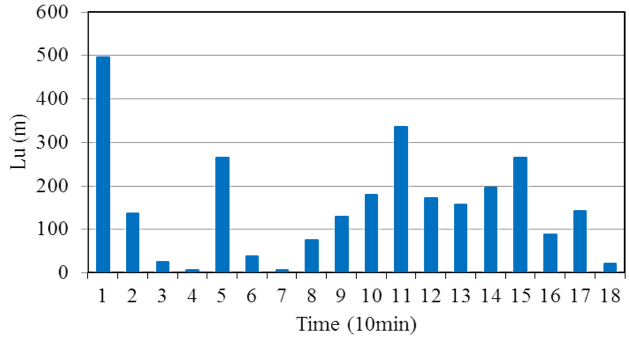

Fig. 2: Turbulence integral length scale

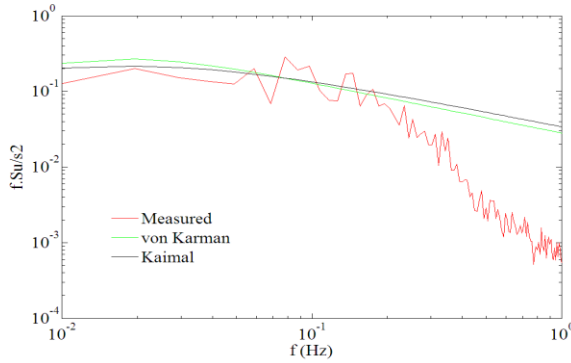

Fig. 3: PSD of along-wind velocity fluctuations

As shown in Fig. 3 von Karman best fit with lower frequency range from 0.01 to 0.11 Hz, and Kaimal spectrum had a quite similar trend over the same frequency period.

3.4 Spatial correlation

The normalized cross-spectrum describes the statistical dependence between the turbulence components at two points at a given frequency f. The root-coherence function is defined as the absolute value of the normalized cross-spectrum and given by:

$$\sqrt{Coh} = |S_N| = \left| \frac{S_{uu}(P_1, P_2, f)}{\sqrt{S_u(P_1, f) S_u(P_2, f)}} \right| = \exp(-k\frac{fx}{U}) \quad (4)$$

Where S_{uu} is cross-spectrum of the two longitudinal turbulence components at point P1 and P2, respectively and S_u is the power spectrum, k the decay factor is set to be 8; x is the transverse distance and U the mean wind speed.

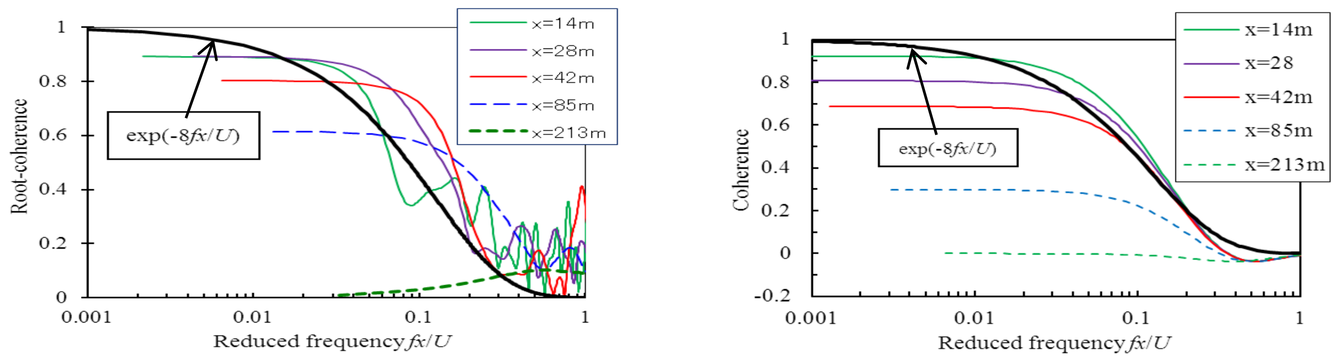

Fig. 4: Spatial correlation of measurement (left) and proposed form (right)

As shown in Fig. 4 the normalized cross-spectrum decrease when the distance between two points increase and also demonstrated the fitting curve is proposed by Eq. (4). The proposed coherence by Krenk (1995) (right side) [2, 4] is expression better than the conventional formula Eq. (4).

4. CONCLUSIONS

The turbulence intensity varies with mean wind speed from 4% to 16%. The turbulence integral length scales differ greatly and very sensitive each 10 minutes time interval. The measured PSD of typhoon coincided well with the von Karman and Kaimal spectrum in lower frequency. The spatial correlations of turbulent along-wind velocity reduce with the distance, and alternative coherence form is well displayed.

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