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Effects of Coherence on Heaving Response and Torsional Response

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Abstract In frequency domain buffeting analysis, Spatial correlation of approaching flow of fluctuating wind speed is regarded as one of important parameters in gust response prediction of bridges. The spatial correlation of the variable wind speed is expressed and used as coherence. The buffeting response is computed mode by mode, neglecting aerodynamic coupling, while joint mode acceptance function describes the distribution of buffeting forces along the bridges. This paper deals with the contribution of joint mode acceptance on the heaving and torsional responses prediction applying the aerodynamic admittance function estimated in this thesis. Therefore, well-known coherences of Davenport and Karman are concentrated in considering the joint mode acceptance for response analysis and the results are compared with those of JMA=1. It is confirmed that taking into account the coherence in investigating responses of a structure gives closer result with the experimentally obtained response.

Key Words: *Correlation, Coherence, Buffeting, Joint Mode Acceptance, Responses.*

1. INTRODUCTION:

The experimental results carried out by Shaopeng Li (2017) [84] also demonstrate that the spanwise correlation of the lift on the aerofoil is more strongly correlated than that on the rectangular cylinders because of the attachment of flow. This information brings interest to investigate the effect of coherence on the buffeting response of flatter sections. [1].

2. CONSIDERATION OF COHERENCE AND JOINT MODE ACCEPTANCE ON BUFFETING ANALYSIS:

The coherence representing the correlation of each frequency component of the variable wind speed between two spatially separated points is expressed by proposed by Davenport [3].

$$Coh_D = exp\left[-\lambda_D \frac{f(y_1 - y_2)}{\overline{U}}\right] \tag{1}$$

Although this equation approximates the measured value with the decay factor as a parameter, it is possible to overestimate the correlation in the low frequency range in f = 0, coh = 1 regardless of the distance between two spatially separated points, but during actual turbulence, the distances between the two points are disturbed, it is generally smaller than 1. On the other hand, the coherence derived from the spectral representation of von Karman in isotropic turbulence can be expressed by the coherence even in the low frequency range. It is conventionally used as a method that can more accurately evaluate the effect that it becomes smaller than 1, and a simple display formula is proposed by Irwin [2].

$$Coh_K = exp\left[-\lambda_K \frac{f(y_1 - y_2)}{2\pi L_w} 0.747\sqrt{1 + 70.78\frac{fL_w}{\overline{U}}}\right] \tag{2}$$

Joint mode acceptance is a spatial correction coefficient that associates the power spectral density of the variable aerodynamic force corresponding to the rth order mode with the power spectrum density of the aerodynamic force at a certain target point and is generally expressed in the span direction. It is uniquely determined by the spatial correlation structure of the variable aerodynamic forces between two distant points. It is obtained by multiplying the coherency of variable aerodynamic forces acting on two different points by the vibration mode form, by double integration in the span direction.

Generally, it is uniquely determined by the spatial correlation structure of the variable aerodynamic force between two points separated in the span direction, and its value never exceeds 1 for all frequency components.

Using the Davenport's coherence [3]

$$|J(f)^2| = \frac{1}{l^2}\int_0^l \int_0^l exp\left[-\lambda_D \frac{f(y_1 - y_2)}{\bar{U}}\right] dy_1\, dy_2 = \frac{1}{{D_y}^2}\left[D_y - 1 + \exp(-D_y)\right] \quad (3)$$

where,

$$D_y = \frac{\lambda_D f l}{\bar{U}}$$

Using the Karman's coherence [4]

$$|J(f)^2| = \frac{1}{l^2}\int_0^l \int_0^l exp\left[-\lambda_K \frac{f(y_1 - y_2)}{2\pi L_w} 0.747\sqrt{1 + 70.78\frac{fL_w}{\bar{U}}}\right] dy_1\, dy_2 = \frac{1}{{K_y}^2}\left[K_y - 1 + \exp(-K_y)\right] \quad (4)$$

where,

$$K_y = \lambda_K \frac{f(y_1 - y_2)}{2\pi L_w} 0.747\sqrt{1 + 70.78\frac{fL_w}{\bar{U}}}$$

The turbulence scale at the model centre is about 3.7 cm for w component. [5] The decay factor, k for determining the coherence of the Davenport type and Karman type is 8.

3. RESULTS AND DISCUSSION ON EFFECT OF JOINT MODE ACCEPTANCE ON HEAVING AND TORSIONAL RESPONSES OF RETANGULAR SECTION:

The heaving and torsional displacements of B/D=5 with variable joint mode acceptances in the mean wind speed between 2.8 m/s and 7.4 m/s are shown in Figure 1 and 2. It is clearly that Davenport acceptance and Karman acceptance are always lesser than 1, hence the responses with Davenport acceptance and Karman acceptance are conditionally less than those with JMA=1 condition in which it is assuming that the spatial correlation of the gust aerodynamic force and the spatial correlation of the contact flow are equal.

The Davenport condition and Karman condition are seemed to display indifferent value in lower frequency. On the other hand, the response values become desperate in higher frequency region of various wind velocity for both lift and torsional response; in higher frequency, Davenport condition is always greater than the Karman condition. It is said that the Davenport condition overestimates the spatial correlation characteristics of the approach flow especially for low frequency components, hence the response characteristics is the same as the spatial characteristics [5].

However, in this analysis, it can be shown that Davenport condition and Karman condition produce the indifferent response in heaving displacement till just after the heaving natural frequency of the structure. These two conditions are not alike anymore in torsional response; i.e. the responses are not the same after frequency of 2 Hz as shown in Figure 1and 2.

According to the calculation procedure, the responses depends on power spectrum density of gust wind, mechanical admittance of the structure, and aerodynamic admittance between the fluctuation wind and the structure. It is represented that the tailing edge of the experimentally measured is divergent from the buffeting analysis response for all the described mean wind speed here. Anyway, the divergent between the experimental response and analysis response becomes smaller with higher mean wind speed.

The reason is that the experimental response is directly obtained from the measured gust wind spectrum and the analysis response is corresponding to the formulated vertical gust wind spectrum that can be little incompatible to the actual condition. Also, in the case of peak response value of the analysis result which overestimate the experimental value, it can be said the experimentally defined mechanical admittance is variable with respect to the mean wind speed but the mechanical admittance used in this analysis is unaltered for all mean wind speeds.

If the aerodynamic admittance function is considered, the analysis response using aerodynamic admittance is discovered to be closed with the experimental response. Although the analysis response is nonidentical with experimental response in lower mean wind speed of 2.8 m/s and 3.7 m/s, it can be seen that the analysis response of Davenport and Karman conditions match with the experimental one in the higher mean wind speed.

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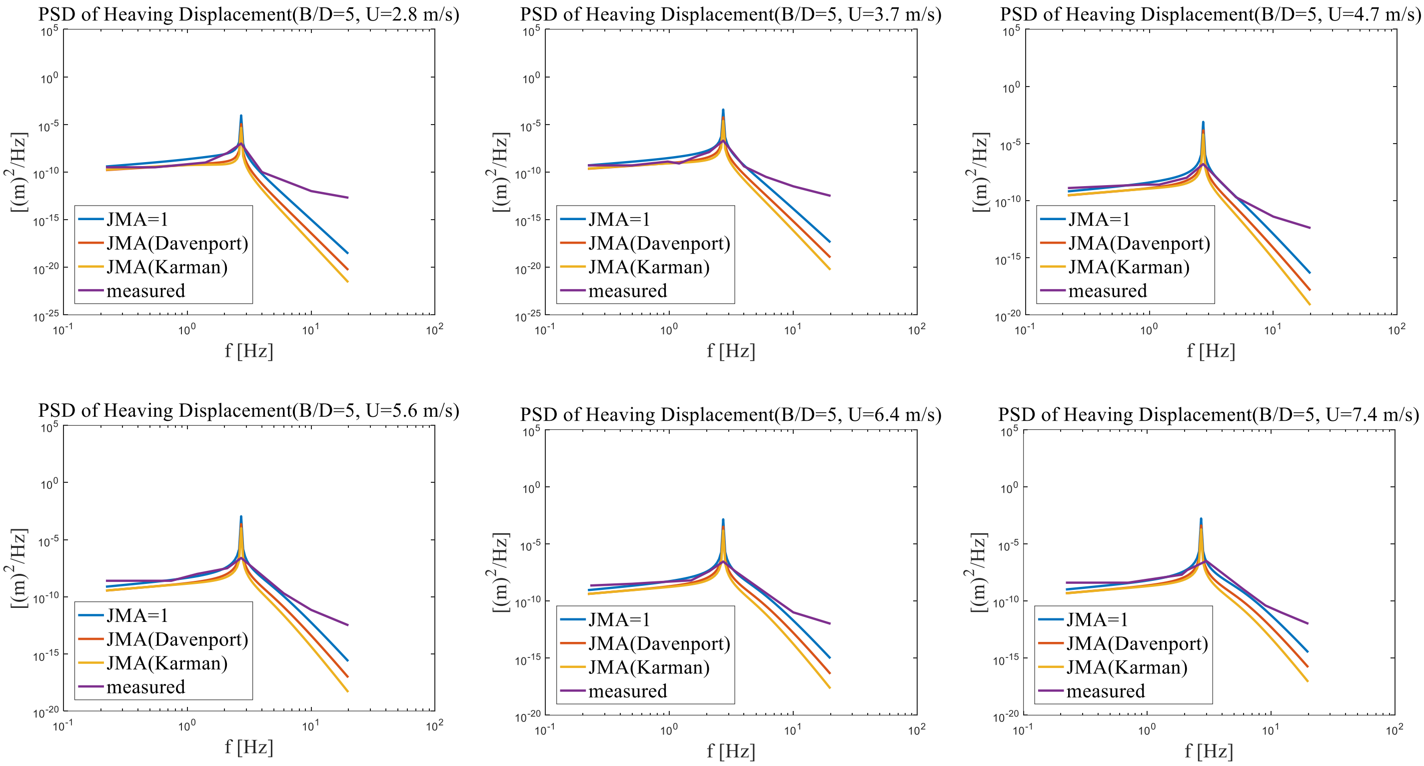

Figure1. Power Spectrum Density of Vertical Displacement of B/D=5 with Different Joint Mode Acceptance

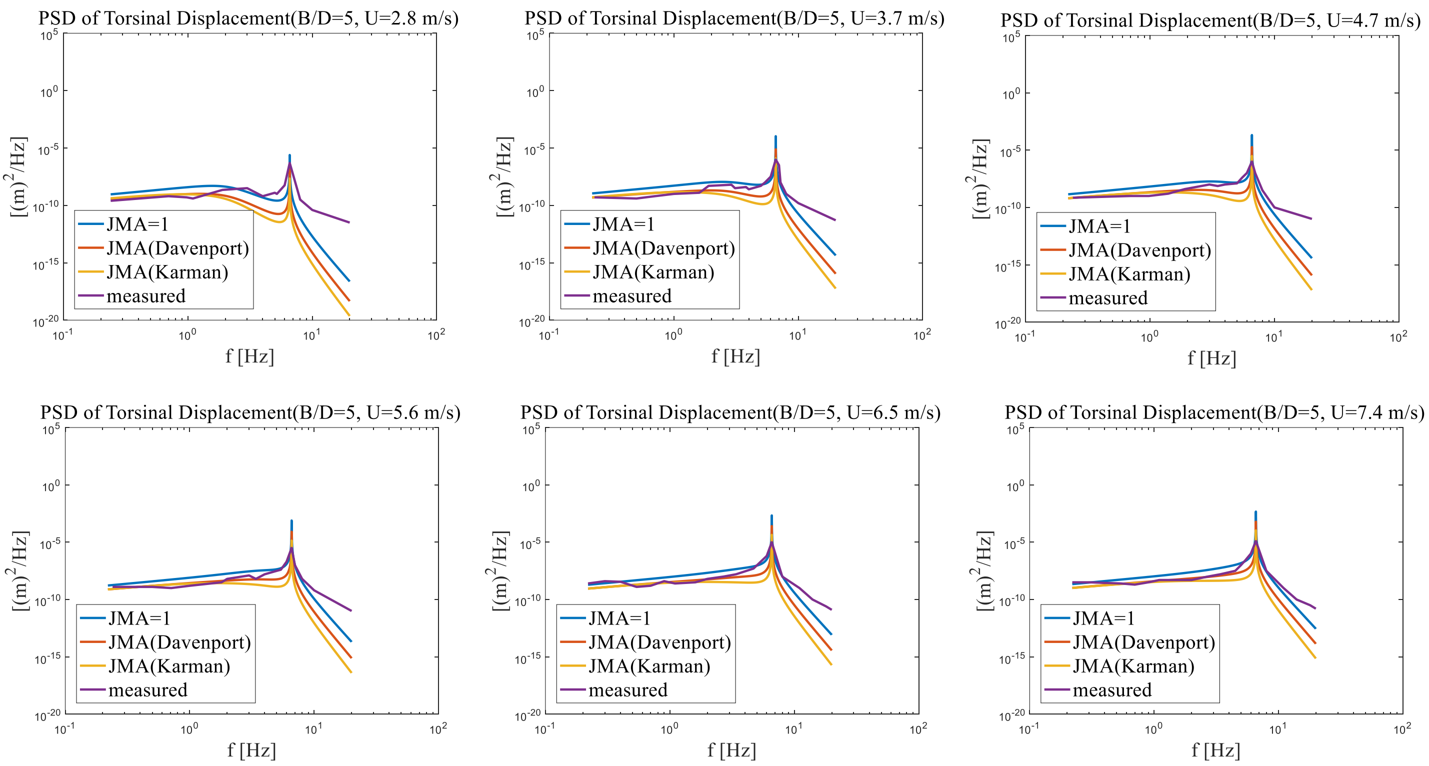

Figure 2. Power Spectrum Density of Torsional Displacement of B/D=5 with Different Joint Mode Acceptances

4. CONCLUSION:

This paper expresses the following facts;

- Davenport condition and Karman condition produce the indifferent response in heaving displacement till just after the heaving natural frequency of the structure. These two conditions are not alike anymore in torsional response.

- The analysis response of Davenport and Karman conditions match with the experimental one in the higher mean wind speed.
- Taking into consideration of the effect of coherence and joint mode acceptance in response prediction produce closer results with the actual conditions than JMA=1.

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