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ESTIMATION OF AERODYNAMIC ADMITTANCE BY NUMERICAL COMPUTAION

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1 INTRODUCTION

The present study describes the estimation of gust forces acting on bridge decks using numerical computations. When evaluating the gust response of a bridge using gust response analysis in frequency domain, aerodynamic admittance functions for the bridge deck and other members need to be defined. The aerodynamic admittance function of a bridge deck depends on its cross section[1][2], because the gust force acting on the bridge deck is generated not only from approaching gusty wind but also from the separated wind flow inherent in the deck cross section. In the usual way, wind tunnel tests for each cross section are carried out to evaluate the gust force, however, they are time-consuming and costly.

In this paper, the estimation procedure of aerodynamic admittance function is discussed. The aerodynamic admittance functions of several cross sections were calculated and were compared with wind tunnel test results.

2 COMPUTATION METHOD[3]

The two-dimensional incompressible Navier-Stokes equations are used as the governing equations. The numerical algorithm is based on the method of pseudocompressibility[4]. The convective terms are discretized by the fifth-order upwind differential scheme and the implicit method of second-order is employed as a time integration algorithm. The k-ω SST turbulence model[5] is used. An overset grid system is used in the present computation where an O-type grid around the body is overlapped on a background grid of H-type as shown in Fig.(1).

This paper focuses on lift fluctuation in the vertical gust. At the inlet boundary of the computational domain, the vertical gust is generated by controlling the inflow angle. The fluctuation in the along-wind direction is negligibly small because of a small inclination angle. The aerodynamic admittance was calculated directly from power spectrums of the computed lift forces and wind velocity at the assumed position of the body obtained from the computation performed beforehand for free-field without the body.

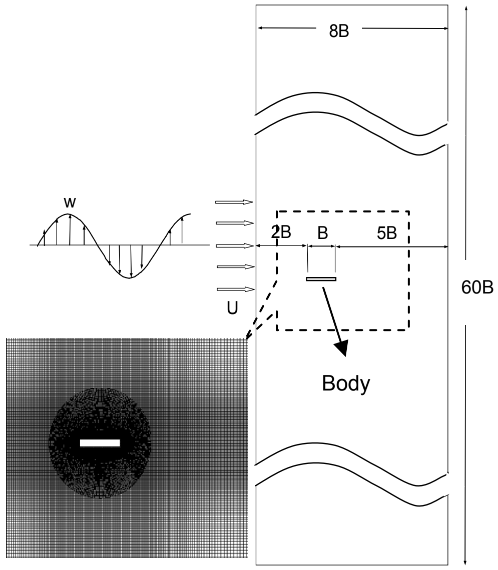


Figure 1 : Computational domain

3 CALCULATION CONDITIONS

A random gust which has a power spectrum similar to natural wind and sinusoidal gust were used. The vertical turbulence intensities of both flows were set virtually the same. Three basic cross sections shown in Table 1 were addressed.

Table 1: Calculation Conditions

		B/D=200	B/D=5	Hexagonal
Grid	Surrounding	285×83	293×45	265×43
	Background	294×459		
Time step (ΔtU/B)		0.01		
Reynolds Number（Re=UB/ν）		1.4×10^{5}		
Turbulent Properties		Random gust : Iw = 2.1% Sinusoidal gust : Iw = 2.2%		

B: Chord length, D: Depth of cross section, U: Wind speed, Iw: Turbulent intensity of vertical component

4 AERODYNAMIC ADMITTANCE FUNCTIONS

Fig.(2) shows fluctuating wind velocity of the vertical component and lift coefficients in the same period of time. It suggests that gust forces depend on cross-section shape. Aerodynamic admittance function can be evaluated based on these data.

First of all, the analysis method described above was validated through the calculation of a thin plate whose aerodynamic property has been established by aerofoil theory. In this study, a rectangular cylinder of B/D =200 was employed as a thin plate. Fig.(3) shows the computed result of aerodynamic admittance function together with the Sears Function. These two are found to agree with each other well. In addition, it was clarified that aerodynamic admittance functions in random gust and sinusoidal gust also corresponded with each other. This means that superimposition is applicable in estimating gust forces in relatively small wind fluctuation.

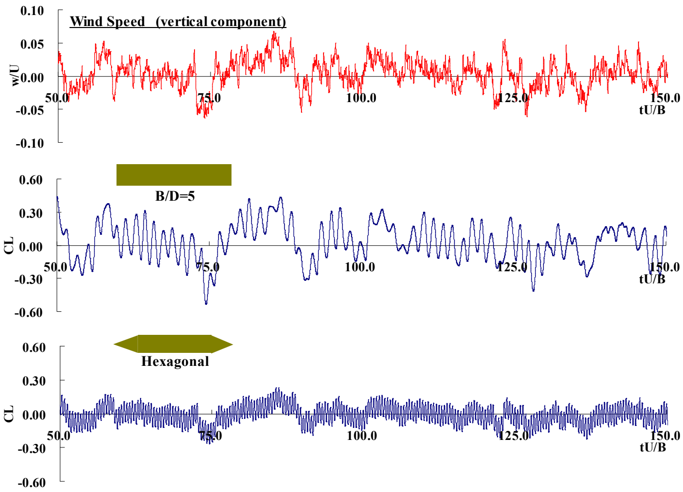
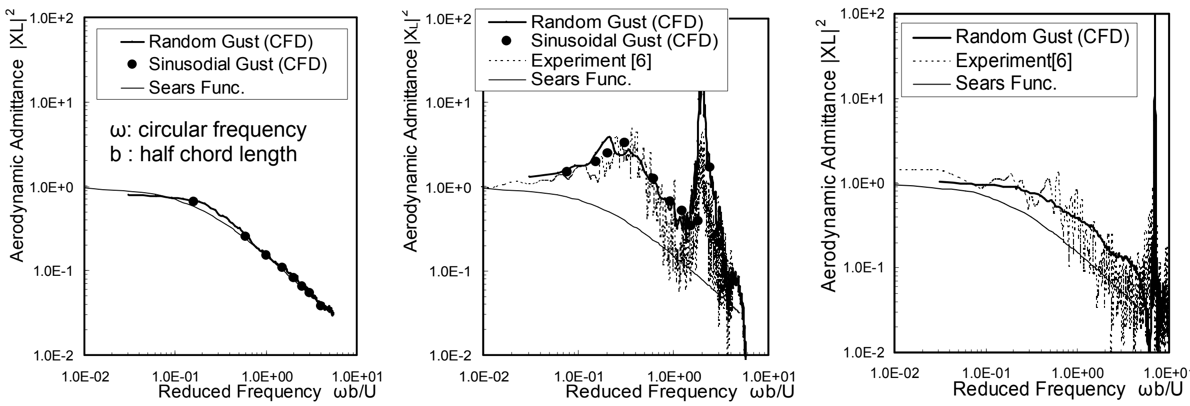


Figure 2 : Time histories of fluctuations of wind velocity and lift forces

As for the rectangular cylinder of B/D=5 and hexagonal cross section, the feature of aerodynamic admittance is found to be well simulated by the present computation. The reduced frequencies at the highest peaks correspond with the Strouhal Number.



(1) B/D=200 (2) B/D=5 (3) Hexagonal

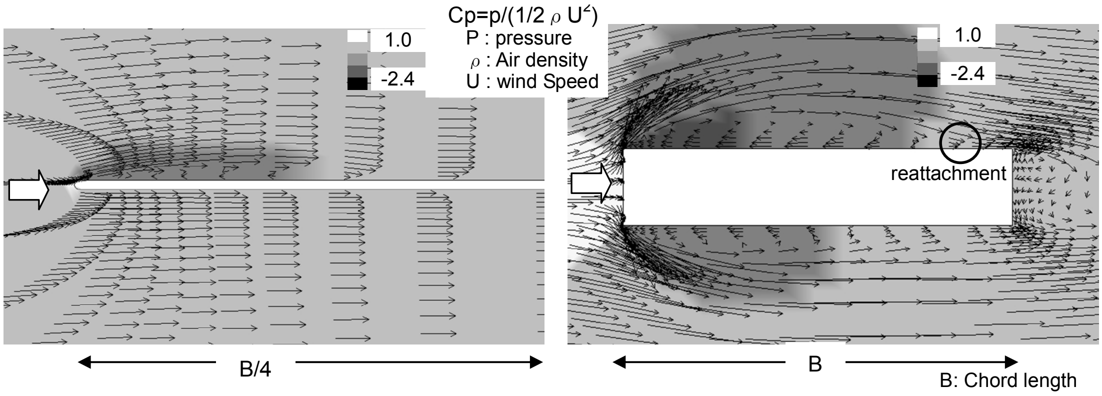
Figure 3: Aerodynamic admittance functions

5 FLOW PATTERNS AROUND THE CROSS SECTIONS

In order to discuss the difference of aerodynamic admittances between B/D=200 and B/D=5, flow patterns around the each cross section were examined. Typical instantaneous flow patterns at the moment that the upward lift force is maximum in the sinusoidal gust are shown in Fig.(4). In these figures, the distributions of velocity vector and pressure are indicated by arrows and by the shade of gray, respectively.

As for the B/D=200 cross section, a thin separated shear layer can be observed in a small area around the leading edge on the upper surface when the flow is blowing up. The characteristic of gust force is similar to that of airfoil. On the other hand, it is found that the massive separated shear layer is formed and the flow reattached near the trailing edge in the case of

B/D=5. The reattach point tends to move back and forth synchronously with vertical fluctuation of flow. It results in amplifying the fluctuating lift force due to vertical gust.



(1) B/D=200 (2) B/D=5

Figure 4: Instantaneous flow patterns in vertical gust

6 CONCLUSIONS

Aerodynamic admittance for rectangular cylinder of B/D=200 predicted by CFD well agreed with the Sears Function. As for the rectangular and hexagonal cylinder, the calculation results agreed well with an experimental result, too. CFD seems like a promising tool for predicting gust force characteristics of bridge decks.

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