NUMERICAL STUDY ON WIND FLOW AROUND BOX GIRDER SECTION WITH FLAP COUNTERMEASURE

Yokohama National University Student Member ○ Tran Anh Dat
Yokohama National University Regular Member Hiroshi Katsuchi
Yokohama National University Fellow Member Hitoshi Yamada
Yokohama National University Regular Member Mayuko Nishio

1. INTRODUCTION

Under the wind load, the safety of long span bridges must be thoroughly investigated to not only satisfy critical states but also meet fully necessary requirements for serviceability. Nowadays, box girder section has been often used in long span bridges because of its own advantages. In most cases, box girder configurations have been selected on economic efficiency than aerodynamic stable characteristics. Therefore, it results in aerodynamic instability phenomena of span structure. Normally, aerodynamic countermeasures are considered to attach to girder as a suppressing solution. The countermeasure selection primarily depends on experiments carried out in wind tunnel. The best one will be chosen on investigated models. Expensive time has lasted case by case with regard to each countermeasure as well as various positions and dimensions of one specific type. On the other hand, experimental models do not support necessary information to explain flow behavior. Recently, CFD has become a useful tool to study flow pattern, where one can combine with experimental results to deeply comprehend flow mechanism. In this paper, the flap-countermeasures attached to box girder with many different gaps and angles to suppress the vortex-induced vibration are analyzed by CFD to investigate flow behavior. The study aims to clarify the effect of flap in amplitude oscillation reduction. All cases, Reynolds-Averaged Navier-Stoke (RANS) simulation with $k-\varepsilon$ model is applied.

2. GOVERNING EQUATIONS

The governing equations used RANS model can, for incompressible flows without body forces, be written in tensor notation and Cartesian coordinates as:

$$\frac{\partial(\rho\overline{u_i})}{\partial x_i}=0\,;\quad \frac{\partial(\rho\overline{u_i})}{\partial t}+\frac{\partial}{\partial x_j}(\rho\overline{u_i}\,\overline{u_j}+\rho\overline{u_i'u_j'})=-\frac{\partial\overline{p}}{\partial x_i}+\frac{\partial\overline{\tau}_{ij}}{\partial x_j} \tag{1}$$

where $\partial\overline{\tau}_{ij}$ are the mean viscous stress tensor components: $\partial\overline{\tau}_{ij}=\mu\left(\frac{\partial\overline{u_i}}{\partial x_j}+\frac{\partial\overline{u_j}}{\partial x_i}\right)$ (2)

The $k-\varepsilon$ turbulence model is used to close the equations. Simulations are carried out by software STAR-CCM+.

3. ANALYTICAL CONDITION

Table 1 shows the analytical conditions. In addition, Fig.1 depicts the section model of box girder with flap countermeasure, where the length of flap is 1000 mm and flap is changed the gap a (150 mm, 600 mm, 800 mm) and the angle α (0^o, 10^o, 30^o). The width and height of analysis domain are 20D and 40D, respectively, where D is the height of box girder. Fine mesh is used in the vicinity of the section and coarser mesh is used at the areas far from section such as inlet, outlet zone… The non-slip boundary is assigned at the perimeter of section, the top and bottom wall.

Parameter	Units	Value
Width (B)	(m)	0.30
Height (D)	(m)	0.094
Aspect Ratio (B/D)		3.20
Number of element		140.000-150.000
Reynolds number		1.104
Wind Velocity	(m/s)	1.70
Time step (Δt)	(s)	0.005

Table 1. Dimension and analysis conditions

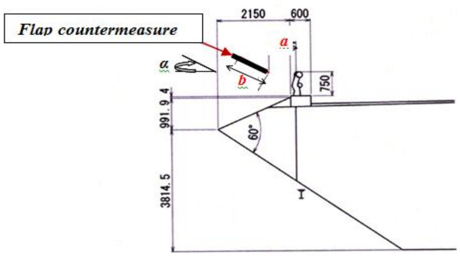


Fig.1. Geometry of box girder and flap countermeasure

4. RESULTS AND DISCUSSIONS

At first, numerical analysis simulation is checked in term of comparison three force component coefficients from wind tunnel test for basic section with various attack angles of wind flow. The obtained values have agreed with the experimental ones (Fig.2). Next, simulations are conducted with the present of flap-countermeasures. In wind tunnel test, vortex-induced vibration amplitude is measured with many different configurations of flap (Fig.3).

Keywords: CFD, Box girder, Flap, RANS model, Three force component coefficients, RMS, Base pressure coefficient.
Contact address: Structural Eng. Lab., Dept. of Civil Eng., Yokohama National University, Yokohama 240-8501, Japan.

Base on CFD simulations, power spectrum density (PSD) of vertical velocity at a point in vortex wake region (Fig.4) show that it has the maximum value in basic section case and this value decreases gradually with flap attached to the section, specially with enough gap and angle cases of flap such as 1000/800/30 (length/gap/angle of flap). On the other hand, three mean force component coefficients and their root mean square (RMS) also demonstrate that the 30 angle of flap cases will has smaller fluctuation and more stable than the others (Fig.5). In addition, RMS of pressure coefficient around the section in Fig.6 has progressive value when the angle of flap approaching to 0 degree. Fig.7 depicts the pattern of wind flow. If the gap and angle is sufficient, the flow will be intercepted by flap and go down stronger to the upper surface of faring. Hence, it will control vortex wake region become more regular and reduce oscillation amplitude.

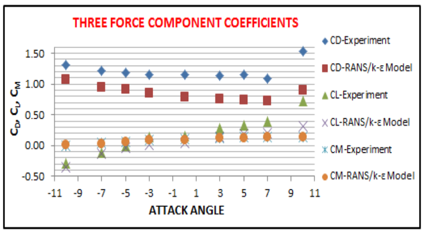


Fig.2. Three force coefficients of basic section

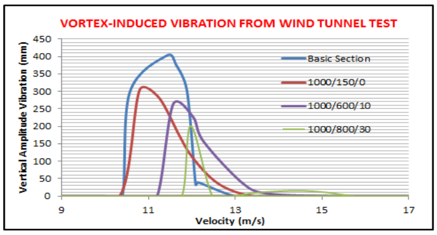


Fig.3. Vortex-induced vibration from wind tunnel

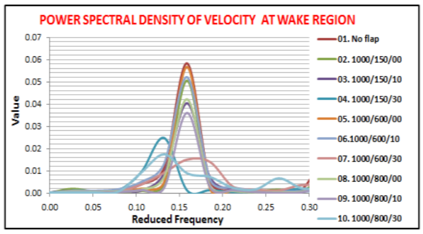


Fig.4. PSD of vertical velocity at a point in wake region - CFD result

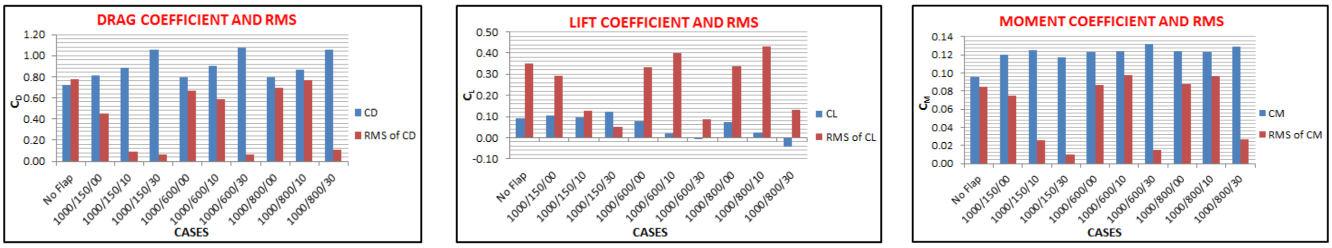
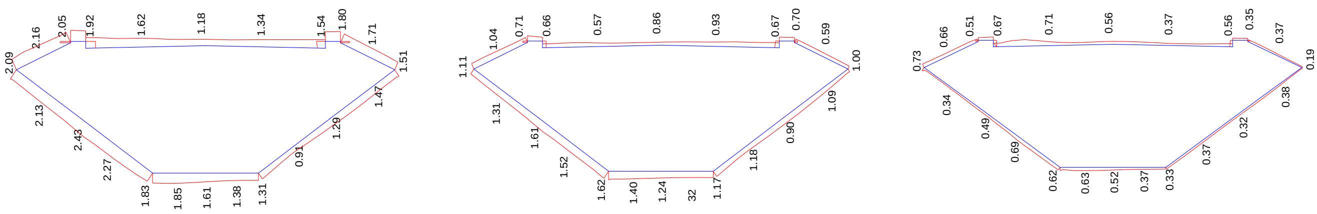
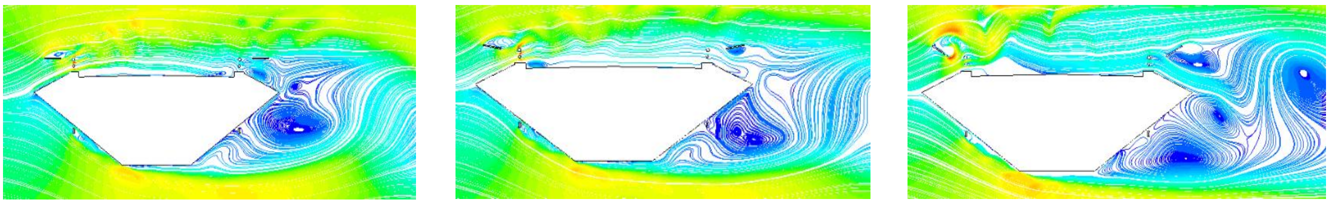


Fig.5. Three mean force component coefficients and their RMS



a. 1000/800/0 Case b. 1000/800/10 Case c. 1000/800/30 Case

Fig.6. RMS of pressure coefficient around box girder section - Distribution diagram



a. 1000/800/0 Case b. 1000/800/10 Case c. 1000/800/30 Case

Fig.7. Wind flow pattern around box girder section

5. CONCLUSIONS

The presence of flap on box girder section has resulted in the change of wind flow behavior and has brought the significant effect in diminishing vortex-induced oscillation amplitude. Numerical analysis CFD using RANS model obtained in this paper has led a good agreement to the experimental results from wind tunnel test. From the numerical study, flow pattern and RMS of pressure supply comprehensive investigation for the role of flap. Thence, flap with sufficient large gap and angle is recommended to suppress the vibration amplitude for box girder under wind load.

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