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Numerical Investigation of Aerodynamic Interference on Wind Loads for a Twin Bridge

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Abstract. Numerical investigation has been performed to figure out the aerodynamic interference effects on wind loads for a twin bridge. The distance between the bridge girders varies from 0.2B to 1.0B, where B is the girder width, and wind loads (drag, lift and moments) are measured. Due to complicated flow patterns around the girders, large eddy simulation has been employed in this study. Visualization of the flow field shows that the leeward girder disturbs the wake shed from windward girder and triggers fluctuating wind loads. As the distance between girders increases, rotational behavior of leeward girder increases with the distance while windward girder shows no significant flow fluctuations.

Keywords: aerodynamic interference effect; twin bridge; large eddy simulation.

1. Introduction

Aerodynamic stability is the main design issue of long-span bridge design and construction since the collapse of Tacoma-narrows bridge. Details of the wind induced responses of slender and flexible structures are tested in the wind tunnel and this approach has been successful in the design of modern long-span bridges. Akashi Kaikyō Bridge, 1991 meters of main span length, was constructed in 1998 through intensive wind tunnel studies. Recently, bridges with more than 3000 meters span length have been proposed such as Sunda strait bridge and Messina bridge with the aid of cutting-edge wind engineering technologies.

Another design issue of long-span bridges is aerodynamic interference effects. While most of the bridges are single girder configuration, Neva cable stayed bridge (Kolyushev and Kiviluoma) and Second Jindo bridge (Donho You) have twin girder configuration. Similar to the aerodynamic interference effects of tall buildings, twin girders experience severe interference effects. The most dominant phenomenon is vortex induced vibrations and corresponding interferences. For a single girder configuration, bluff bridge girder employing fairings may have improved aerodynamic capability. But it may have totally different aerodynamic behaviors when the girder located in parallel.

Numerical investigation has been attempted to figure out the interference effects for a twin girder bridge. Complicated turbulent flow around the girders is modeled using large eddy simulation technique. As an initial phase, girders are fixed and fluctuating wind loads are collected. FSI (fluid-structure interaction) simulation of the twin girders will be the second and future research activities.

2. Numerical Methods

Fig.1 shows the girder and horizontal and vertical dimensions are B=1.574m and H=0.093m, respectively. Fig.2 presents the computational domain and corresponding boundary conditions. Uniform velocity profile at inlet, ouflow condition at outlet and symmetry boundary conditions at upper and low boundaries.

The computational domain is modeled with 400,000 triangular cells. For spatial discretization, 2nd order for pressure and bounded central differencing for momentum equations are used. Fractional step method is employed for pressure-velocity coupling. Smagrinsky-Lilly subgrid scale model based large eddy simulation (LES) is used to solve high Reynolds number turbulent flow.

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Fig.3 shows the twin girder sit in parallel with girder edge distance of L. Current study varies L from 0.2B to 1.0B and assessed the interference effects in terms of wind loads acting on the girders.

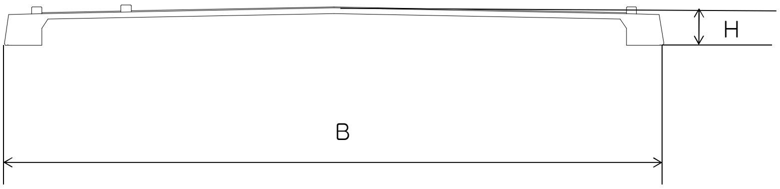


Fig. 1 Single girder (B=girder width, H=girder height)

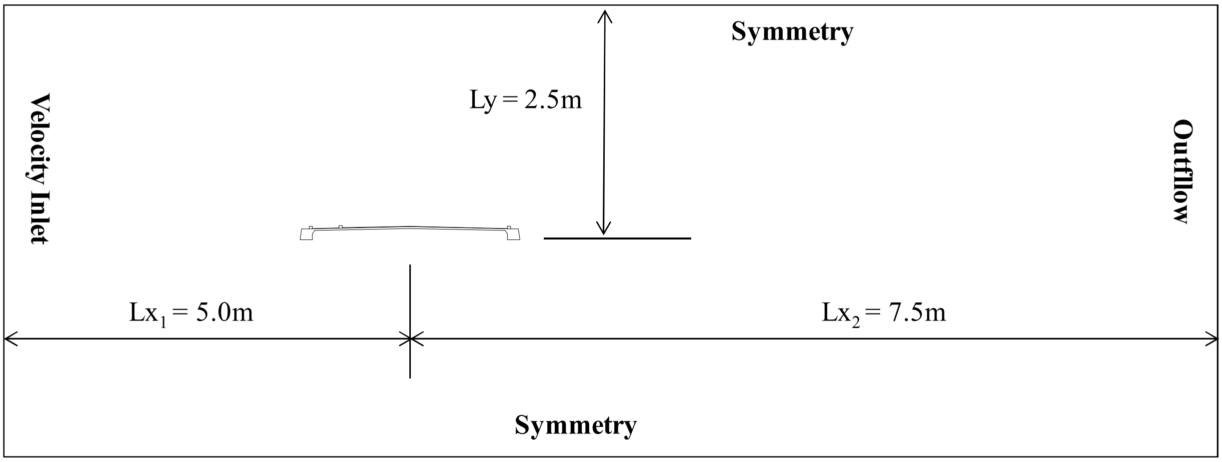


Fig. 2 Computational domain and boundary conditions

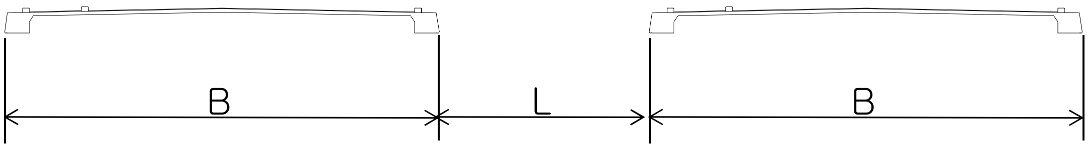


Fig. 3 Twin girder (L=girder edge to edge distance)

3. Results

3.1 Single girder

Turbulent flow around the single deck has been simulated as a reference case. Fig. 4 presents an instantaneous vorticity flow field. LES results are summarized as follows;

a) Mean force coefficients
Mean drag coefficients $C_{D,Mean} = 1.45$
Mean lift coefficients $C_{L,Mean} = 0.24$
Mean moment coefficient $C_{M,Mean} = 0.03$

b) Fluctuating force coefficients
rms drag coefficients $C_{D,rms} = 0.61$

rms lift coefficients $C_{L,rms}=0.19$
rms moment coefficients $C_{M,rms}=0.79$

,where drag Coefficient, C_D = Drag Force / (0.5*air_density*V_{ref}* V_{ref} * H), Lift Coefficient , C_L = Lift Force / (0.5*air_density* V_{ref} * V_{ref} * B), moment Coefficient, C_M = Moment Force / (0.5*air_density* V_{ref} * V_{ref} * B*H), $V_{ref} = V_{inlet}$ = 10m/s.

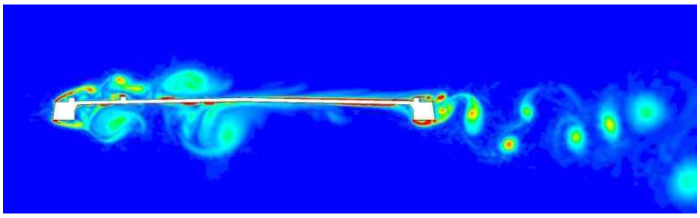


Fig. 4 Vorticity contours of single girder

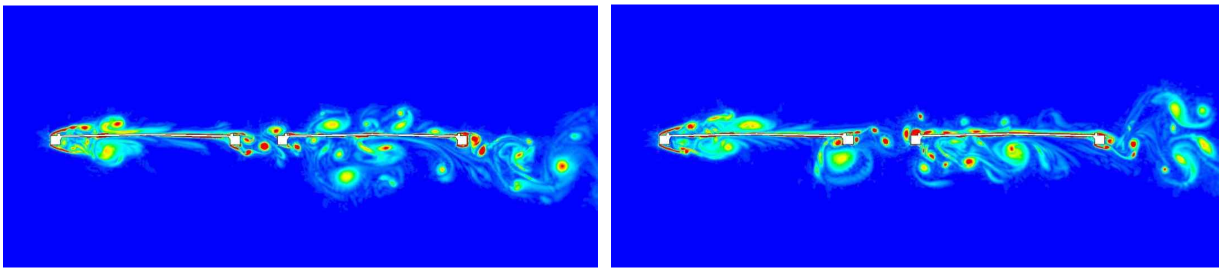
Fig. 4 shows that high shear layers are developed at the upper and lower leading edges. These shear layers are disconnected and developed into a vortical structures shedding downstream along the girder surfaces. In the wake region, eddies shed from trailing edges with different eddy distances.

3.2 Twin girder

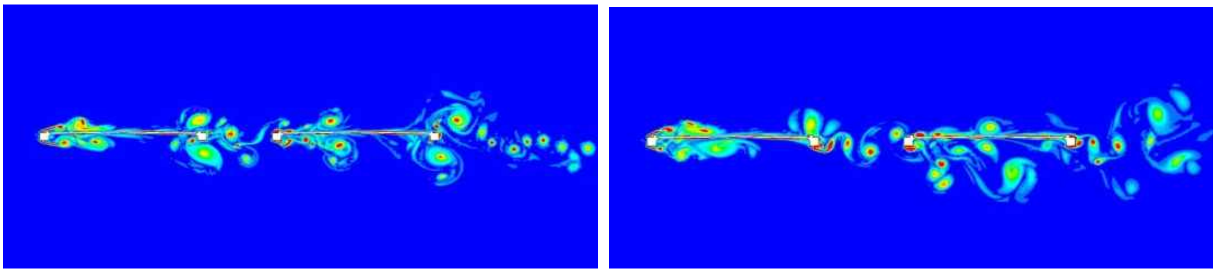
For various girder edge distances of L/B=0.2~1.0, vorticity flow fields are presented in Fig. 5. As L/B increases, vortical flow structures merged and scaled-up eddies impact on the leeward girder.
These vortical flow structures, sometimes called coherent structures, induce fluctuating wind loads on girders. While Fig. 5 shows wind effects on the girders quantitatively, Fig. 6 provides interference effects more clearly.
Fig. 6a shows mean and rms drag coefficients. Mean drag force increases with girder distances but flucutaing drag forces are almost same level. Due to shielding effect, windward girder (G1) exposed to higher speed wind flow resulting in higher mean drag force but leeward girder (G2) experiences lower levels of fluctuating drag forces. The effects of lift force also shows similar trend as shown in Fig. 6b. Comapring with single girder results, windward girder (G1) experiences simlar magnitude of wind loads and effects of leeward girder (G2) to G1 is minimal.
Fig. 6c indicates that interference effects are more dominant for leeward girder (G2) due to rotational wind load. Mean as well fluctuating componets increases with L/B for G2. Note that fluctuating moment coefficient of G2 is almost 10 times bigger than that of G1.

4. **Conclusions**

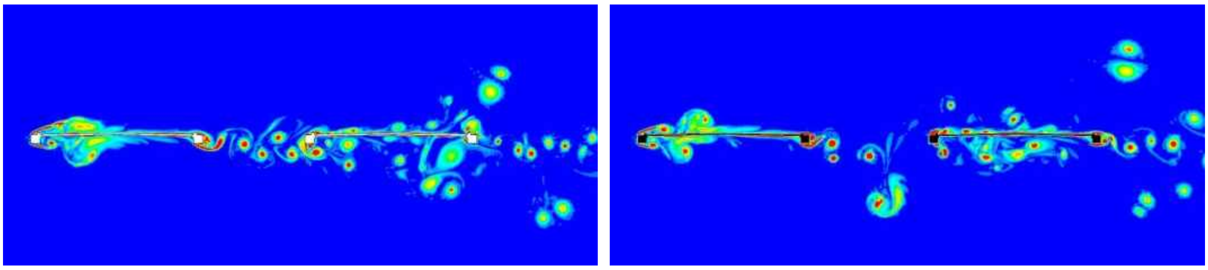
Large eddy simulations of turbulent flow for a single and twin girder have been performed to figure out the aerodynamic interference effects on a twin bridge. For a twin bridge consisted of edge girders, numerical analyses provides that aerodynamic interference effects are dominant only for the leeward girder while wind loads of windward girder (G1) are equivalent level to those of single girder case.
This study assumes that girders are fixed and associated fluctuating wind loads are measured. In reality, girders oscillate due to vortex induced wind loads and the girder motion changes flow field. So the interference effects in reality is much more complicated phenomenon considered in this study. To assess these effects of twin bridge more accurately, fluid-structure interaction simulations of the two girders should be considered.



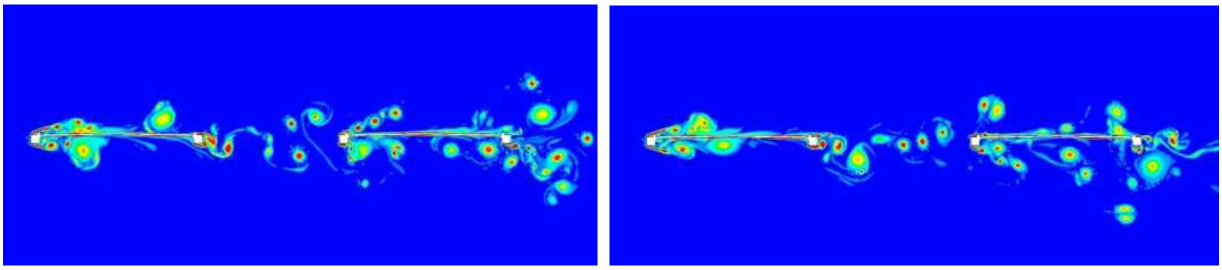
(a) L/B=0.2 (b) L/B=0.3



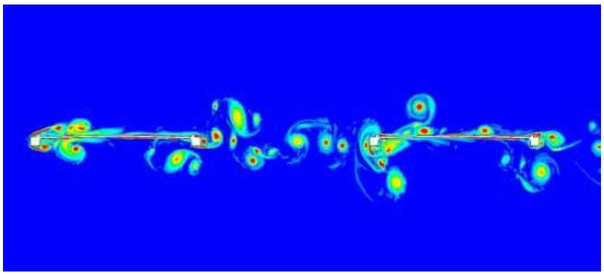
(c) L/B=0.4 (d) L/B=0.5



(e) L/B=0.6 (f) L/B=0.7

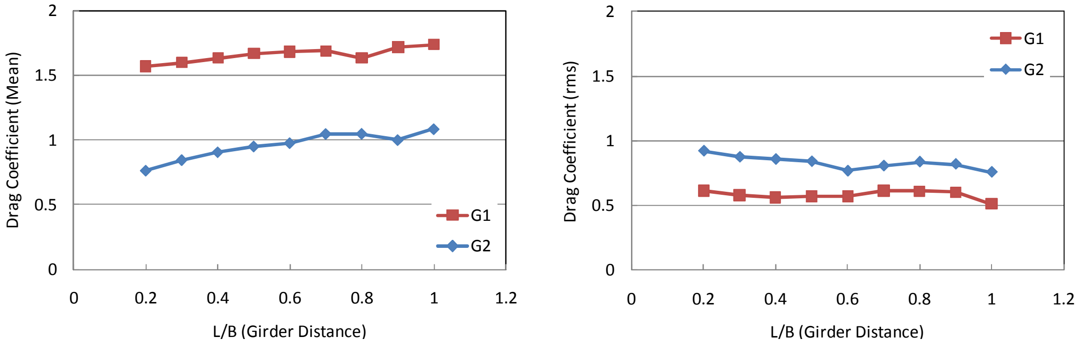


(g) L/B=0.8 (h) L/B=0.9

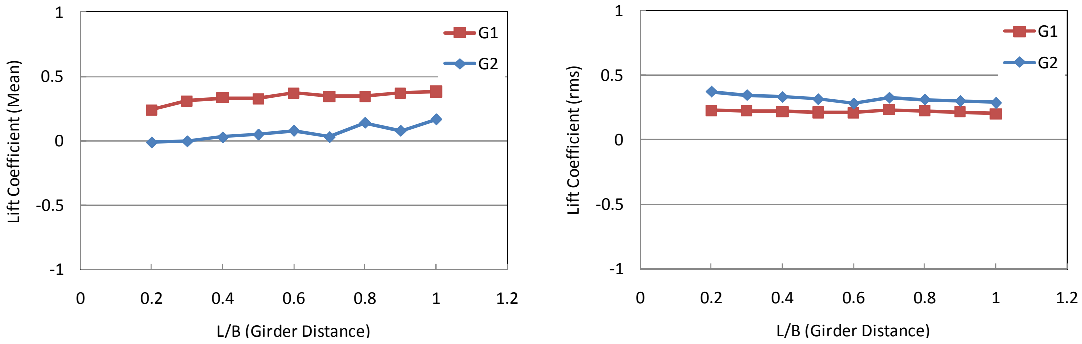


(i) L/B=1.0

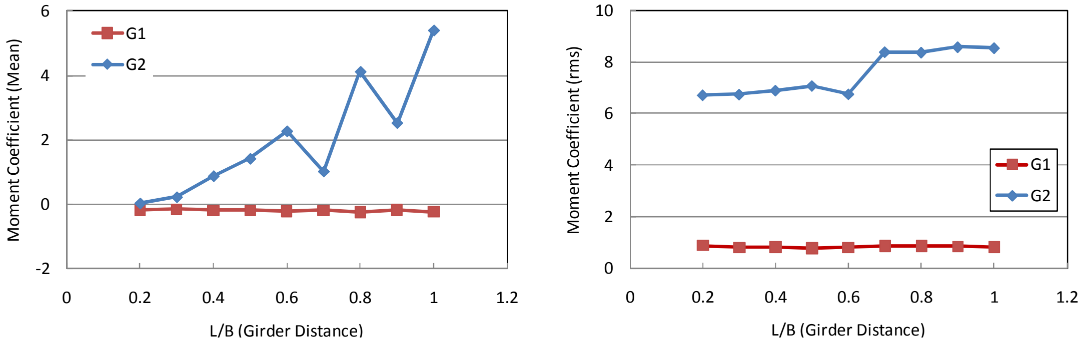
Fig. 5 Vorticity contours around twin girder



(a) Drag coefficents



(b) Lift coefficents



(c) Moment coefficients

Fig. 6 Interference effects: Mean and rms force/moment coefficients versus girder distances

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