1. Introduction

Recently, the butterfly web girder, a type of box girder with side openings, has been introduced to replace the traditional box girder, due to its structural performance advantage. Furthermore, a girder of this type with side ratio about 5 has been confirmed to have better wind-resistance performance. However, the researches related to aerodynamic performance of the box girder with side openings have been rarely touched. Moreover, the investigation on the aerodynamic performance of box girder with side openings in parallel girders situation has never been carried out. This research mainly focuses on the openings’ effects on aerodynamic performance of box girder in single girder and parallel girders situation by using two same butterfly web girders with side ratio of 3.24 in wind tunnel tests.

2. Experimental set-up

The experiments were carried out in uniform flow in the room-circuit Eiffel type wind tunnel in Kyoto University. Two butterfly web girder sectional models with a geometrical scale 1:80 were built. The width and height of the model are 161.9 mm and 50 mm respectively. (Fig 1 (c)) The details of the openings’ size on the side wall of the girder is shown in Fig 1 (d). For the convenience of discussion, the open case is defined as butterfly web girder shown as Fig. 1 (a), while the close case is defined as butterfly web girder covered by the 1mm acrylic plate shown as Fig 1 (b).

For the free vibration tests, in order to simplify the problem, only one vertical degree freedom experiments were carried out for both single girder and parallel girders tests. As a fundamental research, the mass and damping of the system were set small and almost same for the single girder and parallel girders tests. Furthermore, the cases of the parallel girders tests were designed as that the upstream girder was elastically supported and the downstream girder was rigidly connected to the wall of the wind tunnel and vice versa. This is different from the both two girders elastically supporting arrangement in the past research for the convenience of discussion. Besides, according to past research, the distance of the two girders was defined as 2B (B=width of the girder).

3. Experimental results for single girder

3.1 Aerostatic performance of the girder

As shown in Fig 2, the absolute magnitude of lift coefficients of the open case is relatively smaller than that of the close case. And also lift coefficient for the close case shows negative gradient at a relatively larger attack angle range (1 deg. to 4 deg.) than that for the open case (2 deg. to 4 deg.). This indicates that the side openings of the girder would lead to smaller lift and galloping stability at larger attack angle range.

3.2 Aerodynamic performance of the girder

The one degree vertical responses of close case and open case under attack angle +3 deg, are summarized in the Fig 3.

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For the close case, the motion-induced vortex vibration with a largest amplitude 22mm occurs at about reduced wind velocity range 4–5 and galloping occurs at about reduced wind velocity 11. While for the open case, the motion-induced vortex vibration’s largest amplitude turns to be 12 mm at the same reduced wind velocity range 4–5 and the galloping does not occur. This indicates that the openings on the side wall could diminish the motion-induced vortex vibration and lead to galloping stability.

4. Experiment results for parallel girders
4.1 Aerodynamic performance of the upstream girder with a stationary downstream girder

The vertical aerodynamic performance of upstream girder with a stationary downstream girder under attack angle +3 deg. is summarized in Fig. 4. According to Fig. 4, by comparing the ‘close-close’ case and ‘open-close’ case, the motion-induced vortex vibration with a largest amplitude about 22 mm at reduced wind velocity range 4–5 and the galloping with a critical reduced wind velocity about 6 occur for the upstream close case, while the largest amplitude of the motion-induced vortex vibration turns to be 14 mm and the galloping critical reduced wind velocity turns to be about 9 for the upstream open case. The same result could be concluded by comparing the ‘close-open’ case and ‘open-open’ case in Fig. 4. This indicates that the openings on the side wall of the upstream girder could diminish the motion-induced vortex vibration of upstream girder and lead to better galloping stability of the upstream girder regardless of the downstream girder’s type.

4.2 Aerodynamic performance of the downstream girder with a stationary upstream girder

The vertical aerodynamic performance of the downstream girder with a stationary upstream girder under attack angle +3 deg. is summarized in the Fig. 5. According to Fig. 5, the motion-induced vortex vibration and galloping are diminished and another wind velocity restricted vibration occurs at reduced wind velocity range 7-10 for the downstream girder. By comparing the ‘close-close’ case and ‘close-open’ case, the largest amplitude for this vibration of close case downstream girder is about 35 mm while for the open case downstream girder, the largest amplitude for this vibration is about 27 mm. The same result could be concluded by comparing the ‘open-close’ case and ‘open-open’ case. Thus, this wind velocity restricted vibration is diminished by the openings on the side wall of the downstream girder regardless of upstream girder’s type. And this wind velocity restricted vibration may be caused by the forced vibration due to the wake flow of the upstream girder.

5. Conclusion

The openings on the side wall of the girder could lead to better aerodynamic performance of the box girder for the single girder. For the parallel girders, the openings on the side wall of the girder could lead to better aerodynamic performance of the upstream or downstream girder regardless of stationary downstream or stationary upstream girder’s type.

Reference