Feasibility Study on Aerodynamically Stable Suspension Bridge with Simplified Girder Structures

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Summary

Feasibility of an aerodynamically stable suspension bridge with a simplified girder was studied by conducting a 1/40-scaled section model wind-tunnel test and structural analyses. An open grating deck, triangular faring, center stay and diagonal bracing as well as additional mass were tried to improve the aerodynamic stability. Finally, possible solution for an aerodynamically stable simplified girder structure was proposed.

Keywords: Suspension bridge; aerodynamic stability, wind-tunnel test; simplified deck; open grating deck.

1. Introduction

Suspension bridge is the most suitable form for long-span bridges from the viewpoint of structural efficiency. However, a long-span suspension bridge is susceptible to wind effects and tends to be less economically efficient. In this study, simplified girder structures, as shown in Fig. 1 such as a composite concrete deck with steel girders and an open-grating deck with steel girders, are applied to a long-span suspension bridge, and their feasibility is investigated by means of structural analysis and wind-tunnel test.

Fig. 1: Edge girder structure

Fig.2 Section model of open-grating

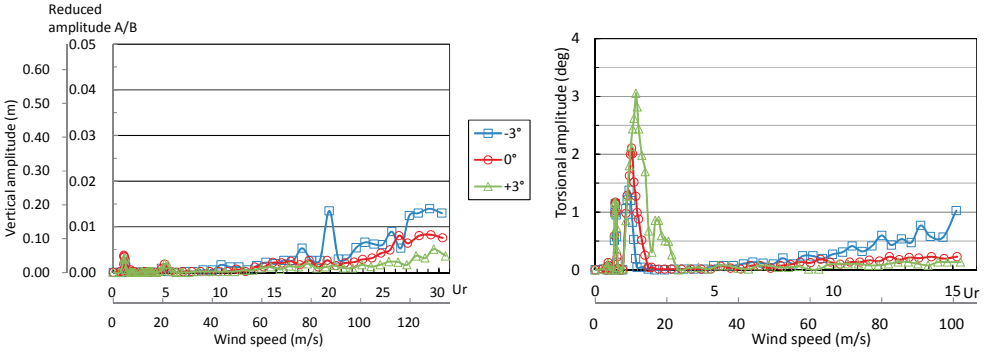
2. Modelling and wind-tunnel test

Model suspension bridges with the main span of 540m, the deck width of 13m and the sag ratio of 1/10 were firstly designed. Structural parameters of deck type (RC, composited and open grating), number of girders (2, 3, and 6) and hanger-cable interval (10, 15 and 20m) were changed. Based on structural calculation results, their aerodynamic stability was investigated by a 1/40 section-model wind-tunnel test, as shown in Fig.2. Triangular-shape fairings were also considered to improve the aerodynamic stability.

Test results showed that open-grating deck girder exhibited large-amplitude torsional vortex-induced vibration, flutter never occurred however, as shown in Fig. 3. On the other hand, solid deck girder exhibited torsional flutter and small-amplitude vortex-induced vibration, as shown in Fig. 4.

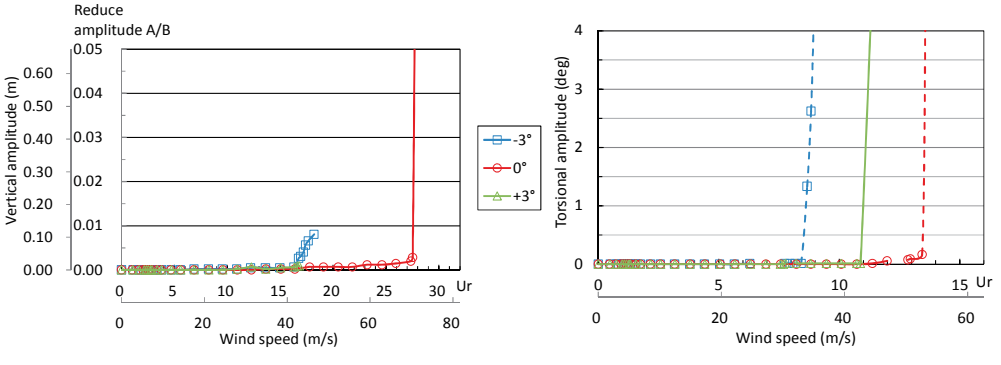
Based on the test results, structural countermeasures to increase torsional natural frequency and flutter onset wind speed were considered. It was found that cable ties between main cables and girder, and diagonal bracing under the girder could increase the torsional frequency effectively.

Based on the wind-tunnel test result (Case 20 in Fig. 4), putting diagonal bracings below the girder (solid deck, triangular faring and increase weight) increased the flutter onset wind speed to more than 50m/s and 80m/s at -3 and 0 degree angles of attack, respectively. This will make the girder structure aerodynamically feasible except for severe wind condition areas.



(a) Vertical *(b) Torsion*

Fig. 3 Vibration amplitude vs. wind speed (Case 1)



(a) Vertical *(b) Torsion*

Fig. 4 Vibration amplitude vs. wind speed (Case 20)

3. Conclusions

Feasibility and improvement of aerodynamic stability of simplified suspension-bridge girder structures for 500-1,00m span was studied by structural analysis and wind-tunnel test. The wind-tunnel test showed that a solid deck supported by two edge girder structure with triangular-shape faring provided the possible feasibility of flutter onset wind speed. On the other hand, a steel grating deck structure exhibited large amplitude torsional vortex-induced vibration. Further improvement of flutter onset wind speed of the solid deck structure was realized by cable stays or diagonal bracings. Flutter onset wind speed with diagonal bracings increased to more than 50m/s and 80m/s at -3 and 0 degree angles of attack, respectively. This will make the simplified girder structure proposed in this study aerodynamically feasible except for severe wind condition areas.