Improving Aerodynamic Stability of Long-Span Bridges with slight adjustment on Girder Sections

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Summary

For long-span cable-supported bridges, aerodynamic flutter control measures, such as central-slotting, have been proven to be very effective through both theoretical and experimental investigations, but will change the original girder sections significantly. In this paper, the flutter performance improvements on two typical girder sections were achieved by adjusting the arrangement of inspection rails, which only made slight modifications to the original girder section. The flutter controlling effect was verified through a series of wind tunnel tests, and the focus was put on the optimal position of inspection rails and other parameters as well. The research results indicate that inspection rails can be very helpful to improve the flutter performance of long-span cable-supported bridges with appropriate positioning. Its influence on the vortex-induced vibration performance and corresponding countermeasure was finally investigated.

Keywords: Long span bridge; flutter instability; flutter control measure; inspection rail; vortex-induced vibration; central stabilizer; guide vane.

1. Introduction

Several aerodynamic flutter control measures, such as central-slotting and vertical or horizontal stabilizers, which all have relatively significant changes to the original girder sections, have been proven to be effective through both theoretical and experimental investigations. However, sometimes this kind of change to the original girder section is not acceptable. Can relatively small adjustment to the aerodynamic configuration of girder section be effective to improve structural aerodynamic performance to meet with the requirements? In this paper, the aerodynamic improvement on two typical girder sections, single box girder section with cantilevered slab and central-slotted box girder section, was achieved by adjusting the arrangement of inspection rails, which only made slight modifications to the original girder section.

2. Aerodynamic improvement for box girder with cantilevered slab

2.1 Flutter performance of the original girder section

Box girder with cantilevered slab has been widely used in the construction of cable-stayed bridges with a main span from 100m to 500m. Fig. 1 shows the main girder section of the main navigational bridge in the East Sea Bridge located in Shanghai. The wind tunnel tested results indicate that the flutter onset speed decreases dramatically when the wind angle of attack turns positive and can not meet with the wind speed requirement.

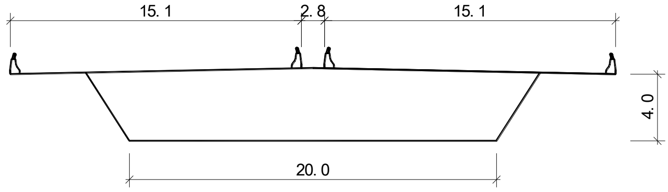

Fig. 1: Box girder with cantilevered slab

https://doi.org/10.2749/222137809796068073
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2.2 Aerodynamic improvement

It can be inferred from above results that adjusting aerodynamic configuration of the windward inclined web and the bottom slab may affect the aerodynamic stability of this type of girder section significantly. So the effect of adjusting the position of inspection rails was investigated through wind tunnel tests. The flutter critical speed was improved by 11% after inspection rails were positioned at the bottom of the inclined web, thus the wind speed requirement can be satisfied.

3. Aerodynamic improvement for central-slotted box girder

3.1 Improvement on flutter performance

Previous studies reported in the literature and investigations carried out by the authors all support the conclusion that central-slotted box girder has better flutter performance than single box girder. However, under some circumstances we need to further improve the flutter performance of long-span bridges with central-slotted box girder. Investigation was carried out to examine the flutter control effect of adjusting the position of inspection rails for central-slotted box girder as shown in Fig. 2, which was adopted in Xihoumen Bridge with the main span of 1650m.

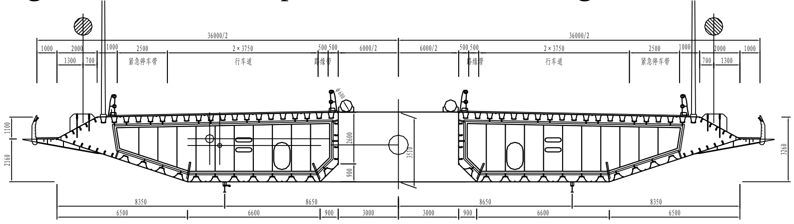

Fig. 2: Central-slotted box girder

According to the results, the effect of different positioning of inspection rails on the structural flutter performance is relatively limited. The maximum improved ratio of the flutter critical speed is 3.7%. However, it does help the bridge structure meet the wind speed requirement of 78.7m/s. Furthermore, we tried adjusting the distance between the top of the inspection rail and the bottom of the inclined web, and investigated the influence of this kind of adjustment on the structural aerodynamic stability. It is found that the flutter performance varies with the change of the distance between the inspection rail and the inclined web, and there possibly exits an optimum distance which is more or less similar to the optimum slot width of central-slotted box girder.

3.2 Vortex-induced vibration performance

Although central-slotted box girder has better flutter performance, other wind-induced problem especially vortex-induced vibration has been encountered in corresponding studies. Through wind tunnel tests, it is found that the position of inspection rails has little influence on the structural vortex-induced vibration performance, and the vibration can be suppressed only when the rails were removed, but this is impracticable. In order to mitigate the oscillation, guide vanes were installed at the bottom slab near central slot, and their effectiveness was verified by wind tunnel tests.

4. Conclusion

The improvement on flutter performance for two typical girder sections, single box girder section with cantilevered slab and central-slotted box girder section, were achieved by adjusting the arrangement of inspection rails, which only made slight modifications to the original girder section. The research results indicate that, with the appropriate position and the appropriate distance between the top of inspection rail and the bottom of girder slab, inspection rails can be very helpful to improve the flutter performance of long-span cable-supported bridges. The influence of different positioning of inspection rails on the vortex-induced vibration performance of central-slotted box girder was then investigated, and corresponding countermeasure, the installation of guide vanes, was finally proposed and verified by large-scale sectional model wind tunnel test.

5. Acknowledgements

The work described in this paper is part of a research project financially supported by the Natural Science Foundation of China under the Grants 50608059, 50538050 and 90715039, and the Hi-Tech Research and Development Program of China under the Grant 2006AA11Z108.