Equivalent Wind Loading of Long-span Arch Bridges

YongXin YANG
Associate Professor
State Key Lab for Disaster Reduction in Civil Eng.
Tongji University
Shanghai, 200092, China
yang_y_x@tongji.edu.cn

YongXin Yang, born 1974, received his Ph. D degree from Tongji University in 2002. He has worked in Tongji University for 10 years.

YaoJun GE
Professor
State Key Lab for Disaster Reduction in Civil Eng.
Tongji University
Shanghai, 200092, China
yaojunge@tongji.edu.cn

Yaojun Ge, born 1958, and received his Ph. D degree from Tongji University. He is currently the Lab Director and the Chairman of Department of Bridge Engineering.

Summary

With the consideration of usually bluff cross sections of arch ribs and ever-growing span length, it is necessary to carry out careful investigation on wind loading of long-span arch bridges in order to ensure aerodynamic safety of arch ribs and the whole bridge. However, compared with the main girder, even the static wind load of an arch rib is more complicated for the commonly change of elevation, cross section shape and inclination angle along the axis, while different types of possible wind-induced vibrations make the dynamic wind loading more complicated. Based on engineering practices on long-span arch bridges in China, the analysis of different combinations of equivalent wind loading for different construction stages of arch bridges, including the determination of static wind load for some complicated arch rib structures were investigated and discussed.

Keywords: Long-span arch bridge; equivalent wind loading; static wind loading; wind-induced vibration; buffeting; vortex-induced vibration.

1. Introduction

With the consideration of usually bluff cross sections of arch ribs and ever-growing span length, it is necessary to carry out careful design in aerodynamic aspects on wind-induced responses and wind loading of long-span arch bridges in order to ensure aerodynamic stability and wind loading safety of arch ribs and the completed bridge under construction and after completion.

2. Static wind loading

The static wind load or the aerodynamic forces of an arch rib is more complicated than a horizontally positioned main girder, because of the commonly change of elevation, cross section shape and inclination angle along the axis of an arch rib.

2.1 Segmental evaluation method

In segmental evaluation method, an arch rib is divided into several segments along the arch axis. The number of segments shouldn't be too small to avoid significant errors, and too large to cause too much experimental workload and time. Then the measurement of aerodynamic force coefficients for different arch rib segments will be conducted. The total static wind loading of the arch rib can be evaluated considering different mean wind speed and different aerodynamic force coefficients along the arch axis.

2.2 Modification for Reynolds Number Effect

When circular sections are used in arch rib structures, the difference between the Reynolds-numbers in wind tunnel tests and in real wind field may have significant effect on the tested results of aerodynamic force coefficients. Therefore, it is necessary to predict the aerodynamic drag coefficients of CFST arch ribs for the prototype bridge at higher Reynolds Number condition from the current wind tunnel test results. This can be realised through the comparisons between the

https://doi.org/10.2749/222137813808627767
Distributed by structurae

calculated and the experimental results of the drag coefficients for one circular cylinder at different Reynolds Number conditions, and between the calculated results of the drag coefficients for the entire cross section composed of 8 CFSTs at these two Reynolds Number conditions.

3. Equivalent static wind loading

With the increase of span length, long-span arch bridges become more and more prone to various wind-induced vibrations due to the decrease of structural rigidity. This has made the evaluation of dynamic wind loading more complicated.

3.1 Gust wind loading

If an arch bridge is relatively rigid, and there isn't significant wind-induced vibration, the total wind loading, or the equivalent wind loading, which is normally the summation of static wind loading and dynamic wind loading, or equivalent static wind loading, can be treated as gust wind loading. The method to calculate gust wind loading is similar to that of static wind loading, and the only difference is to replace design wind speed with gust wind speed in gust wind loading calculation.

3.2 Buffeting loading

The equivalent static wind load related to resonant buffeting responses can be calculated by conventional Inertia Wind Loading Method. So the equivalent wind load can be evaluated by the following formulas.

3.3 Vortex-induced vibration (VIV) loading

With the consideration of usually bluff cross sections of arch ribs and ever-growing span length, vortex-induced vibration may happen when lacking adequate structural damping. This has been experienced in the wind tunnel tests of Shanghai Lupu Bridge. It is necessary to evaluate the vortex-induced vibration loading (VIV loading) and compare it with conventional buffeting loading to ensure the load-bearing safety of a long-span arch bridge.

3.4 Comprehensive evaluation

For the half-through structure like Lupu Bridge, since the structural stiffness of the central span is relatively small whereas that of the triangular frame structure from the side span to the joint of the rib and the girder is quite large, it is more appropriate to apply different equivalent wind loading to different regions of the structure.

4. Conclusion

Segmental evaluation method was established as an efficient and practical measure to evaluate the static wind loading of an arch bridge. When circular sections are used in arch ribs, it is necessary to take into account the Reynolds Number effect and a prediction method for the static wind loading of a prototype bridge from wind tunnel results was proposed. Three types of equivalent static wind loading concerning different types of wind-induced vibration were investigated and compared, while the comprehensive evaluation for a long-span arch bridge was finally discussed.

5. Acknowledgement

The work described in this paper is supported by the Natural Science Foundation of China under the Grants 51078276 and 51021140005, the Ministry of Science and Technology of China under the Grants SLDRCE10-B-05, and the Ministry of Transport of China under the Grants KLWRBMT-04.