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ASSESSMENT OF VIBRATION SERVICEABILITY OF A LARGE-SPAN CABLE-SUPPORTED FOOTBRIDGE IN THE SCENIC AREA

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Summary

Footbridges of the large span are prone to exhibit significant vibration when subjected to the dynamic excitation, which affects their serviceability. Thus many international codes regulate a dynamic check procedure. However, different provisions for such as load models and evaluation criteria are presented in different codes. Through comparison and reflection of several widely adopted codes, differences of these practical methods are put forward in this paper. Focusing on pedestrian density, a key parameter of the load model, field tests and investigations are conducted, after which a practical load model for high pedestrian density scenario is proposed and analyzed via numerical simulation based on a large-span cable-supported footbridge. Meanwhile, the buffeting response analysis is performed and wind-induced vibration of the deck has been obtained. Then the wind induced vibration comfort evaluation is carried out and shows the essential need of considering wind influence on the serviceability of large-span footbridges.

Keywords: footbridge; vibration serviceability; pedestrian density; comfort; wind induced vibration; buffeting response.

1. Introduction

Achievements in the topic of the footbridge dynamics are numerous. By referring to the research, many footbridge design codes have been established. However, differences exist in some aspects in international codes. Moreover, the large span footbridge which is of pretty low natural frequency and bears large pedestrian loads is scarcely taken particular consideration to. This kind of footbridge not only has a more prominent pedestrian-induced comfort problem but is more sensitive to wind loads which may probably lead to significant vibrations.

This paper firstly gives a brief reflection on current international codes. And a practical load model is proposed through analyzing the statistics from the field investigations and tests. Then the wind vibration simulation is conducted to analyze the effect of wind loads on the comfort for the large span cable-supported footbridge. Through the whole research a cable-supported footbridge, with a span of 420m, in a scenic area in China is used to do the analysis.

2. Reflection on Current Design Codes

Differences especially in the aspect of the load model and the comfort evaluation criteria among various design codes are quite evident through comparing. Besides, the current comfort design codes do not specify the exactly applicable bridge types and span ranges. Moreover the fact that pedestrian density in urban areas and scenic spots may be quite different is not given special consideration to by international codes.

Finally, for large span footbridge located in the windy areas, the influence of wind loads needs to be considered during the comfort design process.

3. Project Overview and Dynamic Properties

The cable-supported footbridge is over a valley of which the depth is 143m in a scenic area. It's a single-span cable-supported bridge with two framed concrete pylons and gravity anchorages. It has a main span of 420m and two back spans of 38m and 48m respectively. The pylon is 38.61m high and the ratio of height to span is 1/12. The girder, of which the width is 4 m, consists of bottom crossbeams and upper longitudinal beams. Two windproof cables are installed under the deck and connected to the deck by windproof ropes. The FE-model is adopted to analyze the dynamic properties. The main vertical and horizontal modes within are obtained. According to the results, most modes are located within the critical frequency ranges of pedestrian forces.

4. Pedestrian-induced Vibration Serviceability

According to field investigations in 10 tourist areas it is found that in most time of a day the maximum pedestrian density is far more than 1.5pers/m^2 and can be even 4~5pers/m^2. According to field test results on 30 bridges during daily peak time, the maximum pedestrian density is obtained as 4.6pers/m^2.

Then three pedestrian-stream load models with different parameters are adopted for pedestrian-induced vibration numerical simulation. It is shown that although the pedestrian density of M-a is the lowest, the force amplitude of M-a turns to be the highest. And from the simulated results, it is suggested that for large span footbridge in such as tourist areas the pedestrian density need to be set to a higher level than the current one in international codes.

5. Wind-induced Vibration Serviceability

The cable-supported footbridge located over the valley or above the river is likely to suffer the wind load. Because of the sensitivity to vibration of the human perception, the comfort of the footbridge can be easily influenced by the wind-induced vibration. Thus wind-induced vibration analysis is carried out via numerical simulation. This paper simulates the random progress of wind speed by applying FFT technique and aero-parameters by CFD simulation.

From the simulated response, it can be seen that the horizontal vibration is very sensitive to the wind load. As for the comfort classes, the vertical vibration induced by wind buffeting forces is not a thread to the comfort while the horizontal vibration leads to a serious comfort problem. Thus, for large span cable-supported footbridge which has a slender girder, it is essential to consider the wind load effect on the vibration comfort even though the wind speed seems to be too low to influence the structure safety.

6. Conclusion

The present paper has discussed existing current practical design methods. Practical load model has been proposed according to field investigations and tests. The focus is to analyze the appropriate pedestrian density for the design of large span cabled-stayed footbridges which are in areas of large pedestrian density. Besides, wind-induced vibration is analyzed to invoke attention for the importance of this aspect which is usually ignored during the comfort design. The main conclusions can be summarized as follow:

1) Current practical comfort design methods do not specify the exactly applicable bridge types and span range. The existing methods give little consideration to large span footbridges;

2) The current suggestion of maximum pedestrian density in international codes cannot represent the reality in some areas for the normal time and do not suit large span footbridge in such as tourist areas. The pedestrian density need to be set to a higher level than the current level in international codes;

3) Wind load effect prominently affects the comfort of the large span cable-supported footbridge. It is essential to consider the wind load effect on the vibration comfort.