Wind and extremely long bridges – a challenge for computer aided design

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Summary

With ever increasing span lengths of bridges thoroughly investigation of wind related phenomena has become more and more a topic of interest. Many effects were observed on already existing bridges and suitable theoretical models were developed. As bridges with such span lengths are becoming more and more a standard situation in bridge design and engineering, also the need for according design tools increases. In this article the necessary steps to expand existing models and to incorporate them into the design process is outlined. Practical examples for different aspects are discussed.

Keywords: Wind, CFD, vortex shedding, flutter, buffeting.

1. Introduction

Modern construction techniques and materials as well as increasing experience and expertise in bridge design allow for still increasing span lengths of large bridges. The needs of well established infrastructure and the trend to make our ways as short as possible demand to construct bridges where it would not have been possible a few decades ago, for example across wide spans of open water. In principle this improvement process is based on the development of new methods and/or materials, followed by a phase in which this new development is pushed to the limit of applicability.

Most of the bridges of such enormous span length are also subject to strong wind forces due to their exposed placement. Because of their slenderness and related dynamic behaviour it is no longer sufficient to treat wind gusts and other fluctuations by equivalent static wind forces. Instead different investigation methods developed for such extreme situations must be applied to examine the interaction of oncoming wind and bridge. Many of these methods were inspired and motivated by observations made on existing bridges or by comparison to similar effects in the aeronautic industry.

An important topic in wind analysis is the data management and information interchange. Because of the complexity of the task, many engineers working on different fields must work closely together. This starts with the measurement and evaluation of meteorological data to describe the local wind situation and ends with final wind check calculations and according decisions. In this sense, not only the analysis methods, but also the data storage and interchange model plays an important role to accomplish an efficient design process. To this end, a software implementation that serves as data container as well as analysis tool was developed. In this paper, the used concepts and methods are presented, and different aspects of the calculation are discussed with practical examples.

2. Numerical modelling of interaction of bridges with wind

The first step to the numerical modelling is a careful investigation of the airflow around the concerned bridge cross sections. This is done by applying a CFD module based on the Discrete

https://doi.org/10.2749/222137908796292740
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Vortex Method (DVM). By applied post processing statistical evaluation, a set of steady state aerodynamic coefficients and flutter derivatives can be obtained.

The subsequent wind buffeting analysis separates static and dynamic wind force contributions. The static part can be applied as distributed constant load. The dynamic wind load can be split into aerodynamic damping and stiffness and contributions due to fluctuating wind. The structural response is calculated by transforming the equations into modal space and frequency domain. By providing suitable wind profile data the excitation power spectrum can be calculated and the structure peak response can be estimated by statistical methods.

By solving simplified versions of the buffeting and flutter equations, wind checks can be obtained for galloping, torsional divergence, torsional flutter and classical flutter phenomena. According critical wind velocities can be estimated.

3. Application example

Calculations were performed for the Hardanger Bridge in Norway. Some results of the wind buffeting analysis are shown in Fig. 1.

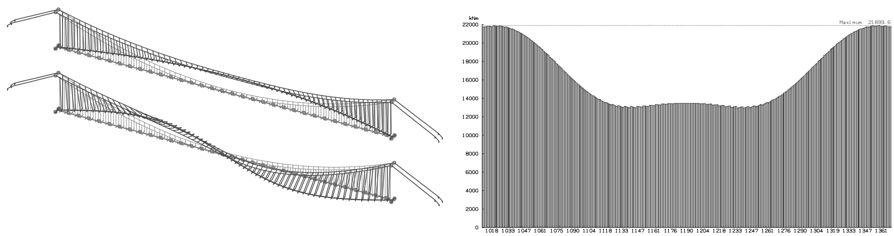

Fig. 1. First two eigenmodes (left) and internal longitudinal twisting moment due to dynamic wind (right) of Hardanger Bridge.

4. Summary and conclusions

In this paper the necessary steps for a complete computer aided wind design of long span bridges were discussed. The theory of the analysis process can be split into three parts: first the airflow around the structures cross sections are characterized by means of CFD methods. The structural response is then estimated with a wind buffeting analysis based on a quasi-steady theory. Additionally, wind design checks can be applied to estimate critical wind velocities.

For the design process it is important to provide the possibility to perform the calculations for different cross section variations as well as wind scenarios. This has been taken into account by providing two storage containers for aerodynamic coefficients (“aero class”) and wind profiles. This information can be arbitrarily combined to check every possible situation.

The developed computer program was applied to perform different wind calculations for the planned Hardanger suspension bridge. A comparison of the deck twisting moment for static and dynamic wind revealed the importance of such wind buffeting calculations.

5. References

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