International Wind Engineering Seminar 4: Developments in Bridge Aerodynamics

Thursday January 7th 2021,12.00 UK time

Main Speaker

Dr John Owen, School of Engineering, University of Nottingham, United Kingdom, The Response of Bridges to Wind – Some Lessons from Monitoring Large Bridges

Short presentations

Prof Steve Cai, Louisiana State University, Time domain simulation of turbulence effects on the aerodynamic flutter of long span bridges.

Prof Claudio Mannini, University of Florence, Nonlinear modelling of self-excited forces for a long-span bridge under turbulent wind

Prof Ole Andre Øiseth, Norwegian University of Science and Technology. Lessons learned from long-term wind and acceleration monitoring of the Hardanger Bridge.

Prof Luca Caracoglia, North Eastern University, Boston, Relevance of Uncertainty Quantification to Study Wind Load Variability and its Effects on Long-Span Bridge Aeroelasticity

Abstracts

The Response of Bridges to Wind – Some Lessons from Monitoring Large Bridges. This presentation will consider the lessons that can be learnt from monitoring the wind induced response of long span bridges by reviewing monitoring exercises on three different bridges. Developments in instrumentation and data analysis will briefly be reviewed before looking at specific wind response phenomena. The presentation will consider observations of vortex induced vibration and buffeting response and consider how these can be used to improve design predictions and modelling methods. With regard to buffeting, the influence of uncertainty in wind field parameters on the response of the bridge will be examined and the consequences for design identified. An example of non-stationary response due to thunderstorm activity will be presented, which demonstrates that non-stationary wind features can lead to significant structural response. The presentation will conclude by looking forward to how best to exploit the data from monitoring systems installed as "standard" on new bridges.

Time-Domain Simulations of Turbulence Effects on the Aerodynamic Flutter of Long-Span Bridges. Though turbulence effects on bridge flutter have been studied in the last few decades, its true effects remain a debate due to the limitation of previous wind tunnel facilities. In order to investigate and explain the effect of wind turbulence on the flutter instability, a time-domain simulation is carried out, which avoids the complicated random parametric excitation analysis used in previous studies. The simulations show the turbulence can change the vibration patterns and weaken the spatial vibration correlation to some extent. Due to this stabilizing effect, the critical flutter velocity is increased by 5% to 10% over that under smooth flow.

Nonlinear modelling of self-excited forces for a long-span bridge under turbulent wind. The prediction of the dynamic response of a long-span bridge under turbulent wind is a complicated task due to the important role played by nonlinearities and fluid memory. It is well known that a key issue is the nonlinear dependence of self-excited forces on the unsteady angle of attack induced by large-scale turbulence. The advantages of a relatively simple time-variant model over the classical linear time-invariant approaches are discussed and quantified based on a specific wind tunnel test campaign. In particular, the experiments for two different bridge sections revealed the viability for practical engineering applications of the basic assumption of slowly-varying angle of attack.

Lessons learned from long-term wind and acceleration monitoring of the Hardanger Bridge. The Hardanger Bridge is spanning the Hardanger fjord which is located at the west coast of Norway. A comprehensive monitoring campaign started in 2013 shortly after the bridge was opened to traffic and it is still ongoing. The monitoring data has revealed that uncertain turbulence parameters have a significant impact on the observed dynamic response and that the current design practice underestimates the dynamic response of the bridge severely. The monitoring data also underlines that nonstationary events can be severe and govern the bride design. This presentation outlines the lessons learned and gives an introduction to the methods developed for improved response predictions.

Relevance of Uncertainty Quantification to Study Wind Load Variability and its Effects on Long-Span Bridge Aeroelasticity. This short presentation will examine past and recent research activities in the field of bridge aeroelasticity under the influence of uncertain, experimentally measured loads and modeling simplifications. Description will include: (1) probability-based, stochastic algorithms for evaluating buffeting response influenced by various error sources, (2) Monte-Carlo sampling used to analyze bridge performance over time through life-cycle cost estimation, and (3) flutter reliability contaminated by random Scanlan (flutter) derivatives. In this context, the presentation will briefly introduce how Artificial Intelligence may be employed to investigate flutter occurrence without requiring solution of the multimode equations. Application examples will be derived from models of either existing or simulated long-span bridges.

Speaker biographies

Dr John S Owen is an Associate Professor in the Department of Civil Engineering at the University of Nottingham, where he has been for 27 years, serving two terms as Head of Department. He is a past chair of the UK Wind Engineering Society and was co-chair of the 6th European and African Conference on Wind Engineering. John's principal research interests are in the dynamic response of structures to the wind and the use of dynamic data in structural health monitoring. He has been involved in monitoring the response of long span bridges to wind for many years, initially leading the monitoring programme on the Kessock Bridge (Scotland) and more recently working on the Forth Road Bridge (Scotland) and Phu My Bridge (Vietnam). John has also worked closely with colleagues in computational wind engineering to simulate the aero-elastic behaviour of bridge sections and has led a number of wind tunnel studies on section and full aero-elastic bridge models. He was responsible for the design and commissioning of the atmospheric boundary layer wind tunnel at Nottingham. Most recently, John has been working on the resilience of infrastructure in Typhoons developing a risk based methodology for networks in Vietnam.

Steve Cai is the coordinator of Structures Group at Louisiana State University and the holder of the Edwin B. and Norma S. McNeil Distinguished Professorship since 2010. He had his BS, MS and PhD from Zhejiang University, Tsinghua University, and Univ. of Maryland, respectively. His research interests include bridge performance evaluation, hazard mitigation of costal infrastructures (and vehicles) under wave/wind actions, and long-span bridge aerodynamics. He has served on many editorial boards and technical committees. Other major professional services include served as Secretary and Treasurer of American Association for Wind Engineering for more than 10 years.

Claudio Mannini is an assistant professor of the Department of Civil and Environmental Engineering, University of Florence, Italy. He got his Ph.D. in 2006. He received the ANIV Award in 2008, the IAWE Junior Award in 2011, and the EASD Junior Research Prize in 2014. His main research interests are bluff-body aerodynamics and wind-induced vibrations, addressed from theoretical, computational and experimental points of view. Since his Ph.D. thesis, he has always been enthralled by the aerodynamics of long-span bridges.

Ole Øiseth is a full professor in structural dynamics at the Department of Structural Engineering at the Norwegian University of Science and Technology. He is the head of the structural mechanics research group and the educational coordinator of the study program in civil and environmental engineering. The dynamics of structures subjected to environmental loading is his main research field. His research interests are stochastic dynamics, wind engineering, marine engineering, structural reliability and structural health monitoring. He has supervised 20 PhD candidates and 80 master students within these research fields since 2012.

Luca Caracoglia is currently an Associate Professor in the Department of Civil and Environmental Engineering of Northeastern University, Boston, Massachusetts, USA. His research interests are in structural dynamics, random vibration, wind engineering, fluid-structure interaction of civil engineering structures, linear and nonlinear cable network dynamics, wind-based energy harvesting systems and wind energy. Luca Caracoglia received the NSF CAREER Award in 2009. He was elected Fellow of the American Society of Civil Engineers in 2020.