DYNAMIC LOAD TESTS ON NON-CONVENTIONAL FOOTBRIDGES

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Summary

Dynamic effects often predominate in footbridge conceptual design, particularly in lightweight and slender systems. Both wind and pedestrians transmit dynamic forces to the structure and may induce vibrations, thus generating user comfort-related issues or even fatigue resistance or structural safety problems. It is therefore important to predict the effect of dynamic actions during the design stage. Since vibration amplitude and frequency depend on a substantial number of parameters, dynamic analysis and computer modelling are subject to important uncertainties, especially as regards footbridges with non-conventional structural systems. Furthermore, the establishment of performance requirements based on a general definition of comfort, as is the case in most current codes and standards, is inadequate and may stifle innovative design because many bridges may fail to meet such requirements. A procedure was therefore deployed in the design and construction of a series of non-standard footbridges, integrating theoretical and experimental verification of their dynamic structural behaviour to ensure suitable user comfort levels.

Keywords: innovative footbridges; slenderness; vibration; acceleration; damping; performance requirement; comfort; evaluation; uncertainties; dynamic load tests.

1. Introduction

Footbridges play an important role both in new urban developments and urban renewal projects that aim to make cities more pedestrian friendly. Due to their in-city location, such footbridges are often highly visible. Hence, public opinion in many communities is contributing to the growing demand for structures that are more than just utilitarian. Powerful tools for design and analysis afford engineers considerable freedom in developing innovative solutions with a view to satisfying this demand. In addition, thanks to new materials and the use of sophisticated bridge construction equipment, longer spans can be built with slender and cost-effective lightweight structures.

Vibrations become more perceptible with increasing footbridge slenderness due to the decline in stiffness and mass inertia. Wind- or pedestrian-induced excitation may cause vertical, horizontal or torsional deck vibrations. In footbridges with spatial structural systems, pedestrian-bridge interaction may even lead to lateral lock-in. Although structural collapse, fatigue or other damage attributable to footfall-induced vibrations are very rare, footbridges should be designed for dynamic as well as static actions, since vibrations may cause users substantial discomfort. In many codes and standards, dynamic problems are addressed by defining limits for the natural frequencies of the structures or for the accelerations or deformations associated with pedestrian-induced vibrations. Such approaches are usually conservative and fail to deal with all the parameters relevant to human sensitivity to vibrations, which is highly subjective [1]. This, together with the fact that the natural frequencies and accelerations calculated by analytical or numerical methods are subject to uncertainties, may hinder pedestrian bridge design. Indeed, the dynamic behaviour of footbridges depends on many parameters whose impact on vibrations is uncertain. These include material properties, structural system complexity, including the boundary conditions, deck surfacing, guard rails and street furniture. Numerical modelling should be as realistic as possible with regard to all the parameters relevant to dynamic behaviour, for otherwise the design stage findings may be inaccurate, rendering rational decision-making about the acceptability of a planned solution impossible.

For the foregoing reasons, the strategy to ensure suitable comfort levels for pedestrian bridge users should be based not only on the numerical verification of serviceability requirements at the design stage, but also on dynamic load tests to be conducted before the finished bridge is opened for use by the general public. In light of the possibility of unfavourable