Civil Engineering Structural Dynamics

PEDESTRIAN-INDUCED LATERAL VIBRATIONS OF FOOTBRIDGES

Experimental studies and probabilistic modelling

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Abstract

Pedestrian-induced lateral excitation has become a major concern in the design of footbridges, following the temporary closure of Paris' Solférino and London's Millennium footbridges in 1999 and 2000. Subsequent research has revealed that numerous other bridges are prone to similar excessive lateral vibrations when exposed to large pedestrian crowds.

The vibrations have often been attributed to a synchronisation between the pedestrian and the bridge, commonly denoted “lock-in” or “Synchronous Lateral Excitation” (SLE), referring to the observation that pedestrians seem to modify their gait to match the frequency and phase to that of the bridge. This has lead to the development of several sophisticated pedestrian load models, which rely on this assumption. Nevertheless, there is a general dispute regarding the fundamental nature of human-structure interaction and the importance of synchronisation.

In this lecture, the results from a comprehensive experimental analysis of lateral forces generated by single pedestrians during continuous walking on a treadmill are presented. Two different conditions were investigated; initially the treadmill is fixed and then it is laterally driven in a sinusoidal motion at varying combinations of frequencies (0.33-1.07 Hz) and amplitude (4.5-48 mm). The experimental campaign was carried out in the summer of 2009 and involved seventy-one test subjects and covered approximately 55 km of walking distributed on almost 5000 individual tests. A qualitative interpretation of the test results is provided, with main emphasis to test the hypothesis that synchronisation is necessary for generating large amplitude vibrations.

Furthermore, the quantitative analysis is presented in terms of a probabilistic load model for the frequency and amplitude dependent pedestrian-induced lateral forces. The application of this load model is presented, through numerical response simulations and comparison with full-scale measurements.




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