



## STUDIES ON VIBRATION SERVICEABILITY ASSESSMENT OF ALUMINUM PEDESTRIAN BRIDGES

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### ABSTRACT

Vibration serviceability is often the governing design factor for slender, lightweight footbridges. However, there is currently a large gap that exists between our understanding from a modeling perspective and their actual vibration behaviour. Recent experimental tests conducted at the University of Waterloo have underscored these discrepancies and have provided a unique opportunity to not only validate many of the models currently in use, but also to propose new modifications to better align with experimental test results. Specifically, issues such as how to design for lateral vibrations and crowd-induced loading and calibration of load factors, will be addressed in this presentation. Recent results obtained by the pedestrian bridge research group at the University of Waterloo through their extensive crowd-testing program on a full-scale aluminum pedestrian bridge located at the university will aim to address both of these issues. The ultimate objectives of this experimental program are to validate or extrapolate existing analytical frameworks, and to develop new, practical models that can be used in a design guideline to better account for lateral vibrations and crowd-induced loading.

### 1. EXECUTIVE SUMMARY

Vibration serviceability is often the governing design criterion for slender, lightweight pedestrian bridges. However, there is currently a large gap that exists between our understanding from a modelling perspective and their actual vibration behaviour, which inhibits designers from making confident and economical design decisions. Over the course of the last few decades, a number of models have been proposed to quantify both the lateral forces exerted by pedestrians on the structure and the underlying mechanisms that trigger resonance (Fujino and Siringoringo 2015). From a designer's perspective, the ideal end result of these models is the synthesis of a vibration serviceability design procedure that can be implemented in a relevant design guideline. However, while a few of these models have been verified numerically using field data collected from landmark structures such as the Millennium Bridge in London (Dallard 2001), experimental validation beyond the testing used to formulate these models has often been limited. The lack of a reliable means to validate these models on full-scale structures has created uncertainty in the models, and has left code writing committees divided in regards to which model or design criterion to use in their guidelines.

The pedestrian bridge research group at the University of Waterloo aims to address these concerns through recent and future test results obtained through their extensive crowd-testing program on a full-scale aluminum pedestrian bridge located at the university (Dey et al. 2016). The crowd-testing program is providing a unique opportunity to validate many of the models currently in use. Existing models for lateral pedestrian-induced forces and vibrations and models for direct and parametric resonance, as well as pedestrian-structure dynamic interactions, crowd-synchronization and the calibration of dynamic load factors will be investigated. The program will provide the data needed to propose modifications to existing design procedures or the development of new ones. In addition, the crowd-testing program will offer new and unique insights into the vibration behaviour of slender structures.

In addition to these experimental studies, an analytical parametric study is being conducted to determine the governing failure mode for a typical aluminum pony truss pedestrian bridge as a function of the overall structure dimensions. The study will consider static strength criteria (flexural failure and compression chord buckling) and vibration serviceability criteria based on existing codes. Preliminary results have shown that slender aluminum pedestrian bridges do transition from being strength critical to vibration critical as the span of the structure increases. The determination of these key transition points will aid designers in making the appropriate decisions when designing slender aluminum pedestrian bridges, such as when to consider the use of dampers to improve the performance and economy of the structure.

Keywords: Vibration serviceability, lateral vibration, crowd-induced loading, Aluminum pedestrian bridges, footbridge dynamics

## REFERENCES

Dallard, P., et al. 2001. The London Millennium footbridge. *The Structural Engineer*, 79(22): 17-33

Dey, P., Sychterz, A., Narasimhan, S., and Walbridge, S. 2016. Performance of Pedestrian-Load Models through Experimental Studies on Lightweight Aluminum Bridges, *Journal of Bridge Engineering*.

Fujino, Y. and Siringoringo, D.M. 2015. Conceptual Review of Pedestrian-Induced Lateral Vibration and Crowd Synchronization Problem on Footbridges. *Journal of Bridge Engineering*, 10.1061/(ASCE)BE.1943-5592.0000822 , C4015001.