# Implementation of a Passive Control System in a Lively Footbridge

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## Summary

The paper describes the studies developed for the assessment and mitigation of vibrations on a footbridge located in Portugal. The design of this steel arch footbridge with 60 m chord pointed to a lively behaviour that was investigated upon construction. The decision to install a passive control system based on two tuned mass dampers (TMDs) to mitigate vertical vibrations implied an experimental characterisation of the footbridge, the tuning of the TMDs and the verification of their efficiency, which are object of the present work.

**Keywords:** Footbridge vibrations; Tuned mass dampers; Dynamic Testing.

## 1. Introduction

Whether constructed in steel or in concrete, certain ranges of spans in footbridges are associated with proneness to pedestrian induced vibrations. In effect, susceptibility to vertical vibrations frequently exists for spans longer than 50 m, while spans of 80 m to 120 m may be prone to horizontal vibrations and lock-in.

Recent guidelines and recommendations have brought an important insight into the problem of characterisation of pedestrian induced effects, providing in particular methodologies for quantification of loads and for assessment of the degree of comfort of a footbridge at design stage. These constitute important tools in the design of structures, allowing the optimisation of structures and the early prediction of measures to mitigate vibrations of the constructed structures.

However, the uncertainties related with the characteristics of the final constructed structures, and the difficulties in defining realistic load models to represent pedestrian traffic in footbridges, justify the need to treat the problem of pedestrian induced vibrations in two steps. In the first phase, during design, the susceptibility of the footbridge to pedestrian vibrations is studied by means of numerical modelling. This may eventually lead to design modifications involving the supports, the choice of material for the slabs (concrete, composite, steel), or the local stiffening of the structure in areas potentially reserved to accommodate damper devices. In a second phase, the experimental assessment of the dynamic properties of the constructed structure allows for a final decision on the need and characteristics of control measures.

The two-phase design approach is being more and more used in footbridges, taking profit of economic and accurate means for experimental assessment of structures. It has been used in particular in the structure that is object of the present paper. A numerical study developed by the Structural Engineer on a steel arch footbridge with 60 m chord (Fig. 1) has led to the identification of potential vertical and horizontal vibrations and to the preliminary design of a control system based on tuned mass dampers (TMDs). The assessment of the dynamic properties of the constructed footbridge based on ambient and free vibration tests allowed the calibration of numerical model and the design of final TMDs. Fig. 2 (a) shows an example of the comparison between identified and calculated modal configurations for the first and third vibration modes.



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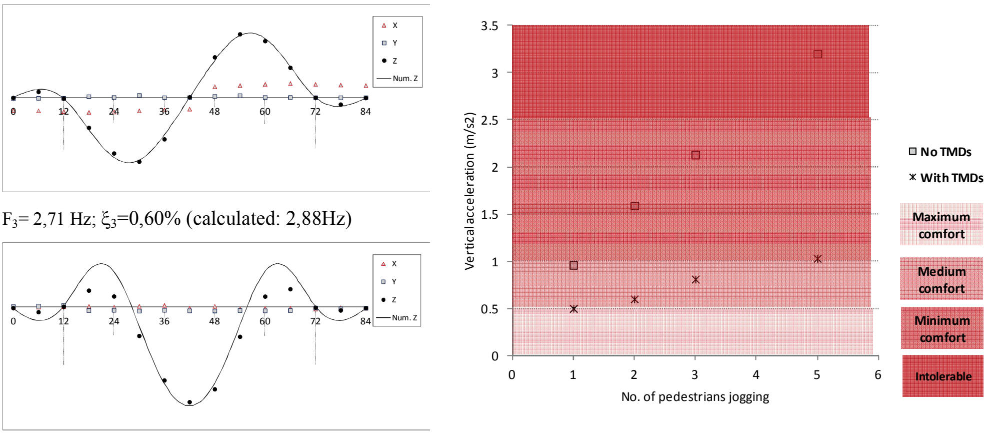
(a) (b)

*Fig. 1: (a) General view of footbridge at Parque da Rabada, Portugal; (b) Installation of TMD*

$F_1$= 1,64 Hz; $\xi_1$=1,34% (calculated: 1,50 Hz)




(a) (b)

*Fig. 2: (a) Identified modal configuration, comparison with calibrated model; (b) measured acceleration during jogging, without and with TMDs*

The installation of 2 TMDs with a total mass of 2100 kg proved to be an efficient measure to mitigate vibrations. In effect, it could be checked that, even though the maximum damping attained by the controlled structure was below predicted according to theory, the maximum amplitudes of vibration induced by joggers (Fig. 2b) or by large crowds, measured during inauguration, allowed the classification of the footbridge as providing medium comfort for the first situation and maximum comfort for the latter.