DOI: 10.24904/footbridge2017.09512

APPLICATION OF THE TUNED MASS DAMPER CONCEPT TO THE MODELLING OF PEDESTRIAN-STRUCTURE INTERACTION

Elsa CAETANO

CONSTRUCT/FEUP
University of Porto
Porto, Portugal

ecaetano@fe.up.pt

Cássio GASPAR

Structural Eng. Dept.
State Univ. Rio de Janeiro – UERJ
Rio de Janeiro, Brazil

cassio.gaspar@fe.up.pt

José G. SANTOS SILVA

Structural Eng. Dept.
State Univ. Rio de Janeiro – UERJ
Rio de Janeiro, Brazil

jgss@uerj.br

Carlos MOUTINHO

CONSTRUCT/FEUP
University of Porto
Porto, Portugal

moutinho@fe.up.pt

Keywords: human-structure interaction; vertical vibration; biodynamic models; dynamic testing

Summary

Following well-known events of pedestrian induced vibrations in relevant footbridges, intensive research programs have been conducted all over the world aiming at characterising accurately the actions induced by pedestrians on footbridges and at defining acceptability criteria according to specific aspects, as the function and expected use. When dealing with footbridge design, besides the typical uncertainties related with the accurate characterisation of boundary conditions or with the definition of the actual structural damping, the transfer of the characterization of the single pedestrian loads to an equivalent crowd loading becomes problematic, as issues regarding synchronization between pedestrians or synchronization between pedestrians and the footbridge may lead to completely different load scales and to an unrealistic response prediction. This is particularly enhanced by the fact that structural damping is usually very low and the loads induced by pedestrians have a near-deterministic and often a near-resonant character.

In former studies and standards addressing footbridges, for example [1, 2], the loads induced by single pedestrians were treated as deterministic functions with periodic character. Recent research works have used information from studies on the biomechanics of the human body and, with different levels of simplification, pedestrian mass, stiffness and damping have been introduced in the characterization of human induced loads [3-8].

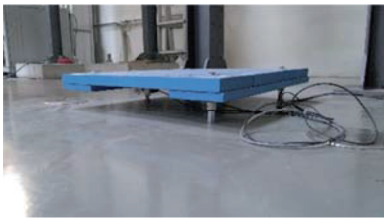
Considering the dominant mass of the footbridge by comparison with the mass of the pedestrian crowd, it is understandable that the properties of the footbridge govern the dynamic behaviour of the system. However, as in any association of a primary structural system with a subsystem, internal resonances may define ranges of frequencies where considerable interaction occurs.

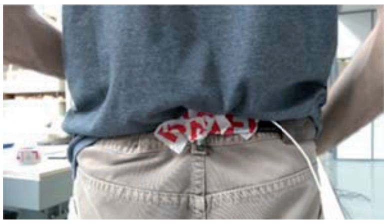
The concept behind the present paper lies on the fact that the crowd can be simulated by means of an equivalent mass, frequency and damping, whose values are defined in ranges that include the typical values of the parameters used in the design of tuned mass dampers (TMDs). Therefore, pedestrians can be treated

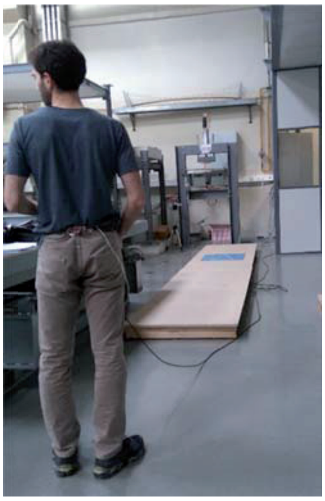
as tuned mass dampers. Since TMDs are only effective in near-resonant conditions, it is then expected that the presence of a crowd may also contribute to the mitigation of the dynamic response of the footbridge with regard to that obtained from an independent loading of the structure, as long as the natural frequency lies close to the footbridge natural frequency. In the light of this concept, a second aspect can be perceived: for the ranges of frequencies where internal resonances occur, the dynamic interaction between the pedestrian/ crowd and the structure increases and may modify the characteristics of the applied loads themselves.

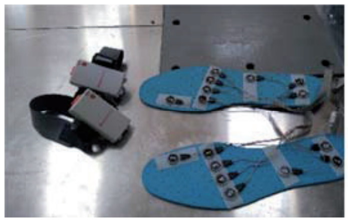
In the present paper, the dynamic loads induced by walking pedestrians are estimated on different surfaces, together with the recording of the body acceleration (Fig. 1). The combined use of estimated force and body acceleration provides estimates of the pedestrian dynamic parameters when idealized as an SDOF. It is observed that these parameters fit well the parameters presented in the literature regarding natural frequency and mass. However, a lower damping ratio is obtained, which reduces with the increase of walking frequency.

Extending data obtained with a single pedestrian to the simulation of a crowd by means of a statistical distribution of the person's parameters, allows the characterization of the equivalent modal parameters of a footbridge modified by the presence of a walking crowd. The most relevant aspect of this modelling is the increased damping, which can explain the typical lower than calculated measured response due to crowd loading. However, it is further noticed that human-structure interaction also modifies the amplitude of the applied loads in the vicinity of a resonance. This has been evidenced for one single pedestrian, but quantification of the load reduction at resonance requires further investigation.


(a)


(b)


(c)


(d)


(e)


(f)

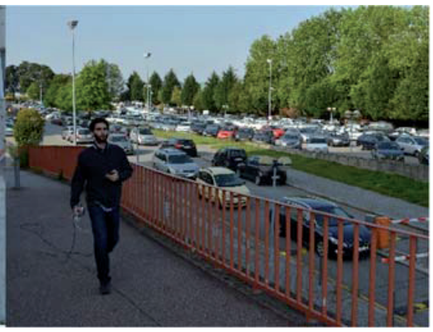

(g)

Fig. 1. Instrumentation for measurement of applied force and pressure when walking on a rigid platform, a) force platform mounted on a set of three load cells, b) piezoelectric accelerometer, c) rigid platform and instrumented person, d) foot sensors, e) mounting of foot sensors, f) g) pedestrian walking over footbridge instrumented with accelerometer and foot sensors