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Design and dynamic behaviour of footbridges
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Dynamic tests on a "lively" footbridge

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This paper addresses the dynamic study developed on a stress-ribbon footbridge that was recently constructed at the new Campus of the Faculty of Engineering of the University of Porto.

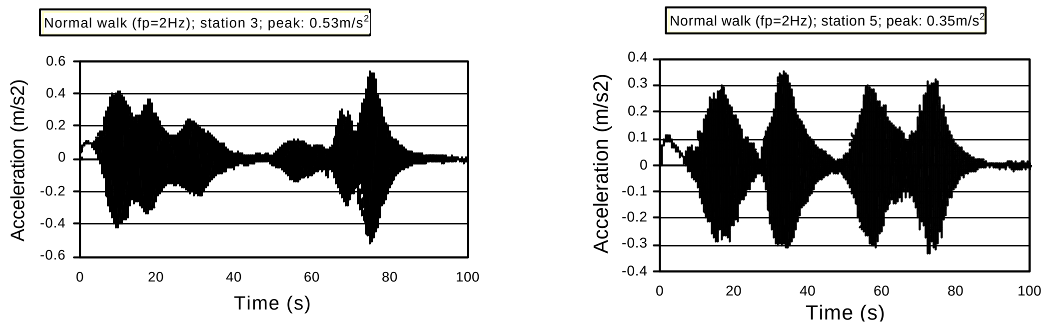
The bridge provides a pedestrian link between the main buildings and the student's canteen and parking areas, as shown in Figure 1, and is characterised by a very slender concrete slab continuous over two spans 28m and 30m long. It has been in use for about one year. To the best of our knowledge, no extreme vibration was ever reported, but vertical oscillations are clearly perceptible under pedestrian use. This fact suggested the development of a numerical and experimental study to assess the current levels of vibration and to provide a comparison with limit values specified by international codes. The study comprehended the development of a finite element model of the bridge, which was checked and re-evaluated following an ambient vibration survey performed using piezoelectric accelerometers. Then, the finite element model was used to simulate the dynamic effects induced by the walking of a pedestrian. The calculated response was compared with the response measured on the bridge and with limit values recommended by international codes.

Fig. 1 View of footbridge

This investigation has shown that the dynamic behaviour of the bridge is rather complex, with a significant degree of nonlinearity and a high dependence on the construction procedure. A consequence of this fact is that the actual bridge characteristics differ slightly from the design.

A second aspect to emphasize is the important role of experimental testing for the correct assessment of the dynamic behaviour of any bridge. In effect, the identification of natural frequencies and vibration modes based on site measurements was determinant for the calibration of the finite element model. Furthermore, the measurement of damping coefficients under service loads was paramount for the calculation of the bridge response.

With respect to the verification of acceptability vibration criteria, a set of measurements were performed, in which one person weighting 835N has passed over the bridge at different walking rates, trying to excite the bridge at the main frequencies. Figure 2 shows the measured acceleration at 1/3[rd] and centre of the larger span induced on the bridge at a pacing rate of 2Hz for the two-way crossing. A maximum acceleration of 0.53m/s^2 was measured. This value is relatively high, although within the acceptability tolerance.



(a) *(b)*

Fig. 2 Walking of single pedestrian at a pacing rate of 2Hz: **(a) 1/3[rd] span; (b) Mid-span**

Considering the influence of several pedestrians simultaneously on the bridge, an enhancement factor is calculated, according to Matsumoto.

The conclusion is that, under service loads, the footbridge vibrates within acceptable tolerance limits. But it can undergo large vibrations for a high density of pedestrian use with a matching pacing rate of 2Hz. It should be considered however that both the small length of the bridge and the variation in the slope of the walking deck attenuate this possibility. Beyond that, the expected increase of damping for large amplitudes of oscillation can also reduce such effect.