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EXPERIMENTAL VERIFICATION OF THE DYNAMIC PERFORMANCE OF A FOOTBRIDGE UNDER HIGH PEDESTRIAN DENSITIES

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Summary

Although the dynamic performance of footbridges under high crowd densities is often imperative for the design, official standards and guidelines are currently forced to rely on load models that are oversimplified and based on numerous assumptions that remain to be validated. The present contribution presents a unique case where the dynamic performance of a footbridge under high pedestrian densities is verified experimentally. The dynamic characteristics of the empty structure and the structure occupied by a large number of persons standing still are identified. A clear decrease in effective frequency and an increase in effective damping ratio is observed for an increasing number of persons on the deck. In addition, the dynamic performance under high pedestrian densities is observed. It is shown that the maximum acceleration levels predicted by the design guides are two times larger than the experimental observations.

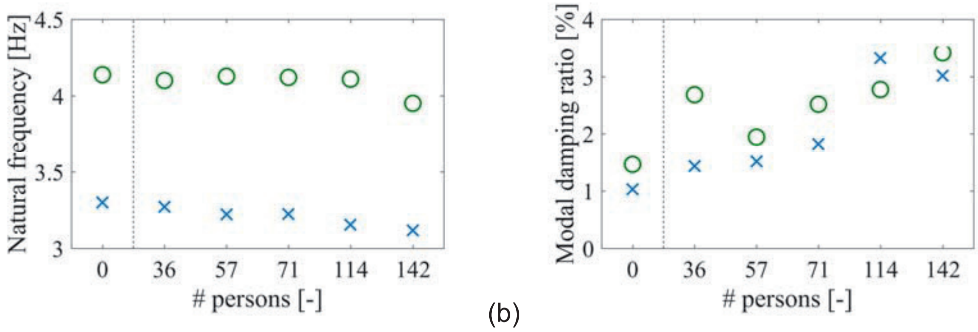
Keywords: dynamics; vibration serviceability; human-induced vibrations; full-scale experimental study; high pedestrian densities

1. Waalse Krook South Footbridge

The Waalse Krook South footbridge is a steel footbridge with a single span of 25 m and a width of 6 m. Based on a detailed finite element model, two modes are predicted with a natural frequency below 5.5 Hz: a vertical bending mode (2.59 Hz) and a torsional mode (3.73 Hz).

2. Full-scale experimental study

First, the operational modal analysis is performed for the empty footbridge. Two modes with a frequency up to 5.5 Hz are identified: a vertical bending mode (3.30 Hz) and a torsional mode (4.14 Hz). Second, the operational modal analysis is performed for an increasing number of pedestrians standing still on the bridge. It is expected that, as a result of the interaction between the human body and the footbridge, the effective modal characteristics of the coupled crowd-structure system can differ (significantly) from that of the empty footbridge [1]–[3]. Fig. 1 presents the identified effective frequency and effective damping ratio of the first and the second mode of the coupled crowd-structure system in terms of the number of persons on the bridge deck. For both modes, a clear decrease in the effective frequency and an increase in the effective damping ratio can be observed for an increasing number of persons on the bridge deck. Third, the experimental study considered walking excitation by high pedestrian densities (up to 1 pers./m²).

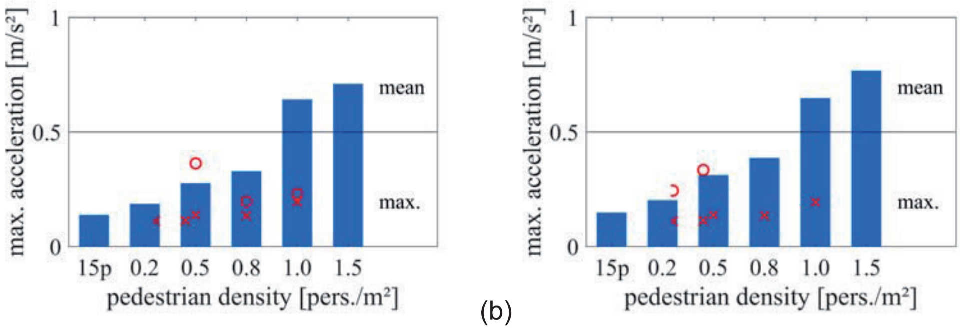


(a) (b)

Fig. 1 The identified effective frequency (a) and effective damping ratio (b) for the first (x) and second (o) mode of the coupled crowd-structure system, in terms of the number of persons on the bridge deck.

3. Vibration serviceability assessment

The results from the numerical analysis and the full-scale experimental study are combined to (re)assess the vibration serviceability of the footbridge. The structural response is predicted based on the current codes of practice [4] and the experimentally identified modal characteristics of the empty footbridge. The results are presented in Fig. 2, and compared with the corresponding maximum acceleration levels observed during the tests. Based on this updated analysis, it can be concluded that the footbridge is characterised by a low sensitivity to human-induced vibrations. In addition, these results show that the structural response predicted by the design guides is (significantly) higher than the corresponding experimental observations. The latter is due to the fact that (1) the design guides predict the 95-percentile value of the acceleration levels to which end the experimentally observed time window cannot be considered sufficiently long, and (2) the design guides do not account for the increase in effective damping ratio as a result of the presence of the crowd.



(a) (b)

Fig. 2 Reassessment of the vertical vibration serviceability of (a) the first mode and (b) the second mode, and the comparison with the maximum acceleration levels as observed during the tests (x).

4. Acknowledgements

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5. References

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