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A FULL PROBABILISTIC MODEL FOR LOADS INDUCED BY WALKING

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Summary

In recent years, extensive tests at the Ruhr-Universität Bochum have been performed to study the inter- and intra-subject variability of walking incuded loads using a long instrumented walkway of 28 m. These high-quality experiments can be used as a benchmark for results obtained from walking on instrumented treadmill devices. The paper indicates that the latter studies should be used only with special care for the evaluation of the serviceablity of a structure in regard to vibrations, since the relation between step frequency and load amplitude is somehow biased and the inter- and intra-subject variablite is homogeninized. The frequency content of the induced loads is compared to the idealized load model in today's Standards and guidelines, which assume a perfectly repeated load pattern. Strictly speaking, the idealized model only leads to realistic results for full resonance with the step frequency. A refined model is proposed which re-models the observed load patterns by a set of cubic splines applying nine control points. The proposed load model is able to reproduce the maximum accelerations with only very small deviations up to frequencies of 13 Hz. For the simulation of the load process, the inner correlation structure of the basic variables has to be studied. The analysis shows that two gender-specific models are required. The final probabilistic load model is a powerful tool for the evaluation of the serviceability of pedestrian structures and floors under random pedestrian flow.

Keywords: walking induced loads; appropriate experimental technique; inter- and intra-individual scatter; vertical vibrations; intermediate harmonics; serviceability; pedestrian structures; floors

Today's Standards and guidelines dealing with loads induced by walking are based on the assumption that the load sequence can be idealized as a perfect repetition of a specific load pattern. Thus, the frequency content of walking loads involves only integer multiples of the basic step frequency. A refined analysis reveals that the basic walking parameters step frequency, step length and step width and the load amplitudes may vary considerably from step to step. The respective span differs from person to person. For the realistic evaluation of the serviceability of a pedestrian structure or a floor, it is therefore vital to consider the inter- and intra-individual scatter in the walking parameters and corresponding induced loads.

The required benchmark data for a more realistic load model are obtained from a long instrumented walkway which is crossed by a sufficient large number of single persons walking at a freely chosen speed. The basic idea of an instrumented walkway is to observe and measure walking parameters and walking induced loads in a situation which is comparable to unrestricted walking on ground. Thus, beside an instrumented section, sufficient long lead-in and lead-out sections are required to avoid any biasing effects from an accelerated or decelerated motion. The test section of the EKIB walkway consists of four measuring modules each having a length of 4 m, thus being able to monitor the loads over a fetch of 16 m. The lead-in section has a length of 4 m; the lead-out section is 8 m long.

Altogether, 227 subjects have participated in the tests, 38 female and 189 male persons. A typical sequence of steps is shown in figure 1. A refined model is proposed which re-constructs the observed load patterns by a set of cubic splines applying nine control points. The quality of this proposed load model can be evaluated by comparing the maximum accelerations of a simple beam obtained for the truly measured load sequences and the re-modelled load sequences. The comparison is performed for a range of natural frequencies from 0.5 Hz to 20 Hz (figure 2). The proposed load model gives excellent to good agreement up to natural frequencies of 13 Hz to 15 Hz. Deviations larger than 10% only occur for frequencies beyond 13 Hz. The observed walking parameters for the left and right leg and the corresponding control points form the basis for a consistent probabilistic model.

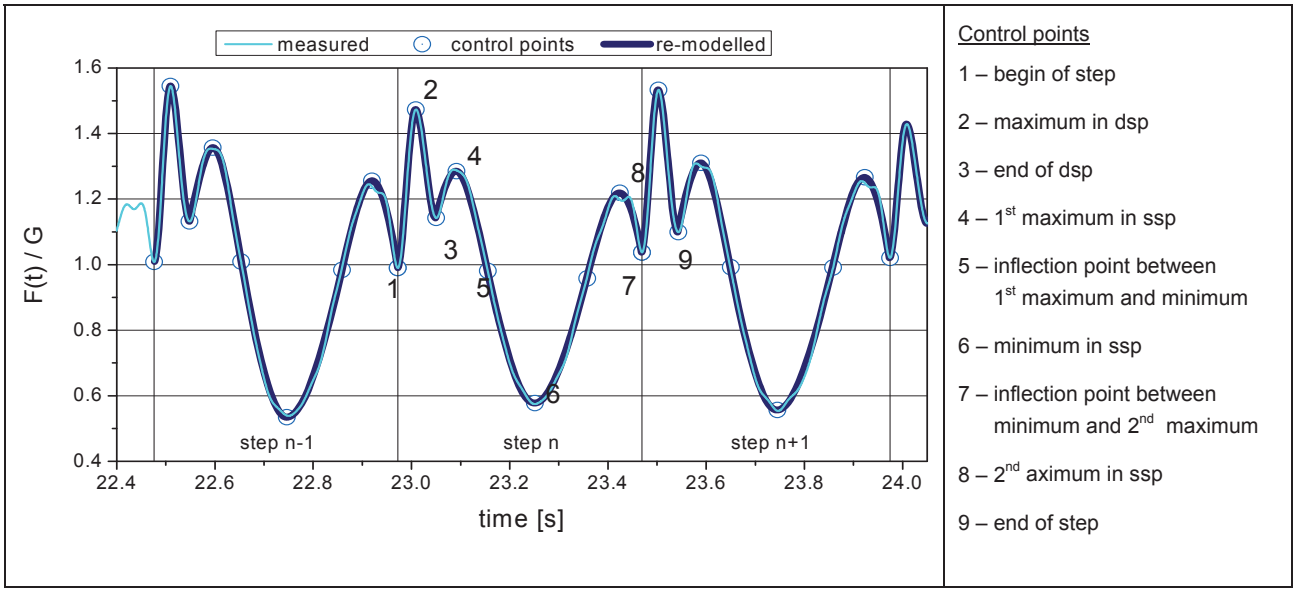

Fig. 1. Re-modelling the walking induced loads for each individual step based on characteristic points

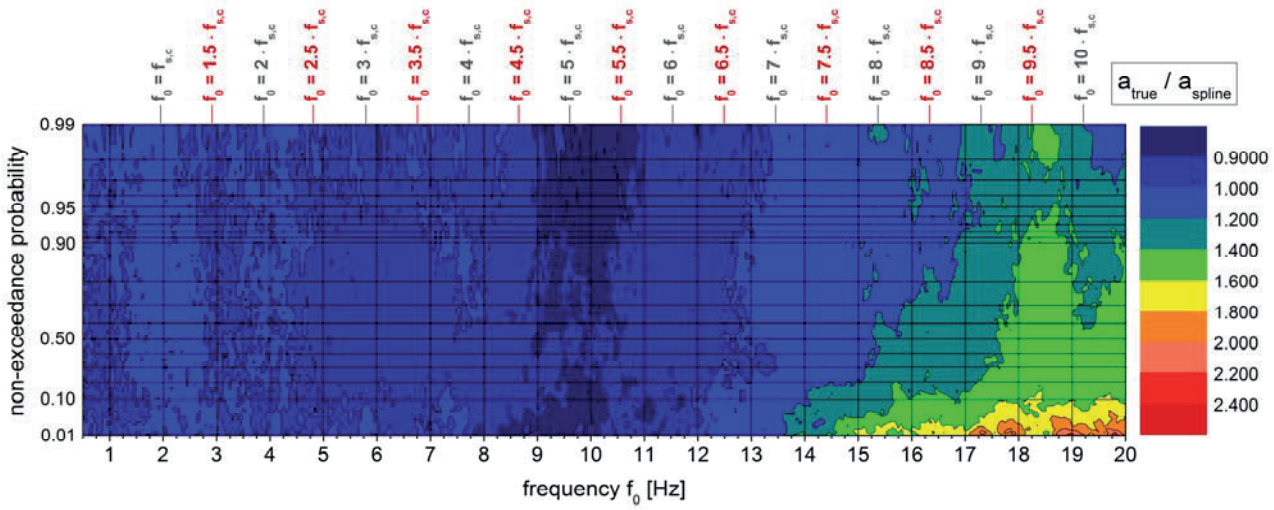

Fig. 2. Contour plot of the ratio of the true maximum acceleration to the maximum acceleration applying the re-modelled load time series, frequency distribution of the ratio for the 5%, 50% and 95% percentile

The analysis shows that two gender-specific models are required. As basic probabilistic model, multi-correlated normal distributions are introduced, considering the inter- and intra-individual scatter in the walking and loading parameters. The developed routines form a powerful tool for the efficient and reliable evaluation of the serviceability of pedestrian structures and floors under random pedestrian flow.