DOI: 10.24904/footbridge2017.09630

PERCEPTIBILITY OF VIBRATIONS BY PEDESTRIANS

Benjamin CZWIKLA

Civil Engineer
Ruhr-Universität Bochum
Bochum, Germany

Benjamin.czwikla@rub.de

Michael KASPERSKI

Privatdozent
Ruhr-Universität Bochum
Bochum, Germany

michael.kasperski@rub.de

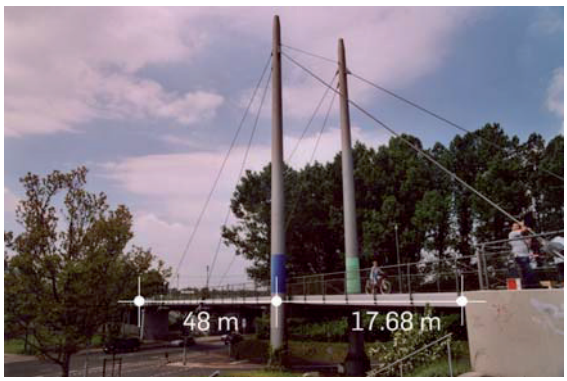
Summary

The serviceability criteria for pedestrian structures against vibrations in many recent Standards and guidelines are not based on a consistent probabilistic concept considering the large natural scatter in human responses. While earlier recommendations are the results of on engineering judgement based on a few experiments, the fairly large and still deterministic limiting values in actual design recommendations seem to have no sound scientific justification. The actual study discusses the different serviceability effects as listed in ISO 10137, and points out that beside the question to comfort further and more severe aspects have to be taken into account like fear, interference with activities and possibility of injury. Furthermore, the paper summarizes the known features in the random scatter of perception and evaluation of vibrations for passive persons. The basic random scatter in regard to vibration perception for walking persons is analysed based on field experiments with soldiers marching in step. A marker is dropped as soon as the person feels the vibration. The position of the marker is used to identify the individual times when vibrations have been percieved during the crossing process. The experienced vibration cycle before dropping the marker contains the required threshold information. The perception threshold values of 42 persons are used to identify a theoretical model for the probability distribution. Further tests give first rough estimates for the threshold levels in regard to interference and distortion effects.

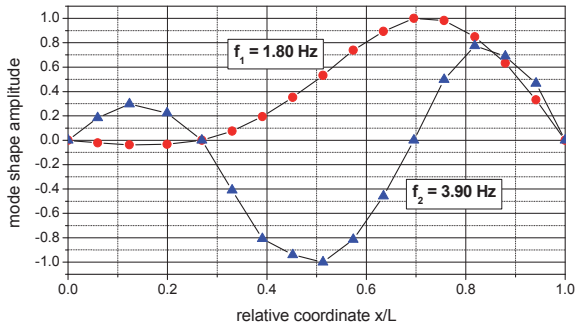
Keywords: vertical vibrations; serviceability; pedestrian structures; perceptibility; design criteria; interference with walking; randomness; probabilistic model

Pedestrian bridges may be subject to pedestrian induced vibrations. These vibrations may cause serviceability problems for human occupants. The serviceability criteria for pedestrian structures against vibrations in many recent Standards and guidelines are not based on a consistent probabilistic concept considering the large natural scatter in human responses. Basic aim of this paper is to contribute to a scientific debate in regard to the development of appropriate serviceability criteria considering the randomness in the subjective evaluations. Starting point are experiments to identify the threshold level for the perceptability of vertical vibrations by active, i.e. walking persons.

Object of the study is the OLGA-bridge (Figure 1) in the city of Oberhausen. Groups of three soldiers are marching side by side in step with a step frequency of 1.8 Hz which equals the fundamental frequency of the bridge. The position of the group and the bridge accelerations are monitored during the crossing process. Each soldier wears a small balloon filled with sand. The test persons are instructed to drop this marker as soon as they feel the bridge vibration. The position of the dropped marker and the control times allow identifying the experienced acceleration in the vibration cycle before the marker is dropped. Altogether 45 male soldiers from the Glückauf barracks at Unna participated.



view of the OLGA-bridge

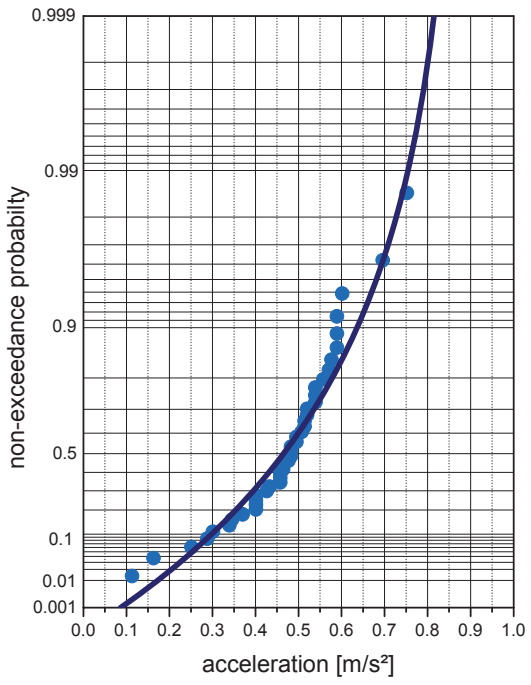


basic mode shapes

Fig. 1. View of the Olga-bridge at Oberhausen and basic mode shapes.

The threshold of perceptibility has a mean value of 0.47 m/s² and a variation coefficient of 27%. Based on a frequency analysis with a resolution of 0.03 Hz it can be concluded that ten groups meet the triggering 1.8 Hz signal. Four groups are slightly slower with 1.78 Hz; one group ignores the triggering beat completely and marches with the 1.9 Hz standard pace. The trace of the observed non-exceedance probabilty of the perceived vibration is shown in figure 2, plotted in Gumbel probability paper. A clear curvature can be identified, suggesting that the type III extreme value distribution can be used as theoretical model. The estimated maximum acceleration that can be perceived by any person then becomes 0.88 m/s². Compared to a standing person, on average the walking person is less sensitive to vibrations by a factor of 45.

Additional tests indicate that beyond 1 m/s² maximum acceleration interference with the walking process is likely to occur. When the accelerations exceed 2 m/s², some of the test persons loose balance and stumble thus interrupting the excitation process. Accordingly, the limiting values in recent Standards and guidelines are too large.



Type III extreme value distribution

$$F(x) = \exp\left[-\left(f_1 - f_2 \cdot \frac{x - m}{\sigma}\right)^{1/\tau}\right]$$

m - mean value = 0.466 m/s²

σ - standard deviation = 0.130 m/s²

τ - shape parameter = 0.282

$$x_{max} = m + \sigma \cdot \frac{f_1}{f_2} = 0.88 \text{ m/s}^2$$

$$f_1 = \Gamma(1+\tau)$$
$$f_2 = \sqrt{\Gamma(1+2\cdot\tau) - f_1^2} \quad (7)$$

Γ - Gamma function

Fig. 2. Trace of the non-exceedance probability of the perceived vibration for male persons exciting a bridge with the basic step frequency.